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April 1st, 2010
Renesas Electronics Corporation

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H8S/2148 Group, H8S/2144 Group,
H8S/2148F-ZTAT™, H8S/2147N F-ZTAT™,
H8S/2144F-ZTAT™, H8S/2142F-ZTAT™

Hardware Manual

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

H8S/2148	HD6432148S	H8S/2147N	HD64F2147N
	HD6432148SW		HD64F2147NV
	HD64F2148	H8S/2144	HD6432144S
	HD64F2148V		HD64F2144
	HD64F2148A		HD64F2144V
	HD64F2148AV		HD64F2144A
H8S/2147	HD6432147S		HD64F2144AV
	HD6432147SW	H8S/2143	HD6432143S
	HD64F2147A	H8S/2142	HD6432142
	HD64F2147AV		HD64F2142R
	HD64F2142RV		

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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 they 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 through the chip and a low level is input on the reset pin. During the period where the state is undefined, the register settings and the output state of each pin are also undefined. Be sure to initialize your system so that it does not malfunction because of processing while it is in an 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 data may have been allocated to these addresses. Do not access these registers; test operation is not guaranteed if they are accessed.

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Programs based on the high-level language C can also be run efficiently.

Single-power-supply flash memory (F-ZTAT™*) and mask ROM versions are available, providing a quick and flexible response to conditions from ramp-up through full-scale production, even for applications with frequently changing specifications.

On-chip peripheral functions include a 16-bit free-running timer (FRT), 8-bit timer (TMR), watchdog timer (WDT), two PWM timers (PWM and PWMX), a serial communication interface (SCI, IrDA), PS/2-compatible keyboard buffer controller, host interface (HIF), D/A converter (DAC), A/D converter (ADC), and I/O ports. An I²C bus interface (IIC) can also be included as an option.

An on-chip data transfer controller (DTC) is also provided, enabling high-speed data transfer without CPU intervention.

The H8S/2148 Group has all the above on-chip supporting functions, and can also be configured with an IIC module as an option. The H8S/2144 Group comprises reduced-function versions with fewer TMR channels, and no PWM, keyboard buffer controller, HIF, IIC, or DTC module. The H8S/2147N with fewer TMR channels, no DTC and some other functions.

Use of the H8S/2148 Group, H8S/2144 Group, H8S/2147N enables compact, high-performance systems to be implemented easily. The comprehensive PC-related interface functions and matrix key-scan functions are ideal for applications such as notebook PC keyboard controller, intelligent battery and power supply control, while the various timer functions and the interconnectability (timer connection), plus the interlinked operation of the I²C bus interface and data transfer controller (DTC), in particular, make these devices ideal for use in PC modules. In addition, the combination of F-ZTAT™* and reduced-function versions is ideal for applications such as CD-ROM drive units in which on-chip program memory is essential to meet performance requirements, product start-up times are short, and program modifications may be necessary end-product assembly.

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Product names	H8S/2148, H8S/2147	H8S/2147N	H8S/2147N H8S/2147 H8S/2147
Bus controller (BSC)	Available (16 bits)	Available (16 bits)	Available (16 bits)
Data transfer controller (DTC)	Available	—	—
8-bit PWM timer (PWM)	×16	×16	—
14-bit PWM timer (PWMX)	×2	×2	×2
16-bit free-running timer (FRT)	×1	×1	×1
8-bit timer (TMR)	×4	×3	×3
Timer connection	Available	—	—
Watchdog timer (WDT)	×2	×2	×2
Serial communication interface (SCI)	×3	×3	×3
I ² C bus interface (IIC)	×2 (option)	×2 (option)	—
Keyboard buffer controller (PS/2 compatible)	×3	×3	—
Host interface (HIF)	×4	×4	—
D/A converter	×2	×2	×2
A/D converter	Analog inputs	×8	×8
	Expansion A/D inputs	×16	×16

1.1 Overview	4	Host interface specification in table 1.1 amended • 8-bit host interface (ISA) port	
Table 1.1 Overview	6	Product lineup specification in table 1.1 amended	
Product Code^{§2}			
Group	Mask ROM Versions	F-ZTAT Versions	ROM/RAM (Bytes)
H8S/2148	HD6432148S	HD64F2148	128 k/4 k
		HD64F2148V ^{§2}	
	HD6432148SW ^{§1}	HD64F2148A	64 k/2 k
		HD64F2148AV ^{§2}	
H8S/2147N	—	HD64F2147A	64 k/2 k
		HD64F2147AV ^{§2}	
H8S/2144	HD6432144S	HD64F2147N	128 k/4 k
		HD64F2147NV ^{§2}	
		HD64F2144A	
	HD6432143S	HD64F2144V ^{§2}	96 k/4 k
		HD64F2144AV ^{§2}	
HD6432142	HD64F2142R	64 k/2 k	
		HD64F2142RV ^{§2}	
Notes: 1. W indicates the I ² C bus option. 2. V indicates the 3-V version. Please refer to appendix Code Lineup.			
1.2 Internal Block Diagram	7	Figure 1.1 (a) amended (Before) STBY → (After) STBY	
Figure 1.1 (a) Internal Block Diagram of H8S/2148 Group			
Figure 1.1 (b) Internal Block Diagram of H8S/2147N	8	Figure 1.1 (b) amended (Before) IIC × 2ch → (After) IIC × 2ch (option)	

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Operating Mode	21	Modes 2 and 3 in single chip modes of pin 95 amended (Before) P82 → (After) P82/HIFSD																													
1.3.3 Pin Functions	30	Table 1.3 amended																													
Table 1.3 Pin Functions		<table border="1"> <thead> <tr> <th rowspan="2">Type</th> <th rowspan="2">Symbol</th> <th colspan="2">Pin No.</th> <th rowspan="2">I/O</th> <th rowspan="2">Name and Function</th> </tr> <tr> <th>FP-100B</th> <th>TFP-100B</th> </tr> </thead> <tbody> <tr> <td rowspan="4">Host interface (HIF)</td> <td>HIRQ11</td> <td>52</td> <td></td> <td rowspan="4">Output</td> <td rowspan="4">Host interrupt 11, 1, 12, 3, and 4 interrupt requests to the host.</td> </tr> <tr> <td>HIRQ1</td> <td>53</td> <td></td> </tr> <tr> <td>HIRQ12</td> <td>54</td> <td></td> </tr> <tr> <td>HIRQ3</td> <td>91</td> <td></td> </tr> <tr> <td></td> <td></td> <td>90</td> <td></td> <td></td> <td></td> </tr> </tbody> </table>	Type	Symbol	Pin No.		I/O	Name and Function	FP-100B	TFP-100B	Host interface (HIF)	HIRQ11	52		Output	Host interrupt 11, 1, 12, 3, and 4 interrupt requests to the host.	HIRQ1	53		HIRQ12	54		HIRQ3	91				90			
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2.6.1 Overview	52	Instruction in arithmetic operations amended																													
Table 2.1 Instruction Classification		(Before) EG → (After) NEG																													
3.2.4 Serial Timer Control Register (STCR)	89	Bit 3 bit table amended																													
		<table border="1"> <thead> <tr> <th colspan="2">Bit 3</th> </tr> <tr> <th>FLSHE</th> <th>Description</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>Addresses H'(FF)FF80 to H'(FF)FF87 are used for power-down mode and supporting module control register access</td> </tr> <tr> <td>1</td> <td>Addresses H'(FF)FF80 to H'(FF)FF87 are used for flash memory control register access (F-ZTAT version only)</td> </tr> </tbody> </table>	Bit 3		FLSHE	Description	0	Addresses H'(FF)FF80 to H'(FF)FF87 are used for power-down mode and supporting module control register access	1	Addresses H'(FF)FF80 to H'(FF)FF87 are used for flash memory control register access (F-ZTAT version only)																					
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4.5 Stack Status after Exception Handling Figure 4.5 (2) Stack Status after Exception Handling (Advanced Mode)	111	Note * deleted from figure 4.5 (2)																													

Table 8.1 H8S/2148
Group Port Functions

Port	Description	Pins	Expanded Modes		S
			Mode 1	Mode 2, Mode 3 (EXPE = 1)	
Port A	• 8-bit I/O port	PA7/A23/ $\overline{\text{KIN15}}$ / CIN15/PS2CD PA6/A22/ $\overline{\text{KIN14}}$ / CIN14/PS2CC PA5/A21/ $\overline{\text{KIN13}}$ / CIN13/PS2BD PA4/A20/ $\overline{\text{KIN12}}$ / CIN12/PS2BC PA3/A19/ $\overline{\text{KIN11}}$ / CIN11/PS2AD PA2/A18/ $\overline{\text{KIN10}}$ / CIN10/PS2AC PA1/A17/ $\overline{\text{KIN9}}$ / CIN9 PA0/A16/ $\overline{\text{KIN8}}$ / CIN8	I/O port also functioning as key-sense interrupt input ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$), expansion A/D converter input (CIN15 to CIN8), and keyboard buffer controller input/output (PS2CD, PS2CC, PS2BD, PS2BC, PS2AD, PS2AC)	I/O port also functioning as address output (A23 to A16), key-sense interrupt input ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$), expansion A/D converter input (CIN15 to CIN8), and keyboard buffer controller input/ output (PS2CD, PS2CC, PS2BD, PS2BC, PS2AD, PS2AC)	I/O p key-s ($\overline{\text{KIN}}$ expa input keyb input PS2 PS2A

Table 8.2 H8S/2147N
Port Functions

Port	Description	Pins	Expanded Modes		S
			Mode 1	Mode 2, Mode 3 (EXPE = 1)	
Port A	• 8-bit I/O port	PA7/A23/ $\overline{\text{KIN15}}$ / CIN15/PS2CD PA6/A22/ $\overline{\text{KIN14}}$ / CIN14/PS2CC PA5/A21/ $\overline{\text{KIN13}}$ / CIN13/PS2BD PA4/A20/ $\overline{\text{KIN12}}$ / CIN12/PS2BC PA3/A19/ $\overline{\text{KIN11}}$ / CIN11/PS2AD PA2/A18/ $\overline{\text{KIN10}}$ / CIN10/PS2AC PA1/A17/ $\overline{\text{KIN9}}$ / CIN9 PA0/A16/ $\overline{\text{KIN8}}$ / CIN8	I/O port also functioning as key-sense interrupt input ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$), expansion A/D converter input (CIN15 to CIN8), and keyboard buffer controller input/output (PS2CD, PS2CC, PS2BD, PS2BC, PS2AD, PS2AC)	I/O port also functioning as address output (A23 to A16), key-sense interrupt input ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$), expansion A/D converter input (CIN15 to CIN8), and keyboard buffer controller input/ output (PS2CD, PS2CC, PS2BD, PS2BC, PS2AD, PS2AC)	I/O p key-s ($\overline{\text{KIN}}$ A/D to C buffe input PS2 PS2A

8.7.2 Register Configuration	247	Table 8.14 amended (Before) System control register → (After) System control register 2
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8.9.3 Pin Functions	258	P81/GA20/CS2 selection method and pin function amended
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Pin **Selection Method and Pin Functions**

P81/GA20/CS2 The pin function is switched as shown below according to the operating mode, bit CS2E in SYSCR, bit FGA20E in HICR or P81DDR.

Operating mode	Not slave mode		Slave mode		
	FGA20E	—		0	
CS2E	—		0		1
P81DDR	0	1	0	1	—
Pin function	P81 input pin	P81 output pin	P81 input pin	P81 output pin	CS2 input pin

This pin should be used as the GA20 output pin or CS2 input pin 2 or 3 (EXPE = 0).

This pin can always be used as the KIN9 or CIN9 input pin.

PA0/A16/KIN8/
CIN8

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

Operating mode	Modes 1, 2 (EXPE = 0), 3		Mode 2 (EXPE = 1)	
	PA0DDR	0	1	0
IOSE	—	—	—	0
Pin function	PA0 input pin	PA0 output pin	PA0 input pin	A16 output pin
	KIN8 input pin, CIN8 input pin			

This pin can always be used as the KIN8 or CIN8 input pin.

9.3.1 Correspondence between PWM Data Register Contents and Output Waveform

Table 9.4 Duty Cycle of Basic Pulse

Description of upper 6 bits changed to of upper 4 bits

10.3 Bus Master Interface

10.4 Operation

Table 10.4 Settings and Operation (Examples when $\phi = 10$ MHz)

299

Description amended

... Example 2: Read DADRA

MOV.W @DADRA, R0 ; Transfer contents of DADRA to R0

303

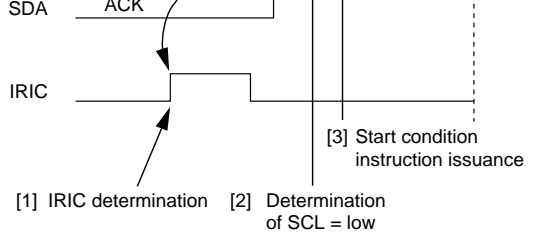
Table 10.4 amended

CKS	Resolution T (μs)	CFS	Base Cycle (μs)	Conversion Cycle (μs)	T _L (if OS = 0) T _H (if OS = 1)	Fixed DADR	
						Precision (Bits)	B ₃
0	0.1	0	6.4	1638.4	1. Always low (or high) level output (DADR = H'0001 to H'03FD)	14	
1	0.2	0	12.8	3276.8	1. Always low (or high) level output (DADR = H'0001 to H'03FD)	14	

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Retransmission



550 to Description added

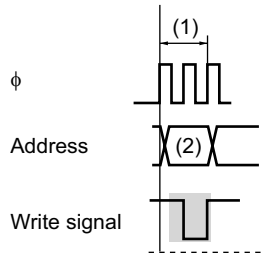
557

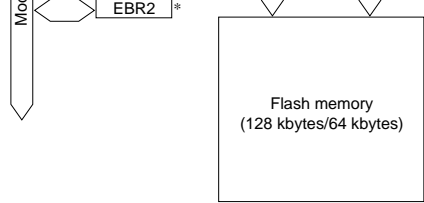
- Notes on WAIT Function
- Notes on ICDR Reads and ICCR Access in Slave Mode
- Notes on TRS Bit Setting in Slave Mode
- Notes on Arbitration Lost in Master Mode
- Notes on Interrupt Occurrence after ACKB Reception
- Notes on TRS Bit Setting and ICDR Register Access

20.4.3 Input Sampling and A/D Conversion Time 628

Figure 20.5 A/D Conversion Time

Figure 20.5 amended

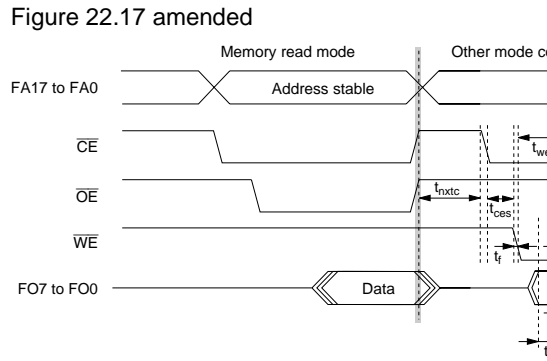


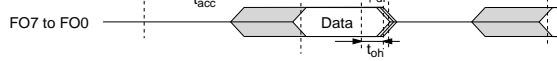


22.5.3	Erase Block Registers 1 and 2 (EBR1, EBR2)	653	Bit figure amended Read/Write description of bits 7 to 2 (Before) — *2
22.10.1	Programmer Mode Setting	671	Note amended In programmer mode, ... Renesas Technology microcontroller device types with 128-kbyte ^{*1*3} or 64-kbyte ^{*2*3} on-chip memory. ... Note: 3. Use products other than the A-mask version: H8S/2148, H8S/2147N, H8S/2144, and H8S/2142

22.10.4 Memory Read Mode

Figure 22.17 Timing Waveforms when Entering Another Mode from Memory Read Mode

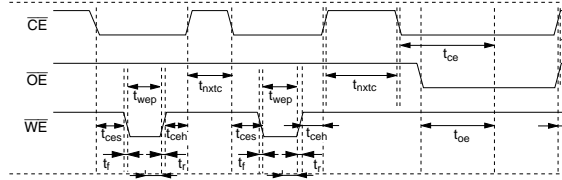




22.10.7 Status Read Mode 681

Figure 22.22 amended

Figure 22.22 Status Read Mode Timing Waveforms



23.5.3 Erase Block Registers 1 and 2 (EBR1, EBR2) 699

Bit figure amended

Read/Write description of bits 7 to 2 (Before) —*2 →

Bit	1	0
EBR1	EB9/*2	EB8/*2
Initial value	0	0
Read/Write	R/W*1*2	R/W*1*2

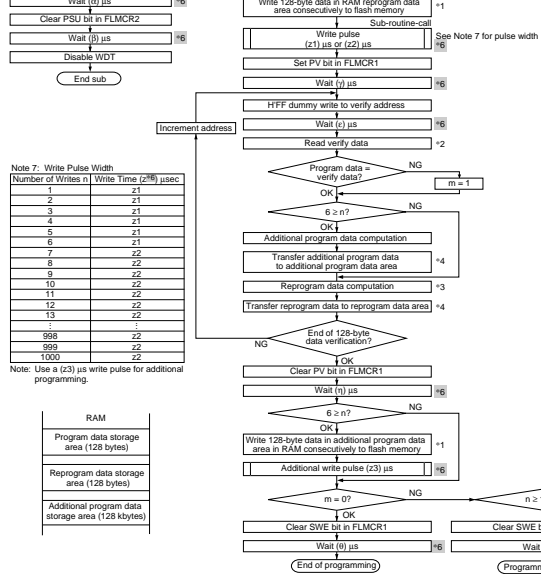
Note 2 amended

Note: 2. Bits EB8 and EB9 are not present in the 64 versions; they must not be set to 1.

Table 23.5 Flash Memory Erase Blocks 700

64-kbyte description added to table 23.5

Block (Size)		Address
128-kbyte Version	64-kbyte Version	
EB0 (1 kbyte)	EB0 (1 kbyte)	H'(00)0000 to H'(00)03FF
EB1 (1 kbyte)	EB1 (1 kbyte)	H'(00)0400 to H'(00)07FF
EB2 (1 kbyte)	EB2 (1 kbyte)	H'(00)0800 to H'(00)0BFF
EB3 (1 kbytes)	EB3 (1 kbytes)	H'(00)0C00 to H'(00)0FFF
EB4 (28 kbytes)	EB4 (28 kbytes)	H'(00)1000 to H'(00)7FFF
EB5 (16 kbytes)	EB5 (16 kbytes)	H'(00)8000 to H'(00)BFFF
EB6 (8 kbytes)	EB6 (8 kbytes)	H'(00)C000 to H'(00)DFFF
EB7 (8 kbytes)	EB7 (8 kbytes)	H'00E000 to H'00FFFF
EB8 (32 kbytes)	—	H'010000 to H'017FFF
EB9 (32 kbytes)	—	H'018000 to H'01FFFF



Note 7: Write Pulse Width

Number of Writes n	Write Time (z ³) μsec
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
14	z2
15	z2
16	z2
17	z2
18	z2
19	z2
20	z2
21	z2
22	z2
23	z2
24	z2
25	z2
26	z2
27	z2
28	z2
29	z2
30	z2
31	z2
32	z2
33	z2
34	z2
35	z2
36	z2
37	z2
38	z2
39	z2
40	z2
41	z2
42	z2
43	z2
44	z2
45	z2
46	z2
47	z2
48	z2
49	z2
50	z2
51	z2
52	z2
53	z2
54	z2
55	z2
56	z2
57	z2
58	z2
59	z2
60	z2
61	z2
62	z2
63	z2
64	z2
65	z2
66	z2
67	z2
68	z2
69	z2
70	z2
71	z2
72	z2
73	z2
74	z2
75	z2
76	z2
77	z2
78	z2
79	z2
80	z2
81	z2
82	z2
83	z2
84	z2
85	z2
86	z2
87	z2
88	z2
89	z2
90	z2
91	z2
92	z2
93	z2
94	z2
95	z2
96	z2
97	z2
98	z2
99	z2
100	z2

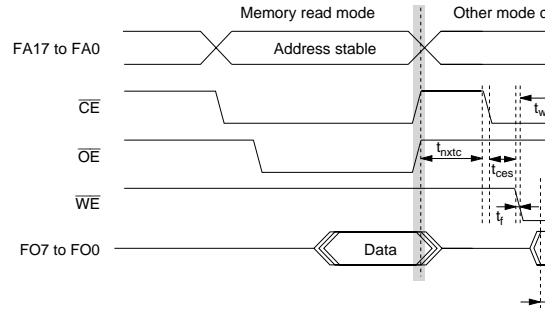
Note: Use a (z3) μs write pulse for additional programming.

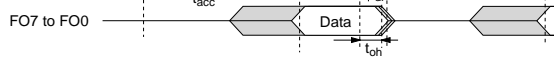
RAM
Program data storage area (128 bytes)
Reprogram data storage area (128 bytes)
Additional program data storage area (128 kbytes)

23.10.4 Memory Read Mode

Figure 23.17 Timing Waveforms when Entering Another Read Mode

Figure 23.17 amended

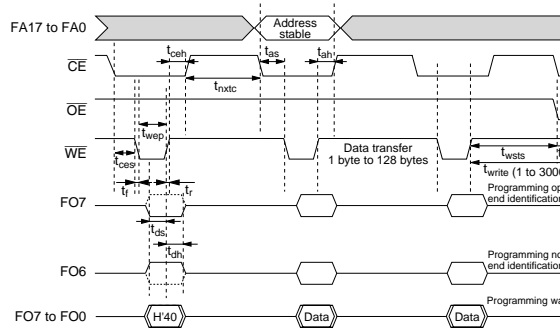




23.10.5 Auto-Program Mode

Figure 23.20 Auto-Program Mode Timing Waveforms

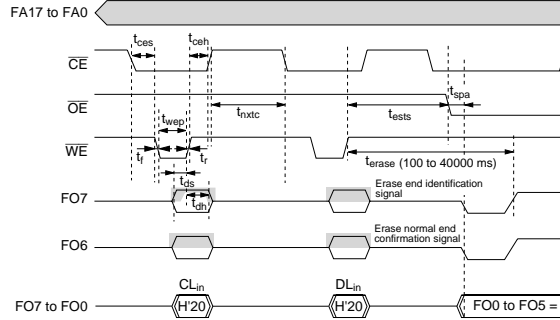
Figure 23.20 amended



23.10.6 Auto-Erase Mode

Figure 23.21 Auto-Erase Mode Timing Waveforms

Figure 23.21 amended



24.7 Subclock Input Circuit 740 **Note on Subclock Usage**

Description added

25.12 Usage Notes

764

Section 25.12 added

26.2.6 Flash Memory Characteristics

799

Table 26.15 amended

Table 26.15 Flash Memory Characteristics (Programming/erasing operating range)

Item	Symbol	Min	Typ	Max	Unit
Reprogramming count	N_{VEC}	100 ⁹⁸	10000 ⁹⁹	—	Times
Data retention time ⁹¹⁰	t_{DRP}	10	—	—	Years
Programming Wait time after SWE-bit setting ⁹¹	x	10	—	—	µs

800

Notes 8 to 10 added

Notes: 8. Minimum number of times for which all characteristics are guaranteed after rewriting (Guard is 1 to minimum value).

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

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

26.3.3 AC Characteristics

819

Table 26.20 amended

Table 26.20 Clock Timing

Item	Symbol	Condition A		Condition B		Condition C		Unit
		20 MHz		16 MHz		10 MHz		
		Min	Max	Min	Max	Min	Max	
Oscillation settling time at reset (crystal)	t_{OSC1}	10	—	10	—	20	—	ms
Oscillation settling time in software standby (crystal)	t_{OSC2}	8	—	8	—	8	—	ms

Table 26.25 I²C Bus Timing

829

Table 26.25 amended

Item	Symbol	Ratings			Unit	Test Condition
		Min	Typ	Max		
SCL, SDA input fall time	t_{Sf}	—	—	300	ns	
SCL, SDA output fall time	t_{of}	20 + 0.1 C _b	—	250	ns	
SCL, SDA input spike pulse elimination time	t_{sp}	—	—	1	t_{sp}	

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Characteristics
 Table 26.29 Flash
 Memory Characteristics
 (Programming/erasing
 operating range)

Item amended (Before) Wait time after dummy write
 Wait time after H'FF dummy write

Symbol of wait time after SWE-bit clear (Before) \ominus –

Item	Symbol	Min	Typ	Max	Unit
Reprogramming count	N_{REC}	100 ⁹⁸	10000 ⁹⁹	—	Tim
Data retention time ^{9,10}	t_{DRP}	10	—	—	Yea
Programming Wait time after SWE-bit setting ⁹¹	x	1	—	—	μ s

834 Notes 8 to 10 added

Notes: 8. Minimum number of times for which all characteristics are guaranteed after rewriting (Guarantee is 1 to 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 performed within the specification range, including the minimum

26.4.3 AC Characteristics
 Table 26.35 Control Signal Timing

849 Unit of t_{NMIH} amended
 (Before) \square → (After) ns

Table 26.37 Timing of On-Chip Supporting Modules (1)

854, 855 Units of t_{PRS} , t_{PRH} , t_{FTIS} , t_{FTCS} , t_{TMRS} , t_{TMCS} amended
 (Before) \square → (After) ns

Units of t_{FTCWL} , t_{TMCWL} , synchronous t_{Soyc} amended
 (Before) \square → (After) t_{cyc}

Unit of t_{SCKI} amended
 (Before) 1.5 → (After) t_{cyc}

26.4.4 A/D Conversion Characteristics
 Table 26.41 A/D Conversion Characteristics (CIN15 to CIN0 Input: 134/266-State Conversion)

860 Table condition amended
 Table condition A (Before) ..., $T_a = -20$ to $+75^\circ\text{C}$ (reference specifications), $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications) → (After) ... $T_a = -20$ to $+75^\circ\text{C}$

is 1 to minimum value).

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

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

26.5.3 AC Characteristics
Table 26.49 Control Signal Timing

877

Unit of t_{NMIH} amended
(Before) (blank) → (After) ns

26.5.6 Flash Memory Characteristics
Table 26.55 Flash Memory Characteristics (Programming/erasing operating range)

885

Table 26.55 amended

Item	Symbol	Min	Typ	Max	U
Reprogramming count	N_{WEC}	100 ⁹⁾	10000 ⁹⁾	—	T
Data retention time ⁹⁾¹⁰⁾	t_{DRP}	10	—	—	Y
Programming Wait time after SWE-bit setting ⁹⁾¹⁾	x	10	—	—	μ

886

Notes 8 to 10 added
Notes: 8. Minimum number of times for which all characteristics are guaranteed after rewriting (Guard is 1 to minimum value).
9. Reference value for 25°C (as a guideline, rewrite normally function up to this value).
10. Data retention characteristic when rewriting is within the specification range, including the minimum

26.6.3 AC Characteristics
Table 26.61 Control Signal Timing

900

Unit of t_{NMIH} amended
(Before) (blank) → (After) ns

characteristics are guaranteed after rewriting (Guaranteed minimum value for the maximum value).

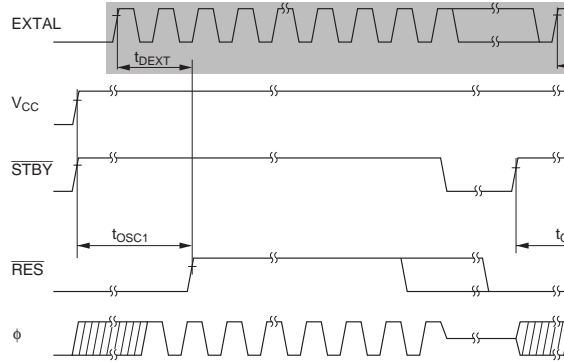
9. Reference value for 25°C (as a guideline, rewriting normally function up to this value).

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

26.7.2 Clock Timing 912

Figure 26.6 Oscillation Settling Timing

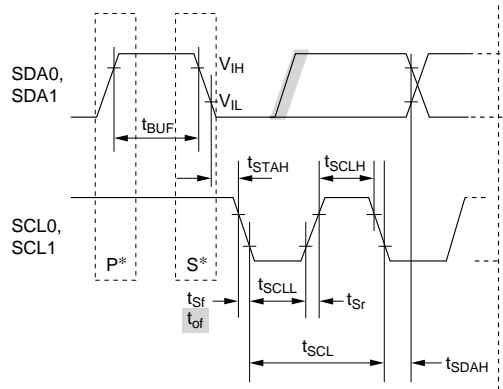
Figure 26.6 amended



26.7.5 Timing of On-Chip Supporting Modules 924

Figure 26.28 I²C Bus Interface Input/Output Timing (Option)

Figure 26.28 amended



4. Shift Instructions

	Mnemonic	Size	Addressing Mode and Instruction Length (Bytes)								Operation
			#xx	Rn	@(d,ERn)	@(ERn)/ERn+	@aa	@(d,PC)	@@aa		
SHLR	SHLR,B,Rd	B	2								
	SHLR,B,#2,Rd	B	2								
	SHLR,W,Rd	W	2								
	SHLR,W,#2,Rd	W	2								
	SHLR,L,ERd	L	2								
SHLR,L,#2,ERd	L	2									

6. Branch Instructions

	Mnemonic	Size	Addressing Mode and Instruction Length (Bytes)								Operation
			#xx	Rn	@(d,ERn)	@(ERn)/ERn+	@aa	@(d,PC)	@@aa		
JMP	JMP @ERn	—		2							PC←ERn
	JMP @aa:24	—					4				PC←aa:24
	JMP @@aa:8	—						2			PC←@aa:8
BSR	BSR d:8	—						2			PC←@-SP,PC←PC+d:8
	BSR d:16	—						4			PC←@-SP,PC←PC+d:16
JSR	JSR @ERn	—		2							PC←@-SP,PC←ERn
	JSR @aa:24	—					4				PC←@-SP,PC←aa:24
	JSR @@aa:8	—						2			PC←@-SP,PC←@aa:8
RTS	RTS	—						2			PC←@SP+

Table A.2 Instruction Codes

Instruction	Mnemonic	Size	Instruction Length (Bytes)			
			1st Byte	2nd Byte	3rd Byte	4th Byte
LDC	LDC @aa:16,CCR	W	0	1	4	0
	LDC @aa:16,EXR	W	0	1	4	1

is set (IRQnSCB = IRQnSCA = 0) and IRQn input is high*

- When IRQn interrupt exception handling is executed while falling, rising, or both-edge detection is set (IRQnSCB = 1 or IRQnSCA = 1)*

Note: * When a product, in which a DTC is incorporated, is used in the following settings, the corresponding flag is automatically cleared even when exception handling, which is a clear condition, is executed and the bit is held at 1.

(1) When DTCEA3 is set to 1 (ADI is set to an interrupt source), IRQ4F flag is not automatically cleared.

(2) When DTCEA2 is set to 1 (ICIA is set to an interrupt source), IRQ5F flag is not automatically cleared.

(3) When DTCEA1 is set to 1 (ICIB is set to an interrupt source), IRQ6F flag is not automatically cleared.

(4) When DTCEA0 is set to 1 (OCIA is set to an interrupt source), IRQ7F flag is not automatically cleared.

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

1019 ABRKCR—H'FEF4 Interrupt Controller

Read/Write description amended

Bit 7 (Before) R/W → (After) R

1021 FLMCR1—H'FF80 Flash Memory

Initial value description amended

Bit 7 (Before) 0 → (After) 1

Bit	7	6	5	4	3	2
EBR2	EB7	EB6	EB5	EB4	EB3	EB2
Initial value	0	0	0	0	0	0
Read/Write	R/W*1	R/W	R/W	R/W	R/W	R/W

1030 ICCR1—H'FF88 IIC1
 ICCR0—H'FFD8 IIC0
 Figure amended

 |
 I²C bus interface enable

0	I ² C bus interface module disabled, with SCL and SDA signal pins set to port function SAR and SARX can be accessed
1	I ² C bus interface module enabled for transfer operations (pins SCL and SDA are driving the bus) ICMR and ICDR can be accessed

1059 SYSCR—H'FFC4 System
 Figure amended

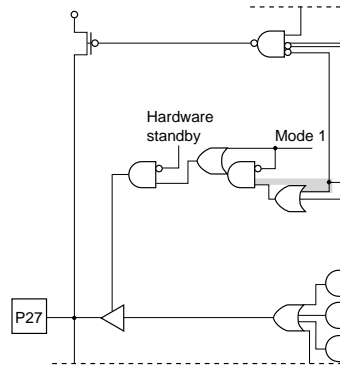
 |
 IOS enable

0	The AS/IOS pin functions as the address strobe pin (Low output when accessing an external area)
1	The AS/IOS pin functions as the I/O strobe pin (Low output when accessing a specified address from H'(FF)F000)

Note: * In the H8S/2148 F-ZTAT A-mask version and H8S/2147 F-ZTAT A-mask version, the address range is from H'(FF)F000 to H'(FF)F7FF.

C.2 Port 2 Block 1089 Figure C.4 amended
 Diagrams

Figure C.4 Port 2 Block
 Diagram (Pin P27)



Appendix F Product Code Lineup 1128 Package code in table F.1 amended
 HD64F2144ATE20 (Before) FP-100B → (After) TFP
 Table F.1 H8S/2148 Group and H8S/2144 Group Product Code Lineup
 HD64F2144AVFA10 (Before) TFP-100B → (After) F

Appendix G Package Dimensions 1129 Figure G.1 replaced

Figure G.1 Package Dimensions (FP-100B)

Figure G.2 Package Dimensions (TFP-100B) 1130 Figure G.2 replaced

1.3.2	Pin Functions in Each Operating Mode
1.3.3	Pin Functions
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2.1.1	Features
2.1.2	Differences between H8S/2600 CPU and H8S/2000 CPU
2.1.3	Differences from H8/300 CPU
2.1.4	Differences from H8/300H CPU
2.2	CPU Operating Modes
2.3	Address Space
2.4	Register Configuration
2.4.1	Overview
2.4.2	General Registers
2.4.3	Control Registers
2.4.4	Initial Register Values
2.5	Data Formats
2.5.1	General Register Data Formats
2.5.2	Memory Data Formats
2.6	Instruction Set
2.6.1	Overview
2.6.2	Instructions and Addressing Modes
2.6.3	Table of Instructions Classified by Function
2.6.4	Basic Instruction Formats
2.6.5	Notes on Use of Bit-Manipulation Instructions
2.7	Addressing Modes and Effective Address Calculation
2.7.1	Addressing Mode
2.7.2	Effective Address Calculation
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2.8.1	Overview
2.8.2	Reset State
2.8.3	Exception-Handling State
2.8.4	Program Execution State

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3.1.1	Operating Mode Selection
3.1.2	Register Configuration
3.2	Register Descriptions
3.2.1	Mode Control Register (MDCR)
3.2.2	System Control Register (SYSCR)
3.2.3	Bus Control Register (BCR)
3.2.4	Serial Timer Control Register (STCR)
3.3	Operating Mode Descriptions
3.3.1	Mode 1
3.3.2	Mode 2
3.3.3	Mode 3
3.4	Pin Functions in Each Operating Mode
3.5	Memory Map in Each Operating Mode
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4.1	Overview
4.1.1	Exception Handling Types and Priority
4.1.2	Exception Handling Operation
4.1.3	Exception Sources and Vector Table
4.2	Reset
4.2.1	Overview
4.2.2	Reset Sequence
4.2.3	Interrupts after Reset
4.3	Interrupts
4.4	Trap Instruction
4.5	Stack Status after Exception Handling
4.6	Notes on Use of the Stack

5.2.3	IRQ Enable Register (IER)
5.2.4	IRQ Sense Control Registers H and L (ISCRH, ISCRL).....
5.2.5	IRQ Status Register (ISR).....
5.2.6	Keyboard Matrix Interrupt Mask Register (KMIMR)
5.2.7	Keyboard Matrix Interrupt Mask Register (KMIMRA).....
5.2.8	Address Break Control Register (ABRKCR).....
5.2.9	Break Address Registers A, B, C (BARA, BARB, BARC).....
5.3	Interrupt Sources
5.3.1	External Interrupts
5.3.2	Internal Interrupts.....
5.3.3	Interrupt Exception Vector Table
5.4	Address Breaks
5.4.1	Features
5.4.2	Block Diagram
5.4.3	Operation
5.4.4	Usage Notes
5.5	Interrupt Operation.....
5.5.1	Interrupt Control Modes and Interrupt Operation
5.5.2	Interrupt Control Mode 0
5.5.3	Interrupt Control Mode 1
5.5.4	Interrupt Exception Handling Sequence
5.5.5	Interrupt Response Times
5.6	Usage Notes
5.6.1	Contention between Interrupt Generation and Disabling.....
5.6.2	Instructions That Disable Interrupts.....
5.6.3	Interrupts during Execution of EEPMOV Instruction.....
5.7	DTC Activation by Interrupt.....
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6.3.1	Bus Specifications.....
6.3.2	Advanced Mode.....
6.3.3	Normal Mode.....
6.3.4	I/O Select Signal
6.4	Basic Bus Interface
6.4.1	Overview.....
6.4.2	Data Size and Data Alignment.....
6.4.3	Valid Strobes.....
6.4.4	Basic Timing.....
6.4.5	Wait Control
6.5	Burst ROM Interface.....
6.5.1	Overview.....
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6.5.3	Wait Control
6.6	Idle Cycle
6.6.1	Operation
6.6.2	Pin States in Idle Cycle
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6.7.3	Bus Transfer Timing.....

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7.1.2	Block Diagram.....
7.1.3	Register Configuration.....
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7.2.1	DTC Mode Register A (MRA)
7.2.2	DTC Mode Register B (MRB).....
7.2.3	DTC Source Address Register (SAR).....

7.3.3	DTC Vector Table.....
7.3.4	Location of Register Information in Address Space
7.3.5	Normal Mode.....
7.3.6	Repeat Mode.....
7.3.7	Block Transfer Mode
7.3.8	Chain Transfer
7.3.9	Operation Timing.....
7.3.10	Number of DTC Execution States.....
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7.3.12	Examples of Use of the DTC
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8.2.2	Register Configuration.....
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8.2.4	MOS Input Pull-Up Function.....
8.3	Port 2.....
8.3.1	Overview.....
8.3.2	Register Configuration.....
8.3.3	Pin Functions in Each Mode
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8.4	Port 3.....
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8.9		Port 8.....
	8.9.1	Overview.....
	8.9.2	Register Configuration.....
	8.9.3	Pin Functions
8.10		Port 9.....
	8.10.1	Overview.....
	8.10.2	Register Configuration.....
	8.10.3	Pin Functions
8.11		Port A.....
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8.12		Port B.....
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9.1		Overview.....
	9.1.1	Features.....
	9.1.2	Block Diagram.....
	9.1.3	Pin Configuration.....
	9.1.4	Register Configuration.....
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9.2.10	Module Stop Control Register (MSTPCR)
9.3	Operation
9.3.1	Correspondence between PWM Data Register Contents and Output Waveform.....
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10.1.2	Block Diagram
10.1.3	Pin Configuration.....
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10.2	Register Descriptions
10.2.1	PWM (D/A) Counter (DACNT)
10.2.2	D/A Data Registers A and B (DADRA and DADRB).....
10.2.3	PWM D/A Control Register (DACR).....
10.2.4	Module Stop Control Register (MSTPCR)
10.3	Bus Master Interface
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11.1.1	Features
11.1.2	Block Diagram
11.1.3	Input and Output Pins
11.1.4	Register Configuration.....
11.2	Register Descriptions
11.2.1	Free-Running Counter (FRC)
11.2.2	Output Compare Registers A and B (OCRA, OCRB)
11.2.3	Input Capture Registers A to D (ICRA to ICRD)
11.2.4	Output Compare Registers AR and AF (OCRAR, OCRAF)
11.2.5	Output Compare Register DM (OCRDM).....
11.2.6	Timer Interrupt Enable Register (TIER)

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11.3.5	Timing of Input Capture Flag (ICF) Setting
11.3.6	Setting of Output Compare Flags A and B (OCFA, OCFB)
11.3.7	Setting of FRC Overflow Flag (OVF)
11.3.8	Automatic Addition of OCRA and OCRAR/OCRAF
11.3.9	ICRD and OCRDM Mask Signal Generation
11.4	Interrupts
11.5	Sample Application
11.6	Usage Notes
Section 12	8-Bit Timers
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12.1.1	Features
12.1.2	Block Diagram
12.1.3	Pin Configuration
12.1.4	Register Configuration
12.2	Register Descriptions
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12.2.2	Time Constant Register A (TCORA)
12.2.3	Time Constant Register B (TCORB)
12.2.4	Timer Control Register (TCR)
12.2.5	Timer Control/Status Register (TCSR)
12.2.6	Serial/Timer Control Register (STCR)
12.2.7	System Control Register (SYSCR)
12.2.8	Timer Connection Register S (TCONRS)
12.2.9	Input Capture Register (TICR) [TMRX Additional Function]
12.2.10	Time Constant Register C (TCORC) [TMRX Additional Function]
12.2.11	Input Capture Registers R and F (TICRR, TICRF) [TMRX Additional Functions]
12.2.12	Timer Input Select Register (TISR) [TMRY Additional Function]
12.2.13	Module Stop Control Register (MSTPCR)
12.3	Operation
12.3.1	TCNT Incrementation Timing

	12.6.2	Contention between TCNT Write and Increment
	12.6.3	Contention between TCOR Write and Compare-Match
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	13.1.2	Block Diagram
	13.1.3	Input and Output Pins
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	13.2	Register Descriptions
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	13.2.4	Edge Sense Register (SEDGR)
	13.2.5	Module Stop Control Register (MSTPCR)
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The H8/2000 CPU has an internal 32-bit architecture, is provided with sixteen 16-bit registers and a concise, optimized instruction set designed for high-speed operation, and address a 16-Mbyte linear address space. The instruction set is upward-compatible with H8/300L and H8/300H CPU instructions at the object-code level, facilitating migration from the H8/300L, or H8/300H Series.

On-chip supporting modules required for system configuration include a data transfer controller (DTC) bus master, ROM and RAM, a 16-bit free-running timer module (FRT), 8-bit timer (TMR), watchdog timer module (WDT), two PWM timers (PWM and PWMX), serial communication interface (SCI), PS/2-compatible keyboard buffer controller, host interface, D/A converter (DAC), A/D converter (ADC), and I/O ports. An I²C bus interface (IIC) is incorporated as an option.

The on-chip ROM is either flash memory (F-ZTAT™*) or mask ROM, with a capacity of 64 kbytes or 64 kbytes. ROM is connected to the CPU via a 16-bit data bus, enabling both byte and word data to be accessed in one state. Instruction fetching has been speeded up, and processing speed increased.

Three operating modes, modes 1 to 3, are provided, and there is a choice of address space in single-chip mode or externally expanded modes.

The features of this LSI are shown in table 1.1.

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

- High-speed arithmetic operations
 - 8/16/32-bit register-register add/subtract: 50 ns (20-MHz op)
 - 16 × 16-bit register-register multiply: 1000 ns (20-MHz op)
 - 32 ÷ 16-bit register-register divide: 1000 ns (20-MHz op)
- Instruction set suitable for high-speed operation
 - Sixty-five basic instructions
 - 8/16/32-bit transfer/arithmetic and logic instructions
 - Unsigned/signed multiply and divide instructions
 - Powerful bit-manipulation instructions
- Two CPU operating modes
 - Normal mode: 64-kbyte address space
 - Advanced mode: 16-Mbyte address space

Operating modes

- Three MCU operating modes

Mode	CPU Operating Mode	Description	On-Chip ROM	External
				Initial Value
1	Normal	Expanded mode with on-chip ROM disabled	Disabled	8 bits
2	Advanced	Single-chip mode	Enabled	None
		Expanded mode with on-chip ROM enabled	Enabled	8 bits
3	Normal	Single-chip mode	Enabled	None
		Expanded mode with on-chip ROM enabled	Enabled	8 bits

	<ul style="list-style-type: none"> Transfer possible in repeat mode, block transfer mode, etc. Request can be sent to CPU for interrupt that activated DT
16-bit free-running timer module (FRT: 1 channel)	<ul style="list-style-type: none"> One 16-bit free-running counter (also usable for external event counting) Two output compare outputs Four input capture inputs (with buffer operation capability)
8-bit timer module (2 channels: TMR0, TMR1)	<p>Each channel has:</p> <ul style="list-style-type: none"> One 8-bit up-counter (also usable for external event counting) Two timer constant registers The two channels can be connected
Timer connection and 8-bit timer module (TMR) (2 channels: TMRX, TMRY) (Timer connection and TMRX provided in H8S/2148 Group)	<p>Input/output and FRT, TMR1, TMRX, TMRY can be interconnected</p> <ul style="list-style-type: none"> Measurement of input signal or frequency-divided waveform width and cycle (FRT, TMR1) Output of waveform obtained by modification of input signal (TMR1) Determination of input signal duty cycle (TMRX) Output of waveform synchronized with input signal (FRT, TMR1, TMRY) Automatic generation of cyclical waveform (FRT, TMRY)
Watchdog timer module (WDT: 2 channels)	<ul style="list-style-type: none"> Watchdog timer or interval timer function selectable Subclock operation capability (channel 1 only)
8-bit PWM timer (PWM) (H8S/2148 Group and H8S/2147N)	<ul style="list-style-type: none"> Up to 16 outputs Pulse duty cycle settable from 0 to 100% Resolution: 1/256 1.25 MHz maximum carrier frequency (20-MHz operation)

SCI with IrDA: 1 channel (SCI2)	<ul style="list-style-type: none"> Asynchronous mode or synchronous mode selectable Multiprocessor communication function Compatible with IrDA specification version 1.0 TxD and RxD encoding/decoding in IrDA format
Keyboard buffer controller (PS2: 3 channels) (H8S/2148 Group, H8S/2147N)	<ul style="list-style-type: none"> Compatible with PS/2 interface Direct manipulation of transmission output by software Receive data input to 8-bit shift register Data receive completed interrupt, parity error detection, stop monitoring
Host interface (HIF) (H8S/2148 Group, H8S/2147N)	<ul style="list-style-type: none"> 8-bit host interface (ISA) port Five host interrupt requests (HIRQ11, HIRQ1, HIRQ12, HIRQ3, HIRQ4) Normal and fast A20 gate output Four register sets (each comprising two data registers and two control registers)
Keyboard controller	<ul style="list-style-type: none"> Matrix keyboard control using keyboard scan with wakeup in keyboard sense port configuration
A/D converter	<ul style="list-style-type: none"> Resolution: 10 bits Input: <ul style="list-style-type: none"> 8 channels (dedicated analog pins) 16 channels (same pins as keyboard sense port) High-speed conversion: 6.7 μs minimum conversion time (200 kHz operation) Single or scan mode selectable Sample-and-hold function A/D conversion can be activated by external trigger or timer

memory

- Flash memory or mask ROM
- High-speed static RAM

Product Name	ROM	RAM
H8S/2144, H8S/2148	128 kbytes	4 kbytes
H8S/2143	96 kbytes	4 kbytes
H8S/2142, H8S/2147, H8S/2147N	64 kbytes	2 kbytes

- Interrupt controller
- Nine external interrupt pins (NMI, $\overline{\text{IRQ0}}$ to $\overline{\text{IRQ7}}$)
 - 44 internal interrupt sources
 - Three priority levels settable

- Power-down state
- Medium-speed mode
 - Sleep mode
 - Module stop mode
 - Software standby mode
 - Hardware standby mode
 - Subclock operation

- Clock pulse generator
- Built-in duty correction circuit

- Packages
- 100-pin plastic QFP (FP-100B)
 - 100-pin plastic TQFP (TFP-100B)

- I²C bus interface
(IIC: 2 channels)
(option in H8S/2148
Group and
H8S/2147N)
- Conforms to Philips I²C bus interface standard
 - Single master mode/slave mode
 - Arbitration lost condition can be identified
 - Supports two slave addresses

	HD6432147S	HD64F2147A	64 k/2 k
	HD6432147SW* ¹	HD64F2147AV* ²	
H8S/2147N	—	HD64F2147N HD64F2147NV* ²	64 k/2 k
H8S/2144	HD6432144S	HD64F2144 HD64F2144V* ² HD64F2144A HD64F2144AV* ²	128 k/4 k
	HD6432143S	—	96 k/4 k
	HD6432142	HD64F2142R HD64F2142RV* ²	64 k/2 k

- Notes: 1. W indicates the I²C bus option.
2. V indicates the 3-V version. Please refer to appendix Code Lineup.

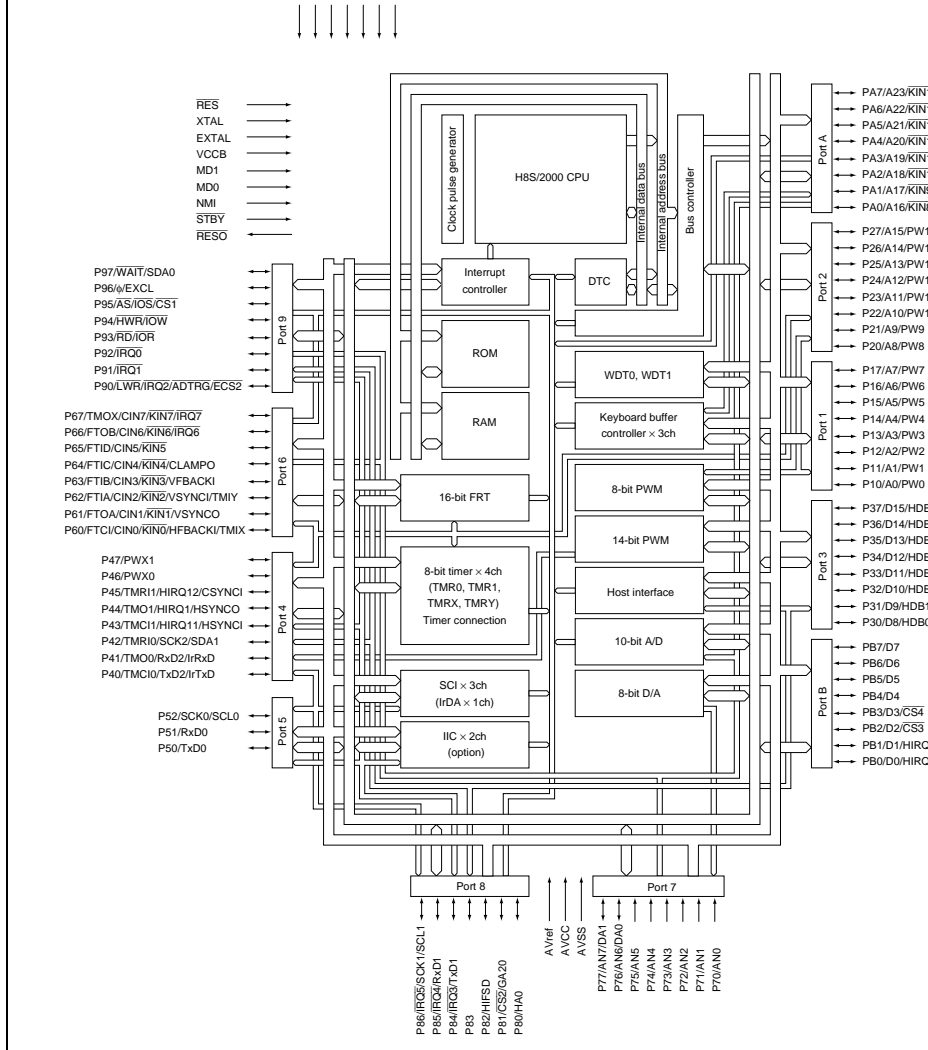


Figure 1.1 (a) Internal Block Diagram of H8S/2148 Group

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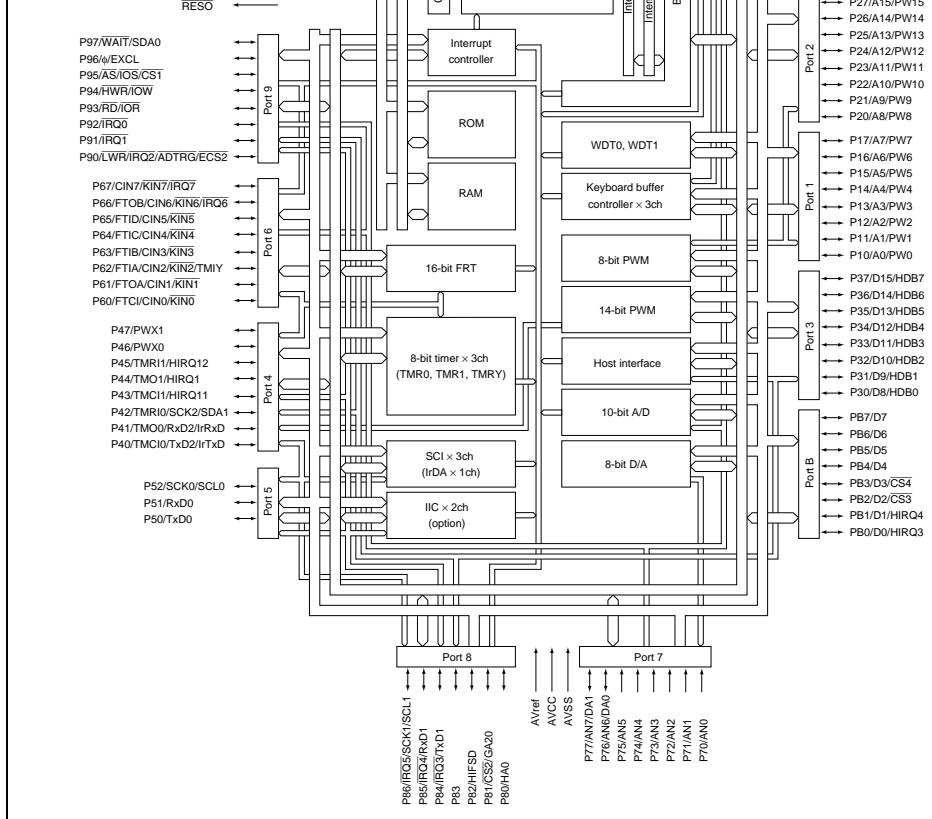


Figure 1.1 (b) Internal Block Diagram of H8S/2147N

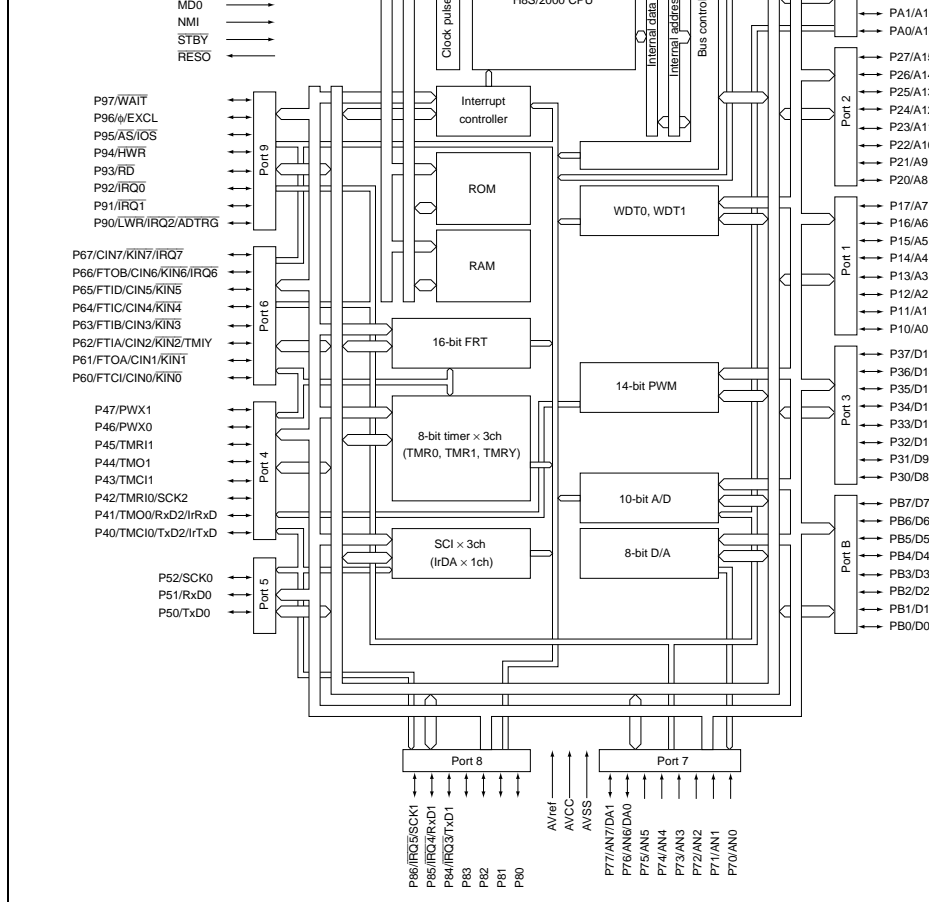


Figure 1.1 (c) Internal Block Diagram of H8S/2144 Group

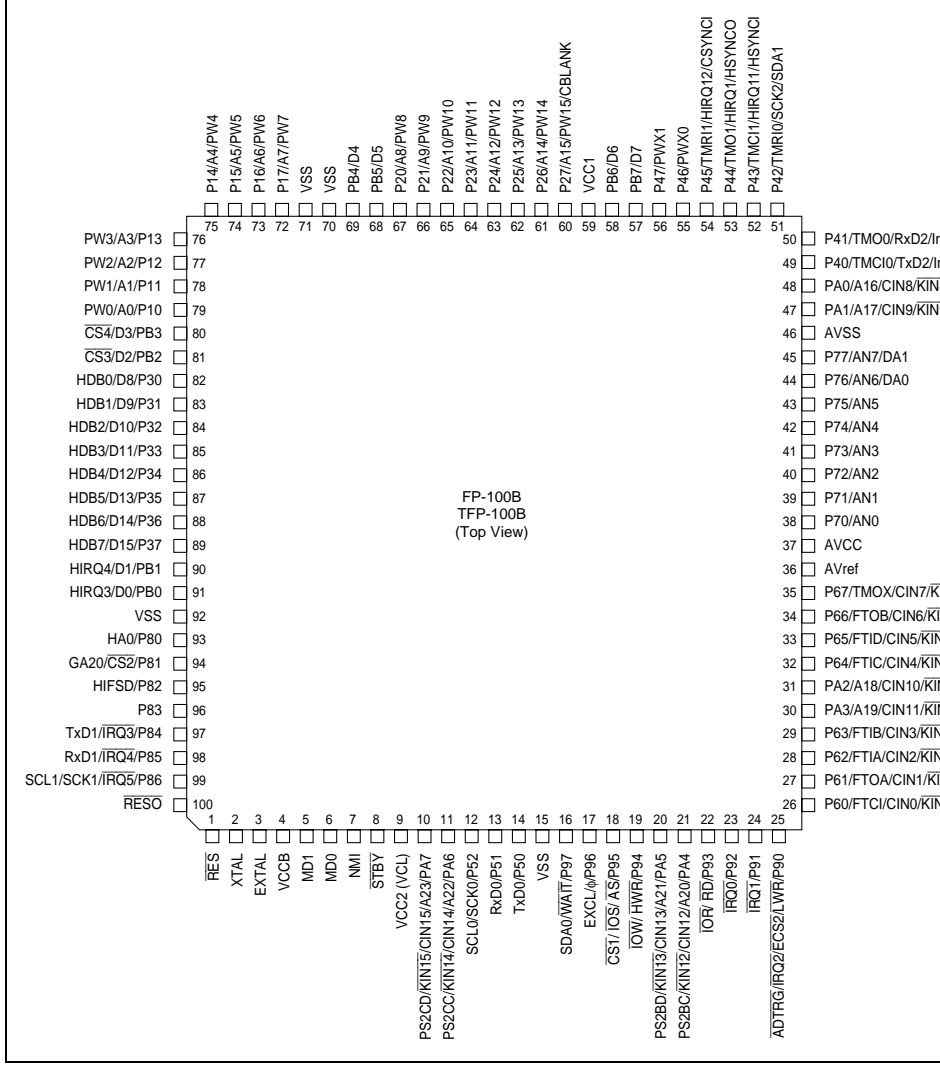


Figure 1.2 (a) Pin Arrangement of H8S/2148 Group (FP-100B, TFP-100B: To

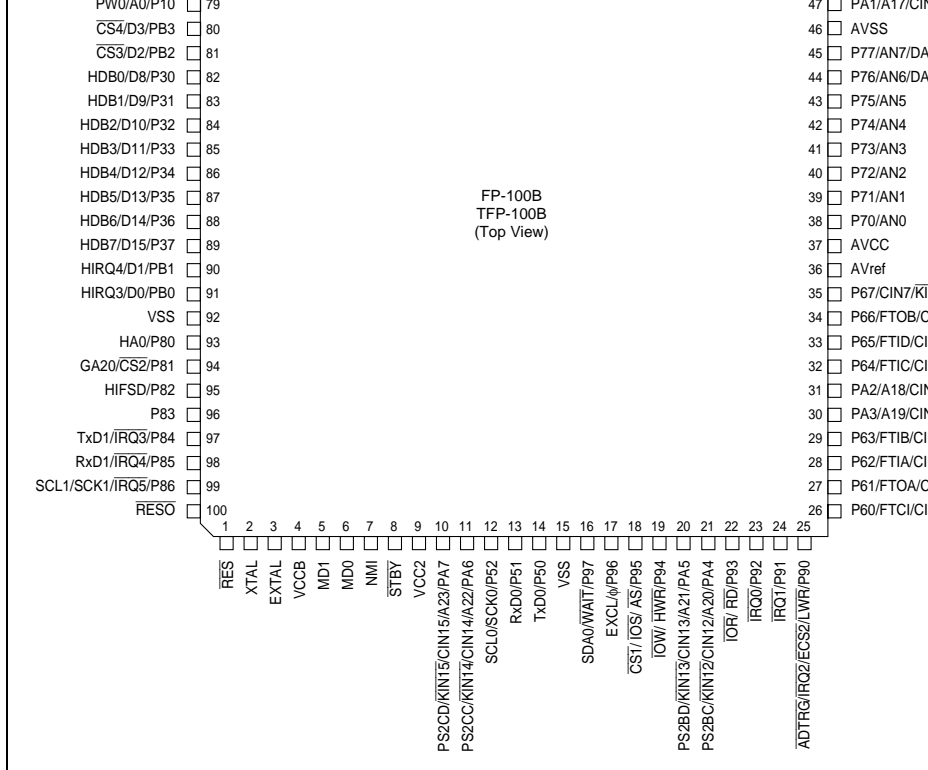


Figure 1.2 (b) Pin Arrangement of H8S/2147N (FP-100B, TFP-100B: Top

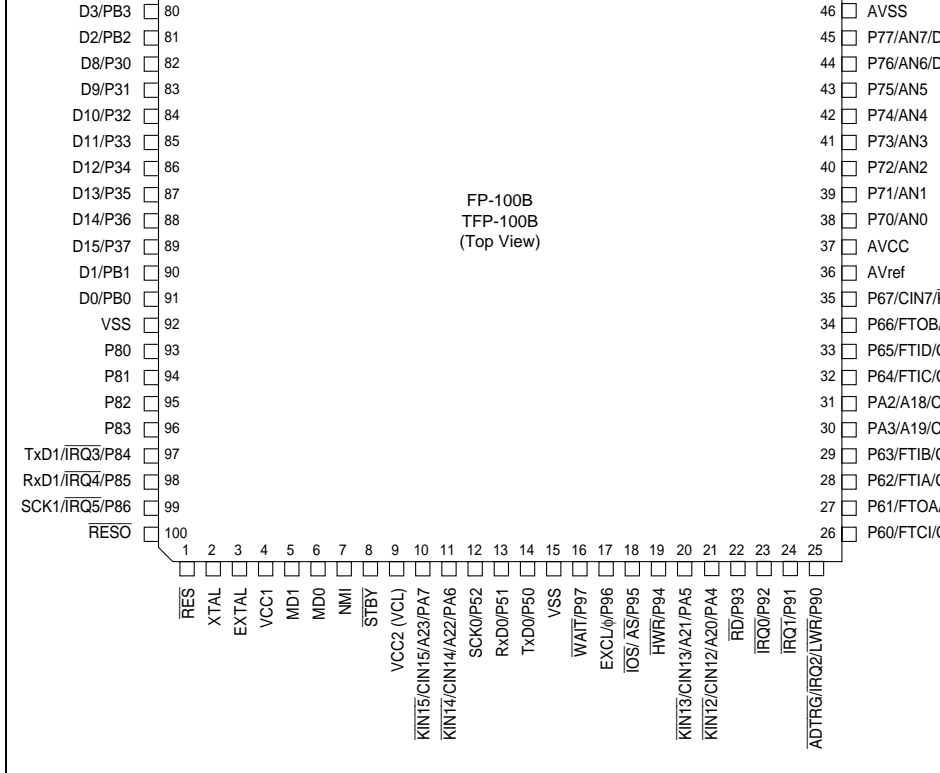


Figure 1.2 (c) Pin Arrangement of H8S/2144 Group (FP-100B, TFP-100B: To

FP-100B TFP-100B	Mode 1	Mode 2 (EXPE = 1)	Mode 2 (EXPE = 0) Mode 3 (EXPE = 0)	Flas Wri
1	RES	RES	RES	RES
2	XTAL	XTAL	XTAL	XTA
3	EXTAL	EXTAL	EXTAL	EXT
4	VCCB	VCCB	VCCB	VCC
5	MD1	MD1	MD1	VSS
6	MD0	MD0	MD0	VSS
7	NMI	NMI	NMI	FA9
8	STBY	STBY	STBY	VCC
9	VCC2 (VCL)	VCC2 (VCL)	VCC2 (VCL)	VCC
10	PA7/CIN15/ KIN15/PS2CD	A23/PA7/CIN15/ KIN15/PS2CD	PA7/CIN15/ KIN15/PS2CD	NC
11	PA6/CIN14/ KIN14/PS2CC	A22/PA6/CIN14/ KIN14/PS2CC	PA6/CIN14/ KIN14/PS2CC	NC
12	P52/SCK0/SCL0	P52/SCK0/SCL0	P52/SCK0/SCL0	NC
13	P51/RxD0	P51/RxD0	P51/RxD0	FA1
14	P50/TxD0	P50/TxD0	P50/TxD0	NC
15	VSS	VSS	VSS	VSS
16	P97/WAIT/SDA0	P97/WAIT/SDA0	P97/SDA0	VCC
17	P96/φ/EXCL	P96/φ/EXCL	P96/φ/EXCL	NC
18	AS/IOS	AS/IOS	P95/CS1	FA1
19	HWR	HWR	P94/IOW	FA1
20	PA5/CIN13/ KIN13/PS2BD	A21/PA5/CIN13/ KIN13/PS2BD	PA5/CIN13/ KIN13/PS2BD	NC
21	PA4/CIN12/ KIN12/PS2BC	A20/PA4/CIN12/ KIN12/PS2BC	PA4/CIN12/ KIN12/PS2BC	NC

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25	LWR/P90/IRQ2/ ADTRG	LWR/P90/IRQ2/ ADTRG	P90/IRQ2/ADTRG/ ECS2	VCC
26	P60/FTCI/CIN0/ KIN0/TMIX/ HFBACKI	P60/FTCI/CIN0/ KIN0/TMIX/ HFBACKI	P60/FTCI/CIN0/ KIN0/TMIX/ HFBACKI	NC
27	P61/FTOA/CIN1/ KIN1/VSYNCO	P61/FTOA/CIN1/ KIN1/VSYNCO	P61/FTOA/CIN1/ KIN1/VSYNCO	NC
28	P62/FTIA/CIN2/ KIN2/TMIY/ VSYNCI	P62/FTIA/CIN2/ KIN2/TMIY/ VSYNCI	P62/FTIA/CIN2/ KIN2/TMIY/ VSYNCI	NC
29	P63/FTIB/CIN3/ KIN3/VFBACKI	P63/FTIB/CIN3/ KIN3/VFBACKI	P63/FTIB/CIN3/ KIN3/VFBACKI	NC
30	PA3/CIN11/ KIN11/PS2AD	A19/PA3/CIN11/ KIN11/PS2AD	PA3/CIN11/ KIN11/PS2AD	NC
31	PA2/CIN10/ KIN10/PS2AC	A18/PA2/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	VSS
36	AVref	AVref	AVref	VCC
37	AVCC	AVCC	AVCC	VCC
38	P70/AN0	P70/AN0	P70/AN0	NC
39	P71/AN1	P71/AN1	P71/AN1	NC
40	P72/AN2	P72/AN2	P72/AN2	NC
41	P73/AN3	P73/AN3	P73/AN3	NC

43	P77/AN7/DA1	P77/AN7/DA1	P77/AN7/DA1	NC
46	AVSS	AVSS	AVSS	VSS
47	PA1/CIN9/KIN9	A17/PA1/CIN9/ KIN9	PA1/CIN9/KIN9	NC
48	PA0/CIN8/KIN8	A16/PA0/CIN8/KIN8	PA0/CIN8/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	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	PB7/D7	PB7	NC
58	PB6/D6	PB6/D6	PB6	NC
59	VCC1	VCC1	VCC1	VCC1
60	A15	A15/P27/PW15/ CBLANK	P27/PW15/ CBLANK	\overline{CE}
61	A14	A14/P26/PW14	P26/PW14	FA1
62	A13	A13/P25/PW13	P25/PW13	FA1
63	A12	A12/P24/PW12	P24/PW12	FA1
64	A11	A11/P23/PW11	P23/PW11	FA1

68	PB3/D3	PB3/D3	PB3	NC
69	PB4/D4	PB4/D4	PB4	NC
70	VSS	VSS	VSS	VSS
71	VSS	VSS	VSS	VSS
72	A7	A7/P17/PW7	P17/PW7	FA7
73	A6	A6/P16/PW6	P16/PW6	FA6
74	A5	A5/P15/PW5	P15/PW5	FA5
75	A4	A4/P14/PW4	P14/PW4	FA4
76	A3	A3/P13/PW3	P13/PW3	FA3
77	A2	A2/P12/PW2	P12/PW2	FA2
78	A1	A1/P11/PW1	P11/PW1	FA1
79	A0	A0/P10/PW0	P10/PW0	FA0
80	PB3/D3	PB3/D3	PB3/ $\overline{CS4}$	NC
81	PB2/D2	PB2/D2	PB2/ $\overline{CS3}$	NC
82	D8	D8	P30/HDB0	FO0
83	D9	D9	P31/HDB1	FO1
84	D10	D10	P32/HDB2	FO2
85	D11	D11	P33/HDB3	FO3
86	D12	D12	P34/HDB4	FO4
87	D13	D13	P35/HDB5	FO5
88	D14	D14	P36/HDB6	FO6
89	D15	D15	P37/HDB7	FO7
90	PB1/D1	PB1/D1	PB1/HIRQ4	NC
91	PB0/D0	PB0/D0	PB0/HIRQ3	NC
92	VSS	VSS	VSS	VSS
93	P80	P80	P80/HA0	NC

97	P84/ $\overline{\text{IRQ5}}$ /RxD1	P84/ $\overline{\text{IRQ5}}$ /RxD1	P84/ $\overline{\text{IRQ5}}$ /RxD1	NC
98	P85/ $\overline{\text{IRQ4}}$ /RxD1	P85/ $\overline{\text{IRQ4}}$ /RxD1	P85/ $\overline{\text{IRQ4}}$ /RxD1	NC
99	P86/ $\overline{\text{IRQ5}}$ /SCK1/ SCL1	P86/ $\overline{\text{IRQ5}}$ /SCK1/ SCL1	P86/ $\overline{\text{IRQ5}}$ /SCK1/ SCL1	NC
100	$\overline{\text{RES0}}$	$\overline{\text{RES0}}$	$\overline{\text{RES0}}$	NC

3	EXTAL	EXTAL	EXTAL	EXTA
4	VCCB	VCCB	VCCB	VCC
5	MD1	MD1	MD1	VSS
6	MD0	MD0	MD0	VSS
7	NMI	NMI	NMI	FA9
8	$\overline{\text{STBY}}$	$\overline{\text{STBY}}$	$\overline{\text{STBY}}$	VCC
9	VCC2	VCC2	VCC2	VCC
10	PA7/CIN15/ $\overline{\text{KIN15/PS2CD}}$	A23/PA7/CIN15/ $\overline{\text{KIN15/PS2CD}}$	PA7/CIN15/ $\overline{\text{KIN15/PS2CD}}$	NC
11	PA6/CIN14/ $\overline{\text{KIN14/PS2CC}}$	A22/PA6/CIN14/ $\overline{\text{KIN14/PS2CC}}$	PA6/CIN14/ $\overline{\text{KIN14/PS2CC}}$	NC
12	P52/SCK0/SCL0	P52/SCK0/SCL0	P52/SCK0/SCL0	NC
13	P51/RxD0	P51/RxD0	P51/RxD0	FA17
14	P50/TxD0	P50/TxD0	P50/TxD0	NC
15	VSS	VSS	VSS	VSS
16	P97/ $\overline{\text{WAIT/SDA0}}$	P97/ $\overline{\text{WAIT/SDA0}}$	P97/SDA0	VCC
17	ϕ /P96/EXCL	ϕ /P96/EXCL	P96/ ϕ /EXCL	NC
18	$\overline{\text{AS/IOS}}$	$\overline{\text{AS/IOS}}$	P95/ $\overline{\text{CS1}}$	FA16
19	$\overline{\text{HWR}}$	$\overline{\text{HWR}}$	P94/ $\overline{\text{IOW}}$	FA15
20	PA5/CIN13/ $\overline{\text{KIN13/PS2BD}}$	A21/PA5/CIN13/ $\overline{\text{KIN13/PS2BD}}$	PA5/CIN13/ $\overline{\text{KIN13/PS2BD}}$	NC
21	PA4/CIN12/ $\overline{\text{KIN12/PS2BC}}$	A20/PA4/CIN12/ $\overline{\text{KIN12/PS2BC}}$	PA4/CIN12/ $\overline{\text{KIN12/PS2BC}}$	NC
22	$\overline{\text{RD}}$	$\overline{\text{RD}}$	P93/ $\overline{\text{IOR}}$	$\overline{\text{WE}}$
23	P92/ $\overline{\text{IRQ0}}$	P92/ $\overline{\text{IRQ0}}$	P92/ $\overline{\text{IRQ0}}$	VSS
24	P91/ $\overline{\text{IRQ1}}$	P91/ $\overline{\text{IRQ1}}$	P91/ $\overline{\text{IRQ1}}$	VCC

27	P61/FTOA/CIN1/ KIN1	P61/FTOA/CIN1/ KIN1	P61/FTOA/CIN1/ KIN1	NC
28	P62/FTIA/CIN2/ KIN2/TMIY	P62/FTIA/CIN2/ KIN2/TMIY	P62/FTIA/CIN2/ KIN2/TMIY	NC
29	P63/FTIB/CIN3/ KIN3	P63/FTIB/CIN3/ KIN3	P63/FTIB/CIN3/ KIN3	NC
30	PA3/CIN11/ KIN11/PS2AD	A19/PA3/CIN11/ KIN11/PS2AD	PA3/CIN11/ KIN11/PS2AD	NC
31	PA2/CIN10/ KIN10/PS2AC	A18/PA2/CIN10/ KIN10/PS2AC	PA2/CIN10/ KIN10/PS2AC	NC
32	P64/FTIC/CIN4/ KIN4	P64/FTIC/CIN4/ KIN4	P64/FTIC/CIN4/ KIN4	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/CIN7/KIN7/ IRQ7	P67/CIN7/KIN7/ IRQ7	P67/CIN7/KIN7/ IRQ7	VSS
36	AVref	AVref	AVref	VCC
37	AVCC	AVCC	AVCC	VCC
38	P70/AN0	P70/AN0	P70/AN0	NC
39	P71/AN1	P71/AN1	P71/AN1	NC
40	P72/AN2	P72/AN2	P72/AN2	NC
41	P73/AN3	P73/AN3	P73/AN3	NC
42	P74/AN4	P74/AN4	P74/AN4	NC
43	P75/AN5	P75/AN5	P75/AN5	NC
44	P76/AN6/DA0	P76/AN6/DA0	P76/AN6/DA0	NC
45	P77/AN7/DA1	P77/AN7/DA1	P77/AN7/DA1	NC

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	P42/TMRI0/ SCK2/SDA1	P42/TMRI0/ SCK2/SDA1	P42/TMRI0/ SCK2/SDA1	NC
52	P43/TMCI1	P43/TMCI1	P43/TMCI1/HIRQ11	NC
53	P44/TMO1	P44/TMO1	P44/TMO1/HIRQ1	NC
54	P45/TMRI1	P45/TMRI1	P45/TMRI1/HIRQ12	NC
55	P46/PWX0	P46/PWX0	P46/PWX0	NC
56	P47/PWX1	P47/PWX1	P47/PWX1	NC
57	PB7/D7	PB7/D7	PB7	NC
58	PB6/D6	PB6/D6	PB6	NC
59	VCC1	VCC1	VCC1	VCC
60	A15	A15/P27/PW15	P27/PW15	\overline{CE}
61	A14	A14/P26/PW14	P26/PW14	FA14
62	A13	A13/P25/PW13	P25/PW13	FA13
63	A12	A12/P24/PW12	P24/PW12	FA12
64	A11	A11/P23/PW11	P23/PW11	FA11
65	A10	A10/P22/PW10	P22/PW10	FA10
66	A9	A9/P21/PW9	P21/PW9	\overline{OE}
67	A8	A8/P20/PW8	P20/PW8	FA8
68	PB5/D5	PB5/D5	PB5	NC
69	PB4/D4	PB4/D4	PB4	NC
70	VSS	VSS	VSS	VSS
71	VSS	VSS	VSS	VSS

75	A4	A4/P14/PW4	P14/PW4	FA4
76	A3	A3/P13/PW3	P13/PW3	FA3
77	A2	A2/P12/PW2	P12/PW2	FA2
78	A1	A1/P11/PW1	P11/PW1	FA1
79	A0	A0/P10/PW0	P10/PW0	FA0
80	PB3/D3	PB3/D3	PB3/ $\overline{CS4}$	NC
81	PB2/D2	PB2/D2	PB2/ $\overline{CS3}$	NC
82	D8	D8	P30/HDB0	FO0
83	D9	D9	P31/HDB1	FO1
84	D10	D10	P32/HDB2	FO2
85	D11	D11	P33/HDB3	FO3
86	D12	D12	P34/HDB4	FO4
87	D13	D13	P35/HDB5	FO5
88	D14	D14	P36/HDB6	FO6
89	D15	D15	P37/HDB7	FO7
90	PB1/D1	PB1/D1	PB1/HIRQ4	NC
91	PB0/D0	PB0/D0	PB0/HIRQ3	NC
92	VSS	VSS	VSS	VSS
93	P80	P80	P80/HA0	NC
94	P81	P81	P81/ $\overline{CS2}$ /GA20	NC
95	P82	P82	P82/HIFSD	NC
96	P83	P83	P83	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	P86/ $\overline{IRQ5}$ /SCK1/ SCL1	P86/ $\overline{IRQ5}$ /SCK1/ SCL1	P86/ $\overline{IRQ5}$ /SCK1/ SCL1	NC
100	$\overline{RES0}$	$\overline{RES0}$	$\overline{RES0}$	NC

3	EXTAL	EXTAL	EXTAL	EXTAL
4	VCC1	VCC1	VCC1	VCC1
5	MD1	MD1	MD1	VSS
6	MD0	MD0	MD0	VSS
7	NMI	NMI	NMI	FA9
8	$\overline{\text{STBY}}$	$\overline{\text{STBY}}$	$\overline{\text{STBY}}$	VCC1
9	VCC2 (VCL)	VCC2 (VCL)	VCC2 (VCL)	VCC1
10	PA7/CIN15/ $\overline{\text{KIN15}}$	A23/PA7/CIN15/ $\overline{\text{KIN15}}$	PA7/CIN15/ $\overline{\text{KIN15}}$	NC
11	PA6/CIN14/ $\overline{\text{KIN14}}$	A22/PA6/CIN14/ $\overline{\text{KIN14}}$	PA6/CIN14/ $\overline{\text{KIN14}}$	NC
12	P52/SCK0	P52/SCK0	P52/SCK0	NC
13	P51/RxD0	P51/RxD0	P51/RxD0	FA17
14	P50/TxD0	P50/TxD0	P50/TxD0	NC
15	VSS	VSS	VSS	VSS
16	P97/ $\overline{\text{WAIT}}$	P97/ $\overline{\text{WAIT}}$	P97	VCC1
17	ϕ /P96/EXCL	ϕ /P96/EXCL	P96/ ϕ /EXCL	NC
18	$\overline{\text{AS}}/\overline{\text{IOS}}$	$\overline{\text{AS}}/\overline{\text{IOS}}$	P95	FA16
19	$\overline{\text{HWR}}$	$\overline{\text{HWR}}$	P94	FA15
20	PA5/CIN13/ $\overline{\text{KIN13}}$	A21/PA5/CIN13/ $\overline{\text{KIN13}}$	PA5/CIN13/ $\overline{\text{KIN13}}$	NC
21	PA4/CIN12/ $\overline{\text{KIN12}}$	A20/PA4/CIN12/ $\overline{\text{KIN12}}$	PA4/CIN12/ $\overline{\text{KIN12}}$	NC
22	$\overline{\text{RD}}$	$\overline{\text{RD}}$	P93	$\overline{\text{WE}}$
23	P92/ $\overline{\text{IRQ0}}$	P92/ $\overline{\text{IRQ0}}$	P92/ $\overline{\text{IRQ0}}$	VSS
24	P91/ $\overline{\text{IRQ1}}$	P91/ $\overline{\text{IRQ1}}$	P91/ $\overline{\text{IRQ1}}$	VCC1

27	P61/FTOA/ CIN1/KIN1	P61/FTOA/CIN1/ KIN1	P61/FTOA/CIN1/ KIN1	NC
28	P62/FTIA/CIN2/ KIN2/TMIY	P62/FTIA/CIN2/ KIN2/TMIY	P62/FTIA/CIN2/ KIN2/TMIY	NC
29	P63/FTIB/CIN3/ KIN3	P63/FTIB/CIN3/ KIN3	P63/FTIB/CIN3/ KIN3	NC
30	PA3/CIN11/ KIN11	A19/PA3/CIN11/ KIN11	PA3/CIN11/ KIN11	NC
31	PA2/CIN10/ KIN10	A18/PA2/CIN10/ KIN10	PA2/CIN10/ KIN10	NC
32	P64/FTIC/CIN4/ KIN4	P64/FTIC/CIN4/ KIN4	P64/FTIC/CIN4/ KIN4	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/CIN7/KIN7/ IRQ7	P67/CIN7/KIN7/ IRQ7	P67/CIN7/KIN7/ IRQ7	VSS
36	AVref	AVref	AVref	VCC
37	AVCC	AVCC	AVCC	VCC
38	P70/AN0	P70/AN0	P70/AN0	NC
39	P71/AN1	P71/AN1	P71/AN1	NC
40	P72/AN2	P72/AN2	P72/AN2	NC
41	P73/AN3	P73/AN3	P73/AN3	NC
42	P74/AN4	P74/AN4	P74/AN4	NC
43	P75/AN5	P75/AN5	P75/AN5	NC
44	P76/AN6/DA0	P76/AN6/DA0	P76/AN6/DA0	NC
45	P77/AN7/DA1	P77/AN7/DA1	P77/AN7/DA1	NC

49	P40/TMC10/ TxD2/IrTxD	P40/TMC10/ TxD2/IrTxD	P40/TMC10/ TxD2/IrTxD	NC
50	P41/TMO0/ RxD2/IrRxD	P41/TMO0/ RxD2/IrRxD	P41/TMO0/ RxD2/IrRxD	NC
51	P42/TMRI0/ SCK2	P42/TMRI0/ SCK2	P42/TMRI0/ SCK2	NC
52	P43/TMCI1	P43/TMCI1	P43/TMCI1	NC
53	P44/TMO1	P44/TMO1	P44/TMO1	NC
54	P45/TMRI1	P45/TMRI1	P45/TMRI1	NC
55	P46/PWX0	P46/PWX0	P46/PWX0	NC
56	P47/PWX1	P47/PWX1	P47/PWX1	NC
57	PB7/D7	PB7/D7	PB7	NC
58	PB6/D6	PB6/D6	PB6	NC
59	VCC1	VCC1	VCC1	VCC
60	A15	A15/P27	P27	\overline{CE}
61	A14	A14/P26	P26	FA14
62	A13	A13/P25	P25	FA13
63	A12	A12/P24	P24	FA12
64	A11	A11/P23	P23	FA11
65	A10	A10/P22	P22	FA10
66	A9	A9/P21	P21	\overline{OE}
67	A8	A8/P20	P20	FA8
68	PB5/D5	PB5/D5	PB5	NC
69	PB4/D4	PB4/D4	PB4	NC
70	VSS	VSS	VSS	VSS
71	VSS	VSS	VSS	VSS

75	A4	A4/P14	P14	FA4
76	A3	A3/P13	P13	FA3
77	A2	A2/P12	P12	FA2
78	A1	A1/P11	P11	FA1
79	A0	A0/P10	P10	FA0
80	PB3/D3	PB3/D3	PB3	NC
81	PB2/D2	PB2/D2	PB2	NC
82	D8	D8	P30	FO8
83	D9	D9	P31	FO9
84	D10	D10	P32	FO10
85	D11	D11	P33	FO11
86	D12	D12	P34	FO12
87	D13	D13	P35	FO13
88	D14	D14	P36	FO14
89	D15	D15	P37	FO15
90	PB1/D1	PB1/D1	PB1	NC
91	PB0/D0	PB0/D0	PB0	NC
92	VSS	VSS	VSS	VSS
93	P80	P80	P80	NC
94	P81	P81	P81	NC
95	P82	P82	P82	NC
96	P83	P83	P83	NC
97	P84/ $\overline{\text{IRQ3}}$ /TxD1	P84/ $\overline{\text{IRQ3}}$ /TxD1	P84/ $\overline{\text{IRQ3}}$ /TxD1	NC
98	P85/ $\overline{\text{IRQ4}}$ /RxD1	P85/ $\overline{\text{IRQ4}}$ /RxD1	P85/ $\overline{\text{IRQ4}}$ /RxD1	NC
99	P86/ $\overline{\text{IRQ5}}$ /SCK1	P86/ $\overline{\text{IRQ5}}$ /SCK1	P86/ $\overline{\text{IRQ5}}$ /SCK1	NC
100	$\overline{\text{RES0}}$	$\overline{\text{RES0}}$	$\overline{\text{RES0}}$	NC

Power supply	VCC1	4 [H8S/2144 Group only], 59	Input	Power supply: For connection to the power supply. All VCC1 and VCC2* pins should be connected to the system power supply.
	VCC2	9*		
	VCL	9*	Input	
	VCCB	4 [H8S/2148 Group and H8S/2147N only]	Input	Input/output buffer power supply: Power supply for the port A input/output buffer.
	VSS	15, 70, 71, 92	Input	Ground: All VSS pins should be connected to the system power supply (0 V).
Clock	XTAL	2	Input	Connected to a crystal oscillator. See section 26, Clock Pulse Generator, for typical connection diagrams for a crystal oscillator and external input.
	EXTAL	3	Input	Connected to a crystal oscillator. The E2 can also input an external clock. See section 26, Clock Pulse Generator, for typical connection diagrams for a crystal oscillator and external input.
	ϕ	17	Output	System clock: Supplies the system clock to external devices.
	EXCL	17	Input	External subclock input: Input a 32.768 kHz external subclock.

MD1	MD0	Mode	Description
0	1	Mode 1	Normal Expanded mo on-chip ROM
1	0	Mode 2	Advanced Expanded mo on-chip ROM single-chip m
1	1	Mode 3	Normal Expanded mo on-chip ROM single-chip m

System control	$\overline{\text{RES}}$	1	Input	Reset input: When this pin is driven low, the device enters reset.
	$\overline{\text{RESO}}$	100	Output	Reset output: Outputs reset signal to the device.
	$\overline{\text{STBY}}$	8	Input	Standby: When this pin is driven low, the device is made to hardware standby mode.
Address bus	A23 to A16	10, 11, 20, 21, 30, 31, 47, 48	Output	Address bus (advanced): Outputs address for 16-Mbyte space is used.
	A15 to A0	60 to 67, 72 to 79	Output	Address bus: These pins output an address for 16-Mbyte space is used.
Data bus	D15 to D8	89 to 82	Input/output	Data bus (upper): Bidirectional data bus. Used for 8-bit data and upper byte of 16-bit data.
	D7 to D0	57, 58, 68, 69, 80, 81, 90, 91	Input/output	Data bus (lower): Bidirectional data bus. Used for lower byte of 16-bit data.

	HWR	19	Output	High write: When this pin is low, it indicates the external address space is being written. The upper half of the data bus is valid.
	LWR	25	Output	Low write: When this pin is low, it indicates the external address space is being written. The lower half of the data bus is valid.
	AS/IOS	18	Output	Address strobe: When this pin is low, it indicates that address output on the address bus is valid.
Interrupt signals	NMI	7	Input	Nonmaskable interrupt: Requests a non-maskable interrupt.
	$\overline{\text{IRQ0}}$ to $\overline{\text{IRQ7}}$	23 to 25, 97 to 99, 34, 35	Input	Interrupt request 0 to 7: These pins request a maskable interrupt.
16-bit free-running timer (FRT)	FTCI	26	Input	FRT counter clock input: Input pin for the free-running counter clock signal.
	FTOA	27	Output	FRT output compare A output: The output pin for compare A output.
	FTOB	34	Output	FRT output compare B output: The output pin for compare B output.
	FTIA	28	Input	FRT input capture A input: The input pin for capture A input.
	FTIB	29	Input	FRT input capture B input: The input pin for capture B input.
	FTIC	32	Input	FRT input capture C input: The input pin for capture C input.
	FTID	33	Input	FRT input capture D input: The input pin for capture D input.

	TMRI0	51	Input	Counter external reset input: TMRO counter reset input pins.
	TMRI1	54		
	TMIX	26	Input	Counter external clock input and reset: Dual function as TMRX and TMRY counter input pin and reset input pin.
	TMIY	28		
PWM timer (PWM)	PW15 to PW0	60 to 67, 72 to 79	Output	PWM timer output: PWM timer pulse
14-bit PWM timer (PWMX)	PWX0 PWX1	55 56	Output	PWMX timer output: PWM D/A pulse
Serial communication interface (SCI0, SCI1, SCI2)	TxD0	14	Output	Transmit data: Data output pins.
	TxD1	97		
	TxD2	49		
	RxD0	13	Input	Receive data: Data input pins.
	RxD1	98		
	RxD2	50		
	SCK0	12	Input/output	Serial clock: Clock input/output pins. The SCK0 output type is NMOS push-pull in the H8S/2148 Group and H8S/2147N, and open-drain in the H8S/2144 Group.
	SCK1	99		
	SCK2	51		
SCI with IrDA (SCI2)	IrTxD	49	Output	IrDA transmit data/receive data: Input/output pins for data encoded for IrDA use.
	IrRxD	50	Input	
Keyboard Buffer controller (PS2)	PS2AC	31	Input/output	PS2 clock: Keyboard buffer controller synchronization clock input/output pins.
	PS2BC	21		
	PS2CC	11		
	PS2AD	30	Input/output	PS2 data: Keyboard buffer controller data input/output pins.
	PS2BD	20	Output	
	PS2CD	10		

	<u>CS4</u>				
	<u>IOR</u>	22	Input	I/O read: Input pin that enables reading host interface.	
	<u>IOW</u>	19	Input	I/O write: Input pin that enables writing interface.	
	HA0	93	Input	Command/data: Input pin that indicates an access is a data access or command.	
	GA20	94	Output	GATE A20: A20 gate control signal output.	
	HIRQ11	52	Output	Host interrupt 11, 1, 12, 3, and 4: Output interrupt requests to the host.	
	HIRQ1	53			
	HIRQ12	54			
	HIRQ3	91			
	HIRQ4	90			
	HIFSD	95	Input	Host interface shutdown: Control input to place host interface input/output pins in impedance/cutoff state.	
Keyboard control	<u>KIN0</u> to	26 to 29, 32 to 35, 48, 47, 31, 30, 21, 20, 11, 10	Input	Keyboard input: Matrix keyboard input. Normally, P10 to P17 and P20 to P27 are key-scan outputs. This enables a maximum output × 16-input, 256-key matrix to be connected.	
	<u>KIN15</u>				
A/D converter (ADC)	AN7 to AN0	45 to 38	Input	Analog input: A/D converter analog input.	
	CIN0 to CIN15	26 to 29, 32 to 35, 48, 47, 31, 30, 21, 20, 11, 10	Input	Expansion A/D inputs: Expansion A/D inputs can be connected to the A/D converter, but they are also used as digital input/output pins. If used as digital input/output pins, precision will fall.	
	<u>ADTRG</u>	25	Input	A/D conversion external trigger input: Input of an external trigger to start A/D conversion.	

D/A converter				When the A/D and D/A converters are used, the AVref pin should be connected to the system power supply (+5 V or +3 V).
	AVref	36	Input	Analog reference voltage: The reference voltage supply pin for the A/D converter and D/A converter. When the A/D and D/A converters are used, this pin should be connected to the system power supply (+5 V or +3 V).
	AVSS	46	Input	Analog ground: The ground pin for the A/D converter and D/A converter. This pin should be connected to the system power supply ground.
Timer connection	VSYNCI, HSYNCI, CSYNCI, VFBACKI, HFBACKI	28, 52, 54, 29, 26	Input	Timer connection input: Timer connection synchronous signal input pins.
	VSYNCO, HSYNCO, CLAMPO, CBLANK	27, 53, 32, 60	Output	Timer connection output: Timer connection synchronous signal output pins.
I ² C bus interface (IIC) (option)	SCL0, SCL1	12, 99	Input/output	I²C clock input/output (channels 0 and 1): I ² C clock I/O pins. These pins have a bus drive function. The SCL0 output form is NMOS open-drain.
	SDA0, SDA1	16, 51	Input/output	I²C data input/output (channels 0 and 1): I ² C data I/O pins. These pins have a bus drive function. The SDA0 output form is NMOS open-drain.

P28 to P30	85 to 87	Input/output	Each pin can be selected in the port 2 data direction register (P2DDR). These pins have built-in input pull-ups, and also have LED drive capability.
P37 to P39	89 to 91	Input/output	Port 3: Eight input/output pins. The data direction of each pin can be selected in the port 3 data direction register (P3DDR). These pins have built-in input pull-ups, and also have LED drive capability.
P47 to P49	56 to 58	Input/output	Port 4: Eight input/output pins. The data direction of each pin can be selected in the port 4 data direction register (P4DDR).
P52 to P54	12 to 14	Input/output	Port 5: Three input/output pins. The data direction of each pin can be selected in the port 5 data direction register (P5DDR). P52 is an N-channel push-pull output in the H8S/2148 Group and H8S/2147N, and is a CMOS output in the H8S/2144 Group.
P67 to P69	35 to 37 29 to 31	Input/output	Port 6: Eight input/output pins. The data direction of each pin can be selected in the port 6 data direction register (P6DDR). These pins have built-in input pull-ups.
P77 to P79	45 to 47 38 to 40	Input	Port 7: Eight input pins.
P86 to P88	99 to 101	Input/output	Port 8: Seven input/output pins. The data direction of each pin can be selected in the port 8 data direction register (P8DDR).
P97 to P99	16 to 18 22 to 24	Input/output	Port 9: Eight input/output pins. The data direction of each pin (except P96) can be selected in the port 9 data direction register (P9DDR). P97 is an N-channel push-pull output in the H8S/2148 Group and H8S/2147N, and is a CMOS output in the H8S/2144 Group.

PB0 69, 80, 81, 90, 91 output of each pin can be selected in the port direction register (PBDDR). These pins have MOS input pull-ups.

Note: * In F-ZTAT and mask ROM versions of HD64F2148A, HD64F2147A, HD64F2148S, HD6432148SW, HD6432147S, HD6432147SW, HD6432148S, HD6432143S pin NO.9 is VCL pin and is not VCC pin.

2.1.1 Features

The H8S/2000 CPU has the following features.

- Upward-compatible with H8/300 and H8/300H CPUs
 - Can execute H8/300 and H8/300H object programs
- General-register architecture
 - Sixteen 16-bit general registers (also usable as sixteen 8-bit registers or eight 32-bit registers)
- Sixty-five basic instructions
 - 8/16/32-bit arithmetic and logic instructions
 - Multiply and divide instructions
 - Powerful bit-manipulation instructions
- Eight addressing modes
 - Register direct [Rn]
 - Register indirect [@ERn]
 - Register indirect with displacement [@(d:16,ERn) or @(d:32,ERn)]
 - Register indirect with post-increment or pre-decrement [@ERn+ or @-ERn]
 - Absolute address [@aa:8, @aa:16, @aa:24, or @aa:32]
 - Immediate [#xx:8, #xx:16, or #xx:32]
 - Program-counter relative [@(d:8,PC) or @(d:16,PC)]
 - Memory indirect [@@aa:8]
- 16-Mbyte address space
 - Program: 16 Mbytes
 - Data: 16 Mbytes (4 Gbytes architecturally)

— 32 ÷ 16-bit register-register divide: 1000 ns

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

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

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

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

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

There are also differences in the address space, EXR register functions, power-down state, and other features depending on the product.

- Advanced mode supports a maximum 16-Mbyte address space.
- Enhanced addressing
 - The addressing modes have been enhanced to make effective use of the 16-Mb space.
- Enhanced instructions
 - Addressing modes of bit-manipulation instructions have been enhanced.
 - Signed multiply and divide instructions have been added.
 - Two-bit shift instructions have been added.
 - Instructions for saving and restoring multiple registers have been added.
 - A test and set instruction has been added.
- Higher speed
 - Basic instructions execute twice as fast.

2.1.4 Differences from H8/300H CPU

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

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

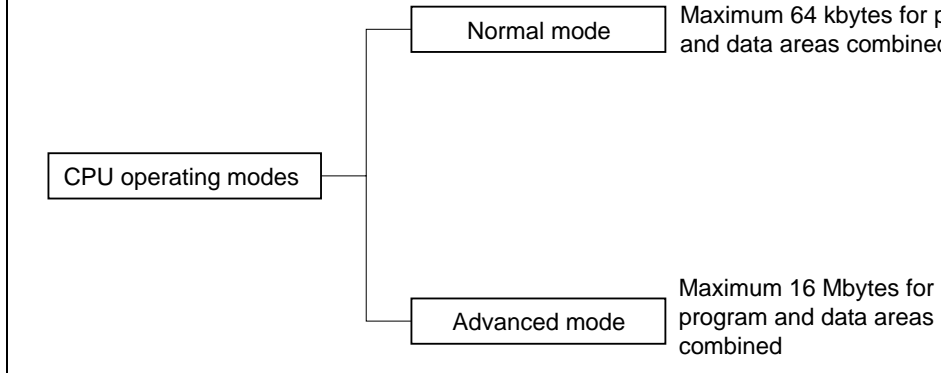


Figure 2.1 CPU Operating Modes

(1) Normal Mode

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

Address Space: A maximum address space of 64 kbytes can be accessed.

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

Instruction Set: All instructions and addressing modes can be used. Only the lower 16-bit effective addresses (EA) are valid.

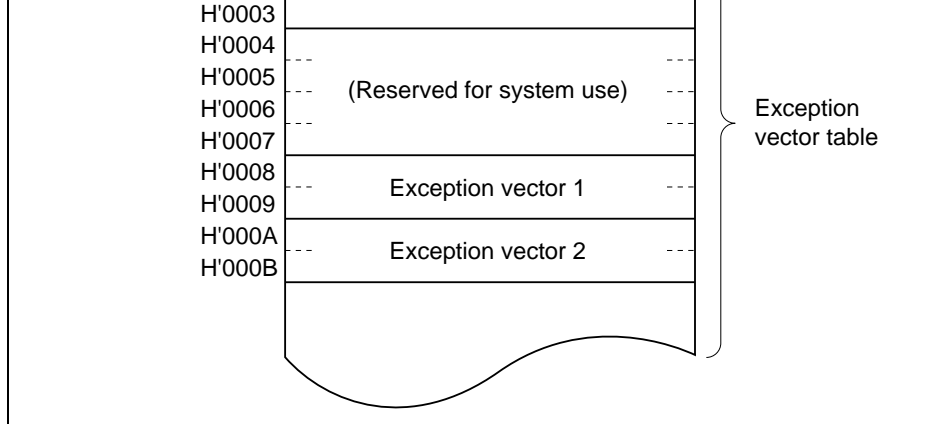


Figure 2.2 Exception Vector Table (Normal Mode)

The memory indirect addressing mode (@@aa:8) employed in the JMP and JSR instructions uses an 8-bit absolute address included in the instruction code to specify a memory operand. This operand contains a branch address. In normal mode the operand is a 16-bit word operand, providing a 16-bit branch address. Branch addresses can be stored in the top area from H'0000 to H'000B, and that this area is also used for the exception vector table.

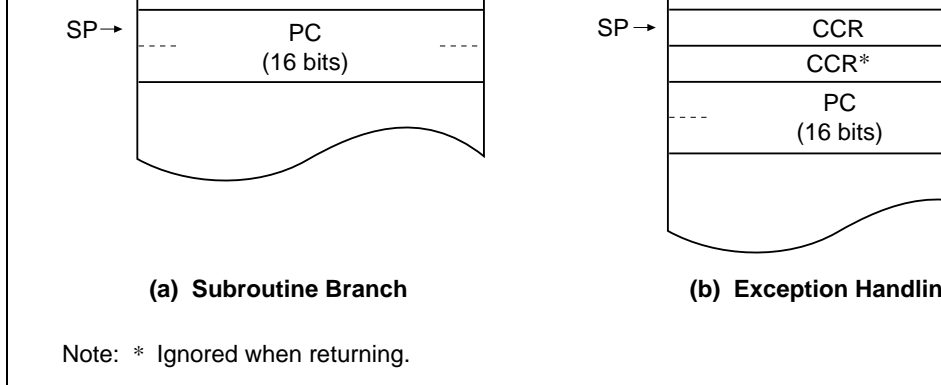


Figure 2.3 Stack Structure in Normal Mode

(2) Advanced Mode

Address Space: Linear access is provided to a 16-Mbyte maximum address space (architecturally divided into a maximum 16-Mbyte program area and a maximum 4-Gbyte data area, with a maximum of 4 Gbytes for program and data areas combined).

Extended Registers (En): The extended registers (E0 to E7) can be used as 16-bit registers or as the upper 16-bit segments of 32-bit registers or address registers.

Instruction Set: All instructions and addressing modes can be used.

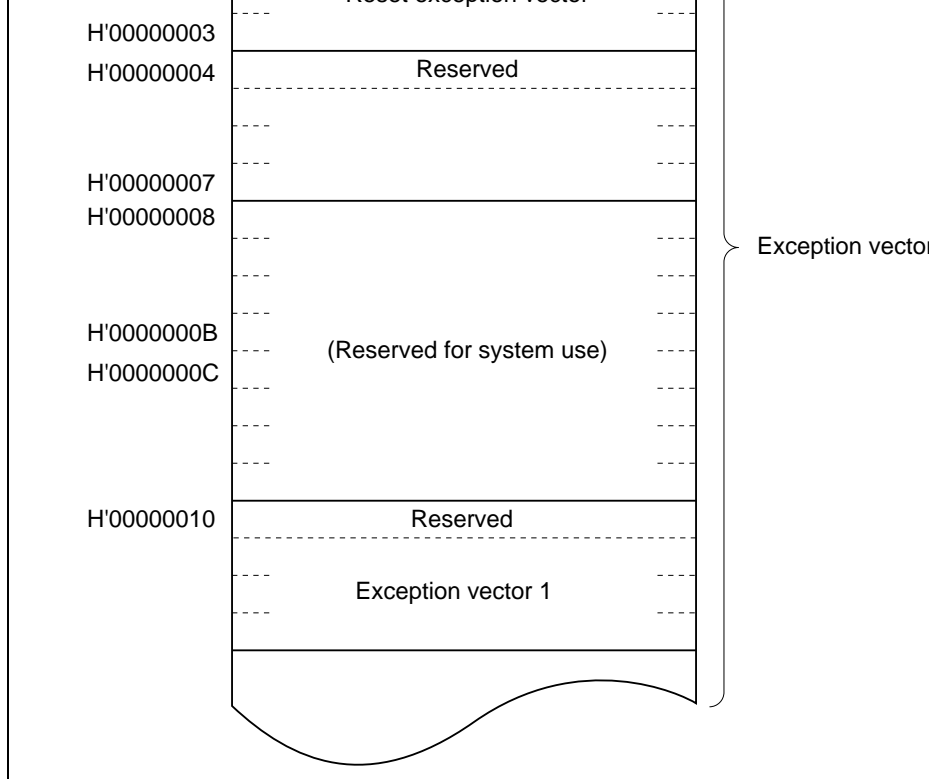


Figure 2.4 Exception Vector Table (Advanced Mode)

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

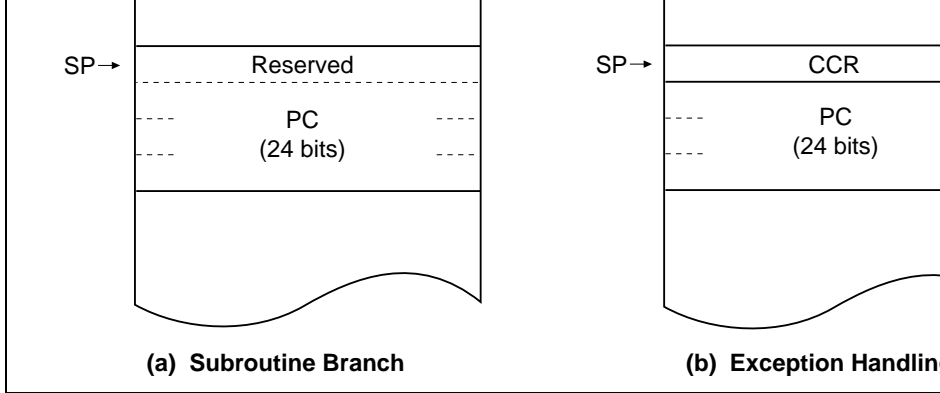


Figure 2.5 Stack Structure in Advanced Mode

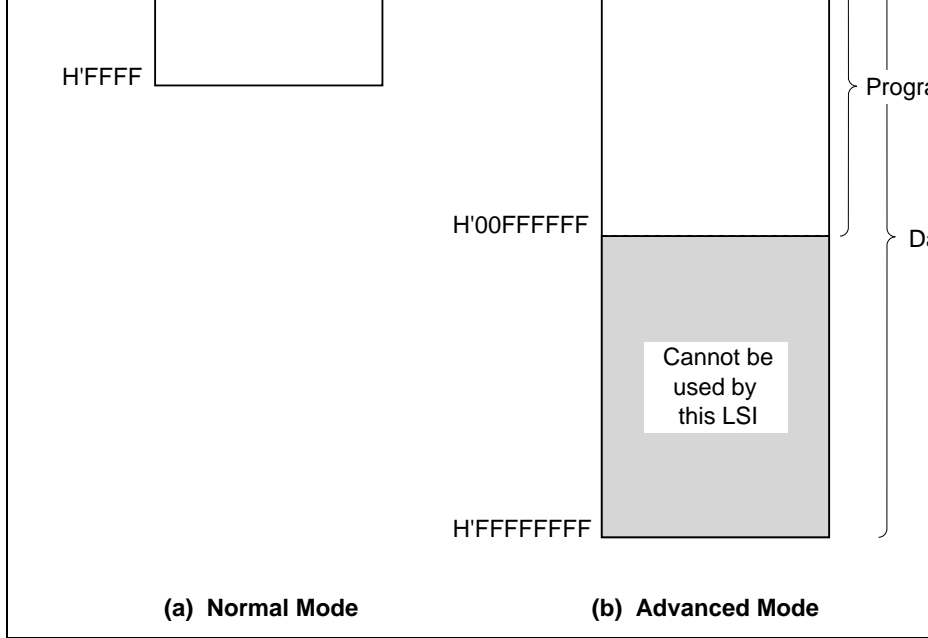
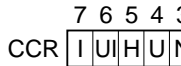
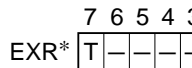
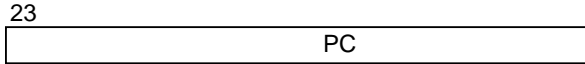


Figure 2.6 Memory Map

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

Control Registers (CR)



Legend:

SP:	Stack pointer	H:	Half-carry flag
PC:	Program counter	U:	User bit
EXR:	Extended control register	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 2.7 CPU Registers

registers. The E registers (E0 to E7) are also referred to as extended registers.

The R registers divide into 8-bit general registers designated by the letters RH (R0H to R7H) and RL (R0L to R7L). These registers are functionally equivalent, providing a maximum of 16 8-bit registers.

Figure 2.8 illustrates the usage of the general registers. The usage of each register can be used independently.

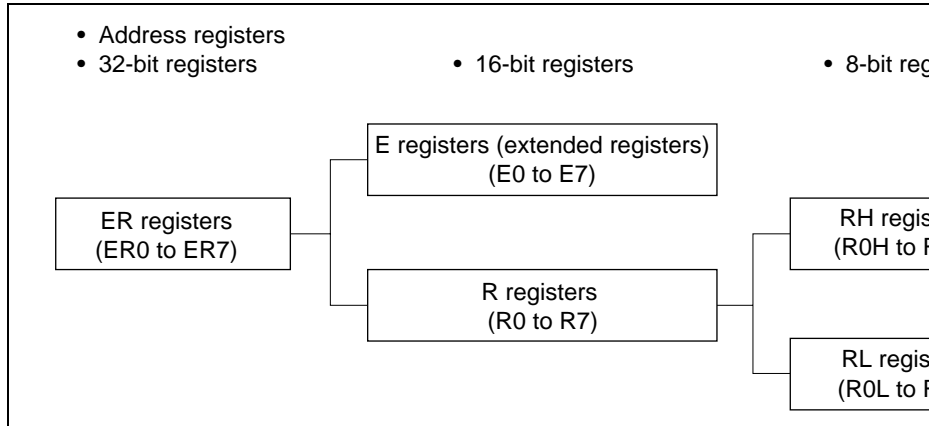


Figure 2.8 Usage of General Registers

General register ER7 has the function of stack pointer (SP) in addition to its general-register function, and is used implicitly in exception handling and subroutine calls. Figure 2.9 shows the stack.

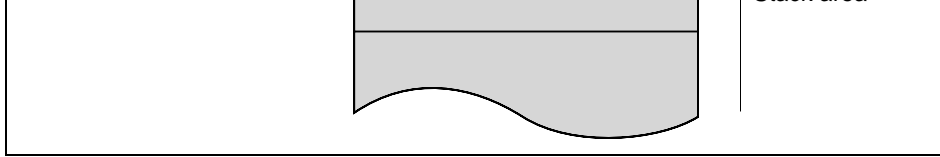


Figure 2.9 Stack

2.4.3 Control Registers

The control registers are the 24-bit program counter (PC), 8-bit extended control register (EXR) and 8-bit condition-code register (CCR).

(1) Program Counter (PC)

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

(2) Extended Control Register (EXR)

An 8-bit register. In this LSI, this register does not affect operation.

Bit 7—Trace Bit (T): This bit is reserved. In this LSI, this bit does not affect operation.

Bits 6 to 3—Reserved: These bits are reserved. They are always read as 1.

Bits 2 to 0—Interrupt Mask Bits (I2 to I0): These bits are reserved. In this LSI, these bits do not affect operation.

Bit 6—User Bit or Interrupt Mask Bit (UI): Can be written and read by software using the LDC, STC, ANDC, ORC, and XORC instructions. This bit can also be used as an interrupt bit. For details, refer to section 5, Interrupt Controller.

Bit 5—Half-Carry Flag (H): When the ADD.B, ADDX.B, SUB.B, SUBX.B, CMP.B, or CMPL.B instruction is executed, this flag is set to 1 if there is a carry or borrow at bit 3, and cleared to 0 otherwise. When the ADD.W, SUB.W, CMP.W, or NEG.W instruction is executed, the H flag is set to 1 if there is a carry or borrow at bit 11, and cleared to 0 otherwise. When the ADD.L, SUB.L, CMP.L, or NEG.L instruction is executed, the H flag is set to 1 if there is a carry or borrow at bit 27, and cleared to 0 otherwise.

Bit 4—User Bit (U): Can be written and read by software using the LDC, STC, ANDC, ORC, and XORC instructions.

Bit 3—Negative Flag (N): Stores the value of the most significant bit (sign bit) of data.

Bit 2—Zero Flag (Z): Set to 1 to indicate zero data, and cleared to 0 to indicate non-zero data.

Bit 1—Overflow Flag (V): Set to 1 when an arithmetic overflow occurs, and cleared to 0 otherwise.

Bit 0—Carry Flag (C): Set to 1 when a carry occurs, and cleared to 0 otherwise. Use the following instructions to set or clear the carry flag:

- Add instructions, to indicate a carry
- Subtract instructions, to indicate a borrow
- Shift and rotate instructions, to store the carry

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

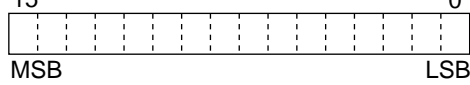
Some instructions leave some or all of the flag bits unchanged. For the action of each instruction on the flag bits, refer to appendix A.1, Instruction.

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

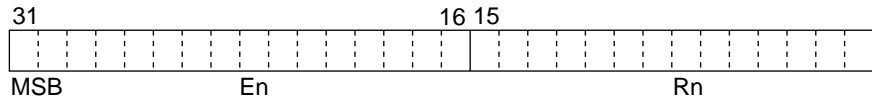
Figure 2.10 shows the data formats in general registers.

Data Type	General Register	Data Format
1-bit data	RnH	
1-bit data	RnL	
4-bit BCD data	RnH	
4-bit BCD data	RnL	
Byte data	RnH	
Byte data	RnL	

Figure 2.10 General Register Data Formats



Longword data ERn



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 2.10 General Register Data Formats (cont)

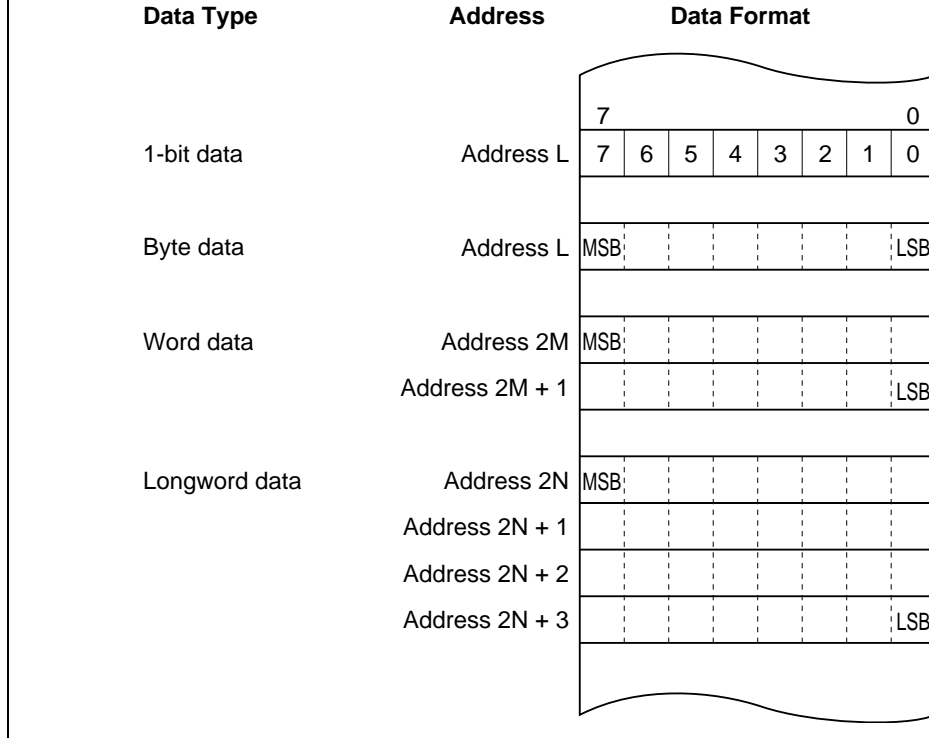


Figure 2.11 Memory Data Formats

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

Function	Instructions	Size
Data transfer	MOV	BW
	POP ^{*1} , PUSH ^{*1}	WL
	LDM ^{*5} , STM ^{*5}	L
	MOVFP ^{*3} , MOVTPE ^{*3}	B
Arithmetic operations	ADD, SUB, CMP, NEG	BW
	ADDX, SUBX, DAA, DAS	B
	INC, DEC	BW
	ADDS, SUBS	L
	MULXU, DIVXU, MULXS, DIVXS	BW
	EXTU, EXTS	WL
	TAS ^{*4}	B
Logic operations	AND, OR, XOR, NOT	BW
Shift	SHAL, SHAR, SHLL, SHLR, ROTL, ROTR, ROTXL, ROTXR	BW
Bit-manipulation	BSET, BCLR, BNOT, BTST, BLD, BILD, BST, BIST, BAND, B 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	—

Legend: B: Byte
W: Word
L: Longword

- 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 and MOV.L @-SP.
2. Bcc is the general name for conditional branch instructions.
3. Cannot be used in this LSI.
4. Only register ER0, ER1, ER4, or ER5 should be used when using the TAS instruction.
5. Only registers ER0 to ER6 should be used when using the STM/LDM instructions.

Function	Instruction	#xx	Rn	@ERn	@(d:16,ERn)	@(d:32, ERn)	@-ERn/@EI	@aa:8	@aa:16	@aa:24	@aa:32	@(d:8, PC)	@(d:16, PC)
Data transfer	MOV	BWL	BWL	BWL	BWL	BWL	BWL	B	BWL	—	BWL	—	—
	POP, PUSH	—	—	—	—	—	—	—	—	—	—	—	—
	LDM ^{*3} , STM ^{*3}	—	—	—	—	—	—	—	—	—	—	—	—
	MOVFPEx ^{*1} , MOVTPE ^{*1}	—	—	—	—	—	—	—	B	—	—	—	—
Arithmetic operations	ADD, CMP	BWL	BWL	—	—	—	—	—	—	—	—	—	—
	SUB	WL	BWL	—	—	—	—	—	—	—	—	—	—
	ADDX, SUBX	B	B	—	—	—	—	—	—	—	—	—	—
	ADDS, SUBS	—	L	—	—	—	—	—	—	—	—	—	—
	INC, DEC	—	BWL	—	—	—	—	—	—	—	—	—	—
	DAA, DAS	—	B	—	—	—	—	—	—	—	—	—	—
	MULXU, DIVXU	—	BW	—	—	—	—	—	—	—	—	—	—
	MULXS, DIVXS	—	BW	—	—	—	—	—	—	—	—	—	—
	NEG	—	BWL	—	—	—	—	—	—	—	—	—	—
	EXTU, EXTS	—	WL	—	—	—	—	—	—	—	—	—	—
	TAS ^{*2}	—	—	B	—	—	—	—	—	—	—	—	—
Logic operations	AND, OR, XOR	BWL	BWL	—	—	—	—	—	—	—	—	—	—
	NOT	—	BWL	—	—	—	—	—	—	—	—	—	—
Shift		—	BWL	—	—	—	—	—	—	—	—	—	
Bit-manipulation		—	B	B	—	—	—	B	B	—	B	—	
Branch	Bcc, BSR	—	—	—	—	—	—	—	—	—	—	○	○
	JMP, JSR	—	—	—	—	—	—	—	—	○	—	—	—
	RTS	—	—	—	—	—	—	—	—	—	—	—	—

	LDC	B	B	W	W	W	W	—	W	—	W	—	—
	STC	—	B	W	W	W	W	—	W	—	W	—	—
	ANDC, ORC, XORC	B	—	—	—	—	—	—	—	—	—	—	—
	NOP	—	—	—	—	—	—	—	—	—	—	—	—
Block data transfer		—	—	—	—	—	—	—	—	—	—	—	—

Legend:

B: Byte

W: Word

L: Longword

- Notes:
1. Cannot be used in this LSI.
 2. Only register ER0, ER1, ER4, or ER5 should be used when using the TAS instruction.
 3. Only registers ER0 to ER6 should be used when using the STM/LDM instructions.

Rn	General register [*]
ERn	General register (32-bit register)
(EAd)	Destination operand
(EAs)	Source operand
EXR	Extended control register
CCR	Condition-code register
N	N (negative) flag in CCR
Z	Z (zero) flag in CCR
V	V (overflow) flag in CCR
C	C (carry) flag in CCR
PC	Program counter
SP	Stack pointer
#IMM	Immediate data
disp	Displacement
+	Addition
−	Subtraction
×	Multiplication
÷	Division
^	Logical AND
∨	Logical OR
⊕	Logical exclusive OR
→	Move
¬	NOT (logical complement)
:8/:16/:24/:32	8-, 16-, 24-, or 32-bit length
Note:	* General registers include 8-bit registers (R0H to R7H, R0L to R7L), 16-bit registers (R8 to R7, E0 to E7), and 32-bit registers (ER0 to ER7).

POP	W/L	<p>@SP+ → Rn Pops a general register from the stack. POP.W Rn is identical to MOV.W @SP+, Rn. POP.L ERn is identical to MOV.L @SP+, ERn.</p>
PUSH	W/L	<p>Rn → @-SP Pushes a general register onto the stack. PUSH.W Rn is identical to MOV.W Rn, @-SP. PUSH.L ERn is identical to MOV.L ERn, @-SP.</p>
LDM ^{*3}	L	<p>@SP+ → Rn (register list) Pops two or more general registers from the stack.</p>
STM ^{*3}	L	<p>Rn (register list) → @-SP Pushes two or more general registers onto the stack.</p>

in two general registers, or on immediate data in a general register.

INC DEC	B/W/L	$Rd \pm 1 \rightarrow Rd$, $Rd \pm 2 \rightarrow Rd$ Increments or decrements a general register. (Byte operands can be incremented or decremented by 1 only.)
ADDS SUBS	L	$Rd \pm 1 \rightarrow Rd$, $Rd \pm 2 \rightarrow Rd$, $Rd \pm 4 \rightarrow Rd$ Adds or subtracts the value 1, 2, or 4 to or from a 32-bit register.
DAA DAS	B	Rd decimal adjust $\rightarrow Rd$ Decimal-adjusts an addition or subtraction result in a general register by referring to the CCR to perform BCD data.
MULXU	B/W	$Rd \times Rs \rightarrow Rd$ Performs unsigned multiplication on data in two general registers: either 8 bits \times 8 bits \rightarrow 16 bits or 16 bits \rightarrow 32 bits.
MULXS	B/W	$Rd \times Rs \rightarrow Rd$ Performs signed multiplication on data in two general registers: either 8 bits \times 8 bits \rightarrow 16 bits or 16 bits \rightarrow 32 bits.
DIVXU	B/W	$Rd \div Rs \rightarrow Rd$ Performs unsigned division on data in two general registers: either 16 bits \div 8 bits \rightarrow 8-bit quotient and 8-bit remainder or 32 bits \div 16 bits \rightarrow 16-bit quotient and 16-bit remainder.

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

	NOT	B/W/L	\neg (Rd) \rightarrow (Rd) Takes the one's complement (logical complement) of the general register contents.
Shift operations	SHAL SHAR	B/W/L	Rd (shift) \rightarrow Rd Performs an arithmetic shift on general register contents. A 1-bit or 2-bit shift is possible.
	SHLL SHLR	B/W/L	Rd (shift) \rightarrow Rd Performs a logical shift on general register contents. A 1-bit or 2-bit shift is possible.
	ROTL ROTR	B/W/L	Rd (rotate) \rightarrow Rd Rotates general register contents. 1-bit or 2-bit rotation is possible.
	ROTXL ROTXR	B/W/L	Rd (rotate) \rightarrow Rd Rotates general register contents through the carry flag. 1-bit or 2-bit rotation is possible.

immediate data or the lower three bits of a general register.

BNOT	B	\neg (<bit-No.> of <EAd>) \rightarrow (<bit-No.> of <EAd>) Inverts a specified bit in a general register or memory operand. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BTST	B	\neg (<bit-No.> of <EAd>) \rightarrow Z Tests a specified bit in a general register or memory operand and sets or clears the Z flag according to the result. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BAND	B	$C \wedge$ (<bit-No.> of <EAd>) \rightarrow C ANDs the carry flag with a specified bit in a general register or memory operand and stores the result in the carry flag.
BIAND	B	$C \wedge \neg$ (<bit-No.> of <EAd>) \rightarrow C ANDs the carry flag with the inverse of a specified bit in a general register or memory operand and stores the result in the carry flag. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BOR	B	$C \vee$ (<bit-No.> of <EAd>) \rightarrow C ORs the carry flag with a specified bit in a general register or memory operand and stores the result in the carry flag.
BIOR	B	$C \vee \neg$ (<bit-No.> of <EAd>) \rightarrow C ORs the carry flag with the inverse of a specified bit in a general register or memory operand and stores the result in the carry flag. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.

		The bit number is specified by 3-bit immediate
BLD	B	(<bit-No.> of <EAd>) → C Transfers a specified bit in a general register or memory operand to the carry flag.
BILD	B	\neg (<bit-No.> of <EAd>) → C Transfers the inverse of a specified bit in a general register or memory operand to the carry flag. The bit number is specified by 3-bit immediate
BST	B	C → (<bit-No.> of <EAd>) Transfers the carry flag value to a specified general register or memory operand.
BIST	B	\neg C → (<bit-No.> of <EAd>) Transfers the inverse of the carry flag value to a specified bit in a general register or memory operand. The bit number is specified by 3-bit immediate

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 ⊕ Z
BLT	Less than	N ⊕ Z
BGT	Greater than	Z ∨ (N ⊕ Z)
BLE	Less or equal	Z ∨ (N ⊕ Z)

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

STC	B/W	CCR \rightarrow (EAd), EXR \rightarrow (EAd) Transfers CCR or EXR contents to a general purpose memory. Although CCR and EXR are 8-bit registers, word-size transfers are performed between registers and memory. The upper 8 bits are valid.
ANDC	B	CCR \wedge #IMM \rightarrow CCR, EXR \wedge #IMM \rightarrow EXR Logically ANDs the CCR or EXR contents with immediate data.
ORC	B	CCR \vee #IMM \rightarrow CCR, EXR \vee #IMM \rightarrow EXR Logically ORs the CCR or EXR contents with immediate data.
XORC	B	CCR \oplus #IMM \rightarrow CCR, EXR \oplus #IMM \rightarrow EXR Logically exclusive-ORs the CCR or EXR contents with immediate data.
NOP	—	PC + 2 \rightarrow PC Only increments the program counter.

Until R4 = 0

else next;

Block transfer instruction. Transfers the number of bytes specified by R4L or R4 from locations starting at the address indicated by ER5 to locations starting at the address indicated by ER6. After the transfer, the instruction is executed.

Notes: 1. Size refers to the operand size.

B: Byte

W: Word

L: Longword

2. Only register ER0, ER1, ER4, or ER5 should be used when using the TAS instruction.
3. Only registers ER0 to ER6 should be used when using the STM/LDM instructions.

2.6.4 Basic Instruction Formats

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

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

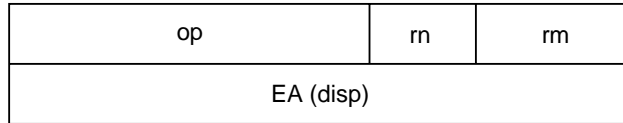
Register Field: Specifies a general register. Address registers are specified by 3 bits, data registers by 3 bits or 4 bits. Some instructions have two register fields. Some have no register fields.

Effective Address Extension: Eight, 16, or 32 bits specifying immediate data, an absolute address, or a displacement.

Condition Field: Specifies the branching condition of Bcc instructions.

Figure 2.12 shows examples of instruction formats.

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



MOV.B @(d:16, R

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



BRA d:16, etc

Figure 2.12 Instruction Formats (Examples)

2.6.5 Notes on Use of Bit-Manipulation Instructions

The BSET, BCLR, BNOT, BST, and BIST instructions read a byte of data, carry out bit manipulation, then write back the byte of data. Caution is therefore required when using these instructions on a register containing write-only bits, or a port.

The BCLR instruction can be used to clear internal I/O register flags to 0. In this case, the flag need not be read beforehand if it is clear that it has been set to 1 in an interrupt handling routine, etc.

2.7 Addressing Modes and Effective Address Calculation

2.7.1 Addressing Mode

The CPU supports the eight addressing modes listed in table 2.4. Each instruction uses one or more of these addressing modes. Arithmetic and logic instructions can use the register direct and immediate modes. Data transfer instructions can use all addressing modes except program counter relative and memory indirect. Bit-manipulation instructions use register direct, register

3	Register indirect with displacement	@(d:16,ERn)/@(d:32,ERn)
4	Register indirect with post-increment Register indirect with pre-decrement	@ERn+ @-ERn
5	Absolute address	@aa:8/@aa:16/@aa:24/@aa:32
6	Immediate	#xx:8/#xx:16/#xx:32
7	Program-counter relative	@(d:8,PC)/@(d:16,PC)
8	Memory indirect	@@aa:8

Register Direct—Rn

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

Register Indirect—@ERn

The register field of the instruction code specifies an address register (ERn) which contains the address of the operand in memory. If the address is a program instruction address, the 16 bits are valid and the upper 8 bits are all assumed to be 0 (H'00).

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

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

- Register indirect with pre-decrement—@-ERn

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

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

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

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

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

Table 2.5 indicates the accessible absolute address ranges.

Table 2.5 Absolute Address Access Ranges

Absolute Address		Normal Mode	Advanced Mode
Data address	8 bits (@aa:8)	H'FF00 to H'FFFF	H'FFFF00 to H'FFFFFF
	16 bits (@aa:16)	H'0000 to H'FFFF	H'000000 to H'0000FF H'FF8000 to H'FFFFFF
	32 bits (@aa:32)		H'000000 to H'FFFFFF
Program instruction address	24 bits (@aa:24)		

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

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

Memory Indirect—@@aa:8

This mode can be used by the JMP and JSR instructions. The instruction code contains an absolute address specifying a memory operand. This memory operand contains a branch address. The upper bits of the absolute address are all assumed to be 0, so the address range is 0 to 255 (H'0000 to H'00FF in normal mode, H'000000 to H'0000FF in advanced mode). In normal mode, the memory operand is a word operand and the branch address is 16 bits long. In advanced mode, the memory operand is a longword operand, the first byte of which is assumed to be all 0s.

Note that the first part of the address range is also the exception vector area. For further details, refer to section 4, Exception Handling.

(a) Normal Mode

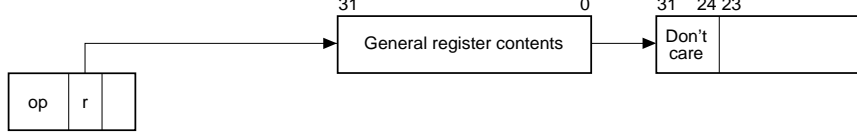
(b) Advanced Mode

Figure 2.13 Branch Address Specification in Memory Indirect Mode

If an odd address is specified in word or longword memory access, or as a branch address, the least significant bit is regarded as 0, causing data to be accessed or an instruction code to be fetched at the address preceding the specified address. (For further information, see Section 2.7.1 Memory Data Formats.)

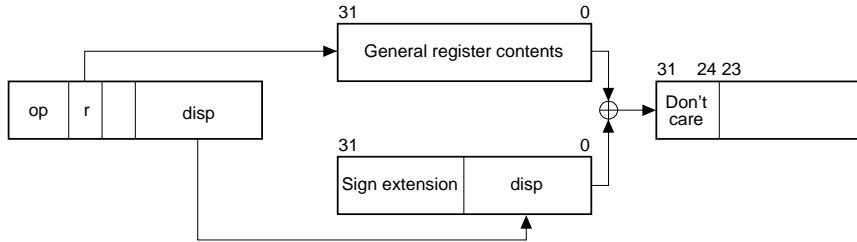
2.7.2 Effective Address Calculation

Table 2.6 indicates how effective addresses are calculated in each addressing mode. In indirect mode the upper 8 bits of the effective address are ignored in order to generate a 16-bit



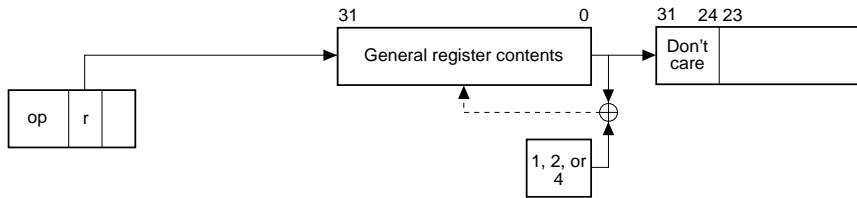
3 Register indirect with displacement

@(d:16, ERn) or @(d:32, ERn)

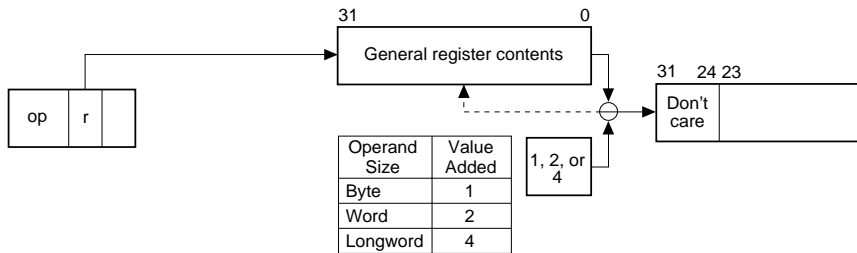


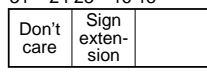
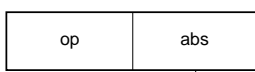
4 Register indirect with post-increment or pre-decrement

- Register indirect with post-increment @ERn+

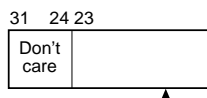
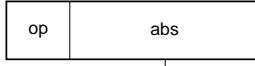


- Register indirect with pre-decrement @-ERn

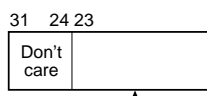




@aa:24

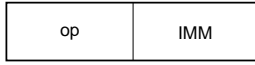


@aa:32

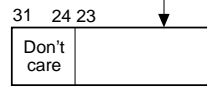
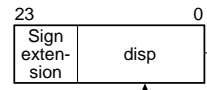
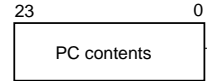


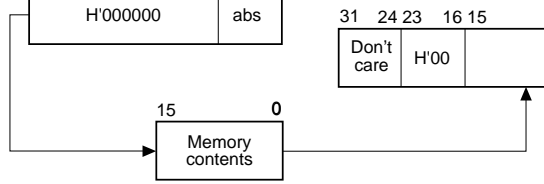
6 Immediate #xx:8/#xx:16/#xx:32

Operand is imm

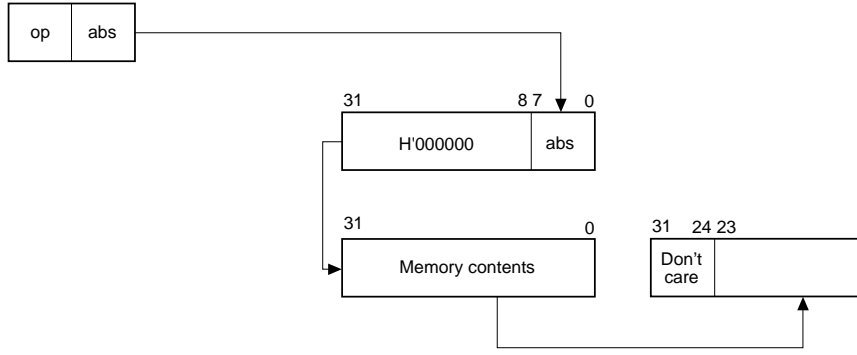


7 Program-counter relative
@(d:8, PC)/@(d:16, PC)





- Advanced mode



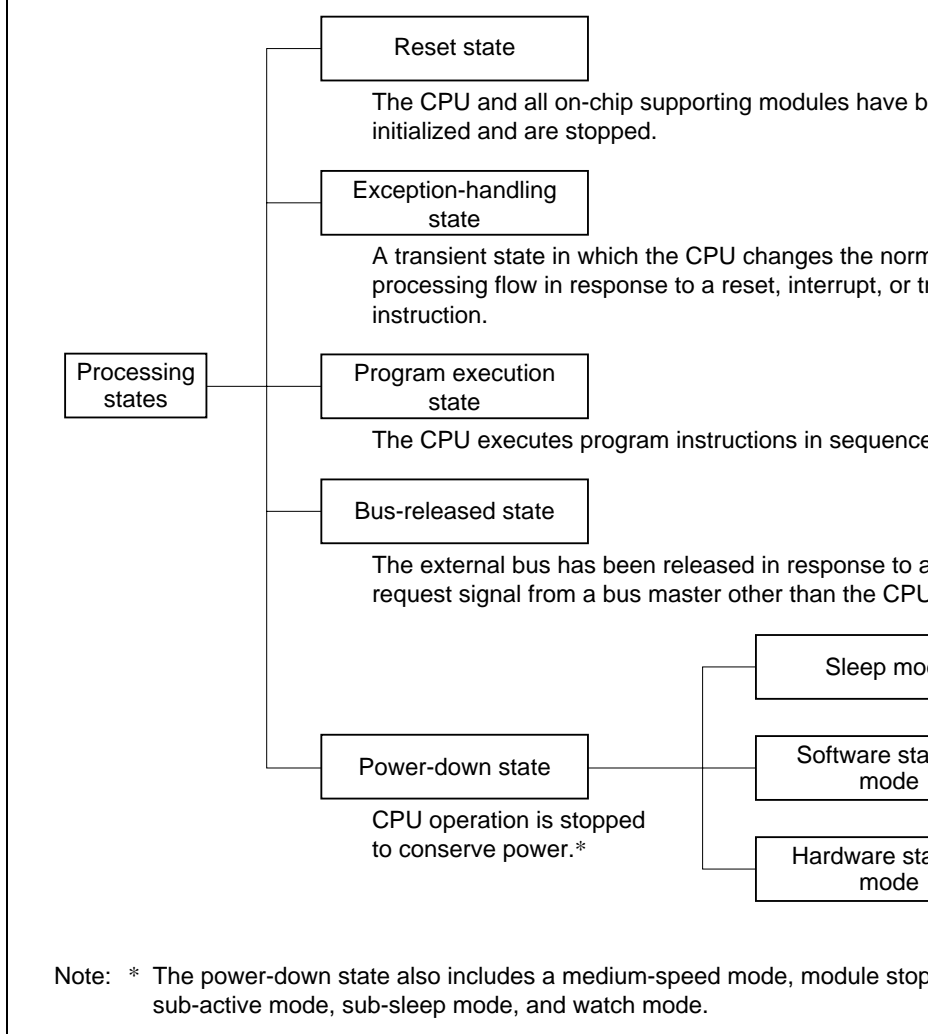


Figure 2.14 Processing States

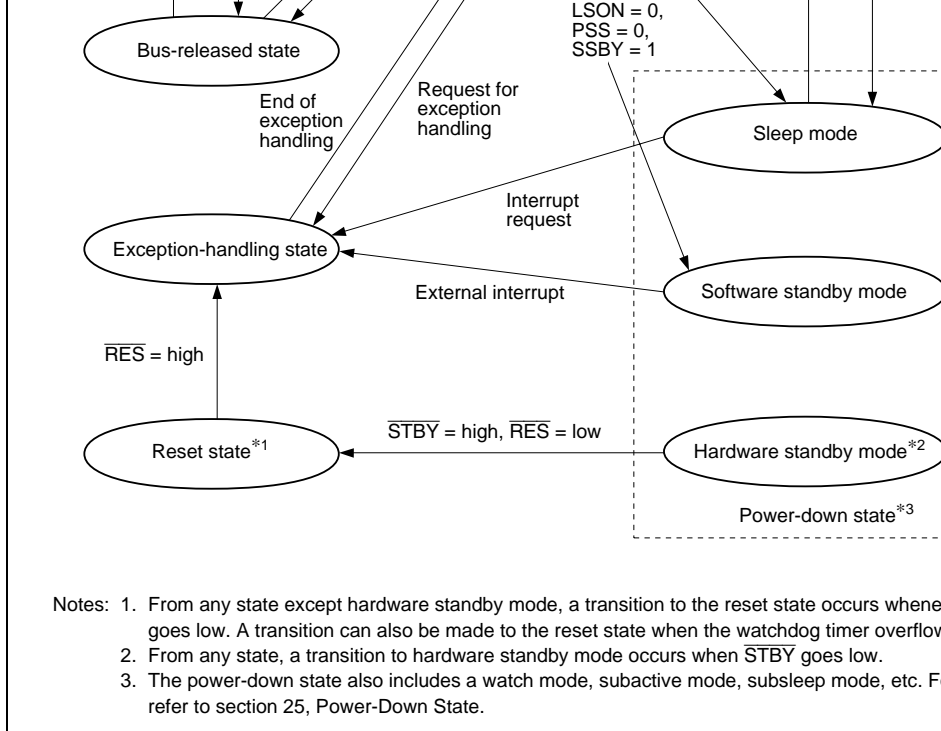


Figure 2.15 State Transitions

2.8.2 Reset State

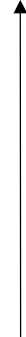
When the \overline{RES} input goes low all current processing stops and the CPU enters the reset state. In the reset state, interrupts are disabled. Reset exception handling starts when the \overline{RES} changes from low to high.

The reset state can also be entered by a watchdog timer overflow. For details, refer to section 25, Watchdog Timer (WDT).

Exception handling is performed for resets, interrupts, and trap instructions. Table 2.7 shows the types of exception handling and their priority. Trap instruction exception handling is always accepted in the program execution state.

Exception handling and the stack structure depend on the interrupt control mode set in the interrupt control register.

Table 2.7 Exception Handling Types and Priority

Priority	Type of Exception	Detection Timing	Start of Exception Handling
High  Low	Reset	Synchronized with clock	Exception handling starts immediately after a transition at the RES pin when the watchdog timer overflows.
	Interrupt	End of instruction execution or end of exception-handling sequence* ¹	When an interrupt is detected, exception handling starts at the end of the current instruction or the current exception-handling sequence.
	Trap instruction	When TRAPA instruction is executed	Exception handling starts when a trap (TRAPA) instruction is executed.* ²

Notes: 1. Interrupts are not detected at the end of the ANDC, ORC, XORC, and LDC instructions or immediately after reset exception handling.

2. Trap instruction exception handling is always accepted in the program execution state.

Reset Exception Handling

After the $\overline{\text{RES}}$ pin has gone low and the reset state has been entered, when $\overline{\text{RES}}$ goes high, reset exception handling starts. When reset exception handling starts the CPU fetches the reset vector address (vector) from the exception vector table and starts program execution from that address. All interrupts, including NMI, are disabled during reset exception handling and after it.

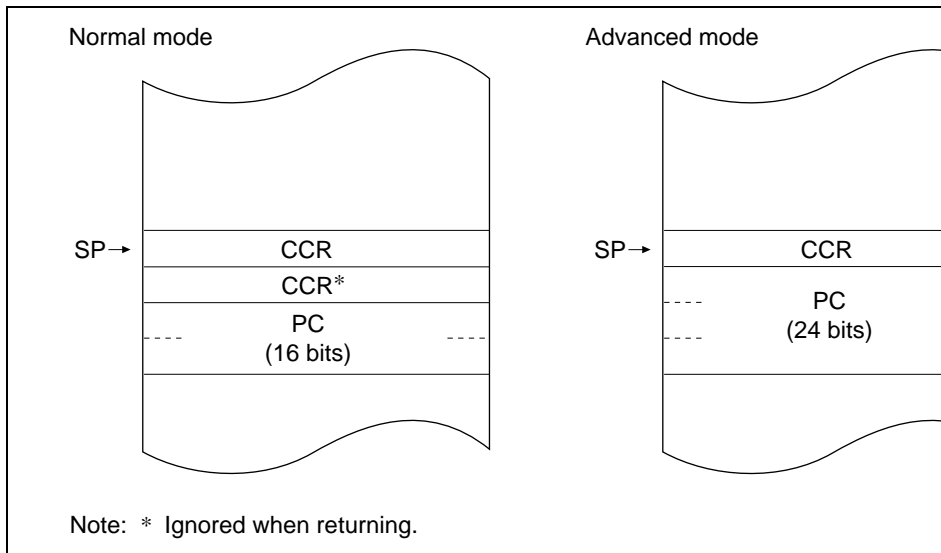


Figure 2.16 Stack Structure after Exception Handling (Examples)

2.8.4 Program Execution State

In this state the CPU executes program instructions in sequence.

2.8.5 Bus-Released State

This is a state in which the bus has been released in response to a bus request from a bus master other than the CPU. While the bus is released, all CPU internal operations are halted.

There is one other bus master in addition to the CPU: the data transfer controller (DTC).

For further details, refer to section 6, Bus Controller.

mode, subsleep mode, and watch mode are power-down modes that use subclock input details, refer to section 25, Power-Down State.

Sleep Mode

A transition to sleep mode is made if the SLEEP instruction is executed while the software standby bit (SSBY) in the standby control register (SBYCR) and the LSON bit in the control register (LPWRCR) are both cleared to 0. In sleep mode, CPU operations stop immediately after execution of the SLEEP instruction. The contents of CPU registers

Software Standby Mode

A transition to software standby mode is made if the SLEEP instruction is executed with the SSBY bit in SBYCR is set to 1 and the LSON bit in LPWRCR and the PSS bit in the control/status register (TCSR) are both cleared to 0. In software standby mode, the CPU halt and all MCU operations stop. As long as a specified voltage is supplied, the contents of registers and on-chip RAM are retained. The I/O ports also remain in their existing state.

Hardware Standby Mode

A transition to hardware standby mode is made when the $\overline{\text{STBY}}$ pin goes low. In hardware standby mode, the CPU and clock halt and all MCU operations stop. The on-chip supply modules are reset, but as long as a specified voltage is supplied, on-chip RAM contents are retained.

2.9.2 On-Chip Memory (ROM, RAM)

On-chip memory is accessed in one state. The data bus is 16 bits wide, permitting both word transfer instruction. Figure 2.17 shows the on-chip memory access cycle. Figure 2.18 shows the pin states.

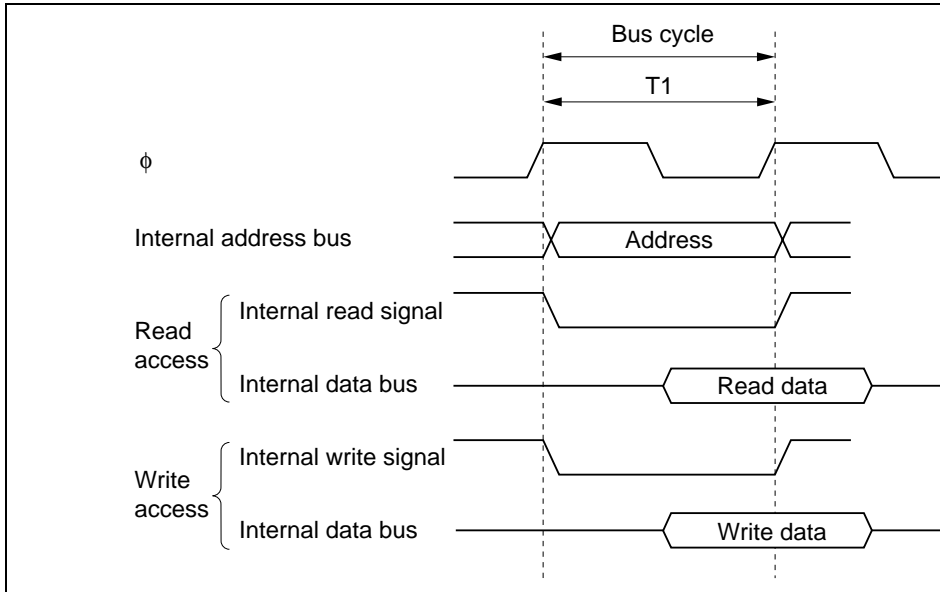


Figure 2.17 On-Chip Memory Access Cycle

\overline{AS}	High
\overline{RD}	High
$\overline{HWR}, \overline{LWR}$	High
Data bus	High impedance

Figure 2.18 Pin States during On-Chip Memory Access

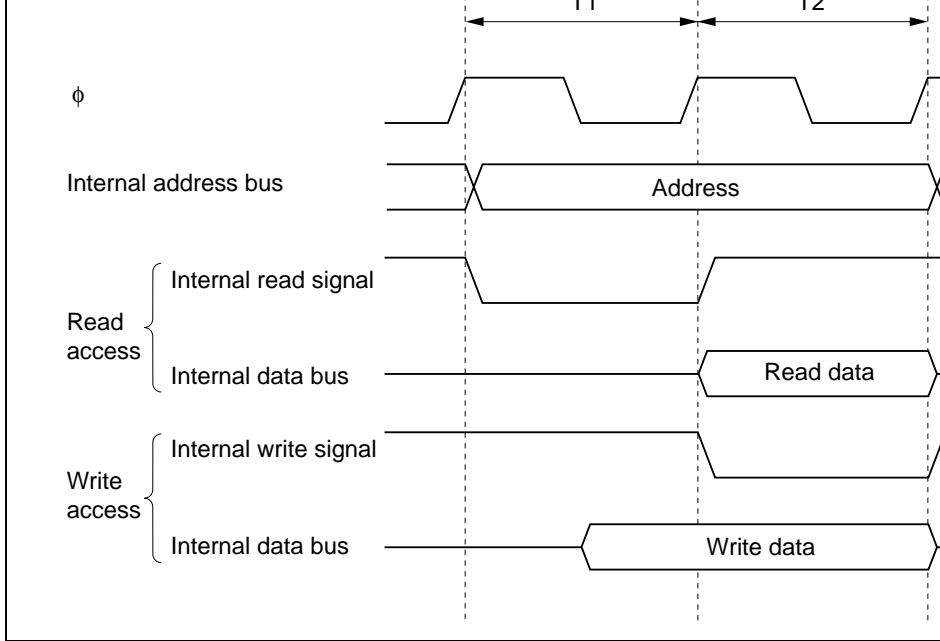


Figure 2.19 On-Chip Supporting Module Access Cycle

\overline{AS}	High
\overline{RD}	High
$\overline{HWR}, \overline{LWR}$	High
Data bus	High impedance

Figure 2.20 Pin States during On-Chip Supporting Module Access

2.9.4 External Address Space Access Timing

The external address space is accessed with an 8-bit or 16-bit data bus width in a two- or three-state bus cycle. In three-state access, wait states can be inserted. For further details, see section 6, Bus Controller.

2.10.2 STM/LDM Instruction

ER7 is not used as the register that can be saved (STM)/restored (LDM) when using STM instruction, because ER7 is the stack pointer. Two, three, or four registers can be saved in 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 H8S and H8C/C++ compilers.

operating mode and enabling/disabling of on-chip ROM, by setting the mode pins (MD1, MD0).

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

The CPU's architecture allows for 4 Gbytes of address space, but this LSI actually accommodates a maximum of 16 Mbytes.

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

This LSI can only be used in modes 1 to 3. This means that the mode pins must select these modes. Do not change the inputs at the mode pins during operation.

Name	Abbreviation	R/W	Initial Value	Address
Mode control register	MDCR	R/W	Undetermined	H'FF
System control register	SYSCR	R/W	H'09	H'FF
Bus control register	BCR	R/W	H'D7	H'FF
Serial/timer control register	STCR	R/W	H'00	H'FF

Note: * Lower 16 bits of the address.

3.2 Register Descriptions

3.2.1 Mode Control Register (MDCR)

Bit	7	6	5	4	3	2	1
	EXPE	—	—	—	—	—	MDS1
Initial value	—*	0	0	0	0	0	—*
Read/Write	R/W*	—	—	—	—	—	R

Note: * Determined by pins MD1 and MD0.

MDCR is an 8-bit read-only register that indicates the operating mode setting and the current operating mode of the MCU.

The EXPE bit is initialized in coordination with the mode pin states by a reset and in hardware standby mode.

Bits 6 to 2—Reserved: These bits cannot be modified and are always read as 0.

Bits 1 and 0—Mode Select 1 and 0 (MDS1, MDS0): These bits indicate the input levels of MD1 and MD0 (the current operating mode). Bits MDS1 and MDS0 correspond to MD1 and MD0. MDS1 and MDS0 are read-only bits—they cannot be written to. The mode pin (MD0) input levels are latched into these bits when MDCR is read.

3.2.2 System Control Register (SYSCR)

Bit	7	6	5	4	3	2	1
	CS2E	IOSE	INTM1	INTM0	XRST	NMIEG	HIE
Initial value	0	0	0	0	1	0	0
Read/Write	R/W	R/W	R	R/W	R	R/W	R/W

SYSCR is an 8-bit readable/writable register that performs selection of system pin functions, source monitoring, interrupt control mode selection, NMI detected edge selection, supporting module pin location selection, supporting module register access control, and RAM access control.

Only bits 7, 6, 3, 1, and 0 are described here. For a detailed description of these bits, refer to the description of the relevant modules (host interface, bus controller, watchdog timer, etc.). For information on bits 5, 4, and 2, see section 5.2.1, System Control Register (SYSCR).

SYSCR is initialized to H'09 by a reset and in hardware standby mode. It is not initialized in software standby mode.

Bit 7—Chip Select 2 Enable (CS2E): Specifies the location of the host interface controller (CS2). For details, see section 18, Host Interface. The H8S/2144 Group does not incorporate a host interface, so do not set this bit to 1 in the H8S/2144 Group.

Note: * In the H8S/2148 F-Z1A1 A-mask version and H8S/2147 F-Z1A1 A-mask version, the address range is from H'(FF)F000 to H'(FF)F7FF.

Bit 3—External Reset (XRST): Indicates the reset source. When the watchdog timer is enabled, a reset can be generated by watchdog timer overflow as well as by external reset input. XRST is a read-only bit. It is set to 1 by an external reset and cleared to 0 by watchdog timer overflow.

Bit 3

XRST	Description
0	A reset is generated by watchdog timer overflow
1	A reset is generated by an external reset

Bit 1—Host Interface Enable (HIE): This bit controls CPU access to the host interface data registers and control registers (HICR, IDR1, ODR1, STR1, IDR2, ODR2, and STR2), the keyboard controller and MOS input pull-up control registers (KMIMR, KMPCR, and KMPCR), the 8-bit timer (channel X and Y) data registers and control registers (TCRX/TCRY, TCSRX/TCSRY, TICRR/TCORAY, TICRF/TCORBY, TCNTX/TCNTY, TCORC/TICORC, TCORAX, and TCORBX), and the timer connection control registers (TCONRI, TCONRS, TCONRS, and SEDGR).

Bit 1

HIE	Description
0	In areas H'(FF)FFF0 to H'(FF)FFF7 and H'(FF)FFFC to H'(FF)FFFF, CPU access to 8-bit timer (channel X and Y) data registers and control registers, and timer connection control registers, is permitted
1	In areas H'(FF)FFF0 to H'(FF)FFF7 and H'(FF)FFFC to H'(FF)FFFF, CPU access to host interface data registers and control registers, and keyboard controller and MOS input pull-up control registers, is permitted

3.2.3 Bus Control Register (BCR)

Bit	7	6	5	4	3	2	1
	ICIS1	ICIS0	BRSTRM	BRSTS1	BRSTS0	—	IOS1
Initial value	1	1	0	1	0	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

BCR is an 8-bit readable/writable register that specifies the external memory space access range and the I/O area range when the \overline{AS} pin is designated for use as the I/O strobe. For details, see section 6.2.1, Bus Control Register (BCR).

BCR is initialized to H'D7 by a reset and in hardware standby mode.

Bits 1 and 0—IOS Select 1 and 0 (IOS1, IOS0): These bits specify the addresses for which the $\overline{AS}/\overline{IOS}$ pin output goes low when IOSE = 1.

BCR		
Bit 1	Bit 0	
IOS1	IOS0	Description
0	0	The $\overline{AS}/\overline{IOS}$ pin output goes low in accesses to addresses H'(FF)F000 to H'(FF)F03F
	1	The $\overline{AS}/\overline{IOS}$ pin output goes low in accesses to addresses H'(FF)F000 to H'(FF)F0FF
1	0	The $\overline{AS}/\overline{IOS}$ pin output goes low in accesses to addresses H'(FF)F000 to H'(FF)F3FF
	1	The $\overline{AS}/\overline{IOS}$ pin output goes low in accesses to addresses H'(FF)F000 to H'(FF)FE4F*

Note: * In the H8S/2148 F-ZTAT A-mask version and H8S/2147 F-ZTAT A-mask version, the address range is from H'(FF)F000 to H'(FF)F7FF.

(when the on-chip IIC option is included), an on-chip flash memory control (in F-ZTA) and also selects the TCNT input clock. For details of functions other than register access see the descriptions of the relevant modules. If a module controlled by STCR is not used, write 1 to the corresponding bit.

STCR is initialized to H'00 by a reset and in hardware standby mode.

Bits 7 to 5—I²C Control (IICS, IICX1, IICX0): These bits control the bus buffer function of port A and the operation of the I²C bus interface when the on-chip IIC option is included. For details, see section 16.2.7, Serial/Timer Control Register (STCR).

Bit 4—I²C Master Enable (IICE): Controls CPU access to the I²C bus interface data registers and control registers (ICCR, ICSR, ICDR/SARX, and ICMR/SAR), the PWMX data registers and control registers (DADRAH/DACR, DADRAL, DADRBH/DACNTH, and DADRBL/DACNTH) and the SCI control registers (SMR, BRR, and SCMR).

Bit 4

IICE	Description
0	Addresses H'(FF)FF88 and H'(FF)FF89, and H'(FF)FF8E and H'(FF)FF8F, for SCI1 control register access Addresses H'(FF)FFA0 and H'(FF)FFA1, and H'(FF)FFA6 and H'(FF)FFA7, for SCI2 control register access Addresses H'(FF)FFD8 and H'(FF)FFD9, and H'(FF)FFDE and H'(FF)FFDF, for SCI0 control register access
1	Addresses H'(FF)FF88 and H'(FF)FF89, and H'(FF)FF8E and H'(FF)FF8F, for IIC1 data register and control register access Addresses H'(FF)FFA0 and H'(FF)FFA1, and H'(FF)FFA6 and H'(FF)FFA7, for PWMX data register and control register access Addresses H'(FF)FFD8 and H'(FF)FFD9, and H'(FF)FFDE and H'(FF)FFDF, for IIC0 data register and control register access

1	Addresses H'(FF)FF80 to H'(FF)FF87 are used for flash memory control register access (F-ZTAT version only)
---	--

Bit 2—Reserved: Do not write 1 to this bit.

Bits 1 and 0—Internal Clock Select 1 and 0 (ICKS1, ICKS0): These bits, together with CKS2 to CKS0 in TCR, select the clock to be input to TCNT. For details, see section 10.1.1.1 Timer Control Register (TCR).

3.3 Operating Mode Descriptions

3.3.1 Mode 1

The CPU can access a 64-kbyte address space in normal mode. The on-chip ROM is connected to ports 1 and 2.

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

3.3.2 Mode 2

The CPU can access a 16-Mbyte address space in advanced mode. The on-chip ROM is connected to ports 1 and 2. After a reset, single-chip mode is set, and the EXPE bit in MDCR must be set to 1 in order to access external addresses.

When the EXPE bit in MDCR is set to 1, ports 1, 2 and A function as input ports after a reset. They can be set to output addresses by setting the corresponding bits in the data direction register (DDR) to 1. Port 3 functions as a data bus, and part of port 9 carries bus control signals. Clearing the ABW bit to 0 in the WSCR register makes port B a data bus.

the ABW bit to 0 in the WSCR register makes port B a data bus.

In this operating mode, the available amount of on-chip ROM in products with 64 kbytes of ROM is limited to 56 kbytes.

3.4 Pin Functions in Each Operating Mode

The pin functions of ports 1 to 3, 9, A, and B vary depending on the operating mode. Table 3.3 shows their functions in each operating mode.

Table 3.3 Pin Functions in Each Mode

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

Legend:

P: I/O port

A: Address bus output

D: Data bus I/O

C: Control signals, clock I/O

*: After reset

(normal mode).

Do not access the reserved area and addresses of modules not supported by the product. Normal operation is not guaranteed when these regions are accessed.

For details, see section 6, Bus Controller.

	External address space		On-chip ROM		On-chip
		H'DFFF		H'DFFF	
H'E080			External address space		
	On-chip RAM*	H'E080		H'E080	On-chip
H'EFFF			External address space		
	External address space	H'EFFF		H'EFFF	
H'FE50	Internal I/O registers 2	H'FE50	Internal I/O registers 2	H'FE50	Internal I/O r
H'FEFF		H'FEFF		H'FEFF	
H'FF00	On-chip RAM (128 bytes)*	H'FF00	On-chip RAM (128 bytes)*	H'FF00	On-chip (128 by
H'FF7F		H'FF7F		H'FF7F	
H'FF80	Internal I/O registers 1	H'FF80	Internal I/O registers 1	H'FF80	Internal I/O r
H'FFFF		H'FFFF		H'FFFF	

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

Figure 3.1 H8S/2148 (Except for F-ZTAT A-Mask Version) and H8S/2144 Memory Map
Each Operating Mode

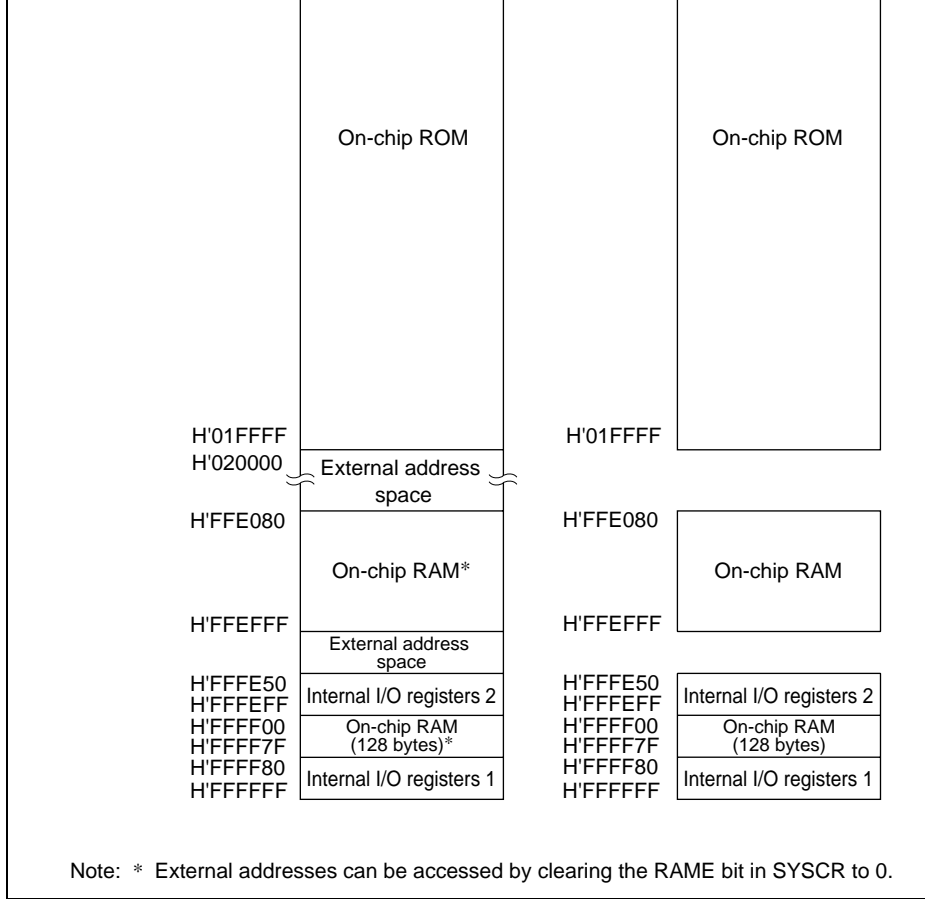


Figure 3.1 H8S/2148 (Except for F-ZTAT A-Mask Version) and H8S/2144 Memory Map in Each Operating Mode (cont)

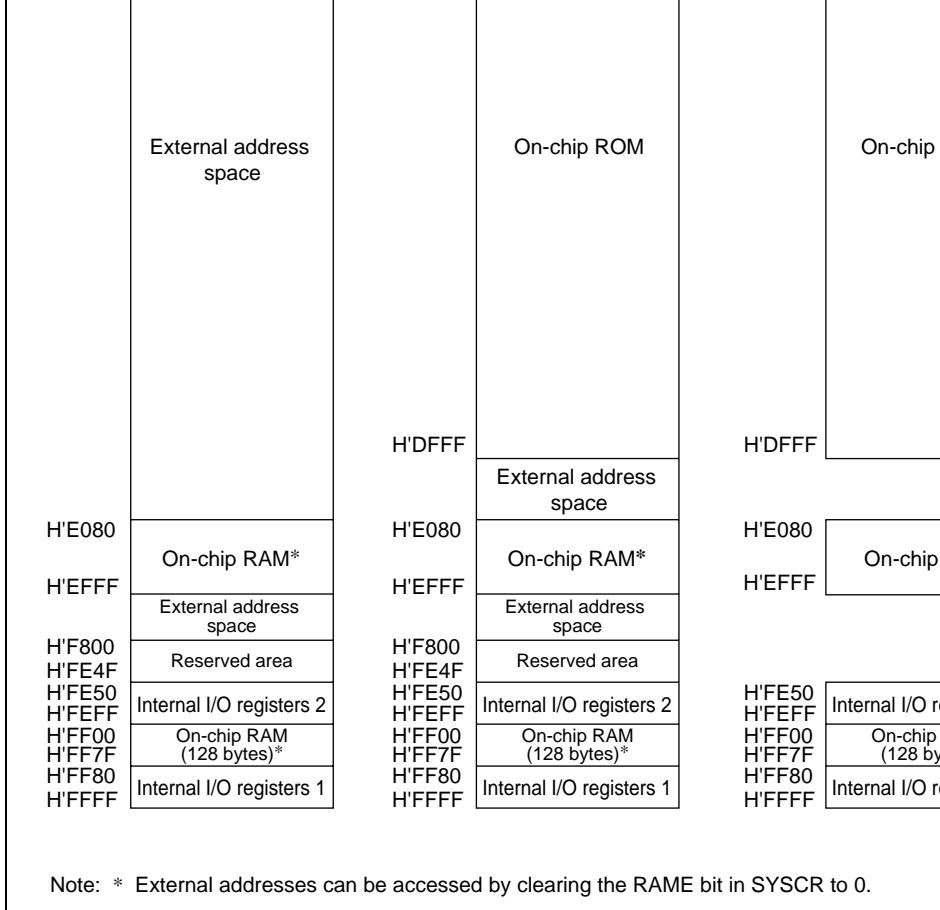
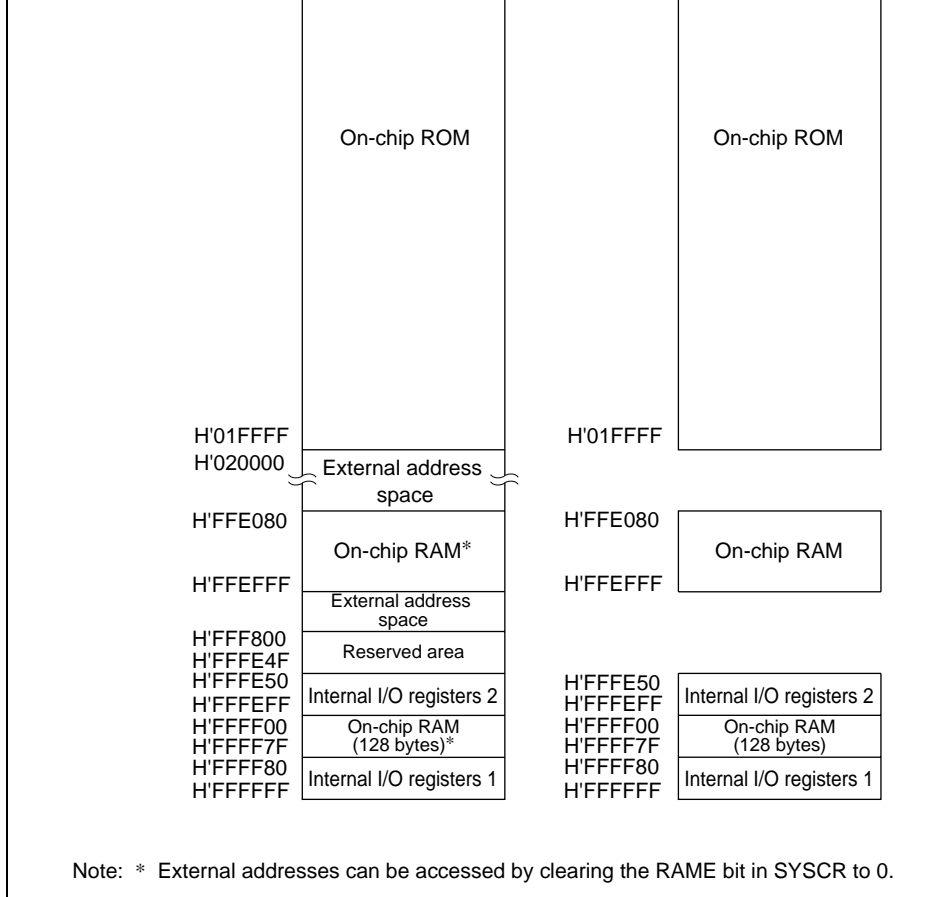


Figure 3.2 H8S/2148 F-ZTAT A-Mask Version Memory Map in Each Operating Mode



**Figure 3.2 H8S/2148 F-ZTAT A-Mask Version Memory Map in Each Operat
(cont)**

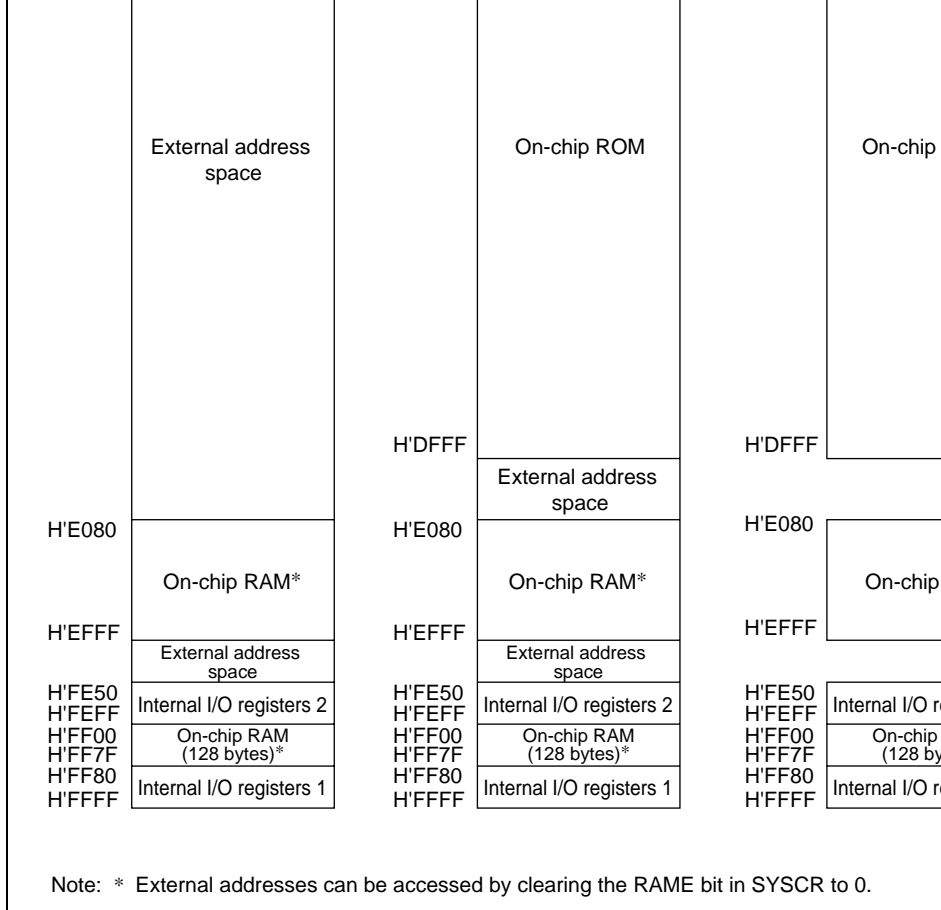


Figure 3.3 H8S/2143 Memory Map in Each Operating Mode

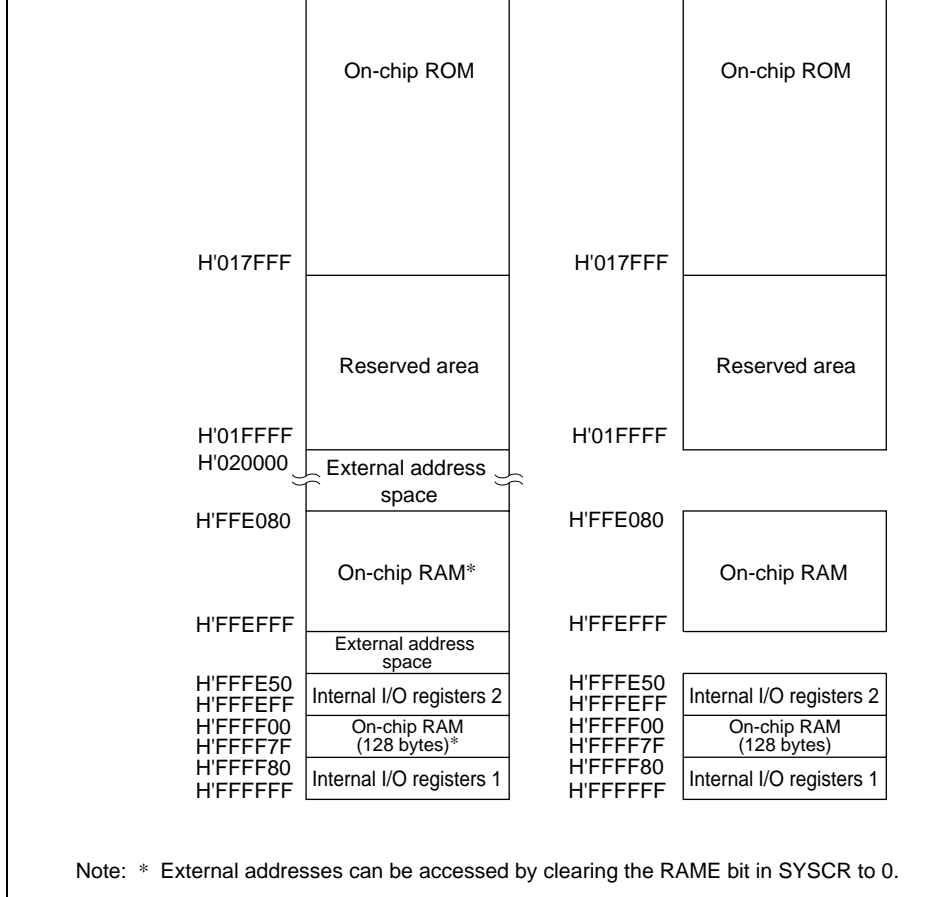


Figure 3.3 H8S/2143 Memory Map in Each Operating Mode (cont)

	External address space		On-chip ROM		On-chip
		H'DFFF		H'DFFF	
			External address space		
H'E080	Reserved area*	H'E080	Reserved area*	H'E080	Reserve
H'E880	On-chip RAM*	H'E880	On-chip RAM*	H'E880	On-chip
H'EFFF	External address space	H'EFFF	External address space	H'EFFF	
H'FE50	Internal I/O registers 2	H'FE50	Internal I/O registers 2	H'FE50	Internal I/O r
H'FEFF	On-chip RAM (128 bytes)*	H'FEFF	On-chip RAM (128 bytes)*	H'FEFF	On-chip (128 b
H'FF00		H'FF00		H'FF00	
H'FF7F		H'FF7F		H'FF7F	
H'FF80	Internal I/O registers 1	H'FF80	Internal I/O registers 1	H'FF80	Internal I/O r
H'FFFF		H'FFFF		H'FFFF	

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

Figure 3.4 H8S/2147 (Except for F-ZTAT A-Mask Version), H8S/2147N, and H8S/2147R Memory Map in Each Operating Mode

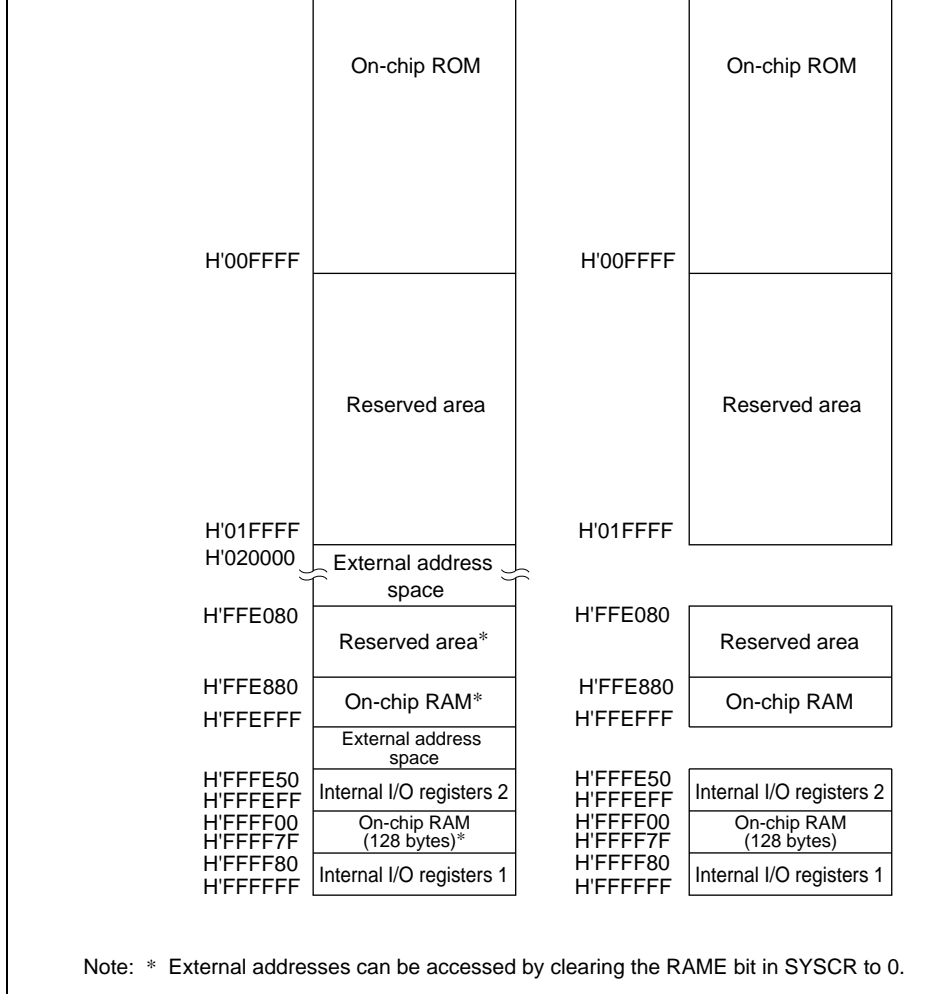


Figure 3.4 H8S/2147 (Except for F-ZTAT A-Mask Version), H8S/2147N, and Memory Map in Each Operating Mode (cont)

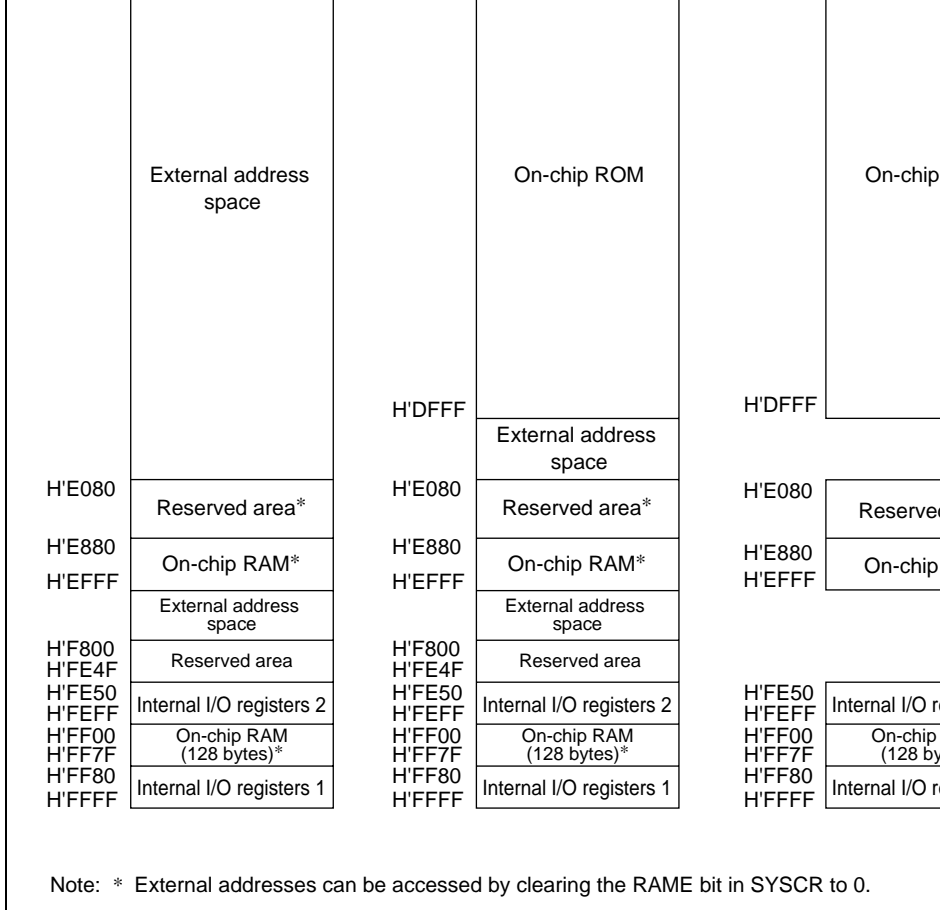
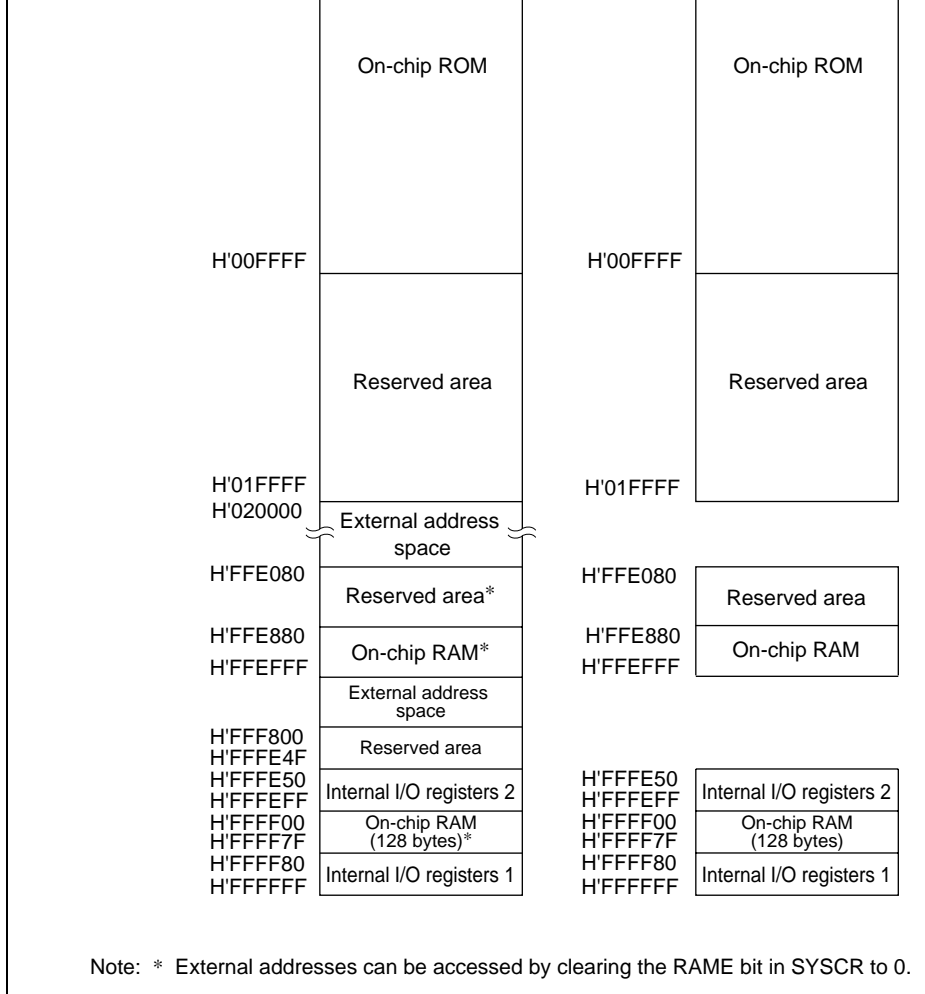


Figure 3.5 H8S/2147 F-ZTAT A-Mask Version Memory Map in Each Operating Mode




**Figure 3.5 H8S/2147 F-ZTAT A-Mask Version Memory Map in Each Operat
(cont)**

Exception handling is prioritized as shown in table 4.1. If two or more exceptions occur simultaneously, they are accepted and processed in order of priority. Trap instruction exceptions are accepted at all times in the program execution state.

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

Table 4.1 Exception Types and Priority

Priority	Exception Type	Start of Exception Handling
High 	Reset	Starts immediately after a low-to-high transition on the $\overline{\text{RES}}$ pin, or when the watchdog timer overflows.
	Trace ^{*1}	Starts when execution of the current instruction causes a trace exception. Exception handling ends, if the trace (T) bit is cleared.
	Interrupt	Starts when execution of the current instruction causes an interrupt exception. Exception handling ends, if an interrupt request is not issued. ^{*2}
	Direct transition	Started by a direct transition resulting from execution of the SLEEP instruction.
Low	Trap instruction (TRAPA) ^{*3}	Started by execution of a trap instruction (TRAPA).

- Notes:
- Traces are enabled only in interrupt control modes 2 and 3. (They cannot be enabled in modes 0 and 1 of this LSI.) Trace exception handling is not executed after execution of an RTN instruction.
 - Interrupt detection is not performed on completion of ANDC, ORC, XORC, or SLEEP instruction execution, or on completion of reset exception handling.
 - Trap instruction exception handling requests are accepted at all times in the program execution state.

For a reset exception, steps 2 and 3 above are carried out.

4.1.3 Exception Sources and Vector Table

The exception sources are classified as shown in figure 4.1. Different vector addresses assigned to different exception sources.

Table 4.2 lists the exception sources and their vector addresses.

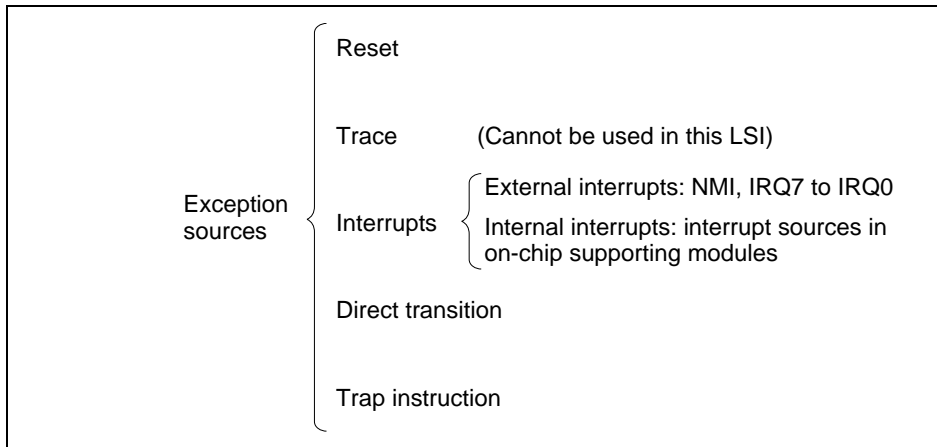


Figure 4.1 Exception Sources

		4	H'0008 to H'0009	H'0010 to
		5	H'000A to H'000B	H'0014 to
Direct transition		6	H'000C to H'000D	H'0018 to
External interrupt	NMI	7	H'000E to H'000F	H'001C to
Trap instruction (4 sources)		8	H'0010 to H'0011	H'0020 to
		9	H'0012 to H'0013	H'0024 to
		10	H'0014 to H'0015	H'0028 to
		11	H'0016 to H'0017	H'002C to
Reserved for system use		12	H'0018 to H'0019	H'0030 to
		13	H'001A to H'001B	H'0034 to
		14	H'001C to H'001D	H'0038 to
		15	H'001E to H'001F	H'003C to
External interrupt	IRQ0	16	H'0020 to H'0021	H'0040 to
	IRQ1	17	H'0022 to H'0023	H'0044 to
	IRQ2	18	H'0024 to H'0025	H'0048 to
	IRQ3	19	H'0026 to H'0027	H'004C to
	IRQ4	20	H'0028 to H'0029	H'0050 to
	IRQ5	21	H'002A to H'002B	H'0054 to
	IRQ6	22	H'002C to H'002D	H'0058 to
	IRQ7	23	H'002E to H'002F	H'005C to
Internal interrupt ^{*2}		24	H'0030 to H'0031	H'0060 to
		103	H'00CE to H'00CF	H'019C to

Notes: 1. Lower 16 bits of the address.

2. For details on internal interrupt vectors, see section 5.3.3, Interrupt Exception Table.

Immediately after a reset, interrupt control mode 0 is set.

Reset exception handling begins when the $\overline{\text{RES}}$ pin changes from low to high.

The MCUs can also be reset by overflow of the watchdog timer. For details, see section Watchdog Timer (WDT).

4.2.2 Reset Sequence

The MCU enters the reset state when the $\overline{\text{RES}}$ pin goes low.

To ensure that the chip is reset, hold the $\overline{\text{RES}}$ pin low for at least 20 ms when powering reset the chip during operation, hold the $\overline{\text{RES}}$ pin low for at least 20 states. For pin states, see appendix D.1, Port States in Each Processing State.

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

- [1] The internal state of the CPU and the registers of the on-chip supporting modules are initialized, and the I bit is set to 1 in CCR.
- [2] The reset exception vector address is read and transferred to the PC, and program execution starts from the address indicated by the PC.

Figures 4.2 and 4.3 show examples of the reset sequence.

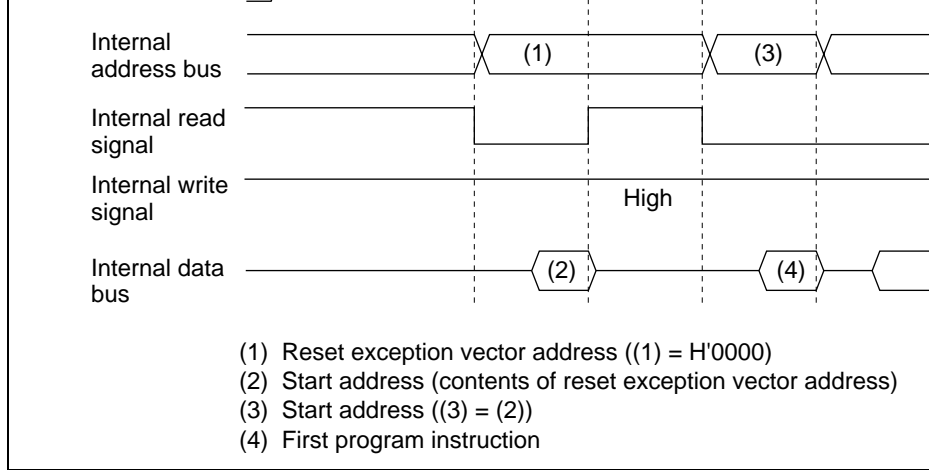


Figure 4.2 Reset Sequence (Mode 3)

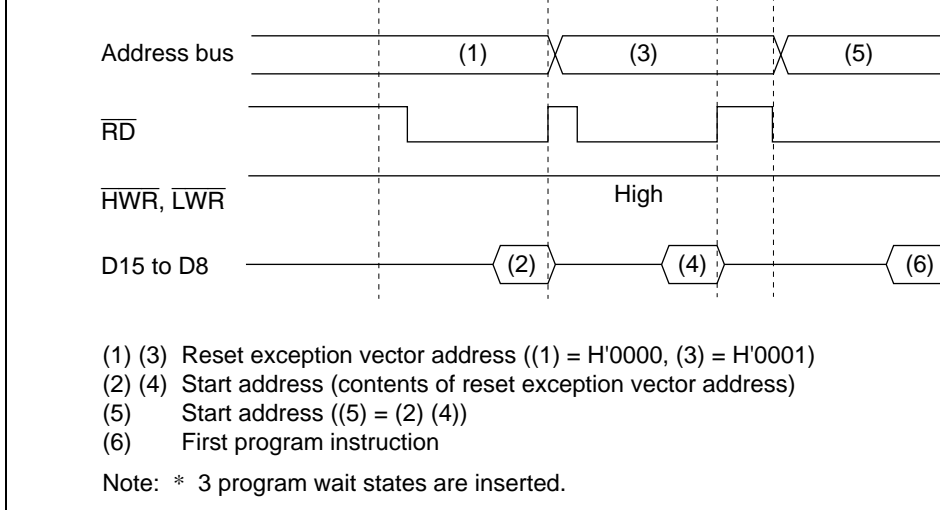


Figure 4.3 Reset Sequence (Mode 1)

4.2.3 Interrupts after Reset

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

transfer controller (DTC), A/D converter (ADC), host interface (HIF), keyboard buffer (PS2), and I²C bus interface (option). Each interrupt source has a separate vector address.

NMI is the highest-priority interrupt. Interrupts are controlled by the interrupt controller. The interrupt controller has two interrupt control modes and can assign interrupts other than the address break to either three priority/mask levels to enable multiplexed interrupt control.

For details on interrupts, see section 5, Interrupt Controller.

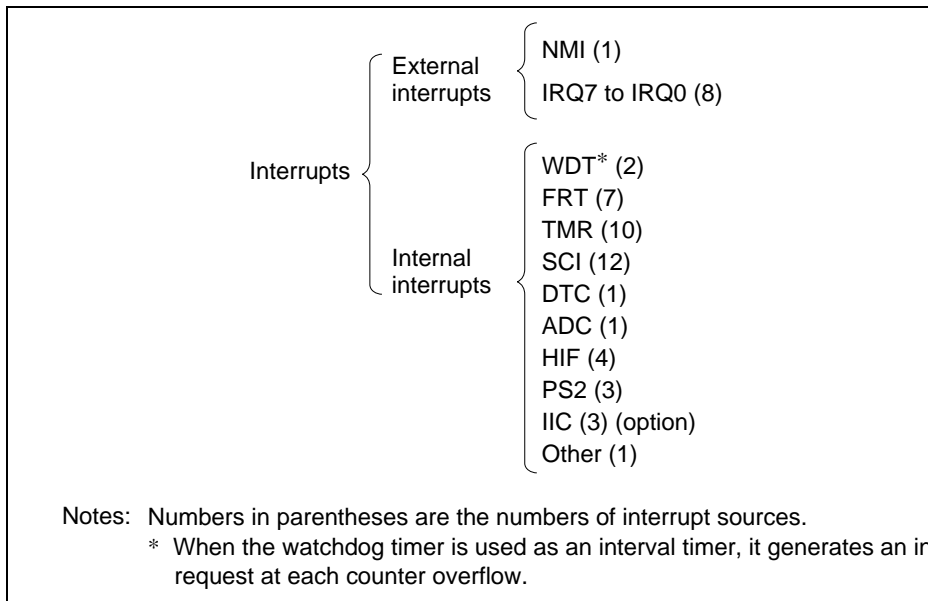


Figure 4.4 Interrupt Sources and Number of Interrupts

Table 4.3 Status of CCR and EXR after Trap Instruction Exception Handling

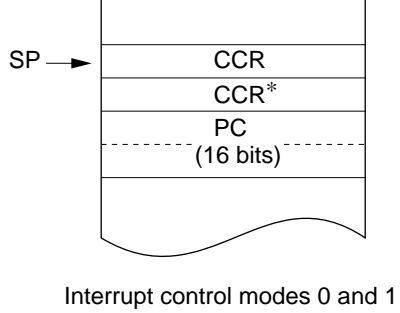
Interrupt Control Mode	CCR		EXR	
	I	UI	I2 to I0	T
0	1	—	—	—
1	1	1	—	—

Legend:

1: Set to 1

0: Cleared to 0

—: Retains value prior to execution.



Note: * Ignored on return.

Figure 4.5 (1) Stack Status after Exception Handling (Normal Mode)

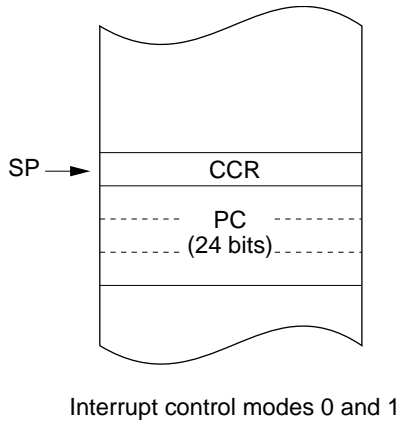


Figure 4.5 (2) Stack Status after Exception Handling (Advanced Mode)

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

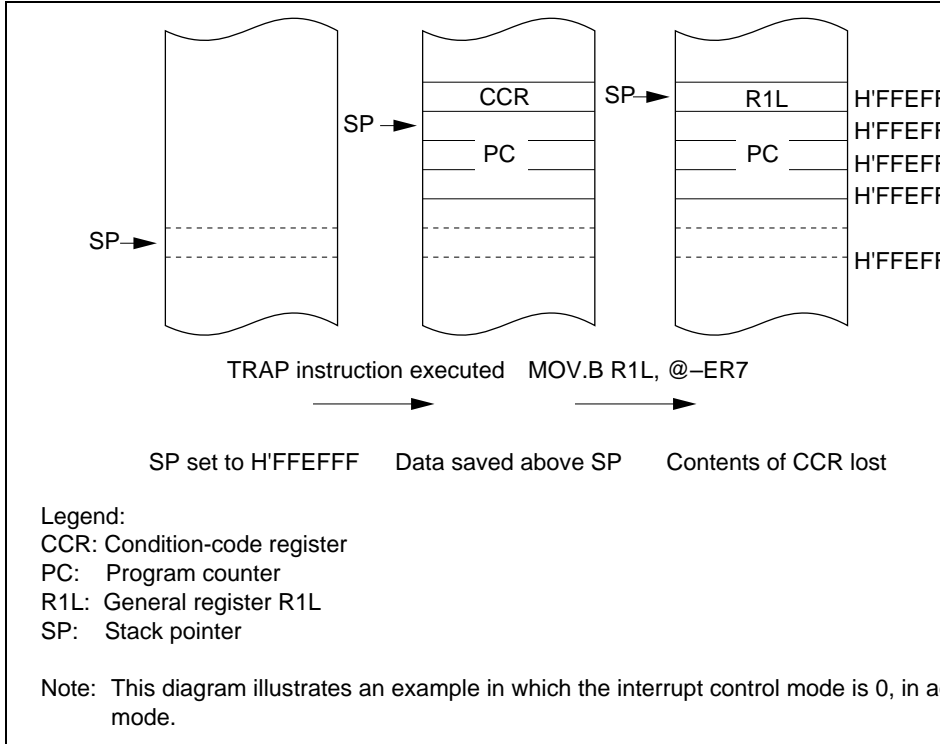


Figure 4.6 Operation when SP Value Is Odd

following features:

- Two interrupt control modes
 - Either of two interrupt control modes can be set by means of the INTM1 and INTM0 bits in the system control register (SYSCR).
- Priorities settable with ICR
 - An interrupt control register (ICR) is provided for setting interrupt priorities. The priority levels can be set for each module for all interrupts except NMI and address bus error.
- Independent vector addresses
 - All interrupt sources are assigned independent vector addresses, making it unnecessary for the source to be identified in the interrupt handling routine.
- Twenty-three external interrupt pins (nine external sources)
 - NMI is the highest-priority interrupt, and is accepted at all times. A rising or falling edge of the NMI pin can be selected for the NMI interrupt.
 - Falling edge, rising edge, or both edge detection, or level sensing, at pins $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$ can be selected for interrupts IRQ7 to 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 eight external interrupt inputs ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$). $\overline{\text{KIN15}}$ to $\overline{\text{KIN0}}$ can be masked individually by the user program.
- DTC control
 - DTC activation is controlled by means of interrupts.

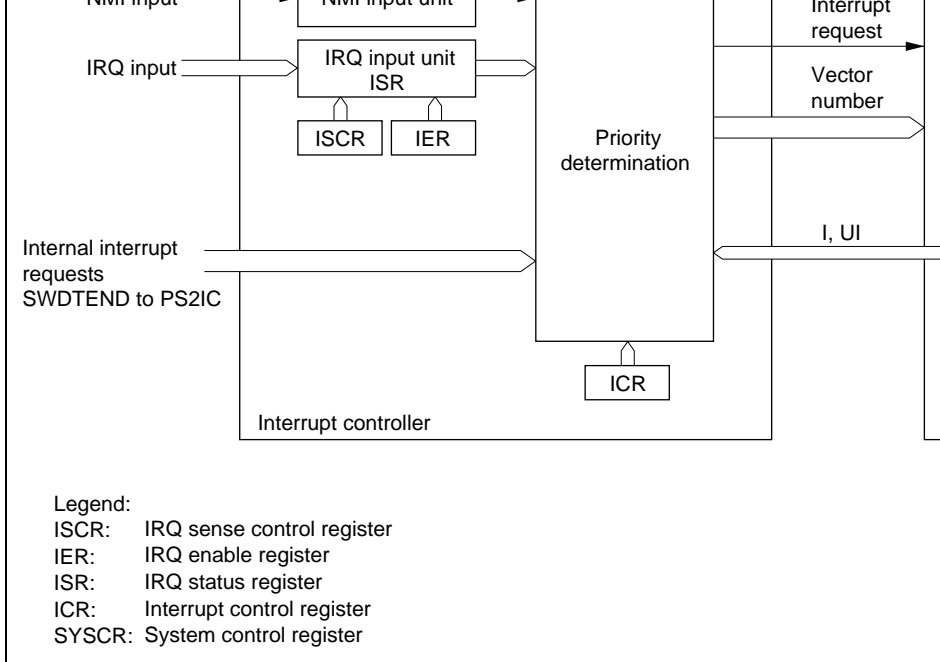


Figure 5.1 Block Diagram of Interrupt Controller

External interrupt requests 7 to 0	$\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$	Input	Maskable external interrupts; rising or falling edge, or level sensing, can be selected.
Key input interrupt requests 15 to 0	$\overline{\text{KIN15}}$ to $\overline{\text{KIN0}}$	Input	Maskable external interrupts: falling edge or level sensing can be selected.

IRQ sense control register L	ISCR_L	R/W	H'00	H'F
IRQ enable register	IER	R/W	H'00	H'F
IRQ status register	ISR	R/(W) ^{*2}	H'00	H'F
Keyboard matrix interrupt mask register	KMIMR	R/W	H'BF	H'F
Keyboard matrix interrupt mask register A	KMIMRA	R/W	H'FF	H'F
Interrupt control register A	ICRA	R/W	H'00	H'F
Interrupt control register B	ICRB	R/W	H'00	H'F
Interrupt control register C	ICRC	R/W	H'00	H'F
Address break control register	ABRKCR	R/W	H'00	H'F
Break address register A	BARA	R/W	H'00	H'F
Break address register B	BARB	R/W	H'00	H'F
Break address register C	BARC	R/W	H'00	H'F

Notes: 1. Lower 16 bits of the address.

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

3. When setting KMIMR and KMIMRA, the HIE bit in SYSCR must be set to 1, MSTP2 bit in MSTPCRL must be set to 0.

SYSCR is an 8-bit readable/writable register that selects the interrupt control mode, and the detected edge for NMI, among other functions.

Only bits 5, 4, and 2 are described here; for details on the other bits, see section 3.2.2, Control Register (SYSCR).

SYSCR is initialized to H'09 by a reset and in hardware standby mode. It is not initialized in software standby mode.

Bits 5 and 4—Interrupt Control Mode 1 and 0 (INTM1, INTM0): These bits select the interrupt control modes for the interrupt controller. The INTM1 bit must not be set to 0.

Bit 5	Bit 4	Interrupt Control Mode	Description
INTM1	INTM0		
0	0	0	Interrupts are controlled by I bit
	1	1	Interrupts are controlled by I and UI bits and ICM bit
1	0	2	Cannot be used in this LSI
	1	3	Cannot be used in this LSI

Bit 2—NMI Edge Select (NMIEG): Selects the input edge for the NMI pin.

Bit 2	Description
NMIEG	
0	Interrupt request generated at falling edge of NMI input
1	Interrupt request generated at rising edge of NMI input



interrupts other than NMI and address break.

The correspondence between ICR settings and interrupt sources is shown in table 5.3.

The ICR registers are initialized to H'00 by a reset and in hardware standby mode.

Bit n—Interrupt Control Level (ICRn): Sets the control level for the corresponding interrupt source.

Bit n

ICRn	Description
0	Corresponding interrupt source is control level 0 (non-priority)
1	Corresponding interrupt source is control level 1 (priority)

Note: n = 7 to 0

Table 5.3 Correspondence between Interrupt Sources and ICR Settings

Register	Bits						
	7	6	5	4	3	2	1
ICRA	IRQ0	IRQ1	IRQ2 IRQ3	IRQ4 IRQ5	IRQ6 IRQ7	DTC	Watchdog timer 0
ICRB	A/D converter	Free-running timer	—	—	8-bit timer channel 0	8-bit timer channel 1	8-bit timer channels X, Y
ICRC	SCI channel 0	SCI channel 1	SCI channel 2	IIC channel 0 (option)	IIC channel 1 (option)	—	—

IRQ7 to IRQ0.

IER is initialized to H'00 by a reset and in hardware standby mode.

Bits 7 to 0—IRQ7 to IRQ0 Enable (IRQ7E to IRQ0E): These bits select whether IRQ7 to IRQ0 are enabled or disabled.

Bit n

IRQnE	Description
0	IRQn interrupt disabled
1	IRQn interrupt enabled

Note: n = 7 to 0

5.2.4 IRQ Sense Control Registers H and L (ISCRH, ISCRL)

- ISCRH

Bit	15	14	13	12	11	10	9
	IRQ7SCB	IRQ7SCA	IRQ6SCB	IRQ6SCA	IRQ5SCB	IRQ5SCA	IRQ4SCB
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

- ISCRL

Bit	7	6	5	4	3	2	1
	IRQ3SCB	IRQ3SCA	IRQ2SCB	IRQ2SCA	IRQ1SCB	IRQ1SCA	IRQ0SCB
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

IRQ7SCB to IRQ0SCB	IRQ7SCA to IRQ0SCA	Description
0	0	Interrupt request generated at $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$ input low level
	1	Interrupt request generated at falling edge of $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$ input
1	0	Interrupt request generated at rising edge of $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$ input
	1	Interrupt request generated at both falling and rising edges of $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$ input

5.2.5 IRQ Status Register (ISR)

Bit	7	6	5	4	3	2	1
	IRQ7F	IRQ6F	IRQ5F	IRQ4F	IRQ3F	IRQ2F	IRQ1F
Initial value	0	0	0	0	0	0	0
Read/Write	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*

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

ISR is an 8-bit readable/writable register that indicates the status of IRQ7 to IRQ0 interrupt requests.

ISR is initialized to H'00 by a reset and in hardware standby mode.

(IRQnSCB = IRQnSCA = 0) and $\overline{\text{IRQn}}$ input is high*

- When IRQn interrupt exception handling is executed while falling, rising, or both-edge detection is set (IRQnSCB = 1 or IRQnSCA = 1)*

1 [Setting conditions]

- When $\overline{\text{IRQn}}$ input goes low when low-level detection is set (IRQnSCB = 1)
(IRQnSCA = 0)
- When a falling edge occurs in $\overline{\text{IRQn}}$ input while falling edge detection is set (IRQnSCB = 0, IRQnSCA = 1)
- When a rising edge occurs in $\overline{\text{IRQn}}$ input while rising edge detection is set (IRQnSCB = 1, IRQnSCA = 0)
- When a falling or rising edge occurs in $\overline{\text{IRQn}}$ input while both-edge detection is set (IRQnSCB = IRQnSCA = 1)

Notes: n = 7 to 0

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

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

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

interrupt inputs (pins $\overline{KIN7}$ to $\overline{KIN0}$). To enable key-sense input interrupts from multiple inputs in keyboard matrix scanning/sensing, clear the corresponding mask bits to 0.

KMIMR is initialized to H'BF by a reset and in hardware standby mode and only $\overline{IRQ6}$ input is enabled.

Bits 7 to 0—Keyboard Matrix Interrupt Mask (KMIMR7 to KMIMR0): These bits control key-sense input interrupt requests (KIN7 to KIN0).

Bits 7 to 0

KMIMR7 to

KMIMR0 Description

0	Key-sense input interrupt requests enabled
1	Key-sense input interrupt requests disabled (Initial value)*

Note: * However, the initial value of KMIMR6 is 0 because the KMIMR6 bit controls interrupt request masking and key-sense input enabling.

5.2.7 Keyboard Matrix Interrupt Mask Register (KMIMRA)

Bit	7	6	5	4	3	2	1
	KMIMR15	KMIMR14	KMIMR13	KMIMR12	KMIMR11	KMIMR10	KMIMR9
Initial value	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

KMIMRA is an 8-bit readable/writable register that performs mask control for the keyboard matrix interrupt inputs (pins $\overline{KIN15}$ to $\overline{KIN8}$). To enable key-sense input interrupts from multiple pin inputs in keyboard matrix scanning/sensing, clear the corresponding mask bits to 0.

KMIMRA is initialized to H'FF by a reset and in hardware standby mode.

Figure 5.2 shows the relationship between interrupts IRQ7 and IRQ6, interrupts KIN1 and registers KMIMR and KMIMRA.

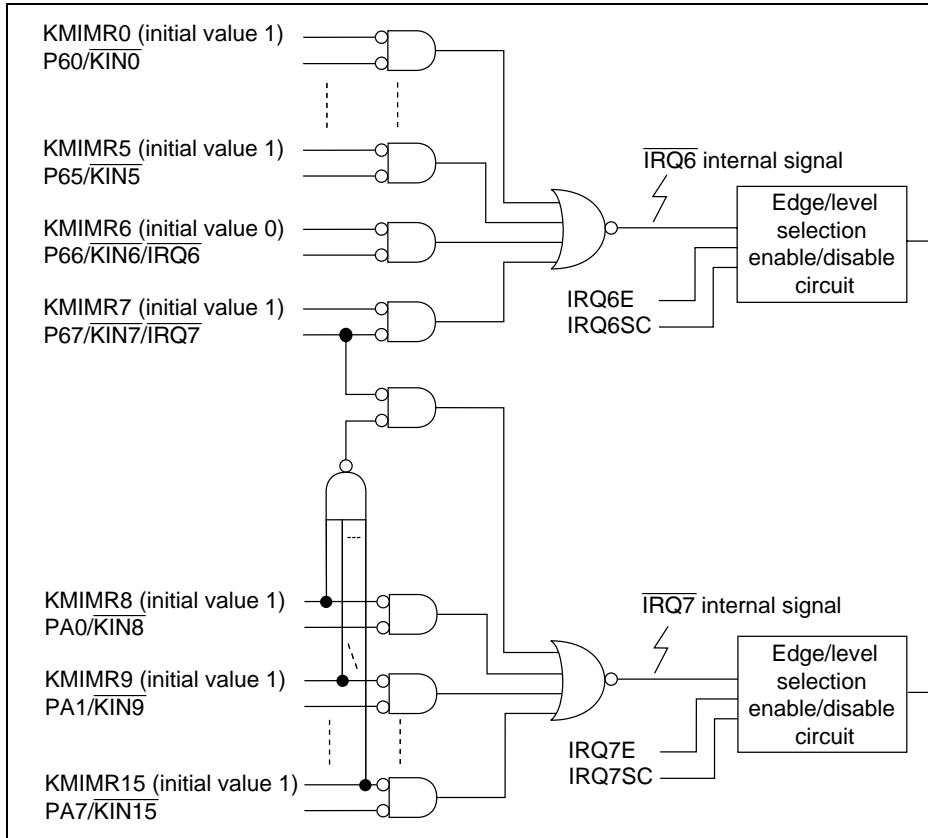


Figure 5.2 Relationship between Interrupts IRQ7 and IRQ6, Interrupts KIN1 and Registers KMIMR and KMIMRA

	CMF	—	—	—	—	—	—
Initial value	0	0	0	0	0	0	0
Read/Write	R	—	—	—	—	—	—

ABRKCR is an 8-bit readable/writable register that performs address break control.

ABRKCR is initialized to H'00 by a reset and in hardware standby mode. It is not initialized in software standby mode.

Bit 7—Condition Match Flag (CMF): This is the address break source flag, used to indicate when the address set by BAR has been prefetched. When the CMF flag and BIE flag are both set, an address break is requested.

Bit 7

CMF	Description
0	[Clearing condition] When address break interrupt exception handling is executed
1	[Setting condition] When address set by BARA to BARC is prefetched while BIE = 1

Bits 6 to 1—Reserved: These bits cannot be modified and are always read as 0.

Bit 0—Break Interrupt Enable (BIE): Selects address break enabling or disabling.

Bit 0

BIE	Description
0	Address break disabled
1	Address break enabled

Bit	7	6	5	4	3	2	1
BARB	A15	A14	A13	A12	A11	A10	A9
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Bit	7	6	5	4	3	2	1
BARC	A7	A6	A5	A4	A3	A2	A1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

BAR consists of three 8-bit readable/writable registers (BARA, BARB, and BARC), and specify the address at which an address break is to be executed.

Each of the BAR registers is initialized to H'00 by a reset and in hardware standby mode, and not initialized in software standby mode.

BARA Bits 7 to 0—Address 23 to 16 (A23 to A16)

BARB Bits 7 to 0—Address 15 to 8 (A15 to A8)

BARC Bits 7 to 1—Address 7 to 1 (A7 to A1)

These bits specify the address at which an address break is to be executed. BAR bits A7 to A1 are compared with internal address bus lines A23 to A1, respectively.

The address at which the first instruction byte is located should be specified as the break address. Occurrence of the address break condition may not be recognized for other addresses.

In normal mode, no comparison is made with address lines A23 to A16.

BARC Bit 0—Reserved: This bit cannot be modified and is always read as 0.

IRQ6 interrupt source. Of these, NMI, IRQ7, IRQ6, and IRQ2 to IRQ0 can be used to interrupt the H8S/2148 Group or H8S/2144 Group chip from software standby mode.

NMI Interrupt

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

The vector number for NMI interrupt exception handling is 7.

IRQ7 to IRQ0 Interrupts

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

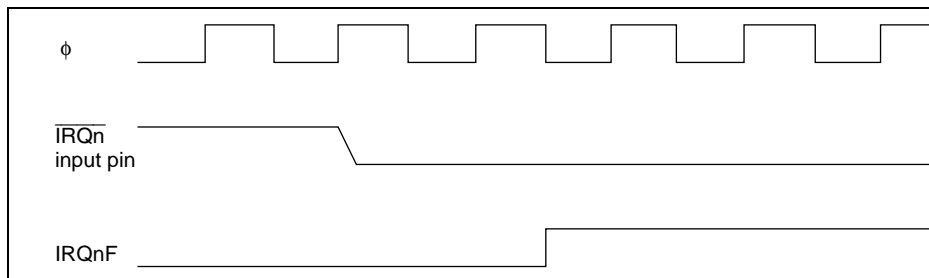
- Using ISCR, it is possible to select whether an interrupt is generated by a low level, falling edge, rising edge, or both edges, at pins $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$.
- Enabling or disabling of interrupt requests IRQ7 to IRQ0 can be selected with IER.
- The interrupt control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

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

Note: n: 7 to 0

Figure 5.3 Block Diagram of Interrupts IRQ7 to IRQ0

Figure 5.4 shows the timing of IRQnF setting.

**Figure 5.4 Timing of IRQnF Setting**

The vector numbers for IRQ7 to IRQ0 interrupt exception handling are 23 to 16.

Detection of IRQ7 to IRQ0 interrupts does not depend on whether the relevant pin has input or output. Therefore, when a pin is used as an external interrupt input pin, clear the corresponding DDR bit to 0 and do not use the pin as an I/O pin for another function. If the $\overline{\text{IRQ6}}$ pin is assigned as the IRQ6 interrupt input pin, then set the KMIMR6 bit to 0.

When the $\overline{\text{IRQ7}}$ pin is used as the IRQ7 interrupt input pin, bits KMIMR15 to KMIMR7 should be set to 1. If any of these bits is cleared to 0, interrupt input from the $\overline{\text{IRQ7}}$ pin will be disabled.

As interrupt request flags IRQ7F to IRQ0F are set when the setting condition is met, refer to the IER setting, only the necessary flags should be referenced.

interrupt request status indications, are all in accordance with the IRQ₆ and IRQ₇ interrupt settings.

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

5.3.2 Internal Interrupts

There are 43 sources for internal interrupts from on-chip supporting modules, plus one interrupt source (address break).

- For each on-chip supporting module there are flags that indicate the interrupt request status and enable bits that select enabling or disabling of these interrupts. If any one of the flags is 1, an interrupt request is issued to the interrupt controller.
- The interrupt control level can be set by means of ICR.
- The DTC can be activated by an FRT, TMR, SCI, or other interrupt request. When activated by an interrupt, the interrupt control mode and interrupt mask bits have no effect.

5.3.3 Interrupt Exception Vector Table

Table 5.4 shows interrupt exception handling sources, vector addresses, and interrupt priorities. For default priorities, the lower the vector number, the higher the priority.

Priorities among modules can be set by means of ICR. The situation when two or more modules are set to the same priority, and priorities within a module, are fixed as shown in table 5.4.

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		23	H'002E	H'00005C	
SWDTEND (software activation interrupt end)	DTC	24	H'0030	H'000060	ICRA
WOVI0 (interval timer)	Watchdog timer 0	25	H'0032	H'000064	ICRA
WOVI1 (interval timer)	Watchdog timer 1	26	H'0034	H'000068	ICRA
Address break (PC break)	—	27	H'0036	H'00006C	
ADI (A/D conversion end)	A/D	28	H'0038	H'000070	ICRA
Reserved	—	29 to 47	H'003A to H'005E	H'000074 to H'0000BC	
ICIA (input capture A)	Free-running timer	48	H'0060	H'0000C0	ICRA
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		55	H'006E	H'0000DC	
Reserved	—	56 to 63	H'0070 to H'007E	H'0000E0 to H'0000FC	

CMIA1 (compare-match A)	8-bit timer channel 1	68	H'0088	H'000110	ICRC
CMIB1 (compare-match B)		69	H'008A	H'000114	
OVI1 (overflow)		70	H'008C	H'000118	
Reserved		71	H'008E	H'00011C	
CMIA2 (compare-match A)	8-bit timer channels Y, X	72	H'0090	H'000120	ICRC
CMIB2 (compare-match B)		73	H'0092	H'000124	
OVI2 (overflow)		74	H'0094	H'000128	
ICIX (input capture X)		75	H'0096	H'00012C	
IBF1 (IDR1 reception completed)	Host interface	76	H'0098	H'000130	ICRC
IBF2 (IDR2 reception completed)		77	H'009A	H'000134	
IBF3 (IDR3 reception completed)		78	H'009C	H'000138	
IBF4 (IDR4 reception completed)		79	H'009E	H'00013C	
ERI0 (receive error 0)	SCI channel 0	80	H'00A0	H'000140	ICRC
RXI0 (reception completed 0)		81	H'00A2	H'000144	
TXI0 (transmit data empty 0)		82	H'00A4	H'000148	
TEI0 (transmission end 0)		83	H'00A6	H'00014C	
ERI1 (receive error 1)	SCI channel 1	84	H'00A8	H'000150	ICRC
RXI1 (reception completed 1)		85	H'00AA	H'000154	
TXI1 (transmit data empty 1)		86	H'00AC	H'000158	
TEI1 (transmission end 1)		87	H'00AE	H'00015C	
ERI2 (receive error 2)	SCI channel 2	88	H'00B0	H'000160	ICRC
RXI2 (reception completed 2)		89	H'00B2	H'000164	
TXI2 (transmit data empty 2)		90	H'00B4	H'000168	
TEI2 (transmission end 2)		91	H'00B6	H'00016C	
IICI0 (1-byte transmission/ reception completed)	IIC channel 0 (option)	92	H'00B8	H'000170	ICRC
DDCSWI (format switch)		93	H'00BA	H'000174	

PS2IC (reception completed C)	controller (PS2)	98	H'00C4	H'000188
Reserved		99	H'00C6	H'00018C
Reserved	—	100 to 103	H'00C8 to H'00CE	H'000190 to H'00019C

This function can be used to detect the beginning of execution of a bug location in the program and branch to a correction routine.

5.4.2 Block Diagram

A block diagram of the address break function is shown in figure 5.5.

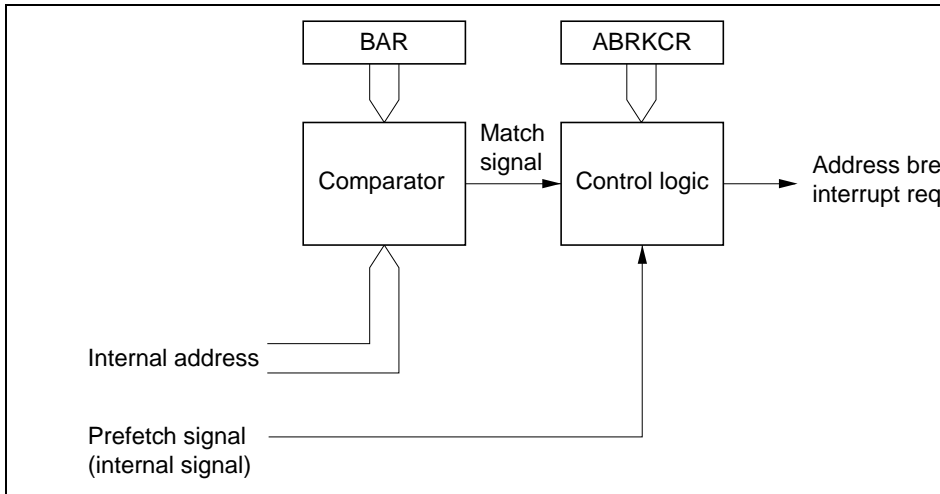


Figure 5.5 Block Diagram of Address Break Function

The register settings when the address break function is used are as follows.

1. Set the break address in bits A23 to A1 in BAR.
2. Set the BIE bit in ABRKCR to 1 to enable address breaks. An address break will not be requested if the BIE bit is cleared to 0.

When the setting condition occurs, the CMF flag in ABRKCR is set to 1 and an interrupt is requested. If necessary, the source should be identified in the interrupt handling routine.

5.4.4 Usage Notes

- With the address break function, the address at which the first instruction byte is located should be specified as the break address. Occurrence of the address break condition is not recognized for other addresses.
- In normal mode, no comparison is made with address lines A23 to A16.
- If a branch instruction (Bcc, BSR), jump instruction (JMP, JSR), RTS instruction, or instruction is located immediately before the address set in BAR, execution of this instruction will output a prefetch signal for that address, and an address break may be requested. This can be prevented by not making a break address setting for an address immediately following these instructions, or by determining within the interrupt handling routine whether interrupt handling was initiated by a genuine condition occurrence.
- As an address break interrupt is generated by a combination of the internal prefetch signal and the address, the timing of the start of interrupt exception handling depends on the content of the instruction in the execution cycle of the instruction at the set address and the preceding instruction. Figure 10-1 shows some address timing examples.

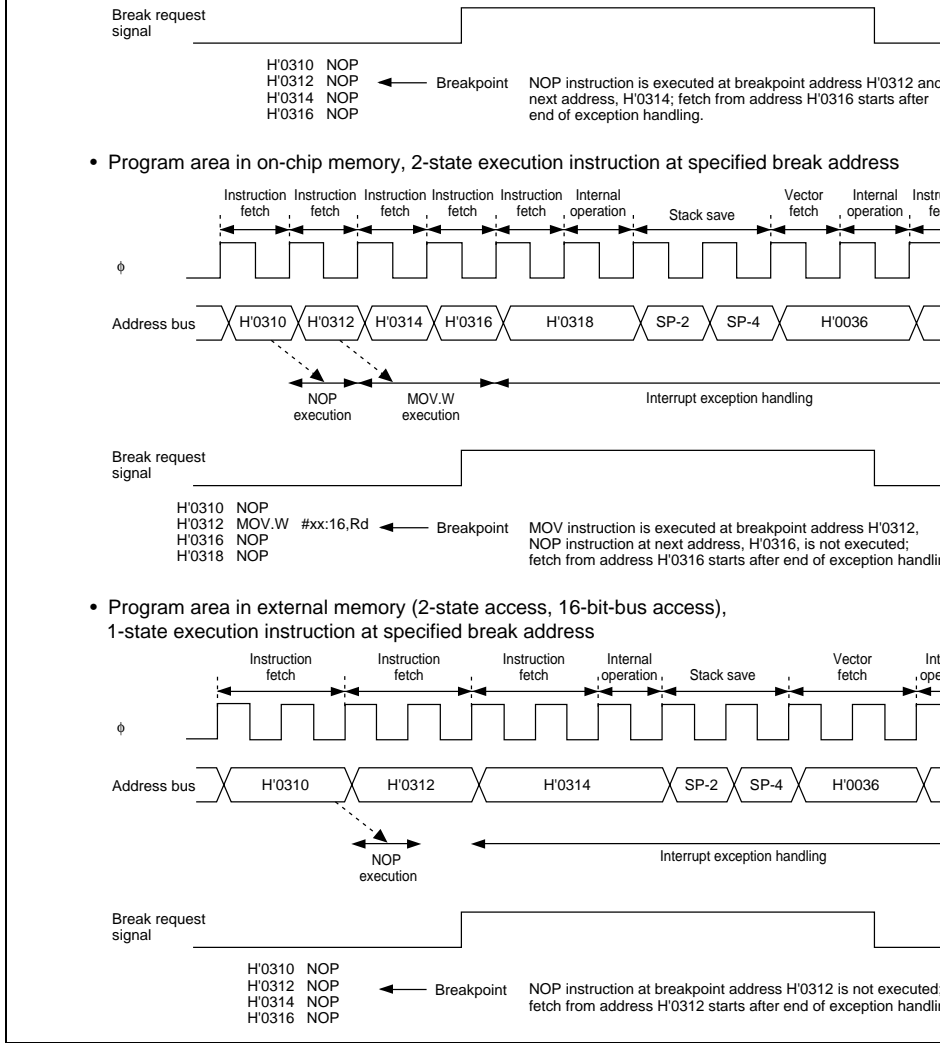


Figure 5.6 Examples of Address Break Timing



enable bit is provided for each interrupt. Clearing an enable bit to 0 disables the corresponding interrupt request. Interrupt sources for which the enable bits are set to 1 are controlled by the interrupt controller.

Table 5.5 shows the interrupt control modes.

The interrupt controller performs interrupt control according to the interrupt control mode selected by the INTM1 and INTM0 bits in SYSCR, the priorities set in ICR, and the masking status selected by the I and UI bits in the CPU's CCR.

Table 5.5 Interrupt Control Modes

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

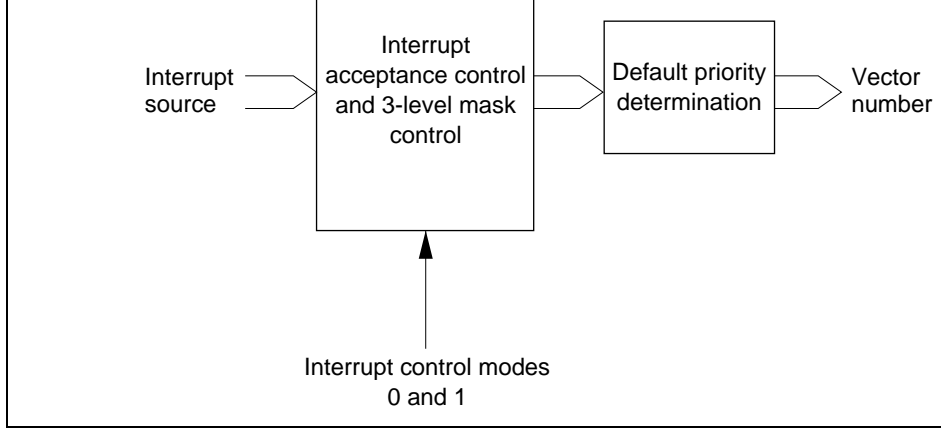


Figure 5.7 Block Diagram of Interrupt Control Operation

Interrupt Acceptance Control and 3-Level Control

In interrupt control modes 0 and 1, interrupt acceptance control and 3-level mask control are performed by means of the I and UI bits in CCR, and ICR (control level).

Table 5.6 shows the interrupts selected in each interrupt control mode.

Legend:

*: Don't care

Default Priority Determination

The priority is determined for the selected interrupt, and a vector number is generated.

If the same value is set for ICR, acceptance of multiple interrupts is enabled, and so on. The interrupt source with the highest priority according to the preset default priorities is selected, and a vector number is generated.

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

Table 5.7 shows operations and control signal functions in each interrupt control mode.

Table 5.7 Operations and Control Signal Functions in Each Interrupt Control Mode

Interrupt Control Mode	Setting		Interrupt Acceptance Control 3-Level Control				Default Priority Determination
	INTM1	INTM0		I	UI	ICR	
0	0	0	○	IM	—	PR	○
1	0	1	○	IM	IM	PR	○

Legend:

○: Interrupt operation control performed

IM: Used as interrupt mask bit

PR: Sets priority

—: Not used

interrupt request is sent to the interrupt controller.

2. When interrupt requests are sent to the interrupt controller, a control level 1 interrupt according to the control level set in ICR, has priority for selection, and other interrupts are held pending. If a number of interrupt requests with the same control level setting are generated at the same time, the interrupt request with the highest priority according to the priority system shown in table 5.4 is selected.
3. The I bit is then referenced. If the I bit is cleared to 0, the interrupt request is accepted. If the I bit is set to 1, only NMI and address break interrupt are accepted, and other interrupts are held pending.
4. When an interrupt request is accepted, interrupt exception handling starts after execution of the current instruction has been completed.
5. The PC and CCR are saved to the stack area by interrupt exception handling. The PC value on the stack shows the address of the first instruction to be executed after returning from the interrupt handling routine.
6. Next, the I bit in CCR is set to 1. This disables all interrupts except NMI and address break interrupt.
7. A vector address is generated for the accepted interrupt, and execution of the interrupt handling routine starts at the address indicated by the contents of that vector address.

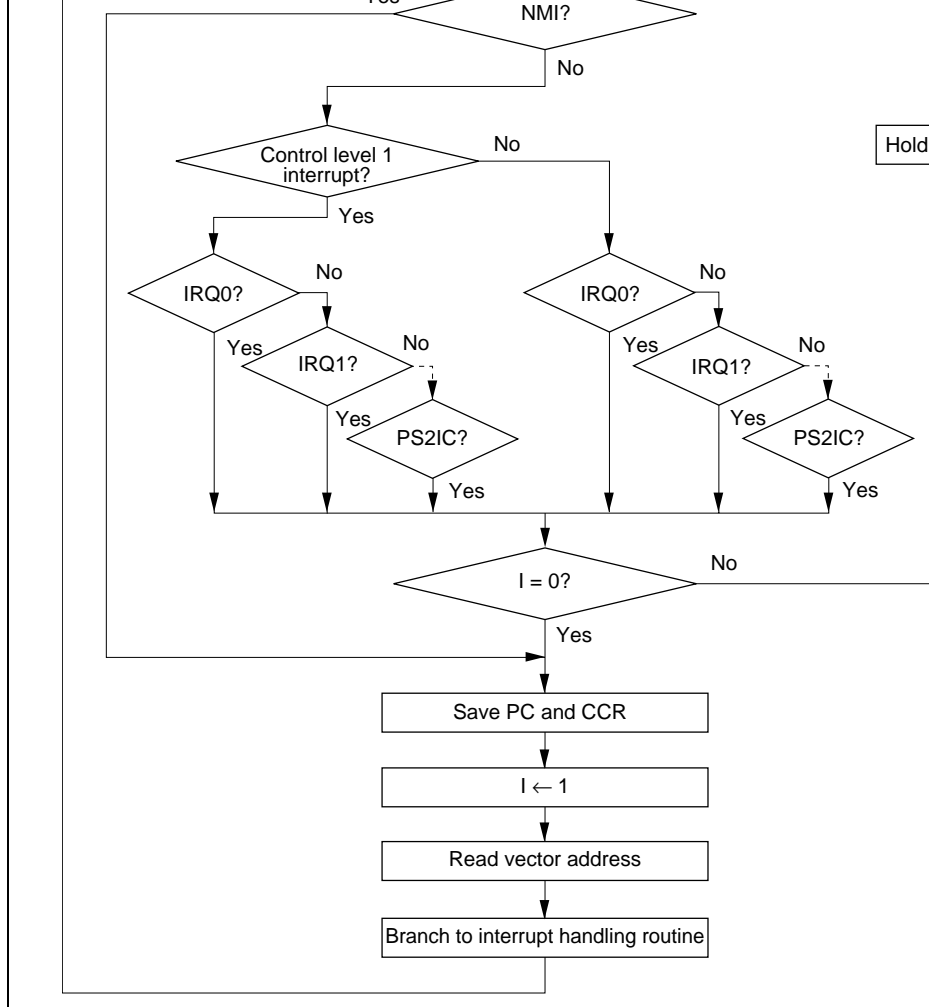


Figure 5.8 Flowchart of Procedure Up to Interrupt Acceptance in Interrupt Control Mode 0

disabled when both the I bit and the UI bit are set to 1.

For example, if the interrupt enable bit for an interrupt request is set to 1, and H'20, H'0 are set in ICRA, ICRB, and ICRC, respectively, (i.e. IRQ2 and IRQ3 interrupts are set level 1 and other interrupts to control level 0), the situation is as follows:

- When $I = 0$, all interrupts are enabled
(Priority order: NMI > IRQ2 > IRQ3 > address break > IRQ0 > IRQ1 ...)
- When $I = 1$ and $UI = 0$, only NMI, IRQ2, IRQ3 and address break interrupts are enabled
- When $I = 1$ and $UI = 1$, only NMI and address break interrupts are enabled

Figure 5.9 shows the state transitions in these cases.

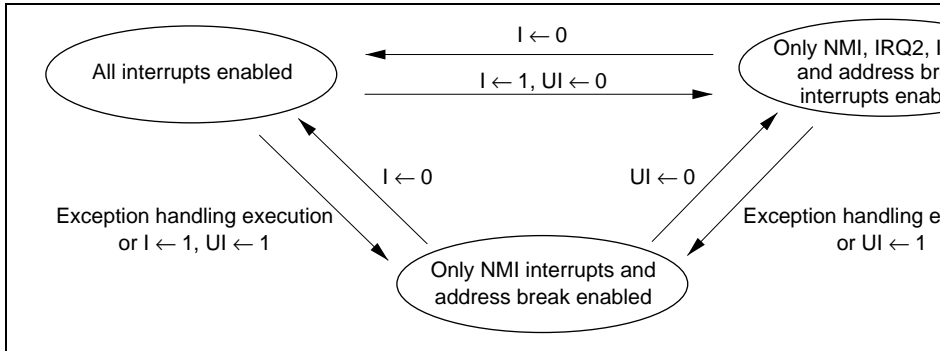


Figure 5.9 Example of State Transitions in Interrupt Control Mode 1

priority system shown in table 5.4 is selected.

3. The I bit is then referenced. If the I bit is cleared to 0, the UI bit has no effect.
An interrupt request set to interrupt control level 0 is accepted when the I bit is cleared to 0. If the I bit is set to 1, only an NMI and address break interrupts are accepted, and other interrupt requests are held pending.
An interrupt request set to interrupt control level 1 has priority over an interrupt request set to interrupt control level 0, and is accepted if the I bit is cleared to 0, or if the I bit is set to 1 and the UI bit is cleared to 0.
When both the I bit and the UI bit are set to 1, only an NMI and address break interrupt requests are accepted, and other interrupt requests are held pending.
4. When an interrupt request is accepted, interrupt exception handling starts after execution of the current instruction has been completed.
5. The PC and CCR are saved to the stack area by interrupt exception handling. The top of the stack shows the address of the first instruction to be executed after returning from the interrupt handling routine.
6. Next, the I and UI bits in CCR are set to 1. This disables all interrupts except NMI and address break.
7. A vector address is generated for the accepted interrupt, and execution of the interrupt handling routine starts at the address indicated by the contents of that vector address.

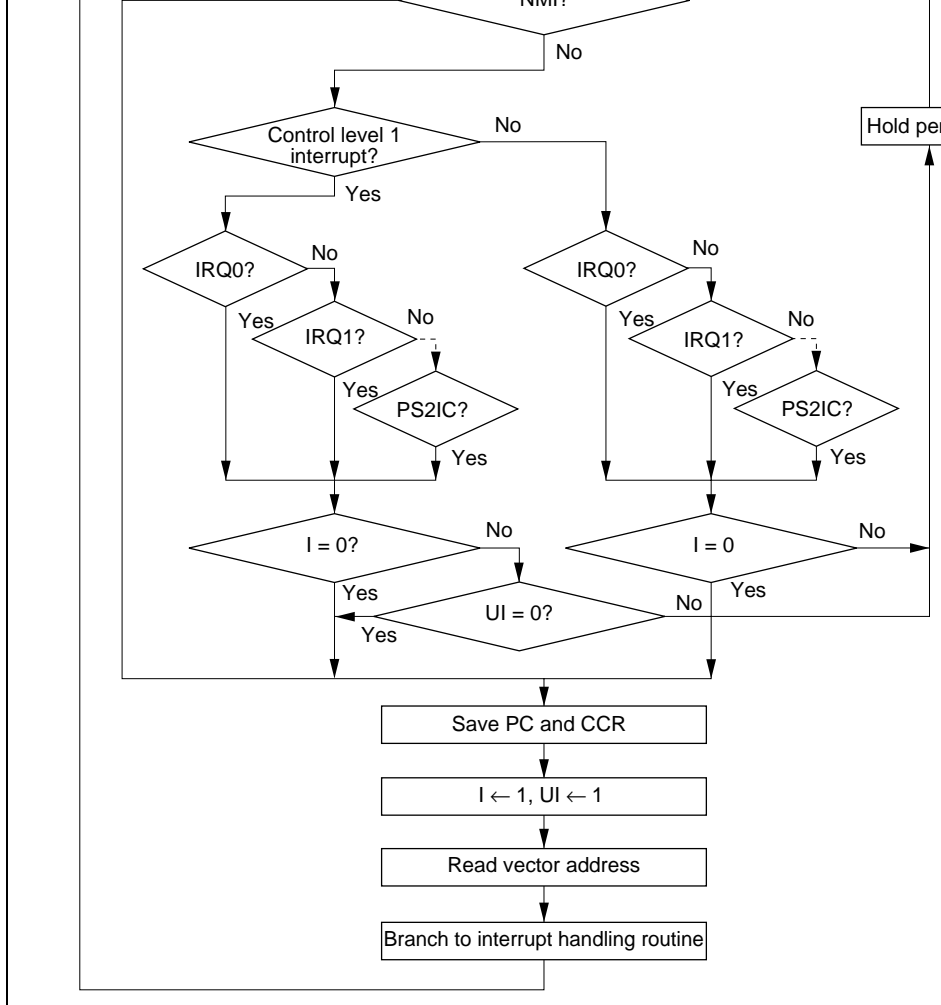


Figure 5.10 Flowchart of Procedure Up to Interrupt Acceptance in Interrupt Control Mode 1

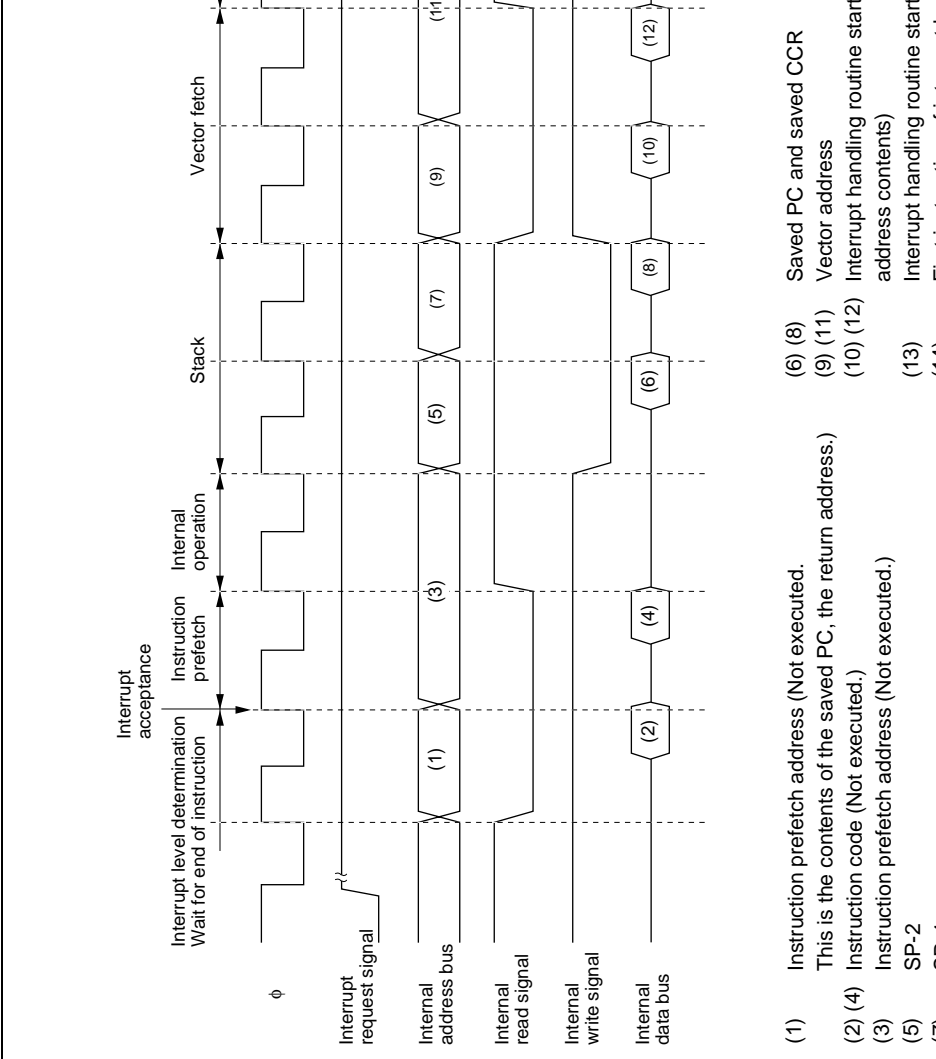


Figure 5.11 Interrupt Exception Handling

Table 5.8 Interrupt Response Times

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

Notes: 1. Two states in case of internal interrupt.

2. Refers to MULXS and DIVXS instructions.

3. Prefetch after interrupt acceptance and interrupt handling routine prefetch.

4. Internal processing after interrupt acceptance and internal processing after

Table 5.9 Number of States in Interrupt Handling Routine Execution

	Symbol	Internal Memory	Object of Access		
			External Device		
			8-Bit Bus		16-B
			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 an external device access

MOV, if an interrupt is generated during execution of the instruction, the interrupt condition is still enabled on completion of the instruction, and so interrupt exception handling for that interrupt will be executed on completion of the instruction. However, if there is an interrupt request of higher priority than that interrupt, interrupt exception handling will be executed for the higher-priority interrupt, and the lower-priority interrupt will be ignored.

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

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

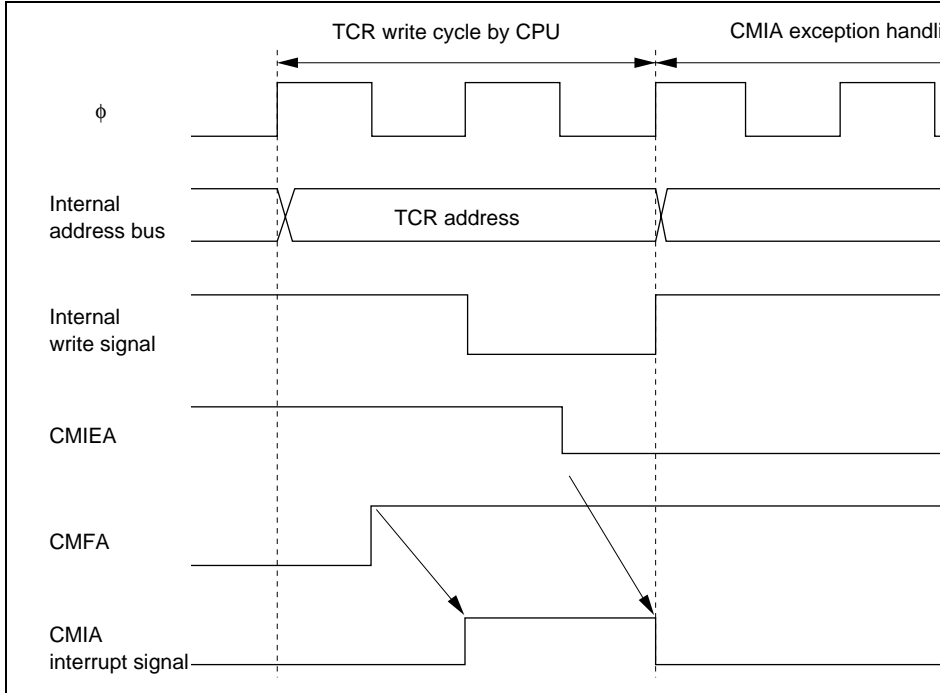


Figure 5.12 Contention between Interrupt Generation and Disabling

two states after execution of the instruction ends.

5.6.3 Interrupts during Execution of EEPMOV Instruction

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

With the EEPMOV.B instruction, an interrupt request (including NMI) issued during execution 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 stack is the address of the next instruction.

Therefore, if an interrupt is generated during execution of an EEPMOV.W instruction, the following coding should be used.

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

- Both of the above

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

5.7.2 Block Diagram

Figure 5.13 shows a block diagram of the DTC and interrupt controller.

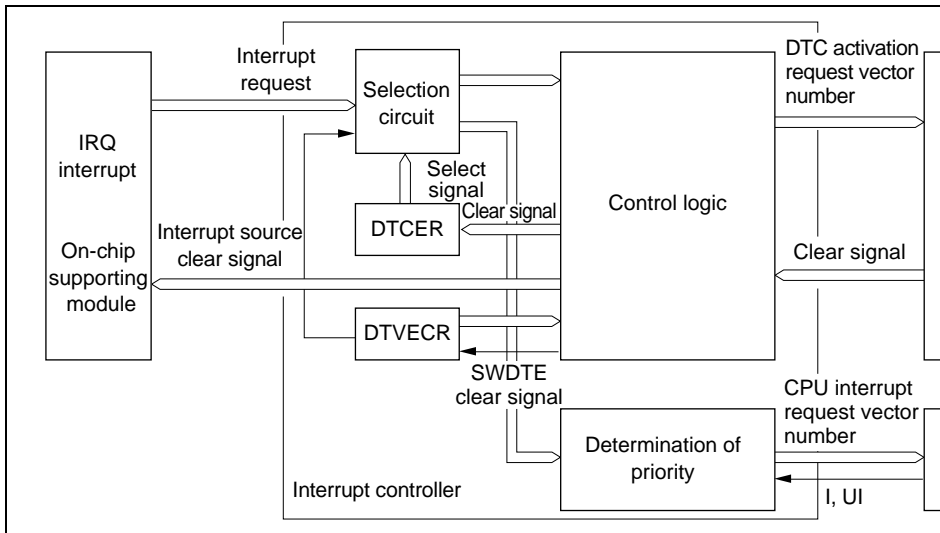


Figure 5.13 Interrupt Control for DTC

following the DTC data transfer the DTCE bit is cleared to 0 and an interrupt request is sent to the CPU.

Determination of Priority: The DTC activation source is selected in accordance with the priority order, and is not affected by mask or priority levels. See section 7.3.3, DTC V for the respective priorities.

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

Table 5.10 summarizes interrupt source selection and interrupt source clearance control according to the settings of the DTCE bit of DTCERA to DTCERE in the DTC and the DISEL bit in the DTC.

Table 5.10 Interrupt Source Selection and Clearing Control

Settings		Interrupt Source Selection/Clearing	
DTC		DTC	CPU
DTCE	DISEL		
0	*	×	Δ
1	0	Δ	×
	1	○	Δ

Legend:

- Δ: The relevant interrupt is used. Interrupt source clearing is performed.
(The CPU should clear the source flag in the interrupt handling routine.)
- : The relevant interrupt is used. The interrupt source is not cleared.
- ×: The relevant bit cannot be used.
- *: Don't care

The bus controller also has a bus arbitration function, and controls the operation of the bus masters: the CPU and data transfer controller (DTC).

6.1.1 Features

The features of the bus controller are listed below.

- Basic bus interface
 - 2-state access or 3-state access can be selected
 - Program wait states can be inserted
- Burst ROM interface
 - External space can be designated as ROM interface space
 - 1-state or 2-state burst access can be selected
- Idle cycle insertion
 - An idle cycle can be inserted when an external write cycle immediately follows a read cycle
- Bus arbitration function
 - Includes a bus arbiter that arbitrates bus mastership between the CPU and DTC

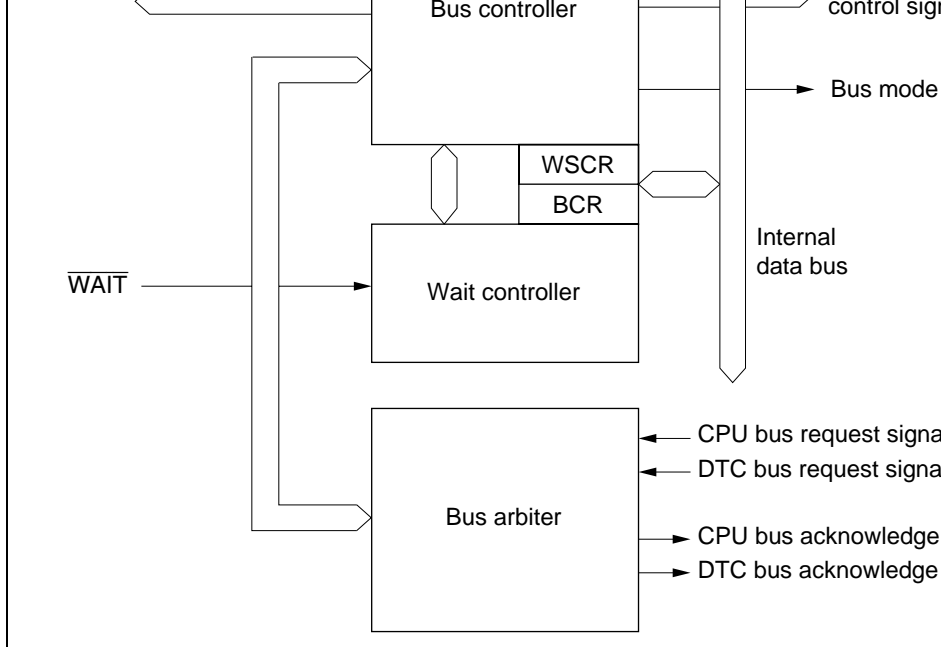


Figure 6.1 Block Diagram of Bus Controller

I/O select	$\overline{\text{IOS}}$	Output	I/O select signal (when IOSE bit is set)
Read	$\overline{\text{RD}}$	Output	Strobe signal indicating that external memory is being read
High write	$\overline{\text{HWR}}$	Output	Strobe signal indicating that external memory is being written to, and that the upper 8 bits (D15 to D8) is enabled
Low write	$\overline{\text{LWR}}$	Output	Strobe signal indicating that external memory is being written to, and that the lower 8 bits (D7 to D0) is enabled
Wait	$\overline{\text{WAIT}}$	Input	Wait request signal when external memory access space is accessed

6.1.4 Register Configuration

Table 6.2 summarizes the registers of the bus controller.

Table 6.2 Bus Controller Registers

Name	Abbreviation	R/W	Initial Value	Address
Bus control register	BCR	R/W	H'D7	H'F0
Wait state control register	WSCR	R/W	H'33	H'F1

Note: * Lower 16 bits of the address.

BCR is an 8-bit readable/writable register that specifies the external memory space access and the extent of the I/O area when the I/O strobe function has been selected for the AS

BCR is initialized to H'D7 by a reset and in hardware standby mode. It is not initialized in software standby mode.

Bit 7—Idle Cycle Insert 1 (ICIS1): Reserved. Do not write 0 to this bit.

Bit 6—Idle Cycle Insert 0 (ICIS0): Selects whether or not a one-state idle cycle is to be inserted between bus cycles when successive external read and external write cycles are performed.

Bit 6

ICIS0	Description
0	Idle cycle not inserted in case of successive external read and external write cycles.
1	Idle cycle inserted in case of successive external read and external write cycles. (In

Bit 5—Burst ROM Enable (BRSTRM): Selects whether external space is designated as burst ROM interface space. The selection applies to the entire external space.

Bit 5

BRSTRM	Description
0	Basic bus interface (In
1	Burst ROM interface



Bit 3—Burst Cycle Select 0 (BRSTS0): Selects the number of words that can be accessed in a burst ROM interface burst access.

Bit 3

BRSTS0	Description
0	Max. 4 words in burst access
1	Max. 8 words in burst access

Bit 2—Reserved: Do not write 0 to this bit.

Bits 1 and 0—IOS Select 1 and 0 (IOS1, IOS0): See table 6.4.

6.2.2 Wait State Control Register (WSCR)

Bit	7	6	5	4	3	2	1
	RAMS	RAM0	ABW	AST	WMS1	WMS0	WC1
Initial value	0	0	1	1	0	0	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

WSCR is an 8-bit readable/writable register that specifies the data bus width, number of wait states, wait mode, and number of wait states for external memory space. The on-chip internal I/O register bus width and number of access states are fixed, irrespective of the settings.

WSCR is initialized to H'33 by a reset and in hardware standby mode. It is not initialized in software standby mode.

0	External memory space is designated as 10-bit access space	(In
1	External memory space is designated as 8-bit access space	(In

Bit 4—Access State Control (AST): Specifies whether the external memory space is 2-state access space or 3-state access space, and simultaneously enables or disables wait state insertion.

Bit 4

AST	Description
0	External memory space is designated as 2-state access space Wait state insertion in external memory space accesses is disabled
1	External memory space is designated as 3-state access space Wait state insertion in external memory space accesses is enabled

Bits 3 and 2—Wait Mode Select 1 and 0 (WMS1, WMS0): These bits select the wait mode when external memory space is accessed while the AST bit is set to 1.

Bit 3	Bit 2	Description
WMS1	WMS0	
0	0	Program wait mode
	1	Wait-disabled mode
1	0	Pin wait mode
	1	Pin auto-wait mode

6.3 Overview of Bus Control

6.3.1 Bus Specifications

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

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

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

Number of Access States: Two or three access states can be selected with the AST bit. When 2-state access space is designated, wait insertion is disabled. The number of access states for the burst ROM interface is determined without regard to the AST bit setting.

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

Table 6.3 shows the bus specifications for each basic bus interface area.

						1			1
						1			2
						0			3
						1			3
1	0	—	—	—	—	8	2	0	0
	1	0	1	—	—	8	3	0	0
		—*	—*	0	0	0	3	0	0
						1			1
						1			2
						0			3
						1			3

Note: * Except when WMS1 = 0 and WMS0 = 1

6.3.2 Advanced Mode

The initial state of the external space is basic bus interface, three-state access space. In enabled expanded mode, the space excluding the on-chip ROM, on-chip RAM, and internal I/O registers is external space. The on-chip RAM is enabled when the RAME bit in the system control register (SYSCR) is set to 1; when the RAME bit is cleared to 0, the on-chip RAM is disabled and the corresponding space becomes external space.

6.3.3 Normal Mode

The initial state of the external memory space is basic bus interface, three-state access space. In ROM-disabled expanded mode, the space excluding the on-chip RAM and internal I/O registers is external space. In ROM-enabled expanded mode, the space excluding the on-chip ROM, on-chip RAM, and internal I/O registers is external space. The on-chip RAM is enabled when the RAME bit in the system control register (SYSCR) is set to 1; when the RAME bit is cleared to 0, the on-chip RAM is disabled and the corresponding space becomes external space.

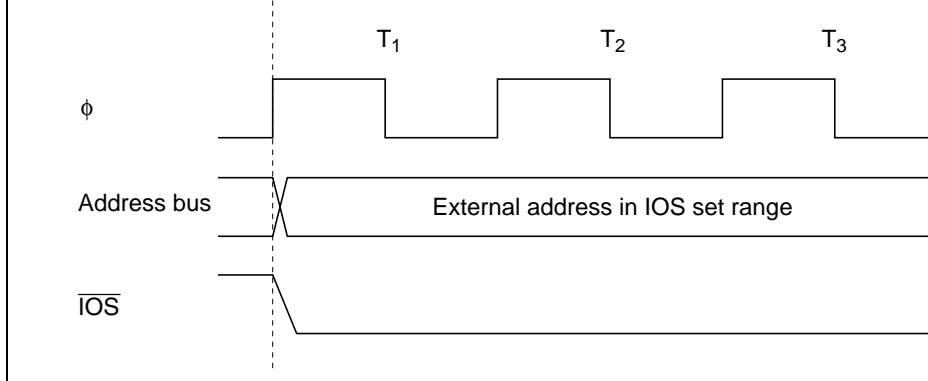


Figure 6.2 $\overline{\text{IOS}}$ Signal Output Timing

Enabling or disabling of $\overline{\text{IOS}}$ signal output is controlled by the setting of the IOSE bit. In expanded mode, this pin operates as the $\overline{\text{AS}}$ output pin after a reset, and therefore the SYSCR must be set to 1 in order to use this pin as the $\overline{\text{IOS}}$ signal output. See section Ports, for details.

The range of addresses for which the $\overline{\text{IOS}}$ signal is output can be set with bits IOS1 and IOS0. The $\overline{\text{IOS}}$ signal address ranges are shown in table 6.4.

Table 6.4 $\overline{\text{IOS}}$ Signal Output Range Settings

IOS1	IOS0	$\overline{\text{IOS}}$ Signal Output Range
0	0	H'(FF)F000 to H'(FF)F03F
	1	H'(FF)F000 to H'(FF)FOFF
1	0	H'(FF)F000 to H'(FF)F3FF
	1	H'(FF)F000 to H'(FF)FE4F*

Note: * In the H8S/2148 and H8S/2147 F-ZTAT A-mask version, the address range is H'(FF)F000 to H'(FF)F7FF.

6.4.2 Data Size and Data Alignment

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

8-Bit Access Space

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

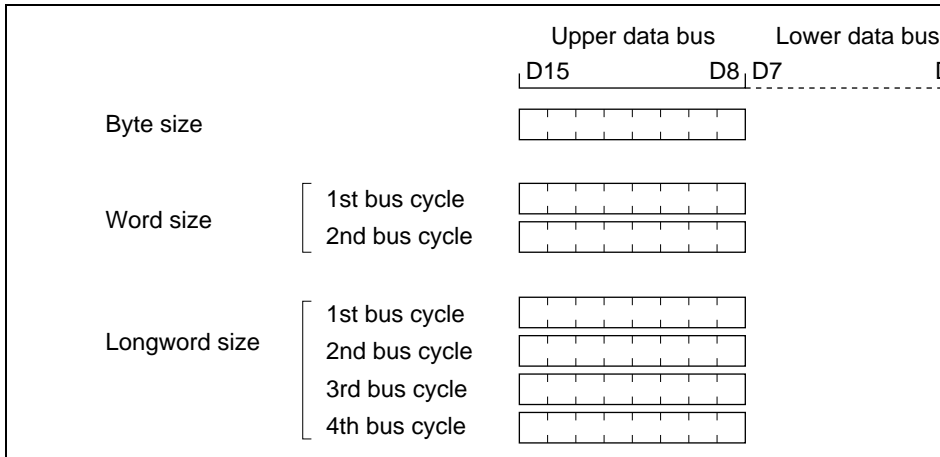


Figure 6.3 Access Sizes and Data Alignment Control (8-Bit Access Space)

address.

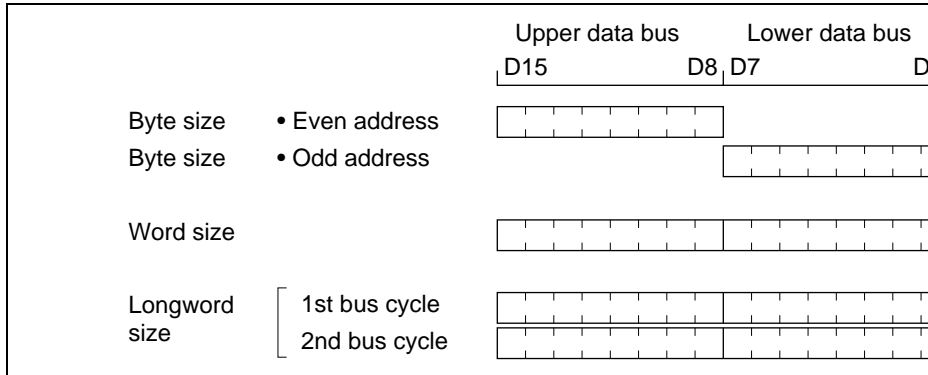


Figure 6.4 Access Sizes and Data Alignment Control (16-Bit Access Sp

Table 6.5 Data Buses Used and Valid Strobes

Area	Access Size	Read/Write	Address	Valid Strobe	Upper Data Bus (D15 to D8)	Lower Data Bus (D7 to D0)
8-bit access space	Byte	Read	—	\overline{RD}	Valid	Port, etc.
		Write	—	\overline{HWR}		Port, etc.
16-bit access space	Byte	Read	Even	\overline{RD}	Valid	Invalid
			Odd		Invalid	Valid
		Write	Even	\overline{HWR}	Valid	Undefined
			Odd	\overline{LWR}	Undefined	Valid
	Word	Read	—	\overline{RD}	Valid	Valid
		Write	—		$\overline{HWR}, \overline{LWR}$	Valid

Legend:

Undefined: Undefined data is output.

Invalid: Input state; input value is ignored.

Port, etc.: Pins are used as port or on-chip supporting module input/output pins, and not bus pins.

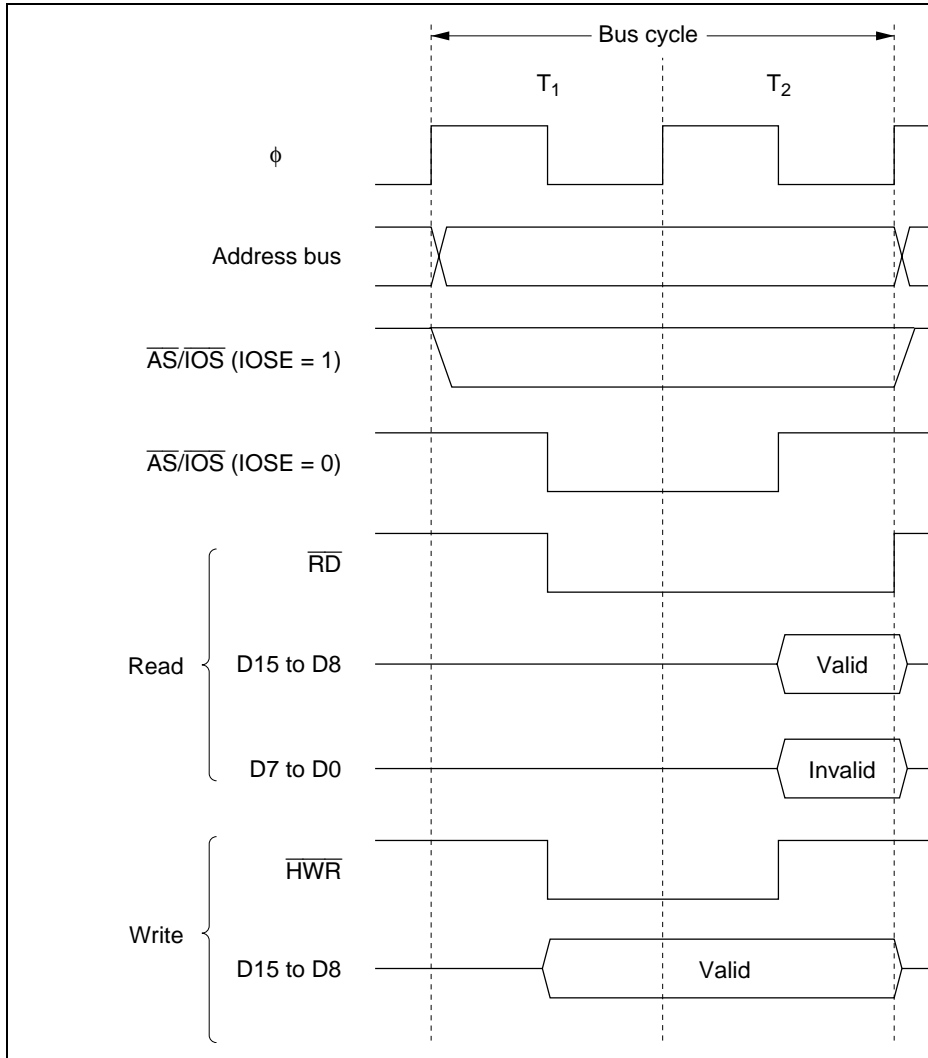


Figure 6.5 Bus Timing for 8-Bit 2-State Access Space

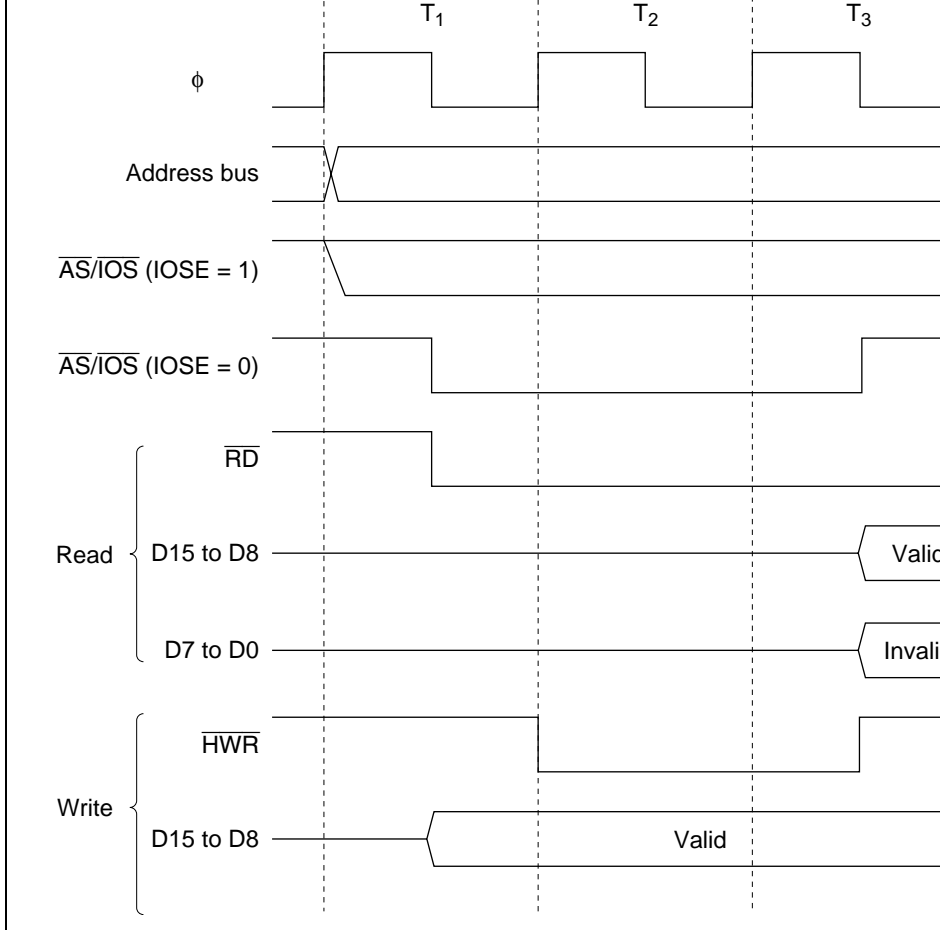


Figure 6.6 Bus Timing for 8-Bit 3-State Access Space

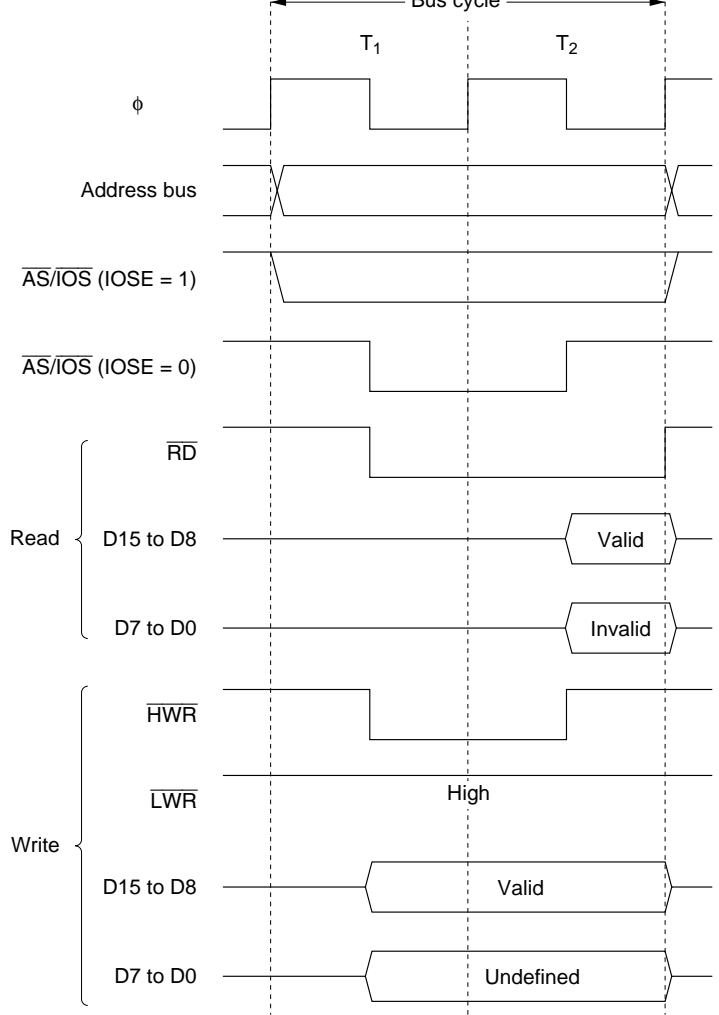
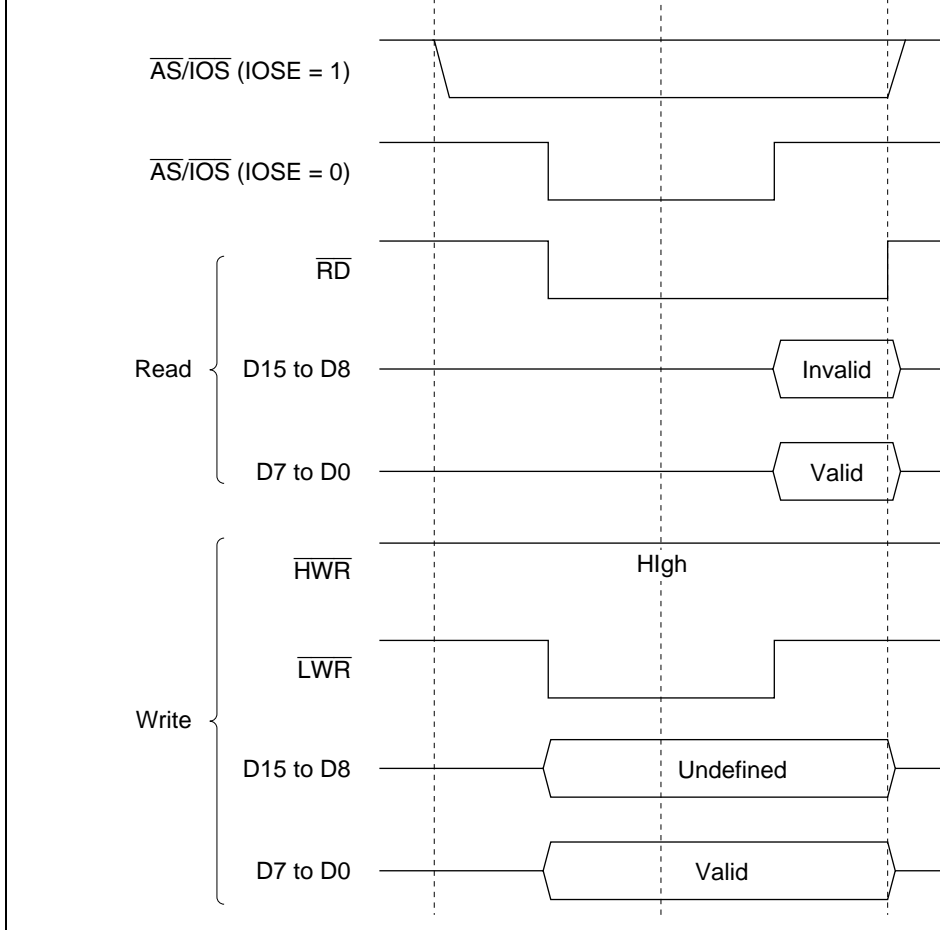
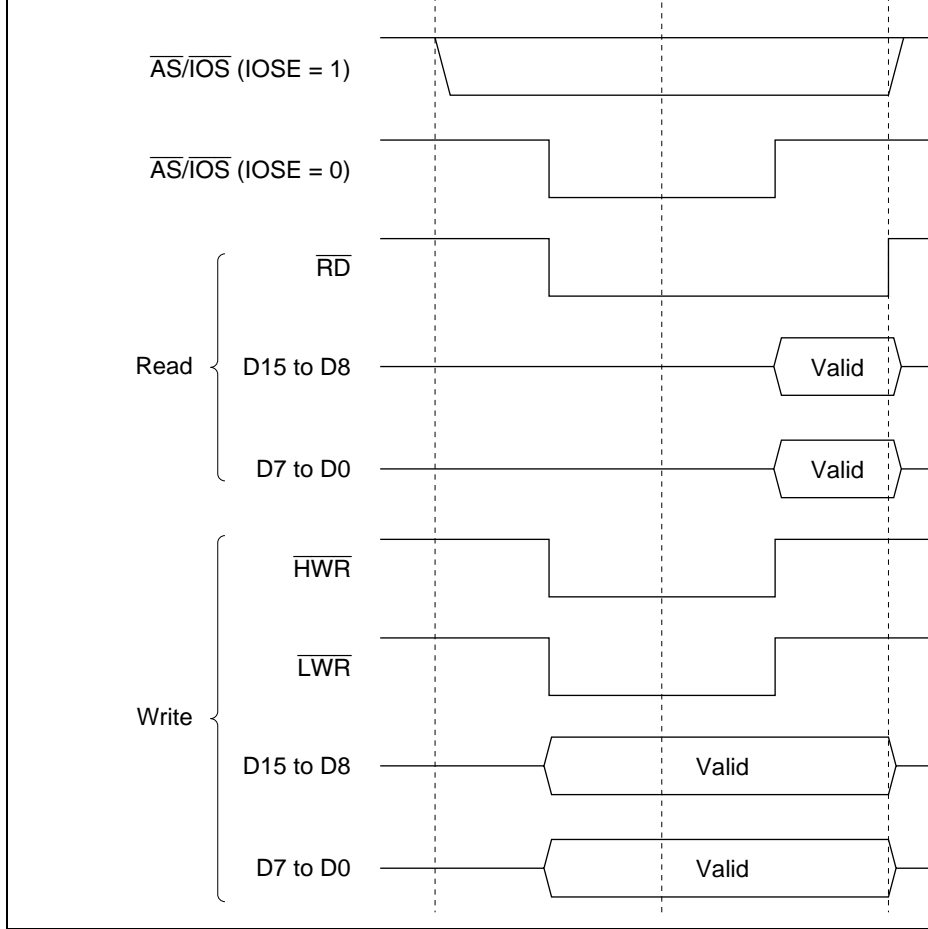


Figure 6.7 16-Bit, 2-State Access Space Bus Timing (1)
(Even Address Byte Access)



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



**Figure 6.9 16-Bit, 2-State Access Space Bus Timing (3)
(Word Access)**

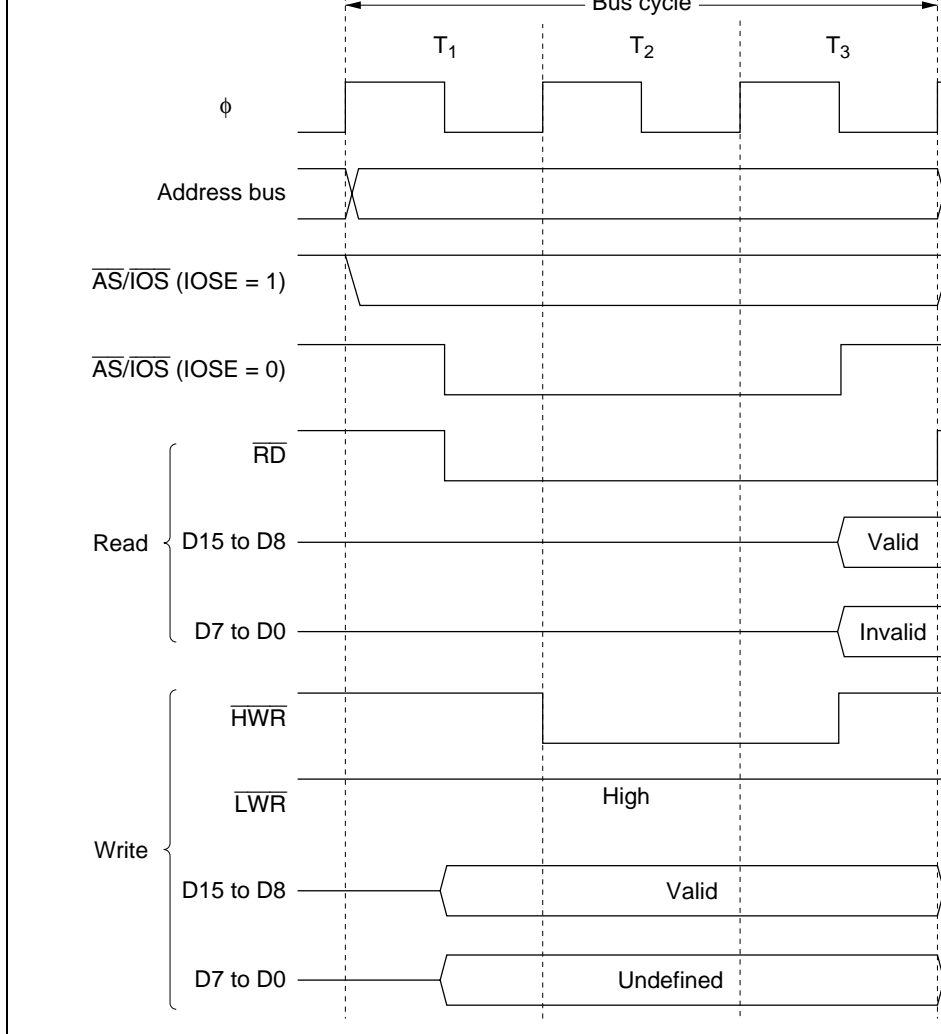
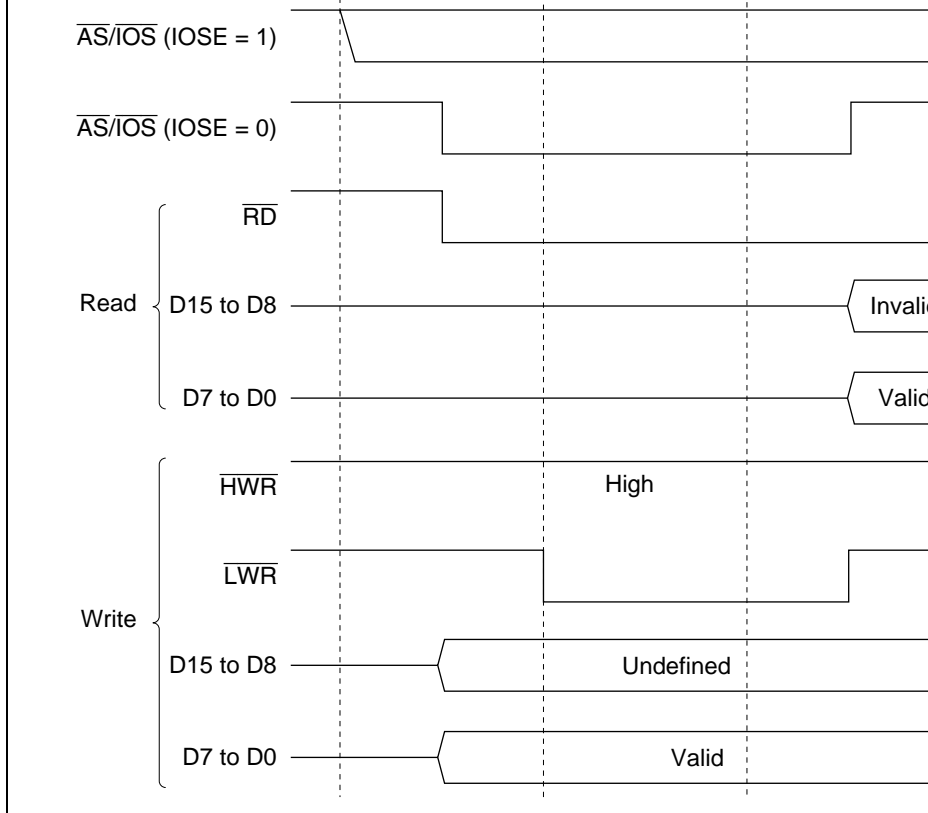
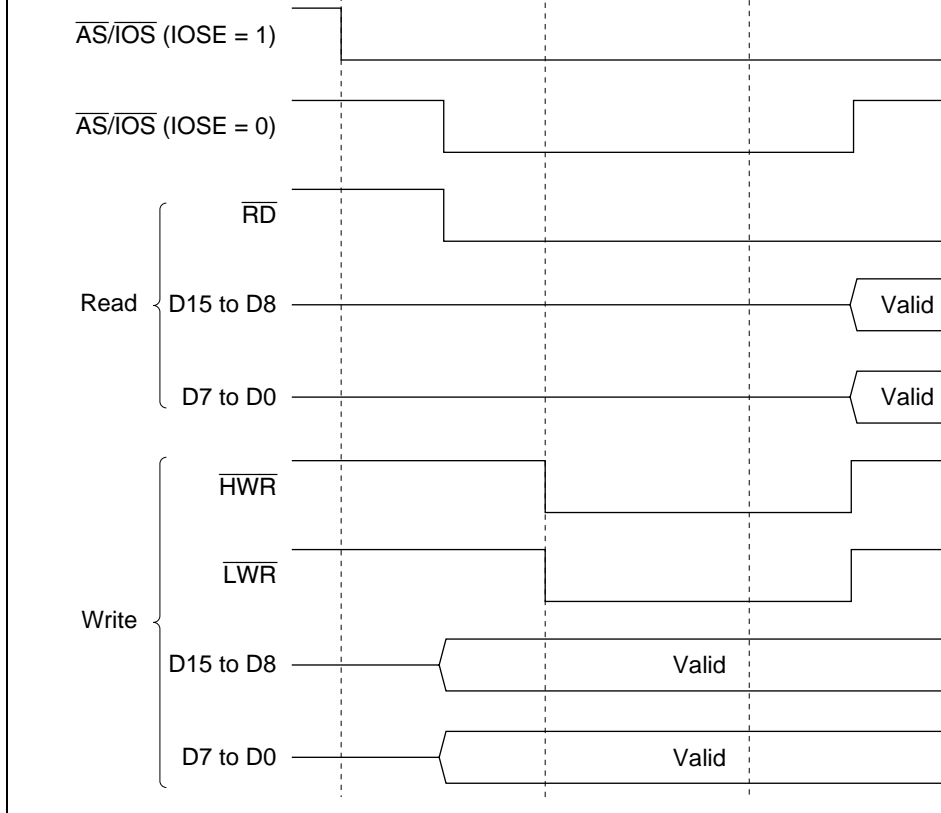


Figure 6.10 16-Bit, 3-State Access Space Bus Timing (1)
(Even Address Byte Access)



**Figure 6.11 16-Bit, 3-State Access Space Bus Timing (2)
(Odd Address Byte Access)**



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

Pin Wait Mode: In pin wait mode, the number of T_w states specified by bits WC1 and WC0 are always inserted between the T_2 and T_3 states when external space is accessed. If the $\overline{\text{WAIT}}$ pin is low at the fall of ϕ in the last T_2 or T_w state, another T_w state is inserted. If the $\overline{\text{WAIT}}$ pin remains low, T_w states are inserted until it goes high.

Pin wait mode is useful for inserting four or more wait states, or for changing the number of wait states for different external devices.

Pin Auto-Wait Mode: In pin auto-wait mode, if the $\overline{\text{WAIT}}$ pin is low at the fall of ϕ in the last T_2 state, the number of T_w states specified by bits WC1 and WC0 are inserted when external space is accessed. No additional T_w states are inserted even if the $\overline{\text{WAIT}}$ pin remains low. Pin auto-wait mode can be used for an easy interface to low-speed memory, simply by routing the clock signal to the $\overline{\text{WAIT}}$ pin.

Figure 6.13 shows an example of wait state insertion timing.

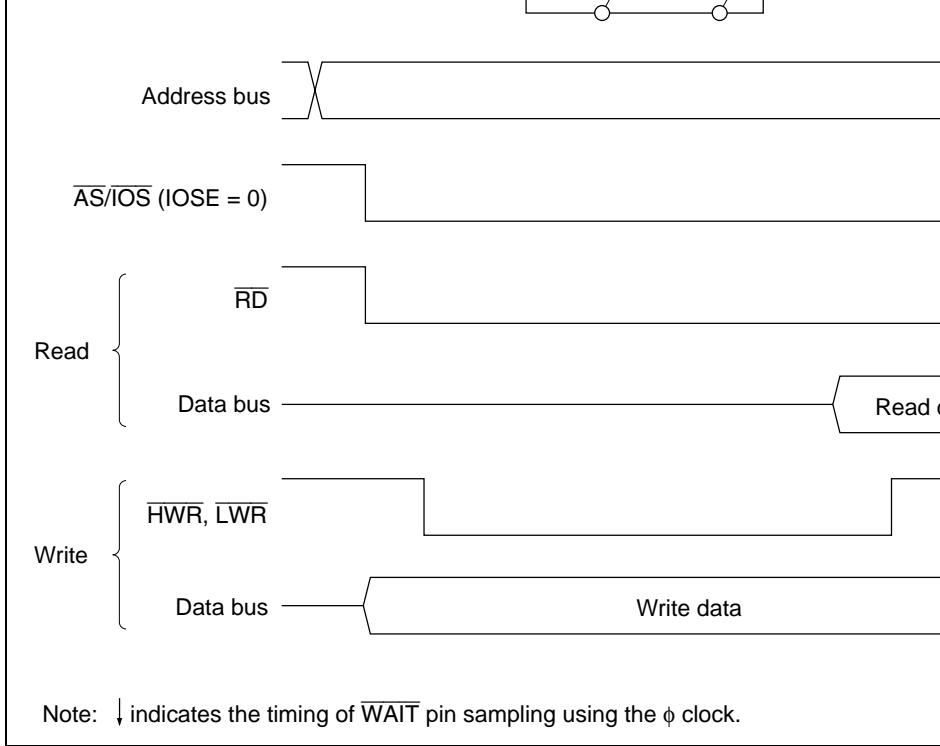


Figure 6.13 Example of Wait State Insertion Timing

The settings after a reset are: 3-state access, insertion of 3 program wait states, and \overline{WAIT} disabled.

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

6.5.2 Basic Timing

The number of states in the initial cycle (full access) of the burst ROM interface is in accordance with the setting of the AST bit. Also, when the AST bit is set to 1, wait state insertion is possible. One or two states can be selected for the burst cycle, according to the setting of the BRSTS0 and BRSTS1 bits in BCR. Wait states cannot be inserted.

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

The basic access timing for burst ROM space is shown in figures 6.14 (a) and (b). The timing shown in figure 6.14 (a) is for the case where the AST and BRSTS1 bits are both set to 1. The timing in figure 6.14 (b) is for the case where both these bits are cleared to 0.

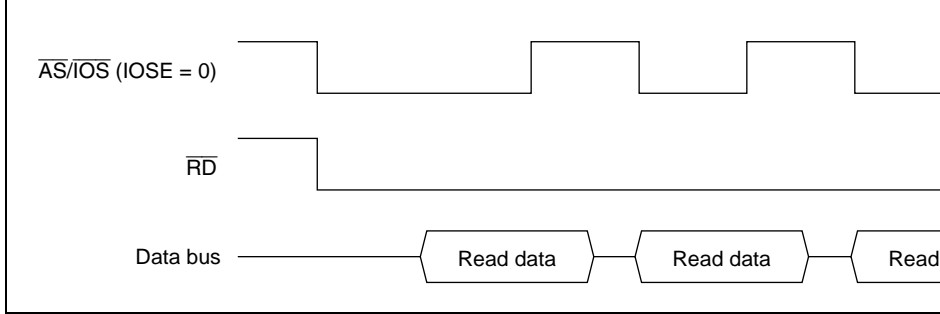


Figure 6.14 (a) Example of Burst ROM Access Timing (when AST = BRSTS)

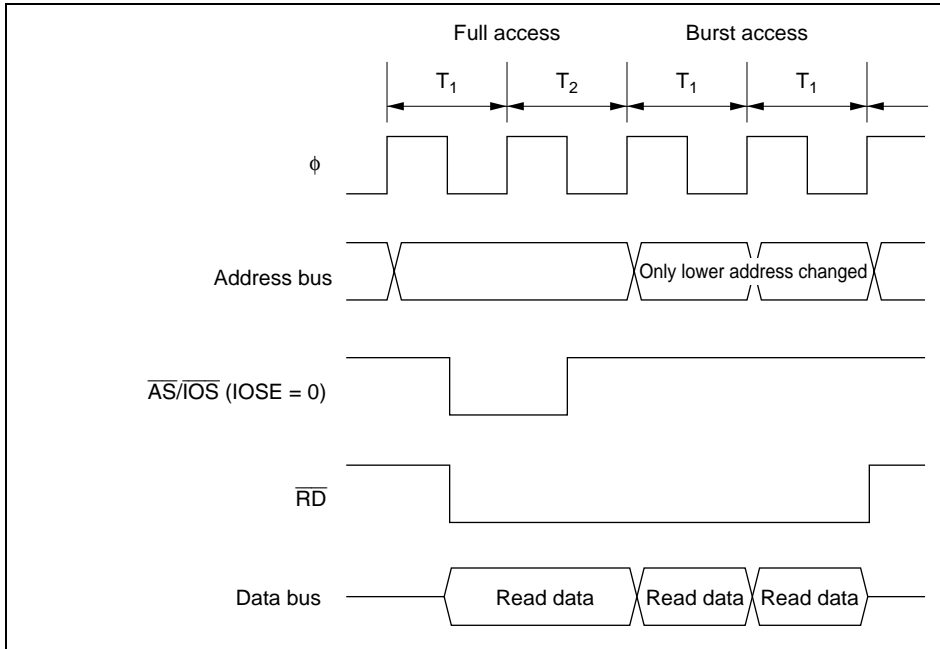


Figure 6.14 (b) Example of Burst ROM Access Timing (when AST = BRSTS)

6.6.1 Operation

When this LSI chip accesses external space, it can insert a 1-state idle cycle (T_1) between cycles when a write cycle occurs immediately after a read cycle. By inserting an idle cycle, if possible, for example, to avoid data collisions between ROM, with a long output floating time, high-speed memory, I/O interfaces, and so on.

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

Figure 6.15 shows an example of the operation in this case. In this example, bus cycle A is a read cycle from ROM with a long output floating time, and bus cycle B is a CPU write cycle. In (a), an idle cycle is not inserted, and a collision occurs in cycle B between the read data from the CPU and the CPU write data. In (b), an idle cycle is inserted, and a data collision is prevented.

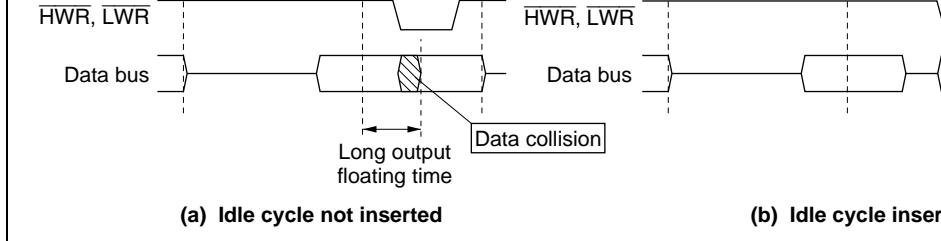


Figure 6.15 Example of Idle Cycle Operation

6.6.2 Pin States in Idle Cycle

Table 6.6 shows pin states in an idle cycle.

Table 6.6 Pin States in Idle Cycle

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

bus arbiter determines priorities at the prescribed timing, and permits use of the bus by the bus master that has received the bus request acknowledge signal. The selected bus master then takes possession of the bus and begins its operation.

6.7.2 Operation

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

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

(High) DTC > CPU (Low)

The CPU is the lowest-priority bus master, and if a bus request is received from the DTC, the bus arbiter transfers the bus to the DTC. The timing for transfer of the bus is as follows:

- The bus is transferred at a break between bus cycles. However, if a bus cycle is executing discrete operations, as in the case of a longword-size access, the bus is not transferred until the operations are complete.
See appendix A.5, Bus States during Instruction Execution, for timings at which the bus is transferred.
- If the CPU is in sleep mode, it transfers the bus immediately.

DTC

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

The DTC does not release the bus until it has completed a series of processing operations.

7.1.1 Features

- Transfer possible over any number of channels
 - Transfer information is stored in memory
 - One activation source can trigger a number of data transfers (chain transfer)
- Wide range of transfer modes
 - Normal, repeat, and block transfer modes available
 - Incrementing, decrementing, and fixing of transfer source and destination addresses selected
- Direct specification of 16-Mbyte address space possible
 - 24-bit transfer source and destination addresses can be specified
- Transfer can be set in byte or word units
- A CPU interrupt can be requested for the interrupt that activated the DTC
 - An interrupt request can be issued to the CPU after one data transfer ends
 - An interrupt request can be issued to the CPU after all specified data transfers
- Activation by software is possible
- Module stop mode can be set
 - The initial setting enables DTC registers to be accessed. DTC operation is halted in module stop mode

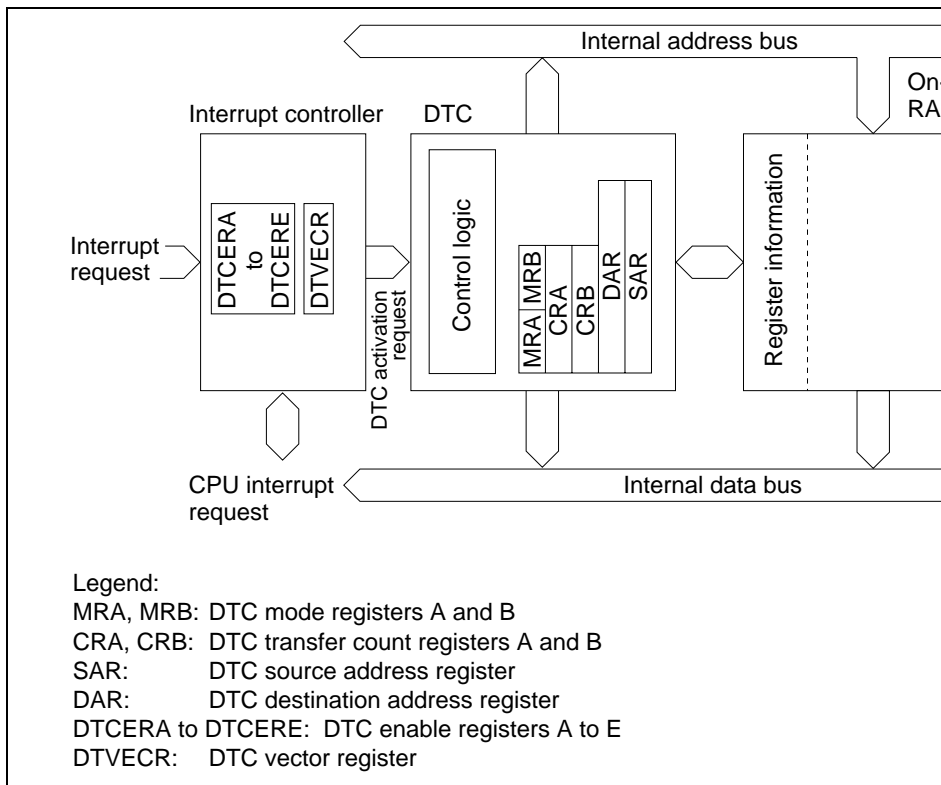


Figure 7.1 Block Diagram of DTC

DTC source address register	SAR	—*2	Undefined	—*3
DTC destination address register	DAR	—*2	Undefined	—*3
DTC transfer count register A	CRA	—*2	Undefined	—*3
DTC transfer count register B	CRB	—*2	Undefined	—*3
DTC enable registers	DTCER*4	R/W	H'00	H'FEFE
DTC vector register	DTVECR*4	R/W	H'00	H'FEF3
Module stop control register	MSTPCRH	R/W	H'3F	H'FF86
	MSTPCRL	R/W	H'FF	H'FF87

- Notes:
1. Lower 16 bits of the address.
 2. Registers within the DTC cannot be read or written to directly.
 3. Allocated to on-chip RAM addresses H'EC00 to H'FFFF as register information. They cannot be located in external memory space.
When the DTC is used, do not clear the RAME bit in SYSCR to 0.
 4. The H8S/2144 Group and H8S/2147N do not include an on-chip DTC, and DTCER and DTVECR register addresses should not be accessed by the CPU.

MRA is an 8-bit register that controls the DTC operating mode.

Bits 7 and 6—Source Address Mode 1 and 0 (SM1, SM0): These bits specify whether SAR is to be incremented, decremented, or left fixed after a data transfer.

Bit 7	Bit 6	
SM1	SM0	Description
0	—	SAR is fixed
1	0	SAR is incremented after a transfer (by 1 when Sz = 0; by 2 when Sz = 1)
	1	SAR is decremented after a transfer (by 1 when Sz = 0; by 2 when Sz = 1)

Bits 5 and 4—Destination Address Mode 1 and 0 (DM1, DM0): These bits specify whether DAR is to be incremented, decremented, or left fixed after a data transfer.

Bit 5	Bit 4	
DM1	DM0	Description
0	—	DAR is fixed
1	0	DAR is incremented after a transfer (by 1 when Sz = 0; by 2 when Sz = 1)
	1	DAR is decremented after a transfer (by 1 when Sz = 0; by 2 when Sz = 1)

Bit 1—DTC Transfer Mode Select (DTS): Specifies whether the source side or the destination side is set to be a repeat area or block area, in repeat mode or block transfer mode.

Bit 1

DTS	Description
0	Destination side is repeat area or block area
1	Source side is repeat area or block area

Bit 0—DTC Data Transfer Size (Sz): Specifies the size of data to be transferred.

Bit 0

Sz	Description
0	Byte-size transfer
1	Word-size transfer

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

Bit 7—DTC Chain Transfer Enable (CHNE): Specifies chain transfer. In chain transfer mode, multiple data transfers can be performed consecutively in response to a single transfer request. With data transfer for which CHNE is set to 1, there is no determination of the end of the transfer, the number of transfers, clearing of the interrupt source flag, or clearing of DTCER.

Bit 7

CHNE	Description
0	End of DTC data transfer (activation waiting state is entered)
1	DTC chain transfer (new register information is read, then data is transferred)

Bit 6—DTC Interrupt Select (DISEL): Specifies whether interrupt requests to the CPU are disabled or enabled after a data transfer.

Bit 6

DISEL	Description
0	After a data transfer ends, the CPU interrupt is disabled unless the transfer request is received (the DTC clears the interrupt source flag of the activating interrupt to 0)
1	After a data transfer ends, the CPU interrupt is enabled (the DTC does not clear the interrupt source flag of the activating interrupt to 0)

Bits 5 to 0—Reserved: In the H8S/2148 Group these bits have no effect on DTC operation and should always be written with 0.

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

7.2.4 DTC Destination Address Register (DAR)

Bit	23	22	21	20	19	---	---	4	3	2
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Initial value	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	---	---	Unde- fined	Unde- fined	Unde- fined
Read/write	—	—	—	—	—	---	---	—	—	—

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

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

In normal mode, the entire CRA register functions as a 16-bit transfer counter (1 to 65,536), decremented by 1 every time data is transferred, and transfer ends when the count reaches H'0000.

In repeat mode or block transfer mode, CRA is divided into two parts: the upper 8 bits (CRAH) and the lower 8 bits (CRAL). CRAH holds the number of transfers while CRAL functions as an 8-bit transfer counter (1 to 256). CRAL is decremented by 1 every time data is transferred. The contents of CRAH are transferred when the count reaches H'00. This operation is repeated until the contents of CRAH reach H'00.

7.2.6 DTC Transfer Count Register B (CRB)

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2
Initial value	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined	Undefined
Read/Write	—	—	—	—	—	—	—	—	—	—	—	—	—	—

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 65,536) that is decremented by 1 every time data is transferred, and transfer ends when the count reaches H'0000.

with bits corresponding to the interrupt sources that can activate the DTC. These bits can disable DTC service for the corresponding interrupt sources.

The DTC enable registers are initialized to H'00 by a reset and in hardware standby mode.

Bit n—DTC Activation Enable (DTCEn)

Bit n

DTCEn	Description
0	DTC activation by interrupt is disabled [Clearing conditions] <ul style="list-style-type: none">• When data transfer ends with the DISEL bit set to 1• When the specified number of transfers end
1	DTC activation by interrupt is enabled [Holding condition] When the DISEL bit is 0 and the specified number of transfers have not ended

Note: n = 7 to 0

A DTCE bit can be set for each interrupt source that can activate the DTC. The correspondence between interrupt sources and DTCE bits is shown in table 7.4, together with the vectors generated by the interrupt controller in each case.

For DTCE bit setting, read/write operations must be performed using bit-manipulation instructions such as BSET and BCLR. For the initial setting only, however, when multiple activation bits are set at one time, it is possible to disable interrupts and write after executing a dummy instruction to the relevant register.

is read.

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

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

Bit 7—DTC Software Activation Enable (SWDTE): Specifies enabling or disabling software activation. To clear the SWDTE bit by software, read SWDTE when set to 1, in the bit.

Bit 7

SWDTE	Description
0	DTC software activation is disabled (Initial condition) [Clearing condition] When the DISEL bit is 0 and the specified number of transfers have not occurred
1	DTC software activation is enabled [Holding conditions] <ul style="list-style-type: none">• When data transfer ends with the DISEL bit set to 1• When the specified number of transfers end• During software-activated data transfer

Bits 6 to 0—DTC Software Activation Vectors 6 to 0 (DTVEC6 to DTVEC0): These bits specify a vector number for DTC software activation.

The vector address is $H'0400 + (\text{vector number}) \ll 1$ (where $\ll 1$ indicates a 1-bit left shift). For example, if $DTVEC6$ to $DTVEC0 = H'10$, the vector address is $H'0420$.

MSTPCR, comprising two 8-bit readable/writable registers, performs module stop mo

When the MSTP14 bit in MSTPCR is set to 1, the DTC operation stops at the end of t and a transition is made to module stop mode. Note that 1 cannot be written to the MS when the DTC is being activated. For details, see section 25.5, Module Stop Mode.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not in software standby mode.

MSTPCRH Bit 6—Module Stop (MSTP14): Specifies the DTC module stop mode.

MSTPCRH

Bit 6

MSTP14	Description
0	DTC module stop mode is cleared
1	DTC module stop mode is set

7.3 Operation

7.3.1 Overview

When activated, the DTC reads register information that is already stored in memory and transfers data on the basis of that register information. After the data transfer, it writes updated register information back to memory. Pre-storage of register information in memory makes it possible to transfer data over any required number of channels. Setting the CHNE bit to 1 makes the DTC perform a number of transfers with a single activation.

Figure 7.2 shows a flowchart of DTC operation.

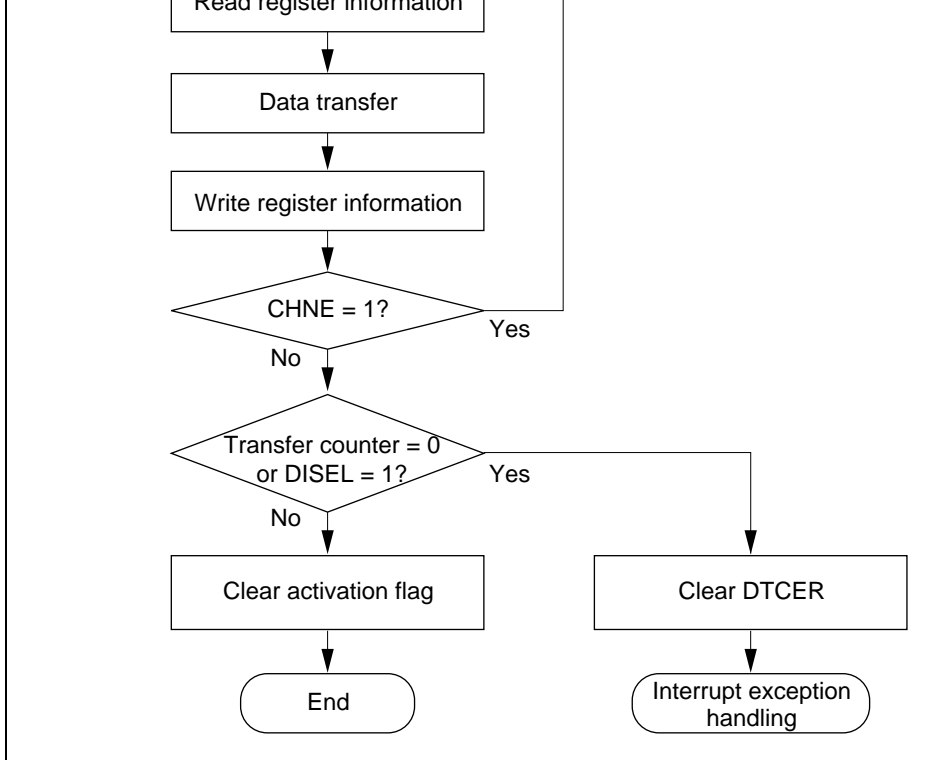


Figure 7.2 Flowchart of DTC Operation

The DTC transfer mode can be normal mode, repeat mode, or block transfer mode.

The 24-bit SAR designates the DTC transfer source address and the 24-bit DAR designates the transfer destination address. After each transfer, SAR and DAR are independently incremented, decremented, or left fixed.

Table 7.2 outlines the functions of the DTC.

- Memory addresses are incremented or decremented by 1 or 2
 - Up to 65,536 transfers possible
 - Repeat mode
 - One transfer request transfers one byte or one word
 - Memory addresses are incremented or decremented by 1 or 2
 - After the specified number of transfers (1 to 256), the initial state resumes and operation continues
 - Block transfer mode
 - One transfer request transfers a block of the specified size
 - Block size is from 1 to 256 bytes or words
 - Up to 65,536 transfers possible
 - A block area can be designated at either the source or destination
- Host interface I2C
 - SCI TXI or RXI
 - A/D converter ADI
 - IIC IICI
 - Software
-

7.3.2 Activation Sources

The DTC operates when activated by an interrupt or by a write to DTVECR by software (software activation). An interrupt request can be directed to the CPU or DTC, as designated by the corresponding DTICR bit. The interrupt request is directed to the DTC when the corresponding DTICR bit is set to 1, and to the CPU when the bit is cleared to 0.

At the end of one data transfer (or the last of the consecutive transfers in the case of channel transfer), the interrupt source or the corresponding DTICR bit is cleared. Table 7.3 shows activation sources and DTICR clearing.

Interrupt activation	<ul style="list-style-type: none"> • Corresponding DTCEr bit held at 1 • Activation source flag cleared to 0 	<ul style="list-style-type: none"> • Corresponding DTCEr bit • Activation source flag held • Activation source interrupt r • sent to CPU
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Figure 7.3 shows a block diagram of activation source control. For details see section 5 Controller.

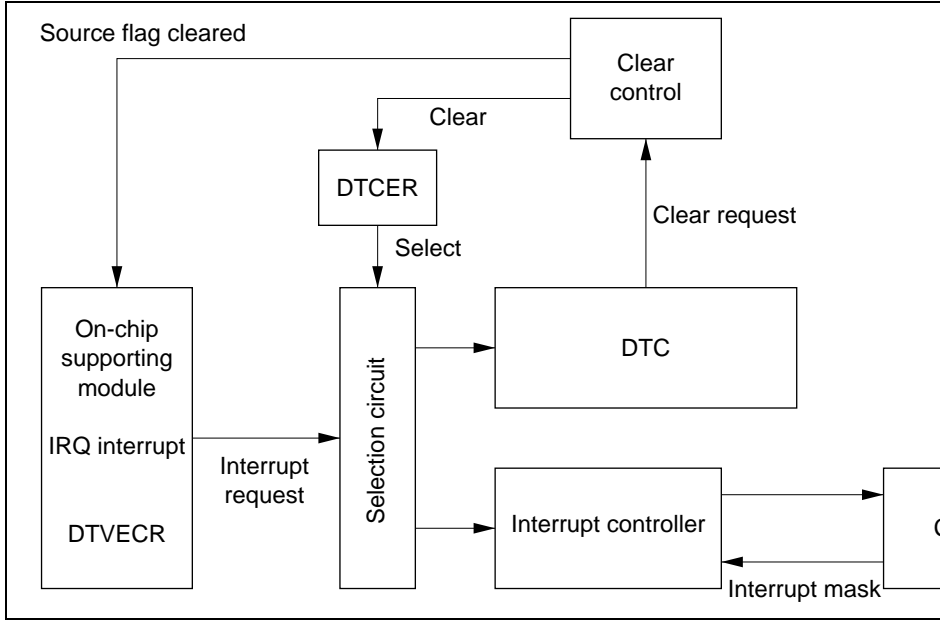


Figure 7.3 Block Diagram of DTC Activation Source Control

When an interrupt has been designated a DTC activation source, existing CPU mask level and interrupt controller priorities have no effect. If there is more than one activation source active at the same time, the DTC is activated in accordance with the default priorities.

The DTC reads the start address of the register information from the vector address set by the activation source, and then reads the register information from that start address. The register information can be placed at predetermined addresses in the on-chip RAM. The start address of the register information should be an integral multiple of four.

The configuration of the vector address is the same in both normal and advanced mode. The unit being used in both cases. These two bytes specify the lower bits of the address in the on-chip RAM.

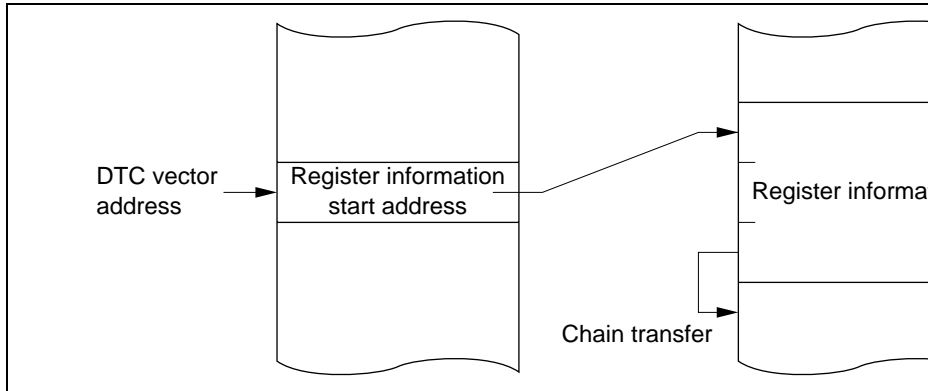


Figure 7.4 Correspondence between DTC Vector Address and Register Information

IRQ2		18	H'0424	DTCEA
IRQ3		19	H'0426	DTCEA
ADI (A/D conversion end)	A/D	28	H'0438	DTCEA
ICIA (FRT input capture A)	FRT	48	H'0460	DTCEA
ICIB (FRT input capture B)		49	H'0462	DTCEA
OCIA (FRT output compare A)		52	H'0468	DTCEA
OCIB (FRT output compare B)		54	H'046A	DTCEB
CMIA0 (TMR0 compare-match A)	TMR0	64	H'0480	DTCEB
CMIB0 (TMR0 compare-match B)		65	H'0482	DTCEB
CMIA1 (TMR1 compare-match A)	TMR1	68	H'0488	DTCEB
CMIB1 (TMR1 compare-match B)		69	H'048A	DTCEC
CMIA Y (TMRY compare-match A)	TMRY	72	H'0490	DTCEC
CMIB Y (TMRY compare-match B)		73	H'0492	DTCEC
IBF1 (IDR1 reception completed)	HIF	76	H'0498	DTCEC
IBF2 (IDR2 reception completed)		77	H'049A	DTCEC
RX10 (reception completed 0)	SCI channel 0	81	H'04A2	DTCEC
TX10 (transmit data empty 0)		82	H'04A4	DTCEC
RX11 (reception completed 1)	SCI channel 1	85	H'04AA	DTCEC
TX11 (transmit data empty 1)		86	H'04AC	DTCED
RX12 (reception completed 2)	SCI channel 2	89	H'04B2	DTCED
TX12 (transmit data empty 2)		90	H'04B4	DTCED
IIC10 (IIC0 1-byte transmission/ reception completed)	IIC0 (option)	92	H'04B8	DTCED
IIC11 (IIC1 1-byte transmission/ reception completed)	IIC1 (option)	94	H'04BC	DTCED

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

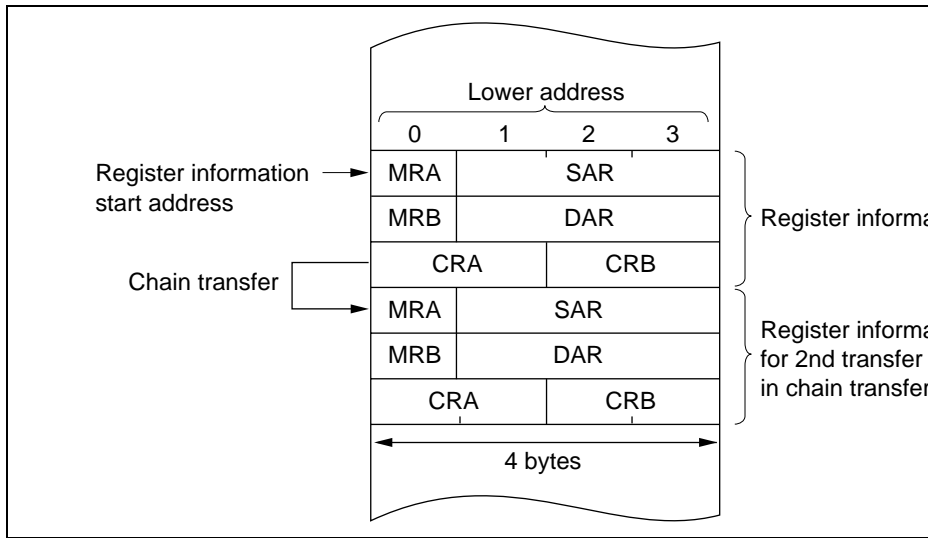


Figure 7.5 Location of DTC Register Information in Address Space

Table 7.5 Register Information in Normal Mode

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

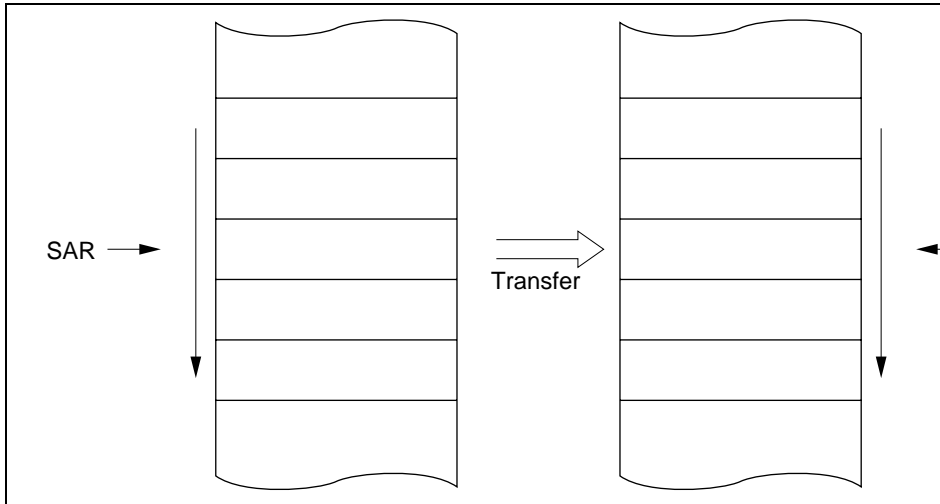


Figure 7.6 Memory Mapping in Normal Mode

Table 7.6 lists the register information in repeat mode and figure 7.7 shows memory mapping in repeat mode.

Table 7.6 Register Information in Repeat Mode

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

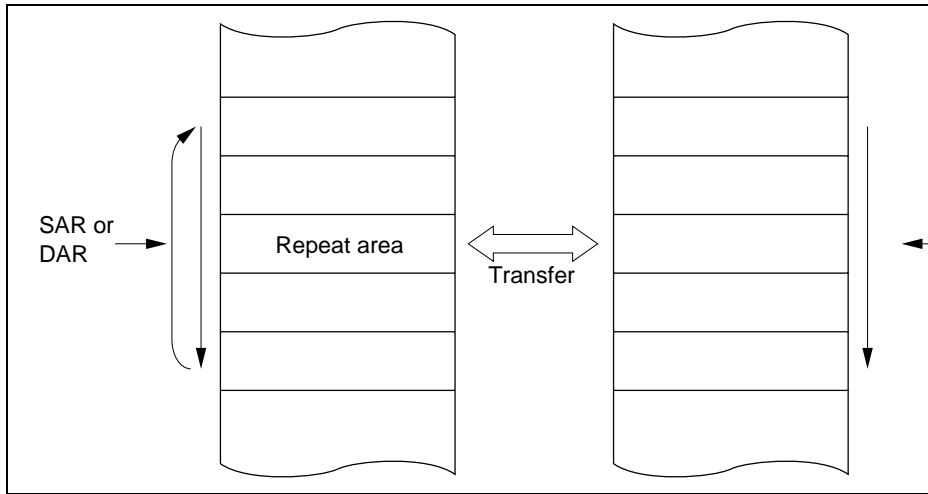


Figure 7.7 Memory Mapping in Repeat Mode

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

Table 7.7 lists the register information in block transfer mode and figure 7.8 shows memory mapping in block transfer mode.

Table 7.7 Register Information in Block Transfer Mode

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

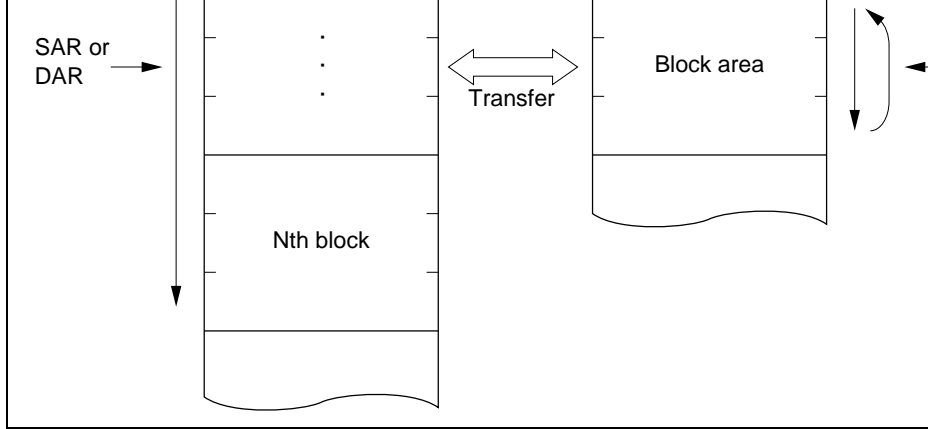


Figure 7.8 Memory Mapping in Block Transfer Mode

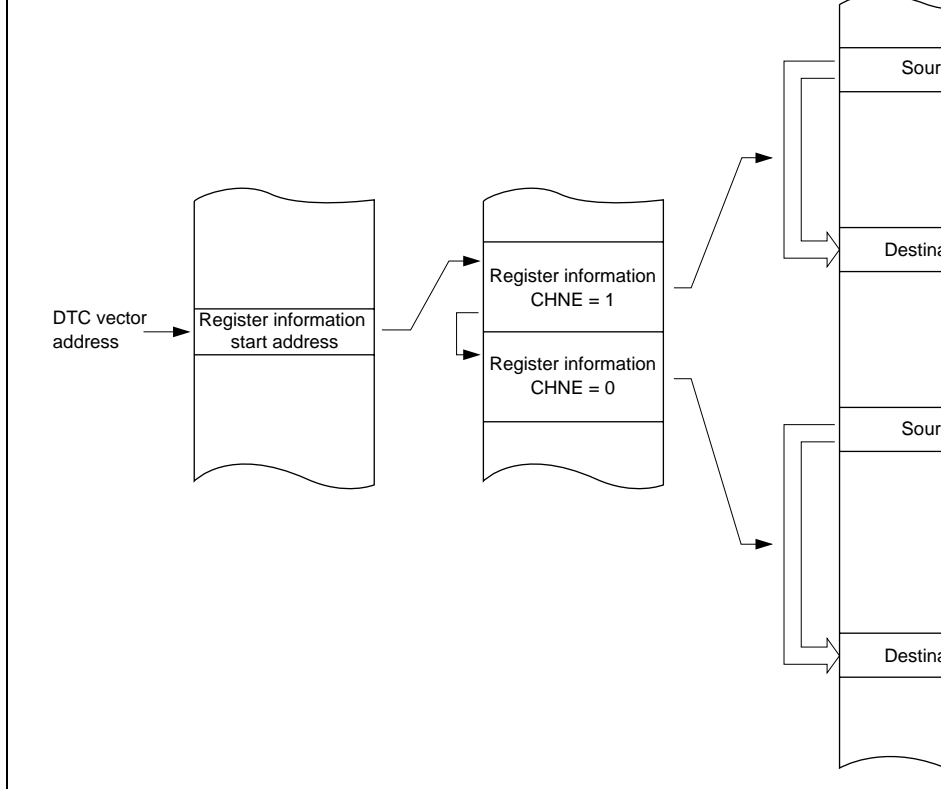


Figure 7.9 Memory Mapping in Chain Transfer

In the case of transfer with CHNE set to 1, an interrupt request to the CPU is not generated at the end of the specified number of transfers or by setting of the DISEL bit to 1, and the interrupt source flag for the activation source is not affected.

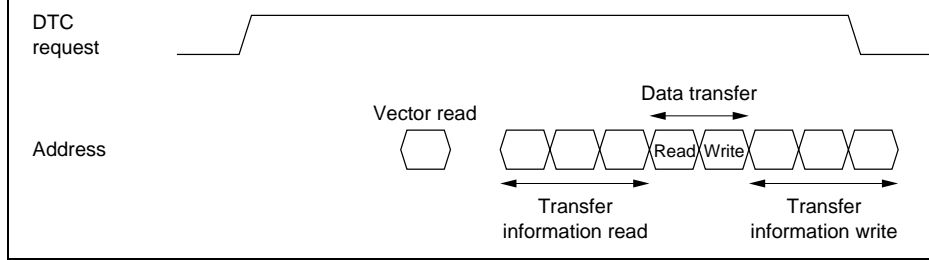


Figure 7.10 DTC Operation Timing (Normal Mode or Repeat Mode)

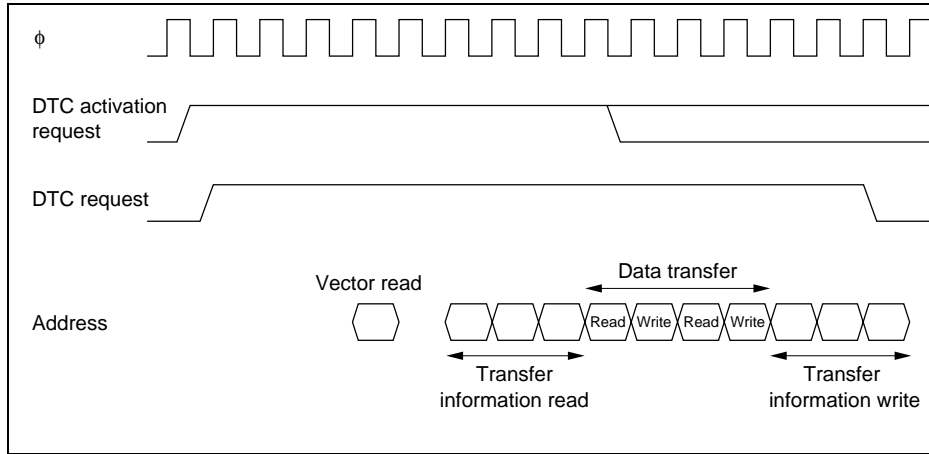


Figure 7.11 DTC Operation Timing (Block Transfer Mode, with Block Size)

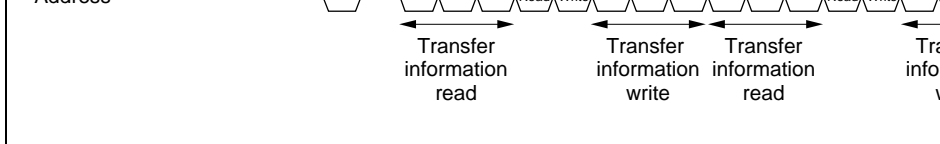


Figure 7.12 DTC Operation Timing (Chain Transfer)

7.3.10 Number of DTC Execution States

Table 7.8 lists execution phases for a single DTC data transfer, and table 7.9 shows the states required for each execution phase.

Table 7.8 DTC Execution Phases

Mode	Vector Read	Register Information Read/Write	Data Read	Data Write	In Op M
	I	J	K	L	
Normal	1	6	1	1	3
Repeat	1	6	1	1	3
Block transfer	1	6	N	N	3

Legend:

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

Register information read/write	S_j	1	1	2	2	2	3+m	2
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	1	1	1	1	1	1

The number of execution states is calculated from the formula below. Note that Σ means the sum of all transfers activated by one activation event (the number for which the CHNE bit is set to 1 plus 1).

$$\text{Number of execution states} = I \cdot S_i + \Sigma (J \cdot S_j + K \cdot S_k + L \cdot S_L) + M \cdot S_M$$

For example, when the DTC vector address table is located in on-chip ROM, normal read and data is transferred from the on-chip ROM to an internal I/O register, the time required for DTC operation is 13 states. The time from activation to the end of the data write is 10

3. Set the corresponding bit in DTCER to 1.
4. Set the enable bits for the interrupt sources to be used as the activation sources to 1. The DTC is activated when an interrupt used as an activation source is generated.
5. After the end of one data transfer, or after the specified number of data transfers have occurred, the DTCE bit is cleared to 0 and a CPU interrupt is requested. If the DTC is to continue transferring data, set the DTCE bit to 1.

Activation by Software

The procedure for using the DTC with software activation is as follows:

1. Set the MRA, MRB, SAR, DAR, CRA, and CRB register information in the on-chip registers.
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 in the SWDTE bit and the vector number to DTVECR.
5. Check the vector number written to DTVECR.
6. After the end of one data transfer, if the DISEL bit is 0 and a CPU interrupt is not requested, the SWDTE bit is cleared to 0. If the DTC is to continue transferring data, set the SWDTE bit to 1. When the DISEL bit is 1, or after the specified number of data transfers have occurred, the SWDTE bit is held at 1 and a CPU interrupt is requested.

SCI RDR address in SAR, the start address of the RAM area where the data will be stored in DAR, and 128 (H'0080) in CRA. CRB can be set to any value.

2. Set the start address of the register information at the DTC vector address.
3. Set the corresponding bit in DTCER to 1.
4. Set the SCI to the appropriate receive mode. Set the RIE bit in SCR to 1 to enable receive interrupt. Set the RXIEN bit in SCI to 1 to enable receive interrupt. When a receive operation is complete (RXI) interrupt is generated. Since the generation of a receive error during the SCI receive operation will disable subsequent reception, the CPU should be enabled to accept receive interrupts.
5. Each time reception of one byte of data ends on the SCI, the RDRF flag in SSR is set to 1. When the RXI interrupt is generated, and the DTC is activated. The receive data is transferred to RAM by the DTC. DAR is incremented and CRA is decremented. The RDRF flag is automatically cleared to 0.
6. When CRA becomes 0 after the 128 data transfers have ended, the RDRF flag is cleared to 0, the DTCE bit is cleared to 0, and an RXI interrupt request is sent to the CPU. The interrupt handling routine should perform wrap-up processing.

- 0). Set the transfer source address (H'1000) in SAR, the destination address (H'2000) and 128 (H'8080) in CRA. Set 1 (H'0001) in CRB.
2. Set the start address of the register information at the DTC vector address (H'04C0).
3. Check that the SWDTE bit in DTVECR is 0. Check that there is currently no transfer by software.
4. Write 1 to the SWDTE bit and the vector number (H'60) to DTVECR. The write data is 0.
5. Read DTVECR again and check that it is set to the vector number (H'60). If it is not, it indicates that the write failed. This is presumably because an interrupt occurred between 3 and 4 and led to a different software activation. To activate this transfer, go back to 3.
6. If the write was successful, the DTC is activated and a block of 128 bytes of data is transferred.
7. After the transfer, an SWDTEND interrupt occurs. The interrupt handling routine sets the SWDTE bit to 0 and perform other wrap-up processing.

When the DISEL bit is 1 and one data transfer has ended, or the specified number of transfers have ended, after data transfer ends, the SWDTE bit is held at 1 and an SWDTEND interrupt is generated. The interrupt handling routine should clear the SWDTE bit to 0.

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

7.5 Usage Notes

Module Stop

When the MSTP14 bit in MSTPCR is set to 1, the DTC clock stops, and the DTC enters module stop state. However, 1 cannot be written in the MSTP14 bit while the DTC is in module stop state. When the DTC is placed in the module stop state, the DTCER registers must all be in module stop state when the MSTP14 bit is set to 1.

On-Chip RAM

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

DTCE Bit Setting

For DTCE bit setting, read/write operations must be performed using bit-manipulation instructions such as BSET and BCLR. For the initial setting only, however, when multiple activation bits are set at one time, it is possible to disable interrupts and write after executing a dummy instruction to the relevant register.

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

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

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, 2, and 3 can drive a 10 mA sink current).

PA4 to PA7 in port A have bus buffer drive capability. In the H8S/2148 Group and H8S/2147N Group, P52 in port 5 and P97 in port 9 are NMOS push-pull outputs.

Note that the H8S/2144 Group and H8S/2147N have subset specifications that do not support some supporting modules. For differences in pin functions, see table 8.1, H8S/2148 Group Port Functions, table 8.2, H8S/2147N Port Functions, and table 8.3, H8S/2144 Group Port Functions.

	<ul style="list-style-type: none"> • LED drive capability 			lower address output (A7 to A0) or PWM timer output (PW7 to PW0)	
Port 2	<ul style="list-style-type: none"> • 8-bit I/O port • Built-in MOS input pull-ups • LED drive capability 	P27/A15/PW15/CBLANK P26/A14/PW14 P25/A13/PW13 P24/A12/PW12 P23/A11/PW11 P22/A10/PW10 P21/A9/PW9 P20/A8/PW8	Upper address output (A15 to A8)	When DDR = 0 (after reset): input port or timer connection output (CBLANK) When DDR = 1: upper address output (A15 to A8), PWM timer output (PW15 to PW8), timer connection output (CBLANK), or output ports (P27 to P24)	I/O port also for PWM timer output (PW8) and timer connection output (CBLANK)
Port 3	<ul style="list-style-type: none"> • 8-bit I/O port • Built-in MOS input pull-ups • LED drive capability 	P37 to P30/ HDB7 to HDB0/ D15 to D8	Data bus input/output (D15 to D8)		I/O port also for host interface input/output (HDB0)

		P43/TMC11/ HIRQ11/HSYNCI P42/TMRI0/ SCK2/SDA1 P41/TMO0/ RxD2/IrRxD P40/TMC10/ TxD2/IrTxD	RxD2, SCK2), IrDA interface input/output (IrTxD, IrRxD), and I ² C bus interface 1 (option) input/output (SDA1)	input/output CSYNCI, HS interface hos interrupt req (HIRQ12, HI HIRQ11), SC output (TxD2 SCK2), IrDA input/output and I ² C bus i (option) inpu (SDA1)
Port 5	• 3-bit I/O port	P52/SCK0/SCL0 P51/RxD0 P50/TxD0	I/O port also functioning as SCI0 input/output (TxD SCK0) and I ² C bus interface 0 (option) input/output	
Port 6	• 8-bit I/O port	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	I/O port also functioning as external interrupt input FRT input/output (FTCI, FTOA, FTIA, FTIB, FTIC, 8-bit timer X and Y input/output (TMOX, TMIX, TM connection input/output (CLAMPO, VFBACKI, VSY VSYNCO, HFBACKI), key-sense interrupt input ($\overline{\text{K}}$ and expansion A/D converter input (CIN7 to CIN0)	

		P72/AN2 P71/AN1 P70/AN0		
Port 8	• 7-bit I/O port	P86/ $\overline{\text{IRQ5}}$ /SCK1/ SCL1 P85/ $\overline{\text{IRQ4}}$ /RxD1 P84/ $\overline{\text{IRQ3}}$ /TxD1 P83 P82/HIFSD P81/ $\overline{\text{CS2}}$ /GA20 P80/HA0	I/O port also functioning as external interrupt input ($\overline{\text{IRQ5}}$, $\overline{\text{IRQ4}}$, $\overline{\text{IRQ3}}$), SCI1 input/output (TxD1, RxD1, SCK1), and I ² C bus interface 1 (option) input/output (SCL1)	I/O port also functioning as external interrupt input ($\overline{\text{IRQ5}}$, $\overline{\text{IRQ4}}$, $\overline{\text{IRQ3}}$), SCI1 input/output (TxD1, RxD1, SCK1), host interface control input/output (GA20, HA0, HIFSD), and I ² C bus interface 1 (option) input/output (SCL1)
Port 9	• 8-bit I/O port	P97/ $\overline{\text{WAIT}}$ /SDA0	I/O port also functioning as expanded data bus control input ($\overline{\text{WAIT}}$) and I ² C bus interface 0 (option) input/output (SDA0)	I/O port also functioning as expanded data bus control input ($\overline{\text{WAIT}}$) and I ² C bus interface 0 (option) input/output (SDA0)
		P96/ ϕ /EXCL	When DDR = 0: input port or EXCL input When DDR = 1 (after reset): ϕ output	When DDR = 0 (after reset): input port When DDR = 1: ϕ output
		P95/ $\overline{\text{AS}}$ / $\overline{\text{IOS}}$ / $\overline{\text{CS1}}$ P94/ $\overline{\text{HWR}}$ / $\overline{\text{IOW}}$ P93/ $\overline{\text{RD}}$ / $\overline{\text{IOR}}$	Expanded data bus control output ($\overline{\text{AS}}$ / $\overline{\text{IOS}}$, HWR, RD)	I/O port also functioning as host interface control input/output ($\overline{\text{CS1}}$, IOW, IOR)

			trigger input (ADTRG)	(ADTRG), and interface con (ECS2)	
Port A	<ul style="list-style-type: none"> 8-bit I/O port 	PA7/A23/ $\overline{\text{KIN15}}$ / CIN15/PS2CD PA6/A22/ $\overline{\text{KIN14}}$ / CIN14/PS2CC PA5/A21/ $\overline{\text{KIN13}}$ / CIN13/PS2BD PA4/A20/ $\overline{\text{KIN12}}$ / CIN12/PS2BC PA3/A19/ $\overline{\text{KIN11}}$ / CIN11/PS2AD PA2/A18/ $\overline{\text{KIN10}}$ / CIN10/PS2AC PA1/A17/ $\overline{\text{KIN9}}$ / CIN9 PA0/A16/ $\overline{\text{KIN8}}$ / CIN8	I/O port also functioning as key-sense interrupt input ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$), expansion A/D converter input (CIN15 to CIN8), and keyboard buffer controller input/output (PS2CD, PS2CC, PS2BD, PS2BC, PS2AD, PS2AC)	I/O port also functioning as address output (A23 to A16), key-sense interrupt input ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$), expansion A/D converter input (CIN15 to CIN8), and keyboard buffer controller input/output (PS2CD, PS2CC, PS2BD, PS2BC, PS2AD, PS2AC)	I/O port also key-sense in ($\overline{\text{KIN15}}$ to $\overline{\text{KIN1}}$), expansion A input (CIN15), keyboard bu input/output (PS2CC, PS2BD, PS2AD, PS2AC)
Port B	<ul style="list-style-type: none"> 8-bit I/O port 	PB7/D7 PB6/D6 PB5/D5 PB4/D4 PB3/D3/ $\overline{\text{CS4}}$ PB2/D2/ $\overline{\text{CS3}}$ PB1/D1/HIRQ4 PB0/D0/HIRQ3	In 8-bit bus mode (ABW = 1): I/O port In 16-bit bus mode (ABW = 0): data bus input/output (D7 to D0)	I/O port also HIF control i pins ($\overline{\text{CS3}}$, $\overline{\text{CS4}}$, HIRQ4)	

	<ul style="list-style-type: none"> • LED drive capability 			lower address output (A7 to A0) or PWM timer output (PW7 to PW0)	
Port 2	<ul style="list-style-type: none"> • 8-bit I/O port • Built-in MOS input pull-ups • LED drive capability 	P27/A15/PW15 P26/A14/PW14 P25/A13/PW13 P24/A12/PW12 P23/A11/PW11 P22/A10/PW10 P21/A9/PW9 P20/A8/PW8	Upper address output (A15 to A8)	When DDR = 0 (after reset): input port When DDR = 1: upper address output (A15 to A8), PWM timer output (PW15 to PW8), or output ports (P27 to P24)	I/O port also functions as PWM timer output (PW8)
Port 3	<ul style="list-style-type: none"> • 8-bit I/O port • Built-in MOS input pull-ups • LED drive capability 	P37 to P30/ HDB7 to HDB0/ D15 to D8	Data bus input/output (D15 to D8)		I/O port also functions as host interface input/output (HDB0)
Port 4	<ul style="list-style-type: none"> • 8-bit I/O port 	P47/PWX1 P46/PWX0 P45/TMRI1/ HIRQ12 P44/TMO1/ HIRQ1 P43/TMCI1/ HIRQ11 P42/TMRI0/ SCK2/SDA1 P41/TMO0/ RxD2/IrRxD P40/TMCI0/ TxD2/IrTxD	I/O port also functioning as 14-bit PWM timer output (PWX1, PWX0), 8-bit timer 0 and 1 input/output (TMCI0, TMRI0, TMO0, TMCI1, TMRI1, TMO1), SCI2 input/output (TxD2, RxD2, SCK2), IrDA interface input/output (IrTxD, IrRxD), and I ² C bus interface 1 (option) input/output (SDA1)		I/O port also functions as 14-bit PWM timer output (PWX1, PWX0), 8-bit timer 0 and 1 input/output (TMCI0, TMRI0, TMO0, TMCI1, TMRI1, TMO1), SCI2 input/output (TxD2, RxD2, SCK2), IrDA interface input/output (IrTxD, IrRxD), and I ² C bus interface 1 (option) input/output (SDA1)

		P66/ $\overline{\text{IRQ6}}$ / $\overline{\text{FTIOB}}$ / $\overline{\text{KIN6}}$ / $\overline{\text{CIN6}}$ P65/ $\overline{\text{FTID}}$ / $\overline{\text{KIN5}}$ / $\overline{\text{CIN5}}$ P64/ $\overline{\text{FTIC}}$ / $\overline{\text{KIN4}}$ / $\overline{\text{CIN4}}$ P63/ $\overline{\text{FTIB}}$ / $\overline{\text{KIN3}}$ / $\overline{\text{CIN3}}$ P62/ $\overline{\text{FTIA}}$ / $\overline{\text{TMIY}}$ / $\overline{\text{KIN2}}$ / $\overline{\text{CIN2}}$ P61/ $\overline{\text{FTOA}}$ / $\overline{\text{KIN1}}$ / $\overline{\text{CIN1}}$ P60/ $\overline{\text{FTCI}}$ / $\overline{\text{KIN0}}$ / $\overline{\text{CIN0}}$	$\overline{\text{KIN0}}$, and expansion A/D converter input ($\overline{\text{CIN7}}$ to	
Port 7	• 8-bit I/O port	P77/ $\overline{\text{AN7}}$ / $\overline{\text{DA1}}$ P76/ $\overline{\text{AN6}}$ / $\overline{\text{DA0}}$ P75/ $\overline{\text{AN5}}$ P74/ $\overline{\text{AN4}}$ P73/ $\overline{\text{AN3}}$ P72/ $\overline{\text{AN2}}$ P71/ $\overline{\text{AN1}}$ P70/ $\overline{\text{AN0}}$	Input port also functioning as A/D converter analog $\overline{\text{AN0}}$ and D/A converter analog output ($\overline{\text{DA1}}$, $\overline{\text{DA0}}$)	
Port 8	• 7-bit I/O port	P86/ $\overline{\text{IRQ5}}$ / $\overline{\text{SCK1}}$ / $\overline{\text{SCL1}}$ P85/ $\overline{\text{IRQ4}}$ / $\overline{\text{RxD1}}$ P84/ $\overline{\text{IRQ3}}$ / $\overline{\text{TxD1}}$ P83 P82/ $\overline{\text{HIFSD}}$ P81/ $\overline{\text{CS2}}$ / $\overline{\text{GA20}}$ P80/ $\overline{\text{HA0}}$	I/O port also functioning as external interrupt input ($\overline{\text{IRQ5}}$, $\overline{\text{IRQ4}}$, $\overline{\text{IRQ3}}$), SCI1 input/output ($\overline{\text{TxD1}}$, $\overline{\text{RxD1}}$, $\overline{\text{SCK1}}$), and I ² C bus interface 1 (option) input/output ($\overline{\text{SCL1}}$)	I/O port also external inter ($\overline{\text{IRQ5}}$, $\overline{\text{IRQ4}}$ input/output $\overline{\text{SCK1}}$), host control input $\overline{\text{GA20}}$, $\overline{\text{HA0}}$, I ² C bus inter input/output

			EXOE input When DDR = 1 (after reset): ϕ output	When DDR = 1: ϕ output	
		P95/ $\overline{\text{AS}}$ / $\overline{\text{IOS}}$ / $\overline{\text{CS1}}$ P94/ $\overline{\text{HWR}}$ / $\overline{\text{IOW}}$ P93/ $\overline{\text{RD}}$ / $\overline{\text{IOR}}$	Expanded data bus control output ($\overline{\text{AS}}$ / $\overline{\text{IOS}}$, $\overline{\text{HWR}}$, $\overline{\text{RD}}$)		I/O port also functioning as host interface control ($\overline{\text{CS1}}$, $\overline{\text{IOW}}$, $\overline{\text{IOR}}$)
		P92/ $\overline{\text{IRQ0}}$ P91/ $\overline{\text{IRQ1}}$	I/O port also functioning as external interrupt input ($\overline{\text{IRQ0}}$, $\overline{\text{IRQ1}}$)		
		P90/ $\overline{\text{LWR}}$ / $\overline{\text{IRQ2}}$ / $\overline{\text{ADTRG}}$ / $\overline{\text{ECS2}}$	I/O port also functioning as expanded data bus control output ($\overline{\text{LWR}}$), external interrupt input ($\overline{\text{IRQ2}}$), and A/D converter external trigger input ($\overline{\text{ADTRG}}$)		I/O port also functioning as external interrupt input ($\overline{\text{IRQ2}}$), A/D converter external trigger input ($\overline{\text{ADTRG}}$), and interface control ($\overline{\text{ECS2}}$)
Port A	• 8-bit I/O port	PA7/A23/ $\overline{\text{KIN15}}$ / CIN15/PS2CD PA6/A22/ $\overline{\text{KIN14}}$ / CIN14/PS2CC PA5/A21/ $\overline{\text{KIN13}}$ / CIN13/PS2BD PA4/A20/ $\overline{\text{KIN12}}$ / CIN12/PS2BC PA3/A19/ $\overline{\text{KIN11}}$ / CIN11/PS2AD PA2/A18/ $\overline{\text{KIN10}}$ / CIN10/PS2AC PA1/A17/ $\overline{\text{KIN9}}$ / CIN9 PA0/A16/ $\overline{\text{KIN8}}$ / CIN8	I/O port also functioning as key-sense interrupt input ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$), expansion A/D converter input (CIN15 to CIN8), and keyboard buffer controller input/output (PS2CD, PS2CC, PS2BD, PS2BC, PS2AD, PS2AC)	I/O port also functioning as address output (A23 to A16), key-sense interrupt input ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$), expansion A/D converter input (CIN15 to CIN8), and keyboard buffer controller input/output (PS2CD, PS2CC, PS2BD, PS2BC, PS2AD, PS2AC)	I/O port also functioning as key-sense interrupt input ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$), A/D converter input/output (CIN15 to CIN8), and keyboard buffer controller input/output (PS2CD, PS2CC, PS2BD, PS2BC, PS2AD, PS2AC)

		PB2/D2/CS3 PB1/D1/HIRQ4 PB0/D0/HIRQ3		
--	--	--	--	--



	• LED drive capability			output (A7 to A0)	
Port 2	<ul style="list-style-type: none"> • 8-bit I/O port • Built-in MOS input pull-ups • LED drive capability 	P27 to P20/ A15 to A8	Upper address output (A15 to A8)	<p>When DDR = 0 (after reset): input port</p> <p>When DDR = 1: upper address output (A15 to A8) or output port (P27 to P24)</p>	I/O port
Port 3	<ul style="list-style-type: none"> • 8-bit I/O port • Built-in MOS input pull-ups • LED drive capability 	P37 to P30/ D15 to D8	Data bus input/output (D15 to D8)		I/O port
Port 4	• 8-bit I/O port	P47/PWX1 P46/PWX0 P45/TMRI1 P44/TMO1 P43/TMCI1 P42/TMRI0/SCK2 P41/TMO0/RxD2/ IrxD P40/TMCI0/ TxD2/IrTxD	I/O port also functioning as 14-bit PWM timer output (PWX0), 8-bit timer 0 and 1 input/output (TMCI0, TMCI1, TMRI1, TMO1), SCI2 input/output (TxD2, Rx2) and IrDA interface input/output (IrTxD, IrRxD)		
Port 5	• 3-bit I/O port	P52/SCK0 P51/RxD0 P50/TxD0	I/O port also functioning as SCI0 input/output (TxD0, SCK0)		

		P64/FTIC/ $\overline{\text{KIN4}}$ / CIN4 P63/FTIB/ $\overline{\text{KIN3}}$ / CIN3 P62/FTIA/TMIY/ $\overline{\text{KIN2}}$ /CIN2 P61/FTOA/ $\overline{\text{KIN1}}$ / CIN1 P60/FTCI/ $\overline{\text{KIN0}}$ / CIN0	
Port 7	• 8-bit input port	P77/AN7/DA1 P76/AN6/DA0 P75/AN5 P74/AN4 P73/AN3 P72/AN2 P71/AN1 P70/AN0	Input port also functioning as A/D converter analog (AN0) and D/A converter analog output (DA1, DA0)
Port 8	• 7-bit I/O port	P86/ $\overline{\text{IRQ5}}$ /SCK1 P85/ $\overline{\text{IRQ4}}$ /RxD1 P84/ $\overline{\text{IRQ3}}$ /TxD1 P83 P82 P81 P80	I/O port also functioning as external interrupt input ($\overline{\text{IRQ3}}$) and SCI1 input/output (TxD1, RxD1, SCK1)

			when $\overline{\text{DDR}} = 1$ (after reset): ϕ output		
		P95/ $\overline{\text{AS/IOS}}$ P94/ $\overline{\text{HWR}}$ P93/ $\overline{\text{RD}}$	Expanded data bus control output($\overline{\text{AS/IOS}}$, $\overline{\text{HWR}}$, $\overline{\text{RD}}$)	I/O port	
		P92/ $\overline{\text{IRQ0}}$ P91/ $\overline{\text{IRQ1}}$	I/O port also functioning as external interrupt input (I/O port)		
		P90/ $\overline{\text{LWR/}}$ $\overline{\text{IRQ2/ADTRG}}$	I/O port also functioning as expanded data bus control output ($\overline{\text{LWR}}$), external interrupt input ($\overline{\text{IRQ2}}$), and A/D converter external trigger input ($\overline{\text{ADTRG}}$)	I/O port also functioning as external interrupt input ($\overline{\text{IRQ2}}$) and A/D converter external trigger input ($\overline{\text{ADTRG}}$)	
Port A	• 8-bit I/O port	PA7 to PA0/ A23 to A16/ $\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$ / CIN15 to CIN8	I/O port also functioning as key-sense interrupt input ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$), and expansion A/D converter input (CIN15 to CIN8)	I/O port also functioning as address output (A23 to A16), key-sense interrupt input ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$), and expansion A/D converter input (CIN15 to CIN8)	I/O port also functioning as key-sense interrupt input ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$) and expansion A/D converter input (CIN15 to CIN8)
Port B	• 8-bit I/O port	PB7 to PB0/ D7 to D0	In 8-bit bus mode (ABW = 1): I/O port In 16-bit bus mode (ABW = 0): data bus input/output (D7 to D0)	I/O port	

Figure 8.1 shows the port 1 pin configuration.

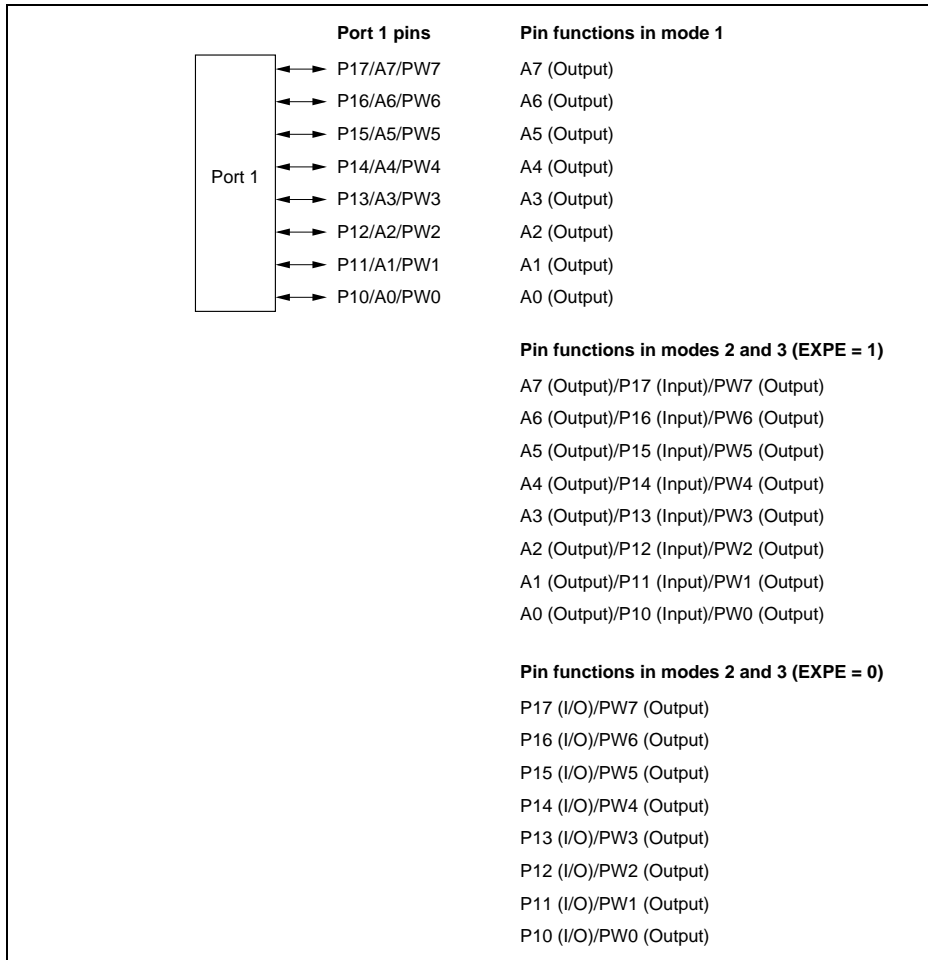


Figure 8.1 Port 1 Pin Functions

Port 1 MOS pull-up control register	P1PCR	R/W	H'00	H'FF
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Note: * Lower 16 bits of the address.

Port 1 Data Direction Register (P1DDR)

Bit	7	6	5	4	3	2	1
	P17DDR	P16DDR	P15DDR	P14DDR	P13DDR	P12DDR	P11DDR
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

P1DDR is an 8-bit write-only register, the individual bits of which specify input or output pins of port 1. P1DDR cannot be read; if it is, an undefined value will be returned.

P1DDR is initialized to H'00 by a reset and in hardware standby mode. It retains its prior value in software standby mode. The address output pins maintain their output state in a transition to software standby mode.

- Mode 1
The corresponding port 1 pins are address outputs, regardless of the P1DDR setting. In hardware standby mode, the address outputs go to the high-impedance state.
- Modes 2 and 3 (EXPE = 1)
The corresponding port 1 pins are address outputs or PWM outputs when P1DDR bits are cleared to 1, and input ports when cleared to 0.
- Modes 2 and 3 (EXPE = 0)
The corresponding port 1 pins are output ports or PWM outputs when P1DDR bits are cleared to 1, and input ports when cleared to 0.

If a port 1 read is performed while P1DDR bits are set to 1, the P1DR values are read regardless of the actual pin states. If a port 1 read is performed while P1DDR bits are 0, the pin states are read.

P1DR is initialized to H'00 by a reset and in hardware standby mode. It retains its previous value in software standby mode.

Port 1 MOS Pull-Up Control Register (P1PCR)

Bit	7	6	5	4	3	2	1
	P17PCR	P16PCR	P15PCR	P14PCR	P13PCR	P12PCR	P11PCR
Initial value	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

P1PCR is an 8-bit readable/writable register that controls the port 1 built-in MOS input pull-up on a bit-by-bit basis.

In modes 2 and 3, the MOS input pull-up is turned on when a P1PCR bit is set to 1 while the corresponding P1DDR bit is cleared to 0 (input port setting).

P1PCR is initialized to H'00 by a reset and in hardware standby mode. It retains its previous value in software standby mode.

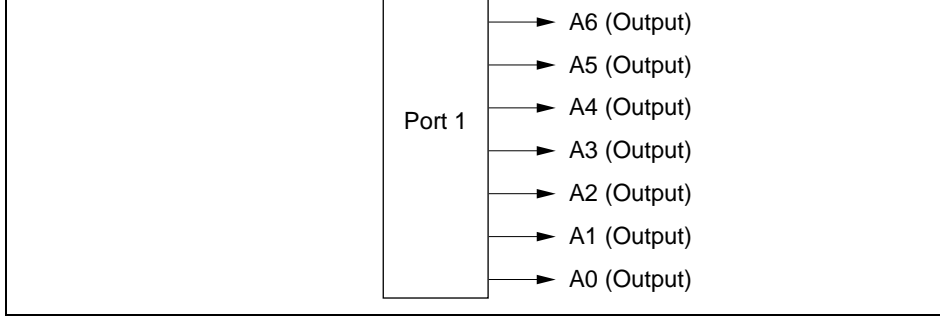


Figure 8.2 Port 1 Pin Functions (Mode 1)

Modes 2 and 3 (EXPE = 1)

In modes 2 and 3 (when EXPE = 1), port 1 pins function as address outputs, PWM outputs, and input ports, and input or output can be specified on a bit-by-bit basis. When a bit in P1DIR is set to 1, the corresponding pin functions as an address output or PWM output, and when cleared as an input port.

The port 1 pin functions are shown in figure 8.3.

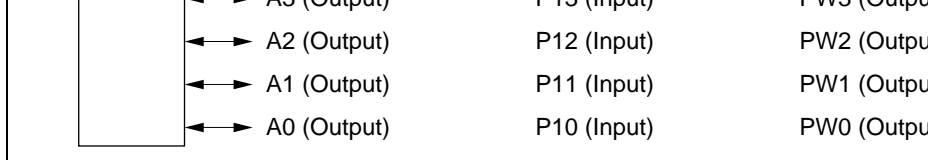


Figure 8.3 Port 1 Pin Functions (Modes 2 and 3 (EXPE = 1))

Modes 2 and 3 (EXPE = 0)

In modes 2 and 3 (when EXPE = 0), port 1 pins function as PWM outputs or I/O ports. Input or output can be specified on a bit-by-bit basis. When a bit in P1DDR is set to 1, the corresponding pin functions as a PWM output or output port, and when cleared to 0, as an input port.

The port 1 pin functions are shown in figure 8.4.

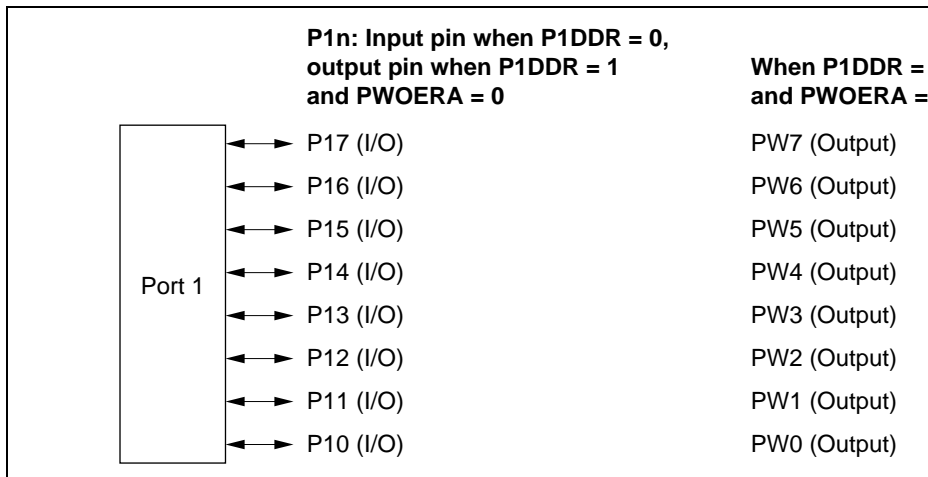


Figure 8.4 Port 1 Pin Functions (Modes 2 and 3 (EXPE = 0))

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

Table 8.5 summarizes the MOS input pull-up states.

Table 8.5 MOS Input Pull-Up States (Port 1)

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

Legend:

Off: MOS input pull-up is always off.

On/Off: On when P1DDR = 0 and P1PCR = 1; otherwise off.

8.3 Port 2

8.3.1 Overview

Port 2 is an 8-bit I/O port. Port 2 pins also function as address bus output pins (A15 to A8), PWM output pins (PW15 to PW8) (H8S/2148 Group and H8S/2147N only), and the timer connection output pin (CBLANK) (H8S/2148 Group only). Port 2 functions change according to the operating mode. Port 2 has a built-in MOS input pull-up function that can be controlled by software.

Figure 8.5 shows the port 2 pin configuration.

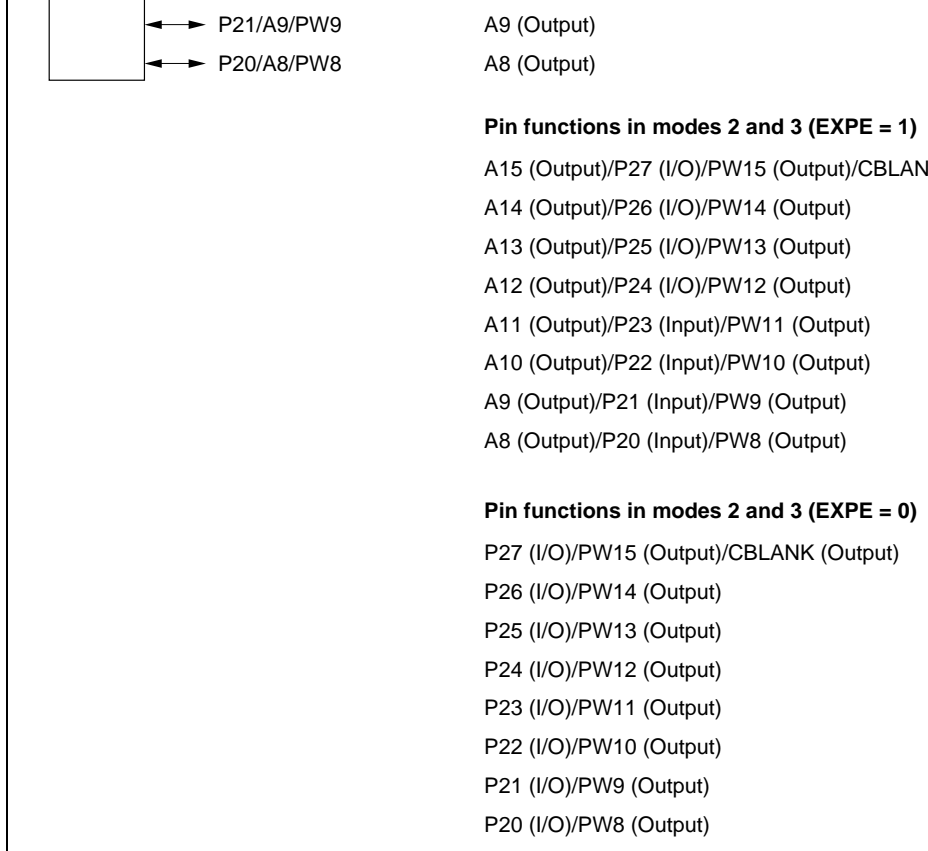


Figure 8.5 Port 2 Pin Functions

Port 2 MOS pull-up control register	P2PCR	R/W	H'00	H'FF
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Note: * Lower 16 bits of the address.

Port 2 Data Direction Register (P2DDR)

Bit	7	6	5	4	3	2	1
	P27DDR	P26DDR	P25DDR	P24DDR	P23DDR	P22DDR	P21DDR
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

P2DDR is an 8-bit write-only register, the individual bits of which specify input or output pins of port 2. P2DDR cannot be read; if it is, an undefined value will be returned.

P2DDR is initialized to H'00 by a reset and in hardware standby mode. It retains its prior value in software standby mode. The address output pins maintain their output state in a transition to software standby mode.

- Mode 1

The corresponding port 2 pins are address outputs, regardless of the P2DDR setting. In hardware standby mode, the address outputs go to the high-impedance state.

- Modes 2 and 3 (EXPE = 1)

The corresponding port 2 pins are address outputs or PWM outputs when P2DDR bit is set to 1, and input ports when cleared to 0. P27 to P24 are switched from address output ports by setting the IOSE bit to 1.

P27 can be used as an on-chip supporting module output pin regardless of the P27DDR setting, but to ensure normal access to external space, P27 should not be set as an on-chip supporting module output pin when port 2 pins are used as address output pins.

	P27DR	P26DR	P25DR	P24DR	P23DR	P22DR	P21DR
Initial value	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

P2DR is an 8-bit readable/writable register that stores output data for the port 2 pins (1-7). If a port 2 read is performed while P2DDR bits are set to 1, the P2DR values are read regardless of the actual pin states. If a port 2 read is performed while P2DDR bits are 0, the pin states are read.

P2DR is initialized to H'00 by a reset and in hardware standby mode. It retains its previous value in software standby mode.

Port 2 MOS Pull-Up Control Register (P2PCR)

Bit	7	6	5	4	3	2	1
	P27PCR	P26PCR	P25PCR	P24PCR	P23PCR	P22PCR	P21PCR
Initial value	0	0	0	0	0	0	0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

P2PCR is an 8-bit readable/writable register that controls the port 2 built-in MOS input pull-up on a bit-by-bit basis.

In modes 2 and 3, the MOS input pull-up is turned on when a P2PCR bit is set to 1 while the corresponding P2DDR bit is cleared to 0 (input port setting).

P2PCR is initialized to H'00 by a reset and in hardware standby mode. It retains its previous value in software standby mode.

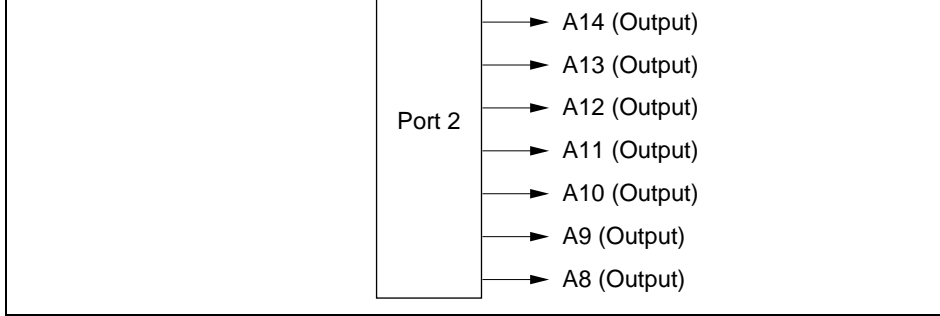


Figure 8.6 Port 2 Pin Functions (Mode 1)

Modes 2 and 3 (EXPE = 1)

In modes 2 and 3 (when EXPE = 1), port 2 pins function as address outputs, PWM output ports, and input or output can be specified on a bit-by-bit basis. When a bit in P2DDR is set, the corresponding pin functions as an address output or PWM output, and when cleared, it functions as an input port. P27 to P24 are switched from address outputs to output ports by setting the P2DIR bit. P27 can be used as an on-chip supporting module output pin regardless of the P27DIR bit, but to ensure normal access to external space, P27 should not be set as an on-chip supporting module output pin when port 2 pins are used as address output pins.

The port 2 pin functions are shown in figure 8.7.

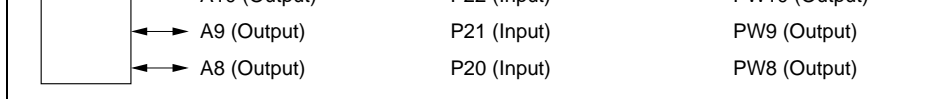


Figure 8.7 Port 2 Pin Functions (Modes 2 and 3 (EXPE = 1))

Modes 2 and 3 (EXPE = 0)

In modes 2 and 3 (when EXPE = 0), port 2 pins function as PWM outputs (P27 can also function as the timer connection output (CBLANK)) or I/O ports, and input or output can be selected on a bit-by-bit basis. When a bit in P2DDR is set to 1, the corresponding pin functions as an output port, and when cleared to 0, as an input port. P27 can be used as an output pin for a supporting module output pin regardless of the P27DDR setting.

The port 2 pin functions are shown in figure 8.8.

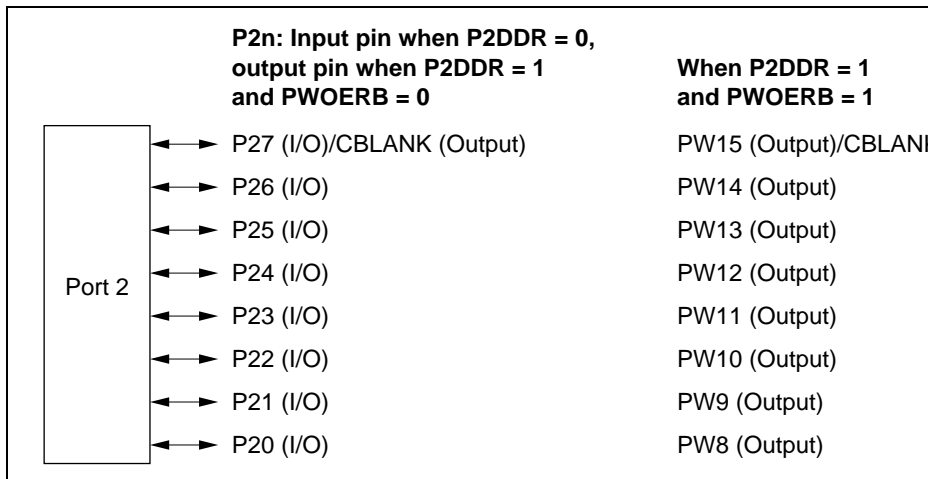


Figure 8.8 Port 2 Pin Functions (Modes 2 and 3 (EXPE = 0))

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

Table 8.7 summarizes the MOS input pull-up states.

Table 8.7 MOS Input Pull-Up States (Port 2)

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

Legend:

Off: MOS input pull-up is always off.

On/Off: On when P2DDR = 0 and P2PCR = 1; otherwise off.

Figure 8.9 shows the port 3 pin configuration.

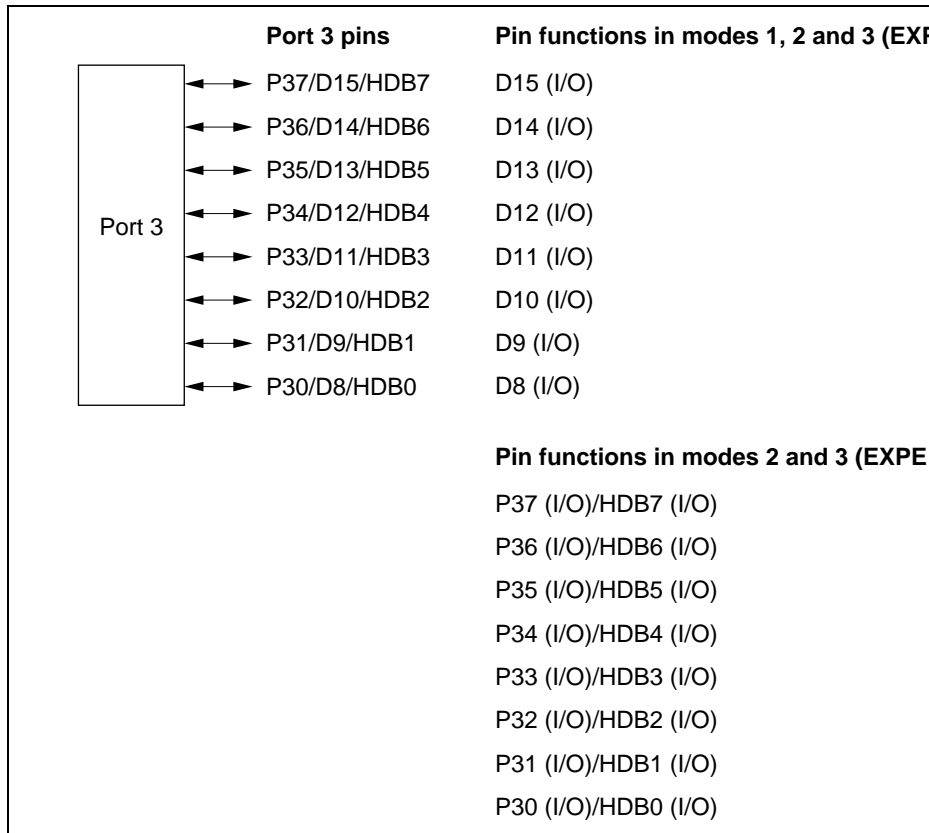


Figure 8.9 Port 3 Pin Functions

Port 3 MOS pull-up control register	P3PCR	R/W	H'00	H'FF
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Note: * Lower 16 bits of the address.

Port 3 Data Direction Register (P3DDR)

Bit	7	6	5	4	3	2	1
	P37DDR	P36DDR	P35DDR	P34DDR	P33DDR	P32DDR	P31DDR
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

P3DDR is an 8-bit write-only register, the individual bits of which specify input or output pins of port 3. P3DDR cannot be read; if it is, an undefined value will be returned.

P3DDR is initialized to H'00 by a reset and in hardware standby mode. It retains its prior value in software standby mode.

- Modes 1, 2, and 3 (EXPE = 1)

The input/output direction specified by P3DDR is ignored, and pins automatically function as data I/O pins.

After a reset, and in hardware standby mode or software standby mode, the data I/O pins are in the high-impedance state.

- Modes 2 and 3 (EXPE = 0)

The corresponding port 3 pins are output ports when P3DDR bits are set to 1, and input ports when cleared to 0.

If a port 3 read is performed while P3DDR bits are set to 1, the P3DR values are read regardless of the actual pin states. If a port 3 read is performed while P3DDR bits are 0, the pin states are read.

P3DR is initialized to H'00 by a reset and in hardware standby mode. It retains its previous value in software standby mode.

Port 3 MOS Pull-Up Control Register (P3PCR)

Bit	7	6	5	4	3	2	1
	P37PCR	P36PCR	P35PCR	P34PCR	P33PCR	P32PCR	P31PCR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

P3PCR is an 8-bit readable/writable register that controls the port 3 built-in MOS input pull-up function on a bit-by-bit basis.

In modes 2 and 3 (when EXPE = 0), the MOS input pull-up is turned on when a P3PCR bit is set to 1 while the corresponding P3DDR bit is cleared to 0 (input port setting).

P3PCR is initialized to H'00 by a reset and in hardware standby mode. It retains its previous value in software standby mode.

The MOS input pull-up function cannot be used in slave mode (when the host interface is enabled).

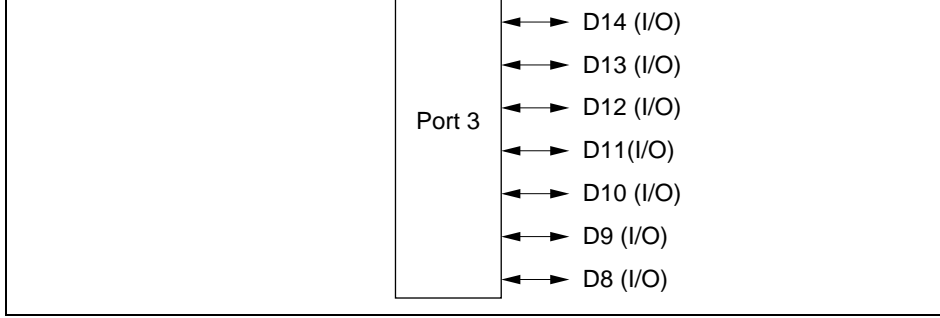


Figure 8.10 Port 3 Pin Functions (Modes 1, 2, and 3 (EXPE = 1))

Modes 2 and 3 (EXPE = 0)

In modes 2 and 3 (when EXPE = 0), port 3 functions as host interface data bus I/O pins (HDB0) or as I/O ports. When the HI12E bit is set to 1 in SYSCR2 and a transition is made to slave mode, port 3 functions as the host interface data bus. In slave mode, P3DR and P3DIR should be cleared to H'00. When the HI12E bit is cleared to 0, port 3 functions as an I/O port. An input or output can be specified on a bit-by-bit basis. When a bit in P3DDR is set to 1, the corresponding pin functions as an output port, and when cleared to 0, as an input port.

The port 3 pin functions are shown in figure 8.11.

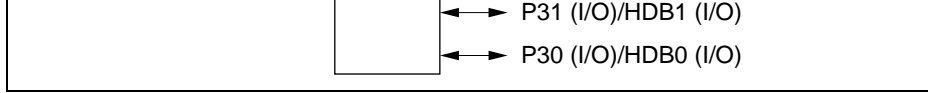


Figure 8.11 Port 3 Pin Functions (Modes 2 and 3 (EXPE = 0))

8.4.4 MOS Input Pull-Up Function

Port 3 has a built-in MOS input pull-up function that can be controlled by software. The input pull-up function can be used in modes 2 and 3 (when EXPE = 0), and can be set on or off on a bit-by-bit basis.

When a P3DDR bit is cleared to 0 in mode 2 or 3 (when EXPE = 0), setting the corresponding P3PCR bit to 1 turns on the MOS input pull-up for that pin.

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

Table 8.9 summarizes the MOS input pull-up states.

Table 8.9 MOS Input Pull-Up States (Port 3)

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

Legend:

Off: MOS input pull-up is always off.

On/Off: On when P3DDR = 0 and P3PCR = 1; otherwise off.

(HIRQ12, HIRQ1, HIRQ11) (H8S/2148 Group and H8S/2147N only), and the IIC1 I/O (SDA1) (option in H8S/2148 Group and H8S/2147N only). Port 4 pin functions are the operating modes.

Figure 8.12 shows the port 4 pin configuration.

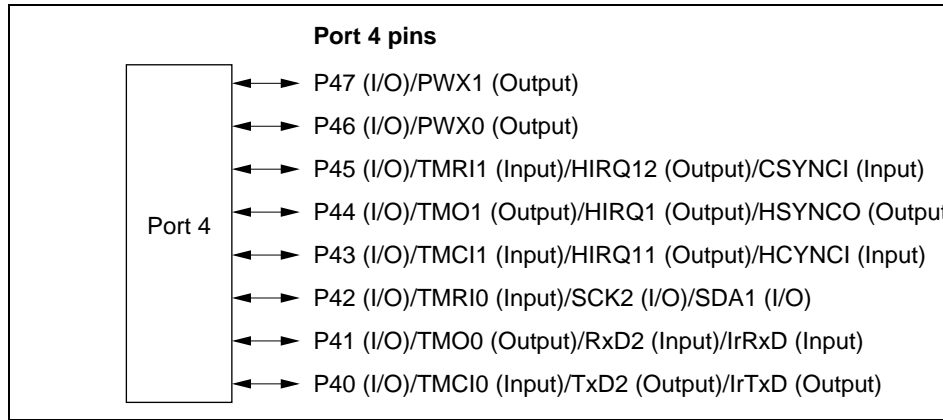


Figure 8.12 Port 4 Pin Functions

8.5.2 Register Configuration

Table 8.10 shows the port 4 register configuration.

Table 8.10 Port 4 Registers

Name	Abbreviation	R/W	Initial Value	Address
Port 4 data direction register	P4DDR	W	H'00	H'FF
Port 4 data register	P4DR	R/W	H'00	H'FF

Note: * Lower 16 bits of the address.

P4DDR is an 8-bit write-only register, the individual bits of which specify input or output pins of port 4. P4DDR cannot be read; if it is, an undefined value will be returned.

When a bit in P4DDR is set to 1, the corresponding pin functions as an output port, and is cleared to 0, as an input port.

P4DDR is initialized to H'00 by a reset and in hardware standby mode. It retains its previous value in software standby mode. As 14-bit PWM and SCI2 are initialized in software standby mode, the pin states are determined by the TMR0, TMR1, HIF, IIC1, P4DDR, and P4DR specifications.

Port 4 Data Register (P4DR)

Bit	7	6	5	4	3	2	1
	P47DR	P46DR	P45DR	P44DR	P43DR	P42DR	P41DR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

P4DR is an 8-bit readable/writable register that stores output data for the port 4 pins (P40-P47). If a port 4 read is performed while P4DDR bits are set to 1, the P4DR values are read regardless of the actual pin states. If a port 4 read is performed while P4DDR bits are 0, the pin states are read.

P4DR is initialized to H'00 by a reset and in hardware standby mode. It retains its previous value in software standby mode.

8.5.3 Pin Functions

Port 4 pins also function as 14-bit PWM output pins (PWX1, PWX0), 8-bit timer 0 and timer 1 I/O pins (TMCI0, TMRI0, TMO0, TMCI1, TMRI1, TMO1), timer connection pins (CSYNCI, HSYNCI, HSYNCO), SCI2 I/O pins (TxD2, RxD2, SCK2), IrDA interface pins (IrDA1, IrDA2).

P47DDR	0	1	-
Pin function	P47 input pin	P47 output pin	PWX1 c

P46/PWX0

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

OEA	0		
P46DDR	0	1	-
Pin function	P46 input pin	P46 output pin	PWX0 c

P45/TMR11/
HIRQ12/CSYNCI

The pin function is switched as shown below according to the combination of the operating mode and bit P45DDR.

P45DDR	0	1	
Operating mode	—	Not slave mode	Slave mode
Pin function	P45 input pin	P45 output pin	HIRQ12
	TMR11 input pin, CSYNCI input pin		

When bits CCLR1 and CCLR0 in TCR1 of TMR1 are set to 1, this pin can be used as the TMR11 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 operating mode, bits OS3 to OS0 in TCSR of TMR1, bit HOE in TCSR of the timer connection function, and bit P44DDR.

HOE	0			
OS3 to OS0	All 0		Not all 0	
P44DDR	0	1		—
Operating mode	—	Not slave mode	Slave mode	—
Pin function	P44 input pin	P44 output pin	HIRQ1 output pin	TMO1 output pin

When an external clock is selected with bits CKS2 to CKS0 in TCR, this pin is used as the TMC11 input pin. It can also be used as the input pin.

P42/TMRI0/
SCK2/SDA1

The pin function is switched as shown below according to the com bit ICE in ICCR of IIC1, bits CKE1 and CKE0 in SCR of SCI2, bit C of SCI2, and bit P42DDR.

ICE	0				
CKE1	0				1
C/A	0			1	—
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				

When this pin is used as the SDA1 I/O pin, bits CKE1 and CKE0 in SCI2 and bit C/A in SMR of SCI2 must all be cleared to 0. SDA1 is only output, and has direct bus drive capability.

When bits CCLR1 and CCLR0 in TCR0 of TMR0 are set to 1, this as the TMRI0 input pin.

When this pin is used as the TMO0 output pin, bit RE in SCR of SCI2 is cleared to 0.

P40/TMCI0/TxD2/IrTxD The pin function is switched as shown below according to the combination of bit TE in SCR of SCI2 and bit P40DDR.

TE	0		
P40DDR	0	1	-
Pin function	P40 input pin	P40 output pin	TxD2 output pin
	TMCI0 input pin		

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

Figure 8.13 shows the port 5 pin configuration.

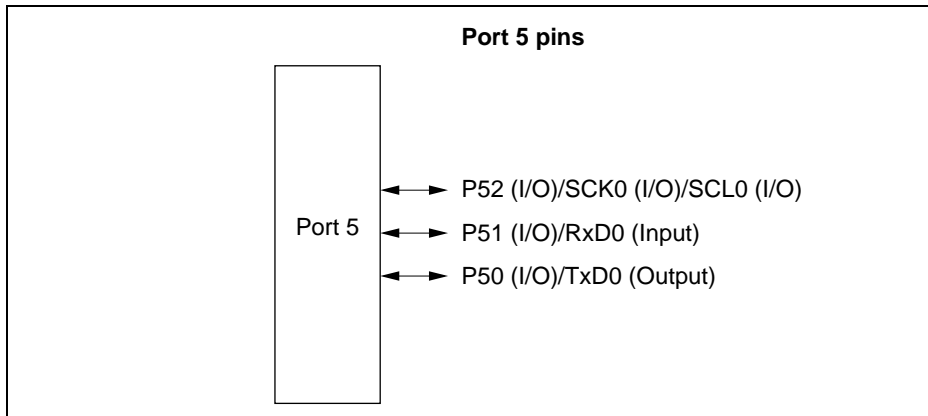


Figure 8.13 Port 5 Pin Functions

8.6.2 Register Configuration

Table 8.12 shows the port 5 register configuration.

Table 8.12 Port 5 Registers

Name	Abbreviation	R/W	Initial Value	Address
Port 5 data direction register	P5DDR	W	H'F8	H'F8
Port 5 data register	P5DR	R/W	H'F8	H'F8

Note: * Lower 16 bits of the address.

pins of port 5. P5DDR cannot be read; if it is, an undefined value will be returned. Bits reserved.

Setting a P5DDR bit to 1 makes the corresponding port 5 pin an output pin, while clearing to 0 makes the pin an input pin.

P5DDR is initialized to H'F8 by a reset and in hardware standby mode. It retains its prior value in software standby mode. As SCI0 is initialized, the pin states are determined by the IIC0, P5DDR, and P5DR specifications.

Port 5 Data Register (P5DR)

Bit	7	6	5	4	3	2	1
	—	—	—	—	—	P52DR	P51DR
Initial value	1	1	1	1	1	0	0
Read/Write	—	—	—	—	—	R/W	R/W

P5DR is an 8-bit readable/writable register that stores output data for the port 5 pins (P50 to P57). If a port 5 read is performed while P5DDR bits are set to 1, the P5DR values are read directly regardless of the actual pin states. If a port 5 read is performed while P5DDR bits are cleared, the pin states are read.

Bits 7 to 3 are reserved; they cannot be modified and are always read as 1.

P5DR is initialized to H'F8 by a reset and in hardware standby mode. It retains its prior value in software standby mode.

bits CKE1 and CKE0 in SCR of SCI0, bit C/A in SMR of SCI0, bit IIC0 of IIC0, and bit P52DDR.

ICE	0				
CKE1	0				1
C/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

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

SCL0 is an NMOS open-drain output, and has direct bus drive capability. In the H8S/2148 Group and H8S/2147N, when set as the P52 output pin, this pin is an NMOS push-pull output.

P51/RxD0

The pin function is switched as shown below according to the combination of bit RE in SCR of SCI0 and bit P51DDR.

RE	0		
P51DDR	0	1	
Pin function	P51 input pin	P51 output pin	RxD0

P50/TxD0

The pin function is switched as shown below according to the combination of bit TE in SCR of SCI0 and bit P50DDR.

TE	0		
P50DDR	0	1	
Pin function	P50 input pin	P50 output pin	TxD0

pins (KIN7 to KIN0), expansion A/D converter input pins (CIN7 to CIN0), and external input pins ($\overline{\text{IRQ}}7$, $\overline{\text{IRQ}}6$). In the H8S/2148 Group and H8S/2147N, the port 6 input level is switched in four stages. Port 6 pin functions are the same in all operating modes.

Figure 8.14 shows the port 6 pin configuration.

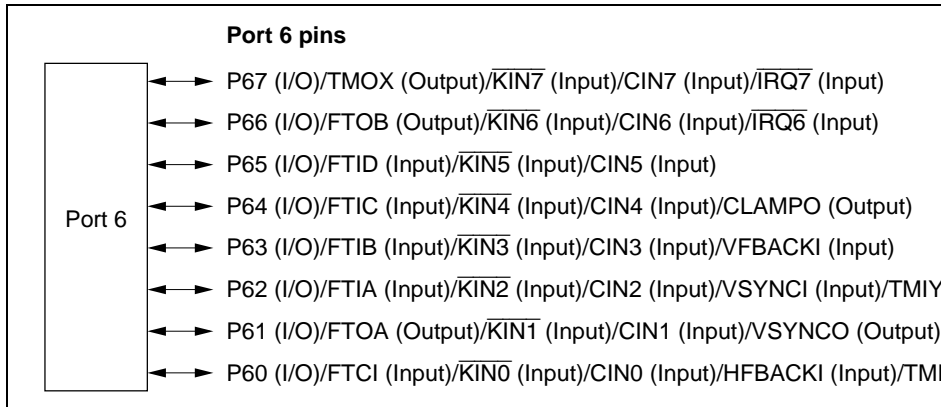


Figure 8.14 Port 6 Pin Functions

Port 6 MOS pull-up control register	KMPCR	R/W	H'00	H'
System control register 2	SYSCR2	R/W	H'00	H'

- Notes: 1. Lower 16 bits of the address.
2. KMPCR has the same address as TICRR/TCORAY of TMRX/TMRY. To set KMPCR, set the HIE bit to 1 in SYSCR and set the MSTP2 bit to 0 in MSTP2R.

Port 6 Data Direction Register (P6DDR)

Bit	7	6	5	4	3	2	1
	P67DDR	P66DDR	P65DDR	P64DDR	P63DDR	P62DDR	P61DDR
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

P6DDR is an 8-bit write-only register, the individual bits of which specify input or output pins of port 6. P6DDR cannot be read; if it is, an undefined value will be returned.

Setting a P6DDR bit to 1 makes the corresponding port 6 pin an output pin, while clearing it to 0 makes the pin an input pin.

P6DDR is initialized to H'00 by a reset and in hardware standby mode. It retains its previous value in software standby mode.

If a port 6 read is performed while P6DDR bits are set to 1, the P6DR values are read regardless of the actual pin states. If a port 6 read is performed while P6DDR bits are cleared, the pin states are read.

P6DR is initialized to H'00 by a reset and in hardware standby mode. It retains its prior value in software standby mode.

Port 6 MOS Pull-Up Control Register (KMPCR)

Bit	7	6	5	4	3	2	1
	KM7PCR	KM6PCR	KM5PCR	KM4PCR	KM3PCR	KM2PCR	KM1PCR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

KMPCR is an 8-bit readable/writable register that controls the port 6 built-in MOS input pull-up on a bit-by-bit basis.

The MOS input pull-up is turned on when a KMPCR bit is set to 1 while the corresponding P6DDR bit is cleared to 0 (input port setting).

KMPCR is initialized to H'00 by a reset and in hardware standby mode. It retains its prior value in software standby mode.

operation of host interface functions.

Only bits 7, 6, and 5 are described here. See section 18.2.2, System Control Register 2 for information on bits 4 to 0.

SYSCR2 is initialized to H'00 by a reset and in hardware standby mode.

Bits 7 and 6—Key Wakeup Level 1 and 0 (KWUL1, KWUL0): The port 6 input level can be changed by software, using these bits. The setting of these bits also changes the of the pin functions multiplexed with port 6.

Bit 7	Bit 6	Description
0	0	Standard input level is selected as port 6 input level (
	1	Input level 1 is selected as port 6 input level
1	0	Input level 2 is selected as port 6 input level
	1	Input level 3 is selected as port 6 input level

Bit 5—Port 6 Input Pull-Up Extra (P6PUE): Controls and selects the current specification for the port 6 MOS input pull-up function connected by means of KMPCR settings.

Bit 5	Description
0	Standard current specification is selected for port 6 MOS input pull-up function (
1	Current-limit specification is selected for port 6 MOS input pull-up function

Table 8.15 Port 6 Pin Functions**Pin Selection Method and Pin Functions**

P67/TMOX/ $\overline{\text{IRQ7}}$ / $\overline{\text{KIN7}}$ /CIN7 The pin function is switched as shown below according to the combination of bits OS3 to OS0 in TCSR of TMRX and bit P67DDR.

OS3 to OS0	All 0		Not
P67DDR	0	1	-
Pin function	P67 input pin	P67 output pin	TMOX c
	$\overline{\text{IRQ7}}$ input pin, $\overline{\text{KIN7}}$ input pin, CIN7 input p		

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

P66/FTOB/ $\overline{\text{IRQ6}}$ / $\overline{\text{KIN6}}$ /CIN6 The pin function is switched as shown below according to the combination of bit OEB in TOCR of the FRT and bit P66DDR.

OEB	0		
P66DDR	0	1	-
Pin function	P66 input pin	P66 output pin	FTOB c
	$\overline{\text{IRQ6}}$ input pin, $\overline{\text{KIN6}}$ input pin, CIN6 input p		

This pin is used as the $\overline{\text{IRQ6}}$ input pin when bit IRQ6E is set to 1 in TOCR. It can always be used as the $\overline{\text{KIN6}}$ or CIN6 input pin.

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

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

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

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

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

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

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

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

P62DDR	0	1
Pin function	P62 input pin	P62 output pin
	FTIA input pin, VSYNCl input pin, TMIY input pin, $\overline{\text{KIN2}}$ input pin, CIN2 input pin	

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

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

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

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

When this pin is used as the VSYNCO pin, bit OEA in TOCR of the FRT must be cleared to 0.

This pin can always be used as the $\overline{\text{KIN1}}$ or CIN1 input pin.

8.7.4 MOS Input Pull-Up Function

Port 6 has a built-in MOS input pull-up function that can be controlled by software. The input pull-up function can be used in any operating mode, and can be specified as on or off on a bit-by-bit basis.

When a P6DDR bit is cleared to 0, setting the corresponding KMPCR bit to 1 turns on the input pull-up for that pin. The MOS input pull-up current specification can be changed by the value of the P6PUE bit. When a pin is designated as an on-chip supporting module output pin, the input pull-up is always off.

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

Table 8.16 summarizes the MOS input pull-up states.

Table 8.16 MOS Input Pull-Up States (Port 6)

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

Legend:

Off: MOS input pull-up is always off.

On/Off: On when P6DDR = 0 and KMPCR = 1; otherwise off.

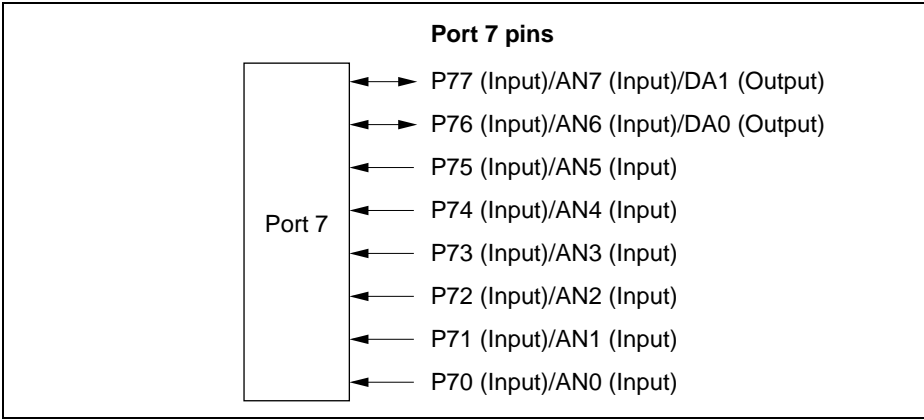


Figure 8.15 Port 7 Pin Functions

8.8.2 Register Configuration

Table 8.17 shows the port 7 register configuration. Port 7 is an input-only port, and does not have a data direction register or data register.

Table 8.17 Port 7 Registers

Name	Abbreviation	R/W	Initial Value	Address
Port 7 input data register	P7PIN	R	Undefined	H'F0000000

- Notes: 1. Lower 16 bits of the address.
 2. P7PIN has the same address as PBDDR.

When a P7PIN read is performed, the pin states are always read.

P7PIN has the same address as PBDDR; if a write is performed, data will be written into the port B data register and the port B setting will be changed.

8.8.3 Pin Functions

Port 7 pins also function as the A/D converter analog input pins (AN0 to AN7) and D/A converter analog output pins (DA0, DA1).

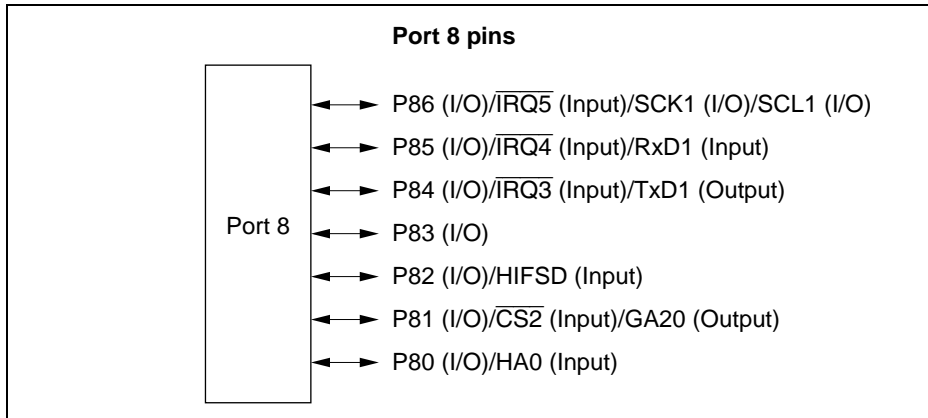


Figure 8.16 Port 8 Pin Functions

8.9.2 Register Configuration

Table 8.18 summarizes the port 8 registers.

Table 8.18 Port 8 Registers

Name	Abbreviation	R/W	Initial Value	Address
Port 8 data direction register	P8DDR	W	H'80	H'F0
Port 8 data register	P8DR	R/W	H'80	H'F0

- Notes: 1. Lower 16 bits of the address.
 2. P8DDR has the same address as PBPIN.

pins of port 8. P8DDR has the same address as PBPIN, and if read, the port B state will be returned.

Setting a P8DDR bit to 1 makes the corresponding port 8 pin an output pin, while clearing it to 0 makes the pin an input pin.

P8DDR is initialized to H'80 by a reset and in hardware standby mode. It retains its prior value in software standby mode.

Port 8 Data Register (P8DR)

Bit	7	6	5	4	3	2	1
	—	P86DR	P85DR	P84DR	P83DR	P82DR	P81DR
Initial value	1	0	0	0	0	0	0
Read/Write	—	R/W	R/W	R/W	R/W	R/W	R/W

P8DR is a 7-bit readable/writable register that stores output data for the port 8 pins (P80 to P87). When a port 8 read is performed while P8DDR bits are set to 1, the P8DR values are read directly from the register regardless of the actual pin states. If a port 8 read is performed while P8DDR bits are cleared to 0, the pin states are read.

P8DR is initialized to H'80 by a reset and in hardware standby mode. It retains its prior value in software standby mode.

8.9.3 Pin Functions

Port 8 pins also function as SCI1 I/O pins (TxD1, RxD1, SCK1), the IIC1 I/O pin (SCI1 I/O pins ($\overline{CS2}$, GA20, HA0, HIFSD), and external interrupt input pins ($\overline{IRQ5}$ to $\overline{IRQ3}$). The pin functions are shown in table 8.19.

C/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
	IRQ5 input pin				

When the IRQ5E bit in IER is set to 1, this pin is used as the $\overline{\text{IRQ5}}$.
 When this pin is used as the SCL1 I/O pin, bits CKE1 and CKE0 in SCI1 and bit C/ $\overline{\text{A}}$ in SMR of SCI1 must all be cleared to 0. SCL1 is only output, and has direct bus drive capability.

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

The pin function is switched as shown below according to the control bit RE in SCR of SCI1 and bit P85DDR.

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

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

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

The pin function is switched as shown below according to the control bit TE in SCR of SCI1 and bit P84DDR.

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

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

mode				
SDE	—		0	
P82DDR	0	1	0	1
Pin function	P82 input pin	P82 output pin	P82 input pin	P82 output pin

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

The pin function is switched as shown below according to the combined operating mode, bit CS2E in SYSCR, bit FGA20E in HICR of the H81P81DDR.

Operating mode	Not slave mode		Slave mode			
	FGA20E	—		0		
CS2E	—		0		1	
P81DDR	0	1	0	1	—	0
Pin function	P81 input pin	P81 output pin	P81 input pin	P81 output pin	$\overline{\text{CS2}}$ input pin	P81 input pin

This pin should be used as the GA20 output pin or $\overline{\text{CS2}}$ input pin on 2 or 3 (EXPE = 0).

P80/HA0

The pin function is switched as shown below according to the combined operating mode and bit P80DDR.

Operating mode	Not slave mode		Slave mode
	P80DDR	0	1
Pin function	P80 input pin	P80 output pin	HA0 in

pins (AS/IOS, RD, HWR, LWR, WAIT), and the system clock (ϕ) output pin. In H8S/2147N, P97 is an NMOS push-pull output. SDA0 is an NMOS open-drain output and has direct bus drive capability.

Figure 8.17 shows the port 9 pin configuration.

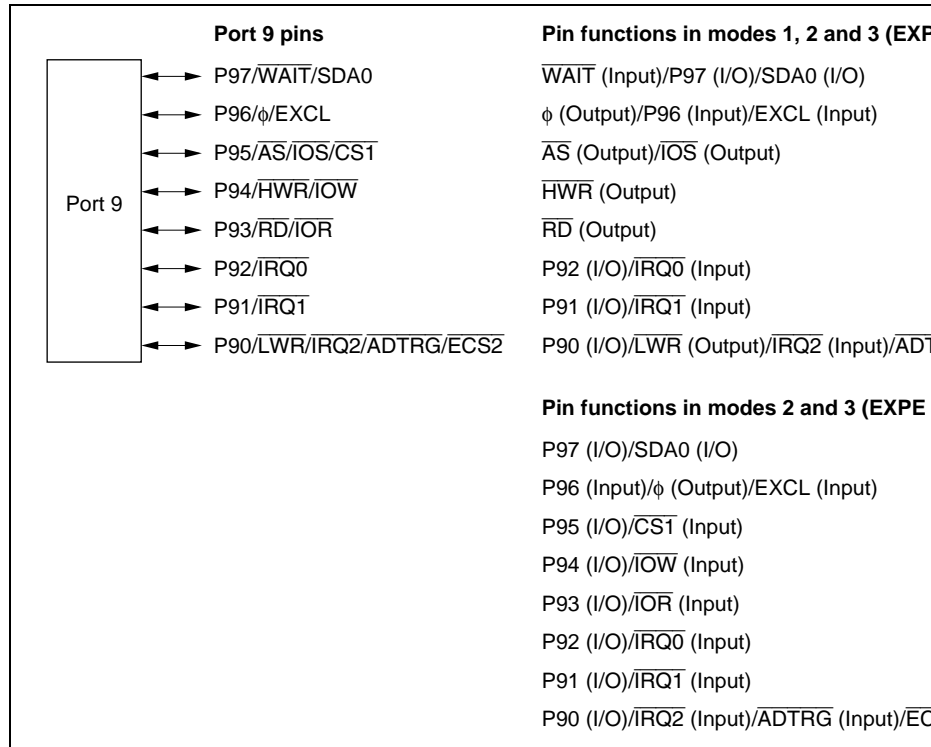


Figure 8.17 Port 9 Pin Functions



- Notes:
1. Lower 16 bits of the address.
 2. Initial value depends on the mode.

Port 9 Data Direction Register (P9DDR)

Bit	7	6	5	4	3	2	1
	P97DDR	P96DDR	P95DDR	P94DDR	P93DDR	P92DDR	P91DDR
Mode 1							
Initial value	0	1	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W
Modes 2 and 3							
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

P9DDR is an 8-bit write-only register, the individual bits of which specify input or output pins of port 9. P9DDR cannot be read; if it is, an undefined value will be returned.

P9DDR is initialized to H'40 (mode 1) or H'00 (modes 2 and 3) by a reset and in hardware mode. It retains its prior state in software standby mode.

- Modes 1, 2 and 3 (EXPE = 1)

Pin P97 functions as a bus control input ($\overline{\text{WAIT}}$), the IIC0 I/O pin (SDA0), or an I/O pin according to the wait mode setting. When P97 functions as an I/O port, it becomes an output port when P97DDR is set to 1, and an input port when P97DDR is cleared to 0.

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

Pins P95 to P93 automatically become bus control outputs ($\overline{\text{AS}}/\overline{\text{IOS}}$, $\overline{\text{HWR}}$, $\overline{\text{RD}}$), regardless of the input/output direction indicated by P95DDR to P93DDR.

Pins P92 and P91 become output ports when P92DDR and P91DDR are set to 1, and input ports when P92DDR and P91DDR are cleared to 0.

Port 9 Data Register (P9DR)

Bit	7	6	5	4	3	2	1
	P97DR	P96DR	P95DR	P94DR	P93DR	P92DR	P91DR
Initial value	0	—*	0	0	0	0	0
Read/Write	R/W	R	R/W	R/W	R/W	R/W	R/W

Note: * Determined by the state of pin P96.

P9DR is an 8-bit readable/writable register that stores output data for the port 9 pins (1-8). With the exception of P96, if a port 9 read is performed while P9DDR bits are set to 1, the values are read directly, regardless of the actual pin states. If a port 9 read is performed while P9DDR bits are cleared to 0, the pin states are read.

P9DR is initialized to H'00 by a reset and in hardware standby mode. It retains its prior value in software standby mode.

8.10.3 Pin Functions

Port 9 pins also function as external interrupt input pins ($\overline{\text{IRQ0}}$ to $\overline{\text{IRQ2}}$), the A/D conversion input pin ($\overline{\text{ADTRG}}$), HIF input pins ($\overline{\text{ECS2}}$, $\overline{\text{CS1}}$, $\overline{\text{IOW}}$, $\overline{\text{IOR}}$), the IIC0 I/O pin ($\overline{\text{SDA0}}$), subclock input pin ($\overline{\text{EXCL}}$), bus control signal I/O pins ($\overline{\text{AS/IOS}}$, $\overline{\text{RD}}$, $\overline{\text{HWR}}$, $\overline{\text{LWR}}$, $\overline{\text{W}}$), and the system clock (ϕ) output pin. The pin functions differ between the mode 1, 2, and 3 expanded modes and the mode 2 and 3 ($\text{EXPE} = 0$) single-chip modes. The port 9 pin functions are shown in table 8.21.

P97DDR	0	1	—	—	0	1
Pin function	P97 input pin	P97 output pin	SDA0 I/O pin	WAIT input pin	P97 input pin	P97 output pin

When this pin is set as the P97 output pin in the H8S/2148 Group or H8S/2147N, it is an NMOS push-pull output. SDA0 is an NMOS open-drain output, and has direct bus drive capability.

P96/ ϕ /EXCL

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

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

When this pin is used as the EXCL input pin, P96DDR should be cleared.

P95/AS/IOS/CS1

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

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

	output pin	input pin	output pin	
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P93/ \overline{RD} / \overline{IOR}

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

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

P92/ $\overline{IRQ0}$

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

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	

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

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
		$\overline{\text{IRQ2}}$ input pin, $\overline{\text{ADTRG}}$ input pin			

When the IRQ2E bit in IER is set to 1 in mode 1, 2, or 3 ($\text{EXPE} = 1$), ABW bit in WSCR set to 1, or in mode 2 and 3 ($\text{EXPE} = 0$), this pin is the $\overline{\text{IRQ2}}$ input pin.

When TRGS1 and TRGS0 in ADCR of the A/D converter are both set to 1, this pin is used as the $\overline{\text{ADTRG}}$ input pin.

modes. Figure 8.18 shows the port A pin configuration.

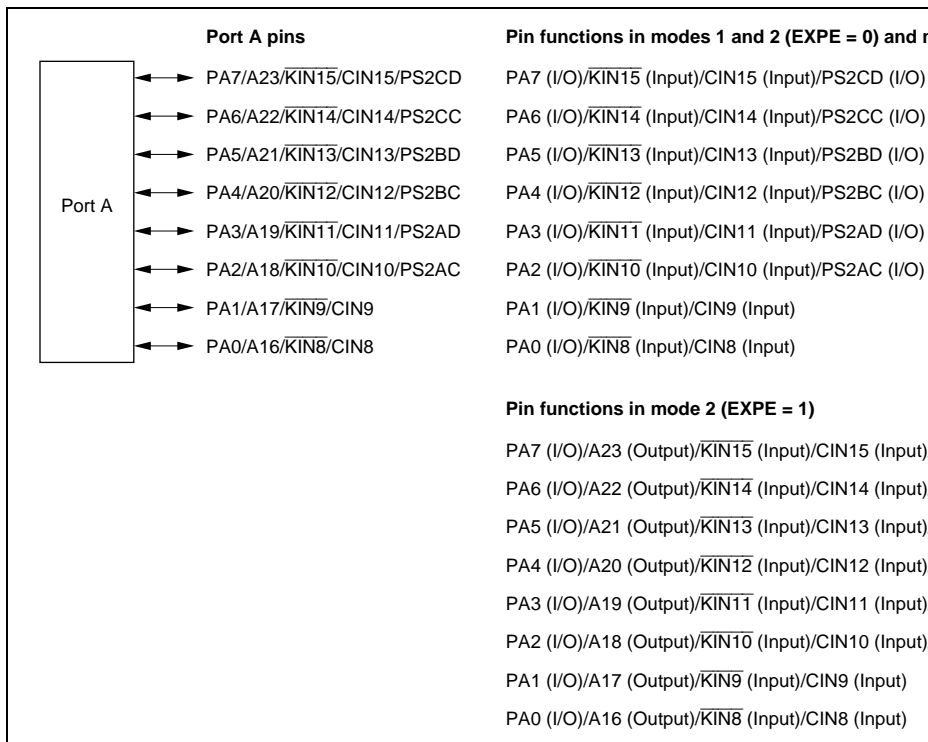


Figure 8.18 Port A Pin Functions

Port A input data register	PAPIN	R	Undefined	H'FF
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- Notes: 1. Lower 16 bits of the address.
 2. PADDR and PAPIN have the same address.

Port A Data Direction Register (PADDR)

Bit	7	6	5	4	3	2	1
	PA7DDR	PA6DDR	PA5DDR	PA4DDR	PA3DDR	PA2DDR	PA1DDR
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

PADDR is an 8-bit write-only register, the individual bits of which specify input or output pins of port A.

Setting a PADDR bit to 1 makes the corresponding port A pin an output pin, while clearing it to 0 makes the pin an input pin.

PADDR is initialized to H'00 by a reset and in hardware standby mode. It retains its previous value in software standby mode.

Port A Output Data Register (PAODR)

Bit	7	6	5	4	3	2	1
	PA7ODR	PA6ODR	PA5ODR	PA4ODR	PA3ODR	PA2ODR	PA1ODR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

PAODR is an 8-bit readable/writable register that stores output data for the port A pins (PA7 to PA0). PAODR can always be read or written to, regardless of the contents of PADDR.

Note: * Determined by the state of pins PA7 to PA0.

Reading PAPH always returns the pin states.

8.11.3 Pin Functions

Port A pins also function as keyboard buffer controller I/O pins (PS2AC, PS2AD, PS2BD, PS2CC, PS2CD), key-sense interrupt input pins ($\overline{\text{KIN15}}$ to $\overline{\text{KIN8}}$), expansion converter input pins (CIN15 to CIN8), and address output pins (A23 to A16). The port functions are shown in table 8.23.

Table 8.23 Port A Pin Functions

Pin	Selection Method and Pin Functions
-----	------------------------------------

PA7/A23/PS2CD/ $\overline{\text{KIN15}}$ /CIN15	The pin function is switched as shown below according to the com operating mode, the KBIOE bit in KBCR2H of the keyboard buffer the IOSE bit in SYSCR, and bit PA7DDR.
--	--

Operating mode	Modes 1, 2 (EXPE = 0), 3			Mode 2 (EXPE		
	0		1	0		
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 inp					

When the IICS bit in STCR is set to 1, this pin functions as a bus b pin can always be used as the PS2CD, $\overline{\text{KIN15}}$, or CIN15 input pin.

IOSE	—	—	—	—	0	1
Pin function	PA6 input pin	PA6 output pin	PS2CC output pin	PA6 input pin	A22 output pin	PA6 output pin
	KIN14 input pin, CIN14 input pin, PS2CC input pin					

When the IICS bit in STCR is set to 1, this pin functions as a bus buffer. The pin can always be used as the PS2CC, KIN14, or CIN14 input pin.

**PA5/A21/PS2BD/
KIN13/CIN13**

The pin function is switched as shown below according to the combination of the operating mode, the KBIOE bit in KBCR1H of the keyboard buffer controller, the IOSE bit in SYSCR, and bit PA5DDR.

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
	KIN13 input pin, CIN13 input pin, PS2BD input pin					

When the IICS bit in STCR is set to 1, this pin functions as a bus buffer. The pin can always be used as the PS2BD, KIN13, or CIN13 input pin.

IOSE	—	—	—	—	0	1
Pin function	PA4 input pin	PA4 output pin	PS2BC output pin	PA4 input pin	A20 output pin	PA output pin
	KIN12 input pin, CIN12 input pin, PS2BC input pin					

When the IICS bit in STCR is set to 1, this pin functions as a bus buffer. This pin can always be used as the PS2BC, KIN12, or CIN12 input pin.

**PA3/A19/PS2AD/
KIN11/CIN11**

The pin function is switched as shown below according to the current operating mode, the KBIOE bit in KBCR0H of the keyboard buffer controller, the IOSE bit in SYSCR, and bit PA3DDR.

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	PA output pin
	KIN11 input pin, CIN11 input pin, PS2AD input pin					

This pin can always be used as the PS2AD, KIN11, or CIN11 input pin.

IOSE	—	—	—	—	0	1
Pin function	PA2 input pin	PA2 output pin	PS2AC output pin	PA2 input pin	A18 output pin	PA2 output pin
	KIN10 input pin, CIN10 input pin, PS2AC input pin					

This pin can always be used as the PS2AC, $\overline{\text{KIN10}}$, or CIN10 input pin.

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

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

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

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

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

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

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

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

input pull-up is always off.

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

Table 8.24 summarizes the MOS input pull-up states.

Table 8.24 MOS Input Pull-Up States (Port A)

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

Legend:

Off: MOS input pull-up is always off.

On/Off: On when PADDR = 0 and PAODR = 1; otherwise off.

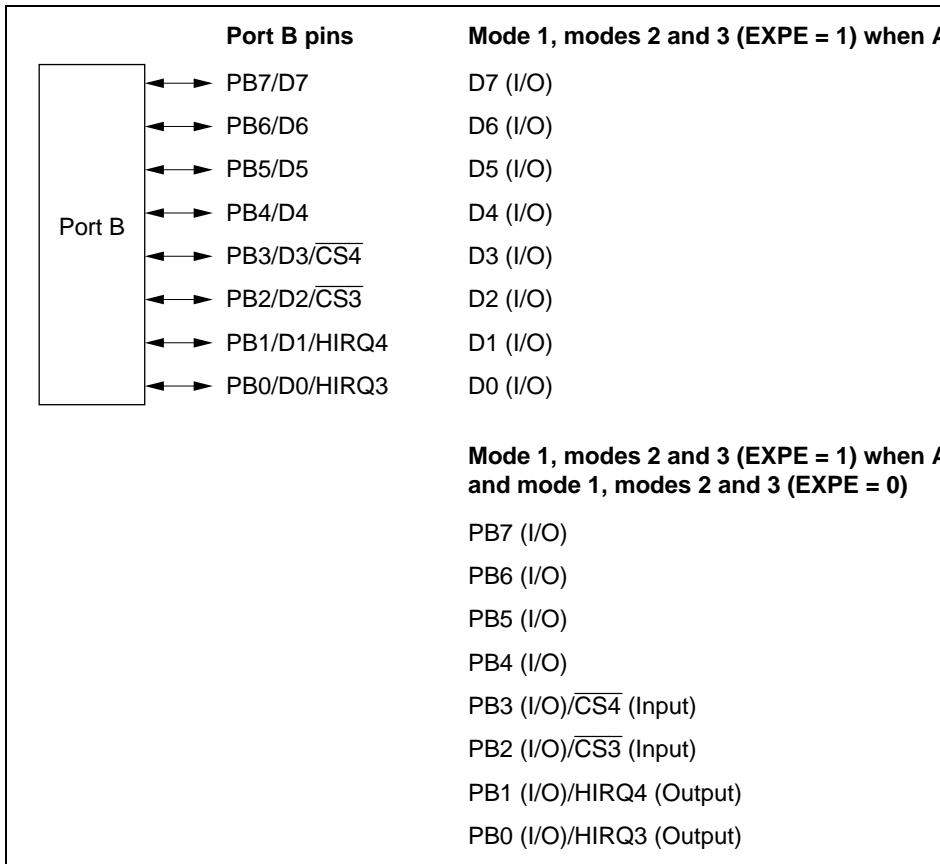


Figure 8.19 Port B Pin Functions

- Notes:
1. Lower 16 bits of the address.
 2. PBDDR has the same address as P7PIN.
 3. PBPIN has the same address as P8DDR.

Port B Data Direction Register (PBDDR)

Bit	7	6	5	4	3	2	1
	PB7DDR	PB6DDR	PB5DDR	PB4DDR	PB3DDR	PB2DDR	PB1DDR
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

PBDDR is an 8-bit write-only register, the individual bits of which specify input or output pins of port B. PBDDR has the same address as P7PIN, and if read, the port 7 pin status is returned.

Setting a PBDDR bit to 1 makes the corresponding port B pin an output pin, while clearing it to 0 makes the pin an input pin.

PBDDR is initialized to H'00 by a reset and in hardware standby mode. It retains its port B pin status in software standby mode.

- Modes 1, 2 and 3 (EXPE = 1)
 When the ABW bit in WSCR is cleared to 0, port B pins automatically become data pins (D7 to D0), regardless of the input/output direction indicated by PBDDR. When the ABW bit is 1, a port B pin becomes an output port if the corresponding PBDDR bit is set to 1, and an input port if the bit is cleared to 0.
 Data I/O pins go to the high-impedance state after a reset, and in hardware standby mode and software standby mode.

Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

PBODR is an 8-bit readable/writable register that stores output data for the port B pins (PB7 to PB0). PBODR can always be read or written to, regardless of the contents of PBDDR.

PBODR is initialized to H'00 by a reset and in hardware standby mode. It retains its previous value in software standby mode.

Port B Input Data Register (PBPIN)

Bit	7	6	5	4	3	2	1
	PB7PIN	PB6PIN	PB5PIN	PB4PIN	PB3PIN	PB2PIN	PB1PIN
Initial value	—*	—*	—*	—*	—*	—*	—*
Read/Write	R	R	R	R	R	R	R

Note: * Determined by the state of pins PB7 to PB0.

Reading PBPIN always returns the pin states.

PBPIN has the same address as P8DDR. If a write is performed, data will be written to P8DDR and the port 8 settings will change.

PB7/D7

The pin function is switched as shown below according to the combination of the operating mode, bit PB7DDR, and bit ABW in WSCR.

Operating mode	Modes 1, 2, 3 (EXPE = 1)			Mode (EXPE = 0)
	0	1		
ABW	0	1		—
PB7DDR	—	0	1	0
Pin function	D7 I/O pin	PB7 input pin	PB7 output pin	PB7 input pin

PB6/D6

The pin function is switched as shown below according to the combination of the operating mode, bit PB6DDR, and bit ABW in WSCR.

Operating mode	Modes 1, 2, 3 (EXPE = 1)			Mode (EXPE = 0)
	0	1		
ABW	0	1		—
PB6DDR	—	0	1	0
Pin function	D6 I/O pin	PB6 input pin	PB6 output pin	PB6 input pin

PB5/D5

The pin function is switched as shown below according to the combination of the operating mode, bit PB5DDR, and bit ABW in WSCR.

Operating mode	Modes 1, 2, 3 (EXPE = 1)			Mode (EXPE = 0)
	0	1		
ABW	0	1		—
PB5DDR	—	0	1	0
Pin function	D5 I/O pin	PB5 input pin	PB5 output pin	PB5 input pin

	I/O pin	input pin	output pin	input pin	
--	---------	-----------	------------	-----------	--

PB3/D3/ $\overline{\text{CS4}}$

The pin function is switched as shown below according to the combination of the operating mode, bits HI12E and CS4E in SYSCR2, bit ABW in SYSCR3, and bit PB3DDR.

Operating mode	Modes 1, 2, 3 (EXPE = 1)			Modes 2, 3 (EXPE = 0)	
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

PB2/D2/ $\overline{\text{CS3}}$

The pin function is switched as shown below according to the combination of the operating mode, bits HI12E and CS3E in SYSCR2, bit ABW in SYSCR3, and bit PB2DDR.

Operating mode	Modes 1, 2, 3 (EXPE = 1)			Modes 2, 3 (EXPE = 0)	
HI12E	—			Either cleared to 0	
CS3E	—				
ABW	0	1		—	
PB2DDR	—	0	1	0	1
Pin function	D2 I/O pin	PB2 input pin	PB2 output pin	PB2 input pin	PB2 output pin

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

PB0/D0/HIRQ3 The pin function is switched as shown below according to the combination of the operating mode, bits HI12E and CS3E in SYSCR2, bit ABW in SYSCR2, and bit PB0DDR.

Operating mode	Modes 1, 2, 3 (EXPE = 1)			Modes 2, 3 (EXPE = 0)	
HI12E	—			Either cleared to 0	
CS3E	—				
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

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

Table 8.27 summarizes the MOS input pull-up states.

Table 8.27 MOS Input Pull-Up States (Port B)

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

Legend:

Off: MOS input pull-up is always off.

On/Off: On when PBDDR = 0 and PBODR = 1; otherwise off.

output. Sixteen output waveforms are generated from a common time base, enabling output with a high carrier frequency to be produced using pulse division. The PWM timer has sixteen 8-bit PWM data registers (PWDRs), and an output pulse with a duty cycle 100% can be obtained as specified by PWDR and the port data register (P1DR or P2DR).

9.1.1 Features

The PWM timer module has the following features.

- Operable at a maximum carrier frequency of 1.25 MHz using pulse division (at 20% operation)
- Duty cycles from 0 to 100% with 1/256 resolution (100% duty realized by port output)
- Direct or inverted PWM output, and PWM output enable/disable control

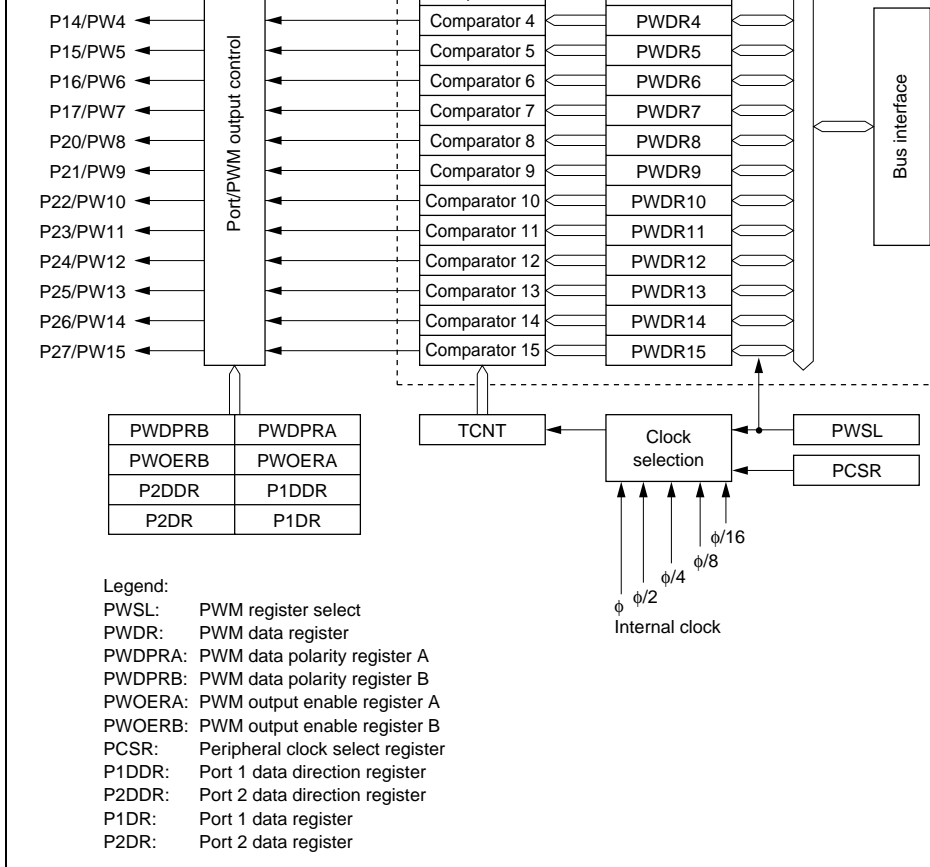


Figure 9.1 Block Diagram of PWM Timer Module

9.1.4 Register Configuration

Table 9.2 lists the registers of the PWM timer module.

Table 9.2 PWM Timer Module Registers

Name	Abbreviation	R/W	Initial Value	Address
PWM register select	PWSL	R/W	H'20	H'00000020
PWM data registers 0 to 15	PWDR0 to PWDR15	R/W	H'00	H'00000000 to H'00000010
PWM data polarity register A	PWDpra	R/W	H'00	H'00000011
PWM data polarity register B	PWDprb	R/W	H'00	H'00000012
PWM output enable register A	PWOera	R/W	H'00	H'00000013
PWM output enable register B	PWOerb	R/W	H'00	H'00000014
Port 1 data direction register	P1DDR	W	H'00	H'00000015
Port 2 data direction register	P2DDR	W	H'00	H'00000016
Port 1 data register	P1DR	R/W	H'00	H'00000017
Port 2 data register	P2DR	R/W	H'00	H'00000018
Peripheral clock select register	PCSR	R/W	H'00	H'00000019
Module stop control register	MSTPCRH	R/W	H'3F	H'00000021
	MSTPCRL	R/W	H'FF	H'00000022

- Note:
1. Lower 16 bits of the address.
 2. Some registers in the 8-bit timer are assigned in the addresses as other registers. In this case, register selection is performed by the FLSHE bit in the serial timer control register (STCR).

PWSL is an 8-bit readable/writable register used to select the PWM timer input clock and PWM data register.

PWSL is initialized to H'20 by a reset, and in the standby modes, watch mode, subactive mode, subsleep mode, and module stop mode.

Bits 7 and 6—PWM Clock Enable, PWM Clock Select (PWCKE, PWCKS): These bits, together with bits PWCKA and PWCKB in PCSR, select the internal clock input to the PWM timer.

PWSL		PCSR		Description
Bit 7	Bit 6	Bit 2	Bit 1	
PWCKE	PWCKS	PWCKB	PWCKA	
0	—	—	—	Clock input is disabled (In
1	0	—	—	ϕ (system clock) is selected
	1	0	0	$\phi/2$ is selected
			1	$\phi/4$ is selected
	1	1	0	$\phi/8$ is selected
1			$\phi/16$ is selected	

The PWM resolution, PWM conversion period, and carrier frequency depend on the selected internal clock, and can be found from the following equations.

$$\begin{aligned} \text{Resolution (minimum pulse width)} &= 1/\text{internal clock frequency} \\ \text{PWM conversion period} &= \text{resolution} \times 256 \\ \text{Carrier frequency} &= 16/\text{PWM conversion period} \end{aligned}$$

Thus, with a 20-MHz system clock (ϕ), the resolution, PWM conversion period, and carrier frequency are as shown below.



Bit 5—Reserved: This bit is always read as 1 and cannot be modified.

Bit 4—Reserved: This bit is always read as 0 and cannot be modified.

Bits 3 to 0—Register Select (RS3 to RS0): These bits select the PWM data register.

Bit 3	Bit 2	Bit 1	Bit 0	Register Selection	
RS3	RS2	RS1	RS0		
0	0	0	0	PWDR0 selected	
			1	PWDR1 selected	
		1	0	PWDR2 selected	
			1	PWDR3 selected	
	1	0	0	0	PWDR4 selected
				1	PWDR5 selected
		1	0	0	PWDR6 selected
				1	PWDR7 selected
1	0	0	0	PWDR8 selected	
			1	PWDR9 selected	
		1	0	0	PWDR10 selected
				1	PWDR11 selected
	1	0	0	0	PWDR12 selected
				1	PWDR13 selected
		1	0	0	PWDR14 selected
				1	PWDR15 selected

be output, and the number of additional pulses. The value set in PWDR corresponds to the ratio in the conversion period. The upper 4 bits specify the duty cycle of the basic pulse 15/16 with a resolution of 1/16. The lower 4 bits specify how many extra pulses are to be output within the conversion period comprising 16 basic pulses. Thus, a specification of 0/256 is possible for 0/1 ratios within the conversion period. For 256/256 (100%) output, port 0 should be used.

PWDR is initialized to H'00 by a reset, and in the standby modes, watch mode, subaction mode, subsleep mode, and module stop mode.

9.2.3 PWM Data Polarity Registers A and B (PWDPRA and PWDPRB)

PWDPRA

Bit	7	6	5	4	3	2	1
	OS7	OS6	OS5	OS4	OS3	OS2	OS1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

PWDPRB

Bit	7	6	5	4	3	2	1
	OS15	OS14	OS13	OS12	OS11	OS10	OS9
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Each PWDPRA is an 8-bit readable/writable register that controls the polarity of the PWM outputs. Bits OS0 to OS7 correspond to outputs PW0 to PW7. Bits OS8 to OS15 correspond to outputs PW8 to PW15.

PWOERA

Bit	7	6	5	4	3	2	1
	OE7	OE6	OE5	OE4	OE3	OE2	OE1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

PWOERB

Bit	7	6	5	4	3	2	1
	OE15	OE14	OE13	OE12	OE11	OE10	OE9
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Each PWOER is an 8-bit readable/writable register that switches between PWM output and port output. Bits OE15 to OE0 correspond to outputs PW15 to PW0. To set a pin in the output mode, setting the port direction register is also necessary. Bits P17DDR to P10DDR correspond to outputs PW7 to PW0, and bits P27DDR to P20DDR correspond to outputs PW15 to PW8.

PWOER is initialized to H'00 by a reset and in hardware standby mode.

DDR	OE	Description
0	0	Port input (Initial value)
	1	Port input
1	0	Port output or PWM 256/256 output
	1	PWM output (0 to 255/256 output)

PCSR is an 8-bit readable/writable register that selects the PWM timer input clock.

PCSR is initialized to H'00 by a reset, and in hardware standby mode.

Bits 7 to 3—Reserved: These bits cannot be modified and are always read as 0.

Bits 2 and 1—PWM Clock Select (PWCKB, PWCKA): Together with bits PWCKE and PWCKS in PWSL, these bits select the internal clock input to TCNT in the PWM timer. For details, see section 9.2.1, PWM Register Select (PWSL).

Bit 0—Reserved: Do not set this bit to 1.

9.2.6 Port 1 Data Direction Register (P1DDR)

Bit	7	6	5	4	3	2	1
	P17DDR	P16DDR	P15DDR	P14DDR	P13DDR	P12DDR	P11DDR
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

P1DDR is an 8-bit write-only register that specifies the input/output direction and PWM output for each pin of port 1 on a bit-by-bit basis.

Port 1 pins are multiplexed with pins PW0 to PW7. The bit corresponding to a pin to be used as a PWM output should be set to 1.

For details on P1DDR, see section 8.2, Port 1.

each pin of port J on a bit-by-bit basis.

Port 2 pins are multiplexed with pins PW8 to PW15. The bit corresponding to a pin to PWM output should be set to 1.

For details on P2DDR, see section 8.3, Port 2.

9.2.8 Port 1 Data Register (P1DR)

Bit	7	6	5	4	3	2	1
	P17DR	P16DR	P15DR	P14DR	P13DR	P12DR	P11DR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

P1DR is an 8-bit readable/writable register used to fix PWM output at 1 (when OS = 0, OS = 1).

For details on P1DR, see section 8.2, Port 1.

9.2.9 Port 2 Data Register (P2DR)

Bit	7	6	5	4	3	2	1
	P27DR	P26DR	P25DR	P24DR	P23DR	P22DR	P21DR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

P2DR is an 8-bit readable/writable register used to fix PWM output at 1 (when OS = 0, OS = 1).

For details on P2DR, see section 8.3, Port 2.

MSTPCR comprises two 8-bit readable/writable registers, and is used to perform module stop mode control.

When the MSTP11 bit is set to 1, 8-bit PWM timer operation is halted and a transition to module stop mode. For details, see section 25.5, Module Stop Mode.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not initialized in software standby mode.

MSTPCRH Bit 3—Module Stop (MSTP11): Specifies PWM module stop mode.

MSTPCRH
Bit 3

MSTP11	Description	
0	PWM module stop mode is cleared	
1	PWM module stop mode is set	(In

Upper 4 Bits	Basic Pulse Waveform (Internal)
0000	0 1 2 3 4 5 6 7 8 9 A B C D E F 0
0001	
0010	
0011	
0100	
0101	
0110	
0111	
⋮	
1000	
1001	
1010	
1011	
1100	
1101	
1110	
1111	

0000														
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	
1011		Yes		Yes	Yes	Yes	Yes				Yes	Yes	Yes	
1100		Yes	Yes	Yes		Yes	Yes	Yes			Yes	Yes	Yes	
1101		Yes	Yes	Yes		Yes	Yes	Yes			Yes	Yes	Yes	Yes
1110		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

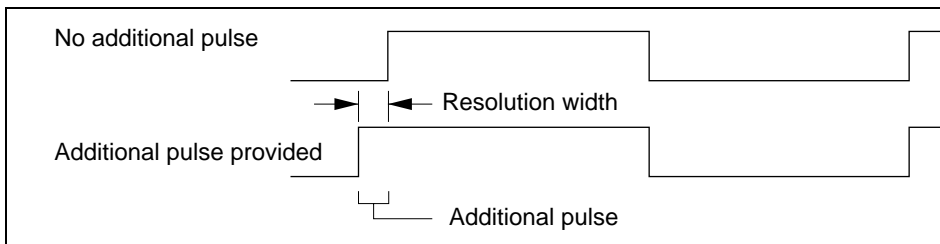


Figure 9.2 Example of Additional Pulse Timing (when Upper 4 Bits of PWDR)

Both channels share the same counter (DACNT) and control register (DACR).

10.1.1 Features

The features of the 14-bit PWM (D/A) are listed below.

- The pulse is subdivided into multiple base cycles to reduce ripple.
- Two resolution settings and two base cycle settings are available

The resolution can be set equal to one or two system clock cycles. The base cycle equal to $T \times 64$ or $T \times 256$, where T is the resolution.

- Four operating rates

The two resolution settings and two base cycle settings combine to give a selection of operating rates.

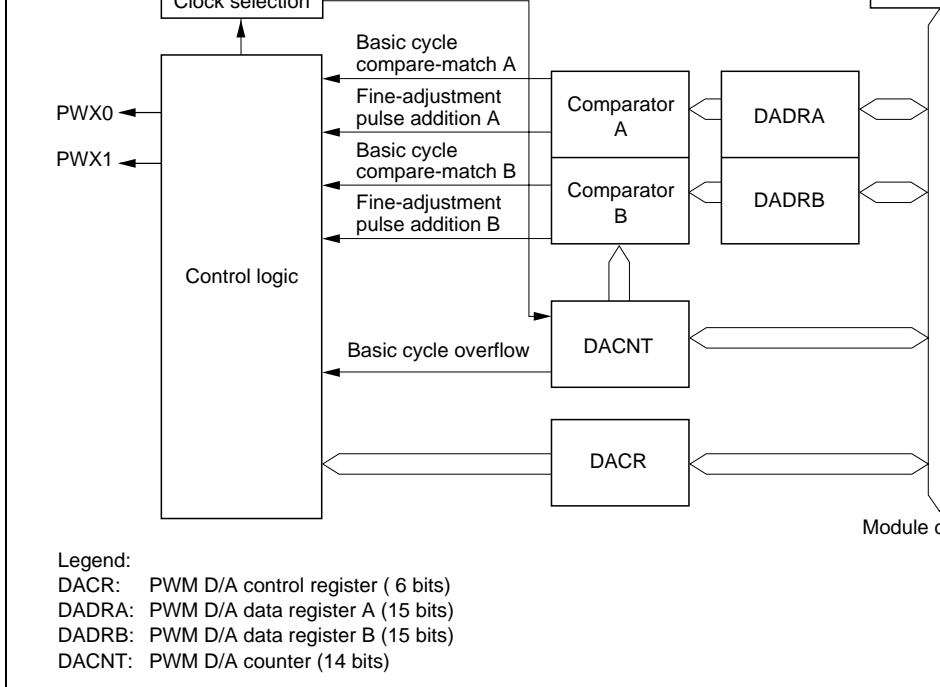


Figure 10.1 PWM D/A Block Diagram

10.1.4 Register Configuration

Table 10.2 lists the registers of the PWM (D/A) module.

Table 10.2 Register Configuration

Name	Abbreviation	R/W	Initial value	Address
PWM D/A control register	DACR	R/W	H'30	H'0000
PWM D/A data register A high	DADRAH	R/W	H'FF	H'0004
PWM D/A data register A low	DADRAL	R/W	H'FF	H'0008
PWM D/A data register B high	DADRBH	R/W	H'FF	H'000C
PWM D/A data register B low	DADRBL	R/W	H'FF	H'0010
PWM D/A counter high	DACNTH	R/W	H'00	H'0014
PWM D/A counter low	DACNTL	R/W	H'03	H'0018
Module stop control register	MSTPCRH	R/W	H'3F	H'001C
	MSTPCRL	R/W	H'FF	H'0020

- Notes:
1. Lower 16 bits of the address.
 2. Registers in the 14-bit PWM timer are assigned to the same addresses as the 16-bit PWM timer registers. In this case, register selection is performed by the IICE bit in the stop control register (STCR), and also the same addresses are shared by DADRBL, DADRAL, DACR, and by DADRBH and DACNTH. Switching is performed by the REGS bit in DADRBL or DADRBH.

Initial value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

DACNT is a 14-bit readable/writable up-counter that increments on an input clock pulse. The input clock is selected by the clock select bit (CKS) in DACR. The CPU can read and write the DACNT value, but since DACNT is a 16-bit register, data transfers between it and the CPU are performed using a temporary register (TEMP). See section 10.3, Bus Master Interface.

DACNT functions as the time base for both PWM (D/A) channels. When a channel operates with 14-bit precision, it uses all DACNT bits. When a channel operates with 12-bit precision, it uses the lower 12 (counter) bits and ignores the upper two (counter) bits.

DACNT is initialized to H'0003 by a reset, in the standby modes, watch mode, subactive mode, subsleep mode, and module stop mode, and by the PWME bit.

Bit 1 of DACNTL (CPU) is not used, and is always read as 1.

DACNTL Bit 0—Register Select (REGS): DADRA and DACR, and DADR B and DACNT are located at the same addresses. The REGS bit specifies which registers can be accessed. Bit 0 can be accessed regardless of whether DADR B or DACNT is selected.

Bit 0

REGS	Description
0	DADRA and DADR B can be accessed
1	DACR and DACNT can be accessed

Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
DADRB	DA13	DA12	DA11	DA10	DA9	DA8	DA7	DA6	DA5	DA4	DA3	DA2	DA1	DA0	
Initial value	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

There are two 16-bit readable/writable D/A data registers: DADRA and DADRB. DA13 corresponds to PWM (D/A) channel A, and DADRB to PWM (D/A) channel B. The CPU can read and write the PWM (D/A) data register values, but since DADRA and DADRB are 16-bit registers, data transfers between them and the CPU are performed using a temporary register (TEMP). See section 10.3, Bus Master Interface, for details.

The least significant (CPU) bit of DADRA is not used and is always read as 1.

DADR is initialized to H'FFFF by a reset, and in the standby modes, watch mode, subsleep mode, and module stop mode.

Bits 15 to 3—PWM D/A Data 13 to 0 (DA13 to DA0): The digital value to be converted to an analog value is set in the upper 14 bits of the PWM (D/A) data register.

In each base cycle, the DACNT value is continually compared with these upper 14 bits to determine the duty cycle of the output waveform, and to decide whether to output a fine adjustment pulse equal in width to the resolution. To enable this operation, the data register must be set within a range that depends on the carrier frequency select bit (CFS). If the DACNT is outside this range, the PWM output is held constant.

A channel can be operated with 12-bit precision by keeping the two lowest data bits (DA2 and DA1) cleared to 0 and writing the data to be converted in the upper 12 bits. The two lowest bits correspond to the two highest counter (DACNT) bits.

DADRA Bit 0—Reserved: This bit cannot be modified and is always read as 1.

DADRB Bit 0—Register Select (REGS): DADRA and DACR, and DADRB and DACNT are located at the same addresses. The REGS bit specifies which registers can be accessed. The REGS bit can be accessed regardless of whether DADRB or DACNT is selected.

Bit 0

REGS	Description
0	DADRA and DADRB can be accessed
1	DACR and DACNT can be accessed

10.2.3 PWM D/A Control Register (DACR)

Bit	7	6	5	4	3	2	1
	TEST	PWME	—	—	OEB	OEA	OS
Initial value	0	0	1	1	0	0	0
Read/Write	R/W	R/W	—	—	R/W	R/W	R/W

DACR is an 8-bit readable/writable register that selects test mode, enables the PWM output, selects the output phase and operating speed.

DACR is initialized to H'30 by a reset, and in the standby modes, watch mode, subactive mode, subsleep mode, and module stop mode.

Bit 7—Test Mode (TEST): Selects test mode, which is used in testing the chip. Normal operation should be cleared to 0.

PWME	Description
0	DACNT operates as a 14-bit up-counter
1	DACNT halts at H'0003

Bits 5 and 4—Reserved: These bits cannot be modified and are always read as 1.

Bit 3—Output Enable B (OEB): Enables or disables output on PWM (D/A) channel B.

Bit 3

OEB	Description
0	PWM (D/A) channel B output (at the PWX1 pin) is disabled
1	PWM (D/A) channel B output (at the PWX1 pin) is enabled

Bit 2—Output Enable A (OEA): Enables or disables output on PWM (D/A) channel A.

Bit 2

OEA	Description
0	PWM (D/A) channel A output (at the PWX0 pin) is disabled
1	PWM (D/A) channel A output (at the PWX0 pin) is enabled

Bit 1—Output Select (OS): Selects the phase of the PWM (D/A) output.

Bit 1

OS	Description
0	Direct PWM output
1	Inverted PWM output

10.2.4 Module Stop Control Register (MSTPCR)

Bit	MSTPCRH								MSTPCRL					
	7	6	5	4	3	2	1	0	7	6	5	4	3	2
	MSTP15	MSTP14	MSTP13	MSTP12	MSTP11	MSTP10	MSTP9	MSTP8	MSTP7	MSTP6	MSTP5	MSTP4	MSTP3	MSTP2
Initial value	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

MSTPCR comprises two 8-bit readable/writable registers, and is used to perform module stop mode control.

When the MSTP11 bit is set to 1, 14-bit PWM timer operation is halted and a transition to module stop mode. For details, see section 25.5, Module Stop Mode.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not initialized in software standby mode.

MSTPCRH Bit 3—Module Stop (MSTP11): Specifies PWMX module stop mode.

MSTPCRH

Bit 3

MSTP11	Description
0	PWMX module stop mode is cleared
1	PWMX module stop mode is set (In

When the upper byte is written, the upper-byte write data is stored in TEMP. Next, when the lower byte is written, the lower-byte write data and TEMP value are combined, and the combined 16-bit value is written in the register.

- Read

When the upper byte is read, the upper-byte value is transferred to the CPU and the value is transferred to TEMP. Next, when the lower byte is read, the lower-byte value and TEMP is transferred to the CPU.

These registers should always be accessed 16 bits at a time using an MOV instruction (one access or two consecutive byte accesses), and the upper byte should always be accessed first, followed by the lower byte. Correct data will not be transferred if only the upper byte or only the lower byte is accessed. Also note that a bit-manipulation instruction cannot be used to access these registers.

Figure 10.2 shows the data flow for access to DACNT. The other registers are accessed in a similar manner.

Example 1: Write to DACNT

```
MOV.W R0, @DACNT ; Write R0 contents to DACNT
```

Example 2: Read DADRA

```
MOV.W @DADRA, R0 ; Transfer contents of DADRA to R0
```

(first) and lower byte (second).

×: This type of access may give incorrect results.

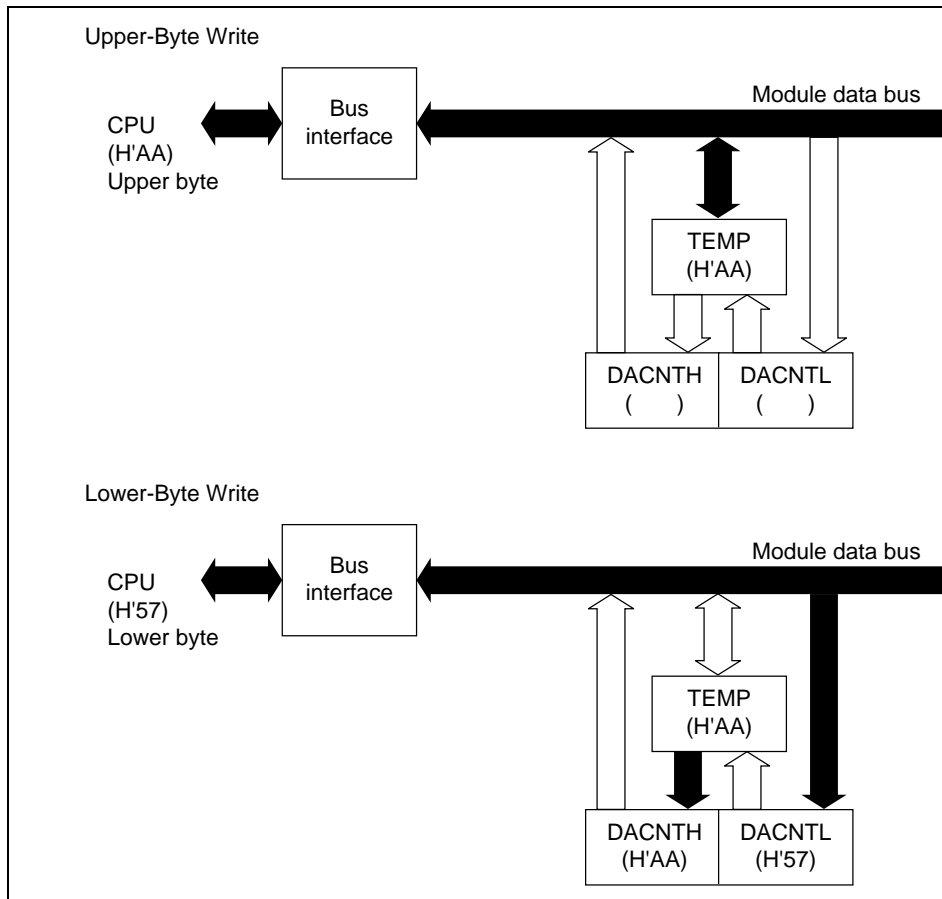


Figure 10.2 (a) Access to DACNT (CPU Writes H'AA57 to DACNT)

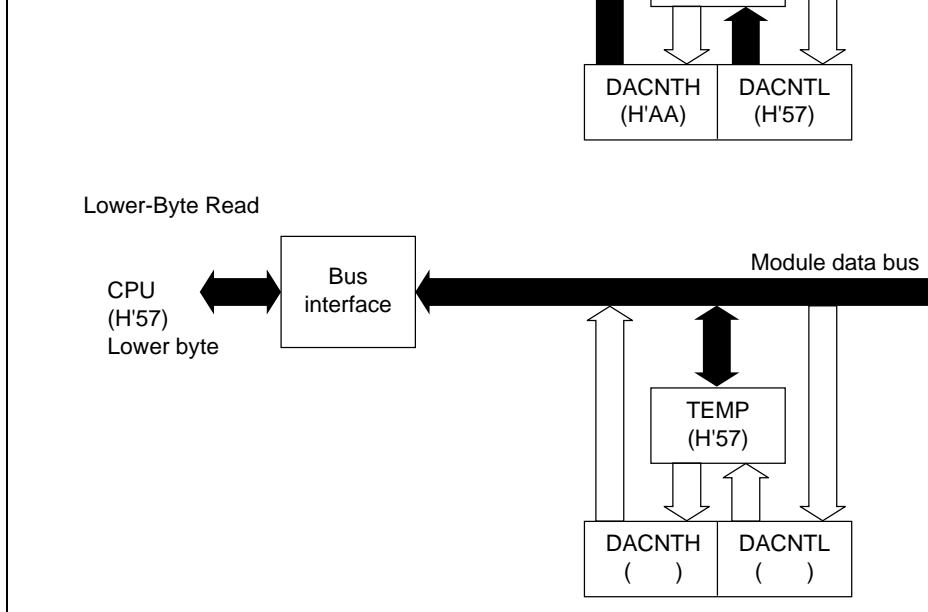


Figure 10.2 (b) Access to DACNT (CPU Reads H'AA57 from DACNT)

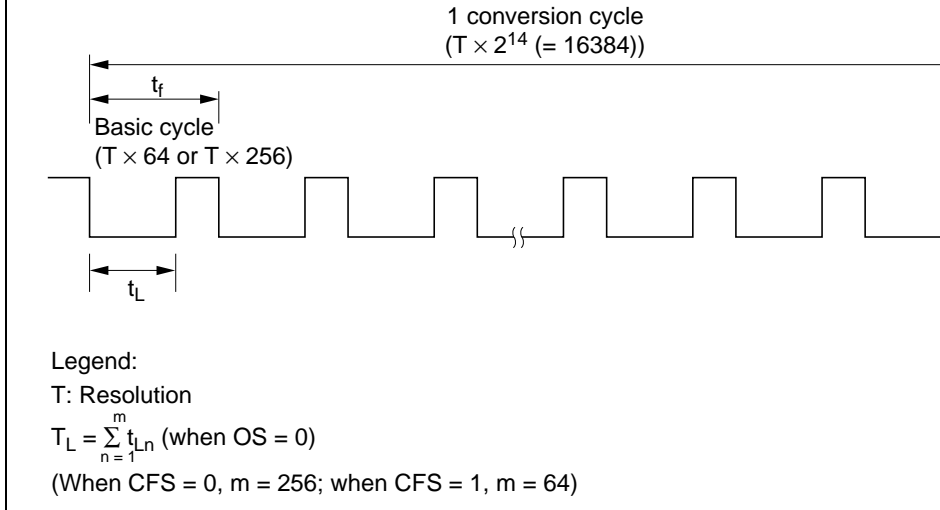


Figure 10.3 PWM D/A Operation

Table 10.4 summarizes the relationships of the CKS, CFS, and OS bit settings to the resolution, base cycle, and conversion cycle. The PWM output remains flat unless DADR contains a certain minimum value. Table 10.4 indicates the range of DADR settings that give an output waveform like the one in figure 10.3, and lists the conversion cycle length when low-order bits are kept cleared to 0, reducing the conversion precision to 12 bits or 10 bits.

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

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

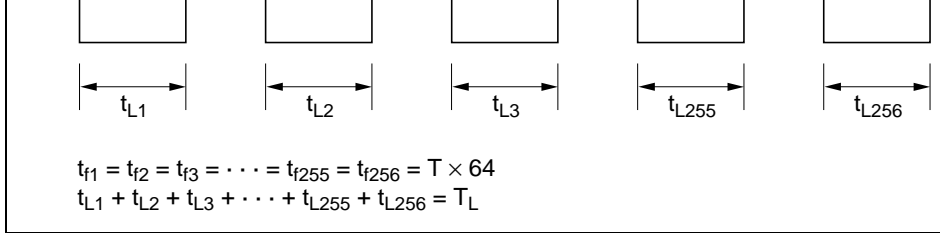


Figure 10.4 (1) Output Waveform

b. CFS = 1 [base cycle = resolution (T) × 256]

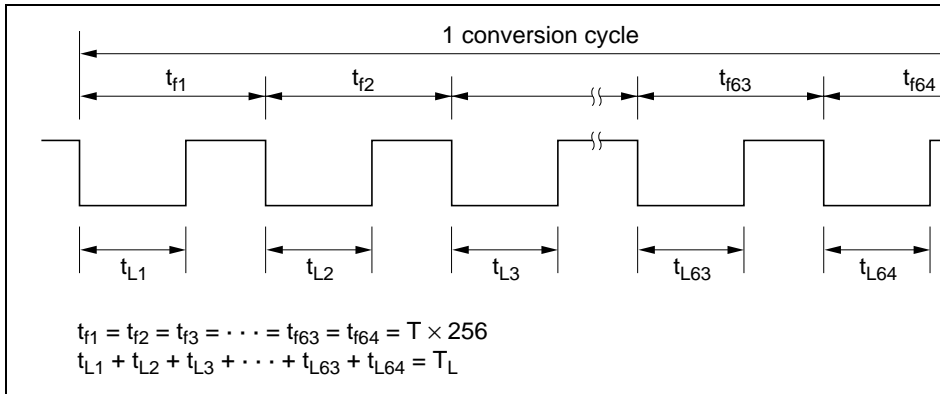


Figure 10.4 (2) Output Waveform

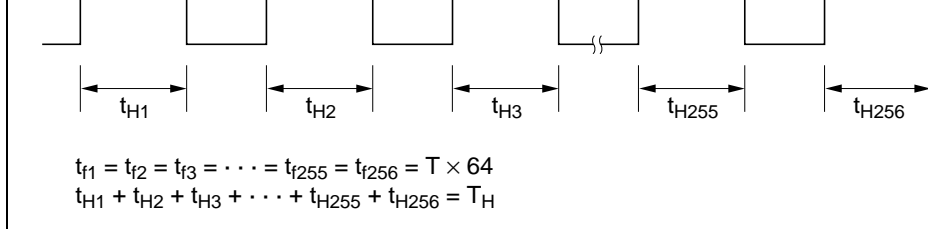


Figure 10.4 (3) Output Waveform

b. CFS = 1 [base cycle = resolution (T) × 256]

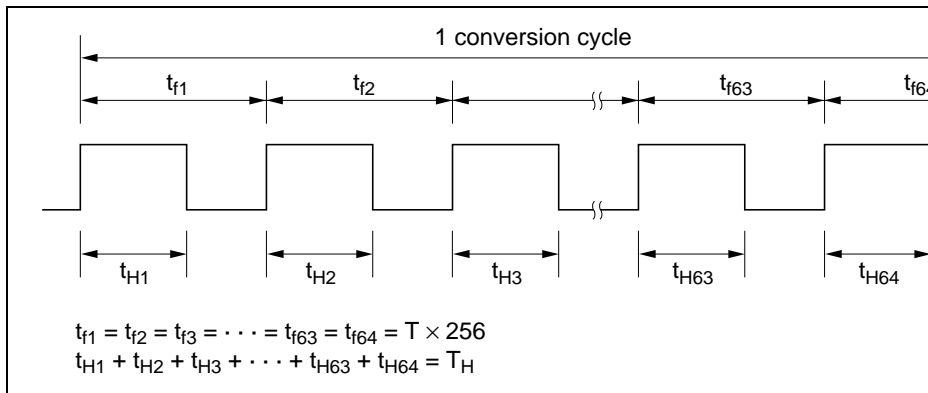


Figure 10.4 (4) Output Waveform

external clock periods.

11.1.1 Features

The features of the free-running timer module are listed below.

- Selection of four clock sources
 - The free-running counter can be driven by an internal clock source ($\phi/2$, $\phi/8$, or external clock input (enabling use as an external event counter).
- Two independent comparators
 - Each comparator can generate an independent waveform.
- Four input capture channels
 - The current count can be captured on the rising or falling edge (selectable) of a signal.
 - The four input capture registers can be used separately, or in a buffer mode.
- Counter can be cleared under program control
 - 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 can be requested independently.
- Special functions provided by automatic addition function
 - The contents of OCRAR and OCRAF can be added to the contents of OCRA automatically, enabling a periodic waveform to be generated without software.
 - The contents of ICRD can be added automatically to the contents of OCRDM input capture operations in this interval to be restricted.

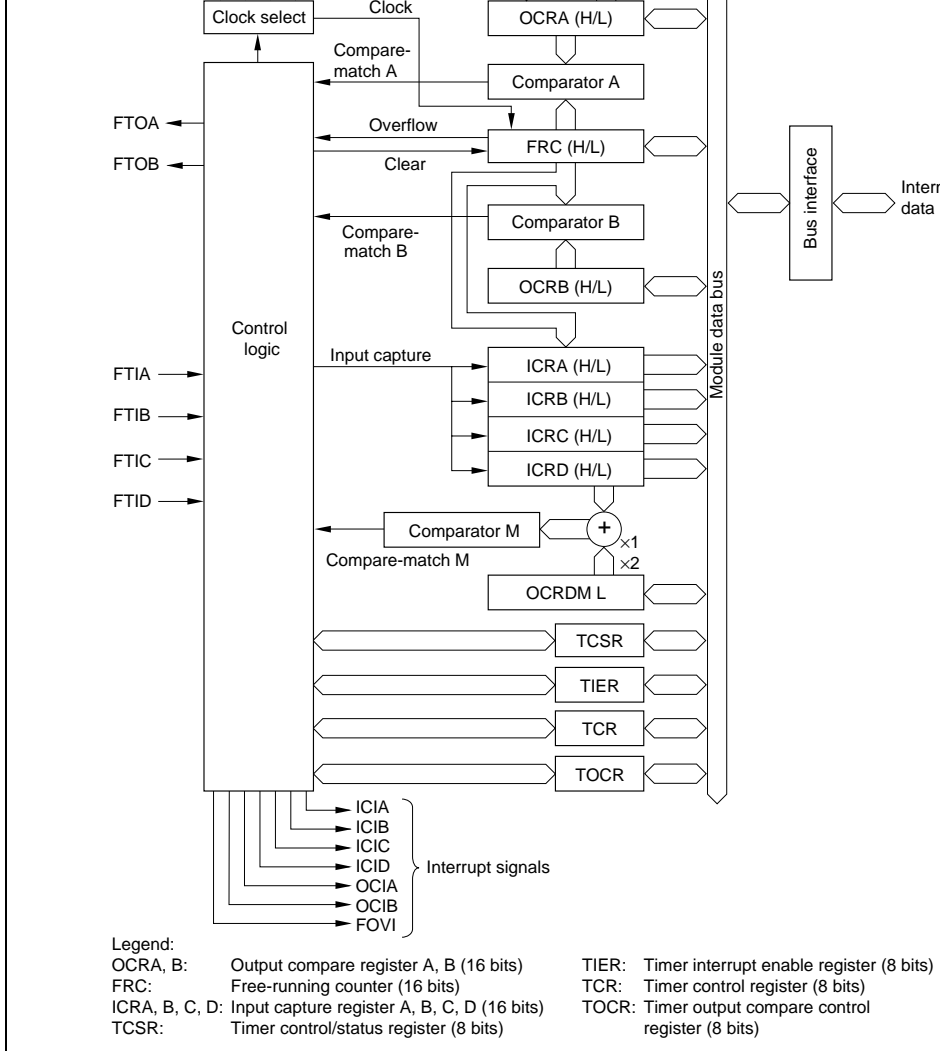


Figure 11.1 Block Diagram of 16-Bit Free-Running Timer

Output compare B	FTOB	Output	Output compare B output
Input capture A	FTIA	Input	Input capture A input
Input capture B	FTIB	Input	Input capture B input
Input capture C	FTIC	Input	Input capture C input
Input capture D	FTID	Input	Input capture D input

Free-running counter	FRC	R/W	H'0000	H'FF5
Output compare register A	OCRA	R/W	H'FFFF	H'FF5
Output compare register B	OCRB	R/W	H'FFFF	H'FF5
Timer control register	TCR	R/W	H'00	H'FF5
Timer output compare control register	TOCR	R/W	H'00	H'FF5
Input capture register A	ICRA	R	H'0000	H'FF5
Input capture register B	ICRB	R	H'0000	H'FF5
Input capture register C	ICRC	R	H'0000	H'FF5
Input capture register D	ICRD	R	H'0000	H'FF5
Output compare register AR	OCRAR	R/W	H'FFFF	H'FF5
Output compare register AF	OCRAF	R/W	H'FFFF	H'FF5
Output compare register DM	OCRDM	R/W	H'0000	H'FF5
Module stop control register	MSTPCRH	R/W	H'3F	H'FF5
	MSTPCRL	R/W	H'FF	H'FF5

- Notes:
1. Lower 16 bits of the address.
 2. Bits 7 to 1 are read-only; only 0 can be written to clear the flags.
Bit 0 is readable/writable.
 3. OCRA and OCRB share the same address. Access is controlled by the OCR bit in TOCR.
 4. ICRA, ICRB, and ICRC share the same addresses with OCRAR, OCRAF, and OCRDM. Access is controlled by the ICRS bit in TOCR.

FRC is a 16-bit readable/writable up-counter that increments on an internal pulse generated by the clock source. The clock source is selected by bits CKS1 and CKS0 in TCR.

FRC can also be cleared by compare-match A.

When FRC overflows from H'FFFF to H'0000, the overflow flag (OVF) in TCSR is set.

FRC is initialized to H'0000 by a reset and in hardware standby mode.

11.2.2 Output Compare Registers A and B (OCRA, OCRB)

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2
Initial value	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

OCRA and OCRB are 16-bit readable/writable registers, the contents of which are compared with the value in the FRC. When a match is detected, the corresponding output flags (OCFA or OCFB) is set in TCSR.

In addition, if the output enable bit (OEA or OEB) in TOCR is set to 1, when OCR and FRC values match, the logic level selected by the output level bit (OLVLA or OLVLB) in TOCR is output at the output compare pin (FTOA or FTOB). Following a reset, the FTOA and FTOB output levels are 0 until the first compare-match.

OCR is initialized to H'FFFF by a reset and in hardware standby mode.

When the rising or falling edge of the signal at an input capture input pin (FTIA to FTID) is detected, the current FRC value is copied to the corresponding input capture register (ICRA to ICRD). At the same time, the corresponding input capture flag (ICFA to ICFD) in TCSR is set to 1. The input capture edge is selected by the input edge select bits (IEDGA to IEDGD) in TCSR.

ICRC and ICRD can be used as ICRA and ICRB buffer registers, respectively, and can perform buffer operations, by means of buffer enable bits A and B (BUFEA, BUFEB) in TCSR.

Figure 11.2 shows the connections when ICRC is specified as the ICRA buffer register (ICRA = ICRC). When ICRC is used as the ICRA buffer, both rising and falling edges can be specified for the transitions of the external input signal by setting $IEDGA \neq IEDGC$. When $IEDGA = IEDGC$, either the rising or falling edge is designated. See table 11.3.

Note: The FRC contents are transferred to the input capture register regardless of the state of the input capture flag (ICF).

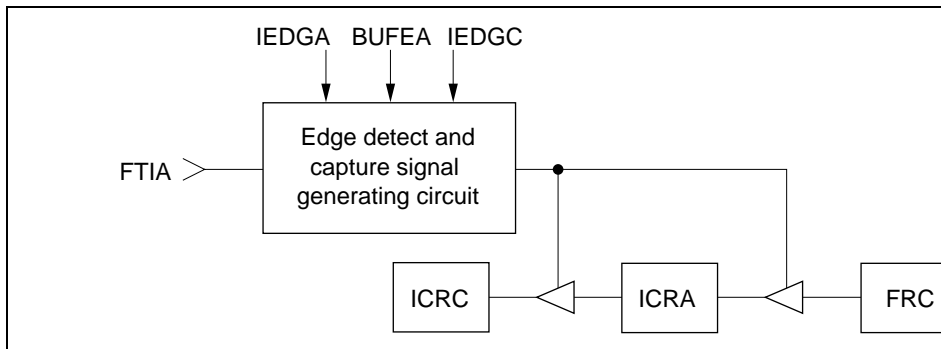


Figure 11.2 Input Capture Buffering (Example)

To ensure input capture, the width of the input capture pulse should be at least 1.5 system clock periods (1.5ϕ). When triggering is enabled on both edges, the input capture pulse width should be at least 2.5 system clock periods (2.5ϕ).

ICR is initialized to H'0000 by a reset and in hardware standby mode.

11.2.4 Output Compare Registers AR and AF (OCRAR, OCRAF)

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2
Initial value	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

OCRAR and OCRAF are 16-bit readable/writable registers.

When the OCRAMS bit in TOCR is set to 1, the operation of OCRA is changed to include the automatic addition of OCRAR and OCRAF. The contents of OCRAR and OCRAF are automatically added alternately to OCRA, and the result is written to OCRA. The write operation is performed on the occurrence of compare-match A. In the first compare-match A after the OCRAMS bit is set to 1, OCRAF is added.

The operation due to compare-match A varies according to whether the compare-match A is the first occurrence following addition of OCRAR or OCRAF. The value of the OLVLA bit in TOCR is ignored, and 0 is output on a compare-match A following addition of OCRAF, while 1 is output on a compare-match A following addition of OCRAR.

When the OCRA automatic addition function is used, do not set internal clock $\phi/2$ counter input clock together with an OCRAR (or OCRAF) value of H'0001 or less.

OCRAR and OCRAF are initialized to H'FFFF by a reset and in hardware standby mode.

When the ICRDMS bit in TOCR is set to 1 and the contents of OCRDM are other than the operation of ICRD is changed to include the use of OCRDM. The point at which D occurs is taken as the start of a mask interval. Next, twice the contents of OCRDM is the contents of ICRD, and the result is compared with the FRC value. The point at which values match is taken as the end of the mask interval. New input capture D events are during the mask interval.

A mask interval is not generated when the ICRDMS bit is set to 1 and the contents of OCRDM are H'0000.

OCRDM is initialized to H'0000 by a reset and in hardware standby mode.

11.2.6 Timer Interrupt Enable Register (TIER)

Bit	7	6	5	4	3	2	1
	ICIAE	ICIBE	ICICE	ICIDE	OCIAE	OCIBE	OVIE
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

TIER is an 8-bit readable/writable register that enables and disables interrupts.

TIER is initialized to H'01 by a reset and in hardware standby mode.

Bit 7—Input Capture Interrupt A Enable (ICIAE): Selects whether to request input capture interrupt A (ICIA) when input capture flag A (ICFA) in TCSR is set to 1.

Bit 6

ICIBE	Description
0	Input capture interrupt request B (ICIB) is disabled
1	Input capture interrupt request B (ICIB) is enabled

Bit 5—Input Capture Interrupt C Enable (ICICE): Selects whether to request input capture interrupt C (ICIC) when input capture flag C (ICFC) in TCSR is set to 1.

Bit 5

ICICE	Description
0	Input capture interrupt request C (ICIC) is disabled
1	Input capture interrupt request C (ICIC) is enabled

Bit 4—Input Capture Interrupt D Enable (ICIDE): Selects whether to request input capture interrupt D (ICID) when input capture flag D (ICFD) in TCSR is set to 1.

Bit 4

ICIDE	Description
0	Input capture interrupt request D (ICID) is disabled
1	Input capture interrupt request D (ICID) is enabled

Bit 3—Output Compare Interrupt A Enable (OCIAE): Selects whether to request output compare interrupt A (OCIA) when output compare flag A (OCFA) in TCSR is set to 1.

Bit 3

OCIAE	Description
0	Output compare interrupt request A (OCIA) is disabled
1	Output compare interrupt request A (OCIA) is enabled

Bit 1—Timer Overflow Interrupt Enable (OVIE): Selects whether to request a new timer overflow interrupt (FOVI) when the timer overflow flag (OVF) in TCSR is set to 1.

Bit 1

OVIE	Description
0	Timer overflow interrupt request (FOVI) is disabled (Ir)
1	Timer overflow interrupt request (FOVI) is enabled

Bit 0—Reserved: This bit cannot be modified and is always read as 1.

11.2.7 Timer Control/Status Register (TCSR)

Bit	7	6	5	4	3	2	1
	ICFA	ICFB	ICFC	ICFD	OCFA	OCFB	OVF
Initial value	0	0	0	0	0	0	0
Read/Write	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*

Note: * Only 0 can be written in bits 7 to 1 to clear these flags.

TCSR is an 8-bit register used for counter clear selection and control of interrupt request.

TCSR is initialized to H'00 by a reset and in hardware standby mode.

Timing is described in section 11.3, Operation.

Bit 7—Input Capture Flag A (ICFA): This status flag indicates that the FRC value has been transferred to ICRA by means of an input capture signal. When BUFEA = 1, ICFA indicates that the old ICRA value has been moved into ICRC and the new FRC value has been transferred to ICRA.

ICFA must be cleared by software. It is set by hardware, however, and cannot be set by software.

Bit 6—Input Capture Flag B (ICFB): This status flag indicates that the FRC value has been transferred to ICRB by means of an input capture signal. When BUFE_B = 1, ICFB indicates that the old ICRB value has been moved into ICRD and the new FRC value has been transferred to ICRB.

ICFB must be cleared by software. It is set by hardware, however, and cannot be set by software.

Bit 6

ICFB	Description
0	[Clearing condition] Read ICFB when ICFB = 1, then write 0 in ICFB
1	[Setting condition] When an input capture signal causes the FRC value to be transferred to ICRB

Bit 5—Input Capture Flag C (ICFC): This status flag indicates that the FRC value has been transferred to ICRC by means of an input capture signal. When BUFE_A = 1, on occurrence of a signal transition in FTIC (input capture signal) specified by the IEDGC bit, ICFC is set. If BUFE_A = 0, ICFC is not transferred to ICRC. Therefore, in buffer operation, ICFC can be used as an external interrupt signal (by setting the ICICE bit to 1).

ICFC must be cleared by software. It is set by hardware, however, and cannot be set by software.

Bit 5

ICFC	Description
0	[Clearing condition] Read ICFC when ICFC = 1, then write 0 in ICFC
1	[Setting condition] When an input capture signal is received

ICFD	Description
0	[Clearing condition] Read ICFD when ICFD = 1, then write 0 in ICFD
1	[Setting condition] When an input capture signal is received

Bit 3—Output Compare Flag A (OCFA): This status flag indicates that the FRC value is equal to the OCRA value. This flag must be cleared by software. It is set by hardware, however, cannot be set by software.

Bit 3

OCFA	Description
0	[Clearing condition] Read OCFA when OCFA = 1, then write 0 in OCFA
1	[Setting condition] When FRC = OCRA

Bit 2—Output Compare Flag B (OCFB): This status flag indicates that the FRC value is equal to the OCRB value. This flag must be cleared by software. It is set by hardware, however, cannot be set by software.

Bit 2

OCFB	Description
0	[Clearing condition] Read OCFB when OCFB = 1, then write 0 in OCFB
1	[Setting condition] When FRC = OCRB

1 [Setting condition]
 When FRC changes from H'FFFF to H'0000

Bit 0—Counter Clear A (CCLRA): This bit selects whether the FRC is to be cleared at compare-match A (when the FRC and OCRA values match).

Bit 0

CCLRA	Description
0	FRC clearing is disabled
1	FRC is cleared at compare-match A

11.2.8 Timer Control Register (TCR)

Bit	7	6	5	4	3	2	1
	IEDGA	IEDGB	IEDGC	IEDGD	BUFEA	BUFEB	CKS1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

TCR is an 8-bit readable/writable register that selects the rising or falling edge of the input signals, enables the input capture buffer mode, and selects the FRC clock source.

TCR is initialized to H'00 by a reset and in hardware standby mode

Bit 7—Input Edge Select A (IEDGA): Selects the rising or falling edge of the input signal (FTIA).

Bit 6

IEDGB	Description	
0	Capture on the falling edge of FTIB	(In
1	Capture on the rising edge of FTIB	

Bit 5—Input Edge Select C (IEDGC): Selects the rising or falling edge of the input capture signal (FTIC).

Bit 5

IEDGC	Description	
0	Capture on the falling edge of FTIC	(In
1	Capture on the rising edge of FTIC	

Bit 4—Input Edge Select D (IEDGD): Selects the rising or falling edge of the input capture signal (FTID).

Bit 4

IEDGD	Description	
0	Capture on the falling edge of FTID	(In
1	Capture on the rising edge of FTID	

Bit 3—Buffer Enable A (BUFEA): Selects whether ICRC is to be used as a buffer register for input capture A (ICRA).

Bit 3

BUFEA	Description	
0	ICRC is not used as a buffer register for input capture A	(In
1	ICRC is used as a buffer register for input capture A	

Bits 1 and 0—Clock Select (CKS1, CKS0): Select external clock input or one of three clock sources for the FRC. External clock pulses are counted on the rising edge of signal on the external clock input pin (FTCI).

Bit 1	Bit 0	
CKS1	CKS0	Description
0	0	$\phi/2$ internal clock source
	1	$\phi/8$ internal clock source
1	0	$\phi/32$ internal clock source
	1	External clock source (rising edge)

11.2.9 Timer Output Compare Control Register (TOCR)

Bit	7	6	5	4	3	2	1
	ICRDMS	OCRAMS	ICRS	OCRS	OEA	OEB	OLVLA
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

TOCR is an 8-bit readable/writable register that enables output from the output compare registers. It selects the output levels, switches access between output compare registers A and B, controls the ICRD and OCRA operating mode, and switches access to input capture registers A, B, and C.

TOCR is initialized to H'00 by a reset and in hardware standby mode.

Bit 7—Input Capture D Mode Select (ICRDMS): Specifies whether ICRD is used in the input capture D operating mode or in the operating mode using OCRDM.

Bit 6**OCRAMS Description**

0	The normal operating mode is specified for OCRA	(In
1	The operating mode using OCRAR and OCRAF is specified for OCRA	

Bit 5—Input Capture Register Select (ICRS): The same addresses are shared by ICRA, OCRAR, by ICRB and OCRAF, and by ICRC and OCRDM. The ICRS bit determines which registers are selected when the shared addresses are read or written to. The operation of ICRB, and ICRC is not affected.

Bit 5**ICRS Description**

0	The ICRA, ICRB, and ICRC registers are selected	(In
1	The OCRAR, OCRAF, and OCRDM registers are selected	

Bit 4—Output Compare Register Select (OCRS): OCRA and OCRB share the same address. When this address is accessed, the OCRS bit selects which register is accessed. This bit does not affect the operation of OCRA or OCRB.

Bit 4**OCRS Description**

0	The OCRA register is selected	(In
1	The OCRB register is selected	

Bit 2—Output Enable B (OEB): Enables or disables output of the output compare B (FTOB).

Bit 2

OEB	Description
0	Output compare B output is disabled
1	Output compare B output is enabled

Bit 1—Output Level A (OLVLA): Selects the logic level to be output at the FTOA pin in response to compare-match A (signal indicating a match between the FRC and OCRA). When the OCRAMS bit is 1, this bit is ignored.

Bit 1

OLVLA	Description
0	0 output at compare-match A
1	1 output at compare-match A

Bit 0—Output Level B (OLVLB): Selects the logic level to be output at the FTOB pin in response to compare-match B (signal indicating a match between the FRC and OCRB).

Bit 0

OLVLB	Description
0	0 output at compare-match B
1	1 output at compare-match B

MSTPCR, comprising two 8-bit readable/writable registers, performs module stop mod

When the MSTP13 bit is set to 1, FRT operation is stopped at the end of the bus cycle, module stop mode is entered. For details, see section 25.5, Module Stop Mode.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not in software standby mode.

MSTPCRH Bit 5—Module Stop (MSTP13): Specifies the FRT module stop mode.

Bit 5

MSTPCRH	Description
0	FRT module stop mode is cleared
1	FRT module stop mode is set (In

Any of three internal clocks ($\phi/2$, $\phi/8$, or $\phi/32$) created by division of the system clock selected by making the appropriate setting in bits CKS1 and CKS0 in TCR. Figure 11.3 shows increment timing.

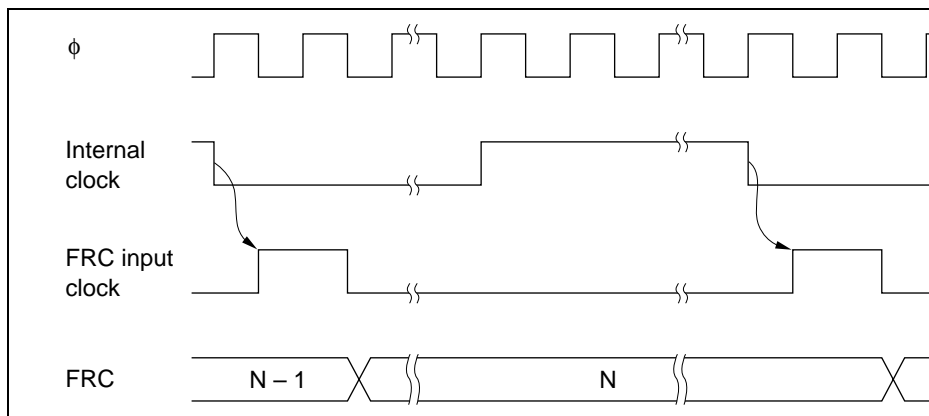


Figure 11.3 Increment Timing with Internal Clock Source

External Clock

If external clock input is selected by bits CKS1 and CKS0 in TCR, FRC increments on the rising edge of the external clock signal.

The pulse width of the external clock signal must be at least 1.5 system clock (ϕ) period. The counter will not increment correctly if the pulse width is shorter than 1.5 system clock periods.

Figure 11.4 shows the increment timing.

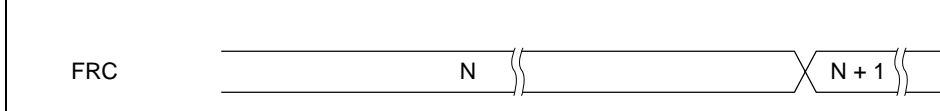


Figure 11.4 Increment Timing with External Clock Source

11.3.2 Output Compare Output Timing

When a compare-match occurs, the logic level selected by the output level bit (OLVLA or OLVLB) in TOCR is output at the output compare pin (FTOA or FTOB). Figure 11.5 shows the timing of this operation for compare-match A.

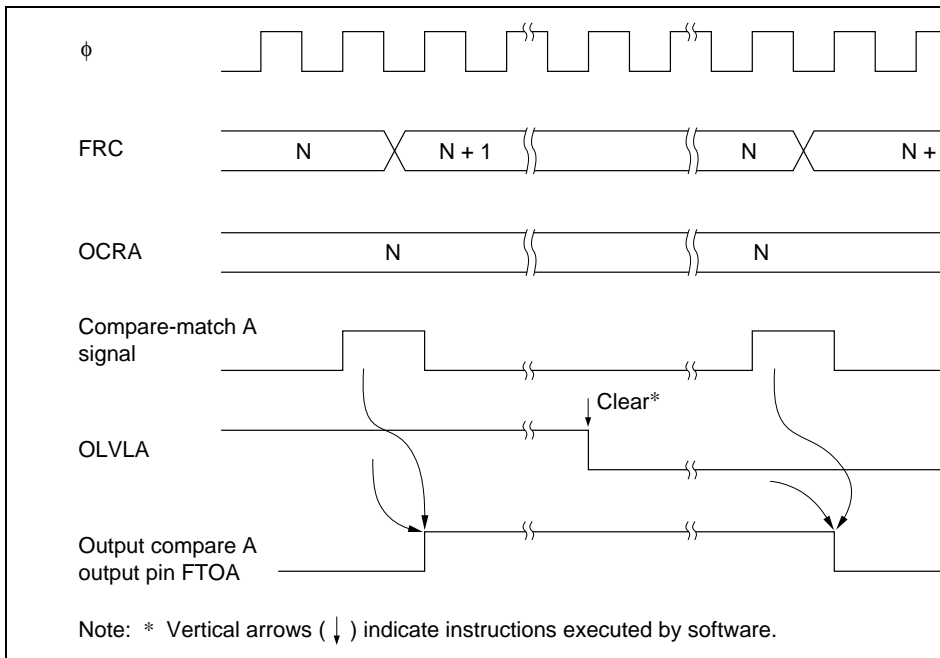


Figure 11.5 Timing of Output Compare A Output

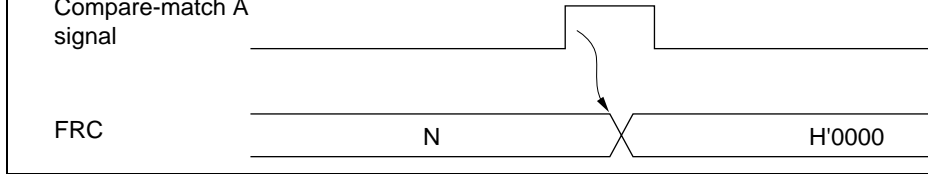


Figure 11.6 Clearing of FRC by Compare-Match A

11.3.4 Input Capture Input Timing

Input Capture Input Timing

An internal input capture signal is generated from the rising or falling edge of the signal at the input capture pin, as selected by the corresponding IEDG_x (x = A to D) bit in TCR. Figure 11.7 shows the usual input capture timing when the rising edge is selected (IEDG_x = 1).

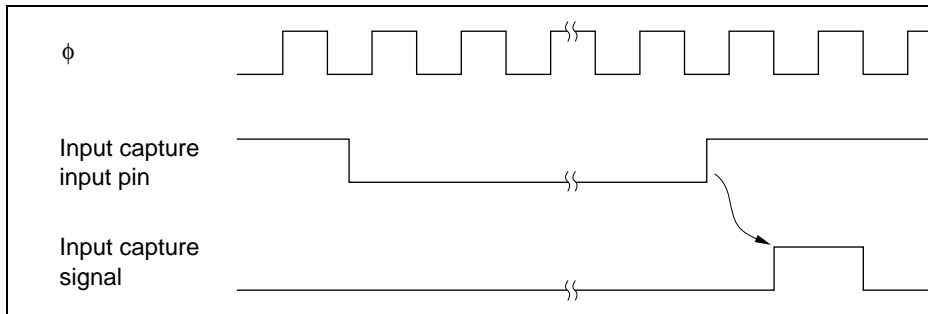


Figure 11.7 Input Capture Signal Timing (Usual Case)

If the upper byte of ICRA/B/C/D is being read when the corresponding input capture signal arrives, the internal input capture signal is delayed by one system clock (ϕ) period. Figure 11.8 shows the timing for this case.



Figure 11.8 Input Capture Signal Timing (Input Capture Input when ICRA/B/C)

Buffered Input Capture Input Timing

ICRC and ICRD can operate as buffers for ICRA and ICRB.

Figure 11.9 shows how input capture operates when ICRA and ICRC are used in buffered mode. IEDGA and IEDGC are set to different values (IEDGA = 0 and IEDGC = 1, or IEDGA = 1 and IEDGC = 0), so that input capture is performed on both the rising and falling edges of I

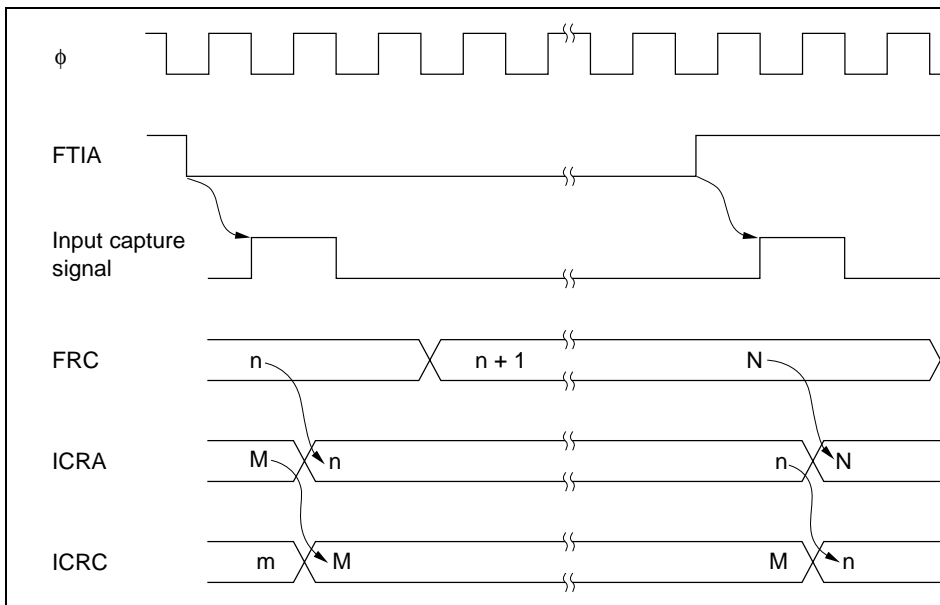
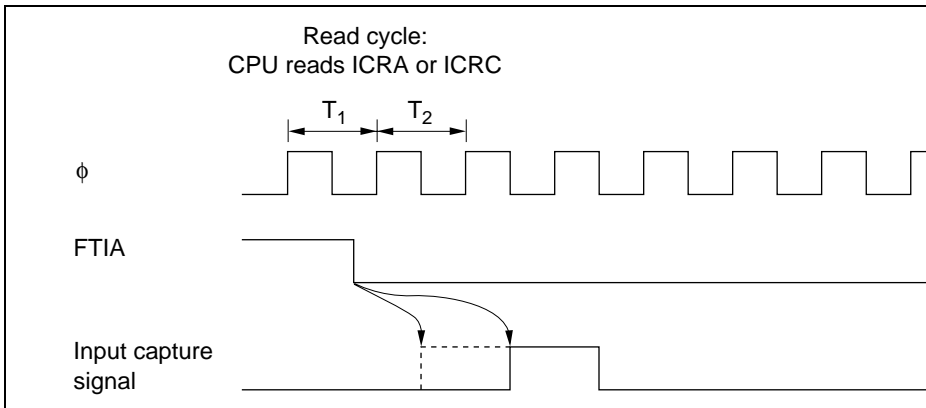


Figure 11.9 Buffered Input Capture Timing (Usual Case)

Input capture is delayed by one system clock (ϕ) period. Figure 11.10 shows the timing when BUFEA = 1.



**Figure 11.10 Buffered Input Capture Timing
(Input Capture Input when ICRA or ICRC Is Read)**

11.3.5 Timing of Input Capture Flag (ICF) Setting

The input capture flag ICF_x (x = A, B, C, D) is set to 1 by the internal input capture signal. The ICF_x value is simultaneously transferred to the corresponding input capture register (ICR_x). Figure 11.11 shows the timing of this operation.

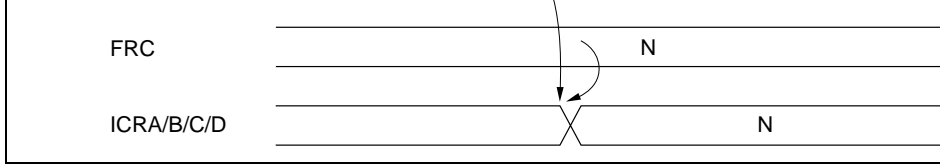


Figure 11.11 Setting of Input Capture Flag (ICFA/B/C/D)

11.3.6 Setting of Output Compare Flags A and B (OCFA, OCFB)

The output compare flags are set to 1 by an internal compare-match signal generated when the FRC value matches the OCRA or OCRB value. This compare-match signal is generated at the state in which the two values match, just before FRC increments to a new value.

Accordingly, when the FRC and OCR values match, the compare-match signal is not generated until the next period of the clock source. Figure 11.12 shows the timing of the setting of OCFA and OCFB.

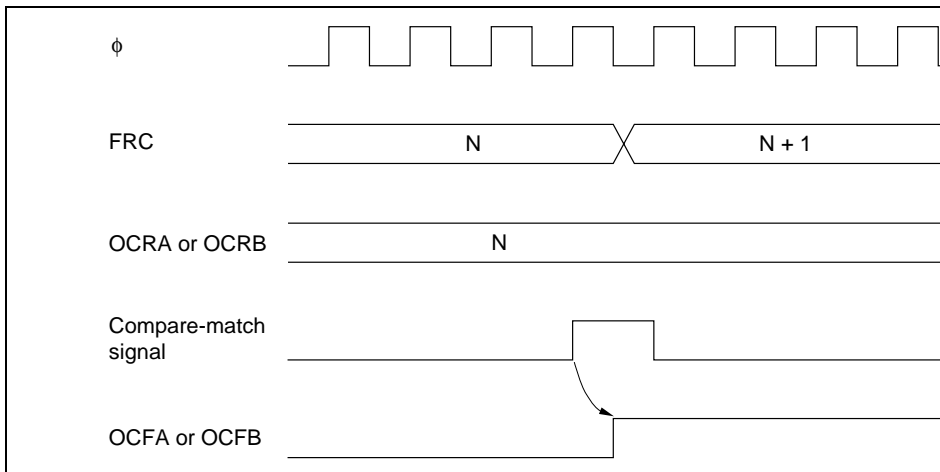


Figure 11.12 Setting of Output Compare Flag (OCFA, OCFB)

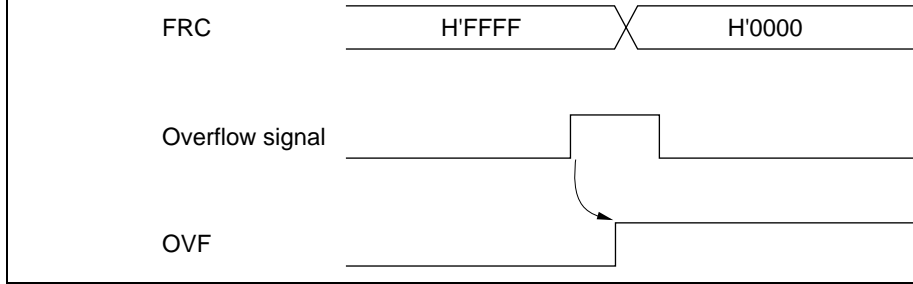


Figure 11.13 Setting of Overflow Flag (OVF)

11.3.8 Automatic Addition of OCRA and OCRAR/OCRAF

When the OCRAMS bit in TOCR is set to 1, the contents of OCRAR and OCRAF are automatically added to OCRA alternately, and when an OCRA compare-match occurs OCRA is performed. The OCRA write timing is shown in figure 11.14.

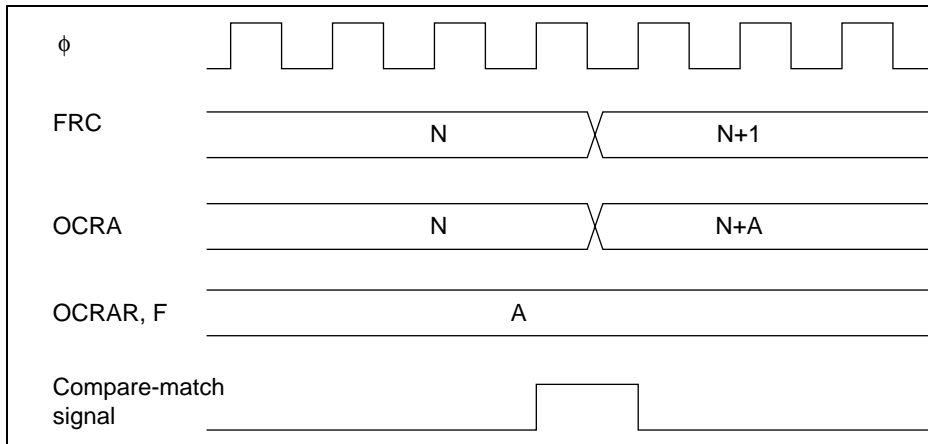


Figure 11.14 OCRA Automatic Addition Timing

an FRC compare-match. The mask signal clearing timing is shown in figure 11.16.

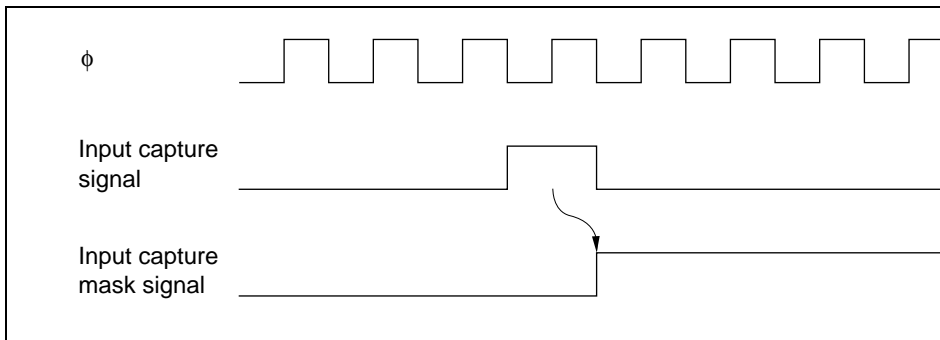


Figure 11.15 Input Capture Mask Signal Setting Timing

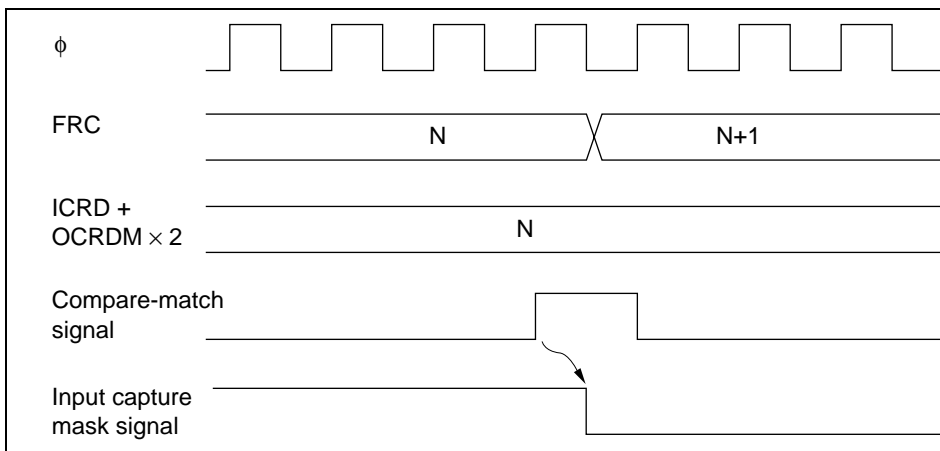


Figure 11.16 Input Capture Mask Signal Clearing Timing

Interrupt	Description	DTC Activation
ICIA	Requested by ICFA	Possible
ICIB	Requested by ICFB	Possible
ICIC	Requested by ICFC	Not possible
ICID	Requested by ICFD	Not possible
OCIA	Requested by OCFA	Possible
OCIB	Requested by OCFB	Possible
FOVI	Requested by OVF	Not possible

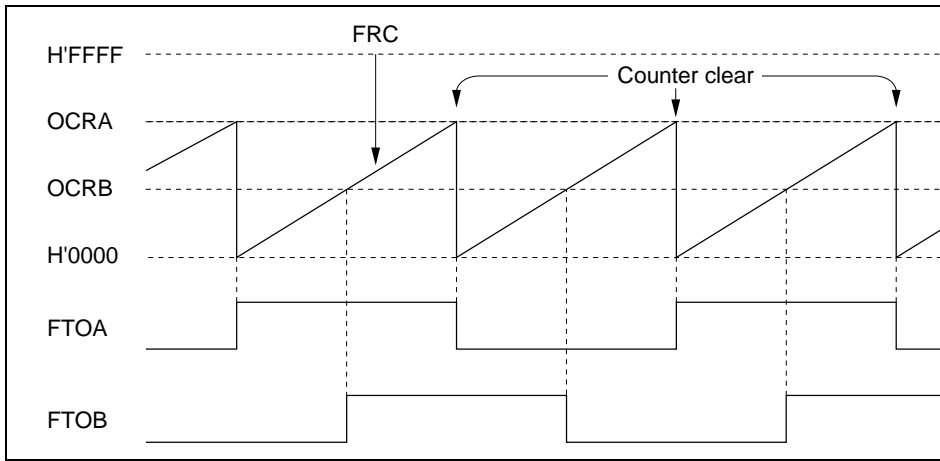


Figure 11.17 Pulse Output (Example)

signal takes priority and the write is not performed.

Figure 11.18 shows this type of contention.

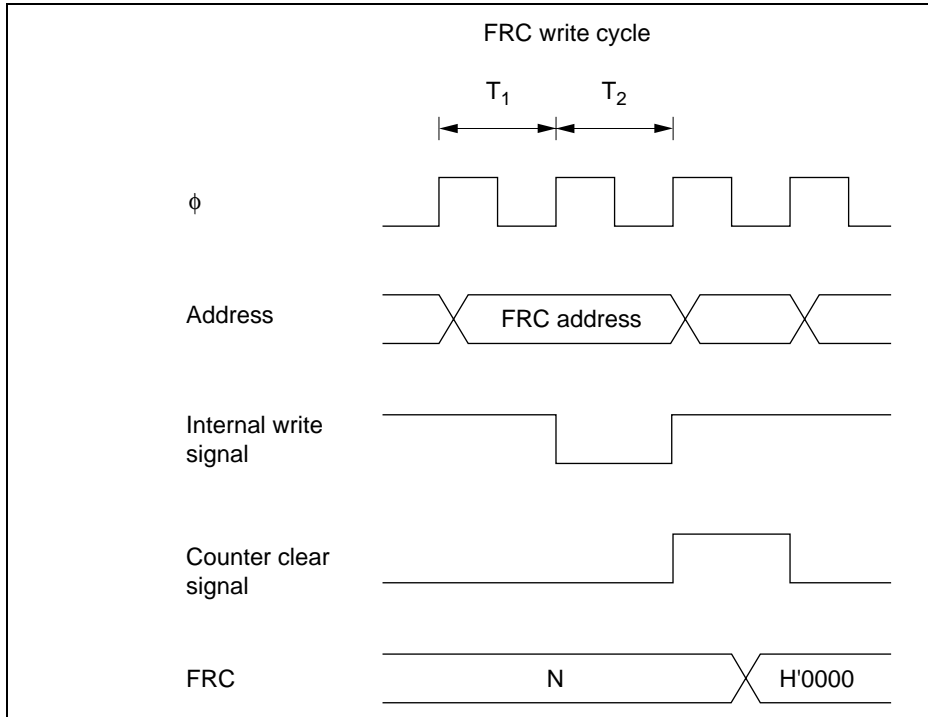


Figure 11.18 FRC Write-Clear Contention

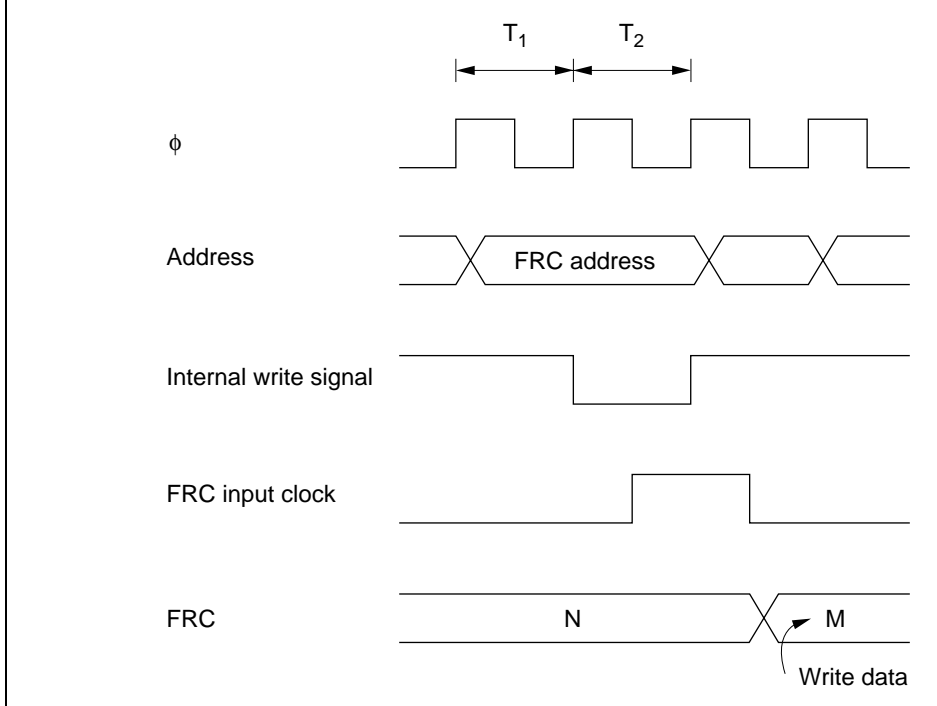
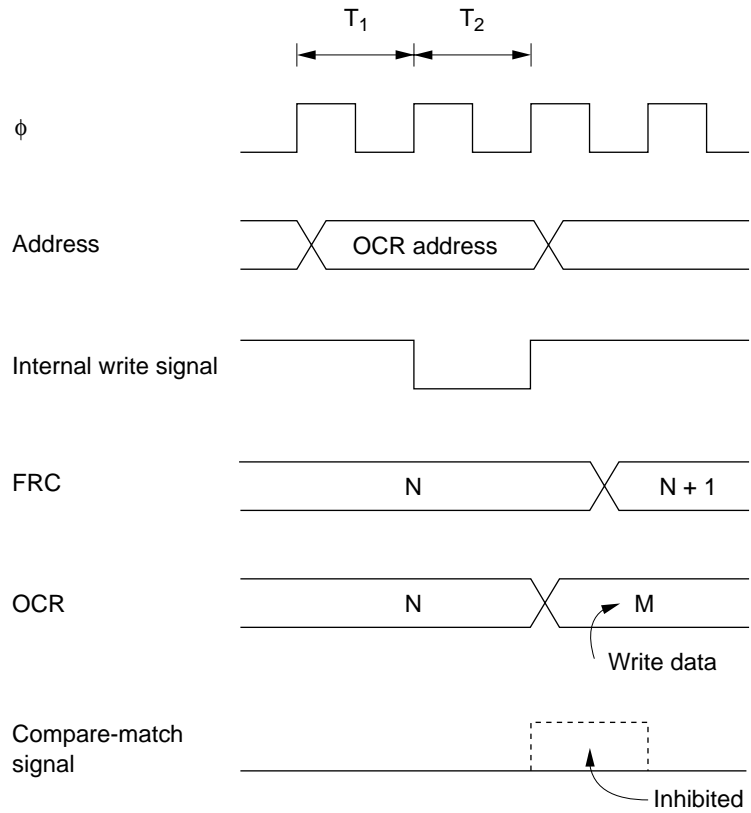


Figure 11.19 FRC Write-Increment Contention

Contention between OCR Write and Compare-Match

If a compare-match occurs during the state after an OCRA or OCRB write cycle, the write cycle has priority and the compare-match signal is inhibited.

Figure 11.20 shows this type of contention.



**Figure 11.20 Contention between OCR Write and Compare-Match
(When Automatic Addition Function Is Not Used)**

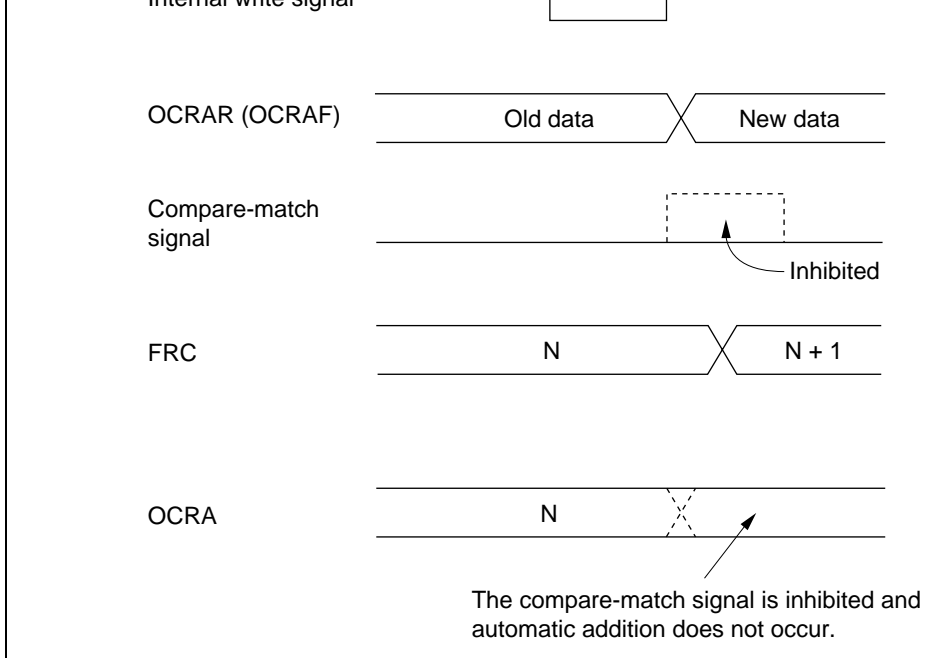
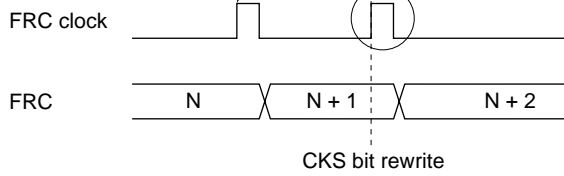


Figure 11.21 Contention between OCRAR/OCRAF Write and Compare-M (When Automatic Addition Function Is Not Used)

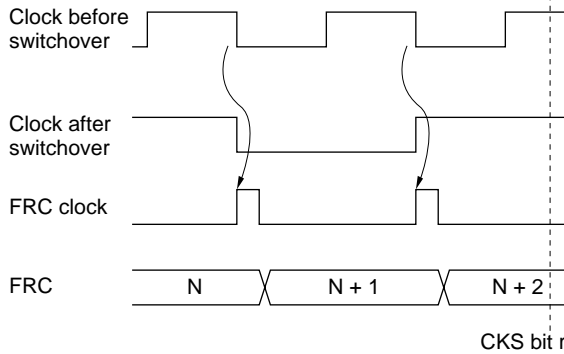
Switching between an internal and external clock can also cause FRC to increment.

Table 11.5 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	<p data-bbox="663 261 780 304">Clock before switchover</p> <p data-bbox="663 336 780 379">Clock after switchover</p> <p data-bbox="663 427 763 448">FRC clock</p> <p data-bbox="663 496 707 517">FRC</p> <p data-bbox="871 555 1012 576">CKS bit rewrite</p>
2	Switching from low to high	<p data-bbox="663 612 780 655">Clock before switchover</p> <p data-bbox="663 687 780 730">Clock after switchover</p> <p data-bbox="663 778 763 799">FRC clock</p> <p data-bbox="663 847 707 868">FRC</p> <p data-bbox="1045 911 1185 932">CKS bit rewrite</p>



4 Switching from high to high



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

be used as a multifunction timer in a variety of applications, such as generation of a pulse wave output with an arbitrary duty cycle.

The H8S/2148 Group also has two similar 8-bit timer channels (TMRX and TMRY), the H8S/2144 Group and H8S/2147N has one (TMRY). These channels can be used in a configuration using the timer connection function. TMRX and TMRY have greater interrupt and interrupt function related restrictions than TMR0 and TMR1.

12.1.1 Features

- Selection of clock sources
 - TMR0, TMR1: The counter input clock can be selected from six internal clock sources or an external clock (enabling use as an external event counter).
 - TMRX, TMRY: The counter input clock can be selected from three internal clock sources or an external clock (enabling use as an external event counter).
- Selection of three ways to clear the counters
 - The counters can be cleared on compare-match A or B, or by an external reset signal.
- Timer output controlled by two compare-match signals
 - The timer output signal in each channel is controlled by two independent compare-match signals, enabling the timer to be used for various applications, such as the generation of a pulse output or PWM output with an arbitrary duty cycle.
(Note: TMRY does not have a timer output pin.)
- Cascading of the two channels (TMR0, TMR1)
 - Operation as a 16-bit timer can be performed using channel 0 as the upper half and channel 1 as the lower half (16-bit count mode).
 - Channel 1 can be used to count channel 0 compare-match occurrences (compare-match count mode).
- Multiple interrupt sources for each channel
 - TMR0, TMR1, TMRY: Two compare-match interrupts and one overflow interrupt can be requested independently.
 - TMRX: One input capture source is available.

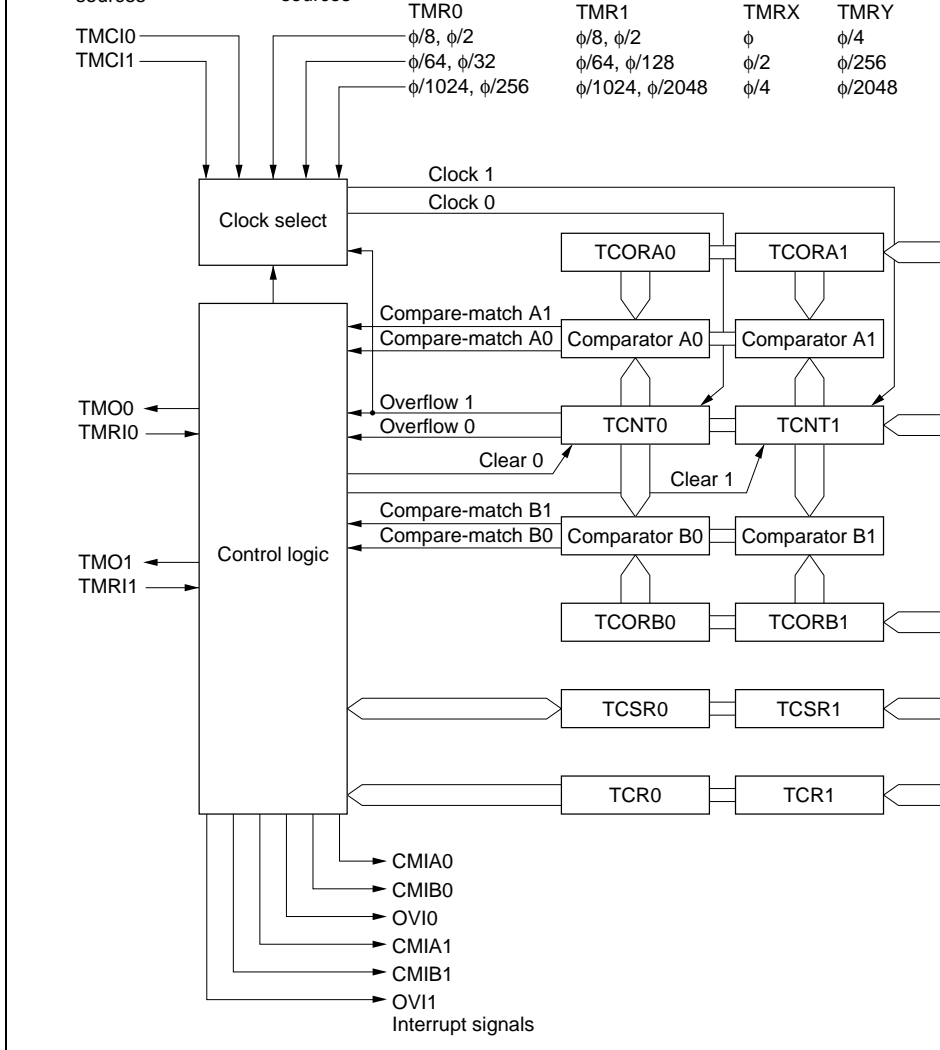


Figure 12.1 Block Diagram of 8-Bit Timer Module

	Timer reset input	TMRI0	Input	External reset input for th
1	Timer output	TMO1	Output	Output controlled by com
	Timer clock input	TMCI1	Input	External clock input for th
	Timer reset input	TMRI1	Input	External reset input for th
X	Timer output	TMOX	Output	Output controlled by com
	Timer clock/ reset input	HFBACKI/TMIX (TMCIX/TMRIY)	Input	External clock/reset inpu counter
Y	Timer clock/reset input	VSYNCI/TMIY (TMCIX/TMRIY)	Input	External clock/reset inpu counter

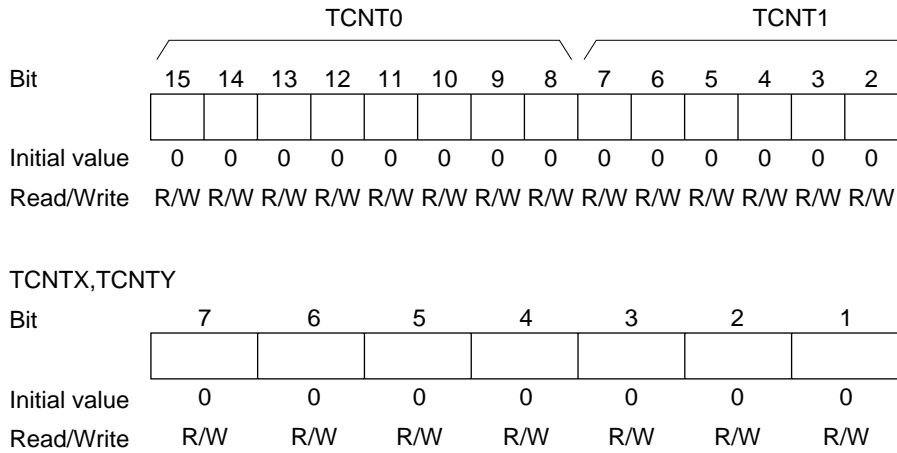
Note: * The abbreviations TMO, TMCI, and TMRI are used in the text, omitting the number.

Channel X and Y I/O pins have the same internal configuration as channels 0-3 and therefore the same abbreviations are used.

	Time constant register A0	TCORA0	R/W	H'FF
	Time constant register B0	TCORB0	R/W	H'FF
	Time counter 0	TCNT0	R/W	H'00
1	Timer control register 1	TCR1	R/W	H'00
	Timer control/status register 1	TCSR1	R/(W) ^{*2}	H'10
	Time constant register A1	TCORA1	R/W	H'FF
	Time constant register B1	TCORB1	R/W	H'FF
	Timer counter 1	TCNT1	R/W	H'00
Common	Serial/timer control register	STCR	R/W	H'00
	Module stop control register	MSTPCRH	R/W	H'3F
		MSTPCRL	R/W	H'FF
	Timer connection register S	TCONRS	R/W	H'00
X	Timer control register X	TCRX	R/W	H'00
	Timer control/status register X	TCSRX	R/(W) ^{*2}	H'00
	Time constant register AX	TCORAX	R/W	H'FF
	Time constant register BX	TCORBX	R/W	H'FF
	Timer counter X	TCNTX	R/W	H'00
	Time constant register C	TCORC	R/W	H'FF
	Input capture register R	TICRR	R	H'00
	Input capture register F	TICRF	R	H'00
Y	Timer control register Y	TCRY	R/W	H'00
	Timer control/status register Y	TCSRY	R/(W) ^{*2}	H'00
	Time constant register AY	TCORAY	R/W	H'FF
	Time constant register BY	TCORBY	R/W	H'FF
	Timer counter Y	TCNTY	R/W	H'00
	Timer input select register	TISR	R/W	H'FE

- Notes:
1. Lower 16 bits of the address.
 2. Only 0 can be written in bits 7 to 5, to clear these flags.
 3. The abbreviations TCR, TCSR, TCORA, TCORB, and TCNT are used in the table, omitting the channel designation (0, 1, X, or Y).

12.2.1 Timer Counter (TCNT)



Each TCNT is an 8-bit readable/writable up-counter.

TCNT0 and TCNT1 comprise a single 16-bit register, so they can be accessed together in a single access.

TCNT increments on pulses generated from an internal or external clock source. This clock source is selected by clock select bits CKS2 to CKS0 in TCR.

TCNT can be cleared by an external reset input signal or compare-match signal. Counter clear bits CCLR1 and CCLR0 in TCR select the method of clearing.

When TCNT overflows from H'FF to H'00, the overflow flag (OVF) in TCSR is set to 1.

The timer counters are initialized to H'00 by a reset and in hardware standby mode.

TCORAX, TCORAY

Bit	7	6	5	4	3	2	1
Initial value	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

TCORA is an 8-bit readable/writable register.

TCORA0 and TCORA1 comprise a single 16-bit register, so they can be accessed together with a word access.

TCORA is continually compared with the value in TCNT. When a match is detected, the corresponding compare-match flag A (CMFA) in TCSR is set. Note, however, that compare-match flags are disabled during the T2 state of a TCORA write cycle.

The timer output can be freely controlled by these compare-match signals and the setting of the output select bits OS1 and OS0 in TCSR.

TCORA is initialized to H'FF by a reset and in hardware standby mode.

TCORB, TCORBY

Bit	7	6	5	4	3	2	1
Initial value	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

TCORB is an 8-bit readable/writable register. TCORB0 and TCORB1 comprise a single register, so they can be accessed together by word access.

TCORB is continually compared with the value in TCNT. When a match is detected, the corresponding compare-match flag B (CMFB) in TCSR is set. Note, however, that this flag is disabled during the T2 state of a TCORB write cycle.

The timer output can be freely controlled by these compare-match signals and the setpoint output select bits OS3 and OS2 in TCSR.

TCORB is initialized to H'FF by a reset and in hardware standby mode.

TCR is an 8-bit readable/writable register that selects the clock source and the time at which TCNT is cleared, and enables interrupts.

TCR is initialized to H'00 by a reset and in hardware standby mode.

For details of the timing, see section 12.3, Operation.

Bit 7—Compare-Match Interrupt Enable B (CMIEB): Selects whether the CMFB interrupt request (CMIB) is enabled or disabled when the CMFB flag in TCSR is set to 1.

Note that a CMIB interrupt is not requested by TMRX, regardless of the CMIEB value.

Bit 7

CMIEB	Description
0	CMFB interrupt request (CMIB) is disabled (In
1	CMFB interrupt request (CMIB) is enabled

Bit 6—Compare-Match Interrupt Enable A (CMIEA): Selects whether the CMFA interrupt request (CMIA) is enabled or disabled when the CMFA flag in TCSR is set to 1.

Note that a CMIA interrupt is not requested by TMRX, regardless of the CMIEA value.

Bit 6

CMIEA	Description
0	CMFA interrupt request (CMIA) is disabled (In
1	CMFA interrupt request (CMIA) is enabled

1 OVF interrupt request (OVI) is enabled

Bits 4 and 3—Counter Clear 1 and 0 (CCLR1, CCLR0): These bits select the method by which the timer counter is cleared: by compare-match A or B, or by an external reset input.

Bit 4	Bit 3	Description
CCLR1	CCLR0	
0	0	Clearing is disabled
	1	Cleared on compare-match A
1	0	Cleared on compare-match B
	1	Cleared on rising edge of external reset input

Some functions differ between channel 0 and channel 1, because of the cascading function.

Channel	TCR			STCR		Description
	Bit 2	Bit 1	Bit 0	Bit 1	Bit 0	
	CKS2	CKS1	CKS0	ICKS1	ICKS0	
0	0	0	0	—	—	Clock input disabled (Initial value)
	0	0	1	—	0	$\phi/8$ internal clock source, counted on the falling edge
	0	0	1	—	1	$\phi/2$ internal clock source, counted on the falling edge
	0	1	0	—	0	$\phi/64$ internal clock source, counted on the falling edge
	0	1	0	—	1	$\phi/32$ internal clock source, counted on the falling edge
	0	1	1	—	0	$\phi/1024$ internal clock source, counted on the falling edge
	0	1	1	—	1	$\phi/256$ internal clock source, counted on the falling edge
	1	0	0	—	—	Counted on TCNT1 overflow signal*
1	0	0	0	—	—	Clock input disabled (Initial value)
	0	0	1	0	—	$\phi/8$ internal clock source, counted on the falling edge
	0	0	1	1	—	$\phi/2$ internal clock source, counted on the falling edge
	0	1	0	0	—	$\phi/64$ internal clock source, counted on the falling edge
	0	1	0	1	—	$\phi/128$ internal clock source, counted on the falling edge
	0	1	1	0	—	$\phi/1024$ internal clock source, counted on the falling edge
	0	1	1	1	—	$\phi/2048$ internal clock source, counted on the falling edge
	1	0	0	—	—	Counted on TCNT0 compare-match A*

	1	0	0	—	—	Clock input disabled	(Ini
Y	0	0	0	—	—	Clock input disabled	(Ini
	0	0	1	—	—	$\phi/4$ internal clock source, counted on the	
	0	1	0	—	—	$\phi/256$ internal clock source, counted on the	
	0	1	1	—	—	$\phi/2048$ internal clock source, counted on the	
	1	0	0	—	—	Clock input disabled	
Common	1	0	1	—	—	External clock source, counted at rising e	
	1	1	0	—	—	External clock source, counted at falling e	
	1	1	1	—	—	External clock source, counted at both ris	
						falling edges	

Note: * If the count input of channel 0 is the TCNT1 overflow signal and that of channel 1 is the TCNT0 compare-match signal, no incrementing clock will be generated. Do not set the setting.

TCSR1

Bit	7	6	5	4	3	2	1
	CMFB	CMFA	OVF	—	OS3	OS2	OS1
Initial value	0	0	0	1	0	0	0
Read/Write	R/(W)*	R/(W)*	R/(W)*	—	R/W	R/W	R/W

TCSRX

Bit	7	6	5	4	3	2	1
	CMFB	CMFA	OVF	ICF	OS3	OS2	OS1
Initial value	0	0	0	0	0	0	0
Read/Write	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/W	R/W	R/W

TCSRY

Bit	7	6	5	4	3	2	1
	CMFB	CMFA	OVF	ICIE	OS3	OS2	OS1
Initial value	0	0	0	0	0	0	0
Read/Write	R/(W)*	R/(W)*	R/(W)*	R/W	R/W	R/W	R/W

Note: * Only 0 can be written in bits 7 to 5, and in bit 4 in TCSRX, to clear these flags.

TCSR is an 8-bit register that indicates compare-match and overflow statuses (and input status in TMRX only), and controls compare-match output.

TCSR0, TCSRX, and TCSRY are initialized to H'00, and TCSR1 is initialized to H'10, and in hardware standby mode.

1 [Setting condition]
When TCNT = TCORB

Bit 6—Compare-match Flag A (CMFA): Status flag indicating whether the values of TCNT and TCORA match.

Bit 6

CMFA	Description
0	[Clearing conditions] <ul style="list-style-type: none">• Read CMFA when CMFA = 1, then write 0 in CMFA• When the DTC is activated by a CMIA interrupt
1	[Setting condition] When TCNT = TCORA

Bit 5—Timer Overflow Flag (OVF): Status flag indicating that TCNT has overflowed from H'FF to H'00).

Bit 5

OVF	Description
0	[Clearing condition] Read OVF when OVF = 1, then write 0 in OVF
1	[Setting condition] When TCNT overflows from H'FF to H'00

TCSR1

Bit 4—Reserved: This bit cannot be modified and is always read as 1.

TCSRX

Bit 4—Input Capture Flag (ICF): Status flag that indicates detection of a rising edge by a falling edge in the external reset signal after the ICST bit in TCONRI has been set

Bit 4

ICF	Description
0	[Clearing condition] Read ICF when ICF = 1, then write 0 in ICF
1	[Setting condition] When a rising edge followed by a falling edge is detected in the external reset signal after the ICST bit in TCONRI has been set to 1

TCSRY

Bit 4—Input Capture Interrupt Enable (ICIE): Selects enabling or disabling of the interrupt request by ICF (ICIX) when the ICF bit in TCSRX is set to 1.

Bit 4

ICIE	Description
0	Interrupt request by ICF (ICIX) is disabled
1	Interrupt request by ICF (ICIX) is enabled

Timer output is disabled when bits OS3 to OS0 are all 0.

After a reset, the timer output is 0 until the first compare-match occurs.

Bit 3	Bit 2	
OS3	OS2	Description
0	0	No change when compare-match B occurs (
	1	0 is output when compare-match B occurs
1	0	1 is output when compare-match B occurs
	1	Output is inverted when compare-match B occurs (toggle ou

Bit 1	Bit 0	
OS1	OS0	Description
0	0	No change when compare-match A occurs (
	1	0 is output when compare-match A occurs
1	0	1 is output when compare-match A occurs
	1	Output is inverted when compare-match A occurs (toggle ou

STCR is an 8-bit readable/writable register that controls register access, the IIC operation (when the on-chip IIC option is included), and on-chip flash memory (in F-ZTAT version). STCR also selects the TCNT input clock.

For details on functions not related to the 8-bit timers, see section 3.2.4, Serial Timer Control Register (STCR), and the descriptions of the relevant modules. If a module controlled by STCR is not used, do not write 1 to the corresponding bit.

STCR is initialized to H'00 by a reset and in hardware standby mode.

Bits 7 to 4—I²C Control (IICS, IICX1, IICX0, IICE): These bits control the bus buffer operation of port A and the operation of the I²C bus interface when the IIC option is included on-chip. For details, see section 16.2.7, Serial/Timer Control Register (STCR), for details.

Bit 3—Flash Memory Control Register Enable (FLSHE): Controls CPU access to the timer control registers, the power-down mode control registers, and the supporting memory control registers. See section 3.2.4, Serial Timer Control Register (STCR), for details.

Bit 2—Reserved: Do not write 1 to this bit.

Bits 1 and 0—Internal Clock Select 1 and 0 (ICKS1, ICKS0): These bits, together with CKS2 to CKS0 in TCR, select the clock to be input to TCNT. For details, see section 16.2.7, Timer Control Register (TCR).

Bit 1—Host Interface Enable (HIE): Controls CPU access to 8-bit timer (channel X and Y) registers and control registers, and timer connection control registers.

Bit 1

HIE	Description
0	CPU access to 8-bit timer (channel X and Y) data registers and control registers and timer connection control registers, is enabled (In
1	CPU access to 8-bit timer (channel X and Y) data registers and control registers and timer connection control registers, is disabled

12.2.8 Timer Connection Register S (TCONRS)

Bit	7	6	5	4	3	2	1
	TMRX/Y	ISGENE	HOMOD1	HOMOD0	VOMOD1	VOMOD0	CLMOD1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

TCONRS is an 8-bit readable/writable register that controls access to the TMRX and Y registers and timer connection operation.

TCONRS is initialized to H'00 by a reset and in hardware standby mode.

0	TMRX	TMRX	TMRX	TMRX	TMRX	TMRX	TMRX
(Initial value)	TCRX	TCSRX	TICRR	TICRF	TCNTX	TCORC	TCORAX
1	TMRY	TMRY	TMRY	TMRY	TMRY	TMRY	
	TCRY	TCSRY	TCORAY	TCORBY	TCNTY	TISR	

12.2.9 Input Capture Register (TICR) [TMRX Additional Function]

Bit	7	6	5	4	3	2	1
Initial value	0	0	0	0	0	0	0
Read/Write	—	—	—	—	—	—	—

TICR is an 8-bit internal register to which the contents of TCNT are transferred on the of external reset input. The CPU cannot read or write to TICR directly.

The TICR function is used in timer connection. For details, see section 13, Timer Conn

TCCORC is an 8-bit read-only register. The sum of the contents of TCCORC and TCNT is continually compared with the value in TCNT. When a match is detected, a compare-signal is generated. Note, however, that comparison is disabled during the T2 state of a write cycle and a TICC input capture cycle.

TCORC is initialized to H'FF by a reset and in hardware standby mode.

The TCORC function is used in timer connection. For details, see section 13, Timer Connection.

12.2.11 Input Capture Registers R and F (TICRR, TICRF) [TMRX Additional]

Bit	7	6	5	4	3	2	1
Initial value	0	0	0	0	0	0	0
Read/Write	R	R	R	R	R	R	R

TICRR and TICRF are 8-bit read-only registers. When the ICST bit in TCONRI is set, TICRR and TICRF capture the contents of TCNT successively on the rise and fall of the reset input. When one capture operation ends, the ICST bit is cleared to 0.

TICRR and TICRF are each initialized to H'00 by a reset and in hardware standby mode.

The TICRR and TICRF functions are used in timer connection. For details, see section 12, Input Capture Operation, and section 13, Timer Connection.

TISR is an 8-bit readable/writable register that selects the external clock/reset signal source for the counter.

TISR is initialized to H'FE by a reset and in hardware standby mode.

Bits 7 to 1—Reserved: Do not write 0 to these bits.

Bit 0—Input Select (IS): Selects the internal synchronization signal (IVG signal) or the external clock/reset input pin (VSYNCl/TMIY (TMCIY/TMRIY)) as the external clock/reset signal for the counter.

Bit 0

IS	Description
0	IVG signal is selected (H8S/2148 Group) External clock/reset input is disabled (H8S/2144 Group and H8S/2147N)
1	VSYNCl/TMIY (TMCIY/TMRIY) is selected

MSTPCR comprises two 8-bit readable/writable registers, and is used to perform module control.

When the MSTP12 bit or MSTP8 bit is set to 1, 8-bit timer operation is halted on channel 0 or channels X and Y, respectively, and a transition is made to module stop mode. For more information, see section 25.5, Module Stop Mode.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not initialized in software standby mode.

MSTPCRH Bit 4—Module Stop (MSTP12): Specifies 8-bit timer (channel 0/1) module stop mode.

**MSTPCRH
Bit 4**

MSTP12	Description
0	8-bit timer (channel 0/1) module stop mode is cleared
1	8-bit timer (channel 0/1) module stop mode is set (In

MSTPCRH Bit 0—Module Stop (MSTP8): Specifies 8-bit timer (channel X/Y) and timer connection module stop mode.

**MSTPCRH
Bit 0**

MSTP8	Description
0	8-bit timer (channel X/Y) and timer connection module stop mode is cleared
1	8-bit timer (channel X/Y) and timer connection module stop mode is set (In

An internal clock created by dividing the system clock (ϕ) can be selected by setting bit CKS0 in TCR. Figure 12.2 shows the count timing.

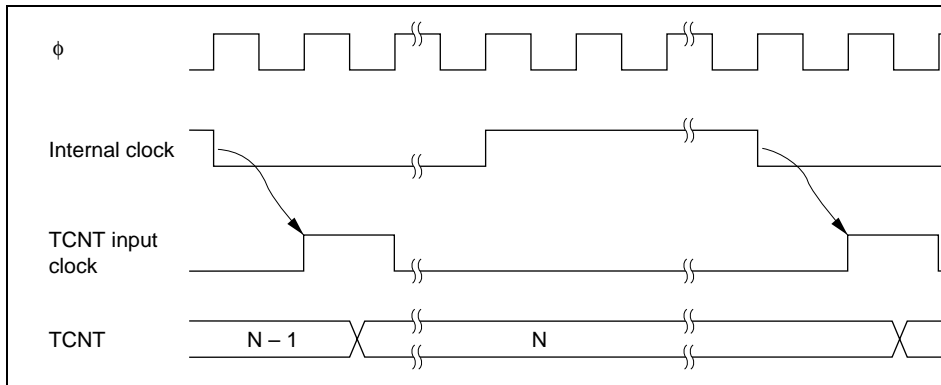


Figure 12.2 Count Timing for Internal Clock Input

External Clock

Three incrementation methods can be selected by setting bits CKS2 to CKS0 in TCR: a rising edge, the falling edge, and both rising and falling edges.

Note that the external clock pulse width must be at least 1.5 states for incrementation at a rising edge, and at least 2.5 states for incrementation at both edges. The counter will not increment correctly if the pulse width is less than these values.

Figure 12.3 shows the timing of incrementation at both edges of an external clock signal.

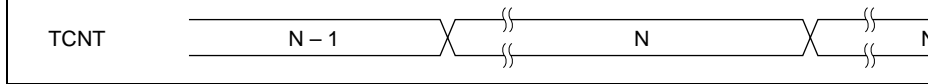


Figure 12.3 Count Timing for External Clock Input

12.3.2 Compare-Match Timing

Setting of Compare-Match Flags A and B (CMFA, CMFB)

The CMFA and CMFB flags in TCSR are set to 1 by a compare-match signal generated when the TCOR and TCNT values match. The compare-match signal is generated at the last state of the timer counter when the match is true, just before the timer counter is updated.

Therefore, when TCOR and TCNT match, the compare-match signal is not generated at the next incrementation clock input. Figure 12.4 shows this timing.

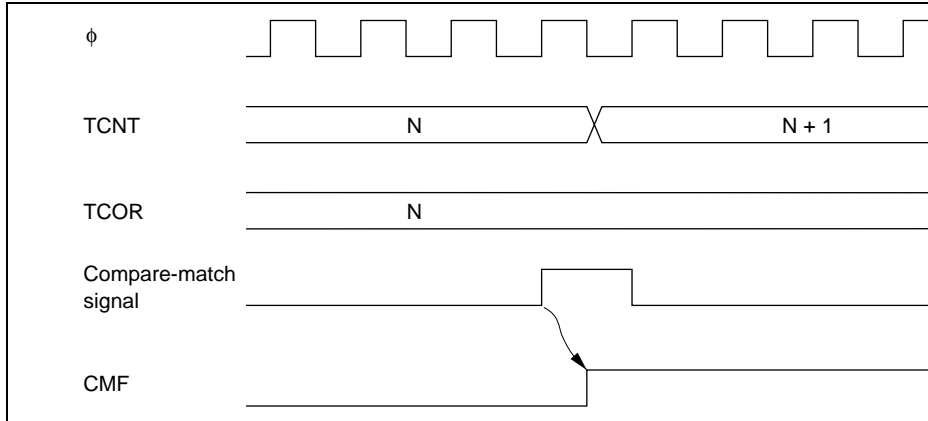


Figure 12.4 Timing of CMF Setting

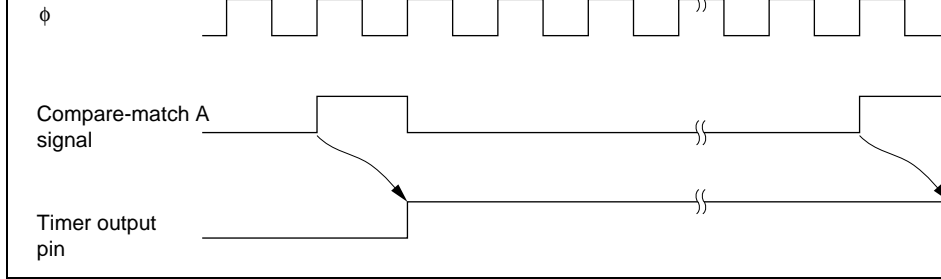


Figure 12.5 Timing of Timer Output

Timing of Compare-Match Clear

TCNT is cleared when compare-match A or B occurs, depending on the setting of the CCLR0 bits in TCR. Figure 12.6 shows the timing of this operation.

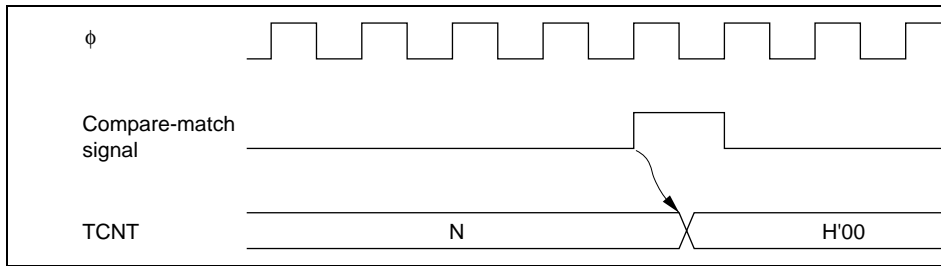


Figure 12.6 Timing of Compare-Match Clear

12.3.3 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 μ s. Figure 12.7 shows the timing of this operation.

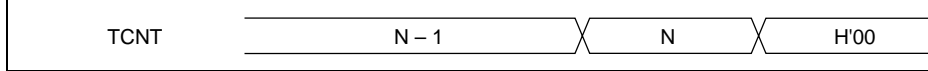


Figure 12.7 Timing of Clearing by External Reset Input

12.3.4 Timing of Overflow Flag (OVF) Setting

OVF in TCSR is set to 1 when the timer count overflows (changes from H'FF to H'00). 12.8 shows the timing of this operation.

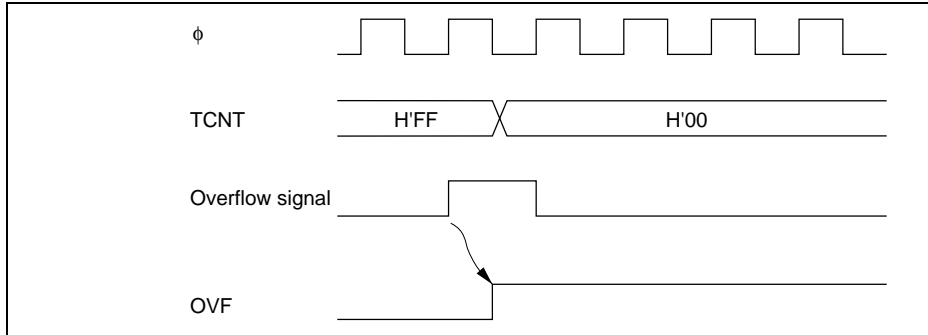


Figure 12.8 Timing of OVF Setting

12.3.5 Operation with Cascaded Connection

If bits CKS2 to CKS0 in either TCR0 or TCR1 are set to B'100, the 8-bit timers of the channels are cascaded. With this configuration, a single 16-bit timer can be used (16-bit mode) or compare-matches of 8-bit channel 0 can be counted by the timer of channel match count mode). In this case, the timer operates as described below.

- Counter clear specification
 - If the CCLR1 and CCLR0 bits in TCR0 have been set for counter clear at completion, the 16-bit counter (TCNT0 and TCNT1 together) is cleared when a 16-bit compare-match occurs. The 16-bit counter (TCNT0 and TCNT1 together) is cleared even if counter clear by the TMRI0 pin has also been set.
 - The settings of the CCLR1 and CCLR0 bits in TCR1 are ignored. The lower 8 bits of the counter are cleared independently.
- Pin output
 - Control of output from the TMO0 pin by bits OS3 to OS0 in TCSR0 is in accordance with the 16-bit compare-match conditions.
 - Control of output from the TMO1 pin by bits OS3 to OS0 in TCSR1 is in accordance with the lower 8-bit compare-match conditions.

Compare-Match Count Mode

When bits CKS2 to CKS0 in TCR1 are B'100, TCNT1 counts compare-match A's for channel 1.

Channels 0 and 1 are controlled independently. Conditions such as setting of the CMF0 and CMF1 bits, generation of interrupts, output from the TMO pin, and counter clearing are in accordance with the settings for each channel.

Usage Note

If the 16-bit count mode and compare-match count mode are set simultaneously, the input pulses for TCNT0 and TCNT1 are not generated and thus the counters will stop operating. Simultaneous setting of these two modes should therefore be avoided.

(1) Input capture input timing

Figure 12.9 shows the timing of the input capture operation.

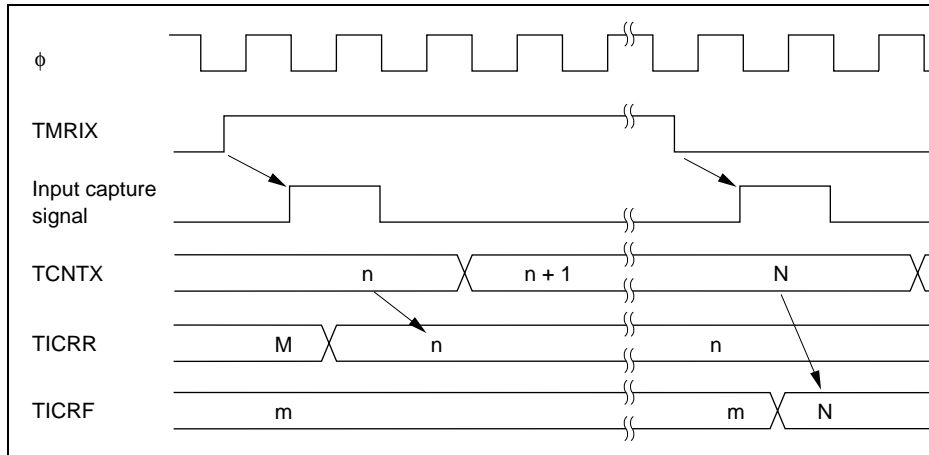


Figure 12.9 Timing of Input Capture Operation

If the input capture signal enters while TICRR and TICRF are being read, it is internal one system clock (ϕ) period. Figure 12.10 shows the timing of this operation.



Figure 12.10 Timing of Input Capture Signal
(When Input Capture Input Signal Enters while TICRR and TICRF Are Being)

(2) Input capture signal input selection

Input capture input signal (TMRX) in TMRX is switched by setting bits in the TCONR

Figure 12.11 and Table 12.3 show the input capture signal selections.

See section 13.2.1, Timer Connection Register I (TCONRI), for details.

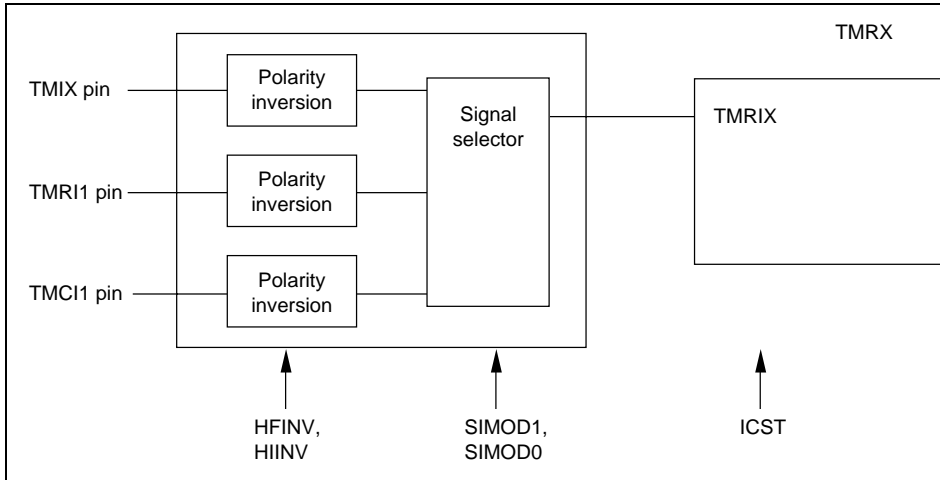


Figure 12.11 Switching of Input Capture Signal

	1	—	0	TMR11 pin input signal
		—	1	Inverted signal of TMR11
1	1	—	0	TMCI1 pin input signal
		—	1	Inverted signal of TMCI1

12.4 Interrupt Sources

The TMR0, TMR1, and TMR Y 8-bit timers can generate three types of interrupt: compare A and B (CMIA and CMIB), and overflow (OVI). TMRX can generate only an ICIX. An interrupt is requested when the corresponding interrupt enable bit is set in TCR or TCRX. Independent signals are sent to the interrupt controller for each interrupt. It is also possible to activate the DTC by means of CMIA and CMIB interrupts from TMR0, TMR1 and TMR Y.

An overview of 8-bit timer interrupt sources is given in tables 12.4 to 12.6.

Table 12.4 TMR0 and TMR1 8-Bit Timer Interrupt Sources

Interrupt source	Description	DTC Activation	Interrupt
CMIA	Requested by CMFA	Possible	High
CMIB	Requested by CMFB	Possible	↑
OVI	Requested by OVF	Not possible	Low

Table 12.5 TMRX 8-Bit Timer Interrupt Source

Interrupt source	Description	DTC Activation
ICIX	Requested by ICF	Not possible

12.5 8-Bit Timer Application Example

In the example below, the 8-bit timer is used to generate a pulse output with a selected as shown in figure 12.12. The control bits are set as follows:

- In TCR, CCLR1 is cleared to 0 and CCLR0 is set to 1 so that the timer counter is cleared at TCORA compare-match.
- In TCSR, bits OS3 to OS0 are set to B'0110, causing 1 output at a TCORA compare-match and 0 output at a TCORB compare-match.

With these settings, the 8-bit timer provides output of pulses at a rate determined by TCORB and a pulse width determined by TCORB. No software intervention is required.

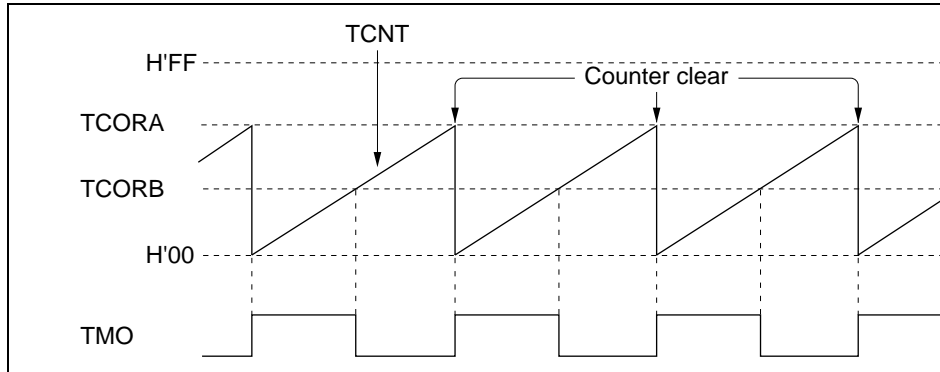


Figure 12.12 Pulse Output (Example)

takes priority, so that the counter is cleared and the write is not performed. Figure 12.13 shows this operation.

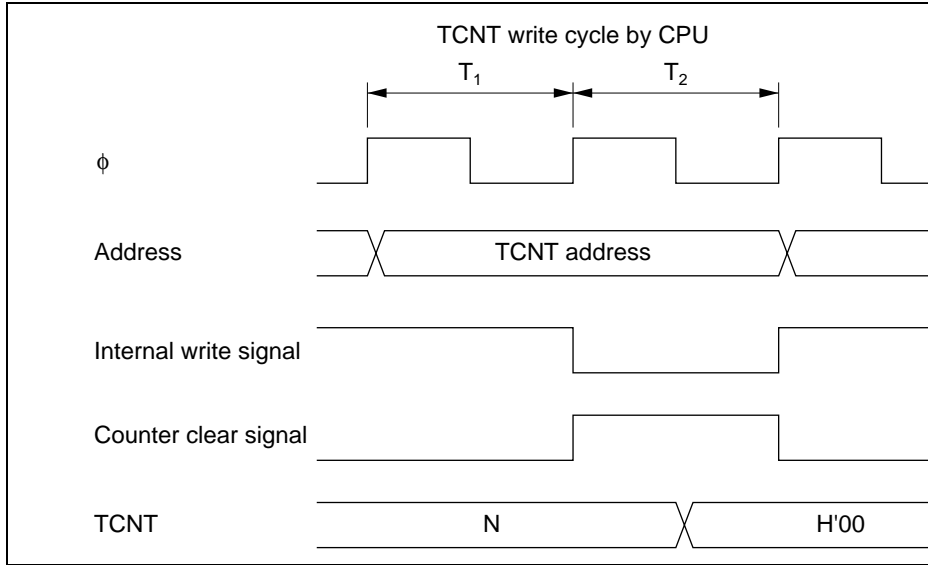


Figure 12.13 Contention between TCNT Write and Clear

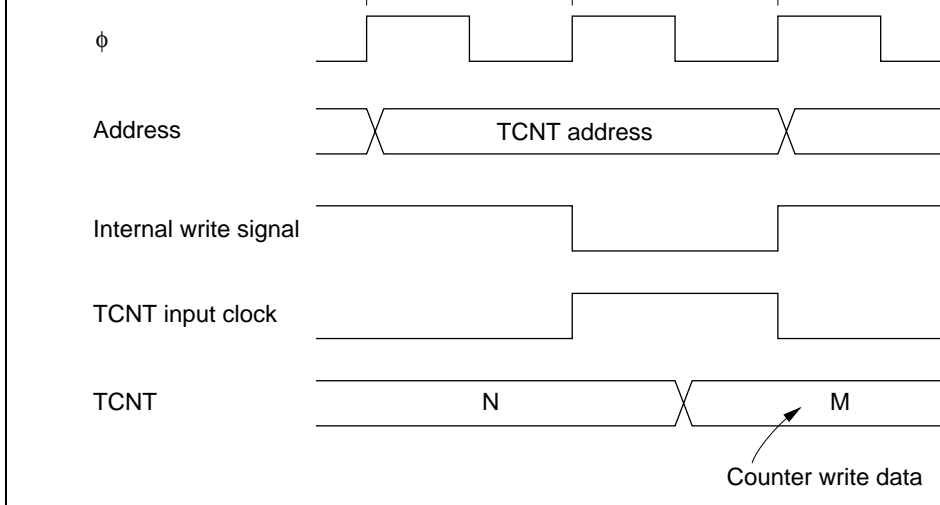


Figure 12.14 Contention between TCNT Write and Increment

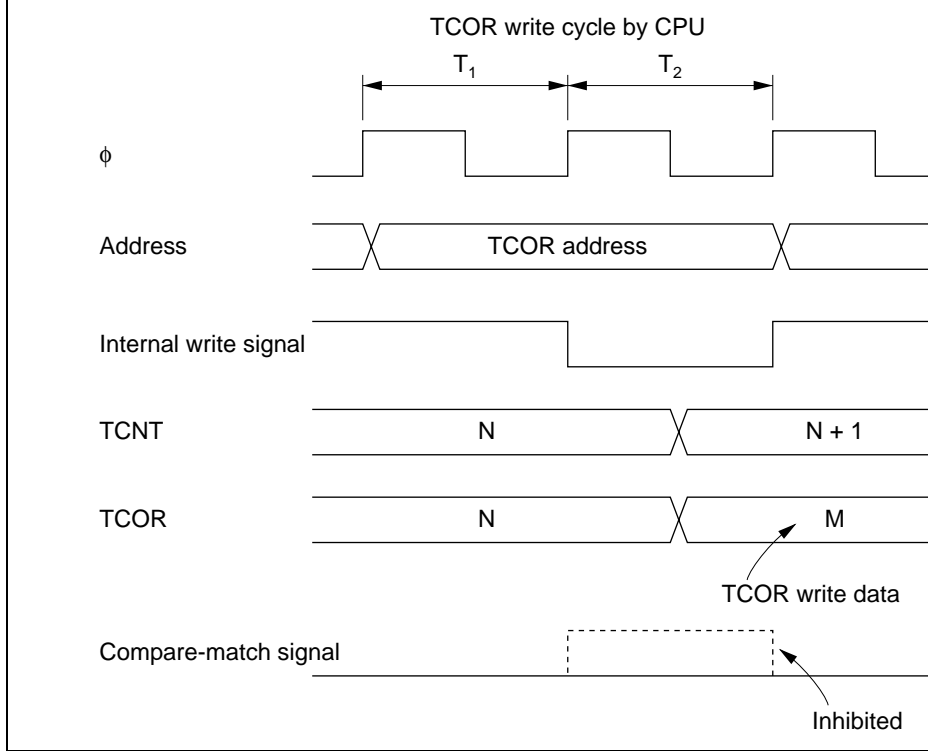


Figure 12.15 Contention between TCOR Write and Compare-Match

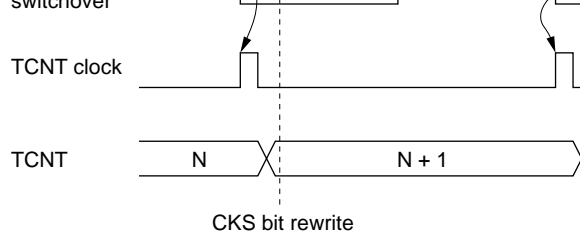
Toggle output	High
1 output	↑
0 output	
No change	Low

12.6.5 Switching of Internal Clocks and TCNT Operation

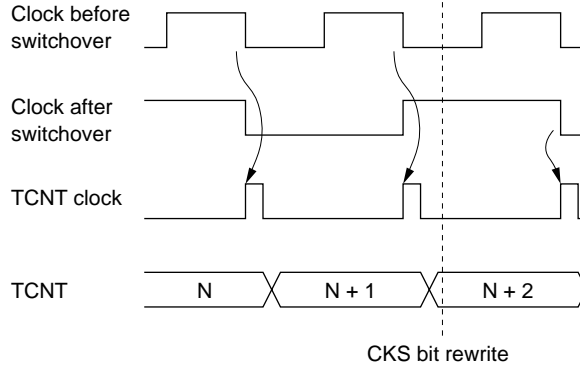
TCNT may increment erroneously when the internal clock is switched over. Table 12.8 shows the relationship between the timing at which the internal clock is switched (by writing to the CKS0 and CKS1 bits) and the TCNT operation.

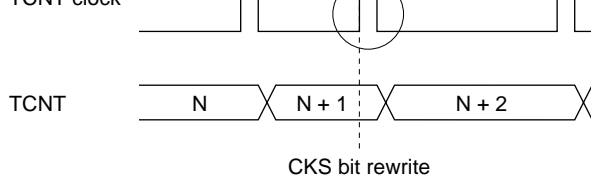
When the TCNT clock is generated from an internal clock, the falling edge of the internal clock pulse is detected. If clock switching causes a change from high to low level, as shown in Table 12.8, a TCNT clock pulse is generated on the assumption that the switchover is a falling edge. This increments TCNT.

Erroneous incrementation can also happen when switching between internal and external clocks.

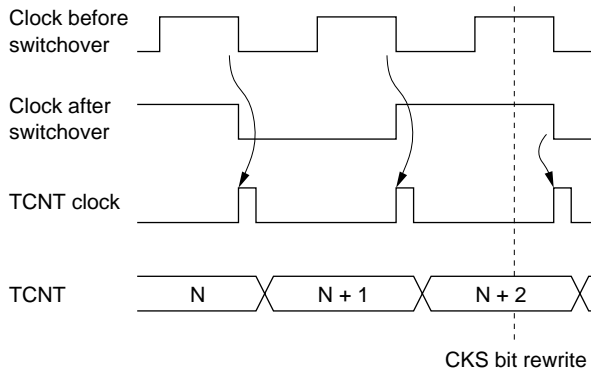


2 Switching from low to high^{*2}





4 Switching from high to high



- Notes:
1. Includes switching from low to stop, and from stop to low.
 2. Includes switching from stop to high.
 3. Includes switching from high to stop.
 4. Generated on the assumption that the switchover is a falling edge; TCNT is incremented.

input output of the single free running timer (FRT) channel and the three 6-bit timer channels (TMR1, TMRX, and TMR Y). This capability can be used to implement complex functions such as PWM decoding and clamp waveform output. All the timers are initially set for independent operation.

13.1.1 Features

The features of the timer connection facility are as follows.

- Five input pins and four output pins, all of which can be designated for phase inverse operation. Positive logic is assumed for all signals used within the timer connection facility.
- An edge-detection circuit is connected to the input pins, simplifying signal input detection.
- TMRX can be used for PWM input signal decoding and clamp waveform generation.
- An external clock signal divided by TMR1 can be used as the FRT capture input signal.
- An internal synchronization signal can be generated using the FRT and TMR Y.
- A signal generated/modified using an input signal and timer connection can be selected as an output.

13.1.2 Block Diagram

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

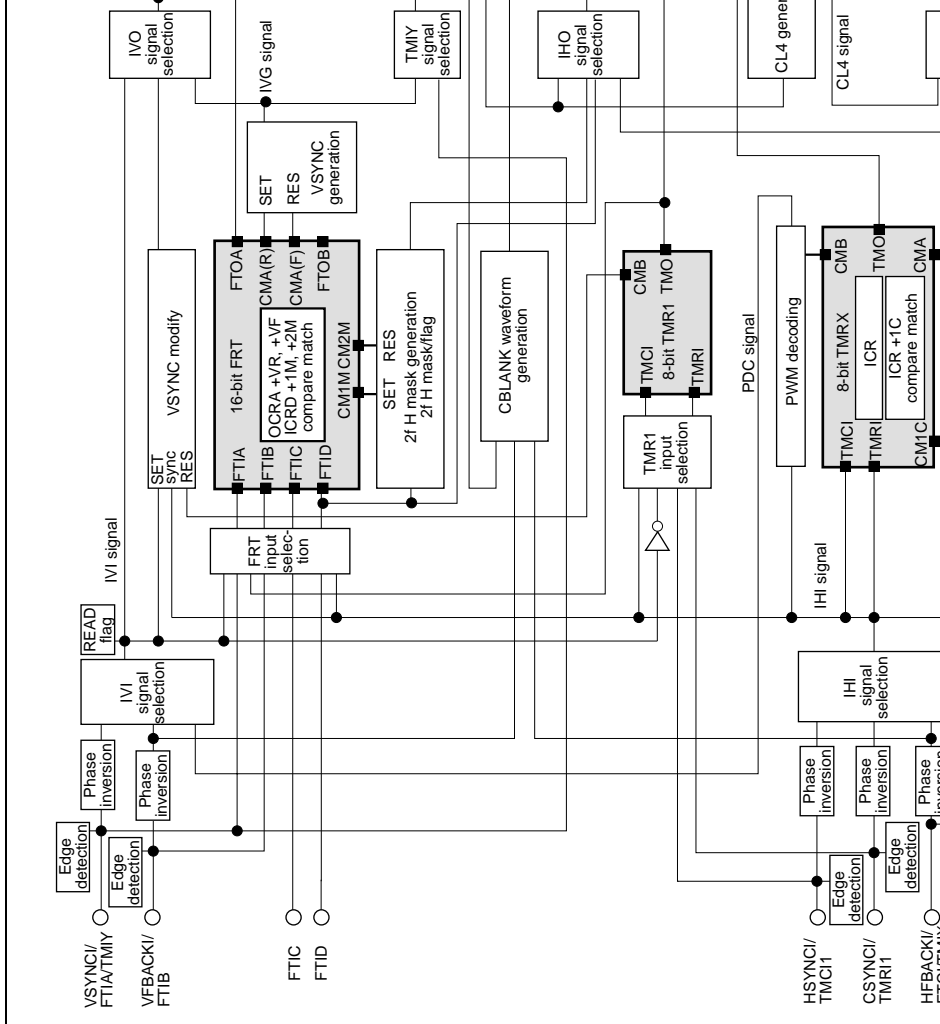


Figure 13.1 Block Diagram of Timer Connection Facility

signal input pin			input pin or F11A input pin
Horizontal synchronization signal input pin	HSYNCI	Input	Horizontal synchronization input pin or TMCI1 input pin
Composite synchronization signal input pin	CSYNCI	Input	Composite synchronization input pin or TMRI1 input pin
Spare vertical synchronization signal input pin	VFBACKI	Input	Spare vertical synchronization signal input pin or FTIC input pin
Spare horizontal synchronization signal input pin	HFBACKI	Input	Spare horizontal synchronization signal input pin or FTIC input pin/TMIX input pin
Vertical synchronization signal output pin	VSYNCO	Output	Vertical synchronization output pin or FTOA output pin
Horizontal synchronization signal output pin	HSYNCO	Output	Horizontal synchronization output pin or TMO1 output pin
Clamp waveform output pin	CLAMPO	Output	Clamp waveform output pin/FTIC input pin
Blanking waveform output pin	CBLANK	Output	Blanking waveform output pin

Timer connection register O	TCONRO	R/W	H'00	H'FF
Timer connection register S	TCONRS	R/W	H'00	H'FF
Edge sense register	SEDGR	R/(W) ^{*2}	H'00 ^{*3}	H'FF
Module stop control register	MSTPRH	R/W	H'3F	H'FF
	MSTPRL	R/W	H'FF	H'FF

- Notes:
1. Lower 16 bits of the address.
 2. Bits 7 to 2: Only 0 can be written to clear the flags.
 3. Bits 1 and 0: Undefined (reflect the pin states).

13.2 Register Descriptions

13.2.1 Timer Connection Register I (TCONRI)

Bit	7	6	5	4	3	2	1
	SIMOD1	SIMOD0	SCONE	ICST	HFINV	VFINV	HIINV
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

TCONRI is an 8-bit readable/writable register that controls connection between timers, source for synchronization signal input, phase inversion, etc.

TCONRI is initialized to H'00 by a reset and in hardware standby mode.

Bit 5—Synchronization Signal Connection Enable (SCONE): Selects the signal source for the FRT FTI input and the TMR1 TMC11/TMRI1 input.

Bit 5		Description				
SCONE	Mode	FTIA	FTIB	FTIC	FTID	TMR1
0	Normal connection (Initial value)	FTIA input	FTIB input	FTIC input	FTID input	TMR1 input
1	Synchronization signal connection mode	IVI signal	TMO1 signal	VFBACKI input	IHI signal	IHI signal

Bit 4—Input Capture Start Bit (ICST): The TMRX external reset input (TMRX) is connected to the IHI signal. TMRX has input capture registers (TICR, TICRR, and TICRF). TICR and TICRF can measure the width of a short pulse by means of a single capture operation under the control of the ICST bit. When a rising edge followed by a falling edge is detected on TMRX, the ICST bit is set to 1, the contents of TCNT at those points are captured into TICRR and TICRF, respectively, and the ICST bit is cleared to 0.

Bit 4	
ICST	Description
0	The TICRR and TICRF input capture functions are stopped (Clearing condition) When a rising edge followed by a falling edge is detected on TMRX
1	The TICRR and TICRF input capture functions are operating (Waiting for detection of a rising edge followed by a falling edge on TMRX) (Setting condition) When 1 is written in ICST after reading ICST = 0

0	The HFBACKI pin state is used directly as the HFBACKI input	(In
1	The HFBACKI pin state is inverted before use as the HFBACKI input	

Bit 2

VFINV	Description	
0	The VFBACKI pin state is used directly as the VFBACKI input	(In
1	The VFBACKI pin state is inverted before use as the VFBACKI input	

Bit 1

HIINV	Description	
0	The HSYNCI and CSYNCI pin states are used directly as the HSYNCI and CSYNCI inputs	(In
1	The HSYNCI and CSYNCI pin states are inverted before use as the HSYNCI and CSYNCI inputs	

Bit 0

VIINV	Description	
0	The VSYNCI pin state is used directly as the VSYNCI input	(In
1	The VSYNCI pin state is inverted before use as the VSYNCI input	

etc.

TCONRO is initialized to H'00 by a reset and in hardware standby mode.

Bits 7 and 4—Output Enable (HOE, VOE, CLOE, CBOE): These bits control enabling/disabling of horizontal synchronization signal (HSYNCO), vertical synchronization signal (VSYNCO), clamp waveform (CLAMPO), and blanking waveform (CBLANK). When output is disabled, the state of the relevant pin is determined by the port DR and TMR, and PWM settings.

Output enabling/disabling control does not affect the port, FRT, or TMR input functions. FRT and TMR input signal sources are determined by the SCONE bit in TCONRI.

Bit 7

HOE	Description
0	The P44/TMO1/HIRQ1/HSYNCO pin functions as the P44/TMO1/HIRQ1 pin
1	The P44/TMO1/HIRQ1/HSYNCO pin functions as the HSYNCO pin

Bit 6

VOE	Description
0	The P61/FTOA/ $\overline{\text{KIN1}}$ /CIN1/VSYNCO pin functions as the P61/FTOA/ $\overline{\text{KIN1}}$ /CIN1 pin
1	The P61/FTOA/ $\overline{\text{KIN1}}$ /CIN1/VSYNCO pin functions as the VSYNCO pin

CBOE	Description
0	The P27/A15/PW15/CBLANK pin functions as the P27/A15/PW15 pin (Ir
1	In mode 1 (expanded mode with on-chip ROM disabled): The P27/A15/PW15/CBLANK pin functions as the A15 pin In modes 2 and 3 (modes with on-chip ROM enabled): The P27/A15/PW15/CBLANK pin functions as the CBLANK pin

Bits 3 to 0—Output Synchronization Signal Inversion (HOINV, VOINV, CLOINV, CBOINV): These bits select inversion of the output phase of the horizontal synchronization (HSYNCO), the vertical synchronization signal (VSYNCO), the clamp waveform (CLAMPO) and the blank waveform (CBLANK).

Bit 3

HOINV	Description
0	The IHO signal is used directly as the HSYNCO output (Ir
1	The IHO signal is inverted before use as the HSYNCO output

Bit 2

VOINV	Description
0	The IVO signal is used directly as the VSYNCO output (Ir
1	The IVO signal is inverted before use as the VSYNCO output

Bit 1

CLOINV	Description
0	The CLO signal (CL1, CL2, CL3, or CL4 signal) is used directly as the CLAMPO output (Ir
1	The CLO signal (CL1, CL2, CL3, or CL4 signal) is inverted before use as the CLAMPO output

Bit	7	6	5	4	3	2	1
	TMRX/Y	ISGENE	HOMOD1	HOMOD0	VOMOD1	VOMOD0	CLMOD1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

TCONRS is an 8-bit readable/writable register that selects 8-bit timer TMRX/TMRY the synchronization signal output signal source and generation method.

TCONRS is initialized to H'00 by a reset and in hardware standby mode.

Bit 7—TMRX/TMRY Access Select (TMRX/Y): The TMRX and TMRY registers are accessed when the HIE bit in SYSCR is cleared to 0. In the H8S/2148 Group, some of the TMRX registers and the TMRY registers are assigned to the same memory space addresses (H'FFF0 to H'FFF5), and the TMRX/Y bit determines which registers are accessed. In the H8S/2147N and H8S/2147N, there is no control of TMRY register access by this bit.

Bit 7

TMRX/Y	Description
0	The TMRX registers are accessed at addresses H'FFF0 to H'FFF5
1	The TMRY registers are accessed at addresses H'FFF0 to H'FFF5

Bit 6—Internal Synchronization Signal Select (ISGENE): Selects internal synchronization signals (IHG, IVG, and CL4 signals) as the signal sources for the IHO, IVO, and CLC

	1	0	The CL1 signal is selected
		1	
1	0	0	The IHG signal is selected
		1	
	1	0	
		1	

Bits 3 and 2—Vertical Synchronization Output Mode Select 1 and 0 (VOMOD1, VOMOD0)

These bits select the signal source and generation method for the IVO signal.

Bit 6	Bit 3	Bit 2	Description
ISGENE	VOMOD1	VOMOD0	
0	0	0	The IVI signal (without fall modification or IHI synchronization) is selected (In
		1	The IVI signal (without fall modification, with IHI synchronization) is selected
	1	0	The IVI signal (with fall modification, without IHI synchronization) is selected
		1	The IVI signal (with fall modification and IHI synchronization) is selected
1	0	0	The IVG signal is selected
		1	
	1	0	
		1	

		1	
1	0	0	The CL4 signal is selected
		1	
	1	0	
		1	

13.2.4 Edge Sense Register (SEDGR)

Bit	7	6	5	4	3	2	1
	VEDG	HEDG	CEDG	HFEDG	VFEDG	PREQF	IHI
Initial value	0	0	0	0	0	0	—*2
Read/Write	R/(W)*1	R/(W)*1	R/(W)*1	R/(W)*1	R/(W)*1	R/(W)*1	R

- Notes: 1. Only 0 can be written, to clear the flags.
 2. The initial value is undefined since it depends on the pin states.

SEDGR is an 8-bit readable/writable register used to detect a rising edge on the timer input pins and the occurrence of 2fH modification, and to determine the phase of the I signals.

The upper 6 bits of SEDGR are initialized to 0 by a reset and in hardware standby mode. The initial value of the lower 2 bits is undefined, since it depends on the pin states.

Bit 6—HSYNCI Edge (HEDG): Detects a rising edge on the HSYNCI pin.

Bit 6

HEDG	Description	
0	[Clearing condition] When 0 is written in HEDG after reading HEDG = 1	(In
1	[Setting condition] When a rising edge is detected on the HSYNCI pin	

Bit 5—CSYNCI Edge (CEDG): Detects a rising edge on the CSYNCI pin.

Bit 5

CEDG	Description	
0	[Clearing condition] When 0 is written in CEDG after reading CEDG = 1	(In
1	[Setting condition] When a rising edge is detected on the CSYNCI pin	

Bit 4—HFBACKI Edge (HFEDG): Detects a rising edge on the HFBACKI pin.

Bit 4

HFEDG	Description	
0	[Clearing condition] When 0 is written in HFEDG after reading HFEDG = 1	(In
1	[Setting condition] When a rising edge is detected on the HFBACKI pin	

Bit 2—Pre-Equalization Flag (PREQF): Detects the occurrence of an IHI signal 2fH modification condition. The generation of a falling/rising edge in the IHI signal during an interval is expressed as the occurrence of a 2fH modification condition. For details, see 13.3.4, IHI Signal 2fH Modification.

Bit 2

PREQF	Description
0	[Clearing condition] When 0 is written in PREQF after reading PREQF = 1
1	[Setting condition] When an IHI signal 2fH modification condition is detected

Bit 1—IHI Signal Level (IHI): Indicates the current level of the IHI signal. Signal source phase inversion selection for the IHI signal depends on the contents of TCONRI. Read TCONRI to determine whether the input signal is positive or negative, then maintain the IHI signal phase by modifying TCONRI.

Bit 1

IHI	Description
0	The IHI signal is low
1	The IHI signal is high

13.2.5 Module Stop Control Register (MSTPCR)

Bit	MSTPCRH								MSTPCRL					
	7	6	5	4	3	2	1	0	7	6	5	4	3	2
	MSTP15	MSTP14	MSTP13	MSTP12	MSTP11	MSTP10	MSTP9	MSTP8	MSTP7	MSTP6	MSTP5	MSTP4	MSTP3	MSTP2
Initial value	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

MSTPCR, comprising two 8-bit readable/writable registers, performs module stop mode. When the MSTP13, MSTP12, and MSTP8 bits are set to 1, the 16-bit free-running timer channels 0 and 1, and 8-bit timer channels X and Y and timer connection, respectively, are disabled and enter module stop mode. See section 25.5., Module Stop Mode, for details.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not initialized in software standby mode.

MSTPCRH Bit 5—Module Stop (MSTP13): Specifies FRT module stop mode.

MSTPCRH

Bit 5

MSTP13	Description
0	FRT module stop mode is cleared
1	FRT module stop mode is set (In

MSTPCRH Bit 0—Module Stop (MSTP8): Specifies 8-bit timer channel X and Y and timer connection module stop mode.

**MSTPCRH
Bit 0**

MSTP8	Description
0	8-bit timer channel X and Y and timer connection module stop mode is cleared
1	8-bit timer channel X and Y and timer connection module stop mode is set

13.3 Operation

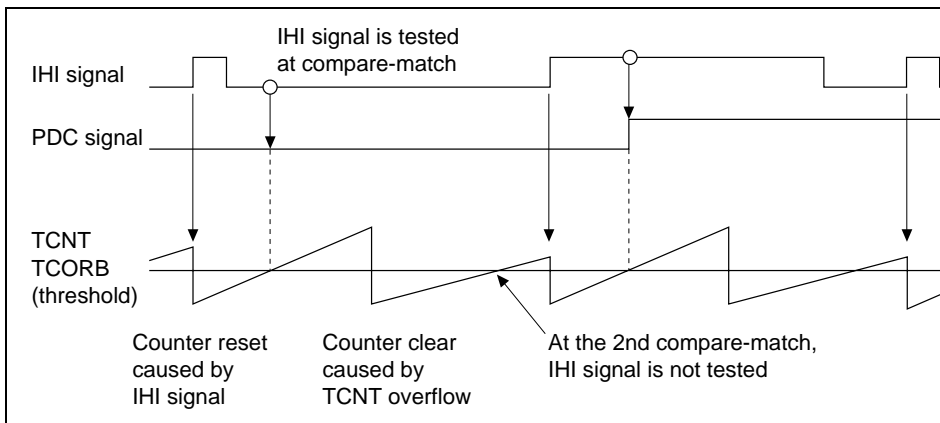
13.3.1 PWM Decoding (PDC Signal Generation)

The timer connection facility and TMRX can be used to decode a PWM signal in which the pulse widths are represented by the pulse width. To do this, a signal in which a rising edge is generated at regular intervals must be selected as the IHI signal.

The timer counter (TCNT) in TMRX is set to count the internal clock pulses and to be reset by the rising edge of the external reset signal (IHI signal). The value to be used as the threshold for deciding the pulse width is written in TCORB. The PWM decoder contains a delay latch that uses the IHI signal as data and compare-match signal B (CMB) as a clock, and the stable output signal (the result of the pulse width decision) at the compare-match signal B timing after being reset by the rise of the IHI signal is output as the PDC signal. The pulse width setting threshold is determined by the TICRR and TICRF of TMRX can be used to determine the pulse width decision threshold. Examples of TCR and TCORB settings are shown in tables 13.3 and 13.4, and the timing diagram is shown in figure 13.2.

Table 13.4 Examples of TCORB (Pulse Width Threshold) Settings

	ϕ : 10 MHz	ϕ : 12 MHz	ϕ : 16 MHz	ϕ : 20 MHz
H'07	0.8 μ s	0.67 μ s	0.5 μ s	0.4 μ s
H'0F	1.6 μ s	1.33 μ s	1 μ s	0.8 μ s
H'1F	3.2 μ s	2.67 μ s	2 μ s	1.6 μ s
H'3F	6.4 μ s	5.33 μ s	4 μ s	3.2 μ s
H'7F	12.8 μ s	10.67 μ s	8 μ s	6.4 μ s

**Figure 13.2 Timing Chart for PWM Decoding**

and the CL2 signal can be specified by TCORA.

The rise of the CL3 signal can be specified as simultaneous with the sampling of the f signal using the system clock, and the fall of the CL3 signal can be specified by TCORC. The CL3 signal can also fall when the IHI signal rises.

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

The value to be used as the CL1 signal pulse width is written in TCORA. Write a value 1 or more in TCORA when internal clock ϕ is selected as the TMRX counter clock, and a value H'01 or more when $\phi/2$ is selected. When internal clock ϕ is selected, the CL1 signal pulse width is (TCORA set value +3 \pm 0.5). When the CL2 signal is used, the setting must be made so that the 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. The TMRX captures the value of TCNT at the inverse of the external reset signal edge (in the falling edge of the IHI signal). The timing of the fall of the CL3 signal is determined by the contents of TICR and TCORC. Caution is required if the rising edge of the IHI signal is used for the fall timing set by the contents of TCORC, since the IHI signal will cause the CL3 signal to rise.

Examples of TMRX TCR settings are the same as those in table 13.3. The clamp waveforms and timing charts are shown in figures 13.3 and 13.4.

Since the rise of the CL1 and CL2 signals is synchronized with the edge of the IHI signal, their fall is synchronized with the system clock, the pulse width variation is equivalent to the resolution of the system clock.

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

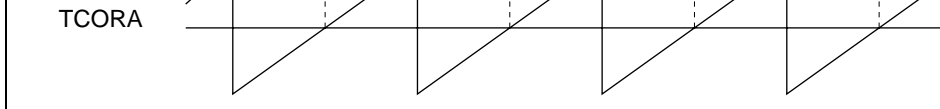


Figure 13.3 Timing Chart for Clamp Waveform Generation (CL1 and CL2 Signals)

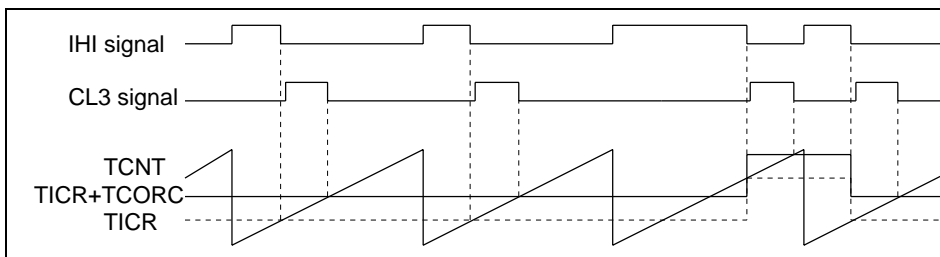


Figure 13.4 Timing Chart for Clamp Waveform Generation (CL3 Signal)

13.3.3 Measurement of 8-Bit Timer Divided Waveform Period

The timer connection facility, TMR1, and the free-running timer (FRT) can be used to measure the period of an IHI signal divided waveform. Since TMR1 can be cleared by a rising edge of the IHI signal, the rise and fall of the IHI signal divided waveform can be virtually synchronized with the IHI signal. This enables period measurement to be carried out efficiently.

To measure the period of an IHI signal divided waveform, TCNT in TMR1 is set to count the external clock (IHI signal) pulses and to be cleared on the rising edge of the external clock (inverted IHI signal). The value to be used as the division factor is written in TCORA, and the TMO output method is specified by the OS bits in TCSR. Examples of TCR and TCSR are shown in table 13.5, and the timing chart for measurement of the IHI signal and IHI signal divided waveform periods is shown in figure 13.5. The period of the IHI signal divided waveform is given by $(ICRD(3) - ICRD(2)) \times \text{the resolution}$.

	2 to 0	CKS2 to CKS0	101	TCNT is incremented on falling edge of the external clock signal (IVI signal)
TCSR in TMR1	3 to 0	OS3 to OS0	0011	Not changed by compare-match A, and output inverted by compare-match B (toggle output): division by 256
			1001	or when TCORB < TCORA, output inverted on compare-match B, and output inverted on compare-match A: division by 256
TCR in FRT	6	IEDGB	0/1	0: FRC value is transferred to TCNT on falling edge of input B (IHI divided signal waveform)
				1: FRC value is transferred to TCNT on rising edge of input B (IHI divided signal waveform)
	1 and 0	CKS1, CKS0	01	FRC is incremented on input B clock: $\phi/8$
TCSR in FRT	0	CCLRA	0	FRC clearing is disabled

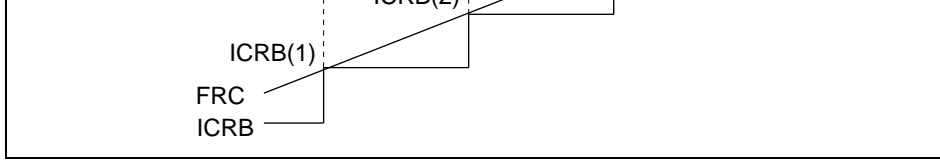


Figure 13.5 Timing Chart for Measurement of IHI Signal and IHI Signal Divided Waveform Periods

13.3.4 IHI Signal and 2fH Modification

By using the timer connection FRT, even if there is a part of the IHI signal with twice the frequency, this can be eliminated. In order for this function to operate properly, the duty 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 interval between the two compare-matches is called a mask interval. A value equivalent to approximately 1/3 the IHI signal period is written in OCRDM. ICRD is set so that capture is performed on the rise of the IHI signal.

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

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

TCOR in FRT	7	ICRDMS	1	ICRD is set to the operation which OCRDM is used
OCRDM in FRT	7 to 0	OCRDM7 to 0	H'01 to H'FF	Specifies the period during which ICRD operation is masked

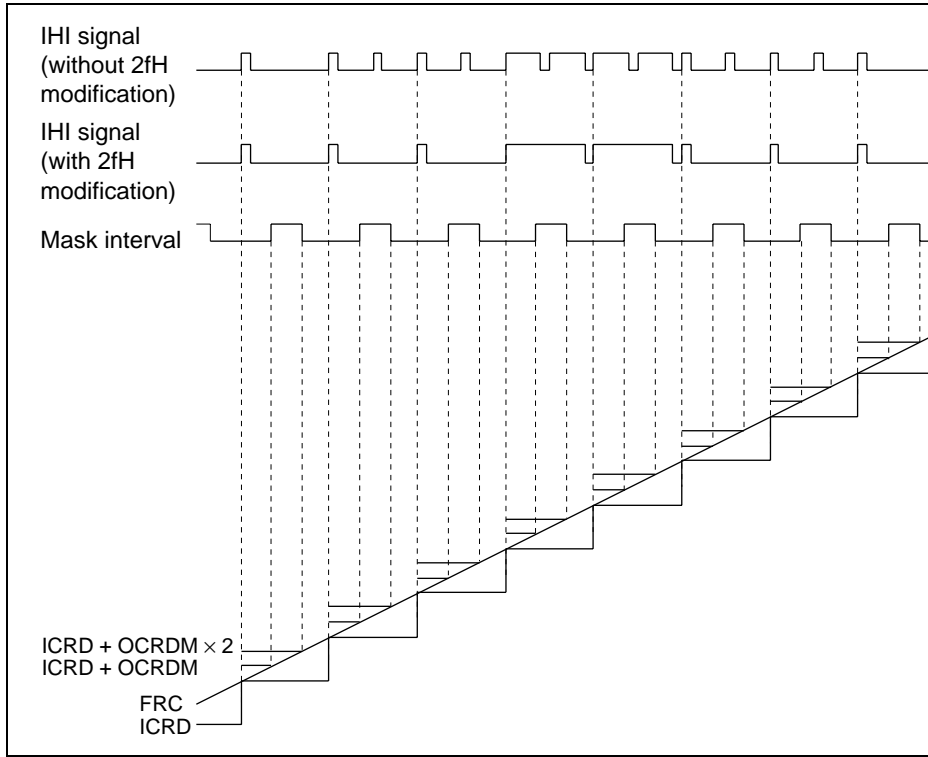


Figure 13.6 2fH Modification Timing Chart

written in TCORB.

Since the IVI signal supplied to the IVO signal selection circuit is normally set on the rise of the IVI signal and reset on the fall, its waveform is the same as that of the original IVI signal. If fall modification is selected, a reset is performed on a TMR1 TCORB compare-match.

The fall of the waveform generated in this way can be synchronized with the rise of the IVO signal regardless of whether or not fall modification is selected.

Examples of TMR1 TCORB, TCR, and TCSR settings are shown in table 13.7, and the IVO signal modification/IHI synchronization timing chart is shown in figure 13.7.

	2 to 0	CKS2 to CKS0	101	TCNT is incremented on the rise of the external clock (IHI signal)
TCSR in TMR1	3 to 0	OS3 to OS0	0011	Not changed by compare-match A, inverted by compare-match A output)
			1001	when $TCORB \leq TCORA$, 1 output of compare-match B, 0 output of compare-match A
TOCRB in TMR1			H'03 (example)	Compare-match on the 4th (example) of the IHI signal after the rise of the IHI signal, inverse of the IVI signal

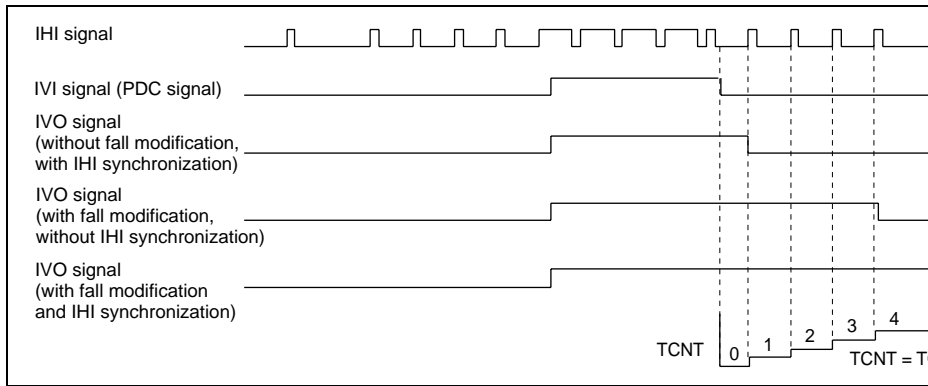


Figure 13.7 Fall Modification/IHI Synchronization Timing Chart

OCRAR or OCRAF, alternately, each time a compare-match occurs. A value corresponding to the 0 interval of the IVG signal is written in OCRAR, and a value corresponding to the 1 interval of the IVG signal is written in OCRAF. The IVG signal is set by a compare-match after an OCRAR addition, and reset by a compare-match after an OCRAF addition.

The IHG signal is the TMRY 8-bit timer output. TMRY is set to count internal clock periods. The IHG signal is cleared on TCORA compare-match, to fix the period and set the timer output. The IVG signal is connected to the TMRY reset input (TRST) so as to reset the timer output. The IVG signal is connected as the TMRY reset input (TRST) so as to reset the timer output. The rise of the IVG signal can be treated in the same way as a TCORA compare-match.

The CL4 signal is a waveform that rises within one system clock period after the fall of the IVG signal, and has a 1 interval of 6 system clock periods.

Examples of settings of TCORA, TCORB, TCR, and TCSR in TMRY, and OCRAR, OCRAF, and TCR in the FRT, are shown in table 13.8, and the IHG signal/IVG signal timing chart is shown in figure 13.8.

	4 and 3	CCLR1, CCLR0	01	TCNT is cleared by compare-
	2 to 0	CKS2 to CKS0	001	TCNT is incremented on inter $\phi/4$
TCSR in TMRY	3 to 0	OS3 to OS0	0110	0 output on compare-match B 1 output on compare-match A
TOCRA in TMRY			H'3F (example)	IHG signal period = $\phi \times 256$
TOCRB in TMRY			H'03 (example)	IHG signal 1 interval = $\phi \times 16$
TCR in FRT	1 and 0	CKS1, CKS0	01	FRC is incremented on intern
OCRAR in FRT			H'7FEF (example)	IVG signal 0 interval = $\phi \times 262016$
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

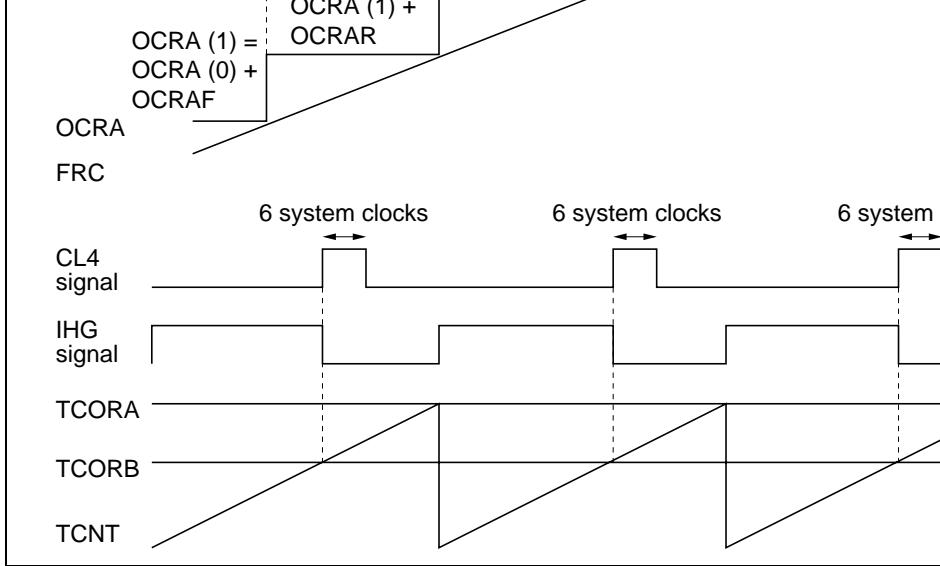


Figure 13.8 IVG Signal/IHG Signal/CL4 Signal Timing Chart

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 before output
		IHG signal	Internal synchronization signal is output directly
S-on-G mode	CSYNCl input	IHI signal (without 2fH modification)	CSYNCl input (composite synchronization signal) is output directly
		IHI signal (with 2fH modification)	Double-frequency part of CSYNCl input (composite synchronization signal) is eliminated before output
		CL1 signal	CSYNCl input (composite synchronization signal) horizontal synchronization signal part is changed before output
		IHG signal	Internal synchronization signal is output directly
Composite mode	HSYNCl input	IHI signal (without 2fH modification)	HSYNCl input (composite synchronization signal) is output directly
		IHI signal (with 2fH modification)	Double-frequency part of HSYNCl input (composite synchronization signal) is eliminated before output
		CL1 signal	HSYNCl input (composite synchronization signal) horizontal synchronization signal part is changed before output
		IHG signal	Internal synchronization signal is output directly
Separate mode	HSYNCl input	IHI signal (without 2fH modification)	HSYNCl input (horizontal synchronization signal) is output directly
		IHI signal (with 2fH modification)	Meaningless unless there is a double-f part in the HSYNCl input (horizontal synchronization signal)
		CL1 signal	HSYNCl input (horizontal synchronization signal) interval is changed before output
		IHG signal	Internal synchronization signal is output directly

No signal	VFBACKI input	IVI signal (without fall modification or IHI synchronization)	VFBACKI input is output directly
		IVI signal (without fall modification, with IHI synchronization)	Meaningless unless VFBACKI input synchronized with HFBACKI input
		IVI signal (with fall modification, without IHI synchronization)	VFBACKI input fall is modified before output
		IVI signal (with fall modification and IHI synchronization)	VFBACKI input fall is modified and synchronized with HFBACKI input before output
		IVG signal	Internal synchronization signal is output
S-on-G mode or composite mode	PDC signal	IVI signal (without fall modification or IHI synchronization)	CSYNCl/HSYNCl input (composite synchronization signal) vertical synchronization signal part is separated before output
		IVI signal (without fall modification, with IHI synchronization)	CSYNCl/HSYNCl input (composite synchronization signal) vertical synchronization signal part is separated, signal is synchronized with CSYNCl input before output
		IVI signal (with fall modification, without IHI synchronization)	CSYNCl/HSYNCl input (composite synchronization signal) vertical synchronization signal part is separated, fall is modified before output
		IVI signal (with fall modification and IHI synchronization)	CSYNCl/HSYNCl input (composite synchronization signal) vertical synchronization signal part is separated, fall is modified, and signal is synchronized with CSYNCl/HSYNCl input before output
		IVG signal	Internal synchronization signal is output

IVI signal (with fall modification, without IHI synchronization)	fall is modified before output
IVI signal (with fall modification and IHI synchronization)	VSYNCl input (vertical synchronization fall is modified and signal is synchronized) HSYNCl input (horizontal synchronization signal) before output
IVG signal	Internal synchronization signal is

13.3.9 CBLANK Output

Using the signals generated/selected with timer connection, it is possible to generate a blanking waveform 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 TCON. IVO signal.

The composition logic is shown in figure 13.9.

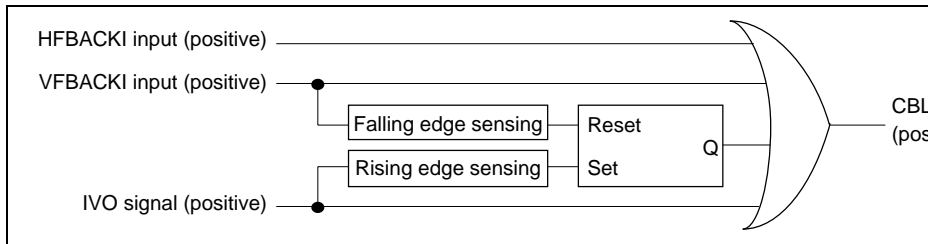


Figure 13.9 CBLANK Output Waveform Generation

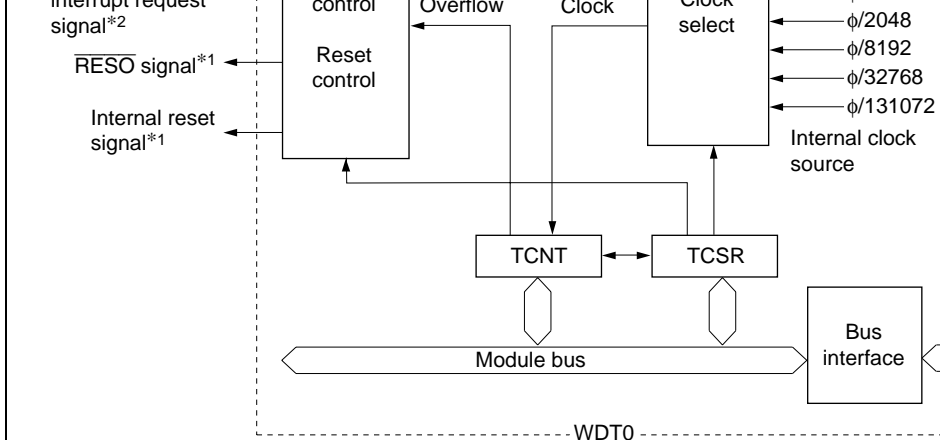
also generate an internal reset signal or internal NMI interrupt signal.

When this watchdog function is not needed, the WDT can be used as an interval timer. In timer mode, an interval timer interrupt is generated each time the counter overflows.

14.1.1 Features

WDT features are listed below.

- Switchable between watchdog timer mode and interval timer mode
- Internal reset or internal interrupt generated when the timer counter overflows
 - WOVI interrupt generation in interval timer mode
 - Choice of internal reset or NMI interrupt generation in watchdog timer mode
- $\overline{\text{RESO}}$ output in watchdog timer mode
 - In watchdog timer mode, a low-level signal is output from the $\overline{\text{RESO}}$ pin when the counter overflows (when internal reset is selected)
- Choice of 8 (WDT0) or 16 (WDT1) counter input clocks
 - Maximum WDT interval: system clock period \times 131072 \times 256
 - Subclock can be selected for the WDT1 input counter
 - Maximum interval when the subclock is selected: subclock period \times 256 \times 256



Legend:

TCSR: Timer control/status register

TCNT: Timer counter

- Notes:
1. $\overline{\text{RESO}}$ pin output goes low when the internal reset signal is generated by overflow of either WDT0 or WDT1. The reset of the WDT that overflowed first takes precedence over the internal reset signal.
 2. The internal NMI interrupt request signal can be output independently by either WDT0 or WDT1. The interrupt controller does not distinguish between NMI interrupt requests from WDT0 and WDT1.

Figure 14.1 (a) Block Diagram of WDT0

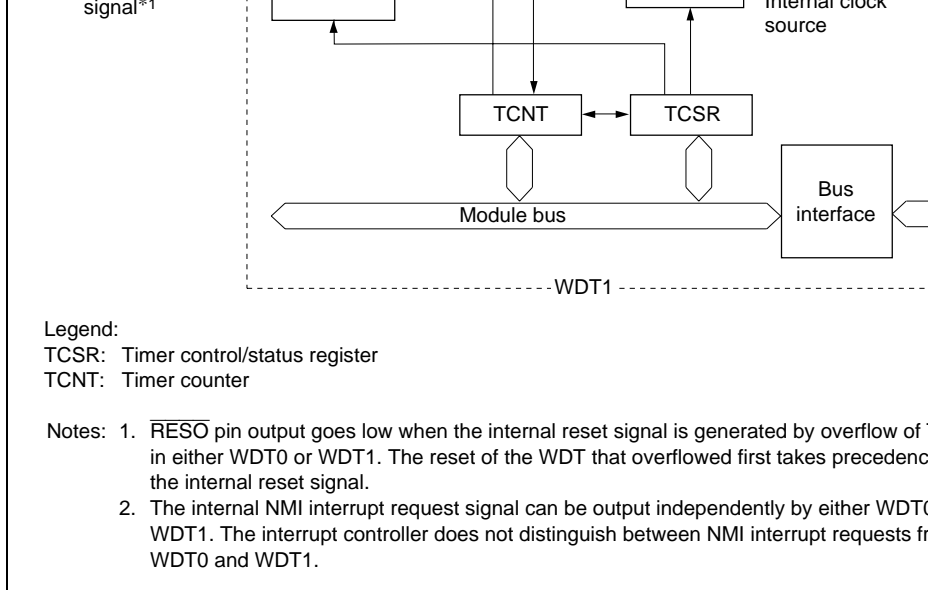


Figure 14.1 (b) Block Diagram of WDT1

14.1.3 Pin Configuration

Table 14.1 describes the WDT input pin.

Table 14.1 WDT Pin

Name	Symbol	I/O	Function
Reset output pin	$\overline{\text{RESO}}$	Output	Watchdog timer mode counter overflow output
External subclock input pin	EXCL	Input	WDT1 prescaler counter input clock

0	Timer control/status register 0	TCSR0	R/(W) ^{*3}	H'00	H'FFA8
	Timer counter 0	TCNT0	R/W	H'00	H'FFA8
1	Timer control/status register 1	TCSR1	R/(W) ^{*3}	H'00	H'FFEA
	Timer counter 1	TCNT1	R/W	H'00	H'FFEA
Common	System control register	SYSCR	R/W	H'09	H'FFC4

- Notes:
1. Lower 16 bits of the address.
 2. For details of write operations, see section 14.2.4, Notes on Register Access.
 3. Only 0 can be written in bit 7, to clear the flag.

14.2 Register Descriptions

14.2.1 Timer Counter (TCNT)

Bit	7	6	5	4	3	2	1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

TCNT is an 8-bit readable/writable* up-counter.

When the TME bit is set to 1 in TCSR, TCNT starts counting pulses generated from the clock source selected by bits CKS2 to CKS0 in TCSR. When the count overflows (changes from H'FF to H'00), the OVF flag in TCSR is set to 1. Watchdog timer overflow signal (\overline{RES}), an internal reset, NMI interrupt, interval timer interrupt (WOVI), etc., can be generated on the mode selected by the $\overline{WT/IT}$ bit and $\overline{RST/NMI}$ bit.

• TCSR0

Bit	7	6	5	4	3	2	1
	OVF	WT/ \overline{IT}	TME	RSTS	RST/ \overline{NMI}	CKS2	CKS1
Initial value	0	0	0	0	0	0	0
Read/Write	R/(W)*	R/W	R/W	R/W	R/W	R/W	R/W

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

• TCSR1

Bit	7	6	5	4	3	2	1
	OVF	WT/ \overline{IT}	TME	PSS	RST/ \overline{NMI}	CKS2	CKS1
Initial value	0	0	0	0	0	0	0
Read/Write	R/(W)*	R/W	R/W	R/W	R/W	R/W	R/W

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

TCSR is an 8-bit readable/writable* register. Its functions include selecting the clock input to TCNT, and the timer mode.

TCR is initialized to H'00 by a reset and in hardware standby mode. It is not initialized in software standby mode.

Note: * TCSR is write-protected by a password to prevent accidental overwriting. For details, see section 14.2.4, Notes on Register Access.

1	[Setting condition] When TCNT overflows (changes from H'FF to H'00) (When internal reset request generation is selected in watchdog timer mode, cleared automatically by the internal reset.)
---	---

Note: * When OVF is polled and the interval timer interrupt is disabled, OVF = 1 must occur at least twice.

Bit 6—Timer Mode Select (WT/IT): Selects whether the WDT is used as a watchdog timer or interval timer. If used as an interval timer, the WDT generates an interval timer interrupt (WOVI) when TCNT overflows. If used as a watchdog timer, the WDT generates a reset interrupt when TCNT overflows. When internal reset is selected in watchdog timer mode, a low-level signal is output from the $\overline{\text{RESO}}$ pin.

Bit 6

WT/IT	Description
0	Interval timer mode: Sends the CPU an interval timer interrupt request (WOVI) when TCNT overflows (Initial reset request is not generated)
1	Watchdog timer mode: Generates a reset or NMI interrupt when TCNT overflows. At the same time, a low-level signal is output from the $\overline{\text{RESO}}$ pin (when internal reset is selected)

Bit 5—Timer Enable (TME): Selects whether TCNT runs or is halted.

Bit 5

TME	Description
0	TCNT is initialized to H'00 and halted
1	TCNT counts

Bit 3—Reset or NMI ($\overline{\text{RST/NMI}}$): Specifies whether an internal reset or NMI interrupt is requested on TCNT overflow in watchdog timer mode.

Bit 3

RST/NMI	Description
0	An NMI interrupt is requested
1	An internal reset is requested

Bits 2 to 0—Clock Select 2 to 0 (CKS2 to CKS0): These bits select an internal clock obtained by dividing the system clock (ϕ), or subclock (ϕ SUB) for input to TCNT.

- WDT0 input clock selection

Bit 2	Bit 1	Bit 0	Description	
CKS2	CKS1	CKS0	Clock	Overflow Period* (when $\phi = 20$)
0	0	0	$\phi/2$ (Initial value)	25.6 μ s
		1	$\phi/64$	819.2 μ s
	1	0	$\phi/128$	1.6 ms
		1	$\phi/512$	6.6 ms
1	0	0	$\phi/2048$	26.2 ms
		1	$\phi/8192$	104.9 ms
	1	0	$\phi/32768$	419.4 ms
		1	$\phi/131072$	1.68 s

Note: * The overflow period is the time from when TCNT starts counting up from H'0000 to H'FFFF after overflow occurs.

			1	$\phi/512$	6.6 ms
1	0	0	1	$\phi/2048$	26.2 ms
			1	$\phi/8192$	104.9 ms
		1	0	$\phi/32768$	419.4 ms
			1	$\phi/131072$	1.68 s
1	0	0	0	$\phi\text{SUB}/2$	15.6 ms
			1	$\phi\text{SUB}/4$	31.3 ms
		1	0	$\phi\text{SUB}/8$	62.5 ms
			1	$\phi\text{SUB}/16$	125 ms
	1	0	0	$\phi\text{SUB}/32$	250 ms
			1	$\phi\text{SUB}/64$	500 ms
		1	0	$\phi\text{SUB}/128$	1 s
			1	$\phi\text{SUB}/256$	2 s

Note: * The overflow period is the time from when TCNT starts counting up from H'0 overflow occurs.

14.2.3 System Control Register (SYSCR)

Bit	7	6	5	4	3	2	1
	CS2E	IOSE	INTM1	INTM0	XRST	NMIEG	HIE
Initial value	0	0	0	0	1	0	0
Read/Write	R/W	R/W	R	R/W	R	R/W	R/W

Only bit 3 is described here. For details on functions not related to the watchdog timer, sections 3.2.2 and 5.2.1, System Control Register (SYSCR), and the descriptions of the modules.

Bit 3—External Reset (XRST): Indicates the reset source. When the watchdog timer reset can be generated by watchdog timer overflow in addition to external reset input. X

14.2.4 Notes on Register Access

The watchdog timer's TCNT and TCSR registers differ from other registers in being read-only and not to be written to. The procedures for writing to and reading these registers are given below.

Writing to TCNT and TCSR (Example of WDT0)

These registers must be written to by a word transfer instruction. They cannot be written to by byte transfer instructions.

Figure 14.2 shows the format of data written to TCNT and TCSR. TCNT and TCSR both use the same write address. For a write to TCNT, the upper byte of the written word must contain H'5A and the lower byte must contain the write data. For a write to TCSR, the upper byte of the written word must contain H'A5 and the lower byte must contain the write data. This transfers the write data from the lower byte to TCNT or TCSR.

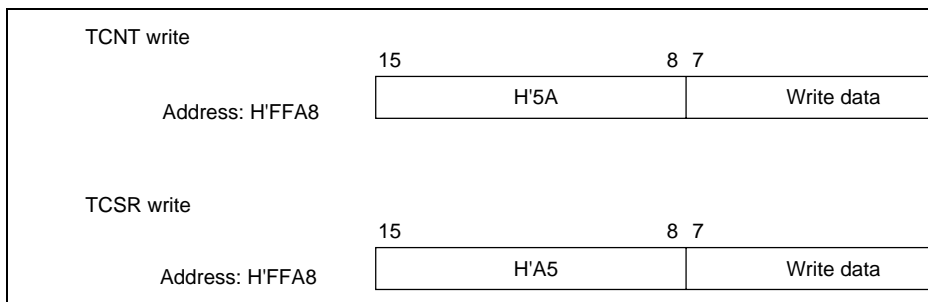


Figure 14.2 Format of Data Written to TCNT and TCSR (Example of WDT0)

Reading TCNT and TCSR (Example of WDT0)

These registers are read in the same way as other registers. The read addresses are H'FFA8 for TCSR, and H'FFA9 for TCNT.

internal reset or NMI interrupt request is generated.

When the $\overline{\text{RST/NMI}}$ bit is set to 1, the chip is reset for 518 system clock periods (518 ϕ counter overflow, and at the same time a low-level signal is output from the $\overline{\text{RESO}}$ pin states. This is illustrated in figure 14.3. The system can be reset using this $\overline{\text{RESO}}$ signal.

When the $\overline{\text{RST/NMI}}$ bit cleared to 0, an NMI interrupt request is generated by a counter. In this case, the $\overline{\text{RESO}}$ output signal remains high.

An internal reset request from the watchdog timer and reset input from the $\overline{\text{RES}}$ pin are handled via the same vector. The reset source can be identified from the value of the XRST bit in SYSCR .

If a reset caused by an input signal from the $\overline{\text{RES}}$ pin and a reset caused by WDT overflow occur simultaneously, 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 NMI pin are handled via the same vector. Simultaneous handling of a watchdog timer NMI interrupt request and an NMI pin interrupt request must therefore be avoided.

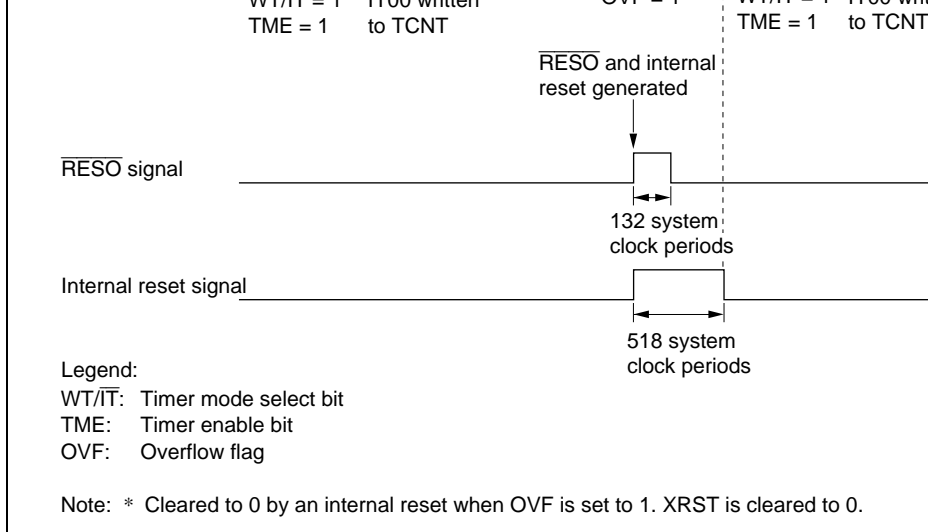


Figure 14.3 Operation in Watchdog Timer Mode ($\overline{RST}/\overline{NMI} = 1$)

14.3.2 Interval Timer Operation

To use the WDT as an interval timer, clear the $\overline{WT}/\overline{IT}$ bit in TCSR to 0 and set the \overline{TM} bit to 1. An interval timer interrupt (WOVI) is generated each time TCNT overflows, provided WDT is operating as an interval timer, as shown in figure 14.4. This function can be used to generate interrupt requests at regular intervals.

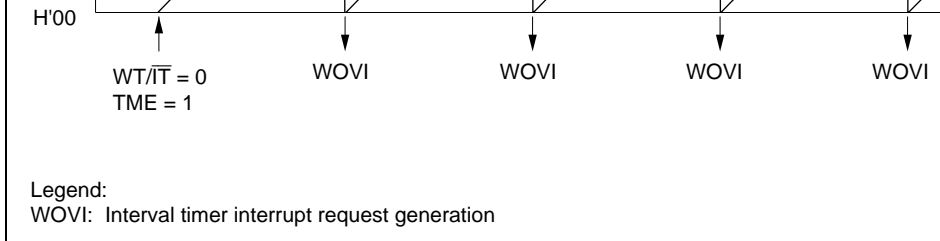


Figure 14.4 Operation in Interval Timer Mode

14.3.3 Timing of Setting of Overflow Flag (OVF)

The OVF flag is set to 1 if TCNT overflows during interval timer operation. At the same time an interval timer interrupt (WOVI) is requested. This timing is shown in figure 14.5.

If NMI request generation is selected in watchdog timer mode, when TCNT overflows a bit in TCSR is set to 1 and at the same time an NMI interrupt is requested.

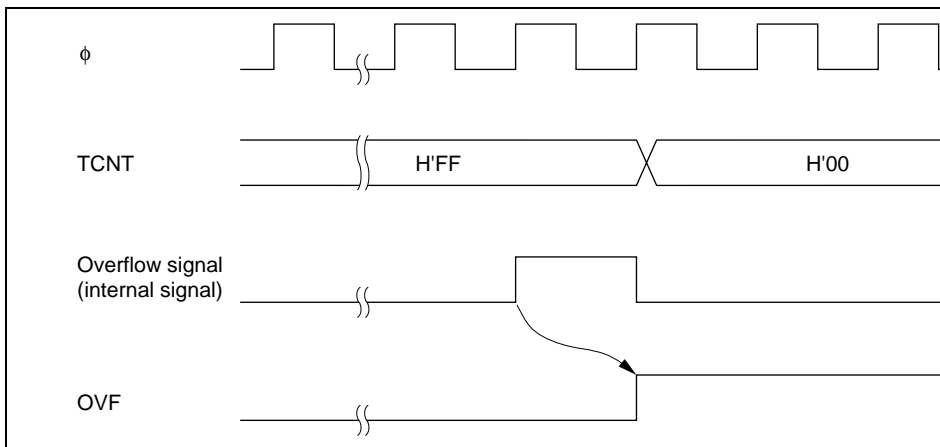


Figure 14.5 Timing of OVF Setting

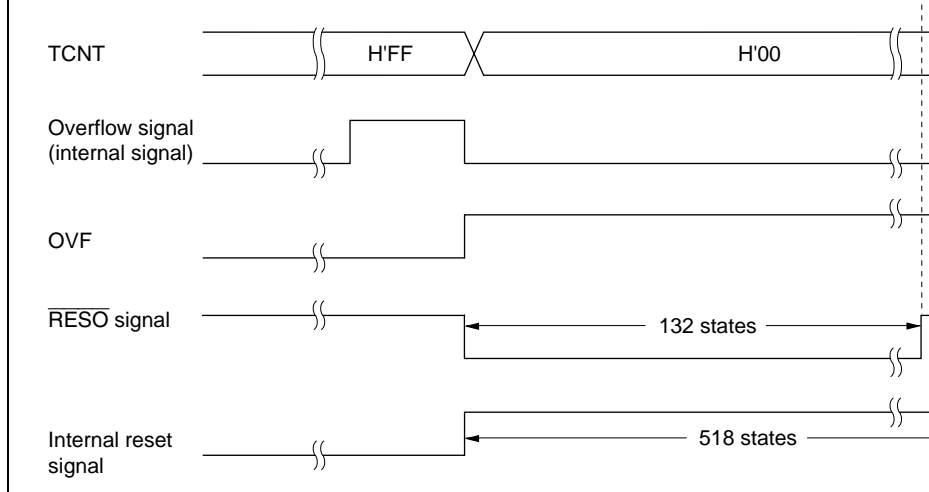


Figure 14.6 $\overline{\text{RESO}}$ Signal Output Timing

14.4 Interrupts

During interval timer mode operation, an overflow generates an interval timer interrupt. The interval timer interrupt is requested whenever the OVF flag is set to 1 in TCSR. OVF is cleared to 0 in the interrupt handling routine. When NMI interrupt request generation is enabled in watchdog timer mode, an overflow generates an NMI interrupt request.

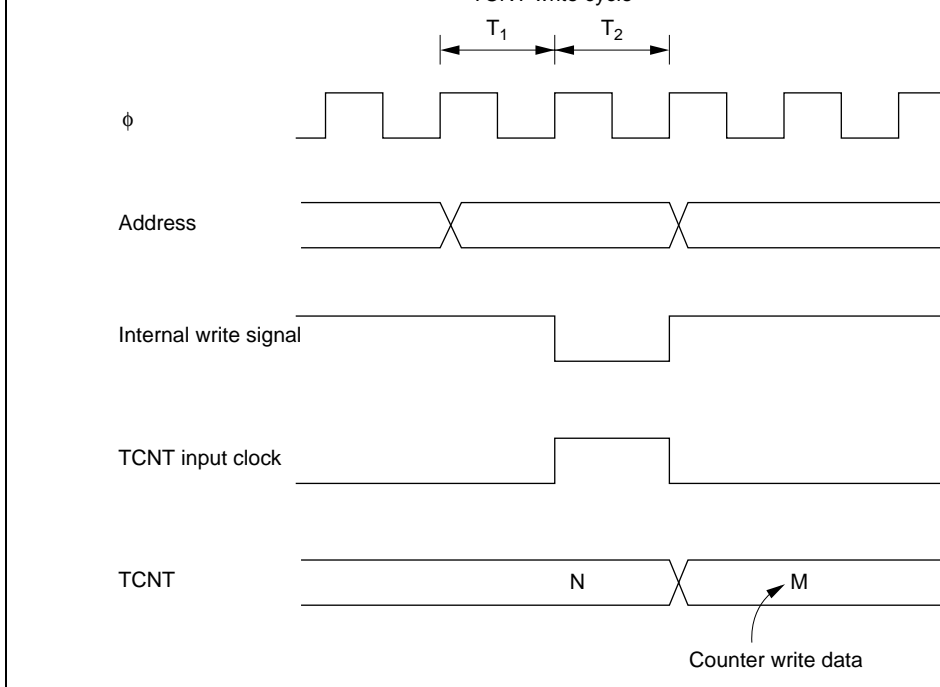


Figure 14.7 Contention between TCNT Write and Increment

14.5.2 Changing Value of CKS2 to CKS0

If bits CKS2 to CKS0 in TCSR are written to while the WDT is operating, errors could occur in the incrementation. Software must stop the watchdog timer (by clearing the TME bit to 0) before changing the value of bits CKS2 to CKS0.

If the $\overline{\text{RESO}}$ output signal is input to the chip's $\overline{\text{RES}}$ pin, the chip will not be initialized. Ensure that the $\overline{\text{RESO}}$ signal is not logically input to the chip's $\overline{\text{RES}}$ pin. When resetting a system with the $\overline{\text{RESO}}$ signal, use a circuit such as that shown in figure 14.8.

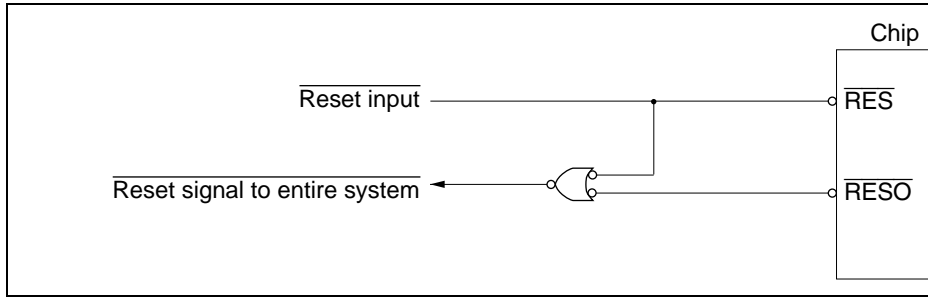


Figure 14.8 Sample Circuit for System Reset by $\overline{\text{RESO}}$ Signal

14.5.5 Counter Value in Transitions between High-Speed Mode, Subactive Mode and Watch Mode

If the mode is switched between high-speed mode and subactive mode or between high-speed mode and watch mode when WDT1 is used as a realtime clock counter, an error will occur in the counter value when the internal clock is switched.

When the mode is switched from high-speed mode to subactive mode or watch mode, increment timing is delayed by approximately 2 or 3 clock cycles when the WDT1 counter is switched from the main clock to the subclock.

Also, since the main clock oscillator is halted during subclock operation, when the mode is switched from watch mode or subactive mode to high-speed mode, the clock is not synchronized until the internal oscillation stabilizes. As a result, after oscillation is started, counter increments occur during the oscillation stabilization time set by bits STS2 to STS0 in SBYCR, and there is a corresponding discrepancy in the counter value.

flag set and TCSR read is occurred, OVF = 1 is read but OVF can not be cleared by writing 0 to OVF.

In this case, reading TCSR when OVF = 1 two times meet the requirements of OVF clear condition. Please read TCSR when OVF = 1 two times before writing with 0 to OVF.

```
LOOP    BTST.B    #7, @TCSR        ; OVF flag read
        BEQ      LOOP          ; if OVF=1, exit from loop
        MOV.B    @TCSR, R0L      ; OVF=1 read again
        MOV.W    #H'A521, R0     ; OVF flag clear
        MOV.W    R0,@TCSR       ; :
```

One of the three SCI channels can transmit and receive IrDA communication waveform IrDA specification version 1.0.

15.1.1 Features

SCI features are listed below.

- Choice of asynchronous or synchronous serial communication mode

Asynchronous mode:

- Serial data communication is executed using an asynchronous system in which synchronization is achieved character by character

Serial data communication can be carried out with standard asynchronous communication chips such as a Universal Asynchronous Receiver/Transmitter (UART) or Asynchronous Communication Interface Adapter (ACIA)

- A multiprocessor communication function is provided that enables serial data communication with a number of processors

- Choice of 12 serial data transfer formats

Data length: 7 or 8 bits

Stop bit length: 1 or 2 bits

Parity: Even, odd, or none

Multiprocessor bit: 1 or 0

- Receive error detection: Parity, overrun, and framing errors

- Break detection: Break can be detected by reading the RxD pin level directly in case of a framing error

- Full-duplex communication capability
 - The transmitter and receiver are mutually independent, enabling transmission and reception to be executed simultaneously
 - Double-buffering is used in both the transmitter and the receiver, enabling continuous transmission and continuous reception of serial data
- LSB-first or MSB-first transfer can be selected
 - This selection can be made regardless of the communication mode (with the exception of 7-bit data transfer in asynchronous mode)*

Note: * LSB-first transfer is used in the examples in this section.

- Built-in baud rate generator allows any bit rate to be selected
- Choice of serial clock source: internal clock from baud rate generator or external clock from SCK pin
- Capability of transmit and receive clock output
 - The P86/SCK1 and P42/SCK2 pins are CMOS type outputs
 - The P52/SCK0 pin is an NMOS push-pull type output in the H8S/2148 Group and H8S/2147N, and is a CMOS output in the H8S/2144 Group (When the P52/SCK0 is used as an output in the H8S/2148 Group and H8S/2147N, external pull-up resistor must be connected in order to output high level)
- The transmit-data-empty interrupt and receive-data-full interrupt can activate the data transfer controller (DTC) to execute data transfer
- Four interrupt sources
 - Four interrupt sources (transmit-data-empty, transmit-end, receive-data-full, and receive-error) that can issue requests independently
 - The transmit-data-empty interrupt and receive-data-full interrupt can activate the data transfer controller (DTC) to execute data transfer

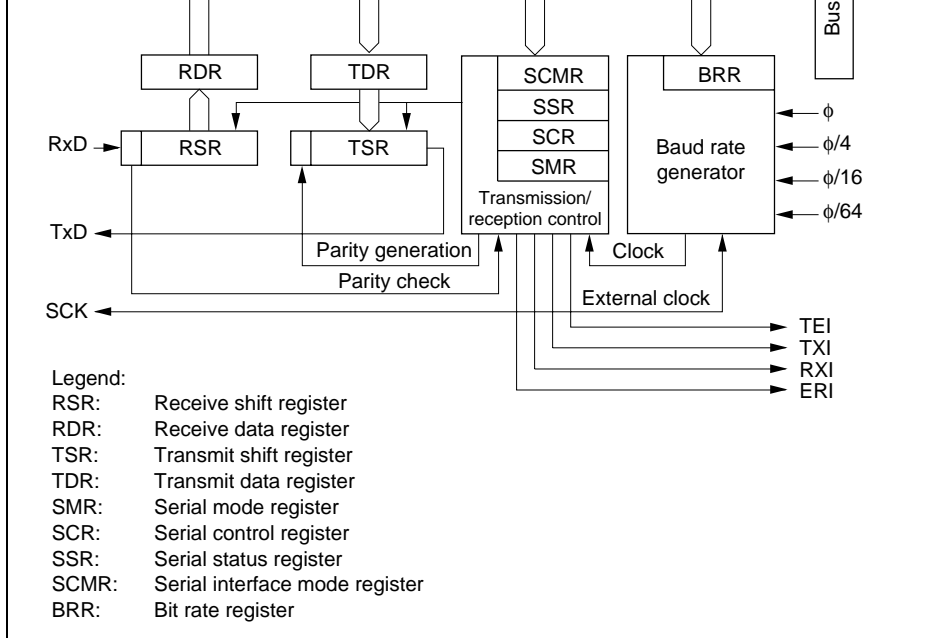


Figure 15.1 Block Diagram of SCI

	Transmit data pin 0	TxD0	Output	SCI0 transmit data output
1	Serial clock pin 1	SCK1	I/O	SCI1 clock input/output
	Receive data pin 1	RxD1	Input	SCI1 receive data input
	Transmit data pin 1	TxD1	Output	SCI1 transmit data output
2	Serial clock pin 2	SCK2	I/O	SCI2 clock input/output
	Receive data pin 2	RxD2/IrRxD	Input	SCI2 receive data input (normal/IrDA)
	Transmit data pin 2	TxD2/IrTxD	Output	SCI2 transmit data output (normal/IrDA)

Note: * The abbreviations SCK, RxD, and TxD are used in the text, omitting the channel number.

15.1.4 Register Configuration

The SCI has the internal registers shown in table 15.2. These registers are used to specify asynchronous mode or synchronous mode, the data format, and the bit rate, and to control transmitter/receiver.

	Receive data register 0	RDR0	R	H'00
	Serial interface mode register 0	SCMR0	R/W	H'F2
1	Serial mode register 1	SMR1	R/W	H'00
	Bit rate register 1	BRR1	R/W	H'FF
	Serial control register 1	SCR1	R/W	H'00
	Transmit data register 1	TDR1	R/W	H'FF
	Serial status register 1	SSR1	R/(W) ^{*2}	H'84
	Receive data register 1	RDR1	R	H'00
	Serial interface mode register 1	SCMR1	R/W	H'F2
2	Serial mode register 2	SMR2	R/W	H'00
	Bit rate register 2	BRR2	R/W	H'FF
	Serial control register 2	SCR2	R/W	H'00
	Transmit data register 2	TDR2	R/W	H'FF
	Serial status register 2	SSR2	R/(W) ^{*2}	H'84
	Receive data register 2	RDR2	R	H'00
	Serial interface mode register 2	SCMR2	R/W	H'F2
	Keyboard comparator control register	KBCOMP	R/W	H'00
Common	Module stop control register	MSTPCRH	R/W	H'3F
		MSTPCRL	R/W	H'FF

- Notes:
1. Lower 16 bits of the address.
 2. Only 0 can be written, to clear flags.
 3. Some serial communication interface registers are assigned to the same address as other registers. In this case, register selection is performed by the IICE bit in the timer control register (STCR).

RSR is a register used to receive serial data.

The SCI sets serial data input from the RxD pin in RSR in the order received, starting with the LSB (bit 0), and converts it to parallel data. When one byte of data has been received, it is transferred to RDR automatically.

RSR cannot be directly read or written to by the CPU.

15.2.2 Receive Data Register (RDR)

Bit	7	6	5	4	3	2	1
Initial value	0	0	0	0	0	0	0
Read/Write	R	R	R	R	R	R	R

RDR is a register that stores received serial data.

When the SCI has received one byte of serial data, it transfers the received serial data from RSR to RDR where it is stored, and completes the receive operation. After this, RSR is ready to receive the next byte of data.

Since RSR and RDR function as a double buffer in this way, continuous receive operations can be performed.

RDR is a read-only register, and cannot be written to by the CPU.

RDR is initialized to H'00 by a reset, and in standby mode, watch mode, subactive mode, and module stop mode.

To perform serial data transmission, the SCI first transfers transmit data from TDR to TSR, and transmission started, automatically. However, data transfer from TDR to TSR is performed if the TDRE bit in SSR is set to 1.

When transmission of one byte is completed, the next transmit data is transferred from TSR, and transmission started, automatically. However, data transfer from TDR to TSR is performed if the TDRE bit in SSR is set to 1.

TSR cannot be directly read or written to by the CPU.

15.2.4 Transmit Data Register (TDR)

Bit	7	6	5	4	3	2	1
Initial value	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

TDR is an 8-bit register that stores data for serial transmission.

When the SCI detects that TSR is empty, it transfers the transmit data written in TDR to TSR, and starts serial transmission. Continuous serial transmission can be carried out by writing transmit data to TDR during serial transmission of the data in TSR.

TDR can be read or written to by the CPU at all times.

TDR is initialized to H'FF by a reset, and in standby mode, watch mode, subactive mode, and module stop mode.



generator clock source.

SMR can be read or written to by the CPU at all times.

SMR is initialized to H'00 by a reset, and in standby mode, watch mode, subactive mode, mode, and module stop mode.

Bit 7—Communication Mode (C/Ā): Selects asynchronous mode or synchronous mode SCI operating mode.

Bit 7

C/Ā	Description
0	Asynchronous mode (L)
1	Synchronous mode

Bit 6—Character Length (CHR): Selects 7 or 8 bits as the data length in asynchronous mode, a fixed data length of 8 bits is used regardless of the CHR setting.

Bit 6

CHR	Description
0	8-bit data (L)
1	7-bit data*

Note: * When 7-bit data is selected, the MSB (bit 7) of TDR is not transmitted, and L first/MSB-first selection is not available.

1 Parity bit addition and checking enabled*

Note: * When the PE bit is set to 1, the parity (even or odd) specified by the O/\bar{E} bit is used to transmit data before transmission. In reception, the parity bit is checked for (even or odd) specified by the O/\bar{E} bit.

Bit 4—Parity Mode (O/\bar{E}): Selects either even or odd parity for use in parity addition and checking.

The O/\bar{E} bit setting is only valid when the PE bit is set to 1, enabling parity bit addition and checking, in asynchronous mode. The O/\bar{E} bit setting is invalid in synchronous mode, and parity bit addition and checking is disabled in asynchronous mode, and when a multiprocessor is used.

Bit 4

O/\bar{E}	Description
0	Even parity* ¹
1	Odd parity* ²

Notes: 1. When even parity is set, parity bit addition is performed in transmission so that the total number of 1 bits in the transmit character plus the parity bit is even. In reception, a check is performed to see if the total number of 1 bits in the character plus the parity bit is even.

2. When odd parity is set, parity bit addition is performed in transmission so that the total number of 1 bits in the transmit character plus the parity bit is odd. In reception, a check is performed to see if the total number of 1 bits in the character plus the parity bit is odd.

- Notes:
1. In transmission, a single 1 bit (stop bit) is added to the end of a transmit character before it is sent.
 2. In transmission, two 1 bits (stop bits) are added to the end of a transmit character before it is sent.

In reception, only the first stop bit is checked, regardless of the STOP bit setting. If the stop bit is 1, it is treated as a stop bit; if it is 0, it is treated as the start bit of the next character.

Bit 2—Multiprocessor Mode (MP): Selects multiprocessor format. When multiprocessor mode is selected, the PE bit and O/E bit parity settings are invalid. The MP bit setting is only valid in asynchronous mode; it is invalid in synchronous mode.

For details of the multiprocessor communication function, see section 15.3.3, Multiprocessor Communication Function.

Bit 2

MP	Description
0	Multiprocessor function disabled
1	Multiprocessor format selected

Bits 1 and 0—Clock Select 1 and 0 (CKS1, CKS0): These bits select the clock source for the baud rate generator. The clock source can be selected from ϕ , $\phi/4$, $\phi/16$, and $\phi/64$, according to the setting of bits CKS1 and CKS0.

For the relation between the clock source, the bit rate register setting, and the baud rate, see section 15.2.8, Bit Rate Register (BRR).

15.2.6 Serial Control Register (SCR)

Bit	7	6	5	4	3	2	1
	TIE	RIE	TE	RE	MPIE	TEIE	CKE1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

SCR is a register that performs enabling or disabling of SCI transfer operations, serial transfer in asynchronous mode, and interrupt requests, and selection of the serial clock source.

SCR can be read or written to by the CPU at all times.

SCR is initialized to H'00 by a reset, and in standby mode, watch mode, subactive mode, and module stop mode.

Bit 7—Transmit Interrupt Enable (TIE): Enables or disables transmit-data-empty interrupt (TXI) request generation when serial transmit data is transferred from TDR to TSR and the TXI flag in SSR is set to 1.

Bit 7

TIE	Description
0	Transmit-data-empty interrupt (TXI) request disabled*
1	Transmit-data-empty interrupt (TXI) request enabled

Note: * TXI interrupt request cancellation can be performed by reading 1 from the TXI flag, then clearing it to 0, or clearing the TIE bit to 0.

1 Receive-data-full interrupt (RXI) request and receive-error interrupt (ERI) request enabled

Note: * RXI and ERI interrupt request cancellation can be performed by reading 1 from RDRF, FER, PER, or ORER flag, then clearing the flag to 0, or clearing the flag to 0.

Bit 5—Transmit Enable (TE): Enables or disables the start of serial transmission by the SMR.

Bit 5

TE	Description
0	Transmission disabled* ¹
1	Transmission enabled* ²

Notes: 1. The TDRE flag in SSR is fixed at 1.
2. In this state, serial transmission is started when transmit data is written to TDRE flag in SSR is cleared to 0.
SMR setting must be performed to decide the transmission format before setting bit to 1.

Bit 4—Receive Enable (RE): Enables or disables the start of serial reception by the SMR.

Bit 4

RE	Description
0	Reception disabled* ¹
1	Reception enabled* ²

Notes: 1. Clearing the RE bit to 0 does not affect the RDRF, FER, PER, and ORER flags. They retain their states.
2. Serial reception is started in this state when a start bit is detected in asynchronous mode or serial clock input is detected in synchronous mode.
SMR setting must be performed to decide the reception format before setting bit to 1.

0	<p>Multiprocessor interrupts disabled (normal reception performed)</p> <p>[Clearing conditions]</p> <ul style="list-style-type: none"> • When the MPIE bit is cleared to 0 • When data with MPB = 1 is received
1	<p>Multiprocessor interrupts enabled*</p> <p>Receive interrupt (RXI) requests, receive-error interrupt (ERI) requests, and all of the RDRF, FER, and ORER flags in SSR are disabled until data with the multiprocessor bit set to 1 is received.</p>

Note: * When receive data including MPB = 0 is received, receive data transfer from RDR, receive error detection, and setting of the RDRF, FER, and ORER flag is not performed. When receive data with MPB = 1 is received, the MPB bit is set to 1, the MPIE bit is cleared to 0 automatically, and generation of RXI and ERI interrupts (when the TIE and RIE bits in SCR are set to 1) and FER and ORER flag setting is enabled.

Bit 2—Transmit End Interrupt Enable (TEIE): Enables or disables transmit-end interrupt (TEI) request generation if there is no valid transmit data in TDR when the MSB is transmitted.

Bit 2

TEIE	Description
0	Transmit-end interrupt (TEI) request disabled*
1	Transmit-end interrupt (TEI) request enabled*

Note: * TEI cancellation can be performed by reading 1 from the TDRE flag in SSR, clearing it to 0 and clearing the TEND flag to 0, or clearing the TEIE bit to 0.

Bits 1 and 0—Clock Enable 1 and 0 (CKE1, CKE0): These bits are used to select the clock source and enable or disable clock output from the SCK pin. The combination of the CKE1 and CKE0 bits determines whether the SCK pin functions as an I/O port, the serial clock output pin, or the serial clock input pin.

The setting of the CKE0 bit, however, is only valid for internal clock operation (CKE1 = 0) in asynchronous mode. The CKE0 bit setting is invalid in synchronous mode, and in the



		Synchronous mode	Internal clock/SCK pin functions as serial output ^{*1}
	1	Asynchronous mode	Internal clock/SCK pin functions as clock
		Synchronous mode	Internal clock/SCK pin functions as serial output
1	0	Asynchronous mode	External clock/SCK pin functions as clock
		Synchronous mode	External clock/SCK pin functions as serial input
	1	Asynchronous mode	External clock/SCK pin functions as clock
		Synchronous mode	External clock/SCK pin functions as serial input

- Notes: 1. Initial value
2. Outputs a clock of the same frequency as the bit rate.
3. Inputs a clock with a frequency 16 times the bit rate.

15.2.7 Serial Status Register (SSR)

Bit	7	6	5	4	3	2	1
	TDRE	RDRF	ORER	FER	PER	TEND	MPB
Initial value	1	0	0	0	0	1	0
Read/Write	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R	R

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

SSR is an 8-bit register containing status flags that indicate the operating status of the S multi-processor bits.

SSR can be read or written to by the CPU at all times. However, 1 cannot be written to TDRE, RDRF, ORER, PER, and FER. Also note that in order to clear these flags they must be read as 1 beforehand. The TEND flag and MPB flag are read-only flags and cannot be

	<ul style="list-style-type: none"> • When 0 is written in TDRE after reading TDRE = 1 • When the DTC is activated by a TXI interrupt and writes data to TDR
1	[Setting conditions] <ul style="list-style-type: none"> • When the TE bit in SCR is 0 • When data is transferred from TDR to TSR and data can be written to

Bit 6—Receive Data Register Full (RDRF): Indicates that the received data is stored

Bit 6

RDRF	Description
0	[Clearing conditions] <ul style="list-style-type: none"> • When 0 is written in RDRF after reading RDRF = 1 • When the DTC is activated by an RXI interrupt and reads data from RDR
1	[Setting condition] When serial reception ends normally and receive data is transferred from

Note: RDR and the RDRF flag are not affected and retain their previous values when detected during reception or when the RE bit in SCR is cleared to 0.

If reception of the next data is completed while the RDRF flag is still set to 1, an error will occur and the receive data will be lost.

When the next serial reception is completed while RDRF = 1^{*2}

- Notes:
1. The ORER flag is not affected and retains its previous state when the RE bit is cleared to 0.
 2. The receive data prior to the overrun error is retained in RDR, and the data received subsequently is lost. Also, subsequent serial reception cannot be continued until the ORER flag is set to 1. In synchronous mode, serial transmission cannot be continued either.

Bit 4—Framing Error (FER): Indicates that a framing error occurred during reception in asynchronous mode, causing abnormal termination.

Bit 4

FER	Description
0	[Clearing condition] When 0 is written in FER after reading FER = 1
1	[Setting condition] When the SCI checks the stop bit at the end of the receive data when reception is complete and the stop bit is 0 ^{*2}

- Notes:
1. The FER flag is not affected and retains its previous state when the RE bit is cleared to 0.
 2. In 2-stop-bit mode, only the first stop bit is checked for a value of 0; the second stop bit is not checked. If a framing error occurs, the receive data is transferred to RDR, and the RDRF flag is not set. Also, subsequent serial reception cannot be continued until the FER flag is set to 1. In synchronous mode, serial transmission cannot be continued either.

When, in reception, the number of 1 bits in the receive data plus the parity match the parity setting (even or odd) specified by the O/E bit in SMR*2

- Notes:
1. The PER flag is not affected and retains its previous state when the RE bit is cleared to 0.
 2. If a parity error occurs, the receive data is transferred to RDR but the RDRF flag is not set. Also, subsequent serial reception cannot be continued while the PER flag is set.
 1. In synchronous mode, serial transmission cannot be continued, either.

Bit 2—Transmit End (TEND): Indicates that there is no valid data in TDR when the transmit character is sent, and transmission has been ended.

The TEND flag is read-only and cannot be modified.

Bit 2

TEND	Description
0	[Clearing conditions] <ul style="list-style-type: none">• When 0 is written in TDRE after reading TDRE = 1• When the DTC is activated by a TXI interrupt and writes data to TDR
1	[Setting conditions] <ul style="list-style-type: none">• When the TE bit in SCR is 0• When TDRE = 1 at transmission of the last bit of a 1-byte serial transmission

	When data with a 0 multiprocessor bit is received
1	[Setting condition] When data with a 1 multiprocessor bit is received

Note: * Retains its previous state when the RE bit in SCR is cleared to 0 with multiprocessor format.

Bit 0—Multiprocessor Bit Transfer (MPBT): When transmission is performed using multiprocessor format in asynchronous mode, MPBT stores the multiprocessor bit to be transmitted data.

The MPBT bit setting is invalid when a multiprocessor format is not used, when not transmitting data and in synchronous mode.

Bit 0

MPBT	Description
0	Data with a 0 multiprocessor bit is transmitted (0)
1	Data with a 1 multiprocessor bit is transmitted (1)

generator operating clock selected by bits CKS1 and CKS0 in SMR.

BRR can be read or written to by the CPU at all times.

BRR is initialized to H'FF by a reset, and in standby mode, watch mode, subactive mode, mode, and module stop mode.

As baud rate generator control is performed independently for each channel, different values can be set for each channel.

Table 15.3 shows sample BRR settings in asynchronous mode, and table 15.4 shows sample BRR settings in synchronous mode.

300	0	207	0.16	0	217	0.21	0	255	0.00	1	77
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	77
2400	0	25	0.16	0	26	1.14	0	31	0.00	0	38
4800	0	12	0.16	0	13	-2.48	0	15	0.00	0	19
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)

Bit Rate (bits/s)	$\phi = 3.6864$ MHz			$\phi = 4$ MHz			$\phi = 4.9152$ MHz			$\phi =$	
	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	88
150	1	191	0.00	1	207	0.16	1	255	0.00	2	64
300	1	95	0.00	1	103	0.16	1	127	0.00	1	12
600	0	191	0.00	0	207	0.16	0	255	0.00	1	64
1200	0	95	0.00	0	103	0.16	0	127	0.00	0	12
2400	0	47	0.00	0	51	0.16	0	63	0.00	0	64
4800	0	23	0.00	0	25	0.16	0	31	0.00	0	32
9600	0	11	0.00	0	12	0.16	0	15	0.00	0	15
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

600	1	77	0.16	1	79	0.00	1	95	0.00	1	2
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	7
38400	0	4	-2.34	0	4	0.00	0	5	0.00	—	—

Bit Rate (bits/s)	Operating Frequency ϕ (MHz)										
	$\phi = 9.8304$ MHz			$\phi = 10$ MHz			$\phi = 12$ MHz			$\phi = 1$	
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N
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	7
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	7
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	7
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

600	1	181	0.16	1	191	0.00	1	207	0.16	1	22
1200	1	90	0.16	1	95	0.00	1	103	0.16	1	11
2400	0	181	0.16	0	191	0.00	0	207	0.16	0	22
4800	0	90	0.16	0	95	0.00	0	103	0.16	0	11
9600	0	45	-0.93	0	47	0.00	0	51	0.16	0	55
19200	0	22	-0.93	0	23	0.00	0	25	0.16	0	27
31250	0	13	0.00	0	14	-1.70	0	15	0.00	0	16
38400	—	—	—	0	11	0.00	0	12	0.16	0	13

Bit Rate (bits/s)	Operating Frequency ϕ (MHz)								
	$\phi = 18$ MHz			$\phi = 19.6608$ MHz			$\phi = 20$ MHz		
	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	116	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	116	0.16	0	127	0.00	0	129	0.16
9600	0	58	-0.69	0	63	0.00	0	64	0.16
19200	0	28	1.02	0	31	0.00	0	32	-1.36
31250	0	17	0.00	0	19	-1.70	0	19	0.00
38400	0	14	-2.34	0	15	0.00	0	15	1.73

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

Legend:

Blank: Cannot be set.

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

*: Continuous transfer is not possible.

Note: As far as possible, the setting should be made so that the error is no more than

$$N = \frac{\phi}{8 \times 2^{2n-1} \times B} \times 10^6 - 1$$

Where B: Bit rate (bits/s)

N: BRR setting for baud rate generator ($0 \leq N \leq 255$)

ϕ : Operating frequency (MHz)

n: Baud rate generator input clock ($n = 0$ to 3)

(See the table below for the relation between n and the clock.)

n	Clock	SMR Setting	
		CKS1	CKS0
0	ϕ	0	0
1	$\phi/4$	0	1
2	$\phi/16$	1	0
3	$\phi/64$	1	1

The bit rate error in asynchronous mode is found from the following equation:

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

2.4376	76800	0	0
3	93750	0	0
3.6864	115200	0	0
4	125000	0	0
4.9152	153600	0	0
5	156250	0	0
6	187500	0	0
6.144	192000	0	0
7.3728	230400	0	0
8	250000	0	0
9.8304	307200	0	0
10	312500	0	0
12	375000	0	0
12.288	384000	0	0
14	437500	0	0
14.7456	460800	0	0
16	500000	0	0
17.2032	537600	0	0
18	562500	0	0
19.6608	614400	0	0
20	625000	0	0

4	1.0000	62500
4.9152	1.2288	76800
5	1.2500	78125
6	1.5000	93750
6.144	1.5360	96000
7.3728	1.8432	115200
8	2.0000	125000
9.8304	2.4576	153600
10	2.5000	156250
12	3.0000	187500
12.288	3.0720	192000
14	3.5000	218750
14.7456	3.6864	230400
16	4.0000	250000
17.2032	4.3008	268800
18	4.5000	281250
19.6608	4.9152	307200
20	5.0000	312500

12	2.0000	2000000.0
14	2.3333	2333333.3
16	2.6667	2666666.7
18	3.0000	3000000.0
20	3.3333	3333333.3

15.2.9 Serial Interface Mode Register (SCMR)

Bit	7	6	5	4	3	2	1
	—	—	—	—	SDIR	SINV	—
Initial value	1	1	1	1	0	0	1
Read/Write	—	—	—	—	R/W	R/W	—

SCMR is an 8-bit readable/writable register used to select SCI functions.

SCMR is initialized to H'F2 by a reset, and in standby mode, watch mode, subactive mode, subsleep mode, and module stop mode.

Bits 7 to 4—Reserved: These bits cannot be modified and are always read as 1.

Bit 3—Data Transfer Direction (SDIR): Selects the serial/parallel conversion format.

Bit 3

SDIR	Description
0	TDR contents are transmitted LSB-first Receive data is stored in RDR LSB-first
1	TDR contents are transmitted MSB-first Receive data is stored in RDR MSB-first

1 TDR contents are inverted before being transmitted
 Receive data is stored in RDR in inverted form

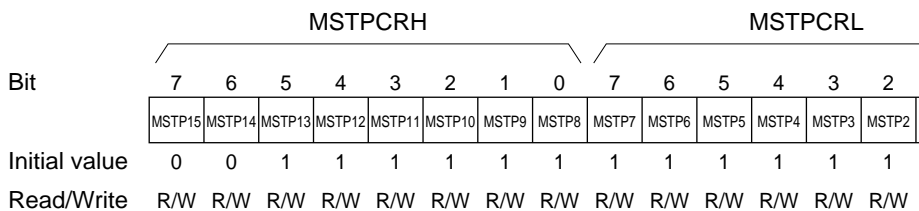
Bit 1—Reserved: This bit cannot be modified and is always read as 1.

Bit 0—Serial Communication Interface Mode Select (SMIF): Reserved bit. 1 should not be written in this bit.

Bit 0

SMIF	Description
0	Normal SCI mode
1	Reserved mode

15.2.10 Module Stop Control Register (MSTPCR)



MSTPCR, comprising two 8-bit readable/writable registers, performs module stop mode. When bit MSTP7, MSTP6, or MSTP5 is set to 1, SCIO, SCI1, or SCI2 operation, respectively, stops at the end of the bus cycle and a transition is made to module stop mode. For details, see section 25.5, Module Stop Mode.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not initialized in software standby mode.

Bit 6—Module Stop (MSTP6): Specifies the SCI1 module stop mode.

MSTPCRL

Bit 6

MSTP6	Description
--------------	--------------------

0	SCI1 module stop mode is cleared
---	----------------------------------

1	SCI1 module stop mode is set
---	------------------------------

Bit 5—Module Stop (MSTP5): Specifies the SCI2 module stop mode.

MSTPCRL

Bit 5

MSTP5	Description
--------------	--------------------

0	SCI2 module stop mode is cleared
---	----------------------------------

1	SCI2 module stop mode is set
---	------------------------------

converter.

KBCOMP is initialized to H'00 by a reset and in hardware standby mode.

Bit 7—IrDA Enable (IrE): Specifies normal SCI operation or IrDA operation for SCI input/output.

Bit 7

IrE	Description
0	The TxD2/IrTxD and RxD2/IrRxD pins function as TxD2 and RxD2 (
1	The TxD2/IrTxD and RxD2/IrRxD pins function as IrTxD and IrRxD

Bits 6 to 4—IrDA Clock Select 2 to 0 (IrCKS2 to IrCKS0): These bits specify the hi width in IrTxD output pulse encoding when the IrDA function is enabled.

Bit 6	Bit 5	Bit 4	Description
0	0	0	$B \times 3/16$ (3/16 of the bit rate) (
		1	$\phi/2$
	1	0	$\phi/4$
		1	$\phi/8$
1	0	0	$\phi/16$
		1	$\phi/32$
	1	0	$\phi/64$
		1	$\phi/128$

Bits 3 to 0—Keyboard Comparator Control: See the description in section 20, A/D

Selection of asynchronous or synchronous mode and the transmission format is made as shown in table 15.8. The SCI clock is determined by a combination of the $\overline{C/\overline{A}}$ bit in the CKE1 and CKE0 bits in SCR, as shown in table 15.9.

Asynchronous Mode:

- Data length: Choice of 7 or 8 bits
- Choice of parity addition, multiprocessor bit addition, and addition of 1 or 2 stop bits. A combination of these parameters determines the transfer format and character length.
- Detection of framing, parity, and overrun errors, and breaks, during reception
- Choice of internal or external clock as SCI clock source
 - When internal clock is selected:

The SCI operates on the baud rate generator clock and a clock with the same frequency as the bit rate can be output
 - When external clock is selected:

A clock with a frequency of 16 times the bit rate must be input (the built-in baud rate generator is not used)

Synchronous Mode:

- Transfer format: Fixed 8-bit data
- Detection of overrun errors during reception
- Choice of internal or external clock as SCI clock source
 - When internal clock is selected:

The SCI operates on the baud rate generator clock and a serial clock is output
 - When external clock is selected:

The built-in baud rate generator is not used, and the SCI operates on the input

			1	0				Yes
				1				
1			0	0		7-bit data		No
				1				
			1	0				Yes
				1				
0	1	—	0	0	Asynchronous mode (multi-processor format)	8-bit data	Yes	No
			—	1				
1		—	0	0		7-bit data		
			—	1				
1	—	—	—	—	Synchronous mode	8-bit data	No	

Table 15.9 SMR and SCR Settings and SCI Clock Source Selection

SMR	SCR Setting			SCI Transfer Clock	
	Bit 7	Bit 1	Bit 0	Clock Source	SCK Pin Function
C/ \bar{A}	CKE1	CKE0	Mode		
0	0	0	Asynchronous mode	Internal	SCI does not use SCK pin Outputs clock with same frequency as the bit rate
		1			
1	0	0	Synchronous mode	Internal	Outputs serial clock
		1			
1	1	0	Synchronous mode	External	Inputs clock with frequency of 1/2 the bit rate
		1			
1	1	0	Synchronous mode	External	Inputs serial clock
		1			

that data can be read or written during transmission or reception, enabling continuous transfer.

Figure 15.2 shows the general format for asynchronous serial communication.

In asynchronous serial communication, the transmission line is usually held in the mark level). The SCI monitors the transmission line, and when it goes to the space state (low level), recognizes a start bit and starts serial communication.

One serial communication character consists of a start bit (low level), followed by data (in first order), a parity bit (high or low level), and finally one or two stop bits (high level).

In asynchronous mode, the SCI performs synchronization at the falling edge of the start bit reception. The SCI samples the data on the 8th pulse of a clock with a frequency of 16 times the baud rate, so that the transfer data is latched at the center of each bit.

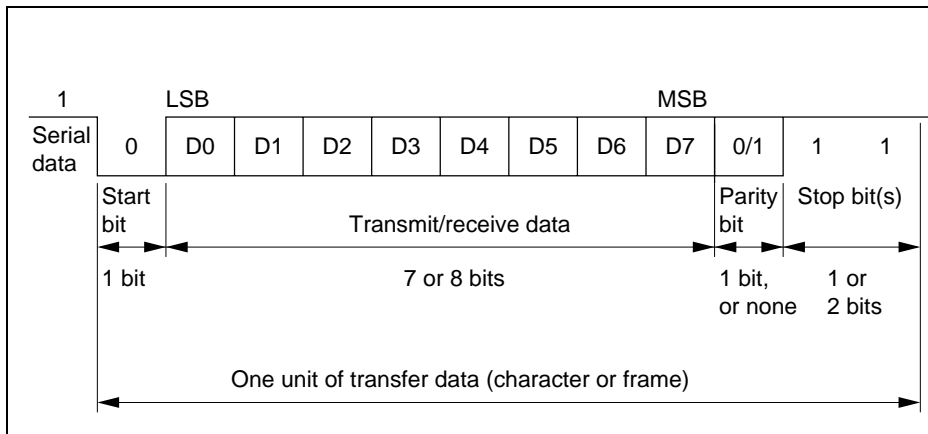


Figure 15.2 Data Format in Asynchronous Communication (Example with 8-Bit Data, Parity, Two Stop Bits)

0	0	0	0	S	8-bit data	STOP
0	0	0	1	S	8-bit data	STOP
0	1	0	0	S	8-bit data	P
0	1	0	1	S	8-bit data	P
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
0	—	1	0	S	8-bit data	MPB
0	—	1	1	S	8-bit data	MPB
1	—	1	0	S	7-bit data	MPB STOP
1	—	1	1	S	7-bit data	MPB STOP

Legend:

S: Start bit

STOP: Stop bit

P: Parity bit

MPB: Multiprocessor bit

When the SCI is operated on an internal clock, the clock can be output from the SCK pin. The frequency of the clock output in this case is equal to the bit rate, and the phase is such that the rising edge of the clock is at the center of each transmit data bit, as shown in figure 15.3.

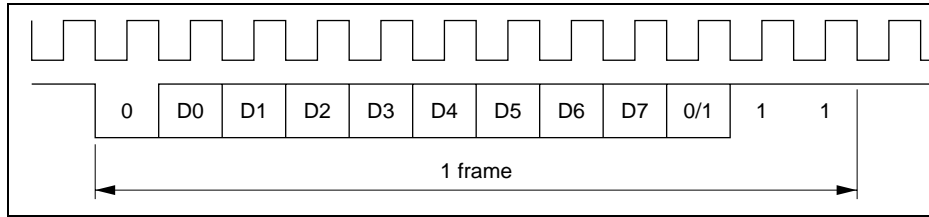


Figure 15.3 Relation between Output Clock and Transfer Data Phase (Asynchronous Mode)

Data Transfer Operations

SCI Initialization (Asynchronous Mode): Before transmitting and receiving data, first clear the TE and RE bits in SCR to 0, then initialize the SCI as described below.

When the operating mode, transfer format, etc., is changed, the TE and RE bits must be cleared to 0 before making the change using the following procedure. When the TE bit is cleared, the TDRE flag is set to 1 and TSR is initialized. Note that clearing the RE bit to 0 does not clear the contents of the RDRF, PER, FER, and ORER flags, or the contents of RDR.

When an external clock is used the clock should not be stopped during operation, including initialization, since operation is uncertain.

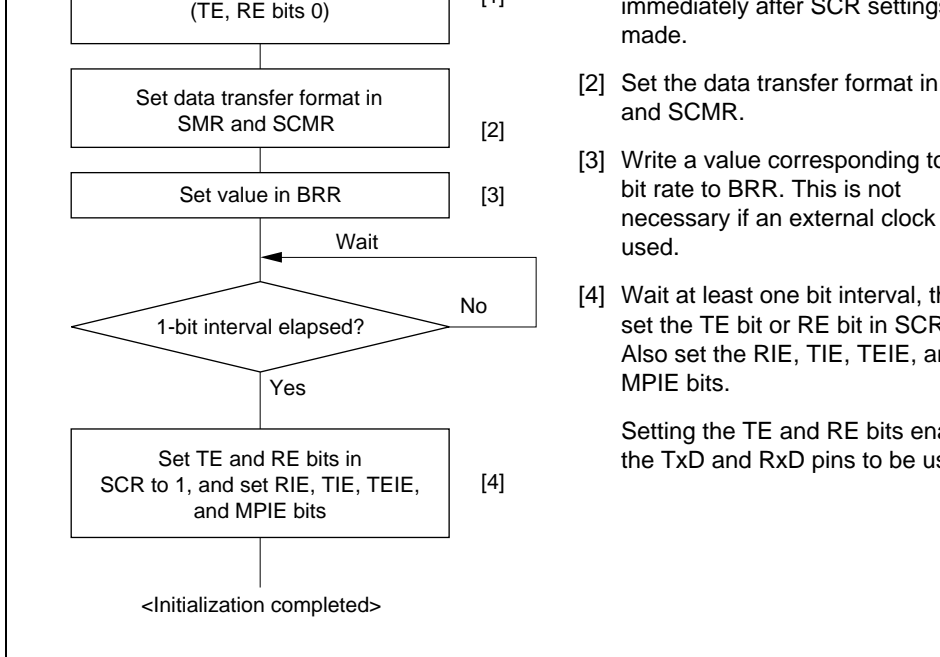
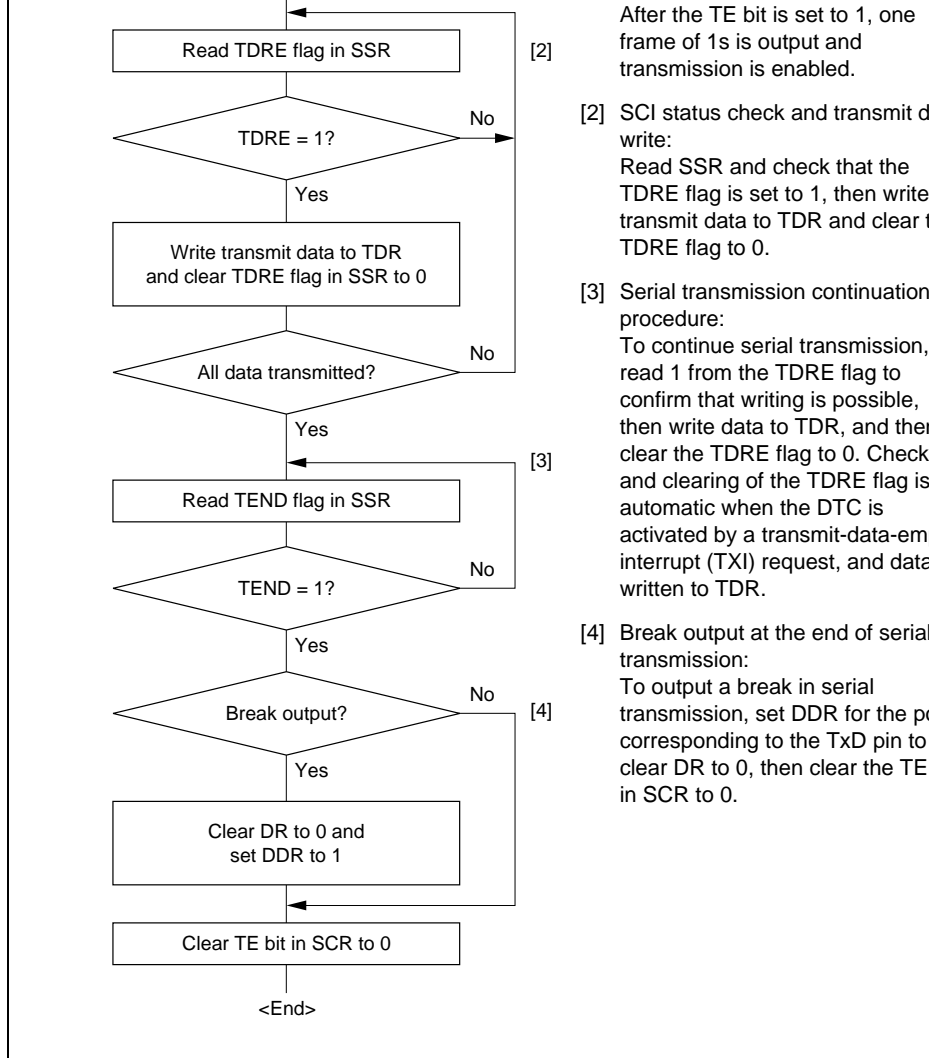


Figure 15.4 Sample SCI Initialization Flowchart



- [2] After the TE bit is set to 1, one frame of 1s is output and transmission is enabled.
- [2] SCI status check and transmit data write:
Read SSR and check that the TDRE flag is set to 1, then write transmit data to TDR and clear the TDRE flag to 0.
- [3] Serial transmission continuation procedure:
To continue serial transmission, read 1 from the TDRE flag to confirm that writing is possible, then write data to TDR, and then clear the TDRE flag to 0. Check and clearing of the TDRE flag is automatic when the DTC is activated by a transmit-data-empty interrupt (TXI) request, and data is written to TDR.
- [4] Break output at the end of serial transmission:
To output a break in serial transmission, set DDR for the pin corresponding to the TxD pin to clear DR to 0, then clear the TE bit in SCR to 0.

Figure 15.5 Sample Serial Transmission Flowchart



The serial transmit data is sent from the TXD pin in the following order:

- a. Start bit:
One 0-bit is output.
 - b. Transmit data:
8-bit or 7-bit data is output in LSB-first order.
 - c. Parity bit or multiprocessor bit:
One parity bit (even or odd parity), or one multiprocessor bit is output.
A format in which neither a parity bit nor a multiprocessor bit is output can also be selected.
 - d. Stop bit(s):
One or two 1-bits (stop bits) are output.
 - e. Mark state:
1 is output continuously until the start bit that starts the next transmission is sent.
3. The SCI checks the TDRE flag at the timing for sending the stop bit.
- If the TDRE flag is cleared to 0, the data is transferred from TDR to TSR, the stop bit is sent, and then serial transmission of the next frame is started.
- If the TDRE flag is set to 1, the TEND flag in SSR is set to 1, the stop bit is sent, and a mark state is entered in which 1 is output continuously. If the TEIE bit in SCR is set to 1 at this time, a TEI interrupt request is generated.

Figure 15.6 shows an example of the operation for transmission in asynchronous mode.

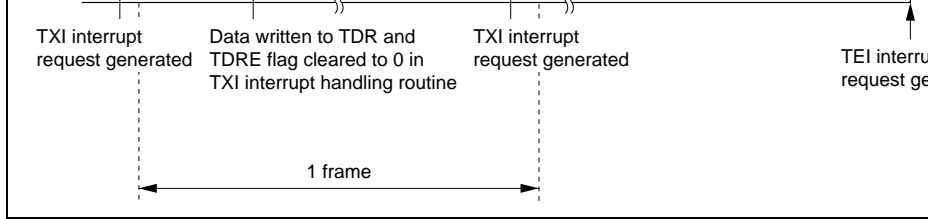
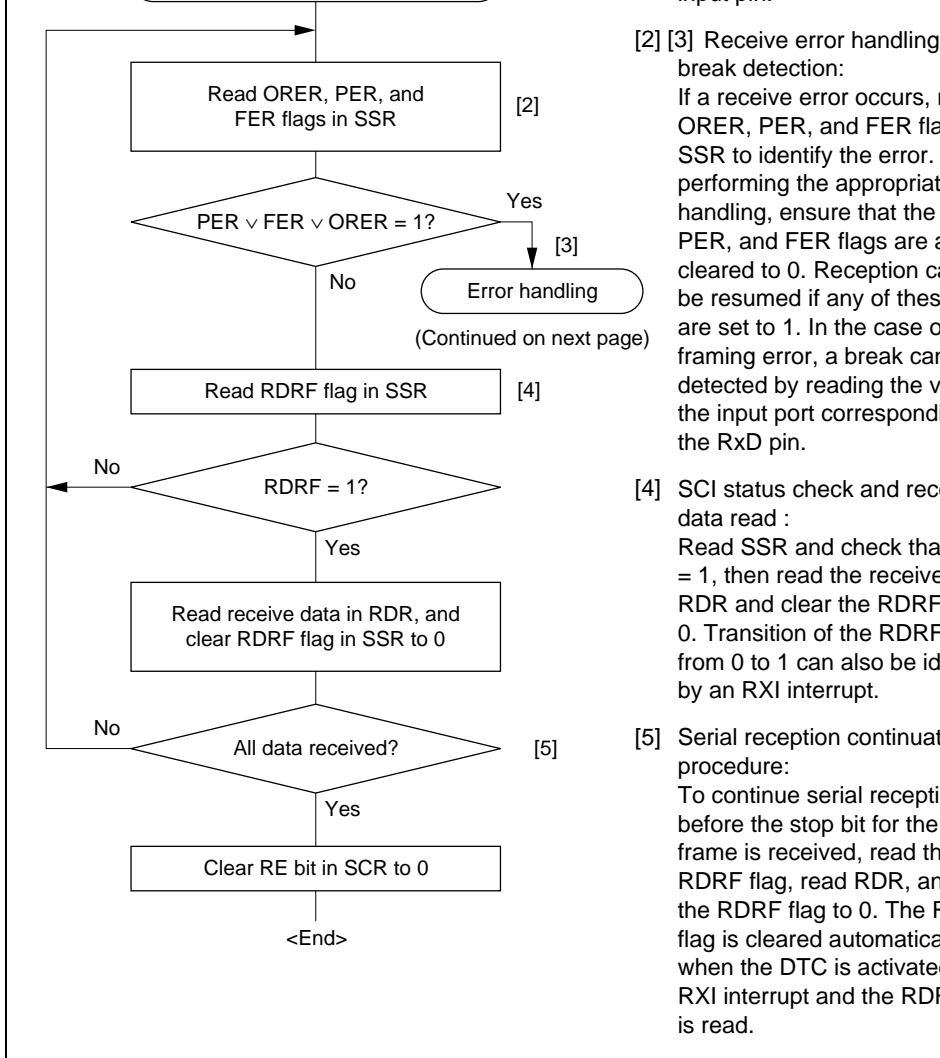


Figure 15.6 Example of Operation in Transmission in Asynchronous Mode (Example with 8-Bit Data, Parity, One Stop Bit)



- [2] [3] Receive error handling break detection:
If a receive error occurs, read the ORER, PER, and FER flags in the SSR to identify the error. When performing the appropriate error handling, ensure that the ORER, PER, and FER flags are all cleared to 0. Reception can be resumed if any of these flags are set to 1. In the case of a framing error, a break can be detected by reading the value of the input port corresponding to the Rx pin.
- [4] SCI status check and receive data read :
Read SSR and check that RDRF = 1, then read the receive data in RDR and clear the RDRF flag to 0. Transition of the RDRF flag from 0 to 1 can also be identified by an RXI interrupt.
- [5] Serial reception continuation procedure:
To continue serial reception before the stop bit for the next frame is received, read the RDRF flag, read RDR, and clear the RDRF flag to 0. The RDRF flag is cleared automatically when the DTC is activated. After the RXI interrupt and the RDR is read.

Figure 15.7 Sample Serial Reception Data Flowchart

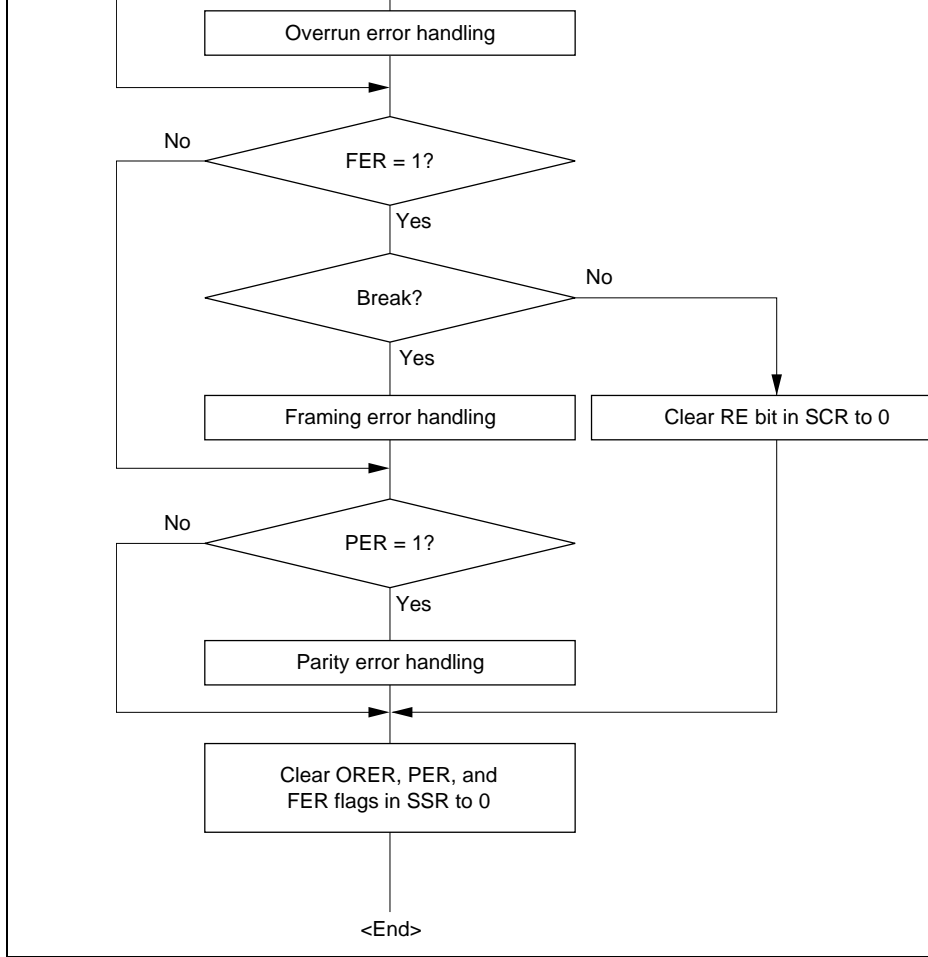


Figure 15.7 Sample Serial Reception Data Flowchart (cont)

a. Parity check:

The SCI checks whether the number of 1 bits in the receive data agrees with the (even or odd) set in the O/\bar{E} bit in SMR.

b. Stop bit check:

The SCI checks whether the stop bit is 1.

If there are two stop bits, only the first is checked.

c. Status check:

The SCI checks whether the RDRF flag is 0, indicating that the receive data cannot be transferred from RSR to RDR.

If all the above checks are passed, the RDRF flag is set to 1, and the receive data is transferred from RSR to RDR.

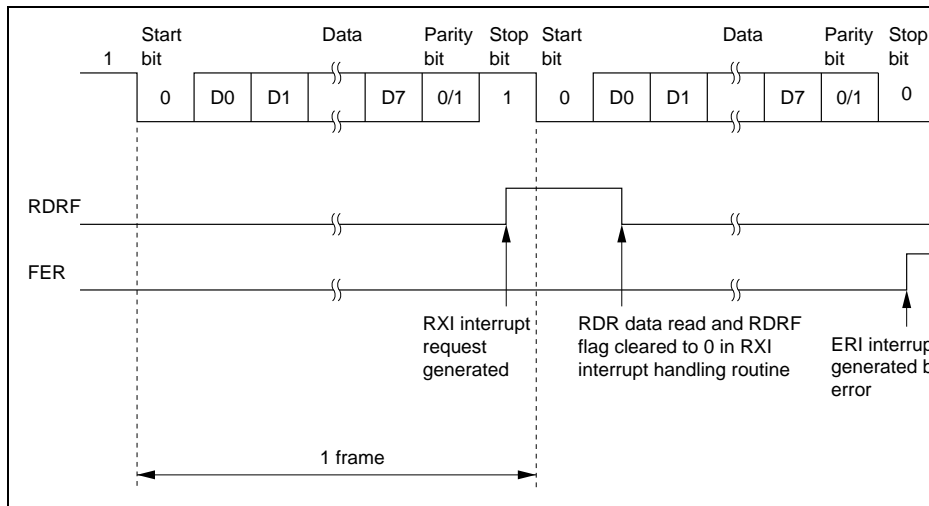
If a receive error* is detected in the error check, the operation is as shown in table 1.

Note: * Subsequent receive operations cannot be performed when a receive error has occurred. Also note that the RDRF flag is not set to 1 in reception, and so the error flag is cleared to 0.

4. If the RIE bit in SCR is set to 1 when the RDRF flag changes to 1, a receive-data-full (RXI) request is generated.

Also, if the RIE bit in SCR is set to 1 when the ORER, PER, or FER flag changes to 1, a receive-error interrupt (ERI) request is generated.

Figure 15.8 shows an example of the operation for reception in asynchronous mode.



**Figure 15.8 Example of SCI Operation in Reception
(Example with 8-Bit Data, Parity, One Stop Bit)**

The serial communication cycle consists of two component cycles: an ID transmission cycle which specifies the receiving station, and a data transmission cycle. The multiprocessor format is used to differentiate between the ID transmission cycle and the data transmission cycle.

The transmitting station first sends the ID of the receiving station with which it wants to communicate in serial communication as data with a 1 multiprocessor bit added. It then sends transmit data with a 0 multiprocessor bit added.

The receiving station skips the data until data with a 1 multiprocessor bit is sent.

When data with a 1 multiprocessor bit is received, the receiving station compares that data with its own ID. The station whose ID matches then receives the data sent next. Stations whose ID does not match continue to skip the data until data with a 1 multiprocessor bit is again received. In this way, data communication is carried out among a number of processors.

Figure 15.9 shows an example of inter-processor communication using a multiprocessor format.

Data Transfer Format

There are four data transfer formats.

When a multiprocessor format is specified, the parity bit specification is invalid.

For details, see table 15.10.

Clock

See the section on asynchronous mode.

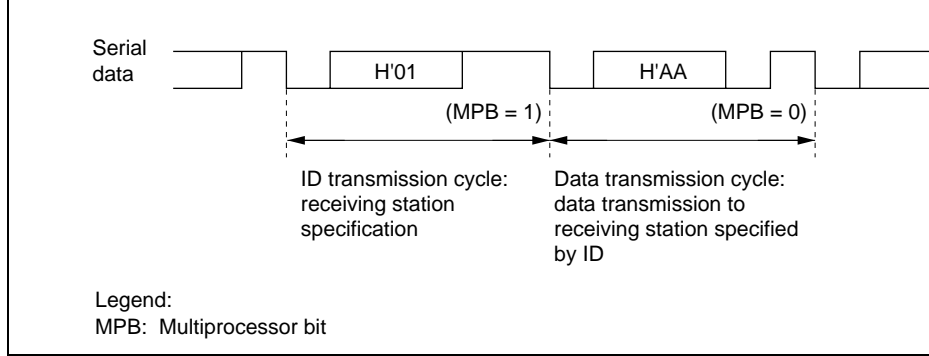
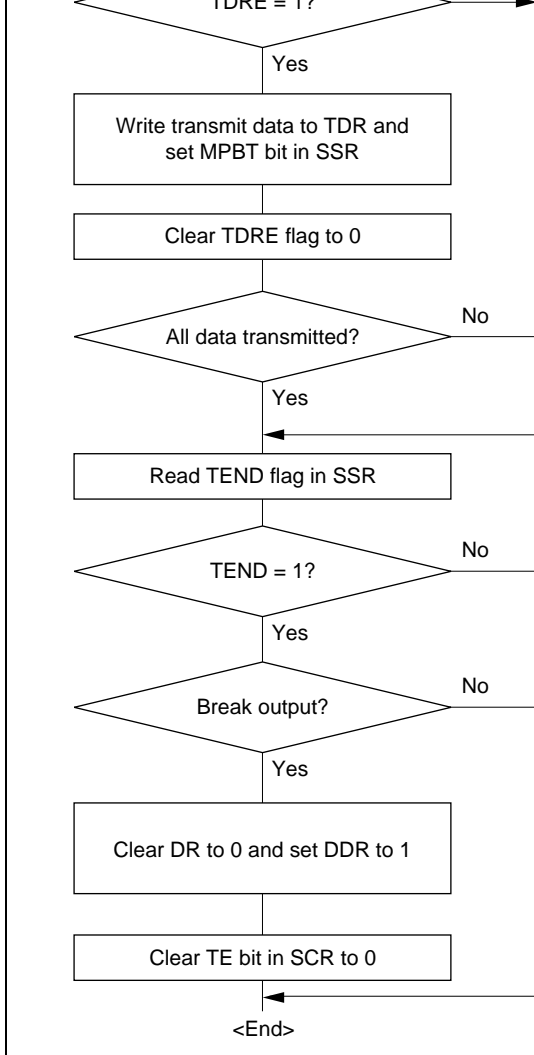


Figure 15.9 Example of Inter-Processor Communication Using Multiprocessor Bit (Transmission of Data H'AA to Receiving Station A)

Data Transfer Operations

Multiprocessor Serial Data Transmission: Figure 15.10 shows a sample flowchart for multiprocessor serial data transmission.

The following procedure should be used for multiprocessor serial data transmission.



data write:
 Read SSR and check that the TDRE flag is set to 1, then write transmit data to TDR. Set the MPBT bit in SSR to 0 or 1. Finally, clear the TDRE flag

[3] Serial transmission continuation procedure:
 To continue serial transmission, be sure to read 1 from the TEND flag to confirm that writing is possible, then write data to TDR and then clear the TDRE flag to 0. Checking and clearing of the TDRE flag is automatic when DTC is activated by a transmit data-empty interrupt (TXI) request, and data is written to TDR.

[4] Break output at the end of serial transmission:
 To output a break in serial transmission, set the port DDR to 1, clear DR to 0, then clear the TE bit in SCR to 0.

Figure 15.10 Sample Multiprocessor Serial Transmission Flowchart

- The serial transmit data is sent from the TXD pin in the following order:
- a. Start bit:
One 0-bit is output.
 - b. Transmit data:
8-bit or 7-bit data is output in LSB-first order.
 - c. Multiprocessor bit
One multiprocessor bit (MPBT value) is output.
 - d. Stop bit(s):
One or two 1-bits (stop bits) are output.
 - e. Mark state:
1 is output continuously until the start bit that starts the next transmission is sent.
3. The SCI checks the TDRE flag at the timing for sending the stop bit.
If the TDRE flag is cleared to 0, data is transferred from TDR to TSR, the stop bit is sent, and then serial transmission of the next frame is started.
If the TDRE flag is set to 1, the TEND flag in SSR is set to 1, the stop bit is sent, and a mark state is entered in which 1 is output continuously. If the TEIE bit in SCR is set to 1 at this time, a transmit-end interrupt (TEI) request is generated.

Figure 15.11 shows an example of SCI operation for transmission using a multiprocessor

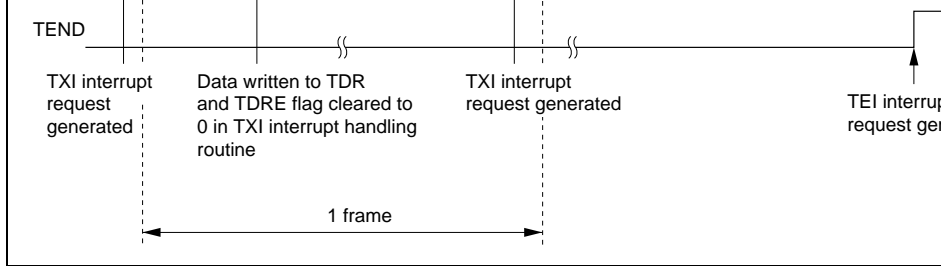
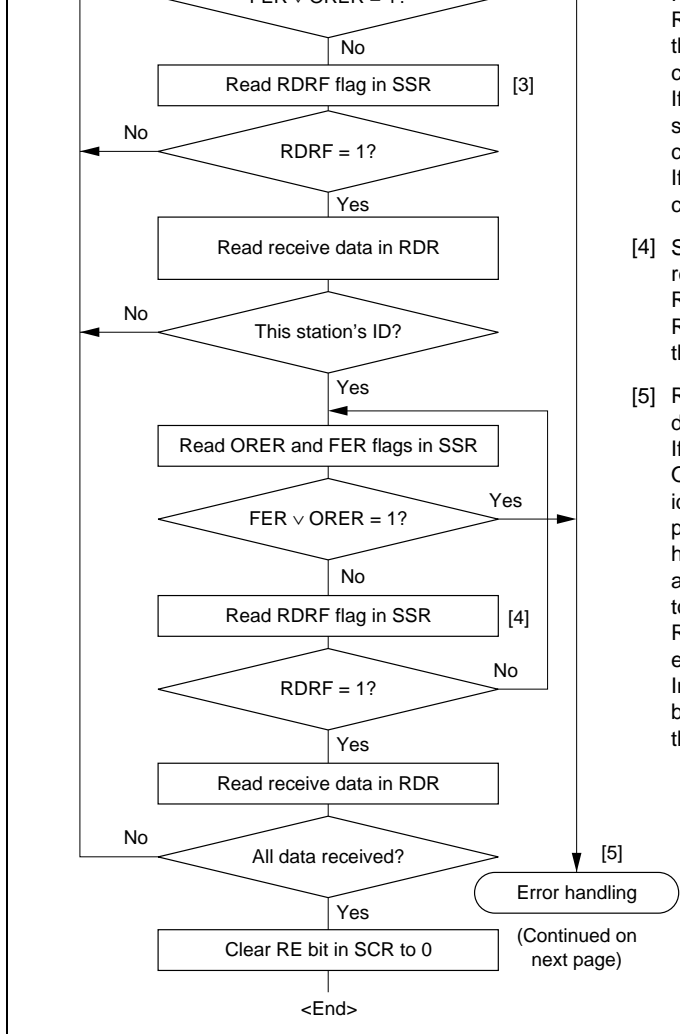


Figure 15.11 Example of SCI Operation in Transmission (Example with 8-Bit Data, Multiprocessor Bit, One Stop Bit)

Multiprocessor Serial Data Reception: Figure 15.12 shows a sample flowchart for multiprocessor serial reception.

The following procedure should be used for multiprocessor serial data reception.



RDRF flag is set to 1, then the receive data in RDR and compare it with this station's ID. If the data is not this station's ID, set the MPIE bit to 1 again, 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 handling and detection:
If a receive error occurs, read the ORER and FER flags in SSR to identify the error. After performing the appropriate error handling, ensure that the ORER and FER flags are both cleared to 0. Reception cannot be resumed until either of these flags is set to 0. In the case of a framing error, a break can be detected by reading the RxD pin value.

Figure 15.12 Sample Multiprocessor Serial Reception Flowchart



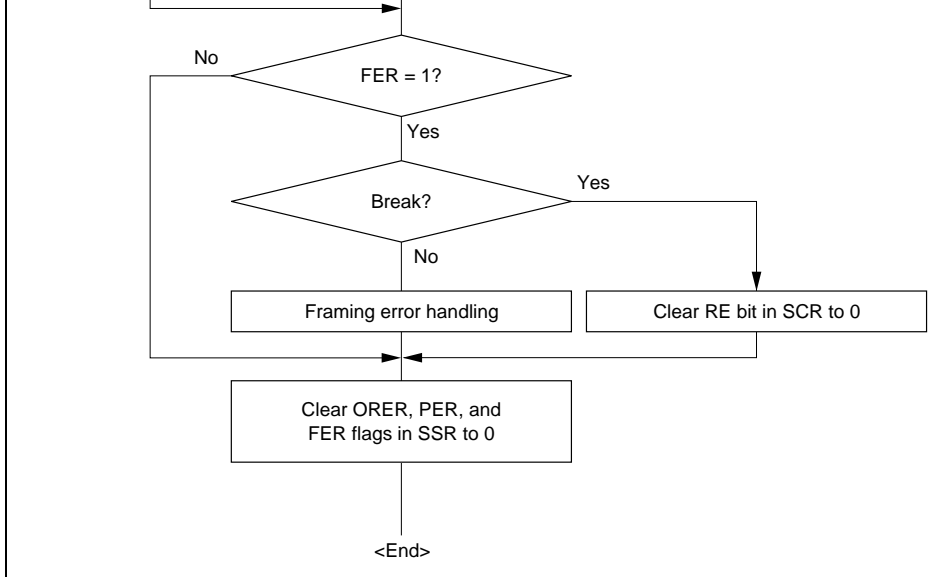


Figure 15.12 Sample Multiprocessor Serial Reception Flowchart (cont)

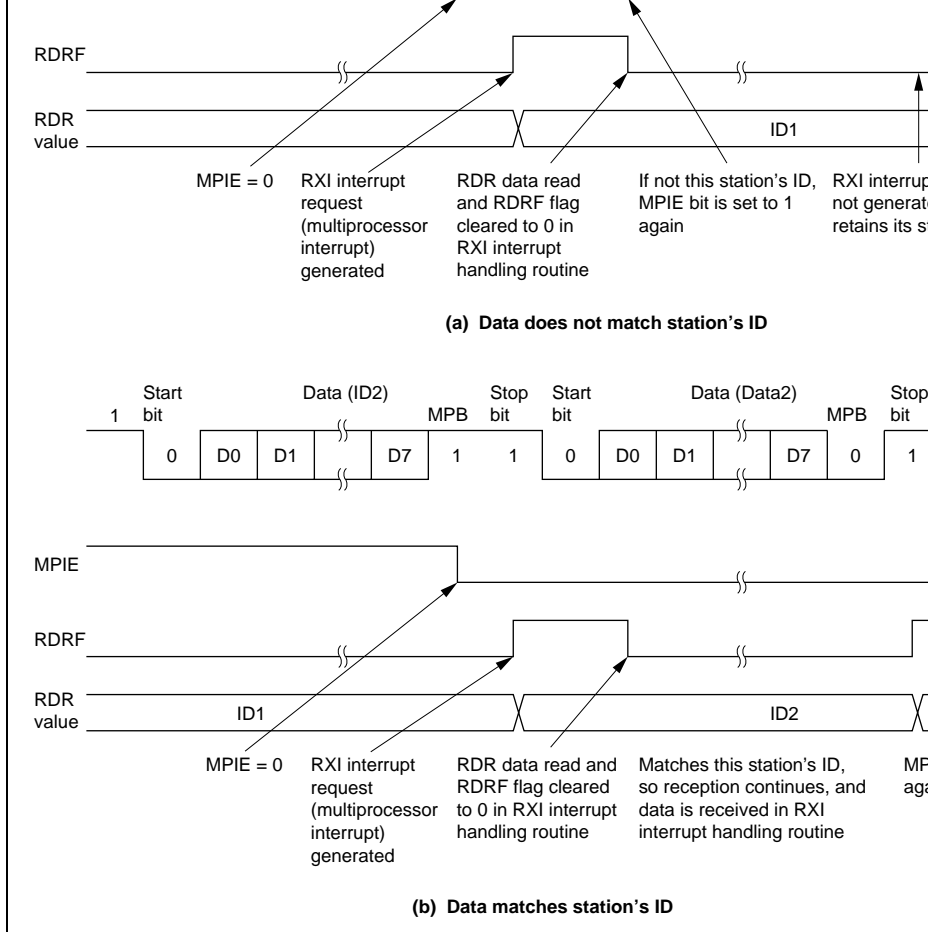


Figure 15.13 Example of SCI Operation in Reception (Example with 8-Bit Data, Multiprocessor Bit, One Stop Bit)

Figure 15.14 shows the general format for synchronous serial communication.

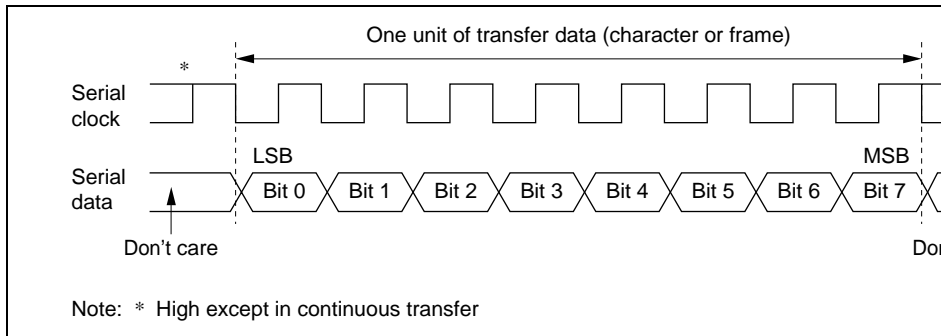


Figure 15.14 Data Format in Synchronous Communication

In synchronous serial communication, data on the transmission line is output from one of the serial clock to the next. Data is guaranteed valid at the rising edge of the serial clock.

In synchronous serial communication, one character consists of data output starting with the LSB and ending with the MSB. After the MSB is output, the transmission line holds the MSB.

In synchronous mode, the SCI receives data in synchronization with the rising edge of the serial clock.

Data Transfer Format

A fixed 8-bit data format is used.

No parity or multiprocessor bits are added.

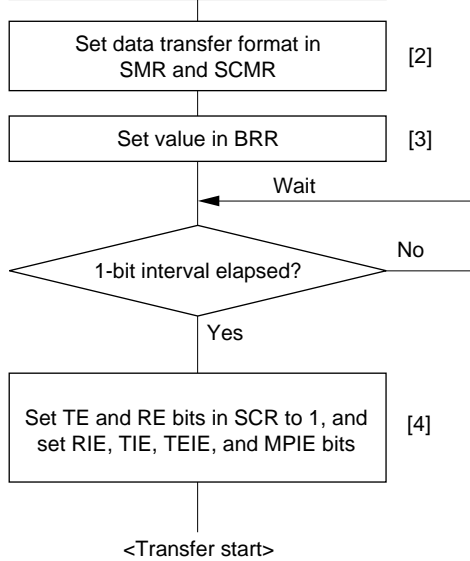
performed the clock is fixed high. When only receive operations are performed, however, the serial clock is output until an overrun error occurs or the RE bit is cleared to 0. To perform operations in units of one character, select an external clock as the clock source.

Data Transfer Operations

SCI Initialization (Synchronous Mode): Before transmitting and receiving data, first clear the TE and RE bits in SCR to 0, then initialize the SCI as described below.

When the operating mode, transfer format, etc., is changed, the TE and RE bits must be cleared to 0 before making the change using the following procedure. When the TE bit is cleared, the TDRE flag is set to 1 and TSR is initialized. Note that clearing the RE bit to 0 does not clear the settings of the RDRF, PER, FER, and ORER flags, or the contents of RDR.

Figure 15.15 shows a sample SCI initialization flowchart.

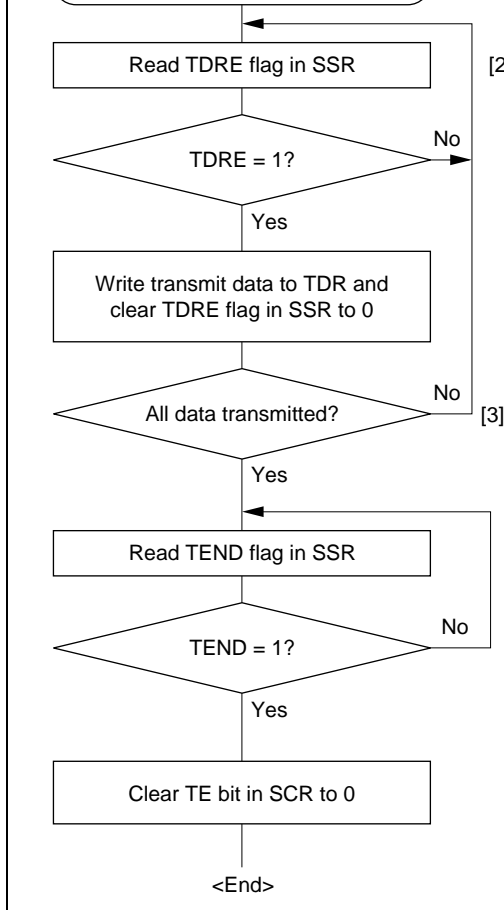


external clock is used.

[4] Wait at least one bit interval, then 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 enable TxD and RxD pins to be used.

Note: In simultaneous transmit and receive operations, the TE bit and RE bit should both be set to 0 or set to 1 simultaneously.

Figure 15.15 Sample SCI Initialization Flowchart



- [2] SCI status check and transmit write:
 Read SSR and check that the flag is set to 1, then write transmit data to TDR and clear the TDRE flag to 0.
- [3] Serial transmission continuation procedure:
 To continue serial transmission, ensure to read 1 from the TDRE flag to confirm that writing is possible. Then write data to TDR, and then clear the TDRE flag to 0.
 Checking and clearing of the TEND flag is automatic when the DTEN bit is activated by a transmit-data-end interrupt (TXI) request and data is written to TDR.

Figure 15.16 Sample Serial Transmission Flowchart

external clock has been specified, data is output synchronized with the input clock.

The serial transmit data is sent from the TxD pin starting with the LSB (bit 0) and ending with the MSB (bit 7).

3. The SCI checks the TDRE flag at the timing for sending the MSB (bit 7).

If the TDRE flag is cleared to 0, data is transferred from TDR to TSR, and serial transmission of the next frame is started.

If the TDRE flag is set to 1, the TEND flag in SSR is set to 1, the MSB (bit 7) is sent from the TxD pin maintains its state.

If the TEIE bit in SCR is set to 1 at this time, a transmit-end interrupt (TEI) request is generated.

4. After completion of serial transmission, the SCK pin is held in a constant state.

Figure 15.17 shows an example of SCI operation in transmission.

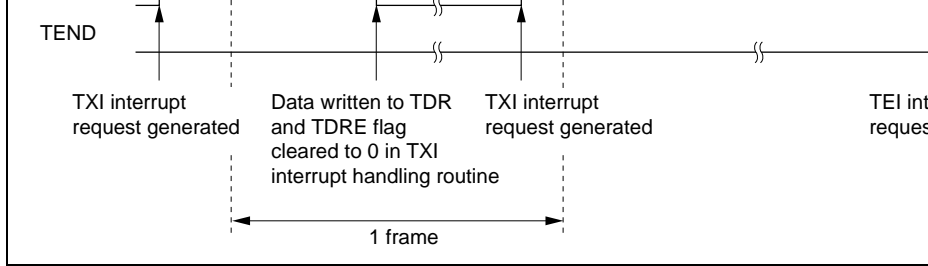


Figure 15.17 Example of SCI Operation in Transmission

Serial Data Reception (Synchronous Mode): Figure 15.18 shows a sample flowchart for serial data reception.

The following procedure should be used for serial data reception.

When changing the operating mode from asynchronous to synchronous, be sure to check and clear the ORER, PER, and FER flags to 0.

The RDRF flag will not be set if the FER or PER flag is set to 1, and neither transmit nor receive operations will be possible.

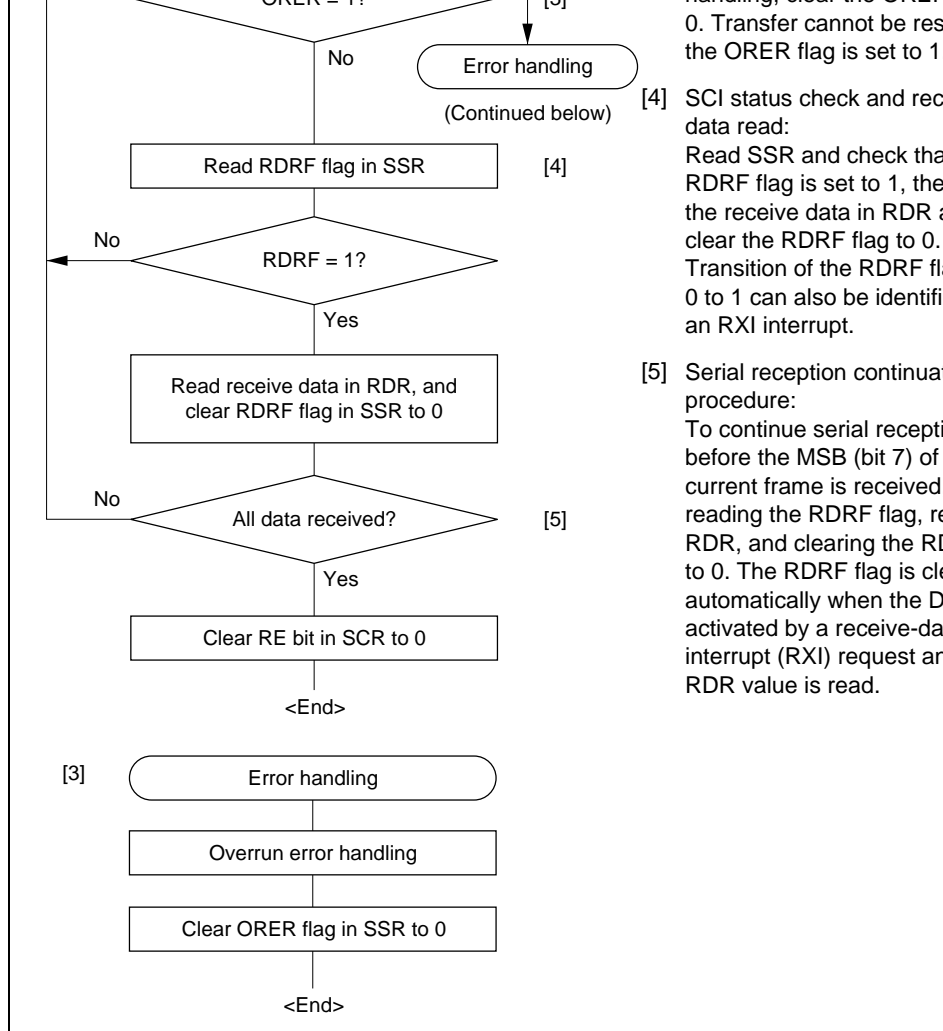


Figure 15.18 Sample Serial Reception Flowchart

Neither transmit nor receive operations can be performed subsequently when a receive error has been found in the error check.

3. If the RIE bit in SCR is set to 1 when the RDRF flag changes to 1, a receive-data-ready (RXI) request is generated.

Also, if the RIE bit in SCR is set to 1 when the ORER flag changes to 1, a receive-overrun interrupt (ERI) request is generated.

Figure 15.19 shows an example of SCI operation in reception.

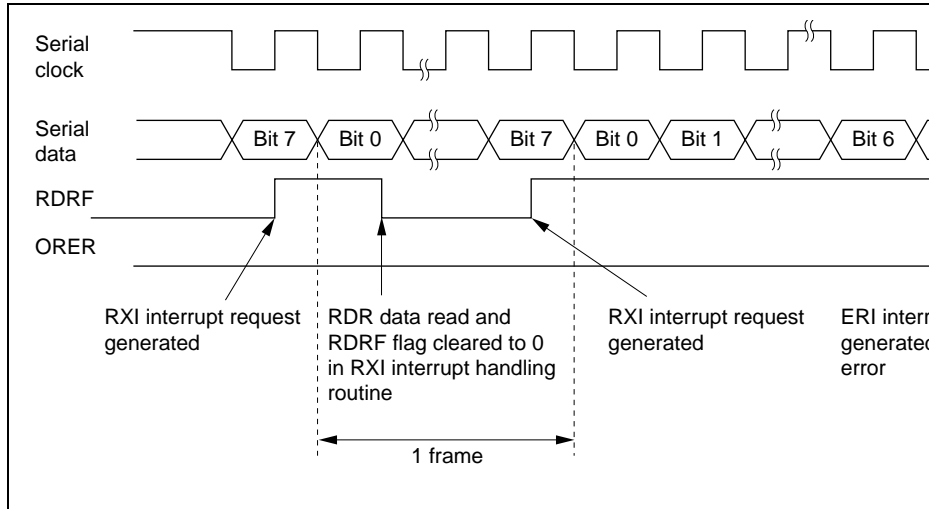
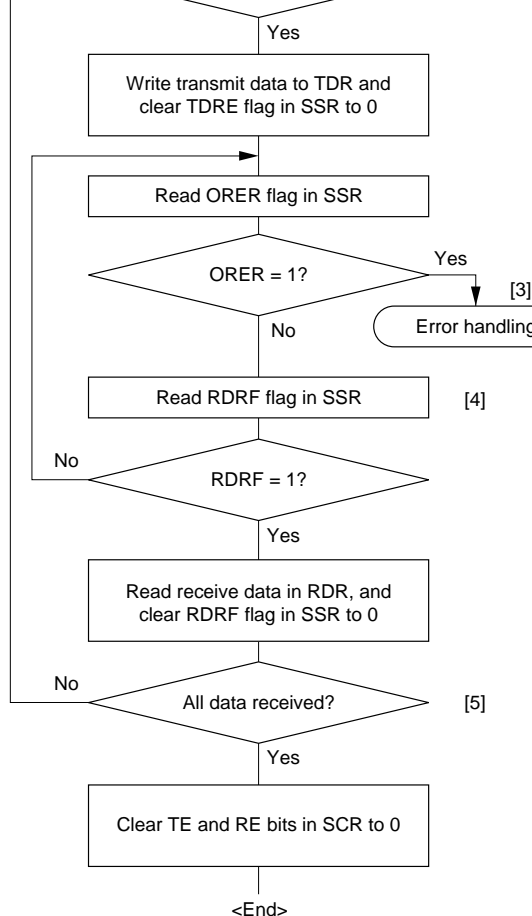


Figure 15.19 Example of SCI Operation in Reception

Simultaneous Serial Data Transmission and Reception (Synchronous Mode): Figure 15.20 shows a sample flowchart for simultaneous serial transmit and receive operations.

The following procedure should be used for simultaneous serial data transmit and receive operations.



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.

- transmit data to TDR and clear TDRE flag to 0.
- Transition of the TDRE flag to 1 can also be identified by an interrupt.
- [3] Receive error handling:
If a receive error occurs, read the ORER flag in SSR, and after performing the appropriate error handling, clear the ORER flag. Transmission/reception can be resumed if the ORER flag is 0.
- [4] SCI status check and receive data read:
Read SSR and check that the RDRF flag is set to 1, then read receive data in RDR and clear the RDRF flag to 0. Transition of the RDRF flag from 0 to 1 can also be identified by an RXI interrupt.
- [5] Serial transmission/reception continuation procedure:
To continue serial transmission/reception, before the MSB (bit 7) of the current frame is received, read the RDRF flag, read the RDR, and clearing the RDRF flag to 0. Also, before the MSB (bit 7) of the current frame is transmitted, read 1 from the TDRE flag to confirm that writing is possible. Write data to TDR and clear the TDRE flag to 0.
- Checking and clearing of the TDRE flag is automatic when the DTC is activated by a transmit-data full interrupt (TXI) request and data is written to TDR. Also, the RDRF flag is cleared automatically when the DTC is activated by a receive-data full interrupt (RXI) request and the RDR value is read.

Figure 15.20 Sample Flowchart of Simultaneous Serial Transmit and Receive Operation

In the IrDA specification version 1.0 system, communication is started at a transfer rate of 115.2 kbps, and subsequently the transfer rate can be varied as necessary. As the IrDA interface LSI does not include a function for varying the transfer rate automatically, the transfer rate must be changed by software.

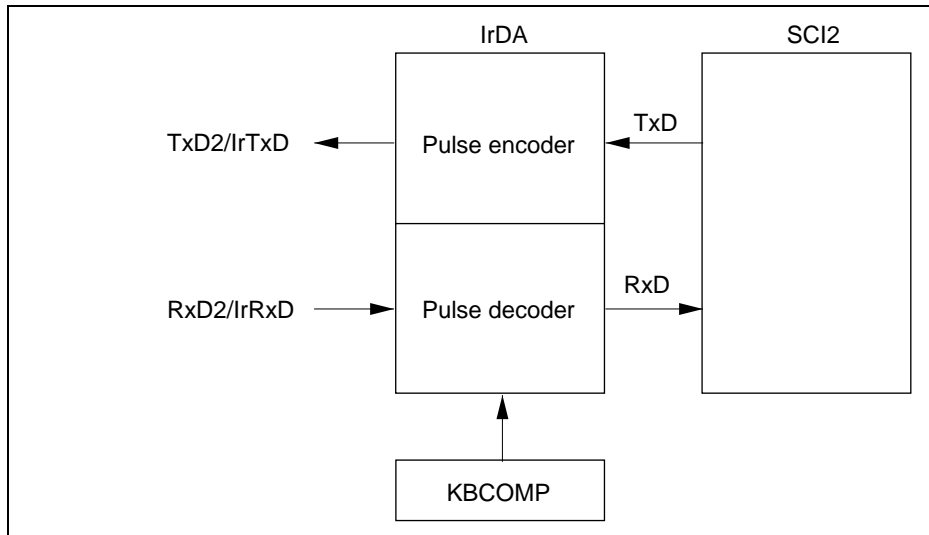


Figure 15.21 Block Diagram of IrDA Function

Transmission

In transmission, the output signal (UART frame) from the SCI is converted to an IR frame by the IrDA interface (see figure 15.22).

When the serial data is 0, a high-level pulse of 3/16 the bit rate (interval equivalent to 3/16 of one bit) is output (initial value). The high-level pulse can be varied according to the bits IrCKS2 to IrCKS0 in KBCOMP.

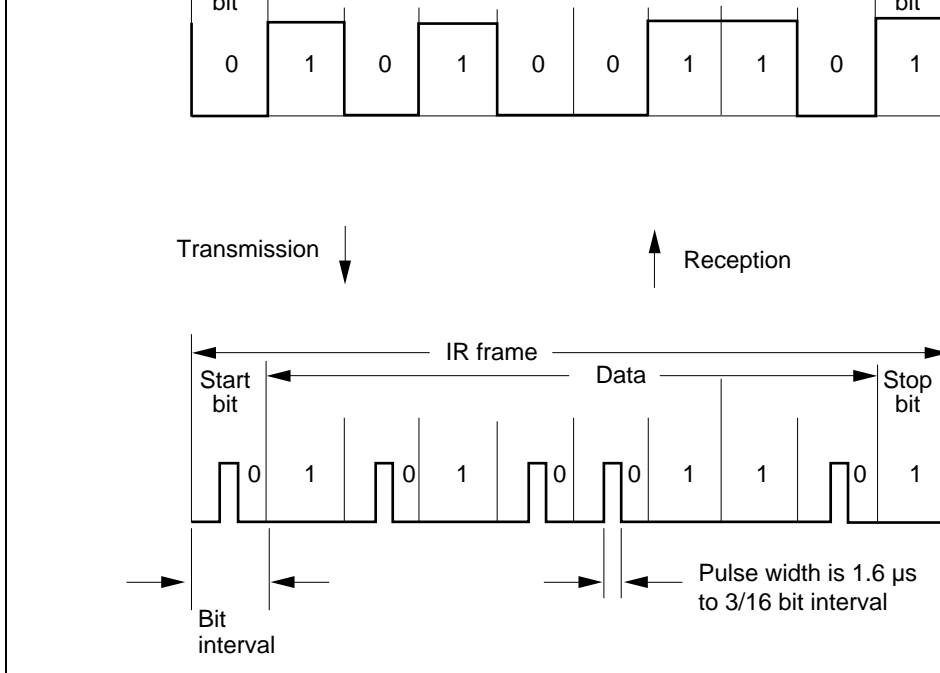


Figure 15.22 IrDA Transmit/Receive Operations

Reception

In reception, IR frame data is converted to a UART frame by the IrDA interface, and in SCI.

When a high-level pulse is detected, 0 data is output, and if there is no pulse during a bit interval, 1 data is output. Note that a pulse shorter than the minimum pulse width of 1.4 μs will be identified as a 0 signal.

Operating Frequency ϕ (MHz)	2400	9600	19200	38400	57600
	78.13	19.53	9.77	4.88	3.26
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
4.9152	011	011	011	011	011
5	011	011	011	011	011
6	100	100	100	100	100
6.144	100	100	100	100	100
7.3728	100	100	100	100	100
8	100	100	100	100	100
9.8304	100	100	100	100	100
10	100	100	100	100	100
12	101	101	101	101	101
12.288	101	101	101	101	101
14	101	101	101	101	101
14.7456	101	101	101	101	101
16	101	101	101	101	101
16.9344	101	101	101	101	101
17.2032	101	101	101	101	101
18	101	101	101	101	101
19.6608	101	101	101	101	101
20	101	101	101	101	101

Legend:

—: An SCI bit rate setting cannot be mode.

in SSR is set to 1, a TEI interrupt request is generated. A TXI interrupt can activate the DTC to perform data transfer. The TDRE flag is cleared to 0 automatically when data transfer is performed by the DTC. The DTC cannot be activated by a TEI interrupt request.

When the RDRF flag in SSR is set to 1, an RXI interrupt request is generated. When the ORER, FER, or PER flag in SSR is set to 1, an ERI interrupt request is generated. An RXI interrupt can activate the DTC to perform data transfer. The RDRF flag is cleared to 0 automatically when data transfer is performed by the DTC. The DTC cannot be activated by an ERI interrupt request.

Table 15.13 SCI Interrupt Sources

Channel	Interrupt Source	Description	DTC Activation
0	ERI	Receive error (ORER, FER, or PER)	Not possible
	RXI	Receive data register full (RDRF)	Possible
	TXI	Transmit data register empty (TDRE)	Possible
	TEI	Transmit end (TEND)	Not possible
1	ERI	Receive error (ORER, FER, or PER)	Not possible
	RXI	Receive data register full (RDRF)	Possible
	TXI	Transmit data register empty (TDRE)	Possible
	TEI	Transmit end (TEND)	Not possible
2	ERI	Receive error (ORER, FER, or PER)	Not possible
	RXI	Receive data register full (RDRF)	Possible
	TXI	Transmit data register empty (TDRE)	Possible
	TEI	Transmit end (TEND)	Not possible

Note: * The table shows the initial state immediately after a reset. Relative channel priority can be changed by the interrupt controller.

The TEI interrupt is requested when the TEND flag is set to 1 while the TEIE bit is set to 1. The TEND flag is cleared at the same time as the TDRE flag. Consequently, if a TEI interrupt

Relation between Writes to TDR and the TDRE Flag

The TDRE flag in SSR is a status flag that indicates that transmit data has been transferred from TDR to TSR. When the SCI transfers data from TDR to TSR, the TDRE flag is set to 1.

Data can be written to TDR regardless of the state of the TDRE flag. However, if new data is written to TDR when the TDRE flag is cleared to 0, the data stored in TDR will be lost. It is therefore essential to check that the TDRE flag is set to 1 before writing transmit data to TDR.

Operation when Multiple Receive Errors Occur Simultaneously

If a number of receive errors occur at the same time, the state of the status flags in SSR is shown in table 15.14. If there is an overrun error, data is not transferred from RSR to RDR. If there is a framing error, the receive data is lost.

Table 15.14 State of SSR Status Flags and Transfer of Receive Data

RDRF	SSR Status Flags			Receive Data Transfer	Receive Errors
	ORER	FER	PER	RSR to RDR	
1	1	0	0	X	Overrun error
0	0	1	0	O	Framing error
0	0	0	1	O	Parity error
1	1	1	0	X	Overrun error + framing error
1	1	0	1	X	Overrun error + parity error
0	0	1	1	O	Framing error + parity error
1	1	1	1	X	Overrun error + framing error + parity error

Notes: O: Receive data is transferred from RSR to RDR.

X: Receive data is not transferred from RSR to RDR.

Sending a Break

The TxD pin has a dual function as an I/O port whose direction (input or output) is determined by the value of DR and DDR. This feature can be used to send a break.

Between serial transmission initialization and setting of the TE bit to 1, the mark state is determined by the value of DR (the pin does not function as the TxD pin until the TE bit is set to 1). Consequently, DDR and DR for the port corresponding to the TxD pin should first be set to 0.

To send a break during serial transmission, first clear DR to 0, then clear the TE bit to 0.

When the TE bit is cleared to 0, the transmitter is initialized regardless of the current transmission state, the TxD pin becomes an I/O port, and 0 is output from the TxD pin.

Receive Error Flags and Transmit Operations (Synchronous Mode Only)

Transmission cannot be started when a receive error flag (ORER, PER, or FER) is set to 1. The TDRE flag is cleared to 0. Be sure to clear the receive error flags to 0 before starting transmission.

Note also that receive error flags cannot be cleared to 0 even if the RE bit is cleared to 0.

Receive Data Sampling Timing and Reception Margin in Asynchronous Mode

In asynchronous mode, the SCI operates on a base clock with a frequency of 16 times the baud rate.

In reception, the SCI samples the falling edge of the start bit using the base clock, and performs internal synchronization. Receive data is latched internally at the rising edge of the 8th base clock. This is illustrated in figure 15.23.

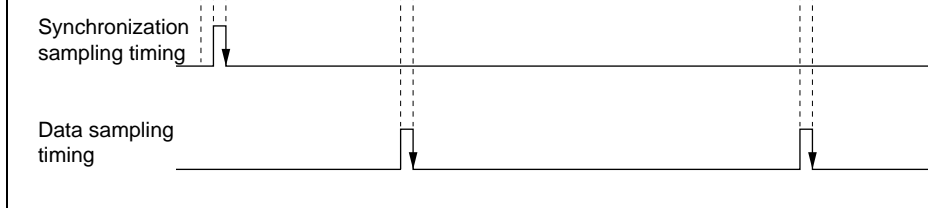


Figure 15.23 Receive Data Sampling Timing in Asynchronous Mode

Thus the receive margin in asynchronous mode is given by equation (1) below.

$$M = \left| \left(0.5 - \frac{1}{2N} \right) - (L - 0.5)F - \frac{|D - 0.5|}{N} (1 + F) \right| \times 100\% \quad \text{..... (1)}$$

- Where M: Receive margin (%)
- N: Ratio of bit rate to clock (N = 16)
- D: Clock duty (D = 0 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 equation (1), a receive margin of 46.875% is given by equation (2) below.

When D = 0.5 and F = 0,

$$M = \left(0.5 - \frac{1}{2 \times 16} \right) \times 100\% = 46.875\% \quad \text{..... (2)}$$

However, this is only a theoretical value, and a margin of 20% to 30% should be allowed in system design.

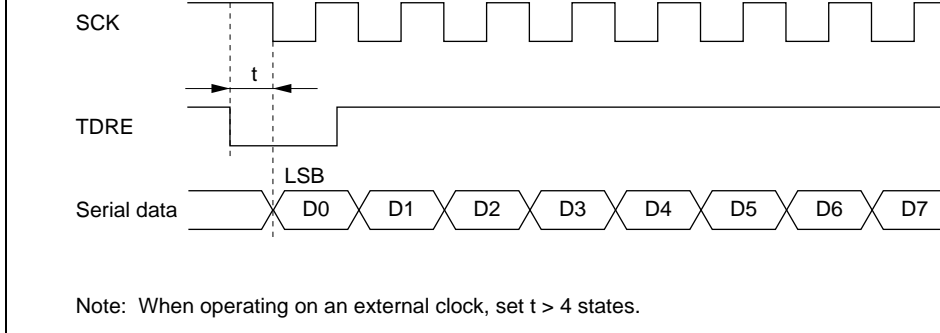


Figure 15.24 Example of Synchronous Transmission by DTC

Examples: HD6432147SWFA

2. The product number is identical for F-ZTAT versions. However, be sure to inform Renesas sales representative if you will be using this option.

16.1 Overview

A two-channel I²C bus interface is available for the H8S/2148 Group and H8S/2147N option. The I²C bus interface conforms to and provides a subset of the Philips I²C bus (bus) interface functions. The register configuration that controls the I²C bus differs from Philips configuration, however.

Each I²C bus interface channel uses only one data line (SDA) and one clock line (SCL) for data, saving board and connector space.

16.1.1 Features

- Selection of addressing format or non-addressing format
 - I²C bus format: addressing format with acknowledge bit, for master/slave operation
 - Serial format: non-addressing format without acknowledge bit, for master operation
- 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 acknowledge output levels when receiving (I²C bus format)
- Automatic loading of acknowledge bit when transmitting (I²C bus format)
- Wait function in master mode (I²C bus format)

A wait can be inserted by driving the SCL pin low after data transfer, excluding acknowledgement. The wait can be cleared by clearing the interrupt flag.

- Stop condition detection
- Selection of 16 internal clocks (in master mode)
- Direct bus drive (with SCL and SDA pins)
 - Two pins—P52/SCL0 and P97/SDA0—(normally NMOS push-pull outputs) function as NMOS open-drain outputs when the bus drive function is selected.
 - Two pins—P86/SCL1 and P42/SDA1—(normally CMOS pins) function as NMOS open-drain outputs when the bus drive function is selected.
- Automatic switching from formatless mode to I²C bus format (channel 0 only)
 - Formatless operation (no start/stop conditions, non-addressing mode) in slave mode
 - Operation using a common data pin (SDA) and independent clock pins (VSYN0)
 - Automatic switching from formatless mode to I²C bus format on the fall of the SCL pin

16.1.2 Block Diagram

Figure 16.1 shows a block diagram of the I²C bus interface.

Figure 16.2 shows an example of I/O pin connections to external circuits. Channel 0 I/O pins differ in structure, and have different specifications for permissible input and output voltages. For details, see section 26, Electrical Characteristics.

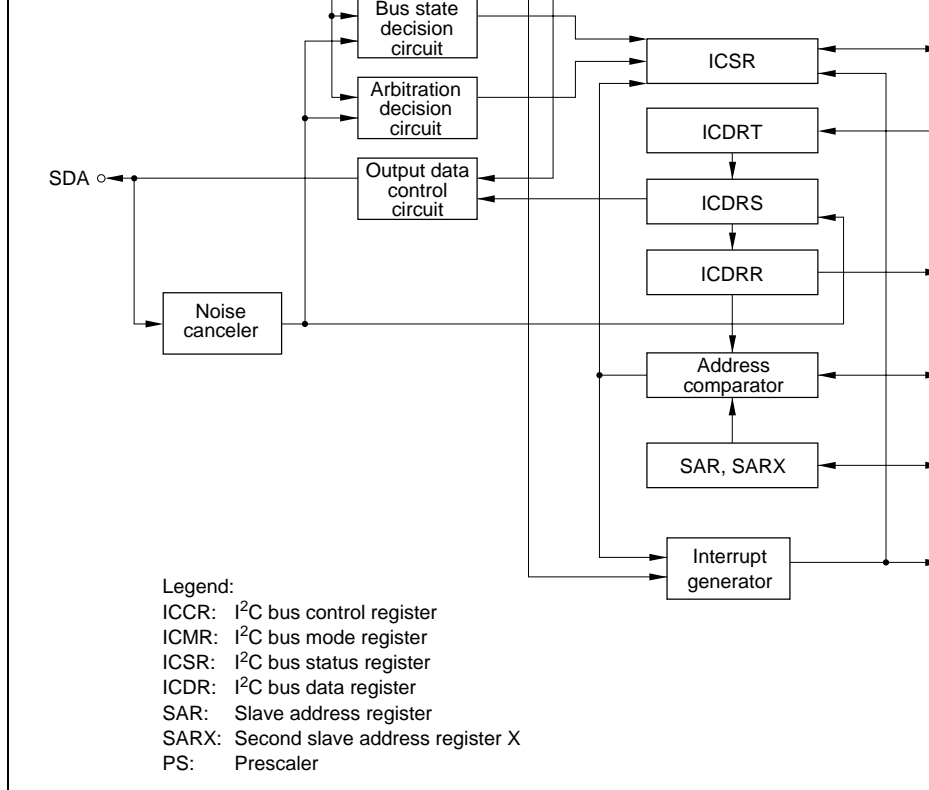


Figure 16.1 Block Diagram of I²C Bus Interface

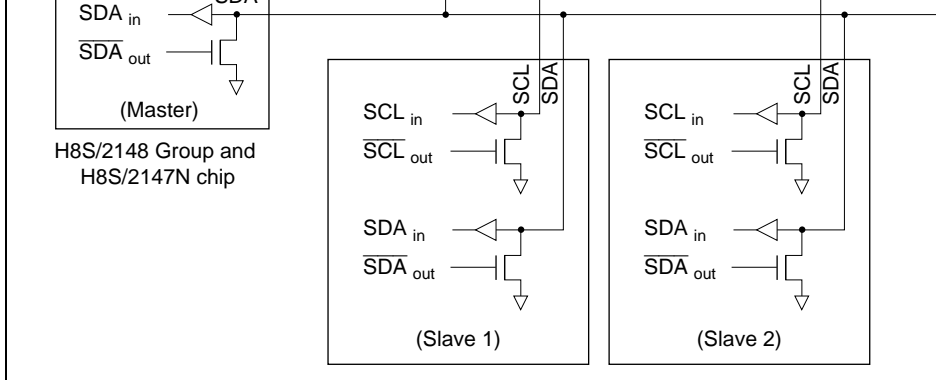


Figure 16.2 I²C Bus Interface Connections
(Example: H8S/2148 Group and H8S/2147N Chip as Master)

16.1.3 Input/Output Pins

Table 16.1 summarizes the input/output pins used by the I²C bus interface.

Table 16.1 I²C Bus Interface Pins

Channel	Name	Abbreviation*	I/O	Function
0	Serial clock	SCL0	I/O	IIC0 serial clock input
	Serial data	SDA0	I/O	IIC0 serial data input
	Formatless serial clock	VSYNCl	Input	IIC0 formatless serial clock
1	Serial clock	SCL1	I/O	IIC1 serial clock input
	Serial data	SDA1	I/O	IIC1 serial data input

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

	I ² C bus data register	ICDR0	R/W	—	H
	I ² C bus mode register	ICMR0	R/W	H'00	H
	Slave address register	SAR0	R/W	H'00	H
	Second slave address register	SARX0	R/W	H'01	H
1	I ² C bus control register	ICCR1	R/W	H'01	H
	I ² C bus status register	ICSR1	R/W	H'00	H
	I ² C bus data register	ICDR1	R/W	—	H
	I ² C bus mode register	ICMR1	R/W	H'00	H
	Slave address register	SAR1	R/W	H'00	H
	Second slave address register	SARX1	R/W	H'01	H
Common	Serial/timer control register	STCR	R/W	H'00	H
	DDC switch register	DDCSWR	R/W	H'0F	H
	Module stop control register	MSTPCRH	R/W	H'3F	H
		MSTPCRL	R/W	H'FF	H

- Notes: 1. Lower 16 bits of the address.
2. The register that can be written or read depends on the ICE bit in the I²C bus control register. The slave address register can be accessed when ICE = 0, and the mode register can be accessed when ICE = 1.
- The I²C bus interface registers are assigned to the same addresses as other registers. Register selection is performed by means of the IICE bit in the serial/timer control register (STCR).

- ICDRR

Bit	7	6	5	4	3	2	1
	ICDRR7	ICDRR6	ICDRR5	ICDRR4	ICDRR3	ICDRR2	ICDRR1
Initial value	—	—	—	—	—	—	—
Read/Write	R	R	R	R	R	R	R

- ICDRS

Bit	7	6	5	4	3	2	1
	ICDRS7	ICDRS6	ICDRS5	ICDRS4	ICDRS3	ICDRS2	ICDRS1
Initial value	—	—	—	—	—	—	—
Read/Write	—	—	—	—	—	—	—

- ICDRT

Bit	7	6	5	4	3	2	1
	ICDRT7	ICDRT6	ICDRT5	ICDRT4	ICDRT3	ICDRT2	ICDRT1
Initial value	—	—	—	—	—	—	—
Read/Write	W	W	W	W	W	W	W

- TDRE, RDRF (internal flags)

Bit	—
	TDRE
Initial value	0
Read/Write	—

transmission/reception of one frame of data using ICDRS, data is transferred automatically from ICDRT to ICDRS. If IIC is in receive mode and no previous data remains in ICDRR (flag is 0) following transmission/reception of one frame of data using ICDRS, data is transferred automatically from ICDRS to ICDRR.

If the number of bits in a frame, excluding the acknowledge bit, is less than 8, transmit and receive data are stored differently. Transmit data should be written justified toward the MSB side when $MLS = 0$, and toward the LSB side when $MLS = 1$. Receive data bits read from the MSB side should be treated as valid when $MLS = 0$, and bits read from the MSB side when $MLS = 1$.

ICDR is assigned to the same address as SARX, and can be written and read only when the IIC bit is set to 1 in ICCR.

The value of ICDR is undefined after a reset.

The TDRE and RDRF flags are set and cleared under the conditions shown below. Setting TDRE and RDRF flags affects the status of the interrupt flags.

- In receive mode (TRS = 0)
(A 0 write to TRS during transfer is valid after reception of a frame containing an acknowledge bit)

1	<p>The next transmit data can be written in ICDR (ICDRT)</p> <p>[Setting conditions]</p> <ul style="list-style-type: none"> • In transmit mode (TRS = 1), when a start condition is detected in the bus after a start condition is issued in master mode with the I²C bus format or 7-bit bus format selected • At the first transmit mode setting (TRS = 1) (first transmit mode setting), the mode is switched from I²C bus mode to formatless mode • When data is transferred from ICDRT to ICDRS (Data transfer from ICDRT to ICDRS when TRS = 1 and TDRE = 0, and ICDRT is empty) • When detecting a start condition and then switching from slave receive mode (TRS = 0) state to transmit mode (TRS = 1) (first transmit mode switching only)
---	--

RDRF	Description
0	<p>The data in ICDR (ICDRR) is invalid (Invalid data)</p> <p>[Clearing condition]</p> <p>When ICDR (ICDRR) receive data is read in receive mode</p>
1	<p>The ICDR (ICDRR) receive data can be read</p> <p>[Setting condition]</p> <p>When data is transferred from ICDRS to ICDRR (Data transfer from ICDRS to ICDRR in case of normal termination with TRS = 1, RDRF = 0)</p>

communication format. When the chip is in slave mode (and the addressing format is 0), the upper 7 bits of SAR match the upper 7 bits of the first frame received after a start condition. In this mode, the chip operates as the slave device specified by the master device. SAR is assigned the slave address as ICMR, and can be written and read only when the ICE bit is cleared to 0 in hardware standby mode.

SAR is initialized to H'00 by a reset and in hardware standby mode.

Bits 7 to 1—Slave Address (SVA6 to SVA0): Set a unique address in bits SVA6 to SVA0, differing from the addresses of other slave devices connected to the I²C bus.

Bit 0—Format Select (FS): Used together with the FSX bit in SARX and the SW bit in DDCSWR to select the communication format.

- I²C bus format: addressing format with acknowledge bit
- Synchronous serial format: non-addressing format without acknowledge bit, for master mode only
- Formatless mode (channel 0 only): non-addressing format with or without acknowledge bit, slave mode only, start/stop conditions not detected

The FS bit also specifies whether or not SAR slave address recognition is performed in master mode.

			<ul style="list-style-type: none"> • SARX slave address ignored
	1	0	I ² C bus format <ul style="list-style-type: none"> • SAR slave address ignored • SARX slave address recognized
		1	Synchronous serial format <ul style="list-style-type: none"> • SAR and SARX slave addresses ignored
1	0	0	Formatless mode (start/stop conditions not detected) <ul style="list-style-type: none"> • Acknowledge bit used
	0	1	
	1	0	
	1	1	Formatless mode* (start/stop conditions not detected) <ul style="list-style-type: none"> • No acknowledge bit

Note: * Do not set this mode when automatic switching to the I²C bus format is performed by means of the DDCSWR setting.

16.2.3 Second Slave Address Register (SARX)

Bit	7	6	5	4	3	2	1
	SVAX6	SVAX5	SVAX4	SVAX3	SVAX2	SVAX1	SVAX0
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

SARX is an 8-bit readable/writable register that stores the second slave address and selects the communication format. When the chip is in slave mode (and the addressing format is selected), the upper 7 bits of SARX match the upper 7 bits of the first frame received after a start condition. In this mode, the chip operates as the slave device specified by the master device. SARX is assigned the slave address as ICDR, and can be written and read only when the ICE bit is cleared to 0 in ICDR.

SARX is initialized to H'01 by a reset and in hardware standby mode.

- Formatless mode: non-addressing format with or without acknowledge bit, slave n start/stop conditions not detected

The FSX bit also specifies whether or not SARX slave address recognition is performed in formatless mode. For details, see the description of the FS bit in SAR.

16.2.4 I²C Bus Mode Register (ICMR)

Bit	7	6	5	4	3	2	1
	MLS	WAIT	CKS2	CKS1	CKS0	BC2	BC1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

ICMR is an 8-bit readable/writable register that selects whether the MSB or LSB is transferred first, performs master mode wait control, and selects the master mode transfer clock frequency for the transfer bit count. ICMR is assigned to the same address as SAR. ICMR can be written only when read only when the ICE bit is set to 1 in ICCR.

ICMR is initialized to H'00 by a reset and in hardware standby mode.

Bit 7—MSB-First/LSB-First Select (MLS): Selects whether data is transferred MSB-first or LSB-first.

If the number of bits in a frame, excluding the acknowledge bit, is less than 8, transmit and receive data are stored differently. Transmit data should be written justified toward the MSB side when MLS = 0, and toward the LSB side when MLS = 1. Receive data bits read from the MSB side should be treated as valid when MLS = 0, and bits read from the LSB side when

Do not set this bit to 1 when the I²C bus format is used.

fall of the clock for the final data bit, the IRIC flag is set to 1 in ICCR, and a wait state (with SCL at the low level). When the IRIC flag is cleared to 0 in ICCR, the wait state and acknowledge bit is transferred. If WAIT is cleared to 0, data and acknowledge bits are transferred consecutively with no wait inserted.

The IRIC flag in ICCR is set to 1 on completion of the acknowledge bit transfer, regardless of the WAIT setting.

The setting of this bit is invalid in slave mode.

Bit 6

WAIT	Description	
0	Data and acknowledge bits transferred consecutively	(Initial)
1	Wait inserted between data and acknowledge bits	

			0	0	φ/20	175 kHz	200 kHz	250 kHz	300 kHz	375 kHz
			1	0	φ/40	125 kHz	200 kHz	250 kHz	400 kHz	
			1	0	φ/48	104 kHz	167 kHz	208 kHz	333 kHz	
					1	φ/64	78.1 kHz	125 kHz	156 kHz	250 kHz
	1		0	0	φ/80	62.5 kHz	100 kHz	125 kHz	200 kHz	
					1	φ/100	50.0 kHz	80.0 kHz	100 kHz	160 kHz
			1	0	φ/112	44.6 kHz	71.4 kHz	89.3 kHz	143 kHz	
					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	φ/80	62.5 kHz	100 kHz	125 kHz	200 kHz
			1	0	φ/96	52.1 kHz	83.3 kHz	104 kHz	167 kHz	
					1	φ/128	39.1 kHz	62.5 kHz	78.1 kHz	125 kHz
	1		0	0	φ/160	31.3 kHz	50.0 kHz	62.5 kHz	100 kHz	
					1	φ/200	25.0 kHz	40.0 kHz	50.0 kHz	80.0 kHz
			1	0	φ/224	22.3 kHz	35.7 kHz	44.6 kHz	71.4 kHz	
					1	φ/256	19.5 kHz	31.3 kHz	39.1 kHz	62.5 kHz

Note: * Outside the I²C bus interface specification range (normal mode: max. 100 kHz, speed mode: max. 400 kHz).

Bits 2 to 0—Bit Counter (BC2 to BC0): Bits BC2 to BC0 specify the number of bits transferred next. With the I²C bus format (when the FS bit in SAR or the FSX bit in SDA is set), the data is transferred with one additional acknowledge bit. Bit BC2 to BC0 settings should be made during an interval between transfer frames. If bits BC2 to BC0 are set to a value other than 000, the setting should be made while the SCL line is low.

The bit counter is initialized to 000 by a reset and when a start condition is detected. The bit counter returns to 000 at the end of a data transfer, including the acknowledge bit.

	1	5	6
1	0	6	7
	1	7	8

16.2.5 I²C Bus Control Register (ICCR)

Bit	7	6	5	4	3	2	1
	ICE	IEIC	MST	TRS	ACKE	BBSY	IRIC
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/(W)*

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

ICCR is an 8-bit readable/writable register that enables or disables the I²C bus interface, disables interrupts, selects master or slave mode and transmission or reception, enables acknowledgement, confirms the I²C bus interface bus status, issues start/stop conditions, performs interrupt flag confirmation.

ICCR is initialized to H'01 by a reset and in hardware standby mode.

Bit 7—I²C Bus Interface Enable (ICE): Selects whether or not the I²C bus interface is used. When ICE is set to 1, port pins function as SCL and SDA input/output pins and transmission operations are enabled. When ICE is cleared to 0, the I²C bus interface module is halted and internal states are cleared.

The SAR and SARX registers can be accessed when ICE is 0. The ICMR and ICDR registers can be accessed when ICE is 1.

Bit 6—I²C Bus Interface Interrupt Enable (IEIC): Enables or disables interrupts from the I²C bus interface to the CPU.

Bit 6

IEIC	Description
0	Interrupts disabled
1	Interrupts enabled

Bit 5—Master/Slave Select (MST)

Bit 4—Transmit/Receive Select (TRS)

MST selects whether the I²C bus interface operates in master mode or slave mode.

TRS selects whether the I²C bus interface operates in transmit mode or receive mode.

In master mode with the I²C bus format, when arbitration is lost, MST and TRS are both active-low hardware, causing a transition to slave receive mode. In slave receive mode with the 7-bit address format (FS = 0 or FSX = 0), hardware automatically selects transmit or receive mode based on the R/W bit in the first frame after a start condition.

Modification of the TRS bit during transfer is deferred until transfer of the frame content is completed, and the changeover is made after completion of the transfer.

MST and TRS select the operating mode as follows.

Bit 5**MST****Description**

0	Slave mode [Clearing conditions] 1. When 0 is written by software 2. When bus arbitration is lost after transmission is started in I ² C bus format mode	(Initial)
1	Master mode [Setting conditions] 1. When 1 is written by software (in cases other than clearing condition 2) 2. When 1 is written in MST after reading MST = 0 (in case of clearing condition 2)	

Bit 4**TRS****Description**

0	Receive mode [Clearing conditions] 1. When 0 is written by software (in cases other than setting condition 3) 2. When 0 is written in TRS after reading TRS = 1 (in case of clearing condition 3) 3. When bus arbitration is lost after transmission is started in I ² C bus format mode 4. When the SW bit in DDCCSWR changes from 1 to 0	(Initial)
1	Transmit mode [Setting conditions] 1. When 1 is written by software (in cases other than clearing conditions 3 and 4) 2. When 1 is written in TRS after reading TRS = 0 (in case of clearing condition 3 and 4) 3. When a 1 is received as the R/W bit of the first frame in I ² C bus format mode	

completion of data transmission, regardless of the value of the acknowledge bit. When the acknowledge bit is 0, the TDRE, IRIC, and IRTR flags are set on completion of data transmission. When the acknowledge bit is 1, the TDRE, IRIC, and IRTR flags are set on completion of data transmission. When the acknowledge bit is 0, and the IRIC flag alone is set on completion of data transmission, the DTC is activated. When the acknowledge bit is 1.

When the DTC is activated, the TDRE, IRIC, and IRTR flags are cleared to 0 after the number of data transfers have been executed. Consequently, interrupts are not generated during continuous data transfer, but if data transmission is completed with a 1 acknowledge bit, the DTC is not activated and an interrupt is generated, if enabled.

Depending on the receiving device, the acknowledge bit may be significant, in indicating the completion of processing of the received data, for instance, or may be fixed at 1 and have no significance.

Bit 3

ACKE	Description
0	The value of the acknowledge bit is ignored, and continuous transfer is performed
1	If the acknowledge bit is 1, continuous transfer is interrupted

Bit 2—Bus Busy (BBSY): The BBSY flag can be read to check whether the I²C bus is busy or free. In master mode, this bit is also used to issue start and stop conditions.

A high-to-low transition of SDA while SCL is high is recognized as a start condition, setting BBSY to 1. A low-to-high transition of SDA while SCL is high is recognized as a stop condition, clearing BBSY to 0.

To issue a start condition, use a MOV instruction to write 1 in BBSY and 0 in SCP. A stop condition is issued in the same way. To issue a stop condition, use a MOV instruction to write 0 in BBSY and 0 in SCP. It is not possible to write to BBSY in slave mode; the interface must be set to master transmit mode before issuing a start condition. MST and BBSY should both be set to 1 before writing 1 in BBSY and 0 in SCP.

Bit 1—I²C Bus Interface Interrupt Request Flag (IRIC): Indicates that the I²C bus interface has issued an interrupt request to the CPU. IRIC is set to 1 at the end of a data transfer, when a start address or general call address is detected in slave receive mode, when bus arbitration is lost in master transmit mode, and when a stop condition is detected. IRIC is set at different times depending on the FS bit in SAR and the WAIT bit in ICMR. See section 16.3.6, IRIC Status and Timing and SCL Control. The conditions under which IRIC is set also differ depending on the setting of the ACKE bit in ICCR.

IRIC is cleared by reading IRIC after it has been set to 1, then writing 0 in IRIC.

When the DTC is used, IRIC is cleared automatically and transfer can be performed continuously without CPU intervention.

[Setting conditions]

- I²C bus format master mode
 1. When a start condition is detected in the bus line state after a start condition (when the TDRE flag is set to 1 because of first frame transmission)
 2. When a wait is inserted between the data and acknowledge bit when WAIT = 1
 3. At the end of data transfer (at the rise of the 9th transmit/receive clock pulse when no wait is inserted, (when a wait is inserted (WAIT=1), at the fall of the 8th transmit/receive clock pulse)
 4. When a slave address is received after bus arbitration is lost (when the AL flag is set to 1)
 5. When 1 is received as the acknowledge bit when the ACKE bit is 1 (when the ACKB bit is set to 1)
- I²C bus format slave mode
 1. When the slave address (SVA, SVAX) matches (when the AAS and AASX flags are set to 1) and at the end of data transfer up to the subsequent retransmission start condition detection (when the TDRE or RDRF flag is set to 1)
 2. When the general call address is detected (when FS = 0 and the ADZ flag is set to 1) and at the end of data transfer up to the subsequent retransmission start condition detection (when the TDRE or RDRF flag is set to 1)
 3. When 1 is received as the acknowledge bit when the ACKE bit is 1 (when the ACKB bit is set to 1)
 4. When a stop condition is detected (when the STOP or ESTP flag is set to 1)
- Synchronous serial format, and formatless mode
 1. At the end of data transfer (when the TDRE or RDRF flag is set to 1)
 2. When a start condition is detected with serial format selected
 3. When the SW bit is set to 1 in DDCSWR

Except the above, when the conditions to set the TDRE or RDRF internal flag to 1 is

Even when the IRIC flag and IRTR flag are set, the TDRE or RDRF internal flag may be cleared. The IRIC and IRTR flags are not cleared at the end of the specified number of transfers. The TDRE or RDRF flag is cleared, however, since a continuous transfer using the DTC. The TDRE or RDRF flag is cleared, however, since a specified number of ICDR reads or writes have been completed.

Table 16.3 shows the relationship between the flags and the transfer states.

Table 16.3 Flags and Transfer States

MST	TRS	BBSY	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB	State
1/0	1/0	0	0	0	0	0	0	0	0	0	Idle state (flag required)
1	1	0	0	0	0	0	0	0	0	0	Start condition
1	1	1	0	0	1	0	0	0	0	0	Start condition
1	1/0	1	0	0	0	0	0	0	0	0/1	Master mode v
1	1/0	1	0	0	1	0	0	0	0	0/1	Master mode t receive end
0	0	1	0	0	0	1/0	1	1/0	1/0	0	Arbitration lost
0	0	1	0	0	0	0	0	1	0	0	SAR match by slave mode
0	0	1	0	0	0	0	0	1	1	0	General call ac
0	0	1	0	0	0	1	0	0	0	0	SARX match
0	1/0	1	0	0	0	0	0	0	0	0/1	Slave mode transmit/receiv (except after S
0	1/0	1	0	0	1	1	0	0	0	0	Slave mode transmit/receiv
0	1	1	0	0	0	1	0	0	0	1	SARX match)
0	1/0	0	1/0	1/0	0	0	0	0	0	0/1	Stop condition

1 Reading always returns a value of 1
Writing is ignored

16.2.6 I²C Bus Status Register (ICSR)

Bit	7	6	5	4	3	2	1
	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ
Initial value	0	0	0	0	0	0	0
Read/Write	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*

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

ICSR is an 8-bit readable/writable register that performs flag confirmation and acknowledgment and control.

ICSR is initialized to H'00 by a reset and in hardware standby mode.

	2. When the IRIC flag is cleared to 0
1	<ul style="list-style-type: none"> In I²C bus format slave mode Error stop condition detected [Setting condition] When a stop condition is detected during frame transfer In other modes No meaning

Bit 6—Normal Stop Condition Detection Flag (STOP): Indicates that a stop condition is detected after completion of frame transfer in I²C bus format slave mode.

Bit 6

STOP	Description
0	No normal stop condition (Initial value) [Clearing conditions] <ol style="list-style-type: none"> When 0 is written in STOP after reading STOP = 1 When the IRIC flag is cleared to 0
1	<ul style="list-style-type: none"> In I²C bus format slave mode Normal stop condition detected [Setting condition] When a stop condition is detected after completion of frame transfer In other modes No meaning

Bit 5—I²C Bus Interface Continuous Transmission/Reception Interrupt Request Flag (IRTR): Indicates that the I²C bus interface has issued an interrupt request to the CPU, the source is completion of reception/transmission of one frame in continuous transmission mode for which DTC activation is possible. When the IRTR flag is set to 1, the IRIC flag is also set to 1 at the same time.

1. When 0 is written in IRTR after reading IRTR = 1
2. When the IRIC flag is cleared to 0

1	Continuous transfer state [Setting conditions] <ul style="list-style-type: none"> • In I²C bus interface slave mode When the TDRE or RDRF flag is set to 1 when AASX = 1 • In other modes When the TDRE or RDRF flag is set to 1
---	--

Bit 4—Second Slave Address Recognition Flag (AASX): In I²C bus format slave receive mode, this flag is set to 1 if the first frame following a start condition matches bits SVAX6 to SARX.

AASX is cleared by reading AASX after it has been set to 1, then writing 0 in AASX. AASX is also cleared automatically when a start condition is detected.

Bit 4

AASX	Description
0	Second slave address not recognized (In master mode) [Clearing conditions] <ol style="list-style-type: none"> 1. When 0 is written in AASX after reading AASX = 1 2. When a start condition is detected 3. In master mode
1	Second slave address recognized [Setting condition] When the second slave address is detected in slave receive mode while F

Bit 3

AL	Description
0	Bus arbitration won (Initial condition) [Clearing conditions] 1. When ICDR data is written (transmit mode) or read (receive mode) 2. When 0 is written in AL after reading AL = 1
1	Arbitration lost [Setting conditions] 1. If the internal SDA and SDA pin disagree at the rise of SCL in master transmit mode 2. If the internal SCL line is high at the fall of SCL in master transmit mode

Bit 2—Slave Address Recognition Flag (AAS): In I²C bus format slave receive mode, AAS is set to 1 if the first frame following a start condition matches bits SVA6 to SVA0 in SA0. If a general call address (H'00) is detected.

AAS is cleared by reading AAS after it has been set to 1, then writing 0 in AAS. In transmit mode, AAS is reset automatically by write access to ICDR in transmit mode, or read access to ICDR in receive mode.

1 Slave address or general call address recognized
[Setting condition]
When the slave address or general call address is detected in slave receive mode while FS = 0

Bit 1—General Call Address Recognition Flag (ADZ): In I²C bus format slave receive mode, this flag is set to 1 if the first frame following a start condition is the general call address.

ADZ is cleared by reading ADZ after it has been set to 1, then writing 0 in ADZ. In slave mode, ADZ is reset automatically by write access to ICDR in transmit mode, or read access to ICDR in receive mode.

Bit 1

ADZ	Description
0	General call address not recognized [Clearing conditions] 1. When ICDR data is written (transmit mode) or read (receive mode) 2. When 0 is written in ADZ after reading ADZ = 1 3. In master mode
1	General call address recognized [Setting condition] When the general call address is detected in slave receive mode while FSX = 0

When this bit is written to, the acknowledge data transmitted at the receipt is rewritten of the TRS value. The data loaded from the receiving device is retained, therefore take care using bit-manipulation instructions.

Bit 0

ACKB	Description
0	Receive mode: 0 is output at acknowledge output timing (I Transmit mode: Indicates that the receiving device has acknowledged the c is 0)
1	Receive mode: 1 is output at acknowledge output timing Transmit mode: Indicates that the receiving device has not acknowledged t (signal is 1)

16.2.7 Serial/Timer Control Register (STCR)

Bit	7	6	5	4	3	2	1
	IICS	IICX1	IICX0	IICE	FLSHE	—	ICKS1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

STCR is an 8-bit readable/writable register that controls register access, the I²C interface mode (when the on-chip IIC option is included), and on-chip flash memory (F-ZTAT v and selects the TCNT input clock source. For details of functions not related to the I²C interface, see section 3.2.4, Serial Timer Control Register (STCR), and the descriptions relevant modules. If a module controlled by STCR is not used, do not write 1 to the cor bit.

STCR is initialized to H'00 by a reset and in hardware standby mode.

Bits 6 and 5—I²C Transfer Select 1 and 0 (IICX1 and 0): This bit, together with bit CKS0 in ICMR, selects the transfer rate in master mode. For details, see section 16.2. Mode Register (ICMR).

Bit 4—I²C Master Enable (IICE): Controls CPU access to the I²C bus interface data registers (ICCR, ICSR, ICDR/SARX, ICMR/SAR).

Bit 4

IICE	Description
0	CPU access to I ² C bus interface data and control registers is disabled
1	CPU access to I ² C bus interface data and control registers is enabled

Bit 3—Flash Memory Control Register Enable (FLSHE): Controls CPU access to memory control registers, the power-down mode control registers, and the supporting control registers. See section 3.2.4, Serial Timer Control Register (STCR), for details.

Bit 2—Reserved: Do not write 1 to this bit.

Bits 1 and 0—Internal Clock Source Select 1 and 0 (ICKS1, ICKS0): These bits, together with bits CKS2 to CKS0 in TCR, select the clock input to the timer counters (TCNT). For details, see section 12.2.4, Timer Control Register (TCR).

2. Always read as 1.

DDCSWR is an 8-bit readable/writable register that is used to initialize IIC and control internal latch clearance.

DDCSWR is initialized to H'0F by a reset and in hardware standby mode.

Bit 7—DDC Mode Switch Enable (SWE): Selects the function for automatically switching channel 0 from formatless mode to the I²C bus format.

Bit 7

SWE	Description
0	Automatic switching of IIC channel 0 from formatless mode to I ² C bus format disabled (In
1	Automatic switching of IIC channel 0 from formatless mode to I ² C bus format enabled

Bit 6—DDC Mode Switch (SW): Selects either formatless mode or the I²C bus format channel 0.

Bit 6

SW	Description
0	IIC channel 0 is used with the I ² C bus format (In [Clearing conditions] 1. When 0 is written by software 2. When a falling edge is detected on the SCL pin when SWE = 1
1	IIC channel 0 is used in formatless mode [Setting condition] When 1 is written in SW after reading SW = 0

Bit 4—DDC Mode Switch Interrupt Flag (IF): Flag that indicates an interrupt request to the CPU when automatic format switching is executed for IIC channel 0.

Bit 4

IF	Description
0	No interrupt is requested when automatic format switching is executed [Clearing condition] When 0 is written in IF after reading IF = 1
1	An interrupt is requested when automatic format switching is executed [setting condition] When a falling edge is detected on the SCL pin when SWE = 1

Bits 3 to 0—IIC Clear 3 to 0 (CLR3 to CLR0): These bits control initialization of the state of IIC0 and IIC1.

These bits can only be written to; if read they will always return a value of 1.

When a write operation is performed on these bits, a clear signal is generated for the internal circuit of the corresponding module(s), and the internal state of the IIC module(s) is initialized.

The write data for these bits is not retained. To perform IIC clearance, bits CLR3 to CLR0 must be written to simultaneously using an MOV instruction. Do not use a bit-manipulation instruction such as BCLR.

When clearing is required again, all the bits must be written to in accordance with the procedure described above.

16.2.9 Module Stop Control Register (MSTPCR)

Bit	MSTPCRH								MSTPCRL					
	7	6	5	4	3	2	1	0	7	6	5	4	3	2
	MSTP15	MSTP14	MSTP13	MSTP12	MSTP11	MSTP10	MSTP9	MSTP8	MSTP7	MSTP6	MSTP5	MSTP4	MSTP3	MSTP2
Initial value	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

MSTPCR comprises two 8-bit readable/writable registers, and is used to perform module stop mode control.

When the MSTP4 or MSTP3 bit is set to 1, operation of the corresponding IIC channel ends at the end of the bus cycle, and a transition is made to module stop mode. For details, see 25.5, Module Stop Mode.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not initialized in software standby mode.

MSTPCRL Bit 4—Module Stop (MSTP4): Specifies IIC channel 0 module stop mode.

MSTPCRL

Bit 4

MSTP4	Description
0	IIC channel 0 module stop mode is cleared
1	IIC channel 0 module stop mode is set (I)

16.3 Operation

16.3.1 I²C Bus Data Format

The I²C bus interface has serial and I²C bus formats.

The I²C bus formats are addressing formats with an acknowledge bit. These are shown in figure 16.3 (a) and (b). The first frame following a start condition always consists of 8 bits.

IIC channel 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. Although start conditions must be issued, this format can be used as a synchronous serial format. This is shown in figure 16.5.

Figure 16.6 shows the I²C bus timing.

The symbols used in figures 16.3 to 16.6 are explained in table 16.4.

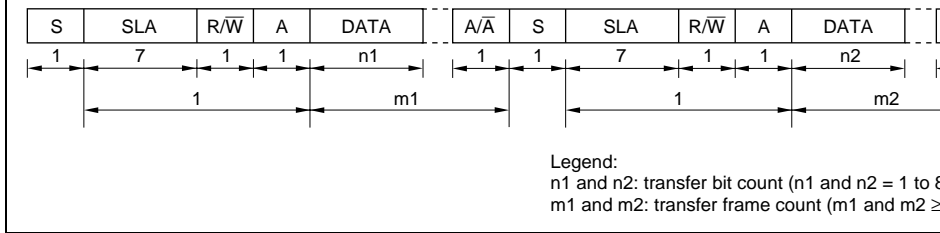


Figure 16.3 I²C Bus Data Formats (I²C Bus Formats)

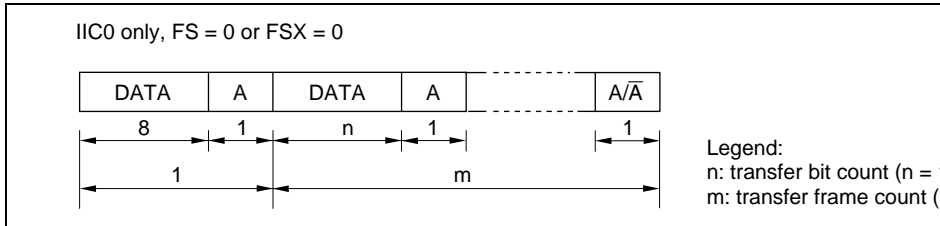


Figure 16.4 Formatless

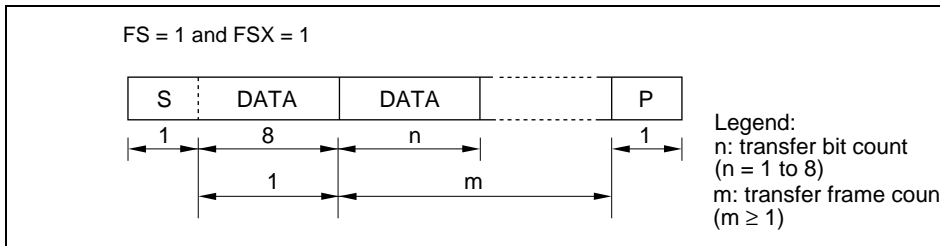


Figure 16.5 I²C Bus Data Format (Serial Format)

Table 16.4 I²C Bus Data Format Symbols**Legend**

S	Start condition. The master device drives SDA from high to low while SCL is high.
SLA	Slave address, by which the master device selects a slave device
R/W	Indicates the direction of data transfer: from the slave device to the master device when R/W is 1, or from the master device to the slave device when R/W is 0.
A	Acknowledge. The receiving device (the slave in master transmit mode, or the master in master receive mode) drives SDA low to acknowledge a transfer
DATA	Transferred data. The bit length is set by bits BC2 to BC0 in ICMR. The MSB-first format is selected by bit MLS in ICMR
P	Stop condition. The master device drives SDA from low to high while SCL is high.

16.3.2 Master Transmit Operation

In I²C bus format master transmit mode, the master device outputs the transmit clock and data, and the slave device returns an acknowledge signal.

The transmission procedure and operations by which data is sequentially transmitted in master transmit mode, in synchronization with ICDR write operations, are described below.

- (1) Set the ICE bit in ICCR to 1. Set bits MLS, WAIT, and CKS2 to CKS0 in ICMR, and STCR, according to the operation mode.
- (2) Read the BBSY flag to confirm that the bus is free.
- (3) Set the MST and TRS bits to 1 in ICCR to select master transmit mode.
- (4) Write 1 to BBSY and 0 to SCP. This switches SDA from high to low when SCL is high and generates the start condition.
- (5) When the start condition is generated, the IRIC and IRTR flags are set to 1. If the IRIC flag is set to 1 and ICCR has been set to 1, an interrupt request is sent to the CPU.

cleared, the end of transfer cannot be identified.

The master device sequentially sends the transmit clock and the data written to ICDR. The timing is shown in figure 16.7. The selected slave device (i.e., the slave device with the matching slave address) drives SDA low at the 9th transmit clock pulse and returns to high to acknowledge signal.

- (7) When one frame of data has been transmitted, the IRIC flag is set to 1 at the rise of the transmit clock pulse. After one frame has been transmitted, SCL is automatically forced to high in synchronization with the internal clock until the next transmit data is written.
- (8) Read the ACKB bit to confirm that ACKB is 0. When the slave device has not returned an acknowledge signal and ACKB remains 1, execute the transmit end processing described in step (12) and perform transmit operation again.
- (9) Write the next data to be transmitted in ICDR. To indicate the end of data transfer, write the IRIC flag to 0.

As described in step (6) above, writing to ICDR and clearing of the IRIC flag must be executed continuously so that no interrupt is inserted.

The next frame is transmitted in synchronization with the internal clock.

- (10) When one frame of data has been transmitted, the IRIC flag is set to 1 at the rise of the transmit clock pulse. After one frame has been transmitted, SCL is automatically forced to high in synchronization with the internal clock until the next transmit data is written.
- (11) Read the ACKB bit of ICSR. Confirm that the slave device has returned an acknowledge signal and ACKB is 0. When more data is to be transmitted, return to step (9) to execute transmit operation. If the slave device has not returned an acknowledge signal and ACKB is 1, execute the transmit end processing described in step (12).
- (12) Clear the IRIC flag to 0. Write BBSY and SCP of ICCR to 0. By doing so, SDA is driven from low to high while SCL is high and the transmit stop condition is generated.

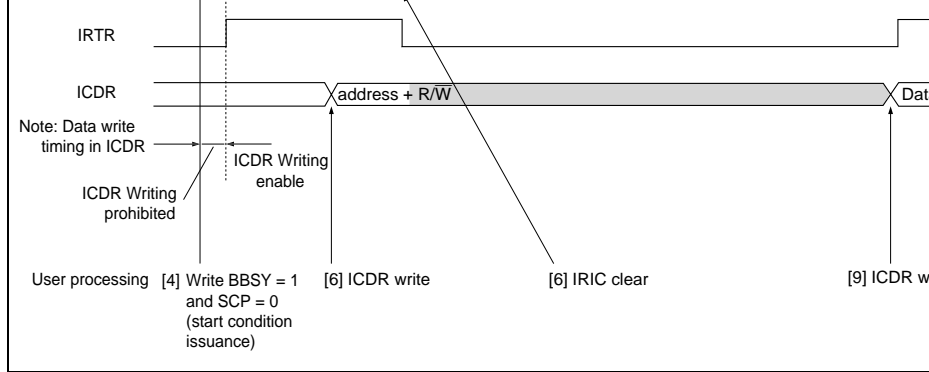


Figure 16.7 Example of Master Transmit Mode Operation Timing (MLS = WAIT = 0)

16.3.3 Master Receive Operation

In master receive mode, the master device outputs the receive clock, receives data, and acknowledges. The slave device transmits data.

The receive procedure and operations by which data is sequentially received in synchronization with ICDR read operations, are described below.

- (1) Clear the TRS bit of ICCR to 0 and switch from transmit mode to receive mode. Set the WAIT bit to 1 and clear the ACKB bit of ICSR to 0 (acknowledge data setting).
- (2) When ICDR is read (dummy data read), reception is started and the receive clock and data is received, in synchronization with the internal clock. To indicate the write, the IRIC flag to 0.

Reading from ICDR and clearing of the IRIC flag must be executed continuously. If an interrupt is inserted.

If a period of time that is equal to transfer one byte has elapsed by the time the IRIC flag is cleared, the end of transfer cannot be identified.

- (5) When one frame of data has been transmitted, the IRIC and IRTR flags are set to 1 at the rise of the 9th transmit clock pulse.
- The master device continues to output the receive clock for the next receive data.
- (6) Read the ICDR receive data.
- (7) Clear the IRIC flag to indicate the next wait.
- From clearing of the IRIC flag to completion of data transmission as described in steps (6), and (7), must be performed within the time taken to transfer one byte, because of the wait state as described in step (4) (or (9)).
- (8) The IRIC flag is set to 1 at the fall of the 8th one-frame reception clock pulse. SCL is automatically fixed low in synchronization with the internal clock until the IRIC flag is cleared. If this frame is the final reception frame, execute the end processing as described in step (10).
- (9) Clear the IRIC flag to 0 to release from the wait state. The master device outputs the reception clock pulse, sets SDA to low, and returns an acknowledge signal.
- By repeating steps (5) to (9) above, more data can be received.
- (10) Set the ACKB bit of ICSR to 1 and set the acknowledge data for the final reception frame. Set the TRS bit of ICCR to 1 to change receive mode to transmit mode.
- (11) Clear the IRIC flag to release from the wait state.
- (12) When one frame of data has been received, the IRIC flag is set to 1 at the rise of the reception clock pulse.
- (13) Clear the WAIT bit of ICMR to 0 to cancel wait mode. Read the ICDR receive data and clear the IRIC flag to 0.
- Clear the IRIC flag only when WAIT = 0.
- (If the stop-condition generation command is executed after clearing the IRIC flag and then clearing the WAIT bit to 0, the SDA line is fixed low and the stop condition is generated.)
- (14) Write 0 to BBSY and SCP. This changes SDA from low to high when SCL is high and generates the stop condition.

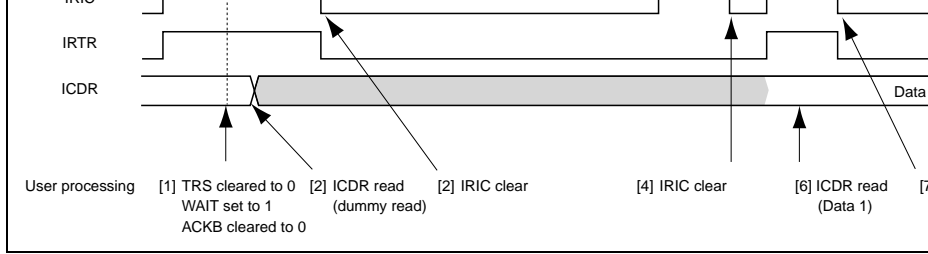


Figure 16.8 (a) Example of Master Receive Mode Operation Timing
 (MLS = ACKB = 0, WAIT = 1)

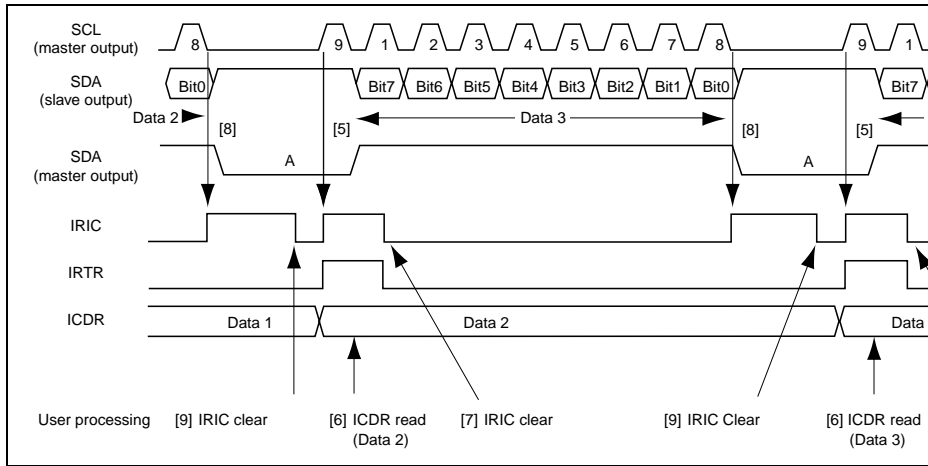


Figure 16.8 (b) Example of Master Receive Mode Operation Timing
 (MLS = ACKB = 0, WAIT = 1)

- [2] When the start condition output by the master device is detected, the BBSY flag in ICCR is cleared to 1.
- [3] When the slave address matches in the first frame following the start condition, the slave device operates as the slave device specified by the master device. If the 8th data bit ($\overline{R/W}$) TRS bit in ICCR remains cleared to 0, and slave receive operation is performed.
- [4] At the 9th clock pulse of the receive frame, the slave device drives SDA low and sends an acknowledge signal. At the same time, the IRIC flag in ICCR is set to 1. If the IEICR in ICCR has been set to 1, an interrupt request is sent to the CPU. If the RDRF internal flag in ICCR has been cleared to 0, it is set to 1, and the receive operation continues. If the RDRF internal flag has been set to 1, the slave device drives SCL low from the fall of the receive clock. The data in ICDR is read into ICDR.
- [5] Read ICDR and clear the IRIC flag in ICCR to 0. The RDRF flag is cleared to 0.

Receive operations can be performed continuously by repeating steps [4] and [5]. When SCL is changed from low to high when SCL is high, and the stop condition is detected, the BBSY flag in ICCR is cleared to 0.

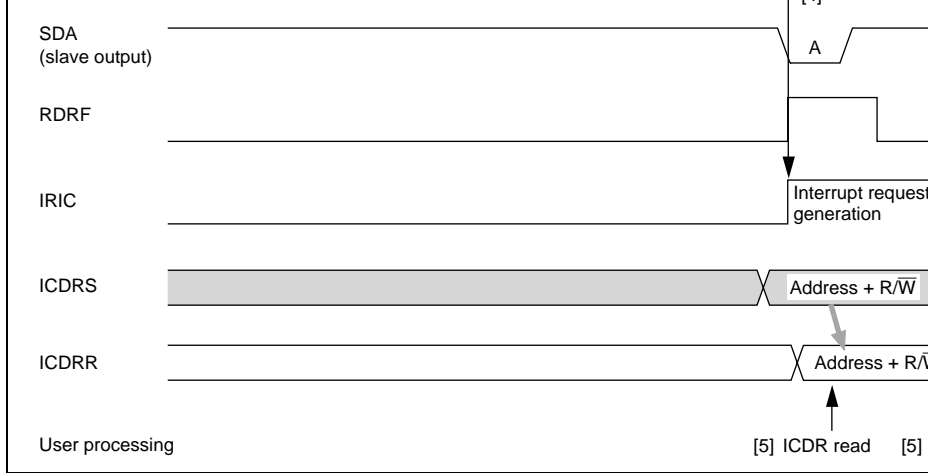


Figure 16.9 Example of Slave Receive Mode Operation Timing (1) (MLS = A

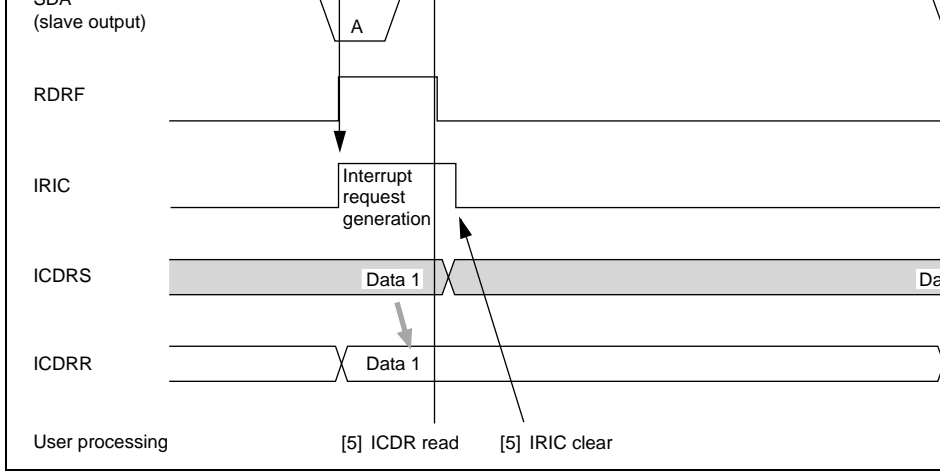


Figure 16.10 Example of Slave Receive Mode Operation Timing (2) (MLS = A)

- [2] When the slave address matches in the first frame following detection of the start of the slave device drives SDA low at the 9th clock pulse and returns an acknowledge signal. At the same time, the IRIC flag in ICCR is set to 1. If the IEIC bit in ICCR has been set to 1, an interrupt request is sent to the CPU. If the 8th data bit (R/\overline{W}) is 1, the TRS bit in ICCR is set to 1, and the mode changes to slave transmit mode automatically. The TDRE internal flag is set to 1. The slave device drives SCL low from the fall of the transmit clock until data is written to ICDR.
- [3] After clearing the IRIC flag to 0, write data to ICDR. The TDRE internal flag is cleared to 0. The written data is transferred to ICDRS, and the TDRE internal flag and the IRIC flag are set to 1 again. After clearing the IRIC flag to 0, write the next data to ICDR. The slave device sequentially sends the data written into ICDR in accordance with the timing shown by the master device at the timing shown in figure 16.11.
- [4] When one frame of data has been transmitted, the IRIC flag in ICCR is set to 1 at the 9th transmit clock pulse. If the TDRE internal flag has been set to 1, this slave device drives SCL low from the fall of the transmit clock until data is written to ICDR. The slave device drives SDA low at the 9th clock pulse, and returns an acknowledge signal. When the acknowledge signal is stored in the ACKB bit in ICSR, this bit can be used to detect whether the transfer operation was performed normally. When the TDRE internal flag is cleared to 0, data written into ICDR is transferred to ICDRS, transmission is started, and the TDRE internal flag and the IRIC and IRTR flags are set to 1 again.
- [5] To continue transmission, clear the IRIC flag to 0, then write the next data to be transmitted into ICDR. The TDRE internal flag is cleared to 0.

Transmit operations can be performed continuously by repeating steps [4] and [5]. To stop transmission, write H'FF to ICDR to release SDA on the slave side. When SDA is changed from low to high when SCL is high, and the stop condition is detected, the BBSY flag in ICSR is cleared to 0.

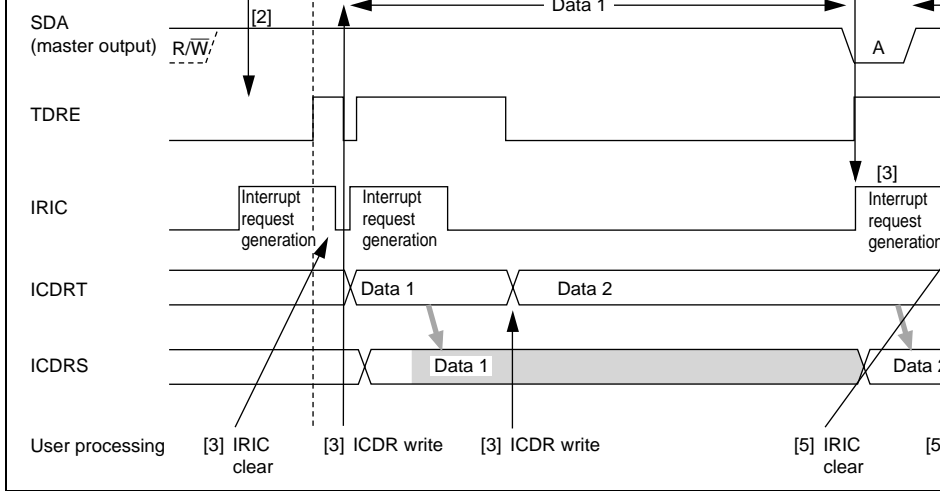
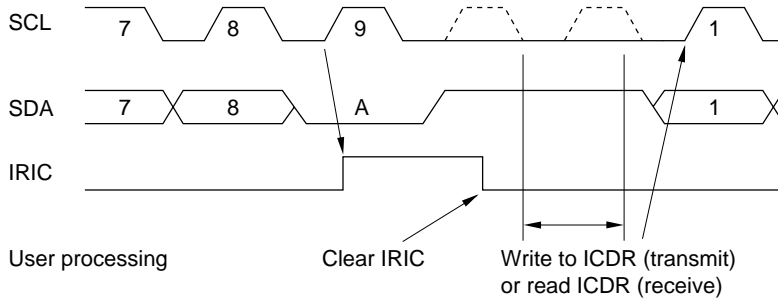
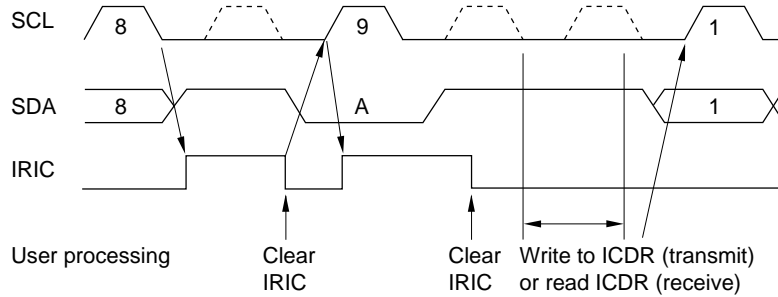


Figure 16.11 Example of Slave Transmit Mode Operation Timing (MLS)



(b) When WAIT = 1, and FS = 0 or FSX = 0 (I²C bus format, wait inserted)



(c) When FS = 1 and FSX = 1 (synchronous serial format)

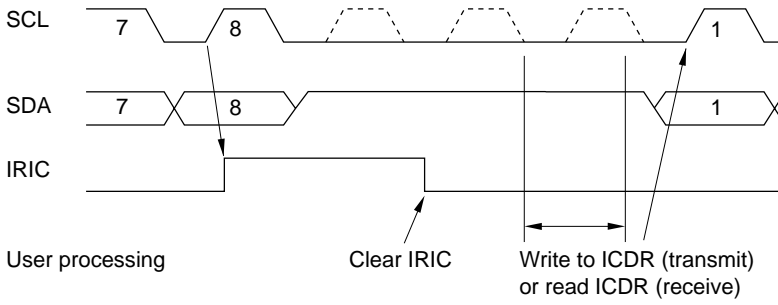


Figure 16.12 IRIC Setting Timing and SCL Control

- Separate clock pins for formatless operation (VSYNCl) and I²C bus format operation
- A fixed 1 level for the SCL pin during formatless operation (the SCL pin does not output a low level)
- Settings of bits other than TRS in ICCR that allow I²C bus format operation

Automatic switching is performed from formatless mode to the I²C bus format when the DDCCSWR is automatically cleared to 0 on detection of a falling edge on the SCL pin. Switching from the I²C bus format to formatless mode is achieved by having software set the SW bit of DDCCSWR to 1.

In formatless mode, bits (such as MSL and TRS) that control the I²C bus interface operation must not be modified. When switching from the I²C bus format to formatless mode, set the SW bit to 1 or clear it to 0 according to the transmit data (transmission or reception) in formatless mode, then set the SW bit to 1. After automatic switching from formatless mode to the I²C bus format (slave mode), in order to wait for slave address reception, the TRS bit is automatically cleared to 0.

If a falling edge is detected on the SCL pin during formatless operation, the I²C bus interface operating mode is switched to the I²C bus format without waiting for a stop condition to be detected.

number of transfer data bytes is known in slave mode.

Table 16.5 Examples of Operation Using the DTC

Item	Master Transmit Mode	Master Receive Mode	Slave Transmit Mode	Slave Receive Mode
Slave address + R/W bit transmission/reception	Transmission by DTC (ICDR write)	Transmission by CPU (ICDR write)	Reception by CPU (ICDR read)	Reception by CPU (ICDR read)
Dummy data read	—	Processing by CPU (ICDR read)	—	—
Actual data transmission/reception	Transmission by DTC (ICDR write)	Reception by DTC (ICDR read)	Transmission by DTC (ICDR write)	Reception by CPU (ICDR read)
Dummy data (H'FF) write	—	—	Processing by DTC (ICDR write)	—
Last frame processing	Not necessary	Reception by CPU (ICDR read)	Not necessary	Reception by CPU (ICDR read)
Transfer request processing after last frame processing	1st time: Clearing by CPU 2nd time: End condition issuance by CPU	Not necessary	Automatic clearing on detection of end condition during transmission of dummy data (H'FF)	Not necessary
Setting of number of DTC transfer data frames	Transmission: Actual data count + 1 (+1 equivalent to slave address + R/W bits)	Reception: Actual data count	Transmission: Actual data count + 1 (+1 equivalent to dummy data (H'FF))	Reception: Actual data count

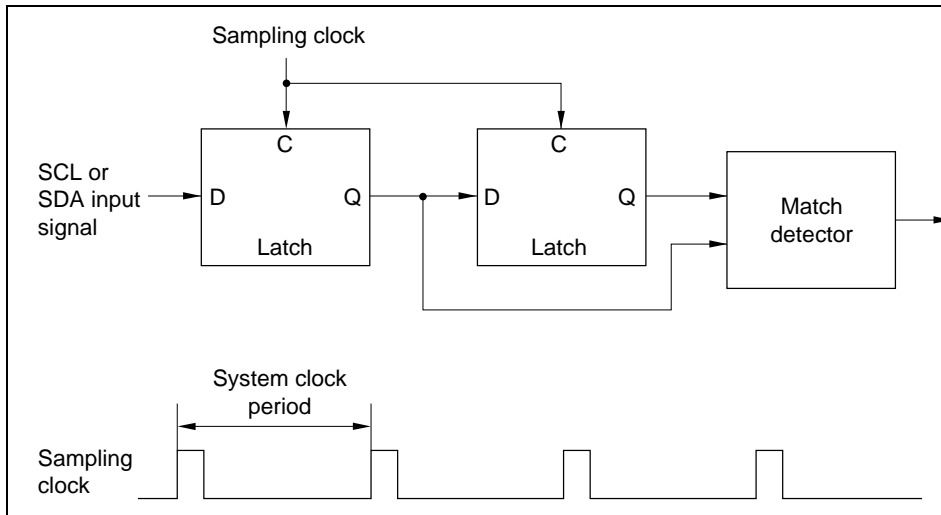


Figure 16.13 Block Diagram of Noise Canceler

16.3.10 Sample Flowcharts

Figures 16.14 to 16.17 show sample flowcharts for using the I²C bus interface in each mode.

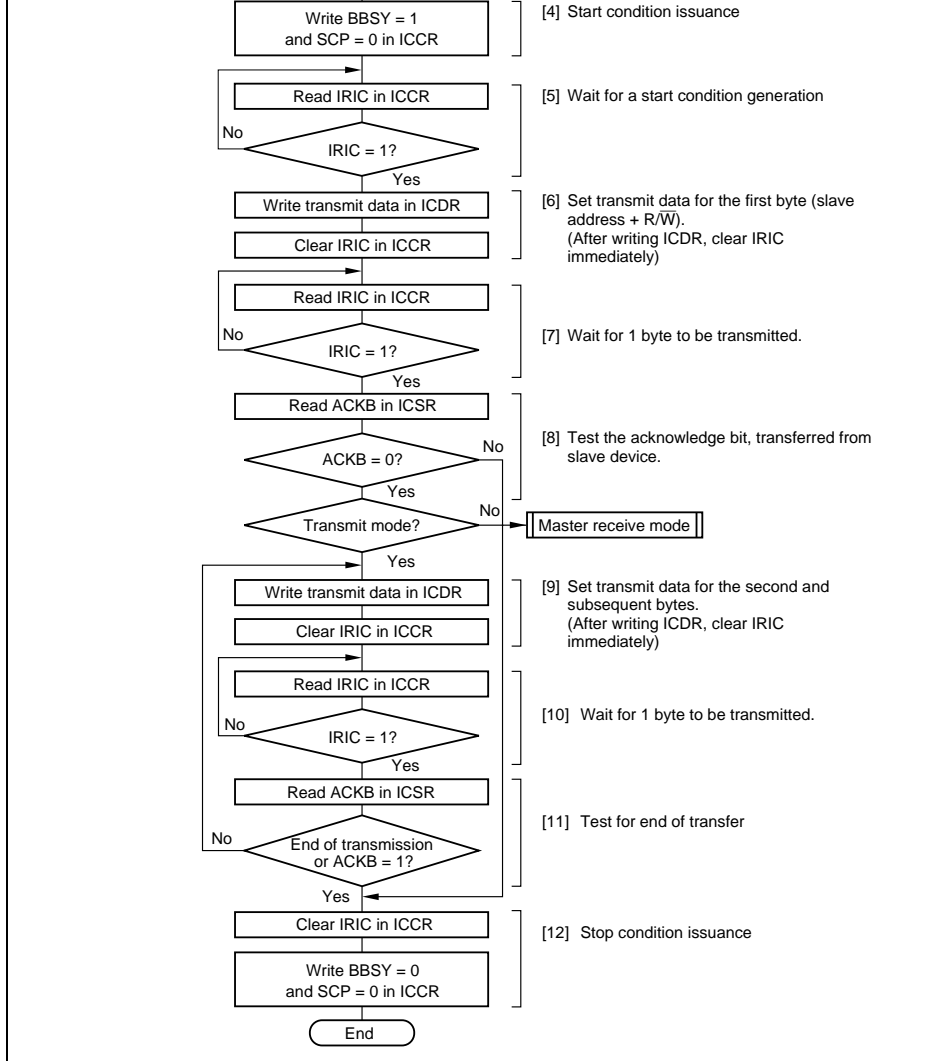


Figure 16.14 Flowchart for Master Transmit Mode (Example)

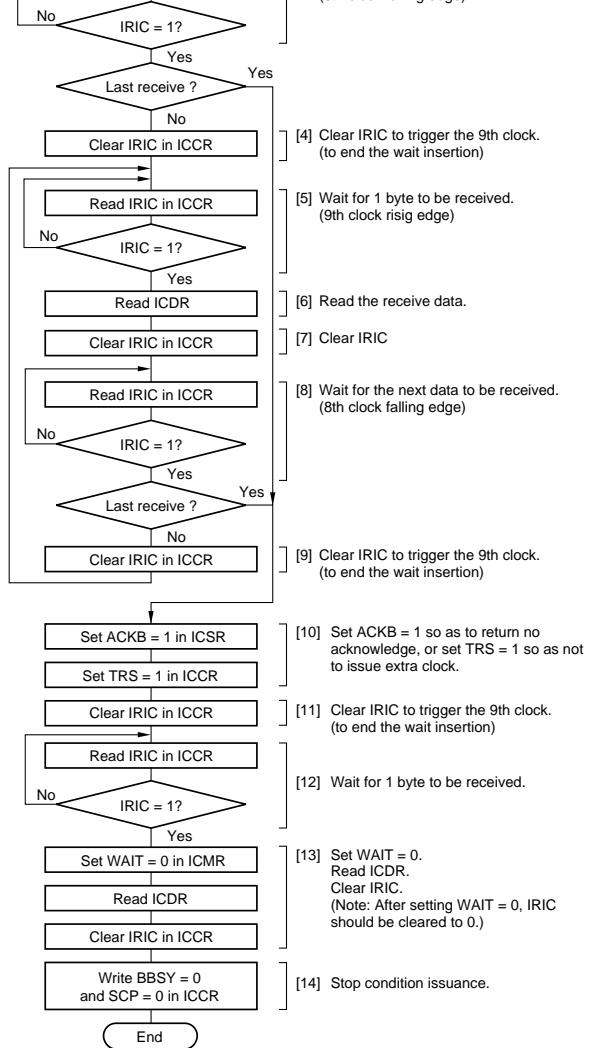


Figure 16.15 Flowchart for Master Receive Mode (Example)

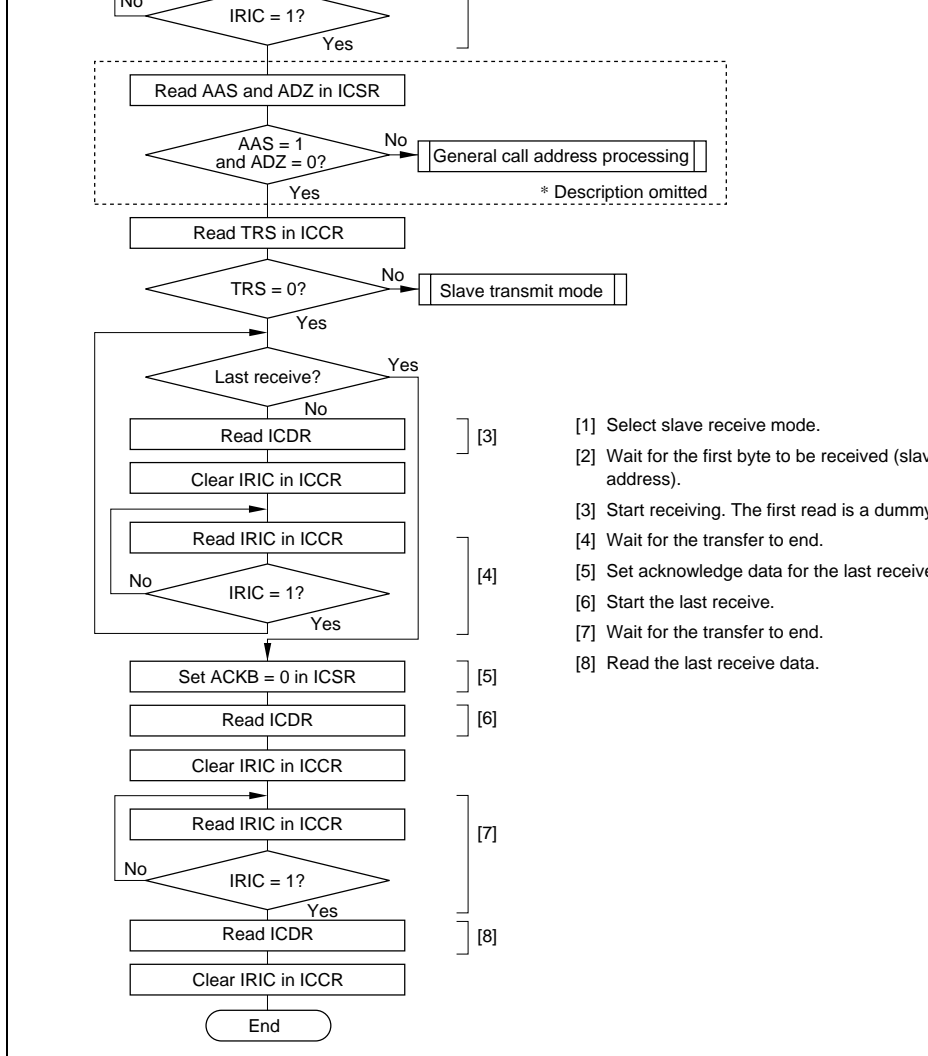


Figure 16.16 Flowchart for Slave Receive Mode (Example)

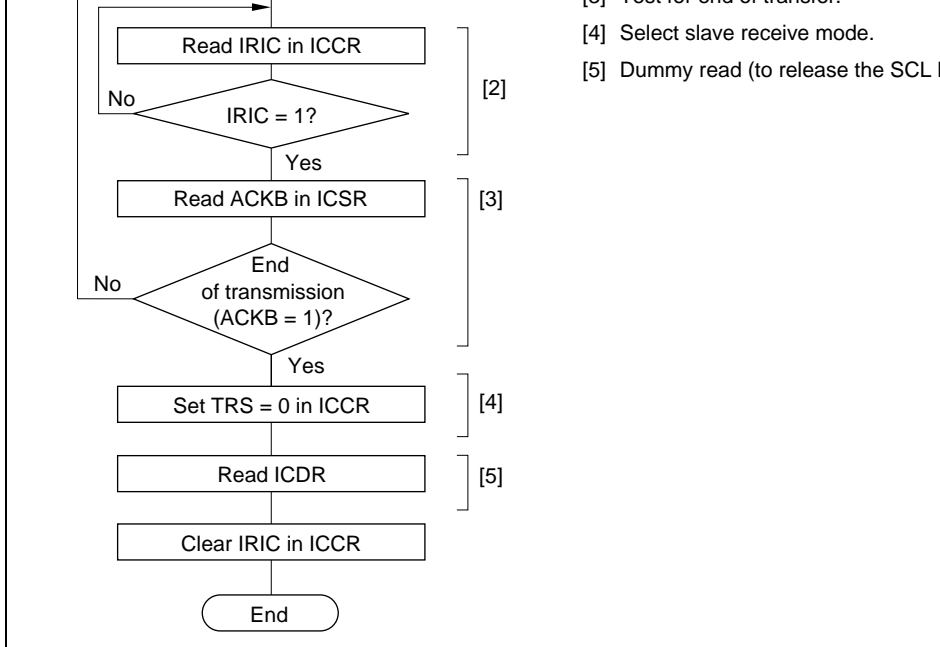


Figure 16.17 Flowchart for Slave Transmit Mode (Example)

Scope of Initialization:

The initialization executed by this function covers the following items:

- TDRE and RDRF internal flags
- Transmit/receive sequencer and internal operating clock counter
- Internal latches for retaining the output state of the SCL and SDA pins (wait, clock output, etc.)

The following items are not initialized:

- Actual register values (ICDR, SAR, SARX, ICMR, ICCR, ICSR, DDCCSWR, STC)
- Internal latches used to retain register read information for setting/clearing flags in ICCR, ICSR, and DDCCSWR registers
- The value of the ICMR register bit counter (BC2 to BC0)
- Generated interrupt sources (interrupt sources transferred to the interrupt controller)

Notes on Initialization:

- Interrupt flags and interrupt sources are not cleared, and so flag clearing measures taken as necessary.
- Basically, other register flags are not cleared either, and so flag clearing measures taken as necessary.
- When initialization is performed by means of the DDCCSWR register, the write data CLR3 to CLR0 is not retained. To perform IIC clearance, bits CLR3 to CLR0 must be simultaneously using an MOV instruction. Do not use a bit-manipulation instruction BCLR. Similarly, when clearing is required again, all the bits must be written to simultaneously in accordance with the setting.
- If a flag clearing setting is made during transmission/reception, the IIC module will stop transmitting/receiving at that point and the SCL and SDA pins will be released. When transmission/reception is started again, register initialization, etc., must be carried out as necessary to enable correct communication as a system.

- bit.
2. Execute a stop condition issuance instruction (write 0 to BBSY and SCP) to clear the bit to 0, and wait for two transfer rate clock cycles.
 3. Re-execute initialization of the internal state by setting of bit CLR3 to CLR0 or by setting of ICE bit.
 4. Initialize (re-set) the IIC registers.

16.4 Usage Notes

- In master mode, if an instruction to generate a start condition is immediately followed by an instruction to generate a stop condition, neither condition will be output correctly. To generate consecutive start and stop conditions, after issuing the instruction that generates the start condition, read the relevant ports, check that SCL and SDA are both low, then issue the instruction that generates the stop condition. Note that SCL may not yet have gone high when BBSY is cleared to 0.
- Either of the following two conditions will start the next transfer. Pay attention to the conditions when reading or writing to ICDR.
 - Write access to ICDR when ICE = 1 and TRS = 1 (including automatic transfer from ICDRT to ICDRS)
 - Read access to ICDR when ICE = 1 and TRS = 0 (including automatic transfer from ICDRS to ICDRR)
- Table 16.6 shows the timing of SCL and SDA output in synchronization with the internal clock. Timings on the bus are determined by the rise and fall times of signals affected by 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}	$1t_{SCLO} - 3t_{cyc}$	ns
Data output setup time (slave)		$1t_{SCLL} - (6t_{cyc} \text{ or } 12t_{cyc}^*)$	
Data output hold time	t_{SDAHO}	$3t_{cyc}$	ns

Note: * $6t_{cyc}$ when IICX is 0, $12t_{cyc}$ when 1.

- SCL and SDA input is sampled in synchronization with the internal clock. The AC therefore depends on the system clock cycle t_{cyc} , as shown in I²C Bus Timing in section 26.9. Electrical Characteristics, and as shown in table 26.10. Note that the I²C bus interface timing specifications will not be met with a system clock frequency of less than 5 MHz.
- The I²C bus interface specification for the SCL rise time t_{sr} is under 1000 ns (300 ns in speed mode). In master mode, the I²C bus interface monitors the SCL line and synchronizes one bit at a time during communication. If t_{sr} (the time for SCL to go from low to V_{CC}) is longer than the time determined by the input clock of the I²C bus interface, the high period of SCL is extended. The SCL rise time is determined by the pull-up resistance and load capacitance on the SCL line. To insure proper operation at the set transfer rate, adjust the pull-up resistance and load capacitance so that the SCL rise time does not exceed the values given in table 26.10 below.

		mode					
1	17.5t _{cyc}	Standard mode	1000 ns	1000 ns	1000 ns	1000 ns	1000 ns
		High-speed mode	300 ns	300 ns	300 ns	300 ns	300 ns

- The I²C bus interface specifications for the SCL and SDA rise and fall times are 1000 ns and 300 ns. The I²C bus interface SCL and SDA output timing is prescribed by t_{cyc}, table 16.6. However, because of the rise and fall times, the I²C bus interface specifications cannot be satisfied at the maximum transfer rate. Table 16.8 shows output timing calculations at different operating frequencies, including the worst-case influence of rise and fall times.

t_{BUFO} fails to meet the I²C bus interface specifications at any frequency. The solution is (a) to provide coding to secure the necessary interval (approximately 1 μs) between issuance of a stop condition and issuance of a start condition, or (b) to select devices whose input timing permits this output timing for use as slave devices connected to the I²C bus.

t_{SCLL0} in high-speed mode and t_{STAS0} in standard mode fail to satisfy the I²C bus interface specifications for worst-case calculations of t_{sr}/t_{sr}. Possible solutions that should be considered include (a) adjusting the rise and fall times by means of a pull-up resistor and capacitor, (b) reducing the transfer rate to meet the specifications, or (c) selecting devices whose input timing permits this output timing for use as slave devices connected to the I²C bus.

		High-speed mode	-300	600	950	950	950	950
t_{SCLO}	$0.5t_{\text{SCLO}} (-t_{\text{Sr}})$	Standard mode	-250	4700	4750	4750	4750	4750
		High-speed mode	-250	1300	1000 ^{*1}	1000 ^{*1}	1000 ^{*1}	1000 ^{*1}
t_{BUFO}	$0.5t_{\text{SCLO}} - 1t_{\text{cyc}} (-t_{\text{Sr}})$	Standard mode	-1000	4700	3800 ^{*1}	3875 ^{*1}	3900 ^{*1}	3938 ^{*1}
		High-speed mode	-300	1300	750 ^{*1}	825 ^{*1}	850 ^{*1}	888 ^{*1}
t_{STAHO}	$0.5t_{\text{SCLO}} - 1t_{\text{cyc}} (-t_{\text{Sr}})$	Standard mode	-250	4000	4550	4625	4650	4688
		High-speed mode	-250	600	800	875	900	938
t_{STASO}	$1t_{\text{SCLO}} (-t_{\text{Sr}})$	Standard mode	-1000	4700	9000	9000	9000	9000
		High-speed mode	-300	600	2200	2200	2200	2200
t_{STOSO}	$0.5t_{\text{SCLO}} + 2t_{\text{cyc}} (-t_{\text{Sr}})$	Standard mode	-1000	4000	4400	4250	4200	4125
		High-speed mode	-300	600	1350	1200	1150	1075
t_{SDASO} (master)	$1t_{\text{SCLO}}^{*3} - 3t_{\text{cyc}} (-t_{\text{Sr}})$	Standard mode	-1000	250	3100	3325	3400	3513
		High-speed mode	-300	100	400	625	700	813
t_{SDASO} (slave)	$1t_{\text{SCLL}}^{*3} - 12t_{\text{cyc}}^{*2} (-t_{\text{Sr}})$	Standard mode	-1000	250	1300	2200	2500	2950
		High-speed mode	-300	100	-1400 ^{*1}	-500 ^{*1}	-200 ^{*1}	250

- Notes: 1. Does not meet the I²C bus interface specification. Remedial action such as the following is necessary: (a) secure a start/stop condition issuance interval; (b) adjust the fall times by means of a pull-up resistor and capacitive load; (c) reduce the timing of the IICX output; (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 registers CKS0 to CKS2. Depending on the frequency it may not be possible to achieve the maximum transfer rate; therefore whether or not the I²C bus interface specification is met must be determined in accordance with the actual setting conditions.
2. Value when the IICX bit is set to 1. When the IICX bit is cleared to 0, the value is $-6t_{\text{cyd}}$.
 3. Calculated using the I²C bus specification values (standard mode: 4700 ns min., speed mode: 1300 ns min.).

- Note on ICDR Read at End of Master Reception

To halt reception at the end of a receive operation in master receive mode, set the TRS bit to 1 and write 0 to BBSY and SCP in ICCR. This changes SDA from low to high when TRS is set high, and generates the stop condition. After this, receive data can be read by means of an ICDR read, but if data remains in the buffer the ICDRS receive data will not be transferred to ICDR, and so it will not be possible to read the second byte of data.

If it is necessary to read the second byte of data, issue the stop condition in master receive mode (i.e. with the TRS bit cleared to 0). When reading the receive data, first confirm that the BBSY bit in the ICCR register is cleared to 0, the stop condition has been generated, and the bus has been released, then read the ICDR register with TRS cleared to 0.

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

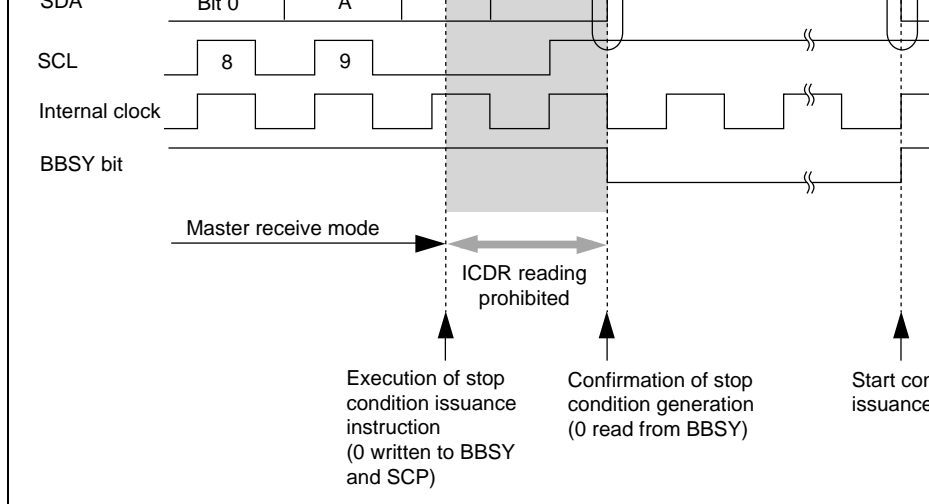


Figure 16.18 Points for Attention Concerning Reading of Master Receive

- Notes on Start Condition Issuance for Retransmission

Figure 16.19 shows the timing of start condition issuance for retransmission, and subsequently writing data to ICDR, together with the corresponding flowchart. After start condition issuance is done and determined the start condition, write the transmit data as shown below.

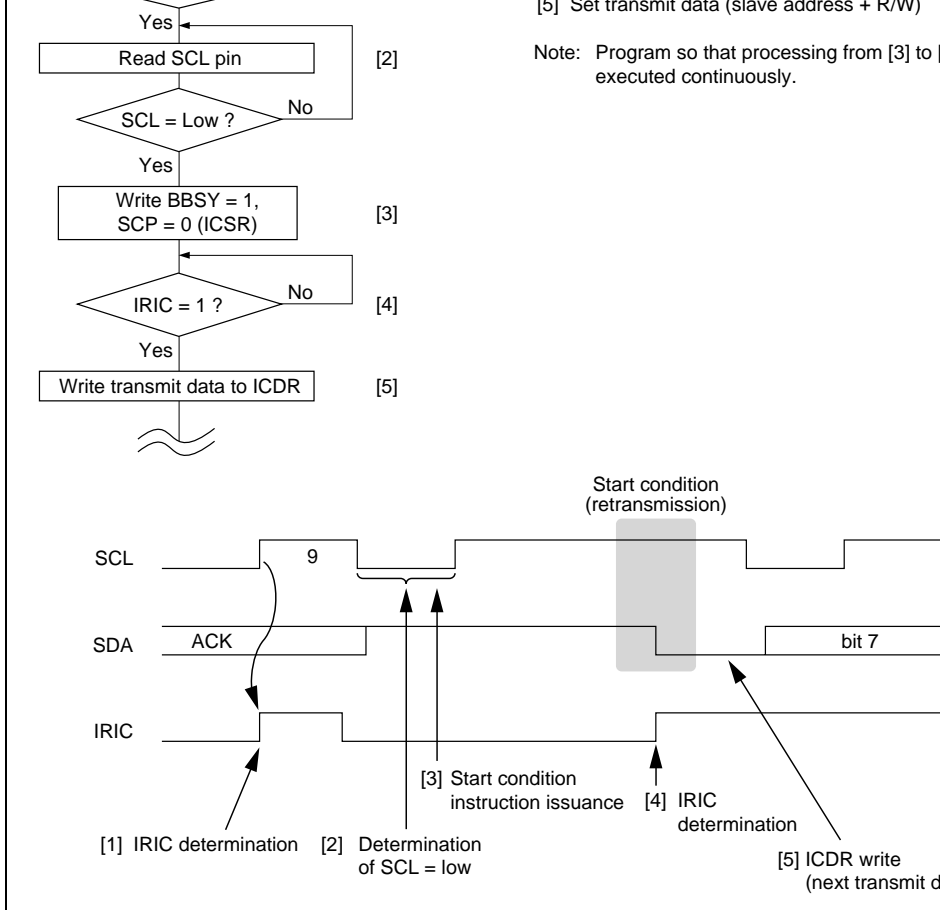


Figure 16.19 Flowchart and Timing of Start Condition Instruction Issuance Retransmission

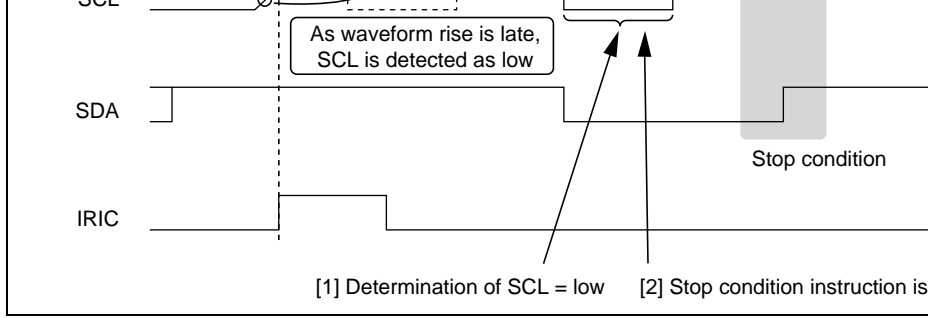


Figure 16.20 Timing of Stop Condition Issuance

— Error phenomenon

Normally, WAIT State will be cancelled by clearing the IRIC flag bit from 1 to 0 on the fall of the 8th clock in WAIT State. In this case, if the IRIC flag bit is cleared before the 7th clock fall and the 8th clock fall, the IRIC flag clear-data will be retained into the WAIT State. Therefore, the WAIT State will be cancelled right after WAIT insertion on 8th clock.

— Restrictions

Please clear the IRIC flag before the rise of the 7th clock (the counter value of BC2 through BC0 should be 2 or greater), after the IRIC flag is set to 1 on the rise of the 8th clock.

If the IRIC flag-clear is delayed due to the interrupt or other processes and the counter value of BC2 through BC0 is turned to 1 or 0, please confirm the SCL pins are in L' state after the rise of the 8th clock. The counter value of BC2 through BC0 is turned to 0, and clear the IRIC flag. (See figure 16.21)

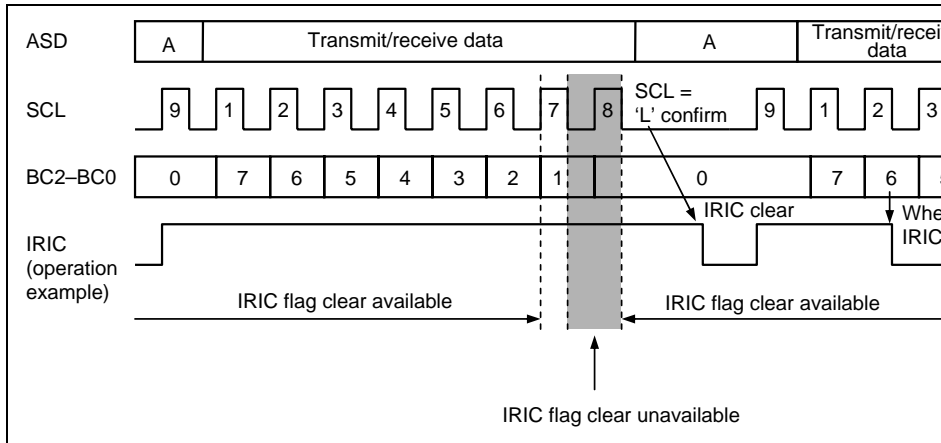


Figure 16.21 IRIC Flag Clear Timing on WAIT Operation

To ensure that the interrupt processing is performed properly, one of the following conditions should be applied.

- (1) Make sure that reading received data from the ICDR register, or reading or writing to the ICCR register, is completed before the next slave address receive operation starts.
- (2) Monitor the BC2 to BC0 counter in the ICMR register and, when the value of BC2 to BC0 is 000 (8th or 9th clock cycle), allow a waiting time of at least 2 transfer clock cycles in order to involve the problem period in question before reading from the ICDR register, or reading or writing to the ICCR register.

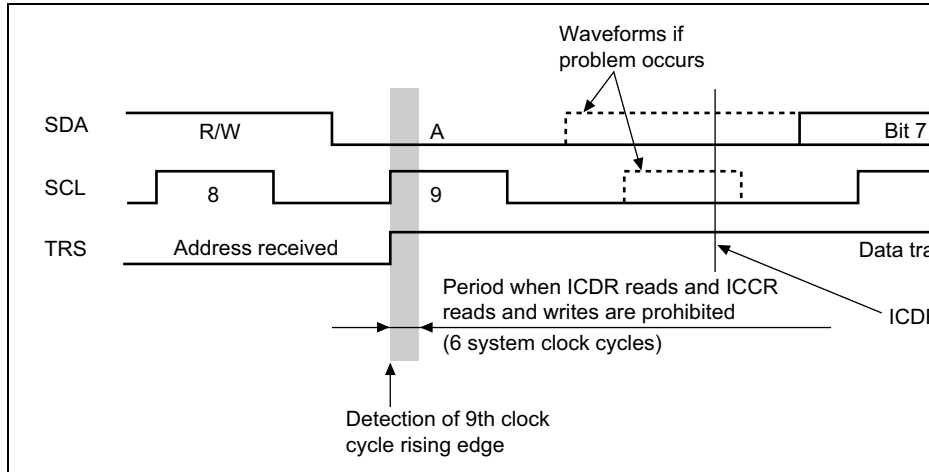


Figure 16.22 ICDR Read and ICCR Access Timing in Slave Transmit Mode

This results in the actual internal value of the TRS bit remaining 1 (transmit mode) acknowledge bit being sent at the 9th clock cycle address receive completion in the address receive operation following a restart condition input with no stop condition intervening.

When receiving an address in the slave mode, clear the TRS bit to 0 during the period indicated as (a) in figure 16.23.

To cancel the holding of the SCL bit low by the wait function in the slave mode, clear the TRS bit to 0 and then perform a dummy read of the ICDR register.

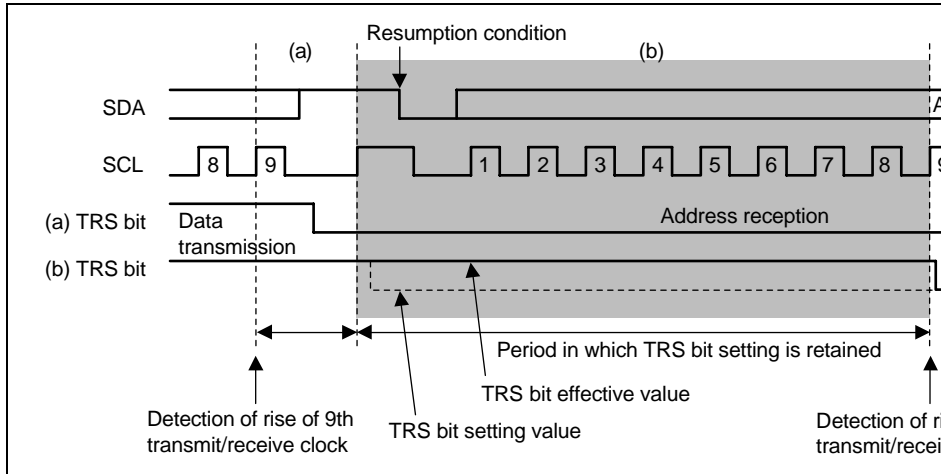


Figure 16.23 TRS Bit Setting Timing in Slave Mode

figure 16.24.)

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 one data has been transmitted or received.

When arbitration is lost during transmitting the second frame or subsequent frame, avoidance measures.

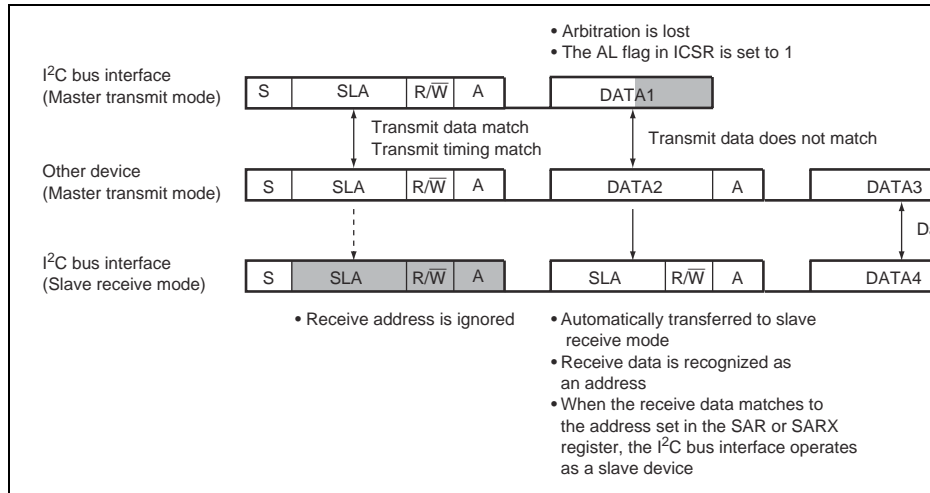


Figure 16.24 Diagram of Erroneous Operation when Arbitration is Lost

Though it is prohibited in the normal I²C protocol, the same problem may occur when the AL bit is erroneously set to 1 and a transition to master mode is occurred during data transmission or reception in slave mode. In multi-master mode, pay attention to the setting of the AL bit when a bus conflict may occur. In this case, the MST bit in the ICCR register should be set according to the order below.

- (a) Make sure that the BBSY flag in the ICCR register is 0 and the bus is free before setting the MST bit.
- (b) Set the MST bit to 1.

to 1

- Rising edge of the 9th transmit/receive clock is input to the SCL pin

When the above two conditions are satisfied in slave receive mode, an unnecessary interrupt occurs.

Figure 16.25 shows the note on interrupt occurrence in slave mode after receiving acknowledge bit (ACKB = 1).

- (1) For the last transmit data in master transmit mode or slave transmit mode, 1 is received as the acknowledge bit.

If the ACKE bit in ICCR is set to 1 at this time, the ACKB bit in ICSR is set to 1.

- (2) After switching to slave receive mode, the start condition is input, and address reception is performed next.
- (3) Even if the received address does not match the address set in SAR or SARX, the ACKB flag is set to 1 at the rise of the 9th transmit/receive clock, thus causing an interrupt to occur.

Note that if the slave address matches, an interrupt is to be generated at the rise of the 9th transmit/receive clock as normal operation, so this is not erroneous operation.

— Restriction

In a transmit operation of the I²C bus interface module, carry out the following countermeasures.

- (1) After 1 is received as the acknowledge bit for transmit data, clear the ACKE bit in ICCR to 0 to clear the ACKB bit to 0.
- (2) To enable acknowledge bit reception afterwards, set the ACKE bit to 1 again.

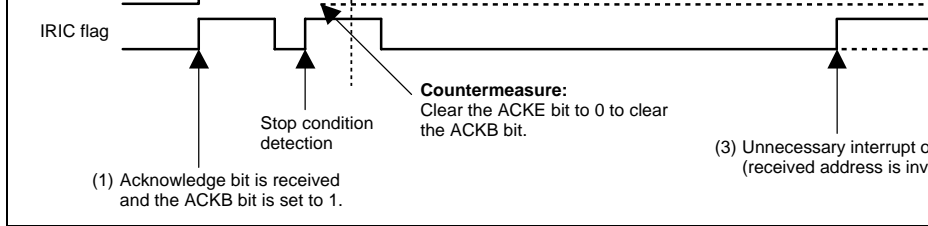


Figure 16.25 Note on Interrupt Occurrence in Slave Mode after ACKB = 1 R

- (1) When previously received 2-bytes data remains in ICDR unread (ICDRS at 0).
- (2) Reads ICDR register after switching to transmit mode (TRS = 1). (RDRF = 0).
- (3) Sets to receive mode (TRS = 0), after transmitting Rev.1 frame of issued start condition by master mode.

— Slave mode

Figure 16.27 shows the notes on ICDR writing (TRS = 0) in slave mode.

- (1) Writes ICDR register in receive mode (TRS = 0), after entering the start condition in slave mode (TDRE = 0 state).

Address match with Rev.1 frame, receive 1 by R/W bit, and switches to transmit mode (TRS = 1).

When these conditions are satisfied, the low fixation of the SCL pins is cancelled without ICDR register access after Rev.1 frame is transferred.

— Restriction

Please carry out the following countermeasures when transmitting/receiving via IIC interface module.

- (1) Please read the ICDR registers in receive mode, and write them in transmit mode.
- (2) In receiving operation with master mode, please issue the start condition after clearing the internal flag of the IIC bus interface module, using CLR3 to CLR0 bit of DDCCSWR register on bus-free state (BBSY = 0).

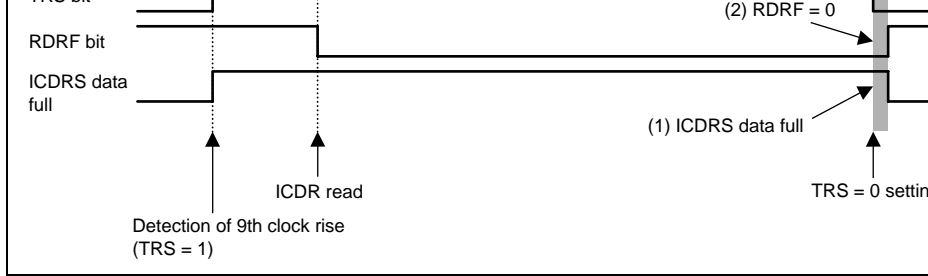


Figure 16.26 Notes on ICDR Reading with TRS = 1 Setting in Master Mode

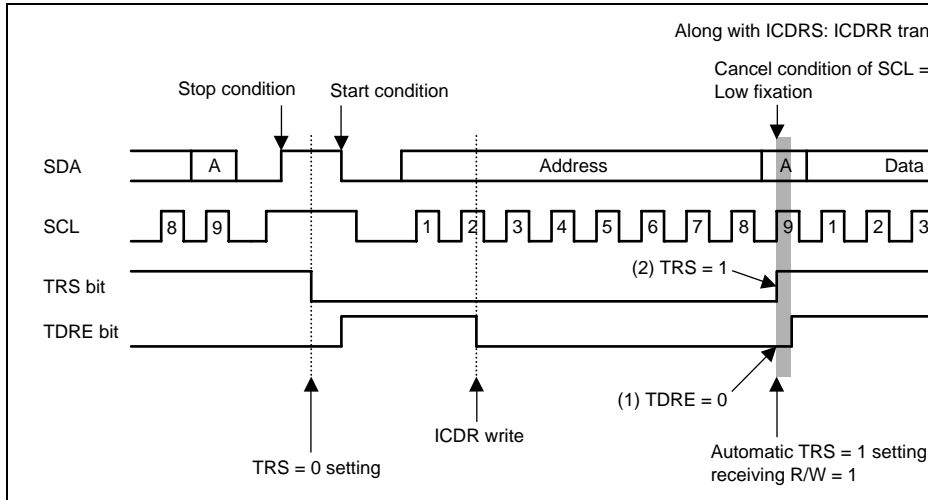


Figure 16.27 Notes on ICDR Writing with TRS = 0 Setting in Slave Mode

designated 0, 1, and 2. The keyboard buffer controller is provided with functions conforming to the PS/2 interface specifications.

Data transfer using the keyboard buffer controller employs a data line (KD) and a clock line (KCLK), providing economical use of connectors, board surface area, etc. Figure 17.1 shows how the keyboard buffer controller is connected.

17.1.1 Features

- Conforms to PS/2 interface specifications
- Direct bus drive (via the KCLK and KD pins)
- Interrupt sources: on completion of data reception and on detection of clock edge
- Error detection: parity error and stop bit monitoring

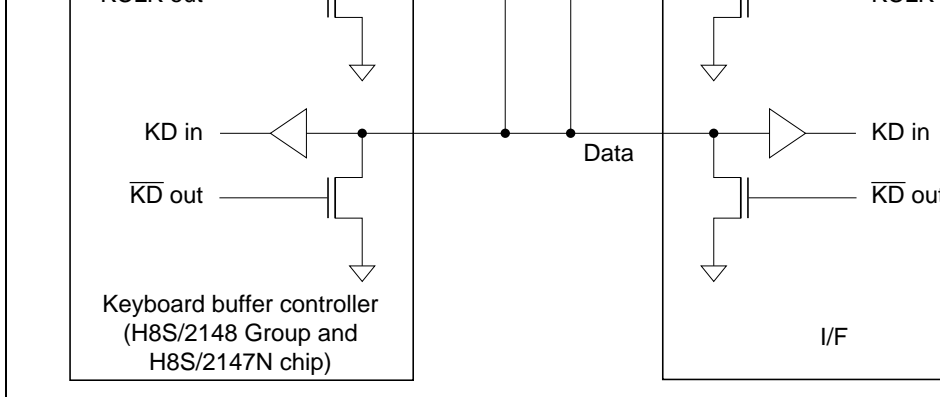


Figure 17.1 Keyboard Buffer Controller Connection

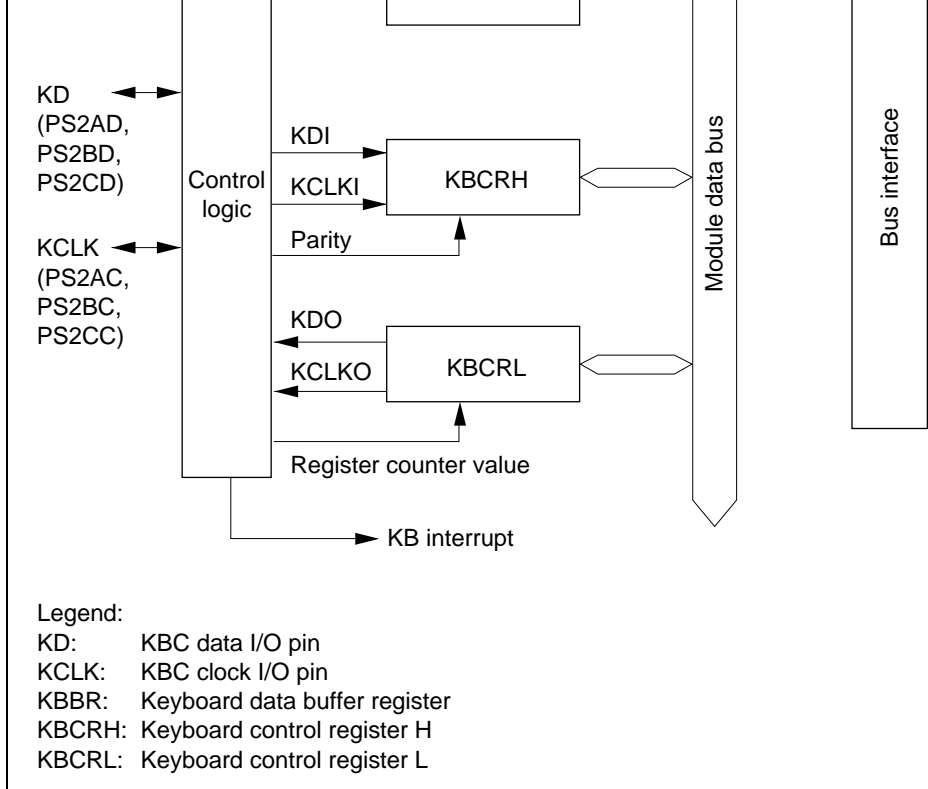


Figure 17.2 Block Diagram of Keyboard Buffer Controller

1	KBC clock I/O pin (KCLK1)	PS2BC	I/O	KBC clock inp
	KBC data I/O pin (KD1)	PS2BD	I/O	KBC data inp
2	KBC clock I/O pin (KCLK2)	PS2CC	I/O	KBC clock inp
	KBC data I/O pin (KD2)	PS2CD	I/O	KBC data inp

Note: * These are the external I/O pin names. In the text, clock I/O pins are referred and data I/O pins as KD, omitting the channel designations.

17.1.4 Register Configuration

Table 17.2 lists the registers of the keyboard buffer controller.

Table 17.2 Keyboard Buffer Controller Registers

Channel	Name	Abbreviation	R/W	Initial Value
0	Keyboard control register H	KBCRH0	R/(W) ^{*2}	H'70
	Keyboard control register L	KBCRL0	R/W	H'70
	Keyboard data buffer register	KBBR0	R	H'00
1	Keyboard control register H	KBCRH1	R/(W) ^{*2}	H'70
	Keyboard control register L	KBCRL1	R/W	H'70
	Keyboard data buffer register	KBBR1	R	H'00
2	Keyboard control register H	KBCRH2	R/(W) ^{*2}	H'70
	Keyboard control register L	KBCRL2	R/W	H'70
	Keyboard data buffer register	KBBR2	R	H'00
Common	Module stop control register	MSTPCRH	R/W	H'3F
		MSTPCRL	R/W	H'FF

Notes: 1. Lower 16 bits of the address.

2. Only 0 can be written in bits 2 and 1, to clear the flags.

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

KBCRH is an 8-bit readable/writable register that indicates the operating status of the buffer controller.

KBCRH is initialized to H'70 by a reset, and in standby mode, watch mode, subactive subsleep mode, and module stop mode. Bits 6, 5, and 2 to 0 are also initialized when KBCRH is cleared to 0.

Bit 7—Keyboard In/Out Enable (KBIOE): Selects whether or not the keyboard buffer controller is used. When KBIOE is set to 1, the keyboard buffer controller is enabled for transmission and reception and the port pins function as KCLK and KD I/O pins. When cleared to 0, the keyboard buffer controller stops functioning and the port pins go to the impedance state.

Bit 7

KBIOE	Description
0	The keyboard buffer controller is non-operational (KCLK and KD signal port functions)
1	The keyboard buffer controller is enabled for transmission and reception (KCLK and KD signal pins are in the bus drive state)

Bit 6—Keyboard Clock In (KCLKI): Monitors the KCLK I/O pin. This bit cannot be written.

Bit 6

KCLKI	Description
0	KCLK I/O pin is low
1	KCLK I/O pin is high

as the keyboard buffer register full flag or as the KCLK fall interrupt flag. When KBFS is cleared to 0, the KBE bit in the KBCRL register should be cleared to 0 to disable reception.

Bit 4

KBFSEL	Description
0	KBF bit is used as KCLK fall interrupt flag
1	KBF bit is used as keyboard buffer register full flag (In

Bit 3—Keyboard Interrupt Enable (KBIE): Enables or disables interrupts from the keyboard buffer controller to the CPU.

Bit 3

KBIE	Description
0	Interrupt requests are disabled (In
1	Interrupt requests are enabled

Bit 2—Keyboard Buffer Register Full (KBF): Indicates that data reception has been completed and the received data is in the keyboard data buffer register (KBBR).

Bit 2

KBF	Description
0	[Clearing condition] (In Read KBF when KBF =1, then write 0 in KBF
1	[Setting conditions] <ul style="list-style-type: none"> When data has been received normally and has been transferred to keyboard data buffer register (keyboard buffer register full flag) When a KCLK falling edge is detected (while KBFSEL = 0) (KCLK interrupt)

Bit 0—Keyboard Stop (KBS): Indicates the receive data stop bit. Valid only when K

Bit 0

KBS	Description
0	0 stop bit received
1	1 stop bit received

17.2.2 Keyboard Control Register L (KBCRL)

Bit	7	6	5	4	3	2	1
	KBE	KCLKO	KDO	—	RXCR3	RXCR2	RXCR1
Initial value	0	1	1	1	0	0	0
Read/Write	R/W	R/W	R/W	—	R	R	R

KBCRL is an 8-bit readable/writable register that enables the receive counter count and the keyboard buffer controller pin output.

KBCRL is initialized to H'70 by a reset, and in standby mode, watch mode, subactive subsleep mode, and module stop mode.

Bit 7—Keyboard Enable (KBE): Enables or disables loading of receive data into the data buffer register (KBBR).

Bit 7

KBE	Description
0	Loading of receive data into KBBR is disabled
1	Loading of receive data into KBBR is enabled

Bit 5

KDO	Description
0	Keyboard buffer controller data I/O pin is low
1	Keyboard buffer controller data I/O pin is high (Ir

Bit 4—Reserved: This bit cannot be modified and is always read as 1.

Bits 3 to 0—Receive Counter (RXCR3 to RXCR0): These bits indicate the received data. Their value is incremented on the fall of KCLK. These bits cannot be modified.

The receive counter is initialized to 0000 by a reset and when 0 is written in KBE. Its value is incremented to 0000 after a stop bit is received.

Bit 3	Bit 2	Bit 1	Bit 0	Receive Data Contents			
RXCR3	RXCR2	RXCR1	RXCR0				
0	0	0	0	—			
			1	Start bit			
		1	1	0	0	KB0	
					1	KB1	
					0	KB2	
					1	KB3	
				1	0	0	KB4
						1	KB5
						0	KB6
						1	KB7
1	0	0	0	Parity bit			
			1	—			
		1	—	—	—		

KBBR is initialized to H'00 by a reset, in standby mode, watch mode, subactive mode, mode, and module stop mode, and when KBIOE is cleared to 0.

17.2.4 Module Stop Control Register (MSTPCR)

Bit	MSTPCRH								MSTPCRL							
	7	6	5	4	3	2	1	0	7	6	5	4	3	2		
	MSTP15	MSTP14	MSTP13	MSTP12	MSTP11	MSTP10	MSTP9	MSTP8	MSTP7	MSTP6	MSTP5	MSTP4	MSTP3	MSTP2		
Initial value	0	0	1	1	1	1	1	1	1	1	1	1	1	1		
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W		

MSTPCR, comprising two 8-bit readable/writable register, performs module stop mode. When the MSTP2 bit is set to 1, the keyboard buffer controller halts and enters module stop mode. See section 25.5, Module Stop Mode, for details.

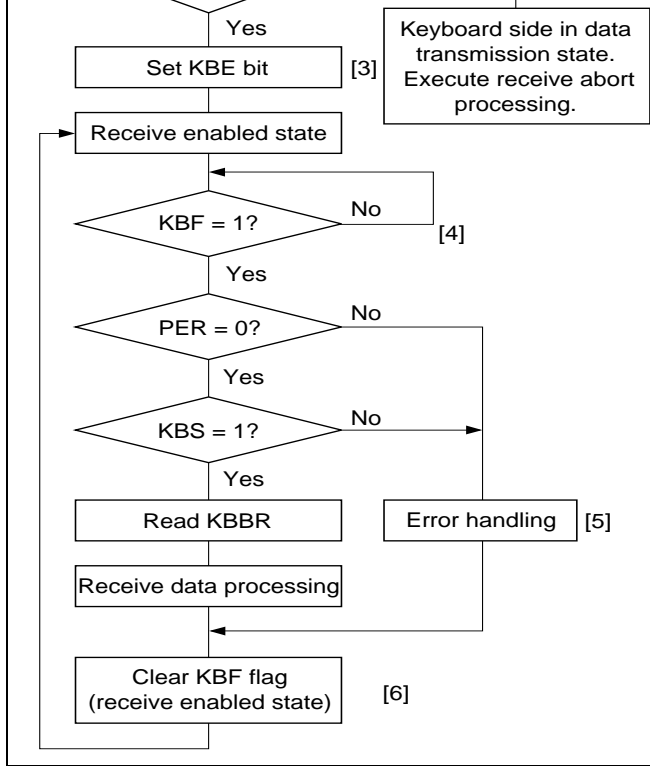
MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not initialized in software standby mode.

MSTPCRL Bit 2—Module Stop (MSTP2): Specifies keyboard buffer controller module stop mode.

MSTPCRL

Bit 2

MSTP2	Description
0	Keyboard buffer controller module stop mode is cleared
1	Keyboard buffer controller module stop mode is set ()



Keyboard side in data transmission state. Execute receive abort processing.

[3] Detect the start bit on the keyboard side. Receive data in synchronization with KCLK.

[4] When a stop bit is received, the keyboard buffer controller drives KBE low to disable keyboard transmission (auto-inhibit). If the KBIE bit is set in KBCRH, an interrupt request is sent to the CPU at the same time.

[5] Perform receive data error processing.

[6] Clear the KBF flag in KBCRL. At the same time, the system automatically drives KCLK high, and the receive enable state is set.

The receive operation is continued by repeating [3] to [6].

Figure 17.3 Sample Receive Processing Flowchart

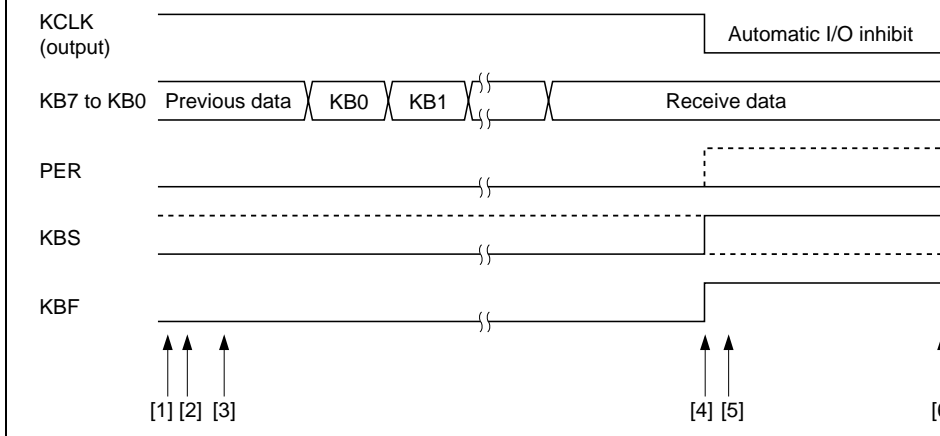


Figure 17.4 Receive Timing

17.3.2 Transmit Operation

In a transmit operation, KCLK (clock) is an output on the keyboard side, and KD (data) is an output on the H8S/2148 Group and H8S/2147N chip (system) side. KD outputs a start bit, 8 data bits (LSB-first), an odd parity bit, and a stop bit, in that order. The KD value is valid while KCLK is high. A sample transmit processing flowchart is shown in figure 17.5, and the transmit timing diagram is shown in figure 17.6.

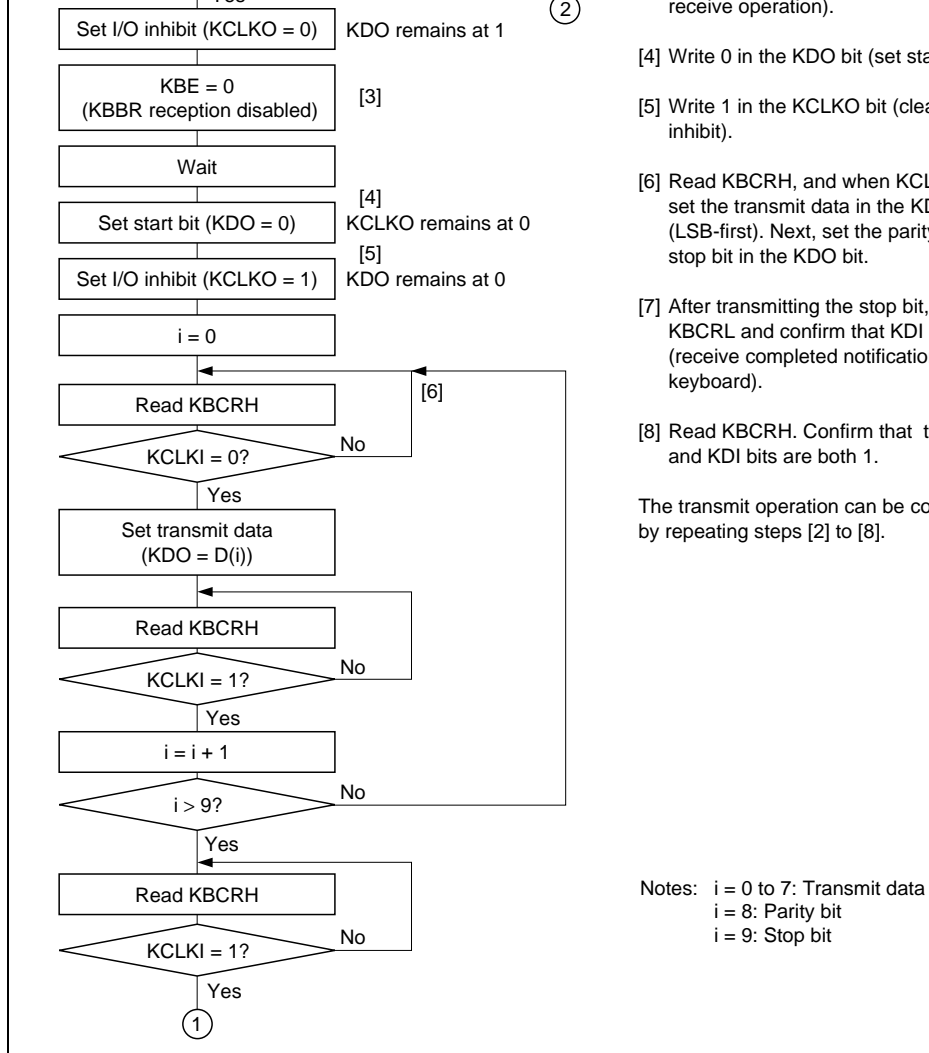


Figure 17.5 Sample Transmit Processing Flowchart

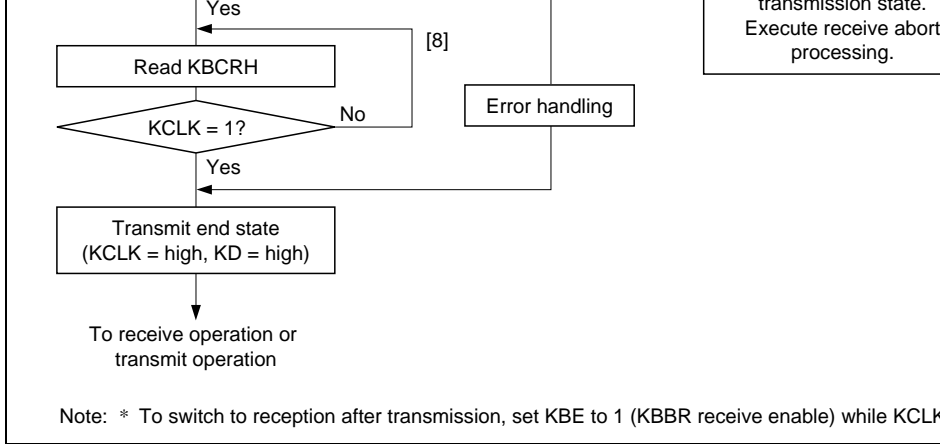


Figure 17.5 Sample Transmit Processing Flowchart (cont)

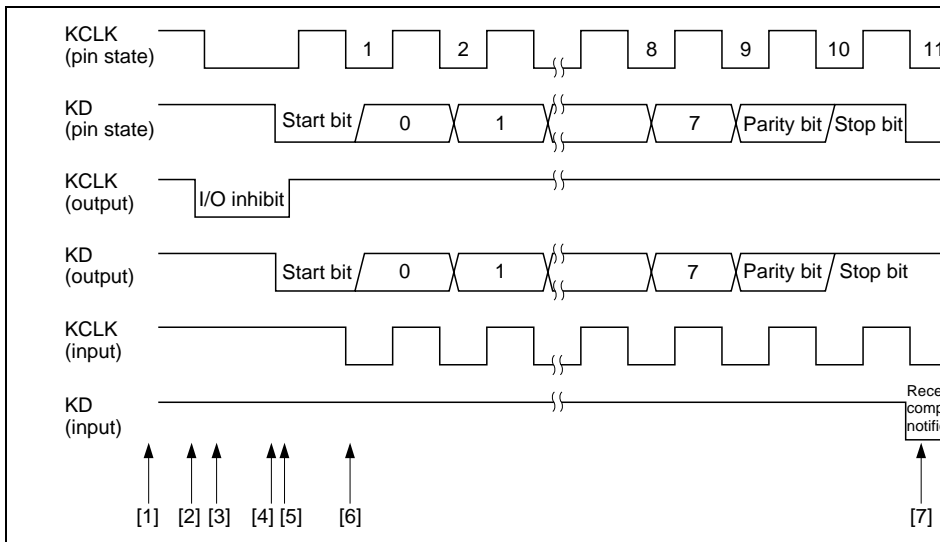


Figure 17.6 Transmit Timing

clock low for a certain period. A sample receive abort processing flowchart is shown in figure 17.7, and the receive abort timing in figure 17.8.



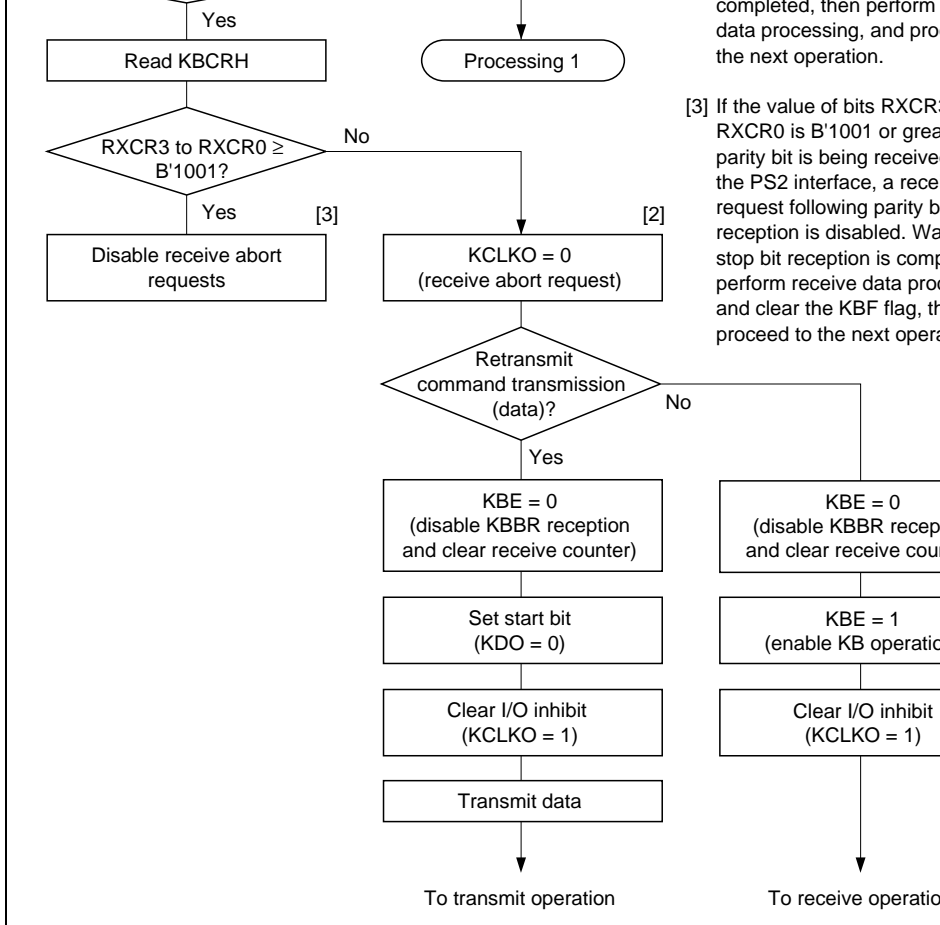


Figure 17.7 Sample Receive Abort Processing Flowchart



Figure 17.7 Sample Receive Abort Processing Flowchart (cont)

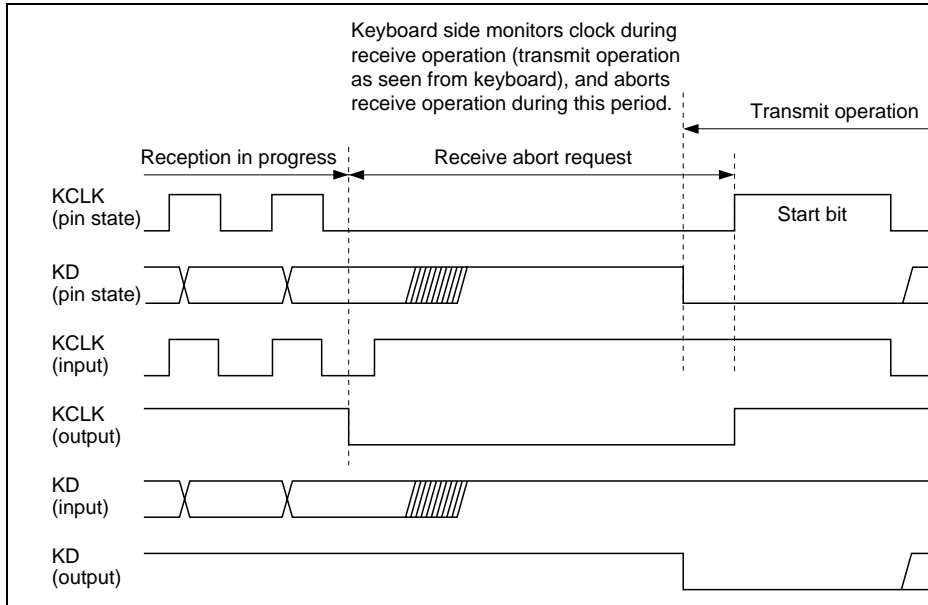


Figure 17.8 Receive Abort and Transmit Start (Transmission/Reception Switch) Timing

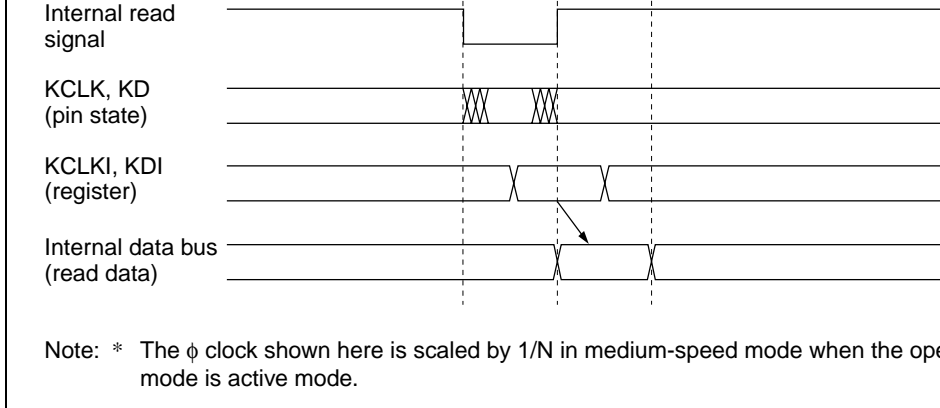


Figure 17.9 KCLKI and KDI Read Timing

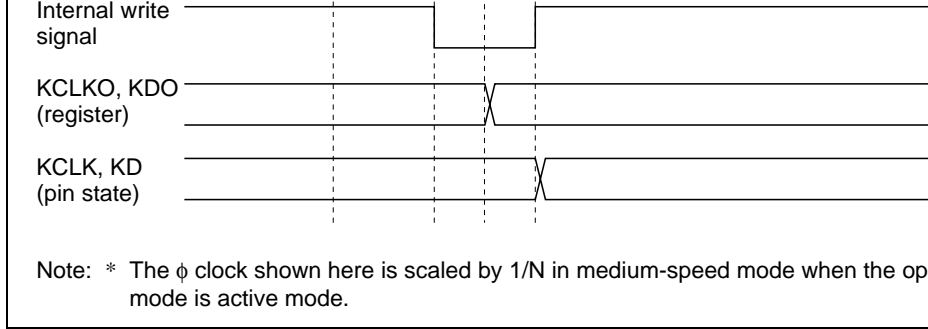


Figure 17.10 KCLKO and KDO Write Timing

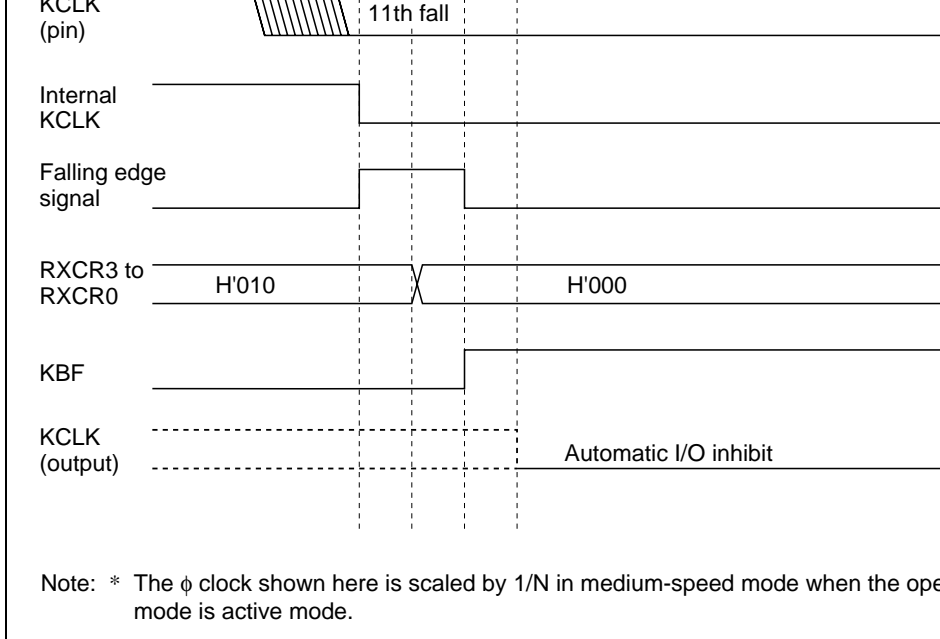


Figure 17.11 KBF Setting and KCLK Automatic I/O Inhibit Generation Timing

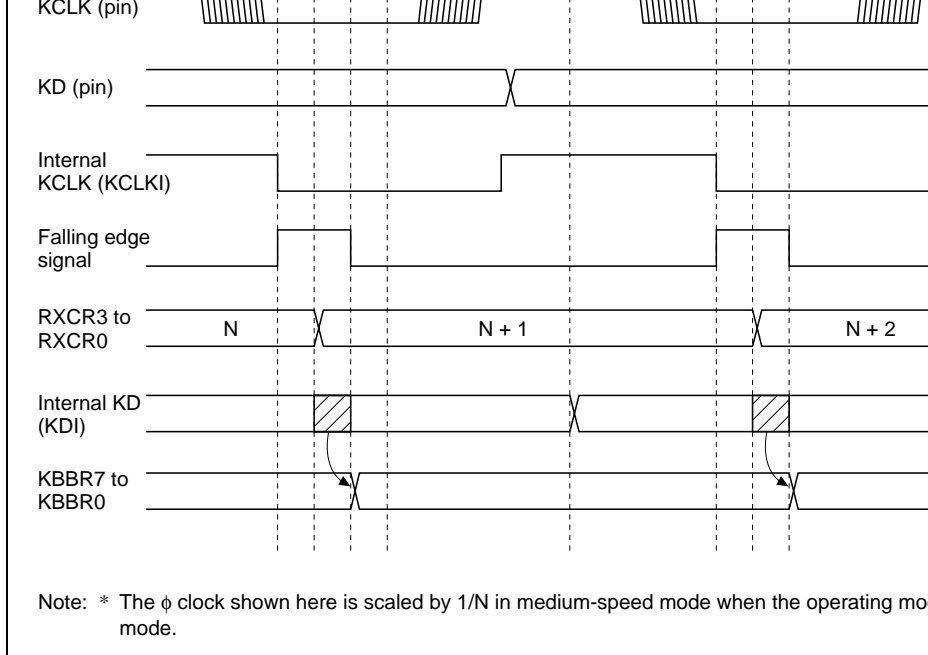


Figure 17.12 Receive Counter and KBBR Data Load Timing

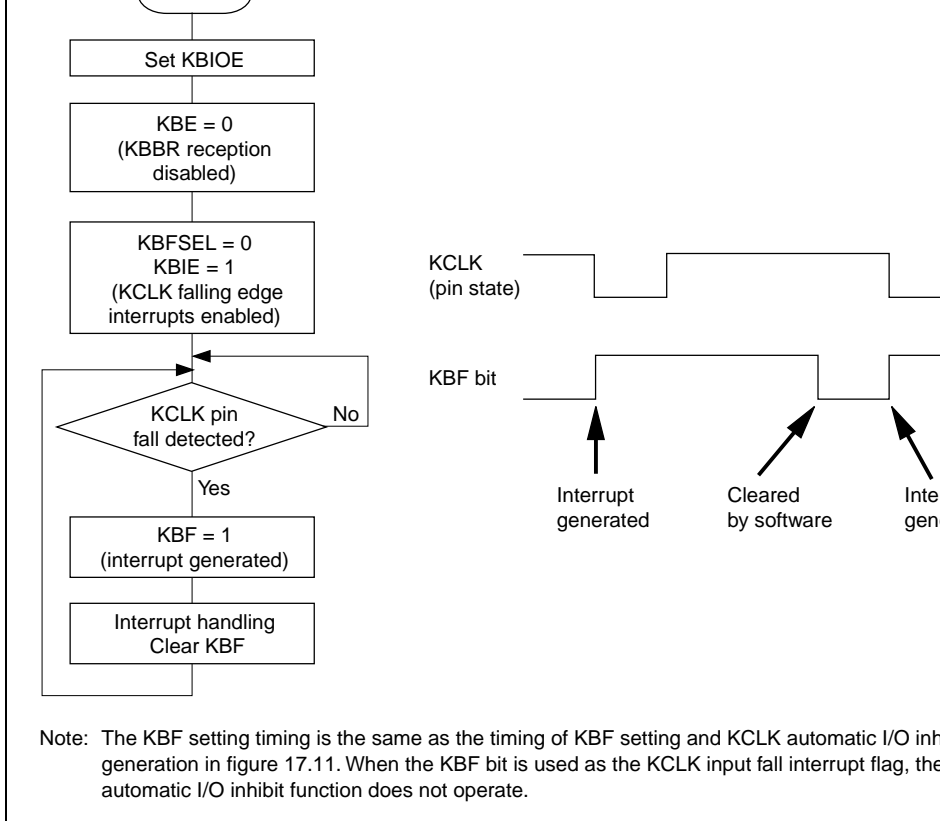


Figure 17.13 Example of KCLK Input Fall Interrupt Operation

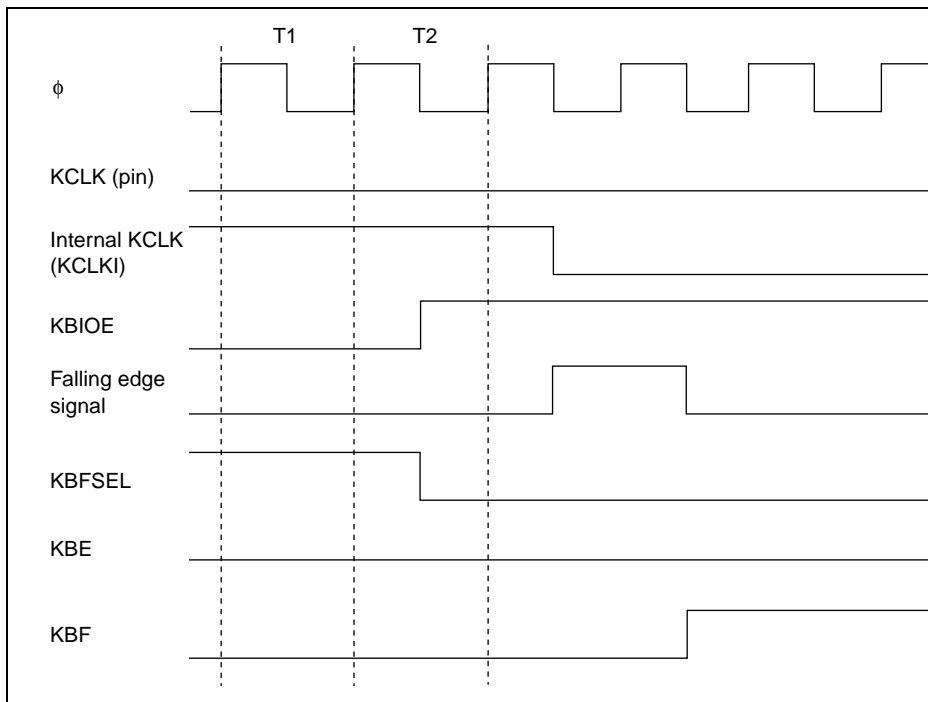


Figure 17.14 KBIOE Setting and KCLK Falling Edge Detection Timing

connection to an IBM bus, widely used as the internal bus in personal computers. The interface provides a four-channel parallel interface between the on-chip CPU and a host processor. The host interface is available only when the HI12E bit is set to 1 in SYSCR2. This mode is available only in slave mode, because it is designed for a master-slave communication system in which the H8S/2148 Group and H8S/2147N chip is slaved to a host processor.

18.1.1 Features

The features of the host interface are summarized below.

The host interface consists of 8-byte data registers, 4-byte status registers, a 2-byte command register, fast A20 gate logic, and a host interrupt request circuit. Communication is controlled by seven control signals from the host processor ($\overline{CS1}$, $\overline{CS2}$ or $\overline{ECS2}$, $\overline{CS3}$, $\overline{CS4}$, HA0, $\overline{IO/\overline{IOW}}$), six output signals to the host processor (GA20, HIRQ1, HIRQ11, HIRQ12, HIRQ13, HIRQ4), and an 8-bit bidirectional command/data bus (HDB7 to HDB0). The $\overline{CS1}$, $\overline{CS2}$, $\overline{CS3}$, and $\overline{CS4}$ signals select one of the four interface channels.

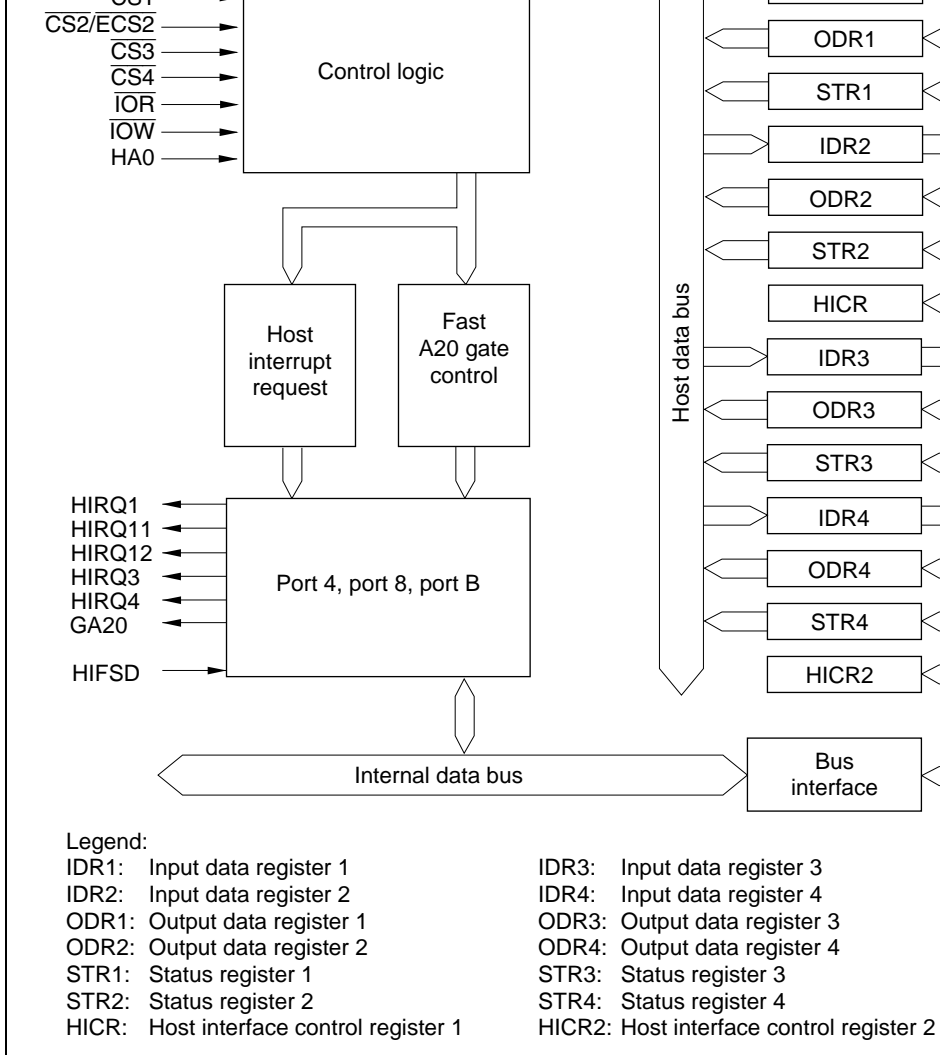


Figure 18.1 Block Diagram of Host Interface

Chip select 1	$\overline{CS1}$	P95	Input	Host interface chip select signal ODR1, STR1
Chip select 2*	$\overline{CS2}$	P81	Input	Host interface chip select signal ODR2, STR2
	$\overline{ECS2}$	P90		
Chip select 3	$\overline{CS3}$	PB2	Input	Host interface chip select signal ODR3, STR3
Chip select 4	$\overline{CS4}$	PB3	Input	Host interface chip select signal ODR4, STR4
Command/data	HA0	P80	Input	Host interface address select signal In host read access, this signal selects the status registers (STR1 to STR4) or the data registers (ODR1 to ODR4). In host write access to the data registers (IDTR1 to IDTR4 and IDTR4), this signal indicates the host is writing a command or data.
Data bus	HDB7 to HDB0	P37 to P30	I/O	Host interface data bus
Host interrupt 1	HIRQ1	P44	Output	Interrupt output 1 to host
Host interrupt 11	HIRQ11	P43	Output	Interrupt output 11 to host
Host interrupt 12	HIRQ12	P45	Output	Interrupt output 12 to host
Host interrupt 3	HIRQ3	PB0	Output	Interrupt output 3 to host
Host interrupt 4	HIRQ4	PB1	Output	Interrupt output 4 to host
Gate A20	GA20	P81	Output	A20 gate control signal output
HIF shutdown	HIFSD	P82	Input	Host interface shutdown control signal

Note: * Selection of $\overline{CS2}$ or $\overline{ECS2}$ is by means of the CS2E bit in STCR and the FGA20E bit in HICR. Host interface channel 2 and the CS2 pin can be used when CS2E = 0, CS2E = 1, $\overline{CS2}$ is used when FGA20E = 0, and $\overline{ECS2}$ is used when FGA20E = 1. In the manual, both are referred to as $\overline{CS2}$.

System control register	SYSCR	R/W ^{*1}	—	H'09	H'FFC4	—	—	—
System control register 2	SYSCR2	R/W	—	H'00	H'FF83	—	—	—
Host interface control register 1	HICR	R/W	—	H'F8	H'FFF0	—	—	—
Host interface control register 2	HICR2	R/W	—	H'F8	H'FE80	—	—	—
Input data register 1	IDR1	R	W	—	H'FFF4	0	1	1
Output data register 1	ODR1	R/W	R	—	H'FFF5	0	1	1
Status register 1	STR1	R/(W) ^{*2}	R	H'00	H'FFF6	0	1	1
Input data register 2	IDR2	R	W	—	H'FFFC	1	0	1
Output data register 2	ODR2	R/W	R	—	H'FFFD	1	0	1
Status register 2	STR2	R/(W) ^{*2}	R	H'00	H'FFFE	1	0	1
Input data register 3	IDR3	R	W	—	H'FE84	1	1	0
Output data register 3	ODR3	R/W	R	—	H'FE85	1	1	0
Status register 3	STR3	R/(W) ^{*2}	R	H'00	H'FE86	1	1	0
Input data register 4	IDR4	R	W	—	H'FE8C	1	1	1
Output data register 4	ODR4	R/W	R	—	H'FE8D	1	1	1
Status register 4	STR4	R/(W) ^{*2}	R	H'00	H'FE8E	1	1	1
Module stop control register	MSTPCRH	R/W	—	H'3F	H'FF86	—	—	—
	MSTPCRL	R/W	—	H'FF	H'FF87	—	—	—

- Notes:
1. Bits 5 and 3 are read-only bits.
 2. The user-defined bits (bits 7 to 4 and 2) are read/write accessible from the slave processor.
 3. Address when accessed from the slave processor. The lower 16 bits of the address are shown.
 4. Pin inputs used in access from the host processor.
 5. The HA0 input discriminates between writing of commands and data.

SYSCR is an 8-bit readable/writable register which controls H8S/2148 Group chip options. The host interface registers, HICR, IDR1, ODR1, STR1, IDR2, ODR2, and STR2 can be accessed when the HIE bit is set to 1. HICR2, IDR3, ODR3, STR3, IDR4, ODR4, and STR4 can be accessed regardless of the setting of the HIE bit. The host interface $\overline{CS2}$ and $\overline{ECS2}$ are controlled by the CS2E bit in SYSCR and the FGA20E bit in HICR. See section 3.2.2, Host Interface Control Register (SYSCR), and section 5.2.1, System Control Register (SYSCR), for information on other SYSCR bits. SYSCR is initialized to H'09 by a reset and in hardware standby mode.

Bit 7—CS2 Enable Bit (CS2E): Used together with the FGA20E bit in HICR to select the pin function that performs the $\overline{CS2}$ function.

SYSCR Bit 7	HICR Bit 0	Description
0	0	$\overline{CS2}$ pin function halted ($\overline{CS2}$ fixed high internally)
	1	
1	0	$\overline{CS2}$ pin function selected for P81/ $\overline{CS2}$ pin
	1	$\overline{CS2}$ pin function selected for P90/ $\overline{ECS2}$ pin

18.2.2 System Control Register 2 (SYSCR2)

Bit	7	6	5	4	3	2	1
	KWUL1	KWUL0	P6PUE	—	SDE	CS4E	CS3E
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	—	R/W	R/W	R/W

SYSCR2 is an 8-bit readable/writable register which controls chip operations. Host interface functions are enabled or disabled by the HI12E bit in SYSCR2. The number of channels that can be used can be extended to a maximum of four by means of the CS3E bit and CS4E bit. SYSCR2 is initialized to H'00 by a reset and in hardware standby mode.

Bits 7 and 6—Key Wakeup Level 1 and 0 (KWUL1, KWUL0): The port 6 input level is set and changed by software. For details see section 8, I/O Ports.

Bit 5—Port 6 Input Pull-Up Extra (P6PUE): Controls and selects the current specification of the port 6 MOS input pull-up function connected by means of KMPCR settings. For details see section 8, I/O Ports.

Bit 4—Reserved: Do not write 1 to this bit.

Bit 2—CS4 Enable (CS4E): Enables or disables host interface channel 4 functions in slave mode. When these functions are enabled, channel 4 pins are enabled and processing can be performed for data transfer between the slave and the host.

Bit 2

CS4E	Description
0	Host interface pin channel 4 functions disabled
1	Host interface pin channel 4 functions enabled

Bit 1—CS3 Enable (CS3E): Enables or disables host interface channel 3 functions in slave mode. When these functions are enabled, channel 3 pins are enabled and processing can be performed for data transfer between the slave and the host.

Bit 1

CS3E	Description
0	Host interface pin channel 3 functions disabled
1	Host interface pin channel 3 functions enabled

Bit 0—Host Interface Enable Bit (HI12E): Enables or disables host interface functions in slave mode. When the host interface functions are enabled, slave mode is entered and processing is performed for data transfer between the slave and host.

Bit 0

HI12E	Description
0	Host interface functions are disabled
1	Host interface functions are enabled

- HICR2

Bit	7	6	5	4	3	2	1
	—	—	—	—	—	IBFIE4	IBFIE3
Initial value	1	1	1	1	1	0	0
Slave Read/Write	—	—	—	—	—	R/W	R/W
Host Read/Write	—	—	—	—	—	—	—

HICR is an 8-bit readable/writable register which controls host interface channel 1 and the fast A20 gate function. HICR2 is an 8-bit readable/writable register which controls interface channel 3 and 4 interrupts. HICR and HICR2 are initialized to H'F8 by a reset in hardware standby mode.

Bits 7 to 3—Reserved: These bits cannot be modified and are always read as 1.

HICR Bits 2 and 1—Input Data Register Full Interrupt Enable 2 and 1 (IBFIE2, IBFIE1)
HICR2 Bits 2 and 1—Input Data Register Full Interrupt Enable 4 and 3 (IBFIE4, IBFIE3)
 These bits enable or disable the IBF1, IBF2, IBF3, and IBF4 interrupts to the internal CPU.

—	—	1	—	request disabled Input data register (IDR2) reception completed request enabled
—	0	—	—	Input data register (IDR3) reception completed request disabled
—	1	—	—	Input data register (IDR3) reception completed request enabled
0	—	—	—	Input data register (IDR4) reception completed request disabled
1	—	—	—	Input data register (IDR4) reception completed request enabled

HICR Bit 0—Fast A20 Gate Function Enable (FGA20E): Enables or disables the fast A20 gate function. When the fast A20 gate is disabled, the normal A20 gate can be implemented. This bit is used for the firmware operation of the P81 output.

**HICR
Bit 0**

FGA20E	Description
0	Fast A20 gate function disabled
1	Fast A20 gate function enabled

HICR2 Bit 0—Reserved: Do not set this bit to 1.

IDR1 is an 8-bit read-only register to the slave processor, and an 8-bit write-only register to the host processor. When \overline{CSn} ($n = 1$ to 4) is low, information on the host data bus is written to IDRn at the rising edge of \overline{IOW} . The HA0 state is also latched into the C/D bit in STRn whether the written information is a command or data.

The initial values of IDR1 after a reset and in standby mode are undetermined.

18.2.5 Output Data Register 1 (ODR)

Bit	7	6	5	4	3	2	1
	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1
Initial value	—	—	—	—	—	—	—
Slave Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Host Read/Write	R	R	R	R	R	R	R

ODR1 is an 8-bit readable/writable register to the slave processor, and an 8-bit read-only register to the host processor. The ODRn contents are output on the host data bus when HA0 is high ($n = 1$ to 4) is low, and \overline{IOR} is low.

The initial values of ODR1 after a reset and in standby mode are undetermined.

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

STR_n (n = 1 to 4) is an 8-bit register that indicates status information during host interrupt processing. Bits 3, 1, and 0 are read-only bits to both the host and slave processors.

STR is initialized to H'00 by a reset and in hardware standby mode.

Bits 7 to 4 and Bit 2—Defined by User (DBU): The user can use these bits as necessary.

Bit 3—Command/Data (C/ \bar{D}): Receives the HA0 input when the host processor writes to IDR1 and indicates whether IDR1 contains data or a command.

Bit 3

C/ \bar{D}	Description
0	Contents of input data register (IDR1) are data
1	Contents of input data register (IDR1) are a command

Bit 1—Input Buffer Full (IBF): Set to 1 when the host processor writes to IDR1. This is an internal interrupt source to the slave processor. IBF is cleared to 0 when the slave processor reads IDR1.

The IBF flag setting and clearing conditions are different when the fast A20 gate is used. For details see table 18.7.

Bit 1

IBF	Description
0	[Clearing condition] When the slave processor reads IDR1
1	[Setting condition] When the host processor writes to IDR1

Table 18.3 shows the conditions for setting and clearing the STR flags.

Table 18.3 Set/Clear Timing for STR Flags

Flag	Setting Condition	Clearing Condition
C/\overline{D}	Rising edge of host's write signal (\overline{IOW}) when HA0 is high	Rising edge of host's write signal (\overline{IOW}) when HA0 is low
IBF*	Rising edge of host's write signal (\overline{IOW}) when writing to IDR1	Falling edge of slave's internal read signal (\overline{IOR}) when reading IDR1
OBF	Falling edge of slave's internal write signal (\overline{WR}) when writing to ODR1	Rising edge of host's read signal (\overline{IOR}) when reading ODR1

Note: * The IBF flag setting and clearing conditions are different when the fast A20 decoder is used. For details see table 18.7.

MSTPCR, comprising two 8-bit readable/writable registers, performs module stop mode. When the MSTP2 bit is set to 1, the host interface halts and enters module stop mode. 25.5, Module Stop Mode, for details.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not in software standby mode.

MSTPCRL Bit 2—Module Stop (MSTP2): Specifies host interface module stop mode

MSTPCRL

Bit 2

MSTP2	Description
0	Host interface module stop mode is cleared
1	Host interface module stop mode is set

18.3 Operation

18.3.1 Host Interface Activation

The HIF (slave mode) is activated by setting the HI12E bit (bit 0) in SYSCR2 to 1 in slave mode. When the HIF (slave mode) is activated, all related I/O ports (data port 3, control port 9, and host interrupt request port 4) become dedicated host interface ports. Setting the HI12E bit and CS4E bit to 1 enables the number of HIF channels to be extended to a four, and channel 3 and 4 related I/O port (part of port B for control and host interrupt requests) become host interface port.

Table 18.4 shows HIF host interface channel selection and pin operation.

	1		Host interface channel 1 and 4 functions operating Operation of channels 2 and 3 halted (No operation as $\overline{CS2}$ or $\overline{ECS2}$ and $\overline{CS3}$ inputs. Pins P90, PB0, and PB2 operate as I/O ports.)
1	0		Host interface channel 1 and 3 functions operating Operation of channels 2 and 4 halted (No operation as $\overline{CS2}$ or $\overline{ECS2}$ and $\overline{CS4}$ inputs. Pins P90, PB1, and PB3 operate as I/O ports.)
	1		Host interface channel 1, 3, and 4 functions operating Operation of channel 2 halted (No operation as $\overline{CS2}$ or $\overline{ECS2}$ input. Pins P43, P81 operate as I/O ports.)
1	0	0	Host interface channel 1 and 2 functions operating Operation of channels 3 and 4 halted (No operation as $\overline{CS3}$ and $\overline{CS4}$ inputs. Pins PB0 to P81 operate as I/O ports.)
	1		Host interface channel 1, 2, and 4 functions operating Operation of channel 3 halted (No operation as $\overline{CS3}$ input. Pins PB0 and PB2 operate as I/O ports.)
	1	0	Host interface channel 1 to 3 functions operating Operation of channel 4 halted (No operation as $\overline{CS4}$ input. Pins PB1 and PB3 operate as I/O ports.)
	1		Host interface channel 1 to 4 functions operating

For host read/write timing, see section 26.7.5, Timing of On-Chip Supporting Modules

		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 register n (C)
	1	0	Idle state
		1	Idle state

Note: n = 1 to 4

18.3.3 A20 Gate

The A20 gate signal can mask address A20 to emulate an addressing mode used by personal computers with an 8086^{*}-family CPU. In slave mode, a regular-speed A20 gate signal is output under firmware control. Fast A20 gate output is enabled by setting the FGA20E bit to 1 in HICR (H'FFF0).

Note: * Intel microprocessor.

Regular A20 Gate Operation

Output of the A20 gate signal can be controlled by an H'D1 command followed by data. When the slave processor receives data, it normally uses an interrupt routine activated by the IBP pin to read IDR1. If the data follows an H'D1 command, software copies bit 1 of the data to the gate A20 pin.

Fast A20 Gate Operation

When the FGA20E bit is set to 1, P81/GA20 is used for output of a fast A20 gate signal. P81DDR must be set to 1 to assign this pin for output. The initial output from this pin is logic 1, which is the initial value. Afterward, the host processor can manipulate the output.

Pin Name	Setting Condition	Clearing Condition
GA20 (P81)	Rising edge of the host's write signal (\overline{IOW}) when bit 1 of the written data is 1 and the data follows an H'D1 host command	Rising edge of the host's write (\overline{IOW}) when bit 1 of the written data is 1 and the data follows an H'D1 host command Also, when bit FGA20E in HICR is set to 0

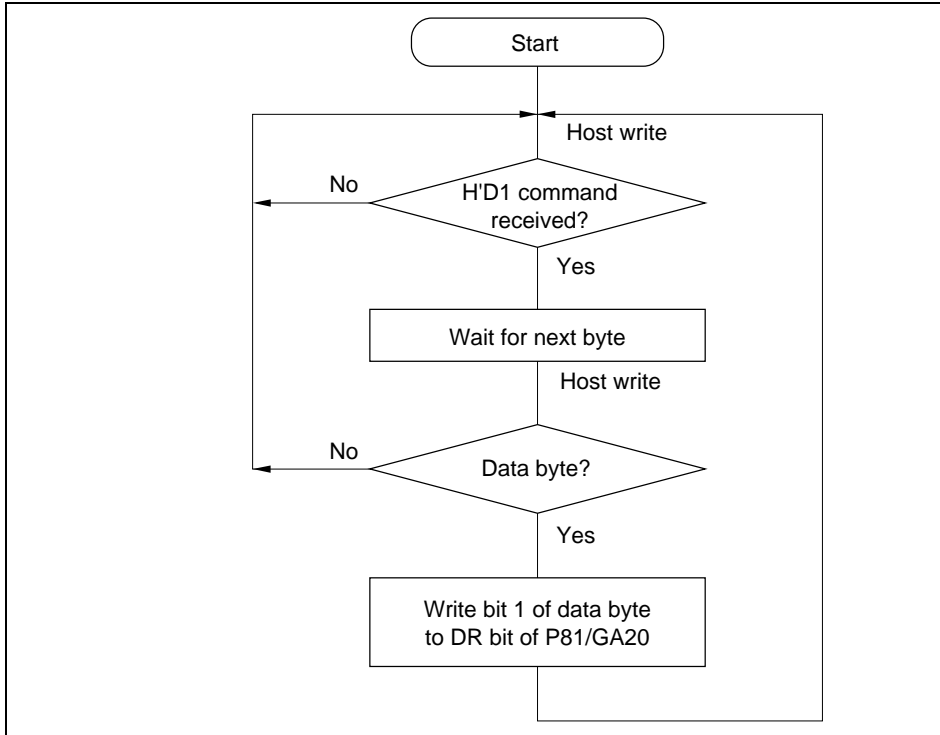


Figure 18.2 GA20 Output

1	H'FF command	0	Q (0)	
1	H'D1 command	0	Q	Turn-on sequence
0	1 data ^{*1}	0	1	(abbreviated for)
1/0	Command other than H'FF and H'D1	1	Q (1)	
1	H'D1 command	0	Q	Turn-off sequence
0	0 data ^{*2}	0	0	(abbreviated for)
1/0	Command other than H'FF and H'D1	1	Q (0)	
1	H'D1 command	0	Q	Cancelled sequence
1	Command other than H'D1	1	Q	
1	H'D1 command	0	Q	Retriggered sequence
1	H'D1 command	0	Q	
1	H'D1 command	0	Q	Consecutively
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.

18.3.4 Host Interface Pin Shutdown Function

Host interface output can be placed in the high-impedance state according to the state of the HIFSD pin. Setting the SDE bit to 1 in the SYSCR2 register enables the HIFSD pin interrupt. The HIF constantly monitors the HIFSD pin, and when this pin goes low, places the host interface output pins (HIRQ1, HIRQ11, HIRQ12, HIRQ3, HIRQ4, and GA20) in the high-impedance state. At the same time, the host interface input pins ($\overline{CS1}$, $\overline{CS2}$ or $\overline{ECS2}$, $\overline{CS3}$, $\overline{CS4}$, \overline{IOW} , \overline{I} , $\overline{HA0}$) are disabled (fixed at the high input state internally) regardless of the pin states, and signals of the multiplexed functions of these pins (input block) are similarly fixed internally. As a result, the host interface I/O pins (HDB7 to HDB0) also go to the high-impedance state.

This state is maintained while the HIFSD pin is low, and when the HIFSD pin returns to the high level state, the pins are restored to their normal operation as host interface pins.

$\overline{CS1}$	P95	O	Input	Slave mode
$\overline{CS2}$	P81	Δ	Input	Slave mode and CS2E = 1 and FG
$\overline{ECS2}$	P90	Δ	Input	Slave mode and CS2E = 1 and FG
$\overline{CS3}$	PB2	Δ	Input	Slave mode and CS3E = 1
$\overline{CS4}$	PB3	Δ	Input	Slave mode and CS4E = 1
HA0	P80	O	Input	Slave mode
HDB7 to HDB0	P37 to P30	O	I/O	Slave mode
HIRQ11	P43	Δ	Output	Slave mode and CS2E = 1 and P4
HIRQ1	P44	Δ	Output	Slave mode and P44DDR = 1
HIRQ12	P45	Δ	Output	Slave mode and P45DDR = 1
HIRQ3	PB0	Δ	Output	Slave mode and CS3E = 1 and PB
HIRQ4	PB1	Δ	Output	Slave mode and CS4E = 1 and PB
GA20	P81	Δ	Output	Slave mode and FGA20E = 1
HIFSD	P82	—	Input	Slave mode and SDE = 1

Legend:

O: Pins shut down by shutdown function

The $\overline{IRQ2/ADTRG}$ input signal is also fixed in the case of P90 shutdown, the \overline{TMCI} signal in the case of P43 shutdown, and the $\overline{TMRI/CSYNCI}$ in the case of P45 shutdown.

Δ : Pins shut down only when the HIF function is selected by means of a register setting.

—: Pin not shut down

Note: Slave mode: Single-chip mode and HI12E = 1

Table 18.9 Input Buffer Full Interrupts

Interrupt	Description
IBF1	Requested when IBFIE1 is set to 1 and IDR1 is full
IBF2	Requested when IBFIE2 is set to 1 and IDR2 is full
IBF3	Requested when IBFIE3 is set to 1 and IDR3 is full
IBF4	Requested when IBFIE4 is set to 1 and IDR4 is full

18.4.2 HIRQ11, HIRQ1, HIRQ12, HIRQ3, and HIRQ4

In slave mode (single-chip mode, with HI12E = 1 in SYSCR2), bits P45DR to P43DR are the data register (P4DR) and bits PB1ODR and PB0ODR in the port B data register (PBODR) be used as host interrupt request latches

The corresponding bits in P4DR are cleared to 0 by the host processor's read signal (\overline{IO}) and HA0 are low, when \overline{IO} goes low and the host reads ODR1, HIRQ1 and HIRQ12 to 0. If $\overline{CS2}$ and HA0 are low, when \overline{IO} goes low and the host reads ODR2, HIRQ11 to 0. The corresponding bit in PBODR is cleared to 0 by the host's read signal (\overline{IO}). If $\overline{CS2}$ and HA0 are low, when \overline{IO} goes low and the host reads ODR3, HIRQ3 is cleared to 0. If $\overline{CS2}$ and HA0 are low, when \overline{IO} goes low and the host reads ODR4, HIRQ4 is cleared to 0. The host interrupt request, normally on-chip firmware writes 1 in the corresponding bit. In the interrupt, the host's interrupt handling routine reads the output data register (ODR1, ODR2, ODR3, or ODR4) and this clears the host interrupt latch to 0.

Table 18.10 indicates how these bits are set and cleared. Figure 18.3 shows the process flowchart form.

(P45)	then writes 1	host reads output data regi
HIRQ3 (PB0)	Internal CPU reads 0 from bit PB0ODR, then writes 1	Internal CPU writes 0 in bit or host reads output data r
HIRQ4 (PB1)	Internal CPU reads 0 from bit PB1ODR, then writes 1	Internal CPU writes 0 in bit or host reads output data r

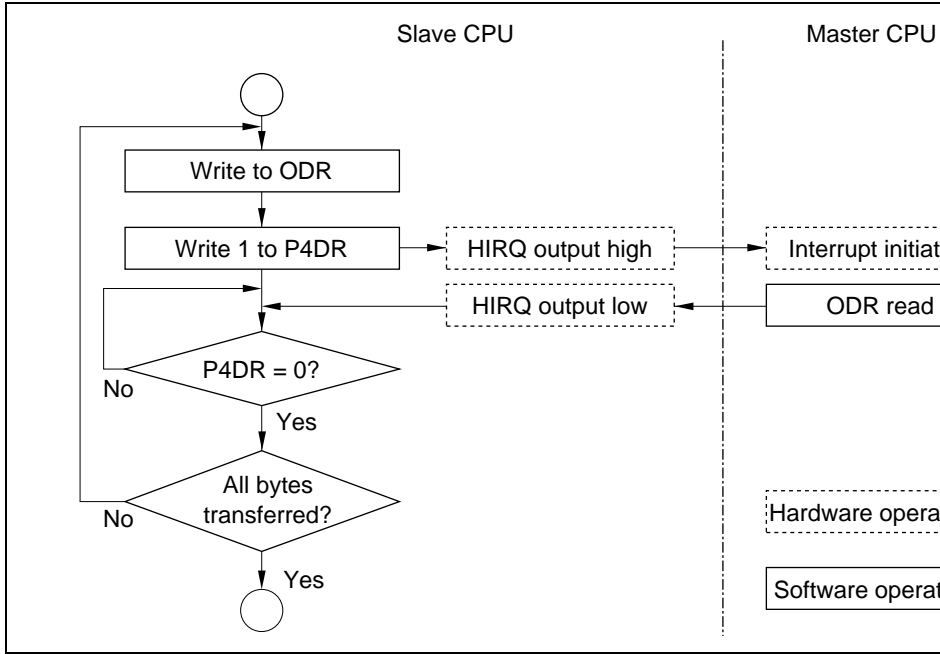


Figure 18.3 HIRQ Output Flowchart (Example of Channels 1 and 2)

The following points require attention when using the host interface.

(1) Host and slave transmission/reception procedures

The host interface provides buffering of asynchronous data from the host and slave but an interface protocol must be followed to implement necessary functions and avoid contention. For example, if the host and slave processors try to access the same input data register simultaneously, the data will be corrupted. Interrupts can be used to develop a simple and effective protocol.

(2) Preventing data contention on the HDB

When the HIF function is used ($HI12E = 1$ in SYSCR2) and channel 3 or channel 4 is set as deselected ($CS3E = 0$ or $CS4E = 0$ in SYSCR2), apply either of the following conditions.

1. Ensure that the \overline{CS} pin for the deselected channel is fixed high.
2. Do not perform port B reads.

(3) Preventing through-current in pins $\overline{CS1}$ to $\overline{CS4}$

Also, if two or more of pins $\overline{CS1}$ to $\overline{CS4}$ are driven low simultaneously in attempting ODR access, signal contention will occur within the chip, and a through-current may occur. This usage must therefore be avoided.

Features of the D/A converter module are listed below.

- Eight-bit resolution
- Two-channel output
- Maximum conversion time: 10 μ s (with 20-pF load capacitance)
- Output voltage: 0 V to AV_{ref}
- D/A output retention in software standby mode

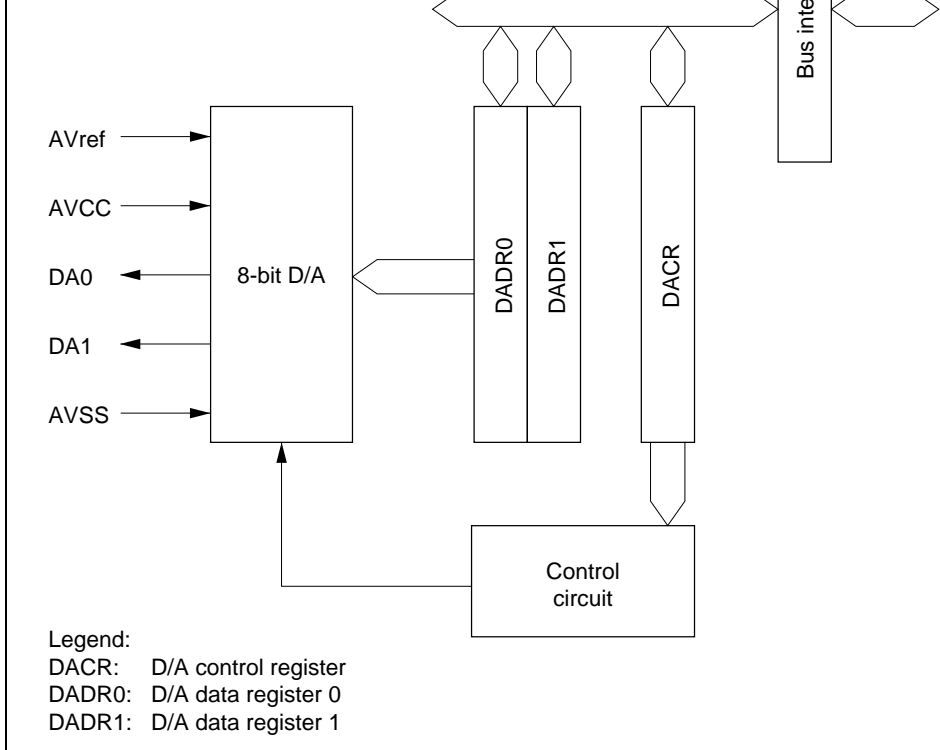


Figure 19.1 Block Diagram of D/A Converter

Analog output 0	DA0	Output	Analog output channel 0
Analog output 1	DA1	Output	Analog output channel 1
Reference voltage pin	AVref	Input	Reference voltage for analog circuit

19.1.4 Register Configuration

Table 19.2 lists the registers of the D/A converter module.

Table 19.2 D/A Converter Registers

Name	Abbreviation	R/W	Initial Value	Address
D/A data register 0	DADR0	R/W	H'00	H'FF
D/A data register 1	DADR1	R/W	H'00	H'FF
D/A control register	DACR	R/W	H'1F	H'FF
Module stop control register	MSTPCRH	R/W	H'3F	H'FF
	MSTPCRL	R/W	H'FF	H'FF

Note: * Lower 16 bits of the address.

D/A data registers 0 and 1 (DADR0 and DADR1) are 8-bit readable/writable registers that store the digital data to be converted. When analog output is enabled, the value in the D/A data register is converted and output continuously at the analog output pin.

The D/A data registers are initialized to H'00 by a reset and in hardware standby mode.

19.2.2 D/A Control Register (DACR)

Bit	7	6	5	4	3	2	1
	DAOE1	DAOE0	DAE	—	—	—	—
Initial value	0	0	0	1	1	1	1
Read/Write	R/W	R/W	R/W	—	—	—	—

DACR is an 8-bit readable/writable register that controls the operation of the D/A conversion module.

DACR is initialized to H'1F by a reset and in hardware standby mode.

Bit 7—D/A Output Enable 1 (DAOE1): Controls D/A conversion and analog output.

Bit 7

DAOE1	Description
0	Analog output DA1 is disabled (In
1	D/A conversion is enabled on channel 1. Analog output DA1 is enabled

DAOE1. D/A conversion is controlled independently on channels 0 and 1 when DAE = 0. Channels 0 and 1 are controlled together when DAE = 1.

Output of the converted results is always controlled independently by DAOE0 and DAOE1.

Bit 7	Bit 6	Bit 5	
DAOE1	DAOE0	DAE	D/A conversion
0	0	*	Disabled on channels 0 and 1
		1	Enabled on channel 0 Disabled on channel 1
	1	1	Enabled on channels 0 and 1
1	0	0	Disabled on channel 0 Enabled on channel 1
		1	Enabled on channels 0 and 1
	1	*	Enabled on channels 0 and 1

Legend:

*: Don't care

If the chip enters software standby mode while D/A conversion is enabled, the D/A output is retained and the analog power supply current is the same as during D/A conversion. If necessary to reduce the analog power supply current in software standby mode, disable the D/A output by clearing the DAOE0, DAOE1, and DAE bits to 0.

Bits 4 to 0—Reserved: These bits cannot be modified and are always read as 1.

MSTPCR, comprising two 8-bit readable/writable registers, performs module stop mode. When the MSTP10 bit is set to 1, the D/A converter halts and enters module stop mode of the bus cycle. See section 25.5, Module Stop Mode, for details.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not in software standby mode.

MSTPCRH Bit 2—Module Stop (MSTP10): Specifies D/A converter module stop mode.

MSTPCRH

Bit 2

MSTP10	Description
0	D/A converter module stop mode is cleared
1	D/A converter module stop mode is set (In

- Software writes the data to be converted in DADR0.
 - D/A conversion begins when the DAOE0 bit in DACR is set to 1. After the elapse conversion time, analog output appears at the DA0 pin. The output value is $(AV_{ref} \times \text{value})/256$.
- This output continues until a new value is written in DADR0 or the DAOE0 bit is cleared.
- If a new value is written in DADR0, conversion begins immediately. Output of the result begins after the conversion time.
 - When the DAOE0 bit is cleared to 0, DA0 becomes an input pin.

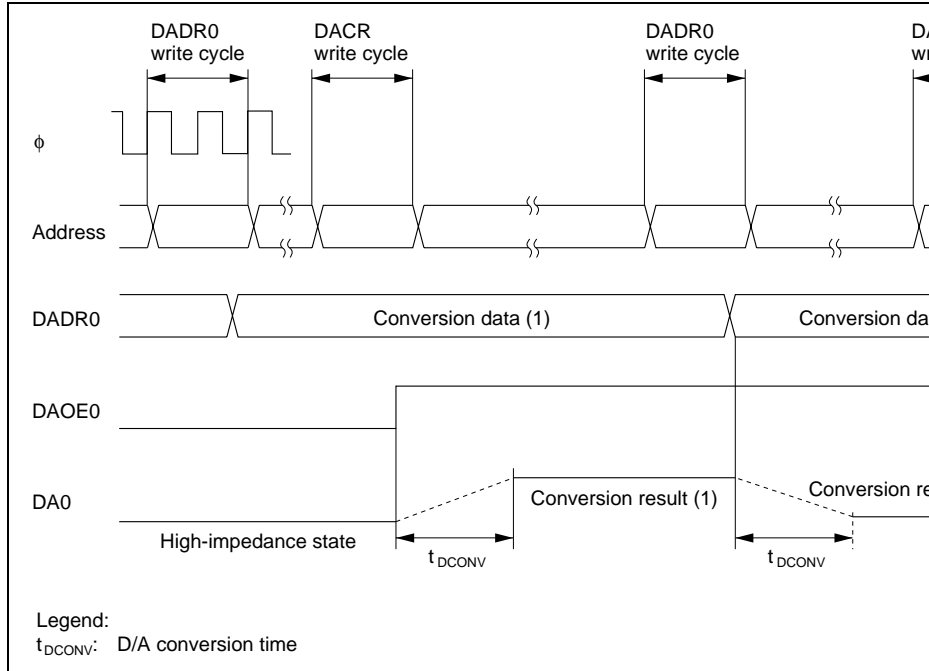


Figure 19.2 D/A Conversion (Example)

In addition to the eight analog input channels, up to 16 channels of digital input can be used for A/D conversion. Since the conversion precision falls when digital input is selected, digital input is ideal for use by a comparator identifying multi-valued inputs, for example.

20.1.1 Features

A/D converter features are listed below.

- 10-bit resolution
- Eight (analog) or 16 (digital) input channels
- Settable analog conversion voltage range
 - The analog conversion voltage range is set using the reference power supply voltage (AVref) as the analog reference voltage
- High-speed conversion
 - Minimum conversion time: 6.7 μ s per channel (at 20-MHz operation)
- Choice of single mode or scan mode
 - 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
 - Choice of software or timer conversion start trigger (8-bit timer), or $\overline{\text{ADTRG}}$ pin
- A/D conversion end interrupt generation
 - An A/D conversion end interrupt (ADI) request can be generated at the end of conversion

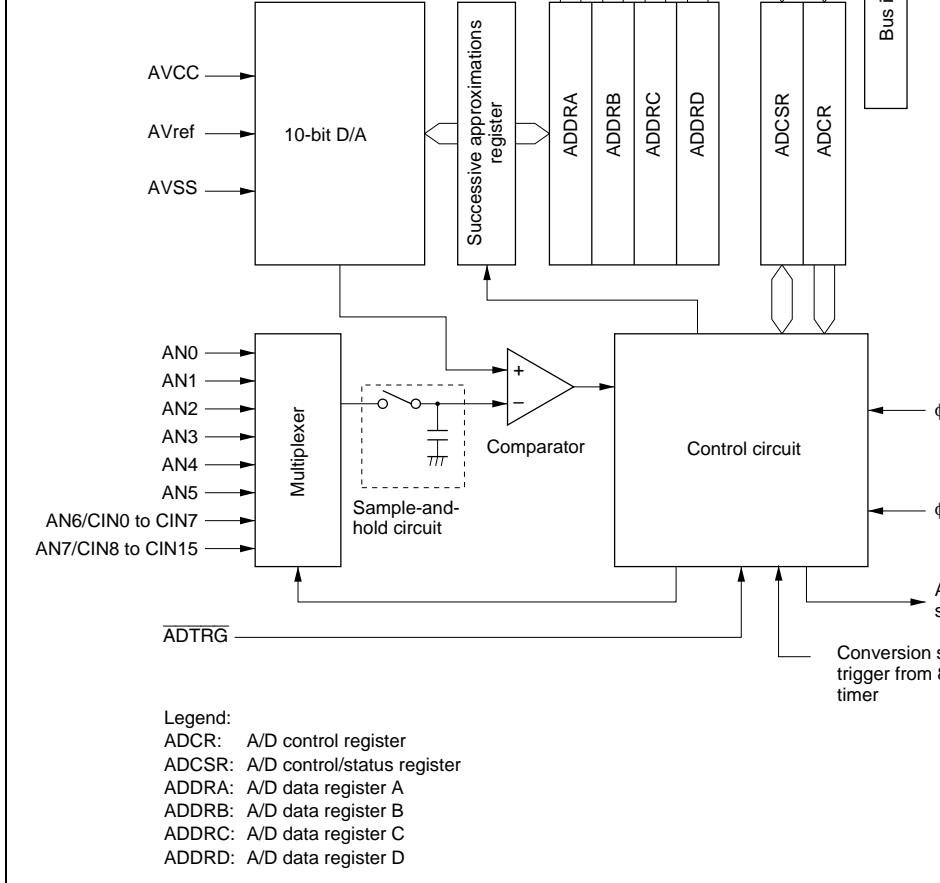


Figure 20.1 Block Diagram of A/D Converter

Analog power supply pin	AVCC	Input	Analog block power supply
Analog ground pin	AVSS	Input	Analog block ground and A/D reference voltage
Reference power supply pin	AVref	Input	A/D conversion reference voltage
Analog input pin 0	AN0	Input	Analog input channel 0
Analog input pin 1	AN1	Input	Analog input channel 1
Analog input pin 2	AN2	Input	Analog input channel 2
Analog input pin 3	AN3	Input	Analog input channel 3
Analog input pin 4	AN4	Input	Analog input channel 4
Analog input pin 5	AN5	Input	Analog input channel 5
Analog input pin 6	AN6	Input	Analog input channel 6
Analog input pin 7	AN7	Input	Analog input channel 7
A/D external trigger input pin	$\overline{\text{ADTRG}}$	Input	External trigger input for starting conversion
Expansion A/D input pins 0 to 15	CIN0 to CIN15	Input	Expansion A/D conversion input pin) channels 0 to 15

A/D data register BH	ADDRBH	R	H'00	H'
A/D data register BL	ADDRBL	R	H'00	H'
A/D data register CH	ADDRCH	R	H'00	H'
A/D data register CL	ADDRCL	R	H'00	H'
A/D data register DH	ADDRDH	R	H'00	H'
A/D data register DL	ADDRDL	R	H'00	H'
A/D control/status register	ADCSR	R/(W) ^{*2}	H'00	H'
A/D control register	ADCR	R/W	H'3F	H'
Module stop control register	MSTPCRH	R/W	H'3F	H'
	MSTPCRL	R/W	H'FF	H'
Keyboard comparator control register	KBCOMP	R/W	H'00	H'

- Notes: 1. Lower 16 bits of the address.
2. Only 0 can be written in bit 7, to clear the flag.

20.2 Register Descriptions

20.2.1 A/D Data Registers A to D (ADDRA to ADDR D)

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2
	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	AD1	AD0	—	—	—	—
Initial value	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R

There are four 16-bit read-only ADDR registers, ADDRA to ADDR D, used to store the A/D conversion.

the lower byte, data transfer is performed via a temporary register (TEMP). For details, see Section 20.3, Interface to Bus Master.

The ADDR registers are initialized to H'0000 by a reset, and in standby mode, watch mode, subactive mode, subsleep mode, and module stop mode.

Table 20.3 Analog Input Channels and Corresponding ADDR Registers

Analog Input Channel		A/D Data Register
Group 0	Group 1	
AN0	AN4	ADDRA
AN1	AN5	ADDRB
AN2	AN6 or CIN0 to CIN7	ADDRC
AN3	AN7 or CIN8 to CIN15	ADDRD

20.2.2 A/D Control/Status Register (ADCSR)

Bit	7	6	5	4	3	2	1
	ADF	ADIE	ADST	SCAN	CKS	CH2	CH1
Initial value	0	0	0	0	0	0	0
Read/Write	R/(W)*	R/W	R/W	R/W	R/W	R/W	R/W

Note: * Only 0 can be written in bit 7, to clear the flag.

ADCSR is an 8-bit readable/writable register that controls A/D conversion operations.

ADCSR is initialized to H'00 by a reset, and in standby mode, watch mode, subactive mode, subsleep mode, and module stop mode.

- Single mode: When A/D conversion ends
- Scan mode: When A/D conversion ends on all specified channels

Bit 6—A/D Interrupt Enable (ADIE): Selects enabling or disabling of interrupt (ADI) at the end of A/D conversion.

Bit 6

ADIE	Description
0	A/D conversion end interrupt (ADI) request is disabled
1	A/D conversion end interrupt (ADI) request is enabled

Bit 5—A/D Start (ADST): Selects starting or stopping of A/D conversion. Holds a value during A/D conversion.

The ADST bit can be set to 1 by software, a timer conversion start trigger, or the A/D external trigger input pin ($\overline{\text{ADTRG}}$).

Bit 5

ADST	Description
0	A/D conversion stopped
1	<p>Single mode: A/D conversion is started. Cleared to 0 automatically when conversion on the specified channel ends</p> <p>Scan mode: A/D conversion is started. Conversion continues sequentially on selected channels until ADST is cleared to 0 by software, a reset, or a transition to standby mode or module stop mode</p>

Bit 4—Scan Mode (SCAN): Selects single mode or scan mode as the A/D conversion mode. See section 20.4, Operation, for single mode and scan mode operation. Only set bit while conversion is stopped.

Bit 3**CKS** **Description**

0 Conversion time = 266 states (max.)

1 Conversion time = 134 states (max.)

Bits 2 to 0—Channel Select 2 to 0 (CH2 to CH0): Together with the SCAN bit, these bits select the analog input channel(s).

One analog input channel can be switched to digital input.

Only set the input channel while conversion is stopped.

Group Selection	Channel Selection		Description	
	CH2	CH1	CH0	Single Mode Scan Mode
0	0	0	AN0	(Initial value) AN0
		1	AN1	AN0, AN1
	1	0	AN2	AN0 to AN2
		1	AN3	AN0 to AN3
1	0	0	AN4	AN4
		1	AN5	AN4, AN5
	1	0	AN6 or CIN0 to CIN7	AN4, AN5, AN6 or CIN0 to CIN7
		1	AN7 or CIN8 to CIN15	AN4, AN5, AN6 or CIN0 to CIN7, AN7 or CIN8 to CIN15

conversion operations.

ADCR is initialized to H'3F by a reset, and in standby mode, watch mode, subactive mode, subsleep mode, and module stop mode.

Bits 7 and 6—Timer Trigger Select 1 and 0 (TRGS1, TRGS0): These bits select enabling or disabling of the start of A/D conversion by a trigger signal. Only set bits TRGS1 and TRGS0 while conversion is stopped.

Bit 7	Bit 6	
TRGS1	TRGS0	Description
0	0	Start of A/D conversion by external trigger is disabled (1)
	1	Start of A/D conversion by external trigger is disabled
1	0	Start of A/D conversion by external trigger (8-bit timer) is enabled
	1	Start of A/D conversion by external trigger pin is enabled

Bits 5 to 0—Reserved: Should always be written with 1.

Note: Some of these bits are readable/writable in products other than the HD64F2148, HD64F2147N, HD64F2144, HD64F2142R and HD6432142, however, when writing, be sure to write 1 here for software compatibility.

the CIN input channels for A/D conversion.

KBCOMP is initialized to H'00 by a reset and in hardware standby mode.

Bits 7 to 4—IrDA Control: See the description in section 15.2.11, Keyboard Comparison Register (KBCOMP).

Bit 3—Keyboard A/D Enable (KBADE): Selects either analog input pins (AN6, AN7) or digital input pins (CIN0 to CIN7, CIN8 to CIN15) for A/D converter channel 6 and channel 7.

Bits 2 to 0—Keyboard A/D Channel Select 2 to 0 (KBCH2 to KBCH0): These bits select the input channels for A/D conversion from among the digital input pins. Only set the input channels when A/D conversion is stopped.

Bit 3 KBADE	Bit 2 KBCH2	Bit 1 KBCH1	Bit 0 KBCH0	A/D Converter Channel 6 Input	A/D Converter Channel 7 Input	
0	—	—	—	AN6	AN7	
1	0	0	0	CIN0	CIN8	
			1	CIN1	CIN9	
			0	CIN2	CIN10	
	1	0	0	1	CIN3	CIN11
				0	CIN4	CIN12
				1	CIN5	CIN13
				0	CIN6	CIN14
1	1	1	0	CIN7	CIN15	
			1	CIN7	CIN15	

MSTPCR, comprising two 8-bit readable/writable registers, performs module stop mode

When the MSTP9 bit in MSTPCR is set to 1, A/D converter operation stops at the end of the current cycle and a transition is made to module stop mode. Registers cannot be read or written in module stop mode. For details, see section 25.5, Module Stop Mode.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not initialized in software standby mode.

MSTPCRH Bit 1—Module Stop (MSTP9): Specifies the A/D converter module stop mode.

MSTPCRH

Bit 1

MSTP9	Description
0	A/D converter module stop mode is cleared
1	A/D converter module stop mode is set

When reading ADDR, always read the upper byte before the lower byte. It is possible to read the upper byte, but if only the lower byte is read, incorrect data may be obtained.

Figure 20.2 shows the data flow for ADDR access.

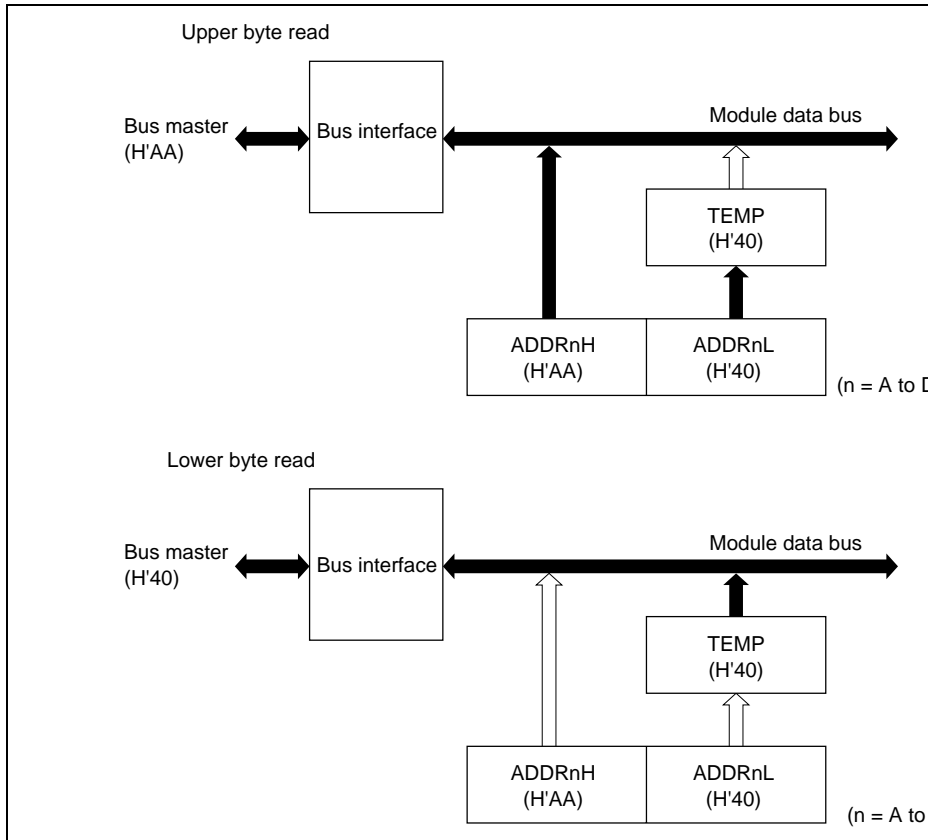


Figure 20.2 ADDR Access Operation (Reading H'AA40)

conversion is started when the ADSC bit is set to 1 by software, or by external trigger. The ADST bit remains set to 1 during A/D conversion, and is automatically cleared to 0 when conversion ends.

On completion of conversion, the ADF flag is set to 1. If the ADIE bit is set to 1 at this time, an ADI interrupt request is generated. The ADF flag is cleared by writing 0 after reading ADFR.

When the operating mode or analog input channel must be changed during analog conversion, to prevent incorrect operation, first clear the ADST bit to 0 in ADCSR to halt A/D conversion. After making the necessary changes, set the ADST bit to 1 to start A/D conversion again. The operating mode can be set at the same time as the operating mode or input channel is changed.

Typical operations when channel 1 (AN1) is selected in single mode are described next. Figure 20.3 shows a timing diagram for this example.

1. Single mode is selected ($SCAN = 0$), input channel AN1 is selected ($CH1 = 0$, $CH0 = 1$), A/D interrupt is enabled ($ADIE = 1$), and A/D conversion is started ($ADST = 1$).
2. When A/D conversion is completed, the result is transferred to ADDR0. At the same time, the ADF flag is set to 1, the ADST bit is cleared to 0, and the A/D converter becomes idle.
3. Since $ADF = 1$ and $ADIE = 1$, an ADI interrupt is requested.
4. The A/D interrupt handling routine starts.
5. The routine reads ADCSR, then writes 0 to the ADF flag.
6. The routine reads and processes the conversion result (ADDR0).
7. Execution of the A/D interrupt handling routine ends. After that, if the ADST bit is set to 1, A/D conversion starts again and steps 2 to 7 are repeated.

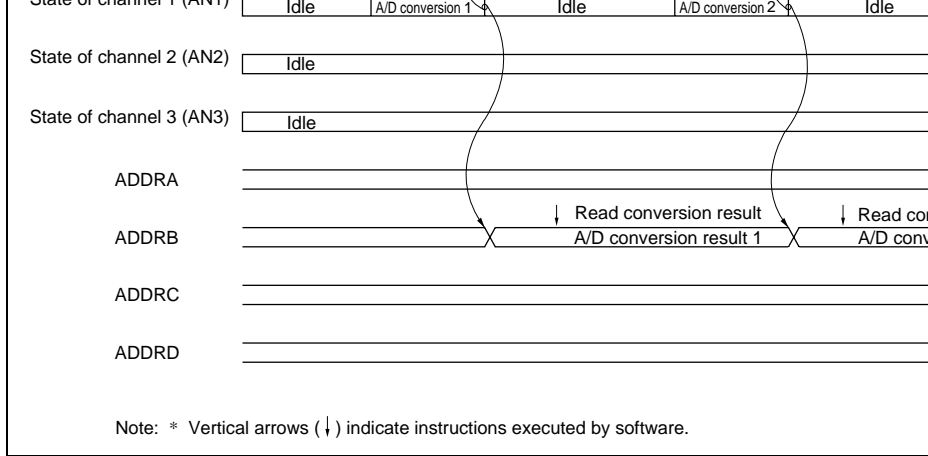


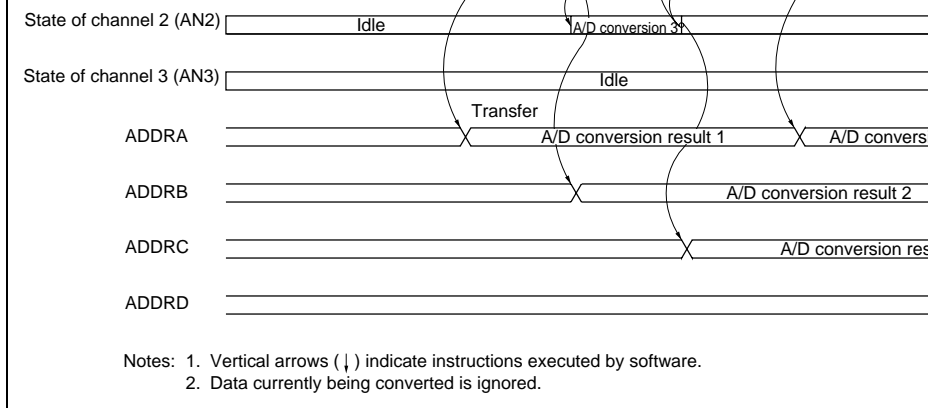
Figure 20.3 Example of A/D Converter Operation (Single Mode, Channel 1)

registers corresponding to the channels.

When the operating mode or analog input channel must be changed during analog conversion, to prevent incorrect operation, first clear the ADST bit to 0 in ADCSR to halt A/D conversion. After making the necessary changes, set the ADST bit to 1 to start A/D conversion again. The ADST bit can be set at the same time as the operating mode or input channel is changed.

Typical operations when three channels (AN0 to AN2) are selected in scan mode are described next. Figure 20.4 shows a timing diagram for this example.

1. Scan mode is selected (SCAN = 1), scan group 0 is selected (CH2 = 0), analog input channels AN0 to AN2 are selected (CH1 = 1, CH0 = 0), and A/D conversion is started (ADSC = 1).
2. When A/D conversion of the first channel (AN0) is completed, the result is transferred to the AD_CONVERTER register (AD_CONVERTER = ADDRA). Next, conversion of the second channel (AN1) starts automatically.
3. Conversion proceeds in the same way through the third channel (AN2).
4. When conversion of all the selected channels (AN0 to AN2) is completed, the ADIF bit is set to 1 and conversion of the first channel (AN0) starts again. If the ADIE bit is set to 1, an ADI interrupt is requested after A/D conversion ends.
5. Steps 2 to 4 are repeated as long as the ADST bit remains set to 1. When the ADST bit is cleared to 0, A/D conversion stops. After that, if the ADST bit is set to 1, A/D conversion starts again from the first channel (AN0).



**Figure 20.4 Example of A/D Converter Operation
 (Scan Mode, Channels AN0 to AN2 Selected)**

In scan mode, the values given in table 20.4 apply to the first conversion time. In the subsequent conversions the conversion time is fixed at 256 states when CKS = 0 or 128 when CKS = 1.

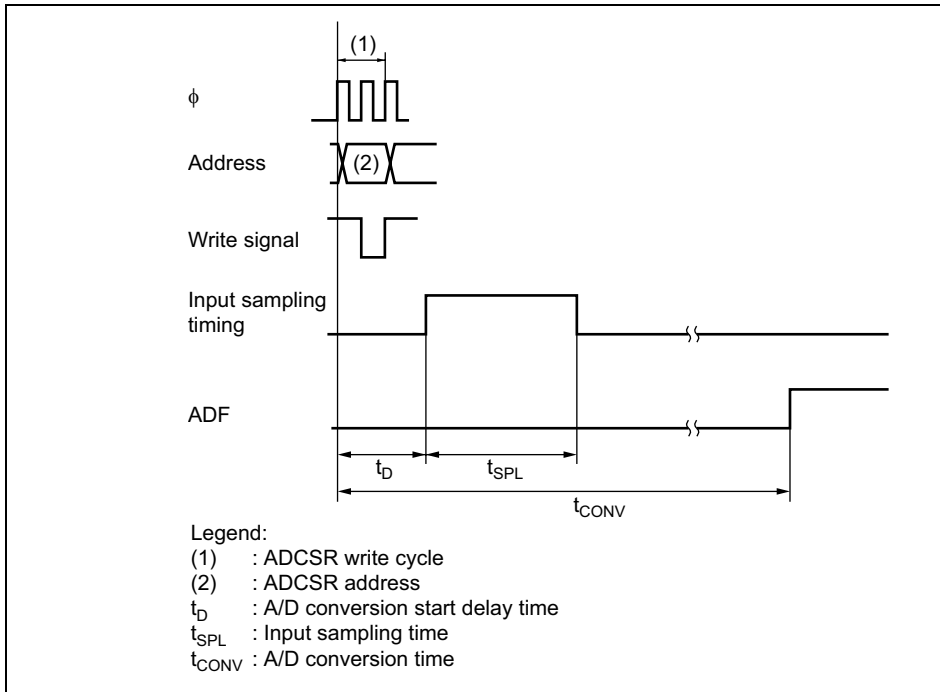


Figure 20.5 A/D Conversion Timing

20.4.4 External Trigger Input Timing

A/D conversion can be externally triggered. When the TRGS1 and TRGS0 bits are set in ADSCR, external trigger input is enabled at the $\overline{\text{ADTRG}}$ pin. A falling edge at the $\overline{\text{ADTRG}}$ pin sets the ADST bit to 1 in ADCSR, starting A/D conversion. Other operations, in both single and scan modes, are the same as when the ADST bit is set to 1 by software. Figure 20.6 shows

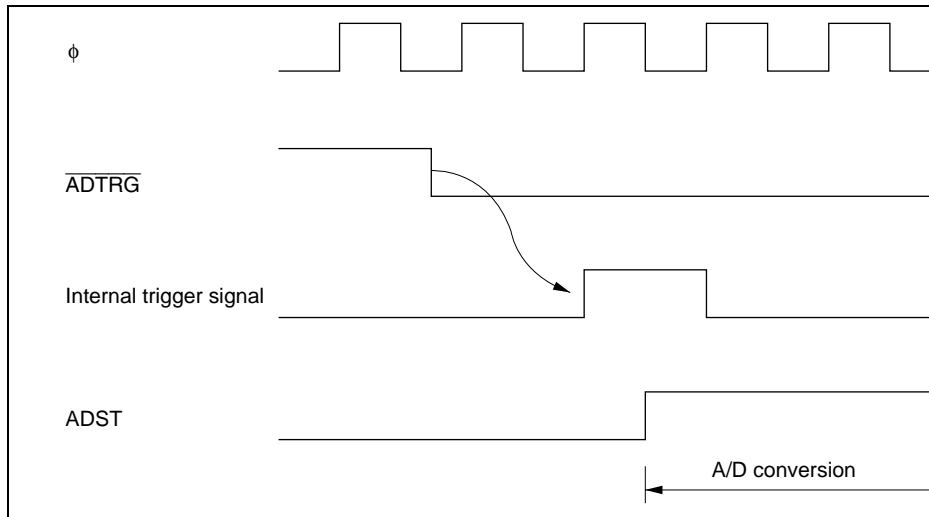


Figure 20.6 External Trigger Input Timing

20.5 Interrupts

The A/D converter generates an interrupt (ADI) at the end of A/D conversion. The ADIFR request can be enabled or disabled by the ADIFR bit in ADCSR.

range $AV_{SS} \leq AN_n \leq AV_{ref}$ ($n = 0$ to 7).

2. Digital input voltage range

The voltage applied to the CIN_n digital input pins should be in the range $AV_{SS} \leq CIN_n \leq AV_{ref}$ and $V_{SS} \leq CIN_n \leq V_{CC}$ ($n = 0$ to 15).

3. Relation between AV_{CC} , AV_{SS} and V_{CC} , V_{SS}

As the relationship between AV_{CC} , AV_{SS} and V_{CC} , V_{SS} , set $AV_{SS} = V_{SS}$. If the A/D converter is not used, the AVCC and AVSS pins must on no account be left open.

4. Setting Range of AVref Pin:

The reference voltage supplied via the AVref pin should be in the range $AV_{ref} \leq AV_{ref} \leq AV_{ref}$.

If conditions 1 to 4 above are not met, the reliability of the device may be adversely affected.

Notes on Board Design

In board design, digital circuitry and analog circuitry should be as mutually isolated as possible and layout in which digital circuit signal lines and analog circuit signal lines cross or are in close proximity should be avoided as far as possible. Failure to do so may result in incorrect operation of the analog circuitry due to inductance, adversely affecting A/D conversion values.

Also, digital circuitry must be isolated from the analog input signals (AN0 to AN7), analog reference power supply (AVref), and analog power supply (AVCC) by the analog ground (AVSS). Also, the analog ground (AVSS) should be connected at one point to a stable digital ground on the board.

Notes on Noise Countermeasures

A protection circuit connected to prevent damage due to an abnormal voltage such as a surge at the analog input pins (AN0 to AN7) or analog reference power supply pin (AVref) should be connected between AVCC and AVSS as shown in figure 20.7.

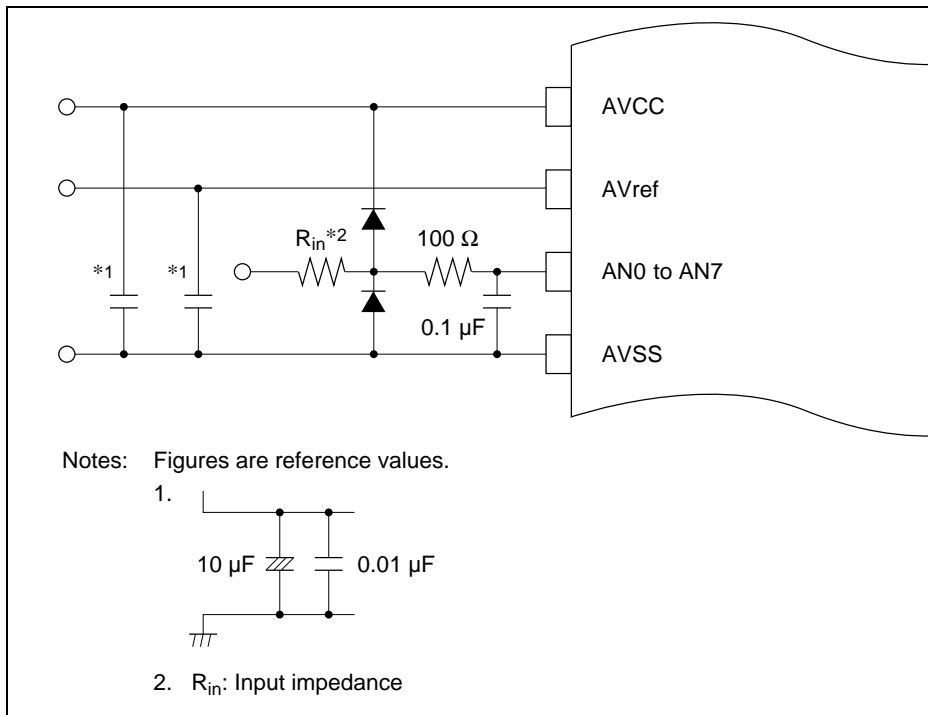


Figure 20.7 Example of Analog Input Protection Circuit

Table 20.5 Analog Pin Ratings

Item	Min	Max	Unit
Analog input capacitance	—	20	pF
Permissible signal source impedance	—	10*	k Ω

Note: * When $V_{CC} = 4.0$ to 5.5 V and $\phi \leq 12$ MHz.

A/D Conversion Precision Definitions

The A/D conversion precision in this LSI is defined as follows.

- Resolution
The number of A/D converter digital output codes
- Offset error
The deviation of the analog input voltage value from the ideal A/D conversion characteristic when the digital output changes from the minimum voltage value B'0000000000 (H'000) to B'0000000001 (H'001) (see figure 20.10).
- Full-scale error
The deviation of the analog input voltage value from the ideal A/D conversion characteristic when the digital output changes from B'1111111110 (H'3FE) to B'1111111111 (H'3FF) (see figure 20.11).
- Quantization error
The deviation inherent in the A/D converter, given by 1/2 LSB (see figure 20.9).
- Nonlinearity error
The error with respect to the ideal A/D conversion characteristic between the zero voltage and the full-scale voltage. Does not include the offset error, full-scale error, or quantization error.
- Absolute precision
The deviation between the digital value and the analog input value. Includes the offset error, full-scale error, quantization error, and nonlinearity error.

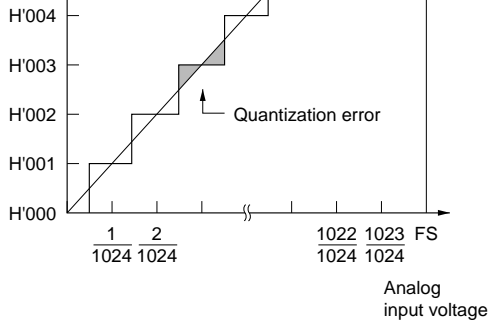


Figure 20.9 A/D Conversion Precision Definitions (1)

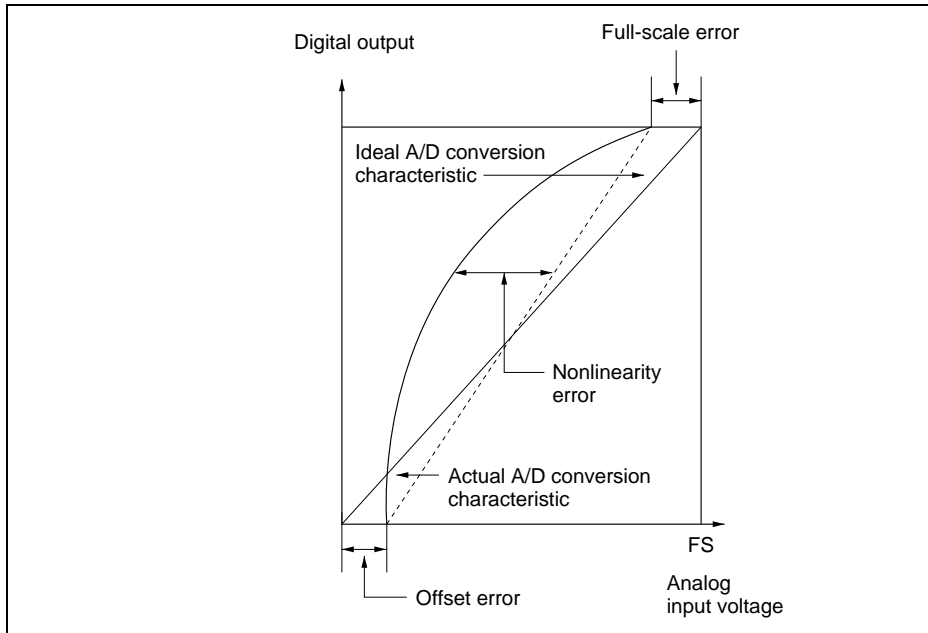


Figure 20.10 A/D Conversion Precision Definitions (2)

However, if a large capacitance is provided externally, the input load will essentially consist only of the internal input resistance of 10 kΩ, and the signal source impedance is ignored.

But since a low-pass filter effect is obtained in this case, it may not be possible to follow a signal with a large differential coefficient (e.g., 5 mV/μsec or greater).

When converting a high-speed analog signal, a low-impedance buffer should be inserted.

Influences on Absolute Precision

Adding capacitance results in coupling with GND, and therefore noise in GND may also affect absolute precision. Be sure to make the connection to an electrically stable GND, such as AV_{SS}.

Care is also required to insure that filter circuits do not communicate with digital signals on the mounting board, so acting as antennas.

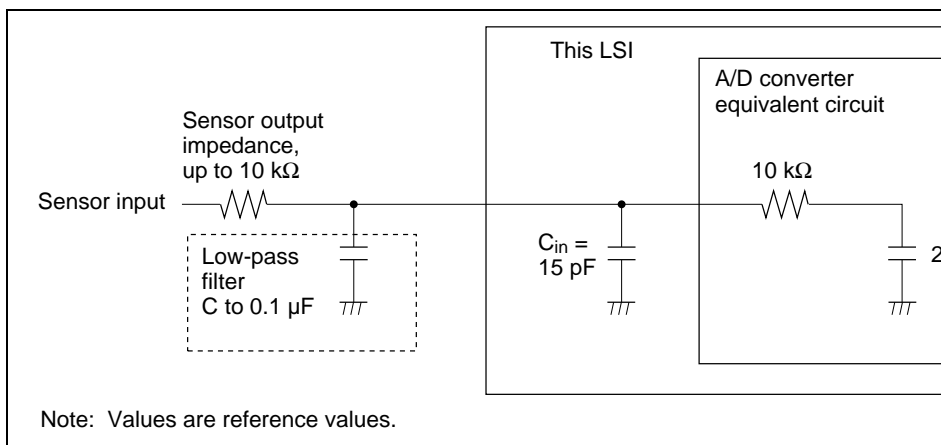


Figure 20.11 Example of Analog Input Circuit

makes it possible to perform fast word data transfer.

The on-chip RAM can be enabled or disabled by means of the RAM enable bit (RAMEN) in the system control register (SYSCR).

21.1.1 Block Diagram

Figure 21.1 shows a block diagram of the on-chip RAM.

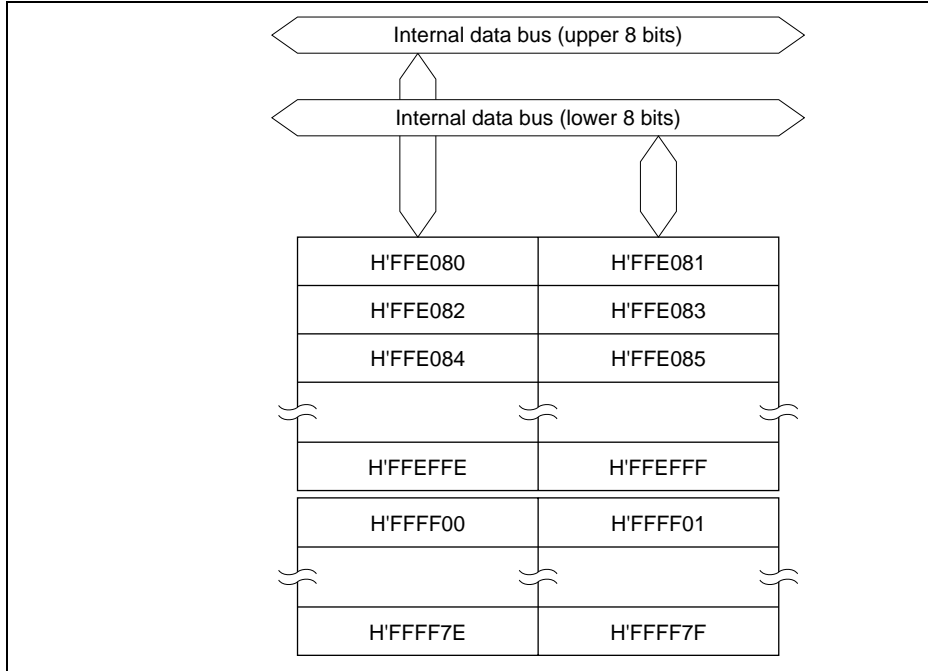


Figure 21.1 Block Diagram of RAM (H8S/2148, H8S/2144, H8S/2143)

21.2 System Control Register (SYSCR)

Bit	7	6	5	4	3	2	1
	CS2E	IOSE	INTM1	INTM0	XRST	NMIEG	HIE
Initial value	0	0	0	0	1	0	0
Read/Write	R/W	R/W	R	R/W	R	R/W	R/W

The on-chip RAM is enabled or disabled by the RAME bit in SYSCR. For details of ot SYSCR, see section 3.2.2, System Control Register (SYSCR).

Bit 0—RAM Enable (RAME): Enables or disables the on-chip RAM. The RAME bit initialized when the reset state is released. It is not initialized in software standby mode.

Bit 0

RAME	Description
0	On-chip RAM is disabled
1	On-chip RAM is enabled

H'(FF)EFFF and H'(FF)FF00 to H'(FF)FF7F, are directed to the off-chip address space.

Since the on-chip RAM is connected to the bus master by a 16-bit data bus, it can be written and read in byte or word units. Each type of access is performed in one state.

Even addresses use the upper 8 bits, and odd addresses use the lower 8 bits. Word data is written at an even address.

21.3.2 Single-Chip Mode (Modes 2 and 3 (EXPE = 0))

When the RAME bit is set to 1, accesses to H8S/2148, H8S/2144, and H8S/2143 addresses H'(FF)E080 to H'(FF)EFFF and H'(FF)FF00 to H'(FF)FF7F, and H8S/2147, H8S/2146, H8S/2142 addresses H'(FF)E880 to H'(FF)EFFF and H'(FF)FF00 to H'(FF)FF7F, are directed to the on-chip RAM. When the RAME bit is cleared to 0, the on-chip RAM is not accessed. Undefined values are read from these bits, and writing is invalid.

Since the on-chip RAM is connected to the bus master by a 16-bit data bus, it can be written and read in byte or word units. Each type of access is performed in one state.

Even addresses use the upper 8 bits, and odd addresses use the lower 8 bits. Word data is written at an even address.

The H8S/2148 and H8S/2144 have 128 kbytes of on-chip ROM (flash memory or mask ROM). The H8S/2143 has 96 kbytes, the H8S/2147, H8S/2147N, and H8S/2142 have 64 kbytes. The on-chip ROM is connected to the CPU by a 16-bit data bus. The CPU accesses both byte and word states, enabling faster instruction fetches and higher processing speed.

The mode pins (MD1 and MD0) and the EXPE bit in MDCR can be set to enable or disable access to the on-chip ROM.

The flash memory versions of the H8S/2148, H8S/2147N, H8S/2144, and H8S/2142 can be programmed in-circuit and programmed on-board as well as with a general-purpose PROM programmer.

22.1.1 Block Diagram

Figure 22.1 shows a block diagram of the ROM.

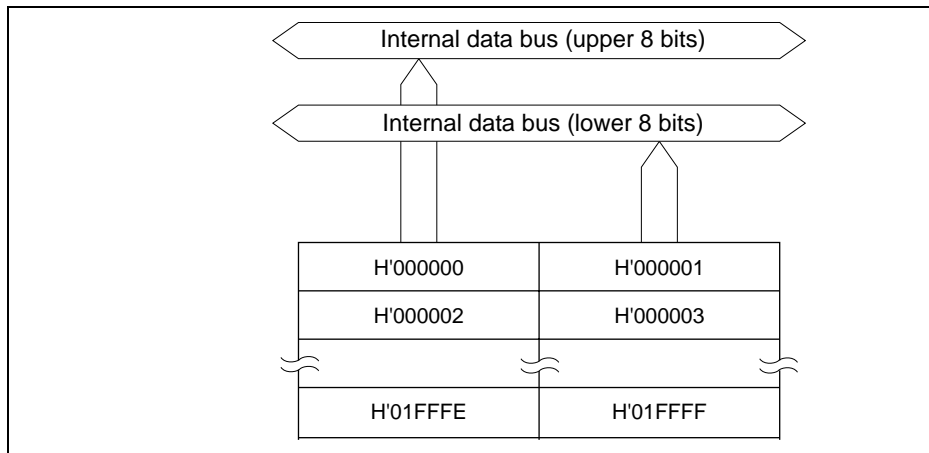


Figure 22.1 ROM Block Diagram (H8S/2148, H8S/2144)

Note: * Lower 16 bits of the address.

22.2 Register Descriptions

22.2.1 Mode Control Register (MDCR)

Bit	7	6	5	4	3	2	1
	EXPE	—	—	—	—	—	MDS1
Initial value	—*	0	0	0	0	0	—*
Read/Write	R/W*	—	—	—	—	—	R

Note: * Determined by the MD1 and MD0 pins.

MDCR is an 8-bit register used to set this group operating mode and monitor the current mode.

The EXPE bit is initialized in accordance with the mode pin states by a reset and in hardware standby mode.

Bit 7—Expanded Mode Enable (EXPE): Sets expanded mode. In mode 1, EXPE is fixed and cannot be modified. In modes 2 and 3, EXPE has an initial value of 0 and can be re-written.

Bit 7

EXPE	Description
0	Single-chip mode selected
1	Expanded mode selected

The on-chip ROM is connected to the CPU by a 16-bit data bus, and both byte and word data can be accessed in one state. Even addresses are connected to the upper 8 bits, and odd addresses are connected to the lower 8 bits. Word data must start at an even address.

The mode pins (MD1 and MD0) and the EXPE bit in MDCR can be set to enable or disable access to the on-chip ROM, as shown in table 22.2.

In normal mode, the maximum amount of ROM that can be used is 56 kbytes.

Table 22.2 Operating Modes and ROM

MCU Operating Mode	Operating Mode		Mode Pins		MDCR	
	CPU Operating Mode	Description	MD1	MD0	EXPE	On-
					0	1
Mode 1	Normal	Expanded mode with on-chip ROM disabled	0	1	1	Disa
Mode 2	Advanced	Single-chip mode	1	0	0	Ena
	Advanced	Expanded mode with on-chip ROM enabled			1	
Mode 3	Normal	Single-chip mode		1	0	Ena
	Normal	Expanded mode with on-chip ROM enabled			1	(ma

Note: * 128 kbytes in the H8S/2148 and H8S/2144, 96 kbytes in the H8S/2143, 64 kbytes in the H8S/2147, H8S/2147N, and H8S/2142.

- Erase mode
- Program-verify mode
- Erase-verify mode
- Programming/erase methods

The flash memory is programmed 32 bytes at a time. Erasing is performed by block (single-block units). When erasing multiple blocks, the individual blocks must be erased sequentially. Block erasing can be performed as required on 1-kbyte, 8-kbyte, 16-kbyte, and 32-kbyte blocks.
- Programming/erase times

The flash memory programming time is 10 ms (typ.) for simultaneous 32-byte programming equivalent to 300 μ s (typ.) per byte, and the erase time is 100 ms (typ.) per block.
- Reprogramming capability

The flash memory can be reprogrammed up to 100 times.
- On-board programming modes

There are two modes in which flash memory can be programmed/erased/verified on-board.

 - Boot mode
 - User program mode
- Automatic bit rate adjustment

With data transfer in boot mode, the bit rate of the chip can be automatically adjusted to the transfer bit rate of the host.
- Protect modes

There are three protect modes, hardware, software, and error protect, which allow pin status to be designated for flash memory program/erase/verify operations.
- Programmer mode

Flash memory can be programmed/erased in programmer mode, using a PROM programmer as well as in on-board programming mode.

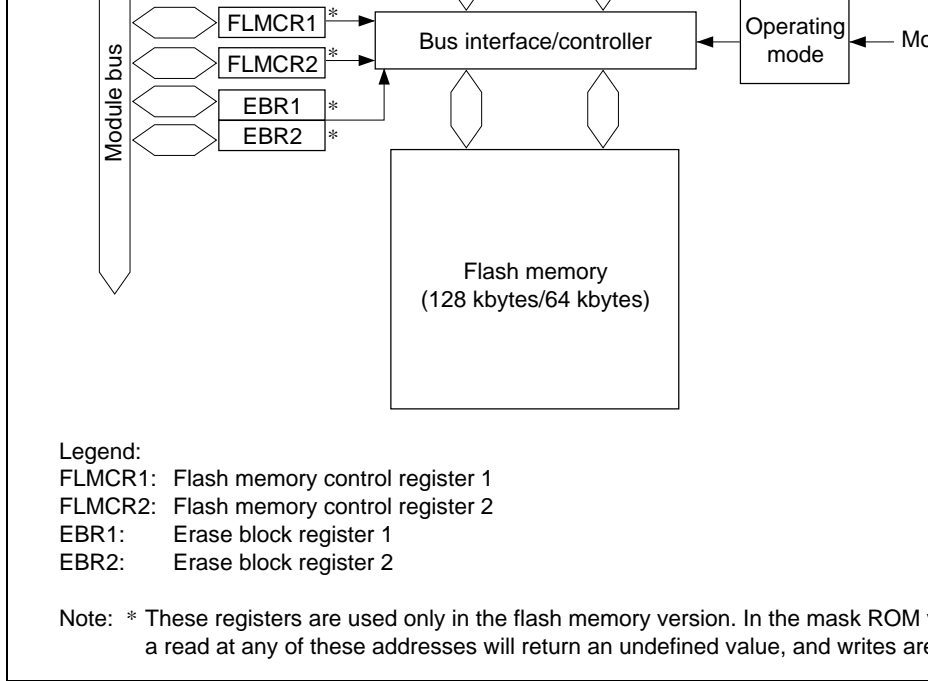


Figure 22.2 Block Diagram of Flash Memory

mode.

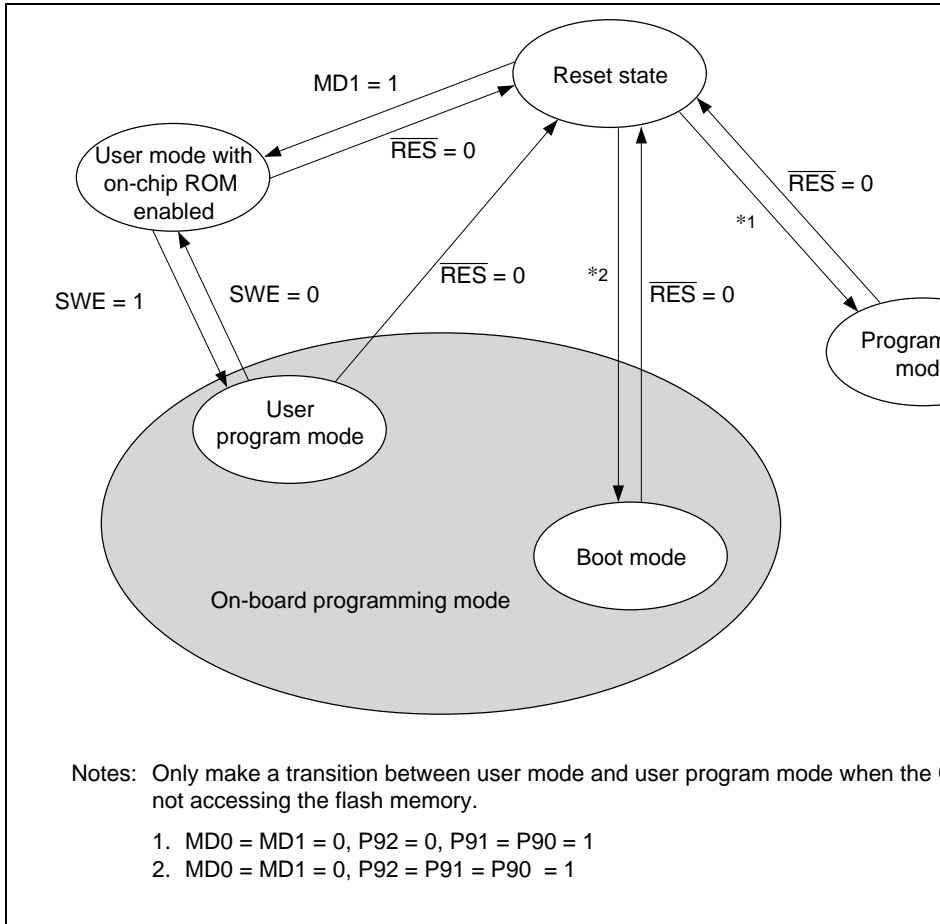
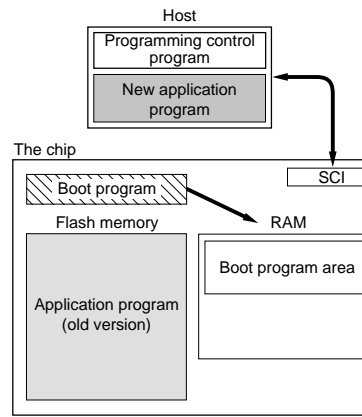
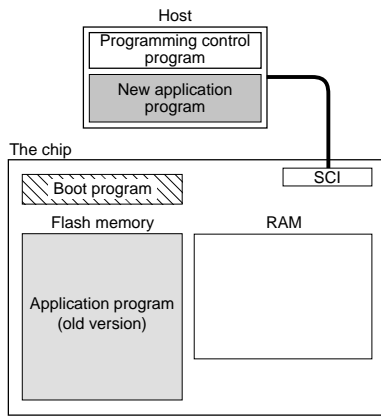
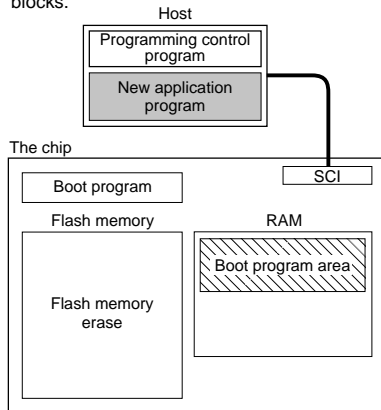


Figure 22.3 Flash Memory Mode Transitions



3. Flash memory initialization

The erase program in the boot program area (in RAM) is executed, and the flash memory is initialized (to H'FF). In boot mode, entire flash memory erasure is performed, without regard to blocks.



4. Writing new application program

The programming control program transferred from the host to RAM by SCI communication is executed, and the new application program from the host is written into the flash memory.

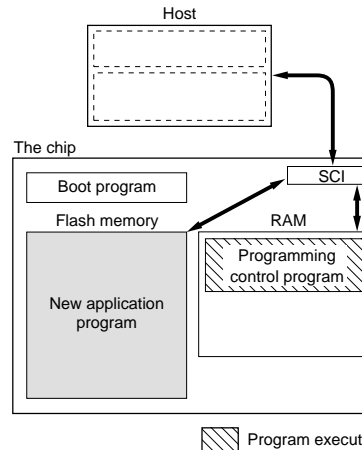
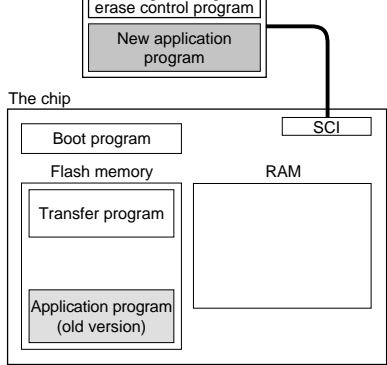
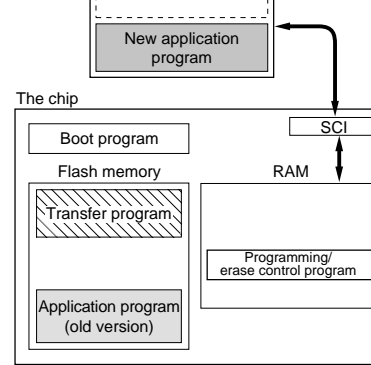


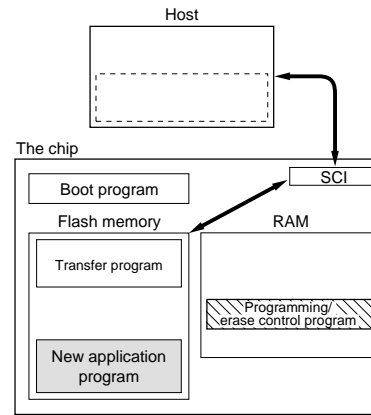
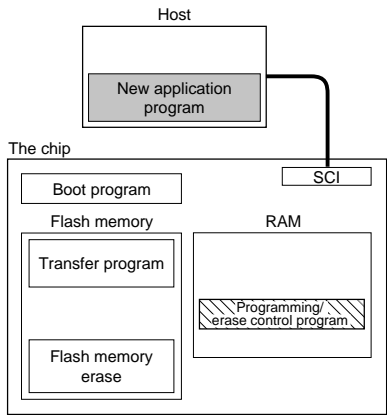
Figure 22.4 Boot Mode



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 written into the erased flash memory block. Do not write to unerased blocks.




 Program execution

Figure 22.5 User Program Mode (Example)

Block Configuration

The flash memory is divided into two 32-kbyte blocks (128-kbyte version only), two 8-kbyte blocks, one 16-kbyte block, one 28-kbyte block, and four 1-kbyte blocks.

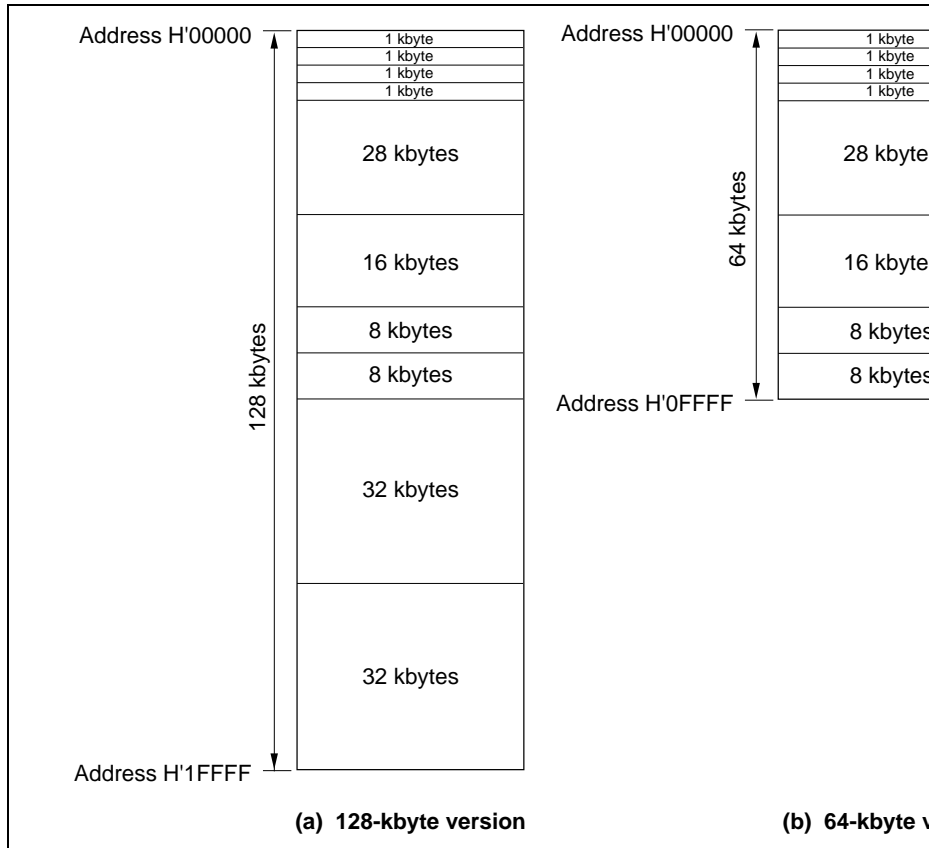


Figure 22.6 Flash Memory Block Configuration

Mode 0	MD0	Input	Sets MCU operating mode
Port 92	P92	Input	Sets MCU operating mode when MD1
Port 91	P91	Input	Sets MCU operating mode when MD1
Port 90	P90	Input	Sets MCU operating mode when MD1
Transmit data	TxD1	Output	Serial transmit data output
Receive data	RxD1	Input	Serial receive data input

22.4.5 Register Configuration

The registers used to control the on-chip flash memory when enabled are shown in table 22.4. In order for these registers to be accessed, the FLSHE bit must be set to 1 in STCR.

Table 22.4 Flash Memory Registers

Register Name	Abbreviation	R/W	Initial Value	Address
Flash memory control register 1	FLMCR1 ^{*5}	R/W ^{*3}	H'80	H'F0
Flash memory control register 2	FLMCR2 ^{*5}	R/W ^{*3}	H'00 ^{*4}	H'F4
Erase block register 1	EBR1 ^{*5}	R/W ^{*3}	H'00 ^{*4}	H'F8
Erase block register 2	EBR2 ^{*5}	R/W ^{*3}	H'00 ^{*4}	H'FC
Serial/timer control register	STCR	R/W	H'00	H'FE

- Notes:
1. Lower 16 bits of the address.
 2. Flash memory registers share addresses with other registers. Register selection is performed by the FLSHE bit in the serial/timer control register (STCR).
 3. In modes in which the on-chip flash memory is disabled, a read will return H'00 and writes are invalid.
 4. The SWE bit in FLMCR1 is not set, these registers are initialized to H'00.
 5. FLMCR1, FLMCR2, EBR1, and EBR2 are 8-bit registers. Only byte accesses are valid for these registers, the access requiring 2 states. These registers are used only in the on-chip flash memory version. In the mask ROM version, a read at any of these addresses will return an undefined value, and writes are invalid.

FLMCR1 is an 8-bit register used for flash memory operating mode control. Program or erase-verify mode is entered by setting SWE to 1. Program mode is entered by setting SWE to 1, then setting the PSU bit in FLMCR2, and finally setting the P bit. Erase mode is entered by setting SWE to 1, then setting the ESU bit in FLMCR2, and finally setting the E bit. FLMCR1 is initialized to H'80 by a reset, and in hardware standby mode, software standby mode, mode, subsleep mode, and watch mode. When on-chip flash memory is disabled, a read of H'00, and writes are invalid.

Writes to the EV and PV bits in FLMCR1 are enabled only when SWE=1; writes to the ESU bit only when SWE = 1, and ESU = 1; and writes to the P bit only when SWE = 1, and PSU = 1.

Bit 7—Flash Write Enable (FWE): Controls programming and erasing of the on-chip flash memory. This bit cannot be modified and is always read as 1.

Bit 6—Software Write Enable (SWE): Enables or disables flash memory programming. SWE should be set before setting bits ESU, PSU, EV, PV, E, P, and EB9 to EB0, and should be cleared at the same time as these bits.

Bit 6

SWE	Description
0	Writes disabled
1	Writes enabled

Bits 5 and 4—Reserved: These bits cannot be modified and are always read as 0.

Bit 2—Program-Verify (PV): Selects program-verify mode transition or clearing. Do not set the SWE, ESU, PSU, EV, E, or P bit at the same time.

Bit 2

PV	Description
0	Program-verify mode cleared
1	Transition to program-verify mode [Setting condition] When SWE = 1

Bit 1—Erase (E): Selects erase mode transition or clearing. Do not set the SWE, ESU, PV, or P bit at the same time.

Bit 1

E	Description
0	Erase mode cleared
1	Transition to erase mode [Setting condition] When SWE = 1, and ESU = 1

22.5.2 Flash Memory Control Register 2 (FLMCR2)

Bit	7	6	5	4	3	2	1
	FLER	—	—	—	—	—	ESU
Initial value	0	0	0	0	0	0	0
Read/Write	R	—	—	—	—	—	R/W

FLMCR2 is an 8-bit register that monitors the presence or absence of flash memory protection (error protection) and performs setup for flash memory program/erase mode. The register is initialized to H'00 by a reset, and in hardware standby mode. The ESU and PSU bits are set to 0 in software standby mode, subactive mode, subsleep mode, and watch mode.

When on-chip flash memory is disabled, a read will return H'00, and writes are invalid.

Bit 7—Flash Memory Error (FLER): Indicates that an error has occurred during a flash memory operation (programming or erasing). When FLER is set to 1, flash memory goes to error protection state.

Bits 6 to 2—Reserved: Always write 0 when writing to these bits.

Bit 1—Erase Setup (ESU): Prepares for a transition to erase mode. Set this bit to 1 before setting the E bit to 1 in FLMCR1. Do not set the SWE, PSU, EV, PV, E, or P bit at the same time.

Bit 1

ESU	Description
0	Erase setup cleared (Initial value)
1	Erase setup [Setting condition] When SWE = 1

Bit 0—Program Setup (PSU): Prepares for a transition to program mode. Set this bit to 1 before setting the P bit to 1 in FLMCR1. Do not set the SWE, ESU, EV, PV, E, or P bit at the same time.

Bit 0

PSU	Description
0	Program setup cleared (Initial value)
1	Program setup [Setting condition] When SWE = 1

EBR2	EB7	EB6	EB5	EB4	EB3	EB2	EB1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W* ¹	R/W	R/W	R/W	R/W	R/W	R/W

- Notes:
1. In normal mode, these bits cannot be modified and are always read as 0.
 2. Bits EB8 and EB9 are not present in the 64-kbyte versions; they must not be set.

EBR1 and EBR2 are registers that specify the flash memory erase area block by block. Bits 7 to 0 in EBR1 (128 kB versions only) and bits 7 to 0 in EBR2 are readable/writable bits. In normal mode, EBR1 and EBR2 are each initialized to H'00 by a reset, in hardware standby mode, software standby mode, subactive mode, subsleep mode, and watch mode, and the SWE bit in FLMCR1 is not set. When a bit in EBR1 or EBR2 is set, the corresponding block can be erased. Other blocks are protected. Set only one bit in EBR1 or EBR2 (more than one bit cannot be set). When flash memory is disabled, a read will return H'00, and writes are invalid.

The flash memory block configuration is shown in table 22.5.

EB4 (28 kbytes)	EB4 (28 kbytes)	H'(00)1000 to H'(00)7FFF
EB5 (16 kbytes)	EB5 (16 kbytes)	H'(00)8000 to H'(00)BFFF
EB6 (8 kbytes)	EB6 (8 kbytes)	H'(00)C000 to H'(00)DFFF
EB7 (8 kbytes)	EB7 (8 kbytes)	H'00E000 to H'00FFFF
EB8 (32 kbytes)	—	H'010000 to H'017FFF
EB9 (32 kbytes)	—	H'018000 to H'01FFFF

22.5.4 Serial/Timer Control Register (STCR)

Bit	7	6	5	4	3	2	1
	IICS	IICX1	IICX0	IICE	FLSHE	—	ICKS1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

STCR is an 8-bit readable/writable register that controls register access, the IIC operation (when the on-chip IIC option is included), and on-chip flash memory control (in F-ZTA versions), and also selects the TCNT input clock. For details on functions not related to flash memory, see section 3.2.4, Serial Timer Control Register (STCR), and description of individual modules. If a module controlled by STCR is not used, do not write 1 to the corresponding bit.

STCR is initialized to H'00 by a reset and in hardware standby mode.

Bits 7 to 4—I²C Control (IICS, IICX1, IICX0, IICE): When the on-chip IIC option is included, these bits control the operation of the I²C bus interface. For details, see section 16, I²C Bus Interface.



Bit 2—Reserved: Do not write 1 to this bit.

Bits 1 and 0—Internal Clock Select 1 and 0 (ICKS1, ICKS0): These bits control 8-bit operation. See section 12, 8-Bit Timers, for details.

22.6 On-Board Programming Modes

When pins are set to on-board programming mode, program/erase/verify operations can be performed on the on-chip flash memory. There are two on-board programming modes: boot mode and user program mode. The pin settings for transition to each of these modes are shown in Table 22.6. For a diagram of the transitions to the various flash memory modes, see figure 22.6.

Only advanced mode setting is possible for boot mode.

In the case of user program mode, established in advanced mode or normal mode, depends on the setting of the MD0 pin. In normal mode, only programming of a 56-kbyte area of flash memory is possible.

Table 22.6 Setting On-Board Programming Modes

Mode Name	Mode				
	CPU Operating Mode	MD1	MD0	P92	P91
Boot mode	Advanced mode	0	0	1*	1*
User program mode	Advanced mode	1	0	—	—
	Normal mode		1	—	—

Note: * Can be used as I/O ports after boot mode is initiated.

the transfer is completed, control branches to the start address of the programming control program area and the programming control program execution state is entered (flash memory programming is performed).

The transferred programming control program must therefore include coding that follows the programming algorithm given later.

The system configuration in boot mode is shown in figure 22.7, and the boot program memory execution procedure in figure 22.8.

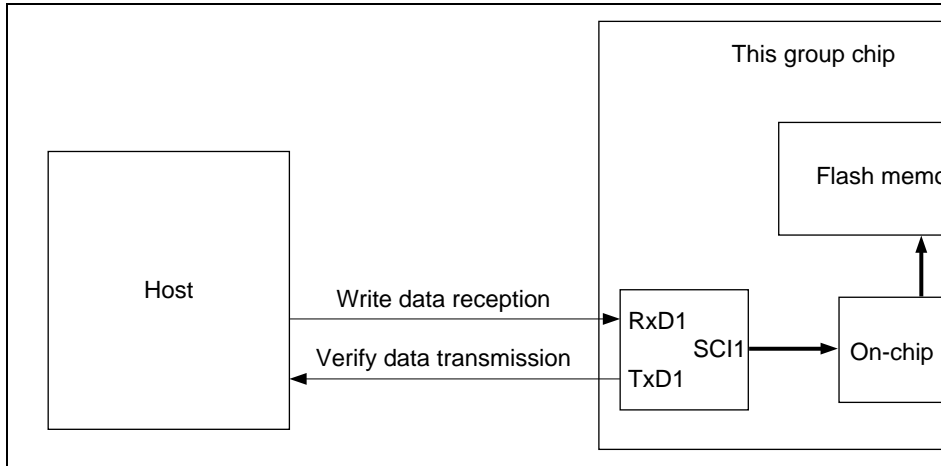


Figure 22.7 System Configuration in Boot Mode

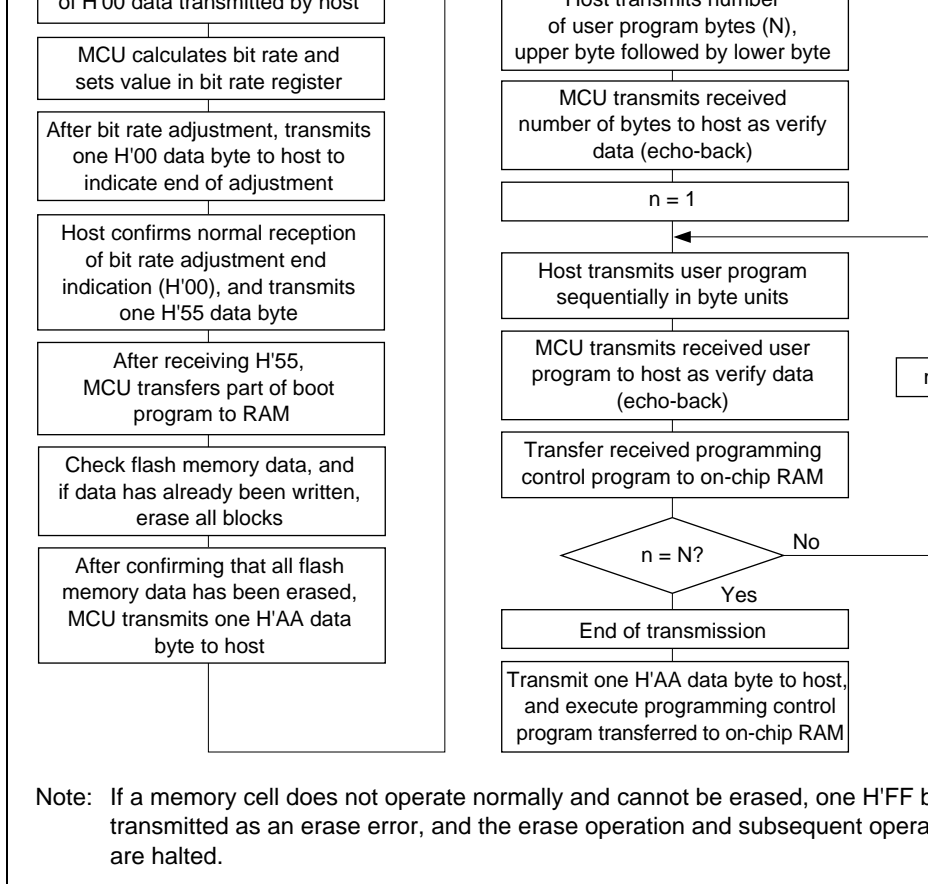


Figure 22.8 Boot Mode Execution Procedure

Figure 22.9 RxD1 Input Signal when Using Automatic SCI Bit Rate Adjust

When boot mode is initiated, this group MCU measures the low period of the asynchronous communication data (H'00) transmitted continuously from the host. The SCI transmit/receive format should be set as follows: 8-bit data, 1 stop bit, no parity. The MCU calculates the transmission from the host from the measured low period, and transmits one H'00 byte to the host to indicate the end of bit rate adjustment. The host should confirm that this adjustment indication (H'00) has been received normally, and transmit one H'55 byte to the MCU. If the adjustment cannot be performed normally, initiate boot mode again (reset), and repeat the above operation. Depending on the host's transmission bit rate and the MCU's system clock frequency, there may be a discrepancy between the bit rates of the host and the MCU. To ensure correct SCI communication, the host's transfer bit rate should be set to (2400, 4800, or 9600) bps.

Table 22.7 shows typical host transfer bit rates and system clock frequencies for which automatic adjustment of the MCU's bit rate is possible. The boot program should be executed within the system clock range.

Table 22.7 System Clock Frequencies for which Automatic Adjustment of This Group Bit Rate Is Possible

Host Bit Rate	System Clock Frequency for which Automatic Adjustment of This Group Bit Rate Is Possible
9600 bps	8 MHz to 20 MHz
4800 bps	4 MHz to 20 MHz
2400 bps	2 MHz to 18 MHz

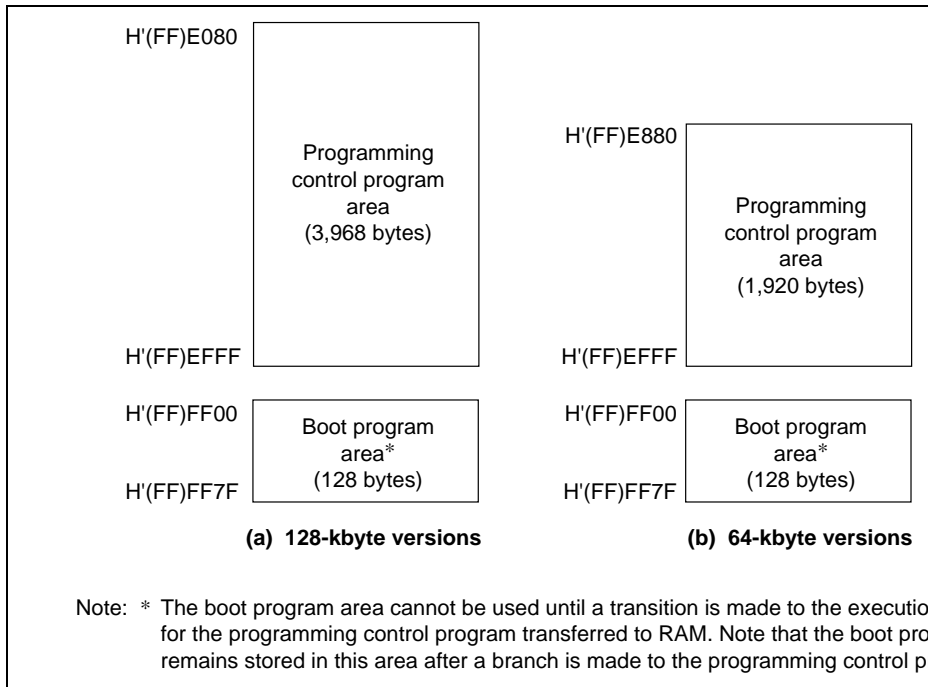


Figure 22.10 RAM Areas in Boot Mode

Notes on Use of User Mode

- When the chip comes out of reset in boot mode, it measures the low period of the SCI's RxD1 pin. The reset should end with RxD1 high. After the reset ends, it takes a few states for the chip to get ready to measure the low period of the RxD1 input.
- In boot mode, if any data has been programmed into the flash memory (if all data in flash memory blocks are erased. Boot mode is for use when user program mode is activated, such as the first time on-board programming is performed, or if the program active in user program mode is accidentally erased.

The contents of the CPU's internal general registers are undefined at this time, so the registers must be initialized immediately after branching to the programming control program. In particular, since the stack pointer (SP) is used implicitly in subroutine calls, etc., it must be specified for use by the programming control program.

The initial values of other on-chip registers are not changed.

- Boot mode can be entered by making the pin settings shown in table 22.6 and executing reset-start.

When the chip detects the boot mode setting at reset release^{*1}, P92, P91, and P90 can be used as I/O ports.

Boot mode can be cleared by driving the reset pin low, waiting at least 20 states, then driving the mode pins, and executing reset release^{*1}. Boot mode can also be cleared by a Watchdog overflow reset.

The mode pin input levels must not be changed in boot mode.

- If the mode pin input levels are changed (for example, from low to high) during a reset state of ports with multiplexed address functions and bus control output pins (\overline{AS} , \overline{R}), the state of these pins will change according to the change in the microcomputer's operating mode^{*2}.

Therefore, care must be taken to make pin settings to prevent these pins from becoming signal pins during a reset, or to prevent collision with signals outside the microcomputer.

- Notes:
1. Mode pin input must satisfy the mode programming setup time ($t_{MDS} = 4$ states) with respect to the reset release timing.
 2. Ports with multiplexed address functions will output a low level as the address mode pin setting is for mode 1 is entered during a reset. In other modes, they go to the high-impedance state. The bus control output signals will output a low level if mode pin setting is for mode 1 is entered during a reset. In other modes, they go to the high-impedance state.

would in mode 2 and 3.

The flash memory itself cannot be read while the SWE bit is set to 1 to perform programming and erasing, so the control program that performs programming and erasing should be run from RAM or external memory.

Figure 22.11 shows the procedure for executing the program/erase control program which is transferred to on-chip RAM.

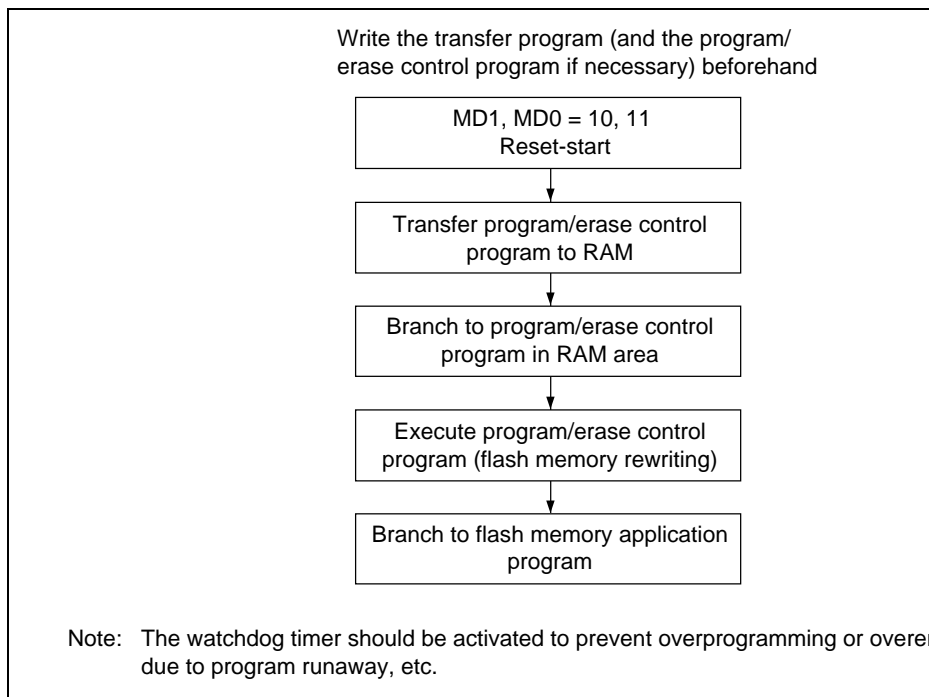


Figure 22.11 User Program Mode Execution Procedure

located and executed in on-chip RAM or external memory.

- Notes:
1. Operation is not guaranteed if setting/resetting of the SWE, EV, PV, E, and FLMCR1, and the ESU and PSU bits in FLMCR2, is executed by a program in memory.
 2. Perform programming in the erased state. Do not perform additional programming at previously programmed addresses.

22.7.1 Program Mode

Follow the procedure shown in the program/program-verify flowchart in figure 21.12 to write data or programs to flash memory. Performing program operations according to this flowchart will enable data or programs to be written to flash memory without subjecting the device to high voltage stress or sacrificing program data reliability. Programming should be carried out 32 bytes at a time.

For the wait times (x , y , z , α , β , γ , ϵ , η) after setting/clearing individual bits in flash memory control registers 1 and 2 (FLMCR1, FLMCR2) and the maximum number of writes (N), see section 26.2.6, Flash Memory Characteristics.

Following the elapse of (x) μs or more after the SWE bit is set to 1 in flash memory control register 1 (FLMCR1), 32-byte program data is stored in the program data area and reprogram data area, and the 32-byte data in the reprogram data area written consecutively to the write data area. The lower 8 bits of the first address written to must be H'00, H'20, H'40, H'60, H'80, H'A0, H'C0, or H'E0. Thirty-two consecutive byte data transfers are performed. The program address and program data are latched in the flash memory. A 32-byte data transfer must be performed even if writing fewer than 32 bytes; in this case, H'FF data must be written to the extra address.

Next, the watchdog timer is set to prevent overprogramming in the event of program run error. Set a value greater than ($y + z + \alpha + \beta$) μs as the WDT overflow period. After this, prepare for program mode (program setup) is carried out by setting the PSU bit in FLMCR2, and after an elapse of (y) μs or more, the operating mode is switched to program mode by setting the

After the elapse of a given programming time, the programming mode is exited (the timer in FLMCR1 is cleared, then the PSU bit in FLMCR2 is cleared at least (α) μ s later). The timer is cleared after the elapse of (β) μ s or more, and the operating mode is switched to program-verify mode by setting the PV bit in FLMCR1. Before reading in program-verify mode, a dummy write of H'FF data should be made to the addresses to be read. The dummy write should be executed after the elapse of (γ) μ s or more. When the flash memory is read in this state (the data is read in 16-bit units), the data at the latched address is read. Wait at least (ϵ) μ s after the dummy write before performing this read operation. Next, the originally written data is compared with the verify data, and reprogram data is computed (see figure 22.12) and transferred to the reprogram data area. After 32 bytes of data have been verified, exit program-verify mode, wait for (δ) μ s, then clear the SWE bit in FLMCR1. If reprogramming is necessary, set program mode and repeat the program/program-verify sequence as before. However, ensure that the program/program-verify sequence is not repeated more than (N) times on the same bit.

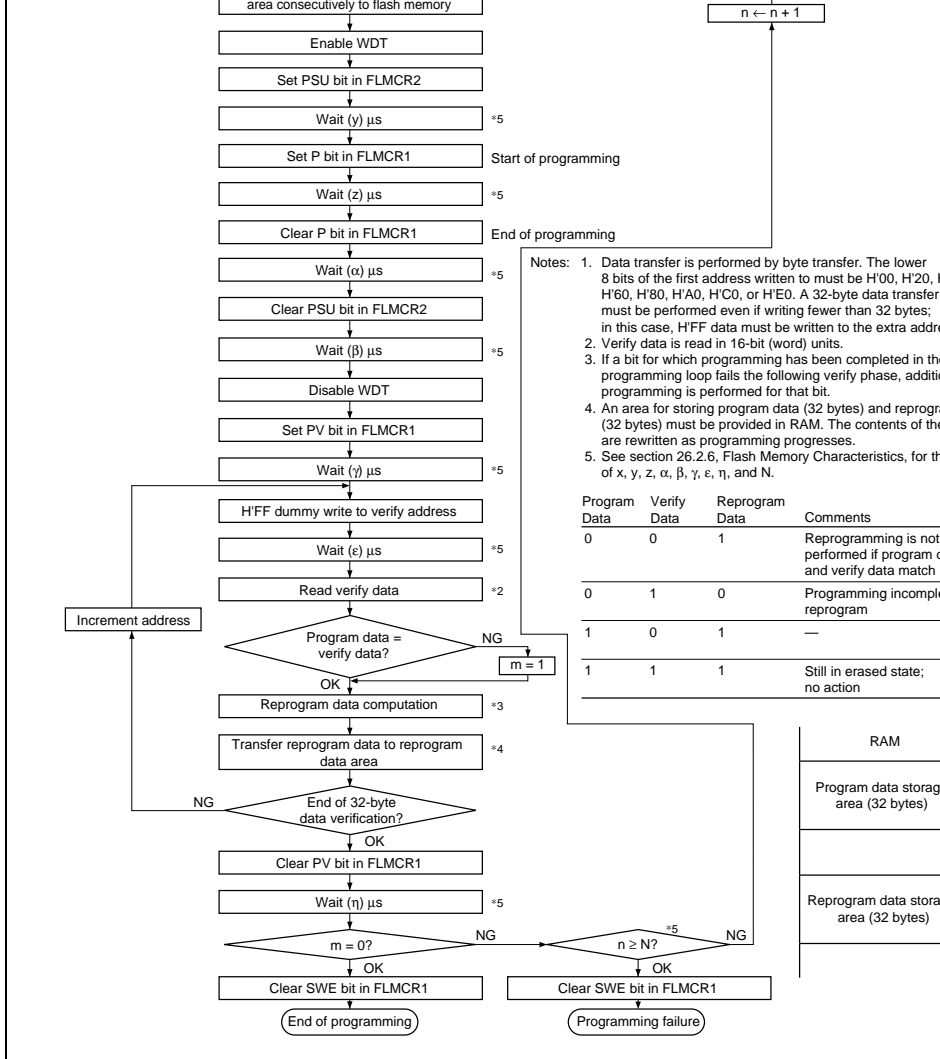


Figure 22.12 Program/Program-Verify Flowchart

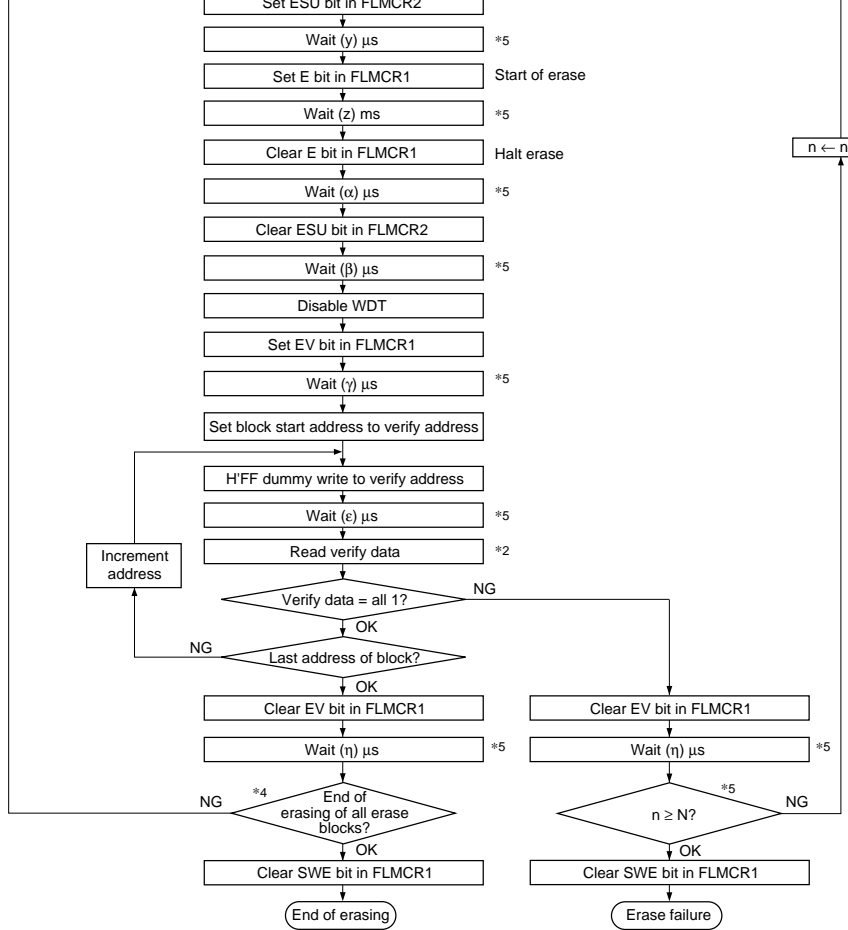
To perform data or program erasure, make a 1 bit setting for the flash memory area to erase block register 1 or 2 (EBR1 or EBR2) at least (x) μ s after setting the SWE bit to memory control register 1 (FLMCR1). Next, the watchdog timer is set to prevent over the event of program runaway, etc. Set a value greater than ($y + z + \alpha + \beta$) ms as the V overflow period. After this, preparation for erase mode (erase setup) is carried out by ESU bit in FLMCR2, and after the elapse of (y) μ s or more, the operating mode is switched to erase mode by setting the E bit in FLMCR1. The time during which the E bit is set is memory erase time. Ensure that the erase time does not exceed (z) ms.

Note: With flash memory erasing, preprogramming (setting all data in the memory to 0) is not necessary before starting the erase procedure.

22.7.4 Erase-Verify Mode

In erase-verify mode, data is read after memory has been erased to check whether it has been correctly erased.

After the elapse of the erase time, erase mode is exited (the E bit in FLMCR1 is cleared). After the ESU bit in FLMCR2 is cleared at least (α) μ s later), the watchdog timer is cleared after the elapse of (β) μ s or more, and the operating mode is switched to erase-verify mode by setting the E bit in FLMCR1. Before reading in erase-verify mode, a dummy write of H'FF data should be performed to the addresses to be read. The dummy write should be executed after the elapse of (γ) μ s. When the flash memory is read in this state (verify data is read in 16-bit units), the data at the latched address is read. Wait at least (ϵ) μ s after the dummy write before performing the read operation. If the read data has been erased (all 1), a dummy write is performed to the next address and erase-verify is performed. If the read data has not been erased, set erase mode again and repeat the erase/erase-verify sequence in the same way. However, ensure that the erase/erase-verify sequence is not repeated more than (N) times. When verification is completed, return to normal operating mode, and wait for at least (η) μ s. If erasure has been completed on all the erase blocks, clear the SWE bit in FLMCR1. If there are any unerased blocks, make a 1 bit setting in EBR2 for the flash memory area to be erased, and repeat the erase/erase-verify sequence in the same way.



- Notes:
1. Preprogramming (setting erase block data to all 0) is not necessary.
 2. Verify data is read in 16-bit (W) units.
 3. Set only one bit in EBR1 or EBR2. More than one bit cannot be set.
 4. Erasing is performed in block units. To erase a number of blocks, the individual blocks must be erased sequentially.
 5. See section 26.2.6, Flash Memory Characteristics, for the values of x, y, z, α, β, γ, ε, η, and N.

Figure 22.13 Erase/Erase-Verify Flowchart (Single-Block Erase)



disabled or aborted. Hardware protection is reset by settings in flash memory control registers 1 and 2 (FLMCR1, FLMCR2) and erase block registers 1 and 2 (EBR1, EBR2). (See table 22.9.)

Table 22.8 Hardware Protection

Item	Description	Function Program
Reset/standby protection	<ul style="list-style-type: none"> In a reset (including a WDT overflow reset), software standby mode, subactive mode, subsleep mode, and watch mode, FLMCR1, FLMCR2, EBR1, and EBR2 are initialized, and the program/erase-protected state is entered. In a reset via the $\overline{\text{RES}}$ pin, the reset state is not entered unless the $\overline{\text{RES}}$ pin is held low until oscillation stabilizes after powering on. In the case of a reset during operation, hold the $\overline{\text{RES}}$ pin low for the $\overline{\text{RES}}$ pulse width specified in the AC Characteristics section. 	Yes

22.8.2 Software Protection

Software protection can be implemented by setting the SWE bit in FLMCR1 and erase block registers 1 and 2 (EBR1, EBR2). When software protection is in effect, setting the P bit in flash memory control register 1 (FLMCR1) does not cause a transition to program mode. (See table 22.9.)

protection

by settings in erase block registers 1 and 2 (EBR1, EBR2).

- Setting EBR1 and EBR2 to H'00 places all blocks in the erase-protected state.
-

22.8.3 Error Protection

In error protection, an error is detected when MCU runaway occurs during flash memory programming/erasing, or operation is not performed in accordance with the program/erase algorithm, and the program/erase operation is aborted. Aborting the program/erase operation prevents damage to the flash memory due to overprogramming or overerasing.

If the MCU malfunctions during flash memory programming/erasing, the FLER bit is set, FLMCR2 and the error protection state is entered. The FLMCR1, FLMCR2, EBR1, and EBR2 settings are retained, but program mode or erase mode is aborted at the point at which the error occurred. Program mode or erase mode cannot be re-entered by re-setting the P or E bit. The PV and EV bit setting is enabled, and a transition can be made to verify mode.

FLER bit setting conditions are as follows:

- When flash memory is read during programming/erasing (including a vector read or program fetch)
- Immediately after exception handling (excluding a reset) during programming/erasing
- When a SLEEP instruction (transition to software standby, sleep, subactive, subsleep, or deep sleep mode) is executed during programming/erasing
- When the bus is released during programming/erasing

Error protection is released only by a reset and in hardware standby mode.

Figure 22.14 shows the flash memory state transition diagram.

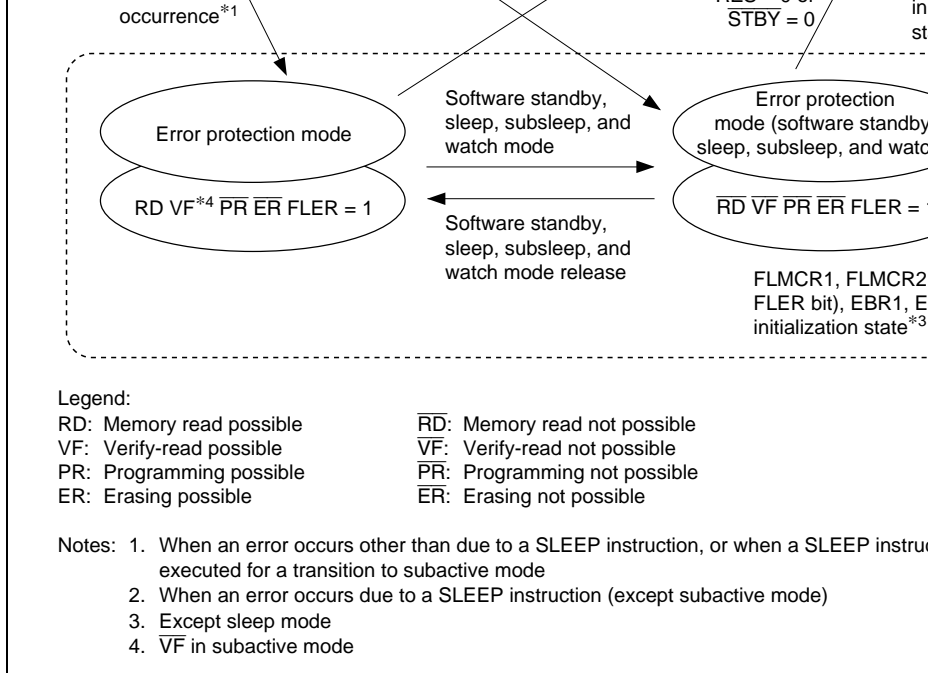


Figure 22.14 Flash Memory State Transitions

2. In the interrupt exception handling sequence during programming or erasing, the vector address may not be read correctly*, possibly resulting in MCU runaway.
3. If interrupt occurred during boot program execution, it would not be possible to execute the normal boot mode sequence.

For these reasons, in on-board programming mode alone there are conditions for disabling the interrupt, as an exception to the general rule. However, this provision does not guarantee the interrupt during erasing and programming or MCU operation. All interrupt requests, including NMI interrupt, must therefore be disabled inside and outside the MCU when programming or erasing flash memory. Interrupt is also disabled in the error-protection state while the P or E bit remains set in the error-protection state.

- Notes:
1. Interrupt requests must be disabled inside and outside the MCU until the programming control program has completed programming.
 2. The vector may not be read correctly in this case for the following two reasons:
 - If flash memory is read while being programmed or erased (while the P or E bit is set in FLMCR1), correct read data will not be obtained (undetermined values may be returned).
 - If the interrupt entry in the vector table has not been programmed yet, in the event of an interrupt exception handling will not be executed correctly.

auto-erase mode, and status read mode are supported with these device types. In auto-erase mode, auto-erase mode, and status read mode, a status polling procedure is used, and in auto-erase mode, detailed internal signals are output after execution of an auto-program or auto-erase operation.

Table 22.10 shows programmer mode pin settings.

- Notes:
1. Applies to the H8S/2148 and H8S/2144.
 2. Applies to the H8/2147N and H8S/2142.
 3. Use products other than the A-mask version of the H8S/2148, H8S/2147N, H8S/2147M, and H8S/2142 (in either 5-V or 3-V version) with the writing voltage for the programmer set to 5.0 V. Do not use the A-mask version with a 5.0-V PROGRAMMER setting.

Table 22.10 Programmer Mode Pin Settings

Pin Names	Setting/External Circuit Connections
Mode pins: MD1, MD0	Low-level input to MD1, MD0
$\overline{\text{STBY}}$ pin	High-level input (Hardware standby mode not set)
$\overline{\text{RES}}$ pin	Power-on reset circuit
XTAL and EXTAL pins	Oscillation circuit
Other setting pins: P97, P92, P91, P90, P67	Low-level input to P92, P67, high-level input to P97, P91, P90

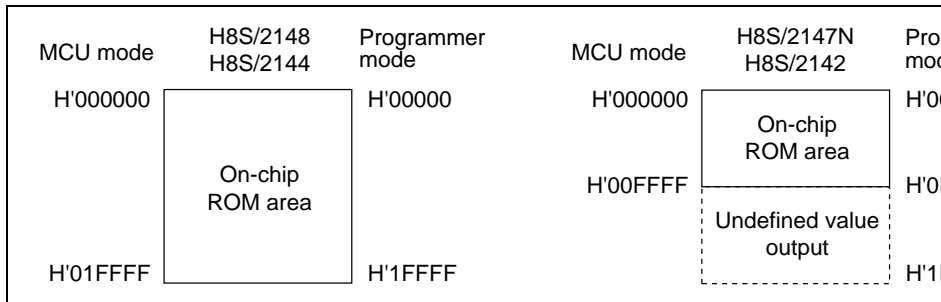


Figure 22.15 Memory Map in Programmer mode

22.10.3 Programmer Mode Operation

Table 22.11 shows how the different operating modes are set when using programmer mode. Table 22.12 lists the commands used in programmer mode. Details of each mode are given in Table 22.13.

- **Memory Read Mode**
Memory read mode supports byte reads.
- **Auto-Program Mode**
Auto-program mode supports programming of 128 bytes at a time. Status polling is used to confirm the end of auto-programming.
- **Auto-Erase Mode**
Auto-erase mode supports automatic erasing of the entire flash memory. Status polling is used to confirm the end of auto-erasing.
- **Status Read Mode**
Status polling is used for auto-programming and auto-erasing, and normal termination is confirmed by reading the FO6 signal. In status read mode, error information is output if an error occurs.

- Notes: 1. Chip disable is not a standby state; internally, it is an operation state.
 2. Ain indicates that there is also address input in auto-program mode.

Table 22.12 Programmer Mode Commands

Command Name	Number of Cycles	1st Cycle		2nd Cycle		
		Mode	Address	Data	Mode	Address
Memory read mode	1 + n	Write	X	H'00	Read	RA
Auto-program mode	129	Write	X	H'40	Write	WA
Auto-erase mode	2	Write	X	H'20	Write	X
Status read mode	2	Write	X	H'71	Write	X

- Notes: 1. In auto-program mode, 129 cycles are required for command writing by a single 128-byte write.
 2. In memory read mode, the number of cycles depends on the number of address cycles (n).

22.10.4 Memory Read Mode

- After the end of an auto-program, auto-erase, or status read operation, the command write is entered. To read memory contents, a transition must be made to memory read mode by means of a command write before the read is executed.
- Command writes can be performed in memory read mode, just as in the command write mode.
- Once memory read mode has been entered, consecutive reads can be performed.
- After power-on, memory read mode is entered.



Data hold time	t_{dh}	50	—	ns
Data setup time	t_{ds}	50	—	ns
Write pulse width	t_{wep}	70	—	ns
\overline{WE} rise time	t_r	—	30	ns
\overline{WE} fall time	t_f	—	30	ns

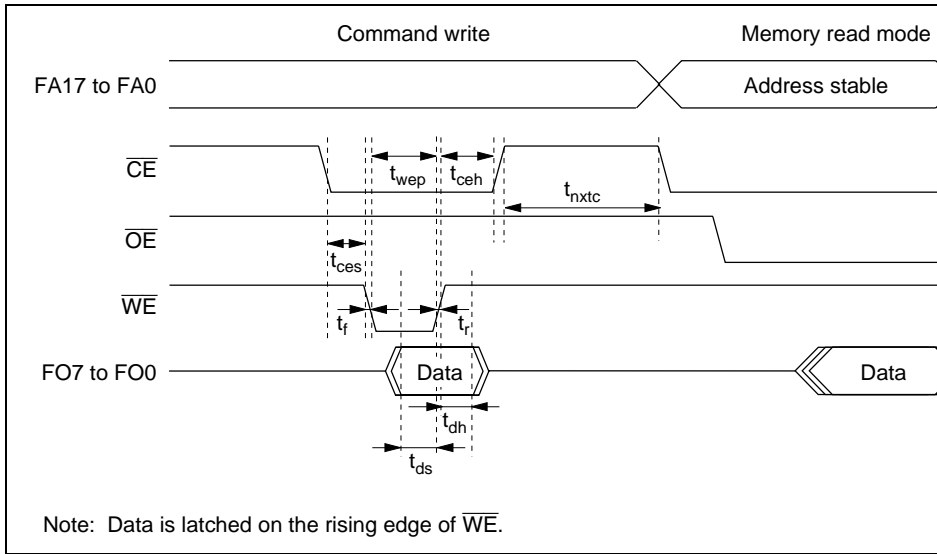


Figure 22.16 Memory Read Mode Timing Waveforms after Command W

Data hold time	t_{dh}	50	—	ns
Data setup time	t_{ds}	50	—	ns
Write pulse width	t_{wep}	70	—	ns
\overline{WE} rise time	t_r	—	30	ns
\overline{WE} fall time	t_f	—	30	ns

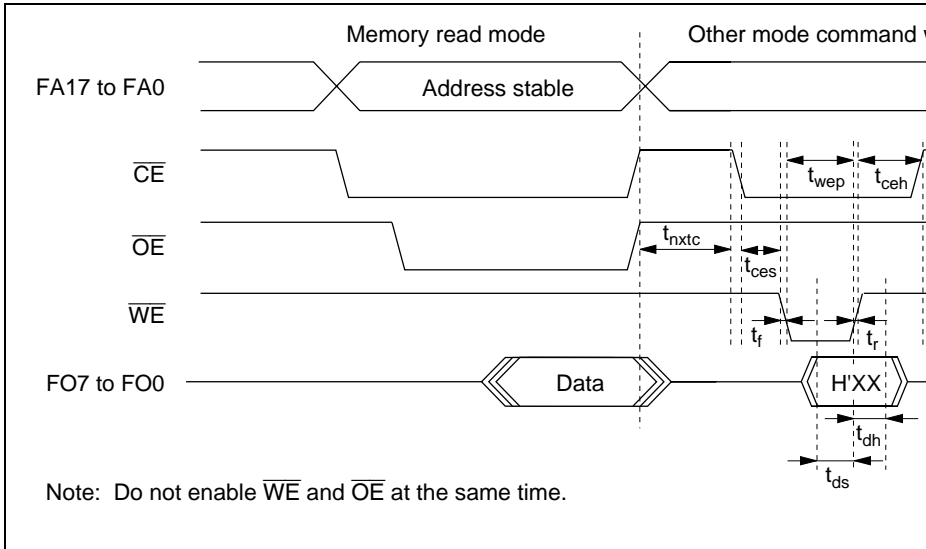


Figure 22.17 Timing Waveforms when Entering Another Mode from Memory

Output disable delay time	t_{df}	—	100	ns
Data output hold time	t_{oh}	5	—	ns

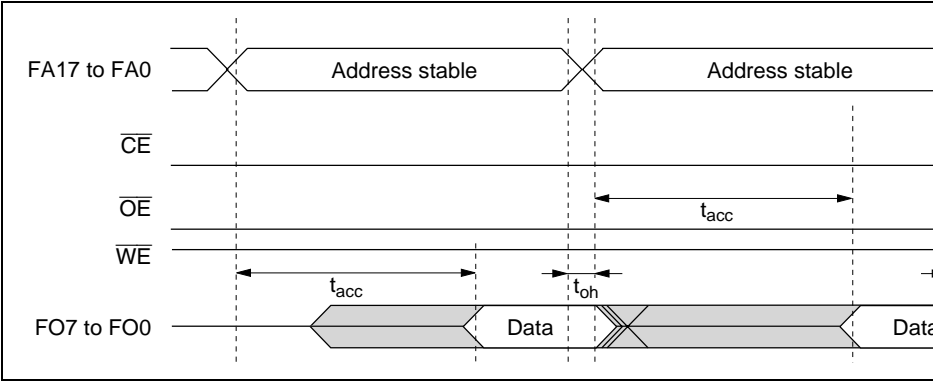


Figure 22.18 Timing Waveforms for $\overline{CE}/\overline{OE}$ Enable State Read

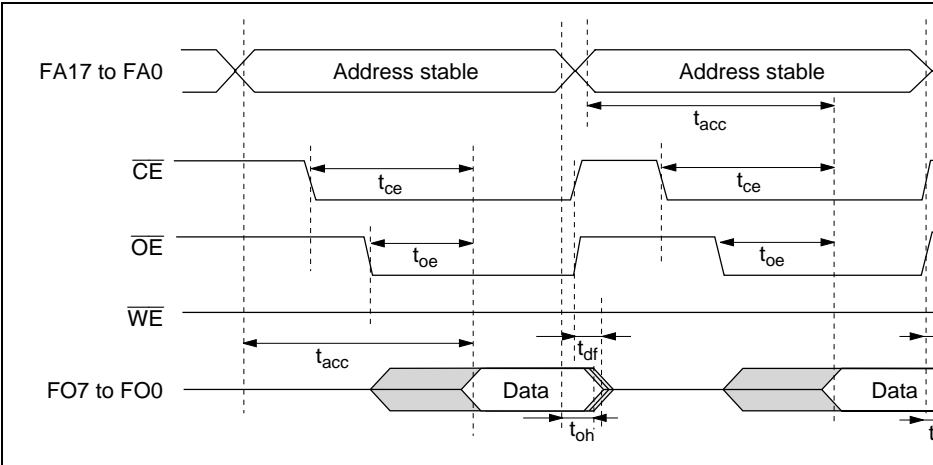


Figure 22.19 Timing Waveforms for $\overline{CE}/\overline{OE}$ Clocked Read

Command write cycle	t_{nxtc}	20	—	μs
$\overline{\text{CE}}$ hold time	t_{ceh}	0	—	ns
$\overline{\text{CE}}$ setup time	t_{ces}	0	—	ns
Data hold time	t_{dh}	50	—	ns
Data setup time	t_{ds}	50	—	ns
Write pulse width	t_{wep}	70	—	ns
Status polling start time	t_{wsts}	1	—	ms
Status polling access time	t_{spa}	—	150	ns
Address setup time	t_{as}	0	—	ns
Address hold time	t_{ah}	60	—	ns
Memory write time	t_{write}	1	3000	ms
$\overline{\text{WE}}$ rise time	t_{r}	—	30	ns
$\overline{\text{WE}}$ fall time	t_{f}	—	30	ns

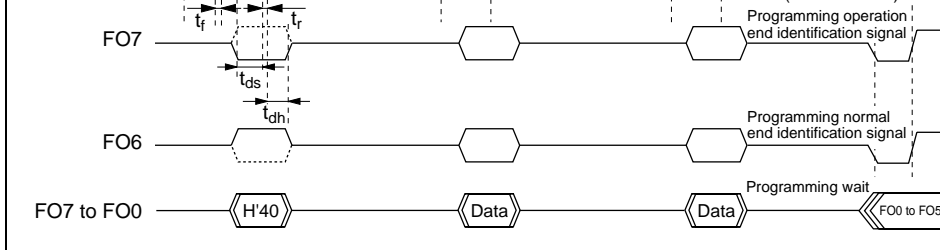


Figure 22.20 Auto-Program Mode Timing Waveforms

Notes on Use of Auto-Program Mode

- In auto-program mode, 128 bytes are programmed simultaneously. This should be done by executing 128 consecutive byte transfers.
- A 128-byte data transfer is necessary even when programming fewer than 128 bytes. In this case, H'FF data must be written to the extra addresses.
- The lower 8 bits of the transfer address must be H'00 or H'80. If a value other than a valid address is input, processing will switch to a memory write operation but a write error will be flagged.
- Memory address transfer is performed in the second cycle (figure 22.20). Do not perform another transfer after the second cycle.
- Do not perform a command write during a programming operation.
- Perform one auto-programming operation for a 128-byte block for each address. Characteristics are not guaranteed for two or more programming operations.
- Confirm normal end of auto-programming by checking FO6. Alternatively, status register FO7 can also be used for this purpose (FO7 status polling uses the auto-program operation end identification pin).
- The status polling FO6 and FO7 pin information is retained until the next command write. Until the next command write is performed, reading is possible by enabling \overline{CE} and

Command write cycle	t_{nxtc}	20	—	μ s
\overline{CE} hold time	t_{ceh}	0	—	ns
\overline{CE} setup time	t_{ces}	0	—	ns
Data hold time	t_{dh}	50	—	ns
Data setup time	t_{ds}	50	—	ns
Write pulse width	t_{wep}	70	—	ns
Status polling start time	t_{ests}	1	—	ms
Status polling access time	t_{spa}	—	150	ns
Memory erase time	t_{erase}	100	40000	ms
\overline{WE} rise time	t_r	—	30	ns
\overline{WE} fall time	t_f	—	30	ns

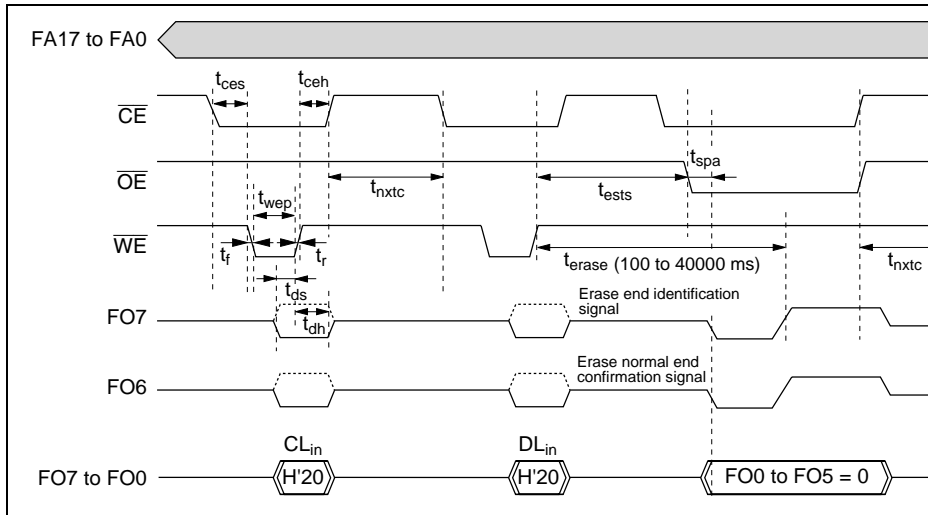


Figure 22.21 Auto-Erase Mode Timing Waveforms

22.10.7 Status Read Mode

- Status read mode is used to identify what type of abnormal end has occurred. Use the return code when an abnormal end occurs in auto-program mode or auto-erase mode.
- The return code is retained until a command write for other than status read mode is performed.

Table 22.18 AC Characteristics in Status Read Mode

Conditions: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $T_a = 25^\circ\text{C} \pm 5^\circ\text{C}$

Item	Symbol	Min	Max	Unit
Command write cycle	t_{nxtc}	20	—	μs
$\overline{\text{CE}}$ hold time	t_{ceh}	0	—	ns
$\overline{\text{CE}}$ setup time	t_{ces}	0	—	ns
Data hold time	t_{dh}	50	—	ns
Data setup time	t_{ds}	50	—	ns
Write pulse width	t_{wep}	70	—	ns
$\overline{\text{OE}}$ output delay time	t_{oe}	—	150	ns
Disable delay time	t_{df}	—	100	ns
$\overline{\text{CE}}$ output delay time	t_{ce}	—	150	ns
$\overline{\text{WE}}$ rise time	t_r	—	30	ns
$\overline{\text{WE}}$ fall time	t_f	—	30	ns

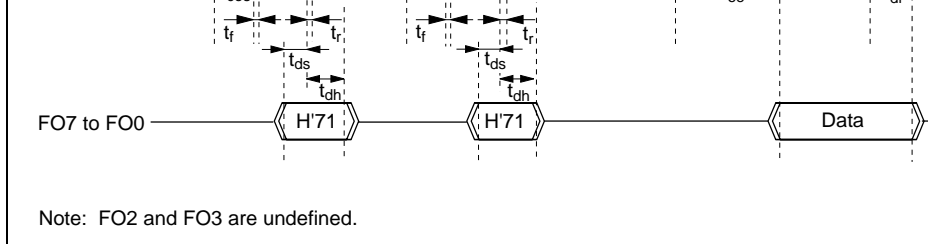


Figure 22.22 Status Read Mode Timing Waveforms

Table 22.19 Status Read Mode Return Commands

Pin Name	FO7	FO6	FO5	FO4	FO3	FO2	FO1
Attribute	Normal end identification	Command error	Programming error	Erase error	—	—	Programming or erase count exceeded
Initial value	0	0	0	0	0	0	0
Indications	Normal end: 0	Command error: 1	Programming error: 1	Erase error: 1	—	—	Count exceeded: 1
	Abnormal end: 1	Otherwise: 0	Otherwise: 0	Otherwise: 0			Otherwise: 0

Note: FO2 and FO3 are undefined.

22.10.8 Status Polling

- The FO7 status polling flag indicates the operating status in auto-program or auto-erase mode.
- The FO6 status polling flag indicates a normal or abnormal end in auto-program or auto-erase mode.

22.10.9 Programmer Mode Transition Time

Commands cannot be accepted during the oscillation stabilization period or the programmer mode setup period. After the programmer mode setup time, a transition is made to memory read mode. After the memory read mode, a transition is made to auto-program mode. After the auto-program mode, a transition is made to auto-erase mode. After the auto-erase mode, a transition is made to command wait state. After the command wait state, a transition is made to normal/abnormal end identification. After the normal/abnormal end identification, a transition is made to done state.

Table 22.21 Command Wait State Transition Time Specifications

Item	Symbol	Min	Max
Standby release (oscillation stabilization time)	t_{osc1}	20	—
Programmer mode setup time	t_{bmv}	10	—
V_{CC} hold time	t_{dwn}	0	—

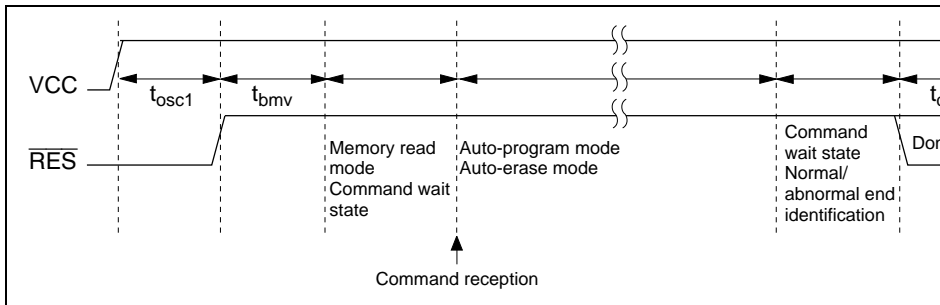


Figure 22.23 Oscillation Stabilization Time, Programmer Mode Setup Time, and Supply Fall Sequence

- Notes: 1. The flash memory is initially in the erased state when the device is shipped.
For other chips for which the erasure history is unknown, it is recommended that an erasing operation be executed to check and supplement the initialization (erase) level.
2. Auto-programming should be performed once only on the same address block.

22.11 Flash Memory Programming and Erasing Precautions

Precautions concerning the use of on-board programming mode and programmer mode are summarized below.

Use the specified voltages and timing for programming and erasing.

Applied voltages in excess of the rating can permanently damage the device. For a PROM programmer, use Renesas Technology microcomputer device types with 128-kbyte or more on-chip flash memory that support a 5.0-V programming voltage.

Do not select the HN28F101 or use a programming voltage of 3.3 V for the PROM programmer and only use the specified socket adapter. Incorrect use will result in damaging the device.

Powering on and off

When applying or disconnecting V_{CC} , fix the \overline{RES} pin low and place the flash memory in hardware protection state.

The power-on and power-off timing requirements should also be satisfied in the event of a failure and subsequent recovery.

Use the recommended algorithm when programming and erasing flash memory.

The recommended algorithm enables programming and erasing to be carried out without subjecting the device to voltage stress or sacrificing program data reliability. When setting the E bit in FLMCR1, the watchdog timer should be set beforehand as a precaution against a runaway, etc.

Do not set or clear the SWE bit during program execution in flash memory.

Clear the SWE bit before executing a program or reading data in flash memory. When the SWE bit is set, data in flash memory can be rewritten, but flash memory should only be accessed for verify operations (verification during programming/erasing).

Before programming, check that the chip is correctly mounted in the PROM programmer.
Overcurrent damage to the device can result if the index marks on the PROM programmer socket adapter, and chip are not correctly aligned.

Do not touch the socket adapter or chip during programming.
Touching either of these can cause contact faults and write errors.

22.12 Note on Switching from F-ZTAT Version to Mask ROM Version

The mask ROM version does not have the internal registers for flash memory control that are provided in the F-ZTAT version. Table 22.22 lists the registers that are present in the F-ZTAT version but not in the mask ROM version. If a register listed in table 22.22 is read in the mask ROM version, an undefined value will be returned. Therefore, if application software developed on the F-ZTAT version is switched to a mask ROM version product, it must be modified so that the registers in table 22.22 have no effect.

Table 22.22 Registers Present in F-ZTAT Version but Absent in Mask ROM Version

Register	Abbreviation	Address
Flash memory control register 1	FLMCR1	H'FF80
Flash memory control register 2	FLMCR2	H'FF81
Erase block register 1	EBR1	H'FF82
Erase block register 2	EBR2	H'FF83

H8S/2148 F-ZTAT A-mask version and H8S/2144 F-ZTAT A-mask version have 128 kbytes of on-chip flash memory. H8S/2147 F-ZTAT A-mask version has 64 kbytes of on-chip flash memory. The flash memory is connected to the bus master by a 16-bit data bus. The bus master accesses both byte and word in one state, enabling faster instruction fetches and higher processing speed.

The mode pins (MD1 and MD0) and the EXPE bit in MDCR can be set to enable or disable access to the on-chip ROM.

The flash memory versions of this group can be erased and programmed on-board as well as by using a general-purpose PROM programmer.

23.1.1 Block Diagram

Figure 23.1 shows a block diagram of the ROM.

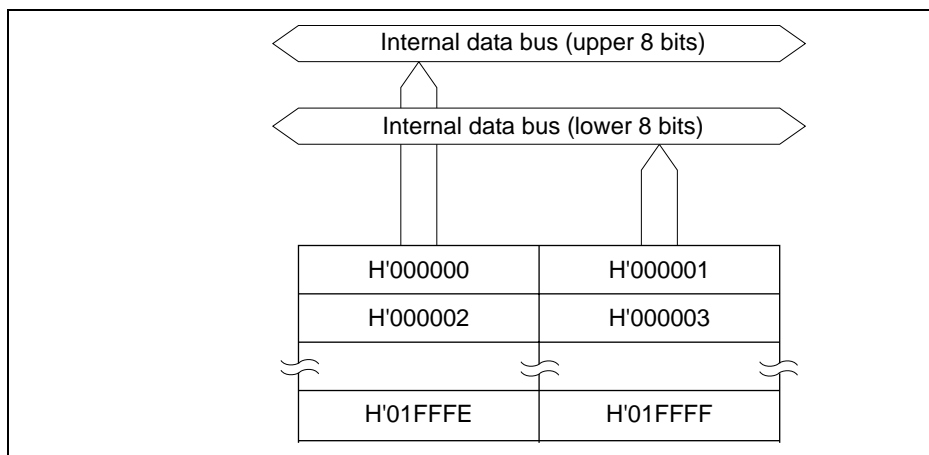


Figure 23.1 ROM Block Diagram
(A-mask versions of the H8S/2148 F-ZTAT and H8S/2144 F-ZTAT)

Note: * Lower 16 bits of the address.

23.2 Register Descriptions

23.2.1 Mode Control Register (MDCR)

Bit	7	6	5	4	3	2	1
	EXPE	—	—	—	—	—	MDS1
Initial value	—*	0	0	0	0	0	—*
Read/Write	R/W*	—	—	—	—	—	R

Note: * Determined by the MD1 and MD0 pins.

MDCR is an 8-bit read-only register used to set this group operating mode and monitor operating mode.

The EXPE bit is initialized in accordance with the mode pin states by a reset and in hardware standby mode.

Bit 7—Expanded Mode Enable (EXPE): Sets expanded mode. In mode 1, EXPE is fixed and cannot be modified. In modes 2 and 3, EXPE has an initial value of 0 and can be read and written.

Bit 7

EXPE	Description
0	Single-chip mode selected
1	Expanded mode selected

The on-chip flash memory is connected to the CPU by a 16-bit data bus, and both byte and word data is accessed in one state. Even addresses are connected to the upper 8 bits, and odd addresses are connected to the lower 8 bits. Word data must start at an even address.

The mode pins (MD1 and MD0) and the EXPE bit in MDCR can be set to enable or disable access to on-chip ROM, as shown in table 23.2.

In normal mode, the maximum amount of ROM that can be used is 56 kbytes.

Table 23.2 Operating Modes and ROM

Operating Mode						
MCU Operating Mode	CPU Operating Mode	Description	Mode Pins		MDCR	On-chip ROM
			MD1	MD0	EXPE	
Mode 1	Normal	Expanded mode with on-chip ROM disabled	0	1	1	Disabled
Mode 2	Advanced	Single-chip mode	1	0	0	Enabled
	Advanced	Expanded mode with on-chip ROM enabled			1	
Mode 3	Normal	Single-chip mode		1	0	Enabled (56 kbytes)
	Normal	Expanded mode with on-chip ROM enabled			1	

Note: * H8S/2148 F-ZTAT A-mask version and H8S/2144 F-ZTAT A-mask version has 128 kbytes, and H8S/2147 F-ZTAT A-mask version has 64 kbytes of on-chip ROM.

- Erase mode
- Program-verify mode
- Erase-verify mode
- Programming/erase methods

The flash memory is programmed 128 bytes at a time. Erasing is performed by block (single-block units). When erasing multiple blocks, the individual blocks must be erased sequentially. Block erasing can be performed as required on 1-kbyte, 28-kbyte, 16-kbyte, and 32-kbyte blocks.
- Programming/erase times

The flash memory programming time is 10 ms (typ.) for simultaneous 128-byte programming equivalent to approximately 80 μ s (typ.) per byte, and the erase time is 100 ms (typ.).
- Reprogramming capability

The flash memory can be reprogrammed up to 100 times.
- On-board programming modes

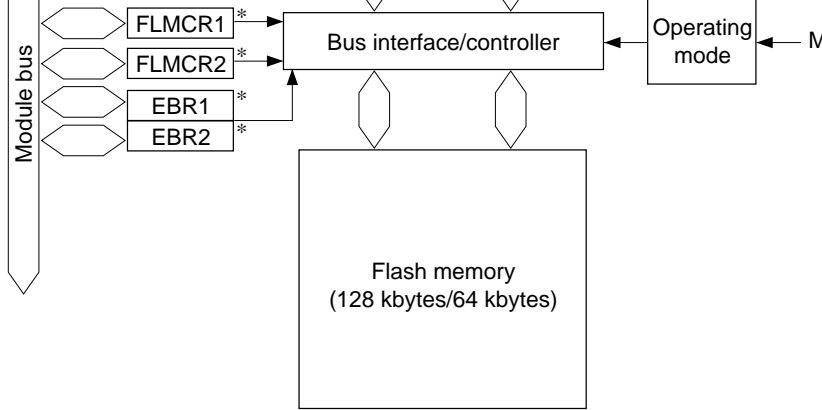
There are two modes in which flash memory can be programmed/erased/verified on-board.

 - Boot mode
 - User program mode
- Automatic bit rate adjustment

With data transfer in boot mode, the bit rate of the chip can be automatically adjusted to the transfer bit rate of the host.
- Protect modes

There are three protect modes, hardware, software, and error protect, which allow program status to be designated for flash memory program/erase/verify operations.
- Programmer mode

Flash memory can be programmed/erased in programmer mode, using a PROM programmer as well as in on-board programming mode.



Legend:

FLMCR1: Flash memory control register 1

FLMCR2: Flash memory control register 2

EBR1: Erase block register 1

EBR2: Erase block register 2

Note: * These registers are used only in the flash memory version. In the mask ROM version, a read at any of these addresses will return an undefined value, and writes are not allowed.

Figure 23.2 Block Diagram of Flash Memory

mode.

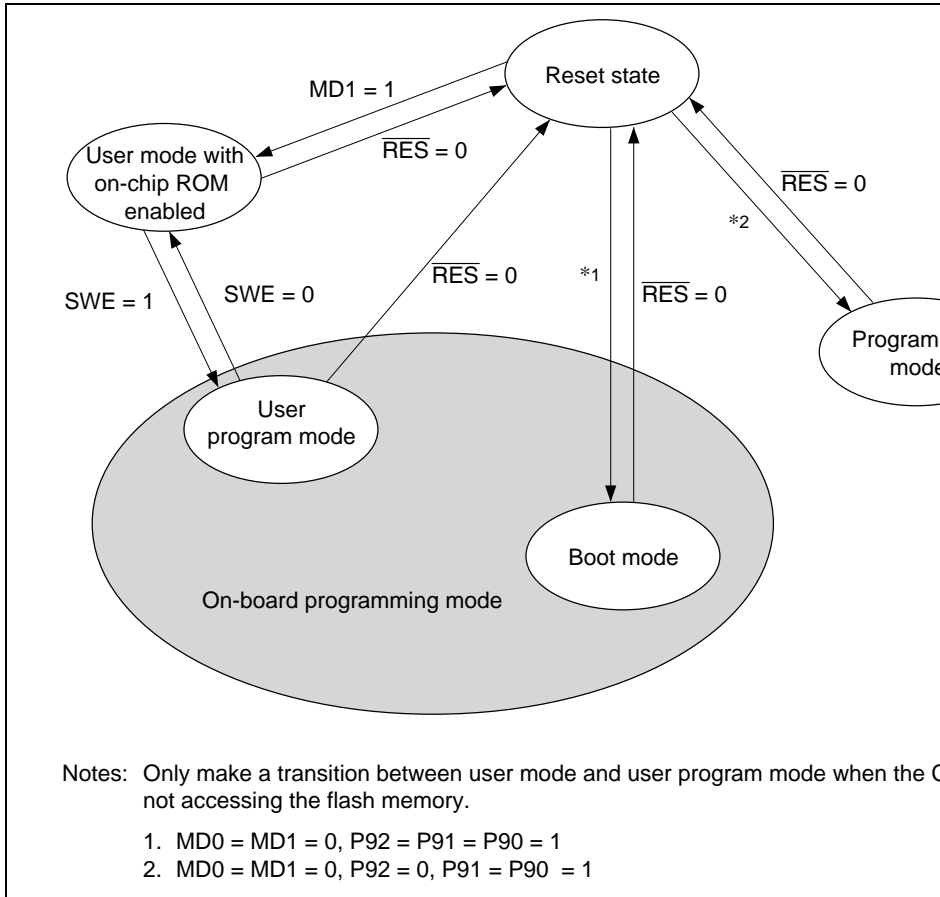
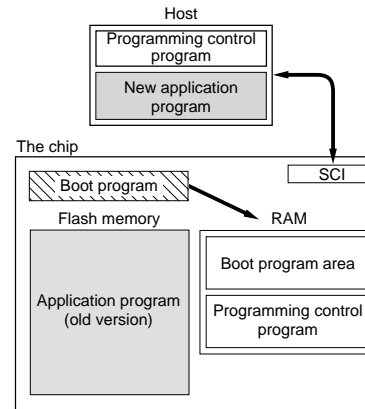
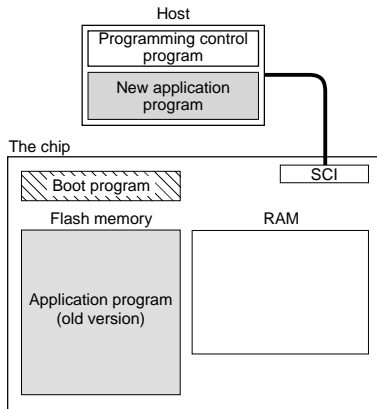
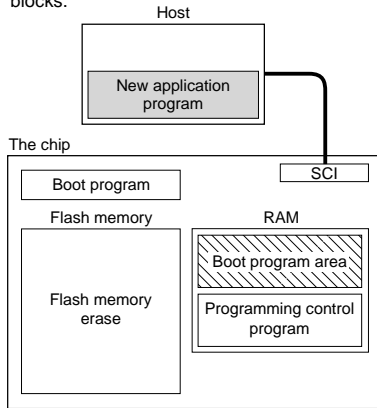


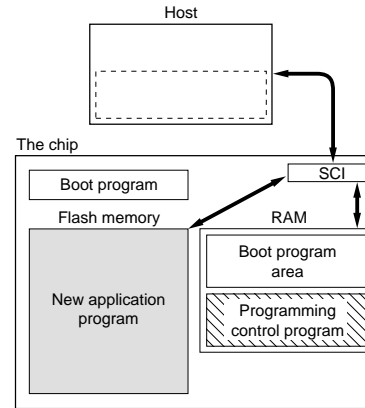
Figure 23.3 Flash Memory Mode Transitions



- Flash memory initialization
The erase program in the boot program area (in RAM) is executed, and the flash memory is initialized (to H'FF). In boot mode, entire flash memory erasure is performed, without regard to blocks.

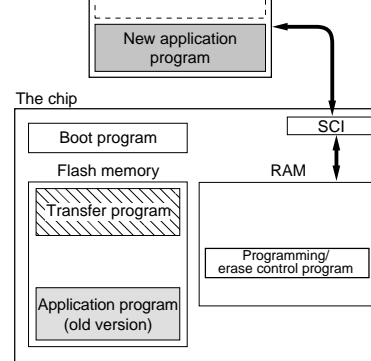
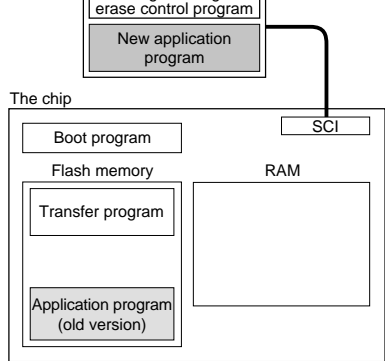


- Writing new application program
The programming control program transferred from the host to RAM by SCI communication is executed, and the new application program from the host is written into the flash memory.



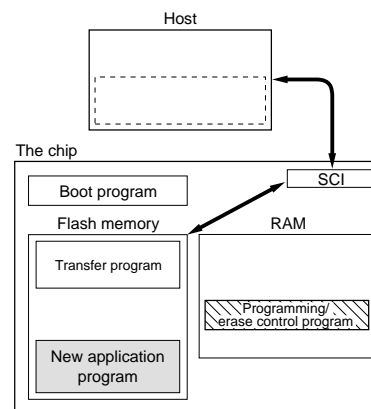
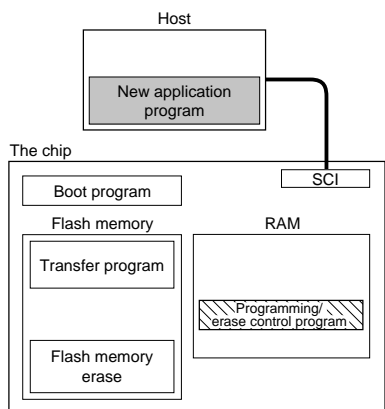
Program execution

Figure 23.4 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 written into the erased flash memory blocks. Do not write to unerased blocks.



Program execution

Figure 23.5 User Program Mode (Example)

Block Configuration

The flash memory is divided into two 32-kbyte blocks (128-kbyte version only), two 8-kbyte blocks, one 16-kbyte block, one 28-kbyte block, and four 1-kbyte blocks.

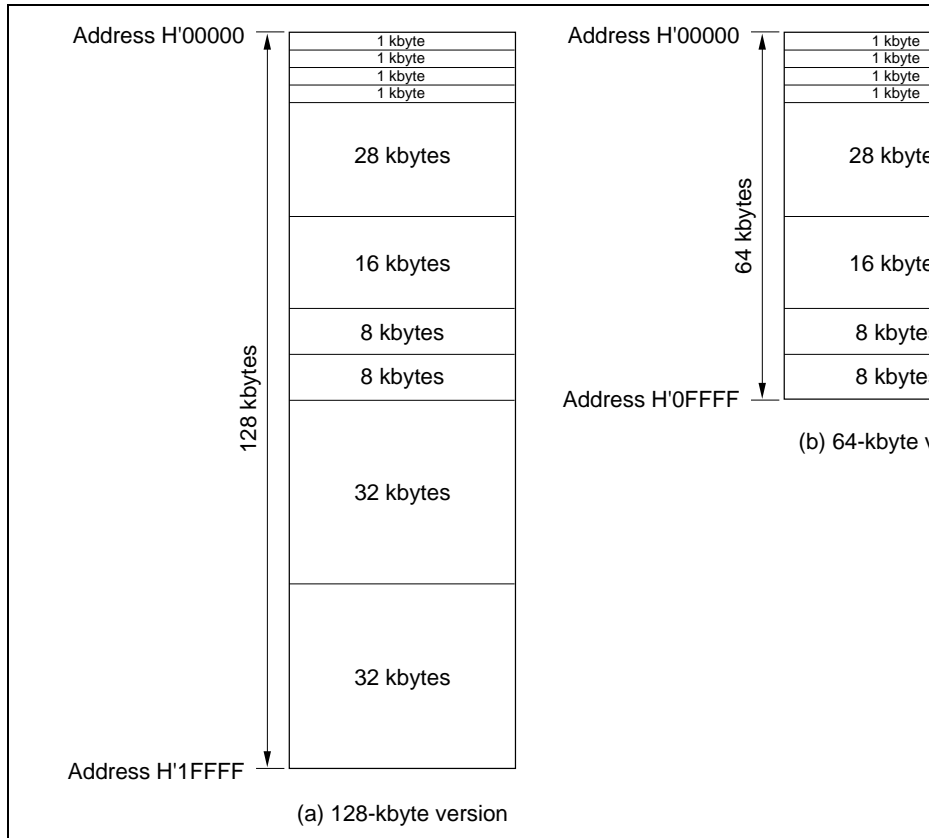


Figure 23.6 Flash Memory Block Configuration

Mode 0	MD0	Input	Sets MCU operating mode
Port 92	P92	Input	Sets MCU operating mode when MD1 = 1
Port 91	P91	Input	Sets MCU operating mode when MD1 = 0
Port 90	P90	Input	Sets MCU operating mode when MD1 = 0
Transmit data	TxD1	Output	Serial transmit data output
Receive data	RxD1	Input	Serial receive data input

23.4.5 Register Configuration

The registers used to control the on-chip flash memory when enabled are shown in table 23.4. In order for these registers to be accessed, the FLSHE bit must be set to 1 in STCR.

Table 23.4 Flash Memory Registers

Register Name	Abbreviation	R/W	Initial Value	Address
Flash memory control register 1	FLMCR1 ^{*5}	R/W ^{*3}	H'80	H'00000000
Flash memory control register 2	FLMCR2 ^{*5}	R/W ^{*3}	H'00 ^{*4}	H'00000001
Erase block register 1	EBR1 ^{*5}	R/W ^{*3}	H'00 ^{*4}	H'00000002
Erase block register 2	EBR2 ^{*5}	R/W ^{*3}	H'00 ^{*4}	H'00000003
Serial/timer control register	STCR	R/W	H'00	H'00000004

- Notes:
1. Lower 16 bits of the address.
 2. Flash memory registers share addresses with other registers. Register selection is performed by the FLSHE bit in the serial/timer control register (STCR).
 3. In modes in which the on-chip flash memory is disabled, a read will return H'FF and writes are invalid.
 4. When the SWE bit in FLMCR1 is not set, these registers are initialized to H'00.
 5. FLMCR1, FLMCR2, EBR1, and EBR2 are 8-bit registers. Only byte accesses are allowed. For these registers, the access requiring 2 states.

FLMCR1 is an 8-bit register used for flash memory operating mode control. Program or erase-verify mode is entered by setting SWE to 1. Program mode is entered by setting SWE to 1, then setting the PSU bit in FLMCR2, and finally setting the P bit. Erase mode is entered by setting SWE to 1, then setting the ESU bit in FLMCR2, and finally setting the E bit. FLMCR1 is initialized to H'80 by a reset, and in hardware standby mode, software standby mode, mode, subsleep mode, and watch mode. When on-chip flash memory is disabled, a read of H'00, and writes are invalid.

Writes to the EV and PV bits in FLMCR1 are enabled only when SWE=1; writes to the ESU bit only when SWE = 1, and ESU = 1; and writes to the P bit only when SWE = 1, and PSU = 1.

Bit 7—Flash Write Enable (FWE): Sets hardware protection against flash memory programming/erasing. This bit cannot be modified and is always read as 1.

Bit 6—Software Write Enable (SWE): Enables or disables flash memory programming. SWE should be set before setting bits ESU, PSU, EV, PV, E, P, and EB9 to EB0, and should be cleared at the same time as these bits.

Bit 6

SWE	Description
0	Writes disabled
1	Writes enabled

Bit 5 and 4—Reserved: These bits cannot be modified and are always read as 0.

Bit 2—Program-Verify (PV): Selects program-verify mode transition or clearing. Do not set the SWE, ESU, PSU, EV, E, or P bit at the same time.

Bit 2

PV	Description
0	Program-verify mode cleared
1	Transition to program-verify mode [Setting condition] When SWE = 1

Bit 1—Erase (E): Selects erase mode transition or clearing. Do not set the SWE, ESU, PV, or P bit at the same time.

Bit 1

E	Description
0	Erase mode cleared
1	Transition to erase mode [Setting condition] When SWE = 1, and ESU = 1

23.5.2 Flash Memory Control Register 2 (FLMCR2)

Bit	7	6	5	4	3	2	1
	FLER	—	—	—	—	—	ESU
Initial value	0	0	0	0	0	0	0
Read/Write	R	—	—	—	—	—	R/W

FLMCR2 is an 8-bit register that monitors the presence or absence of flash memory protection (error protection) and performs setup for flash memory program/erase mode. The register is initialized to H'00 by a reset, and in hardware standby mode. The ESU and PSU bits are set to 0 in software standby mode, subactive mode, subsleep mode, and watch mode.

When on-chip flash memory is disabled, a read will return H'00 and writes are invalid.

Bit 7—Flash Memory Error (FLER): Indicates that an error has occurred during an erase of flash memory (programming or erasing). When FLER is set to 1, flash memory goes to error protection state.

Bits 6 to 2—Reserved: Always write 0 when writing to these bits.

Bit 1—Erase Setup (ESU): Prepares for a transition to erase mode. Set this bit to 1 before setting the E bit to 1 in FLMCR1. Do not set the SWE, PSU, EV, PV, E, or P bit at the same time.

Bit 1

ESU	Description
0	Erase setup cleared
1	Erase setup [Setting condition] When SWE = 1

Bit 0—Program Setup (PSU): Prepares for a transition to program mode. Set this bit to 1 before setting the P bit to 1 in FLMCR1. Do not set the SWE, ESU, EV, PV, E, or P bit at the same time.

Bit 0

PSU	Description
0	Program setup cleared
1	Program setup [Setting condition] When SWE = 1

EBR2	EB7	EB6	EB5	EB4	EB3	EB2	EB1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W ^{*1}	R/W	R/W	R/W	R/W	R/W	R/W

- Notes: 1. In normal mode, these bits cannot be modified and are always read as 0.
2. Bits EB8 and EB9 are not present in the 64-kbyte versions; they must not be set.

EBR1 and EBR2 are registers that specify the flash memory erase area block by block. Bit 7 in EBR1 and bits 7 to 0 in EBR2 are readable/writable bits. EBR1 and EBR2 are each initialized to H'00 by a reset, in hardware standby mode, software standby mode, subactive mode, and watch mode, and when the SWE bit in FLMCR1 is not set. When a bit in EBR2 is set, the corresponding block can be erased. Other blocks are erase-protected. When a bit in EBR1 and EBR2 (more than one bit cannot be set). When on-chip flash memory is read, a read will return H'00, and writes are invalid.

The flash memory block configuration is shown in table 23.5.

EB4 (28 kbytes)	EB4 (28 kbytes)	H'(00)1000 to H'(00)7FFF
EB5 (16 kbytes)	EB5 (16 kbytes)	H'(00)8000 to H'(00)BFFF
EB6 (8 kbytes)	EB6 (8 kbytes)	H'(00)C000 to H'(00)DFFF
EB7 (8 kbytes)	EB7 (8 kbytes)	H'00E000 to H'00FFFF
EB8 (32 kbytes)	—	H'010000 to H'017FFF
EB9 (32 kbytes)	—	H'018000 to H'01FFFF

23.5.4 Serial/Timer Control Register (STCR)

Bit	7	6	5	4	3	2	1
	IICS	IICX1	IICX0	IICE	FLSHE	—	ICKS1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

STCR is an 8-bit readable/writable register that controls register access, the IIC operation (when the on-chip IIC option is included), and on-chip flash memory, and also selects the input clock. For details on functions not related to on-chip flash memory, see section 3. Serial/Timer Control Register (STCR), and descriptions of individual modules. If a module controlled by STCR is not used, do not write 1 to the corresponding bit.

STCR is initialized to H'00 by a reset and in hardware standby mode.

Bits 7 to 4—I²C Control (IICS, IICX1, IICX0, IICE): These bits control the operation of the I²C bus interface for the I²C on-chip option. For details, see section 16, I²C Bus Interface.



Bit 2—Reserved: Do not write 1 to this bit.

Bits 1 and 0—Internal Clock Select 1 and 0 (ICKS1, ICKS0): These bits control 8-bit operation. See section 12, 8-Bit Timers, for details.

23.6 On-Board Programming Modes

When pins are set to on-board programming mode, program/erase/verify operations can be performed on the on-chip flash memory. There are two on-board programming modes: boot mode and user program mode. The pin settings for transition to each of these modes are shown in Table 23.6. For a diagram of the transitions to the various flash memory modes, see figure 23.6.

Only advanced mode setting is possible for boot mode.

In the case of user program mode, established in advanced mode or normal mode, depends on the setting of the MD0 pin. In normal mode, only programming of a 56-kbyte area of flash memory is possible.

Table 23.6 Setting On-Board Programming Modes

Mode Name	Mode				
	CPU Operating Mode	MD1	MD0	P92	P91
Boot mode	Advanced mode	0	0	1*	1*
User program mode	Advanced mode	1	0	—	—
	Normal mode		1	—	—

Note: * Can be used as I/O ports after boot mode is initiated.

completed, control branches to the start address of the programming control program and the programming control program execution state is entered (flash memory programming is performed).

The transferred programming control program must therefore include coding that follows the programming algorithm given later.

The system configuration in boot mode is shown in figure 23.7, and the boot program execution procedure in figure 23.8.

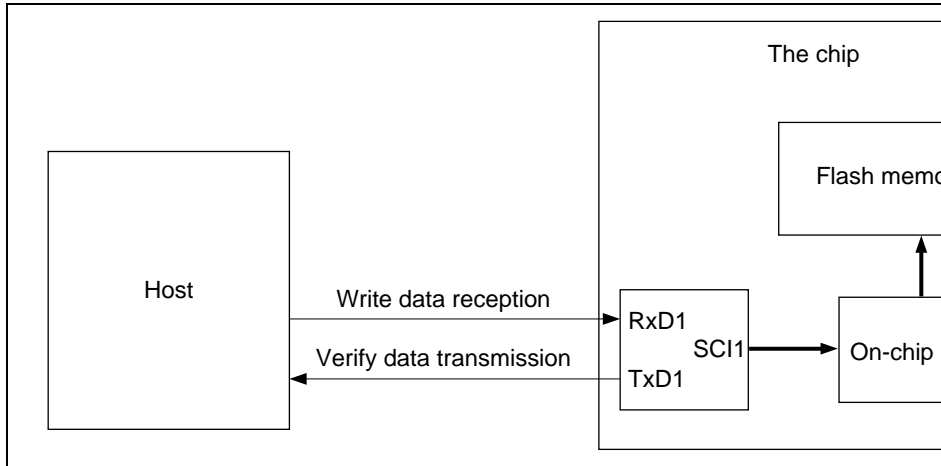
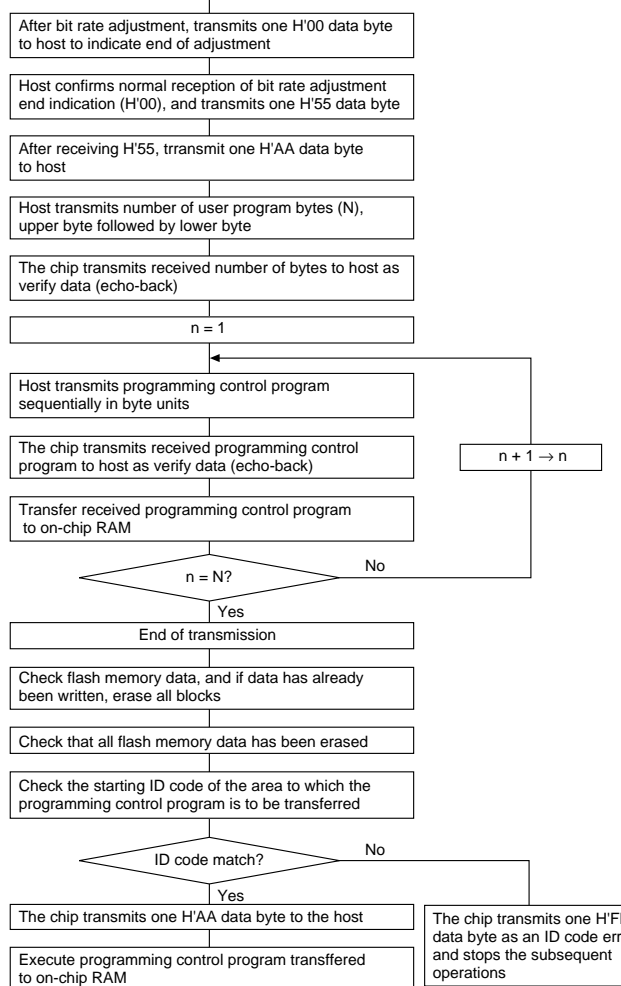


Figure 23.7 System Configuration in Boot Mode



Note: If a memory cell does not operate normally and cannot be erased, one H'FF byte is transmitted as an erase error. The erase operation and subsequent operations are halted.

Figure 23.8 Boot Mode Execution Procedure

When boot mode is initiated, the chip measures the low period of the asynchronous SCI communication data (H'00) transmitted continuously from the host. The SCI transmit/receive format should be set as follows: 8-bit data, 1 stop bit, no parity. The chip calculates the time of the transmission from the host from the measured low period, and transmits one H'00 byte to the host to indicate the end of bit rate adjustment. The host should confirm that this adjustment indication (H'00) has been received normally, and transmit one H'55 byte to the chip. If this cannot be performed normally, initiate boot mode again (reset), and repeat the above operation. Depending on the host's transmission bit rate and the chips system clock frequency, there is a discrepancy between the bit rates of the host and the chip. To ensure correct SCI operation, the host's transfer bit rate should be set to (4800, 9600, or 19200) bps.

Table 23.7 shows typical host transfer bit rates and system clock frequencies for which automatic adjustment of the chips bit rate is possible. The boot program should be executed within the system clock range.

Table 23.7 System Clock Frequencies for Which Automatic Adjustment of the Chip Bit Rate Is Possible

Host Bit Rate	System Clock Frequency for Which Automatic Adjustment of Bit Rate Is Possible
19200 bps	8 MHz to 20 MHz
9600 bps	4 MHz to 20 MHz
4800 bps	2 MHz to 18 MHz

On-Chip RAM Area Divisions in Boot Mode

In boot mode, the 1920-byte area from H'(FF)E880 to H'(FF) EFFF and the 128-byte area from H'(FF)FF00 to H'(FF)FF7F is reserved for use by the boot program, as shown in figure 23.8. The area to which the programming control program is transferred is H'(FF)E080 to H'(FF)E087 (16 bytes). In the 64-kbyte version, this is a reserved area that is used only during the boot mode. However, the 8-byte area from H'(FF)E080 to H'(FF)E087 is reserved for ID codes as shown in figure 23.9.

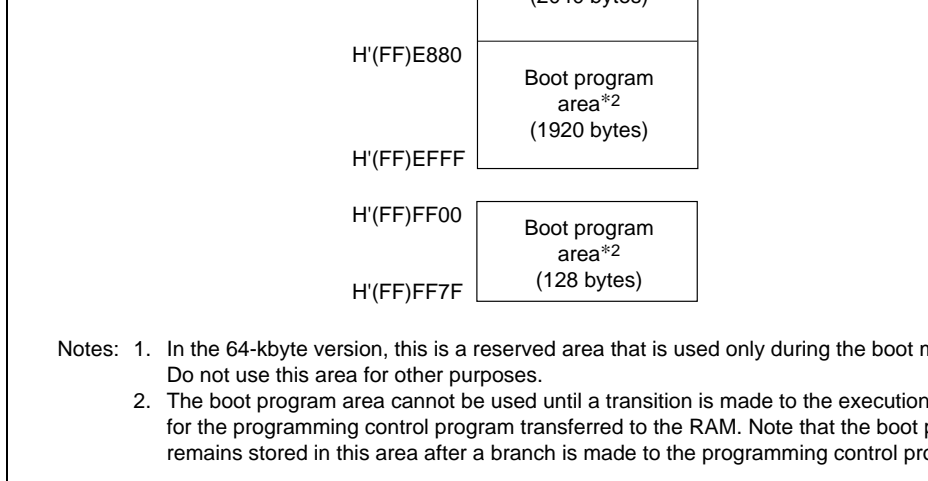
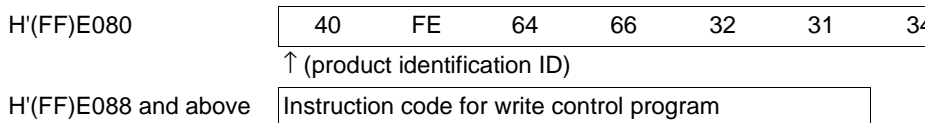


Figure 23.10 RAM Areas in Boot Mode

In the boot mode of this chip, the content in the 8-byte ID code area shown below is checked to determine whether or not there is a programming control program that corresponds to the chip. The content is checked.



When a new programming control program for use in boot mode is created, add the 8-byte code described above to the head of the program.

Notes on Use of Boot Mode

- When the chip comes out of reset in boot mode, it measures the low period of the SCI's RxD1 pin. The reset should end with RxD1 high. After the reset ends, it takes a certain amount of time for the chip to get ready to measure the low period of the RxD1 input.

- Before branching to the programming control program (RAM area H'(FF)E088), the microcomputer terminates transmit and receive operations by the on-chip SCI (channel 1) (by clearing the TXIF and TE bits in SCR to 0), but the adjusted bit rate value remains set in BRR. The transmit output pin, TxD1, goes to the high-level output state (P84DDR = 1, P84DR = 1). The contents of the CPU's internal general registers are undefined at this time, so the registers must be initialized immediately after branching to the programming control program. In particular, since the stack pointer (SP) is used implicitly in subroutine calls, etc., the SP must be specified for use by the programming control program. The initial values of other on-chip registers are not changed.

- Boot mode can be entered by making the pin settings shown in table 23.6 and executing reset-start.

When the chip detects the boot mode setting at reset release^{*1}, P92, P91, and P90 can be used as I/O ports.

Boot mode can be cleared by driving the reset pin low, waiting at least 20 states, then driving the mode pins, and executing reset release^{*1}. Boot mode can also be cleared by a Watchdog overflow reset. The mode pin input levels must not be changed in boot mode.

- If the mode pin input levels are changed (for example, from low to high) during a reset, the state of ports with multiplexed address functions and bus control output pins (\overline{AS} , \overline{R} , etc.) will change according to the change in the microcomputer's operating mode^{*2}.

Therefore, care must be taken to make pin settings to prevent these pins from becoming signal pins during a reset, or to prevent collision with signals outside the microcomputer.

- Notes:
1. Mode pins input must satisfy the mode programming setup time ($t_{MDS} = 4$ states) with respect to the reset release timing.
 2. Ports with multiplexed address functions will output a low level as the address mode pin setting is for mode 1 is entered during a reset. In other modes, they will go to the high-impedance state. The bus control output signals will output a low level if mode pin setting is for mode 1 is entered during a reset. In other modes, they will go to the high-impedance state.

would in mode 2 and 3.

The flash memory itself cannot be read while the SWE bit is set to 1 to perform programming and erasing, so the control program that performs programming and erasing should be run from RAM or external memory.

Figure 23.11 shows the procedure for executing the program/erase control program which is transferred to on-chip RAM.

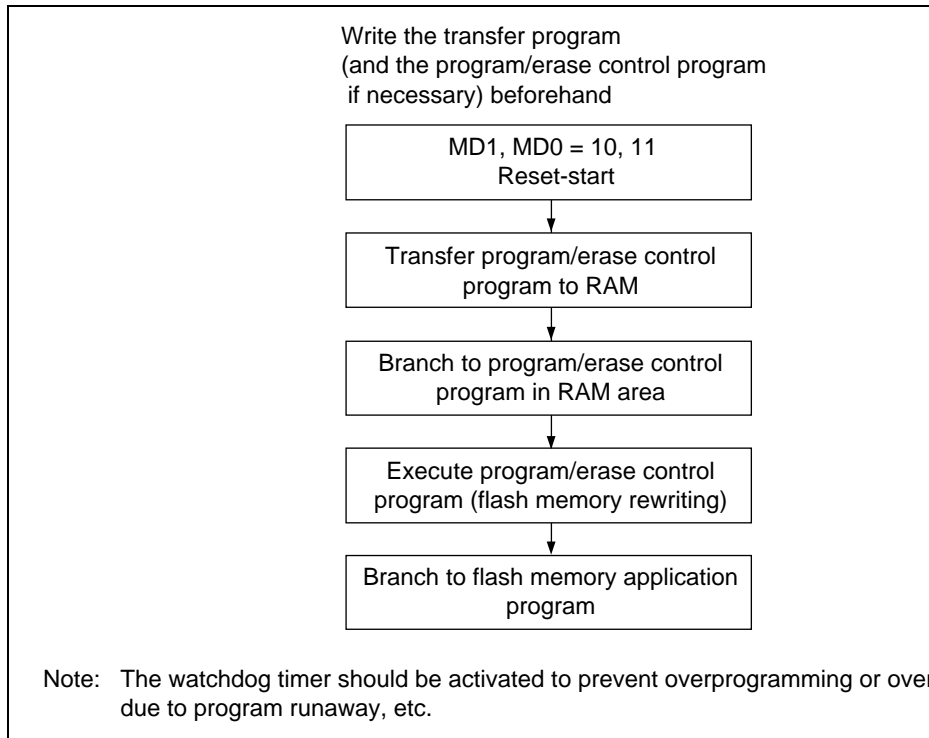


Figure 23.11 User Program Mode Execution Procedure

located and executed in on-chip RAM or external memory.

- Notes:
1. Operation is not guaranteed if setting/resetting of the SWE, EV, PV, E, and FLMCR1, and the ESU and PSU bits in FLMCR2, is executed by a program in memory.
 2. Perform programming in the erased state. Do not perform additional programming at previously programmed addresses.

23.7.1 Program Mode

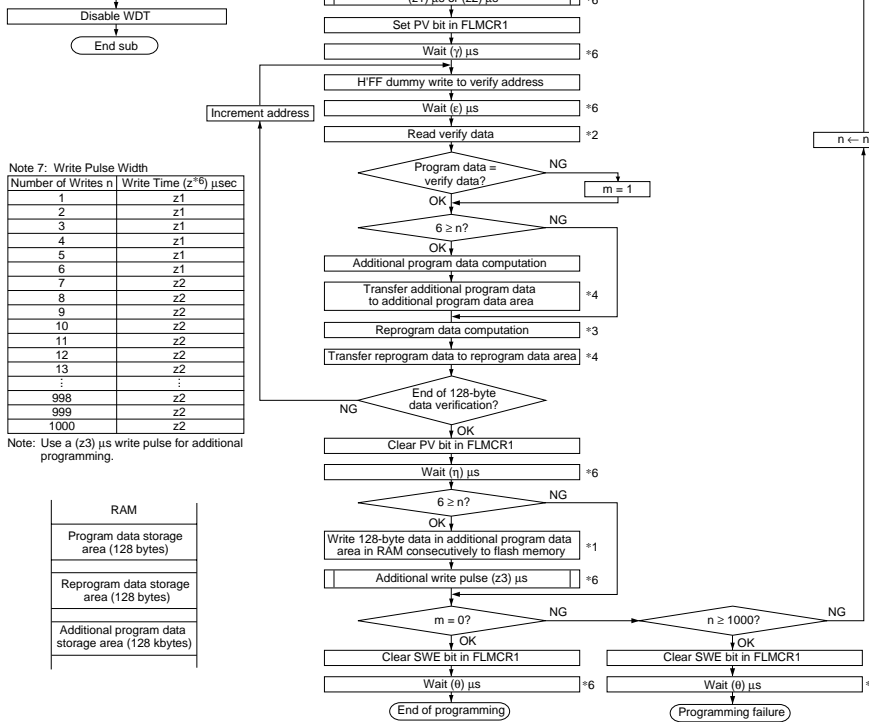
Follow the procedure shown in the program/program-verify flowchart in figure 23.12 to write data or programs to flash memory. Performing program operations according to this flowchart enables data or programs to be written to flash memory without subjecting the device to high stress or sacrificing program data reliability. Programming should be carried out 128 bytes at a time.

The wait times (x , y , $z1$, $z2$, $z3$, α , β , γ , ϵ , η , θ) after setting/clearing individual bits in flash memory control registers 1 and 2 (FLMCR1, FLMCR2) and the maximum number of writes are listed in table 26.2.6, Flash Memory Characteristics.

Following the elapse of (x) μs or more after the SWE bit is set to 1 in flash memory control register 1 (FLMCR1), 128-byte program data is stored in the program data area and reprogram data area, and the 128-byte data in the reprogram data area written consecutively to the addresses. The lower 8 bits of the first address written to must be H'00 or H'80. 128 consecutive 128-byte data transfers are performed. The program address and program data are latched in flash memory. A 128-byte data transfer must be performed even if writing fewer than 128 bytes. In the case of H'FF data must be written to the extra addresses.

Next, the watchdog timer is set to prevent overprogramming in the event of program run time. Set a value greater than ($y + z2 + \alpha + \beta$) μs as the WDT overflow period. After this, preparation for program mode (program setup) is carried out by setting the PSU bit in FLMCR2, and after an elapse of (y) μs or more, the operating mode is switched to program mode by setting the P bit in FLMCR1. The time during which the P bit is set is the flash memory programming time.

After the elapse of a given programming time, the programming mode is exited (the timer in FLMCR1 is cleared, then the PSU bit in FLMCR2 is cleared at least (α) μ s later). The timer is cleared after the elapse of (β) μ s or more, and the operating mode is switched to program-verify mode by setting the PV bit in FLMCR1. Before reading in program-verify mode, a dummy write of H'FF data should be made to the addresses to be read. The dummy write should be executed after the elapse of (γ) μ s or more. When the flash memory is read in this state (the data is read in 16-bit units), the data at the latched address is read. Wait at least (ϵ) μ s after the dummy write before performing this read operation. Next, the originally written data is compared with the read verify data, and reprogram data is computed (see figure 23.12) and transferred to the reprogram data area. After 128 bytes of data have been verified, exit program-verify mode, wait at least (η) μ s. If the programming count is less than 6, the 128-byte data in the additional reprogram data area should be written consecutively to the write addresses, and additional programming should be performed. Next clear the SWE bit in FLMCR1, and wait at least (θ) μ s. If reprogramming is necessary, set program mode again, and repeat the program/program-verify sequence. However, ensure that the program/program-verify sequence is not repeated more than 6 times for the same bits.



- Notes:
- Data transfer is performed by byte transfer. The lower 8 bits of the first address written to must be H00 or H80. A 128-byte data transfer must be performed if writing fewer than 128 bytes; in this case, H'FF data must be written to the extra addresses.
 - Verify data is read in 16-bit (word) units.
 - Even bits for which programming has been completed in the 128-byte programming loop will be subjected to additional programming if they fail the subsequent verify operation.
 - A 128-byte area for storing program data, a 128-byte area for storing reprogram data, and a 128-byte area for storing additional program data must be provided in RAM. The reprogram and additional program data contents are modified as programming proceeds.
 - The write pulse of (z1) μs or (z2) μs is applied according to the progress of the programming operation. See Note 7 for the pulse widths. When writing of program data is executed, a (z3) μs write pulse should be applied. Reprogram data X means reprogram data when the write pulse is applied.
 - See section 26.2.6, Flash Memory Characteristics, for the values of x, y, z1, z2, z3, α, β, γ, ε, η, θ, and N.

Program Data Computation Chart

Original Data (D)	Verify Data (V)	Reprogram Data (X)	Comments
0	0	1	Programming completed
	1	0	Programming incomplete; reprogram
1	0	1	
	1	1	Still in erased state; no action

Additional Program Data Computation Chart

Reprogram Data (X)	Verify Data (V)	Additional Program Data (Y)	Comments
0	0	0	Additional programming executed
	1	1	Additional programming not executed
1	0	1	
	1	1	Additional programming not executed

Figure 23.12 Program/Program-Verify Flowchart

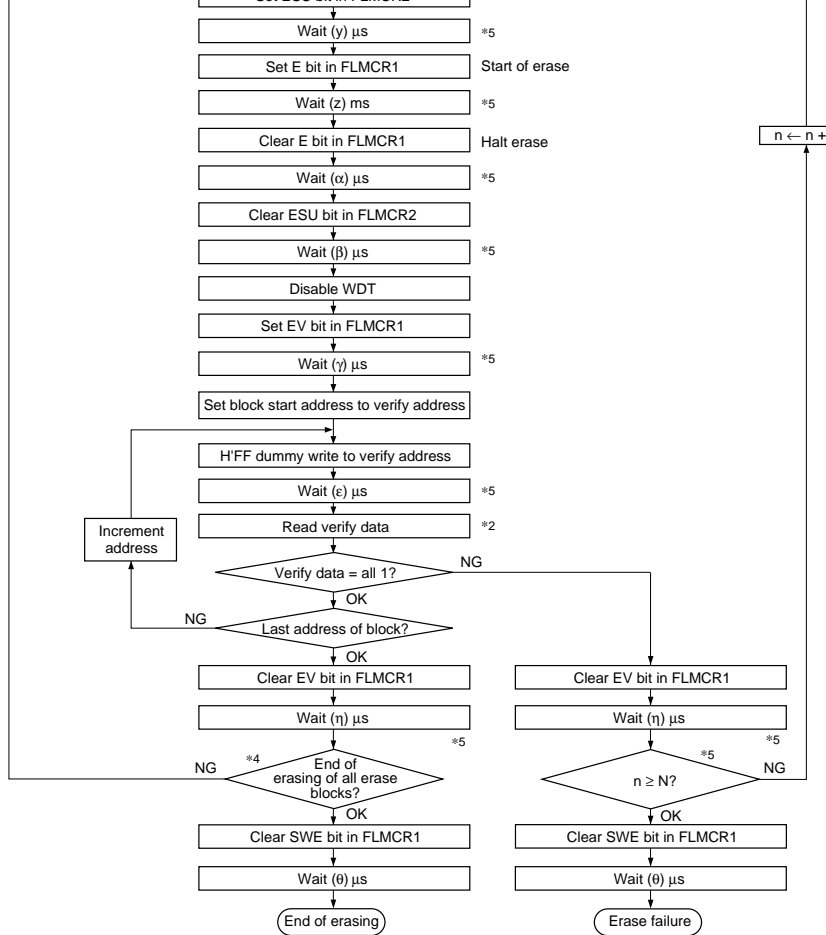
To perform data or program erasure, make a 1 bit setting for the flash memory area to erase block register 1 or 2 (EBR1 or EBR2) at least (x) μ s after setting the SWE bit to memory control register 1 (FLMCR1). Next, the watchdog timer is set to prevent over the event of program runaway, etc. Set a value greater than ($y + z + \alpha + \beta$) ms as the V overflow period. After this, preparation for erase mode (erase setup) is carried out by ESU bit in FLMCR2, and after the elapse of (y) μ s or more, the operating mode is switched to erase mode by setting the E bit in FLMCR1. The time during which the E bit is set is memory erase time. Ensure that the erase time does not exceed (z) ms.

Note: With flash memory erasing, preprogramming (setting all data in the memory to 0) is not necessary before starting the erase procedure.

23.7.4 Erase-Verify Mode

In erase-verify mode, data is read after memory has been erased to check whether it has been correctly erased.

After the elapse of the erase time, erase mode is exited (the E bit in FLMCR1 is cleared). After the ESU bit in FLMCR2 is cleared at least (α) μ s later), the watchdog timer is cleared after the elapse of (β) μ s or more, and the operating mode is switched to erase-verify mode by setting the E bit in FLMCR1. Before reading in erase-verify mode, a dummy write of H'FF data should be performed to the addresses to be read. The dummy write should be executed after the elapse of (γ) μ s. When the flash memory is read in this state (verify data is read in 16-bit units), the data at the latched address is read. Wait at least (ϵ) μ s after the dummy write before performing the read operation. If the read data has been erased (all 1), a dummy write is performed to the next address and erase-verify is performed. If the read data has not been erased, set erase mode again and repeat the erase/erase-verify sequence in the same way. However, ensure that the erase/erase-verify sequence is not repeated more than (N) times. When verification is completed, return to normal mode, and wait for at least (η) μ s. If erasure has been completed on all the erase blocks, clear the SWE bit in FLMCR1, and wait (θ) μ s. If there are any unerased blocks, make a 1 bit setting in EBR1 or EBR2 for the flash memory area to be erased, and repeat the erase/erase-verify sequence in the same way.



- Notes:
1. Preprogramming (setting erase block data to all 0) is not necessary.
 2. Verify data is read in 16-bit (W) units.
 3. Set only one bit in EBR1 or EBR2. More than one bit cannot be set.
 4. Erasing is performed in block units. To erase a number of blocks, the individual blocks must be erased sequentially.
 5. See Section 26.2.6, Flash Memory Characteristics, for the values of x, y, z, α, β, γ, ε, η, θ, and N.

Figure 23.13 Erase/Erase-Verify Flowchart (Single-Block Erase)

disabled or aborted. Hardware protection is reset by settings in flash memory control registers 1 and 2 (FLMCR1, FLMCR2) and erase block registers 1 and 2 (EBR1, EBR2). (See table 23.9.)

Table 23.8 Hardware Protection

Item	Description	Function Program
Reset/standby protection	<ul style="list-style-type: none"> <li data-bbox="530 225 1042 424">• In a reset (including a WDT overflow reset) and in hardware standby mode, software standby mode, subactive mode, subsleep mode, and watch mode, FLMCR1, FLMCR2, EBR1, and EBR2 are initialized, and the program/erase-protected state is entered. <li data-bbox="530 437 1042 635">• In a reset via the $\overline{\text{RES}}$ pin, the reset state is not entered unless the $\overline{\text{RES}}$ pin is held low until oscillation stabilizes after powering on. In the case of a reset during operation, hold the $\overline{\text{RES}}$ pin low for the $\overline{\text{RES}}$ pulse width specified in the AC Characteristics section. 	Yes

23.8.2 Software Protection

Software protection can be implemented by setting the SWE bit in FLMCR1 and erase block registers 1 and 2 (EBR1, EBR2). When software protection is in effect, setting the P bit in flash memory control register 1 (FLMCR1) does not cause a transition to program mode. (See table 23.9.)

protection

by settings in erase block registers 1 and 2 (EBR1, EBR2).

- Setting EBR1 and EBR2 to H'00 places all blocks in the erase-protected state.
-

23.8.3 Error Protection

In error protection, an error is detected when MCU runaway occurs during flash memory programming/erasing, or operation is not performed in accordance with the program/erase algorithm, and the program/erase operation is aborted. Aborting the program/erase operation prevents damage to the flash memory due to overprogramming or overerasing.

If the MCU malfunctions during flash memory programming/erasing, the FLER bit is set, FLMCR2 and the error protection state is entered. The FLMCR1, FLMCR2, EBR1, and EBR2 settings are retained, but program mode or erase mode is aborted at the point at which the error occurred. Program mode or erase mode cannot be re-entered by re-setting the P or E bit. The PV and EV bit setting is enabled, and a transition can be made to verify mode.

FLER bit setting conditions are as follows:

- When flash memory is read during programming/erasing (including a vector read or instruction fetch)
- Immediately after exception handling (excluding a reset) during programming/erasing
- When a SLEEP instruction (including software standby, sleep, subactive, subsleep and deep sleep mode) is executed during programming/erasing
- When the bus is released during programming/erasing

Error protection is released only by a reset and in hardware standby mode.

Figure 23.14 shows the flash memory state transition diagram.

2. In the interrupt exception handling sequence during programming or erasing, the vector address may not be read correctly*, possibly resulting in MCU runaway.
3. If interrupt occurred during boot program execution, it would not be possible to execute the normal boot mode sequence.

For these reasons, in on-board programming mode alone there are conditions for disabling the interrupt, as an exception to the general rule. However, this provision does not guarantee the interrupt is disabled during erasing and programming or MCU operation. All interrupt requests, including NMI interrupt requests, must therefore be disabled inside and outside the MCU when programming or erasing flash memory. Interrupt is also disabled in the error-protection state while the P or E bit remains set in the error-protection state.

- Notes:
1. Interrupt requests must be disabled inside and outside the MCU until the programming or erasing control program has completed programming.
 2. The vector may not be read correctly in this case for the following two reasons:
 - If flash memory is read while being programmed or erased (while the P or E bit is set in FLMCR1), correct read data will not be obtained (undetermined values may be returned).
 - If the interrupt entry in the vector table has not been programmed yet, in the event of an interrupt exception handling will not be executed correctly.

and section 23.11, Flash Memory Programming and Erasing Precautions, for notes on mode. Flash memory read mode, auto-program mode, auto-erase mode, and status read mode are supported with these device types. In auto-program mode, auto-erase mode, and status read mode, a status polling procedure is used, and in status read mode, detailed internal signals are provided during execution of an auto-program or auto-erase operation.

Table 23.10 shows programmer mode pin settings.

Note: * Use products of the H8S/2148 A-mask version, H8S/2147 A-mask version, H8S/2144 A-mask version (in either 5-V or 3-V version) with the writing voltage of the PROM programmer set to 3.3 V. Do not use products other than the A-mask version with 3.3V PROM programmer setting.

Table 23.10 Programmer Mode Pin Settings

Pin Names	Setting/External Circuit Connection
Mode pins: MD1, MD0	Low-level input to MD1, MD0
$\overline{\text{STBY}}$ pin	High-level input (Hardware standby mode not supported)
$\overline{\text{RES}}$ pin	Power-on reset circuit
XTAL and EXTAL pins	Oscillation circuit
Other setting pins: P97, P92, P91, P90, P67	Low-level input to p92, p67, high-level input to P91, P90

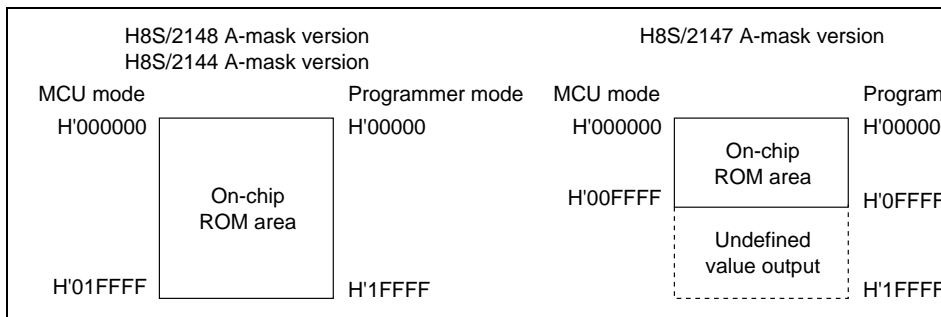


Figure 23.15 Memory Map in Programmer Mode

23.10.3 Programmer Mode Operation

Table 23.11 shows how the different operating modes are set when using programmer mode. Table 23.12 lists the commands used in programmer mode. Details of each mode are given in the following sections.

- **Memory Read Mode**
Memory read mode supports byte reads.
- **Auto-Program Mode**
Auto-program mode supports programming of 128 bytes at a time. Status polling is used to confirm the end of auto-programming.
- **Auto-Erase Mode**
Auto-erase mode supports automatic erasing of the entire flash memory. Status polling is used to confirm the end of auto-erasing.
- **Status Read Mode**
Status polling is used for auto-programming and auto-erasing, and normal termination is confirmed by reading the FO6 signal. In status read mode, error information is output if an error occurs.

- Notes: 1. Chip disable is not a standby state; internally, it is an operation state.
 2. Ain indicates that there is also address input in auto-program mode.

Table 23.12 Programmer Mode Commands

Command Name	Number of Cycles	1st Cycle		2nd Cycle		
		Mode	Address	Data	Mode	Address
Memory read mode	1 + n	Write	X	H'00	Read	RA
Auto-program mode	129	Write	X	H'40	Write	WA
Auto-erase mode	2	Write	X	H'20	Write	X
Status read mode	2	Write	X	H'71	Write	X

- Notes: 1. In auto-program mode, 129 cycles are required for command writing by a single 128-byte write.
 2. In memory read mode, the number of cycles depends on the number of address cycles (n).

23.10.4 Memory Read Mode

- After the end of an auto-program, auto-erase, or status read operation, the command is entered. To read memory contents, a transition must be made to memory read mode by means of a command write before the read is executed.
- Command writes can be performed in memory read mode, just as in the command write mode.
- Once memory read mode has been entered, consecutive reads can be performed.
- After power-on, memory read mode is entered.

Data hold time	t_{dh}	50	—	ns
Data setup time	t_{ds}	50	—	ns
Write pulse width	t_{wep}	70	—	ns
\overline{WE} rise time	t_r	—	30	ns
\overline{WE} fall time	t_f	—	30	ns

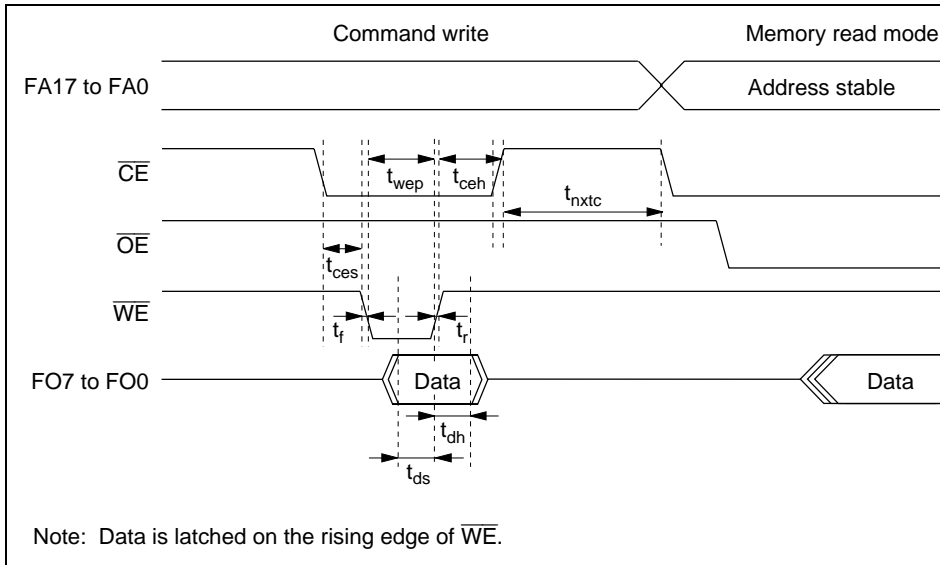


Figure 23.16 Memory Read Mode Timing Waveforms after Command W

Data hold time	t_{dh}	50	—	ns
Data setup time	t_{ds}	50	—	ns
Write pulse width	t_{wep}	70	—	ns
\overline{WE} rise time	t_r	—	30	ns
\overline{WE} fall time	t_f	—	30	ns

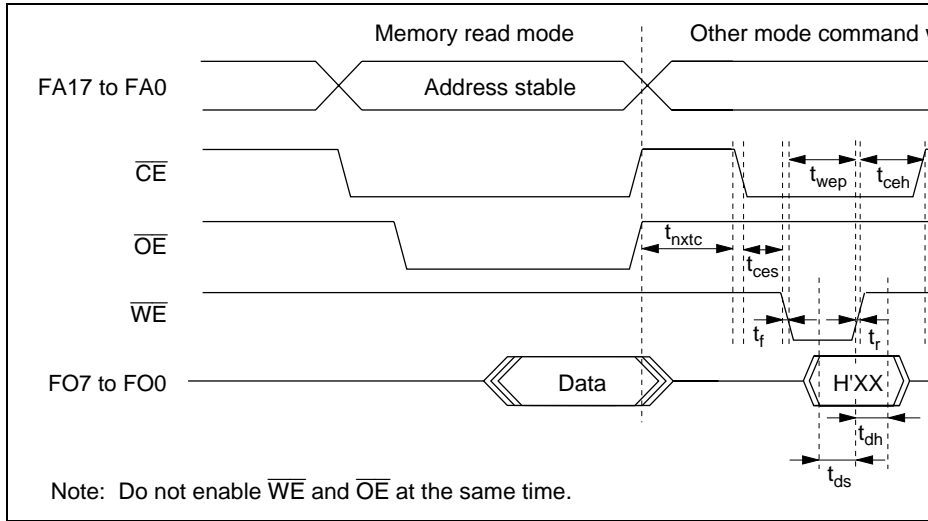


Figure 23.17 Timing Waveforms when Entering Another Mode from Memory

Output disable delay time	t_{df}	—	100	ns
Data output hold time	t_{oh}	5	—	ns

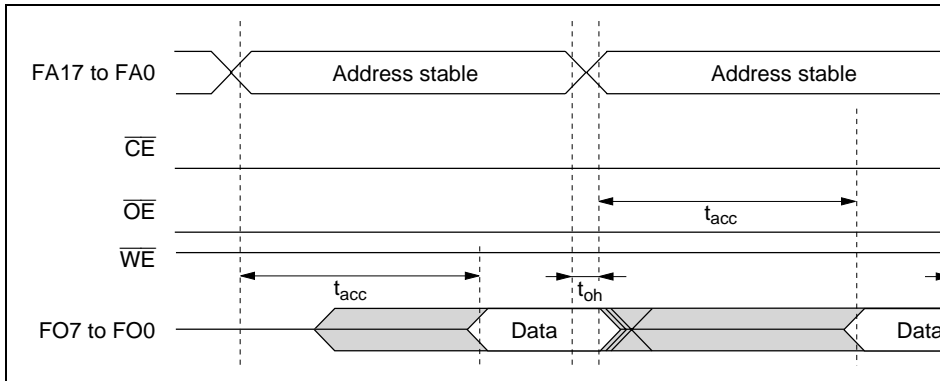


Figure 23.18 Timing Waveforms for $\overline{CE}/\overline{OE}$ Enable State Read

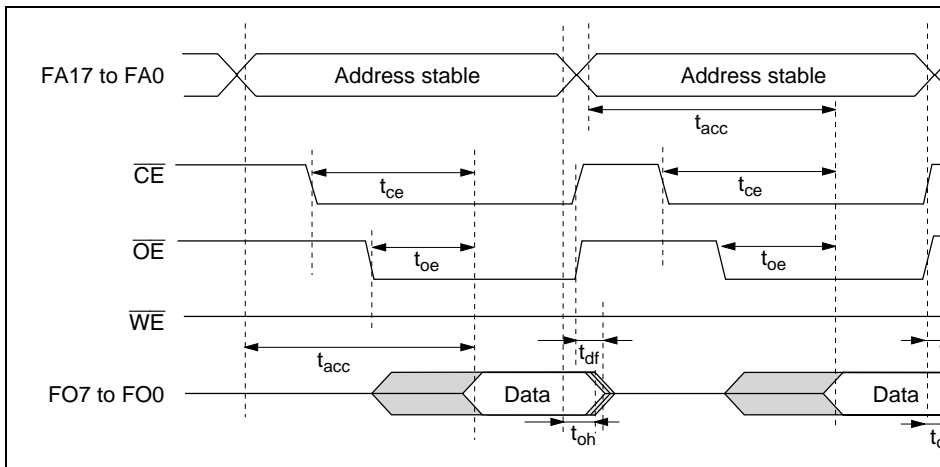


Figure 23.19 Timing Waveforms for $\overline{CE}/\overline{OE}$ Clocked Read

Command write cycle	t_{nxtc}	20	—	μs
$\overline{\text{CE}}$ hold time	t_{ceh}	0	—	ns
$\overline{\text{CE}}$ setup time	t_{ces}	0	—	ns
Data hold time	t_{dh}	50	—	ns
Data setup time	t_{ds}	50	—	ns
Write pulse width	t_{wep}	70	—	ns
Status polling start time	t_{wsts}	1	—	ms
Status polling access time	t_{spa}	—	150	ns
Address setup time	t_{as}	0	—	ns
Address hold time	t_{ah}	60	—	ns
Memory write time	t_{write}	1	3000	ms
$\overline{\text{WE}}$ rise time	t_{r}	—	30	ns
$\overline{\text{WE}}$ fall time	t_{f}	—	30	ns

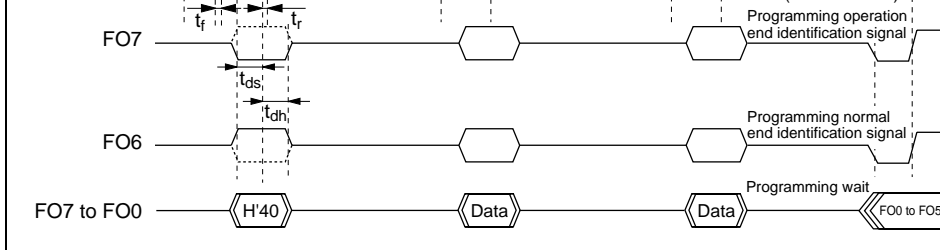


Figure 23.20 Auto-Program Mode Timing Waveforms

Notes on Use of Auto-Program Mode

- In auto-program mode, 128 bytes are programmed simultaneously. This should be done by executing 128 consecutive byte transfers.
- A 128-byte data transfer is necessary even when programming fewer than 128 bytes. In this case, H'FF data must be written to the extra addresses.
- The lower 8 bits of the transfer address must be H'00 or H'80. If a value other than a valid address is input, processing will switch to a memory write operation but a write error will be flagged.
- Memory address transfer is performed in the second cycle (figure 23.20). Do not perform another transfer after the second cycle.
- Do not perform a command write during a programming operation.
- Perform one auto-programming operation for a 128-byte block for each address. Characteristics are not guaranteed for two or more programming operations.
- Confirm normal end of auto-programming by checking FO6. Alternatively, status register FO7 can also be used for this purpose (FO7 status polling uses the auto-program operation end identification pin).
- The status polling FO6 and FO7 pin information is retained until the next command write. Until the next command write is performed, reading is possible by enabling \overline{CE} and

23.10.7 Status Read Mode

- Status read mode is used to identify what type of abnormal end has occurred. Use the return code when an abnormal end occurs in auto-program mode or auto-erase mode.
- The return code is retained until a command write for other than status read mode is performed.

Table 23.18 AC Characteristics in Status Read Mode

Conditions: $V_{CC} = 3.3 \text{ V} \pm 0.3 \text{ V}$, $V_{SS} = 0 \text{ V}$, $T_a = 25^\circ\text{C} \pm 5^\circ\text{C}$

Item	Symbol	Min	Max	Unit
Command write cycle	t_{nxtc}	20	—	μs
$\overline{\text{CE}}$ hold time	t_{ceh}	0	—	ns
$\overline{\text{CE}}$ setup time	t_{ces}	0	—	ns
Data hold time	t_{dh}	50	—	ns
Data setup time	t_{ds}	50	—	ns
Write pulse width	t_{wep}	70	—	ns
$\overline{\text{OE}}$ output delay time	t_{oe}	—	150	ns
Disable delay time	t_{df}	—	100	ns
$\overline{\text{CE}}$ output delay time	t_{ce}	—	150	ns
$\overline{\text{WE}}$ rise time	t_r	—	30	ns
$\overline{\text{WE}}$ fall time	t_f	—	30	ns

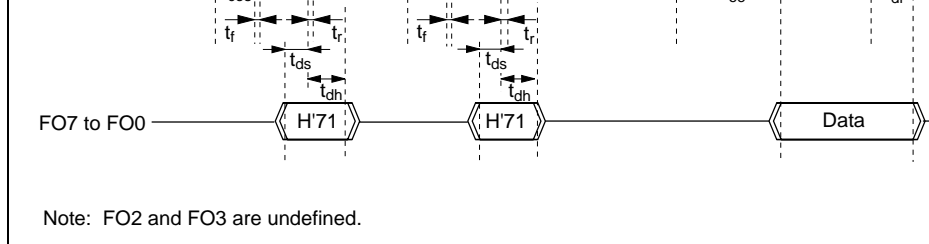


Figure 23.22 Status Read Mode Timing Waveforms

Table 23.19 Status Read Mode Return Commands

Pin Name	FO7	FO6	FO5	FO4	FO3	FO2	FO1
Attribute	Normal end identification	Command error	Programming error	Erase error	—	—	Programming or erase count exceeded
Initial value	0	0	0	0	0	0	0
Indications	Normal end: 0	Command error: 1	Programming error: 1	Erase error: 1	—	—	Count exceeded: 1
	Abnormal end: 1	Otherwise: 0	Otherwise: 0	Otherwise: 0	Otherwise: 0	Otherwise: 0	Otherwise: 0

Note: FO2 and FO3 are undefined.

23.10.8 Status Polling

- The FO7 status polling flag indicates the operating status in auto-program or auto-erase mode.
- The FO6 status polling flag indicates a normal or abnormal end in auto-program or auto-erase mode.

23.10.9 Programmer Mode Transition Time

Commands cannot be accepted during the oscillation stabilization period or the programmer mode setup period. After the programmer mode setup time, a transition is made to memory read mode. After the memory read mode, a transition is made to auto-program mode. After the auto-program mode, a transition is made to auto-erase mode. After the auto-erase mode, a transition is made to command wait state. After the command wait state, a transition is made to normal/abnormal end identification. After the normal/abnormal end identification, a transition is made to done state.

Table 23.21 Command Wait State Transition Time Specifications

Item	Symbol	Min	Max	Unit
Standby release (oscillation stabilization time)	t_{osc1}	20	—	ms
Programmer mode setup time	t_{bmv}	10	—	ms
V_{CC} hold time	t_{dwn}	0	—	ms

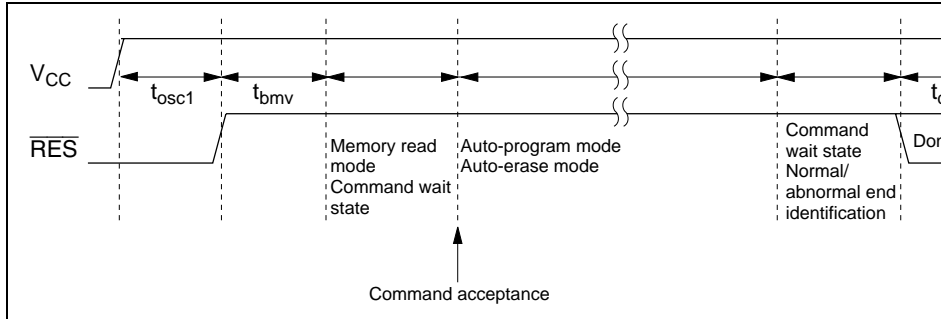


Figure 23.23 Oscillation Stabilization Time, Programmer Mode Setup Time, and Supply Fall Sequence

- Notes: 1. The flash memory is initially in the erased state when the device is shipped.
For other chips for which the erasure history is unknown, it is recommended that an erasing operation (erase) be executed to check and supplement the initialization (erase) level.
2. Auto-programming should be performed once only on the same address block.

23.11 Flash Memory Programming and Erasing Precautions

Precautions concerning the use of on-board programming mode and programmer mode are summarized below.

Use the specified voltages and timing for programming and erasing.

Applied voltages in excess of the rating can permanently damage the device. For a PROM programmer, use Renesas Technology microcomputer device types with 128-kbyte or more on-chip flash memory that support a 3.3-V programming voltage.

Do not select the HN28F101, or use a programming voltage of 5.0 V for the PROM programmer, and only use the specified socket adapter. Incorrect use will result in damaging the device.

Powering on and off

When applying or disconnecting V_{CC} , fix the \overline{RES} pin low and place the flash memory in hardware protection state.

The power-on and power-off timing requirements should also be satisfied in the event of a failure and subsequent recovery.

Use the recommended algorithm when programming and erasing flash memory.

The recommended algorithm enables programming and erasing to be carried out without subjecting the device to voltage stress or sacrificing program data reliability. When setting the E bit in FLMCR1, the watchdog timer should be set beforehand as a precaution against a runaway, etc.

interrupt requests, including PMU, should be disabled when programming and erase memory to give priority to program/erase operations.

Do not perform additional programming. Erase the memory before reprogramming.

In on-board programming, perform only one programming operation on a 128-byte programming unit block. In programmer mode, too, perform only one programming operation on a 128-byte programming unit block. Programming should be carried out with the entire programming unit block erased.

Before programming, check that the chip is correctly mounted in the PROM programming socket adapter, and chip are not correctly aligned.

Overcurrent damage to the device can result if the index marks on the PROM programming socket adapter, and chip are not correctly aligned.

Do not touch the socket adapter or chip during programming.

Touching either of these can cause contact faults and write errors.

23.12 Note on Switching from F-ZTAT Version to Mask ROM Version

The mask ROM version does not have the internal registers for flash memory control that are provided in the F-ZTAT version. Table 23.22 lists the registers that are present in the F-ZTAT version but not in the mask ROM version. If a register listed in table 23.22 is read in the mask ROM version, an undefined value will be returned. Therefore, if application software developed on the F-ZTAT version is switched to a mask ROM version product, it must be modified so that the registers in table 23.22 have no effect.

Table 23.22 Registers Present in F-ZTAT Version but Absent in Mask ROM Version

Register	Abbreviation	Address
Flash memory control register 1	FLMCR1	H'FF80
Flash memory control register 2	FLMCR2	H'FF81
Erase block register 1	EBR1	H'FF82
Erase block register 2	EBR2	H'FF83

The clock pulse generator consists of an oscillator circuit, a duty adjustment circuit, a clock selection circuit, medium-speed clock divider, bus master clock selection circuit, subclock input circuit, and waveform shaping circuit.

24.1.1 Block Diagram

Figure 24.1 shows a block diagram of the clock pulse generator.

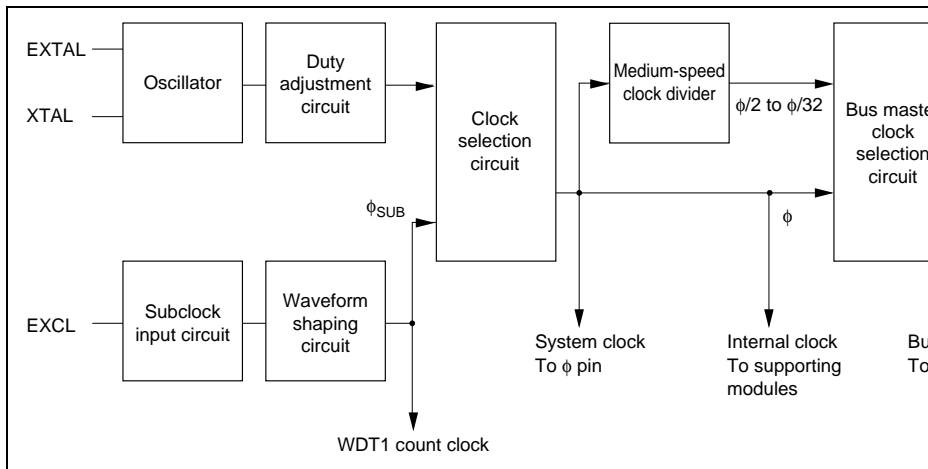


Figure 24.1 Block Diagram of Clock Pulse Generator

Note: * Lower 16 bits of the address.

24.2 Register Descriptions

24.2.1 Standby Control Register (SBYCR)

Bit	7	6	5	4	3	2	1
	SSBY	STS2	STS1	STS0	—	SCK2	SCK1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	—	R/W	R/W

SBYCR is an 8-bit readable/writable register that performs power-down mode control.

Only bits 0 to 2 are described here. For a description of the other bits, see section 25.2. Control Register (SBYCR).

SBYCR is initialized to H'00 by a reset and in hardware standby mode. It is not initialized in software standby mode.

Bits 2 to 0—System Clock Select 2 to 0 (SCK2 to SCK0): These bits select the bus mode for high-speed mode and medium-speed mode.

When operating the device after a transition to subactive mode or watch mode bits SCK2 to SCK0 should all be cleared to 0.

24.2.2 Low-Power Control Register (LPWRCR)

Bit	7	6	5	4	3	2	1
	DTON	LSON	NESEL	EXCLE	—	—	—
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	—	—	—

LPWRCR is an 8-bit readable/writable register that performs power-down mode control.

Only bit 4 is described here. For a description of the other bits, see section 25.2.2, Low-Power Control Register (LPWRCR).

LPWRCR is initialized to H'00 by a reset and in hardware standby mode. It is not initialized in software standby mode.

Bit 4—Subclock Input Enable (EXCLE): Controls subclock input from the EXCL pin.

Bit 4

EXCLE	Description
0	Subclock input from EXCL pin is disabled
1	Subclock input from EXCL pin is enabled

A crystal resonator can be connected as shown in the example in Figure 24.2. Select the resistance R_d according to table 24.2. An AT-cut parallel-resonance crystal should be used.

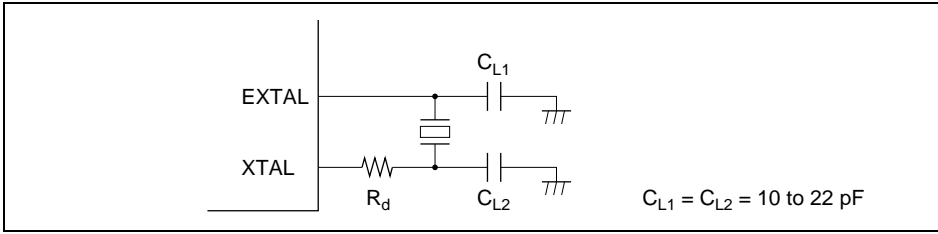


Figure 24.2 Connection of Crystal Resonator (Example)

Table 24.2 Damping Resistance Value

Frequency (MHz)	2	4	8	10	12	16
R_d (Ω)	1k	500	200	0	0	0

Crystal resonator

Figure 24.3 shows the equivalent circuit of the crystal resonator. Use a crystal resonator with the characteristics shown in table 24.3 and the same frequency as the system clock (ϕ).

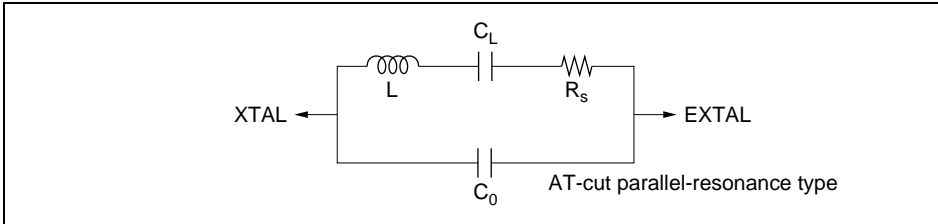


Figure 24.3 Crystal Resonator Equivalent Circuit

When a crystal resonator is connected, the following points should be noted.

Other signal lines should be routed away from the oscillator circuit to prevent inductive interfering with correct oscillation. See figure 24.4.

When designing the board, place the crystal resonator and its load capacitors as close to the XTAL and EXTAL pins.

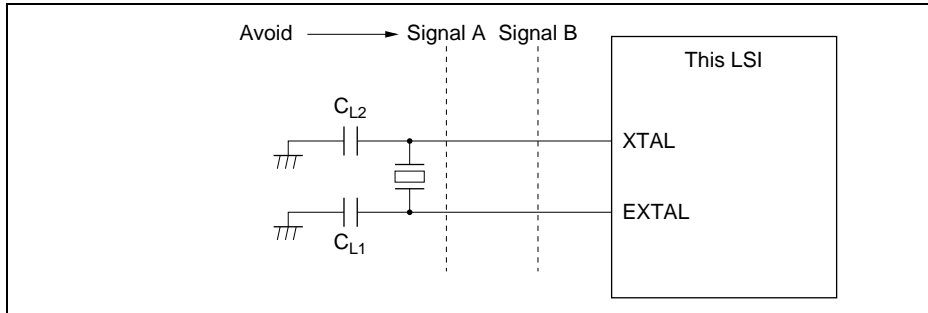
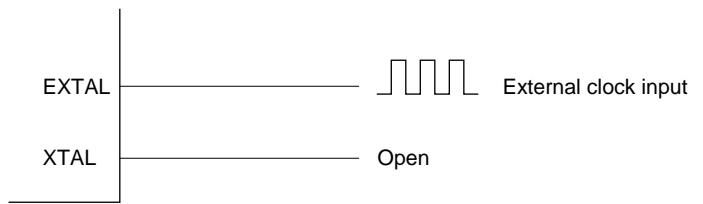
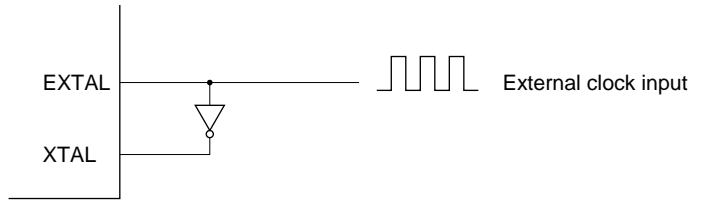


Figure 24.4 Example of Incorrect Board Design



(a) XTAL pin left open



(b) Complementary clock input at XTAL pin

Figure 24.5 External Clock Input (Examples)

Item	Symbol	Min	Max	Min	Max	Unit	Test Condition
External clock input low pulse width	t_{EXL}	40	—	20	—	ns	Figure 24.6
External clock input high pulse width	t_{EXH}	40	—	20	—	ns	
External clock rise time	t_{EXr}	—	10	—	5	ns	
External clock fall time	t_{EXf}	—	10	—	5	ns	
Clock low pulse width	t_{CL}	0.4	0.6	0.4	0.6	t_{cyc}	$\phi \geq 5$ MHz
		80	—	80	—	ns	$\phi < 5$ MHz
Clock high pulse width	t_{CH}	0.4	0.6	0.4	0.6	t_{cyc}	$\phi \geq 5$ MHz
		80	—	80	—	ns	$\phi < 5$ MHz

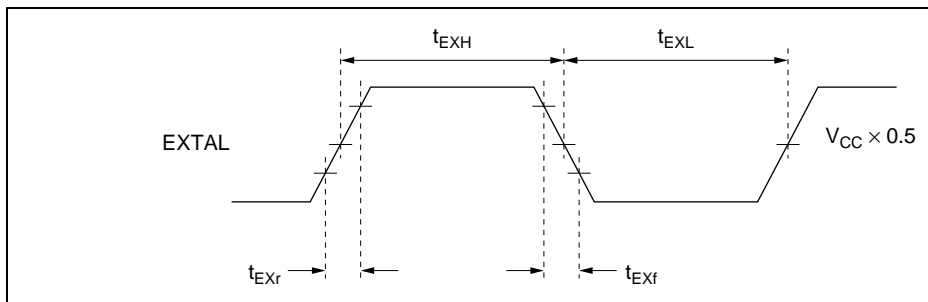


Figure 24.6 External Clock Input Timing

Table 24.5 shows the external clock output settling delay time, and figure 24.7 shows clock output settling delay timing. The oscillator and duty adjustment circuit have a function of adjusting the waveform of the external clock input at the EXTAL pin. When the prescaler signal is input at the EXTAL pin, internal clock signal output is fixed after the elapse of

output settling
delay time

Note: * t_{DEXT} includes $\overline{\text{RES}}$ pulse width (t_{RESW}).

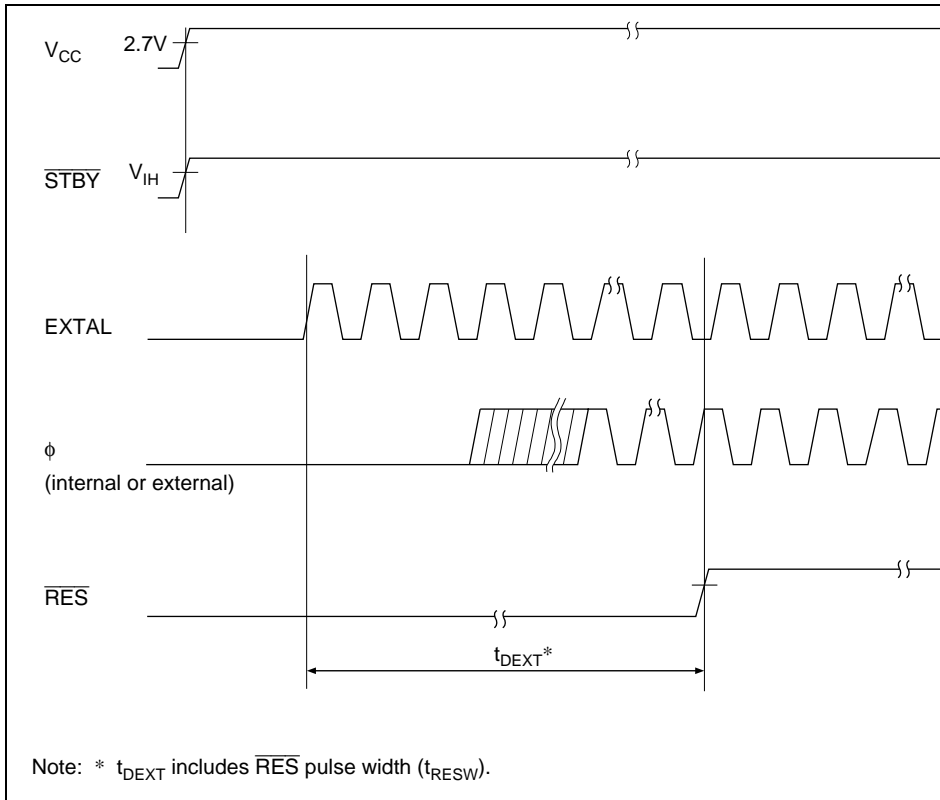


Figure 24.7 External Clock Output Settling Delay Timing

24.6 Bus Master Clock Selection Circuit

The bus master clock selection circuit selects the system clock (ϕ) or one of the medium clocks ($\phi/2$, $\phi/4$, $\phi/8$, $\phi/16$, or $\phi/32$) to be supplied to the bus master, according to the 5 bits SCK2 to SCK0 in SBYCR.

24.7 Subclock Input Circuit

The subclock input circuit controls the subclock input from the EXCL pin.

Inputting the Subclock

When a subclock is used, a 32.768 kHz external clock should be input from the EXCL pin. In this case, clear bit P96DDR to 0 in P9DDR and set bit EXCLE to 1 in LPWRCCR.

The subclock input conditions are shown in table 24.6 and figure 24.8.

Table 24.6 Subclock Input Conditions

Item	Symbol	$V_{CC} = 2.7 \text{ to } 5.5 \text{ V}$			Unit	Test Condition
		Min	Typ	Max		
Subclock input low pulse width	t_{EXCLL}	—	15.26	—	μs	Figure 24.8
Subclock input high pulse width	t_{EXCLH}	—	15.26	—	μs	
Subclock input rise time	t_{EXCLr}	—	—	10	ns	
Subclock input fall time	t_{EXCLf}	—	—	10	ns	

When Subclock Is Not Needed

Do not enable subclock input when the subclock is not needed

Note on Subclock Usage

In transiting to power-down mode, if at least two cycles of the 32-kHz clock are not input, the 32-kHz clock input is enabled (EXCLE = 1) until the SLEEP instruction is executed (power-down mode transition), the subclock input circuit is not initialized and an error may occur in the microcomputer.

Before power-down mode is entered with using the subclock, at least two cycle of the 32-kHz clock should be input after the 32-kHz clock input is enabled (EXCLE = 1).

As described in the hardware manual (clock pulse generator/subclock input circuit), when the subclock is not used, the subclock input should not be enabled (EXCLE = 0).

24.8 Subclock Waveform Shaping Circuit

To eliminate noise in the subclock input from the EXCL pin, this circuit samples the clock obtained by dividing the ϕ clock. The sampling frequency is set with the NESEL and LPWRCR. For details, see sections 24.2.2 and 25.2.2, Low-Power Control Register (LPWRCR). The clock is not sampled in subactive mode, subsleep mode, or watch mode.

is selected as the system clock. In these modes, modules such as CPU, TMR0, TMR1, WDT1, and I/O ports operate on the ϕ SUB clock. The count clock for each timer is obtained by driving the ϕ SUB clock.

so on.

This LSI has the following operating modes:

1. High-speed mode
2. Medium-speed mode
3. Subactive mode
4. Sleep mode
5. Subsleep mode
6. Watch mode
7. Module stop mode
8. Software standby mode
9. Hardware standby mode

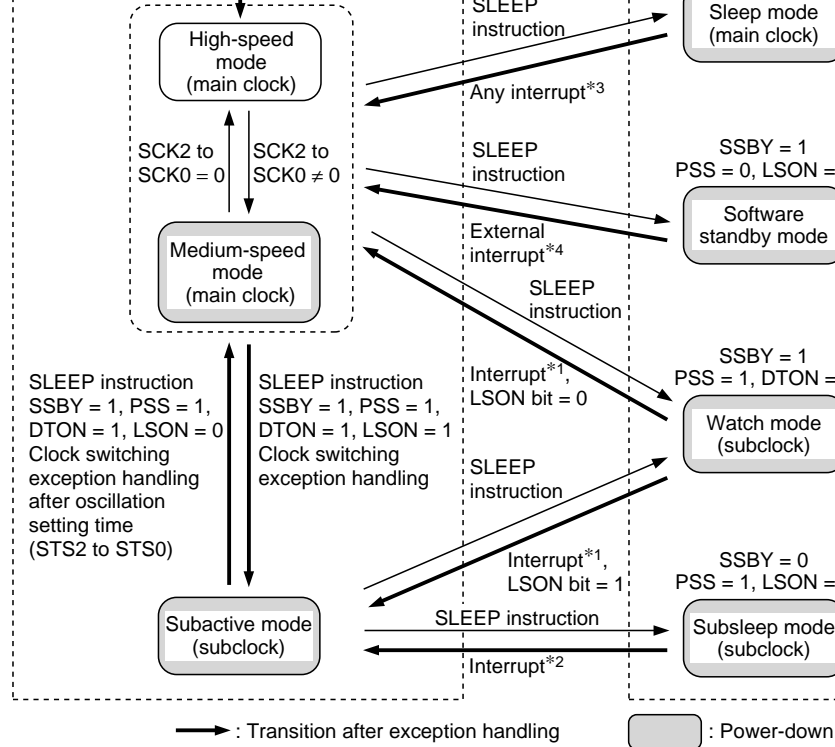
Of these, 2 to 9 are power-down modes. Sleep mode and subsleep mode are CPU modes. High-speed mode is a CPU and bus master mode, subactive mode is a CPU, bus master, and supporting module mode, and module stop mode is an on-chip supporting module mode (including bus masters other than the CPU). Certain combinations of these modes can

After a reset, the MCU is in high-speed mode and module stop mode (excluding the D

Table 25.1 shows the internal chip states in each mode, and table 25.2 shows the conditions for transition to the various modes. Figure 25.1 shows a mode transition diagram.

External interrupts	NMI	Functioning	Functioning	Functioning	Functioning	Functioning	Functioning	Functioning	Functioning	Functioning
	IRQ0									
	IRQ1									
	IRQ2									
On-chip supporting module operation	DTC	Functioning	Medium-speed	Functioning	Functioning/halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	
	WDT1	Functioning	Functioning	Functioning	Functioning	Subclock operation	Subclock operation	Subclock operation	Halted (retained)	
	WDT0	Functioning	Functioning	Functioning	Functioning	Halted (retained)	Subclock operation	Subclock operation	Halted (retained)	
	TMR0, 1	Functioning	Functioning	Functioning	Functioning/halted (retained)	Halted (retained)	Subclock operation	Subclock operation	Halted (retained)	
	FRT	Functioning	Functioning	Functioning	Functioning/halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	Halted (retained)	
	TMRX, Y									
	Timer connection									
	IIC0									
	IIC1									
	SCI0	Functioning	Functioning	Functioning	Functioning/halted (reset)	Halted (reset)	Halted (reset)	Halted (reset)	Halted (reset)	
	SCI1									
	SCI2									
	PWM									
	PWMX									
	HIF, PS2									
	D/A									
A/D										
RAM	Functioning	Functioning	Functioning (DTC)	Functioning	Retained	Functioning	Retained	Retained		
I/O	Functioning	Functioning	Functioning	Functioning	Retained	Functioning	Retained	Retained		

Notes: "Halted (retained)" means that internal register values are retained. The internal state is "operation suspended".
"Halted (reset)" means that internal register values and internal states are initialized.
In module stop mode, only modules for which a stop setting has been made are halted (reset or retained).



Notes: When a transition is made between modes by means of an interrupt, transition cannot be made on interrupt source generation alone. Ensure that interrupt handling is performed after a transition to the interrupt request.

From any state except hardware standby mode, a transition to the reset state occurs when $\overline{\text{RES}}$ goes low.

From any state, a transition to hardware standby mode occurs when $\overline{\text{STBY}}$ goes low.

When a transition is made to watch mode or subactive mode, high-speed mode must be selected.

1. NMI, IRQ0 to IRQ2, IRQ6, IRQ7, and WDT1 interrupts
2. NMI, IRQ0 to IRQ7, and WDT0 interrupts, WDT1 interrupt, TMR0 interrupt, TMR1 interrupt
3. All interrupts
4. NMI, IRQ0 to IRQ2, IRQ6, IRQ7

Figure 25.1 Mode Transitions

	1	0	0	*	Software standby	High-speed medium-speed
	1	0	1	*	—	—
	1	1	0	0	Watch	High-speed
	1	1	1	0	Watch	Subactive
	1	1	0	1	—	—
	1	1	1	1	Subactive	—
Subactive	0	0	*	*	—	—
	0	1	0	*	—	—
	0	1	1	*	Subsleep	Subactive
	1	0	*	*	—	—
	1	1	0	0	Watch	High-speed
	1	1	1	0	Watch	Subactive
	1	1	0	1	High-speed	—
	1	1	1	1	—	—

Legend:

*: Don't care

—: Do not set.

Low-power control register	LPWRCR	R/W	H'00	H
Timer control/status register (WDT1)	TCSR	R/W	H'00	H
Module stop control register	MSTPCRH	R/W	H'3F	H
	MSTPCRL	R/W	H'FF	H

- Notes: 1. Lower 16 bits of the address.
2. Some power down state registers are assigned to the same address as other registers. In this case, register selection is performed by the FLSHE bit in the serial timer register (STCR).

25.2 Register Descriptions

25.2.1 Standby Control Register (SBYCR)

Bit	7	6	5	4	3	2	1
	SSBY	STS2	STS1	STS0	—	SCK2	SCK1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	—	R/W	R/W

SBYCR is an 8-bit readable/writable register that performs power-down mode control.

SBYCR is initialized to H'00 by a reset and in hardware standby mode. It is not initialized in software standby mode.

1	Transition to subsleep mode after execution of SLEEP instruction in subactive mode Transition to watch mode or high-speed mode after execution of SLEEP instruction in subactive mode
---	--

Bits 6 to 4—Standby Timer Select 2 to 0 (STS2 to STS0): These bits select the time the device waits for the clock to stabilize when software standby mode, watch mode, or subactive mode is cleared and a transition is made to high-speed mode or medium-speed mode by means of a specific interrupt or instruction. With crystal oscillation, refer to table 25.4 and make a selection according to the operating frequency so that the standby time is at least 8 ms (the oscillation settling time). With an external clock, any selection can be made.

Bit 6	Bit 5	Bit 4	Description
STS2	STS1	STS0	
0	0	0	Standby time = 8192 states
		1	Standby time = 16384 states
	1	0	Standby time = 32768 states
		1	Standby time = 65536 states
1	0	0	Standby time = 131072 states
		1	Standby time = 262144 states
	1	0	Reserved
		1	Standby time = 16 states*

Note: * This setting must not be used in the flash memory version.

Bit 3—Reserved: This bit cannot be modified and is always read as 0.

	1	0	Medium-speed clock is $\phi/4$
		1	Medium-speed clock is $\phi/8$
1	0	0	Medium-speed clock is $\phi/16$
		1	Medium-speed clock is $\phi/32$
	1	—	—

25.2.2 Low-Power Control Register (LPWRCR)

Bit	7	6	5	4	3	2	1
	DTON	LSON	NESEL	EXCLE	—	—	—
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	—	—	—

LPWRCR is an 8-bit readable/writable register that performs power-down mode control.

LPWRCR is initialized to H'00 by a reset and in hardware standby mode. It is not initialized in software standby mode.

Bit 7—Direct-Transfer On Flag (DTON): Specifies whether a direct transition is made to high-speed mode, medium-speed mode, and subactive mode when making a power-down transition by executing a SLEEP instruction. The operating mode to which the transition occurs after SLEEP instruction execution is determined by a combination of other control bits.

or software standby mode

When a SLEEP instruction is executed in subactive mode, a transition is made to high-speed mode, or a transition is made to subsleep mode

Note: * When a transition is made to watch mode or subactive mode, high-speed mode must be set.

Bit 6—Low-Speed On Flag (LSON): Determines the operating mode in combination with other control bits when making a power-down transition by executing a SLEEP instruction. A transition is made to high-speed mode or to subactive mode when the flag is cleared.

Bit 6

LSON	Description
0	When a SLEEP instruction is executed in high-speed mode or medium-speed mode, a transition is made to sleep mode, software standby mode, or watch mode. When a SLEEP instruction is executed in subactive mode, a transition is made to watch mode, or directly to high-speed mode. After watch mode is cleared, a transition is made to high-speed mode.
1	When a SLEEP instruction is executed in high-speed mode a transition is made to watch mode or subactive mode*. When a SLEEP instruction is executed in subactive mode, a transition is made to subsleep mode or watch mode. After watch mode is cleared, a transition is made to subactive mode.

Note: * When a transition is made to watch mode or subactive mode, high-speed mode must be set.

Bit 5—Noise Elimination Sampling Frequency Select (NESEL): Selects the frequency of the subclock (ϕ SUB) input from the EXCL pin is sampled with the clock (ϕ) generated by the system clock oscillator. When $\phi = 5$ MHz or higher, clear this bit to 0.

EXCLE	Description
0	Subclock input from EXCL pin is disabled
1	Subclock input from EXCL pin is enabled

Bits 3 to 0—Reserved: These bits cannot be modified and are always read as 0.

25.2.3 Timer Control/Status Register (TCSR)

TCSR1

Bit	7	6	5	4	3	2	1
	OVF	WT/IT	TME	PSS	RST/NMI	CKS2	CKS1
Initial value	0	0	0	0	0	0	0
Read/Write	R/(W)*	R/W	R/W	R/W	R/W	R/W	R/W

Note: * Only 0 can be written in bit 7, to clear the flag.

TCSR1 is an 8-bit readable/writable register that performs selection of the WDT1 TCNT clock, mode, etc.

Only bit 4 is described here. For details of the other bits, see section 14.2.2, Timer Control Register (TCSR).

TCSR is initialized to H'00 by a reset and in hardware standby mode. It is not initialized in software standby mode.

Bit 4—Prescaler Select (PSS): Selects the WDT1 TCNT input clock.

This bit also controls the operation in a power-down mode transition. The operating mode which a transition is made after execution of a SLEEP instruction is determined in combination with other control bits.

- 1 TCNT counts ϕ SUB-based prescaler (PSM) divided clock pulses
- When a SLEEP instruction is executed in high-speed mode or medium-speed mode, a transition is made to sleep mode, watch mode*, or subactive mode*
- When a SLEEP instruction is executed in subactive mode, a transition is made to subsleep mode, watch mode, or high-speed mode

Note: * When a transition is made to watch mode or subactive mode, high-speed mode must be set.

25.2.4 Module Stop Control Register (MSTPCR)

Bit	MSTPCRH								MSTPCRL					
	7	6	5	4	3	2	1	0	7	6	5	4	3	2
	MSTP15	MSTP14	MSTP13	MSTP12	MSTP11	MSTP10	MSTP9	MSTP8	MSTP7	MSTP6	MSTP5	MSTP4	MSTP3	MSTP2
Initial value	0	0	1	1	1	1	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

MSTPCR comprises two 8-bit readable/writable registers that perform module stop mode selection.

MSTPCR is initialized to H'3FFF by a reset and in hardware standby mode. It is not initialized in software standby mode.

MSTPCRH and MSTPCRL Bits 7 to 0—Module Stop (MSTP 15 to MSTP 0): The bits specify module stop mode. See table 25.4 for the method of selecting on-chip supporting modules.

MSTPCRH, MSTPCRL Bits 7 to 0

MSTP15 to MSTP0	Description	
0	Module stop mode is cleared	(Initial value of MSTP15, MSTP14, MSTP13, MSTP12, MSTP11, MSTP10, MSTP9, MSTP8, MSTP7, MSTP6, MSTP5, MSTP4, MSTP3, MSTP2)
1	Module stop mode is set	(Initial value of MSTP15, MSTP14, MSTP13, MSTP12, MSTP11, MSTP10, MSTP9, MSTP8, MSTP7, MSTP6, MSTP5, MSTP4, MSTP3, MSTP2)

the bus master operating clock. For example, if $\phi/4$ is selected as the operating clock, memory is accessed in 4 states, and internal I/O registers in 8 states.

Medium-speed mode is cleared by clearing all of bits SCK2 to SCK0 to 0. A transition from high-speed mode and medium-speed mode is cleared at the end of the current bus cycle.

If a SLEEP instruction is executed when the SSBY bit in SBYCR and the LSON bit in LONCR are cleared to 0, a transition is made to sleep mode. When sleep mode is cleared by an interrupt, medium-speed mode is restored.

If a SLEEP instruction is executed when the SSBY bit in SBYCR is set to 1, and the LONCR bit in LPWRCR and the PSS bit in TCSR (WDT1) are both cleared to 0, a transition is made to software standby mode. When software standby mode is cleared by an external interrupt, medium-speed mode is restored.

When the $\overline{\text{RES}}$ pin is driven low, a transition is made to the reset state, and medium-speed mode is cleared. The same applies in the case of a reset caused by overflow of the watchdog timer.

When the $\overline{\text{STBY}}$ pin is driven low, a transition is made to hardware standby mode.

Figure 25.2 shows the timing for transition to and clearance of medium-speed mode.

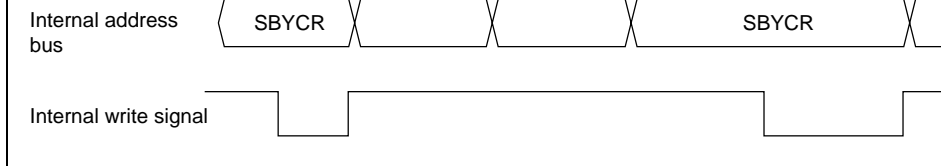


Figure 25.2 Medium-Speed Mode Transition and Clearance Timing

25.4 Sleep Mode

25.4.1 Sleep Mode

If a SLEEP instruction is executed when the SSBY bit in SBYCR and the LSON bit in SBYCR are both cleared to 0, the CPU enters sleep mode. In sleep mode, CPU operation stops but the contents of the CPU's internal registers are retained. Other supporting modules do not stop.

25.4.2 Clearing Sleep Mode

Sleep mode is cleared by any interrupt, or with the $\overline{\text{RES}}$ pin or $\overline{\text{STBY}}$ pin.

Clearing with an Interrupt: When an interrupt request signal is input, sleep mode is cleared and interrupt exception handling is started. Sleep mode will not be cleared if interrupts are masked. Sleep mode is cleared if interrupts other than NMI have been masked by the CPU.

Clearing with the $\overline{\text{RES}}$ Pin: When the $\overline{\text{RES}}$ pin is driven low, the reset state is entered. After the $\overline{\text{RES}}$ pin is driven high after the prescribed reset input period, the CPU begins reset exception handling.

Clearing with the $\overline{\text{STBY}}$ Pin: When the $\overline{\text{STBY}}$ pin is driven low, a transition is made to standby mode.

independently.

Table 25.4 shows MSTP bits and the corresponding on-chip supporting modules.

When the corresponding MSTP bit is cleared to 0, module stop mode is cleared and the module starts operating again at the end of the bus cycle. In module stop mode, the internal state of modules other than the SCI, A/D converter, 8-bit PWM module, and 14-bit PWM module is retained.

After reset release, all modules other than the DTC are in module stop mode.

When an on-chip supporting module is in module stop mode, read/write access to its registers is disabled.

	MSTP10	D/A converter
	MSTP9	A/D converter
	MSTP8	8-bit timers (TMRX, TMRY), timer connection
MSTPCRL	MSTP7	Serial communication interface 0 (SCI0)
	MSTP6	Serial communication interface 1 (SCI1)
	MSTP5	Serial communication interface 2 (SCI2)
	MSTP4*	I ² C bus interface (IIC) channel 0 (option)
	MSTP3*	I ² C bus interface (IIC) channel 1 (option)
	MSTP2	Host interface (HIF), keyboard matrix interrupt mask register (KMIMRA), port 6 MOS pull-up control register (KMPCR), keyboard buffer controller (PS2)
	MSTP1*	—
	MSTP0*	—

Notes: Do not set bit 15 to 1. Bits 1 and 0 can be read or written to, but do not affect operation.

* Must be set to 1 in the H8S/2144 Group and H8S/2147N.

25.5.2 Usage Note

If there is conflict between DTC module stop mode setting and a DTC bus request, the DTC bus request has priority and the MSTP bit will not be set to 1.

Write 1 to the MSTP bit again after the DTC bus cycle.

When using the H8S/2144 Group and H8S/2147N, the MSTP bits for nonexistent modules must be set to 1.

In this mode the oscillator stops, and therefore power dissipation is significantly redu

25.6.2 Clearing Software Standby Mode

Software standby mode is cleared by an external interrupt (NMI pin, or pin $\overline{\text{IRQ0}}$, $\overline{\text{IRQ6}}$, or $\overline{\text{IRQ7}}$), or by means of the $\overline{\text{RES}}$ pin or $\overline{\text{STBY}}$ pin.

Clearing with an Interrupt: When an NMI, IRQ0, IRQ1, IRQ2, IRQ6, or IRQ7 inter signal is input, clock oscillation starts, and after the elapse of the time set in bits STS2 SYSCR, stable clocks are supplied to the entire chip, software standby mode is cleared interrupt exception handling is started.

Software standby mode cannot be cleared with an IRQ0, IRQ1, IRQ2, IRQ6, or IRQ7 the corresponding enable bit has been cleared to 0 or has been masked by the CPU.

Clearing with the $\overline{\text{RES}}$ Pin: When the $\overline{\text{RES}}$ pin is driven low, clock oscillation is star same time as clock oscillation starts, clocks are supplied to the entire chip. Note that t must be held low until clock oscillation stabilizes. When the $\overline{\text{RES}}$ pin goes high, the C reset exception handling.

Clearing with the $\overline{\text{STBY}}$ Pin: When the $\overline{\text{STBY}}$ pin is driven low, a transition is made standby mode.

25.6.3 Setting Oscillation Settling Time after Clearing Software Standby Mod

Bits STS2 to STS0 in SBYCR should be set as described below.

STS2	STS1	STS0	Standby Time	20 MHz	10 MHz	12 MHz	10 MHz	8 MHz	6 MHz	4 MHz
0	0	0	8192 states	0.41	0.51	0.65	0.8	1.0	1.3	2.0
		1	16384 states	0.82	1.0	1.3	1.6	2.0	2.7	4.1
	1	0	32768 states	1.6	2.0	2.7	3.3	4.1	5.5	8.2
		1	65536 states	3.3	4.1	5.5	6.6	8.2	10.9	16.4
1	0	0	131072 states	6.6	8.2	10.9	13.1	16.4	21.8	32.8
		1	262144 states	13.1	16.4	21.8	26.2	32.8	43.6	65.6
	1	0	Reserved	—	—	—	—	—	—	—
		1	16 states*	0.8	1.0	1.3	1.6	2.0	2.7	4.0

: Recommended time setting

Note: * This setting must not be used in the flash memory version.

Using an External Clock

Any value can be set. Normally, use of the minimum time is recommended.

25.6.4 Software Standby Mode Application Example

Figure 25.3 shows an example in which a transition is made to software standby mode on the falling edge on the NMI pin, and software standby mode is cleared at the rising edge on the NMI pin.

In this example, an NMI interrupt is accepted with the NMIEG bit in SYSCR cleared to 0 (falling edge specification), then the NMIEG bit is set to 1 (rising edge specification), the SSBV bit in SYSCR is set to 1, and a SLEEP instruction is executed, causing a transition to software standby mode.

Software standby mode is then cleared at the rising edge on the NMI pin.

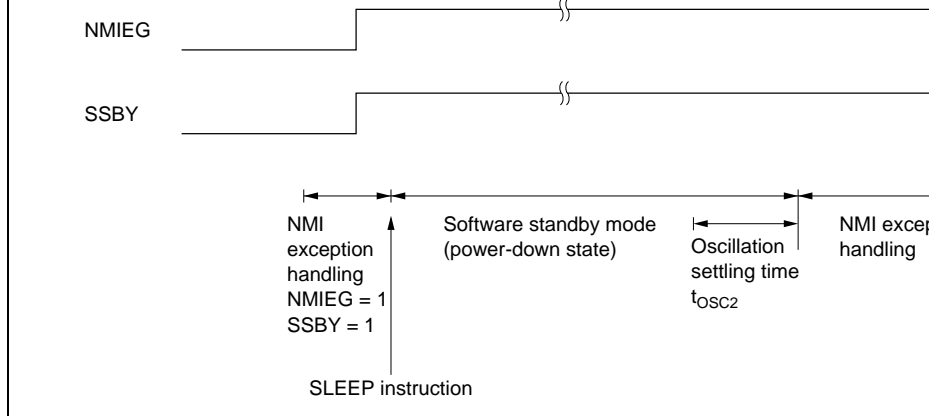


Figure 25.3 Software Standby Mode Application Example

25.6.5 Usage Note

In software standby mode, I/O port states are retained. Therefore, there is no reduction in power dissipation for the output current when a high-level signal is output.

Current dissipation increases while waiting for oscillation to settle.

25.7 Hardware Standby Mode

25.7.1 Hardware Standby Mode

When the \overline{STBY} pin is driven low, a transition is made to hardware standby mode from the active state.

In hardware standby mode, all functions enter the reset state and stop operation, resulting in a significant reduction in power dissipation. As long as the prescribed voltage is supplied, RAM data is retained. I/O ports are set to the high-impedance state.

settling time—when using a crystal oscillator). When the $\overline{\text{RES}}$ pin is subsequently driven low, a transition is made to the program execution state via the reset exception handling state.

25.7.2 Hardware Standby Mode Timing

Figure 25.4 shows an example of hardware standby mode timing.

When the $\overline{\text{STBY}}$ pin is driven low after the $\overline{\text{RES}}$ pin has been driven low, a transition is made to hardware standby mode. Hardware standby mode is cleared by driving the $\overline{\text{STBY}}$ pin high for the oscillation settling time, then changing the $\overline{\text{RES}}$ pin from low to high.

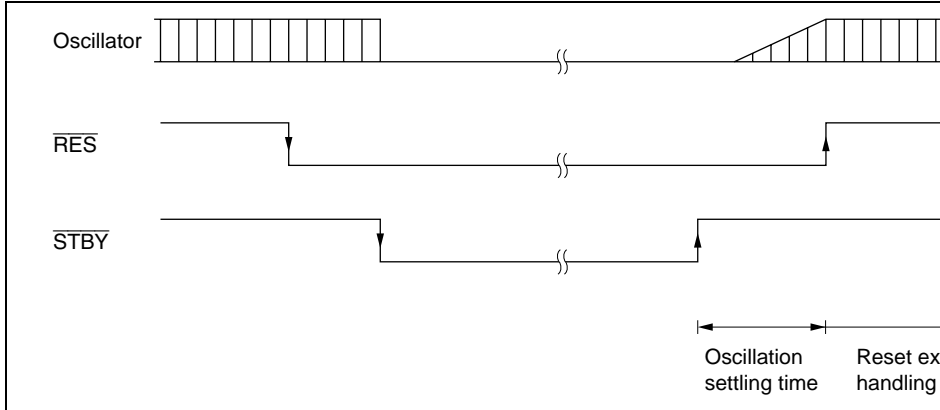


Figure 25.4 Hardware Standby Mode Timing

In this mode, the CPU and all on-chip supporting modules except WDT1 stop. As long as the prescribed voltage is supplied, the contents of some of the CPU's internal registers and RAM are retained, and I/O ports retain their states prior to the transition.

25.8.2 Clearing Watch Mode

Watch mode is cleared by an interrupt ($\overline{\text{WOVI1}}$ interrupt, NMI pin, or pin $\overline{\text{IRQ0}}$, $\overline{\text{IRQ1}}$, $\overline{\text{IRQ2}}$, $\overline{\text{IRQ6}}$, or $\overline{\text{IRQ7}}$), or by means of the $\overline{\text{RES}}$ pin or $\overline{\text{STBY}}$ pin.

Clearing with an Interrupt: When an interrupt request signal is input, watch mode is cleared. A transition is made to high-speed mode or medium-speed mode if the LSON bit in LBSR is cleared to 0, or to subactive mode if the LSON bit is set to 1. When making a transition to high-speed mode, after the elapse of the time set in bits STS2 to STS0 in SBYCR, stable clock is supplied to the entire chip, and interrupt exception handling is started.

Watch mode cannot be cleared with an $\overline{\text{IRQ0}}$, $\overline{\text{IRQ1}}$, $\overline{\text{IRQ2}}$, $\overline{\text{IRQ6}}$, or $\overline{\text{IRQ7}}$ interrupt if the corresponding enable bit has been cleared to 0, or with an on-chip supporting module if the acceptance of the relevant interrupt has been disabled by the interrupt enable register of the CPU.

See section 25.6.3, Setting Oscillation Settling Time after Clearing Software Standby Mode, for the oscillation settling time setting when making a transition from watch mode to high-speed mode.

Clearing with the $\overline{\text{RES}}$ Pin: See “Clearing with the $\overline{\text{RES}}$ Pin” in section 25.6.2, Clearing Software Standby Mode.

Clearing with the $\overline{\text{STBY}}$ Pin: When the $\overline{\text{STBY}}$ pin is driven low, a transition is made from watch mode to standby mode.

In this mode, the CPU and all on-chip supporting modules except TMR0, TMR1, WDT0, and WDT1 stop. As long as the prescribed voltage is supplied, the contents of some of the internal registers and on-chip RAM are retained, and I/O ports retain their states prior to transition.

25.9.2 Clearing Subsleep Mode

Subsleep mode is cleared by an interrupt (on-chip supporting module interrupt, NMI pin, or $\overline{\text{IRQ0}}$ to $\overline{\text{IRQ7}}$), or by means of the $\overline{\text{RES}}$ pin or $\overline{\text{STBY}}$ pin.

Clearing with an Interrupt: When an interrupt request signal is input, subsleep mode is cleared and interrupt exception handling is started. Subsleep mode cannot be cleared with an $\overline{\text{IRQ7}}$ interrupt if the corresponding enable bit has been cleared to 0, or with an on-chip supporting module interrupt if acceptance of the relevant interrupt has been disabled by the interrupt enable register or masked by the CPU.

Clearing with the $\overline{\text{RES}}$ Pin: See “Clearing with the $\overline{\text{RES}}$ Pin” in section 25.6.2, Clearing Standby Mode.

Clearing with the $\overline{\text{STBY}}$ Pin: When the $\overline{\text{STBY}}$ pin is driven low, a transition is made from subsleep mode to standby mode.

a transition is made to subactive mode.

In subactive mode, the CPU performs sequential program execution at low speed on the CPU core. In this mode, all on-chip supporting modules except TMR0, TMR1, WDT0, and WDT1 are disabled.

When operating the device in subactive mode, bits SCK2 to SCK0 in SBYCR must all be cleared to 0.

25.10.2 Clearing Subactive Mode

Subsleep mode is cleared by a SLEEP instruction, or by means of the $\overline{\text{RES}}$ pin or $\overline{\text{STBY}}$ pin.

Clearing with a SLEEP Instruction: When a SLEEP instruction is executed while the DTON bit in SBYCR is set to 1, the DTON bit in LPWRCR is cleared to 0, and the PSS bit in TCSR (WDT1) is set to 1, subactive mode is cleared and a transition is made to watch mode. When a SLEEP instruction is executed while the SSBY bit in SBYCR is cleared to 0, the LSON bit in LPWRCR is set to 1, and the PSS bit in TCSR (WDT1) is set to 1, a transition is made to watch mode. When a SLEEP instruction is executed while the SSBY bit in SBYCR is set to 1, the DTON bit is set to 1 and the LSON bit is cleared to 0 in LPWRCR, and the PSS bit in TCSR (WDT1) is set to 1, a transition is made directly to high-speed mode.

For details of direct transition, see section 25.11, Direct Transition.

Clearing with the $\overline{\text{RES}}$ Pin: See “Clearing with the $\overline{\text{RES}}$ Pin” in section 25.6.2, Clearing Standby Mode.

Clearing with the $\overline{\text{STBY}}$ Pin: When the $\overline{\text{STBY}}$ pin is driven low, a transition is made from subactive mode to standby mode.

direct transition interrupt exception handling is started.

Direct Transition from High-Speed Mode to Subactive Mode: If a SLEEP instruction is executed in high-speed mode while the SSBY bit in SBYCR, the LSON bit and DTON bit in LPWRCR, and the PSS bit in TSCR (WDT1) are all set to 1, a transition is made to subactive mode.

Direct Transition from Subactive Mode to High-Speed Mode: If a SLEEP instruction is executed in subactive mode while the SSBY bit in SBYCR is set to 1, the LSON bit is set to 1 and the DTON bit is set to 1 in LPWRCR, and the PSS bit in TSCR (WDT1) is set to 1, after the elapse of the time set in bits STS2 to STS0 in SBYCR, a transition is made to directly to high-speed mode.

25.12 Usage Notes

1. When making a transition to subactive mode or watch mode, set the DTC to enter module stop mode (write 1 to the relevant bits in MSTPCR), and then read the relevant bits to confirm they are set to 1 before mode transition. Do not clear module stop mode (write 0 to the relevant bits in MSTPCR) until a transition from subactive mode to high-speed mode or medium-speed mode has been performed.

If a DTC activation source occurs in sub-active mode, the DTC will be activated once module stop mode has been cleared and high-speed mode or medium-speed mode has been entered.

2. The on-chip peripheral modules (DTC and TPU) which halt operation in subactive mode cannot clear an interrupt in subactive mode. Therefore, if a transition is made to subactive mode while an interrupt is requested, the CPU interrupt source cannot be cleared. Disable interrupts of each on-chip peripheral module before executing a SLEEP instruction to enter subactive mode or watch mode.

Product/ Power supply	5-V version	Product/ Power supply	3-V version
HD64F2148 HD64F2144 HD64F2142R		HD64F2148V HD64F2144V HD64F2142RV	
VCC1 pin	$V_{cc} = 5.0\text{ V} \pm 10\%$ (fop = 2 to 20 MHz)	VCC1 pin	$V_{cc} = 3.0\text{ V to } 5.5\text{ V}$ (fop = 2 to 20 MHz)
VCC2 pin	$V_{cc} = 4.0\text{ V to } 5.5\text{ V}$ (fop = 2 to 16 MHz)	VCC2 pin	
VCCB pin*	$V_{ccB} = 5.0\text{ V} \pm 10\%$ (fop = 2 to 20 MHz) $V_{ccB} = 4.0\text{ V to } 5.5\text{ V}$ (fop = 2 to 16 MHz)	VCCB pin*	$V_{ccB} = 3.0\text{ V to } 5.5\text{ V}$ (fop = 2 to 20 MHz)
AVCC pin	$AV_{cc} = 5.0\text{ V} \pm 10\%$ (fop = 2 to 20 MHz) $AV_{cc} = 4.0\text{ V to } 5.5\text{ V}$ (fop = 2 to 16 MHz)	AVCC pin	$AV_{cc} = 3.0\text{ V to } 5.5\text{ V}$ (fop = 2 to 20 MHz)

Note: * Available only in the H8S/2148 Group.



VCC1 pin VCC2 pin	$V_{cc} = 5.0\text{ V} \pm 10\%$ (fop = 2 to 20 MHz)	VCC1 pin VCC2 pin	$V_{cc} = 3.0\text{ V to } 5.5\text{ V}$ (fop = 2 to 10 MHz)
VCCB pin	$V_{ccB} = 5.0\text{ V} \pm 10\%$ (fop = 2 to 20 MHz)	VCCB pin	$V_{ccB} = 3.0\text{ V to } 5.5\text{ V}$ (fop = 2 to 10 MHz)
AVCC pin	$AV_{cc} = 5.0\text{ V} \pm 10\%$ (fop = 2 to 20 MHz)	AVCC pin	$AV_{cc} = 3.0\text{ V to } 5.5\text{ V}$ (fop = 2 to 10 MHz)

Table 26.1 Power Supply Voltage and Operating Range (3) (F-ZTAT A-Mask)

Product/ Power supply	5-V version	Product/ Power supply	3-V version
HD64F2148A HD64F2147A HD64F2144A		HD64F2148AV HD64F2147AV HD64F2144AV	
VCC1 pin	$V_{cc} = 5.0\text{ V} \pm 10\%$ (fop = 2 to 20 MHz) $V_{cc} = 4.0\text{ V to } 5.5\text{ V}$ (fop = 2 to 16 MHz)	VCC1 pin	$V_{cc} = 2.7\text{ V to } 3.6\text{ V}$ (fop = 2 to 10 MHz) (CIN in use $V_{cc} = 3.0\text{ V to } 3.6\text{ V}$)
VCL pin (VCC2)	$V_{cl} = \text{C connect}$	VCL pin (VCC2)	$V_{cl} = V_{cc} \text{ connect}$
VCCB pin*	$V_{ccB} = 5.0\text{ V} \pm 10\%$ (fop = 2 to 20 MHz) $V_{ccB} = 4.0\text{ V to } 5.5\text{ V}$ (fop = 2 to 16 MHz)	VCCB pin*	$V_{ccB} = 2.7\text{ V to } 5.5\text{ V}$ (fop = 2 to 10 MHz) (CIN in use $V_{ccB} = 3.0\text{ V to } 5.5\text{ V}$)
AVCC pin	$AV_{cc} = 5.0\text{ V} \pm 10\%$ (fop = 2 to 20 MHz) $AV_{cc} = 4.0\text{ V to } 5.5\text{ V}$ (fop = 2 to 16 MHz)	AVCC pin	$AV_{cc} = 2.7\text{ V to } 3.6\text{ V}$ (fop = 2 to 10 MHz) (CIN in use $AV_{cc} = 3.0\text{ V to } 3.6\text{ V}$)

Note: * Available only in the H8S/2148 Group.

HD6432142			
VCC1 pin	$V_{cc} = 5.0\text{ V} \pm 10\%$	$V_{cc} = 4.0\text{ V to } 5.5\text{ V}$	$V_{cc} = 2.7\text{ V to } 3.6\text{ V}$ (CIN in use $V_{cc} =$
VCL pin (VCC2)	$V_{cl} = \text{C connect}$	$V_{cl} = \text{C connect}$	$V_{cl} = V_{cc} \text{ connect}$
VCCB pin*	$V_{ccB} = 5.0\text{ V} \pm 10\%$	$V_{ccB} = 4.0\text{ V to } 5.5\text{ V}$	$V_{ccB} = 2.7\text{ V to } 5.5\text{ V}$ (CIN in use $V_{ccB} =$
AVCC pin	$AV_{cc} = 5.0\text{ V} \pm 10\%$	$AV_{cc} = 4.0\text{ V to } 5.5\text{ V}$	$AV_{cc} = 2.7\text{ V to } 3.6\text{ V}$ (CIN in use $AV_{cc} =$

Note: * Available only in the H8S/2148 Group.

Table 26.1 Power Supply Voltage and Operating Range (5) (Mask RO)

Product/ Power supply	5-V version	4-V version	3-V version
HD6432142			
VCC1 pin VCC2 pin	$V_{cc} = 5.0\text{ V} \pm 10\%$	$V_{cc} = 4.0\text{ V to } 5.5\text{ V}$	$V_{cc} = 2.7\text{ V to } 5.5\text{ V}$
AVCC pin	$AV_{cc} = 5.0\text{ V} \pm 10\%$	$AV_{cc} = 4.0\text{ V to } 5.5\text{ V}$	$AV_{cc} = 2.7\text{ V to } 5.5\text{ V}$

Item	Symbol	Value
Power supply voltage*	V_{CC}	-0.3 to +7.0
Input/output buffer power supply (power supply for the port A)	V_{CCB}	-0.3 to +7.0
Input voltage (except ports 6, 7, and A)	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 $V_{CCB} + 0.3$
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 $V_{CCB} + 0.3$ and $AV_{CC} + 0.3$
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 input voltage	V_{AN}	-0.3 to $AV_{CC} + 0.3$
Operating temperature	T_{opr}	Regular specifications: -20 to +75 Wide-range specifications: -40 to +85
Operating temperature (flash memory programming/erasing)	T_{opr}	Regular specifications: 0 to +75 Wide-range specifications: 0 to +85
Storage temperature	T_{stg}	-55 to +125

Caution: Permanent damage to the chip may result if absolute maximum ratings are exceeded.

Note: * Power supply voltage for VCC1 and VCC2 pins.

Item		Symbol	Min	Typ	Max	Unit	
Schmitt trigger input voltage	P67 to P60(KWUL = 00) ^{*2 *6} , KIN15 to KIN8 ^{*7 *8} , IRQ2 to IRQ0 ^{*3} , IRQ5 to 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	RES, STBY, NMI, MD1, MD0 EXTAL PA7 to PA0 ^{*7} Port 7 Input pins except (1) and (2) above	(2) V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V
				$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	
				$V_{CC}B \times 0.7$	—	$V_{CC}B + 0.3$	
			2.0	—	$AV_{CC} + 0.3$		
			2.0	—	$V_{CC} + 0.3$		

Output high voltage	All output pins (except P97, and P52 ^{*4} , ^{*5} ^{*8})	V_{OH}	$V_{CC} - 0.5$	—	—	V	I_{OH}	
			$V_{CC}B - 0.5$					
			3.5	—	—	V	I_{OH}	
	P97, P52 ^{*4}		2.5	—	—	V	I_{OH}	
Output low voltage	All output pins (except \overline{RESO}) ^{*5}	V_{OL}	—	—	0.4	V	I_{OL}	
			Ports 1 to 3	—	—	1.0	V	I_{OL}
			\overline{RESO}	—	—	0.4	V	I_{OL}
Input leakage current	\overline{RES}	$ I_{in} $	—	—	10.0	μA	V_{IL} V_{IH}	
	\overline{STBY} , NMI, MD1, MD0		—	—	1.0	μA		
	Port 7		—	—	1.0	μA	V_{IL} A	
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A ^{*8} , B	$ I_{TSL} $	—	—	1.0	μA	V_{IL} V_{IH} V_{OL} V_{OH}	
Input pull-up MOS current	Ports 1 to 3	$-I_P$	50	—	300	μA	V_{IH}	
	Ports A ^{*8} , B, Port 6 (P6PUE = 0)		60	—	500	μA		
	Port 6 (P6PUE = 1)		15	—	150	μA		

		(4) above				
Current dissipation ^{*9}	Normal operation	I_{CC}	—	85	120	mA
	Sleep mode		—	70	100	mA
	Standby mode ^{*10}		—	0.01	5.0	μ A
				—	—	20.0
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA
	Idle		—	0.01	5.0	μ A
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	mA
	Idle		—	0.01	5.0	μ A
Analog power supply voltage ^{*11}		AV_{CC}	4.5	—	5.5	V
			2.0	—	5.5	V
RAM standby voltage		V_{RAM}	2.0	—	—	V

Notes: 1. **Do not leave the AVCC, AV_{ref}, and AVSS pins open even if the A/D converter and D/A converter are not used.**

Even if the A/D converter and D/A converter are not used, apply a value in the range of 2.0 V to 5.5 V to AVCC and AV_{ref} pins by connection to the power supply (V_{CC}) or other method. Ensure that AV_{ref} ≤ AV_{CC}.

- P67 to P60 include supporting module inputs multiplexed on those pins.
- $\overline{IRQ2}$ includes the \overline{ADTRG} signal multiplexed on that pin.
- In the H8S/2148 Group, P52/SCK0/SCL0 and P97/SDA0 are NMOS push-pull outputs. An external pull-up resistor is necessary to provide high-level output from SDA0 (ICE = 1).
In the H8S/2148 Group, P52/SCK0 and P97 (ICE = 0) high levels are driven by the internal pull-up resistor.
- When IICS = 0, ICE = 0, and KBIOE = 0. Low-level output when the bus driver is selected is determined separately.

10. The values are for $V_{\text{RAM}} \leq V_{\text{CC}} < 4.5\text{V}$, $V_{\text{IH min}} = V_{\text{CC}} \times 0.9$, $V_{\text{CCB}} \times 0.9$, and $V_{\text{IL}} = 0.3\text{ V}$.

11. For flash memory program/erase operations, the applicable range is $T_{\text{a}} = 0$ to $+85^{\circ}\text{C}$ (regular specifications) or $T_{\text{a}} = 0$ to $+85^{\circ}\text{C}$ (wide-range specifications).

trigger input voltage	P60(KWUL = 00) ^{*2 *6} , KIN15 to KIN8 ^{*7 *8} , IRQ2 to IRQ0 ^{*3} , IRQ5 to IRQ3	V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	0.4	—	—	V	
		V_T^-	0.8	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.7$ $V_{CC} B \times 0.7$	V	
		$V_T^+ - V_T^-$	0.3	—	—	V	
		V_T^-	$V_{CC} \times 0.3$	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—	V	
		V_T^-	$V_{CC} \times 0.4$	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.8$	V	
Schmitt trigger input voltage (in level switching) ^{*6}	P67 to P60 (KWUL = 01)	$V_T^+ - V_T^-$	$V_{CC} \times 0.03$	—	—	V	
		V_T^-	$V_{CC} \times 0.45$	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.9$	V	
	P67 to P60 (KWUL = 10)	$V_T^+ - V_T^-$	0.05	—	—	V	
		V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V	
		EXTAL	$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
		PA7 to PA0 ^{*7}	$V_{CC} B \times 0.7$	—	$V_{CC} B + 0.3$	V	
	Input high voltage	RES, STBY, NMI, MD1, MD0	Port 7	2.0	—	$AV_{CC} + 0.3$	V
			Input pins except (1) and (2) above	2.0	—	$V_{CC} + 0.3$	V

		Input pins except (1) and (3) above						
Output high voltage	All output pins (except P97, and P52 ^{*4})*5 *8	V_{OH}	$V_{CC} - 0.5$	—	—	V	I_{OH}	
			$V_{CC}B - 0.5$	—	—	V	I_{OH}	
			3.5	—	—	V	V_{CC}	
			3.0	—	—	V	V_{CC}	
	P97, P52 ^{*4}		2.0	—	—	V	V_{CC}	
Output low voltage	All output pins (except \overline{RESO})*5	V_{OL}	—	—	0.4	V	I_{OL}	
			Ports 1 to 3	—	—	1.0	V	I_{OL}
			\overline{RESO}	—	—	0.4	V	I_{OL}
Input leakage current	\overline{RES}	$ I_{in} $	—	—	10.0	μA	V_{in}	
	\overline{STBY} , NMI, MD1, MD0		—	—	1.0	μA	V_{in}	
	Port 7		—	—	1.0	μA	V_{in}	
Three-state leakage current (off state)	Ports 1 to 6 Ports 8, 9, A ^{*8} , B	$ I_{TSL} $	—	—	1.0	μA	V_{in}	

	Ports 1 to 3		30	—	200	μA
	Ports A ^{*8} , B Port 6 (P6PUE = 0)		40	—	400	μA
	Port 6 (P6PUE = 1)		10	—	110	
Input capacitance	$\overline{\text{RES}}$ (4)	C_{in}	—	—	80	pF
	NMI		—	—	50	pF
	P52, P97, P42, P86, PA7 to PA2		—	—	20	pF
	Input pins except (4) above		—	—	15	pF
Current dissipation ^{*9}	Normal operation	I_{CC}	—	70	100	mA
	Sleep mode		—	60	85	mA
	Standby mode ^{*10}		—	0.01	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
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	mA
	Idle		—	0.01	5.0	μA
Analog power supply voltage ^{*11}		AV_{CC}	4.0	—	5.5	V
			2.0	—	5.5	V
RAM standby voltage		V_{RAM}	2.0	—	—	V

SDA0 (ICE = 1).

In the H8S/2148 Group, P52/SCK0 and P97 (ICE = 0) high levels are driven

5. When IICS = 0, ICE = 0, and KBIOE = 0. Low-level output when the bus driver 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 selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
7. The upper limit of the port A applied voltage is $V_{CCB} + 0.3$ V when CIN input is selected, and the lower of $V_{CCB} + 0.3$ V and $AV_{CC} + 0.3$ V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
8. The port A characteristics depend on V_{CCB} , and the other pins characteristics depend on V_{CC} .
9. Current dissipation values are for V_{IH} min = $V_{CC} - 0.5$ V, $V_{CCB} - 0.5$ V, and V_{IL} min = $V_{CC} - 0.5$ V with all output pins unloaded and the on-chip pull-up MOSs in the off state.
10. The values are for $V_{RAM} \leq V_{CC} < 4.0$ V, V_{IH} min = $V_{CC} \times 0.9$, $V_{CCB} \times 0.9$, and V_{IL} min = $V_{CC} - 0.3$ V.
11. For flash memory program/erase operations, the applicable ranges are $V_{CC} = 5.5$ V and $T_a = 0$ to $+75^\circ\text{C}$ (regular specifications) or $T_a = 0$ to $+85^\circ\text{C}$ (wide-range specifications).

voltage	00), KIN15 to KIN8 ^{*7 *8} , IRQ2 to IRQ0 ^{*3} , IRQ5 to IRQ3		V_T^+	—	—	$V_{CC} \times 0.7$	V
			$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	$V_{CC}B \times 0.7$	V
Schmitt trigger input voltage (in level swiching) ^{*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	RES, STBY, NMI, MD1, MD0	(2)	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V
	EXTAL			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V
	PA7 to PA0 ^{*7}			$V_{CC}B \times 0.7$	—	$V_{CC}B + 0.3$	V
	Port 7			$V_{CC} \times 0.7$	—	$AV_{CC} + 0.3$	V
	Input pins except (1) and (2) above			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V

	Input pins except (1) and (3) above		0.8	V	V _{CC}		
Output high voltage	All output pins (except P97, and P52 ^{*4})*5 *8	V _{OH}	V _{CC} - 0.5	—	—	V	I _{CC} (V)
			V _{CC} B - 0.5	—	—	V	I _{CC} (V)
	P97, P52 ^{*4}	1.0	—	—	V	I _{CC} (V)	
Output low voltage	All output pins (except $\overline{\text{RESO}}$)*5	V _{OL}	—	—	0.4	V	I _{CC} (V)
			Ports 1 to 3	—	—	1.0	V
	$\overline{\text{RESO}}$	—	—	0.4	V	I _{CC} (V)	
Input leakage current	$\overline{\text{RES}}$	I _{in}	—	—	10.0	μA	V _{CC}
	$\overline{\text{STBY}}$, NMI, MD1, MD0		—	—	1.0	μA	V _{CC}
	Port 7		—	—	1.0	μA	V _{CC}
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A ^{*8} , B	I _{TSL}	—	—	1.0	μA	V _{CC}

Input capacitance	RES (4)	C_{in}	—	—	80	pF
	NMI		—	—	50	pF
	P52, P97, P42, P86, PA7 to PA2		—	—	20	pF
	Input pins except (4) above		—	—	15	pF
Current dissipation ^{*9}	Normal operation	I_{CC}	—	50	70	mA
	Sleep mode		—	40	60	mA
	Standby mode ^{*10}		—	0.01	5.0	μ A
			—	—	20.0	μ A
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA
	Idle		—	0.01	5.0	μ A
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	mA
	Idle		—	0.01	5.0	μ A
Analog power supply voltage ^{*1}		AV_{CC}	3.0	—	5.5	V
			2.0	—	5.5	V
RAM standby voltage		V_{RAM}	2.0	—	—	V

Notes: 1. **Do not leave the AVCC, AV_{ref}, and AVSS pins open even if the A/D converter and D/A converter are not used.**

Even if the A/D converter and D/A converter are not used, apply a value in the range of 2.0 V to 5.5 V to AVCC and AV_{ref} pins by connection to the power supply (V_{DD}) by other method. Ensure that AV_{ref} ≤ AV_{CC}.

- P67 to P60 include supporting module inputs multiplexed on those pins.
- IRQ2 includes the ADTRG signal multiplexed on that pin.

7. The upper limit of the port A applied voltage is $V_{CC}B + 0.3$ V when CIN input is selected, and the lower of $V_{CC}B + 0.3$ V and $AV_{CC} + 0.3$ V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
8. The port A characteristics depend on $V_{CC}B$, and the other pins characteristics depend on V_{CC} .
9. Current dissipation values are for V_{IH} min = $V_{CC} - 0.5$ V, $V_{CC}B - 0.5$ V, and V_{IL} min = $V_{CC} - 0.5$ V with all output pins unloaded and the on-chip pull-up MOSs in the off state.
10. The values are for $V_{RAM} \leq V_{CC} < 3.0$ V, V_{IH} min = $V_{CC} \times 0.9$, $V_{CC}B \times 0.9$, and V_{IL} min = $V_{CC} - 0.3$ V.
11. For flash memory program/erase operations, the applicable ranges are $V_{CC} = 3.6$ V and $T_a = 0$ to $+75^{\circ}\text{C}$.

	PA7 to PA4 (bus drive function selected)				
	Ports 1, 2, 3		—	—	10
	$\overline{\text{RESO}}$		—	—	3
	Other output pins		—	—	2
Permissible output low current (total)	Total of ports 1, 2, and 3	ΣI_{OL}	—	—	80
	Total of all output pins, including the above		—	—	120
Permissible output high current (per pin)	All output pins	$-I_{\text{OH}}$	—	—	2
Permissible output high current (total)	Total of all output pins	$\Sigma -I_{\text{OH}}$	—	—	40

	RESO		—	—	1
	Other output pins		—	—	1
Permissible output low current (total)	Total of ports 1, 2, and 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 26.1.
 2. When driving a Darlington pair or LED, always insert a current-limiting resistor on the output line, as shown in figures 26.1 and 26.2.



Figure 26.1 Darlington Pair Drive Circuit (Example)

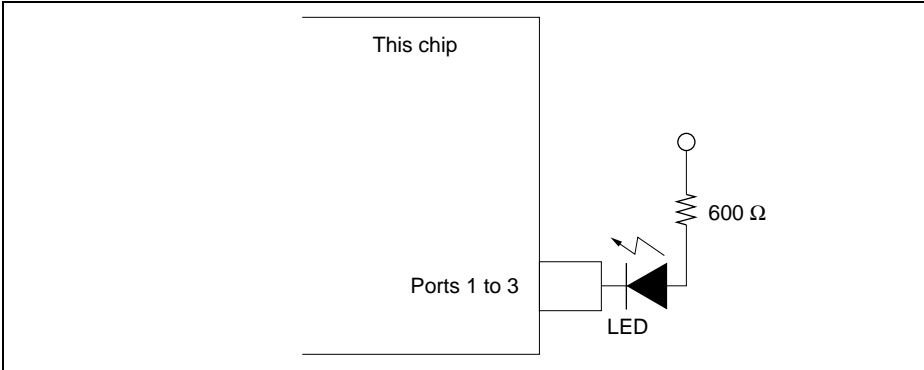


Figure 26.2 LED Drive Circuit (Example)

	$V_T - V_T$	$V_{CC} \times 0.05$	—	—		$V_{CC} = 3.0$ V		
Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	$V_{CC} + 0.5$	V	$V_{CC} = 3.0$ V		
Input low voltage	V_{IL}	-0.5	—	$V_{CC} \times 0.3$		$V_{CC} = 3.0$ V		
Output low voltage	V_{OL}	—	—	0.8	V	$I_{OL} = 16$ mA $V_{CC} = 4.5$ V		
				—	—	0.5		$I_{OL} = 8$ mA
				—	—	0.4		$I_{OL} = 3$ mA
Input capacitance	C_{in}	—	—	20	pF	$V_{in} = 0$ V, $f =$ $T_a = 25^\circ$ C		
Three-state leakage current (off state)	$ I_{TSI} $	—	—	1.0	μ A	$V_{in} = 0.5$ to		
SCL, SDA output fall time	t_{of}	$20 + 0.1 C_b$	—	250	ns	$V_{CC} = 3.0$ V		

Conditions: $V_{CC} = 3.0$ V to 5.5 V, $V_{CCB} = 3.0$ V to 5.5 V, $V_{SS} = 0$ V

Applicable Pins: PS2AC, PS2AD, PS2BC, PS2BD, PS2CC, PS2CD, PA7 to PA4 (bus function selected)

Item	Symbol	Min	Typ	Max	Unit	Test Conditions		
Output low voltage	V_{OL}	—	—	0.8	V	$I_{OL} = 16$ mA, $V_{CCB} = 4.5$ V to		
				—	—	0.5		$I_{OL} = 8$ mA
				—	—	0.4		$I_{OL} = 3$ mA

26.2.3 AC Characteristics

Clock timing, control signal timing, bus timing, and timing of on-chip supporting modules are described in the following.

Figure 26.4 shows the test conditions for the AC characteristics.

Condition A: $V_{CC} = 5.0\text{ V} \pm 10\%$, $V_{CCB} = 5.0\text{ V} \pm 10\%$, $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0\text{ V}$ to 5.5 V , $V_{CCB} = 4.0\text{ V}$ to 5.5 V , $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 3.0\text{ V}$ to 5.5 V , $V_{CCB} = 3.0\text{ V}$ to 5.5 V , $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit
		20 MHz		16 MHz		10 MHz		
		Min	Max	Min	Max	Min	Max	
Clock cycle time	t_{cyc}	50	500	62.5	500	100	500	ns
Clock high pulse width	t_{CH}	17	—	20	—	30	—	ns
Clock low pulse width	t_{CL}	17	—	20	—	30	—	ns
Clock rise time	t_{Cr}	—	8	—	10	—	20	ns
Clock fall time	t_{Cf}	—	8	—	10	—	20	ns
Oscillation settling time at reset (crystal)	t_{OSC1}	10	—	10	—	20	—	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

$T_a = -40$ to $+85^{\circ}\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0$ V to 5.5 V, $V_{CCB} = 4.0$ V to 5.5 V, $V_{SS} = 0$ V, $\phi = 32.768$ kHz, maximum operating frequency, $T_a = -20$ to $+75^{\circ}\text{C}$ (regular specification)
 $T_a = -40$ to $+85^{\circ}\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 3.0$ V to 5.5 V, $V_{CCB} = 3.0$ V to 5.5 V, $V_{SS} = 0$ V, $\phi = 32.768$ kHz, maximum operating frequency, $T_a = -20$ to $+75^{\circ}\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	T _a
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
RES setup time	t_{RESS}	200	—	200	—	300	—	ns	Fi
RES pulse width	t_{RESW}	20	—	20	—	20	—	t_{cyc}	
NMI setup time (NMI)	t_{NMIS}	150	—	150	—	250	—	ns	Fi
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 (IRQ7 to IRQ0)	t_{IRQS}	150	—	150	—	250	—	ns	
IRQ hold time (IRQ7 to IRQ0)	t_{IRQH}	10	—	10	—	10	—	ns	
IRQ pulse width (IRQ7, IRQ6, IRQ2 to IRQ0) (exiting software standby mode)	t_{IRQW}	200	—	200	—	200	—	ns	

$T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0$ V to 5.5 V, $V_{CCB} = 4.0$ V to 5.5 V, $V_{SS} = 0$ V, $\phi = 2$ MHz to ∞ MHz
operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 3.0$ V to 5.5 V, $V_{CCB} = 3.0$ V to 5.5 V, $V_{SS} = 0$ V, $\phi = 2$ MHz to ∞ MHz
operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit
		20 MHz		16 MHz		10 MHz		
		Min	Max	Min	Max	Min	Max	
Address delay time	t_{AD}	—	20	—	30	—	40	ns
Address setup time	t_{AS}	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 20$	—	$0.5 \times t_{cyc} - 30$	—	ns
Address hold time	t_{AH}	$0.5 \times t_{cyc} - 10$	—	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 20$	—	ns
\overline{CS} delay time (IOS)	t_{CSD}	—	20	—	30	—	40	ns
\overline{AS} delay time	t_{ASD}	—	30	—	45	—	60	ns
\overline{RD} delay time 1	t_{RSD1}	—	30	—	45	—	60	ns
\overline{RD} delay time 2	t_{RSD2}	—	30	—	45	—	60	ns
Read data setup time	t_{RDS}	15	—	20	—	35	—	ns
Read data hold time	t_{RDH}	0	—	0	—	0	—	ns

time 2								
Read data access time 3	t_{ACC3}	—	$2.0 \times$ $t_{cyc} -30$	—	$2.0 \times$ $t_{cyc} -40$	—	$2.0 \times$ $t_{cyc} -60$	ns
Read data access time 4	t_{ACC4}	—	$2.5 \times$ $t_{cyc} -25$	—	$2.5 \times$ $t_{cyc} -35$	—	$2.5 \times$ $t_{cyc} -50$	ns
Read data access time 5	t_{ACC5}	—	$3.0 \times$ $t_{cyc} -30$	—	$3.0 \times$ $t_{cyc} -40$	—	$3.0 \times$ $t_{cyc} -60$	ns
\overline{WR} delay time 1	t_{WRD1}	—	30	—	45	—	60	ns
\overline{WR} delay time 2	t_{WRD2}	—	30	—	45	—	60	ns
\overline{WR} pulse width 1	t_{WSW1}	$1.0 \times$ $t_{cyc} -20$	—	$1.0 \times$ $t_{cyc} -30$	—	$1.0 \times$ $t_{cyc} -40$	—	ns
\overline{WR} pulse width 2	t_{WSW2}	$1.5 \times$ $t_{cyc} -20$	—	$1.5 \times$ $t_{cyc} -30$	—	$1.5 \times$ $t_{cyc} -40$	—	ns
Write data delay time	t_{WDD}	—	30	—	45	—	60	ns
Write data setup time	t_{WDS}	0	—	0	—	0	—	ns
Write data hold time	t_{WDH}	10	—	15	—	20	—	ns
\overline{WAIT} setup time	t_{WTS}	30	—	45	—	60	—	ns
\overline{WAIT} hold time	t_{WTH}	5	—	5	—	10	—	ns

Condition C: $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $V_{CCB} = 3.0\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz to }10\text{ MHz}$ to
operating frequency, $T_a = -20\text{ to }+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit
		20 MHz		16 MHz		10 MHz		
		Min	Max	Min	Max	Min	Max	
Address delay time	t_{AD}	—	30	—	45	—	60	ns
Address setup time	t_{AS}	$0.5 \times t_{cyc} - 25$	—	$0.5 \times t_{cyc} - 35$	—	$0.5 \times t_{cyc} - 50$	—	ns
Address hold time	t_{AH}	$0.5 \times t_{cyc} - 10$	—	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 20$	—	ns
\overline{CS} delay time (\overline{IOS})	t_{CSD}	—	30	—	45	—	60	ns
\overline{AS} delay time	t_{ASD}	—	30	—	45	—	60	ns
\overline{RD} delay time 1	t_{RSD1}	—	30	—	45	—	60	ns
\overline{RD} delay time 2	t_{RSD2}	—	30	—	45	—	60	ns
Read data setup time	t_{RDS}	15	—	20	—	35	—	ns
Read data hold time	t_{RDH}	0	—	0	—	0	—	ns
Read data access time 1	t_{ACC1}	—	$1.0 \times t_{cyc} - 40$	—	$1.0 \times t_{cyc} - 55$	—	$1.0 \times t_{cyc} - 80$	ns
Read data access time 2	t_{ACC2}	—	$1.5 \times t_{cyc} - 25$	—	$1.5 \times t_{cyc} - 35$	—	$1.5 \times t_{cyc} - 50$	ns

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time 4								
Read data access time 5	t_{ACC5}	—	$3.0 \times t_{cyc} - 40$	—	$3.0 \times t_{cyc} - 55$	—	$3.0 \times t_{cyc} - 80$	ns
\overline{WR} delay time 1	t_{WRD1}	—	30	—	45	—	60	ns
\overline{WR} delay time 2	t_{WRD2}	—	30	—	45	—	60	ns
\overline{WR} pulse width 1	t_{WSW1}	$1.0 \times t_{cyc} - 20$	—	$1.0 \times t_{cyc} - 30$	—	$1.0 \times t_{cyc} - 40$	—	ns
\overline{WR} pulse width 2	t_{WSW2}	$1.5 \times t_{cyc} - 20$	—	$1.5 \times t_{cyc} - 30$	—	$1.5 \times t_{cyc} - 40$	—	ns
Write data delay time	t_{WDD}	—	30	—	45	—	60	ns
Write data setup time	t_{WDS}	0	—	0	—	0	—	ns
Write data hold time	t_{WDH}	10	—	15	—	20	—	ns
\overline{WAIT} setup time	t_{WTS}	30	—	45	—	60	—	ns
\overline{WAIT} hold time	t_{WTH}	5	—	5	—	10	—	ns

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{CCB} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$,
 maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications)
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$, $V_{CCB} = 4.0 \text{ V to } 5.5 \text{ V}$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$,
 maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications)
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$, $V_{CCB} = 3.0 \text{ V to } 5.5 \text{ V}$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$,
 maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit		
		20 MHz		16 MHz		10 MHz				
		Min	Max	Min	Max	Min	Max			
I/O ports	Output data delay time	t_{PWD}	—	50	—	50	—	100	ns	
	Input data setup time	t_{PRS}	30	—	30	—	50	—		
	Input data hold time	t_{PRH}	30	—	30	—	50	—		
FRT	Timer output delay time	t_{FTOD}	—	50	—	50	—	100	ns	
	Timer input setup time	t_{FTIS}	30	—	30	—	50	—		
	Timer clock input setup time	t_{FTCS}	30	—	30	—	50	—		
	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	—	

		setup time								
	Timer clock	Single edge	t_{TMCWH}	1.5	—	1.5	—	1.5	—	t_{cyc}
	pulse width	Both edges	t_{TMCWL}	2.5	—	2.5	—	2.5	—	
PWM, PWMX	Pulse output delay time		t_{PWOD}	—	50	—	50	—	100	ns
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 (synchronous)		t_{TXD}	—	50	—	50	—	100	ns
	Receive data setup time (synchronous)		t_{RXS}	50	—	50	—	100	—	ns
	Receive data hold time (synchronous)		t_{RXH}	50	—	50	—	100	—	ns
A/D converter	Trigger input setup time		t_{TRGS}	30	—	30	—	50	—	ns
WDT	RESO output delay time		t_{RESD}	—	100	—	120	—	200	ns
	RESO output pulse width		t_{RESOW}	132	—	132	—	132	—	t_{cyc}

Note: * Only supporting modules that can be used in subclock operation

Condition C: $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $V_{CCB} = 3.0\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz to }n$
operating frequency, $T_a = -20\text{ to }+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit		
		20 MHz		16 MHz		10 MHz				
		Min	Max	Min	Max	Min	Max			
HIF read cycle	$\overline{CS}/HA0$ setup time	t_{HAR}	10	—	10	—	10	—	ns	
	$\overline{CS}/HA0$ hold time	t_{HRA}	10	—	10	—	10	—	ns	
	\overline{IOR} pulse width	t_{HRPW}	120	—	120	—	220	—	ns	
	HDB delay time	t_{HRD}	—	100	—	100	—	200	ns	
	HDB hold time	t_{HRF}	0	25	0	25	0	40	ns	
	HIRQ delay time	t_{HIRQ}	—	120	—	120	—	200	ns	
HIF write cycle	$\overline{CS}/HA0$ setup time	t_{HAW}	10	—	10	—	10	—	ns	
	$\overline{CS}/HA0$ hold time	t_{HWA}	10	—	10	—	10	—	ns	
	\overline{IOW} pulse width	t_{HWPW}	60	—	60	—	100	—	ns	
	HDB setup time	Fast A20 gate not used	t_{HDW}	30	—	30	—	50	—	ns
		Fast A20 gate used		45	—	55	—	85	—	ns
	HDB hold time	t_{HWD}	15	—	15	—	25	—	ns	
GA20 delay time	t_{HGA}	—	90	—	90	—	180	ns		

KCLK, KD input data hold time	t_{KBH}	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

SCL input high pulse width	t_{SCLH}	5	—	—	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 16.4, Usage Notes.

$T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

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, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 3.0$ V to 5.5 V, $AV_{CC} = 3.0$ V to 5.5 V, $AV_{ref} = 3.0$ V to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0$ V, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Condition A			Condition B			Condition C		
	20 MHz			16 MHz			10 MHz		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Resolution	10	10	10	10	10	10	10	10	10
Conversion time ^{*5}	—	—	6.7	—	—	8.4	—	—	13.4
Analog input capacitance	—	—	20	—	—	20	—	—	20
Permissible signal-source impedance	—	—	$\frac{10^{*3}}{5^{*4}}$	—	—	$\frac{10^{*3}}{5^{*4}}$	—	—	$\frac{10^{*1}}{5^{*2}}$
Nonlinearity error	—	—	± 3.0	—	—	± 3.0	—	—	± 7.0
Offset error	—	—	± 3.5	—	—	± 3.5	—	—	± 7.5
Full-scale error	—	—	± 3.5	—	—	± 3.5	—	—	± 7.5
Quantization error	—	—	± 0.5	—	—	± 0.5	—	—	± 0.5
Absolute accuracy	—	—	± 4.0	—	—	± 4.0	—	—	± 8.0

- Notes: 1. When $4.0 \text{ V} \leq AV_{CC} \leq 5.5 \text{ V}$
2. When $3.0 \text{ V} \leq AV_{CC} < 4.0 \text{ V}$
3. When conversion time $\geq 11.17 \mu\text{s}$ (CKS = 1 and $\phi \leq 12 \text{ MHz}$, or CKS = 0)
4. When conversion time $< 11.17 \mu\text{s}$ (CKS = 1 and $\phi > 12 \text{ MHz}$)
5. In single mode and $\phi =$ maximum operating frequency.

$V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 3.0\text{ V}$ to 5.5 V , $AV_{CC} = 3.0\text{ V}$ to 5.5 V , $AV_{ref} = 3.0\text{ V}$ to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Condition A			Condition B			Condition C		
	20 MHz			16 MHz			10 MHz		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Resolution	10	10	10	10	10	10	10	10	10
Conversion time ^{*5}	—	—	6.7	—	—	8.4	—	—	13.
Analog input capacitance	—	—	20	—	—	20	—	—	20
Permissible signal-source impedance	—	—	$\frac{10^{*3}}{5^{*4}}$	—	—	$\frac{10^{*3}}{5^{*4}}$	—	—	$\frac{10^{*3}}{5^{*2}}$
Nonlinearity error	—	—	± 5.0	—	—	± 5.0	—	—	± 11
Offset error	—	—	± 5.5	—	—	± 5.5	—	—	± 11
Full-scale error	—	—	± 5.5	—	—	± 5.5	—	—	± 11
Quantization error	—	—	± 0.5	—	—	± 0.5	—	—	± 0.5
Absolute accuracy	—	—	± 6.0	—	—	± 6.0	—	—	± 12

- Notes:
1. When $4.0\text{ V} \leq AV_{CC} \leq 5.5\text{ V}$
 2. When $3.0\text{ V} \leq AV_{CC} < 4.0\text{ V}$
 3. When conversion time $\geq 11.17\ \mu\text{s}$ (CKS = 1 and $\phi \leq 12\text{ MHz}$, or CKS = 0)
 4. When conversion time $< 11.17\ \mu\text{s}$ (CKS = 1 and $\phi > 12\text{ MHz}$)
 5. In single mode and $\phi =$ maximum operating frequency.

$T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

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, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 3.0$ V to 5.5 V, $AV_{CC} = 3.0$ V to 5.5 V, $AV_{ref} = 3.0$ V to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0$ V, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item		Condition A			Condition B			Condition C		
		20 MHz			16 MHz			10 MHz		
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Resolution		8	8	8	8	8	8	8	8	8
Conversion time	With 20-pF load capacitance	—	—	10	—	—	10	—	—	10
Absolute accuracy	With 2-M Ω load resistance	—	± 1.0	± 1.5	—	± 1.0	± 1.5	—	± 2.0	± 3.0
	With 4-M Ω load resistance	—	—	± 1.0	—	—	± 1.0	—	—	± 2.0

Item	Symbol	Min	Typ	Max	Unit	
Programming time ^{*1 *2 *4}	tP	—	10	200	ms/ 32 bytes	
Erase time ^{*1 *3 *6}	tE	—	100	1200	ms/ block	
Reprogramming count	N _{WEC}	100 ^{*8}	10000 ^{*9}	—	Times	
Data retention time ^{*10}	t _{DRP}	10	—	—	Years	
Programming	Wait time after SWE-bit setting ^{*1}	x	10	—	—	μs
	Wait time after PSU-bit setting ^{*1}	y	50	—	—	μs
	Wait time after P-bit setting ^{*1 *4}	z	150	—	200	μs
	Wait time after P-bit clear ^{*1}	α	10	—	—	μs
	Wait time after PSU-bit clear ^{*1}	β	10	—	—	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	4	—	—	μs
	Maximum programming count ^{*1 *4 *5}	N	—	—	1000	Times
Erase	Wait time after SWE-bit setting ^{*1}	x	10	—	—	μs
	Wait time after ESU-bit setting ^{*1}	y	200	—	—	μs
	Wait time after E-bit setting ^{*1 *6}	z	5	—	10	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	5	—	—	μs
Maximum erase count ^{*1 *6 *7}	N	—	—	120	Times	

Notes: 1. Set the times according to the program/erase algorithms.

2. Programming time per 32 bytes (Shows the total period for which the P-bit is set. It does not include the programming verification time.)

7. Number of times when the wait time after E-bit setting (z) = 10 ms.
The number of erases should be set according to the actual set value of (z) to erasing within the maximum erase time (tE(max)).
8. Minimum number of times for which all characteristics are guaranteed after n (Guarantee range is 1 to minimum value).
9. Reference value for 25°C (as a guideline, rewriting should normally function value).
10. Data retention characteristic when rewriting is performed within the specification including the minimum value.

26.2.7 Usage Note

- (1) The F-ZTAT and mask ROM versions have been confirmed as fully meeting the reference values for electrical characteristics shown in this manual. However, actual performance figures, operating margins, noise margins, and other properties may vary due to differences in the manufacturing process, on-chip ROM, layout patterns, etc.
When system evaluation testing is carried out using the F-ZTAT version, the same tests should also be conducted for the mask ROM version when changing over to the mask ROM version.
- (2) On-chip power supply step-down circuit
The H8S/2148 F-ZTAT does not incorporate an internal power supply step-down circuit. When changing over to F-ZTAT versions or mask ROM versions incorporating an internal step-down circuit, the VCC2 pin has the same pin location as the VCL pin in a step-down circuit.
Therefore, note that the circuit patterns differ between these two types of products.

For products incorporating an internal step-down circuit, do not connect the VCL pin to the VCC power supply. (The VCC1 pin must be connected to the VCC power supply as usual.)

The power supply stabilization capacitor must be connected to the VCL pin. Use a monolithic ceramic capacitor of 0.47 μ F (one or two connected in group) and locate it near the pins.

In case the power supply voltage is lower than 3.6 V, connect the capacitor in the same way as the case with no step-down circuit incorporated.

<Products incorporating internal step-down circuit>

HD6432148S, HD6432148SW,
HD6432147S, HD6432147SW
HD6432144S, HD6432143S,
HD64F2148A, HD64F2147A,
HD64F2144A

The location of the VCC2 (V_{CC} power pin in the product not incorporating a step-down circuit, is the same as the a product incorporating an internal step-down circuit.

It is recommended that the by-pass capacitors are connected to the power supply terminals (these are reference values).

<Products not incorporating internal step-down circuit>

HD64F2148(V), HD64F2147N(V),
HD64F2144(V), HD64F2142(V),
HD6432142,
HD6432148SV, HD6432148SVW,
HD6432147SV, HD6432147SVW,
HD6432144SV, HD6432143SV,
HD64F2148AV, HD64F2147AV,
HD64F2144AV

Figure 26.3 Connection of External Capacitor (Mask ROM Type Incorporating Step-Down Circuit and Product Not Incorporating Step-Down Circuit)

Table 26.16 Absolute Maximum Ratings

Item	Symbol	Value
Power supply voltage* ¹	V_{CC}	-0.3 to +7.0
Input/output buffer power supply (power supply for the port A)	V_{CCB}	-0.3 to +7.0
Power supply voltage* ¹ (3 V version)	V_{CC}	-0.3 to +4.3
Power supply voltage* ² (VCL pin)	V_{CL}	-0.3 to +4.3
Input voltage (except ports 6, 7, and A)	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 $V_{CCB} + 0.3$
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 $V_{CCB} + 0.3$ and $AV_{CC} + 0.3$
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)	AV_{CC}	-0.3 to +4.3
Analog input voltage	V_{AN}	-0.3 to $AV_{CC} + 0.3$
Operating temperature	T_{opr}	Regular specifications: -20 to +75 Wide-range specifications: -40 to +85

- Notes:
1. Power supply voltage for VCC1 pin
Never exceed the maximum rating of V_{cl} in the low-power version (3-V version) because both the VCC1 and VCL pins are connected to the V_{cc} power supply.
 2. It is an operating power supply voltage pin on the chip.
Never apply power supply voltage to the VCL pin in the 5- or 4-V version.
Always connect an external capacitor between the VCL pin and ground for voltage stabilization.

Item	Symbol	Min	Typ	Max	Unit	T C		
Schmitt trigger input voltage	P67 to P60(KWUL = 00) ^{*2 *6} , KIN15 to KIN8 ^{*7 *8} , IRQ2 to IRQ0 ^{*3} , IRQ5 to 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	—	—		
			<hr/>					
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	RES, STBY, NMI, MD1, MD0 EXTAL PA7 to PA0 ^{*7} Port 7 Input pins except (1) and (2) above	(2)	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V
				<hr/>				
					$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	
				$V_{CC} B \times 0.7$	—	$V_{CC} B + 0.3$		
				2.0	—	$A V_{CC} + 0.3$		
				2.0	—	$V_{CC} + 0.3$		

Output high voltage	All output pins (except P97, and P52 ^{*4})*5*8	V_{OH}	$V_{CC} - 0.5$	—	—	V
			$V_{CC}B - 0.5$			
	P97, P52 ^{*4}		3.5	—	—	V
Output low voltage	All output pins (except RESO) ^{*5}	V_{OL}	—	—	0.4	V
	Ports 1 to 3		—	—	1.0	V
	RESO		—	—	0.4	V
Input leakage current	RES	$ I_{in} $	—	—	10.0	μA
	STBY, NMI, MD1, MD0		—	—	1.0	μA
	Port 7		—	—	1.0	μA
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A ^{*8} , B	$ I_{TSL} $	—	—	1.0	μA
Input pull-up MOS current	Ports 1 to 3	$-I_p$	30	—	300	μA
	Ports A ^{*8} , B, Port 6 (P6PUE = 0)		60	—	600	μA
	Port 6 (P6PUE = 1)		15	—	200	μA

(4) above

Current dissipation ^{*9}	Normal operation	I_{CC}	—	55	70	mA	f
	Sleep mode		—	36	55	mA	f
	Standby mode ^{*10}		—	1.0	5.0	μ A	T
				—	—	20.0	μ A
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA	
	Idle		—	0.01	5.0	μ A	A tc
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	mA	
	Idle		—	0.01	5.0	μ A	A tc
Analog power supply voltage ^{*1}	AV_{CC}		4.5	—	5.5	V	C
			2.0	—	5.5	V	lc
RAM standby voltage	V_{RAM}		2.0	—	—	V	

Notes: 1. **Do not leave the AVCC, AV_{ref}, and AVSS pins open even if the A/D converter and D/A converter are not used.**

Even if the A/D converter and D/A converter are not used, apply a value in the range of 2.0 V to 5.5 V to AVCC and AV_{ref} pins by connection to the power supply (V_{CC}) or by other method. Ensure that AV_{ref} ≤ AV_{CC}.

- P67 to P60 include supporting module inputs multiplexed on those pins.
- IRQ2 includes the ADTRG signal multiplexed on that pin.
- In the H8S/2148 Group, P52/SCK0/SCL0 and P97/SDA0 are NMOS push-pull outputs. An external pull-up resistor is necessary to provide high-level output from SCK0 and SDA0 (ICE = 1).
In the H8S/2148 Group, P52/SCK0 and P97 (ICE = 0) high levels are driven by the bus driver.
- When IICS = 0, ICE = 0, and KBIOE = 0. Low-level output when the bus driver is selected is determined separately.

10. The values are for $V_{RAM} \leq V_{CC} < 4.5V$, $V_{IH\ min} = V_{CC} - 0.2\ V$, $V_{CCB} - 0.2\ V$, and $0.2\ V$.

trigger input voltage	P60(KWUL = 00) ^{*2 *6} , KIN15 to KIN8 ^{*7 *8} , IRQ2 to IRQ0 ^{*3} , IRQ5 to IRQ3	V_T^+	—	—	$V_{CC} \times 0.7$	V	5. V _{CC} to	
		$V_T^+ - V_T^-$	0.4	—	—	V	4. V _{CC} to	
		V_T^-	0.8	—	—	V	V _{CC}	
		V_T^+	—	—	$V_{CC} \times 0.7$	V	4. V _{CC} to	
					$V_{CC}B \times 0.7$			
		$V_T^+ - V_T^-$	0.3	—	—	V		
		V_T^-	$V_{CC} \times 0.3$	—	—	V	V _{CC}	
		V_T^+	—	—	$V_{CC} \times 0.7$		5.	
		$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—			
		V_T^-	$V_{CC} \times 0.4$	—	—			
Schmitt trigger input voltage (in level switching) ^{*6}	P67 to P60 (KWUL = 01)	V_T^+	—	—	$V_{CC} \times 0.8$			
		$V_T^+ - V_T^-$	$V_{CC} \times 0.03$	—	—			
	P67 to P60 (KWUL = 10)	V_T^-	$V_{CC} \times 0.45$	—	—			
		V_T^+	—	—	$V_{CC} \times 0.9$			
	P67 to P60 (KWUL = 11)	V_T^-	$V_{CC} \times 0.45$	—	—			
		V_T^+	—	—	$V_{CC} \times 0.9$			
	Input high voltage	RES, \overline{STBY} , NMI, MD1, MDO (2) EXTAL PA7 to PA0 ^{*7} Port 7 Input pins except (1) and (2) above	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V	
				$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
				$V_{CC}B \times 0.7$	—	$V_{CC}B + 0.3$	V	
				2.0	—	$AV_{CC} + 0.3$	V	
			2.0	—	$V_{CC} + 0.3$	V		

	NMI, EXTAL, input pins except (1) and (3) above		-0.3	—	0.8	V	
Output high voltage	All output pins (except P97, and P52 ^{*4} , ^{*5} ^{*8})	V_{OH}	$V_{CC} - 0.5$	—	—	V	
			$V_{CC}B - 0.5$	3.5	—	—	V
				3.0	—	—	V
	P97, P52 ^{*4}		1.5	—	—	V	
Output low voltage	All output pins (except RESO) ^{*5}	V_{OL}	—	—	0.4	V	
			Ports 1 to 3	—	—	1.0	V
			\overline{RESO}	—	—	0.4	V
Input leakage current	\overline{RES}	$ I_{in} $	—	—	10.0	μA	
	\overline{STBY} , NMI, MD1, MD0		—	—	1.0	μA	
	Port 7		—	—	1.0	μA	
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A ^{*8} , B	$ I_{TSI} $	—	—	1.0	μA	

	Ports 1 to 3		20	—	200	μA	V_{CC}
	Ports A ^{*8} , B Port 6 (P6PUE = 0)		40	—	500	μA	4. V_{CC} to
	Port 6 (P6PUE = 1)		10	—	150		
Input capacitance	\overline{RES} (4)	C_{in}	—	—	80	pF	V_{CC}
	NMI		—	—	50	pF	f = T_a
	P52, P97, P42, P86, PA7 to PA2		—	—	20	pF	
	Input pins except (4) above		—	—	15	pF	
Current dissipation ^{*9}	Normal operation	I_{CC}	—	45	58	mA	f =
	Sleep mode		—	30	46	mA	f =
	Standby mode ^{*10}		—	1.0	5.0	μA	T_a
			—	—	20.0		50
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA	
	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	mA	
	Idle		—	0.01	5.0	μA	A to
Analog power supply voltage ^{*1}		AV_{CC}	4.0	—	5.5	V	O
			2.0	—	5.5	V	Id
RAM standby voltage		V_{RAM}	2.0	—	—	V	

SDA0 (ICE = 1).

In the H8S/2148 Group, P52/SCK0 and P97 (ICE = 0) high levels are driven.

5. When IICS = 0, ICE = 0, and KBIOE = 0. Low-level output when the bus driver 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 selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
7. The upper limit of the port A applied voltage is $V_{CCB} + 0.3$ V when CIN input is selected, and the lower of $V_{CCB} + 0.3$ V and $AV_{CC} + 0.3$ V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
8. The port A characteristics depend on V_{CCB} , and the other pins characteristics depend on V_{CC} .
9. Current dissipation values are for V_{IH} min = $V_{CC} - 0.2$ V, $V_{CCB} - 0.2$ V, and V_{IL} min = $V_{CC} - 0.2$ V with all output pins unloaded and the on-chip pull-up MOSs in the off state.
10. The values are for $V_{RAM} \leq V_{CC} < 4.0$ V, V_{IH} min = $V_{CC} - 0.2$ V, $V_{CCB} - 0.2$ V, and V_{IL} min = $V_{CC} - 0.2$ V.

voltage	00) , KIN15 to KIN8* ⁷ * ⁸ , IRQ2 to IRQ0* ³ , IRQ5 to IRQ3		V_T^+	—	—	$V_{CC} \times 0.7$	V
			$V_T^- - V_T^+$	$V_{CC} \times 0.05$	—	—	V
Schmitt trigger input voltage (in level switching)* ⁶	P67 to P60 (KWUL = 01)		V_T^-	$V_{CC} \times 0.3$	—	—	V
			V_T^+	—	—	$V_{CC} \times 0.7$	
	P67 to P60 (KWUL = 10)		$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—	
			V_T^-	$V_{CC} \times 0.4$	—	—	
	P67 to P60 (KWUL = 11)		V_T^+	—	—	$V_{CC} \times 0.8$	
			$V_T^+ - V_T^-$	$V_{CC} \times 0.03$	—	—	
			V_T^-	$V_{CC} \times 0.45$	—	—	
			V_T^+	—	—	$V_{CC} \times 0.9$	
			$V_T^+ - V_T^-$	0.05	—	—	
	Input high voltage	RES, STBY, (2) NMI, MD1, MD0	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V
EXTAL			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
PA7 to PA0* ⁷			$V_{CC} B \times 0.7$	—	$V_{CC} B + 0.3$	V	
Port 7			$V_{CC} \times 0.7$	—	$A V_{CC} + 0.3$	V	
Input pins except (1) and (2) above			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	

	NMI, EXTAL, input pins except (1) and (3) above		-0.3	—	$V_{CC} \times 0.2$	V	
Output high voltage	All output pins (except P97, and P52 ^{*4, *5 *8})	V_{OH}	$V_{CC} - 0.5$	—	—	V	
			$V_{CCB} - 0.5$				
			$V_{CC} - 1.0$	—	—	V	
			$V_{CCB} - 1.0$				
	P97, P52 ^{*4}		0.5	—	—	V	
Output low voltage	All output pins (except RESO) ^{*5}	V_{OL}	—	—	0.4	V	
			Ports 1 to 3	—	—	1.0	V
			RESO	—	—	0.4	V
Input leakage current	RES	$ I_{in} $	—	—	10.0	μA	
	STBY, NMI, MD1, MD0		—	—	1.0	μA	
	Port 7		—	—	1.0	μA	
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A ^{*8} , B	$ I_{TSI} $	—	—	1.0	μA	

Input capacitance	RES	(4) C_{in}	—	—	80	pF	f
	NMI		—	—	50	pF	T
	P52, P97, P42, P86, PA7 to PA2		—	—	20	pF	
	Input pins except (4) above		—	—	15	pF	
Current dissipation* ⁹	Normal operation	I_{CC}	—	30	40	mA	f
	Sleep mode		—	20	32	mA	f
	Standby mode* ¹⁰		—	1.0	5.0	μ A	T
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA	
	Idle		—	0.01	5.0	μ A	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	mA	
	Idle		—	0.01	5.0	μ A	A to
Analog power supply voltage* ¹	AV_{CC}		2.7	—	3.6	V	C
			2.0	—	3.6	V	lo
RAM standby voltage	V_{RAM}		2.0	—	—	V	

Notes: 1. **Do not leave the AVCC, AV_{ref}* and AVSS pins open even if the A/D converter and D/A converter are not used.**

Even if the A/D converter and D/A converter are not used, apply a value in the range of 2.0 V to 3.6 V to AVCC and AV_{ref}* pins by connection to the power supply (V_{CC}) or other method. Ensure that $AV_{ref} \leq AV_{CC}$.

- P67 to P60 include supporting module inputs multiplexed on those pins.
- IRQ2 includes the ADTRG signal multiplexed on that pin.

7. The upper limit of the port A applied voltage is $V_{CC}B + 0.3$ V when CIN input is selected, and the lower of $V_{CC}B + 0.3$ V and $AV_{CC} + 0.3$ V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
8. The port A characteristics depend on $V_{CC}B$, and the other pins characteristics depend on V_{CC} .
9. Current dissipation values are for V_{IH} min = $V_{CC} - 0.2$ V, $V_{CC}B - 0.2$ V, and V_{IL} min = $V_{CC} - 0.2$ V with all output pins unloaded and the on-chip pull-up MOSs in the off state.
10. 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} min = $V_{CC} - 0.2$ V.
11. For flash memory program/erase operations, the applicable ranges are V_{CC} = 3.6 V.

	PA7 to PA4 (bus drive function selected)				
	Ports 1, 2, 3		—	—	10
	$\overline{\text{RESO}}$		—	—	3
	Other output pins		—	—	2
Permissible output low current (total)	Total of ports 1, 2, and 3	ΣI_{OL}	—	—	80
	Total of all output pins, including the above		—	—	120
Permissible output high current (per pin)	All output pins	$-I_{\text{OH}}$	—	—	2
Permissible output high current (total)	Total of all output pins	$\Sigma -I_{\text{OH}}$	—	—	40

	<u>RESO</u>		—	—	1
	Other output pins		—	—	1
Permissible output low current (total)	Total of ports 1, 2, and 3	ΣI_{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	$\Sigma -I_{OH}$	—	—	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 resistor on the output line, as show in figures 26.1 and 26.2.

Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	$V_{CC} + 0.5$	V	
Input low voltage	V_{IL}	-0.5	—	$V_{CC} \times 0.3$		
Output low voltage	V_{OL}	—	—	0.8	V	$I_{OL} = 16 \text{ mA}$ $V_{CC} = 4.5 \text{ V}$
				0.5		$I_{OL} = 8 \text{ mA}$
				0.4		$I_{OL} = 3 \text{ mA}$
Input capacitance	C_{in}	—	—	20	pF	$V_{in} = 0 \text{ V}$, $f = 1 \text{ MHz}$ $T_a = 25^\circ\text{C}$
Three-state leakage current (off state)	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5 \text{ V}$
SCL, SDA output fall time	t_{of}	$20 + 0.1 C_b$	—	250	ns	

Conditions: $V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$, $V_{CC} = 2.7 \text{ V to } 3.6 \text{ V}$ (3 V version), $V_{CC}B = 2.7 \text{ V to } 3.6 \text{ V}$, $V_{SS} = 0 \text{ V}$

Applicable Pins: PS2AC, PS2AD, PS2BC, PS2BD, PS2CC, PS2CD, PA7 to PA4 (bus function selected)

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Output low voltage	V_{OL}	—	—	0.8	V	$I_{OL} = 16 \text{ mA}$, $V_{CC}B = 4.5 \text{ V to } 3.6 \text{ V}$
				0.5		$I_{OL} = 8 \text{ mA}$
				0.4		$I_{OL} = 3 \text{ mA}$

26.3.3 AC Characteristics

Clock timing, control signal timing, bus timing, and timing of on-chip supporting modes are described in the following.

Figure 26.4 shows the test conditions for the AC characteristics.

Condition A: $V_{CC} = 5.0\text{ V} \pm 10\%$, $V_{CCB} = 5.0\text{ V} \pm 10\%$, $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0\text{ V}$ to 5.5 V , $V_{CCB} = 4.0\text{ V}$ to 5.5 V , $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7\text{ V}$ to 3.6 V , $V_{CCB} = 2.7\text{ V}$ to 5.5 V , $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit
		20 MHz		16 MHz		10 MHz		
		Min	Max	Min	Max	Min	Max	
Clock cycle time	t_{cyc}	50	500	62.5	500	100	500	ns
Clock high pulse width	t_{CH}	17	—	20	—	30	—	ns
Clock low pulse width	t_{CL}	17	—	20	—	30	—	ns
Clock rise time	t_{Cr}	—	8	—	10	—	20	ns
Clock fall time	t_{Cf}	—	8	—	10	—	20	ns
Oscillation settling time at reset (crystal)	t_{OSC1}	10	—	10	—	20	—	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

$T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0$ V to 5.5 V, $V_{CCB} = 4.0$ V to 5.5 V, $V_{SS} = 0$ V, $\phi = 32.768$ kHz, maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specification)
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7$ V to 3.6 V, $V_{CCB} = 2.7$ V to 5.5 V, $V_{SS} = 0$ V, $\phi = 32.768$ kHz, maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	T _a
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
RES setup time	t_{RESS}	200	—	200	—	300	—	ns	Fi
RES pulse width	t_{RESW}	20	—	20	—	20	—	t_{cyc}	
NMI setup time (NMI)	t_{NMIS}	150	—	150	—	250	—	ns	Fi
NMI hold time (NMI)	t_{NMIH}	10	—	10	—	10	—		
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	200	—	200	—	ns	
IRQ setup time (IRQ7 to IRQ0)	t_{IRQS}	150	—	150	—	250	—	ns	
IRQ hold time (IRQ7 to IRQ0)	t_{IRQH}	10	—	10	—	10	—	ns	
IRQ pulse width (IRQ7, IRQ6, IRQ2 to IRQ0) (exiting software standby mode)	t_{IRQW}	200	—	200	—	200	—	ns	

$T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0$ V to 5.5 V, $V_{CCB} = 4.0$ V to 5.5 V, $V_{SS} = 0$ V, $\phi = 2$ MHz to ∞ MHz, operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7$ V to 3.6 V, $V_{CCB} = 2.7$ V to 5.5 V, $V_{SS} = 0$ V, $\phi = 2$ MHz to ∞ MHz, operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit
		20 MHz		16 MHz		10 MHz		
		Min	Max	Min	Max	Min	Max	
Address delay time	t_{AD}	—	20	—	30	—	40	ns
Address setup time	t_{AS}	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 20$	—	$0.5 \times t_{cyc} - 30$	—	ns
Address hold time	t_{AH}	$0.5 \times t_{cyc} - 10$	—	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 20$	—	ns
\overline{CS} delay time (IOS)	t_{CSD}	—	20	—	30	—	40	ns
\overline{AS} delay time	t_{ASD}	—	30	—	45	—	60	ns
\overline{RD} delay time 1	t_{RSD1}	—	30	—	45	—	60	ns
\overline{RD} delay time 2	t_{RSD2}	—	30	—	45	—	60	ns
Read data setup time	t_{RDS}	15	—	20	—	35	—	ns
Read data hold time	t_{RDH}	0	—	0	—	0	—	ns

time 2								
Read data access time 3	t_{ACC3}	—	$2.0 \times$ $t_{cyc} -30$	—	$2.0 \times$ $t_{cyc} -40$	—	$2.0 \times$ $t_{cyc} -60$	ns
Read data access time 4	t_{ACC4}	—	$2.5 \times$ $t_{cyc} -25$	—	$2.5 \times$ $t_{cyc} -35$	—	$2.5 \times$ $t_{cyc} -50$	ns
Read data access time 5	t_{ACC5}	—	$3.0 \times$ $t_{cyc} -30$	—	$3.0 \times$ $t_{cyc} -40$	—	$3.0 \times$ $t_{cyc} -60$	ns
\overline{WR} delay time 1	t_{WRD1}	—	30	—	45	—	60	ns
\overline{WR} delay time 2	t_{WRD2}	—	30	—	45	—	60	ns
\overline{WR} pulse width 1	t_{WSW1}	$1.0 \times$ $t_{cyc} -20$	—	$1.0 \times$ $t_{cyc} -30$	—	$1.0 \times$ $t_{cyc} -40$	—	ns
\overline{WR} pulse width 2	t_{WSW2}	$1.5 \times$ $t_{cyc} -20$	—	$1.5 \times$ $t_{cyc} -30$	—	$1.5 \times$ $t_{cyc} -40$	—	ns
Write data delay time	t_{WDD}	—	30	—	45	—	60	ns
Write data setup time	t_{WDS}	0	—	0	—	0	—	ns
Write data hold time	t_{WDH}	10	—	15	—	20	—	ns
\overline{WAIT} setup time	t_{WTS}	30	—	45	—	60	—	ns
\overline{WAIT} hold time	t_{WTH}	5	—	5	—	10	—	ns

Condition C: $V_{CC} = 2.7\text{ V to }3.6\text{ V}$, $V_{CCB} = 2.7\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz to }n$
operating frequency, $T_a = -20\text{ to }+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit
		20 MHz		16 MHz		10 MHz		
		Min	Max	Min	Max	Min	Max	
Address delay time	t_{AD}	—	30	—	45	—	60	ns
Address setup time	t_{AS}	$0.5 \times t_{cyc} - 25$	—	$0.5 \times t_{cyc} - 35$	—	$0.5 \times t_{cyc} - 50$	—	ns
Address hold time	t_{AH}	$0.5 \times t_{cyc} - 10$	—	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 20$	—	ns
\overline{CS} delay time (\overline{IOS})	t_{CSD}	—	30	—	45	—	60	ns
\overline{AS} delay time	t_{ASD}	—	30	—	45	—	60	ns
\overline{RD} delay time 1	t_{RSD1}	—	30	—	45	—	60	ns
\overline{RD} delay time 2	t_{RSD2}	—	30	—	45	—	60	ns
Read data setup time	t_{RDS}	15	—	20	—	35	—	ns
Read data hold time	t_{RDH}	0	—	0	—	0	—	ns
Read data access time 1	t_{ACC1}	—	$1.0 \times t_{cyc} - 40$	—	$1.0 \times t_{cyc} - 55$	—	$1.0 \times t_{cyc} - 80$	ns
Read data access time 2	t_{ACC2}	—	$1.5 \times t_{cyc} - 25$	—	$1.5 \times t_{cyc} - 35$	—	$1.5 \times t_{cyc} - 50$	ns

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time 4								
Read data access time 5	t_{ACC5}	—	$3.0 \times t_{cyc} - 40$	—	$3.0 \times t_{cyc} - 55$	—	$3.0 \times t_{cyc} - 80$	ns
\overline{WR} delay time 1	t_{WRD1}	—	30	—	45	—	60	ns
\overline{WR} delay time 2	t_{WRD2}	—	30	—	45	—	60	ns
\overline{WR} pulse width 1	t_{WSW1}	$1.0 \times t_{cyc} - 20$	—	$1.0 \times t_{cyc} - 30$	—	$1.0 \times t_{cyc} - 40$	—	ns
\overline{WR} pulse width 2	t_{WSW2}	$1.5 \times t_{cyc} - 20$	—	$1.5 \times t_{cyc} - 30$	—	$1.5 \times t_{cyc} - 40$	—	ns
Write data delay time	t_{WDD}	—	30	—	45	—	60	ns
Write data setup time	t_{WDS}	0	—	0	—	0	—	ns
Write data hold time	t_{WDH}	10	—	15	—	20	—	ns
\overline{WAIT} setup time	t_{WTS}	30	—	45	—	60	—	ns
\overline{WAIT} hold time	t_{WTH}	5	—	5	—	10	—	ns

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{CCB} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$,
 maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications)
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$, $V_{CCB} = 4.0 \text{ V to } 5.5 \text{ V}$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$,
 maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications)
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V to } 3.6 \text{ V}$, $V_{CCB} = 2.7 \text{ V to } 5.5 \text{ V}$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$,
 maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit		
		20 MHz		16 MHz		10 MHz				
		Min	Max	Min	Max	Min	Max			
I/O ports	Output data delay time	t_{PWD}	—	50	—	50	—	100	ns	
	Input data setup time	t_{PRS}	30	—	30	—	50	—		
	Input data hold time	t_{PRH}	30	—	30	—	50	—		
FRT	Timer output delay time	t_{FTOD}	—	50	—	50	—	100	ns	
	Timer input setup time	t_{FTIS}	30	—	30	—	50	—		
	Timer clock input setup time	t_{FTCS}	30	—	30	—	50	—		
	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	—	

	setup time									
	Timer clock	Single edge	t_{TMCWH}	1.5	—	1.5	—	1.5	—	t_{cyc}
	pulse width	Both edges	t_{TMCWL}	2.5	—	2.5	—	2.5	—	
PWM, PWMX	Pulse output delay time		t_{PWOD}	—	50	—	50	—	100	ns
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 (synchronous)		t_{TXD}	—	50	—	50	—	100	ns
	Receive data setup time (synchronous)		t_{RXS}	50	—	50	—	100	—	ns
	Receive data hold time (synchronous)		t_{RXH}	50	—	50	—	100	—	ns
A/D converter	Trigger input setup time		t_{TRGS}	30	—	30	—	50	—	ns
WDT	RESO output delay time		t_{RESD}	—	100	—	120	—	200	ns
	RESO output pulse width		t_{RESOW}	132	—	132	—	132	—	t_{cyc}

Note: * Only supporting modules that can be used in subclock operation

Condition C: $V_{CC} = 2.7 \text{ V to } 3.6 \text{ V}$, $V_{CCB} = 2.7 \text{ V to } 5.5 \text{ V}$, $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz to } \infty$
operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit		
		20 MHz		16 MHz		10 MHz				
		Min	Max	Min	Max	Min	Max			
HIF read cycle	$\overline{\text{CS}}/\text{HA0}$ setup time	t_{HAR}	10	—	10	—	10	—	ns	
	$\overline{\text{CS}}/\text{HA0}$ hold time	t_{HRA}	10	—	10	—	10	—	ns	
	$\overline{\text{IOR}}$ pulse width	t_{HRPW}	120	—	120	—	220	—	ns	
	HDB delay time	t_{HRD}	—	100	—	100	—	200	ns	
	HDB hold time	t_{HRF}	0	25	0	25	0	40	ns	
	HIRQ delay time	t_{HIRQ}	—	120	—	120	—	200	ns	
HIF write cycle	$\overline{\text{CS}}/\text{HA0}$ setup time	t_{HAW}	10	—	10	—	10	—	ns	
	$\overline{\text{CS}}/\text{HA0}$ hold time	t_{HWA}	10	—	10	—	10	—	ns	
	$\overline{\text{IOW}}$ pulse width	t_{HWPW}	60	—	60	—	100	—	ns	
	HDB setup time	Fast A20 gate not used	t_{HDW}	30	—	30	—	50	—	ns
		Fast A20 gate used		45	—	55	—	85	—	ns
	HDB hold time	t_{HWD}	15	—	15	—	25	—	ns	
GA20 delay time	t_{HGA}	—	90	—	90	—	180	ns		

KCLK, KD input data hold time	t_{KBH}	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

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 output fall time	t_{of}	20 + 0.1 C _b	—	250	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 16.4, Usage Notes.

$T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

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, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

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, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Condition A			Condition B			Condition C		
	20 MHz			16 MHz			10 MHz		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Resolution	10	10	10	10	10	10	10	10	10
Conversion time ^{*3}	—	—	6.7	—	—	8.4	—	—	13.4
Analog input capacitance	—	—	20	—	—	20	—	—	20
Permissible signal-source impedance	—	—	$\frac{10^{*1}}{5^{*2}}$	—	—	$\frac{10^{*1}}{5^{*2}}$	—	—	5
Nonlinearity error	—	—	± 3.0	—	—	± 3.0	—	—	± 7.0
Offset error	—	—	± 3.5	—	—	± 3.5	—	—	± 7.5
Full-scale error	—	—	± 3.5	—	—	± 3.5	—	—	± 7.5
Quantization error	—	—	± 0.5	—	—	± 0.5	—	—	± 0.5
Absolute accuracy	—	—	± 4.0	—	—	± 4.0	—	—	± 8.0

Notes: 1. When conversion time $\geq 11.17 \mu\text{s}$ (CKS = 1 and $\phi \leq 12$ MHz, or CKS = 0)
2. When conversion time $< 11.17 \mu\text{s}$ (CKS = 1 and $\phi > 12$ MHz)
3. In single mode and $\phi =$ maximum operating frequency.

$V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 3.0\text{ V}$ to 3.6 V^{*4} , $AV_{CC} = 3.0\text{ V}$ to 3.6 V^{*4} , $AV_{ref} = 3.0\text{ V}$ to AV_{CC}^{*4} ,
 $V_{CCB} = 3.0\text{ V}$ to 5.5 V^{*4} , $V_{SS} = AV_{SS} = 0\text{ V}$,
 $\phi = 2\text{ MHz}$ to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Condition A			Condition B			Condition C		
	20 MHz			16 MHz			10 MHz		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Resolution	10	10	10	10	10	10	10	10	10
Conversion time ^{*3}	—	—	6.7	—	—	8.4	—	—	13.0
Analog input capacitance	—	—	20	—	—	20	—	—	20
Permissible signal-source impedance	—	—	$\frac{10^{*1}}{5^{*2}}$	—	—	$\frac{10^{*1}}{5^{*2}}$	—	—	5
Nonlinearity error	—	—	± 5.0	—	—	± 5.0	—	—	± 11
Offset error	—	—	± 5.5	—	—	± 5.5	—	—	± 11
Full-scale error	—	—	± 5.5	—	—	± 5.5	—	—	± 11
Quantization error	—	—	± 0.5	—	—	± 0.5	—	—	± 0.5
Absolute accuracy	—	—	± 6.0	—	—	± 6.0	—	—	± 12

Notes: 1. When conversion time $\geq 11.17\ \mu\text{s}$ (CKS = 1 and $\phi \leq 12\text{ MHz}$, or CKS = 0)
 2. When conversion time $< 11.17\ \mu\text{s}$ (CKS = 1 and $\phi > 12\text{ MHz}$)
 3. In single mode and $\phi =$ maximum operating frequency.
 4. When using CIN, the applicable range is $V_{CC} = 3.0\text{ V}$ to 3.6 V , $AV_{CC} = 3.0\text{ V}$ to $AV_{ref} = 3.0\text{ V}$ to 3.6 V , and $V_{CCB} = 3.0\text{ V}$ to 5.5 V .

$T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

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, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

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, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item		Condition A			Condition B			Condition C		
		20 MHz			16 MHz			10 MHz		
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Resolution		8	8	8	8	8	8	8	8	8
Conversion time	With 20-pF load capacitance	—	—	10	—	—	10	—	—	10
Absolute accuracy	With 2-M Ω load resistance	—	± 1.0	± 1.5	—	± 1.0	± 1.5	—	± 2.0	± 3
	With 4-M Ω load resistance	—	—	± 1.0	—	—	± 1.0	—	—	± 2

26.3.6 Flash Memory Characteristics

Table 26.29 shows the flash memory characteristics.

Erase time ^{*1 *3 *6}	tE	—	100	1200	ms/ block	
Reprogramming count	N _{WEC}	100 ^{*8}	10000 ^{*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 H'FF 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	

z2, z3) to allow programming within the maximum programming time ($t_P(\max)$). The wait time after P-bit setting ($z1, z2, z3$) must be changed with the value of the number of writing times (n) as follows.

The number of times for writing n

$1 \leq n \leq 6$ $z1 = 30 \mu\text{s}, z3 = 10 \mu\text{s}$

$7 \leq n \leq 1000$ $z2 = 200 \mu\text{s}$

6. Maximum erase time ($t_E(\max)$)
 $t_E(\max) = \text{Waiting time after E-bit setting (z)} \times \text{Maximum erase count (N)}$
7. Maximum erase count (N) should be set according to the actual setting (z) to erase within the maximum erase time ($t_E(\max)$).
8. Minimum number of times for which all characteristics are guaranteed after erasing (Guarantee range is 1 to minimum value).
9. Reference value for 25°C (as a guideline, rewriting should normally function within the minimum value).
10. Data retention characteristic when rewriting is performed within the specific range including the minimum value.

(2) On-chip power supply step-down circuit

The following products incorporate an internal power supply step-down circuit, which automatically drops down the internal power supply voltage to the optimum internal level: the F-ZTAT A-mask versions of the H8S/2148, H8S/2147, and H8S/2144 (HD64F2148A, HD64F2147A, and HD64F2144A) and the mask ROM versions of H8S/2148, H8S/2147, H8S/2144, and H8S/2143 (HD6432148S, HD6432148SW, HD6432147S, HD6432147SW, HD6432144S, and HD6432143S).

The voltage-stabilization capacitor (0.47 μ F one or two connected in group) must be connected between the VCL (internal power supply step-down) and VSS pins.

Figure 26.3 shows the connection of the external capacitors.

For the 5- or 4-V version whose power supply (V_{CC}) voltage exceeds 3.6 V, do not connect the VCL pin in a product incorporating an internal step-down circuit to the V_{CC} power supply. (Connect the VCC1 pin to the V_{CC} power supply as usual.)

For the 3-V version whose power supply (V_{CC}) voltage is 3.6 V or lower, connect both the VCL and VCC1 pins to the system power supply.

When changing from the F-ZTAT versions not incorporating an internal step-down circuit to the F-ZTAT A-mask versions or mask ROM versions incorporating an internal step-down circuit, the VCL pin has the same pin location as the VCC2 pin. Therefore, note that the pin patterns differ between these two types of products.

Item	Symbol	Value
Power supply voltage*	V_{CC}	-0.3 to +7.0
Input/output buffer power supply (power supply for the port A)	V_{CCB}	-0.3 to +7.0
Input voltage (except ports 6, 7, and A)	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 $V_{CCB} + 0.3$
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 $V_{CCB} + 0.3$ and $AV_{CC} + 0.3$
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 input voltage	V_{AN}	-0.3 to $AV_{CC} + 0.3$
Operating temperature	T_{opr}	Regular specifications: -20 to +75
Operating temperature (flash memory programming/erasing)	T_{opr}	Regular specifications: 0 to +75
Storage temperature	T_{stg}	-55 to +125

Caution: Permanent damage to the chip may result if absolute maximum ratings are exceeded.

Note: * Power supply voltage for VCC1 and VCC2 pins.

Item		Symbol	Min	Typ	Max	Unit
Schmitt trigger input voltage	P67 to P60(KWUL = 00) ^{*2 *6} , KIN15 to KIN8 ^{*7 *8} , IRQ2 to IRQ0 ^{*3} , IRQ5 to 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	RES, STBY, NMI, MD1, MD0 EXTAL PA7 to PA0 ^{*7} Port 7 Input pins except (1) and (2) above	(2) V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V
			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	
			$V_{CC}B \times 0.7$	—	$V_{CC}B + 0.3$	
			2.0	—	$AV_{CC} + 0.3$	
			2.0	—	$V_{CC} + 0.3$	

Output high voltage	All output pins (except P97, and P52 ^{*4} , ^{*5} ^{*8})	V_{OH}	$V_{CC} - 0.5$	—	—	V	I_{OH}	
			$V_{CC}B - 0.5$					
			3.5	—	—	V	I_{OH}	
Output low voltage	All output pins (except \overline{RESO}) ^{*5}	V_{OL}	—	—	0.4	V	I_{OL}	
			Ports 1 to 3	—	—	1.0	V	I_{OL}
			\overline{RESO}	—	—	0.4	V	I_{OL}
Input leakage current	\overline{RES}	$ I_{in} $	—	—	10.0	μA	V	
	\overline{STBY} , NMI, MD1, MD0		—	—	1.0	μA	V	
	Port 7		—	—	1.0	μA	V	
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A ^{*8} , B	$ I_{TSL} $	—	—	1.0	μA	V	
Input pull-up MOS current	Ports 1 to 3	$-I_P$	50	—	300	μA	V	
	Ports A ^{*8} , B, Port 6 (P6PUE = 0)		60	—	500	μA	V	
	Port 6 (P6PUE = 1)		15	—	150	μA	V	

		(4) above				
Current dissipation ^{*9}	Normal operation	I_{CC}	—	75	100	mA
	Sleep mode		—	60	85	mA
	Standby mode ^{*10}		—	0.01	5.0	μ A
				—	—	20.0
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA
	Idle		—	0.01	5.0	μ A
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	mA
	Idle		—	0.01	5.0	μ A
Analog power supply voltage ^{*11}	AV_{CC}	4.5	—	5.5	V	
		2.0	—	5.5	V	
RAM standby voltage	V_{RAM}	2.0	—	—	V	

Notes: 1. **Do not leave the AVCC, AV_{ref}, and AVSS pins open even if the A/D converter and D/A converter are not used.**

Even if the A/D converter and D/A converter are not used, apply a value in the range of 2.0 V to 5.5 V to AVCC and AV_{ref} pins by connection to the power supply (V_{CC}) by other method. Ensure that AV_{ref} ≤ AV_{CC}.

- P67 to P60 include supporting module inputs multiplexed on those pins.
- IRQ2 includes the ADTRG signal multiplexed on that pin.
- In the H8S/2147N, P52/SCK0/SCL0 and P97/SDA0 are NMOS push-pull outputs. An external pull-up resistor is necessary to provide high-level output from SDA0 (ICE = 1).
In the H8S/2147N, P52/SCK0 and P97 (ICE = 0) high levels are driven by I_{OH}.
- When IICS = 0, ICE = 0, and KBIOE = 0. Low-level output when the bus driver is selected is determined separately.

10. The values are for $V_{RAM} \leq V_{CC} < 4.5V$, $V_{IH\ min} = V_{CC} \times 0.9$, $V_{CCB} \times 0.9$, and $V_{IL} = 0.3V$.
11. For flash memory program/erase operations, the applicable range is $T_a = 0$ to 70 (regular specifications).

voltage	00), KIN15 to KIN8 ^{*7 *8} , IRQ2 to IRQ0 ^{*3} , IRQ5 to IRQ3		V_T^+	—	—	$V_{CC} \times 0.7$	V
						$V_{CC}B \times 0.7$	
			$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—	V
				$V_{CC}B \times 0.05$			
Schmitt trigger input voltage (in level swiching) ^{*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	RES, STBY, NMI, MD1, MD0	(2)	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V
	EXTAL			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V
	PA7 to PA0 ^{*7}			$V_{CC}B \times 0.7$	—	$V_{CC}B + 0.3$	V
	Port 7			$V_{CC} \times 0.7$	—	$AV_{CC} + 0.3$	V
	Input pins except (1) and (2) above			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V

	NMI, EXTAL, input pins except (1) and (3) above		-0.3	—	$V_{CC} \times 0.2$	V	4 5	
Output high voltage	All output pins (except P97, and P52 ^{*4})*5 *8	V_{OH}	$V_{CC} - 0.5$	—	—	V	I_{O1}	
			$V_{CC}B - 0.5$					
			$V_{CC} - 1.0$	—	—	V	I_{O2} (M) to =	
			$V_{CC}B - 1.0$				4	
	P97, P52 ^{*4}		1.0	—	—	V	I_{O3}	
Output low voltage	All output pins (except RESO)*5	V_{OL}	—	—	0.4	V	I_{O4}	
			Ports 1 to 3	—	—	1.0	V	I_{O5} (M) I_{O6} (4) 5
			RESO	—	—	0.4	V	I_{O7}
Input leakage current	RES	$ I_{in} $	—	—	10.0	μA	V	
	STBY, NMI, MD1, MD0		—	—	1.0	μA	V	
	Port 7		—	—	1.0	μA	V A	
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A ^{*8} , B	$ I_{TSI} $	—	—	1.0	μA	V V V V	

Input capacitance	RES (4)	C_{in}	—	—	80	pF
	NMI		—	—	50	pF
	P52, P97, P42, P86, PA7 to PA2		—	—	20	pF
	Input pins except (4) above		—	—	15	pF
Current dissipation ^{*9}	Normal operation	I_{CC}	—	45	60	mA
	Sleep mode		—	35	50	mA
	Standby mode ^{*10}		—	0.01	5.0	μ A
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA
	Idle		—	0.01	5.0	μ A
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	mA
	Idle		—	0.01	5.0	μ A
Analog power supply voltage ^{*11}	AV_{CC}		3.0	—	5.5	V
			2.0	—	5.5	V
RAM standby voltage	V_{RAM}		2.0	—	—	V

Notes: 1. **Do not leave the AVCC, AV_{ref}, and AVSS pins open even if the A/D converter and D/A converter are not used.**

Even if the A/D converter and D/A converter are not used, apply a value in the range of 2.0 V to 5.5 V to AVCC and AV_{ref} pins by connection to the power supply (V_{CC}) by other method. Ensure that AV_{ref} ≤ AV_{CC}.

- P67 to P60 include supporting module inputs multiplexed on those pins.
- IRQ2 includes the ADTRG signal multiplexed on that pin.

7. The upper limit of the port A applied voltage is $V_{CC}B + 0.3$ V when CIN input is selected, and the lower of $V_{CC}B + 0.3$ V and $AV_{CC} + 0.3$ V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
8. The port A characteristics depend on $V_{CC}B$, and the other pins characteristics depend on V_{CC} .
9. Current dissipation values are for V_{IH} min = $V_{CC} - 0.5$ V, $V_{CC}B - 0.5$ V, and V_{IL} min = $V_{CC} - 0.5$ V with all output pins unloaded and the on-chip pull-up MOSs in the off state.
10. The values are for $V_{RAM} \leq V_{CC} < 3.0$ V, V_{IH} min = $V_{CC} \times 0.9$, $V_{CC}B \times 0.9$, and V_{IL} min = $V_{CC} - 0.3$ V.
11. For flash memory program/erase operations, the applicable ranges are $V_{CC} = 3.6$ V and $T_a = 0$ to $+75^{\circ}\text{C}$.

	function selected)		—	—	10
	Ports 1, 2, 3		—	—	3
	$\overline{\text{RESO}}$		—	—	2
	Other output pins		—	—	80
Permissible output low current (total)	Total of ports 1, 2, and 3	$\sum I_{OL}$	—	—	120
	Total of all output pins, including the above		—	—	2
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	40
Permissible output high current (total)	Total of all output pins	$\sum -I_{OH}$	—	—	

	RESO		—	—	1
	Other output pins		—	—	1
Permissible output low current (total)	Total of ports 1, 2, and 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 26.1.
 2. When driving a Darlington pair or LED, always insert a current-limiting resistor on the output line, as shown in figures 26.1 and 26.2.

	$V_T - V_T$	$V_{CC} \times 0.05$	—	—		$V_{CC} = 3.0$
Input high voltage	V_{IH}	$V_{CC} \times 0.7$	—	$V_{CC} + 0.5$	V	$V_{CC} = 3.0$
Input low voltage	V_{IL}	-0.5	—	$V_{CC} \times 0.3$		$V_{CC} = 3.0$
Output low voltage	V_{OL}	—	—	0.8	V	$I_{OL} = 16$ mA, $V_{CC} = 4.5$ V
				0.5		$I_{OL} = 8$ mA
				0.4		$I_{OL} = 3$ mA
Input capacitance	C_{in}	—	—	20	pF	$V_{in} = 0$ V, $T_a = 25^\circ\text{C}$
Three-state leakage current (off state)	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5$ to 1.5 V
SCL, SDA output fall time	t_{of}	$20 + 0.1 C_b$	—	250	ns	$V_{CC} = 3.0$ V

Conditions: $V_{CC} = 3.0$ V to 5.5 V, $V_{CCB} = 3.0$ V to 5.5 V, $V_{SS} = 0$ V

Applicable Pins: PS2AC, PS2AD, PS2BC, PS2BD, PS2CC, PS2CD, PA7 to PA4 (bus function selected)

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Output low voltage	V_{OL}	—	—	0.8	V	$I_{OL} = 16$ mA, $V_{CCB} = 4.5$ V
				0.5		$I_{OL} = 8$ mA
				0.4		$I_{OL} = 3$ mA

26.4.3 AC Characteristics

Clock timing, control signal timing, bus timing, and timing of on-chip supporting modes are described in the following.

Figure 26.4 shows the test conditions for the AC characteristics.

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{CCB} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Condition B: $V_{CC} = 3.0 \text{ V}$ to 5.5 V , $V_{CCB} = 3.0 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Unit	Test Condition
		20 MHz		10 MHz			
		Min	Max	Min	Max		
Clock cycle time	t_{cyc}	50	500	100	500	ns	Fig. 10
Clock high pulse width	t_{CH}	17	—	30	—	ns	Fig. 10
Clock low pulse width	t_{CL}	17	—	30	—	ns	
Clock rise time	t_{Cr}	—	8	—	20	ns	
Clock fall time	t_{Cf}	—	8	—	20	ns	
Oscillation settling time at reset (crystal)	t_{OSC1}	10	—	20	—	ms	Fig. 11
Oscillation settling time in software standby (crystal)	t_{OSC2}	8	—	8	—	ms	
External clock output stabilization delay time	t_{DEXT}	500	—	500	—	μs	

Condition B: $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $V_{CCB} = 3.0\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$
 maximum operating frequency, $T_a = -20\text{ to }+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Unit	T C
		20 MHz		10 MHz			
		Min	Max	Min	Max		
RES setup time	t_{RESS}	200	—	300	—	ns	F
RES pulse width	t_{RESW}	20	—	20	—	t_{cyc}	F
NMI setup time (NMI)	t_{NMIS}	150	—	250	—	ns	F
NMI hold time (NMI)	t_{NMIH}	10	—	10	—	ns	
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	200	—	ns	
IRQ setup time (IRQ7 to IRQ0)	t_{IRQS}	150	—	250	—	ns	
IRQ hold time (IRQ7 to IRQ0)	t_{IRQH}	10	—	10	—	ns	
IRQ pulse width (IRQ7, IRQ6, IRQ2 to IRQ0) (exiting software standby mode)	t_{IRQW}	200	—	200	—	ns	

Condition B: $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $V_{CCB} = 3.0\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz to m}$
operating frequency, $T_a = -20\text{ to }+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Unit	Te Co Fig to fig
		20 MHz		10 MHz			
		Min	Max	Min	Max		
Address delay time	t_{AD}	—	20	—	40	ns	
Address setup time	t_{AS}	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 30$	—	ns	
Address hold time	t_{AH}	$0.5 \times t_{cyc} - 10$	—	$0.5 \times t_{cyc} - 20$	—	ns	
\overline{CS} delay time (IOS)	t_{CSD}	—	20	—	40	ns	
\overline{AS} delay time	t_{ASD}	—	30	—	60	ns	
\overline{RD} delay time 1	t_{RSD1}	—	30	—	60	ns	
\overline{RD} delay time 2	t_{RSD2}	—	30	—	60	ns	
Read data setup time	t_{RDS}	15	—	35	—	ns	
Read data hold time	t_{RDH}	0	—	0	—	ns	

time 2						
Read data access time 3	t_{ACC3}	—	$2.0 \times$ $t_{cyc} -30$	—	$2.0 \times$ $t_{cyc} -60$	ns
Read data access time 4	t_{ACC4}	—	$2.5 \times$ $t_{cyc} -25$	—	$2.5 \times$ $t_{cyc} -50$	ns
Read data access time 5	t_{ACC5}	—	$3.0 \times$ $t_{cyc} -30$	—	$3.0 \times$ $t_{cyc} -60$	ns
\overline{WR} delay time 1	t_{WRD1}	—	30	—	60	ns
\overline{WR} delay time 2	t_{WRD2}	—	30	—	60	ns
\overline{WR} pulse width 1	t_{WSW1}	$1.0 \times$ $t_{cyc} -20$	—	$1.0 \times$ $t_{cyc} -40$	—	ns
\overline{WR} pulse width 2	t_{WSW2}	$1.5 \times$ $t_{cyc} -20$	—	$1.5 \times$ $t_{cyc} -40$	—	ns
Write data delay time	t_{WDD}	—	30	—	60	ns
Write data setup time	t_{WDS}	0	—	0	—	ns
Write data hold time	t_{WDH}	10	—	20	—	ns
\overline{WAIT} setup time	t_{WTS}	30	—	60	—	ns
\overline{WAIT} hold time	t_{WTH}	5	—	10	—	ns

Item	Symbol	20 MHz		10 MHz		Unit	Te Co Fig to fig
		Min	Max	Min	Max		
Address delay time	t_{AD}	—	30	—	60	ns	
Address setup time	t_{AS}	$0.5 \times t_{cyc} - 25$	—	$0.5 \times t_{cyc} - 50$	—	ns	
Address hold time	t_{AH}	$0.5 \times t_{cyc} - 10$	—	$0.5 \times t_{cyc} - 20$	—	ns	
\overline{CS} delay time (IOS)	t_{CSD}	—	30	—	60	ns	
\overline{AS} delay time	t_{ASD}	—	30	—	60	ns	
\overline{RD} delay time 1	t_{RSD1}	—	30	—	60	ns	
\overline{RD} delay time 2	t_{RSD2}	—	30	—	60	ns	
Read data setup time	t_{RDS}	15	—	35	—	ns	
Read data hold time	t_{RDH}	0	—	0	—	ns	
Read data access time 1	t_{ACC1}	—	$1.0 \times t_{cyc} - 40$	—	$1.0 \times t_{cyc} - 80$	ns	
Read data access time 2	t_{ACC2}	—	$1.5 \times t_{cyc} - 25$	—	$1.5 \times t_{cyc} - 50$	ns	

time 4						
Read data access time 5	t_{ACC5}	—	$3.0 \times t_{cyc} - 40$	—	$3.0 \times t_{cyc} - 80$	ns
\overline{WR} delay time 1	t_{WRD1}	—	30	—	60	ns
\overline{WR} delay time 2	t_{WRD2}	—	30	—	60	ns
\overline{WR} pulse width 1	t_{WSW1}	$1.0 \times t_{cyc} - 20$	—	$1.0 \times t_{cyc} - 40$	—	ns
\overline{WR} pulse width 2	t_{WSW2}	$1.5 \times t_{cyc} - 20$	—	$1.5 \times t_{cyc} - 40$	—	ns
Write data delay time	t_{WDD}	—	30	—	60	ns
Write data setup time	t_{WDS}	0	—	0	—	ns
Write data hold time	t_{WDH}	10	—	20	—	ns
\overline{WAIT} setup time	t_{WTS}	30	—	60	—	ns
\overline{WAIT} hold time	t_{WTH}	5	—	10	—	ns

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{CC}B = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 20 MHz maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$

Condition B: $V_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$, $V_{CC}B = 3.0 \text{ V to } 5.5 \text{ V}$, $V_{SS} = 0 \text{ V}$, $\phi = 32.768 \text{ kHz}$, 10 MHz maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Unit	
		20 MHz		10 MHz			
		Min	Max	Min	Max		
I/O ports	Output data delay time	t_{PWD}	—	50	—	100	ns
	Input data setup time	t_{PRS}	30	—	50	—	
	Input data hold time	t_{PRH}	30	—	50	—	
FRT	Timer output delay time	t_{FTOD}	—	50	—	100	ns
	Timer input setup time	t_{FTIS}	30	—	50	—	
	Timer clock input setup time	t_{FTCS}	30	—	50	—	
	Timer clock pulse width	Single edge	t_{FTCWH}	1.5	—	1.5	—
Both edges		t_{FTCWL}	2.5	—	2.5	—	

	setup time							
	Timer clock pulse width	Single edge Both edges	t_{TMCWH} t_{TMCWL}	1.5 2.5	— —	1.5 2.5	— —	t_{cyc}
PWM, PWMX	Pulse output delay time		t_{PWOD}	—	50	—	100	ns
SCI	Input clock cycle	Asynchronous	t_{Scyc}	4	—	4	—	t_{cyc}
		Synchronous		6	—	6	—	
	Input clock pulse width		t_{SCKW}	0.4	0.6	0.4	0.6	t_{Scyc}
	Input clock rise time		t_{SCKr}	—	1.5	—	1.5	t_{cyc}
	Input clock fall time		t_{SCKf}	—	1.5	—	1.5	
	Transmit data delay time (synchronous)		t_{TXD}	—	50	—	100	ns
	Receive data setup time (synchronous)		t_{RXS}	50	—	100	—	ns
	Receive data hold time (synchronous)		t_{RXH}	50	—	100	—	ns
A/D converter	Trigger input setup time		t_{TRGS}	30	—	50	—	ns
WDT	RES0 output delay time		t_{RESD}	—	100	—	200	ns
	RES0 output pulse width		t_{RESOW}	132	—	132	—	t_{cyc}

Note: * Only supporting modules that can be used in subclock operation

Item	Symbol	Condition A		Condition B		Unit		
		Min	Max	Min	Max			
		20 MHz		10 MHz				
HIF read cycle	$\overline{\text{CS}}/\text{HA0}$ setup time	t_{HAR}	10	—	10	—	ns	
	$\overline{\text{CS}}/\text{HA0}$ hold time	t_{HRA}	10	—	10	—	ns	
	$\overline{\text{IO}}\overline{\text{R}}$ pulse width	t_{HRPW}	120	—	220	—	ns	
	HDB delay time	t_{HRD}	—	100	—	200	ns	
	HDB hold time	t_{HRF}	0	25	0	40	ns	
	HIRQ delay time	t_{HIRQ}	—	120	—	200	ns	
HIF write cycle	$\overline{\text{CS}}/\text{HA0}$ setup time	t_{HAW}	10	—	10	—	ns	
	$\overline{\text{CS}}/\text{HA0}$ hold time	t_{HWA}	10	—	10	—	ns	
	$\overline{\text{IO}}\overline{\text{W}}$ pulse width	t_{HWPW}	60	—	100	—	ns	
	HDB setup time	Fast A20 gate not used	t_{HDW}	30	—	50	—	ns
		Fast A20 gate used		45	—	85	—	ns
	HDB hold time	t_{HWD}	15	—	25	—	ns	
	GA20 delay time	t_{HGA}	—	90	—	180	ns	

KCLK, KD input data hold time	t_{KBH}	150	—	—	ns
KCLK, KD input data setup time	t_{KBS}	150	—	—	ns
KCLK, KD output delay time	t_{KBOD}	—	—	450	ns
KCLK, KD capacitive load	C_b	—	—	400	pF

SCL input high pulse width	t_{SCLH}	5	—	—	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 16.4, Usage Notes.

$T_a = -20$ to $+75^\circ\text{C}$

Condition B: $V_{CC} = 3.0$ V to 5.5 V, $AV_{CC} = 3.0$ V to 5.5 V, $AV_{ref} = 3.0$ V to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0$ V, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Condition A			Condition B		
	20 MHz			10 MHz		
	Min	Typ	Max	Min	Typ	Max
Resolution	10	10	10	10	10	10
Conversion time ^{*5}	—	—	6.7	—	—	13.4
Analog input capacitance	—	—	20	—	—	20
Permissible signal-source impedance	—	—	$\frac{10^{*3}}{5^{*4}}$	—	—	$\frac{10^{*1}}{5^{*2}}$
Nonlinearity error	—	—	± 3.0	—	—	± 7.0
Offset error	—	—	± 3.5	—	—	± 7.5
Full-scale error	—	—	± 3.5	—	—	± 7.5
Quantization error	—	—	± 0.5	—	—	± 0.5
Absolute accuracy	—	—	± 4.0	—	—	± 8.0

- Notes: 1. When 4.0 V $\leq AV_{CC} \leq 5.5$ V
2. When 3.0 V $\leq AV_{CC} < 4.0$ V
3. When conversion time ≥ 11.17 μs (CKS = 1 and $\phi \leq 12$ MHz, or CKS = 0)
4. When conversion time < 11.17 μs (CKS = 1 and $\phi > 12$ MHz)
5. In single mode and $\phi =$ maximum operating frequency.

T_a = -20 to +75°C

Item	Condition A			Condition B		
	20 MHz			10 MHz		
	Min	Typ	Max	Min	Typ	Max
Resolution	10	10	10	10	10	10
Conversion time ^{*5}	—	—	6.7	—	—	13.4
Analog input capacitance	—	—	20	—	—	20
Permissible signal-source impedance	—	—	$\frac{10^{*3}}{5^{*4}}$	—	—	$\frac{10^{*1}}{5^{*2}}$
Nonlinearity error	—	—	±5.0	—	—	±11.0
Offset error	—	—	±5.5	—	—	±11.5
Full-scale error	—	—	±5.5	—	—	±11.5
Quantization error	—	—	±0.5	—	—	±0.5
Absolute accuracy	—	—	±6.0	—	—	±12.0

Notes: 1. When $4.0\text{ V} \leq AV_{CC} \leq 5.5\text{ V}$

2. When $3.0\text{ V} \leq AV_{CC} < 4.0\text{ V}$

3. When conversion time $\geq 11.17\text{ }\mu\text{s}$ (CKS = 1 and $\phi \leq 12\text{ MHz}$, or CKS = 0)

4. When conversion time $< 11.17\text{ }\mu\text{s}$ (CKS = 1 and $\phi > 12\text{ MHz}$)

5. In single mode and ϕ = maximum operating frequency.

$T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 3.0$ V to 5.5 V, $AV_{CC} = 3.0$ V to 5.5 V, $AV_{ref} = 3.0$ V to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0$ V, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item		Condition A			Condition B		
		20 MHz			10 MHz		
		Min	Typ	Max	Min	Typ	Max
Resolution		8	8	8	8	8	8
Conversion time	With 20-pF load capacitance	—	—	10	—	—	10
Absolute accuracy	With 2-M Ω load resistance	—	± 1.0	± 1.5	—	± 2.0	± 3.0
	With 4-M Ω load resistance	—	—	± 1.0	—	—	± 2.0

Item	Symbol	Min	Typ	Max	Unit	
Programming time ^{*1 *2 *4}	tP	—	10	200	ms/ 32 bytes	
Erase time ^{*1 *3 *6}	tE	—	100	1200	ms/ block	
Reprogramming count	N _{WEC}	100 ^{*8}	10000 ^{*9}	—	Times	
Data retention time ^{*10}	t _{DRP}	10	—	—	Years	
Programming	Wait time after SWE-bit setting ^{*1}	x	10	—	—	μs
	Wait time after PSU-bit setting ^{*1}	y	50	—	—	μs
	Wait time after P-bit setting ^{*1 *4}	z	150	—	200	μs
	Wait time after P-bit clear ^{*1}	α	10	—	—	μs
	Wait time after PSU-bit clear ^{*1}	β	10	—	—	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	4	—	—	μs
	Maximum programming count ^{*1 *4 *5}	N	—	—	1000	Times
Erase	Wait time after SWE-bit setting ^{*1}	x	10	—	—	μs
	Wait time after ESU-bit setting ^{*1}	y	200	—	—	μs
	Wait time after E-bit setting ^{*1 *6}	z	5	—	10	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	5	—	—	μs
Maximum erase count ^{*1 *6 *7}	N	—	—	120	Times	

- Notes: 1. Set the times according to the program/erase algorithms.
2. Programming time per 32 bytes (Shows the total period for which the P-bit is set. It does not include the programming verification time.)

7. Number of times when the wait time after E-bit setting (z) = 10 ms.
The number of erases should be set according to the actual set value of (z) erasing within the maximum erase time ($tE(\max)$).
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 function value).
10. Data retention characteristic when rewriting is performed within the specific including the minimum value.

26.4.7 Usage Note

- (1) The F-ZTAT and mask ROM versions have been confirmed as fully meeting the r values for electrical characteristics shown in this manual. However, actual perform figures, operating margins, noise margins, and other properties may vary due to di the manufacturing process, on-chip ROM, layout patterns, etc.
When system evaluation testing is carried out using the F-ZTAT version, the same tests should also be conducted for the mask ROM version when changing over to t
- (2) On-chip power supply step-down circuit
The H8S/2147N F-ZTAT does not incorporate an internal power supply step-down. When changing over to F-ZTAT versions or mask ROM versions incorporating an step-down circuit, the VCC2 pin has the same pin location as the VCL pin in a step circuit (See figure 26.3).
Therefore, note that the circuit patterns differ between these two types of products

Item	Symbol	Value
Power supply voltage*	V_{CC}	-0.3 to +7.0
Input voltage (except ports 6, 7, and A)	V_{in}	-0.3 to $V_{CC} + 0.3$
Input voltage (CIN input not selected for port 6 and A)	V_{in}	-0.3 to $V_{CC} + 0.3$
Input voltage (CIN input selected for port 6 and A)	V_{in}	-0.3 V to lower of voltages $V_{CC} + 0.3$ and $AV_{CC} + 0.3$
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 input voltage	V_{AN}	-0.3 to $AV_{CC} + 0.3$
Operating temperature	T_{opr}	Regular specifications: -20 to +75 Wide-range specifications: -40 to +85
Operating temperature (flash memory programming/erasing)	T_{opr}	Regular specifications: 0 to +75 Wide-range specifications: 0 to +85
Storage temperature	T_{stg}	-55 to +125

Caution: Permanent damage to the chip may result if absolute maximum ratings are exceeded.

Note: * Power supply voltage for VCC1 and VCC2 pins.

Item		Symbol	Min	Typ	Max	Unit	
Schmitt trigger input voltage	P67 to P60*2*5, (1)	V _T ⁻	1.0	—	—	V	
	KIN15 to KIN8*5, IRQ2 to IRQ0*3, IRQ5 to IRQ3	V _T ⁺	—	—	V _{CC} × 0.7	V	
		V _T ⁺ - V _T ⁻	0.4	—	—	V	
Input high voltage	RES, STBY, (2)	V _{IH}	V _{CC} - 0.7	—	V _{CC} + 0.3	V	
	NMI, MD1, MD0						
	EXTAL, PA7 to PA0*5		V _{CC} × 0.7	—	V _{CC} + 0.3	V	
	Port 7		2.0	—	A V _{CC} + 0.3	V	
	Input pins except (1) and (2) above		2.0	—	V _{CC} + 0.3	V	
Input low voltage	RES, STBY, (3)	V _{IL}	-0.3	—	0.5	V	
	MD1, MD0						
	PA7 to PA0		-0.3	—	1.0	V	
	NMI, EXTAL, input pins except (1) and (3) above		-0.3	—	0.8	V	
Output high voltage	All output pins*4	V _{OH}	V _{CC} - 0.5	—	—	V	
			3.5	—	—	V	
Output low voltage	All output pins (except RESO)*4	V _{OL}	—	—	0.4	V	
			Ports 1 to 3	—	—	1.0	V
			RESO	—	—	0.4	V

Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A, B	$ I_{TS1} $	—	—	1.0	μA	V	
Input pull-up MOS current	Ports 1 to 3	$-I_p$	50	—	300	μA	V	
	Ports 6, A, B		60	—	500	μA		
Input capacitance	$\overline{\text{RES}}$	(4) C_{in}	—	—	80	pF	V	
	$\overline{\text{NMI}}$		—	—	50	pF	f	
	P52, P97, P42, P86 PA7 to PA2		—	—	20	pF	T	
	Input pins except (4) above		—	—	15	pF		
Current dissipation* ⁶	Normal operation	I_{CC}	—	75	100	mA	f	
	Sleep mode		—	60	85	mA		
	Standby mode* ⁷			—	0.01	5.0	μA	T
				—	—	20.0	μA	5
Analog power supply current	During A/D, D/A conversion	$A I_{CC}$	—	1.2	2.0	mA		
	Idle		—	0.01	5.0	μA	A	
Reference power supply current	During A/D conversion	$A I_{ref}$	—	0.5	1.0	mA		
	During A/D, D/A conversion		—	2.0	5.0	mA		
	Idle		—	0.01	5.0	μA	A	

2.0 V to 5.5 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}), or by other method. Ensure that AV_{ref} ≤ AV_{CC}.

2. P67 to P60 include supporting module inputs multiplexed on those pins.
3. $\overline{\text{IRQ2}}$ includes the $\overline{\text{ADTRG}}$ signal multiplexed on that pin.
4. When IICS = 0. Low-level output when the bus drive function is selected is separately.
5. The upper limit of the applied voltage on Ports 6 and A is V_{CC} +0.3 V when not selected, and the lower of V_{CC} +0.3 V and AV_{CC} +0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
6. Current dissipation values are for V_{IH} min = V_{CC} -0.5 V, and V_{IL} max = 0.5 V when output pins unloaded and the on-chip pull-up MOSs in the off state.
7. The values are for V_{RAM} ≤ V_{CC} < 4.5V, V_{IH} min = V_{CC} × 0.9, and V_{IL} max = 0.3 V.
8. For flash memory program/erase operations, the applicable range is T_a = 0 to +85°C (regular specifications) or T_a = 0 to +85°C (wide-range specifications).

trigger input voltage	KIN15 to KIN8 ^{*5} , IRQ2 to IRQ0 ^{*3} , IRQ5 to IRQ3		V_T^+	—	—	$V_{CC} \times 0.7$	V	5.
			$V_T^+ - V_T^-$	0.4	—	—	V	4.
			V_T^-	0.8	—	—	V	V _{CC}
			V_T^+	—	—	$V_{CC} \times 0.7$	V	V _{CC}
			$V_T^+ - V_T^-$	0.3	—	—	V	V _{CC}
Input high voltage	RES, STBY, NMI, MD1, MD0	(2)	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V	V _{CC}
	EXTAL, PA7 to PA0 ^{*5}			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	V _{CC}
	Port 7			2.0	—	$AV_{CC} + 0.3$	V	V _{CC}
	Input pins except (1) and (2) above			2.0	—	$V_{CC} + 0.3$	V	V _{CC}
Input low voltage	RES, STBY, MD1, MD0	(3)	V_{IL}	-0.3	—	0.5	V	V _{CC}
	PA7 to PA0			-0.3	—	1.0	V	V _{CC}
				-0.3	—	0.8	V	V _{CC}
	NMI, EXTAL, input pins except (1) and (3) above			-0.3	—	0.8	V	V _{CC}
Output high voltage	All output pins ^{*4}		V_{OH}	$V_{CC} - 0.5$	—	—	V	I_{OH}
				3.5	—	—	V	I_{OH}
				3.0	—	—	V	I_{OH}

current	MD1, MD0		—	—	1.0	μA	V
	Port 7		—	—	1.0	μA	A
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A, B	$ I_{TSI} $	—	—	1.0	μA	V
Input pull-up MOS current	Ports 1 to 3	$-I_p$	50	—	300	μA	V
	Ports 6, A, B		60	—	500	μA	V
	Ports 1 to 3		30	—	200	μA	V
	Ports 6, A, B		40	—	400	μA	V
Input capacitance	\overline{RES}	(4) C_{in}	—	—	80	pF	V
	NMI		—	—	50	pF	f
	P52, P97, P42, P86, PA7 to PA2		—	—	20	pF	T
	Input pins except (4) above		—	—	15	pF	
Current dissipation* ⁶	Normal operation	I_{cc}	—	65	85	mA	f
	Sleep mode		—	50	70	mA	f
	Standby mode* ⁷		—	0.01	5.0	μA	T
			—	—	20.0	μA	5
Analog power supply current	During A/D, D/A conversion	AI_{cc}	—	1.2	2.0	mA	
	Idle		—	0.01	5.0	μA	A
							t

RAM standby voltage	V_{RAM}	2.0	—	5.5	V	Id
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Notes: 1. **Do not leave the AVCC, AV_{ref}, and AVSS pins open even if the A/D converter and D/A converter are not used.**

Even if the A/D converter and D/A converter are not used, apply a value in the 2.0 V to 5.5 V to AVCC and AV_{ref} pins by connection to the power supply (V_{CC}) or other method. Ensure that AV_{ref} ≤ AV_{CC}.

2. P67 to P60 include supporting module inputs multiplexed on those pins.
3. $\overline{IRQ2}$ includes the \overline{ADTRG} signal multiplexed on that pin.
4. When IICS = 0. Low-level output when the bus drive function is selected is determined separately.
5. The upper limit of the applied voltage on Ports 6 and A is V_{CC} +0.3 V when CIN is not selected, and the lower of V_{CC} +0.3 V and AV_{CC} +0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
6. Current dissipation values are for V_{IH} min = V_{CC} -0.5 V, and V_{IL} max = 0.5 V on all output pins unloaded and the on-chip pull-up MOSs in the off state.
7. The values are for V_{RAM} ≤ V_{CC} < 4.0 V, V_{IH} min = V_{CC} × 0.9, and V_{IL} max = 0.3 V.
8. For flash memory program/erase operations, the applicable ranges are V_{CC} = 2.7 V to 5.5 V and T_a = 0 to +75°C (regular specifications) or T_a = 0 to +85°C (wide-range specifications).

Item		Symbol	Min	Typ	Max	Unit	
Schmitt trigger input voltage	P67 to P60* ² * ⁵ , KIN15 to KIN8* ⁵ , IRQ2 to IRQ0* ³ , IRQ5 to IRQ3	(1)	V_T^-	$V_{CC} \times 0.2$	—	V	
			V_T^+	—	$V_{CC} \times 0.7$	V	
			$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	V	
Input high voltage	RES, STBY, NMI, MD1, MD0 EXTAL, PA7 to PA0* ⁵ Port 7 Input pins except (1) and (2) above	(2)	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V
				$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V
				$V_{CC} \times 0.7$	—	$AV_{CC} + 0.3$	V
				$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V
Input low voltage	RES, STBY, MD1, MD0 PA7 to PA0 NMI, EXTAL, input pins except (1) and (3) above	(3)	V_{IL}	-0.3	—	$V_{CC} \times 0.1$	V
				-0.3	—	$V_{CC} \times 0.2$	V
						0.8	V
				-0.3	—	$V_{CC} \times 0.2$	V
					0.8	V	
Output high voltage	All output pins* ⁴		V_{OH}	$V_{CC} - 0.5$	—	V	
				$V_{CC} - 1.0$	—	V	

	$\overline{\text{RES}}$		—	—	0.4	V	I_{cc}
Input leakage current	$\overline{\text{RES}}$	$ I_{in} $	—	—	10.0	μA	V
	$\overline{\text{STBY}}$, NMI, MD1, MD0		—	—	1.0	μA	V
	Port 7		—	—	1.0	μA	V A
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A, B	$ I_{TSL} $	—	—	1.0	μA	V V
Input pull-up MOS current	Ports 1 to 3	$-I_p$	10	—	150	μA	V
	Ports 6, A, B		30	—	250	μA	V tc
Input capacitance	$\overline{\text{RES}}$	(4) C_{in}	—	—	80	pF	V f
	NMI		—	—	50	pF	T
	P52, P97, P42, P86, PA7 to PA2		—	—	20	pF	
	Input pins except (4) above		—	—	15	pF	
Current dissipation* ⁶	Normal operation	I_{cc}	—	45	60	mA	f
	Sleep mode		—	35	50	mA	
	Standby mode* ⁷		—	0.01	5.0	μA	T
Analog power supply current	During A/D, D/A conversion	AI_{cc}	—	1.2	2.0	mA	5
	Idle		—	0.01	5.0	μA	A o

		3.0	—	5.5	V
		2.0	—	5.5	V
RAM standby voltage	V_{RAM}	2.0	—	—	V

Notes: 1. **Do not leave the AVCC, AV_{ref}, and AVSS pins open even if the A/D converter and D/A converter are not used.**

Even if the A/D converter and D/A converter are not used, apply a value in the range of 2.0 V to 5.5 V to AVCC and AV_{ref} pins by connection to the power supply (V_{CC}) or other method. Ensure that AV_{ref} ≤ AV_{CC}.

2. P67 to P60 include supporting module inputs multiplexed on those pins.
3. IRQ2 includes the ADTRG signal multiplexed on that pin.
4. When IICS = 0. Low-level output when the bus drive function is selected is determined separately.
5. The upper limit of the applied voltage on Ports 6 and A is V_{CC} +0.3 V when the bus drive function is not selected, and the lower of V_{CC} +0.3 V and AV_{CC} +0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
6. Current dissipation values are for V_{IH} min = V_{CC} -0.5 V, and V_{IL} max = 0.5 V when the output pins are unloaded and the on-chip pull-up MOSs are in the off state.
7. The values are for V_{RAM} ≤ V_{CC} < 2.7 V (mask ROM version), and V_{RAM} ≤ V_{CC} < 2.7 V (F-ZTAT version), V_{IH} min = V_{CC} × 0.9, and V_{IL} max = 0.3 V.
8. For flash memory program/erase operations, the applicable ranges are V_{CC} = 3.6 V and Ta = 0 to +75°C. For the F-ZTAT versions, the test condition is V_{CC} = 3.6 V and Ta = 0 to +75°C.

	<u>RESO</u>		—	—	3
	Other output pins		—	—	2
Permissible output low current (total)	Total of ports 1, 2, and 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

Conditions: $V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$ (mask ROM version), $V_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$ (F-ZTAT)
 $V_{SS} = 0 \text{ V}$, $T_a = -20 \text{ to } +75^\circ\text{C}$

Item		Symbol	Min	Typ	Max
Permissible output low current (per pin)	PA7 to PA4 (bus drive function selected)	I_{OL}	—	—	10
	Ports 1, 2, 3		—	—	2
	<u>RESO</u>		—	—	1
	Other output pins		—	—	1
Permissible output low current (total)	Total of ports 1, 2, and 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 26.2.
2. When driving a Darlington pair or LED, always insert a current-limiting resistor on the output line, as show in figures 26.1 and 26.2.

—	—	0.5	$V_{CC} = 4.5 \text{ V}$
—	—	0.4	$I_{OL} = 8 \text{ mA}$
			$I_{OL} = 3 \text{ mA}$

26.5.3 AC Characteristics

Clock timing, control signal timing, bus timing, and timing of on-chip supporting modes are described in the following.

Figure 26.4 shows the test conditions for the AC characteristics.

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency
 $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications), $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$, $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency
 $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications), $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$ (mask ROM version), $V_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$ (F-ZTA)
 $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency, $T_a = -20 \text{ to } +75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	F
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
Clock cycle time	t_{cyc}	50	500	62.5	500	100	500	ns	F
Clock high pulse width	t_{CH}	17	—	20	—	30	—	ns	F
Clock low pulse width	t_{CL}	17	—	20	—	30	—	ns	
Clock rise time	t_{Cr}	—	8	—	10	—	20	ns	
Clock fall time	t_{Cf}	—	8	—	10	—	20	ns	
Oscillation settling time at reset (crystal)	t_{OSC1}	10	—	10	—	20	—	ms	F
Oscillation settling time in software standby (crystal)	t_{OSC2}	8	—	8	—	8	—	ms	F
External clock output stabilization delay time	t_{DEXT}	500	—	500	—	500	—	μs	

range specifications)

Condition B: $V_{CC} = 4.0\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 2 MHz to maximum operating frequency, $T_a = -20\text{ to }+75^\circ\text{C}$ (regular specifications), $T_a = -40\text{ to }+85^\circ\text{C}$ (extended range specifications)

Condition C: $V_{CC} = 2.7\text{ V to }5.5\text{ V}$ (mask ROM version), $V_{CC} = 3.0\text{ V to }5.5\text{ V}$ (F-TM version), $V_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 2 MHz to maximum operating frequency, $T_a = -20\text{ to }+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	Comments
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
RES setup time	t_{RESS}	200	—	200	—	300	—	ns	F
RES pulse width	t_{RESW}	20	—	20	—	20	—	t_{cyc}	
NMI setup time (NMI)	t_{NMIS}	150	—	150	—	250	—	ns	F
NMI hold time (NMI)	t_{NMIH}	10	—	10	—	10	—	ns	
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	200	—	200	—	ns	
IRQ setup time (IRQ7 to IRQ0)	t_{IRQS}	150	—	150	—	250	—	ns	
IRQ hold time (IRQ7 to IRQ0)	t_{IRQH}	10	—	10	—	10	—	ns	
IRQ pulse width (IRQ7, IRQ6, IRQ2 to IRQ0) (exiting software standby mode)	t_{IRQW}	200	—	200	—	200	—	ns	

specifications)

Condition B: $V_{CC} = 4.0\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency, $T_a = -20\text{ to }+75^\circ\text{C}$ (regular specifications), $T_a = -40\text{ to }+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7\text{ V to }5.5\text{ V}$ (mask ROM version), $V_{CC} = 3.0\text{ V to }5.5\text{ V}$ (F-ZTA version), $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency, $T_a = -20\text{ to }+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	Comments
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
Address delay time	t_{AD}	—	20	—	30	—	40	ns	F to fi
Address setup time	t_{AS}	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 20$	—	$0.5 \times t_{cyc} - 30$	—	ns	
Address hold time	t_{AH}	$0.5 \times t_{cyc} - 10$	—	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 20$	—	ns	
\overline{CS} delay time (\overline{IOS})	t_{CSD}	—	20	—	30	—	40	ns	
\overline{AS} delay time	t_{ASD}	—	30	—	45	—	60	ns	
\overline{RD} delay time 1	t_{RSD1}	—	30	—	45	—	60	ns	
\overline{RD} delay time 2	t_{RSD2}	—	30	—	45	—	60	ns	
Read data setup time	t_{RDS}	15	—	20	—	35	—	ns	
Read data hold time	t_{RDH}	0	—	0	—	0	—	ns	

time 2								
Read data access time 3	t_{ACC3}	—	$2.0 \times$ $t_{cyc} -30$	—	$2.0 \times$ $t_{cyc} -40$	—	$2.0 \times$ $t_{cyc} -60$	ns
Read data access time 4	t_{ACC4}	—	$2.5 \times$ $t_{cyc} -25$	—	$2.5 \times$ $t_{cyc} -35$	—	$2.5 \times$ $t_{cyc} -50$	ns
Read data access time 5	t_{ACC5}	—	$3.0 \times$ $t_{cyc} -30$	—	$3.0 \times$ $t_{cyc} -40$	—	$3.0 \times$ $t_{cyc} -60$	ns
\overline{WR} delay time 1	t_{WRD1}	—	30	—	45	—	60	ns
\overline{WR} delay time 2	t_{WRD2}	—	30	—	45	—	60	ns
\overline{WR} pulse width 1	t_{WSW1}	$1.0 \times$ $t_{cyc} -20$	—	$1.0 \times$ $t_{cyc} -30$	—	$1.0 \times$ $t_{cyc} -40$	—	ns
\overline{WR} pulse width 2	t_{WSW2}	$1.5 \times$ $t_{cyc} -20$	—	$1.5 \times$ $t_{cyc} -30$	—	$1.5 \times$ $t_{cyc} -40$	—	ns
Write data delay time	t_{WDD}	—	30	—	45	—	60	ns
Write data setup time	t_{WDS}	0	—	0	—	0	—	ns
Write data hold time	t_{WDH}	10	—	15	—	20	—	ns
\overline{WAIT} setup time	t_{WTS}	30	—	45	—	60	—	ns
\overline{WAIT} hold time	t_{WTH}	5	—	5	—	10	—	ns

frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40$ to $+85^\circ\text{C}$ (range specifications)

Condition B: $V_{CC} = 4.0$ V to 5.5 V, $V_{SS} = 0$ V, $\phi = 32.768$ kHz*, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40$ to $+85^\circ\text{C}$ (range specifications)

Condition C: $V_{CC} = 2.7$ V to 5.5 V (mask ROM version), $V_{CC} = 3.0$ V to 5.5 V (F-ZTA), $V_{SS} = 0$ V, $\phi = 32.768$ kHz*, 2 MHz to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit		
		20 MHz		16 MHz		10 MHz				
		Min	Max	Min	Max	Min	Max			
I/O ports	Output data delay time	$t_{P\text{WD}}$	—	50	—	50	—	100	ns	
	Input data setup time	t_{PRS}	30	—	30	—	50	—		
	Input data hold time	t_{PRH}	30	—	30	—	50	—		
FRT	Timer output delay time	t_{FTOD}	—	50	—	50	—	100	ns	
	Timer input setup time	t_{FTIS}	30	—	30	—	50	—		
	Timer clock input setup time	t_{FTCS}	30	—	30	—	50	—		
	Timer clock pulse width	Single edge	t_{FTCWH}	1.5	—	1.5	—	1.5	—	t_{oyc}
		Both edges	t_{FTCWL}	2.5	—	2.5	—	2.5	—	

		setup time								
	Timer clock pulse width	Single edge	t_{TMCWH}	1.5	—	1.5	—	1.5	—	t_{cyc}
		Both edges	t_{TMCWL}	2.5	—	2.5	—	2.5	—	
PWMX	Pulse output delay time		t_{PWOD}	—	50	—	50	—	100	ns
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 (synchronous)		t_{TXD}	—	50	—	50	—	100	ns
	Receive data setup time (synchronous)		t_{RXS}	50	—	50	—	100	—	ns
	Receive data hold time (synchronous)		t_{RXH}	50	—	50	—	100	—	ns
A/D converter	Trigger input setup time		t_{TRGS}	30	—	30	—	50	—	ns
WDT	RES0 output delay time		t_{RESD}	—	100	—	120	—	200	ns
	RES0 output pulse width		t_{RESOW}	132	—	132	—	132	—	t_{cyc}
Note:	* Only supporting modules that can be used in subclock operation									

Condition B: $V_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$, $AV_{CC} = 4.0 \text{ V to } 5.5 \text{ V}$, $AV_{ref} = 4.0 \text{ V to } AV_{CC}$, $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz to maximum operating frequency}$, $T_a = -20 \text{ to } +75^\circ\text{C}$ (re specifications), $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition C (mask ROM version): $V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $AV_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $AV_{ref} = AV_{CC}$, $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz to maximum operating frequency}$, $T_a = -20 \text{ to } +75^\circ\text{C}$

Condition C (F-ZTAT version): $V_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$, $AV_{CC} = 3.0 \text{ V to } 5.5 \text{ V}$, $AV_{ref} = 3.0 \text{ V to } AV_{CC}$, $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz to maximum operating frequency}$, $T_a = -20 \text{ to } +75^\circ\text{C}$

Item	Condition A			Condition B			Condition C		
	20 MHz			16 MHz			10 MHz		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Resolution	10	10	10	10	10	10	10	10	10
Conversion time ^{*5}	—	—	6.7	—	—	8.4	—	—	13.4
Analog input capacitance	—	—	20	—	—	20	—	—	20
Permissible signal-source impedance	—	—	$\frac{10^{*3}}{5^{*4}}$	—	—	$\frac{10^{*3}}{5^{*4}}$	—	—	$\frac{10^{*1}}{5^{*2}}$
Nonlinearity error	—	—	± 3.0	—	—	± 3.0	—	—	± 7.0
Offset error	—	—	± 3.5	—	—	± 3.5	—	—	± 7.5
Full-scale error	—	—	± 3.5	—	—	± 3.5	—	—	± 7.5
Quantization error	—	—	± 0.5	—	—	± 0.5	—	—	± 0.5
Absolute accuracy	—	—	± 4.0	—	—	± 4.0	—	—	± 8.0

- Notes:
1. When $4.0 \text{ V} \leq AV_{CC} \leq 5.5 \text{ V}$
 2. When $2.7 \text{ V} \leq AV_{CC} < 4.0 \text{ V}$ (mask ROM version) or when $3.0 \text{ V} \leq AV_{CC} < 4.0 \text{ V}$ (version)
 3. When conversion time $\geq 11.17 \mu\text{s}$ (CKS = 1 and $\phi \leq 12 \text{ MHz}$, or CKS = 0)
 4. When conversion time $< 11.17 \mu\text{s}$ (CKS = 1 and $\phi > 12 \text{ MHz}$)
 5. In single mode and $\phi = \text{maximum operating frequency}$.

specifications), $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C (mask ROM version): $V_{cc} = 2.7\text{ V}$ to 5.5 V , $AV_{cc} = 2.7\text{ V}$ to 5.5 V , $AV_{ref} = AV_{cc}$, $V_{ss} = AV_{ss} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Condition C (F-ZTAT version): $V_{cc} = 3.0\text{ V}$ to 5.5 V , $AV_{cc} = 3.0\text{ V}$ to 5.5 V , $AV_{ref} = AV_{cc}$, $V_{ss} = AV_{ss} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Condition A			Condition B			Condition C		
	20 MHz			16 MHz			10 MHz		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Resolution	10	10	10	10	10	10	10	10	10
Conversion time ^{*5}	—	—	6.7	—	—	8.4	—	—	13.0
Analog input capacitance	—	—	20	—	—	20	—	—	20
Permissible signal-source impedance	—	—	$\frac{10^{*3}}{5^{*4}}$	—	—	$\frac{10^{*3}}{5^{*4}}$	—	—	$\frac{10^{*3}}{5^{*2}}$
Nonlinearity error	—	—	± 5.0	—	—	± 5.0	—	—	± 11.0
Offset error	—	—	± 5.5	—	—	± 5.5	—	—	± 11.0
Full-scale error	—	—	± 5.5	—	—	± 5.5	—	—	± 11.0
Quantization error	—	—	± 0.5	—	—	± 0.5	—	—	± 0.5
Absolute accuracy	—	—	± 6.0	—	—	± 6.0	—	—	± 12.0

- Notes: 1. When $4.0\text{ V} \leq AV_{cc} \leq 5.5\text{ V}$
 2. When $2.7\text{ V} \leq AV_{cc} < 4.0\text{ V}$ (mask ROM version) or when $3.0\text{ V} \leq AV_{cc} < 4.0\text{ V}$ (F-ZTAT version)
 3. When conversion time $\geq 11.17\ \mu\text{s}$ (CKS = 1 and $\phi \leq 12\text{ MHz}$, or CKS = 0)
 4. When conversion time $< 11.17\ \mu\text{s}$ (CKS = 1 and $\phi > 12\text{ MHz}$)
 5. In single mode and $\phi =$ maximum operating frequency.

Condition B: $V_{CC} = 4.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 4.0\text{ V to }5.5\text{ V}$, $AV_{ref} = 4.0\text{ V to }AV_{CC}$, $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz to maximum operating frequency}$, $T_a = -20\text{ to }+75^\circ\text{C}$ (reference specifications), $T_a = -40\text{ to }+85^\circ\text{C}$ (wide-range specifications)

Condition C (mask ROM version): $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{ref} = AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz to maximum operating frequency}$, $T_a = -20\text{ to }+75^\circ\text{C}$

Condition C (F-ZTAT version): $V_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{CC} = 3.0\text{ V to }5.5\text{ V}$, $AV_{ref} = 3.0\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz to maximum operating frequency}$, $T_a = -20\text{ to }+75^\circ\text{C}$

Item		Condition A			Condition B			Condition C		
		20 MHz			16 MHz			10 MHz		
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Resolution		8	8	8	8	8	8	8	8	8
Conversion time	With 20 pF load capacitance	—	—	10	—	—	10	—	—	10
Absolute accuracy	With 2 M Ω load resistance	—	± 1.0	± 1.5	—	± 1.0	± 1.5	—	± 2.0	± 3.0
	With 4 M Ω load resistance	—	—	± 1.0	—	—	± 1.0	—	—	± 2.0

Item	Symbol	Min	Typ	Max	Unit	
Programming time ^{*1 *2 *4}	tP	—	10	200	ms/ 32 bytes	
Erase time ^{*1 *3 *6}	tE	—	100	1200	ms/ block	
Reprogramming count	N _{WEC}	100 ^{*8}	10000 ^{*9}	—	Times	
Data retention time ^{*10}	t _{DRP}	10	—	—	Years	
Programming	Wait time after SWE-bit setting ^{*1}	x	10	—	—	μs
	Wait time after PSU-bit setting ^{*1}	y	50	—	—	μs
	Wait time after P-bit setting ^{*1 *4}	z	150	—	200	μs
	Wait time after P-bit clear ^{*1}	α	10	—	—	μs
	Wait time after PSU-bit clear ^{*1}	β	10	—	—	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	4	—	—	μs
	Maximum programming count ^{*1 *4 *5}	N	—	—	1000	Times
Erase	Wait time after SWE-bit setting ^{*1}	x	10	—	—	μs
	Wait time after ESU-bit setting ^{*1}	y	200	—	—	μs
	Wait time after E-bit setting ^{*1 *6}	z	5	—	10	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	5	—	—	μs
Maximum erase count ^{*1 *6 *7}	N	—	—	120	Times	

Notes: 1. Set the times according to the program/erase algorithms.

2. Programming time per 32 bytes (Shows the total period for which the P-bit is set. It does not include the programming verification time.)

7. Number of times when the wait time after E-bit setting (z) = 10 ms.
The number of erases should be set according to the actual set value of (z) to erasing within the maximum erase time (tE (max)).
8. Minimum number of times for which all characteristics are guaranteed after n (Guarantee range is 1 to minimum value).
9. Reference value for 25°C (as a guideline, rewriting should normally function value).
10. Data retention characteristic when rewriting is performed within the specification including the minimum value.

26.5.7 Usage Note

- (1) The F-ZTAT and mask ROM versions have been confirmed as fully meeting the reference values for electrical characteristics shown in this manual. However, actual performance figures, operating margins, noise margins, and other properties may vary due to differences in the manufacturing process, on-chip ROM, layout patterns, etc.
When system evaluation testing is carried out using the F-ZTAT version, the same tests should also be conducted for the mask ROM version when changing over to the mask ROM version.
- (2) On-chip power supply step-down circuit
The H8S/2144F-ZTAT, H8S/2142F-ZTAT, and mask ROM version of H8S/2142 incorporate an internal power supply step-down circuit.
When changing over to F-ZTAT versions or mask ROM versions incorporating an internal step-down circuit, the VCC2 pin has the same pin location as the VCL pin in a step-down circuit (See figure 26.3).
Therefore, note that the circuit patterns differ between these two types of products.

Item	Symbol	Value
Power supply voltage ^{*1}	V_{CC}	-0.3 to +7.0
Power supply voltage ^{*1} (3-V version)	V_{CC}	-0.3 to +4.3
Power supply voltage ^{*2} (VCL pin)	V_{CL}	-0.3 to +4.3
Input voltage (except ports 6, 7, and A)	V_{in}	-0.3 to $V_{CC} + 0.3$
Input voltage (CIN input not selected for port 6 and A)	V_{in}	-0.3 to $V_{CC} + 0.3$
Input voltage (CIN input selected for port 6 and A)	V_{in}	-0.3 V to lower of voltages $V_{CC} + 0.3$ and $AV_{CC} + 0.3$
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)	AV_{CC}	-0.3 to +4.3
Analog input voltage	V_{AN}	-0.3 to $AV_{CC} + 0.3$
Operating temperature	T_{opr}	Regular specifications: -20 to +75 Wide-range specifications: -40 to +125
Operating temperature (flash memory programming/erasing)	T_{opr}	Regular specifications: -20 to +75 Wide-range specifications: -40 to +125
Storage temperature	T_{stg}	-55 to +125

Caution: 1. Permanent damage to the chip may result if absolute maximum ratings exceeded.
2. Never apply more than 7.0 V to any of the pins of the 5- or 4-V version or to any of the pins (except for port A) of the 3-V version.

Notes: 1. Power supply voltage for VCC1 pin.
Never exceed the maximum rating of V_{CL} in the low-power version (3-V version) because both the VCC1 and VCL pins are connected to the V_{CL} power supply.
2. It is an operating power supply voltage pin on the chip.
Never apply power supply voltage to the VCL pin in the 5- or 4-V version. Always connect an external capacitor between the VCL pin and ground for voltage stabilization.

Item		Symbol	Min	Typ	Max	Unit	T	
Schmitt trigger input voltage	P67 to P60 ^{*2 *5} , (1)	V _T ⁻	1.0	—	—	V		
	KIN15 to KIN8 ^{*5} , IRQ2 to IRQ0 ^{*3} ,	V _T ⁺	—	—	V _{CC} × 0.7	V		
	IRQ5 to IRQ3	V _T ⁺ - V _T ⁻	0.4	—	—	V		
Input high voltage	RES, STBY, (2)	V _{IH}	V _{CC} - 0.7	—	V _{CC} + 0.3	V		
	NMI, MD1, MD0							
	EXTAL, PA7 to PA0 ^{*5}		V _{CC} × 0.7	—	V _{CC} + 0.3	V		
	Port 7		2.0	—	A V _{CC} + 0.3	V		
	Input pins except (1) and (2) above		2.0	—	V _{CC} + 0.3	V		
Input low voltage	RES, STBY, (3)	V _{IL}	-0.3	—	0.5	V		
	MD1, MD0							
	PA7 to PA0		-0.3	—	1.0	V		
	NMI, EXTAL, input pins except (1) and (3) above		-0.3	—	0.8	V		
Output high voltage	All output pins ^{*4}	V _{OH}	V _{CC} - 0.5	—	—	V	I _c	
			3.5	—	—	V	I _c	
Output low voltage	All output pins (except RESO) ^{*4}	V _{OL}	—	—	0.4	V	I _c	
			Ports 1 to 3	—	—	1.0	V	I _c
			RESO	—	—	0.4	V	I _c

leakage current (off state)	9, A, B					
Input pull-up MOS current	Ports 1 to 3	$-I_p$	30	—	300	μA
	Ports 6, A, B		60	—	600	μA
Input capacitance	$\overline{\text{RES}}$	(4) C_{in}	—	—	80	pF
	NMI		—	—	50	pF
	P52, P97, P42, P86 PA7 to PA2		—	—	20	pF
	Input pins except (4) above		—	—	15	pF
Current dissipation ^{*6}	Normal operation	I_{cc}	—	55	70	mA
	Sleep mode		—	36	55	mA
	Standby mode ^{*7}		—	1.0	5.0	μA
Analog power supply current	During A/D, D/A conversion	AI_{cc}	—	1.2	2.0	mA
	Idle		—	0.01	5.0	μA
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	mA
	Idle		—	0.01	5.0	μA

2.0 V to 5.5 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{CC}) or other method. Ensure that AV_{ref} ≤ AV_{CC}.

2. P67 to P60 include supporting module inputs multiplexed on those pins.
3. $\overline{\text{IRQ2}}$ includes the $\overline{\text{ADTRG}}$ signal multiplexed on that pin.
4. When IICS = 0. Low-level output when the bus drive function is selected is determined separately.
5. The upper limit of the applied voltage on Ports 6 and A is V_{CC} +0.3 V when CIN is not selected, and the lower of V_{CC} +0.3 V and AV_{CC} +0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
6. Current dissipation values are for V_{IH} min = V_{CC} -0.2 V, and V_{IL} max = 0.2 V when output pins unloaded and the on-chip pull-up MOSs in the off state.
7. The values are for V_{RAM} ≤ V_{CC} < 4.5V, V_{IH} min = V_{CC} -0.2 V, and V_{IL} max = 0.2 V.

trigger input voltage	KIN15 to KIN8 ^{*5} , IRQ2 to IRQ0 ^{*3} ,	V_{IH}	V_T^+	—	—	$V_{CC} \times 0.7$	V
	IRQ5 to IRQ3		$V_T^+ - V_T^-$	0.4	—	—	V
			V_T^-	0.8	—	—	V
			V_T^+	—	—	$V_{CC} \times 0.7$	V
			$V_T^+ - V_T^-$	0.3	—	—	V
Input high voltage	RES, STBY, NMI, MD1, MD0	(2)	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V
	EXTAL, PA7 to PA0 ^{*5}			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V
	Port 7			2.0	—	$AV_{CC} + 0.3$	V
	Input pins except (1) and (2) above			2.0	—	$V_{CC} + 0.3$	V
Input low voltage	RES, STBY, MD1, MD0	(3)	V_{IL}	-0.3	—	0.5	V
	PA7 to PA0			-0.3	—	1.0	V
				-0.3	—	0.8	V
	NMI, EXTAL, input pins except (1) and (3) above			-0.3	—	0.8	V
Output high voltage	All output pins ^{*4}	V_{OH}	$V_{CC} - 0.5$	—	—	V	
			3.5	—	—	V	
			3.0	—	—	V	

current	MD1, MD0		—	—	1.0	μA	V_{IH} A^*	
	Port 7		—	—	1.0	μA	V_{IH} A^*	
Three-state leakage current (off state)	Ports 1 to 6, 8, 9, A, B	$ I_{TSI} $	—	—	1.0	μA	V_{IH} V_{OL}	
Input pull-up MOS current	Ports 1 to 3	$-I_P$	30	—	300	μA	V_{IH} V_{OL}	
	Ports 6, A, B		60	—	600	μA	5.	
	Ports 1 to 3		20	—	200	μA	V_{IH} V_{OL}	
	Ports 6, A, B		40	—	500	μA	V_{OL}	
Input capacitance	\overline{RES}	(4) C_{in}	—	—	80	pF	V_{IH} $f =$ T_a	
	NMI		—	—	50	pF	$f =$ T_a	
	P52, P97, P42, P86, PA7 to PA2		—	—	20	pF	T_a	
	Input pins except (4) above		—	—	15	pF		
Current dissipation ^{*6}	Normal operation	I_{CC}	—	45	58	mA	$f =$	
	Sleep mode		—	30	46	mA	$f =$	
	Standby mode ^{*7}			—	1.0	5.0	μA	T_a
				—	—	20.0	μA	50
Analog power supply current	During A/D, D/A conversion	$A I_{CC}$	—	1.2	2.0	mA		
	Idle		—	0.01	5.0	μA	A^* to	

		2.0	—	5.5	V
RAM standby voltage	V_{RAM}	2.0	—	—	V

Notes: 1. **Do not leave the AVCC, AV_{ref}, and AVSS pins open even if the A/D converter and D/A converter are not used.**

Even if the A/D converter and D/A converter are not used, apply a value in the range of 2.0 V to 5.5 V to AVCC and AV_{ref} pins by connection to the power supply (V_{CC}) or other method. Ensure that AV_{ref} ≤ AV_{CC}.

2. P67 to P60 include supporting module inputs multiplexed on those pins.
3. $\overline{IRQ2}$ includes the \overline{ADTRG} signal multiplexed on that pin.
4. When IICS = 0. Low-level output when the bus drive function is selected is output separately.
5. The upper limit of the applied voltage on Ports 6 and A is V_{CC} +0.3 V when the bus drive function is not selected, and the lower of V_{CC} +0.3 V and AV_{CC} +0.3 V when CIN input is selected. When a pin is in output mode, the output voltage is equivalent to the applied voltage.
6. Current dissipation values are for V_{IH} min = V_{CC} -0.2 V, and V_{IL} max = 0.2 V when the output pins are unloaded and the on-chip pull-up MOSs are in the off state.
7. The values are for V_{RAM} ≤ V_{CC} < 4.0 V, V_{IH} min = V_{CC} -0.2 V, and V_{IL} max = 0.2 V.

voltage	$\overline{\text{IRQ2}}$ to $\overline{\text{IRQ0}}$, $\overline{\text{IRQ5}}$ to $\overline{\text{IRQ3}}$		$V_T^+ - V_T^-$	$V_{CC} \times 0.05$	—	—	V	
Input high voltage	$\overline{\text{RES}}$, $\overline{\text{STBY}}$, $\overline{\text{NMI}}$, $\overline{\text{MD1}}$, $\overline{\text{MD0}}$	(2)	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V	
	$\overline{\text{EXTAL}}$, $\overline{\text{PA7}}$ to $\overline{\text{PA0}}^{*5}$			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
	Port 7			$V_{CC} \times 0.7$	—	$AV_{CC} + 0.3$	V	
	Input pins except (1) and (2) above			$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
Input low voltage	$\overline{\text{RES}}$, $\overline{\text{STBY}}$, $\overline{\text{MD1}}$, $\overline{\text{MD0}}$	(3)	V_{IL}	-0.3	—	$V_{CC} \times 0.1$	V	
	$\overline{\text{PA7}}$ to $\overline{\text{PA0}}$			-0.3	—	$V_{CC} \times 0.2$	V	
	$\overline{\text{NMI}}$, $\overline{\text{EXTAL}}$, input pins except (1) and (3) above			-0.3	—	$V_{CC} \times 0.2$	V	
Output high voltage	All output pins ^{*4}		V_{OH}	$V_{CC} - 0.5$	—	—	V	I_{OH}
				$V_{CC} - 1.0$	—	—	V	I_{OH} (V) to
Output low voltage	All output pins (except $\overline{\text{RESO}}$) ^{*4}		V_{OL}	—	—	0.4	V	I_{OL}
				—	—	1.0	V	I_{OL}
				—	—	0.4	V	I_{OL}
Input leakage current	$\overline{\text{RES}}$		$ I_{in} $	—	—	10.0	μA	V
	$\overline{\text{STBY}}$, $\overline{\text{NMI}}$, $\overline{\text{MD1}}$, $\overline{\text{MD0}}$			—	—	1.0	μA	V
	Port 7			—	—	1.0	μA	V A

Input capacitance	$\overline{\text{RES}}$	(4) C_{in}	—	—	80	pF
	$\overline{\text{NMI}}$		—	—	50	pF
	P52, P97, P42, P86, PA7 to PA2		—	—	20	pF
	Input pins except (4) above		—	—	15	pF
Current dissipation ^{*6}	Normal operation	I_{CC}	—	30	40	mA
	Sleep mode		—	20	32	mA
	Standby mode ^{*7}		—	1.0	5.0	μA
			—	—	20.0	μA
Analog power supply current	During A/D, D/A conversion	AI_{CC}	—	1.2	2.0	mA
	Idle		—	0.01	5.0	μA
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	mA
	Idle		—	0.01	5.0	μA
Analog power supply voltage ^{*1}	AV_{CC}		2.7	—	3.6	V
			2.0	—	3.6	V
RAM standby voltage	V_{RAM}		2.0	—	—	V

Notes: 1. **Do not leave the AV_{CC} , AV_{ref} , and AV_{SS} pins open even if the A/D converter and D/A converter are not used.**

Even if the A/D converter and D/A converter are not used, apply a value in the range of 2.0 V to 3.6 V to AV_{CC} and AV_{ref} pins by connection to the power supply (V_{DD}) by other method. Ensure that $AV_{ref} \leq AV_{CC}$.

2. P67 to P60 include supporting module inputs multiplexed on those pins.

3. $\overline{\text{IRQ2}}$ includes the $\overline{\text{ADTRG}}$ signal multiplexed on that pin.

	<u>RESO</u>		—	—	3
	Other output pins		—	—	2
Permissible output low current (total)	Total of ports 1, 2, and 3	ΣI_{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	$\Sigma -I_{OH}$	—	—	40

Conditions: $V_{CC} = 2.7\text{ V to }3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $T_a = -20\text{ to }+75^\circ\text{C}$

Item		Symbol	Min	Typ	Max
Permissible output low current (per pin)	PA7 to PA4 (bus drive function selected)	I_{OL}	—	—	10
	Ports 1, 2, 3		—	—	2
	<u>RESO</u>		—	—	1
	Other output pins		—	—	1
Permissible output low current (total)	Total of ports 1, 2, and 3	ΣI_{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	$\Sigma -I_{OH}$	—	—	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 resistor on the output line, as show in figures 26.1 and 26.2.

—	—	0.5	$I_{OL} = 8 \text{ mA}$
—	—	0.4	$I_{OL} = 3 \text{ mA}$

26.6.3 AC Characteristics

Clock timing, control signal timing, bus timing, and timing of on-chip supporting modules are described in the following.

Figure 26.4 shows the test conditions for the AC characteristics.

Condition A: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 4.0 \text{ V}$ to 5.5 V , $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7 \text{ V}$ to 3.6 V , $V_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit
		20 MHz		16 MHz		10 MHz		
		Min	Max	Min	Max	Min	Max	
Clock cycle time	t_{cyC}	50	500	62.5	500	100	500	ns
Clock high pulse width	t_{CH}	17	—	20	—	30	—	ns
Clock low pulse width	t_{CL}	17	—	20	—	30	—	ns
Clock rise time	t_{Cr}	—	8	—	10	—	20	ns
Clock fall time	t_{Cf}	—	8	—	10	—	20	ns
Oscillation settling time at reset (crystal)	t_{OSC1}	10	—	10	—	20	—	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

range specifications)

Condition B: $V_{CC} = 4.0\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 2 MHz to maximum of frequency, $T_a = -20\text{ to }+75^\circ\text{C}$ (regular specifications), $T_a = -40\text{ to }+85^\circ\text{C}$ (range specifications)

Condition C: $V_{CC} = 2.7\text{ V to }3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 32.768\text{ kHz}$, 2 MHz to maximum of frequency, $T_a = -20\text{ to }+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit	T _a (°C)
		20 MHz		16 MHz		10 MHz			
		Min	Max	Min	Max	Min	Max		
RES setup time	t_{RESS}	200	—	200	—	300	—	ns	Fi
RES pulse width	t_{RESW}	20	—	20	—	20	—	t_{cyc}	
NMI setup time (NMI)	t_{NMIS}	150	—	150	—	250	—	ns	Fi
NMI hold time (NMI)	t_{NMIH}	10	—	10	—	10	—	ns	
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	200	—	200	—	ns	
IRQ setup time (IRQ7 to IRQ0)	t_{IRQS}	150	—	150	—	250	—	ns	
IRQ hold time (IRQ7 to IRQ0)	t_{IRQH}	10	—	10	—	10	—	ns	
IRQ pulse width (IRQ7, IRQ6, IRQ2 to IRQ0) (exiting software standby mode)	t_{IRQW}	200	—	200	—	200	—	ns	

specifications)

Condition B: $V_{CC} = 4.0\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency
 $T_a = -20\text{ to }+75^\circ\text{C}$ (regular specifications), $T_a = -40\text{ to }+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 2.7\text{ V to }3.6\text{ V}$, $V_{SS} = 0\text{ V}$, $\phi = 2\text{ MHz}$ to maximum operating frequency
 $T_a = -20\text{ to }+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit
		20 MHz		16 MHz		10 MHz		
		Min	Max	Min	Max	Min	Max	
Address delay time	t_{AD}	—	20	—	30	—	40	ns
Address setup time	t_{AS}	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 20$	—	$0.5 \times t_{cyc} - 30$	—	ns
Address hold time	t_{AH}	$0.5 \times t_{cyc} - 10$	—	$0.5 \times t_{cyc} - 15$	—	$0.5 \times t_{cyc} - 20$	—	ns
\overline{CS} delay time (IOS)	t_{CSD}	—	20	—	30	—	40	ns
\overline{AS} delay time	t_{ASD}	—	30	—	45	—	60	ns
\overline{RD} delay time 1	t_{RSD1}	—	30	—	45	—	60	ns
\overline{RD} delay time 2	t_{RSD2}	—	30	—	45	—	60	ns
Read data setup time	t_{RDS}	15	—	20	—	35	—	ns
Read data hold time	t_{RDH}	0	—	0	—	0	—	ns

time 2								
Read data access time 3	t_{ACC3}	—	$2.0 \times$ $t_{cyc} -30$	—	$2.0 \times$ $t_{cyc} -40$	—	$2.0 \times$ $t_{cyc} -60$	ns
Read data access time 4	t_{ACC4}	—	$2.5 \times$ $t_{cyc} -25$	—	$2.5 \times$ $t_{cyc} -35$	—	$2.5 \times$ $t_{cyc} -50$	ns
Read data access time 5	t_{ACC5}	—	$3.0 \times$ $t_{cyc} -30$	—	$3.0 \times$ $t_{cyc} -40$	—	$3.0 \times$ $t_{cyc} -60$	ns
\overline{WR} delay time 1	t_{WRD1}	—	30	—	45	—	60	ns
\overline{WR} delay time 2	t_{WRD2}	—	30	—	45	—	60	ns
\overline{WR} pulse width 1	t_{WSW1}	$1.0 \times$ $t_{cyc} -20$	—	$1.0 \times$ $t_{cyc} -30$	—	$1.0 \times$ $t_{cyc} -40$	—	ns
\overline{WR} pulse width 2	t_{WSW2}	$1.5 \times$ $t_{cyc} -20$	—	$1.5 \times$ $t_{cyc} -30$	—	$1.5 \times$ $t_{cyc} -40$	—	ns
Write data delay time	t_{WDD}	—	30	—	45	—	60	ns
Write data setup time	t_{WDS}	0	—	0	—	0	—	ns
Write data hold time	t_{WDH}	10	—	15	—	20	—	ns
\overline{WAIT} setup time	t_{WTS}	30	—	45	—	60	—	ns
\overline{WAIT} hold time	t_{WTH}	5	—	5	—	10	—	ns

frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40$ to $+85^\circ\text{C}$ (range specifications)

Condition B: $V_{CC} = 4.0$ V to 5.5 V, $V_{SS} = 0$ V, $\phi = 32.768$ kHz*, 2 MHz to maximum frequency, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40$ to $+85^\circ\text{C}$ (range specifications)

Condition C: $V_{CC} = 2.7$ V to 3.6 V, $V_{SS} = 0$ V, $\phi = 32.768$ kHz*, 2 MHz to maximum frequency, $T_a = -20$ to $+75^\circ\text{C}$

Item	Symbol	Condition A		Condition B		Condition C		Unit		
		20 MHz		16 MHz		10 MHz				
		Min	Max	Min	Max	Min	Max			
I/O ports	Output data delay time	t_{PWD}	—	50	—	50	—	100	ns	
	Input data setup time	t_{PRS}	30	—	30	—	50	—		
	Input data hold time	t_{PRH}	30	—	30	—	50	—		
FRT	Timer output delay time	t_{FTOD}	—	50	—	50	—	100	ns	
	Timer input setup time	t_{FTIS}	30	—	30	—	50	—		
	Timer clock input setup time	t_{FTCS}	30	—	30	—	50	—		
	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	—	

		setup time								
	Timer clock	Single edge	t_{TMCWH}	1.5	—	1.5	—	1.5	—	t_{cyc}
	pulse width	Both edges	t_{TMCWL}	2.5	—	2.5	—	2.5	—	
PWMX	Pulse output delay time		t_{PWOD}	—	50	—	50	—	100	ns
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 (synchronous)		t_{TXD}	—	50	—	50	—	100	ns
	Receive data setup time (synchronous)		t_{RXS}	50	—	50	—	100	—	ns
	Receive data hold time (synchronous)		t_{RXH}	50	—	50	—	100	—	ns
A/D converter	Trigger input setup time		t_{TRGS}	30	—	30	—	50	—	ns
WDT	RESO output delay time		t_{RESD}	—	100	—	120	—	200	ns
	RESO output pulse width		t_{RESOW}	132	—	132	—	132	—	t_{cyc}

Note: * Only supporting modules that can be used in subclock operation

$T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

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, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

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, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Condition A			Condition B			Condition C		
	20 MHz			16 MHz			10 MHz		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Resolution	10	10	10	10	10	10	10	10	10
Conversion time ^{*3}	—	—	6.7	—	—	8.4	—	—	13.
Analog input capacitance	—	—	20	—	—	20	—	—	20
Permissible signal-source impedance	—	—	$\frac{10^{*1}}{5^{*2}}$	—	—	$\frac{10^{*1}}{5^{*2}}$	—	—	5
Nonlinearity error	—	—	± 3.0	—	—	± 3.0	—	—	$\pm 7.$
Offset error	—	—	± 3.5	—	—	± 3.5	—	—	$\pm 7.$
Full-scale error	—	—	± 3.5	—	—	± 3.5	—	—	$\pm 7.$
Quantization error	—	—	± 0.5	—	—	± 0.5	—	—	$\pm 0.$
Absolute accuracy	—	—	± 4.0	—	—	± 4.0	—	—	$\pm 8.$

Notes: 1. When conversion time $\geq 11.17 \mu\text{s}$ (CKS = 1 and $\phi \leq 12$ MHz, or CKS = 0)
2. When conversion time $< 11.17 \mu\text{s}$ (CKS = 1 and $\phi > 12$ MHz)
3. In single mode and $\phi =$ maximum operating frequency.

$V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition C: $V_{CC} = 3.0 \text{ V}$ to 3.6 V^{*4} , $AV_{CC} = 3.0 \text{ V}$ to 3.6 V^{*4} , $AV_{ref} = 3.0 \text{ V}$ to AV_{CC}^{*4}
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2 \text{ MHz}$ to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item	Condition A			Condition B			Condition C		
	20 MHz			16 MHz			10 MHz		
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Resolution	10	10	10	10	10	10	10	10	10
Conversion time ^{*3}	—	—	6.7	—	—	8.4	—	—	13.4
Analog input capacitance	—	—	20	—	—	20	—	—	20
Permissible signal-source impedance	—	—	$\frac{10^{*1}}{5^{*2}}$	—	—	$\frac{10^{*1}}{5^{*2}}$	—	—	5
Nonlinearity error	—	—	± 5.0	—	—	± 5.0	—	—	± 11.1
Offset error	—	—	± 5.5	—	—	± 5.5	—	—	± 11.1
Full-scale error	—	—	± 5.5	—	—	± 5.5	—	—	± 11.1
Quantization error	—	—	± 0.5	—	—	± 0.5	—	—	± 0.5
Absolute accuracy	—	—	± 6.0	—	—	± 6.0	—	—	± 12.2

Notes: 1. When conversion time $\geq 11.17 \mu\text{s}$ (CKS = 1 and $\phi \leq 12 \text{ MHz}$, or CKS = 0)
 2. When conversion time $< 11.17 \mu\text{s}$ (CKS = 1 and $\phi > 12 \text{ MHz}$)
 3. In single mode and $\phi =$ maximum operating frequency.
 4. When using CIN, the applicable range is $V_{CC} = 3.0 \text{ V}$ to 3.6 V , $AV_{CC} = 3.0 \text{ V}$ to $AV_{ref} = 3.0 \text{ V}$ to 3.6 V .

$T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

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, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

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, $\phi = 2$ MHz to maximum operating frequency,
 $T_a = -20$ to $+75^\circ\text{C}$

Item		Condition A			Condition B			Condition C		
		20 MHz			16 MHz			10 MHz		
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Resolution		8	8	8	8	8	8	8	8	8
Conversion time	With 20-pF load capacitance	—	—	10	—	—	10	—	—	10
Absolute accuracy	With 2-M Ω load resistance	—	± 1.0	± 1.5	—	± 1.0	± 1.5	—	± 2.0	± 2.5
	With 4-M Ω load resistance	—	—	± 1.0	—	—	± 1.0	—	—	± 1.0

26.6.6 Flash Memory Characteristics

Table 26.67 shows the flash memory characteristics.

Erase time ^{*1 *3 *6}	tE	—	100	1200	ms/ block	
Reprogramming count	N _{WEC}	100 ^{*8}	10000 ^{*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	10	—	—	μs
	Wait time after PSU-bit clear ^{*1}	β	10	—	—	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	4	—	—	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 H'FF 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	

z2, z3) to allow programming within the maximum programming time (tP (n)).
wait time after P-bit setting (z1, z2, z3) must be changed with the value of tP (n) of writing times (n) as follows.

The number of times for writing n

$$1 \leq n \leq 6 \quad z1 = 30 \mu\text{s}, z3 = 10 \mu\text{s}$$

$$7 \leq n \leq 1000 \quad z2 = 200 \mu\text{s}$$

6. Maximum erase time (tE (max))
tE (max) = Waiting time after E-bit setting (z) × Maximum erase count (N)
7. Maximum erase count (N) should be set according to the actual setting (z) erase within the maximum erase time (tE (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 function value).
10. Data retention characteristic when rewriting is performed within the specific including the minimum value.

(2) On-chip power supply step-down circuit

The following products incorporate an internal power supply step-down circuit, which automatically drops down the internal power supply voltage to the optimum internal level: the F-ZTAT A-mask versions of the H8S/2144 (HD64F2144A) and the mask ROM versions of the H8S/2144, and H8S/2143 (HD6432144S and HD6432143S).

The voltage-stabilization capacitor (0.47 μ F one or two connected in series) must be connected between the VCL (internal power supply step-down) and VSS pins.

Figure 26.3 shows the connection of the external capacitors.

For the 5- or 4-V version, do not connect the VCL pin in a product incorporating an internal step-down circuit to the V_{cc} power supply. (Connect the VCC1 pin to the V_{cc} power supply as usual.)

For the 3-V version, connect both the VCL and VCC1 pins to the system power supply.

When changing from the F-ZTAT versions not incorporating an internal step-down circuit to the mask ROM versions incorporating an internal step-down circuit, the VCL pin has the same pin location as the VCC2 pin.

Therefore, note that the circuit patterns differ between these two types of products.

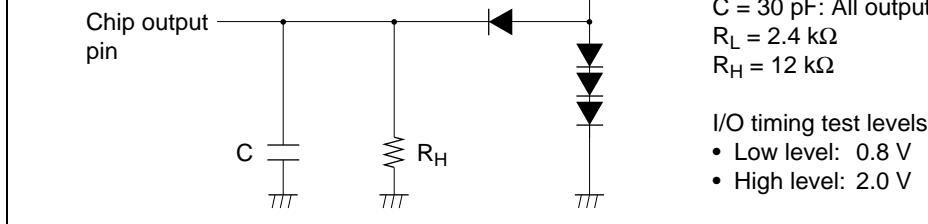


Figure 26.4 Output Load Circuit

26.7.2 Clock Timing

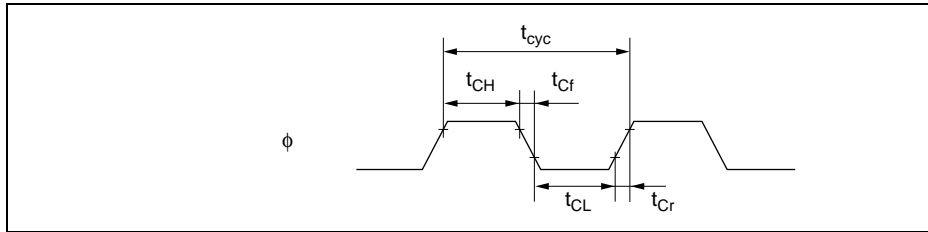


Figure 26.5 System Clock Timing

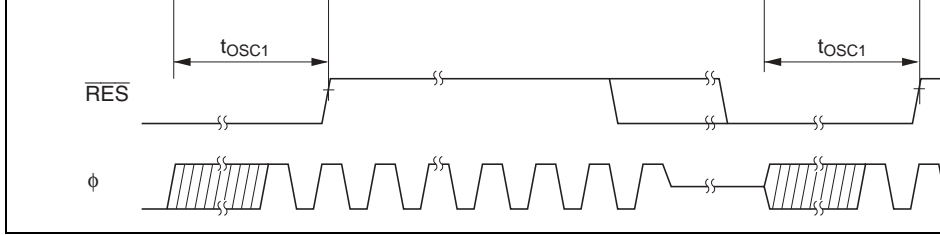


Figure 26.6 Oscillation Settling Timing

26.7.3 Control Signal Timing

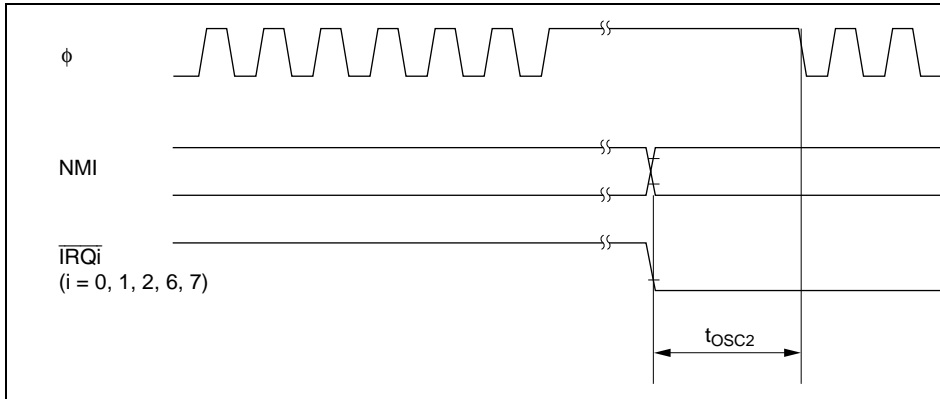


Figure 26.7 Oscillation Settling Timing (Exiting Software Standby Mode)

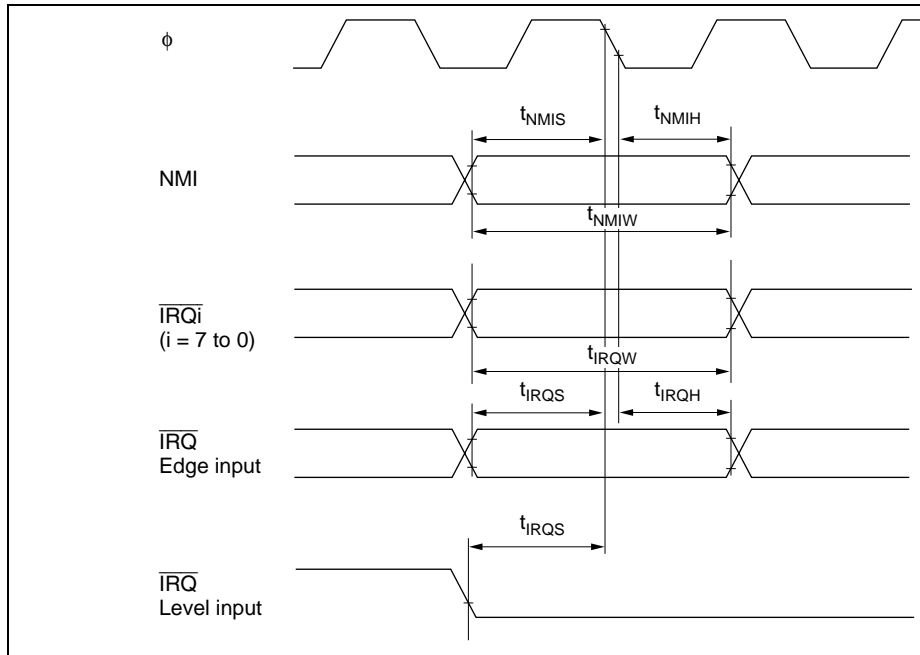
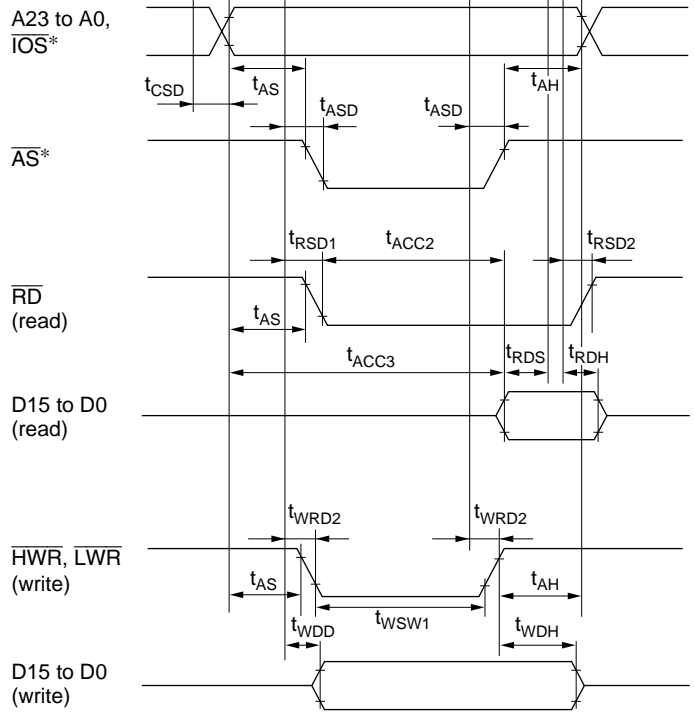


Figure 26.9 Interrupt Input Timing



Note: * \overline{AS} and \overline{IOS} are the same pin. The function is selected by the IOSE bit in SYSC

Figure 26.10 Basic Bus Timing (Two-State Access)

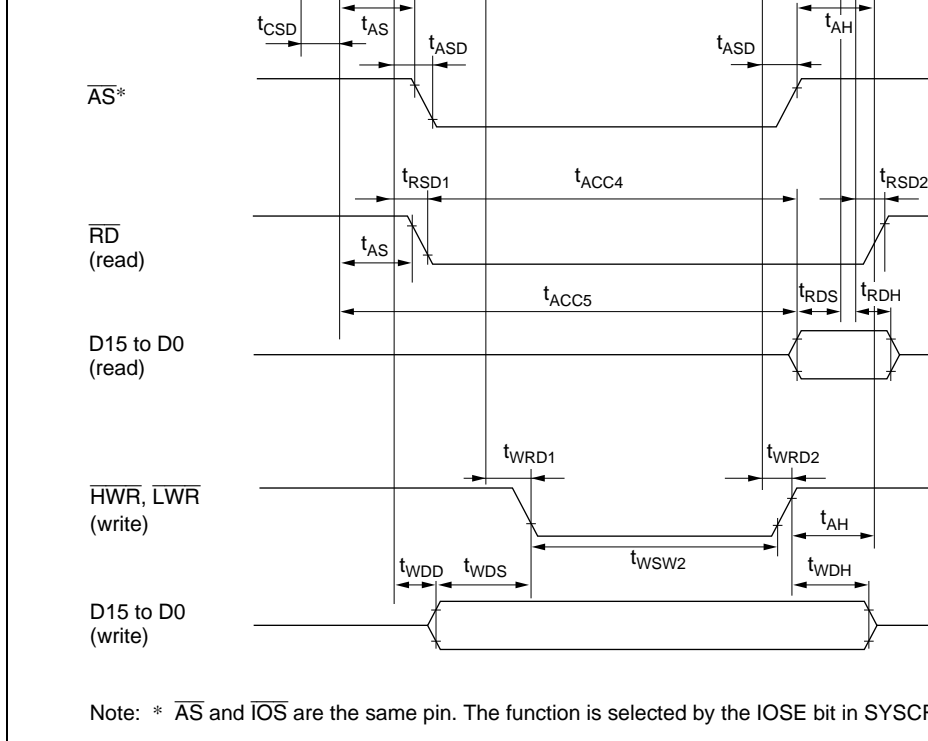


Figure 26.11 Basic Bus Timing (Three-State Access)

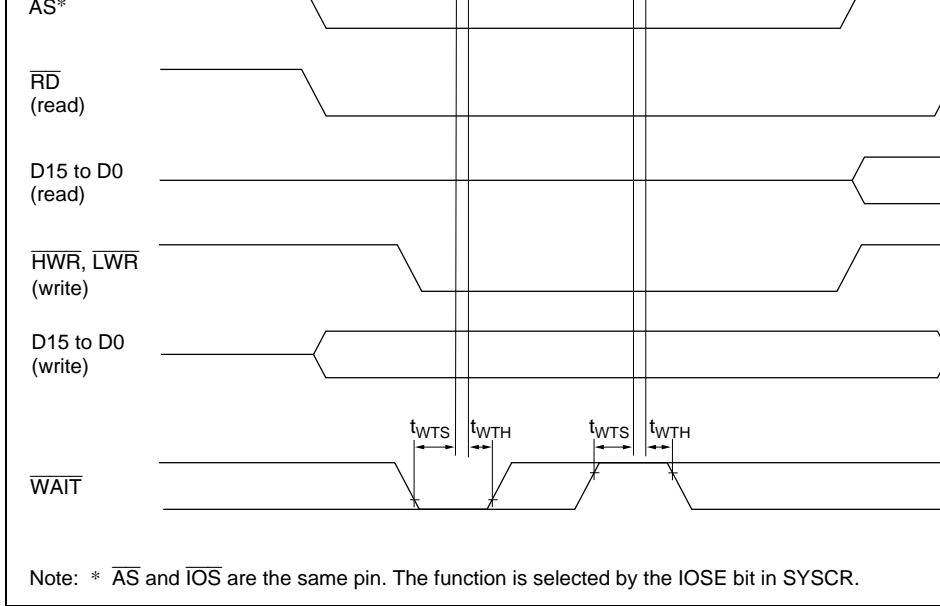


Figure 26.12 Basic Bus Timing (Three-State Access with One Wait State)

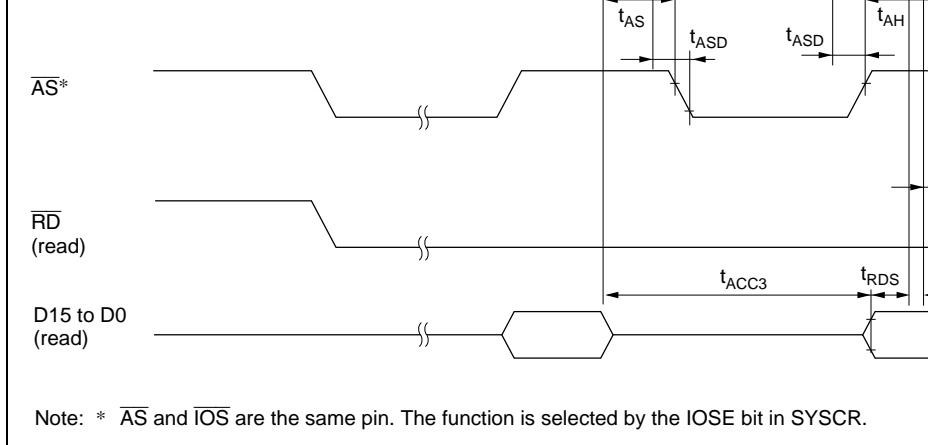


Figure 26.13 Burst ROM Access Timing (Two-State Access)

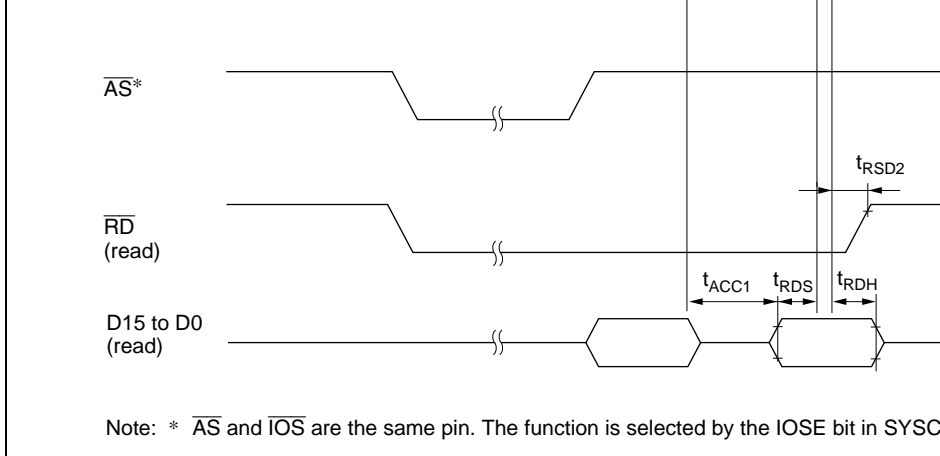


Figure 26.14 Burst ROM Access Timing (One-State Access)

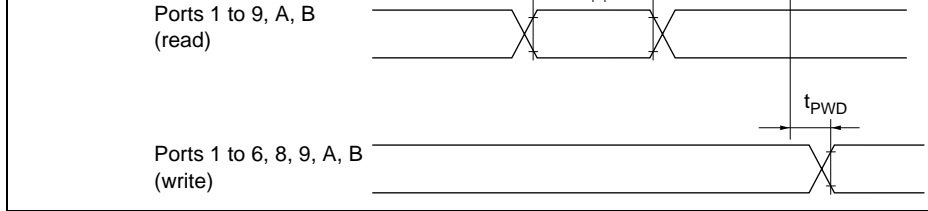


Figure 26.15 I/O Port Input/Output Timing

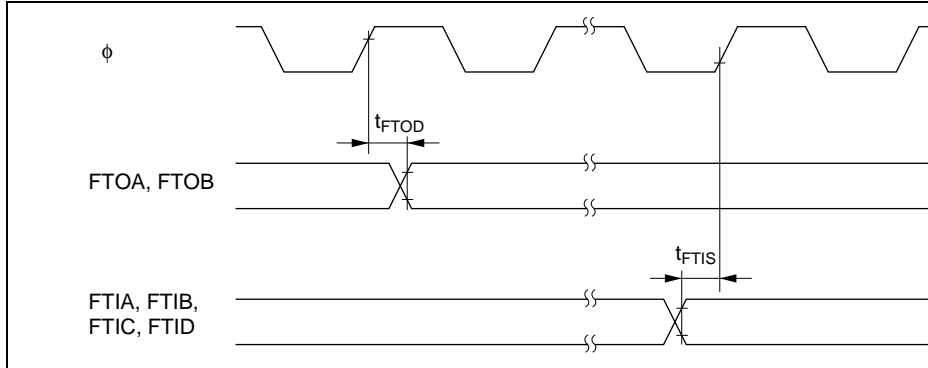


Figure 26.16 FRT Input/Output Timing

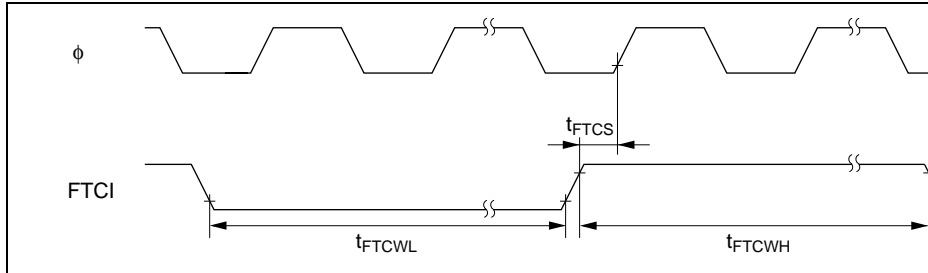


Figure 26.17 FRT Clock Input Timing

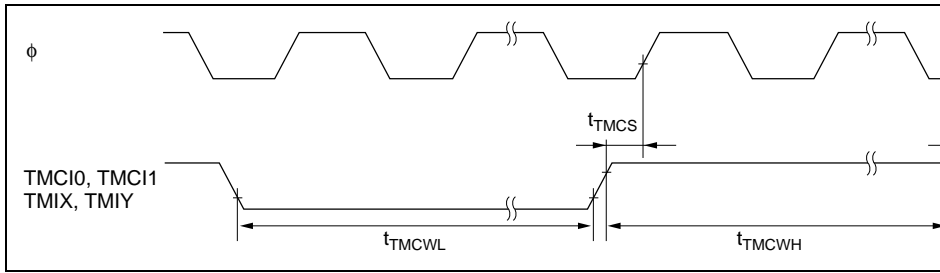


Figure 26.19 8-Bit Timer Clock Input Timing

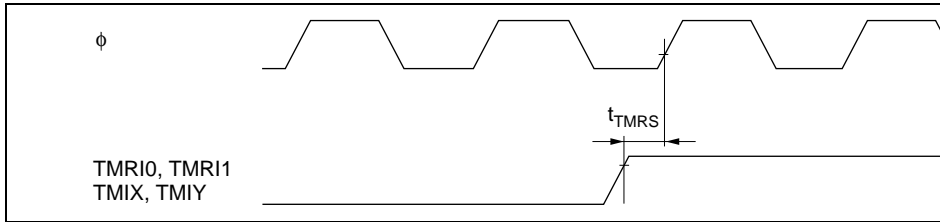


Figure 26.20 8-Bit Timer Reset Input Timing

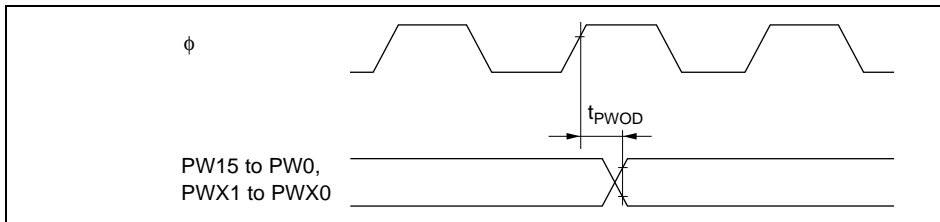


Figure 26.21 PWM, PWMX Output Timing

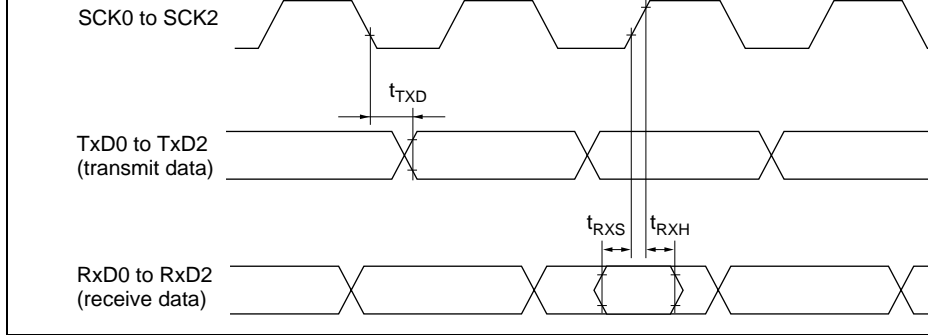


Figure 26.23 SCI Input/Output Timing (Synchronous Mode)

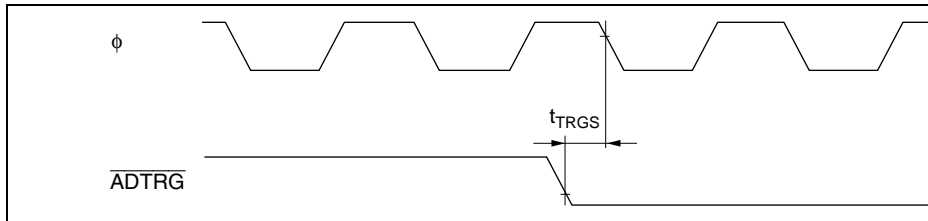


Figure 26.24 A/D Converter External Trigger Input Timing

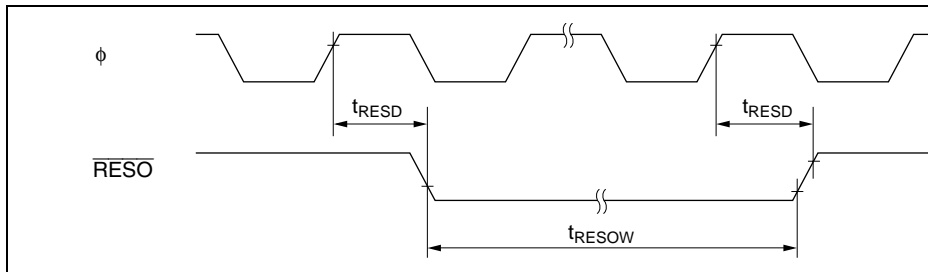
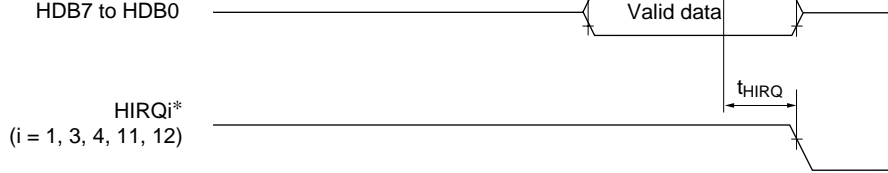


Figure 26.25 WDT Output Timing (\overline{RESO})



Note: * The rising edge timing is the same as the port 4 and port B output timing.
See figure 26.15.

Host interface write timing

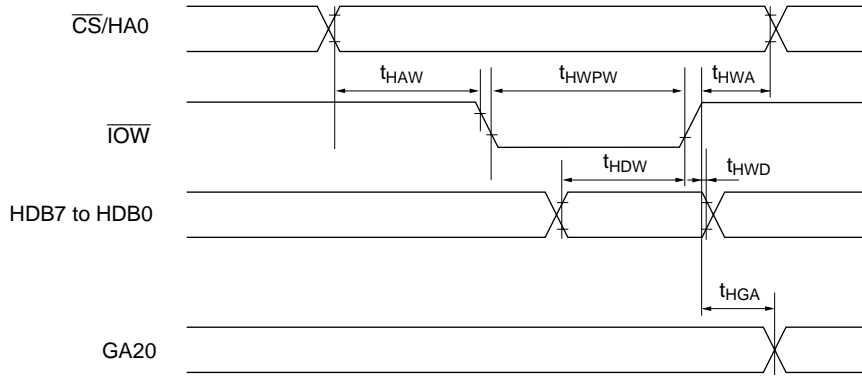
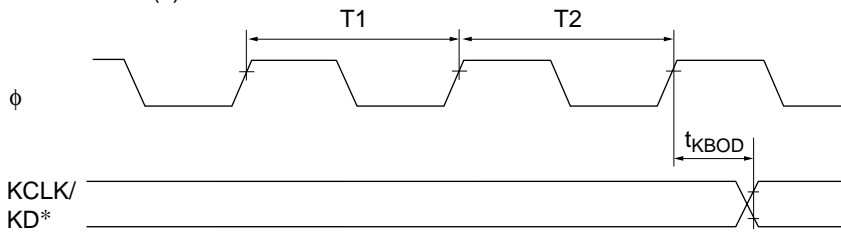
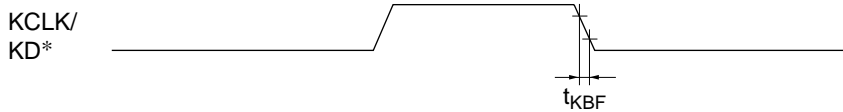


Figure 26.26 Host Interface Timing

2. Transmission (a)



Transmission (b)



Note: ϕ shown here is the clock scaled by $1/N$ when the operating mode is active medium-speed mode.

* KCLK: PS2AC to PS2CC

KD: PS2AD to PS2CD

Figure 26.27 Keyboard Buffer Controller Timing

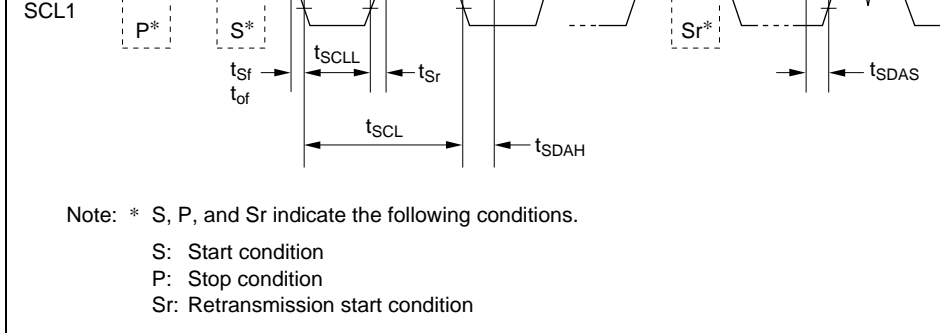


Figure 26.28 I²C Bus Interface Input/Output Timing (Option)

Rn	General register* ¹
ERn	General register (32-bit register)
MAC	Multiply-and-accumulate register (32-bit register)* ²
(EAd)	Destination operand
(EAs)	Source operand
EXR	Extend 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
⊕	Exclusive logical OR
→	Transfer from left-hand operand to right-hand operand, or transition hand state to right-hand state
¬	NOT (logical complement)
() < >	Operand contents
:8/:16/:24/:32	8-, 16-, 24-, or 32-bit length

Notes: 1. General registers include 8-bit registers (R0H to R7H, R0L to R7L), 16-bit registers (R8 to R7, E0 to E7), and 32-bit registers (ER0 to ER7).
2. MAC instructions cannot be used in this LSI.

MOV	MOV.B #xx:8,Rd	B	2							#xx:8→Rd8	—	—	↑
	MOV.B Rs,Rd	B		2						Rs8→Rd8	—	—	↑
	MOV.B @ERs,Rd	B			2					@ERs→Rd8	—	—	↑
	MOV.B @(d:16,ERs),Rd	B				4				@(d:16,ERs)→Rd8	—	—	↑
	MOV.B @(d:32,ERs),Rd	B					8			@(d:32,ERs)→Rd8	—	—	↑
	MOV.B @ERs+,Rd	B						2		@ERs→Rd8,ERs32+1→ERs32	—	—	↑
	MOV.B @aa:8,Rd	B							2	@aa:8→Rd8	—	—	↑
	MOV.B @aa:16,Rd	B								@aa:16→Rd8	—	—	↑
	MOV.B @aa:32,Rd	B								@aa:32→Rd8	—	—	↑
	MOV.B Rs,@ERd	B			2					Rs8→@ERd	—	—	↑
	MOV.B Rs,@(d:16,ERd)	B				4				Rs8→@(d:16,ERd)	—	—	↑
	MOV.B Rs,@(d:32,ERd)	B					8			Rs8→@(d:32,ERd)	—	—	↑
	MOV.B Rs,@-ERd	B						2		ERd32-1→ERd32,Rs8→@ERd	—	—	↑
	MOV.B Rs,@aa:8	B							2	Rs8→@aa:8	—	—	↑
	MOV.B Rs,@aa:16	B								Rs8→@aa:16	—	—	↑
	MOV.B Rs,@aa:32	B								Rs8→@aa:32	—	—	↑
	MOV.W #xx:16,Rd	W	4							#xx:16→Rd16	—	—	↑
	MOV.W Rs,Rd	W		2						Rs16→Rd16	—	—	↑
	MOV.W @ERs,Rd	W			2					@ERs→Rd16	—	—	↑
	MOV.W @(d:16,ERs),Rd	W				4				@(d:16,ERs)→Rd16	—	—	↑
	MOV.W @(d:32,ERs),Rd	W					8			@(d:32,ERs)→Rd16	—	—	↑
	MOV.W @ERs+,Rd	W						2		@ERs→Rd16,ERs32+2→ERs32	—	—	↑
	MOV.W @aa:16,Rd	W							4	@aa:16→Rd16	—	—	↑
	MOV.W @aa:32,Rd	W								@aa:32→Rd16	—	—	↑
	MOV.W Rs,@ERd	W			2					Rs16→@ERd	—	—	↑
	MOV.W Rs,@(d:16,ERd)	W				4				Rs16→@(d:16,ERd)	—	—	↑
	MOV.W Rs,@(d:32,ERd)	W					8			Rs16→@(d:32,ERd)	—	—	↑
	MOV.W Rs,@-ERd	W						2		ERd32-2→ERd32,Rs16→@ERd	—	—	↑
	MOV.W Rs,@aa:16	W							4	Rs16→@aa:16	—	—	↑
	MOV.W Rs,@aa:32	W								Rs16→@aa:32	—	—	↑

	MOV.L @(d:16,ERs),ERd	L				6						@(d:16,ERs)→ERd32	—	—	↓	↓
	MOV.L @(d:32,ERs),ERd	L				10						@(d:32,ERs)→ERd32	—	—	↓	↓
	MOV.L @ERs+,ERd	L				4						@ERs→ERd32,ERs32+4→ERs32	—	—	↓	↓
	MOV.L @aa:16,ERd	L				6						@aa:16→ERd32	—	—	↓	↓
	MOV.L @aa:32,ERd	L				8						@aa:32→ERd32	—	—	↓	↓
	MOV.L ERs,@ERd	L			4							ERs32→@ERd	—	—	↓	↓
	MOV.L ERs,@(d:16,ERd)	L			6							ERs32→@(d:16,ERd)	—	—	↓	↓
	MOV.L ERs,@(d:32,ERd)	L			10							ERs32→@(d:32,ERd)	—	—	↓	↓
	MOV.L ERs,@-ERd	L			4							ERd32-4→ERd32,ERs32→@ERd	—	—	↓	↓
	MOV.L ERs,@aa:16	L			6							ERs32→@aa:16	—	—	↓	↓
	MOV.L ERs,@aa:32	L			8							ERs32→@aa:32	—	—	↓	↓
POP	POP.W Rn	W								2		@SP→Rn16,SP+2→SP	—	—	↓	↓
	POP.L ERn	L								4		@SP→ERn32,SP+4→SP	—	—	↓	↓
PUSH	PUSH.W Rn	W								2		SP-2→SP,Rn16→@SP	—	—	↓	↓
	PUSH.L ERn	L								4		SP-4→SP,ERn32→@SP	—	—	↓	↓
LDM*4	LDM @SP+,(ERm-ERn)	L								4		(@SP→ERn32,SP+4→SP) Repeated for each restored register.	—	—	—	—
STM*4	STM (ERm-ERn),@-SP	L								4		(SP-4→SP,ERn32→@SP) Repeated for each saved register.	—	—	—	—
MOVFP	MOVFP @aa:16,Rd	Cannot be used with this LSI.														
MOVTPE	MOVTPE Rs,@aa:16															

	ADD.B Rs,Rd	B	2															Rd8+Rs8→Rd8	—	↑	↓
	ADD.W #xx:16,Rd	W	4															Rd16+#xx:16→Rd16	—	[3]	↑
	ADD.W Rs,Rd	W	2															Rd16+Rs16→Rd16	—	[3]	↑
	ADD.L #xx:32,ERd	L	6															ERd32+#xx:32→ERd32	—	[4]	↑
	ADD.L ERs,ERd	L	2															ERd32+ERs32→ERd32	—	[4]	↑
ADDX	ADDX #xx:8,Rd	B	2															Rd8+#xx:8-C→Rd8	—	↑	↓
	ADDX Rs,Rd	B	2															Rd8+Rs8-C→Rd8	—	↑	↓
ADDS	ADDS #1,ERd	L	2															ERd32+1→ERd32	—	—	—
	ADDS #2,ERd	L	2															ERd32+2→ERd32	—	—	—
	ADDS #4,ERd	L	2															ERd32+4→ERd32	—	—	—
INC	INC.B Rd	B	2															Rd8+1→Rd8	—	—	↑
	INC.W #1,Rd	W	2															Rd16+1→Rd16	—	—	↑
	INC.W #2,Rd	W	2															Rd16+2→Rd16	—	—	↑
	INC.L #1,ERd	L	2															ERd32+1→ERd32	—	—	↑
	INC.L #2,ERd	L	2															ERd32+2→ERd32	—	—	↑
DAA	DAA Rd	B	2															Rd8 decimal adjust →Rd8	—	*	↑
SUB	SUB.B Rs,Rd	B	2															Rd8-Rs8→Rd8	—	↑	↓
	SUB.W #xx:16,Rd	W	4															Rd16-#xx:16→Rd16	—	[3]	↓
	SUB.W Rs,Rd	W	2															Rd16-Rs16→Rd16	—	[3]	↓
	SUB.L #xx:32,ERd	L	6															ERd32-#xx:32→ERd32	—	[4]	↓
	SUB.L ERs,ERd	L	2															ERd32-ERs32→ERd32	—	[4]	↓
SUBX	SUBX #xx:8,Rd	B	2															Rd8-#xx:8-C→Rd8	—	↑	↓
	SUBX Rs,Rd	B	2															Rd8-Rs8-C→Rd8	—	↑	↓
SUBS	SUBS #1,ERd	L	2															ERd32-1→ERd32	—	—	—
	SUBS #2,ERd	L	2															ERd32-2→ERd32	—	—	—
	SUBS #4,ERd	L	2															ERd32-4→ERd32	—	—	—
DEC	DEC.B Rd	B	2															Rd8-1→Rd8	—	—	↓
	DEC.W #1,Rd	W	2															Rd16-1→Rd16	—	—	↓
	DEC.W #2,Rd	W	2															Rd16-2→Rd16	—	—	↓
	DEC.L #1,ERd	L	2															ERd32-1→ERd32	—	—	↓
	DEC.L #2,ERd	L	2															ERd32-2→ERd32	—	—	↓

CLRMAC	CLRMAC
LDMAC	LDMAC ERs,MACH
	LDMAC ERs,MACL
STMAC	STMAC MACH,ERd
	STMAC MACL,ERd



	AND.B Rs,Rd	B	2															Rd8 \wedge Rs8 \rightarrow Rd8	—	—	\updownarrow	\updownarrow
	AND.W #xx:16,Rd	W	4															Rd16 \wedge #xx:16 \rightarrow Rd16	—	—	\updownarrow	\updownarrow
	AND.W Rs,Rd	W	2															Rd16 \wedge Rs16 \rightarrow Rd16	—	—	\updownarrow	\updownarrow
	AND.L #xx:32,ERd	L	6															ERd32 \wedge #xx:32 \rightarrow ERd32	—	—	\updownarrow	\updownarrow
	AND.L ERs,ERd	L	4															ERd32 \wedge ERs32 \rightarrow ERd32	—	—	\updownarrow	\updownarrow
OR	OR.B #xx:8,Rd	B	2															Rd8 \vee #xx:8 \rightarrow Rd8	—	—	\updownarrow	\updownarrow
	OR.B Rs,Rd	B	2															Rd8 \vee Rs8 \rightarrow Rd8	—	—	\updownarrow	\updownarrow
	OR.W #xx:16,Rd	W	4															Rd16 \vee #xx:16 \rightarrow Rd16	—	—	\updownarrow	\updownarrow
	OR.W Rs,Rd	W	2															Rd16 \vee Rs16 \rightarrow Rd16	—	—	\updownarrow	\updownarrow
	OR.L #xx:32,ERd	L	6															ERd32 \vee #xx:32 \rightarrow ERd32	—	—	\updownarrow	\updownarrow
	OR.L ERs,ERd	L	4															ERd32 \vee ERs32 \rightarrow ERd32	—	—	\updownarrow	\updownarrow
XOR	XOR.B #xx:8,Rd	B	2															Rd8 \oplus #xx:8 \rightarrow Rd8	—	—	\updownarrow	\updownarrow
	XOR.B Rs,Rd	B	2															Rd8 \oplus Rs8 \rightarrow Rd8	—	—	\updownarrow	\updownarrow
	XOR.W #xx:16,Rd	W	4															Rd16 \oplus #xx:16 \rightarrow Rd16	—	—	\updownarrow	\updownarrow
	XOR.W Rs,Rd	W	2															Rd16 \oplus Rs16 \rightarrow Rd16	—	—	\updownarrow	\updownarrow
	XOR.L #xx:32,ERd	L	6															ERd32 \oplus #xx:32 \rightarrow ERd32	—	—	\updownarrow	\updownarrow
	XOR.L ERs,ERd	L	4															ERd32 \oplus ERs32 \rightarrow ERd32	—	—	\updownarrow	\updownarrow
NOT	NOT.B Rd	B	2															\neg Rd8 \rightarrow Rd8	—	—	\updownarrow	\updownarrow
	NOT.W Rd	W	2															\neg Rd16 \rightarrow Rd16	—	—	\updownarrow	\updownarrow
	NOT.L ERd	L	2															\neg ERd32 \rightarrow ERd32	—	—	\updownarrow	\updownarrow

	BTST #xx:3,@aa:16	B				6		\neg (#xx:3 of @aa:16) \rightarrow Z	—	—	—	↓
	BTST #xx:3,@aa:32	B				8		\neg (#xx:3 of @aa:32) \rightarrow Z	—	—	—	↓
	BTST Rn,Rd	B	2					\neg (Rn8 of Rd8) \rightarrow Z	—	—	—	↓
	BTST Rn,@ERd	B		4				\neg (Rn8 of @ERd) \rightarrow Z	—	—	—	↓
	BTST Rn,@aa:8	B				4		\neg (Rn8 of @aa:8) \rightarrow Z	—	—	—	↓
	BTST Rn,@aa:16	B				6		\neg (Rn8 of @aa:16) \rightarrow Z	—	—	—	↓
	BTST Rn,@aa:32	B				8		\neg (Rn8 of @aa:32) \rightarrow Z	—	—	—	↓
BLD	BLD #xx:3,Rd	B	2					(#xx:3 of Rd8) \rightarrow C	—	—	—	—
	BLD #xx:3,@ERd	B		4				(#xx:3 of @ERd) \rightarrow C	—	—	—	—
	BLD #xx:3,@aa:8	B				4		(#xx:3 of @aa:8) \rightarrow C	—	—	—	—
	BLD #xx:3,@aa:16	B				6		(#xx:3 of @aa:16) \rightarrow C	—	—	—	—
	BLD #xx:3,@aa:32	B				8		(#xx:3 of @aa:32) \rightarrow C	—	—	—	—
BILD	BILD #xx:3,Rd	B	2					\neg (#xx:3 of Rd8) \rightarrow C	—	—	—	—
	BILD #xx:3,@ERd	B		4				\neg (#xx:3 of @ERd) \rightarrow C	—	—	—	—
	BILD #xx:3,@aa:8	B				4		\neg (#xx:3 of @aa:8) \rightarrow C	—	—	—	—
	BILD #xx:3,@aa:16	B				6		\neg (#xx:3 of @aa:16) \rightarrow C	—	—	—	—
	BILD #xx:3,@aa:32	B				8		\neg (#xx:3 of @aa:32) \rightarrow C	—	—	—	—
BST	BST #xx:3,Rd	B	2					C \rightarrow (#xx:3 of Rd8)	—	—	—	—
	BST #xx:3,@ERd	B		4				C \rightarrow (#xx:3 of @ERd)	—	—	—	—
	BST #xx:3,@aa:8	B				4		C \rightarrow (#xx:3 of @aa:8)	—	—	—	—
	BST #xx:3,@aa:16	B				6		C \rightarrow (#xx:3 of @aa:16)	—	—	—	—
	BST #xx:3,@aa:32	B				8		C \rightarrow (#xx:3 of @aa:32)	—	—	—	—
BIST	BIST #xx:3,Rd	B	2					\neg C \rightarrow (#xx:3 of Rd8)	—	—	—	—
	BIST #xx:3,@ERd	B		4				\neg C \rightarrow (#xx:3 of @ERd)	—	—	—	—
	BIST #xx:3,@aa:8	B				4		\neg C \rightarrow (#xx:3 of @aa:8)	—	—	—	—
	BIST #xx:3,@aa:16	B				6		\neg C \rightarrow (#xx:3 of @aa:16)	—	—	—	—
	BIST #xx:3,@aa:32	B				8		\neg C \rightarrow (#xx:3 of @aa:32)	—	—	—	—

	BAND #xx:3, @aa:16	B					6	$C \wedge (\#xx:3 \text{ of } @aa:16) \rightarrow C$	—	—	—
	BAND #xx:3, @aa:32	B					8	$C \wedge (\#xx:3 \text{ of } @aa:32) \rightarrow C$	—	—	—
BIAND	BIAND #xx:3, Rd	B	2					$C \wedge [\neg (\#xx:3 \text{ of } Rd8)] \rightarrow C$	—	—	—
	BIAND #xx:3, @ERd	B		4				$C \wedge [\neg (\#xx:3 \text{ of } @ERd)] \rightarrow C$	—	—	—
	BIAND #xx:3, @aa:8	B					4	$C \wedge [\neg (\#xx:3 \text{ of } @aa:8)] \rightarrow C$	—	—	—
	BIAND #xx:3, @aa:16	B					6	$C \wedge [\neg (\#xx:3 \text{ of } @aa:16)] \rightarrow C$	—	—	—
	BIAND #xx:3, @aa:32	B					8	$C \wedge [\neg (\#xx:3 \text{ of } @aa:32)] \rightarrow C$	—	—	—
BOR	BOR #xx:3, Rd	B	2					$C \vee (\#xx:3 \text{ of } Rd8) \rightarrow C$	—	—	—
	BOR #xx:3, @ERd	B		4				$C \vee (\#xx:3 \text{ of } @ERd) \rightarrow C$	—	—	—
	BOR #xx:3, @aa:8	B					4	$C \vee (\#xx:3 \text{ of } @aa:8) \rightarrow C$	—	—	—
	BOR #xx:3, @aa:16	B					6	$C \vee (\#xx:3 \text{ of } @aa:16) \rightarrow C$	—	—	—
	BOR #xx:3, @aa:32	B					8	$C \vee (\#xx:3 \text{ of } @aa:32) \rightarrow C$	—	—	—
BIOR	BIOR #xx:3, Rd	B	2					$C \vee [\neg (\#xx:3 \text{ of } Rd8)] \rightarrow C$	—	—	—
	BIOR #xx:3, @ERd	B		4				$C \vee [\neg (\#xx:3 \text{ of } @ERd)] \rightarrow C$	—	—	—
	BIOR #xx:3, @aa:8	B					4	$C \vee [\neg (\#xx:3 \text{ of } @aa:8)] \rightarrow C$	—	—	—
	BIOR #xx:3, @aa:16	B					6	$C \vee [\neg (\#xx:3 \text{ of } @aa:16)] \rightarrow C$	—	—	—
	BIOR #xx:3, @aa:32	B					8	$C \vee [\neg (\#xx:3 \text{ of } @aa:32)] \rightarrow C$	—	—	—
BXOR	BXOR #xx:3, Rd	B	2					$C \oplus (\#xx:3 \text{ of } Rd8) \rightarrow C$	—	—	—
	BXOR #xx:3, @ERd	B		4				$C \oplus (\#xx:3 \text{ of } @ERd) \rightarrow C$	—	—	—
	BXOR #xx:3, @aa:8	B					4	$C \oplus (\#xx:3 \text{ of } @aa:8) \rightarrow C$	—	—	—
	BXOR #xx:3, @aa:16	B					6	$C \oplus (\#xx:3 \text{ of } @aa:16) \rightarrow C$	—	—	—
	BXOR #xx:3, @aa:32	B					8	$C \oplus (\#xx:3 \text{ of } @aa:32) \rightarrow C$	—	—	—
BIXOR	BIXOR #xx:3, Rd	B	2					$C \oplus [\neg (\#xx:3 \text{ of } Rd8)] \rightarrow C$	—	—	—
	BIXOR #xx:3, @ERd	B		4				$C \oplus [\neg (\#xx:3 \text{ of } @ERd)] \rightarrow C$	—	—	—
	BIXOR #xx:3, @aa:8	B					4	$C \oplus [\neg (\#xx:3 \text{ of } @aa:8)] \rightarrow C$	—	—	—
	BIXOR #xx:3, @aa:16	B					6	$C \oplus [\neg (\#xx:3 \text{ of } @aa:16)] \rightarrow C$	—	—	—
	BIXOR #xx:3, @aa:32	B					8	$C \oplus [\neg (\#xx:3 \text{ of } @aa:32)] \rightarrow C$	—	—	—

BRA d:16(BT d:16)	—					4			else next;				
BRN d:8(BF d:8)	—					2				Never	—	—	—
BRN d:16(BF d:16)	—					4					—	—	—
BHI d:8	—					2				CvZ=0	—	—	—
BHI d:16	—					4					—	—	—
BLS d:8	—					2				CvZ=1	—	—	—
BLS d:16	—					4					—	—	—
BCC d:8(BHS d:8)	—					2				C=0	—	—	—
BCC d:16(BHS d:16)	—					4					—	—	—
BCS d:8(BLO d:8)	—					2				C=1	—	—	—
BCS d:16(BLO d:16)	—					4					—	—	—
BNE d:8	—					2				Z=0	—	—	—
BNE d:16	—					4					—	—	—
BEQ d:8	—					2				Z=1	—	—	—
BEQ d:16	—					4					—	—	—
BVC d:8	—					2				V=0	—	—	—
BVC d:16	—					4					—	—	—
BVS d:8	—					2				V=1	—	—	—
BVS d:16	—					4					—	—	—
BPL d:8	—					2				N=0	—	—	—
BPL d:16	—					4					—	—	—
BMI d:8	—					2				N=1	—	—	—
BMI d:16	—					4					—	—	—
BGE d:8	—					2				N@V=0	—	—	—
BGE d:16	—					4					—	—	—
BLT d:8	—					2				N@V=1	—	—	—
BLT d:16	—					4					—	—	—
BGT d:8	—					2				Zv(N@V)=0	—	—	—
BGT d:16	—					4					—	—	—
BLE d:8	—					2				Zv(N@V)=1	—	—	—
BLE d:16	—					4					—	—	—

BSR	BSR d:8	—						2		PC→@-SP,PC←PC+d:8	—	—	—
	BSR d:16	—						4		PC→@-SP,PC←PC+d:16	—	—	—
JSR	JSR @ERn	—					2			PC→@-SP,PC←ERn	—	—	—
	JSR @aa:24	—						4		PC→@-SP,PC←aa:24	—	—	—
	JSR @aa:8	—						2		PC→@-SP,PC←aa:8	—	—	—
RTS	RTS	—						2		PC←@SP+	—	—	—



RTE	RTE	—																	EXR←@SP+,CCR←@SP+, PC←@SP+	↑	↓	↑	↓
SLEEP	SLEEP	—																	Transition to power-down state	—	—	—	—
LDC	LDC #xx:8,CCR	B	2																#xx:8→CCR	↑	↓	↑	↓
	LDC #xx:8,EXR	B	4																#xx:8→EXR	—	—	—	—
	LDC Rs,CCR	B	2																Rs8→CCR	↑	↓	↑	↓
	LDC Rs,EXR	B	2																Rs8→EXR	—	—	—	—
	LDC @ERs,CCR	W		4															@ERs→CCR	↑	↓	↑	↓
	LDC @ERs,EXR	W		4															@ERs→EXR	—	—	—	—
	LDC @(d:16,ERs),CCR	W			6														@(d:16,ERs)→CCR	↑	↓	↑	↓
	LDC @(d:16,ERs),EXR	W			6														@(d:16,ERs)→EXR	—	—	—	—
	LDC @(d:32,ERs),CCR	W			10														@(d:32,ERs)→CCR	↑	↓	↑	↓
	LDC @(d:32,ERs),EXR	W			10														@(d:32,ERs)→EXR	—	—	—	—
	LDC @ERs+,CCR	W				4													@ERs→CCR,ERs32+2→ERs32	↑	↓	↑	↓
	LDC @ERs+,EXR	W				4													@ERs→EXR,ERs32+2→ERs32	—	—	—	—
	LDC @aa:16,CCR	W					6												@aa:16→CCR	↑	↓	↑	↓
	LDC @aa:16,EXR	W					6												@aa:16→EXR	—	—	—	—
	LDC @aa:32,CCR	W						8											@aa:32→CCR	↑	↓	↑	↓
LDC @aa:32,EXR	W						8											@aa:32→EXR	—	—	—	—	

	STC EXR, @ERd	W			4						EXR→@ERd	—	—	—
	STC CCR, @(d:16,ERd)	W			6						CCR→@(d:16,ERd)	—	—	—
	STC EXR, @(d:16,ERd)	W			6						EXR→@(d:16,ERd)	—	—	—
	STC CCR, @(d:32,ERd)	W			10						CCR→@(d:32,ERd)	—	—	—
	STC EXR, @(d:32,ERd)	W			10						EXR→@(d:32,ERd)	—	—	—
	STC CCR, @-ERd	W				4					ERd32-2→ERd32,CCR→@ERd	—	—	—
	STC EXR, @-ERd	W				4					ERd32-2→ERd32,EXR→@ERd	—	—	—
	STC CCR, @aa:16	W				6					CCR→@aa:16	—	—	—
	STC EXR, @aa:16	W				6					EXR→@aa:16	—	—	—
	STC CCR, @aa:32	W				8					CCR→@aa:32	—	—	—
	STC EXR, @aa:32	W				8					EXR→@aa:32	—	—	—
ANDC	ANDC #xx:8,CCR	B	2								CCR^#xx:8→CCR	↓	↓	↓
	ANDC #xx:8,EXR	B	4								EXR^#xx:8→EXR	—	—	—
ORC	ORC #xx:8,CCR	B	2								CCR v#xx:8→CCR	↓	↓	↓
	ORC #xx:8,EXR	B	4								EXR v#xx:8→EXR	—	—	—
XORC	XORC #xx:8,CCR	B	2								CCR ⊕#xx:8→CCR	↓	↓	↓
	XORC #xx:8,EXR	B	4								EXR ⊕#xx:8→EXR	—	—	—
NOP	NOP	—								2	PC←PC+2	—	—	—

Instruction	Mnemonic	Size	Instruction Format										
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte	8th Byte			
ADD	ADD.B #xx:8,Rd	B	8	rd	IMM								
	ADD.B Rs,Rd	B	0	8	rs	rd							
	ADD.W #xx:16,Rd	W	7	9	1	rd	IMM						
	ADD.W Rs,Rd	W	0	9	rs	rd							
	ADD.L #xx:32,ERd	L	7	A	1	0:erd	IMM						
ADDS	ADD.L ERs,ERd	L	0	A	1:ers	0:erd							
	ADDS #1,ERd	L	0	B	0	0:erd							
	ADDS #2,ERd	L	0	B	8	0:erd							
	ADDS #4,ERd	L	0	B	9	0:erd							
	ADDS #8,ERd	L	0	B	9	0:erd							
ADDX	ADDX #xx:8,Rd	B	9	rd	IMM								
	ADDX Rs,Rd	B	0	E	rs	rd							
AND	AND.B #xx:8,Rd	B	E	rd	IMM								
	AND.B Rs,Rd	B	1	6	rs	rd							
	AND.W #xx:16,Rd	W	7	9	6	rd	IMM						
	AND.W Rs,Rd	W	6	6	rs	rd							
	AND.L #xx:32,ERd	L	7	A	6	0:erd	IMM						
ANDC	AND.L ERs,ERd	L	0	1	F	0	6	6	0:ers	0:erd			
	ANDC #xx:8,CCR	B	0	6	IMM								
	ANDC #xx:8,EXR	B	0	1	4	1	0	6	IMM				
	BAND #xx:3,Rd	B	7	6	0:IMM	rd							
	BAND #xx:3,@ERd	B	7	C	0:erd	0	7	6	0:IMM	0			
Bcc	BAND #xx:3,@aa:8	B	7	E	abs	7	6	0:IMM	0				
	BAND #xx:3,@aa:16	B	6	A	1	0	abs	7	6	0:IMM	0		
	BAND #xx:3,@aa:32	B	6	A	3	0	abs	7	6	0:IMM	0		
	BRA d:8 (BT d:8)	—	4	0	disp								
	BRA d:16 (BT d:16)	—	5	8	0	0	disp						
BRN	BRN d:8 (BF d:8)	—	4	1	disp								
	BRN d:16 (BF d:16)	—	5	8	1	0	disp						

Instruction	Mnemonic	Size	Instruction Format									
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte			
Bcc	BHI d:8	—	4	2	disp							
	BHI d:16	—	5	8	2	0	disp					
	BLS d:8	—	4	3	disp							
	BLS d:16	—	5	8	3	0	disp					
	BCC d:8 (BHS d:8)	—	4	4	disp							
	BCC d:16 (BHS d:16)	—	5	8	4	0	disp					
	BCS d:8 (BLO d:8)	—	4	5	disp							
	BCS d:16 (BLO d:16)	—	5	8	5	0	disp					
	BNE d:8	—	4	6	disp							
	BNE d:16	—	5	8	6	0	disp					
	BEQ d:8	—	4	7	disp							
	BEQ d:16	—	5	8	7	0	disp					
	BVC d:8	—	4	8	disp							
	BVC d:16	—	5	8	8	0	disp					
	BVS d:8	—	4	9	disp							
	BVS d:16	—	5	8	9	0	disp					
BPL d:8	—	4	A	disp								
BPL d:16	—	5	8	A	0	disp						
BMI d:8	—	4	B	disp								
BMI d:16	—	5	8	B	0	disp						
BGE d:8	—	4	C	disp								
BGE d:16	—	5	8	C	0	disp						
BLT d:8	—	4	D	disp								
BLT d:16	—	5	8	D	0	disp						
BGT d:8	—	4	E	disp								
BGT d:16	—	5	8	E	0	disp						
BLE d:8	—	4	F	disp								
BLE d:16	—	5	8	F	0	disp						



Instruction	Mnemonic	Size	Instruction Format															
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte	8th Byte								
BCLR	BCLR #xx:3,Rd	B	7	2	0:IMM	rd												
	BCLR #xx:3,@ERd	B	7	D	0:erd	0	7	2	0:IMM	0								
	BCLR #xx:3,@aa:8	B	7	F	abs		7	2	0:IMM	0								
	BCLR #xx:3,@aa:16	B	6	A	1	8	abs	7	2	0:IMM	0							
	BCLR #xx:3,@aa:32	B	6	A	3	8	abs											
	BCLR Rn,Rd	B	6	2	rn	rd												
BIAND	BCLR Rn,@ERd	B	7	D	0:erd	0	6	2	rn	0								
	BCLR Rn,@aa:8	B	7	F	abs		6	2	rn	0								
	BCLR Rn,@aa:16	B	6	A	1	8	abs	6	2	rn	0							
	BCLR Rn,@aa:32	B	6	A	3	8	abs											
	BIAND #xx:3,Rd	B	7	6	1:IMM	rd												
	BIAND #xx:3,@ERd	B	7	C	0:erd	0	7	6	1:IMM	0								
BILD	BIAND #xx:3,@aa:8	B	7	E	abs		7	6	1:IMM	0								
	BIAND #xx:3,@aa:16	B	6	A	1	0	abs	7	6	1:IMM	0							
	BIAND #xx:3,@aa:32	B	6	A	3	0	abs											
	BILD #xx:3,Rd	B	7	7	1:IMM	rd												
	BILD #xx:3,@ERd	B	7	C	0:erd	0	7	7	1:IMM	0								
	BILD #xx:3,@aa:8	B	7	E	abs		7	7	1:IMM	0								
BIOR	BILD #xx:3,@aa:16	B	6	A	1	0	abs	7	7	1:IMM	0							
	BILD #xx:3,@aa:32	B	6	A	3	0	abs											
	BIOR #xx:3,Rd	B	7	4	1:IMM	rd												
	BIOR #xx:3,@ERd	B	7	C	0:erd	0	7	4	1:IMM	0								
	BIOR #xx:3,@aa:8	B	7	E	abs		7	4	1:IMM	0								
	BIOR #xx:3,@aa:16	B	6	A	1	0	abs	7	4	1:IMM	0							

Instruction	Mnemonic	Size	Instruction Format									
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte			
BIST	BIST #xx:3,Rd	B	6 7	1:IMM; rd								
	BIST #xx:3,@ERd	B	7 D	0:erd 0	6 7	1:IMM; 0						
	BIST #xx:3,@aa:8	B	7 F	abs	6 7	1:IMM; 0						
	BIST #xx:3,@aa:16	B	6 A	1 8	abs	6 7	1:IMM; 0					
	BIST #xx:3,@aa:32	B	6 A	3 8	abs	abs						
BIXOR	BIXOR #xx:3,Rd	B	7 5	1:IMM; rd								
	BIXOR #xx:3,@ERd	B	7 C	0:erd 0	7 5	1:IMM; 0						
	BIXOR #xx:3,@aa:8	B	7 E	abs	7 5	1:IMM; 0						
	BIXOR #xx:3,@aa:16	B	6 A	1 0	abs	7 5	1:IMM; 0					
	BIXOR #xx:3,@aa:32	B	6 A	3 0	abs	abs						
BLD	BLD #xx:3,Rd	B	7 7	0:IMM; rd								
	BLD #xx:3,@ERd	B	7 C	0:erd 0	7 7	0:IMM; 0						
	BLD #xx:3,@aa:8	B	7 E	abs	7 7	0:IMM; 0						
	BLD #xx:3,@aa:16	B	6 A	1 0	abs	7 7	0:IMM; 0					
	BLD #xx:3,@aa:32	B	6 A	3 0	abs	abs						
BNOT	BNOT #xx:3,Rd	B	7 1	0:IMM; rd								
	BNOT #xx:3,@ERd	B	7 D	0:erd 0	7 1	0:IMM; 0						
	BNOT #xx:3,@aa:8	B	7 F	abs	7 1	0:IMM; 0						
	BNOT #xx:3,@aa:16	B	6 A	1 8	abs	7 1	0:IMM; 0					
	BNOT #xx:3,@aa:32	B	6 A	3 8	abs	abs						
	BNOT Rn,Rd	B	6 1	rn rd								
	BNOT Rn,@ERd	B	7 D	0:erd 0	6 1	rn 0						
BNOT Rn,@aa:8	BNOT Rn,@aa:8	B	7 F	abs	6 1	rn 0						
	BNOT Rn,@aa:16	B	6 A	1 8	abs	6 1	rn 0					
	BNOT Rn,@aa:32	B	6 A	3 8	abs	abs						
	BNOT Rn,@aa:8	B	6 A	1 8	abs	6 1	rn 0					
	BNOT Rn,@aa:16	B	6 A	3 8	abs	abs						

Instruction	Mnemonic	Size	Instruction Format									
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte			
BOR	BOR #xx:3,Rd	B	7	4	0:iMMj	rd						
	BOR #xx:3,@ERd	B	7	C	0:erd	0	7	4	0:iMMj	0		
	BOR #xx:3,@aa:8	B	7	E	abs		7	4	0:iMMj	0		
	BOR #xx:3,@aa:16	B	6	A	1	0	abs		7	4	0:iMMj	0
	BOR #xx:3,@aa:32	B	6	A	3	0	abs		abs			
	BSET #xx:3,Rd	B	7	0	0:iMMj	rd						
BSET	BSET #xx:3,@ERd	B	7	D	0:erd	0	7	0	0:iMMj	0		
	BSET #xx:3,@aa:8	B	7	F	abs		7	0	0:iMMj	0		
	BSET #xx:3,@aa:16	B	6	A	1	8	abs		7	0	0:iMMj	0
	BSET #xx:3,@aa:32	B	6	A	3	8	abs		abs			
	BSET Rn,Rd	B	6	0	rn	rd						
	BSET Rn,@ERd	B	7	D	0:erd	0	6	0	rn	0		
BST	BSET Rn,@aa:8	B	7	F	abs		6	0	rn	0		
	BSET Rn,@aa:16	B	6	A	1	8	abs		6	0	rn	0
	BSET Rn,@aa:32	B	6	A	3	8	abs		abs			
	BSR d:8	—	5	5	disp							
	BSR d:16	—	5	C	0	0	disp					
	BST #xx:3,Rd	B	6	7	0:iMMj	rd						
BTST	BST #xx:3,@ERd	B	7	D	0:erd	0	6	7	0:iMMj	0		
	BST #xx:3,@aa:8	B	7	E	abs		7	3	0:iMMj	0		
	BST #xx:3,@aa:16	B	6	A	1	0	abs		6	7	0:iMMj	0
	BST #xx:3,@aa:32	B	6	A	3	0	abs		6	7	0:iMMj	0
	BTST Rn,Rd	B	6	3	rn	rd						
	BTST #xx:3,Rd	B	7	3	0:iMMj	rd						
BTST	BTST #xx:3,@ERd	B	7	C	0:erd	0	7	3	0:iMMj	0		
	BTST #xx:3,@aa:8	B	7	E	abs		7	3	0:iMMj	0		
	BTST #xx:3,@aa:16	B	6	A	1	0	abs		7	3	0:iMMj	0
	BTST #xx:3,@aa:32	B	6	A	3	0	abs		abs			
	BTST Rn,Rd	B	6	3	rn	rd						
	BTST #xx:3,Rd	B	7	3	0:iMMj	rd						

Instruction	Mnemonic	Size	Instruction Format										
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte				
BTST	Rn, @aa:8	B	7	E	abs	6	3	rn	0				
	Rn, @aa:16	B	6	A	1	0	abs		6	3	rn	0	
	Rn, @aa:32	B	6	A	3	0	abs		abs			6	3
BXOR	#xx:3, Rd	B	7	5	0:IMM	rd							
	#xx:3, @ERd	B	7	C	0:erd	0	7	5	0:IMM	0			
	#xx:3, @aa:8	B	7	E	abs	7	5	0:IMM	0				
	#xx:3, @aa:16	B	6	A	1	0	abs		7	5	0:IMM	0	
CLRMAC	#xx:3, @aa:32	B	6	A	3	0	abs					7	5
	CLRMAC	—	Cannot be used with this LSI.										
CMP	#xx:8, Rd	B	A	rd	IMM								
	Rs, Rd	B	1	C	rs	rd							
	#xx:16, Rd	W	7	9	2	rd	IMM						
	Rs, Rd	W	1	D	rs	rd							
	#xx:32, ERd	L	7	A	2	0:erd	IMM						
DAA	ERs, ERd	L	1	F	1:ers	0:erd							
	DAA Rd	B	0	F	0	rd							
DAS	DAS Rd	B	1	F	0	rd							
	DEC.B Rd	B	1	A	0	rd							
DEC	DEC.W #1, Rd	W	1	B	5	rd							
	DEC.W #2, Rd	W	1	B	D	rd							
	DEC.L #1, ERd	L	1	B	7	0:erd							
	DEC.L #2, ERd	L	1	B	F	0:erd							
DIVXS	Rs, Rd	B	0	1	D	0	5	1	rs	rd			
	Rs, ERd	W	0	1	D	0	5	3	rs	0:erd			
DIVXU	Rs, Rd	B	5	1	rs	rd							
	Rs, ERd	W	5	3	rs	0:erd							
EEPMOV	B	—	7	B	5	C	5	9	8	F			
	W	—	7	B	D	4	5	9	8	F			

Instruction	Mnemonic	Size	Instruction Format							
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte	
EXTS	EXTS.W,Rd	W	1 7	D rd						
	EXTS.L,ERd	L	1 7	F 0:erd						
EXTU	EXTU.W,Rd	W	1 7	5 rd						
	EXTU.L,ERd	L	1 7	7 0:erd						
INC	INC.B,Rd	B	0 A	0 rd						
	INC.W #1,Rd	W	0 B	5 rd						
	INC.W #2,Rd	W	0 B	D rd						
	INC.L #1,ERd	L	0 B	7 0:erd						
	INC.L #2,ERd	L	0 B	F 0:erd						
			—	5 9	0:ern 0					
JMP	JMP @ERn	—	5 A		abs					
	JMP @aa:24	—	5 B	abs						
JSR	JMP @aa:8	—	5 B	abs						
	JSR @ERn	—	5 D	0:ern 0						
	JSR @aa:24	—	5 E		abs					
	JSR @aa:8	—	5 F	abs						
LDC	LDC #xx:8,CCR	B	0 7	IMM						
	LDC #xx:8,EXR	B	0 1	4 1	0 7	IMM				
	LDC Rs,CCR	B	0 3	0 rs						
	LDC Rs,EXR	B	0 3	1 rs						
	LDC @ERs,CCR	W	0 1	4 0	6 9	0:ers 0				
	LDC @ERs,EXR	W	0 1	4 1	6 9	0:ers 0				
	LDC @(d:16,ERs),CCR	W	0 1	4 0	6 F	0:ers 0	disp			
	LDC @(d:16,ERs),EXR	W	0 1	4 1	6 F	0:ers 0	disp			
LDC	LDC @(d:32,ERs),CCR	W	0 1	4 0	7 8	0:ers 0	6 B	2 0		
	LDC @(d:32,ERs),EXR	W	0 1	4 1	7 8	0:ers 0	6 B	2 0		
	LDC @ERs+,CCR	W	0 1	4 0	6 D	0:ers 0				
	LDC @ERs+,EXR	W	0 1	4 1	6 D	0:ers 0				
		W	0 1	4 0	6 B	0 0				
		W	0 1	4 0	6 B	0 0				
		W	0 1	4 0	6 B	0 0				
		W	0 1	4 0	6 B	0 0				

Instruction	Mnemonic	Size	Instruction Format								
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte		
LDC	LDC @aa:32,CCR	W	0	1	4	0	6	B	2	0	abs
	LDC @aa:32,EXR	W	0	1	4	1	6	B	2	0	abs
LDM#3	LDM.L @SP+, (ERn-ERn+1)	L	0	1	1	0	6	D	7	0:imm+1	
	LDM.L @SP+, (ERn-ERn+2)	L	0	1	2	0	6	D	7	0:imm+2	
	LDM.L @SP+, (ERn-ERn+3)	L	0	1	3	0	6	D	7	0:imm+3	
LDMAC	LDMAC ERs, MACH	L	Cannot be used with this LSI.								
MAC	LDMAC ERs, MACL	L									
MOV	MAC @ERn+, @ERm+	—									
	MOV.B #xx:8,Rd	B	F	rd	IMM						
	MOV.B Rs,Rd	B	0	C	rs	rd					
	MOV.B @ERs,Rd	B	6	8	0:ers	rd					
	MOV.B @(d:16,ERs),Rd	B	6	E	0:ers	rd	disp				
	MOV.B @(d:32,ERs),Rd	B	7	8	0:ers	0	6	A	2	rd	disp
	MOV.B @ERS+,Rd	B	6	C	0:ers	rd					
	MOV.B @aa:8,Rd	B	2	rd	abs						
	MOV.B @aa:16,Rd	B	6	A	0	rd	abs				
	MOV.B @aa:32,Rd	B	6	A	2	rd					
	MOV.B Rs,@ERd	B	6	8	1:erd	rs					
	MOV.B Rs,@(d:16,ERd)	B	6	E	1:erd	rs	disp				
	MOV.B Rs,@(d:32,ERd)	B	7	8	0:erd	0	6	A	A	rs	disp
	MOV.B Rs,@-ERd	B	6	C	1:erd	rs					
MOV.B Rs,@aa:8	B	3	rs	abs							
MOV.B Rs,@aa:16	B	6	A	8	rs	abs					
MOV.B Rs,@aa:32	B	6	A	A	rs						
MOV.W #xx:16,Rd	W	7	9	0	rd	IMM					
MOV.W Rs,Rd	W	0	D	rs	rd						
MOV.W @ERS,Rd	W	6	9	0:ers	rd						
MOV.W @(d:16,ERs),Rd	W	6	F	0:ers	rd	disp					
MOV.W @(d:32,FRs),Rd	W	7	8	0:ers	0	6	B	2	rd	disp	

Instruction	Mnemonic	Size	Instruction Format																	
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte	8th Byte										
MOV	MOV.W @ERs+,Rd	W	6	D	0:ers	rd														
	MOV.W @aa:16,Rd	W	6	B	0	rd														
	MOV.W @aa:32,Rd	W	6	B	2	rd														
	MOV.W Rs,@ERd	W	6	9	1:erd	rs														
	MOV.W Rs,@(d:16,ERd)	W	6	F	1:erd	rs														
	MOV.W Rs,@(d:32,ERd)	W	7	8	0:erd	0	6	B	A	rs										
	MOV.W Rs,@-ERd	W	6	D	1:erd	rs														
	MOV.W Rs,@aa:16	W	6	B	8	rs														
	MOV.W Rs,@aa:32	W	6	B	A	rs														
	MOV.L #xx:32,Rd	L	7	A	0	0:erd														
	MOV.L ERs,ERd	L	0	F	1:ers	0:erd														
	MOV.L @ERs,ERd	L	0	1	0	0	6	9	0:ers	0:erd										
	MOV.L @(d:16,ERs),ERd	L	0	1	0	0	6	F	0:ers	0:erd										
	MOV.L @(d:32,ERs),ERd	L	0	1	0	0	7	8	0:ers	0	6	B	2	0:erd						
	MOV.L @ERs+,ERd	L	0	1	0	0	6	D	0:ers	0:erd										
MOV.L @aa:16,ERd	L	0	1	0	0	6	B	0	0:erd											
MOV.L @aa:32,ERd	L	0	1	0	0	6	B	2	0:erd											
MOV.L ERs,@ERd	L	0	1	0	0	6	9	1:erd	0:ers											
MOV.L ERs,@(d:16,ERd)	L	0	1	0	0	6	F	1:erd	0:ers											
MOV.L ERs,@(d:32,ERd)*1	L	0	1	0	0	7	8	0:erd	0	6	B	A	0:ers							
MOV.L ERs,@-ERd	L	0	1	0	0	6	D	1:erd	0:ers											
MOV.L ERs,@aa:16	L	0	1	0	0	6	B	8	0:ers											
MOV.L ERs,@aa:32	L	0	1	0	0	6	B	A	0:ers											
MOVFP	MOVFP @aa:16,Rd	B	Cannot be used with this LSI.																	
MOVTP	MOVTP Rs,@aa:16	B																		
MULXS	MULXS.B Rs,Rd	B	0	1	C	0	5	0	rs	rd										
	MULXS.W Rs,ERd	W	0	1	C	0	5	2	rs	0:erd										
MULXU	MULXU.B Rs,Rd	B	5	0	rs	rd														

Instruc- tion	Mnemonic	Size	Instruction Format										
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte	8th Byte			
NEG	NEG.B Rd	B	1	7	8	rd							
	NEG.W Rd	W	1	7	9	rd							
	NEG.L ERd	L	1	7	B	0:erd							
NOP	NOP	—	0	0	0	0							
NOT	NOT.B Rd	B	1	7	0	rd							
	NOT.W Rd	W	1	7	1	rd							
	NOT.L ERd	L	1	7	3	0:erd							
OR	OR.B #xx:8,Rd	B	C	rd	IMM								
	OR.B Rs,Rd	B	1	4	rs	rd							
	OR.W #xx:16,Rd	W	7	9	4	rd	IMM						
	OR.W Rs,Rd	W	6	4	rs	rd							
	OR.L #xx:32,ERd	L	7	A	4	0:erd		IMM					
	OR.L ERs,ERd	L	0	1	F	0	6	4	0:ers	0:erd			
	ORC #xx:8,CCR	B	0	4	IMM								
	ORC #xx:8,EXR	B	0	1	4	1	0	4	IMM				
POP	POP.W Rn	W	6	D	7	rn							
	POP.L ERn	L	0	1	0	0	6	D	7	0:ern			
PUSH	PUSH.W Rn	W	6	D	F	rn							
	PUSH.L ERn	L	0	1	0	0	6	D	F	0:ern			
ROTL	ROTL.B Rd	B	1	2	8	rd							
	ROTL.B #2, Rd	B	1	2	C	rd							
	ROTL.W Rd	W	1	2	9	rd							
	ROTL.W #2, Rd	W	1	2	D	rd							
	ROTL.L ERd	L	1	2	B	0:erd							
ROTL.L #2, ERd	L	1	2	F	0:erd								

Instruction	Mnemonic	Size	Instruction Format										
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte	8th Byte			
ROTR	ROTR.B Rd	B	1	3	8	rd							
	ROTR.B #2, Rd	B	1	3	C	rd							
	ROTR.W Rd	W	1	3	9	rd							
	ROTR.W #2, Rd	W	1	3	D	rd							
	ROTR.L ERd	L	1	3	B	0:erd							
	ROTR.L #2, ERd	L	1	3	F	0:erd							
	ROTXL.B Rd	B	1	2	0	rd							
	ROTXL.B #2, Rd	B	1	2	4	rd							
	ROTXL.W Rd	W	1	2	1	rd							
ROTXR	ROTXL.W #2, Rd	W	1	2	5	rd							
	ROTXL.L ERd	L	1	2	3	0:erd							
	ROTXL.L #2, ERd	L	1	2	7	0:erd							
	ROTXR.B Rd	B	1	3	0	rd							
	ROTXR.B #2, Rd	B	1	3	4	rd							
	ROTXR.W Rd	W	1	3	1	rd							
	ROTXR.W #2, Rd	W	1	3	5	rd							
	ROTXR.L ERd	L	1	3	3	0:erd							
	ROTXR.L #2, ERd	L	1	3	7	0:erd							
RTE	RTE	—	5	6	7	0							
RTS	RTS	—	5	4	7	0							
SHAL	SHAL.B Rd	B	1	0	8	rd							
	SHAL.B #2, Rd	B	1	0	C	rd							
	SHAL.W Rd	W	1	0	9	rd							
	SHAL.W #2, Rd	W	1	0	D	rd							
	SHAL.L ERd	L	1	0	B	0:erd							
	SHAL.L #2, ERd	L	1	0	F	0:erd							

Instruc- tion	Mnemonic	Size	Instruction Format																
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte	8th Byte									
SHAR	SHAR.B Rd	B	1	1	8	rd													
	SHAR.B #2, Rd	B	1	1	C	rd													
	SHAR.W Rd	W	1	1	9	rd													
	SHAR.W #2, Rd	W	1	1	D	rd													
	SHAR.L ERd	L	1	1	B	0:erd													
	SHAR.L #2, ERd	L	1	1	F	0:erd													
SHLL	SHLL.B Rd	B	1	0	0	rd													
	SHLL.B #2, Rd	B	1	0	4	rd													
	SHLL.W Rd	W	1	0	1	rd													
	SHLL.W #2, Rd	W	1	0	5	rd													
	SHLL.L ERd	L	1	0	3	0:erd													
	SHLL.L #2, ERd	L	1	0	7	0:erd													
SHLR	SHLR.B Rd	B	1	1	0	rd													
	SHLR.B #2, Rd	B	1	1	4	rd													
	SHLR.W Rd	W	1	1	1	rd													
	SHLR.W #2, Rd	W	1	1	5	rd													
	SHLR.L ERd	L	1	1	3	0:erd													
	SHLR.L #2, ERd	L	1	1	7	0:erd													
SLEEP	SLEEP	—	0	1	8	0													
STC	STC.B CCR,Rd	B	0	2	0	rd													
	STC.B EXR,Rd	B	0	2	1	rd													
	STC.W CCR,@ERd	W	0	1	4	0			6	9	1:erd	0							
	STC.W EXR,@ERd	W	0	1	4	1			6	9	1:erd	0							
	STC.W CCR,@(d:16,ERd)	W	0	1	4	0			6	F	1:erd	0							
	STC.W EXR,@(d:16,ERd)	W	0	1	4	1			6	F	1:erd	0							
	STC.W CCR,@(d:32,ERd)	W	0	1	4	0			7	8	0:erd	0							
	STC.W EXR,@(d:32,ERd)	W	0	1	4	1			7	8	0:erd	0							
	STC.W CCR,@-ERd	W	0	1	4	0			6	D	1:erd	0							
	STC.W EXR,@-FRd	W	0	1	4	1			6	D	1:erd	0							



Instruction	Mnemonic	Size	Instruction Format								
			1st Byte	2nd Byte	3rd Byte	4th Byte	5th Byte	6th Byte	7th Byte		
STC	STC.W CCR, @aa:16	W	0	1	4	0	6	B	8	0	abs
	STC.W EXR, @aa:16	W	0	1	4	1	6	B	8	0	abs
	STC.W CCR, @aa:32	W	0	1	4	0	6	B	A	0	abs
	STC.W EXR, @aa:32	W	0	1	4	1	6	B	A	0	abs
STM*3	STM.L (ERn-ERn+1), @-SP	L	0	1	1	0	6	D	F	0:ern	
	STM.L (ERn-ERn+2), @-SP	L	0	1	2	0	6	D	F	0:ern	
	STM.L (ERn-ERn+3), @-SP	L	0	1	3	0	6	D	F	0:ern	
STMAC	STMAC MACH,ERd	L	Cannot be used with this LSI.								
	STMAC MACL,ERd	L									
SUB	SUB.B Rs,Rd	B	1	8	rs	rd					
	SUB.W #xx:16,Rd	W	7	9	3	rd		IMM			
	SUB.W Rs,Rd	W	1	9	rs	rd					
	SUB.L #xx:32,ERd	L	7	A	3	0:erd				IMM	
SUBS	SUB.L ERs,ERd	L	1	A	1:ers	0:erd					
	SUBS #1,ERd	L	1	B	0	0:erd					
	SUBS #2,ERd	L	1	B	8	0:erd					
	SUBS #4,ERd	L	1	B	9	0:erd					
	SUBX #xx:8,Rd	B	B	rd	IMM						
TAS	SUBX Rs,Rd	B	1	E	rs	rd					
	TAS @ERd*2	B	0	1	E	0	7	B	0:erd	C	
TRAPA	TRAPA #x:2	—	5	7	00:IMM	0					
XOR	XOR.B #xx:8,Rd	B	D	rd	IMM						
	XOR.B Rs,Rd	B	1	5	rs	rd					
	XOR.W #xx:16,Rd	W	7	9	5	rd		IMM			
	XOR.W Rs,Rd	W	6	5	rs	rd					
	XOR.L #xx:32,ERd	L	7	A	5	0:erd				IMM	
XOR.L ERs,ERd	L	0	1	F	0	6	5	0:ers	0:erd		

Instruc- tion	Mnemonic	Size	Instruction Format								
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte		
XORC	XORC #xx:8,CCR	B	0	5	IMM						
	XORC #xx:8,EXR	B	0	1	4	1	0	5	IMM		

Legend:

IMM: Immediate data (2, 3, 8, 16, or 32 bits)

abs: Absolute address (8, 16, 24, or 32 bits)

disp: Displacement (8, 16, or 32 bits)

rs, rd, rn:

Register field (4 bits, indicating an 8-bit or 16-bit register. rs, rd, and rn correspond to operand formats

ers, erd, ern, erm: Register field (3 bits, indicating an address register or 32-bit register. ers, erd, ern, and erm correspond

to ERn, and ERm, respectively.)

Notes: 1. Bit 7 of the 4th byte of the MOV.L ERs, @ (d:32, ERd) instruction can be either 0 or 1.

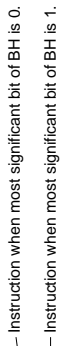
2. Only register ER0, ER1, ER4, or ER5 should be used when using the TAS instruction.

3. Only registers ER0 to ER6 should be used when using the STM/LDM instruction.

The correspondence between register fields and general registers is shown in the following table.

Address Registers		16-Bit Register		8-Bit Register	
32-Bit Register	General Register	Register Field	General Register	Register Field	General Register
000	ER0	0000	R0	0000	R0H
001	ER1	0001	R1	0001	R1H
•	•	•	•	•	•
•	•	•	•	•	•
•	•	•	•	•	•
111	ER7	0111	R7	0111	R7H
		1000	E0	1000	R0L
		1001	E1	1001	R1L
		•	•	•	•
		•	•	•	•
		•	•	•	•
		1111	E7	1111	R7L





1st byte		2nd byte	
AH	AL	BH	BL

Instruction code:

AL	0	1	2	3	4	5	6	7	8	9	A	B	C	D
AH	0	1	2	3	4	5	6	7	8	9	A	B	C	D
	NOP	STC	LDC	LDMAC*	ORC	XORC	ANDC	LDC	LDC	ADD	Table A.3(2)	Table A.3(2)	MOV	A
	Table A.3(2)	Table A.3(2)	Table A.3(2)	Table A.3(2)	OR	XOR	AND	Table A.3(2)	Table A.3(2)	SUB	Table A.3(2)	Table A.3(2)	CMP	S
2														
3														
4	BRA	BRN	BHI	BLS	BCC	BCS	BNE	BEQ	BVC	BVS	BPL	BMI	BGE	BLT
5	MULXU	DIVXU	MULXU	DIVXU	RTS	BSR	RTE	TRAPA	Table A.3(2)		JMP		BSR	J
6	BSET	BNOT	BCLR	BTST	OR	XOR	AND	BST	MOV	MOV	Table A.3(2)			MOV
7					BOR	BXOR	BAND	BLD	MOV	Table A.3(2)	Table A.3(2)	EEMOV		Table A.3
8					BIOR	BIXOR	BIAND	BILD	ADD					
9									ADDX					
A									CMP					
B									SUBX					
C									OR					
D									XOR					
E									AND					
F									MOV					

MOV.B



Note: * Cannot be used with this LSI.

1st byte		2nd byte		
AH	AL	BH	BL	

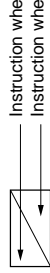
Instruction code:

BH	AH	AL	0	1	2	3	4	5	6	7	8	9	A	B	C
			MOV	LDM	STM	LDC	STC		MAC*		SLEEP		CLRMAC*		Table A.3 (3)
0A			INC							INC					ADD
0B			ADDS					INC			ADDS				MOV
0F			DAA												MOV
10			SHLL			SHLL				SHLL	SHAL				SHAL
11			SHLR			SHLR				SHLR	SHAR				SHAR
12			ROTXL			ROTXL				ROTXL	ROTL				ROTL
13			ROTXR			ROTXR				ROTXR	ROTR				ROTR
17			NOT			NOT		EXTU		EXTU	NEG			NEG	
1A			DEC												SUB
1B			SUBS					DEC		DEC					SUBS
1F			DAS												SUB
58			BRA	BRN	BHI	BLS	BCC	BCS	BNE	BEQ	BVC	BVS	BPL	BMI	BGE
6A			MOV	Table A.3 (4)	MOV	Table A.3 (4)	MOVFP*				MOV		MOV		MOVTP
79			MOV	ADD	CMP	SUB	OR	XOR	AND						
7A			MOV	ADD	CMP	SUB	OR	XOR	AND						

Note: * Cannot be used with this I S

Instruction code:

1st byte		2nd byte		3rd byte			4th byte	
AH	AL	BH	BL	CH	CL	DL	DH	DL



CL	0	1	2	3	4	5	6	7	8	9	A	B	C
AH/AL/BH/BL/CH													
01C05	MULXS		MULXS										
01D05		DIVXS		DIVXS									
01F06					OR	XOR	AND						
7C06*1				BTST									
7C07*1				BTST	BOR	BXOR	BAND	BLD					
7D06*1	BSET	BNOT	BCLR		BIOR	BXOR	BIAND	BILD					
7D07*1	BSET	BNOT	BCLR					BST					
7Eaa6*2				BTST									
7Eaa7*2				BTST	BOR	BXOR	BAND	BLD					
7Faa6*2	BSET	BNOT	BCLR		BIOR	BXOR	BIAND	BILD					
7Faa7*2	BSET	BNOT	BCLR					BST					

Notes: 1. r is the register specification field.
2. aa is the absolute address specification.



Instruction code:

1st byte		2nd byte		3rd byte		4th byte		5th byte		6th byte	
AH	AL	BH	BL	CH	CL	DH	DL	EH	EL	FH	FL



EL	0	1	2	3	4	5	6	7	8	9	A	B	C
AH BH CH DH EH													
6A10aaaa6*				BTST									
6A10aaaa7*					 BOR BXOR BIOR BIXOR 	 BAND BAND 	 BAND BAND 	 BLD BILD 	 BST BIST 				
6A18aaaa6*													
6A18aaaa7*			BCLR										
	BSET	BNOT											

Instruction code:

1st byte		2nd byte		3rd byte		4th byte		5th byte		6th byte		7th byte		8th byte	
AH	AL	BH	BL	CH	CL	DH	DL	EH	EL	FH	FL	GH	GL	HH	HL



GL	0	1	2	3	4	5	6	7	8	9	A	B	C
AH BH L... FH GH													
6A30aaaaaa6*				BTST									
6A30aaaaaaa7*					 BOR BXOR BIOR BIXOR 	 BAND BAND 	 BAND BAND 	 BLD BILD 	 BST BIST 				
6A38aaaaaa6*													
6A38aaaaaaa7*			BCLR										
	BSET	BNOT											

Note: * aa is the absolute address specification

Examples of Calculation of Number of States Required for Execution

Examples: Advanced mode, stack located in external address space, on-chip supporting accessed in two states with 8-bit bus width, external devices accessed in three states with 8-bit bus width and 16-bit bus width.

1. BSET #0, @FFFFC7:8

From table A.5,

$$I = L = 2 \text{ and } J = K = M = N = 0$$

From table A.4,

$$S_I = 4 \text{ and } S_L = 2$$

$$\text{Number of states} = 2 \times 4 + 2 \times 2 = 12$$

2. JSR @@30

From table A.5,

$$I = J = K = 2 \text{ and } L = M = N = 0$$

From table A.4,

$$S_I = S_J = S_K = 4$$

$$\text{Number of states} = 2 \times 4 + 2 \times 4 + 2 \times 4 = 24$$

Branch address fetch	S_J					
Stack operation	S_K					
Byte data access	S_L	2		2	3 + m	
Word data access	S_M	4		4	6 + 2m	
Internal operation	S_N	1	1	1	1	1

Legend:

m: Number of wait states inserted into external device access

	ADD.L #xx:32,ERd	3	
	ADD.L ERs,ERd	1	
ADDS	ADDS #1/2/4,ERd	1	
ADDX	ADDX #xx:8,Rd	1	
	ADDX Rs,Rd	1	
AND	AND.B #xx:8,Rd	1	
	AND.B Rs,Rd	1	
	AND.W #xx:16,Rd	2	
	AND.W Rs,Rd	1	
	AND.L #xx:32,ERd	3	
	AND.L ERs,ERd	2	
ANDC	ANDC #xx:8,CCR	1	
	ANDC #xx:8,EXR	2	
BAND	BAND #xx:3,Rd	1	
	BAND #xx:3,@ERd	2	1
	BAND #xx:3,@aa:8	2	1
	BAND #xx:3,@aa:16	3	1
	BAND #xx:3,@aa:32	4	1
Bcc	BRA d:8 (BT d:8)	2	
	BRN d:8 (BF d:8)	2	
	BHI d:8	2	
	BLS d:8	2	
	BCC d:8 (BHS d:8)	2	
	BCS d:8 (BLO d:8)	2	
	BNE d:8	2	
	BEQ d:8	2	
	BVC d:8	2	
	BVS d:8	2	
	BPL d:8	2	

	BRA d:16 (BT d:16)	2	
	BRN d:16 (BF d:16)	2	
	BHI d:16	2	
	BLS d:16	2	
	BCC d:16 (BHS d:16)	2	
	BCS d:16 (BLO d:16)	2	
	BNE d:16	2	
	BEQ d:16	2	
	BVC d:16	2	
	BVS d:16	2	
	BPL d:16	2	
	BMI d:16	2	
	BGE d:16	2	
	BLT d:16	2	
	BGT d:16	2	
	BLE d:16	2	
<hr/>			
BCLR	BCLR #xx:3,Rd	1	
	BCLR #xx:3,@ERd	2	2
	BCLR #xx:3,@aa:8	2	2
	BCLR #xx:3,@aa:16	3	2
	BCLR #xx:3,@aa:32	4	2
	BCLR Rn,Rd	1	
	BCLR Rn,@ERd	2	2
	BCLR Rn,@aa:8	2	2
	BCLR Rn,@aa:16	3	2
	BCLR Rn,@aa:32	4	2
<hr/>			
BIAND	BIAND #xx:3,Rd	1	
	BIAND #xx:3,@ERd	2	1
	BIAND #xx:3,@aa:8	2	1
	BIAND #xx:3,@aa:16	3	1
	BIAND #xx:3,@aa:32	4	1

BIOR	BIOR #xx:8,Rd	1	
	BIOR #xx:8,@ERd	2	1
	BIOR #xx:8,@aa:8	2	1
	BIOR #xx:8,@aa:16	3	1
BIST	BIOR #xx:8,@aa:32	4	1
	BIST #xx:3,Rd	1	
	BIST #xx:3,@ERd	2	2
	BIST #xx:3,@aa:8	2	2
	BIST #xx:3,@aa:16	3	2
BIXOR	BIST #xx:3,@aa:32	4	2
	BIXOR #xx:3,Rd	1	
	BIXOR #xx:3,@ERd	2	1
	BIXOR #xx:3,@aa:8	2	1
	BIXOR #xx:3,@aa:16	3	1
BLD	BIXOR #xx:3,@aa:32	4	1
	BLD #xx:3,Rd	1	
	BLD #xx:3,@ERd	2	1
	BLD #xx:3,@aa:8	2	1
	BLD #xx:3,@aa:16	3	1
BNOT	BLD #xx:3,@aa:32	4	1
	BNOT #xx:3,Rd	1	
	BNOT #xx:3,@ERd	2	2
	BNOT #xx:3,@aa:8	2	2
	BNOT #xx:3,@aa:16	3	2
	BNOT #xx:3,@aa:32	4	2
	BNOT Rn,Rd	1	
	BNOT Rn,@ERd	2	2
	BNOT Rn,@aa:8	2	2
BNOT Rn,@aa:16	3	2	
	BNOT Rn,@aa:32	4	2

BSET	BSET #xx:3,Rd		1	
	BSET #xx:3,@ERd		2	2
	BSET #xx:3,@aa:8		2	2
	BSET #xx:3,@aa:16		3	2
	BSET #xx:3,@aa:32		4	2
	BSET Rn,Rd		1	
	BSET Rn,@ERd		2	2
	BSET Rn,@aa:8		2	2
	BSET Rn,@aa:16		3	2
	BSET Rn,@aa:32		4	2
BSR	BSR d:8	Normal	2	1
		Advanced	2	2
	BSR d:16	Normal	2	1
		Advanced	2	2
BST	BST #xx:3,Rd		1	
	BST #xx:3,@ERd		2	2
	BST #xx:3,@aa:8		2	2
	BST #xx:3,@aa:16		3	2
	BST #xx:3,@aa:32		4	2
BTST	BTST #xx:3,Rd		1	
	BTST #xx:3,@ERd		2	1
	BTST #xx:3,@aa:8		2	1
	BTST #xx:3,@aa:16		3	1
	BTST #xx:3,@aa:32		4	1
	BTST Rn,Rd		1	
	BTST Rn,@ERd		2	1
	BTST Rn,@aa:8		2	1
	BTST Rn,@aa:16		3	1
	BTST Rn,@aa:32		4	1

CMP	CMP.B #xx:8,Rd	1			
	CMP.B Rs,Rd	1			
	CMP.W #xx:16,Rd	2			
	CMP.W Rs,Rd	1			
	CMP.L #xx:32,ERd	3			
	CMP.L ERs,ERd	1			
DAA	DAA Rd	1			
DAS	DAS Rd	1			
DEC	DEC.B Rd	1			
	DEC.W #1/2,Rd	1			
	DEC.L #1/2,ERd	1			
DIVXS	DIVXS.B Rs,Rd	2			
	DIVXS.W Rs,ERd	2			
DIVXU	DIVXU.B Rs,Rd	1			
	DIVXU.W Rs,ERd	1			
EEPMOV	EEPMOV.B	2		2n+2 ^{*2}	
	EEPMOV.W	2		2n+2 ^{*2}	
EXTS	EXTS.W Rd	1			
	EXTS.L ERd	1			
EXTU	EXTU.W Rd	1			
	EXTU.L ERd	1			
INC	INC.B Rd	1			
	INC.W #1/2,Rd	1			
	INC.L #1/2,ERd	1			
JMP	JMP @ERn	2			
	JMP @aa:24	2			
	JMP @@aa:8	Normal	2	1	
		Advanced	2	2	

LDC	LDC #xx:8,CCR	1	
	LDC #xx:8,EXR	2	
	LDC Rs,CCR	1	
	LDC Rs,EXR	1	
	LDC @ERs,CCR	2	1
	LDC @ERs,EXR	2	1
	LDC @(d:16,ERs),CCR	3	1
	LDC @(d:16,ERs),EXR	3	1
	LDC @(d:32,ERs),CCR	5	1
	LDC @(d:32,ERs),EXR	5	1
	LDC @ERs+,CCR	2	1
	LDC @ERs+,EXR	2	1
	LDC @aa:16,CCR	3	1
	LDC @aa:16,EXR	3	1
	LDC @aa:32,CCR	4	1
	LDC @aa:32,EXR	4	1
LDM ^{*4}	LDML @SP+, (ERn-ERn+1)	2	4
	LDML @SP+, (ERn-ERn+2)	2	6
	LDML @SP+, (ERn-ERn+3)	2	8
LDMAC	LDMAC ERs, MACH	Cannot be used with this LSI.	
	LDMAC ERs, MACL		
MAC	MAC @ERn+, @ERm+		
MOV	MOV.B #xx:8,Rd	1	
	MOV.B Rs,Rd	1	
	MOV.B @ERs,Rd	1	1
	MOV.B @(d:16,ERs),Rd	2	1
	MOV.B @(d:32,ERs),Rd	4	1
	MOV.B @ERs+,Rd	1	1
	MOV.B @aa:8,Rd	1	1
	MOV.B @aa:16,Rd	2	1

MOV.B Rs,@aa:8	1	
MOV.B Rs,@aa:16	2	1
MOV.B Rs,@aa:32	3	1
MOV.W #xx:16,Rd	2	
MOV.W Rs,Rd	1	
MOV.W @ERs,Rd	1	1
MOV.W @(d:16,ERs),Rd	2	1
MOV.W @(d:32,ERs),Rd	4	1
MOV.W @ERs+,Rd	1	1
MOV.W @aa:16,Rd	2	1
MOV.W @aa:32,Rd	3	1
MOV.W Rs,@ERd	1	1
MOV.W Rs,@(d:16,ERd)	2	1
MOV.W Rs,@(d:32,ERd)	4	1
MOV.W Rs,@-ERd	1	1
MOV.W Rs,@aa:16	2	1
MOV.W Rs,@aa:32	3	1
MOV.L #xx:32,ERd	3	
MOV.L ERs,ERd	1	
MOV.L @ERs,ERd	2	2
MOV.L @(d:16,ERs),ERd	3	2
MOV.L @(d:32,ERs),ERd	5	2
MOV.L @ERs+,ERd	2	2
MOV.L @aa:16,ERd	3	2
MOV.L @aa:32,ERd	4	2
MOV.L ERs,@ERd	2	2
MOV.L ERs,@(d:16,ERd)	3	2
MOV.L ERs,@(d:32,ERd)	5	2
MOV.L ERs,@-ERd	2	2
MOV.L ERs,@aa:16	3	2
MOV.L ERs,@aa:32	4	2

	MULXU.W Rs,ERd	1	
NEG	NEG.B Rd	1	
	NEG.W Rd	1	
	NEG.L ERd	1	
NOP	NOP	1	
NOT	NOT.B Rd	1	
	NOT.W Rd	1	
	NOT.L ERd	1	
OR	OR.B #xx:8,Rd	1	
	OR.B Rs,Rd	1	
	OR.W #xx:16,Rd	2	
	OR.W Rs,Rd	1	
	OR.L #xx:32,ERd	3	
	OR.L ERs,ERd	2	
ORC	ORC #xx:8,CCR	1	
	ORC #xx:8,EXR	2	
POP	POP.W Rn	1	1
	POP.L ERn	2	2
PUSH	PUSH.W Rn	1	1
	PUSH.L ERn	2	2
ROTL	ROTL.B Rd	1	
	ROTL.B #2,Rd	1	
	ROTL.W Rd	1	
	ROTL.W #2,Rd	1	
	ROTL.L ERd	1	
	ROTL.L #2,ERd	1	

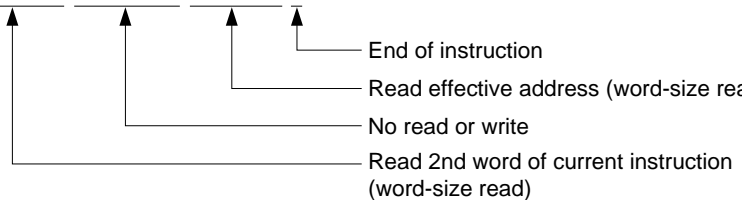
		ROTR.L #2,ERd	1	
ROTXL		ROTXL.B Rd	1	
		ROTXL.B #2,Rd	1	
		ROTXL.W Rd	1	
		ROTXL.W #2,Rd	1	
		ROTXL.L ERd	1	
		ROTXL.L #2,ERd	1	
ROTXR		ROTXR.B Rd	1	
		ROTXR.B #2,Rd	1	
		ROTXR.W Rd	1	
		ROTXR.W #2,Rd	1	
		ROTXR.L ERd	1	
		ROTXR.L #2,ERd	1	
RTE		RTE	2	2/3*1
RTS		Normal	2	1
		Advanced	2	2
SHAL		SHAL.B Rd	1	
		SHAL.B #2,Rd	1	
		SHAL.W Rd	1	
		SHAL.W #2,Rd	1	
		SHAL.L ERd	1	
		SHAL.L #2,ERd	1	
SHAR		SHAR.B Rd	1	
		SHAR.B #2,Rd	1	
		SHAR.W Rd	1	
		SHAR.W #2,Rd	1	
		SHAR.L ERd	1	
		SHAR.L #2,ERd	1	

	SHLR.L #2,ERd	1	
SHLR	SHLR.B Rd	1	
	SHLR.B #2,Rd	1	
	SHLR.W Rd	1	
	SHLR.W #2,Rd	1	
	SHLR.L ERd	1	
	SHLR.L #2,ERd	1	
SLEEP	SLEEP	1	
STC	STC.B CCR,Rd	1	
	STC.B EXR,Rd	1	
	STC.W CCR,@ERd	2	1
	STC.W EXR,@ERd	2	1
	STC.W CCR,@(d:16,ERd)	3	1
	STC.W EXR,@(d:16,ERd)	3	1
	STC.W CCR,@(d:32,ERd)	5	1
	STC.W EXR,@(d:32,ERd)	5	1
	STC.W CCR,@-ERd	2	1
	STC.W EXR,@-ERd	2	1
	STC.W CCR,@aa:16	3	1
	STC.W EXR,@aa:16	3	1
	STC.W CCR,@aa:32	4	1
	STC.W EXR,@aa:32	4	1
	STM ^{*4}	STM.L (ERn-ERn+1),@-SP	2
STM.L (ERn-ERn+2),@-SP		2	6
STM.L (ERn-ERn+3),@-SP		2	8
SUB	SUB.B Rs,Rd	1	
	SUB.W #xx:16,Rd	2	
	SUB.W Rs,Rd	1	
	SUB.L #xx:32,ERd	3	
	SUB.L ERs,ERd	1	

XOR	XOR.B #xx:8,Rd	1
	XOR.B Rs,Rd	1
	XOR.W #xx:16,Rd	2
	XOR.W Rs,Rd	1
	XOR.L #xx:32,ERd	3
	XOR.L ERs,ERd	2
XORC	XORC #xx:8,CCR	1
	XORC #xx:8,EXR	2

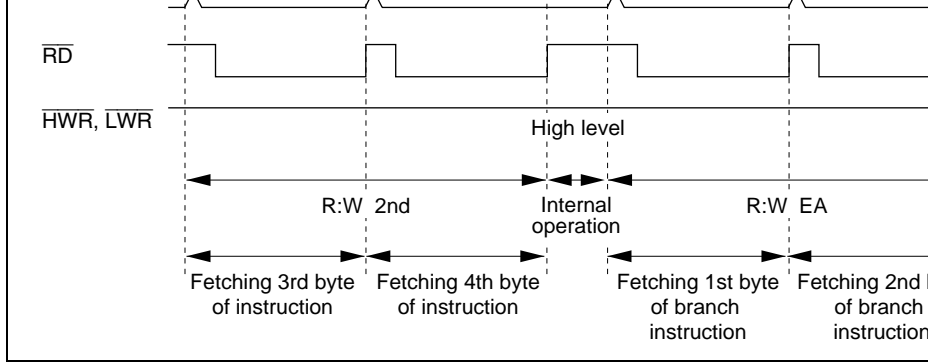
- Notes:
1. 2 when EXR is invalid, 3 when valid.
 2. When n bytes of data are transferred.
 3. Only register ER0, ER1, ER4, or ER5 should be used when using the TAS instruction.
 4. Only registers ER0 to ER6 should be used when using the STM/LDM instructions.

Instruction	1	2	3	4	5	6	7
JMP@aa:24	R:W 2nd	Internal operation, 2 state	R:W EA				



Legend:

R:B	Byte-size read
R:W	Word-size read
W:B	Byte-size write
W:W	Word-size write
:M	Transfer of the bus is not performed immediately after this cycle
2nd	Address of 2nd word (3rd and 4th bytes)
3rd	Address of 3rd word (5th and 6th bytes)
4th	Address of 4th word (7th and 8th bytes)
5th	Address of 5th word (9th and 10th bytes)
NEXT	Start address of instruction following executing instruction
EA	Effective address
VEC	Vector address



**Figure A.1 Address Bus, \overline{RD} , \overline{HWR} , and \overline{LWR} Timing
(8-Bit Bus, Three-State Access, No Wait States)**

ADDS #1/2/4,ERd	R:W NEXT								
ADDX #xx:8,Rd	R:W NEXT								
ADDX Rs,Rd	R:W NEXT								
AND.B #xx:8,Rd	R:W NEXT								
AND.B Rs,Rd	R:W NEXT								
AND.W #xx:16,Rd	R:W 2nd	R:W NEXT							
AND.W Rs,Rd	R:W NEXT								
AND.L #xx:32,ERd	R:W 2nd	R:W 3rd	R:W NEXT						
AND.L ERs,ERd	R:W 2nd	R:W NEXT							
ANDC #xx:8,CCR	R:W NEXT								
ANDC #xx:8,EXR	R:W 2nd	R:W NEXT							
BAND #xx:3,Rd	R:W NEXT								
BAND #xx:3,@ERd	R:W 2nd	R:B EA	R:W:M NEXT						
BAND #xx:3,@aa:8	R:W 2nd	R:B EA	R:W:M NEXT						
BAND #xx:3, @aa:16	R:W 2nd	R:W 3rd	R:B EA	R:W:M NEXT					
BAND #xx:3, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B EA	R:W:M NEXT				
BRA d:8 (BT d:8)	R:W NEXT	R:W EA							
BRN d:8 (BF d:8)	R:W NEXT	R:W EA							
BHI d:8	R:W NEXT	R:W EA							
BLS d:8	R:W NEXT	R:W EA							
BCC d:8 (BHS d:8)	R:W NEXT	R:W EA							
BCS d:8 (BLO d:8)	R:W NEXT	R:W EA							
BNE d:8	R:W NEXT	R:W EA							
BEQ d:8	R:W NEXT	R:W EA							
BVC d:8	R:W NEXT	R:W EA							
BVS d:8	R:W NEXT	R:W EA							
BPL d:8	R:W NEXT	R:W EA							

BRN d:16 (BF d:16)	R:W 2nd	Internal operation, 1 state	R:W EA					
BHI d:16	R:W 2nd	Internal operation, 1 state	R:W EA					
BLS d:16	R:W 2nd	Internal operation, 1 state	R:W EA					
BCC d:16 (BHS d:16)	R:W 2nd	Internal operation, 1 state	R:W EA					
BCS d:16 (BLO d:16)	R:W 2nd	Internal operation, 1 state	R:W EA					
BNE d:16	R:W 2nd	Internal operation, 1 state	R:W EA					
BEQ d:16	R:W 2nd	Internal operation, 1 state	R:W EA					
BVC d:16	R:W 2nd	Internal operation, 1 state	R:W EA					
BVS d:16	R:W 2nd	Internal operation, 1 state	R:W EA					
BPL d:16	R:W 2nd	Internal operation, 1 state	R:W EA					
BMI d:16	R:W 2nd	Internal operation, 1 state	R:W EA					
BGE d:16	R:W 2nd	Internal operation, 1 state	R:W EA					



BCLR #xx:3,Rd	R:W NEXT							
BCLR #xx:3,@ERd	R:W 2nd	R:B:M EA	R:W:M NEXT	W:B EA				
BCLR #xx:3,@aa:8	R:W 2nd	R:B:M EA	R:W:M NEXT	W:B EA				
BCLR#xx:3,@aa:16	R:W 2nd	R:W 3rd	R:B:M EA	R:W:M NEXT	W:B EA			
BCLR#xx:3,@aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:M EA	R:W:M NEXT	W:B EA		
BCLR Rn,Rd	R:W NEXT							
BCLR Rn,@ERd	R:W 2nd	R:B:M EA	R:W:M NEXT	W:B EA				
BCLR Rn,@aa:8	R:W 2nd	R:B:M EA	R:W:M NEXT	W:B EA				
BCLR Rn,@aa:16	R:W 2nd	R:W 3rd	R:B:M EA	R:W:M NEXT	W:B EA			
BCLR Rn,@aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:M EA	R:W:M NEXT	W:B EA		
BIAND #xx:3,Rd	R:W NEXT							
BIAND #xx:3,@ERd	R:W 2nd	R:B EA	R:W:M NEXT					
BIAND #xx:3,@aa:8	R:W 2nd	R:B EA	R:W:M NEXT					
BIAND #xx:3,@aa:16	R:W 2nd	R:W 3rd	R:B EA	R:W:M NEXT				
BIAND #xx:3,@aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B EA	R:W:M NEXT			
BILD #xx:3,Rd	R:W NEXT							
BILD #xx:3,@ERd	R:W 2nd	R:B EA	R:W:M NEXT					
BILD #xx:3,@aa:8	R:W 2nd	R:B EA	R:W:M NEXT					
BILD #xx:3,@aa:16	R:W 2nd	R:W 3rd	R:B: EA	R:W:M NEXT				

BIOR #xx:3, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B EA	R:W:M NEXT			
BIST #xx:3,Rd	R:W NEXT							
BIST #xx:3, @ERd	R:W 2nd	R:B:M EA	R:W:M NEXT	W:B EA				
BIST #xx:3, @aa:8	R:W 2nd	R:B:M EA	R:W:M NEXT	W:B EA				
BIST #xx:3, @aa:16	R:W 2nd	R:W 3rd	R:B:M EA	R:W:M NEXT	W:B EA			
BIST #xx:3, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:M EA	R:W:M NEXT	W:B EA		
BIXOR #xx:3,Rd	R:W NEXT							
BIXOR #xx:3, @ERd	R:W 2nd	R:B EA	R:W:M NEXT					
BIXOR #xx:3, @aa:8	R:W 2nd	R:B EA	R:W:M NEXT					
BIXOR #xx:3, @aa:16	R:W 2nd	R:W 3rd	R:B EA	R:W:M NEXT				
BIXOR #xx:3, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B EA	R:W:M NEXT			
BLD #xx:3,Rd	R:W NEXT							
BLD #xx:3, @ERd	R:W 2nd	R:B EA	R:W:M NEXT					
BLD #xx:3, @aa:8	R:W 2nd	R:B EA	R:W:M NEXT					
BLD #xx:3, @aa:16	R:W 2nd	R:W 3rd	R:B EA	R:W:M NEXT				
BLD #xx:3, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B EA	R:W:M NEXT			
BNOT #xx:3,Rd	R:W NEXT							
BNOT #xx:3, @ERd	R:W 2nd	R:B:M EA	R:W:M NEXT	W:B EA				

BNOT Rn, @aa:8	R:W 2nd	R:B:M EA	R:W:M NEXT	W:B EA				
BNOT Rn, @aa:16	R:W 2nd	R:W 3rd	R:B:M EA	R:W:M NEXT	W:B EA			
BNOT Rn, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:M EA	R:W:M NEXT	W:B EA		
BOR #xx:3, Rd	R:W NEXT							
BOR #xx:3, @ERd	R:W 2nd	R:B EA	R:W:M NEXT					
BOR #xx:3, @aa:8	R:W 2nd	R:B EA	R:W:M NEXT					
BOR #xx:3, @aa:16	R:W 2nd	R:W 3rd	R:B EA	R:W:M NEXT				
BOR #xx:3, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B EA	R:W NEXT			
BSET #xx:3, Rd	R:W NEXT							
BSET #xx:3, @ERd	R:W 2nd	R:B:M EA	R:W:M NEXT	W:B EA				
BSET #xx:3, @aa:8	R:W 2nd	R:B:M EA	R:W:M NEXT	W:B EA				
BSET #xx:3, @aa:16	R:W 2nd	R:W 3rd	R:B:M EA	R:W:M NEXT	W:B EA			
BSET #xx:3, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:M EA	R:W:M NEXT	W:B EA		
BSET Rn, Rd	R:W NEXT							
BSET Rn, @ERd	R:W 2nd	R:B:M EA	R:W:M NEXT	W:B EA				
BSET Rn, @aa:8	R:W 2nd	R:B:M EA	R:W:M NEXT	W:B EA				
BSET Rn, @aa:16	R:W 2nd	R:W 3rd	R:B:M EA	R:W:M NEXT	W:B EA			
BSET Rn, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:M EA	R:W:M NEXT	W:B EA		

				NEXT				
BST #xx:3,@aa:16	R:W 2nd	R:W 3rd	R:B:M EA	R:W:M NEXT	W:B EA			
BST #xx:3,@aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:M EA	R:W:M NEXT	W:B EA		
BTST #xx:3,Rd	R:W NEXT							
BTST #xx:3,@ERd	R:W 2nd	R:B EA	R:W:M NEXT					
BTST #xx:3,@aa:8	R:W 2nd	R:B EA	R:W:M NEXT					
BTST #xx:3, @aa:16	R:W 2nd	R:W 3rd	R:B EA	R:W:M NEXT				
BTST #xx:3, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B EA	R:W:M NEXT			
BTST Rn,Rd	R:W NEXT							
BTST Rn,@ERd	R:W 2nd	R:B EA	R:W:M NEXT					
BTST Rn,@aa:8	R:W 2nd	R:B EA	R:W:M NEXT					
BTST Rn,@aa:16	R:W 2nd	R:W 3rd	R:B EA	R:W:M NEXT				
BTST Rn,@aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B EA	R:W:M NEXT			
BXOR #xx:3,Rd	R:W NEXT							
BXOR #xx:3,@ERd	R:W 2nd	R:B EA	R:W:M NEXT					
BXOR #xx:3,@aa:8	R:W 2nd	R:B EA	R:W:M NEXT					
BXOR #xx:3, @aa:16	R:W 2nd	R:W 3rd	R:B EA	R:W:M NEXT				
BXOR #xx:3, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B EA	R:W:M NEXT			
CLRMAC	Cannot be used in this LSI							

DAS Rd		R:W NEXT							
DEC.B Rd		R:W NEXT							
DEC.W #1/2,Rd		R:W NEXT							
DEC.L #1/2,ERd		R:W NEXT							
DIVXS.B Rs,Rd		R:W 2nd	R:W NEXT	Internal operation, 11 states					
DIVXS.W Rs,ERd		R:W 2nd	R:W NEXT	Internal operation, 19 states					
DIVXU.B Rs,Rd		R:W NEXT	Internal operation, 11 states						
DIVXU.W Rs,ERd		R:W NEXT	Internal operation, 19 states						
EEMOV.B		R:W 2nd	R:B EAs ^{*1}	R:B EAd ^{*1}	R:B EAs ^{*2}	W:B EAd ^{*2}	R:W NEXT		
EEMOV.W		R:W 2nd	R:B EAs ^{*1}	R:B EAd ^{*1}	R:B EAs ^{*2}	W:B EAd ^{*2}	R:W NEXT		
EXTS.W Rd		R:W NEXT			← Repeated n times ^{*2} →				
EXTS.L ERd		R:W NEXT							
EXTU.W Rd		R:W NEXT							
EXTU.L ERd		R:W NEXT							
INC.B Rd		R:W NEXT							
INC.W #1/2,Rd		R:W NEXT							
INC.L #1/2,ERd		R:W NEXT							
JMP @ERn		R:W NEXT	R:W EA						
JMP @aa:24		R:W 2nd	Internal operation, 1 state	R:W EA					
JMP @aa:8	Advanced	R:W NEXT	R:W:M aa:8	R:W aa:8	Internal operation, 1 state	R:W EA			
JSR @ERn	Advanced	R:W NEXT	R:W EA	W:W:M Stack (H)	W:W Stack (L)				
JSR @aa:24	Advanced	R:W 2nd	Internal operation, 1 state	R:W EA	W:W:M Stack (H)	W:W Stack (L)			
JSR @aa:8	Advanced	R:W NEXT	R:W:M aa:8	R:W aa:8	W:W:M Stack (H)	W:W Stack (L)	R:W EA		

LDC@ (d:16,ERs), EXR	R:W 2nd	R:W 3rd	R:W NEXT	R:W EA				
LDC@ (d:32,ERs), CCR	R:W 2nd	R:W 3rd	R:W 4th	R:W 5th	R:W NEXT	R:W EA		
LDC@ (d:32,ERs), EXR	R:W 2nd	R:W 3rd	R:W 4th	R:W 5th	R:W NEXT	R:W EA		
LDC @ERs+,CCR	R:W 2nd	R:W NEXT	Internal operation, 1 state	R:W EA				
LDC @ERs+,EXR	R:W 2nd	R:W NEXT	Internal operation, 1 state	R:W EA				
LDC @aa:16,CCR	R:W 2nd	R:W 3rd	R:W NEXT	R:W EA				
LDC @aa:16,EXR	R:W 2nd	R:W 3rd	R:W NEXT	R:W EA				
LDC @aa:32,CCR	R:W 2nd	R:W 3rd	R:W 4th	R:W NEXT	R:W EA			
LDC @aa:32,EXR	R:W 2nd	R:W 3rd	R:W 4th	R:W NEXT	R:W EA			
LDM.L @SP+, (ERn-ERn+1) ^{*9}	R:W 2nd	R:W:M NEXT	Internal operation, 1 state	R:W:M Stack (H) ^{*3}	R:W Stack (L) ^{*3}			
LDM.L @SP+, (ERn-ERn+2) ^{*9}	R:W 2nd	R:W:M NEXT	Internal operation, 1 state	R:W:M Stack (H) ^{*3}	R:W Stack (L) ^{*3}			
LDM.L @SP+, (ERn-ERn+3) ^{*9}	R:W 2nd	R:W:M NEXT	Internal operation, 1 state	R:W:M Stack (H) ^{*3}	R:W Stack (L) ^{*3}			
LDMAC ERs,MACH	Cannot be used in this LSI							
LDMAC ERs,MACL								
MAC @ERn+, @ERm+								
MOV.B #xx:8,Rd	R:W NEXT							
MOV.B Rs,Rd	R:W NEXT							
MOV.B @ERs,Rd	R:W NEXT	R:B EA						
MOV.B @ (d:16,ERs),Rd	R:W 2nd	R:W NEXT	R:B EA					

MOV.B Rs,@ERd	R:W NEXT	W:B EA						
MOV.B Rs, @(d:16,ERd)	R:W 2nd	R:W NEXT	W:B EA					
MOV.B Rs, @(d:32,ERd)	R:W 2nd	R:W 3rd	R:W 4th	R:W NEXT	W:B EA			
MOV.B Rs,@-ERd	R:W NEXT	Internal operation, 1 state	W:B EA					
MOV.B Rs,@aa:8	R:W NEXT	W:B EA						
MOV.B Rs,@aa:16	R:W 2nd	R:W NEXT	W:B EA					
MOV.B Rs,@aa:32	R:W 2nd	R:W 3rd	R:W NEXT	W:B EA				
MOV.W #xx:16,Rd	R:W 2nd	R:W NEXT						
MOV.W Rs,Rd	R:W NEXT							
MOV.W @ERs,Rd	R:W NEXT	R:W EA						
MOV.W @(d:16,ERs),Rd	R:W 2nd	R:W NEXT	R:W EA					
MOV.W @(d:32,ERs),Rd	R:W 2nd	R:W 3rd	R:W 4th	R:W NEXT	R:W EA			
MOV.W @ERs+,Rd	R:W NEXT	Internal operation, 1 state	R:W EA					
MOV.W @aa:16,Rd	R:W 2nd	R:W NEXT	R:W EA					
MOV.W @aa:32,Rd	R:W 2nd	R:W 3rd	R:W NEXT	R:B EA				
MOV.W Rs,@ERd	R:W NEXT	W:W EA						
MOV.W Rs, @(d:16,ERd)	R:W 2nd	R:W NEXT	W:W EA					
MOV.W Rs, @(d:32,ERd)	R:W 2nd	R:W 3rd	R:W 4th	R:W NEXT	W:W EA			
MOV.W Rs,@-ERd	R:W NEXT	Internal operation, 1 state	W:W EA					
MOV.W Rs,@aa:16	R:W 2nd	R:W NEXT	W:W EA					
MOV.W Rs,@aa:32	R:W 2nd	R:W 3rd	R:W NEXT	W:W EA				

MOV.L @ERs+, ERd	R:W 2nd	R:W:M NEXT	Internal operation, 1 state	R:W:M EA	R:W EA+2			
MOV.L @aa:16, ERd	R:W 2nd	R:W:M 3rd	R:W NEXT	R:W:M EA	R:W EA+2			
MOV.L @aa:32, ERd	R:W 2nd	R:W:M 3rd	R:W 4th	R:W NEXT	R:W:M EA	R:W EA+2		
MOV.L ERs, @ERd	R:W 2nd	R:W:M NEXT	W:W:M EA	W:W EA+2				
MOV.L ERs, @ (d:16, ERd)	R:W 2nd	R:W:M 3rd	R:W NEXT	W:W:M EA	W:W EA+2			
MOV.L ERs, @ (d:32, ERd)	R:W 2nd	R:W:M 3rd	R:W:M 4th	R:W 5th	R:W NEXT	W:W:M EA	W:W EA+2	
MOV.L ERs, @-ERd	R:W 2nd	R:W:M NEXT	Internal operation, 1 state	W:W:M EA	W:W EA+2			
MOV.L ERs, @aa:16	R:W 2nd	R:W:M 3rd	R:W NEXT	W:W:M EA	W:W EA+2			
MOV.L ERs, @aa:32	R:W 2nd	R:W:M 3rd	R:W 4th	R:W NEXT	W:W:M EA	W:W EA+2		
MOVFPE @aa:16, Rd	Cannot be used in this LSI							
MOVTPERs, @aa:16								
MULXS.B Rs, Rd	R:W 2nd	R:W NEXT	Internal operation, 11 states					
MULXS.W Rs, ERd	R:W 2nd	R:W NEXT	Internal operation, 19 states					
MULXU.B Rs, Rd	R:W NEXT	Internal operation, 11 states						
MULXU.W Rs, ERd	R:W NEXT	Internal operation, 19 states						
NEG.B Rd	R:W NEXT							
NEG.W Rd	R:W NEXT							
NEG.L ERd	R:W NEXT							
NOP	R:W NEXT							
NOT.B Rd	R:W NEXT							
NOT.W Rd	R:W NEXT							

ORC #xx:8,CCR	R:W 2nd	R:W NEXT						
POP.W Rn	R:W NEXT	Internal operation, 1 state	R:W EA					
POP.L ERn	R:W 2nd	R:W:M NEXT	Internal operation, 1 state	R:W:M EA	R:W EA+2			
PUSH.W Rn	R:W NEXT	Internal operation, 1 state	W:W EA					
PUSH.L ERn	R:W 2nd	R:W:M NEXT	Internal operation, 1 state	W:W:M EA	W:W EA+2			
ROTL.B Rd	R:W NEXT							
ROTL.B #2,Rd	R:W NEXT							
ROTL.W Rd	R:W NEXT							
ROTL.W #2,Rd	R:W NEXT							
ROTL.L ERd	R:W NEXT							
ROTL.L #2,ERd	R:W NEXT							
ROTR.B Rd	R:W NEXT							
ROTR.B #2,Rd	R:W NEXT							
ROTR.W Rd	R:W NEXT							
ROTR.W #2,Rd	R:W NEXT							
ROTR.L ERd	R:W NEXT							
ROTR.L #2,ERd	R:W NEXT							
ROTXL.B Rd	R:W NEXT							
ROTXL.B #2,Rd	R:W NEXT							
ROTXL.W Rd	R:W NEXT							
ROTXL.W #2,Rd	R:W NEXT							
ROTXL.L ERd	R:W NEXT							

RTS	Advanced	R:W NEXT	R:W:M Stack (H)	R:W Stack (H)	R:W Stack (L)	Internal operation, 1 state	R:W		
SHAL.B Rd		R:W NEXT							
SHAL.B #2,Rd		R:W NEXT							
SHAL.W Rd		R:W NEXT							
SHAL.W #2,Rd		R:W NEXT							
SHAL.L ERd		R:W NEXT							
SHAL.L #2,ERd		R:W NEXT							
SHAR.B Rd		R:W NEXT							
SHAR.B #2,Rd		R:W NEXT							
SHAR.W Rd		R:W NEXT							
SHAR.W #2,Rd		R:W NEXT							
SHAR.L ERd		R:W NEXT							
SHAR.L #2,ERd		R:W NEXT							
SHLL.B Rd		R:W NEXT							
SHLL.B #2,Rd		R:W NEXT							
SHLL.W Rd		R:W NEXT							
SHLL.W #2,Rd		R:W NEXT							
SHLL.L ERd		R:W NEXT							
SHLL.L #2,ERd		R:W NEXT							
SHLR.B Rd		R:W NEXT							
SHLR.B #2,Rd		R:W NEXT							
SHLR.W Rd		R:W NEXT							
SHLR.W #2,Rd		R:W NEXT							
SHLR.L ERd		R:W NEXT							
SHLR.L #2,ERd		R:W NEXT							

@(d:16,ERd)	R:W 2nd	R:W 3rd	R:W NEXT	W:W EA				
STC EXR, @(d:16,ERd)	R:W 2nd	R:W 3rd	R:W NEXT	W:W EA				
STC CCR, @(d:32,ERd)	R:W 2nd	R:W 3rd	R:W 4th	R:W 5th	R:W NEXT	W:W EA		
STC EXR, @(d:32,ERd)	R:W 2nd	R:W 3rd	R:W 4th	R:W 5th	R:W NEXT	W:W EA		
STC CCR,@-ERd	R:W 2nd	R:W NEXT	Internal operation, 1 state	W:W EA				
STC EXR,@-ERd	R:W 2nd	R:W NEXT	Internal operation, 1 state	W:W EA				
STC CCR,@aa:16	R:W 2nd	R:W 3rd	R:W NEXT	W:W EA				
STC EXR,@aa:16	R:W 2nd	R:W 3rd	R:W NEXT	W:W EA				
STC CCR,@aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:W NEXT	W:W EA			
STC EXR,@aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:W NEXT	W:W EA			
STM.L (ERn-ERn+1), @-SP ^{*9}	R:W 2nd	R:W:M NEXT	Internal operation, 1 state	W:W:M Stack (H) *3	W:W Stack (L) *3			
STM.L (ERn-ERn+2), @-SP ^{*9}	R:W 2nd	R:W:M NEXT	Internal operation, 1 state	W:W:M Stack (H) *3	W:W Stack (L) *3			
STM.L (ERn-ERn+3), @-SP ^{*9}	R:W 2nd	R:W:M NEXT	Internal operation, 1 state	W:W:M Stack (H) *3	W:W Stack (L) *3			
STMAC MACH,ERd	Cannot be used in this LSI							
STMAC MACL,ERd								
SUB.B Rs,Rd	R:W NEXT							
SUB.W #xx:16,Rd	R:W 2nd	R:W NEXT						
SUB.W Rs,Rd	R:W NEXT							
SUB.L #xx:32,ERd	R:W 2nd	R:W 3rd	R:W NEXT					
SUB.L ERs,ERd	R:W NEXT							

XOR.B Rs,Rd		R:W NEXT							
XOR.W #xx:16,Rd		R:W 2nd	R:W NEXT						
XOR.W Rs,Rd		R:W NEXT							
XOR.L #xx:32,ERd		R:W 2nd	R:W 3rd	R:W NEXT					
XOR.L ERs,ERd		R:W 2nd	R:W NEXT						
XORC #xx:8,CCR		R:W NEXT							
XORC #xx:8,EXR		R:W 2nd	R:W NEXT						
Reset exception handling	Advanced	R:W:M VEC	R:W VEC+2	Internal operation, 1 state	R:W* ⁵				
Interrupt exception handling	Advanced	R:W* ⁶	Internal operation, 1 state	W:W Stack (L)	W:W Stack (H)	W:W Stack (EXR)	R:W:M VEC	R:W VEC+2	Internal operation, 1 state

- Notes:
1. EAs is the contents of ER5. EAd is the contents of ER6.
 2. EAs is the contents of ER5. EAd is the contents of ER6. Both registers are incremented by 1 after execution of the instruction. n is the initial value of R4L or R4. If n is 0, bus cycles are not executed.
 3. Repeated two times to save or restore two registers, three times for three registers, and four times for four registers.
 4. Start address after return.
 5. Start address of the program.
 6. Prefetch address, equal to two plus the PC value pushed onto the stack. In sleep mode or software standby mode the read operation is replaced by internal operation.
 7. Start address of the interrupt-handling routine.
 8. Only register ER0, ER1, ER4, or ER5 should be used when using the TAS instruction.
 9. Only registers ER0 to ER6 should be used when using the STM/LDM instructions.

HEFFF

MRB	CHNE	DISEL	—	—	—	—	—	—	—
DAR									
CRA									
CRB									

H'FE80	HICR2	—	—	—	—	—	IBFIE4	IBFIE3	—	HIF
H'FE84	IDR3	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0	
H'FE85	ODR3	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0	
H'FE86	STR3	DBU	DBU	DBU	DBU	C/D	DBU	IBF	OBF	
H'FE8C	IDR4	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0	
H'FE8D	ODR4	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0	
H'FE8E	STR4	DBU	DBU	DBU	DBU	C/D	DBU	IBF	OBF	
H'FED8	KBCRH0	KBIOE	KCLKI	KDI	KBFSEL	KBIE	KBF	PER	KBS	Key buf con
H'FED9	KBCRL0	KBE	KCLKO	KDO	—	RXCR3	RXCR2	RXCR1	RXCR0	
H'FEDA	KBBR0	KB7	KB6	KB5	KB4	KB3	KB2	KB1	KB0	
H'FEDC	KBCRH1	KBIOE	KCLKI	KDI	KBFSEL	KBIE	KBF	PER	KBS	
H'FEDD	KBCRL1	KBE	KCLKO	KDO	—	RXCR3	RXCR2	RXCR1	RXCR0	
H'FEDE	KBBR1	KB7	KB6	KB5	KB4	KB3	KB2	KB1	KB0	
H'FEE0	KBCRH2	KBIOE	KCLKI	KDI	KBFSEL	KBIE	KBF	PER	KBS	
H'FEE1	KBCRL2	KBE	KCLKO	KDO	—	RXCR3	RXCR2	RXCR1	RXCR0	
H'FEE2	KBBR2	KB7	KB6	KB5	KB4	KB3	KB2	KB1	KB0	
H'FEE4	KBCOMP	IrE	IrCKS2	IrCKS1	IrCKS0	KBADE	KBCH2	KBCH1	KBCH0	IrD exp A/D IIC
H'FEE6	DDCSWR	SWE	SW	IE	IF	CLR3	CLR2	CLR1	CLR0	

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RENESAS

H'FEF	DTCERB	DTCEB7	DTCEB6	DTCEB5	DTCEB4	DTCEB3	DTCEB2	DTCEB1	DTCEB0	
H'FEF0	DTCERC	DTCEC7	DTCEC6	DTCEC5	DTCEC4	DTCEC3	DTCEC2	DTCEC1	DTCEC0	
H'FEF1	DTCERD	DTCED7	DTCED6	DTCED5	DTCED4	DTCED3	DTCED2	DTCED1	DTCED0	
H'FEF2	DTCERE	DTCEE7	DTCEE6	DTCEE5	DTCEE4	DTCEE3	DTCEE2	DTCEE1	DTCEE0	
H'FEF3	DTVECR	SWDTE	DTVEC6	DTVEC5	DTVEC4	DTVEC3	DTVEC2	DTVEC1	DTVEC0	
H'FEF4	ABRKCR	CMF	—	—	—	—	—	—	BIE	In
H'FEF5	BARA	A23	A22	A21	A20	A19	A18	A17	A16	CO
H'FEF6	BARB	A15	A14	A13	A12	A11	A10	A9	A8	
H'FEF7	BARC	A7	A6	A5	A4	A3	A2	A1	—	
H'FF80	FLMCR1	FWE	SWE	—	—	EV	PV	E	P	FI
H'FF81	FLMCR2	FLER	—	—	—	—	—	ESU	PSU	
H'FF82	PCSR	—	—	—	—	—	PWCKB	PWCKA	—	P
	EBR1	—	—	—	—	—	—	EB9/—	EB8/—	FI
H'FF83	SYSCR2	KWUL1	KWUL0	P6PUE	—	SDE	CS4E	CS3E	HI12E	H
	EBR2	EB7	EB6	EB5	EB4	EB3	EB2	EB1	EB0	FI
H'FF84	SBYCR	SSBY	STS2	STS1	STS0	—	SCK2	SCK1	SCK0	S
H'FF85	LPWRCR	DTON	LSON	NESEL	EXCLE	—	—	—	—	
H'FF86	MSTPCRH	MSTP15	MSTP14	MSTP13	MSTP12	MSTP11	MSTP10	MSTP9	MSTP8	
H'FF87	MSTPCL	MSTP7	MSTP6	MSTP5	MSTP4	MSTP3	MSTP2	MSTP1	MSTP0	
H'FF88	SMR1	C/A	CHR	PE	O/E	STOP	MP	CKS1	CKS0	S
	ICCR1	ICE	IEIC	MST	TRS	ACKE	BBSY	IRIC	SCP	II
H'FF89	BRR1	—	—	—	—	—	—	—	—	S
	ICSR1	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB	II
H'FF8A	SCR1	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0	S
H'FF8B	TDR1	—	—	—	—	—	—	—	—	
H'FF8C	SSR1	TDRE	RDRF	ORER	FER	PER	TEND	MPB	MPBT	
H'FF8D	RDR1	—	—	—	—	—	—	—	—	

H'FF92	FRCH									
H'FF93	FRCL									
H'FF94	OCRAH									
	OCRBH									
H'FF95	OCRAL									
	OCRBL									
H'FF96	TCR	IEDGA	IEDGB	IEDGC	IEDGD	BUFEA	BUFEB	CKS1	CKS0	
H'FF97	TOCR	ICRDMS	OCRAMS	ICRS	OCRS	OEA	OEB	OLVLA	OLVLB	
H'FF98	ICRAH									
	OCRARH									
H'FF99	ICRAL									
	OCRARL									
H'FF9A	ICRBH									
	OCRAFH									
H'FF9B	ICRBL									
	OCRAFL									
H'FF9C	ICRCH									
	OCRDMH	0	0	0	0	0	0	0	0	
H'FF9D	ICRCL									
	OCRDML									
H'FF9E	ICRDH									
H'FF9F	ICRDL									
H'FFA0	SMR2	C/ \bar{A}	CHR	PE	O/ \bar{E}	STOP	MP	CKS1	CKS0	SC
	DADRAH	DA13	DA12	DA11	DA10	DA9	DA8	DA7	DA6	PW
	DACR	TEST	PWME	—	—	OEB	OEA	OS	CKS	
H'FFA1	BRR2									SC
	DADRAL	DA5	DA4	DA3	DA2	DA1	DA0	CFS	—	PW

H'FFA7	DADRBL	DA5	DA4	DA3	DA2	DA1	DA0	CFS	REGS	
	DACNTL							—	REGS	
H'FFA8	TCSR0	OVF	WT/IT	TME	RSTS	RST/NMI	CKS2	CKS1	CKS0	W
	TCNT0									
	(write)									
H'FFA9	TCNT0									
	(read)									
H'FFAA	PAODR	PA7ODR	PA6ODR	PA5ODR	PA4ODR	PA3ODR	PA2ODR	PA1ODR	PA0ODR	P
H'FFAB	PAPIN	PA7PIN	PA6PIN	PA5PIN	PA4PIN	PA3PIN	PA2PIN	PA1PIN	PA0PIN	
	(read)									
	PADDR	PA7DDR	PA6DDR	PA5DDR	PA4DDR	PA3DDR	PA2DDR	PA1DDR	PA0DDR	
	(write)									
H'FFAC	P1PCR	P17PCR	P16PCR	P15PCR	P14PCR	P13PCR	P12PCR	P11PCR	P10PCR	
H'FFAD	P2PCR	P27PCR	P26PCR	P25PCR	P24PCR	P23PCR	P22PCR	P21PCR	P20PCR	
H'FFAE	P3PCR	P37PCR	P36PCR	P35PCR	P34PCR	P33PCR	P32PCR	P31PCR	P30PCR	
H'FFB0	P1DDR	P17DDR	P16DDR	P15DDR	P14DDR	P13DDR	P12DDR	P11DDR	P10DDR	
H'FFB1	P2DDR	P27DDR	P26DDR	P25DDR	P24DDR	P23DDR	P22DDR	P21DDR	P20DDR	
H'FFB2	P1DR	P17DR	P16DR	P15DR	P14DR	P13DR	P12DR	P11DR	P10DR	
H'FFB3	P2DR	P27DR	P26DR	P25DR	P24DR	P23DR	P22DR	P21DR	P20DR	
H'FFB4	P3DDR	P37DDR	P36DDR	P35DDR	P34DDR	P33DDR	P32DDR	P31DDR	P30DDR	
H'FFB5	P4DDR	P47DDR	P46DDR	P45DDR	P44DDR	P43DDR	P42DDR	P41DDR	P40DDR	
H'FFB6	P3DR	P37DR	P36DR	P35DR	P34DR	P33DR	P32DR	P31DR	P30DR	
H'FFB7	P4DR	P47DR	P46DR	P45DR	P44DR	P43DR	P42DR	P41DR	P40DR	
H'FFB8	P5DDR	—	—	—	—	—	P52DDR	P51DDR	P50DDR	
H'FFB9	P6DDR	P67DDR	P66DDR	P65DDR	P64DDR	P63DDR	P62DDR	P61DDR	P60DDR	
H'FFBA	P5DR	—	—	—	—	—	P52DR	P51DR	P50DR	
H'FFBB	P6DR	P67DR	P66DR	P65DR	P64DR	P63DR	P62DR	P61DR	P60DR	
H'FFBC	PBODR	PB7ODR	PB6ODR	PB5ODR	PB4ODR	PB3ODR	PB2ODR	PB1ODR	PB0ODR	
H'FFBD	PBPIN	PB7PIN	PB6PIN	PB5PIN	PB4PIN	PB3PIN	PB2PIN	PB1PIN	PB0PIN	
	(read)									
	P8DDR	—	P86DDR	P85DDR	P84DDR	P83DDR	P82DDR	P81DDR	P80DDR	
	(write)									

H'FFC2	IER	IRQ7E	IRQ6E	IRQ5E	IRQ4E	IRQ3E	IRQ2E	IRQ1E	IRQ0E	Inte con
H'FFC3	STCR	IICS	IICX1	IICX0	IICE	FLSHE	—	ICKS1	ICKS0	Sys
H'FFC4	SYSCR	CS2E	IOSE	INTM1	INTM0	XRST	NMIEG	HIE	RAME	
H'FFC5	MDCR	EXPE	—	—	—	—	—	MDS1	MDS0	
H'FFC6	BCR	ICIS1	ICIS0	BRSTRM	BRSTS1	BRSTS0	—	IOS1	IOS0	Bus con
H'FFC7	WSCR	RAMS	RAM0	ABW	AST	WMS1	WMS0	WC1	WC0	
H'FFC8	TCR0	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TM
H'FFC9	TCR1	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TM
H'FFCA	TCSR0	CMFB	CMFA	OVF	ADTE	OS3	OS2	OS1	OS0	
H'FFCB	TCSR1	CMFB	CMFA	OVF	—	OS3	OS2	OS1	OS0	
H'FFCC	TCORA0									
H'FFCD	TCORA1									
H'FFCE	TCORB0									
H'FFCF	TCORB1									
H'FFD0	TCNT0									
H'FFD1	TCNT1									
H'FFD2	PWOERB	OE15	OE14	OE13	OE12	OE11	OE10	OE9	OE8	PW
H'FFD3	PWOERA	OE7	OE6	OE5	OE4	OE3	OE2	OE1	OE0	
H'FFD4	PWDPRB	OS15	OS14	OS13	OS12	OS11	OS10	OS9	OS8	
H'FFD5	PWDPRA	OS7	OS6	OS5	OS4	OS3	OS2	OS1	OS0	
H'FFD6	PWSL	PWCKE	PWCKS	—	—	RS3	RS2	RS1	RS0	
H'FFD7	PWDR0 to PWDR15									
H'FFD8	SMR0	C/ \bar{A}	CHR	PE	O/ \bar{E}	STOP	MP	CKS1	CKS0	SC
	ICCR0	ICE	IEIC	MST	TRS	ACKE	BBSY	IRIC	SCP	IIC
H'FFD9	BRR0									SC
	ICSR0	ESTP	STOP	IRTR	AASX	AL	AAS	ADZ	ACKB	IIC

H'FFDF	ICMR0	MLS	WAIT	CKS2	CKS1	CKS0	BC2	BC1	BC0	
	SAR0	SVA6	SVA5	SVA4	SVA3	SVA2	SVA1	SVA0	FS	
H'FFE0	ADDRAH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	A
H'FFE1	ADDRAL	AD1	AD0	—	—	—	—	—	—	
H'FFE2	ADDRBH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	
H'FFE3	ADDRBL	AD1	AD0	—	—	—	—	—	—	
H'FFE4	ADDRCH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	
H'FFE5	ADDRCL	AD1	AD0	—	—	—	—	—	—	
H'FFE6	ADDRDH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	
H'FFE7	ADDRDL	AD1	AD0	—	—	—	—	—	—	
H'FFE8	ADCSR	ADF	ADIE	ADST	SCAN	CKS	CH2	CH1	CH0	
H'FFE9	ADCR	TRGS1	TRGS0	—	—	—	—	—	—	
H'FFEA	TCSR1	OVF	WT/IT	TME	PSS	RST/NMI	CKS2	CKS1	CKS0	W
		TCNT1 (write)								
H'FFEB		TCNT1 (read)								
H'FFF0	HICR	—	—	—	—	—	IBFIE2	IBFIE1	FGA20E	H
	TCRX	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TI
	TCRY	CMIEB	CMIEA	OVIE	CCLR1	CCLR0	CKS2	CKS1	CKS0	TI
H'FFF1	KMIMR	KMIMR7	KMIMR6	KMIMR5	KMIMR4	KMIMR3	KMIMR2	KMIMR1	KMIMR0	In cc
	TCSRX	CMFB	CMFA	OVF	ICF	OS3	OS2	OS1	OS0	TI
	TCSRY	CMFB	CMFA	OVF	ICIE	OS3	OS2	OS1	OS0	TI
H'FFF2	KMPCR	KM7PCR	KM6PCR	KM5PCR	KM4PCR	KM3PCR	KM2PCR	KM1PCR	KM0PCR	P
		TICRR								TI
		TCORAY								TI
H'FFF3	KMIMRA	KMIMR15	KMIMR14	KMIMR13	KMIMR12	KMIMR11	KMIMR10	KMIMR9	KMIMR8	In cc
		TICRF								TI
		TCORBY								TI

	TCORAX										TM
H'FFF7	TCORBX										
H'FFF8	DADR0										D/A
H'FFF9	DADR1										
H'FFFA	DACR	DAOE1	DAOE0	DAE	—	—	—	—	—		
H'FFFC	IDR2	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0	HIF	
	TCONRI	SIMOD1	SIMOD0	SCONE	ICST	HFINV	VFINV	HIINV	VIINV	Tim con	
H'FFFD	ODR2	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0	HIF	
	TCONRO	HOE	VOE	CLOE	CBOE	HOINV	VOINV	CLOINV	CBOINV	Tim con	
H'FFFE	STR2	DBU	DBU	DBU	DBU	C/\bar{D}	DBU	IBF	OBF	HIF	
	TCONRS	TMRX/Y	ISGENE	HOMOD1	HOMOD0	VOMOD1	VOMOD0	CLMOD1	CLMOD0	Tim con	
H'FFFF	SEDGR	VEDG	HEDG	CEDG	HFEDG	VFEDG	PREQF	IHI	IVI		

H'FE80	HICR2	MSTP2 = 0	MSTP2 = 0	—
H'FE84	IDR3			
H'FE85	ODR3			
H'FE86	STR3			
H'FE8C	IDR4			
H'FE8D	ODR4			
H'FE8E	STR4			
H'FED8	KBCRH0	MSTP2 = 0	MSTP2 = 0	—
H'FED9	KBCRL0			
H'FEDA	KBBR0			
H'FEDC	KBCRH1			
H'FEDD	KBCRL1			
H'FEDE	KBBR1			
H'FEE0	KBCRH2			
H'FEE1	KBCRL2			
H'FEE2	KBBR2			
H'FEE4	KBCOMP	No conditions	No conditions	No conditions
H'FEE6	DDCSWR	MSTP4 = 0	MSTP4 = 0	—
H'FEE8	ICRA	No conditions	No conditions	No conditions
H'FEE9	ICRB			
H'FEEA	ICRC			
H'FEEB	ISR			
H'FEEC	ISCRH			
H'FEED	ISCR L			
H'FEEE	DTCERA			
H'FEEF	DTCERB			
H'FEF0	DTCERC			
H'FEF1	DTCERD			
H'FEF2	DTCERE			

	EBR1	FLSHE = 1 in STCR		FLSHE = 1 in STCR		FLSHE = 1 in STCR
H'FF83	SYSCR2	FLSHE = 0 in STCR		FLSHE = 0 in STCR		—
	EBR2	FLSHE = 1 in STCR		FLSHE = 1 in STCR		FLSHE = 1 in STCR
H'FF84	SBYCR	FLSHE = 0 in STCR		FLSHE = 0 in STCR		FLSHE = 0 in STCR
H'FF85	LPWRCR					
H'FF86	MSTPCRH					
H'FF87	MSTPCRL					
H'FF88	SMR1	MSTP6 = 0, IICE = 0 in STCR		MSTP6 = 0, IICE = 0 in STCR		MSTP6 = 0, IICE = 0 in STCR
	ICCR1	MSTP3 = 0, IICE = 1 in STCR		MSTP3 = 0, IICE = 1 in STCR		—
H'FF89	BRR1	MSTP6 = 0, IICE = 0 in STCR		MSTP6 = 0, IICE = 0 in STCR		MSTP6 = 0, IICE = 0 in STCR
	ICSR1	MSTP3 = 0, IICE = 1 in STCR		MSTP3 = 0, IICE = 1 in STCR		—
H'FF8A	SCR1	MSTP6 = 0		MSTP6 = 0		MSTP6 = 0
H'FF8B	TDR1					
H'FF8C	SSR1					
H'FF8D	RDR1					
H'FF8E	SCMR1	MSTP6 = 0, IICE = 0 in STCR		MSTP6 = 0, IICE = 0 in STCR		MSTP6 = 0, IICE = 0 in STCR
	ICDR1	MSTP3 = 0, IICE = 1 in STCR	ICE = 1 in ICCR1	MSTP3 = 0, IICE = 1 in STCR	ICE = 1 in ICCR1	—
			ICE = 0 in ICCR1		ICE = 0 in ICCR1	
	SARX1		ICE = 1 in ICCR1	ICE = 1 in ICCR1		
		ICE = 0 in ICCR1	ICE = 0 in ICCR1			
H'FF8F	ICMR1		ICE = 1 in ICCR1		ICE = 1 in ICCR1	
	SAR1		ICE = 0 in ICCR1		ICE = 0 in ICCR1	
H'FF90	TIER	MSTP13 = 0		MSTP13 = 0		MSTP13 = 0
H'FF91	TCSR					
H'FF92	FRCH					
H'FF93	FRCL					

H'FF97	TOCR							ICRS = 0 in TOCR	ICRS = 0 in TOCR	ICRS = TOCR
H'FF98	ICRAH							ICRS = 1 in TOCR	ICRS = 1 in TOCR	ICRS = TOCR
	OCRARH							ICRS = 0 in TOCR	ICRS = 0 in TOCR	ICRS = TOCR
H'FF99	ICRAL							ICRS = 1 in TOCR	ICRS = 1 in TOCR	ICRS = TOCR
	OCRARL							ICRS = 0 in TOCR	ICRS = 0 in TOCR	ICRS = TOCR
H'FF9A	ICRBH							ICRS = 1 in TOCR	ICRS = 1 in TOCR	ICRS = TOCR
	OCRAFH							ICRS = 0 in TOCR	ICRS = 0 in TOCR	ICRS = TOCR
H'FF9B	ICRBL							ICRS = 1 in TOCR	ICRS = 1 in TOCR	ICRS = TOCR
	OCR AFL							ICRS = 0 in TOCR	ICRS = 0 in TOCR	ICRS = TOCR
H'FF9C	ICRCH							ICRS = 1 in TOCR	ICRS = 1 in TOCR	ICRS = TOCR
	OCRDMH							ICRS = 0 in TOCR	ICRS = 0 in TOCR	ICRS = TOCR
H'FF9D	ICRCL							ICRS = 1 in TOCR	ICRS = 1 in TOCR	ICRS = TOCR
	OCR DML							ICRS = 0 in TOCR	ICRS = 0 in TOCR	ICRS = TOCR
H'FF9E	ICRDH									ICRS = TOCR
H'FF9F	ICRDL									ICRS = TOCR
H'FFA0	SMR2	MSTP5 = 0, IICE = 0 in STCR		MSTP5 = 0, IICE = 0 in STCR		MSTP5 = 0, IICE = 0 in STCR				
	DADRAH	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB			
	DACR		REGS = 1 in DACNT/ DADRB		REGS = 1 in DACNT/ DADRB		REGS = 1 in DACNT/ DADRB			

	DADRBH	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB	MSTP11 = 0, IICE = 1 in STCR	REGS = 0 in DACNT/ DADRB
	DACNTH						
H'FFA7	DADRBL		REGS = 0 in DACNT/ DADRB		REGS = 0 in DACNT/ DADRB		REGS = 0 in DACNT/ DADRB
	DACNTL		REGS = 1 in DACNT/ DADRB		REGS = 1 in DACNT/ DADRB		REGS = 1 in DACNT/ DADRB
H'FFA8	TCSR0	No conditions		No conditions		No conditions	
	TCNT0 (write)						
H'FFA9	TCNT0 (read)						
H'FFAA	PAODR0	No conditions		No conditions		No conditions	
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'FFB6	P3DR						
H'FFB7	P4DR						

H'FFBE	P7PIN (read)						
	PBDDR (write)						
H'FFBF	P8DR						
H'FFC0	P9DDR						
H'FFC1	P9DR						
H'FFC2	IER	No conditions	No conditions	No conditions			
H'FFC3	STCR	No conditions	No conditions	No conditions			
H'FFC4	SYSCR						
H'FFC5	MDCR						
H'FFC6	BCR						
H'FFC7	WSCR						
H'FFC8	TCR0				MSTP12 = 0	MSTP12 = 0	MSTP12 = 0
H'FFC9	TCR1						
H'FFCA	TCSR0						
H'FFCB	TCSR1						
H'FFCC	TCORA0						
H'FFCD	TCORA1						
H'FFCE	TCORB0						
H'FFCF	TCORB1						
H'FFD0	TCNT0						
H'FFD1	TCNT1						
H'FFD2	PWOERB	No conditions	No conditions	—			
H'FFD3	PWOERA						
H'FFD4	PWDPRB						
H'FFD5	PWDPRA						

H'FFDB	TDRO					
H'FFDC	SSR0					
H'FFDD	RDR0					
H'FFDE	SCMR0	MSTP7 = 0, IICE = 0 in STCR		MSTP7 = 0, IICE = 0 in STCR		MSTP7 = 0, IICE = 0 in STCR
	ICDR0	MSTP4 = 0, IICE = 1 in STCR	ICE = 1 in ICCR0	MSTP4 = 0, IICE = 1 in STCR	ICE = 1 in ICCR0	—
	SARX0		ICE = 0 in ICCR0		ICE = 0 in ICCR0	
H'FFDF	ICMR0	ICE = 1 in ICCR0	ICE = 0 in ICCR0	ICE = 1 in ICCR0		
	SAR0	ICE = 0 in ICCR0		ICE = 0 in ICCR0		
H'FFE0	ADDRAH	MSTP9 = 0		MSTP9 = 0		MSTP9 = 0
H'FFE1	ADDRAL					
H'FFE2	ADDRBH					
H'FFE3	ADDRBL					
H'FFE4	ADDRCH					
H'FFE5	ADDRCL					
H'FFE6	ADDRDH					
H'FFE7	ADDRDL					
H'FFE8	ADCSR					
H'FFE9	ADCR					
H'FFEA	TCSR1	No conditions		No conditions		No conditions
	TCNT1 (write)					
H'FFEB	TCNT1 (read)					
H'FFF0	HICR	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR		—
	TCRX	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	—		—
	TCRY		TMRX/Y = 1 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR		MSTP8 = 0, HIE = 0 in SYSCR

	TCORAY		TMRX/Y = 1 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	MSTP8 = 0, HIE = 0 in SYSCR
H'FFF3	KMIMRA	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR	MSTP2 = 0, HIE = 1 in SYSCR
	TICRF	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	—	—
	TCORBY		TMRX/Y = 1 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	MSTP8 = 0, HIE = 0 in SYSCR
H'FFF4	IDR1	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR	—
	TCNTX	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	—	
	TCNTY		TMRX/Y = 1 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	MSTP8 = 0, HIE = 0 in SYSCR
H'FFF5	ODR1	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR	—
	TCORC	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	—	
	TISR		TMRX/Y = 1 in TCONRS	MSTP8 = 0, HIE = 0 in SYSCR	MSTP8 = 0, HIE = 0 in SYSCR
H'FFF6	STR1	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR	—
	TCORAX	MSTP8 = 0, HIE = 0 in SYSCR	TMRX/Y = 0 in TCONRS	—	
H'FFF7	TCORBX				
H'FFF8	DADR0	MSTP10 = 0		MSTP10 = 0	MSTP10 = 0
H'FFF9	DADR1				
H'FFFA	DACR				
H'FFFC	IDR2	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR	—
	TCONRI	MSTP8 = 0, HIE = 0 in SYSCR		—	
H'FFFD	ODR2	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR	
	TCONRO	MSTP8 = 0, HIE = 0 in SYSCR		—	
H'FFFE	STR2	MSTP2 = 0, HIE = 1 in SYSCR		MSTP2 = 0, HIE = 1 in SYSCR	
	TCONRS	MSTP8 = 0, HIE = 0 in SYSCR		—	
H'FFFF	SEDGR				

Initial bit values

Bit
Initial value
Read/Write

7	6	5	4	3	2	1	0
DAOE1	DAOE0	DAE	—	—	—	—	—
0	0	0	1	1	1	1	1
R/W	R/W	R/W	—	—	—	—	—

Possible types of access

R	Read only
W	Write only
R/W	Read and write

D/A enabled

DAOE1	DAOE0	DAE	Conversion result
0	0	*	Channel 0 and 1 D/A conversion disabled
		0	Channel 0 D/A conversion enabled Channel 1 D/A conversion disabled
	1	1	Channel 0 and 1 D/A conversion enabled
1	0	0	Channel 0 D/A conversion disabled Channel 1 D/A conversion enabled
		1	Channel 0 and 1 D/A conversion enabled
	1	*	Channel 0 and 1 D/A conversion enabled

D/A output enable 0

0	Analog output DA0 disabled
1	Channel 0 D/A conversion enabled. Analog output DA0 enabled

D/A output enable 1

0	Analog output DA1 disabled
1	Channel 1 D/A conversion enabled. Analog output DA1 enabled

DTC data transfer mode	
0	Byte-size
1	Word-size

DTC transfer mode	
0	Destination side is master or block area
1	Source side is master or block area

DTC mode		
0	0	Normal mode
	1	Repeat mode
1	0	Block transfer mode
	1	—

Destination address mode		
0	—	DAR is fixed
1	0	DAR is incremented after a transfer (by 1 when Sz = 0; by 2 when Sz = 1)
	1	DAR is decremented after a transfer (by 1 when Sz = 0; by 2 when Sz = 1)

Source address mode

0	—	SAR is fixed
1	0	SAR is incremented after a transfer (by 1 when Sz = 0; by 2 when Sz = 1)
	1	SAR is decremented after a transfer (by 1 when Sz = 0; by 2 when Sz = 1)



DTC interrupt select

0	After a data transfer ends, the CPU interrupt is disabled unless the transfer counter is 0
1	After a data transfer ends, the CPU interrupt is enabled

DTC chain transfer enable

0	End of DTC data transfer
1	DTC chain transfer

SAR—DTC Source Address Register

H'EC00–H'EFF

Bit	23	22	21	20	19	---	4	3	2

Initial value	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	---	Unde- fined	Unde- fined	Unde- fined
Read/Write	—	—	—	—	—	---	—	—	—

Specifies DTC transfer data source address

DAR—DTC Destination Address Register

H'EC00–H'EFF

Bit	23	22	21	20	19	---	4	3	2

Initial value	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	---	Unde- fined	Unde- fined	Unde- fined
Read/Write	—	—	—	—	—	---	—	—	—

Specifies DTC transfer data destination address

Specifies the number of DTC data transfers

CRB—DTC Transfer Count Register B

H'EC00–H'EFF

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2
Initial value	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined
Read/Write	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Specifies the number of DTC block data transfers

HICR2—Host Interface Control Register 2

H'FE80

Bit	7	6	5	4	3	2	1
	—	—	—	—	—	IBFIE4	IBFIE3
Initial value	1	1	1	1	1	0	0
Slave R/W	—	—	—	—	—	R/W	R/W
Host R/W	—	—	—	—	—	—	—

Input data register full interrupt enable

IBFIE4	IBFIE3	Description
—	0	Input data register (IDR3) receive complete interrupt is e
—	1	Input data register (IDR3) receive complete interrupt is e
0	—	Input data register (IDR4) receive complete interrupt is c
1	—	Input data register (IDR4) receive complete interrupt is e

Stores host data bus contents at rise of \overline{IOW} when \overline{CS} is low

ODR3—Output Data Register 3

H'FE85

ODR4—Output Data Register 4

H'FE8D

Bit	7	6	5	4	3	2	1
	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1
Initial value	—	—	—	—	—	—	—
Slave R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Host R/W	R	R	R	R	R	R	R

ODR contents are output to the host data bus when $HA0$ is low, \overline{CS} is low, and \overline{IOR} is low

User-defined bits

Output buffer full

0	[Clearing condition] When the host processor reads ODR or the slave processor writes 0 in the ODR.
1	[Setting condition] When the slave processor writes to ODR.

Input buffer full

0	[Clearing condition] When the slave processor reads the input data register.
1	[Setting condition] When the host processor writes to the input data register.

Command/data

0	Contents of input data register (IDR) are output to the host processor.
1	Contents of input data register (IDR) are output to the slave processor.

Keyboard stop—

0	0 stop bit re
1	1 stop bit re

Parity error

0	[Clearing condition] Read PER when PER = 1, then write 0 in PER
1	[Setting condition] When an odd parity error occurs

Keyboard buffer register full

0	[Clearing condition] Read KBF when KBF = 1, then write 0 in KBF
1	[Setting conditions] <ul style="list-style-type: none"> When data has been received normally (KBFSEL = 1, and has been transferred to KBBR (keyboard buffer register full flag)) When a KCLK falling edge has been detected while KBFSEL = 0 (KCLK interrupt flag)

Keyboard interrupt enable

0	Interrupt requests are disabled
1	Interrupt requests are enabled

Keyboard buffer register full select

0	KBF bit is used as KCLK fall interrupt flag
1	KBF bit is used as keyboard buffer full flag

Keyboard data in

0	KD I/O pin is low
1	KD I/O pin is high

Keyboard clock in

0	KCLK I/O pin is low
1	KCLK I/O pin is high

Keyboard in/out enable

0	The keyboard buffer controller is non-operational (KCLK and KD signal pins have port functions)
1	The keyboard buffer controller is enabled for transmission and reception (KCLK and KD signal pins are in the bus drive state)

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

Receive counter

RXCR3	RXCR2	RXCR1	RXCR0	Receive c
0	0	0	0	
			1	St
		1	0	
			1	
	1	0	0	
			1	
		1	0	
			1	
1	0	0	0	
			1	
		1	0	Pa
	1			
	1	—	—	

Keyboard data out

0	Keyboard buffer controller data I/O pin is low
1	Keyboard buffer controller data I/O pin is high

Keyboard clock out

0	Keyboard buffer controller clock I/O pin is low
1	Keyboard buffer controller clock I/O pin is high

Keyboard enable

0	Loading of receive data into KBBR is disabled
1	Loading of receive data into KBBR is enabled

Keyboard comparator control

Bit 3	Bit 2	Bit 1	Bit 0	A/D converter channel 6 input	A/D chan	
KBADE	KBCH2	KBCH1	KBCH0			
0	—	—	—	AN6		
1	0	0	0	CIN0		
			1	CIN1		
		1	0	CIN2		
			1	CIN3		
	1	0	0	0	CIN4	
				1	CIN5	
		1	0	0	CIN6	
				1	CIN7	

IrDA Clock select 2 to 0

0	0	0	$B \times 3/16$ (3/16 of the bit rate)
		1	$\phi/2$
	1	0	$\phi/4$
		1	$\phi/8$
1	0	0	$\phi/16$
		1	$\phi/32$
	1	0	$\phi/64$
		1	$\phi/128$

IrDA enable

0	The TxD2/IrTxD and RxD2/IrRxD pins function as TxD2 and RxD2
1	The TxD2/IrTxD and RxD2/IrRxD pins function as IrTxD and IrRxD

Bit 3	Bit 2	Bit 1	Bit 0	Description
CLR3	CLR2	CLR1	CLR0	
0	0	—	—	Setting prohibited
		0	0	Setting prohibited
	1	0	1	IIC0 internal latch cleared
		0	0	IIC1 internal latch cleared
		1	1	IIC0 and IIC1 internal latches
1	—	—	—	Invalid setting

DDC mode switch interrupt flag

0	No interrupt is requested when automatic format switching is executed [Clearing condition] When 0 is written in IF after reading IF = 1
1	An interrupt is requested when automatic format switching is executed [Setting condition] When a falling edge is detected on the SCL pin when SWE = 1

DDC mode switch interrupt enable bit

0	Interrupt when automatic format switching is executed is disabled
1	Interrupt when automatic format switching is executed is enabled

DDC mode switch

0	IIC channel 0 is used with the I ² C bus format [Clearing conditions] <ul style="list-style-type: none"> When 0 is written by software When a falling edge is detected on the SCL pin when SWE = 1
1	IIC channel 0 is used in formatless mode [Setting condition] When 1 is written in SW after reading SW = 0

DDC mode switch enable

0	Automatic switching of IIC channel 0 from formatless mode to I ² C bus format is disabled
1	Automatic switching of IIC channel 0 from formatless mode to I ² C bus format is enabled

- Notes: 1. Only 0 can be written, to clear the flag.
2. Always read as 1.

Interrupt control level

0	Corresponding interrupt source is control level 0 (non
1	Corresponding interrupt source is control level 1 (prio

Correspondence between Interrupt Sources and ICR Settings

Register	Bits						
	7	6	5	4	3	2	1
ICRA	IRQ0	IRQ1	IRQ2 IRQ3	IRQ4 IRQ5	IRQ6 IRQ7	DTC	Watchdog timer 0
ICRB	A/D converter	Free- running timer	—	—	8-bit timer channel 0	8-bit timer channel 1	8-bit timer channels X, Y
ICRC	SCI channel 0	SCI channel 1	SCI channel 2	IIC channel 0 (option)	IIC channel 1 (option)	—	—

0	<p>[Clearing conditions]</p> <ul style="list-style-type: none"> • Cleared by reading IRQnF when set to 1, then writing 0 in IRQnF • When interrupt exception handling is executed while low-level detection is set (IRQnSCB = IRQnSCA = 0) and $\overline{\text{IRQn}}$ input is high* • When IRQn interrupt exception handling is executed while falling or both-edge detection is set (IRQnSCB = 1 or IRQnSCA = 1)*
1	<p>[Setting conditions]</p> <ul style="list-style-type: none"> • When $\overline{\text{IRQn}}$ input goes low when low-level detection is set (IRQnSCB = IRQnSCA = 0) • When a falling edge occurs in $\overline{\text{IRQn}}$ input while falling edge detection is set (IRQnSCB = 0, IRQnSCA = 1) • When a rising edge occurs in $\overline{\text{IRQn}}$ input while rising edge detection is set (IRQnSCB = 1, IRQnSCA = 0) • When a falling or rising edge occurs in $\overline{\text{IRQn}}$ input while both-edge detection is set (IRQnSCB = IRQnSCA = 1)

Notes: n = 7 to 0

* 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 handling, which is a clear condition, is executed and the bit is held at 1.

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

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

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

Read/Write R/W R/W R/W R/W R/W R/W R/W

IRQ7 to IRQ4 sense control A and B

ISCRH

Bit	7	6	5	4	3	2	1
	IRQ3SCB	IRQ3SCA	IRQ2SCB	IRQ2SCA	IRQ1SCB	IRQ1SCA	IRQ0SCB
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

IRQ3 to IRQ0 sense control A and B

ISCRH bits 7 to 0 ISCRH bits 7 to 0		Description
IRQ7SCB to IRQ0SCB	IRQ7SCA to IRQ0SCA	
0	0	Interrupt request generated at $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$ input at low level
	1	Interrupt request generated at falling edge of $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$ input
1	0	Interrupt request generated at rising edge of $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$ input
	1	Interrupt request generated at both falling and rising edges of $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$ input

0	DTC activation by interrupt is disabled [Clearing conditions] • When data transfer ends with the DISEL bit set to 1 • When the specified number of transfers end
1	DTC activation by interrupt is enabled [Holding condition] When the DISEL bit is 0 and the specified number of transfers have not ended

DTVECR—DTC Vector Register

H'FEF3

Bit	7	6	5	4	3	2	1
	SWDTE	DTVEC6	DTVEC5	DTVEC4	DTVEC3	DTVEC2	DTVEC1
Initial value	0	0	0	0	0	0	0
Read/Write	R/(W)*	R/W	R/W	R/W	R/W	R/W	R/W

Sets vector number for DTC software a

DTC software activation enable

0	DTC software activation is disabled [Clearing condition] When the DISEL bit is 0 and the specified number of transfers not ended
1	DTC software activation is enabled [Holding conditions] • When data transfer ends with the DISEL bit set to 1 • When the specified number of transfers end • During software-activated deta transfer

Note: * A value of 1 can always be written to the SWDTE bit, but 0 can only be written after 1 is read.

0	Address break di
1	Address break e

Condition match flag

0	[Clearing condition] When address break interrupt exception handling is executed
1	[Setting condition] When address set by BARA to BARC is prefetched while BIE =

Specifies address (bits 23 to 16) at which address break is to be g

Bit	7	6	5	4	3	2	1
BARB	A15	A14	A13	A12	A11	A10	A9
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Specifies address (bits 15 to 8) at which address break is to be g

Bit	7	6	5	4	3	2	1
BARC	A7	A6	A5	A4	A3	A2	A1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Specifies address (bits 7 to 1) at which address break is to be g

Program	
0	Program mode cleared
1	Transition to program mode [Setting condition] When SWE = 1, and

Erase	
0	Erase mode cleared
1	Transition to erase mode [Setting condition] When SWE = 1, and ESU = 1

Program-verify	
0	Program-verify mode cleared
1	Transition to program-verify mode [Setting condition] When SWE = 1

Erase-verify	
0	Erase-verify mode cleared
1	Transition to erase-verify mode [Setting condition] When SWE = 1

Software write enable	
0	Writes disabled
1	Writes enabled

Reserved bit

0	Program setup
1	Program setup [Setting condition] When SWE =

Erase setup

0	Erase setup cleared
1	Erase setup [Setting condition] When SWE = 1

Flash memory error

0	Flash memory is operating normally Flash memory program/erase protection (error protection) is disabled [Clearing condition] Reset or hardware standby mode
1	An error has occurred during flash memory programming/erasing Flash memory program/erase protection (error protection) is enabled [Setting condition] See section 22.8.3 or 23.8.3, Error Protection

PWSL		PCSR		Description
Bit 7	Bit 6	Bit 2	Bit 1	
PWCKE	PWCKS	PWCKB	PWCKA	
0	—	—	—	Clock input is disabled
1	0	—	—	ϕ (system clock) is selected
	1	0	0	$\phi/2$ is selected
			1	$\phi/4$ is selected
	1	1	0	$\phi/8$ is selected
1			$\phi/16$ is selected	

Host interface enable	
0	Host interface functions are disabled
1	Host interface functions are enabled

CS3 enable

0	Host interface pin channel functions disabled
1	Host interface pin channel functions enabled

CS4 enable

0	Host interface pin channel functions disabled
1	Host interface pin channel functions enabled

Shutdown enable

0	Host interface pin shutdown function disabled
1	Host interface pin shutdown function enabled

Port 6 input pull-up extra

0	Standard current specification is selected for port 6 input pull-up function
1	Current-limit specification is selected for port 6 MO pull-up function

Key wakeup level 1 and 0

0	0	Standard input level is selected as port 6 input level
	1	Input level 1 is selected as port 6 input level
1	0	Input level 2 is selected as port 6 input level
	1	Input level 3 is selected as port 6 input level

Bit	7	6	5	4	3	2	1	
EBR2	EB7	EB6	EB5	EB4	EB3	EB2	EB1	
Initial value	0	0	0	0	0	0	0	
Read/Write	R/W*1	R/W	R/W	R/W	R/W	R/W	R/W	

- Notes:
1. In normal mode, these bits cannot be modified and are always read as 0.
 2. Bits EB8 and EB9 are not present in the 64-kbyte versions; they must not be used.

Erase Blocks

Block (Size)		Addresses
128-kbyte versions	64-kbyte versions	
EB0 (1 kbyte)	EB0 (1 kbyte)	H'(00)0000 to H'(00)03FF
EB1 (1 kbyte)	EB1 (1 kbyte)	H'(00)0400 to H'(00)07FF
EB2 (1 kbyte)	EB2 (1 kbyte)	H'(00)0800 to H'(00)0BFF
EB3 (1 kbyte)	EB3 (1 kbyte)	H'(00)0C00 to H'(00)0FFF
EB4 (28 kbytes)	EB4 (28 kbytes)	H'(00)1000 to H'(00)7FFF
EB5 (16 kbytes)	EB5 (16 kbytes)	H'(00)8000 to H'(00)BFFF
EB6 (8 kbytes)	EB6 (8 kbytes)	H'(00)C000 to H'(00)DFFF
EB7 (8 kbytes)	EB7 (8 kbytes)	H'00E000 to H'00FFFF
EB8 (32 kbytes)	—	H'010000 to H'017FFF
EB9 (32 kbytes)	—	H'018000 to H'01FFFF

System clock select 2 to 0

0	0	0	Bus master is in high-spe
		1	Medium-speed clock = ϕ/n
	1	0	Medium-speed clock = ϕ/n
		1	Medium-speed clock = ϕ/n
1	0	0	Medium-speed clock = ϕ/n
		1	Medium-speed clock = ϕ/n
	1	—	—

Standby timer select 2 to 0

0	0	0	Standby time = 8192 states
		1	Standby time = 16384 states
	1	0	Standby time = 32768 states
		1	Standby time = 65536 states
1	0	0	Standby time = 131072 states
		1	Standby time = 262144 states
	1	0	Reserved
		1	Standby time = 16 states*

Note: * This setting must not be used in the flash memory vers

Software standby

0	Transition to sleep mode after execution of SLEEP instruction in high-speed or medium-speed mode Transition to subsleep mode on execution of SLEEP instruction in subactive
1	Transition to software standby mode, subactive mode, or watch mode after e of SLEEP instruction in high-speed mode or medium-speed mode Transition to watch mode or high-speed mode after execution of SLEEP instr subactive mode



0	Subclock input from EXCL pin is
1	Subclock input from EXCL pin is

Noise elimination sampling frequency select

0	Sampling at ϕ divided by 32
1	Sampling at ϕ divided by 4

Low-speed on flag

0	<ul style="list-style-type: none"> When a SLEEP instruction is executed in high-speed mode or medium-speed mode, a transition is made to sleep mode, software standby mode, or watch mode* When a SLEEP instruction is executed in subactive mode, a transition is made to watch mode, or directly to high-speed mode After watch mode is cleared, a transition is made to high-speed mode
1	<ul style="list-style-type: none"> When a SLEEP instruction is executed in high-speed mode or medium-speed mode, a transition is made to watch mode or subactive mode* When a SLEEP instruction is executed in subactive mode, a transition is made to subsleep mode or watch mode After watch mode is cleared, a transition is made to subactive mode

Note: * When a transition is made to watch mode or subactive mode, high-speed mode must be set.

Direct-transfer on flag

0	<ul style="list-style-type: none"> When a SLEEP instruction is executed in high-speed mode or medium-speed mode, a transition is made to sleep mode, software standby mode, or watch mode* When a SLEEP instruction is executed in subactive mode, a transition is made to subsleep mode or watch mode
1	<ul style="list-style-type: none"> When a SLEEP instruction is executed in high-speed mode or medium-speed mode, a transition is made directly to subactive mode*, or a transition is made to sleep mode or software standby mode When a SLEEP instruction is executed in subactive mode, a transition is made to high-speed mode, or a transition is made to subsleep mode

Note: * When a transition is made to watch mode or subactive mode, high-speed mode must be set.

Module stop

0	Module stop mode is cleared
1	Module stop mode is set

The correspondence between MSTPCR bits and on-chip supporting modules is shown in the following table.

Register	Bit	Module
MSTPCRH	MSTP15	—
	MSTP14*	Data transfer controller (DTC)
	MSTP13	16-bit free-running timer (FRT)
	MSTP12	8-bit timers (TMR0, TMR1)
	MSTP11	8-bit PWM timer (PWM), 14-bit PWM timer (PWMX)
	MSTP10	D/A converter
	MSTP9	A/D converter
	MSTP8	8-bit timers (TMRX, TMR Y), timer connection
MSTPCRL	MSTP7	Serial communication interface 0 (SCI0)
	MSTP6	Serial communication interface 1 (SCI1)
	MSTP5	Serial communication interface 2 (SCI2)
	MSTP4*	I ² C bus interface (IIC) channel 0 (option)
	MSTP3*	I ² C bus interface (IIC) channel 1 (option)
	MSTP2*	Host interface (HIF), keyboard buffer controller (PS2)
	MSTP1*	—
	MSTP0*	—

Notes: Do not set bit 15 to 1. Bits 1 and 0 can be read and written but do not affect module stop mode.

* Must be set to 1 in the H8S/2144 Group.

Clock sele

0	0	ϕ
	1	$\phi/$
1	0	$\phi/$
	1	$\phi/$

Multiprocessor mode

0	Multiprocessor function
1	Multiprocessor format

Stop bit length

0	1 stop bit
1	2 stop bits

Parity mode

0	Even parity
1	Odd parity

Parity enable

0	Parity bit addition and checking disabled
1	Parity bit addition and checking enabled

Character length

0	8-bit data
1	7-bit data*

Note: * When 7-bit data is selected, the MSB (bit 7) of TDR is not transmitted. Also, LSB-first/MSB-first selection is not available.

Communication mode

0	Asynchronous mode
1	Synchronous mode

Start condition/stop condition prohibit

0	Writing 0 issues a stop condition, in combination with the BBSY flag
1	Reading always returns a value of 1; writing is prohibited

I²C bus interface interrupt request

0	Waiting for transfer, or transfer in progress
1	Interrupt requested

Note: For the clearing and setting conditions, see section 16.2.5, I²C Bus Control Register (ICCR).

Bus busy

0	Bus is free [Clearing condition] When a stop condition is detected
1	Bus is busy [Setting condition] When a start condition is detected

Acknowledge bit judgement selection

0	The value of the acknowledge bit is ignored and continuous transfer is performed
1	If the acknowledge bit is 1, continuous transfer is interrupted

Master/slave select (MST), transmit/receive select

0	0	Slave receive mode
	1	Slave transmit mode
1	0	Master receive mode
	1	Master transmit mode

Note: For details, see section 16.2.5, I²C Bus Control Register (ICCR).

I²C bus interface interrupt enable

0	Interrupts disabled
1	Interrupts enabled

I²C bus interface enable

0	I ² C bus interface module disabled, with SCL and SDA signal pins set to port function SAR and SARX can be accessed
1	I ² C bus interface module enabled for transfer operations (pins SCL and SDA are driving the bus) ICMR and ICDR can be accessed

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

Sets the serial transmit/receive bit rate

Acknowledge bit	
0	Receive mode: 0 is output acknowledge output timing. Transmit mode: indicates the receiving device has acknowledged the data (S).
1	Receive mode: 1 is output acknowledge output timing. Transmit mode: indicates the receiving device has acknowledged the data (S).

General call address recognition flag	
0	General call address not recognized
1	General call address recognized

Slave address recognition flag*2	
0	Slave address or general call address not recognized
1	Slave address or general call address recognized

Arbitration lost*2	
0	Bus arbitration won
1	Arbitration lost

Second slave address recognition flag*2	
0	Second slave address not recognized
1	Second slave address recognized

I ² C bus interface continuous transmission/reception interrupt request	
0	Waiting for transfer, or transfer in progress
1	Continuous transfer state

Normal stop condition detection flag*2	
0	No normal stop condition
1	In I ² C bus format slave mode: Normal stop condition detected In other modes: No meaning

Error stop condition detection flag*2	
0	No error stop condition
1	In I ² C bus format slave mode: Error stop condition detected In other modes: No meaning

- Notes: 1. Only 0 can be written, to clear the flag.
 2. For the clearing and setting conditions, see section 16.2.6, I²C Bus Status Register (ICSR).



Clock enable 1 and 0

0	0	Asynchronous mode	Internal clock/SCK functions as I/O port
		Synchronous mode	Internal clock/SCK functions as serial
1		Asynchronous mode	Internal clock/SCK functions as clock
		Synchronous mode	Internal clock/SCK functions as serial
1	0	Asynchronous mode	External clock/SCK functions as clock
		Synchronous mode	External clock/SCK functions as serial
	1	Asynchronous mode	External clock/SCK functions as clock
		Synchronous mode	External clock/SCK functions as serial

Transmit end interrupt enable

0	Transmit-end interrupt (TEI) request disabled
1	Transmit-end interrupt (TEI) request enabled

Multiprocessor interrupt enable

0	Multiprocessor interrupts disabled (normal reception) [Clearing conditions] <ul style="list-style-type: none"> • When the MPIE bit is cleared to 0 • When data with MPB = 1 is received
1	Multiprocessor interrupts enabled Receive interrupt (RXI) requests, receive-error interrupt requests, and setting of the RDRF, FER, and OREF. SSR are disabled until data with the multiprocessor 1 is received

Transmit interrupt enable

0	Transmit-data-empty interrupt (TXI) request disabled
1	Transmit-data-empty interrupt (TXI) request enabled

Receive interrupt enable

0	Receive-data-full interrupt (RXI) request and receive-error interrupt (ERI) request disabled
1	Receive-data-full interrupt (RXI) request and receive-error interrupt (ERI) request enabled

Receive enable

0	Reception disabled
1	Reception enabled

Transmit enable

0	Transmission disabled
1	Transmission enabled

Stores serial receive data

TDR1—Transmit Data Register 1	H'FF8B
TDR2—Transmit Data Register 2	H'FFA3
TDR0—Transmit Data Register 0	H'FFDB

Bit	7	6	5	4	3	2	1
Initial value	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Stores serial transmit data

Multiprocessor bit transmitted	
0	Data with a 0 multiprocessor bit is transmitted
1	Data with a 1 multiprocessor bit is transmitted

Multiprocessor bit received	
0	[Clearing condition] When data with a 0 multiprocessor bit is received
1	[Setting condition] When data with a 1 multiprocessor bit is received

Transmit end	
0	[Clearing conditions] <ul style="list-style-type: none"> When 0 is written in TDRE after reading TDRE = 1 When the DTC is activated by a TXI interrupt and writes data to TDR
1	[Setting conditions] <ul style="list-style-type: none"> When the TE bit in SCR is 0 When TDRE = 1 at transmission of the last character or a 1-byte serial transmit character

Parity error	
0	[Clearing condition] When 0 is written in PER after reading PER = 1
1	[Setting condition] When, in reception, the number of 1 bits in the received data plus the parity bit does not match the parity (even or odd) specified by the O/E bit in SMR

Framing error	
0	[Clearing condition] When 0 is written in FER after reading FER = 1
1	[Setting condition] When the SCI checks the stop bit at the end of the receive data when reception ends, and the stop bit is 0

Overrun error	
0	[Clearing condition] When 0 is written in ORER after reading ORER = 1
1	[Setting condition] When the next serial reception is completed while RDRF = 1

Receive data register full	
0	[Clearing conditions] <ul style="list-style-type: none"> When 0 is written in RDRF after reading RDRF = 1 When the DTC is activated by an RXI interrupt and reads data from RDR
1	[Setting condition] When serial reception ends normally and receive data is transferred from RSR to RDR

Transmit data register empty

0	[Clearing conditions] <ul style="list-style-type: none"> When 0 is written in TDRE after reading TDRE = 1 When the DTC is activated by a TXI interrupt and writes data to TDR
1	[Setting conditions] <ul style="list-style-type: none"> When the TE bit in SCR is 0 When data is transferred from TDR to TSR and data can be written in TDR

Note: * Only 0 can be written, to



Serial commu
interface mod

0	Normal S
1	Setting p

Data invert

0	TDR contents are transmitted without mod Receive data is stored in RDR without mod
1	TDR contents are inverted before being tra Receive data is stored in RDR in inverted f

Data transfer direction

0	TDR contents are transmitted LSB-first Receive data is stored in RDR LSB-first
1	TDR contents are transmitted MSB-first Receive data is stored in RDR MSB-first

ICDRR

Bit	7	6	5	4	3	2	1
	ICDRR7	ICDRR6	ICDRR5	ICDRR4	ICDRR3	ICDRR2	ICDRR1
Initial value	—	—	—	—	—	—	—
Read/Write	R	R	R	R	R	R	R

ICDRS

Bit	7	6	5	4	3	2	1
	ICDRS7	ICDRS6	ICDRS5	ICDRS4	ICDRS3	ICDRS2	ICDRS1
Initial value	—	—	—	—	—	—	—
Read/Write	—	—	—	—	—	—	—

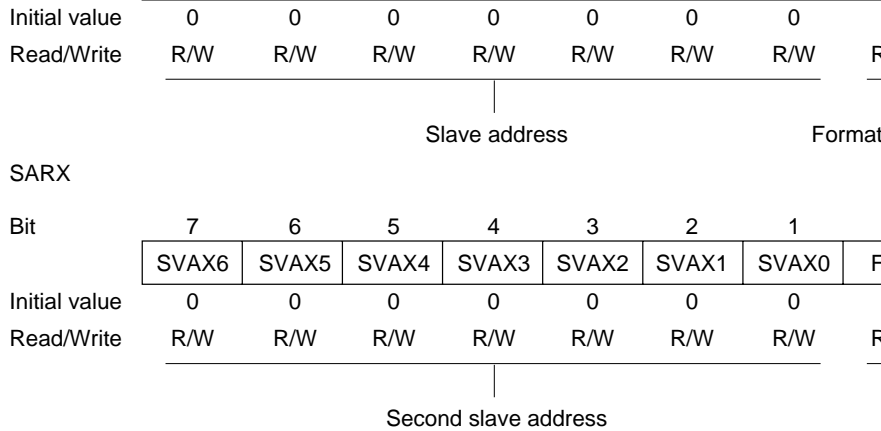
ICDRT

Bit	7	6	5	4	3	2	1
	ICDRT7	ICDRT6	ICDRT5	ICDRT4	ICDRT3	ICDRT2	ICDRT1
Initial value	—	—	—	—	—	—	—
Read/Write	W	W	W	W	W	W	W

TDRE, RDRF (internal flags)

Bit	—
	TDRE
Initial value	0
Read/Write	—

Note: For details, see section 16.2.1, I²C Bus Data Register (ICDR).



Format select

DDCSWR Bit 6	SAR Bit 0	SARX Bit 0	Operating Mode
SW	FS	FSX	
0	0	0	I ² C bus format • SAR and SARX slave addresses recognized
		1	I ² C bus format • SAR slave address recognized • SARX slave address ignored
	1	0	I ² C bus format • SAR slave address ignored • SARX slave address recognized
		1	Synchronous serial format • SAR and SARX slave addresses ignored
1	0	0	Formatless mode (start/stop conditions not detected) • Acknowledge bit used
		1	
	1	0	Formatless mode* (start/stop conditions not detected) • No acknowledge bit
		1	

Note: * Do not set this mode when automatic switching to the I²C bus format is performed by means of the DDCSWR setting.

Bit counter				
BC2	BC1	BC0	Synchronous serial format	I
0	0	0	8	
		1	1	
	1	0	2	
		1	3	
1	0	0	4	
		1	5	
	1	0	6	
		1	7	

Serial clock select

IICX	CKS2	CKS1	CKS0	Clock
0	0	0	0	$\phi/28$
			1	$\phi/40$
		1	0	$\phi/48$
			1	$\phi/64$
	1	0	0	$\phi/80$
			1	$\phi/100$
		1	0	$\phi/112$
			1	$\phi/128$
1	0	0	0	$\phi/56$
			1	$\phi/80$
		1	0	$\phi/96$
			1	$\phi/128$
	1	0	0	$\phi/160$
			1	$\phi/200$
		1	0	$\phi/224$
			1	$\phi/256$

Wait insertion bit

0	Data and acknowledge bits transferred consecutively
1	Wait inserted between data and acknowledge bits

MSB-first/LSB-first select*

0	MSB-first
1	LSB-first

Note: * Do not set this bit to 1 when the I²C bus format is used.

0	Timer overflow interrupt request (FOVI) is disabled
1	Timer overflow interrupt request (FOVI) is enabled

Output compare interrupt B enable

0	Output compare interrupt request B (OCIB) is disabled
1	Output compare interrupt request B (OCIB) is enabled

Output compare interrupt A enable

0	Output compare interrupt request A (OCIA) is disabled
1	Output compare interrupt request A (OCIA) is enabled

Input capture interrupt D enable

0	Input capture interrupt request D (ICID) is disabled
1	Input capture interrupt request D (ICID) is enabled

Input capture interrupt C enable

0	Input capture interrupt request C (ICIC) is disabled
1	Input capture interrupt request C (ICIC) is enabled

Input capture interrupt B enable

0	Input capture interrupt request B (ICIB) is disabled
1	Input capture interrupt request B (ICIB) is enabled

Input capture interrupt A enable

0	Input capture interrupt request A (ICIA) is disabled
1	Input capture interrupt request A (ICIA) is enabled

	disab
1	FRC i comp

Timer overflow flag

0	[Clearing condition] Read OVF when OVF = 1, then write 0 in OVF
1	[Setting condition] When FRC changes from H'FFFF to H'0000

Output compare flag B

0	[Clearing condition] Read OCFB when OCFB = 1, then write 0 in OCFB
1	[Setting condition] When FRC = OCRB

Output compare flag A

0	[Clearing condition] Read OCFA when OCFA = 1, then write 0 in OCFA
1	[Setting condition] When FRC = OCRA

Input capture flag D

0	[Clearing condition] Read ICFD when ICFD = 1, then write 0 in ICFD
1	[Setting condition] When an input capture signal is received

Input capture flag C

0	[Clearing condition] Read ICFC when ICFC = 1, then write 0 in ICFC
1	[Setting condition] When an input capture signal is received

Input capture flag B

0	[Clearing condition] Read ICFB when ICFB = 1, then write 0 in ICFB
1	[Setting condition] When an input capture signal causes the FRC value to be transferred to ICRB

Input capture flag A

0	[Clearing condition] Read ICFA when ICFA = 1, then write 0 in ICFA
1	[Setting condition] When an input capture signal causes the FRC value to be transferred to ICRA

Note: * Only 0 can be written in bits 7 to 1, to clear the flags.

OCRA/OCRB—Output Compare Register A/B**H'FF94**

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2
Initial value	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Constantly compared with FRC value; OCF is set when OCR = FR

0	0	$\phi/2$ internal clock
	1	$\phi/8$ internal clock
1	0	$\phi/32$ internal clock
	1	External clock source (rising edge)

Buffer enable B

0	ICRD is not used as a buffer register for input capture
1	ICRD is used as a buffer register for input capture

Buffer enable A

0	ICRC is not used as a buffer register for input capture A
1	ICRC is used as a buffer register for input capture A

Input edge select D

0	Capture on the falling edge of FTID
1	Capture on the rising edge of FTID

Input edge select C

0	Capture on the falling edge of FTIC
1	Capture on the rising edge of FTIC

Input edge select B

0	Capture on the falling edge of FTIB
1	Capture on the rising edge of FTIB

Input edge select A

0	Capture on the falling edge of FTIA
1	Capture on the rising edge of FTIA

0	0 output at compare match B
1	1 output at compare match B

Output level A

0	0 output at compare match A
1	1 output at compare match A

Output enable B

0	Output compare B output disabled
1	Output compare B output enabled

Output enable A

0	Output compare A output disabled
1	Output compare A output enabled

Output compare register select

0	OCRA register selected
1	OCRB register selected

Input capture register select

0	ICRA, ICRB, and ICRC registers selected
1	OCRAR, OCRAF, and OCRDM registers selected

Output compare A mode select

0	OCRA set to normal operating mode
1	OCRA set to operating mode using OCRAR and OCRAF

Input capture D mode select

0	ICRD set to normal operating mode
1	ICRD set to operating mode using OCRDM

Used for OCRA operation when OCRAMS = 1 in TOCR
 (For details, see section 11.2.4, Output Compare Register
 AR and AF (OCRAR, OCRAF).)

OCRDM—Output Compare Register DM **H'FF9C**

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2
Initial value	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Read/Write	R	R	R	R	R	R	R	R	R/W	R/W	R/W	R/W	R/W	R/W

Used for ICRD operation when ICRDMS = 1 in TOCR
 (For details, see section 11.2.5, Output Compare Register
 DM (OCRDM).)

ICRA—Input Capture Register A **H'FF98**
ICRB—Input Capture Register B **H'FF9A**
ICRC—Input Capture Register C **H'FF9C**
ICRD—Input Capture Register D **H'FF9E**

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2
Initial value	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Read/Write	R	R	R	R	R	R	R	R	R	R	R	R	R	R

Stores FRC value when input capture signal is input
 (ICRC and ICRD can be used for buffer operation.
 For details, see section 11.2.3, Input Capture Register
 A to D (ICRA to ICRD).)

DADRA	DA13	DA12	DA11	DA10	DA9	DA8	DA7	DA6	DA5	DA4	DA3	DA2	DA1	DA0	CF
Initial value	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

DADRB	DA13	DA12	DA11	DA10	DA9	DA8	DA7	DA6	DA5	DA4	DA3	DA2	DA1	DA0	CF
Initial value	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Register select (DADRB only) —

0	DADRA and DADRB can be a
1	DACR and DACNT can be ac

Carrier frequency select

0	Base cycle = resolution (T) × 64 DADR is H'0401 to H'FFFD
1	Base cycle = resolution (T) × 256 DADR is H'0103 to H'FFFF

D/A conversion data

Clock select

0	Operates at resolution of system clock cycle time
1	Operates at resolution of system clock cycle time

Output select

0	Direct PWM output
1	Inverted PWM output

Output enable A

0	PWM (D/A) channel A output (PWX0 output pin) disabled
1	PWM (D/A) channel A output (PWX0 output pin) enabled

Output enable B

0	PWM (D/A) channel B output (PWX1 output pin) disabled
1	PWM (D/A) channel B output (PWX1 output pin) enabled

PWM enable

0	DACNT operates as a 14-bit up-counter
1	DACNT halts at H'0003

Test mode

0	PWM (D/A) in user state: normal operation
1	PWM (D/A) in test state: correct conversion results unobtainable

Initial value 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 Read/Write R/W R/W R/W R/W R/W R/W R/W R/W R/W R/W R/W R/W R/W R/W R/W

Register select _____

0	DADRA and DADR B can be a
1	DACR and DACNT can be ac

Up-counter



0	0	0	φ/2
		1	φ/64
	1	0	φ/128
1		φ/512	
1	0	0	φ/2048
		1	φ/8192
	1	0	φ/32768
		1	φ/131072

Reset or NMI

0	NMI interrupt requested
1	Internal reset requested

Reserved bit

Timer enable

0	TCNT is initialized to H'00 and halted
1	TCNT counts

Timer mode select

0	Interval timer mode: Sends the CPU an interval timer interrupt request (WOVI) when TCNT overflows
1	Watchdog timer mode: Generates a reset or NMI interrupt when TCNT overflows

Overflow flag

0	<p>[Clearing conditions]</p> <ul style="list-style-type: none"> Write 0 in the TME bit Read TCSR when OVF = 1*, then write 0 in OVF
1	<p>[Setting condition]</p> <p>When TCNT overflows (changes from H'FF to H'00) (When internal reset request generation is selected in watchdog timer mode, OVF is cleared automatically by the internal reset.)</p>

Note: * When OVF is polled and the interval timer interrupt is disabled, OVF = 1 must be read at least twice.

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

PAODR—Port A Output Data Register**H'FFAA**

Bit	7	6	5	4	3	2	1
	PA7ODR	PA6ODR	PA5ODR	PA4ODR	PA3ODR	PA2ODR	PA1ODR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Output data for port A pins

PAPIN—Port A Input Data Register**H'FFAB (R)**

Bit	7	6	5	4	3	2	1
	PA7PIN	PA6PIN	PA5PIN	PA4PIN	PA3PIN	PA2PIN	PA1PIN
Initial value	—*	—*	—*	—*	—*	—*	—*
Read/Write	R	R	R	R	R	R	R

Port A pin states

Note: * Determined by state of pins PA7 to PA0.

PADDR—Port A Data Direction Register**H'FFAB (W)**

Bit	7	6	5	4	3	2	1
	PA7DDR	PA6DDR	PA5DDR	PA4DDR	PA3DDR	PA2DDR	PA1DDR
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

Specification of input or output for port A pins

P2PCR—Port 2 MOS Pull-Up Control Register**H'FFAD**

Bit	7	6	5	4	3	2	1
	P27PCR	P26PCR	P25PCR	P24PCR	P23PCR	P22PCR	P21PCR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Control of port 2 built-in MOS input pull-ups

P3PCR—Port 3 MOS Pull-Up Control Register**H'FFAE**

Bit	7	6	5	4	3	2	1
	P37PCR	P36PCR	P35PCR	P34PCR	P33PCR	P32PCR	P31PCR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Control of port 3 built-in MOS input pull-ups

P1DDR—Port 1 Data Direction Register**H'FFB0**

Bit	7	6	5	4	3	2	1
	P17DDR	P16DDR	P15DDR	P14DDR	P13DDR	P12DDR	P11DDR
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

Specification of input or output for port 1 pins

P1DR—Port 1 Data Register**H'FFB2**

Bit	7	6	5	4	3	2	1
	P17DR	P16DR	P15DR	P14DR	P13DR	P12DR	P11DR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Output data for port 1 pins

P2DR—Port 2 Data Register**H'FFB3**

Bit	7	6	5	4	3	2	1
	P27DR	P26DR	P25DR	P24DR	P23DR	P22DR	P21DR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Output data for port 2 pins

P3DDR—Port 3 Data Direction Register**H'FFB4**

Bit	7	6	5	4	3	2	1
	P37DDR	P36DDR	P35DDR	P34DDR	P33DDR	P32DDR	P31DDR
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

Specification of input or output for port 3 pins

P3DR—Port 3 Data Register**H'FFB6**

Bit	7	6	5	4	3	2	1
	P37DR	P36DR	P35DR	P34DR	P33DR	P32DR	P31DR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Output data for port 3 pins

P4DR—Port 4 Data Register**H'FFB7**

Bit	7	6	5	4	3	2	1
	P47DR	P46DR	P45DR	P44DR	P43DR	P42DR	P41DR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Output data for port 4 pins

P5DDR—Port 5 Data Direction Register**H'FFB8**

Bit	7	6	5	4	3	2	1
	—	—	—	—	—	P52DDR	P51DDR
Initial value	1	1	1	1	1	0	0
Read/Write	—	—	—	—	—	W	W

Specification of
output for port

P5DR—Port 5 Data Register**H'FFBA**

Bit	7	6	5	4	3	2	1
	—	—	—	—	—	P52DR	P51DR
Initial value	1	1	1	1	1	0	0
Read/Write	—	—	—	—	—	R/W	R/W

Output data for port 5

P6DR—Port 6 Data Register**H'FFBB**

Bit	7	6	5	4	3	2	1
	P67DR	P66DR	P65DR	P64DR	P63DR	P62DR	P61DR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Output data for port 6 pins

PBODR—Port B Output Data Register**H'FFBC**

Bit	7	6	5	4	3	2	1
	PB7ODR	PB6ODR	PB5ODR	PB4ODR	PB3ODR	PB2ODR	PB1ODR
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Output data for port B pins

PBPIN—Port B Input Data Register**H'FFBD (R)**

Bit	7	6	5	4	3	2	1
	PB7PIN	PB6PIN	PB5PIN	PB4PIN	PB3PIN	PB2PIN	PB1PIN
Initial value	—*	—*	—*	—*	—*	—*	—*
Read/Write	R	R	R	R	R	R	R

Port B pin states

Note: * Determined by state of pins PB7 to PB0.

PBDDR—Port B Data Direction Register**H'FFBE (W)**

Bit	7	6	5	4	3	2	1
	PB7DDR	PB6DDR	PB5DDR	PB4DDR	PB3DDR	PB2DDR	PB1DDR
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

Specification of input or output for port B pins

P7PIN—Port 7 Input Data Register**H'FFBE (R)**

Bit	7	6	5	4	3	2	1
	P77PIN	P76PIN	P75PIN	P74PIN	P73PIN	P72PIN	P71PIN
Initial value	—*	—*	—*	—*	—*	—*	—*
Read/Write	R	R	R	R	R	R	R

Port 7 pin states

Note: * Determined by state of pins P77 to P70.

P9DDR—Port 9 Data Direction Register**H'FFC0**

Bit	7	6	5	4	3	2	1
	P97DDR	P96DDR	P95DDR	P94DDR	P93DDR	P92DDR	P91DDR
Mode 1							
Initial value	0	1	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W
Modes 2 and 3							
Initial value	0	0	0	0	0	0	0
Read/Write	W	W	W	W	W	W	W

Specification of input or output for port 9 pins

P9DR—Port 9 Data Register**H'FFC1**

Bit	7	6	5	4	3	2	1
	P97DR	P96DR	P95DR	P94DR	P93DR	P92DR	P91DR
Initial value	0	—*	0	0	0	0	0
Read/Write	R/W	R	R/W	R/W	R/W	R/W	R/W

Output data for port 9 pins

Note: * Determined by state of pin P96.

0	IRQn interrupt disabled
1	IRQn interrupt enabled

(n = 7 to 0)

Internal Clock
Select*¹

Reserved bit

Flash memory control register enable

0	Flash memory control register not enabled
1	Flash memory control register selected

I²C master enable

0	CPU access to SCI0, SCI1, and SCI2 control registers is disabled
1	CPU access to I ² C bus interface data, PWM control registers is enabled

I²C transfer select 1 and 0*²

I²C extra buffer select

0	PA7 to PA4 are normal I/O pins
1	PA7 to PA4 are I/O pins with bus driving capability

- Notes: 1. Used for 8-bit timer input clock selection. For details, see section 12.2.4, Timer Control Register (TCR).
2. Used for I²C bus interface transfer clock selection. For details, see section 12.2.5, I²C Bus Mode Register (ICMR).

0	On-chip RAM
1	On-chip RAM

Host interface enable

0	Addresses H'(FF)FFF0 to H'(FF)FFF7 and H'(FF)FFFC to H'(FF)FFFD used for access to 8-bit timer X and Y data registers and control registers, and timer control registers
1	Addresses H'(FF)FFF0 to H'(FF)FFF7 and H'(FF)FFFC to H'(FF)FFFD used for access to host interface registers and control registers, keyboard controller and MCU pull-up control registers

NMI edge select

0	Falling edge
1	Rising edge

External reset

0	Reset generated by watchdog timer overflow
1	Reset generated by an external reset

Interrupt control mode select

INTM1	INTM0	Description
0	0	Interrupt control mode 0
	1	Interrupt control mode 1

IOS enable

0	The $\overline{AS}/\overline{IOS}$ pin functions as the address strobe pin (Low output when accessing an external area)
1	The $\overline{AS}/\overline{IOS}$ pin functions as the I/O strobe pin (Low output when accessing a specified address from H'(FF)F000 to H'(FF)FE4F)*

Note: * In the H8S/2148 F-ZTAT A-mask version and H8S/2147 F-ZTAT A-mask version, the address range is from H'(FF)F000 to H'(FF)F7FF.

CS2 enable

SYSCR Bit 7	HICR Bit 0	Description
CS2E	FGA20E	
0	0	CS2 pin function halted (CS2 fixed high internally)
	1	
1	0	CS2 pin function selected for P81/CS2 pin
	1	CS2 pin function selected for P90/ECS2 pin

Expanded mode enable

0	Single-chip mode selected
1	Expanded mode selected

Note: * Determined by the MD1 and MD0 pins.

IOS select

IOS1	IOS0	Address for which A _S output goes low when
0	0	Low in access to address H'(FF)F000 to H'(FF)F0FF
	1	Low in access to address H'(FF)F000 to H'(FF)F0FF
1	0	Low in access to address H'(FF)F000 to H'(FF)F0FF
	1	Low in access to address H'(FF)F000 to H'(FF)F0FF

Burst cycle select 0

0	Max. 4 words in burst access
1	Max. 8 words in burst access

Burst cycle select 1

0	Burst cycle comprises 1 state
1	Burst cycle comprises 2 states

Burst ROM enable

0	Basic bus interface
1	Burst ROM interface

Reserved bit

Idle cycle insert 0

0	Idle cycle not inserted in case of successive external read and external write cycles
1	Idle cycle inserted in case of successive external read and external write cycles

Reserved bits

0	0	No program wa states are ins
	1	1 program wa is inserted in memory spa accesses
1	0	2 program wa are inserted i memory spa accesses
	1	3 program wa are inserted i memory spa accesses

Wait mode select 1 and 0

0	0	Program wait mode
	1	Wait disabled mode
1	0	Pin wait mode
	1	Pin auto-wait mode

Access state control

0	External memory space is designated as access space Wait state insertion in external memory sp accesses is disabled
1	External memory space is designated as access space Wait state insertion in external memory sp accesses is enabled

Bus width control

0	External memory space designated as 16-bit access s
1	External memory space designated as 8-bit access sp

Channel	Clock select 2 to 0			Description
	Bit 2 CKS2	Bit 1 CKS1	Bit 0 CKS0	
0	0	0	0	Clock input disabled
			1*	Internal clock: counting at falling edge
	1	0	0*	Internal clock: counting at falling edge
			1*	Internal clock: counting at falling edge
	1	0	0	Counting at TCNT1 overflow signal
			1	Count at TCNT0 compare match signal
1	0	0	0	Clock input disabled
			1*	Internal clock: counting at falling edge
	1	0	0*	Internal clock: counting at falling edge
			1*	Internal clock: counting at falling edge
	1	0	0	Count at TCNT0 compare match signal
			1	Count at TCNT0 compare match signal
X	0	0	0	Clock input disabled
			1	Internal clock: counting on ϕ
	1	0	0	Internal clock: counting at falling edge
			1	Internal clock: counting at falling edge
1	0	0	Clock input disabled	
		1	Clock input disabled	
Y	0	0	0	Clock input disabled
			1	Internal clock: counting at falling edge
	1	0	0	Internal clock: counting at falling edge
			1	Internal clock: counting at falling edge
1	0	0	Clock input disabled	
		1	Clock input disabled	
All	1	0	1	External clock: counting at rising edge
			0	External clock: counting at falling edge
	1	1	External clock: counting at both edges	

Counter clear 1 and 0	
0	0 Clear is disabled
0	1 Cleared on compare match A
1	0 Cleared on compare match B
1	1 Cleared on rising edge of external reset input

Timer overflow interrupt enable	
0	OVF interrupt request (OVI) is disabled
1	OVF interrupt request (OVI) is enabled

Compare match interrupt enable A	
0	CMFA interrupt request (CMIA) is disabled
1	CMFA interrupt request (CMIA) is enabled

Compare Match Interrupt Enable B	
0	CMFB interrupt request (CMIB) is disabled
1	CMFB interrupt request (CMIB) is enabled

- Notes: 1. Selected by ICKS1 and ICKS0 in STCR. For details, see the Timer Control Register (TCR).
2. If the clock input of channel 0 is the TCNT1 overflow signal, channel 1 is the TCNT0 compare match signal, no interrupt is generated. Do not use this setting.

Output select 1 and 0

0	0	No change at compare match A (toggle output)
	1	0 output at compare match A (toggle output)
1	0	1 output at compare match A (toggle output)
	1	Output inverted at compare match A (toggle output)

Output select 3 and 2

0	0	No change at compare match B
	1	0 output at compare match B
1	0	1 output at compare match B
	1	Output inverted at compare match B (toggle output)

A/D trigger enable

0	A/D converter start requests by compare match A and B are disabled
1	A/D converter start requests by compare match A and B are enabled

Timer overflow flag

0	[Clearing condition] Read OVF when OVF = 1, then write 0 in OVF
1	[Setting condition] When TCNT overflows from H'FF to H'00

Compare match flag A

0	[Clearing conditions] <ul style="list-style-type: none"> Read CMFA when CMFA = 1, then write 0 in CMFA When the DTC is activated by a CMIA interrupt
1	[Setting condition] When TCNT = TCORA

Compare match flag B

0	[Clearing conditions] <ul style="list-style-type: none"> Read CMFB when CMFB = 1, then write 0 in CMFB When the DTC is activated by a CMIB interrupt
1	[Setting condition] When TCNT = TCORB

Note: * Only 0 can be written in bits 7 to 5, to clear the flags.

Output select 1 and 0

0	0	No change at compare match A (toggle output)
	1	0 output at compare match A (toggle output)
1	0	1 output at compare match A (toggle output)
	1	Output inverted at compare match A (toggle output)

Output select 3 and 2

0	0	No change at compare match B (toggle output)
	1	0 output at compare match B (toggle output)
1	0	1 output at compare match B (toggle output)
	1	Output inverted at compare match B (toggle output)

Timer overflow flag

0	[Clearing condition] Read OVF when OVF = 1, then write 0 in OVF
1	[Setting condition] When TCNT overflows from H'FF to H'00

Compare match flag A

0	[Clearing conditions] <ul style="list-style-type: none"> Read CMFA when CMFA = 1, then write 0 in CMFA When the DTC is activated by a CMIA interrupt
1	[Setting condition] When TCNT = TCORA

Compare match flag B

0	[Clearing conditions] <ul style="list-style-type: none"> Read CMFB when CMFB = 1, then write 0 in CMFB When the DTC is activated by a CMIB interrupt
1	[Setting condition] When TCNT = TCORB

Note: * Only 0 can be written in bits 7 to 5, to clear the flags.

Bit	TCORA0 TCORB0								TCORA1 TCORB1					
	15	14	13	12	11	10	9	8	7	6	5	4	3	2
Initial value	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Compare match flag (CMF) is set when TCOR and TCNT values ma

TCORAX, TCORAY TCORBx, TCORBy

Bit	7	6	5	4	3	2	1	0
Initial value	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Compare match flag (CMF) is set when TCOR and TCNT values match

TCORC

Bit	7	6	5	4	3	2	1	0
Initial value	1	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Compare match C signal is generated when sum of TCORC and TICP contents match TCNT value

Initial value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Up-counter

TCNTX, TCNTY

Bit	7	6	5	4	3	2	1	0
Initial value	0	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Up-counter

PWOERB	OE15	OE14	OE13	OE12	OE11	OE10	OE9
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Switching between PWM output and port output

DDR	OE	Description
0	0	Port input
	1	Port input
1	0	Port output or PWM 256/256 outp
	1	PWM output (0 to 255/256 outp

PWDPRA—PWM Data Polarity Register A

H'FFD5

PWDPRB—PWM Data Polarity Register B

H'FFD4

Bit	7	6	5	4	3	2	1
PWDPRA	OS7	OS6	OS5	OS4	OS3	OS2	OS1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Bit	7	6	5	4	3	2	1
PWDPRB	OS15	OS14	OS13	OS12	OS11	OS10	OS9
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

PWM output polarity control

0	PWM direct output (PWDR value corresponds to high width of c
1	PWM inverted output (PWDR value corresponds to low width of

0	0	0	0	PWDR0 sel
			1	PWDR1 sel
		1	0	PWDR2 sel
	1	0	0	PWDR3 sel
			1	PWDR4 sel
		1	0	PWDR5 sel
	1	0	0	PWDR6 sel
			1	PWDR7 sel
		1	0	PWDR8 sel
	1	0	0	PWDR9 sel
			1	PWDR10 sel
		1	0	PWDR11 sel
	1	0	0	PWDR12 sel
			1	PWDR13 sel
		1	0	PWDR14 sel
1	1	PWDR15 sel		

PWM clock enable, PWM clock select

PWSL		PCSR		Description
Bit 7	Bit 6	Bit 2	Bit 1	
PWCKE	PWCKS	PWCKB	PWCKA	
0	—	—	—	Clock input disabled
1	0	—	—	ϕ (system clock) selected
			1	$\phi/2$ selected
	1	0	0	$\phi/4$ selected
			1	$\phi/8$ selected
			1	$\phi/16$ selected

ADDRAH —A/D Data Register AH	H'FFE0	A/D
ADDRAL —A/D Data Register AL	H'FFE1	A/D
ADDRBH —A/D Data Register BH	H'FFE2	A/D
ADDRBL —A/D Data Register BL	H'FFE3	A/D
ADDRCH —A/D Data Register CH	H'FFE4	A/D
ADDRCL —A/D Data Register CL	H'FFE5	A/D
ADDRDH —A/D Data Register DH	H'FFE6	A/D
ADDRDL —A/D Data Register DL	H'FFE7	A/D



Correspondence between analog input channels and ADDR registers

Analog Input Channel		A/D Data Register
Group 0	Group 1	
AN0	AN4	ADDRA
AN1	AN5	ADDRB
AN2	AN6 or CIN0 to CIN7	ADDRC
AN3	AN7 or CIN8 to CIN15	ADDRD

Group selection		Channel selection		Description	
CH2	CH1	CH0	Single mode	Scan	
0	0	0	AN0	AN0	
		1	AN1	AN0, AN1	
	1	0	AN2	AN0, AN1, AN2	
		1	AN3	AN0, AN1, AN2, AN3	
1	0	0	AN4	AN4	
		1	AN5	AN4, AN5	
	1	0	AN6 or CIN0 to 7	AN4, AN5, AN6 or CIN0 to 7	
		1	AN7 or CIN8 to 15	AN4, AN5, AN6 or CIN0 to 7, AN7 or CIN8 to 15	

Clock select

0	Conversion time = 266 states (max.)
1	Conversion time = 134 states (max.)

Scan mode

0	Single mode
1	Scan mode

A/D start

0	A/D conversion stopped
1	<ul style="list-style-type: none"> Single mode: A/D conversion is started. Cleared to 0 automatically when conversion on the specified channel ends Scan mode: A/D conversion is started. Conversion continues sequentially on the selected channels until ADST is cleared to 0 by software, a reset, or a transition to standby mode or module stop mode

A/D interrupt enable

0	A/D conversion end interrupt (ADI) request disabled
1	A/D conversion end interrupt (ADI) request enabled

A/D end flag

0	<p>[Clearing conditions]</p> <ul style="list-style-type: none"> When 0 is written in the to ADF flag after reading ADF = 1 When the DTC is activated by an ADI interrupt, and ADDR is read
1	<p>[Setting conditions]</p> <ul style="list-style-type: none"> Single mode: When A/D conversion ends Scan mode: When A/D conversion ends on all specified channels

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

Timer trigger select

0	0	Start of A/D conversion by external trigger is disabled
	1	Start of A/D conversion by external trigger is disabled
1	0	Start of A/D conversion by external trigger (8-bit timer) is enabled
	1	Start of A/D conversion by external trigger pin is enabled

0	0	0	0
		1	0
			1
	1	0	0
			1
		1	0
			1
1	0	0	0
			1
		1	0
			1
	1	0	0
			1
		1	0
			1

Reset or NMI

0	NMI interrupt requested
1	Internal reset requested

Prescaler select*2

0	TCNT counts on a ϕ -based prescaler (PSM) scaled clock
1	TCNT counts on a ϕ SUB-based prescaler (PSS) scaled clock

Timer enable

0	TCNT is initialized to H'00 and halted
1	TCNT counts

Timer mode select

0	Interval timer mode: Interval timer interrupt request (WOVI) sent to CPU when TCNT overflows
1	Watchdog timer mode: Reset or NMI interrupt request sent to CPU when TCNT overflows

Overflow flag

0	[Clearing conditions] • Write 0 in the TME bit • Read TCSR when OVF = 1*, then write 0 in OVF
1	[Setting condition] When TCNT overflows (changes from H'FF to H'00) (When internal reset request generation is selected in watchdog timer mode, OVF is cleared automatically by the internal reset.)

Note: * When OVF is polled and the interval timer interrupt is disabled, OVF = 1 must be read at least twice.

- Notes: 1. Only 0 can be written, to clear the flag.
2. For operation control when a transition is made to power-down mode, see section 25.2.3, Timer Control/Status Register

Fast gate A20 enable

0	Fast gate A20 function disabled
1	Fast gate A20 function enabled

Input data register full interrupt enable 1

0	Input data register (IDR1) receive complete interrupt is disabled
1	Input data register (IDR1) receive complete interrupt is enabled

Input data register full interrupt enable 2

0	Input data register (IDR2) receive complete interrupt is disabled
1	Input data register (IDR2) receive complete interrupt is enabled

0	0	No change at compare
	1	0 output at compare
1	0	1 output at compare
	1	Output inverted at compare match A (toggle output)

Output select 3 and 2

0	0	No change at compare match
	1	0 output at compare match B
1	0	1 output at compare match B
	1	Output inverted at compare match B (toggle output)

Input capture flag

0	[Clearing condition] When 0 is written in ICF after reading ICF = 1
1	[Setting condition] When a rising edge followed by a falling edge detected in the external reset signal after the ICST bit in TCONRI has been set to 1

Timer overflow flag

0	[Clearing condition] When 0 is written in OVF after reading OVF = 1
1	[Setting condition] When TCNT overflows from H'FF to H'00

Compare match flag A

0	[Clearing conditions] <ul style="list-style-type: none"> When 0 is written in CMFA after reading CMFA = 1 When the DTC is activated by a CMIA interrupt
1	[Setting condition] When TCNT = TCORA

Compare match flag B

0	[Clearing conditions] <ul style="list-style-type: none"> When 0 is written in CMFB after reading CMFB = 1 When the DTC is activated by a CMIB interrupt
1	[Setting condition] When TCNT = TCORB

Note: * Only 0 can be written in bits 7 to 4, to clear the flags.

Output select 1 and 0

0	0	No change at compare
	1	0 output at compare m
1	0	1 output at compare m
	1	Output inverted at com match A (toggle output

Output select 3 and 2

0	0	No change at compare match
	1	0 output at compare match B
1	0	1 output at compare match B
	1	Output inverted at compare match B (toggle output)

Input capture interrupt enable

0	Interrupt request by ICF (ICIX) is disabled
1	Interrupt request by ICF (ICIX) is enabled

Timer overflow flag

0	[Clearing condition] When 0 is written in OVF after reading OVF = 1
1	[Setting condition] When TCNT overflows from H'FF to H'00

Compare match flag A

0	[Clearing conditions] <ul style="list-style-type: none"> When 0 is written in CMFA after reading CMFA = 1 When the DTC is activated by a CMIA interrupt
1	[Setting condition] When TCNT = TCORA

Compare match flag B

0	[Clearing conditions] <ul style="list-style-type: none"> When 0 is written in CMFB after reading CMFB = 1 When the DTC is activated by a CMIB interrupt
1	[Setting condition] When TCNT = TCORB

Note: * Only 0 can be written in bits 7 to 5, to clear the flags.

Keyboard matrix interrupt mask

0	Key-sense input interrupt requests enabled
1	Key-sense input interrupt requests disabled

KMIMRA

Bit	7	6	5	4	3	2	1
	KMIMR15	KMIMR14	KMIMR13	KMIMR12	KMIMR11	KMIMR10	KMIMR9
Initial value	1	1	1	1	1	1	1
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Keyboard matrix interrupt mask

0	Key-sense input interrupt requests enabled
1	Key-sense input interrupt requests disabled

TICRR—Input Capture Register R

H'FFF2

TICRF—Input Capture Register F

H'FFF3

Bit	7	6	5	4	3	2	1
Initial value	0	0	0	0	0	0	0
Read/Write	R	R	R	R	R	R	R

Stores TCNT value at fall of external reset input

Note: KMPCR has the same address as TICRR/TCORAY of TMRX/TMRY.
When selecting KMPCR, set the HIE bit to 1 in SYSCR.

IDR1—Input Data Register 1
IDR2—Input Data Register 2

H'FFF4
H'FFFC

Bit	7	6	5	4	3	2	1
	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1
Initial value	—	—	—	—	—	—	—
Slave R/W	R	R	R	R	R	R	R
Host R/W	W	W	W	W	W	W	W

Stores host data bus contents at rise of \overline{IOW} when \overline{CS} is low

ODR1—Output Data Register 1
ODR2—Output Data Register 2

H'FFF5
H'FFFD

Bit	7	6	5	4	3	2	1
	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1
Initial value	—	—	—	—	—	—	—
Slave R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Host R/W	R	R	R	R	R	R	R

ODR contents are output to the host data bus when HA0 is low, \overline{CS} is low, and \overline{IOR} is low

0	IVG signal is selected (H8S/2148 Group) External clock/reset input is disabled (H8S/2148 Group) H8S/2147N)
1	VSYNCl/TMIY (TMCiY/TMRIY) is selected

User-defined bits

Output buffer full

0	[Clearing condition] When the host processor reads ODR
1	[Setting condition] When the slave processor writes to ODR

Input buffer full

0	[Clearing condition] When the slave processor reads ODR
1	[Setting condition] When the host processor writes to ODR

Command/data

0	Contents of input data register (IDR) are data
1	Contents of input data register (IDR) are command

DADR0—D/A Data Register 0

H'FFF8

D/A

DADR1—D/A Data Register 1

H'FFF9

D/A

Bit	7	6	5	4	3	2	1
Initial value	0	0	0	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Stores data for D/A conversion

DAOE1	DAOE0	DAE	Conversion result
0	0	*	Channel 0 and 1 D/A conversion
	1	0	Channel 0 D/A conversion ena Channel 1 D/A conversion dis
		1	Channel 0 and 1 D/A conversi
1	0	0	Channel 0 D/A conversion disa Channel 1 D/A conversion ena
		1	Channel 0 and 1 D/A conversi
	1	*	Channel 0 and 1 D/A conversi

Legend: *: Don't care

D/A output enable 0

0	Analog output DA0 disabled
1	D/A conversion is enabled on channel 0. Analog output DA0 is enabled

D/A output enable 1

0	Analog output DA1 disabled
1	D/A conversion is enabled on channel 1. Analog output DA1 is enabled

	is used directly as the VSYNCl
1	The VSYNCl is inverted before use as the VSYNCl

Input synchronization signal inversion

0	The HSYNCl and CSYNCl pin states are used directly as the HSYNCl and CSYNCl inputs
1	The HSYNCl and CSYNCl pin states are inverted before use as the HSYNCl and CSYNCl inputs

Input synchronization signal inversion

0	The VFBACKI pin state is used directly as the VFBACKI input
1	The VFBACKI pin state is inverted before use as the VFBACKI input

Input synchronization signal inversion

0	The HFBACKI pin state is used directly as the HFBACKI input
1	The HFBACKI pin state is inverted before use as the HFBACKI input

Input capture start bit

0	The TICRR and TICRF input capture functions are stopped [Clearing condition] When a rising edge followed by a falling edge is detected on TMR1X
1	The TICRR and TICRF input capture functions are operating (Waiting for detection of a rising edge followed by a falling edge on TMR1X) [Setting condition] When 1 is written in ICST after reading ICST = 0

Synchronization signal connection enable

SCONE	Mode	FTIA	FTIB	FTIC	FTID	TMCI1
0	Normal connection	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

Input synchronization mode select 1 and 0

SIMOD1	SIMOD0	Mode	IHI signal	IVI signal
0	0	No signal	HFBACKI input	VFBACKI input
	1	S-on-G mode	CSYNCl input	PDC input
1	0	Composite mode	HSYNCl input	PDC input
	1	Separate mode	HSYNCl input	VSYNCl input

0	The CBLANK signal is used directly as the CBLANK output
1	The CBLANK signal is inverted before use as the CBLANK output

Output synchronization signal inversion

0	The CLO signal (CL1 or CL4 signal) is used directly as the CLAMPO output
1	The CLO signal (CL1 or CL4 signal) is inverted before use as the CLAMPO output

Output synchronization signal inversion

0	The IVO signal is used directly as the VSYNCO output
1	The IVO signal is inverted before use as the VSYNCO output

Output synchronization signal inversion

0	The IHO signal is used directly as the HSYNCO output
1	The IHO signal is inverted before use as the HSYNCO output

Output enable

0	The P27/A15/PW15/CBLANK pin functions as the P27/A15 pin
1	In mode 1 (expanded mode with on-chip ROM disabled): The P27/A15/PW15/CBLANK pin functions as the A15 pin In modes 2 and 3 (expanded modes with on-chip ROM enabled): The P27/A15/PW15/CBLANK pin functions as the CBLANK pin

Output enable

0	The P64/FTIC/KIN4/CIN4/CLAMPO pin functions as the P64/FTIC/KIN4 pin
1	The P64/FTIC/KIN4/CIN4/CLAMPO pin functions as the CLAMPO pin

Output enable

0	The P61/FTOA/KIN1/CIN1/VSYNCO pin functions as the P61/FTOA/KIN1/CIN1 pin
1	The P61/FTOA/KIN1/CIN1/VSYNCO pin functions as the VSYNCO pin

Output enable

0	The P44/TMO1/HIRQ1/HSYNCO pin functions as the P44/TMO1/HIRQ1 pin
1	The P44/TMO1/HIRQ1/HSYNCO pin functions as the HSYNCO pin



0	0	0	The CL1 signal is selected
		1	The CL2 signal is selected
		0	The CL3 signal is selected
1	0	0	The CL4 signal is selected
		1	
	1	0	
		1	

Vertical synchronization output mode select 1 and 0

ISGENE	VOMOD1	VOMOD0	Description
0	0	0	The IVI signal (without fall modification or IHI synchronization) is selected
		1	The IVI signal (without fall modification with IHI synchronization) is selected
	1	0	The IVI signal (with fall modification without IHI synchronization) is selected
		1	The IVI signal (with fall modification and IHI synchronization) is selected
1	0	0	The IVG signal is selected
		1	
	1	0	
		1	

Horizontal synchronization output mode select 1 and 0

ISGENE	HOMOD1	HOMOD0	Description
0	0	0	The IHI signal (without 2fH modification) is selected
		1	The IHI signal (with 2fH modification) is selected
	1	0	The CL1 signal is selected
		1	
1	0	0	The IHG signal is selected
		1	
	1	0	
		1	

Internal synchronization signal select

TMRX/TMRY access select

0	The TMRX registers are accessed at addresses H'FFF0 to H'FFF5
1	The TMRY registers are accessed at addresses H'FFF0 to H'FFF5

1 The IHI signal is

IHI signal level

0	The IHI signal is
1	The IHI signal is

Pre-equalization flag

0	[Clearing condition] When 0 is written in PRE reading PREQF = 1
1	[Setting condition] When an IHI signal 2fH r condition is detected

VFBACKI edge

0	[Clearing condition] When 0 is written in VFEDG after reading
1	[Setting condition] When a rising edge is detected on the VF

HFBACKI edge

0	[Clearing condition] When 0 is written in HFEDG after reading HFED
1	[Setting condition] When a rising edge is detected on the HFBACK

CSYNCI edge

0	[Clearing condition] When 0 is written in CEDG after reading CEDG = 1
1	[Setting condition] When a rising edge is detected on the CSYNCI pin

HSYNCI edge

0	[Clearing condition] When 0 is written in HEDG after reading HEDG = 1
1	[Setting condition] When a rising edge is detected on the HSYNCI pin

VSYNCI edge

0	[Clearing condition] When 0 is written in VEDG after reading VEDG = 1
1	[Setting condition] When a rising edge is detected on the VSYNCI pin

- Notes: 1. Only 0 can be written, to clear the flags.
2. The initial value is undefined since it depends on the pin states.

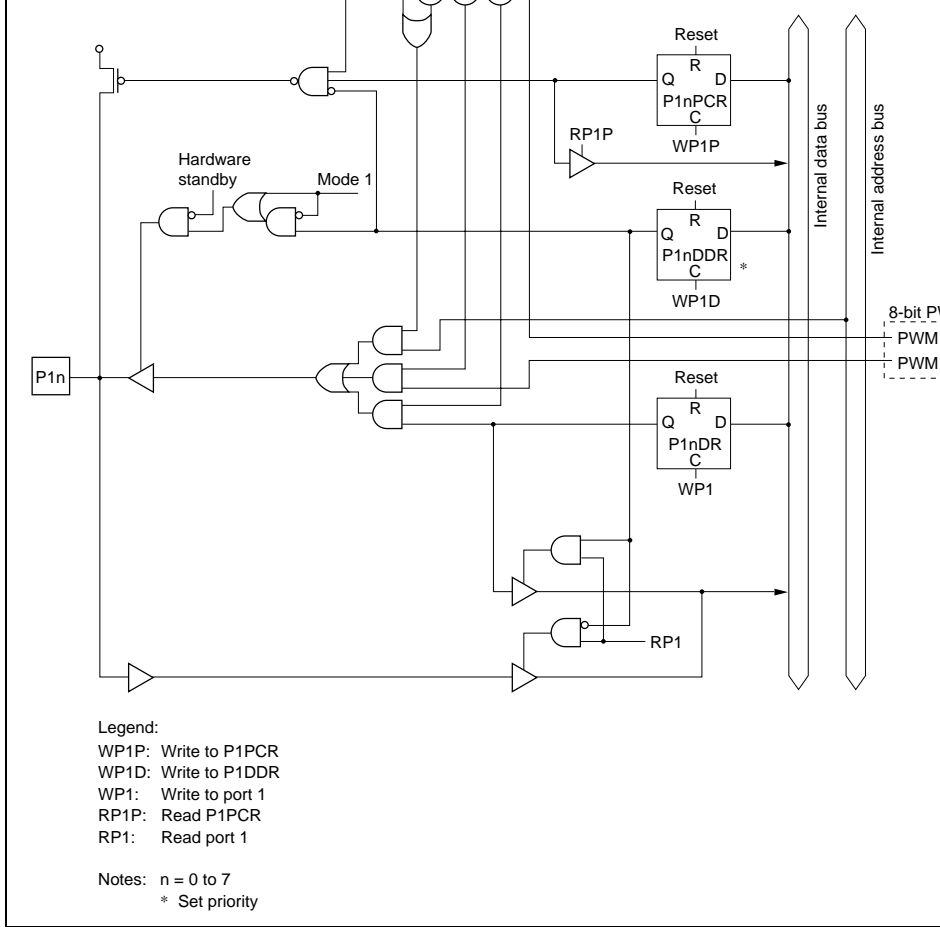


Figure C.1 Port 1 Block Diagram

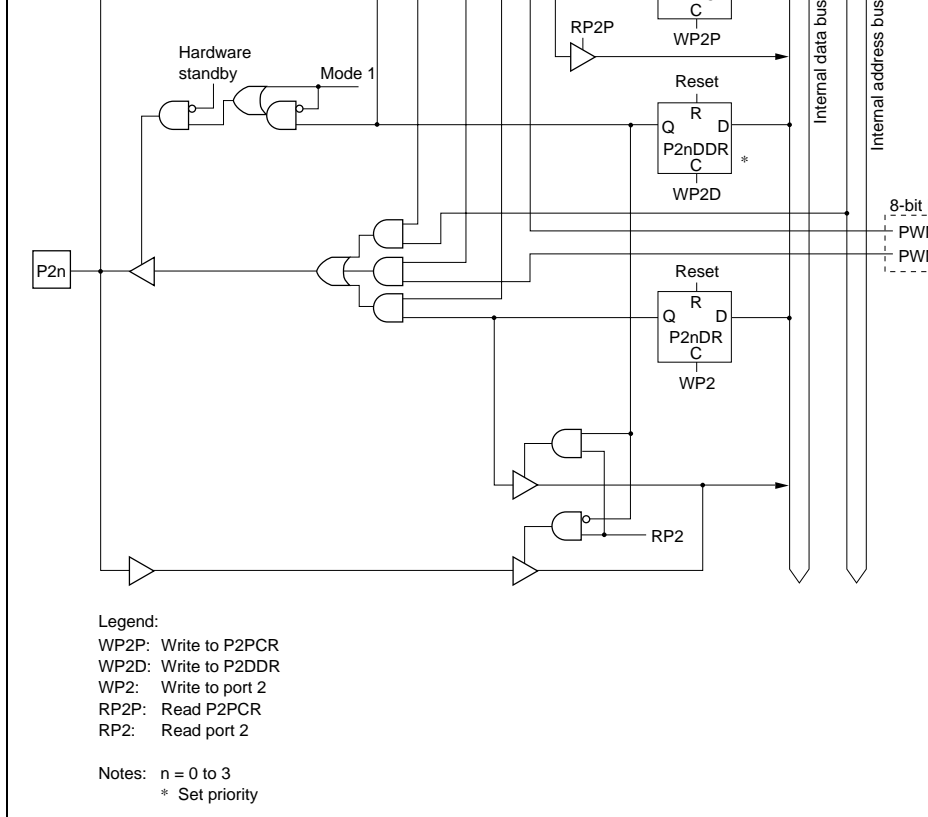


Figure C.2 Port 2 Block Diagram (Pins P20 to P23)

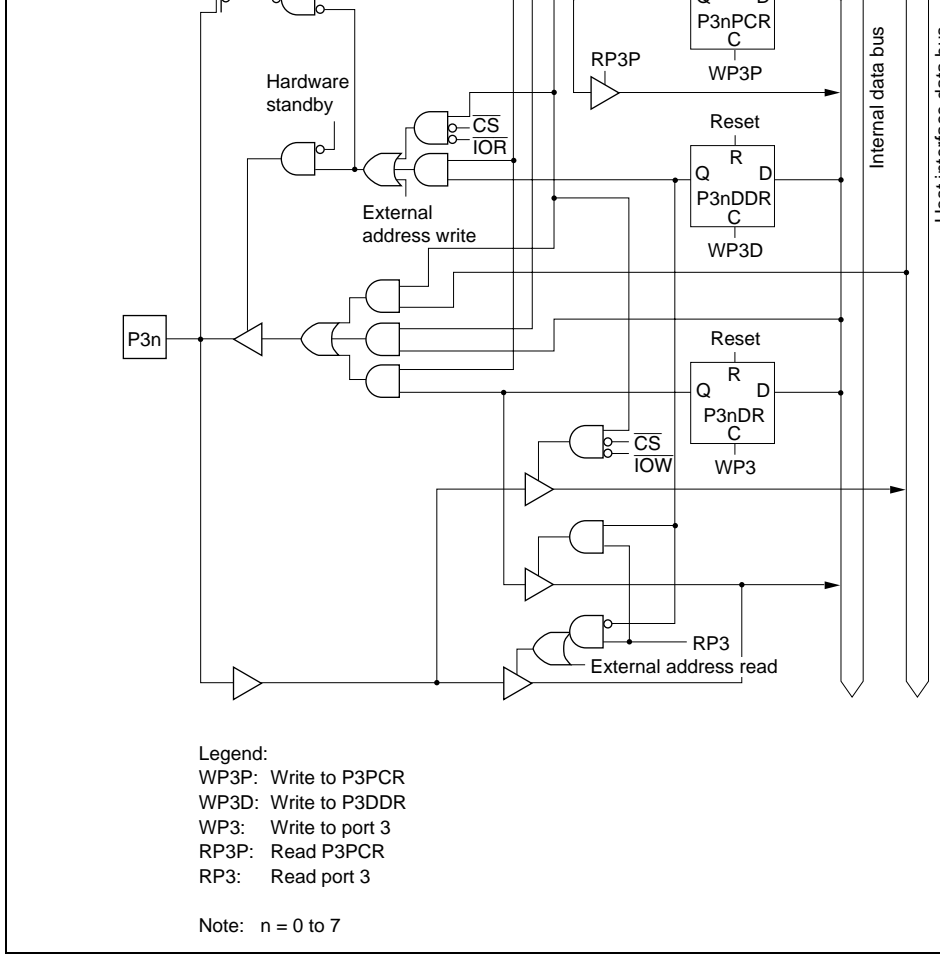


Figure C.5 Port 3 Block Diagram

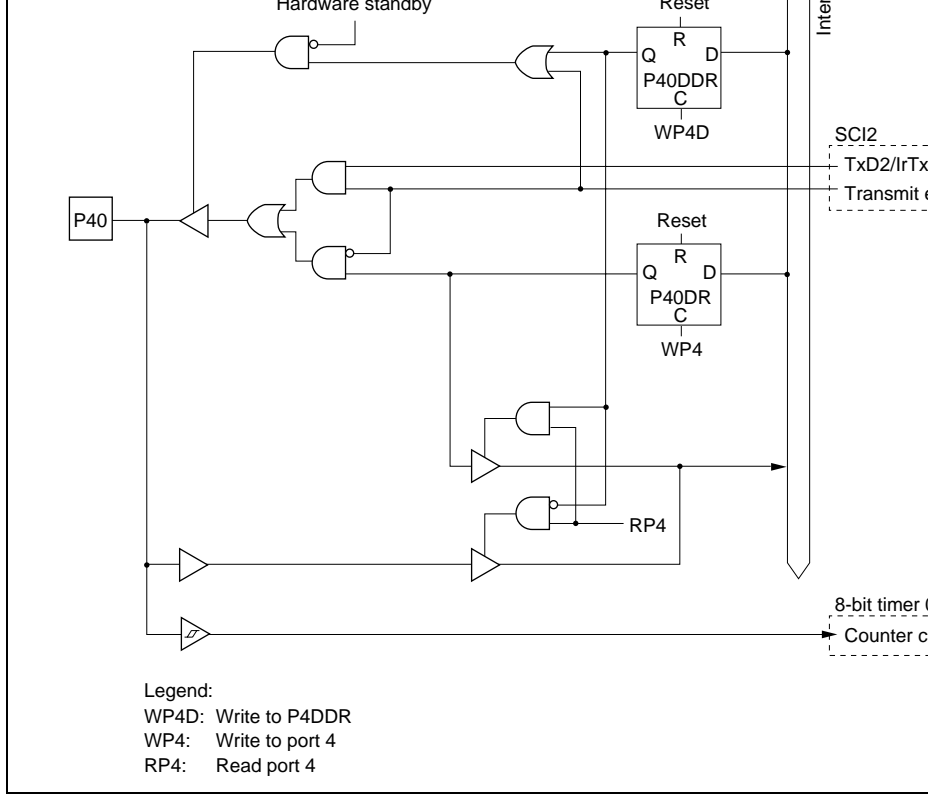


Figure C.6 Port 4 Block Diagram (Pin P40)

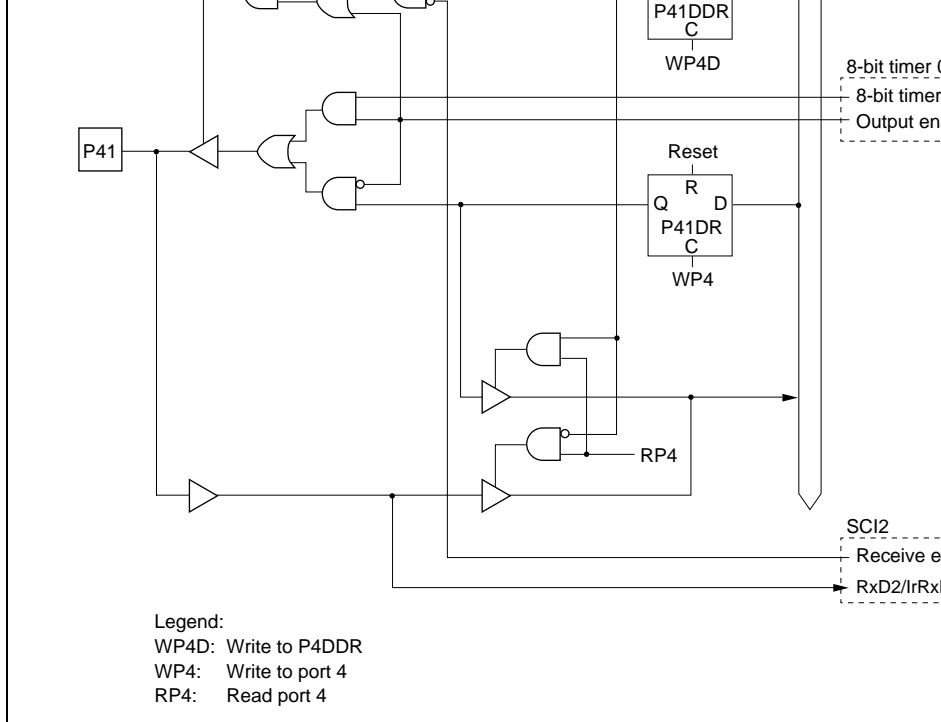


Figure C.7 Port 4 Block Diagram (Pin P41)

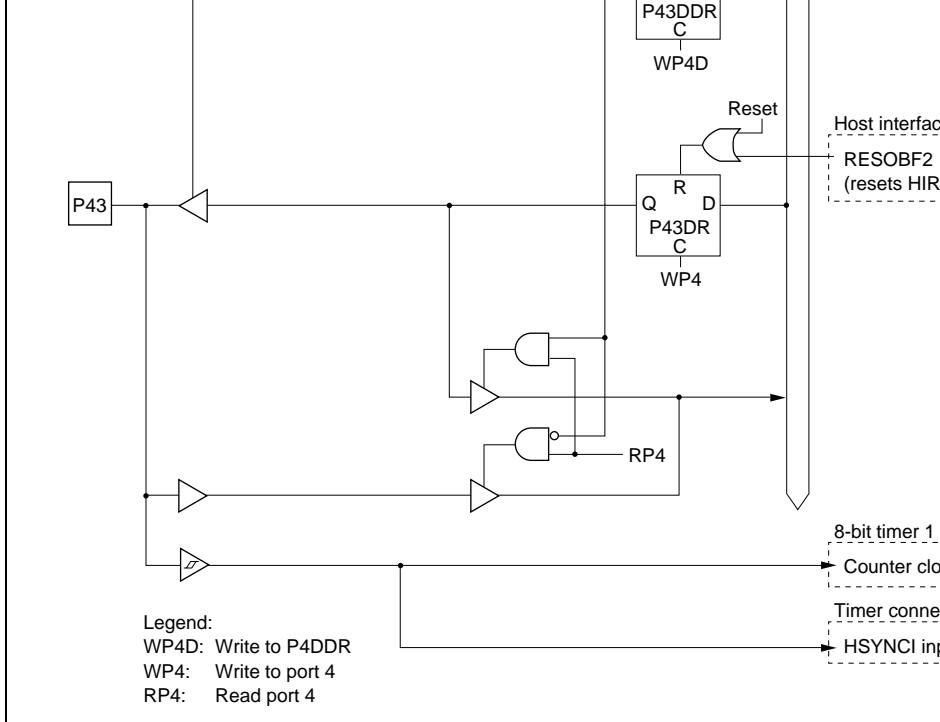


Figure C.9 Port 4 Block Diagram (Pin P43)

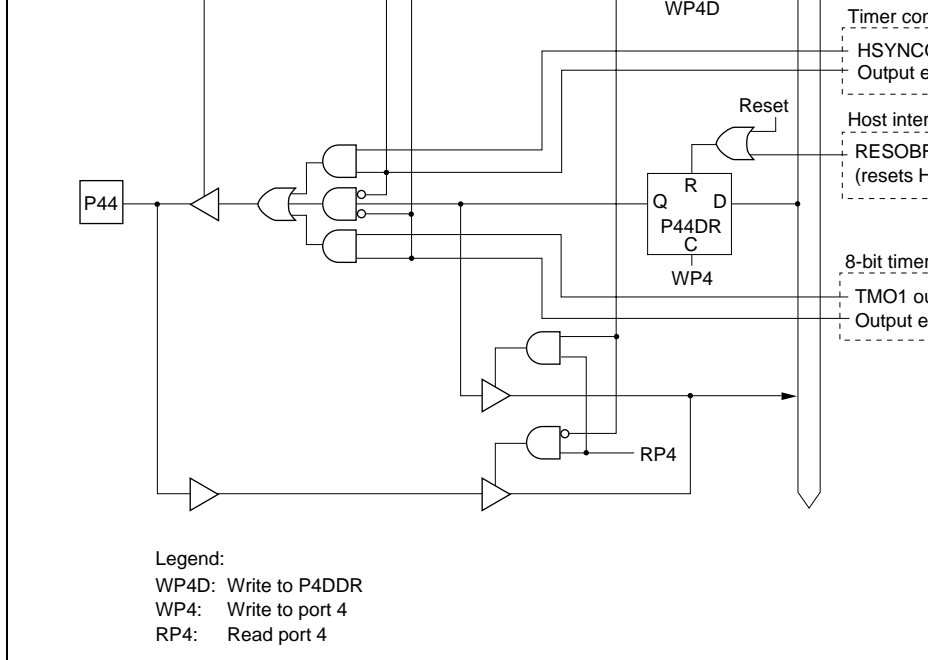


Figure C.10 Port 4 Block Diagram (Pin P44)

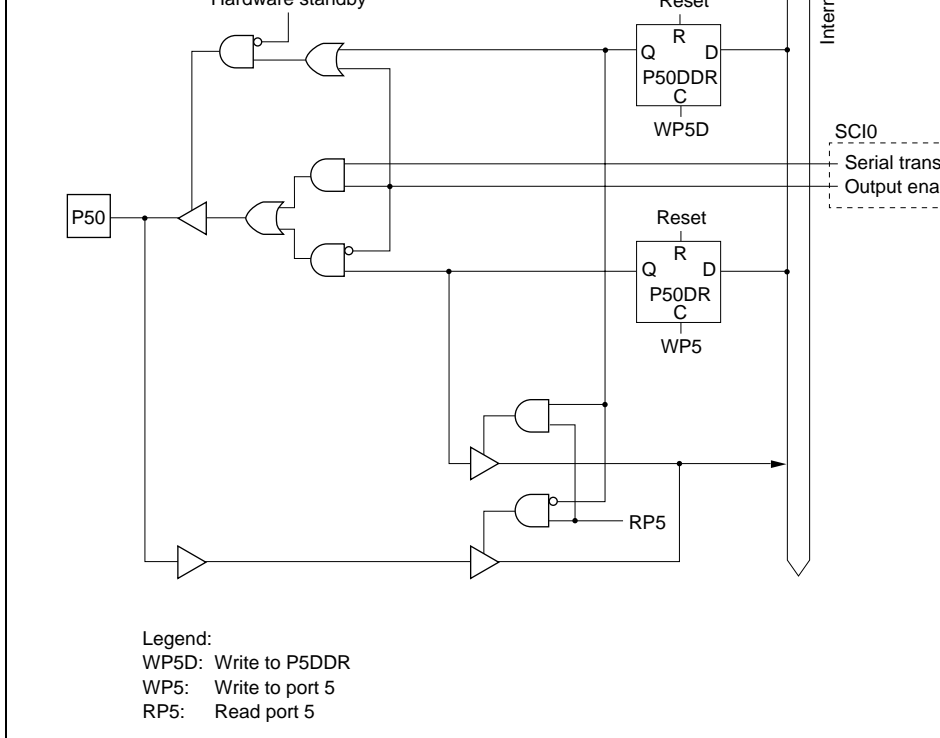


Figure C.13 Port 5 Block Diagram (Pin P50)

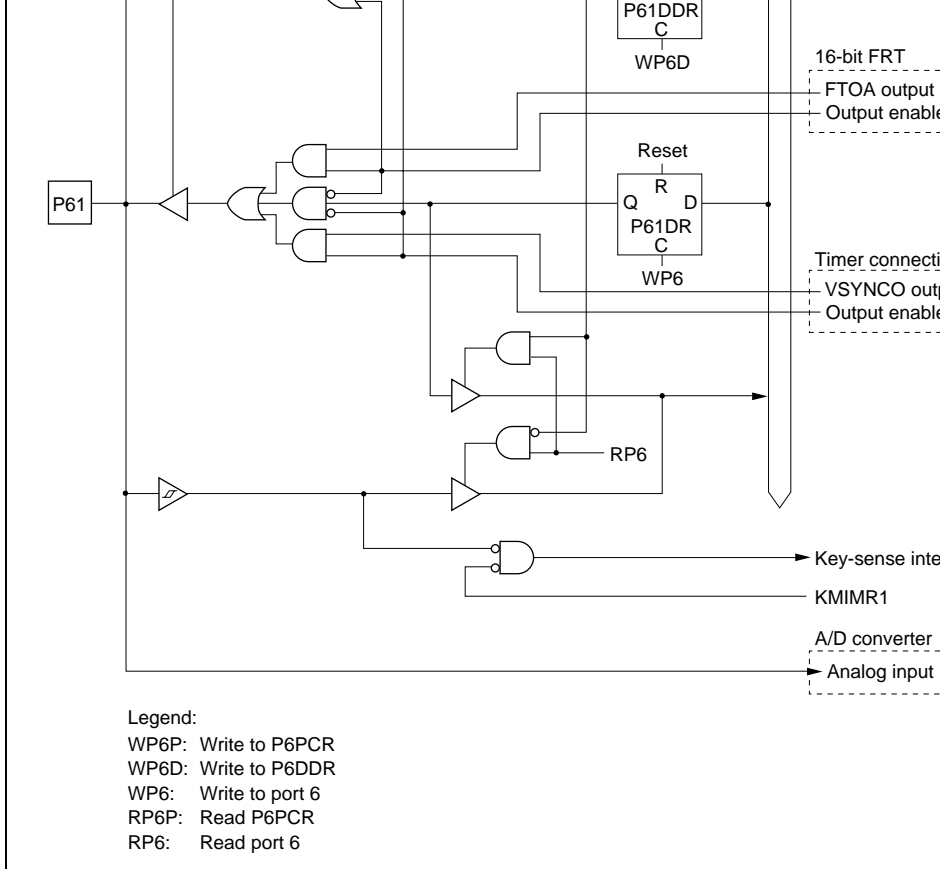


Figure C.17 Port 6 Block Diagram (Pin P61)

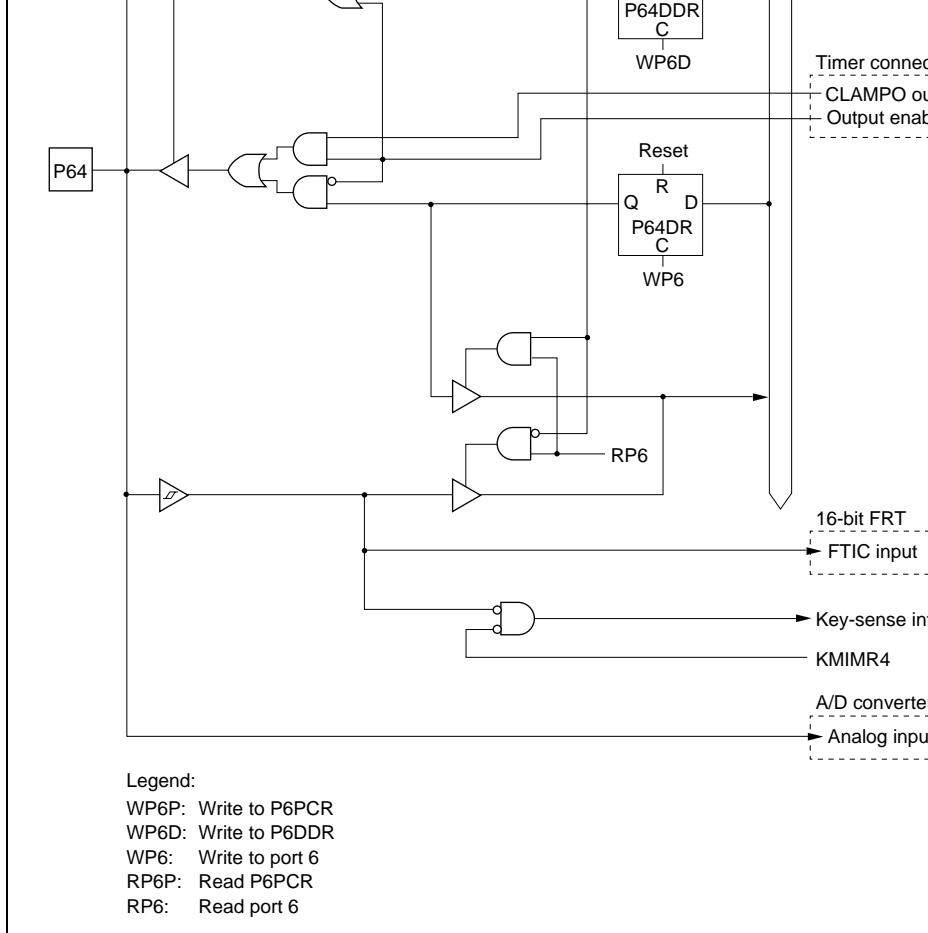


Figure C.18 Port 6 Block Diagram (Pin P64)

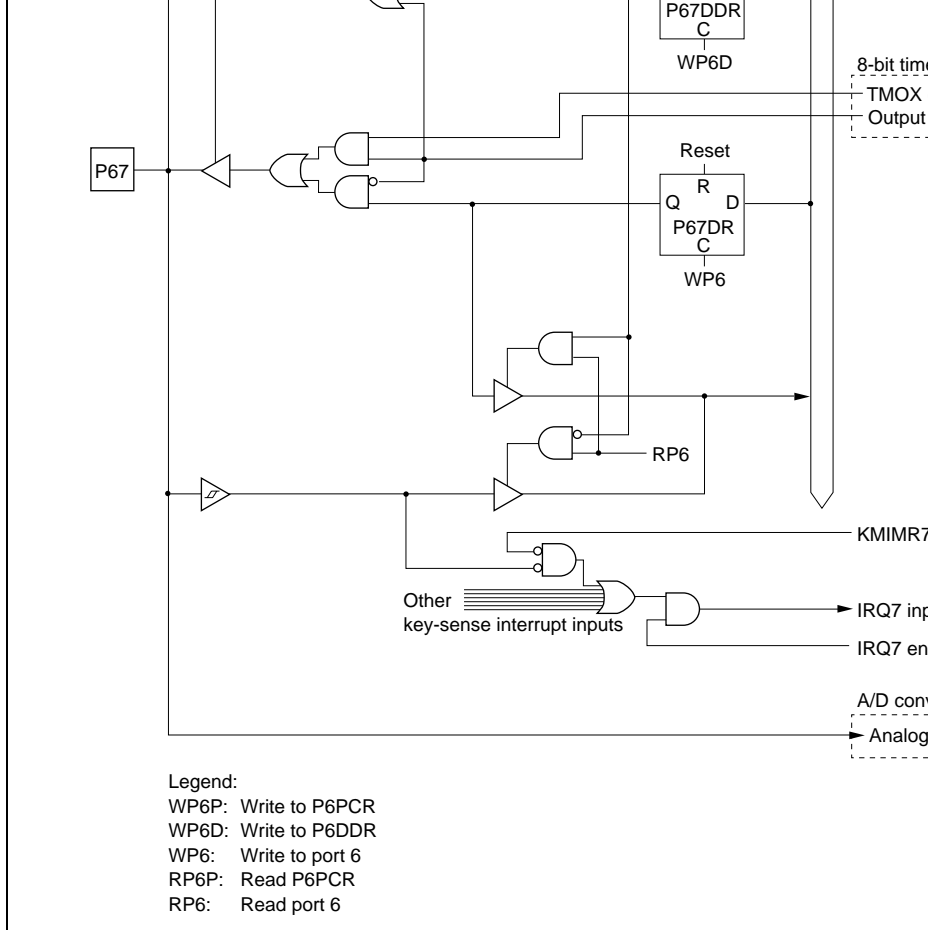


Figure C.20 Port 6 Block Diagram (Pin P67)



Figure C.21 Port 7 Block Diagram (Pins P70 to P75)

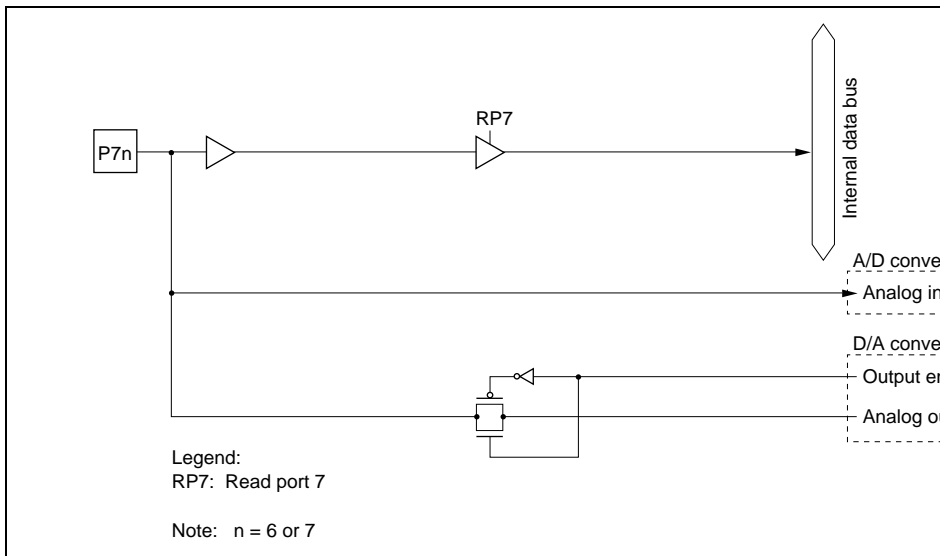


Figure C.22 Port 7 Block Diagram (Pins P76, P77)

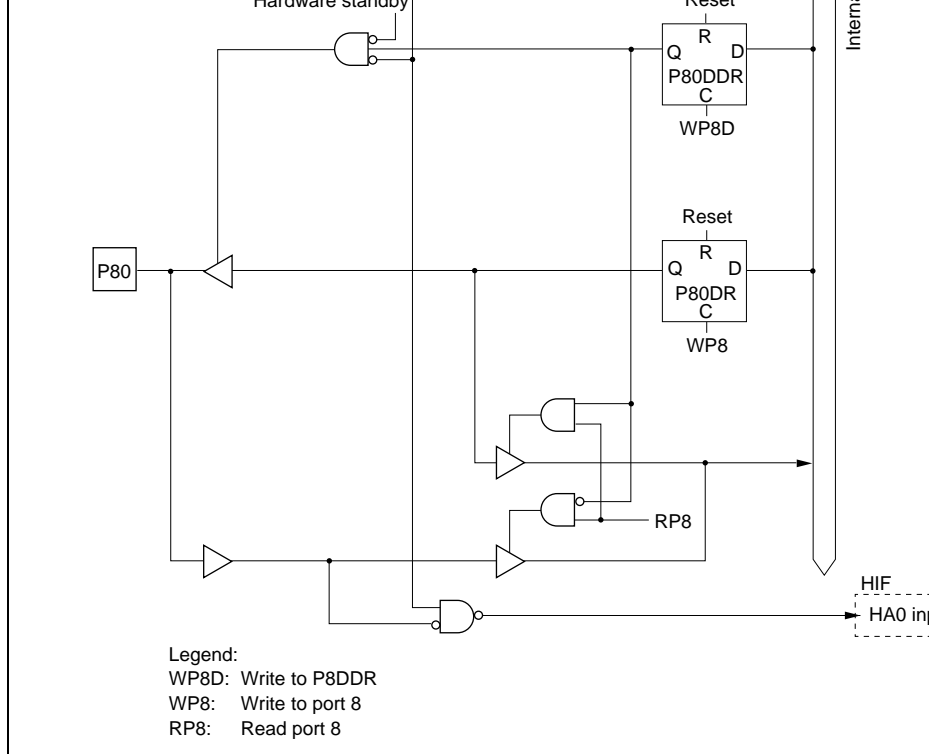


Figure C.23 Port 8 Block Diagram (Pin P80)

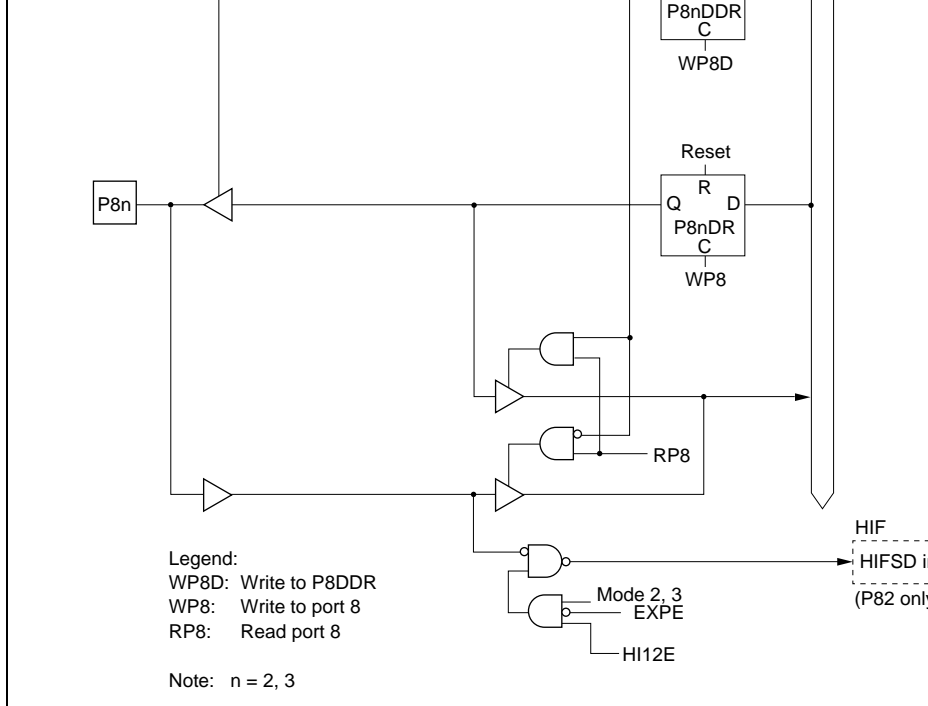


Figure C.25 Port 8 Block Diagram (Pins P82, P83)

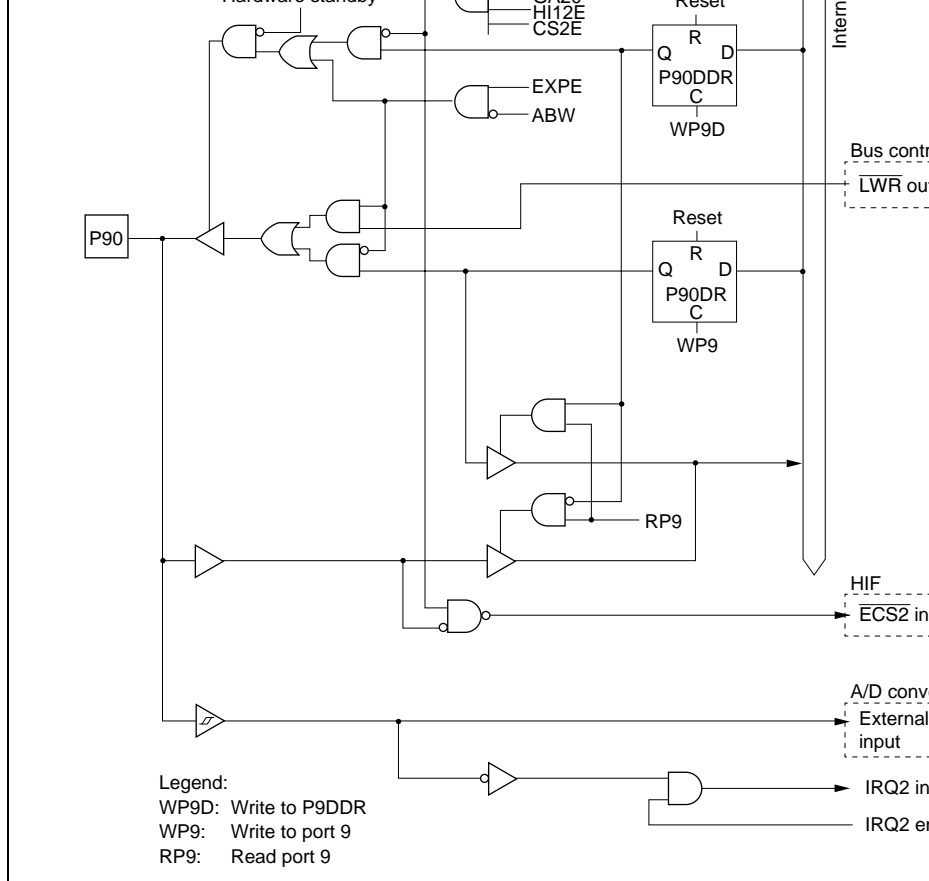


Figure C.29 Port 9 Block Diagram (Pin P90)

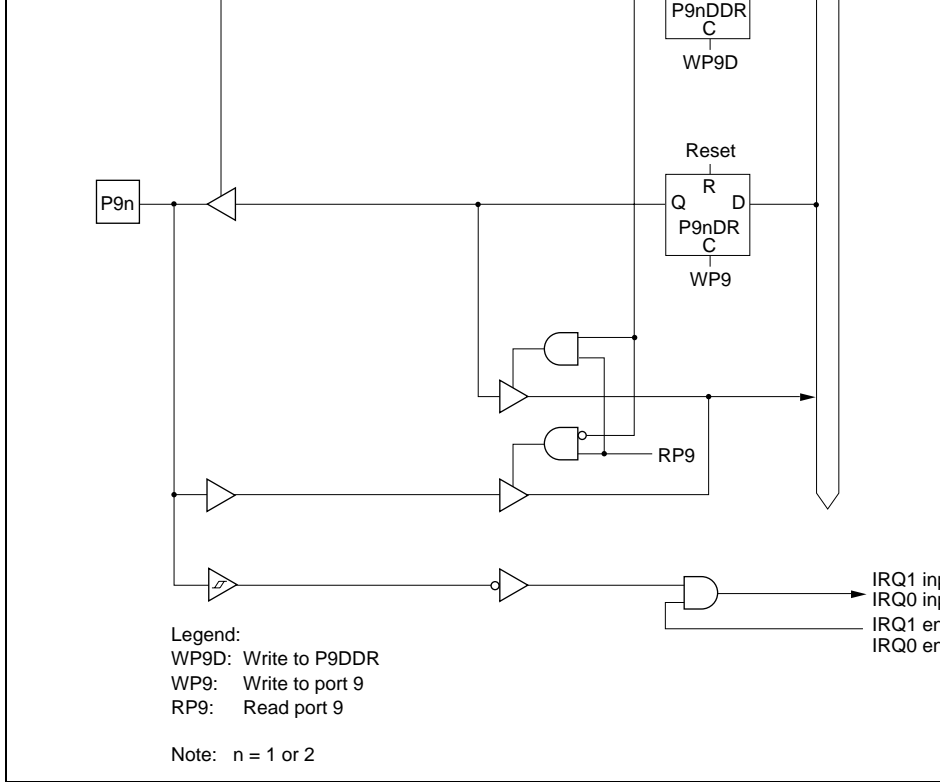


Figure C.30 Port 9 Block Diagram (Pins P91, P92)

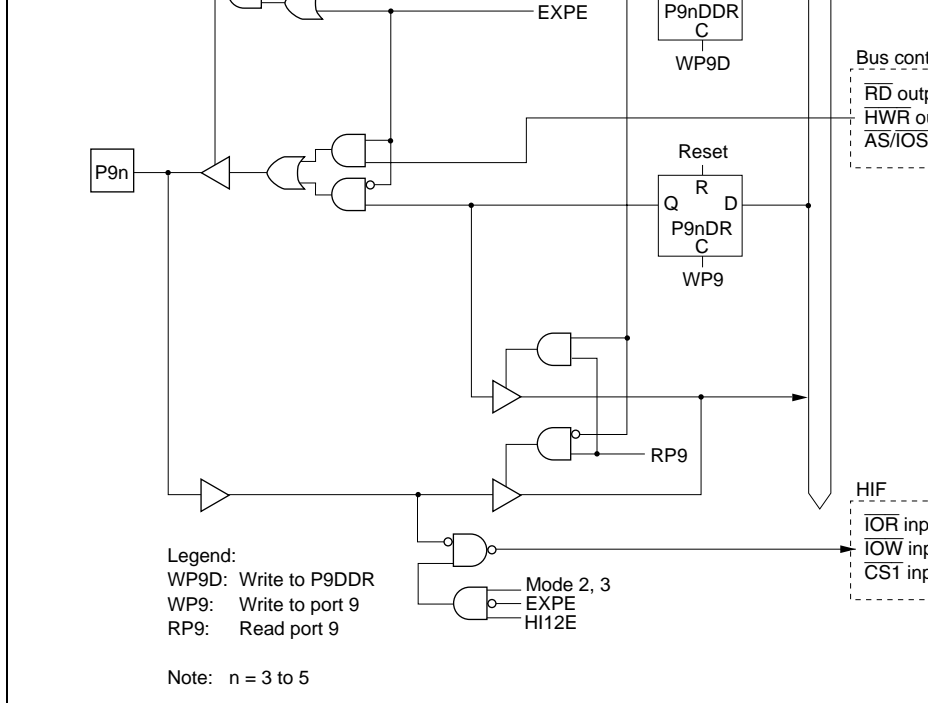


Figure C.31 Port 9 Block Diagram (Pins P93 to P95)

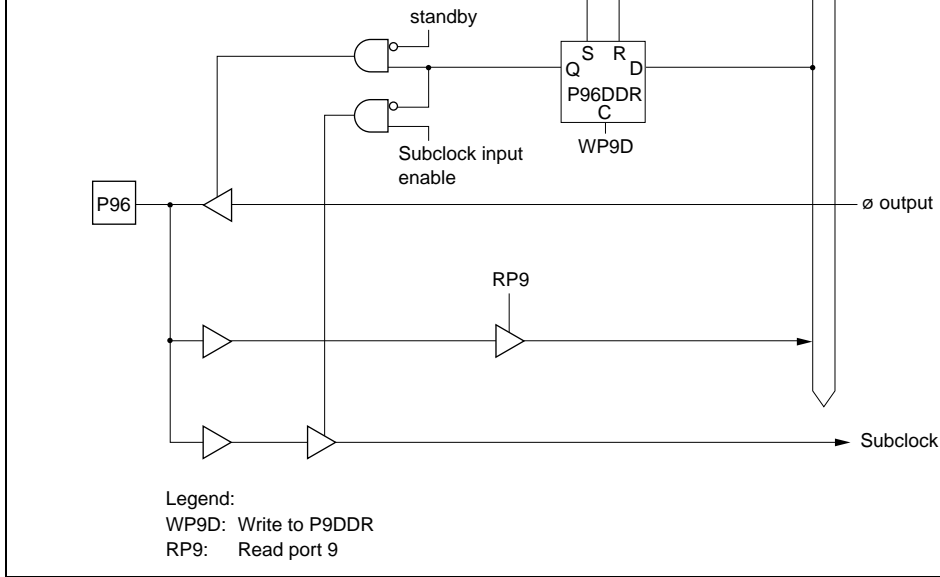


Figure C.32 Port 9 Block Diagram (Pin P96)

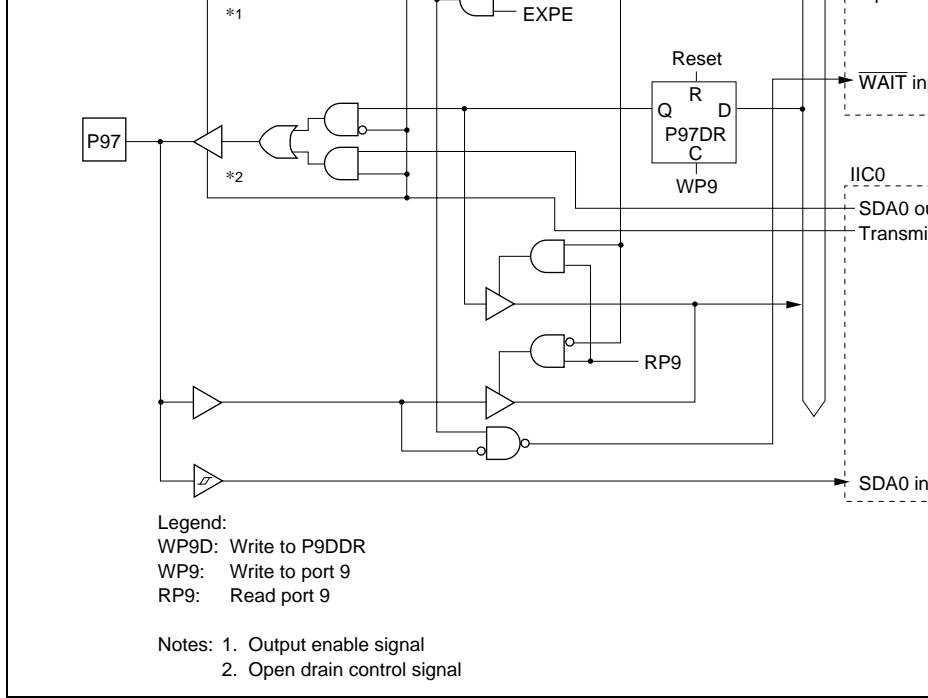


Figure C.33 Port 9 Block Diagram (Pin P97)

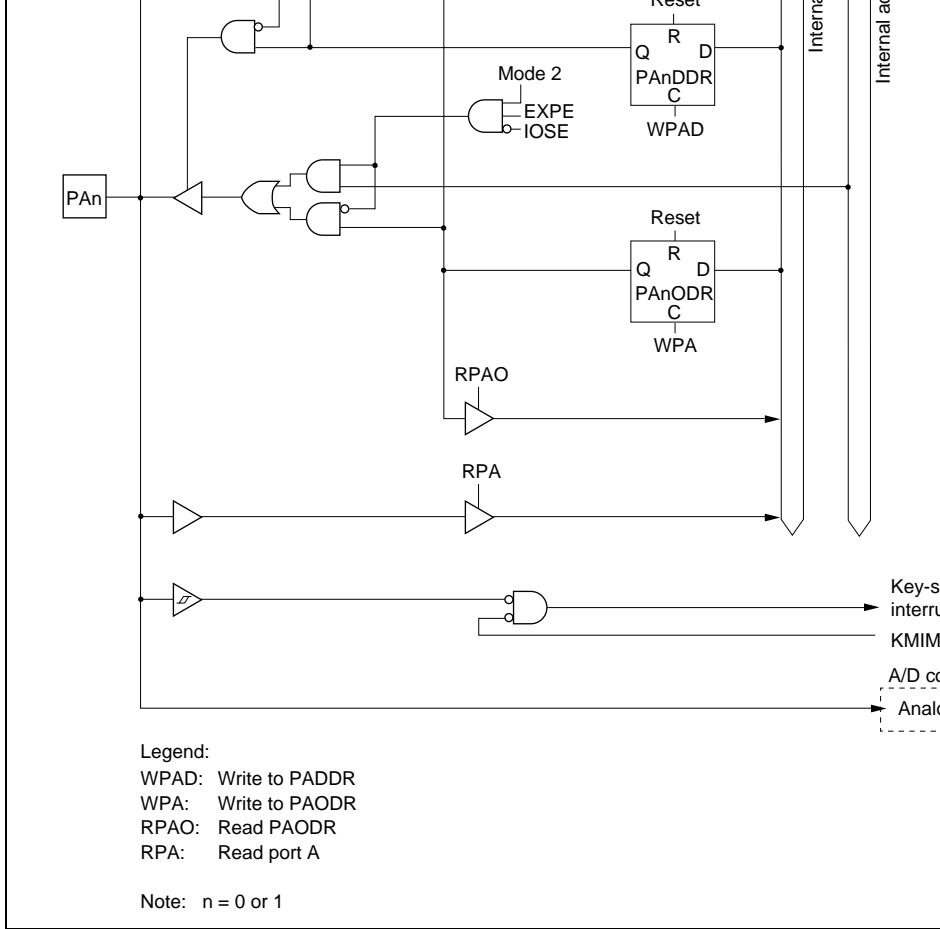


Figure C.34 Port A Block Diagram (Pins PA0, PA1)

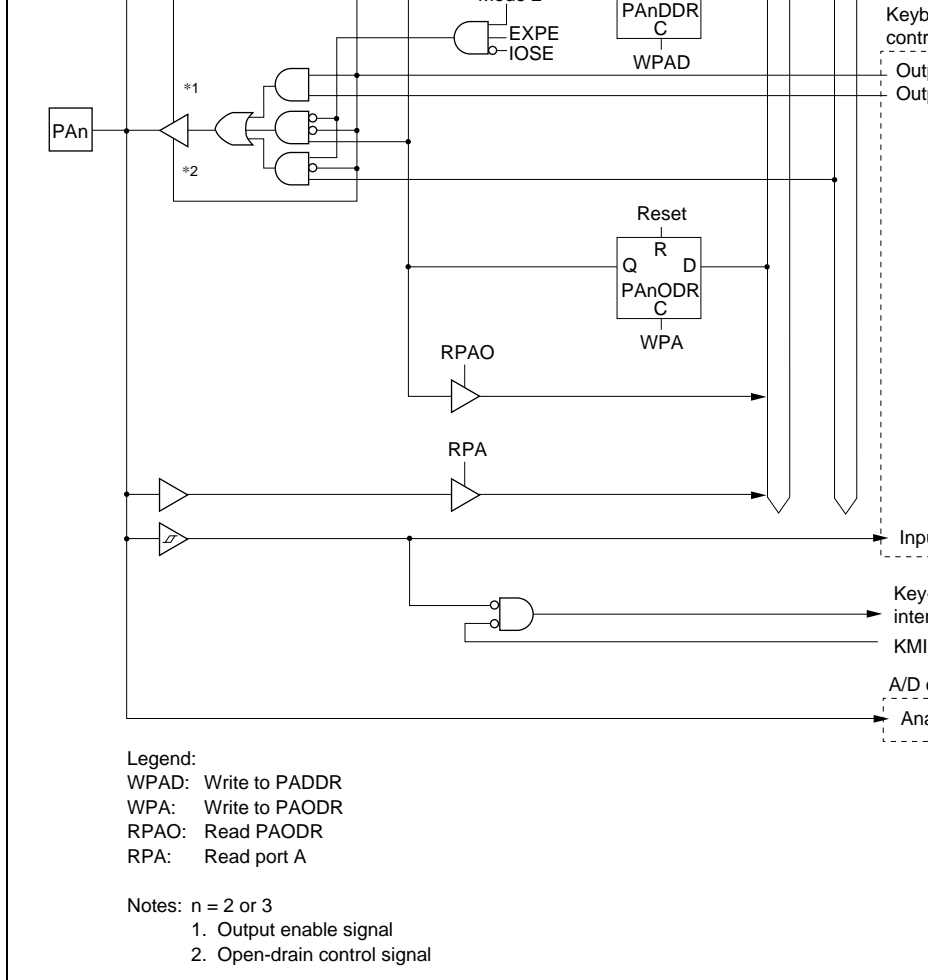


Figure C.35 Port A Block Diagram (Pins PA2, PA3)

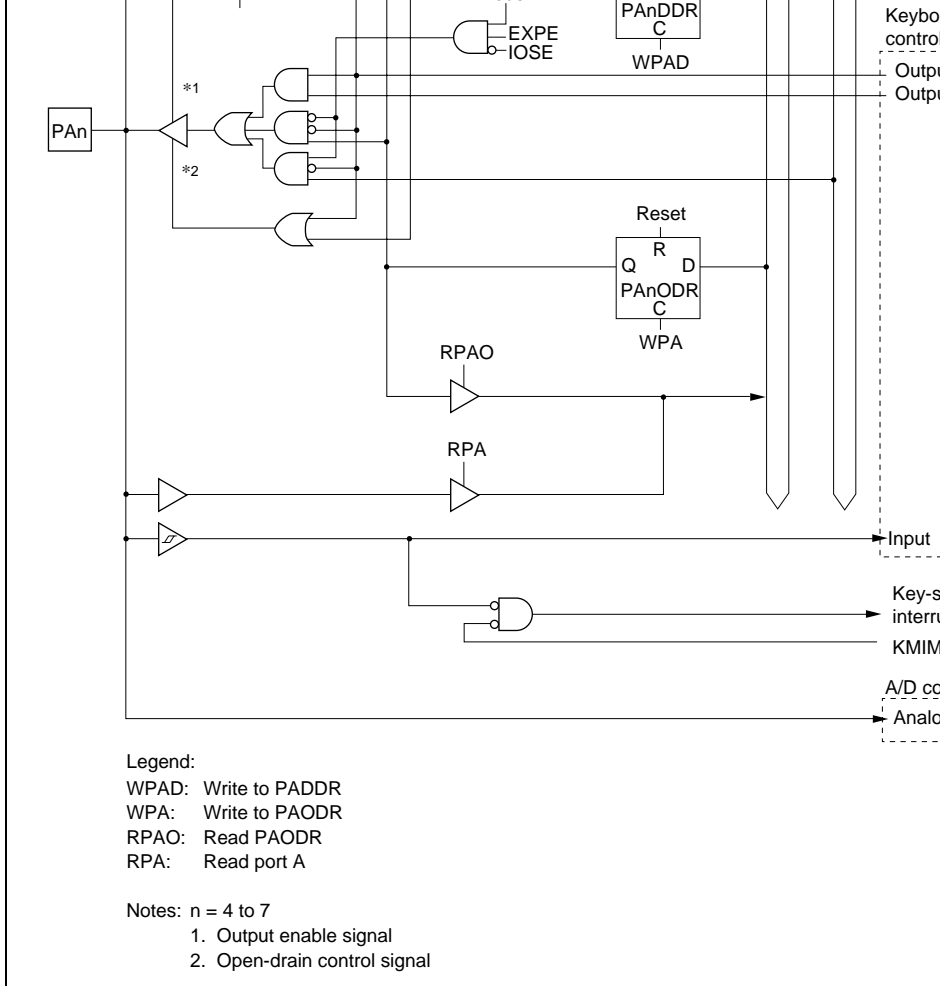


Figure C.36 Port A Block Diagram (Pins PA4 to PA7)

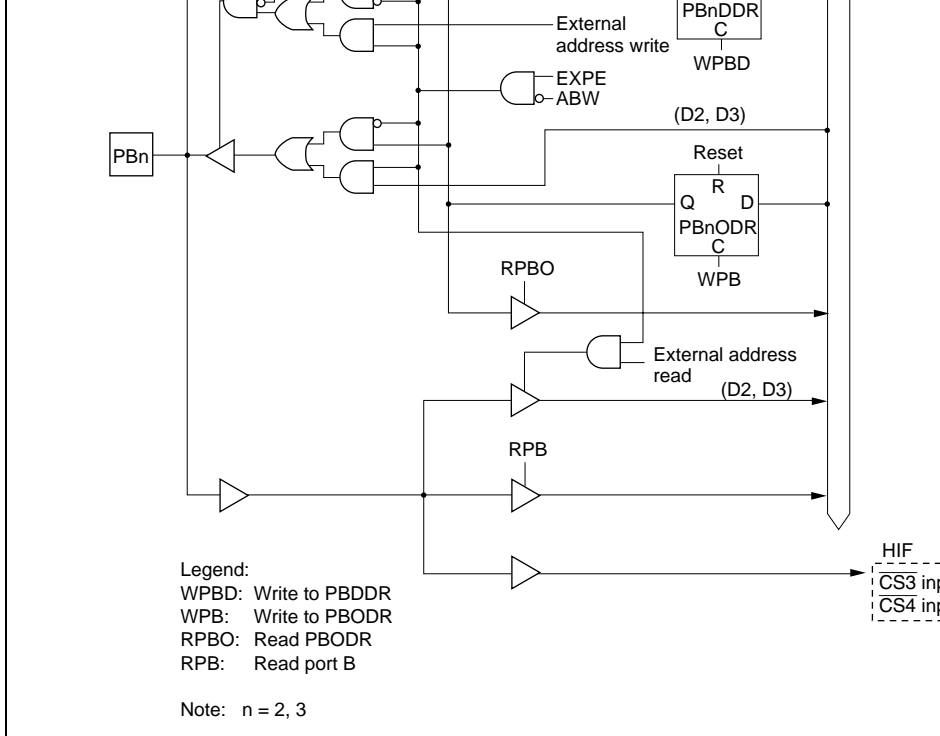
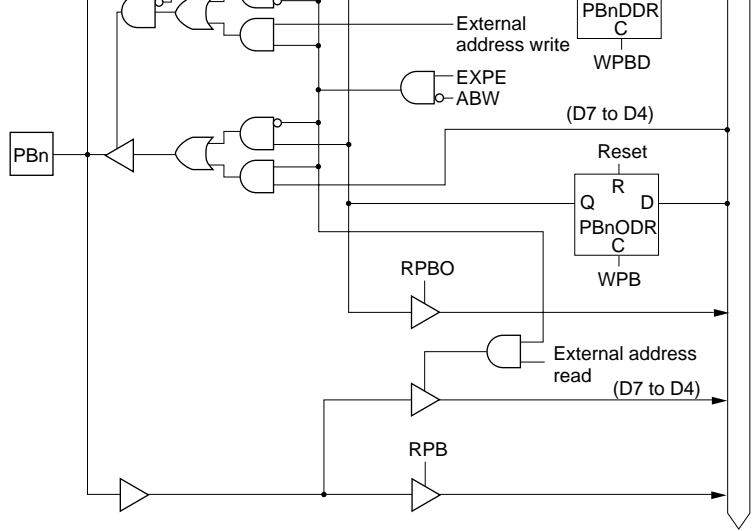


Figure C.38 Port B Block Diagram (Pins PB2 and PB3)



Legend:
 WPBD: Write to PBDDR
 WPB: Write to PBODR
 RPBO: Read PBODR
 RPB: Read port B

Note: n = 4 to 7

Figure C.39 Port B Block Diagram (Pins PB4 to PB7)

Pin Name	mode	Reset mode	mode	mode	mode	mode	mode	mode
Port 1 A7 to A0	1	L	T	keep*	keep*	keep*	keep*	A7 to A0
	2, 3 (EXPE = 1)		T					Address output/ input port
	2, 3 (EXPE = 0)							I/O port
Port 2 A15 to A8	1	L	T	keep*	keep*	keep*	keep*	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)			keep	keep	keep	keep	I/O port
Port 4	1	T	T	keep	keep	keep	keep	I/O port
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)							
Port 5	1	T	T	keep	keep	keep	keep	I/O port
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)							
Port 6	1	T	T	keep	keep	keep	keep	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	keep	keep	keep	keep	I/O port
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)							
Port 97 WAIT	1	T	T	T/keep	T/keep	T/keep	T/keep	WAIT/ I/O port
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)			keep	keep	keep	keep	I/O port

	2, 3 (EXPE = 0)			keep	keep	keep	keep	I/O port
Port 92 to 91	1	T	T	keep	keep	keep	keep	I/O port
	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)							
Port 90	1	T	T	H/keep	H/keep	H/keep	H/keep	LWR/ I/O port
LWR	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)			keep	keep	keep	keep	I/O port
Port A	1	T	T	keep*	keep*	keep*	keep*	I/O port
A23 to A16	2, 3 (EXPE = 1)							A23 to A16/ I/O port
	2, 3 (EXPE = 0)							I/O port
Port B	1	T	T	T/keep	T/keep	T/keep	T/keep	D7 to D0/ I/O port
D7 to D0	2, 3 (EXPE = 1)							
	2, 3 (EXPE = 0)			keep	keep	keep	keep	I/O port

Legend:

H: High

L: Low

T: High-impedance state

keep: Input ports are in the high-impedance state (when DDR = 0 and PCR = 1, MOSFETs remain on).

Output ports maintain their previous state.

Depending on the pins, the on-chip supporting modules may be initialized and their function determined by DDR and DR used.

DDR: Data direction register

Note: * In the case of address output, the last address accessed is retained.

remain low until $\overline{\text{STBY}}$ signal goes low (minimum delay from $\overline{\text{STBY}}$ low to $\overline{\text{RES}}$ h

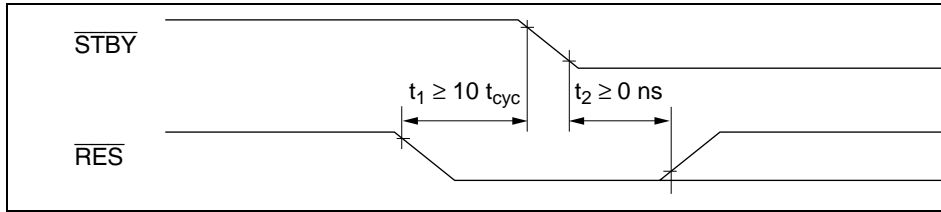


Figure E.1 Timing of Transition to Hardware Standby Mode

- (2) To retain RAM contents with the RAME bit cleared to 0 in SYSCR, or when RAM not need to be retained, $\overline{\text{RES}}$ does not have to be driven low as in (1).

E.2 Timing of Recovery from Hardware Standby Mode

Drive the $\overline{\text{RES}}$ signal low at least 100 ns before $\overline{\text{STBY}}$ goes high to execute a reset.

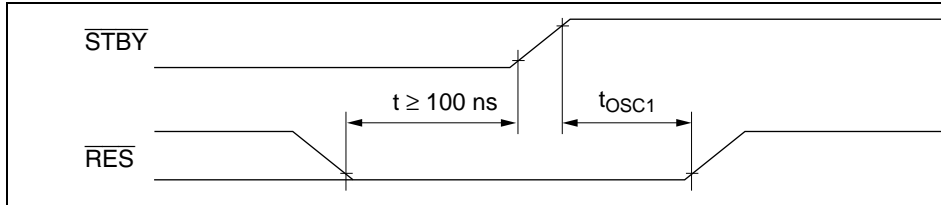


Figure E.2 Timing of Recovery from Hardware Standby Mode

			Version with on-chip I ² C bus interface (5-V version, 4-V version, 3-V version)	HD6432148SW	HD6432148S(V)W(***)FA	100-pin (FP-100)
					HD6432148S(V)W(***)TE	100-pin (TFP-100)
	F-ZTAT version		Standard product (5-V version/4-V version)	HD64F2148	HD64F2148FA20	100-pin (FP-100)
					HD64F2148TE20	100-pin (TFP-100)
			Low-voltage version (3-V version)	HD64F2148V	HD64F2148VFA10	100-pin (FP-100)
					HD64F2148VTE10	100-pin (TFP-100)
	H8S/2147	Mask-ROM version	Standard product (5-V version, 4-V version, 3-V version)	HD6432147S	HD6432147S(V)(***)FA	100-pin (FP-100)
					HD6432147S(V)(***)TE	100-pin (TFP-100)
			Version with on-chip I ² C bus interface (5-V version, 4-V version, 3-V version)	HD6432147SW	HD6432147S(V)W(***)FA	100-pin (FP-100)
					HD6432147S(V)W(***)TE	100-pin (TFP-100)
H8S/2148 Group A-mask version	H8S/2148A	F-ZTAT version A-mask version	Standard product (5-V version/4-V version)	HD64F2148A	HD64F2148AFA20	100-pin (FP-100)
					HD64F2148ATE20	100-pin (TFP-100)
			Low-voltage version (3-V version)	HD64F2148AV	HD64F2148AVFA10	100-pin (FP-100)
					HD64F2148AVTE10	100-pin (TFP-100)
	H8S/2147A	F-ZTAT version A-mask version	Standard product (5-V version/4-V version)	HD64F2147A	HD64F2147AFA20	100-pin (FP-100)
					HD64F2147ATE20	100-pin (TFP-100)
			Low-voltage version (3-V version)	HD64F2147AV	HD64F2147AVFA10	100-pin (FP-100)
					HD64F2147AVTE10	100-pin (TFP-100)

H8S/2144 Group	H8S/2144	Mask-ROM version	Standard product (5-V version, 4-V version, 3-V version)	HD6432144S	HD6432144S(V)(***)FA	100-pin T (FP-100E)	
					HD6432144S(V)(***)TE	100-pin T (TFP-100)	
H8S/2143	Mask-ROM version	Standard product (5-V version, 4-V version, 3-V version)	HD6432143S	HD64F2144	HD64F2144FA20	100-pin C (FP-100E)	
					HD64F2144TE20	100-pin T (TFP-100)	
				Low-voltage version (3-V version)	HD64F2144V	HD64F2144VFA10	100-pin C (FP-100E)
						HD64F2144VTE10	100-pin T (TFP-100)
H8S/2142	Mask-ROM version	Standard product (5-V version, 4-V version, 3-V version)	HD6432142	HD64F2142R	HD6432142(***)FA	100-pin C (FP-100E)	
					HD6432142(***)TE	100-pin T (TFP-100)	
				Low-voltage version (3-V version)	HD64F2142RV	HD64F2142RFA20	100-pin C (FP-100E)
						HD64F2142RTE20	100-pin T (TFP-100)
H8S/2144 Group A-mask version	H8S/2144A	F-ZTAT version A-mask version	Standard product (5-V version/4-V version)	HD64F2144A	HD64F2144AFA20	100-pin C (FP-100E)	
					HD64F2144ATE20	100-pin T (TFP-100)	
				Low-voltage version (3-V version)	HD64F2144AV	HD64F2144AVFA10	100-pin C (FP-100E)
						HD64F2144AVTE10	100-pin T (TFP-100)

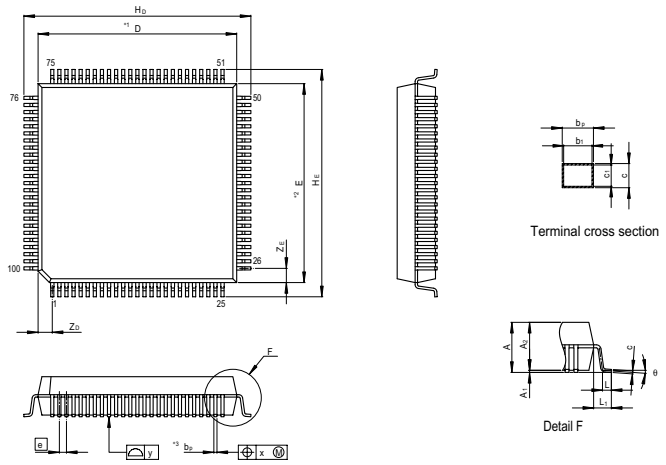
Note: (***) is the ROM code.

The F-ZTAT version of the H8S/2148 has an on-chip I²C bus interface as standard.

The F-ZTAT 5 V/4 V version supports the operating ranges of the 5 V version and the 4 V

The operating range of the F-ZTAT low-voltage version will be decided later.

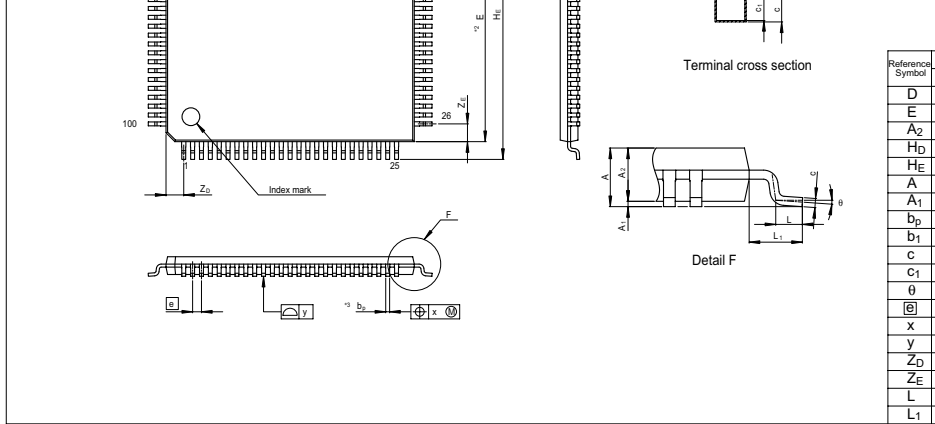
The above table includes products under development. Information on the status of individual products can be obtained from Renesas sales offices.



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2. DIMENSIONS
INCLUDE

Referen Symb ^o
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E
A ₂
H ₀
H _E
A
A ₁
D _P
b ₁
c
C ₁
θ
⊕
x
y
Z _D
Z _E
L
L ₁

Figure G.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
⊖
x
y
Z _D
Z _E
L
L ₁

Figure G.2 Package Dimensions (TFP-100B)

**Renesas 16-Bit Single-Chip Microcomputer
Hardware Manual
H8S/2148 Group, H8S/2144 Group,
H8S/2148FZTAT™, H8S/2147N F-ZTAT™,
H8S/2144F-ZTAT™, H8S/2142F-ZTAT™**

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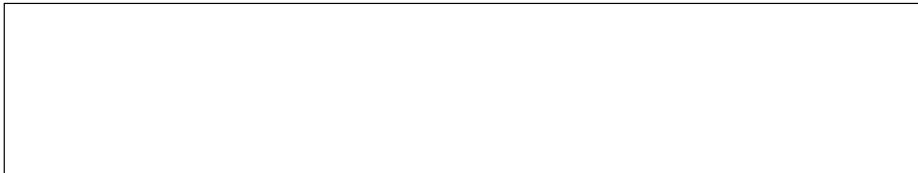
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H8S/2148F-ZTAT™, H8S/2147N F-ZTAT™,
H8S/2144F-ZTAT™, H8S/2142F-ZTAT™
Hardware Manual



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