HD404849 Series

4-Bit Single-Chip Microcomputer

HITACHI

Rev. 6.0
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Description

The HD404849 series of HMCS400-series microcomputers is designed to increase program productivity and also incorporate large-capacity memory. Each microcomputer has an LCD controller/driver, A/D converter, input capture circuit, 32-kHz oscillator for clock use, and four low-power dissipation modes.

The HD404849 series includes the HD404848 with an 8-kword on-chip ROM, the HD4048412 with a 12-kword on-chip ROM, the HD404849 with a 16-kword on-chip ROM, and the HD4074849 with a 16-kword on-chip PROM.

On-chip ROM is available in a PROM (ZTAT™ microcomputer) version and a mask ROM version. A program can be written to the PROM by a PROM writer, which can dramatically shorten system development periods and smooth the process from debugging to mass production. PROM programming specifications are the same as for the 27256.

ZTAT™: Zero Turn Around Time ZTAT is a trademark of Hitachi Ltd.

Features

- 35 I/O pins, including nine high-current pins (15 mA, max.), eight pins multiplexed with LCD segment pins, and four pins multiplexed with analog input pins
- Four timer/counters
- Eight-bit input capture circuit
- Three timer outputs (including two PWM outputs)
- Two event counter inputs (including one in which the detection edge is programmable)
- Clock-synchronous 8-bit serial interface
- A/D converter (8 channels × 8 bits)
  - — Operation voltage 2.7 V to 6.0 V
- LCD driver (32 segments × 4 commons)
- Built-in oscillators
  - — Main clock: Can be driven by ceramic oscillator, crystal oscillator, or external clock.
  - — Subclock: 32.768-kHz crystal
- Ten interrupt sources
  - — Four by external sources, including two in which the detection edge is programmable

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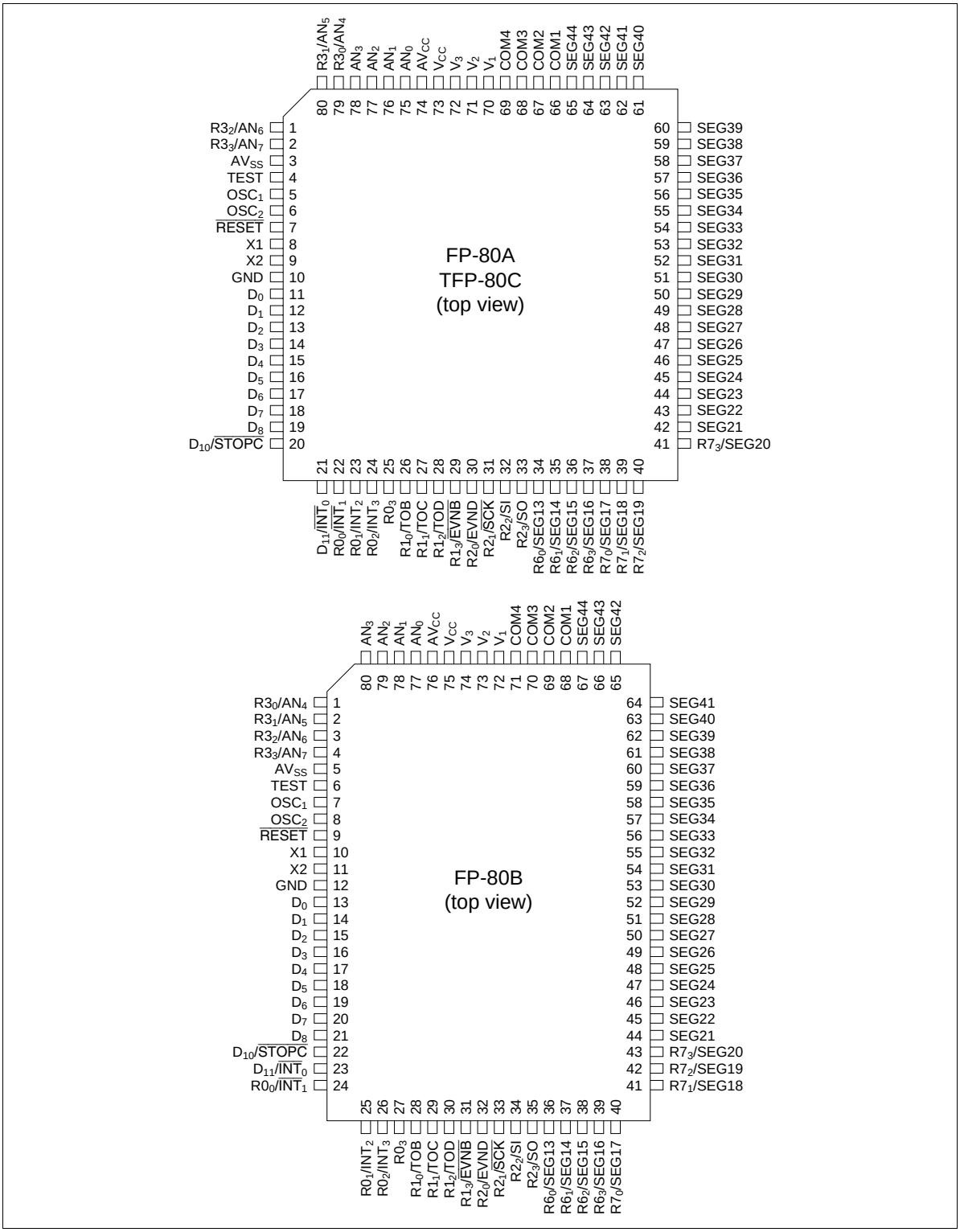
— Six by internal sources
- Subroutine stack up to 16 levels, including interrupts
- Four low-power dissipation modes
  — Standby mode
  — Stop mode
  — Watch mode
  — Subactive mode
- One external input for transition from stop mode to active mode
- Instruction cycle time: 0.89 µs (f_{OSC} = 4.5 MHz)
- Operation voltage
  — V_{CC} = 2.7 V to 6.0 V (subactive mode: 2.2 V to 6.0 V) (HD404848, HD404849)
  — V_{CC} = 2.7 V to 5.5 V (HD4074849)
- Two operating modes
  — MCU mode (HD404848, HD4048412, HD404849)
  — MCU/PROM mode (HD4074849 only)

Ordering Information

Type	Product Name	Model Name	ROM (words)	RAM (digits)	Package
Mask ROM	HD404848	HD404848H	8,192	512	80-pin plastic QFP (FP-80A)
		HD404848FS			80-pin plastic QFP (FP-80B)
		HD404848TF			80-pin plastic TQFP (TFP-80C)
	HD4048412	HD4048412H	12,288	1,184	80-pin plastic QFP (FP-80A)
		HD4048412FS			80-pin plastic QFP (FP-80B)
		HD4048412TF			80-pin plastic TQFP (TFP-80C)
	HD404849	HD404849H	16,384	1,184	80-pin plastic QFP (FP-80A)
		HD404849FS			80-pin plastic QFP (FP-80B)
		HD404849TF			80-pin plastic TQFP (TFP-80C)
ZTAT™	HD4074849	HD4074849H	16,384	1,184	80-pin plastic QFP (FP-80A)
		HD4074849FS			80-pin plastic QFP (FP-80B)
		HD4074849TF			80-pin plastic TQFP (TFP-80C)

Pin Arrangement

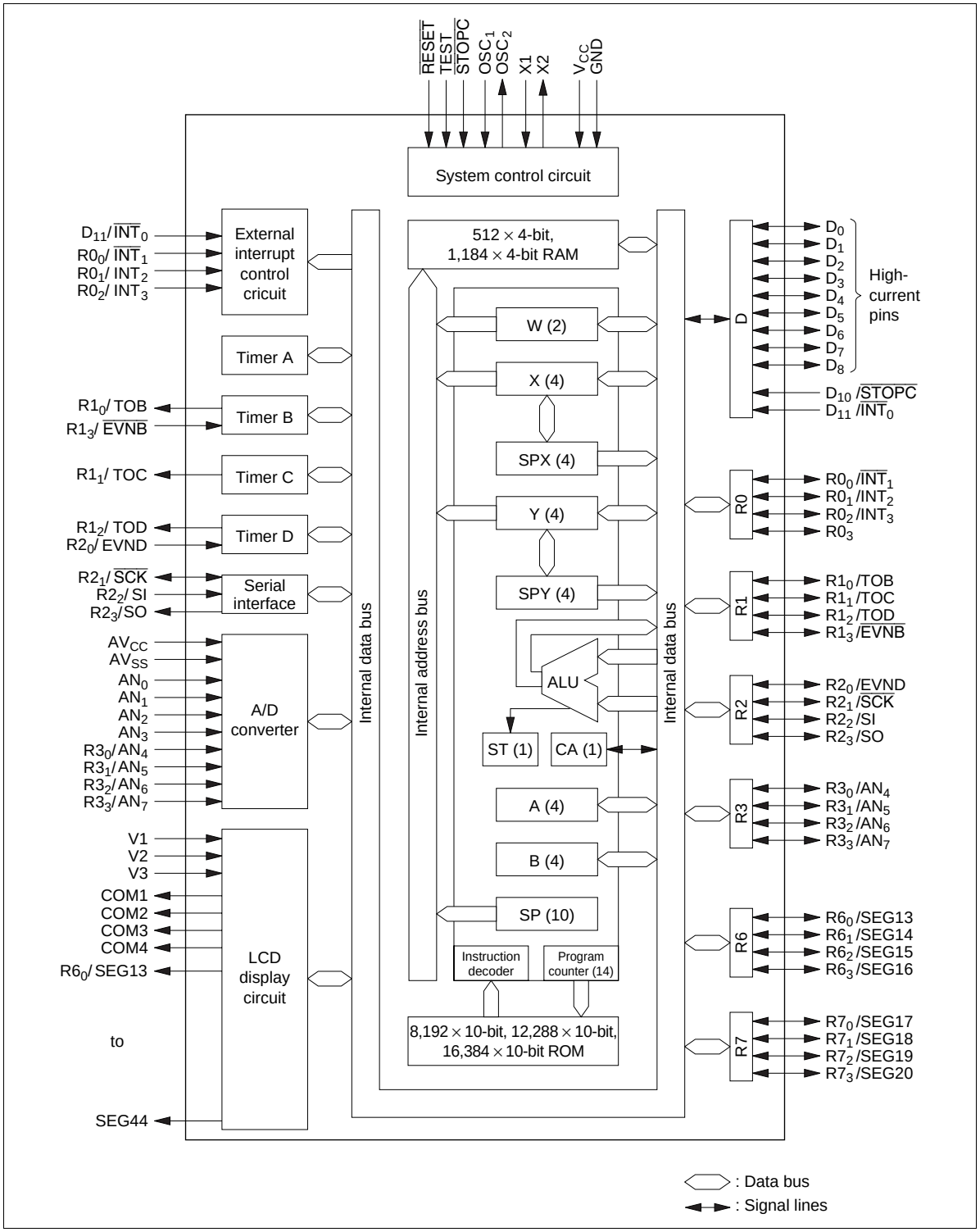


Pin Description

Item	Symbol	Pin Number FP-80A ,TFP-80C	Pin Number FP-80B	I/O	Function
Power supply	V_{CC}	73	75		Applies power voltage
	GND	10	12		Connected to ground
Test	TEST	4	6	I	Used for factory testing only: Connect this pin to GND
Reset	$\overline{RESET}$	7	9	I	Resets the MCU
Oscillator	OSC_1	5	7	I	Input/output pins for the internal oscillator circuit: Connect them to a ceramic oscillator or connect OSC1 to an external oscillator circuit.
	OSC_2	6	8	O	
	X1	8	10	I	Used for a 32.768-kHz crystal for clock purposes. If not to be used, fix the X1 pin to VCC and leave the X2 pin open.
	X2	9	11	O	
Port	D_0–D_8	11–19	13–21	I/O	Input/output pins addressed by individual bits; pins D_0–D_8 are high-current pins that can each supply up to 15 mA
	D_{10}, D_{11}	20, 21	22, 23	I	Input pins addressable by individual bits
	R0–R3, R6, R7	22–33, 79, 80, 1, 2, 34–41	24–35, 1–4, 36–43	I/O	Input/output pins addressable in 4-bit units
Interrupt	$\overline{INT_0}$, $\overline{INT_1}$, INT_2, INT_3	21–24	23–26	I	Input pins for external interrupts
Stop clear	$\overline{STOPC}$	20	22	I	Input pin for transition from stop mode to active mode
Serial	$\overline{SCK}$	31	33	I/O	Serial clock input/output pin
	SI	32	34	I	Serial receive data input pin
	SO	33	35	O	Serial transmit data output pin
Timer	TOB, TOC, TOD	26–28	28–30	O	Timer output pins
	$\overline{EVNB}$, EVND	29, 30	31, 32	I	Event count input pins

Item	Symbol	Pin Number FP-80A, TFP-80C	Pin Number FP-80B	I/O	Function
LCD	V_1, V_2, V_3	70–72	72–74		Power pins for LCD driver. The LCD power supply division resistors can be connected and disconnected as controlled by software. Voltage conditions are: $V_{CC} \geq V_1 \geq V_2 \geq V_3 \geq GND$
	COM1–COM4	66–69	68–71	O	Common signal pins for LCD
	SEG13–SEG44	34–65	36–67	O	Segment signal pins for LCD
A/D converter	AV_{CC}	74	76		Power pin for A/D converter: Connect it to the same potential as V_{CC}, as physically close to the V_{CC} pin as possible
	AV_{SS}	3	5		Ground for AV_{CC}: Connect it to the same potential as GND, as physically close to the GND pin as possible
	AN_0–AN_7	75–80, 1, 2	77–80, 1–4	I	Analog input pins for A/D converter

Block Diagram



Memory Map

ROM Memory Map

The ROM memory map is shown in figure 1 and described below.

Vector Address Area ($0000–$000F): Reserved for JMPL instructions that branch to the start addresses of the reset and interrupt routines. After MCU reset or an interrupt, program execution continues from the vector address.

Zero-Page Subroutine Area ($0000–$003F): Reserved for subroutines. The program branches to a subroutine in this area in response to the CAL instruction.

Pattern Area ($0000–$0FFF): Contains ROM data that can be referenced with the P instruction.

Program Area ($0000–$1FFF: HD404848; $0000–$2FFF: HD4048412; $0000–$3FFF: HD404849, HD4074849): Used for program coding.

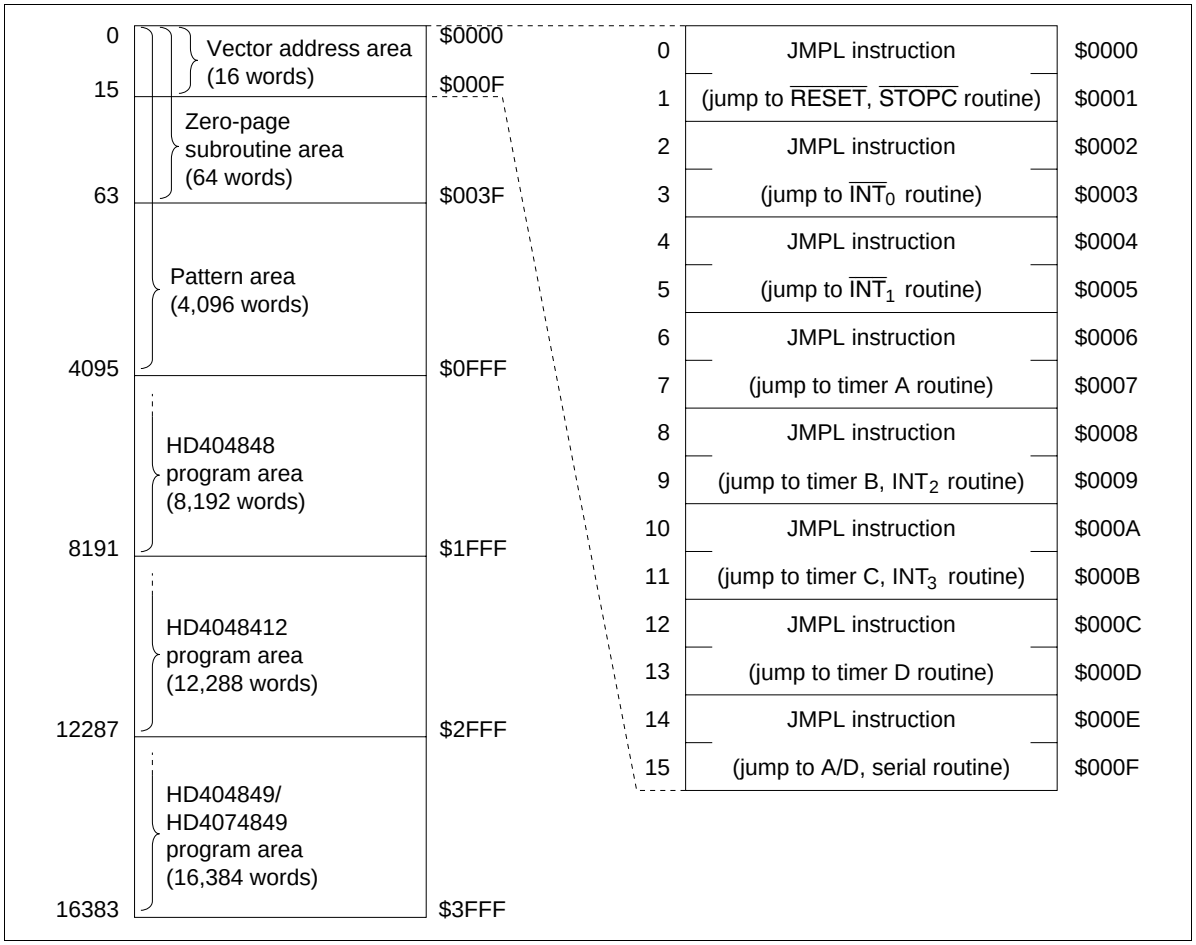


Figure 1 ROM Memory Map

RAM Memory Map

The MCU contains a RAM area consisting of a memory register area, an LCD data area, a data area, and a stack area. In addition, an interrupt control bits area, special register area, and register flag area are mapped onto the same RAM memory space as a RAM-mapped register area outside the above areas. The RAM memory map is shown in figure 2 and described below.

RAM-Mapped Register Area ($000–$03F):

- Interrupt Control Bits Area ($000–$003)
  This area is used for interrupt control bits (figure 3). These bits can be accessed only by RAM bit manipulation instructions (SEM/SEMD, REM/REMD, and TM/TMD). However, note that not all the instructions can be used for each bit. Limitations on using the instructions are shown in figure 4.

- Special Function Register Area ($004–$01F, $024–$03F)
  This area is used as mode registers and data registers for external interrupts, serial interface, timer/counters, LCD, and A/D converter, and is used as data control registers for I/O ports. The structure is shown in figures 2 and 5. These registers can be classified into three types: write-only (W), read-only (R), and read/write (R/W). The SEM, SEMD, REM, and REMD instructions can be used for the LCD control register (LCR: $01B), but RAM bit manipulation instructions cannot be used for other registers.

- Register Flag Area ($020–$023)
  This area is used for the DTON, WDON, and other register flags and interrupt control bits (figure 3). These bits can be accessed only by RAM bit manipulation instructions (SEM/SEMD, REM/REMD, and TM/TMD). However, note that not all the instructions can be used for each bit. Limitations on using the instructions are shown in figure 4.

Memory Register (MR) Area ($040–$04F): Consisting of 16 addresses, this area (MR0–MR15) can be accessed by register-register instructions (LAMR and XMRA). The structure is shown in figure 6.

LCD Data Area ($05C–$07B): Used for storing 32-digit LCD data which is automatically output to LCD segments as display data. Data 1 lights the corresponding LCD segment; data 0 extinguishes it. Refer to the LCD description for details.

Data Area ($090–$21F: HD404848; $090–$2EF: HD4048412, HD404849, HD4074849): 464 digits from $090 to $25F have two banks, which can be selected by setting the bank register (V: $03F). Before accessing this area, set the bank register to the required value (figure 7). The area from $260 to $2EF is accessed without setting the bank register.

Stack Area ($3C0–$3FF): Used for saving the contents of the program counter (PC), status flag (ST), and carry flag (CA) at subroutine call (CAL or CALL instruction) and for interrupts. This area can be used as a 16-level nesting subroutine stack in which one level requires four digits. The data to be saved and the save conditions are shown in figure 6.

The program counter is restored by either the RTN or RTNI instruction, but the status and carry flags can only be restored by the RTNI instruction. Any unused space in this area is used for data storage.

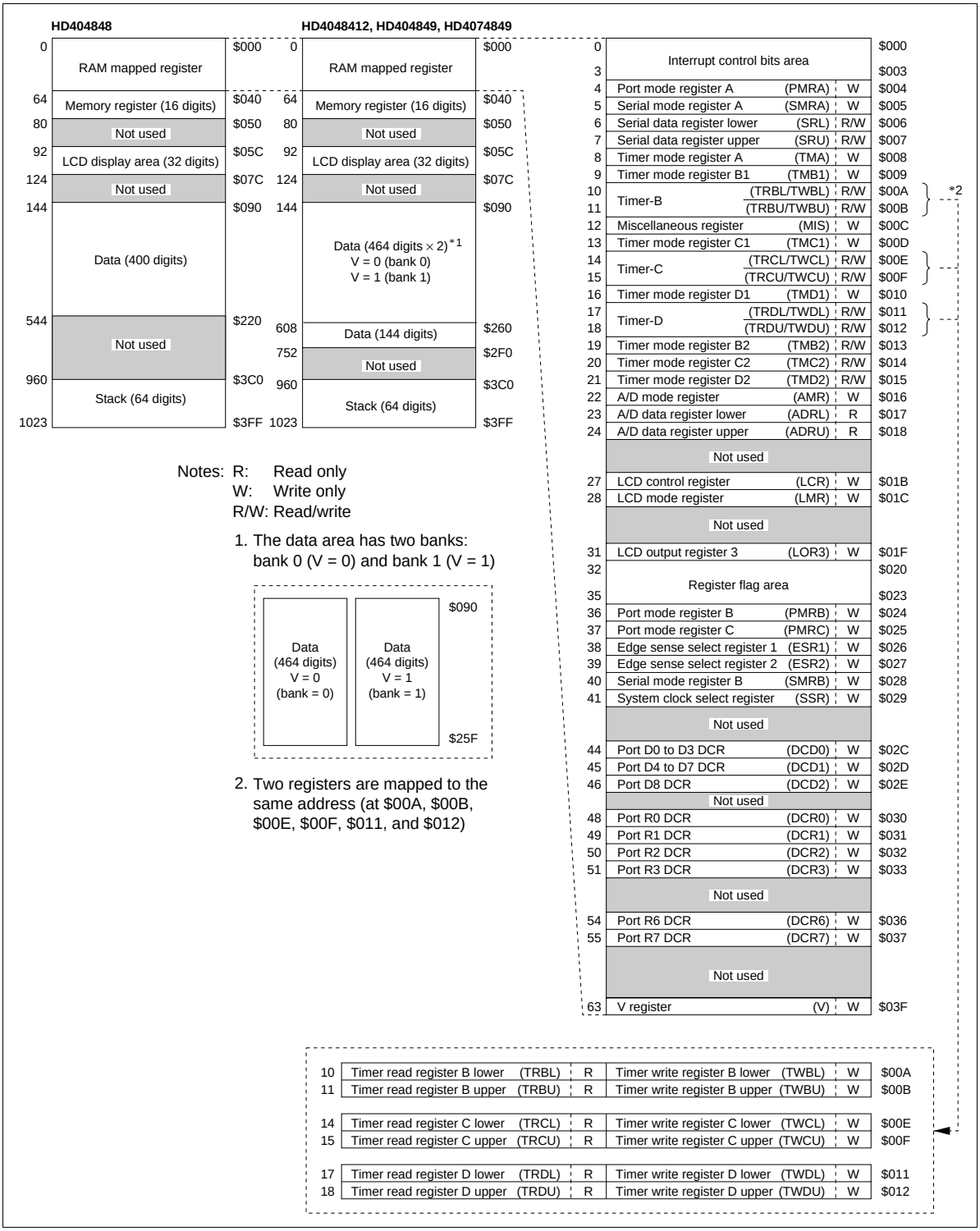


Figure 2 RAM Memory Map

	Bit 3	Bit 2	Bit 1	Bit 0	
0	IM0 (IM of $\overline{INT_0}$)	IF0 (IF of $\overline{INT_0}$)	RSP (Reset SP bit)	IE (Interrupt enable flag)	$000
1	IMTA (IM of timer A)	IFTA (IF of timer A)	IM1 (IM of $\overline{INT_1}$)	IF1 (IF of $\overline{INT_1}$)	$001
2	IMTC (IM of timer C)	IFTC (IF of timer C)	IMTB (IM of timer B)	IFTB (IF of timer B)	$002
3	IMAD (IM of A/D)	IFAD (IF of A/D)	IMTD (IM of timer D)	IFTD (IF of timer D)	$003

(a) Interrupt control bits area

	Bit 3	Bit 2	Bit 1	Bit 0	
32	DTON (Direct transfer on flag)	ADSF (A/D start flag)	WDON (Watchdog on flag)	LSON (Low speed on flag)	$020
33	RAME (RAM enable flag)	IAOF (A/D current off flag)	ICEF (Input capture error flag)	ICSF (Input capture status flag)	$021
34	IM3 (IM of INT_3)	IF3 (IF of INT_3)	IM2 (IM of INT_2)	IF2 (IF of INT_2)	$022
35	IMS (IM of serial interface)	IFS (IF of serial interface)	Not used	Not used	$023

(b) Register flag area

IF: Interrupt request flag
IM: Interrupt mask
IE: Interrupt enable flag
SP: Stack pointer

Figure 3 Configuration of Interrupt Control Bits and Register Flag Areas

Bits in the interrupt control bits area and register flag area can be set and reset by the SEM/SEMD and REM/REMD instructions, and tested with the TM/TMD instructions. Other instructions have no effect on these bits. Note the following restrictions for each bit.

	SEM/SEMD	REM/REMD	TM/TMD
IE	Allowed	Allowed	Allowed
IM			
LSON			
IAOF			
IF	Not executed	Allowed	Allowed
ICSF			
ICEF			
RAME			
RSP	Not executed	Allowed	Inhibited
WDON	Allowed	Not executed	Inhibited
ADSF	Allowed	Inhibited	Allowed
DTON	Not executed in active mode	Allowed	Allowed
	Used in subactive mode		
Not used	Not executed	Not executed	Inhibited

Note: WDON is reset by MCU reset or by $\overline{\text{STOPC}}$ enable for stop mode cancellation.
The REM or REMD instuction must not be executed for ADSF during A/D conversion.
DTON is always reset in active mode.
If the TM or TMD instruction is executed for the inhibited bits or non-existing bits, the value in ST cannot be guaranteed.

Figure 4 Usage Limitations of RAM Bit Manipulation Instructions

	bit3	bit2	bit1	bit0
$000	Interrupt control bits area			
$003				
PMRA $004	Not used	Not used	$R2_2$/SI	$R2_3$/SO
SMRA $005	$R2_1$/$\overline{SCK}$	Serial transmit clock speed selection 1		
SRL $006	Serial data register (lower digit)			
SRU $007	Serial data register (upper digit)			
TMA $008	Timer A/time base	Clock source selection (timer A)		
TMB1 $009	Auto reload on/off	Clock source selection (timer B)		
TRBL/TWBL $00A	Timer B register (lower digit)			
TRBU/TWBU $00B	Timer B register (upper digit)			
MIS $00C	Pull-up MOS control	PMOS SO control	Interrupt frame period selection	
TMC1 $00D	Auto reload on/off	Clock source selection (timer C)		
TRCL/TWCL $00E	Timer C register (lower digit)			
TRCU/TWCU $00F	Timer C register (upper digit)			
TMD1 $010	Auto reload on/off	Clock source selection (timer D)		
TRDL/TWDL $011	Timer D register (lower digit)			
TRDU/TWDU $012	Timer D register (upper digit)			
TMB2 $013	Not used	Not used	Timer B output mode selection	
TMC2 $014	Not used	Timer C output mode selection		
TMD2 $015	Input capture selection	Timer D output mode selection		
AMR $016	Analog channel selection			A/D conversion period
ADRL $017	A/D data register (lower digit)			
ADRU $018	A/D data register (upper digit)			
	Not used			
LCR $01B	*1	*2	LCD power switch	LCD display on/off
LMR $01C	LCD input clock source selection		LCD duty cycle selection	
	Not used			
LOR3 $01F	Not used	R7/SEG17–20	R6/SEG13–16	Not used
$020	Register flag area			
$023				
PMRB $024	Not used	$R0_2$/INT_3	$R0_1$/INT_2	$R0_0$/$\overline{INT_1}$
PMRC $025	D_{11}/$\overline{INT_0}$	D_{10}/$\overline{STOPC}$	$R2_0$/EVND	$R1_3$/$\overline{EVNB}$
ESR1 $026	INT_3 detection edge selection		INT_2 detection edge selection	
ESR2 $027	EVND detection edge selection		Not used	Not used
SMRB $028	Not used	Not used	*3	*4
SSR $029	32-kHz oscillation stop	*5	*6	Not used
	Not used			
DCD0 $02C	Port D_3 DCR	Port D_2 DCR	Port D_1 DCR	Port D_0 DCR
DCD1 $02D	Port D_7 DCR	Port D_6 DCR	Port D_5 DCR	Port D_4 DCR
DCD2 $02E	Not used	Not used	Not used	Port D_8 DCR
	Not used			
DCR0 $030	Port $R0_3$ DCR	Port $R0_2$ DCR	Port $R0_1$ DCR	Port $R0_0$ DCR
DCR1 $031	Port $R1_3$ DCR	Port $R1_2$ DCR	Port $R1_1$ DCR	Port $R1_0$ DCR
DCR2 $032	Port $R2_3$ DCR	Port $R2_2$ DCR	Port $R2_1$ DCR	Port $R2_0$ DCR
DCR3 $033	Port $R3_3$ DCR	Port $R3_2$ DCR	Port $R3_1$ DCR	Port $R3_0$ DCR
	Not used			
DCR6 $036	Port $R6_3$ DCR	Port $R6_2$ DCR	Port $R6_1$ DCR	Port $R6_0$ DCR
DCR7 $037	Port $R7_3$ DCR	Port $R7_2$ DCR	Port $R7_1$ DCR	Port $R7_0$ DCR
	Not used			
V $03F	Not used	Not used	Not used	Bank selection

Notes: 1. LCD display division resistor switch
2. Display on/off in watch mode
3. SO output level control in idle states
4. Transmit clock source selection
5. 32-kHz oscillation division ratio
6. System oscillation frequency selection

Figure 5 Special Function Register Area

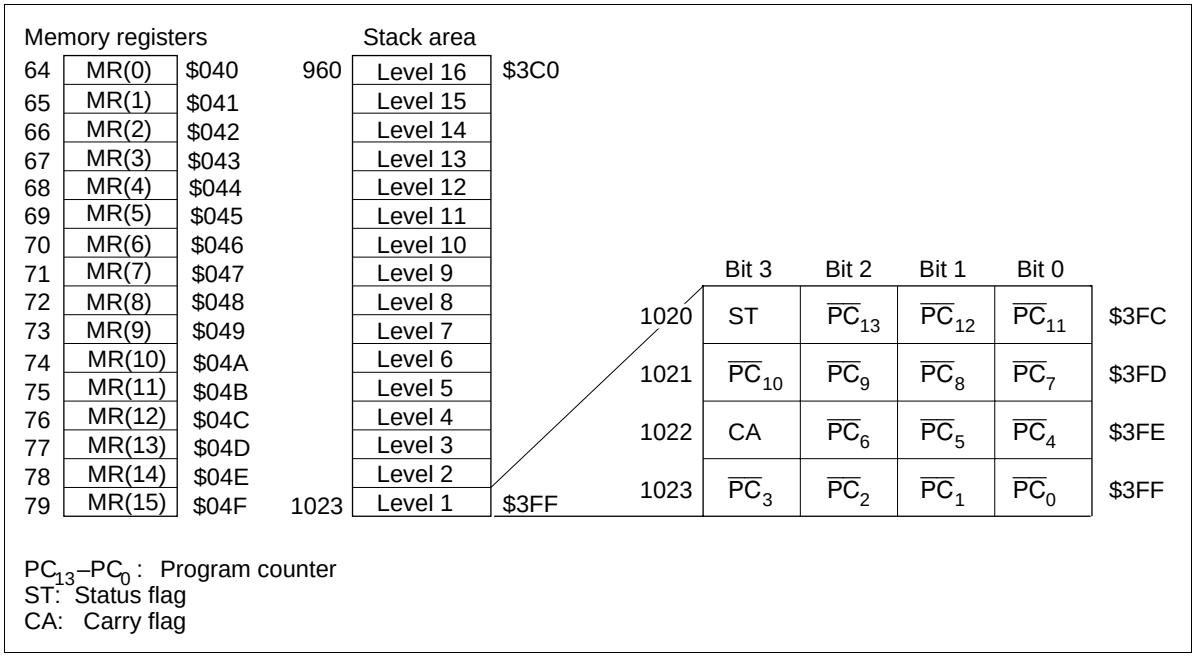


Figure 6 Configuration of Memory Registers and Stack Area, and Stack Position

Bank register (V: $03F)

Bit	3	2	1	0
Initial value	—	—	—	0
Read/Write	—	—	—	R/W
Bit name	Not used	Not used	Not used	V0

V0	Bank area selection
0	Bank 0 is selected
1	Bank 1 is selected

Note: After reset, the value in the bank register is 0, and therefore bank 0 is selected.

Figure 7 Bank Register (V)

Functional Description

Registers and Flags

The MCU has nine registers and two flags for CPU operations. They are shown in figure 8 and described below.

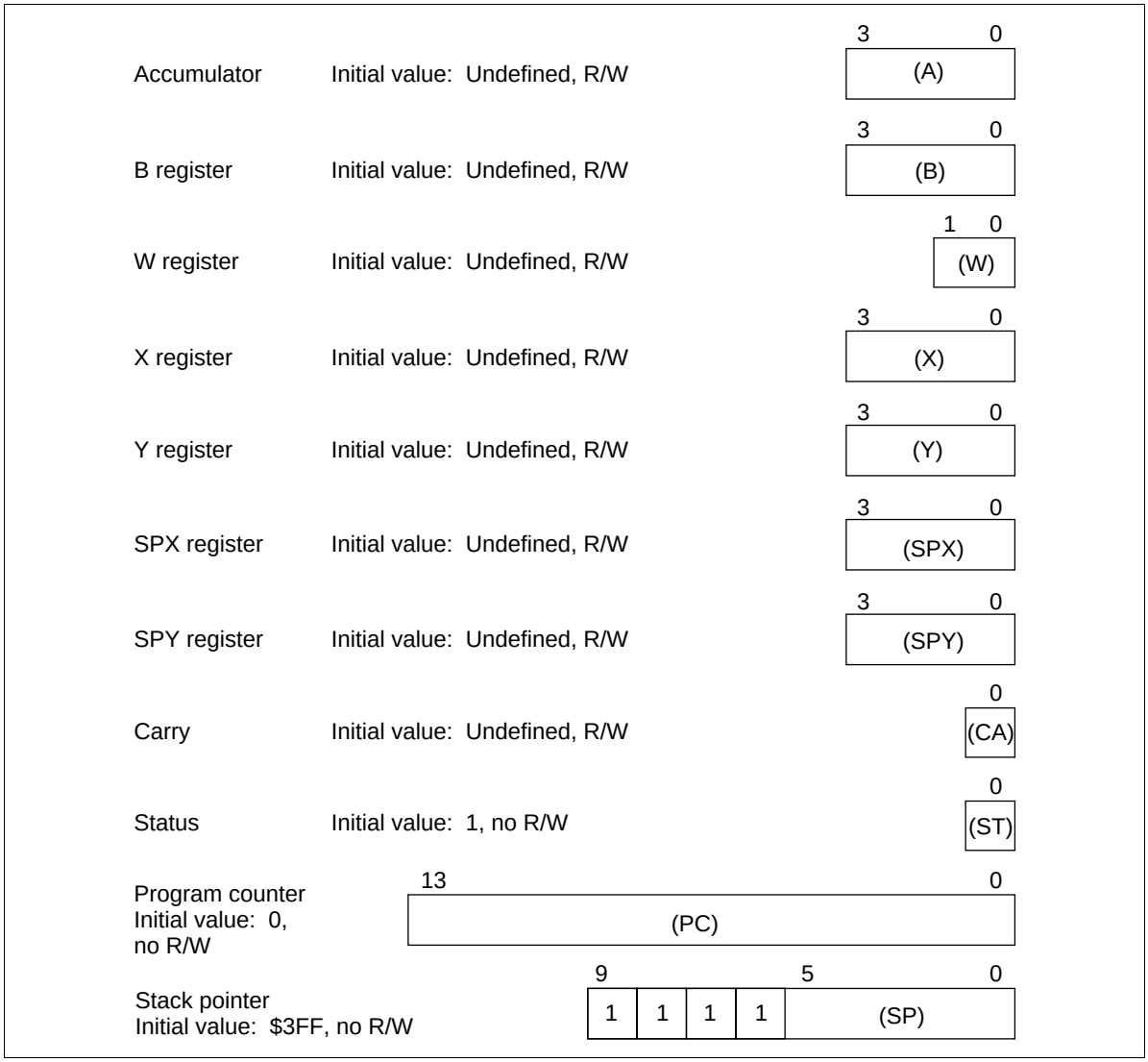


Figure 8 Registers and Flags

Accumulator (A), B Register (B): Four-bit registers used to hold the results from the arithmetic logic unit (ALU) and transfer data between memory, I/O, and other registers.

W Register (W), X Register (X), Y Register (Y): Two-bit (W) and four-bit (X and Y) registers used for indirect RAM addressing. The Y register is also used for D-port addressing.

SPX Register (SPX), SPY Register (SPY): Four-bit registers used to supplement the X and Y registers.

Carry Flag (CA): One-bit flag that stores any ALU overflow generated by an arithmetic operation. CA is affected by the SEC, REC, ROTL, and ROTR instructions. A carry is pushed onto the stack during an interrupt and popped from the stack by the RTNI instruction—but not by the RTN instruction.

Status Flag (ST): One-bit flag that latches any overflow generated by an arithmetic or compare instruction, not-zero decision from the ALU, or result of a bit test. ST is used as a branch condition of the BR, BRL, CAL, and CALL instructions. The contents of ST remain unchanged until the next arithmetic, compare, or bit test instruction is executed, but become 1 after the BR, BRL, CAL, or CALL instruction is read, regardless of whether the instruction is executed or skipped. The contents of ST are pushed onto the stack during an interrupt and popped from the stack by the RTNI instruction—but not by the RTN instruction.

Program Counter (PC): 14-bit binary counter that points to the ROM address of the instruction being executed.

Stack Pointer (SP): Ten-bit pointer that contains the address of the stack area to be used next. The SP is initialized to $3FF by MCU reset. It is decremented by 4 when data is pushed onto the stack, and incremented by 4 when data is popped from the stack. The top four bits of the SP are fixed at 1111, so a stack can be used up to 16 levels.

The SP can be initialized to $3FF in another way: by resetting the RSP bit with the REM or REMD instruction.

Reset

The MCU is reset by inputting a low-level voltage to the $\overline{\text{RESET}}$ pin. At power-on or when stop mode is cancelled, $\overline{\text{RESET}}$ must be low for at least one t_{RC} to enable the oscillator to stabilize. During operation, $\overline{\text{RESET}}$ must be low for at least two instruction cycles.

Initial values after MCU reset are listed in table 1.

Table 1 Initial Values After MCU Reset

Item		Abbr.	Initial Value	Contents
Program counter		(PC)	$0000	Indicates program execution point from start address of ROM area
Status flag		(ST)	1	Enables conditional branching
Stack pointer		(SP)	$3FF	Stack level 0
Interrupt flags/mask	Interrupt enable flag	(IE)	0	Inhibits all interrupts
	Interrupt request flag	(IF)	0	Indicates there is no interrupt request
	Interrupt mask	(IM)	1	Prevents (masks) interrupt requests
I/O	Port data register	(PDR)	All bits 1	Enables output at level 1
	Data control register	(DCD0, DCD1)	All bits 0	Turns output buffer off (to high impedance)
		(DCD2)	- - - 0	
		(DCR0–DCR3, DCR6, DCR7)	All bits 0	
	Port mode register A	(PMRA)	- - 00	Refer to description of port mode register A
	Port mode register B	(PMRB)	- 000	Refer to description of port mode register B
	Port mode register C bits 3, 1, 0	(PMRC3, PMRC1, PMRC0)	000	Refer to description of port mode register C
	Detection edge select register 1	(ESR1)	0000	Disables edge detection
	Detection edge select register 2	(ESR2)	00 - -	Disables edge detection
Timer/ counters, serial interface	Timer mode register A	(TMA)	0000	Refer to description of timer mode register A
	Timer mode register B1	(TMB1)	0000	Refer to description of timer mode register B1
	Timer mode register B2	(TMB2)	- - 00	Refer to description of timer mode register B2
	Timer mode register C1	(TMC1)	0000	Refer to description of timer mode register C1
	Timer mode register C2	(TMC2)	- 000	Refer to description of timer mode register C2
	Timer mode register D1	(TMD1)	0000	Refer to description of timer mode register D1
	Timer mode register D2	(TMD2)	0000	Refer to description of timer mode register D2

Item		Abbr.	Initial Value	Contents
Timer/ counters, serial interface	Serial mode register A	(SMRA)	0000	Refer to description of serial mode register A
	Serial mode register B	(SMRB)	- - X0	Refer to description of serial mode register B
	Prescaler S	(PSS)	$000	—
	Prescaler W	(PSW)	$00	—
	Timer counter A	(TCA)	$00	—
	Timer counter B	(TCB)	$00	—
	Timer counter C	(TCC)	$00	—
	Timer counter D	(TCD)	$00	—
	Timer write register B	(TWBU, TWBL)	$X0	—
	Timer write register C	(TWCU, TWCL)	$X0	—
	Timer write register D	(TWDU, TWDL)	$X0	—
	Octal counter		000	—
A/D	A/D mode register	(AMR)	0000	Refer to description of A/D mode register
	A/D data register	(ADRU, ADRL)	$80	Refer to description of A/D mode register
LCD	LCD control register	(LCR)	0000	Refer to description of LCD control register
	LCD mode register	(LMR)	0000	Refer to description of LCD duty-cycle/clock control register
	LCD output register 3	(LOR3)	- 00 -	Sets R-port/LCD segment pins to R port mode
Bit registers	Low speed on flag	(LSON)	0	Refer to description of operating modes
	Watchdog timer on flag	(WDON)	0	Refer to description of timer C
	A/D start flag	(ADSF)	0	Refer to description of A/D converter
	A/D current off flag	(IAOF)	0	
	Direct transfer on flag	(DTON)	0	Refer to description of operating modes
	Input capture status flag	(ICSF)	0	Refer to description of timer D
	Input capture error flag	(ICEF)	0	Refer to description of timer D
Others	Miscellaneous register	(MIS)	0000	Refer to description of operating modes, I/O, and serial interface
	System clock select register bits 2, 1	(SSR2, SSR1)	00 -	Refer to description of operating modes and oscillation circuits
	Bank register	(V)	- - - 0	Refer to description of RAM memory map

Notes: 1. The statuses of other registers and flags after MCU reset are shown in the following table.
2. X indicates invalid value. – indicates that the bit does not exist.

Item	Abbr.	Status After Cancellation of Stop Modeby $\overline{\text{STOPC}}$ Input	Status After Cancellation of Stop Mode by MCU Reset	Status After all Other Types of Reset
Carry flag	(CA)	Pre-stop-mode values are not guaranteed; values must be initialized by program		Pre-MCU-reset values are not guaranteed; values must be initialized by program
Accumulator	(A)			
B register	(B)			
W register	(W)			
Y/SPX register	(Y/SPX)			
Y/SPY register	(Y/SPY)			
Serial data register	(SRL, SRU)			
A/D data register	(ADRU, L)			
RAM		Pre-stop-mode values are retained		
RAM enable flag	(RAME)	1	0	0
Port mode register C bit 2	(PMRC2)	Pre-stop-mode values are retained	0	0
System clock select register bit 3	(SSR3)			

Interrupts

The MCU has ten interrupt sources: four external signals ($\overline{INT_0}$, $\overline{INT_1}$, INT_2, INT_3), four timer/counters (timers A, B, C, and D), serial interface, and A/D converter.

An interrupt request flag (IF), interrupt mask (IM), and vector address are provided for each interrupt source, and an interrupt enable flag (IE) controls the entire interrupt process.

Some vector addresses are shared by two different interrupts. They are timer B and INT_2, timer C and INT_3, and A/D converter and serial interface interrupts. So the type of request that has occurred must be checked at the beginning of interrupt processing.

Interrupt Control Bits and Interrupt Processing: Locations $000 to $003 and $022 to $023 in RAM are reserved for the interrupt control bits which can be accessed by RAM bit manipulation instructions.

The interrupt request flag (IF) cannot be set by software. MCU reset initializes the interrupt enable flag (IE) and the IF to 0 and the interrupt mask (IM) to 1.

A block diagram of the interrupt control circuit is shown in figure 9, interrupt priorities and vector addresses are listed in table 2, and interrupt processing conditions for the ten interrupt sources are listed in table 3.

An interrupt request occurs when the IF is set to 1 and the IM is set to 0. If the IE is 1 at that point, the interrupt is processed. A priority programmable logic array (PLA) generates the vector address assigned to that interrupt source.

The interrupt processing sequence is shown in figure 10 and an interrupt processing flowchart is shown in figure 11. After an interrupt is acknowledged, the previous instruction is completed in the first cycle. The IE is reset in the second cycle, the carry, status, and program counter values are pushed onto the stack during the second and third cycles, and the program jumps to the vector address to execute the instruction in the third cycle.

Program the JMPL instruction at each vector address, to branch the program to the start address of the interrupt program, and reset the IF by a software instruction within the interrupt program.

Table 2 Vector Addresses and Interrupt Priorities

Reset/Interrupt	Priority	Vector Address
$\overline{RESET}$, $\overline{STOPC}$*	—	$0000
$\overline{INT_0}$	1	$0002
$\overline{INT_1}$	2	$0004
Timer A	3	$0006
Timer B, INT_2	4	$0008
Timer C, INT_3	5	$000A
Timer D	6	$000C
A/D, Serial	7	$000E

Note: * The $\overline{STOPC}$ interrupt request is valid only in stop mode.

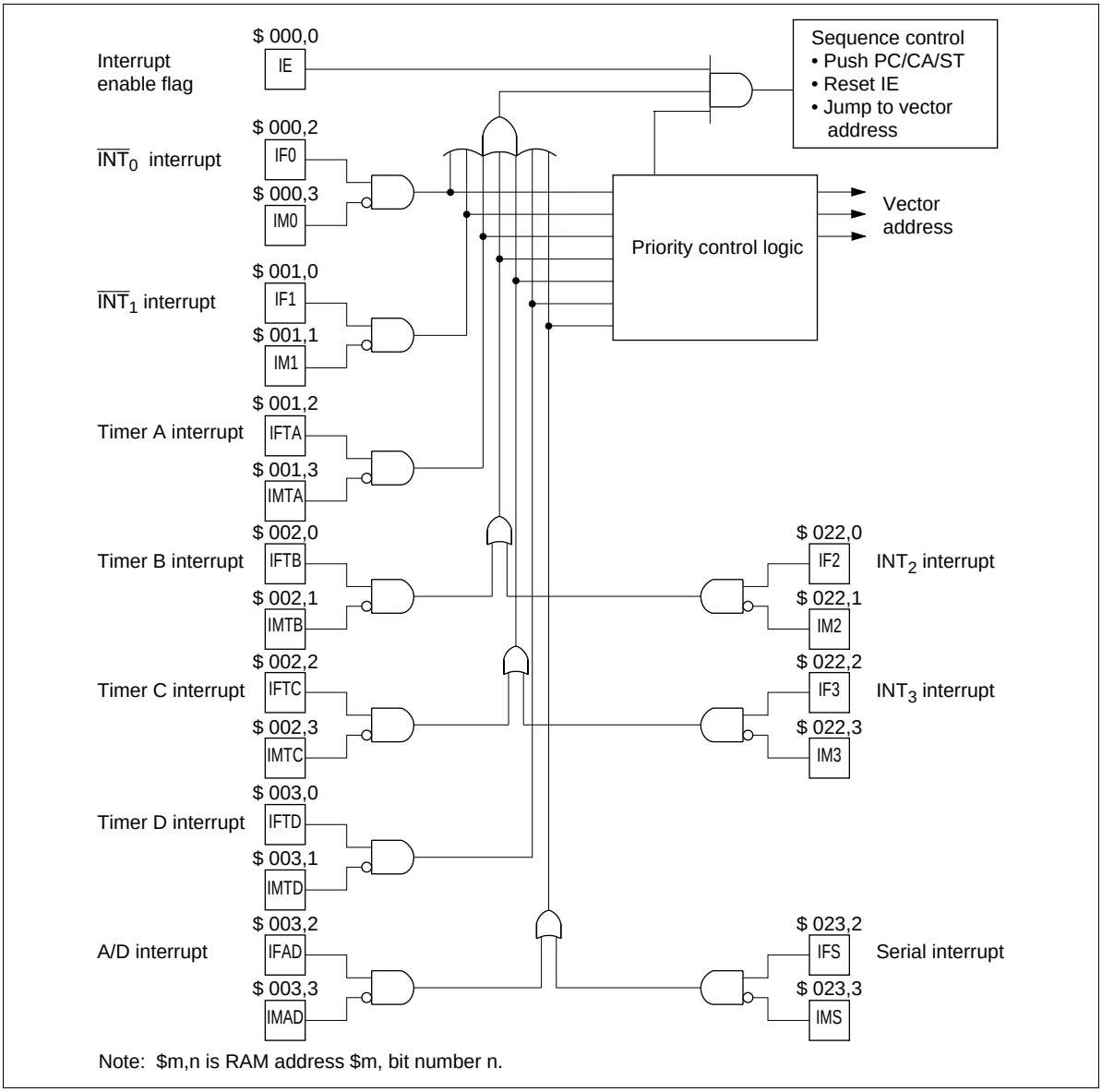


Figure 9 Interrupt Control Circuit

Table 3 Interrupt Processing and Activation Conditions

	Interrupt Source						
Interrupt Control Bit	**$\overline{INT_0}$**	**$\overline{INT_1}$**	**Timer A**	**Timer B or INT_2**	**Timer C or INT_3**	**Timer D**	**A/D or Serial**
IE	1	1	1	1	1	1	1
IF0 • $\overline{IM0}$	1	0	0	0	0	0	0
IF1 • $\overline{IM1}$	*	1	0	0	0	0	0
IFTA • $\overline{IMTA}$	*	*	1	0	0	0	0
IFTB • $\overline{IMTB}$ + IF2 • $\overline{IM2}$	*	*	*	1	0	0	0
IFTC • $\overline{IMTC}$ + IF3 • $\overline{IM3}$	*	*	*	*	1	0	0
IFTD • $\overline{IMTD}$	*	*	*	*	*	1	0
IFAD • $\overline{IMAD}$ + IFS • $\overline{IMS}$	*	*	*	*	*	*	1

Note: Bits marked * can be either 0 or 1. Their values have no effect on operation.

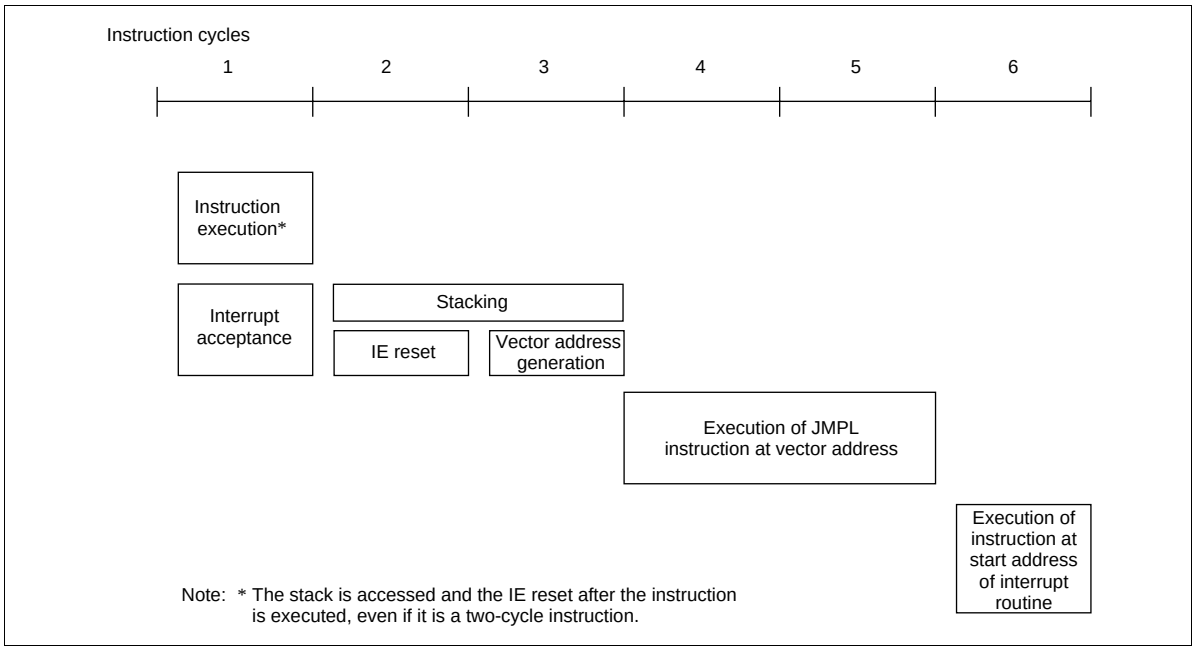


Figure 10 Interrupt Processing Sequence

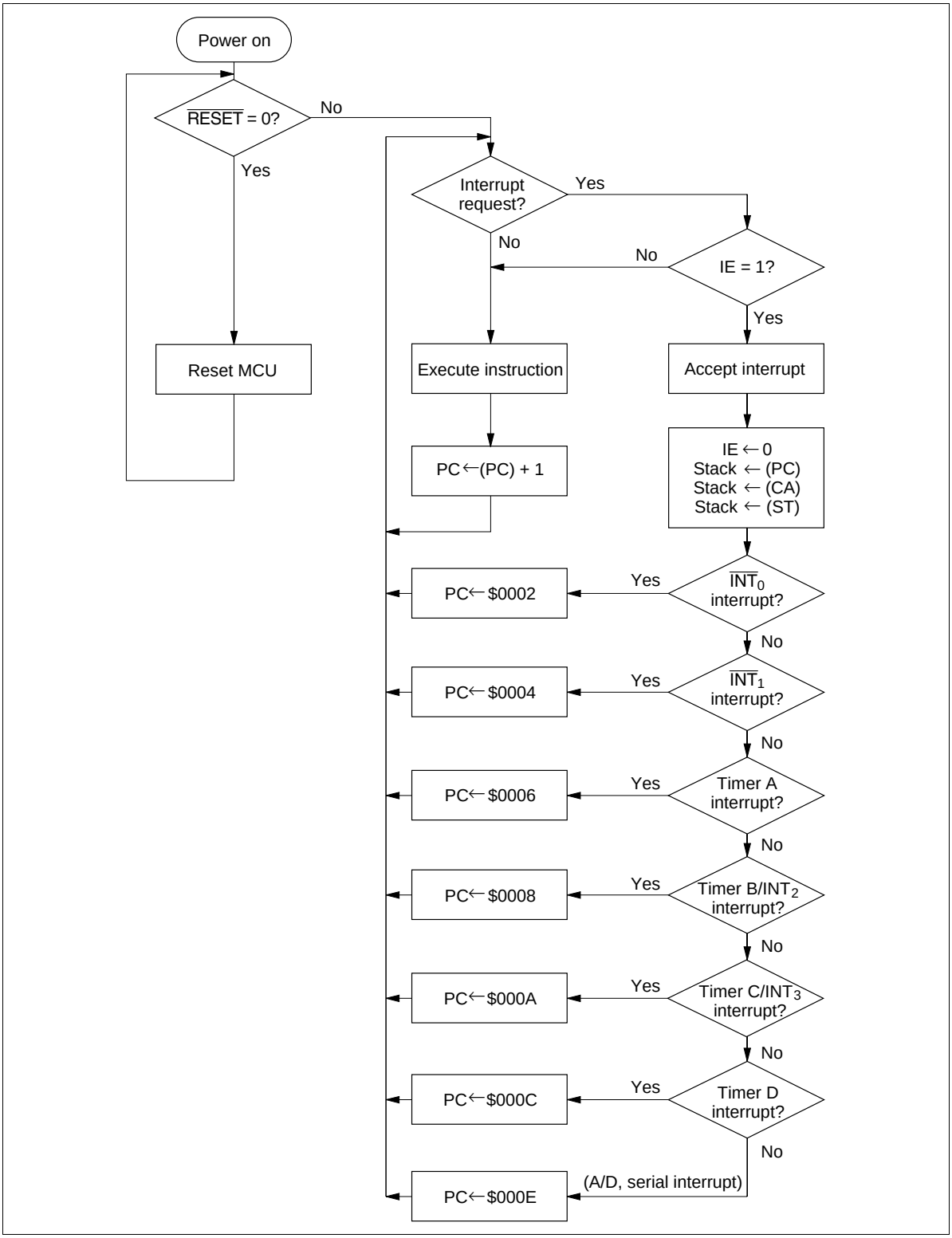


Figure 11 Interrupt Processing Flowchart

Interrupt Enable Flag (IE: $000, Bit 0): Controls the entire interrupt process. It is reset by the interrupt processing and set by the RTNI instruction, as listed in table 4.

Table 4 Interrupt Enable Flag (IE: $000, Bit 0)

IE	Interrupt Enabled/Disabled
0	Disabled
1	Enabled

External Interrupts ($\overline{INT}_0$, $\overline{INT}_1$, INT_2, INT_3): There are four external interrupt signals.

External Interrupt Request Flags (IF0–IF3: $000, $001, $022): IF0 and IF1 are set when the signals input to $\overline{INT}_0$ and $\overline{INT}_1$ are falling, and IF2 and IF3 are set when the signals input to INT_2 and INT_3 are rising or falling, as listed in table 5. The INT_2 and INT_3 interrupt edges are selected by the detection edge select registers (ESR1, ESR2: $026, $027) as shown in figures 12 and 13.

Table 5 External Interrupt Request Flags (IF0–IF3: $000, $001, $022)

IF0–IF3	Interrupt Request
0	No
1	Yes

Detection edge selection register 1 (ESR1: $026)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	ESR13	ESR12	ESR11	ESR10

ESR13	ESR12	INT_3 detection edge
0	0	No detection
	1	Falling-edge detection
1	0	Rising-edge detection
	1	Double-edge detection*

ESR11	ESR10	INT_2 detection edge
0	0	No detection
	1	Falling-edge detection
1	0	Rising-edge detection
	1	Double-edge detection*

Note: * Both falling and rising edges are detected.

Figure 12 Detection Edge Selection Register 1 (ESR1)

Detection edge selection register 2 (ESR2: $027)

Bit	3	2	1	0
Initial value	0	0	—	—
Read/Write	W	W	—	—
Bit name	ESR23	ESR22	Not used	Not used

ESR23	ESR22	EVND detection edge
0	0	No detection
	1	Falling-edge detection
1	0	Rising-edge detection
	1	Double-edge detection*

Note: * Both falling and rising edges are detected.

Figure 13 Detection Edge Selection Register 2 (ESR2)

External Interrupt Masks (IM0–IM3: $000, $001, $022): Prevent (mask) interrupt requests caused by the corresponding external interrupt request flags, as listed in table 6.

Table 6 External Interrupt Masks (IM0–IM3: $000, $001, $022)

IM0–IM3	Interrupt Request
0	Enabled
1	Disabled (masked)

Timer A Interrupt Request Flag (IFTA: $001, Bit 2): Set by overflow output from timer A, as listed in table 7.

Table 7 Timer A Interrupt Request Flag (IFTA: $001, Bit 2)

IFTA	Interrupt Request
0	No
1	Yes

Timer A Interrupt Mask (IMTA: $001, Bit 3): Prevents (masks) an interrupt request caused by the timer A interrupt request flag, as listed in table 8.

Table 8 Timer A Interrupt Mask (IMTA: $001, Bit 3)

IMTA	Interrupt Request
0	Enabled
1	Disabled (masked)

Timer B Interrupt Request Flag (IFTB: $002, Bit 0): Set by overflow output from timer B, as listed in table 9.

Table 9 Timer B Interrupt Request Flag (IFTB: $002, Bit 0)

IFTB	Interrupt Request
0	No
1	Yes

Timer B Interrupt Mask (IMTB: $002, Bit 1): Prevents (masks) an interrupt request caused by the timer B interrupt request flag, as listed in table 10.

Table 10 Timer B Interrupt Mask (IMTB: $002, Bit 1)

IMTB	Interrupt Request
0	Enabled
1	Disabled (masked)

Timer C Interrupt Request Flag (IFTC: $002, Bit 2): Set by overflow output from timer C, as listed in table 11.

Table 11 Timer C Interrupt Request Flag (IFTC: $002, Bit 2)

IFTC	Interrupt Request
0	No
1	Yes

Timer C Interrupt Mask (IMTC: $002, Bit 3): Prevents (masks) an interrupt request caused by the timer C interrupt request flag, as listed in table 12.

Table 12 Timer C Interrupt Mask (IMTC: $002, Bit 3)

IMTC	Interrupt Request
0	Enabled
1	Disabled (masked)

Timer D Interrupt Request Flag (IFTD: $003, Bit 0): Set by overflow output from timer D, or by the rising or falling edge of signals input to EVND when the input capture function is used, as listed in table 13.

Table 13 Timer D Interrupt Request Flag (IFTD: $003, Bit 0)

IFTD	Interrupt Request
0	No
1	Yes

Timer D Interrupt Mask (IMTD: $003, Bit 1): Prevents (masks) an interrupt request caused by the timer D interrupt request flag, as listed in table 14.

Table 14 Timer D Interrupt Mask (IMTD: $003, Bit 1)

IMTD	Interrupt Request
0	Enabled
1	Disabled (masked)

Serial Interrupt Request Flag (IFS: $023, Bit 2): Set when data transfer is completed or when data transfer is suspended, as listed in table 15.

Table 15 Serial Interrupt Request Flag (IFS: $023, Bit 2)

IFS	Interrupt Request
0	No
1	Yes

Serial Interrupt Mask (IMS: $023, Bit 3): Prevents (masks) an interrupt request caused by the serial interrupt request flag, as listed in table 16.

Table 16 Serial Interrupt Mask (IMS: $023, Bit 3)

IMS	Interrupt Request
0	Enabled
1	Disabled (masked)

A/D Interrupt Request Flag (IFAD: $003, Bit 2): Set at the completion of A/D conversion, as listed in table 17.

Table 17 A/D Interrupt Request Flag (IFAD: $003, Bit 2)

IFAD	Interrupt Request
0	No
1	Yes

A/D Interrupt Mask (IMAD: $003, Bit 3): Prevents (masks) an interrupt request caused by the A/D interrupt request flag, as listed in table 18.

Table 18 A/D Interrupt Mask (IMAD: $003, Bit 3)

IMAD	Interrupt Request
0	Enabled
1	Disabled (masked)

Operating Modes

The MCU has five operating modes as shown in table 19. The operations in each mode are listed in tables 20 and 21. Transitions between operating modes are shown in figure 14.

Table 19 Operating Modes and Clock Status

		Mode Name				
		Active	**Standby**	**Stop**	**Watch**	**Subactive*[2]**
Activation method		Reset cancellation, interrupt request $\overline{\text{STOPC}}$ cancellation in stop mode, STOP/SBY instruction in subactive mode (when direct transfer is selected)	SBY instruction	STOP instruction when TMA3 = 0	STOP instruction when TMA3 = 1	$\overline{\text{INT}}_0$ or timer A interrupt request from watch mode
Status	System oscillator	OP	OP	Stopped	Stopped	Stopped
	Subsystem oscillator	OP	OP	OP *[1]	OP	OP
Cancellation method		$\overline{\text{RESET}}$ input, STOP/SBY instruction	$\overline{\text{RESET}}$ input, interrupt request	$\overline{\text{RESET}}$ input, $\overline{\text{STOPC}}$ input in stop mode	$\overline{\text{RESET}}$ input $\overline{\text{INT}}_0$ or timer A interrupt request	$\overline{\text{RESET}}$ input, STOP/SBY instruction

Notes: OP implies in operation.

1. Operating or stopping the oscillator can be selected by setting bit 3 of the system clock select register (SSR: $029).
2. Subactive mode is an optional function; specify it on the function option list.

Table 20 Operations in Low-Power Dissipation Modes

Function	Stop Mode	Watch Mode	Standby Mode	Subactive Mode*[2]
CPU	Reset	Retained	Retained	OP
RAM	Retained	Retained	Retained	OP
Timer A	Reset	OP	OP	OP
Timer B	Reset	Stopped	OP	OP
Timer C	Reset	Stopped	OP	OP
Timer D	Reset	Stopped	OP	OP
Serial	Reset	Stopped*[3]	OP	OP
A/D	Reset	Stopped	OP	Stopped
LCD	Reset	OP*[4]	OP	OP
I/O	Reset*[1]	Retained	Retained	OP

Notes: OP implies in operation.

1. Output pins are at high impedance.
2. Subactive mode is an optional function specified on the function option list.
3. Transmission/reception is activated if a clock is input in external clock mode. However, interrupts stop.
4. When a 32-kHz clock source is used.

Table 21 I/O Status in Low-Power Dissipation Modes

	Output		Input
	Standby Mode, Watch Mode	Stop Mode	Active Mode, Subactive Mode
D_0–D_8	Retained	High impedance	Input enabled
D_{10}, D_{11}	—	—	Input enabled
R0–R3, R6, R7	Retained or output of peripheral functions	High impedance	Input enabled

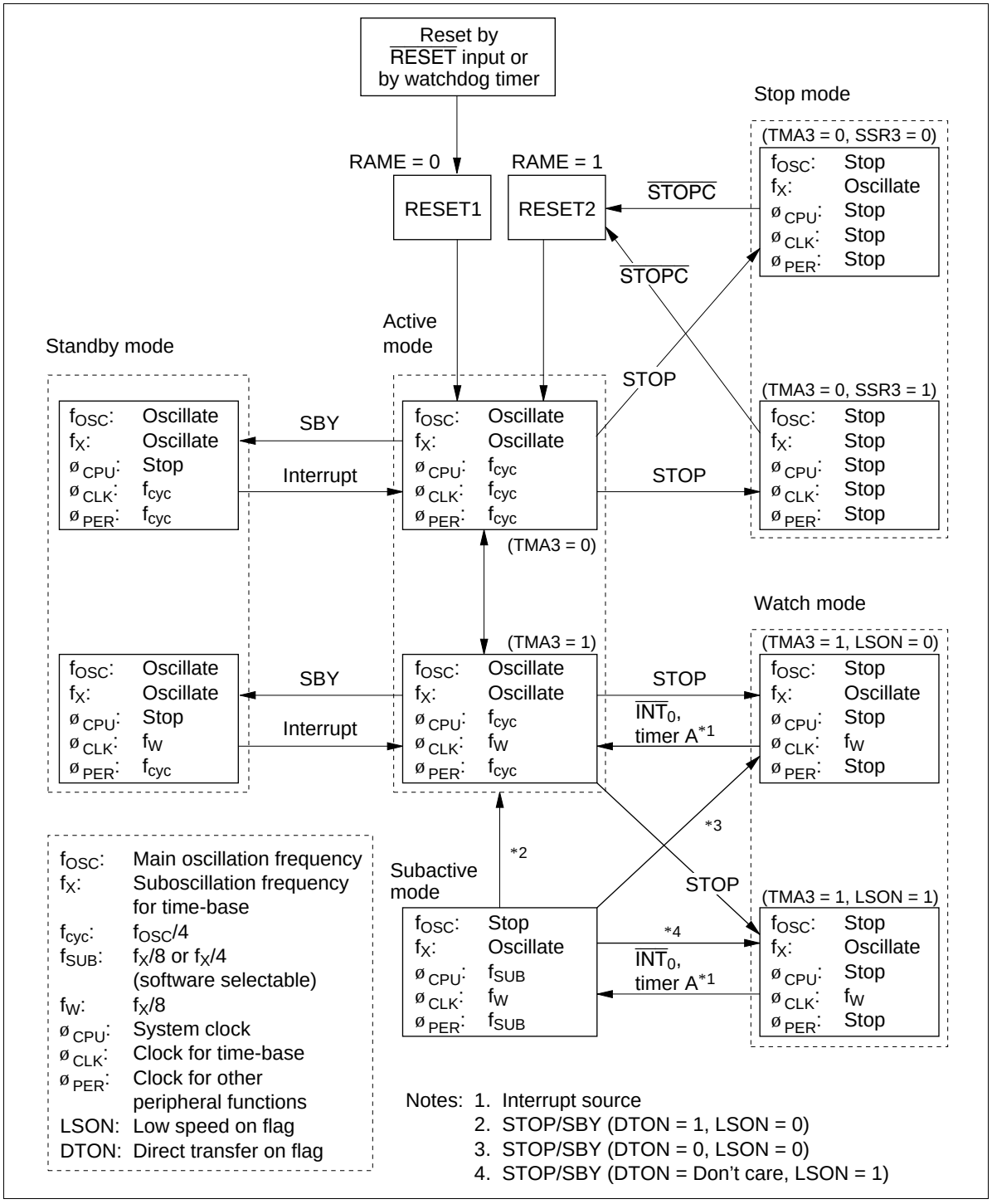


Figure 14 MCU Status Transitions

Active Mode: All MCU functions operate according to the clock generated by the system oscillator OSC_1 and OSC_2.

Standby Mode: In standby mode, the oscillators continue to operate, but the clocks related to instruction execution stop. Therefore, the CPU operation stops, but all RAM and register contents are retained, and the D or R port status, when set to output, is maintained. Peripheral functions such as interrupts, timers, and serial interface continue to operate. The power dissipation in this mode is lower than in active mode because the CPU stops.

The MCU enters standby mode when the SBY instruction is executed in active mode.

Standby mode is terminated by a $\overline{\text{RESET}}$ input or an interrupt request. If it is terminated by $\overline{\text{RESET}}$ input, the MCU is reset as well. After an interrupt request, the MCU enters active mode and executes the next instruction after the SBY instruction. If the interrupt enable flag is 1, the interrupt is then processed; if it is 0, the interrupt request is left pending and normal instruction execution continues. A flowchart of operation in standby mode is shown in figure 15.

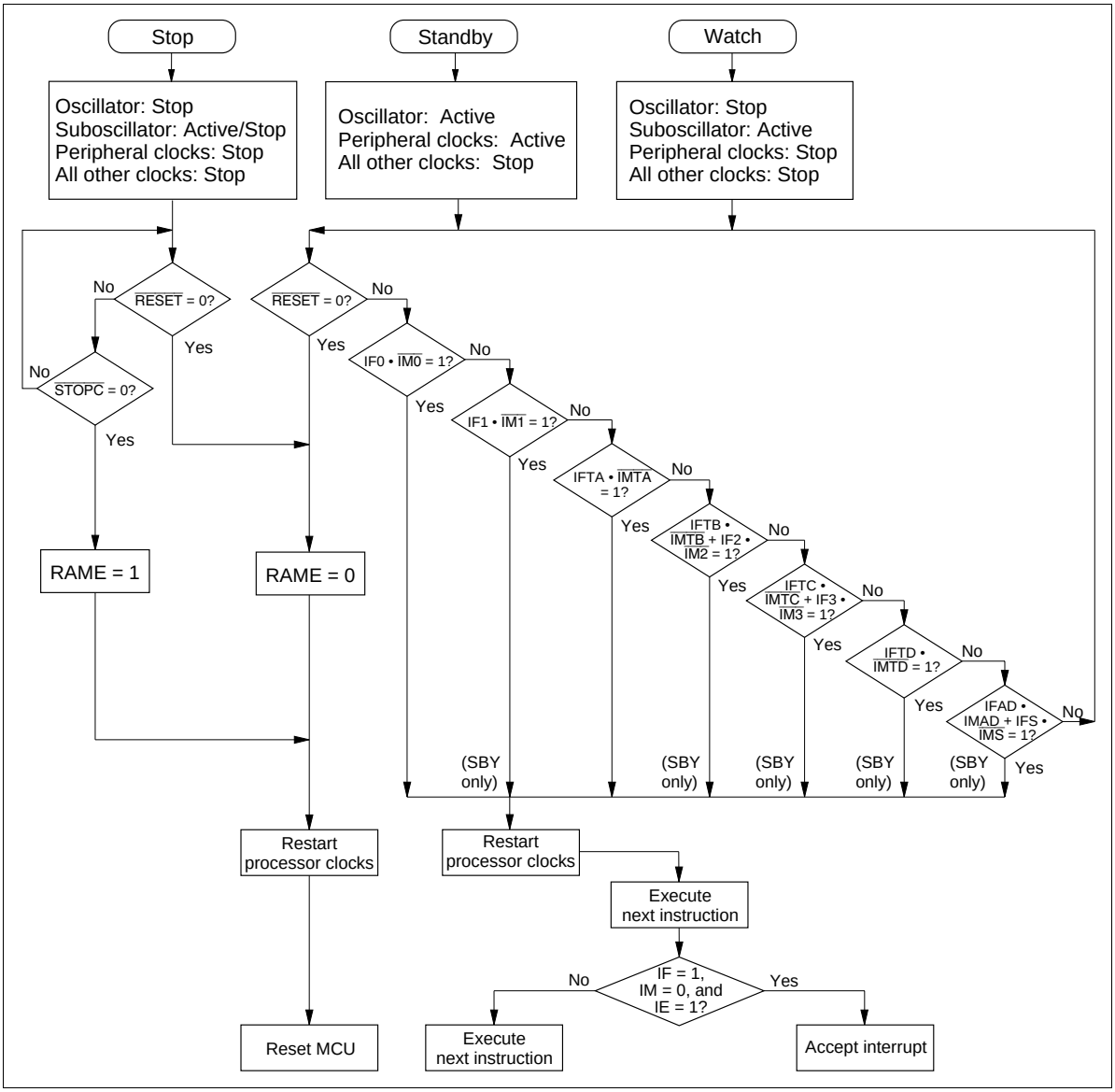


Figure 15 MCU Operation Flowchart

Stop Mode: In stop mode, all MCU operations stop and RAM data is retained. Therefore, the power dissipation in this mode is the least of all modes. The OSC_1 and OSC_2 oscillator stops. The X1 and X2 oscillator can be selected to operate by setting bit 3 of the system clock select register (SSR: $029; operating: SSR3 = 0, stop: SSR3 = 1) (figure 26). The MCU enters stop mode if the STOP instruction is executed in active mode when bit 3 of timer mode register A (TMA: $008) is set to 0 (TMA3 = 0) (figure 41).

Stop mode is terminated by a $\overline{\text{RESET}}$ input or a $\overline{\text{STOPC}}$ input as shown in figure 16. $\overline{\text{RESET}}$ or $\overline{\text{STOPC}}$ must be applied for at least one t_{RC} to stabilize oscillation (refer to the AC Characteristics section). When the MCU restarts after stop mode is cancelled, all RAM contents before entering stop mode are retained,

but the accuracy of the contents of the accumulator, B register, W register, X/SPX register, Y/SPY register, carry flag, and serial data register cannot be guaranteed.

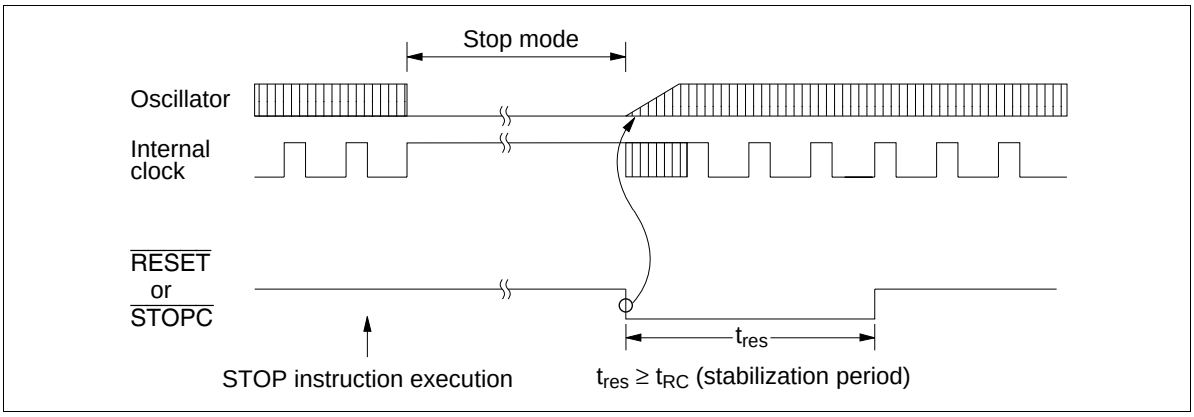


Figure 16 Timing of Stop Mode Cancellation

Watch Mode: In watch mode, the clock function (timer A) using the X1 and X2 oscillator and the LCD function operate, but other function operations stop. Therefore, the power dissipation in this mode is the second least to stop mode, and this mode is convenient when only clock display is used. In this mode, the OSC_1 and OSC_2 oscillator stops, but the X1 and X2 oscillator operates. The MCU enters watch mode if the STOP instruction is executed in active mode when TMA3 = 1, or if the STOP or SBY instruction is executed in subactive mode.

Watch mode is terminated by a $\overline{\text{RESET}}$ input or a timer-A/$\overline{\text{INT}_0}$ interrupt request. For details of $\overline{\text{RESET}}$ input, refer to the Stop Mode section. When terminated by a timer-A/$\overline{\text{INT}_0}$ interrupt request, the MCU enters active mode if LSON = 0, or subactive mode if LSON = 1. After an interrupt request is generated, the time required to enter active mode is t_{RC} for a timer A interrupt, and T_X (where $T + t_{RC} < T_X < 2T + t_{RC}$) for an INT_0 interrupt, as shown in figures 17 and 18.

Operation during mode transition is the same as that at standby mode cancellation (figure 15).

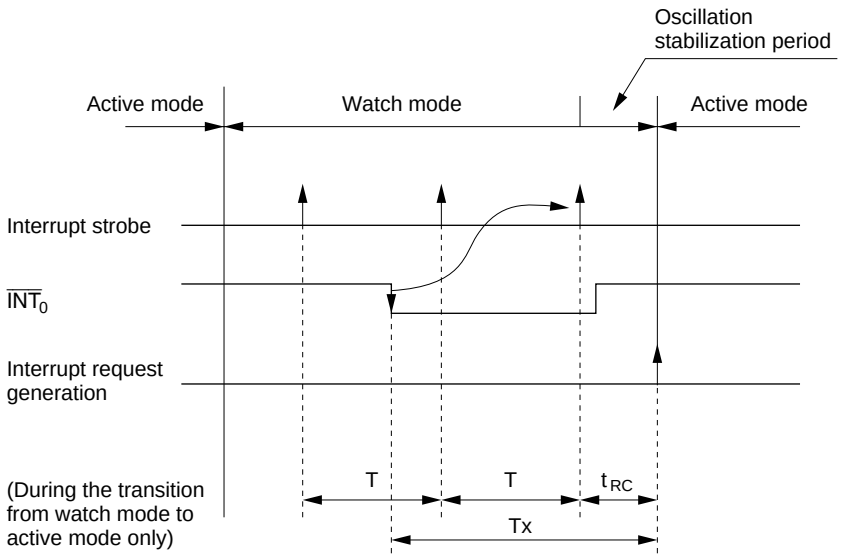


Figure 17 Interrupt Frame

Miscellaneous register (MIS: $00C)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	MIS3	MIS2	MIS1	MIS0

MIS3	MIS2
Buffer control. Refer to figure 38.	

MIS1	MIS0	T*1	t_{RC}*1	Oscillation circuit conditions
0	0	0.24414 ms	0.12207 ms	External clock input
			0.24414 ms*2	
0	1	15.625 ms	7.8125 ms	Ceramic oscillator
1	0	62.5 ms	31.25 ms	Crystal oscillator
1	1	Not used		—

Notes: 1. The values of T and t_{RC} are applied when a 32.768-kHz crystal oscillator is used.
2. The value is applied only when direct transfer operation is used.

Figure 18 Miscellaneous Register (MIS)

Subactive Mode: The OSC_1 and OSC_2 oscillator stops and the MCU operates with a clock generated by the X1 and X2 oscillator. In this mode, functions except the A/D conversion operate. However, because the operating clock slows down, power dissipation is reduced, next least to watch mode.

The CPU instruction execution speed can be selected as 244 µs or 122 µs by setting bit 2 (SSR2) of the system clock select register (SSR: $029). Note that the SSR2 value must be changed in active mode. If the value is changed in subactive mode, the MCU may malfunction.

When the STOP or SBY instruction is executed in subactive mode, the MCU enters either watch or active mode, depending on the statuses of the low speed on flag (LSON: $020, bit 0) and the direct transfer on flag (DTON: $020, bit 3).

Interrupt Frame: In watch and subactive modes, ϕ_{CLK} is applied to timer A and the $\overline{INT_0}$ circuit. Prescaler W and timer A operate as the time-base and generate the timing clock for the interrupt frame. Three interrupt frame lengths (T) can be selected by setting the miscellaneous register (MIS: $00C) (figure 18).

In watch and subactive modes, a timer-A/$\overline{INT_0}$ interrupt is generated synchronously with the interrupt frame. An interrupt request is generated synchronously with an interrupt strobe except during transition to active mode. The falling edge of the $\overline{INT_0}$ signal is input asynchronously with the interrupt frame timing, but it is regarded as input synchronously with the second interrupt strobe clock after the falling edge. An overflow and interrupt request in timer A is generated synchronously with the interrupt strobe.

Direct Transition from Subactive Mode to Active Mode: Available by controlling the direct transfer on flag (DTON: $020, bit 3) and the low speed on flag (LSON: $020, bit 0). The procedures are described below:

- Set LSON to 0 and DTON to 1 in subactive mode.
- Execute the STOP or SBY instruction.
- The MCU automatically enters active mode from subactive mode after waiting for the MCU internal processing time and oscillation stabilization time (figure 19).

Notes: 1. The DTON flag ($020, bit 3) can be set only in subactive mode. It is always reset in active mode.

2. The transition time (T_D) from subactive mode to active mode:

   $t_{RC} < T_D < T + t_{RC}$

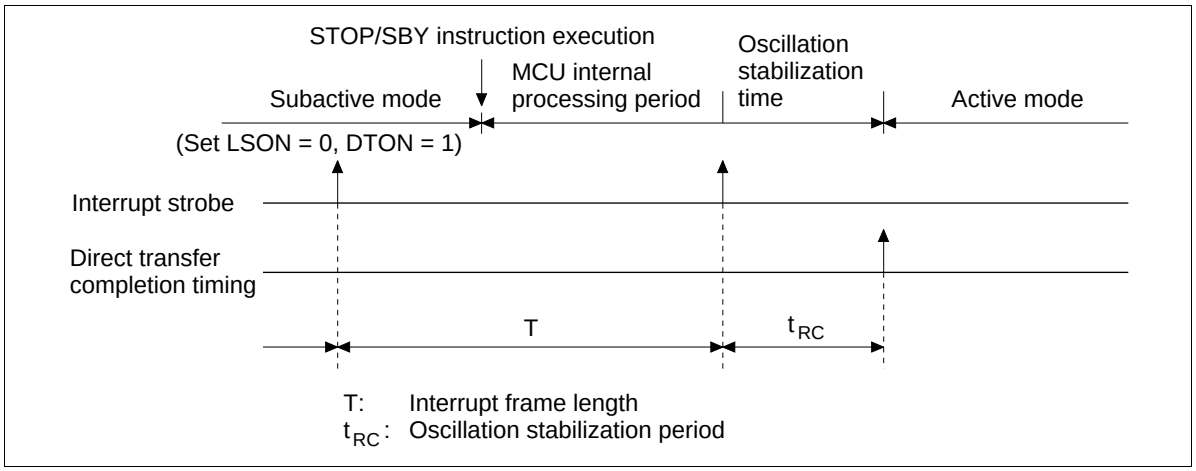


Figure 19 Direct Transition Timing

Stop Mode Cancellation by $\overline{\text{STOPC}}$: The MCU enters active mode from stop mode by inputting $\overline{\text{STOPC}}$ or $\overline{\text{RESET}}$. In either case, the MCU starts instruction execution from the starting address (address 0) of the program. However, the value of the RAM enable flag (RAME: $021, bit 3) differs between cancellation by $\overline{\text{STOPC}}$ and by $\overline{\text{RESET}}$. When stop mode is cancelled by $\overline{\text{RESET}}$, RAME = 0; when cancelled by $\overline{\text{STOPC}}$, RAME = 1. $\overline{\text{RESET}}$ can cancel all modes, but $\overline{\text{STOPC}}$ is valid only in stop mode; $\overline{\text{STOPC}}$ input is ignored in other modes. Therefore, when the program needs to confirm that stop mode has been cancelled by $\overline{\text{STOPC}}$ (for example, when the RAM contents before entering stop mode are used after transition to active mode), execute the TEST instruction on the RAM enable flag (RAME) at the beginning of the program.

MCU Operation Sequence: The MCU operates in the sequence shown in figures 20 to 22. It is reset by an asynchronous $\overline{\text{RESET}}$ input, regardless of its status.

The low-power mode operation sequence is shown in figure 22. With the IE flag cleared and an interrupt flag set together with its interrupt mask cleared, if a STOP/SBY instruction is executed, the instruction is cancelled (regarded as an NOP) and the following instruction is executed. Before executing a STOP/SBY instruction, make sure all interrupt flags are cleared or all interrupts are masked.

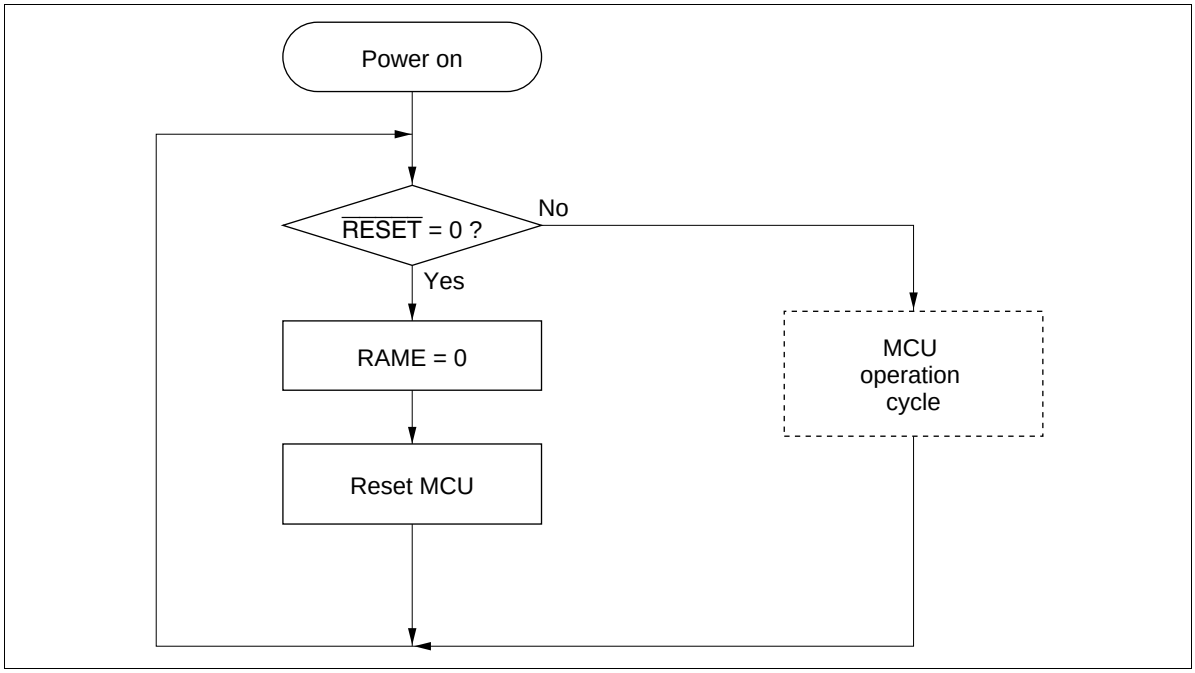


Figure 20 MCU Operating Sequence (Power On)

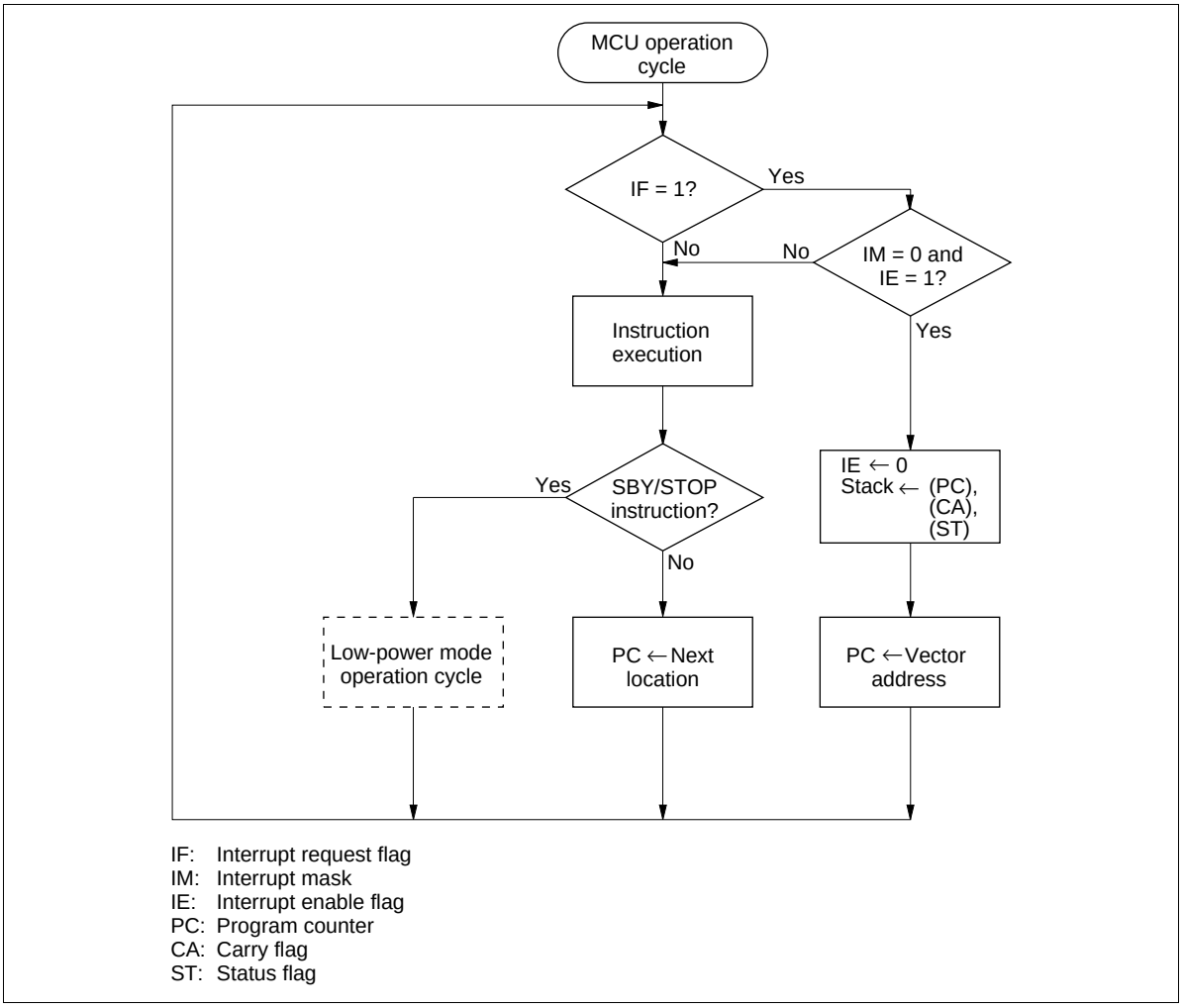


Figure 21 MCU Operating Sequence (MCU Operation Cycle)

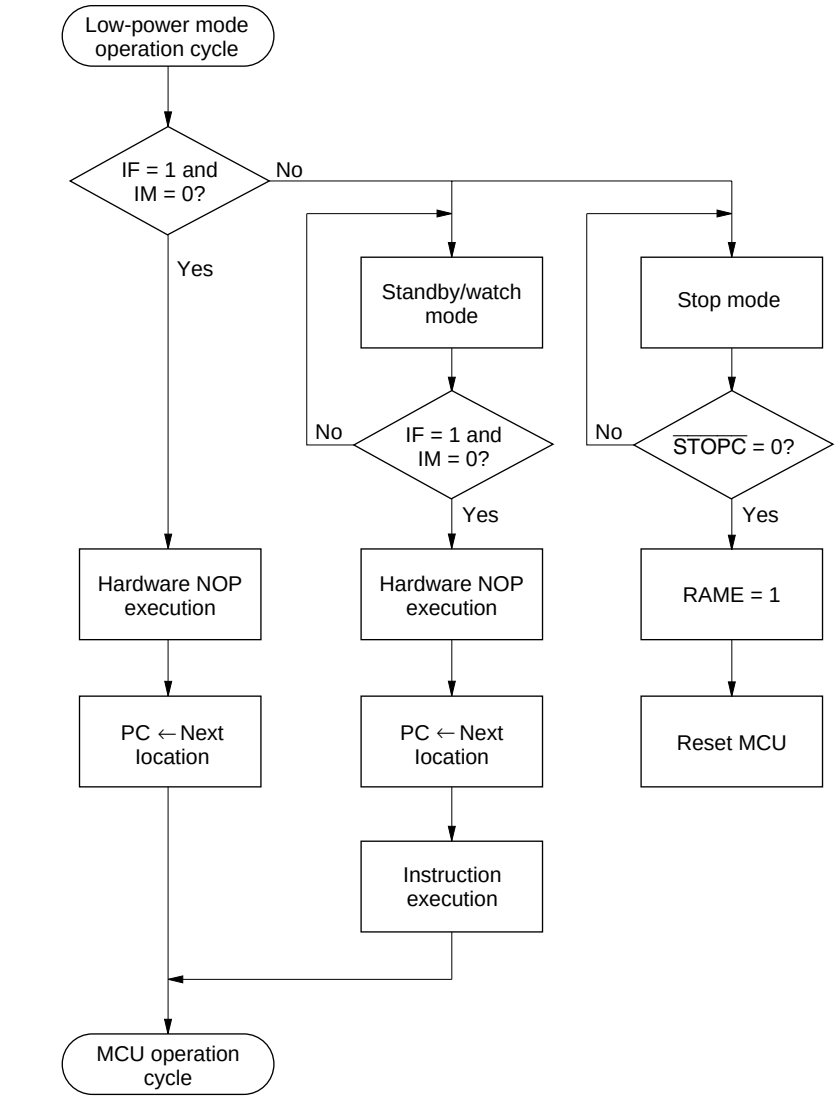


Figure 22 MCU Operating Sequence (Low-Power Mode Operation)

Notes on Use:

- When the MCU is in watch mode or subactive mode, if the high level period before the falling edge of $\overline{INT_0}$ is shorter than the interrupt frame, $\overline{INT_0}$ will not be detected. Also, if the low level period after the falling edge of $\overline{INT_0}$ is shorter than the interrupt frame, $\overline{INT_0}$ will not be detected.

  Edge detection is shown in figure 23. The level of the $\overline{INT_0}$ signal is sampled by a sampling clock. When this sampled value changes from high to low, a falling edge is detected.

In figure 24, the level of the $\overline{INT_0}$ signal is sampled by an interrupt frame. In (a) the sampled value is low at point A, and also low at point B. Therefore, a falling edge will not be detected. In (b), the sampled value is high at point A, and also high at point B. A falling edge will not be detected in this case either.

When the MCU is in watch mode or subactive mode, keep the high level and low level period of $\overline{INT_0}$ longer than the interrupt frame.

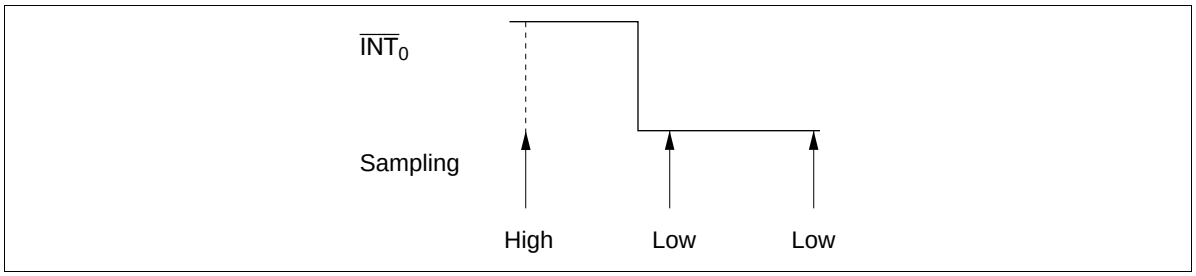


Figure 23 Edge Detection

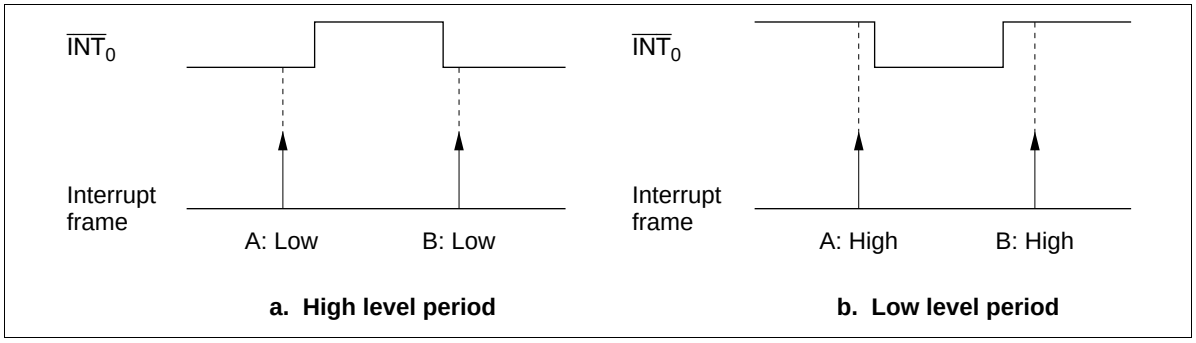


Figure 24 Sampling Example

Internal Oscillator Circuit

A block diagram of the clock generation circuit is shown in figure 25. As shown in table 22, a ceramic or crystal oscillator can be connected to OSC_1 and OSC_2, and a 32.768-kHz oscillator can be connected to X1 and X2. The system oscillator can also be operated by an external clock. Bit 1 (SSR1) of the system clock select register (SSR: $029) must be set according to the fre quency of the oscillator connected to OSC_1 and OSC_2 (figure 26).

Note: If the system clock select register (SSR: $029) setting does not match the oscillator frequency, subsystems using the 32.768-kHz oscillation will malfunction.

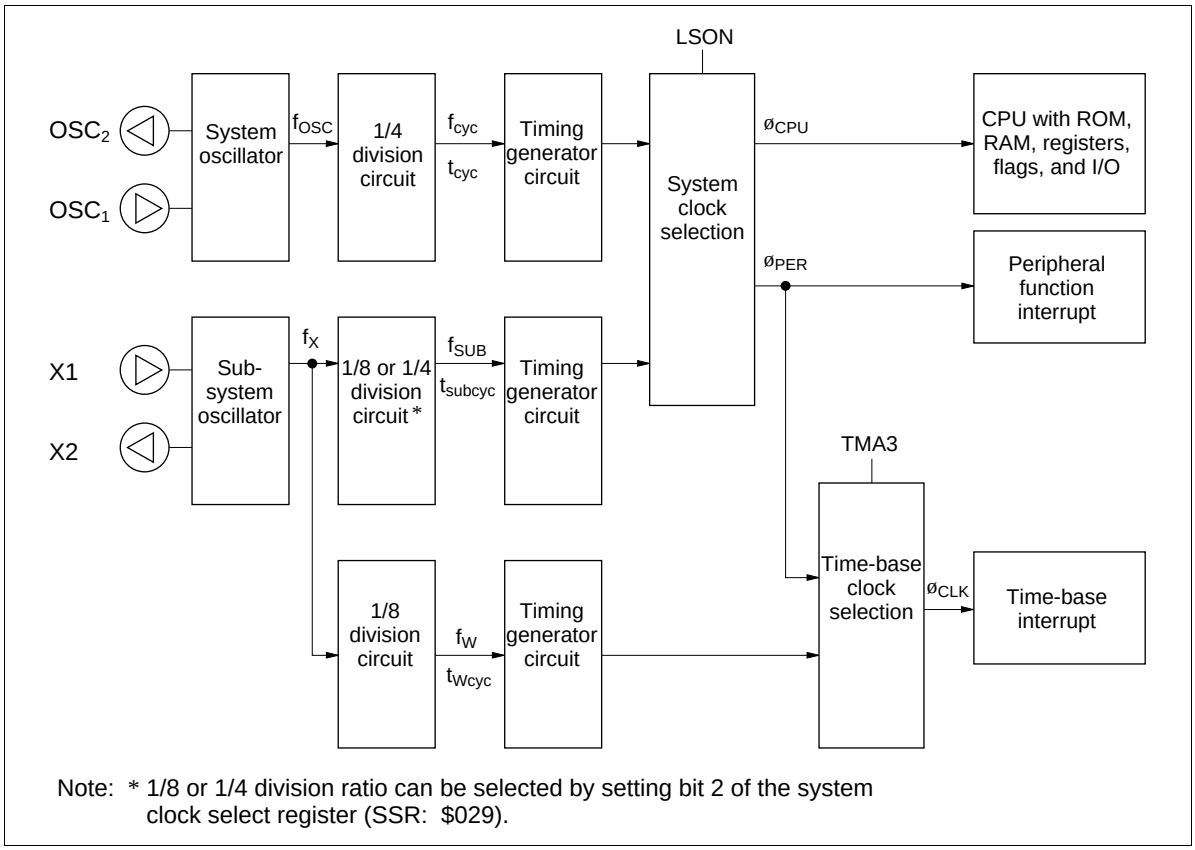


Figure 25 Clock Generation Circuit

System clock select register (SSR: $029)

Bit	3	2	1	0
Initial value	0	0	0	—
Read/Write	W	W	W	—
Bit name	SSR3*	SSR2	SSR1	Not used

SSR3	32-kHz oscillation stop
0	Oscillation operates in stop mode
1	Oscillation stops in stop mode

SSR1	System oscillation frequency selection
0	0.4 MHz – 1.0 MHz
1	1.6 MHz – 4.5 MHz

SSR2	32-kHz oscillation division ratio selection
0	$f_{SUB} = f_X/8$
1	$f_{SUB} = f_X/4$

Note: * SSR3 is cleared only by a $\overline{\text{RESET}}$ input. SSR3 will not be cleared by a $\overline{\text{STOPC}}$ input during stop mode, and will retain its value.
SSR3 will also not be cleared upon entering stop mode.

Figure 26 System Clock Select Register

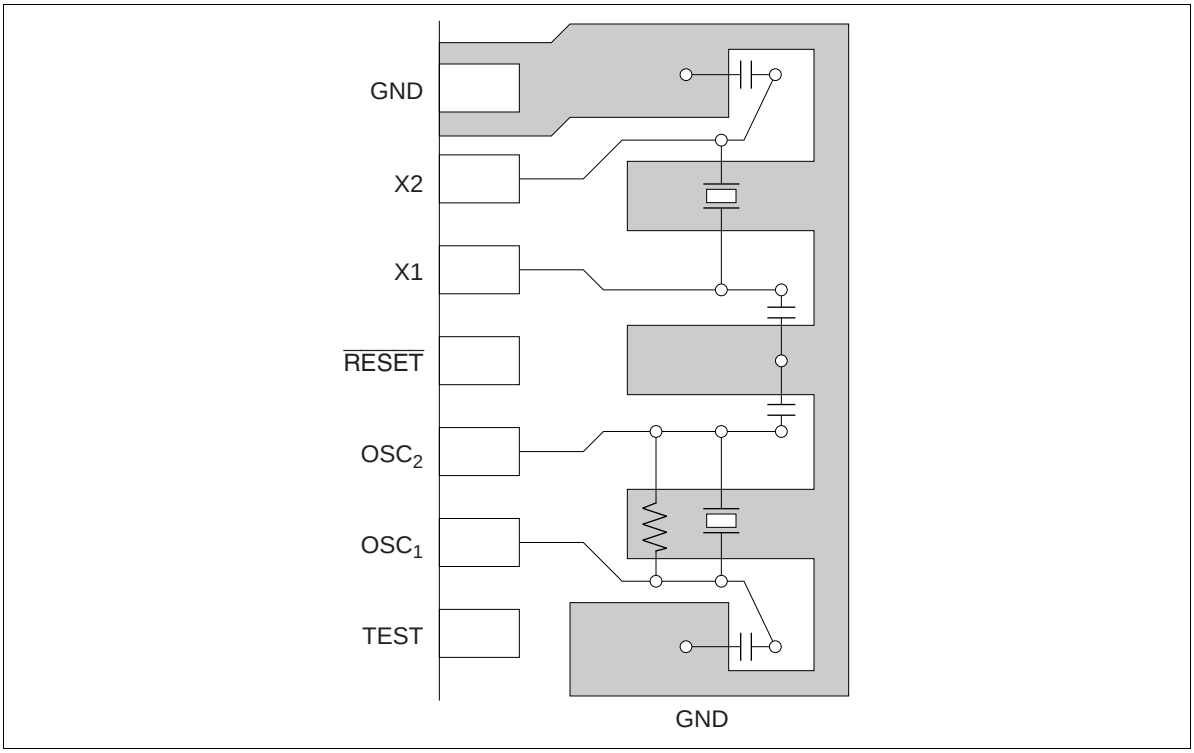
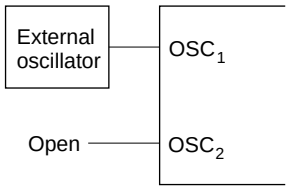
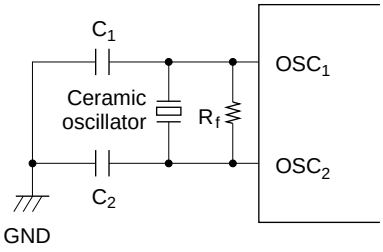
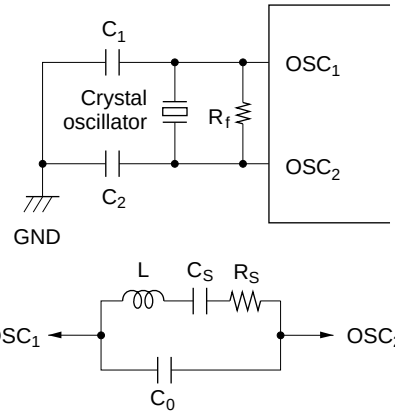
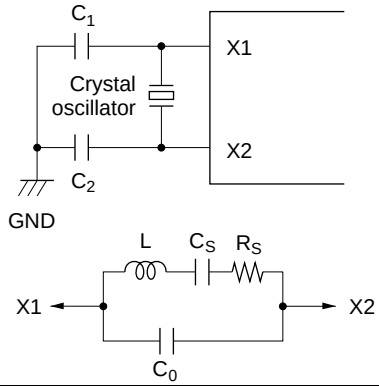


Figure 27 Typical Layout of Crystal and Ceramic Oscillators

Table 22 Oscillator Circuit Examples

	Circuit Configuration	Circuit Constants
External clock operation		
Ceramic oscillator (OSC_1, OSC_2)		Ceramic oscillator: CSA4.00MG (Murata) R_f = 1 MΩ ± 20% $C_1 = C_2$ = 30 pF ± 20%
Crystal oscillator (OSC_1,OSC_2)		R_f = 1 MΩ ± 20% $C_1 = C_2$ = 10 to 22 pF ± 20% Equivalent circuit of crystal oscillator shown at left. C_0: 7 pF max R_S: 100 Ω max
Crystal oscillator (X1, X2)		Crystal: 32.768 kHz: MX38T (Nippon Denpa) $C_1 = C_2$ = 20 pF ± 20% R_S: 14 kΩ C_0: 1.5 pF

Notes: 1. Circuit constants differ by the different types of crystal oscillators and ceramic oscillators, and with the stray capacitance of the board, so consult the manufacturer of the oscillator to determine the circuit parameters.

2. The wiring between the OSC_1 and OSC_2 pins (X1 and X2 pins) and the other elements should be as short as possible, and must not cross other wiring. Refer to figure 27.

3. If not using a 32.768-kHz crystal oscillator, fix the X1 pin to V_{CC} and leave the X2 pin open.

Input/Output

The MCU has 33 input/output pins (D_0–D_8, R0–R3, R6, and R7) and two input pins (D_{10}, D_{11}). The features are described below.

- Nine pins (D_0–D_8) are high-current input/output pins.
- The D_{10}, D_{11}, $R0_0$–$R0_2$, R1–R3, R6, and R7 input/output pins are multiplexed with peripheral function pins such as for the timers or serial interface. For these pins, the peripheral function setting is done prior to the D or R port setting. Therefore, when a peripheral function is selected for a pin, the pin function and input/output selection are automatically switched according to the setting.
- Input or output selection for input/output pins and port or peripheral function selection for multiplexed pins are set by software.
- Peripheral function output pins are CMOS output pins. Only the $R2_3$/SO pin can be set to NMOS open-drain output by software.
- In stop mode, the MCU is reset, and therefore peripheral function selection is cancelled. The data control register (DCD, DCR) is also reset, so input/output pins go to the high-impedance state.
- Each input/output pin has a built-in pull-up MOS, which can be individually turned on or off by software.

I/O buffer configuration is shown in figure 28, programmable I/O circuits are listed in table 23, and I/O pin circuit types are shown in table 24.

Table 23 Programmable I/O Circuits

MIS3 (bit 3 of MIS)		**0**				**1**			
DCD, DCR		**0**		**1**		**0**		**1**	
PDR		**0**	**1**	**0**	**1**	**0**	**1**	**0**	**1**
CMOS buffer	PMOS	—	—	—	On	—	—	—	On
	NMOS	—	—	On	—	—	—	On	—
Pull-up MOS		—	—	—	—	—	On	—	On

Note: — indicates off status.

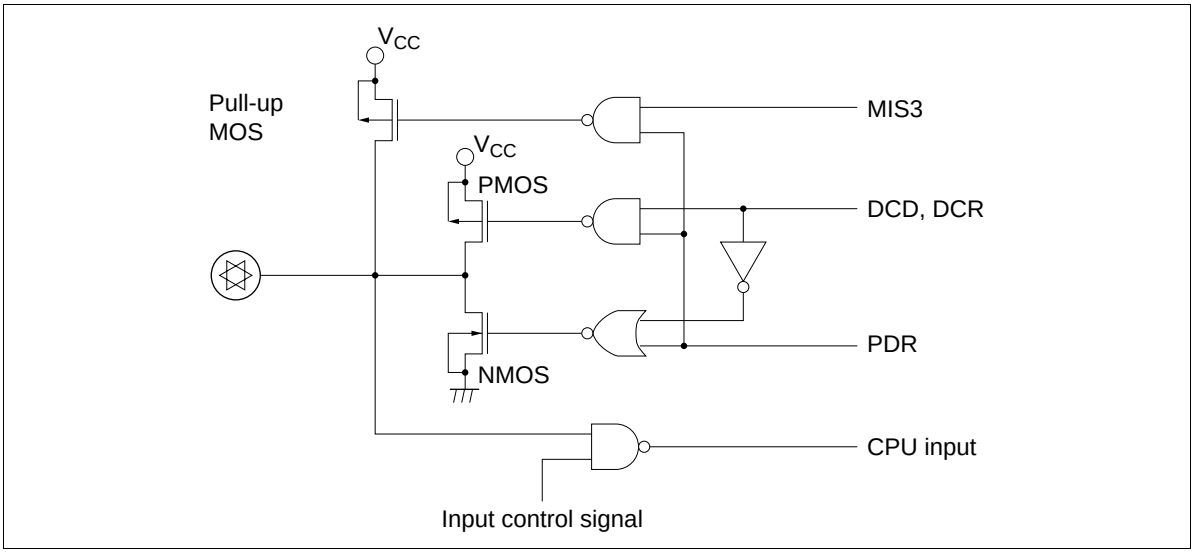
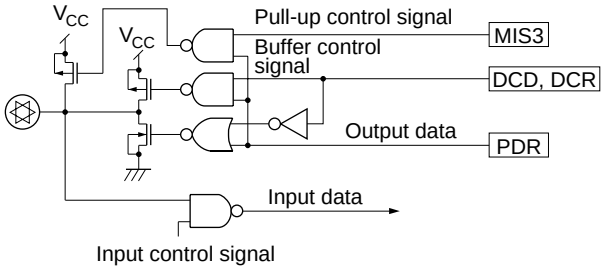
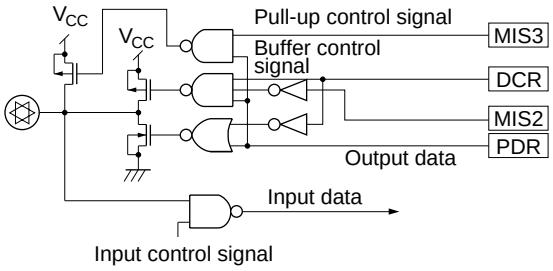
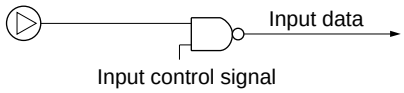
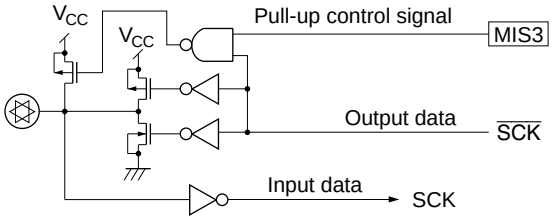
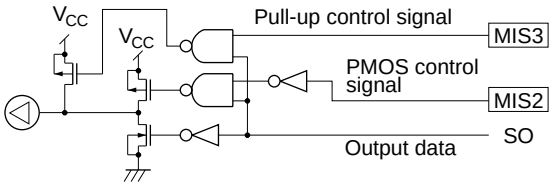
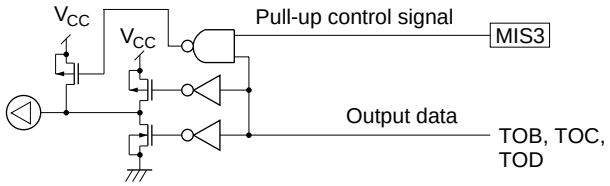
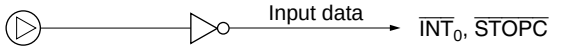
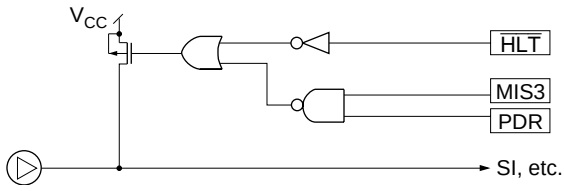
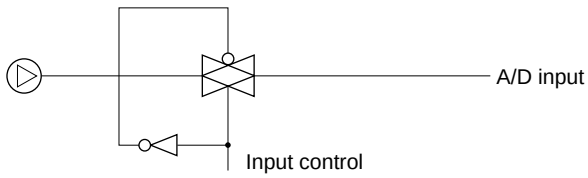
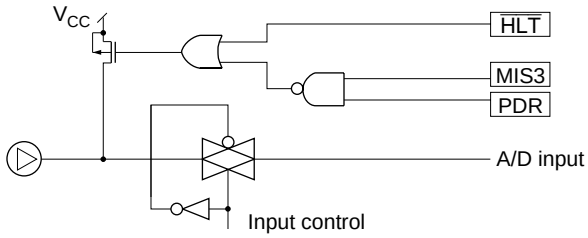


Figure 28 I/O Buffer Configuration

Table 24 Circuit Configurations of I/O Pins

I/O Pin Type		Circuit	Pins
Input/output pins			D_0–D_8 $R0_0$–$R0_3$ $R1_0$–$R1_3$ $R2_0$–$R2_2$ $R3_0$–$R3_3$ $R6_0$–$R6_3$ $R7_0$–$R7_3$
			$R2_3$
Input pins			D_{10}, D_{11}
Peripheral function pins	Input/ output pins		$\overline{SCK}$
	Output pins		SO
			TOB, TOC, TOD

I/O Pin Type		Circuit	Pins
Peripheral function pins	Input pins		$\overline{INT_0}$, $\overline{STOPC}$
			SI, $\overline{INT_1}$, INT_2, INT_3, $\overline{EVNB}$, EVND
			AN_0–AN_3
			AN_4–AN_7

Note: The MCU is reset in stop mode, and an peripheral function selections are cancelled. The I/O control register is reset, so the input/output pins enter high-impedance state.

D Port: Consist of nine input/output pins and two input pins addressed by one bit. D_0–D_8 are high-current I/O pins, and D_{10} and D_{11} are input-only pins.

Pins D_0–D_8 are set by the SED and SEDD instructions, and reset by the RED and REDD instructions. Output data is stored in the port data register (PDR) for each pin. All pins of the D port are tested by the TD and TDD instructions.

The on/off statuses of the output buffers are controlled by D port data control registers (DCD0–DCD2: \$02C–\$02E) that are mapped to memory addresses (figure 29).

Pins D_{10} and D_{11} are multiplexed with peripheral function pins $\overline{STOPC}$ and $\overline{INT_0}$, respectively. The peripheral function modes of these pins are selected by bits 2 and 3 (PMRC2, PMRC3) of port mode register C (PMRC: \$025) (figure 34).

R Ports: 24 input/output pins addressed in 4-bit units. Data is input to these ports by the LAR and LBR instructions, and output from them by the LRA and LRB instructions. Output data is stored in the port data register (PDR) for each pin. The on/off statuses of the output buffers of the R ports are controlled by R port data control registers (DCR0–DCR3, DCR6, DCR7: \$030–\$033, \$036, \$037) that are mapped to memory addresses (figure 29).

Pins $R0_0$–$R0_2$ are multiplexed with peripheral pins $\overline{INT}_1$–INT_3, respectively. The peripheral function modes of these pins are selected by bits 0–2 (PMRB0–PMRB2) of port mode register B (PMRB: $024) (figure 30).

Pins $R1_0$–$R1_2$ are multiplexed with peripheral pins TOB, TOC, and TOD, respectively. The peripheral function modes of these pins are selected by bits 0 and 1 (TMB20, TMB21) of timer mode register B2 (TMB2: $013), bits 0–2 (TMC20–TMC22) of timer mode register C2 (TMC2: $014), and bits 0–3 (TMD20–TMD23) of timer mode register D2 (TMD2: $015) (figures 32, 31, and 33).

Pins $R1_3$ and $R2_0$ are multiplexed with peripheral pins $\overline{EVNB}$ and EVND, respectively. The peripheral function modes of these pins are selected by bits 0 and 1 (PMRC0, PMRC1) of port mode register C (PMRC: $025) (figure 34).

Pins $R2_1$–$R2_3$ are multiplexed with peripheral pins $\overline{SCK}$, SI, and SO, respectively. The peripheral function modes of these pins are selected by bit 3 (SMRA3) of serial mode register A (SMRA: $005), and bits 0 and 1 (PMRA0, PMRA1) of port mode register A (PMRA: $004), as shown in figures 35 and 36.

Ports R6 and R7 are multiplexed with segment pins SEG13–SEG20, respectively. The function modes of these pins can be selected in 4-pin units by setting LCD output register 3 (LOR3: $01F) (figure 37).

Data control register (DCD0 to DCD2: $02C to $02E)
(DCR0 to DCR7: $030 to $037)

DCD0, DCD1

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	DCD03, DCD13	DCD02, DCD12	DCD01, DCD11	DCD00, DCD10

DCD2

Bit	3	2	1	0
Initial value	—	—	—	0
Read/Write	—	—	—	W
Bit name	Not used	Not used	Not used	DCD20

DCR0 to DCR3, DCR6, DCR7

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	DCR03–DCR33 DCR63–DCR73	DCR02–DCR32 DCR62–DCR72	DCR01–DCR31 DCR61–DCR71	DCR00–DCR30 DCR60–DCR70

All Bits	CMOS Buffer On/Off Selection
0	Off (high-impedance)
1	On

Correspondence between ports and DCD/DCR bits

Register Name	Bit 3	Bit 2	Bit 1	Bit 0
DCD0	D_3	D_2	D_1	D_0
DCD1	D_7	D_6	D_5	D_4
DCD2	—	—	—	D_8
DCR0	$R0_3$	$R0_2$	$R0_1$	$R0_0$
DCR1	$R1_3$	$R1_2$	$R1_1$	$R1_0$
DCR2	$R2_3$	$R2_2$	$R2_1$	$R2_0$
DCR3	$R3_3$	$R3_2$	$R3_1$	$R3_0$
DCR6	$R6_3$	$R6_2$	$R6_1$	$R6_0$
DCR7	$R7_3$	$R7_2$	$R7_1$	$R7_0$

Figure 29 Data Control Registers (DCD, DCR)

Port mode register B (PMRB: $024)

Bit	3	2	1	0
Initial value	—	0	0	0
Read/Write	—	W	W	W
Bit name	Not used	PMRB2	PMRB1	PMRB0

PMRB2	$R0_2/INT_3$ mode selection
0	$R0_2$
1	INT_3

PMRB0	$R0_0/\overline{INT}_1$ mode selection
0	$R0_0$
1	$\overline{INT}_1$

PMRB1	$R0_1/INT_2$ mode selection
0	$R0_1$
1	INT_2

Figure 30 Port Mode Register B (PMRB)

Timer mode register C2 (TMC2: $014)

Bit	3	2	1	0
Initial value	—	0	0	0
Read/Write	—	R/W	R/W	R/W
Bit name	Not used	TMC22	TMC21	TMC20

TMC22	TMC21	TMC20	$R1_1$/TOC mode selection	
0	0	0	$R1_1$	$R1_1$ port
		1	TOC	Toggle output
	1	0	TOC	0 output
		1	TOC	1 output
1	0	0	—	Inhibited
		1		
	1	0		
		1	TOC	PWM output

Figure 31 Timer Mode Register C2 (TMC2)

Timer mode register B2 (TMB2: $013)

Bit	3	2	1	0
Initial value	—	—	0	0
Read/Write	—	—	R/W	R/W
Bit name	Not used	Not used	TMB21	TMB20

TMB21	TMB20	$R1_0$/TOB mode selection	
0	0	$R1_0$	$R1_0$ port
	1	TOB	Toggle output
1	0	TOB	0 output
	1	TOB	1 output

Figure 32 Timer Mode Register B2 (TMB2)

Timer mode register D2 (TMD2: $015)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W
Bit name	TMD23	TMD22	TMD21	TMD20

TMD23	TMD22	TMD21	TMD20	$R1_2$/TOD mode selection	
0	0	0	0	$R1_2$	$R1_2$ port
			1	TOD	Toggle output
		1	0	TOD	0 output
			1	TOD	1 output
	1	0	0	—	Inhibited
			1		
		1	0		
			1	TOD	PWM output
1	Don't care	Don't care	Don't care	$R1_2$	Input capture ($R1_2$ port)

Figure 33 Timer Mode Register D2 (TMD2)

Port mode register C (PMRC: $025)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	PMRC3	PMRC2*	PMRC1	PMRC0

PMRC3	$D_{11}/\overline{INT}_0$ mode selection
0	D_{11}
1	$\overline{INT}_0$

PMRC1	$R2_0$/EVND mode selection
0	$R2_0$
1	EVND

PMRC2	$D_{10}/\overline{STOPC}$ mode selection
0	D_{10}
1	$\overline{STOPC}$

PMRC0	$R1_3/\overline{EVNB}$ mode selection
0	$R1_3$
1	$\overline{EVNB}$

Note: * PMRC2 is reset to 0 only by $\overline{RESET}$ input. When $\overline{STOPC}$ is input in stop mode, PMRC2 is not reset but retains its value.

Figure 34 Port Mode Register C (PMRC)

Serial mode register A (SMRA: $005)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	SMRA3	SMRA2	SMRA1	SMRA0

SMRA3	$R2_1/\overline{SCK}$ mode selection
0	$R2_1$
1	$\overline{SCK}$

SMRA2	SMRA1	SMRA0	$\overline{SCK}$	Clock source	Prescaler division ratio
0	0	0	Output	Prescaler	÷2048
		1	Output	Prescaler	÷512
	1	0	Output	Prescaler	÷128
		1	Output	Prescaler	÷32
1	0	0	Output	Prescaler	÷8
		1	Output	Prescaler	÷2
	1	0	Output	System clock	—
		1	Input	External clock	—

Figure 35 Serial Mode Register A (SMRA)

Port mode register A (PMRA: $004)

Bit	3	2	1	0
Initial value	—	—	0	0
Read/Write	—	—	W	W
Bit name	Not used	Not used	PMRA1	PMRA0

PMRA1	$R2_2$/SI mode selection
0	$R2_2$
1	SI

PMRA0	$R2_3$/SO mode selection
0	$R2_3$
1	SO

Figure 36 Port Mode Register A (PMRA)

LCD output register 3 (LOR3: $01F)

Bit	3	2	1	0
Initial value	—	0	0	—
Read/Write	—	W	W	—
Bit name	Not used	LOR32	LOR31	Not used

LOR32	R7/SEG17–SEG20 mode selection
0	R7
1	SEG17–SEG20

LOR31	R6/SEG13–SEG16 mode selection
0	R6
1	SEG13–SEG16

Figure 37 LCD Output Register 3 (LOR3)

Pull-Up MOS Transistor Control: A program-controlled pull-up MOS transistor is provided for each input/output pin other than input-only pins D_{10} and D_{11}. The on/off status of all these transistors is controlled by bit 3 (MIS3) of the miscellaneous register (MIS: $00C), and the on/off status of an individual transistor can also be controlled by the port data register (PDR) of the corresponding pin—enabling on/off control of that pin alone (table 23 and figure 38).

The on/off status of each transistor and the peripheral function mode of each pin can be set independently.

Miscellaneous register (MIS: $00C)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	MIS3	MIS2	MIS1	MIS0

MIS3	Pull-up MOS on/off selection
0	Off
1	On

MIS2	CMOS buffer on/off selection for pin $R2_3$/SO
0	On
1	Off

MIS1	MIS0
t_{RC} selection. Refer to figure 18 in the operation modes section.	

Figure 38 Miscellaneous Register (MIS)

How to Deal with Unused I/O Pins: I/O pins that are not needed by the user system (floating) must be connected to V_{CC} to prevent LSI malfunctions due to noise. These pins must either be pulled up to V_{CC} by their pull-up MOS transistors or by resistors of about 100 kΩ.

Prescalers

The MCU has two prescalers, S and W.

The prescaler operating conditions are listed in table 25, and the prescalers output supply is shown in figure 39. The timer A–D input clocks except external events, the serial transmit clock except the external clock, and the LCD controller/driver operating clock are selected from the prescaler outputs, depending on corresponding mode registers.

Prescaler Operation

Prescaler S: 11-bit counter that inputs the system clock signal. After being reset to $000 by MCU reset, prescaler S divides the system clock. Prescaler S keeps counting, except in watch and subactive modes and at MCU reset.

Prescaler W: Five-bit counter that inputs the divided X1 input clock signal (32-kHz crystal oscillation). After being reset to $00 by MCU reset, prescaler W divides the input clock. Prescaler W can be reset by software.

Table 25 Prescaler Operating Conditions

Prescaler	Input Clock	Reset Conditions	Stop Conditions
Prescaler S	System clock (in active and standby mode), subsystem clock (in subactive mode)	MCU reset	MCU reset, stop mode, watch mode
Prescaler W	32-kHz crystal oscillation	MCU reset, software	MCU reset, stop mode

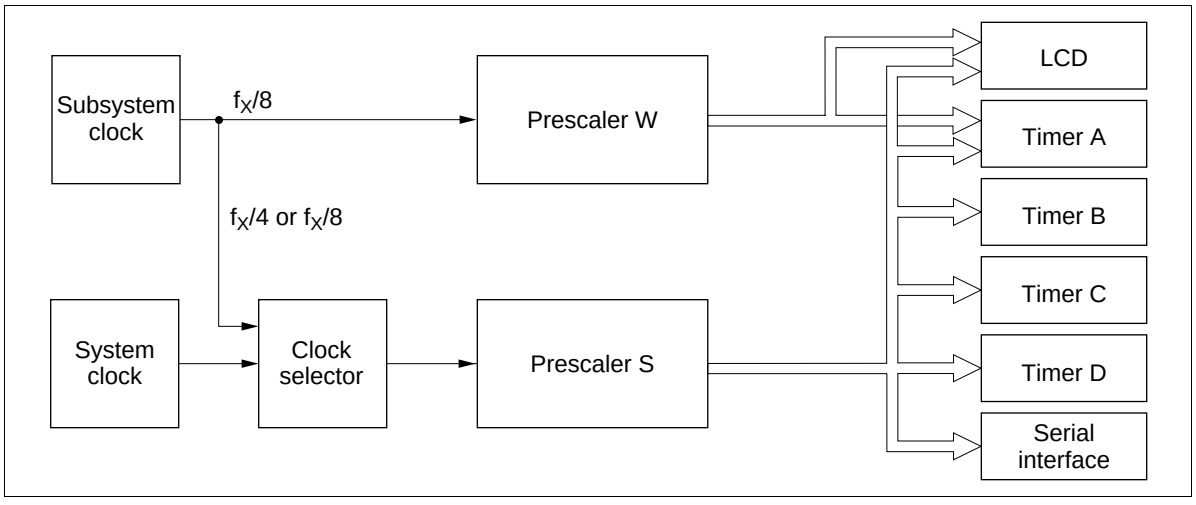


Figure 39 Prescaler Output Supply

Timers

The MCU has four timer/counters (A to D).

- Timer A: Free-running timer
- Timer B: Multifunction timer
- Timer C: Multifunction timer
- Timer D: Multifunction timer

Timer A is an 8-bit free-running timer. Timers B–D are 8-bit multifunction timers, whose functions are listed in table 26. The operating modes are selected by software.

Table 26 Timer Functions

Functions		Timer A	Timer B	Timer C	Timer D
Clock source	Prescaler S	Available	Available	Available	Available
	Prescaler W	Available	—	—	—
	External event	—	Available	—	Available
Timer functions	Free-running	Available	Available	Available	Available
	Time-base	Available	—	—	—
	Event counter	—	Available	—	Available
	Reload	—	Available	Available	Available
	Watchdog	—	—	Available	—
	Input capture	—	—	—	Available
Timer outputs	Toggle	—	Available	Available	Available
	0 output	—	Available	Available	Available
	1 output	—	Available	Available	Available
	PWM	—	—	Available	Available

Note: — implies not available.

Timer A

Timer A Functions: Timer A has the following functions.

- Free-running timer
- Clock time-base

The block diagram of timer A is shown in figure 40.

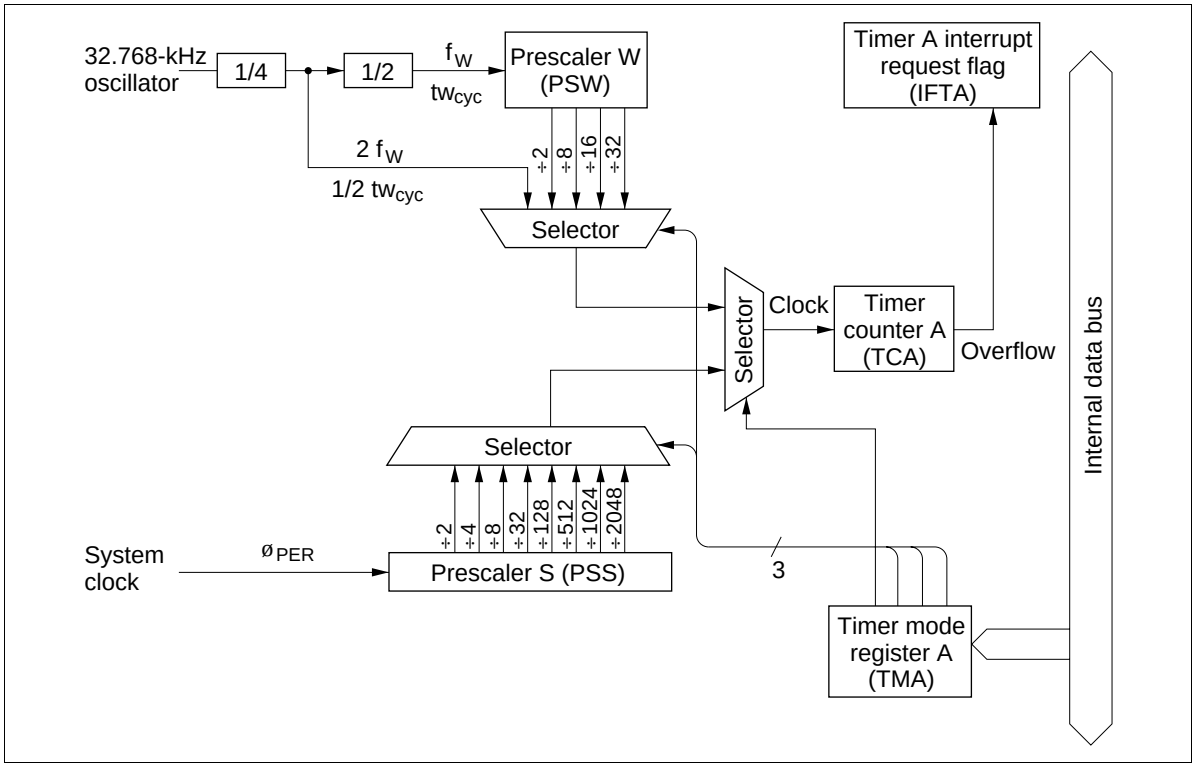


Figure 40 Block Diagram of Timer A

Timer A Operations:

- Free-running timer operation: The input clock for timer A is selected by timer mode register A (TMA: $008).

  Timer A is reset to $00 by MCU reset and incremented at each input clock. If an input clock is applied to timer A after it has reached $FF, an overflow is generated, and timer A is reset to $00. The overflow sets the timer A interrupt request flag (IFTA: $001, bit 2). Timer A continues to be incremented after reset to $00, and therefore it generates regular interrupts every 256 clocks.
- Clock time-base operation: Timer A is used as a clock time-base by setting bit 3 (TMA3) of timer mode register A (TMA: $008) to 1. The prescaler W output is applied to timer A, and timer A generates interrupts at the correct timing based on the 32.768-kHz crystal oscillation. In this case, prescaler W and timer A can be reset to $00 by software.

Registers for Timer A Operation: Timer A operating modes are set by the following registers.

- Timer mode register A (TMA: $008): Four-bit write-only register that selects timer A's operating mode and input clock source as shown in figure 41.

Timer mode register A (TMA: $008)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	TMA3	TMA2	TMA1	TMA0

TMA3	TMA2	TMA1	TMA0	Source prescaler	Input clock frequency	Operating mode
0	0	0	0	PSS	$2048t_{cyc}$	Timer A mode
			1	PSS	$1024t_{cyc}$	
		1	0	PSS	$512t_{cyc}$	
			1	PSS	$128t_{cyc}$	
	1	0	0	PSS	$32t_{cyc}$	
			1	PSS	$8t_{cyc}$	
		1	0	PSS	$4t_{cyc}$	
			1	PSS	$2t_{cyc}$	
1	0	0	0	PSW	$32t_{Wcyc}$	Time-base mode
			1	PSW	$16t_{Wcyc}$	
		1	0	PSW	$8t_{Wcyc}$	
			1	PSW	$2t_{Wcyc}$	
	1	0	0	PSW	$1/2t_{Wcyc}$	
			1	Inhibited		
		1	Don't care	PSW and TCA reset		

Note: 1. t_{Wcyc} = 244.14 µs (when a 32.768-kHz crystal oscillator is used)
2. Timer counter overflow output period (seconds) = input clock period (seconds) × 256.
3. If PSW or TCA reset is selected while the LCD is operating, LCD operation halts (power switch goes off and all SEG and COM pins are grounded).
When an LCD is connected for display, the PSW and TCA reset periods must be set in the program to the minimum.
4. The division ratio must not be modified during time-base mode operation, otherwise an overflow cycle error will occur.

Figure 41 Timer Mode Register A (TMA)

Timer B

Timer B Functions: Timer B has the following functions.

- Free-running/reload timer
- External event counter
- Timer output operation (toggle, 0, and 1 outputs)

The block diagram of timer B is shown in figure 42.

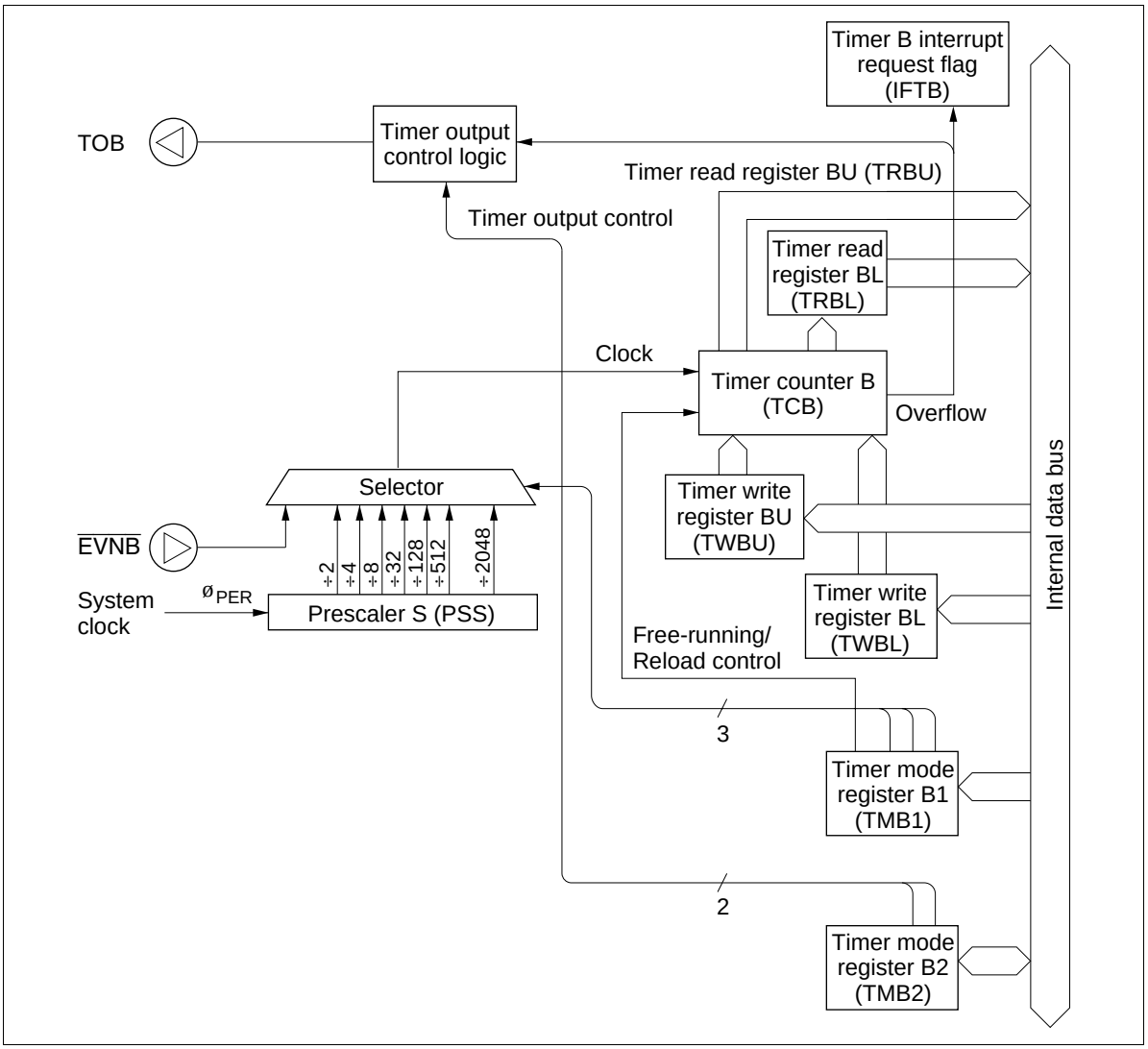


Figure 42 Block Diagram of Timer B

Timer B Operations:

- Free-running/reload timer operation: The free-running/reload operation, input clock source, and prescaler division ratio are selected by timer mode register B1 (TMB1: $009).

  Timer B is initialized to the value set in timer write register B (TWBL: $00A, TWBU: $00B) by software and incremented by one at each clock input. If an input clock is applied to timer B after it has reached $FF, an overflow is generated. In this case, if the reload timer function is enabled, timer B is initialized to its initial value set in timer write register B; if the free-running timer function is enabled, the timer is initialized to $00 and then incremented again.

  The overflow sets the timer B interrupt request flag (IFTB: $002, bit 0). IFTB is reset by software or MCU reset. Refer to figure 3 and table 1 for details.

- External event counter operation: Timer B is used as an external event counter by selecting external event input as the input clock source. In this case, pin $R1_3/\overline{EVNB}$ must be set to $\overline{EVNB}$ by port mode register C (PMRC: $025).

  Timer B is incremented by one at each falling edge of signals input to pin $\overline{EVNB}$. The other operations are basically the same as the free-running/reload timer operation.

- Timer output operation: The following three output modes can be selected for timer B by setting timer mode register B2 (TMB2: $013).

  — Toggle

  — 0 output

  — 1 output

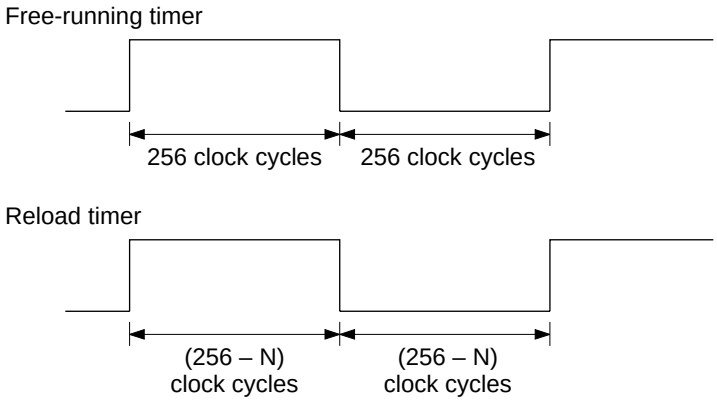
  By selecting the timer output mode, pin $R1_0$/TOB is set to TOB. The output from TOB is reset low by MCU reset.

  — Toggle output: When toggle output mode is selected, the output level is inverted if a clock is input after timer B has reached $FF. By using this function and reload timer function, clock signals can be output at a required frequency for the buzzer. The output waveform is shown in figure 43 (1).

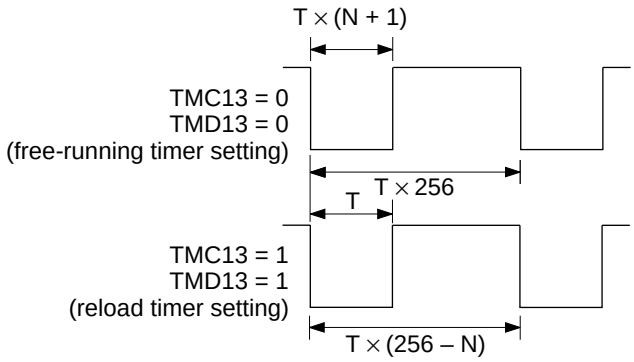
  — 0 output: When 0 output mode is selected, the output level is pulled low if a clock is input after timer B has reached $FF. Note that this function must be used only when the output level is high.

  — 1 output: When 1 output mode is selected, the output level is set high if a clock is input after timer B has reached $FF. Note that this function must be used only when the output level is low.

(1) Toggle output waveform (timers B, C, and D)



(2) PWM output waveform (timers C and D)



Note: The waveform is always fixed low when N = $FF.
T: Input clock period to counter (the clock source and frequency division ratio are controlled in timer mode registers B1, C1, and D1)
N: The value in timer write registers C and D

Figure 43 Timer Output Waveform

Registers for Timer B Operation: By using the following registers, timer B operation modes are selected and the timer B count is read and written.

- Timer mode register B1 (TMB1: $009)
- Timer mode register B2 (TMB2: $013)
- Timer write register B (TWBL: $00A, TWBU: $00B)
- Timer read register B (TRBL: $00A, TRBU: $00B)
- Port mode register C (PMRC: $025)

- Timer mode register B1 (TMB1: $009): Four-bit write-only register that selects the free-running/reload timer function, input clock source, and prescaler division ratio as shown in figure 44. It is reset to $0 by MCU reset.

Timer mode register B1 (TMB1: $009)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	TMB13	TMB12	TMB11	TMB10

TMB13	Free-running/reload timer selection
0	Free-running timer
1	Reload timer

TMB12	TMB11	TMB10	Input clock period and input clock source
0	0	0	$2048t_{cyc}$
		1	$512t_{cyc}$
	1	0	$128t_{cyc}$
		1	$32t_{cyc}$
1	0	0	$8t_{cyc}$
		1	$4t_{cyc}$
	1	0	$2t_{cyc}$
		1	$R1_3/\overline{EVNB}$ (external event input)

Figure 44 Timer Mode Register B1 (TMB1)

Writing to this register is valid from the second instruction execution cycle after the execution of the previous timer mode register B1 write instruction. A timer B initialization by writing to timer write register B (TWBL: $00A, TWBU: $00B) must be programmed to occur after a mode change becomes valid.

- Timer mode register B2 (TMB2: $013): Two-bit read/write register that selects the timer B output mode as shown in figure 45. It is reset to $0 by MCU reset.

Timer mode register B2 (TMB2: $013)

Bit	3	2	1	0
Initial value	—	—	0	0
Read/Write	—	—	R/W	R/W
Bit name	Not used	Not used	TMB21	TMB20

TMB21	TMB20	$R1_0$/TOB mode selection	
0	0	$R1_0$	$R1_0$ port
	1	TOB	Toggle output
1	0	TOB	0 output
	1	TOB	1 output

Figure 45 Timer Mode Register B2 (TMB2)

- Timer write register B (TWBL: $00A, TWBU: $00B): Write-only register consisting of a lower digit (TWBL) and upper digit (TWBU). The lower digit is reset to $0 by MCU reset, but the upper digit value cannot be guaranteed. See figures 46 and 47.

Timer B is initialized by writing to timer write register B (TWBL: $00A, TWBU: $00B). In this case, the lower digit (TWBL) must be written to first, but writing only to the lower digit does not change the timer B value. Timer B is initialized to the value in timer write register B at the same time the upper digit (TWBU) is written to. When timer write register B is written to again and if the lower digit value needs no change, writing only to the upper digit initializes timer B.

Timer write register B (lower digit) (TWBL: $00A)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	TWBL3	TWBL2	TWBL1	TWBL0

Figure 46 Timer Write Register B Lower Digit (TWBL)

Timer write register B (upper digit) (TWBU: $00B)

Bit	3	2	1	0
Initial value	Undefined	Undefined	Undefined	Undefined
Read/Write	W	W	W	W
Bit name	TWBU3	TWBU2	TWBU1	TWBU0

Figure 47 Timer Write Register B Upper Digit (TWBU)

- Timer read register B (TRBL: $00A, TRBU: $00B): Read-only register consisting of a lower digit (TRBL) and upper digit (TRBU) that holds the count of the timer B upper digit. See figures 48 and 49. The upper digit (TRBU) must be read first. At this time, the count of the timer B upper digit is obtained, and the count of the timer B lower digit is latched to the lower digit (TRBL). After this, by reading TRBL, the count of timer B when TRBU was read can be obtained.

Timer read register B (lower digit) (TRBL: $00A)

Bit	3	2	1	0
Initial value	Undefined	Undefined	Undefined	Undefined
Read/Write	R	R	R	R
Bit name	TRBL3	TRBL2	TRBL1	TRBL0

Figure 48 Timer Read Register B Lower Digit (TRBL)

Timer read register B (upper digit) (TRBU: $00B)

Bit	3	2	1	0
Initial value	Undefined	Undefined	Undefined	Undefined
Read/Write	R	R	R	R
Bit name	TRBU3	TRBU2	TRBU1	TRBU0

Figure 49 Timer Read Register B Upper Digit (TRBU)

- Port mode register C (PMRC: $025): Write-only register that selects $R1_3/\overline{EVNB}$ pin function as shown in figure 50. It is reset to $0 by MCU reset.

Port mode register C (PMRC: $025)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	PMRC3	PMRC2	PMRC1	PMRC0

PMRC3	$D_{11}/\overline{INT}_0$ mode selection
0	D_{11}
1	$\overline{INT}_0$

PMRC1	$R2_0$/EVND mode selection
0	$R2_0$
1	EVND

PMRC2	$D_{10}/\overline{STOPC}$ mode selection
0	D_{10}
1	$\overline{STOPC}$

PMRC0	$R1_3/\overline{EVNB}$ mode selection
0	$R1_3$
1	$\overline{EVNB}$

Figure 50 Port Mode Register C (PMRC)

Timer C

Timer C Functions: Timer C has the following functions.

- Free-running/reload timer
- Watchdog timer
- Timer output operation (toggle, 0, 1, and PWM outputs)

The block diagram of timer C is shown in figure 51.

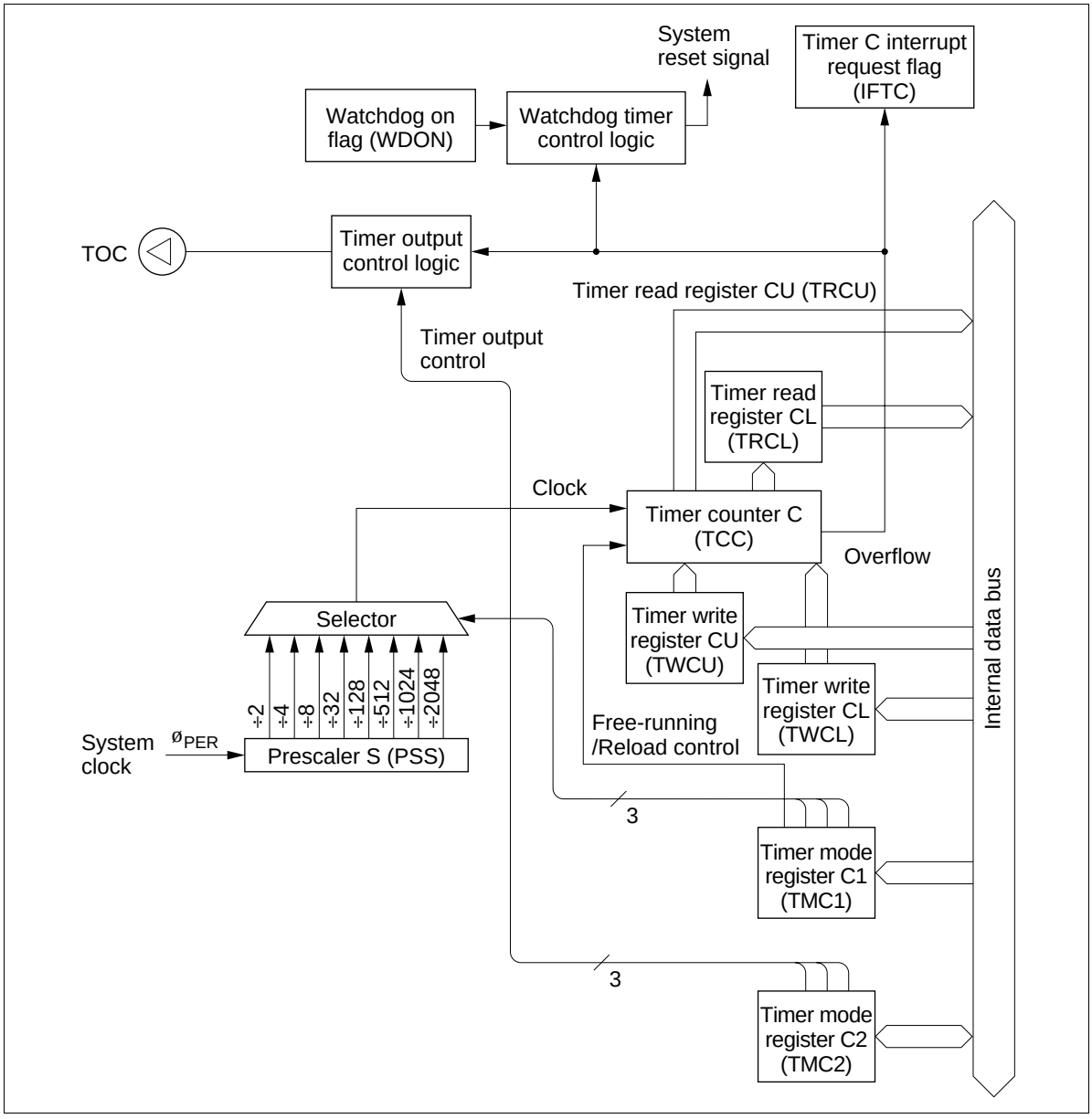


Figure 51 Block Diagram of Timer C

Timer C Operations:

- Free-running/reload timer operation: The free-running/reload operation, input clock source, and prescaler division ratio are selected by timer mode register C1 (TMC1: $00D).

  Timer C is initialized to the value set in timer write register C (TWCL: $00E, TWCU: $00F) by software and incremented by one at each clock input. If an input clock is applied to timer C after it has reached $FF, an overflow is generated. In this case, if the reload timer function is enabled, timer C is initialized to its initial value set in timer write register C; if the free-running timer function is enabled, the timer is initialized to $00 and then incremented again.

  The overflow sets the timer C interrupt request flag (IFTC: $002, bit 2). IFTC is reset by software or MCU reset. Refer to figure 3 and table 1 for details.

- Watchdog timer operation: Timer C is used as a watchdog timer for detecting out-of-control program routines by setting the watchdog on flag (WDON: $020, bit 1) to 1. If a program routine runs out of control and an overflow is generated, the MCU is reset. Program runaway can be controlled by initializing timer C by software before it reaches $FF.

- Timer output operation: The following four output modes can be selected for timer C by setting timer mode register C2 (TMC2: $014).
  - Toggle
  - 0 output
  - 1 output
  - PWM output

  By selecting the timer output mode, pin $R1_1$/TOC is set to TOC. The output from TOC is reset low by MCU reset.
  - Toggle output: The operation is basically the same as that of timer-B's toggle output.
  - 0 output: The operation is basically the same as that of timer-B's 0 output.
  - 1 output: The operation is basically the same as that of timer-B's 1 output.
  - PWM output: When PWM output mode is selected, timer C provides the variable-duty pulse output function. The output waveform differs depending on the contents of timer mode register C1 (TMC1: $00D) and timer write register C (TWCL: $00E, TWCU: $00F). The output waveform is shown in figure 43 (2).

Registers for Timer C Operation: By using the following registers, timer C operation modes are selected and the timer C count is read and written.

- Timer mode register C1 (TMC1: $00D)
- Timer mode register C2 (TMC2: $014)
- Timer write register C (TWCL: $00E, TWCU: $00F)
- Timer read register C (TRCL: $00E, TRCU: $00F)

- Timer mode register C1 (TMC1: $00D): Four-bit write-only register that selects the free-running/reload timer function, input clock source, and prescaler division ratio as shown in figure 52. It is reset to $0 by MCU reset.

Writing to this register is valid from the second instruction execution cycle after the execution of the previous timer mode register C1 write instruction. A timer C initialization by writing to timer write register C (TWCL: $00E, TWCU: $00F) must be programmed to occur after a mode change becomes valid.

Timer mode register C1 (TMC1: $00D)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	TMC13	TMC12	TMC11	TMC10

TMC13	Free-running/reload timer selection
0	Free-running timer
1	Reload timer

TMC12	TMC11	TMC10	Input clock period
0	0	0	$2048t_{cyc}$
		1	$1024t_{cyc}$
	1	0	$512t_{cyc}$
		1	$128t_{cyc}$
1	0	0	$32t_{cyc}$
		1	$8t_{cyc}$
	1	0	$4t_{cyc}$
		1	$2t_{cyc}$

Figure 52 Timer Mode Register C1 (TMC1)

- Timer mode register C2 (TMC2: $014): Three-bit read/write register that selects the timer C output mode as shown in figure 53. It is reset to $0 by MCU reset.

Timer mode register C2 (TMC2: $014)

Bit	3	2	1	0
Initial value	—	0	0	0
Read/Write	—	R/W	R/W	R/W
Bit name	Not used	TMC22	TMC21	TMC20

TMC22	TMC21	TMC20	$R1_1$/TOC mode selection	
0	0	0	$R1_1$	$R1_1$ port
		1	TOC	Toggle output
	1	0	TOC	0 output
		1	TOC	1 output
1	0	0	—	Inhibited
		1		
	1	0		
		1	TOC	PWM output

Figure 53 Timer Mode Register C2 (TMC2)

- Timer write register C (TWCL: $00E, TWCU: $00F): Write-only register consisting of a lower digit (TWCL) and upper digit (TWCU). See figures 54 and 55. The operation of timer write register C is basically the same as that of timer write register B (TWBL: $00A, TWBU: $00B).

Timer write register C (lower digit) (TWCL: $00E)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	TWCL3	TWCL2	TWCL1	TWCL0

Figure 54 Timer Write Register C Lower Digit (TWCL)

Timer write register C (upper digit) (TWCU: $00F)

Bit	3	2	1	0
Initial value	Undefined	Undefined	Undefined	Undefined
Read/Write	W	W	W	W
Bit name	TWCU3	TWCU2	TWCU1	TWCU0

Figure 55 Timer Write Register C Upper Digit (TWCU)

- Timer read register C (TRCL: $00E, TRCU: $00F): Read-only register consisting of a lower digit (TRCL) and upper digit (TRCU) that holds the count of the timer C upper digit. See figures 56 and 57. The operation of timer read register C is basically the same as that of timer read register B (TRBL: $00A, TRBU: $00B).

Timer read register C (lower digit) (TRCL: $00E)

Bit	3	2	1	0
Initial value	Undefined	Undefined	Undefined	Undefined
Read/Write	R	R	R	R
Bit name	TRCL3	TRCL2	TRCL1	TRCL0

Figure 56 Timer Read Register C Lower Digit (TRCL)

Timer read register C (upper digit) (TRCU: $00F)

Bit	3	2	1	0
Initial value	Undefined	Undefined	Undefined	Undefined
Read/Write	R	R	R	R
Bit name	TRCU3	TRCU2	TRCU1	TRCU0

Figure 57 Timer Read Register C Upper Digit (TRCU)

Timer D

Timer D Functions: Timer D has the following functions.

- Free-running/reload timer
- External event counter
- Timer output operation (toggle, 0, 1, and PWM outputs)
- Input capture timer

The block diagram for each operation mode of timer D is shown in figures 58-1 and 58-2.

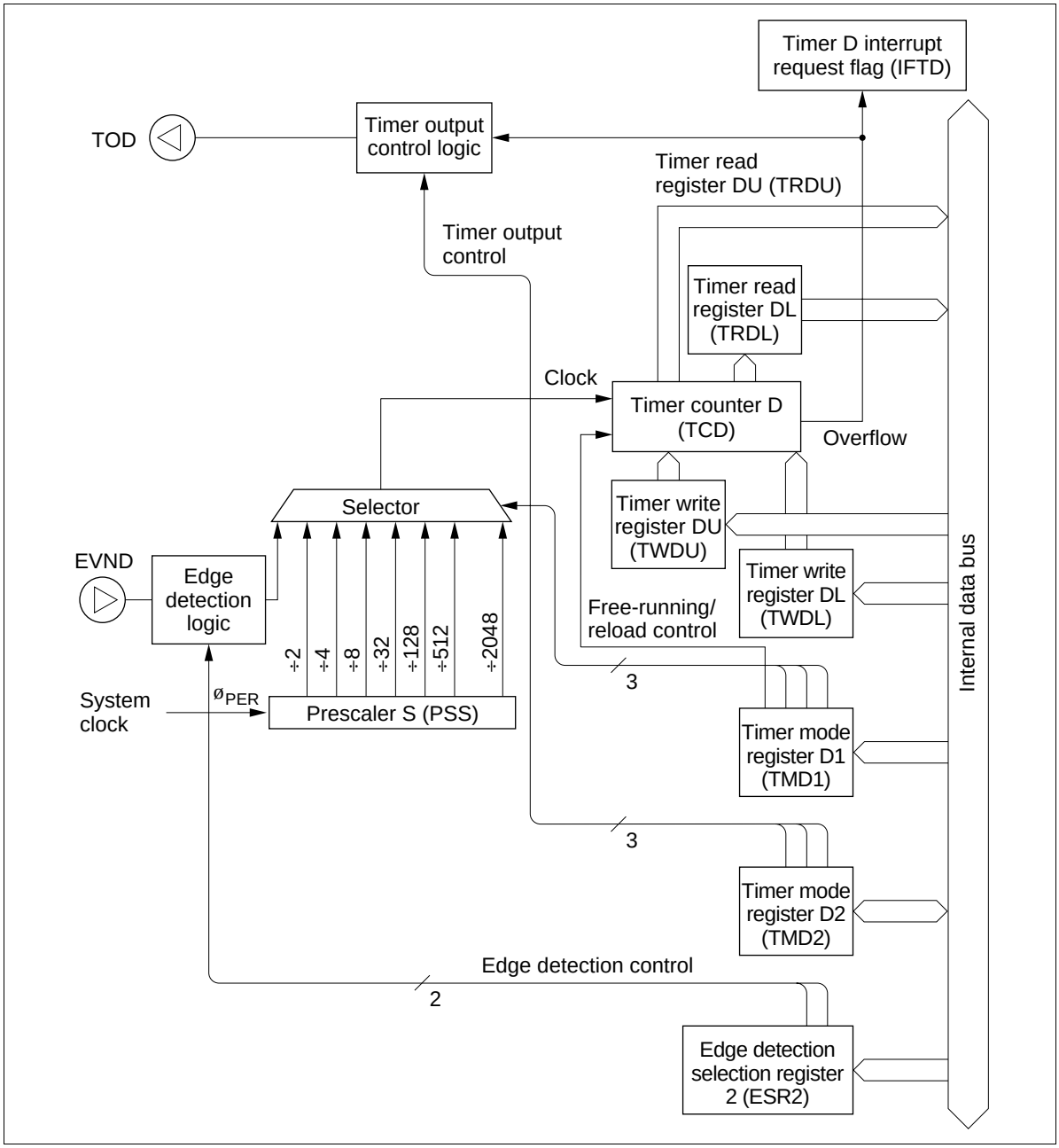


Figure 58-1 Block Diagram of Timer D (in Reload Timer and Event Counter Mode)

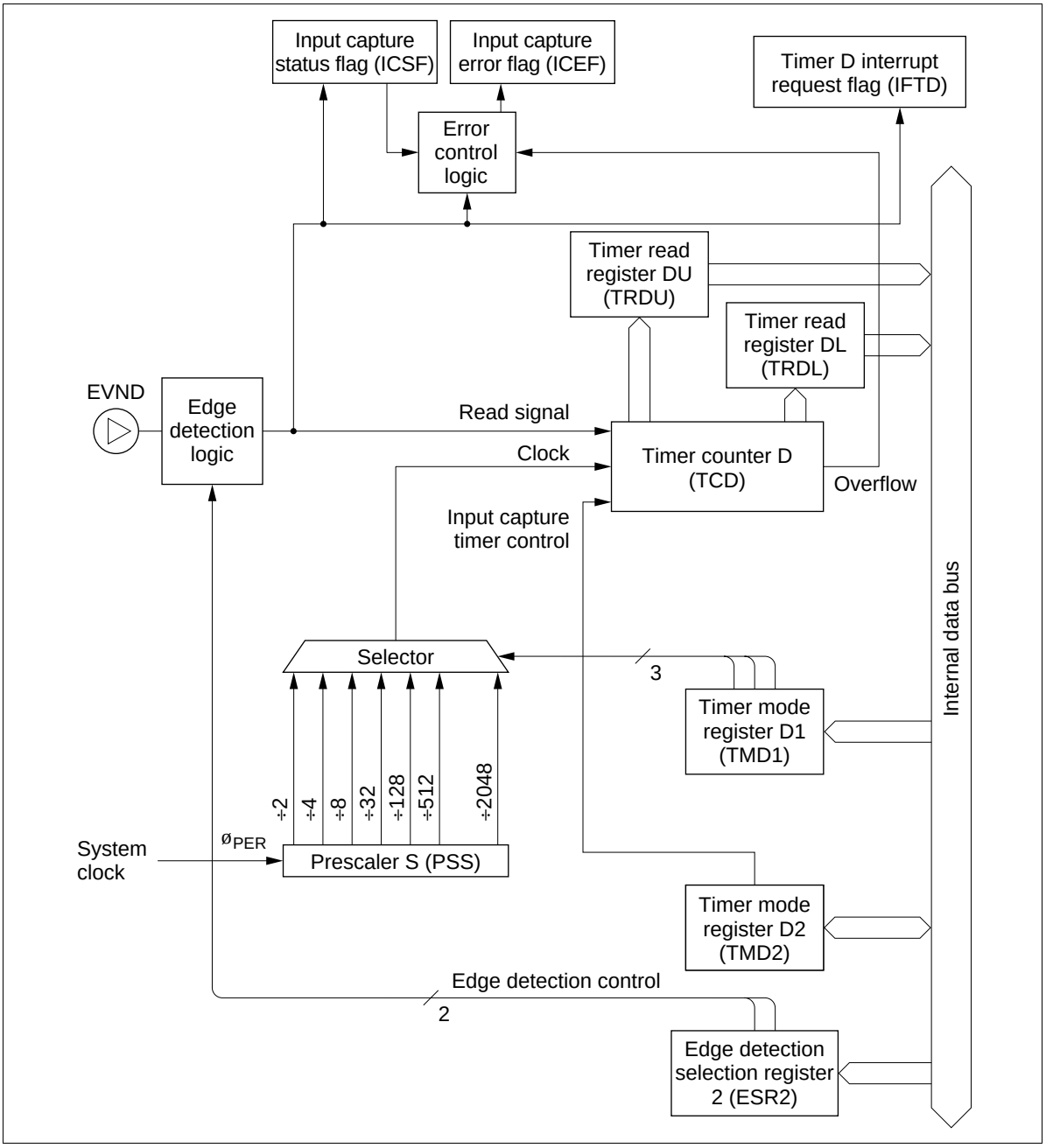


Figure 58-2 Block Diagram of Timer D (in Input Capture Timer Mode)

Timer D Operations:

- Free-running/reload timer operation: The free-running/reload operation, input clock source, and prescaler division ratio are selected by timer mode register D1 (TMD1: $010).

  Timer D is initialized to the value set in timer write register D (TWDL: $011, TWDU: $012) by software and incremented by one at each clock input. If an input clock is applied to timer D after it has reached $FF, an overflow is generated. In this case, if the reload timer function is enabled, timer D is initialized to its initial value set in timer write register D; if the free-running timer function is enabled, the timer is initialized to $00 and then incremented again.

  The overflow sets the timer D interrupt request flag (IFTD: $003, bit 0). IFTD is reset by software or MCU reset. Refer to figure 3 and table 1 for details.

- External event counter operation: Timer D is used as an external event counter by selecting the external event input as an input clock source. In this case, pin $R2_0$/EVND must be set to EVND by port mode register C (PMRC: $025).

  Either falling or rising edge, or both falling and rising edges of input signals can be selected as the external event detection edge by detection edge select register 2 (ESR2: $027). When both rising and falling edges detection is selected, the time between the falling edge and rising edge of input signals must be $2t_{cyc}$ or longer.

  Timer D is incremented by one at each detection edge selected by detection edge select register 2 (ESR2: $027). The other operations are basically the same as the free-running/reload timer operation.

- Timer output operation: The following four output modes can be selected for timer D by setting timer mode register D2 (TMD2: $015).

  — Toggle
  — 0 output
  — 1 output
  — PWM output

  By selecting the timer output mode, pin $R1_2$/TOD is set to TOD. The output from TOD is reset low by MCU reset.

  — Toggle output: The operation is basically the same as that of timer-B's toggle output.
  — 0 output: The operation is basically the same as that of timer-B's 0 output.
  — 1 output: The operation is basically the same as that of timer-B's 1 output.
  — PWM output: The operation is basically the same as that of timer-C's PWM output.

- Input capture timer operation: The input capture timer counts the clock cycles between trigger edges input to pin EVND.

  Either falling or rising edge, or both falling and rising edges of input signals can be selected as the trigger input edge by detection edge select register 2 (ESR2: $027).

  When a trigger edge is input to EVND, the count of timer D is written to timer read register D (TRDL: $011, TRDU: $012), and the timer D interrupt request flag (IFTD: $003, bit 0) and the input capture status flag (ICSF: $021, bit 0) are set. Timer D is reset to $00, and then incremented again. While ICSF is set, if a trigger input edge is applied to timer D, or if timer D generates an overflow, the input capture error flag (ICEF: $021, bit 1) is set. ICSF and ICEF are reset to 0 by MCU reset or by writing 0.

By selecting the input capture operation, pin $R1_2$/TOD is set to $R1_2$ and timer D is reset to $00.

Registers for Timer D Operation: By using the following registers, timer D operation modes are selected and the timer D count is read and written.

- Timer mode register D1 (TMD1: $010)
- Timer mode register D2 (TMD2: $015)
- Timer write register D (TWDL: $011, TWDU: $012)
- Timer read register D (TRDL: $011, TRDU: $012)
- Port mode register C (PMRC: $025)
- Detection edge select register 2 (ESR2: $027)

- Timer mode register D1 (TMD1: $010): Four-bit write-only register that selects the free-running/reload timer function, input clock source, and prescaler division ratio as shown in figure 59. It is reset to $0 by MCU reset.

  Writing to this register is valid from the second instruction execution cycle after the execution of the previous timer mode register D1 (TMD1: $010) write instruction. A timer D initialization by writing to timer write register D (TWDL: $011, TWDU: $012) must be programmed to occur after a mode change becomes valid.

  When selecting the input capture timer operation, select the internal clock as the input clock source.

Timer mode register D1 (TMD1: $010)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	TMD13	TMD12	TMD11	TMD10

TMD13	Free-running/reload timer selection
0	Free-running timer
1	Reload timer

TMD12	TMD11	TMD10	Input clock period and input clock source
0	0	0	$2048t_{cyc}$
		1	$512t_{cyc}$
	1	0	$128t_{cyc}$
		1	$32t_{cyc}$
1	0	0	$8t_{cyc}$
		1	$4t_{cyc}$
	1	0	$2t_{cyc}$
		1	$R2_0$/EVND (external event input)

Figure 59 Timer Mode Register D1 (TMD1)

- Timer mode register D2 (TMD2: $015): Four-bit read/write register that selects the timer D output mode and input capture operation as shown in figure 60. It is reset to $0 by MCU reset.

Timer mode register D2 (TMD2: $015)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W
Bit name	TMD23	TMD22	TMD21	TMD20

TMD23	TMD22	TMD21	TMD20	$R1_2$/TOD mode selection	
0	0	0	0	$R1_2$	$R1_2$ port
			1	TOD	Toggle output
		1	0	TOD	0 output
			1	TOD	1 output
	1	0	0	—	Inhibited
			1		
		1	0		
			1	TOD	PWM output
1	Don't care	Don't care	Don't care	$R1_2$	Input capture ($R1_2$ port)

Figure 60 Timer Mode Register D2 (TMD2)

- Timer write register D (TWDL: $011, TWDU: $012): Write-only register consisting of a lower digit (TWDL) and upper digit (TWDU). See figures 61 and 62. The operation of timer write register D is basically the same as that of timer write register B (TWBL: $00A, TWBU: $00B).

Timer write register D (lower digit) (TWDL: $011)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	TWDL3	TWDL2	TWDL1	TWDL0

Figure 61 Timer Write Register D Lower Digit (TWDL)

Timer write register D (upper digit) (TWDU: $012)

Bit	3	2	1	0
Initial value	Undefined	Undefined	Undefined	Undefined
Read/Write	W	W	W	W
Bit name	TWDU3	TWDU2	TWDU1	TWDU0

Figure 62 Timer Write Register D Upper Digit (TWDU)

- Timer read register D (TRDL: $011, TRDU: $012): Read-only register consisting of a lower digit (TRDL) and upper digit (TRDU). See figures 63 and 64. The operation of timer read register D is basically the same as that of timer read register B (TRBL: $00A, TRBU: $00B).

  When the input capture timer operation is selected and if the count of timer D is read after a trigger is input, either the lower or upper digit can be read first.

Timer read register D (lower digit) (TRDL: $011)

Bit	3	2	1	0
Initial value	Undefined	Undefined	Undefined	Undefined
Read/Write	R	R	R	R
Bit name	TRDL3	TRDL2	TRDL1	TRDL0

Figure 63 Timer Read Register D Lower Digit (TRDL)

Timer read register D (upper digit) (TRDU: $012)

Bit	3	2	1	0
Initial value	Undefined	Undefined	Undefined	Undefined
Read/Write	R	R	R	R
Bit name	TRDU3	TRDU2	TRDU1	TRDU0

Figure 64 Timer Read Register D Upper Digit (TRDU)

- Port mode register C (PMRC: $025): Write-only register that selects $R2_0$/EVND pin function as shown in figure 50. It is reset to $0 by MCU reset.

- Detection edge select register 2 (ESR2: $027): Write-only register that selects the detection edge of signals input to pin EVND as shown in figure 65. It is reset to $0 by MCU reset.

Detection edge register 2 (ESR2: $027)

Bit	3	2	1	0
Initial value	0	0	—	—
Read/Write	W	W	—	—
Bit name	ESR23	ESR22	Not used	Not used

ESR23	ESR22	EVND detection edge
0	0	No detection
	1	Falling-edge detection
1	0	Rising-edge detection
	1	Double-edge detection*

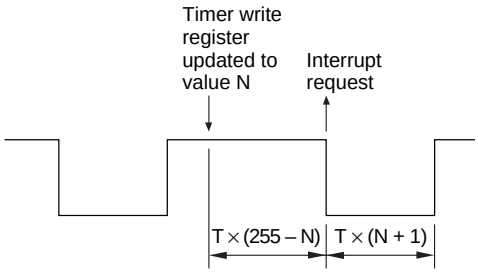
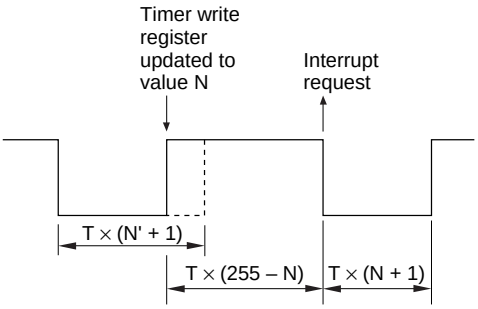
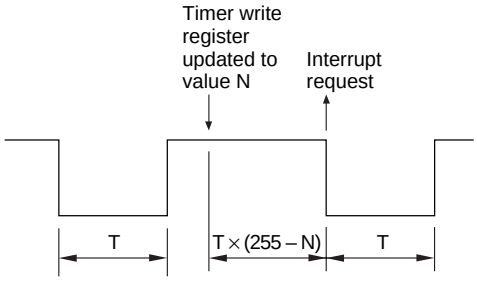
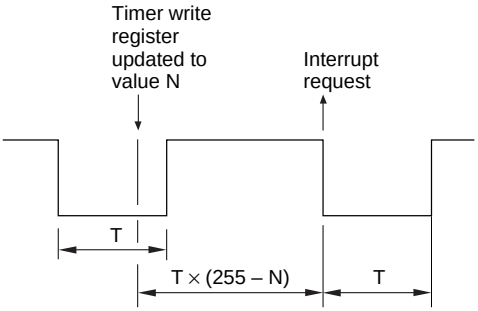
Note: * Both falling and rising edges are detected.

Figure 65 Detection Edge Select Register 2 (ESR2)

Notes on Use

When using the timer output as PWM output, note the following point. From the update of the timer write register until the occurrence of the overflow interrupt, the PWM output differs from the period and duty settings, as shown in table 27. The PWM output should therefore not be used until after the overflow interrupt following the update of the timer write register. After the overflow, the PWM output will have the set period and duty cycle.

Table 27 PWM Output Following Update of Timer Write Register

Mode	PWM Output Timer Write Register is Updated during High PWM Output	PWM Output Timer Write Register is Updated during Low PWM Output
Free running		
Reload		

Serial Interface

The serial interface serially transfers and receives 8-bit data, and includes the following features.

- Multiple transmit clock sources
  - External clock
  - Internal prescaler output clock
  - System clock
- Output level control in idle states

Five registers, an octal counter are also configured for the serial interface as follows.

- Serial data register (SRL: $006, SRU: $007)
- Serial mode register A (SMRA: $005)
- Serial mode register B (SMRB: $028)
- Port mode register A (PMRA: $004)
- Miscellaneous register (MIS: $00C)
- Octal counter (OC)
- Selector

The block diagram of the serial interface is shown in figure 66.

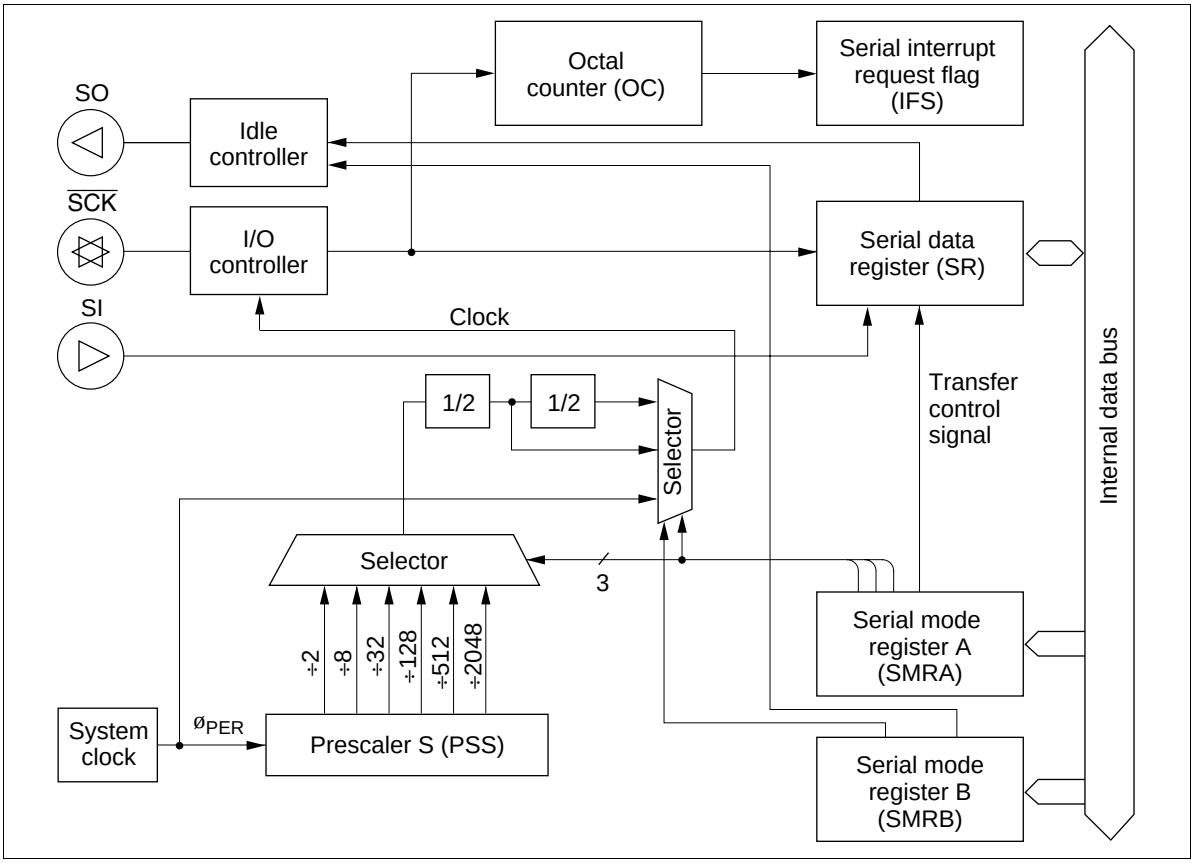


Figure 66 Block Diagram of Serial Interface

Serial Interface Operation

Selecting and Changing the Operating Mode: Table 28 lists the serial interface's operating modes. To select an operating mode, use one of these combinations of port mode register A (PMRA: $004) and serial mode register A (SMRA: $005) settings; to change the operating mode, always initialize the serial interface internally by writing data to serial mode register A. Note that the serial interface is initialized by writing data to serial mode register A. Refer to the following Serial Mode Register A section for details.

Table 28 Serial Interface Operating Modes

SMRA	PMRA		
Bit 3	**Bit 1**	**Bit 0**	**Operating Mode**
1	0	0	Clock continuous output mode
		1	Transmit mode
	1	0	Receive mode
		1	Transmit/receive mode

Pin Setting: The $R2_1/\overline{SCK}$ pin is controlled by writing data to serial mode register A (SMRA: $005). The $R2_2$/SI and $R2_3$/SO pins are controlled by writing data to port mode register A (PMRA: $004). Refer to the following Registers for Serial Interface section for details.

Transmit Clock Source Setting: The transmit clock source is set by writing data to serial mode register A (SMRA: $005) and serial mode register B (SMRB: $028). Refer to the following Registers for Serial Interface section for details.

Data Setting: Serial data is set by writing data to the serial data register (SRL: $006, SRU, $007). Receive data is obtained by reading the contents of the serial data register. The serial data is shifted by the transmit clock and is input from or output to an external system.

The output level of the SO pin remains unsettled until the first data is output after MCU reset, or until the output level control in idle states is performed.

Transfer Control: The serial interface is activated by the STS instruction. The octal counter is reset to 000 by this instruction, and it increments at the rising edge of the transmit clock. When the eighth transmit clock signal is input or when serial transmission/receive is discontinued, the octal counter is reset to 000, the serial interrupt request flag (IFS: $023, bit 2) is set, and the transfer stops.

When the prescaler output is selected as the transmit clock, the transmit clock frequency is selected as $4t_{cyc}$ to $8192t_{cyc}$ by setting bits 0 to 2 (SMRA0– SMRA2) of serial mode register A (SMRA: $005) and bit 0 (SMRB0) of serial mode register B (SMRB: $028) as listed in table 29.

Table 29 Serial Transmit Clock (Prescaler Output)

SMRB	SMRA				
Bit 0	**Bit 2**	**Bit 1**	**Bit 0**	**Prescaler Division Ratio**	**Transmit Clock Frequency**
0	0	0	0	÷ 2048	$4096t_{cyc}$
			1	÷ 512	$1024t_{cyc}$
		1	0	÷ 128	$256t_{cyc}$
			1	÷ 32	$64t_{cyc}$
	1	0	0	÷ 8	$16t_{cyc}$
			1	÷ 2	$4t_{cyc}$
1	0	0	0	÷ 4096	$8192t_{cyc}$
			1	÷ 1024	$2048t_{cyc}$
		1	0	÷ 256	$512t_{cyc}$
			1	÷ 64	$128t_{cyc}$
	1	0	0	÷ 16	$32t_{cyc}$
			1	÷ 4	$8t_{cyc}$

Operating States: The serial interface has the following operating states; transitions between them are shown in figure 67.

- STS wait state
- Transmit clock wait state
- Transfer state
- Continuous clock output state (only in internal clock mode)

- STS wait state: The serial interface enters STS wait state by MCU reset (00, 10 in figure 67). In STS wait state, the serial interface is initialized and the transmit clock is ignored. If the STS instruction is then executed (01, 11), the serial interface enters transmit clock wait state.

- Transmit clock wait state: Transmit clock wait state is the period between the STS execution and the falling edge of the first transmit clock. In transmit clock wait state, input of the transmit clock (02, 12) increments the octal counter, shifts the serial data register, and puts the serial interface in transfer state. However, note that if clock continuous output mode is selected in internal clock mode, the serial interface does not enter transfer state but enters clock continuous output state (17).

  The serial interface enters STS wait state by writing data to serial mode register A (SMRA: $005) (04, 14) in transmit clock wait state.

- Transfer state: Transfer state is the period between the falling edge of the first clock and the rising edge of the eighth clock. In transfer state, the input of eight clocks or the execution of the STS instruction sets the octal counter to 000, and the serial interface enters another state. When the STS instruction is executed (05, 15), transmit clock wait state is entered. When eight clocks are input, transmit clock wait state is entered (03) in external clock mode, and STS wait state is entered (13) in internal clock mode. In internal clock mode, the transmit clock stops after outputting eight clocks.

  In transfer state, writing data to serial mode register A (SMRA: $005) (06, 16) initializes the serial interface, and STS wait state is entered.

  If the state changes from transfer to another state, the serial interrupt request flag (IFS: $023, bit 2) is set by the octal counter that is reset to 000.

- Clock continuous output state (only in internal clock mode): Clock continuous output state is entered only in internal clock mode. In this state, the serial interface does not transmit/receive data but only outputs the transmit clock from the $\overline{\text{SCK}}$ pin.

  When bits 0 and 1 (PMRA0, PMRA1) of port mode register A (PMRA: $004) are 00 in transmit clock wait state and if the transmit clock is input (17), the serial interface enters clock continuous output state. If serial mode register A (SMRA: $005) is written to in clock continuous output mode (18), STS wait state is entered.

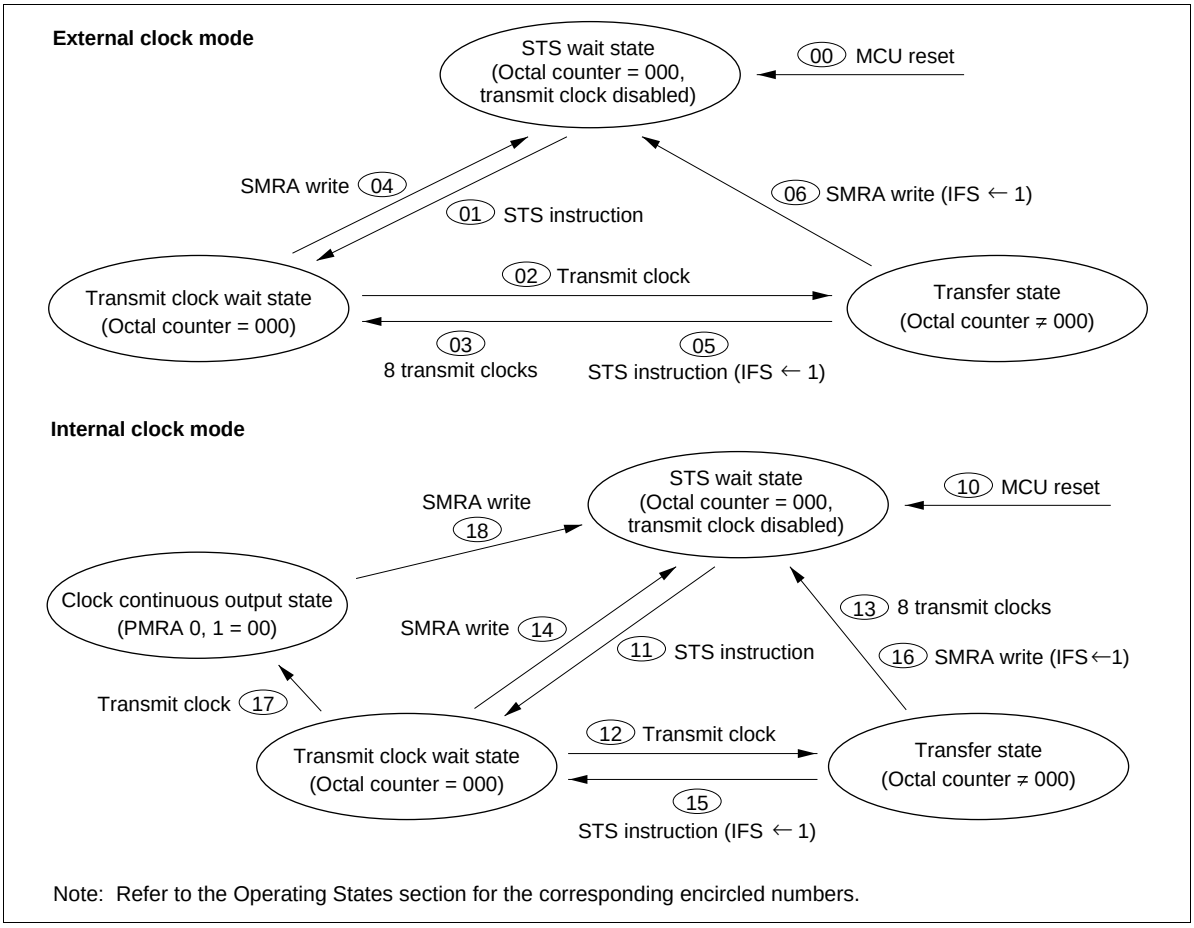


Figure 67 Serial Interface State Transitions

Output Level Control in Idle States: In idle states, that is, STS wait state and transmit clock wait state, the output level of the SO pin can be controlled by setting bit 1 (SMRB1) of serial mode register B (SMRB: $028) to 0 or 1. The output level control example is shown in figure 68. Note that the output level cannot be controlled in transfer state.

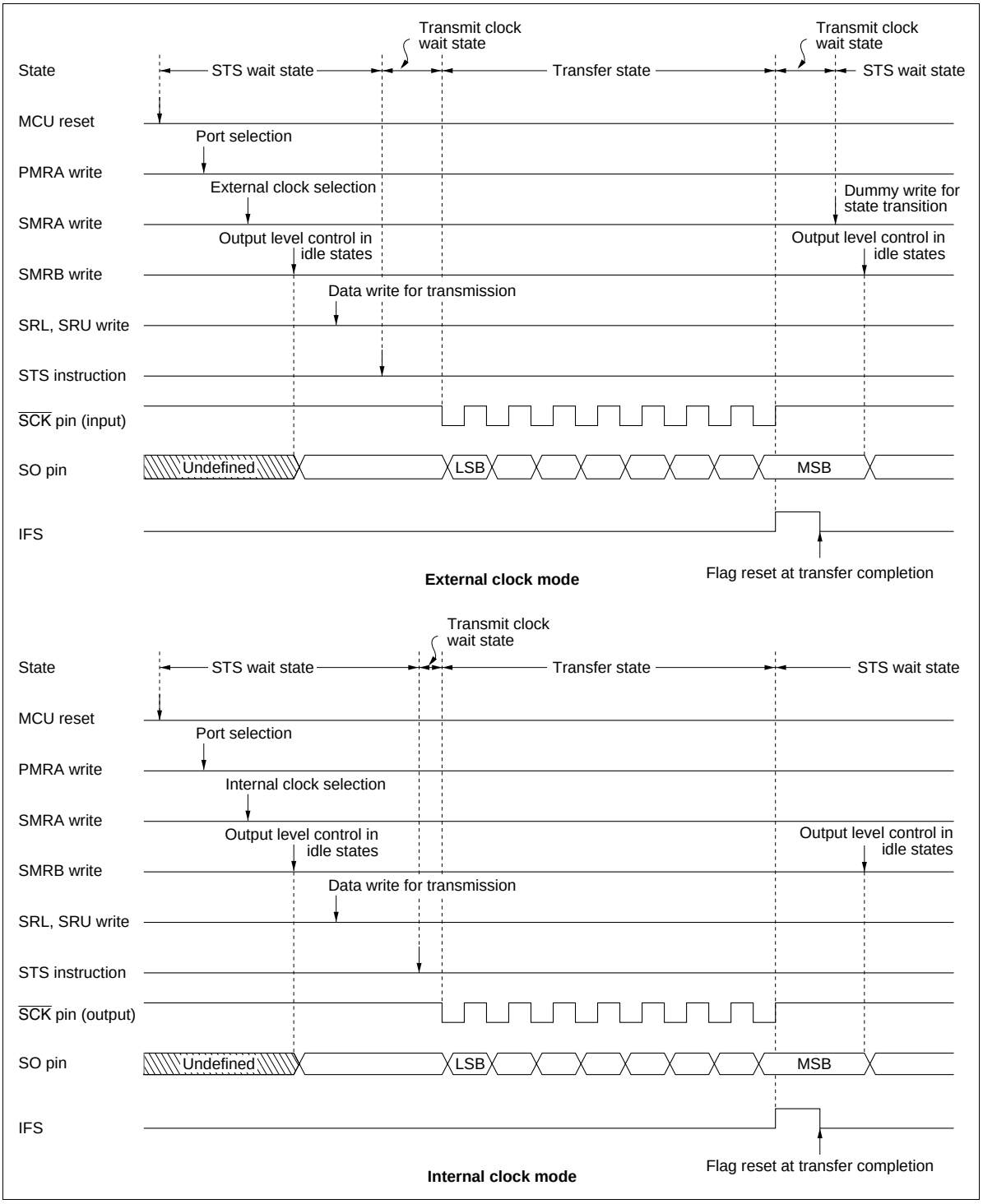
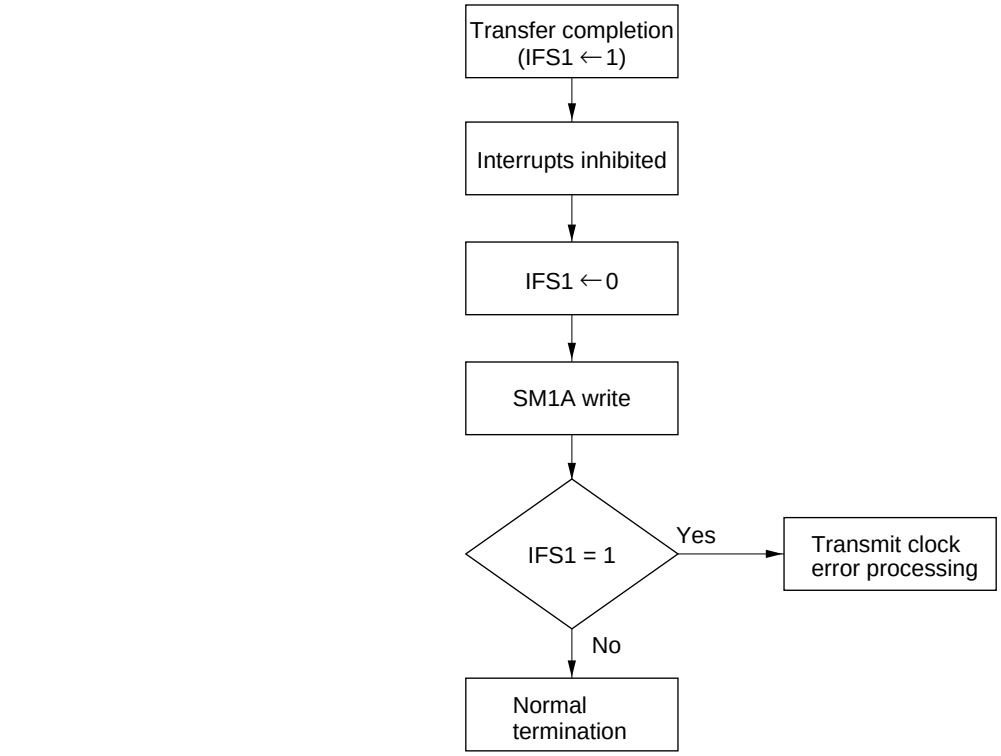


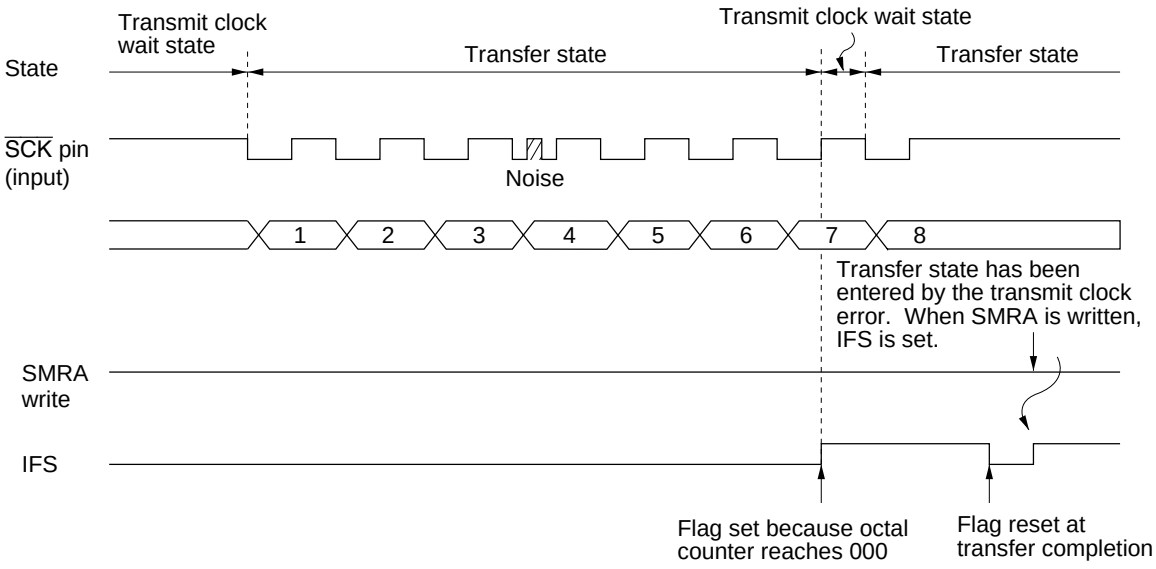
Figure 68 Example of Serial Interface Operation Sequence

Transmit Clock Error Detection (In External Clock Mode): The serial interface will malfunction if a spurious pulse caused by external noise conflicts with a normal transmit clock during transfer. A transmit clock error of this type can be detected as shown in figure 69.

If more than eight transmit clocks are input in transfer state, at the eighth clock including a spurious pulse by noise, the octal counter reaches 000, the serial interrupt request flag (IFS: $023, bit 2) is set, and transmit clock wait state is entered. At the falling edge of the next normal clock signal, the transfer state is entered. After the transfer completion processing is performed and IFS is reset, writing to serial mode register A (SMRA: $005) changes the state from transfer to STS wait. At this time IFS is set again, and therefore the error can be detected.



Transmit clock error detection flowchart



Transmit clock error detection procedures

Figure 69 Transmit Clock Error Detection

Notes on Use:

- Initialization after writing to registers: If port mode register A (PMRA: $004) is written to in transmit clock wait state or in transfer state, the serial interface must be initialized by writing to serial mode register A (SMRA: $005) again.

- Setting the serial interrupt request flag (IFS: $023, bit 2): If the state is changed from transfer to another by writing to serial mode register A (SMRA: $005) or executing the STS instruction during the first low pulse of the transmit clock, the serial interrupt request flag is not set. To set the serial interrupt request flag, serial mode register A write or STS instruction execution must be programmed to be executed after confirming that the $\overline{SCK}$ pin is at 1, that is, after executing the input instruction to port R2.

Registers for Serial Interface

The serial interface operation is selected, and serial data is read and written by the following registers.

— Serial Mode Register A (SMRA: $005)
— Serial Mode Register B (SMRB: $028)
— Serial Data Register (SRL: $006, SRU: $007)
— Port Mode Register A (PMRA: $004)
— Miscellaneous Register (MIS: $00C)

Serial Mode Register A (SMRA: $005): This register has the following functions (figure 70).

- $R2_1/\overline{SCK}$ pin function selection
- Transfer clock selection
- Prescaler division ratio selection
- Serial interface initialization

Serial mode register A (SMRA: $005) is a 4-bit write-only register. It is reset to $0 by MCU reset.

A write signal input to serial mode register A (SMRA: $005) discontinues the input of the transmit clock to the serial data register and octal counter, and the octal counter is reset to 000. Therefore, if a write is performed during data transfer, the data transfer is discontinued and the serial interrupt request flag (IFS: $023, bit 2) is set.

Written data is valid from the second instruction execution cycle after a write operation, so the STS instruction must be executed at least two cycles after a write operation.

Serial mode register A (SMRA: $005)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	SMRA3	SMRA2	SMRA1	SMRA0

SMRA3	$R2_1/\overline{SCK}$ mode selection
0	$R2_1$
1	$\overline{SCK}$

SMRA2	SMRA1	SMRA0	$\overline{SCK}$	Clock source	Prescaler division ratio
0	0	0	Output	Prescaler	Refer to table 29
		1			
	1	0			
		1			
1	0	0			
		1			
	1	0	Output	System clock	—
		1	Input	External clock	—

Figure 70 Serial Mode Register A (SMRA)

Serial Mode Register B (SMRB: $028): This register has the following functions (figure 71).

- Prescaler division ratio selection
- Output level control in idle states

Serial mode register B (SMRB: $028) is a 2-bit write-only register. It cannot be written during data transfer.

By setting bit 0 (SMRB0) of this register, the prescaler division ratio is selected. Only bit 0 (SMRB0) can be reset to 0 by MCU reset. Bit 1 (SMRB1) is used to control the output level of the SO pin in idle states. The output level changes at the same time that SMRB1 is written to.

Serial mode register B (SMRB: $028)

Bit	3	2	1	0
Initial value	—	—	Undefined	0
Read/Write	—	—	W	W
Bit name	Not used	Not used	SMRB1	SMRB0

SMRB1	Output level control in idle states
0	Low level
1	High level

SMRB0	Transmit clock division ratio
0	Prescaler output divided by 2
1	Prescaler output divided by 4

Figure 71 Serial Mode Register B (SMRB)

Serial Data Register (SRL: $006, SRU: $007): The serial data register configuration is shown in figures 72 and 73. This register has the following functions.

- Transmission data write and shift
- Receive data shift and read

Writing data in this register is output from the SO pin, LSB first, synchronously with the falling edge of the transmit clock; data is input, LSB first, through the SI pin at the rising edge of the transmit clock. Input/output timing is shown in figure 74.

Data cannot be read or written during serial data transfer. If a read/write occurs during transfer, the accuracy of the resultant data cannot be guaranteed.

Serial data register (lower digit) (SRL: $006)

Bit	3	2	1	0
Initial value	Undefined	Undefined	Undefined	Undefined
Read/Write	R/W	R/W	R/W	R/W
Bit name	SR3	SR2	SR1	SR0

Figure 72 Serial Data Register (SRL)

Serial data register (upper digit) (SRU: $007)

Bit	3	2	1	0
Initial value	Undefined	Undefined	Undefined	Undefined
Read/Write	R/W	R/W	R/W	R/W
Bit name	SR7	SR6	SR5	SR4

Figure 73 Serial Data Register (SRU)

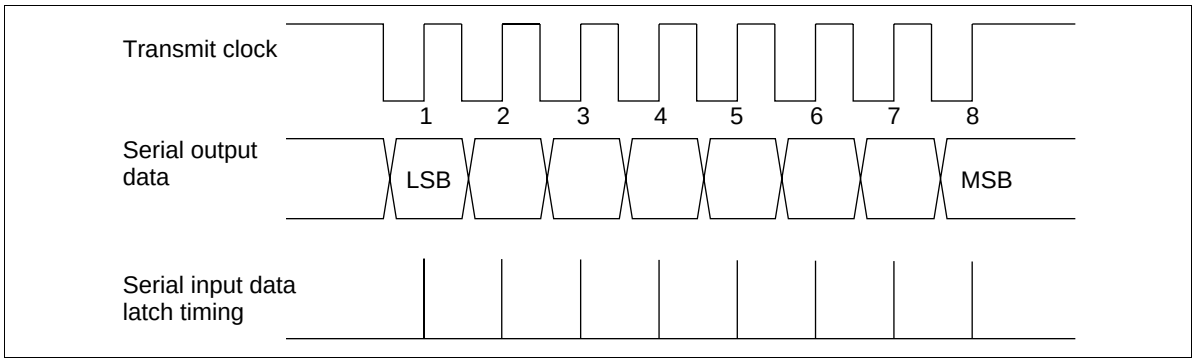


Figure 74 Serial Interface Input/Output Timing

Port Mode Register A (PMRA: $004): This register has the following functions (figure 75).

- $R2_2$/SI pin function selection
- $R2_3$/SO pin function selection

Port mode register A (PMRA: $004) is a 2-bit write-only register, and is reset to $0 by MCU reset.

Port mode register A (PMRA: $004)

Bit	3	2	1	0
Initial value	—	—	0	0
Read/Write	—	—	W	W
Bit name	Not used	Not used	PMRA1	PMRA0

PMRA1	$R2_2$/SI mode selection
0	$R2_2$
1	SI

PMRA0	$R2_3$/SO mode selection
0	$R2_3$
1	SO

Figure 75 Port Mode Register A (PMRA)

Miscellaneous Register (MIS: $00C): This register has the following function (figure 76).

- $R2_3$/SO pin PMOS control

Miscellaneous register (MIS: $00C) is a 4-bit write-only register and is reset to $0 by MCU reset.

Miscellaneous register (MIS: $00C)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	MIS3	MIS2	MIS1	MIS0

MIS3	Pull-up MOS on/off selection
0	Off
1	On

MIS2	$R2_3$/SO PMOS on/off selection
0	On
1	Off

MIS1	MIS0	t_{RC}*
0	0	0.12207 ms
		0.24414 ms
	1	7.8125 ms
1	0	31.25 ms
	1	Not used

Note: * Refer to figure 18.

Figure 76 Miscellaneous Register (MIS)

A/D Converter

The MCU has a built-in A/D converter that uses successive approximations with a resistor ladder. It can measure eight analog inputs with 8-bit resolution. As shown in the block diagram of figure 77, the A/D converter has a 4-bit A/D mode register, a 4-bit plus 4-bit A/D data register, a 1-bit A/D start flag, and a 1-bit A/D current off flag.

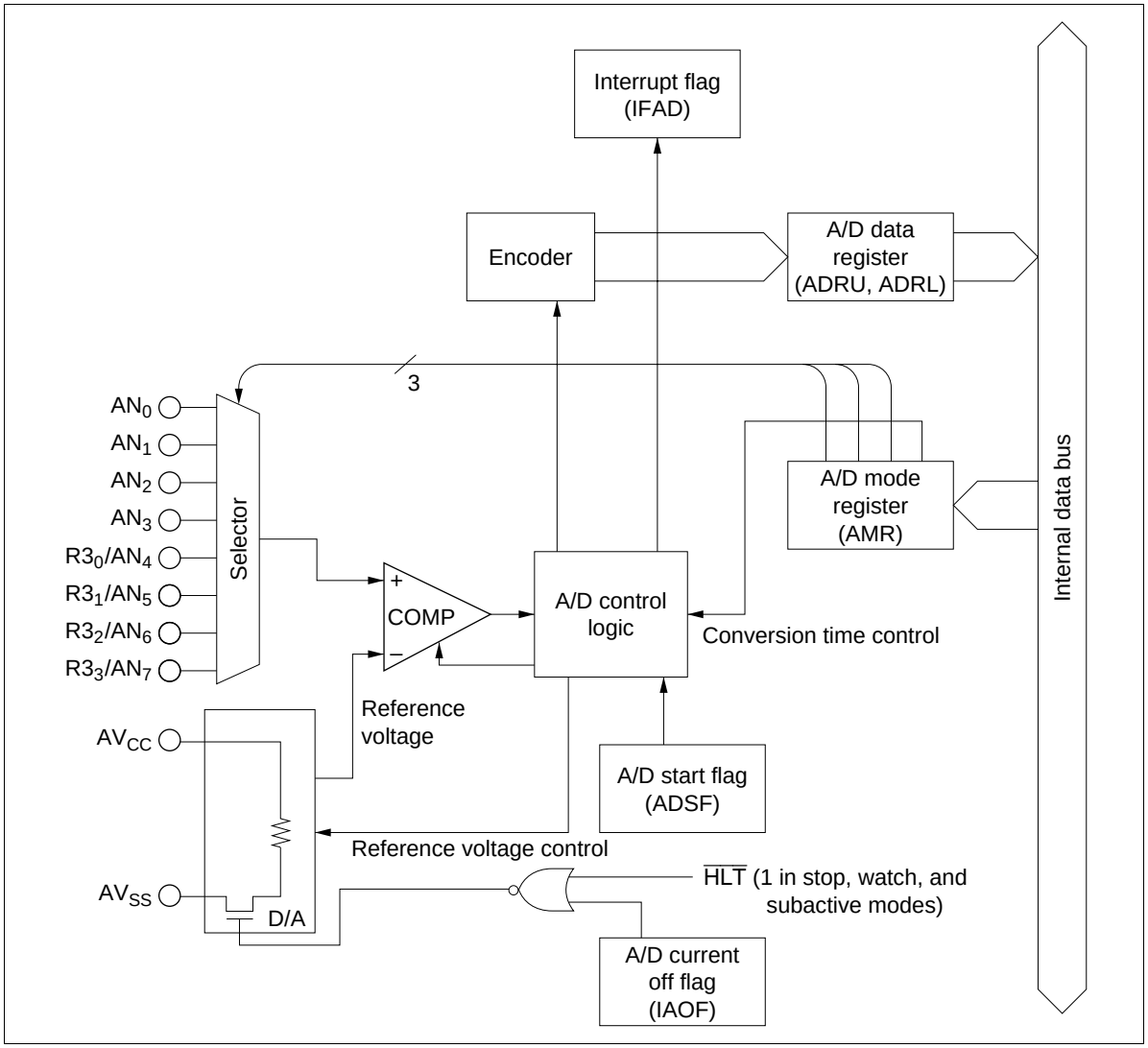


Figure 77 Block Diagram of A/D Converter

A/D Mode Register (AMR: $016): Four-bit write-only register which selects the A/D conversion period and indicates analog input pin information. Bit 0 of the A/D mode register selects the A/D conversion period, and bits 1 to 3 select a channel, as shown in figure 78.

A/D mode register (AMR: $016)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	AMR3	AMR2	AMR1	AMR0

AMR3	AMR2	AMR1	Analog input selection
0	0	0	AN_0
0	1	0	AN_1
1	0	0	AN_2
1	1	0	AN_3
0	0	1	AN_4
0	1	1	AN_5
1	0	1	AN_6
1	1	1	AN_7

AMR0	Conversion time
0	$34t_{cyc}$
1	$67t_{cyc}$

Figure 78 A/D Mode Register (AMR)

A/D Data Register (ADRL: $017, ADRU: $018): 8-bit read-only register consisting of a 4-bit lower digit and 4-bit upper digit. This register is not cleared by reset. Any data read during A/D conversion is not guaranteed. After the completion of A/D conversion, the resultant eight-bit data is held in this register until the start of the next conversion (figures 79, 80, and 81).

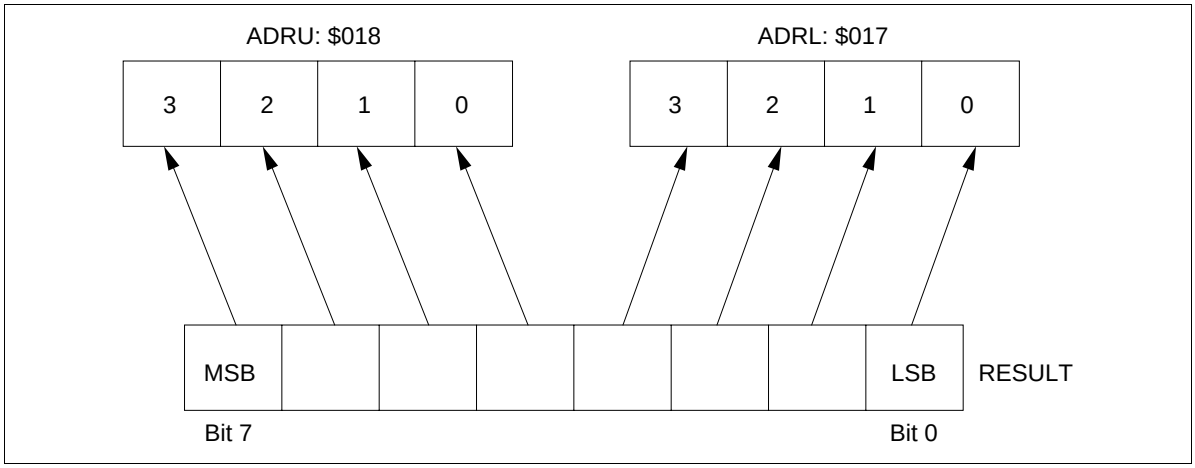


Figure 79 A/D Data Registers

A/D data register (lower digit) (ADRL: $017)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	R	R	R	R
Bit name	ADRL3	ADRL2	ADRL1	ADRL0

Figure 80 A/D Data Register Lower Digit (ADRL)

A/D data register (upper digit) (ADRU: $018)

Bit	3	2	1	0
Initial value	1	0	0	0
Read/Write	R	R	R	R
Bit name	ADRU3	ADRU2	ADRU1	ADRU0

Figure 81 A/D Data Register Upper Digit (ADRU)

A/D Start Flag (ADSF: $020, Bit 2): One-bit flag that initiates A/D conversion when set to 1. At the completion of A/D conversion, the converted data is stored in the A/D data register and the A/D start flag is cleared. Refer to figure 82.

A/D start flag (ADSF: $020, bit 2)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W
Bit name	DTON	ADSF	WDON	LSON

DTON
Refer to the description of operating modes

WDON
Refer to the description of timers

ADSF (A/D start flag)	
1	A/D conversion started
0	A/D conversion completed

LSON
Refer to the description of operating modes

Figure 82 A/D Start Flag (ADSF)

A/D Current Off Flag (IAOF: $021, Bit 2): By setting this 1-bit flag to 1, the current flowing through the ladder resistor of the A/D converter is cut off during standby and active modes. See figure 83.

A/D current off flag (IAOF: $021, bit 2)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	R/W	R/W	R/W	R/W
Bit name	RAME	IAOF	ICEF	ICSF

RAME
Refer to description of operating modes

ICEF
Refer to description of timers

IAOF (A/D current off flag)	
1	Current I_{AD} is cut off.
0	Current I_{AD} flows.

ICSF
Refer to description of timers

Figure 83 A/D Current Off Flag (IAOF)

Note on Use: Use the SEM and SEMD instructions to write data to the A/D start flag (ADSF: $020, bit 2), but make sure that the A/D start flag is not written to during A/D conversion. Data read from the A/D data register (ADRL: $017, ADRU: $018) during A/D conversion cannot be guaranteed.

The A/D converter does not operate in the stop, watch, and subactive modes because it relies on the clock from OSC, which is stopped in these modes. During these low-power dissipation modes, current through the resistor ladder is cut off to decrease the power input.

The port data register (PDR) is initialized to 1 by an MCU reset. At this time, if pull-up MOS is selected as active by bit 3 of the miscellaneous register (MIS3), the port will be pulled up to V_{CC}. When using a shared R port/analog input pin as an input pin, clear PDR to 0. Otherwise, if pull-up MOS is selected by MIS3 and PDR is set to 1, a pin selected by bit 1 of the A/D mode register as an analog pin will remain pulled up.

LCD Controller/Driver

The MCU has an LCD controller and driver which drive 4 common signal pins and 32 segment pins. The controller consists of a RAM area in which display data is stored, a display control register (LCR: $01B), and a duty-cycle/clock-control register (LMR: $01C) (figure 84).

Four duty cycles and the LCD clock are programmable, and a built-in dual-port RAM ensures that display data can be automatically transmitted to the segment signal pins without program intervention. If a 32-kHz oscillation clock is selected as the LCD clock source, the LCD can even be used in watch mode, in which the system clock stops.

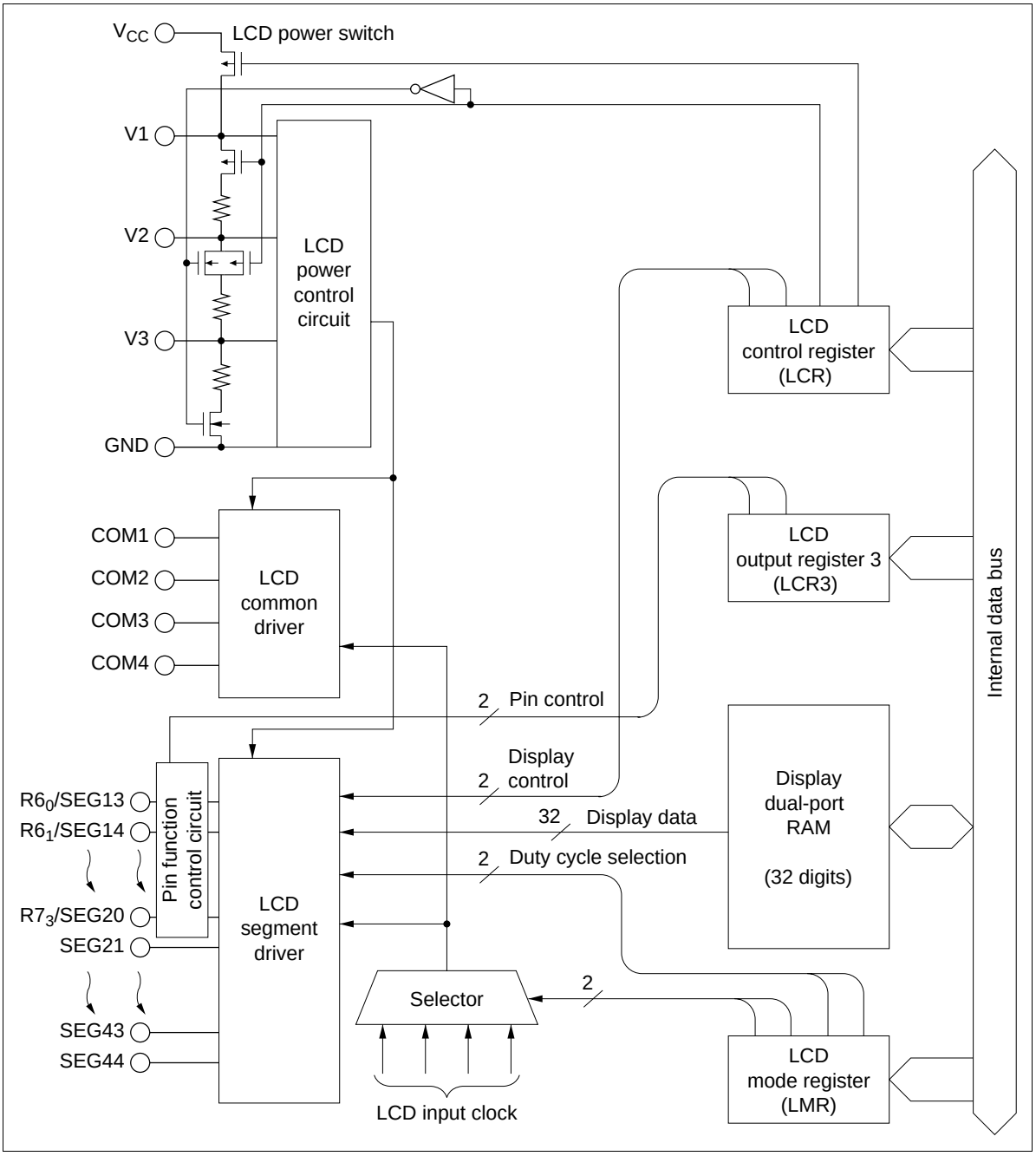


Figure 84 Block Diagram of LCD Controller/Driver

LCD Data Area and Segment Data ($05C–$07B): As shown in figure 85, each bit of the storage area corresponds to one of four duty cycles. If data is written to an area corresponding to a certain duty cycle, it is automatically output to the corresponding segments as display data.

	Bit 3	Bit 2	Bit 1	Bit 0	
92	SEG13	SEG13	SEG13	SEG13	$05C
93	SEG14	SEG14	SEG14	SEG14	$05D
94	SEG15	SEG15	SEG15	SEG15	$05E
95	SEG16	SEG16	SEG16	SEG16	$05F
96	SEG17	SEG17	SEG17	SEG17	$060
97	SEG18	SEG18	SEG18	SEG18	$061
98	SEG19	SEG19	SEG19	SEG19	$062
99	SEG20	SEG20	SEG20	SEG20	$063
100	SEG21	SEG21	SEG21	SEG21	$064
101	SEG22	SEG22	SEG22	SEG22	$065
102	SEG23	SEG23	SEG23	SEG23	$066
103	SEG24	SEG24	SEG24	SEG24	$067
104	SEG25	SEG25	SEG25	SEG25	$068
105	SEG26	SEG26	SEG26	SEG26	$069
106	SEG27	SEG27	SEG27	SEG27	$06A
107	SEG28	SEG28	SEG28	SEG28	$06B
	COM4	COM3	COM2	COM1	

	Bit 3	Bit 2	Bit 1	Bit 0	
108	SEG29	SEG29	SEG29	SEG29	$06C
109	SEG30	SEG30	SEG30	SEG30	$06D
110	SEG31	SEG31	SEG31	SEG31	$06E
111	SEG32	SEG32	SEG32	SEG32	$06F
112	SEG33	SEG33	SEG33	SEG33	$070
113	SEG34	SEG34	SEG34	SEG34	$071
114	SEG35	SEG35	SEG35	SEG35	$072
115	SEG36	SEG36	SEG36	SEG36	$073
116	SEG37	SEG37	SEG37	SEG37	$074
117	SEG38	SEG38	SEG38	SEG38	$075
118	SEG39	SEG39	SEG39	SEG39	$076
119	SEG40	SEG40	SEG40	SEG40	$077
120	SEG41	SEG41	SEG41	SEG41	$078
121	SEG42	SEG42	SEG42	SEG42	$079
122	SEG43	SEG43	SEG43	SEG43	$07A
123	SEG44	SEG44	SEG44	SEG44	$07B
	COM4	COM3	COM2	COM1	

Figure 85 Configuration of LCD RAM Area (for Dual-Port RAM)

LCD Control Register (LCR: $01B): Four-bit write-only register which controls LCD blanking, on/off switching of the liquid-crystal display's power supply division resistor, display in watch and subactive modes, and connection of the LCD division resistor, as shown in figure 86.

- Blank/display
  Blank: Segment signals are turned off, regardless of LCD RAM data setting.
  Display: LCD RAM data is output as segment signals.

- Power switch on/off
  Off: The power switch is off.
  On: The power switch is on and V_1 is V_{CC}.

- Watch/subactive mode display
  Off: In watch and subactive modes, all common and segment pins are grounded and the liquid-crystal power switch is turned off.
  On: In watch and subactive modes, LCD RAM data is output as segment signals.

- LCD power supply division resistor switch
  Off: Division resistor is disconnected.
  On: Division resistor is connected.

LCD display control register (LCR: $01B)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	LCR3	LCR2	LCR1	LCR0

LCR3	LCD power supply division resistor switch
0	On
1	Off

LCR2	Display on/off selection in watch and subactive modes
0	Off
1	On

LCR1	Power switch on/off
0	Off
1	On

LCR0	Blank/display
0	Blank
1	Display

Figure 86 LCD Control Register (LCR)

LCD Duty-Cycle/Clock Control Register (LMR: $01C): Four-bit write-only register which selects the display duty cycle and LCD clock source, as shown in figure 87. The dependence of frame frequency on duty cycle is listed in table 30.

LCD duty cycle/clock control register (LMR: $01C)

Bit	3	2	1	0
Initial value	0	0	0	0
Read/Write	W	W	W	W
Bit name	LMR3	LMR2	LMR1	LMR0

LMR3	LMR2	Input clock source selection
0	0	CL0 (32.768 × duty/64: when 32.768-kHz oscillation is used)
0	1	CL1 (f_{OSC} × duty cycle/1024)
1	0	CL2 (f_{OSC} × duty cycle/8192)
1	1	CL3 (refer to table 29)

LMR1	LMR0	Duty cycle selection
0	0	1/4 duty
0	1	1/3 duty
1	0	1/2 duty
1	1	Static

Figure 87 LCD Duty-Cycle/Clock Control Register (LMR)

Table 30 LCD Frame Frequencies for Different Duty Cycles

				Frame Frequencies			
Duty Cycle	**LMR3**	**LMR2**		**f_{osc} = 400 kHz**	**f_{osc} = 800 kHZ**	**f_{osc} = 2 MHz**	**f_{osc} = 4 MHz**
Static	0	0	CL0	512 Hz	512 Hz	512 Hz	512 Hz
		1	CL1	390.6 Hz	781.3 Hz	1953 Hz	3906 Hz
	1	0	CL2	48.8 Hz	97.7 Hz	244.1 Hz	488.3 Hz
		1	CL3*	24.4 Hz	48.8 Hz	122.1 Hz	244.1 Hz
				64 Hz	64 Hz	64 Hz	64 Hz
1/2	0	0	CL0	256 Hz	256 Hz	256 Hz	256 Hz
		1	CL1	195.3 Hz	390.6 Hz	976.6 Hz	1953 Hz
	1	0	CL2	24.4 Hz	48.8 Hz	122.1 Hz	244.1 Hz
		1	CL3*	12.2 Hz	24.4 Hz	61 Hz	122.1 Hz
				32 Hz	32 Hz	32 Hz	32 Hz
1/3	0	0	CL0	170.7 Hz	170.7 Hz	170.7 Hz	170.7 Hz
		1	CL1	130.2 Hz	260.4 Hz	651 Hz	1302 Hz
	1	0	CL2	16.3 Hz	32.6 Hz	81.4 Hz	162.8 Hz
		1	CL3*	8.1 Hz	16.3 Hz	40.7 Hz	81.4 Hz
				21.3 Hz	21.3 Hz	21.3 Hz	21.3 Hz
1/4	0	0	CL0	128 Hz	128 Hz	128 Hz	128 Hz
		1	CL1	97.7 Hz	195.3 Hz	488.3 Hz	976.6 Hz
	1	0	CL2	12.2 Hz	24.4 Hz	61 Hz	122.1 Hz
		1	CL3*	6.1 Hz	12.2 Hz	30.5 Hz	61 Hz
				16 Hz	16 Hz	16 Hz	16 Hz

Note: * The division ratio depends on the value of bit 3 of timer mode register A (TMA).
Upper value: When TMA3 = 0, CL3 = $f_{OSC} \times$ duty cycle/16384.
Lower value: When TMA3 = 1, CL3 = 32.768 kHz $\times$ duty cycle/512.

LCD Output Register 3 (LOR3: $01F): Write-only register used to specify ports R6 and R7 as pins SEG13–SEG20 in 4-pin units (figure 88).

LCD output register 3 (LOR3: $01F)

Bit	3	2	1	0
Initial value	—	0	0	—
Read/Write	—	W	W	—
Bit name	Not used	LOR32	LOR31	Not used

LOR32	R7/SEG17–SEG20 mode selection
0	R7
1	SEG17–SEG20

LOR31	R6/SEG13–SEG16 mode selection
0	R6
1	SEG13–SEG16

Figure 88 LCD Output Register 3 (LOR3)

Large Liquid-Crystal Panel Drive and V_{LCD}: If the capacitance of the LCD is very large while being driven, decrease the capacitance by attaching external resistors in parallel, as shown in figure 89.

The size of these resistors cannot be simply calculated from the LCD load capacitance because the matrix configuration of the LCD complicates the paths of charge/discharge currents flowing through the capacitors—the resistance will also vary with lighting conditions. This size must be determined by trial-and-error, taking into account the power dissipation of the device using the LCD, but a resistance of 1 to 10 kΩ is usually suitable. (Another effective method is to attach capacitors of 0.1 to 0.3 μF.)

Always turn off the power switch (set bit 1 of the LCR to 0) before changing the liquid-crystal drive voltage (V_{LCD}).

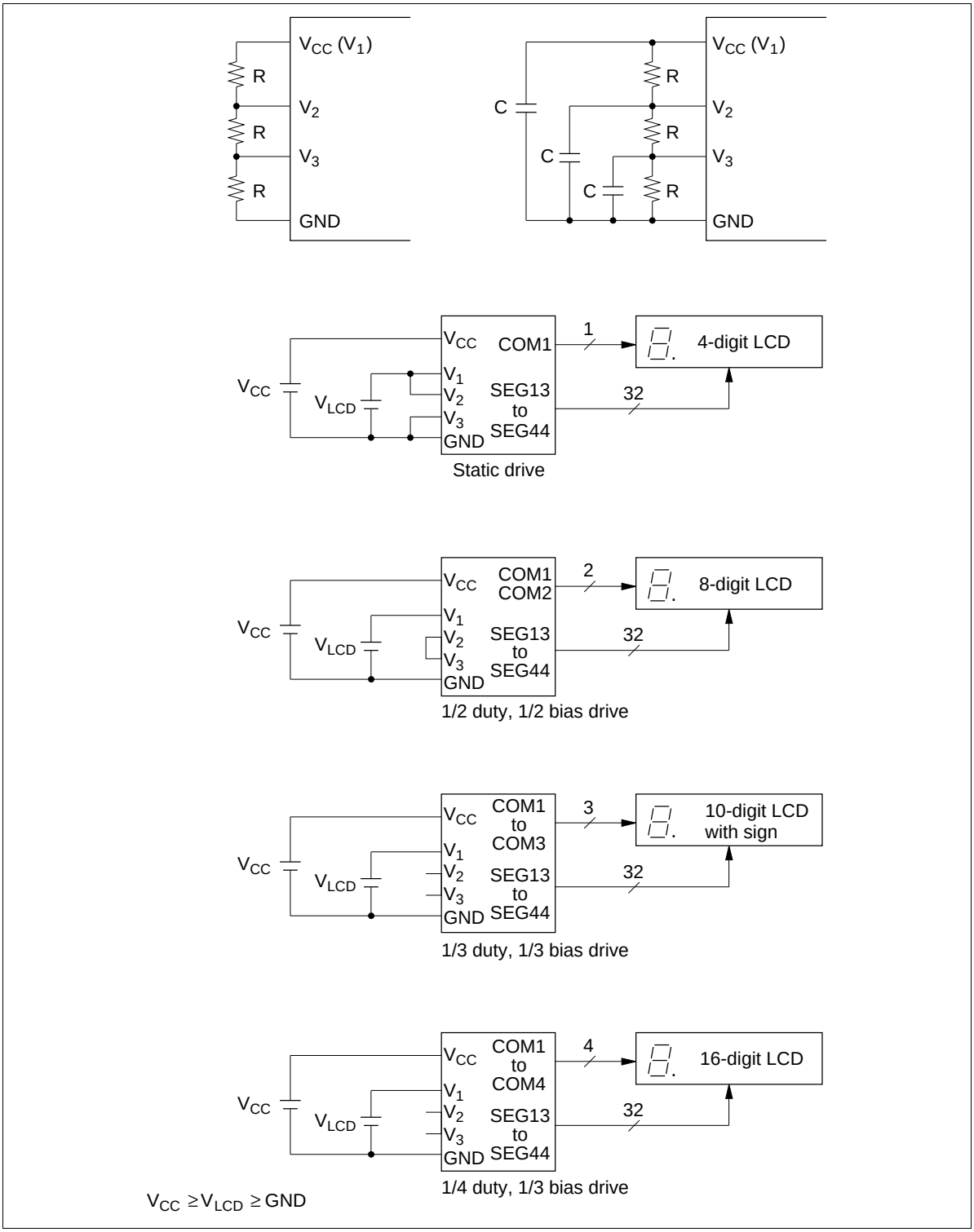


Figure 89 LCD Connection Examples

Programmable ROM (HD4074849)

The HD4074849 is a ZTAT™ microcomputer with built-in PROM that can be programmed in PROM mode.

Pin Description by Mode

Pin No.		MCU Mode		PROM Mode		Pin No		MCU Mode		PROM Mode	
FP-80A, TFP- 80C	FP-80B	Pin Name	I/O	Pin Name	I/O	FP- 80A, TFP-80C	FP-80B	Pin Name	I/O	Pin Name	I/O
1	3	$R3_2/AN_6$	I/O	A_3	I	28	30	$R1_2$/TOD	I/O	A_7	I
2	4	$R3_3/AN_7$	I/O	A_4	I	29	31	$R1_3/\overline{EVNB}$	I/O	A_8	I
3	5	AV_{SS}		GND		30	32	$R2_0$/EVND	I/O	A_0	I
4	6	TEST	I	TEST	I	31	33	$R2_1/\overline{SCK}$	I/O	O_0	I/O
5	7	OSC_1	I	V_{CC}		32	34	$R2_2$/SI	I/O	O_1	I/O
6	8	OSC_2	O			33	35	$R2_3$/SO	I/O	O_2	I/O
7	9	$\overline{RESET}$	I	$\overline{RESET}$	I	34	36	$R6_0$/SEG13	I/O	O_3	I/O
8	10	X1	I	GND		35	37	$R6_1$/SEG14	I/O	O_4	I/O
9	11	X2	O			36	38	$R6_2$/SEG15	I/O	O_4	I/O
10	12	GND		GND		37	39	$R6_3$/SEG16	I/O	O_3	I/O
11	13	D_0	I/O	$\overline{CE}$	I	38	40	$R7_0$/SEG17	I/O	O_2	I/O
12	14	D_1	I/O	$\overline{OE}$	I	39	41	$R7_1$/SEG18	I/O	O_1	I/O
13	15	D_2	I/O	V_{CC}		40	42	$R7_2$/SEG19	I/O	O_0	I/O
14	16	D_3	I/O	V_{CC}		41	43	$R7_3$/SEG20	I/O	V_{CC}	
15	17	D_4	I/O	A_{10}	I	42	44	SEG21	O		
16	18	D_5	I/O	A_{11}	I	43	45	SEG22	O		
17	19	D_6	I/O	A_{12}	I	44	46	SEG23	O		
18	20	D_7	I/O	A_{13}	I	45	47	SEG24	O		
19	21	D_8	I/O	A_{14}	I	46	48	SEG25	O		
20	22	$D_{10}/\overline{STOPC}$	I	A_9	I	47	49	SEG26	O		
21	23	$D_{11}/\overline{INT}_0$	I	V_{PP}		48	50	SEG27	O		
22	24	$R0_0/\overline{INT}_1$	I/O	$\overline{M}_0$	I	49	51	SEG28	O		
23	25	$R0_1/INT_2$	I/O	$\overline{M}_1$	I	50	52	SEG29	O		
24	26	$R0_2/INT_3$	I/O			51	53	SEG30	O		
25	27	$R0_3$	I/O			52	54	SEG31	O		
26	28	$R1_0$/TOB	I/O	A_5	I	53	55	SEG32	O		
27	29	$R1_1$/TOC	I/O	A_6	I	54	56	SEG33	O		

Pin No.		MCU Mode		PROM Mode		Pin No		MCU Mode		PROM Mode	
FP-80A, TFP- 80C	FP-80B	Pin Name	I/O	Pin Name	I/O	FP- 80A, TFP-80C	FP-80B	Pin Name	I/O	Pin Name	I/O
55	57	SEG34	O			68	70	COM3	O		
56	58	SEG35	O			69	71	COM4	O		
57	59	SEG36	O			70	72	V1			
58	60	SEG37	O			71	73	V2			
59	61	SEG38	O			72	74	V3			
60	62	SEG39	O			73	75	V_{CC}		V_{CC}	
61	63	SEG40	O			74	76	AV_{CC}		V_{CC}	
62	64	SEG41	O			75	77	AN0	I		
63	65	SEG42	O			76	78	AN1	I		
64	66	SEG43	O			77	79	AN2	I		
65	67	SEG44	O			78	80	AN3	I		
66	68	COM1	O			79	1	$R3_0/AN_4$	I/O	A_1	I
67	69	COM2	O			80	2	$R3_1/AN_5$	I/O	A_2	I

Notes: 1. I/O: Input/output pin, I: Input pin, O: Output pin
2. Each of O_0–O_4 has two pins; before using, each pair must be connected together.

PROM Mode Pin Functions

V_{PP}: Applies the programming voltage (12.5 V ± 0.3 V) to the built-in PROM.

$\overline{CE}$: Inputs a control signal to enable PROM programming and verification.

$\overline{OE}$: Inputs a data output control signal for verification.

A_0–A_{14}: Act as address input pins of the built-in PROM.

O_0–O_4: Act as data bus input pins of the built-in PROM. Each of O_0–O_4 has two pins; before using these pins, connect each pair together.

$\overline{M}_0$, $\overline{M}_1$, $\overline{RESET}$, TEST: Used to set PROM mode. The MCU is set to PROM mode by pulling $\overline{M}_0$, $\overline{M}_1$, and $\overline{RESET}$ low, and $\overline{TEST}$ high.

Other Pins: Connect pins AV_{CC}, OSC_1, D_2, D_3, $R7_3$/SEG20, and V_{CC} to V_{CC}. Connect pins AV_{SS} and X1 to GND. Leave other pins open.

Programming the Built-In PROM

The MCU's built-in PROM is programmed in PROM mode. PROM mode is set by pulling $\overline{RESET}$, $\overline{M}_0$, and $\overline{M}_1$ low, and TEST high. In PROM mode, the MCU does not operate, but it can be programmed in the

same way as any other commercial 27256-type EPROM using a standard PROM programmer and an 80-to-28-pin socket adapter. Recommended PROM programmers and socket adapters are listed in table 31.

Since an HMCS400-series instruction is ten bits long, the HMCS400-series MCU has a built-in conversion circuit to enable the use of a general-purpose PROM programmer. As shown in figure 90, this circuit splits each instruction into five lower bits and five upper bits that are read from or written to consecutive addresses. This means that if, for example, 16 kwords of built-in PROM are to be programmed by a general-purpose PROM programmer, a 32-kbyte address space ($0000–$7FFF) must be specified.

Table 31 Recommended PROM Programmers and Socket Adapters

PROM Programmer

Manufacturer	Model name
DATA I/O Corp.	121B 29B
AVAL Corp.	PKW–1000

Socket Adapter

Package	Model Name	Manufacturer
FP-80A	HS4849ESH01H	Hitachi
FP-80B	HS4849ESF01H	
TFP-80C	HS4849ESN01H	

Warnings

1. Always specify addresses $0000 to $7FFF when programming with a PROM programmer. If address $8000 or higher is accessed, the PROM may not be programmed or verified correctly. Set all data in unused addresses to $FF.

   Note that the plastic-package version cannot be erased and reprogrammed.
2. Make sure that the PROM programmer, socket adapter, and LSI are aligned correctly (their pin 1 positions match), otherwise overcurrents may damage the LSI. Before starting programming, make sure that the LSI is firmly fixed in the socket adapter and the socket adapter is firmly fixed onto the programmer.
3. PROM programmers have two voltages (V_{PP}): 12.5 V and 21 V. Remember that Hitachi devices require a V_{PP} of 12.5 V—the 21-V setting will damage them. 12.5 V is the Intel 27256 setting.

Programming and Verification

The built-in PROM of the MCU can be programmed at high speed without risk of voltage stress or damage to data reliability.

Programming and verification modes are selected as listed in table 32, the memory map in PROM mode is shown in figure 90.

Table 32 PROM Mode Selection

	Pin			
Mode	**$\overline{CE}$**	**$\overline{OE}$**	**V_{PP}**	**O_0–O_4**
Programming	Low	High	V_{PP}	Data input
Verification	High	Low	V_{PP}	Data output
Programming inhibited	High	High	V_{PP}	High impedance

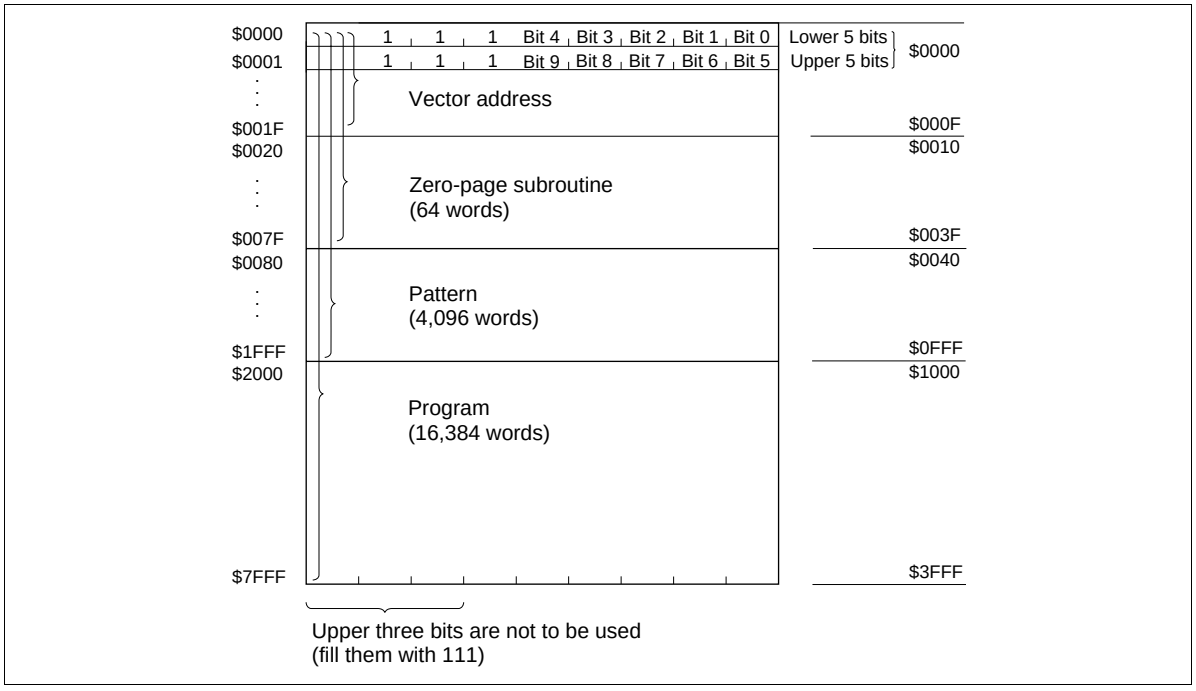


Figure 90 Memory Map in PROM Mode

Addressing Modes

RAM Addressing Modes

The MCU has three RAM addressing modes, as shown in figure 91 and described below.

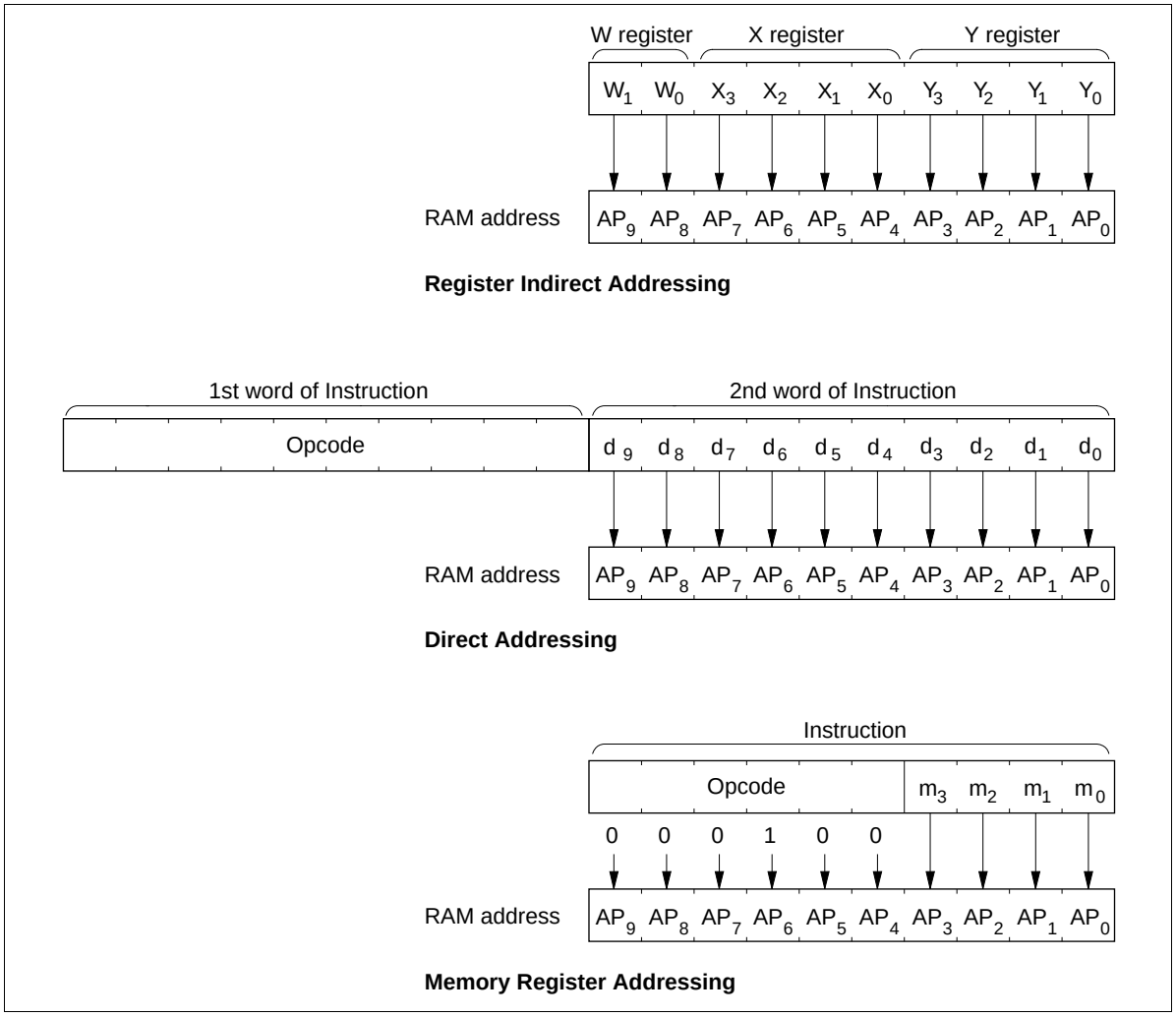


Figure 91 RAM Addressing Modes

Register Indirect Addressing Mode: The contents of the W, X, and Y registers (10 bits in total) are used as a RAM address. When the area from $090 to $25F is used, a bank must be selected by the bank register (V: $03F).

Direct Addressing Mode: A direct addressing instruction consists of two words. The first word contains the opcode, and the contents of the second word (10 bits) are used as a RAM address.

Memory Register Addressing Mode: The memory registers (MR), which are located in 16 addresses from $040 to $04F, are accessed with the LAMR and XMRA instructions.

ROM Addressing Modes and the P Instruction

The MCU has four ROM addressing modes, as shown in figure 92 and described below.

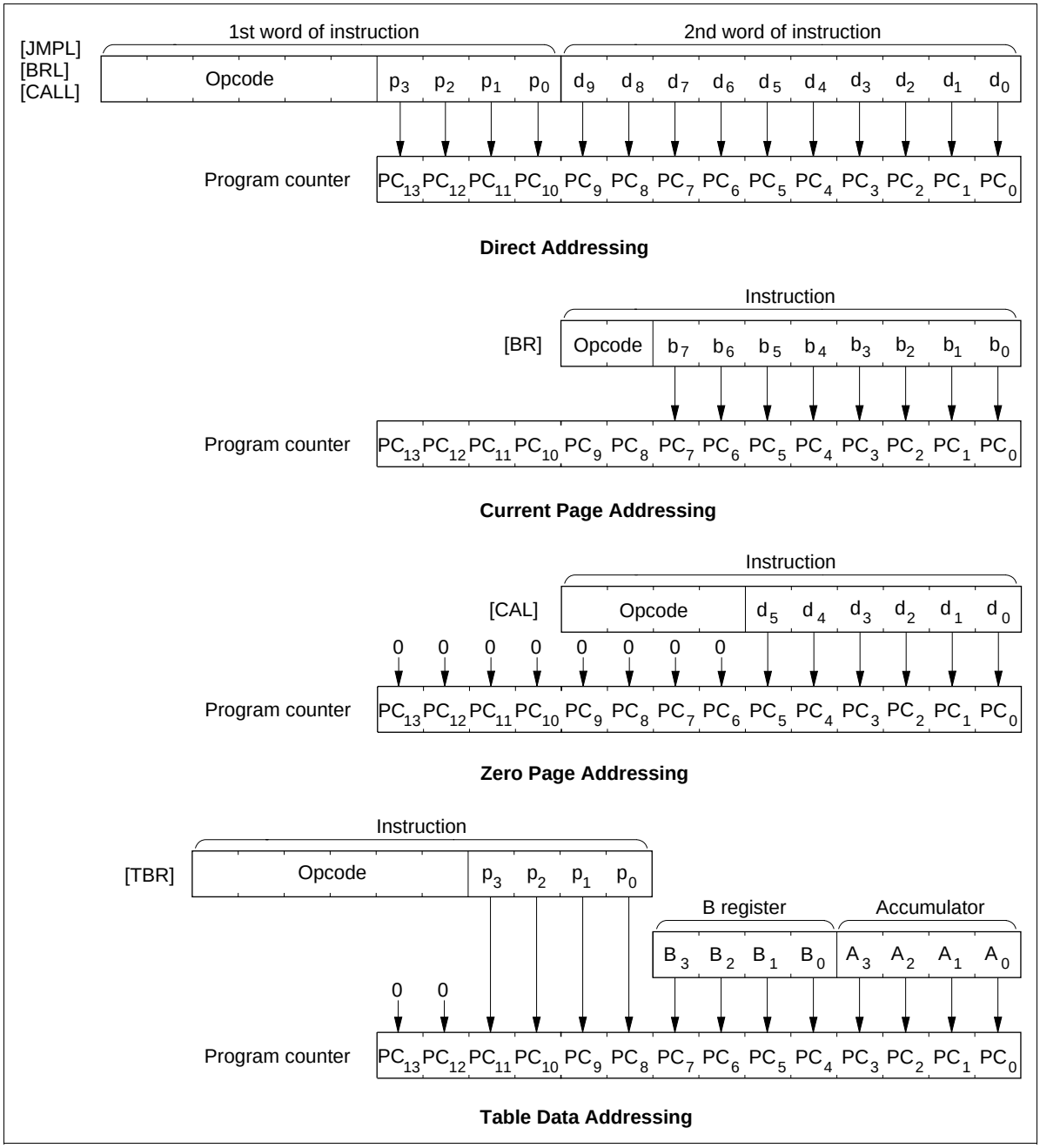


Figure 92 ROM Addressing Modes

Direct Addressing Mode: A program can branch to any address in the ROM memory space by executing the JMPL, BRL, or CALL instruction. Each of these instructions replaces the 14 program counter bits (PC_{13}–PC_0) with 14-bit immediate data.

Current Page Addressing Mode: The MCU has 64 pages of ROM with 256 words per page. A program can branch to any address in the current page by executing the BR instruction. This instruction replaces the eight low-order bits of the program counter (PC_7–PC_0) with eight-bit immediate data. If the BR instruction is on a page boundary (address 256n + 255), executing that instruction transfers the PC contents to the next physical page, as shown in figure 94. This means that the execution of the BR instruction on a page boundary will make the program branch to the next page.

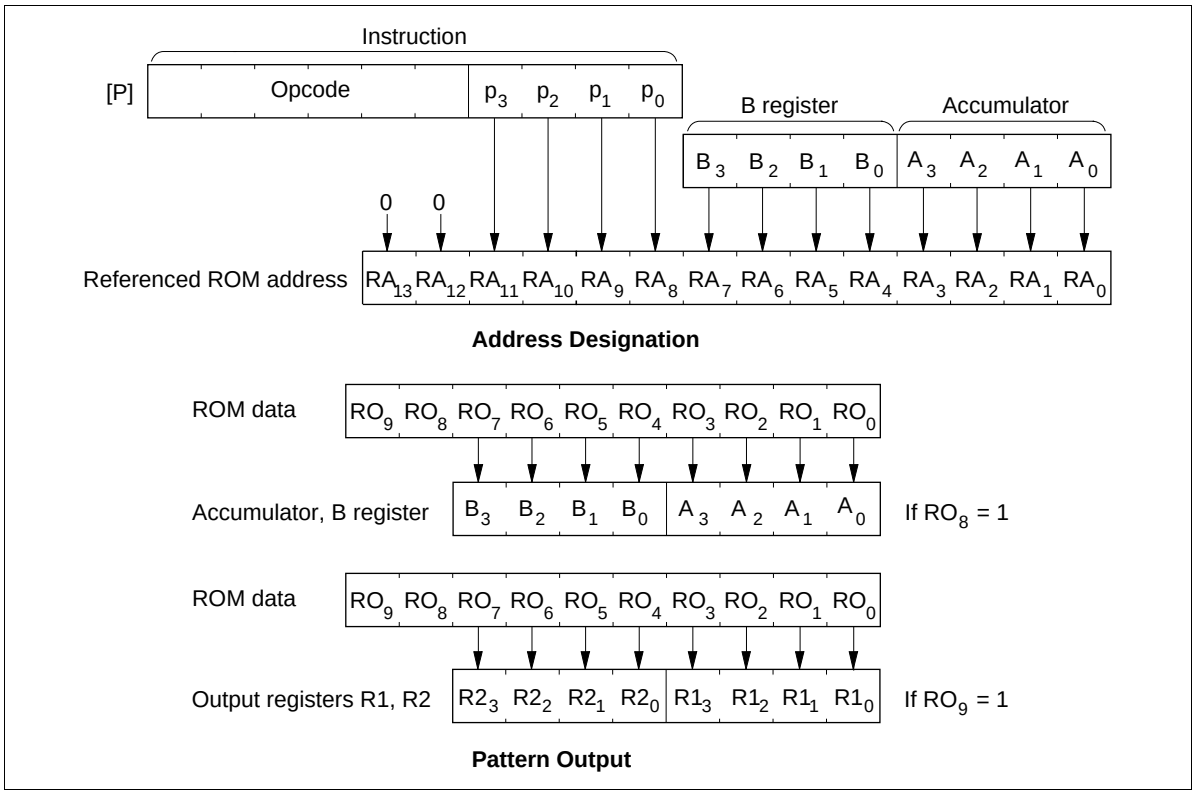


Figure 93 P Instruction

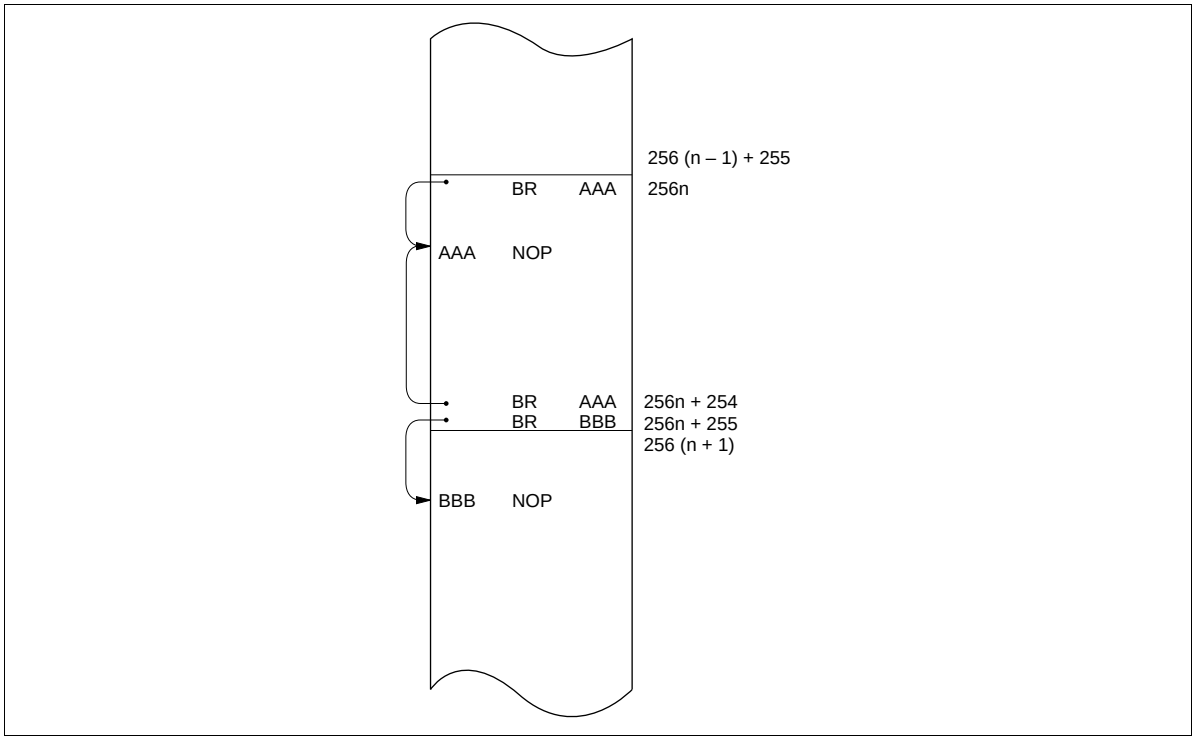


Figure 94 Branching when the Branch Destination is on a Page Boundary

Note that the HMCS400-series cross macroassembler has an automatic paging feature for ROM pages.

Zero-Page Addressing Mode: A program can branch to the zero-page subroutine area located at $0000–$003F by executing the CAL instruction. When the CAL instruction is executed, 6 bits of immediate data are placed in the six low-order bits of the program counter (PC_5–PC_0), and 0s are placed in the eight high-order bits (PC_{13}–PC_6).

Table Data Addressing Mode: A program can branch to an address determined by the contents of four-bit immediate data, the accumulator, and the B register by executing the TBR instruction.

P Instruction: ROM data addressed in table data addressing mode can be referenced with the P instruction as shown in figure 93. If bit 8 of the ROM data is 1, the lower eight bits of ROM data are written to the accumulator and the B register. If bit 9 is 1, the lower eight bits of ROM data are written to the R1 and R2 port output registers. If both bits 8 and 9 are 1, ROM data is written to the accumulator and the B register, and also to the R1 and R2 port output registers at the same time.

The P instruction has no effect on the program counter.

Absolute Maximum Ratings

Item	Symbol	Value	Unit	Notes
Supply voltage	V_{CC}	–0.3 to +7.0	V	
Programming voltage	V_{PP}	–0.3 to +14.0	V	1
Pin voltage	V_T	–0.3 to V_{CC} + 0.3	V	
Total permissible input current	$\sum I_o$	100	mA	2
Total permissible output current	$-\sum I_o$	50	mA	3
Maximum input current	I_o	4	mA	4, 5
		30	mA	4, 6
Maximum output current	$-I_o$	4	mA	7, 8
Operating temperature	T_{opr}	–20 to +75	°C	
Storage temperature	T_{stg}	–55 to +125	°C	

Notes: Permanent damage may occur if these absolute maximum ratings are exceeded. Normal operation must be under the conditions stated in the electrical characteristics tables. If these conditions are exceeded, the LSI may malfunction or its reliability may be affected.

1. Applies to D_{11} (V_{PP}) of the HD4074849.
2. The total permissible input current is the total of input currents simultaneously flowing in from all the I/O pins to ground.
3. The total permissible output current is the total of output currents simultaneously flowing out from V_{CC} to all I/O pins.
4. The maximum input current is the maximum current flowing from each I/O pin to ground.
5. Applies to R0–R3, R6, and R7.
6. Applies to D_0–D_8.
7. The maximum output current is the maximum current flowing out from V_{CC} to each I/O pin.
8. Applies to D_0–D_8, R0–3, R6, and R7.

Electrical Characteristics

DC Characteristics (HD404848/HD4048412/HD404849: V_{CC} = 2.7 to 6.0 V, GND = 0 V, T_a = –20°C to +75°C; HD4074849: V_{CC} = 2.7 to 5.5 V, GND = 0 V, T_a = –20°C to +75°C, unless otherwise specified)

Item	Symbol	Pin(s)	Min	Typ	Max	Unit	Test Condition	Notes
Input high voltage	V_{IH}	$\overline{RESET}$, $\overline{SCK}$, SI, $\overline{INT_0}$, $\overline{INT_1}$, INT_2, INT_3, $\overline{STOPC}$, $\overline{EVNB}$, EVND	0.9V_{CC}	—	V_{CC} + 0.3	V	—	
		OSC_1	V_{CC} – 0.3	—	V_{CC} + 0.3	V	External clock operation	
Input low voltage	V_{IL}	$\overline{RESET}$, $\overline{SCK}$, SI, $\overline{INT_0}$, $\overline{INT_1}$, INT_2, INT_3, $\overline{STOPC}$, $\overline{EVNB}$, EVND	–0.3	—	0.1V_{CC}	V	—	
		OSC_1	–0.3	—	0.3	V	External clock operation	
Output high voltage	V_{OH}	$\overline{SCK}$, SO, TOB, TOC, TOD	V_{CC} – 1.0	—	—	V	$-I_{OH}$ = 0.5 mA	
Output low voltage	V_{OL}	$\overline{SCK}$, SO, TOB, TOC, TOD	—	—	0.4	V	I_{OL} = 0.4 mA	
I/O leakage current	$\|I_{IL}\|$	$\overline{RESET}$, $\overline{SCK}$, SI, $\overline{INT_0}$, $\overline{INT_1}$, INT_2, INT_3, $\overline{STOPC}$, $\overline{EVNB}$, EVND, OSC_1, TOB, TOC, TOD, SO	—	—	1.0	µA	V_{in} = 0 V to V_{CC}	1
Current dissipation in active mode	I_{CC1}	V_{CC}	—	3	6	mA	V_{CC} = 5.0 V, f_{OSC} = 4 MHz	2
	I_{CC2}	V_{CC}	—	0.6	1.8	mA	V_{CC} = 3.0 V, f_{OSC} = 800 kHz	2
Current dissipation in standby mode	I_{SBY1}	V_{CC}	—	1.0	2.0	mA	V_{CC} = 5.0 V, f_{OSC} = 4 MHz, LCD on	3
	I_{SBY2}	V_{CC}	—	0.2	0.7	mA	V_{CC} = 3.0 V, f_{OSC} = 800 kHz LCD on	3

Item	Symbol	Pin(s)	Min	Typ	Max	Unit	Test Condition	Notes
Current dissipation in subactive mode	I_{SUB}	V_{CC}	—	25	50	µA	V_{CC} = 3.0 V, LCD on	4, 7, 8
			—	35	70	µA	V_{CC} = 3.0 V, LCD on	5, 7, 8
			—	70	150	µA	V_{CC} = 3.0 V, LCD on	6, 7, 8
Current dissipation in watch mode	I_{WTC1}	V_{CC}	—	15	40	µA	V_{CC} = 3.0 V, LCD on	8
	I_{WTC2}	V_{CC}	—	5	10	µA	V_{CC} = 3.0 V, LCD off	8
Current dissipation in stop mode	I_{STOP}	V_{CC}	—	—	5	µA	V_{CC} = 3.0 V no 32-kHz oscillator	8
Stop mode retaining voltage	V_{STOP}	V_{CC}	1.5	—	—	V	No 32-kHz oscillator	9

Notes:
1. Output buffer current is excluded.
2. I_{CC1} and I_{CC2} are the source currents when no I/O current is flowing while the MCU is in reset state.
   Test conditions: MCU: Reset
   Pins: $\overline{\text{RESET}}$ and TEST at GND
3. I_{SBY1} and I_{SBY2} are the source currents when no I/O current is flowing while the MCU timer is operating.
   Test conditions: MCU: I/O reset
   Standby mode
   Pins: $\overline{\text{RESET}}$ at V_{CC}
   TEST at GND
   D_0–D_8, D_{10}, D_{11}, R0–R3, R6, R7 at V_{CC}
4. Applies to HD404848.
5. Applies to HD4048412 and HD404849.
6. Applies to HD4074849.
7. When the LCD power supply division resistor is connected (LCR3 = 0).
8. These are the source currents when no I/O current is flowing.
   Test conditions: Pins: $\overline{\text{RESET}}$ at V_{CC}
   TEST at GND
   D_0–D_8, D_{10}, D_{11}, R0–R3, R6, R7 at V_{CC}
9. Test condition voltage necessary for RAM data retention.

I/O Characteristics for Standard Pins (HD404848/HD4048412/HD404849: V_{CC} = 2.7 to 6.0 V, GND = 0 V, T_a = –20°C to +75°C; HD4074849: V_{CC} = 2.7 to 5.5 V, GND = 0 V, T_a = –20°C to +75°C, unless otherwise specified)

Item	Symbol	Pin(s)	Min	Typ	Max	Unit	Test Condition	Notes
Input high voltage	V_{IH}	D_{10}, D_{11}, R0–R3, R6, R7	$0.7V_{CC}$	—	V_{CC} + 0.3	V	—	
Input low voltage	V_{IL}	D_{10}, D_{11}, R0–R3, R6, R7	–0.3	—	$0.3V_{CC}$	V	—	
Output high voltage	V_{OH}	R0–R3, R6, R7	V_{CC} – 1.0	—	—	V	$–I_{OH}$ = 0.5 mA	
Output low voltage	V_{OL}	R0–R3, R6, R7	—	—	0.4	V	I_{OL} = 0.4 mA	
I/O leakage current	$\|I_{IL}\|$	D_{10}, R0–R3, R6, R7	—	—	1	µA	V_{in} = 0 V to V_{CC}	1
		D_{11}	—	—	1	µA	V_{in} = 0 V to V_{CC}	1, 2
			—	—	1	µA	V_{in} = V_{CC} – 0.3 V to V_{CC}	1, 3
			—	—	20	µA	V_{in} = 0 V to 0.3 V	1, 3
Pull-up MOS current	$–I_{PU}$	R0–R3, R6, R7	10	50	150	µA	V_{CC} = 3.0 V, V_{in} = 0 V	

Notes: 1. Output buffer current is excluded.
2. Applies to HD404848, HD4048412, and HD404849.
3. Applies to HD4074849.

I/O Characteristics for High-Current Pins (HD404848/HD4048412/HD404849: V_{CC} = 2.7 to 6.0 V, GND = 0 V, T_a = –20°C to +75°C; HD4074849: V_{CC} = 2.7 to 5.5 V, GND = 0 V, T_a = –20°C to +75°C, unless otherwise specified)

Item	Symbol	Pin(s)	Min	Typ	Max	Unit	Test Condition	Note
Input high voltage	V_{IH}	D_0–D_8	0.7V_{CC}	—	V_{CC} + 0.3	V	—	
Input low voltage	V_{IL}	D_0–D_8	–0.3	—	0.3V_{CC}	V	—	
Output high voltage	V_{OH}	D_0–D_8	V_{CC} – 1.0	—	—	V	$–I_{OH}$ = 0.5 mA	
Output low voltage	V_{OL}	D_0–D_8	—	—	0.4	V	I_{OL} = 0.4 mA	
			—	—	2.0	V	I_{OL} = 15 mA, V_{CC} = 4.5 V to 6.0 V	1
I/O leakage current	$\|I_{IL}\|$	D_0–D_8	—	—	1	µA	V_{in} = 0 V to V_{CC}	2
Pull-up MOS current	$–I_{PU}$	D_0–D_8	10	50	150	µA	V_{CC} = 3 V, V_{in} = 0 V	

Note: 1. The test condition of HD4074849 is V_{CC} = 4.5 V to 5.5 V.
2. Output buffer current is excluded.

LCD Circuit Characteristics (HD404848/HD4048412/HD404849: V_{CC} = 2.7 to 6.0 V, GND = 0 V, T_a = –20°C to +75°C; HD4074849: V_{CC} = 2.7 to 5.5 V, GND = 0 V, T_a = –20°C to +75°C, unless otherwise specified)

Item	Symbol	Pin(s)	Min	Typ	Max	Unit	Test Condition	Note
Segment driver voltage drop	V_{DS}	SEG13–SEG44	—	—	0.6	V	I_d = 3 µA	1
Common driver voltage drop	V_{DC}	COM1–COM4	—	—	0.3	V	I_d = 3 µA	1
LCD power supply division resistance	R_W		50	300	900	kΩ	Between V_1 and GND	
LCD voltage	V_{LCD}	V1	2.7	—	V_{CC}	V		2

Notes: 1. V_{DS} and V_{DC} are the voltage drops from power supply pins V1, V2, V3, and GND to each segment pin and each common pin, respectively.
2. When V_{LCD} is supplied from an external source, the following relations must be retained:
$V_{CC} \geq V1 \geq V2 \geq V3 \geq GND$

A/D Converter Characteristics (HD404848/HD4048412/HD404849: V_{CC} = 2.7 to 6.0 V, GND = 0 V, T_a = –20°C to +75°C; HD4074849: V_{CC} = 2.7 to 5.5 V, GND = 0 V, T_a = –20°C to +75°C, unless otherwise specified)

Item	Symbol	Pin(s)	Min	Typ	Max	Unit	Test Condition	Note
Analog power voltage	AV_{CC}	AV_{CC}	V_{CC} – 0.3	V_{CC}	V_{CC} + 0.3	V	—	1
Analog input voltage	AV_{in}	AN_0–AN_7	AV_{SS}	—	AV_{CC}	V	—	
Current between AV_{CC} and AV_{SS}	I_{AD}	—	—	—	200	µA	V_{CC} = AV_{CC} = 5.0 V	
Analog input capacitance	CA_{in}	AN_0–AN_7	—	15	—	pF	—	
Resolution	—	—	8	8	8	Bit		
Number of inputs	—	—	0	—	8	Channel	—	
Absolute accuracy	—	—	—	—	± 2.0	LSB		
Conversion time	—	—	34	—	67	t_{cyc}	—	
Input impedance	—	AN_0–AN_7	1	—	—	MΩ		

Note: 1. Connect to V_{CC} when the A/D converter is not used.

AC Characteristics (HD404848/HD4048412/HD404849: V_{CC} = 2.7 to 6.0 V, GND = 0 V, T_a = –20°C to +75°C; HD4074849: V_{CC} = 2.7 to 5.5 V, GND = 0 V, T_a = –20°C to +75°C, unless otherwise specified)

Item	Symbol	Pin(s)	Min	Typ	Max	Unit	Test Condition	Note
Clock oscillation frequency	f_{OSC}	OSC_1, OSC_2	0.4	—	4.5	MHz	1/4 division	1
		X1, X2	—	32.768	—	kHz	—	
Instruction cycle time	t_{cyc}	—	0.89	—	10	µs		
	t_{subcyc}	—	—	244.14	—	µs	32-kHz oscillator, 1/8 division	2
			—	122.07	—	µs	32-kHz oscillator, 1/4 division	2
Oscillation stabilization time (ceramic oscillator)	t_{RC}	OSC_1, OSC_2	—	—	7.5	ms		3
Oscillation stabilization time (crystal oscillator)	t_{RC}	OSC_1, OSC_2	—	—	30	ms	—	3
		X1, X2	—	—	2	s	T_a = –10°C to+60°C	3
External clock high width	t_{CPH}	OSC_1	105	—	—	ns	f_{OSC} = 4 MHz	4
External clock low width	t_{CPL}	OSC_1	105	—	—	ns	f_{OSC} = 4 MHz	4
External clock rise time	t_{CPr}	OSC_1	—	—	20	ns	f_{OSC} = 4 MHz	4
External clock fall time	t_{CPf}	OSC_1	—	—	20	ns	f_{OSC} = 4 MHz	4
$\overline{INT_0}$–INT_3, $\overline{EVNB}$, EVND high widths	t_{IH}	$\overline{INT_0}$–INT_3, $\overline{EVNB}$, EVND	2	—	—	t_{cyc}/ t_{subcyc}	—	5
$\overline{INT_0}$–INT_3, $\overline{EVNB}$, EVND low widths	t_{IL}	$\overline{INT_0}$–INT_3, $\overline{EVNB}$, EVND	2	—	—	t_{cyc}/ t_{subcyc}	—	5
$\overline{RESET}$ low width	t_{RSTL}	$\overline{RESET}$	2	—	—	t_{cyc}	—	6
$\overline{STOPC}$ low width	t_{STPL}	$\overline{STOPC}$	1	—	—	t_{RC}	—	7
$\overline{RESET}$ rise time	t_{RSTr}	$\overline{RESET}$	—	—	20	ms	—	6
$\overline{STOPC}$ rise time	t_{STPr}	$\overline{STOPC}$	—	—	20	ms	—	7
Input capacitance	C_{in}	All pins except D_{11}	—	—	15	pF	f = 1 MHz, V_{in} = 0 V	
		D_{11}	—	—	180	pF	f = 1 MHz, V_{in} = 0 V	8

Notes: 1. When the subsystem oscillator (32.768-kHz crystal oscillator) is used, f_{OSC} must operate under one of the following conditions: 0.4 MHz ≤ f_{OSC} ≤ 1.0 MHz or 1.6 MHz ≤ f_{OSC} ≤ 4.5 MHz. Set bit 1 of the system clock select register (SSR: $029) to 0 for the former, and 1 for the latter.

2. For the HD404848, HD4048412, and HD404849, instructions can be executed during subactive mode if V_{CC} = 2.2 V to 6.0 V.

3. The oscillation stabilization time is defined as the time required for the oscillator to stabilize in the following three cases:
   - After V_{CC} reaches 2.7 V at power-on
   - After $\overline{RESET}$ input goes low when stop mode is cancelled

• After $\overline{\text{STOPC}}$ input goes low when stop mode is cancelled

At power-on or when stop mode is cancelled, $\overline{\text{RESET}}$ or $\overline{\text{STOPC}}$ must be input for at least t_{RC} to ensure the oscillation stabilization time. If using a ceramic or crystal oscillator, contact its manufacturer to determine what stabilization time is required since it will depend on the circuit constants and stray capacitances.

4. See figure 95.
5. See figure 96.
6. See figure 97.
7. See figure 98.
8. The max value for the HD404848, HD4048412, HD404849 is 15 pF.

Serial Interface Timing Characteristics (HD404848/HD4048412/HD404849: V_{CC} = 2.7 to 6.0 V, GND = 0 V, T_a = –20°C to +75°C; HD4074849: V_{CC} = 2.7 to 5.5 V, GND = 0 V, T_a = –20°C to +75°C, unless otherwise specified)

During Transmit Clock Output

Item	Symbol	Pin	Min	Typ	Max	Unit	Test Condition	Note
Transmit clock cycle time	t_{Scyc}	$\overline{\text{SCK}}$	1.0	—	—	t_{cyc}	Load shown in figure 100	1
Transmit clock high width	t_{SCKH}	$\overline{\text{SCK}}$	0.4	—	—	t_{Scyc}	Load shown in figure 100	1
Transmit clock low width	t_{SCKL}	$\overline{\text{SCK}}$	0.4	—	—	t_{Scyc}	Load shown in figure 100	1
Transmit clock rise time	t_{SCKr}	$\overline{\text{SCK}}$	—	—	100	ns	Load shown in figure 100	1
Transmit clock fall time	t_{SCKf}	$\overline{\text{SCK}}$	—	—	100	ns	Load shown in figure 100	1
Serial output data delay time	t_{DSO}	SO	—	—	300	ns	Load shown in figure 100	1
Serial input data setup time	t_{SSI}	SI	200	—	—	ns	—	1
Serial input data hold time	t_{HSI}	SI	200	—	—	ns	—	1

Note: 1. Refer to figure 99.

During Transmit Clock Input

Item	Symbol	Pin	Min	Typ	Max	Unit	Test Condition	Note
Transmit clock cycle time	t_{Scyc}	$\overline{SCK}$	1.0	—	—	t_{cyc}	—	1
Transmit clock high width	t_{SCKH}	$\overline{SCK}$	0.4	—	—	t_{Scyc}	—	1
Transmit clock low width	t_{SCKL}	$\overline{SCK}$	0.4	—	—	t_{Scyc}	—	1
Transmit clock rise time	t_{SCKr}	$\overline{SCK}$	—	—	100	ns	—	1
Transmit clock fall time	t_{SCKf}	$\overline{SCK}$	—	—	100	ns	—	1
Transmit output data delay time	t_{DSO}	SO	—	—	300	ns	Load shown in figure 100	1
Serial input data setup time	t_{SSI}	SI	200	—	—	ns	—	1
Serial input data hold time	t_{HSI}	SI	200	—	—	ns	—	1

Note: 1. Refer to figure 99.

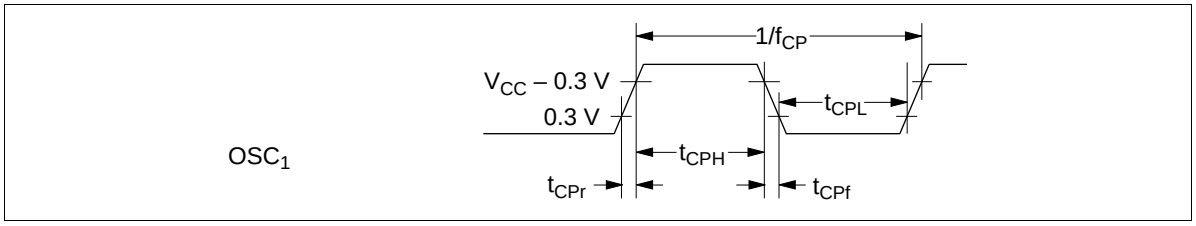


Figure 95 External Clock Timing

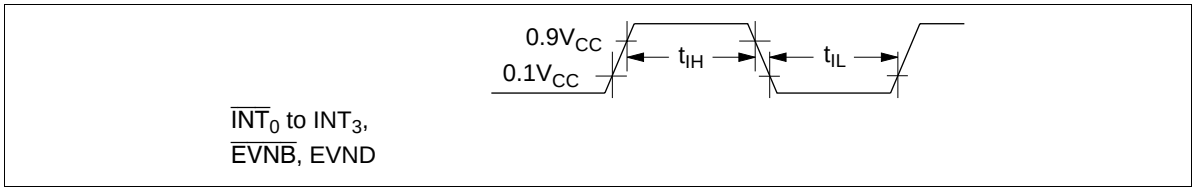


Figure 96 Interrupt Timing

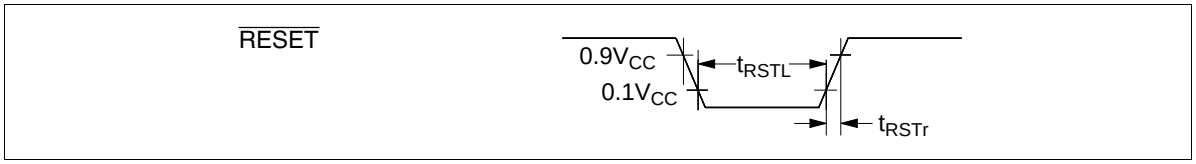


Figure 97 Reset Timing

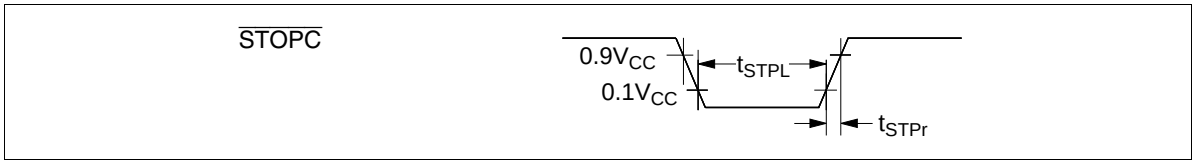
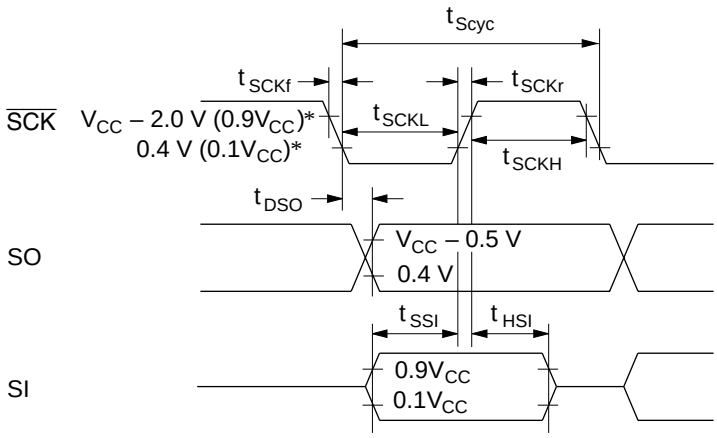


Figure 98 $\overline{\text{STOPC}}$ Timing



Note: * V_{CC} – 2.0 V and 0.4 V are the threshold voltages for transmit clock output, and 0.9V_{CC} and 0.1V_{CC} are the threshold voltages for transmit clock input.

Figure 99 Serial Interface Timing

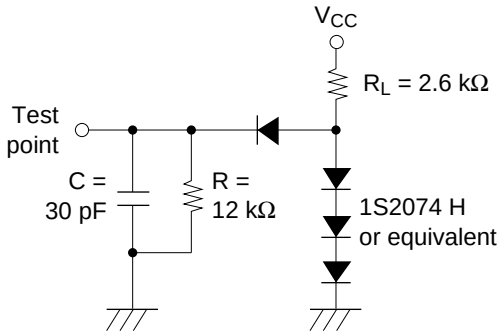


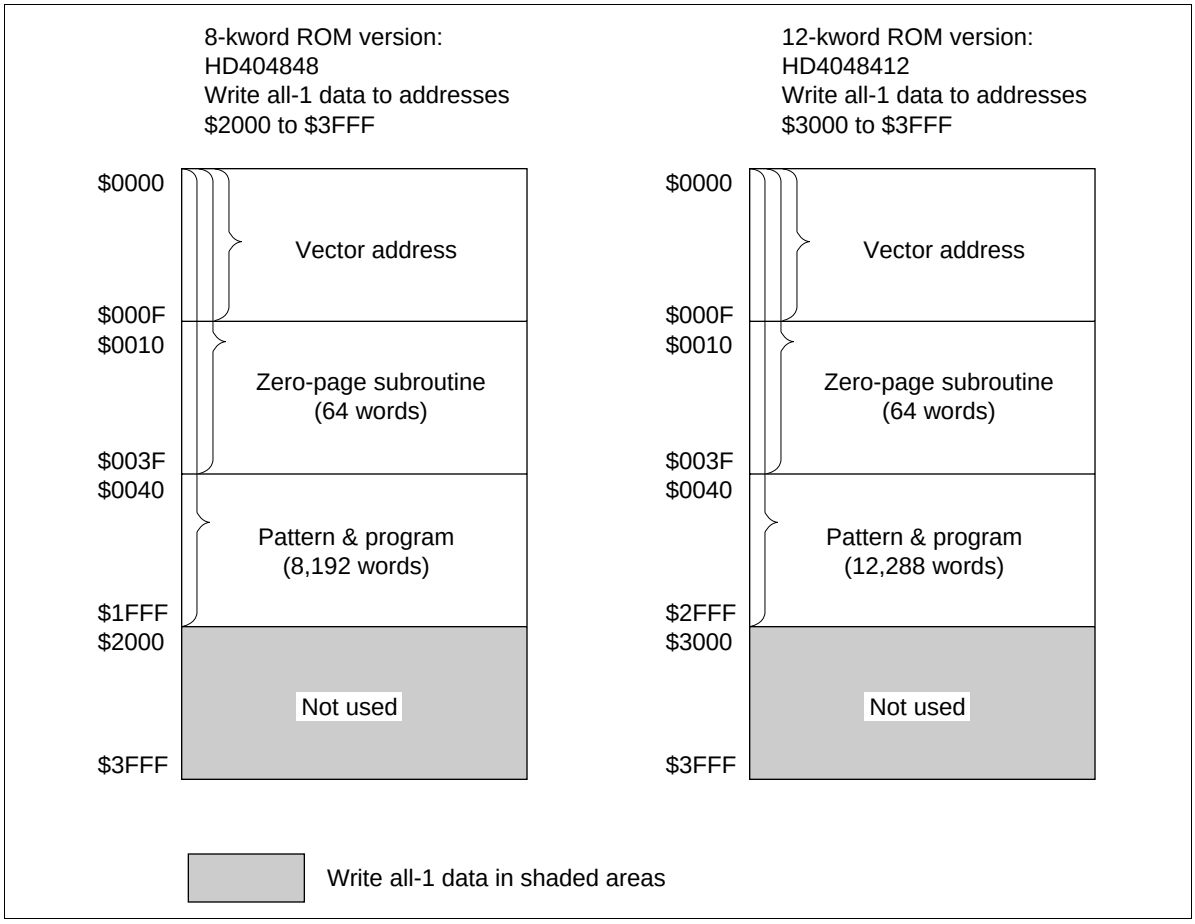
Figure 100 Timing Load Circuit

Notes on ROM Out

Please pay attention to the following items regarding ROM out.

On ROM out, fill the ROM area indicated below with 1s to create the same data size as a 16-kword version (HD404849). A 16-kword data size is required to change ROM data to mask manufacturing data since the program used is for a 16-kword version.

This limitation applies when using an EPROM or a data base.



HD404848/HD4048412/HD404849 Option List

Please check off the appropriate applications and enter the necessary information.

Date of order	/ /
Customer	
Department	
Name	
ROM code name	
LSI number	

1. ROM Size

☐	HD404848	8-kword
☐	HD4048412	12-kword
☐	HD404849	16-kword

2. Optional Functions

* ☐	With 32-kHz CPU operation, with time-base for clock
* ☐	Without 32-kHz CPU operation, with time-base for clock
☐	Without 32-kHz CPU operation, without time-base

Note: * Options marked with an asterisk require a subsystem crystal oscillator (X1, X2).

3. ROM Code Media

Please specify the first type below (the upper bits and lower bits are mixed together), when using the EPROM on-package microcomputer type (including ZTAT™ version).

☐	EPROM: The upper bits and lower bits are mixed together. The upper five bits and lower five bits are programmed to the same EPROM in alternating order (i.e., LULULU...).
☐	EPROM: The upper bits and lower bits are separated. The upper five bits and lower five bits are programmed to different EPROMs.

4. Oscillator for OSC1 and OSC2

☐	Ceramic oscillator	f = MHz
☐	Crystal oscillator	f = MHz
☐	External clock	f = MHz

5. Stop mode

☐	Used
☐	Not used

6. Package

☐	FP-80A
☐	FP-80B
☐	TFP-80C

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