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H8S/2350 Series

H8S/2351, HD6432351,
H8S/2350, HD6412350

Hardware Manual



ADE-602-111A

Rev. 2.0

3/10/03

Hitachi, Ltd.

MC-Setsu

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The H8S/2000 CPU can execute basic instructions in one state, and is provided with sixteen 16-bit general registers with a 32-bit internal configuration, and a concise and optimized instruction set. The CPU can handle a 16 Mbyte linear address space (architecturally 4 Gbytes). Programs based on the high-level language C can also be run efficiently.

The address space is divided into eight areas. The data bus width and access states can be selected for each of these areas, and various kinds of memory can be connected fast and easily.

On-chip memory consists of large-capacity ROM (H8S/2351 only) and RAM.

On-chip supporting functions include a 16-bit timer pulse unit (TPU), programmable pulse generator (PPG), watchdog timer (WDT), serial communication interface (SCI), A/D converter, D/A converter, and I/O ports.

In addition, an on-chip DMA controller (DMAC) and data transfer controller (DTC) are provided, enabling high-speed data transfer without CPU intervention.

Use of the H8S/2350 Series enables easy implementation of compact, high-performance systems capable of processing large volumes of data.

This manual describes the hardware of the H8S/2350 Series. Refer to the H8S/2600 Series and H8S/2000 Series Programming Manual for a detailed description of the instruction set.

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The H8S/2350 Series is a series of microcomputers (MCUs: microcomputer units), built around the H8S/2000 CPU, employing Hitachi's proprietary architecture, and equipped with peripheral functions on-chip.

The H8S/2000 CPU has an internal 32-bit architecture, is provided with sixteen 16-bit general registers and a concise, optimized instruction set designed for high-speed operation, and can address a 16-Mbyte linear address space. The instruction set is upward-compatible with H8/300 and H8/300H CPU instructions at the object-code level, facilitating migration from the H8/300, H8/300L, or H8/300H Series.

On-chip peripheral functions required for system configuration include DMA controller (DMAC) and data transfer controller (DTC) bus masters, ROM (H8S/2351 only) and RAM memory, a 16-bit timer-pulse unit (TPU), programmable pulse generator (PPG), watchdog timer (WDT), serial communication interface (SCI), A/D converter, D/A converter, and I/O ports.

The H8S/2351 has on-chip mask ROM.

The H8S/2351 supports seven operating modes (modes 1 to 7), while the H8S/2350 supports three operating modes (modes 1, 4, and 5). There is a choice of address space and single-chip mode or expansion mode.

The features of the H8S/2350 Series are shown in Table 1-1.

or eight 32-bit registers)

- High-speed operation suitable for realtime control
 - Maximum clock rate: 20 MHz
 - High-speed arithmetic operations
 - 8/16/32-bit register-register add/subtract : 50 ns
 - 16 × 16-bit register-register multiply : 1000 ns
 - 32 ÷ 16-bit register-register divide : 1000 ns
- Instruction set suitable for high-speed operation
 - Sixty-five basic instructions
 - 8/16/32-bit move/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

Bus controller

- Address space divided into 8 areas, with bus specifications settable independently for each area
- Chip select output possible for each area
- Choice of 8-bit or 16-bit access space for each area
- 2-state or 3-state access space can be designated for each area
- Number of program wait states can be set for each area
- Burst ROM directly connectable
- Maximum 8-Mbyte DRAM directly connectable (or use of interval timer possible)
- External bus release function

DMA controller (DMAC)

- Choice of short address mode or full address mode
 - 4 channels in short address mode
 - 2 channels in full address mode
 - Transfer possible in repeat mode, block transfer mode, etc.
 - Single address mode transfer possible
 - Can be activated by internal interrupt
-

	source	<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 DTC 									
16-bit timer-pulse unit (TPU)		<ul style="list-style-type: none"> • 6-channel 16-bit timer on-chip • Pulse I/O processing capability for up to 16 pins' • Automatic 2-phase encoder count capability 									
Programmable pulse generator (PPG)		<ul style="list-style-type: none"> • Maximum 16-bit pulse output possible with TPU as time base • Output trigger selectable in 4-bit groups • Non-overlap margin can be set • Direct output or inverse output setting possible 									
Watchdog timer		<ul style="list-style-type: none"> • Watchdog timer or interval timer selectable 									
Serial communication interface (SCI) 2 channels		<ul style="list-style-type: none"> • Asynchronous mode or synchronous mode selectable • Multiprocessor communication function • Smart card interface function 									
A/D converter		<ul style="list-style-type: none"> • Resolution: 10 bits • Input: 8 channels • High-speed conversion : 6.7 μs minimum conversion time (at 20 MHz operation) • Single or scan mode selectable • Sample and hold circuit • A/D conversion can be activated by external trigger or timer trigger 									
D/A converter		<ul style="list-style-type: none"> • Resolution: 8 bits • Output: 2 channels 									
I/O ports		<ul style="list-style-type: none"> • 87 I/O pins, 8 input-only pins 									
Memory		<ul style="list-style-type: none"> • Mask ROM • High-speed static RAM <table border="1"> <thead> <tr> <th>Product Name</th> <th>ROM</th> <th>RAM</th> </tr> </thead> <tbody> <tr> <td>H8S/2350</td> <td>—</td> <td>2 kbytes</td> </tr> <tr> <td>H8S/2351</td> <td>64 kbytes</td> <td>2 kbytes</td> </tr> </tbody> </table>	Product Name	ROM	RAM	H8S/2350	—	2 kbytes	H8S/2351	64 kbytes	2 kbytes
Product Name	ROM	RAM									
H8S/2350	—	2 kbytes									
H8S/2351	64 kbytes	2 kbytes									
Interrupt controller		<ul style="list-style-type: none"> • Nine external interrupt pins (NMI, $\overline{\text{IRQ0}}$ to $\overline{\text{IRQ7}}$) • 42 internal interrupt sources • Eight priority levels settable 									

- Sleep mode
- Module stop mode
- Software standby mode
- Hardware standby mode

Operating modes Seven MCU operating modes

CPU Operating Mode	Description	On-Chip ROM	External Data Bus		
			Initial Value	Maximum Value	
1	Normal	On-chip ROM disabled expansion mode	Disabled	8 bits	16 bits
2*		On-chip ROM enabled expansion mode	Enabled	8 bits	16 bits
3*		Single-chip mode	Enabled	—	
4	Advanced	On-chip ROM disabled expansion mode	Disabled	16 bits	16 bits
5		On-chip ROM disabled expansion mode	Disabled	8 bits	16 bits
6*		On-chip ROM enabled expansion mode	Enabled	8 bits	16 bits
7*		Single-chip mode	Enabled	—	

Note: * Only applies to the H8S/2351.

Clock pulse generator

- Built-in duty correction circuit

Packages

- 120-pin plastic TQFP (TFP-120)
- 128-pin plastic QFP (FP-128)

Product lineup

Model Name			
ROMless Version	Mask ROM Version	ROM/RAM (Bytes)	Packages
—	HD6432351	64 k/2 k	TFP-120 FP-128
HD6412350	—	—/2 k	TFP-120 FP-128

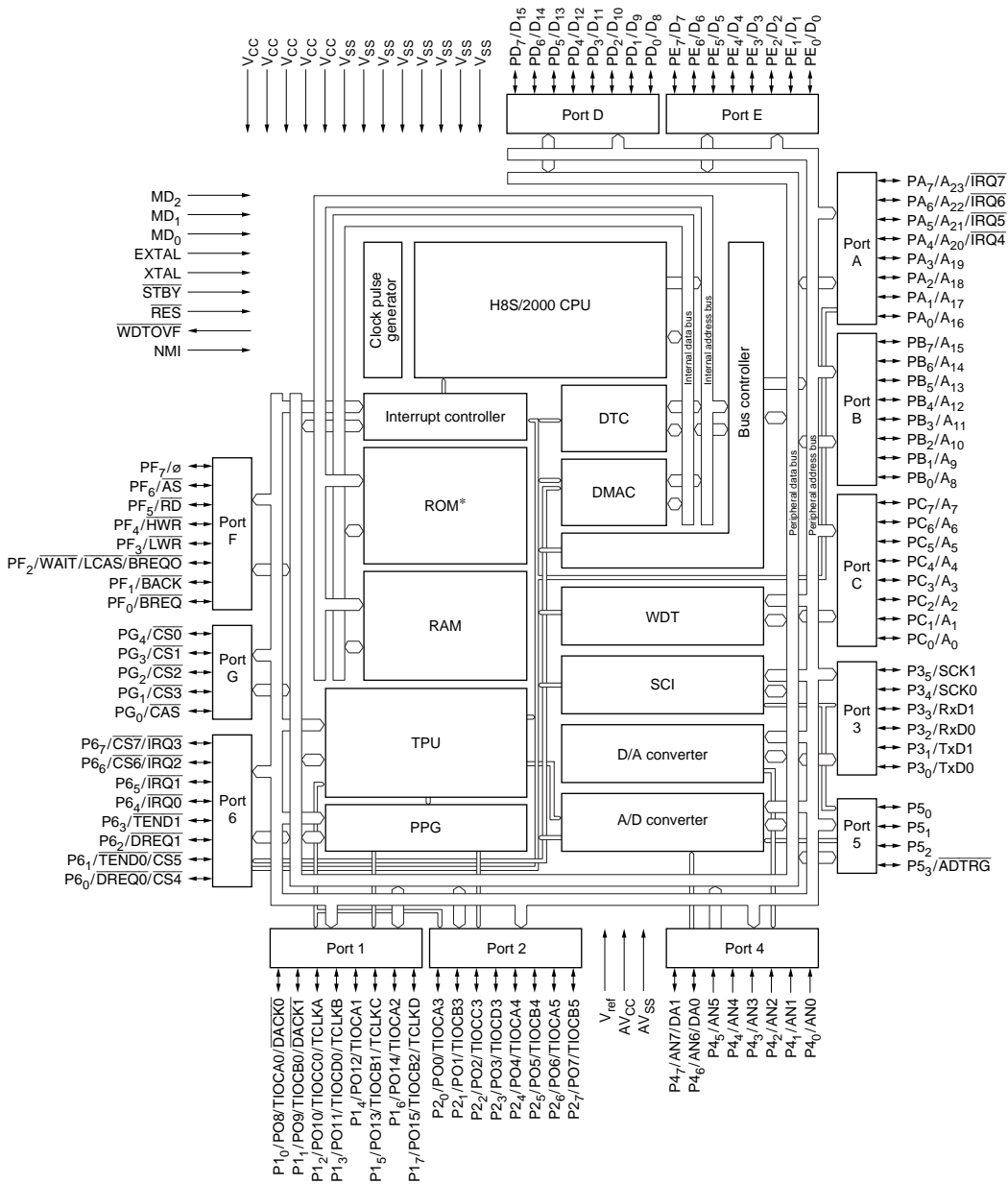


Figure 1-1 Block Diagram

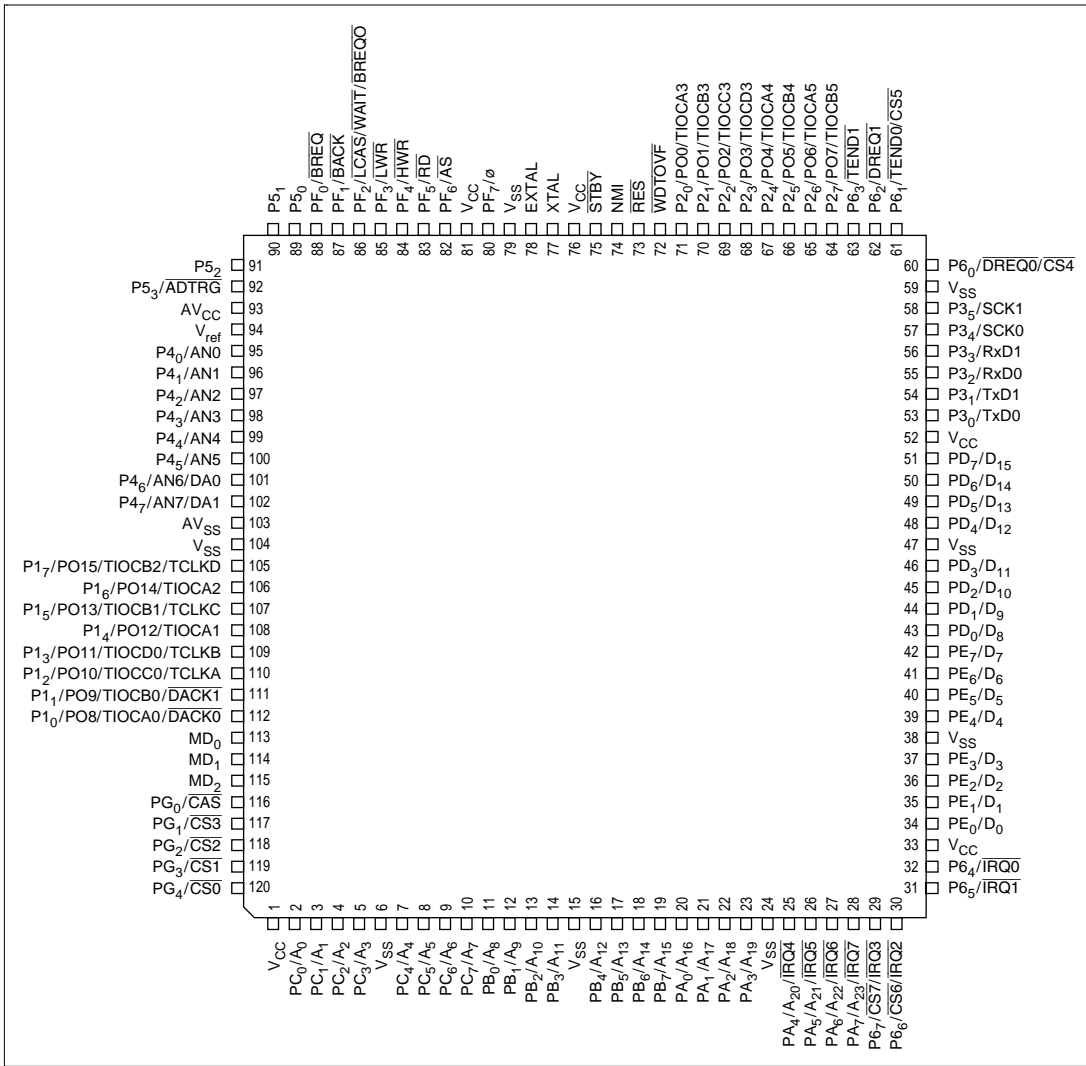


Figure 1-2 Pin Arrangement (TFP-120: Top View)

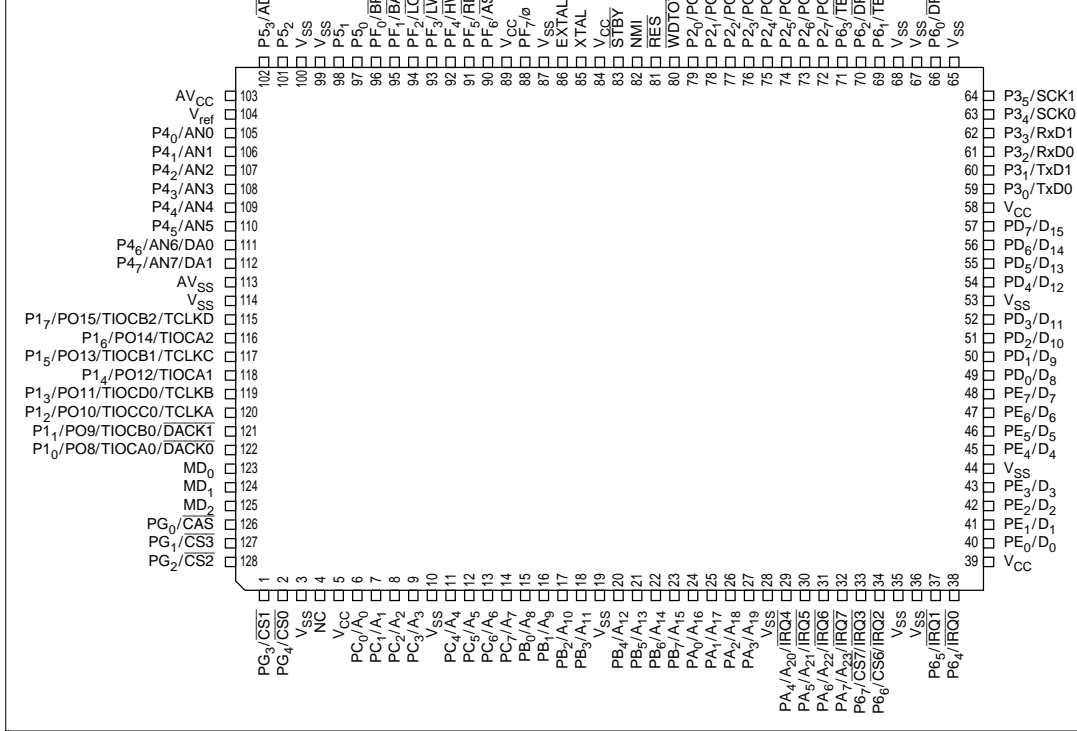


Figure 1-3 Pin Arrangement (FP-128: Top View)

Table 1-2 Pin Functions in Each Operating Mode

Pin No.		Pin Name						
TFP-120	FP-128	Mode 1	Mode 2*	Mode 3*	Mode 4	Mode 5	Mode 6*	Mode 7*
1	5	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}
2	6	A ₀	PC ₀ /A ₀	PC ₀	A ₀	A ₀	PC ₀ /A ₀	PC ₀
3	7	A ₁	PC ₁ /A ₁	PC ₁	A ₁	A ₁	PC ₁ /A ₁	PC ₁
4	8	A ₂	PC ₂ /A ₂	PC ₂	A ₂	A ₂	PC ₂ /A ₂	PC ₂
5	9	A ₃	PC ₃ /A ₃	PC ₃	A ₃	A ₃	PC ₃ /A ₃	PC ₃
6	10	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
7	11	A ₄	PC ₄ /A ₄	PC ₄	A ₄	A ₄	PC ₄ /A ₄	PC ₄
8	12	A ₅	PC ₅ /A ₅	PC ₅	A ₅	A ₅	PC ₅ /A ₅	PC ₅
9	13	A ₆	PC ₆ /A ₆	PC ₆	A ₆	A ₆	PC ₆ /A ₆	PC ₆
10	14	A ₇	PC ₇ /A ₇	PC ₇	A ₇	A ₇	PC ₇ /A ₇	PC ₇
11	15	A ₈	PB ₀ /A ₈	PB ₀	A ₈	A ₈	PB ₀ /A ₈	PB ₀
12	16	A ₉	PB ₁ /A ₉	PB ₁	A ₉	A ₉	PB ₁ /A ₉	PB ₁
13	17	A ₁₀	PB ₂ /A ₁₀	PB ₂	A ₁₀	A ₁₀	PB ₂ /A ₁₀	PB ₂
14	18	A ₁₁	PB ₃ /A ₁₁	PB ₃	A ₁₁	A ₁₁	PB ₃ /A ₁₁	PB ₃
15	19	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
16	20	A ₁₂	PB ₄ /A ₁₂	PB ₄	A ₁₂	A ₁₂	PB ₄ /A ₁₂	PB ₄
17	21	A ₁₃	PB ₅ /A ₁₃	PB ₅	A ₁₃	A ₁₃	PB ₅ /A ₁₃	PB ₅
18	22	A ₁₄	PB ₆ /A ₁₄	PB ₆	A ₁₄	A ₁₄	PB ₆ /A ₁₄	PB ₆
19	23	A ₁₅	PB ₇ /A ₁₅	PB ₇	A ₁₅	A ₁₅	PB ₇ /A ₁₅	PB ₇
20	24	PA ₀	PA ₀	PA ₀	A ₁₆	A ₁₆	PA ₀ /A ₁₆	PA ₀
21	25	PA ₁	PA ₁	PA ₁	A ₁₇	A ₁₇	PA ₁ /A ₁₇	PA ₁
22	26	PA ₂	PA ₂	PA ₂	A ₁₈	A ₁₈	PA ₂ /A ₁₈	PA ₂
23	27	PA ₃	PA ₃	PA ₃	A ₁₉	A ₁₉	PA ₃ /A ₁₉	PA ₃
24	28	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
25	29	PA ₄ /IRQ4	PA ₄ /IRQ4	PA ₄ /IRQ4	A ₂₀	A ₂₀	PA ₄ /A ₂₀ / IRQ4	PA ₄ /IRQ4
26	30	PA ₅ /IRQ5	PA ₅ /IRQ5	PA ₅ /IRQ5	PA ₅ /A ₂₁ / IRQ5	PA ₅ /A ₂₁ / IRQ5	PA ₅ /A ₂₁ / IRQ5	PA ₅ /IRQ5
27	31	PA ₆ /IRQ6	PA ₆ /IRQ6	PA ₆ /IRQ6	PA ₆ /A ₂₂ / IRQ6	PA ₆ /A ₂₂ / IRQ6	PA ₆ /A ₂₂ / IRQ6	PA ₆ /IRQ6

28	32	PA ₇ /IRQ7	PA ₇ /IRQ7	PA ₇ /IRQ7	PA ₇ /A ₂₃ /IRQ7	PA ₇ /A ₂₃ /IRQ7	PA ₇ /A ₂₃ /IRQ7	PA ₇ /IRQ7
29	33	P6 ₇ /IRQ3	P6 ₇ /IRQ3	P6 ₇ /IRQ3	P6 ₇ /IRQ3/ CS7	P6 ₇ /IRQ3/ CS7	P6 ₇ /IRQ3/ CS7	P6 ₇ /IRQ3
30	34	P6 ₆ /IRQ2	P6 ₆ /IRQ2	P6 ₆ /IRQ2	P6 ₆ /IRQ2/ CS6	P6 ₆ /IRQ2/ CS6	P6 ₆ /IRQ2/ CS6	P6 ₆ /IRQ2
—	35	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
—	36	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
31	37	P6 ₅ /IRQ1	P6 ₅ /IRQ1	P6 ₅ /IRQ1	P6 ₅ /IRQ1	P6 ₅ /IRQ1	P6 ₅ /IRQ1	P6 ₅ /IRQ1
32	38	P6 ₄ /IRQ0	P6 ₄ /IRQ0	P6 ₄ /IRQ0	P6 ₄ /IRQ0	P6 ₄ /IRQ0	P6 ₄ /IRQ0	P6 ₄ /IRQ0
33	39	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}
34	40	PE ₀ /D ₀	PE ₀ /D ₀	PE ₀	PE ₀ /D ₀	PE ₀ /D ₀	PE ₀ /D ₀	PE ₀
35	41	PE ₁ /D ₁	PE ₁ /D ₁	PE ₁	PE ₁ /D ₁	PE ₁ /D ₁	PE ₁ /D ₁	PE ₁
36	42	PE ₂ /D ₂	PE ₂ /D ₂	PE ₂	PE ₂ /D ₂	PE ₂ /D ₂	PE ₂ /D ₂	PE ₂
37	43	PE ₃ /D ₃	PE ₃ /D ₃	PE ₃	PE ₃ /D ₃	PE ₃ /D ₃	PE ₃ /D ₃	PE ₃
38	44	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
39	45	PE ₄ /D ₄	PE ₄ /D ₄	PE ₄	PE ₄ /D ₄	PE ₄ /D ₄	PE ₄ /D ₄	PE ₄
40	46	PE ₅ /D ₅	PE ₅ /D ₅	PE ₅	PE ₅ /D ₅	PE ₅ /D ₅	PE ₅ /D ₅	PE ₅
41	47	PE ₆ /D ₆	PE ₆ /D ₆	PE ₆	PE ₆ /D ₆	PE ₆ /D ₆	PE ₆ /D ₆	PE ₆
42	48	PE ₇ /D ₇	PE ₇ /D ₇	PE ₇	PE ₇ /D ₇	PE ₇ /D ₇	PE ₇ /D ₇	PE ₇
43	49	D ₈	D ₈	PD ₀	D ₈	D ₈	D ₈	PD ₀
44	50	D ₉	D ₉	PD ₁	D ₉	D ₉	D ₉	PD ₁
45	51	D ₁₀	D ₁₀	PD ₂	D ₁₀	D ₁₀	D ₁₀	PD ₂
46	52	D ₁₁	D ₁₁	PD ₃	D ₁₁	D ₁₁	D ₁₁	PD ₃
47	53	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
48	54	D ₁₂	D ₁₂	PD ₄	D ₁₂	D ₁₂	D ₁₂	PD ₄
49	55	D ₁₃	D ₁₃	PD ₅	D ₁₃	D ₁₃	D ₁₃	PD ₅
50	56	D ₁₄	D ₁₄	PD ₆	D ₁₄	D ₁₄	D ₁₄	PD ₆
51	57	D ₁₅	D ₁₅	PD ₇	D ₁₅	D ₁₅	D ₁₅	PD ₇
52	58	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}
53	59	P3 ₀ /TxD0	P3 ₀ /TxD0	P3 ₀ /TxD0	P3 ₀ /TxD0	P3 ₀ /TxD0	P3 ₀ /TxD0	P3 ₀ /TxD0
54	60	P3 ₁ /TxD1	P3 ₁ /TxD1	P3 ₁ /TxD1	P3 ₁ /TxD1	P3 ₁ /TxD1	P3 ₁ /TxD1	P3 ₁ /TxD1
55	61	P3 ₂ /RxD0	P3 ₂ /RxD0	P3 ₂ /RxD0	P3 ₂ /RxD0	P3 ₂ /RxD0	P3 ₂ /RxD0	P3 ₂ /RxD0

56	62	P3 ₃ /RXD1	P3 ₃ /RXD1	P3 ₃ /RXD1	P3 ₃ /RXD1	P3 ₃ /RXD1	P3 ₃ /RXD1	P3 ₃ /RXD1
57	63	P3 ₄ /SCK0	P3 ₄ /SCK0	P3 ₄ /SCK0	P3 ₄ /SCK0	P3 ₄ /SCK0	P3 ₄ /SCK0	P3 ₄ /SCK0
58	64	P3 ₅ /SCK1	P3 ₅ /SCK1	P3 ₅ /SCK1	P3 ₅ /SCK1	P3 ₅ /SCK1	P3 ₅ /SCK1	P3 ₅ /SCK1
59	65	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
60	66	P6 ₀ / DREQ0	P6 ₀ / DREQ0	P6 ₀ / DREQ0	P6 ₀ / DREQ0/ CS4	P6 ₀ / DREQ0/ CS4	P6 ₀ / DREQ0/ CS4	P6 ₀ / DREQ0
—	67	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
—	68	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
61	69	P6 ₁ / TEND0	P6 ₁ / TEND0	P6 ₁ / TEND0	P6 ₁ / TEND0/ CS5	P6 ₁ / TEND0/ CS5	P6 ₁ / TEND0/ CS5	P6 ₁ / TEND0
62	70	P6 ₂ / DREQ1	P6 ₂ / DREQ1	P6 ₂ / DREQ1	P6 ₂ / DREQ1	P6 ₂ / DREQ1	P6 ₂ / DREQ1	P6 ₂ / DREQ1
63	71	P6 ₃ / TEND1	P6 ₃ / TEND1	P6 ₃ / TEND1	P6 ₃ / TEND1	P6 ₃ / TEND1	P6 ₃ / TEND1	P6 ₃ / TEND1
64	72	P2 ₇ /PO7/ TIOCB5	P2 ₇ /PO7/ TIOCB5	P2 ₇ /PO7/ TIOCB5	P2 ₇ /PO7/ TIOCB5	P2 ₇ /PO7/ TIOCB5	P2 ₇ /PO7/ TIOCB5	P2 ₇ /PO7/ TIOCB5
65	73	P2 ₆ /PO6/ TIOCA5	P2 ₆ /PO6/ TIOCA5	P2 ₆ /PO6/ TIOCA5	P2 ₆ /PO6/ TIOCA5	P2 ₆ /PO6/ TIOCA5	P2 ₆ /PO6/ TIOCA5	P2 ₆ /PO6/ TIOCA5
66	74	P2 ₅ /PO5/ TIOCB4	P2 ₅ /PO5/ TIOCB4	P2 ₅ /PO5/ TIOCB4	P2 ₅ /PO5/ TIOCB4	P2 ₅ /PO5/ TIOCB4	P2 ₅ /PO5/ TIOCB4	P2 ₅ /PO5/ TIOCB4
67	75	P2 ₄ /PO4/ TIOCA4	P2 ₄ /PO4/ TIOCA4	P2 ₄ /PO4/ TIOCA4	P2 ₄ /PO4/ TIOCA4	P2 ₄ /PO4/ TIOCA4	P2 ₄ /PO4/ TIOCA4	P2 ₄ /PO4/ TIOCA4
68	76	P2 ₃ /PO3/ TIOCD3	P2 ₃ /PO3/ TIOCD3	P2 ₃ /PO3/ TIOCD3	P2 ₃ /PO3/ TIOCD3	P2 ₃ /PO3/ TIOCD3	P2 ₃ /PO3/ TIOCD3	P2 ₃ /PO3/ TIOCD3
69	77	P2 ₂ /PO2/ TIOCC3	P2 ₂ /PO2/ TIOCC3	P2 ₂ /PO2/ TIOCC3	P2 ₂ /PO2/ TIOCC3	P2 ₂ /PO2/ TIOCC3	P2 ₂ /PO2/ TIOCC3	P2 ₂ /PO2/ TIOCC3
70	78	P2 ₁ /PO1/ TIOCB3	P2 ₁ /PO1/ TIOCB3	P2 ₁ /PO1/ TIOCB3	P2 ₁ /PO1/ TIOCB3	P2 ₁ /PO1/ TIOCB3	P2 ₁ /PO1/ TIOCB3	P2 ₁ /PO1/ TIOCB3
71	79	P2 ₀ /PO0/ TIOCA3	P2 ₀ /PO0/ TIOCA3	P2 ₀ /PO0/ TIOCA3	P2 ₀ /PO0/ TIOCA3	P2 ₀ /PO0/ TIOCA3	P2 ₀ /PO0/ TIOCA3	P2 ₀ /PO0/ TIOCA3
72	80	WDTOVF	WDTOVF	WDTOVF	WDTOVF	WDTOVF	WDTOVF	WDTOVF
73	81	$\overline{\text{RES}}$	RES	$\overline{\text{RES}}$	RES	$\overline{\text{RES}}$	RES	$\overline{\text{RES}}$
74	82	NMI	NMI	NMI	NMI	NMI	NMI	NMI

75	83	STBY	STBY	STBY	STBY	STBY	STBY	STBY
76	84	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}
77	85	XTAL	XTAL	XTAL	XTAL	XTAL	XTAL	XTAL
78	86	EXTAL	EXTAL	EXTAL	EXTAL	EXTAL	EXTAL	EXTAL
79	87	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
80	88	PF ₇ /∅	PF ₇ /∅	PF ₇ /∅	PF ₇ /∅	PF ₇ /∅	PF ₇ /∅	PF ₇ /∅
81	89	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}
82	90	\overline{AS}	\overline{AS}	PF ₆	\overline{AS}	\overline{AS}	\overline{AS}	PF ₆
83	91	\overline{RD}	\overline{RD}	PF ₅	\overline{RD}	\overline{RD}	\overline{RD}	PF ₅
84	92	\overline{HWR}	\overline{HWR}	PF ₄	\overline{HWR}	\overline{HWR}	\overline{HWR}	PF ₄
85	93	\overline{LWR}	\overline{LWR}	PF ₃	\overline{LWR}	\overline{LWR}	\overline{LWR}	PF ₃
86	94	PF ₂ /WAIT/ BREQO	PF ₂ /WAIT/ BREQO	PF ₂	PF ₂ /LCAS/ WAIT/ BREQO	PF ₂ /LCAS/ WAIT/ BREQO	PF ₂ /LCAS/ WAIT/ BREQO	PF ₂
87	95	PF ₁ /BACK	PF ₁ /BACK	PF ₁	PF ₁ /BACK	PF ₁ /BACK	PF ₁ /BACK	PF ₁
88	96	PF ₀ /BREQ	PF ₀ /BREQ	PF ₀	PF ₀ /BREQ	PF ₀ /BREQ	PF ₀ /BREQ	PF ₀
89	97	P5 ₀	P5 ₀	P5 ₀	P5 ₀	P5 ₀	P5 ₀	P5 ₀
90	98	P5 ₁	P5 ₁	P5 ₁	P5 ₁	P5 ₁	P5 ₁	P5 ₁
—	99	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
—	100	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
91	101	P5 ₂	P5 ₂	P5 ₂	P5 ₂	P5 ₂	P5 ₂	P5 ₂
92	102	P5 ₃ / \overline{ADTRG}	P5 ₃ / \overline{ADTRG}	P5 ₃ / \overline{ADTRG}	P5 ₃ / \overline{ADTRG}	P5 ₃ / \overline{ADTRG}	P5 ₃ / \overline{ADTRG}	P5 ₃ / \overline{ADTRG}
93	103	AV _{CC}	AV _{CC}	AV _{CC}	AV _{CC}	AV _{CC}	AV _{CC}	AV _{CC}
94	104	V _{ref}	V _{ref}	V _{ref}	V _{ref}	V _{ref}	V _{ref}	V _{ref}
95	105	P4 ₀ /AN0	P4 ₀ /AN0	P4 ₀ /AN0	P4 ₀ /AN0	P4 ₀ /AN0	P4 ₀ /AN0	P4 ₀ /AN0
96	106	P4 ₁ /AN1	P4 ₁ /AN1	P4 ₁ /AN1	P4 ₁ /AN1	P4 ₁ /AN1	P4 ₁ /AN1	P4 ₁ /AN1
97	107	P4 ₂ /AN2	P4 ₂ /AN2	P4 ₂ /AN2	P4 ₂ /AN2	P4 ₂ /AN2	P4 ₂ /AN2	P4 ₂ /AN2
98	108	P4 ₃ /AN3	P4 ₃ /AN3	P4 ₃ /AN3	P4 ₃ /AN3	P4 ₃ /AN3	P4 ₃ /AN3	P4 ₃ /AN3
99	109	P4 ₄ /AN4	P4 ₄ /AN4	P4 ₄ /AN4	P4 ₄ /AN4	P4 ₄ /AN4	P4 ₄ /AN4	P4 ₄ /AN4
100	110	P4 ₅ /AN5	P4 ₅ /AN5	P4 ₅ /AN5	P4 ₅ /AN5	P4 ₅ /AN5	P4 ₅ /AN5	P4 ₅ /AN5
101	111	P4 ₆ /AN6/ DA0	P4 ₆ /AN6/ DA0	P4 ₆ /AN6/ DA0	P4 ₆ /AN6/ DA0	P4 ₆ /AN6/ DA0	P4 ₆ /AN6/ DA0	P4 ₆ /AN6/ DA0

102	112	P ₄₇ /AN ₇ /DA1	P ₄₇ /AN ₇ /DA1	P ₄₇ /AN ₇ /DA1	P ₄₇ /AN ₇ /DA1	P ₄₇ /AN ₇ /DA1	P ₄₇ /AN ₇ /DA1	P ₄₇ /AN ₇ /DA1
103	113	AV _{SS}	AV _{SS}	AV _{SS}	AV _{SS}	AV _{SS}	AV _{SS}	AV _{SS}
104	114	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
105	115	P ₁₇ /PO15/ TIOCB2/ TCLKD	P ₁₇ /PO15/ TIOCB2/ TCLKD	P ₁₇ /PO15/ TIOCB2/ TCLKD	P ₁₇ /PO15/ TIOCB2/ TCLKD	P ₁₇ /PO15/ TIOCB2/ TCLKD	P ₁₇ /PO15/ TIOCB2/ TCLKD	P ₁₇ /PO15/ TIOCB2/ TCLKD
106	116	P ₁₆ /PO14/ TIOCA2	P ₁₆ /PO14/ TIOCA2	P ₁₆ /PO14/ TIOCA2	P ₁₆ /PO14/ TIOCA2	P ₁₆ /PO14/ TIOCA2	P ₁₆ /PO14/ TIOCA2	P ₁₆ /PO14/ TIOCA2
107	117	P ₁₅ /PO13/ TIOCB1/ TCLKC	P ₁₅ /PO13/ TIOCB1/ TCLKC	P ₁₅ /PO13/ TIOCB1/ TCLKC	P ₁₅ /PO13/ TIOCB1/ TCLKC	P ₁₅ /PO13/ TIOCB1/ TCLKC	P ₁₅ /PO13/ TIOCB1/ TCLKC	P ₁₅ /PO13/ TIOCB1/ TCLKC
108	118	P ₁₄ /PO12/ TIOCA1	P ₁₄ /PO12/ TIOCA1	P ₁₄ /PO12/ TIOCA1	P ₁₄ /PO12/ TIOCA1	P ₁₄ /PO12/ TIOCA1	P ₁₄ /PO12/ TIOCA1	P ₁₄ /PO12/ TIOCA1
109	119	P ₁₃ /PO11/ TIOCD0/ TCLKB	P ₁₃ /PO11/ TIOCD0/ TCLKB	P ₁₃ /PO11/ TIOCD0/ TCLKB	P ₁₃ /PO11/ TIOCD0/ TCLKB	P ₁₃ /PO11/ TIOCD0/ TCLKB	P ₁₃ /PO11/ TIOCD0/ TCLKB	P ₁₃ /PO11/ TIOCD0/ TCLKB
110	120	P ₁₂ /PO10/ TIOCC0/ TCLKA	P ₁₂ /PO10/ TIOCC0/ TCLKA	P ₁₂ /PO10/ TIOCC0/ TCLKA	P ₁₂ /PO10/ TIOCC0/ TCLKA	P ₁₂ /PO10/ TIOCC0/ TCLKA	P ₁₂ /PO10/ TIOCC0/ TCLKA	P ₁₂ /PO10/ TIOCC0/ TCLKA
111	121	P ₁₁ /PO9/ TIOCB0/ DACK1	P ₁₁ /PO9/ TIOCB0/ DACK1	P ₁₁ /PO9/ TIOCB0/ DACK1	P ₁₁ /PO9/ TIOCB0/ DACK1	P ₁₁ /PO9/ TIOCB0/ DACK1	P ₁₁ /PO9/ TIOCB0/ DACK1	P ₁₁ /PO9/ TIOCB0/ DACK1
112	122	P ₁₀ /PO8/ TIOCA0/ DACK0	P ₁₀ /PO8/ TIOCA0/ DACK0	P ₁₀ /PO8/ TIOCA0/ DACK0	P ₁₀ /PO8/ TIOCA0/ DACK0	P ₁₀ /PO8/ TIOCA0/ DACK0	P ₁₀ /PO8/ TIOCA0/ DACK0	P ₁₀ /PO8/ TIOCA0/ DACK0
113	123	MD ₀	MD ₀	MD ₀	MD ₀	MD ₀	MD ₀	MD ₀
114	124	MD ₁	MD ₁	MD ₁	MD ₁	MD ₁	MD ₁	MD ₁
115	125	MD ₂	MD ₂	MD ₂	MD ₂	MD ₂	MD ₂	MD ₂
116	126	PG ₀	PG ₀	PG ₀	PG ₀ /CAS	PG ₀ /CAS	PG ₀ /CAS	PG ₀
117	127	PG ₁	PG ₁	PG ₁	PG ₁ /CS3	PG ₁ /CS3	PG ₁ /CS3	PG ₁
118	128	PG ₂	PG ₂	PG ₂	PG ₂ /CS2	PG ₂ /CS2	PG ₂ /CS2	PG ₂
119	1	PG ₃	PG ₃	PG ₃	PG ₃ /CS1	PG ₃ /CS1	PG ₃ /CS1	PG ₃
120	2	PG ₄ /CS0	PG ₄ /CS0	PG ₄	PG ₄ /CS0	PG ₄ /CS0	PG ₄ /CS0	PG ₄
—	3	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}	V _{SS}
—	4	NC	NC	NC	NC	NC	NC	NC

Note: NC pins should be connected to V_{SS} or left open.

* Only applies to the H8S/2351.

Table 1-5 Pin Functions

Type	Symbol	Pin No.		I/O	Name and Function
		TFP-120	FP-128		
Power	V _{CC}	1, 33, 52, 76, 81	5, 39, 58, 84, 89	Input	Power supply: For connection to the power supply. All V _{CC} pins should be connected to the system power supply.
	V _{SS}	6, 15, 24, 38, 47, 59, 79, 104	3, 10, 19, 28, 35, 36, 44, 53, 65, 67, 68, 87, 99, 100, 114	Input	Ground: For connection to ground (0 V). All V _{SS} pins should be connected to the system power supply (0 V).
Clock	XTAL	77	85	Input	Connects to a crystal oscillator. See section 19, Clock Pulse Generator, for typical connection diagrams for a crystal oscillator and external clock input.
	EXTAL	78	86	Input	Connects to a crystal oscillator. The EXTAL pin can also input an external clock. See section 19, Clock Pulse Generator, for typical connection diagrams for a crystal oscillator and external clock input.
	∅	80	88	Output	System clock: Supplies the system clock to an external device.

Operating mode control	MD ₂ to MD ₀	113 to 113	123 to 123	Input	Mode pins. These pins set the operating mode. The relation between the settings of pins MD ₂ to MD ₀ and the operating mode is shown below. These pins should not be changed while the H8S/2350 Series is operating.																																				
					<table border="1"> <thead> <tr> <th>MD2</th> <th>MD1</th> <th>MD0</th> <th>Operating Mode</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>0</td> <td>0</td> <td>—</td> </tr> <tr> <td></td> <td></td> <td>1</td> <td>Mode 1</td> </tr> <tr> <td></td> <td>1</td> <td>0</td> <td>Mode 2*</td> </tr> <tr> <td></td> <td></td> <td>1</td> <td>Mode 3*</td> </tr> <tr> <td>1</td> <td>0</td> <td>0</td> <td>Mode 4</td> </tr> <tr> <td></td> <td></td> <td>1</td> <td>Mode 5</td> </tr> <tr> <td></td> <td>1</td> <td>0</td> <td>Mode 6*</td> </tr> <tr> <td></td> <td></td> <td>1</td> <td>Mode 7*</td> </tr> </tbody> </table>	MD2	MD1	MD0	Operating Mode	0	0	0	—			1	Mode 1		1	0	Mode 2*			1	Mode 3*	1	0	0	Mode 4			1	Mode 5		1	0	Mode 6*			1	Mode 7*
MD2	MD1	MD0	Operating Mode																																						
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	1	0	Mode 6*																																						
		1	Mode 7*																																						
Note: * Only applies to the H8S/2351.																																									

System control	$\overline{\text{RES}}$	73	81	Input	Reset input: When this pin is driven low, the chip is reset. The type of reset can be selected according to the NMI input level. At power-on, the NMI pin input level should be set high.
	$\overline{\text{STBY}}$	75	83	Input	Standby: When this pin is driven low, a transition is made to hardware standby mode.
	$\overline{\text{BREQ}}$	88	96	Input	Bus request: Used by an external bus master to issue a bus request to the H8S/2350 Series.
	$\overline{\text{BREQO}}$	86	94	Output	Bus request output: The external bus request signal used when an internal bus master accesses external space in the external bus-released state.
	$\overline{\text{BACK}}$	87	95	Output	Bus request acknowledge: Indicates that the bus has been released to an external bus master.

Interrupts	NMI	74	82	Input	Nonmaskable interrupt. Requests a nonmaskable interrupt. When this pin is not used, it should be fixed high.
	$\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$	28 to 25, 29 to 32	32 to 29, 33, 34, 37, 38	Input	Interrupt request 7 to 0: These pins request a maskable interrupt.
Address bus	A_{23} to A_0	28 to 25, 23 to 16, 14 to 7, 5 to 2	32 to 29, 27 to 20, 18 to 11, 9 to 6	Output	Address bus: These pins output an address.
Data bus	D_{15} to D_0	51 to 48, 46 to 39, 37 to 34	57 to 54, 52 to 45, 43 to 40	I/O	Data bus: These pins constitute a bidirectional data bus.
Bus control	$\overline{\text{CS7}}$ to $\overline{\text{CS0}}$	29, 30, 61, 60, 117 to 120	33, 34, 69, 66, 127, 128, 1, 2	Output	Chip select: Signals for selecting areas 7 to 0.
	$\overline{\text{AS}}$	82	90	Output	Address strobe: When this pin is low, it indicates that address output on the address bus is enabled.
	$\overline{\text{RD}}$	83	91	Output	Read: When this pin is low, it indicates that the external address space can be read.
	$\overline{\text{HWR}}$	84	92	Output	High write/write enable: A strobe signal that writes to external space and indicates that the upper half (D_{15} to D_8) of the data bus is enabled. The 2CAS type DRAM write enable signal.
	$\overline{\text{LWR}}$	85	93	Output	Low write: A strobe signal that writes to external space and indicates that the lower half (D_7 to D_0) of the data bus is enabled.
	$\overline{\text{CAS}}$	116	126	Output	Upper column address strobe/column address strobe: The 2CAS type DRAM upper column address strobe signal.

Bus control	WAIT	88	94	Input	wait. Requests insertion of a wait state in the bus cycle when accessing external 3-state address space.
	LCAS	86	94	Output	Lower column address strobe: The 2-CAS type DRAM lower column address strobe signal
DMA controller (DMAC)	DREQ1, DREQ0	62, 60	70, 66	Input	DMA request 1 and 0: These pins request DMAC activation.
	TEND1, TEND0	63, 61	71, 69	Output	DMA transfer end 1 and 0: These pins indicate the end of DMAC data transfer.
	DACK1, DACK0	111, 112	121, 122	Output	DMA transfer acknowledge 1 and 0: These are the DMAC single address transfer acknowledge pins.
16-bit timer-pulse unit (TPU)	TCLKD to TCLKA	105, 107, 109, 110	115, 117, 119, 120	Input	Clock input D to A: These pins input an external clock.
	TIOCA0, TIOCB0, TIOCC0, TIOCD0	112 to 109	122 to 119	I/O	Input capture/ output compare match A0 to D0: The TGR0A to TGR0D input capture input or output compare output, or PWM output pins.
	TIOCA1, TIOCB1	108, 107	118, 117	I/O	Input capture/ output compare match A1 and B1: The TGR1A and TGR1B input capture input or output compare output, or PWM output pins.
	TIOCA2, TIOCB2	106, 105	116, 115	I/O	Input capture/ output compare match A2 and B2: The TGR2A and TGR2B input capture input or output compare output, or PWM output pins.
	TIOCA3, TIOCB3, TIOCC3, TIOCD3	71 to 68	79 to 76	I/O	Input capture/ output compare match A3 to D3: The TGR3A to TGR3D input capture input or output compare output, or PWM output pins.

16-bit timer-pulse unit (TPU)	TIOCA4, TIOCB4	67, 68	73, 74	I/O	Input capture/ output compare match A4 and B4: The TGR4A and TGR4B input capture input or output compare output, or PWM output pins.
	TIOCA5, TIOCB5	65, 64	73, 72	I/O	Input capture/ output compare match A5 and B5: The TGR5A and TGR5B input capture input or output compare output, or PWM output pins.
Programmable pulse generator (PPG)	PO15 to PO0	105 to 112, 64 to 71	115 to 122, 72 to 79	Output	Pulse output 15 to 0: Pulse output pins.
Watchdog timer (WDT)	WDTOVF	72	80	Output	Watchdog timer overflows: The counter overflows signal output pin in watchdog timer mode.
Serial communication interface (SCI) Smart Card interface	TxD1, TxD0	54, 53	60, 59	Output	Transmit data (channel 0, 1): Data output pins.
	RxD1, RxD0	56, 55	62, 61	Input	Receive data (channel 0, 1): Data input pins.
	SCK1, SCK0	58, 57	64, 63	I/O	Serial clock (channel 0, 1): Clock I/O pins.
A/D converter	AN7 to AN0	102 to 95	112 to 105	Input	Analog 7 to 0: Analog input pins.
	ADTRG	92	102	Input	A/D conversion external trigger input: Pin for input of an external trigger to start A/D conversion.
D/A converter	DA1, DA0	102, 101	112, 111	Output	Analog output: D/A converter analog output pins.

A/D converter and D/A converter	AV _{CC}	93	103	Input	This is the power supply pin for the A/D converter and D/A converter. When the A/D converter and D/A converter are not used, this pin should be connected to the system power supply (+5 V).
	AV _{SS}	103	113	Input	This is the ground pin for the A/D converter and D/A converter. This pin should be connected to the system power supply (0 V).
	V _{ref}	94	104	Input	This is the reference voltage input pin for the A/D converter and D/A converter. When the A/D converter and D/A converter are not used, this pin should be connected to the system power supply (+5 V).
I/O ports	P1 ₇ to P1 ₀	105 to 112	115 to 122	I/O	Port 1: An 8-bit I/O port. Input or output can be designated for each bit by means of the port 1 data direction register (P1DDR).
	P2 ₇ to P2 ₀	64 to 71	72 to 79	I/O	Port 2: An 8-bit I/O port. Input or output can be designated for each bit by means of the port 2 data direction register (P2DDR).
	P3 ₅ to P3 ₀	58 to 53	64 to 59	I/O	Port 3: A 6-bit I/O port. Input or output can be designated for each bit by means of the port 3 data direction register (P3DDR).
	P4 ₇ to P4 ₀	102 to 95	112 to 105	Input	Port 4: An 8-bit input port.
	P5 ₃ to P5 ₀	92 to 89	102, 101, 98, 97	I/O	Port 5: A 4-bit I/O port. Input or output can be designated for each bit by means of the port 5 data direction register (P5DDR).

I/O ports

PF ₇ to PF ₀	29 to 32, 63 to 60	33, 34, 37, 38, 71 to 69, 66	I/O	Port G: An 8-bit I/O port. Input or output can be designated for each bit by means of the port G data direction register (PGDDR).
PA ₇ to PA ₀	28 to 25, 23 to 20	32 to 29, 27 to 24	I/O	Port A: An 8-bit I/O port. Input or output can be designated for each bit by means of the port A data direction register (PADDDR).
PB ₇ to PB ₀	19 to 16, 14 to 11	23 to 20, 18 to 15	I/O	Port B*: An 8-bit I/O port. Input or output can be designated for each bit by means of the port B data direction register (PBDDR).
PC ₇ to PC ₀	10 to 7, 5 to 2	14 to 11, 9 to 6	I/O	Port C*: An 8-bit I/O port. Input or output can be designated for each bit by means of the port C data direction register (PCDDR).
PD ₇ to PD ₀	51 to 48, 46 to 43	57 to 54, 52 to 49	I/O	Port D*: An 8-bit I/O port. Input or output can be designated for each bit by means of the port D data direction register (PDDDR).
PE ₇ to PE ₀	42 to 39, 37 to 34	48 to 45, 43 to 40	I/O	Port E: An 8-bit I/O port. Input or output can be designated for each bit by means of the port E data direction register (PEDDDR).
PF ₇ to PF ₀	80, 82 to 88	88, 90 to 96	I/O	Port F: An 8-bit I/O port. Input or output can be designated for each bit by means of the port F data direction register (PFDDR).
PG ₄ to PG ₀	120 to 116	2, 1, 128 to 126	I/O	Port G: A 5-bit I/O port. Input or output can be designated for each bit by means of the port G data direction register (PGDDR).

Note: * Only applies to the H8S/2351.

The H8S/2000 CPU is a high-speed central processing unit with an internal 32-bit architecture that is upward-compatible with the H8/300 and H8/300H CPUs. The H8S/2000 CPU has sixteen 16-bit general registers, can address a 16-Mbyte (architecturally 4-Gbyte) linear address space, and is ideal for realtime control.

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)

- 8×8 -bit register-register multiply : 600 ns
- $16 \div 8$ -bit register-register divide : 600 ns
- 16×16 -bit register-register multiply : 1000 ns
- $32 \div 16$ -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 as shown below.

- Register configuration

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

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

The number of execution states of the MULXU and MULXS instructions.

Instruction	Mnemonic	Internal Operation	
		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, CCR and EXR functions, power-down state, etc., depending on the product.

- Eight 16-bit expanded registers, and one 8-bit control register, have been added.
- Expanded address space
 - Normal mode supports the same 64-kbyte address space as the H8/300 CPU.
 - Advanced mode supports a maximum 16-Mbyte address space.
- Enhanced addressing
 - The addressing modes have been enhanced to make effective use of the 16-Mbyte address space.
- Enhanced instructions
 - Addressing modes of bit-manipulation instructions have been enhanced.
 - Signed multiply and divide instructions have been added.
 - Two-bit shift 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.

program and data areas combined). The mode is selected by the mode pins of the microcontroller.

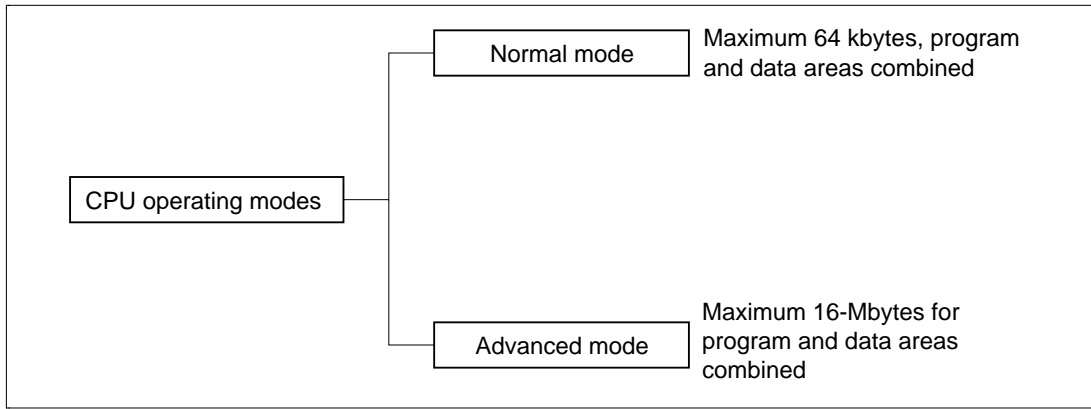


Figure 2-1 CPU Operating Modes

(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. If the general register is referenced in the register indirect addressing mode with pre-decrement (@-Rn) or post-increment (@Rn+) and a carry or borrow occurs, however, the value in the corresponding extended register (En) will be affected.

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

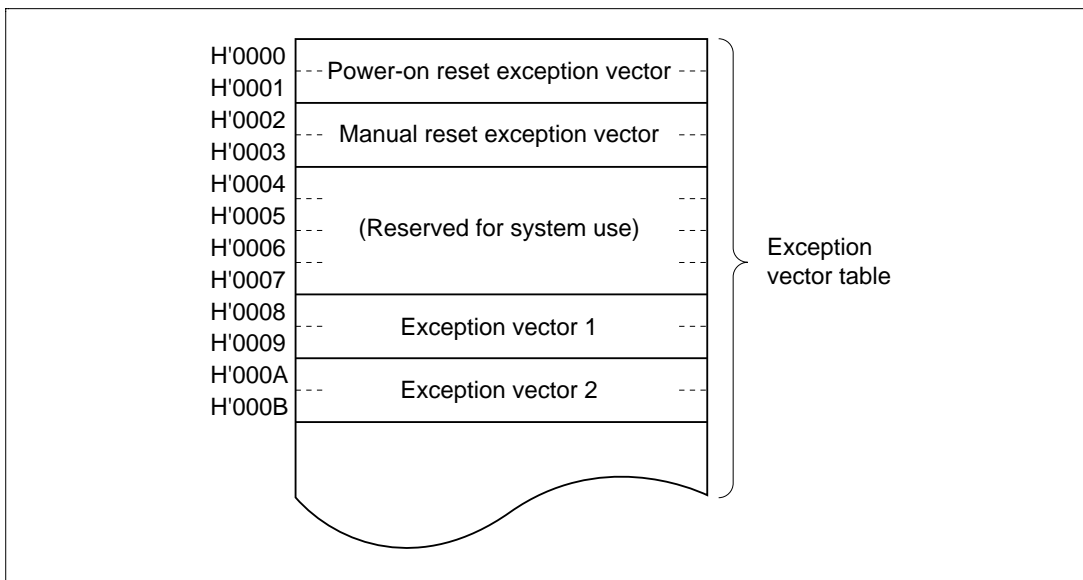


Figure 2-2 Exception Vector Table (Normal Mode)

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

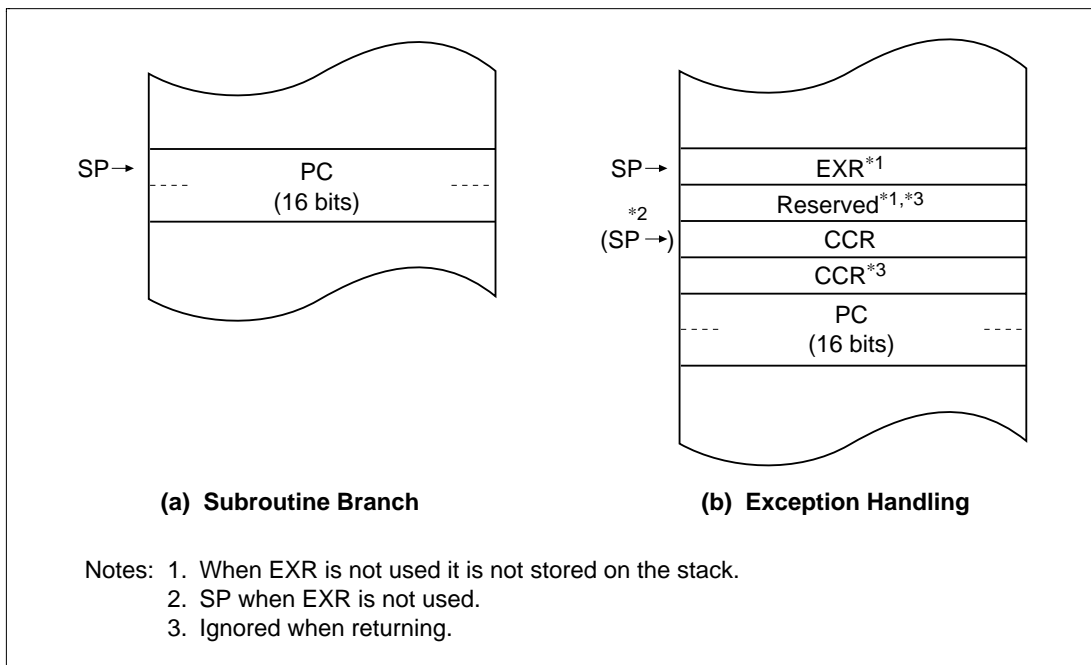


Figure 2-3 Stack Structure in Normal Mode

(2) Advanced Mode

Address Space: Linear access is provided to a 16-Mbyte maximum address space (architecturally 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.

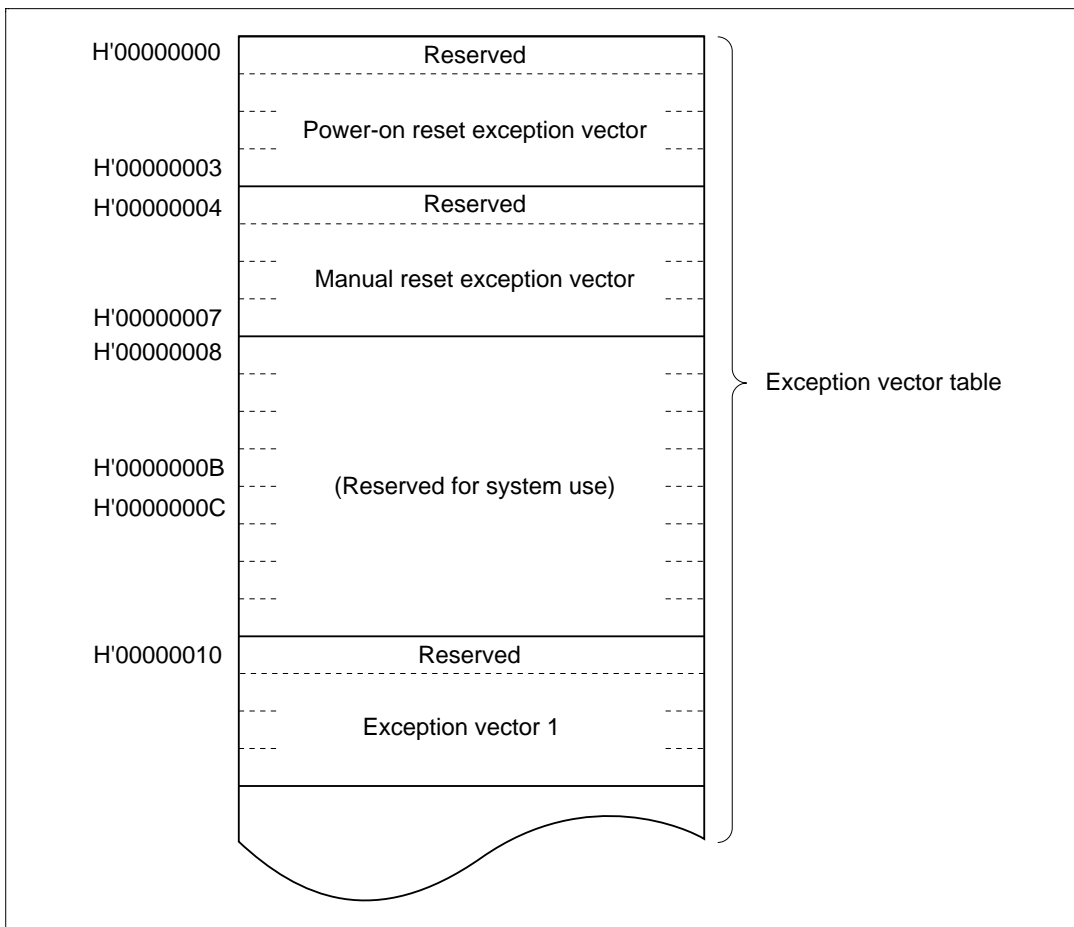
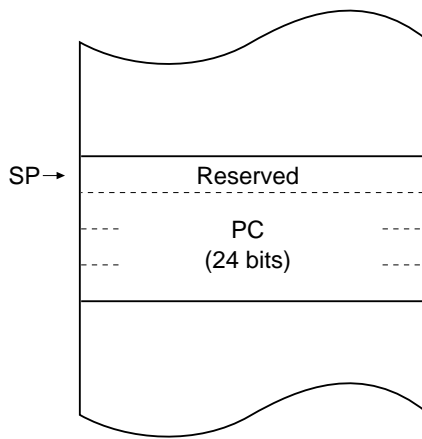
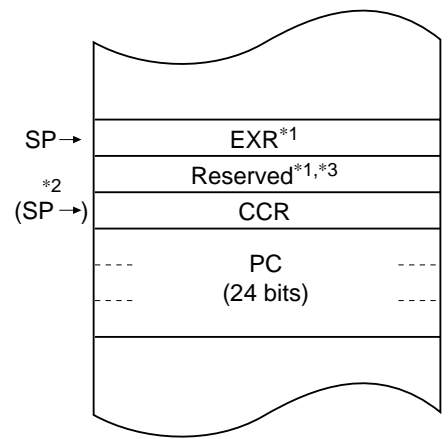


Figure 2-4 Exception Vector Table (Advanced Mode)

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



(a) Subroutine Branch



(b) Exception Handling

- Notes:
1. When EXR is not used it is not stored on the stack.
 2. SP when EXR is not used.
 3. Ignored when returning.

Figure 2-5 Stack Structure in Advanced Mode

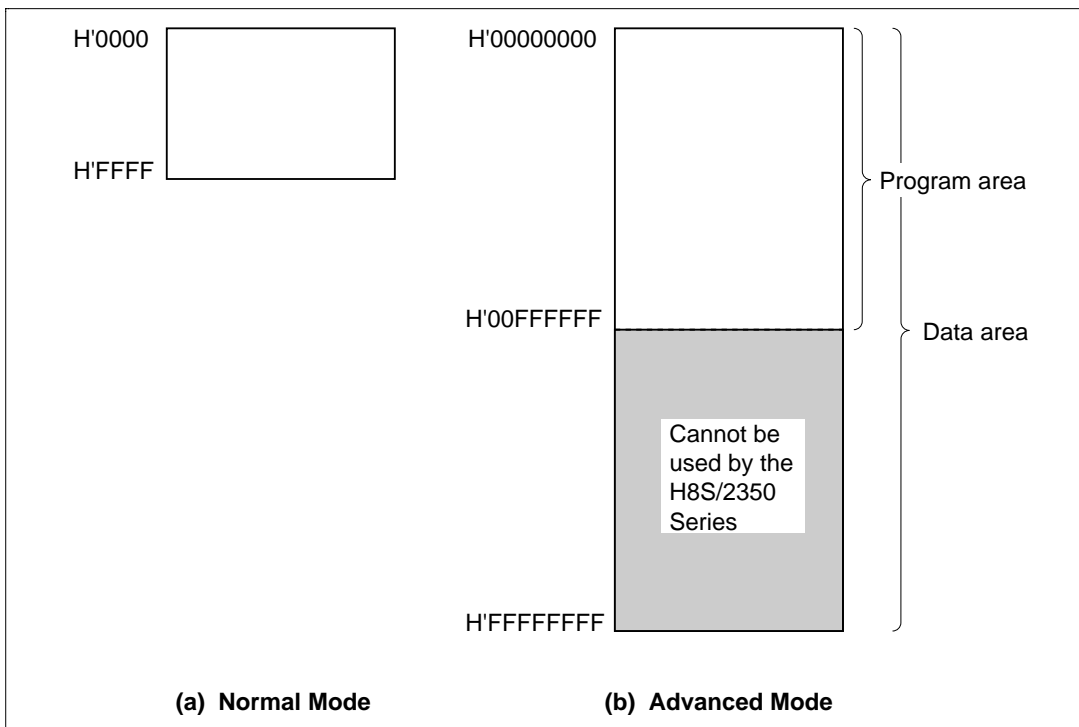


Figure 2-6 Memory Map

The CPU has the internal registers shown in figure 2-7. There are two types of registers: general registers and control registers.

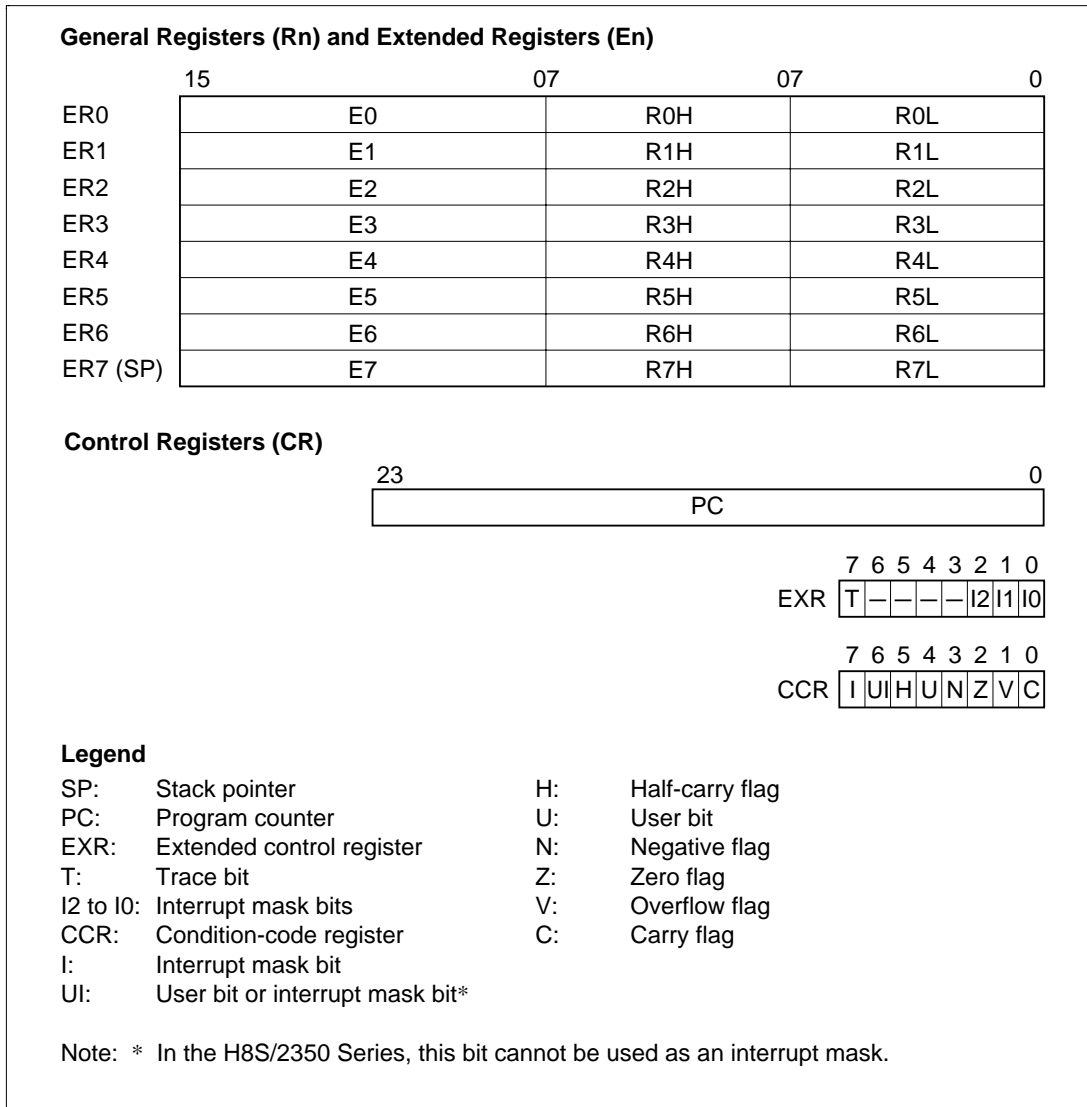


Figure 2-7 CPU Registers

as 32-bit registers or address registers, they are designated by the letters ER (ER0 to ER7).

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

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

Figure 2-8 illustrates the usage of the general registers. The usage of each register can be selected independently.

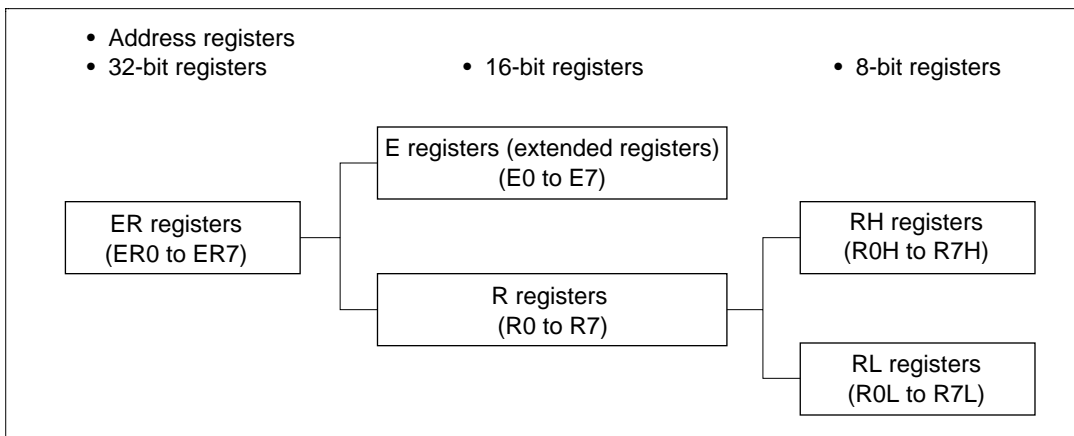


Figure 2-8 Usage of General Registers

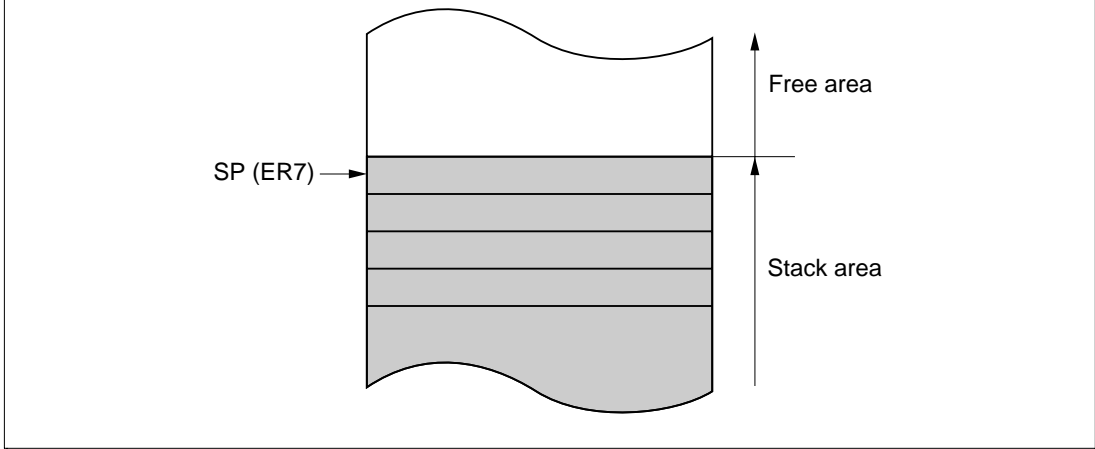


Figure 2-9 Stack

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 length of all CPU instructions is 2 bytes (one word), so the least significant PC bit is ignored. (When an instruction is fetched, the least significant PC bit is regarded as 0.)

(2) Extended Control Register (EXR): This 8-bit register contains the trace bit (T) and three interrupt mask bits (I2 to I0).

Bit 7—Trace Bit (T): Selects trace mode. When this bit is cleared to 0, instructions are executed in sequence. When this bit is set to 1, a trace exception is generated each time an instruction is executed.

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

instructions is executed, except for STC.

(3) Condition-Code Register (CCR): This 8-bit register contains internal CPU status information, including an interrupt mask bit (I) and half-carry (H), negative (N), zero (Z), overflow (V), and carry (C) flags.

Bit 7—Interrupt Mask Bit (I): Masks interrupts other than NMI when set to 1. (NMI is accepted regardless of the I bit setting.) The I bit is set to 1 by hardware at the start of an exception-handling sequence. For details, refer to section 5, Interrupt Controller.

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. With the H8S/2350 Series, this bit cannot be used as an interrupt mask bit.

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

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 at other times.

Bit 0—Carry Flag (C): Set to 1 when a carry occurs, and cleared to 0 otherwise. Used by:

- Add instructions, to indicate a carry
- Subtract instructions, to indicate a borrow
- Shift and rotate instructions, to store the value shifted out of the end bit

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

(Bcc) instructions.

2.4.4 Initial Register Values

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

2.5.1 General Register Data Formats

Figure 2-10 shows the data formats in general registers.

Data Type	Register Number	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

bit of the address is regarded as 0, so the access starts at the preceding address. This also applies to instruction fetches.

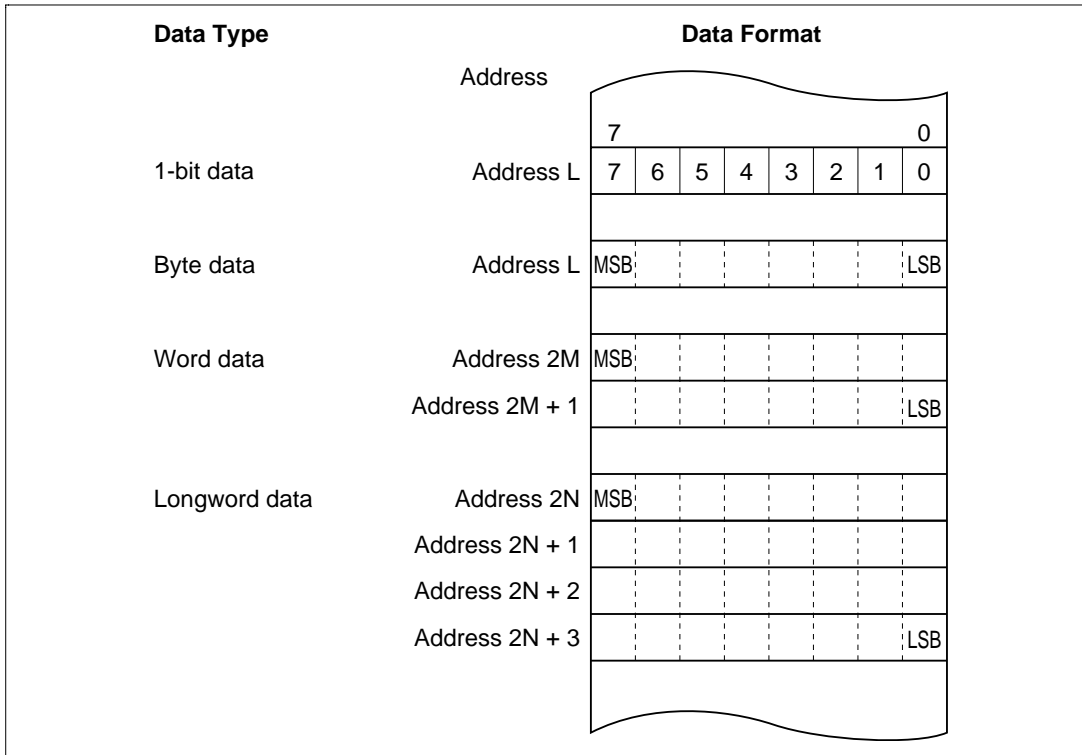


Figure 2-11 Memory Data Formats

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

The H8S/2000 CPU has 65 types of instructions. The instructions are classified by function in table 2-1.

Table 2-1 Instruction Classification

Function	Instructions	Size	Types
Data transfer	MOV	BWL	5
	POP* ¹ , PUSH* ¹	WL	
	LDM, STM	L	
	MOVFP, MOVTP ^{*3}	B	
Arithmetic operations	ADD, SUB, CMP, NEG	BWL	19
	ADDX, SUBX, DAA, DAS	B	
	INC, DEC	BWL	
	ADDS, SUBS	L	
	MULXU, DIVXU, MULXS, DIVXS	BW	
	EXTU, EXTS	WL	
	TAS	B	
Logic operations	AND, OR, XOR, NOT	BWL	4
Shift	SHAL, SHAR, SHLL, SHLR, ROTL, ROTR, ROTXL, ROTXR	BWL	8
Bit manipulation	BSET, BCLR, BNOT, BTST, BLD, BILD, BST, BIST, BAND, BIAN, BOR, BIOR, BXOR, BIXOR	B	14
Branch	Bcc* ² , JMP, BSR, JSR, RTS	—	5
System control	TRAPA, RTE, SLEEP, LDC, STC, ANDC, ORC, XORC, NOP	—	9
Block data transfer	EEPMOV	—	1

Notes: B-byte size; W-word size; L-longword size.

1. POP.W Rn and PUSH.W Rn are identical to MOV.W @SP+, Rn and MOV.W Rn, @-SP. POP.L ERn and PUSH.L ERn are identical to MOV.L @SP+, ERn and MOV.L ERn, @-SP.
2. Bcc is the general name for conditional branch instructions.
3. Cannot be used in the H8S/2350 Series.

Table 2-2 Combinations of Instructions and Addressing Modes

Function	Instruction	Addressing Modes														
		#xx	Rn	@ ERn	@(d:16,ERn)	@(d:32,ERn)	@-ERn@ERn+	@aa:8	@aa:16	@aa:24	@aa:32	@(d:8,PC)	@(d:16,PC)	@aa:8	—	
Data transfer	MOV	BWL	BWL	BWL	BWL	BWL	BWL	B	BWL	—	—	—	—	—	—	—
	POP, PUSH	—	—	—	—	—	—	—	—	—	—	—	—	—	—	WL
	LDM, STM	—	—	—	—	—	—	—	—	—	—	—	—	—	—	L
	MOVFP, MOVTP*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
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	—	—	B	—	—	—	—	—	—	—	—	—	—	—	—

Note: * Cannot be used in the H8S/2350 Series.

Operation Notation

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

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

general register and memory, or moves immediate data to a general register.

MOVFP	B	Cannot be used in the H8S/2350 Series.
MOVTP	B	Cannot be used in the H8S/2350 Series.
POP	W/L	@SP+ → Rn Pops a register from the stack. POP.W Rn is identical to MOV.W @SP+, Rn. POP.L ERn is identical to MOV.L @SP+, ERn.
PUSH	W/L	Rn → @-SP Pushes a register onto the stack. PUSH.W Rn is identical to MOV.W Rn, @-SP. PUSH.L ERn is identical to MOV.L ERn, @-SP.
LDM	L	@SP+ → Rn (register list) Pops two or more general registers from the stack.
STM	L	Rn (register list) → @-SP Pushes two or more general registers onto the stack.

Note: * Size refers to the operand size.

B: Byte

W: Word

L: Longword

registers, or on immediate data and data in a general register. (Immediate byte data cannot be subtracted from byte data in a general register. Use the SUBX or ADD instruction.)

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

Note: * Size refers to the operand size.

- B: Byte
- W: Word
- L: Longword

registers: either 16 bits ÷ 8 bits → 8-bit quotient and 8-bit remainder or 32 bits ÷ 16 bits → 16-bit quotient and 16-bit remainder.

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

Note: * Size refers to the operand size.

B: Byte

W: Word

L: Longword

	OR	B/W/L	$Rd \vee Rs \rightarrow Rd$, $Rd \vee \#IMM \rightarrow Rd$ Performs a logical OR operation on a general register and another general register or immediate data.
	XOR	B/W/L	$Rd \oplus Rs \rightarrow Rd$, $Rd \oplus \#IMM \rightarrow Rd$ Performs a logical exclusive OR operation on a general register and another general register or immediate data.
	NOT	B/W/L	$\neg (Rd) \rightarrow (Rd)$ Takes the one's complement of general register contents.
Shift operations	SHAL SHAR	B/W/L	$Rd \text{ (shift)} \rightarrow Rd$ Performs an arithmetic shift on general register contents. 1-bit or 2-bit shift is possible.
	SHLL SHLR	B/W/L	$Rd \text{ (shift)} \rightarrow Rd$ Performs a logical shift on general register contents. 1-bit or 2-bit shift is possible.
	ROTL ROTR	B/W/L	$Rd \text{ (rotate)} \rightarrow Rd$ Rotates general register contents. 1-bit or 2-bit rotation is possible.
	ROTXL ROTXR	B/W/L	$Rd \text{ (rotate)} \rightarrow Rd$ Rotates general register contents through the carry flag. 1-bit or 2-bit rotation is possible.

Note: * Size refers to the operand size.

B: Byte
W: Word
L: Longword

operand to 1. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.

BCLR	B	$0 \rightarrow \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle$ Clears a specified bit in a general register or memory operand to 0. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BNOT	B	$\neg \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle \rightarrow \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle$ Inverts a specified bit in a general register or memory operand. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BTST	B	$\neg \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle \rightarrow Z$ Tests a specified bit in a general register or memory operand and sets or clears the Z flag accordingly. The bit number is specified by 3-bit immediate data or the lower three bits of a general register.
BAND	B	$C \wedge \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle \rightarrow C$ ANDs the carry flag with a specified bit in a general register or memory operand and stores the result in the carry flag.
BIAND	B	$C \wedge \neg \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle \rightarrow C$ ANDs the carry flag with the inverse of a specified bit in a general register or memory operand and stores the result in the carry flag. The bit number is specified by 3-bit immediate data.
BOR	B	$C \vee \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle \rightarrow C$ ORs the carry flag with a specified bit in a general register or memory operand and stores the result in the carry flag.
BIOR	B	$C \vee \neg \langle \text{bit-No.} \rangle \text{ of } \langle \text{EAd} \rangle \rightarrow C$ ORs the carry flag with the inverse of a specified bit in a general register or memory operand and stores the result in the carry flag. The bit number is specified by 3-bit immediate data.

Note: * Size refers to the operand size.

B: Byte

instructions

		general register or memory operand and stores the result in the carry flag.
BIXOR	B	$C \oplus \neg (\text{<bit-No.> of <EAd>}) \rightarrow C$ Exclusive-ORs the carry flag with the inverse of a specified bit in a general register or memory operand and stores the result in the carry flag. The bit number is specified by 3-bit immediate data.
BLD	B	$(\text{<bit-No.> of <EAd>}) \rightarrow C$ Transfers a specified bit in a general register or memory operand to the carry flag.
BILD	B	$\neg (\text{<bit-No.> of <EAd>}) \rightarrow C$ Transfers the inverse of a specified bit in a general register or memory operand to the carry flag. The bit number is specified by 3-bit immediate data.
BST	B	$C \rightarrow (\text{<bit-No.> of <EAd>})$ Transfers the carry flag value to a specified bit in a general register or memory operand.
BIST	B	$\neg C \rightarrow (\text{<bit-No.> of <EAd>})$ Transfers the inverse of the carry flag value to a specified bit in a general register or memory operand. The bit number is specified by 3-bit immediate data.

Note: * Size refers to the operand size.

B: Byte

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

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

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

Note: * Size refers to the operand size.

B: Byte

W: Word

instruction

EEPMOV.W	—	<p style="margin: 0;">R4L-1 → R4L Until R4L = 0 else next; if R4 ≠ 0 then Repeat @ER5+ → @ER6+ R4-1 → R4 Until R4 = 0 else next; Transfers a data block according to parameters set in general registers R4L or R4, ER5, and ER6. R4L or R4: size of block (bytes) ER5: starting source address ER6: starting destination address Execution of the next instruction begins as soon as the transfer is completed.</p>
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Figure 2-12 shows examples of instruction formats.

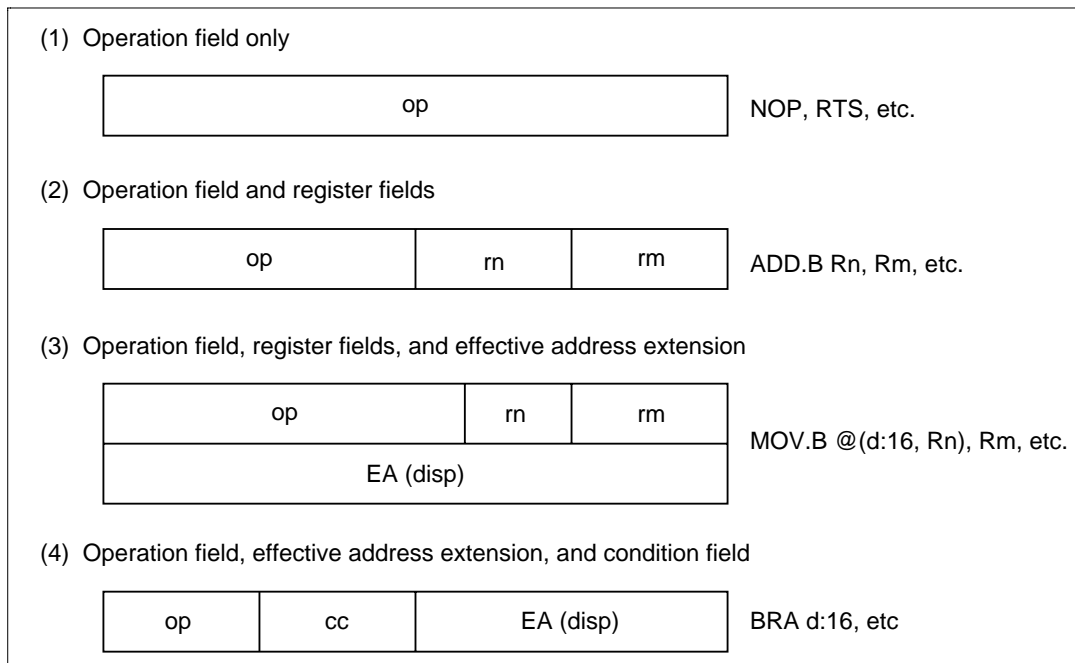


Figure 2-12 Instruction Formats (Examples)

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

(2) 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 field.

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

(4) Condition Field: Specifies the branching condition of Bcc instructions.

The CPU supports the eight addressing modes listed in table 2-4. Each instruction uses a subset of these addressing modes. Arithmetic and logic instructions can use the register direct and immediate modes. Data transfer instructions can use all addressing modes except program-counter relative and memory indirect. Bit manipulation instructions use register direct, register indirect, or absolute addressing mode to specify an operand, and register direct (BSET, BCLR, BNOT, and BTST instructions) or immediate (3-bit) addressing mode to specify a bit number in the operand.

Table 2-4 Addressing Modes

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

(1) Register Direct—Rn: The register field of the instruction specifies an 8-, 16-, or 32-bit general register containing the operand. R0H to R7H and R0L to R7L can be specified as 8-bit registers. R0 to R7 and E0 to E7 can be specified as 16-bit registers. ER0 to ER7 can be specified as 32-bit registers.

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

(3) Register Indirect with Displacement—@(d:16, ERn) or @(d:32, ERn): A 16-bit or 32-bit displacement contained in the instruction is added to an address register (ERn) specified by the register field of the instruction, and the sum gives the address of a memory operand. A 16-bit displacement is sign-extended when added.

register contents and the sum is stored in the address register. The value added is 1 for byte access, 2 for word transfer instruction, or 4 for longword transfer instruction. For word or longword transfer instruction, the register value should be even.

- Register indirect with pre-decrement—@-ERn

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

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

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

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

Table 2-5 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'007FFF, H'FF8000 to H'FFFFFF
	32 bits (@aa:32)		H'000000 to H'FFFFFF
Program instruction address	24 bits (@aa:24)		

number. The TRAPA instruction contains 2-bit immediate data in its instruction code, specifying a vector address.

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

(8) Memory Indirect—@aa:8**:** This mode can be used by the JMP and JSR instructions. The instruction code contains an 8-bit absolute address specifying a memory operand. This memory operand contains a branch address. The upper bits of the absolute address are all assumed to be 0, so the address range is 0 to 255 (H'0000 to H'00FF in normal mode, H'000000 to H'0000FF in advanced mode). In normal mode the memory operand is a word operand and the branch address is 16 bits long. In advanced mode the memory operand is a longword operand, the first byte of which is assumed to be all 0 (H'00).

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

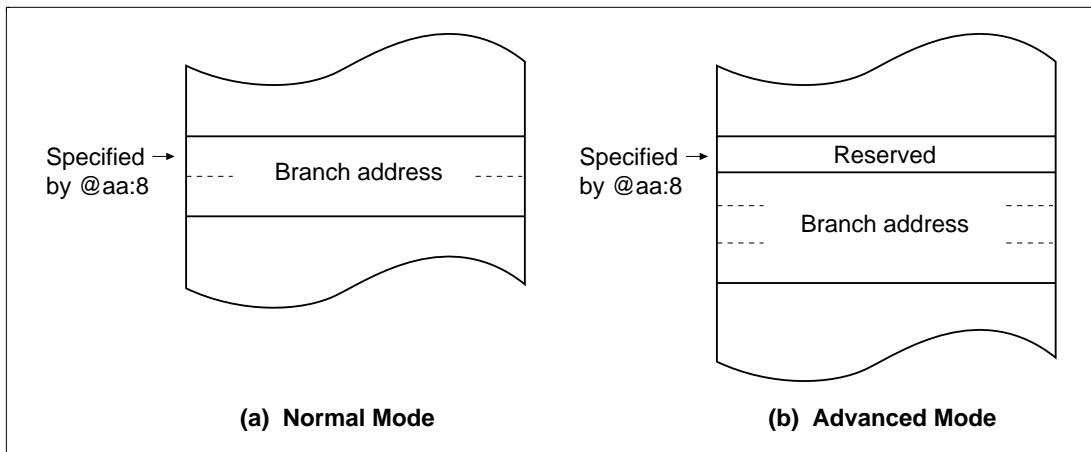


Figure 2-13 Branch Address Specification in Memory Indirect Mode

2.7.2 Effective Address Calculation

Table 2-6 indicates how effective addresses are calculated in each addressing mode. In normal mode the upper 8 bits of the effective address are ignored in order to generate a 16-bit address.

Table 2-6 Effective Address Calculation

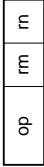

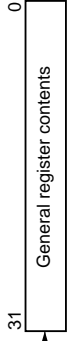
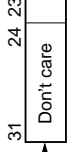

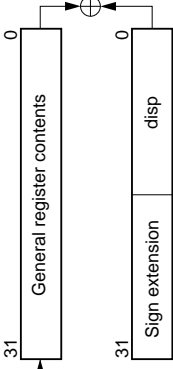
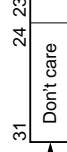


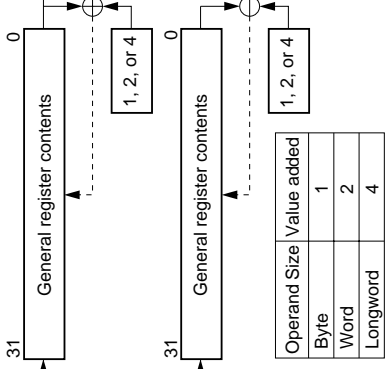
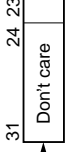
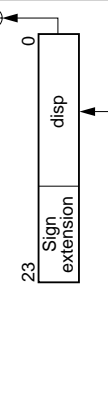
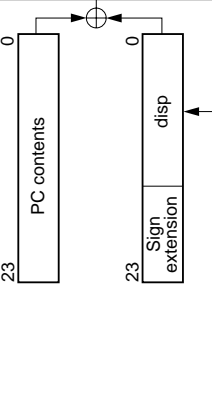
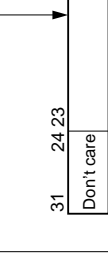
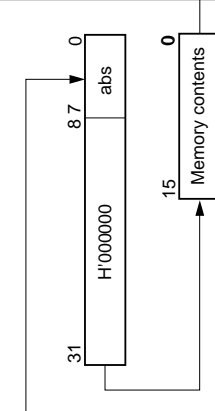
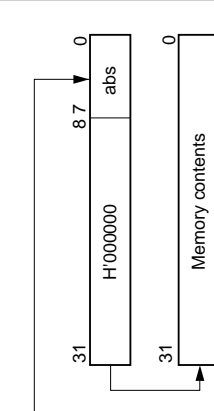
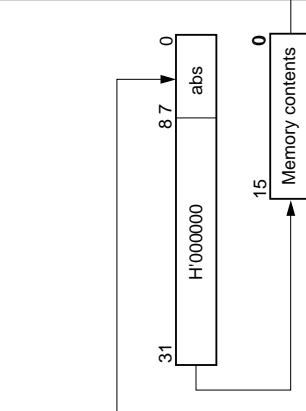
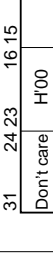
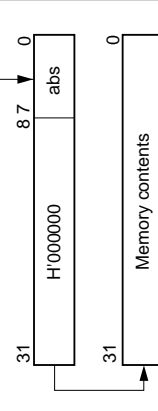
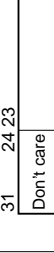
No.	Addressing Mode and Instruction Format	Effective Address Calculation	Effective Address								
1	Register direct (Rn) 		Operand is general register								
2	Register indirect (@ERn) 										
3	Register indirect with displacement @(d:16, ERn) or @(d:32, ERn) 										
4	Register indirect with post-increment or pre-decrement • Register indirect with post-increment @ERn+  • Register indirect with pre-decrement @-ERn 	 <table border="1" data-bbox="1200 399 1307 624"> <thead> <tr> <th>Operand Size</th> <th>Value added</th> </tr> </thead> <tbody> <tr> <td>Byte</td> <td>1</td> </tr> <tr> <td>Word</td> <td>2</td> </tr> <tr> <td>Longword</td> <td>4</td> </tr> </tbody> </table>	Operand Size	Value added	Byte	1	Word	2	Longword	4	
Operand Size	Value added										
Byte	1										
Word	2										
Longword	4										

Table 2-6 Effective Address Calculation (cont)

No.	Addressing Mode and Instruction Format	Effective Address Calculation	Effective Address
5	<p>Absolute address</p> <p>@aa:8</p> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> op abs </div> <p>@aa:16</p> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> op abs </div> <p>@aa:24</p> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> op abs </div> <p>@aa:32</p> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> op abs </div>		<div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> 31 24 23 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> Don't care H'FFFF </div> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> 31 24 23 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> Don't care Sign extension </div> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> 31 24 23 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> Don't care </div> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> 31 24 23 </div> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> Don't care </div>
6	<p>Immediate #xx:8/#xx:16/#xx:32</p> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin-left: 20px;"> op IMM </div>		<p>Operand is immediate data</p>

Table 2-6 Effective Address Calculation (cont)

No.	Addressing Mode and Instruction Format	Effective Address Calculation	Effective Address
7	<p>Program-counter relative @(dt:8, PC)/@(dt:16, PC)</p> 		
8	<p>Memory indirect @aa:8</p> <ul style="list-style-type: none"> • Normal mode  <ul style="list-style-type: none"> • Advanced mode 		
			

The CPU has five main processing states: the reset state, exception handling state, program execution state, bus-released state, and power-down state. Figure 2-14 shows a diagram of the processing states. Figure 2-15 indicates the state transitions.

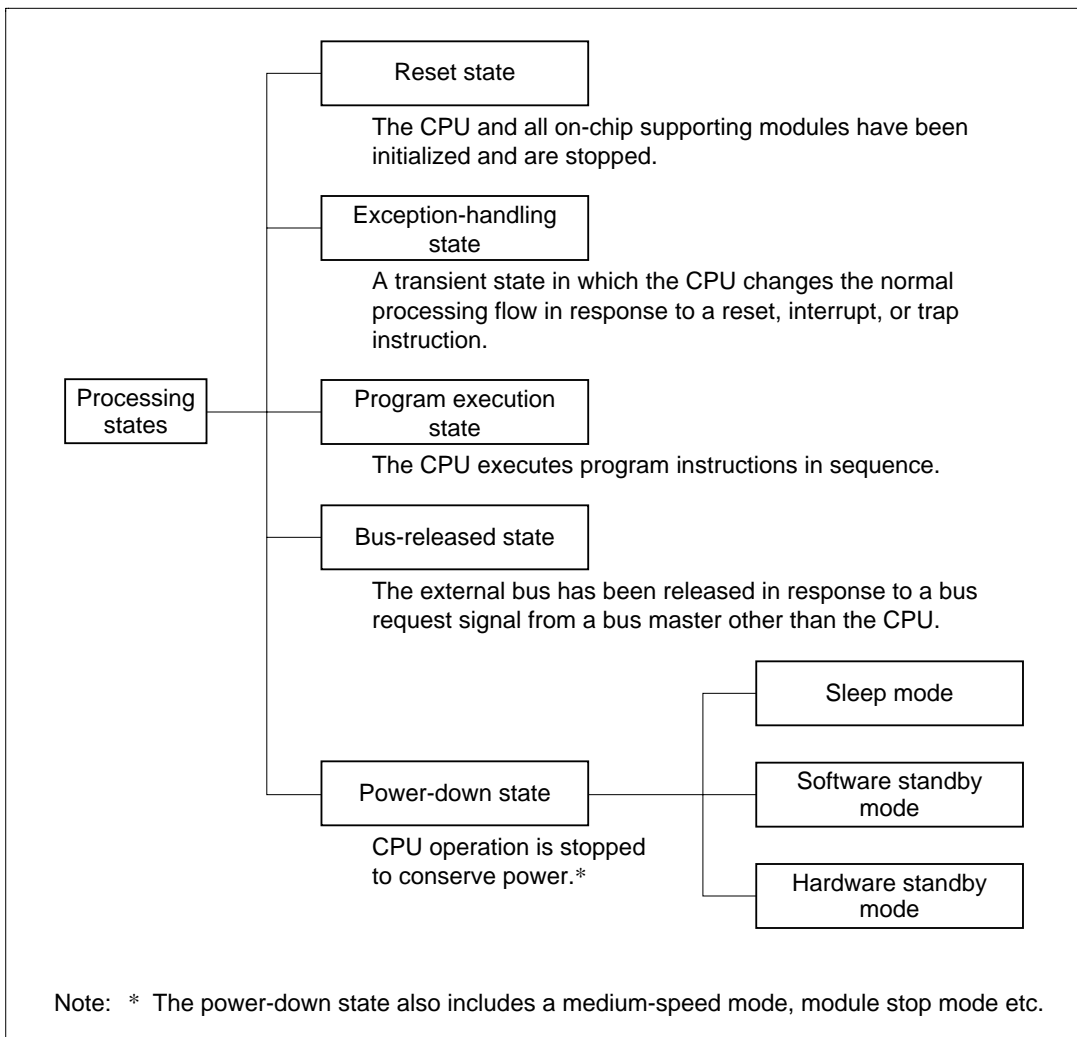
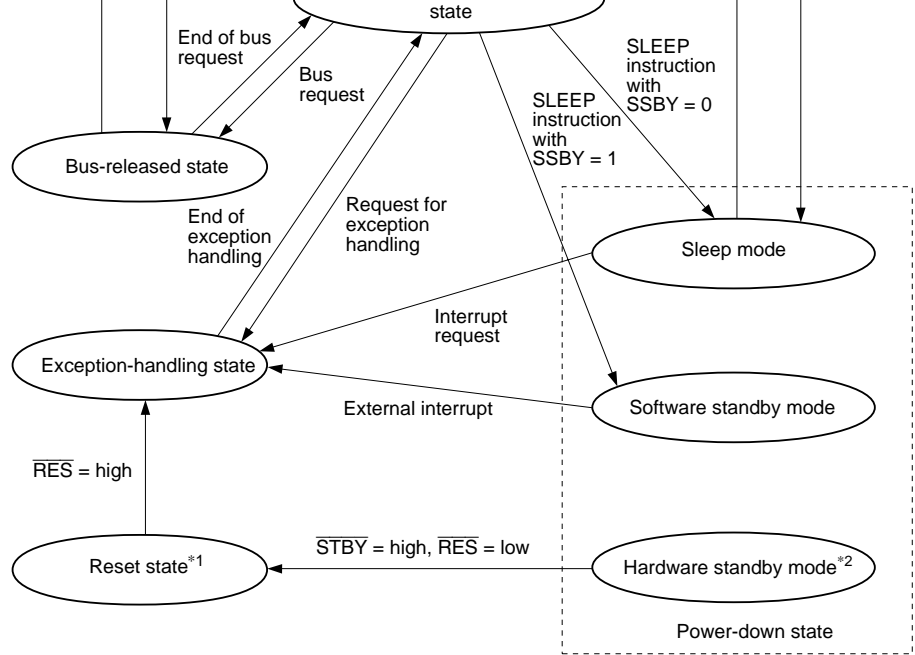


Figure 2-14 Processing States



- Notes: 1. From any state except hardware standby mode, a transition to the reset state occurs whenever \overline{RES} goes low. A transition can also be made to the reset state when the watchdog timer overflows.
 2. From any state, a transition to hardware standby mode occurs when \overline{STBY} goes low.

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. The CPU enters the power-on reset state when the NMI pin is high, or the manual reset state when the NMI pin is low. All interrupts are masked in the reset state. Reset exception handling starts when the \overline{RES} signal changes from low to high.

The reset state can also be entered by a watchdog timer overflow. For details, refer to section 12, Watchdog Timer.

(1) Types of Exception Handling and Their Priority

Exception handling is performed for traces, resets, interrupts, and trap instructions. Table 2-7 indicates 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 SYSCR.

Table 2-7 Exception Handling Types and Priority

Priority	Type of Exception	Detection Timing	Start of Exception Handling
High	Reset	Synchronized with clock	Exception handling starts immediately after a low-to-high transition at the $\overline{\text{RES}}$ pin, or when the watchdog timer overflows.
↑	Trace	End of instruction execution or end of exception-handling sequence* ¹	When the trace (T) bit is set to 1, the trace starts at the end of the current instruction or current exception-handling sequence
	Interrupt	End of instruction execution or end of exception-handling sequence* ²	When an interrupt is requested, exception handling starts at the end of the current instruction or current exception-handling sequence
	Trap instruction	When TRAPA instruction is executed	Exception handling starts when a trap (TRAPA) instruction is executed* ³
Low			

- Notes: 1. Traces are enabled only in interrupt control mode 2. Trace exception-handling is not executed at the end of the RTE instruction.
2. Interrupts are not detected at the end of the ANDC, ORC, XORC, and LDC instructions, or immediately after reset exception handling.
3. Trap instruction exception handling is always accepted, in the program execution state.

fetches a start 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 ends.

(3) Traces

Traces are enabled only in interrupt control mode 2. Trace mode is entered when the T bit of EXR is set to 1. When trace mode is established, trace exception handling starts at the end of each instruction.

At the end of a trace exception-handling sequence, the T bit of EXR is cleared to 0 and trace mode is cleared. Interrupt masks are not affected.

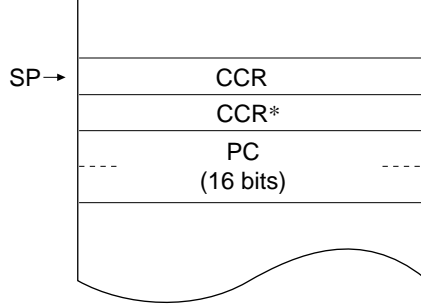
The T bit saved on the stack retains its value of 1, and when the RTE instruction is executed to return from the trace exception-handling routine, trace mode is entered again. Trace exception-handling is not executed at the end of the RTE instruction.

Trace mode is not entered in interrupt control mode 0, regardless of the state of the T bit.

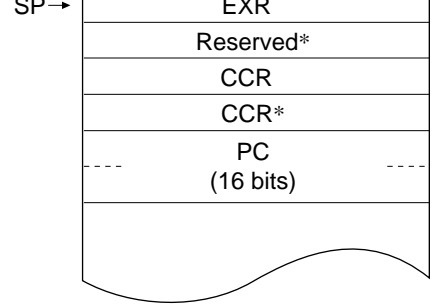
(4) Interrupt Exception Handling and Trap Instruction Exception Handling

When interrupt or trap-instruction exception handling begins, the CPU references the stack pointer (ER7) and pushes the program counter and other control registers onto the stack. Next, the CPU alters the settings of the interrupt mask bits in the control registers. Then the CPU fetches a start address (vector) from the exception vector table and program execution starts from that start address.

Figure 2-16 shows the stack after exception handling ends.

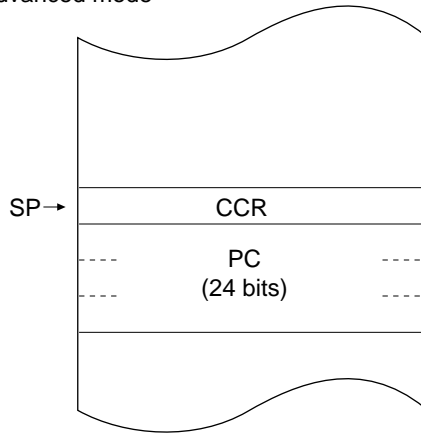


(a) Interrupt control mode 0

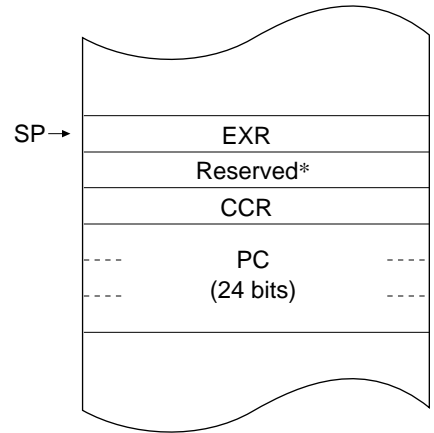


(b) Interrupt control mode 2

Advanced mode



(c) Interrupt control mode 0



(d) Interrupt control mode 2

Note: *Ignored when returning.

Figure 2-16 Stack Structure after Exception Handling (Examples)

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, the CPU halts.

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.

2.8.6 Power-Down State

The power-down state includes both modes in which the CPU stops operating and modes in which the CPU does not stop. There are three modes in which the CPU stops operating: sleep mode, software standby mode, and hardware standby mode. There are also two other power-down modes: medium-speed mode, and module stop mode. In medium-speed mode the CPU and other bus masters operate on a medium-speed clock. Module stop mode permits halting of the operation of individual modules, other than the CPU. For details, refer to section 20, Power-Down State.

(1) 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) is cleared to 0. In sleep mode, CPU operations stop immediately after execution of the SLEEP instruction. The contents of CPU registers are retained.

(2) Software Standby Mode: A transition to software standby mode is made if the SLEEP instruction is executed while the SSBY bit in SBYCR is set to 1. In software standby mode, the CPU and clock halt and all MCU operations stop. As long as a specified voltage is supplied, the contents of CPU registers and on-chip RAM are retained. The I/O ports also remain in their existing states.

(3) 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 supporting modules are reset, but as long as a specified voltage is supplied, on-chip RAM contents are retained.

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

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 byte and word transfer instruction. Figure 2-17 shows the on-chip memory access cycle. Figure 2-18 shows the pin states.

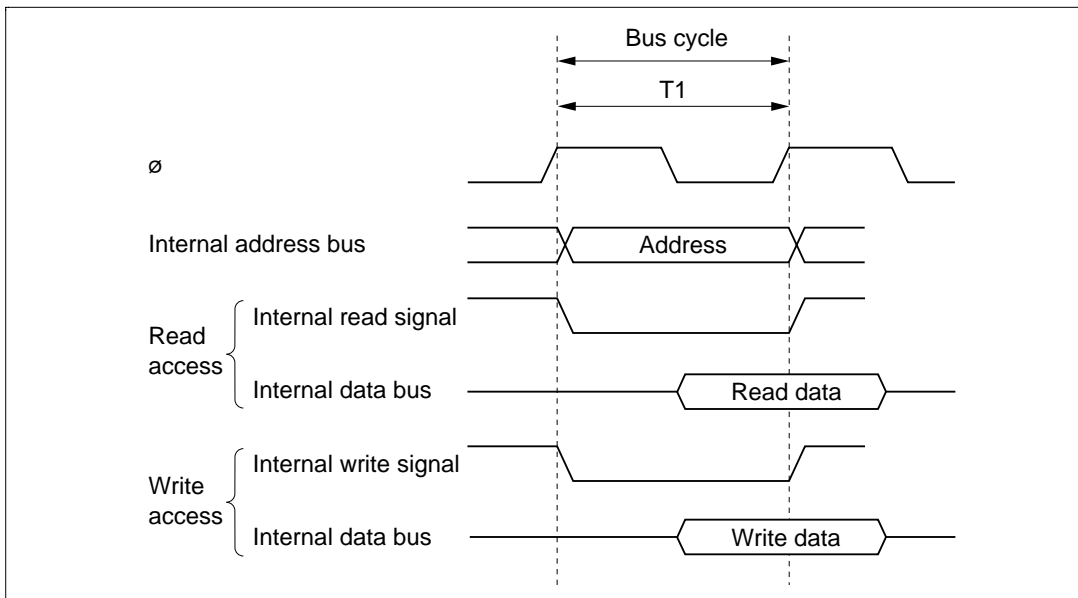


Figure 2-17 On-Chip Memory Access Cycle

Address bus	Unchanged
\overline{AS}	High
\overline{RD}	High
$\overline{HWR}, \overline{LWR}$	High
Data bus	High-impedance state

Figure 2-18 Pin States during On-Chip Memory Access

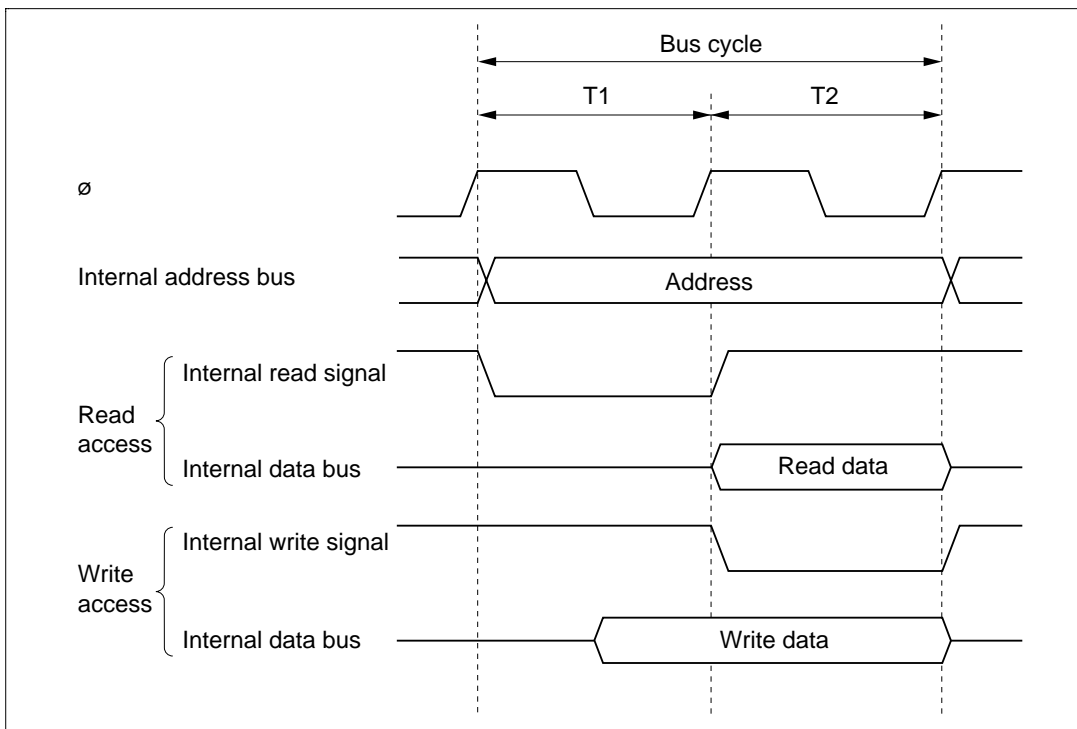


Figure 2-19 On-Chip Supporting Module Access Cycle

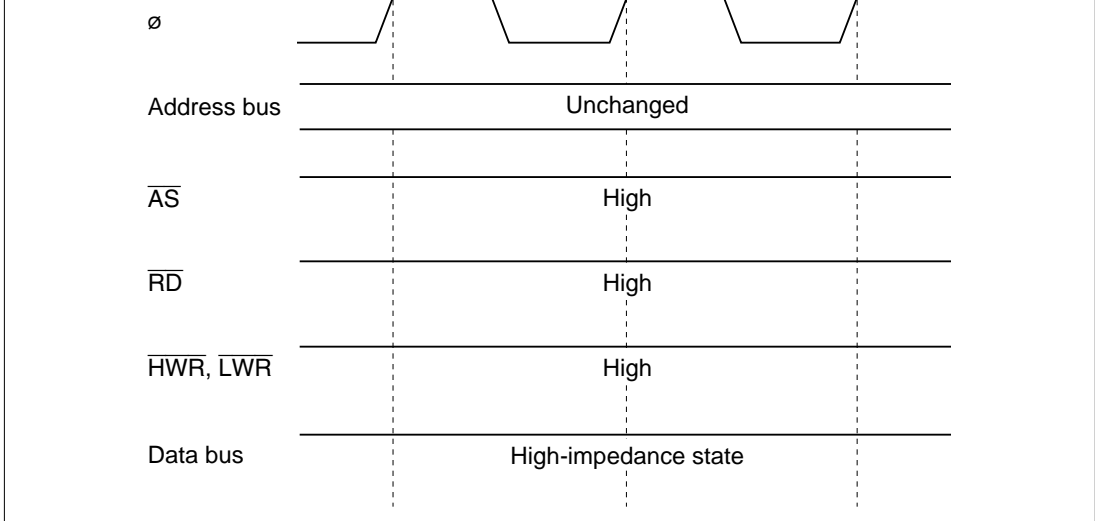


Figure 2-20 Pin States during On-Chip Supporting Module Access

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-state or three-state bus cycle. In three-state access, wait states can be inserted. For further details, refer to section 6, Bus Controller.

3.1.1 H8S/2350 Operating Mode Selection

The H8S/2350 has three operating modes (modes 1, 4, and 5). These modes are determined by the mode pin (MD₂ to MD₀) settings. The CPU operating mode and initial bus width can be selected as shown in table 3-1.

Table 3-1 lists the MCU operating modes.

Table 3-1 MCU Operating Mode Selection (H8S/2350)

MCU Operating Mode	MD ₂	MD ₁	MD ₀	CPU Operating Mode	Description	On-Chip ROM	External Data Bus	
							Initial Width	Max. Width
0	0	0	0	—	—	—	—	—
1			1	Normal	On-chip ROM disabled, Disabled expanded mode	8 bits	16 bits	16 bits
2		1	0	—	—	—	—	—
3			1	—	—	—	—	—
4	1	0	0	Advanced	On-chip ROM disabled, Disabled expanded mode	16 bits	16 bits	16 bits
5			1	—	—	8 bits	16 bits	16 bits
6		1	0	—	—	—	—	—
7			1	—	—	—	—	—

The CPU's architecture allows for 4 Gbytes of address space, but the H8S/2350 actually accesses a maximum of 16 Mbytes.

Modes 1, 4, and 5 are externally expanded modes that allow access to external memory and peripheral devices.

The external expansion modes allow switching between 8-bit and 16-bit bus modes. After program execution starts, an 8-bit or 16-bit address space can be set for each area, depending on the bus controller setting. If 16-bit access is selected for any one area, 16-bit bus mode is set; if 8-bit access is selected for all areas, 8-bit bus mode is set.

Note that the functions of each pin depend on the operating mode.

The H8S/2351 has seven operating modes (modes 1 to 7). These modes enable selection of the CPU operating mode, enabling/disabling of on-chip ROM, and the initial bus width setting, by setting the mode pins (MD₂ to MD₀).

Table 3-2 lists the MCU operating modes.

Table 3-2 MCU Operating Mode Selection (H8S/2351)

MCU Operating Mode	MD ₂	MD ₁	MD ₀	CPU Operating Mode	Description	On-Chip ROM	External Data Bus	
							Initial Width	Max. Width
0	0	0	0	—	—	—	—	—
1			1	Normal	On-chip ROM disabled, expanded mode	Disabled	8 bits	16 bits
2		1	0		On-chip ROM enabled, expanded mode	Enabled	8 bits	16 bits
3			1		Single-chip mode		—	—
4	1	0	0	Advanced	On-chip ROM disabled, expanded mode	Disabled	16 bits	16 bits
5			1				8 bits	16 bits
6		1	0		On-chip ROM enabled, expanded mode	Enabled	8 bits	16 bits
7			1		Single-chip mode		—	—

The CPU's architecture allows for 4 Gbytes of address space, but the H8S/2351 actually accesses a maximum of 16 Mbytes.

Modes 1, 2, and 4 to 6 are externally expanded modes that allow access to external memory and peripheral devices.

The external expansion modes allow switching between 8-bit and 16-bit bus modes. After program execution starts, an 8-bit or 16-bit address space can be set for each area, depending on the bus controller setting. If 16-bit access is selected for any one area, 16-bit bus mode is set; if 8-bit access is selected for all areas, 8-bit bus mode is set.

Note that the functions of each pin depend on the operating mode.

The H8S/2350 Series has a mode control register (MDCR) that indicates the inputs at the mode pins (MD_2 to MD_0), and a system control register (SYSCR) that controls the operation of the H8S/2350 Series. Table 3-3 summarizes these registers.

Table 3-3 MCU Registers

Name	Abbreviation	R/W	Initial Value	Address*
Mode control register	MDCR	R	Undetermined	H'FF3B
System control register	SYSCR	R/W	H'01	H'FF39

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	0
		—	—	—	—	—	MDS2	MDS1	MDS0
Initial value:		1	0	0	0	0	—*	—*	—*
R/W	:	—	—	—	—	—	R	R	R

Note: * Determined by pins MD_2 to MD_0 .

MDCR is an 8-bit read-only register that indicates the current operating mode of the H8S/2350 Series.

Bit 7—Reserved: Read-only bit, always read as 1.

Bits 6 to 3—Reserved: Read-only bits, always read as 0.

Bits 2 to 0—Mode Select 2 to 0 (MDS2 to MDS0): These bits indicate the input levels at pins MD_2 to MD_0 (the current operating mode). Bits MDS2 to MDS0 correspond to MD_2 to MD_0 . MDS2 to MDS0 are read-only bits, they cannot be written to. The mode pin (MD_2 to MD_0) input levels are latched into these bits when MDCR is read. These latches are canceled by a power-on reset, but are retained after a manual reset.

Initial value: 0 0 0 0 0 0 0 1
 R/W : R/W — R/W R/W R/W — R/W R/W

Bit 7—Reserved: Only 0 should be written to this bit.

Bit 6—Reserved: Read-only bit, always read as 0.

Bits 5 and 4—Interrupt Control Mode 1 and 0 (INTM1, INTM0): These bits select the control mode of the interrupt controller. For details of the interrupt control modes, see section 5.4.1, Interrupt Control Modes and Interrupt Operation.

Bit 5 INTM1	Bit 4 INTM0	Interrupt Control Mode	Description
0	0	0	Control of interrupts by I bit (Initial value)
	1	—	Setting prohibited
1	0	2	Control of interrupts by I2 to I0 bits and IPR
	1	—	Setting prohibited

Bit 3—NMI Edge Select (NMIEG): Selects the valid edge of the NMI interrupt input.

Bit 3 NMIEG	Description
0	An interrupt is requested at the falling edge of NMI input (Initial value)
1	An interrupt is requested at the rising edge of NMI input

Bit 2—Reserved: Read-only bit, always read as 0.

Bit 1—Reserved: Only 0 should be written to this bit.

Bit 0—RAM Enable (RAME): Enables or disables the on-chip RAM. The RAME bit is initialized when the reset status 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 (Initial value)

The CPU can access a 64-kbyte address space in normal mode. The on-chip ROM is disabled, and 8-bit bus mode is set, immediately after a reset.

Ports B and C function as an address bus, port D functions as a data bus, and part of port F carries bus control signals. However, note that if 16-bit access is designated by the bus controller, the bus mode switches to 16 bits and port E becomes a data bus.

3.3.2 Mode 2 (H8S/2351 Only)

The CPU can access a 64-kbyte address space in normal mode. The on-chip ROM is enabled, and 8-bit bus mode is set, immediately after a reset.

Ports B and C function as input ports immediately after a reset. They can each be set to output addresses by setting the corresponding bits in the data direction register (DDR) to 1. Port D functions as a data bus, and part of port F carries bus control signals. However, note that if 16-bit access is designated by the bus controller, the bus mode switches to 16 bits and port E becomes a data bus.

The amount of on-chip ROM that can be used is limited to 56 kbytes.

3.3.3 Mode 3 (H8S/2351 Only)

The CPU can access a 64-kbyte address space in normal mode. The on-chip ROM is enabled, but external addresses cannot be accessed.

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

The amount of on-chip ROM that can be used is limited to 56 kbytes.

3.3.4 Mode 4

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

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

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

carries bus control signals.

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

3.3.6 Mode 6 (H8S/2351 Only)

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

Ports A, B and C function as input ports immediately after a reset. They can each be set to output addresses by setting the corresponding bits in the data direction register (DDR) to 1. Port D functions as a data bus, and part of port F carries bus control signals.

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

3.3.7 Mode 7 (H8S/2351 Only)

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

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

Table 3-4 Pin Functions in Each Mode

Port		Mode 1	Mode 2* ²	Mode 3* ²	Mode 4	Mode 5	Mode 6* ²	Mode 7* ²
Port A	PA ₇ to PA ₅	P	P	P	P* ¹ /A	P* ¹ /A	P* ¹ /A	P
	PA ₄ to PA ₀				A	A		
Port B		A	P* ¹ /A	P	A	A	P* ¹ /A	P
Port C		A	P* ¹ /A	P	A	A	P* ¹ /A	P
Port D		D	D	P	D	D	D	P
Port E		P* ¹ /D	P* ¹ /D	P	P/D* ¹	P* ¹ /D	P* ¹ /D	P
Port F	PF ₇	P/C* ¹	P/C* ¹	P* ¹ /C	P/C* ¹	P/C* ¹	P/C* ¹	P* ¹ /C
	PF ₆ to PF ₃	C	C	P	C	C	C	P
	PF ₂ to PF ₀	P* ¹ /C	P* ¹ /C		P* ¹ /C	P* ¹ /C	P* ¹ /C	

Legend

P: I/O port

A: Address bus output

D: Data bus I/O

C: Control signals, clock I/O

*1: After reset

*2: Only applies to the H8S/2351

3.5 Memory Map in Each Operating Mode

Figure 3-1 shows a memory map for each of the operating modes.

The address space is 64 kbytes in modes 1 to 3 (normal modes), and 16 Mbytes in modes 4 to 7 (advanced modes).

The H8S/2351's on-chip ROM contains 64 kbytes, but only 56 kbytes are available in modes 2 and 3 (normal modes).

The address space is divided into eight areas for modes 4 to 7. For details, see section 6, Bus Controller.

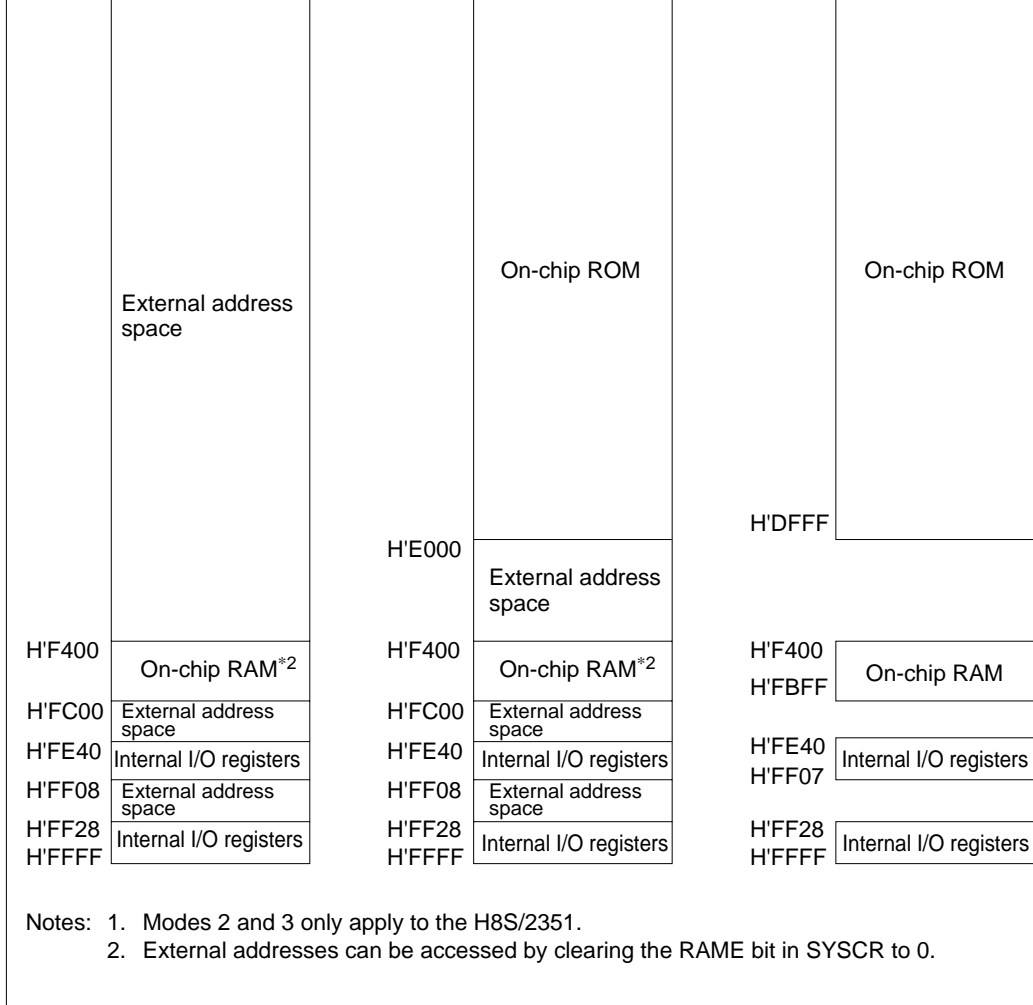


Figure 3-1 Memory Map in Each Operating Mode

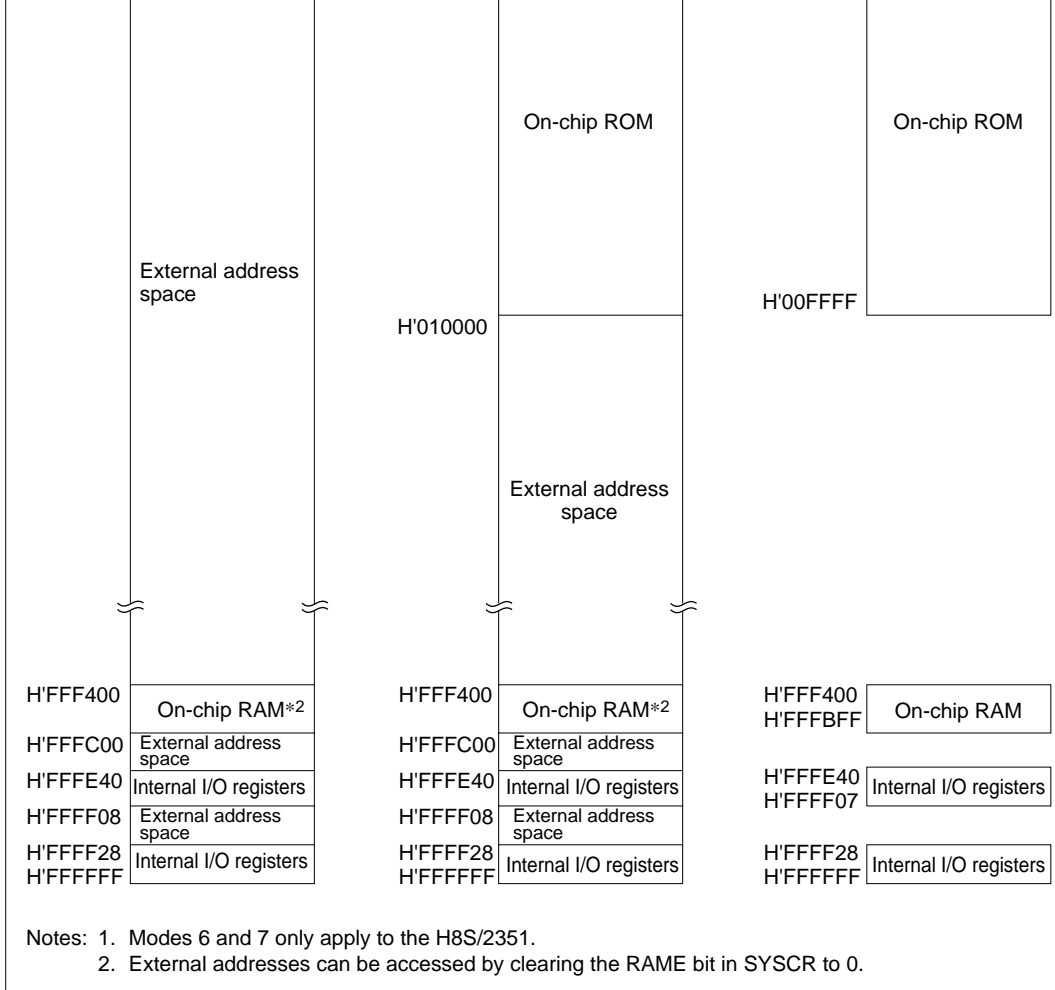


Figure 3-1 Memory Map in Each Operating Mode (cont)

4.1.1 Exception Handling Types and Priority

As table 4-1 indicates, exception handling may be caused by a reset, trap instruction, or interrupt. Exception handling is prioritized as shown in table 4-1. If two or more exceptions occur simultaneously, they are accepted and processed in order of priority. Trap instruction 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 of SYSCR.

Table 4-1 Exception Types and Priority

Priority	Exception Type	Start of Exception Handling
High ↑	Reset	Starts immediately after a low-to-high transition at the $\overline{\text{RES}}$ pin, or when the watchdog timer overflows. The CPU enters the power-on reset state when the NMI pin is high, or the manual reset state when the NMI pin is low.
	Trace* ¹	Starts when execution of the current instruction or exception handling ends, if the trace (T) bit is set to 1
	Interrupt	Starts when execution of the current instruction or exception handling ends, if an interrupt request has been issued* ²
Low	Trap instruction (TRAPA)* ³	Started by execution of a trap instruction (TRAPA)

- Notes: 1. Traces are enabled only in interrupt control mode 2. Trace exception handling is not executed after execution of an RTE instruction.
 2. Interrupt detection is not performed on completion of ANDC, ORC, XORC, or LDC instruction execution, or on completion of reset exception handling.
 3. Trap instruction exception handling requests are accepted at all times in program execution state.

1. The program counter (PC), condition code register (CCR), and extended register (EXR) are pushed onto the stack.
2. The interrupt mask bits are updated. The T bit is cleared to 0.
3. A vector address corresponding to the exception source is generated, and program execution starts from that address.

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

4.1.3 Exception Vector Table

The exception sources are classified as shown in figure 4-1. Different vector addresses are assigned to different exception sources.

Table 4-2 lists the exception sources and their vector addresses.

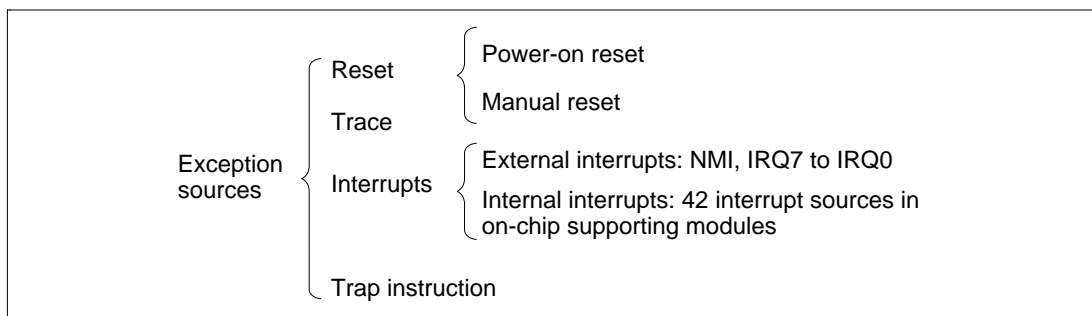


Figure 4-1 Exception Sources

In modes 6 and 7 in the H8S/2351, the on-chip ROM available for use after a power-on reset is the 64-kbyte area comprising addresses H'000000 to H'00FFFF. Care is required when setting vector addresses.

Power-on reset		0	H'0000 to H'0001	H'0000 to H'0003
Manual reset		1		H'0004 to H'0007
Reserved for system use		2		H'0004 to H'0006
		3		H'0006 to H'0007
		4		H'0008 to H'0009
Trace		5	H'000A to H'000B	H'0014 to H'0017
Reserved for system use		6	H'000C to H'000D	H'0018 to H'001B
External interrupt	NMI	7		H'000E to H'000F
Trap instruction (4 sources)		8		H'0010 to H'0011
		9		H'0012 to H'0013
		10		H'0014 to H'0015
		11		H'0016 to H'0017
Reserved for system use		12		H'0018 to H'0019
		13		H'001A to H'001B
		14		H'001C to H'001D
		15		H'001E to H'001F
External interrupt	IRQ0	16		H'0020 to H'0021
	IRQ1	17		H'0022 to H'0023
	IRQ2	18		H'0024 to H'0025
	IRQ3	19		H'0026 to H'0027
	IRQ4	20		H'0028 to H'0029
	IRQ5	21		H'002A to H'002B
	IRQ6	22		H'002C to H'002D
Internal interrupt* ²		23		H'002E to H'002F
		24		H'0030 to H'0031
		91		H'00B6 to H'00B7
				H'016C to H'016F

Notes: 1. Lower 16 bits of the address.

2. For details of internal interrupt vectors, see section 5.3.3, Interrupt Exception Handling Vector Table.

A reset has the highest exception priority.

When the $\overline{\text{RES}}$ pin goes low, all processing halts and the H8S/2350 Series enters the reset state. A reset initializes the internal state of the CPU and the registers of on-chip supporting modules. 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 level of the NMI pin at reset determines whether the type of reset is a power-on reset or a manual reset.

The H8S/2350 Series can also be reset by overflow of the watchdog timer. For details see section 12, Watchdog Timer.

4.2.2 Reset Types

A reset can be of either of two types: a power-on reset or a manual reset. Reset types are shown in table 4-3. A power-on reset should be used when powering on.

The internal state of the CPU is initialized by either type of reset. A power-on reset also initializes all the registers in the on-chip supporting modules, while a manual reset initializes all the registers in the on-chip supporting modules except for the bus controller and I/O ports, which retain their previous states.

With a manual reset, since the on-chip supporting modules are initialized, ports used as on-chip supporting module I/O pins are switched to I/O ports controlled by DDR and DR.

Table 4-3 Reset Types

Type	Reset Transition Conditions		Internal State	
	NMI	$\overline{\text{RES}}$	CPU	On-Chip Supporting Modules
Power-on reset	High	Low	Initialized	Initialized
Manual reset	Low	Low	Initialized	Initialized, except for bus controller and I/O ports

A reset caused by the watchdog timer can also be of either of two types: a power-on reset or a manual reset.

To ensure that the H8S/2350 Series is reset, hold the $\overline{\text{RES}}$ pin low for at least 20 ns at power-up. To reset the H8S/2350 Series during operation, hold the $\overline{\text{RES}}$ pin low for at least 20 states.

When the $\overline{\text{RES}}$ pin goes high after being held low for the necessary time, the H8S/2350 Series starts reset exception handling as follows:

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

Figures 4-2 and 4-3 show examples of the reset sequence.

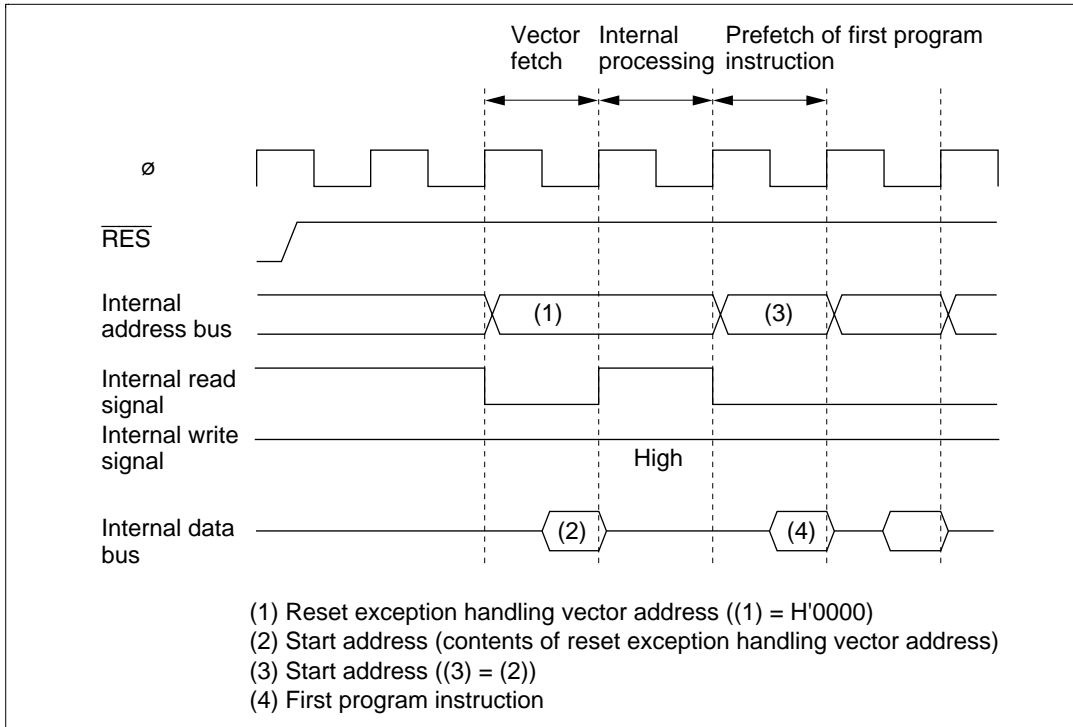
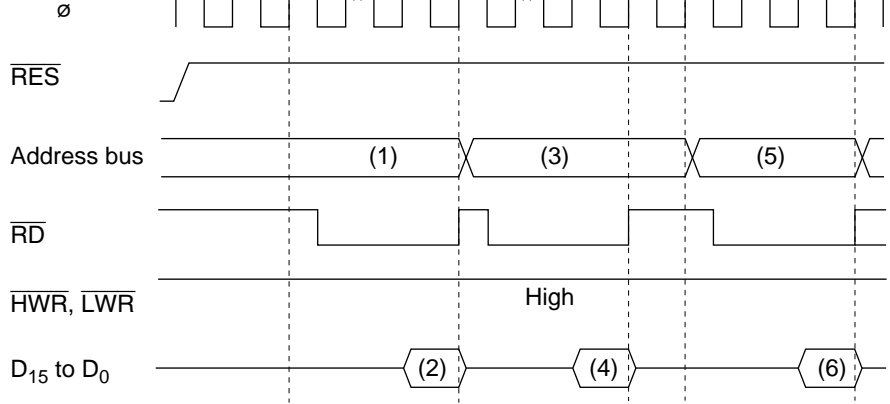


Figure 4-2 Reset Sequence (Modes 2 and 3)



(1) (3) Reset exception handling vector address ((1) = H'000000, (3) = H'000002)

(2) (4) Start address (contents of reset exception handling vector address)

(5) Start address ((5) = (2) (4))

(6) First program instruction

Note: * 3 program wait states are inserted.

Figure 4-3 Reset Sequence (Mode 4)

4.2.4 Interrupts after Reset

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

4.2.5 State of On-Chip Supporting Modules after Reset Release

After reset release, MSTPCR is initialized to H'3FFF and all modules except the DMAC and DTC enter module stop mode. Consequently, on-chip supporting module registers cannot be read or written to. Register reading and writing is enabled when module stop mode is exited.

Interrupt Controller.

If the T bit in EXR is set to 1, trace mode is activated. In trace mode, a trace exception occurs on completion of each instruction.

Trace mode is canceled by clearing the T bit in EXR to 0. It is not affected by interrupt masking.

Table 4-4 shows the state of CCR and EXR after execution of trace exception handling.

Interrupts are accepted even within the trace exception handling routine.

The T bit saved on the stack retains its value of 1, and when control is returned from the trace exception handling routine by the RTE instruction, trace mode resumes.

Trace exception handling is not carried out after execution of the RTE instruction.

Table 4-4 Status of CCR and EXR after Trace Exception Handling

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

Legend

1: Set to 1

0: Cleared to 0

—: Retains value prior to execution.

and the number of interrupts of each type.

The on-chip supporting modules that can request interrupts include the watchdog timer (WDT), refresh timer, 16-bit timer-pulse unit (TPU), serial communication interface (SCI), data transfer controller (DTC), DMA controller (DMAC), and A/D converter. 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 NMI to eight priority/mask levels to enable multiplexed interrupt control.

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

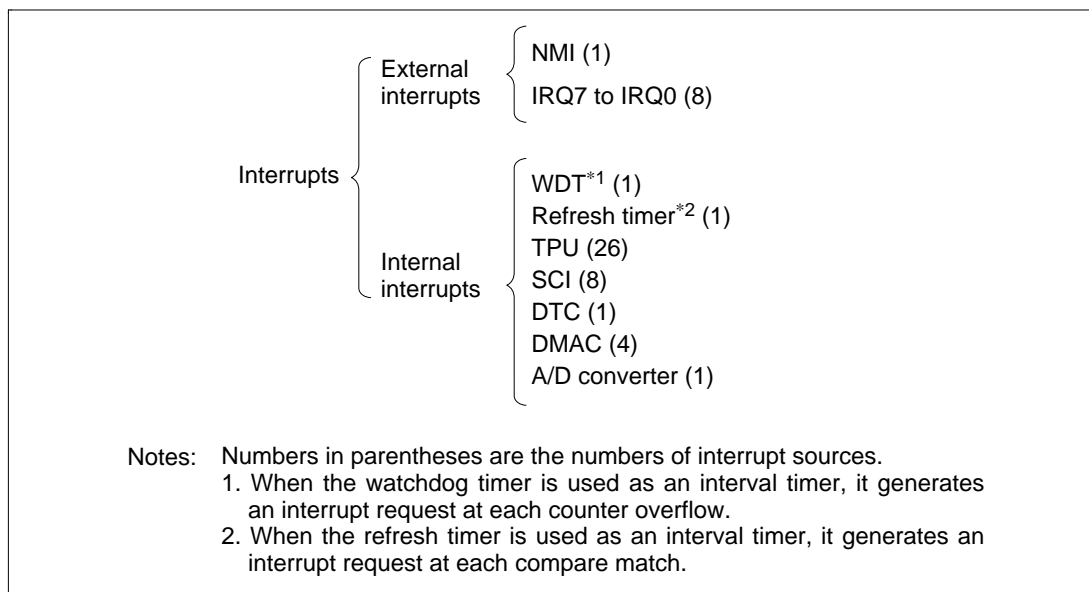


Figure 4-4 Interrupt Sources and Number of Interrupts

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

Table 4-5 shows the status of CCR and EXR after execution of trap instruction exception handling.

Table 4-5 Status of CCR and EXR after Trap Instruction Exception Handling

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

Legend

1: Set to 1

0: Cleared to 0

—: Retains value prior to execution.

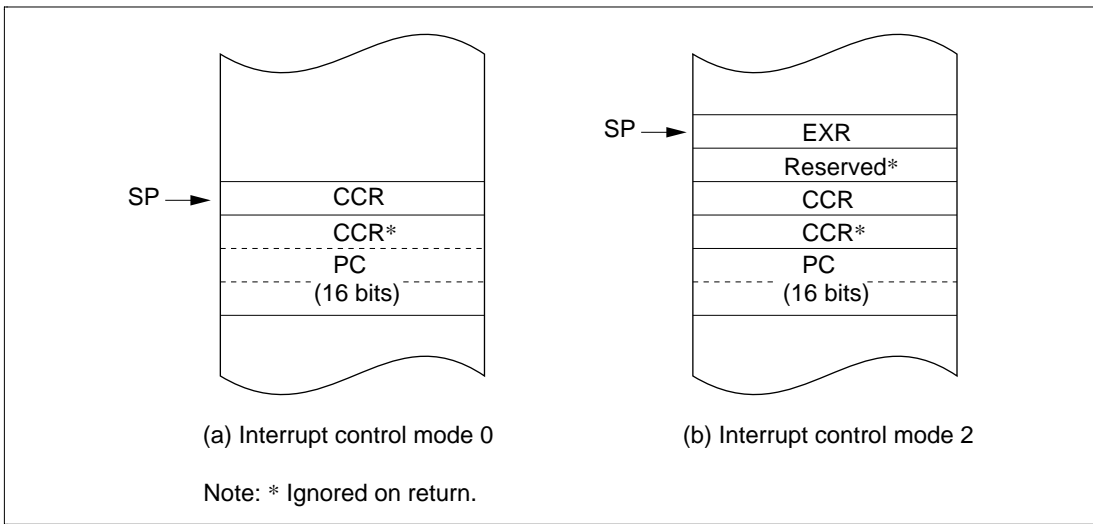


Figure 4-5 (1) Stack Status after Exception Handling (Normal Modes)

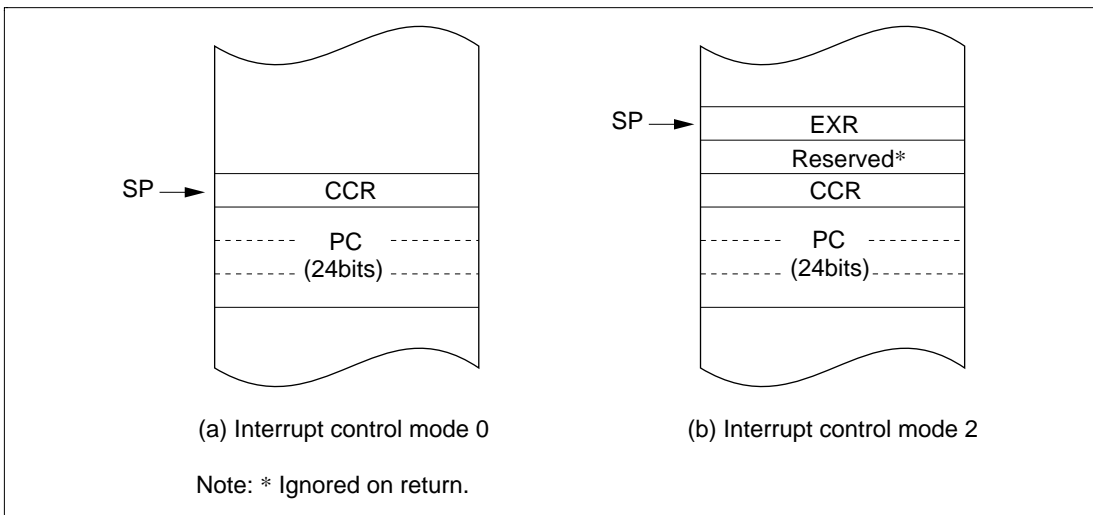


Figure 4-5 (2) Stack Status after Exception Handling (Advanced Modes)

instruction, and the value of the stack pointer (SP, ER7) should always be kept even. Use the following instructions to save registers:

```
PUSH.W  Rn    (or MOV.W Rn, @-SP)
PUSH.L  ERn   (or MOV.L ERn, @-SP)
```

Use the following instructions to restore registers:

```
POP.W   Rn    (or MOV.W @SP+, Rn)
POP.L   ERn   (or MOV.L @SP+, ERn)
```

Setting SP to an odd value may lead to a malfunction. Figure 4-6 shows an example of what happens when the SP value is odd.

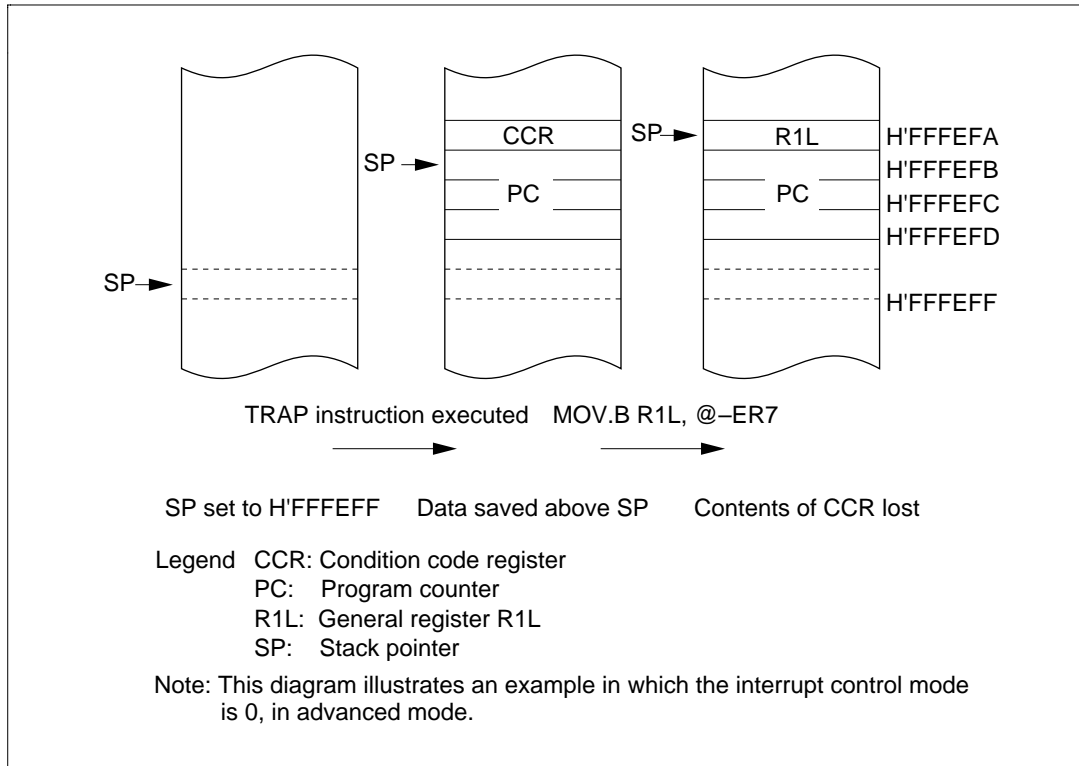


Figure 4-6 Operation when SP Value is Odd

5.1.1 Features

The H8S/2350 Series controls interrupts by means of an interrupt controller. The interrupt controller has the following features:

- Two interrupt control modes
 - Any of two interrupt control modes can be set by means of the INTM1 and INTM0 bits in the system control register (SYSCR).
- Priorities settable with IPR
 - An interrupt priority register (IPR) is provided for setting interrupt priorities. Eight priority levels can be set for each module for all interrupts except NMI.
 - NMI is assigned the highest priority level of 8, and can be accepted at all times.
- Independent vector addresses
 - All interrupt sources are assigned independent vector addresses, making it unnecessary for the source to be identified in the interrupt handling routine.
- Nine external interrupts
 - NMI is the highest-priority interrupt, and is accepted at all times. Rising edge or falling edge can be selected for NMI.
 - Falling edge, rising edge, or both edge detection, or level sensing, can be selected for IRQ7 to IRQ0.
- DTC and DMAC control
 - DTC and DMAC activation is performed by means of interrupts.

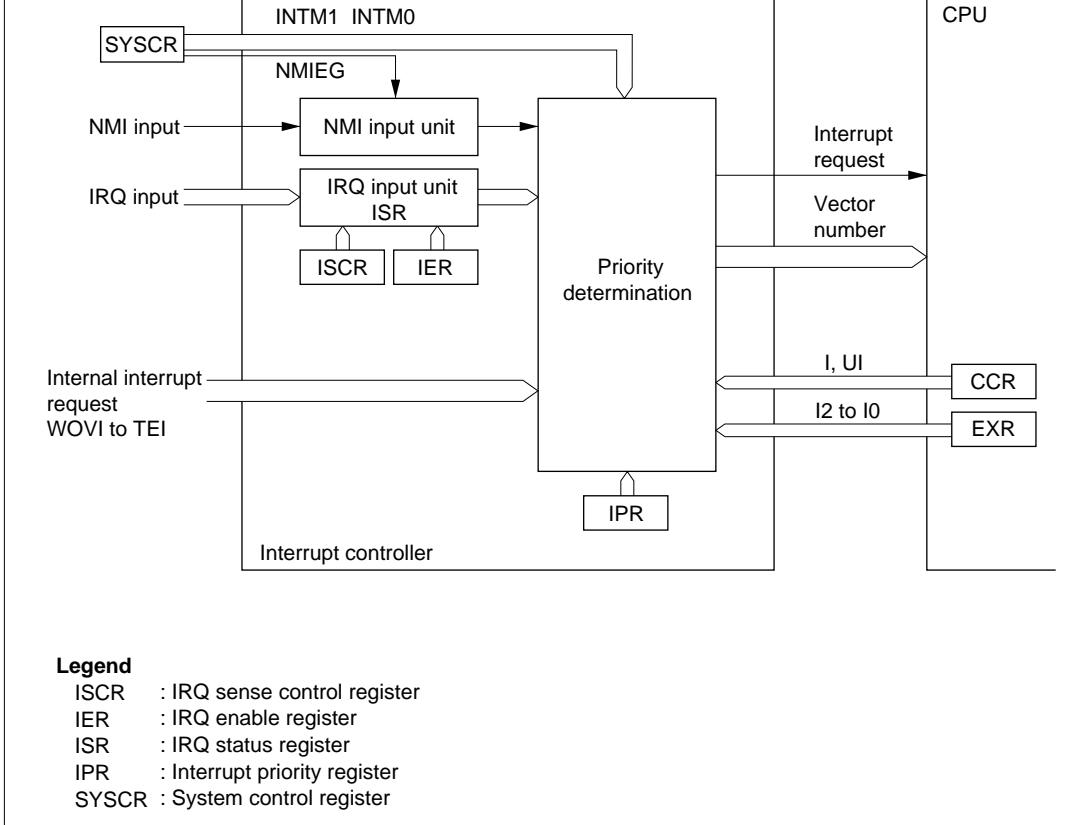


Figure 5-1 Block Diagram of Interrupt Controller

Name	Symbol	I/O	Function
Nonmaskable interrupt	NMI	Input	Nonmaskable external interrupt; rising or falling edge can be selected
External interrupt requests 7 to 0	$\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$	Input	Maskable external interrupts; rising, falling, or both edges, or level sensing, can be selected

5.1.4 Register Configuration

Table 5-2 summarizes the registers of the interrupt controller.

Table 5-2 Interrupt Controller Registers

Name	Abbreviation	R/W	Initial Value	Address* ¹
System control register	SYSCR	R/W	H'01	H'FF39
IRQ sense control register H	ISCRH	R/W	H'00	H'FF2C
IRQ sense control register L	ISCR L	R/W	H'00	H'FF2D
IRQ enable register	IER	R/W	H'00	H'FF2E
IRQ status register	ISR	R/(W)* ²	H'00	H'FF2F
Interrupt priority register A	IPRA	R/W	H'77	H'FEC4
Interrupt priority register B	IPRB	R/W	H'77	H'FEC5
Interrupt priority register C	IPRC	R/W	H'77	H'FEC6
Interrupt priority register D	IPRD	R/W	H'77	H'FEC7
Interrupt priority register E	IPRE	R/W	H'77	H'FEC8
Interrupt priority register F	IPRF	R/W	H'77	H'FEC9
Interrupt priority register G	IPRG	R/W	H'77	H'FECA
Interrupt priority register H	IPRH	R/W	H'77	H'FECB
Interrupt priority register I	IPRI	R/W	H'77	H'FECC
Interrupt priority register J	IPRJ	R/W	H'77	H'FECD
Interrupt priority register K	IPRK	R/W	H'77	H'FECE

Notes: 1. Lower 16 bits of the address.

2. Can only be written with 0 for flag clearing.

Bit	:	7	6	5	4	3	2	1	0
		—	—	INTM1	INTM0	NMIEG	—	—	RAME
Initial value:		0	0	0	0	0	0	0	1
R/W	:	R/W	—	R/W	R/W	R/W	—	R/W	R/W

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

Only bits 5 to 3 are described here; for details of the other bits, see section 3.2.2, System Control Register (SYSCR).

SYSCR is initialized to H'01 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 one of two interrupt control modes for the interrupt controller.

Bit 5 INTM1	Bit 4 INTM0	Interrupt Control Mode	Description
0	0	0	Interrupts are controlled by I bit (Initial value)
	1	—	Setting prohibited
1	0	2	Interrupts are controlled by bits I2 to I0, and IPR
	1	—	Setting prohibited

Bit 3—NMI Edge Select (NMIEG): Selects the input edge for the NMI pin.

Bit 3 NMIEG	Description
0	Interrupt request generated at falling edge of NMI input (Initial value)
1	Interrupt request generated at rising edge of NMI input

Initial value: 0 1 1 1 0 1 1 1
R/W : — R/W R/W R/W — R/W R/W R/W

The IPR registers are eleven 8-bit readable/writable registers that set priorities (levels 7 to 0) for interrupts other than NMI.

The correspondence between IPR settings and interrupt sources is shown in table 5-3.

The IPR registers set a priority (level 7 to 0) for each interrupt source other than NMI.

The IPR registers are initialized to H'77 by a reset and in hardware standby mode.

Bits 7 and 3—Reserved: Read-only bits, always read as 0.

Table 5-3 Correspondence between Interrupt Sources and IPR Settings

Register	Bits	
	6 to 4	2 to 0
IPRA	IRQ0	IRQ1
IPRB	IRQ2 IRQ3	IRQ4 IRQ5
IPRC	IRQ6 IRQ7	DTC
IPRD	Watchdog timer	Refresh timer
IPRE	—*	A/D converter
IPRF	TPU channel 0	TPU channel 1
IPRG	TPU channel 2	TPU channel 3
IPRH	TPU channel 4	TPU channel 5
IPRI	—*	—*
IPRJ	DMAC	SCI channel 0
IPRK	SCI channel 1	—*

Note: * Reserved bits. These bits cannot be modified and are always read as 1.

When interrupt requests are generated, the highest-priority interrupt according to the priority levels set in the IPR registers is selected. This interrupt level is then compared with the interrupt mask level set by the interrupt mask bits (I2 to I0) in the extend register (EXR) in the CPU, and if the priority level of the interrupt is higher than the set mask level, an interrupt request is issued to the CPU.

5.2.3 IRQ Enable Register (IER)

IER is an 8-bit readable/writable register that controls enabling and disabling of interrupt requests IRQ7 to IRQ0.

Bit	:	7	6	5	4	3	2	1	0
		IRQ7E	IRQ6E	IRQ5E	IRQ4E	IRQ3E	IRQ2E	IRQ1E	IRQ0E
Initial value:		0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

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 interrupts disabled (Initial value)
1		IRQn interrupts enabled

(n = 7 to 0)

	IRQ7SCB	IRQ7SCA	IRQ6SCB	IRQ6SCA	IRQ5SCB	IRQ5SCA	IRQ4SCB	IRQ4SCA
Initial value:	0	0	0	0	0	0	0	0
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

ISCR

Bit :	7	6	5	4	3	2	1	0
	IRQ3SCB	IRQ3SCA	IRQ2SCB	IRQ2SCA	IRQ1SCB	IRQ1SCA	IRQ0SCB	IRQ0SCA
Initial value:	0	0	0	0	0	0	0	0
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

ISCR registers are 16-bit readable/writable registers that select rising edge, falling edge, or both edge detection, or level sensing, for the input at pins $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$.

ISCR registers are initialized to H'0000 by a reset and in hardware standby mode.

Bits 15 to 0: IRQ7 Sense Control A and B (IRQ7SCA, IRQ7SCB) to IRQ0 Sense Control A and B (IRQ0SCA, IRQ0SCB)

Bits 15 to 0

IRQ7SCB to IRQ0SCB	IRQ7SCA to IRQ0SCA	Description
0	0	Interrupt request generated at $\overline{\text{IRQ7}}$ to $\overline{\text{IRQ0}}$ input low level (initial value)
	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

Initial value: 0 0 0 0 0 0 0 0
R/W : R/(W)* 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.

Bits 7 to 0—IRQ7 to IRQ0 flags (IRQ7F to IRQ0F): These bits indicate the status of IRQ7 to IRQ0 interrupt requests.

Bit n IRQnF	Description
0	[Clearing conditions] (Initial value) <ul style="list-style-type: none"> • Cleared by reading IRQnF flag when IRQnF = 1, then writing 0 to IRQnF flag • When interrupt exception handling is executed when low-level detection is set (IRQnSCB = IRQnSCA = 0) and $\overline{\text{IRQn}}$ input is high • When IRQn interrupt exception handling is executed when falling, rising, or both-edge detection is set (IRQnSCB = 1 or IRQnSCA = 1) • When the DTC is activated by an IRQn interrupt, and the DISEL bit in MRB of the DTC is cleared to 0
1	[Setting conditions] <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 when falling edge detection is set (IRQnSCB = 0, IRQnSCA = 1) • When a rising edge occurs in $\overline{\text{IRQn}}$ input when rising edge detection is set (IRQnSCB = 1, IRQnSCA = 0) • When a falling or rising edge occurs in $\overline{\text{IRQn}}$ input when both-edge detection is set (IRQnSCB = IRQnSCA = 1)

(n = 7 to 0)

5.3.1 External Interrupts

There are nine external interrupts: NMI and IRQ7 to IRQ0. Of these, NMI and IRQ2 to IRQ0 can be used to restore the H8S/2350 Series from software standby mode.

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

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 priority level can be set with IPR.
- The status of interrupt requests IRQ7 to IRQ0 is indicated in ISR. ISR flags can be cleared to 0 by software.

A block diagram of interrupts IRQ7 to IRQ0 is shown in figure 5-2.

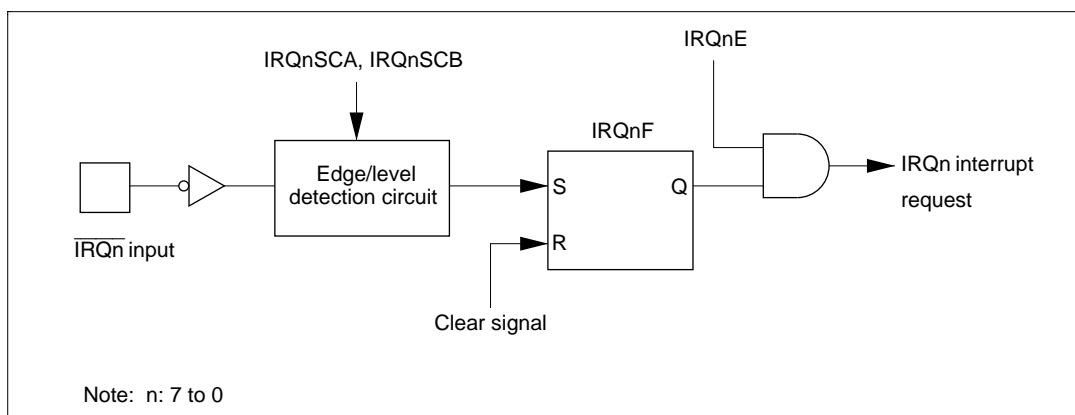


Figure 5-2 Block Diagram of Interrupts IRQ7 to IRQ0

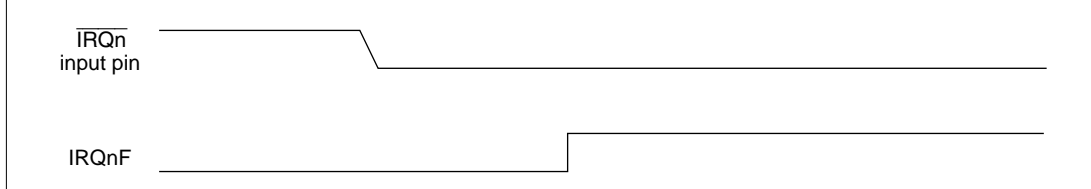


Figure 5-3 Timing of Setting IRQnF

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 been set for input or output. However, when a pin is used as an external interrupt input pin, do not clear the corresponding DDR to 0 and use the pin as an I/O pin for another function.

5.3.2 Internal Interrupts

There are 42 sources for internal interrupts from on-chip supporting modules.

- 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 both of these are set to 1 for a particular interrupt source, an interrupt request is issued to the interrupt controller.
- The interrupt priority level can be set by means of IPR.
- The DMAC and DTC can be activated by a TPU, SCI, or other interrupt request. When the DMAC or DTC is activated by an interrupt, the interrupt control mode and interrupt mask bits are not affected.

5.3.3 Interrupt Exception Handling 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 the IPR. 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.

NMI	External	7	H'000E	H'001C		High
IRQ0	pin	16	H'0020	H'0040	IPRA6 to 4	↑
IRQ1		17	H'0022	H'0044	IPRA2 to 0	
IRQ2		18	H'0024	H'0048	IPRB6 to 4	
IRQ3		19	H'0026	H'004C		
IRQ4		20	H'0028	H'0050	IPRB2 to 0	
IRQ5		21	H'002A	H'0054		
IRQ6		22	H'002C	H'0058	IPRC6 to 4	
IRQ7		23	H'002E	H'005C		
SWDTEND (software activation interrupt end)	DTC	24	H'0030	H'0060	IPRC2 to 0	
WOVI (interval timer)	Watchdog timer	25	H'0032	H'0064	IPRD6 to 4	
CMI (compare match)	Refresh controller	26	H'0034	H'0068	IPRD2 to 0	
Reserved	—	27	H'0036	H'006C	IPRE6 to 4	
ADI (A/D conversion end)	A/D	28	H'0038	H'0070	IPRE2 to 0	
Reserved	—	29	H'003A	H'0074		
		30	H'003C	H'0078		
		31	H'003E	H'007C		
TGI0A (TGR0A input capture/compare match)	TPU channel 0	32	H'0040	H'0080	IPRF6 to 4	
TGI0B (TGR0B input capture/compare match)		33	H'0042	H'0084		
TGI0C (TGR0C input capture/compare match)		34	H'0044	H'0088		
TGI0D (TGR0D input capture/compare match)		35	H'0046	H'008C		
TCI0V (overflow 0)		36	H'0048	H'0090		
Reserved	—	37	H'004A	H'0094		
		38	H'004C	H'0098		
		39	H'004E	H'009C		
						Low

Note: * Lower 16 bits of the start address.

Reserved	—	64	H'0080	H'0100	High ↑
		65	H'0082	H'0104	
		66	H'0084	H'0108	
		67	H'0086	H'010C	
		68	H'0088	H'0110	
		69	H'008A	H'0114	
		70	H'008C	H'0118	
		71	H'008E	H'011C	
DEND0A (channel 0/ channel 0A transfer end)	DMAC	72	H'0090	H'0120	IPRJ6 to 4
DEND0B (channel 0B transfer end)		73	H'0092	H'0124	
DEND1A (channel 1/ channel 1A transfer end)		74	H'0094	H'0128	
DEND1B (channel 1B transfer end)		75	H'0096	H'012C	
Reserved	—	76	H'0098	H'0130	
		77	H'009A	H'0134	
		78	H'009C	H'0138	
		79	H'009E	H'013C	
ERI0 (receive error 0)	SCI	80	H'00A0	H'0140	IPRJ2 to 0
RXI0 (reception completed 0)	channel 0	81	H'00A2	H'0144	
TXI0 (transmit data empty 0)		82	H'00A4	H'0148	
TEI0 (transmission end 0)		83	H'00A6	H'014C	
ERI1 (receive error 1)	SCI	84	H'00A8	H'0150	IPRK6 to 4
RXI1 (reception completed 1)	channel 1	85	H'00AA	H'0154	
TXI1 (transmit data empty 1)		86	H'00AC	H'0158	
TEI1 (transmission end 1)		87	H'00AE	H'015C	
Reserved	—	88	H'00B0	H'0160	IPRK2 to 0
		89	H'00B2	H'0164	
		90	H'00B4	H'0168	
		91	H'00B6	H'016C	
					Low

Note: * Lower 16 bits of the start address.

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

Table 5-5 shows the interrupt control modes.

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

Table 5-5 Interrupt Control Modes

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

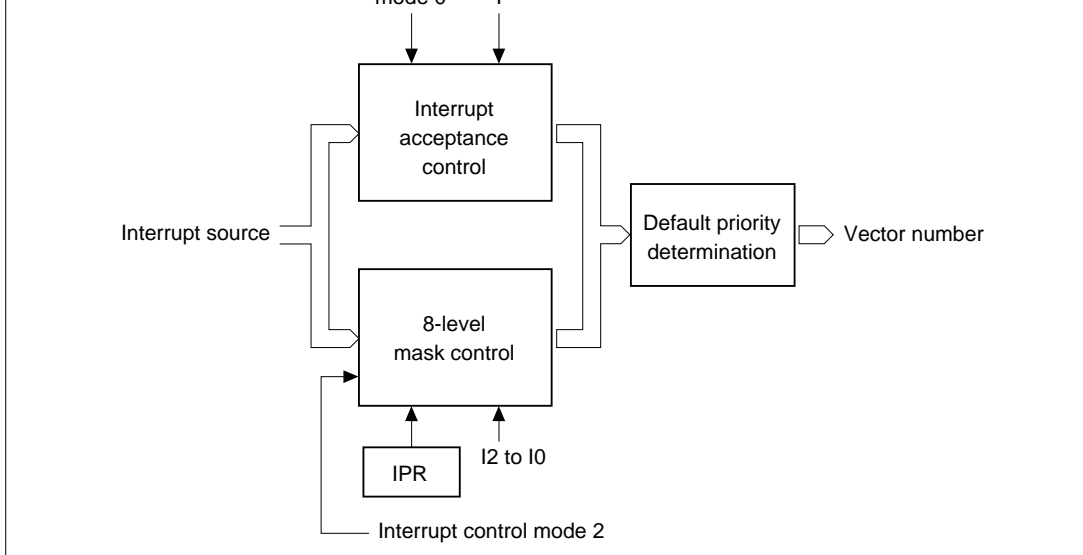


Figure 5-4 Block Diagram of Interrupt Control Operation

(1) Interrupt Acceptance Control

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

Table 5-6 shows the interrupts selected in each interrupt control mode.

Table 5-6 Interrupts Selected in Each Interrupt Control Mode (1)

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

Legend

* : Don't care

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

Table 5-7 Interrupts Selected in Each Interrupt Control Mode (2)

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

(3) Default Priority Determination

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

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

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

Table 5-8 shows operations and control signal functions in each interrupt control mode.

Table 5-8 Operations and Control Signal Functions in Each Interrupt Control Mode

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

Legend

- : Interrupt operation control performed
- X : No operation. (All interrupts enabled)
- IM : Used as interrupt mask bit
- PR : Sets priority.
- : Not used.
- *¹ : Set to 1 when interrupt is accepted.
- *² : Keep the initial setting.

Figure 5-5 shows a flowchart of the interrupt acceptance operation in this case.

- [1] If an interrupt source occurs when the corresponding interrupt enable bit is set to 1, an interrupt request is sent to the interrupt controller.
- [2] 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 an NMI interrupt is accepted, and other interrupt requests are held pending.
- [3] Interrupt requests are sent to the interrupt controller, the highest-ranked interrupt according to the priority system is accepted, and other interrupt requests are held pending.
- [4] When 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 saved on the stack shows the address of the first instruction to be executed after returning from the interrupt handling routine.
- [6] Next, the I bit in CCR is set to 1. This masks all interrupts except NMI.
- [7] 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.

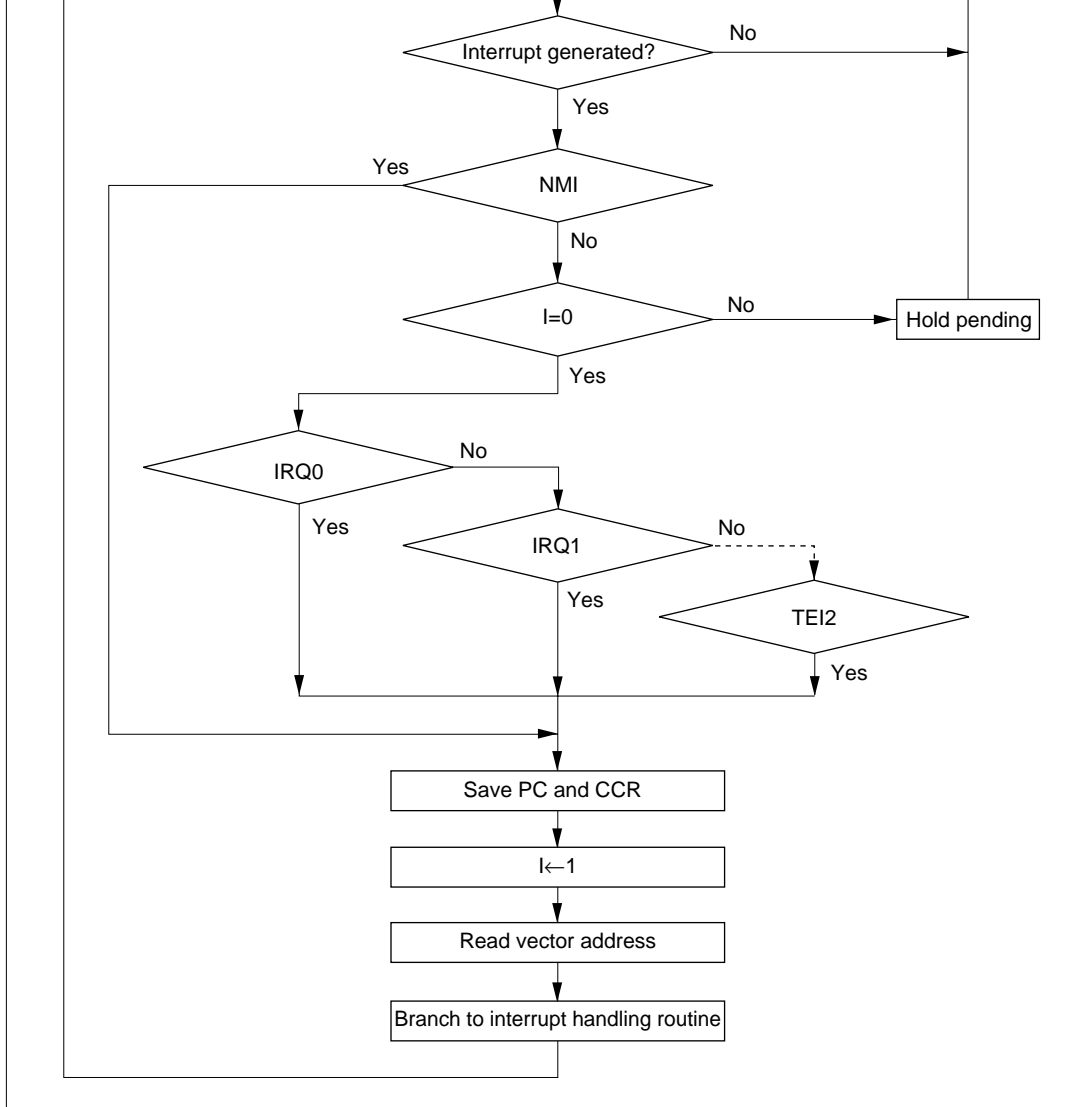


Figure 5-5 Flowchart of Procedure Up to Interrupt Acceptance in Interrupt Control Mode 0

Figure 5-6 shows a flowchart of the interrupt acceptance operation in this case.

- [1] If an interrupt source occurs when the corresponding interrupt enable bit is set to 1, an interrupt request is sent to the interrupt controller.
- [2] When interrupt requests are sent to the interrupt controller, the interrupt with the highest priority according to the interrupt priority levels set in IPR is selected, and lower-priority interrupt requests are held pending. If a number of interrupt requests with the same priority are generated at the same time, the interrupt request with the highest priority according to the priority system shown in table 5-4 is selected.
- [3] Next, the priority of the selected interrupt request is compared with the interrupt mask level set in EXR. An interrupt request with a priority no higher than the mask level set at that time is held pending, and only an interrupt request with a priority higher than the interrupt mask level is accepted.
- [4] When an interrupt request is accepted, interrupt exception handling starts after execution of the current instruction has been completed.
- [5] The PC, CCR, and EXR are saved to the stack area by interrupt exception handling. The PC saved on the stack shows the address of the first instruction to be executed after returning from the interrupt handling routine.
- [6] The T bit in EXR is cleared to 0. The interrupt mask level is rewritten with the priority level of the accepted interrupt.
If the accepted interrupt is NMI, the interrupt mask level is set to H'7.
- [7] 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.

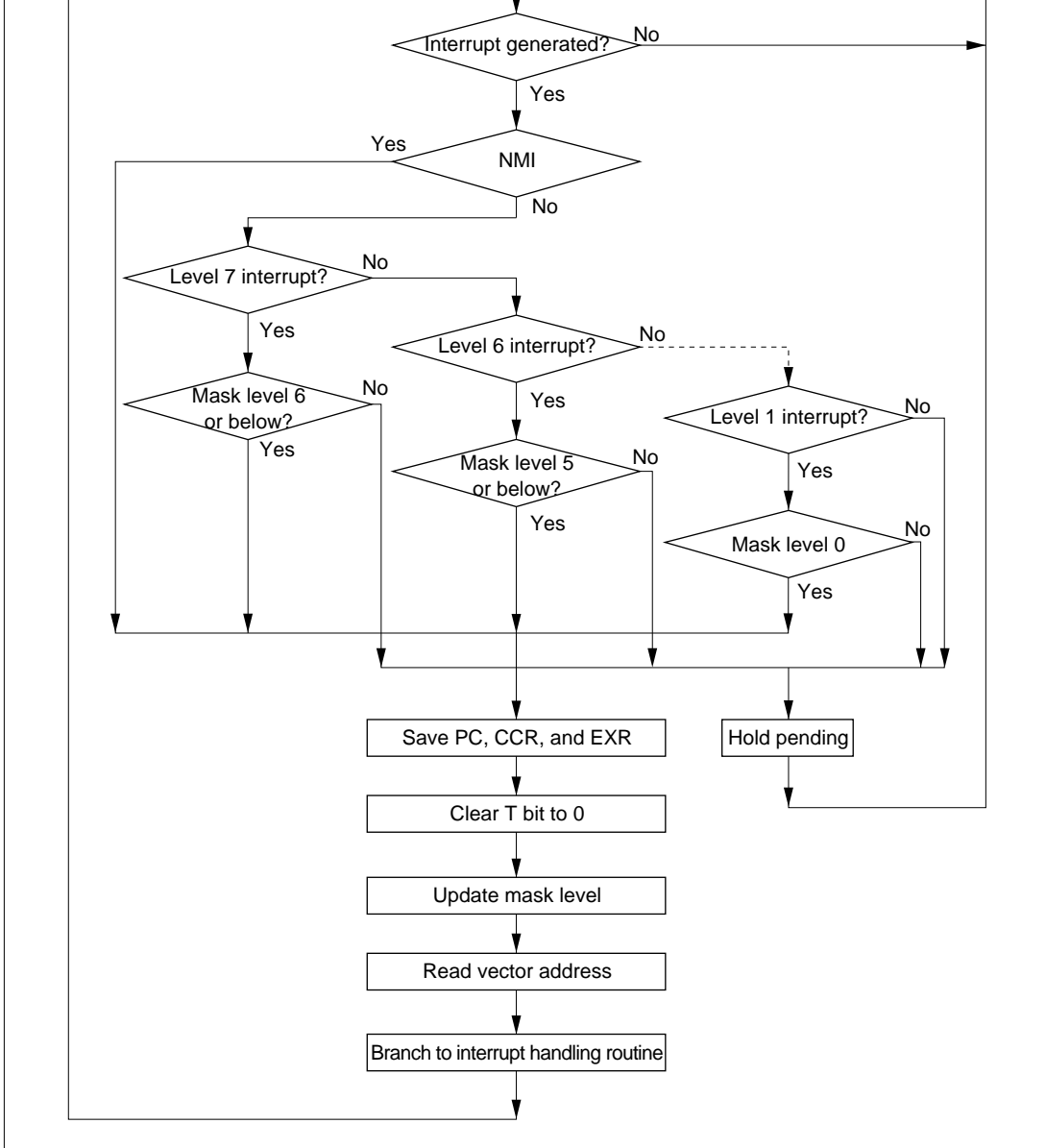


Figure 5-6 Flowchart of Procedure Up to Interrupt Acceptance in Interrupt Control Mode 2

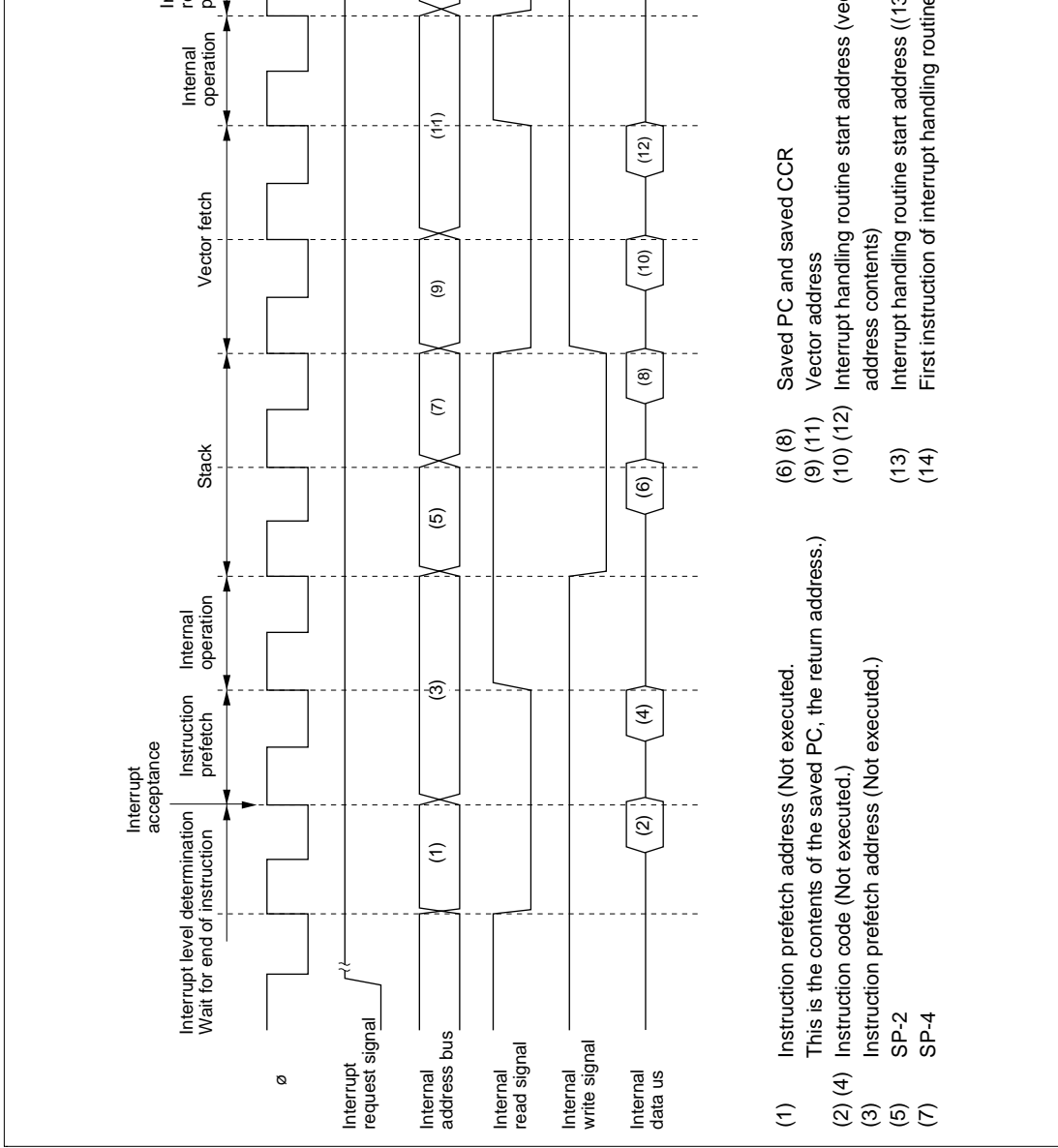


Figure 5-7 Interrupt Exception Handling

Table 5-9 shows interrupt response times - the interval between generation of an interrupt request and execution of the first instruction in the interrupt handling routine. The execution status symbols used in table 5-9 are explained in table 5-10.

Note: * Only applies to the H8S/2351.

Table 5-9 Interrupt Response Times

No.	Execution Status	Normal Mode		Advanced Mode	
		INTM1 = 0	INTM1 = 1	INTM1 = 0	INTM1 = 1
1	Interrupt priority determination* ¹	3	3	3	3
2	Number of wait states until executing instruction ends* ²	1 to $19+2\cdot S_I$	1 to $19+2\cdot S_I$	1 to $19+2\cdot S_I$	1 to $19+2\cdot S_I$
3	PC, CCR, EXR stack save	$2\cdot S_K$	$3\cdot S_K$	$2\cdot S_K$	$3\cdot S_K$
4	Vector fetch	S_I	S_I	$2\cdot S_I$	$2\cdot S_I$
5	Instruction fetch* ³	$2\cdot S_I$	$2\cdot S_I$	$2\cdot S_I$	$2\cdot S_I$
6	Internal processing* ⁴	2	2	2	2
Total (using on-chip memory)		11 to 31	12 to 32	12 to 32	13 to 33

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

Table 5-10 Number of States in Interrupt Handling Routine Execution Statuses

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

Legend

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

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

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

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

Figure 5-8 shows an example in which the TGIEA bit in the TPU's TIER0 register is cleared to 0.

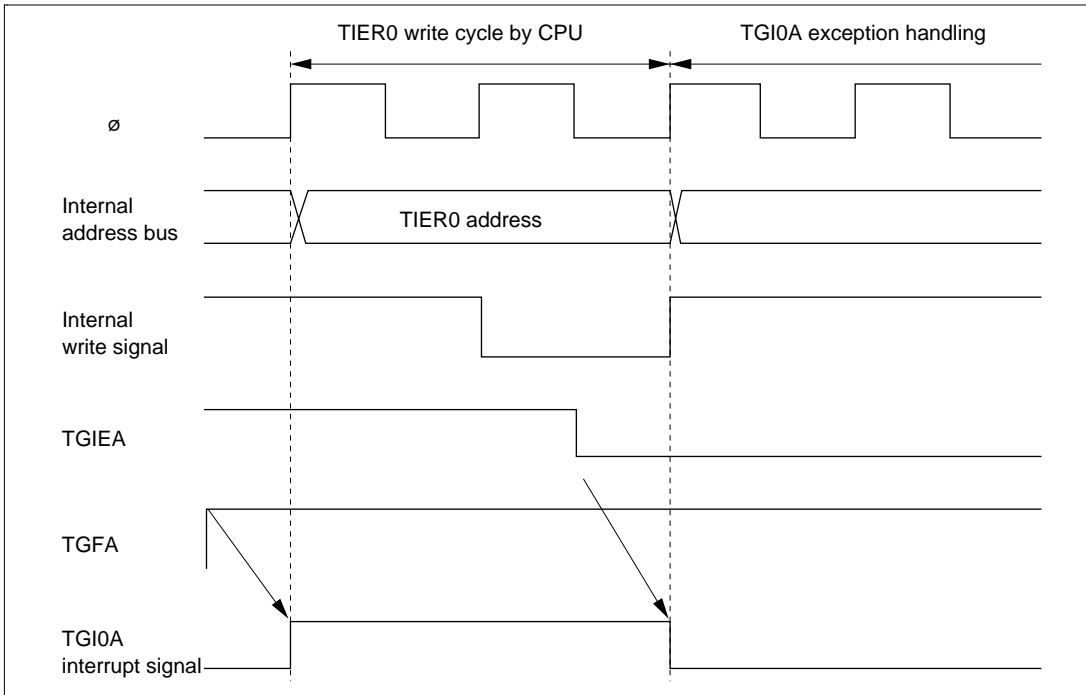


Figure 5-8 Contention between Interrupt Generation and Disabling

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

two states after execution of the instruction ends.

5.5.3 Times when Interrupts are Disabled

There are times when interrupt acceptance is disabled by the interrupt controller.

The interrupt controller disables interrupt acceptance for a 3-state period after the CPU has updated the mask level with an LDC, ANDC, ORC, or XORC instruction.

5.5.4 Interrupts during Execution of EEPMOV Instruction

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

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

With the EEPMOV.W instruction, if an interrupt request is issued during the transfer, interrupt exception handling starts at a break in the transfer cycle. The PC value saved on the stack in this case is the address of the next instruction.

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

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

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

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

For details of interrupt requests that can be used with to activate the DTC or DMAC, see section 8, Data Transfer Controller, and section 7, DMA Controller.

5.6.2 Block Diagram

Figure 5-9 shows a block diagram of the DTC and DMAC interrupt controller.

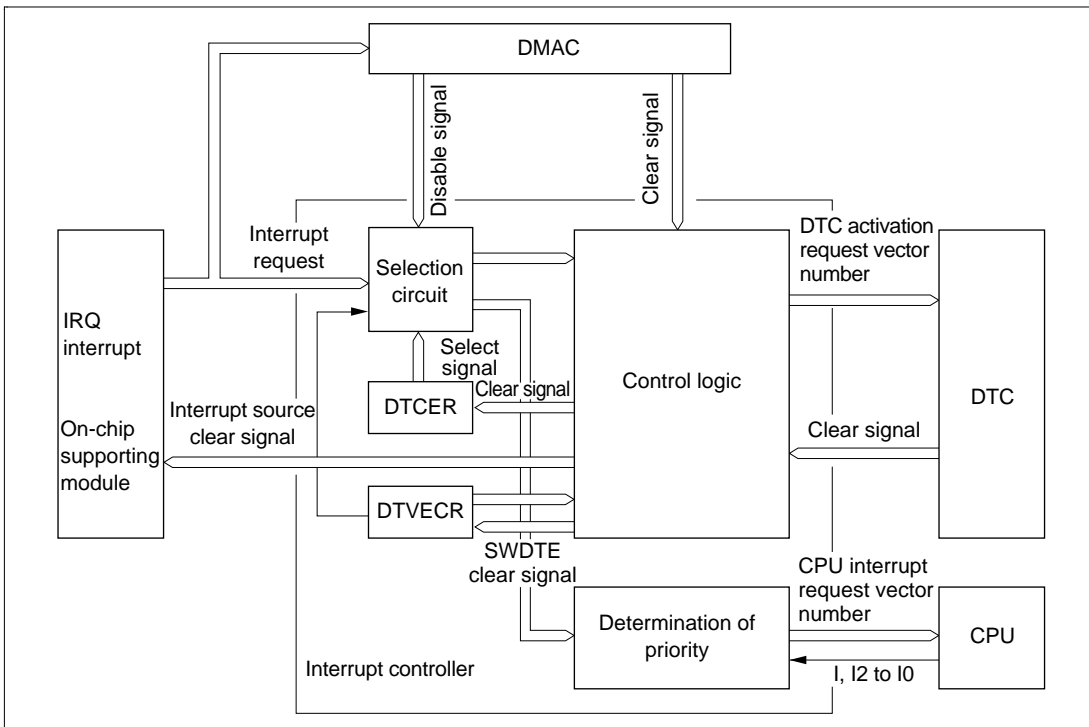


Figure 5-9 Interrupt Control for DTC and DMAC

each channel. The activation source for each DMAC channel is selected with bits DTF3 to DTF0 in DMACR. Whether the selected activation source is to be managed by the DMAC can be selected with the DTA bit of DMABCR. When the DTA bit is set to 1, the interrupt source constituting that DMAC activation source is not a DTC activation source or CPU interrupt source.

For interrupt sources other than interrupts managed by the DMAC, it is possible to select DTC activation request or CPU interrupt request with the DTCE bit of DTCEA to DTCEF in the DTC.

After a DTC data transfer, the DTCE bit can be cleared to 0 and an interrupt request sent to the CPU in accordance with the specification of the DISEL bit of MRB in the DTC.

When the DTC has performed the specified number of data transfers and the transfer counter value is zero, the DTCE bit is cleared to 0 and an interrupt request is sent to the CPU after the DTC data transfer.

(2) Determination of Priority: The DTC activation source is selected in accordance with the default priority order, and is not affected by mask or priority levels. See section 7.6, Interrupts, and section 8.3.3, DTC Vector Table, for the respective priorities.

With the DMAC, the activation source is input directly to each channel.

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

If the same interrupt is selected as a DMAC activation source and a DTC activation source or CPU interrupt source, operations are performed for them independently according to their respective operating statuses and bus mastership priorities.

Table 5-11 summarizes interrupt source selection and interrupt source clearance control according to the settings of the DTA bit of DMABCR in the DMAC, the DTCE bit of DTCEA to DTCEF in the DTC and the DISEL bit of MRB in the DTC.

DTA	DTC	DISEL	DMAC	DTC	CPU
0	0	*	○	X	△
	1	0	○	△	X
		1		○	○
1	*	*	△	X	X

Legend

- △ : 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.
- X : The relevant bit cannot be used.
- * : Don't care

(4) Notes on Use: SCI and A/D converter interrupt sources are cleared when the DMAC or DTC reads or writes to the prescribed register, and are not dependent upon the DTA bit or DISEL bit.

The H8S/2350 Series has a built-in bus controller (BSC) that manages the external address space divided into eight areas. The bus specifications, such as bus width and number of access states, can be set independently for each area, enabling multiple memories to be connected easily.

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

6.1.1 Features

The features of the bus controller are listed below.

- Manages external address space in area units
 - In advanced mode, manages the external space as 8 areas of 2-Mbytes
 - In normal mode, manages the external space as a single area
 - Bus specifications can be set independently for each area
 - DRAM/burst ROM interfaces can be set
- Basic bus interface
 - Chip select ($\overline{CS0}$ to $\overline{CS7}$) can be output for areas 0 to 7
 - 8-bit access or 16-bit access can be selected for each area
 - 2-state access or 3-state access can be selected for each area
 - Program wait states can be inserted for each area
- DRAM interface
 - DRAM interface can be set for areas 2 to 5 (in advanced mode)
 - Row address/column address multiplexed output (8/9/10 bits)
 - Two byte access methods (2-CAS)
 - Burst operation (fast page mode)
 - T_p cycle insertion to secure RAS precharging time
 - Choice of CAS-before-RAS refreshing or self-refreshing
- Burst ROM interface
 - Burst ROM interface can be set for area 0
 - Choice of 1- or 2-state burst access

- Write buffer functions
 - External write cycle and internal access can be executed in parallel
 - DMAC single-address mode and internal access can be executed in parallel
- Bus arbitration function
 - Includes a bus arbiter that arbitrates bus mastership among the CPU, DMAC, and DTC
- Other features
 - Refresh counter (refresh timer) can be used as an interval timer
 - External bus release function

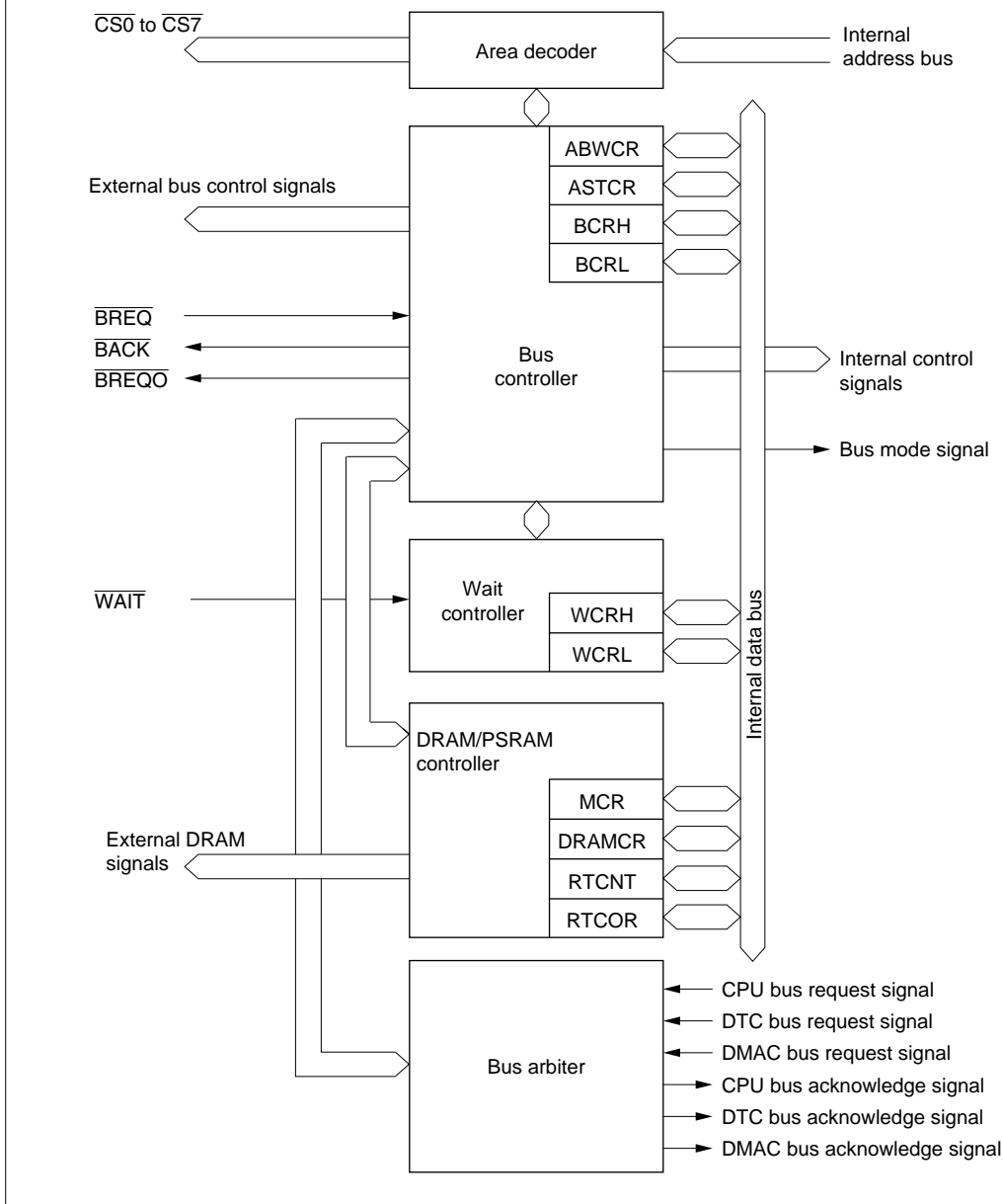


Figure 6-1 Block Diagram of Bus Controller

Name	Symbol	I/O	Function
Address strobe	\overline{AS}	Output	Strobe signal indicating that address output on address bus is enabled.
Read	\overline{RD}	Output	Strobe signal indicating that external space is being read.
High write/write enable	\overline{HWR}	Output	Strobe signal indicating that external space is to be written, and upper half (D_{15} to D_8) of data bus is enabled. 2-CAS DRAM write enable signal.
Low write	\overline{LWR}	Output	Strobe signal indicating that external space is to be written, and lower half (D_7 to D_0) of data bus is enabled.
Chip select 0	$\overline{CS0}$	Output	Strobe signal indicating that area 0 is selected.
Chip select 1	$\overline{CS1}$	Output	Strobe signal indicating that area 1 is selected.
Chip select 2/row address strobe 2	$\overline{CS2}$	Output	Strobe signal indicating that area 2 is selected. DRAM row address strobe signal when area 2 is in DRAM space.
Chip select 3/row address strobe 3	$\overline{CS3}$	Output	Strobe signal indicating that area 3 is selected. DRAM row address strobe signal when area 3 is in DRAM space.
Chip select 4/row address strobe 4	$\overline{CS4}$	Output	Strobe signal indicating that area 4 is selected. DRAM row address strobe signal when area 4 is in DRAM space.
Chip select 5/row address strobe 5	$\overline{CS5}$	Output	Strobe signal indicating that area 5 is selected. DRAM row address strobe signal when area 5 is in DRAM space.
Chip select 6	$\overline{CS6}$	Output	Strobe signal indicating that area 6 is selected.
Chip select 7	$\overline{CS7}$	Output	Strobe signal indicating that area 7 is selected.

Lower column strobe	$\overline{\text{LCAS}}$	Output	DRAM lower column address strobe signal.
Wait	$\overline{\text{WAIT}}$	Input	Wait request signal when accessing external 3-state access space.
Bus request	$\overline{\text{BREQ}}$	Input	Request signal that releases bus to external device.
Bus request acknowledge	$\overline{\text{BACK}}$	Output	Acknowledge signal indicating that bus has been released.
Bus request output	$\overline{\text{BREQO}}$	Output	External bus request signal used when internal bus master accesses external space when external bus is released.

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* ¹
			Power-On Reset	Manual Reset	
Bus width control register	ABWCR	R/W	H'FF/H'00* ²	Retained	H'FED0
Access state control register	ASTCR	R/W	H'FF	Retained	H'FED1
Wait control register H	WCRH	R/W	H'FF	Retained	H'FED2
Wait control register L	WCRL	R/W	H'FF	Retained	H'FED3
Bus control register H	BCRH	R/W	H'D0	Retained	H'FED4
Bus control register L	BCRL	R/W	H'3C	Retained	H'FED5
Memory control register	MCR	R/W	H'00	Retained	H'FED6
DRAM control register	DRAMCR	R/W	H'00	Retained	H'FED7
Refresh timer/counter	RTCNT	R/W	H'00	Retained	H'FED8
Refresh time constant register	RTCOR	R/W	H'FF	Retained	H'FED9

Notes: 1. Lower 16 bits of the address.

2. Determined by the MCU operating mode.

Bit	:	7	6	5	4	3	2	1	0
		ABW7	ABW6	ABW5	ABW4	ABW3	ABW2	ABW1	ABW0
Modes 1 to 3, 5 to 7*									
Initial value	:	1	1	1	1	1	1	1	1
RW	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Mode 4									
Initial value	:	0	0	0	0	0	0	0	0
RW	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

ABWCR is an 8-bit readable/writable register that designates each area for either 8-bit access or 16-bit access.

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

In normal mode, the settings of bits ABW7 to ABW1 have no effect on operation.

After a power-on reset and in hardware standby mode, ABWCR is initialized to H'FF in modes 1, 2, 3, and 5, 6, 7*, and to H'00 in mode 4. It is not initialized by a manual reset or in software standby mode.

Note: * Modes 2, 3, 6 and 7 only apply to the H8S/2351.

Bits 7 to 0—Area 7 to 0 Bus Width Control (ABW7 to ABW0): These bits select whether the corresponding area is to be designated for 8-bit access or 16-bit access. In normal mode, only part of area 0 is enabled, and the ABW0 bit selects whether external space is to be designated for 8-bit access or 16-bit access.

Bit n	Description
ABWn	
0	Area n is designated for 16-bit access
1	Area n is designated for 8-bit access

(n = 7 to 0)

Initial value :	1	1	1	1	1	1	1	1	1
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

ASTCR is an 8-bit readable/writable register that designates each area as either a 2-state access space or a 3-state access space.

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

In normal mode, the settings of bits AST7 to AST1 have no effect on operation.

ASTCR is initialized to H'FF by a power-on reset and in hardware standby mode. It is not initialized by a manual reset or in software standby mode.

Bits 7 to 0—Area 7 to 0 Access State Control (AST7 to AST0): These bits select whether the corresponding area is to be designated as a 2-state access space or a 3-state access space. In normal mode, only part of area 0 is enabled, and the AST0 bit selects whether external space is to be designated for 2-state access or 3-state access.

Wait state insertion is enabled or disabled at the same time.

Bit n ASTn	Description	
0	Area n is designated for 2-state access Wait state insertion in area n external space is disabled	
1	Area n is designated for 3-state access Wait state insertion in area n external space is enabled	(Initial value)

(n = 7 to 0)

In normal mode, only part of area is 0 is enabled, and bits W01 and W00 select the number of program wait states for the external space . The settings of bits W71, W70 to W11, and W10 have no effect on operation.

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

WCRH and WCRL are initialized to H'FF by a power-on reset and in hardware standby mode. They are not initialized by a manual reset or in software standby mode.

(1) WCRH

Bit	:	7	6	5	4	3	2	1	0
		W71	W70	W61	W60	W51	W50	W41	W40
Initial value	:	1	1	1	1	1	1	1	1
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Bits 7 and 6—Area 7 Wait Control 1 and 0 (W71, W70): These bits select the number of program wait states when area 7 in external space is accessed while the AST7 bit in ASTCR is set to 1.

Bit 7 W71	Bit 6 W70	Description
0	0	Program wait not inserted when external space area 7 is accessed
	1	1 program wait state inserted when external space area 7 is accessed
1	0	2 program wait states inserted when external space area 7 is accessed
	1	3 program wait states inserted when external space area 7 is accessed (Initial value)

W61	W60	Description
0	0	Program wait not inserted when external space area 6 is accessed
	1	1 program wait state inserted when external space area 6 is accessed
1	0	2 program wait states inserted when external space area 6 is accessed
	1	3 program wait states inserted when external space area 6 is accessed (Initial value)

Bits 3 and 2—Area 5 Wait Control 1 and 0 (W51, W50): These bits select the number of program wait states when area 5 in external space is accessed while the AST5 bit in ASTCR is set to 1.

Bit 3 W51	Bit 2 W50	Description
0	0	Program wait not inserted when external space area 5 is accessed
	1	1 program wait state inserted when external space area 5 is accessed
1	0	2 program wait states inserted when external space area 5 is accessed
	1	3 program wait states inserted when external space area 5 is accessed (Initial value)

Bits 1 and 0—Area 4 Wait Control 1 and 0 (W41, W40): These bits select the number of program wait states when area 4 in external space is accessed while the AST4 bit in ASTCR is set to 1.

Bit 1 W41	Bit 0 W40	Description
0	0	Program wait not inserted when external space area 4 is accessed
	1	1 program wait state inserted when external space area 4 is accessed
1	0	2 program wait states inserted when external space area 4 is accessed
	1	3 program wait states inserted when external space area 4 is accessed (Initial value)

Bits 7 and 6—Area 3 Wait Control 1 and 0 (W31, W30): These bits select the number of program wait states when area 3 in external space is accessed while the AST3 bit in ASTCR is set to 1.

Bit 7 W31	Bit 6 W30	Description
0	0	Program wait not inserted when external space area 3 is accessed
	1	1 program wait state inserted when external space area 3 is accessed
1	0	2 program wait states inserted when external space area 3 is accessed
	1	3 program wait states inserted when external space area 3 is accessed (Initial value)

Bits 5 and 4—Area 2 Wait Control 1 and 0 (W21, W20): These bits select the number of program wait states when area 2 in external space is accessed while the AST2 bit in ASTCR is set to 1.

Bit 5 W21	Bit 4 W20	Description
0	0	Program wait not inserted when external space area 2 is accessed
	1	1 program wait state inserted when external space area 2 is accessed
1	0	2 program wait states inserted when external space area 2 is accessed
	1	3 program wait states inserted when external space area 2 is accessed (Initial value)

W11	W10	Description
0	0	Program wait not inserted when external space area 1 is accessed
	1	1 program wait state inserted when external space area 1 is accessed
1	0	2 program wait states inserted when external space area 1 is accessed
	1	3 program wait states inserted when external space area 1 is accessed (Initial value)

Bits 1 and 0—Area 0 Wait Control 1 and 0 (W01, W00): These bits select the number of program wait states when area 0 in external space is accessed while the AST0 bit in ASTCR is set to 1.

Bit 1 W01	Bit 0 W00	Description
0	0	Program wait not inserted when external space area 0 is accessed
	1	1 program wait state inserted when external space area 0 is accessed
1	0	2 program wait states inserted when external space area 0 is accessed
	1	3 program wait states inserted when external space area 0 is accessed (Initial value)

Initial value :	1	1	0	1	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W

BCRH is an 8-bit readable/writable register that selects enabling or disabling of idle cycle insertion, and the memory interface for areas 2 to 5 and area 0.

BCRH is initialized to H'D0 by a power-on reset and in hardware standby mode. It is not initialized by a manual reset or in software standby mode.

Bit 7—Idle Cycle Insert 1 (ICIS1): Selects whether or not one idle cycle state is to be inserted between bus cycles when successive external read cycles are performed in different areas.

Bit 7

ICIS1	Description
0	Idle cycle not inserted in case of successive external read cycles in different areas
1	Idle cycle inserted in case of successive external read cycles in different areas (Initial value)

Bit 6—Idle Cycle Insert 0 (ICIS0): Selects whether or not one idle cycle state 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 (Initial value)

Bit 5—Burst ROM Enable (BRSTRM): Selects whether area 0 is used as a burst ROM interface. In normal mode, the selection can be made from the entire external space.

Bit 5

BRSTRM	Description
0	Area 0 is basic bus interface (Initial value)
1	Area 0 is burst ROM interface

0	Burst cycle comprises 1 state	
1	Burst cycle comprises 2 states	(Initial value)

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	(Initial value)
1	Max. 8 words in burst access	

Bits 2 to 0—RAM Type Select (RMTS2 to RMTS0): These bits select the memory interface for areas 2 to 5 in advanced mode.

When DRAM space is selected, the relevant area is designated as DRAM interface.

Bit 2 RMTS2	Bit 1 RMTS1	Bit 0 RMTS0	Description Area 5	Area 4	Area 3	Area 2
0	0	0	Normal space			
		1	Normal space			DRAM space
	1	0	Normal space			DRAM space
		1	DRAM space			
1	—	—	—			

Note: When areas selected in DRAM space are all 8-bit space, the PF₂ pin can be used as an I/O port, BREQO, or WAIT.

Initial value :	0	0	1	1	1	0	0
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W

BCRL is an 8-bit readable/writable register that performs selection of the external bus-released state protocol, the LCAS signal, DMAC single address transfer, enabling or disabling of the write data buffer function, and enabling or disabling of $\overline{\text{WAIT}}$ pin input.

BCRL is initialized to H'3C by a power-on reset and in hardware standby mode. It is not initialized by a manual reset or in software standby mode.

Bit 7—Bus Release Enable (BRLE): Enables or disables external bus release.

Bit 7	
BRLE	Description
0	External bus release is disabled. $\overline{\text{BREQ}}$, $\overline{\text{BACK}}$, and $\overline{\text{BREQO}}$ can be used as I/O ports. (Initial value)
1	External bus release is enabled.

Bit 6—BREQO Pin Enable (BREQOE): Outputs a signal that requests the external bus master to drop the bus request signal ($\overline{\text{BREQ}}$) in the external bus release state, when an internal bus master performs an external space access, or when a refresh request is generated.

Bit 6	
BREQOE	Description
0	$\overline{\text{BREQO}}$ output disabled. $\overline{\text{BREQO}}$ can be used as I/O port. (Initial value)
1	$\overline{\text{BREQO}}$ output enabled.

Bit 5—Reserved: Only 1 should be written to this bit.

Bit 4—LCAS Select (LCASS): Write 0 to this bit when using the DRAM interface. $\overline{\text{LCAS}}$ pin used for 2-CAS type DRAM interface $\overline{\text{LCAS}}$ signal. $\overline{\text{BREQO}}$ output and $\overline{\text{WAIT}}$ input cannot be used when $\overline{\text{LCAS}}$ signal is used.

0	When DMAC single address transfer is performed in DRAM space, full access is always executed $\overline{\text{DACK}}$ signal goes low from T_r or T_1 cycle	
1	Burst access is possible when DMAC single address transfer is performed in DRAM space $\overline{\text{DACK}}$ signal goes low from T_{c1} or T_2 cycle	(Initial value)

Bit 2—Reserved: Only 1 should be written to this bit.

Bit 1—Write Data Buffer Enable (WDBE): Selects whether or not the write buffer function is used for an external write cycle or DMAC single address cycle.

Bit 1

WDBE	Description	
0	Write data buffer function not used	(Initial value)
1	Write data buffer function used	

Bit 0—WAIT Pin Enable (WAITE): Selects enabling or disabling of wait input by the $\overline{\text{WAIT}}$ pin.

Bit 0

WAITE	Description	
0	Wait input by $\overline{\text{WAIT}}$ pin disabled. $\overline{\text{WAIT}}$ pin can be used as I/O port.	(Initial value)
1	Wait input by $\overline{\text{WAIT}}$ pin enabled	

Initial value : 0 0 0 0 0 0 0 0 0
 R/W : R/W R/W R/W R/W R/W R/W R/W R/W

MCR is an 8-bit readable/writable register that selects the DRAM strobe control method, number of precharge cycles, access mode, address multiplexing shift size, and the number of wait states inserted during refreshing, when areas 2 to 5 are designated as DRAM interface.

MCR is initialized to H'00 by a power-on reset and in hardware standby mode. It is not initialized by a manual reset or in software standby mode.

Bit 7—TP Cycle Control (TPC): Selects whether a 1-state or 2-state precharge cycle (T_p) is to be used when areas 2 to 5 designated as DRAM space are accessed.

Bit 7 TPC	Description	
0	1-state precharge cycle is inserted	(Initial value)
1	2-state precharge cycle is inserted	

Bit 6—Burst Access Enable (BE): Selects enabling or disabling of burst access to areas 2 to 5 designated as DRAM space. DRAM space burst access is performed in fast page mode.

Bit 6 BE	Description	
0	Burst disabled (always full access)	(Initial value)
1	For DRAM space access, access in fast page mode	

the DE bit to 1.

Bit 5	RCDM	Description
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0		DRAM interface: RAS up mode selected (Initial value)
1		DRAM interface: RAS down mode selected

Bit 4—2-CAS Method Select (CW2): Write 1 to this bit when areas 2 to 5 are designated as 8-bit DRAM space, and 0 otherwise.

Bit 4	CW2	Description
--------------	------------	--------------------

0		16-bit DRAM space selected (Initial value)
1		8-bit DRAM space selected

Bit 3 MXC1	Bit 2 MXC0	Description
0	0	8-bit shift (Initial value) <ul style="list-style-type: none"> When 8-bit access space is designated: Row address A₂₃ to A₈ used for comparison When 16-bit access space is designated: Row address A₂₃ to A₉ used for comparison
	1	9-bit shift <ul style="list-style-type: none"> When 8-bit access space is designated: Row address A₂₃ to A₉ used for comparison When 16-bit access space is designated: Row address A₂₃ to A₁₀ used for comparison
1	0	10-bit shift <ul style="list-style-type: none"> When 8-bit access space is designated: Row address A₂₃ to A₁₀ used for comparison When 16-bit access space is designated: Row address A₂₃ to A₁₁ used for comparison
	1	—

Bits 1 and 0—Refresh Cycle Wait Control 1 and 0 (RLW1, RLW0): These bits select the number of wait states to be inserted in a DRAM interface CAS-before-RAS refresh cycle. This setting is used for all areas designated as DRAM space. Wait input by the $\overline{\text{WAIT}}$ pin is disabled.

Bit 1 RLW1	Bit 0 RLW0	Description
0	0	No wait state inserted (Initial value)
	1	1 wait state inserted
1	0	2 wait states inserted
	1	3 wait states inserted

Initial value :	0	0	0	0	0	0	0	0
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

DRAMCR is an 8-bit readable/writable register that selects the DRAM refresh mode and refresh counter clock, and controls the refresh timer.

DRAMCR is initialized to H'00 by a power-on reset and in hardware standby mode. It is not initialized by a manual reset or in software standby mode.

Bit 7—Refresh Control (RFSHE): Selects whether or not refresh control is performed. When refresh control is not performed, the refresh timer can be used as an interval timer. Refresh control is not performed in normal mode.

Bit 7

RFSHE	Description	
0	Refresh control is not performed	(Initial value)
1	Refresh control is performed	

Bit 6—RAS-CAS Wait (RCW): Controls wait state insertion in DRAM interface CAS-before-RAS refreshing.

Bit 6

RCW	Description	
0	Wait state insertion in CAS-before-RAS refreshing disabled RAS falls in T_{Rf} cycle	(Initial value)
1	One wait state inserted in CAS-before-RAS refreshing RAS falls in T_{Rc1} cycle	

RMODE	Description
0	DRAM interface CAS-before-RAS refreshing used (Initial value)
1	Self-refreshing used

Bit 4—Compare Match Flag (CMF): Status flag that indicates a match between the values of RTCNT and RTCOR.

When refresh control is performed (RFSHE = 1), 1 should be written to the CMF bit when writing to DRAMCR.

Bit 4 CMF	Description
0	[Clearing condition] Cleared by reading the CMF flag when CMF = 1, then writing 0 to the CMF flag (Initial value)
1	[Setting condition] Set when RTCNT = RTCOR

Bit 3—Compare Match Interrupt Enable (CMIE): Enables or disables interrupt requests (CMI) by the CMF flag when the CMF flag in DRAMCR is set to 1.

When refresh control is performed (RFSHE = 1), the CMIE bit is always cleared to 0.

Bit 3 CMIE	Description
0	Interrupt request (CMI) by CMF flag disabled (Initial value)
1	Interrupt request (CMI) by CMF flag enabled

CKS2	CKS1	CKS0	Description
0	0	0	Count operation disabled (Initial value)
		1	Count uses $\emptyset/2$
	1	0	Count uses $\emptyset/8$
		1	Count uses $\emptyset/32$
1	0	0	Count uses $\emptyset/128$
		1	Count uses $\emptyset/512$
	1	0	Count uses $\emptyset/2048$
		1	Count uses $\emptyset/4096$

Initial value :	0	0	0	0	0	0	0	0
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

RTCNT is an 8-bit readable/writable up-counter.

RTCNT counts up using the internal clock selected by bits CKS2 to CKS0 in DRAMCR.

When RTCNT matches RTCOR (compare match), the CMF flag in DRAMCR is set to 1 and RTCNT is cleared to H'00. If the RFSHE bit in DRAMCR is set to 1 at this time, a refresh cycle is started. Also, if the CMIE bit in DRAMCR is set to 1, a compare match interrupt (CMI) is generated.

RTCNT is initialized to H'00 by a power-on reset and in hardware standby mode. It is not initialized by a manual reset or in software standby mode.

6.2.9 Refresh Time Constant Register (RTCOR)

Bit :	7	6	5	4	3	2	1	0
	<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 :	1	1	1	1	1	1	1	1
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

RTCOR is an 8-bit readable/writable register that sets the period for compare match operations with RTCNT.

The values of RTCOR and RTCNT are constantly compared, and if they match, the CMF flag in DRAMCR is set to 1 and RTCNT is cleared to H'00.

RTCOR is initialized to H'FF by a power-on reset and in hardware standby mode. It is not initialized by a manual reset or in software standby mode.

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

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

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

(2) Number of Access States: Two or three access states can be selected with ASTCR. An area for which 2-state access is selected functions as a 2-state access space, and an area for which 3-state access is selected functions as a 3-state access space.

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

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

(3) Number of Program Wait States: When 3-state access space is designated by ASTCR, the number of program wait states to be inserted automatically is selected with WCRH and WCRL. From 0 to 3 program wait states can be selected.

Table 6-3 shows the bus specifications for each basic bus interface area.

0	0	—	—	16	2	0
	1	0	0		3	0
			1			1
		1	0			2
			1			3
1	0	—	—	8	2	0
	1	0	0		3	0
			1			1
		1	0			2
			1			3

6.3.3 Memory Interfaces

The H8S/2350 Series memory interfaces comprise a basic bus interface that allows direct connection of ROM, SRAM, and so on; a DRAM interface that allows direct connection of DRAM; and a burst ROM interface that allows direct connection of burst ROM. The interface can be selected independently for each area.

An area for which the basic bus interface is designated functions as normal space, an area for which the DRAM interface is designated functions as DRAM space, and an area for which the burst ROM interface is designated functions as burst ROM space.

further details.

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

When area 0 external space is accessed, the $\overline{CS0}$ signal can be output.

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

Note: * Only applies to the H8S/2351.

Areas 1 and 6: In external expansion mode, all of areas 1 and 6 is external space.

When area 1 and 6 external space is accessed, the $\overline{CS1}$ and $\overline{CS6}$ pin signals respectively can be output.

Only the basic bus interface can be used for areas 1 and 6.

Areas 2 to 5: In external expansion mode, all of areas 2 to 5 is external space.

When area 2 to 5 external space is accessed, signals $\overline{CS2}$ to $\overline{CS5}$ can be output.

Basic bus interface or DRAM interface can be selected for areas 2 to 5. With the DRAM interface, signals $\overline{CS2}$ to $\overline{CS5}$ are used as \overline{RAS} signals.

Area 7: Area 7 includes the on-chip RAM and internal I/O registers. In external expansion mode, the space excluding the 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.

When area 7 external space is accessed, the $\overline{CS7}$ signal can be output.

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

expansion 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 .

When external space is accessed, the $\overline{CS0}$ signal can be output.

The basic bus interface or burst ROM interface can be selected.

Note: * Only applies to the H8S/2351.

signal can be output.

Figure 6-3 shows an example of \overline{CSn} ($n = 0$ to 7) output timing.

Enabling or disabling of the \overline{CSn} signal is performed by setting the data direction register (DDR) for the port corresponding to the particular \overline{CSn} pin.

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

In the H8S/2351's ROM-enabled expansion mode, pins $\overline{CS0}$ to $\overline{CS7}$ are all placed in the input state after a power-on reset, and so the corresponding DDR bits should be set to 1 when outputting signals $\overline{CS0}$ to $\overline{CS7}$.

For details, see section 9, I/O Ports.

When areas 2 to 5 are designated as DRAM space, outputs $\overline{CS2}$ to $\overline{CS5}$ are used as \overline{RAS} signals.

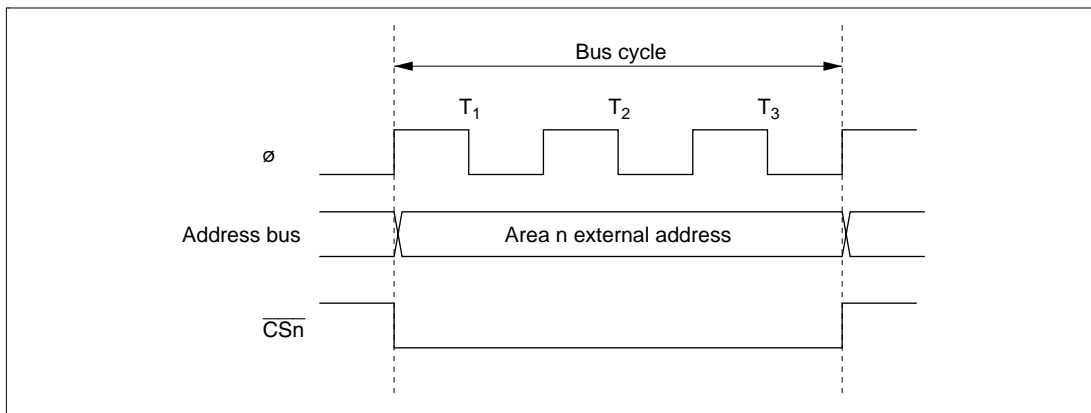


Figure 6-3 \overline{CSn} Signal Output Timing ($n = 0$ to 7)

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

The bus specifications can be selected with ABWCR, ASTCR, WCRH, and WCRL (see table 6-3).

6.4.2 Data Size and Data Alignment

Data sizes for the CPU and other internal bus masters are byte, word, and longword. The bus controller has a data alignment function, and when accessing external space, controls whether the upper data bus (D_{15} to D_8) or lower data bus (D_7 to D_0) 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 6-4 illustrates data alignment control for the 8-bit access space. With the 8-bit access space, the upper data bus (D_{15} to D_8) is always used for accesses. The amount of data that can be accessed at one time is one byte: a word transfer instruction is performed as two byte accesses, and a longword transfer instruction, as four byte accesses.

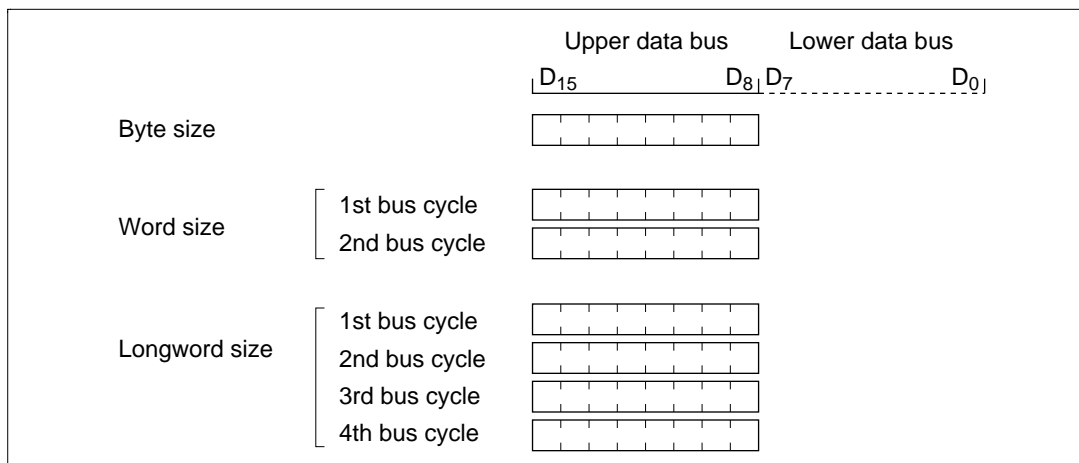


Figure 6-4 Access Sizes and Data Alignment Control (8-Bit Access Space)

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

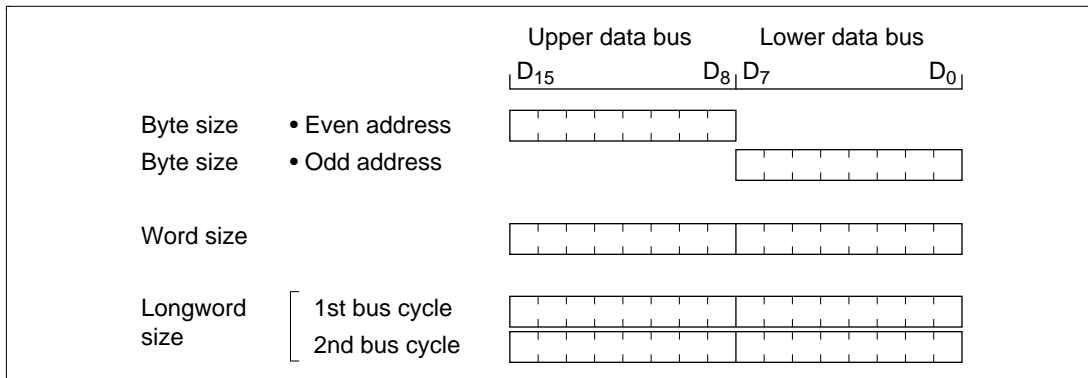


Figure 6-5 Access Sizes and Data Alignment Control (16-Bit Access Space)

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

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

Table 6-4 Data Buses Used and Valid Strobes

Area	Access Size	Read/Write	Address	Valid Strobe	Upper Data Bus (D ₁₅ to D ₈)	Lower data bus (D ₇ to D ₀)
8-bit access space	Byte	Read	—	\overline{RD}	Valid	Invalid
		Write	—	\overline{HWR}		Hi-Z
16-bit access space	Byte	Read	Even	\overline{RD}	Valid	Invalid
			Odd		Invalid	Valid
	Write	Even	\overline{HWR}	Valid	Hi-Z	
		Odd	\overline{LWR}	Hi-Z	Valid	
Word	Read	—	\overline{RD}	Valid	Valid	
		Write	—	$\overline{HWR}, \overline{LWR}$	Valid	Valid

Note: Hi-Z: High impedance

Invalid: Input state; input value is ignored.

The $\overline{\text{LWR}}$ pin is fixed high. Wait states cannot be inserted.

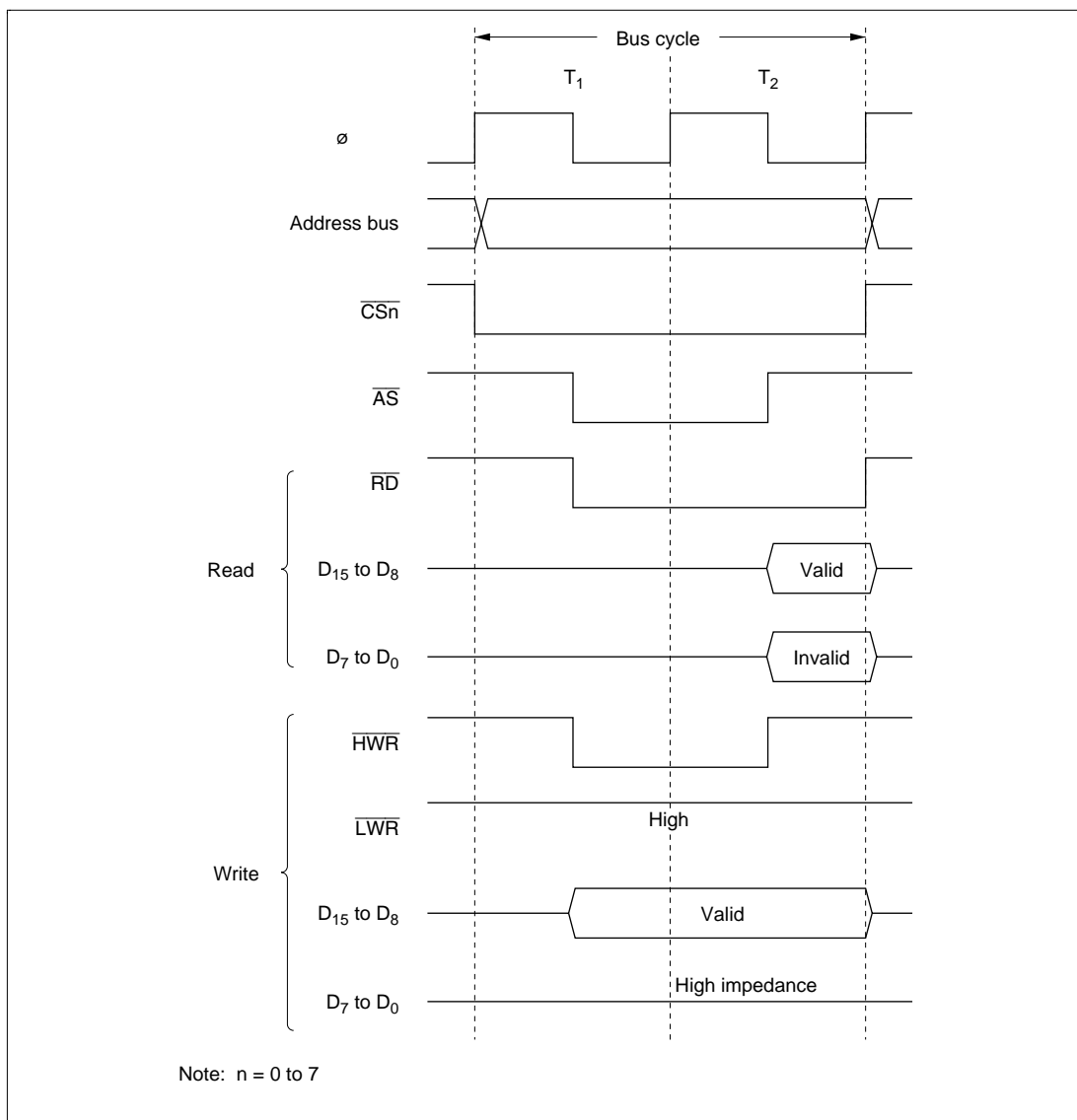


Figure 6-6 Bus Timing for 8-Bit 2-State Access Space

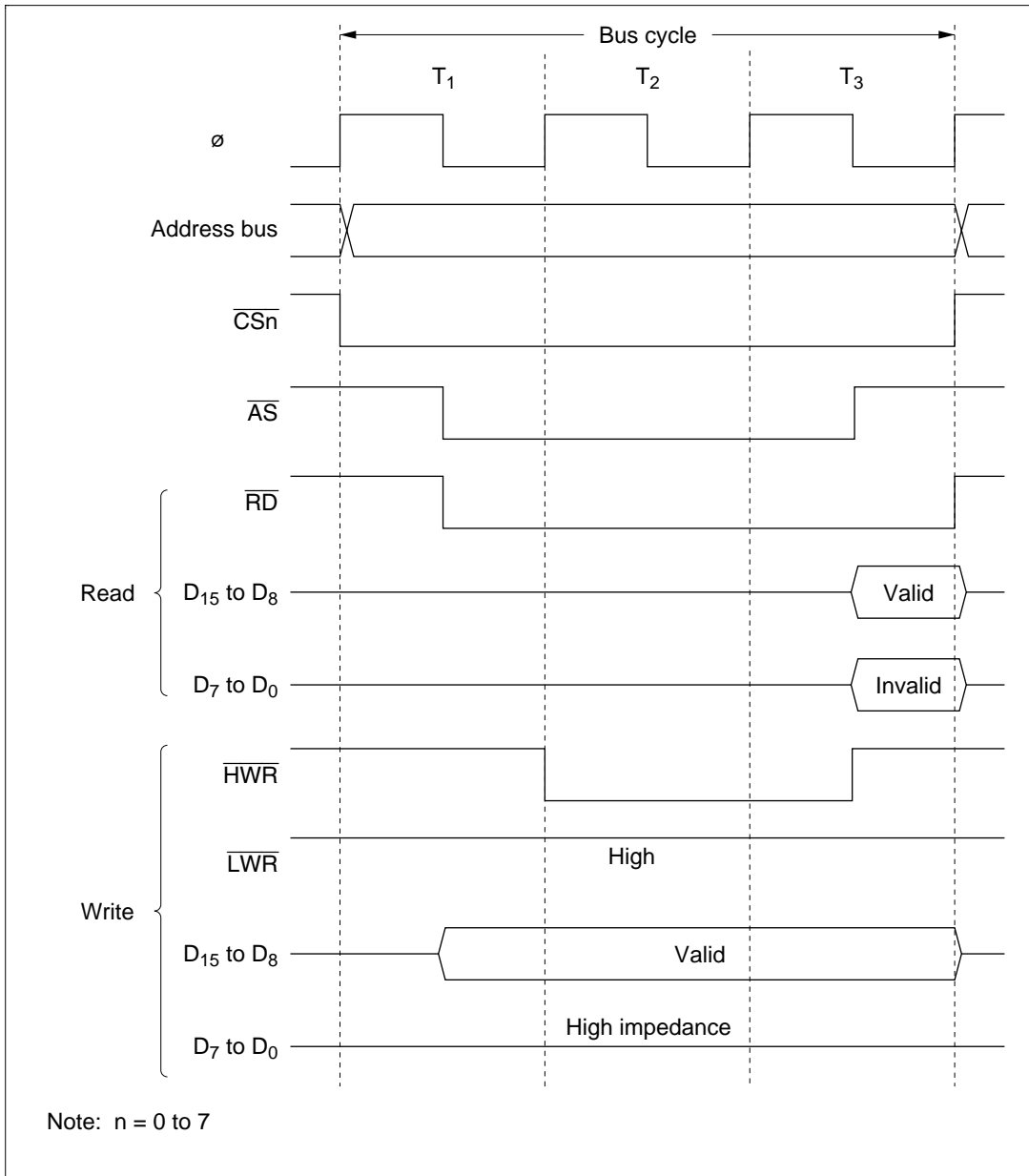


Figure 6-7 Bus Timing for 8-Bit 3-State Access Space

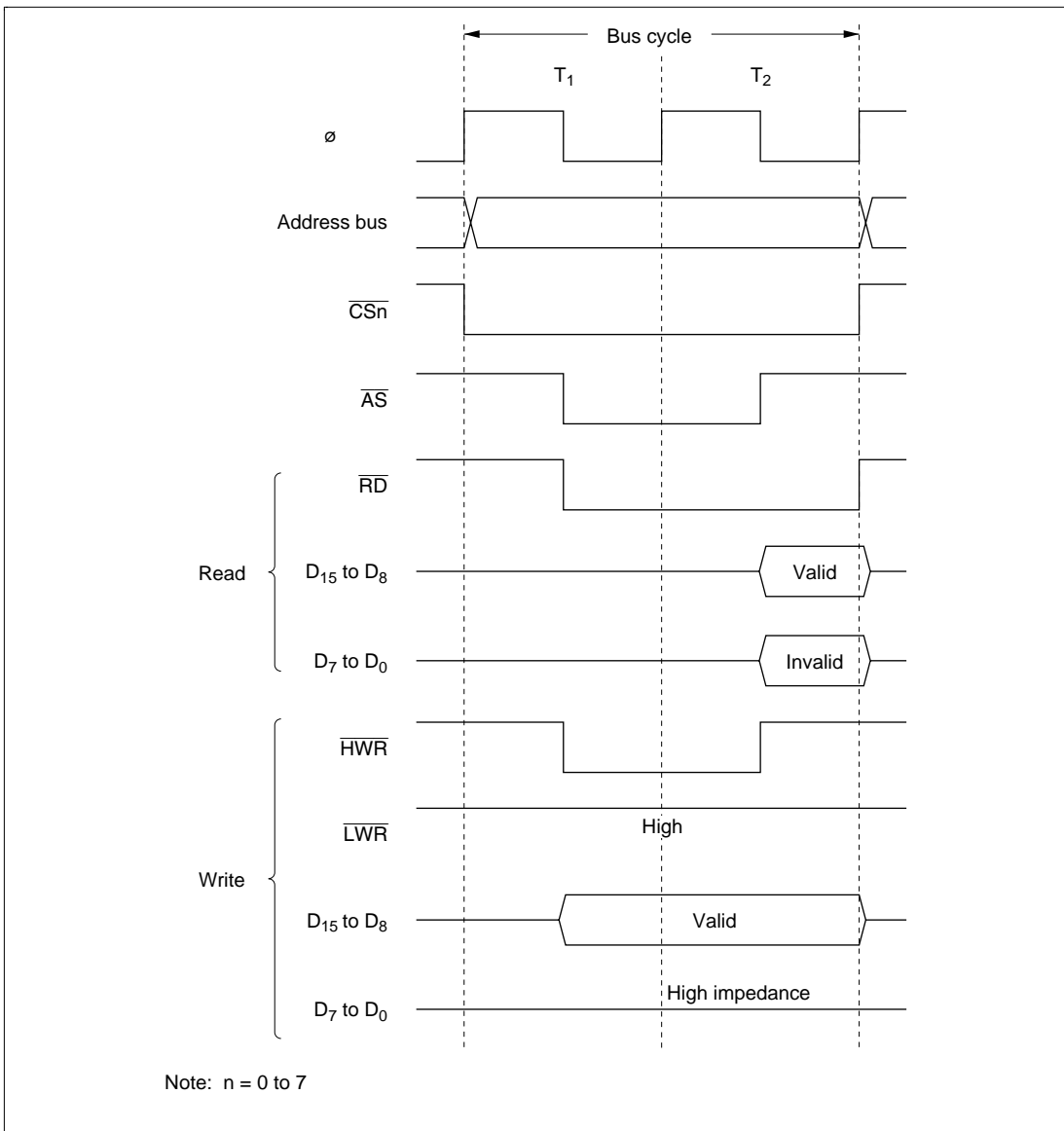


Figure 6-8 Bus Timing for 16-Bit 2-State Access Space (1) (Even Address Byte Access)

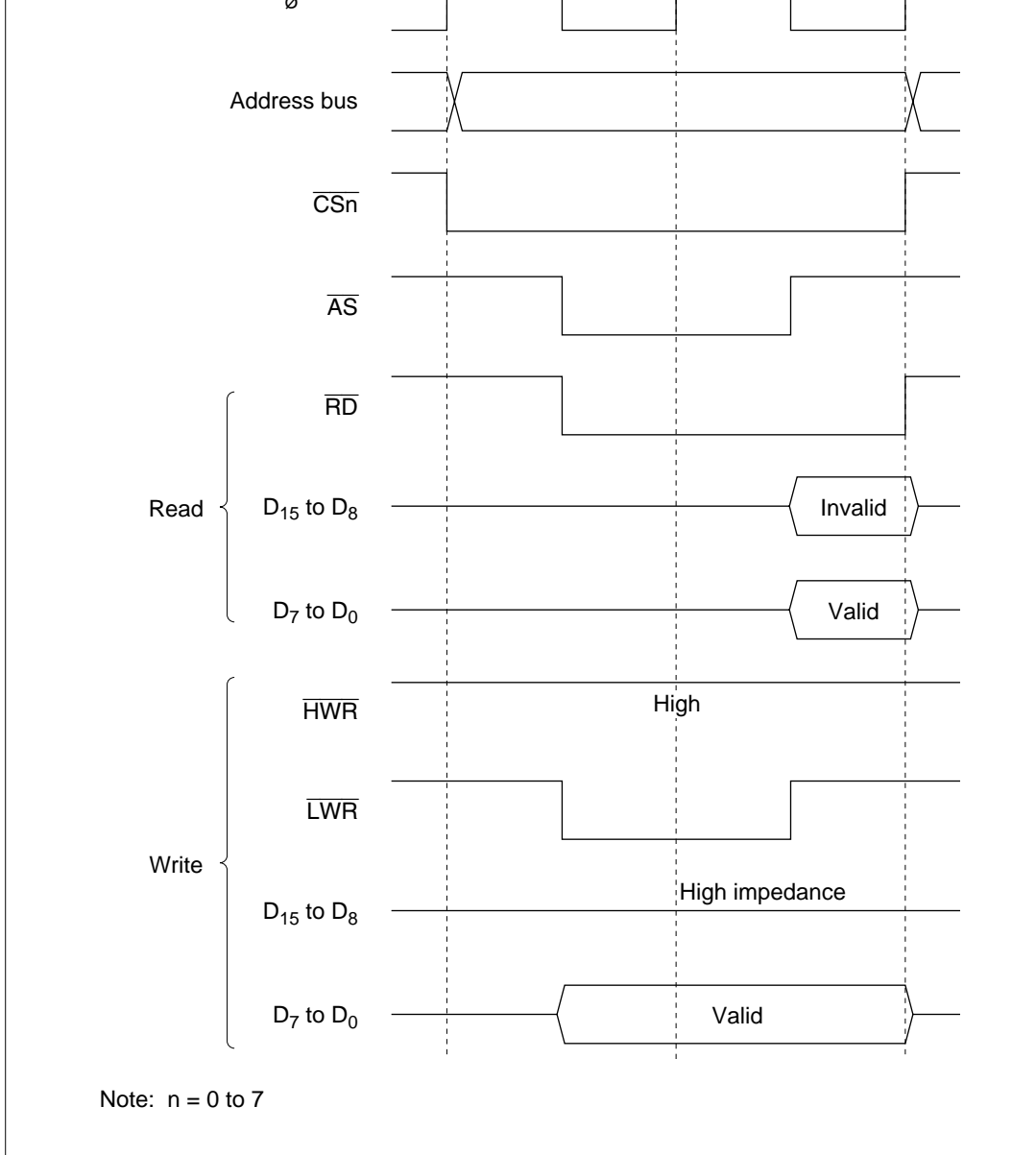
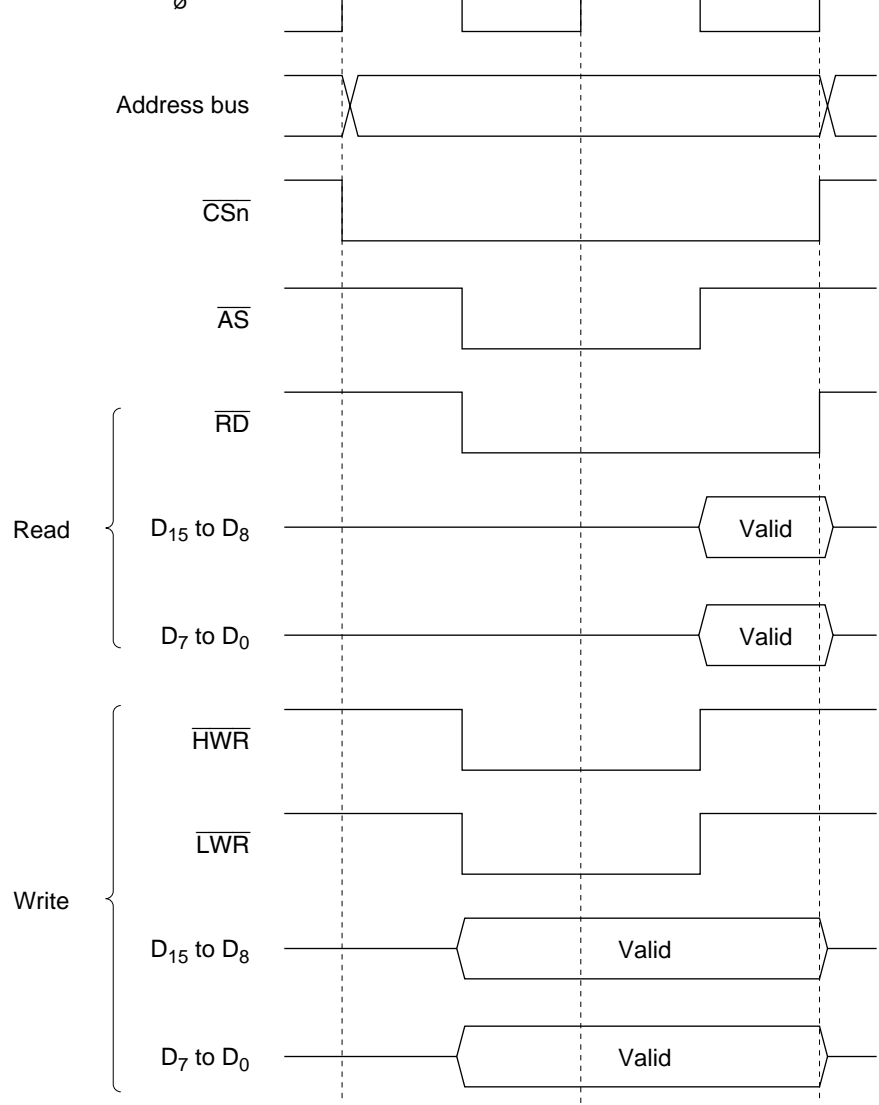


Figure 6-9 Bus Timing for 16-Bit 2-State Access Space (2) (Odd Address Byte Access)



Note: n = 0 to 7

Figure 6-10 Bus Timing for 16-Bit 2-State Access Space (3) (Word Access)

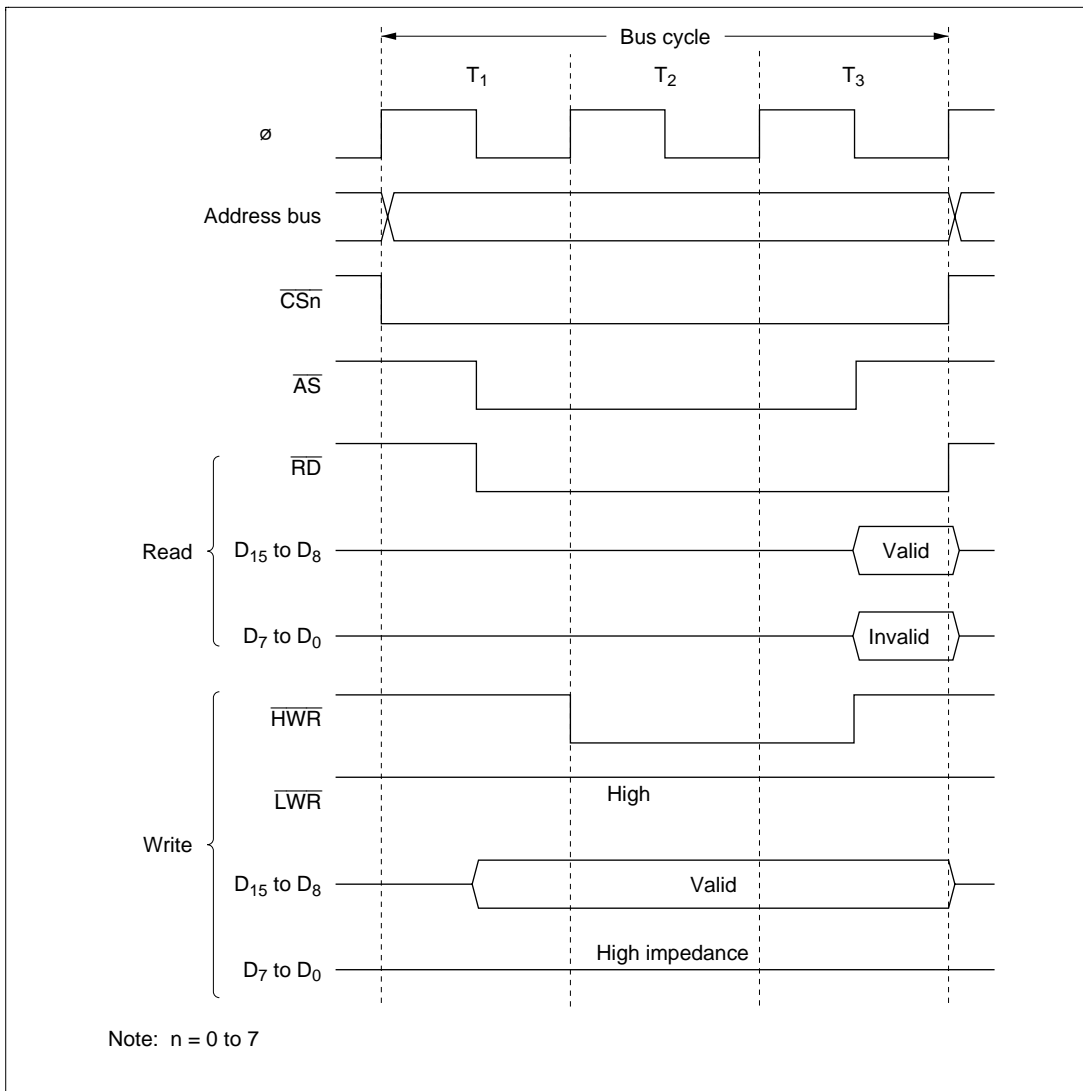


Figure 6-11 Bus Timing for 16-Bit 3-State Access Space (1) (Even Address Byte Access)

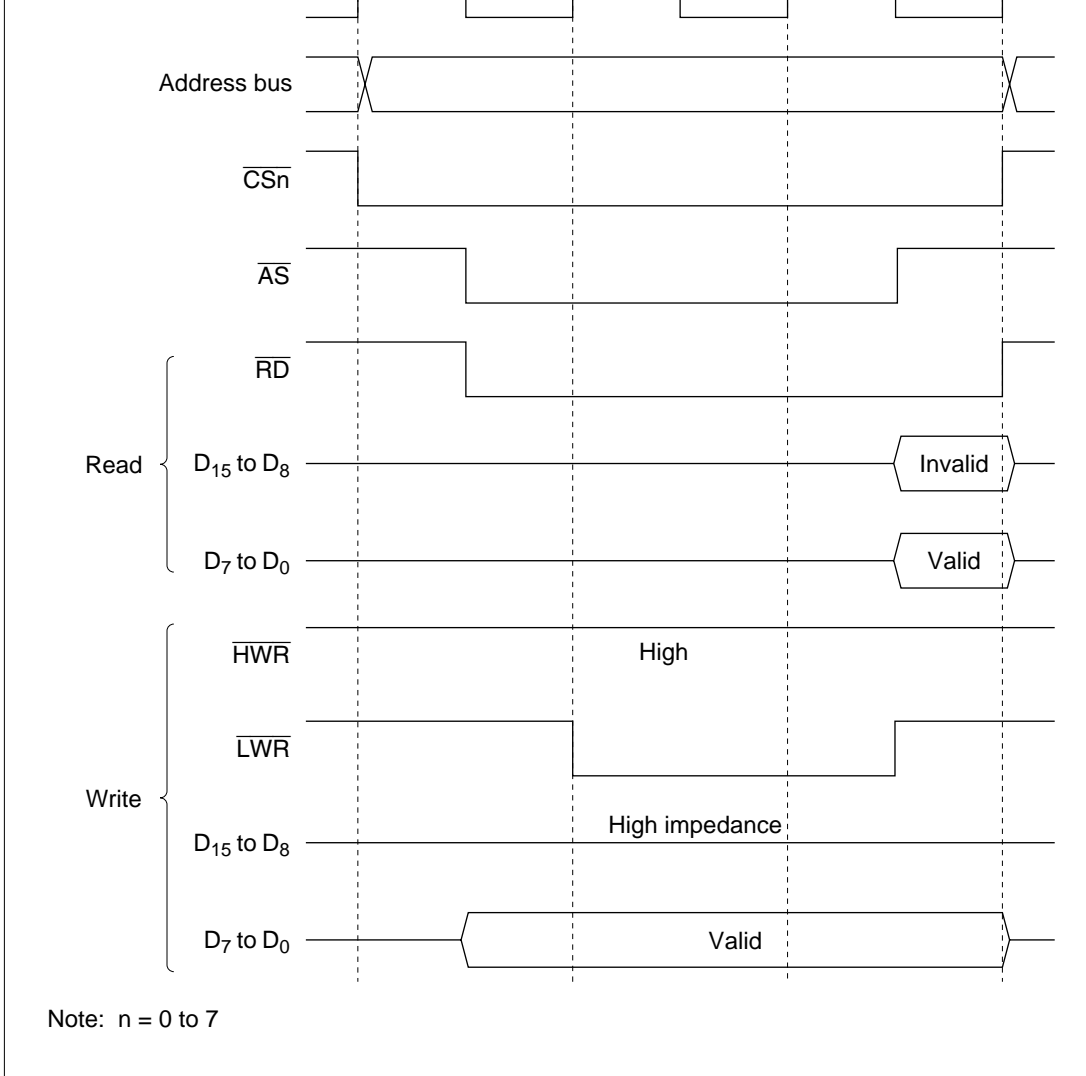


Figure 6-12 Bus Timing for 16-Bit 3-State Access Space (2) (Odd Address Byte Access)

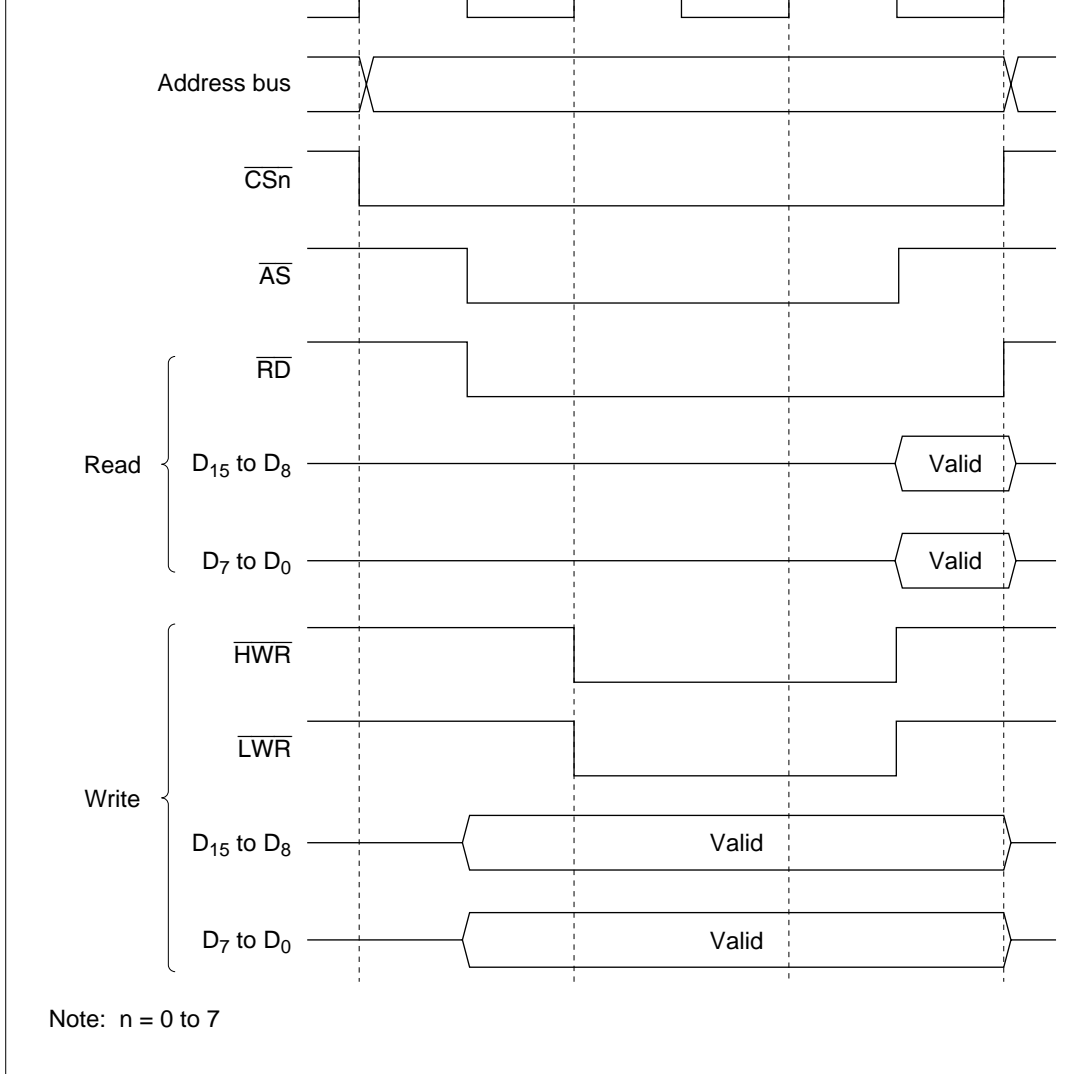


Figure 6-13 Bus Timing for 16-Bit 3-State Access Space (3) (Word Access)

wait insertion using the $\overline{\text{WAIT}}$ pin.

Program Wait Insertion

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

Pin Wait Insertion

Setting the WAITE bit in BCRL to 1 enables wait insertion by means of the $\overline{\text{WAIT}}$ pin. Program wait insertion is first carried out according to the settings in WCRH and WCRL. Then, if the $\overline{\text{WAIT}}$ pin is low at the falling edge of ϕ in the last T_2 or T_w state, a T_w state is inserted. If the $\overline{\text{WAIT}}$ pin is held low, T_w states are inserted until it goes high.

This is useful when inserting four or more T_w states, or when changing the number of T_w states for different external devices.

The WAITE bit setting applies to all areas.

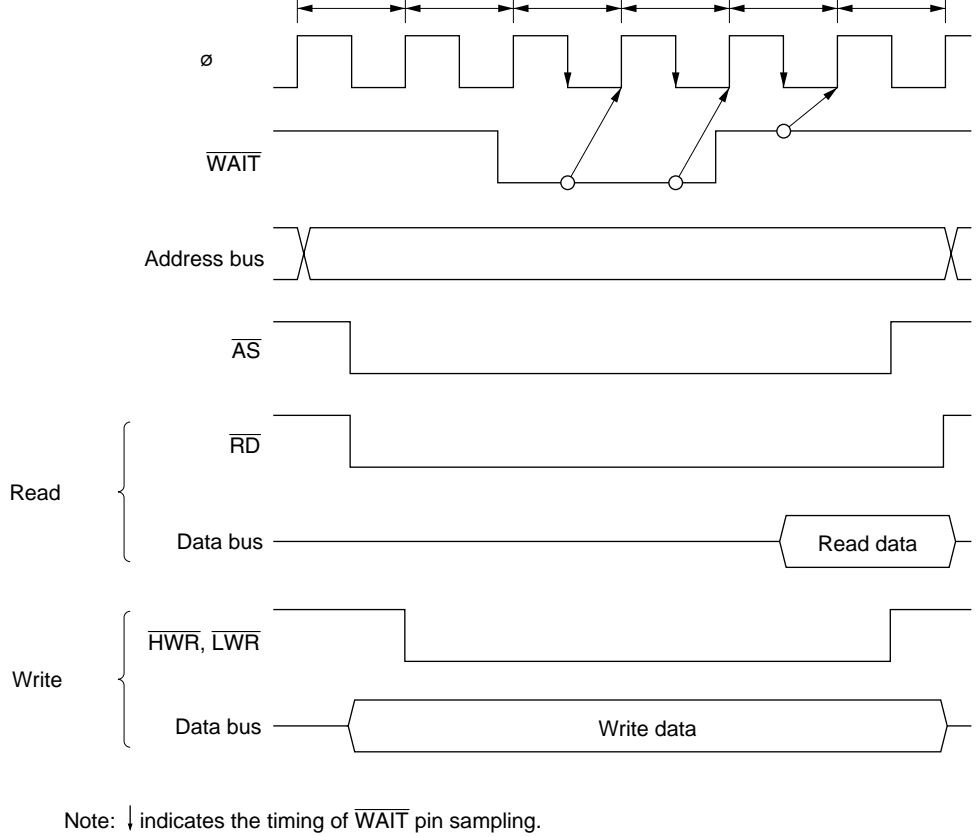


Figure 6-14 Example of Wait State Insertion Timing

The settings after a power-on reset are: 3-state access, 3 program wait state insertion, and $\overline{\text{WAIT}}$ input disabled. When a manual reset is performed, the contents of bus controller registers are retained, and the wait control settings remain the same as before the reset.

When the H8S/2350 Series is in advanced mode, external space areas 2 to 5 can be designated as DRAM space, and DRAM interfacing performed. With the DRAM interface, DRAM can be directly connected to the H8S/2350 Series. A DRAM space of 2, 4, or 8 Mbytes can be set by means of bits RMTS2 to RMTS0 in BCRH. Burst operation is also possible, using fast page mode.

6.5.2 Setting DRAM Space

Areas 2 to 5 are designated as DRAM space by setting bits RMTS2 to RMTS0 in BCRH. The relation between the settings of bits RMTS2 to RMTS0 and DRAM space is shown in table 6-5. Possible DRAM space settings are: one area (area 2), two areas (areas 2 and 3), and four areas (areas 2 to 5).

Table 6-5 Settings of Bits RMTS2 to RMTS0 and Corresponding DRAM Spaces

RMTS2	RMTS1	RMTS0	Area 5	Area 4	Area 3	Area 2
0	0	1	Normal space			DRAM space
	1	0	Normal space		DRAM space	
		1	DRAM space			

6.5.3 Address Multiplexing

With DRAM space, the row address and column address are multiplexed. In address multiplexing, the size of the shift of the row address is selected with bits MXC1 and MXC0 in MCR. Table 6-6 shows the relation between the settings of MXC1 and MXC0 and the shift size.

Table 6-6 Address Multiplexing Settings by Bits MXC1 and MXC0

	MCR		Shift Size	Address Pins															
	MXC1	MXC0		A ₂₃ to A ₁₃	A ₁₂	A ₁₁	A ₁₀	A ₉	A ₈	A ₇	A ₆	A ₅	A ₄	A ₃	A ₂	A ₁	A ₀		
Row address	0	0	8 bits	A ₂₃ to A ₁₃	A ₁₂	A ₁₁	A ₁₀	A ₉	A ₈	A ₇	A ₆	A ₅	A ₄	A ₃	A ₂	A ₁	A ₀		
		1	9 bits	A ₂₃ to A ₁₃	A ₁₂	A ₂₀	A ₁₉	A ₁₈	A ₁₇	A ₁₆	A ₁₅	A ₁₄	A ₁₃	A ₁₂	A ₁₁	A ₁₀	A ₉	A ₈	
	1	0	10 bits	A ₂₃ to A ₁₃	A ₁₂	A ₁₁	A ₂₀	A ₁₉	A ₁₈	A ₁₇	A ₁₆	A ₁₅	A ₁₄	A ₁₃	A ₁₂	A ₁₁	A ₁₀	A ₉	
		1	Setting prohibited	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Column address	—	—	—	A ₂₃ to A ₁₃	A ₁₂	A ₁₁	A ₁₀	A ₉	A ₈	A ₇	A ₆	A ₅	A ₄	A ₃	A ₂	A ₁	A ₀		

In 8-bit DRAM space the upper half of the data bus, D_{15} to D_8 , is enabled, while in 16-bit DRAM space both the upper and lower halves of the data bus, D_{15} to D_0 , are enabled.

Access sizes and data alignment are the same as for the basic bus interface: see section 6.4.2, Data Size and Data Alignment.

6.5.5 Pins Used for DRAM Interface

Table 6-7 shows the pins used for DRAM interfacing and their functions.

Table 6-7 DRAM Interface Pins

Pin	With DRAM Setting	Name	I/O	Function
\overline{HWR}	\overline{WE}	Write enable	Output	When 2-CAS system is set, write enable for DRAM space access.
\overline{LCAS}	\overline{LCAS}	Lower column address strobe	Output	Lower column address strobe for 16-bit DRAM space access
$\overline{CS2}$	$\overline{RAS2}$	Row address strobe 2	Output	Row address strobe when area 2 is designated as DRAM space.
$\overline{CS3}$	$\overline{RAS3}$	Row address strobe 3	Output	Row address strobe when area 3 is designated as DRAM space.
$\overline{CS4}$	$\overline{RAS4}$	Row address strobe 4	Output	Row address strobe when area 4 is designated as DRAM space.
$\overline{CS5}$	$\overline{RAS5}$	Row address strobe 5	Output	Row address strobe when area 5 is designated as DRAM space.
\overline{CAS}	\overline{UCAS}	Upper column address strobe	Output	Upper column address strobe for DRAM space access
\overline{WAIT}	\overline{WAIT}	Wait	Input	Wait request signal
A_{12} to A_0	A_{12} to A_0	Address pins	Output	Row address/column address multiplexed output
D_{15} to D_0	D_{15} to D_0	Data pins	I/O	Data input/output pins

disabling of wait insertion, and do not affect the number of access states. When the corresponding bit in ASTCR is cleared to 0, wait states cannot be inserted in the DRAM access cycle.

The 4 states of the basic timing consist of one T_p (precharge cycle) state, one T_r (row address output cycle), and two T_c (column address output cycle) states, T_{c1} and T_{c2} .

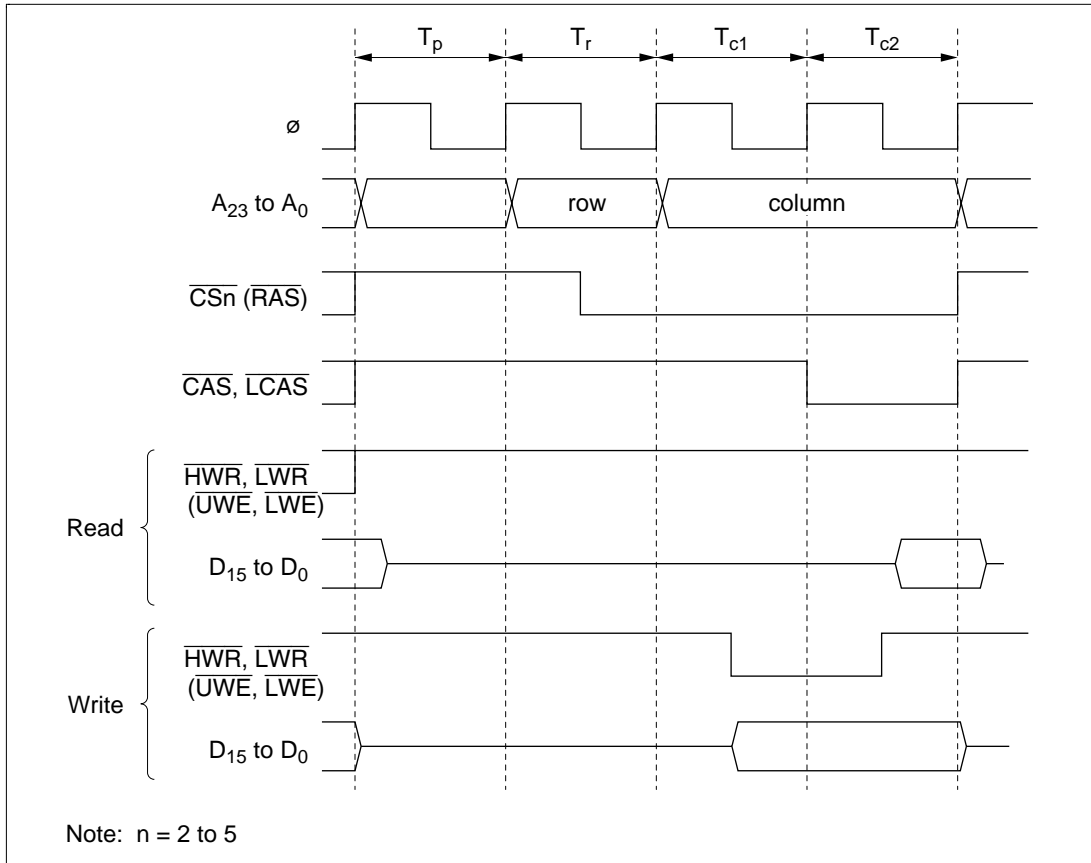


Figure 6-15 Basic Access Timing (2-WE System)

setting the TPC bit in MCR to 1. Set the appropriate number of T_p cycles according to the DRAM connected and the operating frequency of the H8S/2350 Series. Figure 6-16 shows the timing when two T_p states are inserted.

When the TCP bit is set to 1, two T_p states are also used for refresh cycles.

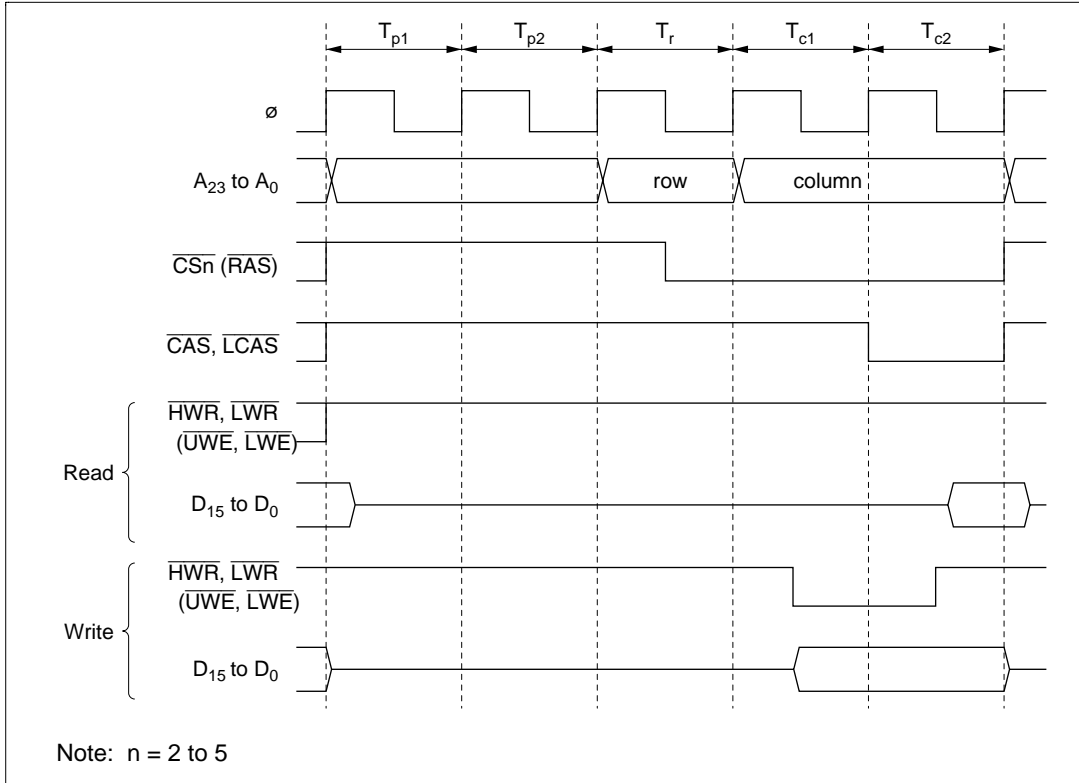


Figure 6-16 Timing with Two Precharge States (2-WE System)

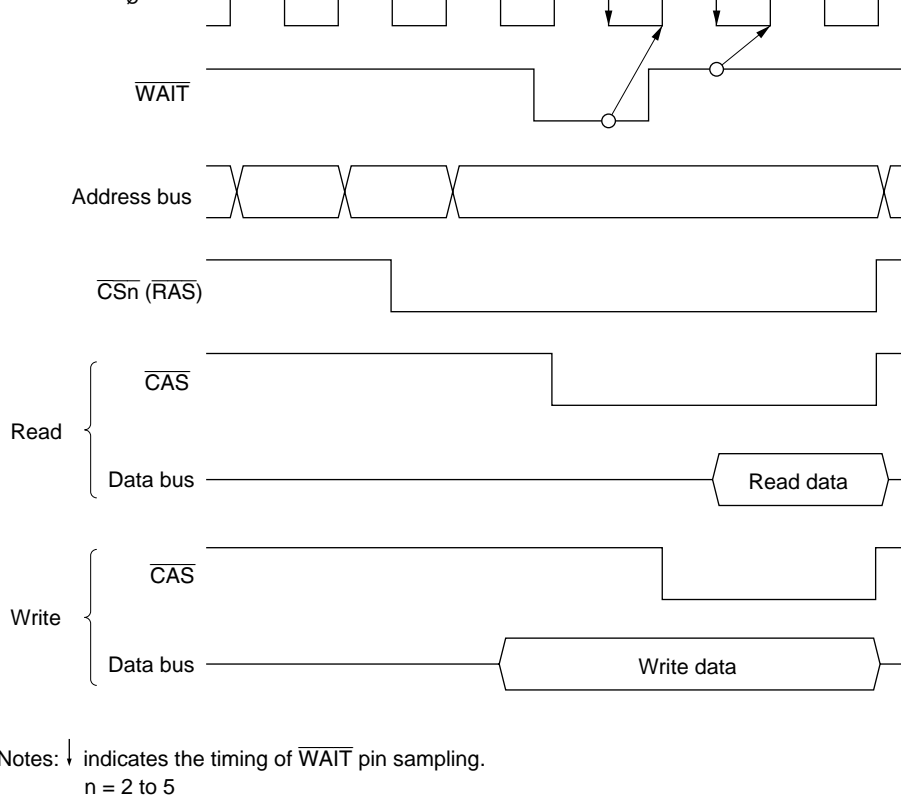
Program Wait Insertion

When the bit in ASTCR corresponding to an area designated as DRAM space is set to 1, from 0 to 3 wait states can be inserted automatically between the T_{c1} state and T_{c2} state, according to the settings of WCRH and WCRL.

Pin Wait Insertion

When the WAITE bit in BCRH is set to 1, wait input by means of the $\overline{\text{WAIT}}$ pin is enabled regardless of the setting of the AST bit in ASTCR. When DRAM space is accessed in this state, a program wait is first inserted. If the $\overline{\text{WAIT}}$ pin is low at the falling edge of ϕ in the last T_{c1} or T_w state, another T_w state is inserted. If the $\overline{\text{WAIT}}$ pin is held low, T_w states are inserted until it goes high.

Figure 6-17 shows an example of wait state insertion timing.



**Figure 6-17 Example of Wait State Insertion Timing
(CW2 = 1, 8-Bit Area Setting for Entire Space)**

When the CW2 bit is cleared to 0 in MCR, the 2-CAS system is selected. Figure 6-18 shows the control timing in the 2-CAS system, and figure 6-19 shows an example 2-CAS system DRAM connection.

When only DRAM with a $\times 8$ configuration is connected, set the CW2 bit to 1 in MCR.

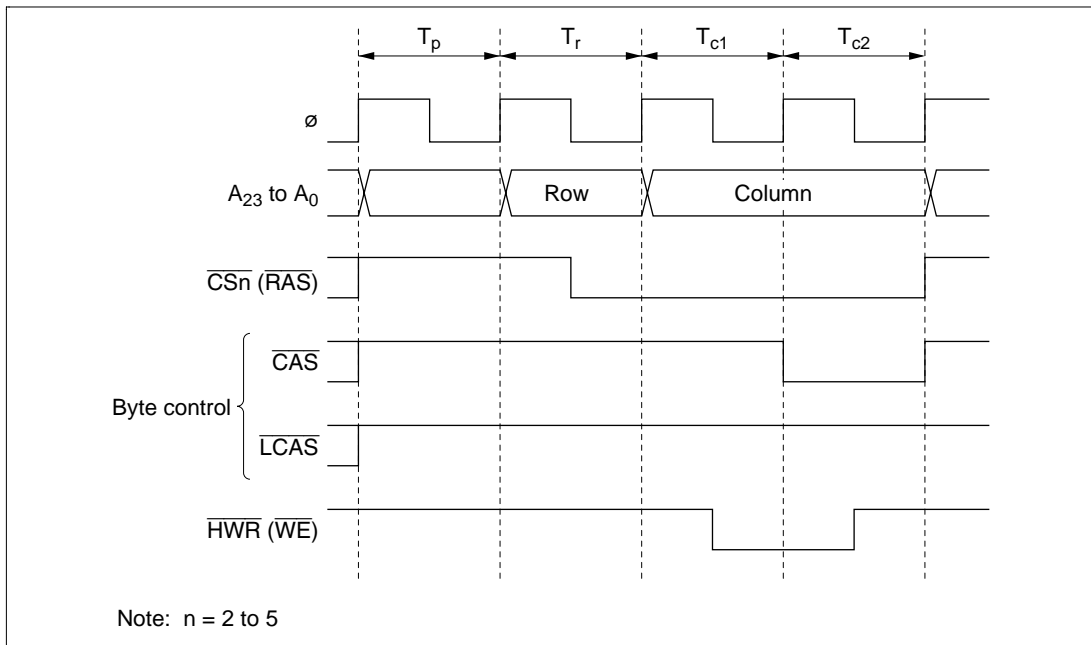


Figure 6-18 2-CAS System Control Timing (Upper Byte Write Access)

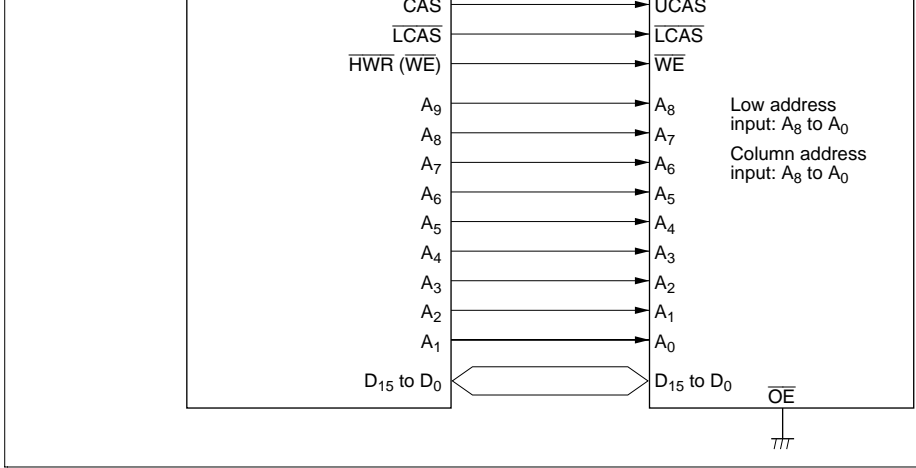


Figure 6-19 Example of 2-CAS System Connection

number of consecutive accesses to the same row address. This mode enables fast (burst) access of data by simply changing the column address after the row address has been output. Burst access can be selected by setting the BE bit in MCR to 1.

(1) Burst Access (Fast Page Mode) Operation Timing

Figure 6-20 shows the operation timing for burst access. When there are consecutive access cycles for DRAM space, the $\overline{\text{CAS}}$ signal and column address output cycles (two states) continue as long as the row address is the same for consecutive access cycles. The row address used for the comparison is set with bits MXC1 and MXC0 in MCR.

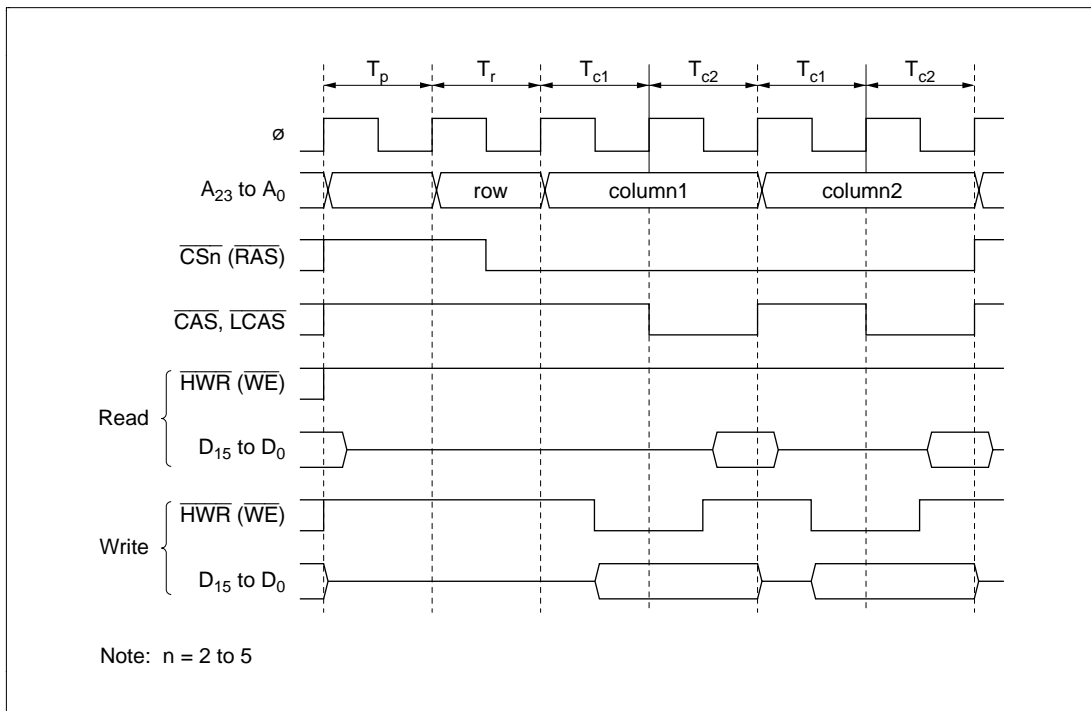


Figure 6-20 Operation Timing in Fast Page Mode (2-WE System)

The bus cycle can also be extended in burst access by inserting wait states. The wait state insertion method and timing are the same as for full access. For details, see section 6.5.8, Wait Control.

DRAM space is accessed again.

- RAS down mode

To select RAS down mode, set the RCDM bit in MCR to 1. If access to DRAM space is interrupted and another space is accessed, the $\overline{\text{RAS}}$ signal is held low during the access to the other space, and burst access is performed if the row address of the next DRAM space access is the same as the row address of the previous DRAM space access. Figure 6-21 shows an example of the timing in RAS down mode.

Note, however, that the $\overline{\text{RAS}}$ signal will go high if a refresh operation interrupts RAS down mode.

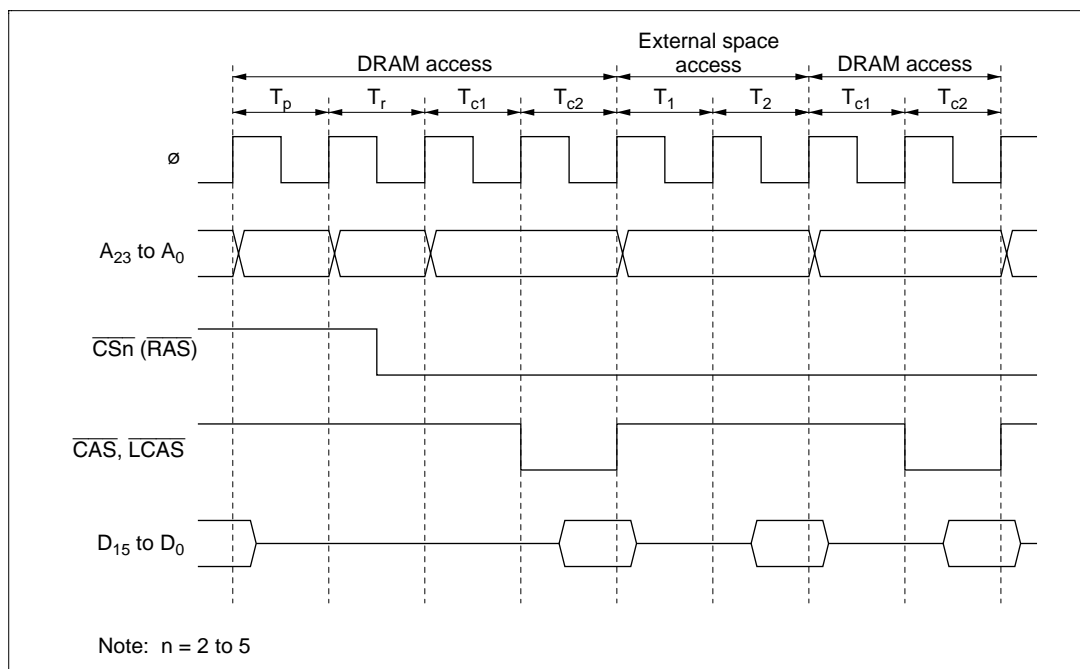


Figure 6-21 Example of Operation Timing in RAS Down Mode

RAS up mode.

In the case of burst ROM space access, the $\overline{\text{RAS}}$ signal is not restored to the high level.

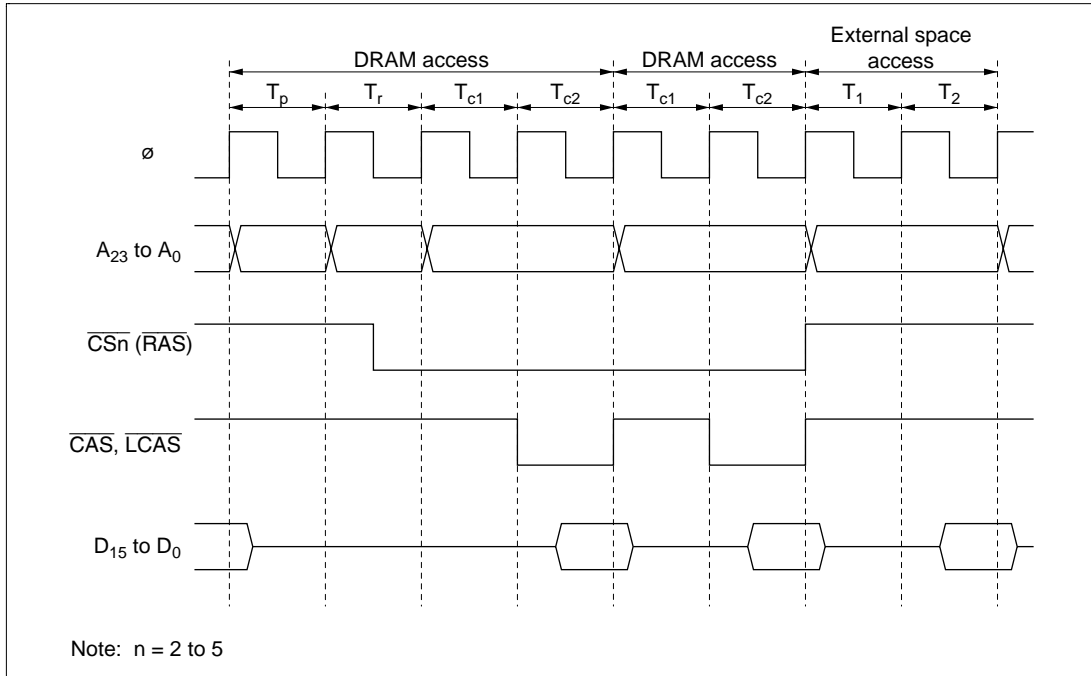


Figure 6-22 Example of Operation Timing in RAS Up Mode

(1) CAS-before-RAS (CBR) Refreshing

To select CBR refreshing, set the RFSHE bit in DRAMCR to 1, and clear the RMODE bit to 0.

With CBR refreshing, RTCNT counts up using the input clock selected by bits CKS2 to CKS0 in DRAMCR, and when the count matches the value set in RTCOR (compare match), refresh control is performed. At the same time, RTCNT is reset and starts counting again from H'00. Refreshing is thus repeated at fixed intervals determined by RTCOR and bits CKS2 to CKS0. Set a value in RTCOR and bits CKS2 to CKS0 that will meet the refreshing interval specification for the DRAM used.

When bits CKS2 to CKS0 are set, RTCNT starts counting up. RTCNT and RTCOR settings should therefore be completed before setting bits CKS2 to CKS0.

Do not clear the CMF flag when refresh control is being performed (RFSHE = 1).

RTCNT operation is shown in figure 6-23, compare match timing in figure 6-24, and CBR refresh timings in figure 6-25.

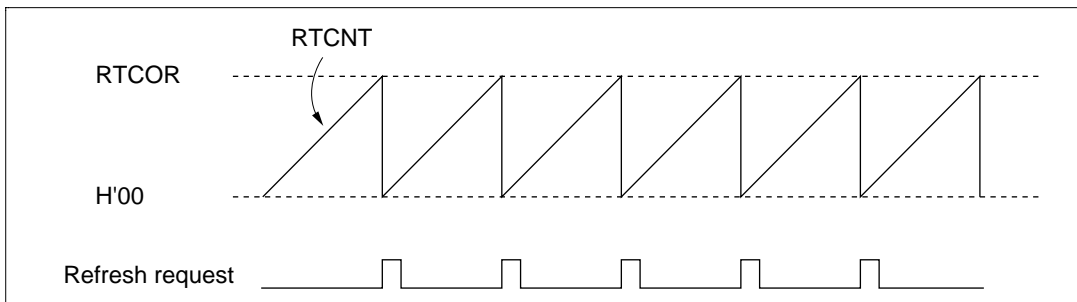


Figure 6-23 RTCNT Operation

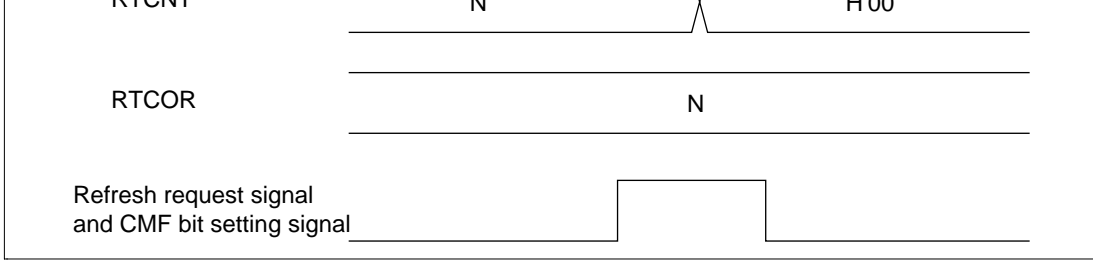


Figure 6-24 Compare Match Timing

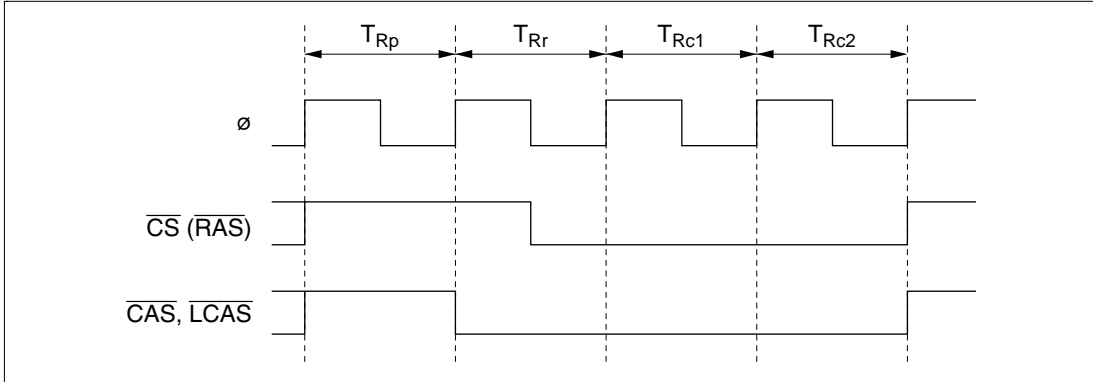


Figure 6-25 CBR Refresh Timing

When the RCW bit is set to 1, $\overline{\text{RAS}}$ signal output is delayed by one cycle. The width of the $\overline{\text{RAS}}$ signal should be adjusted with bits RLW1 and RLW0. These bits are only enabled in refresh operations.

Figure 6-26 shows the timing when the RCW bit is set to 1.

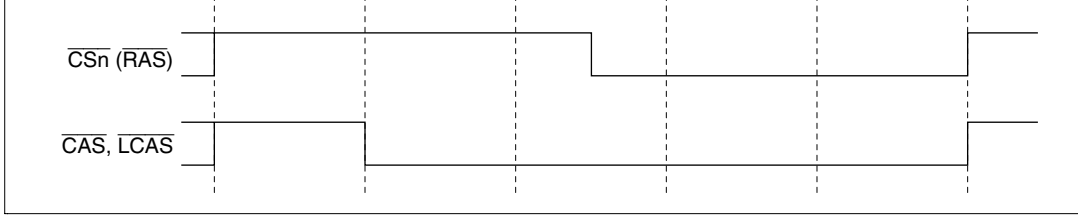


Figure 6-26 CBR Refresh Timing (When RCW = 1, RLW1 = 0, RLW0 = 1)

(2) Self-Refreshing

A self-refresh mode (battery backup mode) is provided for DRAM as a kind of standby mode. In this mode, refresh timing and refresh addresses are generated within the DRAM.

To select self-refreshing, set the RFSHE bit and RMODE bit in DRAMCR to 1. Then, when a SLEEP instruction is executed to enter software standby mode, the $\overline{\text{CAS}}$ and $\overline{\text{RAS}}$ signals are output and DRAM enters self-refresh mode, as shown in figure 6-27.

When software standby mode is exited, the RMODE bit is cleared to 0 and self-refresh mode is cleared.

When switching to software standby mode, if there is a CBR refresh request, CBR refreshing is executed before self-refresh mode is entered.

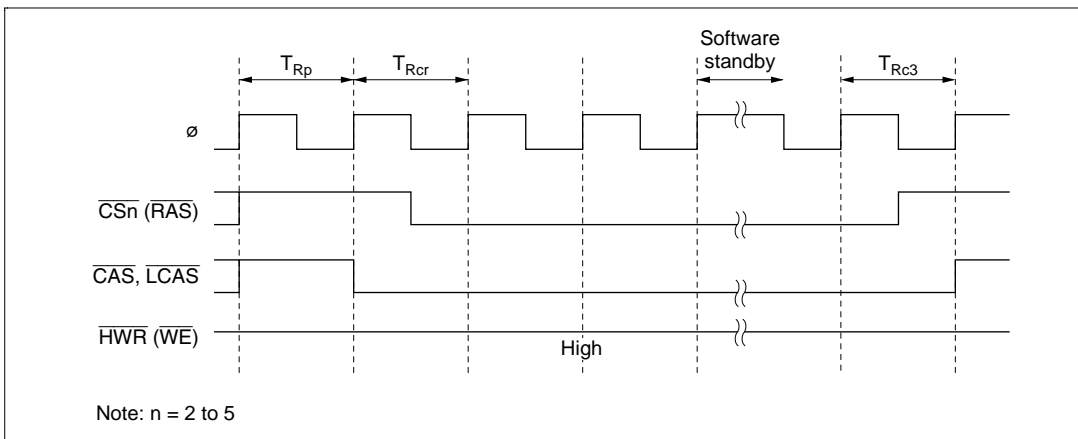


Figure 6-27 Self-Refresh Timing (When CW2 = 1, or CW2 = 0 and LCASS = 0)

time, whether or not burst access is to be performed is selected.

6.6.1 When DDS = 1

Burst access is performed by determining the address only, irrespective of the bus master. The $\overline{\text{DACK}}$ output goes low from the T_{c1} state in the case of the DRAM interface.

Figure 6-28 shows the $\overline{\text{DACK}}$ output timing for the DRAM interface when DDS = 1.

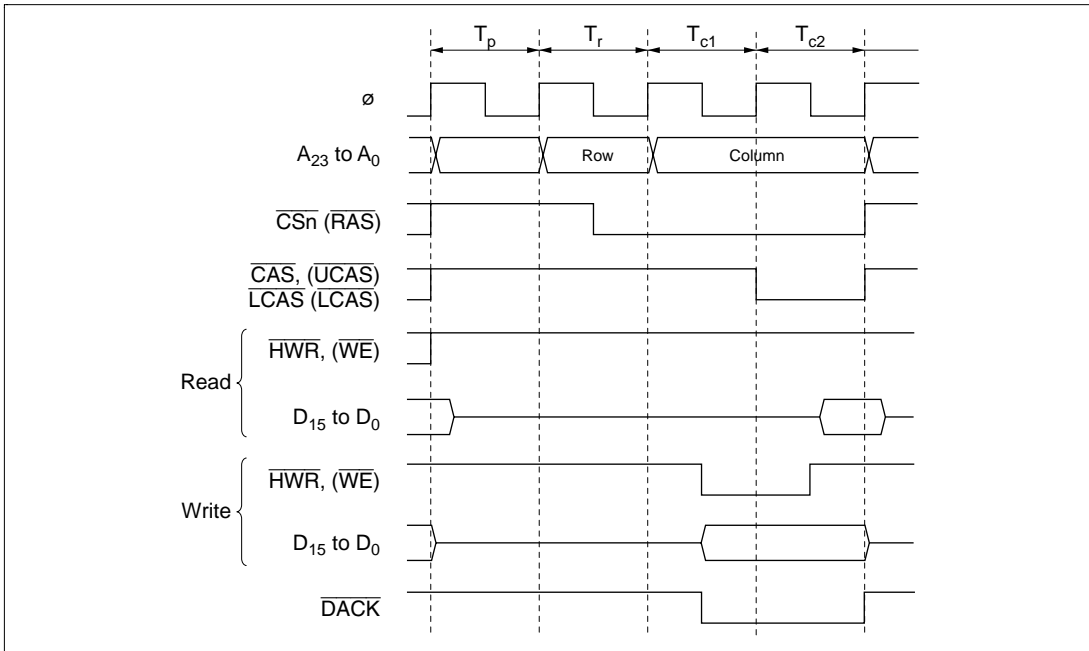


Figure 6-28 $\overline{\text{DACK}}$ Output Timing when DDS = 1 (Example of DRAM Access)

interface.

In modes other than DMAC single address mode, burst access can be used when accessing DRAM space.

Figure 6-29 shows the $\overline{\text{DACK}}$ output timing for the DRAM interface when $\text{DDS} = 0$.

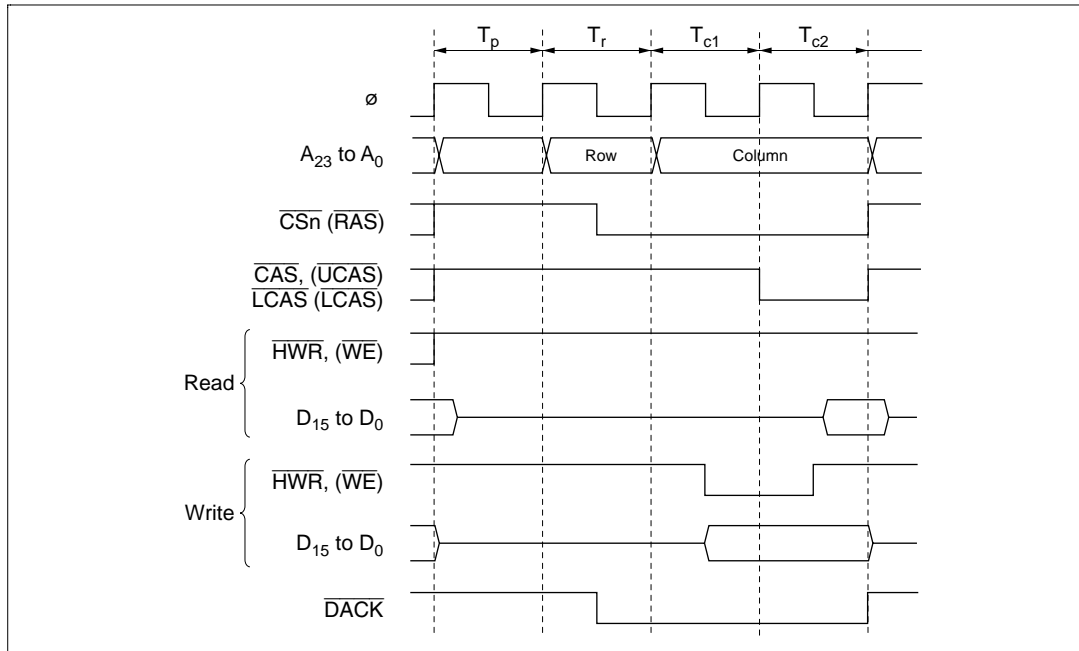


Figure 6-29 $\overline{\text{DACK}}$ Output Timing when $\text{DDS} = 0$ (Example of DRAM Access)

With the H8S/2350 Series, external space area 0 can be designated as burst ROM space, and burst ROM interfacing can be performed. The burst ROM space interface enables 16-bit configuration ROM with burst access capability to be accessed at high speed.

Area 0 can be designated as burst ROM space by means of the BRSTRM bit in BCRH. Consecutive burst accesses of a maximum of 4 words or 8 words can be performed for CPU instruction fetches only. One or two states can be selected for burst access.

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

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

The basic access timing for burst ROM space is shown in figures 6-30 (a) and (b). The timing shown in figure 6-30 (a) is for the case where the AST0 and BRSTS1 bits are both set to 1, and that in figure 6-30 (b) is for the case where both these bits are cleared to 0.

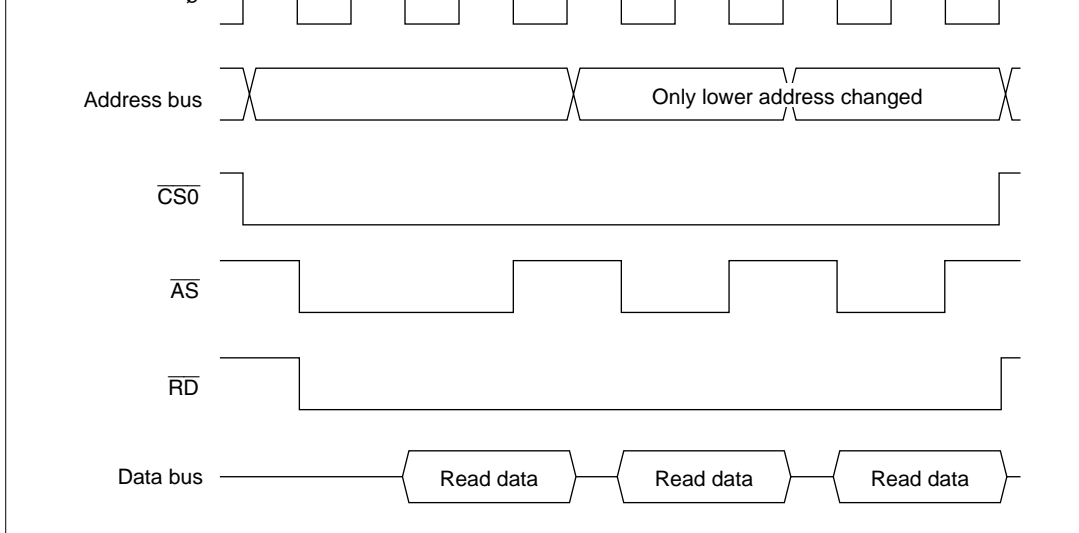


Figure 6-30 (a) Example of Burst ROM Access Timing (When $AST0 = BRSTS1 = 1$)

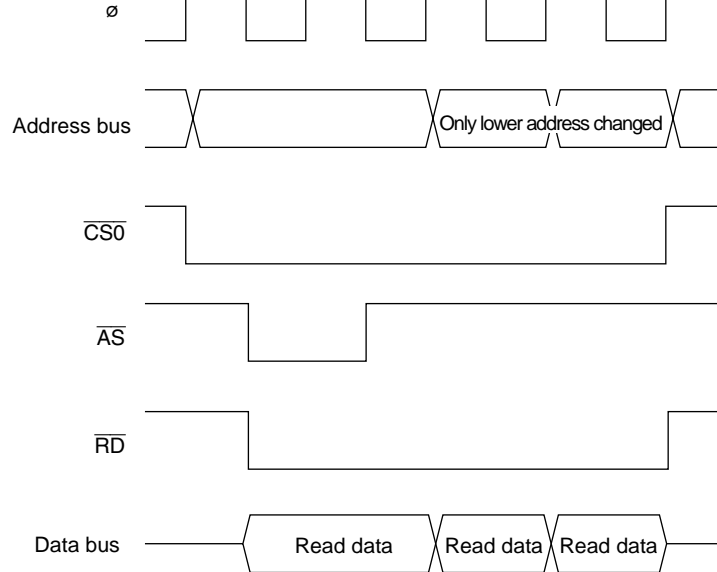


Figure 6-30 (b) Example of Burst ROM Access Timing (When $AST0 = BRSTS1 = 0$)

6.7.3 Wait Control

As with the basic bus interface, either program wait insertion or pin wait insertion using the \overline{WAIT} pin can be used in the initial cycle (full access) of the burst ROM interface. See section 6.4.5, Wait Control.

Wait states cannot be inserted in a burst cycle.

When the H8S/2350 Series accesses external space, it can insert a 1-state idle cycle (T_1) between bus cycles in the following two cases: (1) when read accesses between different areas occur consecutively, and (2) when a write cycle occurs immediately after a read cycle. By inserting an idle cycle it is possible, for example, to avoid data collisions between ROM, with a long output floating time, and high-speed memory, I/O interfaces, and so on.

(1) Consecutive Reads between Different Areas

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

Figure 6-31 shows an example of the operation in this case. In this example, bus cycle A is a read cycle from ROM with a long output floating time, and bus cycle B is a read cycle from SRAM, each being located in a different area. In (a), an idle cycle is not inserted, and a collision occurs in cycle B between the read data from ROM and that from SRAM. In (b), an idle cycle is inserted, and a data collision is prevented.

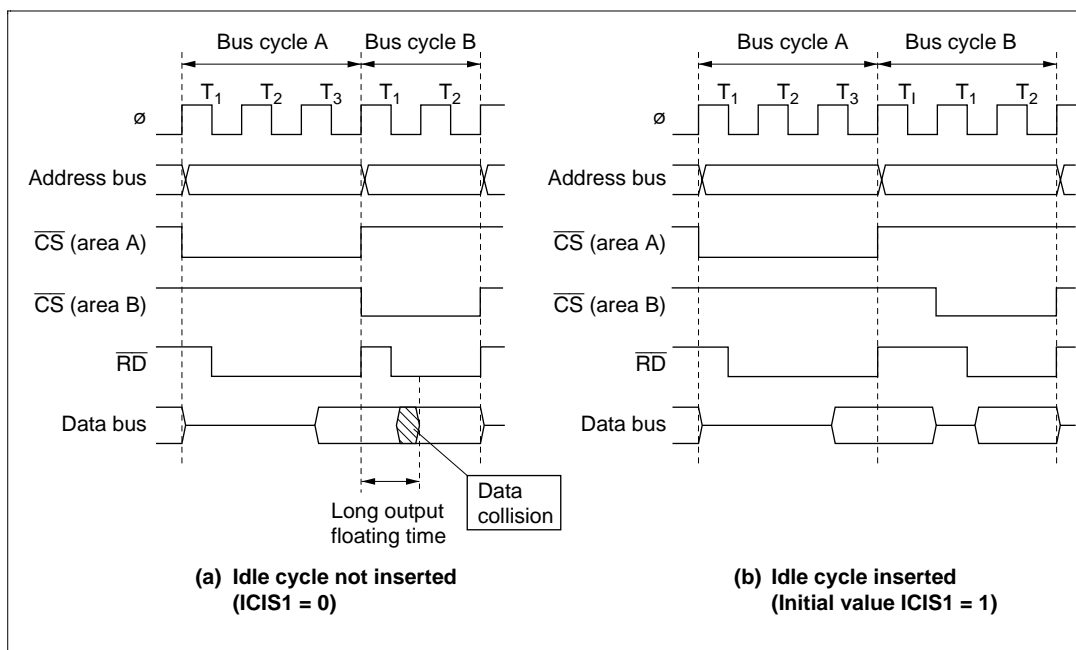


Figure 6-31 Example of Idle Cycle Operation (1)

Figure 6-32 shows an example of the operation in this case. In this example, bus cycle A is a read cycle from ROM with a long output floating time, and bus cycle B is a CPU write cycle. In (a), an idle cycle is not inserted, and a collision occurs in cycle B between the read data from ROM and the CPU write data. In (b), an idle cycle is inserted, and a data collision is prevented.

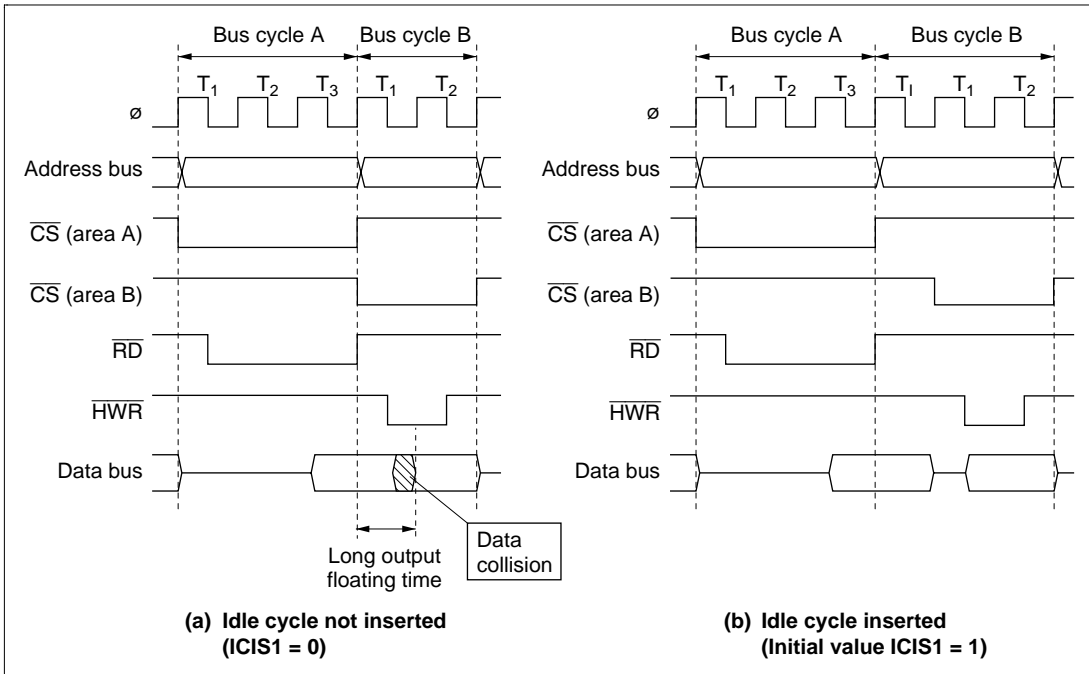


Figure 6-32 Example of Idle Cycle Operation (2)

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

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

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

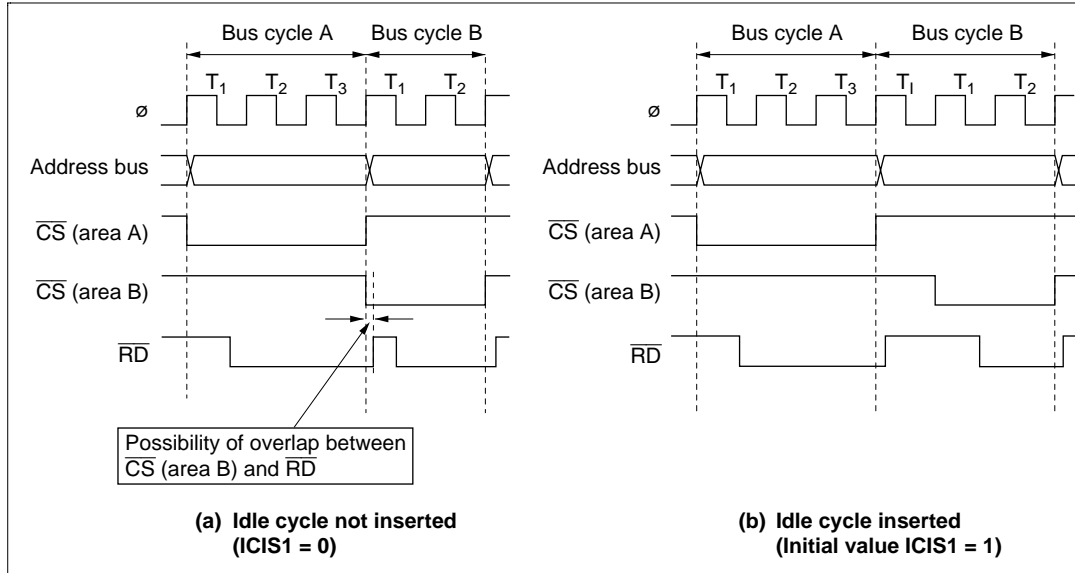


Figure 6-33 Relationship between Chip Select (\overline{CS}) and Read (\overline{RD})

(4) Usage Notes

When DRAM space is accessed, the ICIS0 and ICIS1 bit settings are disabled. In the case of consecutive reads between different areas, for example, if the second access is a DRAM access, only a T_p cycle is inserted, and a T_1 cycle is not. The timing in this case is shown in figure 6-34.

However, in burst access in RAS down mode these settings are enabled, and an idle cycle is inserted. The timing in this case is shown in figures 6-35 (a) and (b).

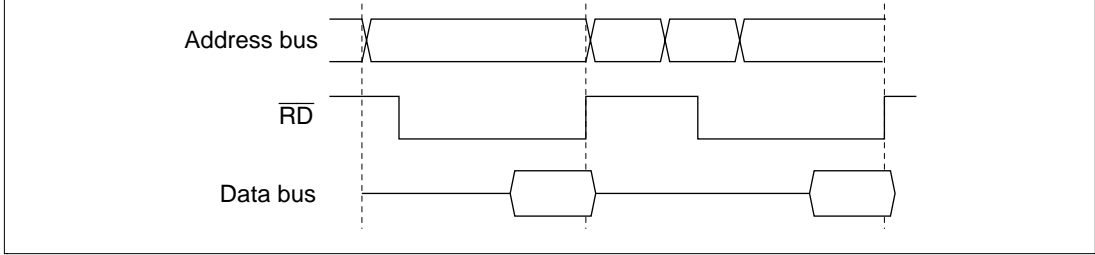


Figure 6-34 Example of DRAM Access after External Read

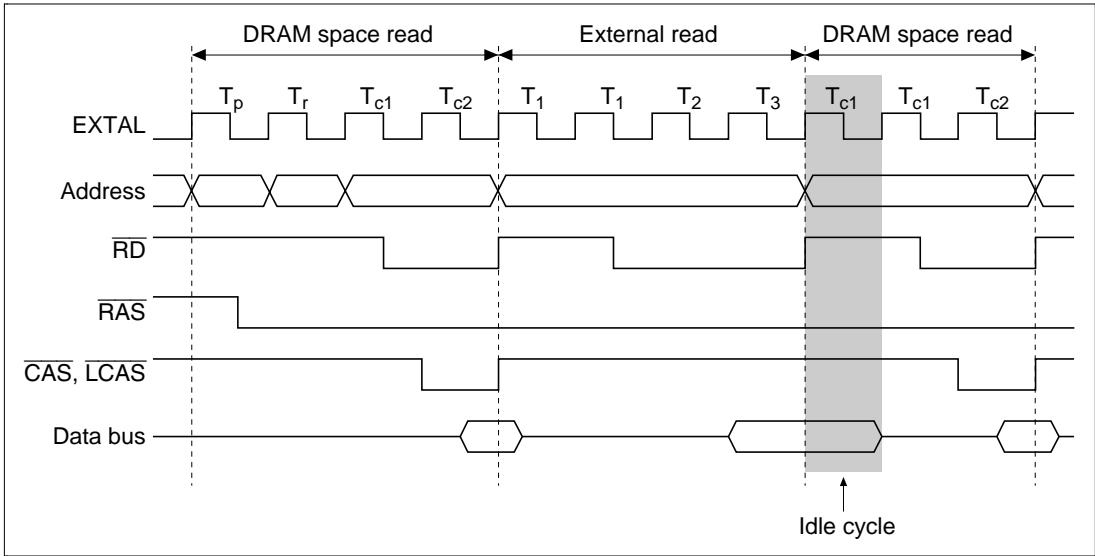


Figure 6-35 (a) Example of Idle Cycle Operation in RAS Down Mode (ICIS1 = 1)

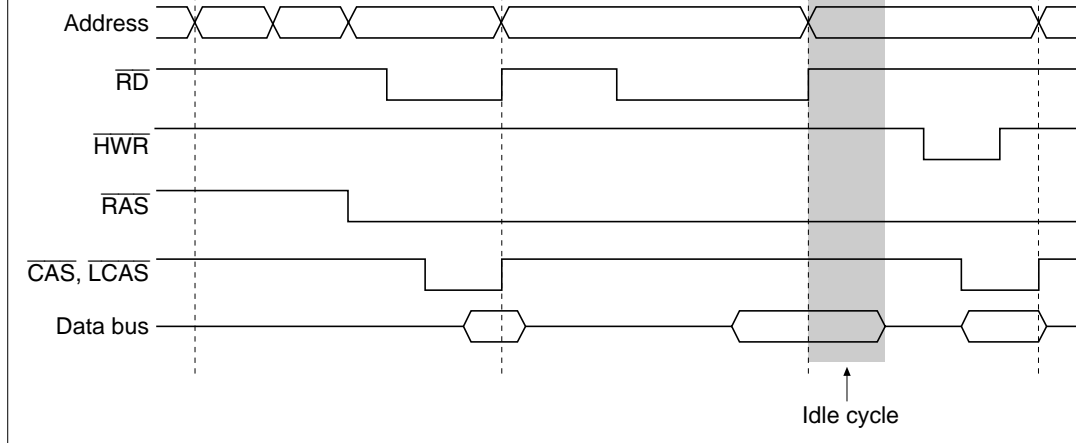


Figure 6-35 (b) Example of Idle Cycle Operation in RAS Down Mode (ICIS0 = 1)

6.8.2 Pin States in Idle Cycle

Table 6-8 shows pin states in an idle cycle.

Table 6-8 Pin States in Idle Cycle

Pins	Pin State
A_{23} to A_0	Contents of next bus cycle
D_{15} to D_0	High impedance
\overline{CSn}	High*
\overline{CAS}	High
\overline{AS}	High
\overline{RD}	High
\overline{HWR}	High
\overline{LWR}	High
\overline{DACKn}	High

Note: * Remains low in DRAM space RAS down mode or a refresh cycle.

parallel with internal accesses. The write data buffer function is made available by setting the WDBE bit in BCRL to 1.

Figure 6-36 shows an example of the timing when the write data buffer function is used. When this function is used, if an external write or DMA single address mode transfer continues for 2 states or longer, and there is an internal access next, only an external write is executed in the first state, but from the next state onward an internal access (on-chip memory or internal I/O register read) is executed in parallel with the external write rather than waiting until it ends.

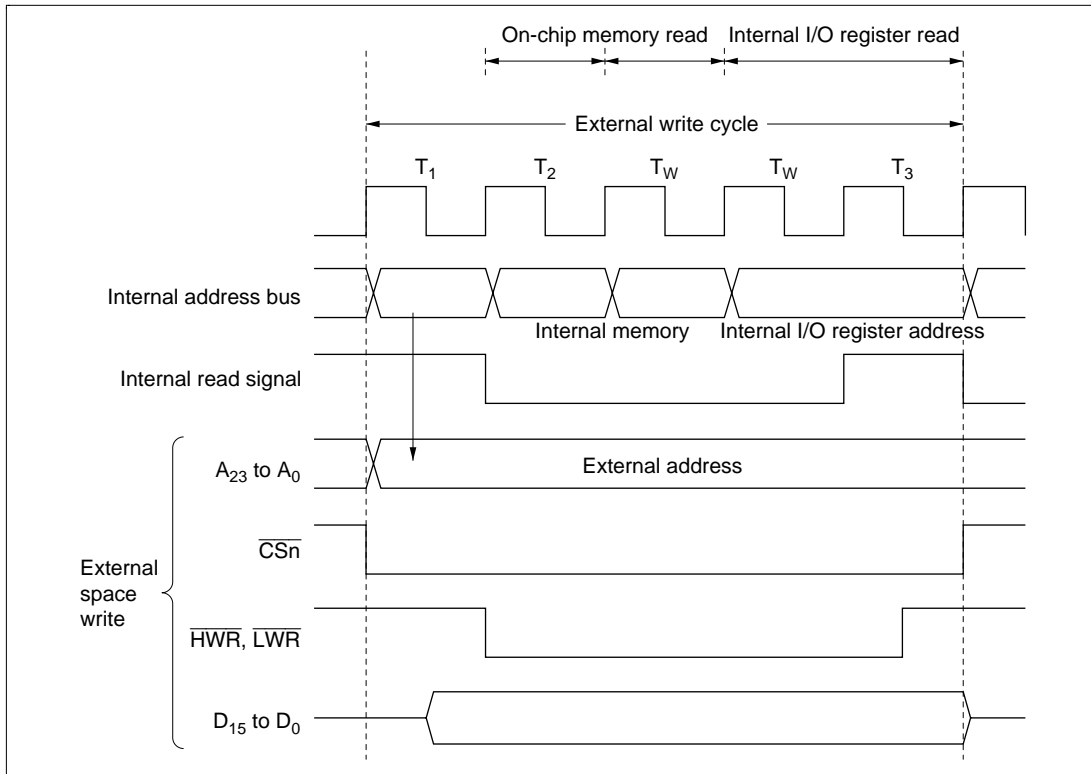


Figure 6-36 Example of Timing when Write Data Buffer Function is Used

The H8S/2350 Series can release the external bus in response to a bus request from an external device. In the external bus released state, the internal bus master continues to operate as long as there is no external access.

If an internal bus master wants to make an external access in the external bus released state, or if a refresh request is generated, it can issue a bus request off-chip.

6.10.2 Operation

In external expansion mode, the bus can be released to an external device by setting the BRLE bit in BCRL to 1. Driving the $\overline{\text{BREQ}}$ pin low issues an external bus request to the H8S/2350 Series. When the $\overline{\text{BREQ}}$ pin is sampled, at the prescribed timing the $\overline{\text{BACK}}$ pin is driven low, and the address bus, data bus, and bus control signals are placed in the high-impedance state, establishing the external bus-released state.

In the external bus released state, an internal bus master can perform accesses using the internal bus. When an internal bus master wants to make an external access, it temporarily defers activation of the bus cycle, and waits for the bus request from the external bus master to be dropped. Even if a refresh request is generated in the external bus released state, refresh control is deferred until the external bus master drops the bus request.

If the BREQOE bit in BCRL is set to 1, when an internal bus master wants to make an external access in the external bus released state, or when a refresh request is generated, the $\overline{\text{BREQO}}$ pin is driven low and a request can be made off-chip to drop the bus request.

When the $\overline{\text{BREQ}}$ pin is driven high, the $\overline{\text{BACK}}$ pin is driven high at the prescribed timing and the external bus released state is terminated.

If an external bus release request and external access occur simultaneously, the order of priority is as follows:

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

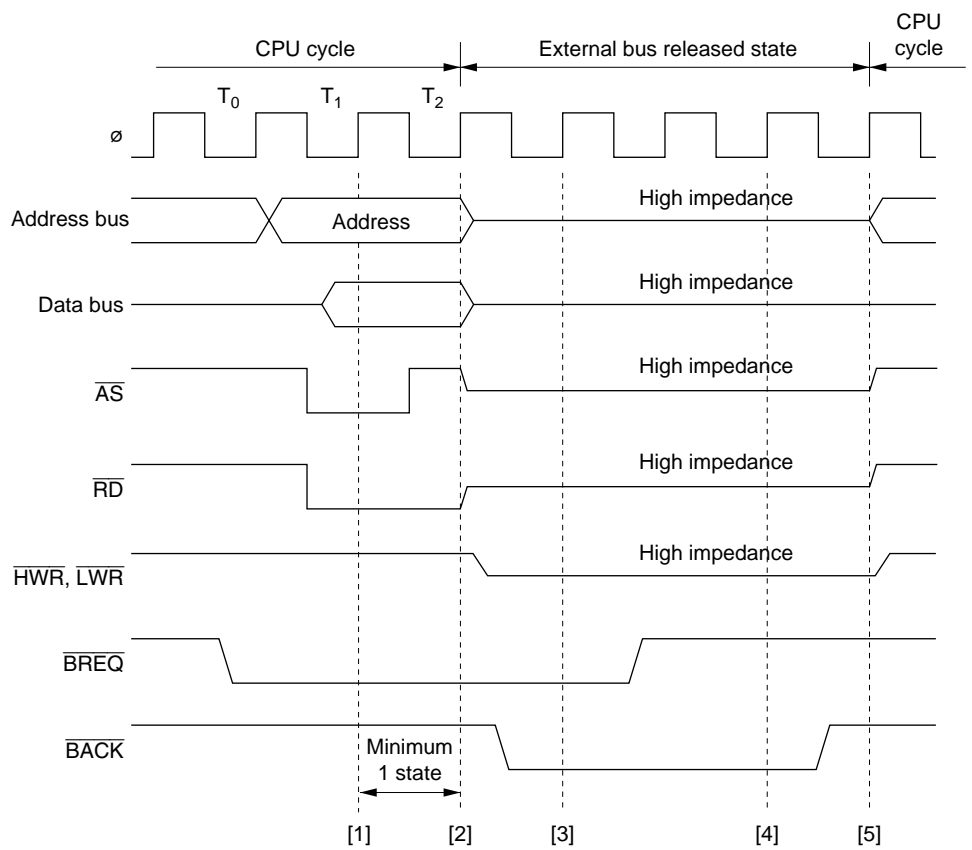
If a refresh request and external bus release request occur simultaneously, the order of priority is as follows:

(High) Refresh > External bus release (Low)

As a refresh and an external access by an internal bus master can be executed simultaneously, there is no relative order of priority for these two operations.

Table 6-2 Pin States in Bus Released State

Pins	Pin State
A_{23} to A_0	High impedance
D_{15} to D_0	High impedance
\overline{CSn}	High impedance
\overline{CAS}	High impedance
\overline{AS}	High impedance
\overline{RD}	High impedance
\overline{HWR}	High impedance
\overline{LWR}	High impedance
\overline{DACKn}	High



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

Figure 6-37 Bus-Released State Transition Timing

6.11 Bus Arbitration

6.11.1 Overview

The H8S/2350 Series has a bus arbiter that arbitrates bus master operations.

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

6.11.2 Operation

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

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

(High) DMAC > DTC > CPU (Low)

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

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

(High) Refresh > External bus release (Low)

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

As a refresh and an external access by an internal bus master can be executed simultaneously, there is no relative order of priority for these two operations.

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

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

- The bus is transferred at a break between bus cycles. However, if a bus cycle is executed in discrete operations, as in the case of a longword-size access, the bus is not transferred between the operations. See Appendix A-5, Bus States During Instruction Execution, for timings at which the bus is not 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 can release the bus after a vector read, a register information read (3 states), a single data transfer, or a register information write (3 states). It does not release the bus during a register information read (3 states), a single data transfer, or a register information write (3 states).

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

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

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

6.11.4 External Bus Release Usage Note

External bus release can be performed on completion of an external bus cycle. The \overline{RD} signal, DRAM interface \overline{RAS} and \overline{CAS} signals remain low until the end of the external bus cycle. Therefore, when external bus release is performed, the \overline{RD} , \overline{RAS} , and \overline{CAS} signals may change from the low level to the high-impedance state.

In a manual reset, the bus controller's registers and internal state are maintained, and an executing external bus cycle is completed. In this case, $\overline{\text{WAIT}}$ input is ignored. Also, since the DMAC is initialized by a manual reset, $\overline{\text{DACK}}$ and $\overline{\text{TEND}}$ output is disabled and these pins become I/O ports controlled by DDR and DR.

The H8S/2350 Series has a built-in DMA controller (DMAC) which can carry out data transfer on up to 4 channels.

7.1.1 Features

The features of the DMAC are listed below.

- Choice of short address mode or full address mode
 - Short address mode
 - Maximum of 4 channels can be used
 - Choice of dual address mode or single address mode
 - In dual address mode, one of the two addresses, transfer source and transfer destination, is specified as 24 bits and the other as 16 bits
 - In single address mode, transfer source or transfer destination address only is specified as 24 bits
 - In single address mode, transfer can be performed in one bus cycle
 - Choice of sequential mode, idle mode, or repeat mode for dual address mode and single address mode
 - Full address mode
 - Maximum of 2 channels can be used
 - Transfer source and transfer destination address specified as 24 bits
 - Choice of normal mode or block transfer mode
- 16-Mbyte address space can be specified directly
- Byte or word can be set as the transfer unit
- Activation sources: internal interrupt, external request, auto-request (depending on transfer mode)
 - Six 16-bit timer-pulse unit (TPU) compare match/input capture interrupts
 - Serial communication interface (SCI0, SCI1) transmission complete interrupt, reception complete interrupt
 - A/D converter conversion end interrupt
 - External request
 - Auto-request

7.1.2 Block Diagram

A block diagram of the DMAC is shown in figure 7-1.

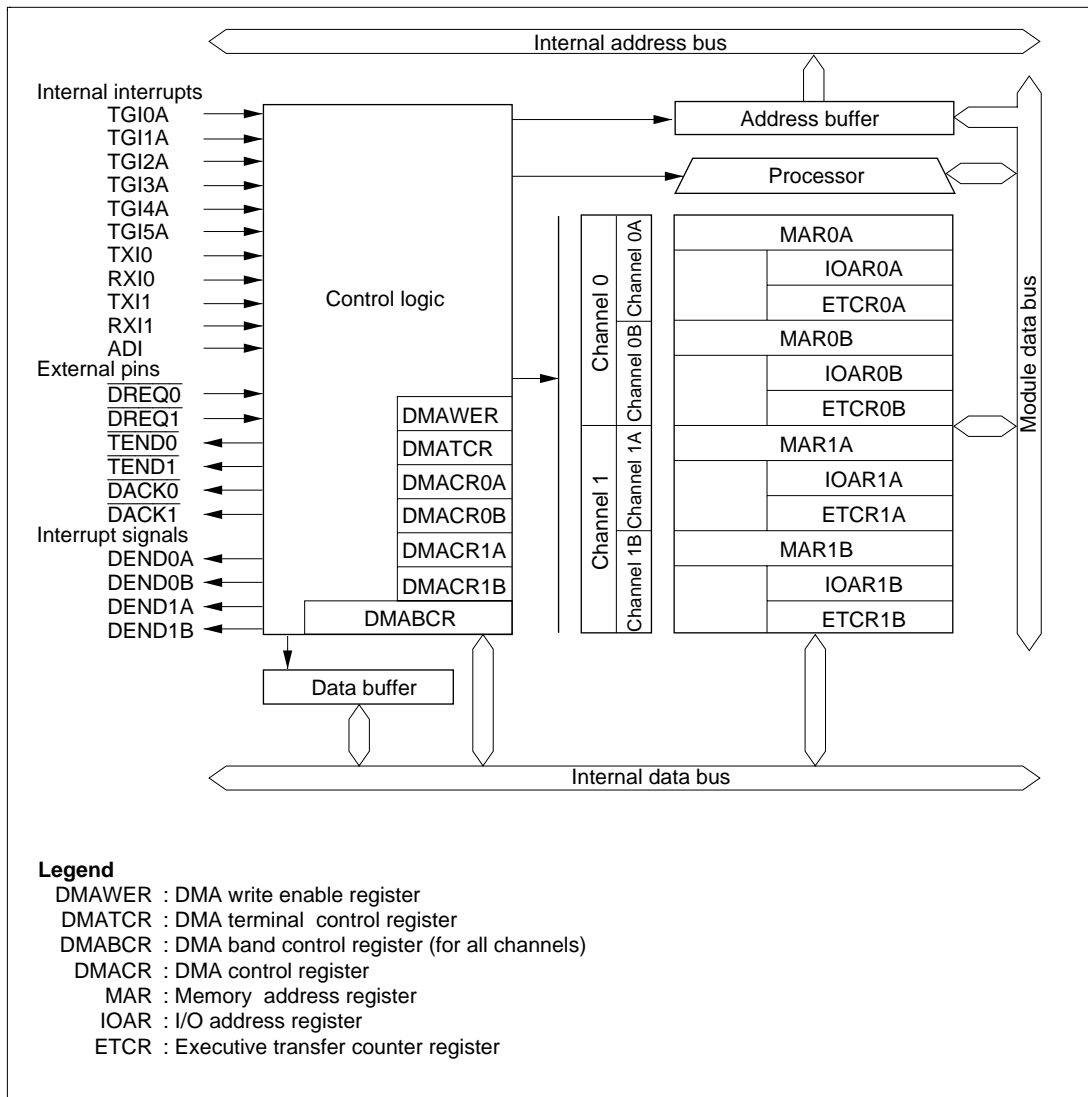


Figure 7-1 Block Diagram of DMAC

Table 7-1 (1) Overview of DMAC Functions (Short Address Mode)

Transfer Mode	Transfer Source	Address Register Bit Length	
		Source	Destination
Dual address mode	<ul style="list-style-type: none"> • TPU channel 0 to 5 compare match/input capture A interrupt • SCI transmission complete interrupt • SCI reception complete interrupt • A/D converter conversion end interrupt • External request 	24/16	16/24
<ul style="list-style-type: none"> • Sequential mode <ul style="list-style-type: none"> — 1-byte or 1-word transfer executed for one transfer request — Memory address incremented/decremented by 1 or 2 — 1 to 65536 transfers • Idle mode <ul style="list-style-type: none"> — 1-byte or 1-word transfer executed for one transfer request — Memory address fixed — 1 to 65536 transfers • Repeat mode <ul style="list-style-type: none"> — 1-byte or 1-word transfer executed for one transfer request — Memory address incremented/decremented by 1 or 2 — After specified number of transfers (1 to 256), initial state is restored and operation continues 			
Single address mode	<ul style="list-style-type: none"> • External request 	24/ $\overline{\text{DACK}}$	$\overline{\text{DACK}}$ /24
<ul style="list-style-type: none"> • 1-byte or 1-word transfer executed for one transfer request • Transfer in 1 bus cycle using $\overline{\text{DACK}}$ pin in place of address specifying I/O • Specifiable for sequential, idle, and repeat modes 			

<ul style="list-style-type: none"> • Auto-request <ul style="list-style-type: none"> — Transfer request retained internally — Transfers continue for the specified number of times (1 to 65536) — Choice of burst or cycle steal transfer 	<ul style="list-style-type: none"> • Auto-request 	
<ul style="list-style-type: none"> • External request <ul style="list-style-type: none"> — 1-byte or 1-word transfer executed for one transfer request — 1 to 65536 transfers 	<ul style="list-style-type: none"> • External request 	
<p>Block transfer mode</p>	<ul style="list-style-type: none"> • TPU channel 0 to 5 	<p>24 24</p>
<ul style="list-style-type: none"> • Specified block size transfer executed for one transfer request • 1 to 65536 transfers • Either source or destination specifiable as block area • Block size: 1 to 256 bytes or words 	<ul style="list-style-type: none"> • compare match/input capture A interrupt • SCI transmission complete interrupt • SCI reception complete interrupt • External request • A/D converter conversion end interrupt 	

In short address mode, external request transfer, single address transfer, and transfer end output are not performed for channel A.

The DMA transfer acknowledge function is used in channel B single address mode in short address mode.

When the $\overline{\text{DREQ}}$ pin is used, do not designate the corresponding port for output.

With regard to the $\overline{\text{DACK}}$ pins, setting single address transfer automatically sets the corresponding port to output, functioning as a $\overline{\text{DACK}}$ pin.

With regard to the $\overline{\text{TEND}}$ pins, whether or not the corresponding port is used as a $\overline{\text{TEND}}$ pin can be specified by means of a register setting.

Table 7-2 DMAC Pins

Channel	Pin Name	Symbol	I/O	Function
0	DMA request 0	$\overline{\text{DREQ0}}$	Input	DMAC channel 0 external request
	DMA transfer acknowledge 0	$\overline{\text{DACK0}}$	Output	DMAC channel 0 single address transfer acknowledge
	DMA transfer end 0	$\overline{\text{TEND0}}$	Output	DMAC channel 0 transfer end
1	DMA request 1	$\overline{\text{DREQ1}}$	Input	DMAC channel 1 external request
	DMA transfer acknowledge 1	$\overline{\text{DACK1}}$	Output	DMAC channel 1 single address transfer acknowledge
	DMA transfer end 1	$\overline{\text{TEND1}}$	Output	DMAC channel 1 transfer end

Table 7-3 DMAC Registers

Channel	Name	Abbreviation	R/W	Initial Value	Address*	Bus Width
0	Memory address register 0A	MAR0A	R/W	Undefined	H'FEE0	16 bits
	I/O address register 0A	IOAR0A	R/W	Undefined	H'FEE4	16 bits
	Transfer count register 0A	ETCR0A	R/W	Undefined	H'FEE6	16 bits
	Memory address register 0B	MAR0B	R/W	Undefined	H'FEE8	16 bits
	I/O address register 0B	IOAR0B	R/W	Undefined	H'FEEC	16 bits
	Transfer count register 0B	ETCR0B	R/W	Undefined	H'FEEE	16 bits
1	Memory address register 1A	MAR1A	R/W	Undefined	H'FEF0	16 bits
	I/O address register 1A	IOAR1A	R/W	Undefined	H'FEF4	16 bits
	Transfer count register 1A	ETCR1A	R/W	Undefined	H'FEF6	16 bits
	Memory address register 1B	MAR1B	R/W	Undefined	H'FEF8	16 bits
	I/O address register 1B	IOAR1B	R/W	Undefined	H'FEFC	16 bits
	Transfer count register 1B	ETCR1B	R/W	Undefined	H'FEFE	16 bits
0, 1	DMA write enable register	DMAWER	R/W	H'00	H'FF00	8 bits
	DMA terminal control register	DMATCR	R/W	H'00	H'FF01	8 bits
	DMA control register 0A	DMACR0A	R/W	H'00	H'FF02	16 bits
	DMA control register 0B	DMACR0B	R/W	H'00	H'FF03	16 bits
	DMA control register 1A	DMACR1A	R/W	H'00	H'FF04	16 bits
	DMA control register 1B	DMACR1B	R/W	H'00	H'FF05	16 bits
	DMA band control register	DMABCR	R/W	H'0000	H'FF06	16 bits
	Module stop control register	MSTPCR	R/W	H'3FFF	H'FF3C	8 bits

Note: * Lower 16 bits of the address.

Short address mode transfer is specified for each channel by clearing the FAE bit in DMABCR to 0, as shown in table 7-4. Short address mode or full address mode can be selected for channels 1 and 0 independently by means of bits FAE1 and FAE0.

Table 7-4 Short Address Mode and Full Address Mode (For 1 Channel: Example of Channel 0)

FAE0	Description																
0	Short address mode specified (channels A and B operate independently)																
Channel 0A	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td colspan="2" style="text-align: center;">MAR0A</td></tr> <tr><td style="width: 50%;"></td><td style="text-align: center;">IOAR0A</td></tr> <tr><td style="width: 50%;"></td><td style="text-align: center;">ETCR0A</td></tr> <tr><td style="width: 50%;"></td><td style="text-align: center;">DMACR0A</td></tr> </table> <div style="display: inline-block; vertical-align: middle; margin-left: 10px;"> <p>← Specifies transfer source/transfer destination address</p> <p>← Specifies transfer destination/transfer source address</p> <p>← Specifies number of transfers</p> <p>← Specifies transfer size, mode, activation source, etc.</p> </div>	MAR0A			IOAR0A		ETCR0A		DMACR0A								
MAR0A																	
	IOAR0A																
	ETCR0A																
	DMACR0A																
Channel 0B	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td colspan="2" style="text-align: center;">MAR0B</td></tr> <tr><td style="width: 50%;"></td><td style="text-align: center;">IOAR0B</td></tr> <tr><td style="width: 50%;"></td><td style="text-align: center;">ETCR0B</td></tr> <tr><td style="width: 50%;"></td><td style="text-align: center;">DMACR0B</td></tr> </table> <div style="display: inline-block; vertical-align: middle; margin-left: 10px;"> <p>← Specifies transfer source/transfer destination address</p> <p>← Specifies transfer destination/transfer source address</p> <p>← Specifies number of transfers</p> <p>← Specifies transfer size, mode, activation source, etc.</p> </div>	MAR0B			IOAR0B		ETCR0B		DMACR0B								
MAR0B																	
	IOAR0B																
	ETCR0B																
	DMACR0B																
1	Full address mode specified (channels A and B operate in combination)																
Channel 0	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr><td colspan="2" style="text-align: center;">MAR0A</td></tr> <tr><td colspan="2" style="text-align: center;">MAR0B</td></tr> <tr><td style="width: 50%;"></td><td style="text-align: center;">IOAR0A</td></tr> <tr><td style="width: 50%;"></td><td style="text-align: center;">IOAR0B</td></tr> <tr><td style="width: 50%;"></td><td style="text-align: center;">ETCR0A</td></tr> <tr><td style="width: 50%;"></td><td style="text-align: center;">ETCR0B</td></tr> <tr><td style="width: 50%;"></td><td style="text-align: center;">DMACR0A</td></tr> <tr><td style="width: 50%;"></td><td style="text-align: center;">DMACR0B</td></tr> </table> <div style="display: inline-block; vertical-align: middle; margin-left: 10px;"> <p>← Specifies transfer source address</p> <p>← Specifies transfer destination address</p> <p>← Not used</p> <p>← Not used</p> <p>← Specifies number of transfers</p> <p>← Specifies number of transfers (used in block transfer mode only)</p> <p>← Specifies transfer size, mode, activation source, etc.</p> </div>	MAR0A		MAR0B			IOAR0A		IOAR0B		ETCR0A		ETCR0B		DMACR0A		DMACR0B
MAR0A																	
MAR0B																	
	IOAR0A																
	IOAR0B																
	ETCR0A																
	ETCR0B																
	DMACR0A																
	DMACR0B																

Initial value :	0	0	0	0	0	0	0	0	*	*	*	*	*	*	*	*																	
R/W :	—	—	—	—	—	—	—	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W																	
Bit :	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0																	
MAR :	<table border="1" style="width:100%; height:20px;"> <tr> <td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td> </tr> </table>																																
Initial value :	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*																	
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	R/W	R/W																	

*: Undefined

MAR is a 32-bit readable/writable register that specifies the transfer source address or destination address.

The upper 8 bits of MAR are reserved: they are always read as 0, and cannot be modified.

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

MAR is incremented or decremented each time a byte or word transfer is executed, so that the address specified by MAR is constantly updated. For details, see section 7.2.4, DMA Control Register (DMACR).

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

Initial value : * * * * * * * * * * * * * * * * * *
 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 R/W R/W
 *: Undefined

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

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

IOAR is invalid in single address mode.

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

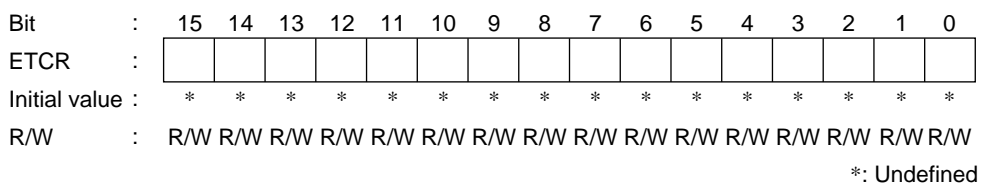
IOAR is not initialized by a reset or in standby mode.

7.2.3 Execute Transfer Count Register (ETCR)

ETCR is a 16-bit readable/writable register that specifies the number of transfers. The setting of this register is different for sequential mode and idle mode on the one hand, and for repeat mode on the other.

(1) Sequential Mode and Idle Mode

Transfer Counter



In sequential mode and idle mode, ETCR functions as a 16-bit transfer counter (with a count range of 1 to 65536). ETCR is decremented by 1 each time a transfer is performed, and when the count reaches H'0000, the DTE bit in DMABCR is cleared, and transfer ends.

ETCRH	:								
Initial value	:	*	*	*	*	*	*	*	*
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Transfer Counter

Bit	:	7	6	5	4	3	2	1	0
ETCRL	:								
Initial value	:	*	*	*	*	*	*	*	*
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

*: Undefined

In repeat mode, ETCR functions as transfer counter ETCRL (with a count range of 1 to 256) and transfer number storage register ETCRH. ETCRL is decremented by 1 each time a transfer is performed, and when the count reaches H'00, ETCRL is loaded with the value in ETCRH. At this point, MAR is automatically restored to the value it had when the count was started. The DTE bit in DMABCR is not cleared, and so transfers can be performed repeatedly until the DTE bit is cleared by the user.

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

7.2.4 DMA Control Register (DMACR)

Bit	:	7	6	5	4	3	2	1	0
DMACR	:	DTSZ	DTID5	RPE	DTDIR	DTF3	DTF2	DTF1	DTF0
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

DMACR is an 8-bit readable/writable register that controls the operation of each DMAC channel.

DMACR is initialized to H'00 by a reset, and in standby mode.

Bit 6—Data Transfer Increment/Decrement (DTID): Selects incrementing or decrementing of MAR every data transfer in sequential mode or repeat mode.

In idle mode, MAR is neither incremented nor decremented.

Bit 6

DTID	Description	
0	MAR is incremented after a data transfer <ul style="list-style-type: none"> When DTSZ = 0, MAR is incremented by 1 after a transfer When DTSZ = 1, MAR is incremented by 2 after a transfer 	(Initial value)
1	MAR is decremented after a data transfer <ul style="list-style-type: none"> When DTSZ = 0, MAR is decremented by 1 after a transfer When DTSZ = 1, MAR is decremented by 2 after a transfer 	

Bit 5—Repeat Enable (RPE): Used in combination with the DTIE bit in DMABCR to select the mode (sequential, idle, or repeat) in which transfer is to be performed.

Bit 5 RPE	DMABCR DTIE	Description	
0	0	Transfer in sequential mode (no transfer end interrupt)	(Initial value)
	1	Transfer in sequential mode (with transfer end interrupt)	
1	0	Transfer in repeat mode (no transfer end interrupt)	
	1	Transfer in idle mode (with transfer end interrupt)	

For details of operation in sequential, idle, and repeat mode, see section 7.5.2, Sequential Mode, section 7.5.3, Idle Mode, and section 7.5.4, Repeat Mode.

SAE	DTDIR	Description
0	0	Transfer with MAR as source address and IOAR as destination address (Initial value)
	1	Transfer with IOAR as source address and MAR as destination address
1	0	Transfer with MAR as source address and $\overline{\text{DACK}}$ pin as write strobe
	1	Transfer with $\overline{\text{DACK}}$ pin as read strobe and MAR as destination address

Bit 3 DTF3	Bit 2 DTF2	Bit 1 DTF1	Bit 0 DTF0	Description	
0	0	0	0	— (Initial value)	
			1	Activated by A/D converter conversion end interrupt	
			1	0	—
				1	—
1	0	0	0	Activated by SCI channel 0 transmission complete interrupt	
			1	Activated by SCI channel 0 reception complete interrupt	
			1	0	Activated by SCI channel 1 transmission complete interrupt
				1	Activated by SCI channel 1 reception complete interrupt
1	0	0	0	Activated by TPU channel 0 compare match/input capture A interrupt	
			1	Activated by TPU channel 1 compare match/input capture A interrupt	
			1	0	Activated by TPU channel 2 compare match/input capture A interrupt
				1	Activated by TPU channel 3 compare match/input capture A interrupt
	1	0	0	0	Activated by TPU channel 4 compare match/input capture A interrupt
				1	Activated by TPU channel 5 compare match/input capture A interrupt
			1	0	—
				1	—

			1	Activated by A/D converter conversion end interrupt
		1	0	Activated by $\overline{\text{DREQ}}$ pin falling edge input*
			1	Activated by $\overline{\text{DREQ}}$ pin low-level input
	1	0	0	Activated by SCI channel 0 transmission complete interrupt
			1	Activated by SCI channel 0 reception complete interrupt
		1	0	Activated by SCI channel 1 transmission complete interrupt
			1	Activated by SCI channel 1 reception complete interrupt
1	0	0	0	Activated by TPU channel 0 compare match/input capture A interrupt
			1	Activated by TPU channel 1 compare match/input capture A interrupt
		1	0	Activated by TPU channel 2 compare match/input capture A interrupt
			1	Activated by TPU channel 3 compare match/input capture A interrupt
	1	0	0	Activated by TPU channel 4 compare match/input capture A interrupt
			1	Activated by TPU channel 5 compare match/input capture A interrupt
		1	0	—
			1	—

Note: * Detected as a low level in the first transfer after transfer is enabled.

The same factor can be selected for more than one channel. In this case, activation starts with the highest-priority channel according to the relative channel priorities. For relative channel priorities, see section 7.5.13, DMAC Multi-Channel Operation.

Initial value :	0	0	0	0	0	0	0	0
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Bit :	7	6	5	4	3	2	1	0
DMABCRL :	DTE1B	DTE1A	DTE0B	DTE0A	DTIE1B	DTIE1A	DTIE0B	DTIE0A
Initial value :	0	0	0	0	0	0	0	0
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

DMABCRL is a 16-bit readable/writable register that controls the operation of each DMAC channel.

DMABCRL is initialized to H'0000 by a reset, and in standby mode.

Bit 15—Full Address Enable 1 (FAE1): Specifies whether channel 1 is to be used in short address mode or full address mode.

In short address mode, channels 1A and 1B are used as independent channels.

Bit 15

FAE1	Description	
0	Short address mode	(Initial value)
1	Full address mode	

Bit 14—Full Address Enable 0 (FAE0): Specifies whether channel 0 is to be used in short address mode or full address mode.

In short address mode, channels 0A and 0B are used as independent channels.

Bit 14

FAE0	Description	
0	Short address mode	(Initial value)
1	Full address mode	

0	Transfer in dual address mode	(Initial value)
1	Transfer in single address mode	

This bit is invalid in full address mode.

Bit 12—Single Address Enable 0 (SAE0): Specifies whether channel 0B is to be used for transfer in dual address mode or single address mode.

Bit 12 SAE0	Description	
0	Transfer in dual address mode	(Initial value)
1	Transfer in single address mode	

This bit is invalid in full address mode.

Bits 11 to 8—Data Transfer Acknowledge (DTA): These bits enable or disable clearing, when DMA transfer is performed, of the internal interrupt source selected by the data transfer factor setting.

When DTE = 1 and DTA = 1, the internal interrupt source selected by the data transfer factor setting is cleared automatically by DMA transfer. When DTE = 1 and DTA = 0, the internal interrupt source selected by the data transfer factor setting does not issue an interrupt request to the CPU or DTC.

When DTE = 0 and DTA = 0, the internal interrupt source selected by the data transfer factor setting is not cleared when a transfer is performed, and can issue an interrupt request to the CPU or DTC in parallel. In this case, the interrupt source should be cleared by the CPU or DTC transfer.

When DTE = 0, the internal interrupt source selected by the data transfer factor setting issues an interrupt request to the CPU or DTC regardless of the DTA bit setting.

DTA1B	Description
0	Clearing of selected internal interrupt source at time of DMA transfer is disabled (Initial value)
1	Clearing of selected internal interrupt source at time of DMA transfer is enabled

Bit 10—Data Transfer Acknowledge 1A (DTA1A): Enables or disables clearing, when DMA transfer is performed, of the internal interrupt source selected by the channel 1A data transfer factor setting.

Bit 10 DTA1A	Description
0	Clearing of selected internal interrupt source at time of DMA transfer is disabled (Initial value)
1	Clearing of selected internal interrupt source at time of DMA transfer is enabled

Bit 9—Data Transfer Acknowledge 0B (DTA0B): Enables or disables clearing, when DMA transfer is performed, of the internal interrupt source selected by the channel 0B data transfer factor setting.

Bit 9 DTA0B	Description
0	Clearing of selected internal interrupt source at time of DMA transfer is disabled (Initial value)
1	Clearing of selected internal interrupt source at time of DMA transfer is enabled

Bit 8—Data Transfer Acknowledge 0A (DTA0A): Enables or disables clearing, when DMA transfer is performed, of the internal interrupt source selected by the channel 0A data transfer factor setting.

Bit 8 DTA0A	Description
0	Clearing of selected internal interrupt source at time of DMA transfer is disabled (Initial value)
1	Clearing of selected internal interrupt source at time of DMA transfer is enabled

end interrupt request to the CPU or DTC.

The conditions for the DTE bit being cleared to 0 are as follows:

- When initialization is performed
- When the specified number of transfers have been completed in a transfer mode other than repeat mode
- When 0 is written to the DTE bit to forcibly abort the transfer, or for a similar reason

When DTE = 1, data transfer is enabled and the DMAC waits for a request by the activation source selected by the data transfer factor setting. When a request is issued by the activation source, DMA transfer is executed.

The condition for the DTE bit being set to 1 is as follows:

- When 1 is written to the DTE bit after the DTE bit is read as 0

Bit 7—Data Transfer Enable 1B (DTE1B): Enables or disables data transfer on channel 1B.

Bit 7

DTE1B	Description	
0	Data transfer disabled	(Initial value)
1	Data transfer enabled	

Bit 6—Data Transfer Enable 1A (DTE1A): Enables or disables data transfer on channel 1A.

Bit 6

DTE1A	Description	
0	Data transfer disabled	(Initial value)
1	Data transfer enabled	

1 Data transfer enabled

Bit 4—Data Transfer Enable 0A (DTE0A): Enables or disables data transfer on channel 0A.

Bit 4

DTE0A	Description
0	Data transfer disabled (Initial value)
1	Data transfer enabled

Bits 3 to 0—Data Transfer End Interrupt Enable (DTIE): These bits enable or disable an interrupt to the CPU or DTC when transfer ends. If the DTIE bit is set to 1 when DTE = 0, the DMAC regards this as indicating the end of a transfer, and issues a transfer end interrupt request to the CPU or DTC.

A transfer end interrupt can be canceled either by clearing the DTIE bit to 0 in the interrupt handling routine, or by performing processing to continue transfer by setting the transfer counter and address register again, and then setting the DTE bit to 1.

Bit 3—Data Transfer Interrupt Enable 1B (DTIE1B): Enables or disables the channel 1B transfer end interrupt.

Bit 3

DTIE1B	Description
0	Transfer end interrupt disabled (Initial value)
1	Transfer end interrupt enabled

Bit 2—Data Transfer Interrupt Enable 1A (DTIE1A): Enables or disables the channel 1A transfer end interrupt.

Bit 2

DTIE1A	Description
0	Transfer end interrupt disabled (Initial value)
1	Transfer end interrupt enabled

0	Transfer end interrupt disabled	(Initial value)
1	Transfer end interrupt enabled	

Bit 0—Data Transfer Interrupt Enable 0A (DTIE0A): Enables or disables the channel 0A transfer end interrupt.

Bit 0		
DTIE0A	Description	
0	Transfer end interrupt disabled	(Initial value)
1	Transfer end interrupt enabled	

7.3.1 Memory Address Register (MAR)

Bit	:	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MAR	:	—	—	—	—	—	—	—	—								
Initial value	:	0	0	0	0	0	0	0	0	*	*	*	*	*	*	*	*
R/W	:	—	—	—	—	—	—	—	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Bit	:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MAR	:																
Initial value	:	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
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	R/W	R/W

*: Undefined

MAR is a 32-bit readable/writable register; MARA functions as the transfer source address register, and MARB as the destination address register.

MAR is composed of two 16-bit registers, MARH and MARL. The upper 8 bits of MARH are reserved: they are always read as 0, and cannot be modified.

MAR is incremented or decremented each time a byte or word transfer is executed, so that the source or destination memory address can be updated automatically. For details, see section 7.3.4, DMA Control Register (DMACR).

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

7.3.2 I/O Address Register (IOAR)

IOAR is not used in full address transfer.

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

(1) Normal Mode

ETCRA

Transfer Counter

Bit	:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ETCR	:																
Initial value	:	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
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	R/W	R/W

*: Undefined

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

ETCRB

ETCRB is not used in normal mode.

(2) Block Transfer Mode

ETCRA

Holds block size

Bit	:	15	14	13	12	11	10	9	8
ETCRAH	:								
Initial value	:	*	*	*	*	*	*	*	*
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Block size counter

Bit	:	7	6	5	4	3	2	1	0
ETCRAL	:								
Initial value	:	*	*	*	*	*	*	*	*
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

*: Undefined

Bit 14—Source Address Increment/Decrement (SAID)

Bit 13—Source Address Increment/Decrement Enable (SAIDE): These bits specify whether source address register MARA is to be incremented, decremented, or left unchanged, when data transfer is performed.

Bit 14 SAID	Bit 13 SAIDE	Description
0	0	MARA is fixed (Initial value)
	1	MARA is incremented after a data transfer <ul style="list-style-type: none"> When DTSZ = 0, MARA is incremented by 1 after a transfer When DTSZ = 1, MARA is incremented by 2 after a transfer
1	0	MARA is fixed
	1	MARA is decremented after a data transfer <ul style="list-style-type: none"> When DTSZ = 0, MARA is decremented by 1 after a transfer When DTSZ = 1, MARA is decremented by 2 after a transfer

Bit 12—Block Direction (BLKDIR)

Bit 11—Block Enable (BLKE): These bits specify whether normal mode or block transfer mode is to be used. If block transfer mode is specified, the BLKDIR bit specifies whether the source side or the destination side is to be the block area.

Bit 12 BLKDIR	Bit 11 BLKE	Description
0	0	Transfer in normal mode (Initial value)
	1	Transfer in block transfer mode, destination side is block area
1	0	Transfer in normal mode
	1	Transfer in block transfer mode, source side is block area

For operation in normal mode and block transfer mode, see section 7.5, Operation.

whether destination address register MARB is to be incremented, decremented, or left unchanged, when data transfer is performed.

Bit 6 DAID	Bit 5 DAIDE	Description
0	0	MARB is fixed (Initial value)
	1	MARB is incremented after a data transfer <ul style="list-style-type: none"> When DTSZ = 0, MARB is incremented by 1 after a transfer When DTSZ = 1, MARB is incremented by 2 after a transfer
1	0	MARB is fixed
	1	MARB is decremented after a data transfer <ul style="list-style-type: none"> When DTSZ = 0, MARB is decremented by 1 after a transfer When DTSZ = 1, MARB is decremented by 2 after a transfer

Bit 4—Reserved: Can be read or written to.

Bits 3 to 0—Data Transfer Factor (DTF3 to DTF0): These bits select the data transfer factor (activation source). The factors that can be specified differ between normal mode and block transfer mode.

- Normal Mode

Bit 3 DTF3	Bit 2 DTF2	Bit 1 DTF1	Bit 0 DTF0	Description
0	0	0	0	— (Initial value)
			1	—
	1	0	0	Activated by $\overline{\text{DREQ}}$ pin falling edge input
			1	Activated by $\overline{\text{DREQ}}$ pin low-level input
		1	0	* —
			1	0
		1	Auto-request (burst)	
1	*	*	*	—

*: Don't care

			1	Activated by A/D converter conversion end interrupt
		1	0	Activated by $\overline{\text{DREQ}}$ pin falling edge input*
			1	Activated by $\overline{\text{DREQ}}$ pin low-level input
	1	0	0	Activated by SCI channel 0 transmission complete interrupt
			1	Activated by SCI channel 0 reception complete interrupt
		1	0	Activated by SCI channel 1 transmission complete interrupt
			1	Activated by SCI channel 1 reception complete interrupt
1	0	0	0	Activated by TPU channel 0 compare match/input capture A interrupt
			1	Activated by TPU channel 1 compare match/input capture A interrupt
		1	0	Activated by TPU channel 2 compare match/input capture A interrupt
			1	Activated by TPU channel 3 compare match/input capture A interrupt
	1	0	0	Activated by TPU channel 4 compare match/input capture A interrupt
			1	Activated by TPU channel 5 compare match/input capture A interrupt
		1	0	—
			1	—

Note: * Detected as a low level in the first transfer after transfer is enabled.

The same factor can be selected for more than one channel. In this case, activation starts with the highest-priority channel according to the relative channel priorities. For relative channel priorities, see section 7.5.13, DMAC Multi-Channel Operation.

Initial value :	0	0	0	0	0	0	0	0
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Bit :	7	6	5	4	3	2	1	0
DMABCRL :	DTME1	DTE1	DTME0	DTE0	DTIE1B	DTIE1A	DTIE0B	DTIE0A
Initial value :	0	0	0	0	0	0	0	0
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

DMABCR is a 16-bit readable/writable register that controls the operation of each DMAC channel.

DMABCR is initialized to H'0000 by a reset, and in standby mode.

Bit 15—Full Address Enable 1 (FAE1): Specifies whether channel 1 is to be used in short address mode or full address mode.

In full address mode, channels 1A and 1B are used together as a single channel.

Bit 15

FAE1	Description	
0	Short address mode	(Initial value)
1	Full address mode	

Bit 14—Full Address Enable 0 (FAE0): Specifies whether channel 0 is to be used in short address mode or full address mode.

In full address mode, channels 0A and 0B are used together as a single channel.

Bit 14

FAE0	Description	
0	Short address mode	(Initial value)
1	Full address mode	

When DTE = 1 and DTA = 1, the internal interrupt source selected by the data transfer factor setting is cleared automatically by DMA transfer. When DTE = 1 and DTA = 0, the internal interrupt source selected by the data transfer factor setting does not issue an interrupt request to the CPU or DTC.

When the DTE = 1 and the DTA = 0, the internal interrupt source selected by the data transfer factor setting is not cleared when a transfer is performed, and can issue an interrupt request to the CPU or DTC in parallel. In this case, the interrupt source should be cleared by the CPU or DTC transfer.

When the DTE = 0, the internal interrupt source selected by the data transfer factor setting issues an interrupt request to the CPU or DTC regardless of the DTA bit setting.

The state of the DTME bit does not affect the above operations.

Bit 11—Data Transfer Acknowledge 1 (DTA1): Enables or disables clearing, when DMA transfer is performed, of the internal interrupt source selected by the channel 1 data transfer factor setting.

Bit 11 DTA1	Description
0	Clearing of selected internal interrupt source at time of DMA transfer is disabled (Initial value)
1	Clearing of selected internal interrupt source at time of DMA transfer is enabled

Bit 9—Data Transfer Acknowledge 0 (DTA0): Enables or disables clearing, when DMA transfer is performed, of the internal interrupt source selected by the channel 0 data transfer factor setting.

Bit 9 DTA0	Description
0	Clearing of selected internal interrupt source at time of DMA transfer is disabled (Initial value)
1	Clearing of selected internal interrupt source at time of DMA transfer is enabled

If the relevant channel is in the middle of a burst mode transfer when an NMI interrupt is generated, the DTME bit is cleared, the transfer is interrupted, and bus mastership passes to the CPU. When the DTME bit is subsequently set to 1 again, the interrupted transfer is resumed. In block transfer mode, however, the DTME bit is not cleared by an NMI interrupt, and transfer is not interrupted.

The conditions for the DTME bit being cleared to 0 are as follows:

- When initialization is performed
- When NMI is input in burst mode
- When 0 is written to the DTME bit

The condition for DTME being set to 1 is as follows:

- When 1 is written to DTME after DTME is read as 0

Bit 7—Data Transfer Master Enable 1 (DTME1): Enables or disables data transfer on channel 1.

Bit 7

DTME1	Description
0	Data transfer disabled. In burst mode, cleared to 0 by an NMI interrupt (Initial value)
1	Data transfer enabled

Bit 5—Data Transfer Master Enable 0 (DTME0): Enables or disables data transfer on channel 0.

Bit 5

DTME0	Description
0	Data transfer disabled. In normal mode, cleared to 0 by an NMI interrupt (Initial value)
1	Data transfer enabled

and interrupt request to the CPU.

The conditions for the DTE bit being cleared to 0 are as follows:

- When initialization is performed
- When the specified number of transfers have been completed
- When 0 is written to the DTE bit to forcibly abort the transfer, or for a similar reason

When $DTE = 1$ and $DTME = 1$, data transfer is enabled and the DMAC waits for a request by the activation source selected by the data transfer factor setting. When a request is issued by the activation source, DMA transfer is executed.

The condition for the DTE bit being set to 1 is as follows:

- When 1 is written to the DTE bit after the DTE bit is read as 0

Bit 6—Data Transfer Enable 1 (DTE1): Enables or disables data transfer on channel 1.

Bit 6 DTE1	Description	
0	Data transfer disabled	(Initial value)
1	Data transfer enabled	

Bit 4—Data Transfer Enable 0 (DTE0): Enables or disables data transfer on channel 0.

Bit 4 DTE0	Description	
0	Data transfer disabled	(Initial value)
1	Data transfer enabled	

Bits 3 and 1—Data Transfer Interrupt Enable B (DTIEB): These bits enable or disable an interrupt to the CPU or DTC when transfer is interrupted. If the DTIEB bit is set to 1 when $DTME = 0$, the DMAC regards this as indicating a break in the transfer, and issues a transfer break interrupt request to the CPU or DTC.

A transfer break interrupt can be canceled either by clearing the DTIEB bit to 0 in the interrupt handling routine, or by performing processing to continue transfer by setting the DTME bit to 1.

0	Transfer break interrupt disabled	(Initial value)
1	Transfer break interrupt enabled	

Bit 1—Data Transfer Interrupt Enable 0B (DTIE0B): Enables or disables the channel 0 transfer break interrupt.

Bit 1		
DTIE0B	Description	
0	Transfer break interrupt disabled	(Initial value)
1	Transfer break interrupt enabled	

Bits 2 and 0—Data Transfer End Interrupt Enable A (DTIEA): These bits enable or disable an interrupt to the CPU or DTC when transfer ends. If DTIEA bit is set to 1 when DTE = 0, the DMAC regards this as indicating the end of a transfer, and issues a transfer end interrupt request to the CPU or DTC.

A transfer end interrupt can be canceled either by clearing the DTIEA bit to 0 in the interrupt handling routine, or by performing processing to continue transfer by setting the transfer counter and address register again, and then setting the DTE bit to 1.

Bit 2—Data Transfer Interrupt Enable 1A (DTIE1A): Enables or disables the channel 1 transfer end interrupt.

Bit 2		
DTIE1A	Description	
0	Transfer end interrupt disabled	(Initial value)
1	Transfer end interrupt enabled	

Bit 0—Data Transfer Interrupt Enable 0A (DTIE0A): Enables or disables the channel 0 transfer end interrupt.

Bit 0		
DTIE0A	Description	
0	Transfer end interrupt disabled	(Initial value)
1	Transfer end interrupt enabled	

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

Figure 7-2 shows the transfer areas for activating the DTC with a channel 0A transfer end interrupt, and reactivating channel 0A. The address register and count register area is re-set by the first DTC transfer, then the control register area is re-set by the second DTC chain transfer.

When re-setting the control register area, perform masking by setting bits in DMAWER to prevent modification of the contents of the other channels.

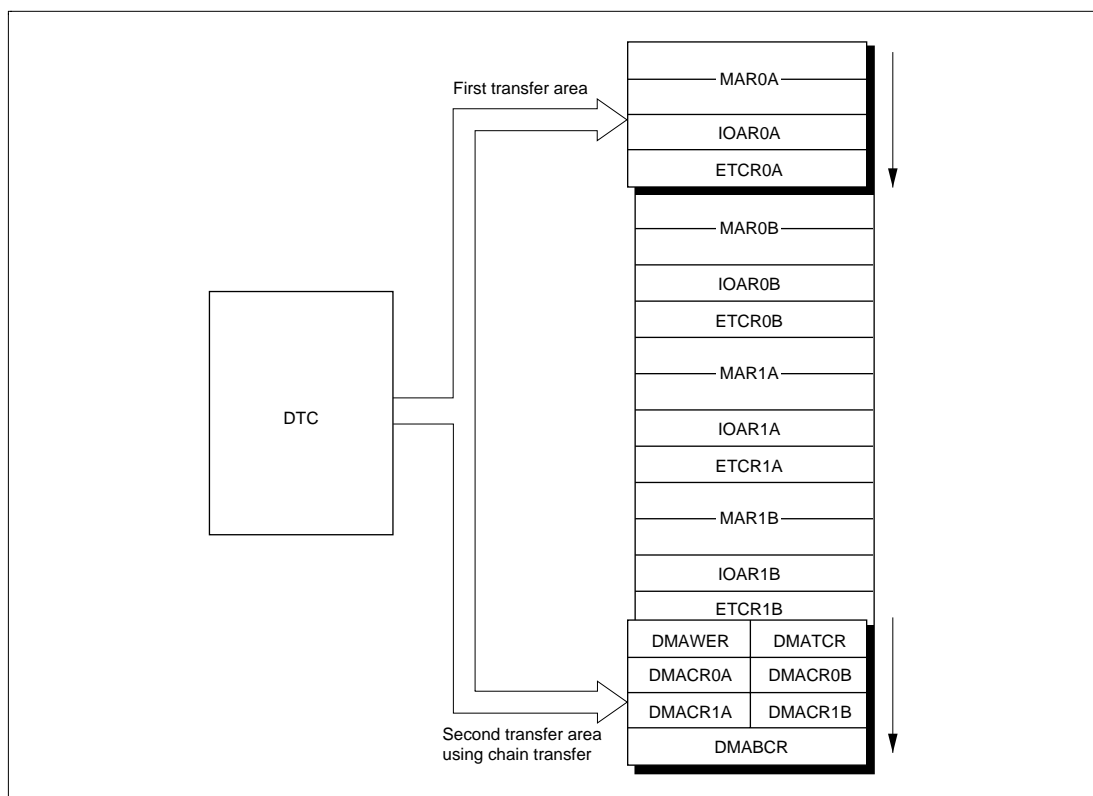


Figure 7-2 Areas for Register Re-Setting by DTC (Example: Channel 0A)

DMAWER is an 8-bit readable/writable register that controls enabling or disabling of writes to the DMACR, DMABCR, and DMATCR by the DTC.

DMAWER is initialized to H'00 by a reset, and in standby mode.

Bits 7 to 4—Reserved: Read-only bits, always read as 0.

Bit 3—Write Enable 1B (WE1B): Enables or disables writes to all bits in DMACR1B, bits 11, 7, and 3 in DMABCR, and bit 5 in DMATCR by the DTC.

Bit 3

WE1B	Description
0	Writes to all bits in DMACR1B, bits 11, 7, and 3 in DMABCR, and bit 5 in DMATCR are disabled (Initial value)
1	Writes to all bits in DMACR1B, bits 11, 7, and 3 in DMABCR, and bit 5 in DMATCR are enabled

Bit 2—Write Enable 1A (WE1A): Enables or disables writes to all bits in DMACR1A, and bits 10, 6, and 2 in DMABCR by the DTC.

Bit 2

WE1A	Description
0	Writes to all bits in DMACR1A, and bits 10, 6, and 2 in DMABCR are disabled (Initial value)
1	Writes to all bits in DMACR1A, and bits 10, 6, and 2 in DMABCR are enabled

0	Writes to all bits in DMACR0B, bits 9, 5, and 1 in DMABCR, and bit 4 in DMATCR are disabled (Initial value)
1	Writes to all bits in DMACR0B, bits 9, 5, and 1 in DMABCR, and bit 4 in DMATCR are enabled

Bit 0—Write Enable 0A (WE0A): Enables or disables writes to all bits in DMACR0A, and bits 8, 4, and 0 in DMABCR.

Bit 0

WE0A	Description
0	Writes to all bits in DMACR0A, and bits 8, 4, and 0 in DMABCR are disabled (Initial value)
1	Writes to all bits in DMACR0A, and bits 8, 4, and 0 in DMABCR are enabled

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

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

MAR, IOAR, and ETCR are always write-enabled regardless of the DMAWER settings. When modifying these registers, the channel for which the modification is to be made should be halted.

Initial value :	0	0	0	0	0	0	0
R/W :	—	—	R/W	R/W	—	—	—

DMATCR is an 8-bit readable/writable register that controls enabling or disabling of DMAC transfer end pin output. A port can be set for output automatically, and a transfer end signal output, by setting the appropriate bit.

DMATCR is initialized to H'00 by a reset, and in standby mode.

Bits 7 and 6—Reserved: Read-only bits, always read as 0.

Bit 5—Transfer End Enable 1 (TEE1): Enables or disables transfer end pin 1 ($\overline{\text{TEND1}}$) output.

Bit 5 TEE1	Description	
0	$\overline{\text{TEND1}}$ pin output disabled	(Initial value)
1	$\overline{\text{TEND1}}$ pin output enabled	

Bit 4—Transfer End Enable 0 (TEE0): Enables or disables transfer end pin 0 ($\overline{\text{TEND0}}$) output.

Bit 4 TEE0	Description	
0	$\overline{\text{TEND0}}$ pin output disabled	(Initial value)
1	$\overline{\text{TEND0}}$ pin output enabled	

The $\overline{\text{TEND}}$ pins are assigned only to channel B in short address mode.

The transfer end signal indicates the transfer cycle in which the transfer counter reached 0, regardless of the transfer source. An exception is block transfer mode, in which the transfer end signal indicates the transfer cycle in which the block counter reached 0.

Bits 3 to 0—Reserved: Read-only bits, always read as 0.

Bit	:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Initial value	:	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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	R/W	R/W

MSTPCR is a 16-bit readable/writable register that performs module stop mode control.

When the MSTP15 bit in MSTPCR is set to 1, the DMAC operation stops at the end of the bus cycle and a transition is made to module stop mode. For details, see section 20.5, 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 15—Module Stop (MSTP15): Specifies the DMAC module stop mode.

Bits 15

MSTP15	Description	
0	DMAC module stop mode cleared	(Initial value)
1	DMAC module stop mode set	

Table 7-5 DMAC Transfer Modes

Transfer Mode		Transfer Source	Remarks
Short address mode	Dual address mode	(1) Sequential mode	<ul style="list-style-type: none"> • Up to 4 channels can operate independently • External request applies to channel B only • Single address mode applies to channel B only • Modes (1), (2), and (3) can also be specified for single address mode
		(2) Idle mode	
		(3) Repeat mode	
	(4) Single address mode		
Full address mode		(5) Normal mode	<ul style="list-style-type: none"> • External request • Auto-request • Max. 2-channel operation, combining channels A and B • With auto-request, burst mode transfer or cycle steal transfer can be selected
		(6) Block transfer mode	

specified number of transfers have been completed. One address is specified as 24 bits, and the other as 16 bits. The transfer direction is programmable.

(2) Idle mode

In response to a single transfer request, the specified number of transfers are carried out, one byte or one word at a time. An interrupt request can be sent to the CPU or DTC when the specified number of transfers have been completed. One address is specified as 24 bits, and the other as 16 bits. The transfer source address and transfer destination address are fixed. The transfer direction is programmable.

(3) Repeat mode

In response to a single transfer request, the specified number of transfers are carried out, one byte or one word at a time. When the specified number of transfers have been completed, the addresses and transfer counter are restored to their original settings, and operation is continued. No interrupt request is sent to the CPU or DTC. One address is specified as 24 bits, and the other as 16 bits. The transfer direction is programmable.

(4) Single address mode

In response to a single transfer request, the specified number of transfers are carried out between external memory and an external device, one byte or one word at a time. Unlike dual address mode, source and destination accesses are performed in parallel. Therefore, either the source or the destination is an external device which can be accessed with a strobe alone, using the $\overline{\text{DACK}}$ pin. One address is specified as 24 bits, and for the other, the pin is set automatically. The transfer direction is programmable.

Modes (1), (2) and (3) can also be specified for single address mode.

(5) Normal mode

- Auto-request

By means of register settings only, the DMAC is activated, and transfer continues until the specified number of transfers have been completed. An interrupt request can be sent to the CPU or DTC when transfer is completed. Both addresses are specified as 24 bits.

— Cycle steal mode: The bus is released to another bus master every byte or word transfer.

— Burst mode: The bus is held and transfer continued until the specified number of transfers have been completed.

(6) Block transfer mode

In response to a single transfer request, a block transfer of the specified block size is carried out. This is repeated the specified number of times, once each time there is a transfer request. At the end of each single block transfer, one address is restored to its original setting. An interrupt request can be sent to the CPU or DTC when the specified number of block transfers have been completed. Both addresses are specified as 24 bits.

executed the number of times specified in ETCR.

One address is specified by MAR, and the other by IOAR. The transfer direction can be specified by the DTDIR bit in DMACR.

Table 7-6 summarizes register functions in sequential mode.

Table 7-6 Register Functions in Sequential Mode

Register	Function		Initial Setting	Operation
	DTDIR = 0	DTDIR = 1		
<div style="display: flex; justify-content: space-between;"> 23 0 </div> <div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> <div style="display: flex; justify-content: space-between;"> MAR </div> </div>	Source address register	Destination address register	Start address of transfer destination or transfer source	Incremented/decrypted every transfer
<div style="display: flex; justify-content: space-between;"> 23 15 0 </div> <div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> <div style="display: flex; justify-content: space-between;"> H'FF IOAR </div> </div>	Destination address register	Source address register	Start address of transfer source or transfer destination	Fixed
<div style="display: flex; justify-content: space-between;"> 15 0 </div> <div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> <div style="border: 1px solid black; width: 100px; height: 15px; text-align: center; margin: 5px auto;">ETCR</div> </div>	Transfer counter		Number of transfers	Decrypted every transfer; transfer ends when count reaches H'0000

Legend

- MAR : Memory address register
- IOAR : I/O address register
- ETCR : Transfer count register
- DTDIR : Data transfer direction bit

MAR specifies the start address of the transfer source or transfer destination as 24 bits. MAR is incremented or decrypted by 1 or 2 each time a byte or word is transferred.

IOAR specifies the lower 16 bits of the other address. The 8 bits above IOAR have a value of H'FF.

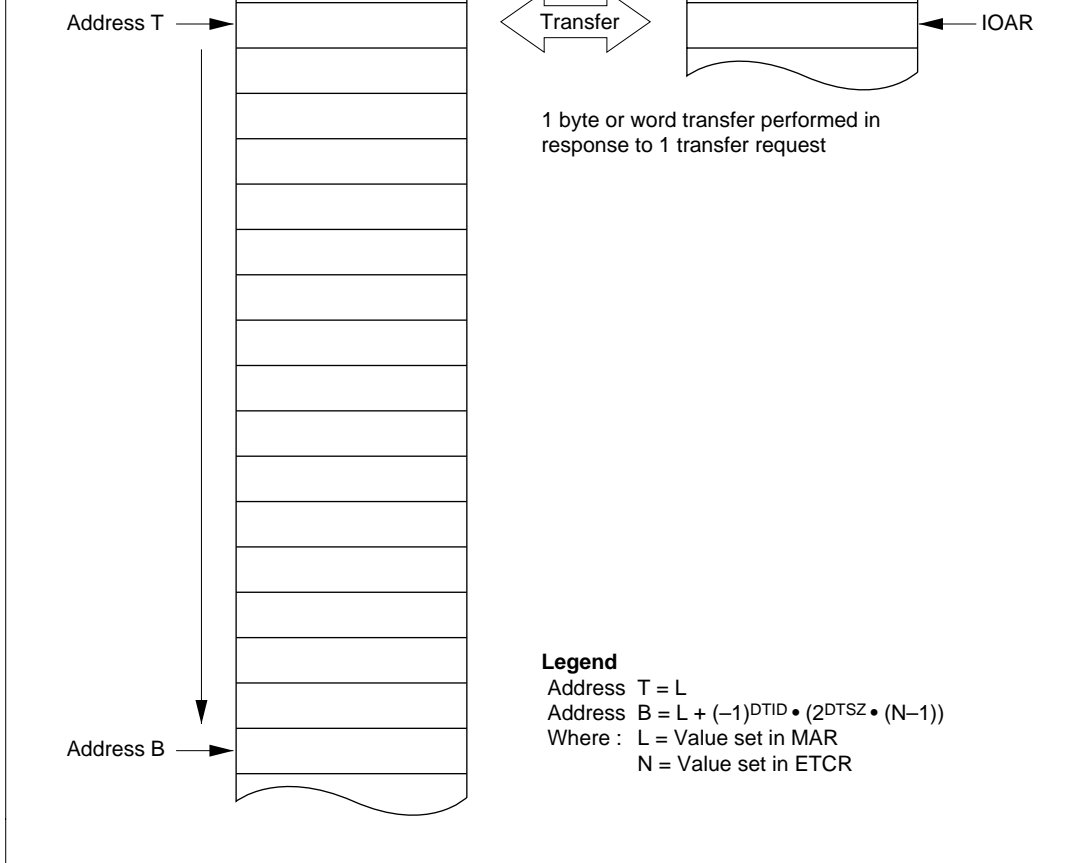


Figure 7-3 Operation in Sequential Mode

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

The maximum number of transfers, when H'0000 is set in ETCR, is 65,536.

Transfer requests (activation sources) consist of A/D converter conversion end interrupts, external requests, SCI transmission complete and reception complete interrupts, and TPU channel 0 to 5 compare match/input capture A interrupts. External requests can be set for channel B only.

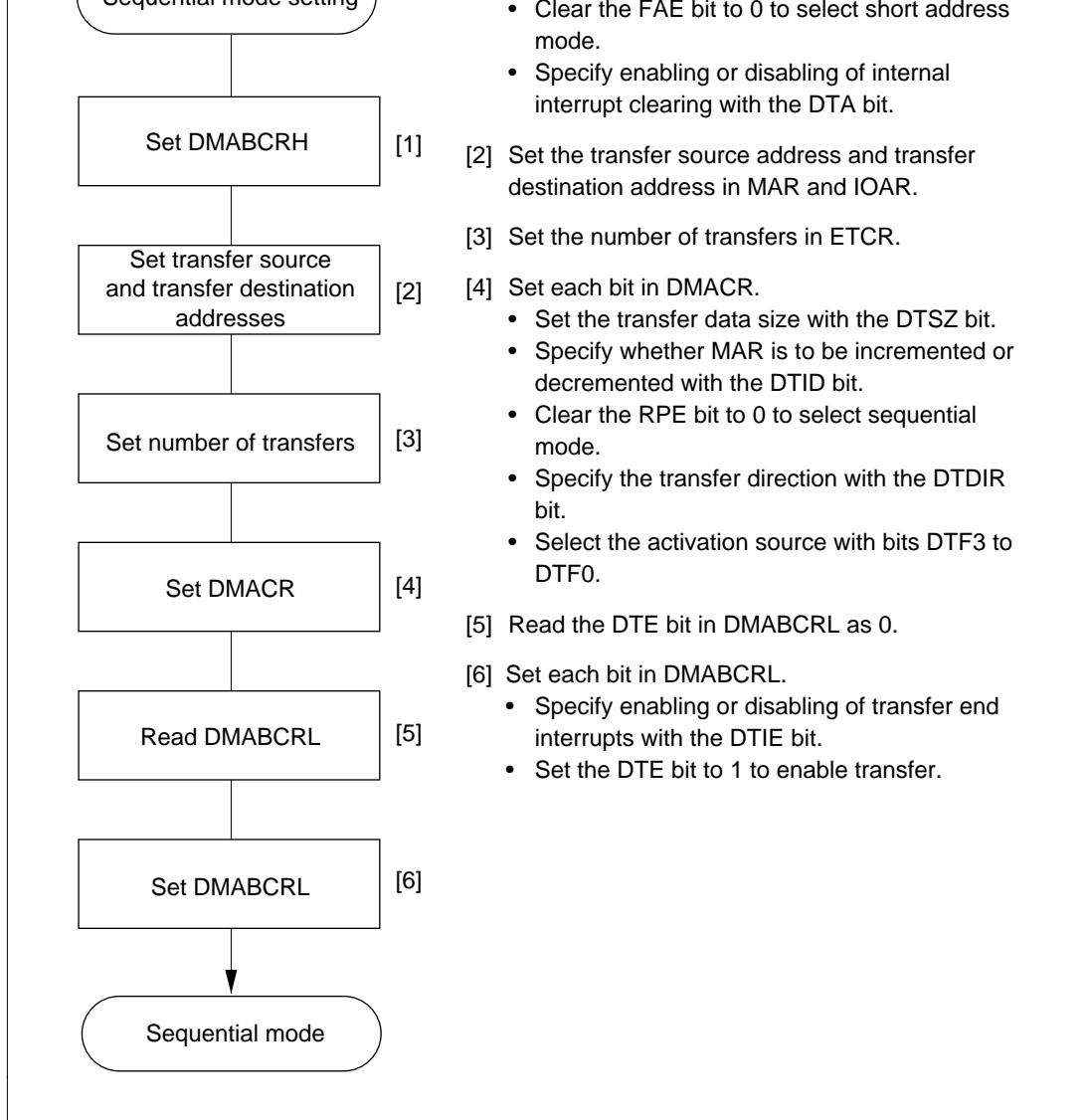


Figure 7-4 Example of Sequential Mode Setting Procedure

of times specified in ETCR.

One address is specified by MAR, and the other by IOAR. The transfer direction can be specified by the DTDIR bit in DMACR.

Table 7-7 summarizes register functions in idle mode.

Table 7-7 Register Functions in Idle Mode

Register	Function		Initial Setting	Operation
	DTDIR = 0	DTDIR = 1		
<div style="display: flex; justify-content: space-between;"> 23 0 </div> <div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> <div style="display: flex; justify-content: space-between;"> MAR </div> </div>	Source address register	Destination address register	Start address of transfer destination or transfer source	Fixed
<div style="display: flex; justify-content: space-between;"> 23 15 0 </div> <div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> <div style="display: flex; justify-content: space-between;"> H'FF IOAR </div> </div>	Destination address register	Source address register	Start address of transfer source or transfer destination	Fixed
<div style="display: flex; justify-content: space-between;"> 15 0 </div> <div style="border: 1px solid black; padding: 5px; margin: 5px 0;"> <div style="display: flex; justify-content: space-between;"> ETCR </div> </div>	Transfer counter		Number of transfers	Decrement every transfer; transfer ends when count reaches H'0000

Legend

MAR : Memory address register

IOAR : I/O address register

ETCR : Transfer count register

DTDIR : Data transfer direction bit

MAR specifies the start address of the transfer source or transfer destination as 24 bits. MAR is neither incremented nor decremented each time a byte or word is transferred.

IOAR specifies the lower 16 bits of the other address. The 8 bits above IOAR have a value of H'FF.

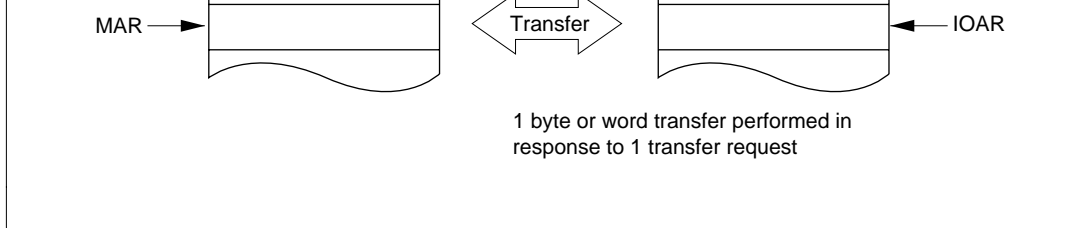


Figure 7-5 Operation in Idle Mode

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

The maximum number of transfers, when H'0000 is set in ETCR, is 65,536.

Transfer requests (activation sources) consist of A/D converter conversion end interrupts, external requests, SCI transmission complete and reception complete interrupts, and TPU channel 0 to 5 compare match/input capture A interrupts. External requests can be set for channel B only.

When the DMAC is used in single address mode, only channel B can be set.

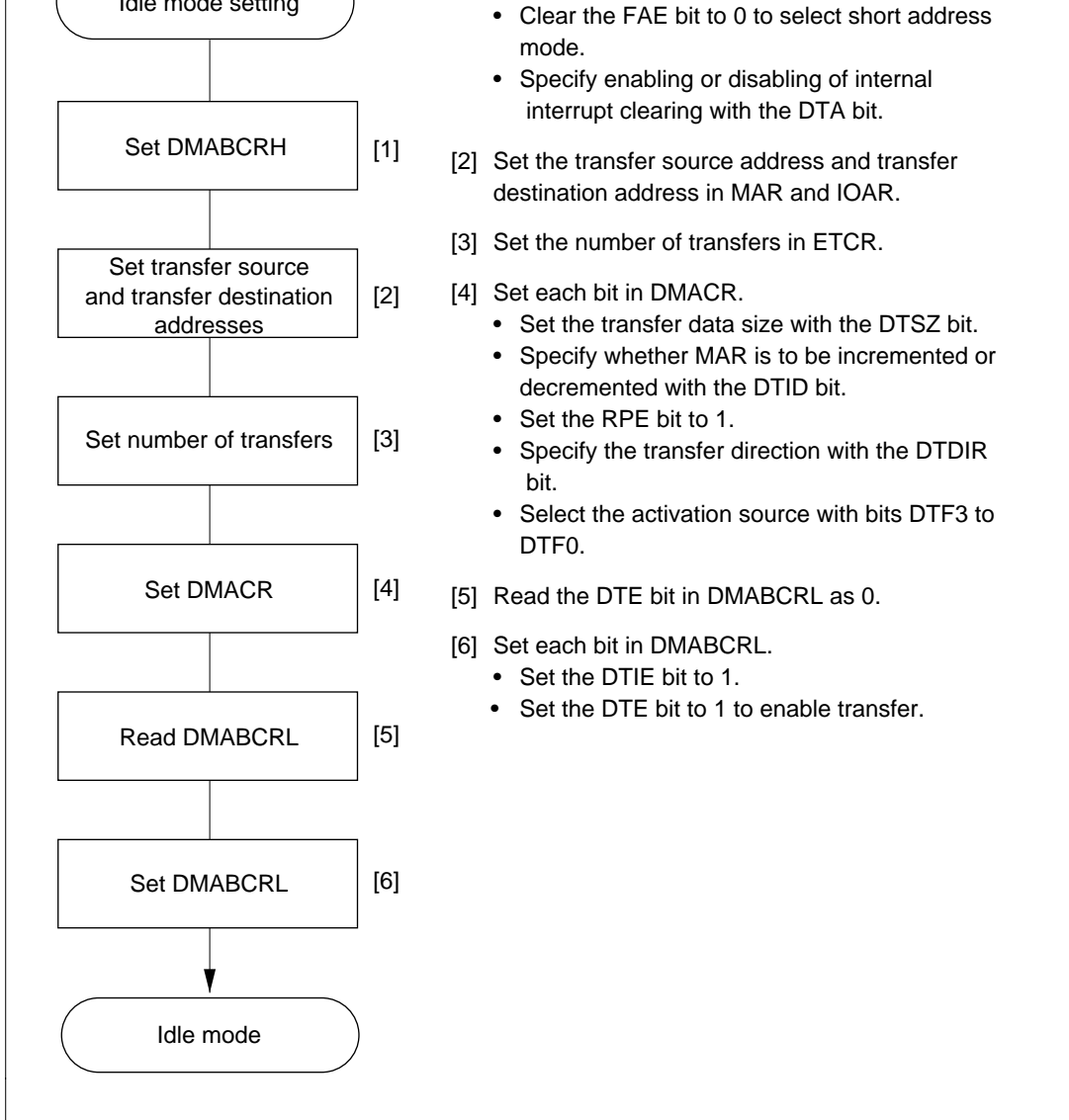


Figure 7-6 Example of Idle Mode Setting Procedure

request, and this is executed the number of times specified in ETCR. On completion of the specified number of transfers, MAR and ETCRL are automatically restored to their original settings and operation continues.

One address is specified by MAR, and the other by IOAR. The transfer direction can be specified by the DTDIR bit in DMACR.

Table 7-8 summarizes register functions in repeat mode.

Table 7-8 Register Functions in Repeat Mode

Register	Function		Initial Setting	Operation
	DTDIR = 0	DTDIR = 1		
<div style="display: flex; justify-content: space-between;"> 23 0 </div> <div style="border: 1px solid black; padding: 2px; margin: 5px 0;"> 23 0 <div style="text-align: center; border: 1px solid black; width: 100px; height: 15px; margin: 0 auto;">MAR</div> </div>	Source address register	Destination address register	Start address of transfer destination or transfer source	Incremented/decremented every transfer. Initial setting is restored when value reaches H'0000
<div style="display: flex; justify-content: space-between;"> 23 15 0 </div> <div style="border: 1px solid black; padding: 2px; margin: 5px 0;"> 23 0 <div style="display: flex; justify-content: space-between; width: 100%; border: 1px solid black; height: 15px;"> H'FF IOAR </div> </div>	Destination address register	Source address register	Start address of transfer source or transfer destination	Fixed
<div style="display: flex; justify-content: space-between;"> 7 0 </div> <div style="border: 1px solid black; padding: 2px; margin: 5px 0;"> 7 0 <div style="text-align: center; border: 1px solid black; width: 60px; height: 15px; margin: 0 auto;">ETCRH</div> </div>	Holds number of transfers		Number of transfers	Fixed

<div style="display: flex; justify-content: space-between;"> 7 0 </div> <div style="border: 1px solid black; padding: 2px; margin: 5px 0;"> 7 0 <div style="text-align: center; border: 1px solid black; width: 60px; height: 15px; margin: 0 auto;">ETCRL</div> </div>	Transfer counter		Number of transfers	Decrement every transfer. Loaded with ETCRH value when count reaches H'00

Legend

- MAR : Memory address register
- IOAR : I/O address register
- ETCR : Transfer count register
- DTDIR : Data transfer direction bit

The number of transfers is specified as 8 bits by ETCRH and ETCRL. The maximum number of transfers, when H'00 is set in both ETCRH and ETCRL, is 256.

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

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

The same value should be set in ETCRH and ETCRL.

In repeat mode, operation continues until the DTE bit is cleared. To end the transfer operation, therefore, you should clear the DTE bit to 0. A transfer end interrupt request is not sent to the CPU or DTC.

By setting the DTE bit to 1 again after it has been cleared, the operation can be restarted from the transfer after that terminated when the DTE bit was cleared.

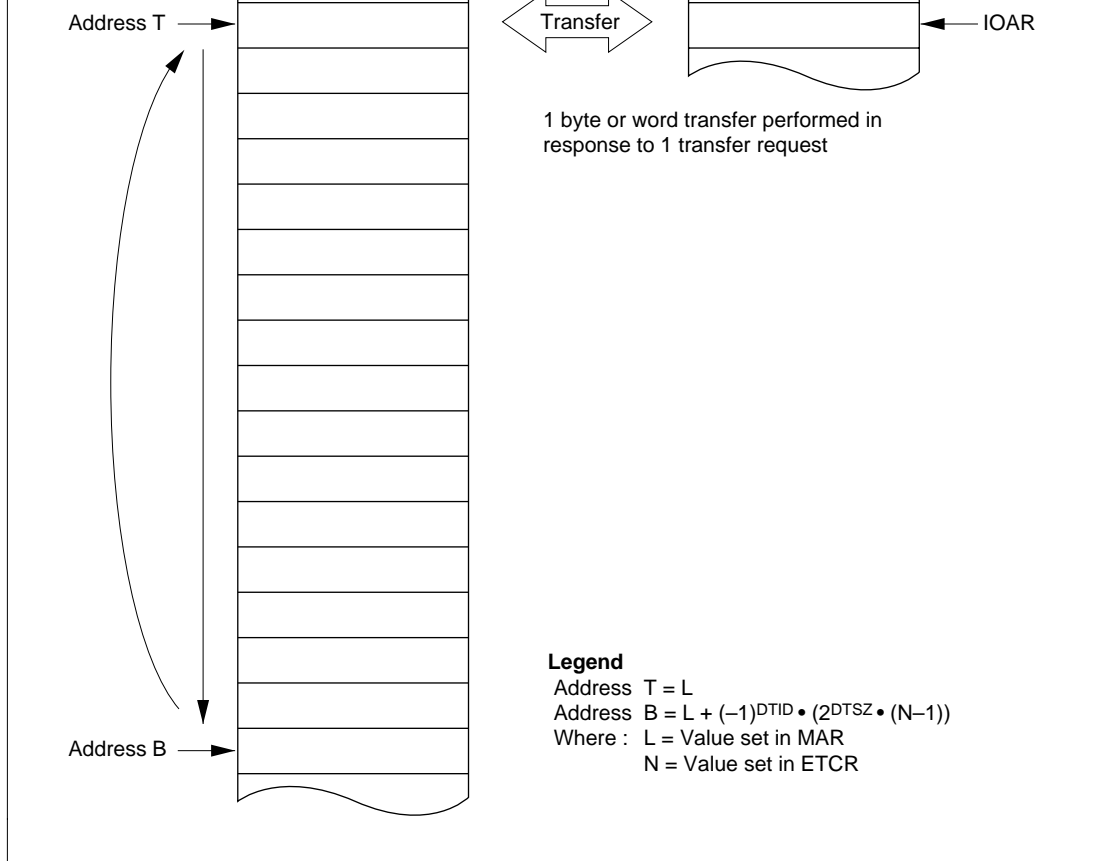


Figure 7-7 Operation in Repeat mode

Transfer requests (activation sources) consist of A/D converter conversion end interrupts, external requests, SCI transmission complete and reception complete interrupts, and TPU channel 0 to 5 compare match/input capture A interrupts. External requests can be set for channel B only.

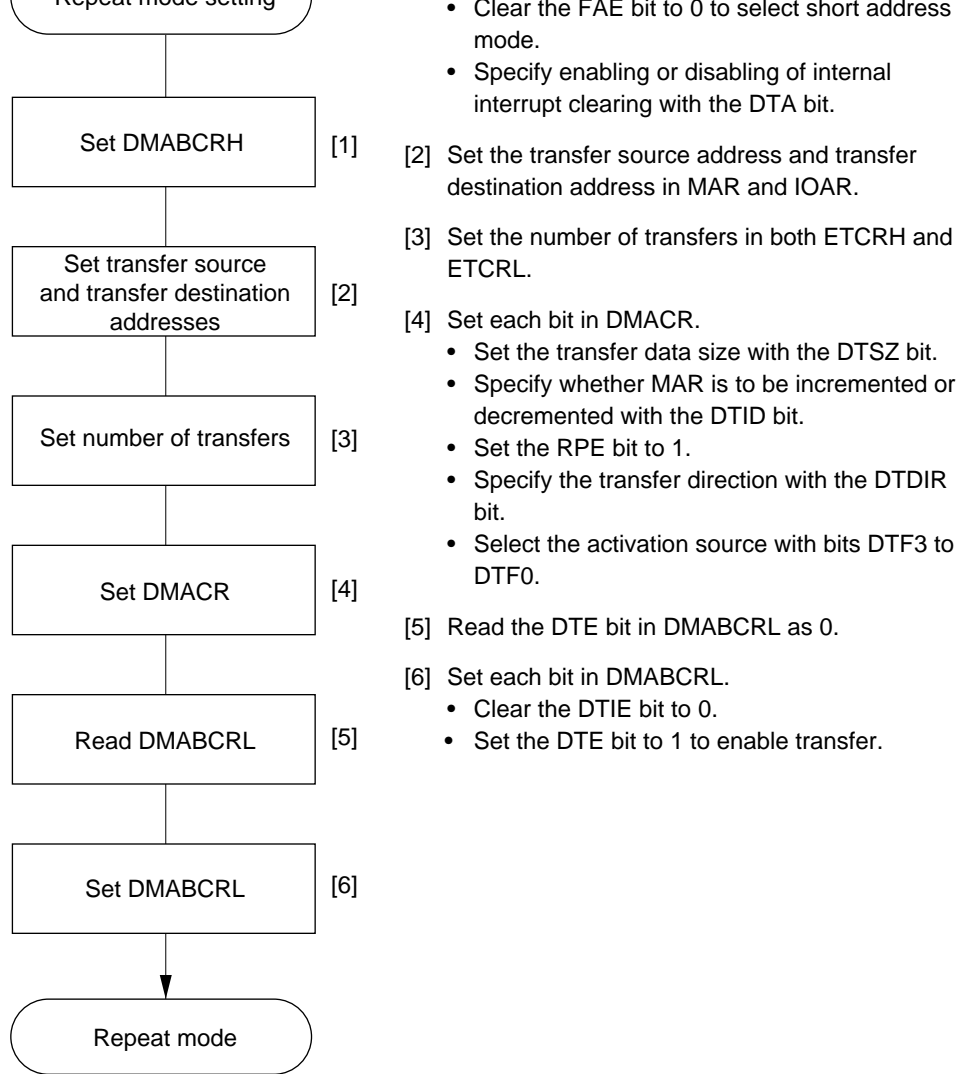


Figure 7-8 Example of Repeat Mode Setting Procedure

One address is specified by MAR, and the other is set automatically to the data transfer acknowledge pin ($\overline{\text{DACK}}$). The transfer direction can be specified by the DTDIR in DMACR.

Table 7-9 summarizes register functions in single address mode.

Table 7-9 Register Functions in Single Address Mode

Register	Function		Initial Setting	Operation
	DTDIR = 0	DTDIR = 1		
<div style="display: flex; align-items: center;"> 23 <div style="border: 1px solid black; padding: 2px; display: flex; align-items: center; justify-content: center; width: 100px;"> 0 0 </div> 0 </div>	Source address register	Destination address register	Start address of transfer destination or transfer source	*
$\overline{\text{DACK}}$ pin	Write strobe	Read strobe	(Set automatically by SAE bit; IOAR is invalid)	Strobe for external device
<div style="display: flex; align-items: center;"> 15 <div style="border: 1px solid black; padding: 2px; display: flex; align-items: center; justify-content: center; width: 60px;"> 0 0 </div> 0 </div>	Transfer counter		Number of transfers	*

Legend

- MAR : Memory address register
- IOAR : I/O address register
- ETCR : Transfer count register
- DTDIR : Data transfer direction bit
- $\overline{\text{DACK}}$: Data transfer acknowledge

Note: * See the operation descriptions in sections 7.5.2, Sequential Mode, 7.5.3, Idle Mode, and 7.5.4, Repeat Mode.

MAR specifies the start address of the transfer source or transfer destination as 24 bits.

IOAR is invalid; in its place the strobe for external devices ($\overline{\text{DACK}}$) is output.

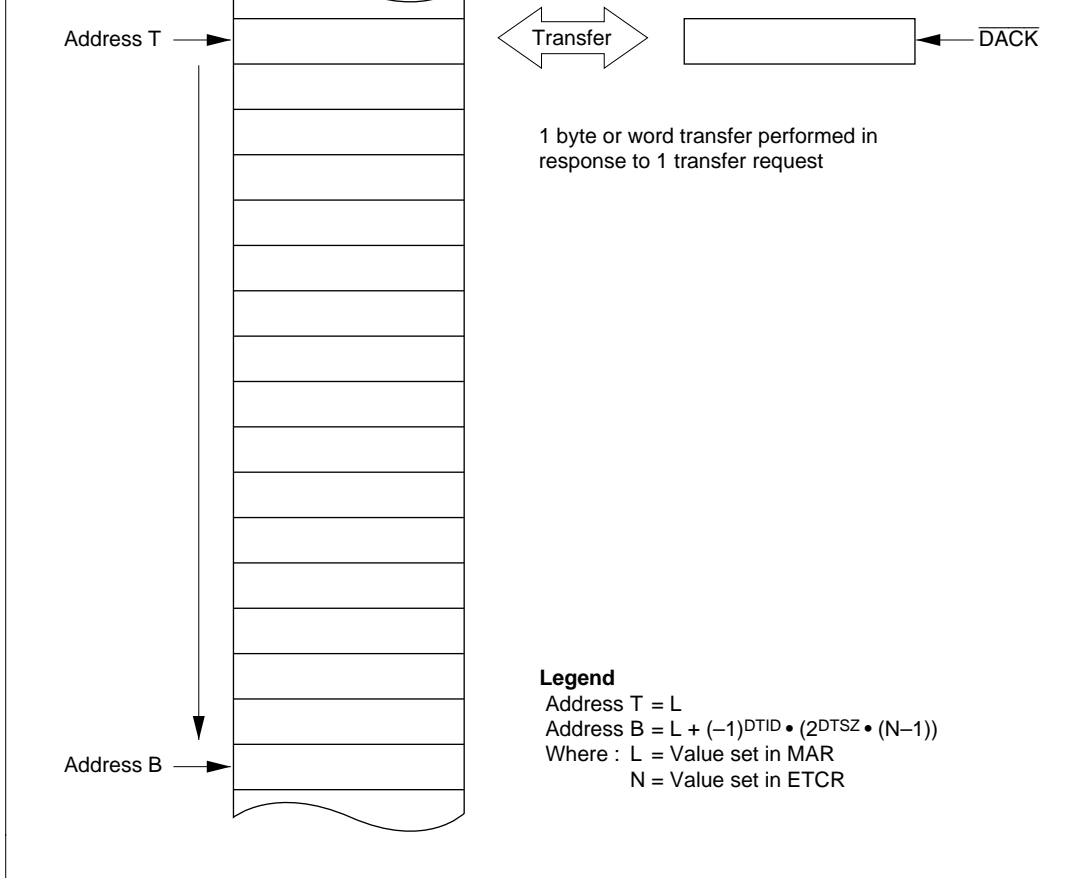


Figure 7-9 Operation in Single Address Mode (When Sequential Mode is Specified)

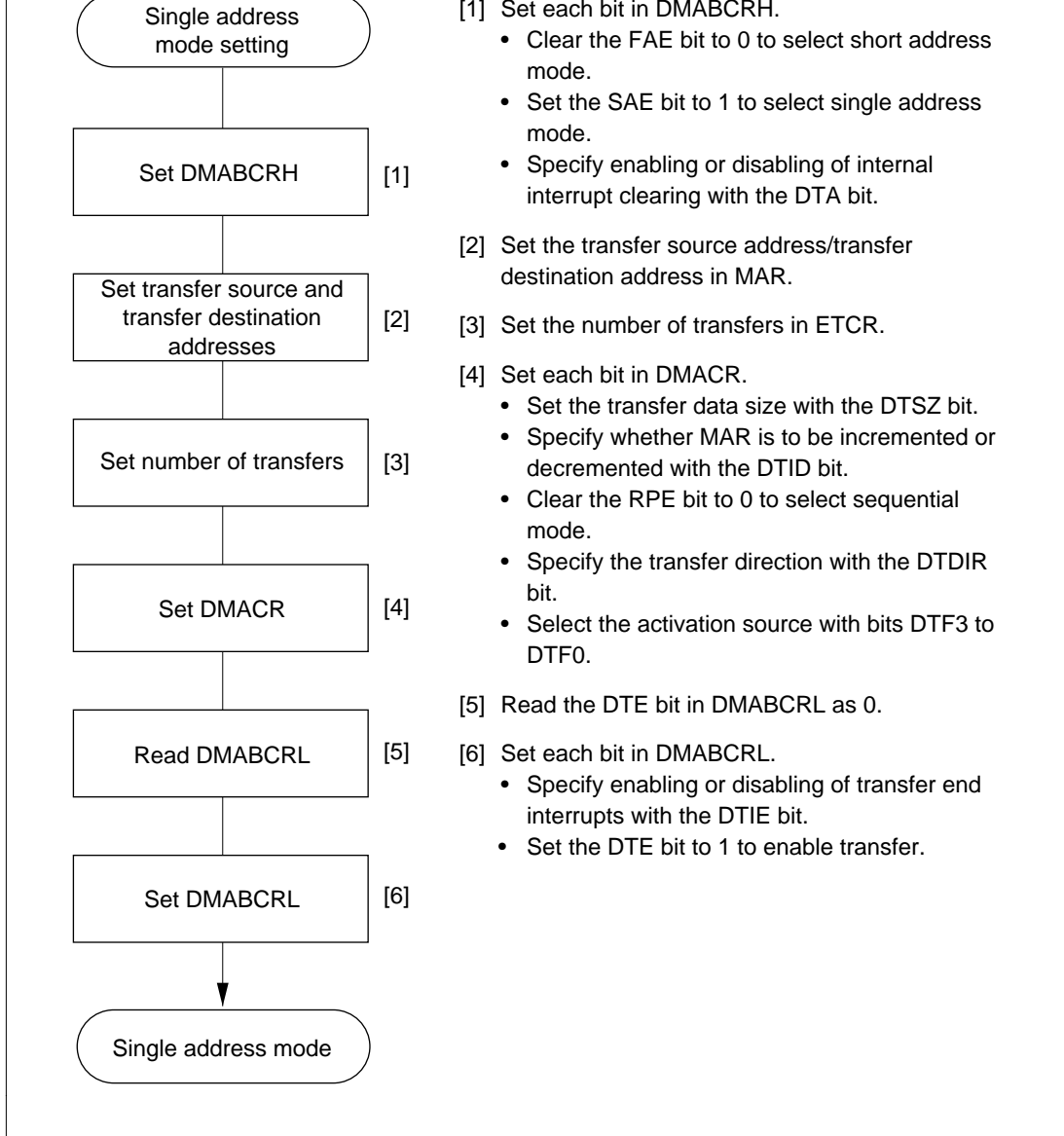


Figure 7-10 Example of Single Address Mode Setting Procedure (When Sequential Mode is Specified)

to 0.

In normal mode, MAR is updated after each byte or word transfer in response to a single transfer request, and this is executed the number of times specified in ETCRA. The transfer source is specified by MARA, and the transfer destination by MARB.

Table 7-10 summarizes register functions in normal mode.

Table 7-10 Register Functions in Normal Mode

Register	Function	Initial Setting	Operation
<div style="display: flex; justify-content: space-between;"> 23 0 </div> <div style="border: 1px solid black; padding: 2px; margin: 2px 0;"> <div style="display: flex; justify-content: space-between;"> </div> <div style="text-align: center; font-weight: bold;">MARA</div> </div>	Source address register	Start address of transfer source	Incremented/decremented every transfer, or fixed
<div style="display: flex; justify-content: space-between;"> 23 0 </div> <div style="border: 1px solid black; padding: 2px; margin: 2px 0;"> <div style="display: flex; justify-content: space-between;"> </div> <div style="text-align: center; font-weight: bold;">MARB</div> </div>	Destination address register	Start address of transfer destination	Incremented/decremented every transfer, or fixed
<div style="display: flex; justify-content: space-between;"> 15 0 </div> <div style="border: 1px solid black; padding: 2px; margin: 2px 0;"> <div style="text-align: center; font-weight: bold;">ETCRA</div> </div>	Transfer counter	Number of transfers	Decremented every transfer; transfer ends when count reaches H'0000

Legend

MARA : Memory address register A

MARB : Memory address register B

ETCRA : Transfer count register A

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

Incrementing, decrementing, or holding a fixed value can be set separately for MARA and MARB.

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

The maximum number of transfers, when H'0000 is set in ETCRA, is 65,536.

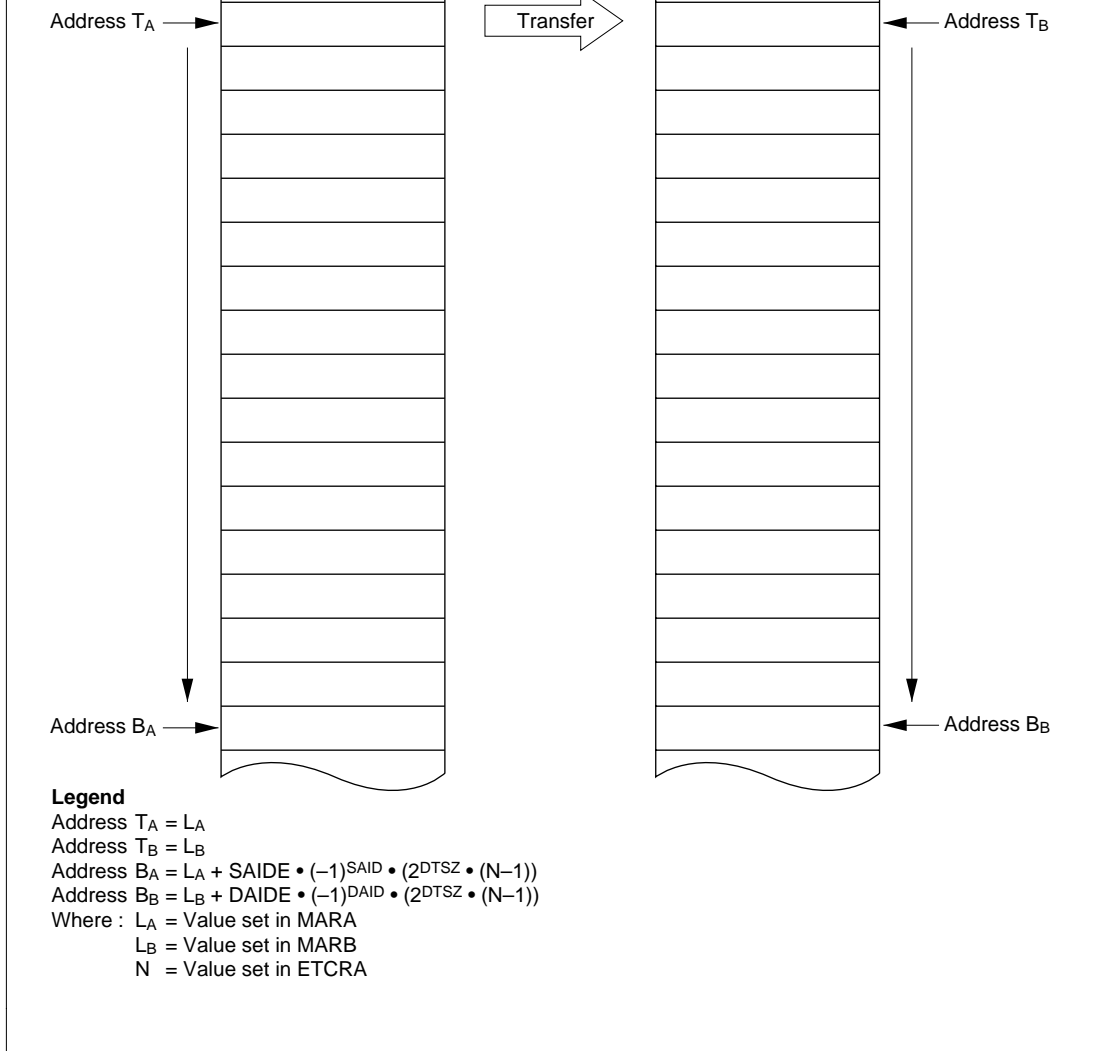


Figure 7-11 Operation in Normal Mode

Transfer requests (activation sources) are external requests and auto-requests.

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

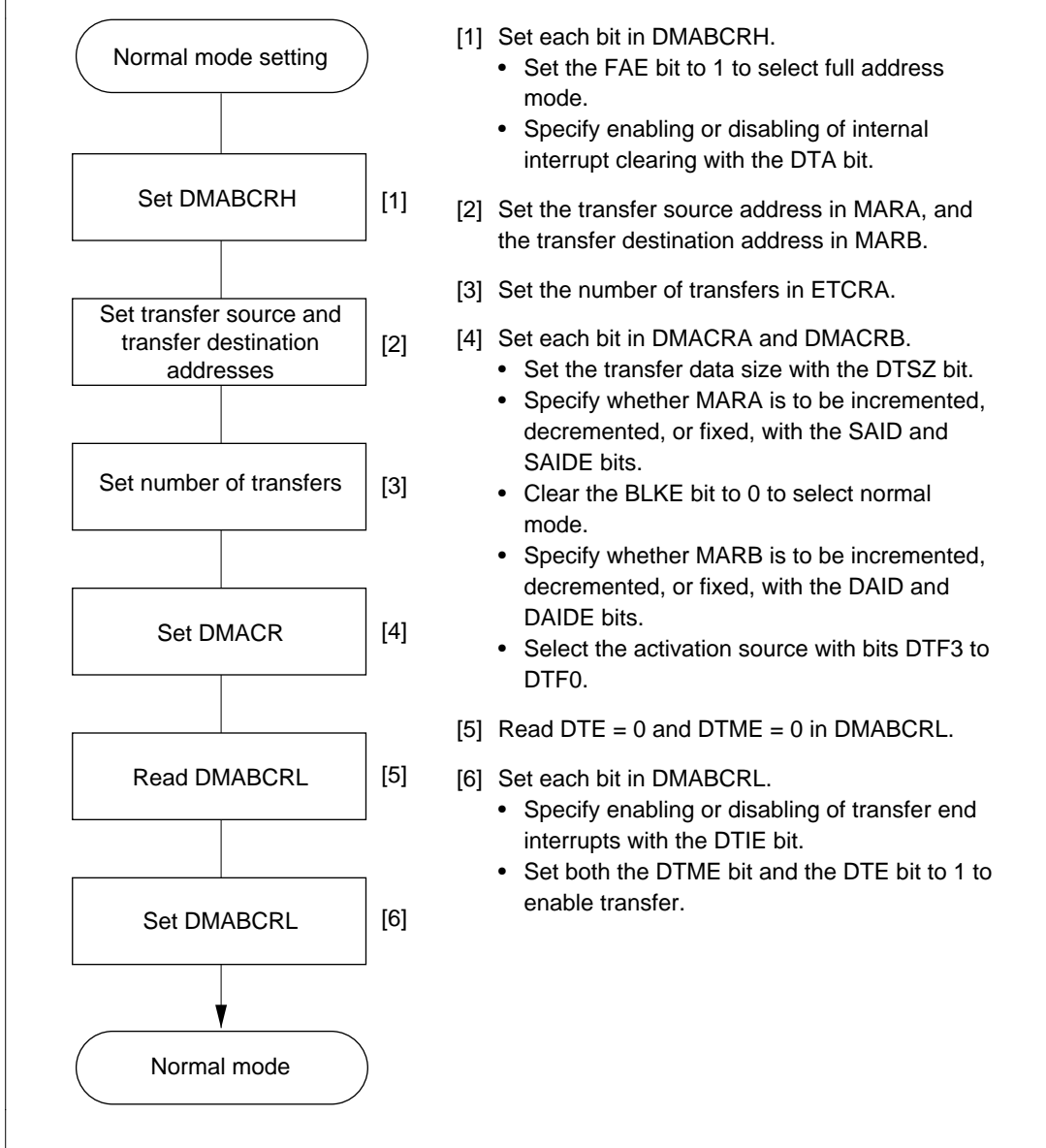


Figure 7-12 Example of Normal Mode Setting Procedure

In block transfer mode, a transfer of the specified block size is carried out in response to a single transfer request, and this is executed the specified number of times. The transfer source is specified by MARA, and the transfer destination by MARB. Either the transfer source or the transfer destination can be selected as a block area (an area composed of a number of bytes or words).

Table 7-11 summarizes register functions in block transfer mode.

Table 7-11 Register Functions in Block Transfer Mode

Register	Function	Initial Setting	Operation
<div style="display: flex; justify-content: space-between;"> 23 0 </div> <div style="border: 1px solid black; padding: 2px; margin: 2px 0;"> <div style="display: flex; justify-content: space-between;"> MARA </div> </div>	Source address register	Start address of transfer source	Incremented/decremented every transfer, or fixed
<div style="display: flex; justify-content: space-between;"> 23 0 </div> <div style="border: 1px solid black; padding: 2px; margin: 2px 0;"> <div style="display: flex; justify-content: space-between;"> MARB </div> </div>	Destination address register	Start address of transfer destination	Incremented/decremented every transfer, or fixed
<div style="display: flex; justify-content: space-between;"> 7 0 </div> <div style="border: 1px solid black; padding: 2px; margin: 2px 0;"> <div style="display: flex; justify-content: space-between;"> ETCRAH </div> </div>	Holds block size	Block size	Fixed
<div style="display: flex; justify-content: space-between;"> 7 0 </div> <div style="border: 1px solid black; padding: 2px; margin: 2px 0;"> <div style="display: flex; justify-content: space-between;"> ETCRAL </div> </div>	Block size counter	Block size	Decrement every transfer; ETCRH value copied when count reaches H'00
<div style="display: flex; justify-content: space-between;"> 15 0 </div> <div style="border: 1px solid black; padding: 2px; margin: 2px 0;"> <div style="display: flex; justify-content: space-between;"> ETCRB </div> </div>	Block transfer counter	Number of block transfers	Decrement every block transfer; transfer ends when count reaches H'0000

Legend

- MARA : Memory address register A
- MARB : Memory address register B
- ETCRA : Transfer count register A
- ETCRB : Transfer count register B

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

Incrementing, decrementing, or holding a fixed value can be set separately for MARA and MARB.

and N in ETCRB.

Figure 7-13 illustrates operation in block transfer mode when MARB is designated as a block area.

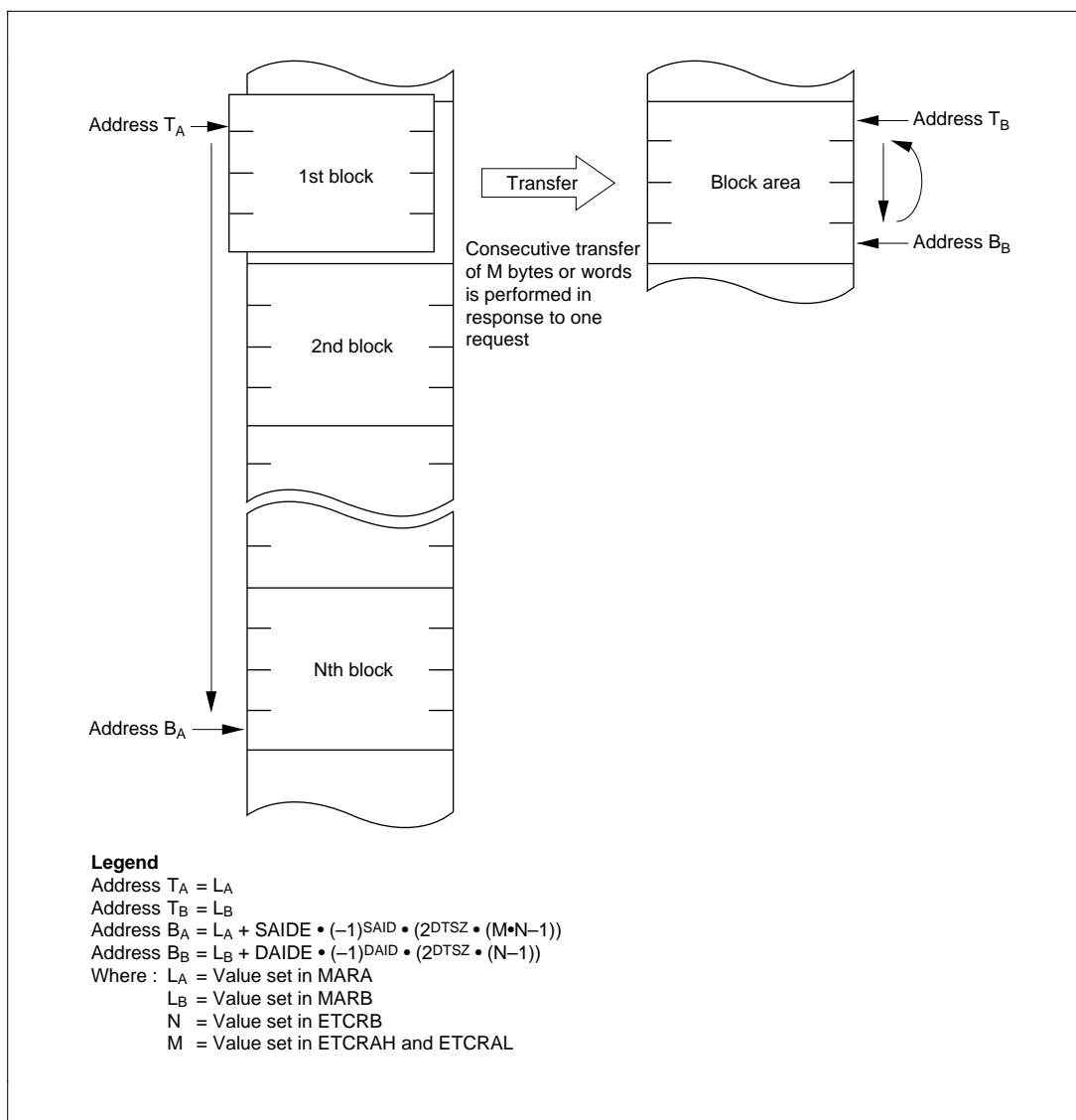


Figure 7-13 Operation in Block Transfer Mode (BLKDIR = 0)

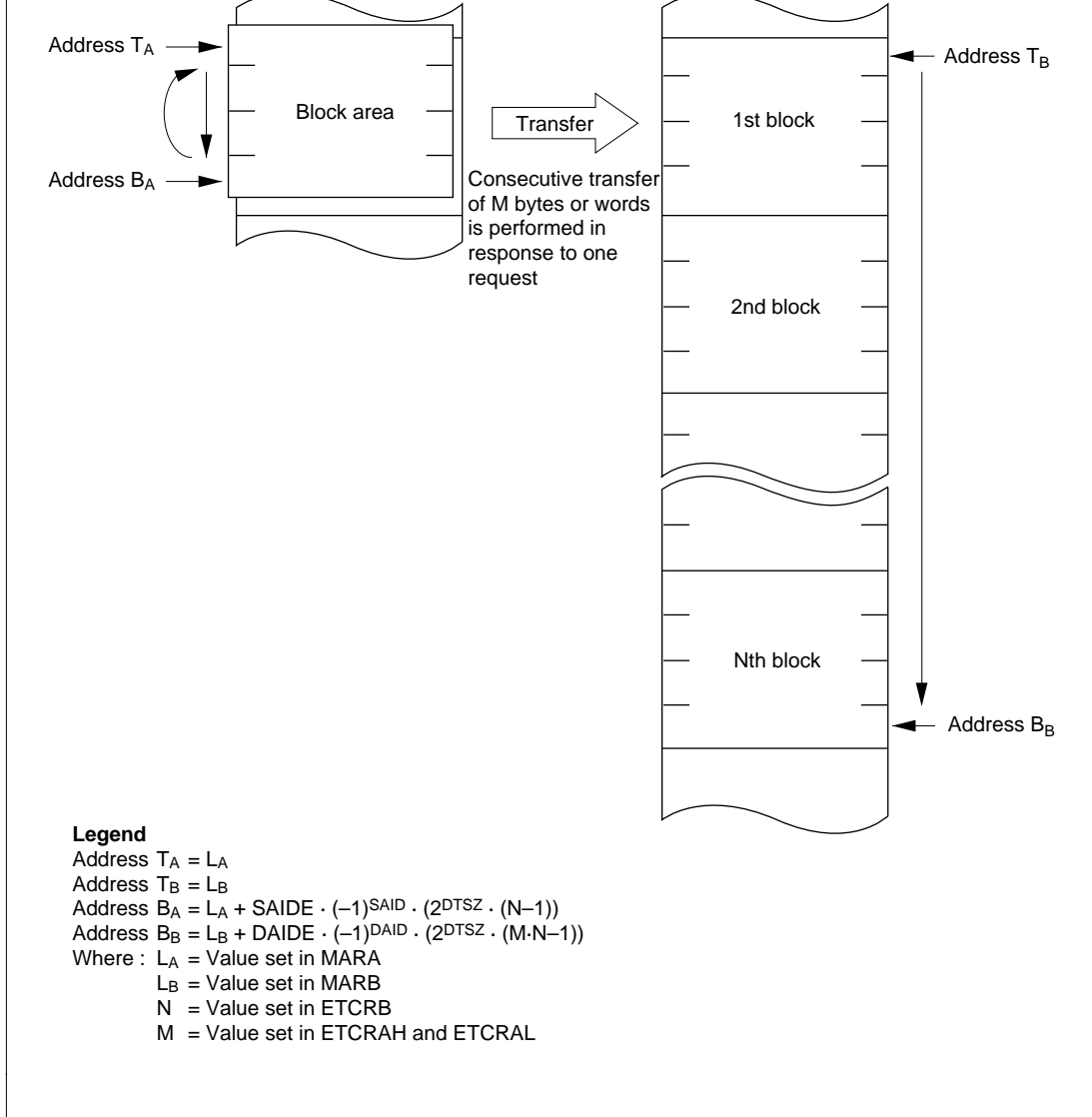


Figure 7-14 Operation in Block Transfer Mode (BLKDIR = 1)

accordance with the DTSE, STAD/STAE, and STADE/STAE bits in DMIFCR.

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

Figure 7-15 shows the operation flow in block transfer mode.

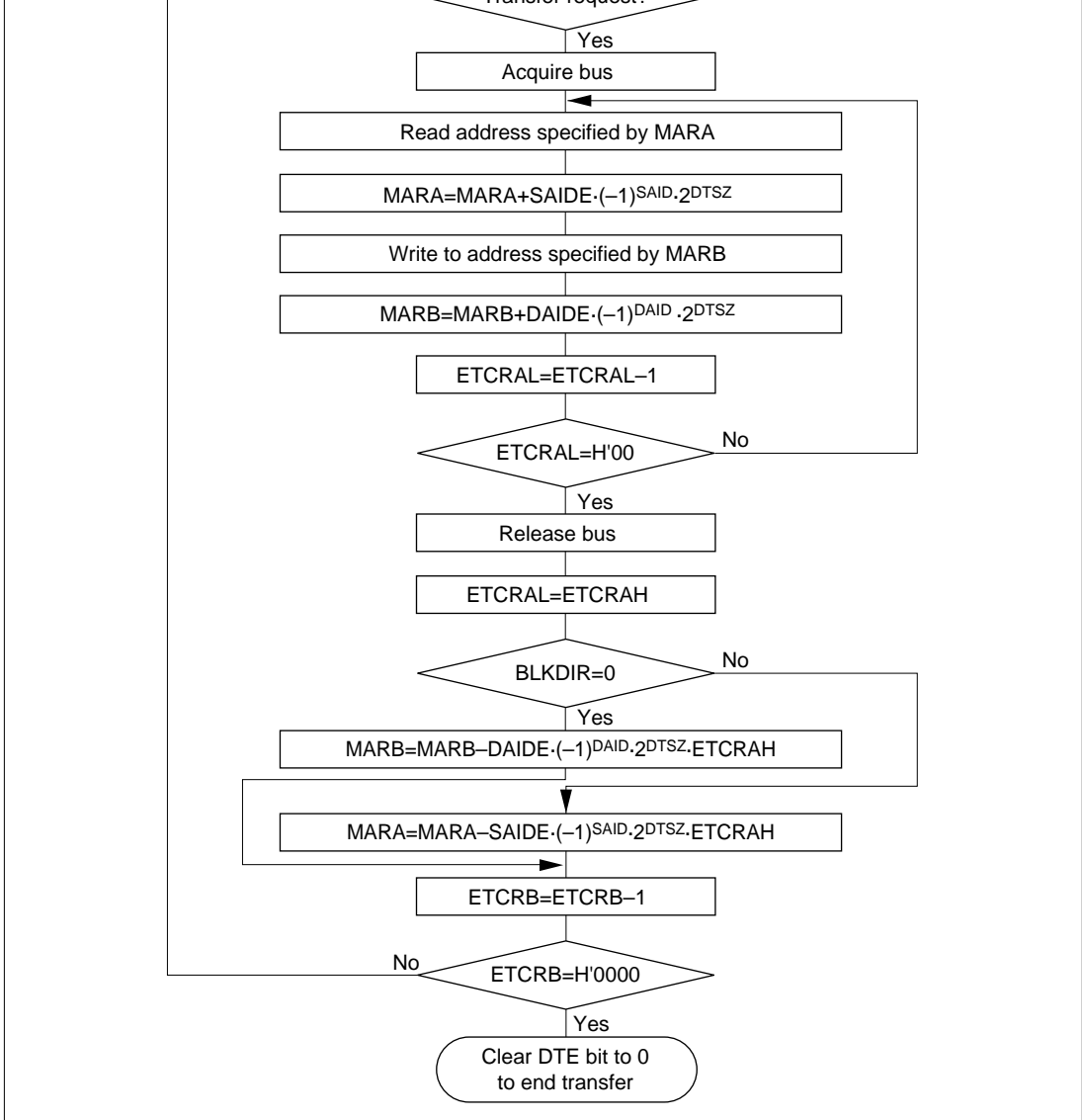


Figure 7-15 Operation Flow in Block Transfer Mode

Transfer requests (activation sources) consist of A/D converter conversion end interrupts, external requests, SCI transmission complete and reception complete interrupts, and TPU channel 0 to 5 compare match/input capture A interrupts.

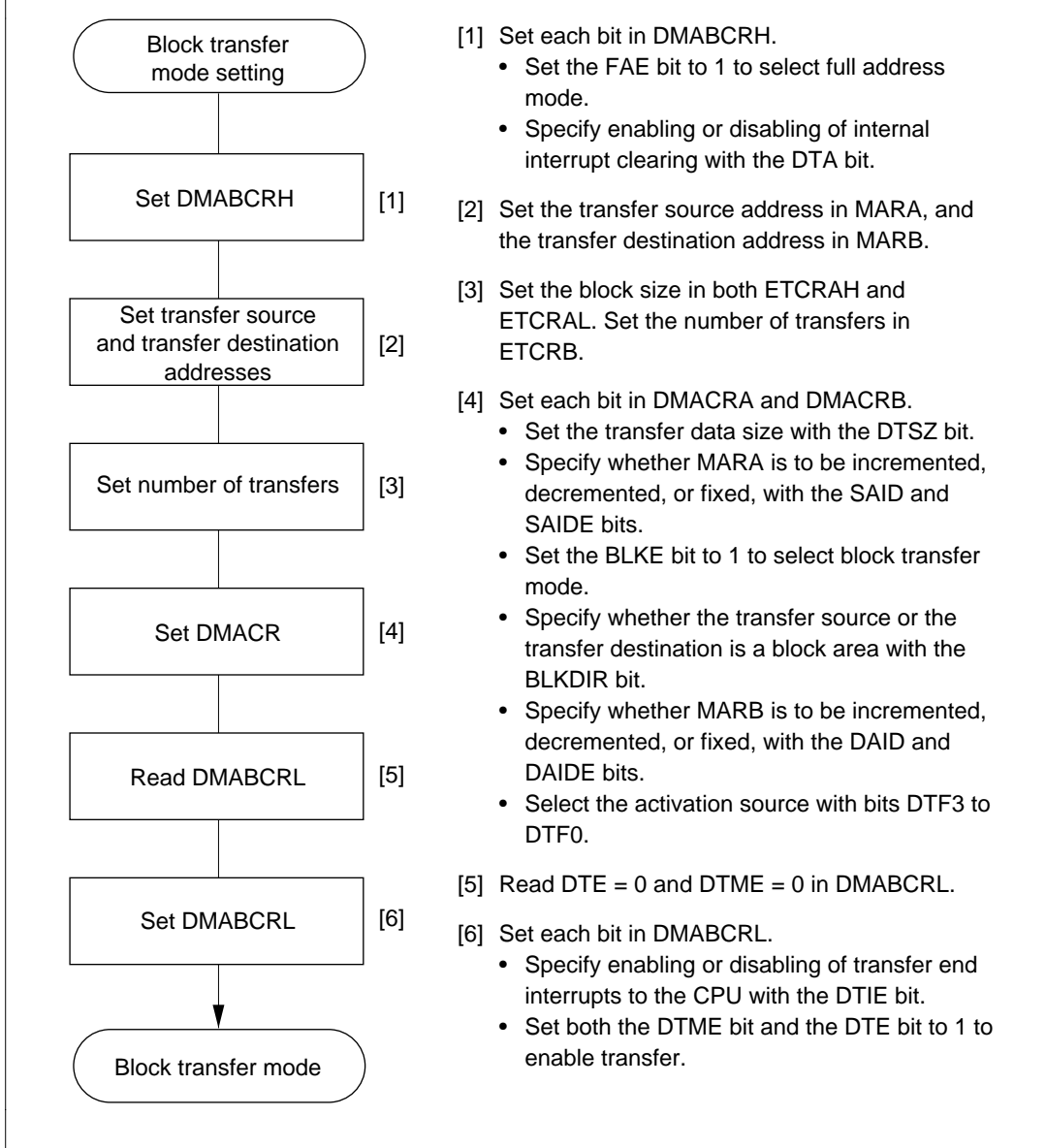


Figure 7-16 Example of Block Transfer Mode Setting Procedure

Table 7-12 DMAC Activation Sources

Activation Source		Short Address Mode		Full Address Mode	
		Channels 0A and 1A	Channels 0B and 1B	Normal Mode	Block Transfer Mode
Internal Interrupts	ADI	○	○	X	○
	TXI0	○	○	X	○
	RXI0	○	○	X	○
	TXI1	○	○	X	○
	RXI1	○	○	X	○
	TGI0A	○	○	X	○
	TGI1A	○	○	X	○
	TGI2A	○	○	X	○
	TGI3A	○	○	X	○
	TGI4A	○	○	X	○
	TGI5A	○	○	X	○
External Requests	$\overline{\text{DREQ}}$ pin falling edge input	X	○	○	○
	$\overline{\text{DREQ}}$ pin low-level input	X	○	○	○
Auto-request		X	X	○	X

Legend

○ : Can be specified

X : Cannot be specified

Activation by Internal Interrupt: An interrupt request selected as a DMAC activation source can be sent simultaneously to the CPU and DTC. For details, see section 5, Interrupt Controller.

With activation by an internal interrupt, the DMAC accepts the request independently of the interrupt controller. Consequently, interrupt controller priority settings are not accepted.

If the DMAC is activated by a CPU interrupt source or an interrupt source that is not used as a DTC activation source ($\text{DTA} = 1$), the interrupt source flag is cleared automatically by the DMA transfer. With ADI, TXI, and RXI interrupts, however, the interrupt source flag is not cleared unless the prescribed register is accessed in a DMA transfer. If the same interrupt is used as an

source is not sent to the DMAC, regardless of the DTA bit. In this case, the relevant interrupt request is sent to the CPU or DTC.

In case of overlap with a CPU interrupt source or DTC activation source ($DTA = 0$), the interrupt request flag is not cleared by the DMAC.

Activation by External Request: If an external request (\overline{DREQ} pin) is specified as an activation source, the relevant port should be set to input mode in advance.

Level sensing or edge sensing can be used for external requests.

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

When edge sensing is selected, a 1-byte or 1-word transfer is executed each time a high-to-low transition is detected on the \overline{DREQ} pin. The next transfer may not be performed if the next edge is input before transfer is completed.

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

Activation by Auto-Request: Auto-request activation is performed by register setting only, and transfer continues to the end.

With auto-request activation, cycle steal mode or burst mode can be selected.

In cycle steal mode, the DMAC releases the bus to another bus master each time a byte or word is transferred. DMA and CPU cycles usually alternate.

In burst mode, the DMAC keeps possession of the bus until the end of the transfer, and transfer is performed continuously.

Single Address Mode: The DMAC can operate in dual address mode in which read cycles and write cycles are separate cycles, or single address mode in which read and write cycles are executed in parallel.

In dual address mode, transfer is performed with the source address and destination address specified separately.

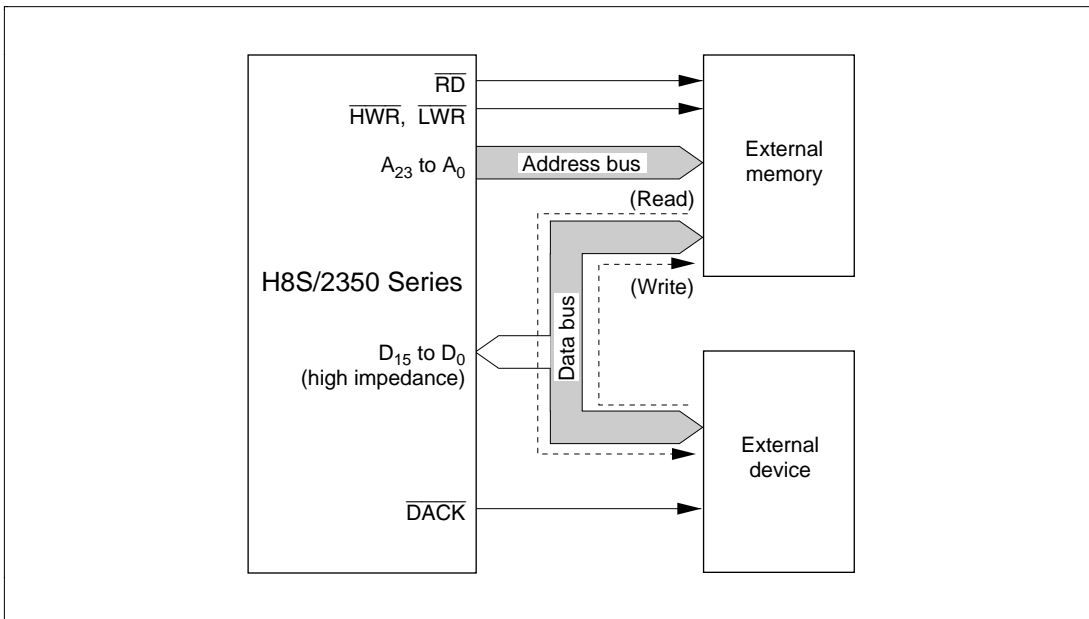


Figure 7-17 Data Bus in Single Address Mode

When using the DMAC for single address mode reading, transfer is performed from external memory to the external device, and the \overline{DACK} pin functions as a write strobe for the external device. When using the DMAC for single address mode writing, transfer is performed from the external device to external memory, and the \overline{DACK} pin functions as a write strobe for the external device. Since there is no directional control for the external device, one or other of the above single directions should be used.

Bus cycles in single address mode are in accordance with the settings of the bus controller for the external memory area. On the external device side, \overline{DACK} is output in synchronization with the address strobe. For details of bus cycles, see section 7.5.11, DMAC Bus Cycles (Single Address Mode).

Do not specify internal space for transfer addresses in single address mode.

the bus is transferred from the CPU to the DMAC, a source address read and destination address write are performed. The bus is not released in response to another bus request, etc., between these read and write operations. As with CPU cycles, DMA cycles conform to the bus controller settings.

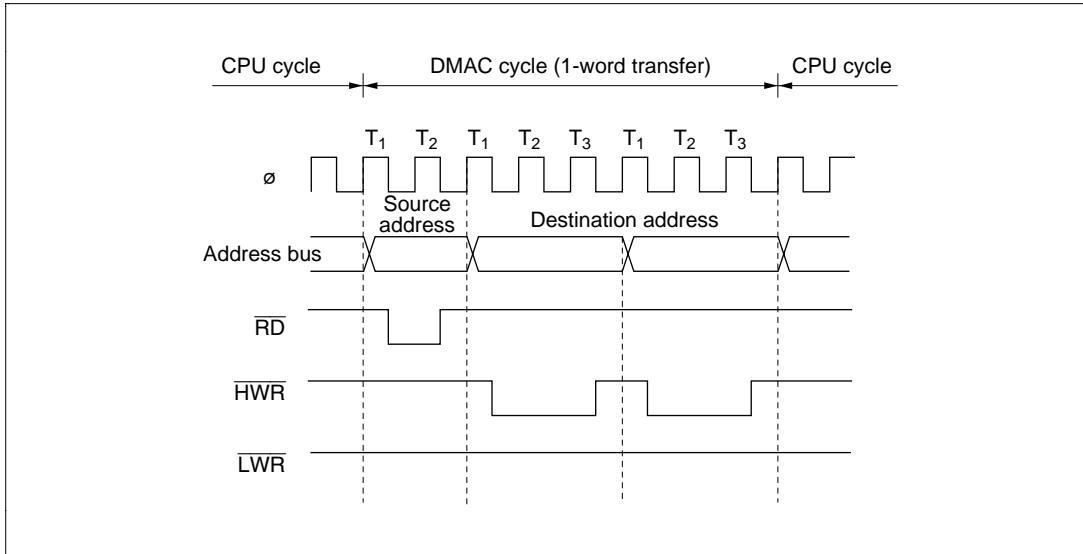


Figure 7-18 Example of DMA Transfer Bus Timing

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

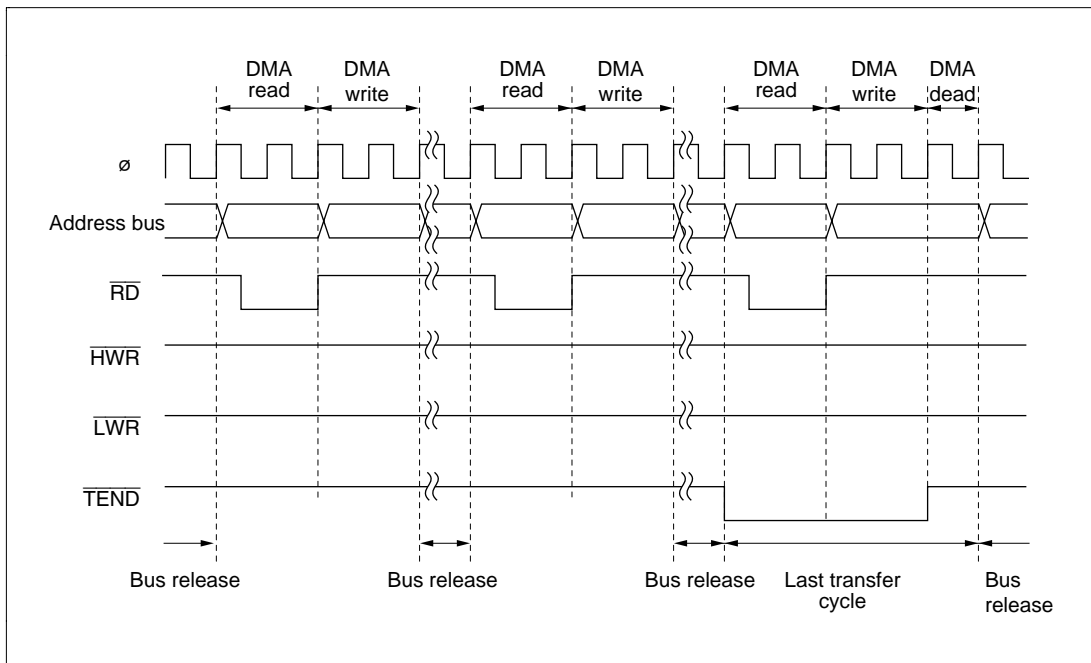


Figure 7-19 Example of Short Address Mode Transfer

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

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

In repeat mode, when $\overline{\text{TEND}}$ output is enabled, $\overline{\text{TEND}}$ output goes low in the transfer cycle in which the transfer counter reaches 0.

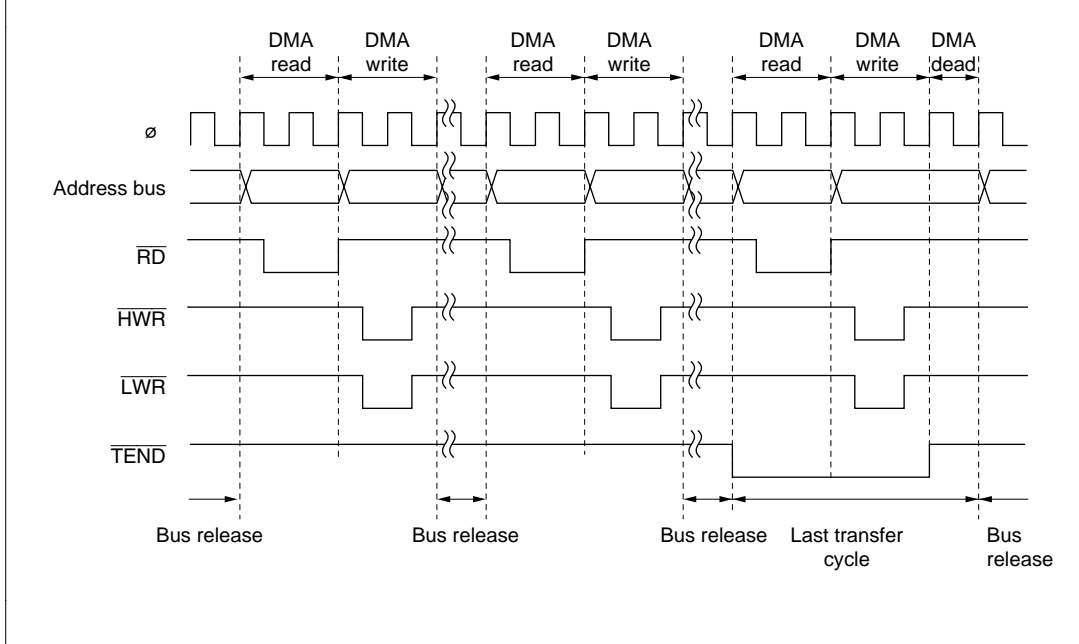


Figure 7-20 Example of Full Address Mode (Cycle Steal) Transfer

A one-byte or one-word transfer is performed, and after the transfer the bus is released. While the bus is released one bus cycle is inserted by the CPU or DTC.

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

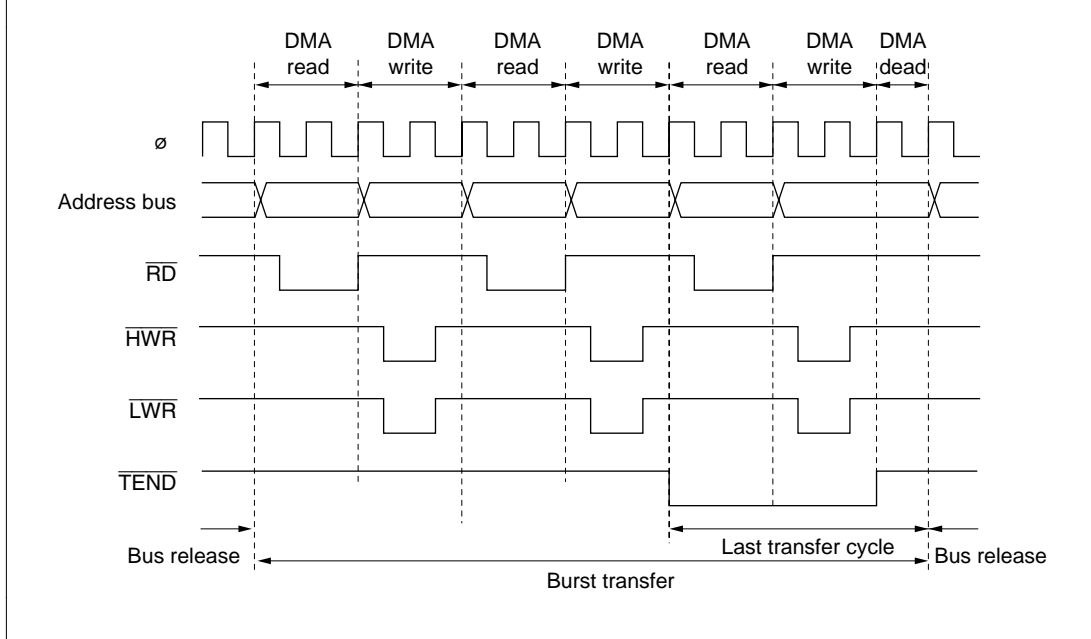


Figure 7-21 Example of Full Address Mode (Burst Mode) Transfer

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

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

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

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

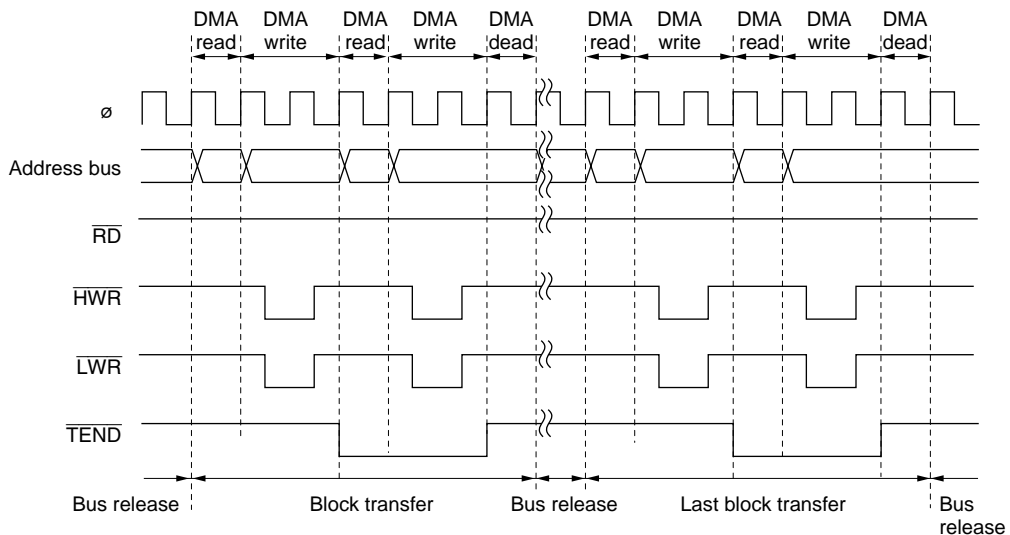
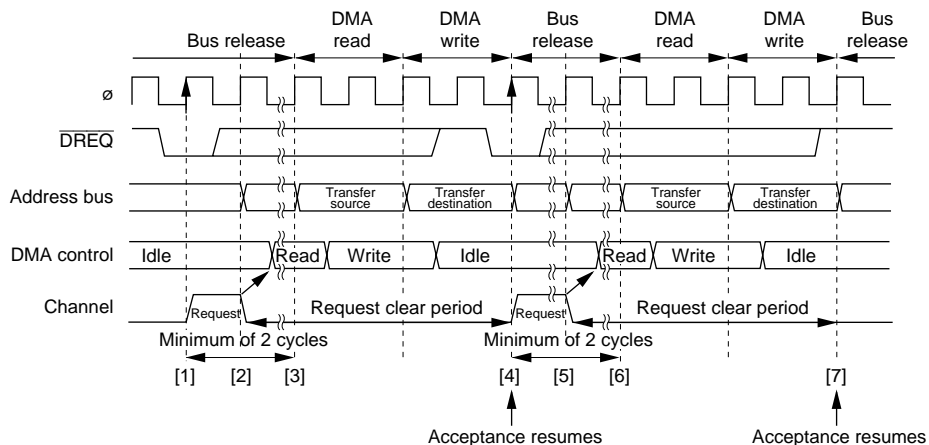


Figure 7-22 Example of Full Address Mode (Block Transfer Mode) Transfer

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

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

One block is transmitted without interruption. NMI generation does not affect block transfer operation.



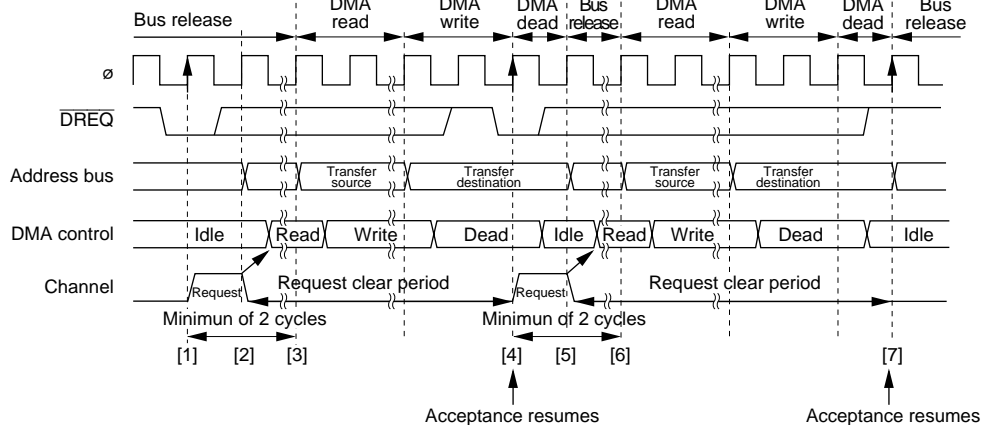
- [1] Acceptance after transfer enabling; the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of ϕ , and the request is held.
- [2] [5] The request is cleared at the next bus break, and activation is started in the DMAC.
- [3] [6] Start of DMA cycle; $\overline{\text{DREQ}}$ pin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

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

Figure 7-23 Example of $\overline{\text{DREQ}}$ Pin Falling Edge Activated Normal Mode Transfer

$\overline{\text{DREQ}}$ pin sampling is performed every cycle, with the rising edge of the next ϕ cycle after the end of the DMABCR write cycle for setting the transfer enabled state as the starting point.

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



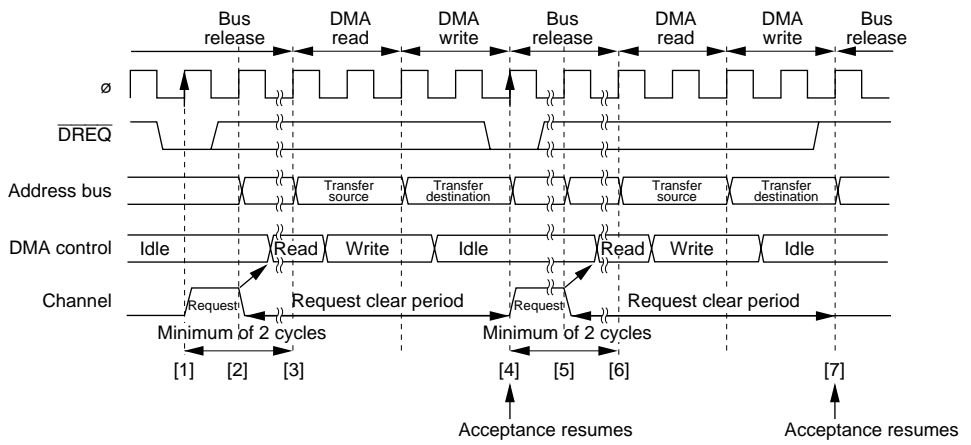
- [1] Acceptance after transfer enabling; the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of ϕ , and the request is held.
- [2] [5] The request is cleared at the next bus break, and activation is started in the DMAC.
- [3] [6] Start of DMA cycle; $\overline{\text{DREQ}}$ pin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

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

Figure 7-24 Example of $\overline{\text{DREQ}}$ Pin Falling Edge Activated Block Transfer Mode Transfer

$\overline{\text{DREQ}}$ pin sampling is performed every cycle, with the rising edge of the next ϕ cycle after the end of the DMABCRC write cycle for setting the transfer enabled state as the starting point.

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



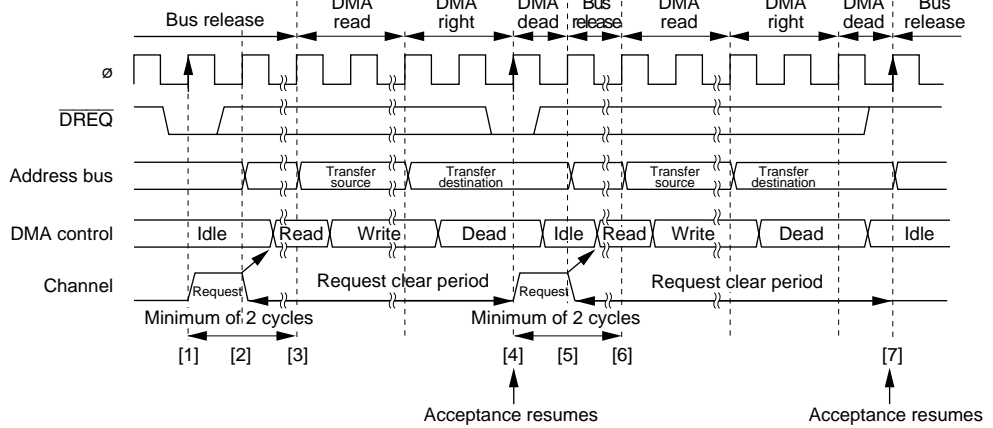
- [1] Acceptance after transfer enabling; the $\overline{\text{DREQ}}$ pin low level is sampled on the rising edge of ϕ , and the request is held.
- [2] [5] The request is cleared at the next bus break, and activation is started in the DMAC.
- [3] [6] The DMA cycle is started.
- [4] [7] Acceptance is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

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

Figure 7-25 Example of $\overline{\text{DREQ}}$ Level Activated Normal Mode Transfer

$\overline{\text{DREQ}}$ pin sampling is performed every cycle, with the rising edge of the next ϕ cycle after the end of the DMABCR write cycle for setting the transfer enabled state as the starting point.

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



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

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

Figure 7-26 Example of $\overline{\text{DREQ}}$ Level Activated Block Transfer Mode Transfer

$\overline{\text{DREQ}}$ pin sampling is performed every cycle, with the rising edge of the next ϕ cycle after the end of the DMABCR write cycle for setting the transfer enabled state as the starting point.

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

access space to an external device.

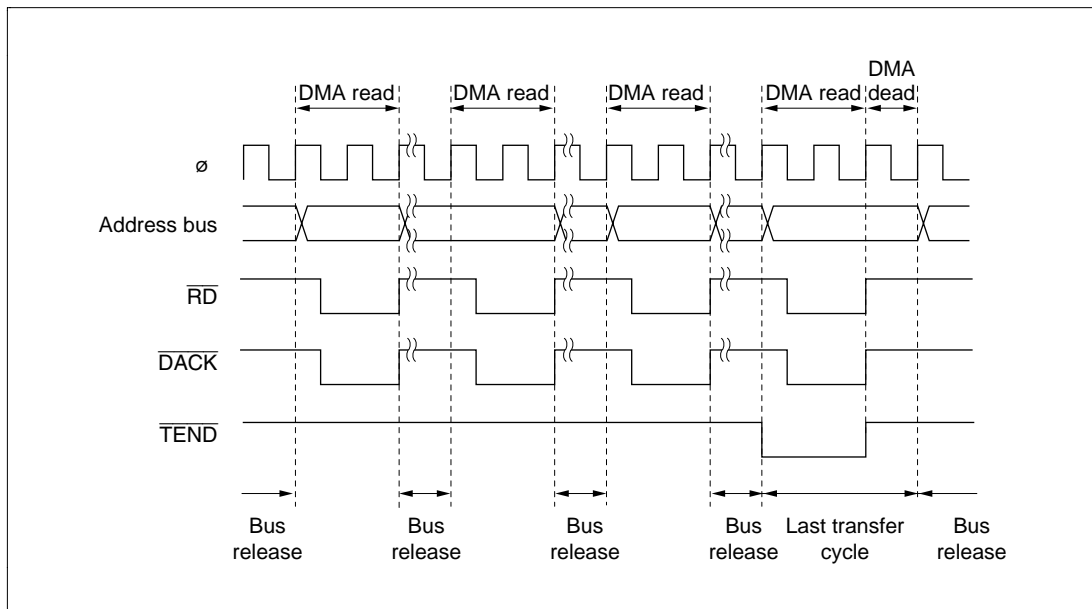


Figure 7-27 Example of Single Address Mode (Byte Read) Transfer

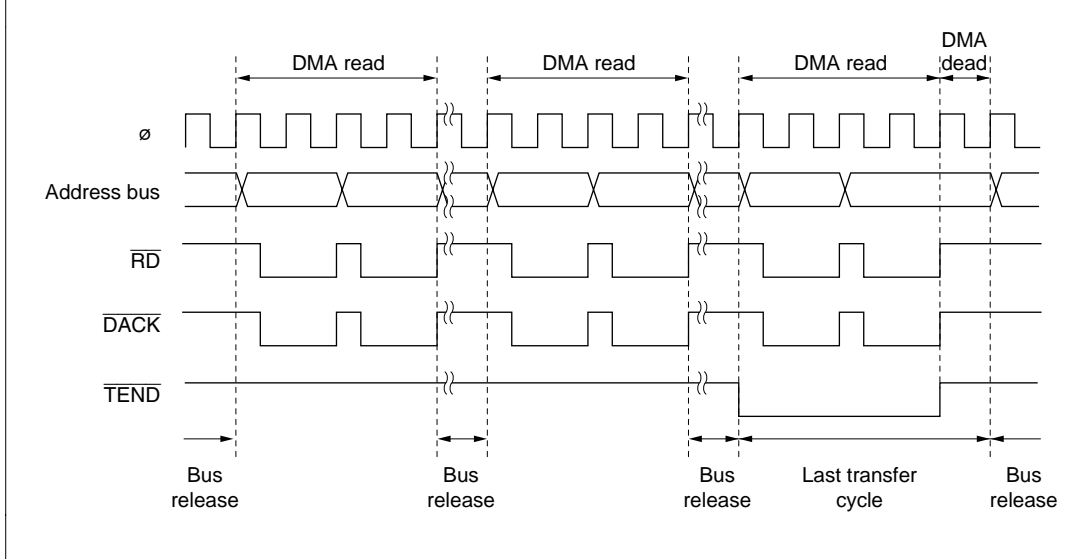


Figure 7-28 Example of Single Address Mode (Word Read) Transfer

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

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

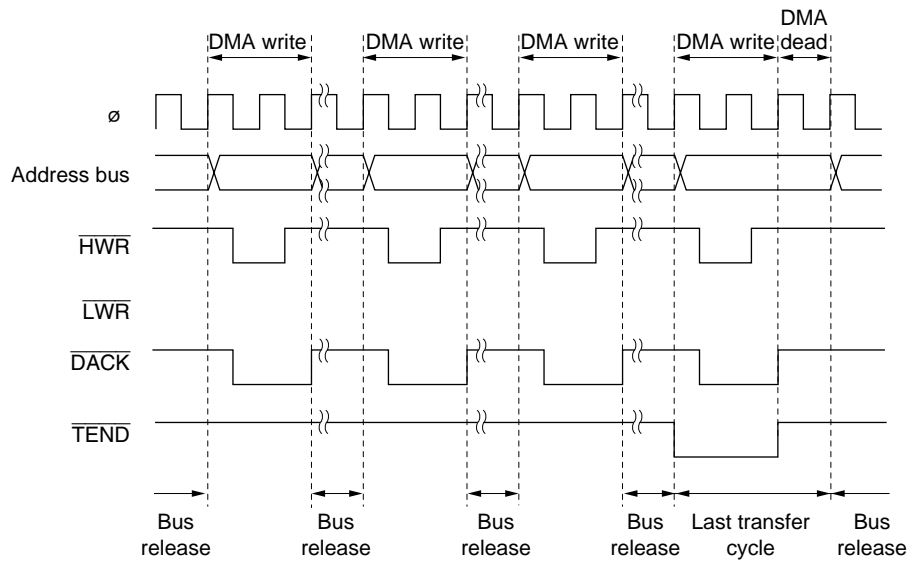


Figure 7-29 Example of Single Address Mode (Byte Write) Transfer

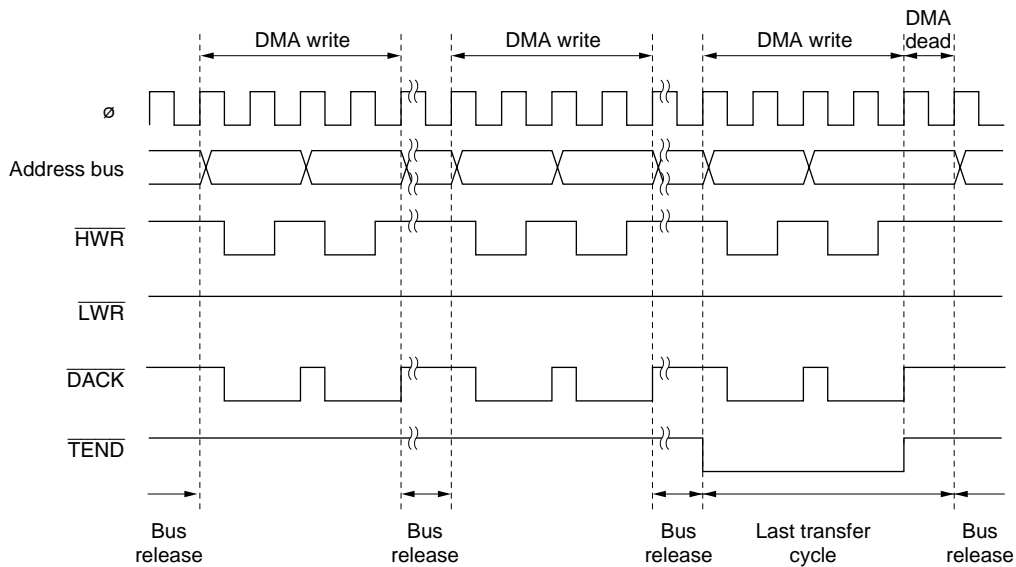
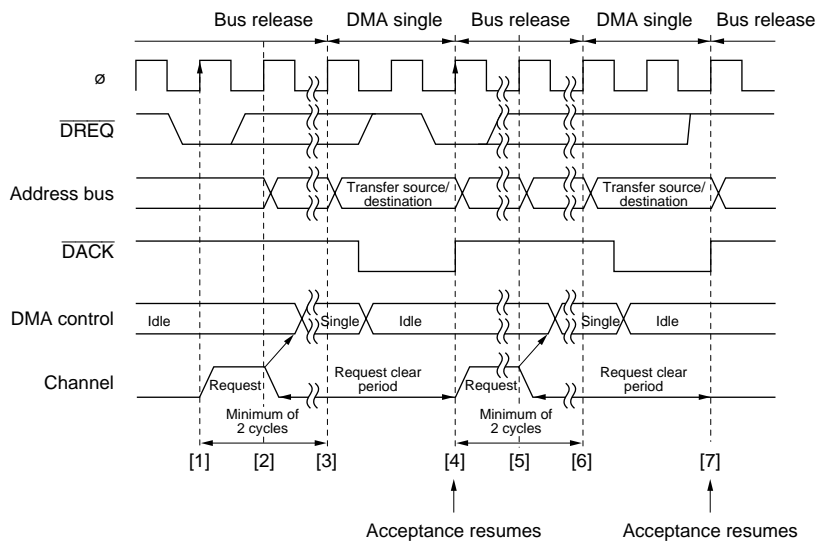


Figure 7-30 Example of Single Address Mode (Word Write) Transfer

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

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



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

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

Figure 7-31 Example of $\overline{\text{DREQ}}$ Pin Falling Edge Activated Single Address Mode Transfer

$\overline{\text{DREQ}}$ pin sampling is performed every cycle, with the rising edge of the next ϕ cycle after the end of the DMABCR write cycle for setting the transfer enabled state as the starting point.

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

When the WDBE bit of BCRL in the bus controller is set to 1, enabling the write data buffer function, dual address transfer external write cycles or single address transfers and internal accesses (on-chip memory or internal I/O registers) are executed in parallel. Internal accesses are independent of the bus master, and DMAC dead cycles are regarded as internal accesses.

A low level can always be output from the $\overline{\text{TEND}}$ pin if the bus cycle in which a low level is to be output is an external bus cycle. However, a low level is not output from the $\overline{\text{TEND}}$ pin if the bus cycle in which a low level is to be output from the $\overline{\text{TEND}}$ pin is an internal bus cycle, and an external write cycle is executed in parallel with this cycle.

Figure 7-33 shows an example of burst mode transfer from on-chip RAM to external memory using the write data buffer function.

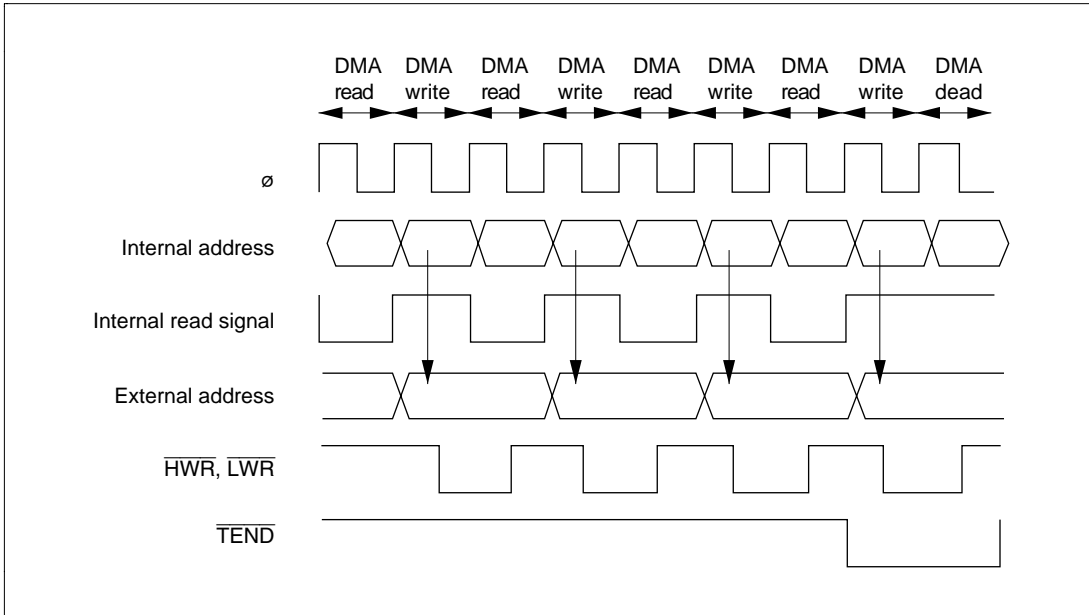


Figure 7-33 Example of Dual Address Transfer Using Write Data Buffer Function

Figure 7-34 shows an example of single address transfer using the write data buffer function. In this example, the CPU program area is in on-chip memory.

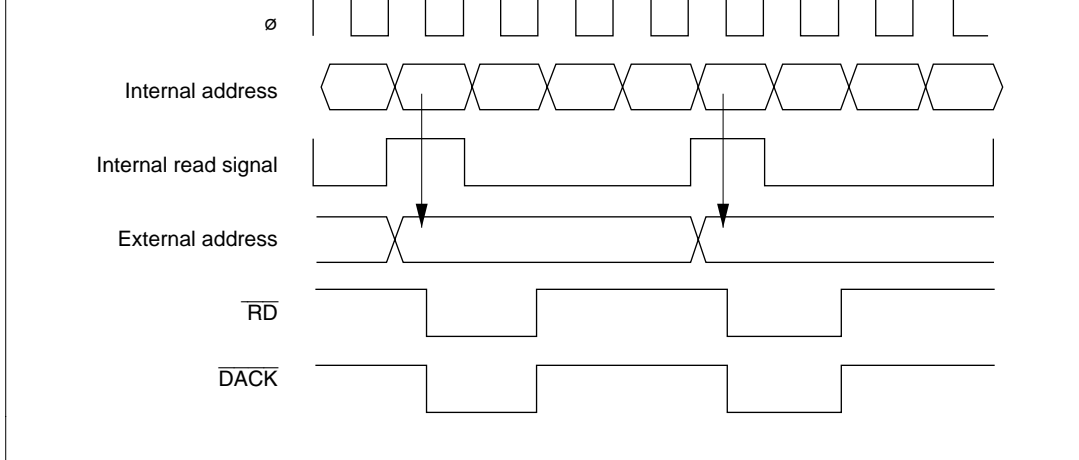


Figure 7-34 Example of Single Address Transfer Using Write Data Buffer Function

When the write data buffer function is activated, the DMAC recognizes that the bus cycle concerned has ended, and starts the next operation. Therefore, DREQ pin sampling is started one state after the start of the DMA write cycle or single address transfer.

7.5.13 DMAC Multi-Channel Operation

The DMAC channel priority order is: channel 0 > channel 1, and channel A > channel B. Table 7-13 summarizes the priority order for DMAC channels.

Table 7-13 DMAC Channel Priority Order

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

During burst transfer, or when one block is being transferred in block transfer, the channel will not be changed until the end of the transfer.

Figure 7-35 shows a transfer example in which transfer requests are issued simultaneously for channels 0A, 0B, and 1.

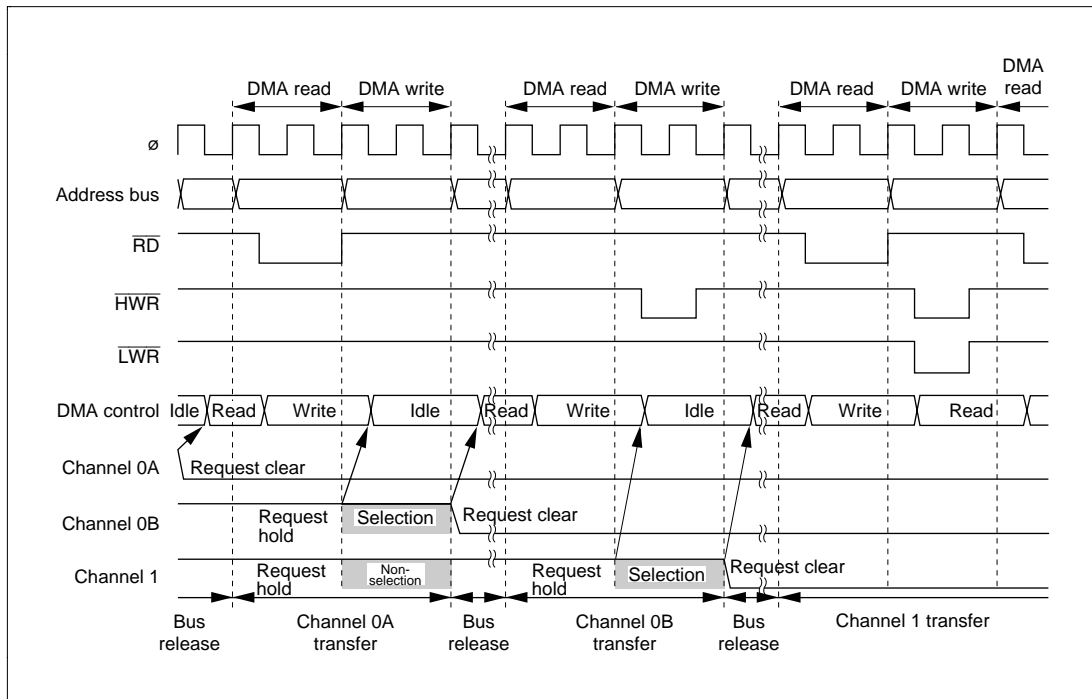


Figure 7-35 Example of Multi-Channel Transfer

and external write in a DMA cycle.

In the case of successive read and write cycles, such as in burst transfer or block transfer, a refresh or external bus released state may be inserted after a write cycle. Since the DTC has a lower priority than the DMAC, the DTC does not operate until the DMAC releases the bus.

When DMA cycle reads or writes are accesses to on-chip memory or internal I/O registers, these DMA cycles can be executed at the same time as refresh cycles or external bus release. However, simultaneous operation may not be possible when a write buffer is used.

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

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

The channel on which transfer was interrupted can be restarted by setting the DTME bit to 1 again. Figure 7-36 shows the procedure for continuing transfer when it has been interrupted by an NMI interrupt on a channel designated for burst mode transfer.

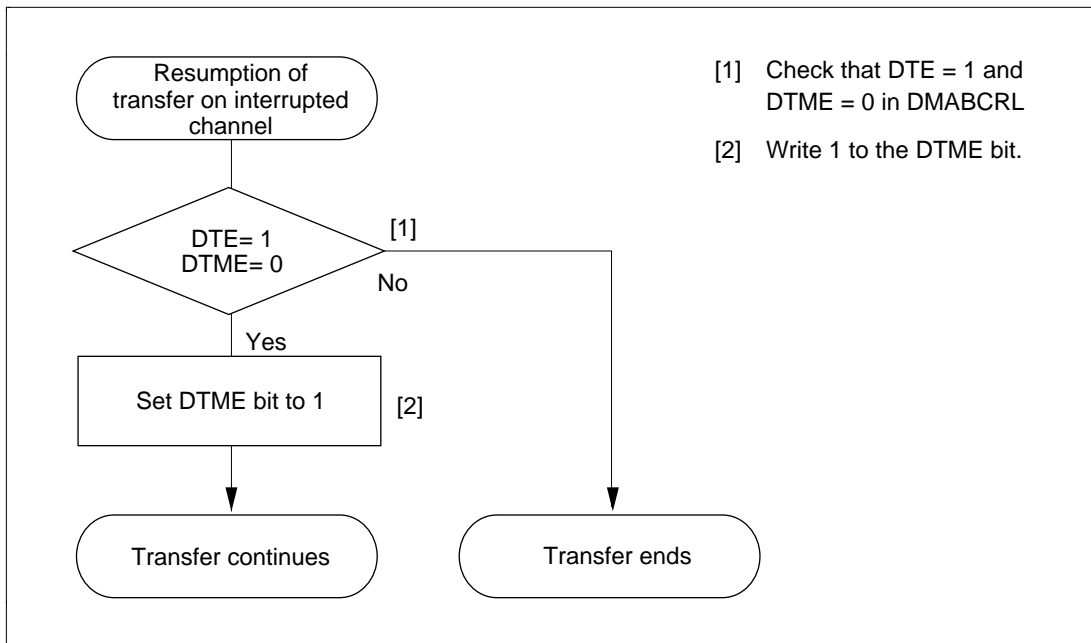


Figure 7-36 Example of Procedure for Continuing Transfer on Channel Interrupted by NMI Interrupt

I again.

In full address mode, the same applies to the DTME bit.

Figure 7-37 shows the procedure for forcibly terminating DMAC operation by software.

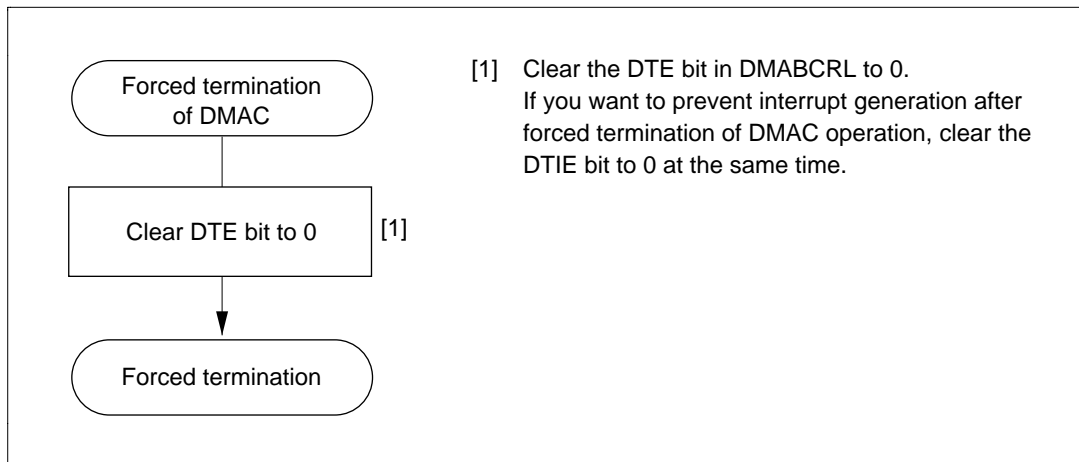


Figure 7-37 Example of Procedure for Forcibly Terminating DMAC Operation

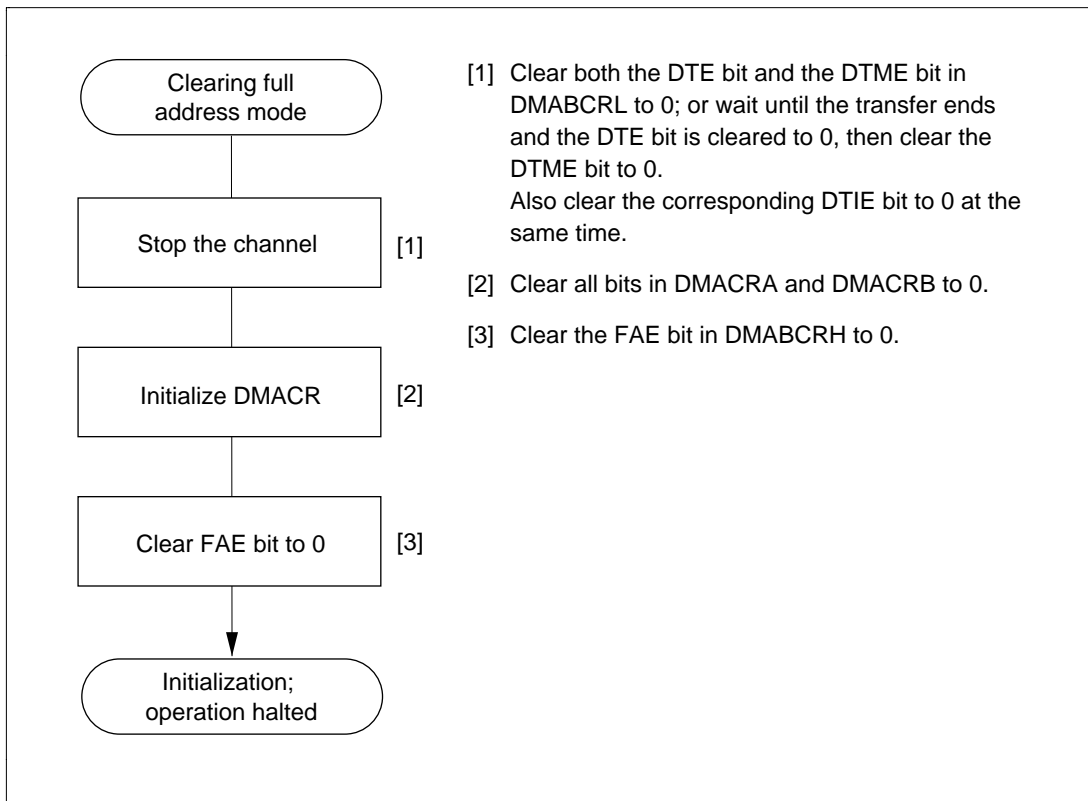


Figure 7-38 Example of Procedure for Clearing Full Address Mode

Table 7-13 Interrupt Source Priority Order

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

Enabling or disabling of each interrupt source is set by means of the DTIE bit for the corresponding channel in DMABCR, and interrupts from each source are sent to the interrupt controller independently.

The relative priority of transfer end interrupts on each channel is decided by the interrupt controller, as shown in table 7-13.

Figure 7-39 shows a block diagram of a transfer end/transfer break interrupt. An interrupt is always generated when the DTIE bit is set to 1 while DTE bit is cleared to 0.

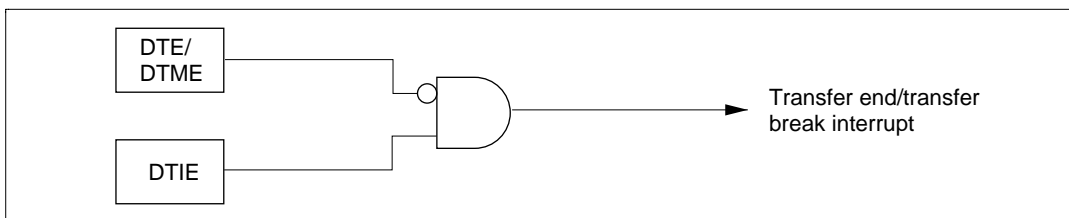


Figure 7-39 Block Diagram of Transfer End/Transfer Break Interrupt

In full address mode, a transfer break interrupt is generated when the DTME bit is cleared to 0 while DTIEB bit is set to 1.

In both short address mode and full address mode, DMABCR should be set so as to prevent the occurrence of a combination that constitutes a condition for interrupt generation during setting.

setting should only be changed when transfer is disabled.

Also, the DMAC register should not be written to in a DMA transfer.

Module Stop: When the MSTP15 bit in MSTPCR is set to 1, the DMAC clock stops, and the module stop state is entered. However, 1 cannot be written to the MSTP15 bit if any of the DMAC channels is enabled. This setting should therefore be made when DMAC operation is stopped.

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

- Transfer end/suspend interrupt (DTE = 0 and DTIE = 1)
- $\overline{\text{TEND}}$ pin enable (TEE = 1)
- $\overline{\text{DACK}}$ pin enable (FAE = 0 and SAE = 1)

Medium-Speed Mode: When the DTA bit is 0, internal interrupt signals specified as DMAC transfer sources are edge-detected.

In medium-speed mode, the DMAC operates on a medium-speed clock, while on-chip supporting modules operate on a high-speed clock. Consequently, if the period in which the relevant interrupt source is cleared by the CPU, DTC, or another DMAC channel, and the next interrupt is generated, is less than one state with respect to the DMAC clock (bus master clock), edge detection may not be possible and the interrupt may be ignored.

Also, in medium-speed mode, $\overline{\text{DREQ}}$ pin sampling is performed on the rising edge of the medium-speed clock.

(a) Write Data Buffer Function and DMAC Register Setting

If the setting of $\overline{\text{DREQ}}$ is changed during execution of an external access by means of the write data buffer function, the external access may not be performed normally. The register that controls external accesses should only be manipulated when external reads, etc., are used with DMAC operation disabled, and the operation is not performed in parallel with external access.

(b) Write Data Buffer Function and DMAC Operation Timing

The DMAC can start its next operation during external access using the write data buffer function. Consequently, the $\overline{\text{DREQ}}$ pin sampling timing, $\overline{\text{TEND}}$ output timing, etc., are different from the case in which the write data buffer function is disabled. Also, internal bus cycles maybe hidden, and not visible.

(c) Write Data Buffer Function and $\overline{\text{TEND}}$ Output

A low level is not output from the $\overline{\text{TEND}}$ pin if the bus cycle in which a low level is to be output from the $\overline{\text{TEND}}$ pin is an internal bus cycle, and an external write cycle is executed in parallel with this cycle. Note, for example, that a low level may not be output from the $\overline{\text{TEND}}$ pin if the write data buffer function is used when data transfer is performed between an internal I/O register and on-chip memory.

If at least one of the DMAC transfer addresses is an external address, a low level is output from the $\overline{\text{TEND}}$ pin.

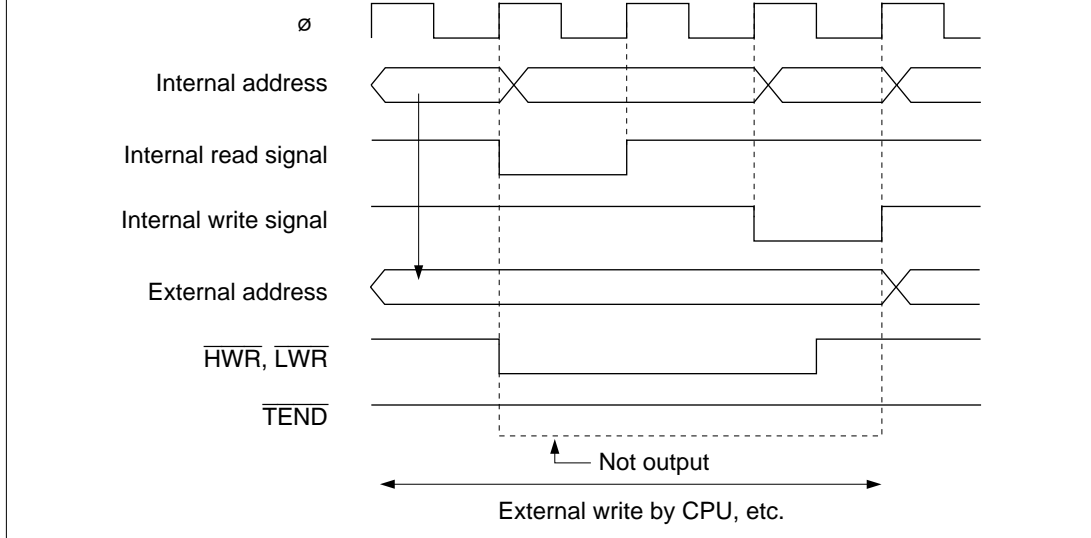


Figure 7-40 Example in Which Low Level is Not Output at \overline{TEND} Pin

Activation by Falling Edge on \overline{DREQ} Pin: \overline{DREQ} pin falling edge detection is performed in synchronization with DMAC internal operations. The operation is as follows:

- [1] Activation request wait state: Waits for detection of a low level on the \overline{DREQ} pin, and switches to [2].
- [2] Transfer wait state: Waits for DMAC data transfer to become possible, and switches to [3].
- [3] Activation request disabled state: Waits for detection of a high level on the \overline{DREQ} pin, and switches to [1].

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

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

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

transfer is executed but flag clearing is not performed for the selected internal interrupt even if DTA is set to 1.

An internal interrupt request following the end of transfer or an abort should be handled by the CPU as necessary.

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

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

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

The H8S/2350 Series includes a data transfer controller (DTC). The DTC can be activated by an interrupt or software, to transfer data.

8.1.1 Features

The features of the DTC are:

- 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 source and destination addresses can be 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 the specified data transfers have completely ended
- Activation by software is possible
- Module stop mode can be set
 - The initial setting enables DTC registers to be accessed. DTC operation is halted by setting module stop mode.

The DTC's register information is stored in the on-chip RAM. A 32-bit bus connects the DTC to the on-chip RAM (1 kbyte), enabling 32-bit/1-state reading and writing of the DTC register information and hence helping to increase processing speed.

Note: * When the DTC is used, the RAME bit in SYSCR must be set to 1.

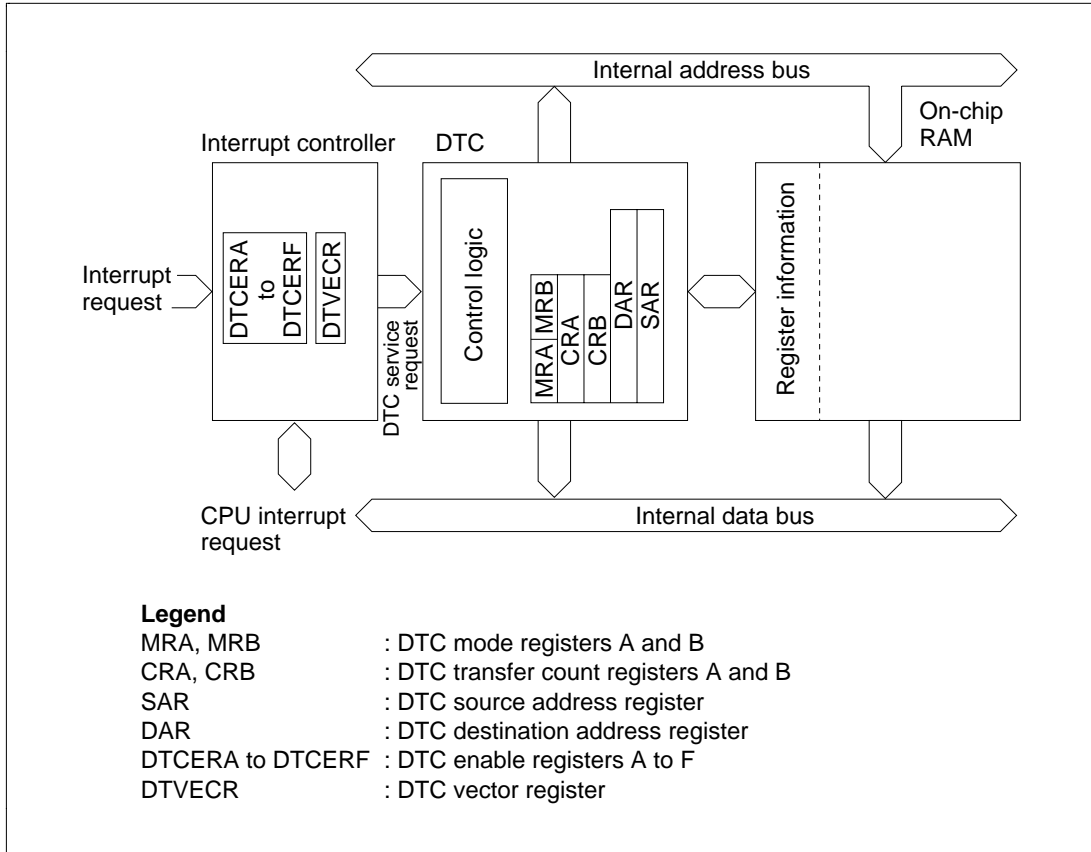


Figure 8-1 Block Diagram of DTC

Table 8-1 DTC Registers

Name	Abbreviation	R/W	Initial Value	Address*¹
DTC mode register A	MRA	—* ²	Undefined	—* ³
DTC mode register B	MRB	—* ²	Undefined	—* ³
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	R/W	H'00	H'FF30 to H'FF35
DTC vector register	DTVECR	R/W	H'00	H'FF37
Module stop control register	MSTPCR	R/W	H'3FFF	H'FF3C

- Notes:
1. Lower 16 bits of the address.
 2. Registers within the DTC cannot be read or written to directly.
 3. Register information is located in on-chip RAM addresses H'F800 to H'FBFF. It cannot be located in external space. When the DTC is used, do not clear the RAME bit in SYSCR to 0.

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

Bit	:	7	6	5	4	3	2	1	0
		SM1	SM0	DM1	DM0	MD1	MD0	DTS	Sz
Initial value	:	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined
R/W	:	—	—	—	—	—	—	—	—

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 SM1	Bit 6 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 DM1	Bit 4 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)

	1	Repeat mode
1	0	Block transfer mode
	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

Initial value:	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined	Unde- fined
R/W	:	—	—	—	—	—	—	—

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

Bit 7—DTC Chain Transfer Enable (CHNE): Specifies chain transfer. With chain transfer, a number of data transfers can be performed consecutively in response to a single transfer request.

In data transfer with CHNE set to 1, determination of the end of the specified number of transfers, clearing of the interrupt source flag, and clearing of DTCER is not performed.

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 counter is 0 (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: These bits have no effect on DTC operation in the H8S/2350 Series, and should always be written with 0.

8.2.8 DTC Vector Register (DTVECR)

Bit	:	7	6	5	4	3	2	1	0
		SWDTE	DTVEC6	DTVEC5	DTVEC4	DTVEC3	DTVEC2	DTVEC1	DTVEC0
Initial value:		0	0	0	0	0	0	0	0
R/W	:	R/(W)*	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Note: * A value of 1 can always be written to the SWDTE bit, but 0 can only be written after 1 is read.

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

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

Bit 7—DTC Software Activation Enable (SWDTE): Enables or disables DTC activation by software.

When clearing the SWDTE bit to 0 by software, write 0 to SWDTE after reading SWDTE set to 1.

Bit 7

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

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 expressed as H'0400 + ((vector number) << 1). <<1 indicates a one-bit left-shift. For example, when DTVEC6 to DTVEC0 = H'10, the vector address is H'0420.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Initial value	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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	R/W	R/W

MSTPCR is a 16-bit readable/writable register that performs module stop mode control.

When the MSTP14 bit in MSTPCR is set to 1, the DTC operation stops at the end of the bus cycle and a transition is made to module stop mode. However, 1 cannot be written in the MSTP14 bit while the DTC is operating. For details, see section 20.5, 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 14—Module Stop (MSTP14): Specifies the DTC module stop mode.

Bit 14

MSTP14	Description	
0	DTC module stop mode cleared	(Initial value)
1	DTC module stop mode set	

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 it possible to perform a number of transfers with a single activation.

Figure 8-2 shows a flowchart of DTC operation.

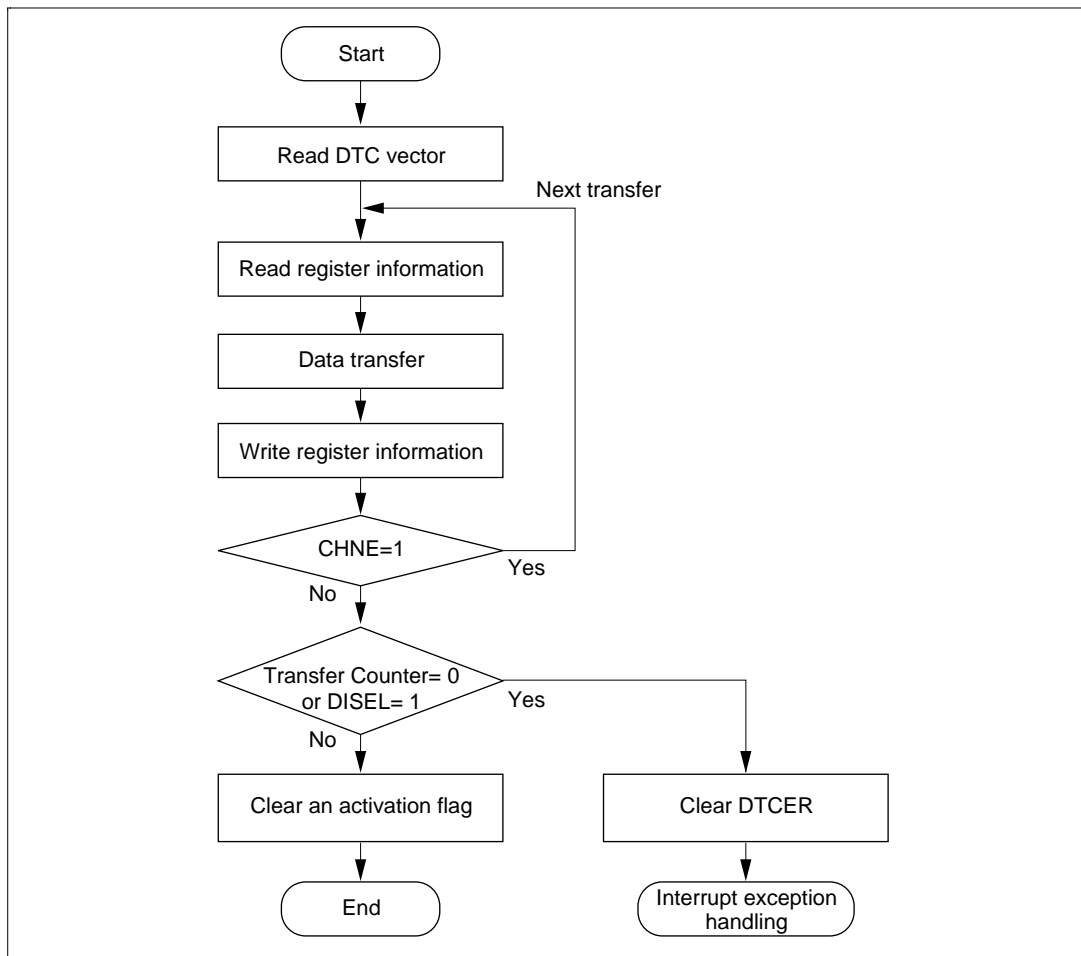


Figure 8-2 Flowchart of DTC Operation

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

Table 8-2 DTC Functions

Transfer Mode	Activation Source	Address Registers	
		Transfer Source	Transfer Destination
<ul style="list-style-type: none"> • Normal mode <ul style="list-style-type: none"> — One transfer request transfers one byte or one word — Memory addresses are incremented or decremented by 1 or 2 — Up to 65,536 transfers possible • Repeat mode <ul style="list-style-type: none"> — 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 <ul style="list-style-type: none"> — 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 	<ul style="list-style-type: none"> • IRQ • TPU TGI • SCI TXI or RXI • A/D converter ADI • DMAC DEND • Software 	24 bits	24 bits

CPU interrupt source when the bit is cleared to 0.

At the end of a data transfer (or the last consecutive transfer in the case of chain transfer), the activation source or corresponding DTCER bit is cleared. Table 8-3 shows activation source and DTCER clearance. The activation source flag, in the case of RXI0, for example, is the RDRF flag of SCIO.

Table 8-3 Activation Source and DTCER Clearance

Activation Source	When the DISEL Bit Is 0 and the Specified Number of Transfers Have Not Ended	When the DISEL Bit Is 1, or when the Specified Number of Transfers Have Ended
Software activation	The SWDTE bit is cleared to 0	The SWDTE bit remains set to 1 An interrupt is issued to the CPU
Interrupt activation	The corresponding DTCER bit remains set to 1 The activation source flag is cleared to 0	The corresponding DTCER bit is cleared to 0 The activation source flag remains set to 1 A request is issued to the CPU for the activation source interrupt

Figure 8-3 shows a block diagram of activation source control. For details see section 5, Interrupt Controller.

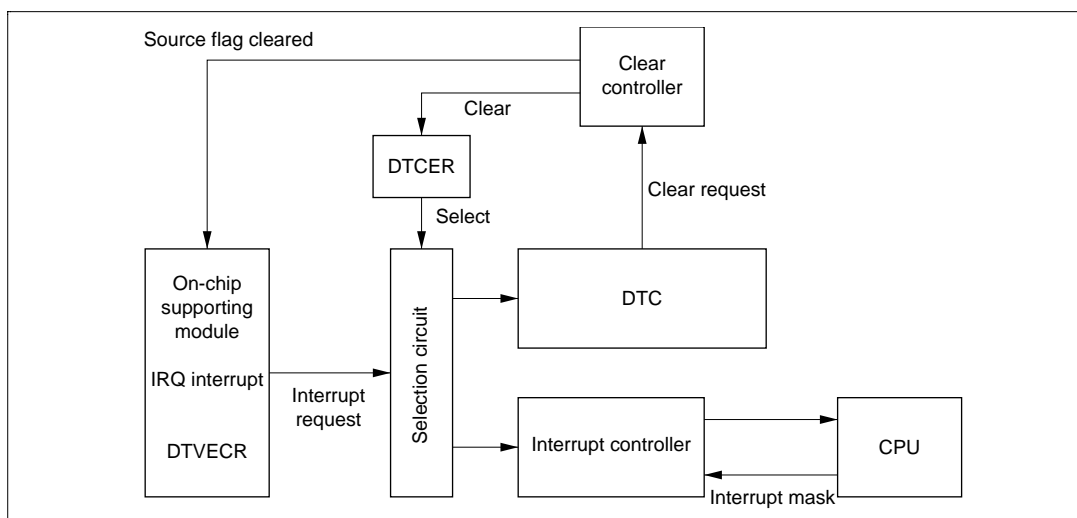


Figure 8-3 Block Diagram of DTC Activation Source Control

8.3.3 DTC Vector Table

Figure 8-4 shows the correspondence between DTC vector addresses and register information.

Table 8-4 shows the correspondence between activation, vector addresses, and DTCER bits. When the DTC is activated by software, the vector address is obtained from: $H'0400 + (DTVECR[6:0] \ll 1)$ (where $\ll 1$ indicates a 1-bit left shift). For example, if DTVECR is H'10, the vector address is H'0420.

The DTC reads the start address of the register information from the vector address set for each activation source, and then reads the register information from that start address. 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 modes, a 2-byte unit being used in both cases. These two bytes specify the lower bits of the address in the on-chip RAM.

Write to DTVECR	Software	DTVECR	H'0400+ (DTVECR [6:0]<<1)	—	High
IRQ0	External pin	16	H'0420	DTCEA7	↑ Low
IRQ1		17	H'0422	DTCEA6	
IRQ2		18	H'0424	DTCEA5	
IRQ3		19	H'0426	DTCEA4	
IRQ4		20	H'0428	DTCEA3	
IRQ5		21	H'042A	DTCEA2	
IRQ6		22	H'042C	DTCEA1	
IRQ7		23	H'042E	DTCEA0	
ADI (A/D conversion end)	A/D	28	H'0438	DTCEB6	
TGI0A (GR0A compare match/ input capture)	TPU channel 0	32	H'0440	DTCEB5	
TGI0B (GR0B compare match/ input capture)		33	H'0442	DTCEB4	
TGI0C (GR0C compare match/ input capture)		34	H'0444	DTCEB3	
TGI0D (GR0D compare match/ input capture)		35	H'0446	DTCEB2	
TGI1A (GR1A compare match/ input capture)	TPU channel 1	40	H'0450	DTCEB1	
TGI1B (GR1B compare match/ input capture)		41	H'0452	DTCEB0	
TGI2A (GR2A compare match/ input capture)	TPU channel 2	44	H'0458	DTCEC7	
TGI2B (GR2B compare match/ input capture)		45	H'045A	DTCEC6	

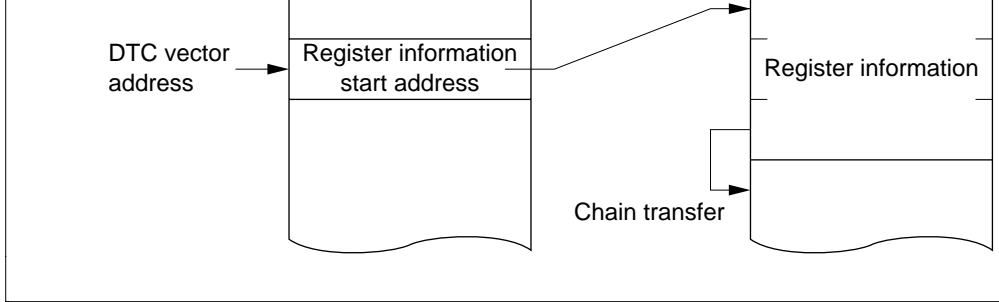


Figure 8-4 Correspondence between DTC Vector Address and Register Information

8.3.4 Location of Register Information in Address Space

Figure 8-5 shows how the register information should be located in the address space.

Locate the MRA, SAR, MRB, DAR, CRA, and CRB registers, in that order, from the start address of the register information (contents of the vector address). In the case of chain transfer, register information should be located in consecutive areas.

Locate the register information in the on-chip RAM (addresses: H'FFF800 to H'FFFBFF).

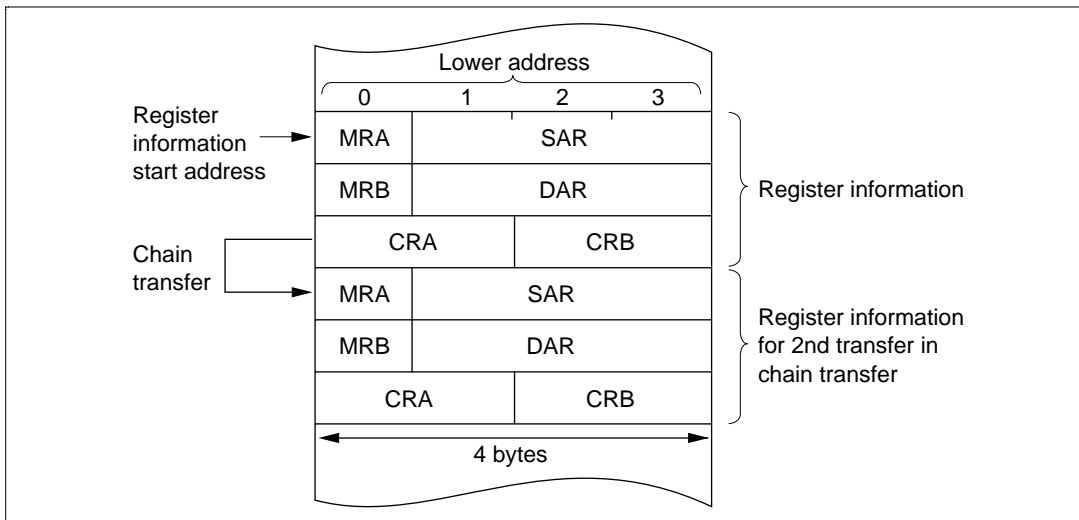


Figure 8-5 Location of Register Information in Address Space

CPU interrupt can be requested.

Table 8-5 lists the register information in normal mode and figure 8-6 shows memory mapping in normal mode.

Table 8-5 Register Information in Normal Mode

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

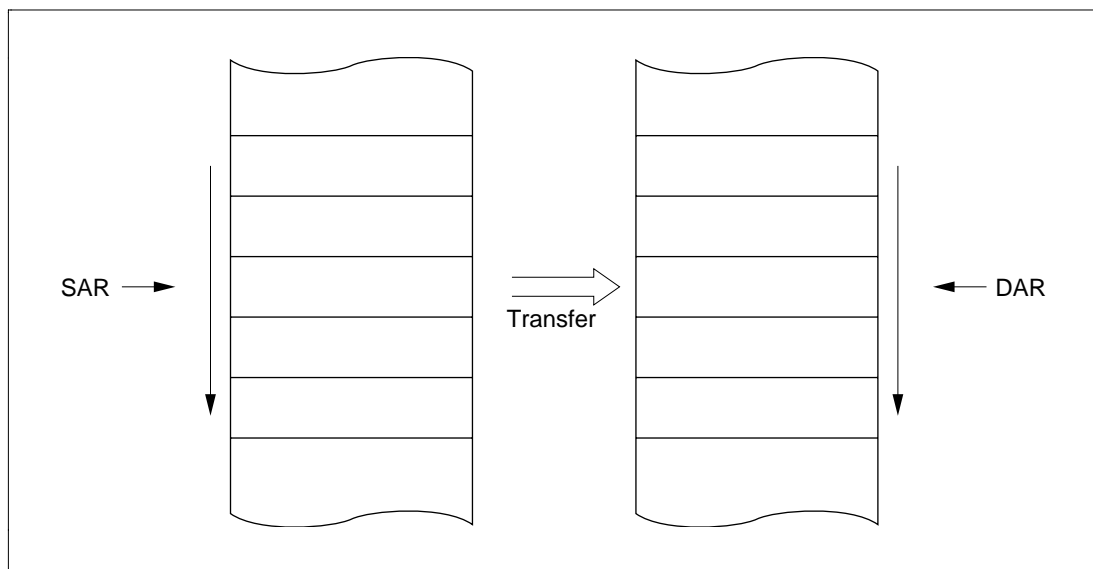


Figure 8-6 Memory Mapping in Normal Mode

From 1 to 256 transfers can be specified. Once the specified number of transfers have ended, the initial state of the transfer counter and the address register specified as the repeat area is restored, and transfer is repeated. In repeat mode the transfer counter value does not reach H'00, and therefore CPU interrupts cannot be requested when DISEL = 0.

Table 8-6 lists the register information in repeat mode and figure 8-7 shows memory mapping in repeat mode.

Table 8-6 Register Information in Repeat Mode

Name	Abbreviation	Function
DTC source address register	SAR	Designates source address
DTC destination address register	DAR	Designates destination address
DTC transfer count register AH	CRAH	Holds number of transfers
DTC transfer count register AL	CRAL	Designates transfer count (8 bits × 2)
DTC transfer count register B	CRB	Not used

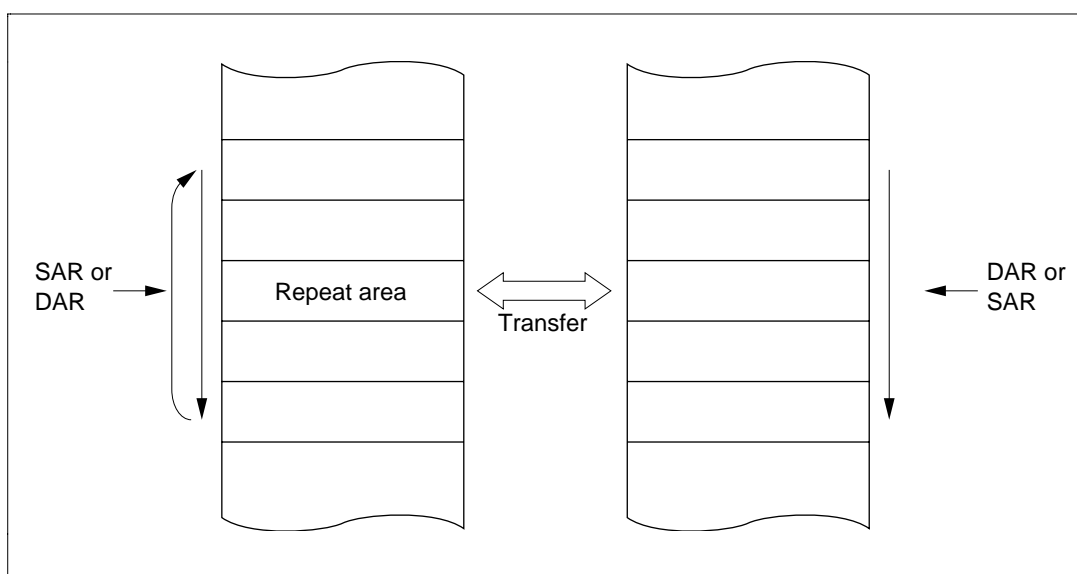


Figure 8-7 Memory Mapping in Repeat Mode

counter and the address register specified as the block area is restored. The other address register is then incremented, decremented, or left fixed.

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

Table 8-7 lists the register information in block transfer mode and figure 8-8 shows memory mapping in block transfer mode.

Table 8-7 Register Information in Block Transfer Mode

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

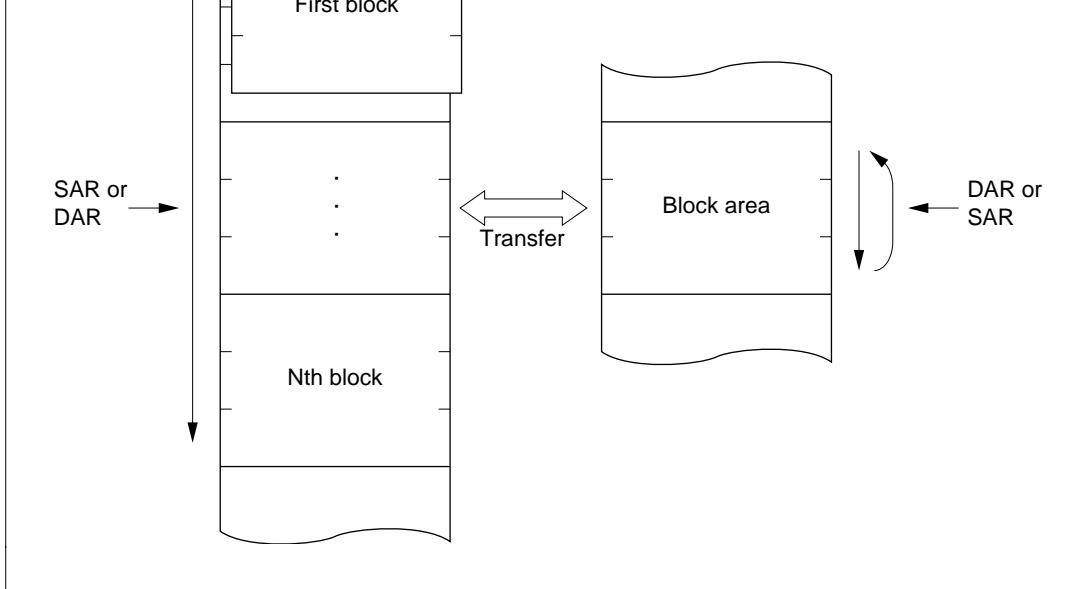


Figure 8-8 Memory Mapping in Block Transfer Mode

transfers, can be set independently.

Figure 8-9 shows the memory map for chain transfer.

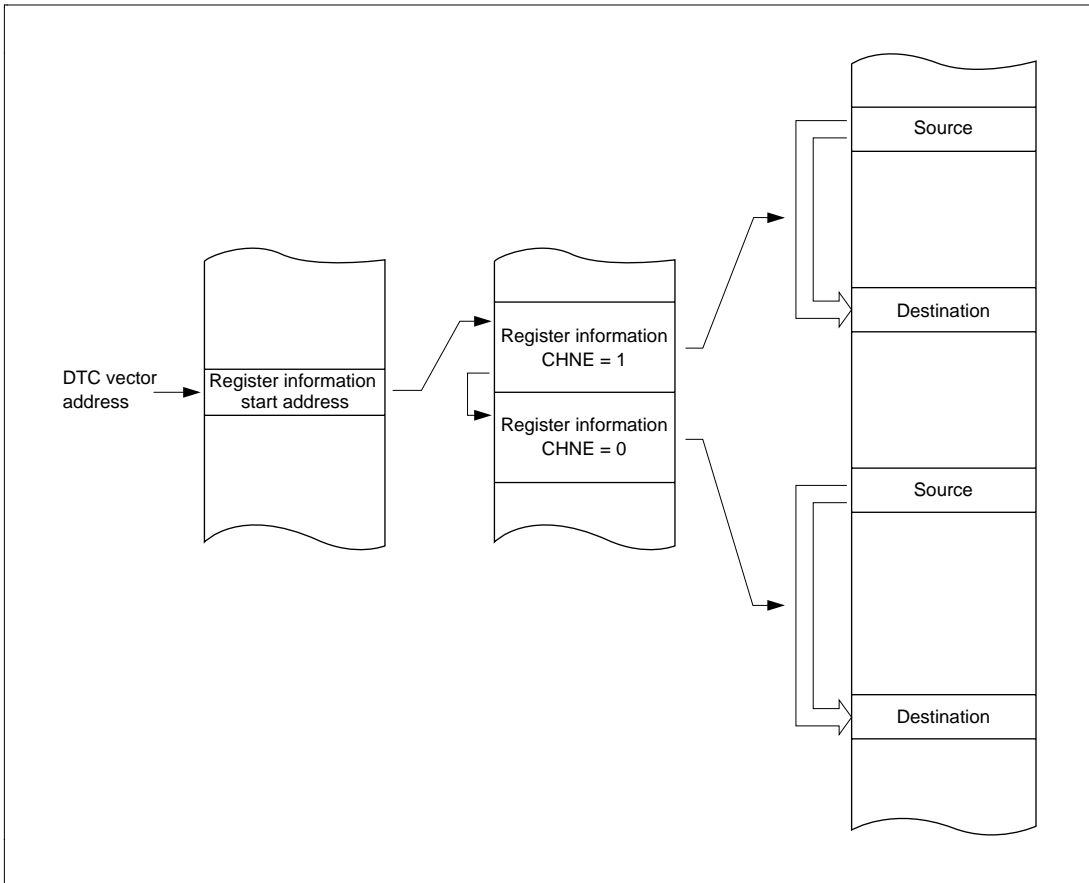


Figure 8-9 Chain Transfer Memory Map

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 DISSEL bit to 1, and the interrupt source flag for the activation source is not affected.

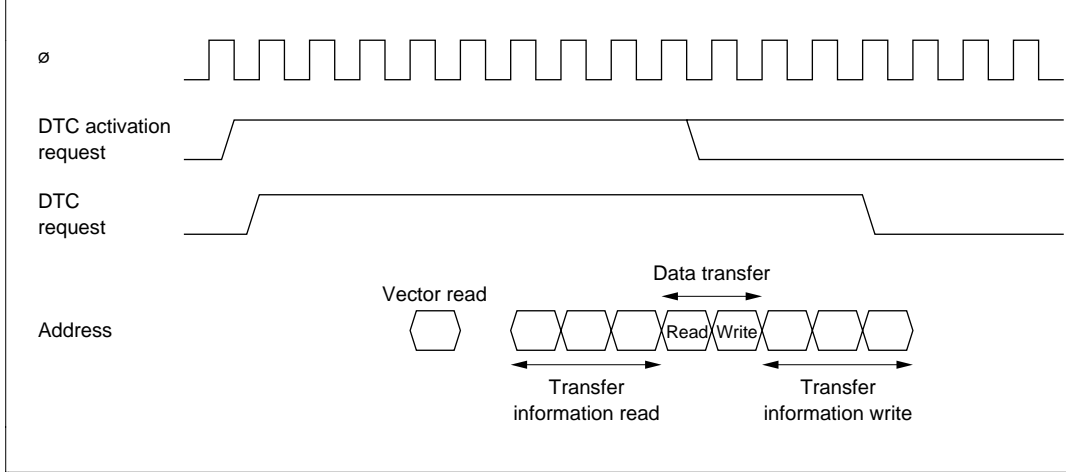


Figure 8-10 DTC Operation Timing (Example in Normal Mode or Repeat Mode)

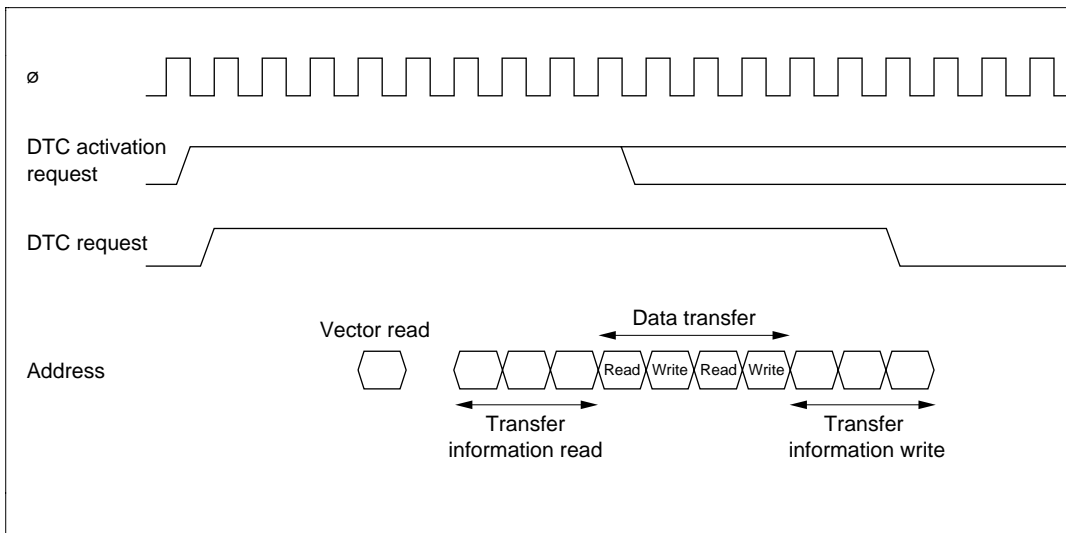


Figure 8-11 DTC Operation Timing (Example of Block Transfer Mode, with Block Size of 2)

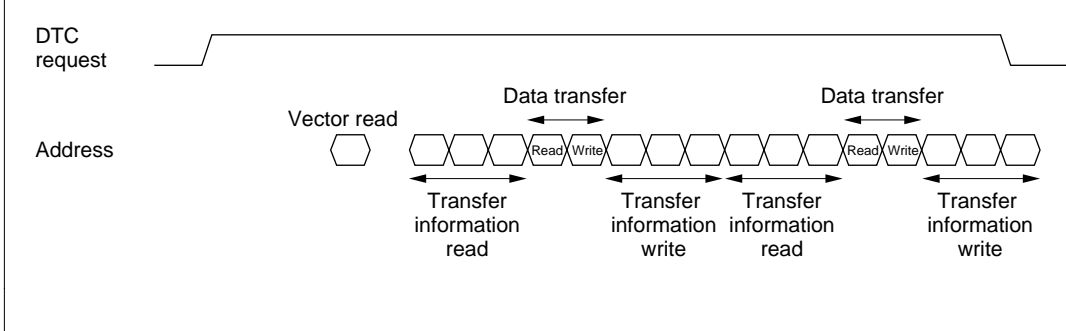


Figure 8-12 DTC Operation Timing (Example of Chain Transfer)

8.3.10 Number of DTC Execution States

Table 8-8 lists execution statuses for a single DTC data transfer, and table 8-9 shows the number of states required for each execution status.

Table 8-8 DTC Execution Statuses

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

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

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

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

$$\text{Number of execution states} = I \cdot S_I + \Sigma (J \cdot S_J + K \cdot S_K + L \cdot S_L) + M \cdot S_M$$

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

- [1] Set the MRA, MRB, SAR, DAR, CRA, and CRB register information in the on-chip RAM.
- [2] Set the start address of the register information in the DTC vector address.
- [3] Set the corresponding bit in DTCER to 1.
- [4] Set the enable bits for the interrupt sources to be used as the activation sources to 1. The DTC is activated when an interrupt used as an activation source is generated.
- [5] After the end of one data transfer, or after the specified number of data transfers have ended, 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 RAM.
- [2] Set the start address of the register information in the DTC vector address.
- [3] Check that the SWDTE bit is 0.
- [4] Write 1 to SWDTE bit and the vector number to DTVECR.
- [5] Check the vector number written to DTVECR.
- [6] After 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 ended, the SWDTE bit is held at 1 and a CPU interrupt is requested.

- [1] Set MRA to fixed source address ($SM1 = SM0 = 0$), incrementing destination address ($DM1 = 1$, $DM0 = 0$), normal mode ($MD1 = MD0 = 0$), and byte size ($Sz = 0$). The DTS bit can have any value. Set MRB for one data transfer by one interrupt ($CHNE = 0$, $DISEL = 0$). Set the SCI RDR address in SAR, the start address of the RAM area where the data will be received in DAR, and 128 (H'0080) in CRA. CRB can be set to any value.
- [2] Set the start address of the register information at the DTC vector address.
- [3] Set the corresponding bit in DTCER to 1.
- [4] Set the SCI to the appropriate receive mode. Set the RIE bit in SCR to 1 to enable the reception complete (RXI) interrupt. Since the generation of a receive error during the SCI reception operation will disable subsequent reception, the CPU should be enabled to accept receive error interrupts.
- [5] Each time reception of one byte of data ends on the SCI, the RDRF flag in SSR is set to 1, an RXI interrupt is generated, and the DTC is activated. The receive data is transferred from RDR to RAM by the DTC. DAR is incremented and CRA is decremented. The RDRF flag is automatically cleared to 0.
- [6] When CRA becomes 0 after the 128 data transfers have ended, the RDRF flag is held at 1, the DTCE bit is cleared to 0, and an RXI interrupt request is sent to the CPU. The interrupt handling routine should perform wrap-up processing.

(2) Chain Transfer

An example of DTC chain transfer is shown in which pulse output is performed using the PPG. Chain transfer can be used to perform pulse output data transfer and PPG output trigger cycle updating. Repeat mode transfer to the PPG's NDR is performed in the first half of the chain transfer, and normal mode transfer to the TPU's TGR in the second half. This is because clearing of the activation source and interrupt generation at the end of the specified number of transfers are restricted to the second half of the chain transfer (transfer when $CHNE = 0$).

- [1] Perform settings for transfer to the PPG's NDR. Set MRA to source address incrementing ($SM1 = 1$, $SM0 = 0$), fixed destination address ($DM1 = DM0 = 0$), repeat mode ($MD1 = 0$, $MD0 = 1$), and word size ($Sz = 1$). Set the source side as a repeat area ($DTS = 1$). Set MRB to chain mode ($CHNE = 1$, $DISEL = 0$). Set the data table start address in SAR, the NDRH address in DAR, and the data table size in CRAH and CRAL. CRB can be set to any value.

- [3] Locate the TPU transfer register information consecutively after the NDR transfer register information.
- [4] Set the start address of the NDR transfer register information to the DTC vector address.
- [5] Set the bit corresponding to TGIA in DTCE to 1.
- [6] Set TGRA as an output compare register (output disabled) with TIOR, and enable the TGIA interrupt with TIER.
- [7] Set the initial output value in PODR, and the next output value in NDR. Set bits in DDR and NDER for which output is to be performed to 1. Using PCR, select the TPU compare match to be used as the output trigger.
- [8] Set the CST bit in TSTR to 1, and start the TCNT count operation.
- [9] Each time a TGRA compare match occurs, the next output value is transferred to NDR and the set value of the next output trigger period is transferred to TGRA. The activation source TGFA flag is cleared.
- [10] When the specified number of transfers are completed (the TPU transfer CRA value is 0), the TGFA flag is held at 1, the DTCE bit is cleared to 0, and a TGIA interrupt request is sent to the CPU. Termination processing should be performed in the interrupt handling routine.

(3) Software Activation

An example is shown in which the DTC is used to transfer a block of 128 bytes of data by means of software activation. The transfer source address is H'1000 and the destination address is H'2000. The vector number is H'60, so the vector address is H'04C0.

- [1] Set MRA to incrementing source address (SM1 = 1, SM0 = 0), incrementing destination address (DM1 = 1, DM0 = 0), block transfer mode (MD1 = 1, MD0 = 0), and byte size (Sz = 0). The DTS bit can have any value. Set MRB for one block transfer by one interrupt (CHNE = 0). Set the transfer source address (H'1000) in SAR, the destination address (H'2000) in DAR, and 128 (H'8080) in CRA. Set 1 (H'0001) in CRB.
- [2] Set the start address of the register information at the DTC vector address (H'04C0).

- [5] Read DTVECR again and check that it is set to the vector number (H'60). If it is not, this indicates that the write failed. This is presumably because an interrupt occurred between steps 3 and 4 and led to a different software activation. To activate this transfer, go back to step 3.
- [6] If the write was successful, the DTC is activated and a block of 128 bytes of data is transferred.
- [7] After the transfer, an SWDTEND interrupt occurs. The interrupt handling routine should clear the SWDTE bit to 0 and perform other wrap-up processing.

8.4 Interrupts

An interrupt request is issued to the CPU when the DTC finishes the specified number of data transfers, or a data transfer for which the DISEL bit was set to 1. In the case of interrupt activation, the interrupt set as the activation source is generated. These interrupts to the CPU are subject to CPU mask level and interrupt controller priority level control.

In the case of activation by software, a software activated data transfer end interrupt (SWDTEND) is generated.

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 a data transfer wait or during data transfer even if the SWDTE 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 the DTC is used, the RAME bit in SYSCR must not be cleared to 0.

DMAC Transfer End Interrupt: When DTC transfer is activated by a DMAC transfer end interrupt, regardless of the transfer counter and DISEL bit, the DMAC's DTE bit is not subject to DTC control, and the write data has priority. Consequently, an interrupt request may not be sent to the CPU when the DTC transfer counter reaches 0.

DTCE Bit Setting: For DTCE bit setting, use bit manipulation instructions such as BSET and BCLR. If all interrupts are masked, multiple activation sources can be set at one time by writing data after executing a dummy read on the relevant register.

The H8S/2350 Series has 12 I/O ports (ports 1, 2, 3, 5, 6, and A to G), and one input-only port (port 4).

Table 9-1 summarizes the port functions. The pins of each port also have other functions.

Each port includes a data direction register (DDR) that controls input/output (not provided for the input-only port), a data register (DR) that stores output data, and a port register (PORT) used to read the pin states.

Ports A to E in the H8S/2351 have a built-in pull-up MOS function, and in addition to DR and DDR, have a MOS input pull-up control register (PCR) to control the on/off state of MOS input pull-up.

Port 3, and port A in the H8S/2351, have an open-drain control register (ODR) that controls the on/off state of the output buffer PMOS.

Ports A to E can drive a single TTL load and 90 pF capacitive load, and ports 1, 2, 3, 5, 6, F, and G can drive a single TTL load and 30 pF capacitive load. All the I/O ports can drive a Darlington transistor when in output mode. Ports 1, A, B, and C can drive an LED (10 mA sink current).

Port 2, and pins 6_4 to 6_7 and A_4 to A_7 , are Schmitt-triggered inputs.

For block diagrams of the ports see appendix C, I/O Port Block Diagrams.

		TCLKD P1 ₆ /PO14/ TIOCA2 P1 ₅ /PO13/ TIOCB1/ TCLKC P1 ₄ /PO12/ TIOCA1 P1 ₃ /PO11/ TIOCD0/ TCLKB P1 ₂ /PO10/ TIOCC0/ TCLKA P1 ₁ /PO9/ TIOCB0/ DACK1 P1 ₀ /PO8/ TIOCA0/ DACK0	TIOCB0, TIOCC0, TIOCD0, TIOCA1, TIOCB1, TIOCA2, TIOCB2) and PPG output pins (PO15 to PO8)
Port 2	<ul style="list-style-type: none"> • 8-bit I/O port • Schmitt-triggered input 	P2 ₇ /PO7/ TIOCB5 P2 ₆ /PO6/ TIOCA5 P2 ₅ /PO5/ TIOCB4 P2 ₄ /PO4/ TIOCA4 P2 ₃ /PO3/ TIOCD3 P2 ₂ /PO2/ TIOCC3 P2 ₁ /PO1/ TIOCB3 P2 ₀ /PO0/ TIOCA3	8-bit I/O port also functioning as TPU I/O pins (TIOCA3, TIOCB3, TIOCC3, TIOCD3, TIOCA4, TIOCB4, TIOCA5, TIOCB5), and PPG output pins (PO7 to PO0)
Port 3	<ul style="list-style-type: none"> • 6-bit I/O port • Open-drain output capability 	P3 ₅ /SCK1 P3 ₄ /SCK0 P3 ₃ /RxD1 P3 ₂ /RxD0 P3 ₁ /TxD1 P3 ₀ /TxD0	6-bit I/O port also functioning as SCL (channels 0 and 1) I/O pins (TxD0, RxD0, SCK0, TxD1, RxD1, SCK1)

Note: 1. Only applies to the H8S/2351.

		P4 ₆ /AN6/ DA0 P4 ₅ /AN5 P4 ₄ /AN4 P4 ₃ /AN3 P4 ₂ /AN2 P4 ₁ /AN1 P4 ₀ /AN0			
Port 5	• 4-bit I/O port	P5 ₃ /ADTRG P5 ₂ P5 ₁ P5 ₀	4-bit I/O port also functioning as A/D converter input pin ($\overline{\text{ADTRG}}$)		
Port 6	• 8-bit I/O port • Schmitt-triggered input (P6 ₄ to P6 ₇)	P6 ₇ /IRQ3/ $\overline{\text{CS7}}$ P6 ₆ /IRQ2/ $\overline{\text{CS6}}$ P6 ₅ /IRQ1 P6 ₄ /IRQ0 P6 ₃ / $\overline{\text{TEND1}}$ P6 ₂ / $\overline{\text{DREQ1}}$ P6 ₁ / $\overline{\text{TEND0}}$ / $\overline{\text{CS5}}$ P6 ₀ / $\overline{\text{DREQ0}}$ / $\overline{\text{CS4}}$	8-bit I/O port also functioning as DMA controller I/O pins ($\overline{\text{DREQ0}}$, $\overline{\text{TEND0}}$, $\overline{\text{DREQ1}}$, $\overline{\text{TEND1}}$) and interrupt input pins (IRQ0 to IRQ3)	8-bit I/O port also functioning as DMA controller I/O pins ($\overline{\text{DREQ0}}$, $\overline{\text{TEND0}}$, $\overline{\text{DREQ1}}$, $\overline{\text{TEND1}}$), bus control output pins ($\overline{\text{CS4}}$ to $\overline{\text{CS7}}$), and interrupt input pins ($\overline{\text{IRQ0}}$ to $\overline{\text{IRQ3}}$)	8-bit I/O port also functioning as interrupt input pins ($\overline{\text{IRQ0}}$ to $\overline{\text{IRQ3}}$)

Note: 1. Only applies to the H8S/2351.

	<ul style="list-style-type: none"> Built-in MOS input pull-up*1 Open-drain output capability*1 Schmitt-triggered input (PA₄ to PA₇) 	PA ₆ /A ₂₂ / IRQ6 PA ₅ /A ₂₁ / IRQ5	IRQ4)		as input ports and interrupt input pins (IRQ7 to IRQ5) When DDR = 1: address output	(after reset): dual function as input ports and interrupt input pins (IRQ7 to IRQ4)	as I/O ports and interrupt input pins (IRQ7 to IRQ4)	
		PA ₄ /A ₂₀ / IRQ4			Address output	When DDR = 1: address output		
		PA ₃ /A ₁₉ to PA ₀ /A ₁₆	I/O ports		Address output	When DDR = 0 (after reset): input ports When DDR = 1: address output	I/O ports	
Port B	<ul style="list-style-type: none"> 8-bit I/O port*1 Built-in MOS input pull-up*1 	PB ₇ /A ₁₅ to PB ₀ /A ₈	Address output	When DDR = 0 (after reset): input port When DDR = 1: address output	I/O port	Address output	When DDR = 0 (after reset): input port When DDR = 1: address output	I/O port
Port C	<ul style="list-style-type: none"> 8-bit I/O port*1 Built-in MOS input pull-up*1 	PC ₇ /A ₇ to PC ₀ /A ₀	Address output	When DDR = 0 (after reset): input port When DDR = 1: address output	I/O port	Address output	When DDR = 0 (after reset): input port When DDR = 1: address output	I/O port

Note: 1. Only applies to the H8S/2351.

	<ul style="list-style-type: none"> Built-in MOS input pull-up*1 					
Port E	<ul style="list-style-type: none"> 8-bit I/O port Built-in MOS input pull-up*1 	PE ₇ /D ₇ to PE ₀ /D ₀	<p>In 8-bit bus mode: I/O port</p> <p>In 16-bit bus mode: data bus input/output</p>	I/O port	<p>In 8-bit bus mode: I/O port</p> <p>In 16-bit bus mode: data bus input/output</p>	I/O port
Port F	<ul style="list-style-type: none"> 8-bit I/O port 	PF ₇ /ø	<p>When DDR = 0: input port</p> <p>When DDR = 1 (after reset): ø output</p>	<p>When DDR = 0 (after reset): input port</p> <p>When DDR = 1: ø output</p>	<p>When DDR = 0: input port</p> <p>When DDR = 1 (after reset): ø output</p>	<p>When DDR = 0 (after reset): input port</p> <p>When DDR = 1: ø output</p>
		PF ₆ /AS PF ₅ /RD PF ₄ /HWR PF ₃ /LWR	AS, RD, HWR, LWR output	I/O port	AS, RD, HWR, LWR output	I/O port
		PF ₂ /LCAS/ WAIT/ BREQO	<p>When WAITE = 0 and BREQOE = 0 (after reset): I/O port</p> <p>When WAITE = 1 and BREQOE = 0: WAIT input</p> <p>When WAITE = 0 and BREQOE = 1: BREQO input</p>	I/O port	<p>When WAITE = 0 and BREQOE = 0 (after reset): I/O port</p> <p>When WAITE = 1 and BREQOE = 0: WAIT input</p> <p>When WAITE = 0 and BREQOE = 1: BREQO output</p> <p>When RMTS2 to RMTS0 = B'001 to B'011, CW2 = 0, and LCASS = 0: LCAS output</p>	I/O port
		PF ₁ /BACK PF ₀ /BREQ	<p>When BRLE = 0 (after reset): I/O port</p> <p>When BRLE = 1: BREQ input, BACK output</p>		<p>When BRLE = 0 (after reset): I/O port</p> <p>When BRLE = 1: BREQ input, BACK output</p>	

Note: 1. Only applies to the H8S/2351.

			When DDR= 1 *3: $\overline{CS0}$ output		When DDR = 1: $\overline{CS0}$ output
		$PG_3/\overline{CS1}$ $PG_2/\overline{CS2}$ $PG_1/\overline{CS3}$	I/O port		When DDR = 0 (after reset): input port When DDR = 1: $\overline{CS1}$, $\overline{CS2}$, $\overline{CS3}$ output
		PG_0/\overline{CAS}			DRAM space set: \overline{CAS} output Otherwise (after reset): I/O port

- Notes:
1. Only applies to the H8S/2351.
 2. After a reset in mode 2 or 6
 3. After a reset in mode 1, 4 or 5

Port 1 is an 8-bit I/O port. Port 1 pins also function as PPG output pins (PO15 to PO8), TPU I/O pins (TCLKA, TCLKB, TCLKC, TCLKD, TIOCA0, TIOCB0, TIOCC0, TIOCD0, TIOCA1, TIOCB1, TIOCA2, and TIOCB2), and DMAC output pins ($\overline{\text{DACK}}_0$ and $\overline{\text{DACK}}_1$). Port 1 pin functions are the same in all operating modes.

Figure 9-1 shows the port 1 pin configuration.

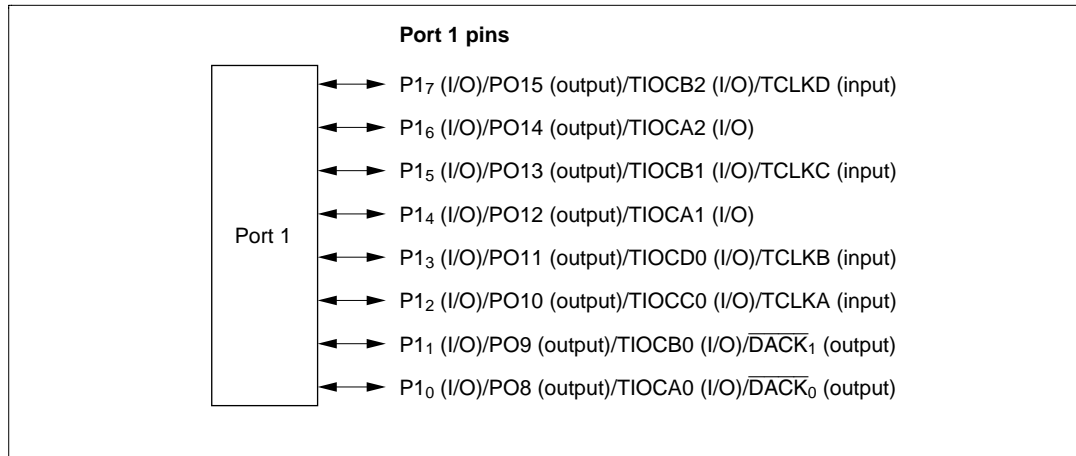


Figure 9-1 Port 1 Pin Functions

Table 9-2 Port 1 Registers

Name	Abbreviation	R/W	Initial Value	Address*
Port 1 data direction register	P1DDR	W	H'00	H'FEB0
Port 1 data register	P1DR	R/W	H'00	H'FF60
Port 1 register	PORT1	R	Undefined	H'FF50

Note: * Lower 16 bits of the address.

Port 1 Data Direction Register (P1DDR)

Bit	:	7	6	5	4	3	2	1	0
		P17DDR	P16DDR	P15DDR	P14DDR	P13DDR	P12DDR	P11DDR	P10DDR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	W	W	W	W	W	W	W	W

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

Setting a P1DDR bit to 1 makes the corresponding port 1 pin an output pin, while clearing the bit to 0 makes the pin an input pin.

P1DDR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode. As the PPG, TPU, and DMAC are initialized by a manual reset, the pin states are determined by the P1DDR and P1DR specifications.

Port 1 Data Register (P1DR)

Bit	:	7	6	5	4	3	2	1	0
		P17DR	P16DR	P15DR	P14DR	P13DR	P12DR	P11DR	P10DR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

P1DR is an 8-bit readable/writable register that stores output data for the port 1 pins (P1₇ to P1₀).

P1DR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Initial value : —* —* —* —* —* —* —* —* —* —*
R/W : R R R R R R R R R R

Note: * Determined by state of pins P1₇ to P1₀.

PORT1 is an 8-bit read-only register that shows the pin states. It cannot be written to. Writing of output data for the port 1 pins (P1₇ to P1₀) must always be performed on P1DR.

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

After a power-on reset and in hardware standby mode, PORT1 contents are determined by the pin states, as P1DDR and P1DR are initialized. PORT1 retains its prior state after a manual reset, and in software standby mode.

TIOCB2), and DMAC output pins (DACK0 and DACK1). Port 1 pin functions are shown in table 9-3.

Table 9-3 Port 1 Pin Functions

Pin Selection Method and Pin Functions

P1₇/PO15/TIOCB2/ TCLKD The pin function is switched as shown below according to the combination of the TPU channel 2 setting by bits MD3 to MD0 in TMDR2, bits IOB3 to IOB0 in TIOR2, bits CCLR1 and CCLR0 in TCR2, bits TPSC2 to TPSC0 in TCR0 and TCR5, bit NDER15 in NDERH, and bit P17DDR.

TPU Channel 2 Setting	Table Below (1)	Table Below (2)		
P17DDR	—	0	1	1
NDER15	—	—	0	1
Pin function	TIOCB2 output	P1 ₇ input	P1 ₇ output	PO15 output
		TIOCB2 input *1		
TCLKD input *2				

- Notes: 1. TIOCB2 input when MD3 to MD0 = B'0000, B'01xx, and IOB3 = 1.
 2. TCLKD input when the setting for either TCR0 or TCR5 is: TPSC2 to TPSC0 = B'111.
 TCLKD input when channels 2 and 4 are set to phase counting mode.

TPU Channel 2 Setting	(2)	(1)	(2)	(2)	(1)	(2)
MD3 to MD0	B'0000, B'01xx		B'0010	B'0011		
IOB3 to IOB0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	—	B'xx00	Other than B'xx00	
CCLR1, CCLR0	—	—	—	—	Other than B'10	B'10
Output function	—	Output compare output	—	—	PWM mode 2 output	—

x: Don't care

TIOR2, bits CCLR1 and CCLR0 in TCR2, bit NDER14 in NDERH, and bit P16DDR.

TPU Channel 2 Setting	Table Below (1)	Table Below (2)		
		P16DDR	—	0
NDER14	—	—	0	1
Pin function	TIOCA2 output	P1 ₆ input	P1 ₆ output	PO14 output
		TIOCA2 input *1		

Note: 1. TIOCA2 input when MD3 to MD0 = B'0000, B'01xx, and IOA3 = 1.

TPU Channel 2 Setting	(2)	(1)	(2)	(1)	(1)	(2)
MD3 to MD0	B'0000, B'01xx		B'001x	B'0011	B'0011	
IOA3 to IOA0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	B'xx00	Other than B'xx00		
CCLR1, CCLR0	—	—	—	—	Other than B'01	B'01
Output function	—	Output compare output	—	PWM mode 1 output *2	PWM mode 2 output	—

x: Don't care

Note: 2. TIOCB2 output is disabled.

TIOR1, bits CCLR1 and CCLR0 in TCR1, bits TPSC2 to TPSC0 in TCR0, TCR2, TCR4, and TCR5, bit NDER13 in NDERH, and bit P15DDR.

TPU Channel 1 Setting	Table Below (1)	Table Below (2)		
		0	1	1
P15DDR	—	0	1	1
NDER13	—	—	0	1
Pin function	TIOCB1 output	P1 ₅ input	P1 ₅ output	PO13 output
		TIOCB1 input * ¹		
TCLKC input * ²				

- Notes: 1. TIOCB1 input when MD3 to MD0 = B'0000, B'01xx and IOB3 to IOB0 = B'10xx.
 2. TCLKC input when the setting for either TCR0 or TCR2 is: TPSC2 to TPSC0 = B'110; or when the setting for either TCR4 or TCR5 is TPSC2 to TPSC0 = B'101.
 TCLKC input when channels 2 and 4 are set to phase counting mode.

TPU Channel 1 Setting	(2)	(1)	(2)	(2)	(1)	(2)
MD3 to MD0	B'0000, B'01xx		B'0010	B'0011		
IOB3 to IOB0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	—	B'xx00	Other than B'xx00	
CCLR1, CCLR0	—	—	—	—	Other than B'10	B'10
Output function	—	Output compare output	—	—	PWM mode 2 output	—

x: Don't care

TIOR1, bits CCLR1 and CCLR0 in TCR1, bit NDER12 in NDERH, and bit P14DDR.

TPU Channel 1 Setting	Table Below (1)	Table Below (2)		
		P14DDR	—	0
NDER12	—	—	0	1
Pin function	TIOCA1 output	P1 ₄ input	P1 ₄ output	PO12 output
		TIOCA1 input * ¹		

Note: 1. TIOCA1 input when MD3 to MD0 = B'0000, B'01xx, IOA3 to IOA0 = B'10xx.

TPU Channel 1 Setting	(2)	(1)	(2)	(1)	(1)	(2)
	MD3 to MD0	B'0000, B'01xx		B'001x	B'0010	B'0011
IOA3 to IOA0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	B'xx00	Other than B'xx00	Other than B'xx00	
CCLR1, CCLR0	—	—	—	—	Other than B'01	B'01
Output function	—	Output compare output	—	PWM mode 1 output* ²	PWM mode 2 output	—

x: Don't care

Note: 2. TIOCB1 output is disabled.

TIOR0L, bits CCLR2 to CCLR0 in TCR0, bits TPSC2 to TPSC0 in TCR0 to TCR2, bit NDER11 in NDERH, and bit P13DDR.

TPU Channel 0 Setting	Table Below (1)	Table Below (2)		
		P13DDR	—	0
NDER11	—	—	0	1
Pin function	TIOCD0 output	P1 ₃ input	P1 ₃ output	PO11 output
		TIOCD0 input *1		
	TCLKB input *2			

- Notes: 1. TIOCD0 input when MD3 to MD0 = B'0000, IOD3 to IOD0 = B'10xx.
 2. TCLKB input when the setting for TCR0 to TCR2 is: TPSC2 to TPSC0 = B'101;
 TCLKB input when channels 1 and 5 are set to phase counting mode.

TPU Channel 0 Setting	(2)	(1)	(2)	(2)	(1)	(2)
MD3 to MD0	B'0000		B'0010	B'0011		
IOD3 to IOD0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	—	B'xx00	Other than B'xx00	
CCLR2 to CCLR0	—	—	—	—	Other than B'110	B'110
Output function	—	Output compare output	—	—	PWM mode 2 output	—

x: Don't care

TIOR0L, bits CCLR2 to CCLR0 in TCR0, bits TPSC2 to TPSC0 in TCR0 to TCR5, bit NDER10 in NDERH, and bit P12DDR.

TPU Channel 0 Setting	Table Below (1)	Table Below (2)		
		P12DDR	—	0
NDER10	—	—	0	1
Pin function	TIOCC0 output	P ₁₂ input	P ₁₂ output	PO10 output
		TIOCC0 input * ¹		
	TCLKA input * ²			

- Notes: 1. TIOCC0 input when MD3 to MD0 = B'0000, and IOC3 to IOC0 = B'10xx.
 2. TCLKA input when the setting for TCR0 to TCR5 is: TPSC2 to TPSC0 = B'100;
 TCLKA input when channels 1 and 5 are set to phase counting mode.

TPU Channel 0 Setting	(2)	(1)	(2)	(1)	(1)	(2)
MD3 to MD0	B'0000		B'001x	B'0010	B'0011	
IOC3 to IOC0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	B'xx00	Other than B'xx00		
CCLR2 to CCLR0	—	—	—	—	Other than B'101	B'101
Output function	—	Output compare output	—	PWM mode 1 output* ³	PWM mode 2 output	—

x: Don't care

- Note: 3. TIOCD0 output is disabled.
 When BFA = 1 or BFB = 1 in TMDR0, output is disabled and setting (2) applies.

TIOR0H, bits CCLR2 to CCLR0 in TCR0, bit NDER9 in NDERH, bit SAE1 in DMABCRH, and bit P11DDR.

SAE1	0				1
TPU Channel 0 Setting	Table Below (1)	Table Below (2)			
P11DDR	—	0	1	1	—
NDER9	—	—	0	1	—
Pin function	TIOCB0 output	P1 ₁ input	P1 ₁ output	PO9 output	$\overline{\text{DACK1}}$ output
		TIOCB0 input * ¹			

Note: 1. TIOCB0 input when MD3 to MD0 = B'0000, and IOB3 to IOB0 = B'10xx.

TPU Channel 0 Setting	(2)	(1)	(2)	(2)	(1)	(2)
MD3 to MD0	B'0000		B'0010	B'0011		
IOB3 to IOB0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	—	B'xx00	Other than B'xx00	
CCLR2 to CCLR0	—	—	—	—	Other than B'010	B'010
Output function	—	Output compare output	—	—	PWM mode 2 output	—

x: Don't care

TIOR0H, bits CCLR2 to CCLR0 in TCR0, bit NDER8 in NDERH, bit SAE0 in DMABCRH, and bit P10DDR.

SAE0	0				1
TPU Channel 0 Setting	Table Below (1)	Table Below (2)			—
P10DDR	—	0	1	1	—
NDER8	—	—	0	1	—
Pin function	TIOCA0 output	P1 ₀ input	P1 ₀ output	PO8 output	$\overline{\text{DACK0}}$ output
		TIOCA0 input * ¹			

Note: 1. TIOCA0 input when MD3 to MD0 = B'0000, and IOA3 to IOA0 = B'10xx.

TPU Channel 0 Setting	(2)	(1)	(2)	(1)	(1)	(2)
MD3 to MD0	B'0000		B'001x	B'0010	B'0011	
IOA3 to IOA0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	B'xx00	Other than B'xx00		
CCLR2 to CCLR0	—	—	—	—	Other than B'001	B'001
Output function	—	Output compare output	—	PWM mode 1 output* ²	PWM mode 2 output	—

x: Don't care

Note: 2. TIOCB0 output is disabled.

Port 2 is an 8-bit I/O port. Port 2 pins also function as PPG output pins (PO7 to PO0) and TPU I/O pins (TIOCA3, TIOCB3, TIOCC3, TIOCD3, TIOCA4, TIOCB4, TIOCA5, and TIOCB5). Port 2 pin functions are the same in all operating modes. Port 2 uses Schmitt-triggered input.

Figure 9-2 shows the port 2 pin configuration.

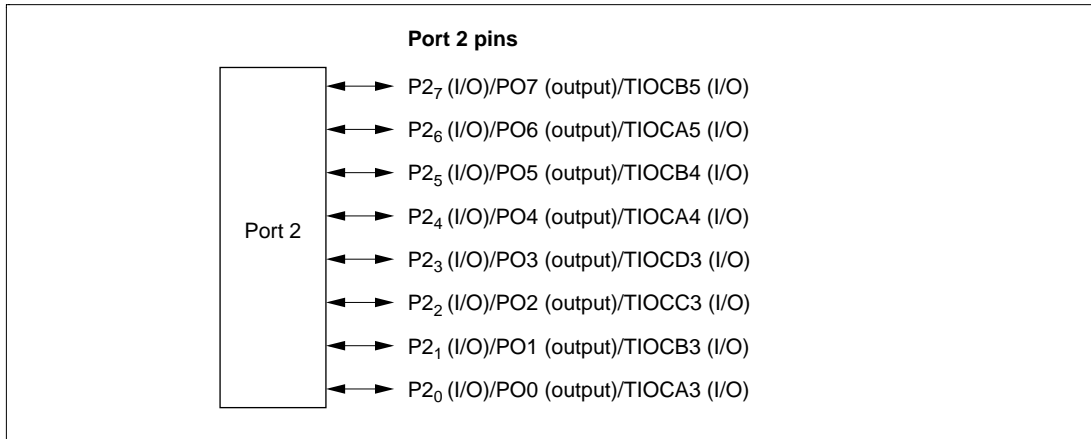


Figure 9-2 Port 2 Pin Functions

Table 9-4 Port 2 Registers

Name	Abbreviation	R/W	Initial Value	Address*
Port 2 data direction register	P2DDR	W	H'00	H'FEB1
Port 2 data register	P2DR	R/W	H'00	H'FF61
Port 2 register	PORT2	R	Undefined	H'FF51

Note: * Lower 16 bits of the address.

Port 2 Data Direction Register (P2DDR)

Bit	:	7	6	5	4	3	2	1	0
		P27DDR	P26DDR	P25DDR	P24DDR	P23DDR	P22DDR	P21DDR	P20DDR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	W	W	W	W	W	W	W	W

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

Setting a P2DDR bit to 1 makes the corresponding port 2 pin an output pin, while clearing the bit to 0 makes the pin an input pin.

P2DDR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode. As the PPG and TPU are initialized by a manual reset, the pin states are determined by the P2DDR and P2DR specifications.

Port 2 Data Register (P2DR)

Bit	:	7	6	5	4	3	2	1	0
		P27DR	P26DR	P25DR	P24DR	P23DR	P22DR	P21DR	P20DR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	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 (P₇ to P₀).

P2DR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Initial value : —* —* —* —* —* —* —* —* —*
R/W : R R R R R R R R

Note: * Determined by state of pins P2₇ to P2₀.

PORT2 is an 8-bit read-only register that shows the pin states. It cannot be written to. Writing of output data for the port 2 pins (P2₇ to P2₀) must always be performed on P2DR.

If a port 2 read is performed while P2DDR bits are set to 1, the P2DR values are read. If a port 2 read is performed while P2DDR bits are cleared to 0, the pin states are read.

After a power-on reset and in hardware standby mode, PORT2 contents are determined by the pin states, as P2DDR and P2DR are initialized. PORT2 retains its prior state after a manual reset, and in software standby mode.

Table 9-5 Port 2 Pin Functions**Pin Selection Method and Pin Functions**

P2₇/PO7/TIOCB5 The pin function is switched as shown below according to the combination of the TPU channel 5 setting by bits MD3 to MD0 in TMDR5, bits IOB3 to IOB0 in TIOR5, bits CCLR1 and CCLR0 in TCR5, bit NDER7 in NDERL, and bit P27DDR.

TPU Channel 5 Setting	Table Below (1)	Table Below (2)		
P27DDR	—	0	1	1
NDER7	—	—	0	1
Pin function	TIOCB5 output	P2 ₇ input	P2 ₇ output	PO7 output
		TIOCB5 input *		

Note: * TIOCB5 input when MD3 to MD0 = B'0000, B'01xx, and IOB3 = 1.

TPU Channel 5 Setting	(2)	(1)	(2)	(2)	(1)	(2)
MD3 to MD0	B'0000, B'01xx		B'0010	B'0011		
IOB3 to IOB0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	—	B'xx00	Other than B'xx00	
CCLR1, CCLR0	—	—	—	—	Other than B'10	B'10
Output function	—	Output compare output	—	—	PWM mode 2 output	—

x: Don't care

TIOR5, bits CCLR1 and CCLR0 in TCR5, bit NDER6 in NDERL, and bit P26DDR.

TPU Channel 5 Setting	Table Below (1)	Table Below (2)		
		P26DDR	—	0
NDER6	—	—	0	1
Pin function	TIOCA5 output	P2 ₆ input	P2 ₆ output	PO6 output
		TIOCA5 input * ¹		

Note: 1. TIOCA5 input when MD3 to MD0 = B'0000, B'01xx, and IOA3 = 1.

TPU Channel 5 Setting	(2)	(1)	(2)	(1)	(1)	(2)
MD3 to MD0	B'0000, B'01xx		B'001x	B'0010	B'0011	
IOA3 to IOA0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	B'xx00	Other than B'xx00		
CCLR1, CCLR0	—	—	—	—	Other than B'01	B'01
Output function	—	Output compare output	—	PWM mode 1 output* ²	PWM mode 2 output	—

x: Don't care

Note: 2. TIOCB5 output is disabled.

IOB0 in TIOR4, bits CCLR1 and CCLR0 in TCR4, bit NDER5 in NDERL, and bit P25DDR.

TPU Channel 4 Setting	Table Below (1)	Table Below (2)		
		P25DDR	—	0
NDER5	—	—	0	1
Pin function	TIOCB4 output	P2 ₅ input	P2 ₅ output	PO5 output
		TIOCB4 input *1		

Note: 1. TIOCB4 input when MD3 to MD0 = B'0000, B'01xx, and IOB3 to IOB0 = B'10xx.

TPU Channel 4 Setting	(2)	(1)	(2)	(2)	(1)	(2)
MD3 to MD0	B'0000, B'01xx		B'0010	B'0011		
IOB3 to IOB0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	—	B'xx00	Other than B'xx00	
CCLR1, CCLR0	—	—	—	—	Other than B'10	B'10
Output function	—	Output compare output	—	—	PWM mode 2 output	—

x: Don't care

TIOR4, bits CCLR1 and CCLR0 in TCR4, bit NDER4 in NDERL, and bit P24DDR.

TPU Channel 4 Setting	Table Below (1)	Table Below (2)		
		P24DDR	—	0
NDER4	—	—	0	1
Pin function	TIOCA4 output	P2 ₄ input	P2 ₄ output	PO4 output
		TIOCA4 input *1		
	TMRI1 input			

Note: 1. TIOCA4 input when MD3 to MD0 = B'0000, B'01xx, and IOA3 to IOA0 = B'10xx.

TPU Channel 4 Setting	(2)	(1)	(2)	(1)	(1)	(2)
MD3 to MD0	B'0000, B'01xx		B'001x	B'0010	B'0011	
IOA3 to IOA0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	B'xx00	Other than B'xx00		
CCLR1, CCLR0	—	—	—	—	Other than B'01	B'01
Output function	—	Output compare output	—	PWM mode 1 output*2	PWM mode 2 output	—

x: Don't care

Note: 2. TIOCB4 output is disabled.

TIOR3L, bits CCLR2 to CCLR0 in TCR3, bit NDER3 in NDERL, and bit P23DDR.

TPU Channel 3 Setting	Table Below (1)	Table Below (2)		
		P23DDR	—	0
NDER3	—	—	0	1
Pin function	TIOCD3 output	P ₂₃ input	P ₂₃ output	PO3 output
		TIOCD3 input * ¹		

Note: 1. TIOCD3 input when MD3 to MD0 = B'0000, and IOD3 to IOD0 = B'10xx.

TPU Channel 3 Setting	(2)	(1)	(2)	(2)	(1)	(2)
MD3 to MD0	B'0000		B'0010	B'0011		
IOD3 to IOD0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	—	B'xx00	Other than B'xx00	
CCLR2 to CCLR0	—	—	—	—	Other than B'110	B'110
Output function	—	Output compare output	—	—	PWM mode 2 output	—

x: Don't care

TIOR3L, bits CCLR2 to CCLR0 in TCR3, bit NDER2 in NDERL, and bit P22DDR.

TPU Channel 3 Setting	Table Below (1)	Table Below (2)		
P22DDR	—	0	1	1
NDER2	—	—	0	1
Pin function	TIOCC3 output	P2 ₂ input	P2 ₂ output	PO2 output
		TIOCC3 input *1		

Note: 1. TIOCC3 input when MD3 to MD0 = B'0000, and IOC3 to IOC0 = B'10xx.

TPU Channel 3 Setting	(2)	(1)	(2)	(1)	(1)	(2)
MD3 to MD0	B'0000		B'001x	B'0010	B'0011	
IOC3 to IOC0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	B'xx00	Other than B'xx00		
CCLR2 to CCLR0	—	—	—	—	Other than B'101	B'101
Output function	—	Output compare output	—	PWM mode 1 output*2	PWM mode 2 output	—

x: Don't care

Note: 2. TIOCD3 output is disabled.
When BFA = 1 or BFB = 1 in TMDR3, output is disabled and setting (2) applies.

TIOR3H, bits CCLR2 to CCLR0 in TCR3, bit NDER1 in NDERL, and bit P21DDR.

TPU Channel 3 Setting	Table Below (1)	Table Below (2)		
		P21DDR	—	0
NDER1	—	—	0	1
Pin function	TIOCB3 output	P2 ₁ input	P2 ₁ output	PO1 output
		TIOCB3 input * ¹		

Note: 1. TIOCB3 input when MD3 to MD0 = B'0000, and IOB3 to IOB0 = B'10xx.

TPU Channel 3 Setting	(2)	(1)	(2)	(2)	(1)	(2)
MD3 to MD0	B'0000		B'0010	B'0011		
IOB3 to IOB0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	—	B'xx00	Other than B'xx00	
CCLR2 to CCLR0	—	—	—	—	Other than B'010	B'010
Output function	—	Output compare output	—	—	PWM mode 2 output	—

x: Don't care

TIOR3H, bits CCLR2 to CCLR0 in TCR3, bit NDER0 in NDERL, and bit P20DDR.

TPU Channel 3 Setting	Table Below (1)	Table Below (2)		
		P20DDR	—	0
NDER0	—	—	0	1
Pin function	TIOCA3 output	P2 ₀ input	P2 ₀ output	PO0 output
		TIOCA3 input *1		

Note: 1. TIOCA3 input when MD3 to MD0 = B'0000, and IOA3 to IOA0 = B'10xx.

TPU Channel 3 Setting	(2)	(1)	(2)	(1)	(1)	(2)
MD3 to MD0	B'0000		B'001x	B'0010	B'0011	
IOA3 to IOA0	B'0000 B'0100 B'1xxx	B'0001 to B'0011 B'0101 to B'0111	B'xx00	Other than B'xx00		
CCLR2 to CCLR0	—	—	—	—	Other than B'001	B'001
Output function	—	Output compare output	—	PWM mode 1 output*2	PWM mode 2 output	—

x: Don't care

Note: 2. TIOCB3 output is disabled.

Port 3 is a 6-bit I/O port. Port 3 pins also function as SCI I/O pins (1xD0, RxD0, SCK0, 1xD1, RxD1, and SCK1). Port 3 pin functions are the same in all operating modes.

Figure 9-3 shows the port 3 pin configuration.

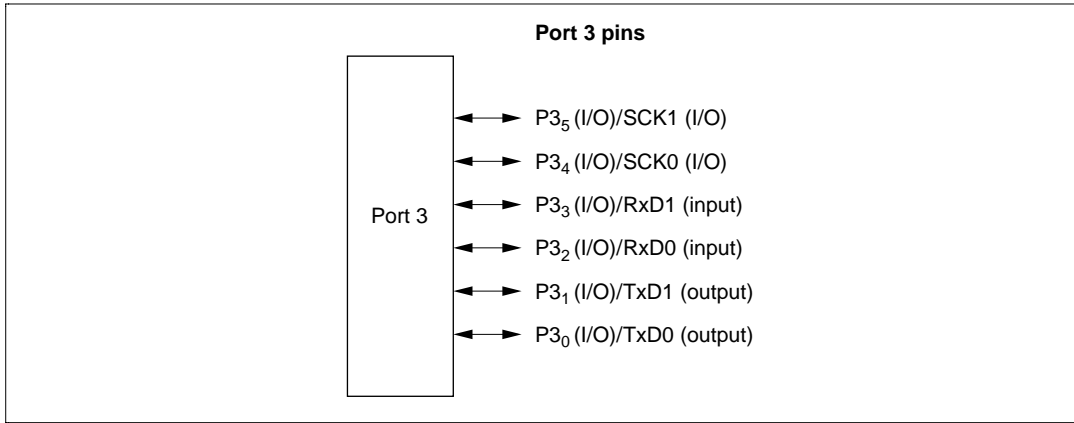


Figure 9-3 Port 3 Pin Functions

9.4.2 Register Configuration

Table 9-6 shows the port 3 register configuration.

Table 9-6 Port 3 Registers

Name	Abbreviation	R/W	Initial Value* ²	Address* ¹
Port 3 data direction register	P3DDR	W	H'00	H'FEB2
Port 3 data register	P3DR	R/W	H'00	H'FF62
Port 3 register	PORT3	R	Undefined	H'FF52
Port 3 open drain control register	P3ODR	R/W	H'00	H'FF76

Notes: 1. Lower 16 bits of the address.
2. Value of bits 5 to 0.

Initial value : Undefined Undefined 0 0 0 0 0 0
R/W : — — W W W W W W

P3DDR is an 8-bit write-only register, the individual bits of which specify input or output for the pins of port 3. Bits 7 and 6 are reserved. P3DDR cannot be read; if it is, an undefined value will be read.

Setting a P3DDR bit to 1 makes the corresponding port 3 pin an output pin, while clearing the bit to 0 makes the pin an input pin.

P3DDR is initialized to H'00 (bits 5 to 0) by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode. As the SCI is initialized, the pin states are determined by the P3DDR and P3DR specifications.

Port 3 Data Register (P3DR)

Bit	:	7	6	5	4	3	2	1	0
		—	—	P35DR	P34DR	P33DR	P32DR	P31DR	P30DR
Initial value	:	Undefined	Undefined	0	0	0	0	0	0
R/W	:	—	—	R/W	R/W	R/W	R/W	R/W	R/W

P3DR is an 8-bit readable/writable register that stores output data for the port 3 pins (P3₅ to P3₀).

Bits 7 and 6 are reserved; they return an undetermined value if read, and cannot be modified.

P3DR is initialized to H'00 (bits 5 to 0) by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Initial value : Undefined Undefined —* —* —* —* —* —*
 R/W : — — R R R R R R

Note: * Determined by state of pins P3₅ to P3₀.

PORT3 is an 8-bit read-only register that shows the pin states. Writing of output data for the port 3 pins (P3₅ to P3₀) must always be performed on P3DR.

Bits 7 and 6 are reserved; they return an undetermined value if read, and cannot be modified.

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

After a power-on reset and in hardware standby mode, PORT3 contents are determined by the pin states, as P3DDR and P3DR are initialized. PORT3 retains its prior state after a manual reset, and in software standby mode.

Port 3 Open Drain Control Register (P3ODR)

Bit	:	7	6	5	4	3	2	1	0
		—	—	P35ODR	P34ODR	P33ODR	P32ODR	P31ODR	P30ODR
Initial value	:	Undefined	Undefined	0	0	0	0	0	0
R/W	:	—	—	R/W	R/W	R/W	R/W	R/W	R/W

P3ODR is an 8-bit readable/writable register that controls the PMOS on/off status for each port 3 pin (P3₅ to P3₀).

Bits 7 and 6 are reserved; they return an undetermined value if read, and cannot be modified.

Setting a P3ODR bit to 1 makes the corresponding port 3 pin an NMOS open-drain output pin, while clearing the bit to 0 makes the pin a CMOS output pin.

P3ODR is initialized to H'00 (bits 5 to 0) by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Pin	Selection Method and Pin Functions				
-----	------------------------------------	--	--	--	--

P3₅/SCK1

The pin function is switched as shown below according to the combination of bit C/\bar{A} in the SCI1 SMR, bits CKE0 and CKE1 in SCR, and bit P35DDR.

CKE1	0				1
C/\bar{A}	0			1	—
CKE0	0		1	—	—
P35DDR	0	1	—	—	—
Pin function	P3 ₅ input pin	P3 ₅ output pin*	SCK1 output pin*	SCK1 output pin*	SCK1 input pin

Note: * When P35ODR = 1, the pin becomes an NMOS open-drain output.

P3₄/SCK0

The pin function is switched as shown below according to the combination of bit C/\bar{A} in the SCI0 SMR, bits CKE0 and CKE1 in SCR, and bit P34DDR.

CKE1	0				1
C/\bar{A}	0			1	—
CKE0	0		1	—	—
P34DDR	0	1	—	—	—
Pin function	P3 ₄ input pin	P3 ₄ output pin*	SCK0 output pin*	SCK0 output pin*	SCK0 input pin

Note: * When P34ODR = 1, the pin becomes an NMOS open-drain output.

RE	0		1
P33DDR	0	1	—
Pin function	P3 ₃ input pin	P3 ₃ output pin*	RxD1 input pin

Note: * When P33ODR = 1, the pin becomes an NMOS open-drain output.

P3₂/RxD0

The pin function is switched as shown below according to the combination of bit RE in the SCI0 SCR, and bit P32DDR.

RE	0		1
P32DDR	0	1	—
Pin function	P3 ₂ input pin	P3 ₂ output pin*	RxD0 input pin

Note: * When P32ODR = 1, the pin becomes an NMOS open-drain output.

P3₁/TxD1

The pin function is switched as shown below according to the combination of bit TE in the SCI1 SCR, and bit P31DDR.

TE	0		1
P31DDR	0	1	—
Pin function	P3 ₁ input pin	P3 ₁ output pin*	TxD1 output pin

Note: * When P31ODR = 1, the pin becomes an NMOS open-drain output.

P3₀/TxD0

The pin function is switched as shown below according to the combination of bit TE in the SCI0 SCR, and bit P30DDR.

TE	0		1
P30DDR	0	1	—
Pin function	P3 ₀ input pin	P3 ₀ output pin*	TxD0 output pin

Note: * When P30ODR = 1, the pin becomes an NMOS open-drain output.

Port 4 is an 8-bit input-only port. Port 4 pins also function as A/D converter analog input pins (AN0 to AN7) and D/A converter analog output pins (DA0 and DA1). Port 4 pin functions are the same in all operating modes. Figure 9-4 shows the port 4 pin configuration.

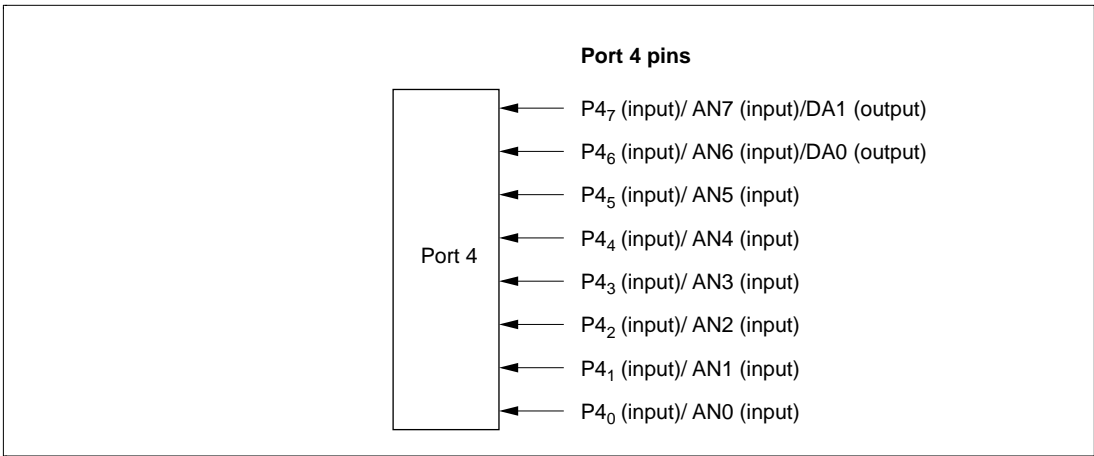


Figure 9-4 Port 4 Pin Functions

Table 9-8 Port 4 Registers

Name	Abbreviation	R/W	Initial Value	Address*
Port 4 register	PORT4	R	Undefined	H'FF53

Note: * Lower 16 bits of the address.

Port 4 Register (PORT4): The pin states are always read when a port 4 read is performed.

Bit	:	7	6	5	4	3	2	1	0
		P47	P46	P45	P44	P43	P42	P41	P40
Initial value	:	—*	—*	—*	—*	—*	—*	—*	—*
R/W	:	R	R	R	R	R	R	R	R

Note: * Determined by state of pins P4₇ to P4₀.

9.5.3 Pin Functions

Port 4 pins also function as A/D converter analog input pins (AN0 to AN7) and D/A converter analog output pins (DA0 and DA1).

Port 5 is a 4-bit I/O port. Port 5 pins also function as the A/D converter input pin ($\overline{\text{ADTRG}}$). Port 5 pin functions are the same in all operating modes. Figure 9-5 shows the port 5 pin configuration.

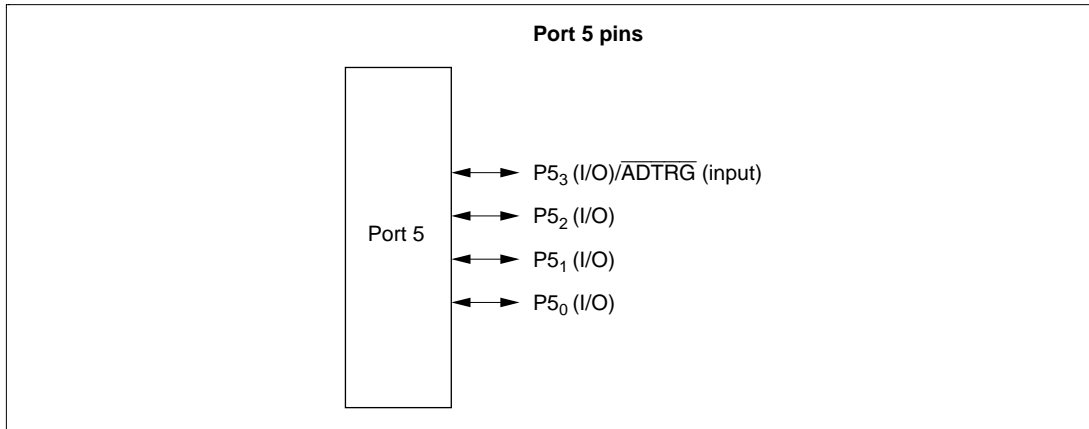


Figure 9-5 Port 5 Pin Functions

9.6.2 Register Configuration

Table 9-9 shows the port 5 register configuration.

Table 9-9 Port 5 Registers

Name	Abbreviation	R/W	Initial Value* ²	Address* ¹
Port 5 data direction register	P5DDR	W	H'0	H'FEB4
Port 5 data register	P5DR	R/W	H'0	H'FF64
Port 5 register	PORT5	R	Undefined	H'FF54

Notes: 1. Lower 16 bits of the address.
2. Value of bits 3 to 0.

Initial value	:	Undefined	Undefined	Undefined	Undefined	0	0	0	0
R/W	:	—	—	—	—	W	W	W	W

P5DDR is an 8-bit write-only register, the individual bits of which specify input or output for the pins of port 5. Bits 7 to 4 are reserved. P5DDR cannot be read; if it is, an undefined value will be read.

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

P5DDR is initialized to H'0 (bits 3 to 0) by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Port 5 Data Register (P5DR)

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	P53DR	P52DR	P51DR	P50DR
Initial value	:	Undefined	Undefined	Undefined	Undefined	0	0	0	0
R/W	:	—	—	—	—	R/W	R/W	R/W	R/W

P5DR is an 8-bit readable/writable register that stores output data for the port 5 pins (P5₃ to P5₀).

Bits 7 to 4 are reserved; they return an undetermined value if read, and cannot be modified.

P5DR is initialized to H'0 (bits 3 to 0) by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Port 5 Register (PORT5)

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	P53	P52	P51	P50
Initial value	:	Undefined	Undefined	Undefined	Undefined	—*	—*	—*	—*
R/W	:	—	—	—	—	R	R	R	R

Note: * Determined by state of pins P5₃ to P5₀.

PORT5 is an 8-bit read-only register that shows the pin states. It cannot be written to. Writing of output data for the port 5 pins (P5₃ to P5₀) must always be performed on P5DR.

After a power-on reset and in hardware standby mode, PORT5 contents are determined by the pin states, as P5DDR and P5DR are initialized. PORT5 retains its prior state after a manual reset, and in software standby mode.

9.6.3 Pin Functions

Port 5 pins also function as the A/D converter input pin ($\overline{\text{ADTRG}}$). Port 5 pin functions are shown in table 9-10.

Table 9-10 Port 5 Pin Functions

Pin	Selection Method and Pin Functions		
P5 ₃ / $\overline{\text{ADTRG}}$	The pin function is switched as shown below according to the combination of bits TRGS1 and TRGS0 in the A/D converter ADCR, and bit P53DDR.		
	P53DDR	0	1
	Pin function	P5 ₃ input pin	P5 ₃ output pin
	$\overline{\text{ADTRG}}$ input pin*		
Note: * $\overline{\text{ADTRG}}$ input when TRGS0 = TRGS1 = 1.			
P5 ₂	The pin function is switched as shown below according to bit P52DDR.		
	P52DDR	0	1
	Pin function	P5 ₂ input pin	P5 ₂ output pin
P5 ₁	The pin function is switched as shown below according to bit P51DDR.		
	P51DDR	0	1
	Pin function	P5 ₁ input pin	P5 ₁ output pin
P5 ₀	The pin function is switched as shown below according to bit P50DDR.		
	P50DDR	0	1
	Pin function	P5 ₀ input pin	P5 ₀ output pin

Port 6 is an 8-bit I/O port. Port 6 pins also function as interrupt pins ($\overline{\text{IRQ0}}$ to $\overline{\text{IRQ3}}$), DMAC I/O pins ($\overline{\text{DREQ0}}$, $\overline{\text{TEND0}}$, $\overline{\text{DREQ1}}$, and $\overline{\text{TEND1}}$), and bus control output pins ($\overline{\text{CS4}}$ to $\overline{\text{CS7}}$). The functions of pins P6₅ to P6₂ are the same in all operating modes, while the functions of pins P6₇, P6₆, P6₁, and P6₀ change according to the operating mode. Pins P6₇ to P6₄ are schmitt-triggered inputs. Figure 9-6 shows the port 6 pin configuration.

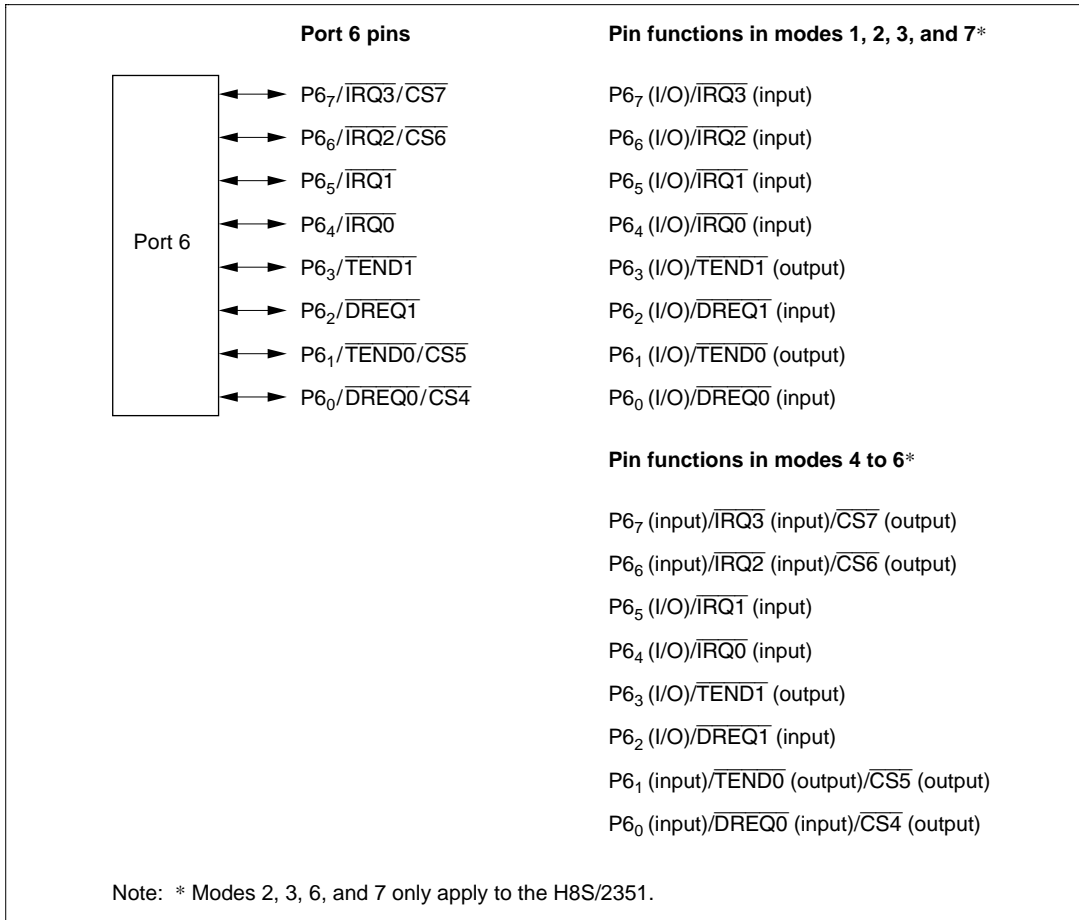


Figure 9-6 Port 6 Pin Functions

Table 9-11 Port 6 Registers

Name	Abbreviation	R/W	Initial Value	Address*
Port 6 data direction register	P6DDR	W	H'00	H'FEB5
Port 6 data register	P6DR	R/W	H'00	H'FF65
Port 6 register	PORT6	R	Undefined	H'FF55

Note: * Lower 16 bits of the address.

Port 6 Data Direction Register (P6DDR)

Bit	:	7	6	5	4	3	2	1	0
		P67DDR	P66DDR	P65DDR	P64DDR	P63DDR	P62DDR	P61DDR	P60DDR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	W	W	W	W	W	W	W	W

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

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

P6DDR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode. As the DMAC is initialized by a manual reset, the pin states are determined by the P6DDR and P6DR specifications.

Port 6 Data Register (P6DR)

Bit	:	7	6	5	4	3	2	1	0
		P67DR	P66DR	P65DR	P64DR	P63DR	P62DR	P61DR	P60DR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

P6DR is an 8-bit readable/writable register that stores output data for the port 6 pins (P6₇ to P6₀).

P6DR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Initial value :	—*	—*	—*	—*	—*	—*	—*	—*	—*
RW :	R	R	R	R	R	R	R	R	R

Note: * Determined by state of pins P6₇ to P6₀.

PORT6 is an 8-bit read-only register that shows the pin states. It cannot be written to. Writing of output data for the port 6 pins (P6₇ to P6₀) must always be performed on P6DR.

If a port 6 read is performed while P6DDR bits are set to 1, the P6DR values are read. If a port 6 read is performed while P6DDR bits are cleared to 0, the pin states are read.

After a power-on reset and in hardware standby mode, PORT6 contents are determined by the pin states, as P6DDR and P6DR are initialized. PORT6 retains its prior state after a manual reset, and in software standby mode.

Table 9-12 Port 6 Pin Functions

Pin	Selection Method and Pin Functions			
P6 ₇ / $\overline{\text{IRQ3}}$ / $\overline{\text{CS7}}$	The pin function is switched as shown below according to bit P67DDR.			
	Mode	Modes 1, 2, 3, 7*		Modes 4 to 6*
	P67DDR	0	1	0 1
	Pin function	P6 ₇ input pin	P6 ₇ output pin	P6 ₇ input pin $\overline{\text{CS7}}$ output pin
	$\overline{\text{IRQ3}}$ interrupt input pin			
P6 ₆ / $\overline{\text{IRQ2}}$ / $\overline{\text{CS6}}$	The pin function is switched as shown below according to bit P66DDR.			
	Mode	Modes 1, 2, 3, 7*		Modes 4 to 6*
	P66DDR	0	1	0 1
	Pin function	P6 ₆ input pin	P6 ₆ output pin	P6 ₆ input pin $\overline{\text{CS6}}$ output pin
	$\overline{\text{IRQ2}}$ interrupt input pin			
P6 ₅ / $\overline{\text{IRQ1}}$	The pin function is switched as shown below according to bit P65DDR.			
	P65DDR	0		1
	Pin function	P6 ₅ input pin		P6 ₅ output pin
		$\overline{\text{IRQ1}}$ interrupt input pin		
P6 ₄ / $\overline{\text{IRQ0}}$	The pin function is switched as shown below according to bit P64DDR.			
	P64DDR	0		1
	Pin function	P6 ₄ input pin		P6 ₄ output pin
		$\overline{\text{IRQ0}}$ interrupt input pin		

Note: * Modes 2, 3, 6, and 7 only apply to the H8S/2351.

TEE1	0		1
P63DDR	0	1	—
Pin function	P6 ₃ input pin	P6 ₃ output pin	$\overline{\text{TEND1}}$ output

P6₂/ $\overline{\text{DREQ1}}$

The pin function is switched as shown below according to bit P62DDR.

P62DDR	0		1
Pin function	P6 ₂ input pin		P6 ₂ output pin
	$\overline{\text{DREQ1}}$ input		

P6₁/ $\overline{\text{TEND0}}$ / $\overline{\text{CS5}}$

The pin function is switched as shown below according to the combination of bit TEE0 in the DMAC DMATCR, and bit P61DDR.

Mode	Modes 1, 2, 3, 7*			Modes 4 to 6*		
TEE0	0		1	0		1
P61DDR	0	1	—	0	1	—
Pin function	P6 ₁ input pin	P6 ₁ output pin	$\overline{\text{TEND0}}$ output	P6 ₁ input pin	$\overline{\text{CS5}}$ output pin	$\overline{\text{TEND0}}$ output

P6₀/ $\overline{\text{DREQ0}}$ / $\overline{\text{CS4}}$

The pin function is switched as shown below according to bit P60DDR.

Mode	Modes 1, 2, 3, 7*			Modes 4 to 6*		
P60DDR	0		1	0		1
Pin function	P6 ₀ input pin	P6 ₀ output pin	P6 ₀ input pin	$\overline{\text{CS4}}$ output pin		
	$\overline{\text{DREQ0}}$ input					

Note: * Modes 2, 3, 6, and 7 only apply to the H8S/2351.

Port A is an 8-bit I/O port. Port A pins also function as address bus outputs and interrupt input pins ($\overline{\text{IRQ4}}$ to $\overline{\text{IRQ7}}$). The pin functions change according to the operating mode.

Port A has a built-in MOS input pull-up function that can be controlled by software (H8S/2351 only). Pins PA₇ to PA₄ are schmitt-triggered inputs.

Figure 9-7 shows the port A pin configuration.

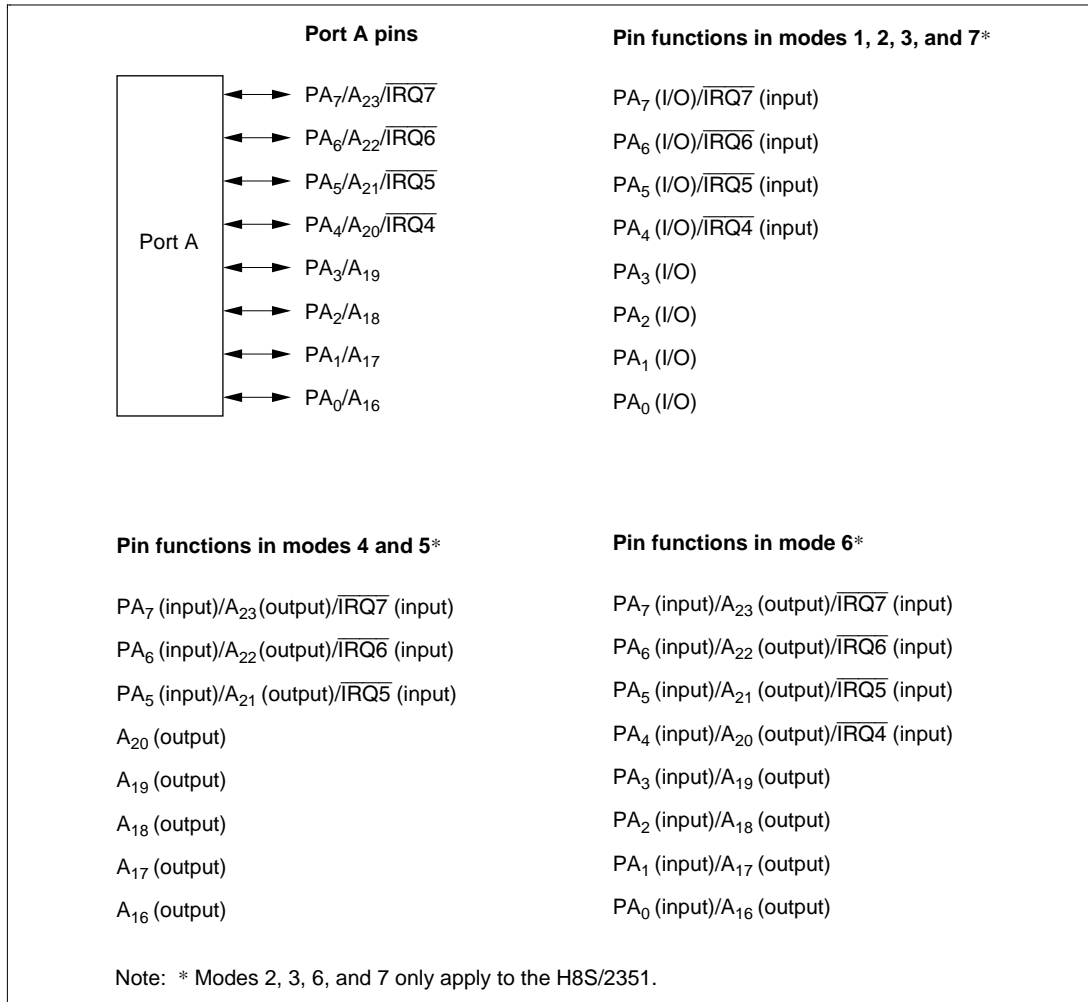


Figure 9-7 Port A Pin Functions

Name	Abbreviation	R/W	Initial Value	Address* ¹
Port A data direction register	PADDR	W	H'00	H'FEB9
Port A data register	PADR	R/W	H'00	H'FF69
Port A register	PORTA	R	Undefined	H'FF59
Port A MOS pull-up control register* ²	PAPCR	R/W	H'00	H'FF70
Port A open-drain control register* ²	PAODR	R/W	H'00	H'FF77

Notes: 1. Lower 16 bits of the address.
2. Only applies to the H8S/2351.

Port A Data Direction Register (PADDR)

Bit	:	7	6	5	4	3	2	1	0
		PA7DDR	PA6DDR	PA5DDR	PA4DDR	PA3DDR	PA2DDR	PA1DDR	PA0DDR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	W	W	W	W	W	W	W	W

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

PADDR is initialized to H'00 by a power-on reset and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode. The OPE bit in SBYCR is used to select whether the address output pins retain their output state or become high-impedance when a transition is made to software standby mode.

- Modes 1, 2, 3, and 7*

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

- Modes 4 and 5

The corresponding port A pins are address outputs irrespective of the value of bits PA4DDR to PA0DDR.

Setting one of bits PA7DDR to PA5DDR to 1 makes the corresponding port A pin an address output, while clearing the bit to 0 makes the pin an input port.

Port A Data Register (PADR)

Bit	:	7	6	5	4	3	2	1	0
		PA7DR	PA6DR	PA5DR	PA4DR	PA3DR	PA2DR	PA1DR	PA0DR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

PADR is an 8-bit readable/writable register that stores output data for the port A pins (PA₇ to PA₀).

PADR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Port A Register (PORTA)

Bit	:	7	6	5	4	3	2	1	0
		PA7	PA6	PA5	PA4	PA3	PA2	PA1	PA0
Initial value	:	—*	—*	—*	—*	—*	—*	—*	—*
R/W	:	R	R	R	R	R	R	R	R

Note: * Determined by state of pins PA₇ to PA₀.

PORTA is an 8-bit read-only register that shows the pin states. It cannot be written to. Writing of output data for the port A pins (PA₇ to PA₀) must always be performed on PADR.

If a port A read is performed while PADDR bits are set to 1, the PADR values are read. If a port A read is performed while PADDR bits are cleared to 0, the pin states are read.

After a power-on reset and in hardware standby mode, PORTA contents are determined by the pin states, as PADDR and PADR are initialized. PORTA retains its prior state after a manual reset, and in software standby mode.

Initial value : 0 0 0 0 0 0 0 0 0
 R/W : R/W R/W R/W R/W R/W R/W R/W R/W R/W

PAPCR is an 8-bit readable/writable register that controls the MOS input pull-up function incorporated into port A on an individual bit basis.

All the bits are valid in modes 1, 2, 3, 6, and 7, and bits 7 to 5 are valid in modes 4 and 5. When a PADDR bit is cleared to 0 (input port setting), setting the corresponding PAPCR bit to 1 turns on the MOS input pull-up for the corresponding pin.

PAPCR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Port A Open Drain Control Register (PAODR) [H8S/2351 Only]

Bit	:	7	6	5	4	3	2	1	0
		PA7ODR	PA6ODR	PA5ODR	PA4ODR	PA3ODR	PA2ODR	PA1ODR	PA0ODR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

PAODR is an 8-bit readable/writable register that controls whether PMOS is on or off for each port A pin (PA₇ to PA₀).

All bits are valid in modes 1, 2, 3, and 7.

Setting a PAODR bit to 1 makes the corresponding port A pin an NMOS open-drain output, while clearing the bit to 0 makes the pin a CMOS output.

PAODR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

while clearing the bit to 0 makes the pin an input port.

Port A pin functions in modes 1, 2, 3, and 7* are shown in figure 9-8.

Note: * Modes 2, 3, and 7 only apply to the H8S/2351.

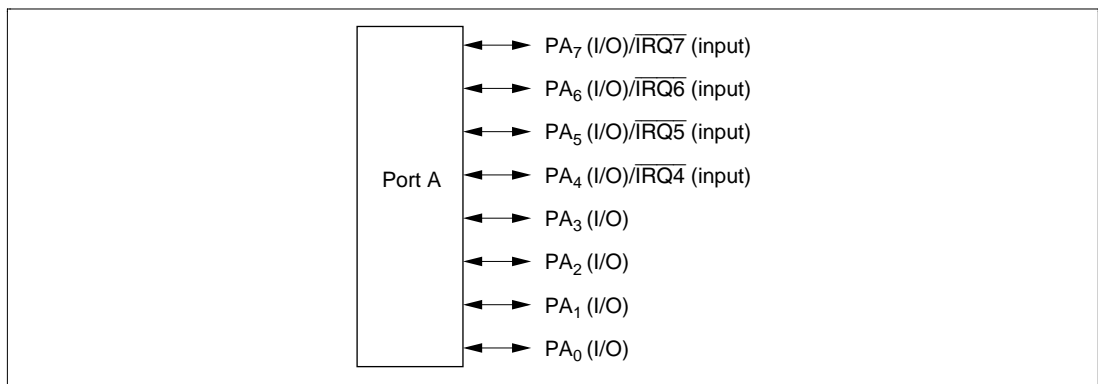


Figure 9-8 Port A Pin Functions (Modes 1, 2, 3, and 7)

the bit to 0 makes the pin an input port.

Port A pin functions in modes 4 and 5 are shown in figure 9-9.

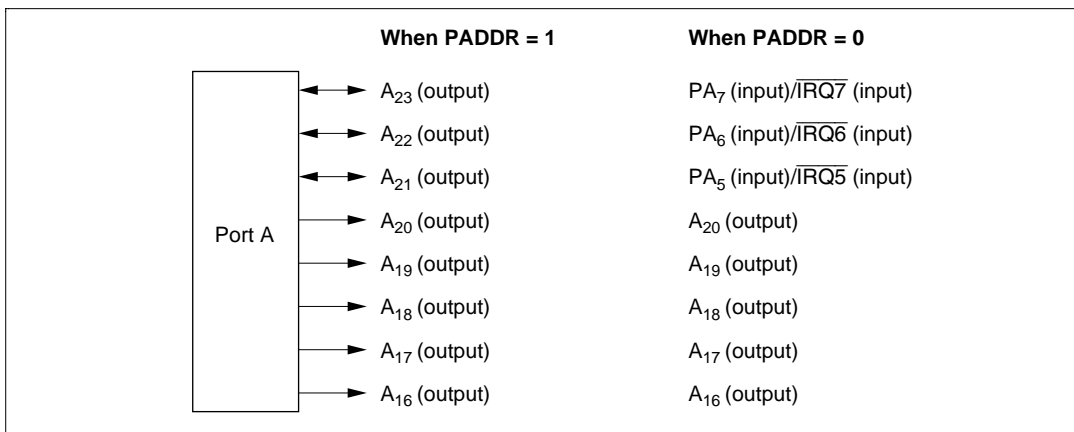


Figure 9-9 Port A Pin Functions (Modes 4 and 5)

Mode 6 [H8S/2351 Only]: In mode 6, port A pins function as address outputs or input ports and interrupt input pins. Input or output can be specified on an individual bit basis. Setting a PADDR bit to 1 makes the corresponding port A pin an address output, while clearing the bit to 0 makes the pin an input port.

Port A pin functions in mode 6 are shown in figure 9-10.

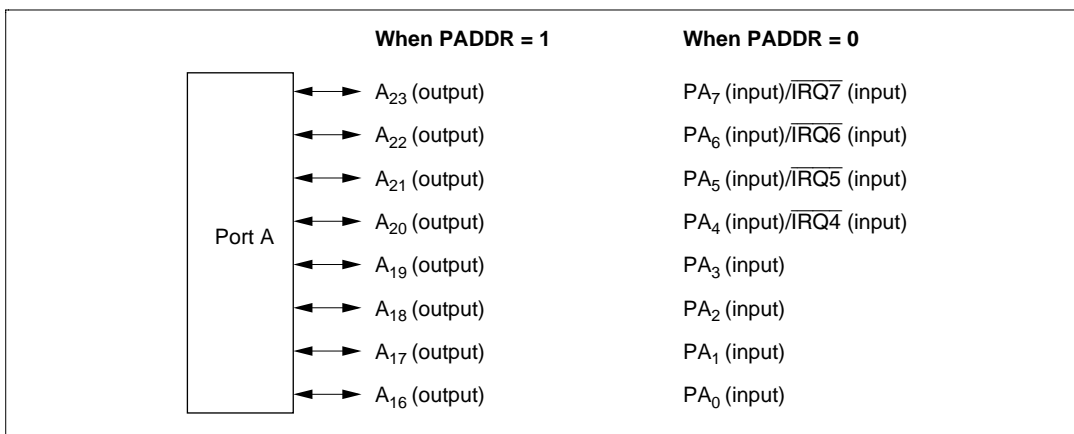


Figure 9-10 Port A Pin Functions (Mode 6)

When a PADDR bit is cleared to 0, setting the corresponding PAPCR 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 power-on reset, and in hardware standby mode. The prior state is retained after a manual reset, and in software standby mode.

Table 9-14 summarizes the MOS input pull-up states.

Table 9-14 MOS Input Pull-Up States (Port A)

Modes	Power-On Reset	Hardware Standby Mode	Manual Reset	Software Standby Mode	In Other Operations
1 to 3, 6, 7 PA ₇ to PA ₀	OFF		ON/OFF		
4, 5 PA ₇ to PA ₅			ON/OFF		
PA ₄ to PA ₀			OFF		

Legend:

OFF : MOS input pull-up is always off.

ON/OFF : On when PADDR = 0 and PAPCR = 1; otherwise off.

Port B is an 8-bit I/O port. Port B has an address bus output function, and the pin functions change according to the operating mode. However, in the H8S/2350, port B pins function only as address outputs.

Port B has a built-in MOS input pull-up function that can be controlled by software (H8S/2351 only).

Figure 9-11 shows the port B pin configuration.

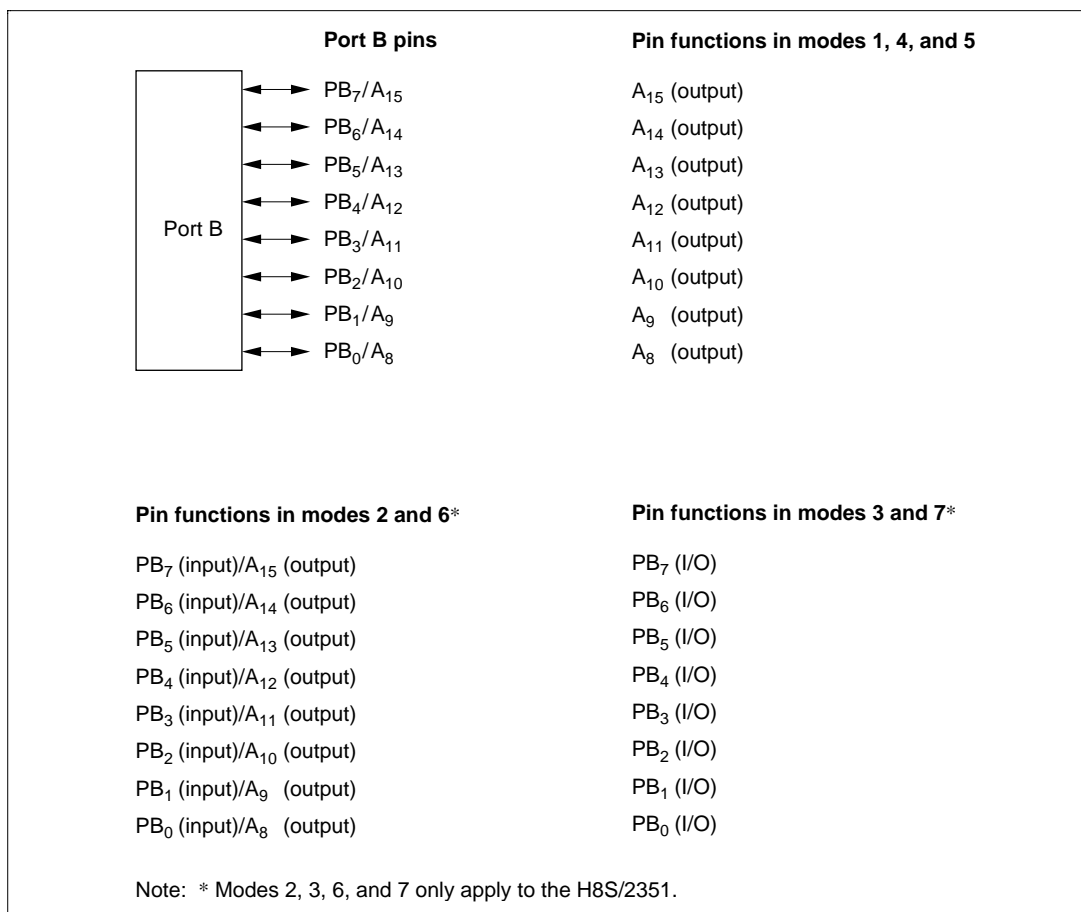


Figure 9-11 Port B Pin Functions

Table 9-13 Port B Registers

Name	Abbreviation	R/W	Initial Value	Address *
Port B data direction register	PBDDR	W	H'00	H'FEBA
Port B data register	PBDR	R/W	H'00	H'FF6A
Port B register	PORTB	R	Undefined	H'FF5A
Port B MOS pull-up control register	PBPCR	R/W	H'00	H'FF71

Note: * Lower 16 bits of the address.

Port B Data Direction Register (PBDDR) [H8S/2351 Only]

Bit	:	7	6	5	4	3	2	1	0								
		<table border="1"> <tr> <td>PB7DDR</td> <td>PB6DDR</td> <td>PB5DDR</td> <td>PB4DDR</td> <td>PB3DDR</td> <td>PB2DDR</td> <td>PB1DDR</td> <td>PB0DDR</td> </tr> </table>								PB7DDR	PB6DDR	PB5DDR	PB4DDR	PB3DDR	PB2DDR	PB1DDR	PB0DDR
PB7DDR	PB6DDR	PB5DDR	PB4DDR	PB3DDR	PB2DDR	PB1DDR	PB0DDR										
Initial value	:	0	0	0	0	0	0	0	0								
R/W	:	W	W	W	W	W	W	W	W								

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

PBDDR is initialized to H'00 by a power-on reset and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode. The OPE bit in SBYCR is used to select whether the address output pins retain their output state or become high-impedance when a transition is made to software standby mode.

- Modes 1, 4, and 5
The corresponding port B pins are address outputs irrespective of the value of the PBDDR bits.
- Modes 2 and 6
Setting a PBDDR bit to 1 makes the corresponding port B pin an address output, while clearing the bit to 0 makes the pin an input port.
- Modes 3 and 7
Setting a PBDDR bit to 1 makes the corresponding port B pin an output port, while clearing the bit to 0 makes the pin an input port.

Initial value : 0 0 0 0 0 0 0 0 0
 R/W : R/W R/W R/W R/W R/W R/W R/W R/W R/W

PBDR is an 8-bit readable/writable register that stores output data for the port B pins (PB₇ to PB₀). PBDR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Port B Register (PORTB) [H8S/2351 Only]

Bit	:	7	6	5	4	3	2	1	0
		PB7	PB6	PB5	PB4	PB3	PB2	PB1	PB0
Initial value	:	—*	—*	—*	—*	—*	—*	—*	—*
R/W	:	R	R	R	R	R	R	R	R

Note: * Determined by state of pins PB₇ to PB₀.

PORTB is an 8-bit read-only register that shows the pin states. It cannot be written to. Writing of output data for the port B pins (PB₇ to PB₀) must always be performed on PBDR.

If a port B read is performed while PBDDR bits are set to 1, the PBDR values are read. If a port B read is performed while PBDDR bits are cleared to 0, the pin states are read.

After a power-on reset and in hardware standby mode, PORTB contents are determined by the pin states, as PBDDR and PBDR are initialized. PORTB retains its prior state after a manual reset, and in software standby mode.

Initial value : 0 0 0 0 0 0 0 0 0
 R/W : R/W R/W R/W R/W R/W R/W R/W R/W

PBPCR is an 8-bit readable/writable register that controls the MOS input pull-up function incorporated into port B on an individual bit basis.

When a PBDDR bit is cleared to 0 (input port setting) in mode 2, 3, 6, or 7, setting the corresponding PBPCR bit to 1 turns on the MOS input pull-up for the corresponding pin.

PBPCR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

9.9.3 Pin Functions

Modes 1, 4, and 5: In modes 1, 4, and 5, port B pins are automatically designated as address outputs.

Port B pin functions in modes 1, 4, and 5 are shown in figure 9-12.

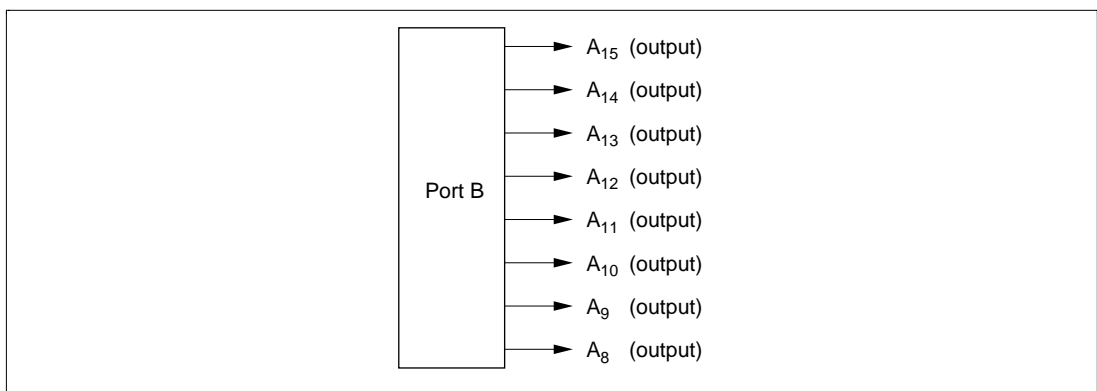


Figure 9-12 Port B Pin Functions (Modes 1, 4, and 5)

Port B pin functions in modes 2 and 6 are shown in figure 9-13.

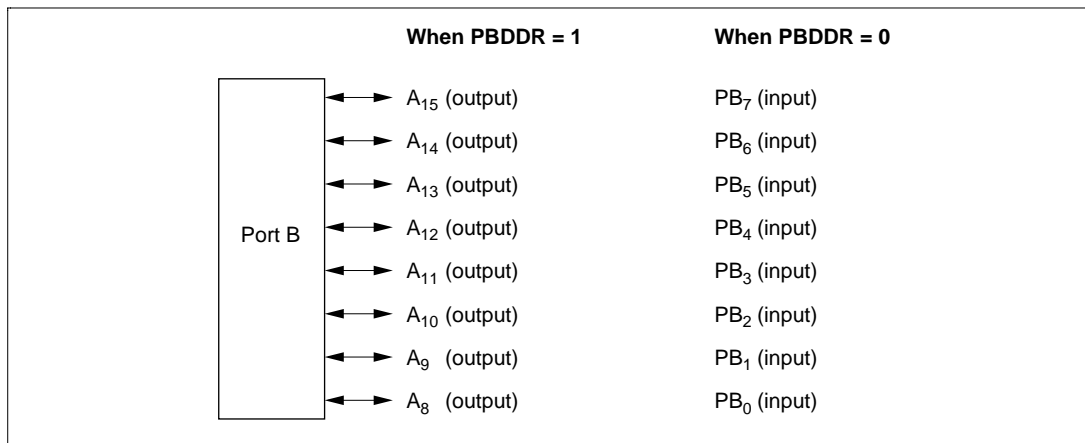


Figure 9-13 Port B Pin Functions (Modes 2 and 6)

Modes 3 and 7 [H8S/2351 Only]: In modes 3 and 7, port B pins function as I/O ports. Input or output can be specified for each pin on an individual bit basis. Setting a PBDDR bit to 1 makes the corresponding port B pin an output port, while clearing the bit to 0 makes the pin an input port.

Port B pin functions in modes 3 and 7 are shown in figure 9-14.

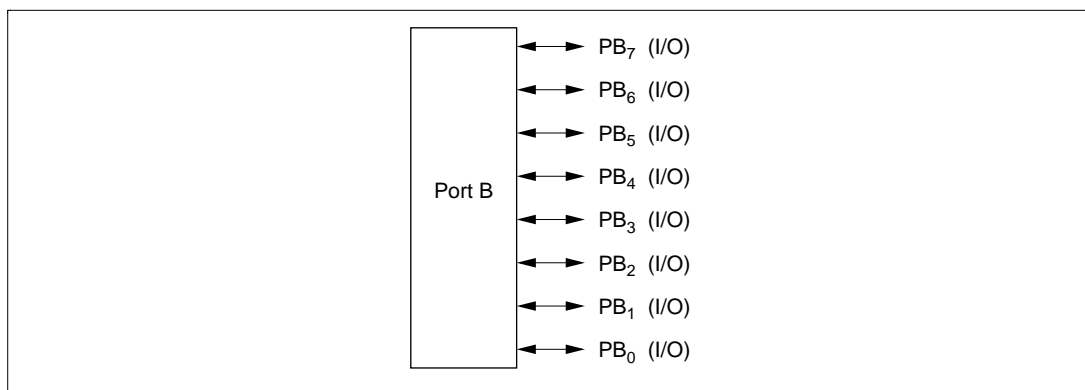


Figure 9-14 Port B Pin Functions (Modes 3 and 7)

individual bit basis.

When a PBDDR bit is cleared to 0 in mode 2, 3, 6, or 7, setting the corresponding PBPCR 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 power-on reset, and in hardware standby mode. The prior state is retained after a manual reset, and in software standby mode.

Table 9-16 summarizes the MOS input pull-up states.

Table 9-16 MOS Input Pull-Up States (Port B)

Modes	Power-On Reset	Hardware Standby Mode	Manual Reset	Software Standby Mode	In Other Operations
1, 4, 5	OFF		OFF		
2, 3, 6, 7			ON/OFF		

Legend:

OFF : MOS input pull-up is always off.

ON/OFF : On when PBDDR = 0 and PBPCR = 1; otherwise off.

Port C is an 8-bit I/O port. Port C has an address bus output function, and the pin functions change according to the operating mode. However, in the H8S/2350, port C pins function only as address outputs.

Port C has a built-in MOS input pull-up function that can be controlled by software (H8S/2351 Only).

Figure 9-15 shows the port C pin configuration.

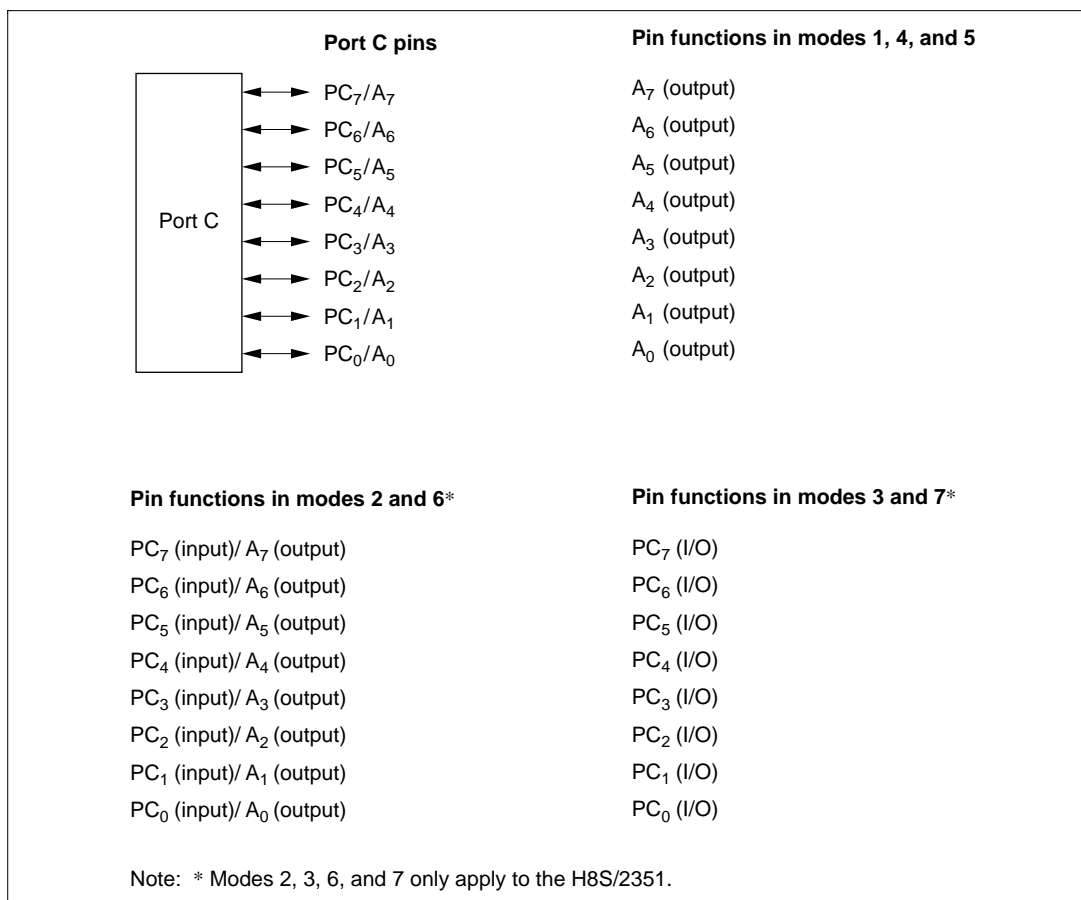


Figure 9-15 Port C Pin Functions

Table 9-17 Port C Registers

Name	Abbreviation	R/W	Initial Value	Address *
Port C data direction register	PCDDR	W	H'00	H'FE8B
Port C data register	PCDR	R/W	H'00	H'FF6B
Port C register	PORTC	R	Undefined	H'FF5B
Port C MOS pull-up control register	PCPCR	R/W	H'00	H'FF72

Note: * Lower 16 bits of the address.

Port C Data Direction Register (PCDDR) [H8S/2351 Only]

Bit	:	7	6	5	4	3	2	1	0
		PC7DDR	PC6DDR	PC5DDR	PC4DDR	PC3DDR	PC2DDR	PC1DDR	PC0DDR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	W	W	W	W	W	W	W	W

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

PCDDR is initialized to H'00 by a power-on reset and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode. The OPE bit in SBYCR is used to select whether the address output pins retain their output state or become high-impedance when a transition is made to software standby mode.

- Modes 1, 4, and 5
The corresponding port C pins are address outputs irrespective of the value of the PCDDR bits.
- Modes 2 and 6
Setting a PCDDR bit to 1 makes the corresponding port C pin an address output, while clearing the bit to 0 makes the pin an input port.
- Modes 3 and 7
Setting a PCDDR bit to 1 makes the corresponding port C pin an output port, while clearing the bit to 0 makes the pin an input port.

Initial value : 0 0 0 0 0 0 0 0 0
 R/W : R/W R/W R/W R/W R/W R/W R/W R/W R/W

PCDR is an 8-bit readable/writable register that stores output data for the port C pins (PC₇ to PC₀).

PCDR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Port C Register (PORTC) [H8S/2351 Only]

Bit	:	7	6	5	4	3	2	1	0
		PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0
Initial value	:	—*	—*	—*	—*	—*	—*	—*	—*
R/W	:	R	R	R	R	R	R	R	R

Note: * Determined by state of pins PC₇ to PC₀.

PORTC is an 8-bit read-only register that shows the pin states. It cannot be written to. Writing of output data for the port C pins (PC₇ to PC₀) must always be performed on PCDR.

If a port C read is performed while PCDDR bits are set to 1, the PCDR values are read. If a port C read is performed while PCDDR bits are cleared to 0, the pin states are read.

After a power-on reset and in hardware standby mode, PORTC contents are determined by the pin states, as PCDDR and PCDR are initialized. PORTC retains its prior state after a manual reset, and in software standby mode.

Initial value : 0 0 0 0 0 0 0 0 0
 R/W : R/W R/W R/W R/W R/W R/W R/W R/W

PCPCR is an 8-bit readable/writable register that controls the MOS input pull-up function incorporated into port C on an individual bit basis.

When a PCDDR bit is cleared to 0 (input port setting) in mode 2, 3, 6, or 7, setting the corresponding PCPCR bit to 1 turns on the MOS input pull-up for the corresponding pin.

PCPCR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

9.10.3 Pin Functions

Modes 1, 4, and 5: In modes 1, 4, and 5, port C pins are automatically designated as address outputs.

Port C pin functions in modes 1, 4, and 5 are shown in figure 9-16.

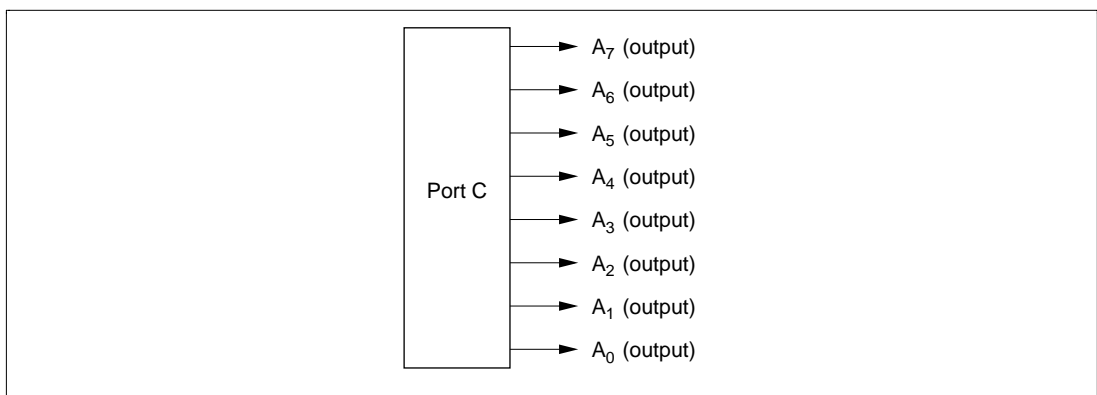


Figure 9-16 Port C Pin Functions (Modes 1, 4, and 5)

Port C pin functions in modes 2 and 6 are shown in figure 9-17.

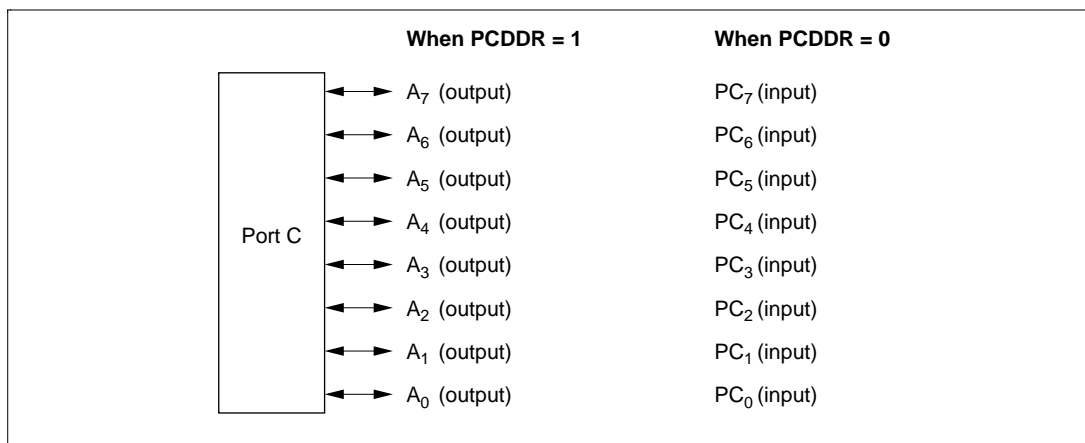


Figure 9-17 Port C Pin Functions (Modes 2 and 6)

Modes 3 and 7 [H8S/2351 Only]: In modes 3 and 7, port C pins function as I/O ports. Input or output can be specified for each pin on an individual bit basis. Setting a PCDDR bit to 1 makes the corresponding port C pin an output port, while clearing the bit to 0 makes the pin an input port.

Port C pin functions in modes 3 and 7 are shown in figure 9-18.

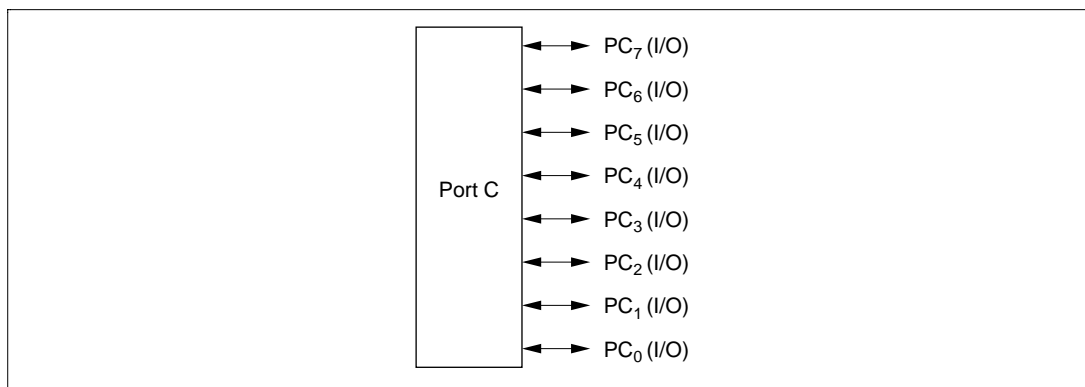


Figure 9-18 Port C Pin Functions (Modes 3 and 7)

individual bit basis.

When a PCDDR bit is cleared to 0 in mode 2, 3, 6, or 7, setting the corresponding PCPCR 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 power-on reset, and in hardware standby mode. The prior state is retained after a manual reset, and in software standby mode.

Table 9-18 summarizes the MOS input pull-up states.

Table 9-18 MOS Input Pull-Up States (Port C)

Modes	Power-On Reset	Hardware Standby Mode	Manual Reset	Software Standby Mode	In Other Operations
1, 4, 5	OFF		OFF		
2, 3, 6, 7			ON/OFF		

Legend:

OFF : MOS input pull-up is always off.

ON/OFF : On when PCDDR = 0 and PCPCR = 1; otherwise off.

Port D is an 8-bit I/O port. Port D has a data bus I/O function, and the pin functions change according to the operating mode. However, in the H8S/2350, port D pins function only as data bus pins.

Port D has a built-in MOS input pull-up function that can be controlled by software (H8S/2351 only).

Figure 9-19 shows the port D pin configuration.

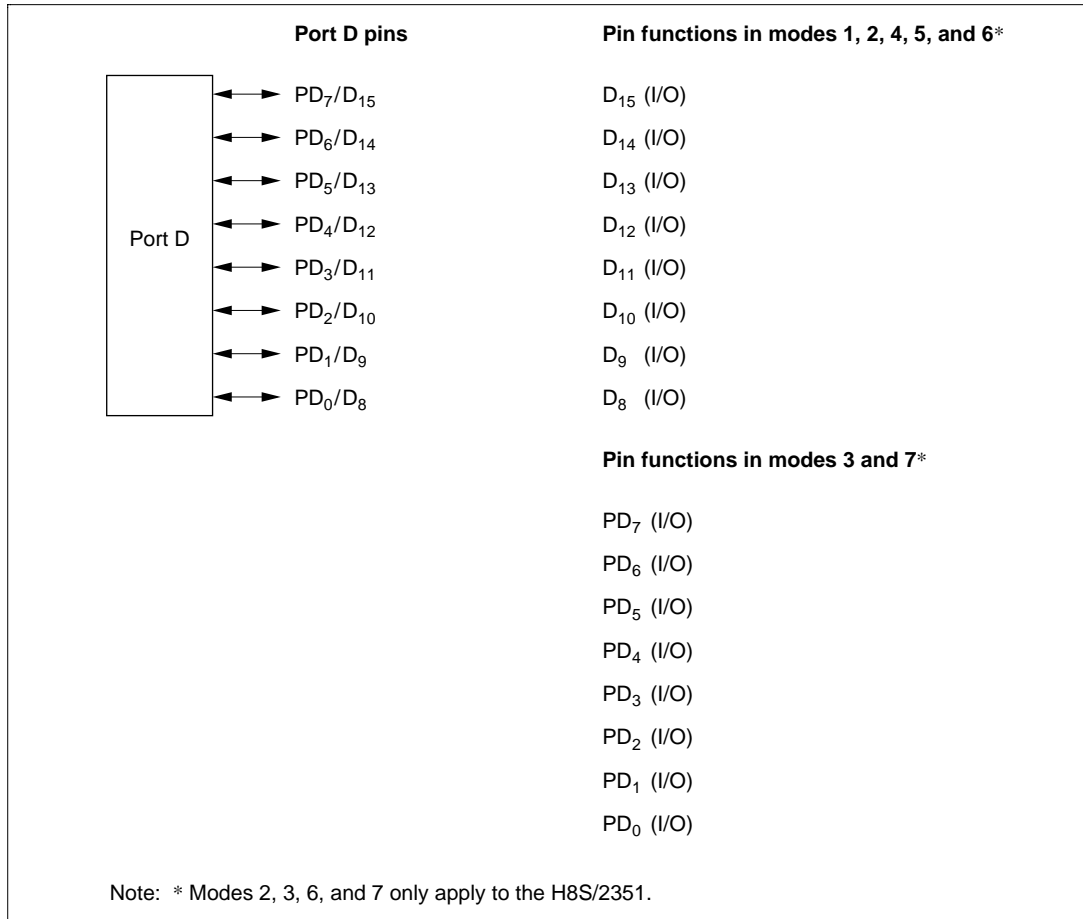


Figure 9-19 Port D Pin Functions

Table 9-19 Port D Registers

Name	Abbreviation	R/W	Initial Value	Address *
Port D data direction register	PDDDR	W	H'00	H'FEBC
Port D data register	PDDR	R/W	H'00	H'FF6C
Port D register	PORTD	R	Undefined	H'FF5C
Port D MOS pull-up control register	PDPCR	R/W	H'00	H'FF73

Note: * Lower 16 bits of the address.

Port D Data Direction Register (PDDDR) [H8S/2351 Only]

Bit	:	7	6	5	4	3	2	1	0
		PD7DDR	PD6DDR	PD5DDR	PD4DDR	PD3DDR	PD2DDR	PD1DDR	PD0DDR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	W	W	W	W	W	W	W	W

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

PDDDR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

- Modes 1, 2, 4, 5, and 6
The input/output direction specification by PDDDR is ignored, and port D is automatically designated for data I/O.
- Modes 3 and 7
Setting a PDDDR bit to 1 makes the corresponding port D pin an output port, while clearing the bit to 0 makes the pin an input port.

Initial value : 0 0 0 0 0 0 0 0 0
 R/W : R/W R/W R/W R/W R/W R/W R/W R/W R/W

PDDR is an 8-bit readable/writable register that stores output data for the port D pins (PD₇ to PD₀).

PDDR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Port D Register (PORTD) [H8S/2351 Only]

Bit	:	7	6	5	4	3	2	1	0
		PD7	PD6	PD5	PD4	PD3	PD2	PD1	PD0
Initial value	:	—*	—*	—*	—*	—*	—*	—*	—*
R/W	:	R	R	R	R	R	R	R	R

Note: * Determined by state of pins PD₇ to PD₀.

PORTD is an 8-bit read-only register that shows the pin states. It cannot be written to. Writing of output data for the port D pins (PD₇ to PD₀) must always be performed on PDDR.

If a port D read is performed while PDDDR bits are set to 1, the PDDR values are read. If a port D read is performed while PDDDR bits are cleared to 0, the pin states are read.

After a power-on reset and in hardware standby mode, PORTD contents are determined by the pin states, as PDDDR and PDDR are initialized. PORTD retains its prior state after a manual reset, and in software standby mode.

Initial value : 0 0 0 0 0 0 0 0 0
 R/W : R/W R/W R/W R/W R/W R/W R/W R/W R/W

PDPCR is an 8-bit readable/writable register that controls the MOS input pull-up function incorporated into port D on an individual bit basis.

When a PDDDR bit is cleared to 0 (input port setting) in mode 3 or 7, setting the corresponding PDPCR bit to 1 turns on the MOS input pull-up for the corresponding pin.

PDPCR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

9.11.3 Pin Functions

Modes 1, 4, and 5 [H8S/2351]; Modes 1, 2, 4, 5, and 6 [H8S/2351]: In modes 1, 2, 4, 5, and 6, port D pins are automatically designated as data I/O pins.

Port D pin functions in modes 1, 2, 4, 5, and 6 are shown in figure 9-20.

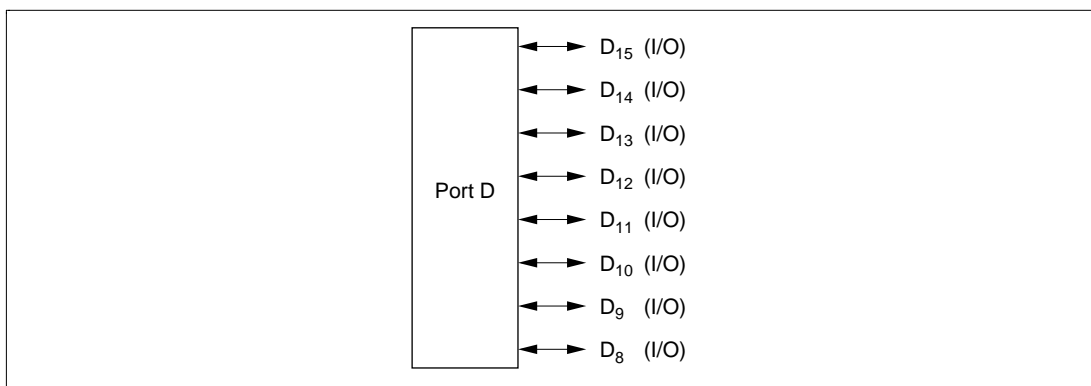


Figure 9-20 Port D Pin Functions (Modes 1, 2, 4, 5, and 6)

Modes 3 and 7 [H8S/2351 Only]: In modes 3 and 7, port D pins function as I/O ports. Input or output can be specified for each pin on an individual bit basis. Setting a PDDDR bit to 1 makes the corresponding port D pin an output port, while clearing the bit to 0 makes the pin an input port.

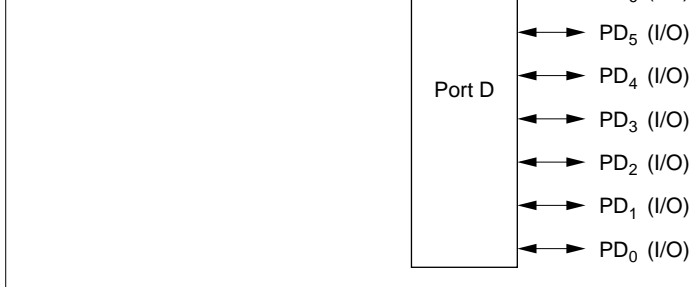


Figure 9-21 Port D Pin Functions (Modes 3 and 7)

9.11.4 MOS Input Pull-Up Function [H8S/2351 Only]

Port D has a built-in MOS input pull-up function that can be controlled by software. This MOS input pull-up function can be used in modes 3 and 7, and can be specified as on or off on an individual bit basis.

When a PDDDR bit is cleared to 0 in mode 3 or 7, setting the corresponding PDPCR 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 power-on reset, and in hardware standby mode. The prior state is retained after a manual reset, and in software standby mode.

Table 9-20 summarizes the MOS input pull-up states.

Table 9-20 MOS Input Pull-Up States (Port D)

Modes	Power-On Reset	Hardware Standby Mode	Manual Reset	Software Standby Mode	In Other Operations
1, 2, 4 to 6	OFF		OFF		
3, 7			ON/OFF		

Legend:

OFF : MOS input pull-up is always off.

ON/OFF : On when PDDDR = 0 and PDPCR = 1; otherwise off.

Port E is an 8-bit I/O port. Port E has a data bus I/O function, and the pin functions change according to the operating mode and whether 8-bit or 16-bit bus mode is selected.

Port E has a built-in MOS input pull-up function that can be controlled by software (H8S/2351 only).

Figure 9-22 shows the port E pin configuration.

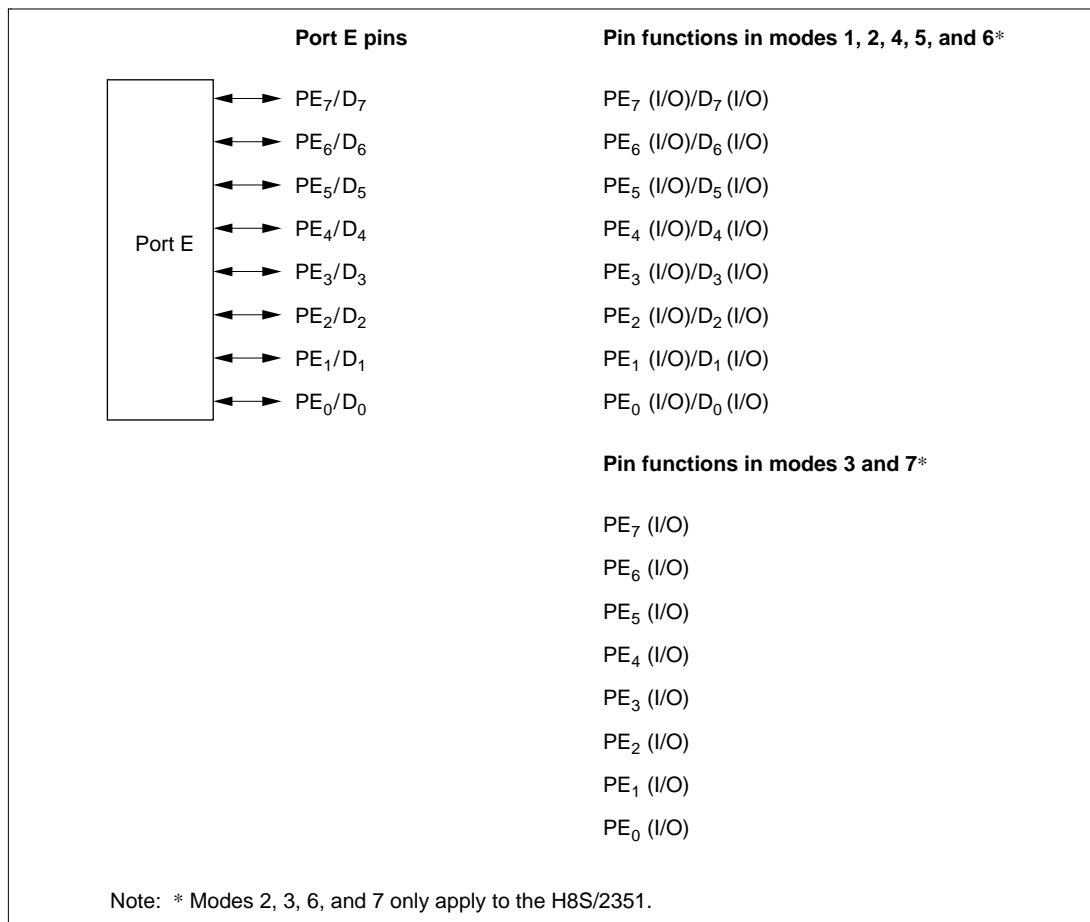


Figure 9-22 Port E Pin Functions

Table 9-21 Port E Registers

Name	Abbreviation	R/W	Initial Value	Address* ¹
Port E data direction register	PEDDR	W	H'00	H'FEBD
Port E data register	PEDR	R/W	H'00	H'FF6D
Port E register	PORTE	R	Undefined	H'FF5D
Port E MOS pull-up control register* ²	PEPCR	R/W	H'00	H'FF74

Notes: 1. Lower 16 bits of the address.
 2. Only applies to the H8S/2351.

Port E Data Direction Register (PEDDR)

Bit	:	7	6	5	4	3	2	1	0
		PE7DDR	PE6DDR	PE5DDR	PE4DDR	PE3DDR	PE2DDR	PE1DDR	PE0DDR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	W	W	W	W	W	W	W	W

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

PEDDR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

- Modes 1, 4, 5 [H8S/2350]; modes 1, 2, 4, 5, and 6 [H8S/2351]
 When 8-bit bus mode has been selected, port E pins function as I/O ports. Setting a PEDDR bit to 1 makes the corresponding port E pin an output port, while clearing the bit to 0 makes the pin an input port.
 When 16-bit bus mode has been selected, the input/output direction specification by PEDDR is ignored, and port E is designated for data I/O.
 For details of 8-bit and 16-bit bus modes, see section 6, Bus Controller.
- Modes 3 and 7 [H8S/2351 only]
 Setting a PEDDR bit to 1 makes the corresponding port E pin an output port, while clearing the bit to 0 makes the pin an input port.

Initial value : 0 0 0 0 0 0 0 0 0
 R/W : R/W R/W R/W R/W R/W R/W R/W R/W

PEDR is an 8-bit readable/writable register that stores output data for the port E pins (PE₇ to PE₀).

PEDR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Port E Register (PORTE)

Bit	:	7	6	5	4	3	2	1	0
		PE7	PE6	PE5	PE4	PE3	PE2	PE1	PE0
Initial value	:	—*	—*	—*	—*	—*	—*	—*	—*
R/W	:	R	R	R	R	R	R	R	R

Note: * Determined by state of pins PE₇ to PE₀.

PORTE is an 8-bit read-only register that shows the pin states. It cannot be written to. Writing of output data for the port E pins (PE₇ to PE₀) must always be performed on PEDR.

If a port E read is performed while PEDDR bits are set to 1, the PEDR values are read. If a port E read is performed while PEDDR bits are cleared to 0, the pin states are read.

After a power-on reset and in hardware standby mode, PORTE contents are determined by the pin states, as PEDDR and PEDR are initialized. PORTE retains its prior state after a manual reset, and in software standby mode.

Port E MOS Pull-Up Control Register (PEPCR) [H8S/2351 Only]

Bit	:	7	6	5	4	3	2	1	0
		PE7PCR	PE6PCR	PE5PCR	PE4PCR	PE3PCR	PE2PCR	PE1PCR	PE0PCR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

PEPCR is an 8-bit readable/writable register that controls the MOS input pull-up function incorporated into port E on an individual bit basis.

prior state after a manual reset, and in software standby mode.

9.12.3 Pin Functions

Modes 1, 4, and 5 [H8S/2350]; Modes 1, 2, 4, 5, and 6 [H8S/2351]: In modes 1, 2, 4, 5, and 6, when 8-bit access is designated and 8-bit bus mode is selected, port E pins are automatically designated as I/O ports. Setting a PEDDR bit to 1 makes the corresponding port E pin an output port, while clearing the bit to 0 makes the pin an input port.

When 16-bit bus mode is selected, the input/output direction specification by PEDDR is ignored, and port E is designated for data I/O.

Port E pin functions in modes 1, 2, 4, 5, and 6 are shown in figure 9-23.

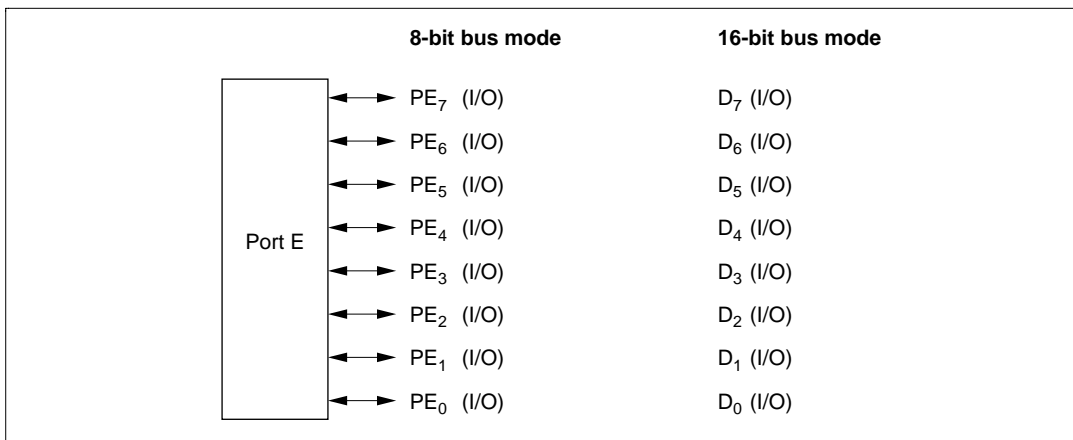


Figure 9-23 Port E Pin Functions (Modes 1, 2, 4, 5, and 6)

Modes 3 and 7 [H8S/2351 Only]: In modes 3 and 7, port E pins function as I/O ports. Input or output can be specified for each pin on a bit-by-bit basis. Setting a PEDDR bit to 1 makes the corresponding port E pin an output port, while clearing the bit to 0 makes the pin an input port.

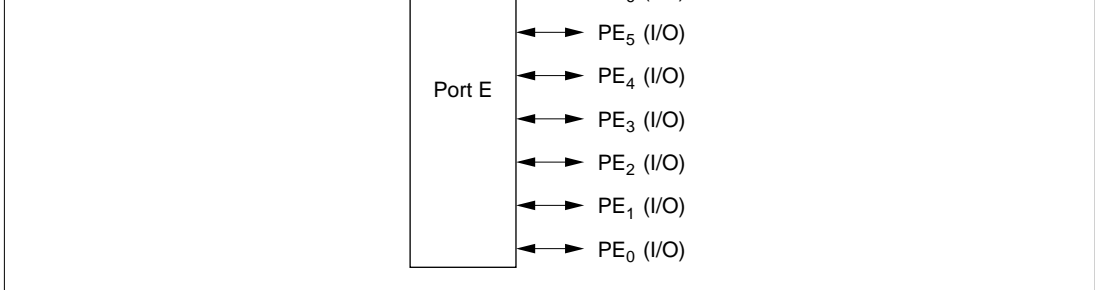


Figure 9-24 Port E Pin Functions (Modes 3 and 7)

9.12.4 MOS Input Pull-Up Function [H8S/2351 Only]

Port E has a built-in MOS input pull-up function that can be controlled by software. This MOS input pull-up function can be used in modes 1, 2, 4, 5, and 6 when 8-bit bus mode is selected, or in mode 3 or 7, and can be specified as on or off on an individual bit basis.

When a PEDDR bit is cleared to 0 in mode 1, 2, 4, 5, or 6 when 8-bit bus mode is selected, or in mode 3 or 7, setting the corresponding PEPCR 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 power-on reset, and in hardware standby mode. The prior state is retained after a manual reset, and in software standby mode.

Table 9-22 summarizes the MOS input pull-up states.

Table 9-22 MOS Input Pull-Up States (Port E)

Modes	Power-On Reset	Hardware Standby Mode	Manual Reset	Software Standby Mode	In Other Operations
3, 7	OFF		ON/OFF		
1, 2, 4 to 6	8-bit bus				
	16-bit bus		OFF		

Legend:

OFF : MOS input pull-up is always off.

ON/OFF : On when PEDDR = 0 and PEPCR = 1; otherwise off.

Port F is an 8-bit I/O port. Port F pins also function as bus control signal input/output pins (\overline{AS} , \overline{RD} , \overline{HWR} , \overline{LWR} , \overline{LCAS} , \overline{WAIT} , \overline{BREQO} , \overline{BREQ} , and \overline{BACK}) and the system clock (\emptyset) output pin.

Figure 9-25 shows the port F pin configuration.

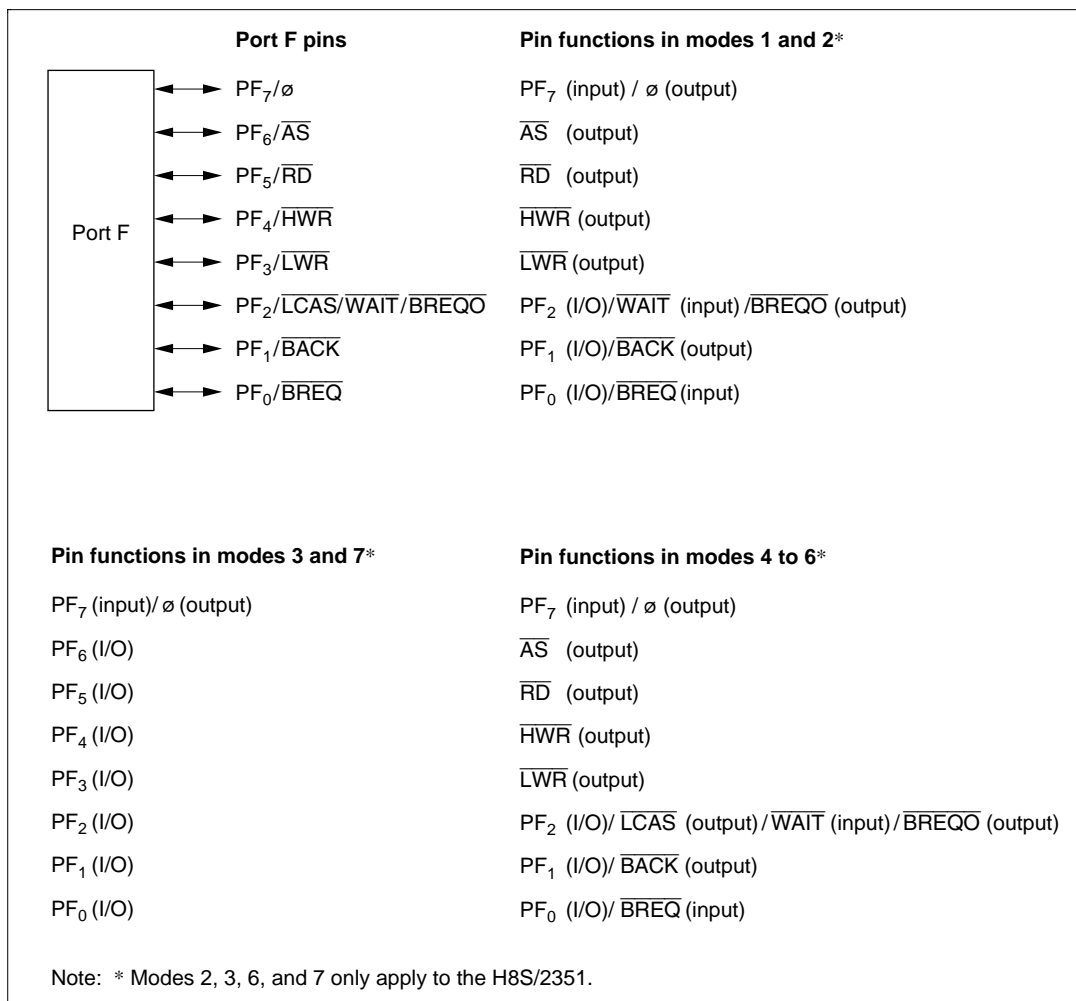


Figure 9-25 Port F Pin Functions

Table 9-23 Port F Registers

Name	Abbreviation	R/W	Initial Value	Address *1
Port F data direction register	PFDDR	W	H'80/H'00*2	H'FEBE
Port F data register	PFDR	R/W	H'00	H'FF6E
Port F register	PORTF	R	Undefined	H'FF5E

Notes: 1. Lower 16 bits of the address.
 2. Initial value depends on the mode.

Port F Data Direction Register (PFDDR)

Bit	7	6	5	4	3	2	1	0
	PF7DDR	PF6DDR	PF5DDR	PF4DDR	PF3DDR	PF2DDR	PF1DDR	PF0DDR
Modes 1, 2, 4, 5, 6								
Initial value :	1	0	0	0	0	0	0	0
R/W :	W	W	W	W	W	W	W	W
Modes 3 and 7								
Initial value :	0	0	0	0	0	0	0	0
R/W :	W	W	W	W	W	W	W	W

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

PFDDR is initialized by a power-on reset, and in hardware standby mode, to H'80 in modes 1, 2, 4, 5, and 6, and to H'00 in modes 3 and 7. It retains its prior state after a manual reset, and in software standby mode. The OPE bit in SBYCR is used to select whether the bus control output pins retain their output state or become high-impedance when a transition is made to software standby mode.

- Modes 1, 4, and 5 [H8S/2350]; modes 1, 2, 4, 5, and 6 [H8S/2351]
 Pin PF₇ functions as the \emptyset output pin when the corresponding PFDDR bit is set to 1, and as an input port when the bit is cleared to 0.
 The input/output direction specified by PFDDR is ignored for pins PF₆ to PF₃, which are automatically designated as bus control outputs (AS, RD, HWR, and LWR).

- Modes 3 and 7 [H8S/2351 only]

Setting a PFDDR bit to 1 makes the corresponding port F pin PF₆ to PF₀ an output port, or in the case of pin PF₇, the \emptyset output pin. Clearing the bit to 0 makes the pin an input port.

Port F Data Register (PFDR)

Bit	:	7	6	5	4	3	2	1	0
		PF7DR	PF6DR	PF5DR	PF4DR	PF3DR	PF2DR	PF1DR	PF0DR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

PFDR is an 8-bit readable/writable register that stores output data for the port F pins (PF₇ to PF₀).

PFDR is initialized to H'00 by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Port F Register (PORTF)

Bit	:	7	6	5	4	3	2	1	0
		PF7	PF6	PF5	PF4	PF3	PF2	PF1	PF0
Initial value	:	—*	—*	—*	—*	—*	—*	—*	—*
R/W	:	R	R	R	R	R	R	R	R

Note: * Determined by state of pins PF₇ to PF₀.

PORTF is an 8-bit read-only register that shows the pin states. Writing of output data for the port F pins (PF₇ to PF₀) must always be performed on PFDR.

If a port F read is performed while PFDDR bits are set to 1, the PFDR values are read. If a port F read is performed while PFDDR bits are cleared to 0, the pin states are read.

After a power-on reset and in hardware standby mode, PORTF contents are determined by the pin states, as PFDDR and PFDR are initialized. PORTF retains its prior state after a manual reset, and in software standby mode.

Table 9-24 Port F Pin Functions

Pin	Selection Method and Pin Functions		
PF ₇ /ø	The pin function is switched as shown below according to bit PF7DDR.		
	PF7DDR	0	1
	Pin function	PF ₇ input pin	ø output pin
PF ₆ / \overline{AS}	The pin function is switched as shown below according to the operating mode and bit PF6DDR.		
	Operating Mode	Modes 1, 2, 4, 5, 6*	Modes 3 and 7*
	PF6DDR	—	0 1
	Pin function	\overline{AS} output pin	PF ₆ input pin PF ₆ output pin
PF ₅ / \overline{RD}	The pin function is switched as shown below according to the operating mode and bit PF5DDR.		
	Operating Mode	Modes 1, 2, 4, 5, 6*	Modes 3 and 7*
	PF5DDR	—	0 1
	Pin function	\overline{RD} output pin	PF ₅ input pin PF ₅ output pin
PF ₄ / \overline{HWR}	The pin function is switched as shown below according to the operating mode and bit PF4DDR.		
	Operating Mode	Modes 1, 2, 4, 5, 6*	Modes 3 and 7*
	PF4DDR	—	0 1
	Pin function	\overline{HWR} output pin	PF ₄ input pin PF ₄ output pin

Note: * Modes 2, 3, 6, and 7 only apply to the H8S/2351.

Operating Mode	Modes 1, 2, 4, 5, 6*	Modes 3 and 7*	
PF3DDR	—	0	1
Pin function	$\overline{\text{LWR}}$ output pin	PF ₃ input pin	PF ₃ output pin

$\overline{\text{PF}}_2/\overline{\text{LCAS}}/\overline{\text{WAIT}}/\overline{\text{BREQO}}$

The pin function is switched as shown below according to the combination of the operating mode, and bits RMTS2 to RMTS0, LCASS, BREQOE, WAITE, ABW5 to ABW2, and PF2DDR.

Operating Mode	Modes 1, 2, 4, 5, 6*					Modes 3 and 7*	
LCASS	0			1*	—		
BREQOE	0		1	—	—		
WAITE	0		1	—	—		
PF2DDR	0	1	—	—	—	0	1
Pin function	PF ₂ input pin	PF ₂ output pin	$\overline{\text{WAIT}}$ input pin	$\overline{\text{BREQO}}$ output pin	$\overline{\text{LCAS}}$ output pin	PF ₂ input pin	PF ₂ output pin

Note: 1. Only in DRAM space 16-bit access in modes 4 to 6 when RMTS2 to RMTS0 = B'001 to B'011.

$\overline{\text{PF}}_1/\overline{\text{BACK}}$

The pin function is switched as shown below according to the combination of the operating mode, and bits BRLE and PF1DDR.

Operating Mode	Modes 1, 2, 4, 5, 6*			Modes 3 and 7*	
BRLE	0		1	—	
PF1DDR	0	1	—	0	1
Pin function	PF ₁ input pin	PF ₁ output pin	$\overline{\text{BACK}}$ output pin	PF ₁ input pin	PF ₁ output pin

Note: * Modes 2, 3, 6, and 7 only apply to the H8S/2351.

Operating Mode	Modes 1, 2, 4, 5, 6*			Modes 3 and 7*	
BRLE	0		1	—	
PF0DDR	0	1	—	0	1
Pin function	PF ₀ input pin	PF ₀ output pin	$\overline{\text{BREQ}}$ input pin	PF ₀ input pin	PF ₀ output pin

Note: * Modes 2, 3, 6, and 7 only apply to the H8S/2351.

Port G is a 5-bit I/O port. Port G pins also function as bus control signal output pins ($\overline{CS0}$ to $\overline{CS3}$, and \overline{CAS}).

Figure 9-26 shows the port G pin configuration.

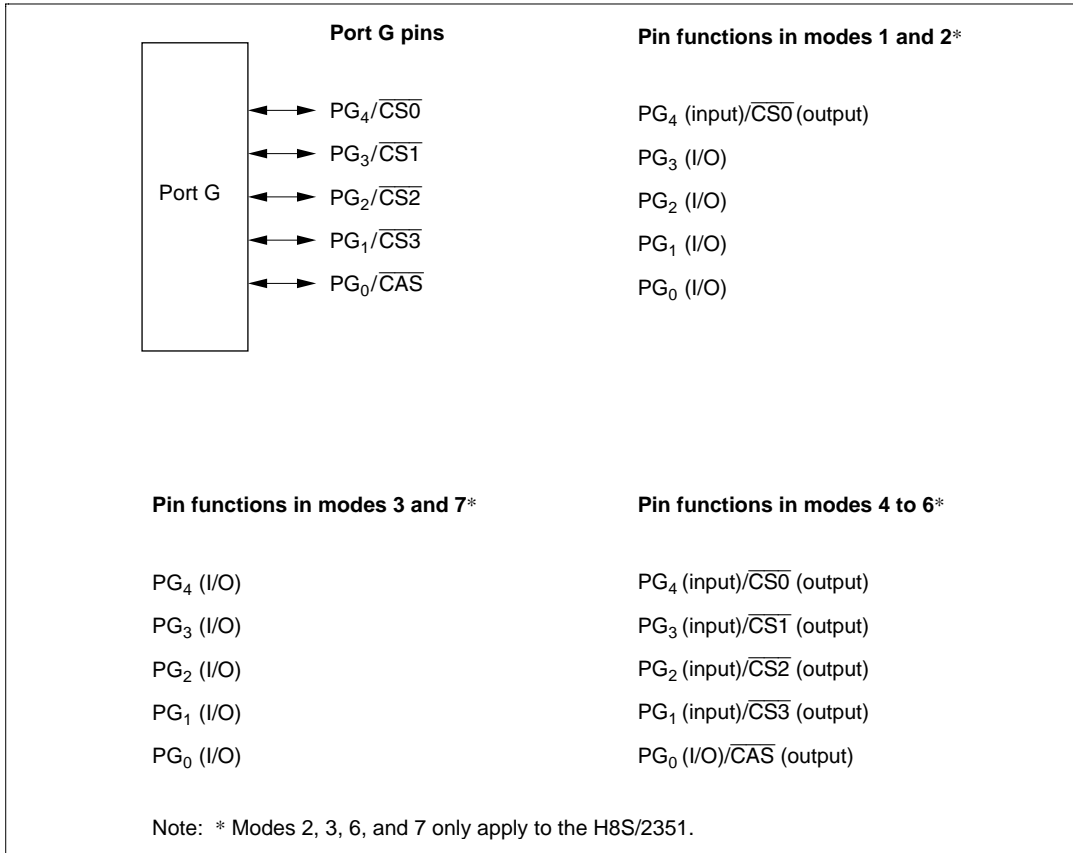


Figure 9-26 Port G Pin Functions

Table 9-23 Port G Registers

Name	Abbreviation	R/W	Initial Value* ²	Address* ¹
Port G data direction register	PGDDR	W	H'10/H'00* ³	H'FEBF
Port G data register	PGDR	R/W	H'00	H'FF6F
Port G register	PORTG	R	Undefined	H'FF5F

Notes: 1. Lower 16 bits of the address.
 2. Value of bits 4 to 0.
 3. Initial value depends on the mode.

Port G Data Direction Register (PGDDR)

Bit	7	6	5	4	3	2	1	0
	—	—	—	PG4DDR	PG3DDR	PG2DDR	PG1DDR	PG0DDR
Modes 1, 4, 5								
Initial value	Undefined	Undefined	Undefined	1	0	0	0	0
R/W	—	—	—	W	W	W	W	W
Modes 2, 3, 6, 7								
Initial value	Undefined	Undefined	Undefined	0	0	0	0	0
R/W	—	—	—	W	W	W	W	W

PGDDR is an 8-bit write-only register, the individual bits of which specify input or output for the pins of port G. PGDDR cannot be read, and bits 7 to 5 are reserved. If PGDDR is read, an undefined value will be read.

The PG4DDR bit is initialized by a power-on reset and in hardware standby mode, to 1 in modes 1, 4, and 5, and to 0 in modes 2, 3, 6, and 7. It retains its prior state after a manual reset and in software standby mode. The OPE bit in SBYCR is used to select whether the bus control output pins retain their output state or become high-impedance when a transition is made to software standby mode.

- Mode 1 [H8S/2350]; modes 1 and 2 [H8S/2351]
 Pin PG₄ functions as a bus control output pin ($\overline{CS0}$) when the corresponding PGDDR bit is set to 1, and as an input port when the bit is cleared to 0.
 For pins PG₃ to PG₀, setting the corresponding PGDDR bit to 1 makes the pin an output port, while clearing the bit to 0 makes the pin an input port.

Pins PG₄ to PG₁ function as bus control output pins ($\overline{CS0}$ to $\overline{CS3}$) when the corresponding PGDDR bits are set to 1, and as input ports when the bits are cleared to 0.

Pin PG₀ functions as the \overline{CAS} output pin when DRAM interface is designated. Otherwise, setting the corresponding PGDDR bit to 1 makes the pin an output port, while clearing the bit to 0 makes the pin an input port. For details of the DRAM interfaces, see section 6, Bus Controller.

Port G Data Register (PGDR)

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	PG4DR	PG3DR	PG2DR	PG1DR	PG0DR
Initial value	:	Undefined	Undefined	Undefined	0	0	0	0	0
R/W	:	—	—	—	R/W	R/W	R/W	R/W	R/W

PGDR is an 8-bit readable/writable register that stores output data for the port G pins (PG₄ to PG₀).

Bits 7 to 5 are reserved; they return an undetermined value if read, and cannot be modified.

PGDR is initialized to H'00 (bits 4 to 0) by a power-on reset, and in hardware standby mode. It retains its prior state after a manual reset, and in software standby mode.

Port G Register (PORTG)

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	PG4	PG3	PG2	PG1	PG0
Initial value	:	Undefined	Undefined	Undefined	—*	—*	—*	—*	—*
R/W	:	—	—	—	R	R	R	R	R

Note: * Determined by state of pins PG₄ to PG₀.

PORTG is an 8-bit read-only register that shows the pin states. It cannot be written to. Writing of output data for the port G pins (PG₄ to PG₀) must always be performed on PGDR.

Bits 7 to 5 are reserved; they return an undetermined value if read, and cannot be modified.

If a port G read is performed while PGDDR bits are set to 1, the PGDR values are read. If a port G read is performed while PGDDR bits are cleared to 0, the pin states are read.

9.14.3 Pin Functions

Port G pins also function as bus control signal output pins ($\overline{CS0}$ to $\overline{CS3}$, and \overline{CAS}). The pin functions are different in modes 1 and 2, modes 3 and 7, and modes 4 to 6. Port G pin functions are shown in table 9-26.

Table 9-26 Port G Pin Functions

Pin	Selection Method and Pin Functions			
$PG_4/\overline{CS0}$	The pin function is switched as shown below according to the operating mode and bit PG4DDR.			
	Operating Mode	Modes 1, 2, 4, 5, 6*		Modes 3 and 7*
	PG4DDR	0	1	0 1
	Pin function	PG_4 input pin	$\overline{CS0}$ output pin	PG_4 input pin PG_4 output pin
$PG_3/\overline{CS1}$	The pin function is switched as shown below according to the operating mode and bit PG3DDR.			
	Operating Mode	Modes 1, 2, 3, 7*		Modes 4 to 6*
	PG3DDR	0	1	0 1
	Pin function	PG_3 input pin	PG_3 output pin	PG_3 input pin $\overline{CS1}$ output pin
$PG_2/\overline{CS2}$	The pin function is switched as shown below according to the operating mode and bit PG2DDR.			
	Operating Mode	Modes 1, 2, 3, 7*		Modes 4 to 6*
	PG2DDR	0	1	0 1
	Pin function	PG_2 input pin	PG_2 output pin	PG_2 input pin $\overline{CS2}$ output pin

Note: * Modes 2, 3, 6, and 7 only apply to the H8S/2351.

Operating Mode	Modes 1, 2, 3, 7*		Modes 4 to 6*	
PG1DDR	0	1	0	1
Pin function	PG ₁ input pin	PG ₁ output pin	PG ₁ input pin	$\overline{\text{CS}}3$ output pin

PG₀/ $\overline{\text{CAS}}$

The pin function is switched as shown below according to the combination of the operating mode and bits RMTS2 to RMTS0 and PG0DDR.

Operating Mode	Modes 1, 2, 3, 7*		Modes 4 to 6*		
RMTS2 to RMTS0	—		B'000, B'100 to B'111	B'001 to B'011	
PG0DDR	0	1	0	1	—
Pin function	PG ₀ input pin	PG ₀ output pin	PG ₀ input pin	PG ₀ output pin	$\overline{\text{CAS}}$ output

Note: * Modes 2, 3, 6, and 7 only apply to the H8S/2351.

The H8S/2350 Series has an on-chip 16-bit timer pulse unit (TPU) that comprises six 16-bit timer channels.

10.1.1 Features

- Maximum 16-pulse input/output
 - A total of 16 timer general registers (TGRs) are provided (four each for channels 0 and 3, and two each for channels 1, 2, 4, and 5), each of which can be set independently as an output compare/input capture register
 - TGRC and TGRD for channels 0 and 3 can also be used as buffer registers
- Selection of 8 counter input clocks for each channel
- The following operations can be set for each channel:
 - Waveform output at compare match: Selection of 0, 1, or toggle output
 - Input capture function: Selection of rising edge, falling edge, or both edge detection
 - Counter clear operation: Counter clearing possible by compare match or input capture
 - Synchronous operation: Multiple timer counters (TCNT) can be written to simultaneously
 - Simultaneous clearing by compare match and input capture possible
 - Register simultaneous input/output possible by counter synchronous operation
 - PWM mode: Any PWM output duty can be set
 - Maximum of 15-phase PWM output possible by combination with synchronous operation
- Buffer operation settable for channels 0 and 3
 - Input capture register double-buffering possible
 - Automatic rewriting of output compare register possible
- Phase counting mode settable independently for each of channels 1, 2, 4, and 5
 - Two-phase encoder pulse up/down-count possible
- Cascaded operation
 - Channel 2 (channel 5) input clock operates as 32-bit counter by setting channel 1 (channel 4) overflow/underflow
- Fast access via internal 16-bit bus
 - Fast access is possible via a 16-bit bus interface

overflow interrupt, and one underflow interrupt can be requested independently

- Automatic transfer of register data
 - Block transfer, 1-word data transfer, and 1-byte data transfer possible by data transfer controller (DTC) or DMA controller (DMAC) activation
- Programmable pulse generator (PPG) output trigger can be generated
 - Channel 0 to 3 compare match/input capture signals can be used as PPG output trigger
- A/D converter conversion start trigger can be generated
 - Channel 0 to 5 compare match A/input capture A signals can be used as A/D converter conversion start trigger
- Module stop mode can be set
 - As the initial setting, TPU operation is halted. Register access is enabled by exiting module stop mode.

Table 10-1 lists the functions of the TPU.

	ø/16 ø/64	ø/16 ø/64	ø/16 ø/64	ø/16 ø/64	ø/16 ø/64	ø/16 ø/64
	TCLKA	ø/256	ø/1024	ø/256	ø/1024	ø/256
	TCLKB	TCLKA	TCLKA	ø/1024	TCLKA	TCLKA
	TCLKC	TCLKB	TCLKB	ø/4096	TCLKC	TCLKC
	TCLKD		TCLKC	TCLKA		TCLKD
General registers	TGR0A TGR0B	TGR1A TGR1B	TGR2A TGR2B	TGR3A TGR3B	TGR4A TGR4B	TGR5A TGR5B
General registers/ buffer registers	TGR0C TGR0D	—	—	TGR3C TGR3D	—	—
I/O pins	TIOCA0 TIOCB0 TIOCC0 TIOCD0	TIOCA1 TIOCB1	TIOCA2 TIOCB2	TIOCA3 TIOCB3 TIOCC3 TIOCD3	TIOCA4 TIOCB4	TIOCA5 TIOCB5
Counter clear function	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture
Compare match output	0 output	○	○	○	○	○
	1 output	○	○	○	○	○
	Toggle output	○	○	○	○	○
Input capture function	○	○	○	○	○	○
Synchronous operation	○	○	○	○	○	○
PWM mode	○	○	○	○	○	○
Phase counting mode	—	○	○	—	○	○
Buffer operation	○	—	—	○	—	—

Legend

○ : Possible

— : Not possible

	match or input capture	match or input capture	match or input capture	match or input capture	match or input capture	match or input capture
DTC activation	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture	TGR compare match or input capture
A/D converter trigger	TGR0A compare match or input capture	TGR1A compare match or input capture	TGR2A compare match or input capture	TGR3A compare match or input capture	TGR4A compare match or input capture	TGR5A compare match or input capture
PPG trigger	TGR0A/ TGR0B compare match or input capture	TGR1A/ TGR1B compare match or input capture	TGR2A/ TGR2B compare match or input capture	TGR3A/ TGR3B compare match or input capture	—	—
Interrupt sources	5 sources <ul style="list-style-type: none"> • Compare match or input capture 0A • Compare match or input capture 0B • Compare match or input capture 0C • Compare match or input capture 0D • Overflow 	4 sources <ul style="list-style-type: none"> • Compare match or input capture 1A • Compare match or input capture 1B • Overflow • Underflow 	4 sources <ul style="list-style-type: none"> • Compare match or input capture 2A • Compare match or input capture 2B • Overflow • Underflow 	5 sources <ul style="list-style-type: none"> • Compare match or input capture 3A • Compare match or input capture 3B • Compare match or input capture 3C • Compare match or input capture 3D • Overflow 	4 sources <ul style="list-style-type: none"> • Compare match or input capture 4A • Compare match or input capture 4B • Overflow • Underflow 	4 sources <ul style="list-style-type: none"> • Compare match or input capture 5A • Compare match or input capture 5B • Overflow • Underflow

Legend

— : Not possible

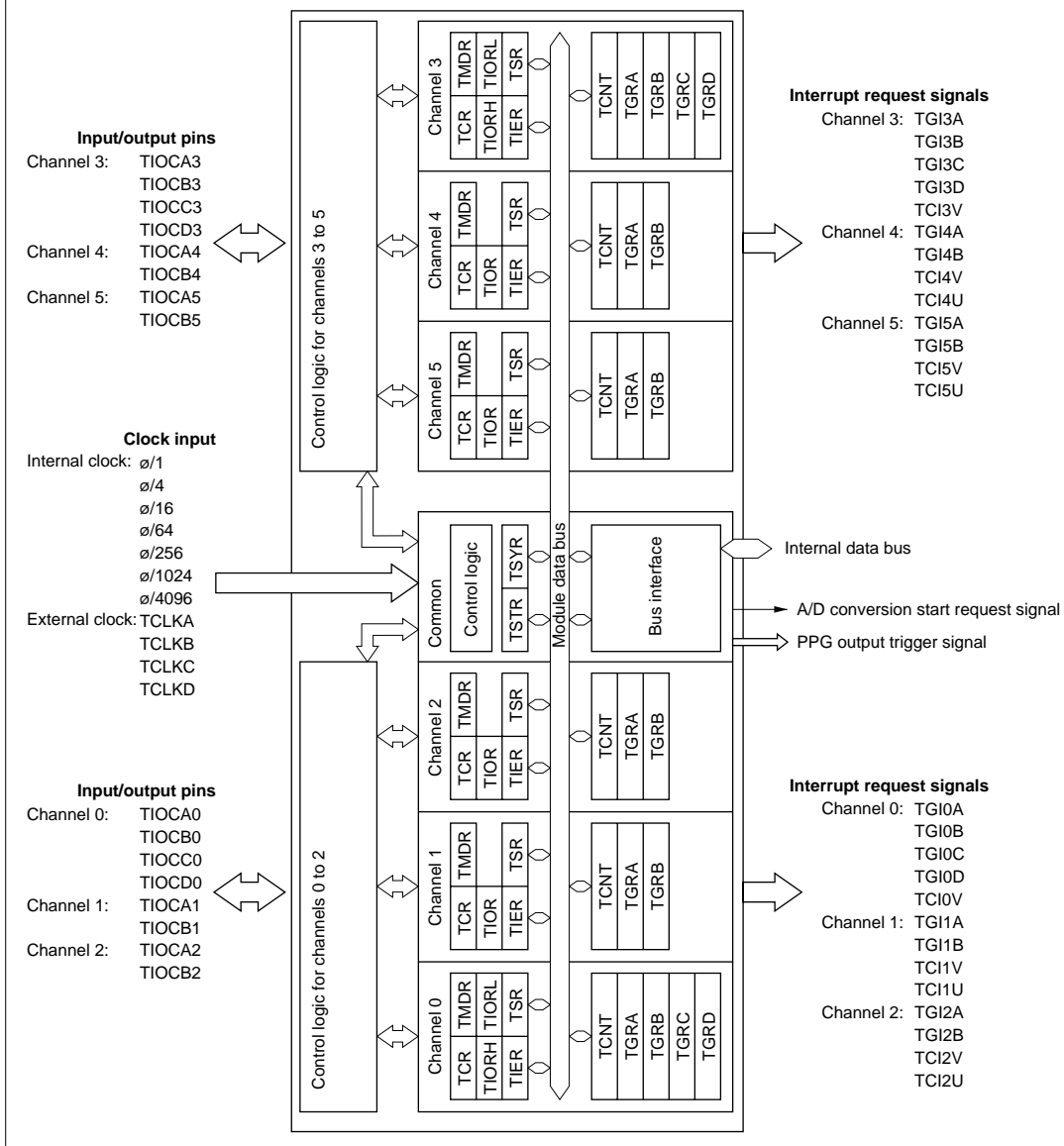


Figure 10-1 Block Diagram of TPU

Table 10-2 TIO Pins

Channel	Name	Symbol	I/O	Function
All	Clock input A	TCLKA	Input	External clock A input pin (Channel 1 and 5 phase counting mode A phase input)
	Clock input B	TCLKB	Input	External clock B input pin (Channel 1 and 5 phase counting mode B phase input)
	Clock input C	TCLKC	Input	External clock C input pin (Channel 2 and 4 phase counting mode A phase input)
	Clock input D	TCLKD	Input	External clock D input pin (Channel 2 and 4 phase counting mode B phase input)
0	Input capture/out compare match A0	TIOCA0	I/O	TGR0A input capture input/output compare output/PWM output pin
	Input capture/out compare match B0	TIOCB0	I/O	TGR0B input capture input/output compare output/PWM output pin
	Input capture/out compare match C0	TIOCC0	I/O	TGR0C input capture input/output compare output/PWM output pin
	Input capture/out compare match D0	TIOCD0	I/O	TGR0D input capture input/output compare output/PWM output pin
1	Input capture/out compare match A1	TIOCA1	I/O	TGR1A input capture input/output compare output/PWM output pin
	Input capture/out compare match B1	TIOCB1	I/O	TGR1B input capture input/output compare output/PWM output pin
2	Input capture/out compare match A2	TIOCA2	I/O	TGR2A input capture input/output compare output/PWM output pin
	Input capture/out compare match B2	TIOCB2	I/O	TGR2B input capture input/output compare output/PWM output pin

	Input capture/output compare match B3	TIOCB3	I/O	TGR3B input capture input/output compare output/PWM output pin
	Input capture/output compare match C3	TIOCC3	I/O	TGR3C input capture input/output compare output/PWM output pin
	Input capture/output compare match D3	TIOCD3	I/O	TGR3D input capture input/output compare output/PWM output pin
4	Input capture/output compare match A4	TIOCA4	I/O	TGR4A input capture input/output compare output/PWM output pin
	Input capture/output compare match B4	TIOCB4	I/O	TGR4B input capture input/output compare output/PWM output pin
5	Input capture/output compare match A5	TIOCA5	I/O	TGR5A input capture input/output compare output/PWM output pin
	Input capture/output compare match B5	TIOCB5	I/O	TGR5B input capture input/output compare output/PWM output pin

Table 10-5 T10 Registers

Channel	Name	Abbreviation	R/W	Initial Value	Address ^{*1}
0	Timer control register 0	TCR0	R/W	H'00	H'FFD0
	Timer mode register 0	TMDR0	R/W	H'C0	H'FFD1
	Timer I/O control register 0H	TIOR0H	R/W	H'00	H'FFD2
	Timer I/O control register 0L	TIOR0L	R/W	H'00	H'FFD3
	Timer interrupt enable register 0	TIER0	R/W	H'40	H'FFD4
	Timer status register 0	TSR0	R/(W) ^{*2}	H'C0	H'FFD5
	Timer counter 0	TCNT0	R/W	H'0000	H'FFD6
	Timer general register 0A	TGR0A	R/W	H'FFFF	H'FFD8
	Timer general register 0B	TGR0B	R/W	H'FFFF	H'FFDA
	Timer general register 0C	TGR0C	R/W	H'FFFF	H'FFDC
	Timer general register 0D	TGR0D	R/W	H'FFFF	H'FFDE
1	Timer control register 1	TCR1	R/W	H'00	H'FFE0
	Timer mode register 1	TMDR1	R/W	H'C0	H'FFE1
	Timer I/O control register 1	TIOR1	R/W	H'00	H'FFE2
	Timer interrupt enable register 1	TIER1	R/W	H'40	H'FFE4
	Timer status register 1	TSR1	R/(W) ^{*2}	H'C0	H'FFE5
	Timer counter 1	TCNT1	R/W	H'0000	H'FFE6
	Timer general register 1A	TGR1A	R/W	H'FFFF	H'FFE8
	Timer general register 1B	TGR1B	R/W	H'FFFF	H'FFEA
2	Timer control register 2	TCR2	R/W	H'00	H'FFF0
	Timer mode register 2	TMDR2	R/W	H'C0	H'FFF1
	Timer I/O control register 2	TIOR2	R/W	H'00	H'FFF2
	Timer interrupt enable register 2	TIER2	R/W	H'40	H'FFF4
	Timer status register 2	TSR2	R/(W) ^{*2}	H'C0	H'FFF5
	Timer counter 2	TCNT2	R/W	H'0000	H'FFF6
	Timer general register 2A	TGR2A	R/W	H'FFFF	H'FFF8
	Timer general register 2B	TGR2B	R/W	H'FFFF	H'FFFA

	Timer mode register 3	TMDR3	R/W	H'00	H'FE81
	Timer I/O control register 3H	TIOR3H	R/W	H'00	H'FE82
	Timer I/O control register 3L	TIOR3L	R/W	H'00	H'FE83
	Timer interrupt enable register 3	TIER3	R/W	H'40	H'FE84
	Timer status register 3	TSR3	R/(W)* ²	H'C0	H'FE85
	Timer counter 3	TCNT3	R/W	H'0000	H'FE86
	Timer general register 3A	TGR3A	R/W	H'FFFF	H'FE88
	Timer general register 3B	TGR3B	R/W	H'FFFF	H'FE8A
	Timer general register 3C	TGR3C	R/W	H'FFFF	H'FE8C
	Timer general register 3D	TGR3D	R/W	H'FFFF	H'FE8E
4	Timer control register 4	TCR4	R/W	H'00	H'FE90
	Timer mode register 4	TMDR4	R/W	H'C0	H'FE91
	Timer I/O control register 4	TIOR4	R/W	H'00	H'FE92
	Timer interrupt enable register 4	TIER4	R/W	H'40	H'FE94
	Timer status register 4	TSR4	R/(W) * ²	H'C0	H'FE95
	Timer counter 4	TCNT4	R/W	H'0000	H'FE96
	Timer general register 4A	TGR4A	R/W	H'FFFF	H'FE98
	Timer general register 4B	TGR4B	R/W	H'FFFF	H'FE9A
5	Timer control register 5	TCR5	R/W	H'00	H'FEA0
	Timer mode register 5	TMDR5	R/W	H'C0	H'FEA1
	Timer I/O control register 5	TIOR5	R/W	H'00	H'FEA2
	Timer interrupt enable register 5	TIER5	R/W	H'40	H'FEA4
	Timer status register 5	TSR5	R/(W) * ²	H'C0	H'FEA5
	Timer counter 5	TCNT5	R/W	H'0000	H'FEA6
	Timer general register 5A	TGR5A	R/W	H'FFFF	H'FEA8
	Timer general register 5B	TGR5B	R/W	H'FFFF	H'FEAA
All	Timer start register	TSTR	R/W	H'00	H'FFC0
	Timer synchro register	TSYR	R/W	H'00	H'FFC1
	Module stop control register	MSTPCR	R/W	H'3FFF	H'FF3C

- Notes: 1. Lower 16 bits of the address.
2. Can only be written with 0 for flag clearing.

Channel 0: TCR0
Channel 3: TCR3

Bit	:	7	6	5	4	3	2	1	0
		CCLR2	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Channel 1: TCR1
Channel 2: TCR2
Channel 4: TCR4
Channel 5: TCR5

Bit	:	7	6	5	4	3	2	1	0
		—	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W

The TCR registers are 8-bit registers that control the TCNT channels. The TPU has six TCR registers, one for each of channels 0 to 5. The TCR registers are initialized to H'00 by a reset, and in hardware standby mode.

TCR register settings should be made only when TCNT operation is stopped.

0, 3	0	0	0	TCNT clearing disabled	(Initial value)
			1	TCNT cleared by TGRA compare match/input capture	
		1	0	TCNT cleared by TGRB compare match/input capture	
			1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation * ¹	
	1	0	0	TCNT clearing disabled	
			1	TCNT cleared by TGRC compare match/input capture * ²	
		1	0	TCNT cleared by TGRD compare match/input capture * ²	
			1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation * ¹	

Channel	Bit 7 Reserved* ³	Bit 6 CCLR1	Bit 5 CCLR0	Description
1, 2, 4, 5	0	0	0	TCNT clearing disabled (Initial value)
			1	TCNT cleared by TGRA compare match/input capture
		1	0	TCNT cleared by TGRB compare match/input capture
			1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation * ¹

- Notes:
1. Synchronous operation setting is performed by setting the SYNC bit in TSYSR to 1.
 2. When TGRC or TGRD is used as a buffer register, TCNT is not cleared because the buffer register setting has priority, and compare match/input capture does not occur.
 3. Bit 7 is reserved in channels 1, 2, 4, and 5. It is always read as 0 and cannot be modified.

Bit 4 CKEG1	Bit 3 CKEG0	Description	
0	0	Count at rising edge	(Initial value)
	1	Count at falling edge	
1	—	Count at both edges	

Note: Internal clock edge selection is valid when the input clock is $\phi/4$ or slower. This setting is ignored if the input clock is $\phi/1$, or when overflow/underflow of another channel is selected.

Bits 2, 1, and 0—Time Prescaler 2, 1, and 0 (TPSC2 to TPSC0): These bits select the TCNT counter clock. The clock source can be selected independently for each channel. Table 10-4 shows the clock sources that can be set for each channel.

Table 10-4 TPU Clock Sources

Channel	Internal Clock							External Clock				Overflow/ Underflow on Another
	$\phi/1$	$\phi/4$	$\phi/16$	$\phi/64$	$\phi/256$	$\phi/1024$	$\phi/4096$	TCLKA	TCLKB	TCLKC	TCLKD	Channel
0	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>				<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	
1	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			<input type="radio"/>	<input type="radio"/>			<input type="radio"/>
2	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>		<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>		
3	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>				
4	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>		<input type="radio"/>		<input type="radio"/>		<input type="radio"/>		<input type="radio"/>
5	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>			<input type="radio"/>		<input type="radio"/>	<input type="radio"/>	

Legend

: Setting

Blank : No setting

		1	0	Internal clock: counts on $\varnothing/16$
			1	Internal clock: counts on $\varnothing/64$
1	0	0	0	External clock: counts on TCLKA pin input
			1	External clock: counts on TCLKB pin input
		1	0	External clock: counts on TCLKC pin input
			1	External clock: counts on TCLKD pin input

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
1	0	0	0	Internal clock: counts on $\varnothing/1$ (Initial value)
			1	Internal clock: counts on $\varnothing/4$
		1	0	Internal clock: counts on $\varnothing/16$
			1	Internal clock: counts on $\varnothing/64$
	1	0	0	External clock: counts on TCLKA pin input
			1	External clock: counts on TCLKB pin input
		1	0	Internal clock: counts on $\varnothing/256$
			1	Counts on TCNT2 overflow/underflow

Note: This setting is ignored when channel 1 is in phase counting mode.

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

Note: This setting is ignored when channel 2 is in phase counting mode.

	1	0	Internal clock: counts on $\varnothing/16$
		1	Internal clock: counts on $\varnothing/64$
1	0	0	External clock: counts on TCLKA pin input
		1	Internal clock: counts on $\varnothing/1024$
	1	0	Internal clock: counts on $\varnothing/256$
		1	Internal clock: counts on $\varnothing/4096$

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
4	0	0	0	Internal clock: counts on $\varnothing/1$ (Initial value)
			1	Internal clock: counts on $\varnothing/4$
		1	0	Internal clock: counts on $\varnothing/16$
			1	Internal clock: counts on $\varnothing/64$
	1	0	0	External clock: counts on TCLKA pin input
			1	External clock: counts on TCLKC pin input
		1	0	Internal clock: counts on $\varnothing/1024$
			1	Counts on TCNT5 overflow/underflow

Note: This setting is ignored when channel 4 is in phase counting mode.

Channel	Bit 2 TPSC2	Bit 1 TPSC1	Bit 0 TPSC0	Description
5	0	0	0	Internal clock: counts on $\varnothing/1$ (Initial value)
			1	Internal clock: counts on $\varnothing/4$
		1	0	Internal clock: counts on $\varnothing/16$
			1	Internal clock: counts on $\varnothing/64$
	1	0	0	External clock: counts on TCLKA pin input
			1	External clock: counts on TCLKC pin input
		1	0	Internal clock: counts on $\varnothing/256$
			1	External clock: counts on TCLKD pin input

Note: This setting is ignored when channel 5 is in phase counting mode.

Bit	:	7	6	5	4	3	2	1	0
		—	—	BFB	BFA	MD3	MD2	MD1	MD0
Initial value	:	1	1	0	0	0	0	0	0
R/W	:	—	—	R/W	R/W	R/W	R/W	R/W	R/W

Channel 1: TMDR1

Channel 2: TMDR2

Channel 4: TMDR4

Channel 5: TMDR5

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	MD3	MD2	MD1	MD0
Initial value	:	1	1	0	0	0	0	0	0
R/W	:	—	—	—	—	R/W	R/W	R/W	R/W

The TMDR registers are 8-bit readable/writable registers that are used to set the operating mode for each channel. The TPU has six TMDR registers, one for each channel. The TMDR registers are initialized to H'C0 by a reset, and in hardware standby mode.

TMDR register settings should be made only when TCNT operation is stopped.

Bits 7 and 6—Reserved: Read-only bits, always read as 1.

Bit 5—Buffer Operation B (BFB): Specifies whether TGRB is to operate in the normal way, or TGRB and TGRD are to be used together for buffer operation. When TGRD is used as a buffer register, TGRD input capture/output compare is not generated.

In channels 1, 2, 4, and 5, which have no TGRD, bit 5 is reserved. It is always read as 0 and cannot be modified.

Bit 5

BFB	Description	
0	TGRB operates normally	(Initial value)
1	TGRB and TGRD used together for buffer operation	

be modified.

Bit 4

BFA	Description	
0	TGRA operates normally	(Initial value)
1	TGRA and TGRC used together for buffer operation	

Bits 3 to 0—Modes 3 to 0 (MD3 to MD0): These bits are used to set the timer operating mode.

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

*: Don't care

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

2. Phase counting mode cannot be set for channels 0 and 3. In this case, 0 should always be written to MD2.

Channel 2: TIOR2

Channel 3: TIOR3H

Channel 4: TIOR4

Channel 5: TIOR5

Bit	:	7	6	5	4	3	2	1	0
		IOB3	IOB2	IOB1	IOB0	IOA3	IOA2	IOA1	IOA0
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Channel 0: TIOR0L

Channel 3: TIOR3L

Bit	:	7	6	5	4	3	2	1	0
		IOD3	IOD2	IOD1	IOD0	IOC3	IOC2	IOC1	IOC0
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Note: When TGRC or TGRD is designated for buffer operation, this setting is invalid and the register operates as a buffer register.

The TIOR registers are 8-bit registers that control the TGR registers. The TPU has eight TIOR registers, two each for channels 0 and 3, and one each for channels 1, 2, 4, and 5. The TIOR registers are initialized to H'00 by a reset, and in hardware standby mode.

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

Channel	Bit 7 IOB3	Bit 6 IOB2	Bit 5 IOB1	Bit 4 IOB0	Description				
0	0	0	0	0	TGR0B is Output disabled (Initial value)				
				1	output compare register				
				0	Initial output is 0	0 output at compare match			
				1	0	output	1 output at compare match		
				1			Toggle output at compare match		
				1	0	0	Output disabled		
				1			Initial output is 1	0 output at compare match	
				1	0		output	1 output at compare match	
				1			Toggle output at compare match		
				1	0	0	0	0	TGR0B is Capture input source is TIOCB0 pin
								1	input capture register
								0	Input capture at rising edge
1	*	Input capture at falling edge							
1	*	Input capture at both edges							
1	*	*	Capture input source is channel 1/count clock					Input capture at TCNT1 count- up/count-down* ¹	

*: Don't care

Note: 1. When bits TPSC2 to TPSC0 in TCR1 are set to B'000 and $\phi/1$ is used as the TCNT1 count clock, this setting is invalid and input capture is not generated.

	1	0	0	register**2	Output	1 output at compare match
			1			Toggle output at compare match
	1	0	0		Output disabled	
			1		Initial output is 1	0 output at compare match
		1	0		output	1 output at compare match
			1			Toggle output at compare match
1	0	0	0	TGR0D is	Capture input	Input capture at rising edge
			1	input	source is	Input capture at falling edge
		1	*	capture	TIOCD0 pin	Input capture at both edges
			*	register**2		
1	*	*	*		Capture input	Input capture at TCNT1
					source is channel	count-up/count-down**1
					1/count clock	

*: Don't care

- Notes:
1. When bits TPSC2 to TPSC0 in TCR1 are set to B'000 and $\emptyset/1$ is used as the TCNT1 count clock, this setting is invalid and input capture is not generated.
 2. When the BFB bit in TMDR0 is set to 1 and TGR0D is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

	1	0	0	1	register	output	1 output at compare match
				1			Toggle output at compare match
	1	0	0	0		Output disabled	
				1		Initial output is 1	0 output at compare match
			1	0		output	1 output at compare match
				1			Toggle output at compare match
1	0	0	0	0	TGR1B is input capture register	Capture input source is TIOCB1 pin	Input capture at rising edge
				1			Input capture at falling edge
			1	*			Input capture at both edges
	1	*	*	*		Capture input source is TGR0C compare match/ input capture	Input capture at generation of TGR0C compare match/ input capture

*: Don't care

Channel	Bit 7 IOB3	Bit 6 IOB2	Bit 5 IOB1	Bit 4 IOB0	Description		
2	0	0	0	0	TGR2B is output compare register	Output disabled	(Initial value)
				1		Initial output is 0	0 output at compare match
			1	0		output	1 output at compare match
				1			Toggle output at compare match
	1	0	0	0		Output disabled	
				1		Initial output is 1	0 output at compare match
			1	0		output	1 output at compare match
				1			Toggle output at compare match
1	*	0	0	0	TGR2B is input capture register	Capture input source is TIOCB2 pin	Input capture at rising edge
				1			Input capture at falling edge
			1	*			Input capture at both edges

*: Don't care

	1	0	0	register	Output	1 output at compare match
			1			Toggle output at compare match
1	0	0	0		Output disabled	
			1		Initial output is 1	0 output at compare match
	1	0	0		output	1 output at compare match
			1			Toggle output at compare match
1	0	0	0	TGR3B is	Capture input	Input capture at rising edge
			1	input	source is	Input capture at falling edge
		1	*	capture	TIOCB3 pin	Input capture at both edges
			*	register		
1	*	*	*		Capture input	Input capture at TCNT4
					source is channel	count-up/count-down* ¹
					4/count clock	

*: Don't care

Note: 1. When bits TPSC2 to TPSC0 in TCR4 are set to B'000 and ø/1 is used as the TCNT4 count clock, this setting is invalid and input capture is not generated.

		1	0	register* ²	Output	1 output at compare match
			1			Toggle output at compare match
1	0	0	0		Output disabled	
			1		Initial output is 1	0 output at compare match
		1	0		output	1 output at compare match
			1			Toggle output at compare match
1	0	0	0	TGR3D is input capture register* ²	Capture input source is TIOCD3 pin	Input capture at rising edge
			1			Input capture at falling edge
		1	*			Input capture at both edges
1	*	*	*		Capture input source is channel 4/count clock	Input capture at TCNT4 count-up/count-down* ¹

*: Don't care

- Notes: 1. When bits TPSC2 to TPSC0 in TCR4 are set to B'000 and $\emptyset/1$ is used as the TCNT4 count clock, this setting is invalid and input capture is not generated.
2. When the BFB bit in TMDR3 is set to 1 and TGR3D is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

		1	0	register	Output	1 output at compare match
			1			Toggle output at compare match
	1	0	0		Output disabled	
			1		Initial output is 1	0 output at compare match
		1	0		output	1 output at compare match
			1			Toggle output at compare match
1	0	0	0	TGR4B is input capture register	Capture input source is TIOCB4 pin	Input capture at rising edge
			1			Input capture at falling edge
		1	*			Input capture at both edges
	1	*	*		Capture input source is TGR3C compare match/ input capture	Input capture at generation of TGR3C compare match/ input capture

*: Don't care

Channel	Bit 7 IOB3	Bit 6 IOB2	Bit 5 IOB1	Bit 4 IOB0	Description	
5	0	0	0	0	TGR5B is output compare register	Output disabled (Initial value)
				1		Initial output is 0
			1	0		output
				1		0 output at compare match
						1 output at compare match
						Toggle output at compare match
		1	0	0		Output disabled
				1		Initial output is 1
			1	0		output
				1		0 output at compare match
						1 output at compare match
						Toggle output at compare match
1	*	0	0	0	TGR5B is input capture register	Capture input source is TIOCB5 pin
				1		
			1	*		
						Input capture at rising edge
						Input capture at falling edge
						Input capture at both edges

*: Don't care

Channel	Bit 3 IOA3	Bit 2 IOA2	Bit 1 IOA1	Bit 0 IOA0	Description
0	0	0	0	0	TGR0A is Output disabled (Initial value)
				1	output compare register
				0	Initial output is 0 output
				1	0 output at compare match
				0	1 output at compare match
				1	Toggle output at compare match
	1	0	0	0	Output disabled
				1	Initial output is 1 output
				0	0 output at compare match
				1	1 output at compare match
				0	Toggle output at compare match
				1	Toggle output at compare match
1	0	0	0	TGR0A is Capture input source is TIOCA0 pin	
			1	input capture register	
			0	Input capture at rising edge	
			1	Input capture at falling edge	
			*	Input capture at both edges	
			1	Input capture at TCNT1 count-up/count-down 1/ count clock	

*: Don't care

	1	0	0	register**1	Output	1 output at compare match
			1			Toggle output at compare match
1	0	0	0		Output disabled	
			1		Initial output is 1	0 output at compare match
		1	0		output	1 output at compare match
			1			Toggle output at compare match
1	0	0	0	TGR0C is	Capture input	Input capture at rising edge
			1	input	source is	Input capture at falling edge
			*	capture	TIOCC0 pin	Input capture at both edges
		1	*	register**1		
1	*	*	*		Capture input	Input capture at TCNT1
					source is channel	count-up/count-down
					1/count clock	

*: Don't care

Note: 1. When the BFA bit in TMDR0 is set to 1 and TGR0C is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

	1	0	0	0	register	Output	1 output at compare match
				1			Toggle output at compare match
	1	0	0	0		Output disabled	
				1		Initial output is 1	0 output at compare match
		1	0	0		output	1 output at compare match
				1			Toggle output at compare match
1	0	0	0	0	TGR1A is input capture register	Capture input source is TIOCA1 pin	Input capture at rising edge
				1			Input capture at falling edge
		1	*	*			Input capture at both edges
	1	*	*	*		Capture input source is TGR0A compare match/ input capture	Input capture at generation of channel 0/TGR0A compare match/input capture

*: Don't care

Channel	Bit 3 IOA3	Bit 2 IOA2	Bit 1 IOA1	Bit 0 IOA0	Description		
2	0	0	0	0	TGR2A is output compare register	Output disabled	(Initial value)
				1		Initial output is 0	0 output at compare match
			1	0		output	1 output at compare match
				1			Toggle output at compare match
		1	0	0		Output disabled	
				1		Initial output is 1	0 output at compare match
			1	0		output	1 output at compare match
				1			Toggle output at compare match
	1	*	0	0	TGR2A is input capture register	Capture input source is TIOCA2 pin	Input capture at rising edge
				1			Input capture at falling edge
			1	*			Input capture at both edges

*: Don't care

	1	0	register	Output	1 output at compare match
		1			Toggle output at compare match
1	0	0		Output disabled	
		1		Initial output is 1	0 output at compare match
	1	0		output	1 output at compare match
		1			Toggle output at compare match
1	0	0	0	TGR3A is	Input capture at rising edge
			1	input	Input capture at falling edge
		1	*	capture	Input capture at both edges
				register	
	1	*	*	Capture input	Input capture at TCNT4
				source is channel	count-up/count-down
				4/count clock	

*: Don't care

		1	0	register*1	Output	1 output at compare match
			1			Toggle output at compare match
1	0	0	0		Output disabled	
			1		Initial output is 1	0 output at compare match
		1	0		output	1 output at compare match
			1			Toggle output at compare match
1	0	0	0	TGR3C is	Capture input	Input capture at rising edge
			1	input	source is	Input capture at falling edge
		1	*	capture	TIOCC3 pin	Input capture at both edges
			*	register*1		
1	*	*	*		Capture input	Input capture at TCNT4
					source is channel	count-up/count-down
					4/count clock	

*: Don't care

Note: 1. When the BFA bit in TMDR3 is set to 1 and TGR3C is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

		1	0	register	Output	1 output at compare match
			1			Toggle output at compare match
	1	0	0		Output disabled	
			1		Initial output is 1	0 output at compare match
		1	0		output	1 output at compare match
			1			Toggle output at compare match
1	0	0	0	TGR4A is	Capture input	Input capture at rising edge
			1	input	source is	Input capture at falling edge
			*	capture	TIOCA4 pin	Input capture at both edges
		1	*	register		
	1	*	*		Capture input	Input capture at generation of
					source is TGR3A	TGR3A compare match/input
					compare match/	capture
					input capture	

*: Don't care

Channel	Bit 3 IOA3	Bit 2 IOA2	Bit 1 IOA1	Bit 0 IOA0	Description	
5	0	0	0	0	TGR5A is	Output disabled (Initial value)
				1	output	Initial output is 0
			1	0	compare	0 output at compare match
				1	register	1 output at compare match
						Toggle output at compare match
		1	0	0		Output disabled
				1		Initial output is 1
			1	0		0 output at compare match
				1		1 output at compare match
						Toggle output at compare match
1	*	0	0	0	TGR5A is	Capture input
				1	input	source is
				*	capture	TIOCA5 pin
			1	*	register	Input capture at both edges

*: Don't care

Bit	:	7	6	5	4	3	2	1	0
		TTGE	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA
Initial value	:	0	1	0	0	0	0	0	0
R/W	:	R/W	—	—	R/W	R/W	R/W	R/W	R/W

Channel 1: TIER1

Channel 2: TIER2

Channel 4: TIER4

Channel 5: TIER5

Bit	:	7	6	5	4	3	2	1	0
		TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
Initial value	:	0	1	0	0	0	0	0	0
R/W	:	R/W	—	R/W	R/W	—	—	R/W	R/W

The TIER registers are 8-bit registers that control enabling or disabling of interrupt requests for each channel. The TPU has six TIER registers, one for each channel. The TIER registers are initialized to H'40 by a reset, and in hardware standby mode.

0	A/D conversion start request generation disabled	(Initial value)
1	A/D conversion start request generation enabled	

Bit 6—Reserved: Read-only bit, always read as 1.

Bit 5—Underflow Interrupt Enable (TCIEU): Enables or disables interrupt requests (TCIU) by the TCFU flag when the TCFU flag in TSR is set to 1 in channels 1 and 2.

In channels 0 and 3, bit 5 is reserved. It is always read as 0 and cannot be modified.

Bit 5

TCIEU	Description	
0	Interrupt requests (TCIU) by TCFU disabled	(Initial value)
1	Interrupt requests (TCIU) by TCFU enabled	

Bit 4—Overflow Interrupt Enable (TCIEV): Enables or disables interrupt requests (TCIV) by the TCFV flag when the TCFV flag in TSR is set to 1.

Bit 4

TCIEV	Description	
0	Interrupt requests (TCIV) by TCFV disabled	(Initial value)
1	Interrupt requests (TCIV) by TCFV enabled	

Bit 3—TGR Interrupt Enable D (TGIED): Enables or disables interrupt requests (TGID) by the TGFD bit when the TGFD bit in TSR is set to 1 in channels 0 and 3.

In channels 1, 2, 4, and 5, bit 3 is reserved. It is always read as 0 and cannot be modified.

Bit 3

TGIED	Description	
0	Interrupt requests (TGID) by TGFD bit disabled	(Initial value)
1	Interrupt requests (TGID) by TGFD bit enabled	

Bit 2	
TGIEC	Description
0	Interrupt requests (TGIC) by TGFC bit disabled (Initial value)
1	Interrupt requests (TGIC) by TGFC bit enabled

Bit 1—TGR Interrupt Enable B (TGIEB): Enables or disables interrupt requests (TGIB) by the TGFB bit when the TGFB bit in TSR is set to 1.

Bit 1	
TGIEB	Description
0	Interrupt requests (TGIB) by TGFB bit disabled (Initial value)
1	Interrupt requests (TGIB) by TGFB bit enabled

Bit 0—TGR Interrupt Enable A (TGIEA): Enables or disables interrupt requests (TGIA) by the TGFA bit when the TGFA bit in TSR is set to 1.

Bit 0	
TGIEA	Description
0	Interrupt requests (TGIA) by TGFA bit disabled (Initial value)
1	Interrupt requests (TGIA) by TGFA bit enabled

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	TCFV	TGFD	TGFC	TGFB	TGFA
Initial value	:	1	1	0	0	0	0	0	0
R/W	:	—	—	—	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*

Note: * Can only be written with 0 for flag clearing.

Channel 1: TSR1

Channel 2: TSR2

Channel 4: TSR4

Channel 5: TSR5

Bit	:	7	6	5	4	3	2	1	0
		TCFD	—	TCFU	TCFV	—	—	TGFB	TGFA
Initial value	:	1	1	0	0	0	0	0	0
R/W	:	R	—	R/(W)*	R/(W)*	—	—	R/(W)*	R/(W)*

Note: * Can only be written with 0 for flag clearing.

The TSR registers are 8-bit registers that indicate the status of each channel. The TPU has six TSR registers, one for each channel. The TSR registers are initialized to H'00 by a reset, and in hardware standby mode.

Bit 7 TCFD	Description
0	TCNT counts down
1	TCNT counts up (Initial value)

Bit 6—Reserved: Read-only bit, always read as 1.

Bit 5—Underflow Flag (TCFU): Status flag that indicates that TCNT underflow has occurred when channels 1, 2, 4, and 5 are set to phase counting mode.

In channels 0 and 3, bit 5 is reserved. It is always read as 0 and cannot be modified.

Bit 5 TCFU	Description
0	[Clearing condition] (Initial value) When 0 is written to TCFU after reading TCFU = 1
1	[Setting condition] When the TCNT value underflows (changes from H'0000 to H'FFFF)

Bit 4—Overflow Flag (TCFV): Status flag that indicates that TCNT overflow has occurred.

Bit 4 TCFV	Description
0	[Clearing condition] (Initial value) When 0 is written to TCFV after reading TCFV = 1
1	[Setting condition] When the TCNT value overflows (changes from H'FFFF to H'0000)

Bit 3 TGFD	Description
0	[Clearing conditions] (Initial value) <ul style="list-style-type: none"> When DTC is activated by TGID interrupt while DIESEL bit of MRB in DTC is 0 When 0 is written to TGFD after reading TGFD = 1
1	[Setting conditions] <ul style="list-style-type: none"> When TCNT = TGRD while TGRD is functioning as output compare register When TCNT value is transferred to TGRD by input capture signal while TGRD is functioning as input capture register

Bit 2—Input Capture/Output Compare Flag C (TGFC): Status flag that indicates the occurrence of TGRC input capture or compare match in channels 0 and 3.

In channels 1, 2, 4, and 5, bit 2 is reserved. It is always read as 0 and cannot be modified.

Bit 2 TGFC	Description
0	[Clearing conditions] (Initial value) <ul style="list-style-type: none"> When DTC is activated by TGIC interrupt while DIESEL bit of MRB in DTC is 0 When 0 is written to TGFC after reading TGFC = 1
1	[Setting conditions] <ul style="list-style-type: none"> When TCNT = TGRC while TGRC is functioning as output compare register When TCNT value is transferred to TGRC by input capture signal while TGRC is functioning as input capture register

0	[Clearing conditions]	(Initial value)
	<ul style="list-style-type: none"> When DTC is activated by TGIB interrupt while DISEL bit of MRB in DTC is 0 When 0 is written to TGFB after reading TGFB = 1 	
1	[Setting conditions]	
	<ul style="list-style-type: none"> When TCNT = TGRB while TGRB is functioning as output compare register When TCNT value is transferred to TGRB by input capture signal while TGRB is functioning as input capture register 	

Bit 0—Input Capture/Output Compare Flag A (TGFA): Status flag that indicates the occurrence of TGRA input capture or compare match.

Bit 0 TGFA	Description	
0	[Clearing conditions]	(Initial value)
	<ul style="list-style-type: none"> When DTC is activated by TGIA interrupt while DISEL bit of MRB in DTC is 0 When DMAC is activated by TGIA interrupt while DTA bit of DMABCR in DMAC is 1 When 0 is written to TGFA after reading TGFA = 1 	
1	[Setting conditions]	
	<ul style="list-style-type: none"> When TCNT = TGRA while TGRA is functioning as output compare register When TCNT value is transferred to TGRA by input capture signal while TGRA is functioning as input capture register 	

Channel 2: TCNT2 (up/down-counter*)

Channel 3: TCNT3 (up-counter)

Channel 4: TCNT4 (up/down-counter*)

Channel 5: TCNT5 (up/down-counter*)

Bit	:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Initial value	:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
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	R/W	R/W

Note : * These counters can be used as up/down-counters only in phase counting mode or when counting overflow/underflow on another channel. In other cases they function as up-counters.

The TCNT registers are 16-bit counters. The TPU has six TCNT counters, one for each channel.

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

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

Initial value :	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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	R/W

The TGR registers are 16-bit registers with a dual function as output compare and input capture registers. The TPU has 16 TGR registers, four each for channels 0 and 3 and two each for channels 1, 2, 4, and 5. TGRC and TGRD for channels 0 and 3 can also be designated for operation as buffer registers*. The TGR registers are initialized to H'FFFF by a reset, and in hardware standby mode.

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

Note: * TGR buffer register combinations are TGRA—TGRC and TGRB—TGRD.

Initial value :	0	0	0	0	0	0	0	0	0
R/W	—	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W

TSTR is an 8-bit readable/writable register that selects operation/stoppage for channels 0 to 5. TSTR is initialized to H'00 by a reset, and in hardware standby mode. When setting the operating mode in TMDR or setting the count clock in TCR, first stop the TCNT counter.

Bits 7 and 6—Reserved: Should always be written with 0.

Bits 5 to 0—Counter Start 5 to 0 (CST5 to CST0): These bits select operation or stoppage for TCNT.

Bit n CSTn	Description	
0	TCNTn count operation is stopped	(Initial value)
1	TCNTn performs count operation	

n = 5 to 0

Note: If 0 is written to the CST bit during operation with the TIOC pin designated for output, the counter stops but the TIOC pin output compare output level is retained. If TIOR is written to when the CST bit is cleared to 0, the pin output level will be changed to the set initial output value.

Initial value :	0	0	0	0	0	0	0	0
R/W :	—	—	R/W	R/W	R/W	R/W	R/W	R/W

TSYR is an 8-bit readable/writable register that selects independent operation or synchronous operation for the channel 0 to 5 TCNT counters. A channel performs synchronous operation when the corresponding bit in TSYR is set to 1.

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

Bits 7 and 6—Reserved: Should always be written with 0.

Bits 5 to 0—Timer Synchro 5 to 0 (SYNC5 to SYNC0): These bits select whether operation is independent of or synchronized with other channels.

When synchronous operation is selected, synchronous presetting of multiple channels*¹, and synchronous clearing through counter clearing on another channel*² are possible.

Bit n SYNCn	Description
0	TCNTn operates independently (TCNT presetting/clearing is unrelated to other channels) (Initial value)
1	TCNTn performs synchronous operation TCNT synchronous presetting/synchronous clearing is possible

n = 5 to 0

- Notes: 1. To set synchronous operation, the SYNC bits for at least two channels must be set to 1.
2. To set synchronous clearing, in addition to the SYNC bit, the TCNT clearing source must also be set by means of bits CCLR2 to CCLR0 in TCR.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Initial value	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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	R/W	R/W

MSTPCR is a 16-bit readable/writable register that performs module stop mode control.

When the MSTP13 bit in MSTPCR is set to 1, TPU operation stops at the end of the bus cycle and a transition is made to module stop mode. Registers cannot be read or written to in module stop mode. For details, see section 20.5, 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 13—Module Stop (MSTP13): Specifies the TPU module stop mode.

Bit 13

MSTP13	Description
0	TPU module stop mode cleared
1	TPU module stop mode set (Initial value)

TCNT and TGR are 16-bit registers. As the data bus to the bus master is 16 bits wide, these registers can be read and written to in 16-bit units.

These registers cannot be read or written to in 8-bit units; 16-bit access must always be used.

An example of 16-bit register access operation is shown in figure 10-2.

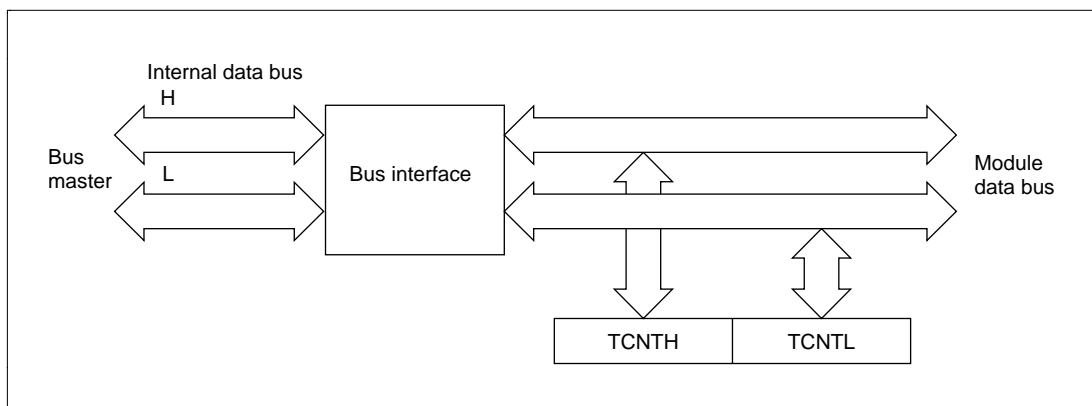


Figure 10-2 16-Bit Register Access Operation [Bus Master ↔ TCNT (16 Bits)]

10.3.2 8-Bit Registers

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

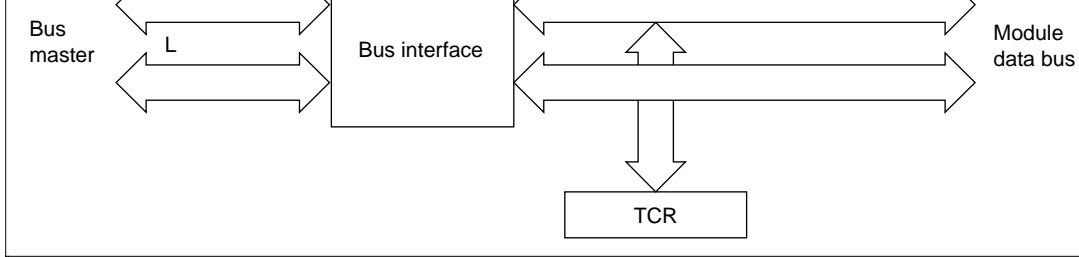


Figure 10-3 8-Bit Register Access Operation [Bus Master ↔ TCR (Upper 8 Bits)]

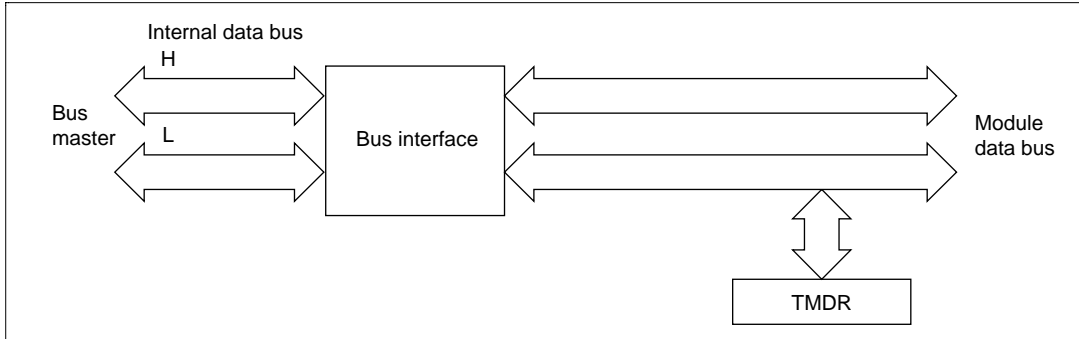


Figure 10-4 8-Bit Register Access Operation [Bus Master ↔ TMDR (Lower 8 Bits)]

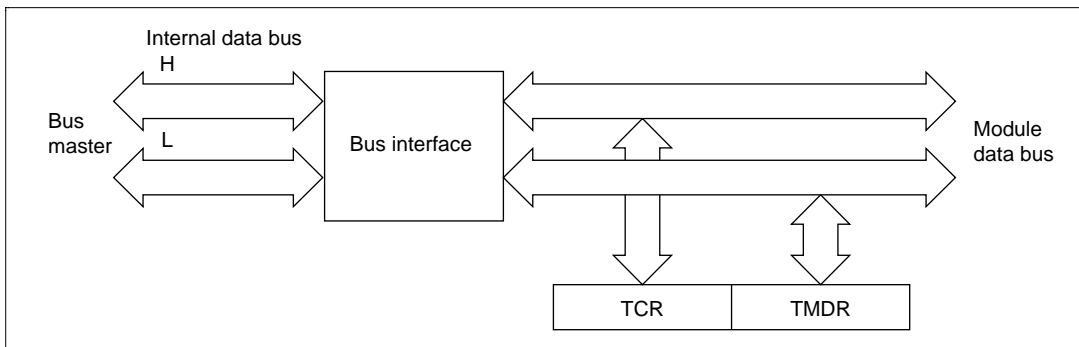


Figure 10-5 8-Bit Register Access Operation [Bus Master ↔ TCR and TMDR (16 Bits)]

Operation in each mode is outlined below.

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

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

Synchronous Operation: When synchronous operation is designated for a channel, TCNT for that channel performs synchronous presetting. That is, when TCNT for a channel designated for synchronous operation is rewritten, the TCNT counters for the other channels are also rewritten at the same time. Synchronous clearing of the TCNT counters is also possible by setting the timer synchronization bits in TSYR for channels designated for synchronous operation.

Buffer Operation

- When TGR is an output compare register
When a compare match occurs, the value in the buffer register for the relevant channel is transferred to TGR.
- When TGR is an input capture register
When input capture occurs, the value in TCNT is transfer to TGR and the value previously held in TGR is transferred to the buffer register.

Cascaded Operation: The channel 1 counter (TCNT1), channel 2 counter (TCNT2), channel 4 counter (TCNT4), and channel 5 counter (TCNT5) can be connected together to operate as a 32-bit counter.

PWM Mode: In this mode, a PWM waveform is output. The output level can be set by means of TIOR. A PWM waveform with a duty of between 0% and 100% can be output, according to the setting of each TGR register.

Phase Counting Mode: In this mode, TCNT is incremented or decremented by detecting the phases of two clocks input from the external clock input pins in channels 1, 2, 4, and 5. When phase counting mode is set, the corresponding TCLK pin functions as the clock pin, and TCNT performs up- or down-counting.

This can be used for two-phase encoder pulse input.

counter, and so on.

- Example of count operation setting procedure

Figure 10-6 shows an example of the count operation setting procedure.

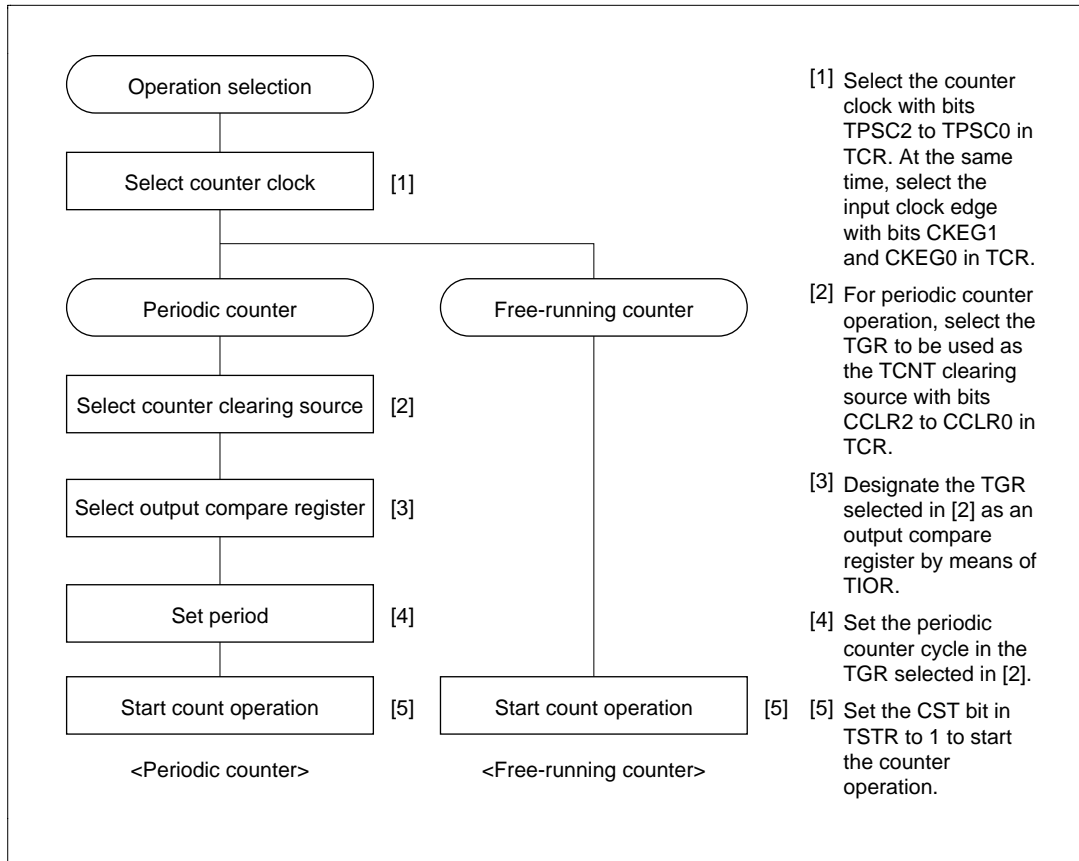


Figure 10-6 Example of Counter Operation Setting Procedure

the TCFV bit in TSR is set to 1. If the value of the corresponding TCIEV bit in TIER is 1 at this point, the TPU requests an interrupt. After overflow, TCNT starts counting up again from H'0000.

Figure 10-7 illustrates free-running counter operation.

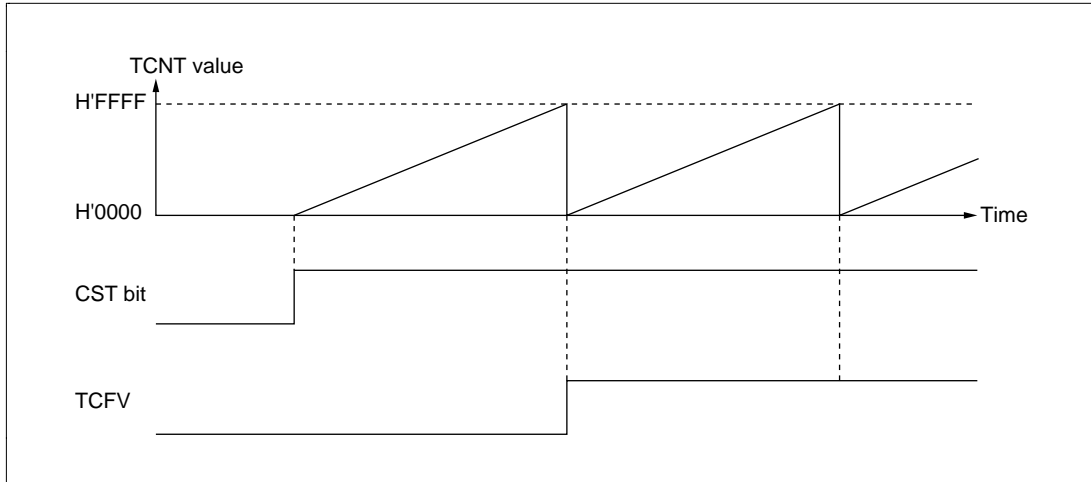


Figure 10-7 Free-Running Counter Operation

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

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

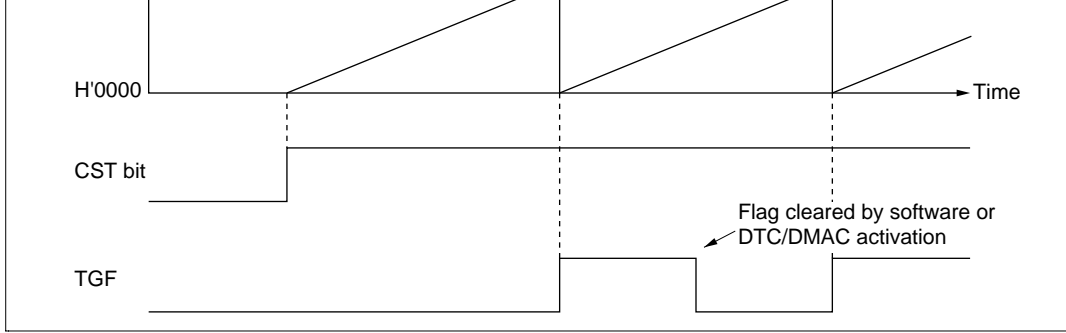


Figure 10-8 Periodic Counter Operation

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

- Example of setting procedure for waveform output by compare match

Figure 10-9 shows an example of the setting procedure for waveform output by compare match

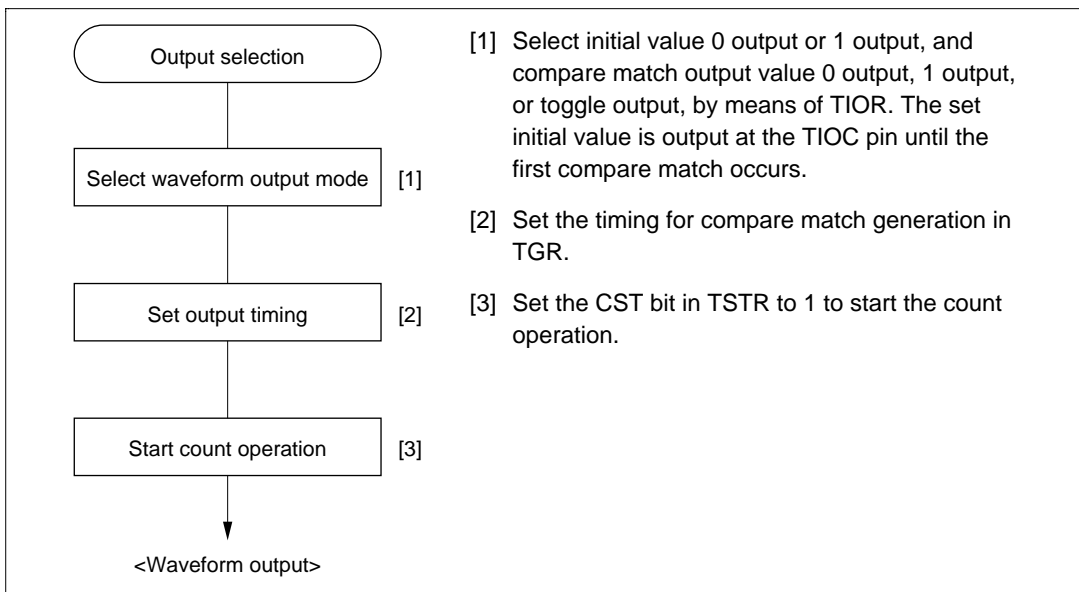


Figure 10-9 Example Of Setting Procedure For Waveform Output By Compare Match

set level and the pin level coincide, the pin level does not change.

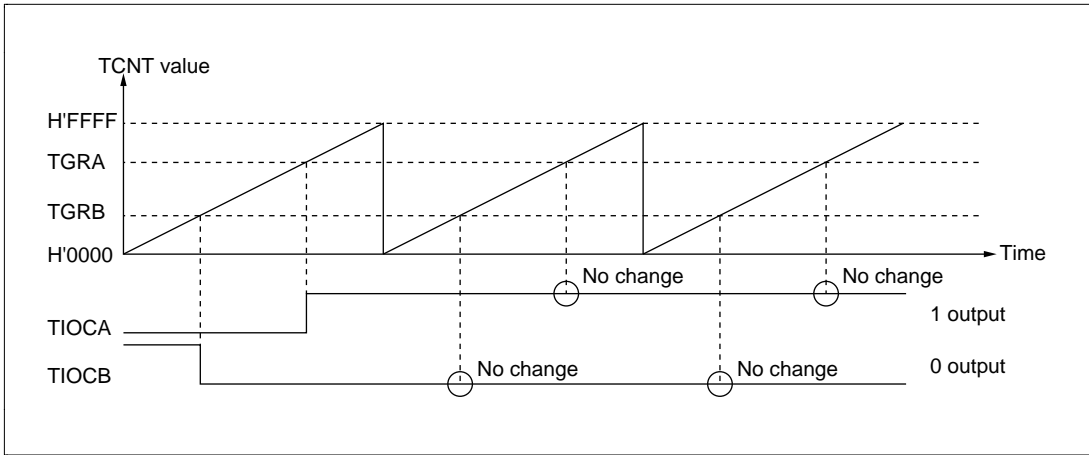


Figure 10-10 Example of 0 Output/1 Output Operation

Figure 10-11 shows an example of toggle output.

In this example TCNT has been designated as a periodic counter (with counter clearing performed by compare match B), and settings have been made so that output is toggled by both compare match A and compare match B.

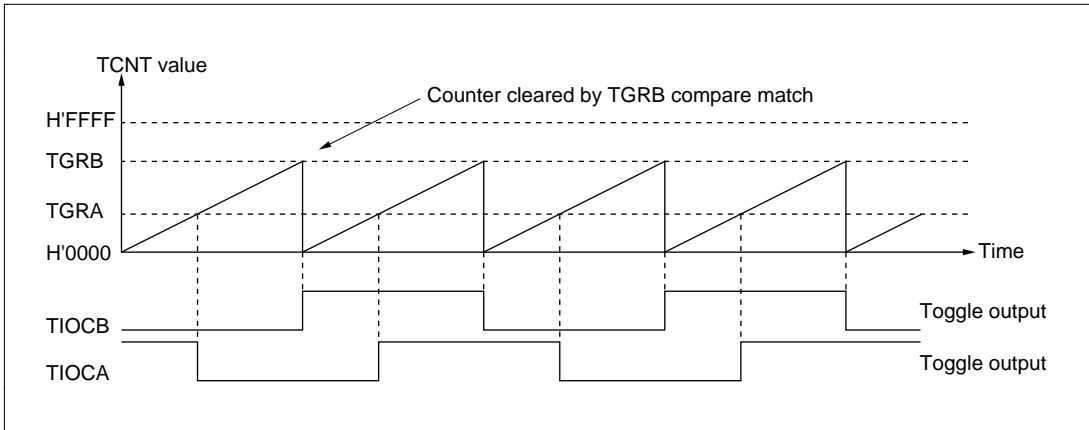


Figure 10-11 Example of Toggle Output Operation

as the input capture source.

Note: When another channel's counter input clock is used as the input capture input for channels 0 and 3, $\emptyset/1$ should not be selected as the counter input clock used for input capture input. Input capture will not be generated if $\emptyset/1$ is selected.

- Example of input capture operation setting procedure

Figure 10-12 shows an example of the input capture operation setting procedure.

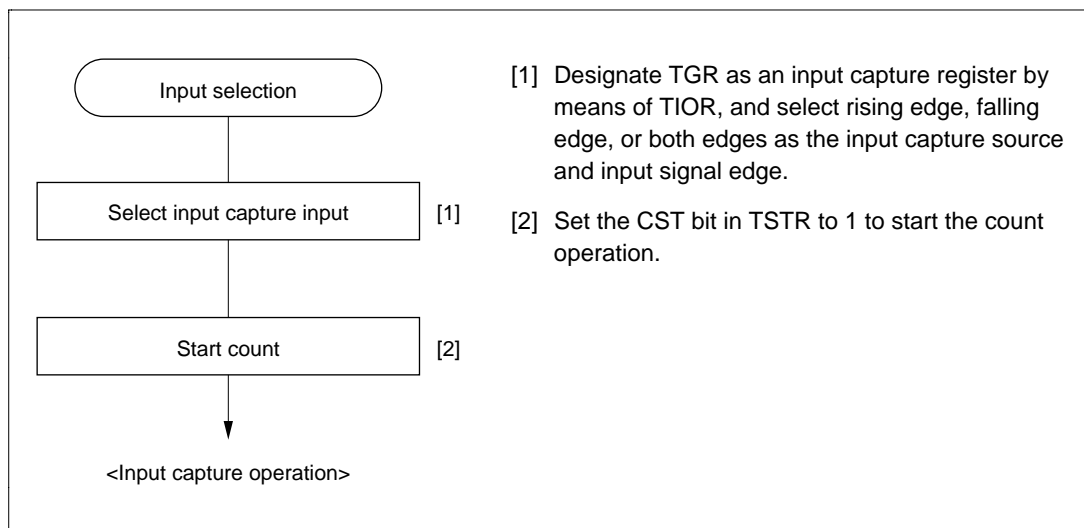


Figure 10-12 Example of Input Capture Operation Setting Procedure

and counter clearing by TGRB input capture has been designated for TCNT.

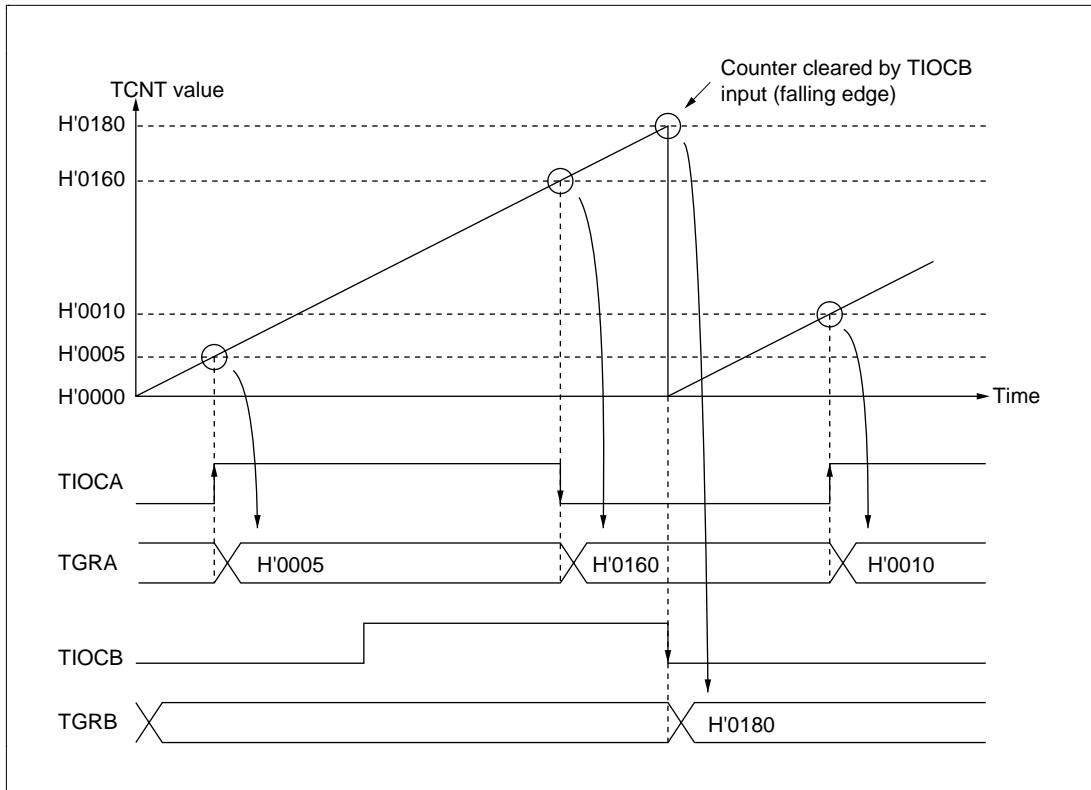


Figure 10-13 Example of Input Capture Operation

simultaneously by making the appropriate setting in TCR (synchronous clearing).

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

Channels 0 to 5 can all be designated for synchronous operation.

Example of Synchronous Operation Setting Procedure: Figure 10-14 shows an example of the synchronous operation setting procedure.

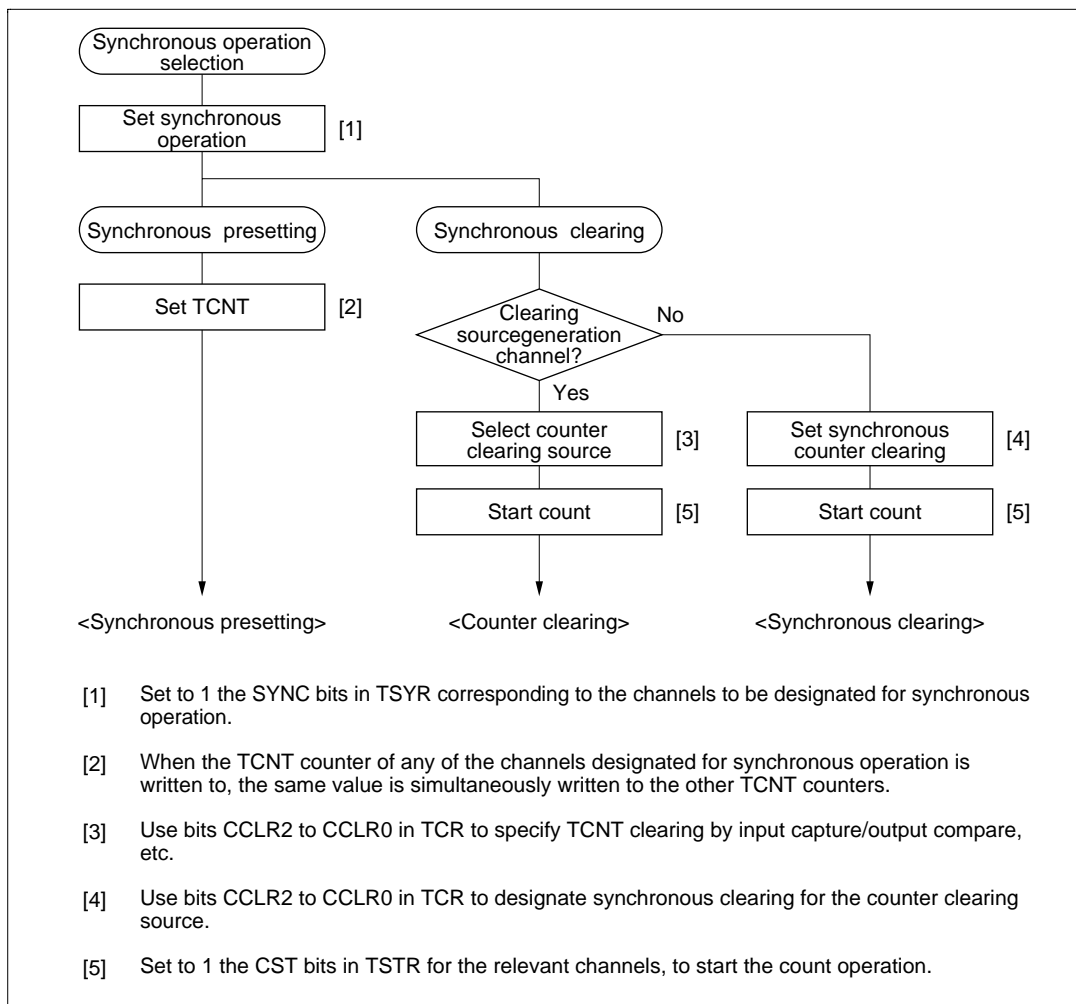


Figure 10-14 Example of Synchronous Operation Setting Procedure

Three-phase PWM waveforms are output from pins TIOC0A, TIOC1A, and TIOC2A. At this time, synchronous presetting, and synchronous clearing by TGR0B compare match, is performed for channel 0 to 2 TCNT counters, and the data set in TGR0B is used as the PWM cycle.

For details of PWM modes, see section 10.4.6, PWM Modes.

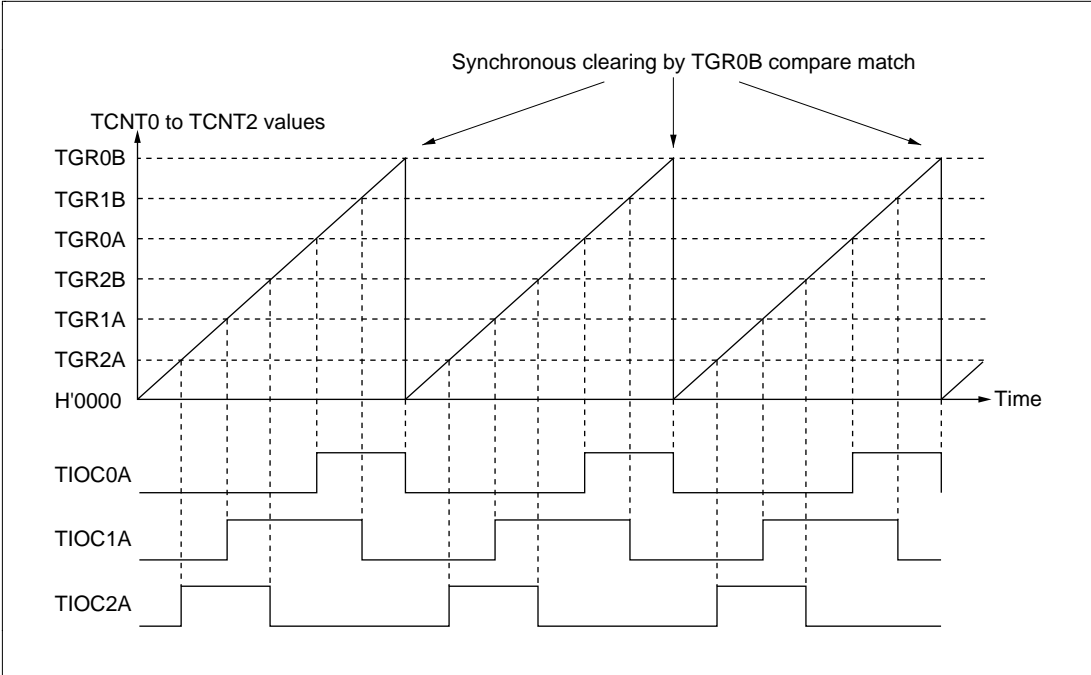


Figure 10-15 Example of Synchronous Operation

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

Table 10-5 shows the register combinations used in buffer operation.

Table 10-5 Register Combinations in Buffer Operation

Channel	Timer General Register	Buffer Register
0	TGR0A	TGR0C
	TGR0B	TGR0D
3	TGR3A	TGR3C
	TGR3B	TGR3D

- When TGR is an output compare register

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

This operation is illustrated in figure 10-16.

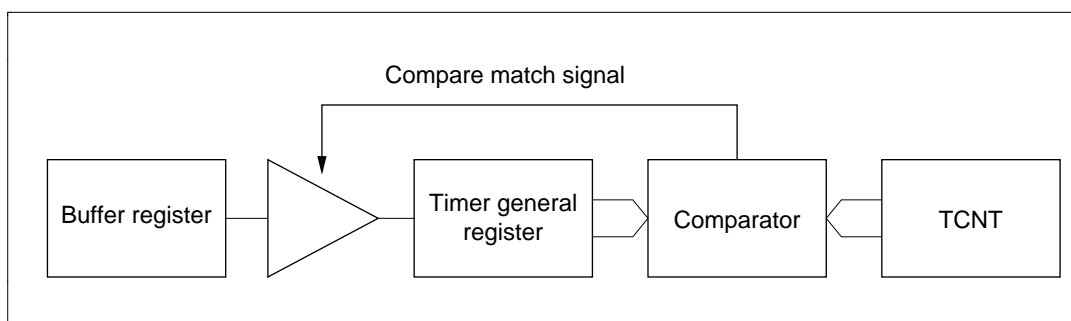


Figure 10-16 Compare Match Buffer Operation

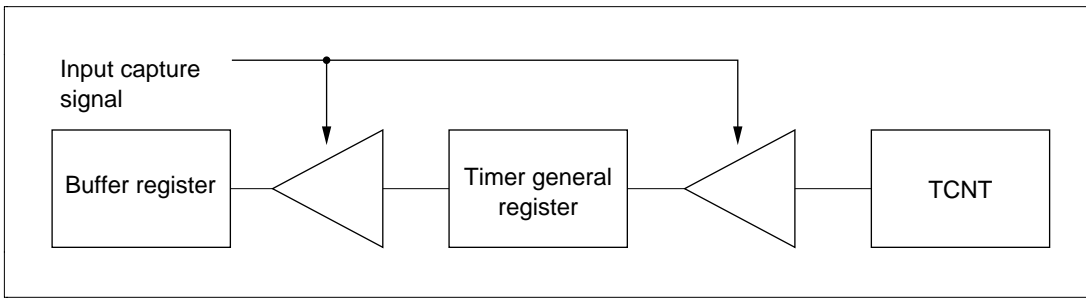


Figure 10-17 Input Capture Buffer Operation

Example of Buffer Operation Setting Procedure: Figure 10-18 shows an example of the buffer operation setting procedure.

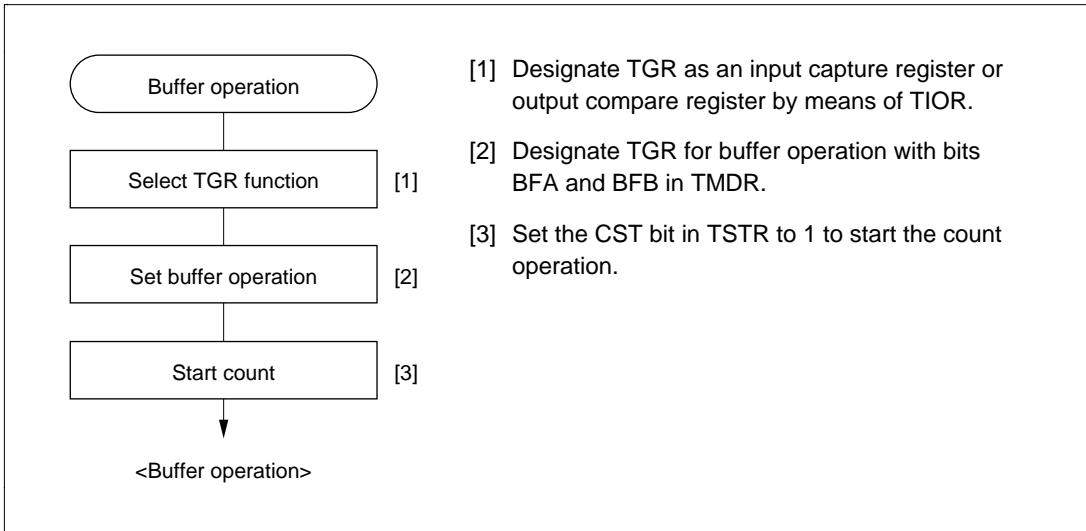


Figure 10-18 Example of Buffer Operation Setting Procedure

in this example are TCNT clearing by compare match B, 1 output at compare match A, and 0 output at compare match B.

As buffer operation has been set, when compare match A occurs the output changes and the value in buffer register TGRC is simultaneously transferred to timer general register TGRA. This operation is repeated each time compare match A occurs.

For details of PWM modes, see section 10.4.6, PWM Modes.

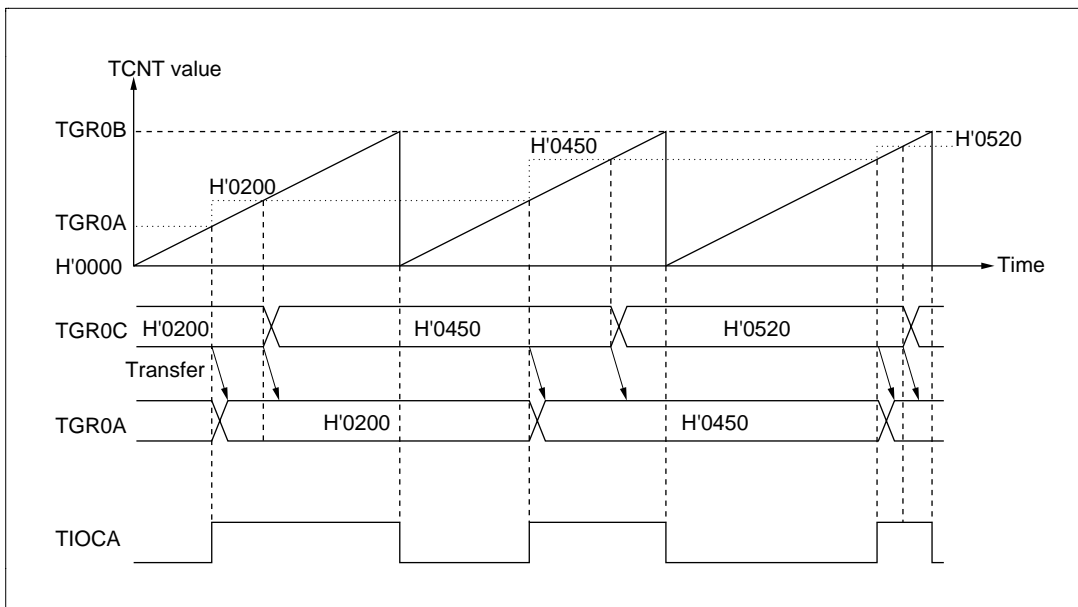


Figure 10-19 Example of Buffer Operation (1)

edges have been selected as the TIOCA pin input capture input edge.

As buffer operation has been set, when the TCNT value is stored in TGRA upon occurrence of input capture A, the value previously stored in TGRA is simultaneously transferred to TGRC.

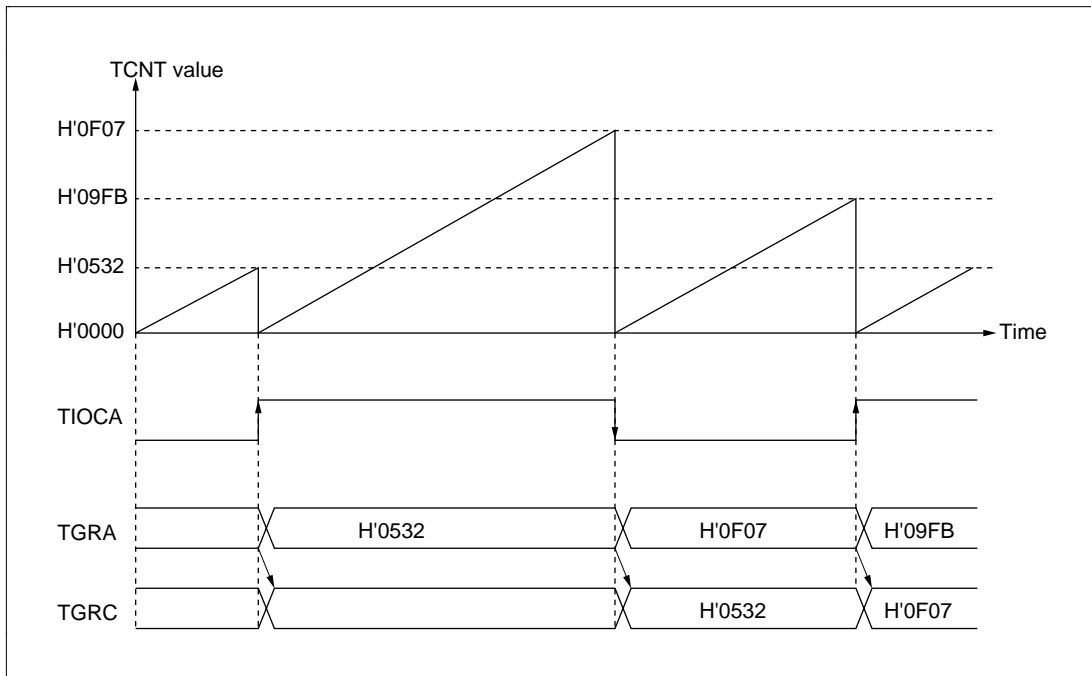


Figure 10-20 Example of Buffer Operation (2)

This function works by counting the channel 1 (channel 4) counter clock upon overflow/underflow of TCNT2 (TCNT5) as set in bits TPSC2 to TPSC0 in TCR.

Underflow occurs only when the lower 16-bit TCNT is in phase-counting mode.

Table 10-6 shows the register combinations used in cascaded operation.

Note: When phase counting mode is set for channel 1 or 4, the counter clock setting is invalid and the counter operates independently in phase counting mode.

Table 10-6 Cascaded Combinations

Combination	Upper 16 Bits	Lower 16 Bits
Channels 1 and 2	TCNT1	TCNT2
Channels 4 and 5	TCNT4	TCNT5

Example of Cascaded Operation Setting Procedure: Figure 10-21 shows an example of the setting procedure for cascaded operation.

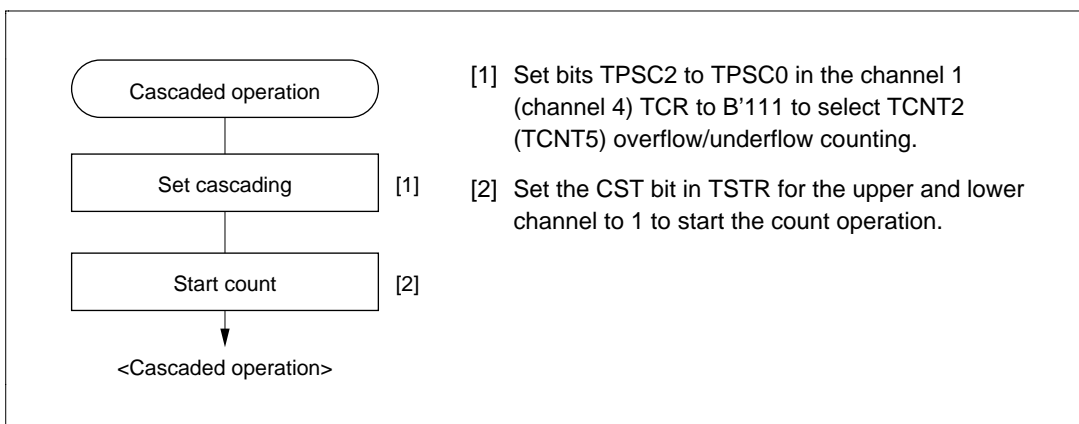


Figure 10-21 Cascaded Operation Setting Procedure

the 32-bit data are transferred to TGR1A, and the lower 16 bits to TGR2A.

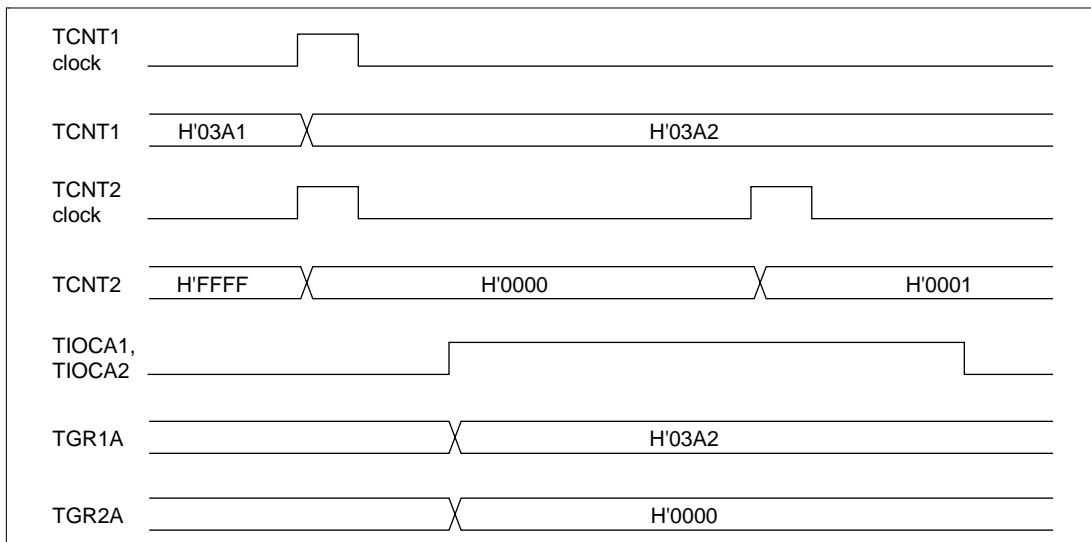


Figure 10-22 Example of Cascaded Operation (1)

Figure 10-23 illustrates the operation when counting upon TCNT2 overflow/underflow has been set for TCNT1, and phase counting mode has been designated for channel 2.

TCNT1 is incremented by TCNT2 overflow and decremented by TCNT2 underflow.

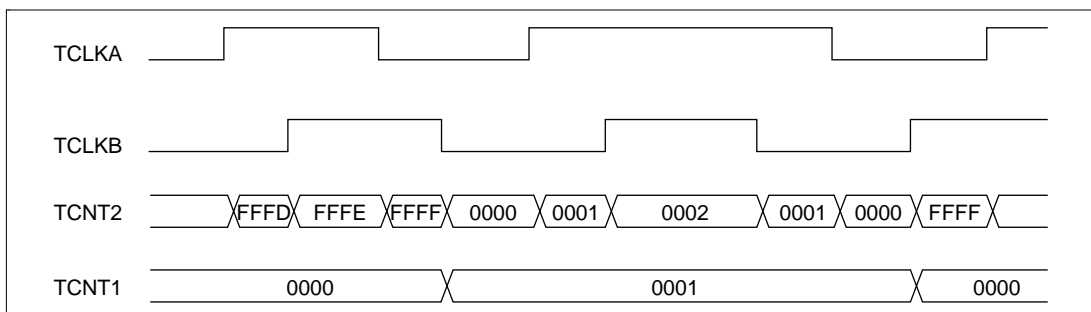


Figure 10-23 Example of Cascaded Operation (2)

Designating TGR compare match as the counter clearing source enables the period to be set in that register. All channels can be designated for PWM mode independently. Synchronous operation is also possible.

There are two PWM modes, as described below.

- PWM mode 1

PWM output is generated from the TIOCA and TIOCC pins by pairing TGRA with TGRB and TGRC with TGRD. The output specified by bits IOA3 to IOA0 and IOC3 to IOC0 in TIOR is output from the TIOCA and TIOCC pins at compare matches A and C, and the output specified by bits IOB3 to IOB0 and IOD3 to IOD0 in TIOR is output at compare matches B and D. The initial output value is the value set in TGRA or TGRC. If the set values of paired TGRs are identical, the output value does not change when a compare match occurs.

In PWM mode 1, a maximum 8-phase PWM output is possible.

- PWM mode 2

PWM output is generated using one TGR as the cycle register and the others as duty registers. The output specified in TIOR is performed by means of compare matches. Upon counter clearing by a synchronization register compare match, the output value of each pin is the initial value set in TIOR. If the set values of the cycle and duty registers are identical, the output value does not change when a compare match occurs.

In PWM mode 2, a maximum 15-phase PWM output is possible by combined use with synchronous operation.

The correspondence between PWM output pins and registers is shown in table 10-7.

0	TGR0A	TIOCA0	TIOCA0
	TGR0B		TIOCB0
	TGR0C	TIOCC0	TIOCC0
	TGR0D		TIOCD0
1	TGR1A	TIOCA1	TIOCA1
	TGR1B		TIOCB1
2	TGR2A	TIOCA2	TIOCA2
	TGR2B		TIOCB2
3	TGR3A	TIOCA3	TIOCA3
	TGR3B		TIOCB3
	TGR3C	TIOCC3	TIOCC3
	TGR3D		TIOCD3
4	TGR4A	TIOCA4	TIOCA4
	TGR4B		TIOCB4
5	TGR5A	TIOCA5	TIOCA5
	TGR5B		TIOCB5

Note: In PWM mode 2, PWM output is not possible for the TGR register in which the period is set.

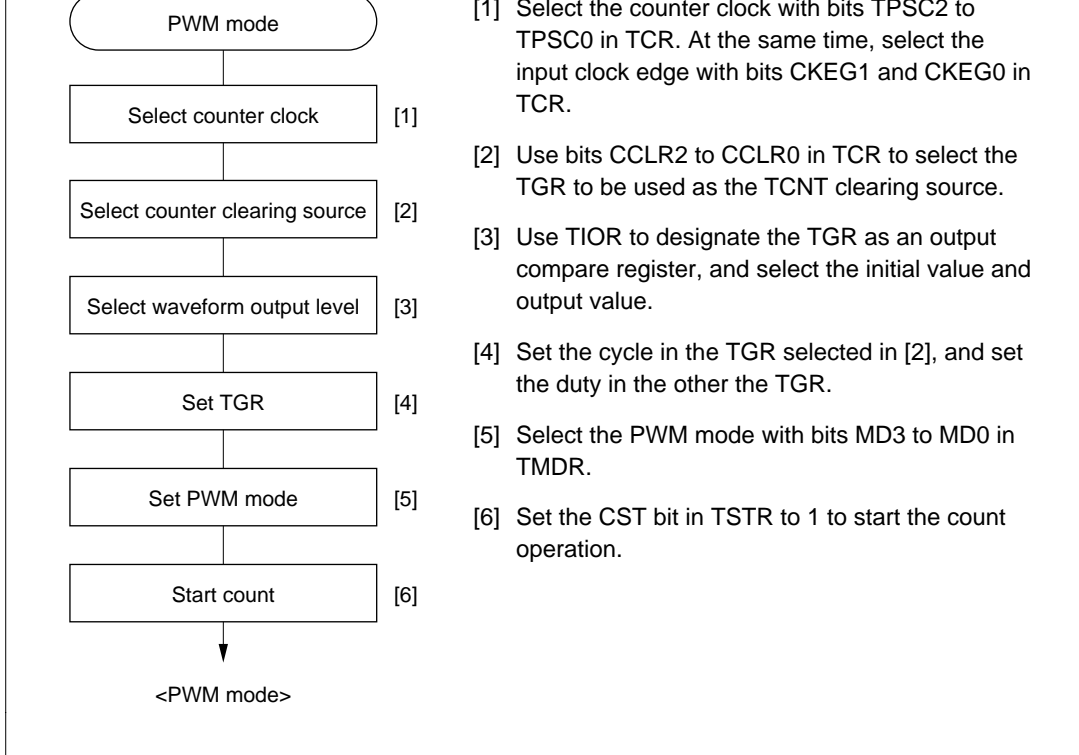


Figure 10-24 Example of PWM Mode Setting Procedure

Examples of PWM Mode Operation: Figure 10-25 shows an example of PWM mode 1 operation.

In this example, TGRA compare match is set as the TCNT clearing source, 0 is set for the TGRA initial output value and output value, and 1 is set as the TGRB output value.

In this case, the value set in TGRA is used as the period, and the values set in TGRB registers as the duty.

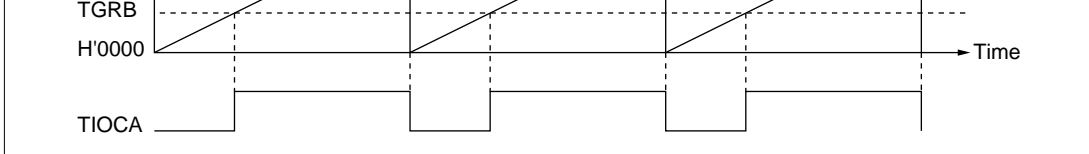


Figure 10-25 Example of PWM Mode Operation (1)

Figure 10-26 shows an example of PWM mode 2 operation.

In this example, synchronous operation is designated for channels 0 and 1, TGR1B compare match is set as the TCNT clearing source, and 0 is set for the initial output value and 1 for the output value of the other TGR registers (TGR0A to TGR0D, TGR1A), to output a 5-phase PWM waveform.

In this case, the value set in TGR1B is used as the cycle, and the values set in the other TGRs as the duty.

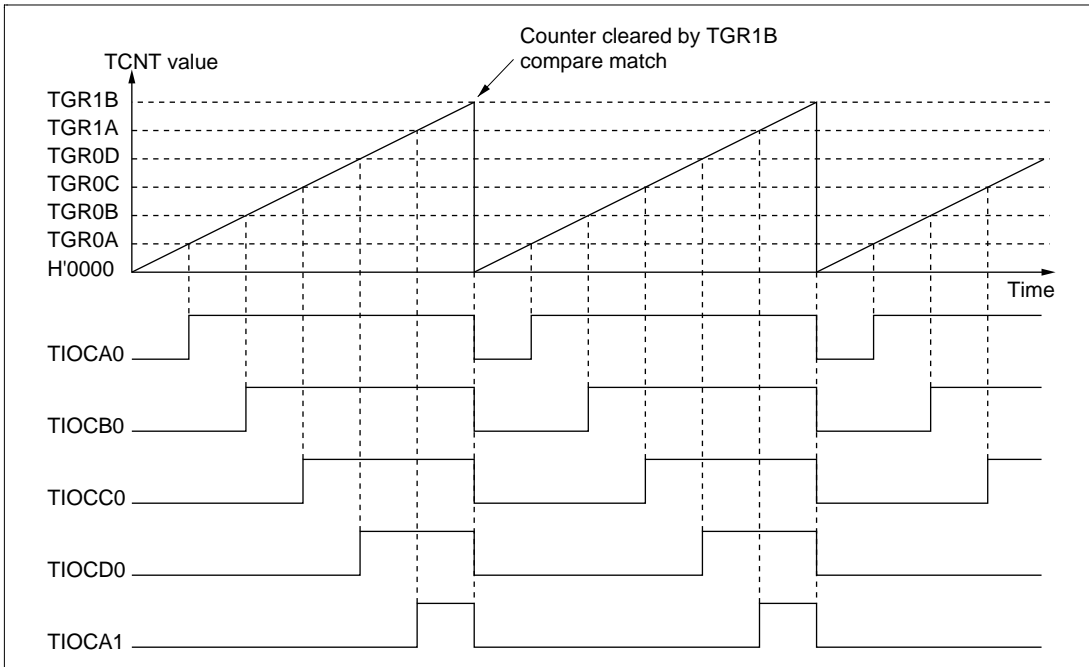


Figure 10-26 Example of PWM Mode Operation (2)

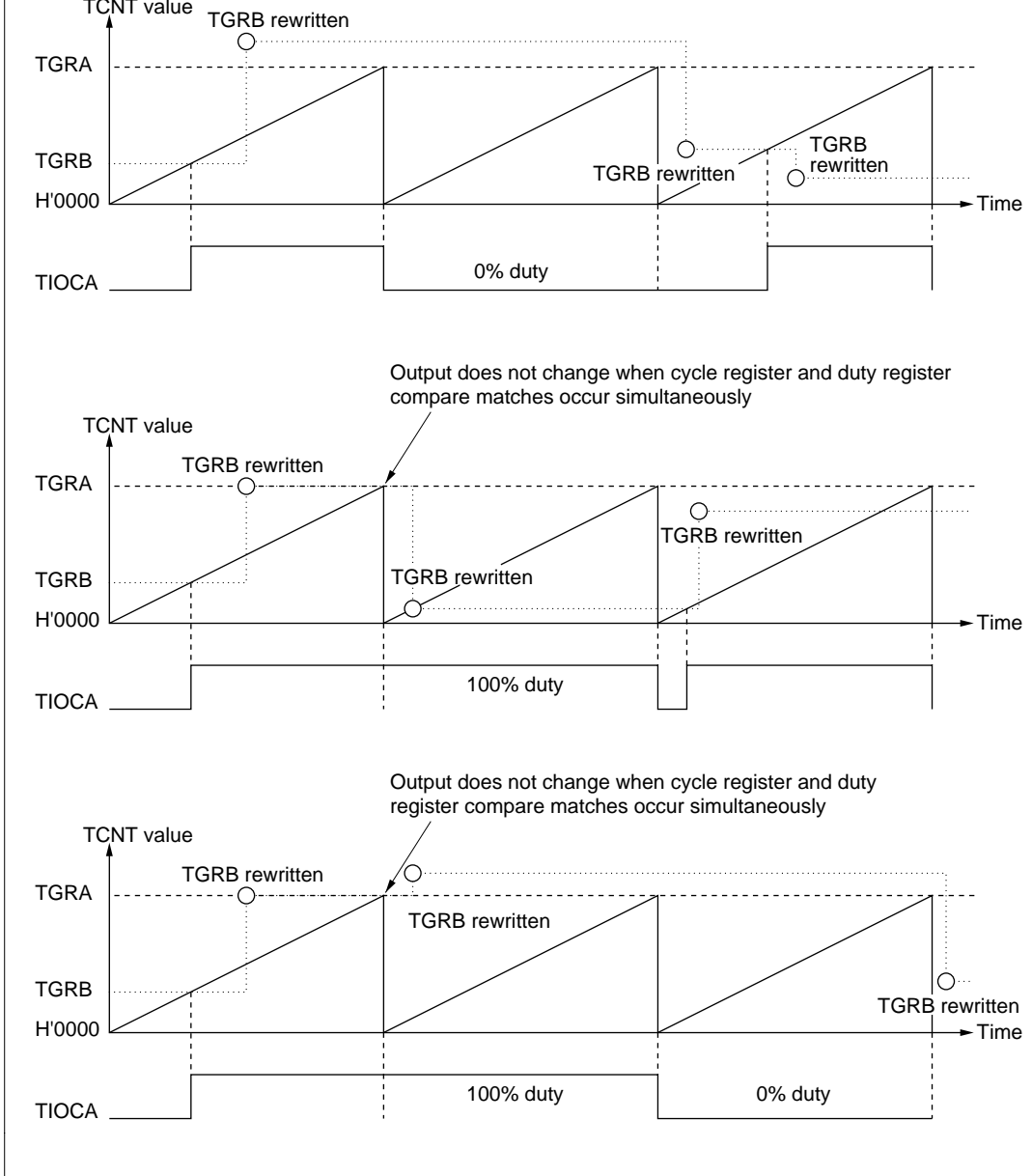


Figure 10-27 Example of PWM Mode Operation (3)

When phase counting mode is set, an external clock is selected as the counter input clock and TCNT operates as an up/down-counter regardless of the setting of bits TPSC2 to TPSC0 and bits CKEG1 and CKEG0 in TCR. However, the functions of bits CCLR1 and CCLR0 in TCR, and of TIOR, TIER, and TGR are valid, and input capture/compare match and interrupt functions can be used.

When overflow occurs while TCNT is counting up, the TCFV flag in TSR is set; when underflow occurs while TCNT is counting down, the TCFU flag is set.

The TCFD bit in TSR is the count direction flag. Reading the TCFD flag provides an indication of whether TCNT is counting up or down.

Table 10-8 shows the correspondence between external clock pins and channels.

Table 10-8 Phase Counting Mode Clock Input Pins

Channels	External Clock Pins	
	A-Phase	B-Phase
When channel 1 or 5 is set to phase counting mode	TCLKA	TCLKB
When channel 2 or 4 is set to phase counting mode	TCLKC	TCLKD

Example of Phase Counting Mode Setting Procedure: Figure 10-28 shows an example of the phase counting mode setting procedure.

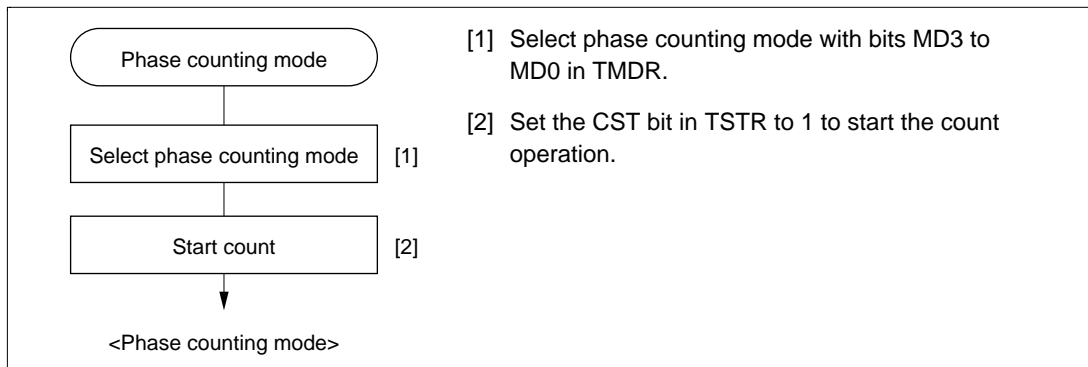


Figure 10-28 Example of Phase Counting Mode Setting Procedure

Figure 10-29 shows an example of phase counting mode 1 operation, and table 10-9 summarizes the TCNT up/down-count conditions.

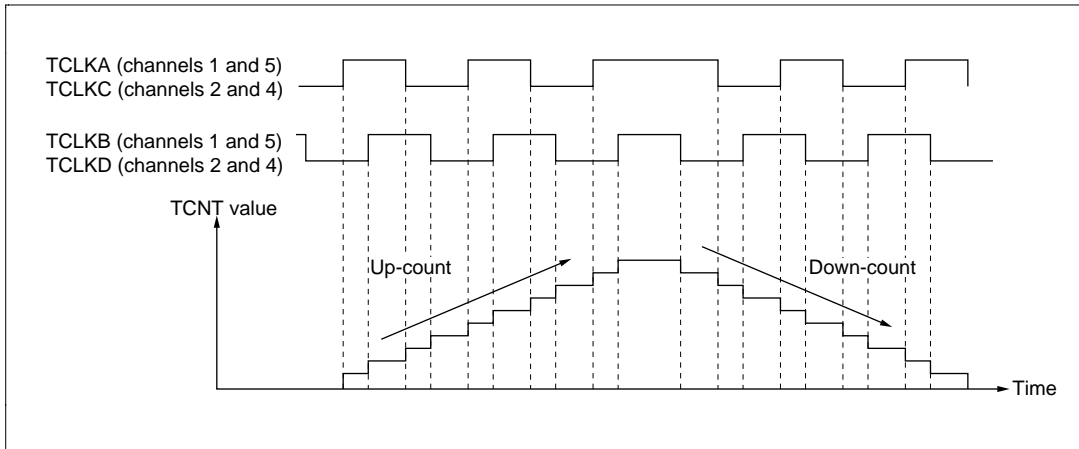


Figure 10-29 Example of Phase Counting Mode 1 Operation

Table 10-9 Up/Down-Count Conditions in Phase Counting Mode 1

TCLKA (Channels 1 and 5) TCLKC (Channels 2 and 4)	TCLKB (Channels 1 and 5) TCLKD (Channels 2 and 4)	Operation
High level		Up-count
Low level		
	Low level	
	High level	
High level		Down-count
Low level		
	High level	
	Low level	

Legend

- : Rising edge
- : Falling edge

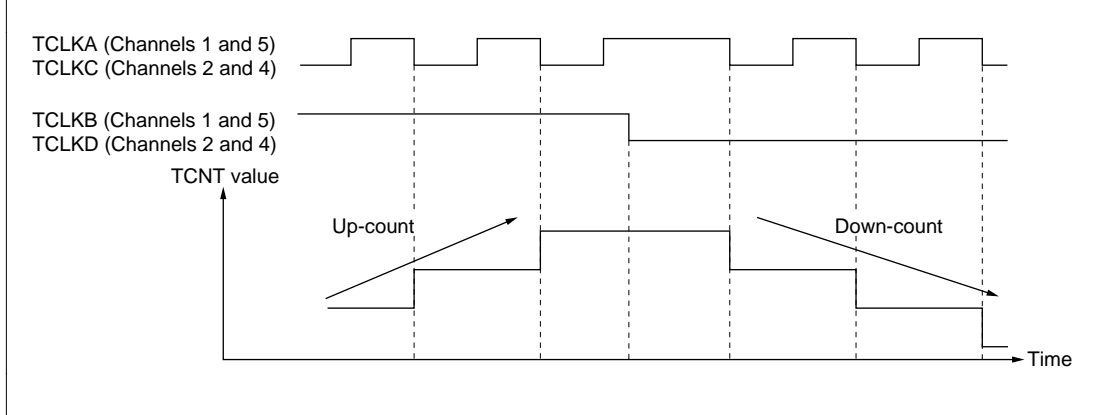


Figure 10-30 Example of Phase Counting Mode 2 Operation

Table 10-10 Up/Down-Count Conditions in Phase Counting Mode 2

TCLKA (Channels 1 and 5) TCLKC (Channels 2 and 4)	TCLKB (Channels 1 and 5) TCLKD (Channels 2 and 4)	Operation
High level		Don't care
Low level		Don't care
	Low level	Don't care
	High level	Up-count
High level		Don't care
Low level		Don't care
	High level	Don't care
	Low level	Down-count

Legend

- : Rising edge
- : Falling edge

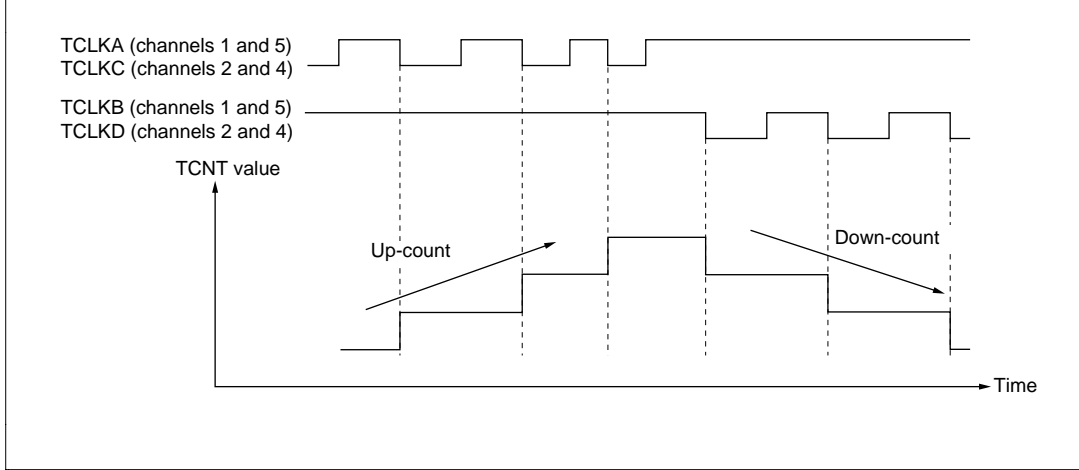


Figure 10-31 Example of Phase Counting Mode 3 Operation

Table 10-11 Up/Down-Count Conditions in Phase Counting Mode 3

TCLKA (Channels 1 and 5) TCLKC (Channels 2 and 4)	TCLKB (Channels 1 and 5) TCLKD (Channels 2 and 4)	Operation
High level	\uparrow	Don't care
Low level	\downarrow	Don't care
\uparrow	Low level	Don't care
\downarrow	High level	Up-count
High level	\downarrow	Down-count
Low level	\uparrow	Don't care
\uparrow	High level	Don't care
\downarrow	Low level	Don't care

Legend

- \uparrow : Rising edge
- \downarrow : Falling edge

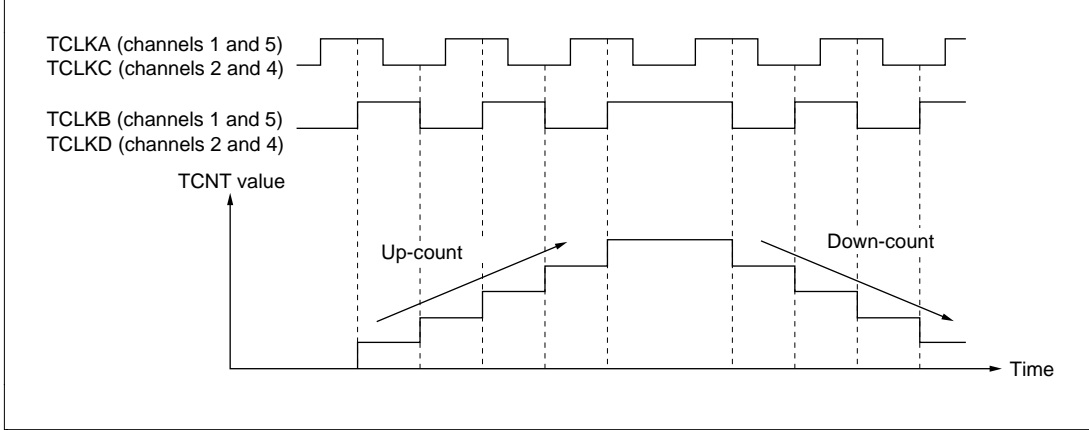


Figure 10-32 Example of Phase Counting Mode 4 Operation

Table 10-12 Up/Down-Count Conditions in Phase Counting Mode 4

TCLKA (Channels 1 and 5) TCLKC (Channels 2 and 4)	TCLKB (Channels 1 and 5) TCLKD (Channels 2 and 4)	Operation
High level		Up-count
Low level		Up-count
	Low level	Don't care
	High level	Don't care
High level		Down-count
Low level		Down-count
	High level	Don't care
	Low level	Don't care

Legend

- : Rising edge
- : Falling edge

to TCLKA and TCLKB.

Channel 0 operates with TCNT counter clearing by TGR0C compare match; TGR0A and TGR0C are used for the compare match function, and are set with the speed control period and position control period. TGR0B is used for input capture, with TGR0B and TGR0D operating in buffer mode. The channel 1 counter input clock is designated as the TGR0B input capture source, and detection of the pulse width of 2-phase encoder 4-multiplication pulses is performed.

TGR1A and TGR1B for channel 1 are designated for input capture, channel 0 TGR0A and TGR0C compare matches are selected as the input capture source, and store the up/down-counter values for the control periods.

This procedure enables accurate position/speed detection to be achieved.

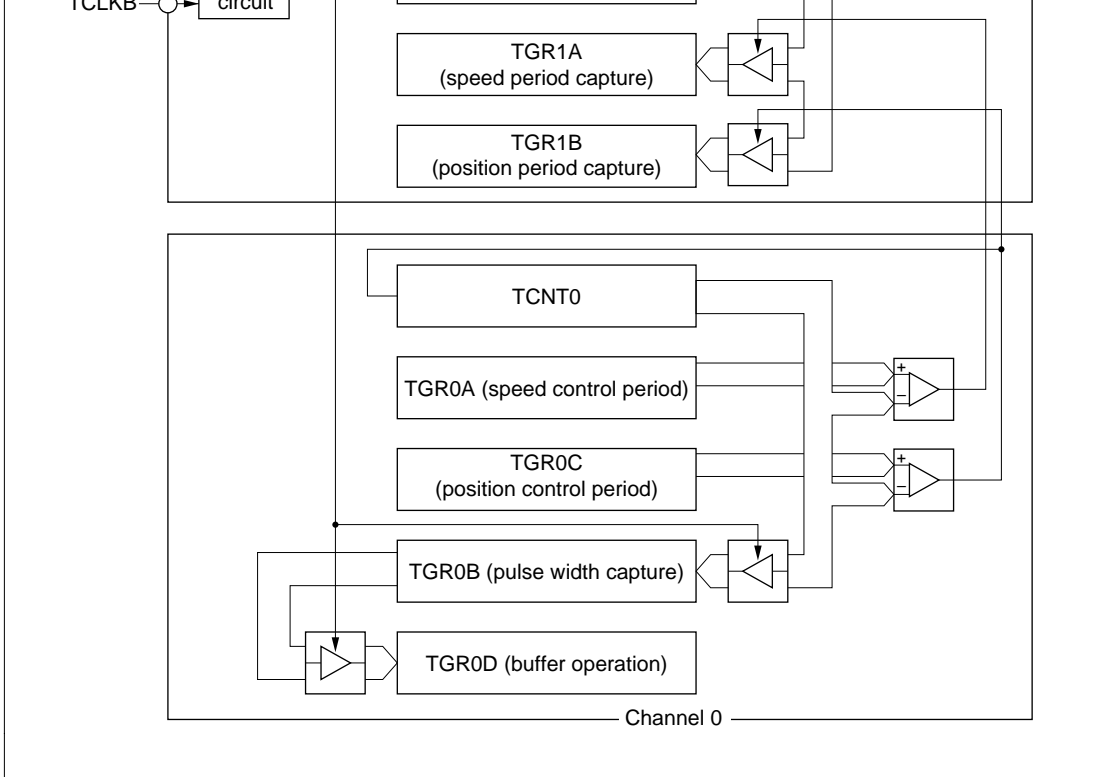


Figure 10-33 Phase Counting Mode Application Example

There are three kinds of TPU interrupt source: TGR input capture/compare match, TCNT overflow, and TCNT underflow. Each interrupt source has its own status flag and enable/disabled bit, allowing generation of interrupt request signals to be enabled or disabled individually.

When an interrupt request is generated, the corresponding status flag in TSR is set to 1. If the corresponding enable/disable bit in TIER is set to 1 at this time, an interrupt is requested. The interrupt request is cleared by clearing the status flag to 0.

Relative channel priorities can be changed by the interrupt controller, but the priority order within a channel is fixed. For details, see section 5, Interrupt Controller.

Table 10-13 lists the TPU interrupt sources.

	TGI0B	TGR0B input capture/compare match	Not possible	Possible	
	TGI0C	TGR0C input capture/compare match	Not possible	Possible	
	TGI0D	TGR0D input capture/compare match	Not possible	Possible	
	TCI0V	TCNT0 overflow	Not possible	Not possible	
1	TGI1A	TGR1A input capture/compare match	Possible	Possible	
	TGI1B	TGR1B input capture/compare match	Not possible	Possible	
	TCI1V	TCNT1 overflow	Not possible	Not possible	
	TCI1U	TCNT1 underflow	Not possible	Not possible	
2	TGI2A	TGR2A input capture/compare match	Possible	Possible	
	TGI2B	TGR2B input capture/compare match	Not possible	Possible	
	TCI2V	TCNT2 overflow	Not possible	Not possible	
	TCI2U	TCNT2 underflow	Not possible	Not possible	
3	TGI3A	TGR3A input capture/compare match	Possible	Possible	
	TGI3B	TGR3B input capture/compare match	Not possible	Possible	
	TGI3C	TGR3C input capture/compare match	Not possible	Possible	
	TGI3D	TGR3D input capture/compare match	Not possible	Possible	
	TCI3V	TCNT3 overflow	Not possible	Not possible	
4	TGI4A	TGR4A input capture/compare match	Possible	Possible	
	TGI4B	TGR4B input capture/compare match	Not possible	Possible	
	TCI4V	TCNT4 overflow	Not possible	Not possible	
	TCI4U	TCNT4 underflow	Not possible	Not possible	
5	TGI5A	TGR5A input capture/compare match	Possible	Possible	
	TGI5B	TGR5B input capture/compare match	Not possible	Possible	
	TCI5V	TCNT5 overflow	Not possible	Not possible	
	TCI5U	TCNT5 underflow	Not possible	Not possible	Low

Note: This table shows the initial state immediately after a reset. The relative channel priorities can be changed by the interrupt controller.

for channels 1, 2, 4, and 5.

Overflow Interrupt: An interrupt is requested if the TCIEV bit in TIER is set to 1 when the TCFV flag in TSR is set to 1 by the occurrence of TCNT overflow on a channel. The interrupt request is cleared by clearing the TCFV flag to 0. The TPU has six overflow interrupts, one for each channel.

Underflow Interrupt: An interrupt is requested if the TCIEU bit in TIER is set to 1 when the TCFU flag in TSR is set to 1 by the occurrence of TCNT underflow on a channel. The interrupt request is cleared by clearing the TCFU flag to 0. The TPU has four underflow interrupts, one each for channels 1, 2, 4, and 5.

10.5.2 DTC/DMAC Activation

DTC Activation: The DTC can be activated by the TGR input capture/compare match interrupt for a channel. For details, see section 8, Data Transfer Controller.

A total of 16 TPU input capture/compare match interrupts can be used as DTC activation sources, four each for channels 0 and 3, and two each for channels 1, 2, 4, and 5.

DMAC Activation: The DMAC can be activated by the TGRA input capture/compare match interrupt for a channel. For details, see section 7, DMA Controller.

In the TPU, a total of six TGRA input capture/compare match interrupts can be used as DMAC activation sources, one for each channel.

10.5.3 A/D Converter Activation

The A/D converter can be activated by the TGRA input capture/compare match for a channel.

If the TTGE bit in TIER is set to 1 when the TGFA flag in TSR is set to 1 by the occurrence of a TGRA input capture/compare match on a particular channel, a request to start A/D conversion is sent to the A/D converter. If the TPU conversion start trigger has been selected on the A/D converter side at this time, A/D conversion is started.

In the TPU, a total of six TGRA input capture/compare match interrupts can be used as A/D converter conversion start sources, one for each channel.

TCNT Count Timing: Figure 10-34 shows TCNT count timing in internal clock operation, and figure 10-35 shows TCNT count timing in external clock operation.

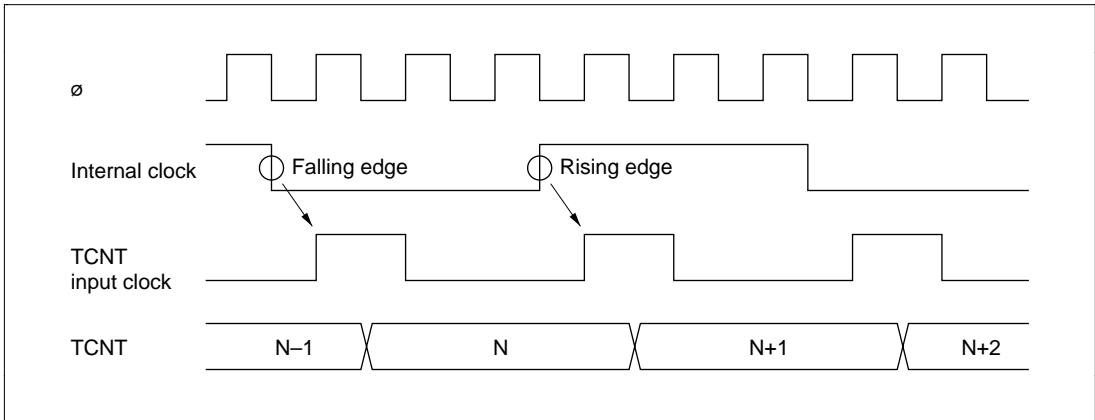


Figure 10-34 Count Timing in Internal Clock Operation

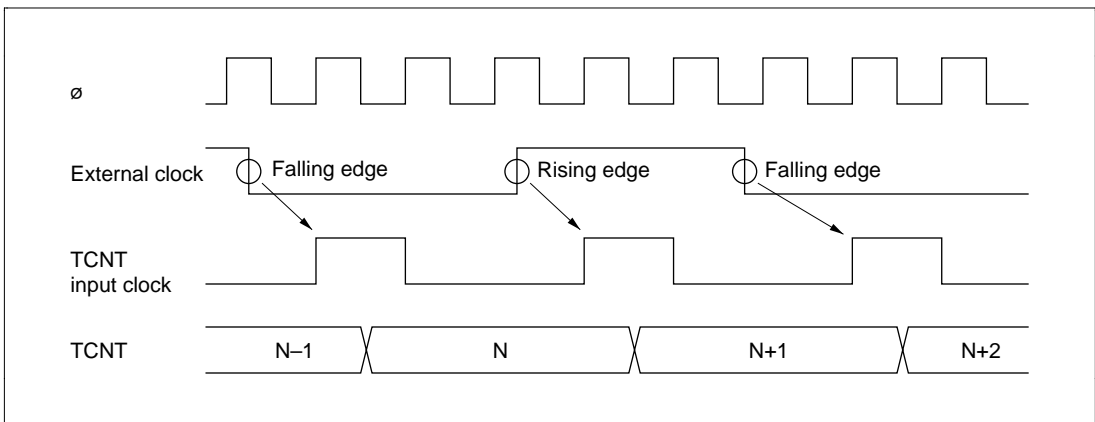


Figure 10-35 Count Timing in External Clock Operation

generated until the TCNT input clock is generated.

Figure 10-36 shows output compare output timing.

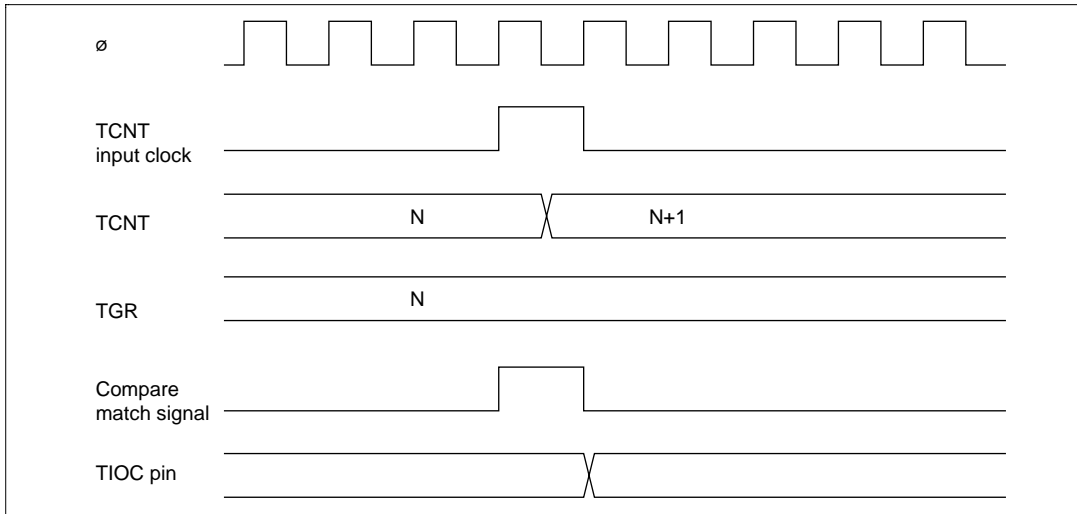


Figure 10-36 Output Compare Output Timing

Input Capture Signal Timing: Figure 10-37 shows input capture signal timing.

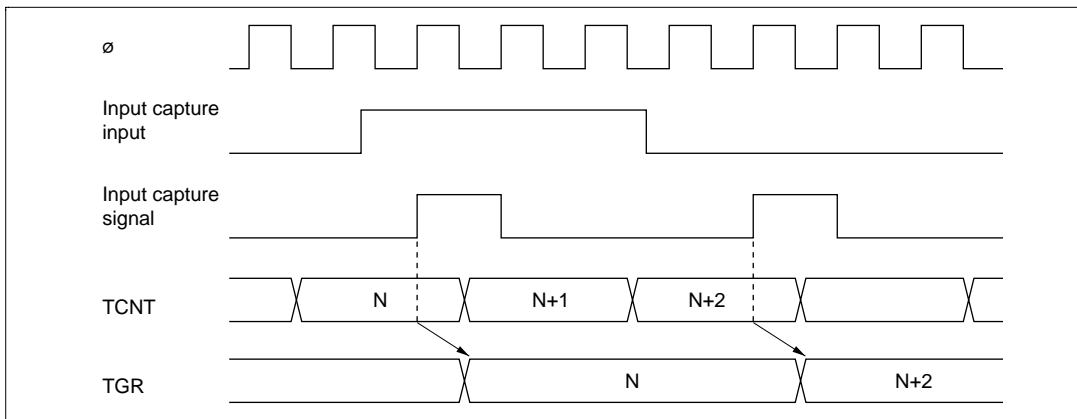


Figure 10-37 Input Capture Input Signal Timing

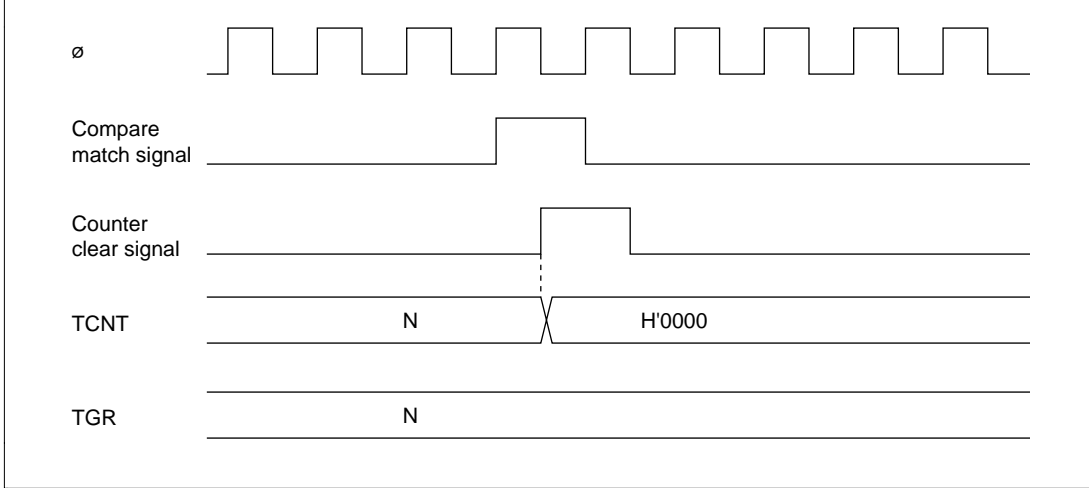


Figure 10-38 Counter Clear Timing (Compare Match)

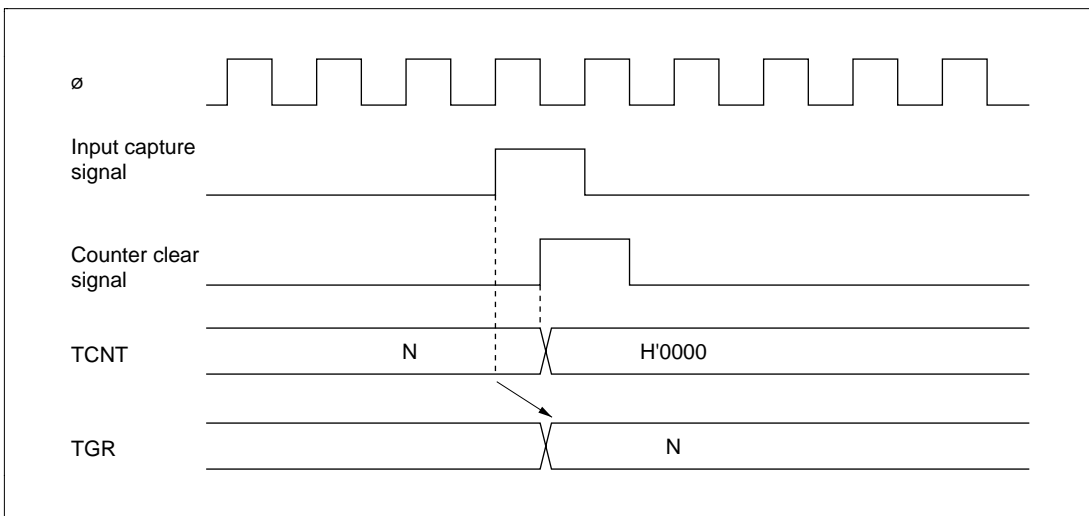


Figure 10-39 Counter Clear Timing (Input Capture)

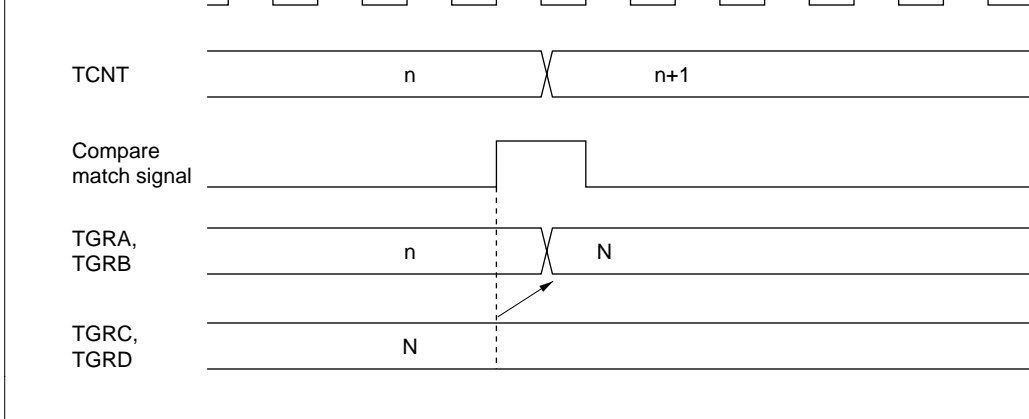


Figure 10-40 Buffer Operation Timing (Compare Match)

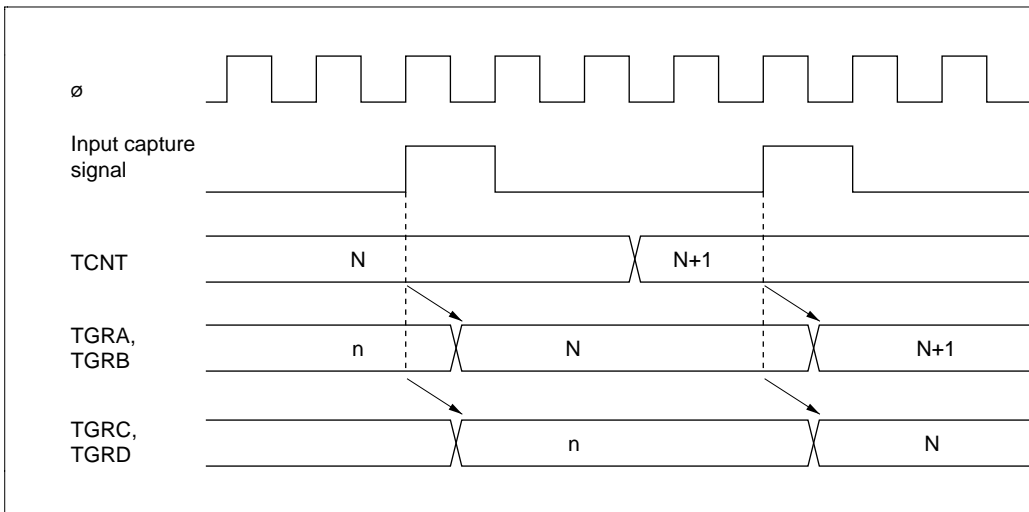


Figure 10-41 Buffer Operation Timing (Input Capture)

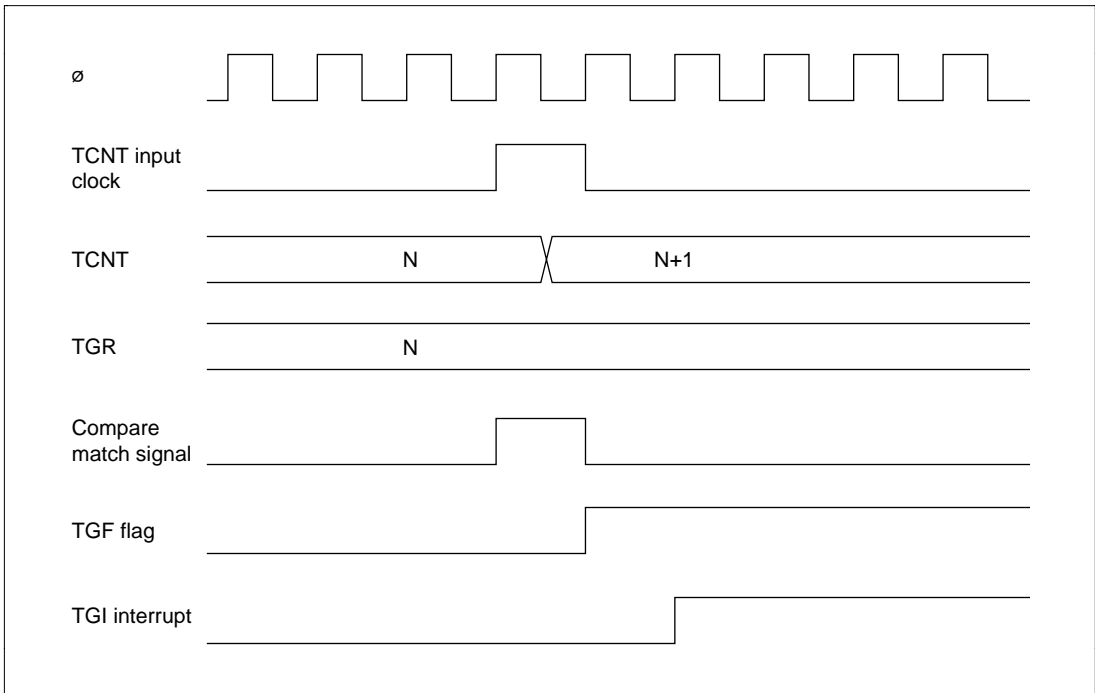


Figure 10-42 TGI Interrupt Timing (Compare Match)

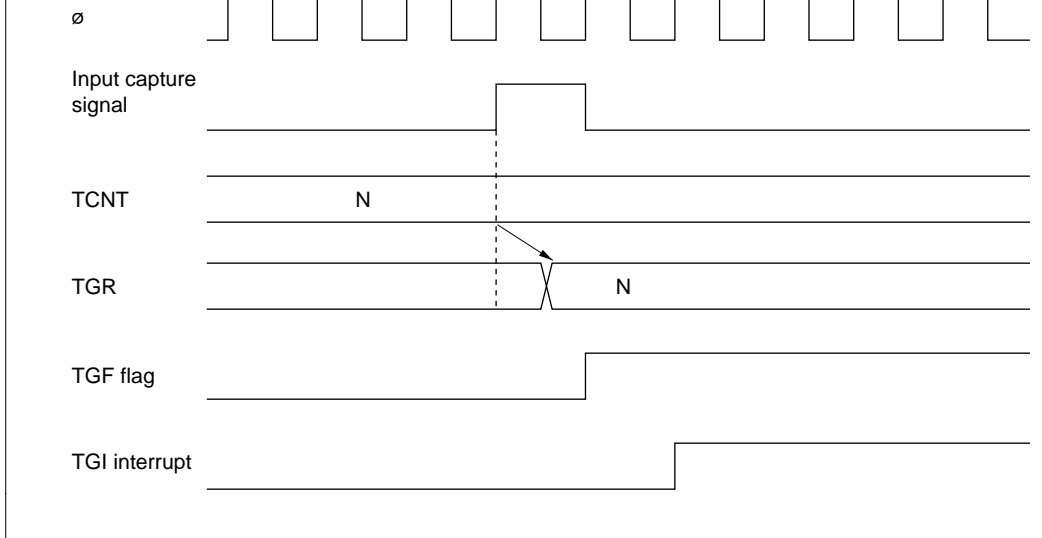


Figure 10-43 TGI Interrupt Timing (Input Capture)

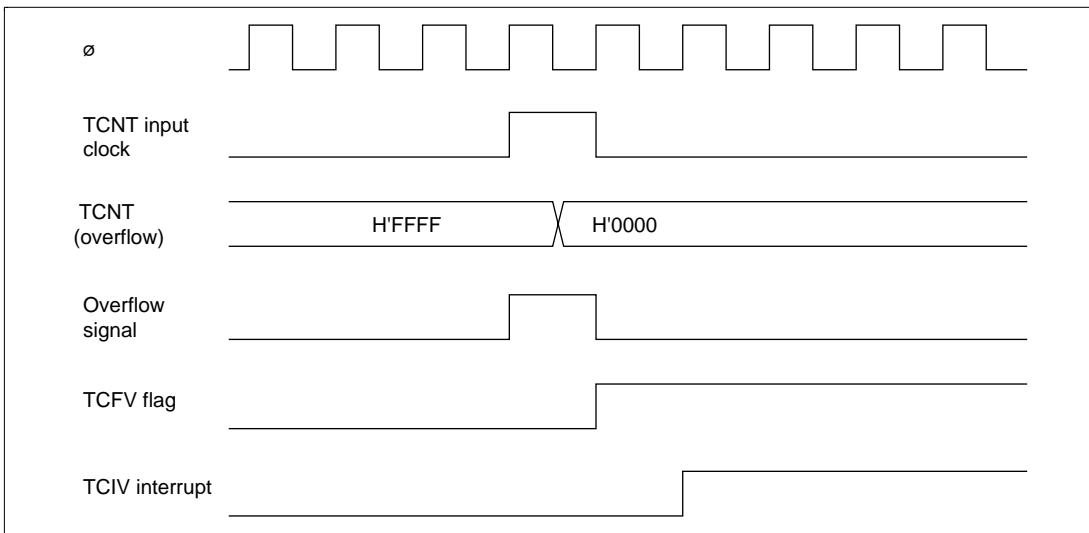


Figure 10-44 TCIV Interrupt Setting Timing

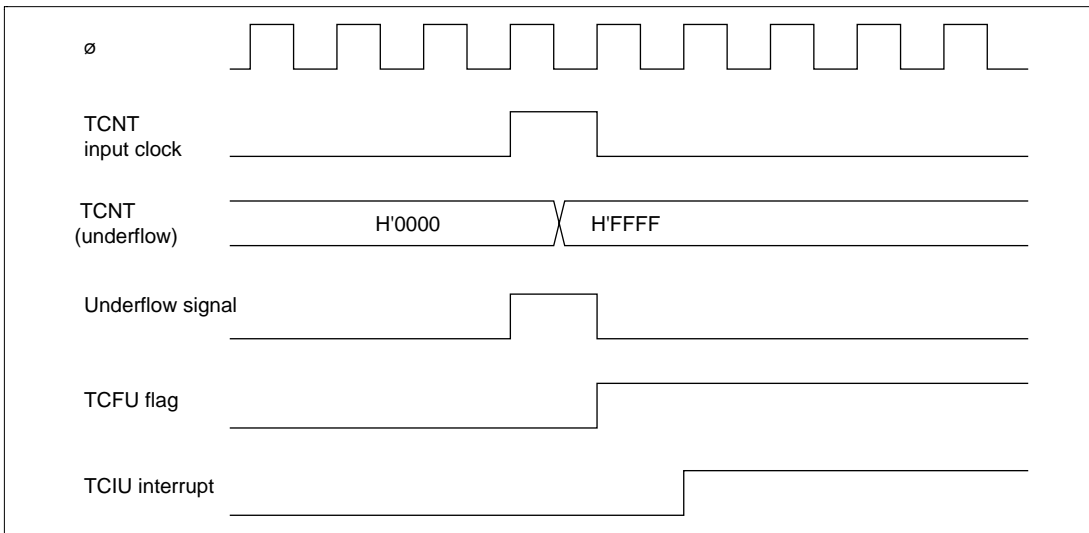


Figure 10-45 TCIU Interrupt Setting Timing

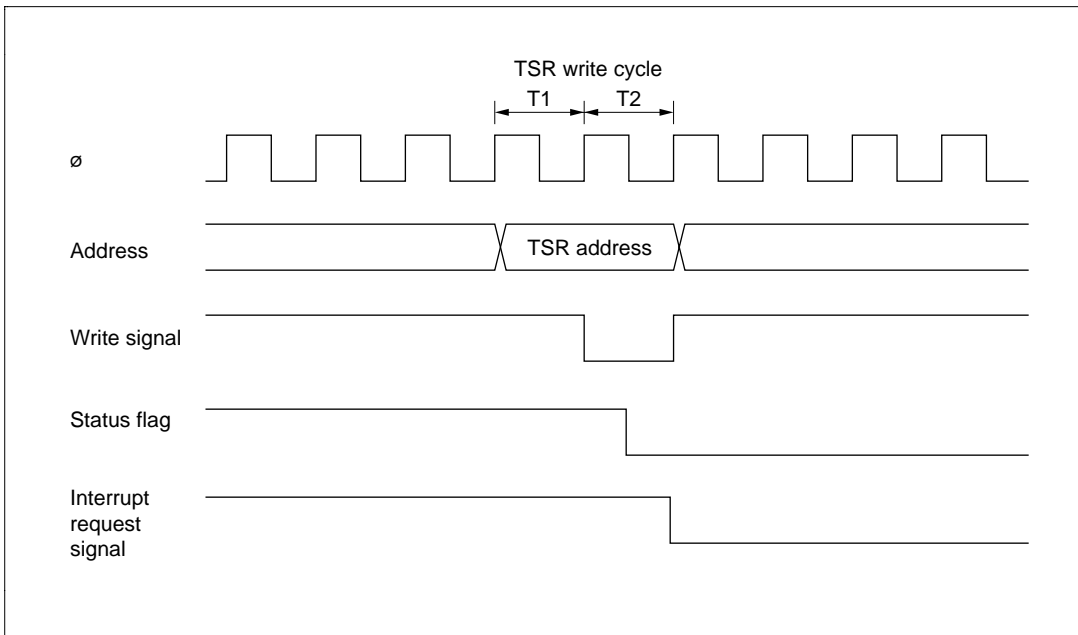


Figure 10-46 Timing for Status Flag Clearing by CPU

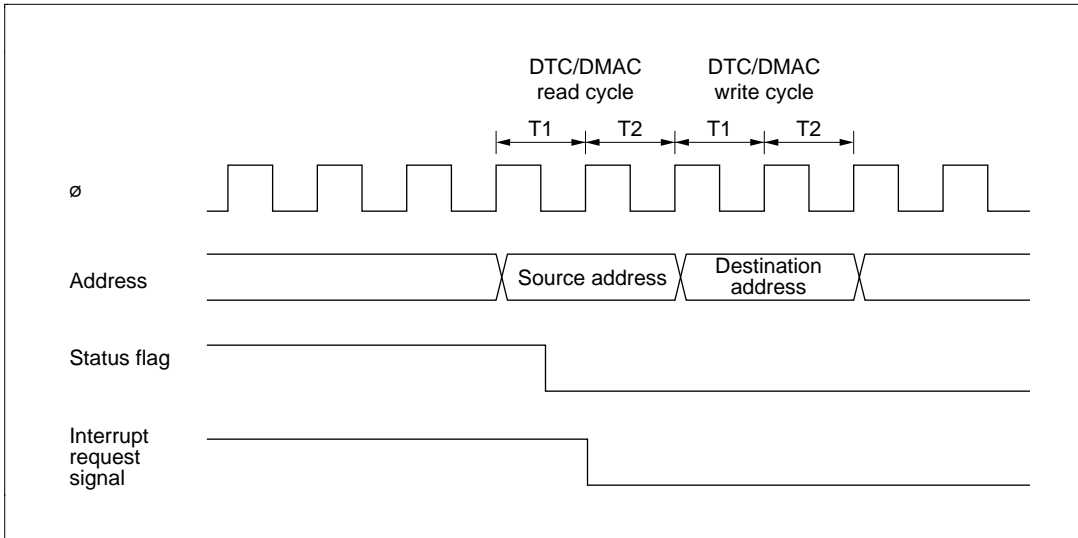


Figure 10-47 Timing for Status Flag Clearing by DTC/DMAC Activation

Input Clock Restrictions: The input clock pulse width must be at least 1.5 states in the case of single-edge detection, and at least 2.5 states in the case of both-edge detection. The TPU will not operate properly with a narrower pulse width.

In phase counting mode, the phase difference and overlap between the two input clocks must be at least 1.5 states, and the pulse width must be at least 2.5 states. Figure 10-48 shows the input clock conditions in phase counting mode.

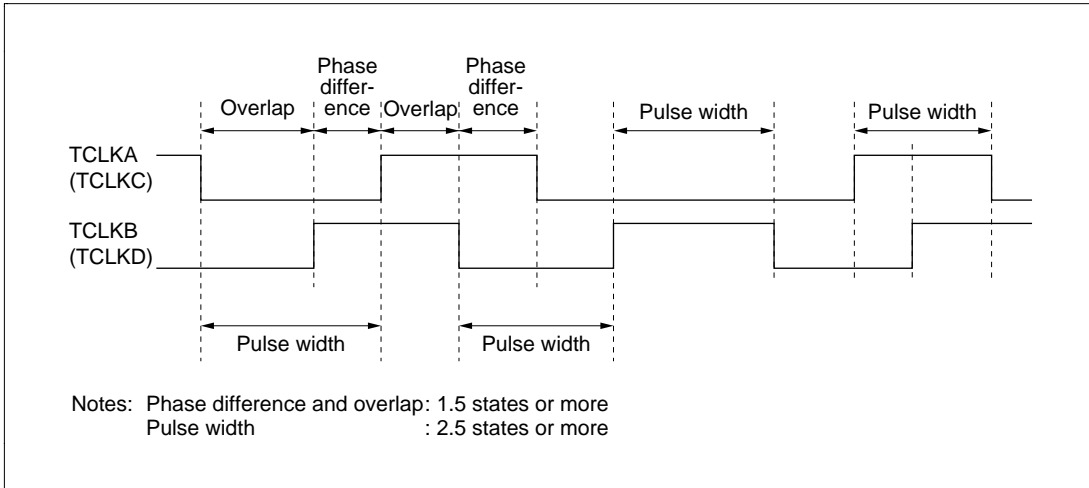


Figure 10-48 Phase Difference, Overlap, and Pulse Width in Phase Counting Mode

Caution on Period Setting: When counter clearing by compare match is set, TCNT is cleared in the final state in which it matches the TGR value (the point at which the count value matched by TCNT is updated). Consequently, the actual counter frequency is given by the following formula:

$$f = \frac{\phi}{(N + 1)}$$

Where f : Counter frequency
 ϕ : Operating frequency
 N : TGR set value

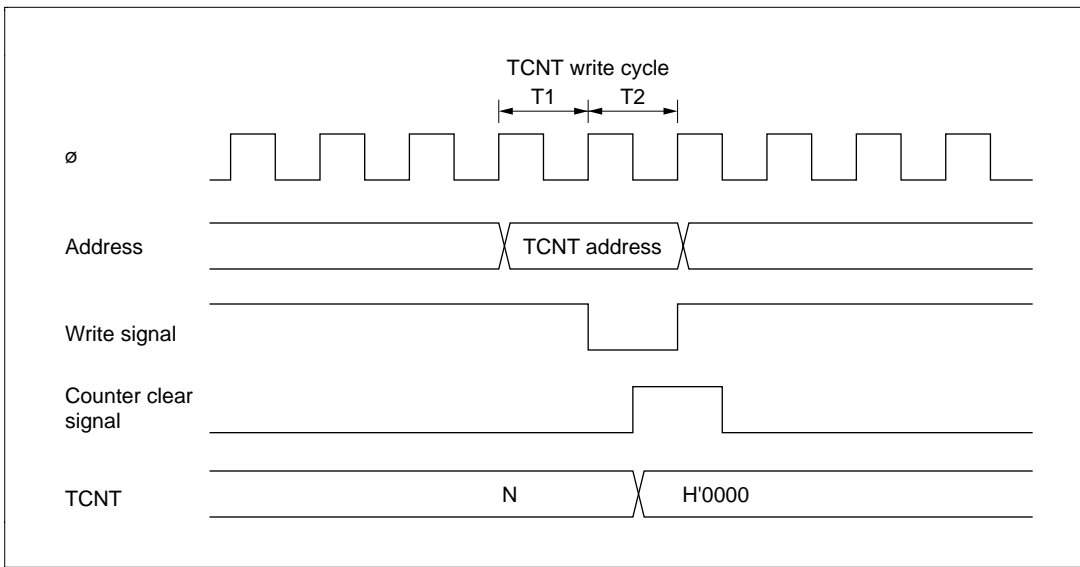


Figure 10-49 Contention between TCNT Write and Clear Operations

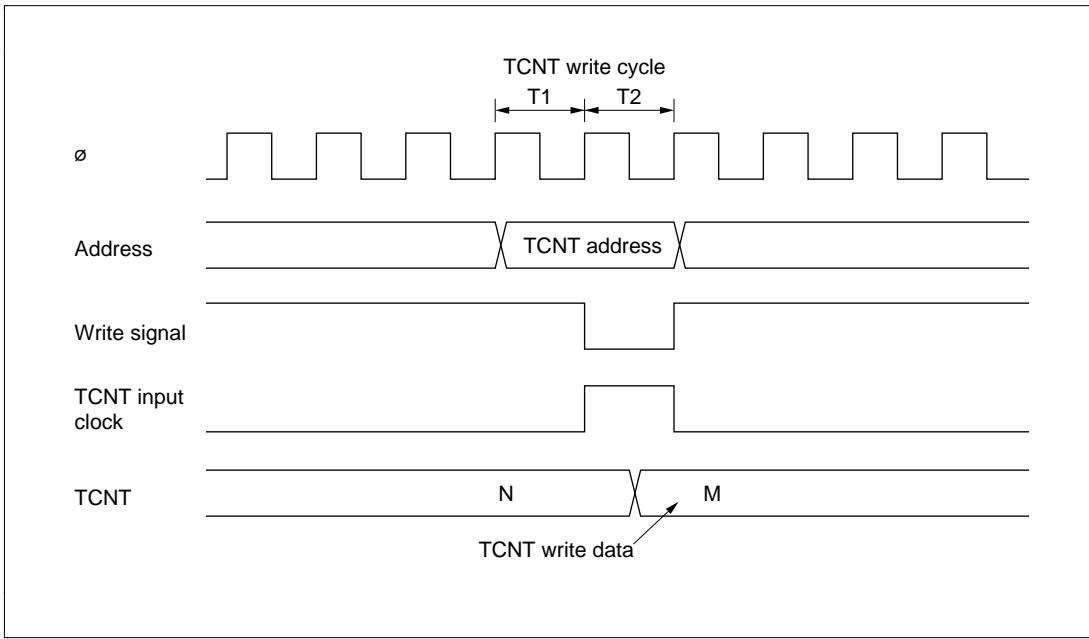


Figure 10-50 Contention between TCNT Write and Increment Operations

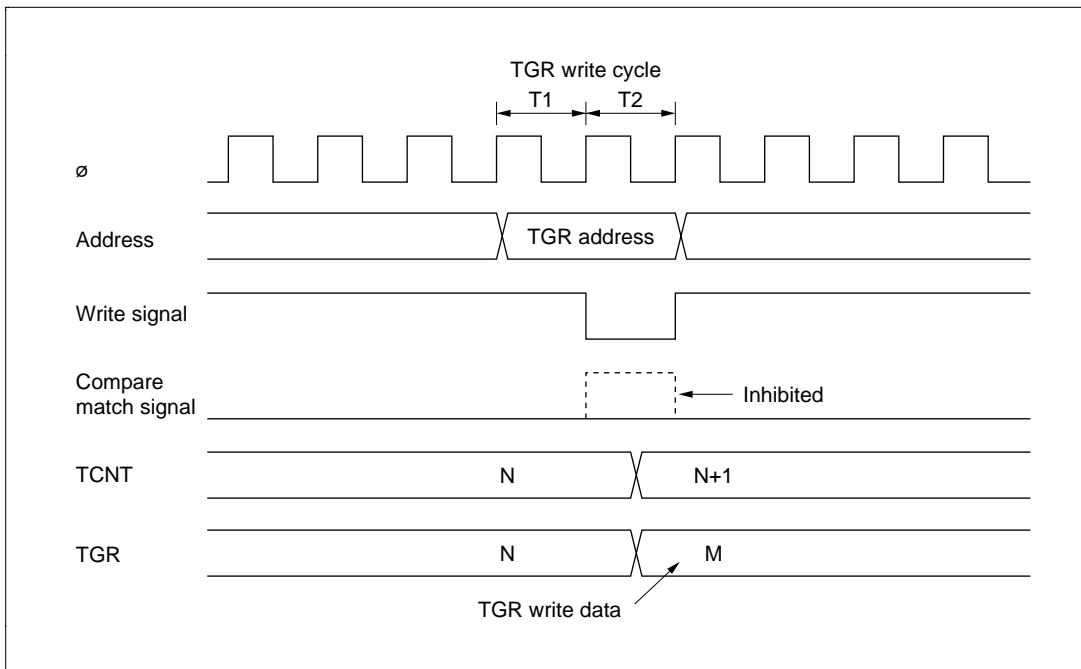


Figure 10-51 Contention between TGR Write and Compare Match

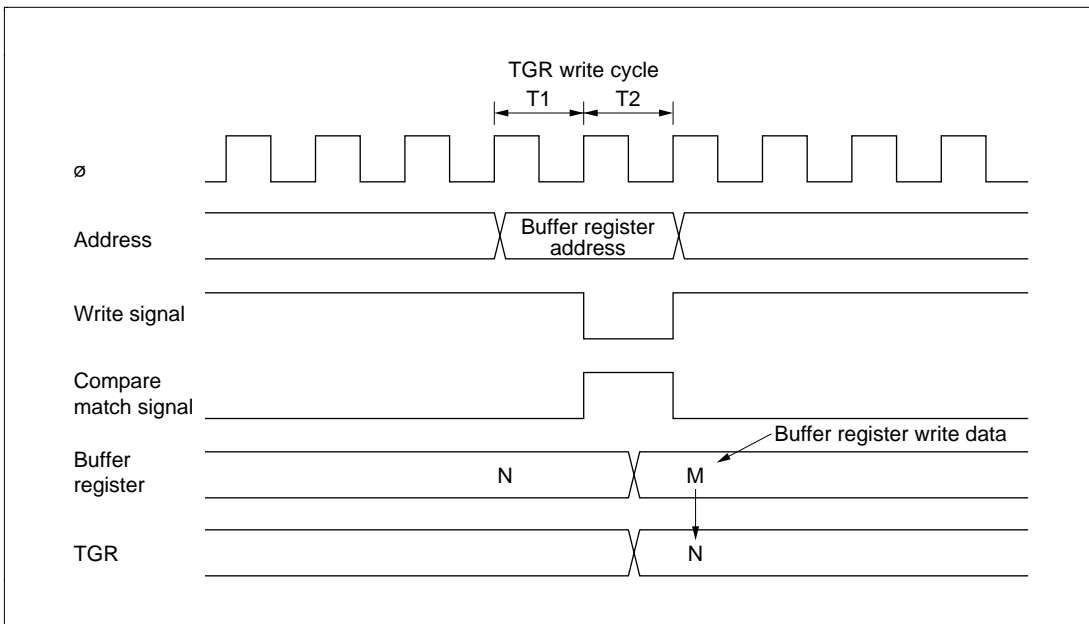


Figure 10-52 Contention between Buffer Register Write and Compare Match

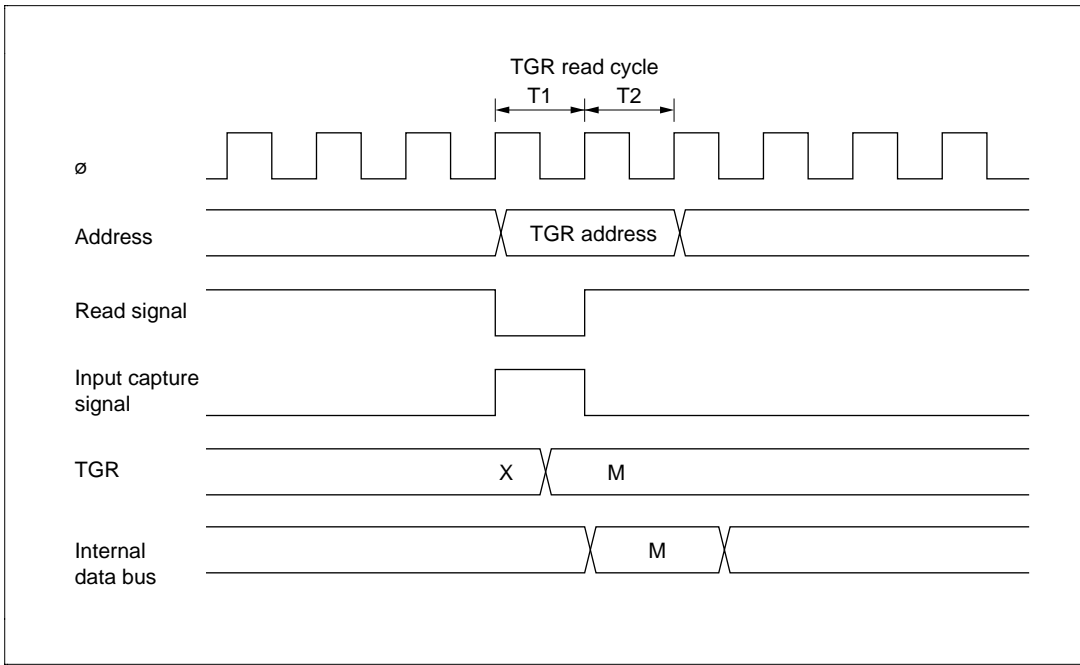


Figure 10-53 Contention between TGR Read and Input Capture

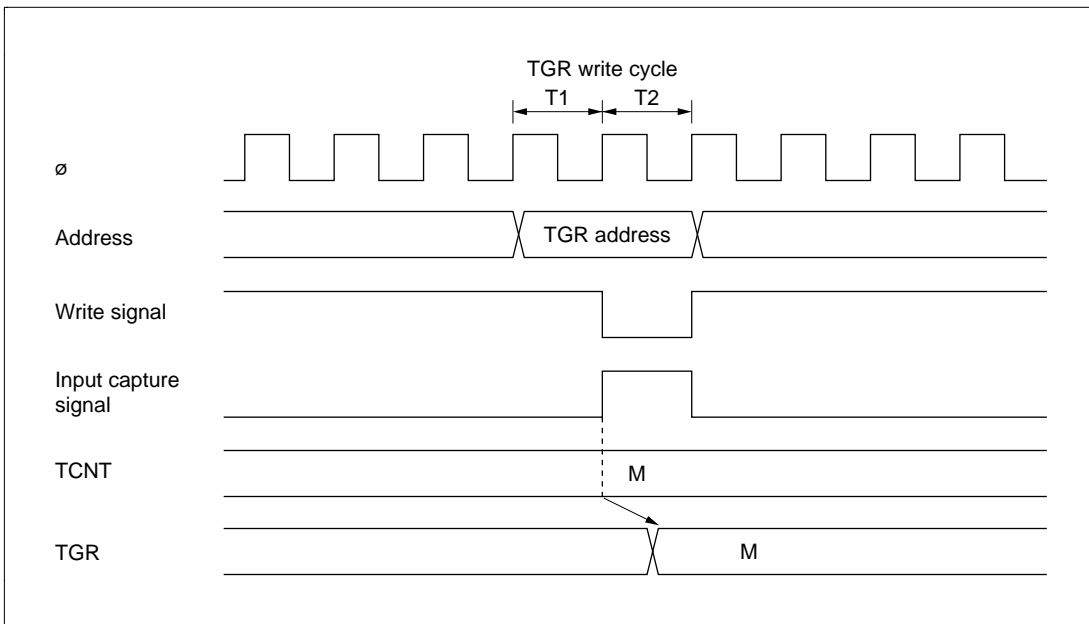


Figure 10-54 Contention between TGR Write and Input Capture

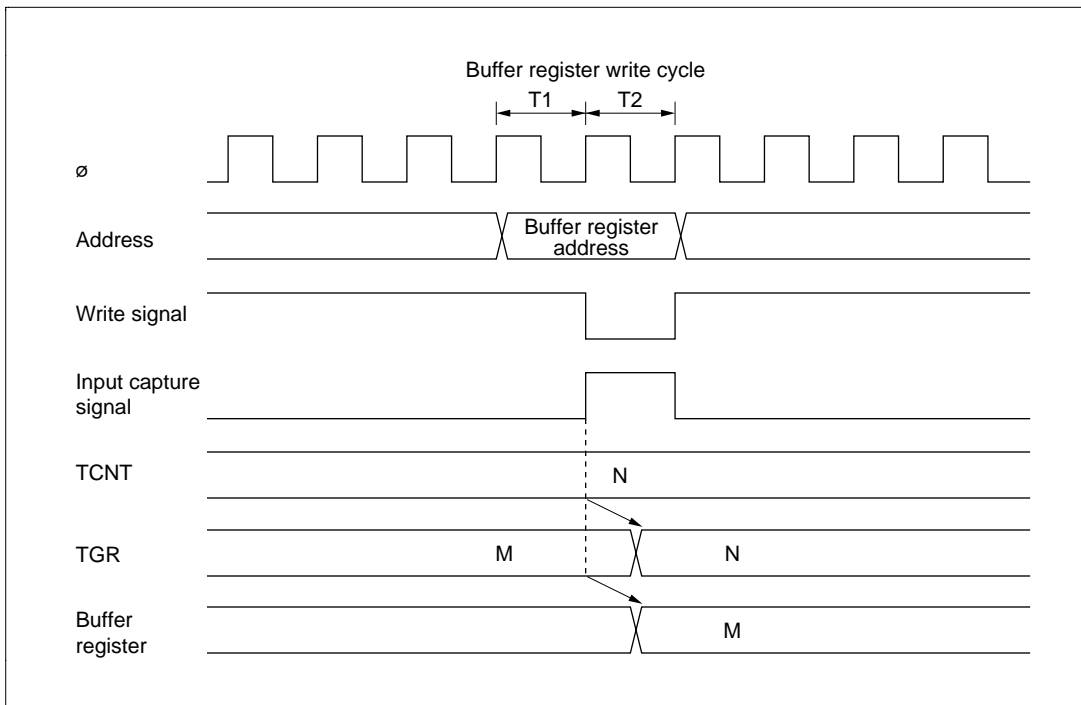


Figure 10-55 Contention between Buffer Register Write and Input Capture

source, and H'FFFF is set in TGR.

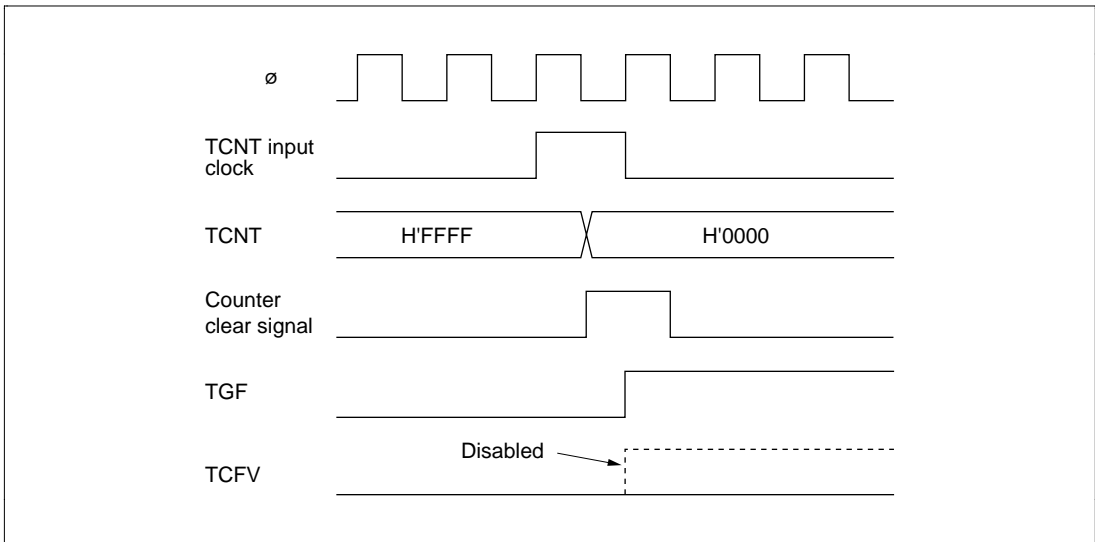


Figure 10-56 Contention between Overflow and Counter Clearing

overflow.

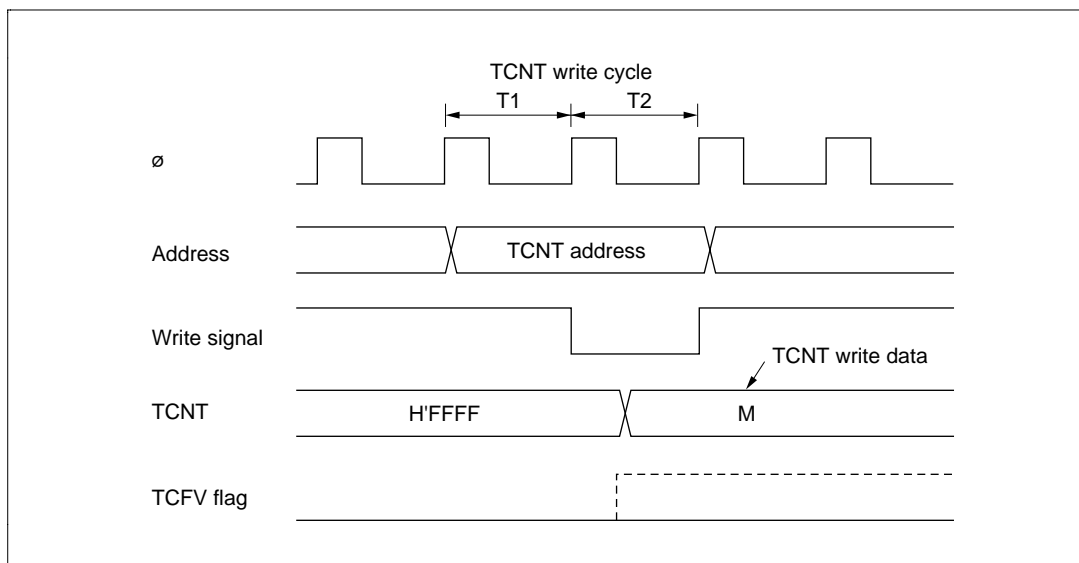


Figure 10-57 Contention between TCNT Write and Overflow

Multiplexing of I/O Pins: In the H8S/2350 Series, the TCLKA input pin is multiplexed with the TIOCC0 I/O pin, the TCLKB input pin with the TIOCD0 I/O pin, the TCLKC input pin with the TIOCB1 I/O pin, and the TCLKD input pin with the TIOCB2 I/O pin. When an external clock is input, compare match output should not be performed from a multiplexed pin.

Interrupts and Module Stop Mode: If module stop mode is entered when an interrupt has been requested, it will not be possible to clear the CPU interrupt source or the DMAC or DTC activation source. Interrupts should therefore be disabled before entering module stop mode.

The H8S/2350 Series has a built-in programmable pulse generator (PPG) that provides pulse outputs by using the 16-bit timer-pulse unit (TPU) as a time base. The PPG pulse outputs are divided into 4-bit groups (group 3 to group 0) that can operate both simultaneously and independently.

11.1.1 Features

PPG features are listed below.

- 16-bit output data
 - Maximum 16-bit data can be output, and output can be enabled on a bit-by-bit basis
- Four output groups
 - Output trigger signals can be selected in 4-bit groups to provide up to four different 4-bit outputs
- Selectable output trigger signals
 - Output trigger signals can be selected for each group from the compare match signals of four TPU channels
- Non-overlap mode
 - A non-overlap margin can be provided between pulse outputs
- Can operate together with the data transfer controller (DTC) and DMA controller (DMAC)
 - The compare match signals selected as output trigger signals can activate the DTC or DMAC for sequential output of data without CPU intervention
- Settable inverted output
 - Inverted data can be output for each group
- Module stop mode can be set
 - As the initial setting, PPG operation is halted. Register access is enabled by exiting module stop mode

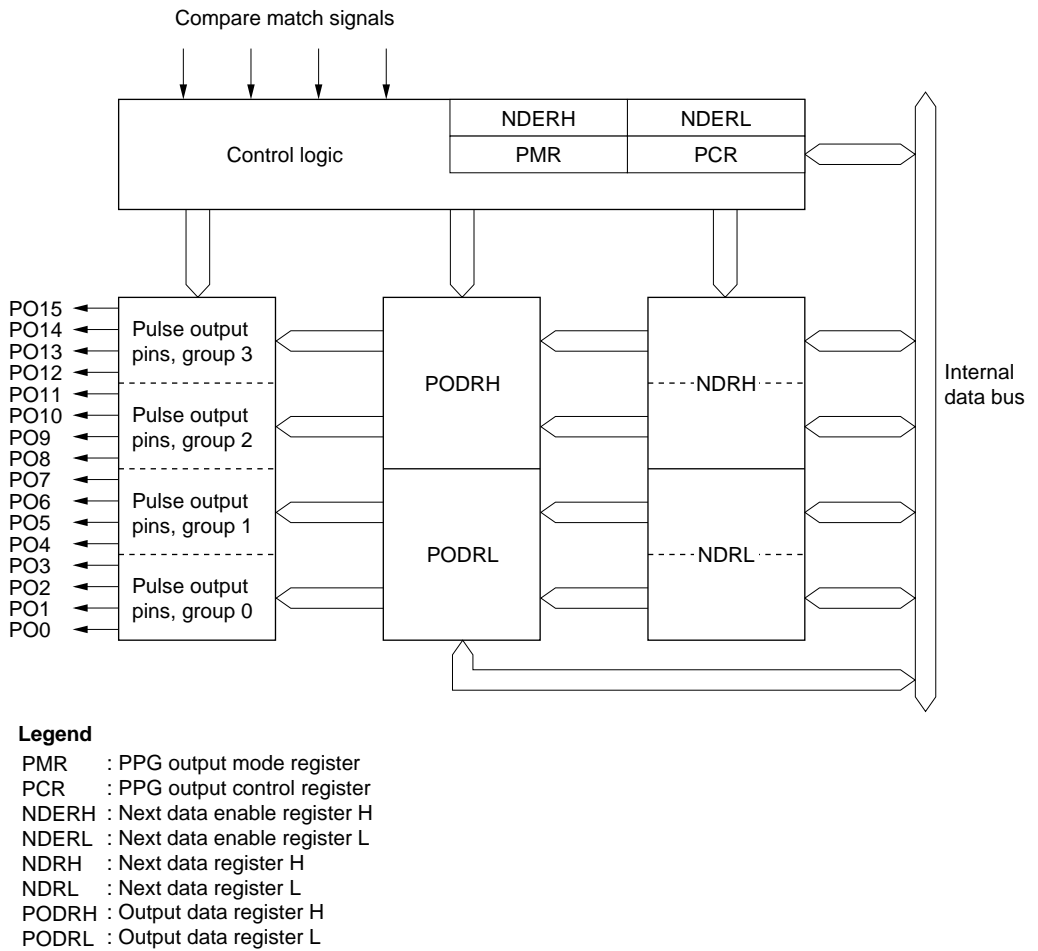


Figure 11-1 Block Diagram of PPG

Table 11-1 TIG Pins

Name	Symbol	I/O	Function
Pulse output 0	PO0	Output	Group 0 pulse output
Pulse output 1	PO1	Output	
Pulse output 2	PO2	Output	
Pulse output 3	PO3	Output	
Pulse output 4	PO4	Output	Group 1 pulse output
Pulse output 5	PO5	Output	
Pulse output 6	PO6	Output	
Pulse output 7	PO7	Output	
Pulse output 8	PO8	Output	Group 2 pulse output
Pulse output 9	PO9	Output	
Pulse output 10	PO10	Output	
Pulse output 11	PO11	Output	
Pulse output 12	PO12	Output	Group 3 pulse output
Pulse output 13	PO13	Output	
Pulse output 14	PO14	Output	
Pulse output 15	PO15	Output	

Table 11-2 PPG Registers

Name	Abbreviation	R/W	Initial Value	Address*¹
PPG output control register	PCR	R/W	H'FF	H'FF46
PPG output mode register	PMR	R/W	H'F0	H'FF47
Next data enable register H	NDERH	R/W	H'00	H'FF48
Next data enable register L	NDERL	R/W	H'00	H'FF49
Output data register H	PODRH	R/(W)* ²	H'00	H'FF4A
Output data register L	PODRL	R/(W)* ²	H'00	H'FF4B
Next data register H	NDRH	R/W	H'00	H'FF4C* ³ H'FF4E
Next data register L	NDRL	R/W	H'00	H'FF4D* ³ H'FF4F
Port 1 data direction register	P1DDR	W	H'00	H'FEB0
Port 2 data direction register	P2DDR	W	H'00	H'FEB1
Module stop control register	MSTPCR	R/W	H'3FFF	H'FF3C

Notes: 1. Lower 16 bits of the address.

2. Bits used for pulse output cannot be written to.

3. When the same output trigger is selected for pulse output groups 2 and 3 by the PCR setting, the NDRH address is H'FF4C. When the output triggers are different, the NDRH address is H'FF4E for group 2 and H'FF4C for group 3.

Similarly, when the same output trigger is selected for pulse output groups 0 and 1 by the PCR setting, the NDRL address is H'FF4D. When the output triggers are different, the NDRL address is H'FF4F for group 0 and H'FF4D for group 1.

NDERH

Bit	:	7	6	5	4	3	2	1	0
		NDER15	NDER14	NDER13	NDER12	NDER11	NDER10	NDER9	NDER8
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

NDERL

Bit	:	7	6	5	4	3	2	1	0
		NDER7	NDER6	NDER5	NDER4	NDER3	NDER2	NDER1	NDER0
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

NDERH and NDERL are 8-bit readable/writable registers that enable or disable pulse output on a bit-by-bit basis.

If a bit is enabled for pulse output by NDERH or NDERL, the NDR value is automatically transferred to the corresponding PODR bit when the TPU compare match event specified by PCR occurs, updating the output value. If pulse output is disabled, the bit value is not transferred from NDR to PODR and the output value does not change.

NDERH and NDERL are each initialized to H'00 by a reset and in hardware standby mode. They are not initialized in software standby mode.

NDERH Bits 7 to 0—Next Data Enable 15 to 8 (NDER15 to NDER8): These bits enable or disable pulse output on a bit-by-bit basis.

Bits 7 to 0

NDER15 to NDER8	Description
0	Pulse outputs PO15 to PO8 are disabled (NDR15 to NDR8 are not transferred to POD15 to POD8) (Initial value)
1	Pulse outputs PO15 to PO8 are enabled (NDR15 to NDR8 are transferred to POD15 to POD8)

0	Pulse outputs PO7 to PO0 are disabled (NDR7 to NDR0 are not transferred to POD7 to POD0) (Initial value)
1	Pulse outputs PO7 to PO0 are enabled (NDR7 to NDR0 are transferred to POD7 to POD0)

11.2.2 Output Data Registers H and L (PODRH, PODRL)

PODRH

Bit	:	7	6	5	4	3	2	1	0
		POD15	POD14	POD13	POD12	POD11	POD10	POD9	POD8
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*

PODRL

Bit	:	7	6	5	4	3	2	1	0
		POD7	POD6	POD5	POD4	POD3	POD2	POD1	POD0
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*

Note: * A bit that has been set for pulse output by NDER is read-only.

PODRH and PODRL are 8-bit readable/writable registers that store output data for use in pulse output.

PODRH and PODRL when the TPU compare match event specified by PCR occurs. The NDRH and NDRL addresses differ depending on whether pulse output groups have the same output trigger or different output triggers. For details see section 11.2.4, Notes on NDR Access.

NDRH and NDRL are each initialized to H'00 by a reset and in hardware standby mode. They are not initialized in software standby mode.

11.2.4 Notes on NDR Access

The NDRH and NDRL addresses differ depending on whether pulse output groups have the same output trigger or different output triggers.

Same Trigger for Pulse Output Groups: If pulse output groups 2 and 3 are triggered by the same compare match event, the NDRH address is H'FF4C. The upper 4 bits belong to group 3 and the lower 4 bits to group 2. Address H'FF4E consists entirely of reserved bits that cannot be modified and are always read as 1.

Address H'FF4C

Bit	:	7	6	5	4	3	2	1	0
		NDR15	NDR14	NDR13	NDR12	NDR11	NDR10	NDR9	NDR8
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Address H'FF4E

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	—	—	—	—
Initial value	:	1	1	1	1	1	1	1	1
R/W	:	—	—	—	—	—	—	—	—

If pulse output groups 0 and 1 are triggered by the same compare match event, the NDRL address is H'FF4D. The upper 4 bits belong to group 1 and the lower 4 bits to group 0. Address H'FF4F consists entirely of reserved bits that cannot be modified and are always read as 1.

R/W : R/W R/W R/W R/W R/W R/W R/W R/W

Address H'FF4F

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	—	—	—	—
Initial value	:	1	1	1	1	1	1	1	1
R/W	:	—	—	—	—	—	—	—	—

Different Triggers for Pulse Output Groups: If pulse output groups 2 and 3 are triggered by different compare match events, the address of the upper 4 bits in NDRH (group 3) is H'FF4C and the address of the lower 4 bits (group 2) is H'FF4E. Bits 3 to 0 of address H'FF4C and bits 7 to 4 of address H'FF4E are reserved bits that cannot be modified and are always read as 1.

Address H'FF4C

Bit	:	7	6	5	4	3	2	1	0
		NDR15	NDR14	NDR13	NDR12	—	—	—	—
Initial value	:	0	0	0	0	1	1	1	1
R/W	:	R/W	R/W	R/W	R/W	—	—	—	—

Address H'FF4E

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	NDR11	NDR10	NDR9	NDR8
Initial value	:	1	1	1	1	0	0	0	0
R/W	:	—	—	—	—	R/W	R/W	R/W	R/W

If pulse output groups 0 and 1 are triggered by different compare match event, the address of the upper 4 bits in NDRL (group 1) is H'FF4D and the address of the lower 4 bits (group 0) is H'FF4F. Bits 3 to 0 of address H'FF4D and bits 7 to 4 of address H'FF4F are reserved bits that cannot be modified and are always read as 1.

Initial value : 0 0 0 0 1 1 1 1
 R/W : R/W R/W R/W R/W — — — —

Address H'FF4F

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	NDR3	NDR2	NDR1	NDR0
Initial value	:	1	1	1	1	0	0	0	0
R/W	:	—	—	—	—	R/W	R/W	R/W	R/W

11.2.5 PPG Output Control Register (PCR)

Bit	:	7	6	5	4	3	2	1	0
		G3CMS1	G3CMS0	G2CMS1	G2CMS0	G1CMS1	G1CMS0	G0CMS1	G0CMS0
Initial value	:	1	1	1	1	1	1	1	1
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

PCR is an 8-bit readable/writable register that selects output trigger signals for PPG outputs on a group-by-group basis.

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

Bits 7 and 6—Group 3 Compare Match Select 1 and 0 (G3CMS1, G3CMS0): These bits select the compare match that triggers pulse output group 3 (pins PO15 to PO12).

		Description
Bit 7 G3CMS1	Bit 6 G3CMS0	Output Trigger for Pulse Output Group 3
0	0	Compare match in TPU channel 0
	1	Compare match in TPU channel 1
1	0	Compare match in TPU channel 2
	1	Compare match in TPU channel 3 (Initial value)

G2CMS1	G2CMS0	Output Trigger for Pulse Output Group 2
0	0	Compare match in TPU channel 0
	1	Compare match in TPU channel 1
1	0	Compare match in TPU channel 2
	1	Compare match in TPU channel 3 (Initial value)

Bits 3 and 2—Group 1 Compare Match Select 1 and 0 (G1CMS1, G1CMS0): These bits select the compare match that triggers pulse output group 1 (pins PO7 to PO4).

		Description
Bit 3 G1CMS1	Bit 2 G1CMS0	Output Trigger for Pulse Output Group 1
0	0	Compare match in TPU channel 0
	1	Compare match in TPU channel 1
1	0	Compare match in TPU channel 2
	1	Compare match in TPU channel 3 (Initial value)

Bits 1 and 0—Group 0 Compare Match Select 1 and 0 (G0CMS1, G0CMS0): These bits select the compare match that triggers pulse output group 0 (pins PO3 to PO0).

		Description
Bit 1 G0CMS1	Bit 0 G0CMS0	Output Trigger for Pulse Output Group 0
0	0	Compare match in TPU channel 0
	1	Compare match in TPU channel 1
1	0	Compare match in TPU channel 2
	1	Compare match in TPU channel 3 (Initial value)

Initial value :	1	1	1	1	0	0	0	0
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

PMR is an 8-bit readable/writable register that selects pulse output inversion and non-overlapping operation for each group.

The output trigger period of a non-overlapping operation PPG output waveform is set in TGRB and the non-overlap margin is set in TGRA. The output values change at compare match A and B.

For details, see section 11.3.4, Non-Overlapping Pulse Output.

PMR is initialized to H'F0 by a reset and in hardware standby mode. It is not initialized in software standby mode.

Bit 7—Group 3 Inversion (G3INV): Selects direct output or inverted output for pulse output group 3 (pins PO15 to PO12).

Bit 7 G3INV	Description
0	Inverted output for pulse output group 3 (low-level output at pin for a 1 in PODRH)
1	Direct output for pulse output group 3 (high-level output at pin for a 1 in PODRH) (Initial value)

Bit 6—Group 2 Inversion (G2INV): Selects direct output or inverted output for pulse output group 2 (pins PO11 to PO8).

Bit 6 G2INV	Description
0	Inverted output for pulse output group 2 (low-level output at pin for a 1 in PODRH)
1	Direct output for pulse output group 2 (high-level output at pin for a 1 in PODRH) (Initial value)

0	Inverted output for pulse output group 1 (low-level output at pin for a 1 in PODRL)
1	Direct output for pulse output group 1 (high-level output at pin for a 1 in PODRL) (Initial value)

Bit 4—Group 0 Inversion (G0INV): Selects direct output or inverted output for pulse output group 0 (pins PO3 to PO0).

Bit 4 G0INV	Description
0	Inverted output for pulse output group 0 (low-level output at pin for a 1 in PODRL)
1	Direct output for pulse output group 0 (high-level output at pin for a 1 in PODRL) (Initial value)

Bit 3—Group 3 Non-Overlap (G3NOV): Selects normal or non-overlapping operation for pulse output group 3 (pins PO15 to PO12).

Bit 3 G3NOV	Description
0	Normal operation in pulse output group 3 (output values updated at compare match A in the selected TPU channel) (Initial value)
1	Non-overlapping operation in pulse output group 3 (independent 1 and 0 output at compare match A or B in the selected TPU channel)

Bit 2—Group 2 Non-Overlap (G2NOV): Selects normal or non-overlapping operation for pulse output group 2 (pins PO11 to PO8).

Bit 2 G2NOV	Description
0	Normal operation in pulse output group 2 (output values updated at compare match A in the selected TPU channel) (Initial value)
1	Non-overlapping operation in pulse output group 2 (independent 1 and 0 output at compare match A or B in the selected TPU channel)

0	Normal operation in pulse output group 1 (output values updated at compare match A in the selected TPU channel)	(Initial value)
1	Non-overlapping operation in pulse output group 1 (independent 1 and 0 output at compare match A or B in the selected TPU channel)	

Bit 0—Group 0 Non-Overlap (G0NOV): Selects normal or non-overlapping operation for pulse output group 0 (pins PO3 to PO0).

Bit 0

G0NOV	Description	
0	Normal operation in pulse output group 0 (output values updated at compare match A in the selected TPU channel)	(Initial value)
1	Non-overlapping operation in pulse output group 0 (independent 1 and 0 output at compare match A or B in the selected TPU channel)	

Initial value	:	0	0	0	0	0	0	0
R/W	:	W	W	W	W	W	W	W

P1DDR is an 8-bit write-only register, the individual bits of which specify input or output for the pins of port 1.

Port 1 is multiplexed with pins PO15 to PO8. Bits corresponding to pins used for PPG output must be set to 1. For further information about P1DDR, see section 9.2, Port 1.

11.2.8 Port 2 Data Direction Register (P2DDR)

Bit	:	7	6	5	4	3	2	1	0
		P27DDR	P26DDR	P25DDR	P24DDR	P23DDR	P22DDR	P21DDR	P20DDR
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	W	W	W	W	W	W	W	W

P2DDR is an 8-bit write-only register, the individual bits of which specify input or output for the pins of port 2.

Port 2 is multiplexed with pins PO7 to PO0. Bits corresponding to pins used for PPG output must be set to 1. For further information about P2DDR, see section 9.3, Port 2.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Initial value	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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	R/W	R/W

MSTPCR is a 16-bit readable/writable register that performs module stop mode control.

When the MSTP11 bit in MSTPCR is set to 1, PPG operation stops at the end of the bus cycle and a transition is made to module stop mode. Registers cannot be read or written to in module stop mode. For details, see section 20.5, 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 11—Module Stop (MSTP11): Specifies the PPG module stop mode.

Bit 11	MSTP11	Description
	0	PPG module stop mode cleared
	1	PPG module stop mode set (Initial value)

PPG pulse output is enabled when the corresponding bits in P1DDR, P2DDR, and NDER are set to 1. In this state the corresponding PODR contents are output.

When the compare match event specified by PCR occurs, the corresponding NDR bit contents are transferred to PODR to update the output values.

Figure 11-2 illustrates the PPG output operation and table 11-3 summarizes the PPG operating conditions.

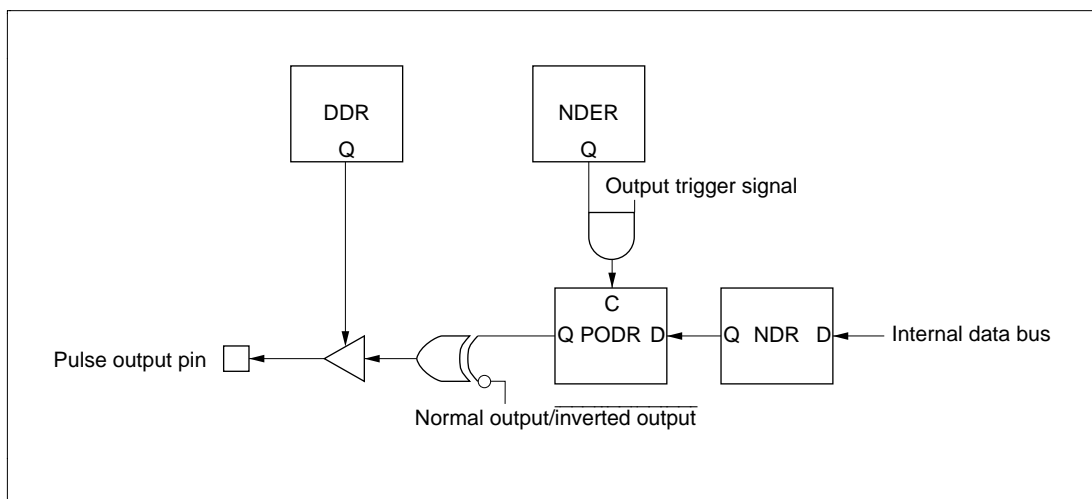


Figure 11-2 PPG Output Operation

Table 11-3 PPG Operating Conditions

NDER	DDR	Pin Function
0	0	Generic input port
	1	Generic output port
1	0	Generic input port (but the PODR bit is a read-only bit, and when compare match occurs, the NDR bit value is transferred to the PODR bit)
	1	PPG pulse output

Sequential output of data of up to 16 bits is possible by writing new output data to NDR before the next compare match. For details of non-overlapping operation, see section 11.3.4, Non-Overlapping Pulse Output.

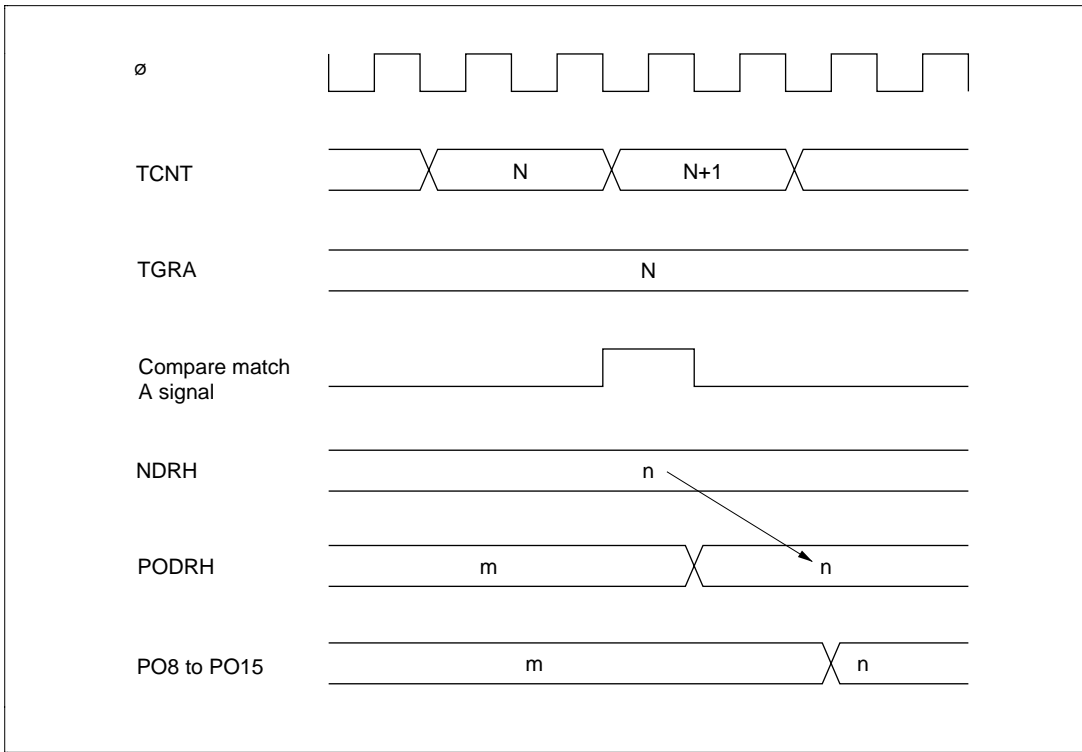
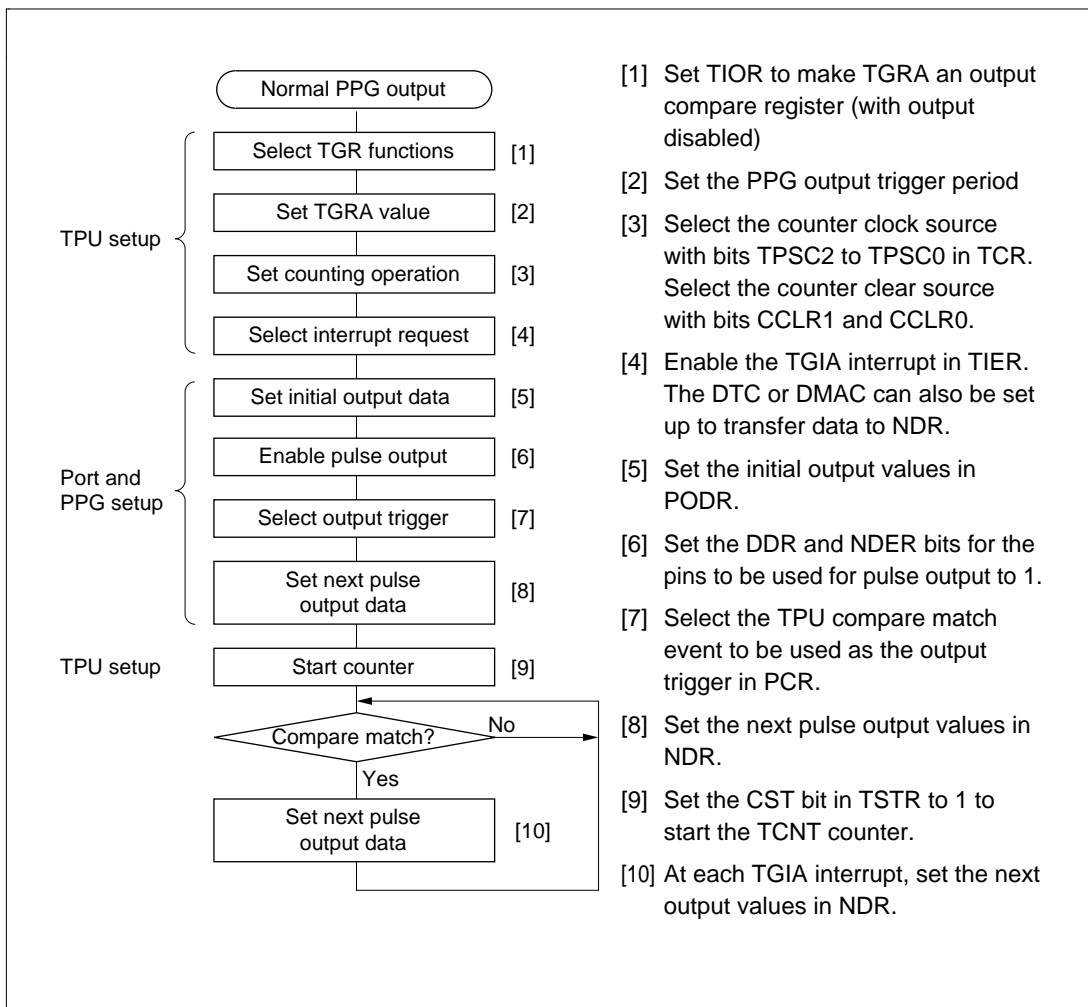


Figure 11-3 Timing of Transfer and Output of NDR Contents (Example)



- [1] Set TIOR to make TGRA an output compare register (with output disabled)
- [2] Set the PPG output trigger period
- [3] Select the counter clock source with bits TPSC2 to TPSC0 in TCR. Select the counter clear source with bits CCLR1 and CCLR0.
- [4] Enable the TGIA interrupt in TIER. The DTC or DMAC can also be set up to transfer data to NDR.
- [5] Set the initial output values in PODR.
- [6] Set the DDR and NDER bits for the pins to be used for pulse output to 1.
- [7] Select the TPU compare match event to be used as the output trigger in PCR.
- [8] Set the next pulse output values in NDR.
- [9] Set the CST bit in TSTR to 1 to start the TCNT counter.
- [10] At each TGIA interrupt, set the next output values in NDR.

Figure 11-4 Setup Procedure for Normal Pulse Output (Example)

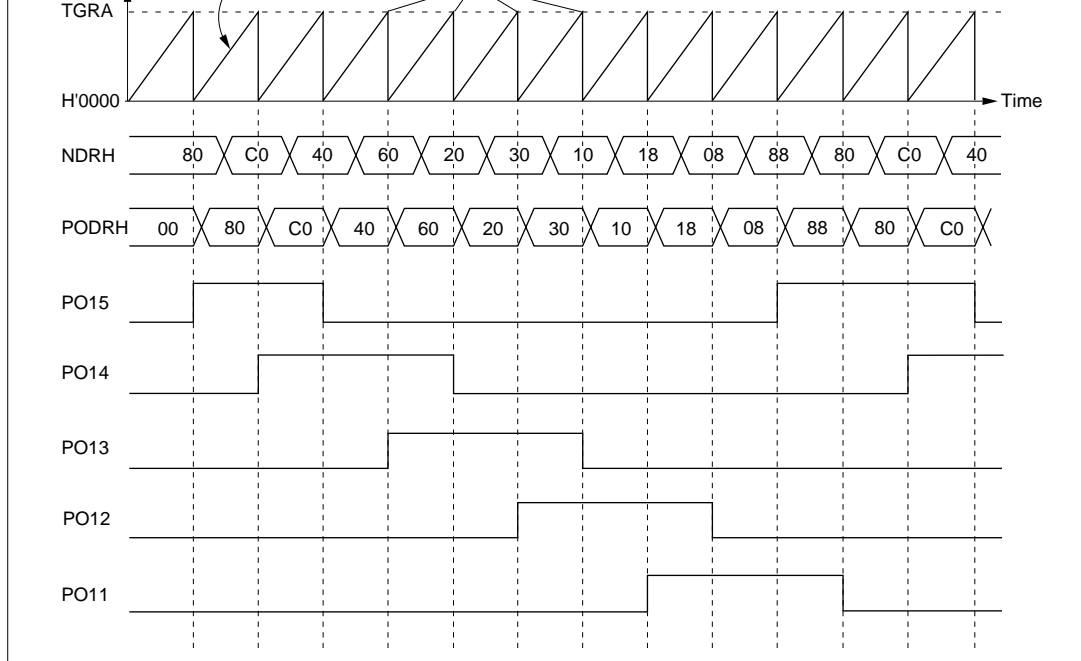
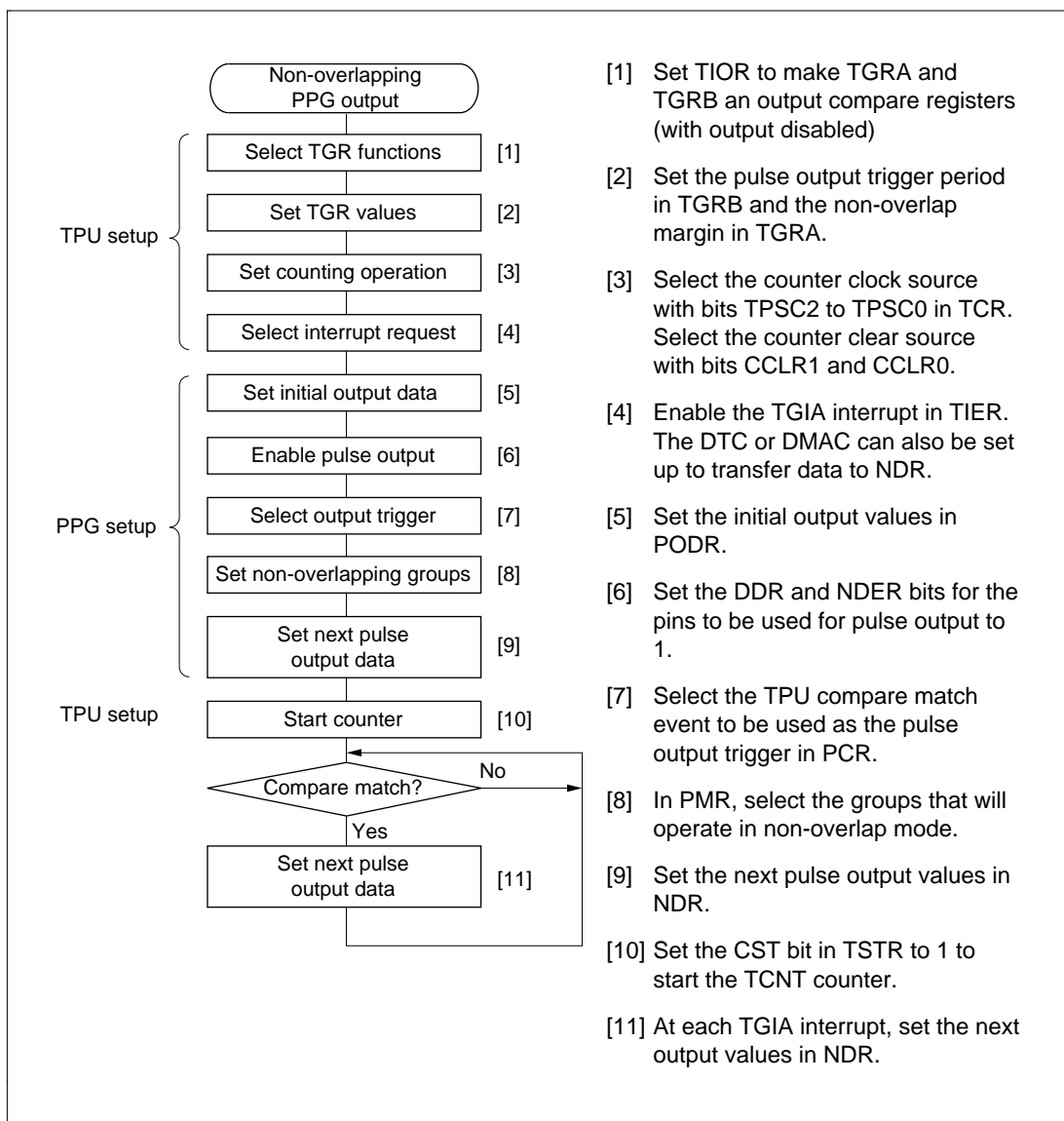


Figure 11-5 Normal Pulse Output Example (Five-Phase Pulse Output)

- [1] Set up the TPU channel to be used as the output trigger channel so that TGRA is an output compare register and the counter will be cleared by compare match A. Set the trigger period in TGRA and set the TGIEA bit in TIER to 1 to enable the compare match A (TGIA) interrupt.
- [2] Write H'F8 in P1DDR and NDERH, and set the G3CMS1, G3CMS0, G2CMS1, and G2CMS0 bits in PCR to select compare match in the TPU channel set up in the previous step to be the output trigger. Write output data H'80 in NDRH.
- [3] The timer counter in the TPU channel starts. When compare match A occurs, the NDRH contents are transferred to PODRH and output. The TGIA interrupt handling routine writes the next output data (H'C0) in NDRH.
- [4] Five-phase overlapping pulse output (one or two phases active at a time) can be obtained subsequently by writing H'40, H'60, H'20, H'30, H'10, H'18, H'08, H'88... at successive TGIA interrupts. If the DTC or DMAC is set for activation by this interrupt, pulse output can be obtained without imposing a load on the CPU.



- [1] Set TIOR to make TGRA and TGRB an output compare registers (with output disabled)
- [2] Set the pulse output trigger period in TGRB and the non-overlap margin in TGRA.
- [3] Select the counter clock source with bits TPSC2 to TPSC0 in TCR. Select the counter clear source with bits CCLR1 and CCLR0.
- [4] Enable the TGIA interrupt in TIER. The DTC or DMAC can also be set up to transfer data to NDR.
- [5] Set the initial output values in PODR.
- [6] Set the DDR and NDER bits for the pins to be used for pulse output to 1.
- [7] Select the TPU compare match event to be used as the pulse output trigger in PCR.
- [8] In PMR, select the groups that will operate in non-overlap mode.
- [9] Set the next pulse output values in NDR.
- [10] Set the CST bit in TSTR to 1 to start the TCNT counter.
- [11] At each TGIA interrupt, set the next output values in NDR.

Figure 11-6 Setup Procedure for Non-Overlapping Pulse Output (Example)

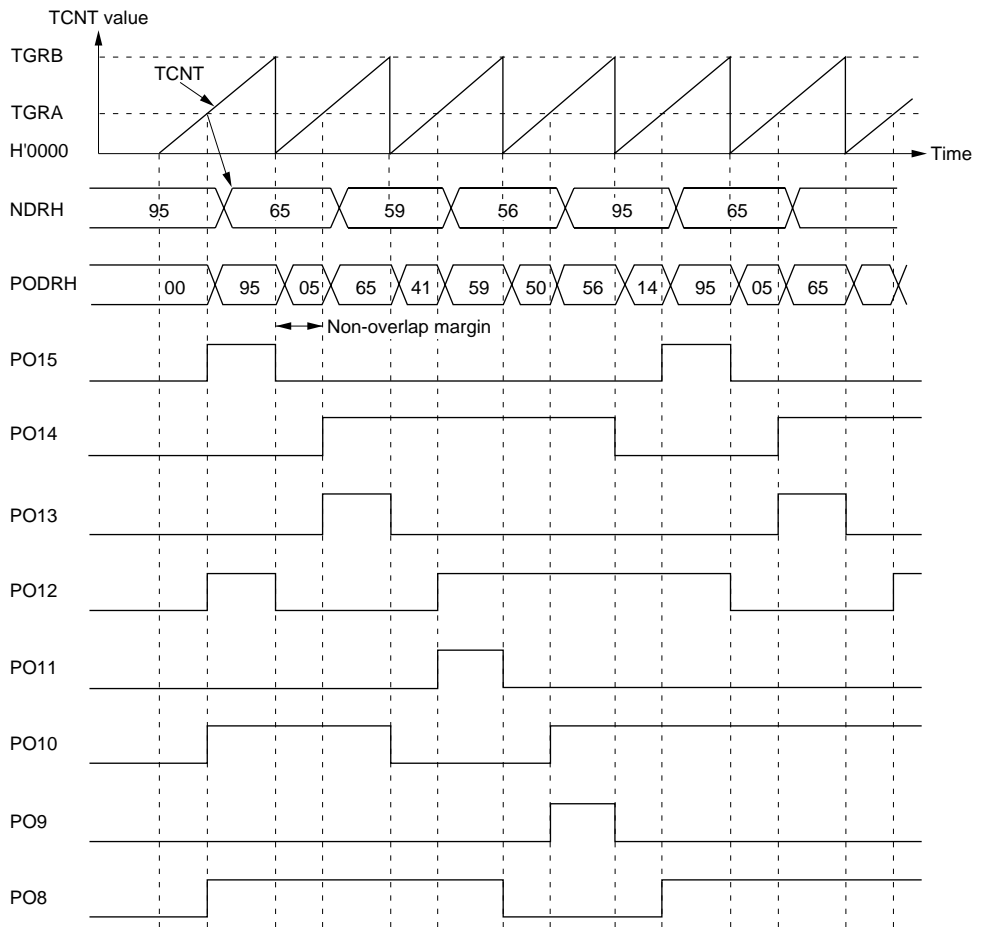


Figure 11-7 Non-Overlapping Pulse Output Example (Four-Phase Complementary)

- [2] Write H'FF in P1DDR and NDERH, and set the G3CMS1, G3CMS0, G2CMS1, and G2CMS0 bits in PCR to select compare match in the TPU channel set up in the previous step to be the output trigger. Set the G3NOV and G2NOV bits in PMR to 1 to select non-overlapping output. Write output data H'95 in NDRH.
- [3] The timer counter in the TPU channel starts. When a compare match with TGRB occurs, outputs change from 1 to 0. When a compare match with TGRA occurs, outputs change from 0 to 1 (the change from 0 to 1 is delayed by the value set in TGRA). The TGIA interrupt handling routine writes the next output data (H'65) in NDRH.
- [4] Four-phase complementary non-overlapping pulse output can be obtained subsequently by writing H'59, H'56, H'95... at successive TGIA interrupts. If the DTC or DMAC is set for activation by this interrupt, pulse output can be obtained without imposing a load on the CPU.

Figure 11-8 shows the outputs when G3INV and G2INV are cleared to 0, in addition to the settings of figure 11-7.

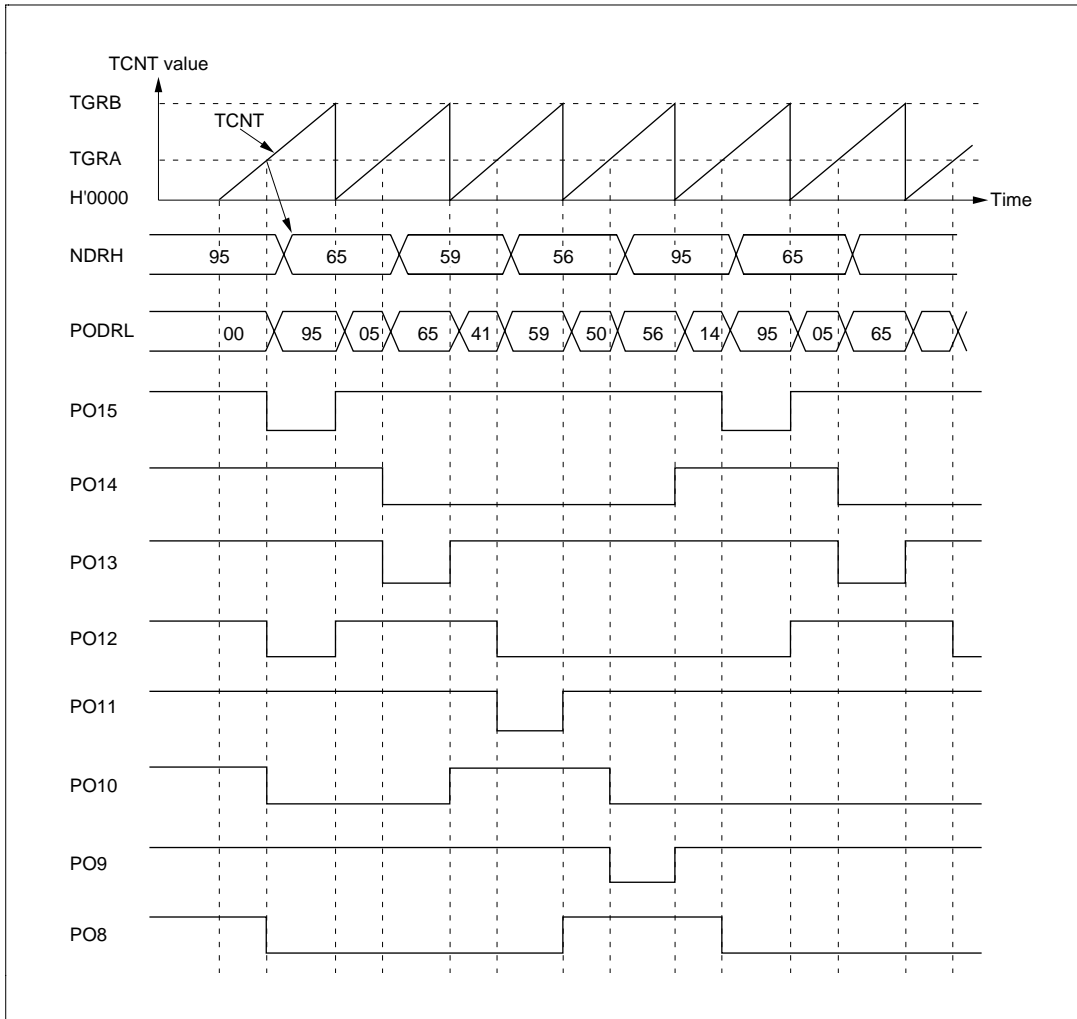


Figure 11-8 Inverted Pulse Output (Example)

triggered by the input capture signal.

Figure 11-9 shows the timing of this output.

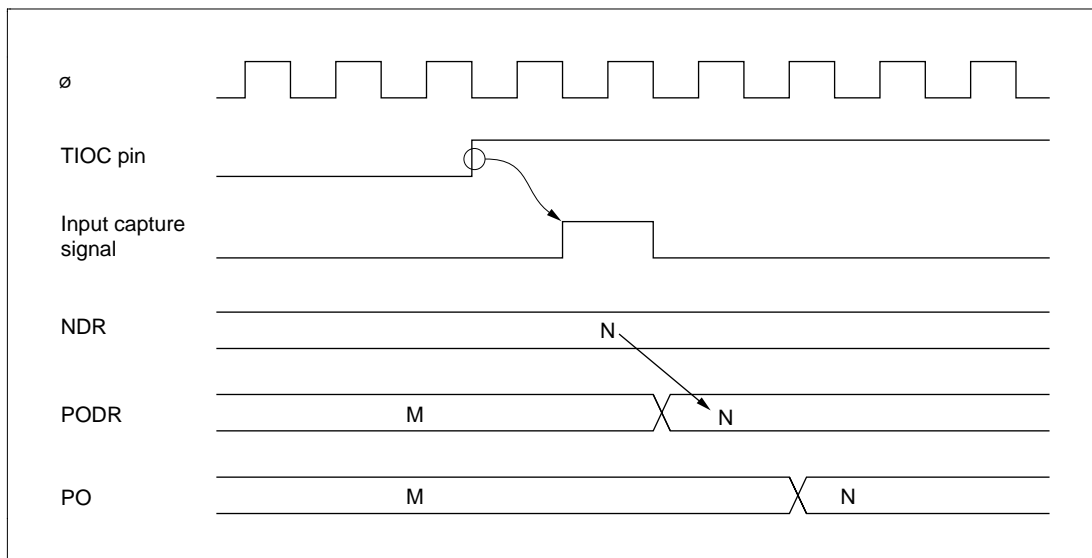


Figure 11-9 Pulse Output Triggered by Input Capture (Example)

cannot be used for pulse output. Note, however, that data transfer from NDR bits to PODR bits takes place, regardless of the usage of the pins.

Pin functions should be changed only under conditions in which the output trigger event will not occur.

Note on Non-Overlapping Output: During non-overlapping operation, the transfer of NDR bits to PODR bits takes place as follows.

- NDR bits are always transferred to PODR bits at compare match A.
- At compare match B, NDR bits are transferred only if their value is 0. Bits are not transferred if their value is 1.

Figure 11-10 illustrates the non-overlapping pulse output operation.

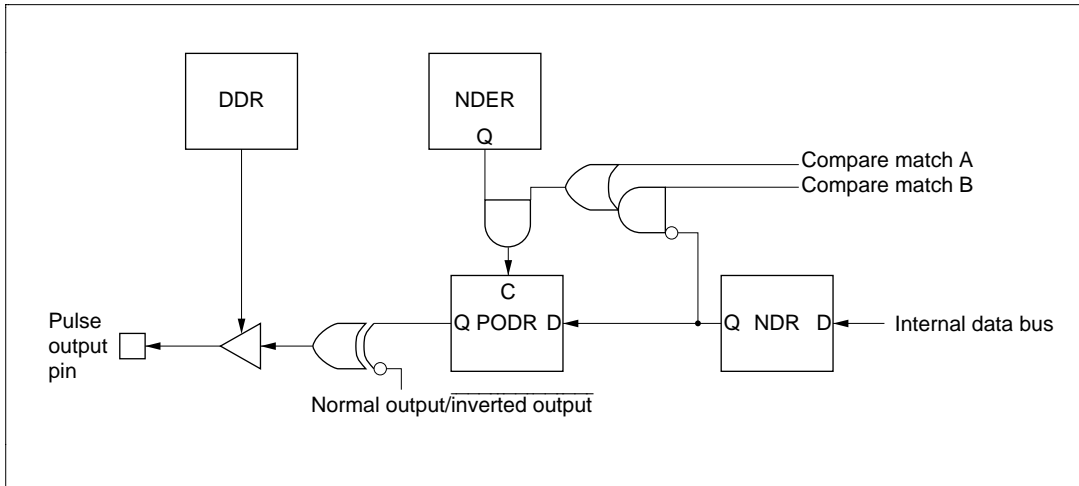


Figure 11-10 Non-Overlapping Pulse Output

NDR, or by having the TGIA interrupt activate the DTC or DMAC. Note, however, that the next data must be written before the next compare match B occurs.

Figure 11-11 shows the timing of this operation.

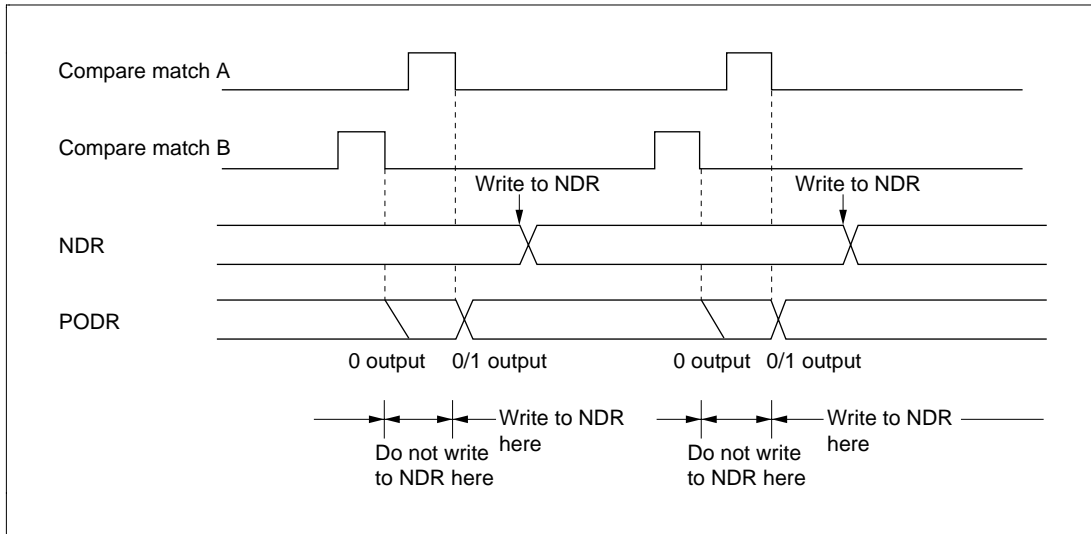


Figure 11-11 Non-Overlapping Operation and NDR Write Timing

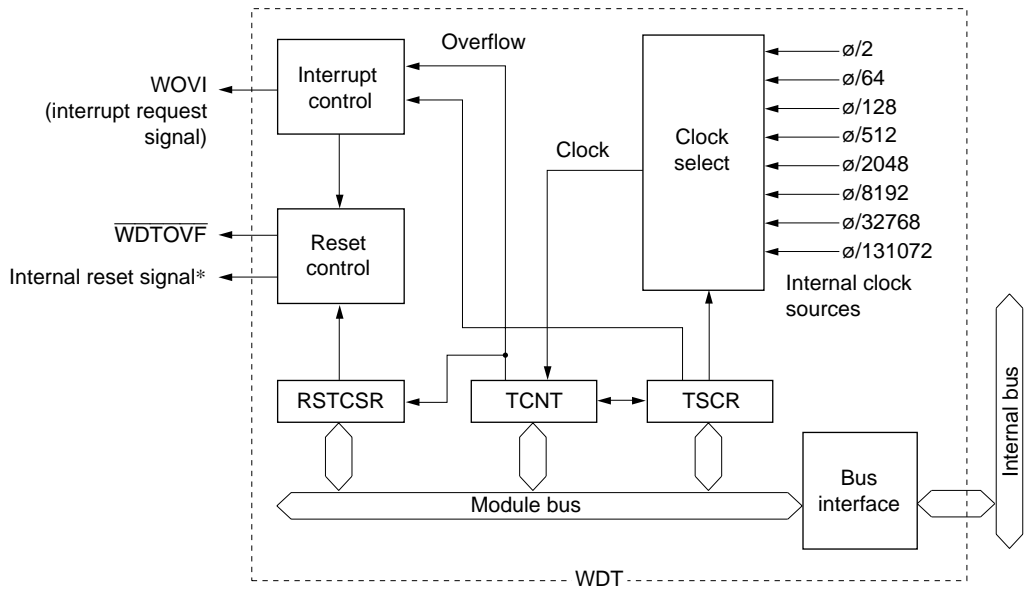
The H8S/2350 Series has a single-channel on-chip watchdog timer (WDT) for monitoring system operation. The WDT outputs an overflow signal ($\overline{\text{WDTOVF}}$) if a system crash prevents the CPU from writing to the timer counter, allowing it to overflow. At the same time, the WDT can also generate an internal reset signal for the H8S/2350 Series.

When this watchdog function is not needed, the WDT can be used as an interval timer. In interval timer operation, an interval timer interrupt is generated each time the counter overflows.

12.1.1 Features

WDT features are listed below.

- Switchable between watchdog timer mode and interval timer mode
- $\overline{\text{WDTOVF}}$ output when in watchdog timer mode
If the counter overflows, the WDT outputs $\overline{\text{WDTOVF}}$. It is possible to select whether or not the entire H8S/2350 Series is reset at the same time. This internal reset can be a power-on reset or a manual reset.
- Interrupt generation when in interval timer mode
If the counter overflows, the WDT generates an interval timer interrupt.
- Choice of eight counter clock sources.



Legend

- TCSR : Timer control/status register
- TCNT : Timer counter
- RSTCSR : Reset control/status register

Note: * The type of internal reset signal depends on a register setting. Either power-on reset or manual reset can be selected.

Figure 12-1 Block Diagram of WDT

Table 12-1 WDT Tim

Name	Symbol	I/O	Function
Watchdog timer overflow	$\overline{\text{WDTOVF}}$	Output	Outputs counter overflow signal in watchdog timer mode

12.1.4 Register Configuration

The WDT has three registers, as summarized in table 12-2. These registers control clock selection, WDT mode switching, and the reset signal.

Table 12-2 WDT Registers

Name	Abbreviation	R/W	Initial Value	Address*¹	
				Write*²	Read
Timer control/status register	TCSR	R/(W)* ³	H'18	H'FFBC	H'FFBC
Timer counter	TCNT	R/W	H'00	H'FFBC	H'FFBD
Reset control/status register	RSTCSR	R/(W)* ³	H'1F	H'FFBE	H'FFBF

Notes: 1. Lower 16 bits of the address.

2. For details of write operations, see section 12.2.4, Notes on Register Access.

3. Only a write of 0 is permitted to bit 7, to clear the flag.

Bit	:	7	6	5	4	3	2	1	0
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	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 internal clock source selected by bits CKS2 to CKS0 in TCSR. When the count overflows (changes from H'FF to H'00), either the watchdog timer overflow signal ($\overline{\text{WDTOVF}}$) or an interval timer interrupt (WOVI) is generated, depending on the mode selected by the WT/ $\overline{\text{IT}}$ bit in TCSR.

TCNT is initialized to H'00 by a reset, in hardware standby mode, or when the TME bit is cleared to 0. It is not initialized in software standby mode.

Note: * TCNT is write-protected by a password to prevent accidental overwriting. For details see section 12.2.4, Notes on Register Access.

12.2.2 Timer Control/Status Register (TCSR)

Bit	:	7	6	5	4	3	2	1	0
		OVF	WT/ $\overline{\text{IT}}$	TME	—	—	CKS2	CKS1	CKS0
Initial value	:	0	0	0	1	1	0	0	0
R/W	:	R/(W)*	R/W	R/W	—	—	R/W	R/W	R/W

Note: * Can only be written with 0 for flag clearing.

TCSR is an 8-bit readable/writable* register. Its functions include selecting the clock source to be input to TCNT, and the timer mode.

TCR is initialized to H'18 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 12.2.4, Notes on Register Access.

0	[Clearing condition] Cleared by reading TCSR when OVF = 1, then writing 0 to OVF	(Initial value)
1	[Setting condition] Set when TCNT overflows (changes from H'FF to H'00) in interval timer mode	

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 request (WOVI) when TCNT overflows. If used as a watchdog timer, the WDT generates the $\overline{\text{WDTOVF}}$ signal when TCNT overflows.

Bit 6 WT/IT	Description	
0	Interval timer: Sends the CPU an interval timer interrupt request (WOVI) when TCNT overflows	(Initial value)
1	Watchdog timer: Generates the $\overline{\text{WDTOVF}}$ signal when TCNT overflows	

Note: * For details of the case where TCNT overflows in watchdog timer mode, see section 12.2.3, Reset Control/Status Register (RSTCSR).

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	(Initial value)
1	TCNT counts	

Bits 4 and 3—Reserved: Read-only bits, always read as 1.

CKS2	CKS1	CKS0	Clock	Overflow Period (when $\phi = 20$ MHz)*
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'00 until overflow occurs.

12.2.3 Reset Control/Status Register (RSTCSR)

Bit	:	7	6	5	4	3	2	1	0
		WOVF	RSTE	RSTS	—	—	—	—	—
Initial value:		0	0	0	1	1	1	1	1
R/W	:	R/(W)*	R/W	R/W	—	—	—	—	—

Note: * Can only be written with 0 for flag clearing.

RSTCSR is an 8-bit readable/writable* register that controls the generation of the internal reset signal when TCNT overflows, and selects the type of internal reset signal.

RSTCSR is initialized to H'1F by a reset signal from the $\overline{\text{RES}}$ pin, but not by the WDT internal reset signal caused by overflows.

Note: * RSTCSR is write-protected by a password to prevent accidental overwriting. For details see section 12.2.4, Notes on Register Access.

0	[Clearing condition] Cleared by reading TCSR when WOVF = 1, then writing 0 to WOVF	(Initial value)
1	[Setting condition] Set when TCNT overflows (changed from H'FF to H'00) during watchdog timer operation	

Bit 6—Reset Enable (RSTE): Specifies whether or not a reset signal is generated in the H8S/2350 Series if TCNT overflows during watchdog timer operation.

Bit 6

RSTE	Description	
0	Reset signal is not generated if TCNT overflows*	(Initial value)
1	Reset signal is generated if TCNT overflows	

Note: * The modules within the H8S/2350 Series are not reset, but TCNT and TCSR within the WDT are reset.

Bit 5—Reset Select (RSTS): Selects the type of internal reset generated if TCNT overflows during watchdog timer operation.

For details of the types of resets, see section 4, Exception Handling.

Bit 5

RSTS	Description	
0	Power-on reset	(Initial value)
1	Manual reset	

Bits 4 to 0—Reserved: Read-only bits, always read as 1.

below.

Writing to TCNT and TCSR: These registers must be written to by a word transfer instruction. They cannot be written to with byte instructions.

Figure 12-2 shows the format of data written to TCNT and TCSR. TCNT and TCSR both have 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.

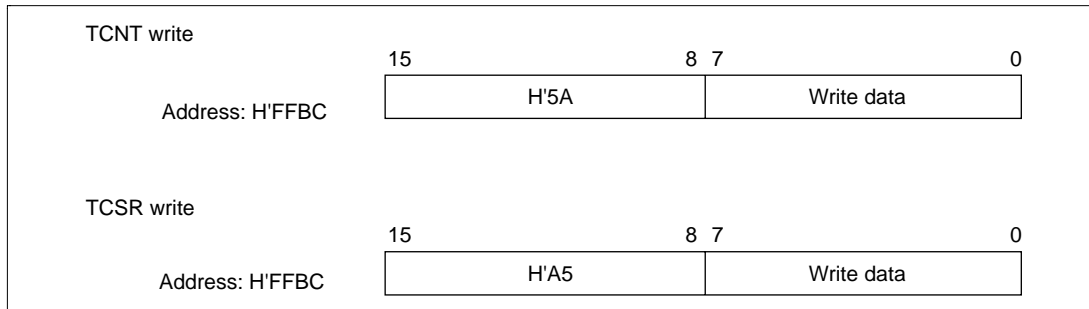


Figure 12-2 Format of Data Written to TCNT and TCSR

To write 0 to the WOVF bit, the write data must have H'A5 in the upper byte and H'00 in the lower byte. This clears the WOVF bit to 0, but has no effect on the RSTE and RSTS bits. To write to the RSTE and RSTS bits, the upper byte must contain H'5A and the lower byte must contain the write data. This writes the values in bits 6 and 5 of the lower byte into the RSTE and RSTS bits, but has no effect on the WOVF bit.

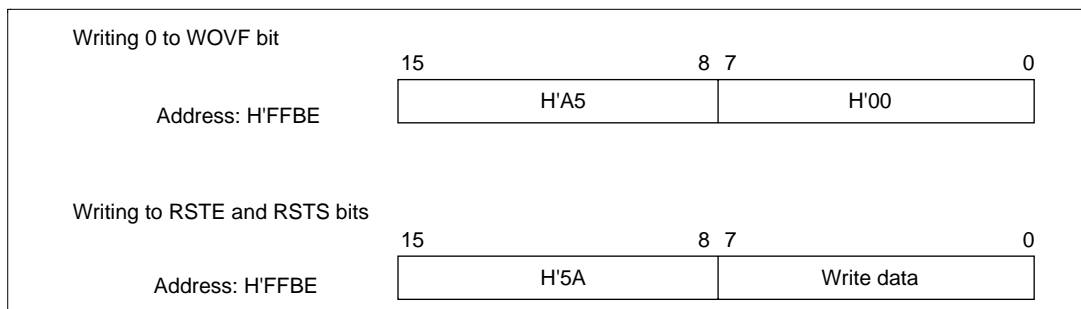


Figure 12-3 Format of Data Written to RSTCSR

Reading TCNT, TCSR, and RSTCSR: These registers are read in the same way as other registers. The read addresses are H'FFBC for TCSR, H'FFBD for TCNT, and H'FFBF for RSTCSR.

To use the WDT as a watchdog timer, set the $\overline{WT/\overline{IT}}$ and TME bits to 1. Software must prevent TCNT overflows by rewriting the TCNT value (normally by writing H'00) before overflows occurs. This ensures that TCNT does not overflow while the system is operating normally. If TCNT overflows without being rewritten because of a system crash or other error, the \overline{WDTOVF} signal is output. This is shown in figure 12-4. This \overline{WDTOVF} signal can be used to reset the system. The \overline{WDTOVF} signal is output for 132 states when RSTE = 1, and for 130 states when RSTE = 0.

If TCNT overflows when 1 is set in the RSTE bit in RSTCSR, a signal that resets the H8S/2350 Series internally is generated at the same time as the \overline{WDTOVF} signal. This reset can be selected as a power-on reset or a manual reset, depending on the setting of the RSTS bit in RSTCSR. The internal reset signal is output for 518 states.

If a reset caused by a signal input to the \overline{RES} pin occurs at the same time as a reset caused by a WDT overflow, the \overline{RES} pin reset has priority and the WOVF bit in RSTCSR is cleared to 0.

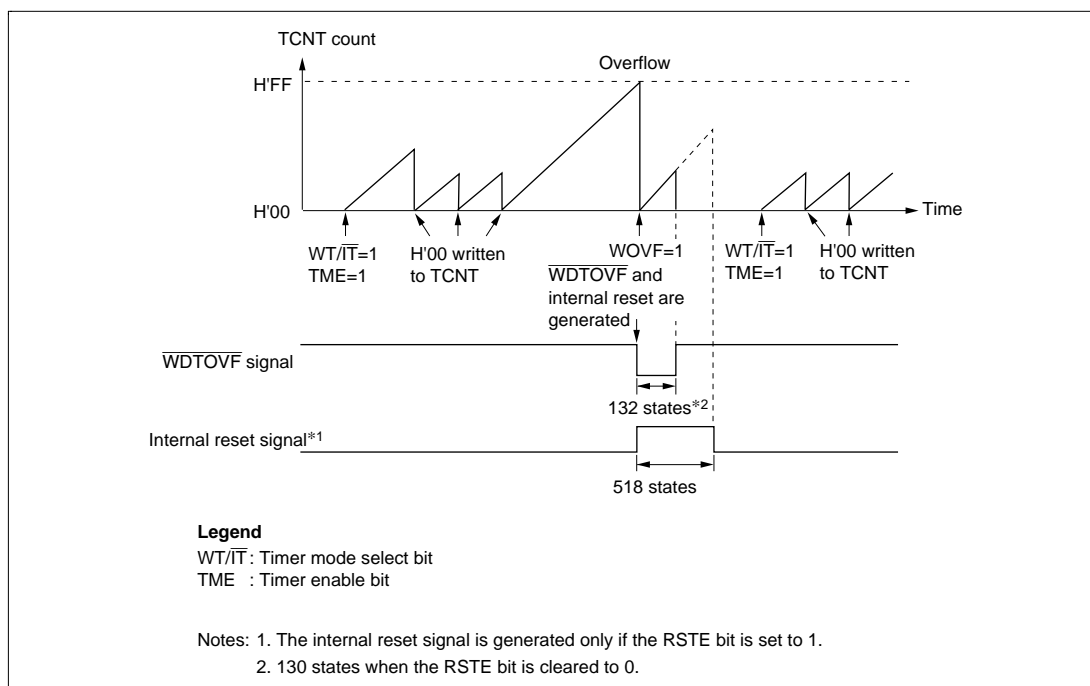


Figure 12-4 Watchdog Timer Operation

WDT is operating as an interval timer, as shown in figure 12-5. This function can be used to generate interrupt requests at regular intervals.

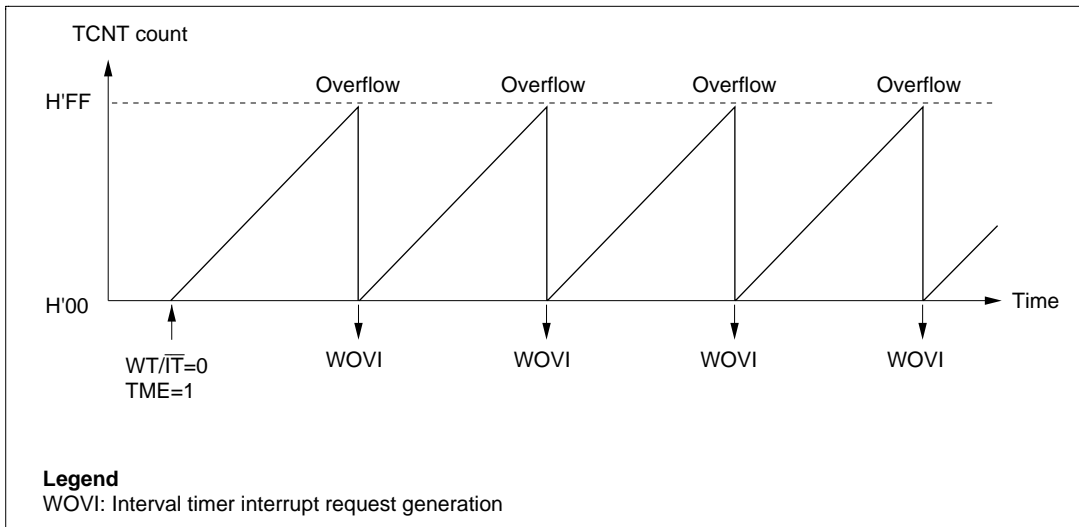


Figure 12-5 Interval Timer Operation

12.3.3 Timing of Setting Overflow Flag (OVF)

The OVF flag is set to 1 if TCNT overflows during interval timer operation. At the same time, an interval timer interrupt (WOV1) is requested. This timing is shown in figure 12-6.

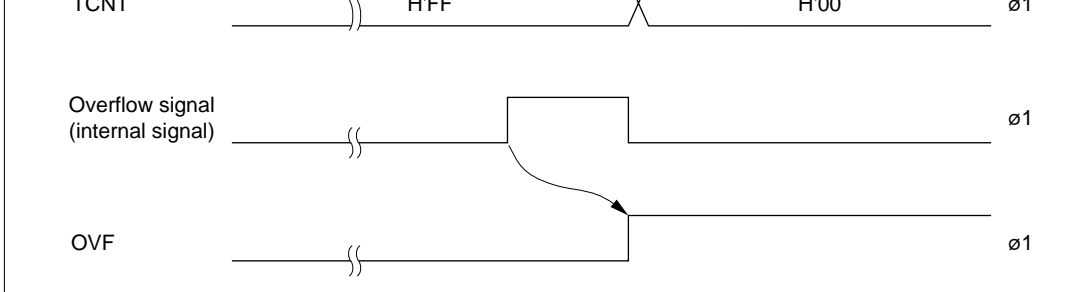


Figure 12-6 Timing of Setting of OVF

12.3.4 Timing of Setting of Watchdog Timer Overflow Flag (WOVF)

The WOVF flag is set to 1 if TCNT overflows during watchdog timer operation. At the same time, the $\overline{\text{WDTOVF}}$ signal goes low. If TCNT overflows while the RSTE bit in RSTCSR is set to 1, an internal reset signal is generated for the entire H8S/2350 Series chip. Figure 12-7 shows the timing in this case.

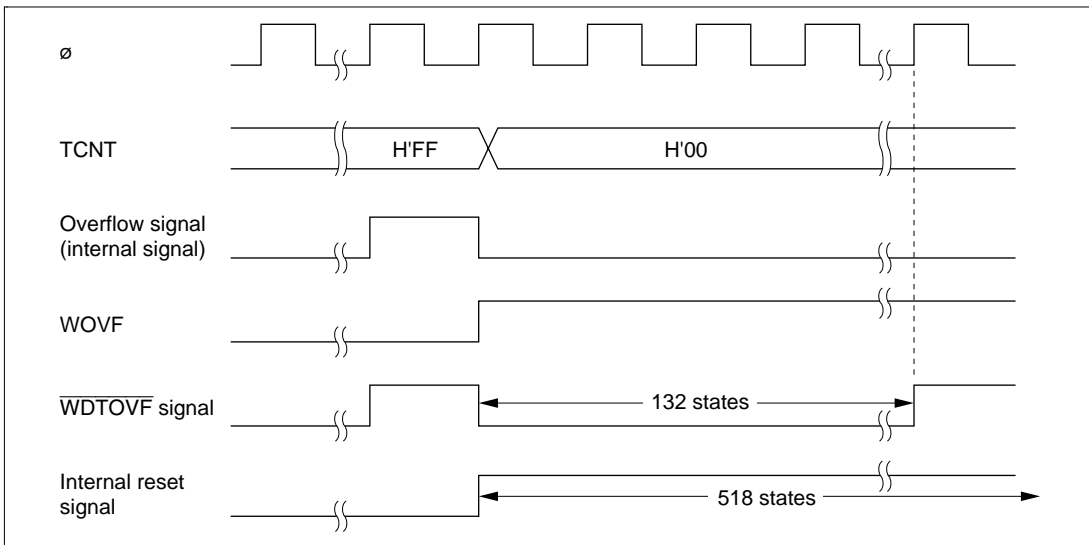


Figure 12-7 Timing of Setting of WOVF

12.5 Usage Notes

12.5.1 Contention between Timer Counter (TCNT) Write and Increment

If a timer counter clock pulse is generated during the T_2 state of a TCNT write cycle, the write takes priority and the timer counter is not incremented. Figure 12-8 shows this operation.

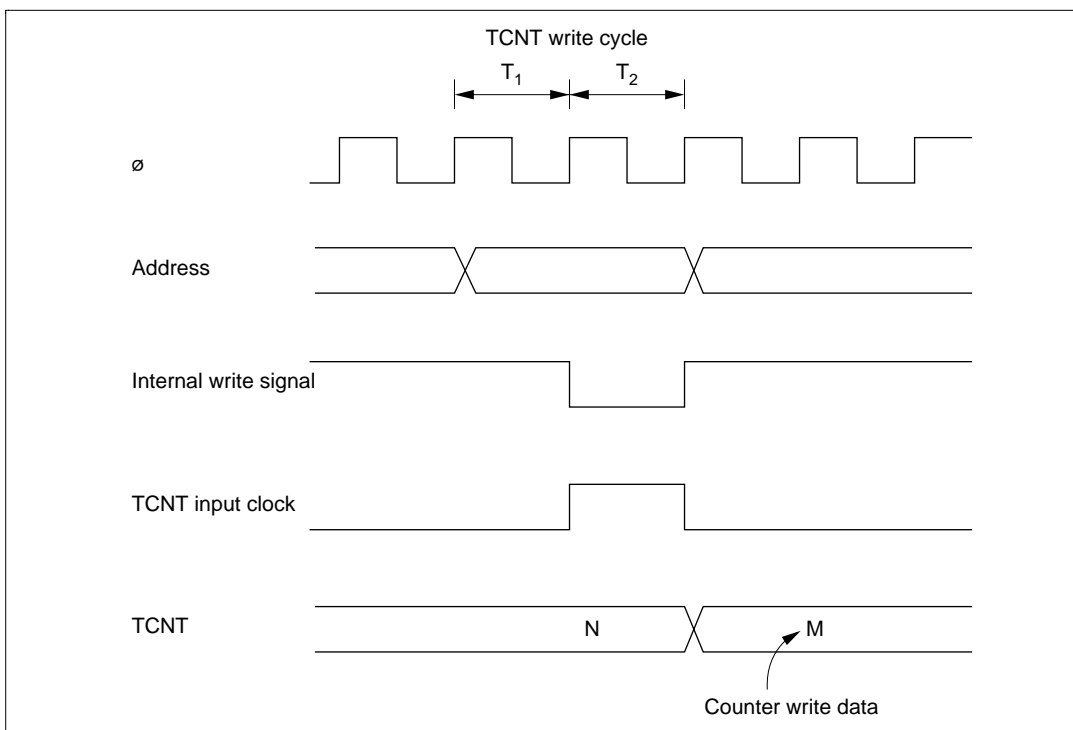


Figure 12-8 Contention between TCNT Write and Increment

12.5.2 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.

clearing the TME bit to 0) before switching the mode.

12.5.4 System Reset by $\overline{\text{WDTOVF}}$ Signal

If the $\overline{\text{WDTOVF}}$ output signal is input to the $\overline{\text{RES}}$ pin of the H8S/2350 Series, the H8S/2350 Series will not be initialized correctly. Make sure that the $\overline{\text{WDTOVF}}$ signal is not input logically to the $\overline{\text{RES}}$ pin. To reset the entire system by means of the $\overline{\text{WDTOVF}}$ signal, use the circuit shown in figure 12-9.

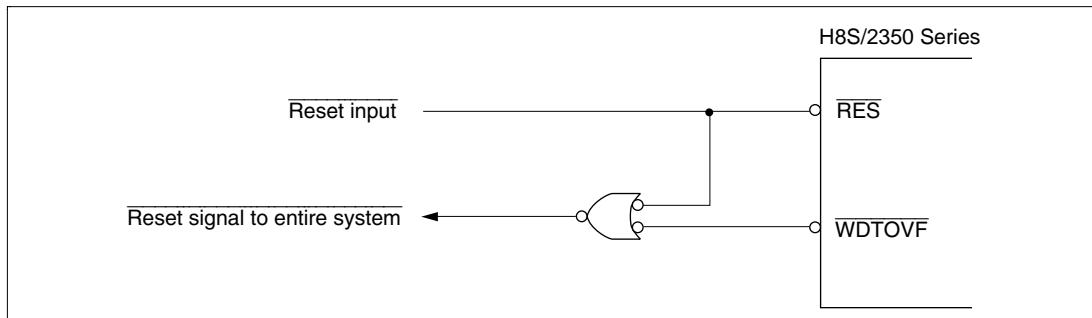


Figure 12-9 Circuit for System Reset by $\overline{\text{WDTOVF}}$ Signal (Example)

12.5.5 Internal Reset in Watchdog Timer Mode

The H8S/2350 Series is not reset internally if TCNT overflows while the RSTE bit is cleared to 0 during watchdog timer operation, but TCNT and TCSR of the WDT are reset.

TCNT, TCSR, and RSTCR cannot be written to while the $\overline{\text{WDTOVF}}$ signal is low. Also note that a read of the WOVF flag is not recognized during this period. To clear the WOVF flag, therefore, read TCSR after the $\overline{\text{WDTOVF}}$ signal goes high, then write 0 to the WOVF flag.

The H8S/2350 Series is equipped with a two-channel serial communication interface (SCI). All two channels have the same functions. The SCI can handle both asynchronous and clocked synchronous serial communication. A function is also provided for serial communication between processors (multiprocessor communication function).

13.1.1 Features

SCI features are listed below.

- Choice of asynchronous or clocked synchronous serial communication mode

Asynchronous mode

- Serial data communication executed using 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

Clocked Synchronous mode

- Serial data communication synchronized with a clock
- Serial data communication can be carried out with other chips that have a synchronous communication function
- One serial data transfer format
 - Data length : 8 bits
- Receive error detection : Overrun errors detected

- On-chip 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
- 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 interrupts can activate the DMA controller (DMAC) or data transfer controller (DTC) to execute data transfer
- Choice of LSB-first or MSB-first transfer
 - Can be selected regardless of the communication mode* (except in the case of asynchronous mode bit data)
- Module stop mode can be set
 - As the initial setting, SCI operation is halted. Register access is enabled by exiting module stop mode.

Note: * Descriptions in this section refer to LSB-first transfer.

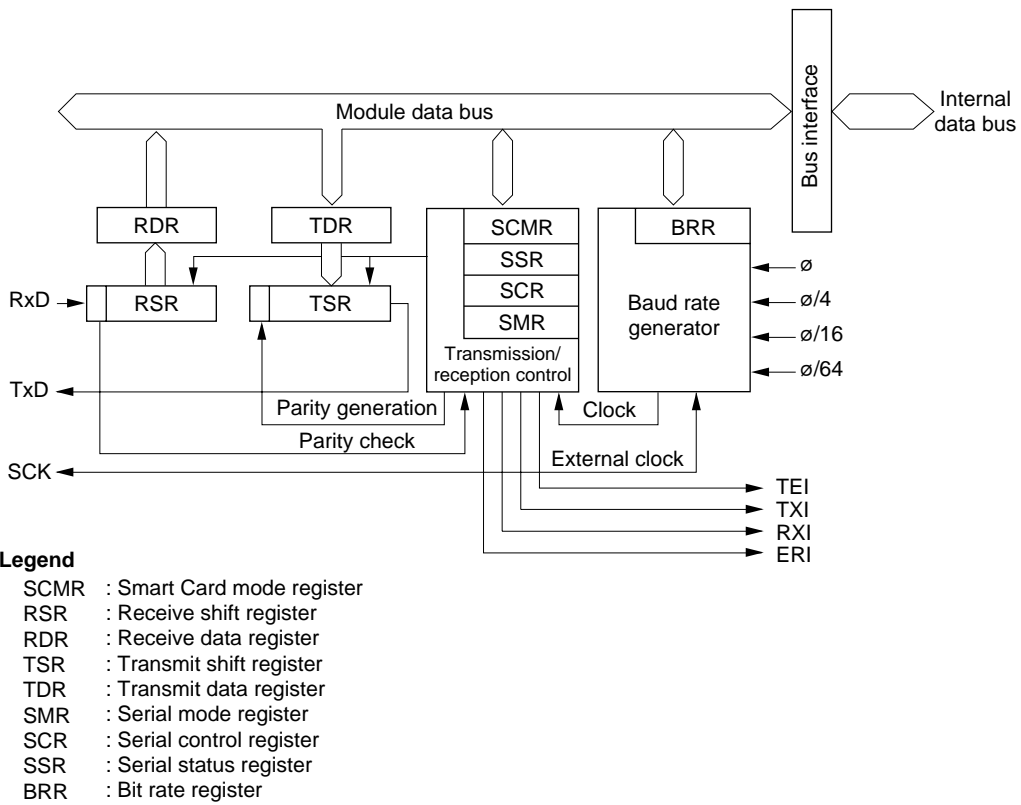


Figure 13-1 Block Diagram of SCI

Channel	Pin Name	Symbol	I/O	Function
0	Serial clock pin 0	SCK0	I/O	SCI0 clock input/output
	Receive data pin 0	RxD0	Input	SCI0 receive data input
	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

Table 13-2 SCI Registers

Channel	Name	Abbreviation	R/W	Initial Value	Address* ¹
0	Serial mode register 0	SMR0	R/W	H'00	H'FF78
	Bit rate register 0	BRR0	R/W	H'FF	H'FF79
	Serial control register 0	SCR0	R/W	H'00	H'FF7A
	Transmit data register 0	TDR0	R/W	H'FF	H'FF7B
	Serial status register 0	SSR0	R/(W)* ²	H'84	H'FF7C
	Receive data register 0	RDR0	R	H'00	H'FF7D
	Smart card mode register 0	SCMR0	R/W	H'F2	H'FF7E
1	Serial mode register 1	SMR1	R/W	H'00	H'FF80
	Bit rate register 1	BRR1	R/W	H'FF	H'FF81
	Serial control register 1	SCR1	R/W	H'00	H'FF82
	Transmit data register 1	TDR1	R/W	H'FF	H'FF83
	Serial status register 1	SSR1	R/(W)* ²	H'84	H'FF84
	Receive data register 1	RDR1	R	H'00	H'FF85
	Smart card mode register 1	SCMR1	R/W	H'F2	H'FF86
All	Module stop control register MSTPCR		R/W	H'3FFF	H'FF3C

Notes: 1. Lower 16 bits of the address.

2. Can only be written with 0 for flag clearing.

Bit	:	7	6	5	4	3	2	1	0										
		<table border="1" style="width: 100%; height: 20px; border-collapse: collapse;"> <tr> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> </tr> </table>																	
R/W	:	—	—	—	—	—	—	—	—										

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.

13.2.2 Receive Data Register (RDR)

Bit	:	7	6	5	4	3	2	1	0										
		<table border="1" style="width: 100%; height: 20px; border-collapse: collapse;"> <tr> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> <td style="width: 12.5%;"></td> </tr> </table>																	
Initial value	:	0	0	0	0	0	0	0	0										
R/W	:	R	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 receive-enabled.

Since RSR and RDR function as a double buffer in this way, enables continuous receive operations to 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 or module stop mode.

TSR is a register used to transmit serial data.

To perform serial data transmission, the SCI first transfers transmit data from TDR to TSR, then sends the data to the TxD pin starting with the LSB (bit 0).

When transmission of one byte is completed, the next transmit data is transferred from TDR to TSR, and transmission started, automatically. However, data transfer from TDR to TSR is not performed if the TDRE bit in SSR is set to 1.

TSR cannot be directly read or written to by the CPU.

13.2.4 Transmit Data Register (TDR)

Bit	:	7	6	5	4	3	2	1	0
Initial value	:	1	1	1	1	1	1	1	1
R/W	:	R/W	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 the next 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 or module stop mode.

Initial value :	0	0	0	0	0	0	0	0	0
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

SMR is an 8-bit register used to set the SCI's serial transfer format and select the baud rate 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 or module stop mode.

Bit 7—Communication Mode (C/A): Selects asynchronous mode or clocked synchronous mode as the SCI operating mode.

Bit 7 C/A	Description	
0	Asynchronous mode	(Initial value)
1	Clocked synchronous mode	

Bit 6—Character Length (CHR): Selects 7 or 8 bits as the data length in asynchronous mode. In clocked synchronous mode, a fixed data length of 8 bits is used regardless of the CHR setting.

Bit 6 CHR	Description	
0	8-bit data	(Initial value)
1	7-bit data*	

Note: * When 7-bit data is selected, the MSB (bit 7) of TDR is not transmitted, and it is not possible to choose between LSB-first or MSB-first transfer.

Bit 5 PE	Description	
0	Parity bit addition and checking disabled	(Initial value)
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 added to transmit data before transmission. In reception, the parity bit is checked for the parity (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 clocked synchronous mode, and when parity addition and checking is disabled in asynchronous mode.

Bit 4 O/\bar{E}	Description	
0	Even parity* ¹	(Initial value)
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 receive 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 receive character plus the parity bit is odd.

STOP	Description
0	1 stop bit: In transmission, a single 1 bit (stop bit) is added to the end of a transmit character before it is sent. (Initial value)
1	2 stop bits: 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 second 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 transmit character.

Bit 2—Multiprocessor Mode (MP): Selects multiprocessor format. When multiprocessor format is selected, the PE bit and O/\bar{E} bit parity settings are invalid. The MP bit setting is only valid in asynchronous mode; it is invalid in clocked synchronous mode.

For details of the multiprocessor communication function, see section 13.3.3, Multiprocessor Communication Function.

Bit 2

MP	Description
0	Multiprocessor function disabled (Initial value)
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 \emptyset , $\emptyset/4$, $\emptyset/16$, and $\emptyset/64$, 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 13.2.8, Bit Rate Register.

Bit 1 CKS1	Bit 0 CKS0	Description
0	0	\emptyset clock (Initial value)
	1	$\emptyset/4$ clock
1	0	$\emptyset/16$ clock
	1	$\emptyset/64$ clock

Initial value : 0 0 0 0 0 0 0 0 0
 R/W : R/W 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 clock output 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 or 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 TDRE flag in SSR is set to 1.

Bit 7

TIE	Description	
0	Transmit data empty interrupt (TXI) requests disabled*	(Initial value)
1	Transmit data empty interrupt (TXI) requests enabled	

Note:* TXI interrupt request cancellation can be performed by reading 1 from the TDRE flag, then clearing it to 0, or clearing the TIE bit to 0.

Bit 6—Receive Interrupt Enable (RIE): Enables or disables receive data full interrupt (RXI) request and receive error interrupt (ERI) request generation when serial receive data is transferred from RSR to RDR and the RDRF flag in SSR is set to 1.

Bit 6

RIE	Description	
0	Receive data full interrupt (RXI) request and receive error interrupt (ERI) request disabled*	(Initial value)
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 the RDRF flag, or the FER, PER, or ORER flag, then clearing the flag to 0, or clearing the RIE bit to 0.

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 TDR and the TDRE flag in SSR is cleared to 0.
SMR setting must be performed to decide the transfer format before setting the TE bit to 1.

Bit 4—Receive Enable (RE): Enables or disables the start of serial reception by the SCI.

Bit 4

RE	Description
0	Reception disabled* ¹ (Initial value)
1	Reception enabled* ²

- Notes:
1. Clearing the RE bit to 0 does not affect the RDRF, FER, PER, and ORER flags, which 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 clocked synchronous mode.
SMR setting must be performed to decide the transfer format before setting the RE bit to 1.

Bit 3 MPIE	Description
0	Multiprocessor interrupts disabled (normal reception performed) (Initial value) [Clearing conditions] <ul style="list-style-type: none"> • When the MPIE bit is cleared to 0 • When MPB= 1 data is received
1	Multiprocessor interrupts enabled* Receive interrupt (RXI) requests, receive error interrupt (ERI) requests, and setting of the RDRF, FER, and ORER flags in SSR are disabled until data with the multiprocessor bit set to 1 is received.

Note: * When receive data including MPB = 0 is received, receive data transfer from RSR to RDR, receive error detection, and setting of the RDRF, FER, and ORER flags in SSR, is not performed. When receive data including MPB = 1 is received, the MPB bit in SSR is set to 1, the MPIE bit is cleared to 0 automatically, and generation of RXI and ERI interrupts (when the TIE and RIE bits in SCR are set to 1) and FER and ORER flag setting is enabled.

Bit 2—Transmit End Interrupt Enable (TEIE): Enables or disables transmit end interrupt (TEI) request generation when there is no valid transmit data in TDR in MSB data transmission.

Bit 2 TEIE	Description
0	Transmit end interrupt (TEI) request disabled* (Initial value)
1	Transmit end interrupt (TEI) request enabled*

Note: * TEI cancellation can be performed by reading 1 from the TDRE flag in SSR, then clearing it to 0 and clearing the TEND flag to 0, or clearing the TEIE bit to 0.

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 clocked synchronous mode, and in the case of external clock operation (CKE1 = 1). Note that the SCI's operating mode must be decided using SMR before setting the CKE1 and CKE0 bits.

For details of clock source selection, see table 13-9 in section 13-3, Operation.

Bit 1 CKE1	Bit 0 CKE0	Description	
0	0	Asynchronous mode	Internal clock/SCK pin functions as I/O port* ¹
		Clocked synchronous mode	Internal clock/SCK pin functions as serial clock output
	1	Asynchronous mode	Internal clock/SCK pin functions as clock output* ²
		Clocked synchronous mode	Internal clock/SCK pin functions as serial clock output
1	0	Asynchronous mode	External clock/SCK pin functions as clock input* ³
		Clocked synchronous mode	External clock/SCK pin functions as serial clock input
	1	Asynchronous mode	External clock/SCK pin functions as clock input* ³
		Clocked synchronous mode	External clock/SCK pin functions as serial clock 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.

Initial value :	1	0	0	0	0	1	0	0
R/W :	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R	R	R/W

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 SCI, and multiprocessor bits.

SSR can be read or written to by the CPU at all times. However, 1 cannot be written to flags 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 modified.

SSR is initialized to H'84 by a reset, and in standby mode or module stop mode.

Bit 7—Transmit Data Register Empty (TDRE): Indicates that data has been transferred from TDR to TSR and the next serial data can be written to TDR.

Bit 7

TDRE	Description
0	[Clearing conditions] <ul style="list-style-type: none"> When 0 is written to TDRE after reading TDRE = 1 When the DMAC or DTC is activated by a TXI interrupt and write data to TDR
1	[Setting conditions] (Initial value) <ul style="list-style-type: none"> When the TE bit in SCR is 0 When data is transferred from TDR to TSR and data can be written to TDR

Bit 6—Receive Data Register Full (RDRF): Indicates that the received data is stored in RDR.

Bit 6

RDRF	Description
0	[Clearing conditions] (Initial value) <ul style="list-style-type: none"> When 0 is written to RDRF after reading RDRF = 1 When the DMAC or DTC is activated by an RXI interrupt and read data from RDR
1	[Setting condition] <p>When serial reception ends normally and receive data is transferred from RSR to RDR</p>

Note: RDR and the RDRF flag are not affected and retain their previous values when an error is 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 overrun error will occur and the receive data will be lost.

0	[Clearing condition] When 0 is written to ORER after reading ORER = 1	(Initial value)*1
1	[Setting condition] When the next serial reception is completed while RDRF = 1	

- Notes:
1. The ORER flag is not affected and retains its previous state when the RE bit in SCR 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 while the ORER flag is set to 1. In clocked 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 to FER after reading FER = 1	(Initial value)*1
1	[Setting condition] When the SCI checks whether the stop bit at the end of the receive data when reception ends, and the stop bit is 0 *2	

- Notes:
1. The FER flag is not affected and retains its previous state when the RE bit in SCR 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 but the RDRF flag is not set. Also, subsequent serial reception cannot be continued while the FER flag is set to 1. In clocked synchronous mode, serial transmission cannot be continued, either.

0	[Clearing condition] When 0 is written to PER after reading PER = 1	(Initial value)* ¹
---	--	-------------------------------

1	[Setting condition] When, in reception, the number of 1 bits in the receive data plus the parity bit does not 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 in SCR 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 to 1. In clocked synchronous mode, serial transmission cannot be continued, either.

Bit 2—Transmit End (TEND): Indicates that there is no valid data in TDR when the last bit of 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 to TDRE after reading TDRE = 1 • When the DMAC or DTC is activated by a TXI interrupt and write 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 transmit character 	(Initial value)

Bit 1—Multiprocessor Bit (MPB): When reception is performed using multiprocessor format in asynchronous mode, MPB stores the multiprocessor bit in the receive data.

MPB is a read-only bit, and cannot be modified.

Bit 1

MPB	Description	
0	[Clearing condition] When data with a 0 multiprocessor bit is received	(Initial value)*
1	[Setting condition] When data with a 1 multiprocessor bit is received	

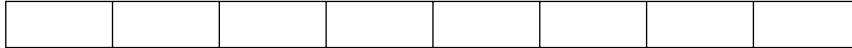
Note: *Retains its previous state when the RE bit in SCR is cleared to 0 with multiprocessor format.

and in clocked synchronous mode.

Bit 0

MPBT	Description
0	Data with a 0 multiprocessor bit is transmitted (Initial value)
1	Data with a 1 multiprocessor bit is transmitted

13.2.8 Bit Rate Register (BRR)

Bit	:	7	6	5	4	3	2	1	0
									
Initial value	:	1	1	1	1	1	1	1	1
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

BRR is an 8-bit register that sets the serial transfer bit rate in accordance with the baud rate 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 or module stop mode.

As baud rate generator control is performed independently for each channel, different values can be set for each channel.

Table 13-3 shows sample BRR settings in asynchronous mode, and table 13-4 shows sample BRR settings in clocked synchronous mode.

110	1	141	0.03	1	148	-0.04	1	174	-0.26	1	212	0.03
150	1	103	0.16	1	108	0.21	1	127	0.00	1	155	0.16
300	0	207	0.16	0	217	0.21	0	255	0.00	1	77	0.16
600	0	103	0.16	0	108	0.21	0	127	0.00	0	155	0.16
1200	0	51	0.16	0	54	-0.70	0	63	0.00	0	77	0.16
2400	0	25	0.16	0	26	1.14	0	31	0.00	0	38	0.16
4800	0	12	0.16	0	13	-2.48	0	15	0.00	0	19	-2.34
9600	0	6	—	0	6	-2.48	0	7	0.00	0	9	-2.34
19200	0	2	—	0	2	—	0	3	0.00	0	4	-2.34
31250	0	1	0.00	0	1	—	0	1	—	0	2	0.00
38400	0	1	—	0	1	—	0	1	0.00	—	—	—

Bit Rate (bit/s)	$\phi = 3.6864$ MHz			$\phi = 4$ MHz			$\phi = 4.9152$ MHz			$\phi = 5$ MHz		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	64	0.70	2	70	0.03	2	86	0.31	2	88	-0.25
150	1	191	0.00	1	207	0.16	1	255	0.00	2	64	0.16
300	1	95	0.00	1	103	0.16	1	127	0.00	1	129	0.16
600	0	191	0.00	0	207	0.16	0	255	0.00	1	64	0.16
1200	0	95	0.00	0	103	0.16	0	127	0.00	0	129	0.16
2400	0	47	0.00	0	51	0.16	0	63	0.00	0	64	0.16
4800	0	23	0.00	0	25	0.16	0	31	0.00	0	32	-1.36
9600	0	11	0.00	0	12	0.16	0	15	0.00	0	15	1.73
19200	0	5	0.00	0	6	—	0	7	0.00	0	7	1.73
31250	—	—	—	0	3	0.00	0	4	-1.70	0	4	0.00
38400	0	2	0.00	0	2	—	0	3	0.00	0	3	1.73

110	2	106	-0.44	2	108	0.08	2	130	-0.07	2	141	0.03
150	2	77	0.16	2	79	0.00	2	95	0.00	2	103	0.16
300	1	155	0.16	1	159	0.00	1	191	0.00	1	207	0.16
600	1	77	0.16	1	79	0.00	1	95	0.00	1	103	0.16
1200	0	155	0.16	0	159	0.00	0	191	0.00	0	207	0.16
2400	0	77	0.16	0	79	0.00	0	95	0.00	0	103	0.16
4800	0	38	0.16	0	39	0.00	0	47	0.00	0	51	0.16
9600	0	19	-2.34	0	19	0.00	0	23	0.00	0	25	0.16
19200	0	9	-2.34	0	9	0.00	0	11	0.00	0	12	0.16
31250	0	5	0.00	0	5	2.40	0	6	5.33	0	7	0.00
38400	0	4	-2.34	0	4	0.00	0	5	0.00	0	6	—

Bit Rate (bit/s)	$\phi = 9.8304$ MHz			$\phi = 10$ MHz			$\phi = 12$ MHz			$\phi = 12.288$ MHz		
	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)	n	N	Error (%)
110	2	174	-0.26	2	177	-0.25	2	212	0.03	2	217	0.08
150	2	127	0.00	2	129	0.16	2	155	0.16	2	159	0.00
300	1	255	0.00	2	64	0.16	2	77	0.16	2	79	0.00
600	1	127	0.00	1	129	0.16	1	155	0.16	1	159	0.00
1200	0	255	0.00	1	64	0.16	1	77	0.16	1	79	0.00
2400	0	127	0.00	0	129	0.16	0	155	0.16	0	159	0.00
4800	0	63	0.00	0	64	0.16	0	77	0.16	0	79	0.00
9600	0	31	0.00	0	32	-1.36	0	38	0.16	0	39	0.00
19200	0	15	0.00	0	15	1.73	0	19	-2.34	0	19	0.00
31250	0	9	-1.70	0	9	0.00	0	11	0.00	0	11	2.40
38400	0	7	0.00	0	7	1.73	0	9	-2.34	0	9	0.00

110	2	248	-0.17	3	64	0.70	3	70	0.03	3	75	0.48
150	2	181	0.16	2	191	0.00	2	207	0.16	2	223	0.00
300	2	90	0.16	2	95	0.00	2	103	0.16	2	111	0.00
600	1	181	0.16	1	191	0.00	1	207	0.16	1	223	0.00
1200	1	90	0.16	1	95	0.00	1	103	0.16	1	111	0.00
2400	0	181	0.16	0	191	0.00	0	207	0.16	0	223	0.00
4800	0	90	0.16	0	95	0.00	0	103	0.16	0	111	0.00
9600	0	45	-0.93	0	47	0.00	0	51	0.16	0	55	0.00
19200	0	22	-0.93	0	23	0.00	0	25	0.16	0	27	0.00
31250	0	13	0.00	0	14	-1.70	0	15	0.00	0	16	1.20
38400	0	10	—	0	11	0.00	0	12	0.16	0	13	0.00

Bit Rate (bit/s)	$\phi = 18 \text{ MHz}$			$\phi = 19.6608 \text{ MHz}$			$\phi = 20 \text{ MHz}$		
	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

110	3	70	—	—								
250	2	124	2	249	3	124	—	—	3	249		
500	1	249	2	124	2	249	—	—	3	124	—	—
1 k	1	124	1	249	2	124	—	—	2	249	—	—
2.5 k	0	199	1	99	1	199	1	249	2	99	2	124
5 k	0	99	0	199	1	99	1	124	1	199	1	249
10 k	0	49	0	99	0	199	0	249	1	99	1	124
25 k	0	19	0	39	0	79	0	99	0	159	0	199
50 k	0	9	0	19	0	39	0	49	0	79	0	99
100 k	0	4	0	9	0	19	0	24	0	39	0	49
250 k	0	1	0	3	0	7	0	9	0	15	0	19
500 k	0	0*	0	1	0	3	0	4	0	7	0	9
1 M			0	0*	0	1	—	—	0	3	0	4
2.5 M							—	—	0	0*	—	—
5 M									—	—	0	0*

Note: As far as possible, the setting should be made so that the error is no more than 1%.

Legend

Blank : Cannot be set.

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

* : Continuous transfer is not possible.

$$64 \times 2^{2n-1} \times B$$

Clocked synchronous mode:

$$N = \frac{\phi}{8 \times 2^{2n-1} \times B} \times 10^6 - 1$$

Where B: Bit rate (bit/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 formula:

$$\text{Error (\%)} = \left\{ \frac{\phi \times 10^6}{(N + 1) \times B \times 64 \times 2^{2n-1}} - 1 \right\} \times 100$$

ϕ (MHz)	Maximum Bit Rate (bit/s)	n	N
2	62500	0	0
2.097152	65536	0	0
2.4576	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

2.097152	0.5243	32768
2.4576	0.6144	38400
3	0.7500	46875
3.6864	0.9216	57600
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

4	0.6667	666666.7
6	1.0000	1000000.0
8	1.3333	1333333.3
10	1.6667	1666666.7
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

Initial value :	1	1	1	1	0	0	1	0
R/W :	—	—	—	—	R/W	R/W	—	R/W

SCMR selects LSB-first or MSB-first by means of bit SDIR. Except in the case of asynchronous mode 7-bit data, LSB-first or MSB-first can be selected regardless of the serial communication mode. The descriptions in this chapter refer to LSB-first transfer.

For details of the other bits in SCMR, see 14.2.1, Smart Card Mode Register (SCMR).

SCMR is initialized to H'F2 by a reset, and in standby mode or module stop mode.

Bits 7 to 4—Reserved: Read-only bits, always read as 1.

Bit 3—Smart Card Data Transfer Direction (SDIR): Selects the serial/parallel conversion format.

This bit is valid when 8-bit data is used as the transmit/receive format.

Bit 3

SDIR	Description	
0	TDR contents are transmitted LSB-first Receive data is stored in RDR LSB-first	(Initial value)
1	TDR contents are transmitted MSB-first Receive data is stored in RDR MSB-first	

Bit 2—Smart Card Data Invert (SINV): When the smart card interface operates as a normal SCI, 0 should be written in this bit.

Bit 1—Reserved: Read-only bit, always read as 1.

Bit 0—Smart Card Interface Mode Select (SMIF): When the smart card interface operates as a normal SCI, 0 should be written in this bit.

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Initial value	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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	R/W	R/W

MSTPCR is a 16-bit readable/writable register that performs module stop mode control.

When the corresponding bit of bits MSTP6 and MSTP5 is set to 1, SCI operation stops at the end of the bus cycle and a transition is made to module stop mode. Registers cannot be read or written to in module stop mode. For details, see section 20.5, 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 SCI channel 1 module stop mode.

Bit 6 MSTP6	Description
0	SCI channel 1 module stop mode cleared
1	SCI channel 1 module stop mode set (Initial value)

Bit 5—Module Stop (MSTP5): Specifies the SCI channel 0 module stop mode.

Bit 5 MSTP5	Description
0	SCI channel 0 module stop mode cleared
1	SCI channel 0 module stop mode set (Initial value)

The SCI can carry out serial communication in two modes: asynchronous mode in which synchronization is achieved character by character, and clocked synchronous mode in which synchronization is achieved with clock pulses.

Selection of asynchronous or clocked synchronous mode and the transmission format is made using SMR as shown in table 13-8. The SCI clock is determined by a combination of the C/\bar{A} bit in SMR and the CKE1 and CKE0 bits in SCR, as shown in table 13-9.

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 (the 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 on-chip baud rate generator is not used)

Clocked 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 off-chip
 - When external clock is selected:

The on-chip baud rate generator is not used, and the SCI operates on the input serial clock

C/A	CHR	MP	PE	STOP	Mode	Length	Bit	Bit	Length
0	0	0	0	0	Asynchronous mode	8-bit data	No	No	1 bit
				1				No	2 bits
				0				Yes	1 bit
				1				Yes	2 bits
	1	0	0	0	7-bit data	7-bit data	No	No	1 bit
				1				No	2 bits
				0				Yes	1 bit
				1				Yes	2 bits
0	1	—	0	Asynchronous mode (multi-processor format)	8-bit data	Yes	No	1 bit	
			1				No	2 bits	
			0				No	1 bit	
			1				No	2 bits	
1	—	—	—	—	Clocked synchronous mode	8-bit data	No	None	None

Table 13-9 SMR and SCR Settings and SCI Clock Source Selection

SMR	SCR Setting			Mode	SCI Transmit/Receive Clock	
	Bit 7	Bit 1	Bit 0		Clock Source	SCK Pin Function
C/A	CKE1	CKE0				
0	0	0	Asynchronous mode	Internal	SCI does not use SCK pin	
		1				Outputs clock with same frequency as bit rate
1	0	0	Clocked synchronous mode	Internal	Outputs serial clock	
		1				Inputs clock with frequency of 16 times the bit rate
1	1	0	Clocked synchronous mode	External	Inputs serial clock	
		1				Inputs serial clock

communication is thus carried out with synchronization established on a character-by-character basis.

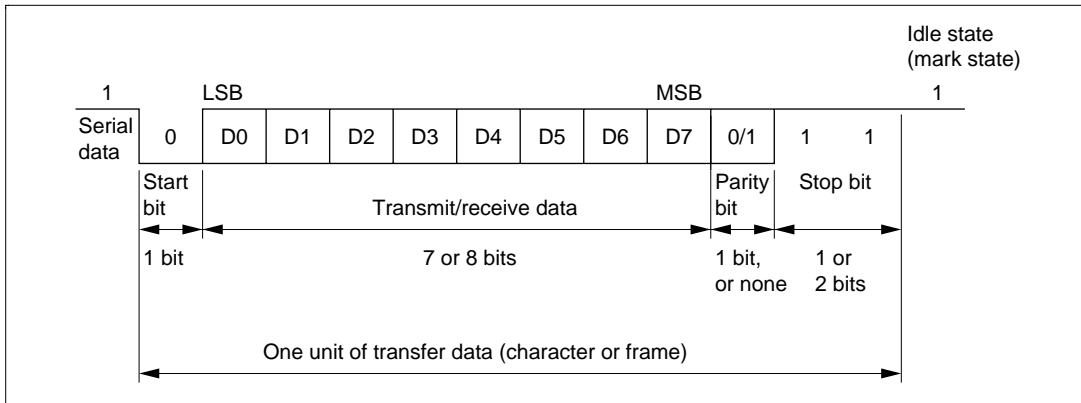
Inside the SCI, the transmitter and receiver are independent units, enabling full-duplex communication. Both the transmitter and the receiver also have a double-buffered structure, so that data can be read or written during transmission or reception, enabling continuous data transfer.

Figure 13-2 shows the general format for asynchronous serial communication.

In asynchronous serial communication, the transmission line is usually held in the mark state (high level). The SCI monitors the transmission line, and when it goes to the space state (low level), recognizes a start bit and starts serial communication.

One serial communication character consists of a start bit (low level), followed by data (in LSB-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 in reception. The SCI samples the data on the 8th pulse of a clock with a frequency of 16 times the length of one bit, so that the transfer data is latched at the center of each bit.



**Figure 13-2 Data Format in Asynchronous Communication
(Example with 8-Bit Data, Parity, Two Stop Bits)**

Data Transfer Format: Table 13-10 shows the data transfer formats that can be used in asynchronous mode. Any of 12 transfer formats can be selected according to the SMR setting.

0	0	0	0	S	8-bit data	STOP
0	0	0	1	S	8-bit data	STOP STOP
0	1	0	0	S	8-bit data	P STOP
0	1	0	1	S	8-bit data	P STOP STOP
1	0	0	0	S	7-bit data	STOP
1	0	0	1	S	7-bit data	STOP STOP
1	1	0	0	S	7-bit data	P STOP
1	1	0	1	S	7-bit data	P STOP STOP
0	—	1	0	S	8-bit data	MPB STOP
0	—	1	1	S	8-bit data	MPB STOP STOP
1	—	1	0	S	7-bit data	MPB STOP
1	—	1	1	S	7-bit data	MPB STOP STOP

Legend

S : Start bit

STOP : Stop bit

P : Parity bit

MPB : Multiprocessor bit

When an external clock is input at the SCK pin, the clock frequency should be 16 times the bit rate used.

When the SCI is operated on an internal clock, the clock can be output from the SCK pin. The frequency of the clock output in this case is equal to the bit rate, and the phase is such that the rising edge of the clock is in the middle of the transmit data, as shown in figure 13-3.

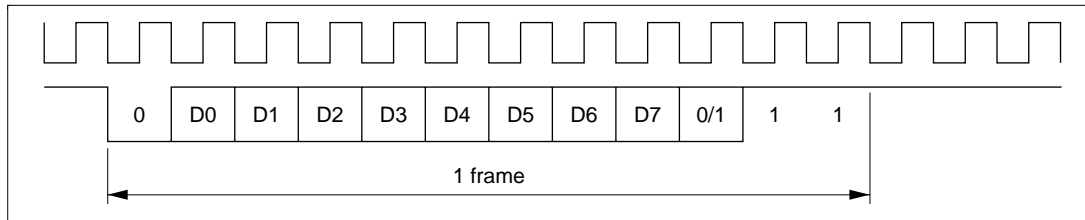


Figure 13-3 Relation between Output Clock and Transfer Data Phase (Asynchronous Mode)

Data Transfer Operations:

- SCI initialization (asynchronous mode)

Before transmitting and receiving data, you should first clear the TE and RE bits in SCR to 0, then initialize the SCI as described below.

When the operating mode, transfer format, etc., is changed, the TE and RE bits must be cleared to 0 before making the change using the following procedure. When the TE bit is cleared to 0, the TDRE flag is set to 1 and TSR is initialized. Note that clearing the RE bit to 0 does not change the contents of the RDRF, PER, FER, and ORER flags, or the contents of RDR.

When an external clock is used the clock should not be stopped during operation, including initialization, since operation is uncertain.

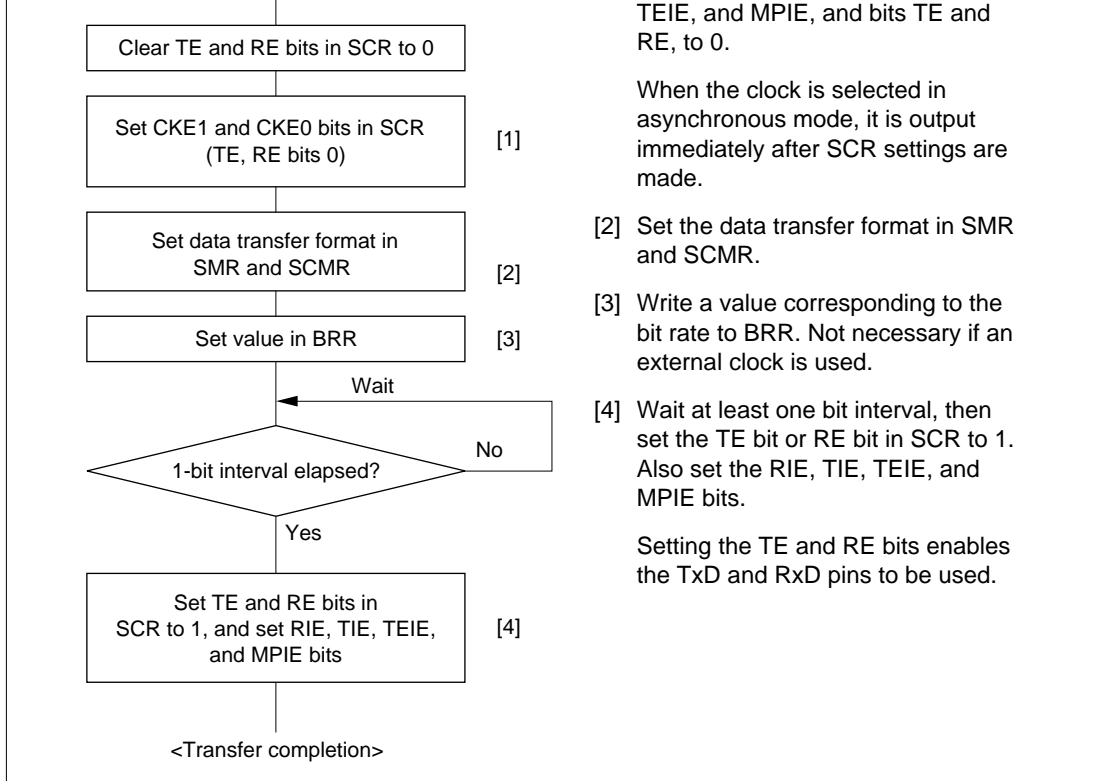


Figure 13-4 Sample SCI Initialization Flowchart

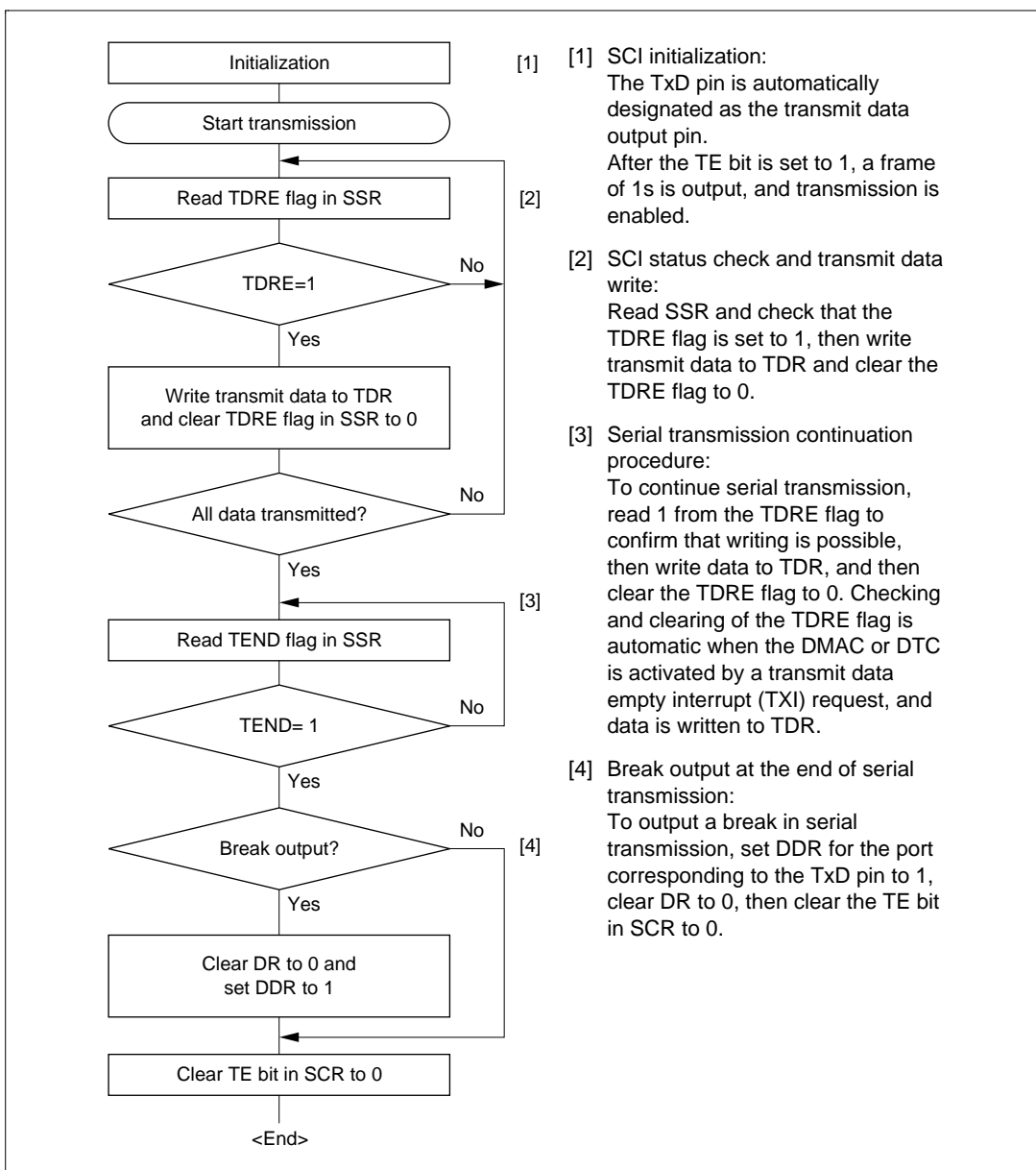
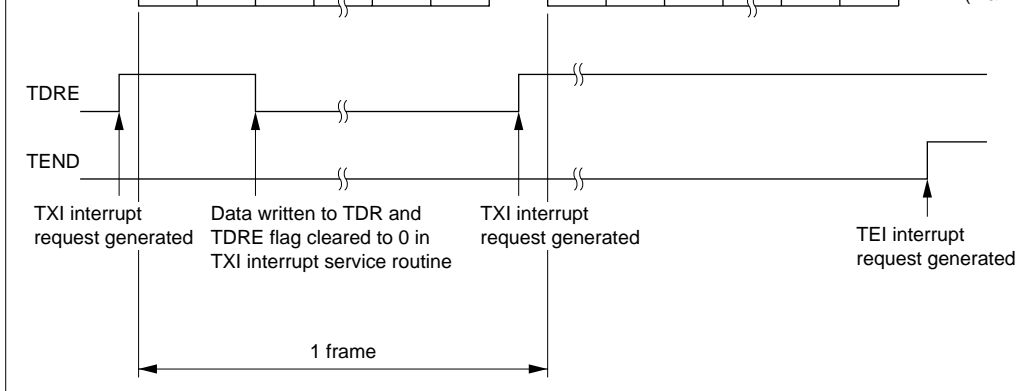


Figure 13-5 Sample Serial Transmission Flowchart

- [2] After transferring data from TDR to TSR, the SCI sets the TDRE flag to 1 and starts transmission.
- If the TIE bit is set to 1 at this time, a transmit data empty interrupt (TXI) is generated. 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 then the “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 13-6 Example of Operation in Transmission in Asynchronous Mode
(Example with 8-Bit Data, Parity, One Stop Bit)**

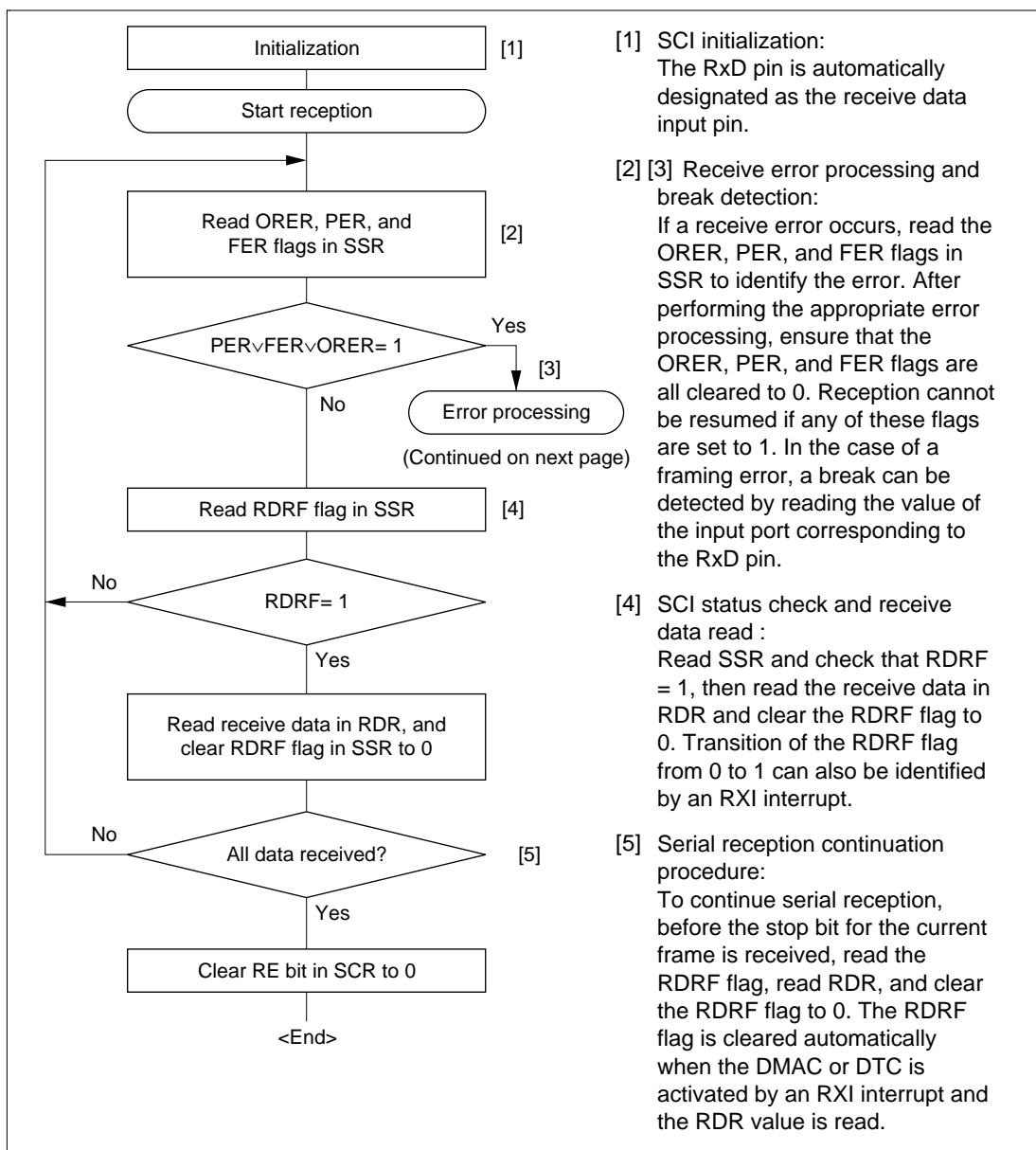


Figure 13-7 Sample Serial Reception Data Flowchart

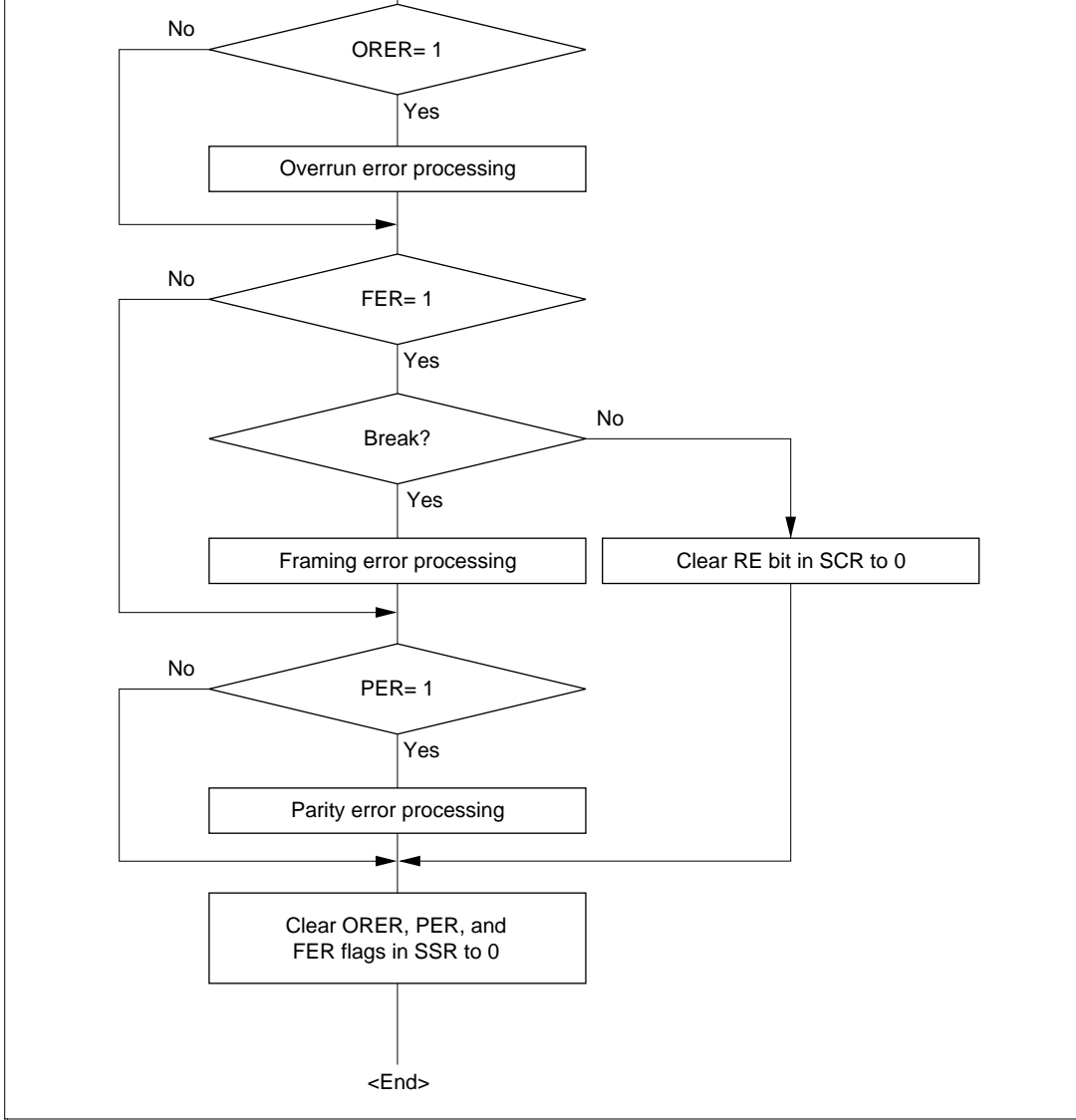


Figure 13-7 Sample Serial Reception Data Flowchart (cont)

[2] The received data is stored in RSR in LSB-to-MSB order.

[3] The parity bit and stop bit are received.

After receiving these bits, the SCI carries out the following checks.

[a] Parity check:

The SCI checks whether the number of 1 bits in the receive data agrees with the parity (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 can 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 stored in RDR.

If a receive error* is detected in the error check, the operation is as shown in table 13-11.

Note: * Subsequent receive operations cannot be performed when a receive error has occurred.

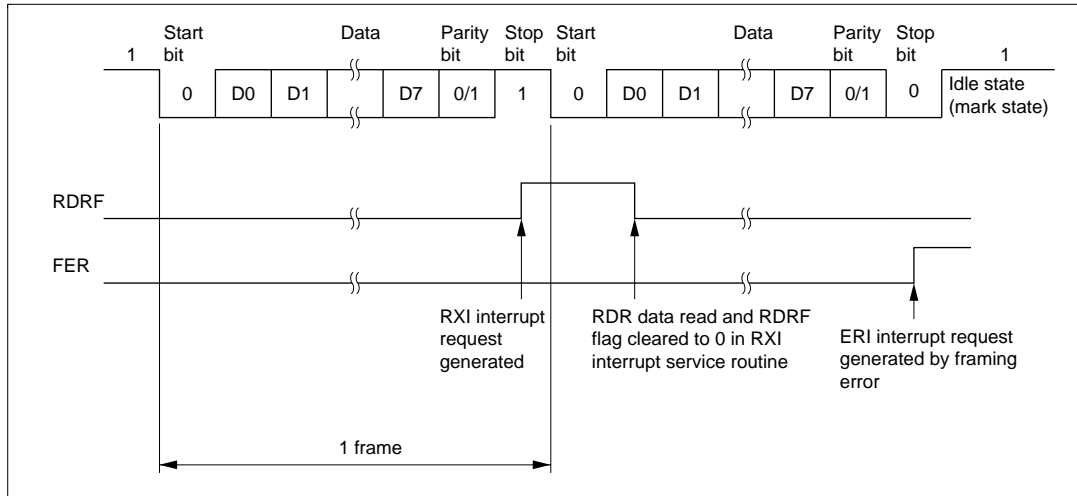
Also note that the RDRF flag is not set to 1 in reception, and so the error flags must be cleared to 0.

[4] If the RIE bit in SCR is set to 1 when the RDRF flag changes to 1, a receive data full interrupt (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.

		in SSR is set to 1	RDR.
Framing error	FER	When the stop bit is 0	Receive data is transferred from RSR to RDR.
Parity error	PER	When the received data differs from the parity (even or odd) set in SMR	Receive data is transferred from RSR to RDR.

Figure 13-8 shows an example of the operation for reception in asynchronous mode.



**Figure 13-8 Example of SCI Operation in Reception
(Example with 8-Bit Data, Parity, One Stop Bit)**

mode. Use of this function enables data transfer to be performed among a number of processors sharing transmission lines.

When multiprocessor communication is carried out, each receiving station is addressed by a unique ID code.

The serial communication cycle consists of two component cycles: an ID transmission cycle which specifies the receiving station, and a data transmission cycle. The multiprocessor bit 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 perform serial communication as data with a 1 multiprocessor bit added. It then sends transmit data as data with a 0 multiprocessor bit added.

The receiving station skips 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 13-9 shows an example of inter-processor communication using the multiprocessor format.

Data Transfer Format: There are four data transfer formats.

When the multiprocessor format is specified, the parity bit specification is invalid.

For details, see table 13-10.

Clock: See the section on asynchronous mode.

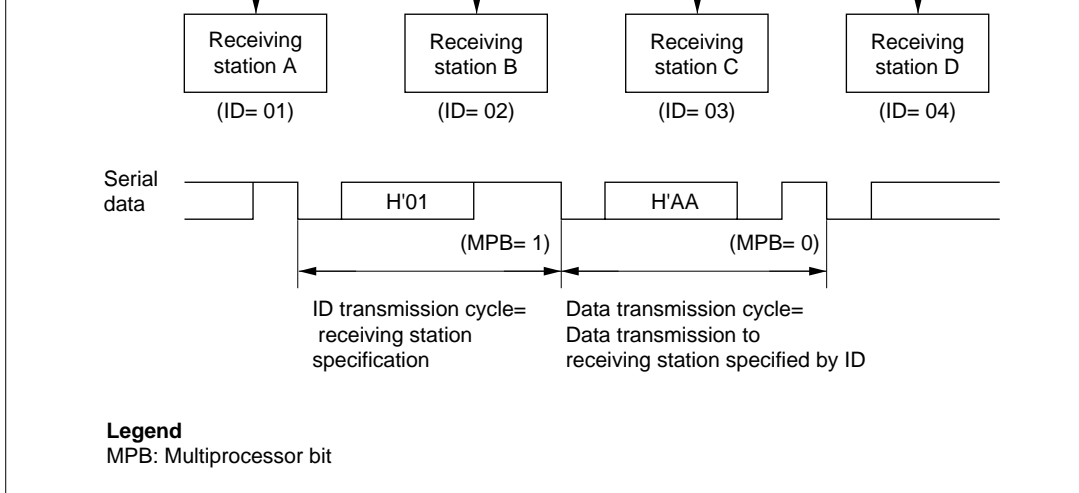


Figure 13-9 Example of Inter-Processor Communication Using Multiprocessor Format (Transmission of Data H'AA to Receiving Station A)

Data Transfer Operations:

- Multiprocessor serial data transmission

Figure 13-10 shows a sample flowchart for multiprocessor serial data transmission.

The following procedure should be used for multiprocessor serial data transmission.

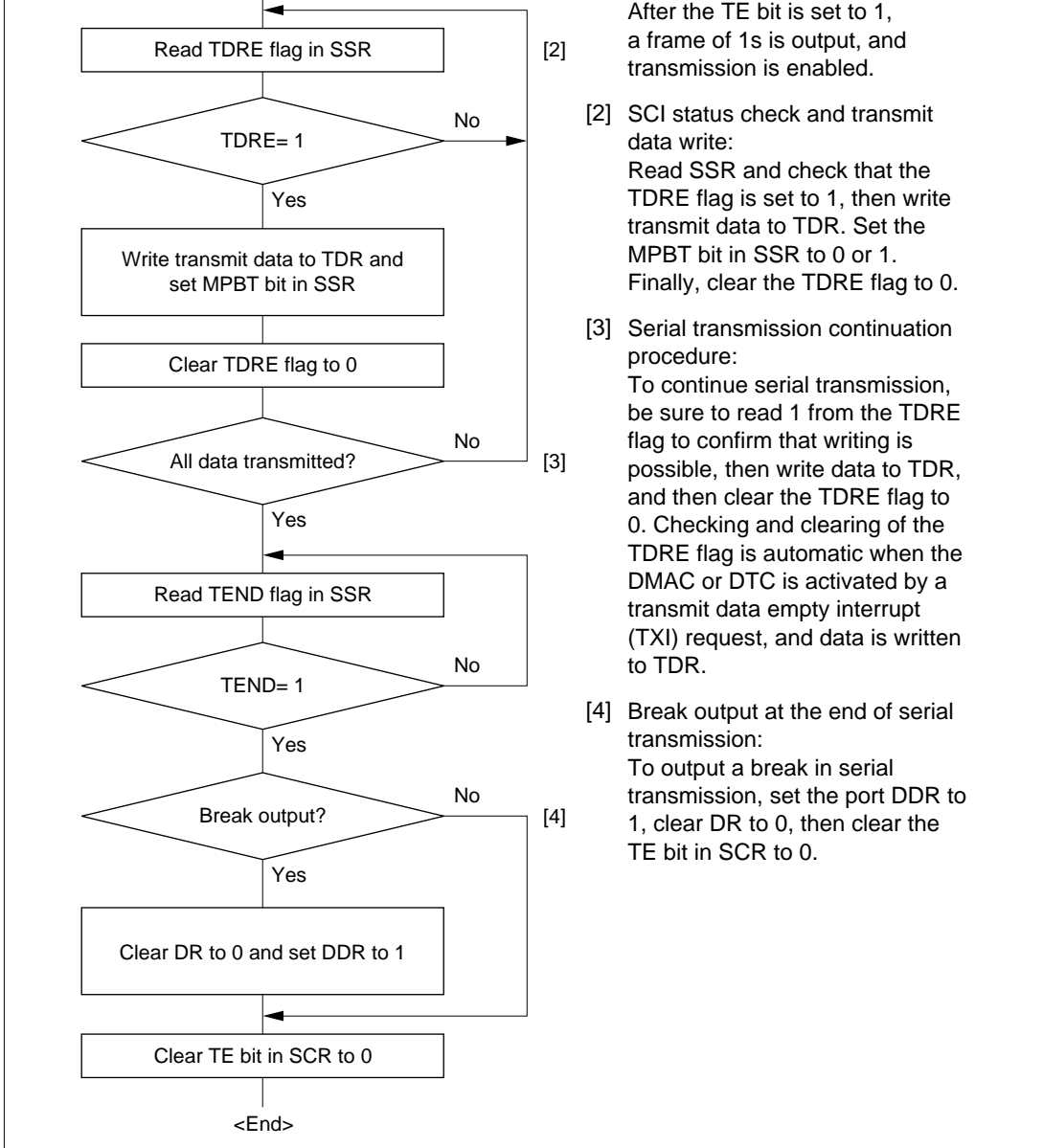


Figure 13-10 Sample Multiprocessor Serial Transmission Flowchart

[2] After transferring data from TDR to TSR, the SCI sets the TDRE flag to 1 and starts transmission.

If the TIE bit is set to 1 at this time, a transmit data empty interrupt (TXI) is generated.

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.

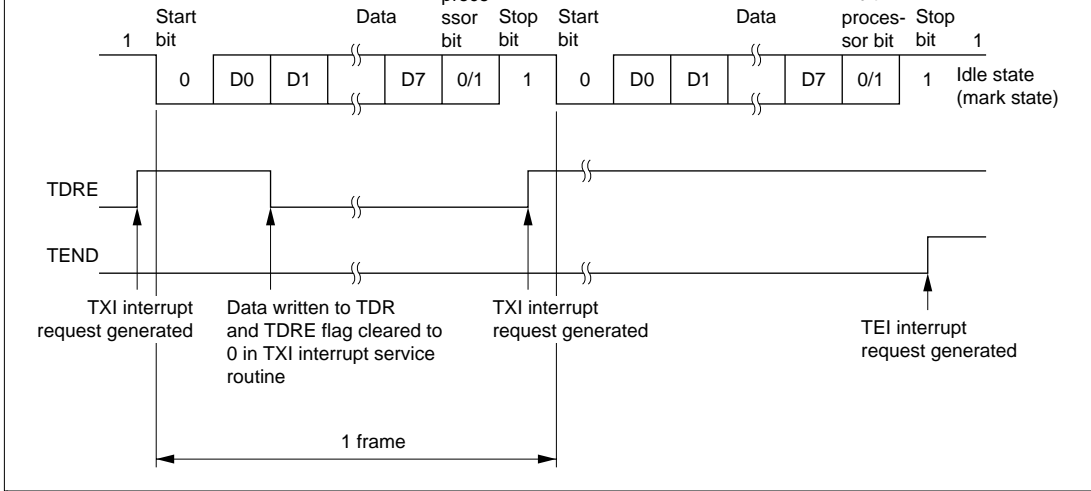
[e] Mark state:

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 then the mark state is entered in which 1 is output continuously. If the TEIE bit in SCR is set to 1 at this time, a transmission end interrupt (TEI) request is generated.



**Figure 13-11 Example of SCI Operation in Transmission
(Example with 8-Bit Data, Multiprocessor Bit, One Stop Bit)**

- Multiprocessor serial data reception

Figure 13-12 shows a sample flowchart for multiprocessor serial reception.

The following procedure should be used for multiprocessor serial data reception.

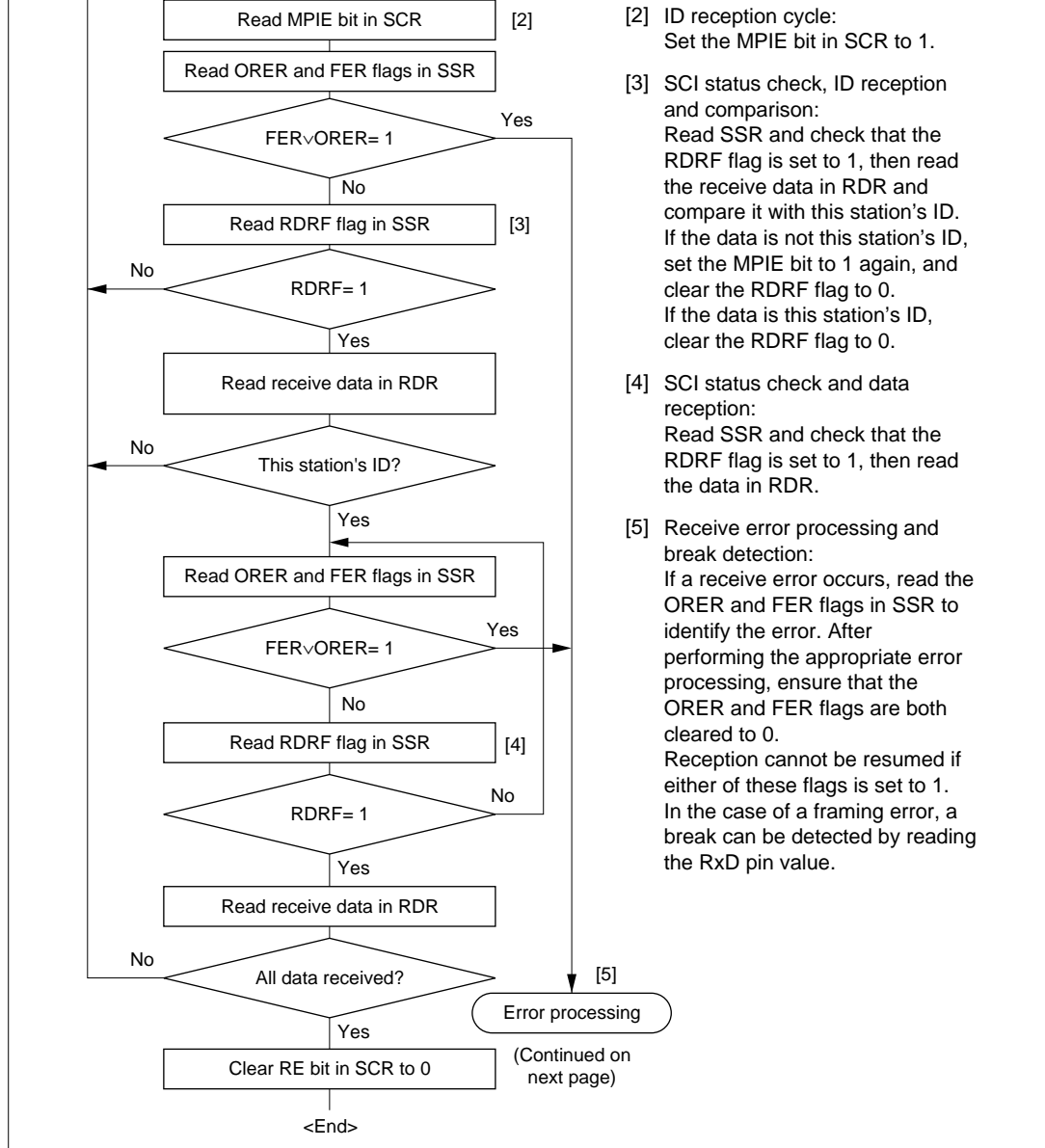


Figure 13-12 Sample Multiprocessor Serial Reception Flowchart

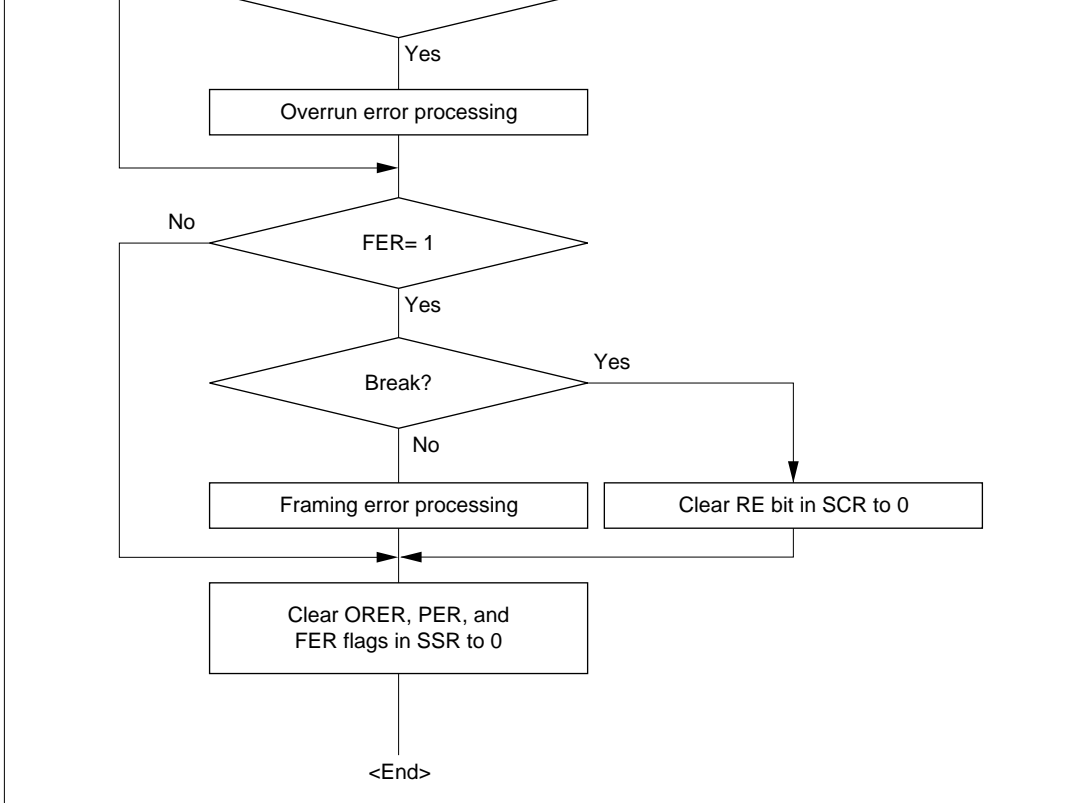
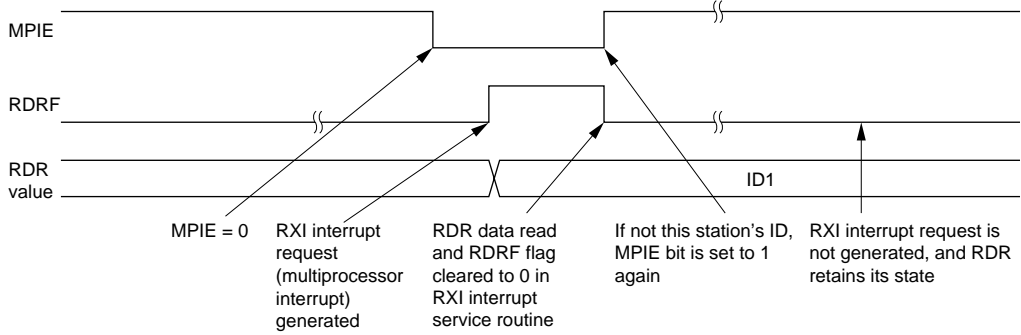
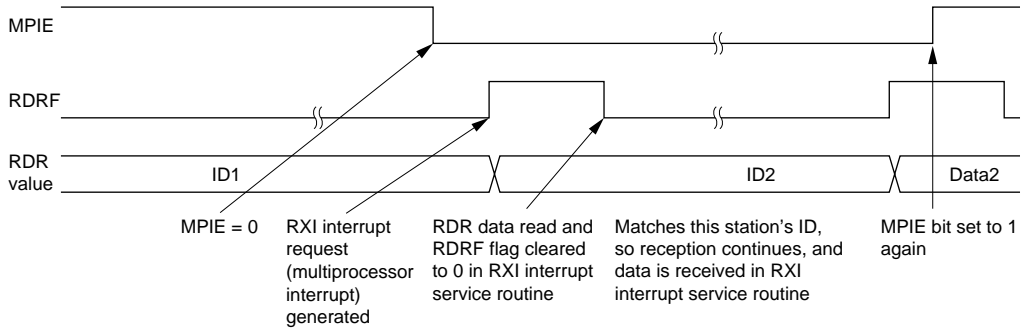
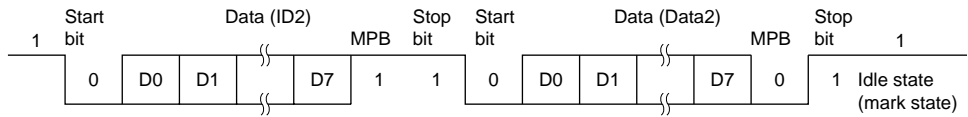


Figure 13-12 Sample Multiprocessor Serial Reception Flowchart (cont)

Figure 13-13 shows an example of SCI operation for multiprocessor format reception.



(a) Data does not match station's ID



(b) Data matches station's ID

**Figure 13-13 Example of SCI Operation in Reception
(Example with 8-Bit Data, Multiprocessor Bit, One Stop Bit)**

- SCI initialization (clocked synchronous mode)

Before transmitting and receiving data, you should first clear the TE and RE bits in SCR to 0, then initialize the SCI as described 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 to 0, the TDRE flag is set to 1 and TSR is initialized. Note that clearing the RE bit to 0 does not change the contents of the RDRF, PER, FER, and ORER flags, or the contents of RDR.

Figure 13-15 shows a sample SCI initialization flowchart.

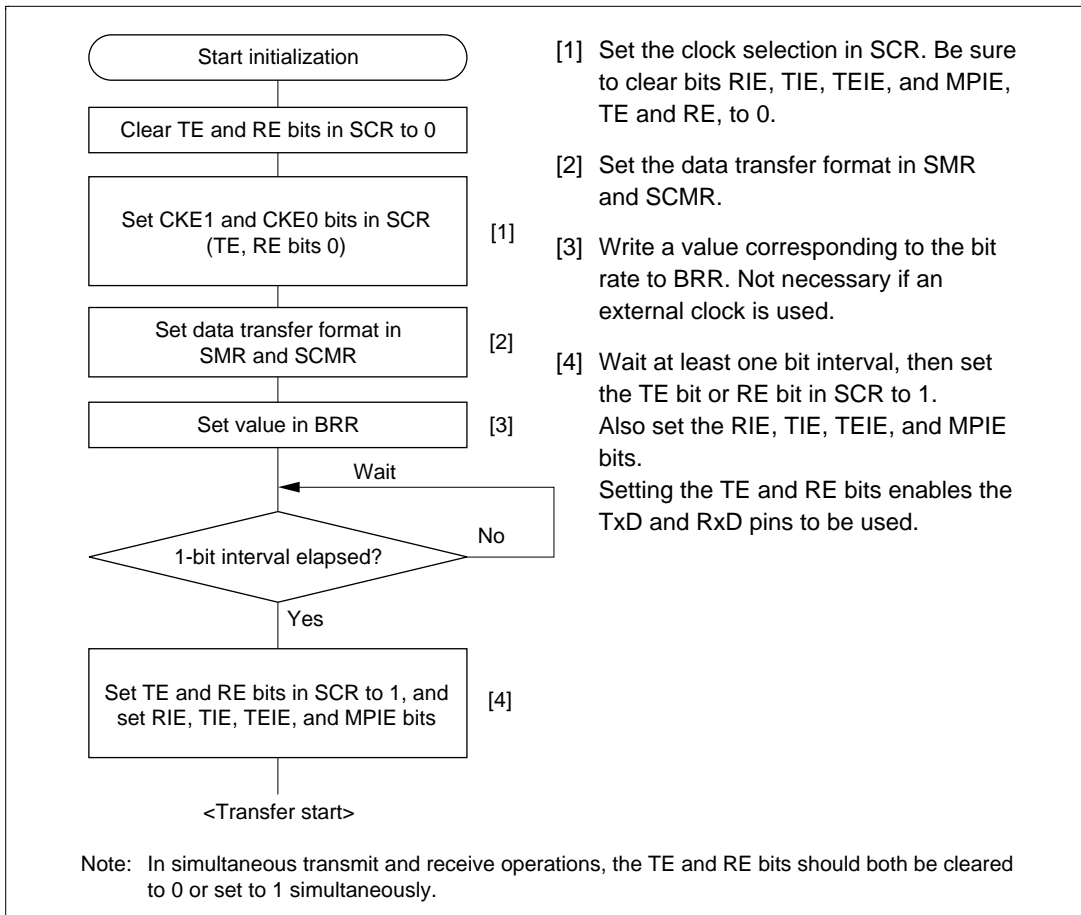


Figure 13-15 Sample SCI Initialization Flowchart

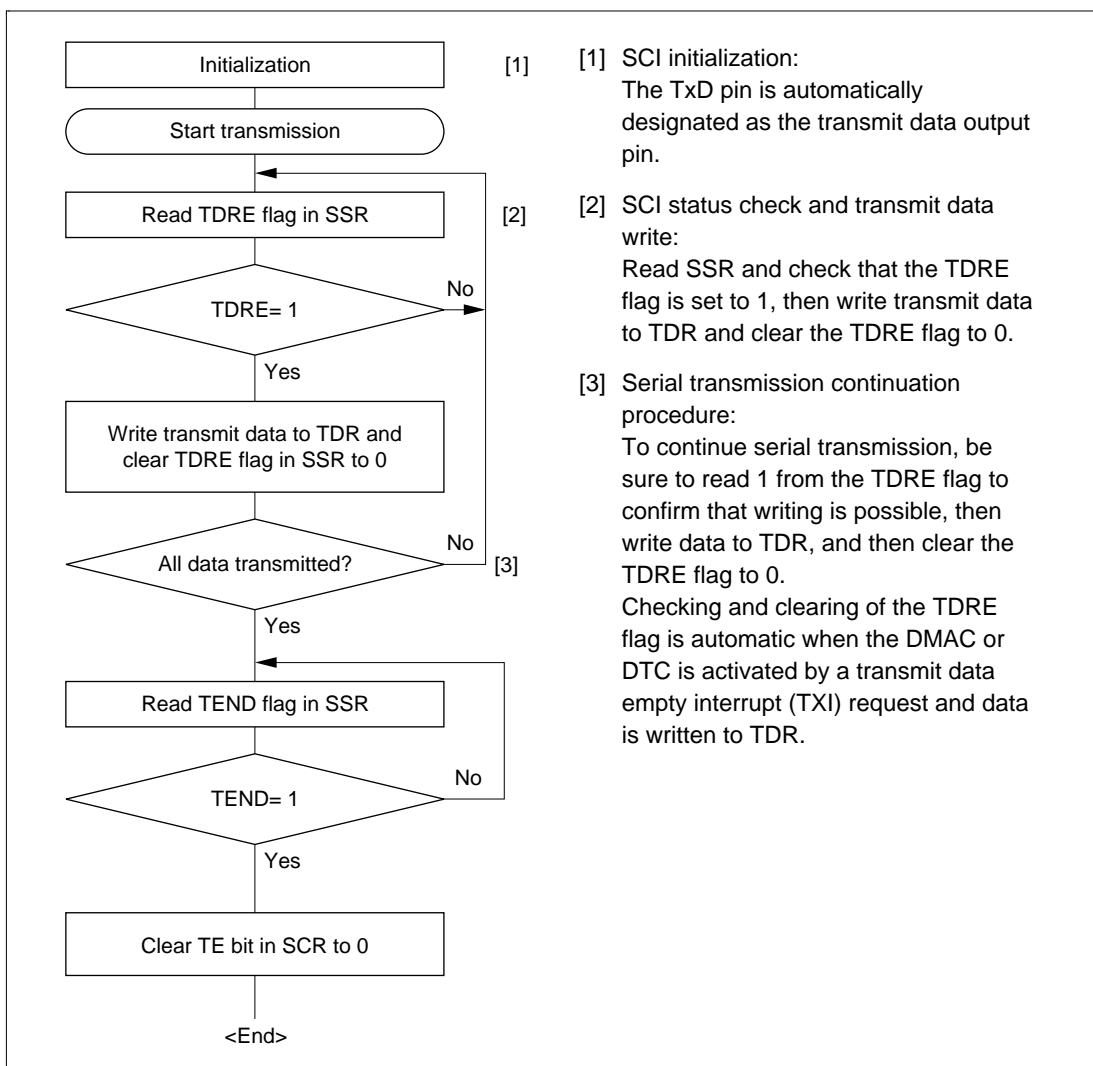


Figure 13-16 Sample Serial Transmission Flowchart

[2] After transferring data from TDR to TSR, the SCI sets the TDRE flag to 1 and starts transmission. If the TIE bit is set to 1 at this time, a transmit data empty interrupt (TXI) is generated.

When clock output mode has been set, the SCI outputs 8 serial clock pulses. When use of an 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, and the TxD pin maintains its state.

If the TEIE bit in SCR is set to 1 at this time, a TEI interrupt request is generated.

[4] After completion of serial transmission, the SCK pin is fixed.

Figure 13-17 shows an example of SCI operation in transmission.

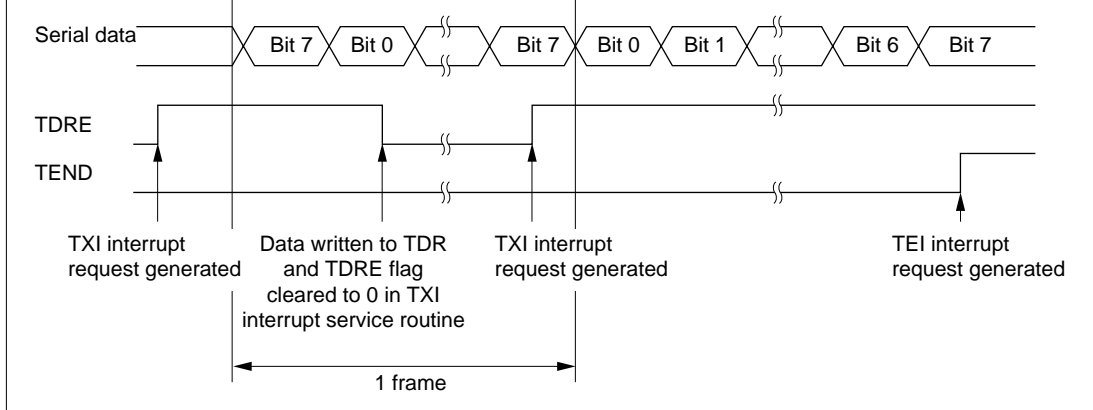


Figure 13-17 Example of SCI Operation in Transmission

- Serial data reception (clocked synchronous mode)

Figure 13-18 shows a sample flowchart for serial reception.

The following procedure should be used for serial data reception.

When changing the operating mode from asynchronous to clocked synchronous, be sure to check that the ORER, PER, and FER flags are all cleared 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.

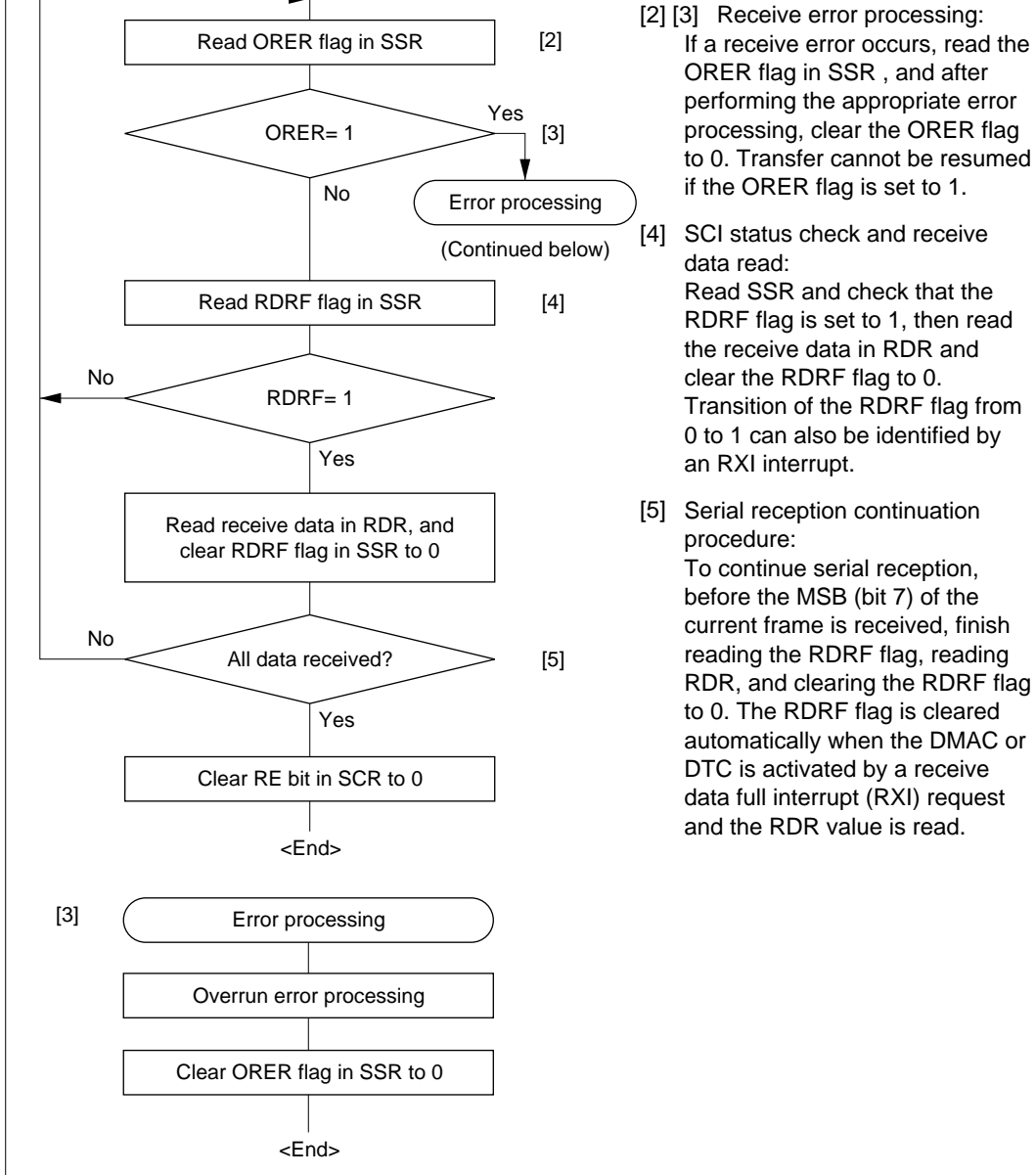


Figure 13-18 Sample Serial Reception Flowchart

After reception, the SCI checks whether the RDRF flag is 0 and the receive data can be transferred from RSR to RDR.

If this check is passed, the RDRF flag is set to 1, and the receive data is stored in RDR. If a receive error is detected in the error check, the operation is as shown in table 13-11.

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 full interrupt (RXI) request is generated.

Also, if the RIE bit in SCR is set to 1 when the ORER flag changes to 1, a receive error interrupt (ERI) request is generated.

Figure 13-19 shows an example of SCI operation in reception.

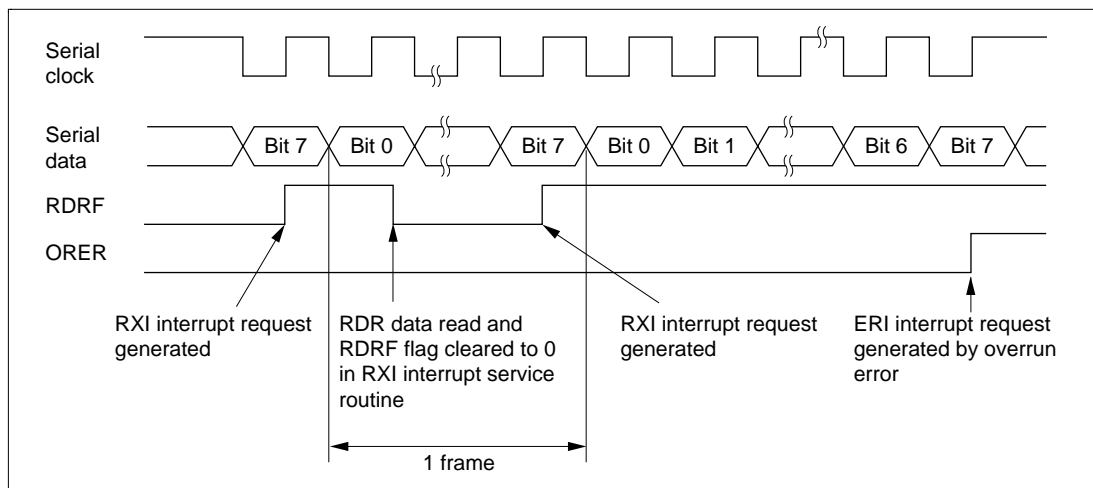
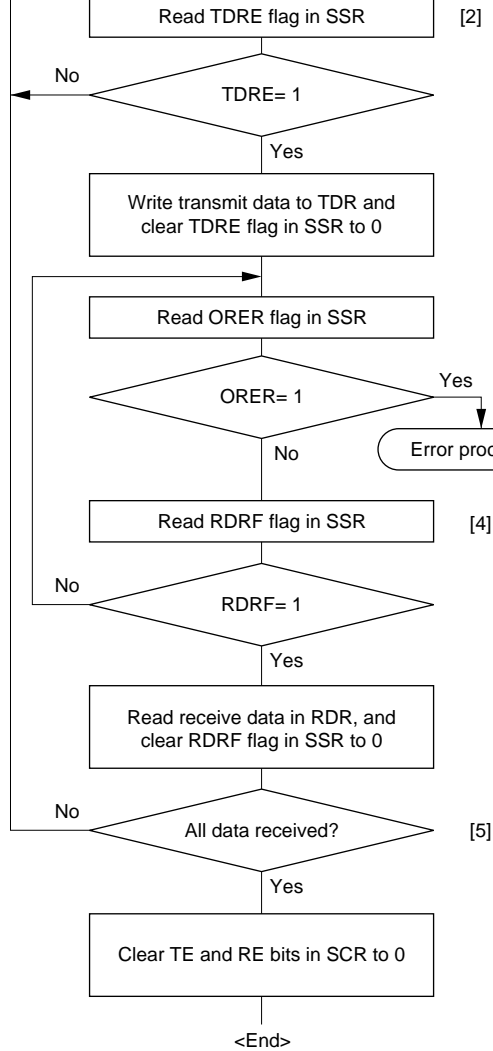


Figure 13-19 Example of SCI Operation in Reception

- Simultaneous serial data transmission and reception (clocked synchronous mode)

Figure 13-20 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.



- operations.
- [2] SCI status check and transmit data write:
Read SSR and check that the TDRE flag is set to 1, then write transmit data to TDR and clear the TDRE flag to 0. Transition of the TDRE flag from 0 to 1 can also be identified by a TXI interrupt.
- [3] Receive error processing:
If a receive error occurs, read the ORER flag in SSR, and after performing the appropriate error processing, clear the ORER flag to 0. Transmission/reception cannot be resumed if the ORER flag is set to 1.
- [4] SCI status check and receive data read:
Read SSR and check that the RDRF flag is set to 1, then read the receive data in RDR and clear the RDRF flag to 0. Transition of the RDRF flag from 0 to 1 can also be identified by an RXI interrupt.
- [5] Serial transmission/reception continuation procedure:
To continue serial transmission/reception, before the MSB (bit 7) of the current frame is received, finish reading the RDRF flag, reading RDR, and clearing the RDRF flag to 0. Also, before the MSB (bit 7) of the current frame is transmitted, read 1 from the TDRE flag to confirm that writing is possible. Then write data to TDR and clear the TDRE flag to 0. Checking and clearing of the TDRE flag is automatic when the DMAC or DTC is activated by a transmit data empty interrupt (TXI) request and data is written to TDR. Also, the RDRF flag is cleared automatically when the DMAC or DTC is activated by a receive data full interrupt (RXI) request and the RDR value is read.
- Note: When switching from transmit or receive operation to simultaneous transmit and receive operations, first clear the TE bit and RE bit to 0, then set both these bits to 1 simultaneously.

Figure 13-20 Sample Flowchart of Simultaneous Serial Transmit and Receive Operations

request. Table 13-12 shows the interrupt sources and their relative priorities. Individual interrupt sources can be enabled or disabled with the TIE, RIE, and TEIE bits in the SCR. Each kind of interrupt request is sent to the interrupt controller independently.

When the TDRE flag in SSR is set to 1, a TXI interrupt request is generated. When the TEND flag in SSR is set to 1, a TEI interrupt request is generated. A TXI interrupt can activate the DMAC or DTC to perform data transfer. The TDRE flag is cleared to 0 automatically when data transfer is performed by the DMAC or DTC. The DMAC and 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, PER, or FER flag in SSR is set to 1, an ERI interrupt request is generated. An RXI interrupt can activate the DMAC or DTC to perform data transfer. The RDRF flag is cleared to 0 automatically when data transfer is performed by the DMAC or DTC. The DMAC and DTC cannot be activated by an ERI interrupt request.

		(ORER, FER, or PER)	possible	possible	↑ Low
	RXI	Interrupt due to receive data full state (RDRF)	Possible	Possible	
	TXI	Interrupt due to transmit data empty state (TDRE)	Possible	Possible	
	TEI	Interrupt due to transmission end (TEND)	Not possible	Not possible	
1	ERI	Interrupt due to receive error (ORER, FER, or PER)	Not possible	Not possible	
	RXI	Interrupt due to receive data full state (RDRF)	Possible	Possible	
	TXI	Interrupt due to transmit data empty state (TDRE)	Possible	Possible	
	TEI	Interrupt due to transmission end (TEND)	Not possible	Not possible	

Note: * This table shows the initial state immediately after a reset. Relative priorities among channels can be changed by means of the interrupt controller.

A 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 and a TXI interrupt are requested simultaneously, the TXI interrupt may have priority for acceptance, with the result that the TDRE and TEND flags are cleared. Note that the TEI interrupt will not be accepted in this case.

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 since it has not yet been transferred to TSR. 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 as shown in table 13-13. If there is an overrun error, data is not transferred from RSR to RDR, and the receive data is lost.

Table 13-13 State of SSR Status Flags and Transfer of Receive Data

SSR Status Flags				Receive Data Transfer	
RDRF	ORER	FER	PER	RSR to RDR	Receive Error Status
1	1	0	0	X	Overrun error
0	0	1	0	○	Framing error
0	0	0	1	○	Parity error
1	1	1	0	X	Overrun error + framing error
1	1	0	1	X	Overrun error + parity error
0	0	1	1	○	Framing error + parity error
1	1	1	1	X	Overrun error + framing error + parity error

Notes: ○: Receive data is transferred from RSR to RDR.

X: Receive data is not transferred from RSR to RDR.

Note that, since the SCI continues the receive operation after receiving a break, even if the FER flag is cleared to 0, it will be set to 1 again.

Sending a Break (Asynchronous Mode Only): The TxD pin has a dual function as an I/O port whose direction (input or output) is determined by DR and DDR. This can be used to send a break.

Between serial transmission initialization and setting of the TE bit to 1, the mark state is replaced 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 are first set to 1.

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 (Clocked Synchronous Mode Only):

Transmission cannot be started when a receive error flag (ORER, PER, or FER) is set to 1, even if the TDRE flag is cleared to 0. Be sure to clear the receive error flags to 0 before starting transmission.

Note also that receive error flags cannot be cleared to 0 even if the RE bit is cleared to 0.

Receive Data Sampling Timing and Reception Margin in Asynchronous Mode:

In asynchronous mode, the SCI operates on a basic clock with a frequency of 16 times the transfer rate.

In reception, the SCI samples the falling edge of the start bit using the basic clock, and performs internal synchronization. Receive data is latched internally at the rising edge of the 8th pulse of the basic clock. This is illustrated in figure 13-21.

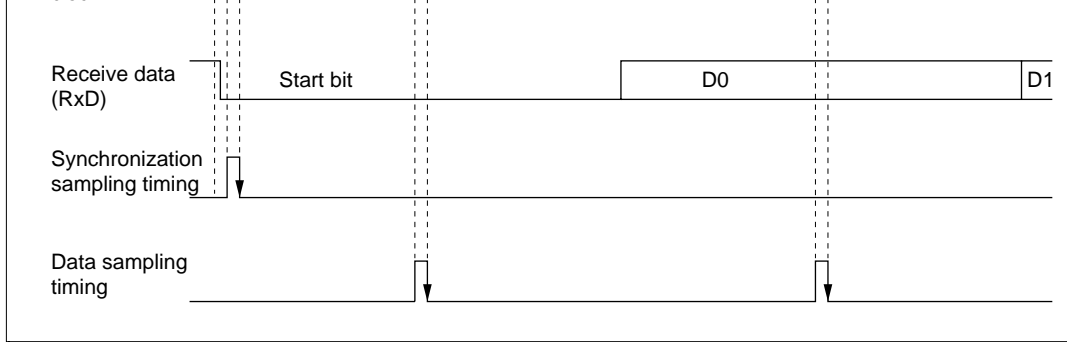


Figure 13-21 Receive Data Sampling Timing in Asynchronous Mode

Thus the reception margin in asynchronous mode is given by formula (1) below.

$$M = \left| \left(0.5 - \frac{1}{2N} \right) - (L - 0.5) F - \frac{|D - 0.5|}{N} (1 + F) \right| \times 100\%$$

... Formula (1)

Where M : Reception 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 formula (1), a reception margin of 46.875% is given by formula (2) below.

When $D = 0.5$ and $F = 0$,

$$M = \left(0.5 - \frac{1}{2 \times 16} \right) \times 100\%$$

$$= 46.875\%$$

... Formula (2)

However, this is only the computed value, and a margin of 20% to 30% should be allowed in system design.

- When RDR is read by the DMAC or DTC, be sure to set the activation source to the relevant SCI reception end interrupt (RXI).

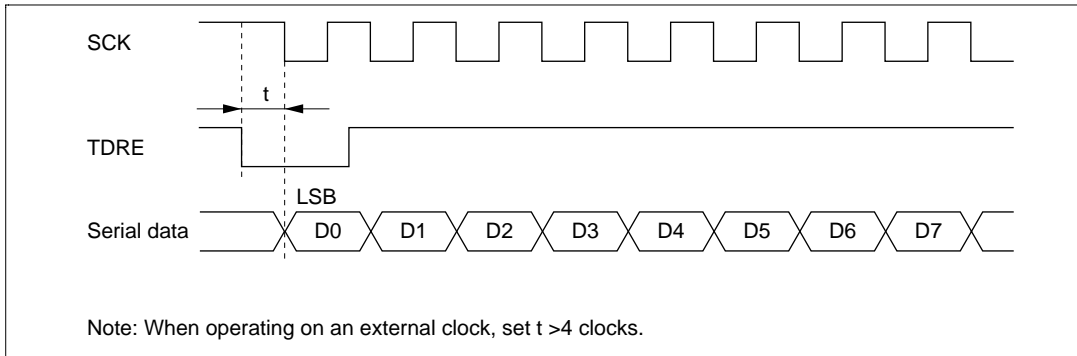


Figure 13-22 Example of Clocked Synchronous Transmission by DTC

SCI supports an IC card (Smart Card) interface conforming to ISO/IEC 7816-3 (Identification Card) as a serial communication interface extension function.

Switching between the normal serial communication interface and the Smart Card interface is carried out by means of a register setting.

14.1.1 Features

Features of the Smart Card interface supported by the H8S/2357 are as follows.

- Asynchronous mode
 - Data length: 8 bits
 - Parity bit generation and checking
 - Transmission of error signal (parity error) in receive mode
 - Error signal detection and automatic data retransmission in transmit mode
 - Direct convention and inverse convention both supported
- On-chip baud rate generator allows any bit rate to be selected
- Three interrupt sources
 - Three interrupt sources (transmit data empty, receive data full, and transmit/receive error) that can issue requests independently
 - The transmit data empty interrupt and receive data full interrupt can activate the DMA controller (DMAC) or data transfer controller (DTC) to execute data transfer

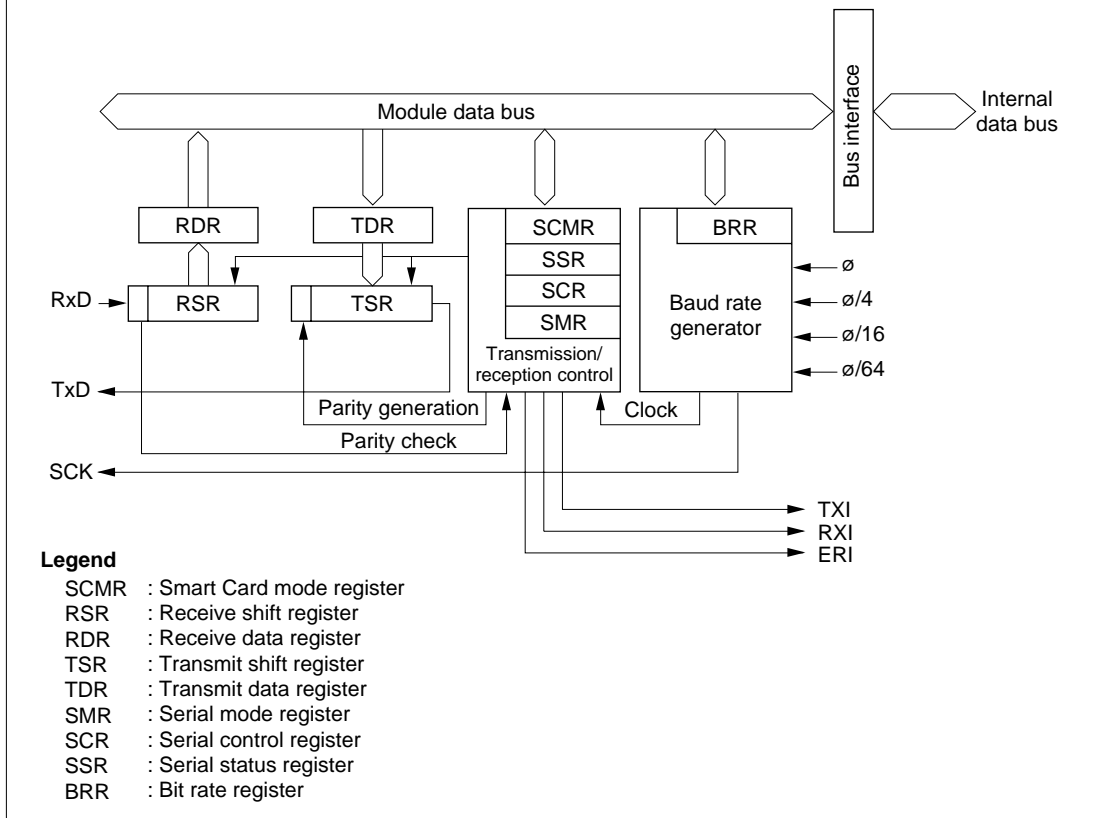


Figure 14-1 Block Diagram of Smart Card Interface

Table 14-1 Smart Card Interface Pins

Channel	Pin Name	Symbol	I/O	Function
0	Serial clock pin 0	SCK0	I/O	SCI0 clock input/output
	Receive data pin 0	RxD0	Input	SCI0 receive data input
	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

Table 14-2 Smart Card Interface Registers

Channel	Name	Abbreviation	R/W	Initial Value	Address*¹
0	Serial mode register 0	SMR0	R/W	H'00	H'FF78
	Bit rate register 0	BRR0	R/W	H'FF	H'FF79
	Serial control register 0	SCR0	R/W	H'00	H'FF7A
	Transmit data register 0	TDR0	R/W	H'FF	H'FF7B
	Serial status register 0	SSR0	R/(W)* ²	H'84	H'FF7C
	Receive data register 0	RDR0	R	H'00	H'FF7D
	Smart card mode register 0	SCMR0	R/W	H'F2	H'FF7E
1	Serial mode register 1	SMR1	R/W	H'00	H'FF80
	Bit rate register 1	BRR1	R/W	H'FF	H'FF81
	Serial control register 1	SCR1	R/W	H'00	H'FF82
	Transmit data register 1	TDR1	R/W	H'FF	H'FF83
	Serial status register 1	SSR1	R/(W)* ²	H'84	H'FF84
	Receive data register 1	RDR1	R	H'00	H'FF85
	Smart card mode register 1	SCMR1	R/W	H'F2	H'FF86
All	Module stop control register	MSTPCR	R/W	H'3FFF	H'FF3C

- Notes: 1. Lower 16 bits of the address.
2. Can only be written with 0 for flag clearing.

14.2.1 Smart Card Mode Register (SCMR)

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	SDIR	SINV	—	SMIF
Initial value :		1	1	1	1	0	0	1	0
R/W	:	—	—	—	—	R/W	R/W	—	R/W

SCMR is an 8-bit readable/writable register that selects the Smart Card interface function.

SCMR is initialized to H'F2 by a reset, and in standby mode or module stop mode.

Bits 7 to 4—Reserved: Read-only bits, always read as 1.

Bit 3—Smart Card 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	(Initial value)
1	TDR contents are transmitted MSB-first Receive data is stored in RDR MSB-first	

Bit 2—Smart Card Data Invert (SINV): Specifies inversion of the data logic level. This function is used together with the SDIR bit for communication with an inverse convention card. The SINV bit does not affect the logic level of the parity bit. For parity-related setting procedures, see section 14.3.4, Register Settings.

Bit 2 SINV	Description	
0	TDR contents are transmitted as they are Receive data is stored as it is in RDR	(Initial value)
1	TDR contents are inverted before being transmitted Receive data is stored in inverted form in RDR	

Bit 0 SMIF	Description	
0	Smart Card interface function is disabled	(Initial value)
1	Smart Card interface function is enabled	

14.2.2 Serial Status Register (SSR)

Bit	7	6	5	4	3	2	1	0
	TDRE	RDRF	ORER	ERS	PER	TEND	MPB	MPBT
Initial value :	1	0	0	0	0	1	0	0
R/W :	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R	R	R/W

Note: * Only 0 can be written to bits 7 to 3, to clear these flags.

Bit 4 of SSR has a different function in Smart Card interface mode. Coupled with this, the setting conditions for bit 2, TEND, are also different.

Bits 7 to 5—Operate in the same way as for the normal SCI. For details, see section 13.2.7, Serial Status Register (SSR).

Bit 4—Error Signal Status (ERS): In Smart Card interface mode, bit 4 indicates the status of the error signal sent back from the receiving end in transmission. Framing errors are not detected in Smart Card interface mode.

Bit 4 ERS	Description	
0	[Clearing condition]	(Initial value)
	<ul style="list-style-type: none"> Upon reset, and in standby mode or module stop mode When 0 is written to ERS after reading ERS = 1 	
1	[Setting condition]	
	When the low level of the error signal is sampled	

Note: Clearing the TE bit in SCR to 0 does not affect the ERS flag, which retains its previous state.

Bit 2 TEND	Description
0	[Clearing conditions] (Initial value) <ul style="list-style-type: none"> When 0 is written to TDRE after reading TDRE = 1 When the DMAC or DTC is activated by a TXI interrupt and write data to TDR
1	[Setting conditions] <ul style="list-style-type: none"> Upon reset, and in standby mode or module stop mode When the TE bit in SCR is 0 and the ERS bit is also 0 When TDRE = 1 and ERS = 0 (normal transmission) 2.5 etu after transmission of a 1-byte serial character when GM = 0 When TDRE = 1 and ERS = 0 (normal transmission) 1.0 etu after transmission of a 1-byte serial character when GM = 1

Note: etu: Elementary Time Unit (time for transfer of 1 bit)

14.2.3 Serial Mode Register (SMR)

Bit	7	6	5	4	3	2	1	0
	GM	CHR	PE	O/ \bar{E}	STOP	MP	CKS1	CKS0
Initial value :	0	0	0	0	0	0	0	0
Set value* :	GM	0	1	O/ \bar{E}	1	0	CKS1	CKS0
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Note: *When the smart card interface is used, be sure to make the 0 or 1 setting shown for bits 6, 5, 3, and 2.

The function of bit 7 of SMR changes in smart card interface mode.

Bit 7—GSM Mode (GM): Sets the smart card interface function to GSM mode.

This bit is cleared to 0 when the normal smart card interface is used. In GSM mode, this bit is set to 1, the timing of setting of the TEND flag that indicates transmission completion is advanced and clock output control mode addition is performed. The contents of the clock output control mode addition are specified by bits 1 and 0 of the serial control register (SCR).

1	<ul style="list-style-type: none"> • Clock output ON/OFF control only <p>GSM mode smart card interface mode operation</p> <ul style="list-style-type: none"> • TEND flag generation 11.0 etu after beginning of start bit • High/low fixing control possible in addition to clock output ON/OFF control (set by SCR)
---	---

Note: etu: Elementary time unit (time for transfer of 1 bit)

Bits 6 to 0—Operate in the same way as for the normal SCI.

For details, see section 13.2.5, Serial Mode Register (SMR).

14.2.4 Serial Control Register (SCR)

Bit	:	7	6	5	4	3	2	1	0
		TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

In smart card interface mode, the function of bits 1 and 0 of SCR changes when bit 7 of the serial mode register (SMR) is set to 1.

Bits 7 to 2—Operate in the same way as for the normal SCI.

For details, see section 13.2.6, Serial Control Register (SCR).

Bits 1 and 0—Clock Enable 1 and 0 (CKE1, CKE0): These bits are used to select the SCI clock source and enable or disable clock output from the SCK pin.

In smart card interface mode, in addition to the normal switching between clock output enabling and disabling, the clock output can be specified as to be fixed high or low.

1	0	0	1	Outputs clock as SCK output pin
1	1	0	0	Operates as SCK output pin, with output fixed low
1	1	0	1	Outputs clock as SCK output pin
1	1	1	0	Operates as SCK output pin, with output fixed high
1	1	1	1	Outputs clock as SCK output pin

14.3 Operation

14.3.1 Overview

The main functions of the Smart Card interface are as follows.

- One frame consists of 8-bit data plus a parity bit.
- In transmission, a guard time of at least 2 etu (Elementary Time Unit: the time for transfer of one bit) is left between the end of the parity bit and the start of the next frame.
- If a parity error is detected during reception, a low error signal level is output for one etu period, 10.5 etu after the start bit.
- If the error signal is sampled during transmission, the same data is transmitted automatically after the elapse of 2 etu or longer.
- Only asynchronous communication is supported; there is no clocked synchronous communication function.

single data transmission line, the TxD pin and RxD pin should be connected with the LSI pin. The data transmission line should be pulled up to the V_{CC} power supply with a resistor.

When the clock generated on the Smart Card interface is used by an IC card, the SCK pin output is input to the CLK pin of the IC card. No connection is needed if the IC card uses an internal clock.

LSI port output is used as the reset signal.

Other pins must normally be connected to the power supply or ground.

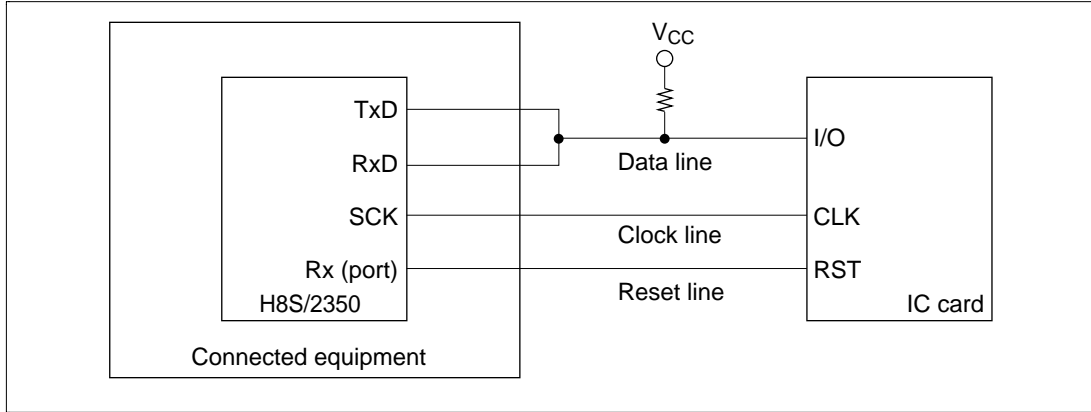


Figure 14-2 Schematic Diagram of Smart Card Interface Pin Connections

Note: If an IC card is not connected, and the TE and RE bits are both set to 1, closed transmission/reception is possible, enabling self-diagnosis to be carried out.

transmitting end, and retransmission of the data is requested. If an error signal is sampled during transmission, the same data is retransmitted.

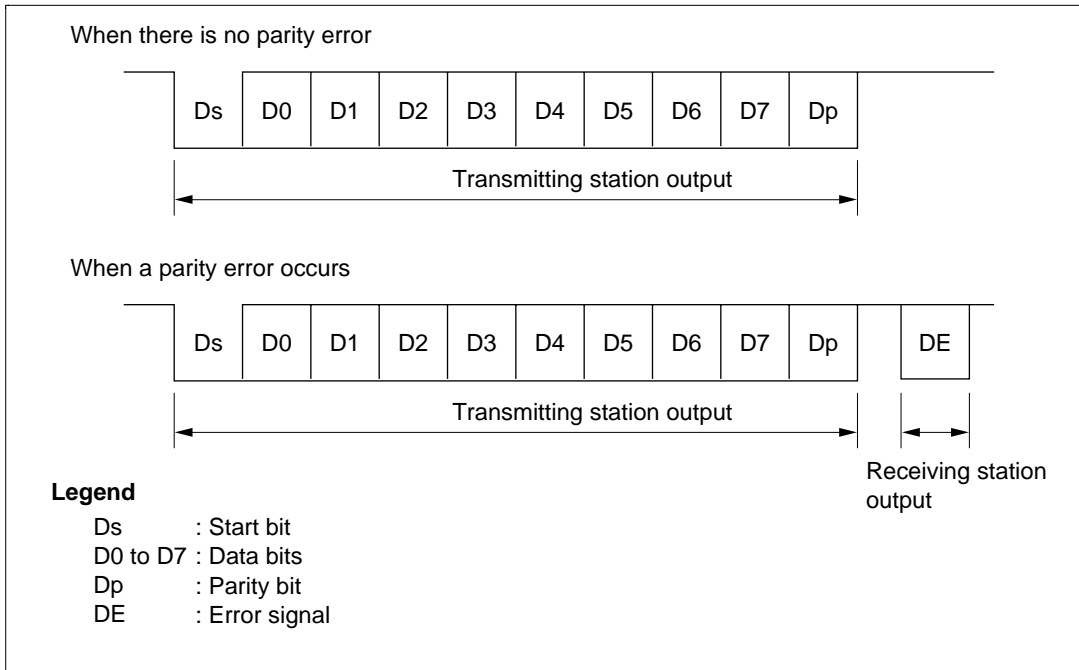


Figure 14-3 Smart Card Interface Data Format

- [2] The transmitting station starts transfer of one frame of data. The data frame starts with a start bit (Ds, low-level), followed by 8 data bits (D0 to D7) and a parity bit (Dp).
- [3] With the Smart Card interface, the data line then returns to the high-impedance state. The data line is pulled high with a pull-up resistor.
- [4] The receiving station carries out a parity check.
- If there is no parity error and the data is received normally, the receiving station waits for reception of the next data.
- If a parity error occurs, however, the receiving station outputs an error signal (DE, low-level) to request retransmission of the data. After outputting the error signal for the prescribed length of time, the receiving station places the signal line in the high-impedance state again. The signal line is pulled high again by a pull-up resistor.
- [5] If the transmitting station does not receive an error signal, it proceeds to transmit the next data frame.
- If it does receive an error signal, however, it returns to step [2] and retransmits the erroneous data.

Bits indicated as 0 or 1 must be set to the value shown. The setting of other bits is described below.

Table 14-3 Smart Card Interface Register Settings

Register	Bit							
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SMR	GM	0	1	O/ \bar{E}	1	0	CKS1	CKS0
BRR	BRR7	BRR6	BRR5	BRR4	BRR3	BRR2	BRR1	BRR0
SCR	TIE	RIE	TE	RE	0	0	CKE1*	CKE0
TDR	TDR7	TDR6	TDR5	TDR4	TDR3	TDR2	TDR1	TDR0
SSR	TDRE	RDRF	ORER	ERS	PER	TEND	0	0
RDR	RDR7	RDR6	RDR5	RDR4	RDR3	RDR2	RDR1	RDR0
SCMR	—	—	—	—	SDIR	SINV	—	SMIF

Notes: — : Unused bit.

*: The CKE1 bit must be cleared to 0 when the GM bit in SMR is cleared to 0.

SMR Setting: The GM bit is cleared to 0 in normal smart card interface mode, and set to 1 in GSM mode. The O/ \bar{E} bit is cleared to 0 if the IC card is of the direct convention type, and set to 1 if of the inverse convention type.

Bits CKS1 and CKS0 select the clock source of the on-chip baud rate generator. See section 14.3.5, Clock.

BRR Setting: BRR is used to set the bit rate. See section 14.3.5, Clock, for the method of calculating the value to be set.

SCR Setting: The function of the TIE, RIE, TE, and RE bits is the same as for the normal SCI. For details, see section 13, Serial Communication Interface.

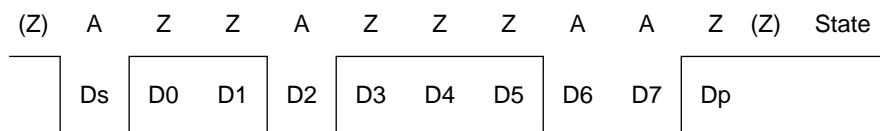
Bits CKE1 and CKE0 specify the clock output. When the GM bit in SMR is cleared to 0, set these bits to B'00 if a clock is not to be output, or to B'01 if a clock is to be output. When the GM bit in SMR is set to 1, clock output is performed. The clock output can also be fixed high or low.

inverse convention type.

The SMIF bit is set to 1 in the case of the Smart Card interface.

Examples of register settings and the waveform of the start character are shown below for the two types of IC card (direct convention and inverse convention).

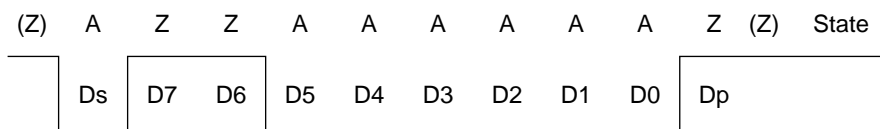
- Direct convention ($SDIR = SINV = O/\bar{E} = 0$)



With the direct convention type, the logic 1 level corresponds to state Z and the logic 0 level to state A, and transfer is performed in LSB-first order. The start character data above is H'3B.

The parity bit is 1 since even parity is stipulated for the Smart Card.

- Inverse convention ($SDIR = SINV = O/\bar{E} = 1$)



With the inverse convention type, the logic 1 level corresponds to state A and the logic 0 level to state Z, and transfer is performed in MSB-first order. The start character data above is H'3F.

The parity bit is 0, corresponding to state Z, since even parity is stipulated for the Smart Card.

With the H8S/2357, inversion specified by the SINV bit applies only to the data bits, D7 to D0. For parity bit inversion, the O/\bar{E} bit in SMR is set to odd parity mode (the same applies to both transmission and reception).

CKS0 bits in SMR. The formula for calculating the bit rate is as shown below. Table 14-5 shows some sample bit rates.

If clock output is selected by setting CKE0 to 1, a clock with a frequency of 372 times the bit rate is output from the SCK pin.

$$B = \frac{\phi}{1488 \times 2^{2n-1} \times (N + 1)} \times 10^6$$

Where: N = Value set in BRR (0 ≤ N ≤ 255)

B = Bit rate (bit/s)

ϕ = Operating frequency (MHz)

n = See table 14-4

Table 14-4 Correspondence between n and CKS1, CKS0

n	CKS1	CKS0
0	0	0
1		1
2	1	0
3		1

Table 14-5 Examples of Bit Rate B (bit/s) for Various BRR Settings (When n = 0)

N	ϕ (MHz)						
	10.00	10.714	13.00	14.285	16.00	18.00	20.00
0	13441	14400	17473	19200	21505	24194	26882
1	6720	7200	8737	9600	10753	12097	13441
2	4480	4800	5824	6400	7168	8065	8961

Note: Bit rates are rounded to the nearest whole number.

$$N = \frac{\phi}{1488 \times 2^{2n-1} \times B} \times 10^6 - 1$$

Table 14-6 Examples of BRR Settings for Bit Rate B (bit/s) (When n = 0)

bit/s	ϕ (MHz)															
	7.1424		10.00		10.7136		13.00		14.2848		16.00		18.00		20.00	
	N	Error	N	Error	N	Error	N	Error	N	Error	N	Error	N	Error	N	Error
9600	0	0.00	1	30	1	25	1	8.99	1	0.00	1	12.01	2	15.99	2	6.60

Table 14-7 Maximum Bit Rate at Various Frequencies (Smart Card Interface Mode)

ϕ (MHz)	Maximum Bit Rate (bit/s)	N	n
7.1424	9600	0	0
10.00	13441	0	0
10.7136	14400	0	0
13.00	17473	0	0
14.2848	19200	0	0
16.00	21505	0	0
18.00	24194	0	0
20.00	26882	0	0

The bit rate error is given by the following formula:

$$\text{Error (\%)} = \left(\frac{\phi}{1488 \times 2^{2n-1} \times B \times (N + 1)} \times 10^6 - 1 \right) \times 100$$

- [1] Clear the TE and RE bits in SCR to 0.
- [2] Clear the error flags ERS, PER, and ORER in SSR to 0.
- [3] Set the O/\bar{E} bit and CKS1 and CKS0 bits in SMR. Clear the C/\bar{A} , CHR, and MP bits to 0, and set the STOP and PE bits to 1.
- [4] Set the SMIF, SDIR, and SINV bits in SCMR.
When the SMIF bit is set to 1, the TxD and RxD pins are both switched from ports to SCI pins, and are placed in the high-impedance state.
- [5] Set the value corresponding to the bit rate in BRR.
- [6] Set the CKE0 bit in SCR. Clear the TIE, RIE, TE, RE, MPIE, TEIE and CKE1 bits to 0.
If the CKE0 bit is set to 1, the clock is output from the SCK pin.
- [7] Wait at least one bit interval, then set the TIE, RIE, TE, and RE bits in SCR. Do not set the TE bit and RE bit at the same time, except for self-diagnosis.

- [1] Perform Smart Card interface mode initialization as described above in Initialization.
- [2] Check that the ERS error flag in SSR is cleared to 0.
- [3] Repeat steps [2] and [3] until it can be confirmed that the TEND flag in SSR is set to 1.
- [4] Write the transmit data to TDR, clear the TDRE flag to 0, and perform the transmit operation. The TEND flag is cleared to 0.
- [5] When transmitting data continuously, go back to step [2].
- [6] To end transmission, clear the TE bit to 0.

With the above processing, interrupt servicing or data transfer by the DMAC or DTC is possible.

If transmission ends and the TEND flag is set to 1 while the TIE bit is set to 1 and interrupt requests are enabled, a transmit data empty interrupt (TXI) request will be generated. If an error occurs in transmission and the ERS flag is set to 1 while the RIE bit is set to 1 and interrupt requests are enabled, a transfer error interrupt (ERI) request will be generated.

The timing for setting the TEND flag depends on the value of the GM bit in SMR. The TEND flag set timing is shown in figure 14-6.

If the DMAC or DTC is activated by a TXI request, the number of bytes set in the DMAC or DTC can be transmitted automatically, including automatic retransmission.

For details, see Interrupt Operations and Data Transfer Operation by DMAC or DTC below.

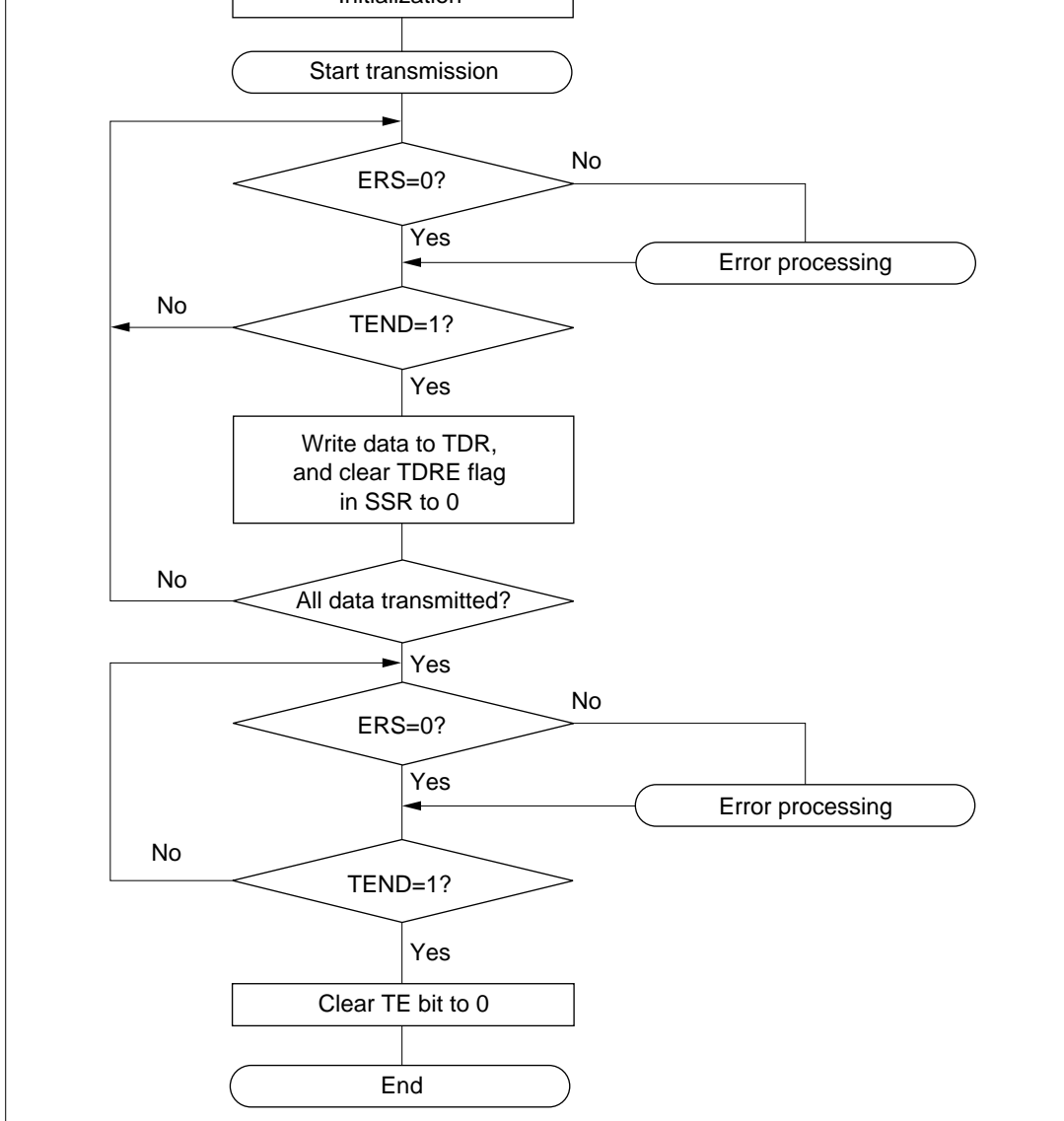


Figure 14-4 Example of Transmission Processing Flow

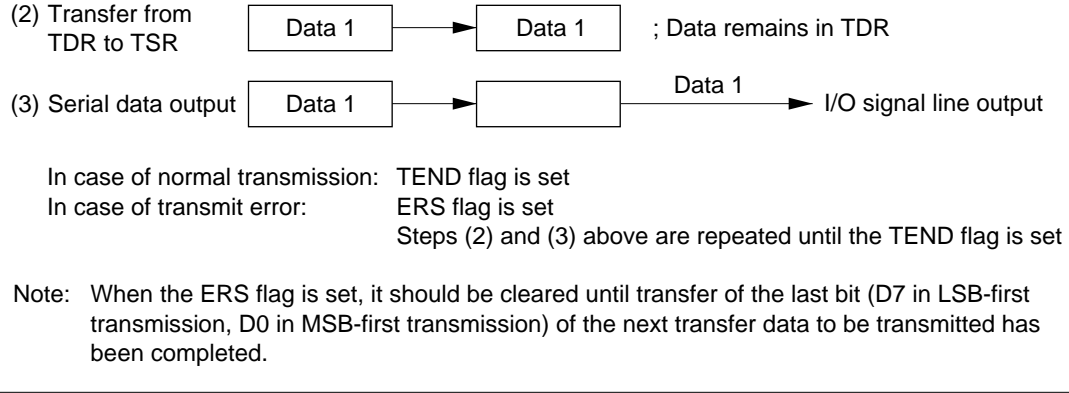


Figure 14-5 Relation Between Transmit Operation and Internal Registers

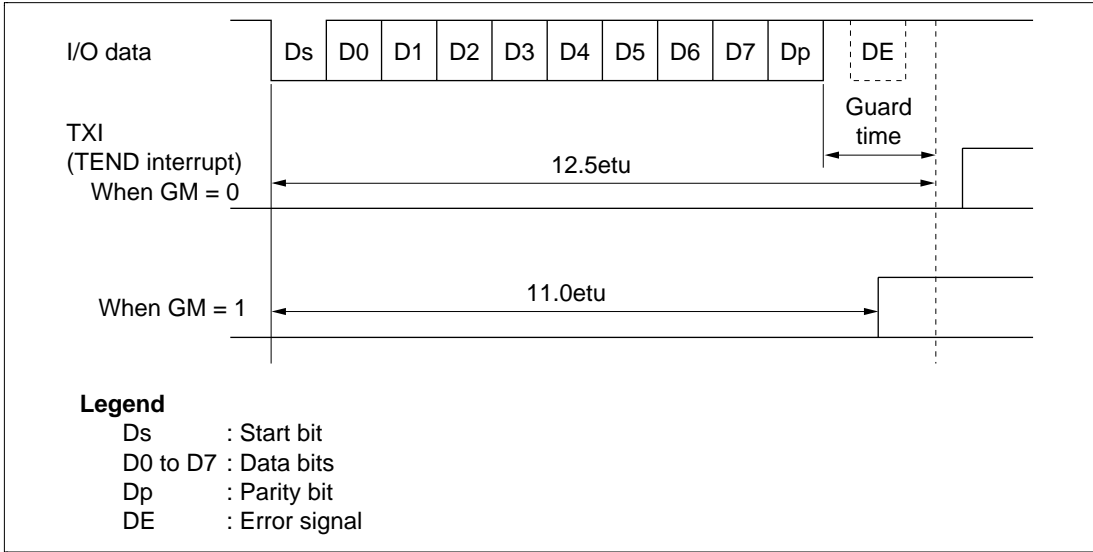


Figure 14-6 TEND Flag Generation Timing in Transmission Operation

[2] Check that the ORER flag and PER flag in SSR are cleared to 0. If either is set, perform the appropriate receive error processing, then clear both the ORER and the PER flag to 0.

[3] Repeat steps [2] and [3] until it can be confirmed that the RDRF flag is set to 1.

[4] Read the receive data from RDR.

[5] When receiving data continuously, clear the RDRF flag to 0 and go back to step [2].

[6] To end reception, clear the RE bit to 0.

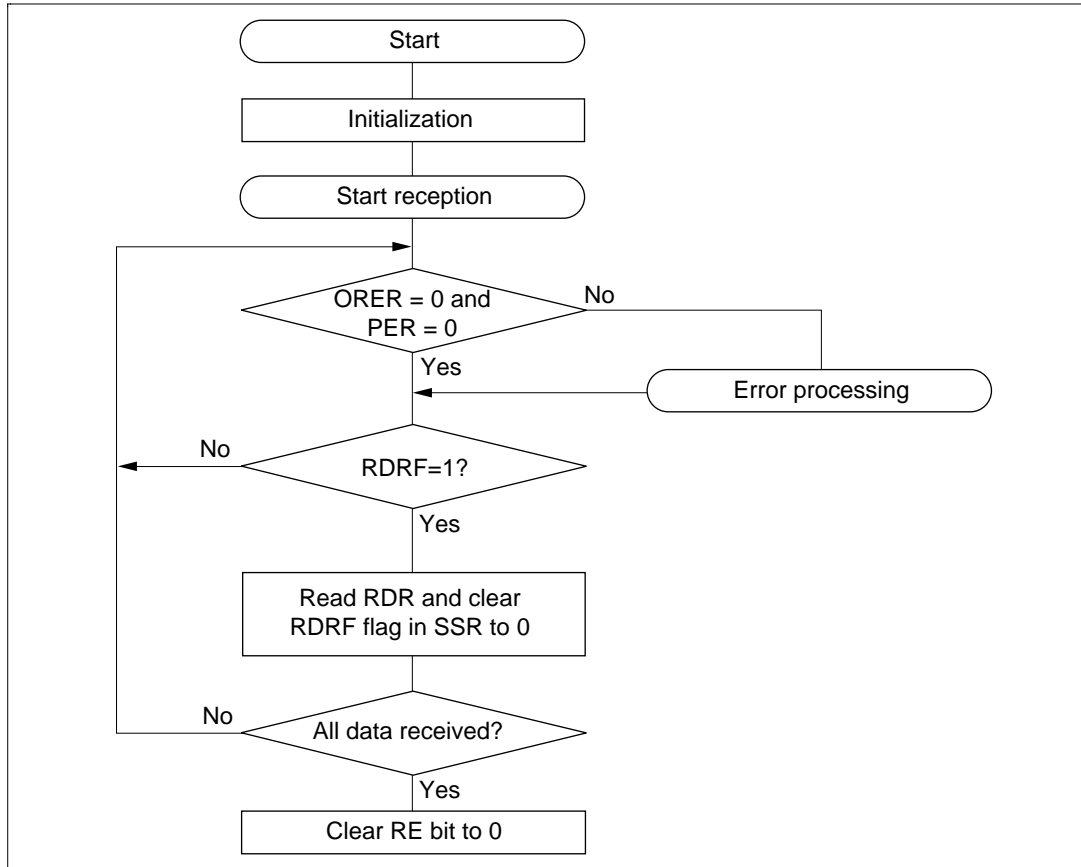


Figure 14-7 Example of Reception Processing Flow

request will be generated.

If the DMAC or DTC is activated by an RXI request, the receive data in which the error occurred is skipped, and only the number of bytes of receive data set in the DMAC or DTC are transferred.

For details, see Interrupt Operation and Data Transfer Operation by DMAC or DTC below.

If a parity error occurs during reception and the PER is set to 1, the received data is still transferred to RDR, and therefore this data can be read.

Mode Switching Operation: When switching from receive mode to transmit mode, first confirm that the receive operation has been completed, then start from initialization, clearing RE bit to 0 and setting TE bit to 1. The RDRF flag or the PER and ORER flags can be used to check that the receive operation has been completed.

When switching from transmit mode to receive mode, first confirm that the transmit operation has been completed, then start from initialization, clearing TE bit to 0 and setting RE bit to 1. The TEND flag can be used to check that the transmit operation has been completed.

Fixing Clock Output Level: When the GSM bit in SMR is set to 1, the clock output level can be fixed with bits CKE1 and CKE0 in SCR. At this time, the minimum clock pulse width can be made the specified width.

Figure 14-8 shows the timing for fixing the clock output level. In this example, GSM is set to 1, CKE1 is cleared to 0, and the CKE0 bit is controlled.

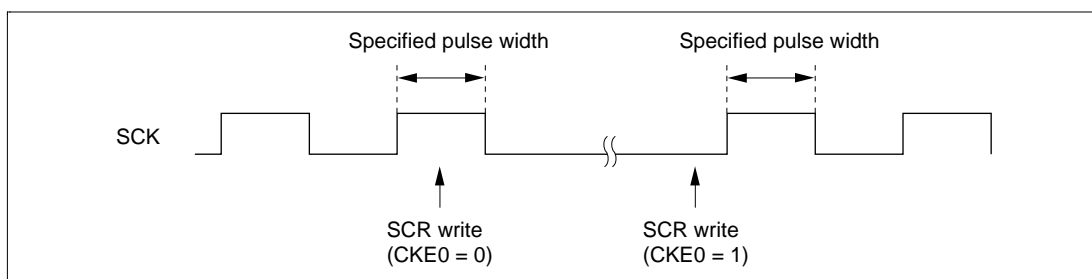


Figure 14-8 Timing for Fixing Clock Output Level

Interrupt Operation: There are three interrupt sources in smart card interface mode: transmit data empty interrupt (TXI) requests, transfer error interrupt (ERI) requests, and receive data full interrupt (RXI) requests. The transmit end interrupt (TEI) request is not used in this mode.

Table 14-8 Smart Card Mode Operating States and Interrupt Sources

Operating State		Flag	Enable Bit	Interrupt Source	DMAC Activation	DTC Activation
Transmit Mode	Normal operation	TEND	TIE	TXI	Possible	Possible
	Error	ERS	RIE	ERI	Not possible	Not possible
Receive Mode	Normal operation	RDRF	RIE	RXI	Possible	Possible
	Error	PER, ORER	RIE	ERI	Not possible	Not possible

Data Transfer Operation by DMAC or DTC: In smart card mode, as with the normal SCI, transfer can be carried out using the DMAC or DTC. In a transmit operation, the TDRE flag is also set to 1 at the same time as the TEND flag in SSR, and a TXI interrupt is generated. If the TXI request is designated beforehand as a DMAC or DTC activation source, the DMAC or DTC will be activated by the TXI request, and transfer of the transmit data will be carried out. The TDRE and TEND flags are automatically cleared to 0 when data transfer is performed by the DMAC or DTC. In the event of an error, the SCI retransmits the same data automatically. The TEND flag remains cleared to 0 during this time, and the DMAC is not activated. Thus, the number of bytes specified by the SCI and DMAC are transmitted automatically even in retransmission following an error. However, the ERS flag is not cleared automatically when an error occurs, and so the RIE bit should be set to 1 beforehand so that an ERI request will be generated in the event of an error, and the ERS flag will be cleared.

When performing transfer using the DMAC or DTC, it is essential to set and enable the DMAC or DTC before carrying out SCI setting. For details of the DMAC and DTC setting procedures, see section 7, DMA Controller (DMAC), and section 8, Data Transfer Controller (DTC).

In a receive operation, an RXI interrupt request is generated when the RDRF flag in SSR is set to 1. If the RXI request is designated beforehand as a DMAC or DTC activation source, the DMAC or DTC will be activated by the RXI request, and transfer of the receive data will be carried out. The RDRF flag is cleared to 0 automatically when data transfer is performed by the DMAC or DTC. If an error occurs, an error flag is set but the RDRF flag is not. Consequently, the DMAC or DTC is not activated, but instead, an ERI interrupt request is sent to the CPU. Therefore, the error flag should be cleared.

- When changing from smart card interface mode to software standby mode
 - [1] Set the data register (DR) and data direction register (DDR) corresponding to the SCK pin to the value for the fixed output state in software standby mode.
 - [2] Write 0 to the TE bit and RE bit in the serial control register (SCR) to halt transmit/receive operation. At the same time, set the CKE1 bit to the value for the fixed output state in software standby mode.
 - [3] Write 0 to the CKE0 bit in SCR to halt the clock.
 - [4] Wait for one serial clock period.
During this interval, clock output is fixed at the specified level, with the duty preserved.
 - [5] Write H'00 to SMR and SCMR.
 - [6] Make the transition to the software standby state.
- When returning to smart card interface mode from software standby mode
 - [7] Exit the software standby state.
 - [8] Set the CKE1 bit in SCR to the value for the fixed output state (current SCK pin state) when software standby mode is initiated.
 - [9] Set smart card interface mode and output the clock. Signal generation is started with the normal duty.

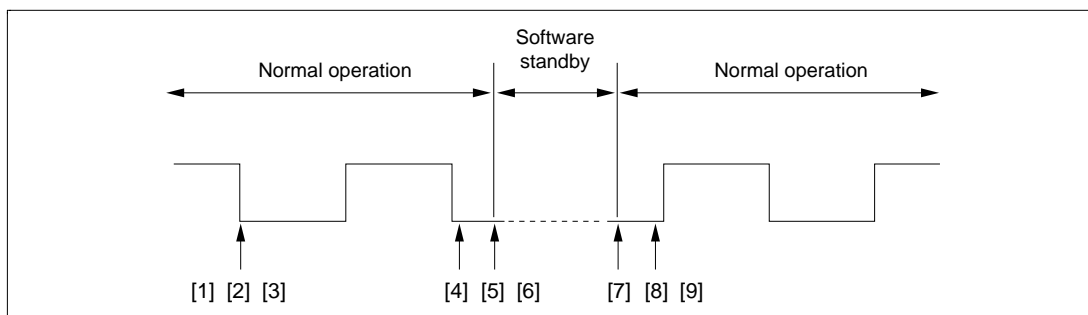


Figure 14-9 Clock Halt and Restart Procedure

[2] Fix the SCK pin to the specified output level with the CKE1 bit in SCR.

[3] Set SMR and SCMR, and switch to smart card mode operation.

[4] Set the CKE0 bit in SCR to 1 to start clock output.

14.4 Usage Notes

The following points should be noted when using the SCI as a Smart Card interface.

Receive Data Sampling Timing and Reception Margin in Smart Card Interface Mode: In Smart Card Interface mode, the SCI operates on a basic clock with a frequency of 372 times the transfer rate.

In reception, the SCI samples the falling edge of the start bit using the basic clock, and performs internal synchronization. Receive data is latched internally at the rising edge of the 186th pulse of the basic clock. This is illustrated in figure 14-10.

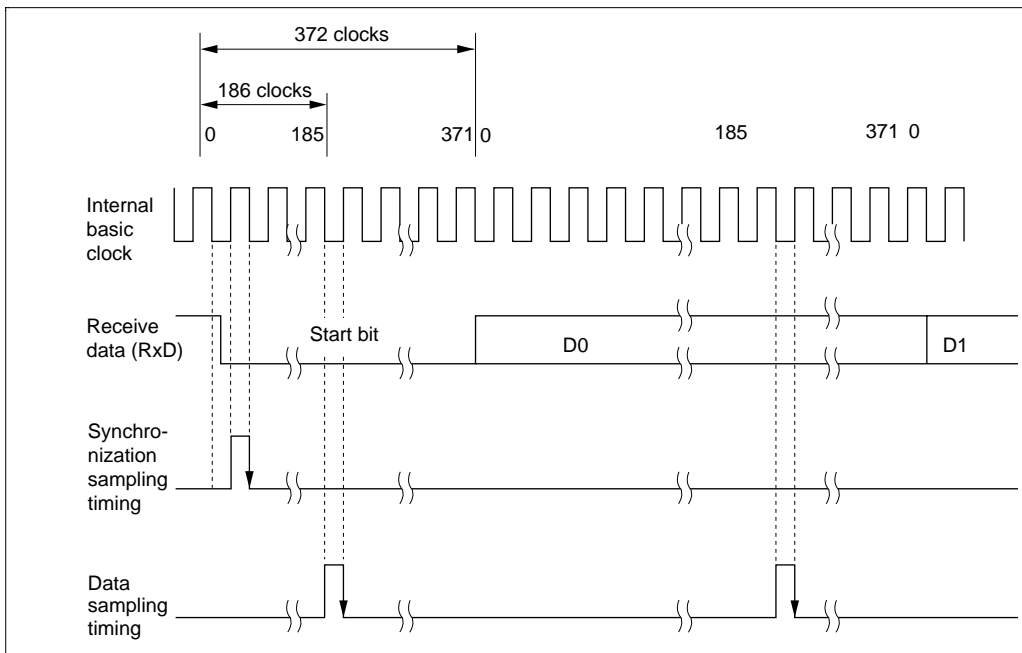


Figure 14-10 Receive Data Sampling Timing in Smart Card Mode

Where M: Reception margin (%)
N: Ratio of bit rate to clock ($N = 372$)
D: Clock duty ($D = 0$ to 1.0)
L: Frame length ($L = 10$)
F: Absolute value of clock frequency deviation

Assuming values of $F = 0$ and $D = 0.5$ in the above formula, the reception margin formula is as follows.

When $D = 0.5$ and $F = 0$,
$$M = (0.5 - 1/2 \times 372) \times 100\%$$
$$= 49.866\%$$

Retransfer Operations: Retransfer operations are performed by the SCI in receive mode and transmit mode as described below.

- Retransfer operation when SCI is in receive mode

Figure 14-11 illustrates the retransfer operation when the SCI is in receive mode.

- [1] If an error is found when the received parity bit is checked, the PER bit in SSR is automatically set to 1. If the RIE bit in SCR is enabled at this time, an ERI interrupt request is generated. The PER bit in SSR should be kept cleared to 0 until the next parity bit is sampled.
- [2] The RDRF bit in SSR is not set for a frame in which an error has occurred.
- [3] If no error is found when the received parity bit is checked, the PER bit in SSR is not set to 1.
- [4] If no error is found when the received parity bit is checked, the receive operation is judged to have been completed normally, and the RDRF flag in SSR is automatically set to 1. If the RIE bit in SCR is enabled at this time, an RXI interrupt request is generated.
If DMAC or DTC data transfer by an RXI source is enabled, the contents of RDR can be read automatically. When the RDR data is read by the DMAC or DTC, the RDRF flag is automatically cleared to 0.
- [5] When a normal frame is received, the pin retains the high-impedance state at the timing for error signal transmission.

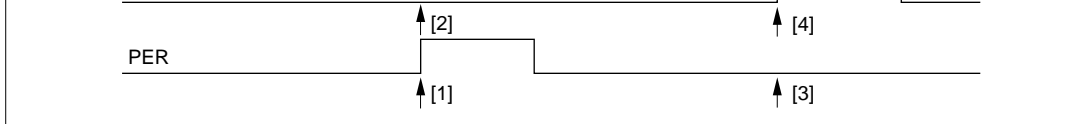


Figure 14-11 Retransfer Operation in SCI Receive Mode

- Retransfer operation when SCI is in transmit mode

Figure 14-12 illustrates the retransfer operation when the SCI is in transmit mode.

- [6] If an error signal is sent back from the receiving end after transmission of one frame is completed, the ERS bit in SSR is set to 1. If the RIE bit in SCR is enabled at this time, an ERI interrupt request is generated. The ERS bit in SSR should be kept cleared to 0 until the next parity bit is sampled.
- [7] The TEND bit in SSR is not set for a frame for which an error signal indicating an abnormality is received.
- [8] If an error signal is not sent back from the receiving end, the ERS bit in SSR is not set.
- [9] If an error signal is not sent back from the receiving end, transmission of one frame, including a retransfer, is judged to have been completed, and the TEND bit in SSR is set to 1. If the TIE bit in SCR is enabled at this time, a TXI interrupt request is generated.

If data transfer by the DMAC or DTC by means of the TXI source is enabled, the next data can be written to TDR automatically. When data is written to TDR by the DMAC or DTC, the TDRE bit is automatically cleared to 0.

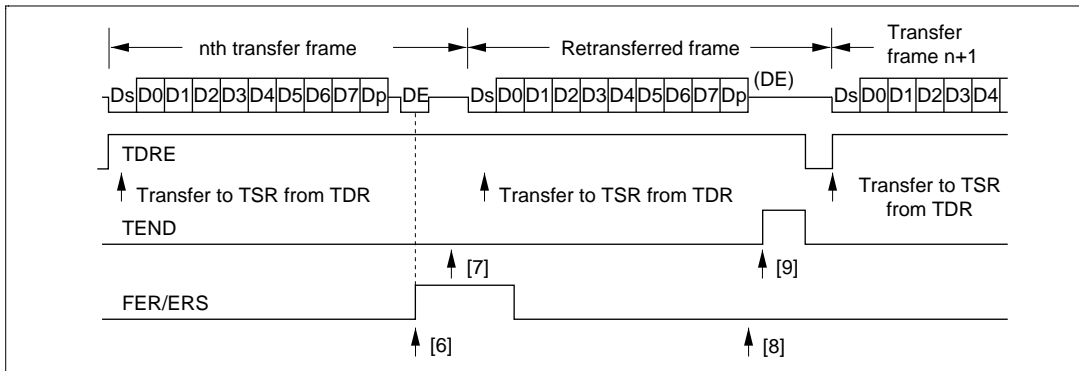


Figure 14-12 Retransfer Operation in SCI Transmit Mode

The H8S/2350 Series incorporates a successive approximation type 10-bit A/D converter that allows up to eight analog input channels to be selected.

15.1.1 Features

A/D converter features are listed below

- 10-bit resolution
- Eight input channels
- Settable analog conversion voltage range
 - Conversion of analog voltages with the reference voltage pin (V_{ref}) 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 (TPU), or \overline{ADTRG} pin
- A/D conversion end interrupt generation
 - A/D conversion end interrupt (ADI) request can be generated at the end of A/D conversion
- Module stop mode can be set
 - As the initial setting, A/D converter operation is halted. Register access is enabled by exiting module stop mode.

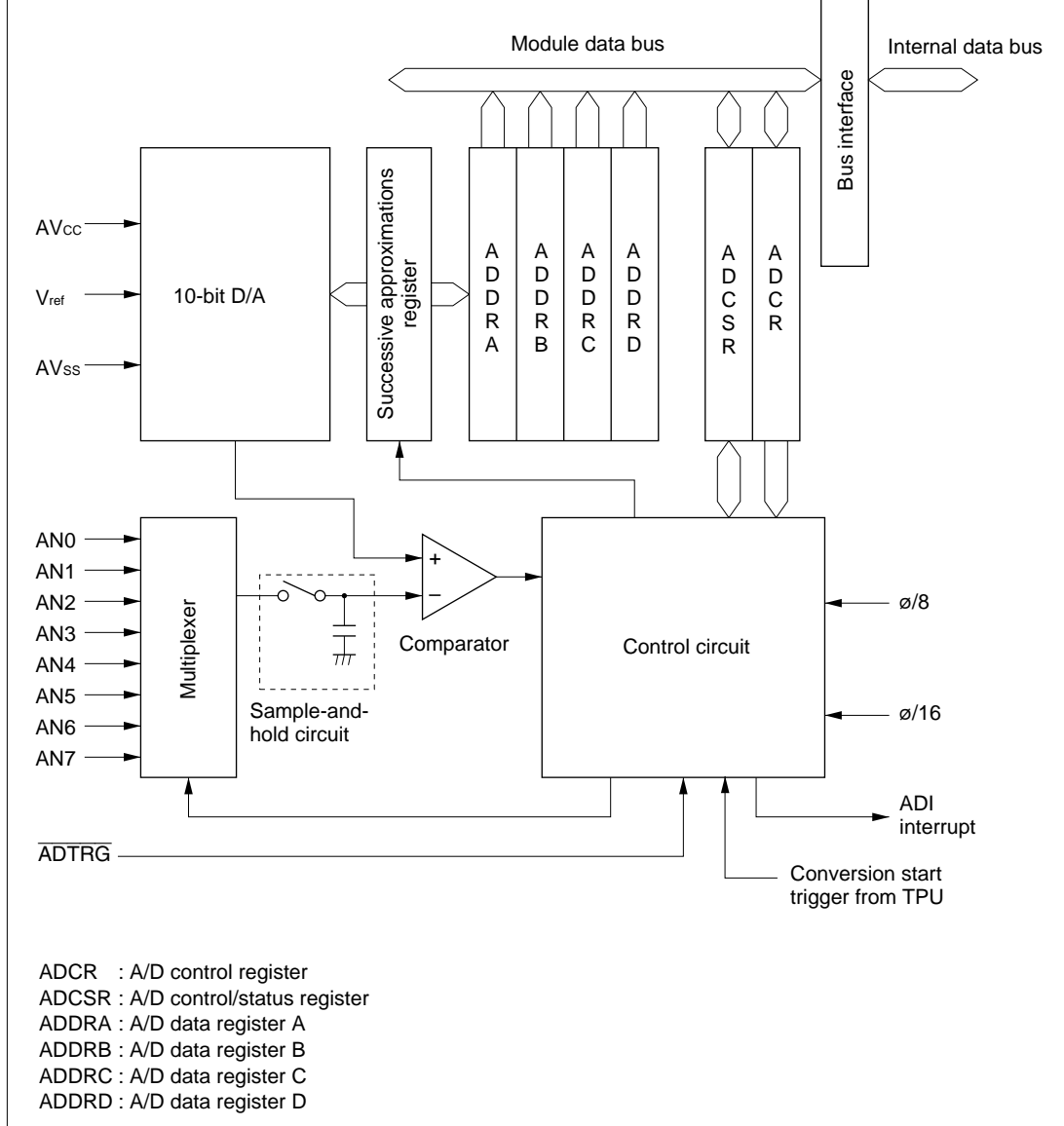


Figure 15-1 Block Diagram of A/D Converter

V_{ref} pin is the A/D conversion reference voltage pin.

The eight analog input pins are divided into two groups: group 0 (AN0 to AN3), and group 1 (AN4 to AN7).

Table 15-1 A/D Converter Pins

Pin Name	Symbol	I/O	Function
Analog power supply pin	AV_{CC}	Input	Analog block power supply
Analog ground pin	AV_{SS}	Input	Analog block ground and A/D conversion reference voltage
Reference voltage pin	V_{ref}	Input	A/D conversion reference voltage
Analog input pin 0	AN0	Input	Group 0 analog inputs
Analog input pin 1	AN1	Input	
Analog input pin 2	AN2	Input	
Analog input pin 3	AN3	Input	
Analog input pin 4	AN4	Input	Group 1 analog inputs
Analog input pin 5	AN5	Input	
Analog input pin 6	AN6	Input	
Analog input pin 7	AN7	Input	
A/D external trigger input pin	\overline{ADTRG}	Input	External trigger input for starting A/D conversion

Name	Abbreviation	R/W	Initial Value	Address*¹
A/D data register AH	ADDRAH	R	H'00	H'FF90
A/D data register AL	ADDRAL	R	H'00	H'FF91
A/D data register BH	ADDRBH	R	H'00	H'FF92
A/D data register BL	ADDRBL	R	H'00	H'FF93
A/D data register CH	ADDRCH	R	H'00	H'FF94
A/D data register CL	ADDRCL	R	H'00	H'FF95
A/D data register DH	ADDRDH	R	H'00	H'FF96
A/D data register DL	ADDRDL	R	H'00	H'FF97
A/D control/status register	ADCSR	R/(W)* ²	H'00	H'FF98
A/D control register	ADCR	R/W	H'3F	H'FF99
Module stop control register	MSTPCR	R/W	H'3FFF	H'FF3C

Notes: 1. Lower 16 bits of the address.

2. Bit 7 can only be written with 0 for flag clearing.

Bit	:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
		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	0	0
R/W	:	R	R	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 results of A/D conversion.

The 10-bit data resulting from A/D conversion is transferred to the ADDR register for the selected channel and stored there. The upper 8 bits of the converted data are transferred to the upper byte (bits 15 to 8) of ADDR, and the lower 2 bits are transferred to the lower byte (bits 7 and 6) and stored. Bits 5 to 0 are always read as 0.

The correspondence between the analog input channels and ADDR registers is shown in table 15-3.

ADDR can always be read by the CPU. The upper byte can be read directly, but for the lower byte, data transfer is performed via a temporary register (TEMP). For details, see section 15.3, Interface to Bus Master.

The ADDR registers are initialized to H'0000 by a reset, and in standby mode or module stop mode.

Table 15-3 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	ADDRC
AN3	AN7	ADDRD

Initial value : 0 0 0 0 0 0 0 0
 R/W : R/(W)* R/W R/W R/W R/W R/W R/W

Note: * Only 0 can be written to bit 7, to clear this flag.

ADCSR is an 8-bit readable/writable register that controls A/D conversion operations and shows the status of the operation.

ADCSR is initialized to H'00 by a reset, and in hardware standby mode or module stop mode.

Bit 7—A/D End Flag (ADF): Status flag that indicates the end of A/D conversion.

Bit 7 ADF	Description	
0	[Clearing conditions] <ul style="list-style-type: none"> • When 0 is written to the ADF flag after reading ADF = 1 • When the DTC is activated by an ADI interrupt and ADDR is read 	(Initial value)
1	[Setting conditions] <ul style="list-style-type: none"> • 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) requests at the end of A/D conversion.

Bit 6 ADIE	Description	
0	A/D conversion end interrupt (ADI) request disabled	(Initial value)
1	A/D conversion end interrupt (ADI) request enabled	

Bit 5	
ADST	Description
0	• A/D conversion stopped (Initial value)
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.

Bit 4—Scan Mode (SCAN): Selects single mode or scan mode as the A/D conversion operating mode. See section 15.4, Operation, for single mode and scan mode operation. Only set the SCAN bit while conversion is stopped (ADST = 0).

Bit 4	
SCAN	Description
0	Single mode (Initial value)
1	Scan mode

Bit 3—Clock Select (CKS): Sets the A/D conversion time. Only change the conversion time while conversion is stopped (ADST = 0).

Bit 3	
CKS	Description
0	Conversion time = 266 states (max.) (Initial value)
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 channels.

Only set the input channel while conversion is stopped (ADST = 0).

		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	AN4 to AN6
		1	AN7	AN4 to AN7

15.2.3 A/D Control Register (ADCR)

Bit	:	7	6	5	4	3	2	1	0
		TRGS1	TRGS0	—	—	—	—	—	—
Initial value	:	0	0	1	1	1	1	1	1
R/W	:	R/W	R/W	—	—	—	—	—	—

ADCR is an 8-bit readable/writable register that enables or disables external triggering of A/D conversion operations.

ADCR is initialized to H'3F by a reset, and in standby mode or module stop mode.

Bits 7 and 6—Timer Trigger Select 1 and 0 (TRGS1, TRGS0): 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 (ADST = 0).

Bit 7 TRGS1	Bit 6 TRGS0	Description
0	0	A/D conversion start by software is enabled (Initial value)
	1	A/D conversion start by TPU conversion start trigger is enabled
1	0	—
	1	A/D conversion start by external trigger pin ($\overline{\text{ADTRG}}$) is enabled

Bits 5 to 0—Reserved: These bits are reserved; they are always read as 1 and cannot be modified.

--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Initial value : 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1

R/W : R/W

MSTPCR is a 16-bit readable/writable register that performs module stop mode control.

When the MSTP9 bit in MSTPCR is set to 1, A/D converter operation stops at the end of the bus cycle and a transition is made to module stop mode. Registers cannot be read or written to in module stop mode. For details, see section 20.5, 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 9—Module Stop (MSTP9): Specifies the A/D converter module stop mode.

Bit 9

MSTP9	Description
0	A/D converter module stop mode cleared
1	A/D converter module stop mode set (Initial value)

A data read from ADDR is performed as follows. When the upper byte is read, the upper byte value is transferred to the CPU and the lower byte value is transferred to TEMP. Next, when the lower byte is read, the TEMP contents are transferred to the CPU.

When reading ADDR, always read the upper byte before the lower byte. It is possible to read only the upper byte, but if only the lower byte is read, incorrect data may be obtained.

Figure 15-2 shows the data flow for ADDR access.

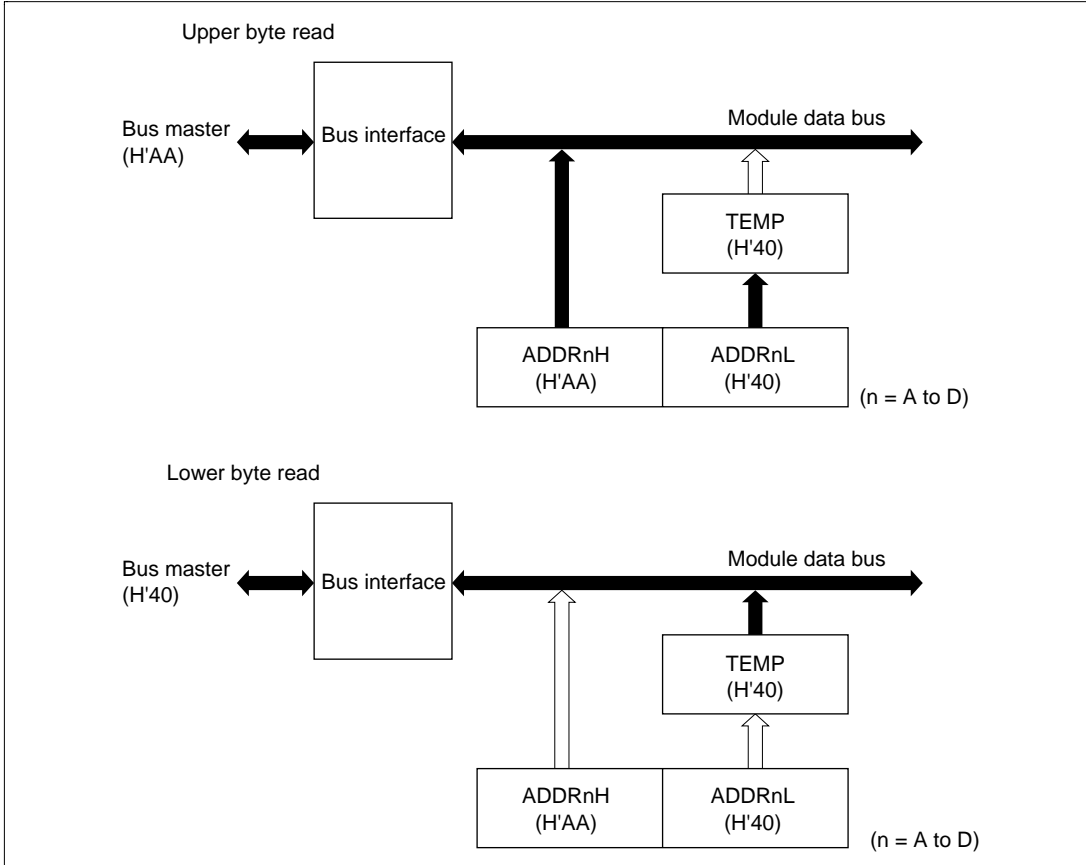


Figure 15-2 ADDR Access Operation (Reading H'AA40)

15.4.1 Single Mode (SCAN = 0)

Single mode is selected when A/D conversion is to be performed on a single channel only. A/D conversion is started when the ADST bit is set to 1, according to the software or external trigger input. 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 ADCSR.

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 channel 1 (AN1) is selected in single mode are described next. Figure 15-3 shows a timing diagram for this example.

- [1] Single mode is selected (SCAN = 0), input channel AN1 is selected (CH2 = 0, CH1 = 0, CH0 = 1), the 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.

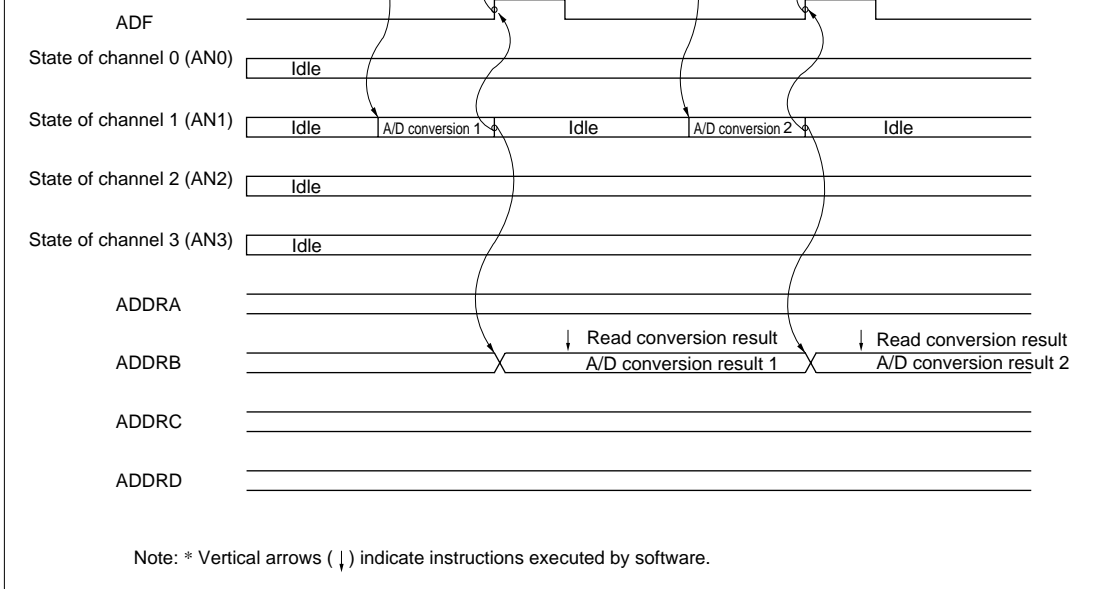


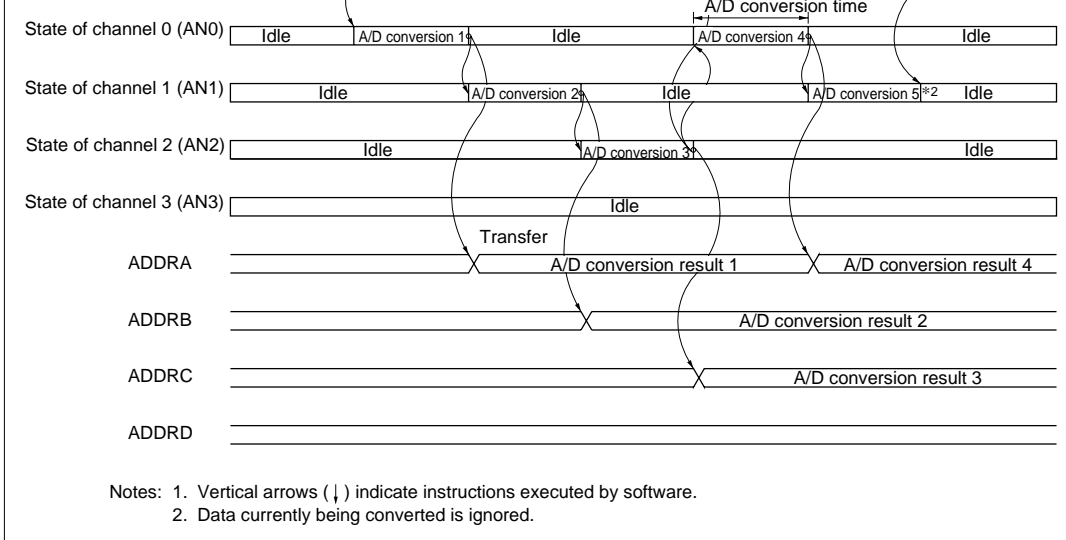
Figure 15-3 Example of A/D Converter Operation (Single Mode, Channel 1 Selected)

first channel ends, conversion of the second channel (AN1) starts immediately. A/D conversion continues cyclically on the selected channels until the ADST bit is cleared to 0. The conversion results are transferred for storage into the ADDR registers corresponding to the channels.

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 15-4 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 (ADST = 1)
- [2] When A/D conversion of the first channel (AN0) is completed, the result is transferred to ADDRA. Next, conversion of the second channel (AN1) starts automatically.
- [3] Conversion proceeds in the same way through the third channel (AN2).
- [4] When conversion of all the selected channels (AN0 to AN2) is completed, the ADF flag is set to 1 and conversion of the first channel (AN0) starts again. If the ADIE bit is set to 1 at this time, an ADI interrupt is requested after A/D conversion ends.
- [5] Steps [2] to [4] are repeated as long as the ADST bit remains set to 1. When the ADST bit is cleared to 0, A/D conversion stops. After that, if the ADST bit is set to 1, A/D conversion starts again from the first channel (AN0).



**Figure 15-4 Example of A/D Converter Operation
(Scan Mode, Channels AN0 to AN2 Selected)**

As indicated in figure 15-5, the A/D conversion time includes t_D and the input sampling time. The length of t_D varies depending on the timing of the write access to ADCSR. The total conversion time therefore varies within the ranges indicated in table 15-4.

In scan mode, the values given in table 15-4 apply to the first conversion time. In the second and subsequent conversions the conversion time is fixed at 256 states when $CKS = 0$ or 128 states when $CKS = 1$.

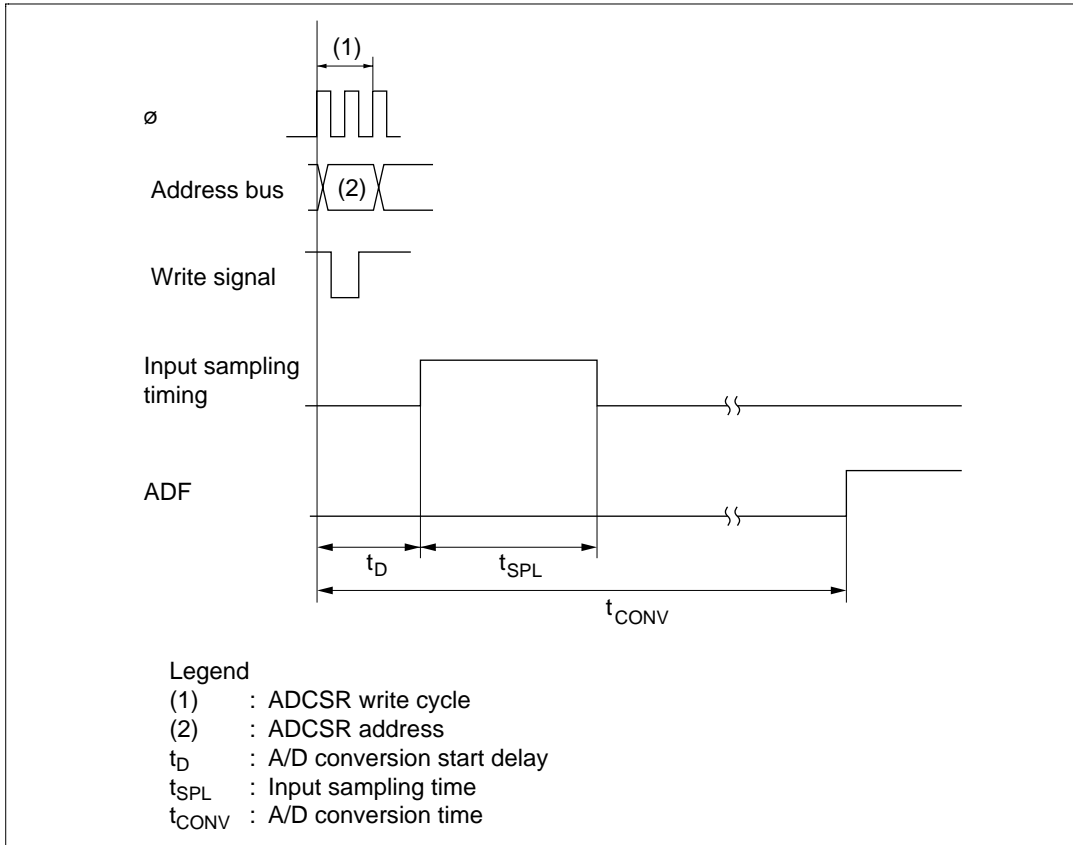


Figure 15-5 A/D Conversion Timing

A/D conversion start delay	t_D	—	10	—	17	0	—	9
Input sampling time	t_{SPL}	—	63	—	—	31	—	—
A/D conversion time	t_{CONV}	259	—	266	131	—	—	134

Note: Values in the table are the number of states.

15.4.4 External Trigger Input Timing

A/D conversion can be externally triggered. When the TRGS1 and TRGS0 bits are set to 11 in ADCR, external trigger input is enabled at the \overline{ADTRG} pin. A falling edge at the \overline{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 if the ADST bit has been set to 1 by software. Figure 15-6 shows the timing.

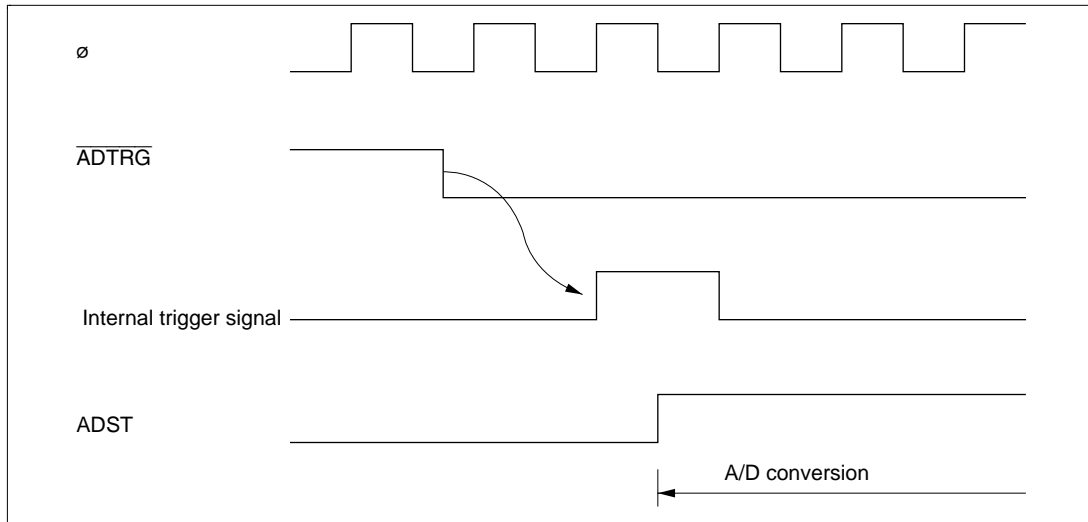


Figure 15-6 External Trigger Input Timing

The DTC or DMAC can be activated by an ADI interrupt. Having the converted data read by the DTC or DMAC in response to an ADI interrupt enables continuous conversion to be achieved without imposing a load on software.

The A/D converter interrupt source is shown in table 15-5.

Table 15-5 A/D Converter Interrupt Source

Interrupt Source	Description	DTC or DMAC Activation
ADI	Interrupt due to end of conversion	Possible

15.6 Usage Notes

The following points should be noted when using the A/D converter.

Setting Range of Analog Power Supply and Other Pins:

(1) Analog input voltage range

The voltage applied to analog input pins AN0 to AN7 during A/D conversion should be in the range $AV_{SS} \leq ANn \leq V_{ref}$.

(2) 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 AV_{CC} and AV_{SS} pins must on no account be left open.

(3) V_{ref} input range

The analog reference voltage input at the V_{ref} pin set in the range $V_{ref} \leq AV_{CC}$.

If conditions (1), (2), and (3) 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.

Notes on Noise Countermeasures: A protection circuit connected to prevent damage due to an abnormal voltage such as an excessive surge at the analog input pins (AN0 to AN7) and analog reference power supply (V_{ref}) should be connected between AV_{CC} and AV_{SS} as shown in figure 15-7.

Also, the bypass capacitors connected to AV_{CC} and V_{ref} and the filter capacitor connected to AN0 to AN7 must be connected to AV_{SS} .

If a filter capacitor is connected as shown in figure 15-7, the input currents at the analog input pins (AN0 to AN7) are averaged, and so an error may arise. Also, when A/D conversion is performed frequently, as in scan mode, if the current charged and discharged by the capacitance of the sample-and-hold circuit in the A/D converter exceeds the current input via the input impedance (R_{in}), an error will arise in the analog input pin voltage. Careful consideration is therefore required when deciding the circuit constants.

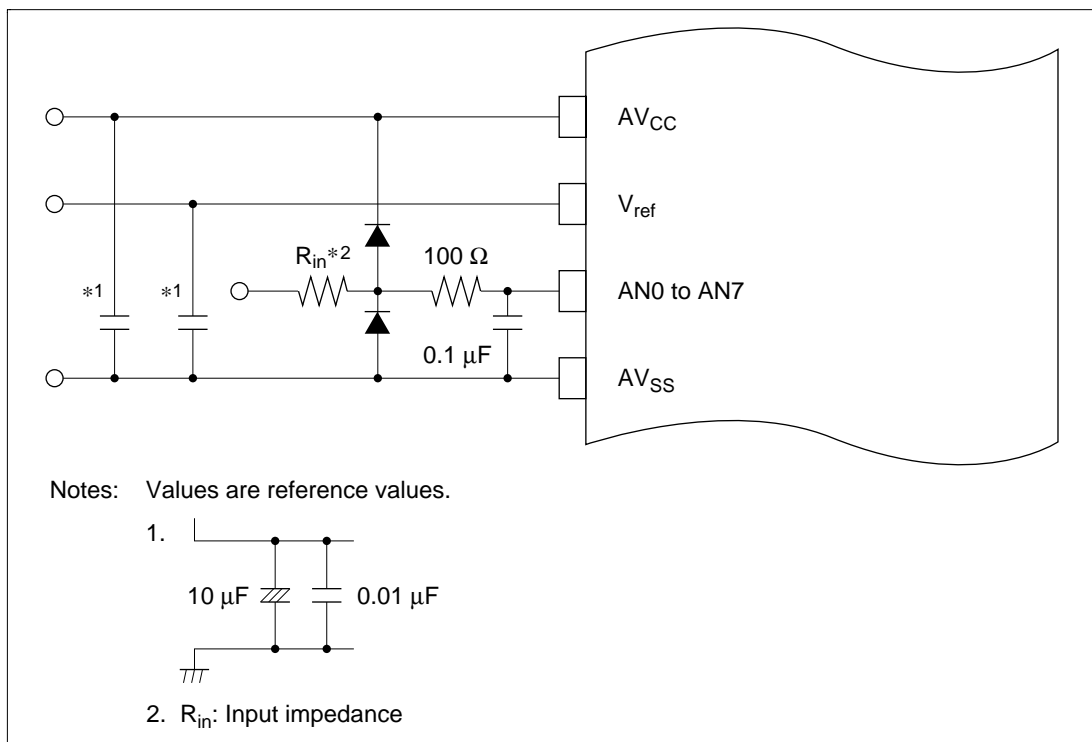
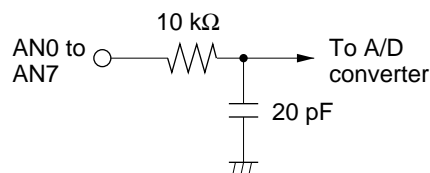


Figure 15-7 Example of Analog Input Protection Circuit

Note: * When $V_{CC} = 4.0\text{ V to }5.5\text{ V}$ and $\phi \leq 12\text{ MHz}$



Note: Values are reference values.

Figure 15-8 Analog Input Pin Equivalent Circuit

A/D Conversion Precision Definitions: H8S/2350 Series A/D conversion precision definitions are given below.

- 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'000000000 (H'000) to B'000000001 (H'001) (see figure 15-10).
- 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'111111110 (H'3FE) to B'111111111 (H'3FF) (see figure 15-10).
- Quantization error
The deviation inherent in the A/D converter, given by 1/2 LSB (see figure 15-9).
- 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.

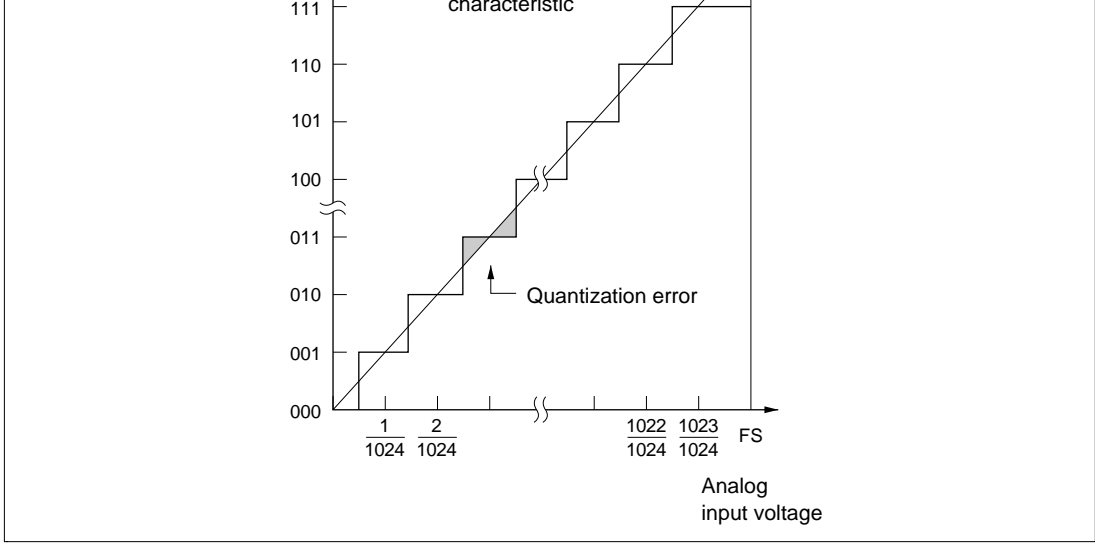


Figure 15-9 A/D Conversion Precision Definitions (1)

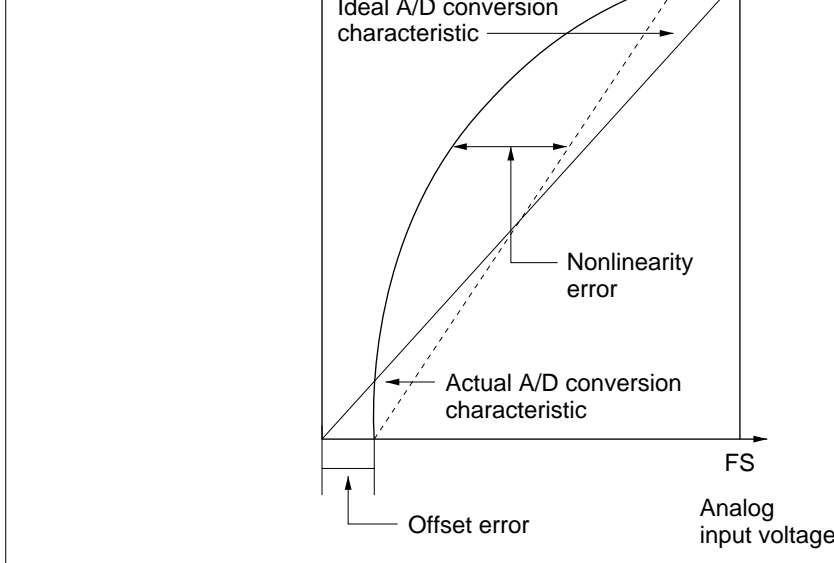


Figure 15-10 A/D Conversion Precision Definitions (2)

Permissible Signal Source Impedance: H8S/2350 Series analog input is designed so that conversion precision is guaranteed for an input signal for which the signal source impedance is 10 k Ω or less. This specification is provided to enable the A/D converter's sample-and-hold circuit input capacitance to be charged within the sampling time; if the sensor output impedance exceeds 10 k Ω , charging may be insufficient and it may not be possible to guarantee the A/D conversion precision.

However, if a large capacitance is provided externally, the input load will essentially comprise only the internal input resistance of 10 k Ω , and the signal source impedance is ignored.

However, since a low-pass filter effect is obtained in this case, it may not be possible to follow an analog signal with a large differential coefficient (e.g., 5 mV/ μ s or greater).

When converting a high-speed analog signal, a low-impedance buffer should be inserted.

mounting board, so acting as antennas.

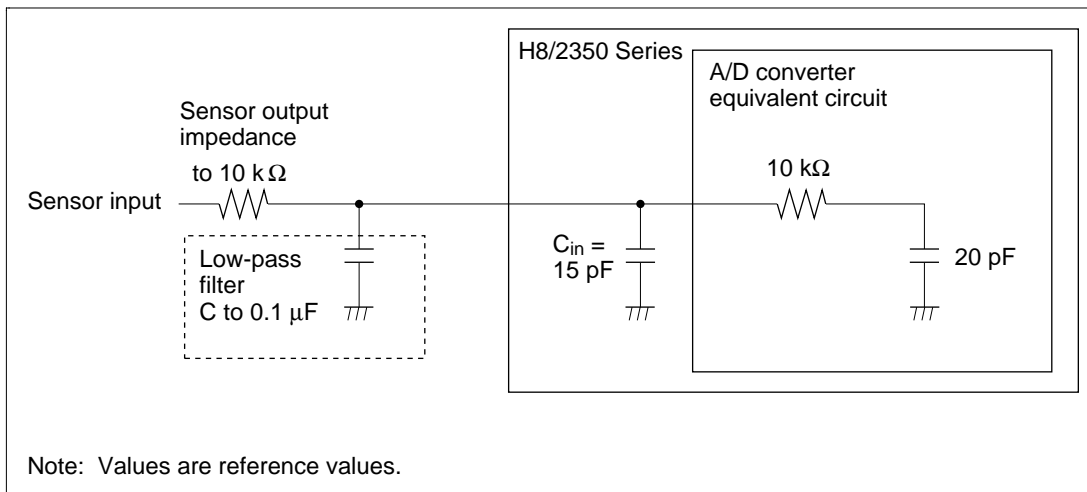


Figure 15-11 Example of Analog Input Circuit

The H8S/2350 Series includes a two-channel D/A converter.

16.1.1 Features

D/A converter features are listed below

- 8-bit resolution
- Two output channels
- Maximum conversion time of 10 μ s (with 20 pF load)
- Output voltage of 0 V to V_{ref}
- D/A output hold function in software standby mode
- Module stop mode can be set
 - As the initial setting, D/A converter operation is halted. Register access is enabled by exiting module stop mode.

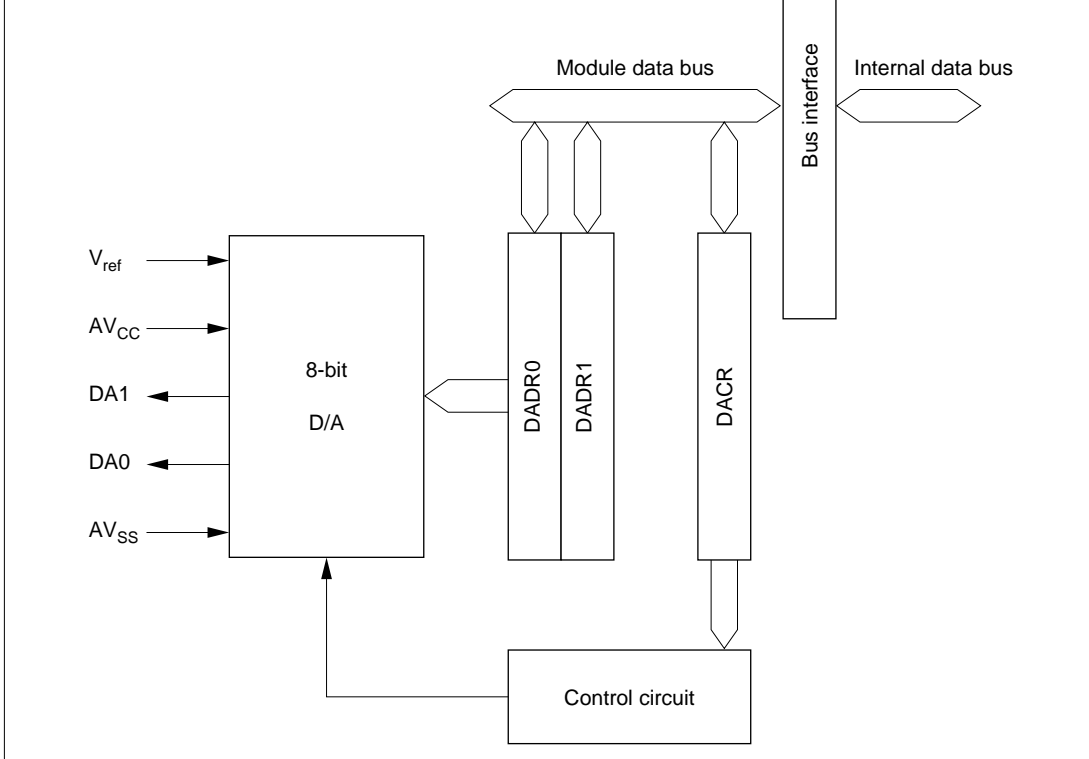


Figure 16-1 Block Diagram of D/A Converter

Pin Name	Symbol	I/O	Function
Analog power pin	AV_{CC}	Input	Analog power source
Analog ground pin	AV_{SS}	Input	Analog ground and reference voltage
Analog output pin 0	DA0	Output	Channel 0 analog output
Analog output pin 1	DA1	Output	Channel 1 analog output
Reference voltage pin	V_{ref}	Input	Analog reference voltage

16.1.4 Register Configuration

Table 16-2 summarizes the registers of the D/A converter.

Table 16-2 D/A Converter Registers

Name	Abbreviation	R/W	Initial Value	Address*
D/A data register 0	DADR0	R/W	H'00	H'FFA4
D/A data register 1	DADR1	R/W	H'00	H'FFA5
D/A control register	DACR	R/W	H'1F	H'FFA6
Module stop control register	MSTPCR	R/W	H'3FFF	H'FF3C

Note:* Lower 16 bits of the address.

Bit	:	7	6	5	4	3	2	1	0
Initial value:		0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

DADR0 and DADR1 are 8-bit readable/writable registers that store data for conversion.

Whenever output is enabled, the values in DADR0 and DADR1 are converted and output from the analog output pins.

DADR0 and DADR1 are each initialized to H'00 by a reset and in hardware standby mode.

16.2.2 D/A Control Register (DACR)

Bit	:	7	6	5	4	3	2	1	0
		DAOE1	DAOE0	DAE	—	—	—	—	—
Initial value:		0	0	0	1	1	1	1	1
R/W	:	R/W	R/W	R/W	—	—	—	—	—

DACR is an 8-bit readable/writable register that controls the operation of the D/A converter.

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 for channel 1.

Bit 7 DAOE1	Description
0	Analog output DA1 is disabled (Initial value)
1	Channel 1 D/A conversion is enabled; analog output DA1 is enabled

0	Analog output DA0 is disabled	(Initial value)
1	Channel 0 D/A conversion is enabled; analog output DA0 is enabled	

Bit 5—D/A Enable (DAE): The DAOE0 and DAOE1 bits both control D/A conversion. When the DAE bit is cleared to 0, the channel 0 and 1 D/A conversions are controlled independently. When the DAE bit is set to 1, the channel 0 and 1 D/A conversions are controlled together.

Output of resultant conversions is always controlled independently by the DAOE0 and DAOE1 bits.

Bit 7 DAOE1	Bit 6 DAOE0	Bit 5 DAE	Description
0	0	*	Channel 0 and 1 D/A conversions disabled
	1	0	Channel 0 D/A conversion enabled Channel 1 D/A conversion disabled
		1	Channel 0 and 1 D/A conversions enabled
1	0	0	Channel 0 D/A conversion disabled Channel 1 D/A conversion enabled
		1	Channel 0 and 1 D/A conversions enabled
	1	*	Channel 0 and 1 D/A conversions enabled

*: Don't care

If the H8S/2350 Series enters software standby mode when D/A conversion is enabled, the D/A output is held and the analog power current is the same as during D/A conversion. When it is necessary to reduce the analog power current in software standby mode, clear both the DAOE0 and DAOE1 bits to 0 to disable D/A output.

Bits 4 to 0—Reserved: Read-only bits, always read as 1.

Initial value	:	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1
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	R/W

MSTPCR is a 16-bit readable/writable register that performs module stop mode control.

When the MSTP10 bit in MSTPCR is set to 1, D/A converter operation stops at the end of the bus cycle and a transition is made to module stop mode. Registers cannot be read or written to in module stop mode. For details, see section 20.5, 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 10—Module Stop (MSTP10): Specifies the D/A converter module stop mode.

Bit 10 MSTP10	Description
0	D/A converter module stop mode cleared
1	D/A converter module stop mode set (Initial value)

D/A conversion is performed continuously while enabled by DACR. If either DADR0 or DADR1 is written to, the new data is immediately converted. The conversion result is output by setting the corresponding DAOE0 or DAOE1 bit to 1.

The operation example described in this section concerns D/A conversion on channel 0. Figure 16-2 shows the timing of this operation.

- [1] Write the conversion data to DADR0.
- [2] Set the DAOE0 bit in DACR to 1. D/A conversion is started and the DA0 pin becomes an output pin. The conversion result is output after the conversion time has elapsed. The output value is expressed by the following formula:

$$\frac{\text{DADR contents}}{256} \times V_{\text{ref}}$$

The conversion results are output continuously until DADR0 is written to again or the DAOE0 bit is cleared to 0.

- [3] If DADR0 is written to again, the new data is immediately converted. The new conversion result is output after the conversion time has elapsed.
- [4] If the DAOE0 bit is cleared to 0, the DA0 pin becomes an input pin.

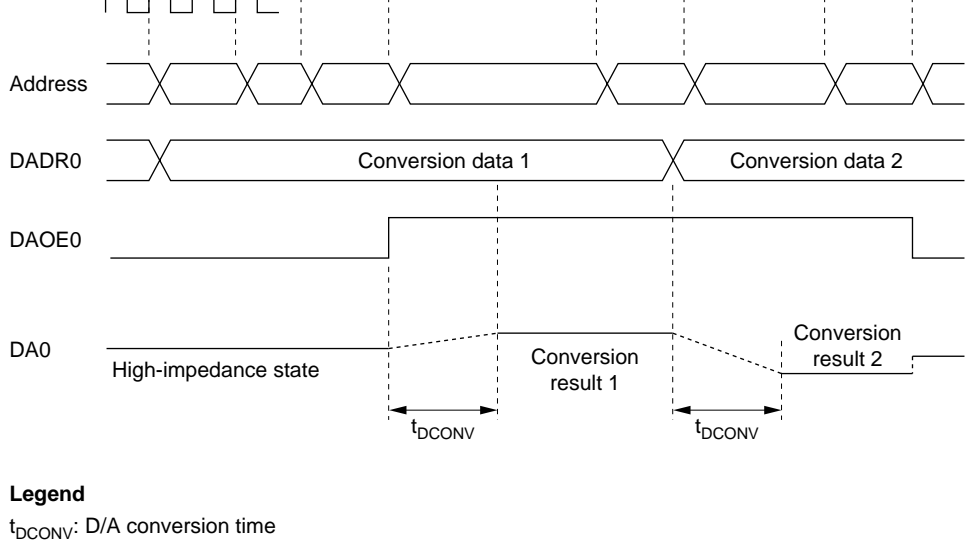


Figure 16-2 Example of D/A Converter Operation

The H8S/2350 Series has 2 kbytes of on-chip high-speed static RAM. The RAM is connected to the CPU by a 16-bit data bus, enabling one-state access by the CPU to both byte data and word data. This 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 (RAME) in the system control register (SYSCR).

17.1.1 Block Diagram

Figure 17-1 shows a block diagram of the on-chip RAM.

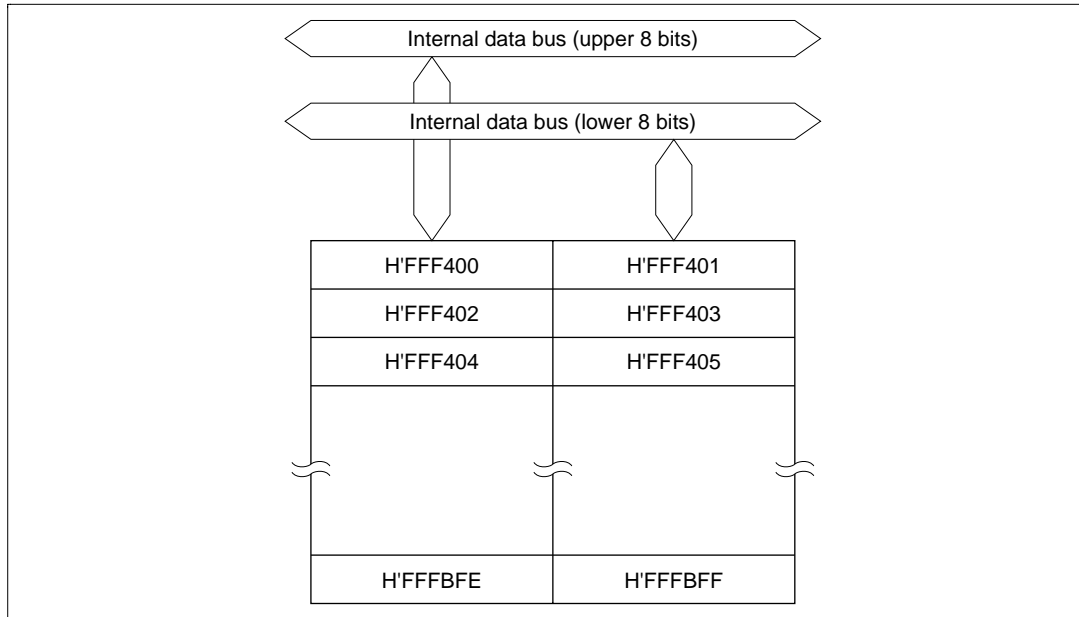


Figure 17-1 Block Diagram of RAM

Table 17-1 RAM Register

Name	Abbreviation	R/W	Initial Value	Address*
System control register	SYSCR	R/W	H'01	H'FF39

Note: * Lower 16 bits of the address.

17.2 Register Descriptions

17.2.1 System Control Register (SYSCR)

Bit	:	7	6	5	4	3	2	1	0
		—	—	INTM1	INTM0	NMIEG	—	—	RAME
Initial value :		0	0	0	0	0	0	0	1
R/W	:	R/W	—	R/W	R/W	R/W	—	R/W	R/W

The on-chip RAM is enabled or disabled by the RAME bit in SYSCR. For details of other bits in 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 is 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 (Initial value)

Since the on-chip RAM is connected to the CPU by an internal 16-bit data bus, it can be written to and read in byte or word units. Each type of access can be performed in one state.

Even addresses use the upper 8 bits, and odd addresses use the lower 8 bits. Word data must start at an even address.

17.4 Usage Note

DTC register information can be located in addresses H'FFF800 to H'FFFBFF. When the DTC is used, the RAME bit must not be cleared to 0.

The H8S/2351 has 64 kbytes of on-chip ROM (mask ROM). The ROM is connected to the H8S/2000 CPU by a 16-bit data bus. The CPU accesses both byte data and word data in one state, making possible rapid instruction fetches and high-speed processing.

The on-chip ROM is enabled or disabled by setting the mode pins (MD₂, MD₁, and MD₀) and bit EAE in BCRL.

18.1.1 Block Diagram

Figure 18-1 shows a block diagram of the on-chip ROM.

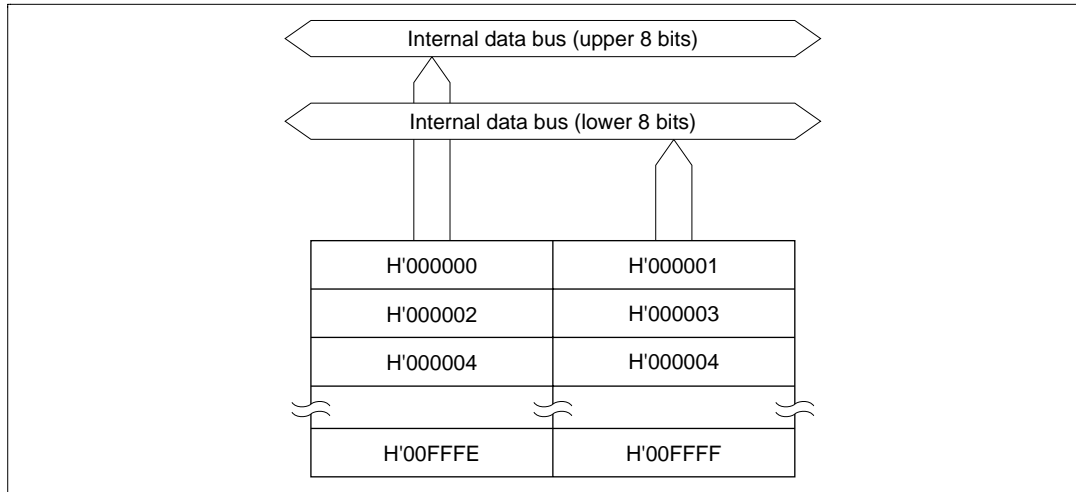


Figure 18-1 Block Diagram of ROM (H8S/2351)

the lower 8 bits. Word data must start at an even address.

The on-chip ROM is enabled and disabled by setting the mode pins (MD₂, MD₁, and MD₀). These settings are shown in table 18-1.

In normal mode, a maximum of 56 kbytes of ROM can be used.

Table 18-1 Operating Modes and ROM Area

Operating Mode	Mode Pin			On-Chip ROM
	MD ₂	MD ₁	MD ₀	
Mode 1 Normal expanded mode with on-chip ROM disabled	0	0	1	Disabled
Mode 2 Normal expanded mode with on-chip ROM enabled		1	0	Enabled (56 kbytes)
Mode 3 Normal single-chip mode			1	
Mode 4 Advanced expanded mode with on-chip ROM disabled	1	0	0	Disabled
Mode 5 Advanced expanded mode with on-chip ROM disabled			1	
Mode 6 Advanced expanded mode with on-chip ROM enabled		1	0	Enabled
Mode 7 Advanced single-chip mode			1	

The H8S/2350 Series has a built-in clock pulse generator (CPG) that generates the system clock (ϕ), the bus master clock, and internal clocks.

The clock pulse generator consists of an oscillator circuit, a duty adjustment circuit, a medium-speed clock divider, and a bus master clock selection circuit.

19.1.1 Block Diagram

Figure 19-1 shows a block diagram of the clock pulse generator.

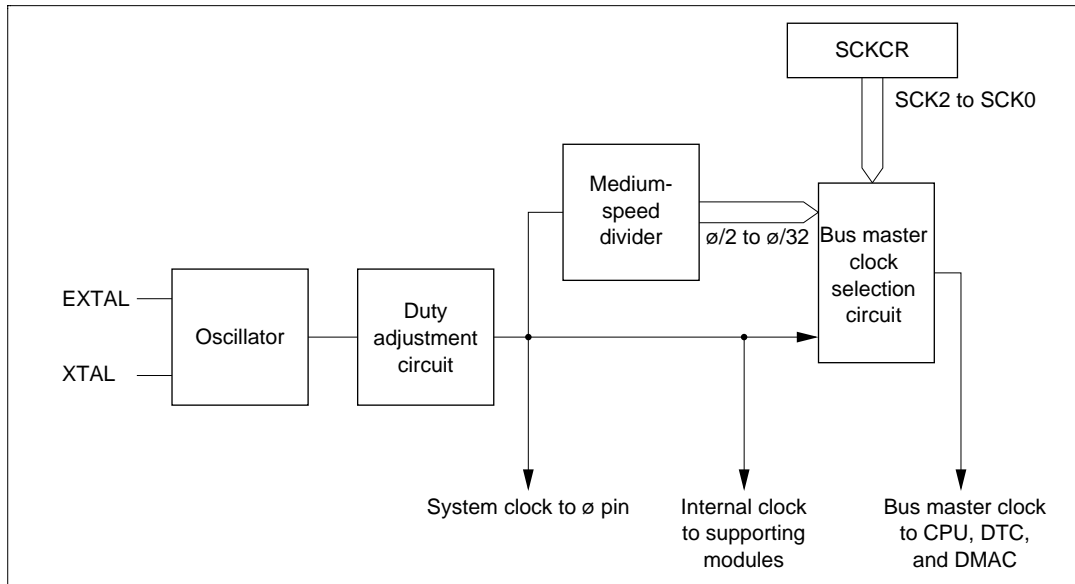


Figure 19-1 Block Diagram of Clock Pulse Generator

Table 17-1 Clock Pulse Generator Register

Name	Abbreviation	R/W	Initial Value	Address*
System clock control register	SCKCR	R/W	H'00	H'FF3A

Note:* Lower 16 bits of the address.

Bit	:	7	6	5	4	3	2	1	0
		PSTOP	—	—	—	—	SCK2	SCK1	SCK0
Initial value:		0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	—	—	—	R/W	R/W	R/W

SCKCR is an 8-bit readable/writable register that performs ϕ clock output control and medium-speed mode control.

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

Bit 7— ϕ Clock Output Disable (PSTOP): Controls ϕ output.

Bit 7 PSTOP	Description			
	Normal Operation	Sleep Mode	Software Standby Mode	Hardware Standby Mode
0	ϕ output (initial value)	ϕ output	Fixed high	High impedance
1	Fixed high	Fixed high	Fixed high	High impedance

Bit 6—Reserved: This bit can be read or written to, but only 0 should be written.

Bits 5 to 3—Reserved: Read-only bits, always read as 0.

Bits 2 to 0—System Clock Select 2 to 0 (SCK2 to SCK0): These bits select the clock for the bus master.

Bit 2 SCK2	Bit 1 SCK1	Bit 0 SCK0	Description
0	0	0	Bus master is in high-speed mode (Initial value)
		1	Medium-speed clock is $\phi/2$
	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	—	—

19.3.1 Connecting a Crystal Resonator

Circuit Configuration: A crystal resonator can be connected as shown in the example in figure 19-2. Select the damping resistance R_d according to table 19-2. An AT-cut parallel-resonance crystal should be used.

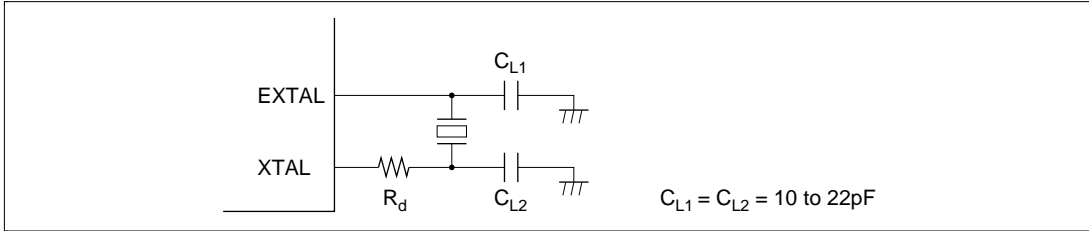


Figure 19-2 Connection of Crystal Resonator (Example)

Table 19-2 Damping Resistance Value

Frequency (MHz)	2	4	8	12	16	20
R_d (Ω)	1k	500	200	0	0	0

Crystal Resonator: Figure 19-3 shows the equivalent circuit of the crystal resonator. Use a crystal resonator that has the characteristics shown in table 19-3 and the same resonance frequency as the system clock (ϕ).

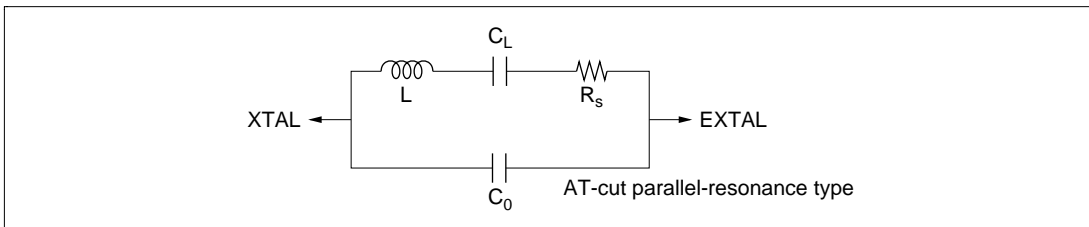


Figure 19-3 Crystal Resonator Equivalent Circuit

Note on Board Design: 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 induction from interfering with correct oscillation. See figure 19-4.

When designing the board, place the crystal resonator and its load capacitors as close as possible to the XTAL and EXTAL pins.

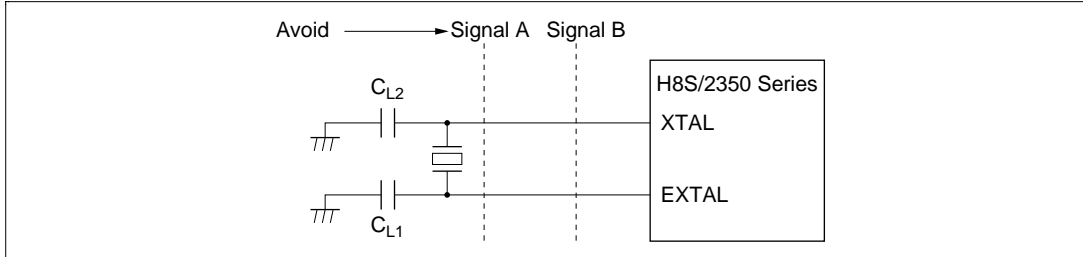


Figure 19-4 Example of Incorrect Board Design

In example (b), make sure that the external clock is held high in standby mode.

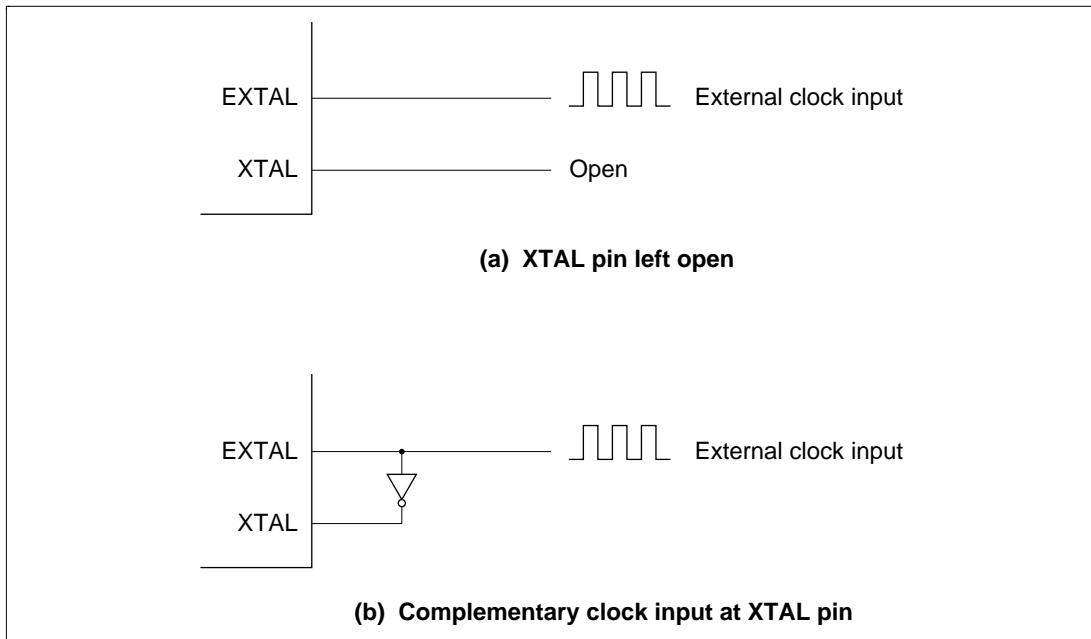


Figure 19-5 External Clock Input (Examples)

External Clock: The external clock signal should have the same frequency as the system clock (ϕ).

Table 19-4 and figure 19-6 show the input conditions for the external clock.

Item	Symbol	Min	Max	Min	Max	Unit	Conditions	
External clock input low pulse width	t_{EXL}	40	—	20	—	ns	Figure 19-6	
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 level	t_{CL}	0.4	0.6	0.4	0.6	t_{cyc}	$\phi \geq 5 \text{ MHz}$	Figure 21-4
		80	—	80	—	ns	$\phi < 5 \text{ MHz}$	
Clock high pulse width level	t_{CH}	0.4	0.6	0.4	0.6	t_{cyc}	$\phi \geq 5 \text{ MHz}$	
		80	—	80	—	ns	$\phi < 5 \text{ MHz}$	

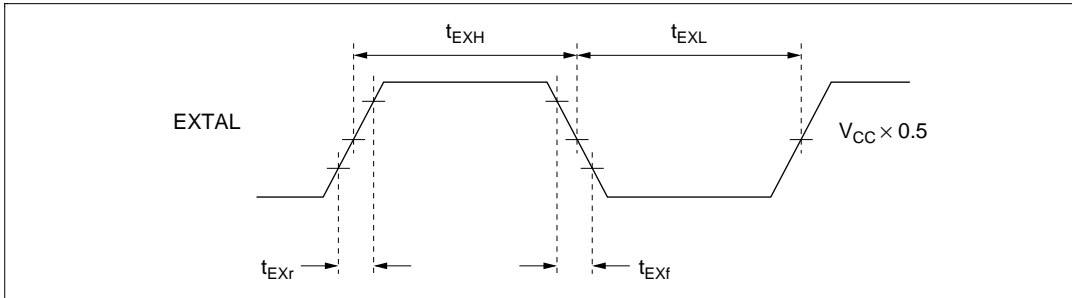


Figure 19-6 External Clock Input Timing

19.5 Medium-Speed Clock Divider

The medium-speed clock divider divides the system clock to generate $\phi/2$, $\phi/4$, $\phi/8$, $\phi/16$, and $\phi/32$.

19.6 Bus Master Clock Selection Circuit

The bus master clock selection circuit selects the system clock (ϕ) or one of the medium-speed clocks ($\phi/2$, $\phi/4$, or $\phi/8$, $\phi/16$, and $\phi/32$) to be supplied to the bus master, according to the settings of the SCK2 to SCK0 bits in SCKCR.

In addition to the normal program execution state, the H8S/2350 Series has five power-down modes in which operation of the CPU and oscillator is halted and power dissipation is reduced. Low-power operation can be achieved by individually controlling the CPU, on-chip supporting modules, and so on.

The H8S/2350 Series operating modes are as follows:

- (1) High-speed mode
- (2) Medium-speed mode
- (3) Sleep mode
- (4) Module stop mode
- (5) Software standby mode
- (6) Hardware standby mode

Of these, (2) to (6) are power-down modes. Sleep mode is a CPU mode, medium-speed mode is a CPU and bus master mode, and module stop mode is an on-chip supporting module mode (including bus masters other than the CPU). A combination of these modes can be set.

After a reset, the H8S/2350 Series is in high-speed mode.

Table 20-1 shows the conditions for transition to the various modes, the status of the CPU, on-chip supporting modules, etc., and the method of clearing each mode.

High speed mode	Control register		Functions	High speed	Functions	High speed	Functions	High speed
Medium-speed mode	Control register		Functions	Medium speed	Functions	High/medium speed * ¹	Functions	High speed
Sleep mode	Instruction	Interrupt	Functions	Halted	Retained	High speed	Functions	High speed
Module stop mode	Control register		Functions	High/medium speed	Functions	Halted	Retained/reset * ²	Retained
Software standby mode	Instruction	External interrupt	Halted	Halted	Retained	Halted	Retained/reset * ²	Retained
Hardware standby mode	Pin		Halted	Halted	Undefined	Halted	Reset	High impedance

- Notes: 1. The bus master operates on the medium-speed clock, and other on-chip supporting modules on the high-speed clock.
2. The SCI and A/D converter are reset, and other on-chip supporting modules retain their state.

20.1.1 Register Configuration

Power-down modes are controlled by the SBYCR, SCKCR, and MSTPCR registers. Table 20-2 summarizes these registers.

Table 20-2 Power-Down Mode Registers

Name	Abbreviation	R/W	Initial Value	Address*
Standby control register	SBYCR	R/W	H'08	H'FF38
System clock control register	SCKCR	R/W	H'00	H'FF3A
Module stop control register H	MSTPCRH	R/W	H'3F	H'FF3C
Module stop control register L	MSTPCRL	R/W	H'FF	H'FF3D

Note: * Lower 16 bits of the address.

Bit	:	7	6	5	4	3	2	1	0
		SSBY	STS2	STS1	STS0	OPE	—	—	—
Initial value	:	0	0	0	0	1	0	0	0
R/W	:	R/W	R/W	R/W	R/W	R/W	—	—	R/W

SBYCR is an 8-bit readable/writable register that performs software standby mode control.

SBYCR is initialized to H'08 by a reset and in hardware standby mode. It is not initialized in software standby mode.

Bit 7—Software Standby (SSBY): Specifies a transition to software standby mode. Remains set to 1 when software standby mode is released by an external interrupt, and a transition is made to normal operation. The SSBY bit should be cleared by writing 0 to it.

Bit 7

SSBY	Description
0	Transition to sleep mode after execution of SLEEP instruction (Initial value)
1	Transition to software standby mode after execution of SLEEP instruction

Bits 6 to 4—Standby Timer Select 2 to 0 (STS2 to STS0): These bits select the time the MCU waits for the clock to stabilize when software standby mode is cleared by an external interrupt. With crystal oscillation, refer to table 20-4 and make a selection according to the operating frequency so that the standby time is at least 8 ms (the oscillation stabilization time). With an external clock, any selection can be made.

Bit 6 STS2	Bit 5 STS1	Bit 4 STS0	Description
0	0	0	Standby time = 8192 states (Initial value)
		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

OPE	Description
0	In software standby mode, address bus and bus control signals are high-impedance
1	In software standby mode, address bus and bus control signals retain output state (Initial value)

Bits 2 and 1—Reserved: Read-only bits, always read as 0.

Bit 0—Reserved: This bit can be read or written to, but only 0 should be written.

20.2.2 System Clock Control Register (SCKCR)

Bit	:	7	6	5	4	3	2	1	0
		PSTOP	—	—	—	—	SCK2	SCK1	SCK0
Initial value	:	0	0	0	0	0	0	0	0
R/W	:	R/W	R/W	—	—	—	R/W	R/W	R/W

SCKCR is an 8-bit readable/writable register that performs ϕ clock output control and medium-speed mode control.

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

Bit 7— ϕ Clock Output Disable (PSTOP): Controls ϕ output.

Bit 7 PSTOP	Description			
	Normal Operating Mode	Sleep Mode	Software Standby Mode	Hardware Standby Mode
0	ϕ output (initial value)	ϕ output	Fixed high	High impedance
1	Fixed high	Fixed high	Fixed high	High impedance

Bits 6—Reserved: This bit can be read or written to, but only 0 should be written.

Bits 5 to 3—Reserved: Read-only bits, always read as 0.

0	0	0	Bus master in high-speed mode	(Initial value)
		1	Medium-speed clock is $\phi/2$	
	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	—	—	

20.2.3 Module Stop Control Register (MSTPCR)

MSTPCRH								MSTPCRL								
Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Initial value	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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	R/W	R/W

MSTPCR is a 16-bit readable/writable register that performs module stop mode control.

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

Bits 15 to 0—Module Stop (MSTP 15 to MSTP 0): These bits specify module stop mode. See table 20-3 for the method of selecting on-chip supporting modules.

Bits 15 to 0

MSTP15 to MSTP0	Description
0	Module stop mode cleared
1	Module stop mode set

the operating clock ($\phi/2$, $\phi/4$, $\phi/8$, $\phi/16$, or $\phi/32$) specified by the SCK2 to SCK0 bits. The bus masters other than the CPU (the DMAC and DTC) also operate in medium-speed mode. On-chip supporting modules other than the bus masters always operate on the high-speed clock (ϕ).

In medium-speed mode, a bus access is executed in the specified number of states with respect to the bus master operating clock. For example, if $\phi/4$ is selected as the operating clock, on-chip memory is accessed in 4 states, and internal I/O registers in 8 states.

Medium-speed mode is cleared by clearing all of bits SCK2 to SCK0 to 0. A transition is made to high-speed mode and medium-speed mode is cleared at the end of the current bus cycle.

If a SLEEP instruction is executed when the SSBY bit in SBYCR is cleared to 0, 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, 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 20-1 shows the timing for transition to and clearance of medium-speed mode.

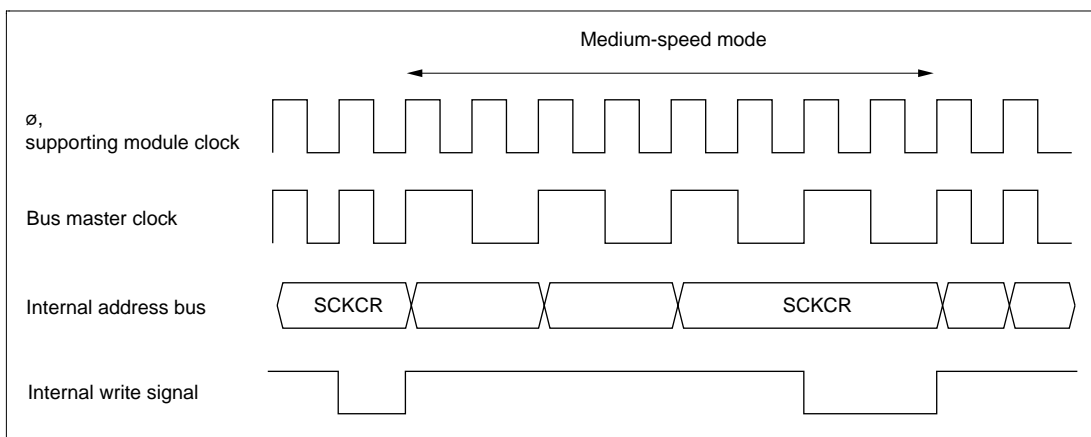


Figure 20-1 Medium-Speed Mode Transition and Clearance Timing

are retained. Other supporting modules do not stop.

Sleep mode is cleared by a reset or any interrupt, and the CPU returns to the normal program execution state via the exception handling state. Sleep mode is not cleared if interrupts are disabled, or if interrupts other than NMI are masked by the CPU.

When the \overline{STBY} pin is driven low, a transition is made to hardware standby mode.

20.5 Module Stop Mode

20.5.1 Module Stop Mode

Module stop mode can be set for individual on-chip supporting modules.

When the corresponding MSTP bit in MSTPCR is set to 1, module operation stops at the end of the bus cycle and a transition is made to module stop mode. The CPU continues operating independently.

Table 20-3 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 at the end of the bus cycle. In module stop mode, the internal states of modules other than the SCI and A/D converter are retained.

After reset clearance, all modules other than DMAC and 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.

Do not make a transition to sleep mode with MSTPCR set to H'FFFF, as this will halt operation of the bus controller.

	MSTP14	Data transfer controller (DTC)
	MSTP13	16-bit timer pulse unit (TPU)
	MSTP12	—
	MSTP11	Programmable pulse generator (PPG)
	MSTP10	D/A converter
	MSTP9	A/D converter
	MSTP8	—
MSTPCR	MSTP7	—
	MSTP6	Serial communication interface (SCI) channel 1
	MSTP5	Serial communication interface (SCI) channel 0
	MSTP4	—
	MSTP3	—
	MSTP2	—
	MSTP1	—
	MSTP0	—

Note: Bits 12, 8, 7, and 4 to 0 can be read or written to, but do not affect operation.

20.5.2 Usage Notes

DMAC/DTC Module Stop: Depending on the operating status of the DMAC or DTC, the MSTP15 and MSTP14 bits may not be set to 1. Setting of the DMAC or DTC module stop mode should be carried out only when the respective module is not activated.

For details, refer to section 7, DMA Controller, and section 8, Data Transfer Controller.

On-Chip Supporting Module Interrupt: Relevant interrupt operations cannot be performed in module stop mode. Consequently, if module stop mode is entered when an interrupt has been requested, it will not be possible to clear the CPU interrupt source or the DMAC or DTC activation source. Interrupts should therefore be disabled before entering module stop mode.

Writing to MSTPCR: MSTPCR should only be written to by the CPU.

If a SLEEP instruction is executed when the SSBY bit in SBYCR is set to 1, software standby mode is entered. In this mode, the CPU, on-chip supporting modules, and oscillator all stop. However, the contents of the CPU's internal registers, RAM data, and the states of on-chip supporting modules other than the SCI and A/D converter, and I/O ports, are retained. Whether the address bus and bus control signals are placed in the high-impedance state or retain the output state can be specified by the OPE bit in SBYCR.

In this mode the oscillator stops, and therefore power dissipation is significantly reduced.

20.6.2 Clearing Software Standby Mode

Software standby mode is cleared by an external interrupt (NMI pin, or pins $\overline{\text{IRQ0}}$ to $\overline{\text{IRQ2}}$), or by means of the $\overline{\text{RES}}$ pin or $\overline{\text{STBY}}$ pin.

- Clearing with an interrupt

When an NMI or IRQ0 to IRQ2 interrupt request signal is input, clock oscillation starts, and after the elapse of the time set in bits STS2 to STS0 in SYSCR, stable clocks are supplied to the entire H8S/2350 Series chip, software standby mode is cleared, and interrupt exception handling is started.

When clearing software standby mode with an IRQ0 to IRQ2 interrupt, set the corresponding enable bit to 1 and ensure that no interrupt with a higher priority than interrupts IRQ0 to IRQ2 is generated. Software standby mode cannot be cleared if the interrupt has been masked on the CPU side or has been designated as a DTC activation source.

- Clearing with the $\overline{\text{RES}}$ pin

When the $\overline{\text{RES}}$ pin is driven low, clock oscillation is started. At the same time as clock oscillation starts, clocks are supplied to the entire H8S/2350 Series chip. Note that the $\overline{\text{RES}}$ pin must be held low until clock oscillation stabilizes. When the $\overline{\text{RES}}$ pin goes high, the CPU begins reset exception handling.

- Clearing with the $\overline{\text{STBY}}$ pin

When the $\overline{\text{STBY}}$ pin is driven low, a transition is made to hardware standby mode.

Using a Crystal Oscillator: Set bits STS2 to STS0 so that the standby time is at least 8 ms (the oscillation stabilization time).

Table 20-4 shows the standby times for different operating frequencies and settings of bits STS2 to STS0.

Table 20-4 Oscillation Stabilization Time Settings

STS2	STS1	STS0	Standby Time	20 MHz	16 MHz	12 MHz	10 MHz	8 MHz	6 MHz	4 MHz	2 MHz	Unit	
0	0	0	8192 states	0.41	0.51	0.68	0.8	1.0	1.3	2.0	4.1	ms	
		1	16384 states	0.82	1.0	1.3	1.6	2.0	2.7	4.1	8.2		
	1	0	32768 states	1.6	2.0	2.7	3.3	4.1	5.5	8.2	16.4		
		1	65536 states	3.3	4.1	5.5	6.6	8.2	10.9	16.4	32.8		
1	0	0	131072 states	6.6	8.2	10.9	13.1	16.4	21.8	32.8	65.5		
		1	262144 states	13.1	16.4	21.8	26.2	32.8	43.6	65.6	131.2		
	1	0	Reserved	—	—	—	—	—	—	—	—		
		1	16 states	0.8	1.0	1.3	1.6	2.0	2.7	4.0	8.0		

 : Recommended time setting

Using an External Clock: Any value can be set. Normally, use of the minimum time is recommended.

20.6.4 Software Standby Mode Application Example

Figure 20-2 shows an example in which a transition is made to software standby mode at the falling edge on the NMI pin, and software standby mode is cleared at the rising edge on the NMI pin.

In this example, an NMI interrupt is accepted with the NMIEG bit in SYSCR cleared to 0 (falling edge specification), then the NMIEG bit is set to 1 (rising edge specification), the SSBY bit is set to 1, and a SLEEP instruction is executed, causing a transition to software standby mode.

Software standby mode is then cleared at the rising edge on the NMI pin.

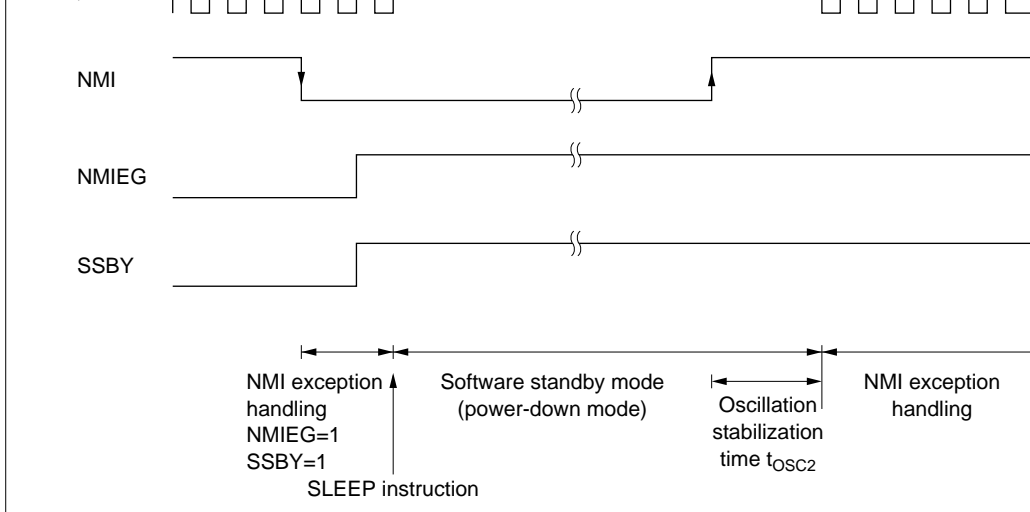


Figure 20-2 Software Standby Mode Application Example

20.6.5 Usage Notes

I/O Port Status: In software standby mode, I/O port states are retained. If the OPE bit is set to 1, the address bus and bus control signal output is also retained. Therefore, there is no reduction in current dissipation for the output current when a high-level signal is output.

Current Dissipation during Oscillation Stabilization Wait Period: Current dissipation increases during the oscillation stabilization wait period.

Write Data Buffer Function: The write data buffer function and software standby mode cannot be used at the same time. When the write data buffer function is used, the WDBE bit in BCRL should be cleared to 0 to cancel the write data buffer function before entering software standby mode. Also check that external writes have finished, by reading external addresses, etc., before executing a SLEEP instruction to enter software standby mode. See section 6.9, Write Data Buffer Function, for details of the write data buffer function.

When the \overline{STBY} pin is driven low, a transition is made to hardware standby mode from any mode.

In hardware standby mode, all functions enter the reset state and stop operation, resulting in a significant reduction in power dissipation. As long as the prescribed voltage is supplied, on-chip RAM data is retained. I/O ports are set to the high-impedance state.

In order to retain on-chip RAM data, the RAME bit in SYSCR should be cleared to 0 before driving the \overline{STBY} pin low.

Do not change the state of the mode pins (MD_2 to MD_0) while the H8S/2350 Series is in hardware standby mode.

Hardware standby mode is cleared by means of the \overline{STBY} pin and the \overline{RES} pin. When the \overline{STBY} pin is driven high while the \overline{RES} pin is low, the reset state is set and clock oscillation is started. Ensure that the \overline{RES} pin is held low until the clock oscillator stabilizes (at least 8 ms—the oscillation stabilization time—when using a crystal oscillator). When the \overline{RES} pin is subsequently driven high, a transition is made to the program execution state via the reset exception handling state.

20.7.2 Hardware Standby Mode Timing

Figure 20-3 shows an example of hardware standby mode timing.

When the \overline{STBY} pin is driven low after the \overline{RES} pin has been driven low, a transition is made to hardware standby mode. Hardware standby mode is cleared by driving the \overline{STBY} pin high, waiting for the oscillation stabilization time, then changing the \overline{RES} pin from low to high.

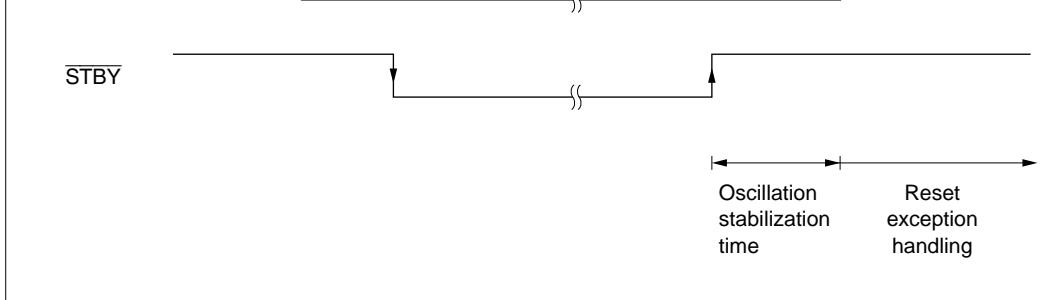


Figure 20-3 Hardware Standby Mode Timing (Example)

20.8 ϕ Clock Output Disabling Function

Output of the ϕ clock can be controlled by means of the PSTOP bit in SCKCR, and DDR for the corresponding port. When the PSTOP bit is set to 1, the ϕ clock stops at the end of the bus cycle, and ϕ output goes high. ϕ clock output is enabled when the PSTOP bit is cleared to 0. When DDR for the corresponding port is cleared to 0, ϕ clock output is disabled and input port mode is set. Table 20-5 shows the state of the ϕ pin in each processing state.

Table 20-5 ϕ Pin State in Each Processing State

DDR	0	1	
PSTOP	—	0	1
Hardware standby mode	High impedance		
Software standby mode	High impedance	Fixed high	
Sleep mode	High impedance	ϕ output	Fixed high
Normal operating state	High impedance	ϕ output	Fixed high

Table 21-1 lists the absolute maximum ratings.

Table 21-1 Absolute Maximum Ratings

Item	Symbol	Value	Unit
Power supply voltage	V_{CC}	-0.3 to +7.0	V
Input voltage (except port 4)	V_{in}	-0.3 to $V_{CC} + 0.3$	V
Input voltage (port 4)	V_{in}	-0.3 to $AV_{CC} + 0.3$	V
Reference voltage	V_{ref}	-0.3 to $AV_{CC} + 0.3$	V
Analog power supply voltage	AV_{CC}	-0.3 to +7.0	V
Analog input voltage	V_{AN}	-0.3 to $AV_{CC} + 0.3$	V
Operating temperature	T_{opr}	Regular specifications: -20 to +75	°C
		Wide-range specifications: -40 to +85	°C
Storage temperature	T_{stg}	-55 to +125	°C

Caution: Permanent damage to the chip may result if absolute maximum rating are exceeded.

Table 21-2 DC Characteristics

Conditions: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{ref} = 4.5 \text{ V}$ to AV_{CC} , $V_{SS} = AV_{SS} = 0 \text{ V}^{*1}$,
 $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications), $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	Port 2,	V_T^-	1.0	—	—	V	
	P6 ₄ to P6 ₇ , PA ₄ to PA ₇	V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	0.4	—	—	V	
Input high voltage	\overline{RES} , \overline{STBY} , NMI, MD ₂ to MD ₀	V_{IH}	$V_{CC} - 0.7$	—	$V_{CC} + 0.3$	V	
	EXTAL		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
	Port 1, 3, 5, B to G, P6 ₀ to P6 ₃ , PA ₀ to PA ₃		2.0	—	$V_{CC} + 0.3$	V	
	Port4		2.0	—	$AV_{CC} + 0.3$	V	
Input low voltage	\overline{RES} , \overline{STBY} , MD ₂ to MD ₀	V_{IL}	-0.3	—	0.5	V	
	NMI, EXTAL, Port 1, 3 to 5, B to G, P6 ₀ to P6 ₃ , PA ₀ to PA ₃		-0.3	—	0.8	V	
Output high voltage	All output pins	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = -200 \mu\text{A}$
			3.5	—	—	V	$I_{OH} = -1 \text{ mA}$
Output low voltage	All output pins	V_{OL}	—	—	0.4	V	$I_{OL} = 1.6 \text{ mA}$
	Port 1, A to C		—	—	1.0	V	$I_{OL} = 10 \text{ mA}$
Input leakage current	\overline{RES}	$ I_{in} $	—	—	10.0	μA	$V_{in} =$ 0.5 to $V_{CC} - 0.5 \text{ V}$
	\overline{STBY} , NMI, MD ₂ to MD ₀		—	—	1.0	μA	
	Port 4		—	—	1.0	μA	$V_{in} =$ 0.5 to $AV_{CC} - 0.5 \text{ V}$

Note: 1. If the A/D and D/A converters are not used, do not leave the AV_{CC} , AV_{SS} , and V_{ref} pins open.

Connect AV_{CC} and V_{ref} to V_{CC} , and connect AV_{SS} to V_{SS} .

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Three-state leakage current (off state)	Port 1 to 3, 5, 6, A to G	$ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
MOS input pull-up current* ⁵	Port A to E	$-I_P$	50	—	300	μA	$V_{in} = 0 \text{ V}$
Input capacitance	$\overline{\text{RES}}$	C_{in}	—	—	80	pF	$V_{in} = 0 \text{ V}$ $f = 1 \text{ MHz}$ $T_a = 25^\circ\text{C}$
	NMI		—	—	50	pF	
	All input pins except $\overline{\text{RES}}$ and NMI		—	—	15	pF	
Current dissipation* ²	Normal operation	I_{CC} * ⁴	—	60 (5.0 V)	95	mA	$f = 20 \text{ MHz}$
	Sleep mode		—	45 (5.0 V)	78	mA	$f = 20 \text{ MHz}$
	Standby mode* ³		—	0.01	5.0	μA	$T_a \leq 50^\circ\text{C}$
Analog power supply current	During A/D and D/A conversion	AI_{CC}	—	0.8 (5.0 V)	2.0	mA	
	Idle		—	0.01	5.0	μA	
Reference current	During A/D and D/A conversion	AI_{CC}	—	1.9 (5.0 V)	3.0	mA	
	Idle		—	0.01	5.0	μA	
RAM standby voltage		V_{RAM}	2.0	—	—	V	

Notes: 1. If the A/D and D/A converters are not used, do not leave the AV_{CC} , AV_{SS} , and V_{ref} pins open.

Connect AV_{CC} and V_{ref} to V_{CC} , and connect AV_{SS} to V_{SS} .

2. Current dissipation values are for $V_{IH} \text{ min} = V_{CC} - 0.5 \text{ V}$ and $V_{IL} \text{ max} = 0.5 \text{ V}$ with all output pins unloaded and the on-chip pull-up transistors in the off state.

3. The values are for $V_{RAM} \leq V_{CC} < 4.5 \text{ V}$, $V_{IH} \text{ min} = V_{CC} \times 0.9$, and $V_{IL} \text{ max} = 0.3 \text{ V}$.

4. I_{CC} depends on V_{CC} and f as follows:

$I_{CC} \text{ max} = 1.0 \text{ (mA)} + 0.85 \text{ (mA/(MHz} \times \text{V))} \times V_{CC} \times f$ [normal mode]

$I_{CC} \text{ max} = 1.0 \text{ (mA)} + 0.7 \text{ (mA/(MHz} \times \text{V))} \times V_{CC} \times f$ [sleep mode]

5. Only applies to the H8S/2351.

Item		Symbol	Min	Typ	Max	Unit	Test Conditions
Schmitt trigger input voltage	Port 2, P6 ₄ to P6 ₇ , PA ₄ to PA ₇	V_T^-	$V_{CC} \times 0.2$	—	—	V	
		V_T^+	—	—	$V_{CC} \times 0.7$	V	
		$V_T^+ - V_T^-$	$V_{CC} \times 0.07$	—	—	V	
Input high voltage	\overline{RES} , \overline{STBY} , NMI, MD ₂ to MD ₀	V_{IH}	$V_{CC} \times 0.9$	—	$V_{CC} + 0.3$	V	
	EXTAL		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
	Port 1, 3, 5, B to G, P6 ₀ to P6 ₃ , PA ₀ to PA ₃		$V_{CC} \times 0.7$	—	$V_{CC} + 0.3$	V	
	Port 4		$V_{CC} \times 0.7$	—	$AV_{CC} + 0.3$	V	
Input low voltage	\overline{RES} , \overline{STBY} , MD ₂ to MD ₀	V_{IL}	-0.3	—	$V_{CC} \times 0.1$	V	
	NMI, EXTAL, Port 1, 3 to 5, B to G, P6 ₀ to P6 ₃ , PA ₀ to PA ₃		-0.3	—	$V_{CC} \times 0.2$	V	$V_{CC} < 4.0$ V
					0.8		$V_{CC} = 4.0$ to 5.5 V
Output high voltage	All output pins	V_{OH}	$V_{CC} - 0.5$	—	—	V	$I_{OH} = -200$ μ A
			$V_{CC} - 1.0$	—	—	V	$I_{OH} = -1$ mA
Output low voltage	All output pins	V_{OL}	—	—	0.4	V	$I_{OL} = 1.6$ mA
	Port 1, A to C		—	—	1.0	V	$V_{CC} \leq 4$ V $I_{OL} = 5$ mA $4.0 < V_{CC} \leq 5.5$ V $I_{OL} = 10$ mA
Input leakage current	\overline{RES}	$ I_{in} $	—	—	10.0	μ A	$V_{in} =$
	\overline{STBY} , NMI, MD ₂ to MD ₀		—	—	1.0	μ A	0.5 to $V_{CC} - 0.5$ V
	Port 4		—	—	1.0	μ A	$V_{in} =$ 0.5 to $AV_{CC} - 0.5$ V

Note: 1. If the A/D and D/A converters are not used, do not leave the AV_{CC} , AV_{SS} , and V_{ref} pins open.

Connect AV_{CC} and V_{ref} to V_{CC} , and connect AV_{SS} to V_{SS} .

Item	Symbol	Min	Typ	Max	Unit	Test Conditions
Three-state leakage current (off state)	Port 1 to 3, 5, 6, A to G $ I_{TSI} $	—	—	1.0	μA	$V_{in} = 0.5 \text{ to } V_{CC} - 0.5 \text{ V}$
MOS input pull-up current* ⁵	Port A to E $-I_P$	10	—	300	μA	$V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}, V_{in} = 0 \text{ V}$
Input capacitance	$\overline{\text{RES}}$ C_{in}	—	—	80	pF	$V_{in} = 0 \text{ V}$ $f = 1 \text{ MHz}$ $T_a = 25^\circ\text{C}$
	NMI	—	—	50	pF	
	All input pins except $\overline{\text{RES}}$ and NMI	—	—	15	pF	
Current dissipation* ²	Normal operation	I_{CC}^{*4}	—	20 (3.0 V)	48	mA $f = 10 \text{ MHz}$
	Sleep mode		—	12 (3.0 V)	40	mA $f = 10 \text{ MHz}$
	Standby mode* ³		—	0.01 —	5.0 20	μA $T_a \leq 50^\circ\text{C}$ $50^\circ\text{C} < T_a$
Analog power supply current	During A/D and D/A conversion	$A I_{CC}$	—	0.2 (3.0 V)	2.0	mA
	Idle		—	0.01	5.0	μA
Reference current	During A/D and D/A conversion	$A I_{CC}$	—	1.2 (3.0 V)	3.0	mA
	Idle		—	0.01	5.0	μA
RAM standby voltage	V_{RAM}	2.0	—	—	V	

Notes: 1. If the A/D and D/A converters are not used, do not leave the AV_{CC} , AV_{SS} , and V_{ref} pins open.

Connect AV_{CC} and V_{ref} to V_{CC} , and connect AV_{SS} to V_{SS} .

- Current dissipation values are for $V_{IH} \text{ min} = V_{CC} - 0.5 \text{ V}$ and $V_{IL} \text{ max} = 0.5 \text{ V}$ with all output pins unloaded and the on-chip pull-up transistors in the off state.
- The values are for $V_{RAM} \leq V_{CC} < 2.7 \text{ V}$, $V_{IH} \text{ min} = V_{CC} \times 0.9$, and $V_{IL} \text{ max} = 0.3 \text{ V}$.
- I_{CC} depends on V_{CC} and f as follows:
 $I_{CC} \text{ max} = 1.0 \text{ (mA)} + 0.85 \text{ (mA/(MHz} \times \text{V))} \times V_{CC} \times f$ [normal mode]
 $I_{CC} \text{ max} = 1.0 \text{ (mA)} + 0.70 \text{ (mA/(MHz} \times \text{V))} \times V_{CC} \times f$ [sleep mode]
- Only applies to the H8S/2351.

Item		Symbol	Min	Typ	Max	Unit
Permissible output low current (per pin)	Port 1, A to C	I_{OL}	—	—	10	mA
	Other output pins		—	—	2.0	mA
Permissible output low current (total)	Total of 32 pins including port 1 and A to C	ΣI_{OL}	—	—	80	mA
	Total of all output pins, including the above		—	—	120	mA
Permissible output high current (per pin)	All output pins	$-I_{OH}$	—	—	2.0	mA
Permissible output high current (total)	Total of all output pins	$\Sigma -I_{OH}$	—	—	40	mA

- Notes: 1. To protect chip reliability, do not exceed the output current values in table 21-3.
2. When driving a darlington pair or LED directly, always insert a current-limiting resistor in the output line, as show in figures 21-1 and 21-2.

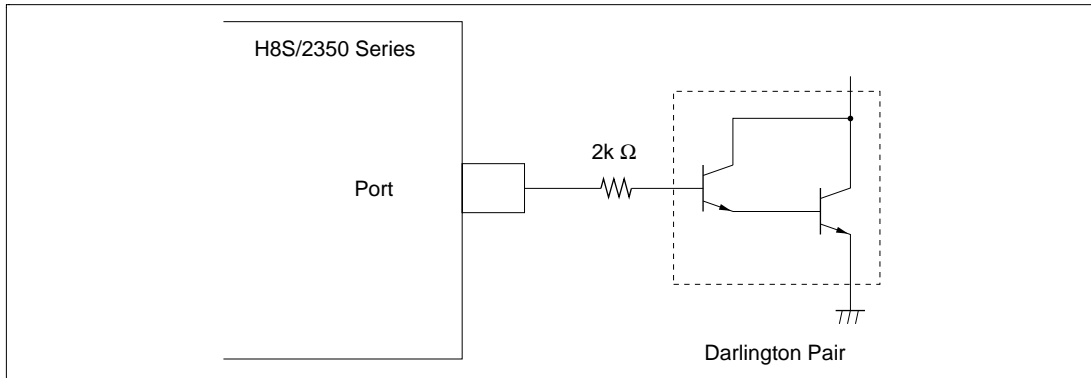


Figure 21-1 Darlington Pair Drive Circuit (Example)

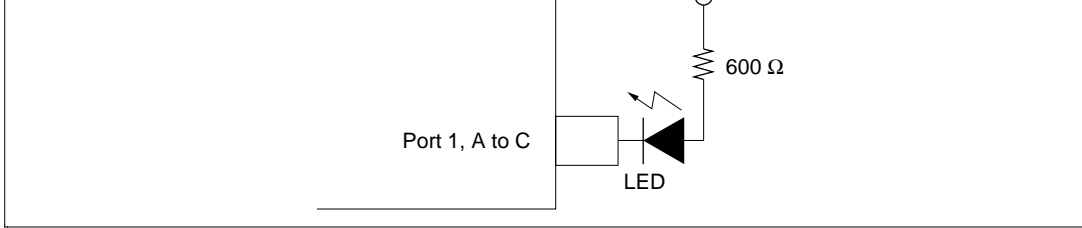


Figure 21-2 LED Drive Circuit (Example)

21.3 AC Characteristics

Figure 21-3 show, the test conditions for the AC characteristics.

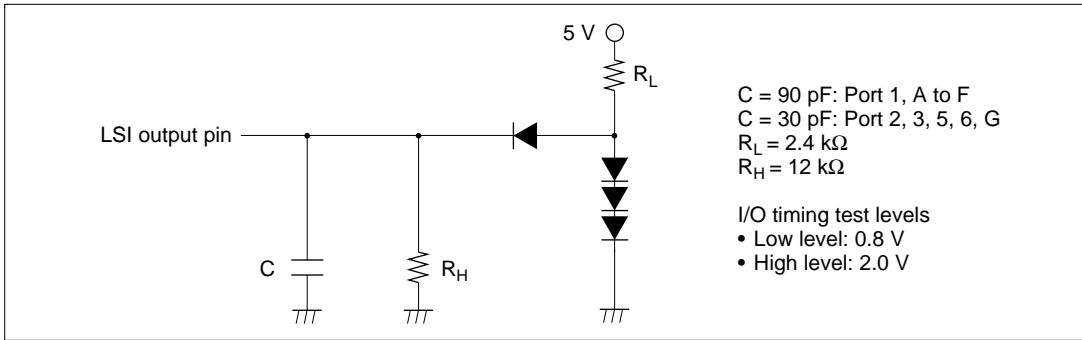


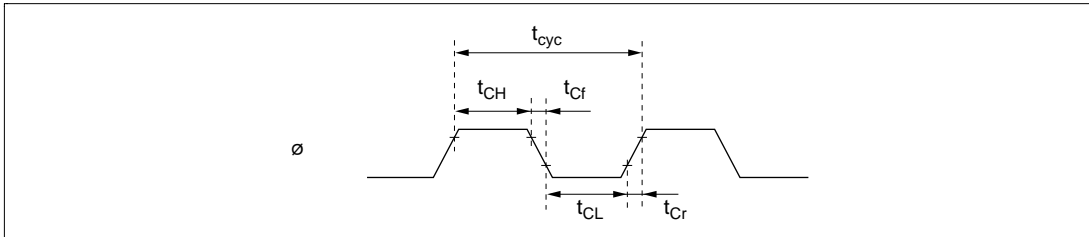
Figure 21-3 Output Load Circuit

Table 21-4 Clock Timing

Condition A: $V_{CC} = 2.7$ to 5.5 V, $AV_{CC} = 2.7$ to 5.5 V, $V_{ref} = 2.7$ V to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0$ V, $\phi = 2$ to 10 MHz, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 5.0$ V $\pm 10\%$, $AV_{CC} = 5.0$ V $\pm 10\%$, $V_{ref} = 4.5$ V to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0$ V, $\phi = 2$ to 20 MHz, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Condition A		Condition B		Unit	Test Conditions
		Min	Max	Min	Max		
Clock cycle time	t_{cyc}	100	500	50	500	ns	Figure 21-4
Clock high pulse width	t_{CH}	35	—	20	—	ns	Figure 21-4
Clock low pulse width	t_{CL}	35	—	20	—	ns	
Clock rise time	t_{Cr}	—	15	—	5	ns	
Clock fall time	t_{Cf}	—	15	—	5	ns	
Clock oscillator setting time at reset (crystal)	t_{OSC1}	20	—	10	—	ms	Figure 21-5
Clock oscillator setting time in software standby (crystal)	t_{OSC2}	20	—	10	—	ms	Figure 20-2
External clock output stabilization delay time	t_{DEXT}	500	—	500	—	μs	Figure 21-5

**Figure 21-4 System Clock Timing**

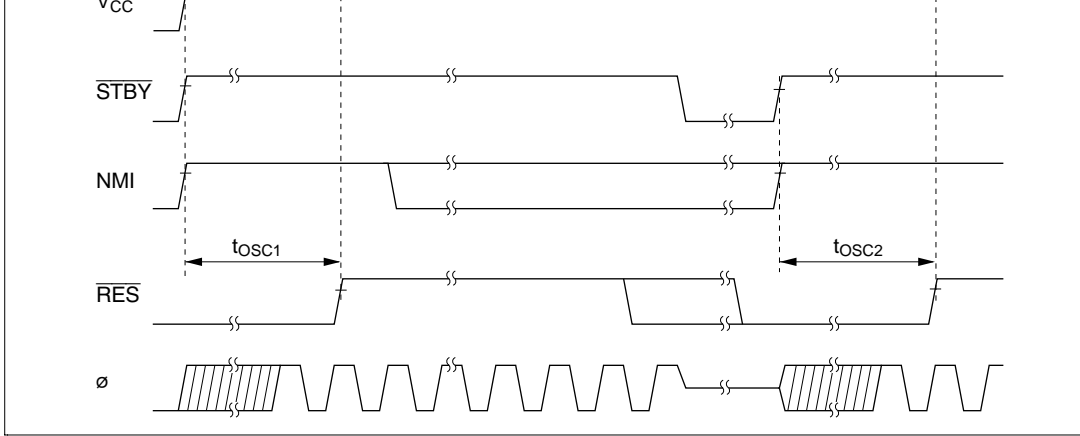


Figure 21-5 Oscillator Settling Timing

Table 21-5 Control Signal Timing

Condition A: $V_{CC} = 2.7$ to 5.5 V, $AV_{CC} = 2.7$ to 5.5 V, $V_{ref} = 2.7$ V to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0$ V, $\phi = 2$ to 10 MHz, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 5.0$ V \pm 10%, $AV_{CC} = 5.0$ V \pm 10%, $V_{ref} = 4.5$ V to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0$ V, $\phi = 2$ to 20 MHz, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Condition A		Condition B		Unit	Test Conditions
		Min	Max	Min	Max		
$\overline{\text{RES}}$ setup time	t_{RESS}	200	—	200	—	ns	Figure 21-6
$\overline{\text{RES}}$ pulse width	t_{RESW}	20	—	20	—	t_{cyc}	
NMI reset setup time	t_{NMIRS}	250	—	200	—	ns	
NMI reset hold time	t_{NMIRH}	200	—	200	—		
NMI setup time	t_{NMIS}	250	—	150	—	ns	Figure 21-7
NMI hold time	t_{NMIH}	10	—	10	—		
NMI pulse width (exiting software standby mode)	t_{NMIW}	200	—	200	—	ns	
$\overline{\text{IRQ}}$ setup time	t_{IRQS}	250	—	150	—	ns	
$\overline{\text{IRQ}}$ hold time	t_{IRQH}	10	—	10	—	ns	
$\overline{\text{IRQ}}$ pulse width (exiting software standby mode)	t_{IRQW}	200	—	200	—	ns	

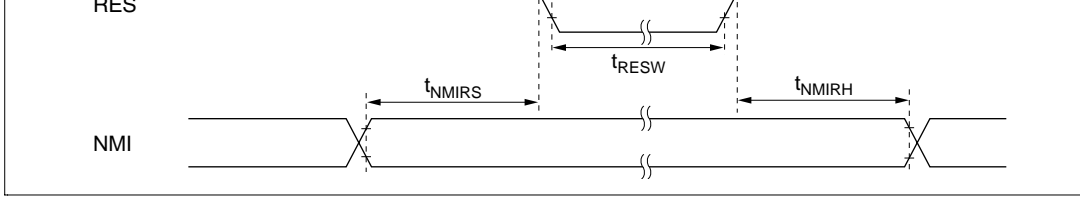


Figure 21-6 Reset Input Timing

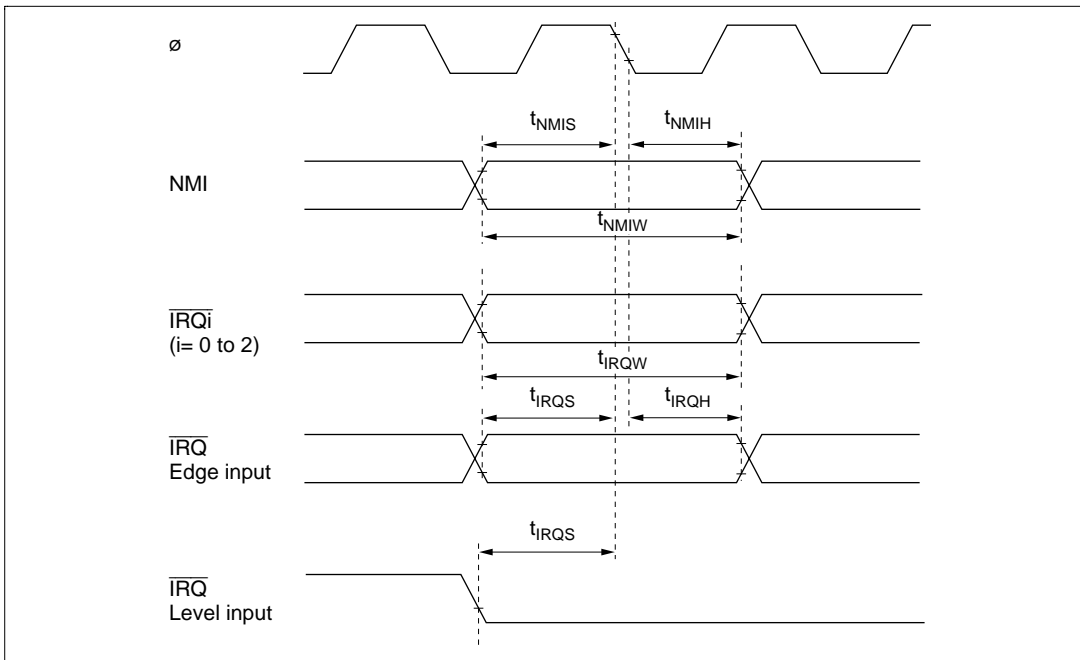


Figure 21-7 Interrupt Input Timing

Table 21-6 Bus Timing

Condition A: $V_{CC} = 2.7$ to 5.5 V, $AV_{CC} = 2.7$ to 5.5 V, $V_{ref} = 2.7$ V to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0$ V, $\phi = 2$ to 10 MHz, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 5.0$ V $\pm 10\%$, $AV_{CC} = 5.0$ V $\pm 10\%$, $V_{ref} = 4.5$ V to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0$ V, $\phi = 2$ to 20 MHz, $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Condition A		Condition B		Unit	Test Conditions
		Min	Max	Min	Max		
Address delay time	t_{AD}	—	40	—	20	ns	Figure 21-8 to
Address setup time	t_{AS}	$0.5 \times$ $t_{cyc} - 30$	—	$0.5 \times$ $t_{cyc} - 15$	—	ns	Figure 21-15
Address hold time	t_{AH}	$0.5 \times$ $t_{cyc} - 20$	—	$0.5 \times$ $t_{cyc} - 10$	—	ns	
Precharge time	t_{PCH}	$1.5 \times$ $t_{cyc} - 40$	—	$1.5 \times$ $t_{cyc} - 20$	—	ns	
\overline{CS} delay time 1	t_{CSD1}	—	40	—	20	ns	
\overline{CS} delay time 2	t_{CSD2}	—	40	—	20	ns	
\overline{AS} delay time	t_{ASD}	—	40	—	20	ns	
\overline{RD} delay time 1	t_{RSD1}	—	40	—	20	ns	
\overline{RD} delay time 2	t_{RSD2}	—	40	—	20	ns	
\overline{CAS} delay time	t_{CASD}	—	40	—	20	ns	
Read data setup time	t_{RDS}	30	—	15	—	ns	
Read data hold time	t_{RDH}	0	—	0	—	ns	
Read data access time1	t_{ACC1}	—	$1.0 \times$ $t_{cyc} - 50$	—	$1.0 \times$ $t_{cyc} - 25$	ns	
Read data access time2	t_{ACC2}	—	$1.5 \times$ $t_{cyc} - 50$	—	$1.5 \times$ $t_{cyc} - 25$	ns	
Read data access time3	t_{ACC3}	—	$2.0 \times$ $t_{cyc} - 50$	—	$2.0 \times$ $t_{cyc} - 25$	ns	

Condition B: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{ref} = 4.5 \text{ V}$ to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2$ to 20 MHz , $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Condition A		Condition B		Unit	Test Conditions
		Min	Max	Min	Max		
Read data access time 4	t_{ACC4}	—	$2.5 \times t_{cyc} - 50$	—	$2.5 \times t_{cyc} - 25$	ns	Figure 21-8 to Figure 21-15
Read data access time 5	t_{ACC5}	—	$3.0 \times t_{cyc} - 50$	—	$3.0 \times t_{cyc} - 25$	ns	
\overline{WR} delay time 1	t_{WRD1}	—	40	—	20	ns	
\overline{WR} delay time 2	t_{WRD2}	—	40	—	20	ns	
\overline{WR} pulse width 1	t_{WSW1}	$1.0 \times t_{cyc} - 40$	—	$1.0 \times t_{cyc} - 20$	—	ns	
\overline{WR} pulse width 2	t_{WSW2}	$1.5 \times t_{cyc} - 40$	—	$1.5 \times t_{cyc} - 20$	—	ns	
Write data delay time	t_{WDD}	—	60	—	30	ns	
Write data setup time	t_{WDS}	$0.5 \times t_{cyc} - 40$	—	$0.5 \times t_{cyc} - 20$	—	ns	
Write data hold time	t_{WDH}	$0.5 \times t_{cyc} - 20$	—	$0.5 \times t_{cyc} - 10$	—	ns	
\overline{WR} setup time	t_{WCS}	$0.5 \times t_{cyc} - 20$	—	$0.5 \times t_{cyc} - 10$	—	ns	
\overline{WR} hold time	t_{WCH}	$0.5 \times t_{cyc} - 20$	—	$0.5 \times t_{cyc} - 10$	—	ns	
\overline{CAS} setup time	t_{CSR}	$0.5 \times t_{cyc} - 20$	—	$0.5 \times t_{cyc} - 10$	—	ns	Figure 21-12
\overline{WAIT} setup time	t_{WTS}	60	—	30	—	ns	Figure 21-10
\overline{WAIT} hold time	t_{WTH}	10	—	5	—	ns	
\overline{BREQ} setup time	t_{BRQS}	60	—	30	—	ns	Figure 21-16
\overline{BACK} delay time	t_{BACD}	—	30	—	15	ns	
Bus-floating time	t_{BZD}	—	100	—	50	ns	
\overline{BREQO} delay time	t_{BRQOD}	—	60	—	30	ns	Figure 21-17

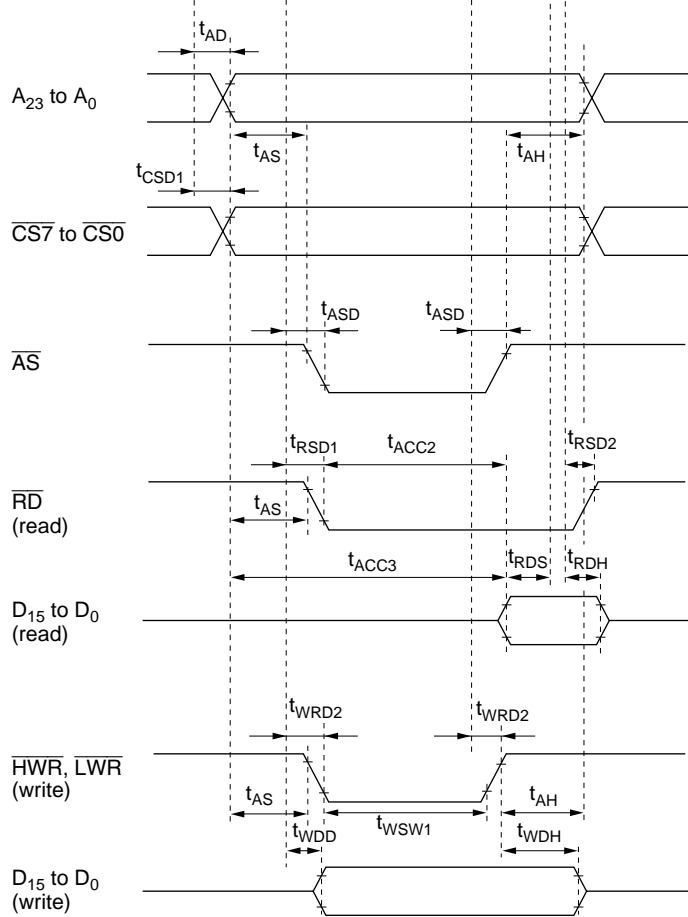


Figure 21-8 Basic Bus Timing (Two-State Access)

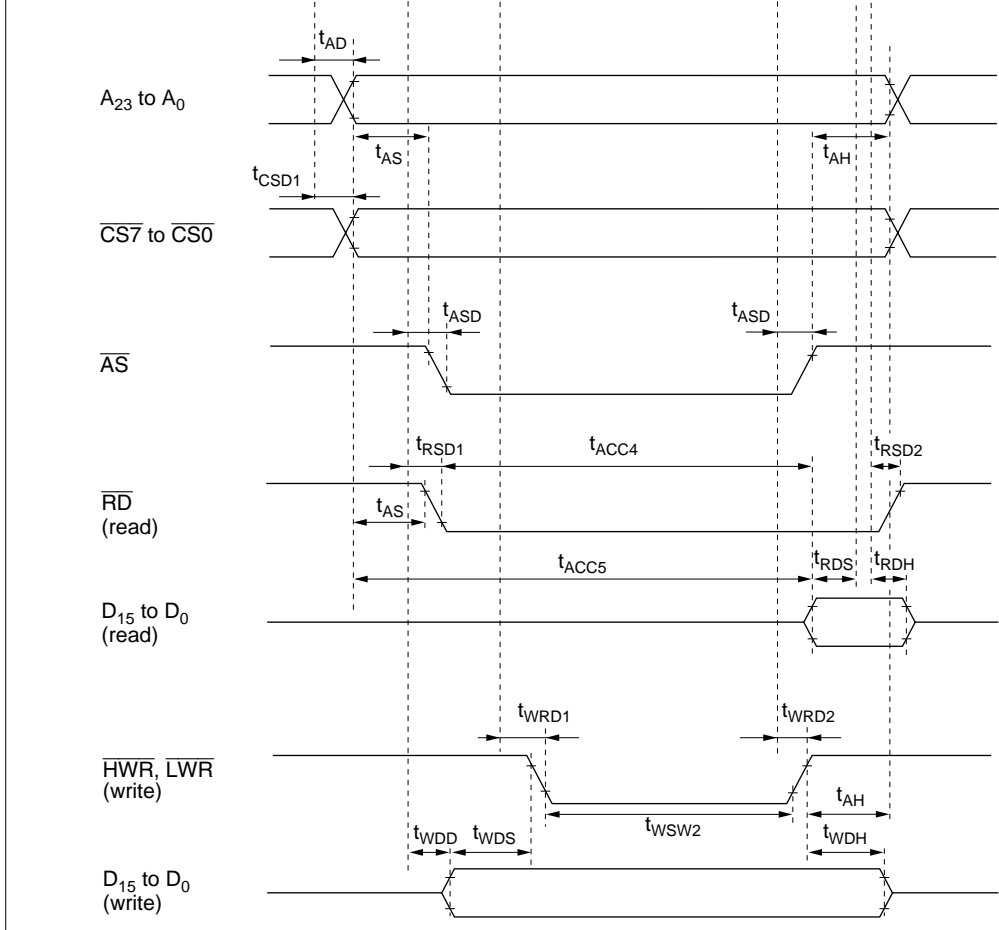


Figure 21-9 Basic Bus Timing (Three-State Access)

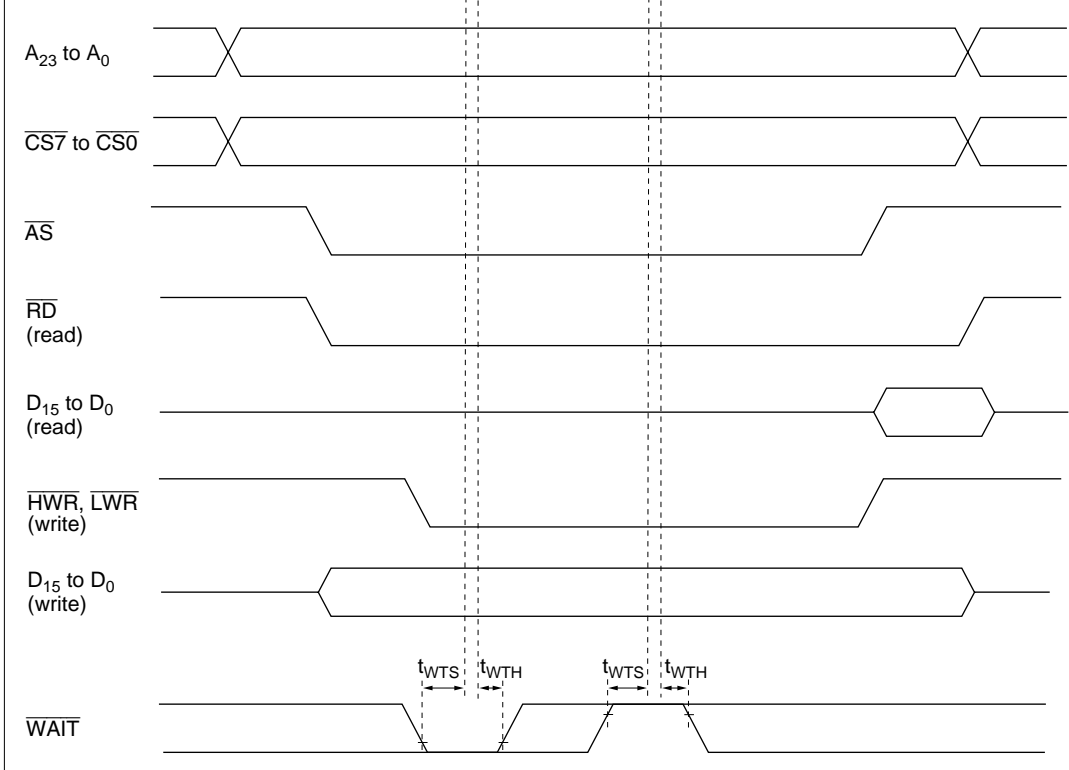


Figure 21-10 Basic Bus Timing (Three-State Access with One Wait State)

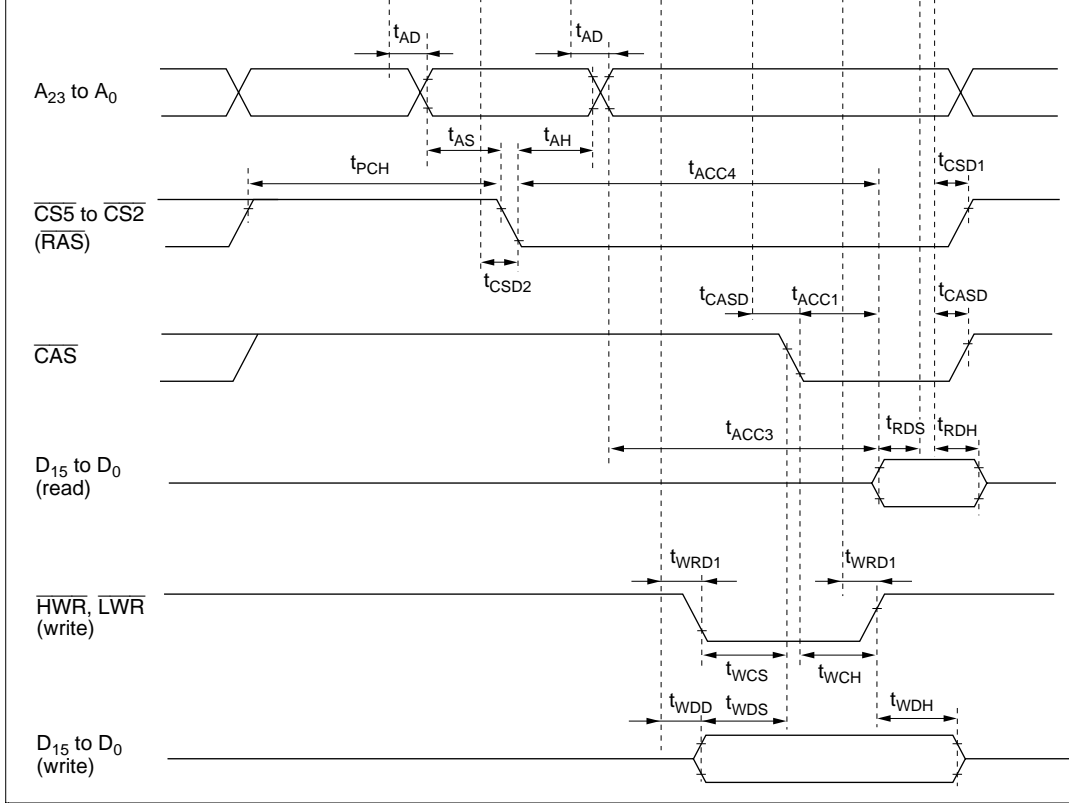


Figure 21-11 DRAM Bus Timing

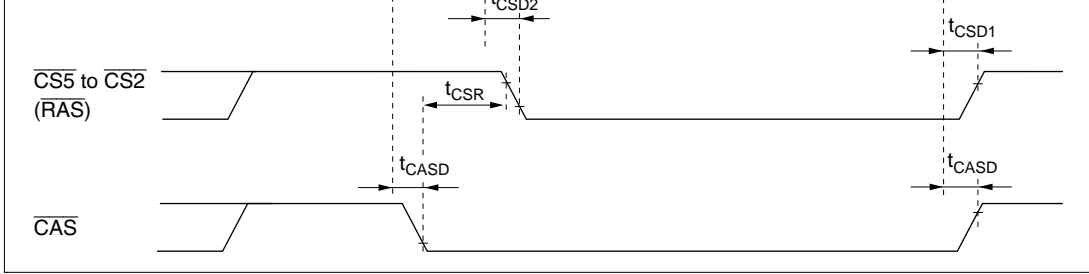


Figure 21-12 CAS-Before-RAS Refresh Timing

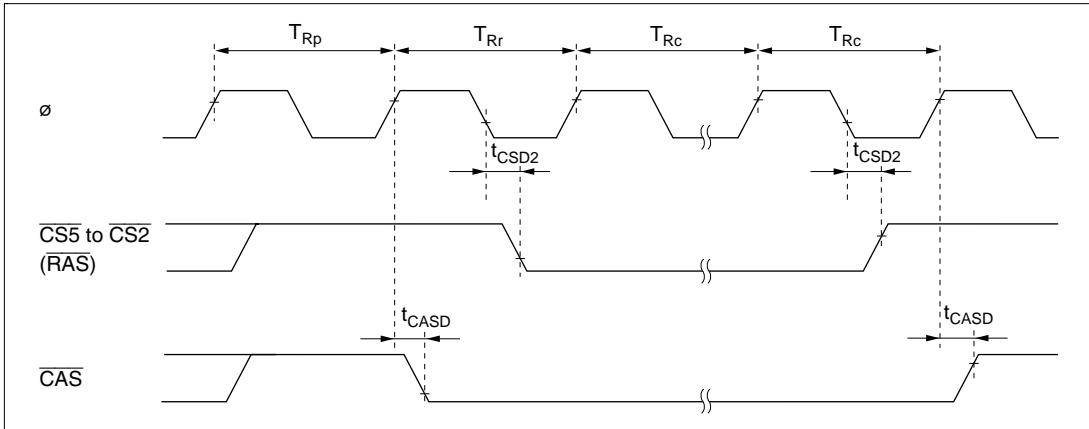


Figure 21-13 Self-Refresh Timing

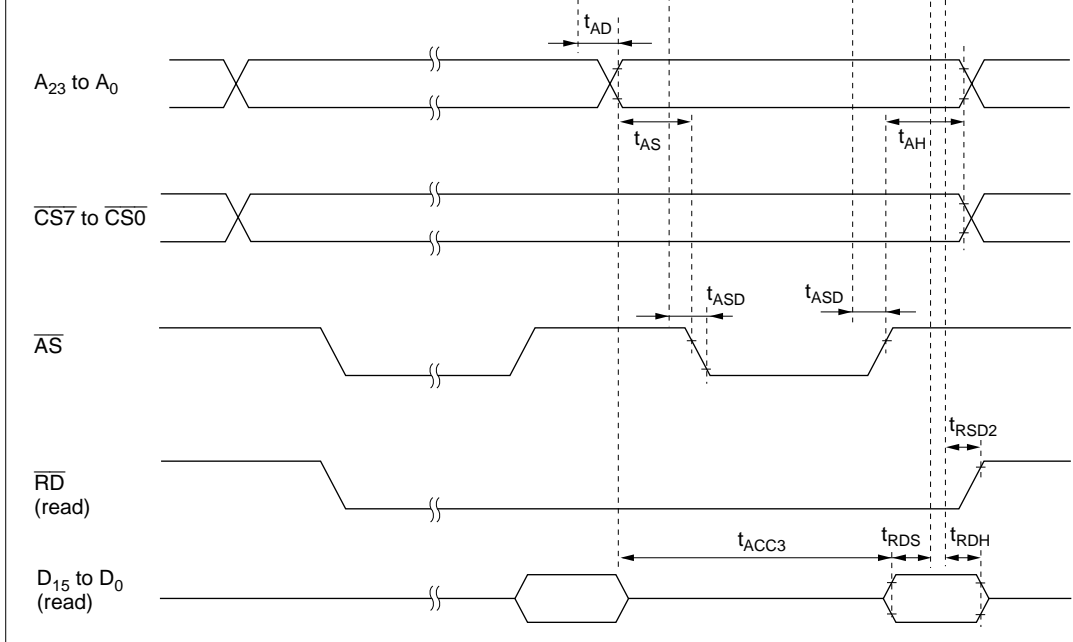


Figure 21-14 Burst ROM Access Timing (Two-State Access)

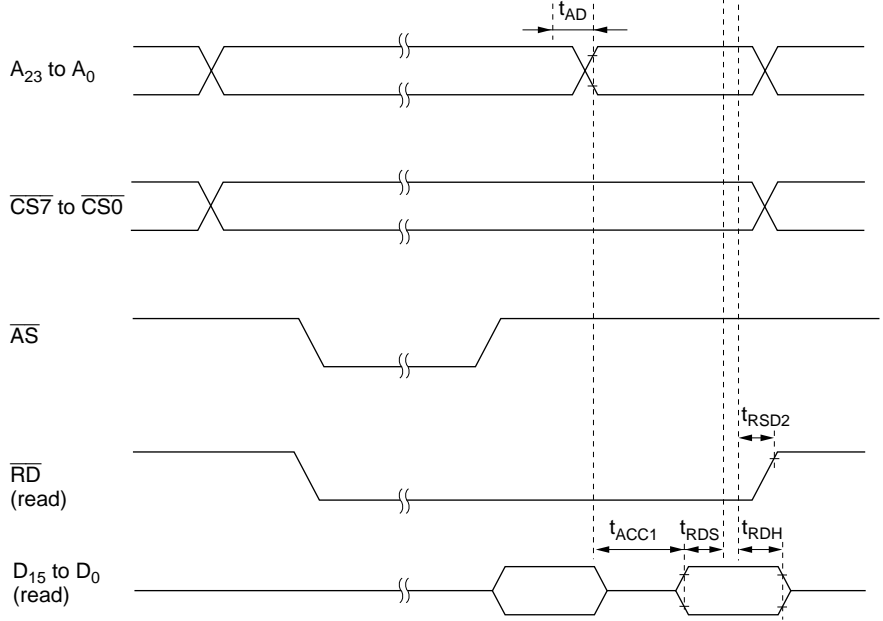


Figure 21-15 Burst ROM Access Timing (One-State Access)

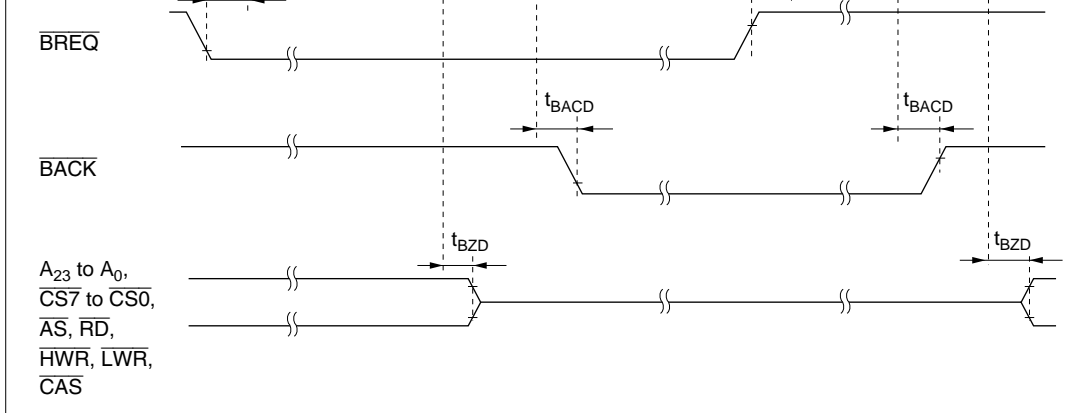


Figure 21-16 External Bus Release Timing

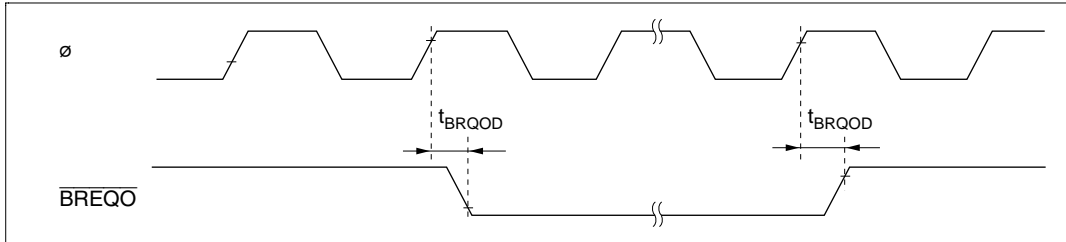


Figure 21-17 External Bus Request Output Timing

Table 21-7 DMAC Timing

Condition A: $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ to }10\text{ MHz}$, $T_a = -20\text{ to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40\text{ to }+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 5.0\text{ V} \pm 10\%$, $AV_{CC} = 5.0\text{ V} \pm 10\%$, $V_{ref} = 4.5\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ to }20\text{ MHz}$, $T_a = -20\text{ to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40\text{ to }+85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Condition A		Condition B		Unit	Test Conditions
		Min	Max	Min	Max		
$\overline{\text{DREQ}}$ setup time	t_{DRQS}	40	—	30	—	ns	Figure 21-21
$\overline{\text{DREQ}}$ hold time	t_{DRQH}	10	—	10	—		
$\overline{\text{TEND}}$ delay time	t_{TED}	—	40	—	20		Figure 21-20
$\overline{\text{DACK}}$ delay time 1	t_{DACD1}	—	40	—	20	ns	Figure 21-18,
$\overline{\text{DACK}}$ delay time 2	t_{DACD2}	—	40	—	20		Figure 21-19

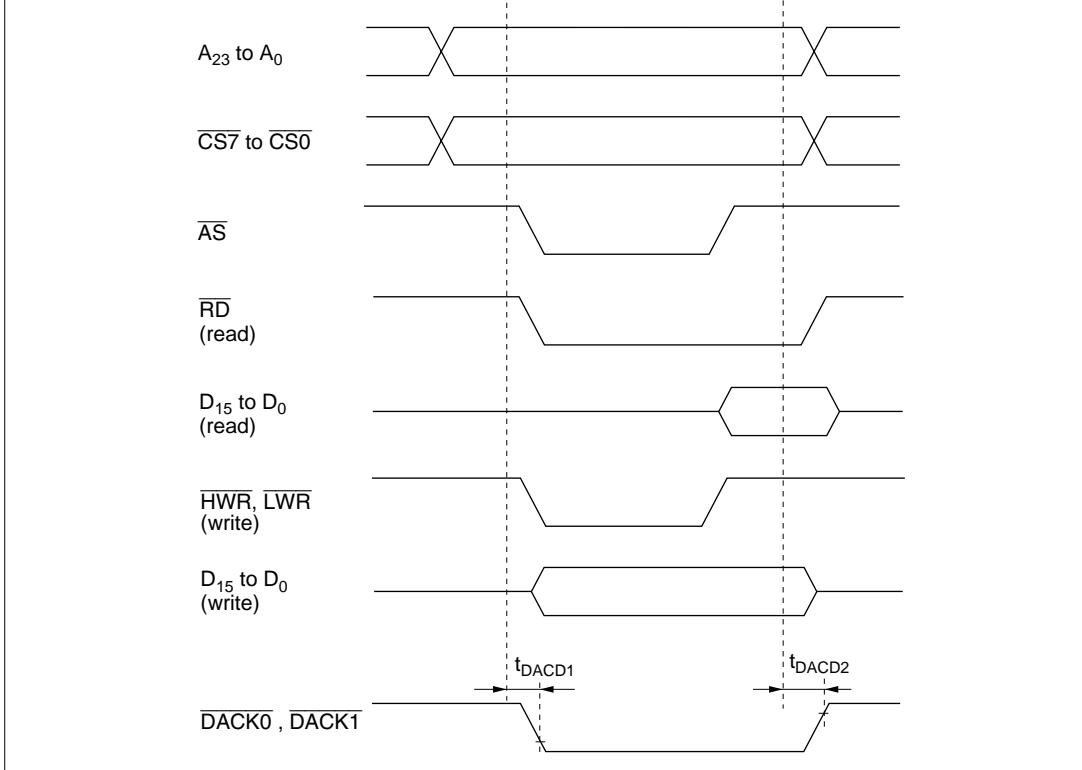


Figure 21-18 DMAC Single Address Transfer Timing (Two-State Access)

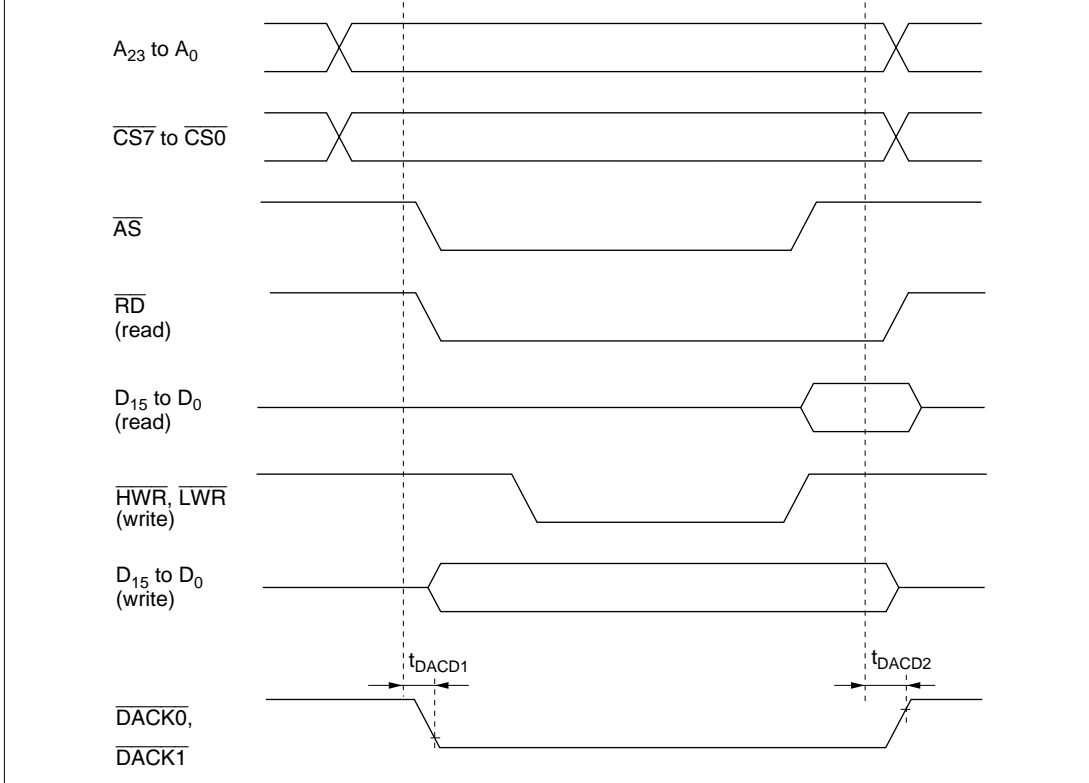


Figure 21-19 DMAC Single Address Transfer Timing (Three-State Access)



Figure 21-20 DMAC $\overline{\text{TEND}}$ Output Timing

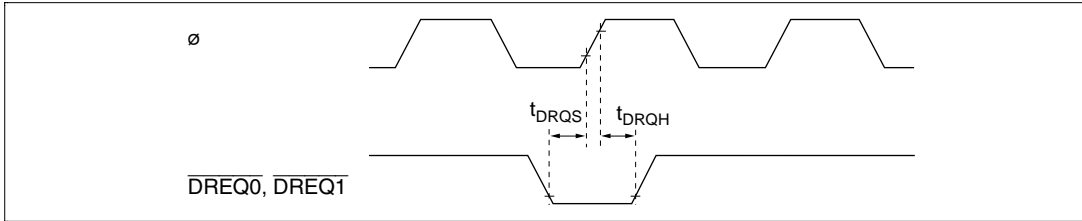


Figure 21-21 DMAC $\overline{\text{DREQ}}$ Input Timing

Table 21-8 Timing of On-Chip Supporting Modules

Condition A: $V_{CC} = 2.7\text{ V to }5.5\text{ V}$, $AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ to }10\text{ MHz}$, $T_a = -20\text{ to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40\text{ to }+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = 5.0\text{ V} \pm 10\%$, $AV_{CC} = 5.0\text{ V} \pm 10\%$, $V_{ref} = 4.5\text{ V to }AV_{CC}$,
 $V_{SS} = AV_{SS} = 0\text{ V}$, $\phi = 2\text{ to }20\text{ MHz}$, $T_a = -20\text{ to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40\text{ to }+85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Condition A		Condition B		Unit	Test Conditions		
		Min	Max	Min	Max				
PORT	Output data delay time	t_{PWD}	—	100	—	50	ns	Figure 21-22	
	Input data setup time	t_{PRS}	50	—	30	—			
	Input data hold time	t_{PRH}	50	—	30	—			
PPG	Pulse output delay time	t_{POD}	—	100	—	50	ns	Figure 21-23	
TPU	Timer output delay time	t_{TOCD}	—	100	—	50	ns	Figure 21-24	
	Timer input setup time	t_{TICS}	50	—	30	—			
	Timer clock input setup time	t_{TCKS}	50	—	30	—	ns	Figure 21-25	
	Timer clock	Single edge	t_{TCKWH}	1.5	—	1.5	—	t_{cyc}	
	pulse width	Both edges	t_{TCKWL}	2.5	—	2.5	—		

Condition B: $V_{CC} = 5.0 \text{ V} \pm 10\%$, $AV_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{ref} = 4.5 \text{ V}$ to AV_{CC} ,
 $V_{SS} = AV_{SS} = 0 \text{ V}$, $\phi = 2$ to 20 MHz , $T_a = -20$ to $+75^\circ\text{C}$ (regular specifications),
 $T_a = -40$ to $+85^\circ\text{C}$ (wide-range specifications)

Item	Symbol	Condition A		Condition B		Unit	Test Conditions		
		Min	Max	Min	Max				
WDT	Overflow output delay time	t_{WOVD}	—	100	—	50	ns	Figure 21-26	
SCI	Input clock cycle	Asynchronous	t_{Syc}	4	—	4	—	t_{cyc}	Figure 21-27
		Synchronous		6	—	6	—		
	Input clock pulse width	t_{SCKW}	0.4	0.6	0.4	0.6		t_{Syc}	
	Input clock rise time	t_{SCKr}	—	1.5	—	1.5		t_{cyc}	
	Input clock fall time	t_{SCKf}	—	1.5	—	1.5			
	Transmit data delay time	t_{TXD}	—	100	—	50		ns	Figure 21-28
	Receive data setup time (synchronous)	t_{RXS}	100	—	50	—		ns	
	Receive data hold time (synchronous)	t_{RXH}	100	—	50	—		ns	
A/D converter	Trigger input setup time	t_{TRGS}	50	—	30	—	ns	Figure 21-29	

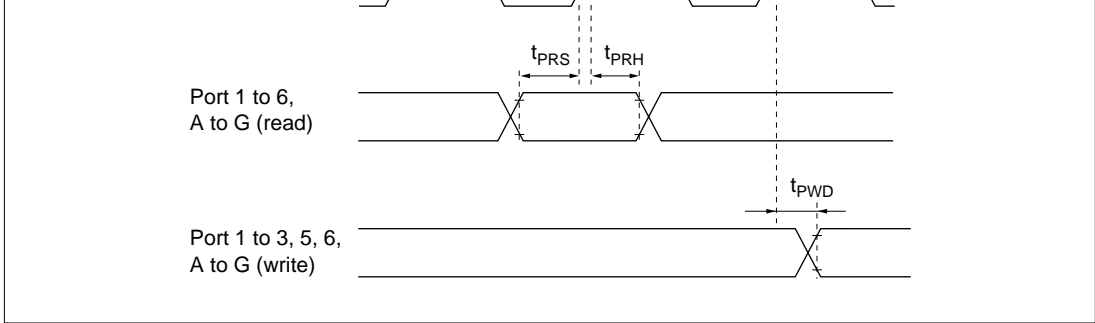


Figure 21-22 I/O Port Input/Output Timing

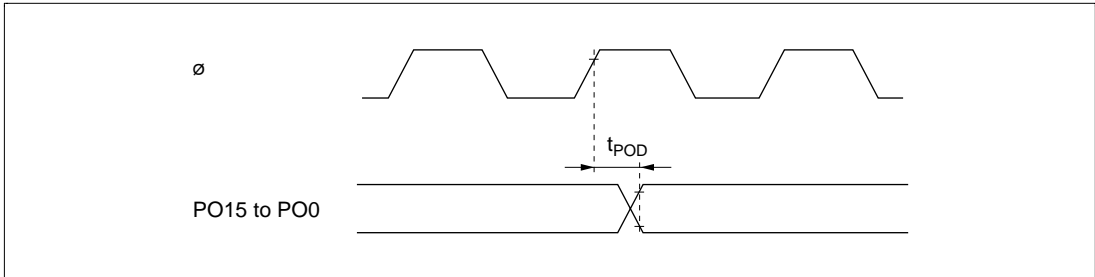


Figure 21-23 PPG Output Timing

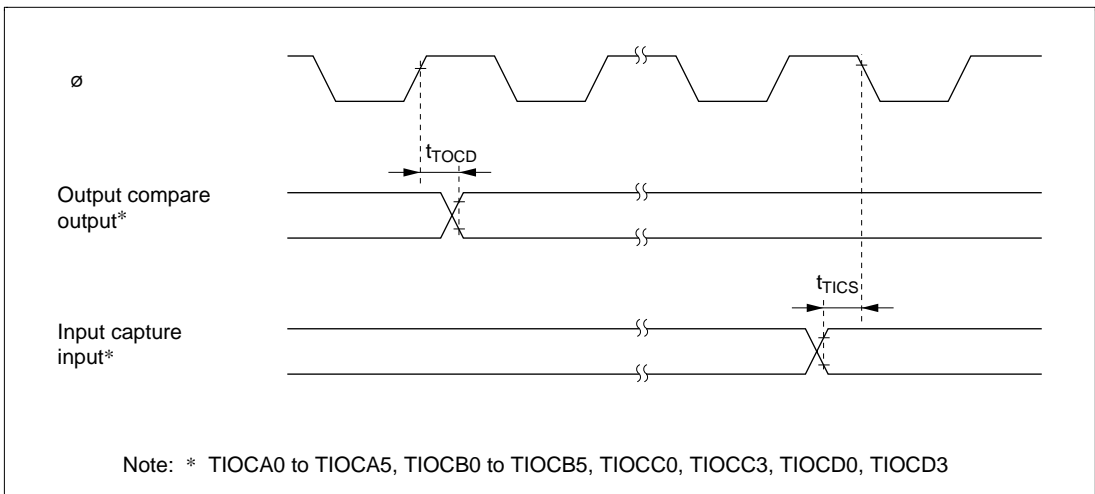


Figure 21-24 TPU Input/Output Timing

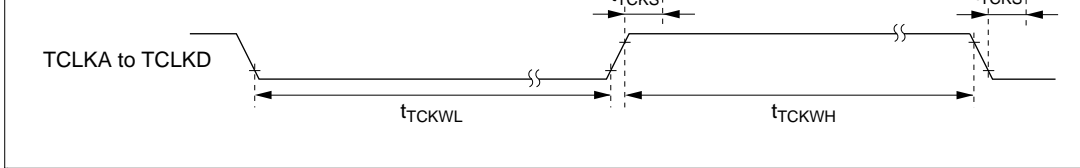


Figure 21-25 TPU Clock Input Timing

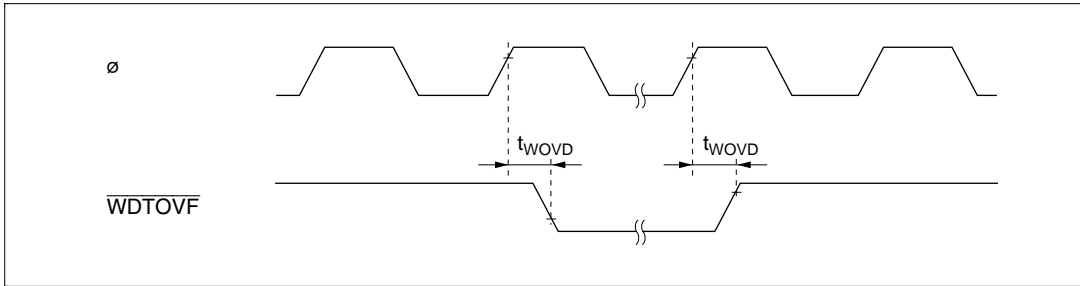


Figure 21-26 WDT Output Timing

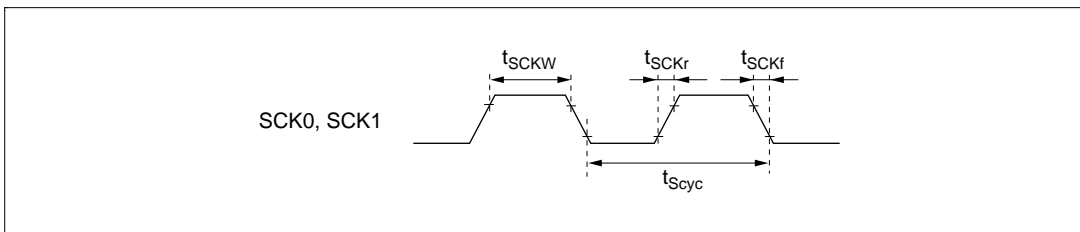


Figure 21-27 SCK Clock Input Timing

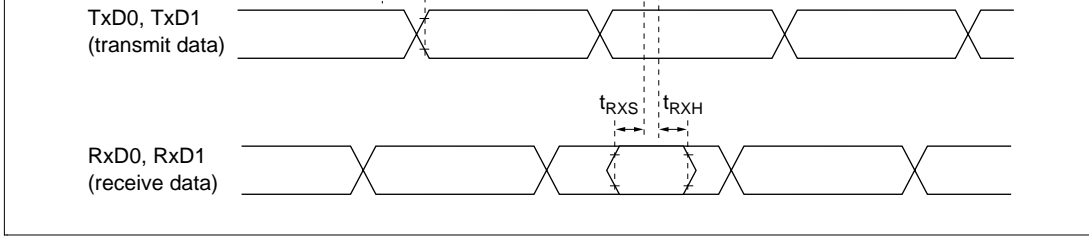


Figure 21-28 SCI Input/Output Timing (Clock Synchronous Mode)

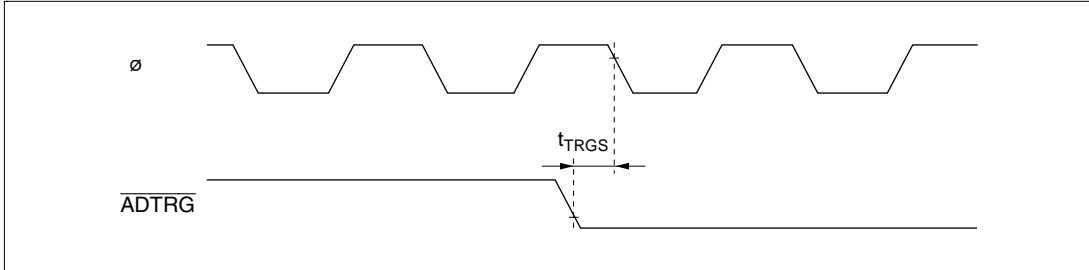


Figure 21-29 A/D Converter External Trigger Input Timing

Table 21-9 A/D Conversion Characteristics

Condition A: $V_{CC} = AV_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$, $V_{ref} = 2.7 \text{ V to } AV_{CC}$, $V_{SS} = AV_{SS} = 0 \text{ V}$,
 $\phi = 2 \text{ to } 10 \text{ MHz}$, $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = AV_{CC} = 5.0 \text{ V} \pm 10\%$, $V_{ref} = 4.5 \text{ V to } AV_{CC}$, $V_{SS} = AV_{SS} = 0 \text{ V}$,
 $\phi = 2 \text{ to } 20 \text{ MHz}$, $T_a = -20 \text{ to } +75^\circ\text{C}$ (regular specifications),
 $T_a = -40 \text{ to } +85^\circ\text{C}$ (wide-range specifications)

Item	Condition A			Condition B			Unit
	Min	Typ	Max	Min	Typ	Max	
Resolution	10	10	10	10	10	10	bits
Conversion time	—	—	13.4	—	—	6.7	μs
Analog input capacitance	—	—	20	—	—	20	pF
Permissible signal-source impedance	—	—	10^{*1}	—	—	10^{*3}	k Ω
	—	—	5^{*2}	—	—	5^{*4}	
Nonlinearity error	—	—	± 6.0	—	—	± 3.0	LSB
Offset error	—	—	± 4.0	—	—	± 2.0	LSB
Full-scale error	—	—	± 4.0	—	—	± 2.0	LSB
Quantization	—	—	± 0.5	—	—	± 0.5	LSB
Absolute accuracy	—	—	± 8.0	—	—	± 4.0	LSB

Notes: 1. $4.0 \text{ V} \leq AV_{CC} \leq 5.5 \text{ V}$

2. $2.7 \text{ V} \leq AV_{CC} < 4.0 \text{ V}$

3. $\phi \leq 12 \text{ MHz}$

4. $\phi > 12 \text{ MHz}$

Table 21-10 D/A Conversion Characteristics

Condition A: $V_{CC} = AV_{CC} = 2.7\text{ V to }5.5\text{ V}$, $V_{ref} = 2.7\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$,
 $\phi = 2\text{ to }10\text{ MHz}$, $T_a = -20\text{ to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40\text{ to }+85^\circ\text{C}$ (wide-range specifications)

Condition B: $V_{CC} = AV_{CC} = 5.0\text{ V} \pm 10\%$, $V_{ref} = 4.5\text{ V to }AV_{CC}$, $V_{SS} = AV_{SS} = 0\text{ V}$,
 $\phi = 2\text{ to }20\text{ MHz}$, $T_a = -20\text{ to }+75^\circ\text{C}$ (regular specifications),
 $T_a = -40\text{ to }+85^\circ\text{C}$ (wide-range specifications)

Item	Condition A			Condition B			Unit	Test Conditions
	Min	Typ	Max	Min	Typ	Max		
Resolution	8	8	8	8	8	8	bit	
Conversion time	—	—	10	—	—	10	μs	20-pF capacitive load
Absolute accuracy	—	± 2.0	± 3.0	—	± 1.0	± 1.5	LSB	2-M Ω resistive load
	—	—	± 2.0	—	—	± 1.0	LSB	4-M Ω resistive load

21.6 Usage Note

Although both the ZTAT and mask ROM versions fully meet the electrical specifications listed in this manual, due to differences in the fabrication process, the on-chip ROM, and the layout patterns, there will be differences in the actual values of the electrical characteristics, the operating margins, the noise margins, and other aspects.

Therefore, if a system is evaluated using the ZTAT version, a similar evaluation should also be performed using the mask ROM version.

Operand Notation

Rd	General register (destination)* ¹
Rs	General register (source)* ¹
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	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
+	Add
−	Subtract
×	Multiply
÷	Divide
^	Logical AND
∨	Logical OR
⊕	Logical exclusive OR
→	Transfer from the operand on the left to the operand on the right, or transition from the state on the left to the state on the right
¬	Logical NOT (logical complement)
() < >	Contents of operand
:8/:16/:24/:32	8-, 16-, 24-, or 32-bit length

- Notes: 1. General registers include 8-bit registers (R0H to R7H, R0L to R7L), 16-bit registers (R0 to R7, E0 to E7), and 32-bit registers (ER0 to ER7).
2. The MAC register cannot be used in the H8S/2350 Series.

*	Undetermined (no guaranteed value)
0	Always cleared to 0
1	Always set to 1
—	Not affected by execution of the instruction

Table A-1 Instruction Set

(1) Data Transfer Instructions

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)							Operation	Condition Code					
		#xx	Rn	@ERN	@(d,ERN)	@-ERN/@ERN+	@aa	@(d,PC)		@aa	I	H	N	Z	V
MOV	B	2							#xx:8→Rd8	—	—	—	—	—	—
	B	2							Rs8→Rd8	—	—	—	—	—	—
	B	2							@ERS→Rd8	—	—	—	—	—	—
	B		4						@(d:16,ERS)→Rd8	—	—	—	—	—	—
	B		8						@(d:32,ERS)→Rd8	—	—	—	—	—	—
	B		2						@ERS→Rd8,ERS32+1→ERS32	—	—	—	—	—	—
	B					2			@aa:8→Rd8	—	—	—	—	—	—
	B					4			@aa:16→Rd8	—	—	—	—	—	—
	B					6			@aa:32→Rd8	—	—	—	—	—	—
	B		2						Rs8→@ERd	—	—	—	—	—	—
	B		4						Rs8→@(d:16,ERd)	—	—	—	—	—	—
	B		8						Rs8→@(d:32,ERd)	—	—	—	—	—	—
	B					2			ERd32-1→ERd32,Rs8→@ERd	—	—	—	—	—	—
	B					2			Rs8→@aa:8	—	—	—	—	—	—
	B					4			Rs8→@aa:16	—	—	—	—	—	—
	B					6			Rs8→@aa:32	—	—	—	—	—	—
	W	4							#xx:16→Rd16	—	—	—	—	—	—
	W	2							Rs16→Rd16	—	—	—	—	—	—
	W	2							@ERS→Rd16	—	—	—	—	—	—

Table A-1 Instruction Set (cont)

(1) Data Transfer Instructions (cont)

	Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)							Operation	Condition Code					
			#xx	Rn	@ERn	@(d,ERn)	@-ERn/@ERN+	@aa	@(d,PC)		@aa	I	H	N	Z	V
MOV	MOV.L ERs,@ERd	L		4						ERs32→@ERd	—	—	↑	↓	0	—
	MOV.L ERs,@(d:16,ERd)	L		6						ERs32→@(d:16,ERd)	—	—	↑	↓	0	—
	MOV.L ERs,@(d:32,ERd)	L		10						ERs32→@(d:32,ERd)	—	—	↑	↓	0	—
	MOV.L ERs,@-ERd	L		4						ERd32-4→ERd32,ERs32→@ERd	—	—	↑	↓	0	—
	MOV.L ERs,@aa:16	L			6					ERs32→@aa:16	—	—	↑	↓	0	—
	MOV.L ERs,@aa:32	L			8					ERs32→@aa:32	—	—	↑	↓	0	—
POP	POP.W Rn	W							2	@SP→Rn16,SP+2→SP	—	—	↑	↓	0	—
PUSH	POP.L ERn	L							4	@SP→ERn32,SP+4→SP	—	—	↑	↓	0	—
	PUSH.W Rn	W							2	SP-2→SP,Rn16→@SP	—	—	↑	↓	0	—
	PUSH.L ERn	L							4	SP-4→SP,ERn32→@SP	—	—	↑	↓	0	—
LDM	LDM @SP+,(ERm-ERn)	L							4	(@SP→ERn32,SP+4→SP) Repeated for each register restored	—	—	—	—	—	—
STM	STM (ERm-ERn),@-SP	L							4	(SP-4→SP,ERn32→@SP) Repeated for each register saved	—	—	—	—	—	—
MOVFP	MOVFP @aa:16,Rd									Cannot be used in the H8S/2350 Series						
MOVTP	MOVTP Rs,@aa:16									Cannot be used in the H8S/2350 Series						

Table A-1 Instruction Set (cont)

(2) Arithmetic Instructions (cont)

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)										Operation	Condition Code													
		#xx	Rn	@ERN	@(d,ERN)	@-ERn/@ERn+	@aa	@(d,PC)	@aa	I	H		N	Z	V	C	N									
SUB	SUB.W Rs,Rd	W	2															[3]	↓	↓	↓	↓	↓	↓		
	SUB.L #xx:32,ERd	L	6																[4]	↓	↓	↓	↓	↓		
	SUB.L ERs,ERd	L	2																[4]	↓	↓	↓	↓	↓		
SUBX	SUBX #xx:8,Rd	B	2																↓	↓	↓	↓	↓	[5]	↓	↓
	SUBX Rs,Rd	B	2																↓	↓	↓	↓	↓	[5]	↓	↓
SUBS	SUBS #1,ERd	L	2																							
	SUBS #2,ERd	L	2																							
	SUBS #4,ERd	L	2																							
	DEC.B Rd	B	2																							
DEC	DEC.W #1,Rd	W	2																							
	DEC.W #2,Rd	W	2																							
	DEC.L #1,ERd	L	2																							
	DEC.L #2,ERd	L	2																							
DAS	DAS Rd	B	2																							
	MULXU.B Rs,Rd	B	2																							
MULXU	MULXU.W Rs,ERd	W	2																							
	MULXS.B Rs,Rd	B	4																							
MULXS	MULXS.W Rs,ERd	W	4																							

Table A-1 Instruction Set (cont)

(2) Arithmetic Instructions (cont)

	Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)							Operation	Condition Code																	
			#xx	Rn	@ERN	@(d,ERN)	@-ERN@ERN+	@aa	@(d,PC)		@aa	I	H	N	Z	V	C											
DIVXU	DIVXU.B Rs,Rd	B	2								Rd16+Rs8→Rd16 (RdH: remainder, RdL: quotient) (unsigned division)							[6]	[7]									
	DIVXU.W Rs,ERd	W	2								ERd32+Rs16→ERd32 (Ed: remainder, Rd: quotient) (unsigned division)								[6]	[7]								
DIVXS	divxs.B Rs,Rd	B	4								Rd16+Rs8→Rd16 (RdH: remainder, RdL: quotient) (signed division)									[8]	[7]							
	DIVXS.W Rs,ERd	W	4								ERd32+Rs16→ERd32 (Ed: remainder, Rd: quotient) (signed division)										[8]	[7]						
CMP	CMP.B #xx:8,Rd	B	2								Rd8-#xx:8																	
	CMP.B Rs,Rd	B	2								Rd8-Rs8																	
	CMP.W #xx:16,Rd	W	4								Rd16-#xx:16																	
	CMP.W Rs,Rd	W	2								Rd16-Rs16																	
NEG	CMP.L #xx:32,ERd	L	6								ERd32-#xx:32																	
	CMP.L ERs,ERd	L	2								ERd32-ERs32																	
	NEG.B Rd	B	2								0-Rd8→Rd8																	
	NEG.W Rd	W	2								0-Rd16→Rd16																	
	NEG.L ERd	L	2								0-ERd32→ERd32																	
	EXTU.W Rd	W	2								0→(<bit 15 to 8> of Rd16)																	
EXTU.L ERd	L	2								0→(<bit 31 to 16> of ERd32)																		

Table A-1 Instruction Set (cont)

(2) Arithmetic Instructions (cont)

	Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)							Operation	Condition Code							
			#xx	Rn	@ERn	@(d,ERn)	@-ERn/@ERn+	@aa	@(d,PC)		@aa	I	H	N	Z	V	C	
EXTS	EXTS.W Rd	W	2											↕	↕	0	—	
	EXTS.L ERd	L	2											↕	↕	0	—	
TAS	TAS @ERd	B		4										↕	↕	0	—	
MAC	MAC @ERn+, @ERn+													↕	↕	0	—	
CLRMAC	CLRMAC																	
LDMAC	LDMAC ERs, MACH																	
	LDMAC ERs, MACL																	
STMAC	STMAC MACH, ERd																	
	STMAC MACL, ERd																	
Cannot be used in the H8S/2350 Series																		

Table A-1 Instruction Set
(3) Logical Instructions

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)								Operation	Condition Code					
		#xx	Rn	@ERN	@ (d, ERn)	@ (FRn)@ERN+	@aa	@ (d, PC)	@ @aa		I	H	N	Z	V	C
AND	AND.B #xx:8,Rd	B	2							Rd8 \wedge #xx:8 \rightarrow Rd8	—	—	\uparrow	\downarrow	0	—
	AND.B Rs,Rd	B	2							Rd8 \wedge Rs8 \rightarrow Rd8	—	—	\uparrow	\downarrow	0	—
	AND.W #xx:16,Rd	W	4							Rd16 \wedge #xx:16 \rightarrow Rd16	—	—	\uparrow	\downarrow	0	—
	AND.W Rs,Rd	W	2							Rd16 \wedge Rs16 \rightarrow Rd16	—	—	\uparrow	\downarrow	0	—
	AND.L #xx:32,ERd	L	6							ERd32 \wedge #xx:32 \rightarrow ERd32	—	—	\uparrow	\downarrow	0	—
	AND.L ERs,ERd	L	4							ERd32 \wedge ERs32 \rightarrow ERd32	—	—	\uparrow	\downarrow	0	—
	OR.B #xx:8,Rd	B	2							Rd8 \vee #xx:8 \rightarrow Rd8	—	—	\uparrow	\downarrow	0	—
OR	OR.B Rs,Rd	B	2							Rd8 \vee Rs8 \rightarrow Rd8	—	—	\uparrow	\downarrow	0	—
	OR.W #xx:16,Rd	W	4							Rd16 \vee #xx:16 \rightarrow Rd16	—	—	\uparrow	\downarrow	0	—
	OR.W Rs,Rd	W	2							Rd16 \vee Rs16 \rightarrow Rd16	—	—	\uparrow	\downarrow	0	—
	OR.L #xx:32,ERd	L	6							ERd32 \vee #xx:32 \rightarrow ERd32	—	—	\uparrow	\downarrow	0	—
	OR.L ERs,ERd	L	4							ERd32 \vee ERs32 \rightarrow ERd32	—	—	\uparrow	\downarrow	0	—
	XOR.B #xx:8,Rd	B	2							Rd8 \oplus #xx:8 \rightarrow Rd8	—	—	\uparrow	\downarrow	0	—
	XOR.B Rs,Rd	B	2							Rd8 \oplus Rs8 \rightarrow Rd8	—	—	\uparrow	\downarrow	0	—
XOR	XOR.W #xx:16,Rd	W	4							Rd16 \oplus #xx:16 \rightarrow Rd16	—	—	\uparrow	\downarrow	0	—
	XOR.W Rs,Rd	W	2							Rd16 \oplus Rs16 \rightarrow Rd16	—	—	\uparrow	\downarrow	0	—
	XOR.L #xx:32,ERd	L	6							ERd32 \oplus #xx:32 \rightarrow ERd32	—	—	\uparrow	\downarrow	0	—
	XOR.L ERs,ERd	L	4							ERd32 \oplus ERs32 \rightarrow ERd32	—	—	\uparrow	\downarrow	0	—
	NOT.B Rd	B	2							\neg Rd8 \rightarrow Rd8	—	—	\uparrow	\downarrow	0	—
	NOT.W Rd	W	2							\neg Rd16 \rightarrow Rd16	—	—	\uparrow	\downarrow	0	—
	NOT.L ERd	L	2							\neg ERd32 \rightarrow ERd32	—	—	\uparrow	\downarrow	0	—

**Table A-1 Instruction Set
(4) Shift Instructions**

Mnemonic	Operand Size		Addressing Mode/ Instruction Length (Bytes)								Operation	Condition Code				
	#xx	Rn	@ERn	@(d,ERn)	@-ERn/@ERn+	@aa	@(d,PC)	@aa	@aa	I		H	N	Z	V	C
SHAL	B	2											↕	↕	↕	↕
	B	2											↕	↕	↕	↕
	W	2											↕	↕	↕	↕
	W	2											↕	↕	↕	↕
	L	2											↕	↕	↕	↕
SHAR	B	2											↕	↕	↕	↕
	B	2											↕	↕	↕	↕
	W	2											↕	↕	↕	↕
	W	2											↕	↕	↕	↕
	L	2											↕	↕	↕	↕
SHLL	B	2											↕	↕	↕	↕
	B	2											↕	↕	↕	↕
	W	2											↕	↕	↕	↕
	W	2											↕	↕	↕	↕
	L	2											↕	↕	↕	↕

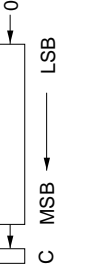
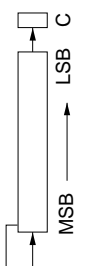


Table A-1 Instruction Set (cont)
 (4) Shift Instructions (cont)

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)						Operation	Condition Code									
		#xx	Rn	@ERn	@(d,ERn)	@-ERn/ERn+	@aa		@(d,PC)	@aa	I	H	N	Z	V	C	N	
SHLR	SHLR.B Rd	B	2												0	↑	0	↑
	SHLR.B #2,Rd	B	2												0	↑	0	↑
	SHLR.W Rd	W	2												0	↑	0	↑
	SHLR.W #2,Rd	W	2												0	↑	0	↑
	SHLR.L ERd	L	2												0	↑	0	↑
	SHLR.L #2,ERd	L	2												0	↑	0	↑
ROTXL	ROTXL.B Rd	B	2												↑	↑	0	↑
	ROTXL.B #2,Rd	B	2												↑	↑	0	↑
	ROTXL.W Rd	W	2												↑	↑	0	↑
	ROTXL.W #2,Rd	W	2												↑	↑	0	↑
	ROTXL.L ERd	L	2												↑	↑	0	↑
	ROTXL.L #2,ERd	L	2												↑	↑	0	↑
ROTXR	ROTXR.B Rd	B	2												↑	↑	0	↑
	ROTXR.B #2,Rd	B	2												↑	↑	0	↑
	ROTXR.W Rd	W	2												↑	↑	0	↑
	ROTXR.W #2,Rd	W	2												↑	↑	0	↑
	ROTXR.L ERd	L	2												↑	↑	0	↑
	ROTXR.L #2,ERd	L	2												↑	↑	0	↑

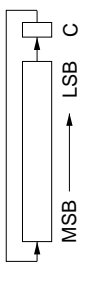
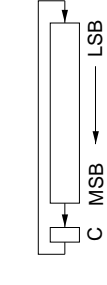
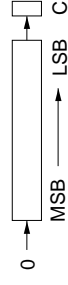


Table A-1 Instruction Set (cont)
 (4) Shift Instructions (cont)

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)							Operation	Condition Code																	
		#xx	Rn	@ERn	@(d,ERn)	@-ERn/@ERn+	@aa	@(d,PC)		@aa	I	H	N	Z	V	C											
ROTL	ROTL.B Rd	B	2									↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕	↕		
	ROTL.B #2,Rd	B	2																								
	ROTL.W Rd	W	2																								
	ROTL.W #2,Rd	W	2																								
	ROTL.L ERd	L	2																								
	ROTL.L #2,ERd	L	2																								
ROTR	ROTR.B Rd	B	2																								
	ROTR.B #2,Rd	B	2																								
	ROTR.W Rd	W	2																								
	ROTR.W #2,Rd	W	2																								
	ROTR.L ERd	L	2																								
	ROTR.L #2,ERd	L	2																								

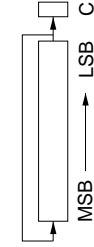
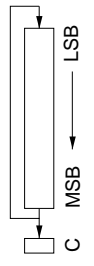


Table A-1 Instruction Set
(5) Bit-Manipulation Instructions

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)							Operation	Condition Code					
		#xx	Rn	@ERn	@(d,ERn)	@-ERn/@ERn+	@aa	@(d,PC) @aa		I	H	N	Z	V	C
BSET	B	2							(#xx:3 of Rd8)←1	—	—	—	—	—	—
	B	4							(#xx:3 of @ERd)←1	—	—	—	—	—	—
	B		4						(#xx:3 of @aa:8)←1	—	—	—	—	—	—
	B			6					(#xx:3 of @aa:16)←1	—	—	—	—	—	—
	B				8				(#xx:3 of @aa:32)←1	—	—	—	—	—	—
	B	2							(Rn8 of Rd8)←1	—	—	—	—	—	—
	B		4						(Rn8 of @ERd)←1	—	—	—	—	—	—
	B			4					(Rn8 of @aa:8)←1	—	—	—	—	—	—
	B			6					(Rn8 of @aa:16)←1	—	—	—	—	—	—
	B				8				(Rn8 of @aa:32)←1	—	—	—	—	—	—
BCLR	B	2							(#xx:3 of Rd8)←0	—	—	—	—	—	—
	B	4							(#xx:3 of @ERd)←0	—	—	—	—	—	—
	B		4						(#xx:3 of @aa:8)←0	—	—	—	—	—	—
	B			6					(#xx:3 of @aa:16)←0	—	—	—	—	—	—
	B				8				(#xx:3 of @aa:32)←0	—	—	—	—	—	—
	B	2							(Rn8 of Rd8)←0	—	—	—	—	—	—
	B		4						(Rn8 of @ERd)←0	—	—	—	—	—	—
	B			4					(Rn8 of @aa:8)←0	—	—	—	—	—	—
	B			6					(Rn8 of @aa:16)←0	—	—	—	—	—	—
	B				6				(Rn8 of @aa:32)←0	—	—	—	—	—	—

Table A-1 Instruction Set (cont)
(5) Bit-Manipulation Instructions (cont)

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)							Operation	Condition Code						
		#xx	Rn	@ERN	@(d,ERn)	@ERN/@ERN+	@aa	@(d,PC)		@aa	I	H	N	Z	V	C
BCLR	B							8		(Rn8 of @aa:32)←0	—	—	—	—	—	
BNOT	B	2								(#xx:3 of Rd8)← [-(#xx:3 of Rd8)]	—	—	—	—	—	
	B		4							(#xx:3 of @ERd)← [- (#xx:3 of @ERd)]	—	—	—	—	—	
BNOT #xx:3, @aa:8	B			4				4		(#xx:3 of @aa:8)← [- (#xx:3 of @aa:8)]	—	—	—	—	—	
	B							6		(#xx:3 of @aa:16)← [- (#xx:3 of @aa:16)]	—	—	—	—	—	
BNOT #xx:3, @aa:32	B							8		(#xx:3 of @aa:32)← [- (#xx:3 of @aa:32)]	—	—	—	—	—	
	B	2								(Rn8 of Rd8)← [-(Rn8 of Rd8)]	—	—	—	—	—	
BNOT Rn, @ERd	B		4							(Rn8 of @ERd)← [-(Rn8 of @ERd)]	—	—	—	—	—	
	B							4		(Rn8 of @aa:8)← [-(Rn8 of @aa:8)]	—	—	—	—	—	
BNOT Rn, @aa:16	B							6		(Rn8 of @aa:16)← [- (Rn8 of @aa:16)]	—	—	—	—	—	
	B							8		(Rn8 of @aa:32)← [- (#xx:3 of @aa:32)]	—	—	—	—	—	
BTST	B	2								¬ (#xx:3 of Rd8)→Z	—	—	—	—	↑	
	B		4							¬ (#xx:3 of @ERd)→Z	—	—	—	—	↑	
	B							4		¬ (#xx:3 of @aa:8)→Z	—	—	—	—	↑	
	B							6		¬ (#xx:3 of @aa:16)→Z	—	—	—	—	↑	

Table A-1 Instruction Set (cont)

(5) Bit-Manipulation Instructions (cont)

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)							Operation	Condition Code					
		#xx	Rn	@ERn	@(d,ERn)	@-ERn/ERn+	@aa	@(d,PC)		@aa	I	H	N	Z	V
BTST	B					8			¬ (#xx:3 of @aa:32)→Z	—	—	—	↑	—	—
	B	2							¬ (Rn8 of Rd8)→Z	—	—	—	↑	—	—
	B		4						¬ (Rn8 of @ERd)→Z	—	—	—	↑	—	—
	B			4					¬ (Rn8 of @aa:8)→Z	—	—	—	↑	—	—
	B				6				¬ (Rn8 of @aa:16)→Z	—	—	—	↑	—	—
BLD	B					8			¬ (Rn8 of @aa:32)→Z	—	—	—	↑	—	—
	B	2							(#xx:3 of Rd8)→C	—	—	—	—	—	↓
	B		4						(#xx:3 of @ERd)→C	—	—	—	—	—	↓
	B			4					(#xx:3 of @aa:8)→C	—	—	—	—	—	↓
	B				6				(#xx:3 of @aa:16)→C	—	—	—	—	—	↓
BILD	B					8			(#xx:3 of @aa:32)→C	—	—	—	—	—	↓
	B	2							¬ (#xx:3 of Rd8)→C	—	—	—	—	—	↑
	B		4						¬ (#xx:3 of @ERd)→C	—	—	—	—	—	↑
	B			4					¬ (#xx:3 of @aa:8)→C	—	—	—	—	—	↑
	B				6				¬ (#xx:3 of @aa:16)→C	—	—	—	—	—	↑
BST	B					8			¬ (#xx:3 of @aa:32)→C	—	—	—	—	—	↑
	B	2							C→(#xx:3 of Rd8)	—	—	—	—	—	—
	B		4						C→(#xx:3 of @ERd)	—	—	—	—	—	—
	B					4			C→(#xx:3 of @aa:8)	—	—	—	—	—	—

Table A-1 Instruction Set (cont)

(5) Bit-Manipulation Instructions (cont)

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)							Operation	Condition Code				
		Rn #xx	FRn	@(d,ERn)	@(d,ERn) -FRn/@ERn+	@aa	@(d,PC)	@aa		I	H	N	Z	V
BST	B							6	C→(#xx:3 of @aa:16)	—	—	—	—	—
	B							8	C→(#xx:3 of @aa:32)	—	—	—	—	—
BIST	B	2							¬ C→(#xx:3 of Rd8)	—	—	—	—	—
	B	4							¬ C→(#xx:3 of @ERd)	—	—	—	—	—
	B			4					¬ C→(#xx:3 of @aa:8)	—	—	—	—	—
	B					4			¬ C→(#xx:3 of @aa:16)	—	—	—	—	—
	B						6		¬ C→(#xx:3 of @aa:16)	—	—	—	—	—
	B							8	¬ C→(#xx:3 of @aa:32)	—	—	—	—	—
BAND	B	2							C∧(#xx:3 of Rd8)→C	—	—	—	—	↑
	B	4							C∧(#xx:3 of @ERd)→C	—	—	—	—	↑
	B			4					C∧(#xx:3 of @aa:8)→C	—	—	—	—	↑
	B					4			C∧(#xx:3 of @aa:16)→C	—	—	—	—	↑
	B						6		C∧(#xx:3 of @aa:16)→C	—	—	—	—	↑
	B							8	C∧(#xx:3 of @aa:32)→C	—	—	—	—	↑
BIAND	B	2							C∧[¬ (#xx:3 of Rd8)]→C	—	—	—	—	↑
	B	4							C∧[¬ (#xx:3 of @ERd)]→C	—	—	—	—	↑
	B			4					C∧[¬ (#xx:3 of @aa:8)]→C	—	—	—	—	↑
	B					4			C∧[¬ (#xx:3 of @aa:16)]→C	—	—	—	—	↑
	B						6		C∧[¬ (#xx:3 of @aa:16)]→C	—	—	—	—	↑
	B							8	C∧[¬ (#xx:3 of @aa:32)]→C	—	—	—	—	↑
BOR	B	2							C∨(#xx:3 of Rd8)→C	—	—	—	—	↑
	B	4							C∨(#xx:3 of @ERd)→C	—	—	—	—	↑

Table A-1 Instruction Set (cont)
 (5) Bit-Manipulation Instructions (cont)

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)							Operation	Condition Code					
		#xx	Rn	@ERN	@(d,ERN)	@-ERN/@ERN+	@aa	@(d,PC)		@aa	I	H	Z	V	C
BOR	B					4			Cv(#xx:3 of @aa:8)→C	—	—	—	—	—	↕
	B					6			Cv(#xx:3 of @aa:16)→C	—	—	—	—	—	↕
	B					8			Cv(#xx:3 of @aa:32)→C	—	—	—	—	—	↕
BIOR	B	2							Cv[- (#xx:3 of Rd8)]→C	—	—	—	—	—	↕
	B		4						Cv[- (#xx:3 of @ERd)]→C	—	—	—	—	—	↕
	B					4			Cv[- (#xx:3 of @aa:8)]→C	—	—	—	—	—	↕
	B					6			Cv[- (#xx:3 of @aa:16)]→C	—	—	—	—	—	↕
	B					8			Cv[- (#xx:3 of @aa:32)]→C	—	—	—	—	—	↕
BXOR	B	2							C⊕(#xx:3 of Rd8)→C	—	—	—	—	—	↕
	B		4						C⊕(#xx:3 of @ERd)→C	—	—	—	—	—	↕
	B					4			C⊕(#xx:3 of @aa:8)→C	—	—	—	—	—	↕
	B					6			C⊕(#xx:3 of @aa:16)→C	—	—	—	—	—	↕
	B					8			C⊕(#xx:3 of @aa:32)→C	—	—	—	—	—	↕
BIXOR	B	2							C⊕[- (#xx:3 of Rd8)]→C	—	—	—	—	—	↕
	B		4						C⊕[- (#xx:3 of @ERd)]→C	—	—	—	—	—	↕
	B					4			C⊕[- (#xx:3 of @aa:8)]→C	—	—	—	—	—	↕
	B					6			C⊕[- (#xx:3 of @aa:16)]→C	—	—	—	—	—	↕
	B					8			C⊕[- (#xx:3 of @aa:32)]→C	—	—	—	—	—	↕

**Table A-1 Instruction Set
(6) Branch Instructions**

Mnemonic	Addressing Mode/ Instruction Length (Bytes)								Operation	Branching Condition	Condition Code					
	Operand Size	#xx	Rn	@ERn	@(d,ERn)	@-ERn/@ERn+	@aa	@(d,PC)			@aa	I	H	N	Z	V
Bcc																
BRA d:8(BT d:8)	—								2		Always	—	—	—	—	—
BRA d:16(BT d:16)	—								4			—	—	—	—	—
BRN d:8(BF d:8)	—								2		Never	—	—	—	—	—
BRN d:16(BF d:16)	—								4			—	—	—	—	—
BHI d:8	—								2		C∨Z=0	—	—	—	—	—
BHI d:16	—								4			—	—	—	—	—
BLS d:8	—								2		C∨Z=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			—	—	—	—	—

Table A-1 Instruction Set (cont)
 (6) Branch Instructions (cont)

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)								Operation	Branching Condition	Condition Code			
		#xx	Rn	@ERn	@(d,ERn)	@-ERn/ERn+	@aa	@(d,PC)	@aa			I	H	N	Z
Bcc	—								2		V=1	—	—	—	—
BVS d:8	—								4			—	—	—	—
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 \oplus V=0	—	—	—	—
BGE d:16	—								4			—	—	—	—
BLT d:8	—								2		N \oplus V=1	—	—	—	—
BLT d:16	—								4			—	—	—	—
BGT d:8	—								2		Z \vee (N \oplus V)=0	—	—	—	—
BGT d:16	—								4			—	—	—	—
BLE d:8	—								2		Z \vee (N \oplus V)=1	—	—	—	—
BLE d:16	—								4			—	—	—	—

Table A-1 Instruction Set (cont)
(6) Branch Instructions (cont)

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)							Operation	Condition Code					
		#xx	Rn	@ERn	@(d,ERn)	@-ERn/ERn+	@aa	@(d,PC)		@aa	I	H	N	Z	V
JMP	JMP @ERn	—	2					1	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-1 Instruction Set
(7) System Control Instructions

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)								Operation	Condition Code						
		Rn	@ ERn	@ (d, ERn)	@ -ERn/@ ERn+	@ aa	@ (d, PC)	@ @aa			I	H	N	Z	V	C	N
TRAPA											PC→@-SP,CCR→@-SP, EXR→@-SP,<vector>→PC	1	—	—	—	—	—
RTE											EXR←@SP+,CCR←@SP+, PC←@SP+	↕	↕	↕	↕	↕	↕
SLEEP											Transition to power-down state	—	—	—	—	—	—
LDC		B	2								#xx:8→CCR	↕	↕	↕	↕	↕	↕
		B	4								#xx:8→EXR	—	—	—	—	—	—
		B	2								Rs8→CCR	↕	↕	↕	↕	↕	↕
		B	2								Rs8→EXR	—	—	—	—	—	—
		W	4								@ERs→CCR	↕	↕	↕	↕	↕	↕
		W	4								@ERs→EXR	—	—	—	—	—	—
		W		6							@(d:16,ERs)→CCR	↕	↕	↕	↕	↕	↕
		W		6							@(d:16,ERs)→EXR	—	—	—	—	—	—
		W		10							@(d:32,ERs)→CCR	↕	↕	↕	↕	↕	↕
		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	—	—	—	—	—	—	

Table A-1 Instruction Set (cont)
(7) System Control Instructions (cont)

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)						Operation	Condition Code								
		#xx	Rn	@ERN	@(d,ERn)	@-ERn/@ERn+	@aa		@(d,PC)	@aa	I	H	N	Z	V	C	N
STC	B	2						CCR→Rd8	—	—	—	—	—	—	—	—	—
	B	2						EXR→Rd8	—	—	—	—	—	—	—	—	—
	W		4					CCR→@ERd	—	—	—	—	—	—	—	—	—
	W		4					EXR→@ERd	—	—	—	—	—	—	—	—	—
	W			6				CCR→@(d:16,ERd)	—	—	—	—	—	—	—	—	—
	W			6				EXR→@(d:16,ERd)	—	—	—	—	—	—	—	—	—
	W			10				CCR→@(d:32,ERd)	—	—	—	—	—	—	—	—	—
	W			10				EXR→@(d:32,ERd)	—	—	—	—	—	—	—	—	—
	W			4				ERd32-2→ERd32,CCR→@ERd	—	—	—	—	—	—	—	—	—
	W			4				ERd32-2→ERd32,EXR→@ERd	—	—	—	—	—	—	—	—	—
	W			6				CCR→@aa:16	—	—	—	—	—	—	—	—	—
	W			6				EXR→@aa:16	—	—	—	—	—	—	—	—	—
	W			8				CCR→@aa:32	—	—	—	—	—	—	—	—	—
	W			8				EXR→@aa:32	—	—	—	—	—	—	—	—	—
ANDC	B	2						CCR^#xx:8→CCR	↑	↑	↑	↑	↑	↑	↑	↑	↑
	B	4						EXR^#xx:8→EXR	—	—	—	—	—	—	—	—	—
ORC	B	2						CCR#xx:8→CCR	↑	↑	↑	↑	↑	↑	↑	↑	↑
	B	4						EXR#xx:8→EXR	—	—	—	—	—	—	—	—	—
XORC	B	2						CCR@#xx:8→CCR	↑	↑	↑	↑	↑	↑	↑	↑	↑
	B	4						EXR@#xx:8→EXR	—	—	—	—	—	—	—	—	—
NOP	—							PC←PC+2	—	—	—	—	—	—	—	—	—

Table A-1 Instruction Set
(8) Block Transfer Instructions

Mnemonic	Operand Size	Addressing Mode/ Instruction Length (Bytes)										Operation	Condition Code						
		#xx	Rn	@ ERn	@ (d, ERn)	@ -ERn/ ERn+	@ aa	@ (d, PC)	@ aa		I		H	Z	V	C	N		
EEPMOV	—											4	if R4L≠0 Repeat @ER5→@ER6 ER5+1→ER5 ER6+1→ER6 R4L-1→R4L Until R4L=0 else next;	—	—	—	—	—	—
EEPMOV.W	—											4	if R4≠0 Repeat @ER5→@ER6 ER5+1→ER5 ER6+1→ER6 R4-1→R4 Until R4=0 else next;	—	—	—	—	—	—

- Notes: 1. The number of states is the number of states required for execution when the instruction and its operands are located in n is the initial value of R4L or R4.
2. Seven states for saving or restoring two registers, nine states for three registers, or eleven states for four registers.
- [1] Cannot be used in the H8S/2350 Series.
 - [2] Set to 1 when a carry or borrow occurs at bit 11; otherwise cleared to 0.
 - [3] Set to 1 when a carry or borrow occurs at bit 27; otherwise cleared to 0.
 - [4] Retains its previous value when the result is zero; otherwise cleared to 0.
 - [5] Set to 1 when the divisor is negative; otherwise cleared to 0.
 - [6] Set to 1 when the divisor is zero; otherwise cleared to 0.
 - [7] Set to 1 when the quotient is negative; otherwise cleared to 0.
 - [8] Set to 1 when the quotient is zero; otherwise cleared to 0.
 - [9] One additional state is required for execution when EXR is valid.

Table A-2 Instruction Codes

Instruction	Mnemonic	Size	Instruction Format												
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th 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							
	ADD.L ERs,ERd	L	0	A	1	ers	0	erd							
ADDS	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 #xx:8,Rd	B	9	rd	IMM										
ADDX	ADDX Rs,Rd	B	0	E	rs	rd									
	ADDX #xx:8,Rd	B	E	rd	IMM										
AND	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							
	AND.L ERs,ERd	L	0	1	F	0	ers	0	erd						
	ANDC #xx:8,CCR	B	0	6	IMM										
ANDC	ANDC #xx:8,EXR	B	0	1	4	1	0	6	IMM						
	BAND #xx:3,Rd	B	7	6	0	IMM	rd								
BAND	BAND #xx:3,@ERd	B	7	C	0	erd	0	7	6	0	IMM	0			
	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			
Bcc	BRA d:8 (BT d:8)	—	4	0	disp										
	BRA d:16 (BT d:16)	—	5	8	0	0	disp								
	BRN d:8 (BF d:8)	—	4	1	disp										
	BRN d:16 (BF d:16)	—	5	8	1	0	disp								

Table A-2 Instruction Codes (cont)

Instruc- tion	Mnemonic	Size	Instruction Format															
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th 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												

Table A-2 Instruction Codes (cont)

Instruction	Mnemonic	Size	Instruction Format																
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th 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													
	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									
BIAND	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									
	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												
	BIAND #xx:3,Rd	B	7	7	1:IMM	rd													
BILD	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									
	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												
	BILD #xx:3,Rd	B	7	4	1:IMM	rd													
	BILD #xx:3,@ERd	B	7	C	0:erd	0	7	4	1:IMM	0									
	BILD #xx:3,@aa:8	B	7	E	abs		7	4	1:IMM	0									
	BILD #xx:3,@aa:16	B	6	A	1	0	abs		7	4	1:IMM	0							
BIOR	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							
	BIOR #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									

Table A-2 Instruction Codes (cont)

Instruc- tion	Mnemonic	Size	Instruction Format															
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th 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						6	7	1:IMM	0
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						7	5	1:IMM	0
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						7	7	0:IMM	0
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									
	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						6	1	rn	0

Table A-2 Instruction Codes (cont)

Instruc- tion	Mnemonic	Size	Instruction Format																	
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th									
BOR	BOR #xx:3,Rd	B	7	4	0:IMM	rd														
	BOR #xx:3,@ERd	B	7	C	0:erd	0	7	4	0:IMM	0										
	BOR #xx:3,@aa:8	B	7	E	abs		7	4	0:IMM	0										
	BOR #xx:3,@aa:16	B	6	A	1	0	abs													
	BOR #xx:3,@aa:32	B	6	A	3	0	abs													
	BSET #xx:3,Rd	B	7	0	0:IMM	rd														
BSET	BSET #xx:3,@ERd	B	7	D	0:erd	0	7	0	0:IMM	0										
	BSET #xx:3,@aa:8	B	7	F	abs		7	0	0:IMM	0										
	BSET #xx:3,@aa:16	B	6	A	1	8	abs													
	BSET #xx:3,@aa:32	B	6	A	3	8	abs													
	BSET Rn,Rd	B	6	0	m	rd														
	BSET Rn,@ERd	B	7	D	0:erd	0	6	0	m	0										
	BSET Rn,@aa:8	B	7	F	abs		6	0	m	0										
	BSET Rn,@aa:16	B	6	A	1	8	abs													
	BSET Rn,@aa:32	B	6	A	3	8	abs													
	BSR d:8	BSR d:8	—	5	5	disp														
	BSR d:16	BSR d:16	—	5	C	0	0	disp												
	BST	BST #xx:3,Rd	B	6	7	0:IMM	rd													
BST #xx:3,@ERd		B	7	D	0:erd	0	6	7	0:IMM	0										
BST #xx:3,@aa:8		B	7	F	abs		6	7	0:IMM	0										
BST #xx:3,@aa:16		B	6	A	1	8	abs													
BST #xx:3,@aa:32		B	6	A	3	8	abs													
BTST #xx:3,Rd		BTST #xx:3,Rd	B	7	3	0:IMM	rd													
BTST	BTST #xx:3,@ERd	B	7	C	0:erd	0	7	3	0:IMM	0										
	BTST #xx:3,@aa:8	B	7	E	abs		7	3	0:IMM	0										
	BTST #xx:3,@aa:16	B	6	A	1	0	abs													
	BTST #xx:3,@aa:32	B	6	A	3	0	abs													
	BTST Rn,Rd	BTST Rn,Rd	B	6	3	m	rd													
	BTST Rn,@ERd	BTST Rn,@ERd	B	7	C	0:erd	0	6	3	m	0									

Table A-2 Instruction Codes (cont)

Instruction	Mnemonic	Size	Instruction Format																		
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th byte										
BTST	BTST Rn, @aa:8	B	7	E	abs	6	3	0	0												
	BTST Rn, @aa:16	B	6	A	1	0	abs														
	BTST Rn, @aa:32	B	6	A	3	0	abs														
BXOR	BXOR #xx:3, Rd	B	7	5	0:IMM	rd															
	BXOR #xx:3, @ERd	B	7	C	0:erd	0	7	5	0:IMM	0											
	BXOR #xx:3, @aa:8	B	7	E	abs		7	5	0:IMM	0											
	BXOR #xx:3, @aa:16	B	6	A	1	0	abs														
	BXOR #xx:3, @aa:32	B	6	A	3	0	abs														
CLRMAC	CLRMAC	—	Cannot be used in the H8S/2350 Series																		
CMP	CMP.B #xx:8, Rd	B	A	rd	IMM																
	CMP.B Rs, Rd	B	1	C	rs	rd															
	CMP.W #xx:16, Rd	W	7	9	2	rd	IMM														
	CMP.W Rs, Rd	W	1	D	rs	rd															
	CMP.L #xx:32, ERd	L	7	A	2	0:erd															
	CMP.L ERs, ERd	L	1	F	1:ers	0:erd															
DAA	DAA Rd	B	0	F	0	rd															
DAS	DAS Rd	B	1	F	0	rd															
DEC	DEC.B Rd	B	1	A	0	rd															
	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	DIVXS.B Rs, Rd	B	0	1	D	0	5	1	rs	rd											
	DIVXS.W Rs, ERd	W	0	1	D	0	5	3	rs	0:erd											
DIVXU	DIVXU.B Rs, Rd	B	5	1	rs	rd															
	DIVXU.W Rs, ERd	W	5	3	rs	0:erd															
EEPMOV	EEPMOV.B	—	7	B	5	C	5	9	8	F											
	EEPMOV.W	—	7	B	D	4	5	9	8	F											

Table A-2 Instruction Codes (cont)

Instruction	Mnemonic	Size	Instruction Format																
			1st byte	2nd byte		3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th 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													
JMP	JMP @ERn	—	5	9	0:ern	0													
	JMP @aa:24	—	5	A		abs													
JSR	JMP @aa:8	—	5	B	abs														
	JSR @ERn	—	5	D	0:ern	0													
	JSR @aa:24	—	5	E		abs													
LDC	JSR @aa:8	—	5	F	abs														
	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									
	LDC @(d:16,ERs),EXR	W	0	1	4	1	6	F	0:ers	0									
	LDC @(d:32,ERs),CCR	W	0	1	4	0	7	8	0:ers	0									
	LDC @(d:32,ERs),EXR	W	0	1	4	1	7	8	0:ers	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									
LDC @aa:16,CCR	W	0	1	4	0	6	B	0	0										
LDC @aa:16,EXR	W	0	1	4	1	6	B	0	0										

Table A-2 Instruction Codes (cont)

Instruction	Mnemonic	Size	Instruction Format										
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th 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	LDM.L @SP+, (ERn-ERn+1)	L	0	1	1	0	6	D	7	0:ern+1			
	LDM.L @SP+, (ERn-ERn+2)	L	0	1	2	0	6	D	7	0:ern+2			
	LDM.L @SP+, (ERn-ERn+3)	L	0	1	3	0	6	D	7	0:ern+3			
LDMAC	LDMAC ERs,MACH	L	Cannot be used in the H8S/2350 Series										
	LDMAC ERs,MACL	L											
MAC	MAC @ERn+, @ERm+	—											
MOV	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	abs						
	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	abs						
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,ERS),Rd	W	7	8	0:ers	0	6	B	2	rd	disp			

Table A-2 Instruction Codes (cont)

Instruction	Mnemonic	Size	Instruction Format																		
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th										
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				abs											
	MOV.W Rs,@ERd	W	6	9	1:erd	rs															
	MOV.W Rs,@(d:16,ERd)	W	6	F	1:erd	rs				disp											
	MOV.W Rs,@(d:32,ERd)	W	7	8	0:erd	0	6	B	A	rs											disp
	MOV.W Rs,@-ERd	W	6	D	1:erd	rs															
	MOV.W Rs,@aa:16	W	6	B	8	rs				abs											
	MOV.W Rs,@aa:32	W	6	B	A	rs				abs											
	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											disp
	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)*	L	0	1	0	0	7	8	0:erd	0											disp	
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												
MOVFPPE @aa:16,Rd	B	Cannot be used in the H8S/2350 Series																			
MOVTPPE @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.B Rs,Rd	B	5	0	rs	rd															
	MULXU.W Rs,ERd	W	5	2	rs	0:erd															

Table A-2 Instruction Codes (cont)

Instruc- tion	Mnemonic	Size	Instruction Format									
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th 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								
	OR.L ERs,ERd	L	0 1	F 0	6 4	0:ers:0: erd						
ORC	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									

Table A-2 Instruction Codes (cont)

Instruction	Mnemonic	Size	Instruction Format																
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th 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	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													
	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	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		—	5	6	7	0													
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													

Table A-2 Instruction Codes (cont)

Instruction	Mnemonic	Size	Instruction Format																
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th								
SHAR	SHAR.B Rd	B	1	8	rd														
	SHAR.B #2, Rd	B	1	C	rd														
	SHAR.W Rd	W	1	9	rd														
	SHAR.W #2, Rd	W	1	D	rd														
	SHAR.L ERd	L	1	B	0: erd														
	SHAR.L #2, ERd	L	1	F	0: erd														
SHLL	SHLL.B Rd	B	1	0	rd														
	SHLL.B #2, Rd	B	1	0	rd														
	SHLL.W Rd	W	1	0	rd														
	SHLL.W #2, Rd	W	1	0	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	disp							
	STC.W EXR, @(d:16, ERd)	W	0	1	4	1	6	F	1	erd	0	disp							
	STC.W CCR, @(d:32, ERd)	W	0	1	4	0	7	8	0	erd	0	6	B	A	0				disp
	STC.W EXR, @(d:32, ERd)	W	0	1	4	1	7	8	0	erd	0	6	B	A	0				disp
	STC.W CCR, @-ERd	W	0	1	4	0	6	D	1	erd	0								
	STC.W EXR, @-ERd	W	0	1	4	1	6	D	1	erd	0								

Table A-2 Instruction Codes (cont)

Instruction	Mnemonic	Size	Instruction Format											
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th 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	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 in the H8S/2350 Series											
	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					
	SUB.L ERs,ERd	L	1	A	1:ers	0:erd								
	SUBS #1,ERd	L	1	B	0	0:erd								
SUBS	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									
	SUBX Rs,Rd	B	1	E	rs	rd								
TAS @ERd	B	0	1	E	0	7	B	0:erd	C					
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					

Table A-2 Instruction Codes (cont)

Instruction	Mnemonic	Size	Instruction Format									
			1st byte	2nd byte	3rd byte	4th byte	5th byte	6th byte	7th byte	8th byte	9th byte	
XORC	XORC #xx:8,CCR	B	0	5	IMM							
	XORC #xx:8,EXR	B	0	1	4	1	0	5	IMM			

Note: * Bit 7 of the 4th byte of the MOV.L ERs, @(d:32,ERd) instruction can be either 1 or 0.

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 specifying an 8-bit or 16-bit register. The symbols rs, rd, and rn correspond to operand symbols

ers, erd, erm, erm: Register field (3 bits specifying an address register or 32-bit register. The symbols ers, erd, erm, and erm correspond to symbols ERs, ERd, ERn, and ERm.)

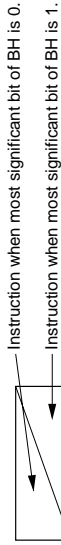
The register fields specify general registers as follows.

Address Register

32-Bit Register		16-Bit Register		8-Bit Register	
Register Field	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

Table A-3 Operation Code Map (1)

Instruction code		1st byte		2nd byte	
		AH	AL	BH	BL



AL/AH	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
0	NOP	Table A.3(2)	STC	LDC	ORC	XORC	ANDC	LDC	LDC	ADD	Table A.3(2)	Table A.3(2)	MOV	ADDX	Table A.3(2)	Table A.3(2)
1	Table A.3(2)	Table A.3(2)	STMAC	LDMAC	OR	XOR	AND	Table A.3(2)	Table A.3(2)	SUB	Table A.3(2)	Table A.3(2)	CMP	SUBX	Table A.3(2)	Table A.3(2)
2	MOV.B															
3																
4	BRA	BRN	BHI	BLS	BCC	BCS	BNE	BEQ	BVC	BVS	BPL	BMI	BGE	BLT	BGT	BLE
5	MULXU	DIVXU	MULXU	DIVXU	RTS	BSR	RTE	TRAPA	Table A.3(2)		JMP		BSR		JSR	
6	BSET	BNOT	BCLR	BTST	OR	XOR	AND	BST	MOV	MOV	Table A.3(2)					
7					BIOR	BXOR	BAND	BLD	BIOR	BIOR	BIOR	BIOR	BIOR	BIOR	BIOR	BIOR
8	ADD															
9	ADDX															
A	CMP															
B	SUBX															
C	OR															
D	XOR															
E	AND															
F	MOV															

Note: * Cannot be used in the H8S/2350 Series.

Table A-3 Operation Code Map (2)

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	D
01	MOV	LDM	STM	LDC	STC		MAC*		SLEEP		CLRMAC*		Table A.3(3)	Table A.3(3)
0A	INC													ADD
0B	ADDS					INC		INC	ADDS					INC
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		EXTS
1A	DEC													SUB
1B	SUBS					DEC		DEC	SUBS					DEC
1F	DAS													CMP
58	BRA	BRN	BHI	BLS	BCC	BCS	BNE	BEQ	BVC	BVS	BPL	BMI	BGE	BLT
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 in the H8S/2350 Series.

Table A-3 Operation Code Map (3)

Instruction code	1st byte		2nd byte		3rd byte			4th byte	
	AH	AL	BH	BL	CH	CL	DH	DL	



Instruction when most sign
Instruction when most sign

Instruction code	0	1	2	3	4	5	6	7	8	9	A	B	C	D
AH/AL/BH/BL/CH	CL													
01C05	MULXS		MULXS											
01D05		DIVXS		DIVXS										
01F06					OR	XOR	AND							
7Cr06 *1				BTST										
7Cr07 *1				BTST	BOR BIOR	BXOR BIXOR	BAND BIAND	BLD BILD	BST BIST					
7Dr06 *1	BSET	BNOT	BCLR											
7Dr07 *1	BSET	BNOT	BCLR											
7Eaa6 *2				BTST										
7Eaa7 *2				BTST	BOR BIOR	BXOR BIXOR	BAND BIAND	BLD BILD	BST BIST					
7Faa6 *2	BSET	BNOT	BCLR											
7Faa7 *2	BSET	BNOT	BCLR											

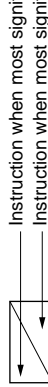
Notes: 1. r is the register specification field.
2. aa is the absolute address specification.

Table A-3 Operation Code Map (4)

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 AHALBHBL...FHFHGLH	0	1	2	3	4	5	6	7	8	9	A	B	C	D
6A10aaaa6*				BTST										
6A10aaaa7*					BOR	BXOR	BAND	BLD						
					BIOR	BIXOR	BIAND	BILD						
6A18aaaa6*								BST						
								BIST						
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 AHALBHBL...FHFHGLH	0	1	2	3	4	5	6	7	8	9	A	B	C	D			
6A30aaaaaaaa6*				BTST													
6A30aaaaaaaa7*					BOR	BXOR	BAND	BLD									
					BIOR	BIXOR	BIAND	BILD									
6A38aaaaaaaa6*								BST									
								BIST									
6A38aaaaaaaa7*			BCLR														
	BSET	BNOT															



Note: * aa is the absolute address specification.

each cycle. The number of states required for execution of an instruction can be calculated from these two tables as follows:

$$\text{Execution states} = I \times S_I + J \times S_J + K \times S_K + L \times S_L + M \times S_M + N \times S_N$$

Examples: Advanced mode, program code and stack located in external memory, on-chip supporting modules accessed in two states with 8-bit bus width, external devices accessed in three states with one wait state and 16-bit bus width.

1. BSET #0, @FFFFC7:8

From table A-5:

$$I = L = 2, \quad J = K = M = N = 0$$

From table A-4:

$$S_I = 4, \quad S_L = 2$$

$$\text{Number of states required for execution} = 2 \times 4 + 2 \times 2 = 12$$

2. JSR @@30

From table A-5:

$$I = J = K = 2, \quad L = M = N = 0$$

From table A-4:

$$S_I = S_J = S_K = 4$$

$$\text{Number of states required for execution} = 2 \times 4 + 2 \times 4 + 2 \times 4 = 24$$

Cycle		On-Chip Memory	Module		8-Bit Bus		16-Bit Bus	
			8-Bit Bus	16-Bit Bus	2-State Access	3-State Access	2-State Access	3-State Access
Instruction fetch	S_I	1	4	2	4	6 + 2m	2	3 + m
Branch address read	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	1	1

Legend

m: Number of wait states inserted into external device access

Instruction	Mnemonic	1	2	3	4
ADD	ADD.B #xx:8,Rd	1			
	ADD.B Rs,Rd	1			
	ADD.W #xx:16,Rd	2			
	ADD.W Rs,Rd	1			
	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			
	BMI d:8	2			
	BGE d:8	2			
	BLT d:8	2			
	BGT d:8	2			
	BLE d:8	2			
	BRA d:16 (BT d:16)	2			1
BRN d:16 (BF d:16)	2			1	

Instruction	Mnemonic	T	J	K	L	M	N
Bcc	BHI d:16	2					1
	BLS d:16	2					1
	BCC d:16 (BHS d:16)	2					1
	BCS d:16 (BLO d:16)	2					1
	BNE d:16	2					1
	BEQ d:16	2					1
	BVC d:16	2					1
	BVS d:16	2					1
	BPL d:16	2					1
	BMI d:16	2					1
	BGE d:16	2					1
	BLT d:16	2					1
	BGT d:16	2					1
	BLE d:16	2					1
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		
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		
BILD	BILD #xx:3,Rd	1					
	BILD #xx:3,@ERd	2			1		
	BILD #xx:3,@aa:8	2			1		
	BILD #xx:3,@aa:16	3			1		
	BILD #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		
	BIOR #xx:8,@aa:32	4			1		

BIST	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
	BIST #xx:3,@aa:32	4	2
BIXOR	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
	BIXOR #xx:3,@aa:32	4	1
BLD	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
	BLD #xx:3,@aa:32	4	1
BNOT	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
BOR	BOR #xx:3,Rd	1	
	BOR #xx:3,@ERd	2	1
	BOR #xx:3,@aa:8	2	1
	BOR #xx:3,@aa:16	3	1
	BOR #xx:3,@aa:32	4	1
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

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				1	
	JMP @@aa:8	Normal	2	1			1
		Advanced	2	2			1
JSR	JSR @ERn	Normal	2		1		
		Advanced	2		2		
	JSR @aa:24	Normal	2			1	1
		Advanced	2			2	1
	JSR @@aa:8	Normal	2	1	1		
		Advanced	2	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	1
	LDC @ERs+,EXR	2				1	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	LDM.L @SP+, (ERn-ERn+1)	2		4		1	
	LDM.L @SP+, (ERn-ERn+2)	2		6		1	
	LDM.L @SP+, (ERn-ERn+3)	2		8		1	
LDMAC	LDMAC ERs,MACH	Cannot be used in the H8S/2350 Series					
	LDMAC ERs,MACL						

Instruction	Mnemonic	1	2	3	4
MAC	MAC @ERn+, @ERm+	Cannot be used in the H8S/2350 Series			
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		1
	MOV.B @aa:8,Rd	1	1		
	MOV.B @aa:16,Rd	2	1		
	MOV.B @aa:32,Rd	3	1		
	MOV.B Rs,@ERd	1	1		
	MOV.B Rs,@(d:16,ERd)	2	1		
	MOV.B Rs,@(d:32,ERd)	4	1		
	MOV.B Rs,@-ERd	1	1		1
	MOV.B Rs,@aa:8	1	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	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	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	1
	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	

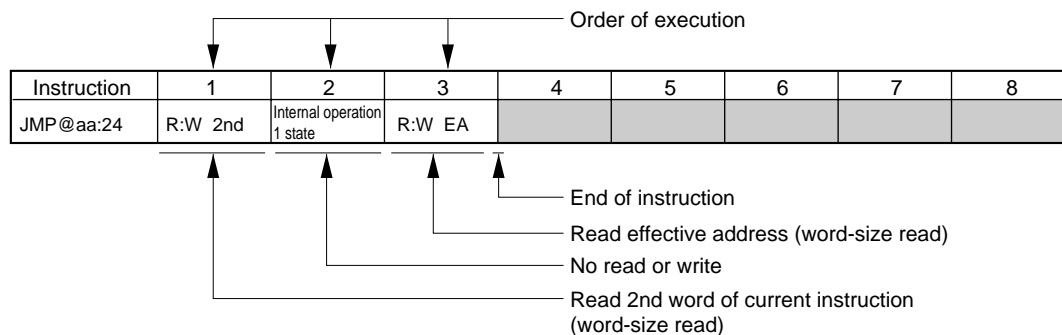
MOV	MOV.L ERs, @(d:32,ERd)	5	2	
	MOV.L ERs, @-ERd	2	2	1
	MOV.L ERs, @aa:16	3	2	
	MOV.L ERs, @aa:32	4	2	
MOVFP	MOVFP @:aa:16,Rd	Can not be used in the H8S/2350 Series		
MOVTPE	MOVTPE Rs, @:aa:16			
MULXS	MULXS.B Rs,Rd	2		11
	MULXS.W Rs,ERd	2		19
MULXU	MULXU.B Rs,Rd	1		11
	MULXU.W Rs,ERd	1		19
NEG	NEG.B 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	1
	POP.L ERn	2	2	1
PUSH	PUSH.W Rn	1	1	1
	PUSH.L ERn	2	2	1
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	ROTR.B Rd	1		
	ROTR.B #2,Rd	1		
	ROTR.W Rd	1		
	ROTR.W #2,Rd	1		
	ROTR.L 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	1
RTS	RTS	Normal	2	1	1
		Advanced	2	2	1
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		
SHLL	SHLL.B Rd		1		
	SHLL.B #2,Rd		1		
	SHLL.W Rd		1		
	SHLL.W #2,Rd		1		
	SHLL.L ERd		1		
	SHLL.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		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	1
	STC.W EXR,@-ERd		2			1	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	STM.L (ERn-ERn+1),@-SP		2	4			1
	STM.L (ERn-ERn+2),@-SP		2	6			1
	STM.L (ERn-ERn+3),@-SP		2	8			1
STMAC	STMAC MACH,ERd	Cannot be used in the H8S/2350 Series					
	STMAC MACL,ERd						
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				
SUBS	SUBS #1/2/4,ERd		1				
SUBX	SUBX #xx:8,Rd		1				
	SUBX Rs,Rd		1				
TAS	TAS @ERd		2		2		
TRAPA	TRAPA #x:2	Normal	2	1	2 / 3 * ¹		2
		Advanced	2	2	2 / 3 * ¹		2
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				

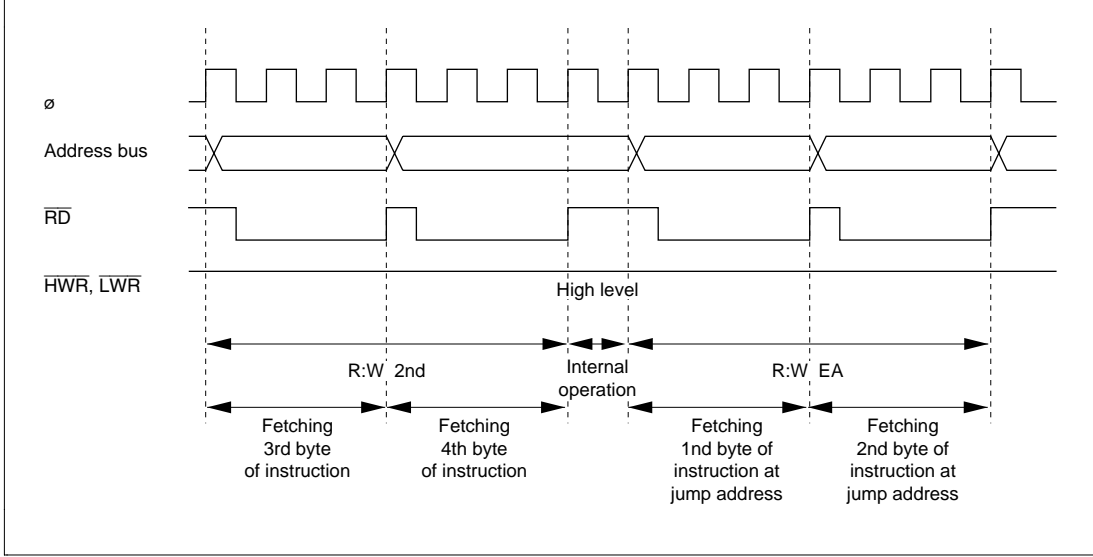
Notes: 1. 2 when EXR is invalid, 3 when EXR is valid.
2. When n bytes of data are transferred.

How to Read the Table:



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	Address of next 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)**

Table A-6 Instruction Execution Cycles

Instruction	1	2	3	4	5	6	7	8
ADD.B #xx:8,Rd	R:W NEXT							
ADD.B Rs,Rd	R:W NEXT							
ADD.W #xx:16,Rd	R:W 2nd	R:W NEXT						
ADD.W Rs,Rd	R:W NEXT							
ADD.L #xx:32,ERd	R:W 2nd	R:W 3rd	R:W NEXT					
ADD.L ERs,ERd	R:W NEXT							
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						
BMI d:8	R:W NEXT	R:W EA						
BGE d:8	R:W NEXT	R:W EA						
BLT d:8	R:W NEXT	R:W EA						
BGT d:8	R:W NEXT	R:W EA						

Table A-6 Instruction Execution Cycles (cont)

Instruction	1	2	3	4	5	6	7	8
BLE d:8	R:W NEXT	R:W EA						
BRA d:16 (BT d:16)	R:W 2nd	Internal operation, 1 state	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					
BLT d:16	R:W 2nd	Internal operation, 1 state	R:W EA					
BGT d:16	R:W 2nd	Internal operation, 1 state	R:W EA					
BLE 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				

Table A-6 Instruction Execution Cycles (cont)

Instruction	1	2	3	4	5	6	7	8
BCLR #xx:3, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:ME A	R:W:M NEXT	W:B EA		
BCLR Rn, Rd	R:W NEXT							
BCLR Rn, @ERd	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BCLR Rn, @aa:8	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BCLR Rn, @aa:16	R:W 2nd	R:W 3rd	R:B:ME A	R:W:M NEXT	W:B EA			
BCLR Rn, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:ME A	R:W:M NEXT	W:B EA		
BI/AND #xx:3, Rd	R:W NEXT							
BI/AND #xx:3, @ERd	R:W 2nd	R:B EA	R:W:M NEXT					
BI/AND #xx:3, @aa:8	R:W 2nd	R:B EA	R:W:M NEXT					
BI/AND #xx:3, @aa:16	R:W 2nd	R:W 3rd	R:B EA	R:W:M NEXT				
BI/AND #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				
BILD #xx:3, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B EA	R:W:M NEXT			
BIOR #xx:3, Rd	R:W NEXT							
BIOR #xx:3, @ERd	R:W 2nd	R:B EA	R:W:M NEXT					
BIOR #xx:3, @aa:8	R:W 2nd	R:B EA	R:W:M NEXT					
BIOR #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:ME A	R:W:M NEXT	W:B EA				
BIST #xx:3, @aa:8	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BIST #xx:3, @aa:16	R:W 2nd	R:W 3rd	R:B:ME A	R:W:M NEXT	W:B EA			
BIST #xx:3, @aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:ME A	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							

Table A-6 Instruction Execution Cycles (cont)

Instruction	1	2	3	4	5	6	7	8
BNOT #xx:3,@ERd	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BNOT #xx:3,@aa:8	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BNOT #xx:3,@aa:16	R:W 2nd	R:W 3rd	R:B:ME A	R:W:M NEXT	W:B EA			
BNOT #xx:3,@aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:ME A	R:W:M NEXT	W:B EA		
BNOT Rn,Rd	R:W NEXT							
BNOT Rn,@ERd	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BNOT Rn,@aa:8	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BNOT Rn,@aa:16	R:W 2nd	R:W 3rd	R:B:ME A	R:W:M NEXT	W:B EA			
BNOT Rn,@aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:ME A	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:M NEXT			
BSET #xx:3,Rd	R:W NEXT							
BSET #xx:3,@ERd	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BSET #xx:3,@aa:8	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BSET #xx:3,@aa:16	R:W 2nd	R:W 3rd	R:B:ME A	R:W:M NEXT	W:B EA			
BSET #xx:3,@aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:ME A	R:W:M NEXT	W:B EA		
BSET Rn,Rd	R:W NEXT							
BSET Rn,@ERd	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BSET Rn,@aa:8	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BSET Rn,@aa:16	R:W 2nd	R:W 3rd	R:B:ME A	R:W:M NEXT	W:B EA			
BSET Rn,@aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:ME A	R:W:M NEXT	W:B EA		
BSR d:8		Normal	W:W stack					
		Advanced	W:W:M stack(H)	W:W stack(L)				
BSR d:16		Normal	R:W EA	W:W stack				
		Advanced	Internal operation; 1 state	W:W:M stack(H)	W:W stack(L)			
			Internal operation; 1 state	W:W:M stack(H)	W:W stack(L)			
BST #xx:3,Rd	R:W NEXT							
BST #xx:3,@ERd	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BST #xx:3,@aa:8	R:W 2nd	R:B:ME A	R:W:M NEXT	W:B EA				
BST #xx:3,@aa:16	R:W 2nd	R:W 3rd	R:B:ME A	R:W:M NEXT	W:B EA			
BST #xx:3,@aa:32	R:W 2nd	R:W 3rd	R:W 4th	R:B:ME A	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					

Table A-6 Instruction Execution Cycles (cont)

Instruction	1	2	3	4	5	6	7	8
BTST #xx:3, @aa:8	R:W 2hd	R:B EA	R:W:M NEXT					
BTST #xx:3, @aa:16	R:W 2hd	R:W 3rd	R:B EA	R:W:M NEXT				
BTST #xx:3, @aa:32	R:W 2hd	R:W 3rd	R:W 4th	R:B EA	R:W:M NEXT			
BTST Rn, Rd	R:W NEXT							
BTST Rn, @ERd	R:W 2hd	R:B EA	R:W:M NEXT					
BTST Rn, @aa:8	R:W 2hd	R:B EA	R:W:M NEXT					
BTST Rn, @aa:16	R:W 2hd	R:W 3rd	R:B EA	R:W:M NEXT				
BTST Rn, @aa:32	R:W 2hd	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 2hd	R:B EA	R:W:M NEXT					
BXOR #xx:3, @aa:8	R:W 2hd	R:B EA	R:W:M NEXT					
BXOR #xx:3, @aa:16	R:W 2hd	R:W 3rd	R:B EA	R:W:M NEXT				
BXOR #xx:3, @aa:32	R:W 2hd	R:W 3rd	R:W 4th	R:B EA	R:W:M NEXT			
CLRMAC	Cannot be used in the H8S/2350 Series							
CMP.B #xx:8, Rd	R:W NEXT							
CMP.B Rs, Rd	R:W NEXT							
CMP.W #xx:16, Rd	R:W 2hd	R:W NEXT						
CMP.W Rs, Rd	R:W NEXT							
CMP.L #xx:32, ERd	R:W 2hd	R:W 3rd	R:W NEXT					
CMP.L ERs, ERd	R:W NEXT							
DAA Rd	R:W NEXT							
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 2hd	R:W NEXT	Internal operation, 11 states					
DIVXS.W Rs, ERd	R:W 2hd	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 2hd	R:B EAs ^{*1}	R:B EAd ^{*1}	R:B EAs ^{*2}	W:B EAd ^{*2}			
EEMOV.W	R:W 2hd	R:B EAs ^{*1}	R:B EAd ^{*1}	R:B EAs ^{*2}	W:B EAd ^{*2}			
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							

Table A-6 Instruction Execution Cycles (cont)

Instruction	1	2	3	4	5	6	7	8
INC.W #1/2,Rd	R:W NEXT							
INCL #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	Normal	R:W aa:8	Internal operation, 1 state	R:W EA				
	Advanced	R:W:M aa:8	R:W aa:8	Internal operation, 1 state	R:W EA			
JSR @ERn	Normal	R:W EA	W:W stack					
	Advanced	R:W EA	W:W:M stack (H)	W:W stack (L)				
JSR @aa:24	Normal	Internal operation, 1 state	R:W EA	W:W stack				
	Advanced	Internal operation, 1 state	R:W EA	W:W:M stack (H)	W:W stack (L)			
JSR @aa:8	Normal	R:W aa:8	W:W stack	R:W EA				
	Advanced	R:W:M aa:8	R:W aa:8	W:W:M stack (H)	W:W stack (L)	R:W EA		
LDC #xx:8,CCR	R:W NEXT							
LDC #xx:8,EXR	R:W 2nd	R:W NEXT						
LDC Rs,CCR	R:W NEXT							
LDC Rs,EXR	R:W NEXT							
LDC @ERs,CCR	R:W 2nd	R:W NEXT	R:W EA					
LDC @ERs,EXR	R:W 2nd	R:W NEXT	R:W EA					
LDC @(d:16,ERs),CCR	R:W 2nd	R:W 3rd	R:W NEXT	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)	R:W 2nd	R:W:M NEXT	Internal operation, 1 state	R:W:M stack (H) ^{*3}	R:W stack (L) ^{*3}			

Table A-6 Instruction Execution Cycles (cont)

Instruction	1	2	3	4	5	6	7	8
LDM.L @SP+,(ERn-ERn+2)	R:W 2nd	R:W NEXT	Internal operation, 1 state	R:W:M stack (H) ^{*3}	R:W stack (L) ^{*3}			
LDM.L @SP+,(ERn-ERn+3)	R:W 2nd	R:W NEXT	Internal operation, 1 state	R:W:M stack (H) ^{*3}	R:W stack (L) ^{*3}			
LDMAC ERs, MACH	Cannot be used in the H8S/2350 Series							
LDMAC ERs, MAQL								
MAC @ERn+, @ERm+	R:W 2nd	R:W NEXT	R:W EAn	R:W EAm				
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 @(d:32,ERs),Rd	R:W 2nd	R:W 3rd	R:W 4th	R:W NEXT	R:B EA			
MOV.B @ERs+,Rd	R:W NEXT	Internal operation, 1 state	R:B EA					
MOV.B @aa:8,Rd	R:W NEXT	R:B EA						
MOV.B @aa:16,Rd	R:W 2nd	R:W NEXT	R:B EA					
MOV.B @aa:32,Rd	R:W 2nd	R:W 3rd	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						

Table A-6 Instruction Execution Cycles (cont)

Instruction	1	2	3	4	5	6	7	8
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:E 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 #xx:32,ERd	R:W 2nd	R:W 3rd	R:W NEXT					
MOV.L ERs,ERd	R:W NEXT							
MOV.L @ERs,ERd	R:W 2nd	R:W:M NEXT	R:W:M EA	R:W EA+2				
MOV.L @(d:16,ERs),ERd	R:W 2nd	R:W:M 3rd	R:W NEXT	R:W:M EA	R:W EA+2			
MOV.L @(d:32,ERs),ERd	R:W 2nd	R:W:M 3rd	R:W:M 4th	R:W 5th	R:W NEXT	R:W:M EA	R:W EA+2	
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		
MOV.FPE @aa:16,Rd	Cannot be used in the H8S/2350 Series							
MOVTYPE Rs,@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							
NOT.L ERd	R:W NEXT							
OR.B #xx:8,Rd	R:W NEXT							
OR.B Rs,Rd	R:W NEXT							

Table A-6 Instruction Execution Cycles (cont)

Instruction	1	2	3	4	5	6	7	8
OR.W #xx:16,Rd	R:W 2nd	R:W NEXT						
OR.W Rs,Rd	R:W NEXT							
OR.L #xx:32,ERd	R:W 2nd	R:W 3rd	R:W NEXT					
OR.L ERs,ERd	R:W 2nd	R:W NEXT						
ORC #xx:8,CCR	R:W NEXT							
ORC #xx:8,EXR	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							
ROTXL.L #2,ERd	R:W NEXT							
ROTXR.B Rd	R:W NEXT							
ROTXR.B #2,Rd	R:W NEXT							
ROTXR.W Rd	R:W NEXT							
ROTXR.W #2,Rd	R:W NEXT							
ROTXR.L ERd	R:W NEXT							

Table A-6 Instruction Execution Cycles (cont)

Instruction	1	2	3	4	5	6	7	8
ROTXR.L #2,ERd	R:W NEXT	R:W stack (EXR)	R:W stack (H)	R:W stack (L)	Internal operation, 1 state	R:W ^{#4}		
RTE	R:W NEXT	R:W stack	Internal operation, 1 state	R:W ^{#4}				
RTS	Normal	R:W stack	Internal operation, 1 state	R:W ^{#4}				
	Advanced	R:W:M stack (H)	R:W stack (L)	Internal operation, 1 state	R:W ^{#4}			
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							
SLEEP	R:W NEXT	Internal operation:M						
STC CCR,Rd	R:W NEXT							
STC EXR,Rd	R:W NEXT							
STC CCR,@ERd	R:W 2nd	R:W NEXT	W:W EA					
STC EXR,@ERd	R:W 2nd	R:W NEXT	W:W EA					
STC CCR,@(d:16,ERd)	R:W 2nd	R:W 3rd	R:W NEXT	W:W EA				

Table A-6 Instruction Execution Cycles (cont)

Instruction	1	2	3	4	5	6	7	8
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	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	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	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 the H8S/2350 Series							
STMAC MACL,ERd	Cannot be used in the H8S/2350 Series							
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							
SUBS #1/2/4,ERd	R:W NEXT							
SUBX #xx:8,Rd	R:W NEXT							
SUBX Rs,Rd	R:W NEXT							
TAS @ERd	R:W 2nd	R:W NEXT	R:B:M EA	W:B EA				
TRAPA #x:2	Normal	Internal operation, 1 state	W:W stack (L)	W:W stack (H)	W:W stack (EXR)	R:W VEC	Internal operation, 1 state	R:W ^{*8}
	Advanced	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
XOR.B #xx:8,Rd	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					

Table A-6 Instruction Execution Cycles (cont)

Instruction	1	2	3	4	5	6	7	8
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	Normal	Internal operation, 1 state	R:W ^{#5}					
	Advanced	R:W VEC+2	Internal operation, 1 state	R:W ^{#5}				
Interrupt exception handling	Normal	Internal operation, 1 state	W:W stack (L)	W:W stack (H)	W:W stack (EXR)	R:W VEC	Internal operation, 1 state	R:W ^{#7}
	Advanced	R:W ^{#6}	Internal operation, 1 state	W:W stack (L)	W:W stack (EXR)	R:W:W 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 value of R4L or R4. If n = 0, these bus cycles are not executed.

3. Repeated two times to save or restore two registers, three times for three registers, or 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 recovery from sleep mode or software standby mode operation is replaced by an internal operation.

7. Start address of the interrupt-handling routine.

m =	{	31 for longword operands
		15 for word operands
		7 for byte operands
Si		The i-th bit of the source operand
Di		The i-th bit of the destination operand
Ri		The i-th bit of the result
Dn		The specified bit in the destination operand
—		Not affected
↕		Modified according to the result of the instruction (see definition)
0		Always cleared to 0
1		Always set to 1
*		Undetermined (no guaranteed value)
Z'		Z flag before instruction execution
C'		C flag before instruction execution

						$N = Rm$ $Z = \overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$ $V = Sm \cdot Dm \cdot \overline{Rm} + \overline{Sm} \cdot \overline{Dm} \cdot Rm$ $C = Sm \cdot Dm + Dm \cdot \overline{Rm} + Sm \cdot \overline{Rm}$
ADDS	—	—	—	—	—	
ADDX	↕	↕	↕	↕	↕	$H = Sm-4 \cdot Dm-4 + Dm-4 \cdot \overline{Rm-4} + Sm-4 \cdot \overline{Rm-4}$ $N = Rm$ $Z = Z' \cdot \overline{Rm} \cdot \dots \cdot \overline{R0}$ $V = Sm \cdot Dm \cdot \overline{Rm} + \overline{Sm} \cdot \overline{Dm} \cdot Rm$ $C = Sm \cdot Dm + Dm \cdot \overline{Rm} + Sm \cdot \overline{Rm}$
AND	—	↕	↕	0	—	$N = Rm$ $Z = \overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$
ANDC	↕	↕	↕	↕	↕	Stores the corresponding bits of the result. No flags change when the operand is EXR.
BAND	—	—	—	—	↕	$C = C' \cdot Dn$
Bcc	—	—	—	—	—	
BCLR	—	—	—	—	—	
BIAND	—	—	—	—	↕	$C = C' \cdot \overline{Dn}$
BILD	—	—	—	—	↕	$C = \overline{Dn}$
BIOR	—	—	—	—	↕	$C = C' + \overline{Dn}$
BIST	—	—	—	—	—	
BIXOR	—	—	—	—	↕	$C = C' \cdot Dn + \overline{C'} \cdot \overline{Dn}$
BLD	—	—	—	—	↕	$C = Dn$
BNOT	—	—	—	—	—	
BOR	—	—	—	—	↕	$C = C' + Dn$
BSET	—	—	—	—	—	
BSR	—	—	—	—	—	
BST	—	—	—	—	—	
BTST	—	—	↕	—	—	$Z = \overline{Dn}$
BXOR	—	—	—	—	↕	$C = C' \cdot \overline{Dn} + \overline{C'} \cdot Dn$
CLRMAC						Cannot be used in the H8S/2350 Series

						$N = R_m$ $Z = \overline{R_m} \cdot \overline{R_{m-1}} \cdot \dots \cdot \overline{R_0}$ $V = \overline{S_m} \cdot D_m \cdot \overline{R_m} + S_m \cdot \overline{D_m} \cdot R_m$ $C = S_m \cdot \overline{D_m} + \overline{D_m} \cdot R_m + S_m \cdot R_m$
DAA	*	↓	↓	*	↓	$N = R_m$ $Z = \overline{R_m} \cdot \overline{R_{m-1}} \cdot \dots \cdot \overline{R_0}$ C: decimal arithmetic carry
DAS	*	↓	↓	*	↓	$N = R_m$ $Z = \overline{R_m} \cdot \overline{R_{m-1}} \cdot \dots \cdot \overline{R_0}$ C: decimal arithmetic borrow
DEC	—	↓	↓	↓	—	$N = R_m$ $Z = \overline{R_m} \cdot \overline{R_{m-1}} \cdot \dots \cdot \overline{R_0}$ $V = D_m \cdot \overline{R_m}$
DIVXS	—	↓	↓	—	—	$N = S_m \cdot \overline{D_m} + \overline{S_m} \cdot D_m$ $Z = \overline{S_m} \cdot \overline{S_{m-1}} \cdot \dots \cdot \overline{S_0}$
DIVXU	—	↓	↓	—	—	$N = S_m$ $Z = \overline{S_m} \cdot \overline{S_{m-1}} \cdot \dots \cdot \overline{S_0}$
EEPMOV	—	—	—	—	—	
EXTS	—	↓	↓	0	—	$N = R_m$ $Z = \overline{R_m} \cdot \overline{R_{m-1}} \cdot \dots \cdot \overline{R_0}$
EXTU	—	0	↓	0	—	$Z = \overline{R_m} \cdot \overline{R_{m-1}} \cdot \dots \cdot \overline{R_0}$
INC	—	↓	↓	↓	—	$N = R_m$ $Z = \overline{R_m} \cdot \overline{R_{m-1}} \cdot \dots \cdot \overline{R_0}$ $V = \overline{D_m} \cdot R_m$
JMP	—	—	—	—	—	
JSR	—	—	—	—	—	
LDC	↓	↓	↓	↓	↓	Stores the corresponding bits of the result. No flags change when the operand is EXR.
LDM	—	—	—	—	—	
LDMAC						Cannot be used in the H8S/2350 Series
MAC						

MOVFP						Can not be used in the H8S/2350 Series
MOVTPE						
MULXS	—	↓	↓	—	—	N = R2m Z = $\overline{R2m} \cdot \overline{R2m-1} \cdot \dots \cdot \overline{R0}$
MULXU	—	—	—	—	—	
NEG	↓	↓	↓	↓	↓	H = Dm-4 + Rm-4 N = Rm Z = $\overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$ V = Dm · Rm C = Dm + Rm
NOP	—	—	—	—	—	
NOT	—	↓	↓	0	—	N = Rm Z = $\overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$
OR	—	↓	↓	0	—	N = Rm Z = $\overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$
ORC	↓	↓	↓	↓	↓	Stores the corresponding bits of the result. No flags change when the operand is EXR.
POP	—	↓	↓	0	—	N = Rm Z = $\overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$
PUSH	—	↓	↓	0	—	N = Rm Z = $\overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$
ROTL	—	↓	↓	0	↓	N = Rm Z = $\overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$ C = Dm (1-bit shift) or C = Dm-1 (2-bit shift)
ROTR	—	↓	↓	0	↓	N = Rm Z = $\overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$ C = D0 (1-bit shift) or C = D1 (2-bit shift)

					$Z = \overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$ C = Dm (1-bit shift) or C = Dm-1 (2-bit shift)	
ROTXR	—	↓	↓	0	↓	N = Rm $Z = \overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$ C = D0 (1-bit shift) or C = D1 (2-bit shift)
RTE	↓	↓	↓	↓	↓	Stores the corresponding bits of the result.
RTS	—	—	—	—	—	
SHAL	—	↓	↓	↓	↓	N = Rm $Z = \overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$ $V = \overline{Dm} \cdot \overline{Dm-1} + \overline{Dm} \cdot \overline{Dm-1}$ (1-bit shift) $V = \overline{Dm} \cdot \overline{Dm-1} \cdot \overline{Dm-2} \cdot \overline{Dm} \cdot \overline{Dm-1} \cdot \overline{Dm-2}$ (2-bit shift) C = Dm (1-bit shift) or C = Dm-1 (2-bit shift)
SHAR	—	↓	↓	0	↓	N = Rm $Z = \overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$ C = D0 (1-bit shift) or C = D1 (2-bit shift)
SHLL	—	↓	↓	0	↓	N = Rm $Z = \overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$ C = Dm (1-bit shift) or C = Dm-1 (2-bit shift)
SHLR	—	0	↓	0	↓	N = Rm $Z = \overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$ C = D0 (1-bit shift) or C = D1 (2-bit shift)
SLEEP	—	—	—	—	—	
STC	—	—	—	—	—	
STM	—	—	—	—	—	
STMAC						Cannot be used in the H8S/2350 Series

						$N = \overline{Rm}$ $Z = \overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$ $V = \overline{Sm} \cdot Dm \cdot \overline{Rm} + Sm \cdot \overline{Dm} \cdot Rm$ $C = Sm \cdot \overline{Dm} + \overline{Dm} \cdot Rm + Sm \cdot Rm$
SUBS	—	—	—	—	—	
SUBX	↕	↕	↕	↕	↕	$H = Sm-4 \cdot \overline{Dm-4} + \overline{Dm-4} \cdot Rm-4 + Sm-4 \cdot Rm-4$ $N = Rm$ $Z = Z' \cdot \overline{Rm} \cdot \dots \cdot \overline{R0}$ $V = \overline{Sm} \cdot Dm \cdot \overline{Rm} + Sm \cdot \overline{Dm} \cdot Rm$ $C = Sm \cdot \overline{Dm} + \overline{Dm} \cdot Rm + Sm \cdot Rm$
TAS	—	↕	↕	0	—	$N = Dm$ $Z = \overline{Dm} \cdot \overline{Dm-1} \cdot \dots \cdot \overline{D0}$
TRAPA	—	—	—	—	—	
XOR	—	↕	↕	0	—	$N = Rm$ $Z = \overline{Rm} \cdot \overline{Rm-1} \cdot \dots \cdot \overline{R0}$
XORC	↕	↕	↕	↕	↕	Stores the corresponding bits of the result. No flags change when the operand is EXR.

Address (low)	Register Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Module Name	Data Bus Width
H'F800 to H'FBFF	MRA	SM1	SM0	DM1	DM0	MD1	MD0	DTS	Sz	DTC	16/32* bit
	SAR										
	MRB	CHNE	DISEL	—	—	—	—	—	—		
	DAR										
	CRA										
	CRB										
H'FE80	TCR3	CCLR2	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0	TPU3	16 bit
H'FE81	TMDR3	—	—	BFB	BFA	MD3	MD2	MD1	MD0		
H'FE82	TIOR3H	IOB3	IOB2	IOB1	IOB0	IOA3	IOA2	IOA1	IOA0		
H'FE83	TIOR3L	IOD3	IOD2	IOD1	IOD0	IOC3	IOC2	IOC1	IOC0		
H'FE84	TIER3	TTGE	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA		
H'FE85	TSR3	—	—	—	TCFV	TGFD	TGFC	TGFB	TGFA		
H'FE86	TCNT3										
H'FE87											
H'FE88	TGR3A										
H'FE89											
H'FE8A	TGR3B										
H'FE8B											
H'FE8C	TGR3C										
H'FE8D											
H'FE8E	TGR3D										
H'FE8F											

Note: * Located in on-chip RAM. The bus width is 32 bits when the DTC accesses this area as register information, and 16 bits otherwise.

H'FE94	TIER4	TTGE	—	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA		
H'FE95	TSR4	TCFD	—	—	TCFU	TCFV	—	—	TGFB	TGFA		
H'FE96	TCNT4											
H'FE97												
H'FE98	TGR4A											
H'FE99												
H'FE9A	TGR4B											
H'FE9B												
H'FEA0	TCR5	—	—	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0	TPU5	16 bit
H'FEA1	TMDR5	—	—	—	—	MD3	MD2	MD1	MD0			
H'FEA2	TIOR5	IOB3	IOB2	IOB1	IOB0	IOA3	IOA2	IOA1	IOA0			
H'FEA4	TIER5	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA			
H'FEA5	TSR5	TCFD	—	TCFU	TCFV	—	—	TGFB	TGFA			
H'FEA6	TCNT5											
H'FEA7												
H'FEA8	TGR5A											
H'FEA9												
H'FEAA	TGR5B											
H'FEAB												
H'FEB0	P1DDR	P17DDR	P16DDR	P15DDR	P14DDR	P13DDR	P12DDR	P11DDR	P10DDR		Port	8 bit
H'FEB1	P2DDR	P27DDR	P26DDR	P25DDR	P24DDR	P23DDR	P22DDR	P21DDR	P20DDR			
H'FEB2	P3DDR	—	—	—	—	P35DDR	P34DDR	P33DDR	P32DDR	P31DDR	P30DDR	
H'FEB4	P5DDR	—	—	—	—	—	—	P53DDR	P52DDR	P51DDR	P50DDR	
H'FEB5	P6DDR	P67DDR	P66DDR	P65DDR	P64DDR	P63DDR	P62DDR	P61DDR	P60DDR			
H'FEB9	PADDR	PA7DDR	PA6DDR	PA5DDR	PA4DDR	PA3DDR	PA2DDR	PA1DDR	PA0DDR			
H'FEBA	PBDDR*	PB7DDR	PB6DDR	PB5DDR	PB4DDR	PB3DDR	PB2DDR	PB1DDR	PB0DDR			
H'FEBB	PCDDR*	PC7DDR	PC6DDR	PC5DDR	PC4DDR	PC3DDR	PC2DDR	PC1DDR	PC0DDR			
H'FEBC	PDDDR*	PD7DDR	PD6DDR	PD5DDR	PD4DDR	PD3DDR	PD2DDR	PD1DDR	PD0DDR			
H'FEBD	PEDDR	PE7DDR	PE6DDR	PE5DDR	PE4DDR	PE3DDR	PE2DDR	PE1DDR	PE0DDR			
H'FEBE	PFDDR	PF7DDR	PF6DDR	PF5DDR	PF4DDR	PF3DDR	PF2DDR	PF1DDR	PF0DDR			
H'FEBF	PGDDR	—	—	—	—	—	—	PG4DDR	PG3DDR	PG2DDR	PG1DDR	PG0DDR

Note: * Only applies to the H8S/2351.

H'FEC7	IPRD	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0		
H'FEC8	IPRE	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0		
H'FEC9	IPRF	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0		
H'FECA	IPRG	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0		
H'FECB	IPRH	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0		
H'FECC	IPRI	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0		
H'FECD	IPRJ	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0		
H'FECE	IPRK	—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0		
H'FED0	ABWCR	ABW7	ABW6	ABW5	ABW4	ABW3	ABW2	ABW1	ABW0	Bus controller	8 bit
H'FED1	ASTCR	AST7	AST6	AST5	AST4	AST3	AST2	AST1	AST0		
H'FED2	WCRH	W71	W70	W61	W60	W51	W50	W41	W40		
H'FED3	WCRL	W31	W30	W21	W20	W11	W10	W01	W00		
H'FED4	BCRH	ICIS1	ICIS0	BRSTRM	BRSTS1	BRSTS0	RMTS2	RMTS1	RMST0		
H'FED5	BCRL	BRLE	BREQOE	EAE	—	LCASS	—	WDBE	WAITE		
H'FED6	MCR	TPC	BE	RCDM	CW2	MXC1	MXC0	RLW1	RLW0		
H'FED7	DRAMCR	RFSHE	RCW	RMODE	CMF	CMIE	CKS2	CKS1	CKS0		
H'FED8	RTCNT										
H'FED9	RTCOR										
H'FEE0	MAR0AH	—	—	—	—	—	—	—	—	DMAC	16 bit
H'FEE1											
H'FEE2	MAR0AL										
H'FEE3											
H'FEE4	IOAR0A										
H'FEE5											
H'FEE6	ETCR0A										
H'FEE7											
H'FEE8	MAR0BH	—	—	—	—	—	—	—	—		
H'FEE9											
H'FEEA	MAR0BL										
H'FEEB											
H'FEEC	IOAR0B										
H'FEED											
H'FEEE	ETCR0B										
H'FEEF											

H'FF2F	ISR	IRQ7F	IRQ6F	IRQ5F	IRQ4F	IRQ3F	IRQ2F	IRQ1F	IRQ0F			
H'FF30 to H'FF35	DT CER	DTCE7	DTCE6	DTCE5	DTCE4	DTCE3	DTCE2	DTCE1	DTCE0	DTC		8 bit
H'FF37	DTVECR	SWDTE	DTVEC6	DTVEC5	DTVEC4	DTVEC3	DTVEC2	DTVEC1	DTVEC0			
H'FF38	SBYCR	SSBY	STS2	STS1	STS0	OPE	—	—	—		Power-down mode	8 bit
H'FF39	SYSCR	—	—	INTM1	INTM0	NMIEG	—	—	RAME	MCU		8 bit
H'FF3A	SCKCR	PSTOP	—	—	—	—	SCK2	SCK1	SCK0		Clock pulse generator	8 bit
H'FF3B	MDCR	—	—	—	—	—	MDS2	MDS1	MDS0	MCU		8 bit
H'FF3C	MSTPCR	MSTP15	MSTP14	MSTP13	MSTP12	MSTP11	MSTP10	MSTP9	MSTP8		Power-down mode	8 bit
H'FF3D	MSTPCR	MSTP7	MSTP6	MSTP5	MSTP4	MSTP3	MSTP2	MSTP1	MSTP0			
H'FF44	Reserved	—	—	—	—	—	—	—	—		Reserved	—
H'FF46	PCR	G3CMS1	G3CMS0	G2CMS1	G2CMS0	G1CMS1	G1CMS0	G0CMS1	G0CMS0		PPG	8 bit
H'FF47	PMR	G3INV	G2INV	G1INV	G0INV	G3NOV	G2NOV	G1NOV	G0NOV			
H'FF48	NDERH	NDER15	NDER14	NDER13	NDER12	NDER11	NDER10	NDER9	NDER8			
H'FF49	NDERL	NDER7	NDER6	NDER5	NDER4	NDER3	NDER2	NDER1	NDER0			
H'FF4A	PODRH	POD15	POD14	POD13	POD12	POD11	POD10	POD9	POD8			
H'FF4B	PODRL	POD7	POD6	POD5	POD4	POD3	POD2	POD1	POD0			
H'FF4C*	NDRH	NDR15	NDR14	NDR13	NDR12	NDR11	NDR10	NDR9	NDR8			
H'FF4D*	NDRL	NDR7	NDR6	NDR5	NDR4	NDR3	NDR2	NDR1	NDR0			
H'FF4E*	NDRH	—	—	—	—	NDR11	NDR10	NDR9	NDR8			
H'FF4F*	NDRL	—	—	—	—	NDR3	NDR2	NDR1	NDR0			

Note: * If the pulse output group 2 and pulse output group 3 output triggers are the same according to the PCR setting, the NDRH address will be H'FF4C, and if different, the address of NDRH for group 2 will be H'FF4E, and that for group 3 will be H'FF4C. Similarly, if the pulse output group 0 and pulse output group 1 output triggers are the same according to the PCR setting, the NDRL address will be H'FF4D, and if different, the address of NDRL for group 0 will be H'FF4F, and that for group 1 will be H'FF4D.

H'FF53	PORT4	P47	P46	P45	P44	P43	P42	P41	P40
H'FF54	PORT5	—	—	—	—	P53	P52	P51	P50
H'FF55	PORT6	P67	P66	P65	P64	P63	P62	P61	P60
H'FF59	PORTA	PA7	PA6	PA5	PA4	PA3	PA2	PA1	PA0
H'FF5A	PORTB*	PB7	PB6	PB5	PB4	PB3	PB2	PB1	PB0
H'FF5B	PORTC*	PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0
H'FF5C	PORTD*	PD7	PD6	PD5	PD4	PD3	PD2	PD1	PD0
H'FF5D	PORTE	PE7	PE6	PE5	PE4	PE3	PE2	PE1	PE0
H'FF5E	PORTF	PF7	PF6	PF5	PF4	PF3	PF2	PF1	PF0
H'FF5F	PORTG	—	—	—	PG4	PG3	PG2	PG1	PG0
H'FF60	P1DR	P17DR	P16DR	P15DR	P14DR	P13DR	P12DR	P11DR	P10DR
H'FF61	P2DR	P27DR	P26DR	P25DR	P24DR	P23DR	P22DR	P21DR	P20DR
H'FF62	P3DR	—	—	P35DR	P34DR	P33DR	P32DR	P31DR	P30DR
H'FF64	P5DR	—	—	—	—	P53DR	P52DR	P51DR	P50DR
H'FF65	P6DR	P67DR	P66DR	P65DR	P64DR	P63DR	P62DR	P61DR	P60DR
H'FF69	PADR	PA7DR	PA6DR	PA5DR	PA4DR	PA3DR	PA2DR	PA1DR	PA0DR
H'FF6A	PBDR*	PB7DR	PB6DR	PB5DR	PB4DR	PB3DR	PB2DR	PB1DR	PB0DR
H'FF6B	PCDR*	PC7DR	PC6DR	PC5DR	PC4DR	PC3DR	PC2DR	PC1DR	PC0DR
H'FF6C	PDDR*	PD7DR	PD6DR	PD5DR	PD4DR	PD3DR	PD2DR	PD1DR	PD0DR
H'FF6D	PEDR	PE7DR	PE6DR	PE5DR	PE4DR	PE3DR	PE2DR	PE1DR	PE0DR
H'FF6E	PFDR	PF7DR	PF6DR	PF5DR	PF4DR	PF3DR	PF2DR	PF1DR	PF0DR
H'FF6F	PGDR	—	—	—	PG4DR	PG3DR	PG2DR	PG1DR	PG0DR
H'FF70	PAPCR	PA7PCR	PA6PCR	PA5PCR	PA4PCR	PA3PCR	PA2PCR	PA1PCR	PA0PCR
H'FF71	PBPCR	PB7PCR	PB6PCR	PB5PCR	PB4PCR	PB3PCR	PB2PCR	PB1PCR	PB0PCR
H'FF72	PCPCR	PC7PCR	PC6PCR	PC5PCR	PC4PCR	PC3PCR	PC2PCR	PC1PCR	PC0PCR
H'FF73	PDPCR	PD7PCR	PD6PCR	PD5PCR	PD4PCR	PD3PCR	PD2PCR	PD1PCR	PD0PCR
H'FF74	PEPCR	PE7PCR	PE6PCR	PE5PCR	PE4PCR	PE3PCR	PE2PCR	PE1PCR	PE0PCR
H'FF76	P3ODR	—	—	P35ODR	P34ODR	P33ODR	P32ODR	P31ODR	P30ODR
H'FF77	PAODR	PA7ODR	PA6ODR	PA5ODR	PA4ODR	PA3ODR	PA2ODR	PA1ODR	PA0ODR

Note: * Only applies to the H8S/2351.

H'FF7A	SCR0	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0		
H'FF7B	TDR0										
H'FF7C	SSR0	TDRE	RDRF	ORER	FER/ ERS*2	PER	TEND	MPB	MPBT		
H'FF7D	RDR0										
H'FF7E	SCMR0	—	—	—	—	SDIR	SINV	—	SMIF		
H'FF80	SMR1	C/ \bar{A} / GM*1	CHR	PE	O/ \bar{E}	STOP	MP	CKS1	CKS0	SCI1, Smart card interface 1	8 bit
H'FF81	BRR1										
H'FF82	SCR1	TIE	RIE	TE	RE	MPIE	TEIE	CKE1	CKE0		
H'FF83	TDR1										
H'FF84	SSR1	TDRE	RDRF	ORER	FER/ ERS*2	PER	TEND	MPB	MPBT		
H'FF85	RDR1										
H'FF86	SCMR1	—	—	—	—	SDIR	SINV	—	SMIF		
H'FF90	ADDRAH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2	A/D converter	8 bit
H'FF91	ADDRAL	AD1	AD0	—	—	—	—	—	—		
H'FF92	ADDRBH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2		
H'FF93	ADDRBL	AD1	AD0	—	—	—	—	—	—		
H'FF94	ADDRCH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2		
H'FF95	ADDRCL	AD1	AD0	—	—	—	—	—	—		
H'FF96	ADDRDH	AD9	AD8	AD7	AD6	AD5	AD4	AD3	AD2		
H'FF97	ADDRDL	AD1	AD0	—	—	—	—	—	—		
H'FF98	ADCSR	ADF	ADIE	ADST	SCAN	CKS	—	CH1	CH0		
H'FF99	ADCR	TRGS1	TRGS0	—	—	—	—	—	—		
H'FFA4	DADR0									D/A converter	8 bit
H'FFA5	DADR1										
H'FFA6	DACR	DAOE1	DAOE0	DAE	—	—	—	—	—		

Notes: 1. Functions as C/ \bar{A} for SCI use, and as GM for smart card interface use.
2. Functions as FER for SCI use, and as ERS for smart card interface use.

(read)	H'FFBF	RSTCSR	WOVF	RSTE	RSTS	—	—	—	—	—		
(read)	H'FFC0	TSTR	—	—	CST5	CST4	CST3	CST2	CST1	CST0	TPU	16 bit
	H'FFC1	TSYR	—	—	SYNC5	SYNC4	SYNC3	SYNC2	SYNC1	SYNC0		
	H'FFD0	TCR0	CCLR2	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0	TPU0	16 bit
	H'FFD1	TMDR0	—	—	BFB	BFA	MD3	MD2	MD1	MD0		
	H'FFD2	TIOR0H	IOB3	IOB2	IOB1	IOB0	IOA3	IOA2	IOA1	IOA0		
	H'FFD3	TIOR0L	IOD3	IOD2	IOD1	IOD0	IOC3	IOC2	IOC1	IOC0		
	H'FFD4	TIER0	TTGE	—	—	TCIEV	TGIED	TGIEC	TGIEB	TGIEA		
	H'FFD5	TSR0	—	—	—	TCFV	TGFD	TGFC	TGFB	TGFA		
	H'FFD6	TCNT0										
	H'FFD7											
	H'FFD8	TGR0A										
	H'FFD9											
	H'FFDA	TGR0B										
	H'FFDB											
	H'FFDC	TGR0C										
	H'FFDD											
	H'FFDE	TGR0D										
	H'FFDF											
	H'FFE0	TCR1	—	CCLR1	CCLR0	CKEG1	CKEG0	TPSC2	TPSC1	TPSC0	TPU1	16 bit
	H'FFE1	TMDR1	—	—	—	—	MD3	MD2	MD1	MD0		
	H'FFE2	TIOR1	IOB3	IOB2	IOB1	IOB0	IOA3	IOA2	IOA1	IOA0		
	H'FFE4	TIER1	TTGE	—	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA	
	H'FFE5	TSR1	TCFD	—	—	TCFU	TCFV	—	—	TGFB	TGFA	
	H'FFE6	TCNT1										
	H'FFE7											
	H'FFE8	TGR1A										
	H'FFE9											
	H'FFEA	TGR1B										
	H'FFEB											

H'FFF4	TIER2	TTGE	—	TCIEU	TCIEV	—	—	TGIEB	TGIEA
H'FFF5	TSR2	TCFD	—	TCFU	TCFV	—	—	TGFB	TGFA
H'FFF6	TCNT2								
H'FFF7									
H'FFF8	TGR2A								
H'FFF9									
H'FFFA	TGR2B								
H'FFFB									

SM1	SM0	DM1	DM0	MD1	MD0	DTS	Sz
-----	-----	-----	-----	-----	-----	-----	----

Initial value : Undefined Undefined Undefined Undefined Undefined Undefined Undefined Undefined

Read/Write : — — — — — — — —

DTC Data Transfer Size

0	Byte-size transfer
1	Word-size transfer

DTC Transfer Mode Select

0	Destination side is repeat area or block area
1	Source side is repeat area 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)

Read/Write :

R/W R/W R/W R/W R/W R/W R/W R/W

Timer Prescaler

0	0	0	Internal clock: counts on $\phi/1$
		1	Internal clock: counts on $\phi/4$
	1	0	Internal clock: counts on $\phi/16$
		1	Internal clock: counts on $\phi/64$
1	0	0	External clock: counts on TCLKA pin input
		1	Internal clock: counts on $\phi/1024$
	1	0	Internal clock: counts on $\phi/256$
		1	Internal clock: counts on $\phi/4096$

Clock Edge

0	0	Count at rising edge
	1	Count at falling edge
1	—	Count at both edges

Counter Clear

0	0	0	TCNT clearing disabled
		1	TCNT cleared by TGRA compare match/input capture
	1	0	TCNT cleared by TGRB compare match/input capture
		1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation *1
1	0	0	TCNT clearing disabled
		1	TCNT cleared by TGRC compare match/input capture *2
	1	0	TCNT cleared by TGRD compare match/input capture *2
		1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation *1

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

Initial value : — — — R/W R/W R/W R/W R/W R/W

Mode

0	0	0	0	Normal operation	
			1	Reserved	
		1	0	0	PWM mode 1
				1	PWM mode 2
	1	0	0	Phase counting mode 1	
			1	Phase counting mode 2	
		1	0	0	Phase counting mode 3
				1	Phase counting mode 4
1	*	*	*	—	

* : Don't care

- Notes: 1. MD3 is a reserved bit. In a write, it should always be written with 0.
 2. Phase counting mode cannot be set for channels 0 and 3. In this case, 0 should always be written to MD2.

Buffer Operation A

0	TGRA operates normally
1	TGRA and TGRC used together for buffer operation

Buffer Operation B

0	TGRB operates normally
1	TGRB and TGRD used together for buffer operation

TGR3A I/O Control

0	0	0	0	TGR3A is output compare register	Output disabled			
					1	0	Initial output is 0 output	0 output at compare match
							1 output at compare match	
		1	0		1	Toggle output at compare match		
		1	0		0	Output disabled		
						1	0	Initial output is 1 output
	1 output at compare match							
	1	0	1	Toggle output at compare match				
	1	0	0	0	TGR3A is input capture register	Capture input source is TIOCA3 pin		
						1	0	Input capture at rising edge
								Input capture at falling edge
		1	0	*		Input capture at both edges		
1		*	*	*		Capture input source is channel 4/count clock		
						Input capture at TCNT4 count-up/count-down		

* : Don't care

TGR3B I/O Control

0	0	0	0	TGR3B is output compare register	Output disabled			
					1	0	Initial output is 0 output	0 output at compare match
							1 output at compare match	
		1	0		1	Toggle output at compare match		
		1	0		0	Output disabled		
						1	0	Initial output is 1 output
	1 output at compare match							
	1	0	1	Toggle output at compare match				
	1	0	0	0	TGR3B is input capture register	Capture input source is TIOCB3 pin		
						1	0	Input capture at rising edge
								Input capture at falling edge
		1	0	*		Input capture at both edges		
1		*	*	*		Capture input source is channel 4/count clock		
						Input capture at TCNT4 count-up/count-down		

* : Don't care

Note: 1. If bits TPSC2 to TPSC0 in TCR4 are set to B'000, and $\emptyset/1$ is used as the TCNT4 count clock, this setting will be invalid and input capture will not occur.

TRG3C I/O Control

0	0	0	0	TGR3C is output compare register	Output disabled	Initial output is 0 output	0 output at compare match			
			1				0	1 output at compare match		
			1				1	Toggle output at compare match		
	1	0	0			TGR3C is input capture register	Output disabled	Initial output is 1 output	0 output at compare match	
			1						0	1 output at compare match
			1						1	Toggle output at compare match
1	0	0	0	TGR3C is input capture register	Capture input source is TIOCC3 pin			Input capture at rising edge		
			1					1	Input capture at falling edge	
			1					*	Input capture at both edges	
		1	*			*	Capture input source is channel 4/count clock	Input capture at TCNT4 count-up/count-down		

* : Don't care

Note: When the BFA bit in TMDR3 is set to 1 and TGR3C is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

TGR3D I/O Control

0	0	0	0	TGR3D is output compare register	Output disabled	Initial output is 0 output	0 output at compare match			
			1				0	1 output at compare match		
			1				1	Toggle output at compare match		
	1	0	0			TGR3D is input capture register	Output disabled	Initial output is 1 output	0 output at compare match	
			1						0	1 output at compare match
			1						1	Toggle output at compare match
1	0	0	0	TGR3D is input capture register	Capture input source is TIOCD3 pin			Input capture at rising edge		
			1					1	Input capture at falling edge	
			1					*	Input capture at both edges	
		1	*			*	Capture input source is channel 4/count clock	Input capture at TCNT4 count-up/count-down*1		

* : Don't care

Notes: When the BFB bit in TMDR3 is set to 1 and TGR3D is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

1 When bits TPSC2 to TPSC0 in TCR4 are set to B'000 and 0/1 is used as the TCNT4 count clock, this setting is invalid and input capture is not generated.

Note: When GRC or GRD is designated for buffer operation, this setting is invalid and the register operates as a buffer register.

Read/Write :

R/W

—

—

R/W

R/W

R/W

R/W

R/W

TGR Interrupt Enable A

0	Interrupt requests (TGIA) by TGFA bit disabled
1	Interrupt requests (TGIA) by TGFA bit enabled

TGR Interrupt Enable B

0	Interrupt requests (TGIB) by TGFB bit disabled
1	Interrupt requests (TGIB) by TGFB bit enabled

TGR Interrupt Enable C

0	Interrupt requests (TGIC) by TGFC bit disabled
1	Interrupt requests (TGIC) by TGFC bit enabled

TGR Interrupt Enable D

0	Interrupt requests (TGID) by TGFD bit disabled
1	Interrupt requests (TGID) by TGFD bit enabled

Overflow Interrupt Enable

0	Interrupt requests (TCIV) by TCFV disabled
1	Interrupt requests (TCIV) by TCFV enabled

A/D Conversion Start Request Enable

0	A/D conversion start request generation disabled
1	A/D conversion start request generation enabled

Input Capture/Output Compare Flag A

0	[Clearing condition] <ul style="list-style-type: none"> • When DTC is activated by TGIA interrupt while DISEL bit of MRB in DTC is 0 • When DMAC is activated by TGIA interrupt while DTA bit of DMABCR in DMAC is 1 • When 0 is written to TGFA after reading TGFA = 1
1	[Setting condition] <ul style="list-style-type: none"> • When TCNT=TGRA while TGRA is functioning as output compare register • When TCNT value is transferred to TGRA by input capture signal while TGRA is functioning as input capture register

Input Capture/Output Compare Flag B

0	[Clearing condition] <ul style="list-style-type: none"> • When DTC is activated by TGIB interrupt while DISEL bit of MRB in DTC is 0 • When 0 is written to TGFB after reading TGFB = 1
1	[Setting condition] <ul style="list-style-type: none"> • When TCNT = TGRB while TGRB is functioning as output compare register • When TCNT value is transferred to TGRB by input capture signal while TGRB is functioning as input capture register

Input Capture/Output Compare Flag C

0	[Clearing condition] <ul style="list-style-type: none"> • When DTC is activated by TGIC interrupt while DISEL bit of MRB in DTC is 0 • When 0 is written to TGFC after reading TGFC = 1
1	[Setting condition] <ul style="list-style-type: none"> • When TCNT = TGRC while TGRC is functioning as output compare register • When TCNT value is transferred to TGRC by input capture signal while TGRC is functioning as input capture register

Input Capture/Output Compare Flag D

0	[Clearing condition] <ul style="list-style-type: none"> • When DTC is activated by TGID interrupt while DISEL bit of MRB in DTC is 0 • When 0 is written to TGFD after reading TGFD = 1
1	[Setting condition] <ul style="list-style-type: none"> • When TCNT = TGRD while TGRD is functioning as output compare register • When TCNT value is transferred to TGRD by input capture signal while TGRD is functioning as input capture register

Overflow Flag

0	[Clearing condition] When 0 is written to TCFV after reading TCFV = 1
1	[Setting condition] When the TCNT value overflows (changes from H'FFFF to H'0000)

Note: * Can only be written with 0 for flag clearing.

Initial value : 0 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 R/W

Up-counter

TGR3A—Timer General Register 3A	H'FE88	TPU3
TGR3B—Timer General Register 3B	H'FE8A	TPU3
TGR3C—Timer General Register 3C	H'FE8C	TPU3
TGR3D—Timer General Register 3D	H'FE8E	TPU3

Bit	:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
		<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"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Initial value	:	1	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	R/W

Timer Prescaler

0	0	0	Internal clock: counts on $\phi/1$
		1	Internal clock: counts on $\phi/4$
	1	0	Internal clock: counts on $\phi/16$
		1	Internal clock: counts on $\phi/64$
1	0	0	External clock: counts on TCLKA pin input
		1	External clock: counts on TCLKC pin input
	1	0	Internal clock: counts on $\phi/1024$
		1	Counts on TCNT5 overflow/underflow

Note: This setting is ignored when channel 4 is in phase counting mode.

Clock Edge

0	0	Count at rising edge
	1	Count at falling edge
1	—	Count at both edges

Note: This setting is ignored when channel 4 is in phase counting mode.

Counter Clear

0	0	TCNT clearing disabled
	1	TCNT cleared by TGRA compare match/input capture
1	0	TCNT cleared by TGRB compare match/input capture
	1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation*

Note: * Synchronous operating setting is performed by setting the SYNC bit TSYR to 1.

Initial value : — — — — R/W R/W R/W R/W

Mode

0	0	0	0	Normal operation
		1	Reserved	
		1	0	PWM mode 1
			1	PWM mode 2
	1	0	0	Phase counting mode 1
			1	Phase counting mode 2
		1	0	Phase counting mode 3
			1	Phase counting mode 4
1	*	*	*	—

* : Don't care

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

TGR4A I/O Control

0	0	0	0	TGR4A is output compare register	Output disabled	
			1		Initial output is 0 output	0 output at compare match
		1	0			1 output at compare match
			1		Toggle output at compare match	
	1	0	0		Output disabled	
			1		Initial output is 1 output	0 output at compare match
		1	0			1 output at compare match
			1		Toggle output at compare match	
1	0	0	TGR4A is input capture register	Capture input source is TIOCA4 pin	Input capture at rising edge	
		1			Input capture at falling edge	
		*			Input capture at both edges	
	1	*	*	Capture input source is TGR3A compare match/ input capture	Input capture at generation of TGR3A compare match/ input capture	

* : Don't care

TGR4B I/O Control

0	0	0	0	TGR4B is output compare register	Output disabled	
			1		Initial output is 0 output	0 output at compare match
		1	0			1 output at compare match
			1		Toggle output at compare match	
	1	0	0		Output disabled	
			1		Initial output is 1 output	0 output at compare match
		1	0			1 output at compare match
			1		Toggle output at compare match	
1	0	0	TGR4B is input capture register	Capture input source is TIOCB4 pin	Input capture at rising edge	
		1			Input capture at falling edge	
		*			Input capture at both edges	
	1	*	*	Capture input source is TGR3C compare match/ input capture	Input capture at generation of TGR3C compare match/ input capture	

* : Don't care

Read/Write :

R/W

—

R/W

R/W

—

—

R/W

R/W

TGR Interrupt Enable A

0	Interrupt requests (TGIA) by TGFA bit disabled
1	Interrupt requests (TGIA) by TGFA bit enabled

TGR Interrupt Enable B

0	Interrupt requests (TGIB) by TGFB bit disabled
1	Interrupt requests (TGIB) by TGFB bit enabled

Overflow Interrupt Enable

0	Interrupt requests (TCIV) by TCFV disabled
1	Interrupt requests (TCIV) by TCFV enabled

Underflow Interrupt Enable

0	Interrupt requests (TCIU) by TCFU disabled
1	Interrupt requests (TCIU) by TCFU enabled

A/D Conversion Start Request Enable

0	A/D conversion start request generation disabled
1	A/D conversion start request generation enabled

Input Capture/Output Compare Flag A

0	[Clearing condition] <ul style="list-style-type: none"> • When DTC is activated by TGIA interrupt while DISEL bit of MRB in DTC is 0 • When DMAC is activated by TGIA interrupt while DTA bit of DMABCR in DMAC is 1 • When 0 is written to TGFA after reading TGFA = 1
1	[Setting conditions] <ul style="list-style-type: none"> • When TCNT = TGRA while TGRA is functioning as output compare register • When TCNT value is transferred to TGRA by input capture signal while TGRA is functioning as input capture register

Input Capture/Output Compare Flag B

0	[Clearing condition] <ul style="list-style-type: none"> • When DTC is activated by TGIB interrupt while DISEL bit of MRB in DTC is 0 • When 0 is written to TGFB after reading TGFB = 1
1	[Setting conditions] <ul style="list-style-type: none"> • When TCNT = TGRB while TGRB is functioning as output compare register • When TCNT value is transferred to TGRB by input capture signal while TGRB is functioning as input capture register

Overflow Flag

0	[Clearing condition] When 0 is written to TCFV after reading TCFV = 1
1	[Setting conditions] When the TCNT value overflows (changes from H'FFFF to H'0000)

Underflow Flag

0	[Clearing condition] When 0 is written to TCFU after reading TCFU = 1
1	[Setting conditions] When the TCNT value underflows (changes from H'0000 to H'FFFF)

Count Direction Flag

0	TCNT counts down
1	TCNT counts up

Note: * Can only be written with 0 for flag clearing.

Initial value : 0 0 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 R/W

Up/down-counter*

Note: * This timer counter can be used as an up/down-counter only in phase counting mode or when performing overflow/underflow counting on another channel. In other cases it functions as an up-counter.

TGR4A—Timer General Register 4A

H'FE98

TPU4

TGR4B—Timer General Register 4B

H'FE9A

TPU4

Bit	:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Initial value	:	1	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	R/W

Time Prescaler

0	0	0	Internal clock: counts on $\phi/1$
		1	Internal clock: counts on $\phi/4$
	1	0	Internal clock: counts on $\phi/16$
		1	Internal clock: counts on $\phi/64$
1	0	0	External clock: counts on TCLKA pin input
		1	External clock: counts on TCLKC pin input
	1	0	Internal clock: counts on $\phi/256$
		1	External clock: counts on TCLKD pin input

Note: This setting is ignored when channel 5 is in phase counting mode.

Clock Edge

0	0	Count at rising edge
	1	Count at falling edge
1	—	Count at both edges

Note: This setting is ignored when channel 5 is in phase counting mode.

Counter Clear

0	0	TCNT clearing disabled
	1	TCNT cleared by TGRA compare match/input capture
1	0	TCNT cleared by TGRB compare match/input capture
	1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation*

Note: * Synchronous operating setting is performed by setting the SYNC bit TSYR to 1.

Initial value : 1 1 0 0 0 0
 Read/Write : — — — — R/W R/W R/W R/W

Mode

0	0	0	0	Normal operation	
			1	Reserved	
		1	0	0	PWM mode 1
				1	PWM mode 2
	1	0	0	Phase counting mode 1	
			1	Phase counting mode 2	
		1	0	0	Phase counting mode 3
				1	Phase counting mode 4
1	*	*	*	—	

* : Don't care

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

TGR5A I/O Control

0	0	0	0	TGR5A is output compare register	Output disabled	Initial output is 0 output	0 output at compare match	
			1				1 output at compare match	
			1				Toggle output at compare match	
	1	0	0		TGR5A is output compare register	Output disabled	Initial output is 1 output	0 output at compare match
			1					1 output at compare match
			1					Toggle output at compare match
1	*	0	TGR5A is input capture register	Capture input source is TIOCA5 pin		Input capture at rising edge		
		1				Input capture at falling edge		
		1				Input capture at both edges		

* : Don't care

TGR5B I/O Control

0	0	0	0	TGR5B is output compare register	Output disabled	Initial output is 0 output	0 output at compare match	
			1				1 output at compare match	
			1				Toggle output at compare match	
	1	0	0		TGR5B is output compare register	Output disabled	Initial output is 1 output	0 output at compare match
			1					1 output at compare match
			1					Toggle output at compare match
1	*	0	TGR5B is input capture register	Capture input source is TIOCB5 pin		Input capture at rising edge		
		1				Input capture at falling edge		
		1				Input capture at both edges		

* : Don't care

Read/Write :

R/W

—

R/W

R/W

—

—

R/W

R/W

TGR Interrupt Enable A

0	Interrupt requests (TGIA) by TGFA bit disabled
1	Interrupt requests (TGIA) by TGFA bit enabled

TGR Interrupt Enable B

0	Interrupt requests (TGIB) by TGFB bit disabled
1	Interrupt requests (TGIB) by TGFB bit enabled

Overflow Interrupt Enable

0	Interrupt requests (TCIV) by TCFV disabled
1	Interrupt requests (TCIV) by TCFV enabled

Underflow Interrupt Enable

0	Interrupt requests (TCIU) by TCFU disabled
1	Interrupt requests (TCIU) by TCFU enabled

A/D Conversion Start Request Enable

0	A/D conversion start request generation disabled
1	A/D conversion start request generation enabled

Input Capture/Output Compare Flag A

0	[Clearing condition] <ul style="list-style-type: none"> When DTC is activated by TGIA interrupt while DISEL bit of MRB in DTC is 0 When DMAC is activated by TGIA interrupt while DTA bit of DMABCR in DMAC is 1 When 0 is written to TGFA after reading TGFA = 1
1	[Setting conditions] <ul style="list-style-type: none"> When TCNT = TGRA while TGRA is functioning as output compare register When TCNT value is transferred to TGRA by input capture signal while TGRA is functioning as input capture register

Input Capture/Output Compare Flag B

0	[Clearing condition] <ul style="list-style-type: none"> When DTC is activated by TGIB interrupt while DISEL bit of MRB in DTC is 0 When 0 is written to TGFB after reading TGFB = 1
1	[Setting conditions] <ul style="list-style-type: none"> When TCNT = TGRB while TGRB is functioning as output compare register When TCNT value is transferred to TGRB by input capture signal while TGRB is functioning as input capture register

Overflow Flag

0	[Clearing condition] When 0 is written to TCFV after reading TCFV = 1
1	[Setting conditions] When the TCNT value overflows (changes from H'FFFF to H'0000)

Underflow Flag

0	[Clearing condition] When 0 is written to TCFU after reading TCFU = 1
1	[Setting conditions] When the TCNT value underflows (changes from H'0000 to H'FFFF)

Count Direction Flag

0	TCNT counts down
1	TCNT counts up

Note: * Can only be written with 0 for flag clearing.

Initial value : 0 0 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 R/W

Up/down-counter*

Note: * This timer counter can be used as an up/down-counter only in phase counting mode or when performing overflow/underflow counting on another channel. In other cases it functions as an up-counter.

TGR5A—Timer General Register 5A

H'FEA8

TPU5

TGR5B—Timer General Register 5B

H'FEAA

TPU5

Bit : 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

 Initial value : 1 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 R/W

P1DDR—Port 1 Data Direction Register

H'FEB0

Port 1

Bit : 7 6 5 4 3 2 1 0

P17DDR	P16DDR	P15DDR	P14DDR	P13DDR	P12DDR	P11DDR	P10DDR
--------	--------	--------	--------	--------	--------	--------	--------

 Initial value : 0 0 0 0 0 0 0 0
 Read/Write : W W W W W W W W

Specify input or output for individual port 1 pins

Initial value :	0	0	0	0	0	0	0
Read/Write :	W	W	W	W	W	W	W

Specify input or output for individual port 2 pins

P3DDR—Port 3 Data Direction Register

H'FEB2

Port 3

Bit :	7	6	5	4	3	2	1	0
	—	—	P35DDR	P34DDR	P33DDR	P32DDR	P31DDR	P30DDR
Initial value :	Undefined	Undefined	0	0	0	0	0	0
Read/Write :	—	—	W	W	W	W	W	W

Specify input or output for individual port 3 pins

P5DDR—Port 5 Data Direction Register

H'FEB4

Port 5

Bit :	7	6	5	4	3	2	1	0
	—	—	—	—	P53DDR	P52DDR	P51DDR	P50DDR
Initial value :	Undefined	Undefined	Undefined	Undefined	0	0	0	0
Read/Write :	—	—	—	—	W	W	W	W

Specify input or output for individual port 5 pins

Initial value :	0	0	0	0	0	0	0	0
Read/Write :	W	W	W	W	W	W	W	W

Specify input or output for individual port 6 pins

PADDR—Port A Data Direction Register **H'FEB9** **Port A**

Bit	:	7	6	5	4	3	2	1	0
		PA7DDR	PA6DDR	PA5DDR	PA4DDR	PA3DDR	PA2DDR	PA1DDR	PA0DDR
Initial value	:	0	0	0	0	0	0	0	0
Read/Write	:	W	W	W	W	W	W	W	W

Specify input or output for individual port A pins

PBDDR—Port B Data Direction Register **H'FEBA** **Port B**
[H8S/2351 Only]

Bit	:	7	6	5	4	3	2	1	0
		PB7DDR	PB6DDR	PB5DDR	PB4DDR	PB3DDR	PB2DDR	PB1DDR	PB0DDR
Initial value	:	0	0	0	0	0	0	0	0
Read/Write	:	W	W	W	W	W	W	W	W

Specify input or output for individual port B pins

	FC7DDR	FC6DDR	FC5DDR	FC4DDR	FC3DDR	FC2DDR	FC1DDR	FC0DDR
Initial value :	0	0	0	0	0	0	0	0
Read/Write :	W	W	W	W	W	W	W	W

Specify input or output for individual port C pins

PDDDR—Port D Data Direction Register

H'FEBC

Port D
[H8S/2351 Only]

Bit :	7	6	5	4	3	2	1	0
	PD7DDR	PD6DDR	PD5DDR	PD4DDR	PD3DDR	PD2DDR	PD1DDR	PD0DDR
Initial value :	0	0	0	0	0	0	0	0
Read/Write :	W	W	W	W	W	W	W	W

Specify input or output for individual port D pins

PEDDR—Port E Data Direction Register

H'FEBD

Port E

Bit :	7	6	5	4	3	2	1	0
	PE7DDR	PE6DDR	PE5DDR	PE4DDR	PE3DDR	PE2DDR	PE1DDR	PE0DDR
Initial value :	0	0	0	0	0	0	0	0
Read/Write :	W	W	W	W	W	W	W	W

Specify input or output for individual port E pins

Modes 1, 2, 4 to 6

Initial value	:	1	0	0	0	0	0	0
Read/Write	:	W	W	W	W	W	W	W

Modes 3, 7

Initial value	:	0	0	0	0	0	0	0
Read/Write	:	W	W	W	W	W	W	W

Specify input or output for individual port F pins

PGDDR—Port G Data Direction Register

H'FEBF

Port G

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	PG4DDR	PG3DDR	PG2DDR	PG1DDR	PG0DDR

Modes 1, 4, 5

Initial value	:	Undefined	Undefined	Undefined	1	0	0	0	0
Read/Write	:	—	—	—	W	W	W	W	W

Modes 2, 3, 6, 7

Initial value	:	Undefined	Undefined	Undefined	0	0	0	0	0
Read/Write	:	—	—	—	W	W	W	W	W

Specify input or output for individual port G pins

IPRE — Interrupt Priority Register E	H'FECA	Interrupt Controller
IPRF — Interrupt Priority Register F	H'FEC9	Interrupt Controller
IPRG — Interrupt Priority Register G	H'FECA	Interrupt Controller
IPRH — Interrupt Priority Register H	H'FECB	Interrupt Controller
IPRI — Interrupt Priority Register I	H'FECC	Interrupt Controller
IPRJ — Interrupt Priority Register J	H'FECD	Interrupt Controller
IPRK — Interrupt Priority Register K	H'FECE	Interrupt Controller

Bit	:	7	6	5	4	3	2	1	0
		—	IPR6	IPR5	IPR4	—	IPR2	IPR1	IPR0
Initial value	:	0	1	1	1	0	1	1	1
Read/Write	:	—	R/W	R/W	R/W	—	R/W	R/W	R/W

|
Set priority (levels 7 to 0) for interrupt sources

Correspondence between Interrupt Sources and IPR Settings

Register	Bits	
	6 to 4	2 to 0
IPRA	IRQ0	IRQ1
IPRB	IRQ2	IRQ4
	IRQ3	IRQ5
IPRC	IRQ6	DTC
	IRQ7	
IPRD	WDT	Refresh timer
IPRE	—*	A/D converter
IPRF	TPU channel 0	TPU channel 1
IPRG	TPU channel 2	TPU channel 3
IPRH	TPU channel 4	TPU channel 5
IPRI	—*	—*
IPRJ	DMAC	SCI channel 0
IPRK	SCI channel 1	—*

Note: * Reserved bits. These bits cannot be modified and are always read as 1.

Modes 1, 2, 3, 5, 7

Initial value :	1	1	1	1	1	1	1	1
R/W :	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Mode 4								
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

Area 7 to 0 Bus Width Control

0	Area n is designated for 16-bit access
1	Area n is designated for 8-bit access

(n = 7 to 0)

ASTCR—Access State Control Register

H'FED1

Bus Controller

Bit :	7	6	5	4	3	2	1	0
	AST7	AST6	AST5	AST4	AST3	AST2	AST1	AST0
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

Area 7 to 0 Access State Control

0	Area n is designated for 2-state access Wait state insertion in area n external space is disabled
1	Area n is designated for 3-state access Wait state insertion in area n external space is enabled

(n = 7 to 0)

Read/Write : R/W R/W R/W R/W R/W R/W R/W R/W

Area 4 Wait Control

0	0	Program wait not inserted
	1	1 program wait state inserted
1	0	2 program wait states inserted
	1	3 program wait states inserted

Area 5 Wait Control

0	0	Program wait not inserted
	1	1 program wait state inserted
1	0	2 program wait states inserted
	1	3 program wait states inserted

Area 6 Wait Control

0	0	Program wait not inserted
	1	1 program wait state inserted
1	0	2 program wait states inserted
	1	3 program wait states inserted

Area 7 Wait Control

0	0	Program wait not inserted
	1	1 program wait state inserted
1	0	2 program wait states inserted
	1	3 program wait states inserted

Read/Write :

R/W

R/W

R/W

R/W

R/W

R/W

R/W

R/W

Area 0 Wait Control

0	0	Program wait not inserted
	1	1 program wait state inserted
1	0	2 program wait states inserted
	1	3 program wait states inserted

Area 1 Wait Control

0	0	Program wait not inserted
	1	1 program wait state inserted
1	0	2 program wait states inserted
	1	3 program wait states inserted

Area 2 Wait Control

0	0	Program wait not inserted
	1	1 program wait state inserted
1	0	2 program wait states inserted
	1	3 program wait states inserted

Area 3 Wait Control

0	0	Program wait not inserted
	1	1 program wait state inserted
1	0	2 program wait states inserted
	1	3 program wait states inserted

Initial value : 1 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

RAM Type Select

RMTS2	RMTS1	RMTS0	Area 5	Area 4	Area 3	Area 2
0	0	0	Normal space			
		1	Normal space			DRAM space
	1	0	Normal space	DRAM space		
		1	DRAM space			
1	—	—	—			

Note: When areas selected in DRAM space are all 8-bit space, the PF₂ pin can be used as an I/O port, BREQ₀, or WAIT.

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

Area 0 Burst ROM Enable

0	Area 0 is basic bus interface
1	Area 0 is burst ROM interface

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

Idle Cycle Insert 1

0	Idle cycle not inserted in case of successive external read cycles in different areas
1	Idle cycle inserted in case of successive external read cycles in different areas

Read/Write :

R/W

R/W

R/W

R/W

R/W

R/W

R/W

R/W

WAIT Pin Enable

0	Wait input by WAIT pin disabled
1	Wait input by WAIT pin enabled

Write Data Buffer Enable

0	Write data buffer function not used
1	Write data buffer function used

Reserved

Only 1 should be written to this bit

DACK Timing Select

0	When DMAC single address transfer is performed in DRAM/PSRAM space, full access is always executed DACK signal goes low from Tr or T1 cycle
1	Burst access is possible when DMAC single address transfer is performed in DRAM/PSRAM space DACK signal goes low from Tc1 or T2 cycle

LCAS Select

Write 0 to this bit when using the DRAM interface

Reserved

Only 0 should be written to this bit

BREQO Pin Enable

0	BREQO output disabled
1	BREQO output enabled

Bus Release Enable

0	External bus release is disabled
1	External bus release is enabled

Read/Write :

R/W

R/W

R/W

R/W

R/W

R/W

R/W

R/W

Refresh Cycle Wait Control

0	0	No wait state inserted
	1	1 wait state inserted
1	0	2 wait states inserted
	1	3 wait states inserted

Multiplex Shift Count

0	0	8-bit shift
	1	9-bit shift
1	0	10-bit shift
	1	—

2-CAS Method Select

0	16-bit DRAM space selected
1	8-bit DRAM space selected

RAS/CS Down Mode

0	DRAM interface: RAS up mode selected
1	DRAM interface: RAS down mode selected

Burst Access Enable

0	Burst disabled (always full access)
1	For DRAM space access, access in fast page mode

TP Cycle Control

0	1-state precharge cycle is inserted
1	2-state precharge cycle is inserted

Initial value : 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

Refresh Counter Clock Select

0	0	0	Count operation disabled
		1	Count uses $\phi/2$
	1	0	Count uses $\phi/8$
		1	Count uses $\phi/32$
1	0	0	Count uses $\phi/128$
		1	Count uses $\phi/512$
	1	0	Count uses $\phi/2048$
		1	Count uses $\phi/4096$

Compare Match Interrupt Enable

0	Interrupt request (CMI) by CMF flag disabled
1	Interrupt request (CMI) by CMF flag enabled

Compare Match Flag

0	[Clearing condition] Cleared by reading the CMF flag when CMF = 1, then writing 0 to the CMF flag
1	[Setting condition] Set when RTCNT = RTCOR

Refresh Mode

0	DRAM interface: CAS-before-RAS refreshing used
1	Self-refreshing used

RAS-CAS Wait

0	Wait state insertion in CAS-before-RAS refreshing disabled $\overline{\text{RAS}}$ falls in T_{Rr} cycle
1	One wait state inserted in CAS-before-RAS refreshing $\overline{\text{RAS}}$ falls in T_{Rc1} cycle

Refresh Control

0	Refresh control is not performed
1	Refresh control is performed

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
 Internal clock count value

RTCOR—Refresh Time Constant Register H'FED9 Bus Controller

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
 Sets the period for compare match operations with RTCNT

MAR0AH—Memory Address Register 0AH H'FEE0 DMAC
MAR0AL—Memory Address Register 0AL H'FEE2 DMAC

Bit : 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16
 MAR0AH :

--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

 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

Bit : 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
 MAR0AL :

--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

 Initial value : * * * * * * * * * * * * * * * *
 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 R/W

* : Undefined

In short address mode: Specifies transfer source/transfer destination address
 In full address mode: Specifies transfer source address

MAR0B	15	14	13	12	11	10	9	8	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
Bit :	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MAR0BL :																
Initial value :	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
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	R/W

* : Undefined

In short address mode: Specifies transfer source/transfer destination address
 In full address mode: Specifies transfer destination address

IOAR0B—I/O Address Register 0B **H'FEEC** **DMAC**

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IOAR0B																
Initial value :	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
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	R/W

* : Undefined

In short address mode: Specifies transfer source/transfer destination address
 In full address mode: Not used

Initial value : * * * * * * * * * * * * * * * * * *
 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 R/W R/W R/W

* : Undefined

In short address mode: Specifies transfer source/transfer destination address
 In full address mode: Not used

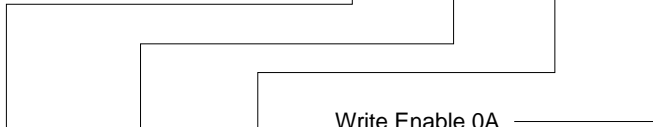
ETCR1A—Transfer Count Register 1A **H'FEF6** **DMAC**

Bit	:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ETCR1A	:																
Initial value	:	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
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	R/W

Sequential mode	Transfer counter	
Idle mode	Transfer counter	
Normal mode	Transfer counter	
Repeat mode	Transfer number storage register	Transfer counter
Block transfer mode	Block size storage register	Block size counter

* : Undefined

Initial value : 0 0 0 0 0 0 0 0
 Read/Write : — — — — R/W R/W R/W R/W



Write Enable 0A

0	Writes to all bits in DMACR0A, and bits 8, 4, and 0 in DMABCR are disabled
1	Writes to all bits in DMACR0A, and bits 8, 4, and 0 in DMABCR are enabled

Write Enable 0B

0	Writes to all bits in DMACR0B, bits 9, 5, and 1 in DMABCR, and bit 4 in DMATCR are disabled
1	Writes to all bits in DMACR0B, bits 9, 5, and 1 in DMABCR, and bit 4 in DMATCR are enabled

Write Enable 1A

0	Writes to all bits in DMACR1A, and bits 10, 6, and 2 in DMABCR are disabled
1	Writes to all bits in DMACR1A, and bits 10, 6, and 2 in DMABCR are enabled

Write Enable 1B

0	Writes to all bits in DMACR1B, bits 11, 7, and 3 in DMABCR, and bit 5 in DMATCR are disabled
1	Writes to all bits in DMACR1B, bits 11, 7, and 3 in DMABCR, and bit 5 in DMATCR are enabled

Initial value : 0 0 0 0 0 0 0 0
 Read/Write : — — R/W R/W — — — —

Transfer End Enable 0

0	$\overline{\text{TEND0}}$ pin output disabled
1	$\overline{\text{TEND0}}$ pin output enabled

Transfer End Enable 1

0	$\overline{\text{TEND1}}$ pin output disabled
1	$\overline{\text{TEND1}}$ pin output enabled

Full address mode

Bit	:	15	14	13	12	11	10	9	8
DMACRA	:	DTSZ	SAID	SAIDE	BLKDIR	BLKE	—	—	—
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

Block Direction/Block Enable

0	0	Transfer in normal mode
	1	Transfer in block transfer mode, destination side is block area
1	0	Transfer in normal mode
	1	Transfer in block transfer mode, source side is block area

Source Address Increment/Decrement

0	0	MARA is fixed
	1	MARA is incremented after a data transfer
1	0	MARA is fixed
	1	MARA is decremented after a data transfer

Data Transfer Size

0	Byte-size transfer
1	Word-size transfer

Data Transfer Factor

DTF 3	DTF 2	DTF 1	DTF 0	Block Transfer Mode	Normal Mode
0	0	0	0	—	—
			1	Activated by A/D converter conversion end interrupt	—
		1	0	Activated by $\overline{\text{DREQ}}$ pin falling edge input	Activated by $\overline{\text{DREQ}}$ pin falling edge input
			1	Activated by $\overline{\text{DREQ}}$ pin low-level input	Activated by $\overline{\text{DREQ}}$ pin low-level input
	1	0	0	Activated by SCI channel 0 transmission complete interrupt	—
			1	Activated by SCI channel 0 reception complete interrupt	—
		1	0	Activated by SCI channel 1 transmission complete interrupt	Auto-request (cycle steal)
			1	Activated by SCI channel 1 reception complete interrupt	Auto-request (burst)
1	0	0	0	Activated by TPU channel 0 compare match/input capture A interrupt	—
			1	Activated by TPU channel 1 compare match/input capture A interrupt	—
		1	0	Activated by TPU channel 2 compare match/input capture A interrupt	—
			1	Activated by TPU channel 3 compare match/input capture A interrupt	—
	1	0	0	Activated by TPU channel 4 compare match/input capture A interrupt	—
			1	Activated by TPU channel 5 compare match/input capture A interrupt	—
		1	0	—	—
			1	—	—

Destination Address Increment/Decrement

0	0	MARB is fixed
	1	MARB is incremented after a data transfer
1	0	MARB is fixed
	1	MARB is decremented after a data transfer

Data Transfer Direction

0	Dual address mode: Transfer with MAR as source address and IOAR as destination address Single address mode: Transfer with MAR as source address and $\overline{\text{DACK}}$ pin as write strobe
1	Dual address mode: Transfer with IOAR as source address and MAR as destination address Single address mode: Transfer with $\overline{\text{DACK}}$ pin as read strobe and MAR as destination address

Repeat Enable

0	Transfer in sequential mode
1	Transfer in repeat mode or idle mode

Data Transfer Increment/Decrement

0	MAR is incremented after a data transfer
1	MAR is decremented after a data transfer

Data Transfer Size

0	Byte-size transfer
1	Word-size transfer

Data Transfer Factor

				Channel A	Channel B	
0	0	0	0	—		
			1	Activated by A/D converter conversion end interrupt		
		1	0	—	Activated by $\overline{\text{DREQ}}$ pin falling edge input	
			1	—	Activated by $\overline{\text{DREQ}}$ pin low-level input	
		1	0	0	Activated by SCI channel 0 transmission complete interrupt	
				1	Activated by SCI channel 0 reception complete interrupt	
	1		0	Activated by SCI channel 1 transmission complete interrupt		
			1	Activated by SCI channel 1 reception complete interrupt		
	1	0	0	0	Activated by TPU channel 0 compare match/input capture A interrupt	
				1	Activated by TPU channel 1 compare match/input capture A interrupt	
			1	0	Activated by TPU channel 2 compare match/input capture A interrupt	
				1	Activated by TPU channel 3 compare match/input capture A interrupt	
1			0	0	Activated by TPU channel 4 compare match/input capture A interrupt	
				1	Activated by TPU channel 5 compare match/input capture A interrupt	
1	0	—				
1	1	—				

DMABCRH :	F AE1	F AE0	—	—	D TA1	—	D TA0	—
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

Channel 0 Data Transfer Acknowledge

0	Clearing of selected internal interrupt source at time of DMA transfer is disabled
1	Clearing of selected internal interrupt source at time of DMA transfer is enabled

Channel 1 Data Transfer Acknowledge

0	Clearing of selected internal interrupt source at time of DMA transfer is disabled
1	Clearing of selected internal interrupt source at time of DMA transfer is enabled

Channel 0 Full Address Enable

0	Short address mode
1	Full address mode

Channel 1 Full Address Enable

0	Short address mode
1	Full address mode

(Continued on next page)

Channel 0 Data Transfer
Interrupt Enable A

0	Transfer end interrupt disabled
1	Transfer end interrupt enabled

Channel 0 Data Transfer Interrupt
Enable B

0	Transfer suspended interrupt disabled
1	Transfer suspended interrupt enabled

Channel 0 Data Transfer
Interrupt Enable A

0	Transfer end interrupt disabled
1	Transfer end interrupt enabled

Channel 1 Data Transfer Interrupt
Enable B

0	Transfer suspended interrupt disabled
1	Transfer suspended interrupt enabled

Channel 0 Data Transfer Enable

0	Data transfer disabled
1	Data transfer enabled

Channel 0 Data Transfer Master Enable

0	Data transfer disabled. In normal mode, cleared to 0 by an NMI interrupt
1	Data transfer enabled

Channel 1 Data Transfer Enable

0	Data transfer disabled
1	Data transfer enabled

Channel 0 Data Transfer Master Enable

0	Data transfer disabled. In normal mode, cleared to 0 by an NMI interrupt
1	Data transfer enabled

(Continued on next page)

Channel 0A Data Transfer Acknowledge

0	Clearing of selected internal interrupt source at time of DMA transfer is disabled
1	Clearing of selected internal interrupt source at time of DMA transfer is enabled

Channel 0B Data Transfer Acknowledge

0	Clearing of selected internal interrupt source at time of DMA transfer is disabled
1	Clearing of selected internal interrupt source at time of DMA transfer is enabled

Channel 1A Data Transfer Acknowledge

0	Clearing of selected internal interrupt source at time of DMA transfer is disabled
1	Clearing of selected internal interrupt source at time of DMA transfer is enabled

Channel 1B Data Transfer Acknowledge

0	Clearing of selected internal interrupt source at time of DMA transfer is disabled
1	Clearing of selected internal interrupt source at time of DMA transfer is enabled

Channel 0B Single Address Enable

0	Transfer in dual address mode
1	Transfer in single address mode

Channel 1B Single Address Enable

0	Transfer in dual address mode
1	Transfer in single address mode

Channel 0 Full Address Enable

0	Short address mode
1	Full address mode

Channel 1 Full Address Enable

0	Short address mode
1	Full address mode

(Continued on next page)

Channel 0A Data Transfer
Interrupt Enable

0	Transfer end interrupt disabled
1	Transfer end interrupt enabled

Channel 0B Data Transfer
Interrupt Enable

0	Transfer end interrupt disabled
1	Transfer end interrupt enabled

Channel 1A Data Transfer Interrupt
Enable

0	Transfer end interrupt disabled
1	Transfer end interrupt enabled

Channel 1B Data Transfer Interrupt
Enable

0	Transfer end interrupt disabled
1	Transfer end interrupt enabled

Channel 0A Data Transfer Enable

0	Data transfer disabled
1	Data transfer enabled

Channel 0B Data Transfer Enable

0	Data transfer disabled
1	Data transfer enabled

Channel 1A Data Transfer Enable

0	Data transfer disabled
1	Data transfer enabled

Channel 1B Data Transfer Enable

0	Data transfer disabled
1	Data transfer enabled

Bit	:	15	14	13	12	11	10	9	8
		IRQ7SCB	IRQ7SCA	IRQ6SCB	IRQ6SCA	IRQ5SCB	IRQ5SCA	IRQ4SCB	IRQ4SCA
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

|
IRQ7 to IRQ4 Sense Control

ISCRL

Bit	:	7	6	5	4	3	2	1	0
		IRQ3SCB	IRQ3SCA	IRQ2SCB	IRQ2SCA	IRQ1SCB	IRQ1SCA	IRQ0SCB	IRQ0SCA
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

|
IRQ3 to IRQ0 Sense Control

IRQ _n SCB	IRQ _n SCA	Interrupt Request Generation
0	0	$\overline{\text{IRQ}}_n$ input low level
	1	Falling edge of $\overline{\text{IRQ}}_n$ input
1	0	Rising edge of $\overline{\text{IRQ}}_n$ input
	1	Both falling and rising edges of $\overline{\text{IRQ}}_n$ input

(n = 7 to 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

IRQn Enable

0	IRQn interrupt disabled
1	IRQn interrupt enabled

(n = 7 to 0)

ISR—IRQ Status Register

H'FF2F

Interrupt Controller

Bit	:	7	6	5	4	3	2	1	0
		IRQ7F	IRQ6F	IRQ5F	IRQ4F	IRQ3F	IRQ2F	IRQ1F	IRQ0F
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)*

Indicate the status of IRQ7 to IRQ0 interrupt requests

Note: * Can only be written with 0 for flag clearing.

Initial value : 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

DTC Activation Enable

0	DTC activation by this interrupt is disabled [Clearing conditions] • When the DISEL bit is 1 and data transfer has ended • When the specified number of transfers have ended
1	DTC activation by this interrupt is enabled [Holding condition] When the DISEL bit is 0 and the specified number of transfers have not ended

Correspondence between Interrupt Sources and DTCER

Register	Bits							
	7	6	5	4	3	2	1	0
DTCERA	IRQ0	IRQ1	IRQ2	IRQ3	IRQ4	IRQ5	IRQ6	IRQ7
DTCERB	—	ADI	TGI0A	TGI0B	TGI0C	TGI0D	TGI1A	TGI1B
DTCERC	TGI2A	TGI2B	TGI3A	TGI3B	TGI3C	TGI3D	TGI4A	TGI4B
DTCERD	—	—	TGI5A	TGI5B	—	—	—	—
DTCERE	DMTEND0A	DMTEND0B	DMTEND1A	DMTEND1B	RXI0	TXI0	RXI1	TXI1
DTCERF	—	—	—	—	—	—	—	—

Initial value : 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

Sets vector number for DTC software activation

DTC Software Activation Enable

0	DTC software activation is disabled [Clearing condition] When the DISEL bit is 0 and the specified number of transfers have not ended
1	DTC software activation is enabled [Holding conditions] <ul style="list-style-type: none"> • When the DISEL bit is 1 and data transfer has ended • When the specified number of transfers have ended • During data transfer due to software activation

Note: * A value of 1 can always be written to the SWDTE bit, but 0 can only be written after 1 is read.

Read/Write : R/W R/W R/W R/W R/W — — R/W

Reserved
Only 0 should be written to this bit

Output Port Enable

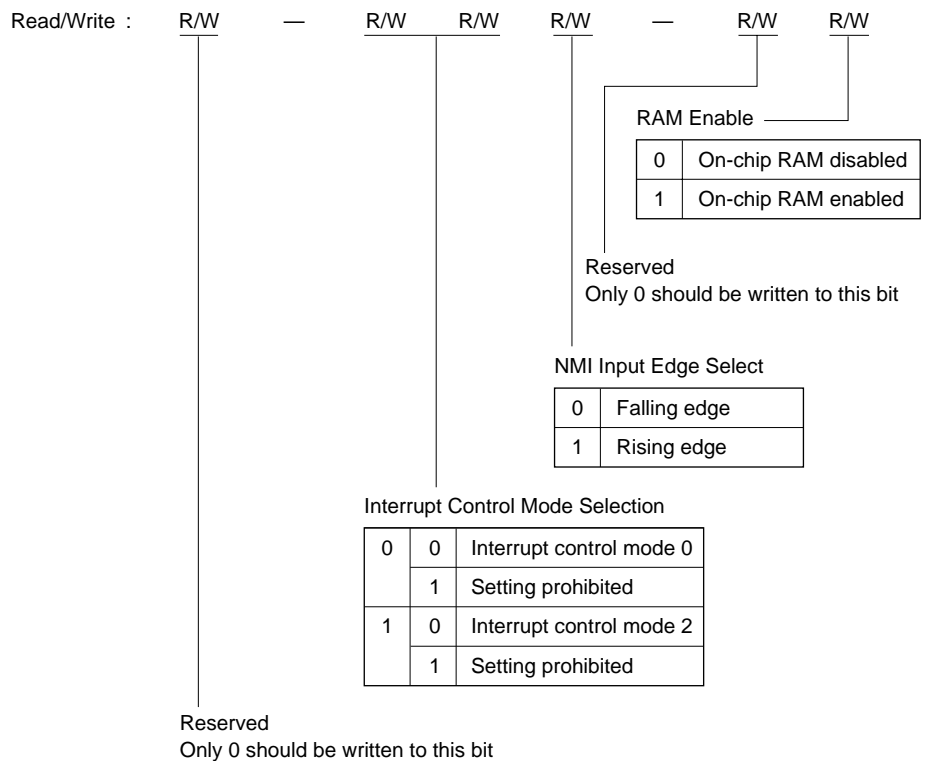
0	In software standby mode, address bus and bus control signals are high-impedance
1	In software standby mode, address bus and bus control signals retain output state

Standby Timer Select

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

Software Standby

0	Transition to sleep mode after execution of SLEEP instruction
1	Transition to software standby mode after execution of SLEEP instruction



Read/Write : R/W R/W — — — R/W R/W R/W

Bus Master Clock Select

0	0	0	Bus master is in high-speed mode
		1	Medium-speed clock is $\phi/2$
	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	—	—

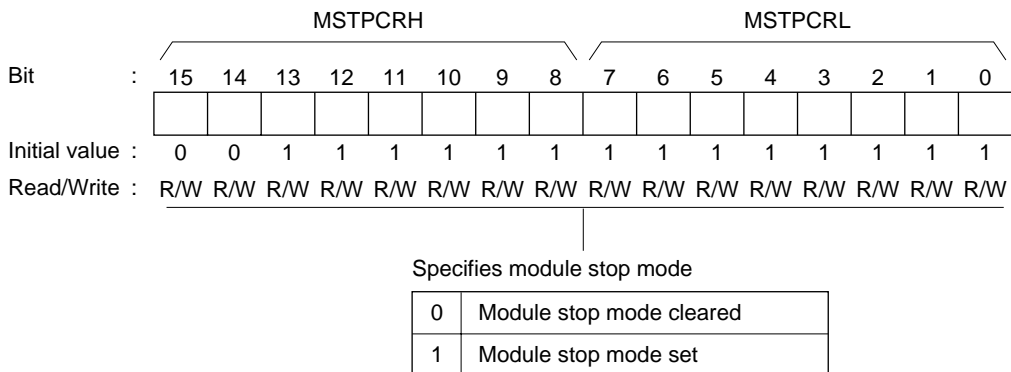
ϕ Clock Output Control

PSTOP	Normal Operation	Sleep Mode	Software Standby Mode	Hardware Standby Mode
0	ϕ output	ϕ output	Fixed high	High impedance
1	Fixed high	Fixed high	Fixed high	High impedance

Initial value : 1 0 0 0 0 — — —
 Read/Write : — — — — — R R R
 Current mode pin operating mode

Note: * Determined by pins MD₂ to MD₀

MSTPCRH — **Module Stop Control Register H** **H'FF3C** **Power-Down State**
MSTPCRL — **Module Stop Control Register L** **H'FF3D** **Power-Down State**



Reserved Register **H'FF44**



Initial value : R/W R/W R/W R/W R/W R/W R/W R/W

Output Trigger for Pulse Output Group 0

0	0	Compare match in TPU channel 0
	1	Compare match in TPU channel 1
1	0	Compare match in TPU channel 2
	1	Compare match in TPU channel 3

Output Trigger for Pulse Output Group 1

0	0	Compare match in TPU channel 0
	1	Compare match in TPU channel 1
1	0	Compare match in TPU channel 2
	1	Compare match in TPU channel 3

Output Trigger for Pulse Output Group 2

0	0	Compare match in TPU channel 0
	1	Compare match in TPU channel 1
1	0	Compare match in TPU channel 2
	1	Compare match in TPU channel 3

Output Trigger for Pulse Output Group 3

0	0	Compare match in TPU channel 0
	1	Compare match in TPU channel 1
1	0	Compare match in TPU channel 2
	1	Compare match in TPU channel 3

Initial value : 1 1 1 1 0 0 0 0
 Read/Write : R/W R/W R/W R/W R/W R/W R/W R/W

Pulse Output Group n Normal/Non-Overlap
 Operation Select

0	Normal operation in pulse output group n (output values updated at compare match A in the selected TPU channel)
1	Non-overlapping operation in pulse output group n (independent 1 and 0 output at compare match A or B in the selected TPU channel)

n=3 to 0

Pulse Output Group n Direct/Inverted Output

0	Inverted output for pulse output group n (low-level output at pin for a 1 in PODRH)
1	Direct output for pulse output group n (high-level output at pin for a 1 in PODRH)

n=3 to 0

Bit	:	7	6	5	4	3	2	1	0
		NDER15	NDER14	NDER13	NDER12	NDER11	NDER10	NDER9	NDER8
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

Pulse Output Enable/Disable

0	Pulse outputs PO15 to PO8 are disabled
1	Pulse outputs PO15 to PO8 are enabled

NDERL

Bit	:	7	6	5	4	3	2	1	0
		NDER7	NDER6	NDER5	NDER4	NDER3	NDER2	NDER1	NDER0
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

Pulse Output Enable/Disable

0	Pulse outputs PO7 to PO0 are disabled
1	Pulse outputs PO7 to PO0 are enabled

Bit	:	7	6	5	4	3	2	1	0
		POD15	POD14	POD13	POD12	POD11	POD10	POD9	POD8
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)*

Stores output data for use in pulse output

PODRL

Bit	:	7	6	5	4	3	2	1	0
		POD7	POD6	POD5	POD4	POD3	POD2	POD1	POD0
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)*

Stores output data for use in pulse output

Note: * A bit that has been set for pulse output by NDER is read-only.

(a) Address: H'FF4C

Bit	:	7	6	5	4	3	2	1	0
		NDR15	NDR14	NDR13	NDR12	NDR11	NDR10	NDR9	NDR8
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

Stores the next data for pulse output groups 3 and 2

(b) Address: H'FF4E

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	—	—	—	—
Initial value	:	1	1	1	1	1	1	1	1
Read/Write	:	—	—	—	—	—	—	—	—

(2) When pulse output group output triggers are different

(a) Address: H'FF4C

Bit	:	7	6	5	4	3	2	1	0
		NDR15	NDR14	NDR13	NDR12	—	—	—	—
Initial value	:	0	0	0	0	1	1	1	1
Read/Write	:	R/W	R/W	R/W	R/W	—	—	—	—

Stores the next data for pulse output group 3

(b) Address: H'FF4E

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	NDR11	NDR10	NDR9	NDR8
Initial value	:	1	1	1	1	0	0	0	0
Read/Write	:	—	—	—	—	R/W	R/W	R/W	R/W

Stores the next data for pulse output group 2

(a) Address: H'FF4D

Bit	:	7	6	5	4	3	2	1	0
		NDR7	NDR6	NDR5	NDR4	NDR3	NDR2	NDR1	NDR0
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

Stores the next data for pulse output groups 1 and 0

(b) Address: H'FF4F

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	—	—	—	—
Initial value	:	1	1	1	1	1	1	1	1
Read/Write	:	—	—	—	—	—	—	—	—

(2) When pulse output group output triggers are different

(a) Address: H'FF4D

Bit	:	7	6	5	4	3	2	1	0
		NDR7	NDR6	NDR5	NDR4	—	—	—	—
Initial value	:	0	0	0	0	1	1	1	1
Read/Write	:	R/W	R/W	R/W	R/W	—	—	—	—

Stores the next data for pulse output group 1

(b) Address: H'FF4F

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	NDR3	NDR2	NDR1	NDR0
Initial value	:	1	1	1	1	0	0	0	0
Read/Write	:	—	—	—	—	R/W	R/W	R/W	R/W

Stores the next data for pulse output group 0

Initial value : —* —* —* —* —* —* —* —*

Read/Write : R R R R R R R R

State of port 1 pins

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

PORT2—Port 2 Register **H'FF51** **Port 2**

Bit	:	7	6	5	4	3	2	1	0
		P27	P26	P25	P24	P23	P22	P21	P20
Initial value	:	—*	—*	—*	—*	—*	—*	—*	—*
Read/Write	:	R	R	R	R	R	R	R	R

State of port 2 pins

Note: * Determined by the state of pins P2₇ to P2₀.

PORT3—Port 3 Register **H'FF52** **Port 3**

Bit	:	7	6	5	4	3	2	1	0
		—	—	P35	P34	P33	P32	P31	P30
Initial value	:	Undefined	Undefined	—*	—*	—*	—*	—*	—*
Read/Write	:	—	—	R	R	R	R	R	R

State of port 3 pins

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

Initial value : —* —* —* —* —* —* —* —*
 Read/Write : R R R R R R R R

State of port 4 pins

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

PORT5—Port 5 Register

H'FF54

Port 5

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	P53	P52	P51	P50
Initial value	:	Undefined	Undefined	Undefined	Undefined	—*	—*	—*	—*
Read/Write	:	—	—	—	—	R	R	R	R

State of port 5 pins

Note: * Determined by the state of pins P5₃ to P5₀.

PORT6—Port 6 Register

H'FF55

Port 6

Bit	:	7	6	5	4	3	2	1	0
		P67	P66	P65	P64	P63	P62	P61	P60
Initial value	:	—*	—*	—*	—*	—*	—*	—*	—*
Read/Write	:	R	R	R	R	R	R	R	R

State of port 6 pins

Note: * Determined by the state of pins P6₇ to P6₀.

Initial value : —* —* —* —* —* —* —* —*

Read/Write : R R R R R R R R

State of port A pins

Note: * Determined by the state of pins PA₇ to PA₀.

PORTB—Port B Register

H'FF5A

**Port B
[H8S/2351 Only]**

Bit	:	7	6	5	4	3	2	1	0
		PB7	PB6	PB5	PB4	PB3	PB2	PB1	PB0
Initial value	:	—*	—*	—*	—*	—*	—*	—*	—*
Read/Write	:	R	R	R	R	R	R	R	R

State of port B pins

Note: * Determined by the state of pins PB₇ to PB₀.

PORTC—Port C Register

H'FF5B

**Port C
[H8S/2351 Only]**

Bit	:	7	6	5	4	3	2	1	0
		PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0
Initial value	:	—*	—*	—*	—*	—*	—*	—*	—*
Read/Write	:	R	R	R	R	R	R	R	R

State of port C pins

Note: * Determined by the state of pins PC₇ to PC₀.

	PD7	PD6	PD5	PD4	PD3	PD2	PD1	PD0
Initial value :	—*	—*	—*	—*	—*	—*	—*	—*
Read/Write :	R	R	R	R	R	R	R	R

State of port D pins

Note: * Determined by the state of pins PD₇ to PD₀.

PORTE—Port E Register

H'FF5D

Port E

Bit	7	6	5	4	3	2	1	0
	PE7	PE6	PE5	PE4	PE3	PE2	PE1	PE0
Initial value :	—*	—*	—*	—*	—*	—*	—*	—*
Read/Write :	R	R	R	R	R	R	R	R

State of port E pins

Note: * Determined by the state of pins PE₇ to PE₀.

PORTF—Port F Register

H'FF5E

Port F

Bit	7	6	5	4	3	2	1	0
	PF7	PF6	PF5	PF4	PF3	PF2	PF1	PF0
Initial value :	—*	—*	—*	—*	—*	—*	—*	—*
Read/Write :	R	R	R	R	R	R	R	R

State of port F pins

Note: * Determined by the state of pins PF₇ to PF₀.

Initial value :
 Read/Write : — — — R R R R R

State of port G pins

Note: * Determined by the state of pins PG₄ to PG₀.

P1DR—Port 1 Data Register **H'FF60** **Port 1**

Bit	:	7	6	5	4	3	2	1	0
		P17DR	P16DR	P15DR	P14DR	P13DR	P12DR	P11DR	P10DR
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

Stores output data for port 1 pins (P1₇ to P1₀)

P2DR—Port 2 Data Register **H'FF61** **Port 2**

Bit	:	7	6	5	4	3	2	1	0
		P27DR	P26DR	P25DR	P24DR	P23DR	P22DR	P21DR	P20DR
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

Stores output data for port 2 pins (P2₇ to P2₀)

Initial value :
 Read/Write : — — R/W R/W R/W R/W R/W R/W

Stores output data for port 3 pins (P3₅ to P3₀)

P5DR—Port 5 Data Register

H'FF64

Port 5

Bit	:	7	6	5	4	3	2	1	0
		—	—	—	—	P53DR	P52DR	P51DR	P50DR
Initial value	:	Undefined	Undefined	Undefined	Undefined	0	0	0	0
Read/Write	:	—	—	—	—	R/W	R/W	R/W	R/W

Stores output data for port 5 pins (P5₃ to P5₀)

P6DR—Port 6 Data Register

H'FF65

Port 6

Bit	:	7	6	5	4	3	2	1	0
		P67DR	P66DR	P65DR	P64DR	P63DR	P62DR	P61DR	P60DR
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

Stores output data for port 6 pins (P6₇ to P6₀)

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

Stores output data for port A pins (PA₇ to PA₀)

PBDR—Port B Data Register

H'FF6A

Port B
[H8S/2351 Only]

Bit	:	7	6	5	4	3	2	1	0
		PB7DR	PB6DR	PB5DR	PB4DR	PB3DR	PB2DR	PB1DR	PB0DR
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

Stores output data for port B pins (PB₇ to PB₀)

PCDR—Port C Data Register

H'FF6B

Port C
[H8S/2351 Only]

Bit	:	7	6	5	4	3	2	1	0
		PC7DR	PC6DR	PC5DR	PC4DR	PC3DR	PC2DR	PC1DR	PC0DR
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

Stores output data for port C pins (PC₇ to PC₀)

	PD7DR	PD6DR	PD5DR	PD4DR	PD3DR	PD2DR	PD1DR	PD0DR
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

Stores output data for port D pins (PD₇ to PD₀)

PEDR—Port E Data Register

H'FF6D

Port E

Bit :	7	6	5	4	3	2	1	0
	PE7DR	PE6DR	PE5DR	PE4DR	PE3DR	PE2DR	PE1DR	PE0DR
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

Stores output data for port E pins (PE₇ to PE₀)

PFDR—Port F Data Register

H'FF6E

Port F

Bit :	7	6	5	4	3	2	1	0
	PF7DR	PF6DR	PF5DR	PF4DR	PF3DR	PF2DR	PF1DR	PF0DR
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

Stores output data for port F pins (PF₇ to PF₀)

Initial value : Undefined Undefined Undefined 0 0 0 0 0
 Read/Write : — — — R/W R/W R/W R/W R/W

Stores output data for port G pins (PG₄ to PG₀)

PAPCR—Port A MOS Pull-Up Control Register H'FF70

Port A
[H8S/2351 Only]

Bit	7	6	5	4	3	2	1	0
	PA7PCR	PA6PCR	PA5PCR	PA4PCR	PA3PCR	PA2PCR	PA1PCR	PA0PCR
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

Controls the MOS input pull-up function incorporated into port A on a bit-by-bit basis

PBPCR—Port B MOS Pull-Up Control Register H'FF71

Port B
[H8S/2351 Only]

Bit	7	6	5	4	3	2	1	0
	PB7PCR	PB6PCR	PB5PCR	PB4PCR	PB3PCR	PB2PCR	PB1PCR	PB0PCR
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

Controls the MOS input pull-up function incorporated into port B on a bit-by-bit basis

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

Controls the MOS input pull-up function incorporated into port C on a bit-by-bit basis

PDPCR—Port D MOS Pull-Up Control Register H'FF73

Port D
[H8S/2351 Only]

Bit :	7	6	5	4	3	2	1	0
	PD7PCR	PD6PCR	PD5PCR	PD4PCR	PD3PCR	PD2PCR	PD1PCR	PD0PCR
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

Controls the MOS input pull-up function incorporated into port D on a bit-by-bit basis

PEPCR—Port E MOS Pull-Up Control Register H'FF74

Port E
[H8S/2351 Only]

Bit :	7	6	5	4	3	2	1	0
	PE7PCR	PE6PCR	PE5PCR	PE4PCR	PE3PCR	PE2PCR	PE1PCR	PE0PCR
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

Controls the MOS input pull-up function incorporated into port E on a bit-by-bit basis

Initial value : Undefined Undefined 0 0 0 0 0 0
 Read/Write : — — R/W R/W R/W R/W R/W R/W

Controls the PMOS on/off status for each port 3 pin (P3₅ to P3₀)

PAODR—Port A Open Drain Control Register H'FF77

**Port A
 [H8S/2351 Only]**

Bit	:	7	6	5	4	3	2	1	0
		PA7ODR	PA6ODR	PA5ODR	PA4ODR	PA3ODR	PA2ODR	PA1ODR	PA0ODR
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

Controls the PMOS on/off status for each port A pin (PA₇ to PA₀)

Initial value : 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

Clock Select

0	0	∅ clock
	1	∅/4 clock
1	0	∅/16 clock
	1	∅/64 clock

Multiprocessor Mode

0	Multiprocessor function disabled
1	Multiprocessor format selected

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.

Asynchronous Mode/Synchronous Mode Select

0	Asynchronous mode
1	Synchronous mode

initial value : 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

Clock Select

0	0	∅ clock
	1	∅/4 clock
1	0	∅/16 clock
	1	∅/64 clock

Multiprocessor Mode

0	Multiprocessor function disabled
1	Setting prohibited

Stop Bit Length

0	Setting prohibited
1	2 stop bits

Parity Mode

0	Even parity
1	Odd parity

Parity Enable

0	Setting prohibited
1	Parity bit addition and checking enabled

Character Length

0	8-bit data
1	Setting prohibited

GSM Mode

0	Normal smart card interface mode operation <ul style="list-style-type: none"> • TEND flag generated 12.5 etu after beginning of start bit • Clock output on/off control only
1	GSM mode smart card interface mode operation <ul style="list-style-type: none"> • TEND flag generated 11.0 etu after beginning of start bit • Fixed high/low-level control possible (set in SCR) in addition to clock output on/off control

Note: etu (Elementary Time Unit): Interval for transfer of one bit

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

Sets the serial transfer bit rate

Note: See section 13.2.8, Bit Rate Register (BRR), for details.

Clock Enable

0	0	Asynchronous mode	Internal clock/SCK pin functions as I/O port
		Synchronous mode	Internal clock/SCK pin functions as serial clock output
1		Asynchronous mode	Internal clock/SCK pin functions as clock output*1
		Synchronous mode	Internal clock/SCK pin functions as serial clock output
1	0	Asynchronous mode	External clock/SCK pin functions as clock input*2
		Synchronous mode	External clock/SCK pin functions as serial clock input
1		Asynchronous mode	External clock/SCK pin functions as clock input*2
		Synchronous mode	External clock/SCK pin functions as serial clock input

Notes: 1. Outputs a clock of the same frequency as the bit rate.
 2. Inputs a clock with a frequency 16 times the bit rate.

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 [Clearing conditions] • When the MPIE bit is cleared to 0 • When MPB= 1 data is received
1	Multiprocessor interrupts enabled Receive interrupt (RXI) requests, receive error interrupt (ERI) requests, and setting of the RDRF, FER, and ORER flags in SSR are disabled until data with the multiprocessor bit set to 1 is received

Receive Enable

0	Reception disabled
1	Reception enabled

Transmit Enable

0	Transmission disabled
1	Transmission 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

Transmit Interrupt Enable

0	Transmit data empty interrupt (TXI) requests disabled
1	Transmit data empty interrupt (TXI) requests enabled

Read/Write :

R/W

R/W

R/W

R/W

R/W

R/W

R/W

R/W

Clock Enable

SMCR	SMR	SCR setting		SCK pin function
SMIF	C/ \bar{A} ,GM	CKE1	CKE0	
0	See SCI specification			
1	0	0	0	Operates as port input pin
1	0	0	1	Clock output as SCK output pin
1	1	0	0	Fixed-low output as SCK output pin
1	1	0	1	Clock output as SCK output pin
1	1	1	0	Fixed-high output as SCK output pin
1	1	1	1	Clock output as SCK output pin

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 [Clearing conditions] <ul style="list-style-type: none"> • When the MPIE bit is cleared to 0 • When MPB= 1 data is received
1	Multiprocessor interrupts enabled Receive interrupt (RXI) requests, receive error interrupt (ERI) requests, and setting of the RDRF, FER, and ORER flags in SSR are disabled until data with the multiprocessor bit set to 1 is received

Receive Enable

0	Reception disabled
1	Reception enabled

Transmit Enable

0	Transmission disabled
1	Transmission 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

Transmit Interrupt Enable

0	Transmit data empty interrupt (TXI) requests disabled
1	Transmit data empty interrupt (TXI) requests enabled

Initial value : 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

Stores data for serial transmission

Read/Write	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R	R	R/W				
								Multiprocessor Bit Transfer <table border="1"> <tr> <td>0</td> <td>Data with a 0 multiprocessor bit is transmitted</td> </tr> <tr> <td>1</td> <td>Data with a 1 multiprocessor bit is transmitted</td> </tr> </table>	0	Data with a 0 multiprocessor bit is transmitted	1	Data with a 1 multiprocessor bit is transmitted
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								Transmit End <table border="1"> <tr> <td>0</td> <td>[Clearing condition] • When 0 is written to TDRE after reading TDRE = 1 • When the DMAC or DTC is activated by a TXI interrupt and write data to TDR</td> </tr> <tr> <td>1</td> <td>[Setting conditions] • When the TE bit in SCR is 0 • When TDRE = 1 at transmission of the last bit of a 1-byte serial transmit character</td> </tr> </table>	0	[Clearing condition] • When 0 is written to TDRE after reading TDRE = 1 • When the DMAC or DTC is activated by a TXI interrupt and write data to TDR	1	[Setting conditions] • When the TE bit in SCR is 0 • When TDRE = 1 at transmission of the last bit of a 1-byte serial transmit character
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								Framing Error <table border="1"> <tr> <td>0</td> <td>[Clearing condition] When 0 is written to FER after reading FER = 1</td> </tr> <tr> <td>1</td> <td>[Setting condition] When the SCI checks whether the stop bit at the end of the receive data when reception ends, and the stop bit is 0</td> </tr> </table>	0	[Clearing condition] When 0 is written to FER after reading FER = 1	1	[Setting condition] When the SCI checks whether the stop bit at the end of the receive data when reception ends, and the stop bit is 0
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0	[Clearing condition] When 0 is written to ORER after reading ORER = 1											
1	[Setting condition] When the next serial reception is completed while RDRF = 1											
								Receive Data Register Full <table border="1"> <tr> <td>0</td> <td>[Clearing condition] • When 0 is written to RDRF after reading RDRF = 1 • When the DMAC or DTC is activated by an RXI interrupt and read data from RDR</td> </tr> <tr> <td>1</td> <td>[Setting condition] When serial reception ends normally and receive data is transferred from RSR to RDR</td> </tr> </table>	0	[Clearing condition] • When 0 is written to RDRF after reading RDRF = 1 • When the DMAC or DTC is activated by an RXI interrupt and read data from RDR	1	[Setting condition] When serial reception ends normally and receive data is transferred from RSR to RDR
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								Transmit Data Register Empty <table border="1"> <tr> <td>0</td> <td>[Clearing condition] • When 0 is written to TDRE after reading TDRE = 1 • When the DMAC or DTC is activated by a TXI interrupt and write data to TDR</td> </tr> <tr> <td>1</td> <td>[Setting condition] • When the TE bit in SCR is 0 • When data is transferred from TDR to TSR and data can be written to TDR</td> </tr> </table>	0	[Clearing condition] • When 0 is written to TDRE after reading TDRE = 1 • When the DMAC or DTC is activated by a TXI interrupt and write data to TDR	1	[Setting condition] • When the TE bit in SCR is 0 • When data is transferred from TDR to TSR and data can be written to TDR
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1	[Setting condition] • When the TE bit in SCR is 0 • When data is transferred from TDR to TSR and data can be written to TDR											

Note: * Can only be written with 0 for flag clearing.

Multiprocessor Bit Transfer

0	Data with a 0 multiprocessor bit is transmitted
1	Data with a 1 multiprocessor bit is transmitted

Multiprocessor Bit

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 condition] <ul style="list-style-type: none"> When 0 is written to TDRE after reading TDRE = 1 When the DMAC or DTC is activated by a TXI interrupt and write data to TDR
1	[Setting conditions] <ul style="list-style-type: none"> On reset, or in standby mode or module stop mode When the TE bit in SCR is 0 and the ERS bit is 0 When TDRE = 1 and ERS = 0 (normal transmission) 2.5 etu after a 1-byte serial character is sent when GM = 0 When TDRE = 1 and ERS = 0 (normal transmission) 1.0 etu after a 1-byte serial character is sent when GM = 1

Note: etu: Elementary Time Unit (the time taken to transmit one bit)

Parity Error

0	[Clearing condition] When 0 is written to PER after reading PER = 1
1	[Setting condition] When, in reception, the number of 1 bits in the receive data plus the parity bit does not match the parity setting (even or odd) specified by the O/E bit in SMR

Error Signal Status

0	[Clearing condition] <ul style="list-style-type: none"> On reset, or in standby mode or module stop mode When 0 is written to ERS after reading ERS = 1
1	[Setting condition] When the error signal is sampled at the low level

Note: Clearing the TE bit in SCR to 0 does not affect the ERS flag, which retains its prior state.

Overrun Error

0	[Clearing condition] When 0 is written to ORER after reading ORER = 1
1	[Setting condition] When the next serial reception is completed while RDRF = 1

Receive Data Register Full

0	[Clearing condition] <ul style="list-style-type: none"> When 0 is written to RDRF after reading RDRF = 1 When the DMAC or DTC is activated by an RXI interrupt and read 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 condition] <ul style="list-style-type: none"> When 0 is written to TDRE after reading TDRE = 1 When the DMAC or DTC is activated by a TXI interrupt and write data to TDR
1	[Setting condition] <ul style="list-style-type: none"> When the TE bit in SCR is 0 When data is transferred from TDR to TSR and data can be written to TDR

Note: * Can only be written with 0 for flag clearing.

Initial value : 0 0 0 0 0 0 0 0
 Read/Write : R R R R R R R R

Stores received serial data

SCMR0—Smart Card Mode Register 0

H'FF7E SCI0, Smart Card Interface 0

Bit	7	6	5	4	3	2	1	0
	—	—	—	—	SDIR	SINV	—	SMIF
Initial value :	1	1	1	1	0	0	1	0
Read/Write :	—	—	—	—	R/W	R/W	—	R/W

Smart Card Interface Mode Select

0	Smart Card interface function is disabled
1	Smart Card interface function is enabled

Smart Card Data Invert

0	TDR contents are transmitted as they are Receive data is stored in RDR as it is
1	TDR contents are inverted before being transmitted Receive data is stored in RDR in inverted form

Smart Card Data 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

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

Clock Select

0	0	∅ clock
	1	∅/4 clock
1	0	∅/16 clock
	1	∅/64 clock

Multiprocessor Mode

0	Multiprocessor function disabled
1	Multiprocessor format selected

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.

Asynchronous Mode/Synchronous Mode Select

0	Asynchronous mode
1	Synchronous mode

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										
							Clock Select <table border="1"> <tr> <td rowspan="2">0</td> <td>0</td> <td>∅ clock</td> </tr> <tr> <td>1</td> <td>∅/4 clock</td> </tr> <tr> <td rowspan="2">1</td> <td>0</td> <td>∅/16 clock</td> </tr> <tr> <td>1</td> <td>∅/64 clock</td> </tr> </table>		0	0	∅ clock	1	∅/4 clock	1	0	∅/16 clock	1	∅/64 clock
0	0	∅ clock																
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							Multiprocessor Mode <table border="1"> <tr> <td>0</td> <td>Multiprocessor function disabled</td> </tr> <tr> <td>1</td> <td>Setting prohibited</td> </tr> </table>		0	Multiprocessor function disabled	1	Setting prohibited						
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1	Setting prohibited																	
							Stop Bit Length <table border="1"> <tr> <td>0</td> <td>Setting prohibited</td> </tr> <tr> <td>1</td> <td>2 stop bits</td> </tr> </table>		0	Setting prohibited	1	2 stop bits						
0	Setting prohibited																	
1	2 stop bits																	
							Parity Mode <table border="1"> <tr> <td>0</td> <td>Even parity</td> </tr> <tr> <td>1</td> <td>Odd parity</td> </tr> </table>		0	Even parity	1	Odd parity						
0	Even parity																	
1	Odd parity																	
							Parity Enable <table border="1"> <tr> <td>0</td> <td>Setting prohibited</td> </tr> <tr> <td>1</td> <td>Parity bit addition and checking enabled</td> </tr> </table>		0	Setting prohibited	1	Parity bit addition and checking enabled						
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1	Parity bit addition and checking enabled																	
							Character Length <table border="1"> <tr> <td>0</td> <td>8-bit data</td> </tr> <tr> <td>1</td> <td>Setting prohibited</td> </tr> </table>		0	8-bit data	1	Setting prohibited						
0	8-bit data																	
1	Setting prohibited																	

GSM Mode _____

0	Normal smart card interface mode operation <ul style="list-style-type: none"> • TEND flag generated 12.5 etu after beginning of start bit • Clock output on/off control only
1	GSM mode smart card interface mode operation <ul style="list-style-type: none"> • TEND flag generated 11.0 etu after beginning of start bit • Fixed high/low-level control possible (set in SCR) in addition to clock output on/off control

Note: etu (Elementary Time Unit): Interval for transfer of one bit

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

Sets the serial transfer bit rate

Note: See section 13.2.8, Bit Rate Register (BRR), for details.

Clock Enable

0	0	Asynchronous mode	Internal clock/SCK pin functions as I/O port
		Synchronous mode	Internal clock/SCK pin functions as serial clock output
1		Asynchronous mode	Internal clock/SCK pin functions as clock output*1
		Synchronous mode	Internal clock/SCK pin functions as serial clock output
1	0	Asynchronous mode	External clock/SCK pin functions as clock input*2
		Synchronous mode	External clock/SCK pin functions as serial clock input
	1	Asynchronous mode	External clock/SCK pin functions as clock input*2
		Synchronous mode	External clock/SCK pin functions as serial clock input

Notes: 1. Outputs a clock of the same frequency as the bit rate.
 2. Inputs a clock with a frequency 16 times the bit rate.

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 [Clearing conditions] <ul style="list-style-type: none"> • When the MPIE bit is cleared to 0 • When MPB= 1 data is received
1	Multiprocessor interrupts enabled Receive interrupt (RXI) requests, receive error interrupt (ERI) requests, and setting of the RDRF, FER, and ORER flags in SSR are disabled until data with the multiprocessor bit set to 1 is received

Receive Enable

0	Reception disabled
1	Reception enabled

Transmit Enable

0	Transmission disabled
1	Transmission 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

Transmit Interrupt Enable

0	Transmit data empty interrupt (TXI) requests disabled
1	Transmit data empty interrupt (TXI) requests enabled

Clock Enable

SMCR	SMR	SCR setting		SCK pin function
		SMIF	C/Ā,GM	
0	See SCI specification			
1	0	0	0	Operates as port input pin
1	0	0	1	Clock output as SCK output pin
1	1	0	0	Fixed-low output as SCK output pin
1	1	0	1	Clock output as SCK output pin
1	1	1	0	Fixed-high output as SCK output pin
1	1	1	1	Clock output as SCK output pin

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 [Clearing conditions] <ul style="list-style-type: none"> • When the MPiE bit is cleared to 0 • When MPB= 1 data is received
1	Multiprocessor interrupts enabled Receive interrupt (RXI) requests, receive error interrupt (ERI) requests, and setting of the RDRF, FER, and ORER flags in SSR are disabled until data with the multiprocessor bit set to 1 is received

Receive Enable

0	Reception disabled
1	Reception enabled

Transmit Enable

0	Transmission disabled
1	Transmission 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

Transmit Interrupt Enable

0	Transmit data empty interrupt (TXI) requests disabled
1	Transmit data empty interrupt (TXI) requests enabled

Initial value : 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

Stores data for serial transmission

Read/Write :	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R/(W)*	R	R	R/W				
Multiprocessor Bit Transfer												
<table border="1"> <tr> <td>0</td> <td>Data with a 0 multiprocessor bit is transmitted</td> </tr> <tr> <td>1</td> <td>Data with a 1 multiprocessor bit is transmitted</td> </tr> </table>									0	Data with a 0 multiprocessor bit is transmitted	1	Data with a 1 multiprocessor bit is transmitted
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Receive Data Register Full												
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1	[Setting condition] When serial reception ends normally and receive data is transferred from RSR to RDR											
Transmit Data Register Empty												
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1	[Setting condition] • When the TE bit in SCR is 0 • When data is transferred from TDR to TSR and data can be written to TDR											

Note: * Can only be written with 0 for flag clearing.

Multiprocessor Bit Transfer

0	Data with a 0 multiprocessor bit is transmitted
1	Data with a 1 multiprocessor bit is transmitted

Multiprocessor Bit

0	[Clearing condition] When data with a 0 multiprocessor bit is received
1	[Setting conditions] When data with a 1 multiprocessor bit is received

Transmit End

0	[Clearing condition] • When 0 is written to TDRE after reading TDRE = 1 • When the DMAC or DTC is activated by a TXI interrupt and write data to TDR
1	[Setting conditions] • On reset, or in standby mode or module stop mode • When the TE bit in SCR is 0 and the ERS bit is 0 • When TDRE = 1 and ERS = 0 (normal transmission) 2.5 etu after a 1-byte serial character is sent when GM = 0 • When TDRE = 1 and ERS = 0 (normal transmission) 1.0 etu after a 1-byte serial character is sent when GM = 1

Note: etu: Elementary Time Unit (the time taken to transmit one bit)

Parity Error

0	[Clearing condition] When 0 is written to PER after reading PER = 1
1	[Setting condition] When, in reception, the number of 1 bits in the receive data plus the parity bit does not match the parity setting (even or odd) specified by the O/E bit in SMR

Error Signal Status

0	[Clearing condition] • On reset, or in standby mode or module stop mode • When 0 is written to ERS after reading ERS = 1
1	[Setting conditions] When the error signal is sampled at the low level

Note: Clearing the TE bit in SCR to 0 does not affect the ERS flag, which retains its prior state.

Overrun Error

0	[Clearing condition] When 0 is written to ORER after reading ORER = 1
1	[Setting condition] When the next serial reception is completed while RDRF = 1

Receive Data Register Full

0	[Clearing condition] • When 0 is written to RDRF after reading RDRF = 1 • When the DMAC or DTC is activated by an RXI interrupt and read 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 condition] • When 0 is written to TDRE after reading TDRE = 1 • When the DMAC or DTC is activated by a TXI interrupt and write data to TDR
1	[Setting condition] • When the TE bit in SCR is 0 • When data is transferred from TDR to TSR and data can be written to TDR

Note: * Can only be written with 0 for flag clearing.

Initial value : 0 0 0 0 0 0 0 0
 Read/Write : R R R R R R R R

Stores received serial data

SCMR1—Smart Card Mode Register 1

H'FF86 SCI1, Smart Card Interface 1

Bit	7	6	5	4	3	2	1	0
	—	—	—	—	SDIR	SINV	—	SMIF
Initial value :	1	1	1	1	0	0	1	0
Read/Write :	—	—	—	—	R/W	R/W	—	R/W

Smart Card Interface Mode Select

0	Smart Card interface function is disabled
1	Smart Card interface function is enabled

Smart Card Data Invert

0	TDR contents are transmitted as they are Receive data is stored in RDR as it is
1	TDR contents are inverted before being transmitted Receive data is stored in RDR in inverted form

Smart Card Data 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

ADDRCL	—	A/D Data Register CL	H'FF95	A/D Converter
ADDRDH	—	A/D Data Register DH	H'FF96	A/D Converter
ADDRDL	—	A/D Data Register DL	H'FF97	A/D Converter

Bit	:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
		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	0	0
Read/Write	:	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

Stores the results of A/D conversion

Analog Input Channel		A/D Data Register
Group 0	Group 1	
AN0	AN4	ADDRA
AN1	AN5	ADDRB
AN2	AN6	ADDRC
AN3	AN7	ADDRD

Initial value : 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

Channel Select

Group select	Channel select			Single Mode	Group Mode
	CH2	CH1	CH0		
0	0	0	0	AN0	AN0
		1	0	AN1	AN0, AN1
	1	0	0	AN2	AN0 to AN2
		1	0	AN3	AN0 to AN3
1	0	0	0	AN4	AN4
		1	0	AN5	AN4, AN5
	1	0	0	AN6	AN4 to AN6
		1	0	AN7	AN4 to AN7

Group 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 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 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 to the 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 one round of conversion has been performed on all specified channels

Note: * Can only be written with 0 for flag clearing.

Initial value : 0 0 1 1 1 1 1 1
 Read/Write : R/W R/W — — — — —

Timer Trigger Select

TRGS1	TRGS1	Description
0	0	A/D conversion start by software is enabled
	1	A/D conversion start by TPU conversion start trigger is enabled
1	0	—
	1	A/D conversion start by external trigger pin ($\overline{\text{ADTRG}}$) is enabled

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

Stores data for D/A conversion

Initial value : 0 0 0 1 1 1 1 1
 Read/Write : R/W R/W R/W — — — —

D/A Output Enable 0

0	Analog output DA0 is disabled
1	Channel 0 D/A conversion is enabled Analog output DA0 is enabled

D/A Output Enable 1

0	Analog output DA1 is disabled
1	Channel 1 D/A conversion is enabled Analog output DA1 is enabled

D/A Conversion Control

DAOE1	DAOE0	DAE	Description	
0	0	*	Channel 0 and 1 D/A conversion disabled	
		1	0	Channel 0 D/A conversion enabled Channel 1 D/A conversion disabled
			1	Channel 0 and 1 D/A conversions 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

* : Don't care

Read/Write : R/(W)* R/W R/W — — R/W R/W R/W

Clock Select

CKS2	CKS1	CKS0	Clock	Overflow period* (when $\phi = 20$ MHz)
0	0	0	$\phi/2$ (initial value)	25.6 μ s
		1	$\phi/64$	819.2 μ s
	1	0	$\phi/128$	1.6ms
		1	$\phi/512$	6.6ms
1	0	0	$\phi/2048$	26.2ms
		1	$\phi/8192$	104.9ms
	1	0	$\phi/32768$	419.4ms
		1	$\phi/131072$	1.68s

Note: * The overflow period is the time from when TCNT starts counting up from H'00 until overflow occurs.

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 the $\overline{\text{WDTOV}}\overline{\text{F}}$ signal when TCNT overflows

Overflow Flag

0	[Clearing condition] Cleared by reading TCSR when OVF = 1, then writing 0 to OVF
1	[Setting condition] Set when TCNT overflows from H'FF to H'00 in interval timer mode

The method for writing to TCSR is different from that for general registers to prevent accidental overwriting. For details see section 12.2.4, Notes on Register Access.

Note: * Can only be written with 0 for flag clearing.

Initial value : 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

RSTCSR—Reset Control/Status Register **H'FFBE (W) H'FFBF (R)** **WDT**

Bit	7	6	5	4	3	2	1	0
	WOVF	RSTE	RSTS	—	—	—	—	—
Initial value	0	0	0	1	1	1	1	1
Read/Write	R/(W)*	R/W	R/W	—	—	—	—	—

Reset Select

0	Power-on reset
1	Manual reset

Reset Enable

0	Reset signal is not generated if TCNT overflows*
1	Reset signal is generated if TCNT overflows

Note: * The modules H8S/2350 Series are not reset, but TCNT and TCSR in WDT are reset.

Watchdog Timer Overflow Flag

0	[Clearing condition] Cleared by reading TCSR when WOVF = 1, then writing 0 to WOVF
1	[Setting condition] Set when TCNT overflows (changed from H'FF to H'00) during watchdog timer operation

Note: * Can only be written with 0 for flag clearing.

The method for writing to RSTCSR is different from that for general registers to prevent accidental overwriting. For details see section 12.2.4, Notes on Register Access.

Initial value : 0 0 0 0 0 0 0 0
 Read/Write : — — R/W R/W R/W R/W R/W R/W

Counter Start

0	TCNTn count operation is stopped
1	TCNTn performs count operation

(n = 5 to 0)

Note: If 0 is written to the CST bit during operation with the TIOC pin designated for output, the counter stops but the TIOC pin output compare output level is retained. If TIOR is written to when the CST bit is cleared to 0, the pin output level will be changed to the set initial output value.

TSYR—Timer Synchro Register

H'FFC1

TPU

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

—	—	SYNC5	SYNC4	SYNC3	SYNC2	SYNC1	SYNC0
---	---	-------	-------	-------	-------	-------	-------

Timer Synchronization

0	TCNTn operates independently (TCNT presetting/clearing is unrelated to other channels)
1	TCNTn performs synchronous operation TCNT synchronous presetting/synchronous clearing is possible

(n = 5 to 0)

- Notes: 1. To set synchronous operation, the SYNC bits for at least two channels must be set to 1.
 2. To set synchronous clearing, in addition to the SYNC bit, the TCNT clearing source must also be set by means of bits CCLR2 to CCLR0 in TCR.

Time Prescaler

0	0	0	Internal clock: counts on $\varnothing/1$
		1	Internal clock: counts on $\varnothing/4$
	1	0	Internal clock: counts on $\varnothing/16$
		1	Internal clock: counts on $\varnothing/64$
1	0	0	External clock: counts on TCLKA pin input
		1	External clock: counts on TCLKB pin input
	1	0	External clock: counts on TCLKC pin input
		1	External clock: counts on TCLKD pin input

Clock Edge

0	0	Count at rising edge
	1	Count at falling edge
1	—	Count at both edges

Counter Clear

0	0	0	TCNT clearing disabled
		1	TCNT cleared by TGRA compare match/input capture
	1	0	TCNT cleared by TGRB compare match/input capture
		1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation*1
1	0	0	TCNT clearing disabled
		1	TCNT cleared by TGRC compare match/input capture*2
	1	0	TCNT cleared by TGRD compare match/input capture*2
		1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation*1

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

Initial value : 1 1 0 0 0 0 0 0
 Read/Write : — — R/W R/W R/W R/W R/W R/W

Mode

0	0	0	0	Normal operation
			1	Reserved
	1	0	0	PWM mode 1
			1	PWM mode 2
	1	0	0	Phase counting mode 1
			1	Phase counting mode 2
		1	0	Phase counting mode 3
			1	Phase counting mode 4
1	*	*	*	—

* : Don't care

- Notes: 1. MD3 is a reserved bit. In a write, it should always be written with 0.
 2. Phase counting mode cannot be set for channels 0 and 3. In this case, 0 should always be written to MD2.

TGRA Buffer Operation

0	TGRA operates normally
1	TGRA and TGRD used together for buffer operation

TGRB Buffer Operation

0	TGRB operates normally
1	TGRB and TGRD used together for buffer operation

TGR0A I/O Control

0	0	0	0	TGR0A is output compare register	Output disabled			
			1		Initial output is 0 output	0 output at compare match		
			0			1 output at compare match		
	1	0	0		Output disabled			
			1		Initial output is 1 output	0 output at compare match		
			0			1 output at compare match		
	1	0	0		0	TGR0A is input capture register	Capture input source is TIOCA0 pin	Input capture at rising edge
					1			Input capture at falling edge
					*			Input capture at both edges
1		*	*	1	Capture input source is channel 1/count clock		Input capture at TCNT1 count-up/count-down	

TGR0B I/O Control

0	0	0	0	TGR0B is output compare register	Output disabled			
			1		Initial output is 0 output	0 output at compare match		
			0			1 output at compare match		
	1	0	0		0	Output disabled		
					1	Initial output is 0 output	0 output at compare match	
					0		1 output at compare match	
	1	0	0		0	TGR0B is input capture register	Capture input source is TIOCB0 pin	Input capture at rising edge
					1			Input capture at falling edge
					*			Input capture at both edges
1		*	*	1	Capture input source is channel 1/count clock		Input capture at TCNT1 count-up/count-down*1	

* : Don't care

* : Don't care

Note: *1. When bits TPSC2 to TPSC0 in TCR1 are set to B'000, and 0/1 is used as the TCNT1 count clock, this setting is invalid and input capture is not generated.

TGR0C I/O Control

0	0	0	0	TGR0C is output compare register	Output disabled	
			1		Initial output is 0 output	0 output at compare match
			1			1 output at compare match
	1	0	0	TGR0C is output compare register	Output disabled	
			1		Initial output is 1 output	0 output at compare match
			1			1 output at compare match
	1	0	0	TGR0C is input capture register	Capture input source is TIOCC0 pin	
			1		Input capture at rising edge	
			*		Input capture at falling edge	
1	*	*	TGR0C is input capture register	Capture input source is channel 1/count clock		
				Input capture at both edges		
				Input capture at TCNT1 count-up/count-down		

* : Don't care

Note: When the BFA bit in TMDR0 is set to 1 and TGR0C is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

TGR0D I/O Control

0	0	0	0	TGR0D is output compare register	Output disabled	
			1		Initial output is 0 output	0 output at compare match
			1			1 output at compare match
	1	0	0	TGR0D is output compare register	Output disabled	
			1		Initial output is 1 output	0 output at compare match
			1			1 output at compare match
	1	0	0	TGR0D is input capture register	Capture input source is TIOCD0 pin	
			1		Input capture at rising edge	
			*		Input capture at falling edge	
1	*	*	TGR0D is input capture register	Capture input source is channel 1/count clock		
				Input capture at both edges		
				Input capture at TCNT1 count-up/count-down* ¹		

* : Don't care

Note: When the BFB bit in TMDR0 is set to 1 and TGR0D is used as a buffer register, this setting is invalid and input capture/output compare is not generated.

¹ When bits TPSC2 to TPSC0 in TCR1 are set to B'000, and $\phi/1$ is used as the TCNT1 count clock, this setting is invalid and input capture is not generated.

Note: When TGRC or TGRD is designated for buffer operation, this setting is invalid and the register operates as a buffer register.

Read/Write :

R/W

—

—

R/W

R/W

R/W

R/W

R/W

TGR Interrupt Enable A

0	Interrupt requests (TGIA) by TGFA bit disabled
1	Interrupt requests (TGIA) by TGFA bit enabled

TGR Interrupt Enable B

0	Interrupt requests (TGIB) by TGFB bit disabled
1	Interrupt requests (TGIB) by TGFB bit enabled

TGR Interrupt Enable C

0	Interrupt requests (TGIC) by TGFC bit disabled
1	Interrupt requests (TGIC) by TGFC bit enabled

TGR Interrupt Enable D

0	Interrupt requests (TGID) by TGFD bit disabled
1	Interrupt requests (TGID) by TGFD bit enabled

Overflow Interrupt Enable

0	Interrupt requests (TCIV) by TCFV disabled
1	Interrupt requests (TCIV) by TCFV enabled

A/D Conversion Start Request Enable

0	A/D conversion start request generation disabled
1	A/D conversion start request generation enabled

Input Capture/Output Compare Flag A

0	<p>[Clearing condition]</p> <ul style="list-style-type: none"> When DTC is activated by TGIA interrupt while DISEL bit of MRB in DTC is 0 When DMAC is activated by TGIA interrupt while DTA bit of DMABCR in DMAC is 1 When 0 is written to TGFA after reading TGFA = 1
1	<p>[Setting conditions]</p> <ul style="list-style-type: none"> When TCNT = TGRA while TGRA is functioning as output compare register When TCNT value is transferred to TGRA by input capture signal while TGRA is functioning as input capture register

Input Capture/Output Compare Flag B

0	<p>[Clearing condition]</p> <ul style="list-style-type: none"> When DTC is activated by TGIB interrupt while DISEL bit of MRB in DTC is 0 When 0 is written to TGF B after reading TGF B = 1
1	<p>[Setting conditions]</p> <ul style="list-style-type: none"> When TCNT = TGRB while TGRB is functioning as output compare register When TCNT value is transferred to TGRB by input capture signal while TGRB is functioning as input capture register

Input Capture/Output Compare Flag C

0	<p>[Clearing condition]</p> <ul style="list-style-type: none"> When DTC is activated by TGIC interrupt while DISEL bit of MRB in DTC is 0 When 0 is written to TGFC after reading TGFC = 1
1	<p>[Setting conditions]</p> <ul style="list-style-type: none"> When TCNT = TGRC while TGRC is functioning as output compare register When TCNT value is transferred to TGRC by input capture signal while TGRC is functioning as input capture register

Input Capture/Output Compare Flag D

0	<p>[Clearing condition]</p> <ul style="list-style-type: none"> When DTC is activated by TGID interrupt while DISEL bit of MRB in DTC is 0 When 0 is written to TGFD after reading TGFD = 1
1	<p>[Setting conditions]</p> <ul style="list-style-type: none"> When TCNT = TGRD while TGRD is functioning as output compare register When TCNT value is transferred to TGRD by input capture signal while TGRD is functioning as input capture register

Overflow Flag

0	<p>[Clearing condition]</p> <p>When 0 is written to TCFV after reading TCFV = 1</p>
1	<p>[Setting conditions]</p> <p>When the TCNT value overflows (changes from H'FFFF to H'0000)</p>

Note: * Can only be written with 0 for flag clearing.

Initial value : 0 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 R/W

Up-counter

TGR0A—Timer General Register 0A	H'FFD8	TPU0
TGR0B—Timer General Register 0B	H'FFDA	TPU0
TGR0C—Timer General Register 0C	H'FFDC	TPU0
TGR0D—Timer General Register 0D	H'FFDE	TPU0

Bit	:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
		<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"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Initial value	:	1	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	R/W

Read/Write : —

R/W R/W R/W R/W R/W R/W R/W

Time Prescaler

0	0	0	Internal clock: counts on $\phi/1$
		1	Internal clock: counts on $\phi/4$
	1	0	Internal clock: counts on $\phi/16$
		1	Internal clock: counts on $\phi/64$
1	0	0	External clock: counts on TCLKA pin input
		1	External clock: counts on TCLKB pin input
	1	0	Internal clock: counts on $\phi/256$
		1	Counts on TCNT2 overflow/underflow

Note: This setting is ignored when channel 1 is in phase counting mode.

Clock Edge

0	0	Count at rising edge
	1	Count at falling edge
1	—	Count at both edges

Note: This setting is ignored when channel 1 is in phase counting mode.

Counter Clear

0	0	TCNT clearing disabled
	1	TCNT cleared by TGRA compare match/input capture
1	0	TCNT cleared by TGRB compare match/input capture
	1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation*

Note: * Synchronous operating setting is performed by setting the SYNC bit in TSYR to 1.

Initial value : 1 1 0 0 0 0
 Read/Write : — — — — R/W R/W R/W R/W

Mode

0	0	0	0	Normal operation	
			1	Reserved	
		1	0	0	PWM mode 1
				1	PWM mode 2
	1	0	0	Phase counting mode 1	
			1	Phase counting mode 2	
		1	0	0	Phase counting mode 3
				1	1Phase counting mode 4
1	*	*	*	—	

* : Don't care

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

TGR1A I/O Control

0	0	0	0	TGR1A is output compare register	Output disabled		
			1		Initial output is 0 output	0 output at compare match	
		1	0			1 output at compare match	
			1		Toggle output at compare match		
	1	0	0		TGR1A is input capture register	Output disabled	
			1			Initial output is 1 output	0 output at compare match
		1	0				1 output at compare match
			1			Toggle output at compare match	
1	0	0	TGR1A is input capture register	Capture input source is TIOCA1 pin		Input capture at rising edge	
		1				Input capture at falling edge	
	*	Input capture at both edges					
	1	*		*		Capture input source is TGR0A compare match/ input capture	Input capture at generation of channel 0/TGR0A compare match/ input capture

* : Don't care

TGR1B I/O Control

0	0	0	0	TGR1B is output compare register	Output disabled		
			1		Initial output is 0 output	0 output at compare match	
		1	0			1 output at compare match	
			1		Toggle output at compare match		
	1	0	0		TGR1B is input capture register	Output disabled	
			1			Initial output is 1 output	0 output at compare match
		1	0				1 output at compare match
			1			Toggle output at compare match	
1	0	0	TGR1B is input capture register	Capture input source is TIOCB1 pin		Input capture at rising edge	
		1				Input capture at falling edge	
	*	Input capture at both edges					
	1	*		*		Capture input source is TGR0C compare match/ input capture	Input capture at generation of TGR0B compare match/ input capture

* : Don't care

Read/Write :

R/W

—

R/W

R/W

—

—

R/W

R/W

TGR Interrupt Enable A

0	Interrupt requests (TGIA) by TGFA bit disabled
1	Interrupt requests (TGIA) by TGFA bit enabled

TGR Interrupt Enable B

0	Interrupt requests (TGIB) by TGFB bit disabled
1	Interrupt requests (TGIB) by TGFB bit enabled

Overflow Interrupt Enable

0	Interrupt requests (TCIV) by TCFV disabled
1	Interrupt requests (TCIV) by TCFV enabled

Underflow Interrupt Enable

0	Interrupt requests (TCIU) by TCFU disabled
1	Interrupt requests (TCIU) by TCFU enabled

A/D Conversion Start Request Enable

0	A/D conversion start request generation disabled
1	A/D conversion start request generation enabled

Read/write :

R — R/(W)* R/(W)* — R/(W)* R/(W)*

Input Capture/Output Compare Flag A

0	[Clearing condition] <ul style="list-style-type: none"> When DTC is activated by TGIA interrupt while DISEL bit of MRB in DTC is 0 When DMAC is activated by TGIA interrupt while DTA bit of DMABCR in DMAC is 1 When 0 is written to TGFA after reading TGFA = 1
1	[Setting conditions] <ul style="list-style-type: none"> When TCNT = TGRA while TGRA is functioning as output compare register When TCNT value is transferred to TGRA by input capture signal while TGRA is functioning as input capture register

Input Capture/Output Compare Flag B

0	[Clearing condition] <ul style="list-style-type: none"> When DTC is activated by TGIB interrupt while DISEL bit of MRB in DTC is 0 When 0 is written to TGFB after reading TGFB = 1
1	[Setting conditions] <ul style="list-style-type: none"> When TCNT = TGRB while TGRB is functioning as output compare register When TCNT value is transferred to TGRB by input capture signal while TGRB is functioning as input capture register

Overflow Flag

0	[Clearing condition] When 0 is written to TCFV after reading TCFV = 1
1	[Setting conditions] When the TCNT value overflows (changes from H'FFFF to H'0000)

Underflow Flag

0	[Clearing condition] When 0 is written to TCFU after reading TCFU = 1
1	[Setting conditions] When the TCNT value underflows (changes from H'0000 to H'FFFF)

Count Direction Flag

0	TCNT counts down
1	TCNT counts up

Note: * Can only be written with 0 for flag clearing.

Read/Write : —

R/W R/W R/W R/W R/W R/W R/W

Time Prescaler

0	0	0	Internal clock: counts on $\phi/1$
		1	Internal clock: counts on $\phi/4$
	1	0	Internal clock: counts on $\phi/16$
		1	Internal clock: counts on $\phi/64$
1	0	0	External clock: counts on TCLKA pin input
		1	External clock: counts on TCLKB pin input
	1	0	External clock: counts on TCLKC pin input
		1	Internal clock: counts on $\phi/1024$

Note: This setting is ignored when channel 2 is in phase counting mode.

Clock Edge

0	0	Count at rising edge
	1	Count at falling edge
1	—	Count at both edges

Note: This setting is ignored when channel 2 is in phase counting mode.

Counter Clear

0	0	TCNT clearing disabled
	1	TCNT cleared by TGRA compare match/input capture
1	0	TCNT cleared by TGRB compare match/input capture
	1	TCNT cleared by counter clearing for another channel performing synchronous clearing/synchronous operation*

Note: * Synchronous operating setting is performed by setting the SYNC bit TSZR to 1.

Initial value : 1 1 0 0 0 0
 Read/Write : — — — — R/W R/W R/W R/W

Mode

0	0	0	0	Normal operation	
			1	Reserved	
		1	0	0	PWM mode 1
				1	PWM mode 2
	1	0	0	Phase counting mode 1	
			1	Phase counting mode 2	
		1	0	0	Phase counting mode 3
				1	Phase counting mode 4
1	*	*	*	—	

* : Don't care

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

TGR2A I/O Control

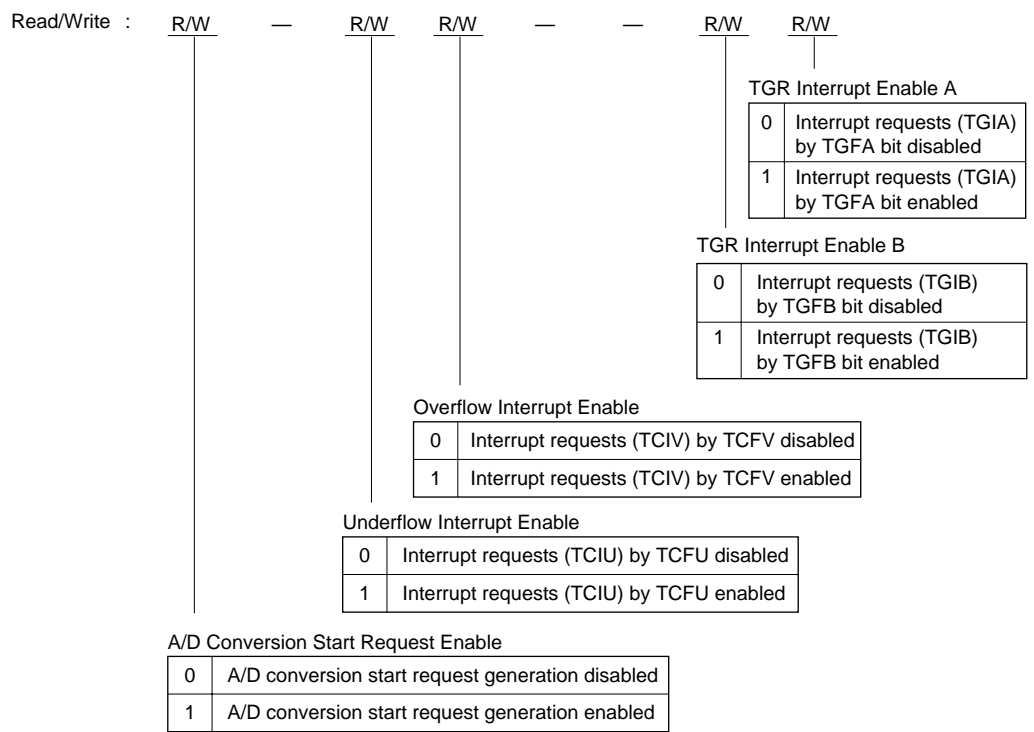
0	0	0	0	TGR2A is output compare register	Output disabled	
			1		Initial output is 0 output	0 output at compare match
		1	0			1 output at compare match
			1		Toggle output at compare match	
	1	0	0		Output disabled	
			1		Initial output is 1 output	0 output at compare match
		1	0			1 output at compare match
			1		Toggle output at compare match	
1	*	0	0	TGR2A is input capture register	Capture input source is TIOCA2 pin	Input capture at rising edge
			1			Input capture at falling edge
		1	*			Input capture at both edges

* : Don't care

TGR2B I/O Control

0	0	0	0	TGR2B is output compare register	Output disabled	
			1		Initial output is 0 output	0 output at compare match
		1	0			1 output at compare match
			1		Toggle output at compare match	
	1	0	0		Output disabled	
			1		Initial output is 1 output	0 output at compare match
		1	0			1 output at compare match
			1		Toggle output at compare match	
1	*	0	0	TGR2B is input capture register	Capture input source is TIOCB2 pin	Input capture at rising edge
			1			Input capture at falling edge
		1	*			Input capture at both edges

* : Don't care



Input Capture/Output Compare Flag A	
0	[Clearing condition] <ul style="list-style-type: none"> • When DTC is activated by TGIA interrupt while DISEL bit of MRB in DTC is 0 • When DMAC is activated by TGIA interrupt while DTA bit of DMABCR in DMAC is 1 • When 0 is written to TGFA after reading TGFA = 1
1	[Setting conditions] <ul style="list-style-type: none"> • When TCNT = TGRA while TGRA is functioning as output compare register • When TCNT value is transferred to TGRA by input capture signal while TGRA is functioning as input capture register

Input Capture/Output Compare Flag B	
0	[Clearing condition] <ul style="list-style-type: none"> • When DTC is activated by TGIB interrupt while DISEL bit of MRB in DTC is 0 • When 0 is written to TGFB after reading TGFB = 1
1	[Setting conditions] <ul style="list-style-type: none"> • When TCNT = TGRB while TGRB is functioning as output compare register • When TCNT value is transferred to TGRB by input capture signal while TGRB is functioning as input capture register

Overflow Flag	
0	[Clearing condition] When 0 is written to TCFV after reading TCFV = 1
1	[Setting conditions] When the TCNT value overflows (changes from H'FFFF to H'0000)

Underflow Flag	
0	[Clearing condition] When 0 is written to TCFU after reading TCFU = 1
1	[Setting conditions] When the TCNT value underflows (changes from H'0000 to H'FFFF)

Count Direction Flag	
0	TCNT counts down
1	TCNT counts up

Note: * Can only be written with 0 for flag clearing.

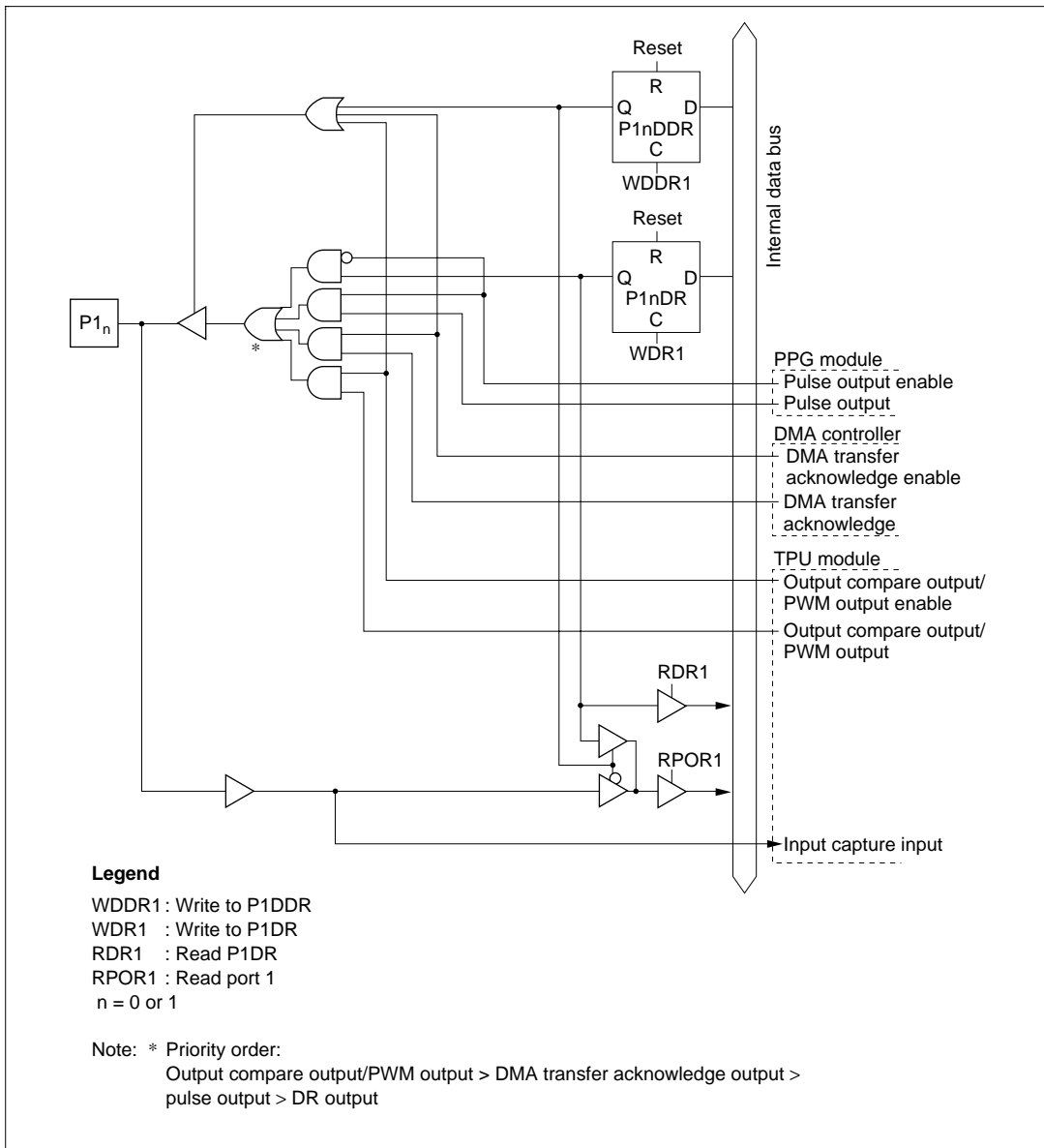


Figure C-1 (a) Port 1 Block Diagram (Pins P1₀ and P1₁)

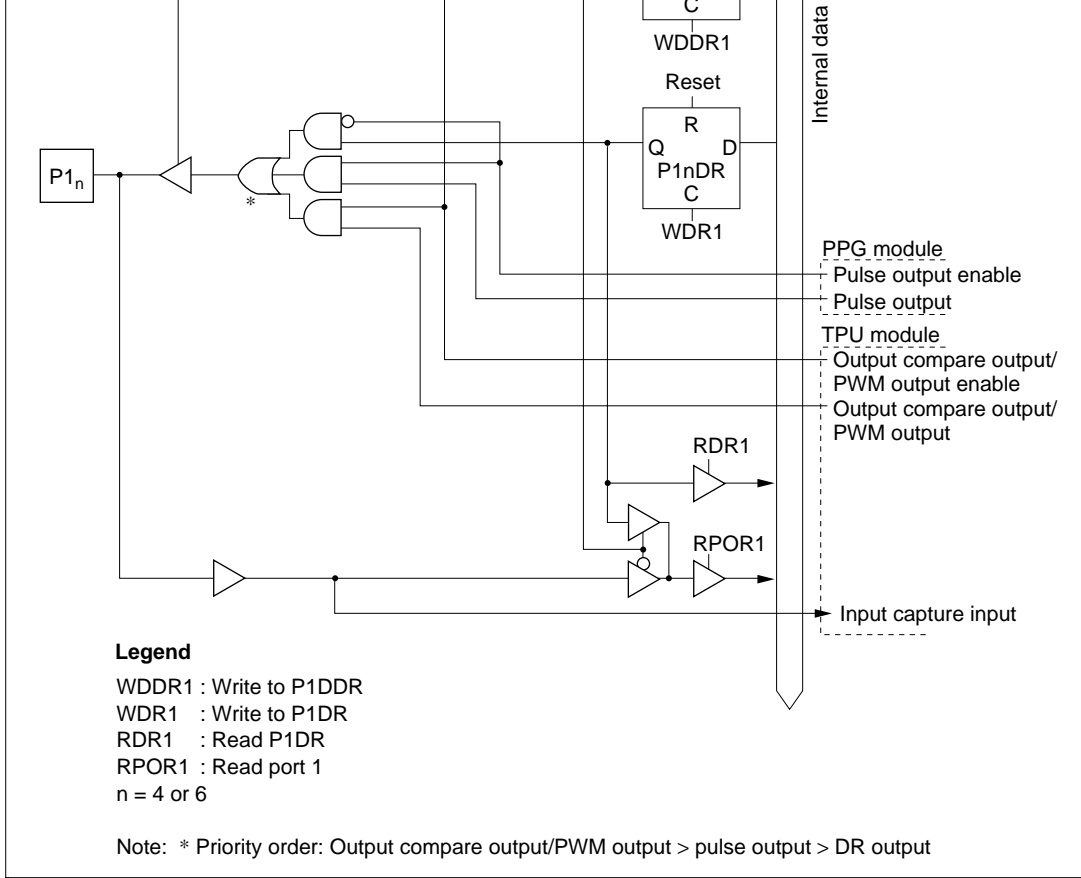
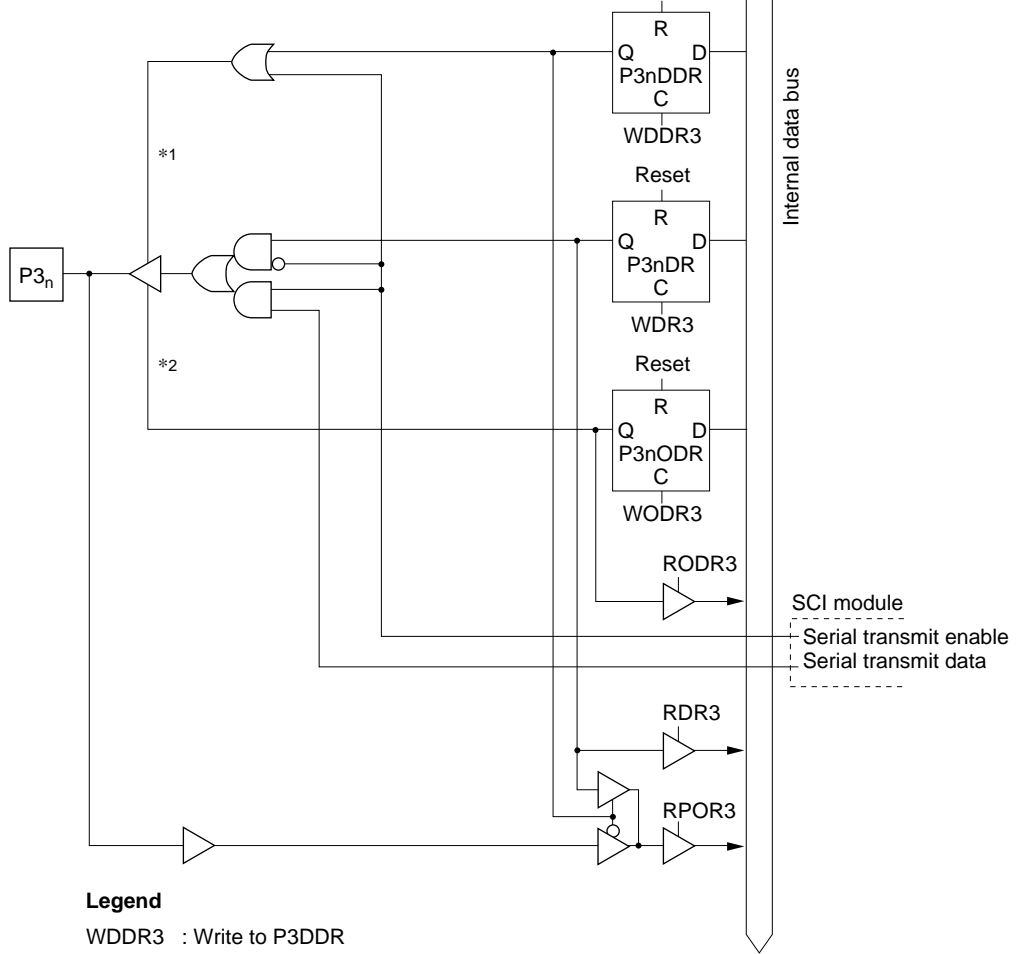


Figure C-1 (c) Port 1 Block Diagram (Pins P1₄ and P1₆)



Legend

- WDDR3 : Write to P3DDR
- WDR3 : Write to P3DR
- WODR3 : Write to P3ODR
- RDR3 : Read P3DR
- RPOR3 : Read port 3
- RODR3 : Read P3ODR
- n = 0 or 1

- Notes: 1. Output enable signal
 2. Open drain control signal

Figure C-3 (a) Port 3 Block Diagram (Pins P3₀ and P3₁)

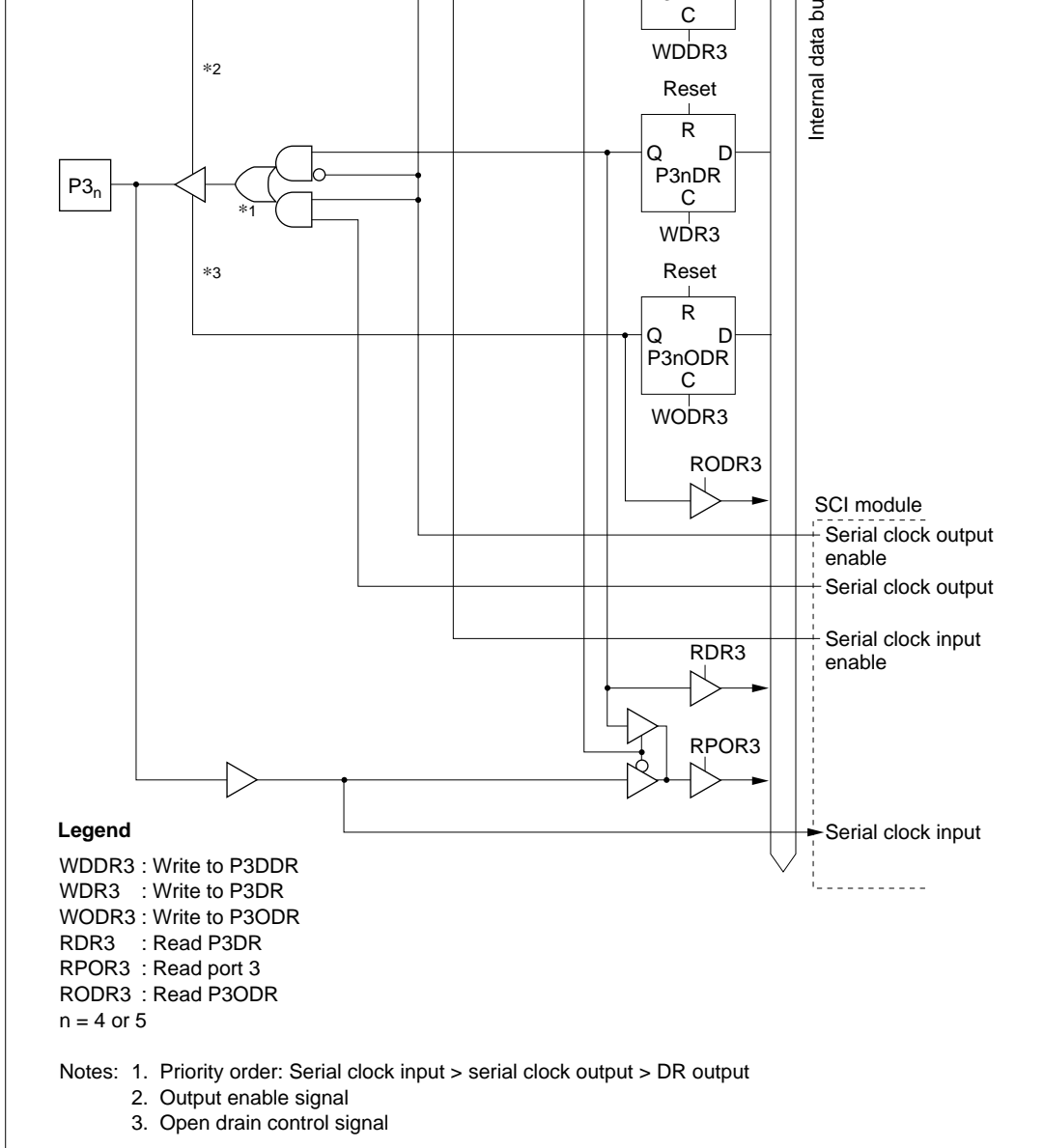


Figure C-3 (c) Port 3 Block Diagram (Pins P3₄ and P3₅)

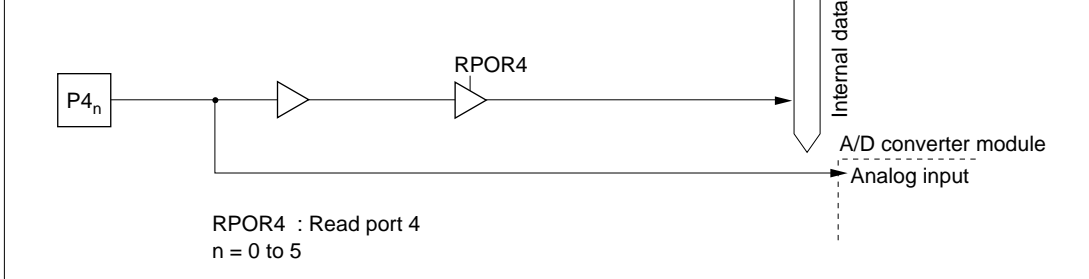


Figure C-4 (a) Port 4 Block Diagram (Pins P4₀ to P4₅)

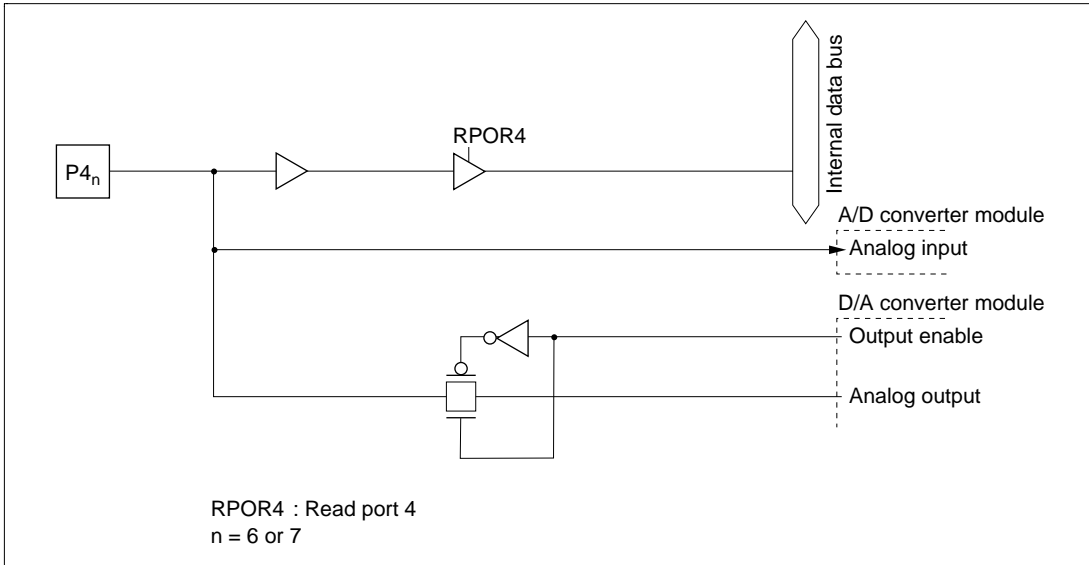
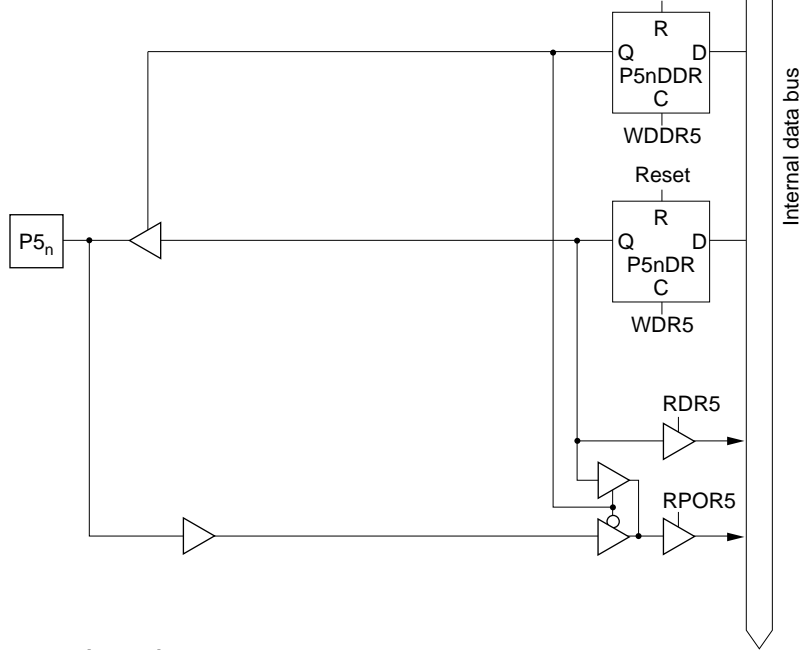


Figure C-4 (b) Port 4 Block Diagram (Pins P4₆ and P4₇)



Legend

WDDR5 : Write to P5DDR
 WDR5 : Write to P5DR
 RDR5 : Read P5DR
 RPOR5 : Read port 5
 n = 0 to 2

Figure C-5 (a) Port 5 Block Diagram (Pins $P5_0$ to $P5_2$)

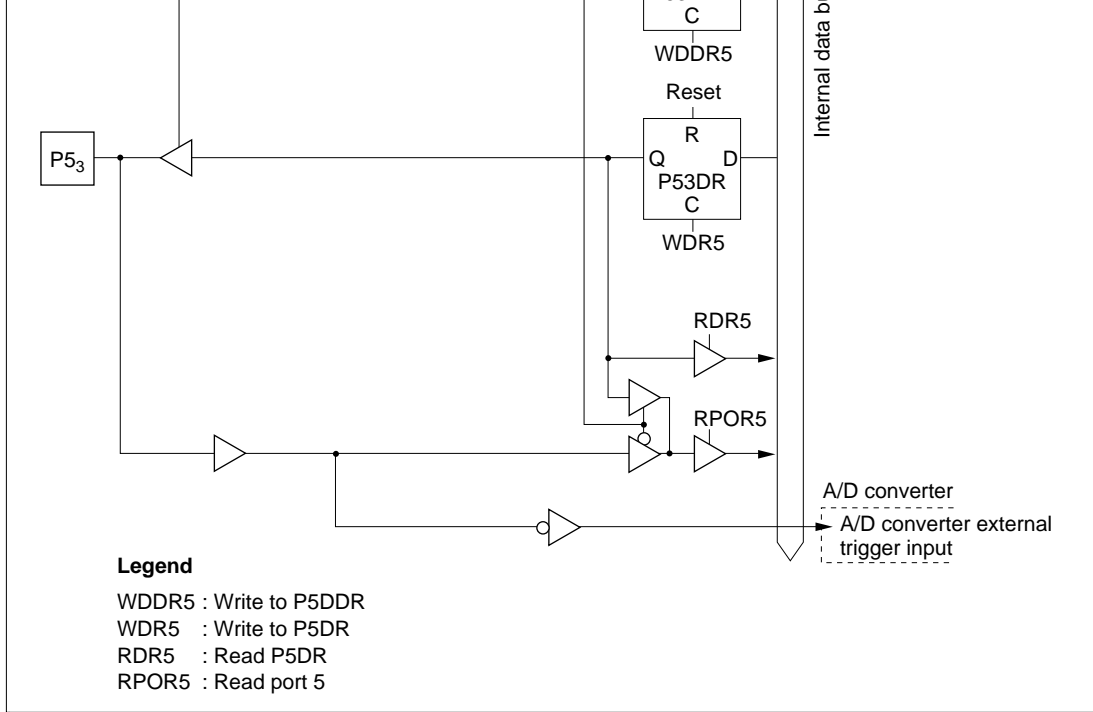


Figure C-5 (b) Port 5 Block Diagram (Pin P5₃)

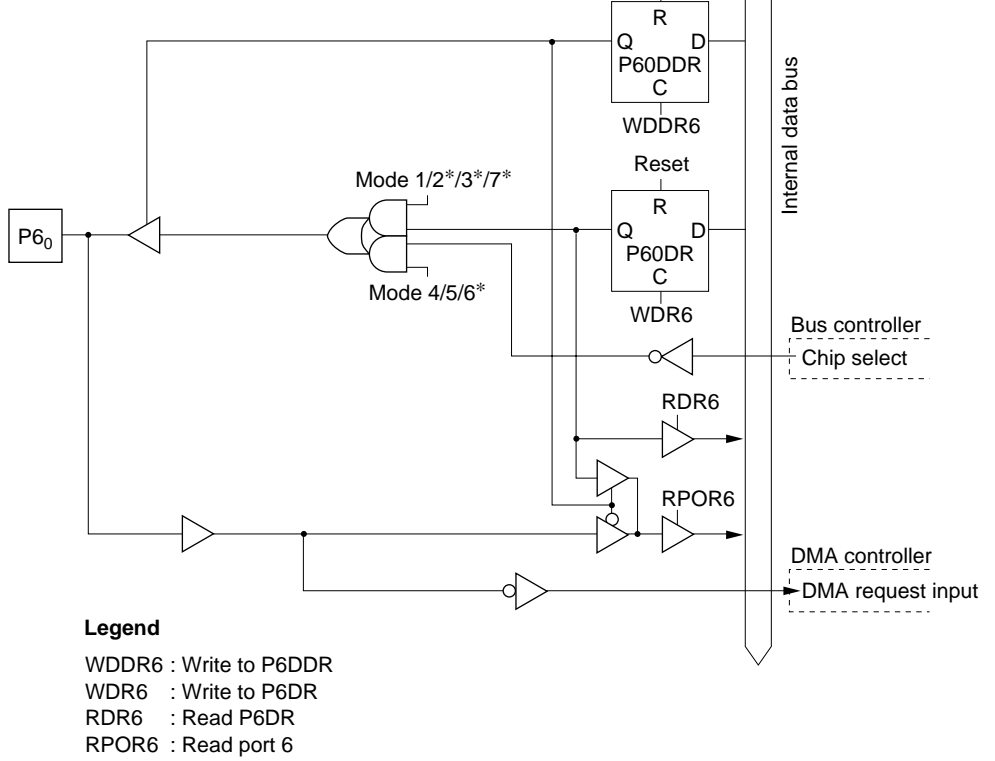


Figure C-6 (a) Port 6 Block Diagram (Pin P6₀)

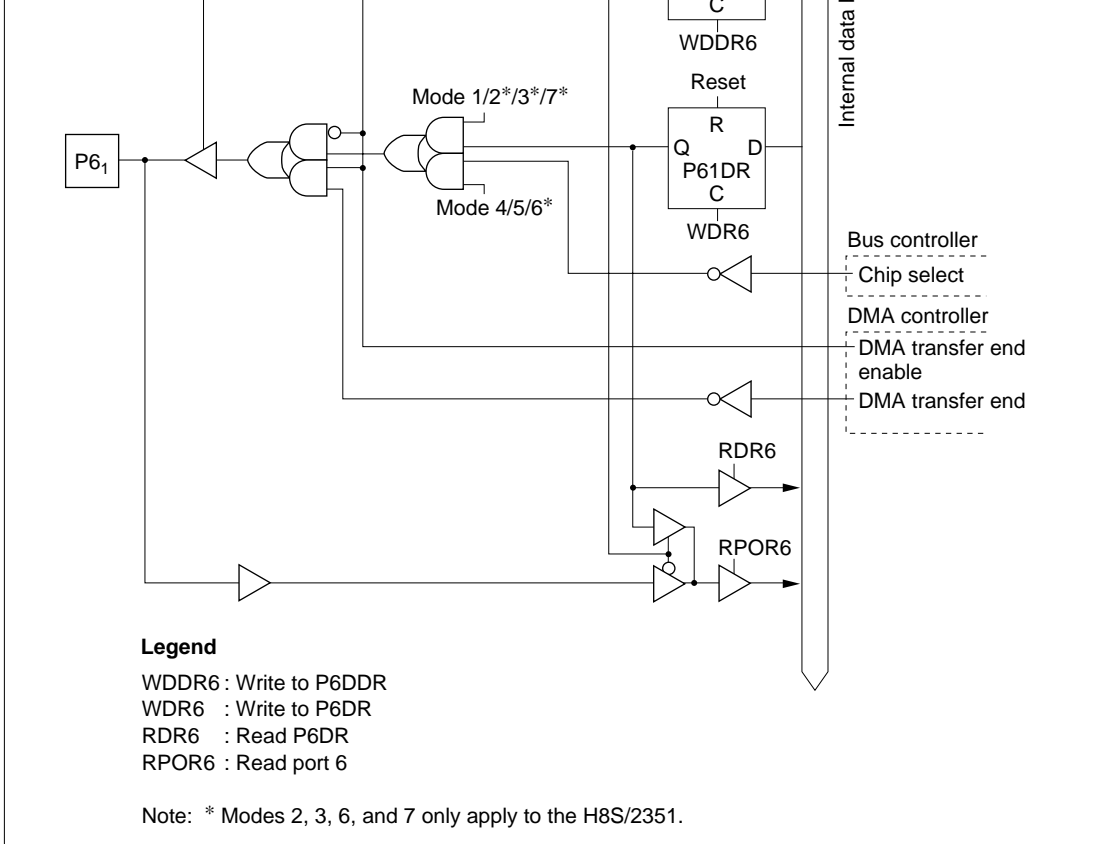


Figure C-6 (b) Port 6 Block Diagram (Pin P6₁)

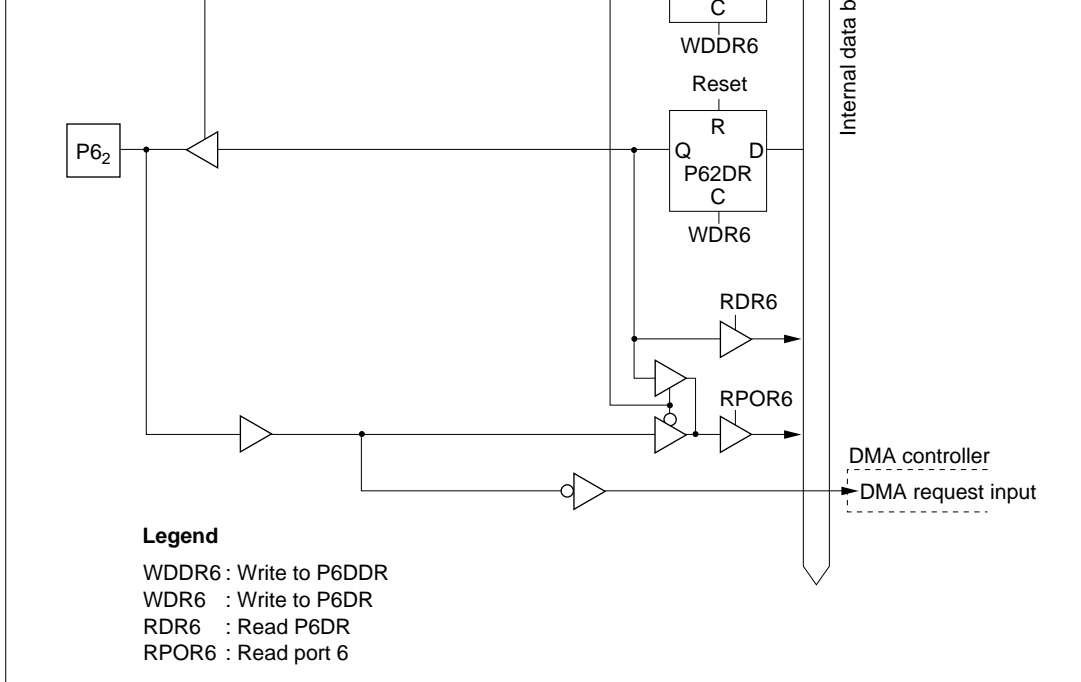


Figure C-6 (c) Port 6 Block Diagram (Pin P6₂)

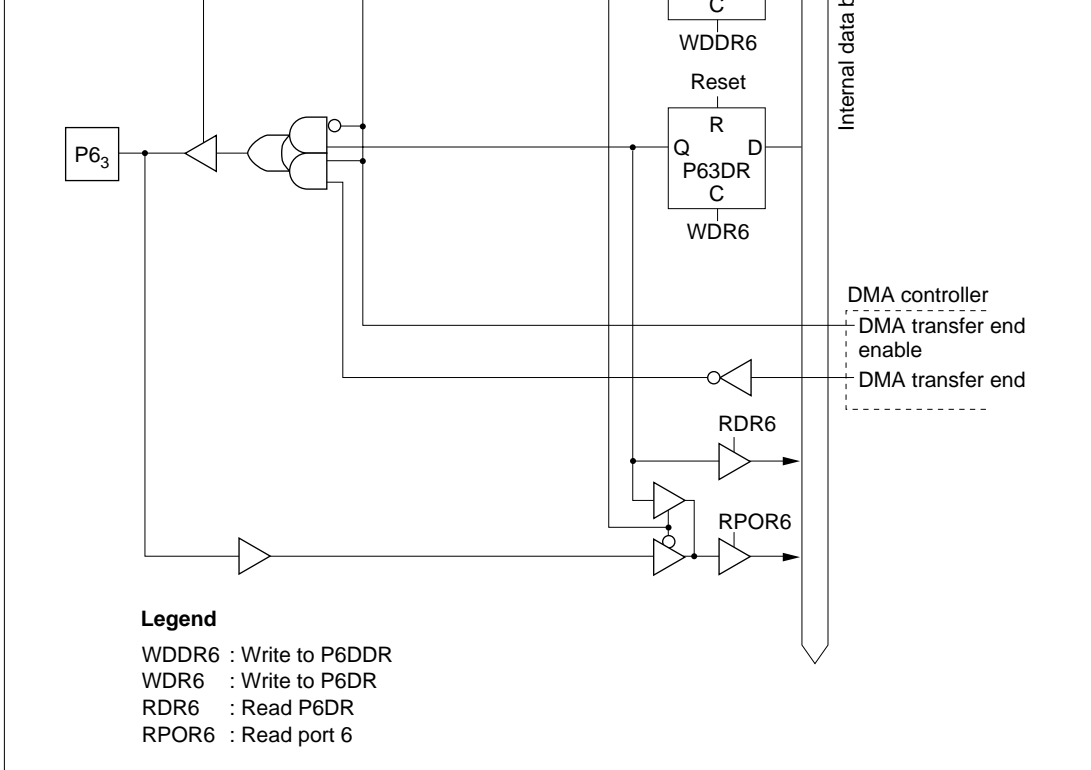


Figure C-6 (d) Port 6 Block Diagram (Pin P6₃)

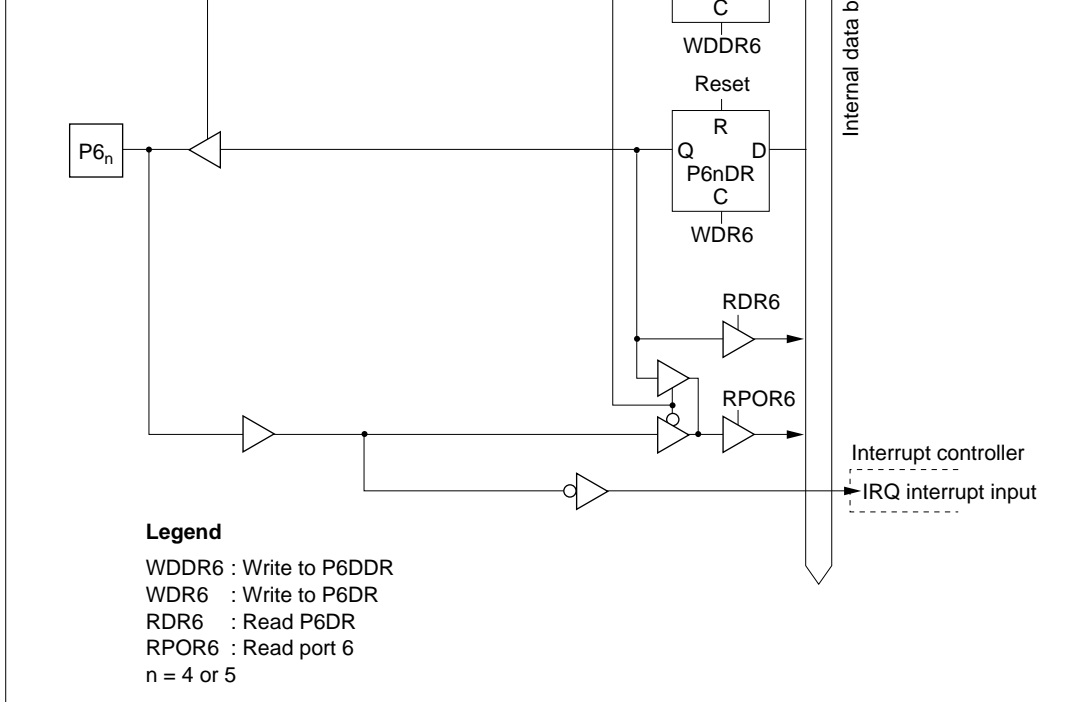


Figure C-6 (e) Port 6 Block Diagram (Pins $P6_4$ and $P6_5$)

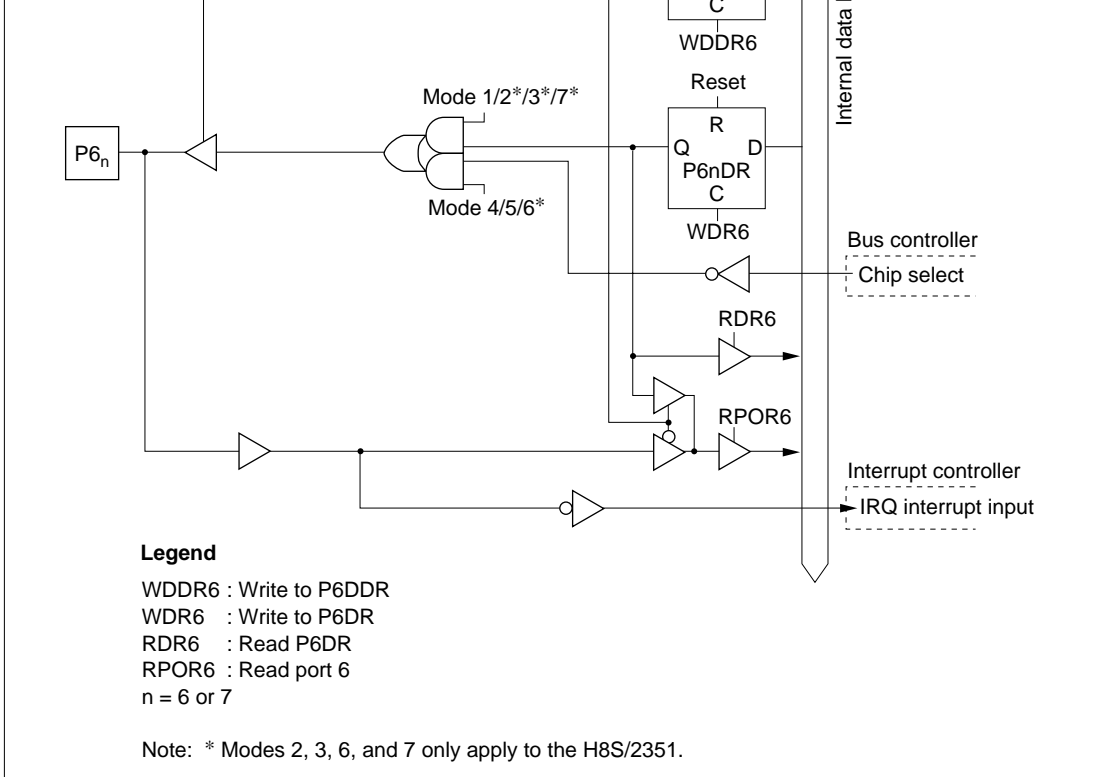


Figure C-6 (f) Port 6 Block Diagram (Pins P6₆ and P6₇)

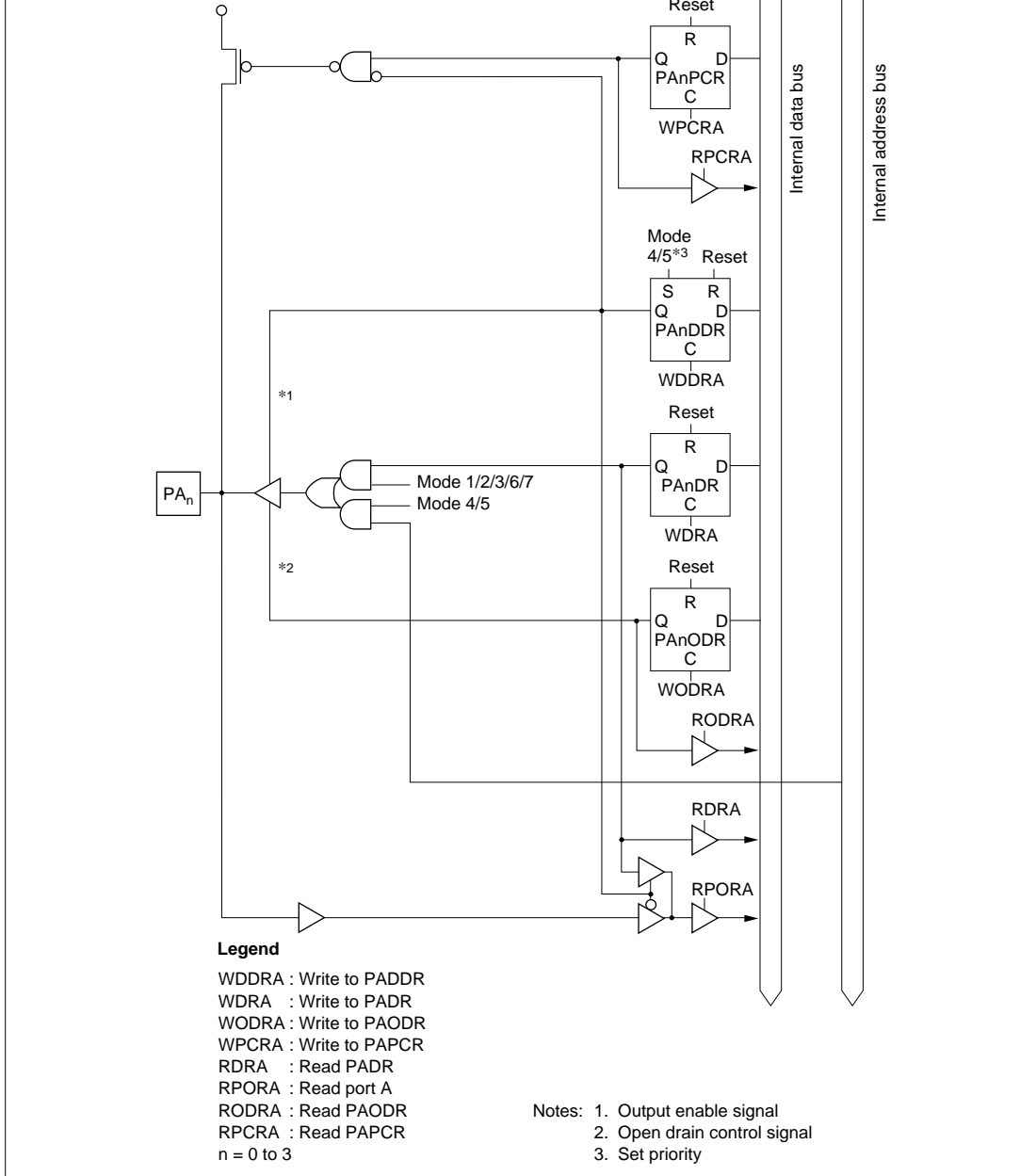


Figure C-7 (a-1) H8S/2351 Port A Block Diagram (Pins PA₀ to PA₃)

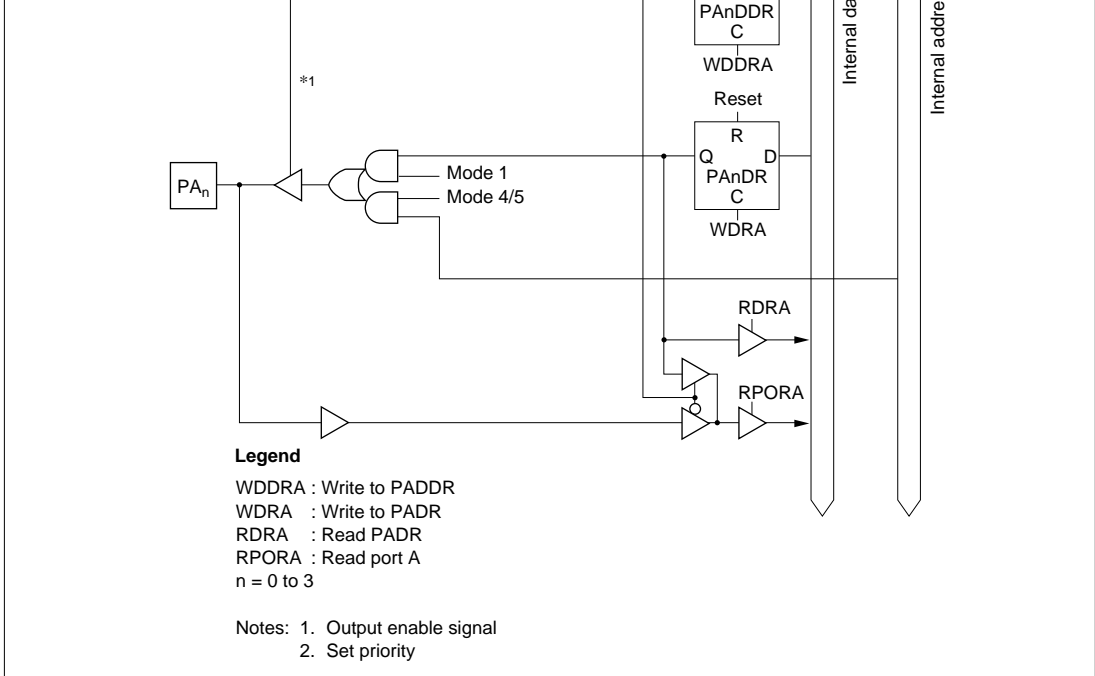


Figure C-7 (a-2) H8S/2350 Port A Block Diagram (Pins PA₀ to PA₃)

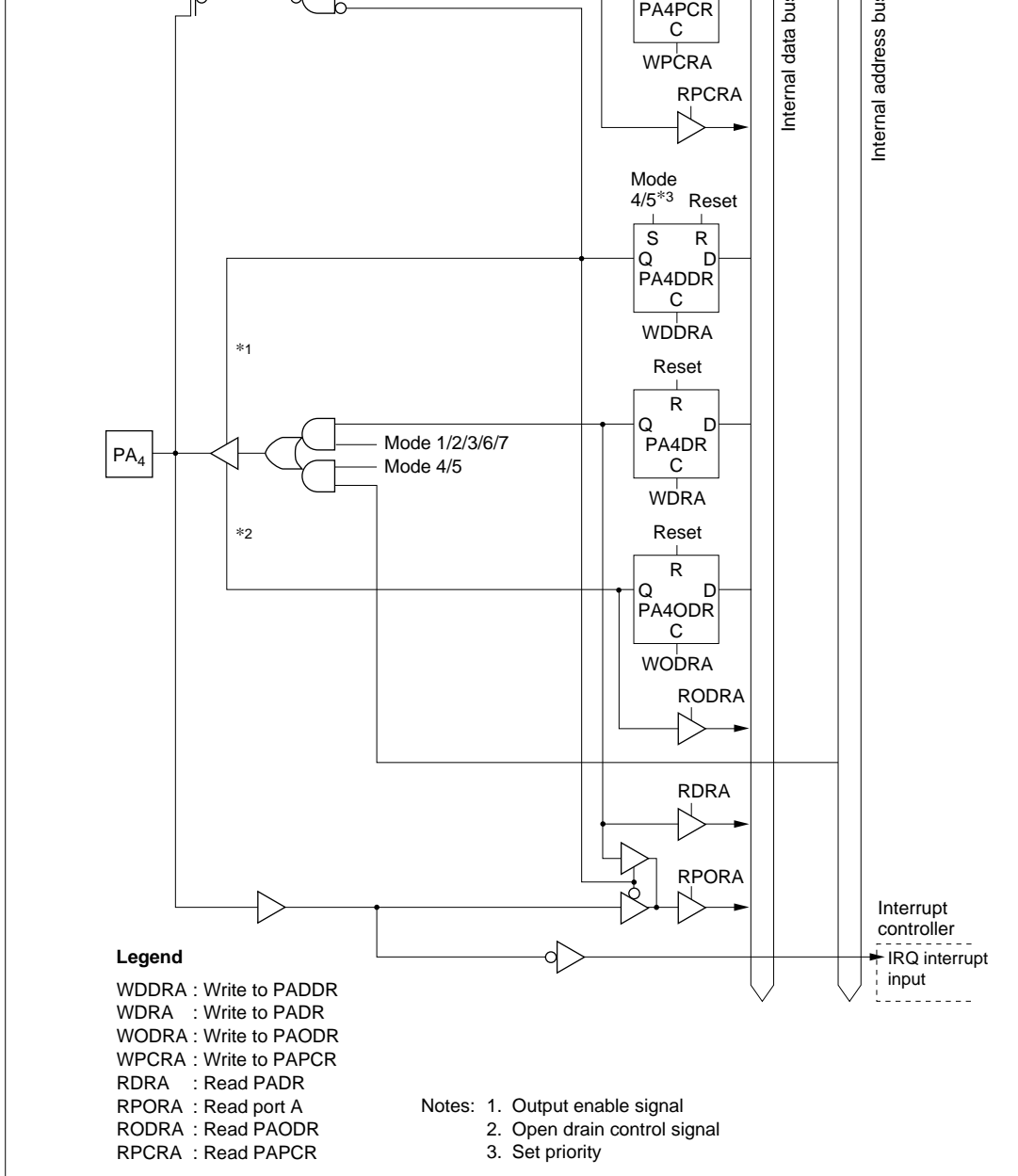


Figure C-7 (b-1) H8S/2351 Port A Block Diagram (Pin PA₄)

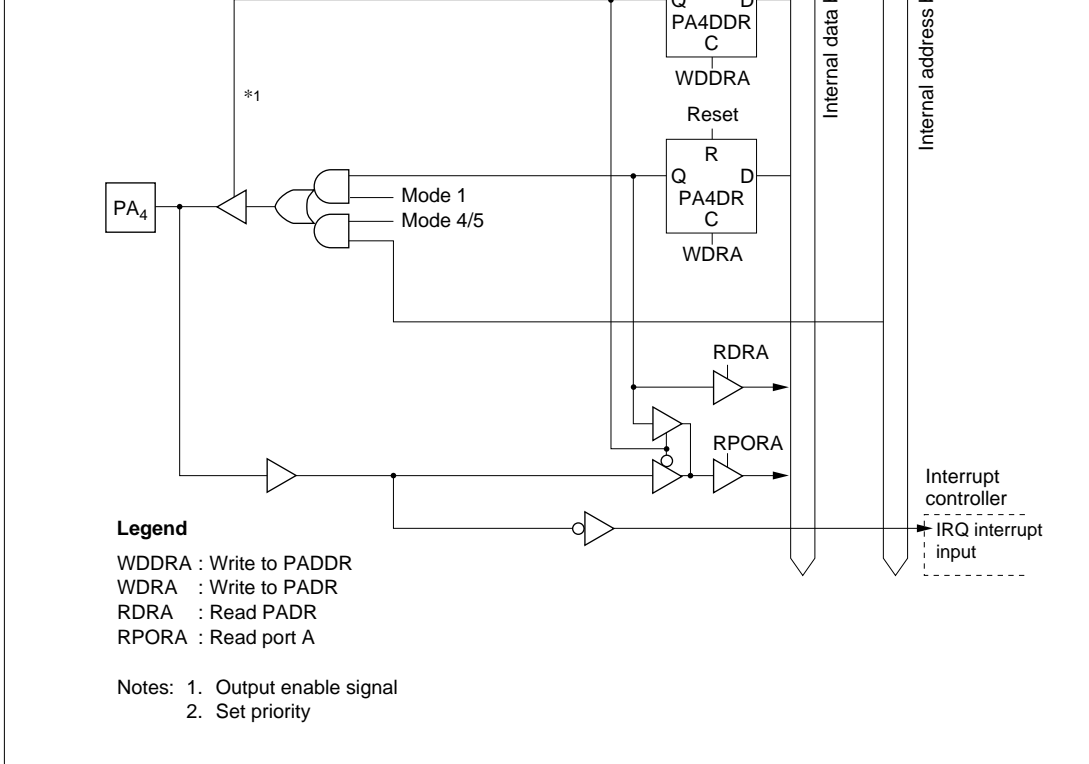


Figure C-7 (b-2) H8S/2350 Port A Block Diagram (Pin PA₄)

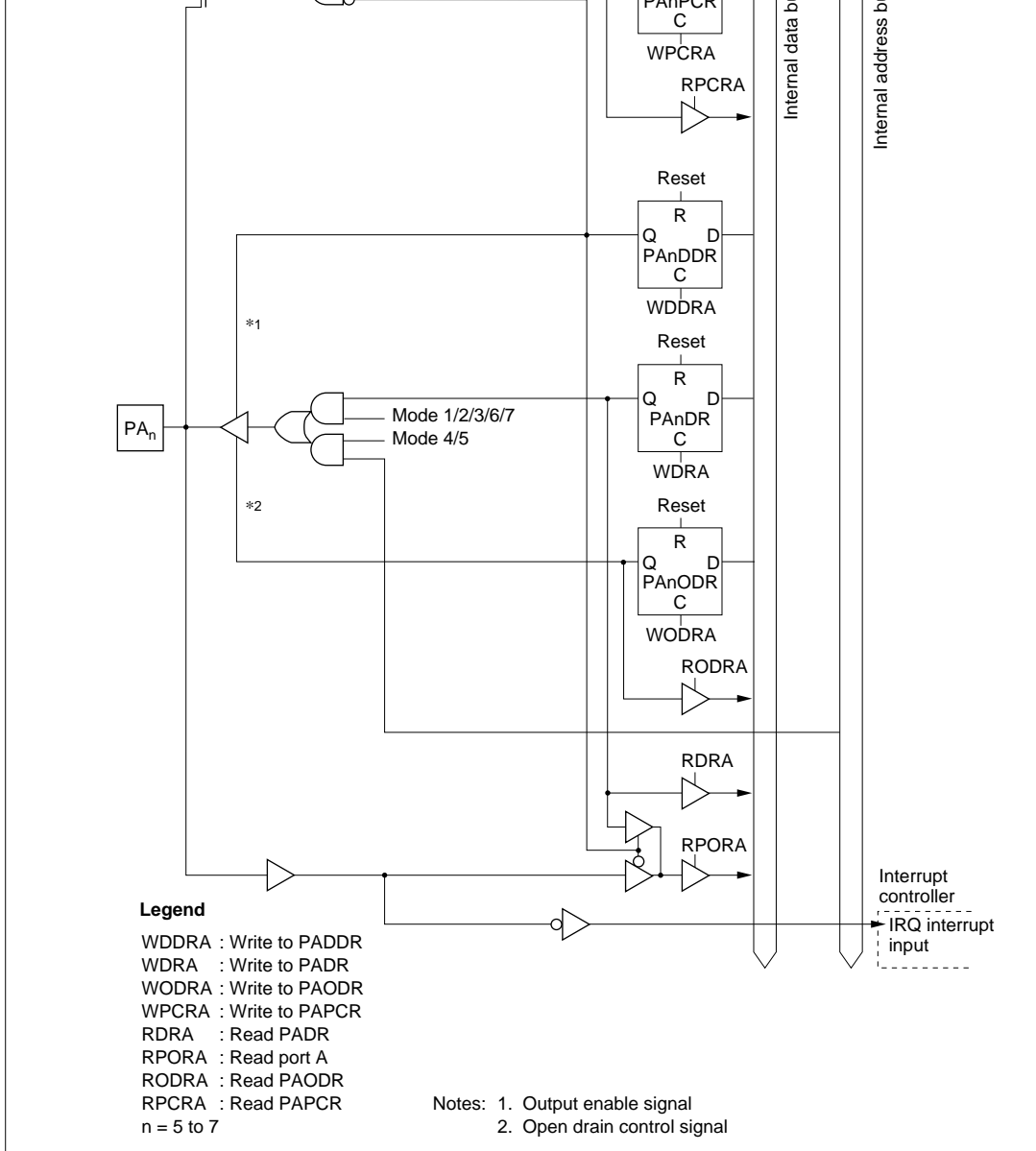


Figure C-7 (c-1) H8S/2351 Port A Block Diagram (Pins PA₅ to PA₇)

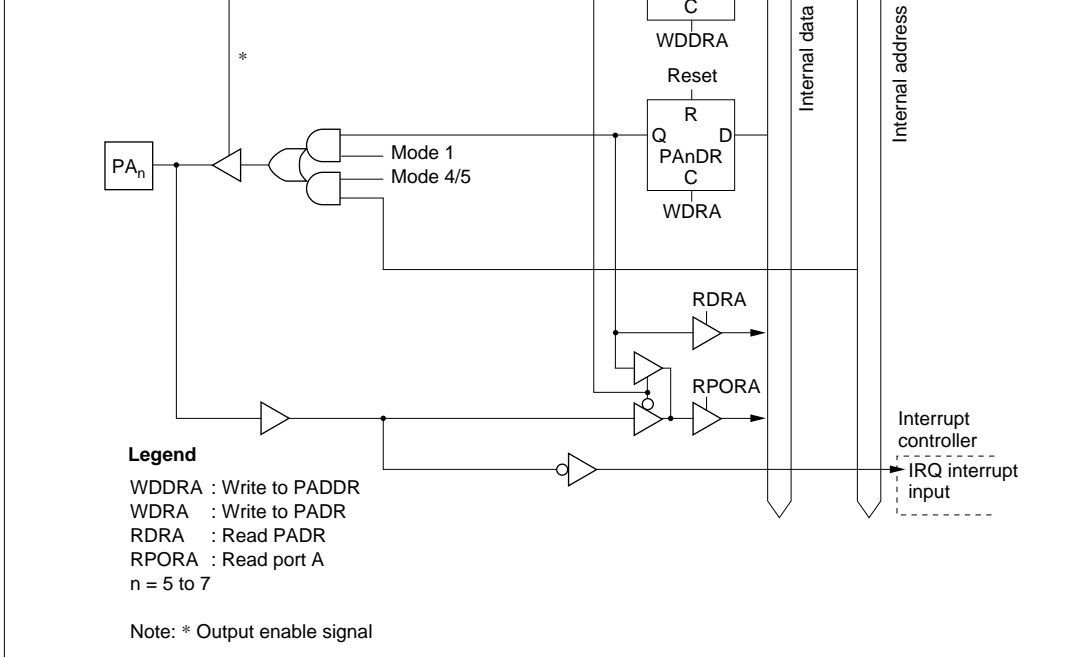


Figure C-7 (c-2) H8S/2350 Port A Block Diagram (Pins PA₅ to PA₇)

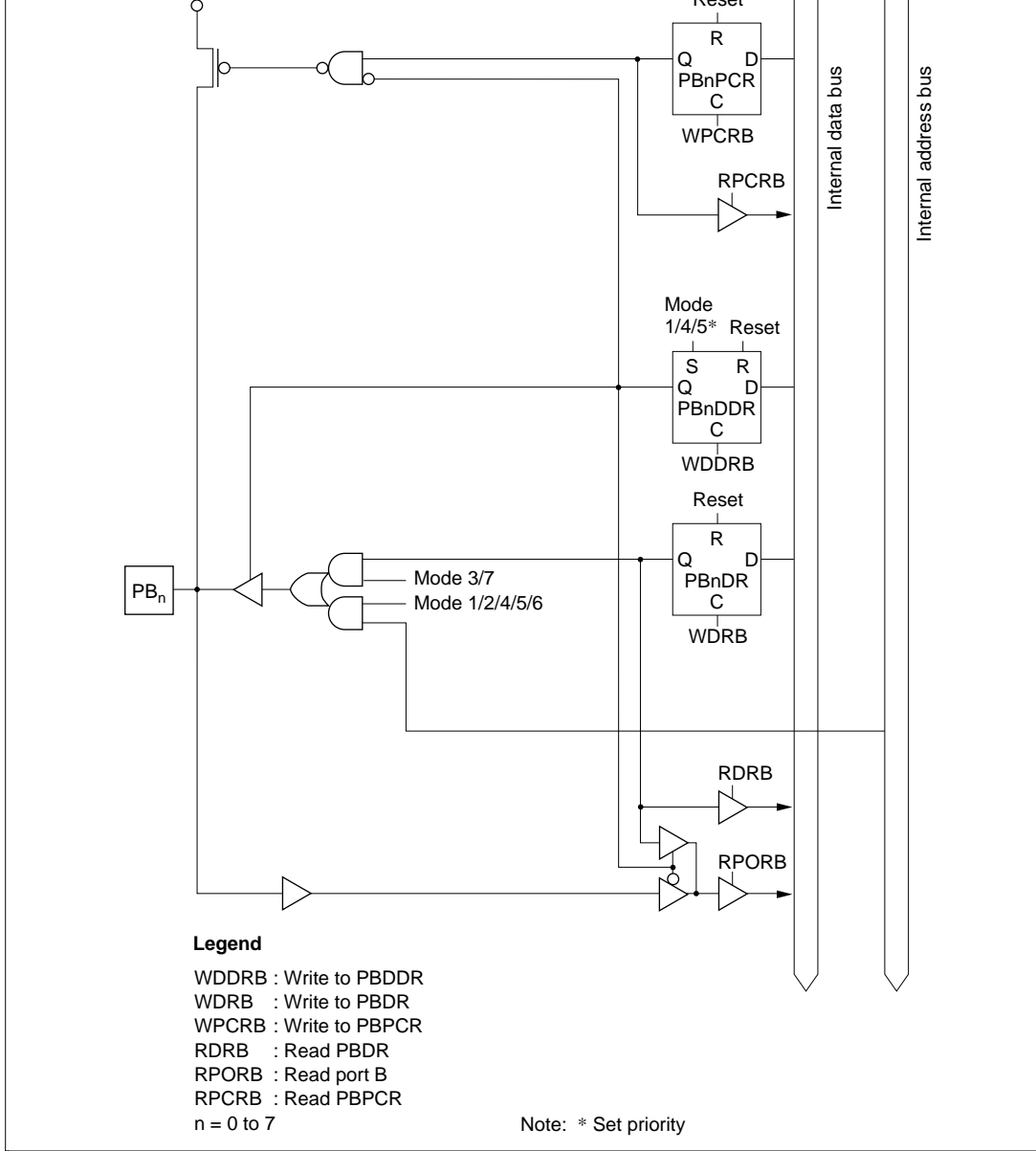


Figure C-8 (a) H8S/2351 Port B Block Diagram (Pin PB_n)

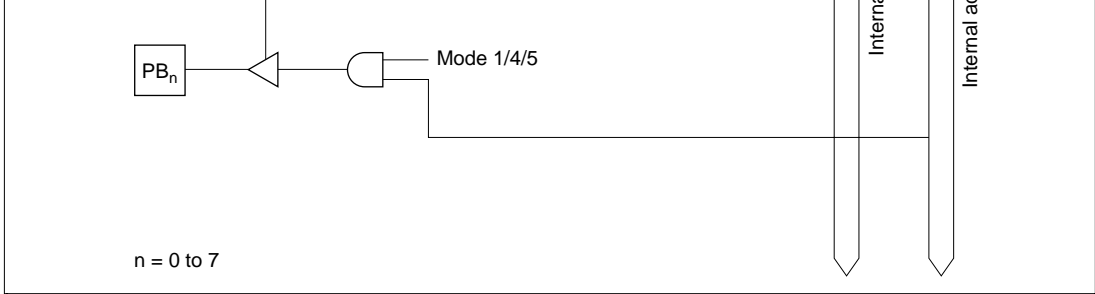


Figure C-8 (b) H8S/2350 Port B Block Diagram (Pin PB_n)

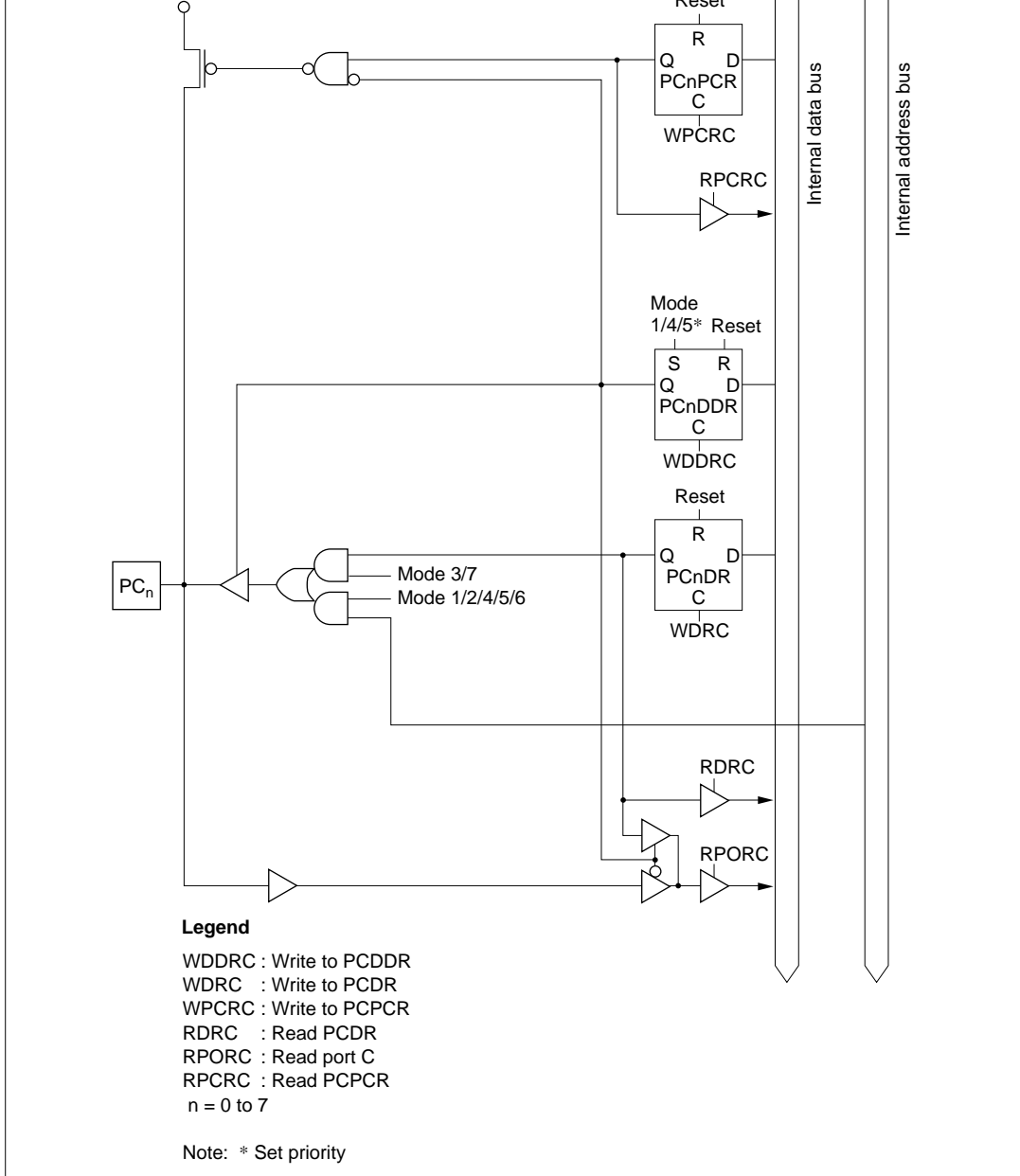


Figure C-9 (a) H8S/2351 Port C Block Diagram (Pin PC_n)

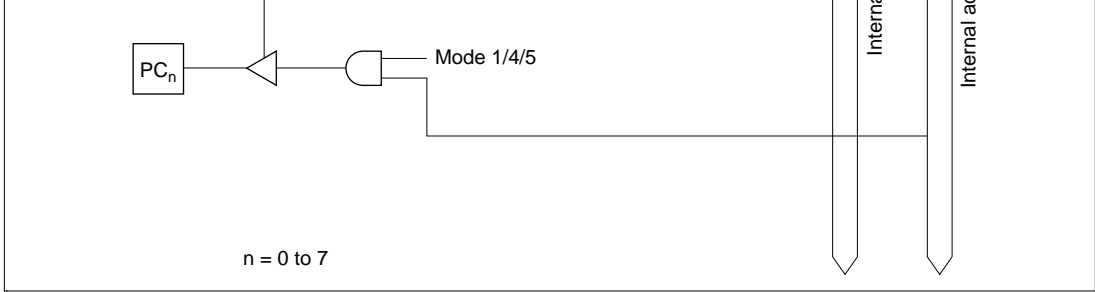


Figure C-9 (b) H8S/2350 Port C Block Diagram (Pin PC_n)

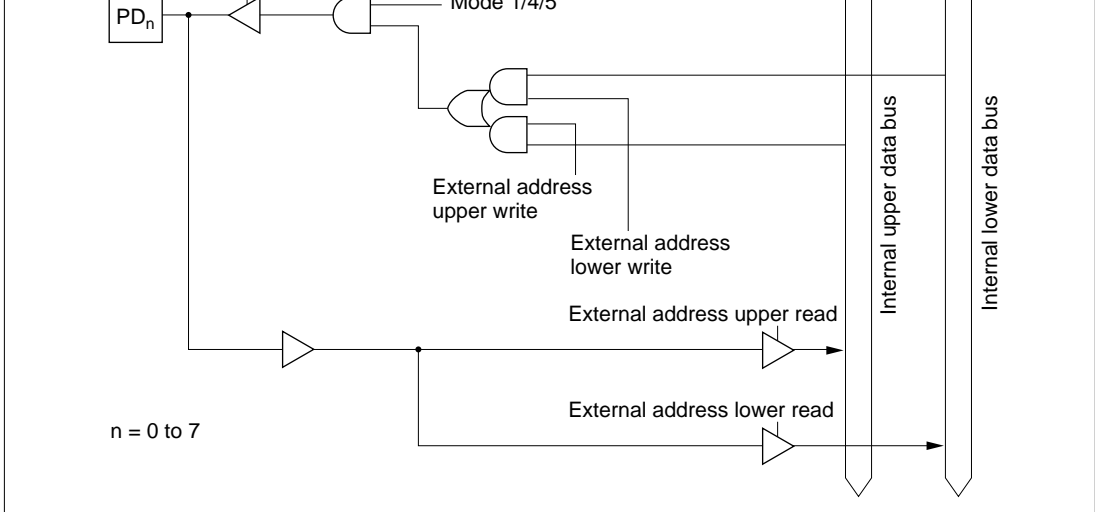
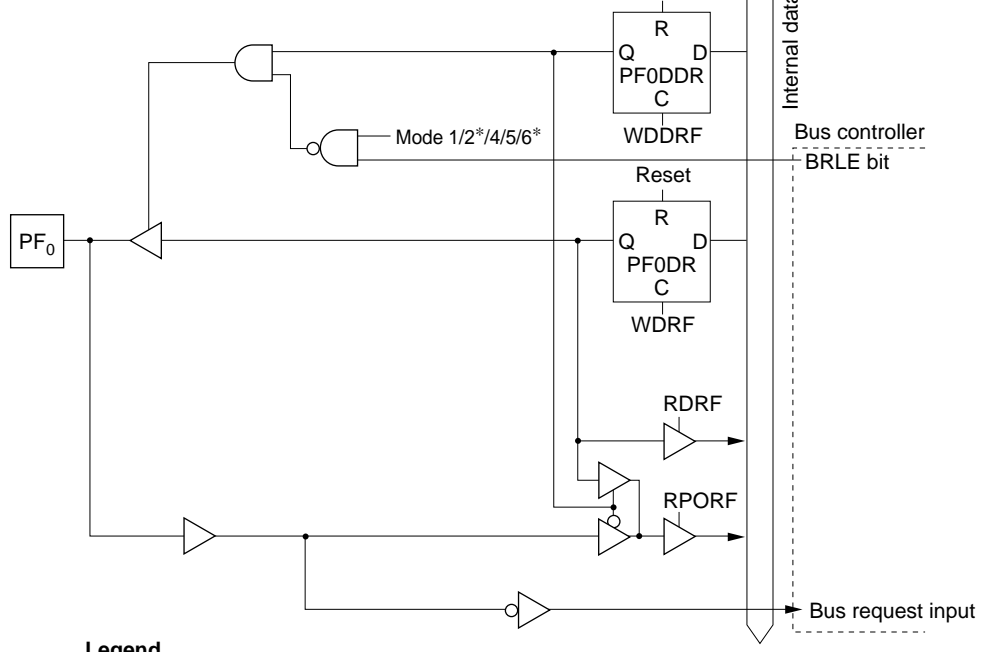


Figure C-10 (b) H8S/2350 Port D Block Diagram (Pin PD_n)



Legend

- WDDRF : Write to PFDDR
- WDRF : Write to PFDR
- RDRF : Read PFDR
- RPORF : Read port F

Note: * Modes 2 and 6 only apply to the H8S/2351.

Figure C-12 (a) Port F Block Diagram (Pin PF₀)

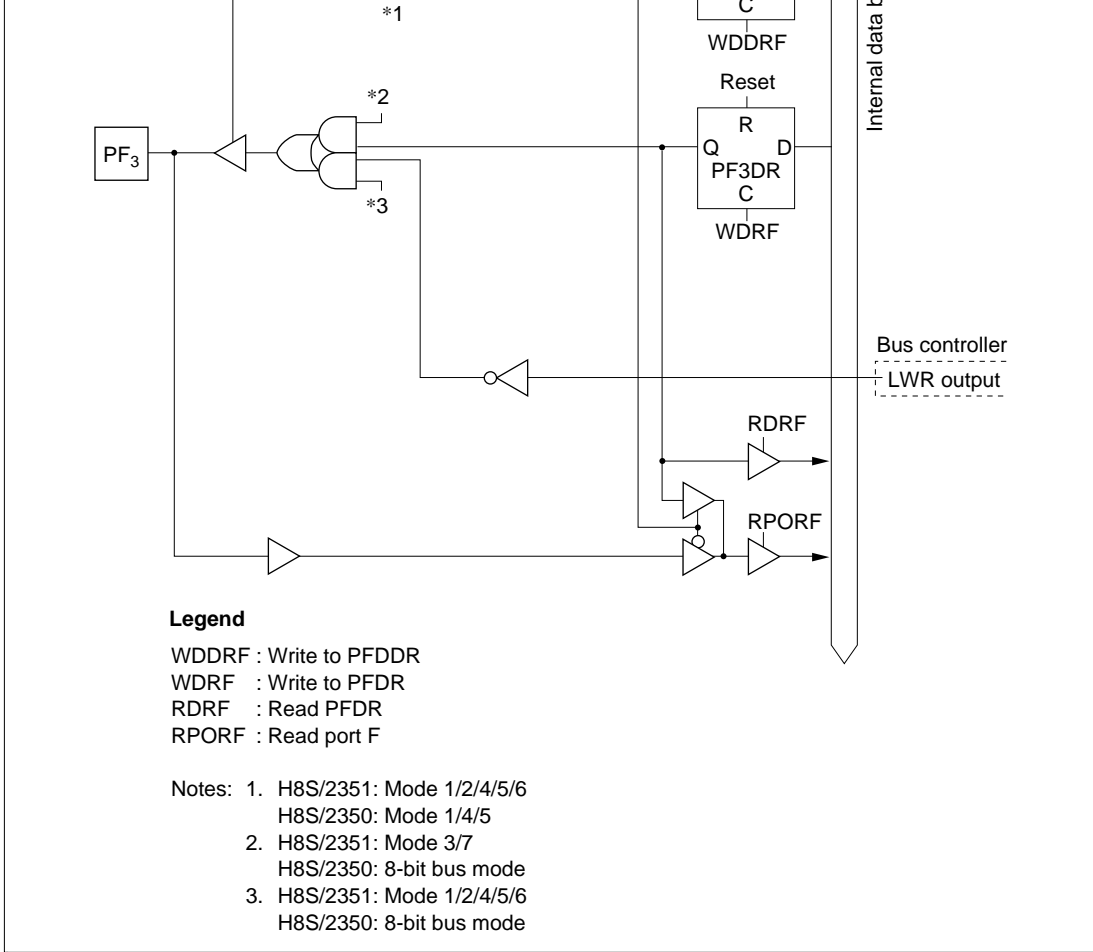
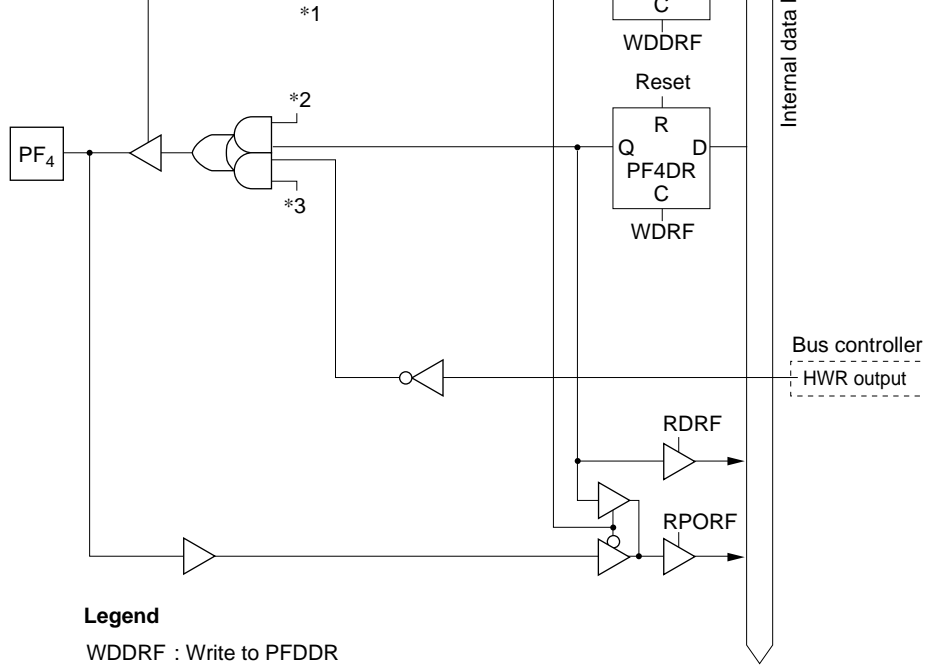


Figure C-12 (d) Port F Block Diagram (Pin PF₃)



Legend

WDDRF : Write to PFDDR
 WDRF : Write to PFDR
 RDRF : Read PFDR
 RPORF : Read port F

Notes: 1. H8S/2351: Mode 1/2/4/5/6
 H8S/2350: Mode 1/4/5
 2. H8S/2351: Mode 3/7
 H8S/2350: 8-bit bus mode
 3. H8S/2351: Mode 1/2/4/5/6
 H8S/2350: 8-bit bus mode

Figure C-12 (e) Port F Block Diagram (Pin PF₄)

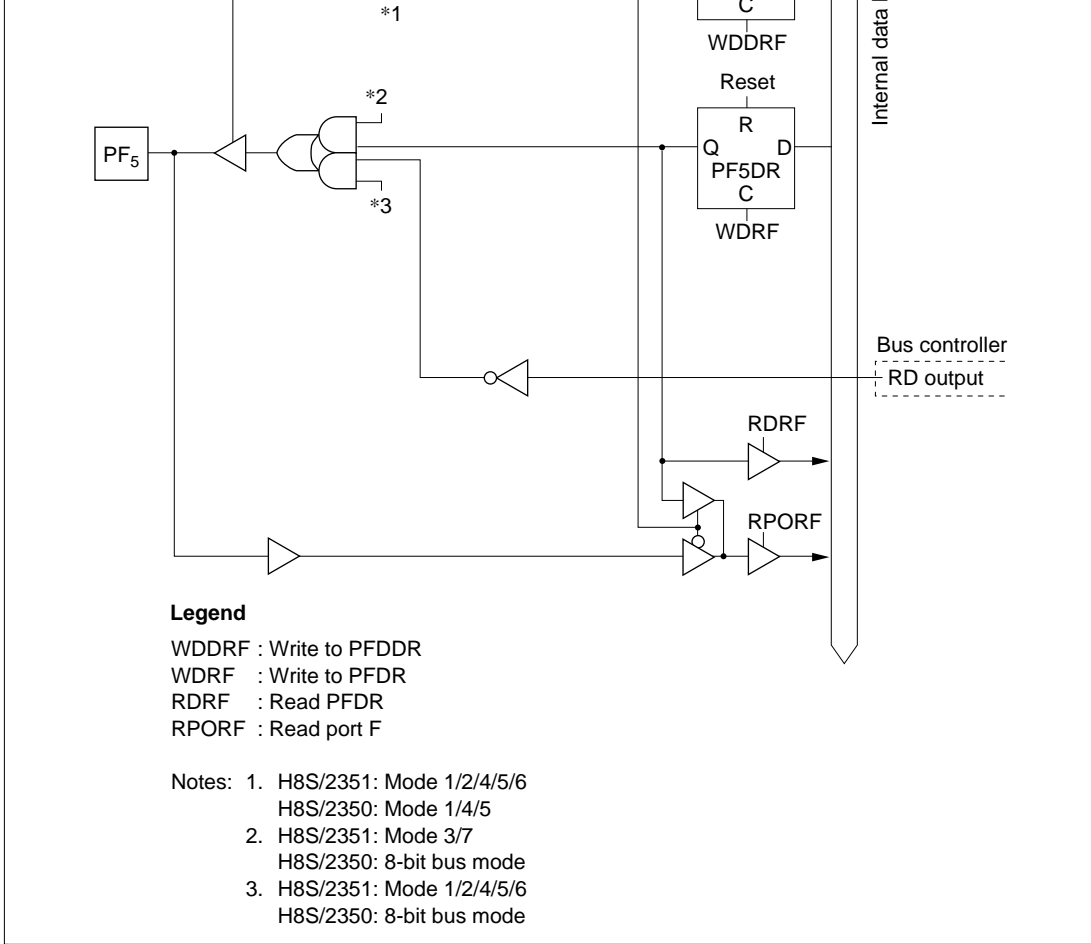
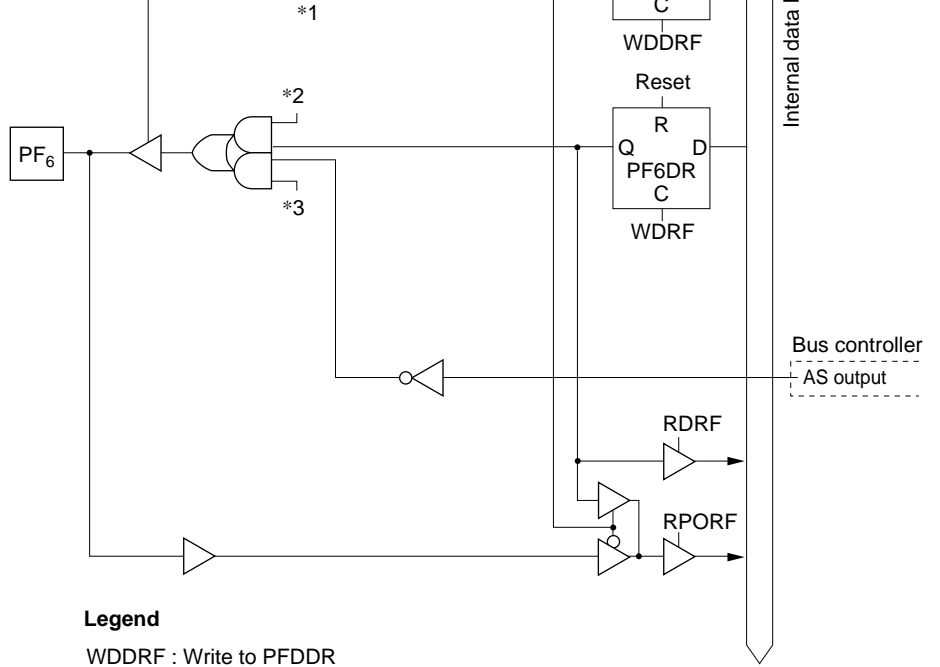


Figure C-12 (f) Port F Block Diagram (Pin PF₅)



Legend

WDDRF : Write to PFDDR

WDRF : Write to PFDR

RDRF : Read PFDR

RPORF : Read port F

- Notes:
1. H8S/2351: Mode 1/2/4/5/6
H8S/2350: Mode 1/4/5
 2. H8S/2351: Mode 3/7
H8S/2350: 8-bit bus mode
 3. H8S/2351: Mode 1/2/4/5/6
H8S/2350: 8-bit bus mode

Figure C-12 (g) Port F Block Diagram (Pin PF₆)

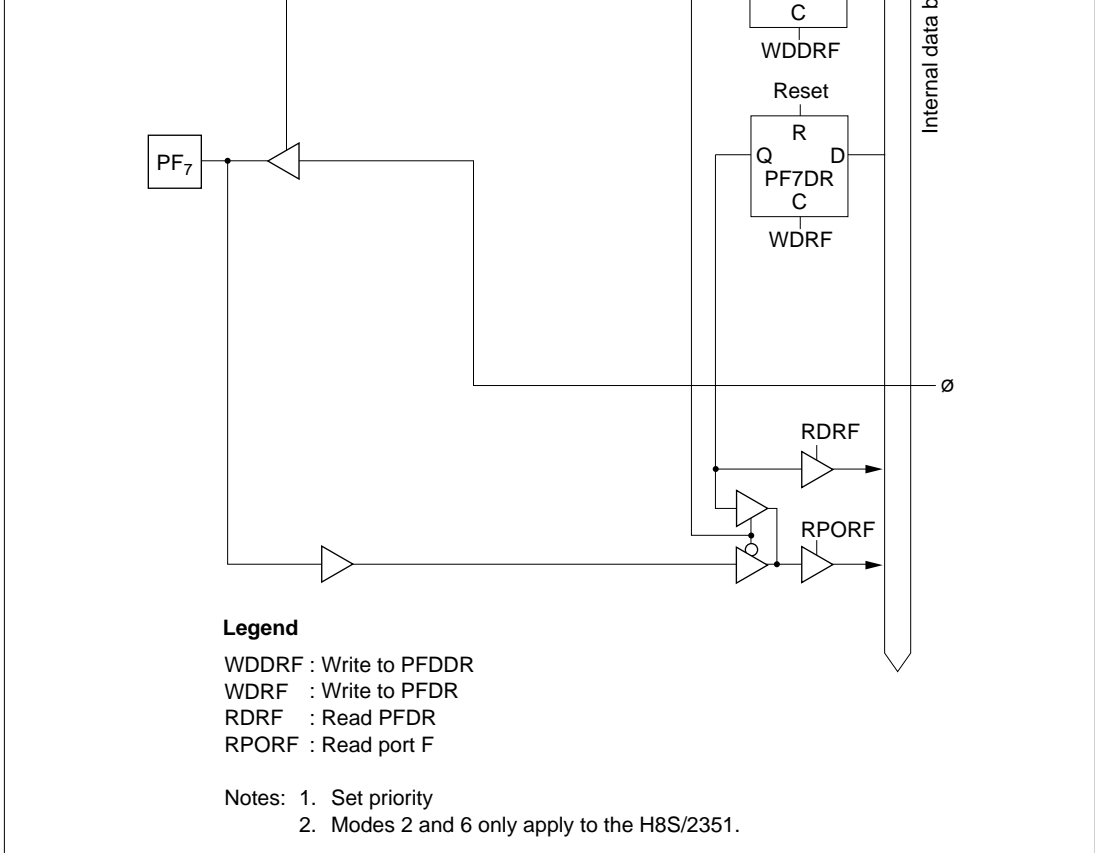


Figure C-12 (h) Port F Block Diagram (Pin PF₇)

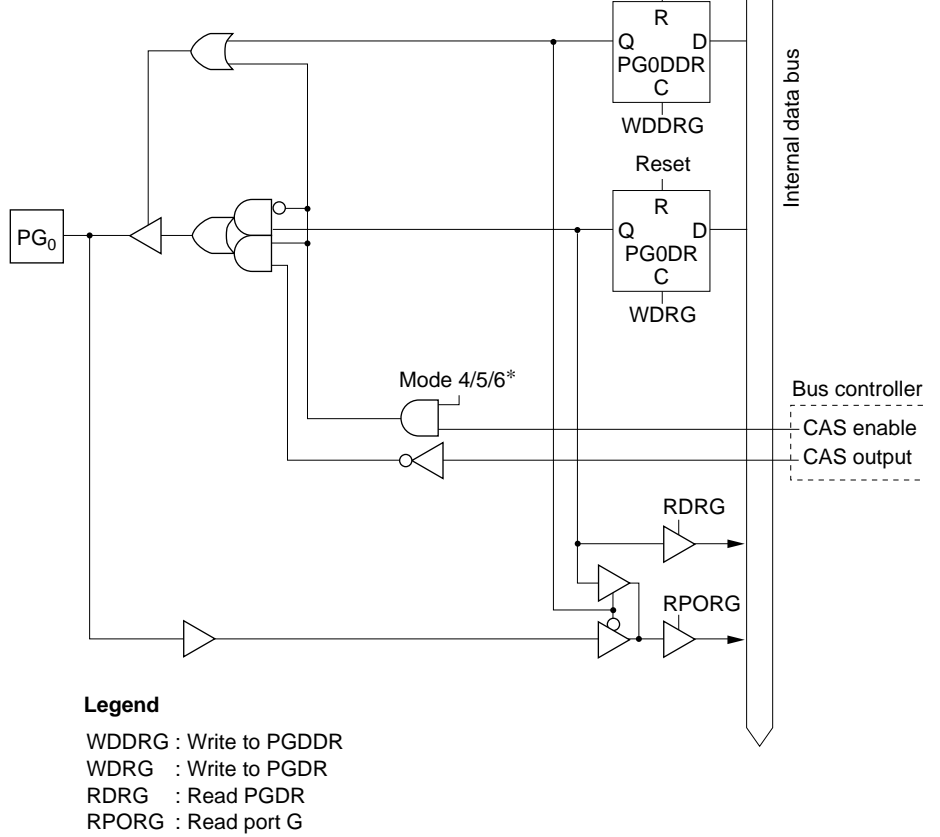


Figure C-13 (a) Port G Block Diagram (Pin PG₀)

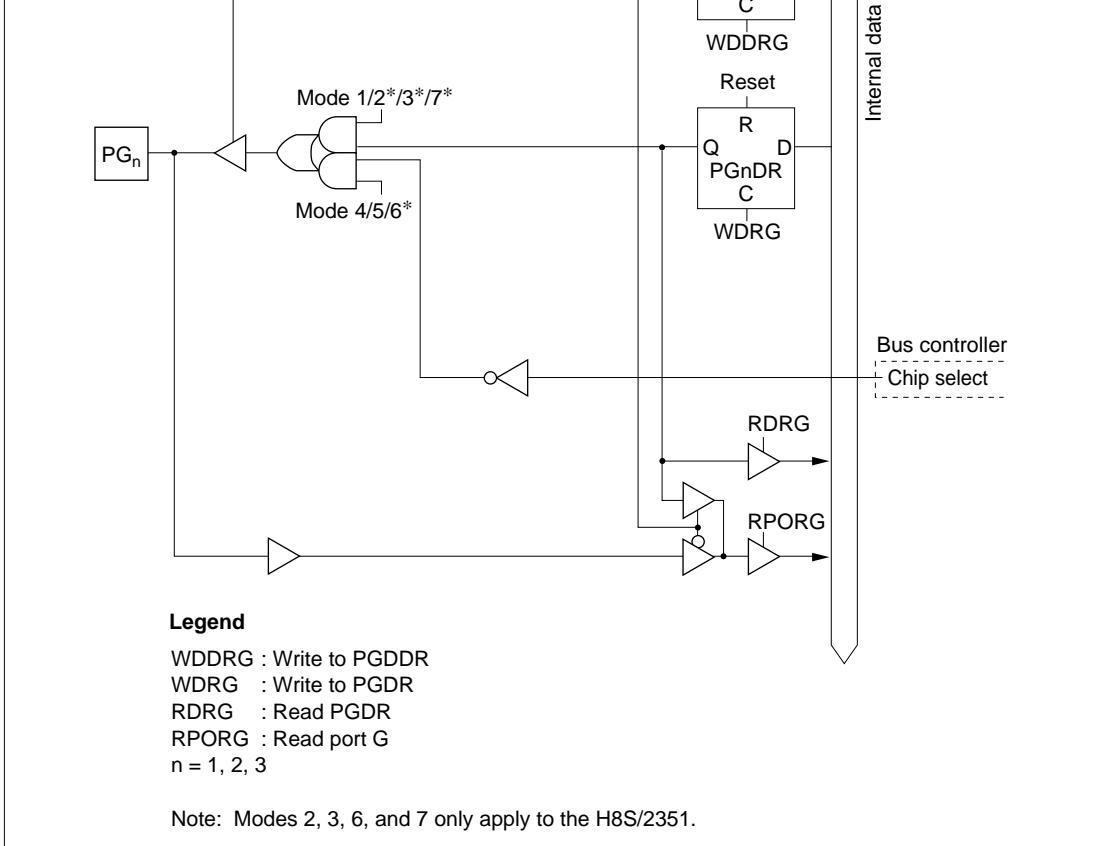


Figure C-13 (b) Port G Block Diagram (Pins PG₁ to PG₃)

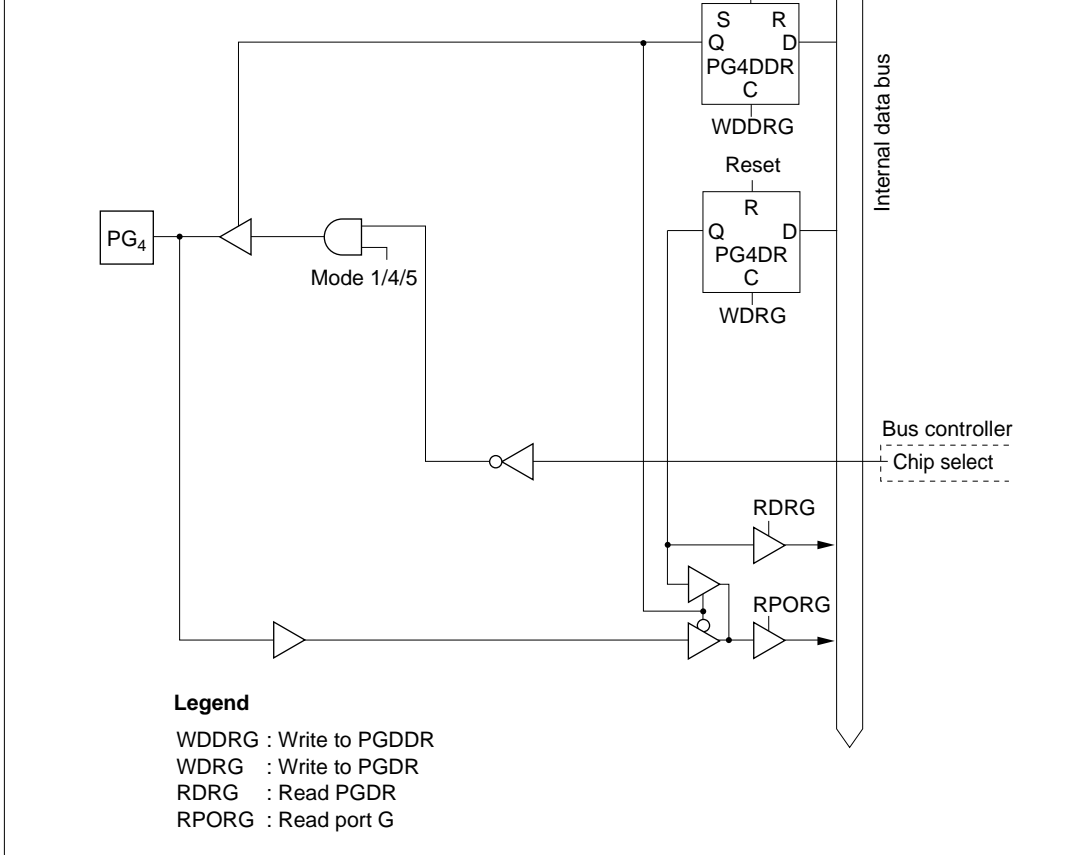


Figure C-13 (c-2) H8S/2350 Port G Block Diagram (Pin PG₄)

Table D-1 I/O Port States in Each Processing State (H8S/2351)

Port Name Pin Name	MCU Operating Mode	Power- On Reset	Manual Reset	Hardware Standby Mode	Software Standby Mode	Bus Release State	Program Execution State Sleep Mode
Port 1	1 to 7	T	kept	T	kept	kept	I/O port
Port 2	1 to 7	T	kept	T	kept	kept	I/O port
Port 3	1 to 7	T	kept	T	kept	kept	I/O port
Port 4	1 to 7	T	T	T	T	T	Input port
Port 5	1 to 7	T	kept	T	kept	kept	I/O port
P6 ₅ to P6 ₂	1 to 7	T	kept	T	kept	kept	I/O port
P6 ₇ / $\overline{CS7}$	1 to 3, 7	T	kept	T	kept	kept	I/O port
P6 ₆ / $\overline{CS6}$ P6 ₇ / $\overline{CS5}$ P6 ₀ / $\overline{CS4}$	4 to 6	T	kept	T	[DDR · OPE = 0] T [DDR · OPE = 1] H	T	[DDR = 0] Input port [DDR = 1] $\overline{CS7}$ to $\overline{CS4}$
Port A	1 to 3, 7	T	kept	T	kept	kept	I/O port
	4, 5	L	kept	T	[OPE = 0] T [OPE = 1] kept	T	Address output
	6	T	kept	T	[DDR · OPE = 0] T [DDR · OPE = 1] kept	T	[DDR = 0] Input port [DDR = 1] Address output
Port B	1, 4, 5	L	kept	T	[OPE = 0] T [OPE = 1] kept	T	Address output
	2, 6	T	kept	T	[DDR · OPE = 0] T [DDR · OPE = 1] kept	T	[DDR = 0] Input port [DDR = 1] Address output
	3, 7	T	kept	T	kept	kept	I/O port

Pin Name	Mode	Reset	Reset	Mode	Mode	State	Sleep Mode	
Port C	1, 4, 5	L	kept	T	[OPE = 0] T [OPE = 1] kept	T	Address output	
	2, 6	T	kept	T	[DDR · OPE = 0] T [DDR · OPE = 1] kept	T	[DDR = 0] Input port [DDR = 1] Address output	
	3, 7	T	kept	T	kept	kept	I/O port	
Port D	1, 2, 4 to 6	T	T*	T	T	T	Data bus	
	3, 7	T	kept	T	kept	kept	I/O port	
Port E	1, 2, 4 to 6	8 bit bus	T	kept	T	kept	kept	I/O port
		16 bit bus	T	T*	T	T	T	Data bus
	3, 7	T	kept	T	kept	kept	I/O port	
PF ₇ /Ø	1, 2, 4 to 6	Clock output	[DDR = 0] T [DDR = 1] Clock output	T	[DDR = 0] Input port [DDR = 1] H	[DDR = 0] Input port [DDR = 1] Clock output	[DDR = 0] Input port [DDR = 1] Clock output	
	3, 7	T	kept	T	[DDR = 0] Input port [DDR = 1] H	[DDR = 0] Input port [DDR = 1] Clock output	[DDR = 0] Input port [DDR = 1] Clock output	
PF ₆ /AS PF ₅ /RD PF ₄ /HWR PF ₃ /LWR	1, 2, 4 to 6	H	H*	T	[OPE = 0] T [OPE = 1] H	T	AS, RD, HWR, LWR	
	3, 7	T	kept	T	kept	kept	I/O port	

Pin Name	Mode	Reset	Reset	Mode	Mode	State	Sleep Mode
PF ₂ / $\overline{\text{LCAS}}$ / $\overline{\text{WAIT}}$ / $\overline{\text{BREQO}}$	1, 2, 4 to 6	T	[BREQOE + WAITE + LCASE = 0] kept [BREQOE = 1] $\overline{\text{BREQO}}$ [WAITE = 1] T [LCASE = 1] H*	T	[BREQOE + WAITE + LCASE = 0] kept [BREQOE = 1] kept [WAITE = 1] T [LCASE = 1, OPE = 0] T [LCASE = 1, OPE = 1] $\overline{\text{LCAS}}$	[BREQOE + WAITE + LCASE = 0] kept [BREQOE = 1] $\overline{\text{BREQO}}$ [WAITE = 1] T [LCASE = 1] T	[BREQOE + WAITE + LCASE = 0] I/O port [BREQOE = 1] $\overline{\text{BREQO}}$ [WAITE = 1] $\overline{\text{WAIT}}$ [LCASE = 1] $\overline{\text{LCAS}}$
	3, 7	T	kept	T	kept	kept	I/O port
PF ₁ / $\overline{\text{BACK}}$	1, 2, 4 to 6	T	[BRLE = 0] kept [BRLE = 1] $\overline{\text{BACK}}$	T	[BRLE = 0] kept [BRLE = 1] H	L	[BRLE = 0] I/O port [BRLE = 1] $\overline{\text{BACK}}$
	3, 7	T	kept	T	kept	kept	I/O port
PF ₀ / $\overline{\text{BREQ}}$	1, 2, 4 to 6	T	[BRLE = 0] kept [BRLE = 1] $\overline{\text{BREQ}}$	T	[BRLE = 0] kept [BRLE = 1] T	T	[BRLE = 0] I/O port [BRLE = 1] $\overline{\text{BREQ}}$
	3, 7	T	kept	T	kept	kept	I/O port
PG ₄ / $\overline{\text{CS0}}$	1, 4, 5	H	[DDR = 0] T	T	[DDR · OPE = 0] T	T	[DDR = 0] Input port
	2, 6	T	[DDR = 1] H*		[DDR · OPE = 1] H		[DDR = 1] $\overline{\text{CS0}}$
	3, 7	T	kept	T	kept	kept	I/O port
PG ₃ / $\overline{\text{CS1}}$	1 to 3, 7	T	kept	T	kept	kept	I/O port
PG ₂ / $\overline{\text{CS2}}$ PG ₁ / $\overline{\text{CS3}}$	4 to 6	T	[DDR = 0] T [DDR = 1] H*	T	[DDR · OPE = 0] T [DDR · OPE = 1] H	T	[DDR = 0] Input port [DDR = 1] $\overline{\text{CS1}}$ to $\overline{\text{CS3}}$

Pin Name	Mode	Reset	Reset	Mode	Mode	State	Sleep Mode
PG0/CAS	1 to 3, 7	T	kept	T	kept	kept	I/O port
	4 to 6	T	[DRAME = 0] kept [DRAME = 1] H*	T	[DRAME = 0] kept [OPE = 0] T [DRAME = 1] OPE = 1] CAS	T	[DRAME = 0] Input port [DRAME = 1] CAS

Legend:

- H : High level
- L : Low level
- T : High impedance
- kept : Input port becomes high-impedance, output port retains state
- DDR : Data direction register
- OPE : Output port enable
- WAITE : Wait input enable
- BRLE : Bus release enable
- BREQOE : BREQO pin enable
- DRAME : DRAM space setting
- LCASE : DRAM space setting, CW2 = LCASS = 0

Note: * Indicates the state after completion of the executing bus cycle.

Port Name Pin Name	MCU Operating Mode	Power- On Reset	Manual Reset	Hardware Standby Mode	Software Standby Mode	Bus Release State	Execution State Sleep Mode
Port 1	1, 4, 5	T	kept	T	kept	kept	I/O port
Port 2	1, 4, 5	T	kept	T	kept	kept	I/O port
Port 3	1, 4, 5	T	kept	T	kept	kept	I/O port
Port 4	1, 4, 5	T	T	T	T	T	Input port
Port 5	1, 4, 5	T	kept	T	kept	kept	I/O port
P6 ₅ to P6 ₂	1, 4, 5	T	kept	T	kept	kept	I/O port
P6 ₇ / $\overline{CS7}$	1	T	kept	T	kept	kept	I/O port
P6 ₆ / $\overline{CS6}$ P6 ₁ / $\overline{CS5}$ P6 ₀ / $\overline{CS4}$	4, 5	T	kept	T	[DDR = 0] T T [DDR = 1] H	T	[DDR = 0] Input port [DDR = 1] $\overline{CS7}$ to $\overline{CS4}$
Port A	1	T	kept	T	kept	kept	I/O port
	4, 5	L	kept	T	[OPE = 0] T [OPE = 1] kept	T	Address output
Port B	1, 4, 5	L	kept	T	[OPE = 0] T [OPE = 1] kept	T	Address output
Port C	1, 4, 5	L	kept	T	[OPE = 0] T [OPE = 1] kept	T	Address output
Port D	1, 5	T	T*	T	T	T	Data bus
Port E	1, 4, 5 8 bit bus	T	kept	T	kept	kept	I/O port
	16 bit bus	T	T*	T	T	T	Data bus
PF ₇ /ø	1, 4, 5	Clock output	[DDR = 0] T [DDR = 1] Clock output	T	[DDR = 0] Input port [DDR = 1] H	[DDR = 0] Input port [DDR = 1] Clock output	[DDR = 0] Input port [DDR = 1] Clock output

Pin Name	Mode	Reset	Reset	Mode	Mode	State	Sleep Mode
PF ₆ / \overline{AS} PF ₉ / \overline{RD} PF ₄ / \overline{HWR} PF ₃ / \overline{LWR}	1, 4, 5	H	H*	T	[OPE = 0] T [OPE = 1] H	T	AS, \overline{RD} , \overline{HWR} , \overline{LWR}
PF ₂ / \overline{LCAS} / \overline{WAIT} / \overline{BREQO}	1, 4, 5	T	[BREQOE + WAITE + LCASE = 0] kept [BREQOE = 1] \overline{BREQO} [WAITE = 1] T [LCASE = 1] H*	T	[BREQOE + WAITE + LCASE = 0] kept [BREQOE = 1] kept [WAITE = 1] T [LCASE = 1, OPE = 0] T [LCASE = 1, OPE = 1] \overline{LCAS}	[BREQOE + WAITE + LCASE = 0] kept [BREQOE = 1] [WAITE = 1] T [LCASE = 1] T	[BREQOE + WAITE + LCASE = 0] I/O port [BREQOE = 1] \overline{BREQO} [WAITE = 1] \overline{WAIT} [LCASE = 1] \overline{LCAS}
PF ₁ / \overline{BACK}	1, 4, 5	T	[BRLE = 0] kept [BRLE = 1] \overline{BACK}	T	[BRLE = 0] kept [BRLE = 1] H	L	[BRLE = 0] I/O port [BRLE = 1] \overline{BACK}
PF ₀ / \overline{BREQ}	1, 2, 4 to 6	T	[BRLE = 0] kept [BRLE = 1] \overline{BREQ}	T	[BRLE = 0] kept [BRLE = 1] T	T	[BRLE = 0] I/O port [BRLE = 1] \overline{BREQ}
PG ₄ / $\overline{CS0}$	1, 4, 5	H	[DDR = 0] T [DDR = 1] H*	T	[DDR · OPE = 0] T [DDR · OPE = 1] H	T	[DDR = 0] Input port [DDR = 1] $\overline{CS0}$
PG ₃ / $\overline{CS1}$ PG ₂ / $\overline{CS2}$ PG ₁ / $\overline{CS3}$	1 4, 5	T T	kept [DDR = 0] T [DDR = 1] H*	T T	kept [DDR · OPE = 0] T [DDR · OPE = 1] H	kept T	I/O port [DDR = 0] Input port [DDR = 1] $\overline{CS1}$ to $\overline{CS3}$

Pin Name	Mode	Reset	Reset	Mode	Mode	State	Sleep Mode
PG ₀ /CAS	1 to 3, 7	T	kept	T	kept	kept	I/O port
	4 to 6	T	[DRAME = 0] kept [DRAME = 1] H*	T	[DRAME = 0] kept [OPE = 0] T [DRAME = 1] OPE = 1 CAS	T	[DRAME = 0] Input port [DRAME = 1] CAS

Legend:

- H : High level
- L : Low level
- T : High impedance
- kept : Input port becomes high-impedance, output port retains state
- DDR : Data direction register
- OPE : Output port enable
- WAITE : Wait input enable
- BRLE : Bus release enable
- BREQOE : BREQO pin enable
- DRAME : DRAM space setting
- LCASE: DRAM space setting, CW2 = LCASS = 0

Note: * Indicates the state after completion of the executing bus cycle.

impedance state.

After detecting a high level at the $\overline{\text{STBY}}$ pin, the chip starts oscillation.

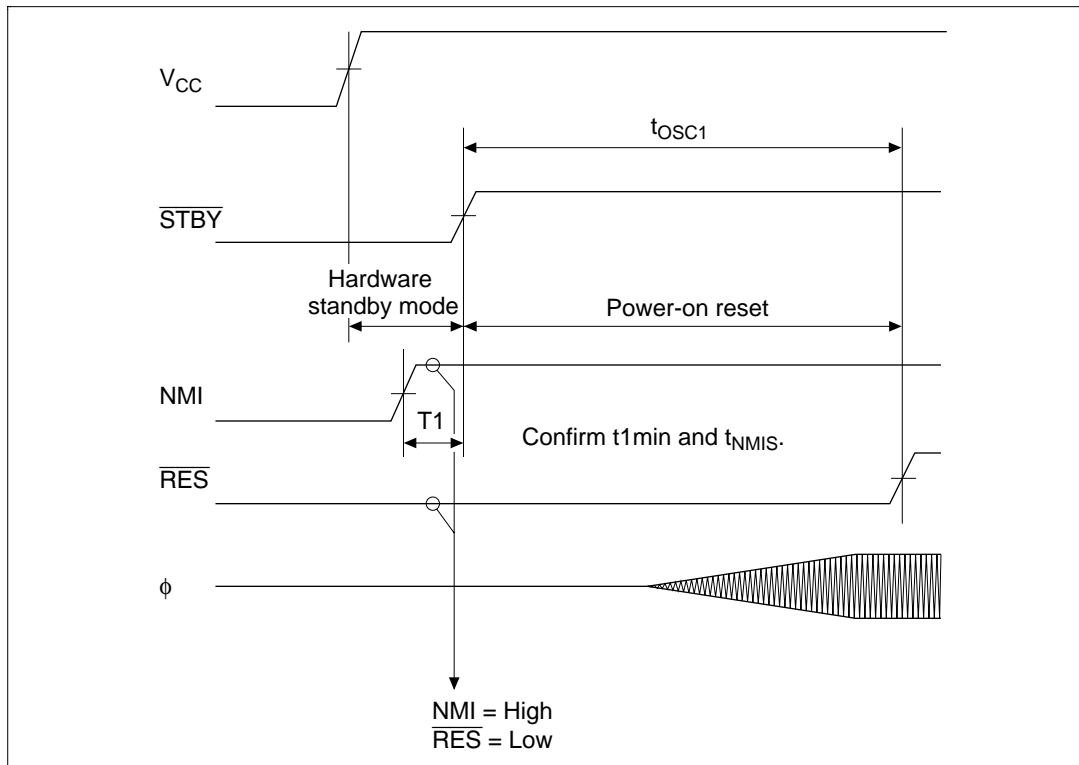


Figure E-2 When Pins Settle from the High-Impedance State at Power-On

Timing of Transition to Hardware Standby Mode

- (1) To retain RAM contents with the RAME bit set to 1 in SYSCR, drive the $\overline{\text{RES}}$ signal low at least $10t_{\text{cyc}}$ before the $\overline{\text{STBY}}$ signal goes low, as shown below. $\overline{\text{RES}}$ must remain low until $\overline{\text{STBY}}$ signal goes low (delay from $\overline{\text{STBY}}$ low to $\overline{\text{RES}}$ high: 0 ns or more).

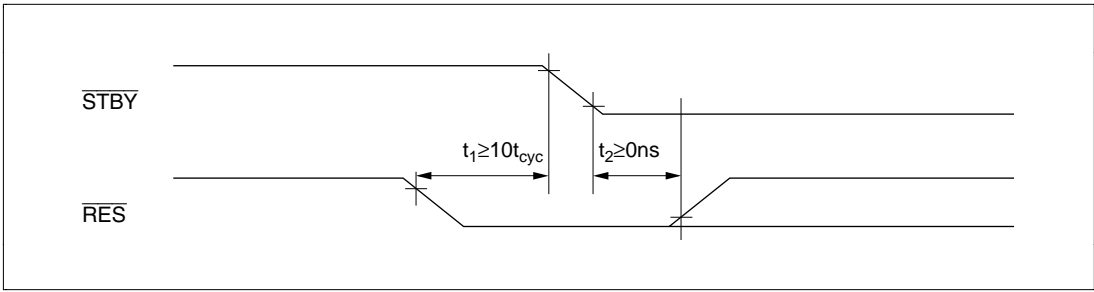


Figure F-1 Timing of Transition to Hardware Standby Mode

- (2) To retain RAM contents with the RAME bit cleared to 0 in SYSCR, or when RAM contents do not need to be retained, $\overline{\text{RES}}$ does not have to be driven low as in (1).

Timing of Recovery from Hardware Standby Mode

Drive the $\overline{\text{RES}}$ signal low and the NMI signal high approximately 100 ns or more before $\overline{\text{STBY}}$ goes high to execute a power-on reset.

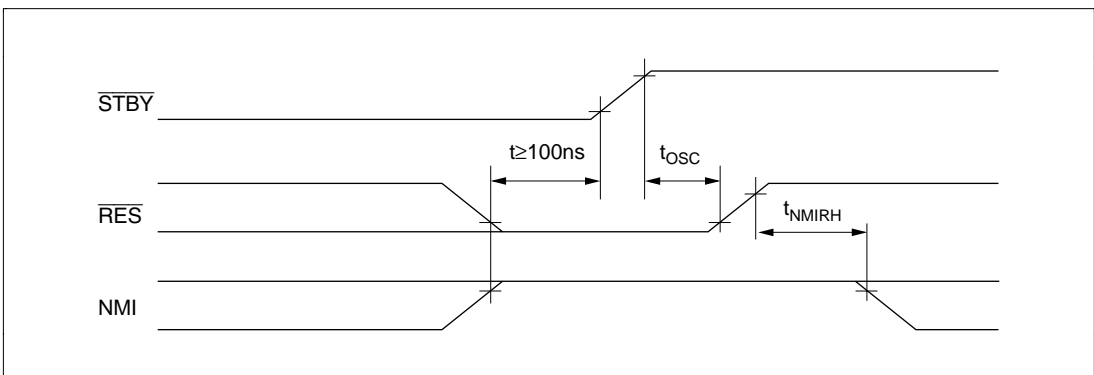


Figure F-2 Timing of Recovery from Hardware Standby Mode

Product Type		Product Code	Mark Code	Package (Hitachi Package Code)
H8S/2351	Mask ROM	HD6432351	HD6432351TE	120-pin TFP (TFP-120)
			HD6432351F	128-pin FP (FP-128)
H8S/2350	Mask ROM	HD6412350	HD6412350TE	120-pin TFP (TFP-120)
			HD6412350F	128-pin FP (FP-128)

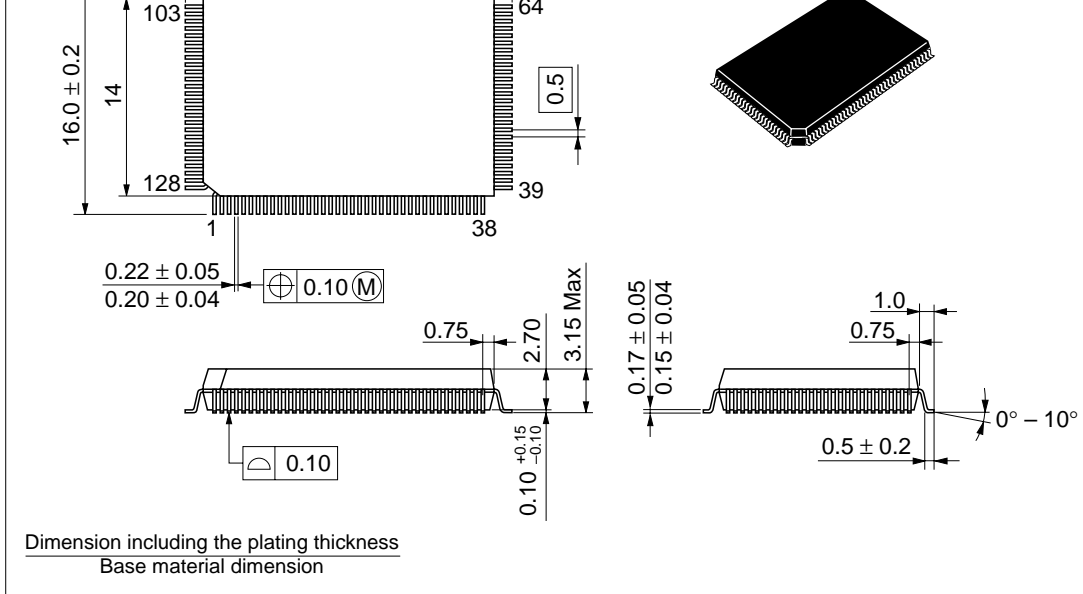


Figure H-2 FP-128 Package Dimensions

H8S/2350 Series Hardware Manual

Publication Date: 1st Edition, May 1997

2nd Edition, December 1997

Published by: Electronic Devices Sales & Marketing Group
Semiconductor & Integrated Circuits
Hitachi, Ltd.

Edited by: Technical Documentation Group

Hitachi Kodaira Semiconductor Co., Ltd.

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