

TOSHIBA

8 Bit Microcontroller
TLCS-870/C Series

TMP86CH12MG

TOSHIBA CORPORATION



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Revision History

Date	Revision	
2006/6/7	1	First Release
2006/6/29	2	Periodical updating.No change in contents.
2006/10/19	3	Contents Revised

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18. Package Dimension

This is a technical document that describes the operating functions and electrical specifications of the 8-bit microcontroller series TLCS-870/C (LSI).



CMOS 8-Bit Microcontroller

TMP86CH12MG

Product No.	ROM (MaskROM)	RAM	Package	FLASH MCU	Emulation Chip
TMP86CH12MG	16384 bytes	512 bytes	P-SSOP30-56-0.65	TMP86FH12MG	TMP86C912XB

1.1 Features

- 8-bit single chip microcomputer TLCS-870/C series
 - Instruction execution time :
 - 0.25 μ s (at 16 MHz)
 - 122 μ s (at 32.768 kHz)
 - 132 types & 731 basic instructions
- 22interrupt sources (External : 6 Internal : 16)
- Input / Output ports (24 pins)
 - Large current output: 8pins (Typ. 20mA), LED direct drive
- Watchdog Timer
- Prescaler
 - Time base timer
 - Divider output function
- 10-bit timer counter: 1ch (2 output pins)
 - 2ports output PPG (Programmed Pulse Generator)
 - 50%duty output mode
 - Variable Duty output mode
 - External-triggered start and stop
 - Emergency stop pin
- 16-bit timer counter: 1 ch
 - Timer, External trigger, Window, Pulse width measurement,

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Event counter, Programmable pulse generate (PPG) modes

8. 8-bit timer counter : 2 ch

- Timer, Event counter, Programmable divider output (PDO),

Pulse width modulation (PWM) output,

Programmable pulse generation (PPG) modes

9. 8-bit SIO: 1 ch

10. 8-bit UART : 1 ch

11. 10-bit successive approximation type AD converter

- Analog input: 8 ch

12. Key-on wakeup : 4 ch

13. Clock operation

Single clock mode

Dual clock mode

14. Low power consumption operation

STOP mode: Oscillation stops. (Battery/Capacitor back-up.)

SLOW1 mode: Low power consumption operation using low-frequency clock.(High-frequency clock stop.)

SLOW2 mode: Low power consumption operation using low-frequency clock.(High-frequency clock oscillate.)

IDLE0 mode: CPU stops, and only the Time-Based-Timer(TBT) on peripherals operate using high frequency clock. Release by falling edge of the source clock which is set by TBTCCR<TBTCK>.

IDLE1 mode: CPU stops and peripherals operate using high frequency clock. Release by interrupts(CPU restarts).

IDLE2 mode: CPU stops and peripherals operate using high and low frequency clock. Release by interrupts. (CPU restarts).

SLEEP0 mode: CPU stops, and only the Time-Based-Timer(TBT) on peripherals operate using low frequency clock.Release by falling edge of the source clock which is set by TBTCCR<TBTCK>.

SLEEP1 mode: CPU stops, and peripherals operate using low frequency clock. Release by interrupt.(CPU restarts).

SLEEP2 mode: CPU stops and peripherals operate using high and low frequency clock. Release by interrupt.

15. Wide operation voltage:

2.7 V to 5.5 V at 8MHz /32.768 kHz

4.5 V to 5.5 V at 16 MHz /32.768 kHz

1.2 Pin Assignment

VSS	1	30	P37 (AIN7)
XIN	2	29	P36 (AIN6/STOP3)
XOUT	3	28	P35 (AIN5/STOP2)
TEST	4	27	P34 (AIN4/STOP1)
VDD	5	26	P33 (AIN3/STOP0)
(XTIN) P21	6	25	P32 (AIN2)
(XTOUT) P22	7	24	P31 (AIN1/INT0)
RESET	8	23	P30 (AIN0/EMG)
(INT5/STOP) P20	9	22	P13 ($\overline{\text{PPG}}$ /INT3)
(TC1/INT4) P14	10	21	P12 ($\overline{\text{DVO}}$)
(TXD) P00	11	20	P11 (TC4/PDO4/PWM4/PPG4)
(RXD) P01	12	19	P10 (TC3/PDO3/PWM3)
(SCK) P02	13	18	P07 (PPG2/INT2)
(SI) P03	14	17	P06 (PPG1/INT1)
(SO) P04	15	16	P05 (TC7)

Figure 1-1 Pin Assignment

1.3 Block Diagram

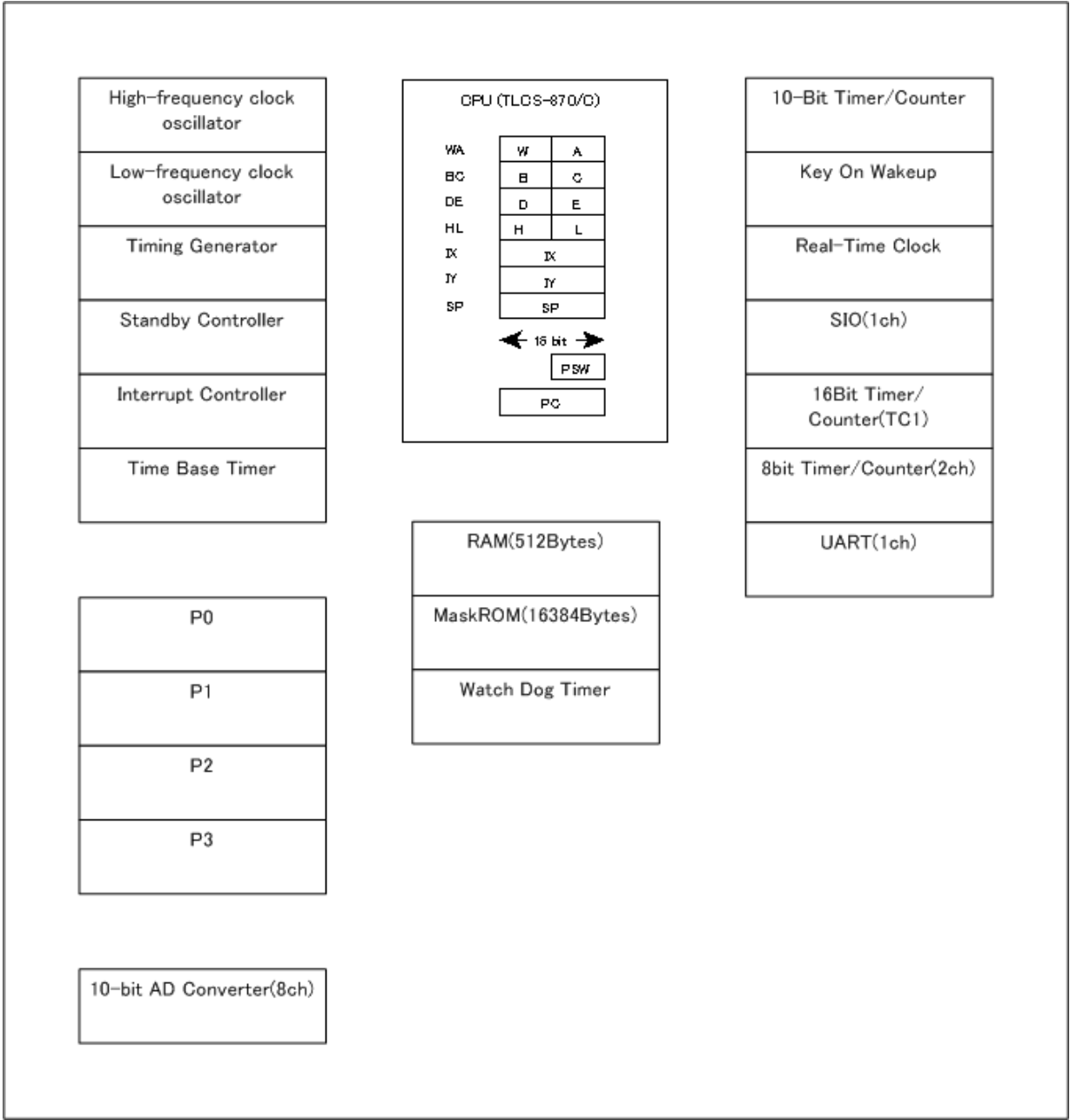


Figure 1-2 Block Diagram

1.4 Pin Names and Functions

Table 1-1 Pin Names and Functions(1/2)

Pin Name	Pin Number	Input/Output	Functions
P07 PPG2 INT2	18	IO O I	PORT07 Timer counter 7 PPG2 output External interrupt 2 input
P06 PPG1 INT1	17	IO O I	PORT06 Timer counter 7 PPG1 output External interrupt 1 input
P05 TC7	16	IO I	PORT05 Timer counter 7 input
P04 SO	15	IO O	PORT04 Serial Data Output
P03 SI	14	IO I	PORT03 Serial Data Input
P02 $\overline{\text{SCK}}$	13	IO IO	PORT02 Serial Clock I/O
P01 RXD	12	IO I	PORT01 UART data input
P00 TXD	11	IO O	PORT00 UART data output
P14 INT4 TC1	10	IO I I	PORT14 External interrupt 4 input TC1 input
P13 $\overline{\text{PPG}}$ INT3	22	IO O I	PORT13 PPG output External interrupt 3 input
P12 $\overline{\text{DVO}}$	21	IO O	PORT12 Divider Output
P11 TC4 $\overline{\text{PDO4/PWM4/PPG4}}$	20	IO I O	PORT11 TC4 input PDO4/PWM4/PPG4 output
P10 TC3 $\overline{\text{PDO3/PWM3}}$	19	IO I O	PORT10 TC3 input PDO3/PWM3 output
P22 XTOUT	7	IO O	PORT22 Resonator connecting pins(32.768kHz) for inputting external clock
P21 XTIN	6	IO I	PORT21 Resonator connecting pins(32.768kHz) for inputting external clock
P20 $\overline{\text{STOP}}$ $\overline{\text{INT5}}$	9	IO I I	PORT20 STOP mode release signal input External interrupt 5 input
P37 AIN7	30	IO I	PORT37 Analog Input7
P36 AIN6 STOP3	29	IO I I	PORT36 Analog Input6 STOP3 input

Table 1-1 Pin Names and Functions(2/2)

Pin Name	Pin Number	Input/Output	Functions
P35 AIN5 STOP2	28	IO I I	PORT35 Analog Input5 STOP2 input
P34 AIN4 STOP1	27	IO I I	PORT34 Analog Input4 STOP1 input
P33 AIN3 STOP0	26	IO I I	PORT33 Analog Input3 STOP0 input
P32 AIN2	25	IO I	PORT32 Analog Input2
P31 AIN1 INT0	24	IO I I	PORT31 Analog Input1 External interrupt 0 input
P30 AIN0 EMG	23	IO I I	PORT30 Analog Input0 Timer counter 7 Emergency stop input
XIN	2	I	Resonator connecting pins for high-frequency clock
XOUT	3	O	Resonator connecting pins for high-frequency clock
RESET	8	I	Reset signal
TEST	4	I	Test pin for out-going test. Normally, be fixed to low.
VDD	5	I	+5V
VSS	1	I	0(GND)

2. Operational Description

2.1 CPU Core Functions

The CPU core consists of a CPU, a system clock controller, and an interrupt controller.
This section provides a description of the CPU core, the program memory, the data memory, and the reset circuit.

2.1.1 Memory Address Map

The TMP86CH12MG memory is composed MaskROM, RAM, DBR(Data buffer register) and SFR(Special function register). They are all mapped in 64-Kbyte address space. Figure 2-1 shows the TMP86CH12MG memory address map.

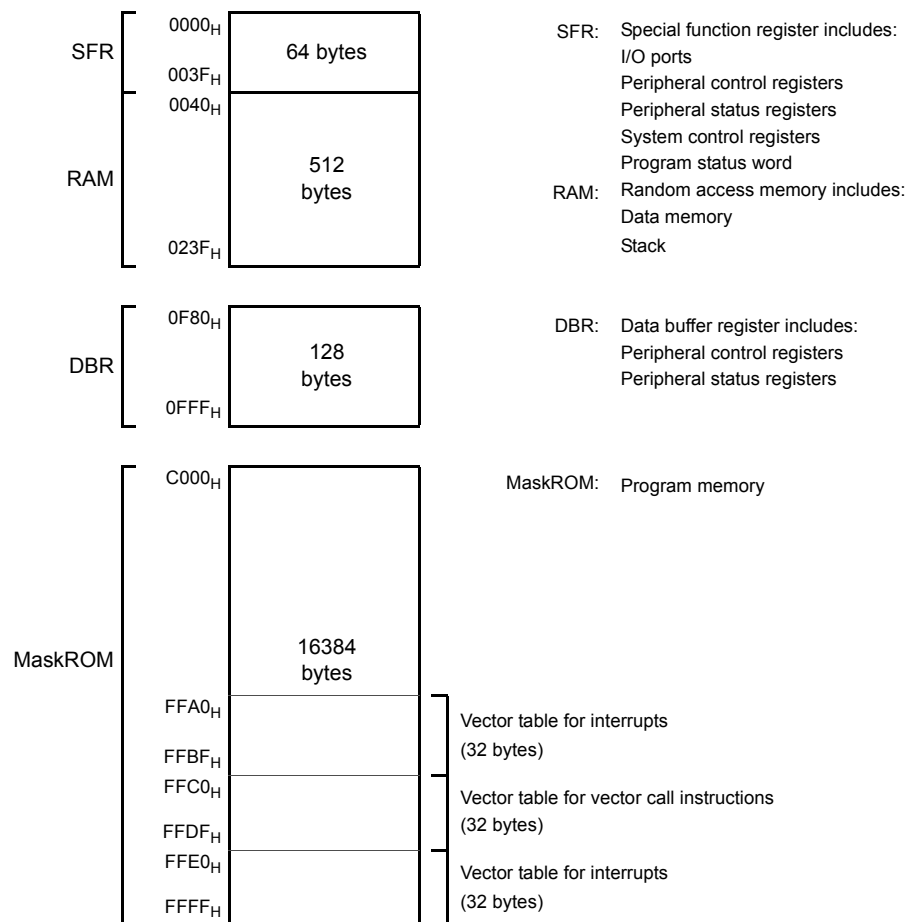


Figure 2-1 Memory Address Map

2.1.2 Program Memory (MaskROM)

The TMP86CH12MG has a 16384 bytes (Address C000H to FFFFH) of program memory (MaskROM).

2.1.3 Data Memory (RAM)

The TMP86CH12MG has 512bytes (Address 0040H to 023FH) of internal RAM. The first 192 bytes (0040H to 00FFH) of the internal RAM are located in the direct area; instructions with shorten operations are available against such an area.

The data memory contents become unstable when the power supply is turned on; therefore, the data memory should be initialized by an initialization routine.

Example :Clears RAM to “00H”. (TMP86CH12MG)

```
LD      HL, 0040H      ; Start address setup
LD      A, H           ; Initial value (00H) setup
LD      BC, 01FFH
SRAMCLR: LD      (HL), A
INC     HL
DEC     BC
JRS     F, SRAMCLR
```

2.2 System Clock Controller

The system clock controller consists of a clock generator, a timing generator, and a standby controller.

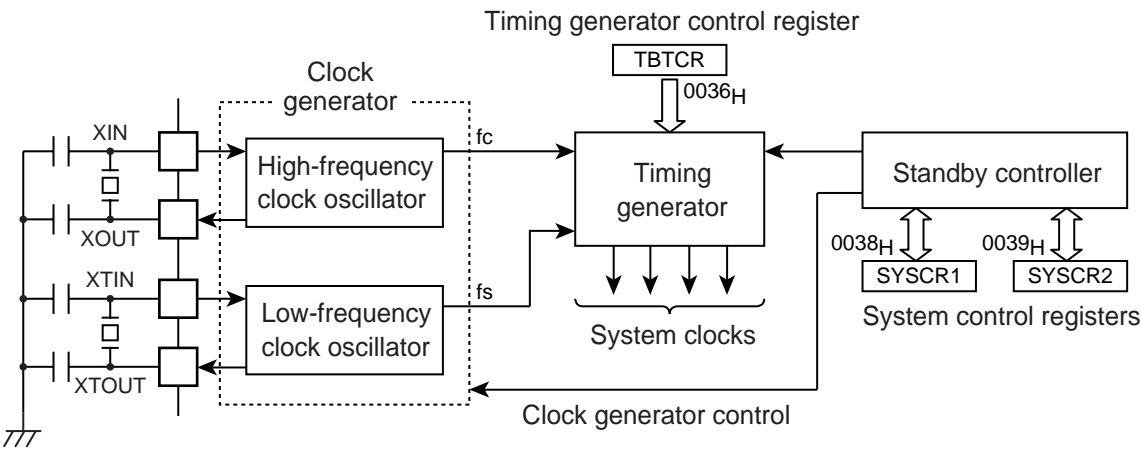


Figure 2-2 System Colck Control

2.2.1 Clock Generator

The clock generator generates the basic clock which provides the system clocks supplied to the CPU core and peripheral hardware. It contains two oscillation circuits: One for the high-frequency clock and one for the low-frequency clock. Power consumption can be reduced by switching of the standby controller to low-power operation based on the low-frequency clock.

The high-frequency (fc) clock and low-frequency (fs) clock can easily be obtained by connecting a resonator between the XIN/XOUT and XTIN/XTOUT pins respectively. Clock input from an external oscillator is also possible. In this case, external clock is applied to XIN/XTIN pin with XOUT/XTOUT pin not connected.

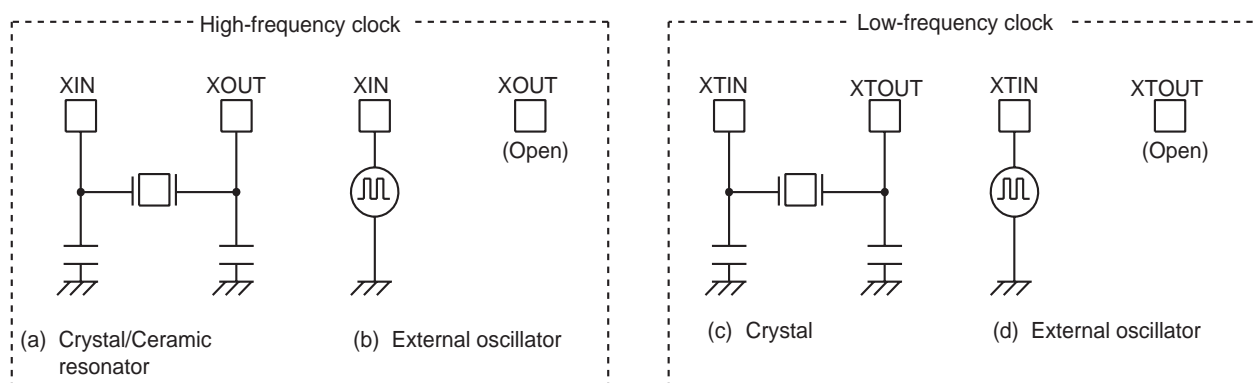


Figure 2-3 Examples of Resonator Connection

Note: The function to monitor the basic clock directly at external is not provided for hardware, however, with disabling all interrupts and watchdog timers, the oscillation frequency can be adjusted by monitoring the pulse which the fixed frequency is outputted to the port by the program.
The system to require the adjustment of the oscillation frequency should create the program for the adjustment in advance.

2.2.2 Timing Generator

The timing generator generates the various system clocks supplied to the CPU core and peripheral hardware from the basic clock (f_c or f_s). The timing generator provides the following functions.

1. Generation of main system clock
2. Generation of divider output (\overline{DVO}) pulses
3. Generation of source clocks for time base timer
4. Generation of source clocks for watchdog timer
5. Generation of internal source clocks for timer/counters
6. Generation of warm-up clocks for releasing STOP mode

2.2.2.1 Configuration of timing generator

The timing generator consists of a 2-stage prescaler, a 21-stage divider, a main system clock generator, and machine cycle counters.

An input clock to the 7th stage of the divider depends on the operating mode, $SYSCR2<SYSCK>$ and $TBTCR<DV7CK>$, that is shown in Figure 2-4. As reset and STOP mode started/canceled, the prescaler and the divider are cleared to “0”.

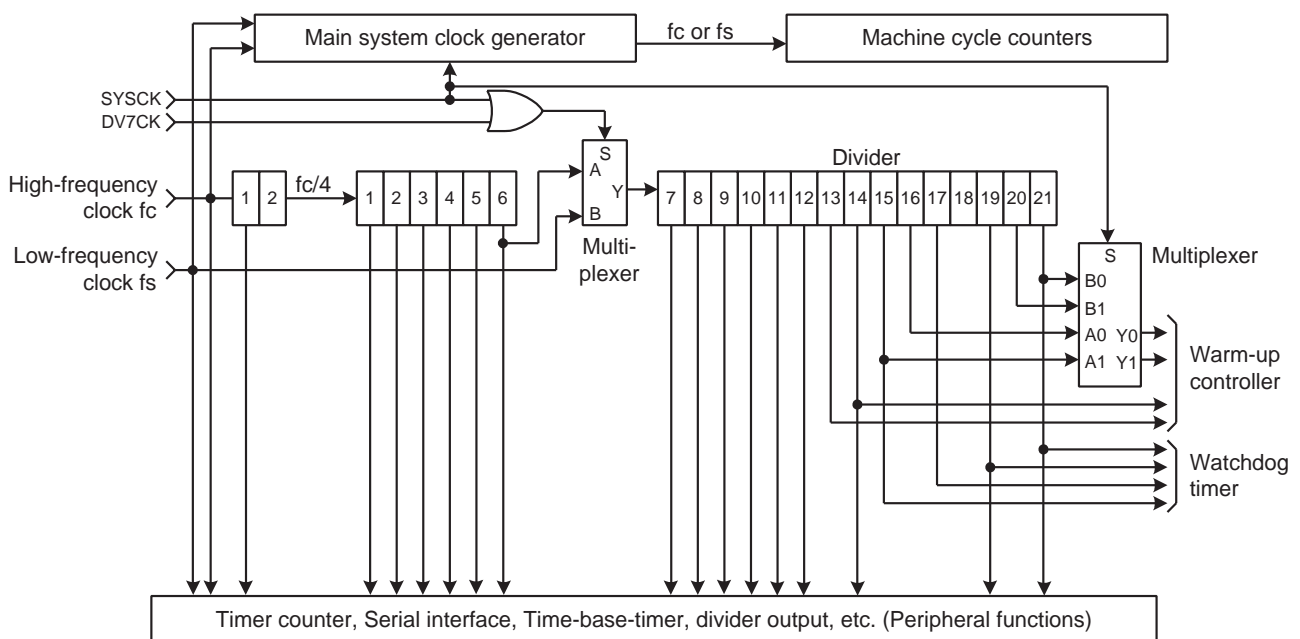


Figure 2-4 Configuration of Timing Generator

Timing Generator Control Register

TBTCR (0036H)	7	6	5	4	3	2	1	0	
	(DVOEN)	(DVOCK)	DV7CK	(TBTEN)		(TBTCK)			(Initial value: 0000 0000)
	DV7CK	Selection of input to the 7th stage of the divider			0: $fc/2^8$ [Hz] 1: fs				R/W

Note 1: In single clock mode, do not set DV7CK to "1".

Note 2: Do not set "1" on DV7CK while the low-frequency clock is not operated stably.

Note 3: fc : High-frequency clock [Hz], fs : Low-frequency clock [Hz], *: Don't care

Note 4: In SLOW1/2 and SLEEP1/2 modes, the DV7CK setting is ineffective, and fs is input to the 7th stage of the divider.

Note 5: When STOP mode is entered from NORMAL1/2 mode, the DV7CK setting is ineffective during the warm-up period after release of STOP mode, and the 6th stage of the divider is input to the 7th stage during this period.

2.2.2.2 Machine cycle

Instruction execution and peripheral hardware operation are synchronized with the main system clock.

The minimum instruction execution unit is called a "machine cycle". There are a total of 10 different types of instructions for the TLCS-870/C Series: Ranging from 1-cycle instructions which require one machine cycle for execution to 10-cycle instructions which require 10 machine cycles for execution. A machine cycle consists of 4 states (S0 to S3), and each state consists of one main system clock.

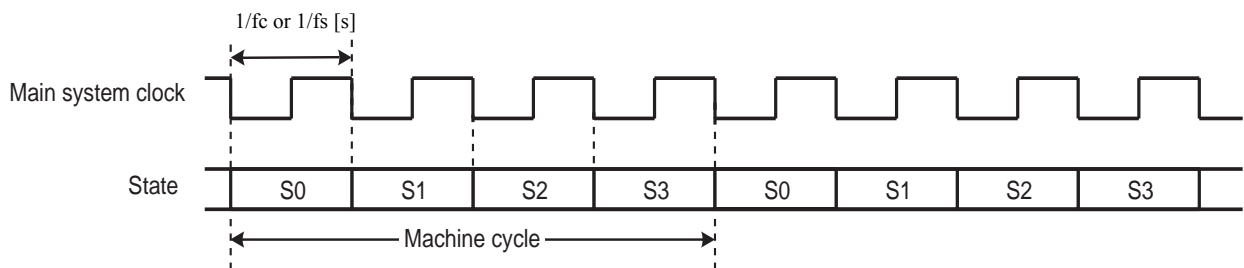


Figure 2-5 Machine Cycle

2.2.3 Operation Mode Control Circuit

The operation mode control circuit starts and stops the oscillation circuits for the high-frequency and low-frequency clocks, and switches the main system clock. There are three operating modes: Single clock mode, dual clock mode and STOP mode. These modes are controlled by the system control registers (SYSCR1 and SYSCR2). Figure 2-6 shows the operating mode transition diagram.

2.2.3.1 Single-clock mode

Only the oscillation circuit for the high-frequency clock is used, and P21 (XTIN) and P22 (XTOUT) pins are used as input/output ports. The main-system clock is obtained from the high-frequency clock. In the single-clock mode, the machine cycle time is $4/fc$ [s].

(1) NORMAL1 mode

In this mode, both the CPU core and on-chip peripherals operate using the high-frequency clock. The TMP86CH12MG is placed in this mode after reset.

(2) IDLE1 mode

In this mode, the internal oscillation circuit remains active. The CPU and the watchdog timer are halted; however on-chip peripherals remain active (Operate using the high-frequency clock).

IDLE1 mode is started by SYSCR2<IDLE> = "1", and IDLE1 mode is released to NORMAL1 mode by an interrupt request from the on-chip peripherals or external interrupt inputs. When the IMF (Interrupt master enable flag) is "1" (Interrupt enable), the execution will resume with the acceptance of the interrupt, and the operation will return to normal after the interrupt service is completed. When the IMF is "0" (Interrupt disable), the execution will resume with the instruction which follows the IDLE1 mode start instruction.

(3) IDLE0 mode

In this mode, all the circuit, except oscillator and the timer-base-timer, stops operation.

This mode is enabled by SYSCR2<TGHALT> = "1".

When IDLE0 mode starts, the CPU stops and the timing generator stops feeding the clock to the peripheral circuits other than TBT. Then, upon detecting the falling edge of the source clock selected with TBTCR<TBTCK>, the timing generator starts feeding the clock to all peripheral circuits.

When returned from IDLE0 mode, the CPU restarts operating, entering NORMAL1 mode back again. IDLE0 mode is entered and returned regardless of how TBTCR<TBTEN> is set. When IMF = "1", EF1 (TBT interrupt individual enable flag) = "1", and TBTCR<TBTEN> = "1", interrupt processing is performed. When IDLE0 mode is entered while TBTCR<TBTEN> = "1", the INTTBT interrupt latch is set after returning to NORMAL1 mode.

2.2.3.2 Dual-clock mode

Both the high-frequency and low-frequency oscillation circuits are used in this mode. P21 (XTIN) and P22 (XTOUT) pins cannot be used as input/output ports. The main system clock is obtained from the high-frequency clock in NORMAL2 and IDLE2 modes, and is obtained from the low-frequency clock in SLOW and SLEEP modes. The machine cycle time is $4/f_c$ [s] in the NORMAL2 and IDLE2 modes, and $4/f_s$ [s] (122 μ s at f_s = 32.768 kHz) in the SLOW and SLEEP modes.

The TLCS-870/C is placed in the signal-clock mode during reset. To use the dual-clock mode, the low-frequency oscillator should be turned on at the start of a program.

(1) NORMAL2 mode

In this mode, the CPU core operates with the high-frequency clock. On-chip peripherals operate using the high-frequency clock and/or low-frequency clock.

(2) SLOW2 mode

In this mode, the CPU core operates with the low-frequency clock, while both the high-frequency clock and the low-frequency clock are operated. As the SYSCR2<SYSCK> becomes "1", the hardware changes into SLOW2 mode. As the SYSCR2<SYSCK> becomes "0", the hardware changes into NORMAL2 mode. As the SYSCR2<XEN> becomes "0", the hardware changes into SLOW1 mode. Do not clear SYSCR2<XTEN> to "0" during SLOW2 mode.

(3) SLOW1 mode

This mode can be used to reduce power-consumption by turning off oscillation of the high-frequency clock. The CPU core and on-chip peripherals operate using the low-frequency clock.

Switching back and forth between SLOW1 and SLOW2 modes are performed by SYSCR2<XEN>. In SLOW1 and SLEEP modes, the input clock to the 1st stage of the divider is stopped; output from the 1st to 6th stages is also stopped.

(4) IDLE2 mode

In this mode, the internal oscillation circuit remain active. The CPU and the watchdog timer are halted; however, on-chip peripherals remain active (Operate using the high-frequency clock and/or the low-frequency clock). Starting and releasing of IDLE2 mode are the same as for IDLE1 mode, except that operation returns to NORMAL2 mode.

(5) SLEEP1 mode

In this mode, the internal oscillation circuit of the low-frequency clock remains active. The CPU, the watchdog timer, and the internal oscillation circuit of the high-frequency clock are halted; however, on-chip peripherals remain active (Operate using the low-frequency clock). Starting and releasing of SLEEP mode are the same as for IDLE1 mode, except that operation returns to SLOW1 mode. In SLOW1 and SLEEP1 modes, the input clock to the 1st stage of the divider is stopped; output from the 1st to 6th stages is also stopped.

(6) SLEEP2 mode

The SLEEP2 mode is the idle mode corresponding to the SLOW2 mode. The status under the SLEEP2 mode is same as that under the SLEEP1 mode, except for the oscillation circuit of the high-frequency clock.

(7) SLEEP0 mode

In this mode, all the circuit, except oscillator and the timer-base-timer, stops operation. This mode is enabled by setting “1” on bit SYSCR2<TGHALT>.

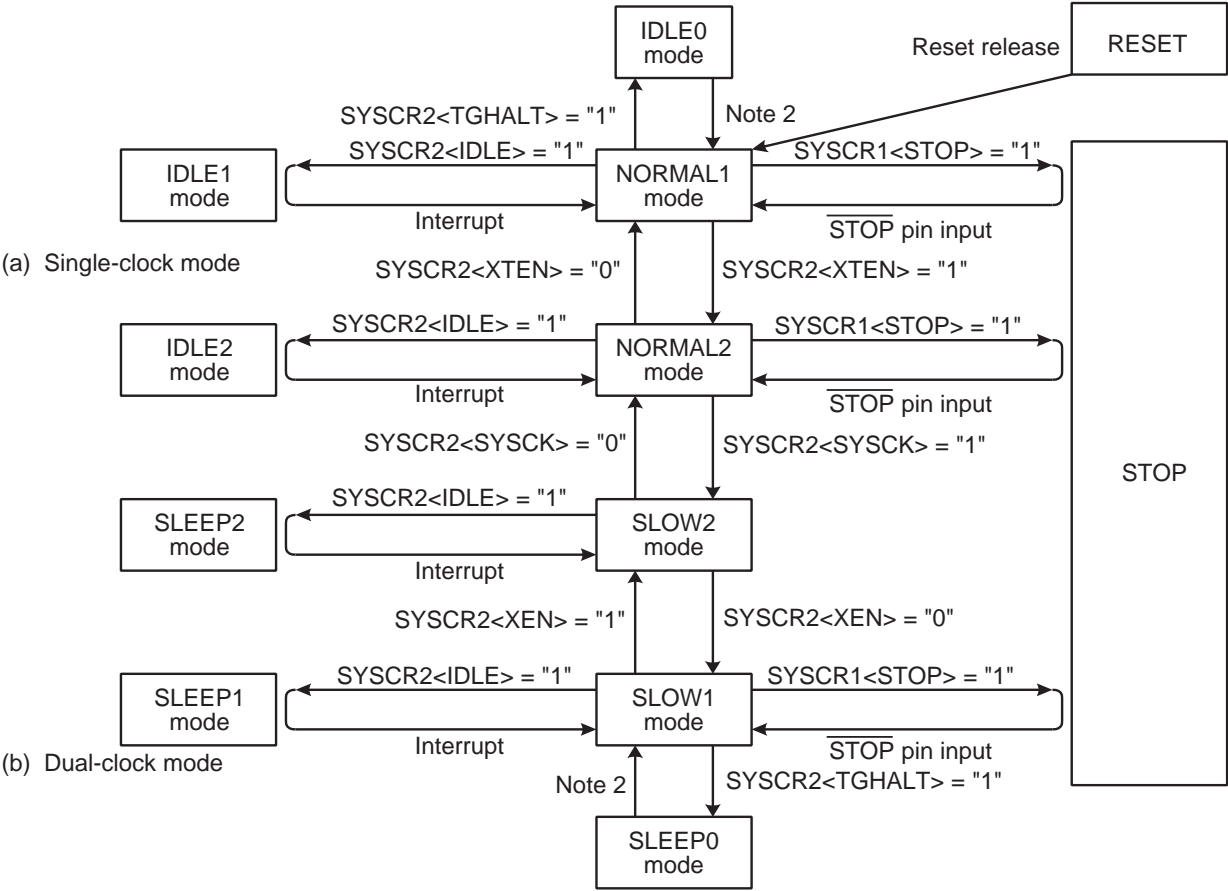
When SLEEP0 mode starts, the CPU stops and the timing generator stops feeding the clock to the peripheral circuits other than TBT. Then, upon detecting the falling edge of the source clock selected with TBTCR<TBTCK>, the timing generator starts feeding the clock to all peripheral circuits.

When returned from SLEEP0 mode, the CPU restarts operating, entering SLOW1 mode back again. SLEEP0 mode is entered and returned regardless of how TBTCR<TBTEN> is set. When IMF = “1”, EF1 (TBT interrupt individual enable flag) = “1”, and TBTCR<TBTEN> = “1”, interrupt processing is performed. When SLEEP0 mode is entered while TBTCR<TBTEN> = “1”, the INTTBT interrupt latch is set after returning to SLOW1 mode.

2.2.3.3 STOP mode

In this mode, the internal oscillation circuit is turned off, causing all system operations to be halted. The internal status immediately prior to the halt is held with a lowest power consumption during STOP mode.

STOP mode is started by the system control register 1 (SYSCR1), and STOP mode is released by a inputting (Either level-sensitive or edge-sensitive can be programmably selected) to the $\overline{\text{STOP}}$ pin. After the warm-up period is completed, the execution resumes with the instruction which follows the STOP mode start instruction.



Note 1: NORMAL1 and NORMAL2 modes are generically called NORMAL; SLOW1 and SLOW2 are called SLOW; IDLE0, IDLE1 and IDLE2 are called IDLE; SLEEP0, SLEEP1 and SLEEP2 are called SLEEP.

Note 2: The mode is released by falling edge of $\text{TBTCR}\langle\text{TBTC}\rangle$ setting.

Figure 2-6 Operating Mode Transition Diagram

Table 2-1 Operating Mode and Conditions

Operating Mode		Oscillator		CPU Core	TBT	Other Peripherals	Machine Cycle Time	
		High Frequency	Low Frequency					
Single clock	RESET	Oscillation	Stop	Reset	Reset	Reset	4/fc [s]	
	NORMAL1			Operate	Operate	Operate		
	IDLE1			Halt		Halt		
	IDLE0							
	STOP	Stop	Halt		–			
Dual clock	NORMAL2	Oscillation	Oscillation	Operate with high frequency	Operate	Operate	4/fc [s]	
	IDLE2			Halt			4/fs [s]	
	SLOW2			Operate with low frequency				
	SLEEP2			Halt				
	SLOW1	Stop		Operate with low frequency		Halt		Halt
	SLEEP1							
	SLEEP0							
	STOP			Stop			Halt	

System Control Register 1

SYSCR1	7	6	5	4	3	2	1	0	
(0038H)	STOP	RELM	RETM	OUTEN	WUT				(Initial value: 0000 00**)

STOP	STOP mode start	0: CPU core and peripherals remain active 1: CPU core and peripherals are halted (Start STOP mode)			R/W
RELM	Release method for STOP mode	0: Edge-sensitive release 1: Level-sensitive release			R/W
RETM	Operating mode after STOP mode	0: Return to NORMAL1/2 mode 1: Return to SLOW1 mode			R/W
OUTEN	Port output during STOP mode	0: High impedance 1: Output kept			R/W
WUT	Warm-up time at releasing STOP mode		Return to NORMAL mode	Return to SLOW mode	R/W
		00	$3 \times 2^{16}/f_c$	$3 \times 2^{13}/f_s$	
		01	$2^{16}/f_c$	$2^{13}/f_s$	
		10	$3 \times 2^{14}/f_c$	$3 \times 2^6/f_s$	
		11	$2^{14}/f_c$	$2^6/f_s$	

Note 1: Always set RETM to "0" when transiting from NORMAL mode to STOP mode. Always set RETM to "1" when transiting from SLOW mode to STOP mode.

Note 2: When STOP mode is released with $\overline{\text{RESET}}$ pin input, a return is made to NORMAL1 regardless of the RETM contents.

Note 3: f_c : High-frequency clock [Hz], f_s : Low-frequency clock [Hz], *: Don't care

Note 4: Bits 1 and 0 in SYSCR1 are read as undefined data when a read instruction is executed.

Note 5: As the hardware becomes STOP mode under OUTEN = "0", input value is fixed to "0"; therefore it may cause external interrupt request on account of falling edge.

Note 6: When the key-on wakeup is used, RELM should be set to "1".

Note 7: Port P20 is used as $\overline{\text{STOP}}$ pin. Therefore, when stop mode is started, OUTEN does not affect to P20, and P20 becomes High-Z mode.

Note 8: The warmig-up time should be set correctly for using oscillator.

System Control Register 2

SYSCR2	7	6	5	4	3	2	1	0	
(0039H)	XEN	XTEN	SYSCK	IDLE		TGHALT			(Initial value: 1000 *0**)

XEN	High-frequency oscillator control	0: Turn off oscillation 1: Turn on oscillation	R/W
XTEN	Low-frequency oscillator control	0: Turn off oscillation 1: Turn on oscillation	
SYSCK	Main system clock select (Write)/main system clock monitor (Read)	0: High-frequency clock (NORMAL1/NORMAL2/IDLE1/IDLE2) 1: Low-frequency clock (SLOW1/SLOW2/SLEEP1/SLEEP2)	
IDLE	CPU and watchdog timer control (IDLE1/2 and SLEEP1/2 modes)	0: CPU and watchdog timer remain active 1: CPU and watchdog timer are stopped (Start IDLE1/2 and SLEEP1/2 modes)	R/W
TGHALT	TG control (IDLE0 and SLEEP0 modes)	0: Feeding clock to all peripherals from TG 1: Stop feeding clock to peripherals except TBT from TG. (Start IDLE0 and SLEEP0 modes)	

Note 1: A reset is applied if both XEN and XTEN are cleared to "0", XEN is cleared to "0" when SYSCK = "0", or XTEN is cleared to "0" when SYSCK = "1".

Note 2: *: Don't care, TG: Timing generator, *: Don't care

Note 3: Bits 3, 1 and 0 in SYSCR2 are always read as undefined value.

Note 4: Do not set IDLE and TGHALT to "1" simultaneously.

Note 5: Because returning from IDLE0/SLEEP0 to NORMAL1/SLOW1 is executed by the asynchronous internal clock, the period of IDLE0/SLEEP0 mode might be shorter than the period setting by $\text{TBTCT} < \text{TBTCK} >$.

Note 6: When IDLE1/2 or SLEEP1/2 mode is released, IDLE is automatically cleared to "0".

Note 7: When IDLE0 or SLEEP0 mode is released, TGHALT is automatically cleared to "0".

Note 8: Before setting TGHALT to "1", be sure to stop peripherals. If peripherals are not stopped, the interrupt latch of peripherals may be set after IDLE0 or SLEEP0 mode is released.

2.2.4 Operating Mode Control

2.2.4.1 STOP mode

STOP mode is controlled by the system control register 1, the $\overline{\text{STOP}}$ pin input and key-on wakeup input (STOP3 to STOP0) which is controlled by the STOP mode release control register (STOPCR). The $\overline{\text{STOP}}$ pin is also used both as a port P20 and an $\overline{\text{INT5}}$ (external interrupt input 5) pin. STOP mode is started by setting SYSCR1<STOP> to “1”. During STOP mode, the following status is maintained.

1. Oscillations are turned off, and all internal operations are halted.
2. The data memory, registers, the program status word and port output latches are all held in the status in effect before STOP mode was entered.
3. The prescaler and the divider of the timing generator are cleared to “0”.
4. The program counter holds the address 2 ahead of the instruction (e.g., [SET (SYSCR1).7]) which started STOP mode.

STOP mode includes a level-sensitive mode and an edge-sensitive mode, either of which can be selected with the SYSCR1<RELM>. Do not use any key-on wakeup input (STOP3 to STOP0) for releasing STOP mode in edge-sensitive mode.

Note 1: The STOP mode can be released by either the STOP or key-on wakeup pin (STOP3 to STOP0). However, because the STOP pin is different from the key-on wakeup and can not inhibit the release input, the STOP pin must be used for releasing STOP mode.

Note 2: During STOP period (from start of STOP mode to end of warm up), due to changes in the external interrupt pin signal, interrupt latches may be set to “1” and interrupts may be accepted immediately after STOP mode is released. Before starting STOP mode, therefore, disable interrupts. Also, before enabling interrupts after STOP mode is released, clear unnecessary interrupt latches.

(1) Level-sensitive release mode (RELM = “1”)

In this mode, STOP mode is released by setting the $\overline{\text{STOP}}$ pin high or setting the STOP3 to STOP0 pin input which is enabled by STOPCR. This mode is used for capacitor backup when the main power supply is cut off and long term battery backup.

Even if an instruction for starting STOP mode is executed while $\overline{\text{STOP}}$ pin input is high or STOP3 to STOP0 input is low, STOP mode does not start but instead the warm-up sequence starts immediately. Thus, to start STOP mode in the level-sensitive release mode, it is necessary for the program to first confirm that the $\overline{\text{STOP}}$ pin input is low or STOP3 to STOP0 input is high. The following two methods can be used for confirmation.

1. Testing a port.
2. Using an external interrupt input $\overline{\text{INT5}}$ ($\overline{\text{INT5}}$ is a falling edge-sensitive input).

Example 1 :Starting STOP mode from NORMAL mode by testing a port P20.

	LD	(SYSCR1). 01010000B	; Sets up the level-sensitive release mode
SSTOPH:	TEST	(P2PRD). 0	; Wait until the $\overline{\text{STOP}}$ pin input goes low level
	JRS	F, SSTOPH	
	DI		; IMF ← 0
	SET	(SYSCR1). 7	; Starts STOP mode

Example 2 :Starting STOP mode from NORMAL mode with an INT5 interrupt.

```

PINT5:      TEST      (P2PRD). 0      ; To reject noise, STOP mode does not start if
           JRS        F, SINT5        port P20 is at high
           LD         (SYSCR1), 01010000B ; Sets up the level-sensitive release mode.
           DI         ; IMF ← 0
           SET        (SYSCR1). 7      ; Starts STOP mode

SINT5:      RETI
    
```

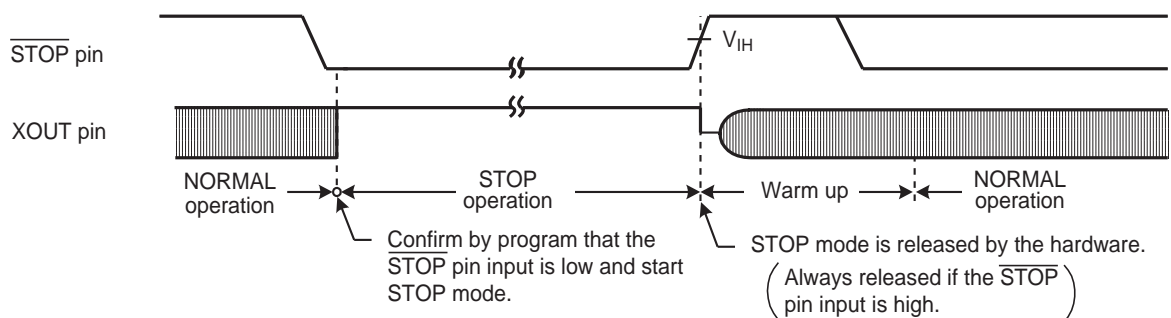


Figure 2-7 Level-sensitive Release Mode

Note 1: Even if the $\overline{\text{STOP}}$ pin input is low after warm-up start, the STOP mode is not restarted.

Note 2: In this case of changing to the level-sensitive mode from the edge-sensitive mode, the release mode is not switched until a rising edge of the $\overline{\text{STOP}}$ pin input is detected.

(2) Edge-sensitive release mode (RELM = "0")

In this mode, STOP mode is released by a rising edge of the $\overline{\text{STOP}}$ pin input. This is used in applications where a relatively short program is executed repeatedly at periodic intervals. This periodic signal (for example, a clock from a low-power consumption oscillator) is input to the $\overline{\text{STOP}}$ pin. In the edge-sensitive release mode, STOP mode is started even when the $\overline{\text{STOP}}$ pin input is high level. Do not use any STOP3 to STOP0 pin input for releasing STOP mode in edge-sensitive release mode.

Example :Starting STOP mode from NORMAL mode

```

DI         ; IMF ← 0

LD         (SYSCR1), 10010000B ; Starts after specified to the edge-sensitive release mode
    
```

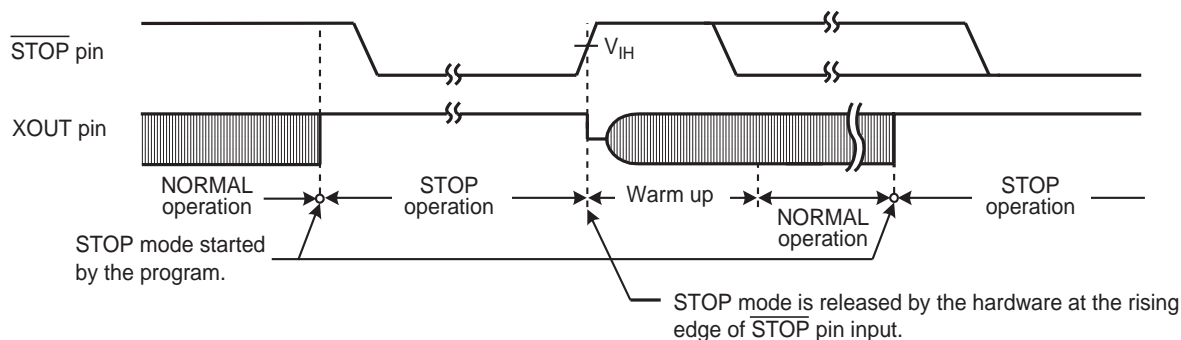


Figure 2-8 Edge-sensitive Release Mode

STOP mode is released by the following sequence.

1. In the dual-clock mode, when returning to NORMAL2, both the high-frequency and low-frequency clock oscillators are turned on; when returning to SLOW1 mode, only the low-frequency clock oscillator is turned on. In the single-clock mode, only the high-frequency clock oscillator is turned on.
2. A warm-up period is inserted to allow oscillation time to stabilize. During warm up, all internal operations remain halted. Four different warm-up times can be selected with the SYSCR1<WUT> in accordance with the resonator characteristics.
3. When the warm-up time has elapsed, normal operation resumes with the instruction following the STOP mode start instruction.

Note 1: When the STOP mode is released, the start is made after the prescaler and the divider of the timing generator are cleared to "0".

Note 2: STOP mode can also be released by inputting low level on the $\overline{\text{RESET}}$ pin, which immediately performs the normal reset operation.

Note 3: When STOP mode is released with a low hold voltage, the following cautions must be observed. The power supply voltage must be at the operating voltage level before releasing STOP mode. The $\overline{\text{RESET}}$ pin input must also be "H" level, rising together with the power supply voltage. In this case, if an external time constant circuit has been connected, the $\overline{\text{RESET}}$ pin input voltage will increase at a slower pace than the power supply voltage. At this time, there is a danger that a reset may occur if input voltage level of the $\overline{\text{RESET}}$ pin drops below the non-inverting high-level input voltage (Hysteresis input).

Table 2-2 Warm-up Time Example (at $f_c = 16.0 \text{ MHz}$, $f_s = 32.768 \text{ kHz}$)

WUT	Warm-up Time [ms]	
	Return to NORMAL Mode	Return to SLOW Mode
00	12.288	750
01	4.096	250
10	3.072	5.85
11	1.024	1.95

Note 1: The warm-up time is obtained by dividing the basic clock by the divider. Therefore, the warm-up time may include a certain amount of error if there is any fluctuation of the oscillation frequency when STOP mode is released. Thus, the warm-up time must be considered as an approximate value.

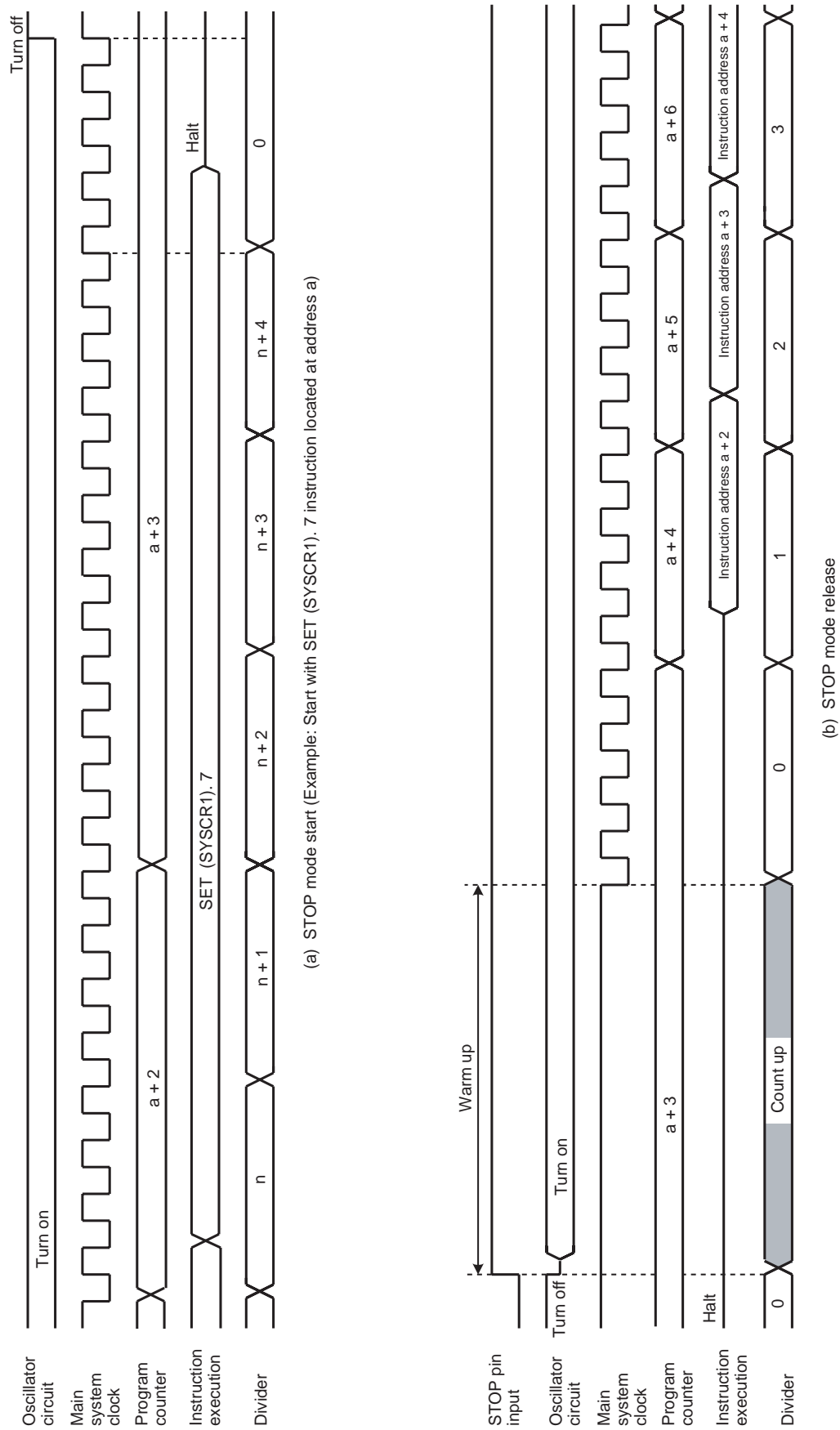


Figure 2-9 STOP Mode Start/Release

2.2.4.2 IDLE1/2 mode and SLEEP1/2 mode

IDLE1/2 and SLEEP1/2 modes are controlled by the system control register 2 (SYSCR2) and maskable interrupts. The following status is maintained during these modes.

1. Operation of the CPU and watchdog timer (WDT) is halted. On-chip peripherals continue to operate.
2. The data memory, CPU registers, program status word and port output latches are all held in the status in effect before these modes were entered.
3. The program counter holds the address 2 ahead of the instruction which starts these modes.

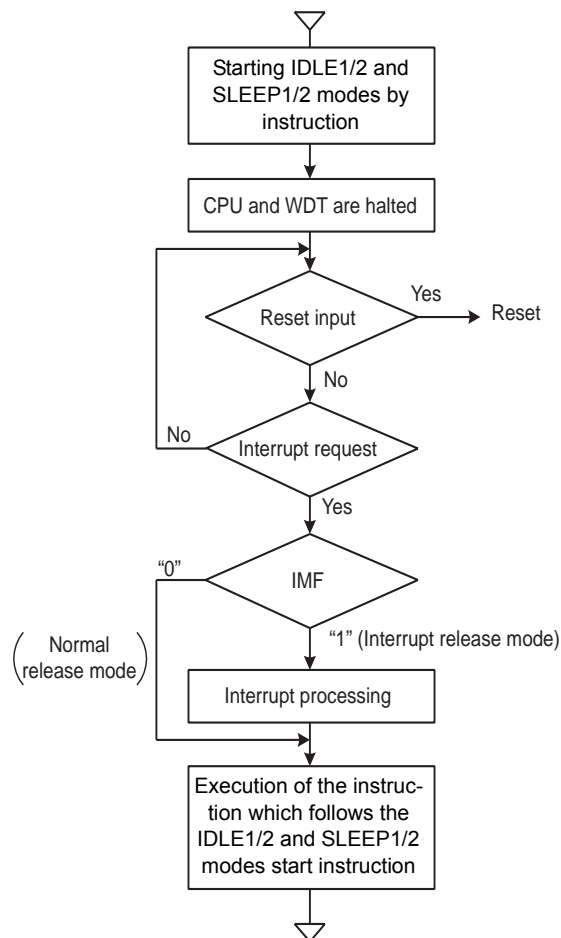


Figure 2-10 IDLE1/2 and SLEEP1/2 Modes

- Start the IDLE1/2 and SLEEP1/2 modes

After IMF is set to "0", set the individual interrupt enable flag (EF) which releases IDLE1/2 and SLEEP1/2 modes. To start IDLE1/2 and SLEEP1/2 modes, set SYSCR2<IDLE> to "1".

- Release the IDLE1/2 and SLEEP1/2 modes

IDLE1/2 and SLEEP1/2 modes include a normal release mode and an interrupt release mode. These modes are selected by interrupt master enable flag (IMF). After releasing IDLE1/2 and SLEEP1/2 modes, the SYSCR2<IDLE> is automatically cleared to "0" and the operation mode is returned to the mode preceding IDLE1/2 and SLEEP1/2 modes.

IDLE1/2 and SLEEP1/2 modes can also be released by inputting low level on the $\overline{\text{RESET}}$ pin. After releasing reset, the operation mode is started from NORMAL1 mode.

(1) Normal release mode (IMF = "0")

IDLE1/2 and SLEEP1/2 modes are released by any interrupt source enabled by the individual interrupt enable flag (EF). After the interrupt is generated, the program operation is resumed from the instruction following the IDLE1/2 and SLEEP1/2 modes start instruction. Normally, the interrupt latches (IL) of the interrupt source used for releasing must be cleared to "0" by load instructions.

(2) Interrupt release mode (IMF = "1")

IDLE1/2 and SLEEP1/2 modes are released by any interrupt source enabled with the individual interrupt enable flag (EF) and the interrupt processing is started. After the interrupt is processed, the program operation is resumed from the instruction following the instruction, which starts IDLE1/2 and SLEEP1/2 modes.

Note: When a watchdog timer interrupts is generated immediately before IDLE1/2 and SLEEP1/2 modes are started, the watchdog timer interrupt will be processed but IDLE1/2 and SLEEP1/2 modes will not be started.

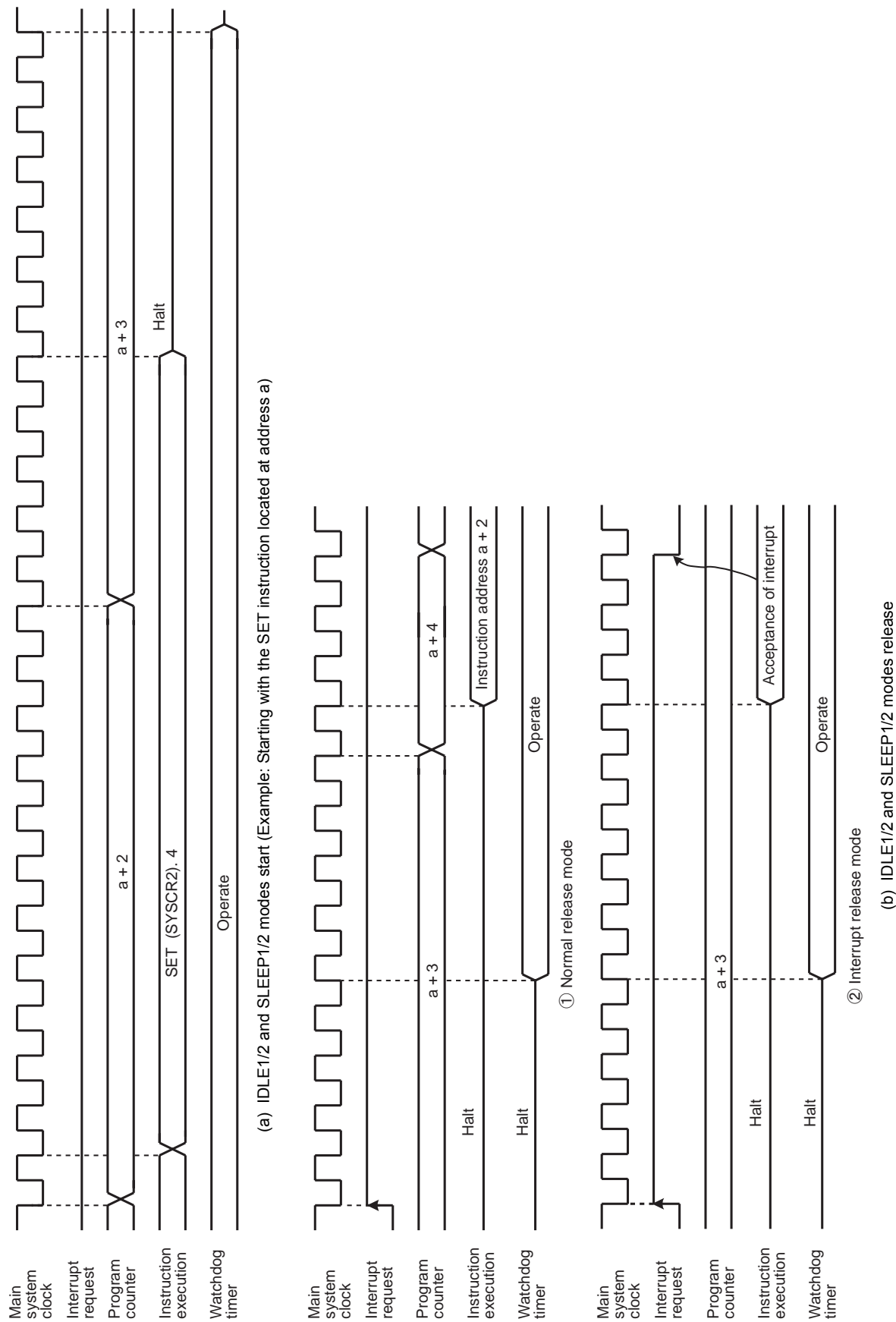


Figure 2-11 IDLE1/2 and SLEEP1/2 Modes Start/Release

2.2.4.3 IDLE0 and SLEEP0 modes (IDLE0, SLEEP0)

IDLE0 and SLEEP0 modes are controlled by the system control register 2 (SYSCR2) and the time base timer control register (TBTCCR). The following status is maintained during IDLE0 and SLEEP0 modes.

1. Timing generator stops feeding clock to peripherals except TBT.
2. The data memory, CPU registers, program status word and port output latches are all held in the status in effect before IDLE0 and SLEEP0 modes were entered.
3. The program counter holds the address 2 ahead of the instruction which starts IDLE0 and SLEEP0 modes.

Note: Before starting IDLE0 or SLEEP0 mode, be sure to stop (Disable) peripherals.

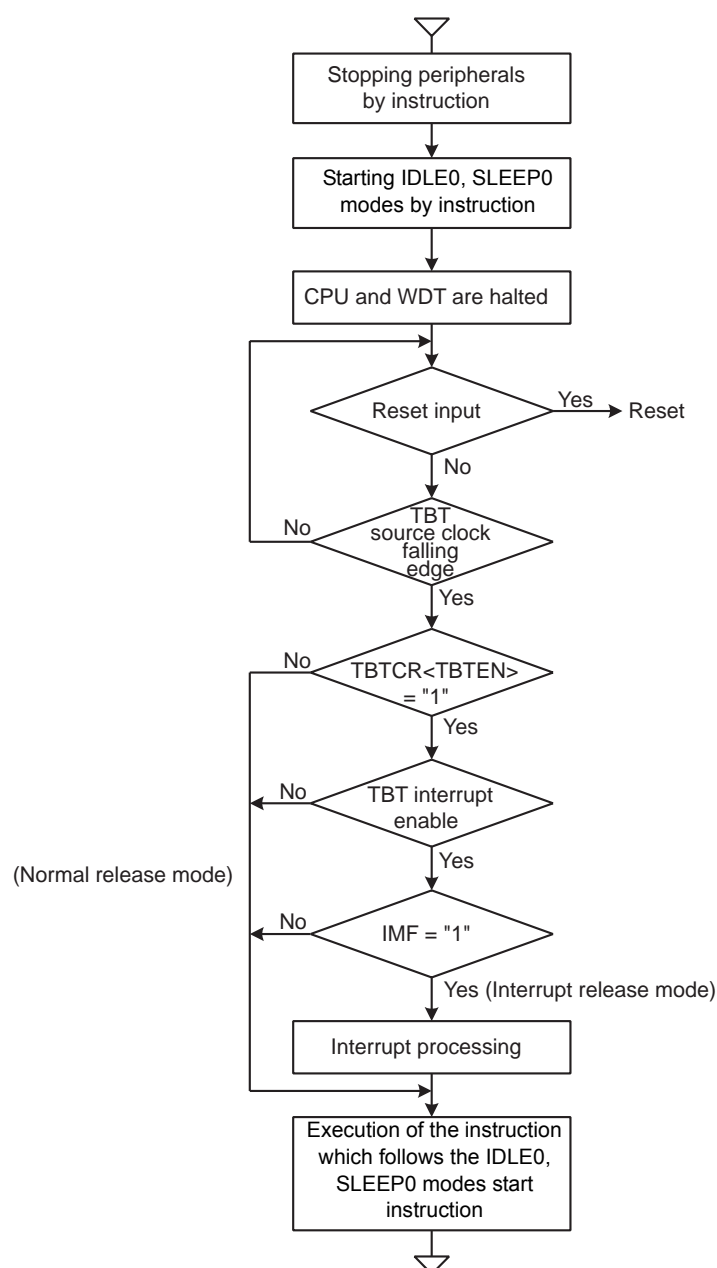


Figure 2-12 IDLE0 and SLEEP0 Modes

- Start the IDLE0 and SLEEP0 modes

Stop (Disable) peripherals such as a timer counter.

To start IDLE0 and SLEEP0 modes, set SYSCR2<TGHALT> to “1”.

- Release the IDLE0 and SLEEP0 modes

IDLE0 and SLEEP0 modes include a normal release mode and an interrupt release mode.

These modes are selected by interrupt master flag (IMF), the individual interrupt enable flag of TBT and TBTCR<TBTEN>.

After releasing IDLE0 and SLEEP0 modes, the SYSCR2<TGHALT> is automatically cleared to “0” and the operation mode is returned to the mode preceding IDLE0 and SLEEP0 modes. Before starting the IDLE0 or SLEEP0 mode, when the TBTCR<TBTEN> is set to “1”, INTTBT interrupt latch is set to “1”.

IDLE0 and SLEEP0 modes can also be released by inputting low level on the $\overline{\text{RESET}}$ pin. After releasing reset, the operation mode is started from NORMAL1 mode.

Note: IDLE0 and SLEEP0 modes start/release without reference to TBTCR<TBTEN> setting.

(1) Normal release mode (IMF•EF1•TBTCR<TBTEN> = “0”)

IDLE0 and SLEEP0 modes are released by the source clock falling edge, which is setting by the TBTCR<TBTCK>. After the falling edge is detected, the program operation is resumed from the instruction following the IDLE0 and SLEEP0 modes start instruction. Before starting the IDLE0 or SLEEP0 mode, when the TBTCR<TBTEN> is set to “1”, INTTBT interrupt latch is set to “1”.

(2) Interrupt release mode (IMF•EF1•TBTCR<TBTEN> = “1”)

IDLE0 and SLEEP0 modes are released by the source clock falling edge, which is setting by the TBTCR<TBTCK> and INTTBT interrupt processing is started.

Note 1: Because returning from IDLE0, SLEEP0 to NORMAL1, SLOW1 is executed by the asynchronous internal clock, the period of IDLE0, SLEEP0 mode might be the shorter than the period setting by TBTCR<TBTCK>.

Note 2: When a watchdog timer interrupt is generated immediately before IDLE0/SLEEP0 mode is started, the watchdog timer interrupt will be processed but IDLE0/SLEEP0 mode will not be started.

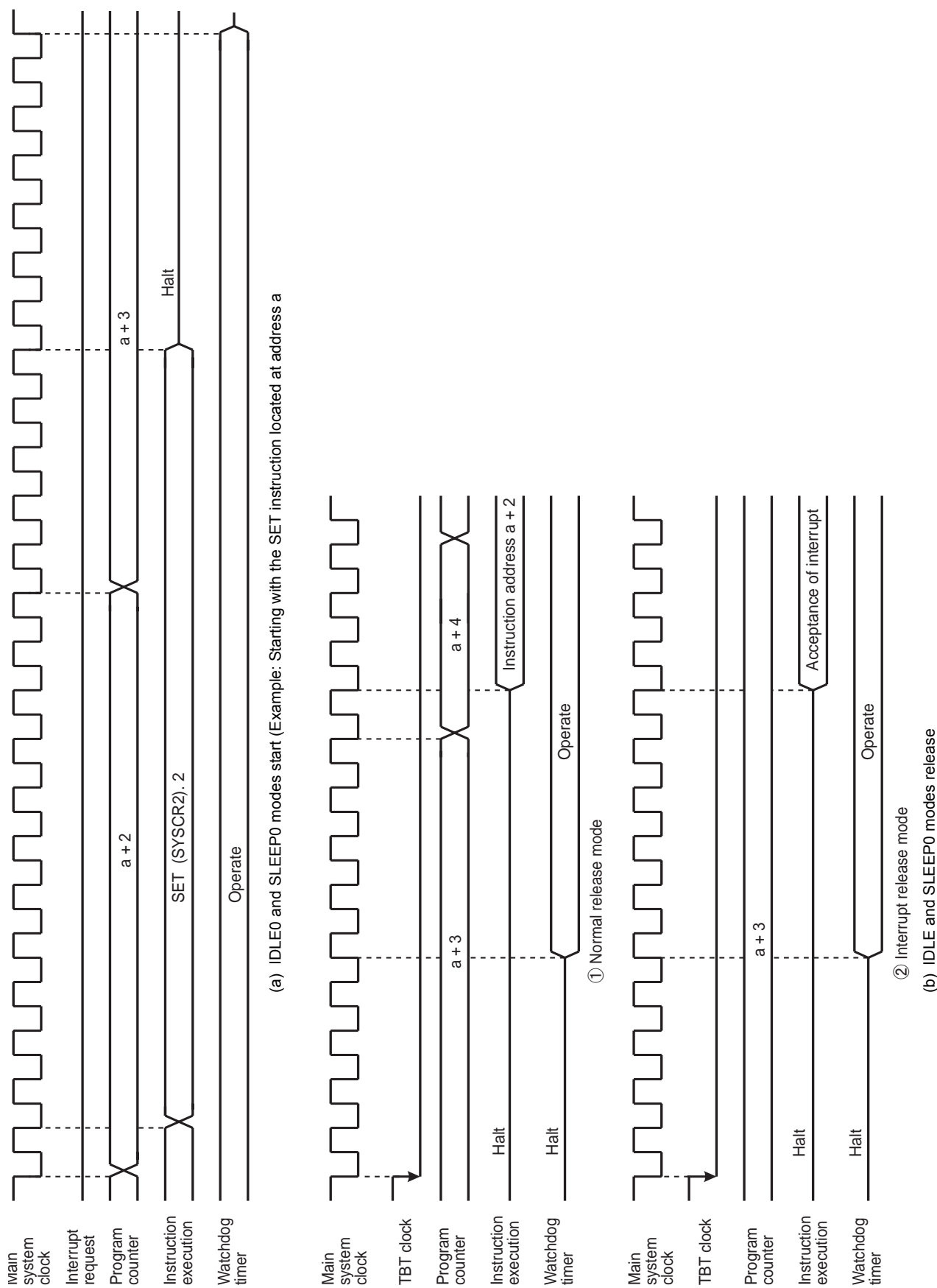


Figure 2-13 IDLE0 and SLEEP0 Modes Start/Release

2.2.4.4 SLOW mode

SLOW mode is controlled by the system control register 2 (SYSCR2).

The following is the methods to switch the mode with the warm-up counter.

(1) Switching from NORMAL2 mode to SLOW1 mode

First, set SYSCR2<SYSCK> to switch the main system clock to the low-frequency clock for SLOW2 mode. Next, clear SYSCR2<XEN> to turn off high-frequency oscillation.

Note: The high-frequency clock can be continued oscillation in order to return to NORMAL2 mode from SLOW mode quickly. Always turn off oscillation of high-frequency clock when switching from SLOW mode to stop mode.

Example 1 :Switching from NORMAL2 mode to SLOW1 mode.

```

SET      (SYSCR2). 5      ; SYSCR2<SYSCK> ← 1
                                (Switches the main system clock to the low-frequency
                                clock for SLOW2)

CLR      (SYSCR2). 7      ; SYSCR2<XEN> ← 0
                                (Turns off high-frequency oscillation)

```

Example 2 :Switching to the SLOW1 mode after low-frequency clock has stabilized.

```

SET      (SYSCR2). 6      ; SYSCR2<XTEN> ← 1

LD       (TC3CR), 43H     ; Sets mode for TC4, 3 (16-bit mode, fs for source)

LD       (TC4CR), 05H     ; Sets warming-up counter mode

LDW      (TTREG3), 8000H   ; Sets warm-up time (Depend on oscillator accompanied)

DI                               ; IMF ← 0

SET      (EIRH). 5        ; Enables INTTC4

EI                               ; IMF ← 1

SET      (TC4CR). 3        ; Starts TC4, 3

:

PINTTC4: CLR      (TC4CR). 3      ; Stops TC4, 3

SET      (SYSCR2). 5      ; SYSCR2<SYSCK> ← 1
                                (Switches the main system clock to the low-frequency clock)

CLR      (SYSCR2). 7      ; SYSCR2<XEN> ← 0
                                (Turns off high-frequency oscillation)

RETI

:

VINTTC4: DW      PINTTC4      ; INTTC4 vector table

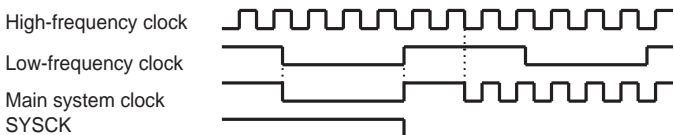
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(2) Switching from SLOW1 mode to NORMAL2 mode

First, set SYSCR2<XEN> to turn on the high-frequency oscillation. When time for stabilization (Warm up) has been taken by the timer/counter (TC4,TC3), clear SYSCR2<SYSCK> to switch the main system clock to the high-frequency clock.

SLOW mode can also be released by inputting low level on the $\overline{\text{RESET}}$ pin. After releasing reset, the operation mode is started from NORMAL1 mode.

Note: After SYSCK is cleared to "0", executing the instructions is continued by the low-frequency clock for the period synchronized with low-frequency and high-frequency clocks.



Example :Switching from the SLOW1 mode to the NORMAL2 mode ($f_c = 16 \text{ MHz}$, warm-up time is 4.0 ms).

	SET	(SYSCR2). 7	; SYSCR2<XEN> \leftarrow 1 (Starts high-frequency oscillation)
	LD	(TC3CR), 63H	; Sets mode for TC4, 3 (16-bit mode, f_c for source)
	LD	(TC4CR), 05H	; Sets warming-up counter mode
	LD	(TTREG4), 0F8H	; Sets warm-up time
	DI		; IMF \leftarrow 0
	SET	(EIRH). 5	; Enables INTTC4
	EI		; IMF \leftarrow 1
	SET	(TC4CR). 3	; Starts TC4, 3
	:		
PINTTC4:	CLR	(TC4CR). 3	; Stops TC4, 3
	CLR	(SYSCR2). 5	; SYSCR2<SYSCK> \leftarrow 0 (Switches the main system clock to the high-frequency clock)
	RETI		
	:		
VINTTC4:	DW	PINTTC4	; INTTC4 vector table

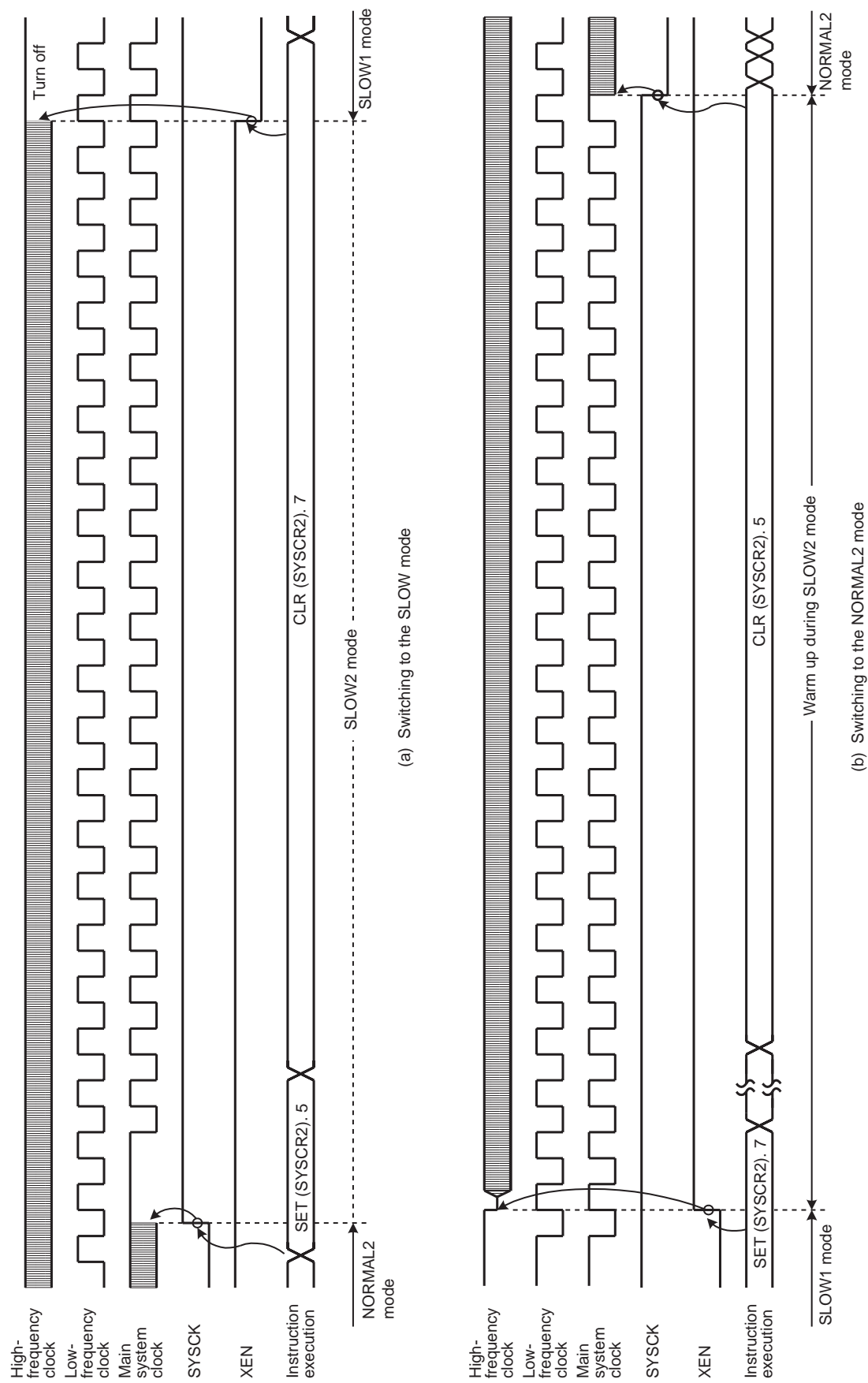


Figure 2-14 Switching between the NORMAL2 and SLOW Modes

2.3 Reset Circuit

The TMP86CH12MG has four types of reset generation procedures: An external reset input, an address trap reset, a watchdog timer reset and a system clock reset. Of these reset, the address trap reset, the watchdog timer and the system clock reset are a malfunction reset. When the malfunction reset request is detected, reset occurs during the maximum $24/f_c[s]$.

The malfunction reset circuit such as watchdog timer reset, address trap reset and system clock reset is not initialized when power is turned on. Therefore, reset may occur during maximum $24/f_c[s]$ ($1.5\mu s$ at 16.0 MHz) when power is turned on.

Table 2-3 shows on-chip hardware initialization by reset action.

Table 2-3 Initializing Internal Status by Reset Action

On-chip Hardware	Initial Value	On-chip Hardware	Initial Value
Program counter (PC)	(FFFEH)	Prescaler and divider of timing generator	0
Stack pointer (SP)	Not initialized		
General-purpose registers (W, A, B, C, D, E, H, L, IX, IY)	Not initialized		
Jump status flag (JF)	Not initialized	Watchdog timer	Enable
Zero flag (ZF)	Not initialized	Output latches of I/O ports	Refer to I/O port circuitry
Carry flag (CF)	Not initialized		
Half carry flag (HF)	Not initialized		
Sign flag (SF)	Not initialized		
Overflow flag (VF)	Not initialized		
Interrupt master enable flag (IMF)	0	Control registers	Refer to each of control register
Interrupt individual enable flags (EF)	0		
Interrupt latches (IL)	0		
		RAM	Not initialized

2.3.1 External Reset Input

The $\overline{\text{RESET}}$ pin contains a Schmitt trigger (Hysteresis) with an internal pull-up resistor.

When the $\overline{\text{RESET}}$ pin is held at “L” level for at least 3 machine cycles ($12/f_c [s]$) with the power supply voltage within the operating voltage range and oscillation stable, a reset is applied and the internal state is initialized.

When the $\overline{\text{RESET}}$ pin input goes high, the reset operation is released and the program execution starts at the vector address stored at addresses FFFEh to FFFFh.

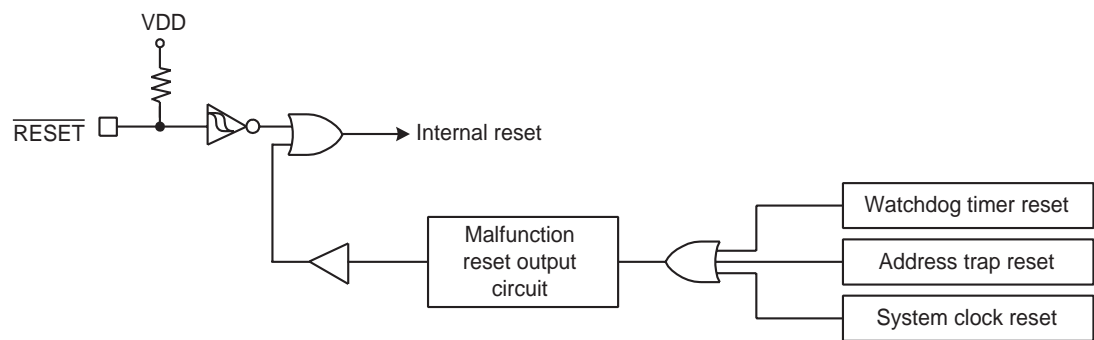
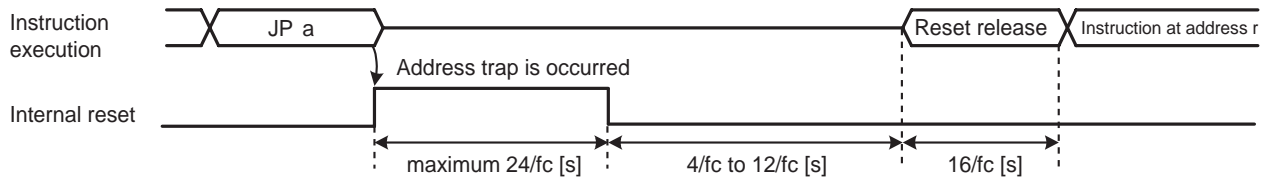


Figure 2-15 Reset Circuit

2.3.2 Address trap reset

If the CPU should start looping for some cause such as noise and an attempt be made to fetch an instruction from the on-chip RAM (when WDTCR1<ATAS> is set to “1”), DBR or the SFR area, address trap reset will be generated. The reset time is maximum $24/f_c$ [s] ($1.5\mu\text{s}$ at 16.0 MHz).

Note: The operating mode under address trapped is alternative of reset or interrupt. The address trap area is alternative.



Note 1: Address “a” is in the SFR, DBR or on-chip RAM (WDTCR1<ATAS> = “1”) space.

Note 2: During reset release, reset vector “r” is read out, and an instruction at address “r” is fetched and decoded.

Figure 2-16 Address Trap Reset

2.3.3 Watchdog timer reset

Refer to Section “Watchdog Timer”.

2.3.4 System clock reset

If the condition as follows is detected, the system clock reset occurs automatically to prevent dead lock of the CPU. (The oscillation is continued without stopping.)

- In case of clearing SYSCR2<XEN> and SYSCR2<XTEN> simultaneously to “0”.
- In case of clearing SYSCR2<XEN> to “0”, when the SYSCR2<SYSCK> is “0”.
- In case of clearing SYSCR2<XTEN> to “0”, when the SYSCR2<SYSCK> is “1”.

The reset time is maximum $24/f_c$ ($1.5\mu\text{s}$ at 16.0 MHz).



3. Interrupt Control Circuit

The TMP86CH12MG has a total of 22 interrupt sources excluding reset. Interrupts can be nested with priorities. Four of the internal interrupt sources are non-maskable while the rest are maskable.

Interrupt sources are provided with interrupt latches (IL), which hold interrupt requests, and independent vectors. The interrupt latch is set to "1" by the generation of its interrupt request which requests the CPU to accept its interrupts. Interrupts are enabled or disabled by software using the interrupt master enable flag (IMF) and interrupt enable flag (EF). If more than one interrupts are generated simultaneously, interrupts are accepted in order which is dominated by hardware. However, there are no prioritized interrupt factors among non-maskable interrupts.

Interrupt Factors		Enable Condition	Interrupt Latch	Vector Address	Priority
Internal/External	(Reset)	Non-maskable	–	FFFE	1
Internal	INTSWI (Software interrupt)	Non-maskable	–	FFFC	2
Internal	INTUNDEF (Executed the undefined instruction interrupt)	Non-maskable	–	FFFC	2
Internal	INTATRAP (Address trap interrupt)	Non-maskable	IL2	FFFA	2
Internal	INTWDT (Watchdog timer interrupt)	Non-maskable	IL3	FFF8	2
Internal	INTIMG	IMF• EF4 = 1	IL4	FFF6	5
-	Reserved	IMF• EF5 = 1	IL5	FFF4	6
External	INT0	IMF• EF6 = 1, INT0EN = 1	IL6	FFF2	7
Internal	INTTC1	IMF• EF7 = 1	IL7	FFF0	8
External	INT1	IMF• EF8 = 1	IL8	FFEE	9
Internal	INTTBT	IMF• EF9 = 1	IL9	FFEC	10
External	INT2	IMF• EF10 = 1	IL10	FFEA	11
Internal	INTTC7T	IMF• EF11 = 1	IL11	FFE8	12
-	Reserved	IMF• EF12 = 1	IL12	FFE6	13
Internal	INTTC4	IMF• EF13 = 1	IL13	FFE4	14
Internal	INTTC3	IMF• EF14 = 1	IL14	FFE2	15
-	Reserved	IMF• EF15 = 1	IL15	FFE0	16
-	Reserved	IMF• EF16 = 1	IL16	FFBE	17
External	INT3	IMF• EF17 = 1	IL17	FFBC	18
Internal	INTSIO	IMF• EF18 = 1	IL18	FFBA	19
Internal	INTADC	IMF• EF19 = 1	IL19	FFB8	20
Internal	INTRXD	IMF• EF20 = 1	IL20	FFB6	21
Internal	INTTXD	IMF• EF21 = 1	IL21	FFB4	22
External	INT4	IMF• EF22 = 1	IL22	FFB2	23
Internal	INTTC7P	IMF• EF23 = 1	IL23	FFB0	24
-	Reserved	IMF• EF24 = 1	IL24	FFAE	25
-	Reserved	IMF• EF25 = 1	IL25	FFAC	26
-	Reserved	IMF• EF26 = 1	IL26	FFAA	27
Internal	INTRTC	IMF• EF27 = 1	IL27	FFA8	28
External	INT5	IMF• EF28 = 1	IL28	FFA6	29
-	Reserved	IMF• EF29 = 1	IL29	FFA4	30
-	Reserved	IMF• EF30 = 1	IL30	FFA2	31
-	Reserved	IMF• EF31 = 1	IL31	FFA0	32

Note 1: To use the address trap interrupt (INTATRAP), clear WDTCR1<ATOUT> to "0" (It is set for the "reset request" after reset is cancelled). For details, see "Address Trap".

Note 2: To use the watchdog timer interrupt (INTWDT), clear WDTCR1<WDTOU> to "0" (It is set for the "Reset request" after reset is released). For details, see "Watchdog Timer".

3.1 Interrupt latches (IL28 to IL2)

An interrupt latch is provided for each interrupt source, except for a software interrupt and an executed the undefined instruction interrupt. When interrupt request is generated, the latch is set to “1”, and the CPU is requested to accept the interrupt if its interrupt is enabled. The interrupt latch is cleared to “0” immediately after accepting interrupt. All interrupt latches are initialized to “0” during reset.

The interrupt latches are located on address 002EH, 002FH, 003CH and 003DH in SFR area. Each latch can be cleared to “0” individually by instruction. However, IL2 and IL3 should not be cleared to “0” by software. For clearing the interrupt latch, load instruction should be used and then IL2 and IL3 should be set to “1”. If the read-modify-write instructions such as bit manipulation or operation instructions are used, interrupt request would be cleared inadequately if interrupt is requested while such instructions are executed.

Interrupt latches are not set to “1” by an instruction.

Since interrupt latches can be read, the status for interrupt requests can be monitored by software.

Note: In main program, before manipulating the interrupt enable flag (EF) or the interrupt latch (IL), be sure to clear IMF to “0” (Disable interrupt by DI instruction). Then set IMF newly again as required after operating on the EF or IL (Enable interrupt by EI instruction)
In interrupt service routine, because the IMF becomes “0” automatically, clearing IMF need not execute normally on interrupt service routine. However, if using multiple interrupt on interrupt service routine, manipulating EF or IL should be executed before setting IMF=“1”.

Example 1 :Clears interrupt latches

```
DI                                ; IMF ← 0
LDW      (ILL), 1110100000111111B ; IL12, IL10 to IL6 ← 0
EI                                ; IMF ← 1
```

Example 2 :Reads interrupt latches

```
LD      WA, (ILL)                ; W ← ILH, A ← ILL
```

Example 3 :Tests interrupt latches

```
TEST      (ILL), 7                ; if IL7 = 1 then jump
JR      F, SSET
```

3.2 Interrupt enable register (EIR)

The interrupt enable register (EIR) enables and disables the acceptance of interrupts, except for the non-maskable interrupts (Software interrupt, undefined instruction interrupt, address trap interrupt and watchdog interrupt). Non-maskable interrupt is accepted regardless of the contents of the EIR.

The EIR consists of an interrupt master enable flag (IMF) and the individual interrupt enable flags (EF). These registers are located on address 002CH, 002DH, 003AH and 003BH in SFR area, and they can be read and written by an instructions (Including read-modify-write instructions such as bit manipulation or operation instructions).

3.2.1 Interrupt master enable flag (IMF)

The interrupt enable register (IMF) enables and disables the acceptance of the whole maskable interrupt. While IMF = “0”, all maskable interrupts are not accepted regardless of the status on each individual interrupt enable flag (EF). By setting IMF to “1”, the interrupt becomes acceptable if the individuals are enabled. When an interrupt is accepted, IMF is cleared to “0” after the latest status on IMF is stacked. Thus the maskable interrupts which follow are disabled. By executing return interrupt instruction [RETI/RETN], the stacked data, which was the status before interrupt acceptance, is loaded on IMF again.

The IMF is located on bit0 in EIRL (Address: 003AH in SFR), and can be read and written by an instruction. The IMF is normally set and cleared by [EI] and [DI] instruction respectively. During reset, the IMF is initialized to “0”.

3.2.2 Individual interrupt enable flags (EF28 to EF4)

Each of these flags enables and disables the acceptance of its maskable interrupt. Setting the corresponding bit of an individual interrupt enable flag to “1” enables acceptance of its interrupt, and setting the bit to “0” disables acceptance. During reset, all the individual interrupt enable flags (EF28 to EF4) are initialized to “0” and all maskable interrupts are not accepted until they are set to “1”.

Note: In main program, before manipulating the interrupt enable flag (EF) or the interrupt latch (IL), be sure to clear IMF to "0" (Disable interrupt by DI instruction). Then set IMF newly again as required after operating on the EF or IL (Enable interrupt by EI instruction)
In interrupt service routine, because the IMF becomes "0" automatically, clearing IMF need not execute normally on interrupt service routine. However, if using multiple interrupt on interrupt service routine, manipulating EF or IL should be executed before setting IMF="1".

Example 1 :Enables interrupts individually and sets IMF

```
DI                                     ; IMF ← 0

LDW      (EIRL), 1110100010100000B   ; EF15 to EF13, EF11, EF7, EF5 ← 1
:                                           Note: IMF should not be set.
:
EI                                     ; IMF ← 1
```

Example 2 :C compiler description example

```
unsigned int _io (3AH) EIRL;          /* 3AH shows EIRL address */
_DI();
EIRL = 10100000B;
:
_EI();
```

Interrupt Latches

(Initial value: *00*0000 00*000**)																
ILH,ILL (003DH, 003CH)	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	–	IL14	IL13	–	IL11	IL10	IL9	IL8	IL7	IL6	–	IL4	IL3	IL2		
ILH (003DH)								ILL (003CH)								

(Initial value: ***00*** 0000000*)																
ILD,ILE (002FH, 002EH)	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	—	—	—	IL28	IL27	—	—	—	IL23	IL22	IL21	IL20	IL19	IL18	IL17	—
ILD (002FH)								ILE (002EH)								

IL28 to IL2	Interrupt latches	at RD 0: No interrupt request 1: Interrupt request	at WR 0: Clears the interrupt request 1: (Interrupt latch is not set.)	R/W
-------------	-------------------	----------------------------------------------------------	------------------------------------------------------------------------------	-----

- Note 1: To clear any one of bits IL7 to IL4, be sure to write "1" into IL2 and IL3.
- Note 2: In main program, before manipulating the interrupt enable flag (EF) or the interrupt latch (IL), be sure to clear IMF to "0" (Disable interrupt by DI instruction). Then set IMF newly again as required after operating on the EF or IL (Enable interrupt by EI instruction)
- In interrupt service routine, because the IMF becomes "0" automatically, clearing IMF need not execute normally on interrupt service routine. However, if using multiple interrupt on interrupt service routine, manipulating EF or IL should be executed before setting IMF="1".
- Note 3: Do not clear IL with read-modify-write instructions such as bit operations.

Interrupt Enable Registers

(Initial value: *00*0000 00*0***0)																
EIRH,EIRL (003BH, 003AH)	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	–	EF14	EF13	–	EF11	EF10	EF9	EF8	EF7	EF6	–	EF4				IMF
EIRH (003BH)								EIRL (003AH)								

(Initial value: ***00*** 0000000*)																
EIRD,EIRE (002DH, 002CH)	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	–	–	–	EF28	EF27	–	–	–	EF23	EF22	EF21	EF20	EF19	EF18	EF17	–
EIRD (002DH)								EIRE (002CH)								

EF28 to EF4	Individual-interrupt enable flag (Specified for each bit)	0: Disables the acceptance of each maskable interrupt. 1: Enables the acceptance of each maskable interrupt.	R/W
IMF	Interrupt master enable flag	0: Disables the acceptance of all maskable interrupts 1: Enables the acceptance of all maskable interrupts	

- Note 1: *: Don't care
- Note 2: Do not set IMF and the interrupt enable flag (EF15 to EF4) to "1" at the same time.
- Note 3: In main program, before manipulating the interrupt enable flag (EF) or the interrupt latch (IL), be sure to clear IMF to "0" (Disable interrupt by DI instruction). Then set IMF newly again as required after operating on the EF or IL (Enable interrupt by EI instruction)
- In interrupt service routine, because the IMF becomes "0" automatically, clearing IMF need not execute normally on interrupt service routine. However, if using multiple interrupt on interrupt service routine, manipulating EF or IL should be executed before setting IMF="1".

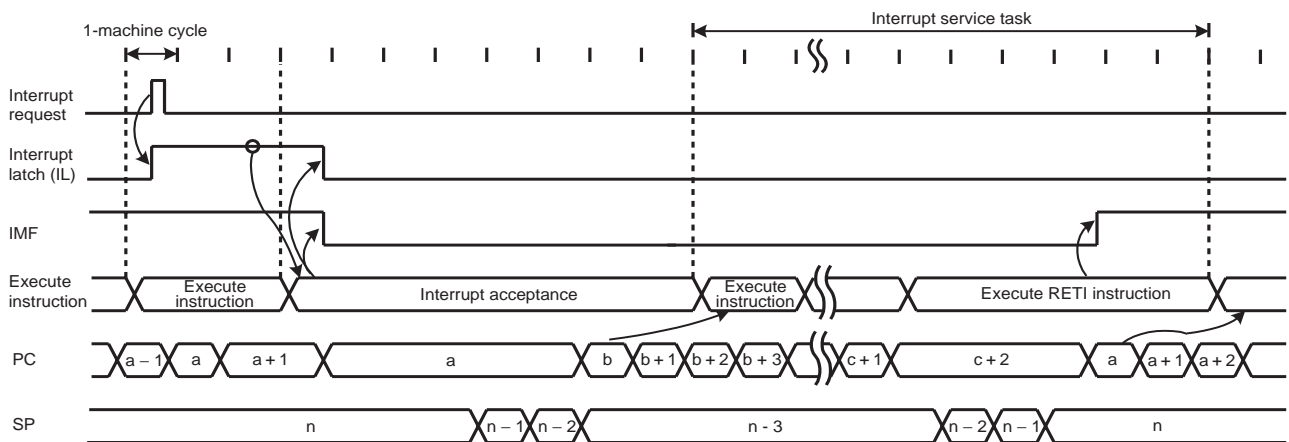
3.3 Interrupt Sequence

An interrupt request, which raised interrupt latch, is held, until interrupt is accepted or interrupt latch is cleared to “0” by resetting or an instruction. Interrupt acceptance sequence requires 8 machine cycles (2 μ s @16 MHz) after the completion of the current instruction. The interrupt service task terminates upon execution of an interrupt return instruction [RETI] (for maskable interrupts) or [RETN] (for non-maskable interrupts). Figure 3-1 shows the timing chart of interrupt acceptance processing.

3.3.1 Interrupt acceptance processing is packaged as follows.

- The interrupt master enable flag (IMF) is cleared to “0” in order to disable the acceptance of any following interrupt.
- The interrupt latch (IL) for the interrupt source accepted is cleared to “0”.
- The contents of the program counter (PC) and the program status word, including the interrupt master enable flag (IMF), are saved (Pushed) on the stack in sequence of PSW + IMF, PCH, PCL. Meanwhile, the stack pointer (SP) is decremented by 3.
- The entry address (Interrupt vector) of the corresponding interrupt service program, loaded on the vector table, is transferred to the program counter.
- The instruction stored at the entry address of the interrupt service program is executed.

Note: When the contents of PSW are saved on the stack, the contents of IMF are also saved.



Note 1: a: Return address entry address, b: Entry address, c: Address which RETI instruction is stored

Note 2: On condition that interrupt is enabled, it takes 38/fc [s] or 38/fs [s] at maximum (If the interrupt latch is set at the first machine cycle on 10 cycle instruction) to start interrupt acceptance processing since its interrupt latch is set.

Figure 3-1 Timing Chart of Interrupt Acceptance/Return Interrupt Instruction

Example: Correspondence between vector table address for INTTBT and the entry address of the interrupt service program

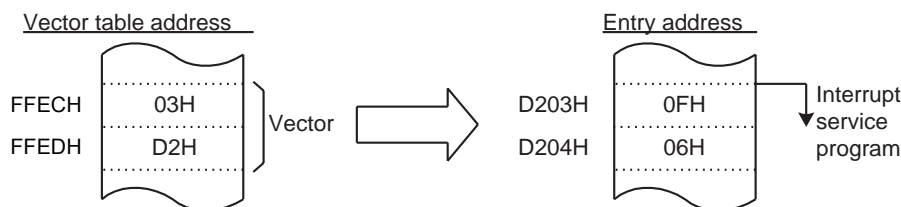


Figure 3-2 Vector table address, Entry address

To avoid overloaded nesting, clear the individual interrupt enable flag whose interrupt is currently serviced, before setting IMF to “1”. As for non-maskable interrupt, keep interrupt service shorten compared with length between interrupt requests; otherwise the status cannot be recovered as non-maskable interrupt would simply nested.

During interrupt acceptance processing, the program counter (PC) and the program status word (PSW, includes IMF) are automatically saved on the stack, but the accumulator and others are not. These registers are saved by software if necessary. When multiple interrupt services are nested, it is also necessary to avoid using the same data memory area for saving registers. The following methods are used to save/restore the general-purpose registers.

If only a specific register is saved or interrupts of the same source are nested, general-purpose registers can be saved/restored using the PUSH/POP instructions.

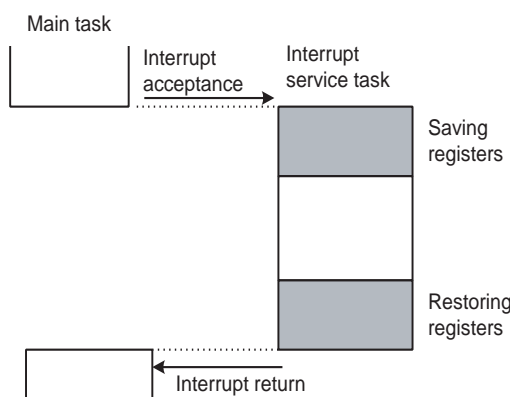
PINTxx:	PUSH	WA	; Save WA register
	(interrupt processing)		
	POP	WA	; Restore WA register
	RETI		; RETURN



To save only a specific register without nested interrupts, data transfer instructions are available.

Example :Save/store register using data transfer instructions

```
PINTxx:      LD      (GSAVA), A      ; Save A register
              (interrupt processing)
              LD      A, (GSAVA)      ; Restore A register
              RETI                     ; RETURN
```



Saving/Restoring general-purpose registers using PUSH/POP data transfer instruction

Figure 3-4 Saving/Restoring General-purpose Registers under Interrupt Processing

3.3.3 Interrupt return

Interrupt return instructions [RETI]/[RETN] perform as follows.

[RETI]/[RETN] Interrupt Return
1. Program counter (PC) and program status word (PSW, includes IMF) are restored from the stack.
2. Stack pointer (SP) is incremented by 3.

As for address trap interrupt (INTATRAP), it is required to alter stacked data for program counter (PC) to restarting address, during interrupt service program.

Note: If [RETN] is executed with the above data unaltered, the program returns to the address trap area and INTATRAP occurs again. When interrupt acceptance processing has completed, stacked data for PCL and PCH are located on address (SP + 1) and (SP + 2) respectively.

Example 1 :Returning from address trap interrupt (INTATRAP) service program

```
PINTxx:      POP      WA              ; Recover SP by 2
              LD      WA, Return Address ;
              PUSH     WA              ; Alter stacked data
              (interrupt processing)
              RETN                     ; RETURN
```

Example 2 :Restarting without returning interrupt
(In this case, PSW (Includes IMF) before interrupt acceptance is discarded.)

```
PINTxx:      INC      SP      ; Recover SP by 3
              INC      SP      ;
              INC      SP      ;
              (interrupt processing)
              LD      EIRL, data      ; Set IMF to "1" or clear it to "0"
              JP      Restart Address ; Jump into restarting address
```

Interrupt requests are sampled during the final cycle of the instruction being executed. Thus, the next interrupt can be accepted immediately after the interrupt return instruction is executed.

- Note 1: It is recommended that stack pointer be return to rate before INTATRAP (Increment 3 times), if return interrupt instruction [RETN] is not utilized during interrupt service program under INTATRAP (such as Example 2).
- Note 2: When the interrupt processing time is longer than the interrupt request generation time, the interrupt service task is performed but not the main task.

3.4 Software Interrupt (INTSW)

Executing the SWI instruction generates a software interrupt and immediately starts interrupt processing (INTSW is highest prioritized interrupt).

Use the SWI instruction only for detection of the address error or for debugging.

3.4.1 Address error detection

FFH is read if for some cause such as noise the CPU attempts to fetch an instruction from a non-existent memory address during single chip mode. Code FFH is the SWI instruction, so a software interrupt is generated and an address error is detected. The address error detection range can be further expanded by writing FFH to unused areas of the program memory. Address trap reset is generated in case that an instruction is fetched from RAM, DBR or SFR areas.

3.4.2 Debugging

Debugging efficiency can be increased by placing the SWI instruction at the software break point setting address.

3.5 Undefined Instruction Interrupt (INTUNDEF)

Taking code which is not defined as authorized instruction for instruction causes INTUNDEF. INTUNDEF is generated when the CPU fetches such a code and tries to execute it. INTUNDEF is accepted even if non-maskable interrupt is in process. Contemporary process is broken and INTUNDEF interrupt process starts, soon after it is requested.

Note: The undefined instruction interrupt (INTUNDEF) forces CPU to jump into vector address, as software interrupt (SWI) does.

3.6 Address Trap Interrupt (INTATRAP)

Fetching instruction from unauthorized area for instructions (Address trapped area) causes reset output or address trap interrupt (INTATRAP). INTATRAP is accepted even if non-maskable interrupt is in process. Contemporary process is broken and INTATRAP interrupt process starts, soon after it is requested.

Note: The operating mode under address trapped, whether to be reset output or interrupt processing, is selected on watchdog timer control register (WDTCR).

3.7 External Interrupts

The TMP86CH12MG has 6 external interrupt inputs. These inputs are equipped with digital noise reject circuits (Pulse inputs of less than a certain time are eliminated as noise).

Edge selection is also possible with INT1 to INT4. The $\overline{\text{INT0}}$ /P31 pin can be configured as either an external interrupt input pin or an input/output port, and is configured as an input port during reset.

Edge selection, noise reject control and $\overline{\text{INT0}}$ /P31 pin function selection are performed by the external interrupt control register (EINTCR).

Source	Pin	Enable Conditions	Release Edge (level)	Digital Noise Reject
INT0	$\overline{\text{INT0}}$	$\text{IMF} \cdot \text{EF6} \cdot \text{INT0EN}=1$	Falling edge	Pulses of less than 2/fc [s] are eliminated as noise. Pulses of 7/fc [s] or more are considered to be signals. In the SLOW or the SLEEP mode, pulses of less than 1/fs [s] are eliminated as noise. Pulses of 3.5/fs [s] or more are considered to be signals.
INT1	INT1	$\text{IMF} \cdot \text{EF8} = 1$	Falling edge or Rising edge	Pulses of less than 15/fc or 63/fc [s] are eliminated as noise. Pulses of 49/fc or 193/fc [s] or more are considered to be signals. In the SLOW or the SLEEP mode, pulses of less than 1/fs [s] are eliminated as noise. Pulses of 3.5/fs [s] or more are considered to be signals.
INT2	INT2	$\text{IMF} \cdot \text{EF10} = 1$	Falling edge or Rising edge	Pulses of less than 7/fc [s] are eliminated as noise. Pulses of 25/fc [s] or more are considered to be signals. In the SLOW or the SLEEP mode, pulses of less than 1/fs [s] are eliminated as noise. Pulses of 3.5/fs [s] or more are considered to be signals.
INT3	INT3	$\text{IMF} \cdot \text{EF17} = 1$	Falling edge or Rising edge	Pulses of less than 7/fc [s] are eliminated as noise. Pulses of 25/fc [s] or more are considered to be signals. In the SLOW or the SLEEP mode, pulses of less than 1/fs [s] are eliminated as noise. Pulses of 3.5/fs [s] or more are considered to be signals.
INT4	INT4	$\text{IMF} \cdot \text{EF22} = 1$	Falling edge, Rising edge, Falling and Rising edge or H level	Pulses of less than 7/fc [s] are eliminated as noise. Pulses of 25/fc [s] or more are considered to be signals. In the SLOW or the SLEEP mode, pulses of less than 1/fs [s] are eliminated as noise. Pulses of 3.5/fs [s] or more are considered to be signals.
INT5	$\overline{\text{INT5}}$	$\text{IMF} \cdot \text{EF28} = 1$	Falling edge	Pulses of less than 2/fc [s] are eliminated as noise. Pulses of 7/fc [s] or more are considered to be signals. In the SLOW or the SLEEP mode, pulses of less than 1/fs [s] are eliminated as noise. Pulses of 3.5/fs [s] or more are considered to be signals.

Note 1: In NORMAL1/2 or IDLE1/2 mode, if a signal with no noise is input on an external interrupt pin, it takes a maximum of "signal establishment time + 6/fs[s]" from the input signal's edge to set the interrupt latch.

Note 2: When INT0EN = "0", IL6 is not set even if a falling edge is detected on the $\overline{\text{INT0}}$ pin input.

Note 3: When a pin with more than one function is used as an output and a change occurs in data or input/output status, an interrupt request signal is generated in a pseudo manner. In this case, it is necessary to perform appropriate processing such as disabling the interrupt enable flag.

External Interrupt Control Register

EINTCR	7	6	5	4	3	2	1	0	
(0037H)	INT1NC	INT0EN	INT4ES	INT3ES	INT2ES	INT1ES			(Initial value: 0000 000*)

INT1NC	Noise reject time select	0: Pulses of less than 63/fc [s] are eliminated as noise 1: Pulses of less than 15/fc [s] are eliminated as noise	R/W
INT0EN	P31/ $\overline{\text{INT0}}$ pin configuration	0: P31 input/output port 1: $\overline{\text{INT0}}$ pin (Port P31 should be set to an input mode)	R/W
INT4 ES	INT4 edge select	00: Rising edge 01: Falling edge 10: Rising edge and Falling edge 11: H level	R/W
INT3 ES	INT3 edge select	0: Rising edge 1: Falling edge	R/W
INT2 ES	INT2 edge select	0: Rising edge 1: Falling edge	R/W
INT1 ES	INT1 edge select	0: Rising edge 1: Falling edge	R/W

- Note 1: fc: High-frequency clock [Hz], *: Don't care
- Note 2: When the system clock frequency is switched between high and low or when the external interrupt control register (EINTCR) is overwritten, the noise canceller may not operate normally. It is recommended that external interrupts are disabled using the interrupt enable register (EIR).
- Note 3: The maximum time from modifying INT1NC until a noise reject time is changed is $2^6/fc$.
- Note 4: In case RESET pin is released while the state of INT4 pin keeps "H" level, the external interrupt 4 request is not generated even if the INT4 edge select is specified as "H" level. The rising edge is needed after RESET pin is released.

4. Special Function Register (SFR)

The TMP86CH12MG adopts the memory mapped I/O system, and all peripheral control and data transfers are performed through the special function register (SFR) or the data buffer register (DBR). The SFR is mapped on address 0000H to 003FH, DBR is mapped on address 0F80H to 0FFFH.

This chapter shows the arrangement of the special function register (SFR) and data buffer register (DBR) for TMP86CH12MG.

4.1 SFR

Address	Read	Write
0000H	P0DR	
0001H	P1DR	
0002H	P2DR	
0003H	P3DR	
0004H	P0OUTCR	
0005H	P1CR	
0006H	P3CR1	
0007H	P3CR2	
0008H	TC7DRAL	
0009H	TC7DRAH	
000AH	TC7DRBL	
000BH	TC7DRBH	
000CH	TC7DRCL	
000DH	TC7DRCH	
000EH	P0PRD	-
000FH	P2PRD	-
0010H	TC1DRAL	
0011H	TC1DRAH	
0012H	TC1DRBL	
0013H	TC1DRBH	
0014H	TC1CR	
0015H	TC3CR	
0016H	TC4CR	
0017H	PWREG3	
0018H	PWREG4	
0019H	TTREG3	
001AH	TTREG4	
001BH	RTCCR	
001CH	Reserved	
001DH	Reserved	
001EH	Reserved	
001FH	ADCDR2	-
0020H	ADCDR1	-
0021H	UARTSR	UARTCR1
0022H	-	UARTCR2
0023H	Reserved	
0024H	Reserved	
0025H	ADCCR1	

Address	Read	Write
0026H	ADCCR2	
0027H	Reserved	
0028H	Reserved	
0029H	TC7CR1	
002AH	TC7CR2	
002BH	TC7CR3	
002CH	EIRE	
002DH	EIRD	
002EH	ILE	
002FH	ILD	
0030H	Reserved	
0031H	-	SIOCR1
0032H	SIOSR	SIOCR2
0033H	Reserved	
0034H	-	WDTCR1
0035H	-	WDTCR2
0036H	TBTCCR	
0037H	EINTCR	
0038H	SYSCR1	
0039H	SYSCR2	
003AH	EIRL	
003BH	EIRH	
003CH	ILL	
003DH	ILH	
003EH	Reserved	
003FH	PSW	

Note 1: Do not access reserved areas by the program.

Note 2: – ; Cannot be accessed.

Note 3: Write-only registers and interrupt latches cannot use the read-modify-write instructions (Bit manipulation instructions such as SET, CLR, etc. and logical operation instructions such as AND, OR, etc.).

4.2 DBR

Address	Read	Write
0F80H	SIOBR0	
0F81H	SIOBR1	
0F82H	SIOBR2	
0F83H	SIOBR3	
0F84H	SIOBR4	
0F85H	SIOBR5	
0F86H	SIOBR6	
0F87H	SIOBR7	
0F88H	-	STOPCR
0F89H	RDBUF	TDBUF
0F8AH	Reserved	
0F8BH	Reserved	
0F8CH	Reserved	
0F8DH	Reserved	
0F8EH	Reserved	
0F8FH	Reserved	
0F90H	Reserved	
0F91H	Reserved	
0F92H	Reserved	
0F93H	Reserved	
0F94H	Reserved	
0F95H	Reserved	
0F96H	Reserved	
0F97H	Reserved	
0F98H	Reserved	
0F99H	Reserved	
0F9AH	Reserved	
0F9BH	Reserved	
0F9CH	Reserved	
0F9DH	Reserved	
0F9EH	Reserved	
0F9FH	Reserved	

4. Special Function Register (SFR)

4.2 DBR

TMP86CH12MG

Address	Read	Write
0FA0H	Reserved	
0FA1H	Reserved	
0FA2H	Reserved	
0FA3H	Reserved	
0FA4H	Reserved	
0FA5H	Reserved	
0FA6H	Reserved	
0FA7H	Reserved	
0FA8H	Reserved	
0FA9H	Reserved	
0FAAH	Reserved	
0FABH	Reserved	
0FACH	Reserved	
0FADH	Reserved	
0FAEH	Reserved	
0FAFH	Reserved	
0FB0H	TC7DRDL	
0FB1H	TC7DRDH	
0FB2H	TC7DREL	
0FB3H	TC7DREH	
0FB4H	TC7CAPAL	-
0FB5H	TC7CAPAH	-
0FB6H	TC7CAPBL	-
0FB7H	TC7CAPBH	-
0FB8H	Reserved	
0FB9H	Reserved	
0FBAH	Reserved	
0FBBH	Reserved	
0FBCH	Reserved	
0FBDH	Reserved	
0FBEH	Reserved	
0FBFH	Reserved	

Address	Read	Write
0FC0H	Reserved	
: :	: :	
0FDFH	Reserved	

Address	Read	Write
0FE0H	Reserved	
: :	: :	
0FFFH	Reserved	

Note 1: Do not access reserved areas by the program.

Note 2: – ; Cannot be accessed.

Note 3: Write-only registers and interrupt latches cannot use the read-modify-write instructions (Bit manipulation instructions such as SET, CLR, etc. and logical operation instructions such as AND, OR, etc.).

5. I/O Ports

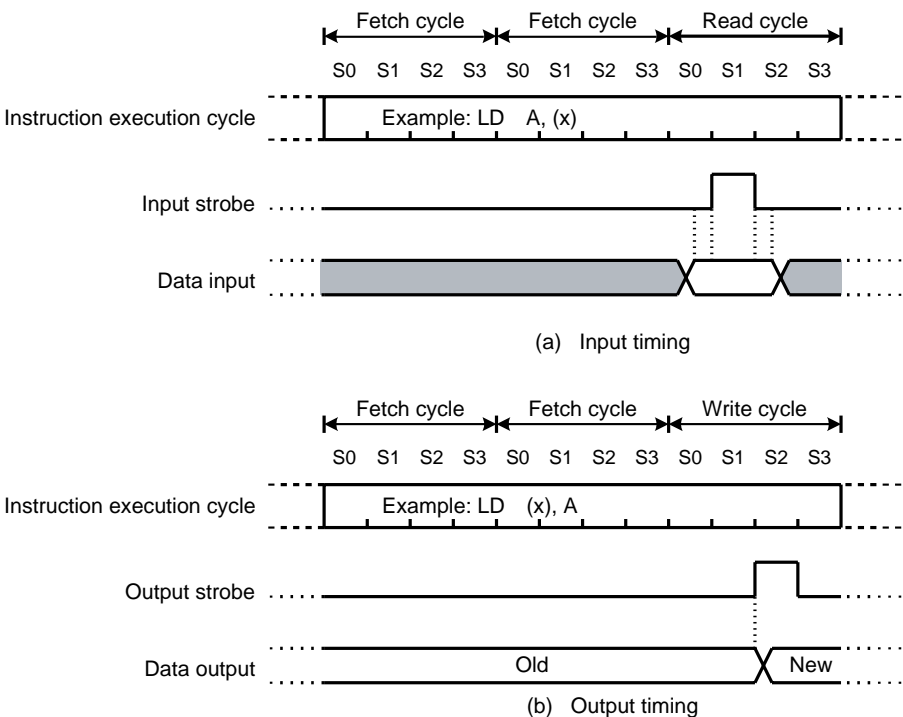
The TMP86CH12MG has 4 parallel input/output ports (24 pins) as follows.

	Primary Function	Secondary Functions
Port P0	8-bit I/O port	External interrupt, serial interface input/output, UART input/output and timer counter input/output.
Port P1	5-bit I/O port	External interrupt and timer counter input/output.
Port P2	3-bit I/O port	Low-frequency resonator connections, external interrupt input, STOP mode release signal input.
Port P3	8-bit I/O port	External interrupt, analog input and STOP mode release signal input.

Each output port contains a latch, which holds the output data. All input ports do not have latches, so the external input data should be externally held until the input data is read from outside or reading should be performed several timer before processing. Figure 5-1 shows input/output timing examples.

External data is read from an I/O port in the S1 state of the read cycle during execution of the read instruction. This timing cannot be recognized from outside, so that transient input such as chattering must be processed by the program.

Output data changes in the S2 state of the write cycle during execution of the instruction which writes to an I/O port.



Note: The positions of the read and write cycles may vary, depending on the instruction.

Figure 5-1 Input/Output Timing (Example)

5.1 Port P0 (P07 to P00)

Port P0 is an 8-bit input/output port.

Port P0 is also used as an external interrupt input, a serial interface input/output, an UART input/output and a timer/counter input/output.

It can be selected whether output circuit of P0 port is a C-MOS output or a sink open drain individually, by setting P0OUTCR. During reset, the P0DR is initialized to "1", and the P0OUTCR is initialized to "0". When a corresponding bit of P0OUTCR is "0". the output circuit is selected to a sink open drain and when a corresponding bit of P0OUTCR is "1", the output circuit is selected to a C-MOS output.

When used as an input port, an external interrupt input, a serial interface input ,an UART input and a timer/counter input , the corresponding output control (P0OUTCR) should be set to "0" after P0DR is set to "1".

When using this port as a PPG1 and/or PPG2 output, set the output latch (P0DR), and then set the P0OUTCR. Next, set the PPG output initial value in the PPG1INI and/or PPG2INI, and set the PPG1OE and/or PPG2OE to "1" to enable PPG output. At this time, the output latch (P0DR) should be set to the same value as the PPG output initial value in the PPG1INI, PPG2INI.

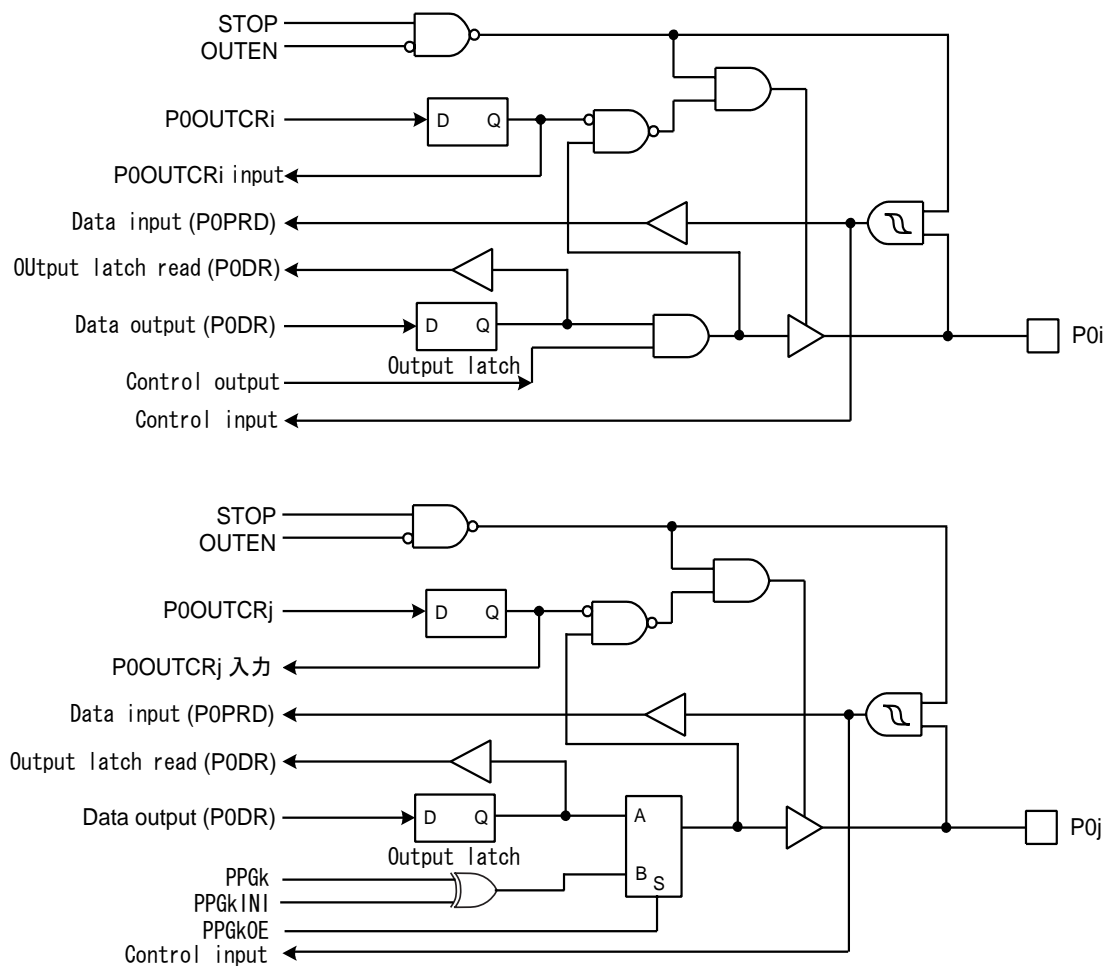
During reset, the P0DR is initialized to "1", and the P0OUTCR is initialized to "0".

P0 port output latch (P0DR) and P0 port terminal input (P0PRD) are located on their respective address.

When read the output latch data, the P0DR should be read. When read the terminal input data, the P0PRD register should be read.

Table 5-1 Register Programming for Multi-function Ports (P07 to P00)

Function	Programmed Value	
	P0DR	P0OUTCR
Port input, external interrupt input, serial interface input, timer counter input or UART input	"1"	"0"
Port "0" output	"0"	Programmingforeach applications
Port "1" output, serial interface output or UART output	"1"	
Timer counter 7 output	Set to the same value as PPG1INI and PPG2INI	



Note: i = 5 to 0, j = 7 and 6, k = 2 and 1

Figure 5-2 Port 0

5. I/O Ports

5.1 Port P0 (P07 to P00)

TMP86CH12MG

P0DR (0000H) R/W	7	6	5	4	3	2	1	0	(Initial value: 1111 1111)
	P07	P06	P05	P04	P03	P02	P01	P00	
	PPG2 INT2	PPG1 INT1	TC7	SO	SI	$\overline{\text{SCK}}$	RXD	TXD	

P0OUTCR (0004H)								(Initial value: 0000 0000)
--------------------	--	--	--	--	--	--	--	----------------------------

P0OUTCR	Port P0 output circuit control (Set for each bit individually)	0: Sink open-drain output 1: C-MOS output	R/W
---------	----------------------------------------------------------------	----------------------------------------------	-----

P0PRD (0008H) Read only	P07	P06	P05	P04	P03	P02	P01	P00
-------------------------------	-----	-----	-----	-----	-----	-----	-----	-----

5.2 Port P1 (P17 to P10)

Port P1 is an 5-bit input/output port which can be configured as an input or output in one-bit unit.

Port P1 is also used as a timer/counter input/output, an external interrupt input and a divider output.

Input/output mode is specified by the P1 control register (P1CR).

During reset, the P1CR is initialized to "0" and port P1 becomes an input mode. And the P1DR is initialized to "0".

When used as an input port, a timer/counter input and an external interrupt input, the corresponding bit of P1CR should be set to "0".

When used as an output port, the corresponding bit of P1CR should be set to "1".

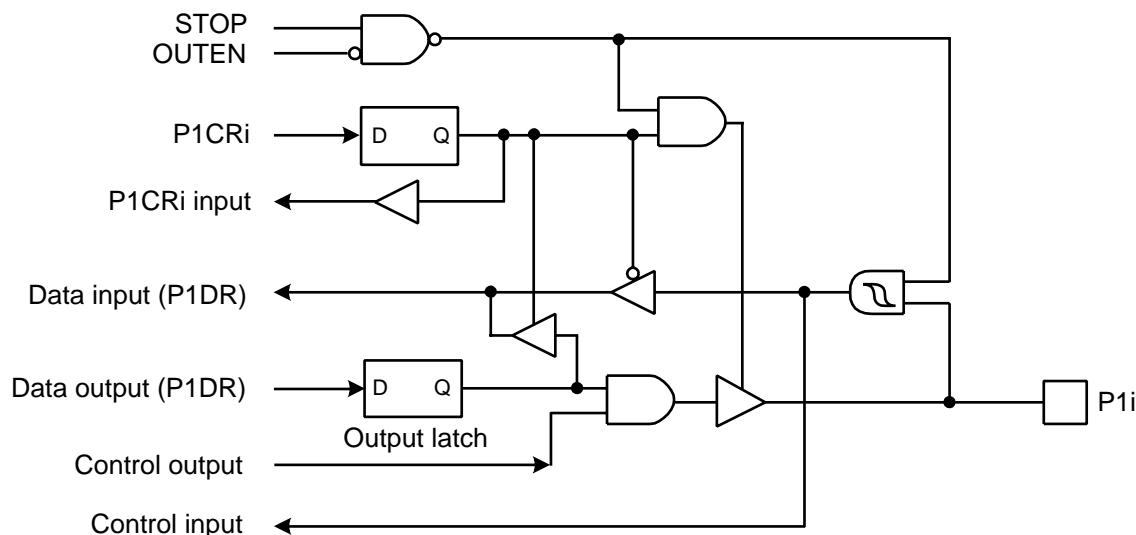
When used as a timer/counter output and a divider output, P1DR is set to "1" beforehand and the corresponding bit of P1CR should be set to "1".

When P1CR is "1", the content of the corresponding output latch is read by reading P1DR. If a read instruction is executed for the P1DR and P1CR, read data of bits 7 to 5 are unstable.

Table 5-2 Register Programming for Multi-function Ports

Function	Programmed Value	
	P1DR	P1CR
Port input, timer/counter input or external interrupt input	*	"0"
Port "0" output	"0"	"1"
Port "1" output, a timer output or a divider output	"1"	"1"

Note: Asterisk (*) indicates "1" or "0" either of which can be selected.



Note: $j = 7$ to 0

Figure 5-3 Port 1

Note: The port set to an input mode reads the terminal input data. Therefore, when the input and output modes are used together, the content of the output latch which is specified as input mode might be changed by executing a bit Manipulation instruction.

5. I/O Ports

5.2 Port P1 (P17 to P10)

TMP86CH12MG

	7	6	5	4	3	2	1	0	
P1DR (0001H) R/W				P14 TC1 INT4	P13 PPG INT3	P12 DVO	P11 TC4 PWM4 PDO4 PPG4	P10 TC3 PWM3 PDO3	(Initial value: ***0 0000)

	7	6	5	4	3	2	1	0	
P1CR (0005H)									(Initial value: ***0 0000)

P1CR	I/O control for port P1 (Specified for each bit)	0: Input mode 1: Output mode	R/W
------	--------------------------------------------------	---------------------------------	-----

5.3 Port P2 (P22 to P20)

Port P2 is a 3-bit input/output port.

It is also used as an external interrupt, a STOP mode release signal input, and low-frequency crystal oscillator connection pins. When used as an input port or a secondary function pins, respective output latch (P2DR) should be set to “1”.

During reset, the P2DR is initialized to “1”.

A low-frequency crystal oscillator (32.768 kHz) is connected to pins P21 (XTIN) and P22 (XTOUT) in the dual-clock mode. In the single-clock mode, pins P21 and P22 can be used as normal input/output ports.

It is recommended that pin P20 should be used as an external interrupt input, a STOP mode release signal input, or an input port. If it is used as an output port, the interrupt latch is set on the falling edge of the output pulse.

P2 port output latch (P2DR) and P2 port terminal input (P2PRD) are located on their respective address.

When read the output latch data, the P2DR should be read and when read the terminal input data, the P2PRD register should be read. If a read instruction is executed for port P2, read data of bits 7 to 3 are unstable.

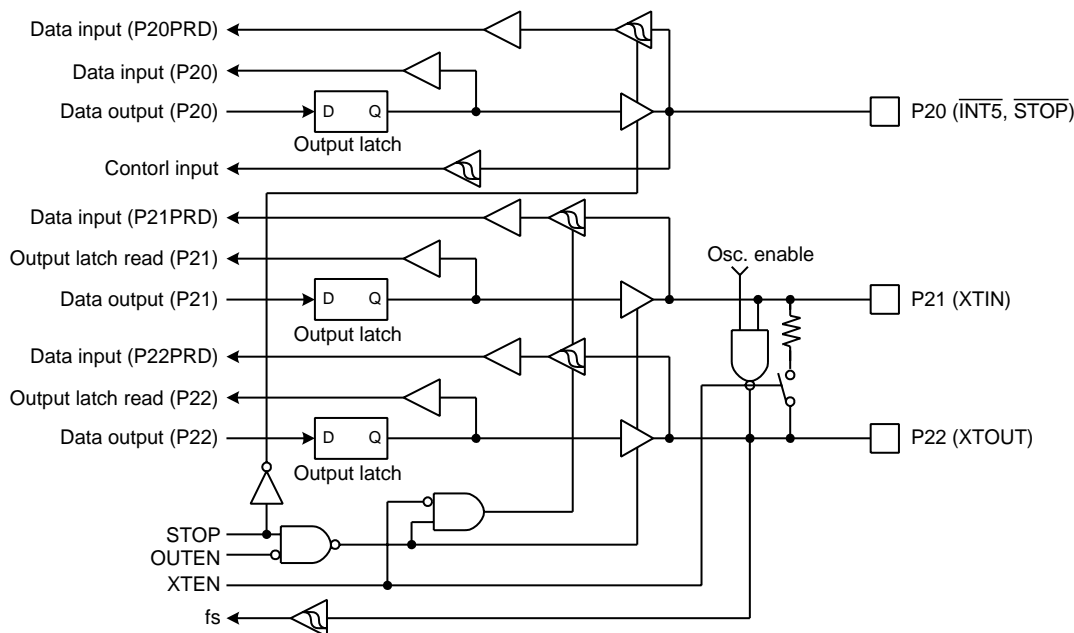


Figure 5-4 Port 2

	7	6	5	4	3	2	1	0	
P2DR (0002H) R/W						P22 XTOUT	P21 XTIN	P20 INT5 STOP	(Initial value: **** *111)
P2PRD (0009H) Read only						P22	P21	P20	

Note: Port P20 is used as $\overline{\text{STOP}}$ pin. Therefore, when stop mode is started, OUTEN does not affect to P20, and P20 becomes high-Z mode.

5.4 Port P3 (P37 to 30)

Port P3 is an 8-bit input/output port which can be configured as an input or output in one-bit unit.

Port P3 is also used as an analog input, key-on wakeup input, an external interrupt and TC7 emergency stop input.

Input/output mode is specified by the P3 control register (P3CR1) and P3 input control register (P3CR2).

During reset, the P3CR1 is initialized to "0" the P3CR2 is initialized to "1" and port P3 becomes an input mode. And the P3DR is initialized to "0".

When used as an output port, the corresponding bit of P3CR1 should be set to "1".

When used as an input port, key-on wakeup input, an external interrupt input and TC7 emergency stop input, the corresponding bit of P3CR1 should be set to "0" and then, the corresponding bit of P3CR2 should be set to "1".

When used as an analog input, the corresponding bit of P3CR1 should be set to "0" and then, the corresponding bit of P6CR2 should be set to "0".

When P3CR1 is "1", the content of the corresponding output latch is read by reading P3DR.

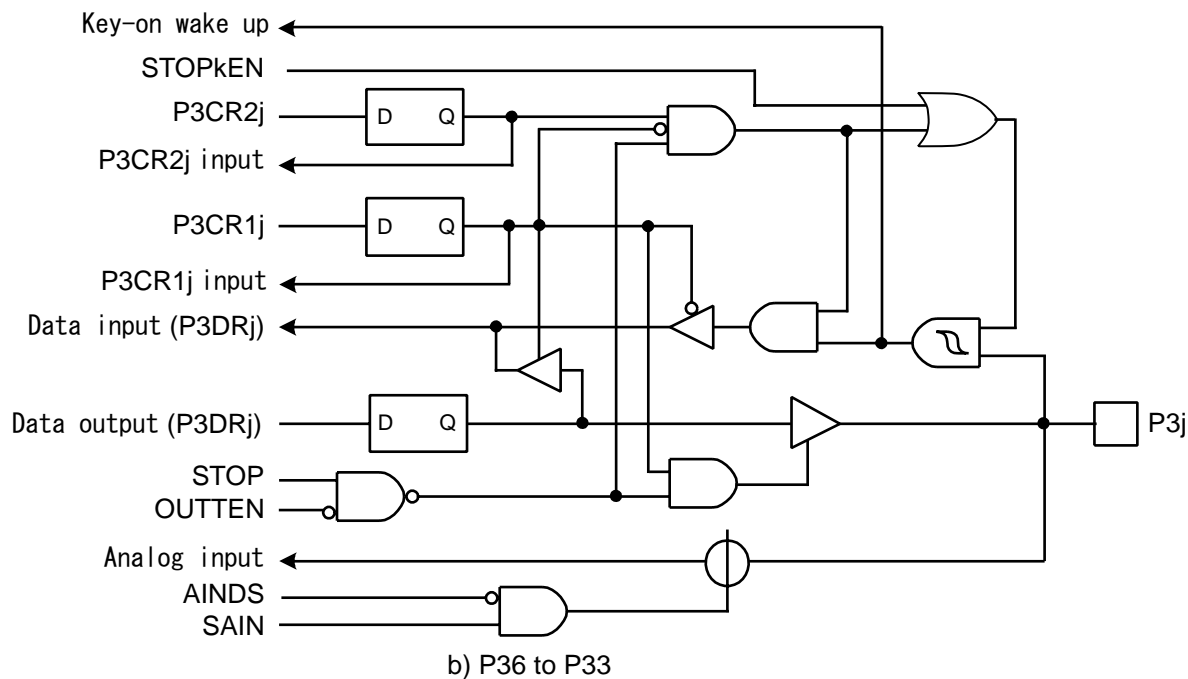
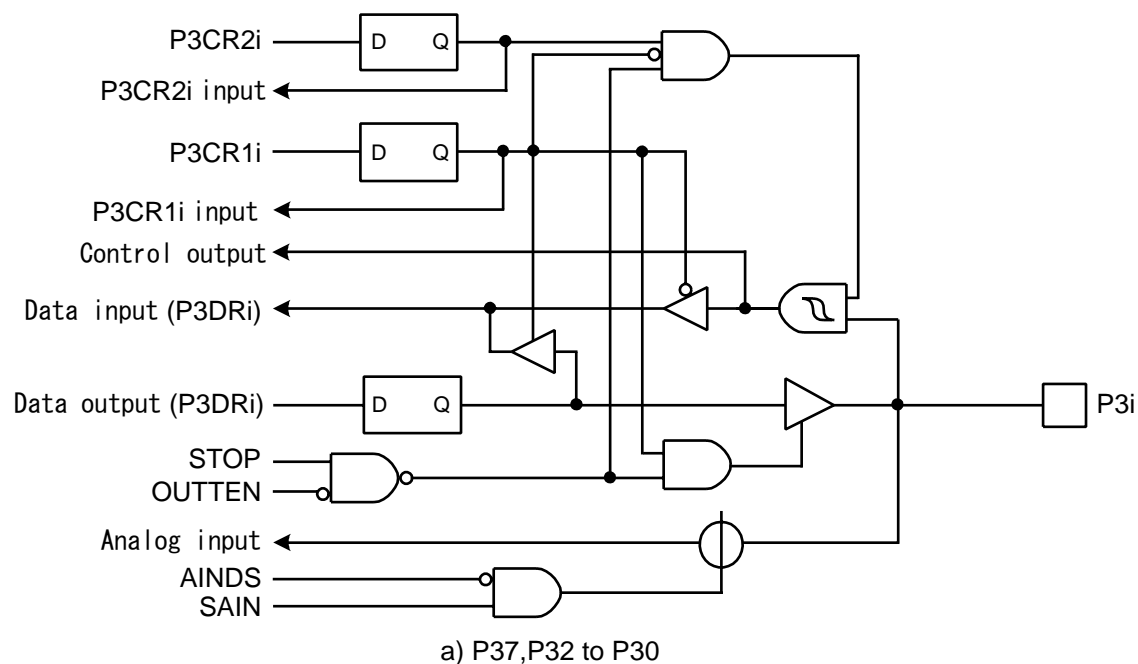
Table 5-3 Register Programming for Multi-function Ports

Function	Programmed Value		
	P3DR	P3CR1	P3CR2
Port input or key-on wakeup input or external input or TC7 emergency stop input	*	"0"	"1"
Analog input	*	"0"	"0"
Port "0" output	"0"	"1"	*
Port "1" output	"1"	"1"	*

Note: Asterisk (*) indicates "1" or "0" either of which can be selected.

Table 5-4 Values Read from P3DR and Register Programming

Conditions		Values Read from P3DR
P3CR1	P3CR2	
"0"	"0"	"0"
"0"	"1"	Terminal input data
"1"	"0"	Output latch contents
	"1"	



Note: i = 7 to 0

Figure 5-5 Port 3

P3DR (0003H) R/W	7	6	5	4	3	2	1	0	(Initial value: 0000 0000)
	P37 AIN7	P36 AIN6 STOP3	P35 AIN5 STOP2	P34 AIN4 STOP1	P33 AIN3 STOP0	P32 AIN2	P31 AIN1 INT0	P30 AIN0 EMG	

P3CR1 (0006H)	7	6	5	4	3	2	1	0	(Initial value: 0000 0000)

P3CR1	I/O control for port P3 (Specified for each bit)	0: Input mode 1: Output mode	R/W
-------	--------------------------------------------------	---------------------------------	-----

P3CR2 (0007H)	7	6	5	4	3	2	1	0	(Initial value: 1111 1111)

P3CR2	P3 port input control (Specified for each bit)	0: Analog input 1: Port input or key-on wakeup input or external interrupt input or TC7 emergency stop input	R/W
-------	------------------------------------------------	-----------------------------------------------------------------------------------------------------------------	-----

Note 1: The port placed in input mode reads the pin input state. Therefore, when the input and output modes are used together, the output latch contents for the port in input mode might be changed by executing a bit manipulation instruction.

Note 2: When used as an analog inport, be sure to clear the corresponding bit of P3CR2 to disable the port input.

Note 3: Do not set the output mode (P3CR1 = "1") for the pin used as an analog input pin.

Note 4: Pins not used for analog input can be used as I/O ports. During AD conversion, output instructions should not be executed to keep a precision. In addition, a variable signal should not be input to a port adjacent to the analog input during AD conversion.

6. Watchdog Timer (WDT)

The watchdog timer is a fail-safe system to detect rapidly the CPU malfunctions such as endless loops due to spurious noises or the deadlock conditions, and return the CPU to a system recovery routine.

The watchdog timer signal for detecting malfunctions can be programmed only once as “reset request” or “interrupt request”. Upon the reset release, this signal is initialized to “reset request”.

When the watchdog timer is not used to detect malfunctions, it can be used as the timer to provide a periodic interrupt.

Note: Care must be taken in system design since the watchdog timer functions are not be operated completely due to effect of disturbing noise.

6.1 Watchdog Timer Configuration

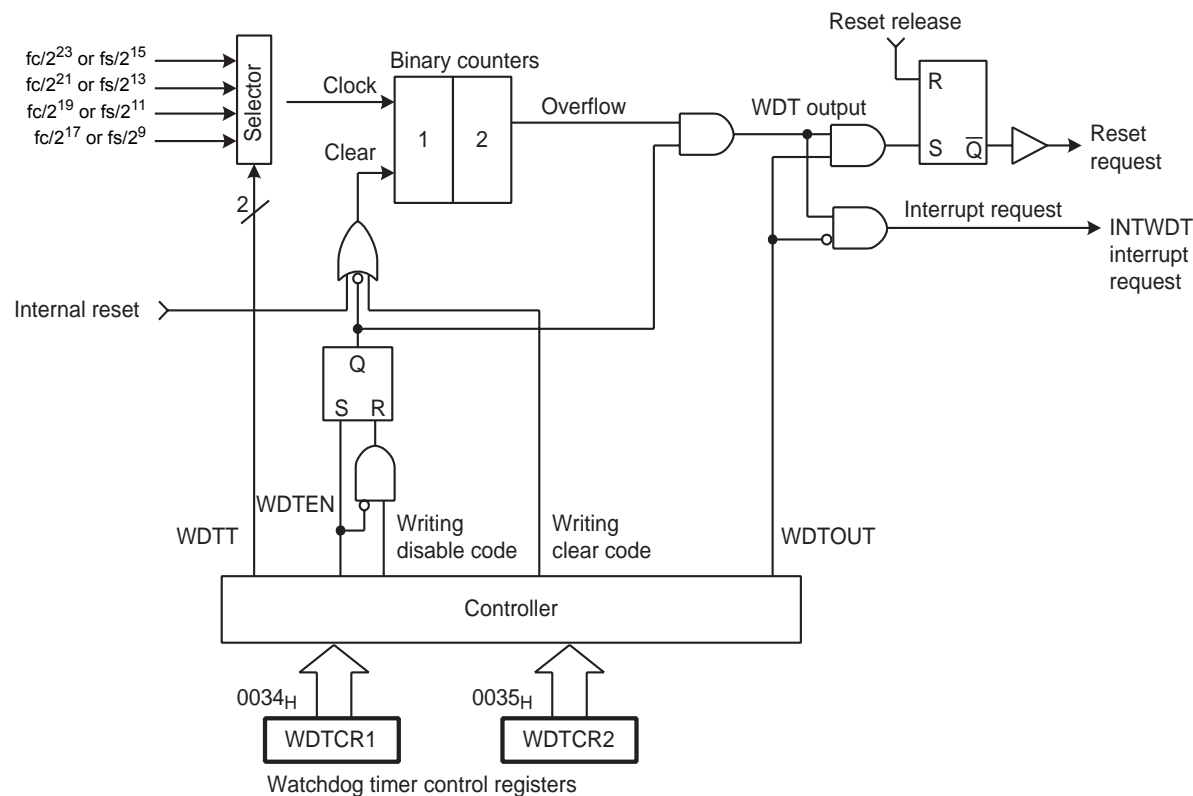


Figure 6-1 Watchdog Timer Configuration

6.2 Watchdog Timer Control

The watchdog timer is controlled by the watchdog timer control registers (WDTCR1 and WDTCR2). The watchdog timer is automatically enabled after the reset release.

6.2.1 Malfunction Detection Methods Using the Watchdog Timer

The CPU malfunction is detected, as shown below.

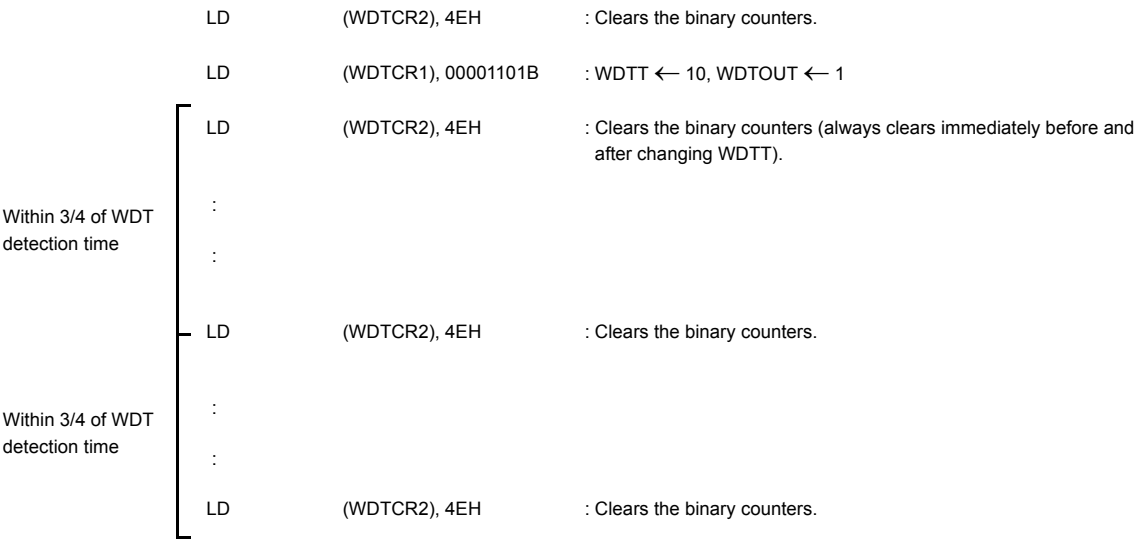
- 1. Set the detection time, select the output, and clear the binary counter.
- 2. Clear the binary counter repeatedly within the specified detection time.

If the CPU malfunctions such as endless loops or the deadlock conditions occur for some reason, the watchdog timer output is activated by the binary-counter overflow unless the binary counters are cleared. When WDTCR1<WDTOUT> is set to “1” at this time, the reset request is generated and then internal hardware is initialized. When WDTCR1<WDTOUT> is set to “0”, a watchdog timer interrupt (INTWDT) is generated.

The watchdog timer temporarily stops counting in the STOP mode including the warm-up or IDLE/SLEEP mode, and automatically restarts (continues counting) when the STOP/IDLE/SLEEP mode is inactivated.

Note: The watchdog timer consists of an internal divider and a two-stage binary counter. When the clear code 4EH is written, only the binary counter is cleared, but not the internal divider. The minimum binary-counter overflow time, that depends on the timing at which the clear code (4EH) is written to the WDTCR2 register, may be 3/4 of the time set in WDTCR1<WDTT>. Therefore, write the clear code using a cycle shorter than 3/4 of the time set to WDTCR1<WDTT>.

Example :Setting the watchdog timer detection time to $2^{21}/f_c$ [s], and resetting the CPU malfunction detection



Watchdog Timer Control Register 1

WDTCR1 (0034H)	7	6	5	4	3	2	1	0	
			(ATAS)	(ATOUT)	WDTEN	WDTT	WDTOUT		(Initial value: **11 1001)

WDTEN	Watchdog timer enable/disable	0: Disable (Writing the disable code to WDTCR2 is required.) 1: Enable				Write only
WDTT	Watchdog timer detection time [s]		NORMAL 1/2 mode		SLOW1/2 mode	Write only
			DV7CK = 0	DV7CK = 1		
		00	2 ²⁵ /fc	2 ¹⁷ /fs	2 ¹⁷ /fs	
		01	2 ²³ /fc	2 ¹⁵ /fs	2 ¹⁵ fs	
		10	2 ²¹ fc	2 ¹³ /fs	2 ¹³ fs	
		11	2 ¹⁹ /fc	2 ¹¹ /fs	2 ¹¹ /fs	
WDTOUT	Watchdog timer output select	0: Interrupt request 1: Reset request				Write only

Note 1: After clearing WDTOUT to "0", the program cannot set it to "1".

Note 2: fc: High-frequency clock [Hz], fs: Low-frequency clock [Hz], *: Don't care

Note 3: WDTCR1 is a write-only register and must not be used with any of read-modify-write instructions. If WDTCR1 is read, a don't care is read.

Note 4: To activate the STOP mode, disable the watchdog timer or clear the counter immediately before entering the STOP mode. After clearing the counter, clear the counter again immediately after the STOP mode is inactivated.

Note 5: To clear WDTCR1, set the register in accordance with the procedures shown in "1.2.3 Watchdog Timer Disable".

Watchdog Timer Control Register 2

WDTCR2 (0035H)	7	6	5	4	3	2	1	0	
									(Initial value: **** *)

WDTCR2	Write Watchdog timer control code	4EH: Clear the watchdog timer binary counter (Clear code) B1H: Disable the watchdog timer (Disable code) D2H: Enable assigning address trap area Others: Invalid	Write only
--------	--------------------------------------	---------------------------------------------------------------------------------------------------------------------------------------------------------------------------	------------

Note 1: The disable code is valid only when WDTCR1<WDTEN> = 0.

Note 2: *: Don't care

Note 3: The binary counter of the watchdog timer must not be cleared by the interrupt task.

Note 4: Write the clear code 4EH using a cycle shorter than 3/4 of the time set in WDTCR1<WDTT>.

6.2.2 Watchdog Timer Enable

Setting WDTCR1<WDTEN> to "1" enables the watchdog timer. Since WDTCR1<WDTEN> is initialized to "1" during reset, the watchdog timer is enabled automatically after the reset release.

6.2.3 Watchdog Timer Disable

To disable the watchdog timer, set the register in accordance with the following procedures. Setting the register in other procedures causes a malfunction of the microcontroller.

1. Set the interrupt master flag (IMF) to “0”.
2. Set WDTCR2 to the clear code (4EH).
3. Set WDTCR1<WDTEN> to “0”.
4. Set WDTCR2 to the disable code (B1H).

Note: While the watchdog timer is disabled, the binary counters of the watchdog timer are cleared.

Example :Disabling the watchdog timer

```

DI                                : IMF ← 0

LD      (WDTCR2), 04EH           : Clears the binary coutner

LDW     (WDTCR1), 0B101H         : WDTEN ← 0, WDTCR2 ← Disable code
    
```

Table 6-1 Watchdog Timer Detection Time (Example: fc = 16.0 MHz, fs = 32.768 kHz)

WDTT	Watchdog Timer Detection Time[s]		
	NORMAL 1/2 mode		SLOW mode
	DV7CK = 0	DV7CK = 1	
00	2.097	4	4
01	524.288 m	1	1
10	131.072 m	250 m	250 m
11	32.768 m	62.5 m	62.5 m

6.2.4 Watchdog Timer Interrupt (INTWDT)

When WDTCR1<WDTOUT> is cleared to “0”, a watchdog timer interrupt request (INTWDT) is generated by the binary-counter overflow.

A watchdog timer interrupt is the non-maskable interrupt which can be accepted regardless of the interrupt master flag (IMF).

When a watchdog timer interrupt is generated while the other interrupt including a watchdog timer interrupt is already accepted, the new watchdog timer interrupt is processed immediately and the previous interrupt is held pending. Therefore, if watchdog timer interrupts are generated continuously without execution of the RETN instruction, too many levels of nesting may cause a malfunction of the microcontroller.

To generate a watchdog timer interrupt, set the stack pointer before setting WDTCR1<WDTOUT>.

Example :Setting watchdog timer interrupt

```

LD      SP, 023FH                : Sets the stack pointer

LD      (WDTCR1), 00001000B      : WDTOUT ← 0
    
```

6.2.5 Watchdog Timer Reset

When a binary-counter overflow occurs while WDTCR1<WDTOUT> is set to “1”, a watchdog timer reset request is generated. When a watchdog timer reset request is generated, the internal hardware is reset. The reset time is maximum $24/f_c$ [s] ($1.5 \mu\text{s}$ @ $f_c = 16.0 \text{ MHz}$).

Note: When a watchdog timer reset is generated in the SLOW1 mode, the reset time is maximum $24/f_c$ (high-frequency clock) since the high-frequency clock oscillator is restarted. However, when crystals have inaccuracies upon start of the high-frequency clock oscillator, the reset time should be considered as an approximate value because it has slight errors.

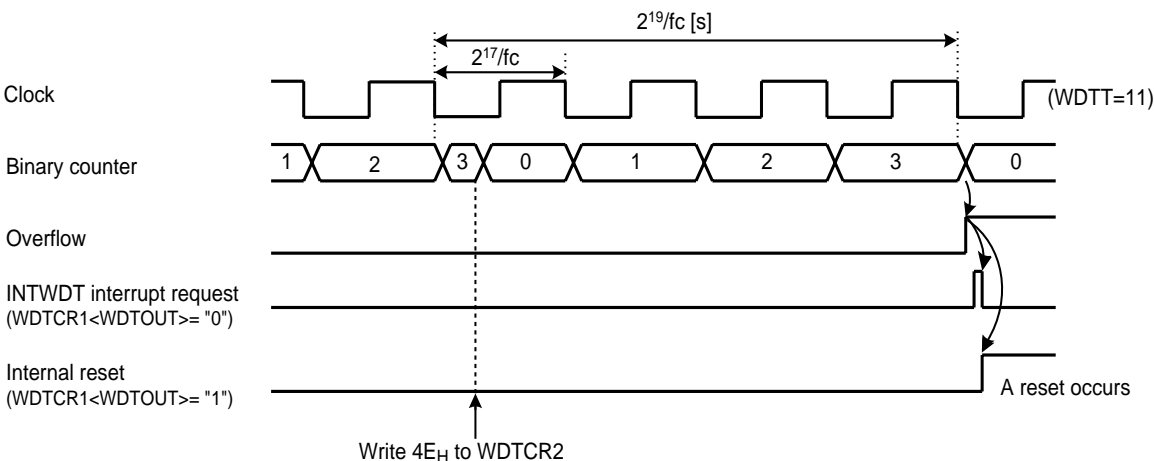


Figure 6-2 Watchdog Timer Interrupt

6.3 Address Trap

The Watchdog Timer Control Register 1 and 2 share the addresses with the control registers to generate address traps.

Watchdog Timer Control Register 1

WDTCR1 (0034H)	7	6	5	4	3	2	1	0	
			ATAS	ATOUT	(WDTEN)	(WDTT)	(WDTOUT)		(Initial value: **11 1001)
ATAS	Select address trap generation in the internal RAM area				0: Generate no address trap 1: Generate address traps (After setting ATAS to “1”, writing the control code D2H to WDTCR2 is required)				Write only
ATOUT	Select opertion at address trap				0: Interrupt request 1: Reset request				

Watchdog Timer Control Register 2

WDTCR2 (0035H)	7	6	5	4	3	2	1	0	
									(Initial value: **** *)
WDTCR2	Write Watchdog timer control code and address trap area control code				D2H: Enable address trap area selection (ATRAP control code) 4EH: Clear the watchdog timer binary counter (WDT clear code) B1H: Disable the watchdog timer (WDT disable code) Others: Invalid				Write only

6.3.1 Selection of Address Trap in Internal RAM (ATAS)

WDTCR1<ATAS> specifies whether or not to generate address traps in the internal RAM area. To execute an instruction in the internal RAM area, clear WDTCR1<ATAS> to “0”. To enable the WDTCR1<ATAS> setting, set WDTCR1<ATAS> and then write D2H to WDTCR2.

Executing an instruction in the SFR or DBR area generates an address trap unconditionally regardless of the setting in WDTCR1<ATAS>.

6.3.2 Selection of Operation at Address Trap (ATOUT)

When an address trap is generated, either the interrupt request or the reset request can be selected by WDTCR1<ATOUT>.

6.3.3 Address Trap Interrupt (INTATRAP)

While WDTCR1<ATOUT> is “0”, if the CPU should start looping for some cause such as noise and an attempt be made to fetch an instruction from the on-chip RAM (while WDTCR1<ATAS> is “1”), DBR or the SFR area, address trap interrupt (INTATRAP) will be generated.

An address trap interrupt is a non-maskable interrupt which can be accepted regardless of the interrupt master flag (IMF).

When an address trap interrupt is generated while the other interrupt including a watchdog timer interrupt is already accepted, the new address trap is processed immediately and the previous interrupt is held pending. Therefore, if address trap interrupts are generated continuously without execution of the RETN instruction, too many levels of nesting may cause a malfunction of the microcontroller.

To generate address trap interrupts, set the stack pointer beforehand.

6.3.4 Address Trap Reset

While WDTCR1<ATOUT> is “1”, if the CPU should start looping for some cause such as noise and an attempt be made to fetch an instruction from the on-chip RAM (while WDTCR1<ATAS> is “1”), DBR or the SFR area, address trap reset will be generated.

When an address trap reset request is generated, the internal hardware is reset. The reset time is maximum $24/f_c$ [s] ($1.5\ \mu\text{s}$ @ $f_c = 16.0\ \text{MHz}$).

Note: When an address trap reset is generated in the SLOW1 mode, the reset time is maximum $24/f_c$ (high-frequency clock) since the high-frequency clock oscillator is restarted. However, when crystals have inaccuracies upon start of the high-frequency clock oscillator, the reset time should be considered as an approximate value because it has slight errors.



7. Time Base Timer (TBT)

The time base timer generates time base for key scanning, dynamic displaying, etc. It also provides a time base timer interrupt (INTTBT).

7.1 Time Base Timer

7.1.1 Configuration

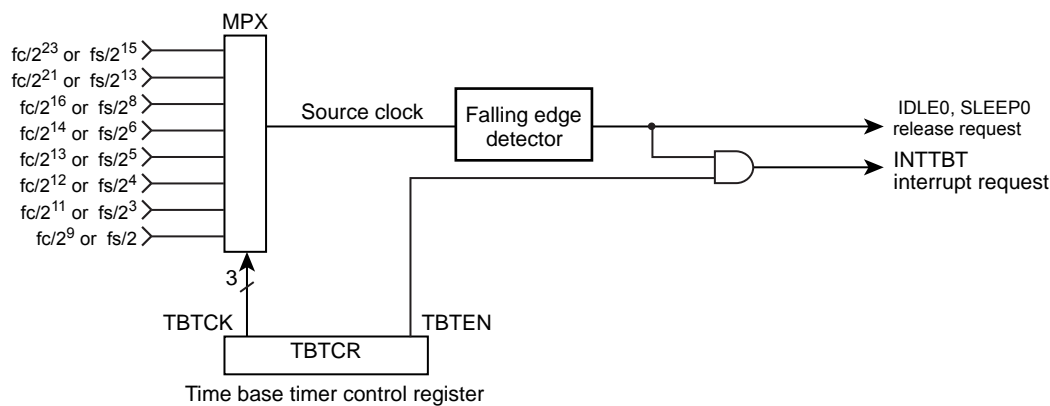


Figure 7-1 Time Base Timer configuration

7.1.2 Control

Time Base Timer is controlled by Time Base Timer control register (TBTCCR).

Time Base Timer Control Register

	7	6	5	4	3	2	1	0	
TBTCCR (0036H)	(DVOEN)	(DVOCK)	(DV7CK)	TBTEN			TBTCK		(Initial Value: 0000 0000)

TBTEN	Time Base Timer enable / disable	0: Disable 1: Enable				
TBTCK	Time Base Timer interrupt Frequency select : [Hz]		NORMAL 1/2, IDLE 1/2 Mode		SLOW 1/2 SLEEP 1/2 Mode	R/W
			DV7CK = 0	DV7CK = 1		
		000	$fc/2^{23}$	$fs/2^{15}$	$fs/2^{15}$	
		001	$fc/2^{21}$	$fs/2^{13}$	$fs/2^{13}$	
		010	$fc/2^{16}$	$fs/2^8$	—	
		011	$fc/2^{14}$	$fs/2^6$	—	
		100	$fc/2^{13}$	$fs/2^5$	—	
		101	$fc/2^{12}$	$fs/2^4$	—	
		110	$fc/2^{11}$	$fs/2^3$	—	
		111	$fc/2^9$	$fs/2$	—	

Note 1: fc; High-frequency clock [Hz], fs; Low-frequency clock [Hz], *; Don't care

Note 2: The interrupt frequency (TBTCK) must be selected with the time base timer disabled (TBTEN="0"). (The interrupt frequency must not be changed with the disable from the enable state.) Both frequency selection and enabling can be performed simultaneously.

Example :Set the time base timer frequency to $f_c/2^{16}$ [Hz] and enable an INTTBT interrupt.

```

LD      (TBTCK) , 00000010B      ; TBTCK ← 010
LD      (TBTCK) , 00001010B      ; TBTEN ← 1
DI                               ; IMF ← 0
SET     (EIRH) . 1

```

Table 7-1 Time Base Timer Interrupt Frequency (Example : $f_c = 16.0$ MHz, $f_s = 32.768$ kHz)

TBTCK	Time Base Timer Interrupt Frequency [Hz]		
	NORMAL1/2, IDLE1/2 Mode	NORMAL1/2, IDLE1/2 Mode	SLOW1/2, SLEEP1/2 Mode
	DV7CK = 0	DV7CK = 1	
000	1.91	1	1
001	7.63	4	4
010	244.14	128	–
011	976.56	512	–
100	1953.13	1024	–
101	3906.25	2048	–
110	7812.5	4096	–
111	31250	16384	–

7.1.3 Function

An INTTBT (Time Base Timer Interrupt) is generated on the first falling edge of source clock (The divider output of the timing generato which is selected by TBTCK.) after time base timer has been enabled.

The divider is not cleared by the program; therefore, only the first interrupt may be generated ahead of the set interrupt period (Figure 7-2).

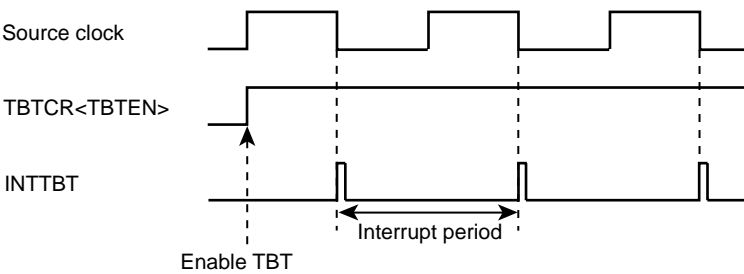


Figure 7-2 Time Base Timer Interrupt

7.2 Divider Output ($\overline{\text{DVO}}$)

Approximately 50% duty pulse can be output using the divider output circuit, which is useful for piezoelectric buzzer drive. Divider output is from $\overline{\text{DVO}}$ pin.

7.2.1 Configuration

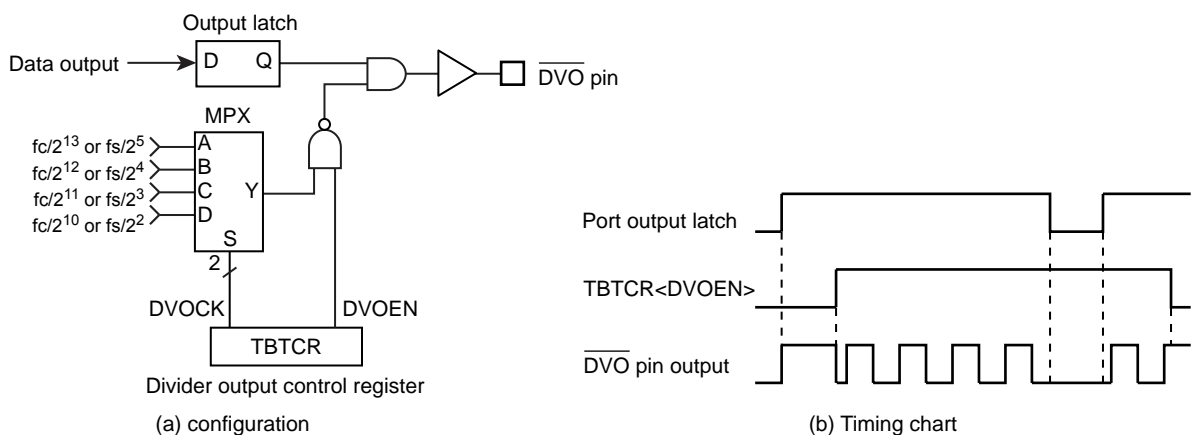


Figure 7-3 Divider Output

7.2.2 Control

The Divider Output is controlled by the Time Base Timer Control Register.

Time Base Timer Control Register

	7	6	5	4	3	2	1	0	
TBTCR (0036H)	DVOEN	DVOCK	(DV7CK)	(TBTEN)	(TBTCK)				(Initial value: 0000 0000)

DVOEN	Divider output enable / disable	0: Disable 1: Enable				R/W
DVOCK	Divider Output ($\overline{\text{DVO}}$) frequency selection: [Hz]		NORMAL1/2, IDLE1/2 Mode		SLOW1/2 SLEEP1/2 Mode	R/W
			DV7CK = 0	DV7CK = 1		
		00	$f_c/2^{13}$	$f_s/2^5$	$f_s/2^5$	
		01	$f_c/2^{12}$	$f_s/2^4$	$f_s/2^4$	
		10	$f_c/2^{11}$	$f_s/2^3$	$f_s/2^3$	
		11	$f_c/2^{10}$	$f_s/2^2$	$f_s/2^2$	

Note: Selection of divider output frequency (DVOCK) must be made while divider output is disabled (DVOEN="0"). Also, in other words, when changing the state of the divider output frequency from enabled (DVOEN="1") to disabled(DVOEN="0"), do not change the setting of the divider output frequency.

Example :1.95 kHz pulse output (fc = 16.0 MHz)

```
LD      (TBTCR) , 00000000B      ; DVOCK ← "00"  
LD      (TBTCR) , 10000000B      ; DVOEN ← "1"
```

Table 7-2 Divider Output Frequency (Example : fc = 16.0 MHz, fs = 32.768 kHz)

DVOCK	Divider Output Frequency [Hz]		
	NORMAL1/2, IDLE1/2 Mode		SLOW1/2, SLEEP1/2 Mode
	DV7CK = 0	DV7CK = 1	
00	1.953 k	1.024 k	1.024 k
01	3.906 k	2.048 k	2.048 k
10	7.813 k	4.096 k	4.096 k
11	15.625 k	8.192 k	8.192 k

8. Real-Time Clock

The TMP86CH12MG include a real time counter (RTC). A low-frequency clock can be used to provide a periodic interrupt (0.0625[s],0.125[s],0.25[s],0.50[s]) at a programmed interval, implement the clock function. The RTC can be used in the mode in which the low-frequency oscillator is active (except for the SLEEP0 mode).

8.1 Configuration

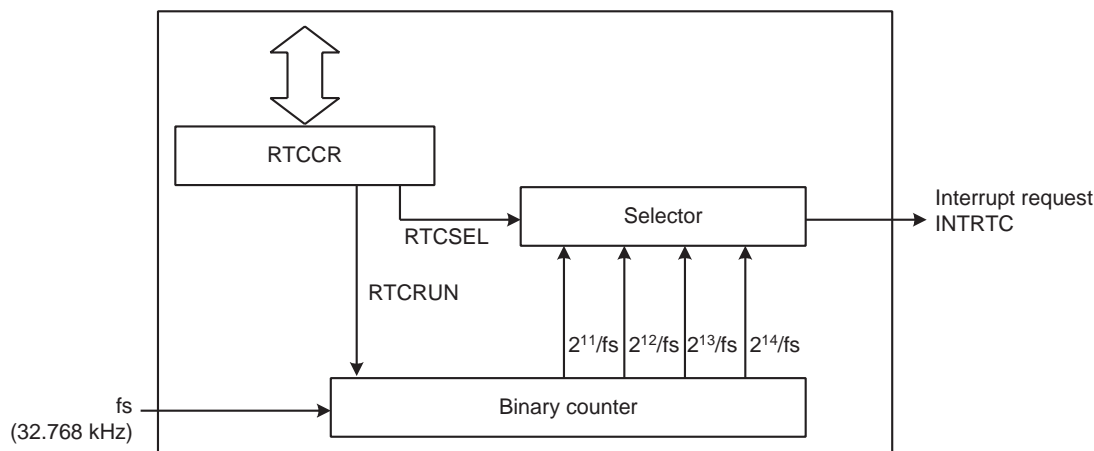


Figure 8-1 Configuration of the RTC

8.2 Control of the RTC

The RTC is controlled by the RTC control register (RTCCR).

RTC Control Register

RTCCR (001BH)	7	6	5	4	3	2	1	0	
						RTCSEL		RTCRUN	(Initial value: **** *000)

RTCSEL	Interrupt generation period (fs = 32.768 kHz)	00: 0.50 [s] 01: 0.25 [s] 10: 0.125 [s] 11: 0.0625 [s]	R/W
RTCRUN	RTC control	0: Stops and clears the binary counter. 1: Starts counting	

- Note 1: Program the RTCCR during low-frequency oscillation (when SYSCR2<XTEN> = "1"). For selecting an interrupt generation period, program the RTCSEL when the timer is inactive (RTCRUN = "0"). During the timer operation, do not change the RTCSEL programming at the same moment the timer stops.
- Note 2: The timer automatically stops, and this register is initialized (the timer's binary counter is also initialized) if one of the following operations is performed while the timer is active:
1. Stopping the low-frequency oscillation (with SYSCR2<XTEN> = "0")
 2. When the TMP86CH12MG are put in STOP or SLEEP0 mode
- Therefore, before activating the timer after releasing from STOP or SLEEP0 mode, reprogram the registers again.
- Note 3: If a read instruction for RTCCR is executed, undefined value is set to bits 7 to 3.
- Note 4: If break processing is performed on the debugger for the development tool during the timer operation, the timer stops counting (contents of the RTCCR isn't altered). When the break is cancelled, processing is restarted from the point at which it was suspended.

8.3 Function

The RTC counts up on the internal low-frequency clock. When RTCCR<RTCRUN> is set to “1”, the binary counter starts counting up. Each time the end of the period specified with RTCCR<RTCSEL> is detected, an INTRTC interrupt is generated, and the binary counter is cleared. The timer continues counting up even after the binary counter is cleared.

9.1 Configuration

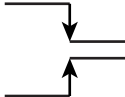
Figure 9-1 10-Bit Timer/Counter 7

9.2 Control

Timer/counter 7 is controlled by timer/counter control register 1 (TC7CR1), timer/counter control register 2 (TC7CR2), timer/counter control register 3 (TC7CR3), 10-bit dead time 1 setup register (TC7DRA), pulse width 1 setup register (TC7DRB), period setup register (TC7DRC), dead time 2 setup register (TC7DRD), pulse width 2 setup register (TC7DRE), and two capture value registers (TC7CAPA and TC7CAPB).

Timer/Counter 7 Control Register 1

TC7CR1 (0029H)	7	6	5	4	3	2	1	0	
	TRGAM	TRGSEL	PPG2INI	PPG1INI	NCRSEL		TC7CK		(Initial value: 0000 0000)

TC7CK	Select a source clock (Supplied to the up counter).		00: fc [Hz] 01: fc/2 [Hz] 10 fc/2 ² [Hz] 11: fc/2 ³ [Hz]	R/W
NCRSEL	Select the duration of noise elimination for TC7 input (after passing through the flip-flop).		00: Eliminate pulses shorter than 16/fc [s] as noise. 01: Eliminate pulses shorter than 8/fc [s] as noise. 10: Eliminate pulses shorter than 4/fc [s] as noise. 11: Do not eliminate noise. (Note)	
PPG1INI	Specify the initial value of PPG1 output.	Select positive or negative logic.	0: Low (Positive logic) 1: High (Negative logic)	
PPG2INI	Specify the initial value of PPG2 output.		0: Low (Positive logic) 1: High (Negative logic)	
TRGSEL	Select a trigger start edge.		0: Start on trigger falling edge. 1: Start on trigger rising edge. 	
TRGAM	Trigger edge acceptance mode		0: Always accept trigger edges. 1: Do not accept trigger edges during active output.	

Note: Due to the circuit configuration, a pulse shorter than $1/f_c$ may be eliminated as noise or accepted as a trigger.

Timer/Counter 7 Control Register 2

TC7CR2 (002AH)	7	6	5	4	3	2	1	0	
	EMGR	EMGIE	PPG2OE	PPG1OE	CSTC		TC7OUT		(Initial value: 0000 0000)

TC7OUT	Select an output waveform mode.	00: PPG1/PPG2 independent output 01: – 10: Output with variable duty ratio 11: Output with 50% duty ratio	R/W
CSTC	Select a count start mode.	00: Command start and capture mode 01: Command start and trigger start mode. 10: Trigger start mode 11: –	
PPG1OE	Enable/disable PPG1 output.	0: Disable 1: Enable	
PPG2OE	Enable/disable PPG2 output.	0: Disable 1: Enable	
EMGIE	Enable/disable input on the EMG pin.	0: Disable input. 1: Enable input.	
EMGR	Cancel the emergency output stop state.	0: – 1: Cancel the emergency output stop state. (Upon canceling the state, this bit is automatically cleared to 0.)	

Timer/Counter 7 Control Register 3

TC7CR3 (002BH)	7	6	5	4	3	2	1	0	
			EMGF	CNTBF	CSIDIS	STM		TC7ST	(Initial value: **00 0000)

- Note 1: The TC7CR1 and TC7CR2 registers should not be rewritten after a timer start (when TC7ST, bit0 of the TC7CR3, is set to 1).
- Note 2: Before attempting to modify the TC7CR1 or TC7CR2, clear TC7ST and then check that CNTBF = 0 to determine that the timer is stopped.
- Note 3: The TC7ST bit only causes the timer to start or stop; it does not indicate the current operating state of the counter. Its value does not change automatically when counting starts or stops
- Note 4: In command start and capture mode or command start and trigger start mode, writing 1 to TC7ST causes the timer to restart immediately. It means that rewriting any bit other than TC7ST in the TC7CR3 after a command start causes the rewriting of TC7ST, resulting in the timer being restarted (PPG output is started from the initial state). When TC7ST is set to 1, rewriting the TC7CR3 (Using a bit manipulation or LD instruction) clears the counter and restarts the timer.
- Note 5: TC7CR2<EMGR> is always read as 0 even after 1 is written.
- Note 6: Data registers are not updated by merely modifying the output mode with TC7CR2<TC7OUT>. After modifying the output mode, reconfigure data registers TC7DRA to TC7DRE. Ensure that the data registers are written in an appropriate order because they are not enabled until the upper byte of the TC7DRC is written.

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TC7DRA							TC7DRAH (0009H)		TC7DRAL (0008H)							
(0009H, 0008H) Read/Write (Initial value: **** **00 0000 0000)																

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
TC7DRB							TC7DRBH (000BH)		TC7DRBL (000AH)								
(000BH, 000AH) Read/Write (Initial value: **** **00 0000 0000)																	

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TC7DRC							TC7DRCH (000DH)		TC7DRCL (000CH)							
(000DH, 000CH) Read/Write (Initial value: **** *00 0000 0000)																

Dead Time 2 Setup Register

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TC7DRD							TC7DRDH (0FB1H)		TC7DRDL (0FB0H)							
(0FB1H, 0FB0H) Read/Write (Initial value: **** **00 0000 0000)																

Pulse Width 2 Setup Register

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TC7DRE							TC7DREH (0FB3H)		TC7DREL (0FB2H)							
(0FB3H, 0FB2H) Read/Write (Initial value: **** **00 0000 0000)																

- Note 1: Data registers TC7DRA to TC7DRE have double-stage configuration, consisting of a data register that stores data written by an instruction and a compare register to be compared with the counter.
- Note 2: When writing data to data registers TC7DRA to TC7DRE, first write the lower byte and then the upper byte.
- Note 3: Unused bits (Bits 10 to 15) in the upper bytes of data registers TC7DRA to TC7DRE are not assigned specific register functions. These bits are always read as 0 even when a 1 is written.
- Note 4: Values read from data registers TC7DRA to TC7DRE may differ from the actual PPG output waveforms due to their double-stage configuration.
- Note 5: Data registers are not updated by merely modifying the output mode with TC7CR2<TC7OUT>. After modifying the output mode, reconfigure data registers TC7DRA to TC7DRE. Ensure that the data registers are written in an appropriate order because they are not enabled until the upper byte of the TC7DRC is written.

Rising-edge Capture Value Register

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TC7CAPA							TC7CAPAH (0FB5H)		TC7CAPAL (0FB4H)							
(0FB5H, 0FB4H) Read only (Initial value: 0000 00** **** ***)																

Falling-edge Capture Value Register

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TC7CAPB							TC7CAPBH (0FB7H)		TC7CAPBL (0FB6H)							
(0FB7H, 0FB6H) Read only (Initial value: 0000 00** **** ***)																

- Note 1: Capture registers (TC7CAPA and TC7CAPB) must be read in the following order: Lower byte of the TC7CAPA, upper byte of the TC7CAPA, lower byte of the TC7CAPB, upper byte of the TC7CAPB.
- Note 2: The next captured data is not updated by reading the TC7CAPA only. The TC7CAPB must also be read.
- Note 3: It is possible to read the TC7CAPB only. Read the lower byte first.
- Note 4: If a capture edge is not detected within a period, the previous capture value is maintained in the next period.
- Note 5: If more than one capture edge is detected within a period, the capture value for the edge detected last is valid in the next period.
- Note 6: Bits 10 to 15 of the TC7CAPA and TC7CAPB are always read as 0.

9.3 Configuring Control and Data Registers

Configure control and data registers in the following order:

1. Configure mode settings: TC7CR1, TC7CR2
2. Configure data registers (Dead time, pulse width):
TC7DRA, TC7DRB, TC7DRD, TC7DRE (only those required for selected mode)
3. Configure data registers (Period): TC7DRC
4. Configure timer start/stop: TC7CR3
 - Data registers have double-stage configuration, consisting of a data register that stores data written by an instruction and a compare register to be compared with the counter.
 - Data stored in a data register is processed according to the output mode specified in the TC7OUT, transferred to the compare register, and then used for comparison with the up counter.
 - Data registers required for the specified output mode are used for data register processing and transfer to the compare register. Ensure that the output mode is specified in the TC7OUT (Bits 0 and 1 of the TC7CR2) before configuring data registers.
 - Writing data to the upper byte of the TC7DRC causes a data transfer request to be issued for data in data registers TC7DRA to TC7DRE. If a counter match or clear occurs while that request is valid, the data is transferred to the compare register and becomes valid for comparison.
 - If a data register is written more than once within a period, the data in the data register that was set when the upper byte of the TC7DRC was written is valid as data for the next period. The data in the data register written last in the first period will be valid for the period that follows the next period.

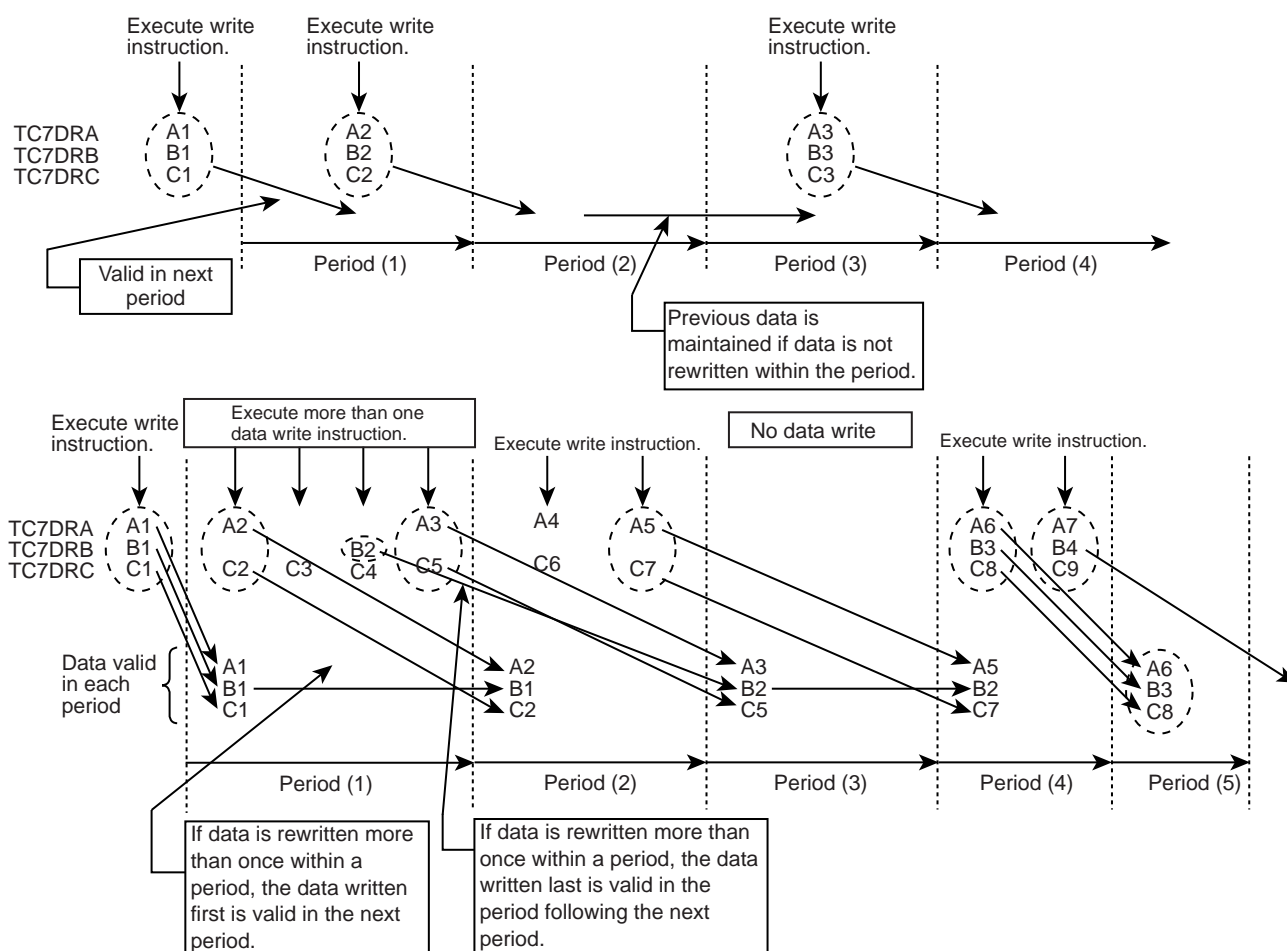


Figure 9-2 Example Configuration of Control/data Registers (1)

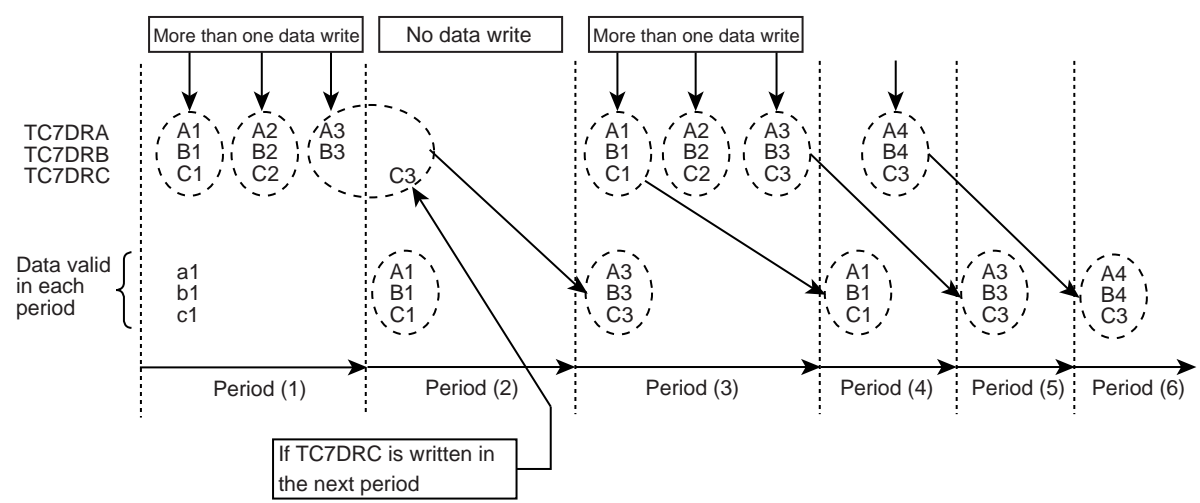


Figure 9-3 Example Configuration of Control/data Registers (2)

9.4 Features

9.4.1 Programmable pulse generator output (PPG output)

The PPG1 and PPG2 pins provide PPG outputs. The output waveform mode for PPG outputs is specified with TC7CR2<TC7OUT> and their waveforms are controlled by comparing the contents of the 10-bit up counter with the data set in data registers (TC7DRA to TC7DRE). Three output waveform modes are available: 50% duty mode, variable duty mode, and PPG1/PPG2 independent mode.

9.4.1.1 50% duty mode

(1) Description

With a period specified in the TC7DRC, the PPG1 and PPG2 pins provide waveforms having a pulse width (Active duration) that equals a half the period.
The PPG1 output is active at the beginning of a period and becomes inactive at half the period. The PPG2 output is inactive at the beginning of a period, becomes active at half the period, and remains active until the end of the period.
If a dead time is specified in the TC7DRA, the pulse width (Active duration) is shortened by the dead time.

(2) Register settings

TC7OUT = “11”, TC7DRA = “dead time”, TC7DRC = “period”

(3) Valid range for data register values

(a) Period:

002H ≤ TC7DRC ≤ 400H (Writing 400H to TC7DRC results in 000H being read from it.)

When the value set in the TC7DRC is an odd number, the PPG2 pulse width is one count longer than the PPG1 pulse width.

(b) Dead time TC7DRA:

$$000H \leq TC7DRA < TC7DRC/2$$

To specify no dead time, set the TC7DRA to 000H.

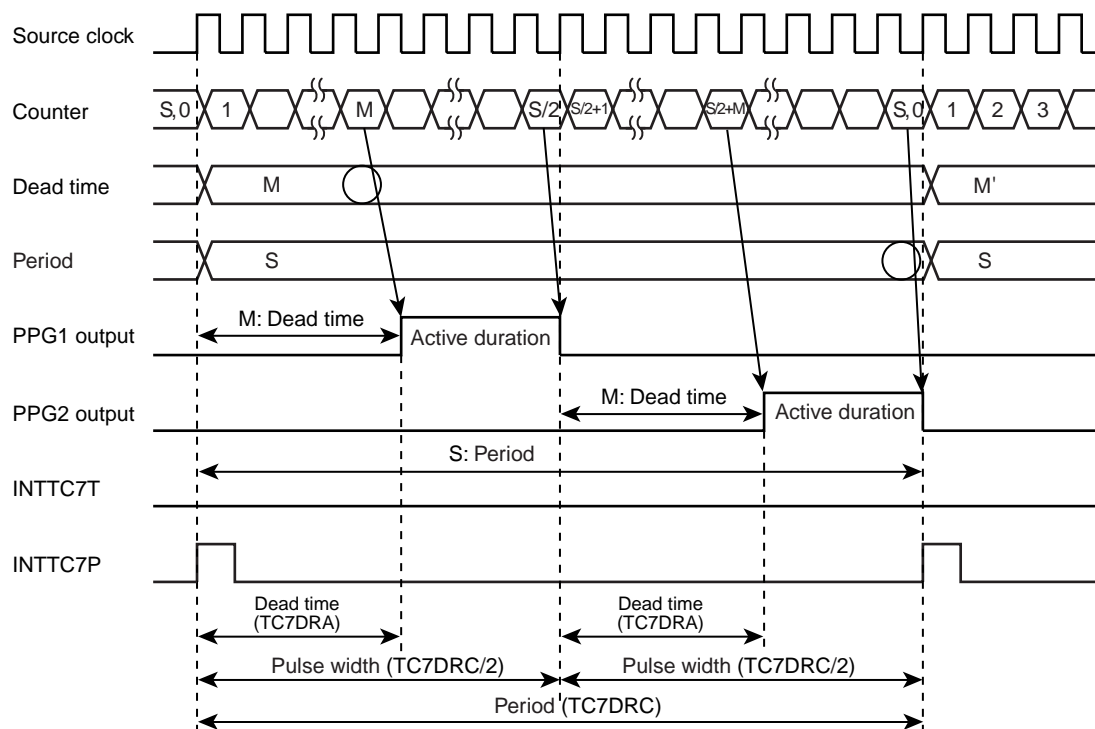


Figure 9-4 Example operation in 50% duty mode:
Command and capture start, positive logic, continuous output

9.4.1.2 Variable duty mode

(1) Description

With a period specified in the TC7DRC and a pulse width in the TC7DRB, the PPG1 pin provides a waveform having the specified pulse width while the PPG2 pin provides a waveform having a pulse width that equals (TC7DRC – TC7DRB).

The PPG1 output is active at the beginning of a period, remains active during the pulse width specified in the TC7DRB, after which it is inactive until the end of the period. The PPG2 output is inactive at the beginning of a period, remains inactive during the pulse width specified in the TC7DRB, after which it is active until the end of the period, that is, during the pulse width of (TC7DRC – TC7DRB).

If a dead time is specified in the TC7DRA, the pulse width (Active duration) is shortened by the dead time.

(2) Register settings

TC7OUT = "10", TC7DRA = "dead time", TC7DRB = "pulse width", TC7DRC = "period"

(3) Valid range for data register values

(a) Period:

$$002H \leq TC7DRB + TC7DRA < TC7DRC \leq 400H$$

(Writing 400H to TC7DRC results in 000H being read from it.)

(b) Pulse width:

$$001H \leq TC7DRB < TC7DRC$$

(c) Dead time:

$$000H \leq TC7DRA < TC7DRB, 000H \leq TC7DRA < (TC7DRC - TC7DRB)$$

(To specify no dead time, set the TC7DRA to 000H.)

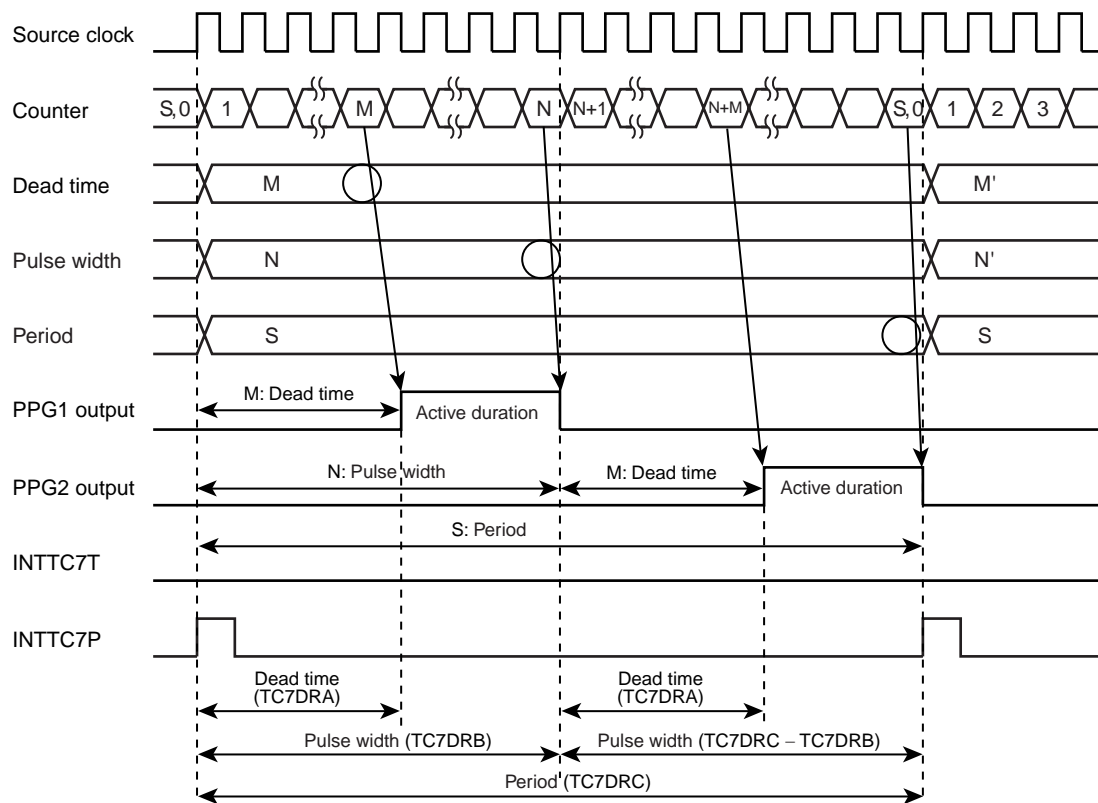


Figure 9-5 Example Operation in Variable Duty Mode:
Command and Capture Start, Positive Logic, Continuous Output

9.4.1.3 PPG1/PPG2 independent mode

(1) Description

For the PPG1 output, specify the dead time in the TC7DRA and pulse width in the TC7DRB. For the PPG2 output, specify the dead time in the TC7DRD and pulse width in the TC7DRE. With a common period specified in the TC7DRC, the PPG1 and PPG2 pins provide waveforms having the specified pulse widths.

The PPG1 output is active at the beginning of a period, remains active during the pulse width specified in the TC7DRB, after which it is inactive until the end of the period.

The PPG2 output is active at the beginning of a period, remains active during the pulse width specified in the TC7DRE, after which it is inactive until the end of the period.

If a dead time is specified in the TC7DRA for the PPG1 output or in the TC7DRD for the PPG2 output, the pulse width (Active duration) is shortened by the dead time.

(2) Register settings

TC7OUT = "00", TC7DRC = "period"

TC7DRA = "PPG1 dead time", TC7DRB = "PPG1 pulse width"

TC7DRD = "PPG2 dead time", TC7DRE = "PPG2 pulse width"

(3) Valid range for data register values

(a) Period:

$002H \leq TC7DRC \leq 400H$

(Writing 400H to TC7DRC results in 000H being read from it.)

(b) Pulse width:

$001H \leq TC7DRB \leq 400H$

(Writing 400H to TC7DRB results in 000H being read from it.)

$001H \leq TC7DRE \leq 400H$

(Writing 400H to TC7DRE results in 000H being read from it.)

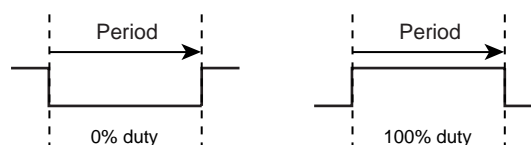
(c) Dead time:

$000H \leq TC7DRA \leq 3FFH$, where $TC7DRA < TC7DRB \leq TC7DRC$

$000H \leq TC7DRD \leq 3FFH$, where $TC7DRD < TC7DRE \leq TC7DRC$

(To specify no dead time, write 000H.)

- Settings for a duty ratio of 0%
 $002H \leq TC7DRC \leq TC7DRA \leq 3FFH$ (PPG1 output)
 $002H \leq TC7DRC \leq TC7DRD \leq 3FFH$ (PPG2 output)
- Settings for a duty ratio greater than 0%, up to 100%
 $000H \leq TC7DRA < TC7DRB \leq TC7DRC \leq 400H$ (PPG1 output)
 $000H \leq TC7DRD < TC7DRE \leq TC7DRC \leq 400H$ (PPG2 output)



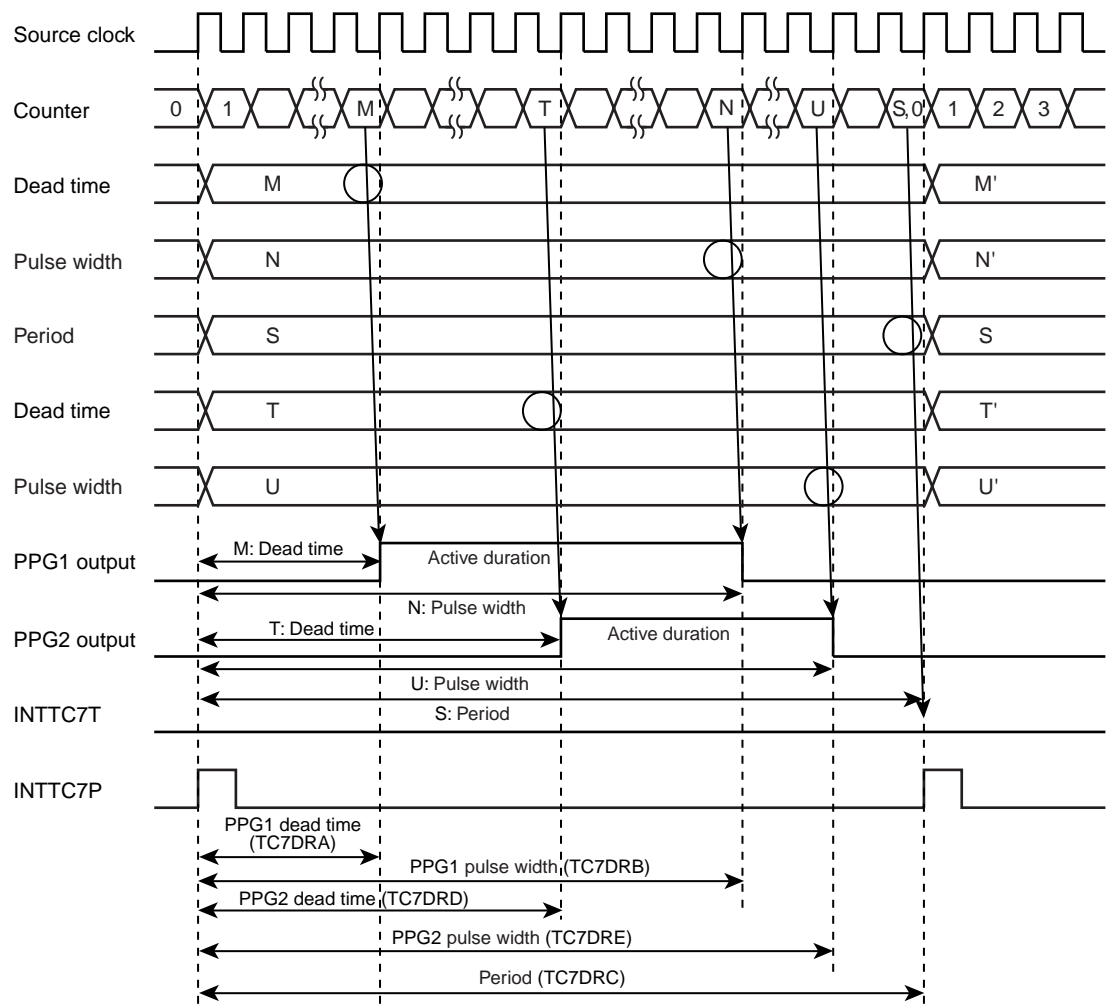


Figure 9-6 Example Operation in PPG1/PPG2 Independent Mode:
Command and Capture Start, Positive Logic, Continuous Output

9.4.2 Starting a count

A count can be started by using a command or TC7 pin input.

9.4.2.1 Command start and capture mode

(1) Description

Writing a 1 to TC7ST causes the current count to be cleared and the counter to start counting. Once the count has reached a specified period, the counter is cleared. The counter subsequently restarts counting if STM specifies continuous mode; it stops counting if STM specifies one-time mode.

Writing a 1 to TC7ST before the count reaches a period causes the counter to be cleared, after which it operates as specified with STM.

The count values at the rising and falling edges on the TC7 pin can be stored in capture registers (Details for the capture are given in a separate section).

(2) Register settings

CSTC = "00": Command start and capture mode

STM: Continuous/one-time output

TC7ST = "1": Starts counting

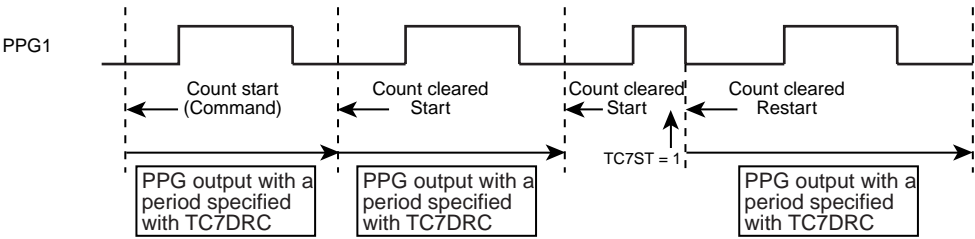


Figure 9-7 Example Operation in Command Start and Capture Mode

9.4.2.2 Command start and trigger start mode

(1) Description

Writing a 1 to TC7ST causes the current count to be cleared and the counter to start counting. The operation is the same as that in command start and capture mode if there is no trigger input on the TC7 pin. If an edge specified with the start edge selection field (TRGSEL) appears on the TC7 pin, however, the timer starts counting. The counter is cleared and stopped while the TC7 pin is driven to the specified clear/stop level. If the TC7 pin is at the clear/stop level when a count start command is issued (1 is written to TC7ST), counting does not start (INTTC7P does not occur) until a trigger start edge appears, causing INTTC7T to occur (A trigger input takes precedence over a command start).

Note: For more information on the acceptance of a trigger, see 9.4.2.5 "Trigger start/stop acceptance mode".

(2) Register settings

CSTC = "01": Command start and trigger start mode

STM: Continuous/one-time output

TC7ST = "1": Starts counting

TRGSEL: Trigger selection

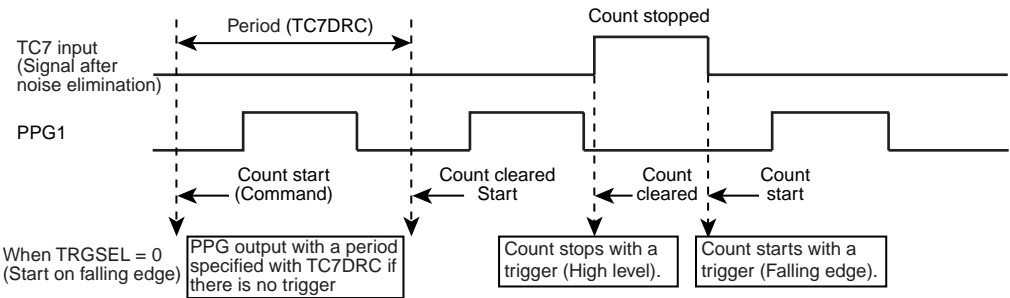


Figure 9-8 Example Operation in Command Start and Trigger Start Mode

9.4.2.3 Trigger start mode

(1) Description

If an edge specified with the start edge selection field (TRGSEL) appears on the TC7 pin, the timer starts counting. The counter is cleared and stopped while the TC7 pin is driven to the specified clear/stop level.

In trigger start mode, writing a 1 to TC7ST is ignored and does not initialize the PPG output.

Note: For more information on the acceptance of a trigger, see 9.4.2.5 “Trigger start/stop acceptance mode”.

(2) Register settings

CSTC = “10”: Trigger start mode

STM: Continuous/one-time output

TC7ST = “1”: Starts waiting for a trigger on the TC7 pin

TRGSEL: Trigger selection

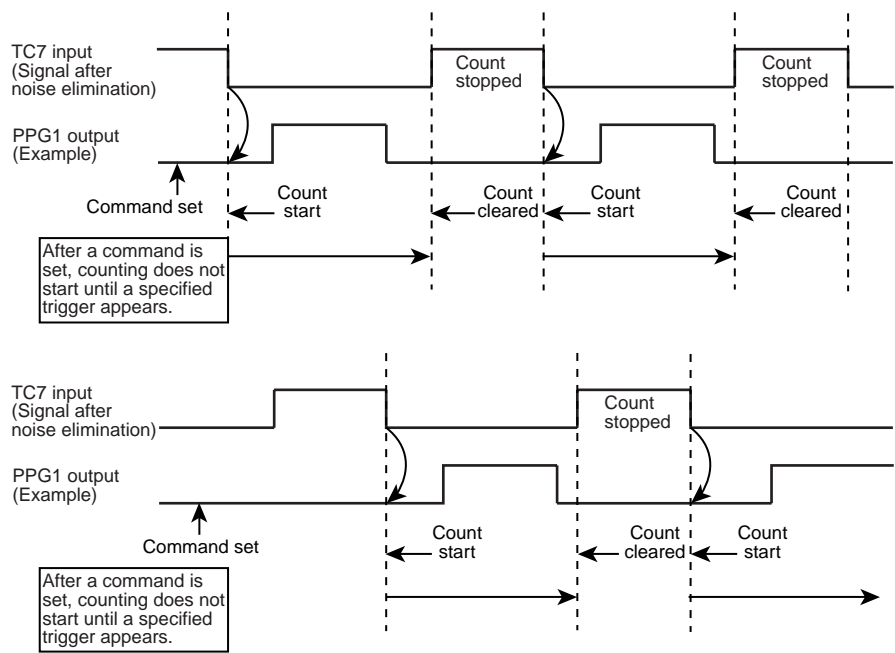


Figure 9-9 Example Operation in Trigger Start Mode

9.4.2.4 Trigger capture mode (CSTC = 00)

(1) Description

When counting starts in command start and capture mode, the count values at the rising and falling edges of the TC7 pin input are captured and stored in capture registers TC7CAPA and TC7CAPB, respectively.

The captured data is first stored in the capture buffer. At the end of the period, the data is transferred from the capture buffer to the capture register. If a trigger input does not appear within a period, the data captured in the previous period remains in the capture buffer and is transferred to the capture register at the end of the period. If more than one trigger edge is detected within a period, the data captured last is written to the capture register.

Captured data must be read in the following order: Lower byte of capture register A (TC7CAPAL), upper byte of capture register A (TC7CAPAH), lower byte of capture register B (TC7CAPBL), and upper byte of capture register B (TC7CAPBH). Note that reading only the rising-edge captured data (TC7CAPA) does not update the next captured data. The falling-edge captured data (TC7CAPB) must also be read.

An attempt to read a captured value from a register other than the upper byte of the TC7CAPB causes the capture registers to enter protected state, in which captured data cannot be updated. Reading a value from the upper byte of the TC7CAPB cancels that state, re-enabling the updating of captured data (The TC7CAPA and TC7CAPB are read as a single set of operation).

Note that the protected state may be still effective immediately after the counter starts. Ensure that a dummy read of capture registers is performed in the first period to cancel the protected state.

The capture feature of the TC7 assumes that a capture trigger (Rising or falling edge) appears within a period. Captured data is updated (An edge is detected) only when the timer is operating (TC7ST = 1). If a timer stop command (TC7ST = 0) is written within a period, captured data will be undefined. Captured data is not updated after a one-time stop command is written. In one-time stop mode, no trigger is accepted after a STOP command is given.

(2) Register settings

CSTC = "00": Command start and capture mode

STM: Continuous/one-time output

TC7ST = "1": Starts counting

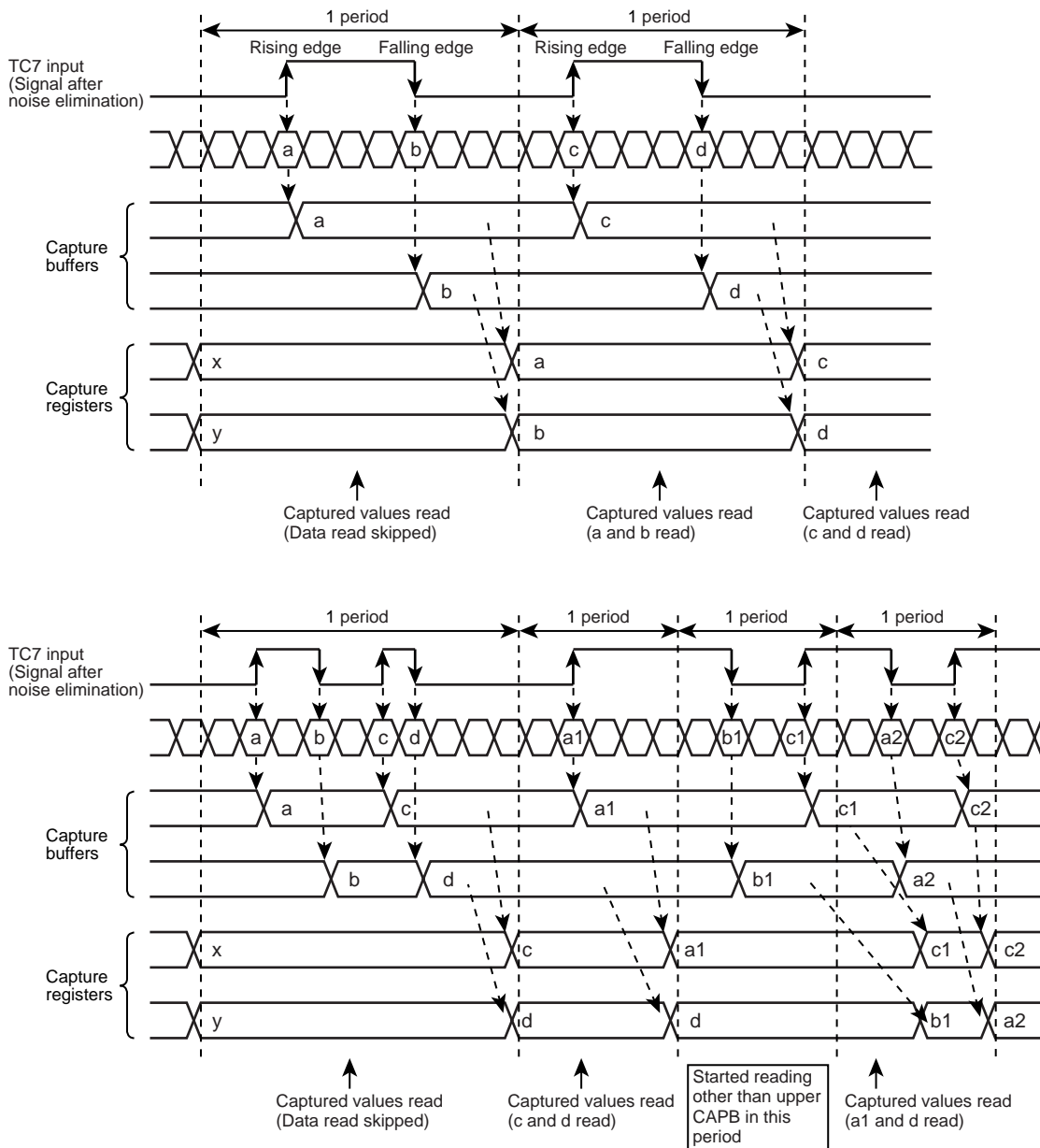


Figure 9-10 Example Operation in Trigger Capture Mode

9.4.2.5 Trigger start/stop acceptance mode

(1) Selecting an input signal logic for the TC7 pin (Trigger input)

The logic for an input trigger signal on the TC7 pin can be specified using TC7CR1<TRGSEL> .

- TRGSEL = 0:
Counting starts on the falling edge. The counter is cleared and stopped while the TC7 pin is high.
- TRGSEL = 1:
Counting starts on the rising edge. The counter is cleared and stopped while the TC7 pin is low.

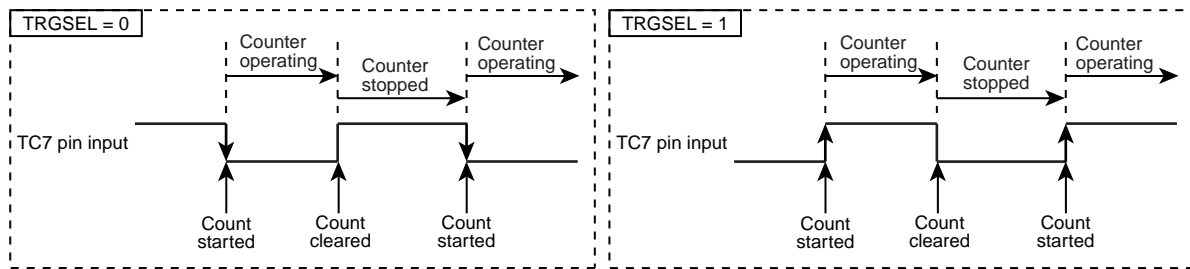
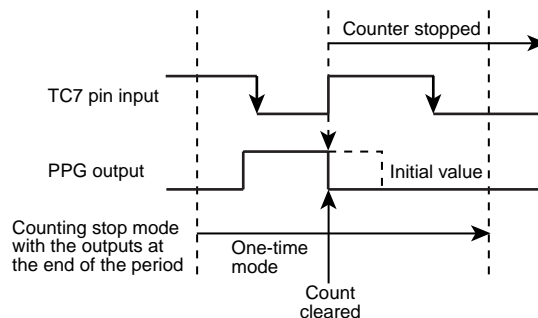


Figure 9-11 Trigger Input Signal

When TRGSEL is set to 0 to select a falling-edge trigger, a falling edge detected on the TC7 pin causes the counter to start counting and a high level on the TC7 pin causes the counter to be cleared and the PPG output to be initialized. The counter is stopped while the TC7 pin input is high.

When TRGSEL is set to 1 to select a rising-edge trigger, a rising edge detected on the TC7 pin causes the counter to start counting and a low level on the TC7 pin causes the counter to be cleared and the PPG output to be initialized. The counter is stopped while the TC7 pin input is low.

In one-time stop mode, the counter accepts a stop trigger but does not accept a start trigger (when a stop trigger is accepted within a period, the output is immediately initialized and the counter is stopped).



All triggers (Start and stop) are ignored when the timer is stopped (TC7ST = 0).

(2) Specifying whether triggers are always accepted or ignored when PPG outputs are active

The TC7CR1<TRGAM> specifies whether triggers from the TC7 pin are always accepted or ignored when the PPG output is active.

- TRGAM = 0:
Triggers from the TC7 pin are always accepted regardless of whether PPG1 and PPG2 outputs are active or inactive. A trigger starts or clears/stops the timer and deactivates PPG1 and PPG2 outputs.
- TRGAM = 1:
Triggers from the TC7 pin are accepted only when PPG1 and PPG2 outputs are inactive. A trigger starts or clears/stops the timer. Triggers are ignored when PPG1 and PPG2 outputs are active.

The active/inactive state of the PPG1 or PPG2 pin has meaning only when output on the pin is enabled with PPG1OE or PPG2OE.

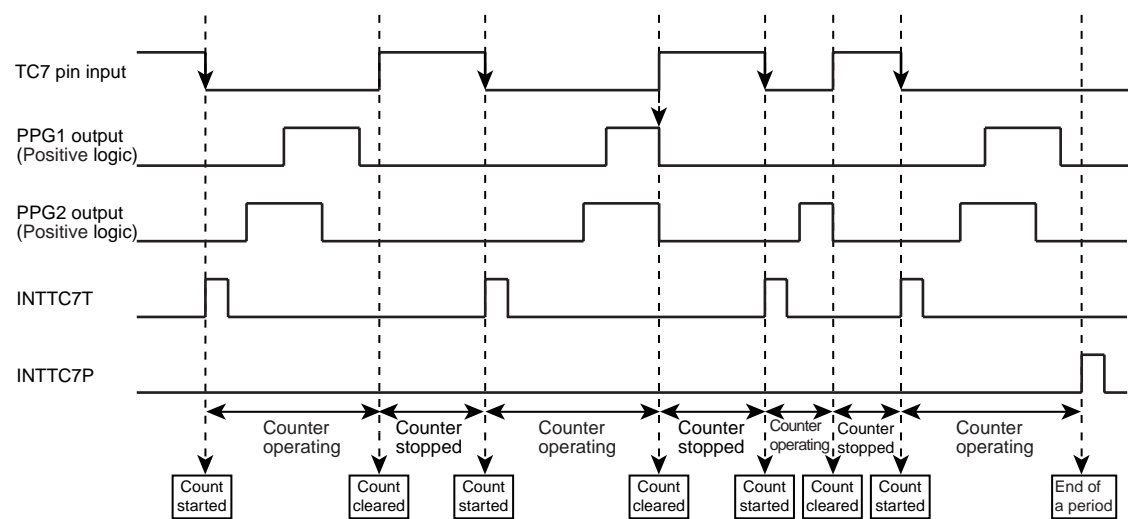


Figure 9-12 Start and Clear/stop Triggers on the TC7 Pin:
 Falling-edge Trigger (Counting stopped at high level), Triggers Always Accepted

(3) Ignoring triggers when PPG outputs are active

Setting TRGAM to 1 specifies that triggers are ignored when PPG outputs are active; trigger edges detected when PPG1 and PPG2 outputs are inactive are accepted and cause the counter to be cleared and stopped. If a trigger is detected when PPG1 and PPG2 outputs are active, the counter does not stop immediately but continues counting until the outputs become inactive. If the trigger signal level is a stop level when the outputs become inactive, the counter is cleared/stopped and waits for a next start trigger. If output is enabled for both PPG1 and PPG2, triggers are accepted only when both PPG1 and PPG2 outputs are inactive.

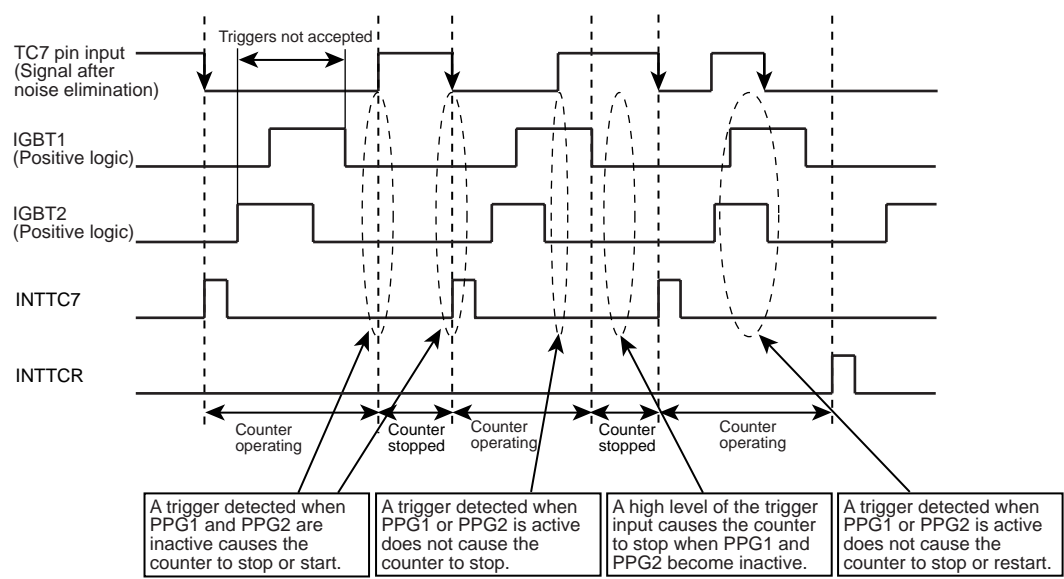


Figure 9-13 Start Triggers on the TC7 Pin:
 Falling-edge Trigger (Counting stopped at high level), Triggers Ignored when PPG Outputs
 are Active

9.4.3 Configuring how the timer stops

Setting TC7ST to 0 causes the timer to stop with the specified output state according to the setting of STM.

9.4.3.1 Counting stopped with the outputs initialized

When STM is set to 00, the counter stops immediately with the PPG1 and PPG2 outputs initialized to the values specified with PPG1INI and PPG2INI.

9.4.3.2 Counting stopped with the outputs maintained

When STM is set to 01, the counter stops immediately with the current PPG1 and PPG2 output states maintained.

To restart the counter from the maintained state (STM = 01), set TC7ST to 1. The counter is restarted with the initial output values, specified with PPG1INI and PPG2INI.

9.4.3.3 Counting stopped with the outputs initialized at the end of the period

When STM is set to 10, the counter continues counting until the end of the current period and then stops. If a stop trigger is detected before the end of the period, however, the counter stops immediately. TC7CR1 and TC7CR2 must not be rewritten before the counter stops completely.

The CNTBF flag (TC7CR3<CNTBF>) can be read to determine whether the counter has stopped.

9.4.4 One-time/continuous output mode

9.4.4.1 One-time output mode

Starting the timer (TC7ST = 1) with STM set to 10 specifies one-time output mode. In this mode, the timer stops counting at the end of a period.

For a trigger start, the counter is stopped until a trigger is detected. A specified trigger restarts counting and the counter stops at the end of the period or when a stop trigger is detected, after which it waits for a trigger again.

For a command start, the counter is stopped until TC7ST is reset to 1.

TC7CR1 and TC7CR2 must not be rewritten before the counter stops completely.

The CNTBF flag (TC7CR3<CNTBF>) can be read to determine whether the counter has stopped.

TC7ST remains set to 1 after the counter is stopped.

When TC7ST is set to 1, setting STM to 10 clears the counter, which then restarts counting from the beginning in one-time output mode.

9.4.4.2 Continuous output mode

Starting the timer (TC7ST = 1) with STM set to 00 or 01 specifies continuous output mode. In this mode, the timer outputs specified waveforms continuously.

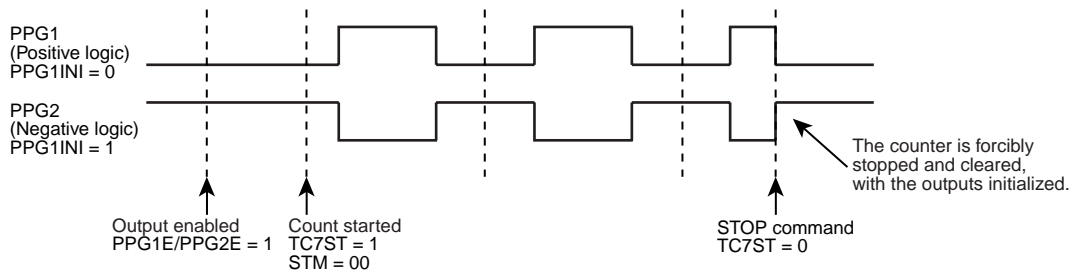


Figure 9-14 Immediately Stopping and Clearing the Counter with the Outputs Initialized (STM = 00)

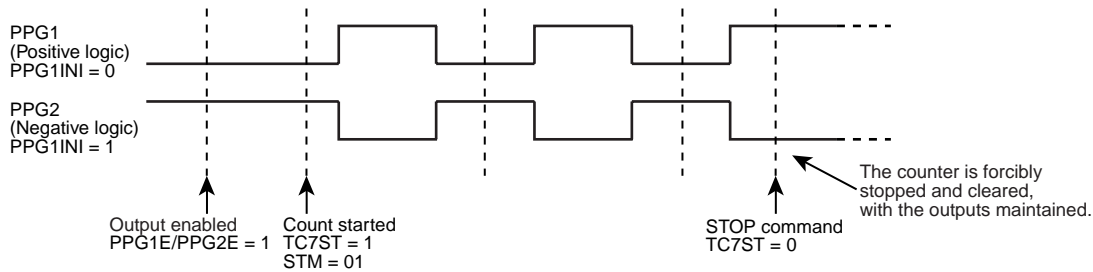


Figure 9-15 Immediately Stopping and Clearing the Counter with the Outputs Maintained (STM = 01)

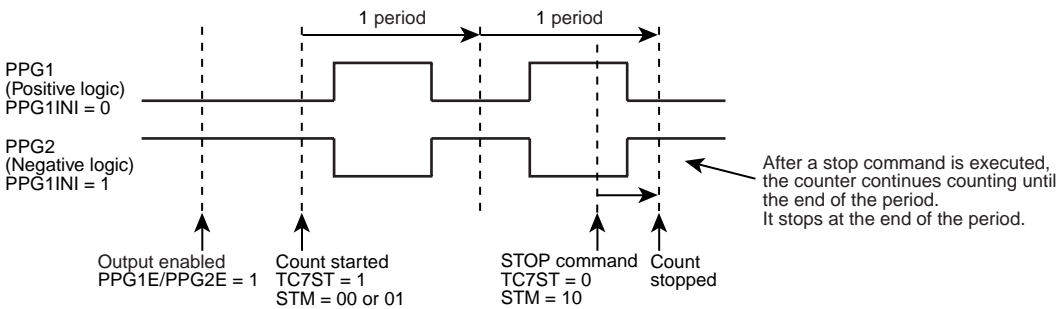


Figure 9-16 Stopping the Counter at the End of the Period (STM = 10)

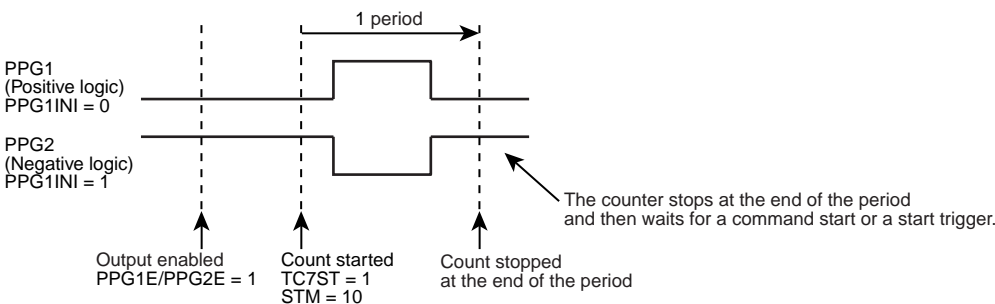


Figure 9-17 Stopping the Counter at the End of the Period (STM = 10): TC7ST = 1, One-time Output Mode

9.4.5 PPG output control (Initial value/output logic, enabling/disabling output)

9.4.5.1 Specifying initial values and output logic for PPG outputs

The PPG1INI and PPG2INI bits (TC7CR1<PPG1INI> and TC7CR1<PPG2INI>) specify the initial values of PPG1 and PPG2 outputs as well as their output logic.

(1) Positive logic output

Setting the bit to 0 specifies that the output is initially low and driven high upon a match between the counter value and specified dead time.

(2) Negative logic output

Setting the bit to 1 specifies that the output is initially high and driven low upon a match between the counter value and specified dead time.

9.4.5.2 Enabling or disabling PPG outputs

The PPG1OE and PPG2OE bits (TC7CR2<PPG1OE> and TC7CR2<PPG2OE>) specify whether PPG outputs are enabled or disabled. When outputs are disabled, no PPG waveforms appear while the counter is operating, allowing the PPG1 and PPG2 pins to be used as normal input/output pins.

The states of the pins when outputs are disabled depend on the settings in port registers.

9.4.5.3 Using the TC7 as a normal timer/counter

The TC7 can be used as a normal timer/counter when PPG outputs are disabled using PPG1E and PPG2E. In that case, use an INTTC7P interrupt, which occurs upon a match with the value specified in the data register (TC7DRC). To start the counter, use start control (TC7S) in command start and capture mode.

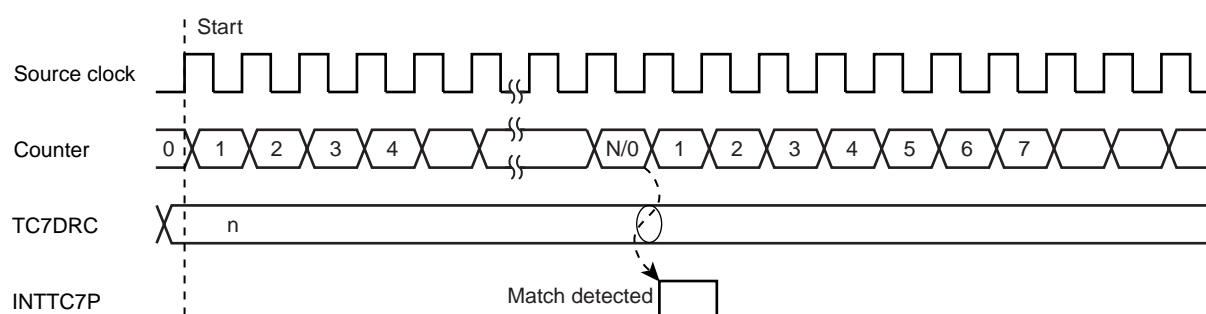


Figure 9-18 Using the TC7 as a Normal Timer/Counter

9.4.6 Eliminating noise from the TC7 pin input

A digital noise canceller eliminates noise from the input signal on the TC7 pin.

The digital noise canceller uses a sampling clock of $f_c/4$, $f_c/2$ or f_c , as specified with NCRSEL, and samples the signal five times. It accepts a level input which is continuous at least over the period of time required for five samplings. Any level input which does not continue over the period of time required for five samplings is canceled as noise.

Table 9-1 Noise Canceller Settings

NCRSEL	Sampling Frequency (Number of Samplings)	Pulse Width Always Assumed as Noise			Pulse Width Always Assumed as Signal		
			At 8 MHz	At 16 MHz		At 8 MHz	At 16 MHz
00	$f_c/4$ (5)	$16/f_c$ [s]	2 [ms]	1 [ms]	$20/f_c$ [s]	2.5 [ms]	1.25 [ms]
01	$f_c/2$ (5)	$8/f_c$ [s]	1 [ms]	500 [ns]	$10/f_c$ [s]	1.25 [ms]	0.625 [ms]
10	f_c (5)	$4/f_c$ [s]	0.5 [ms]	250 [ns]	$5/f_c$ [s]	0.625 [ms]	0.3125 [ms]
11	(None)	None	–	–	($1/f_c$)		

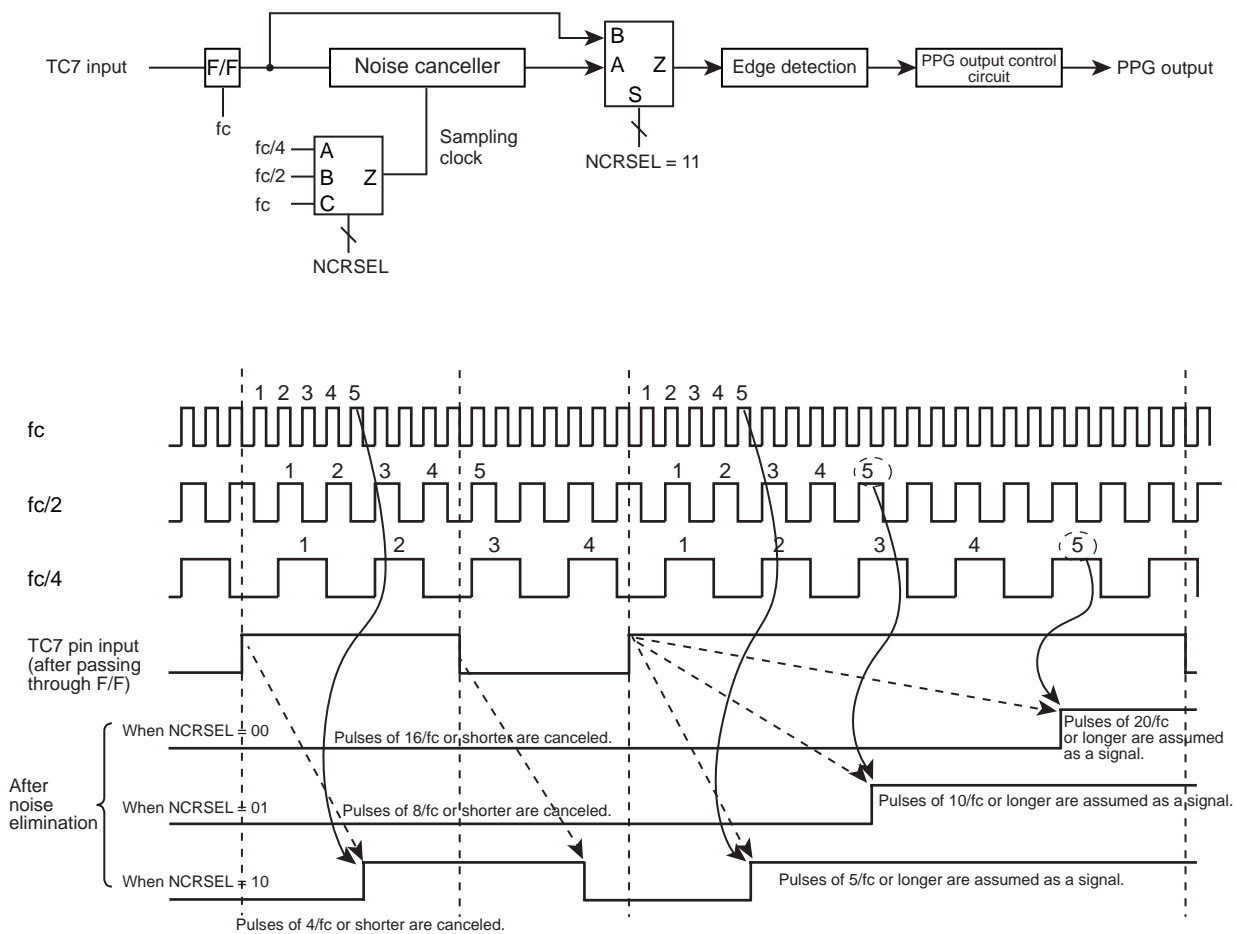


Figure 9-19 Noise Canceller Operation

- When $NCRSEL = 00$, a TC7 input level after passing through the F/F is always canceled if its duration is $16/f_c$ [s] or less and always assumed as a signal if its duration is $20/f_c$ [s] or greater. After the input signal supplied on the TC7 pin passes through the F/F, there is a delay between $21/f_c$ [s] and $24/f_c$ [s] before the PPG outputs vary.
- When $NCRSEL = 01$, a TC7 input level after passing through the F/F is always canceled if its duration is $8/f_c$ [s] or less and always assumed as a signal if its duration is $10/f_c$ [s] or greater. After the input signal supplied on the TC7 pin passes through the F/F, there is a delay between $13/f_c$ [s] and $14/f_c$ [s] before the PPG outputs vary.
- When $NCRSEL = 10$, a TC7 input level after passing through the F/F is always canceled if its duration is $4/f_c$ [s] or less and always assumed as a signal if its duration is $5/f_c$ [s] or greater. After the input signal supplied on the TC7 pin passes through the F/F, there is a delay of $5/f_c$ [s] before the PPG outputs vary.
- When $NCRSEL = 11$, a pulse shorter than $1/f_c$ may be assumed as a signal or canceled as noise in the first-stage F/F. Ensure that input signal pulses are longer than $1/f_c$. After the input signal supplied on the TC7 pin passes through the F/F, there is a delay of $4/f_c$ [s] before the PPG outputs vary.

Note 1: If the pin input level changes while the specified noise elimination threshold is being modified, the noise canceller may assume noise as a pulse or cancel a pulse as noise.

Note 2: If noise occurs in synchronization with the internal sampling timing consecutively, it may be assumed as a signal.

Note 3: The signal supplied on the TC7 pin requires $1/f_c$ [s] or less to pass through the F/F.

9.4.7 Interrupts

The TC7 supports three interrupt sources.

9.4.7.1 INTTC7T (Trigger start interrupt)

A trigger interrupt (INTTC7T) occurs when the counter starts upon the detection of a trigger edge specified with TC7CR1<TRGST>. This interrupt does not occur with a trigger edge for clearing the count. A trigger edge detected in trigger capture mode does not cause an interrupt. A start trigger causes an interrupt even when the counter is stopped in emergency.

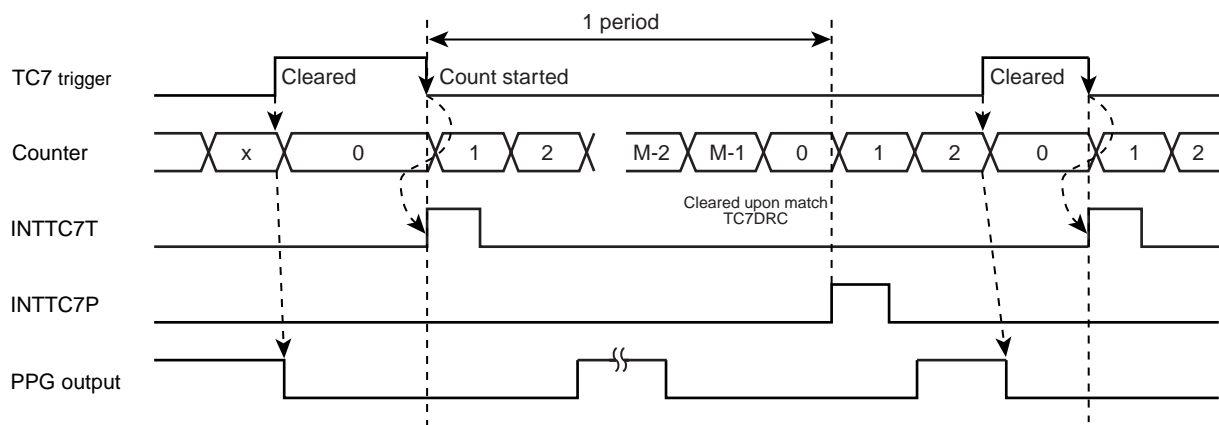


Figure 9-20 Trigger Start Interrupt

9.4.7.2 INTTC7P (Period interrupt)

A period interrupt (INTTC7P) occurs when the counter starts with a command and when the counter is cleared with the specified counter period (TC7DRC) reached, that is, at the end of a period. A match with the set period causes an interrupt even when the counter is stopped in emergency.

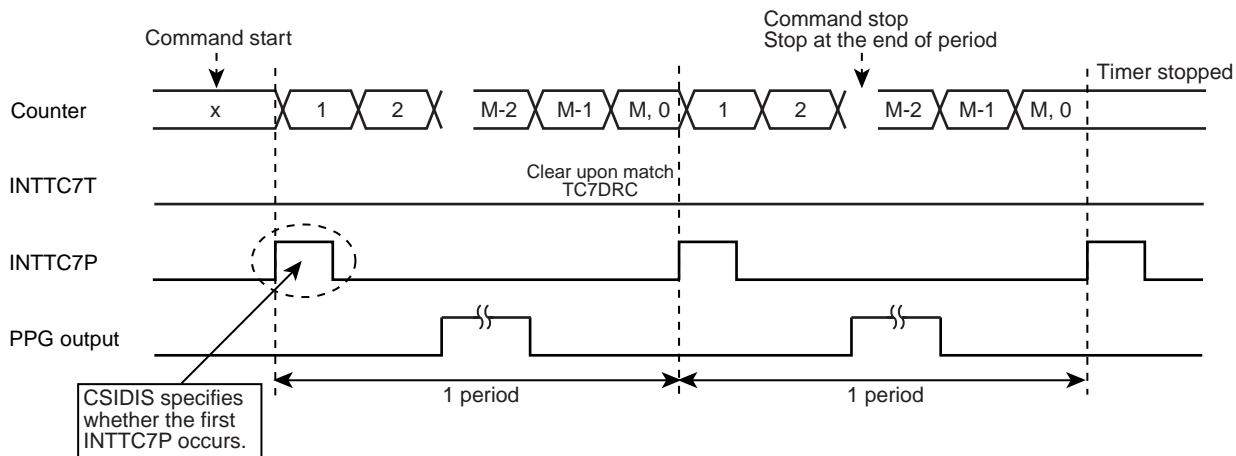


Figure 9-21 Period Interrupt

If a command start is specified (1 is written in TC7ST) when the TC7 pin is at a stop level, the counter does not start (INTTC7P does not occur); a subsequent trigger start edge causes the counter to start and INTTC7T to occur.

9.4.7.3 INTEMG (Emergency output stop interrupt)

An emergency output stop interrupt (INTEMG) occurs when the emergency output stop circuit operates to stop PPG outputs in emergency.

9.4.8 Emergency PPG output stop feature

Setting TC7CR2<EMGIE> to 1 enables the emergency PPG output stop feature (Enables the $\overline{\text{EMG}}$ pin input).

A low level input detected on the $\overline{\text{EMG}}$ pin causes an EMG interrupt (INTEMG) to occur with the PPG waveforms initialized (as specified with PPG1INI and PPG2INI). (Emergency PPG output stop)

This feature only disables PPG outputs without stopping the counter. Use the EMG interrupt handler routine to stop the timer.

Note: Ensure that a low level on the $\overline{\text{EMG}}$ pin continues for at least $4/f_c$ [s]. The emergency PPG output stop feature may not operate normally with a low level shorter than $4/f_c$ [s].

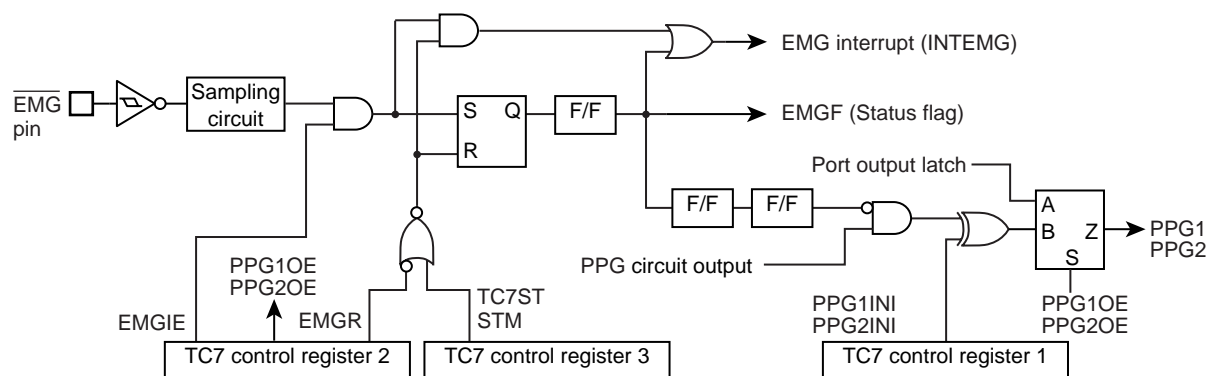


Figure 9-22 EMG Pin

9.4.8.1 Enabling/disabling input on the $\overline{\text{EMG}}$ pin

Setting TC7CR2<EMGIE> to 1 enables input on the $\overline{\text{EMG}}$ pin and setting the bit to 0 disables input on the pin. (Initially, EMGIE is set to 0, disabling an emergency output stop ($\overline{\text{EMG}}$ pin) input.)

The input signal on the $\overline{\text{EMG}}$ pin is valid only when its shared port pin is placed in input mode. Ensure that the shared port pin is placed in input mode before attempting to enable the $\overline{\text{EMG}}$ pin input.

The $\overline{\text{EMG}}$ pin input is sampled using a high-frequency clock. The emergency PPG output stop feature does not operate normally if the high-frequency clock is stopped.

9.4.8.2 Monitoring the emergency PPG output stop state

When the emergency PPG output stop feature activates, the TC7CR3<EMGF> is set to 1. 1 read from EMGF indicates that PPG outputs are disabled by the emergency PPG output stop feature. To restart the timer in that state, first make necessary settings for stopping the timer before canceling the emergency PPG output stop state (by writing 1 to EMGR, bit7 of the TC7CR2) and then reconfiguring the control and data registers to restart the timer.

9.4.8.3 EMG interrupt

An EMG interrupt (INTEMG) occurs when an emergency PPG output stop input is accepted. To use an INTEMG interrupt for some processing, ensure that the interrupt is enabled beforehand.

When the $\overline{\text{EMG}}$ pin is low with EMGIE set to 1 ($\overline{\text{EMG}}$ pin input enabled), an attempt to cancel the emergency PPG output stop state results in an interrupt being generated again, with the emergency PPG output stop state reestablished.

An INTEMG interrupt occurs whenever a stop input is accepted when EMGIE = 1, regardless of whether the timer is operating.

9.4.8.4 Canceling the emergency PPG output stop state

To cancel the emergency PPG output stop state, ensure that the input on the EMG pin is high, set TC7CR3<TC7ST> to 0 and TC7CR3<STM> to 00 to stop the timer, and then set TC7CR2<EMGR> to 1. Setting EMGR to 1 cancels the stop state only when TC7ST = 0 and STM = 00; ensure that TC7ST = 0 and STM = 00 before setting EMGR to 1.

If the input on the EMG pin is low and EMGIE = 1 when the emergency PPG output stop state is canceled, the timer re-enters the emergency PPG output stop state and an INTEMG interrupt occurs.

9.4.8.5 Restarting the timer after canceling the emergency PPG output stop state

To restart the timer after canceling the emergency PPG output stop state, reconfigure the control registers (TC7CR1, TC7CR2, TC7CR3) before restarting the timer.

The timer cannot restart in the emergency PPG output stop state. Monitor the emergency PPG output stop state and cancel the state before reconfiguring the control registers to restart the timer. Ensure that the control registers are reconfigured according to the appropriate procedure for configuring timer operation control.

9.4.8.6 Response time between $\overline{\text{EMG}}$ pin input and PPG outputs being initialized

The time between a low level input being detected on the $\overline{\text{EMG}}$ pin and the PPG outputs being initialized is up to $10/f_c$ [s].

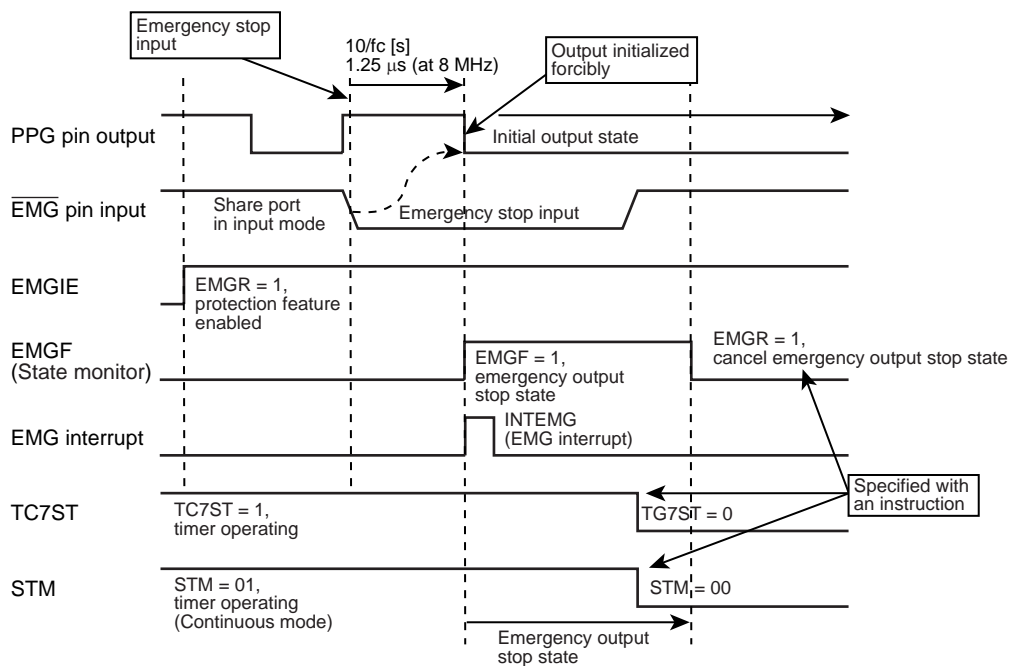


Figure 9-23 Timing between EMG Pin Input being Detected and PPG Outputs being Disabled

9.4.9 TC7 operation and microcontroller operating mode

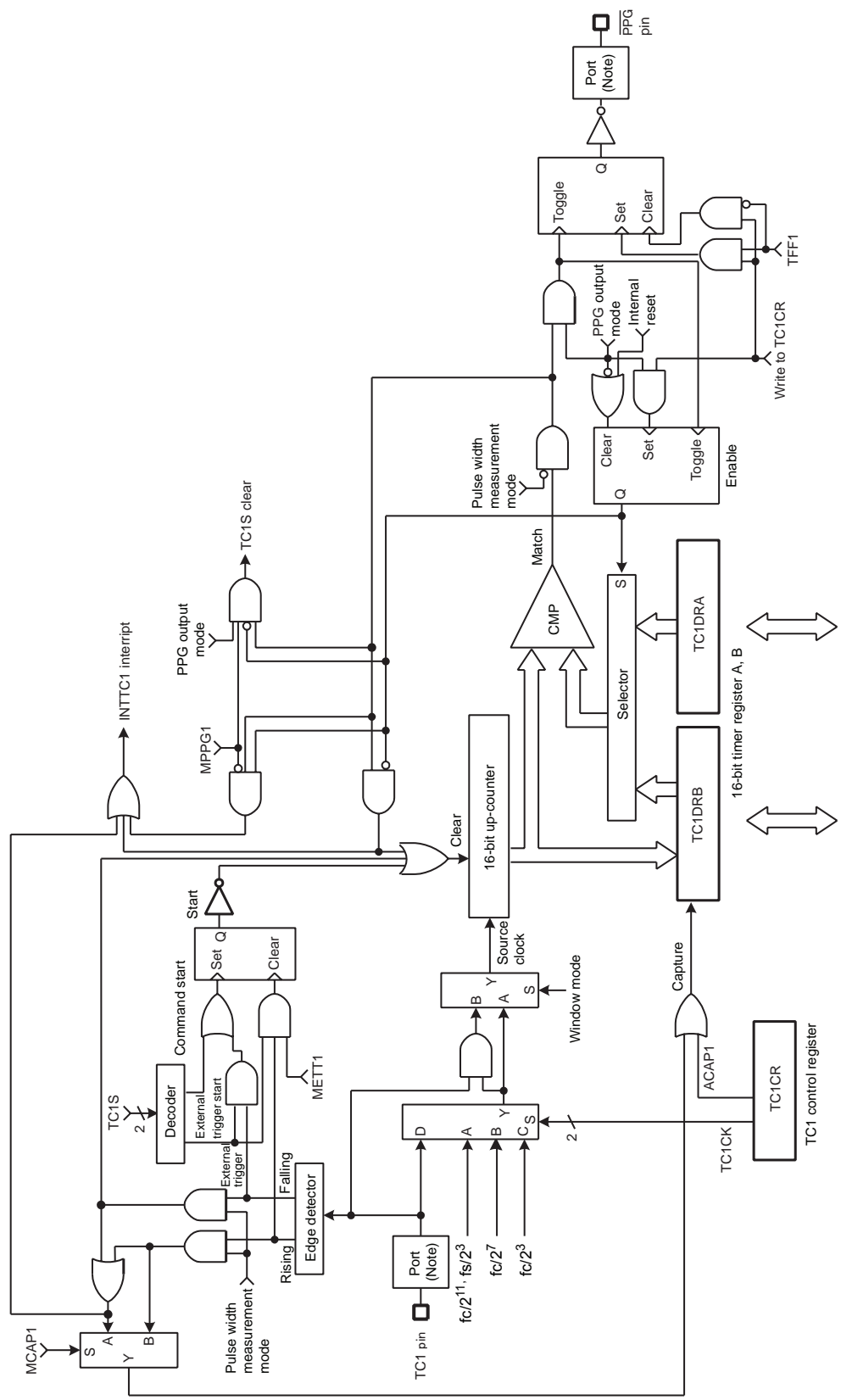
The TC7 operates when the microcontroller is placed in NORMAL1, NORMAL2, IDLE1, or IDLE2 mode. If the mode changes from NORMAL or IDLE to STOP, SLOW, or SLEEP while the TC7 is operating, the TC7 is initialized and stops operating.

To change the microcontroller operating mode from NORMAL or IDLE to STOP, SLOW, or SLEEP, ensure that the TC7 timer is stopped before attempting to execute a mode change instruction.

To change the mode from STOP, SLOW, or SLEEP to NORMAL to restart the TC7, reconfigure all registers according to the appropriate TC7 operation procedure.

10. 16-Bit TimerCounter 1 (TC1)

10.1 Configuration



Note: Function I/O may not operate depending on I/O port setting. For more details, see the chapter "I/O Port".

Figure 10-1 TimerCounter 1 (TC1)

10. 16-Bit TimerCounter 1 (TC1)

10.2 TimerCounter Control

TMP86CH12MG

10.2 TimerCounter Control

The TimerCounter 1 is controlled by the TimerCounter 1 control register (TC1CR) and two 16-bit timer registers (TC1DRA and TC1DRB).

Timer Register

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TC1DRA (0011H, 0010H)	TC1DRAH (0011H) (Initial value: 1111 1111 1111 1111)								TC1DRAL (0010H) Read/Write							
TC1DRB (0013H, 0012H)	TC1DRBH (0013H) (Initial value: 1111 1111 1111 1111)								TC1DRBL (0012H) Read/Write (Write enabled only in the PPG output mode)							

TimerCounter 1 Control Register

	7	6	5	4	3	2	1	0	
TC1CR (0014H)	TFF1	ACAP1 MCAP1 METT1 MPPG1	TC1S	TC1CK	TC1M	Read/Write (Initial value: 0000 0000)			

TFF1	Timer F/F1 control	0: Clear		1: Set					R/W	
ACAP1	Auto capture control	0:Auto-capture disable		1:Auto-capture enable					R/W	
MCAP1	Pulse width measure- ment mode control	0:Double edge capture		1:Single edge capture						
METT1	External trigger timer mode control	0:Trigger start		1:Trigger start and stop						
MPPG1	PPG output control	0:Continuous pulse generation		1:One-shot						
TC1S	TC1 start control		Timer	Extrig- ger	Event	Win- dow	Pulse	PPG	R/W	
		00: Stop and counter clear	0	0	0	0	0	0		
		01: Command start	0	–	–	–	–	0		
		10: Rising edge start (Ex-trigger/Pulse/PPG) Rising edge count (Event) Positive logic count (Window)	–	0	0	0	0	0		
		11: Falling edge start (Ex-trigger/Pulse/PPG) Falling edge count (Event) Negative logic count (Window)	–	0	0	0	0	0		
TC1CK	TC1 source clock select [Hz]		NORMAL 1/2, IDLE 1/2 mode					Divider	SLOW, SLEEP mode	R/W
			DV7CK = 0		DV7CK = 1					
		00	$fc/2^{11}$	$fs/2^3$			DV9	$fs/2^3$		
		01	$fc/2^7$	$fc/2^7$			DV5	–		
		10	$fc/2^3$	$fc/2^3$			DV1	–		
		11	External clock (TC1 pin input)							
TC1M	TC1 operating mode select	00: Timer/external trigger timer/event counter mode 01: Window mode 10: Pulse width measurement mode 11: PPG (Programmable pulse generate) output mode							R/W	

Note 1: fc: High-frequency clock [Hz], fs: Low-frequency clock [Hz]

Note 2: The timer register consists of two shift registers. A value set in the timer register becomes valid at the rising edge of the first source clock pulse that occurs after the upper byte (TC1DRAH and TC1DRBH) is written. Therefore, write the lower byte and the upper byte in this order (it is recommended to write the register with a 16-bit access instruction). Writing only the lower byte (TC1DRAL and TC1DRBL) does not enable the setting of the timer register.

Note 3: To set the mode, source clock, PPG output control and timer F/F control, write to TC1CR1 during TC1S=00. Set the timer F/F1 control until the first timer start after setting the PPG mode.

Note 4: Auto-capture can be used only in the timer, event counter, and window modes.

Note 5: To set the timer registers, the following relationship must be satisfied.

TC1DRA > TC1DRB > 1 (PPG output mode), TC1DRA > 1 (other modes)

Note 6: Set TFF1 to "0" in the mode except PPG output mode.

Note 7: Set TC1DRB after setting TC1M to the PPG output mode.

Note 8: When the STOP mode is entered, the start control (TC1S) is cleared to "00" automatically, and the timer stops. After the STOP mode is exited, set the TC1S to use the timer counter again.

Note 9: Use the auto-capture function in the operative condition of TC1. A captured value may not be fixed if it's read after the execution of the timer stop or auto-capture disable. Read the capture value in a capture enabled condition.

Note 10: Since the up-counter value is captured into TC1DRB by the source clock of up-counter after setting TC1CR<ACAP1> to "1". Therefore, to read the captured value, wait at least one cycle of the internal source clock before reading TC1DRB for the first time.

10.3 Function

TimerCounter 1 has six types of operating modes: timer, external trigger timer, event counter, window, pulse width measurement, programmable pulse generator output modes.

10.3.1 Timer mode

In the timer mode, the up-counter counts up using the internal clock. When a match between the up-counter and the timer register 1A (TC1DRA) value is detected, an INTTC1 interrupt is generated and the up-counter is cleared. After being cleared, the up-counter restarts counting. Setting TC1CR<ACAP1> to "1" captures the up-counter value into the timer register 1B (TC1DRB) with the auto-capture function. Use the auto-capture function in the operative condition of TC1. A captured value may not be fixed if it's read after the execution of the timer stop or auto-capture disable. Read the capture value in a capture enabled condition. Since the up-counter value is captured into TC1DRB by the source clock of up-counter after setting TC1CR<ACAP1> to "1". Therefore, to read the captured value, wait at least one cycle of the internal source clock before reading TC1DRB for the first time.

Table 10-1 Internal Source Clock for TimerCounter 1 (Example: $f_c = 16 \text{ MHz}$, $f_s = 32.768 \text{ kHz}$)

TC1CK	NORMAL 1/2, IDLE 1/2 mode				SLOW, SLEEP mode	
	DV7CK = 0		DV7CK = 1			
	Resolution [μs]	Maximum Time Setting [s]	Resolution [μs]	Maximum Time Setting [s]	Resolution [μs]	Maximum Time Set- ting [s]
00	128	8.39	244.14	16.0	244.14	16.0
01	8.0	0.524	8.0	0.524	—	—
10	0.5	32.77 m	0.5	32.77 m	—	—

Example 1 :Setting the timer mode with source clock $f_c/2^{11}$ [Hz] and generating an interrupt 1 second later ($f_c = 16 \text{ MHz}$, $\text{TBTCR} < \text{DV7CK} > = "0"$)

```
LDW      (TC1DRA), 1E84H      ; Sets the timer register ( $1 \text{ s} \div 2^{11}/f_c = 1\text{E}84\text{H}$ )
DI
; IMF= "0"
SET      (EIRL), 7            ; Enables INTTC1
EI
; IMF= "1"
LD       (TC1CR), 00000000B    ; Selects the source clock and mode
LD       (TC1CR), 00010000B    ; Starts TC1
```

Example 2 :Auto-capture

```
LD       (TC1CR), 01010000B    ; ACAP1 ← 1
:
:
LD       WA, (TC1DRB)          ; Reads the capture value
```

Note: Since the up-counter value is captured into TC1DRB by the source clock of up-counter after setting TC1CR<ACAP1> to "1". Therefore, to read the captured value, wait at least one cycle of the internal source clock before reading TC1DRB for the first time.

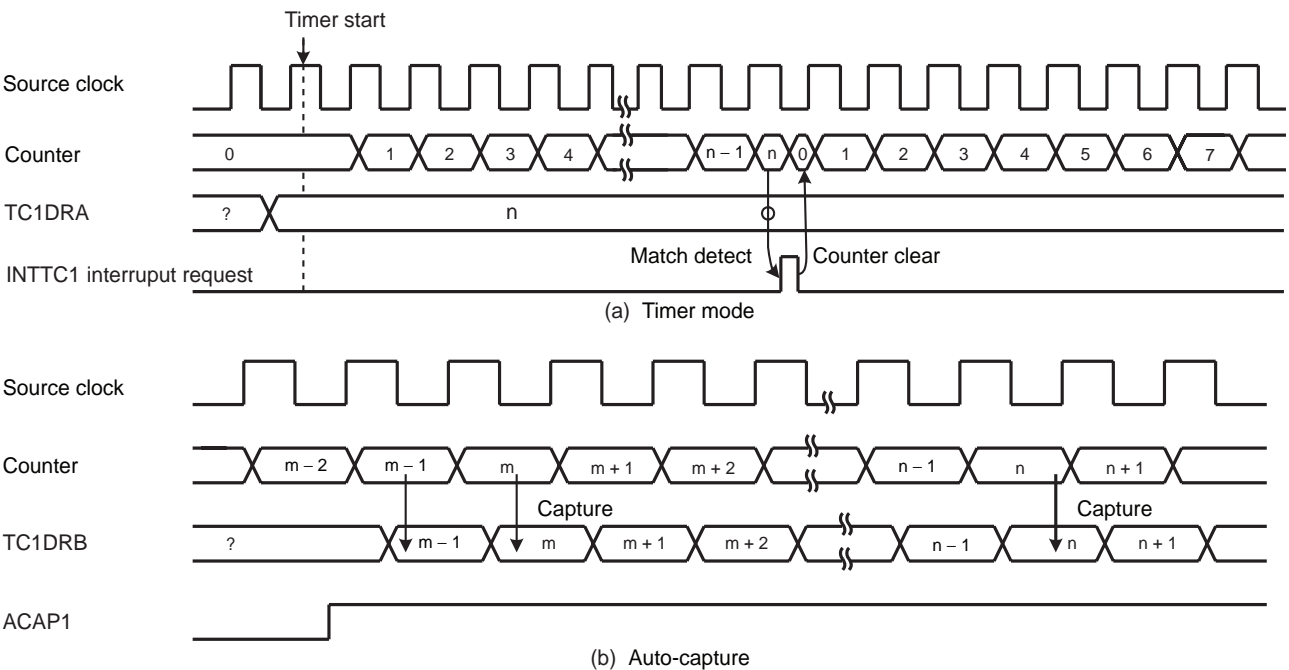


Figure 10-2 Timer Mode Timing Chart

10.3.2 External Trigger Timer Mode

In the external trigger timer mode, the up-counter starts counting by the input pulse triggering of the TC1 pin, and counts up at the edge of the internal clock. For the trigger edge used to start counting, either the rising or falling edge is defined in TC1CR<TC1S>.

- When TC1CR<METT1> is set to “1” (trigger start and stop)

When a match between the up-counter and the TC1DRA value is detected after the timer starts, the up-counter is cleared and halted and an INTTC1 interrupt request is generated.

If the edge opposite to trigger edge is detected before detecting a match between the up-counter and the TC1DRA, the up-counter is cleared and halted without generating an interrupt request. Therefore, this mode can be used to detect exceeding the specified pulse by interrupt.

After being halted, the up-counter restarts counting when the trigger edge is detected.

- When TC1CR<METT1> is set to “0” (trigger start)

When a match between the up-counter and the TC1DRA value is detected after the timer starts, the up-counter is cleared and halted and an INTTC1 interrupt request is generated.

The edge opposite to the trigger edge has no effect in count up. The trigger edge for the next counting is ignored if detecting it before detecting a match between the up-counter and the TC1DRA.

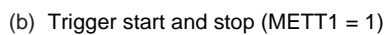
Since the TC1 pin input has the noise rejection, pulses of $4/f_c$ [s] or less are rejected as noise. A pulse width of $12/f_c$ [s] or more is required to ensure edge detection. The rejection circuit is turned off in the SLOW1/2 or SLEEP1/2 mode, but a pulse width of one machine cycle or more is required.

Example 1 :Generating an interrupt 1 ms after the rising edge of the input pulse to the TC1 pin
($f_c = 16$ MHz)

```
LDW      (TC1DRA), 007DH      ;  $1\text{ms} \div 2^7/f_c = 7\text{DH}$ 
DI                          ; IMF= "0"
SET      (EIRL), 7            ; Enables INTTC1 interrupt
EI                          ; IMF= "1"
LD       (TC1CR), 00000100B    ; Selects the source clock and mode
LD       (TC1CR), 00100100B    ; Starts TC1 external trigger, METT1 = 0
```

Example 2 :Generating an interrupt when the low-level pulse with 4 ms or more width is input to the TC1 pin
($f_c = 16$ MHz)

```
LDW      (TC1DRA), 01F4H      ;  $4\text{ms} \div 2^7/f_c = 1\text{F4H}$ 
DI                          ; IMF= "0"
SET      (EIRL), 7            ; Enables INTTC1 interrupt
EI                          ; IMF= "1"
LD       (TC1CR), 00000100B    ; Selects the source clock and mode
LD       (TC1CR), 01110100B    ; Starts TC1 external trigger, METT1 = 0
```



Note: $m < n$

Figure 10-3 External Trigger Timer Mode Timing Chart

10.3.3 Event Counter Mode

In the event counter mode, the up-counter counts up at the edge of the input pulse to the TC1 pin. Either the rising or falling edge of the input pulse is selected as the count up edge in TC1CR<TC1S>.

When a match between the up-counter and the TC1DRA value is detected, an INTTC1 interrupt is generated and the up-counter is cleared. After being cleared, the up-counter restarts counting at each edge of the input pulse to the TC1 pin. Since a match between the up-counter and the value set to TC1DRA is detected at the edge opposite to the selected edge, an INTTC1 interrupt request is generated after a match of the value at the edge opposite to the selected edge.

Two or more machine cycles are required for the low-or high-level pulse input to the TC1 pin.

Setting TC1CR<ACAP1> to “1” captures the up-counter value into TC1DRB with the auto capture function. Use the auto-capture function in the operative condition of TC1. A captured value may not be fixed if it's read after the execution of the timer stop or auto-capture disable. Read the capture value in a capture enabled condition. Since the up-counter value is captured into TC1DRB by the source clock of up-counter after setting TC1CR<ACAP1> to "1". Therefore, to read the captured value, wait at least one cycle of the internal source clock before reading TC1DRB for the first time.

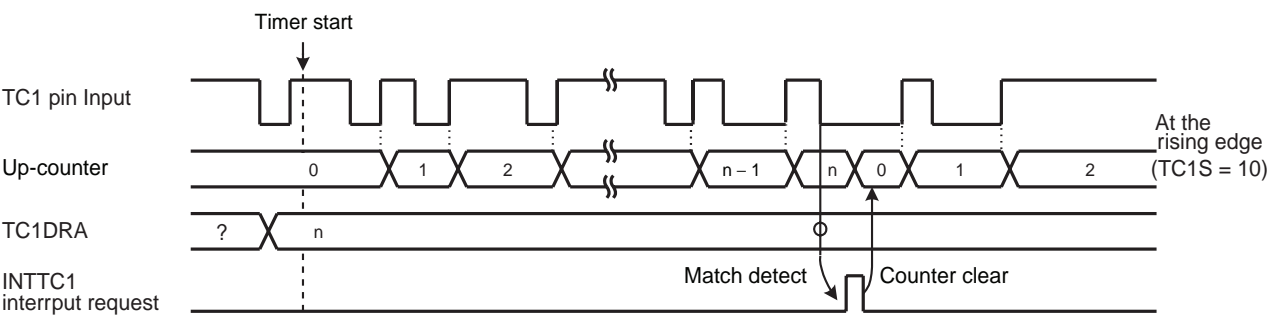


Figure 10-4 Event Counter Mode Timing Chart

Table 10-2 Input Pulse Width to TC1 Pin

	Minimum Pulse Width [s]	
	NORMAL1/2, IDLE1/2 Mode	SLOW1/2, SLEEP1/2 Mode
High-going	$2^3/f_c$	$2^3/f_s$
Low-going	$2^3/f_c$	$2^3/f_s$

10.3.4 Window Mode

In the window mode, the up-counter counts up at the rising edge of the pulse that is logical ANDed product of the input pulse to the TC1 pin (window pulse) and the internal source clock. Either the positive logic (count up during high-going pulse) or negative logic (count up during low-going pulse) can be selected.

When a match between the up-counter and the TC1DRA value is detected, an INTTC1 interrupt is generated and the up-counter is cleared.

Define the window pulse to the frequency which is sufficiently lower than the internal source clock programmed with TC1CR<TC1CK>.

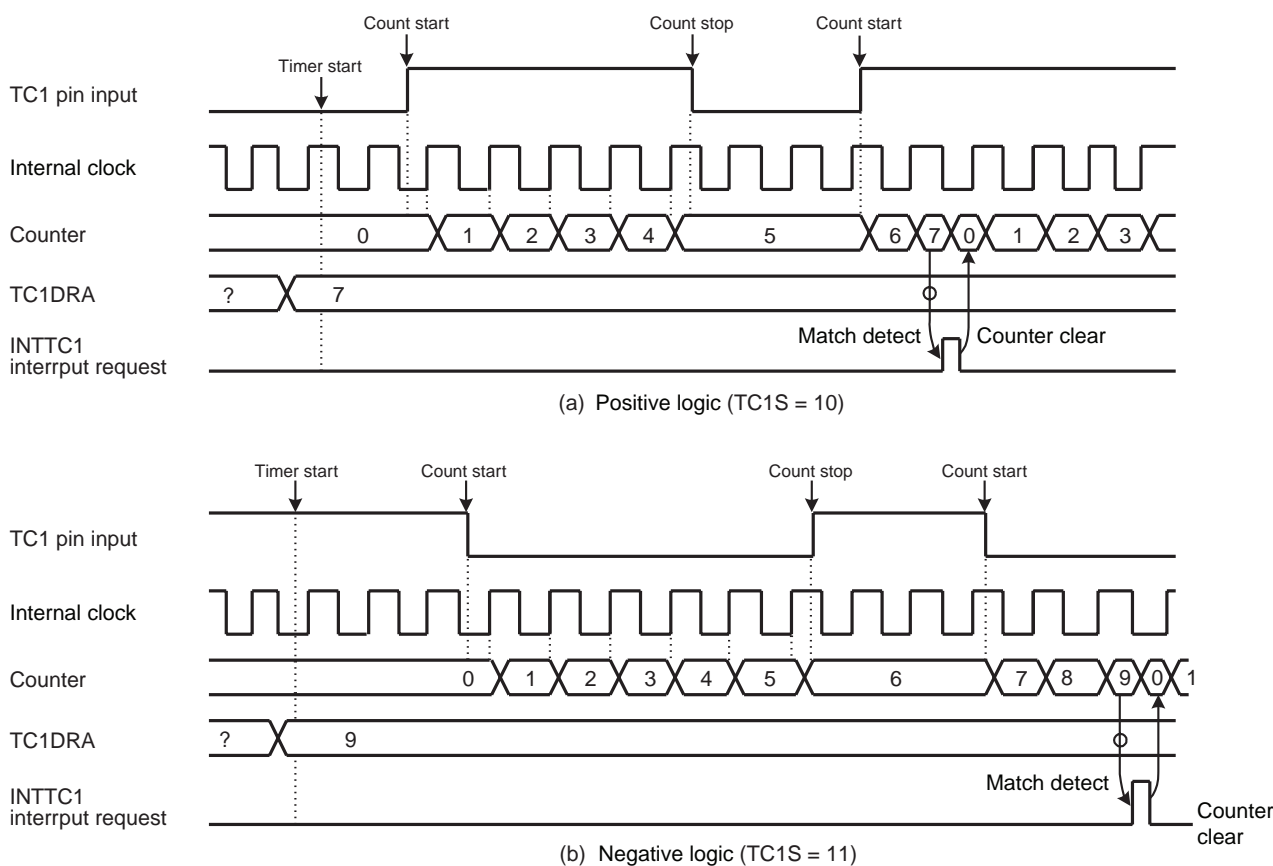


Figure 10-5 Window Mode Timing Chart

10.3.5 Pulse Width Measurement Mode

In the pulse width measurement mode, the up-counter starts counting by the input pulse triggering of the TC1 pin, and counts up at the edge of the internal clock. Either the rising or falling edge of the internal clock is selected as the trigger edge in TC1CR<TC1S>. Either the single- or double-edge capture is selected as the trigger edge in TC1CR<MCAP1>.

- When TC1CR<MCAP1> is set to “1” (single-edge capture)

Either high- or low-level input pulse width can be measured. To measure the high-level input pulse width, set the rising edge to TC1CR<TC1S>. To measure the low-level input pulse width, set the falling edge to TC1CR<TC1S>.

When detecting the edge opposite to the trigger edge used to start counting after the timer starts, the up-counter captures the up-counter value into TC1DRB and generates an INTTC1 interrupt request. The up-counter is cleared at this time, and then restarts counting when detecting the trigger edge used to start counting.

- When TC1CR<MCAP1> is set to “0” (double-edge capture)

The cycle starting with either the high- or low-going input pulse can be measured. To measure the cycle starting with the high-going pulse, set the rising edge to TC1CR<TC1S>. To measure the cycle starting with the low-going pulse, set the falling edge to TC1CR<TC1S>.

When detecting the edge opposite to the trigger edge used to start counting after the timer starts, the up-counter captures the up-counter value into TC1DRB and generates an INTTC1 interrupt request. The up-counter continues counting up, and captures the up-counter value into TC1DRB and generates an INTTC1 interrupt request when detecting the trigger edge used to start counting. The up-counter is cleared at this time, and then continues counting.

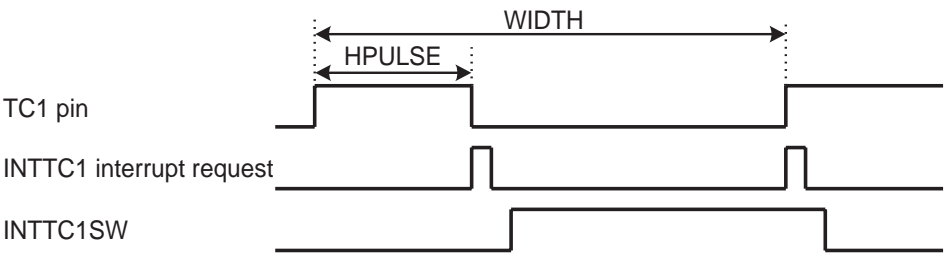
Note 1: The captured value must be read from TC1DRB until the next trigger edge is detected. If not read, the captured value becomes a don't care. It is recommended to use a 16-bit access instruction to read the captured value from TC1DRB.

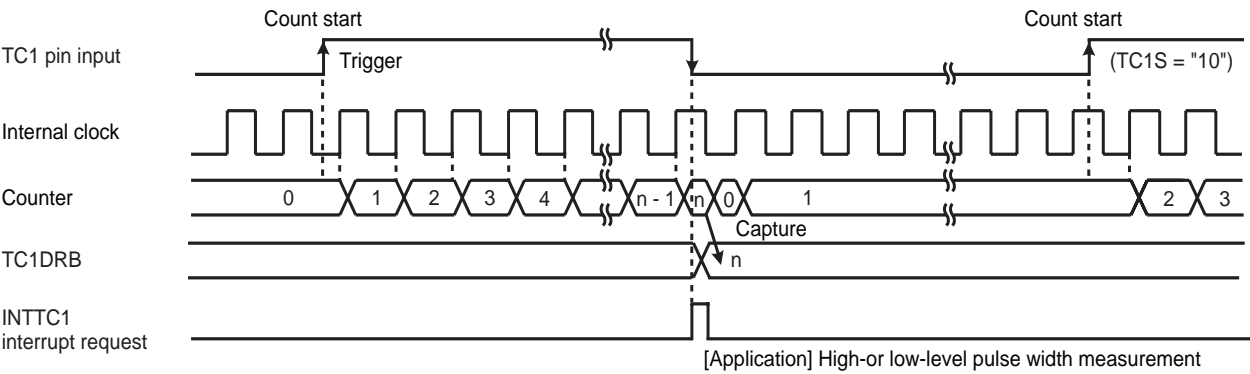
Note 2: For the single-edge capture, the counter after capturing the value stops at “1” until detecting the next edge. Therefore, the second captured value is “1” larger than the captured value immediately after counting starts.

Note 3: The first captured value after the timer starts may be read incorrectly, therefore, ignore the first captured value.

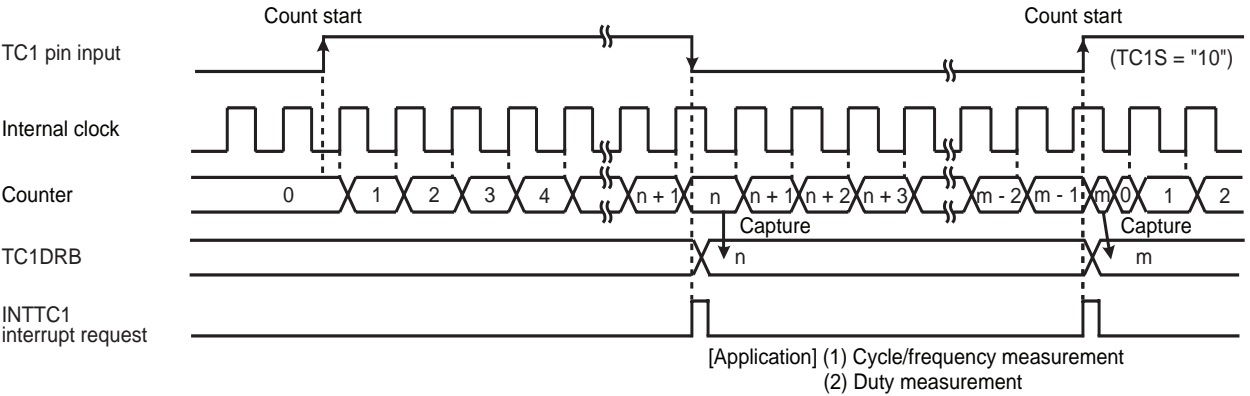
Example :Duty measurement (resolution $f_c/2^7$ [Hz])

	CLR	(INTTC1SW). 0	; INTTC1 service switch initial setting Address set to convert INTTC1SW at each INTTC1
	LD	(TC1CR), 00000110B	; Sets the TC1 mode and source clock
	DI		; IMF= "0"
	SET	(EIRL). 7	; Enables INTTC1
	EI		; IMF= "1"
	LD	(TC1CR), 00100110B	; Starts TC1 with an external trigger at MCAP1 = 0
	:		
PINTTC1:	CPL	(INTTC1SW). 0	; INTTC1 interrupt, inverts and tests INTTC1 service switch
	JRS	F, SINTTC1	
	LD	A, (TC1DRBL)	; Reads TC1DRB (High-level pulse width)
	LD	W,(TC1DRBH)	
	LD	(HPULSE), WA	; Stores high-level pulse width in RAM
	RETI		
SINTTC1:	LD	A, (TC1DRBL)	; Reads TC1DRB (Cycle)
	LD	W,(TC1DRBH)	
	LD	(WIDTH), WA	; Stores cycle in RAM
	:		
	RETI		; Duty calculation
	:		
VINTTC1:	DW	PINTTC1	; INTTC1 Interrupt vector





(a) Single-edge capture (MCAP1 = "1")



(b) Double-edge capture (MCAP1 = "0")

Figure 10-6 Pulse Width Measurement Mode

10.3.6 Programmable Pulse Generate (PPG) Output Mode

In the programmable pulse generation (PPG) mode, an arbitrary duty pulse is generated by counting performed in the internal clock. To start the timer, TC1CR<TC1S> specifies either the edge of the input pulse to the TC1 pin or the command start. TC1CR<MPPG1> specifies whether a duty pulse is produced continuously or not (one-shot pulse).

- When TC1CR<MPPG1> is set to “0” (Continuous pulse generation)

When a match between the up-counter and the TC1DRB value is detected after the timer starts, the level of the PPG pin is inverted and an INTTC1 interrupt request is generated. The up-counter continues counting. When a match between the up-counter and the TC1DRA value is detected, the level of the PPG pin is inverted and an INTTC1 interrupt request is generated. The up-counter is cleared at this time, and then continues counting and pulse generation.

When TC1S is cleared to “00” during PPG output, the PPG pin retains the level immediately before the counter stops.

- When TC1CR<MPPG1> is set to “1” (One-shot pulse generation)

When a match between the up-counter and the TC1DRB value is detected after the timer starts, the level of the PPG pin is inverted and an INTTC1 interrupt request is generated. The up-counter continues counting. When a match between the up-counter and the TC1DRA value is detected, the level of the PPG pin is inverted and an INTTC1 interrupt request is generated. TC1CR<TC1S> is cleared to “00” automatically at this time, and the timer stops. The pulse generated by PPG retains the same level as that when the timer stops.

Since the output level of the PPG pin can be set with TC1CR<TFF1> when the timer starts, a positive or negative pulse can be generated. Since the inverted level of the timer F/F1 output level is output to the PPG pin, specify TC1CR<TFF1> to “0” to set the high level to the PPG pin, and “1” to set the low level to the PPG pin. Upon reset, the timer F/F1 is initialized to “0”.

Note 1: To change TC1DRA or TC1DRB during a run of the timer, set a value sufficiently larger than the count value of the counter. Setting a value smaller than the count value of the counter during a run of the timer may generate a pulse different from that specified.

Note 2: Do not change TC1CR<TFF1> during a run of the timer. TC1CR<TFF1> can be set correctly only at initialization (after reset). When the timer stops during PPG, TC1CR<TFF1> can not be set correctly from this point onward if the PPG output has the level which is inverted of the level when the timer starts. (Setting TC1CR<TFF1> specifies the timer F/F1 to the level inverted of the programmed value.) Therefore, the timer F/F1 needs to be initialized to ensure an arbitrary level of the PPG output. To initialize the timer F/F1, change TC1CR<TC1M> to the timer mode (it is not required to start the timer mode), and then set the PPG mode. Set TC1CR<TFF1> at this time.

Note 3: In the PPG mode, the following relationship must be satisfied.
TC1DRA > TC1DRB

Note 4: Set TC1DRB after changing the mode of TC1M to the PPG mode.

Example :Generating a pulse which is high-going for 800 μ s and low-going for 200 μ s
(fc = 16 MHz)

Setting port

LD	(TC1CR), 10000111B	; Sets the PPG mode, selects the source clock
LDW	(TC1DRA), 007DH	; Sets the cycle ($1\text{ ms} \div 2^7/\text{fc ms} = 007\text{DH}$)
LDW	(TC1DRB), 0019H	; Sets the low-level pulse width ($200\text{ }\mu\text{s} \div 2^7/\text{fc} = 0019\text{H}$)
LD	(TC1CR), 10010111B	; Starts the timer

Example :After stopping PPG, setting the PPG pin to a high-level to restart PPG
(fc = 16 MHz)

Setting port

LD	(TC1CR), 10000111B	; Sets the PPG mode, selects the source clock
LDW	(TC1DRA), 007DH	; Sets the cycle ($1\text{ ms} \div 2^7/\text{fc }\mu\text{s} = 007\text{DH}$)
LDW	(TC1DRB), 0019H	; Sets the low-level pulse width ($200\text{ }\mu\text{s} \div 2^7/\text{fc} = 0019\text{H}$)
LD	(TC1CR), 10010111B	; Starts the timer
:	:	
LD	(TC1CR), 10000111B	; Stops the timer
LD	(TC1CR), 10000100B	; Sets the timer mode
LD	(TC1CR), 00000111B	; Sets the PPG mode, TFF1 = 0
LD	(TC1CR), 00010111B	; Starts the timer

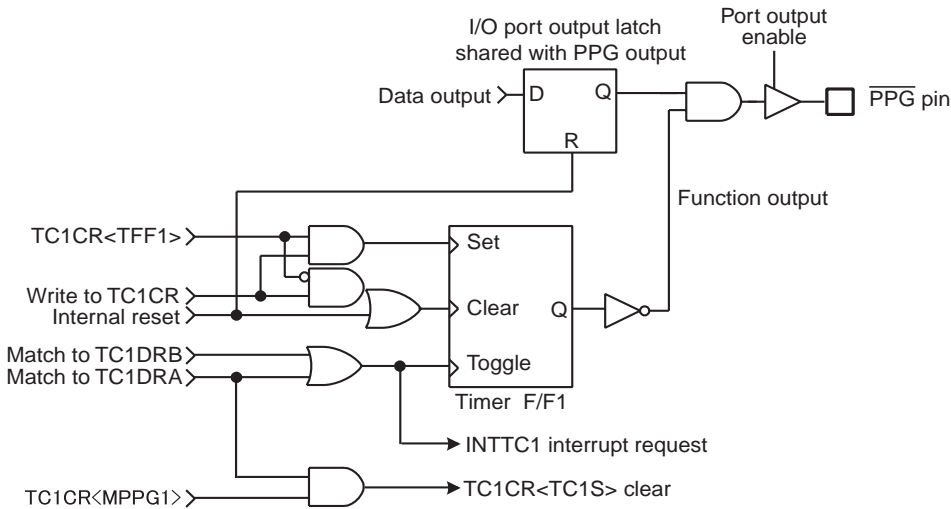
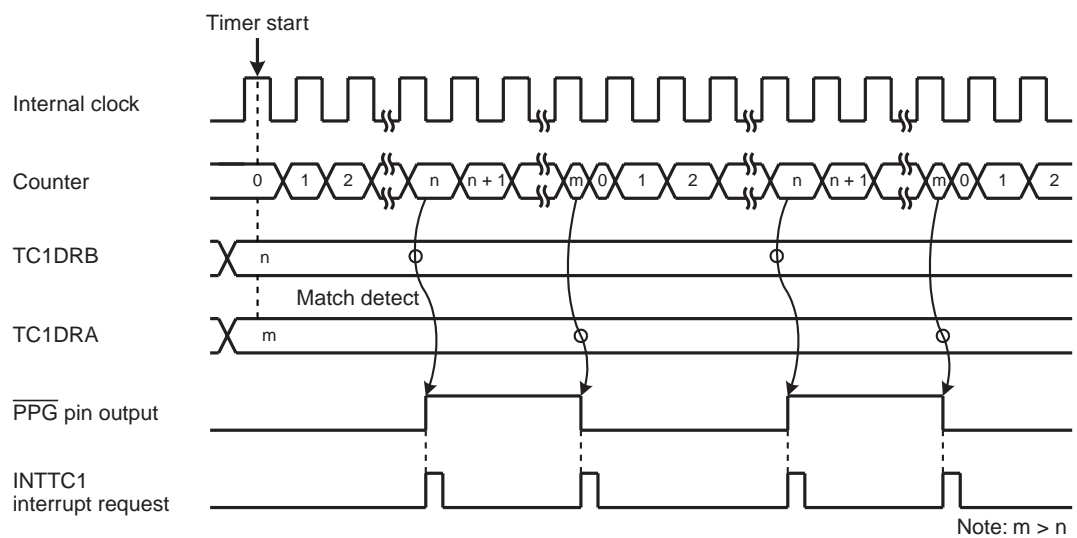
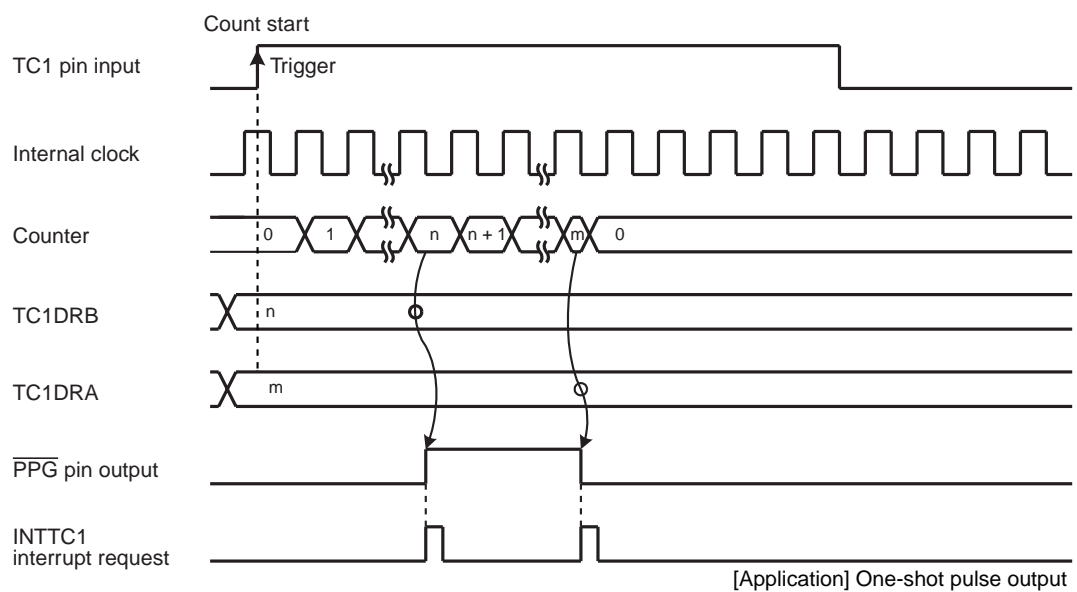


Figure 10-7 $\overline{\text{PPG}}$ Output



(a) Continuous pulse generation ($TC1S = 01$)



[Application] One-shot pulse output

(b) One-shot pulse generation ($TC1S = 10$)

Figure 10-8 PPG Mode Timing Chart



11. 8-Bit TimerCounter (TC3, TC4)

11.1 Configuration

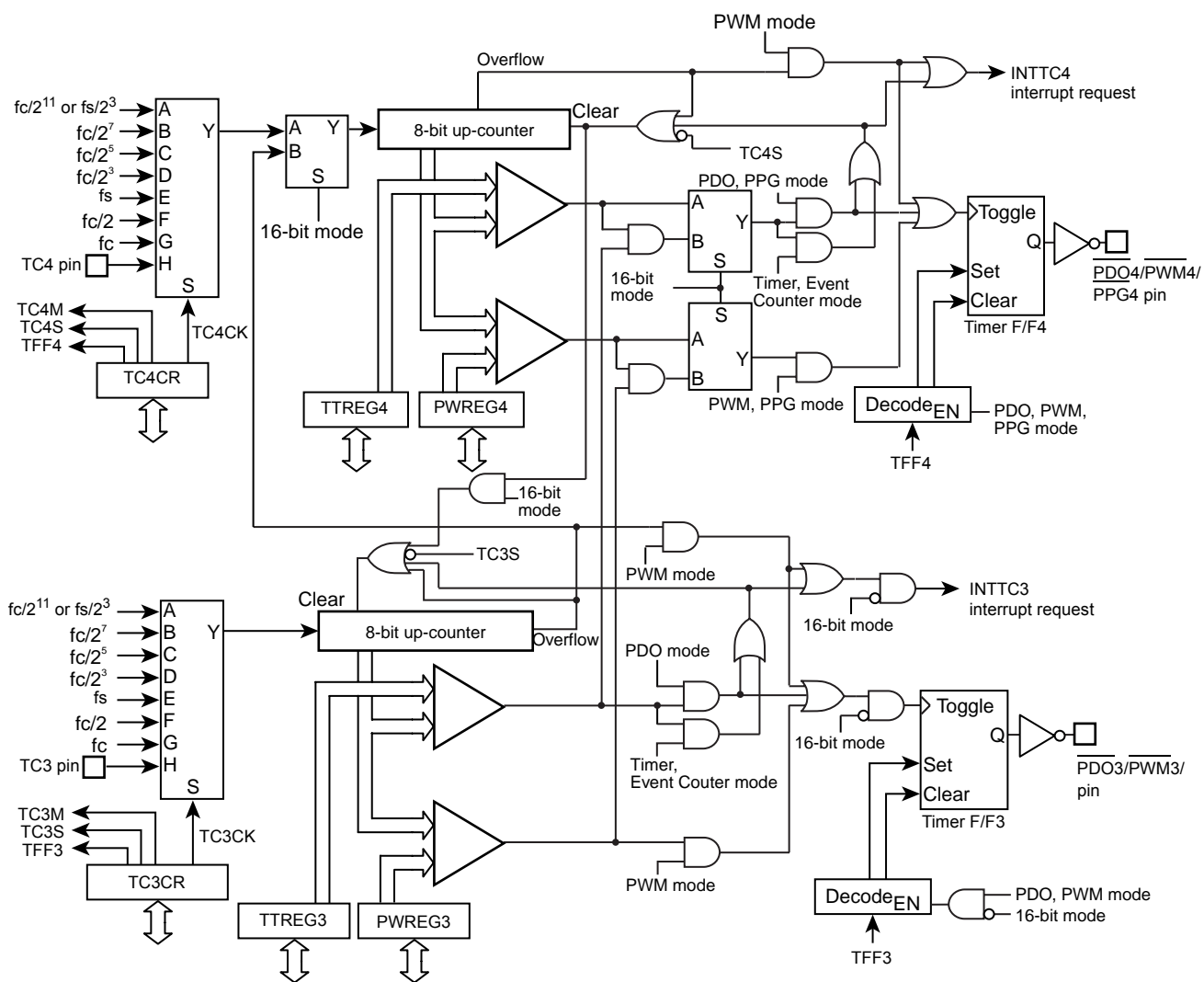


Figure 11-1 8-Bit TimerCounter 3, 4

11.2 TimerCounter Control

The TimerCounter 3 is controlled by the TimerCounter 3 control register (TC3CR) and two 8-bit timer registers (TTREG3, PWREG3).

TimerCounter 3 Timer Register

TTREG3 (0019H) R/W	7	6	5	4	3	2	1	0	(Initial value: 1111 1111)

PWREG3 (0017H) R/W	7	6	5	4	3	2	1	0	(Initial value: 1111 1111)

- Note 1: Do not change the timer register (TTREG3) setting while the timer is running.
- Note 2: Do not change the timer register (PWREG3) setting in the operating mode except the 8-bit and 16-bit PWM modes while the timer is running.

TimerCounter 3 Control Register

TC3CR (0015H)	7	6	5	4	3	2	1	0	(Initial value: 0000 0000)
	TFF3	TC3CK			TC3S	TC3M			

TFF3	Time F/F3 control	0: Clear 1: Set				R/W
TC3CK	Operating clock selection [Hz]		NORMAL1/2, IDLE1/2 mode		SLOW1/2 SLEEP1/2 mode	R/W
			DV7CK = 0	DV7CK = 1		
		000	fc/2 ¹¹	fs/2 ³	fs/2 ³	
		001	fc/2 ⁷	fc/2 ⁷	—	
		010	fc/2 ⁵	fc/2 ⁵	—	
		011	fc/2 ³	fc/2 ³	—	
		100	fs	fs	fs	
		101	fc/2	fc/2	—	
		110	fc	fc	fc (Note 8)	
111	TC3 pin input					
TC3S	TC3 start control	0: Operation stop and counter clear 1: Operation start				R/W
TC3M	TC3M operating mode select	000: 8-bit timer/event counter mode 001: 8-bit programmable divider output (PDO) mode 010: 8-bit pulse width modulation (PWM) output mode 011: 16-bit mode (Each mode is selectable with TC4M.) 1**: Reserved				R/W

- Note 1: fc: High-frequency clock [Hz] fs: Low-frequency clock[Hz]
- Note 2: Do not change the TC3M, TC3CK and TFF3 settings while the timer is running.
- Note 3: To stop the timer operation (TC3S= 1 → 0), do not change the TC3M, TC3CK and TFF3 settings. To start the timer operation (TC3S= 0 → 1), TC3M, TC3CK and TFF3 can be programmed.
- Note 4: To use the TimerCounter in the 16-bit mode, set the operating mode by programming TC4CR<TC4M>, where TC3M must be fixed to 011.
- Note 5: To use the TimerCounter in the 16-bit mode, select the source clock by programming TC3CK. Set the timer start control and timer F/F control by programming TC4CR<TC4S> and TC4CR<TFF4>, respectively.
- Note 6: The operating clock settings are limited depending on the timer operating mode. For the detailed descriptions, see Table 11-1 and Table 11-2.

Note 7: The timer register settings are limited depending on the timer operating mode. For the detailed descriptions, see Table 11-3.

Note 8: The operating clock f_c in the SLOW or SLEEP mode can be used only as the high-frequency warm-up mode.



11. 8-Bit TimerCounter (TC3, TC4)

11.1 Configuration

TMP86CH12MG

The TimerCounter 4 is controlled by the TimerCounter 4 control register (TC4CR) and two 8-bit timer registers (TTREG4 and PWREG4).

TimerCounter 4 Timer Register

TTREG4 (001AH) R/W	7	6	5	4	3	2	1	0	(Initial value: 1111 1111)

PWREG4 (0018H) R/ W	7	6	5	4	3	2	1	0	(Initial value: 1111 1111)

Note 1: Do not change the timer register (TTREG4) setting while the timer is running.

Note 2: Do not change the timer register (PWREG4) setting in the operating mode except the 8-bit and 16-bit PWM modes while the timer is running.

TimerCounter 4 Control Register

TC4CR (0016H)	7	6	5	4	3	2	1	0	(Initial value: 0000 0000)
	TFF4	TC4CK			TC4S	TC4M			

TFF4	Timer F/F4 control	0: Clear 1: Set				R/W
TC4CK	Operating clock selection [Hz]		NORMAL1/2, IDLE1/2 mode		SLOW1/2 SLEEP1/2 mode	R/W
			DV7CK = 0	DV7CK = 1		
		000	fc/2 ¹¹	fs/2 ³	fs/2 ³	
		001	fc/2 ⁷	fc/2 ⁷	—	
		010	fc/2 ⁵	fc/2 ⁵	—	
		011	fc/2 ³	fc/2 ³	—	
		100	fs	fs	fs	
		101	fc/2	fc/2	—	
		110	fc	fc	—	
		111	TC4 pin input			
TC4S	TC4 start control	0: Operation stop and counter clear 1: Operation start				R/W
TC4M	TC4M operating mode select	000: 8-bit timer/event counter mode 001: 8-bit programmable divider output (PDO) mode 010: 8-bit pulse width modulation (PWM) output mode 011: Reserved 100: 16-bit timer/event counter mode 101: Warm-up counter mode 110: 16-bit pulse width modulation (PWM) output mode 111: 16-bit PPG mode				R/W

Note 1: fc: High-frequency clock [Hz] fs: Low-frequency clock [Hz]

Note 2: Do not change the TC4M, TC4CK and TFF4 settings while the timer is running.

Note 3: To stop the timer operation (TC4S= 1 → 0), do not change the TC4M, TC4CK and TFF4 settings.
To start the timer operation (TC4S= 0 → 1), TC4M, TC4CK and TFF4 can be programmed.

Note 4: When TC4M= 1** (upper byte in the 16-bit mode), the source clock becomes the TC4 overflow signal regardless of the TC3CK setting.

Note 5: To use the TimerCounter in the 16-bit mode, select the operating mode by programming TC4M, where TC3CR<TC3 M> must be set to 011.

Note 6: To the TimerCounter in the 16-bit mode, select the source clock by programming TC3CR<TC3CK>. Set the timer start control and timer F/F control by programming TC4S and TFF4, respectively.

Note 7: The operating clock settings are limited depending on the timer operating mode. For the detailed descriptions, see Table 11-1 and Table 11-2.

Note 8: The timer register settings are limited depending on the timer operating mode. For the detailed descriptions, see Table 11-3.

Table 11-1 Operating Mode and Selectable Source Clock (NORMAL1/2 and IDLE1/2 Modes)

Operating mode	$fc/2^{11}$ or $fs/2^3$	$fc/2^7$	$fc/2^5$	$fc/2^3$	fs	$fc/2$	fc	TC3 pin input	TC4 pin input
8-bit timer	O	O	O	O	—	—	—	—	—
8-bit event counter	—	—	—	—	—	—	—	O	O
8-bit PDO	O	O	O	O	—	—	—	—	—
8-bit PWM	O	O	O	O	O	O	O	—	—
16-bit timer	O	O	O	O	—	—	—	—	—
16-bit event counter	—	—	—	—	—	—	—	O	—
Warm-up counter	—	—	—	—	O	—	—	—	—
16-bit PWM	O	O	O	O	O	O	O	O	—
16-bit PPG	O	O	O	O	—	—	—	O	—

Note 1: For 16-bit operations (16-bit timer/event counter, warm-up counter, 16-bit PWM and 16-bit PPG), set its source clock on lower bit (TC3CK).

Note 2: O : Available source clock

Table 11-2 Operating Mode and Selectable Source Clock (SLOW1/2 and SLEEP1/2 Modes)

Operating mode	$fc/2^{11}$ or $fs/2^3$	$fc/2^7$	$fc/2^5$	$fc/2^3$	fs	$fc/2$	fc	TC3 pin input	TC4 pin input
8-bit timer	O	—	—	—	—	—	—	—	—
8-bit event counter	—	—	—	—	—	—	—	O	O
8-bit PDO	O	—	—	—	—	—	—	—	—
8-bit PWM	O	—	—	—	O	—	—	—	—
16-bit timer	O	—	—	—	—	—	—	—	—
16-bit event counter	—	—	—	—	—	—	—	O	—
Warm-up counter	—	—	—	—	—	—	O	—	—
16-bit PWM	O	—	—	—	O	—	—	O	—
16-bit PPG	O	—	—	—	—	—	—	O	—

Note1: For 16-bit operations (16-bit timer/event counter, warm-up counter, 16-bit PWM and 16-bit PPG), set its source clock on lower bit (TC3CK).

Note2: O : Available source clock

Table 11-3 Constraints on Register Values Being Compared

Operating mode	Register Value
8-bit timer/event counter	$1 \leq (TTREGn) \leq 255$
8-bit PDO	$1 \leq (TTREGn) \leq 255$
8-bit PWM	$2 \leq (PWREGn) \leq 254$
16-bit timer/event counter	$1 \leq (TTREG4, 3) \leq 65535$
Warm-up counter	$256 \leq (TTREG4, 3) \leq 65535$
16-bit PWM	$2 \leq (PWREG4, 3) \leq 65534$
16-bit PPG	$1 \leq (PWREG4, 3) < (TTREG4, 3) \leq 65535$ and $(PWREG4, 3) + 1 < (TTREG4, 3)$

Note: n = 3 to 4

11.3 Function

The TimerCounter 3 and 4 have the 8-bit timer, 8-bit event counter, 8-bit programmable divider output (PDO), 8-bit pulse width modulation (PWM) output modes. The TimerCounter 3 and 4 (TC3, 4) are cascadable to form a 16-bit timer. The 16-bit timer has the operating modes such as the 16-bit timer, 16-bit event counter, warm-up counter, 16-bit pulse width modulation (PWM) output and 16-bit programmable pulse generation (PPG) modes.

11.3.1 8-Bit Timer Mode (TC3 and 4)

In the timer mode, the up-counter counts up using the internal clock. When a match between the up-counter and the timer register j (TTREG j) value is detected, an INTTC j interrupt is generated and the up-counter is cleared. After being cleared, the up-counter restarts counting.

Note 1: In the timer mode, fix TCjCR<TFFj> to 0. If not fixed, the $\overline{\text{PDO}}_j$, $\overline{\text{PWM}}_j$ and $\overline{\text{PPG}}_j$ pins may output pulses.

Note 2: In the timer mode, do not change the TTREG j setting while the timer is running. Since TTREG j is not in the shift register configuration in the timer mode, the new value programmed in TTREG j is in effect immediately after the programming. Therefore, if TTREG i is changed while the timer is running, an expected operation may not be obtained.

Note 3: $j = 3, 4$

Table 11-4 Source Clock for TimerCounter 3, 4 (Internal Clock)

Source Clock			Resolution		Repeated Cycle	
NORMAL1/2, IDLE1/2 mode		SLOW1/2, SLEEP1/2 mode	$f_c = 16 \text{ MHz}$	$f_s = 32.768 \text{ kHz}$	$f_c = 16 \text{ MHz}$	$f_s = 32.768 \text{ kHz}$
DV7CK = 0	DV7CK = 1					
$f_c/2^{11} [\text{Hz}]$	$f_s/2^3 [\text{Hz}]$	$f_s/2^3 [\text{Hz}]$	128 μs	244.14 μs	32.6 ms	62.3 ms
$f_c/2^7$	$f_c/2^7$	—	8 μs	—	2.0 ms	—
$f_c/2^5$	$f_c/2^5$	—	2 μs	—	510 μs	—
$f_c/2^3$	$f_c/2^3$	—	500 ns	—	127.5 μs	—

Example :Setting the timer mode with source clock $f_c/2^7 \text{ Hz}$ and generating an interrupt 80 μs later (TimerCounter4, $f_c = 16.0 \text{ MHz}$)

```
LD      (TTREG4), 0AH      : Sets the timer register (80  $\mu\text{s} = 2^7/f_c = 0AH$ ).
DI
SET     (EIRH), 5          : Enables INTTC4 interrupt.
EI
LD      (TC4CR), 00010000B : Sets the operating clock to  $f_c/2^7$ , and 8-bit timer mode.
LD      (TC4CR), 00011000B : Starts TC4.
```

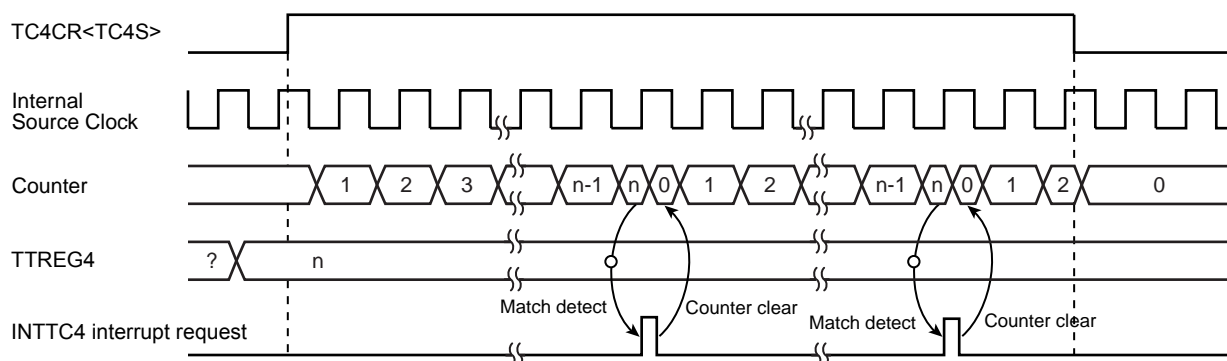


Figure 11-2 8-Bit Timer Mode Timing Chart (TC4)

11.3.2 8-Bit Event Counter Mode (TC3, 4)

In the 8-bit event counter mode, the up-counter counts up at the falling edge of the input pulse to the TCj pin. When a match between the up-counter and the TTREGj value is detected, an INTTCj interrupt is generated and the up-counter is cleared. After being cleared, the up-counter restarts counting at the falling edge of the input pulse to the TCj pin. Two machine cycles are required for the low- or high-level pulse input to the TCj pin. Therefore, a maximum frequency to be supplied is $fc/2^4$ Hz in the NORMAL1/2 or IDLE1/2 mode, and $fs/2^4$ Hz in the SLOW1/2 or SLEEP1/2 mode.

Note 1: In the event counter mode, fix TCjCR<TFFj> to 0. If not fixed, the $\overline{PDO_j}$, $\overline{PWM_j}$ and $\overline{PPG_j}$ pins may output pulses.

Note 2: In the event counter mode, do not change the TTREGj setting while the timer is running. Since TTREGj is not in the shift register configuration in the event counter mode, the new value programmed in TTREGj is in effect immediately after the programming. Therefore, if TTREGi is changed while the timer is running, an expected operation may not be obtained.

Note 3: j = 3, 4

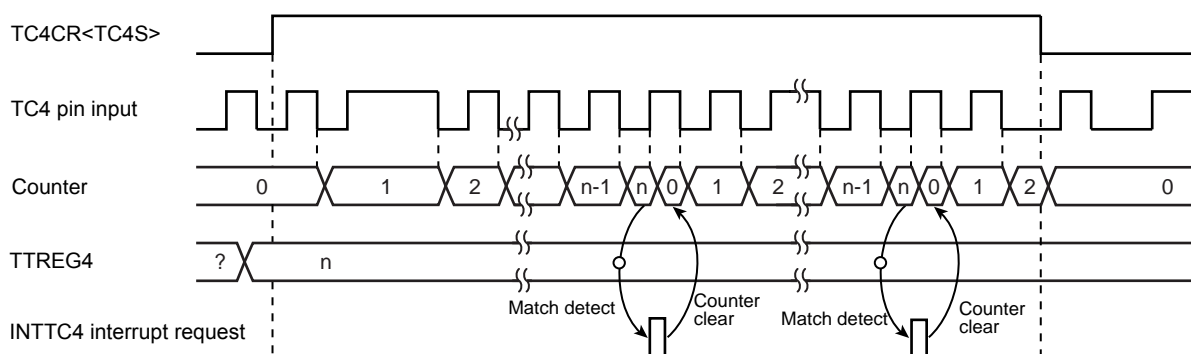


Figure 11-3 8-Bit Event Counter Mode Timing Chart (TC4)

11.3.3 8-Bit Programmable Divider Output (PDO) Mode (TC3, 4)

This mode is used to generate a pulse with a 50% duty cycle from the $\overline{PDO_j}$ pin.

In the PDO mode, the up-counter counts up using the internal clock. When a match between the up-counter and the TTREGj value is detected, the logic level output from the $\overline{PDO_j}$ pin is switched to the opposite state and the up-counter is cleared. The INTTCj interrupt request is generated at the time. The logic state opposite to the timer F/Fj logic level is output from the $\overline{PDO_j}$ pin. An arbitrary value can be set to the timer F/Fj by TCjCR<TFFj>. Upon reset, the timer F/Fj value is initialized to 0.

To use the programmable divider output, set the output latch of the I/O port to 1.

Example :Generating 1024 Hz pulse using TC4 ($f_c = 16.0 \text{ MHz}$)

Setting port		
LD	(TTREG4), 3DH	: $1/1024 \div 2^7 / f_c \div 2 = 3\text{DH}$
LD	(TC4CR), 00010001B	: Sets the operating clock to $f_c/2^7$, and 8-bit PDO mode.
LD	(TC4CR), 00011001B	: Starts TC4.

Note 1: In the programmable divider output mode, do not change the TTREGj setting while the timer is running.
Since TTREGj is not in the shift register configuration in the programmable divider output mode, the new value programmed in TTREGj is in effect immediately after programming. Therefore, if TTREGi is changed while the timer is running, an expected operation may not be obtained.

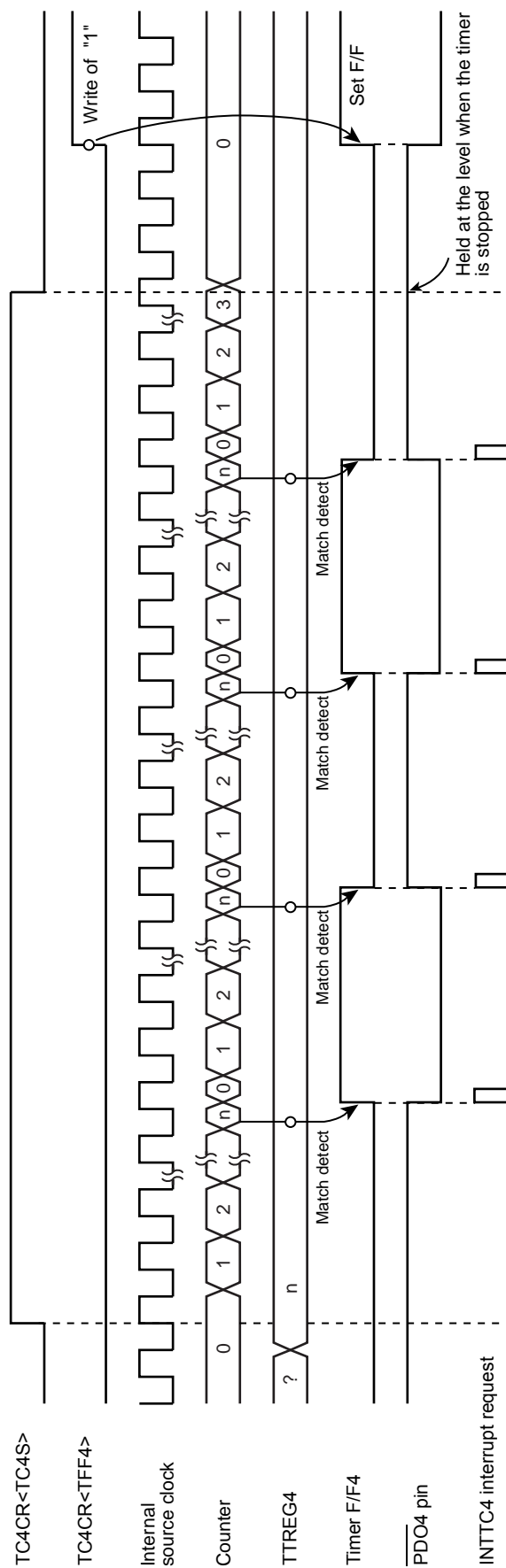
Note 2: When the timer is stopped during PDO output, the $\overline{\text{PDOj}}$ pin holds the output status when the timer is stopped. To change the output status, program TCjCR<TFFj> after the timer is stopped. Do not change the TCjCR<TFFj> setting upon stopping of the timer.

Example: Fixing the $\overline{\text{PDOj}}$ pin to the high level when the TimerCounter is stopped

CLR (TCjCR).3: Stops the timer.

CLR (TCjCR).7: Sets the $\overline{\text{PDOj}}$ pin to the high level.

Note 3: j = 3, 4



11.3.4 8-Bit Pulse Width Modulation (PWM) Output Mode (TC3, 4)

This mode is used to generate a pulse-width modulated (PWM) signals with up to 8 bits of resolution. The up-counter counts up using the internal clock.

When a match between the up-counter and the PWREGj value is detected, the logic level output from the timer F/Fj is switched to the opposite state. The counter continues counting. The logic level output from the timer F/Fj is switched to the opposite state again by the up-counter overflow, and the counter is cleared. The INTTCj interrupt request is generated at this time.

Since the initial value can be set to the timer F/Fj by TCjCR<TFFj>, positive and negative pulses can be generated. Upon reset, the timer F/Fj is cleared to 0.

(The logic level output from the $\overline{\text{PWMj}}$ pin is the opposite to the timer F/Fj logic level.)

Since PWREGj in the PWM mode is serially connected to the shift register, the value set to PWREGj can be changed while the timer is running. The value set to PWREGj during a run of the timer is shifted by the INTTCj interrupt request and loaded into PWREGj. While the timer is stopped, the value is shifted immediately after the programming of PWREGj. If executing the read instruction to PWREGj during PWM output, the value in the shift register is read, but not the value set in PWREGj. Therefore, after writing to PWREGj, the reading data of PWREGj is previous value until INTTCj is generated.

For the pin used for PWM output, the output latch of the I/O port must be set to 1.

Note 1: In the PWM mode, program the timer register PWREGj immediately after the INTTCj interrupt request is generated (normally in the INTTCj interrupt service routine.) If the programming of PWREGj and the interrupt request occur at the same time, an unstable value is shifted, that may result in generation of the pulse different from the programmed value until the next INTTCj interrupt request is generated.

Note 2: When the timer is stopped during PWM output, the $\overline{\text{PWMj}}$ pin holds the output status when the timer is stopped. To change the output status, program TCjCR<TFFj> after the timer is stopped. Do not change the TCjCR<TFFj> upon stopping of the timer.

Example: Fixing the $\overline{\text{PWMj}}$ pin to the high level when the TimerCounter is stopped

CLR (TCjCR).3: Stops the timer.

CLR (TCjCR).7: Sets the $\overline{\text{PWMj}}$ pin to the high level.

Note 3: To enter the STOP mode during PWM output, stop the timer and then enter the STOP mode. If the STOP mode is entered without stopping the timer when fc, fc/2 or fs is selected as the source clock, a pulse is output from the $\overline{\text{PWMj}}$ pin during the warm-up period time after exiting the STOP mode.

Note 4: j = 3, 4

Table 11-5 PWM Output Mode

Source Clock			Resolution		Repeated Cycle	
NORMAL1/2, IDLE1/2 mode		SLOW1/2, SLEEP1/2 mode	fc = 16 MHz	fs = 32.768 kHz	fc = 16 MHz	fs = 32.768 kHz
DV7CK = 0	DV7CK = 1					
fc/2 ¹¹ [Hz]	fs/2 ³ [Hz]	fs/2 ³ [Hz]	128 μ s	244.14 μ s	32.8 ms	62.5 ms
fc/2 ⁷	fc/2 ⁷	—	8 μ s	—	2.05 ms	—
fc/2 ⁵	fc/2 ⁵	—	2 μ s	—	512 μ s	—
fc/2 ³	fc/2 ³	—	500 ns	—	128 μ s	—
fs	fs	fs	30.5 μ s	30.5 μ s	7.81 ms	7.81 ms
fc/2	fc/2	—	125 ns	—	32 μ s	—
fc	fc	—	62.5 ns	—	16 μ s	—

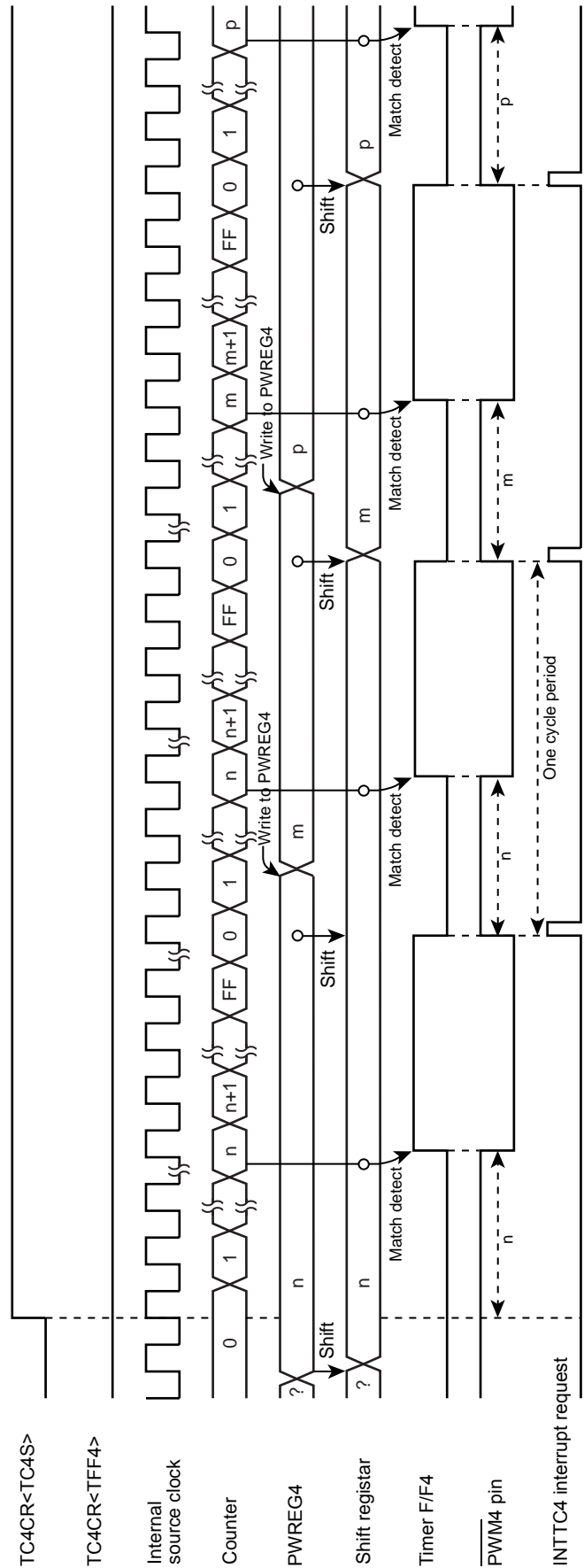


Figure 11-5 8-Bit PWM Mode Timing Chart (TC4)

11.3.5 16-Bit Timer Mode (TC3 and 4)

In the timer mode, the up-counter counts up using the internal clock. The TimerCounter 3 and 4 are cascad-able to form a 16-bit timer.

When a match between the up-counter and the timer register (TTREG3, TTREG4) value is detected after the timer is started by setting TC4CR<TC4S> to 1, an INTTC4 interrupt is generated and the up-counter is cleared. After being cleared, the up-counter continues counting. Program the upper byte and lower byte in this order in the timer register. (Programming only the upper or lower byte should not be attempted.)

- Note 1: In the timer mode, fix TCjCR<TFFj> to 0. If not fixed, the $\overline{\text{PDOj}}$, $\overline{\text{PWMj}}$, and $\overline{\text{PPGj}}$ pins may output a pulse.
- Note 2: In the timer mode, do not change the TTREGj setting while the timer is running. Since TTREGj is not in the shift register configuration in the timer mode, the new value programmed in TTREGj is in effect immediately after programming of TTREGj. Therefore, if TTREGj is changed while the timer is running, an expected operation may not be obtained.
- Note 3: j = 3, 4

Table 11-6 Source Clock for 16-Bit Timer Mode

Source Clock			Resolution		Repeated Cycle	
NORMAL1/2, IDLE1/2 mode		SLOW1/2, SLEEP1/2 mode	fc = 16 MHz	fs = 32.768 kHz	fc = 16 MHz	fs = 32.768 kHz
DV7CK = 0	DV7CK = 1					
fc/2 ¹¹	fs/2 ³	fs/2 ³	128 μs	244.14 μs	8.39 s	16 s
fc/2 ⁷	fc/2 ⁷	—	8 μs	—	524.3 ms	—
fc/2 ⁵	fc/2 ⁵	—	2 μs	—	131.1 ms	—
fc/2 ³	fc/2 ³	—	500 ns	—	32.8 ms	—

Example :Setting the timer mode with source clock fc/2⁷ Hz, and generating an interrupt 300 ms later
(fc = 16.0 MHz)

- LDW (TTREG3), 927CH : Sets the timer register (300 ms÷2⁷/fc = 927CH).
- DI
- SET (EIRH). 5 : Enables INTTC4 interrupt.
- EI
- LD (TC3CR), 13H :Sets the operating cock to fc/2⁷, and 16-bit timer mode (lower byte).
- LD (TC4CR), 04H : Sets the 16-bit timer mode (upper byte).
- LD (TC4CR), 0CH : Starts the timer.

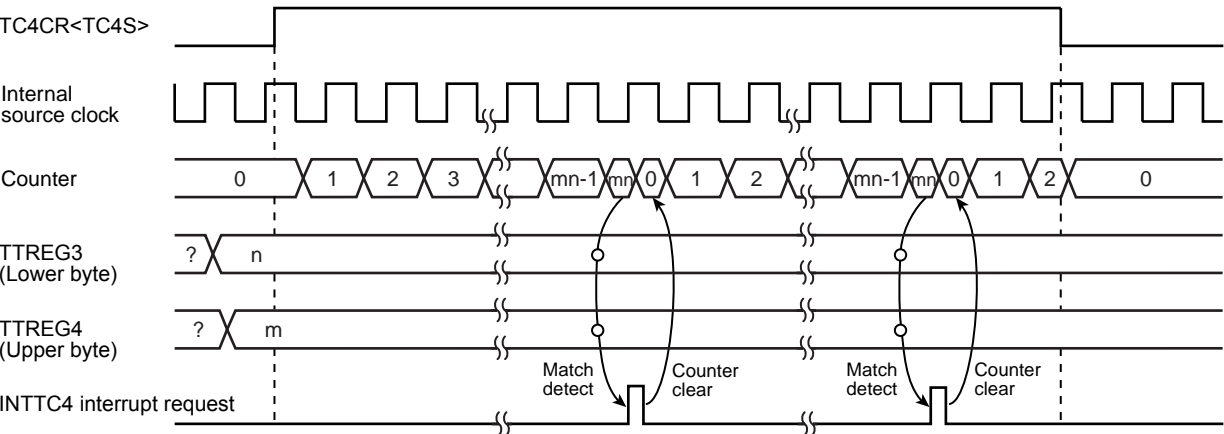


Figure 11-6 16-Bit Timer Mode Timing Chart (TC3 and TC4)

11.3.6 16-Bit Event Counter Mode (TC3 and 4)

In the event counter mode, the up-counter counts up at the falling edge to the TC3 pin. The TimerCounter 3 and 4 are cascadable to form a 16-bit event counter.

When a match between the up-counter and the timer register (TTREG3, TTREG4) value is detected after the timer is started by setting TC4CR<TC4S> to 1, an INTTC4 interrupt is generated and the up-counter is cleared.

After being cleared, the up-counter restarts counting at the falling edge of the input pulse to the TC3 pin. Two machine cycles are required for the low- or high-level pulse input to the TC3 pin.

Therefore, a maximum frequency to be supplied is $f_c/2^4$ Hz in the NORMAL1 or IDLE1 mode, and $f_s/2^4$ in the SLOW1/2 or SLEEP1/2 mode. Program the lower byte (TTREG3), and upper byte (TTREG4) in this order in the timer register. (Programming only the upper or lower byte should not be attempted.)

Note 1: In the event counter mode, fix TCjCR<TFFj> to 0. If not fixed, the \overline{PDOj} , \overline{PWMj} and \overline{PPGj} pins may output pulses.

Note 2: In the event counter mode, do not change the TTREGj setting while the timer is running. Since TTREGj is not in the shift register configuration in the event counter mode, the new value programmed in TTREGj is in effect immediately after the programming. Therefore, if TTREGj is changed while the timer is running, an expected operation may not be obtained.

Note 3: j = 3, 4

11.3.7 16-Bit Pulse Width Modulation (PWM) Output Mode (TC3 and 4)

This mode is used to generate a pulse-width modulated (PWM) signals with up to 16 bits of resolution. The TimerCounter 3 and 4 are cascadable to form the 16-bit PWM signal generator.

The counter counts up using the internal clock or external clock.

When a match between the up-counter and the timer register (PWREG3, PWREG4) value is detected, the logic level output from the timer F/F4 is switched to the opposite state. The counter continues counting. The logic level output from the timer F/F4 is switched to the opposite state again by the counter overflow, and the counter is cleared. The INTTC4 interrupt is generated at this time.

Two machine cycles are required for the high- or low-level pulse input to the TC3 pin. Therefore, a maximum frequency to be supplied is $f_c/2^4$ Hz in the NORMAL1 or IDLE1 mode, and $f_s/2^4$ to in the SLOW1/2 or SLEEP1/2 mode.

Since the initial value can be set to the timer F/F4 by TC4CR<TFF4>, positive and negative pulses can be generated. Upon reset, the timer F/F4 is cleared to 0.

(The logic level output from the $\overline{PWM4}$ pin is the opposite to the timer F/F4 logic level.)

Since PWREG4 and 3 in the PWM mode are serially connected to the shift register, the values set to PWREG4 and 3 can be changed while the timer is running. The values set to PWREG4 and 3 during a run of the timer are shifted by the INTTCj interrupt request and loaded into PWREG4 and 3. While the timer is stopped, the values are shifted immediately after the programming of PWREG4 and 3. Set the lower byte (PWREG3) and upper byte (PWREG3) in this order to program PWREG4 and 3. (Programming only the lower or upper byte of the register should not be attempted.)

If executing the read instruction to PWREG4 and 3 during PWM output, the values set in the shift register is read, but not the values set in PWREG4 and 3. Therefore, after writing to the PWREG4 and 3, reading data of PWREG4 and 3 is previous value until INTTC4 is generated.

For the pin used for PWM output, the output latch of the I/O port must be set to 1.

Note 1: In the PWM mode, program the timer register PWREG4 and 3 immediately after the INTTC4 interrupt request is generated (normally in the INTTC4 interrupt service routine.) If the programming of PWREGj and the interrupt request occur at the same time, an unstable value is shifted, that may result in generation of pulse different from the programmed value until the next INTTC4 interrupt request is generated.

Note 2: When the timer is stopped during PWM output, the $\overline{PWM4}$ pin holds the output status when the timer is stopped. To change the output status, program TC4CR<TFF4> after the timer is stopped. Do not program TC4CR<TFF4> upon stopping of the timer.

Example: Fixing the $\overline{PWM4}$ pin to the high level when the TimerCounter is stopped

CLR (TC4CR).3: Stops the timer.
CLR (TC4CR).7 : Sets the PWM4 pin to the high level.

Note 3: To enter the STOP mode, stop the timer and then enter the STOP mode. If the STOP mode is entered without stopping of the timer when f_c , $f_c/2$ or f_s is selected as the source clock, a pulse is output from the $\overline{\text{PWM4}}$ pin during the warm-up period time after exiting the STOP mode.

Table 11-7 16-Bit PWM Output Mode

Source Clock			Resolution		Repeated Cycle	
NORMAL1/2, IDLE1/2 mode		SLOW1/2, SLEEP1/2 mode	$f_c = 16 \text{ MHz}$	$f_s = 32.768 \text{ kHz}$	$f_c = 16 \text{ MHz}$	$f_s = 32.768 \text{ kHz}$
DV7CK = 0	DV7CK = 1					
$f_c/2^{11}$	$f_s/2^3 \text{ [Hz]}$	$f_s/2^3 \text{ [Hz]}$	128 μs	244.14 μs	8.39 s	16 s
$f_c/2^7$	$f_c/2^7$	—	8 μs	—	524.3 ms	—
$f_c/2^5$	$f_c/2^5$	—	2 μs	—	131.1 ms	—
$f_c/2^3$	$f_c/2^3$	—	500ns	—	32.8 ms	—
f_s	f_s	f_s	30.5 μs	30.5 μs	2 s	2 s
$f_c/2$	$f_c/2$	—	125 ns	—	8.2 ms	—
f_c	f_c	—	62.5 ns	—	4.1 ms	—

Example :Generating a pulse with 1-ms high-level width and a period of 32.768 ms ($f_c = 16.0 \text{ MHz}$)

Setting ports

LDW	(PWREG3), 07D0H	: Sets the pulse width.
LD	(TC3CR), 33H	: Sets the operating clock to $f_c/2^3$, and 16-bit PWM output mode (lower byte).
LD	(TC4CR), 056H	: Sets TFF4 to the initial value 0, and 16-bit PWM signal generation mode (upper byte).
LD	(TC4CR), 05EH	: Starts the timer.

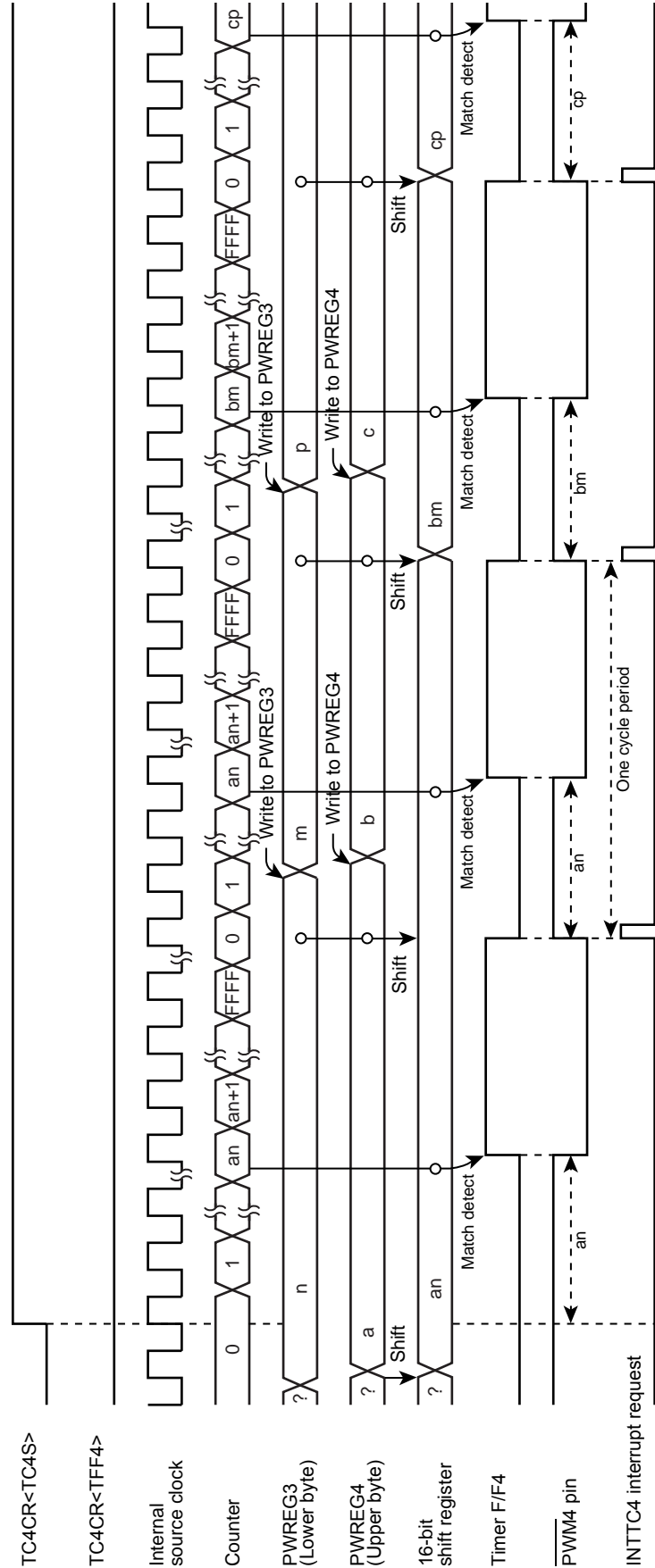


Figure 11-7 16-Bit PWM Mode Timing Chart (TC3 and TC4)

11.3.8 16-Bit Programmable Pulse Generate (PPG) Output Mode (TC3 and 4)

This mode is used to generate pulses with up to 16-bits of resolution. The timer counter 3 and 4 are cascaded to enter the 16-bit PPG mode.

The counter counts up using the internal clock or external clock. When a match between the up-counter and the timer register (PWREG3, PWREG4) value is detected, the logic level output from the timer F/F4 is switched to the opposite state. The counter continues counting. The logic level output from the timer F/F4 is switched to the opposite state again when a match between the up-counter and the timer register (TTREG3, TTREG4) value is detected, and the counter is cleared. The INTTC4 interrupt is generated at this time.

Two machine cycles are required for the high- or low-level pulse input to the TC3 pin. Therefore, a maximum frequency to be supplied is $f_c/2^4$ Hz in the NORMAL1 or IDLE1 mode, and $f_c/2^4$ to in the SLOW1/2 or SLEEP1/2 mode.

Since the initial value can be set to the timer F/F4 by TC4CR<TFF4>, positive and negative pulses can be generated. Upon reset, the timer F/F4 is cleared to 0.

(The logic level output from the $\overline{\text{PPG4}}$ pin is the opposite to the timer F/F4.)

Set the lower byte and upper byte in this order to program the timer register. (TTREG3 → TTREG4, PWREG3 → PWREG4) (Programming only the upper or lower byte should not be attempted.)

For PPG output, set the output latch of the I/O port to 1.

Example :Generating a pulse with 1-ms high-level width and a period of 16.385 ms ($f_c = 16.0$ MHz)

Setting ports		
LDW	(PWREG3), 07D0H	: Sets the pulse width.
LDW	(TTREG3), 8002H	: Sets the cycle period.
LD	(TC3CR), 33H	: Sets the operating clock to $f_c/2^3$, and 16-bit PPG mode (lower byte).
LD	(TC4CR), 057H	: Sets TFF4 to the initial value 0, and 16-bit PPG mode (upper byte).
LD	(TC4CR), 05FH	: Starts the timer.

Note 1: In the PPG mode, do not change the PWREGi and TTREGi settings while the timer is running. Since PWREGi and TTREGi are not in the shift register configuration in the PPG mode, the new values programmed in PWREGi and TTREGi are in effect immediately after programming PWREGi and TTREGi. Therefore, if PWREGi and TTREGi are changed while the timer is running, an expected operation may not be obtained.

Note 2: When the timer is stopped during PPG output, the $\overline{\text{PPG4}}$ pin holds the output status when the timer is stopped. To change the output status, program TC4CR<TFF4> after the timer is stopped. Do not change TC4CR<TFF4> upon stopping of the timer.

Example: Fixing the $\overline{\text{PPG4}}$ pin to the high level when the TimerCounter is stopped

CLR (TC4CR).3: Stops the timer

CLR (TC4CR).7: Sets the $\overline{\text{PPG4}}$ pin to the high level

Note 3: i = 3, 4

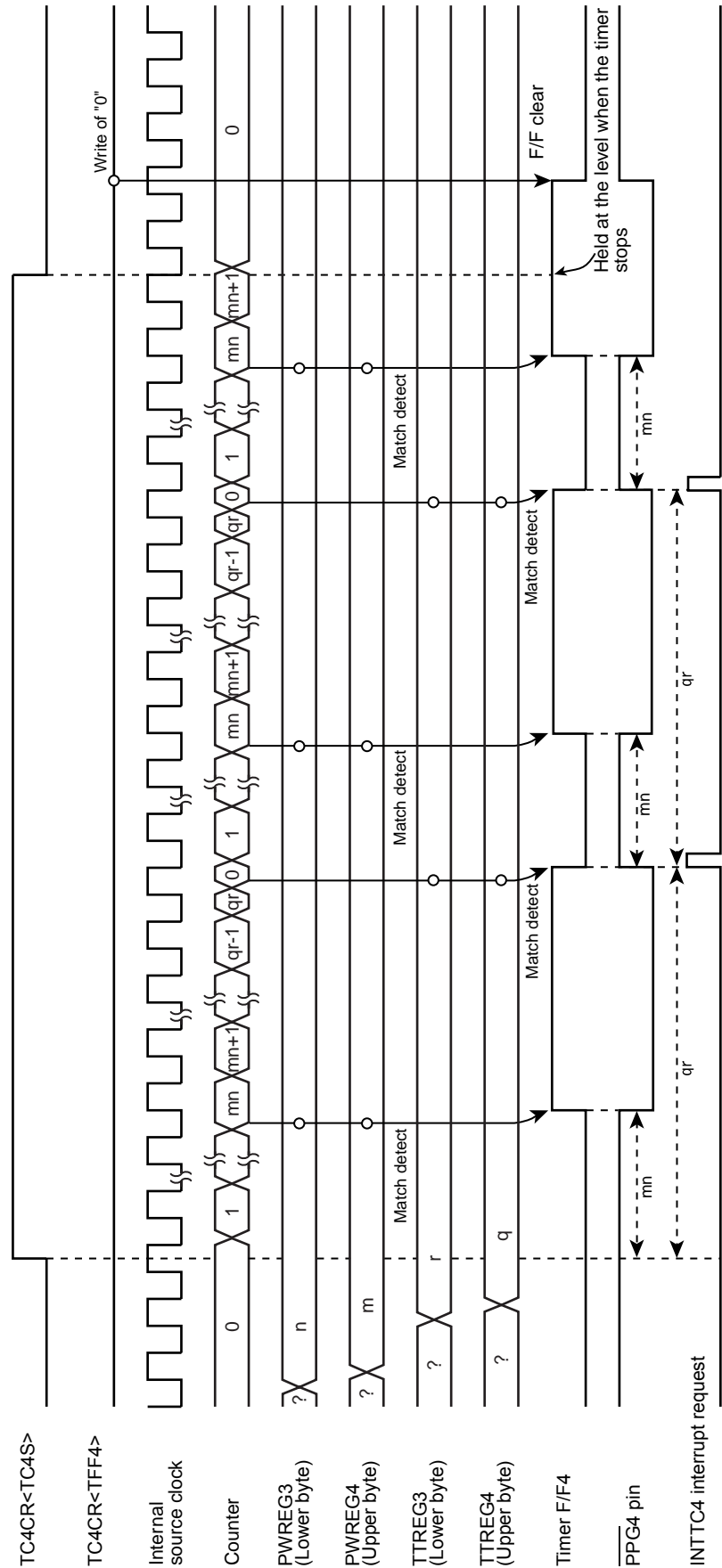


Figure 11-8 16-Bit PPG Mode Timing Chart (TC3 and TC40)

11.3.9 Warm-Up Counter Mode

In this mode, the warm-up period time is obtained to assure oscillation stability when the system clocking is switched between the high-frequency and low-frequency. The timer counter 3 and 4 are cascadable to form a 16-bit TimerCounter. The warm-up counter mode has two types of mode; switching from the high-frequency to low-frequency, and vice-versa.

- Note 1: In the warm-up counter mode, fix TCiCR<TFFi> to 0. If not fixed, the $\overline{PDO_i}$, $\overline{PWM_i}$ and $\overline{PPG_i}$ pins may output pulses.
- Note 2: In the warm-up counter mode, only upper 8 bits of the timer register TTREG4 and 3 are used for match detection and lower 8 bits are not used.
- Note 3: i = 3, 4

11.3.9.1 Low-Frequency Warm-up Counter Mode
(NORMAL1 → NORMAL2 → SLOW2 → SLOW1)

In this mode, the warm-up period time from a stop of the low-frequency clock fs to oscillation stability is obtained. Before starting the timer, set SYSCR2<XTEN> to 1 to oscillate the low-frequency clock. When a match between the up-counter and the timer register (TTREG4, 3) value is detected after the timer is started by setting TC4CR<TC4S> to 1, the counter is cleared by generating the INTTC4 interrupt request. After stopping the timer in the INTTC4 interrupt service routine, set SYSCR2<SYSCK> to 1 to switch the system clock from the high-frequency to low-frequency, and then clear of SYSCR2<XTEN> to 0 to stop the high-frequency clock.

Table 11-8 Setting Time of Low-Frequency Warm-Up Counter Mode (fs = 32.768 kHz)

Maximum Time Setting (TTREG4, 3 = 0100H)	Maximum Time Setting (TTREG4, 3 = FF00H)
7.81 ms	1.99 s

Example :After checking low-frequency clock oscillation stability with TC4 and 3, switching to the SLOW1 mode

	SET	(SYSCR2).6	: SYSCR2<XTEN> ← 1
	LD	(TC3CR), 43H	: Sets TFF3=0, source clock fs, and 16-bit mode.
	LD	(TC4CR), 05H	: Sets TFF4=0, and warm-up counter mode.
	LD	(TTREG3), 8000H	: Sets the warm-up time. (The warm-up time depends on the oscillator characteristic.)
	DI		: IMF ← 0
	SET	(EIRH). 5	: Enables the INTTC4.
	EI		: IMF ← 1
	SET	(TC4CR).3	: Starts TC4 and 3.
	:	:	
PINTTC4:	CLR	(TC4CR).3	: Stops TC4 and 3.
	SET	(SYSCR2).5	: SYSCR2<SYSCK> ← 1 (Switches the system clock to the low-frequency clock.)
	CLR	(SYSCR2).7	: SYSCR2<XEN> ← 0 (Stops the high-frequency clock.)
	RETI		
	:	:	
VINTTC4:	DW	PINTTC4	: INTTC4 vector table

11.3.9.2 High-Frequency Warm-Up Counter Mode
(SLOW1 → SLOW2 → NORMAL2 → NORMAL1)

In this mode, the warm-up period time from a stop of the high-frequency clock f_c to the oscillation stability is obtained. Before starting the timer, set SYSCR2<XEN> to 1 to oscillate the high-frequency clock. When a match between the up-counter and the timer register (TTREG4, 3) value is detected after the timer is started by setting TC4CR<TC4S> to 1, the counter is cleared by generating the INTTC4 interrupt request. After stopping the timer in the INTTC4 interrupt service routine, clear SYSCR2<SYSCK> to 0 to switch the system clock from the low-frequency to high-frequency, and then SYSCR2<XTEN> to 0 to stop the low-frequency clock.

Table 11-9 Setting Time in High-Frequency Warm-Up Counter Mode

Minimum time (TTREG4, 3 = 0100H)	Maximum time (TTREG4, 3 = FF00H)
16 μ s	4.08 ms

Example :After checking high-frequency clock oscillation stability with TC4 and 3, switching to the NORMAL1 mode

	SET	(SYSCR2).7	: SYSCR2<XEN> \leftarrow 1
	LD	(TC3CR), 63H	: Sets TFF3=0, source clock f_s , and 16-bit mode.
	LD	(TC4CR), 05H	: Sets TFF4=0, and warm-up counter mode.
	LD	(TTREG3), 0F800H	: Sets the warm-up time. (The warm-up time depends on the oscillator characteristic.)
	DI		: IMF \leftarrow 0
	SET	(EIRH). 5	: Enables the INTTC4.
	EI		: IMF \leftarrow 1
	SET	(TC4CR).3	: Starts the TC4 and 3.
	:	:	
PINTTC4:	CLR	(TC4CR).3	: Stops the TC4 and 3.
	CLR	(SYSCR2).5	: SYSCR2<SYSCK> \leftarrow 0 (Switches the system clock to the high-frequency clock.)
	CLR	(SYSCR2).6	: SYSCR2<XTEN> \leftarrow 0 (Stops the low-frequency clock.)
	RETI		
	:	:	
VINTTC4:	DW	PINTTC4	: INTTC4 vector table

12. Synchronous Serial Interface (SIO)

The TMP86CH12MG has a clocked-synchronous 8-bit serial interface. Serial interface has an 8-byte transmit and receive data buffer that can automatically and continuously transfer up to 64 bits of data.

Serial interface is connected to outside peripheral devices via SO, SI, SCK port.

12.1 Configuration

SIO control / status register

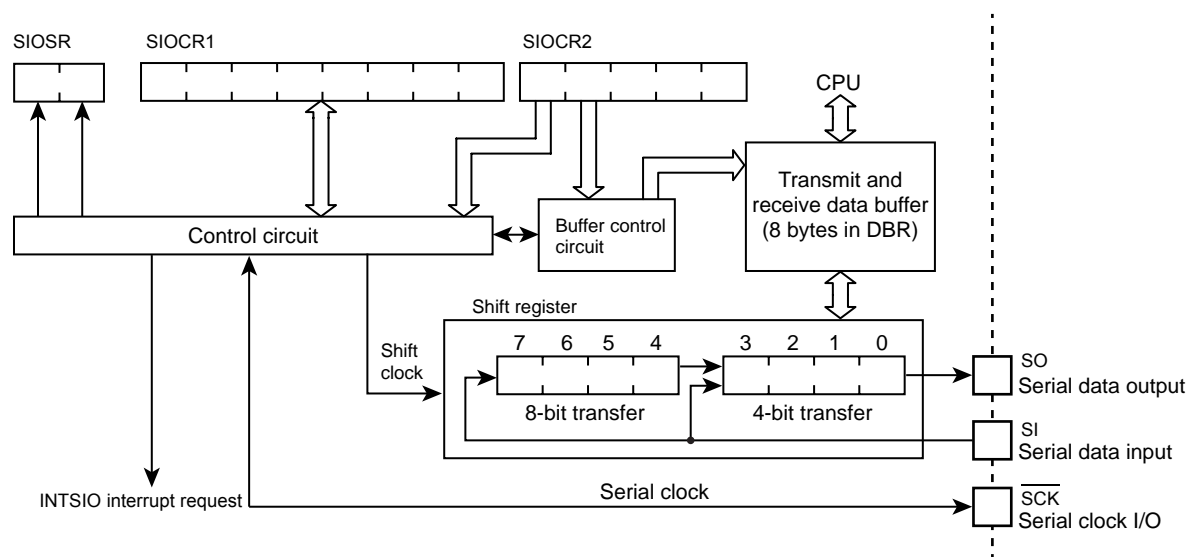


Figure 12-1 Serial Interface

12.2 Control

The serial interface is controlled by SIO control registers (SIOCR1/SIOCR2). The serial interface status can be determined by reading SIO status register (SIOSR).

The transmit and receive data buffer is controlled by the SIOCR2<BUF>. The data buffer is assigned to address 0F80H to 0F87H for SIO in the DBR area, and can continuously transfer up to 8 words (bytes or nibbles) at one time. When the specified number of words has been transferred, a buffer empty (in the transmit mode) or a buffer full (in the receive mode or transmit/receive mode) interrupt (INTSIO) is generated.

When the internal clock is used as the serial clock in the 8-bit receive mode and the 8-bit transmit/receive mode, a fixed interval wait can be applied to the serial clock for each word transferred. Four different wait times can be selected with SIOCR2<WAIT>.

SIO Control Register 1

SIOCR1	7	6	5	4	3	2	1	0	
(0031H)	SIOS	SIOINH	SIOM			SCK			(Initial value: 0000 0000)

SIOS	Indicate transfer start / stop	0: Stop 1: Start			Write only	
SIOINH	Continue / abort transfer	0: Continuously transfer 1: Abort transfer (Automatically cleared after abort)				
SIOM	Transfer mode select	000: 8-bit transmit mode 010: 4-bit transmit mode 100: 8-bit transmit / receive mode 101: 8-bit receive mode 110: 4-bit receive mode Except the above: Reserved				
SCK	Serial clock select		NORMAL1/2, IDLE1/2 mode		SLOW1/2 SLEEP1/2 mode	Write only
			DV7CK = 0	DV7CK = 1		
		000	$fc/2^{13}$	$fs/2^5$	$fs/2^5$	
		001	$fc/2^8$	$fc/2^8$	-	
		010	$fc/2^7$	$fc/2^7$	-	
		011	$fc/2^6$	$fc/2^6$	-	
		100	$fc/2^5$	$fc/2^5$	-	
		101	$fc/2^4$	$fc/2^4$	-	
		110	Reserved			
111	External clock (Input from SCK pin)					

Note 1: fc; High-frequency clock [Hz], fs; Low-frequency clock [Hz]

Note 2: Set SIOS to "0" and SIOINH to "1" when setting the transfer mode or serial clock.

Note 3: SIOCR1 is write-only register, which cannot access any of in read-modify-write instruction such as bit operate, etc.

SIO Control Register 2

SIOCR2	7	6	5	4	3	2	1	0	
(0032H)				WAIT		BUF			(Initial value: ***0 0000)

WAIT	Wait control	Always sets "00" except 8-bit transmit / receive mode. 00: $T_f = T_D$ (Non wait) 01: $T_f = 2T_D$ (Wait) 10: $T_f = 4T_D$ (Wait) 11: $T_f = 8T_D$ (Wait)	Write only
BUF	Number of transfer words (Buffer address in use)	000: 1 word transfer 0F80H 001: 2 words transfer 0F80H ~ 0F81H 010: 3 words transfer 0F80H ~ 0F82H 011: 4 words transfer 0F80H ~ 0F83H 100: 5 words transfer 0F80H ~ 0F84H 101: 6 words transfer 0F80H ~ 0F85H 110: 7 words transfer 0F80H ~ 0F86H 111: 8 words transfer 0F80H ~ 0F87H	

Note 1: The lower 4 bits of each buffer are used during 4-bit transfers. Zeros (0) are stored to the upper 4bits when receiving.

Note 2: Transmitting starts at the lowest address. Received data are also stored starting from the lowest address to the highest address. (The first buffer address transmitted is 0F80H).

Note 3: The value to be loaded to BUF is held after transfer is completed.

Note 4: SIOCR2 must be set when the serial interface is stopped (SIOF = 0).

Note 5: *: Don't care

Note 6: SIOCR2 is write-only register, which cannot access any of in read-modify-write instruction such as bit operate, etc.

SIO Status Register

SIOSR	7	6	5	4	3	2	1	0
(0032H)	SIOF	SEF						

SIOF	Serial transfer operating status monitor	0: Transfer terminated 1: Transfer in process	Read only
SEF	Shift operating status monitor	0: Shift operation terminated 1: Shift operation in process	

Note 1: T_f : Frame time, T_D : Data transfer time

Note 2: After SIOS is cleared to "0", SIOF is cleared to "0" at the termination of transfer or the setting of SIOINH to "1".

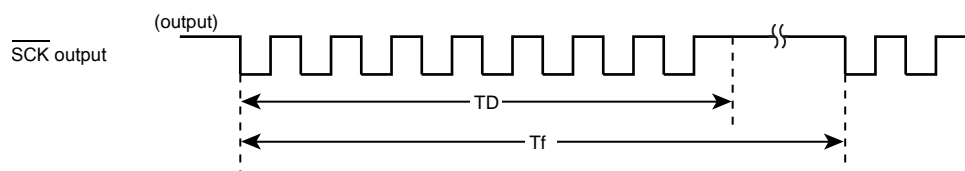


Figure 12-2 Frame time (T_f) and Data transfer time (T_D)

12.3 Serial clock

12.3.1 Clock source

Internal clock or external clock for the source clock is selected by SIOCR1<SCK>.

12.3.1.1 Internal clock

Any of six frequencies can be selected. The serial clock is output to the outside on the SCK pin. The SCK pin goes high when transfer starts.

When data writing (in the transmit mode) or reading (in the receive mode or the transmit/receive mode) cannot keep up with the serial clock rate, there is a wait function that automatically stops the serial clock and holds the next shift operation until the read/write processing is completed.

Table 12-1 Serial Clock Rate

	NORMAL 1/2, IDLE1/2 mode				SLOW1/2, SLEEP1/2 mode	
	DV7CK = 0		DV7CK = 1			
SCK	Clock	Baud Rate	Clock	Baud Rate	Clock	Baud Rate
000	$fc/2^{13}$	1.91 Kbps	$fs/2^5$	1024 bps	$fs/2^5$	1024 bps
001	$fc/2^8$	61.04 Kbps	$fc/2^8$	61.04 Kbps	-	-
010	$fc/2^7$	122.07 Kbps	$fc/2^7$	122.07 Kbps	-	-
011	$fc/2^6$	244.14 Kbps	$fc/2^6$	244.14 Kbps	-	-
100	$fc/2^5$	488.28 Kbps	$fc/2^5$	488.28 Kbps	-	-
101	$fc/2^4$	976.56 Kbps	$fc/2^4$	976.56 Kbps	-	-
110	-	-	-	-	-	-
111	External	External	External	External	External	External

Note: 1 Kbit = 1024 bit (f_c = 16 MHz, f_s = 32.768 kHz)

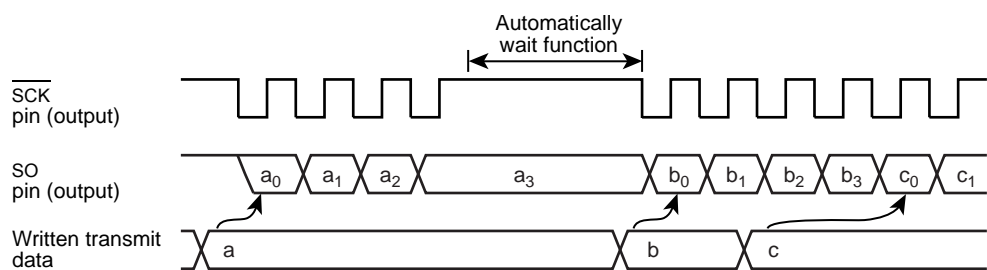


Figure 12-3 Automatic Wait Function (at 4-bit transmit mode)

12.3.1.2 External clock

An external clock connected to the $\overline{\text{SCK}}$ pin is used as the serial clock. In this case, output latch of this port should be set to "1". To ensure shifting, a pulse width of at least 4 machine cycles is required. This pulse is needed for the shift operation to execute certainly. Actually, there is necessary processing time for interrupting, writing, and reading. The minimum pulse is determined by setting the mode and the program. Therefore, maximum transfer frequency will be 488.3K bit/sec (at $f_c=16\text{MHz}$).

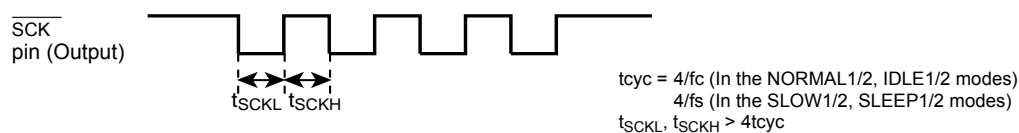


Figure 12-4 External clock pulse width

12.3.2 Shift edge

The leading edge is used to transmit, and the trailing edge is used to receive.

12.3.2.1 Leading edge

Transmitted data are shifted on the leading edge of the serial clock (falling edge of the $\overline{\text{SCK}}$ pin input/output).

12.3.2.2 Trailing edge

Received data are shifted on the trailing edge of the serial clock (rising edge of the $\overline{\text{SCK}}$ pin input/output).

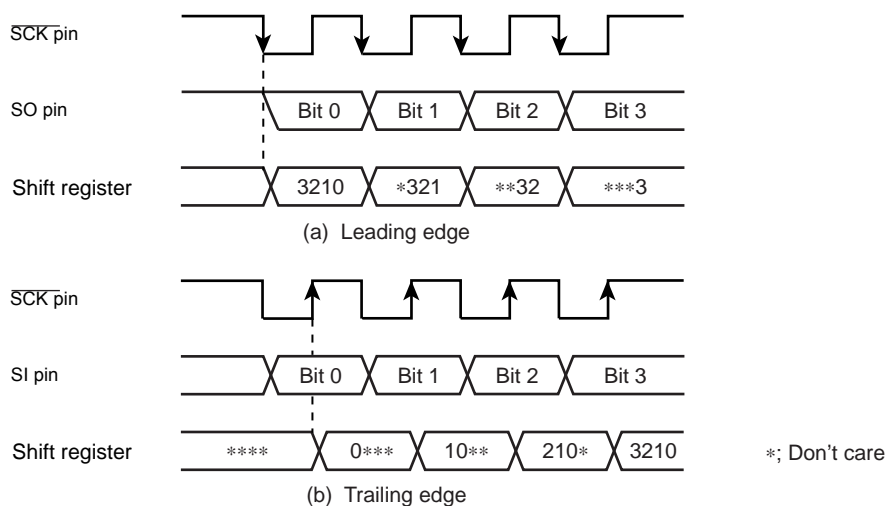


Figure 12-5 Shift edge

12.4 Number of bits to transfer

Either 4-bit or 8-bit serial transfer can be selected. When 4-bit serial transfer is selected, only the lower 4 bits of the transmit/receive data buffer register are used. The upper 4 bits are cleared to “0” when receiving. The data is transferred in sequence starting at the least significant bit (LSB).

12.5 Number of words to transfer

Up to 8 words consisting of 4 bits of data (4-bit serial transfer) or 8 bits (8-bit serial transfer) of data can be transferred continuously. The number of words to be transferred can be selected by SIOCR2<BUF>.

An INTSIO interrupt is generated when the specified number of words has been transferred. If the number of words is to be changed during transfer, the serial interface must be stopped before making the change. The number of words can be changed during automatic-wait operation of an internal clock. In this case, the serial interface is not required to be stopped.

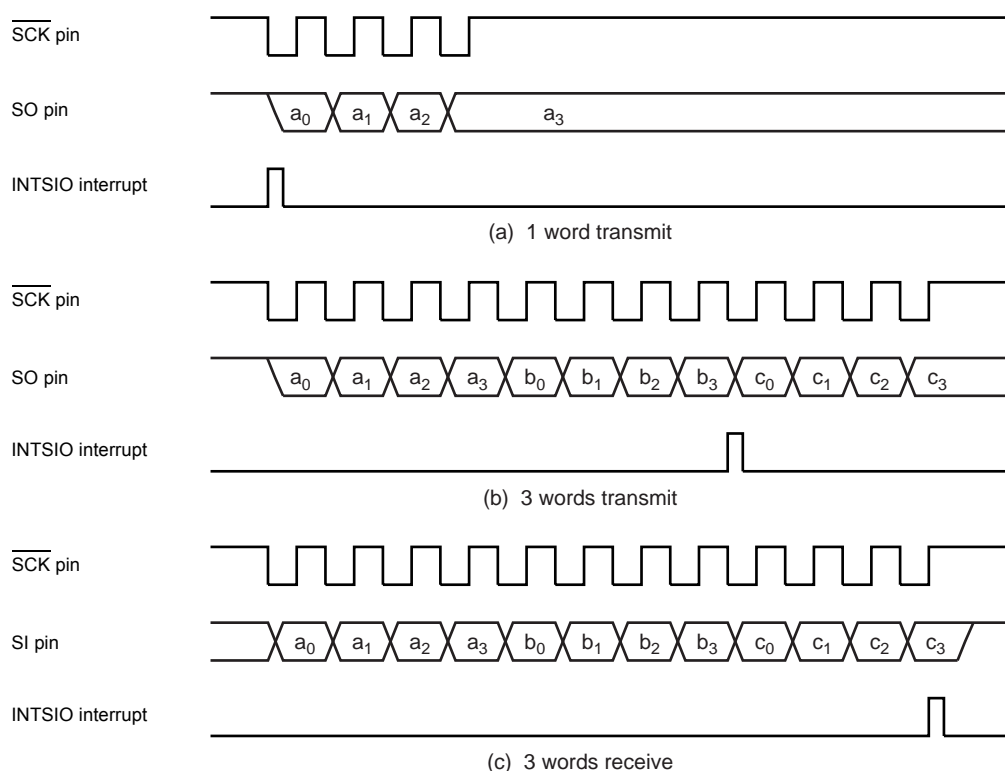


Figure 12-6 Number of words to transfer (Example: 1word = 4bit)

12.6 Transfer Mode

SIOCR1<SIOM> is used to select the transmit, receive, or transmit/receive mode.

12.6.1 4-bit and 8-bit transfer modes

In these modes, firstly set the SIO control register to the transmit mode, and then write first transmit data (number of transfer words to be transferred) to the data buffer registers (DBR).

After the data are written, the transmission is started by setting SIOCR1<SIOS> to “1”. The data are then output sequentially to the SO pin in synchronous with the serial clock, starting with the least significant bit (LSB). As soon as the LSB has been output, the data are transferred from the data buffer register to the shift register. When the final data bit has been transferred and the data buffer register is empty, an INTSIO (Buffer empty) interrupt is generated to request the next transmitted data.

When the internal clock is used, the serial clock will stop and an automatic-wait will be initiated if the next transmitted data are not loaded to the data buffer register by the time the number of data words specified with the SIOCR2<BUF> has been transmitted. Writing even one word of data cancels the automatic-wait; therefore, when transmitting two or more words, always write the next word before transmission of the previous word is completed.

Note: Automatic waits are also canceled by writing to a DBR not being used as a transmit data buffer register; therefore, during SIO do not use such DBR for other applications. For example, when 3 words are transmitted, do not use the DBR of the remained 5 words.

When an external clock is used, the data must be written to the data buffer register before shifting next data. Thus, the transfer speed is determined by the maximum delay time from the generation of the interrupt request to writing of the data to the data buffer register by the interrupt service program.

The transmission is ended by clearing SIOCR1<SIOS> to “0” or setting SIOCR1<SIOINH> to “1” in buffer empty interrupt service program.

SIOCR1<SIOS> is cleared, the operation will end after all bits of words are transmitted.

That the transmission has ended can be determined from the status of SIOSR<SIOF> because SIOSR<SIOF> is cleared to “0” when a transfer is completed.

When SIOCR1<SIOINH> is set, the transmission is immediately ended and SIOSR<SIOF> is cleared to “0”.

When an external clock is used, it is also necessary to clear SIOCR1<SIOS> to “0” before shifting the next data; If SIOCR1<SIOS> is not cleared before shift out, dummy data will be transmitted and the operation will end.

If it is necessary to change the number of words, SIOCR1<SIOS> should be cleared to “0”, then SIOCR2<BUF> must be rewritten after confirming that SIOSR<SIOF> has been cleared to “0”.

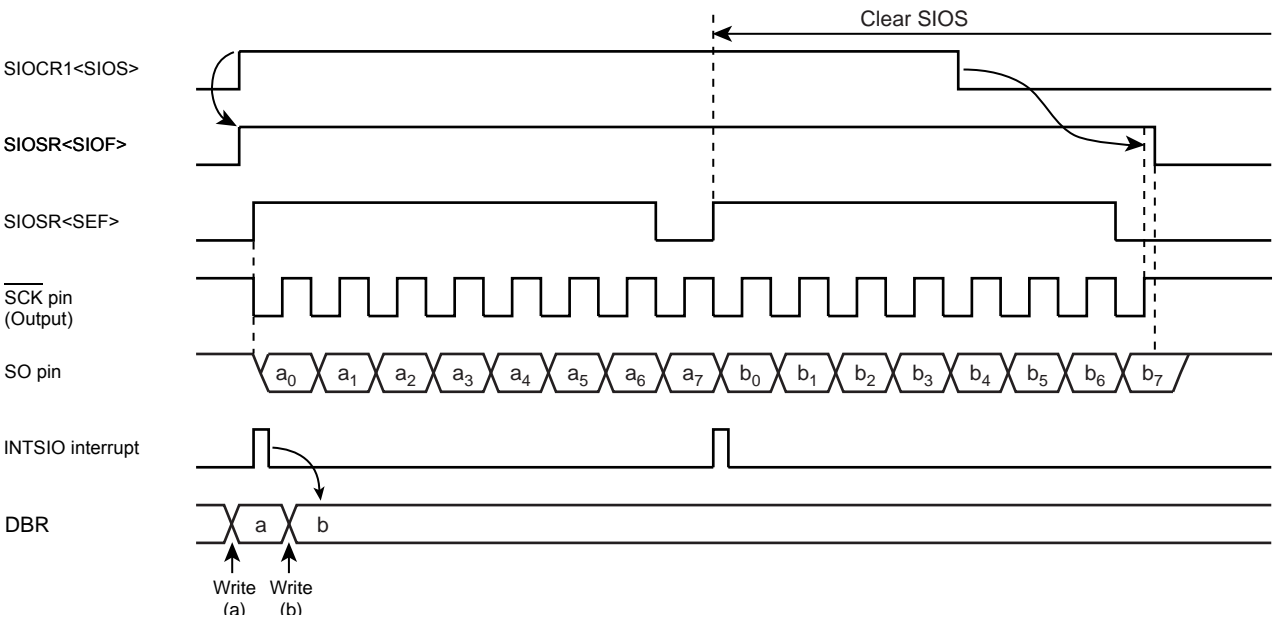


Figure 12-7 Transfer Mode (Example: 8bit, 1word transfer, Internal clock)

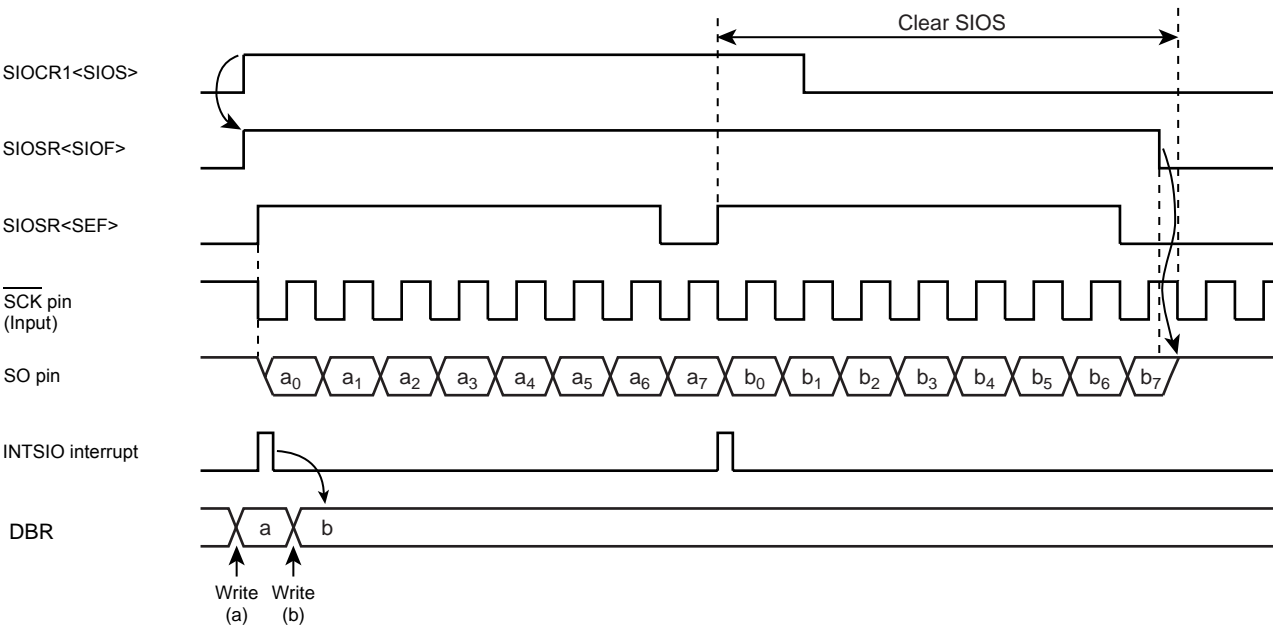


Figure 12-8 Transfer Mode (Example: 8bit, 1word transfer, External clock)

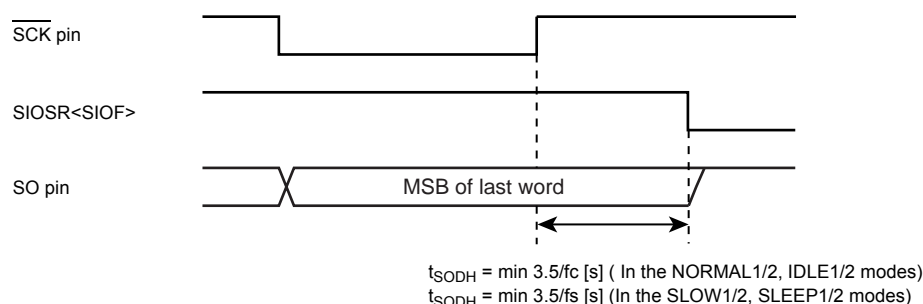


Figure 12-9 Transmitted Data Hold Time at End of Transfer

12.6.2 4-bit and 8-bit receive modes

After setting the control registers to the receive mode, set SIOCR1<SIOS> to “1” to enable receiving. The data are then transferred to the shift register via the SI pin in synchronous with the serial clock. When one word of data has been received, it is transferred from the shift register to the data buffer register (DBR). When the number of words specified with the SIOCR2<BUF> has been received, an INTSIO (Buffer full) interrupt is generated to request that these data be read out. The data are then read from the data buffer registers by the interrupt service program.

When the internal clock is used, and the previous data are not read from the data buffer register before the next data are received, the serial clock will stop and an automatic-wait will be initiated until the data are read. A wait will not be initiated if even one data word has been read.

Note: Waits are also canceled by reading a DBR not being used as a received data buffer register is read; therefore, during SIO do not use such DBR for other applications.

When an external clock is used, the shift operation is synchronized with the external clock; therefore, the previous data are read before the next data are transferred to the data buffer register. If the previous data have not been read, the next data will not be transferred to the data buffer register and the receiving of any more data will be canceled. When an external clock is used, the maximum transfer speed is determined by the delay between the time when the interrupt request is generated and when the data received have been read.

The receiving is ended by clearing SIOCR1<SIOS> to “0” or setting SIOCR1<SIOINH> to “1” in buffer full interrupt service program.

When SIOCR1<SIOS> is cleared, the current data are transferred to the buffer. After SIOCR1<SIOS> cleared, the receiving is ended at the time that the final bit of the data has been received. That the receiving has ended can be determined from the status of SIOSR<SIOF>. SIOSR<SIOF> is cleared to “0” when the receiving is ended. After confirmed the receiving termination, the final receiving data is read. When SIOCR1<SIOINH> is set, the receiving is immediately ended and SIOSR<SIOF> is cleared to “0”. (The received data is ignored, and it is not required to be read out.)

If it is necessary to change the number of words in external clock operation, SIOCR1<SIOS> should be cleared to “0” then SIOCR2<BUF> must be rewritten after confirming that SIOSR<SIOF> has been cleared to “0”. If it is necessary to change the number of words in internal clock, during automatic-wait operation which occurs after completion of data receiving, SIOCR2<BUF> must be rewritten before the received data is read out.

Note: The buffer contents are lost when the transfer mode is switched. If it should become necessary to switch the transfer mode, end receiving by clearing SIOCR1<SIOS> to “0”, read the last data and then switch the transfer mode.

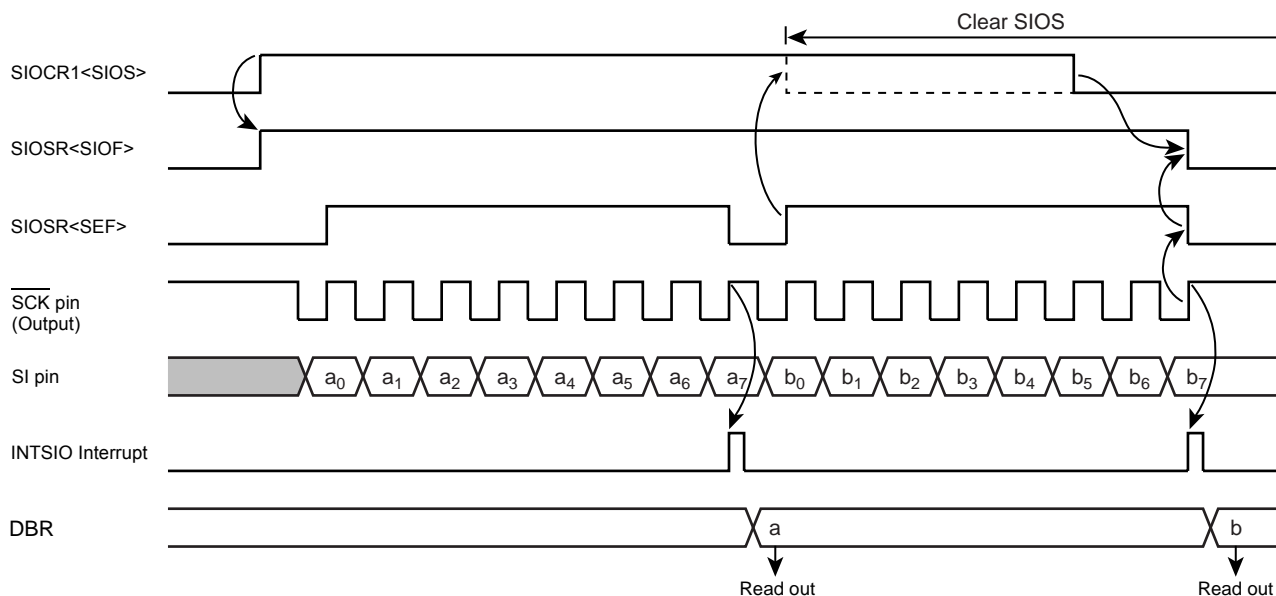


Figure 12-10 Receive Mode (Example: 8bit, 1word transfer, Internal clock)

12.6.3 8-bit transfer / receive mode

After setting the SIO control register to the 8-bit transmit/receive mode, write the data to be transmitted first to the data buffer registers (DBR). After that, enable the transmit/receive by setting SIOCR1<SIOS> to "1". When transmitting, the data are output from the SO pin at leading edges of the serial clock. When receiving, the data are input to the SI pin at the trailing edges of the serial clock. When the all receive is enabled, 8-bit data are transferred from the shift register to the data buffer register. An INTSIO interrupt is generated when the number of data words specified with the SIOCR2<BUF> has been transferred. Usually, read the receive data from the buffer register in the interrupt service. The data buffer register is used for both transmitting and receiving; therefore, always write the data to be transmitted after reading the all received data.

When the internal clock is used, a wait is initiated until the received data are read and the next transfer data are written. A wait will not be initiated if even one transfer data word has been written.

When an external clock is used, the shift operation is synchronized with the external clock; therefore, it is necessary to read the received data and write the data to be transmitted next before starting the next shift operation. When an external clock is used, the transfer speed is determined by the maximum delay between generation of an interrupt request and the received data are read and the data to be transmitted next are written.

The transmit/receive operation is ended by clearing SIOCR1<SIOS> to "0" or setting SIOCR1<SIOINH> to "1" in INTSIO interrupt service program.

When SIOCR1<SIOS> is cleared, the current data are transferred to the buffer. After SIOCR1<SIOS> cleared, the transmitting/receiving is ended at the time that the final bit of the data has been transmitted.

That the transmitting/receiving has ended can be determined from the status of SIOSR<SIOF>. SIOSR<SIOF> is cleared to "0" when the transmitting/receiving is ended.

When SIOCR1<SIOINH> is set, the transmit/receive operation is immediately ended and SIOSR<SIOF> is cleared to "0".

If it is necessary to change the number of words in external clock operation, SIOCR1<SIOS> should be cleared to "0", then SIOCR2<BUF> must be rewritten after confirming that SIOSR<SIOF> has been cleared to "0".

If it is necessary to change the number of words in internal clock, during automatic-wait operation which occurs after completion of transmit/receive operation, SIOCR2<BUF> must be rewritten before reading and writing of the receive/transmit data.

Note: The buffer contents are lost when the transfer mode is switched. If it should become necessary to switch the transfer mode, end receiving by clearing SIOCR1<SIOS> to "0", read the last data and then switch the transfer mode.

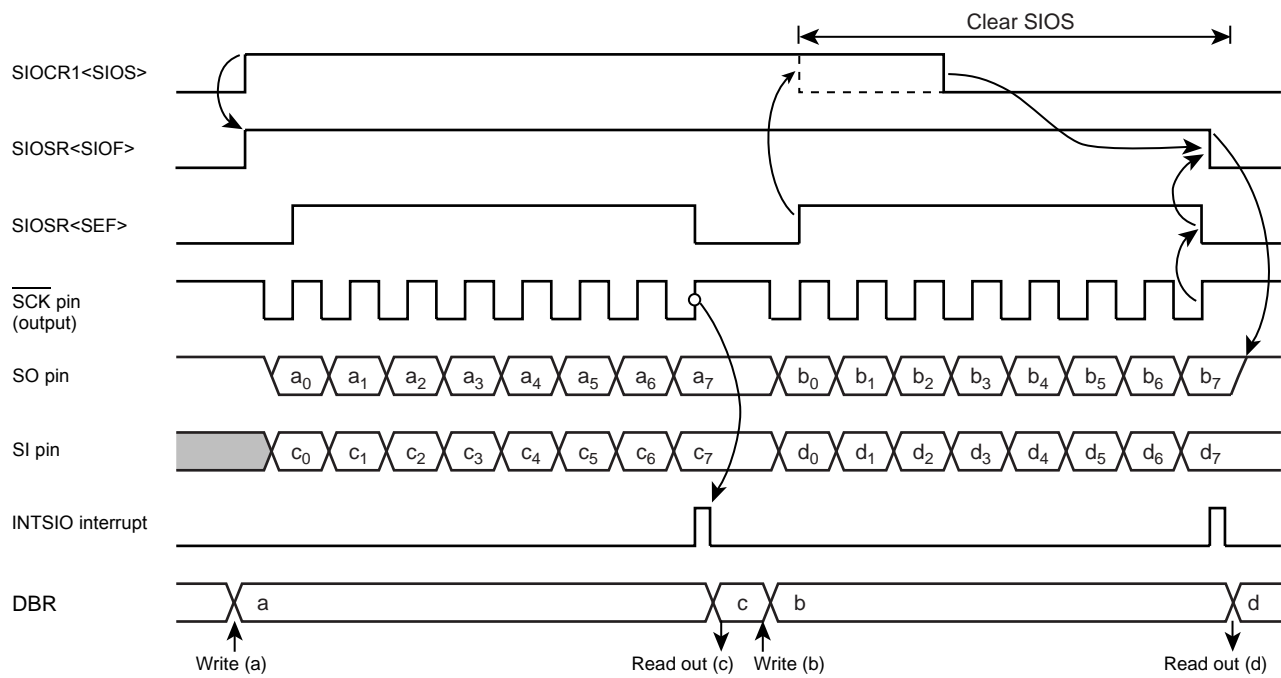


Figure 12-11 Transfer / Receive Mode (Example: 8bit, 1word transfer, Internal clock)

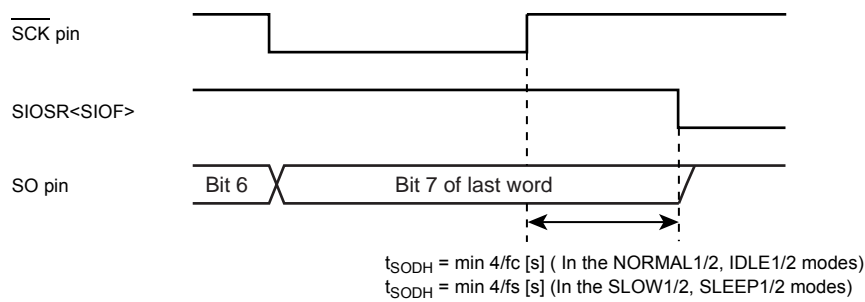


Figure 12-12 Transmitted Data Hold Time at End of Transfer / Receive

13. Asynchronous Serial interface (UART)

13.1 Configuration

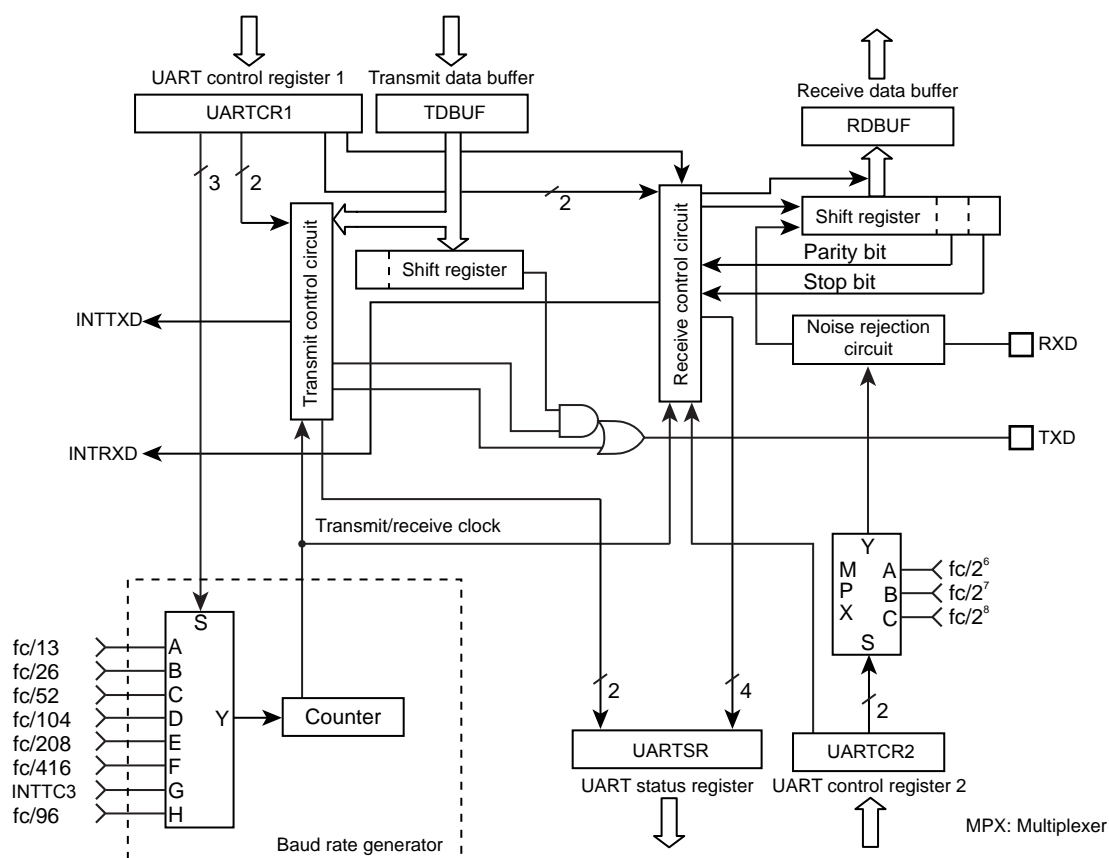


Figure 13-1 UART (Asynchronous Serial Interface)

13.2 Control

UART is controlled by the UART Control Registers (UARTCR1, UARTCR2). The operating status can be monitored using the UART status register (UARTSR).

UART Control Register1

UARTCR1 (0021H)	7	6	5	4	3	2	1	0	
	TXE	RXE	STBT	EVEN	PE	BRG			(Initial value: 0000 0000)

TXE	Transfer operation	0: Disable 1: Enable	Write only
RXE	Receive operation	0: Disable 1: Enable	
STBT	Transmit stop bit length	0: 1 bit 1: 2 bits	
EVEN	Even-numbered parity	0: Odd-numbered parity 1: Even-numbered parity	
PE	Parity addition	0: No parity 1: Parity	
BRG	Transmit clock select	000: fc/13 [Hz] 001: fc/26 010: fc/52 011: fc/104 100: fc/208 101: fc/416 110: TC3 (Input INTTC3) 111: fc/96	

Note 1: When operations are disabled by setting TXE and RXE bit to “0”, the setting becomes valid when data transmit or receive complete. When the transmit data is stored in the transmit data buffer, the data are not transmitted. Even if data transmit is enabled, until new data are written to the transmit data buffer, the current data are not transmitted.

Note 2: The transmit clock and the parity are common to transmit and receive.

Note 3: UARTCR1<RXE> and UARTCR1<TXE> should be set to “0” before UARTCR1<BRG> is changed.

UART Control Register2

UARTCR2 (0022H)	7	6	5	4	3	2	1	0	
						RXDNC	STOPBR		(Initial value: **** *000)

RXDNC	Selection of RXD input noise rejectio time	00: No noise rejection (Hysteresis input) 01: Rejects pulses shorter than 31/fc [s] as noise 10: Rejects pulses shorter than 63/fc [s] as noise 11: Rejects pulses shorter than 127/fc [s] as noise	Write only
STOPBR	Receive stop bit length	0: 1 bit 1: 2 bits	

Note: When UARTCR2<RXDNC> = “01”, pulses longer than 96/fc [s] are always regarded as signals; when UARTCR2<RXDNC> = “10”, longer than 192/fc [s]; and when UARTCR2<RXDNC> = “11”, longer than 384/fc [s].

UART Status Register

UARTSR (0021H)	7	6	5	4	3	2	1	0
	PERR	FERR	OERR	RBFL	TEND	TBEP		(Initial value: 0000 11**)

PERR	Parity error flag	0: No parity error 1: Parity error	Read only
FERR	Framing error flag	0: No framing error 1: Framing error	
OERR	Overrun error flag	0: No overrun error 1: Overrun error	
RBFL	Receive data buffer full flag	0: Receive data buffer empty 1: Receive data buffer full	
TEND	Transmit end flag	0: On transmitting 1: Transmit end	
TBEP	Transmit data buffer empty flag	0: Transmit data buffer full (Transmit data writing is finished) 1: Transmit data buffer empty	

Note: When an INTTXD is generated, TBEP flag is set to "1" automatically.

UART Receive Data Buffer

[illegible]

UART Transmit Data Buffer

[illegible]

13.3 Transfer Data Format

In UART, an one-bit start bit (Low level), stop bit (Bit length selectable at high level, by UARTCR1<STBT>), and parity (Select parity in UARTCR1<PE>; even- or odd-numbered parity by UARTCR1<EVEN>) are added to the transfer data. The transfer data formats are shown as follows.

PE	STBT	Frame Length											
		1	2	3		8	9	10	11	12			
0	0												
0	1												
1	0												
1	1												

Figure 13-2 Transfer Data Format

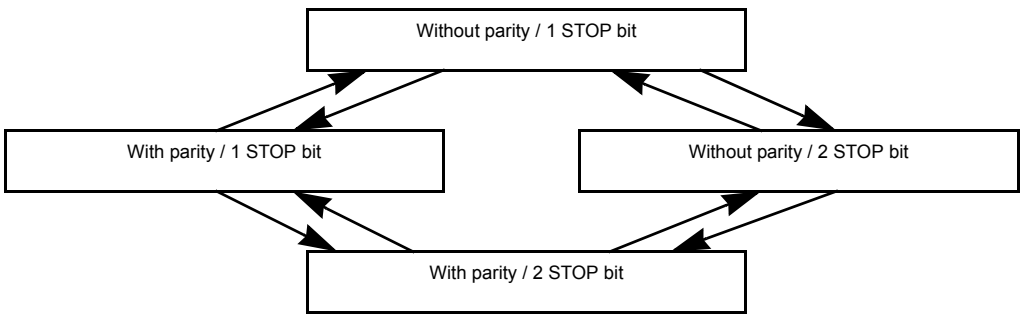


Figure 13-3 Caution on Changing Transfer Data Format

Note: In order to switch the transfer data format, perform transmit operations in the above Figure 13-3 sequence except for the initial setting.

13.4 Transfer Rate

The baud rate of UART is set of UARTCR1<BRG>. The example of the baud rate are shown as follows.

Table 13-1 Transfer Rate (Example)

BRG	Source Clock		
	16 MHz	8 MHz	4 MHz
000	76800 [baud]	38400 [baud]	19200 [baud]
001	38400	19200	9600
010	19200	9600	4800
011	9600	4800	2400
100	4800	2400	1200
101	2400	1200	600

When TC3 is used as the UART transfer rate (when UARTCR1<BRG> = “110”), the transfer clock and transfer rate are determined as follows:

$$\text{Transfer clock [Hz]} = \text{TC3 source clock [Hz]} / \text{TTREG3 setting value}$$

$$\text{Transfer Rate [baud]} = \text{Transfer clock [Hz]} / 16$$

13.5 Data Sampling Method

The UART receiver keeps sampling input using the clock selected by UARTCR1<BRG> until a start bit is detected in RXD pin input. RT clock starts detecting “L” level of the RXD pin. Once a start bit is detected, the start bit, data bits, stop bit(s), and parity bit are sampled at three times of RT7, RT8, and RT9 during one receiver clock interval (RT clock). (RT0 is the position where the bit supposedly starts.) Bit is determined according to majority rule (The data are the same twice or more out of three samplings).

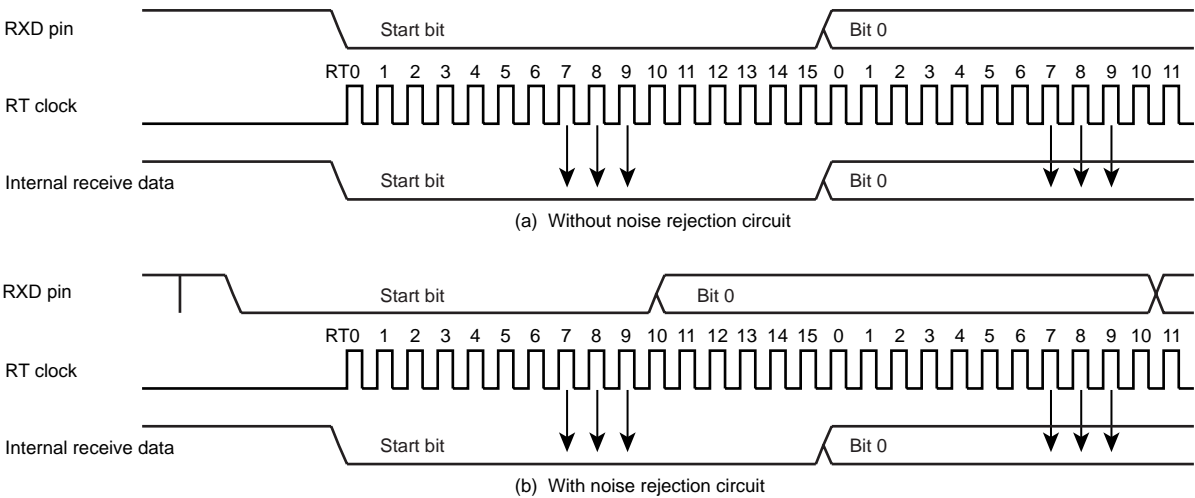


Figure 13-4 Data Sampling Method

13.6 STOP Bit Length

Select a transmit stop bit length (1 bit or 2 bits) by UARTCR1<STBT>.

13.7 Parity

Set parity / no parity by UARTCR1<PE> and set parity type (Odd- or Even-numbered) by UARTCR1<EVEN>.

13.8 Transmit/Receive Operation

13.8.1 Data Transmit Operation

Set UARTCR1<TXE> to “1”. Read UARTSR to check UARTSR<TBEP> = “1”, then write data in TDBUF (Transmit data buffer). Writing data in TDBUF zero-clears UARTSR<TBEP>, transfers the data to the transmit shift register and the data are sequentially output from the TXD pin. The data output include a one-bit start bit, stop bits whose number is specified in UARTCR1<STBT> and a parity bit if parity addition is specified. Select the data transfer baud rate using UARTCR1<BRG>. When data transmit starts, transmit buffer empty flag UARTSR<TBEP> is set to “1” and an INTTXD interrupt is generated.

While UARTCR1<TXE> = “0” and from when “1” is written to UARTCR1<TXE> to when send data are written to TDBUF, the TXD pin is fixed at high level.

When transmitting data, first read UARTSR, then write data in TDBUF. Otherwise, UARTSR<TBEP> is not zero-cleared and transmit does not start.

13.8.2 Data Receive Operation

Set UARTCR1<RXE> to “1”. When data are received via the RXD pin, the receive data are transferred to RDBUF (Receive data buffer). At this time, the data transmitted includes a start bit and stop bit(s) and a parity bit if parity addition is specified. When stop bit(s) are received, data only are extracted and transferred to RDBUF (Receive data buffer). Then the receive buffer full flag UARTSR<RBFL> is set and an INTRXD interrupt is generated. Select the data transfer baud rate using UARTCR1<BRG>.

If an overrun error (OERR) occurs when data are received, the data are not transferred to RDBUF (Receive data buffer) but discarded; data in the RDBUF are not affected.

Note: When a receive operation is disabled by setting UARTCR1<RXE> bit to “0”, the setting becomes valid when data receive is completed. However, if a framing error occurs in data receive, the receive-disabling setting may not become valid. If a framing error occurs, be sure to perform a re-receive operation.

13.9 Status Flag

13.9.1 Parity Error

When parity determined using the receive data bits differs from the received parity bit, the parity error flag UARTSR<PERR> is set to “1”. The UARTSR<PERR> is cleared to “0” when the RDBUF is read after reading the UARTSR.

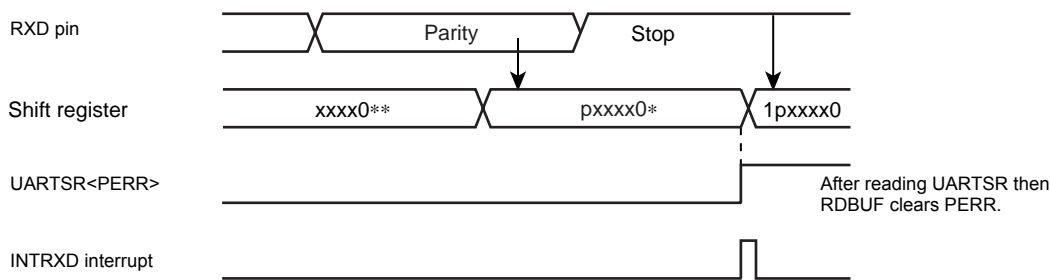


Figure 13-5 Generation of Parity Error

13.9.2 Framing Error

When “0” is sampled as the stop bit in the receive data, framing error flag UARTSR<FERR> is set to “1”. The UARTSR<FERR> is cleared to “0” when the RDBUF is read after reading the UARTSR.

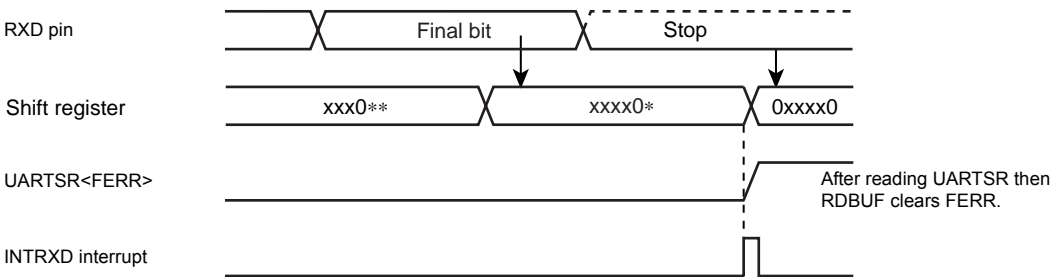


Figure 13-6 Generation of Framing Error

13.9.3 Overrun Error

When all bits in the next data are received while unread data are still in RDBUF, overrun error flag UARTSR<OERR> is set to “1”. In this case, the receive data is discarded; data in RDBUF are not affected. The UARTSR<OERR> is cleared to “0” when the RDBUF is read after reading the UARTSR.

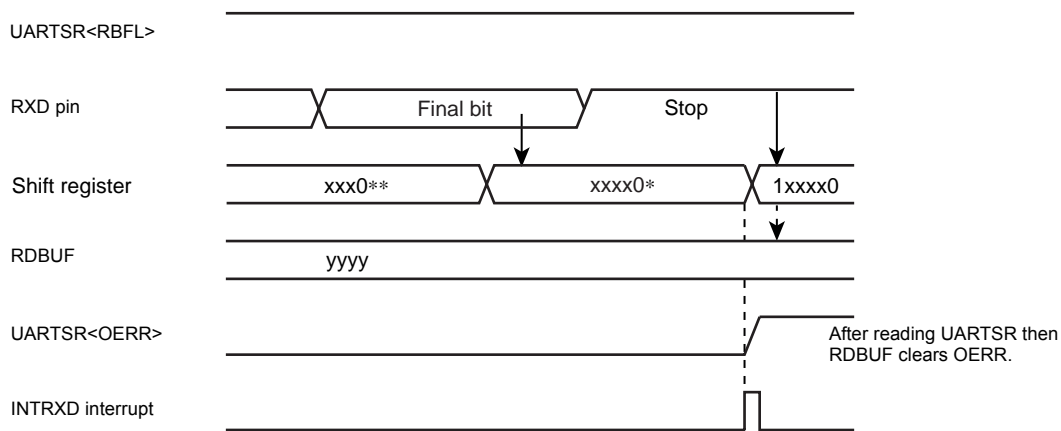


Figure 13-7 Generation of Overrun Error

Note: Receive operations are disabled until the overrun error flag UARTSR<OERR> is cleared.

13.9.4 Receive Data Buffer Full

Loading the received data in RDBUF sets receive data buffer full flag UARTSR<RBFL> to "1". The UARTSR<RBFL> is cleared to "0" when the RDBUF is read after reading the UARTSR.

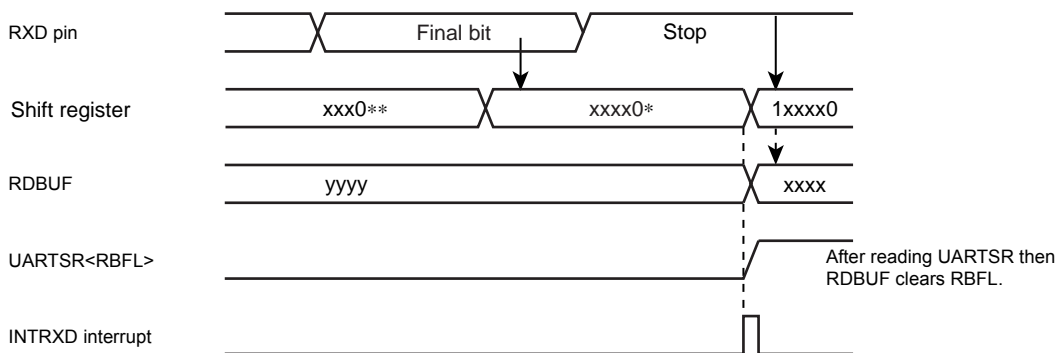


Figure 13-8 Generation of Receive Data Buffer Full

Note: If the overrun error flag UARTSR<OERR> is set during the period between reading the UARTSR and reading the RDBUF, it cannot be cleared by only reading the RDBUF. Therefore, after reading the RDBUF, read the UARTSR again to check whether or not the overrun error flag which should have been cleared still remains set.

13.9.5 Transmit Data Buffer Empty

When no data is in the transmit buffer TDBUF, UARTSR<TBEP> is set to "1", that is, when data in TDBUF are transferred to the transmit shift register and data transmit starts, transmit data buffer empty flag UARTSR<TBEP> is set to "1". The UARTSR<TBEP> is cleared to "0" when the TDBUF is written after reading the UARTSR.

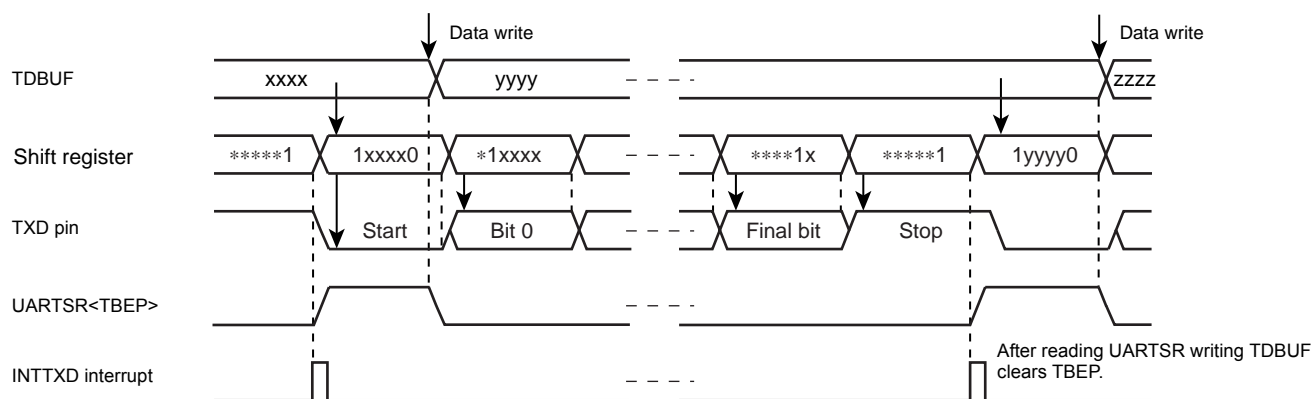


Figure 13-9 Generation of Transmit Data Buffer Empty

13.9.6 Transmit End Flag

When data are transmitted and no data is in TDBUF (UARTSR<TBEP> = “1”), transmit end flag UARTSR<TEND> is set to “1”. The UARTSR<TEND> is cleared to “0” when the data transmit is stated after writing the TDBUF.

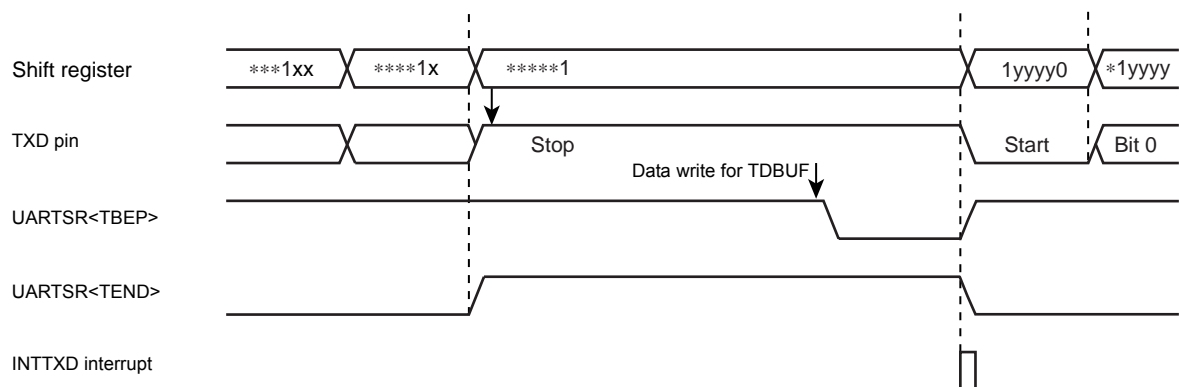


Figure 13-10 Generation of Transmit End Flag and Transmit Data Buffer Empty



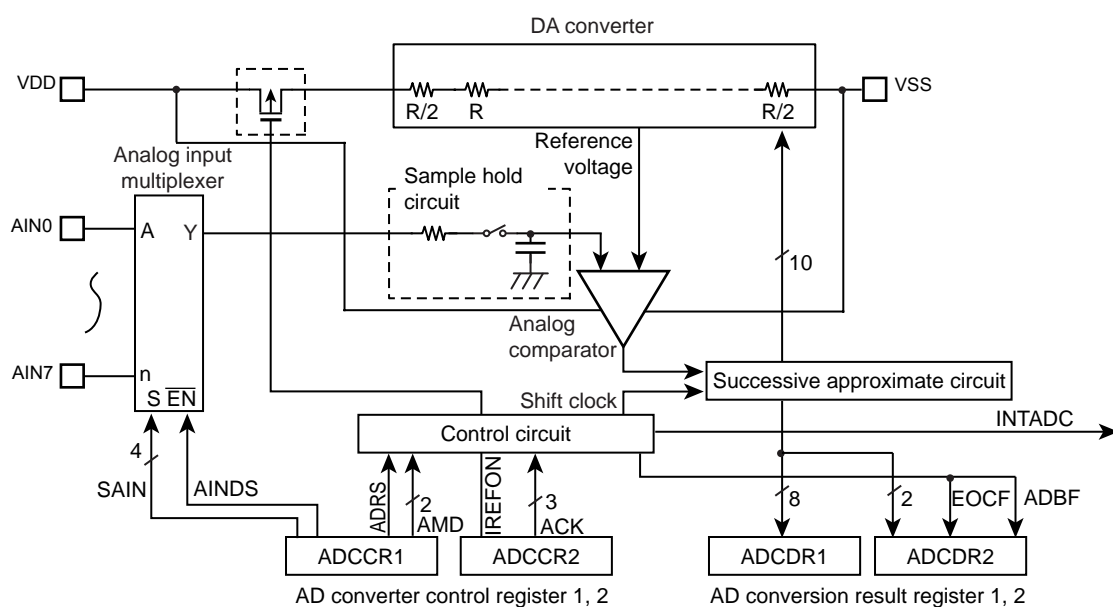
14. 10-bit AD Converter (ADC)

The TMP86CH12MG have a 10-bit successive approximation type AD converter.

14.1 Configuration

The circuit configuration of the 10-bit AD converter is shown in Figure 14-1.

It consists of control register ADCCR1 and ADCCR2, converted value register ADCDR1 and ADCDR2, a DA converter, a sample-hold circuit, a comparator, and a successive comparison circuit.



Note: Before using AD converter, set appropriate value to I/O port register combining a analog input port. For details, see the section on "I/O ports".

Figure 14-1 10-bit AD Converter

14.2 Register configuration

The AD converter consists of the following four registers:

1. AD converter control register 1 (ADCCR1)
This register selects the analog channels and operation mode (Software start or repeat) in which to perform AD conversion and controls the AD converter as it starts operating.
2. AD converter control register 2 (ADCCR2)
This register selects the AD conversion time and controls the connection of the DA converter (Ladder resistor network).
3. AD converted value register 1 (ADCDR1)
This register used to store the digital value fter being converted by the AD converter.
4. AD converted value register 2 (ADCDR2)
This register monitors the operating status of the AD converter.

AD Converter Control Register 1

ADCCR1	7	6	5	4	3	2	1	0	
(0025H)	ADRS	AMD	AINDS						(Initial value: 0001 0000)

ADRS	AD conversion start	0: - 1: AD conversion start	R/W
AMD	AD operating mode	00: AD operation disable 01: Software start mode 10: Reserved 11: Repeat mode	
AINDS	Analog input control	0: Analog input enable 1: Analog input disable	
SAIN	Analog input channel select	0000: AIN0 0001: AIN1 0010: AIN2 0011: AIN3 0100: AIN4 0101: AIN5 0110: AIN6 0111: AIN7 1000: Reserved 1001: Reserved 1010: Reserved 1011: Reserved 1100: Reserved 1101: Reserved 1110: Reserved 1111: Reserved	

- Note 1: Select analog input channel during AD converter stops (ADCCR2<ADBF> = "0").
- Note 2: When the analog input channel is all use disabling, the ADCCR1<AINDS> should be set to "1".
- Note 3: During conversion, Do not perform port output instruction to maintain a precision for all of the pins because analog input port use as general input port. And for port near to analog input, Do not input intense signaling of change.
- Note 4: The ADCCR1<ADRS> is automatically cleared to "0" after starting conversion.
- Note 5: Do not set ADCCR1<ADRS> newly again during AD conversion. Before setting ADCCR1<ADRS> newly again, check ADCDR2<EOCF> to see that the conversion is completed or wait until the interrupt signal (INTADC) is generated (e.g., interrupt handling routine).
- Note 6: After STOP or SLOW/SLEEP mode are started, AD converter control register1 (ADCCR1) is all initialized and no data can be written in this register. Therefore, to use AD converter again, set the ADCCR1 newly after returning to NORMAL1 or NORMAL2 mode.

AD Converter Control Register 2

ADCCR2 (0026H)	7	6	5	4	3	2	1	0	
			IREFON	"1"		ACK		"0"	(Initial value: **0* 000*)

IREFON	DA converter (Ladder resistor) connection control	0: Connected only during AD conversion 1: Always connected	R/W
ACK	AD conversion time select (Refer to the following table about the conversion time)	000: 39/fc 001: Reserved 010: 78/fc 011: 156/fc 100: 312/fc 101: 624/fc 110: 1248/fc 111: Reserved	

Note 1: Always set bit0 in ADCCR2 to "0" and set bit4 in ADCCR2 to "1".

Note 2: When a read instruction for ADCCR2, bit6 to 7 in ADCCR2 read in as undefined data.

Note 3: After STOP or SLOW/SLEEP mode are started, AD converter control register2 (ADCCR2) is all initialized and no data can be written in this register. Therefore, to use AD converter again, set the ADCCR2 newly after returning to NORMAL1 or NORMAL2 mode.

Table 14-1 ACK setting and Conversion time

Condition ACK	Conversion time	16 MHz	8 MHz	4 MHz	2 MHz	10 MHz	5 MHz	2.5 MHz
000	39/fc	-	-	-	19.5 μ s	-	-	15.6 μ s
001	Reserved							
010	78/fc	-	-	19.5 μ s	39.0 μ s	-	15.6 μ s	31.2 μ s
011	156/fc	-	19.5 μ s	39.0 μ s	78.0 μ s	15.6 μ s	31.2 μ s	62.4 μ s
100	312/fc	19.5 μ s	39.0 μ s	78.0 μ s	156.0 μ s	31.2 μ s	62.4 μ s	124.8 μ s
101	624/fc	39.0 μ s	78.0 μ s	156.0 μ s	-	62.4 μ s	124.8 μ s	-
110	1248/fc	78.0 μ s	156.0 μ s	-	-	124.8 μ s	-	-
111	Reserved							

Note 1: Setting for "-" in the above table are inhibited. fc: High Frequency oscillation clock [Hz]

Note 2: Set conversion time setting should be kept more than the following time by Power supply voltage(VDD) .

- VDD = 4.5 to 5.5 V 15.6 μ s and more
- VDD = 2.7 to 5.5 V 31.2 μ s and more

AD Converted value Register 1

ADCDR1 (0020H)	7	6	5	4	3	2	1	0	
	AD09	AD08	AD07	AD06	AD05	AD04	AD03	AD02	(Initial value: 0000 0000)

AD Converted value Register 2

ADCDR2 (001FH)	7	6	5	4	3	2	1	0	
	AD01	AD00	EOCF	ADBF					(Initial value: 0000 ****)

14. 10-bit AD Converter (ADC)
14.2 Register configuration

TMP86CH12MG

EOCF	AD conversion end flag	0: Before or during conversion 1: Conversion completed	Read only
ADBF	AD conversion BUSY flag	0: During stop of AD conversion 1: During AD conversion	

- Note 1: The ADCDR2<EOCF> is cleared to "0" when reading the ADCDR1. Therefore, the AD conversion result should be read to ADCDR2 more first than ADCDR1.
- Note 2: The ADCDR2<ADBF> is set to "1" when AD conversion starts, and cleared to "0" when AD conversion finished. It also is cleared upon entering STOP mode or SLOW mode .
- Note 3: If a read instruction is executed for ADCDR2, read data of bit3 to bit0 are unstable.

14.3 Function

14.3.1 Software Start Mode

After setting ADCCR1<AMD> to “01” (software start mode), set ADCCR1<ADRS> to “1”. AD conversion of the voltage at the analog input pin specified by ADCCR1<SAIN> is thereby started.

After completion of the AD conversion, the conversion result is stored in AD converted value registers (ADCDR1, ADCDR2) and at the same time ADCDR2<EOCF> is set to 1, the AD conversion finished interrupt (INTADC) is generated.

ADRS is automatically cleared after AD conversion has started. Do not set ADCCR1<ADRS> newly again (Restart) during AD conversion. Before setting ADRS newly again, check ADCDR2<EOCF> to see that the conversion is completed or wait until the interrupt signal (INTADC) is generated (e.g., interrupt handling routine).

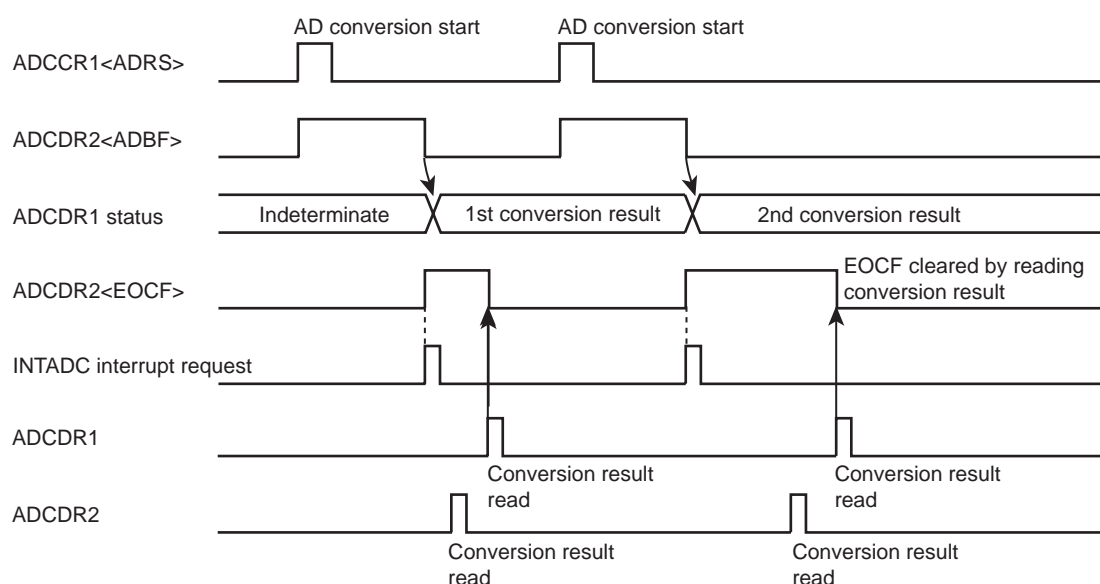


Figure 14-2 Software Start Mode

14.3.2 Repeat Mode

AD conversion of the voltage at the analog input pin specified by ADCCR1<SAIN> is performed repeatedly. In this mode, AD conversion is started by setting ADCCR1<ADRS> to “1” after setting ADCCR1<AMD> to “11” (Repeat mode).

After completion of the AD conversion, the conversion result is stored in AD converted value registers (ADCDR1, ADCDR2) and at the same time ADCDR2<EOCF> is set to 1, the AD conversion finished interrupt (INTADC) is generated.

In repeat mode, each time one AD conversion is completed, the next AD conversion is started. To stop AD conversion, set ADCCR1<AMD> to “00” (Disable mode) by writing 0s. The AD convert operation is stopped immediately. The converted value at this time is not stored in the AD converted value register.

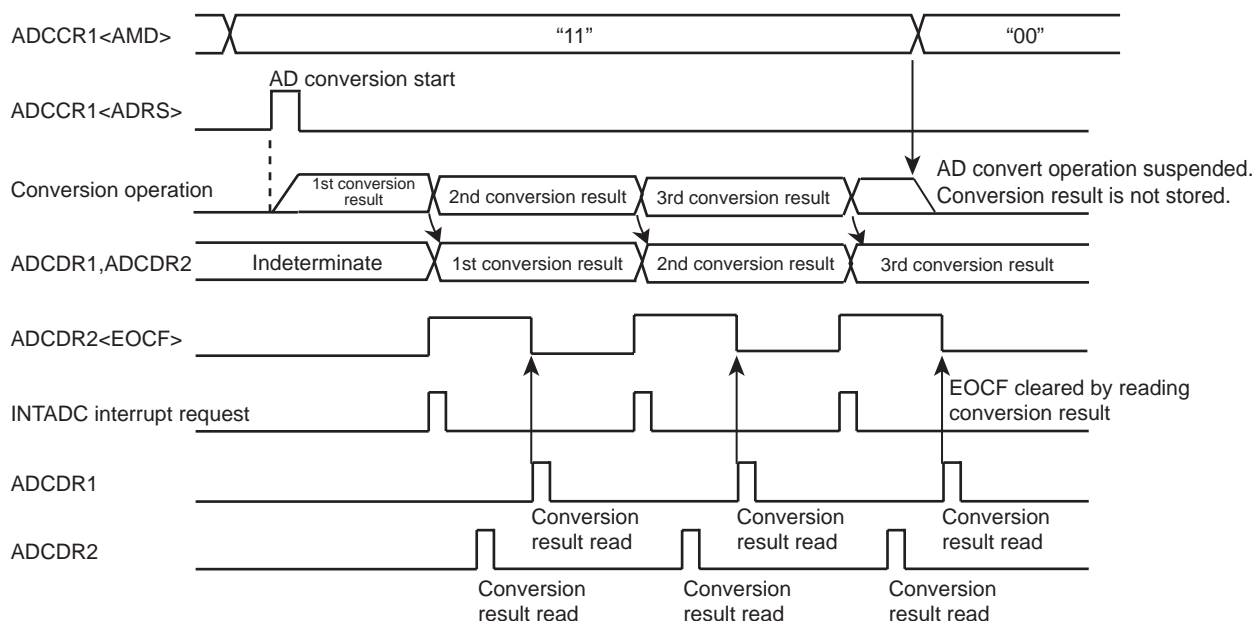


Figure 14-3 Repeat Mode

14.3.3 Register Setting

- Set up the AD converter control register 1 (ADCCR1) as follows:
 - Choose the channel to AD convert using AD input channel select (SAIN).
 - Specify analog input enable for analog input control (AINDS).
 - Specify AMD for the AD converter control operation mode (software or repeat mode).
- Set up the AD converter control register 2 (ADCCR2) as follows:
 - Set the AD conversion time using AD conversion time (ACK). For details on how to set the conversion time, refer to Figure 14-1 and AD converter control register 2.
 - Choose IREFON for DA converter control.
- After setting up (1) and (2) above, set AD conversion start (ADRS) of AD converter control register 1 (ADCCR1) to "1". If software start mode has been selected, AD conversion starts immediately.
- After an elapse of the specified AD conversion time, the AD converted value is stored in AD converted value register 1 (ADCDR1) and the AD conversion finished flag (EOCF) of AD converted value register 2 (ADCDR2) is set to "1", upon which time AD conversion interrupt INTADC is generated.
- EOCF is cleared to "0" by a read of the conversion result. However, if reconverted before a register read, although EOCF is cleared the previous conversion result is retained until the next conversion is completed.

Example :After selecting the conversion time 19.5 μ s at 16 MHz and the analog input channel AIN3 pin, perform AD conversion once. After checking EOCF, read the converted value, store the lower 2 bits in address 0009EH and store the upper 8 bits in address 0009FH in RAM. The operation mode is software start mode.

	: (port setting)	:		;Set port register appropriately before setting AD converter registers.
	:	:		(Refer to section I/O port in details)
	LD	(ADCCR1) , 00100011B		; Select AIN3
	LD	(ADCCR2) , 11011000B		;Select conversion time(312/fc) and operation mode
	SET	(ADCCR1) . 7		; ADRS = 1(AD conversion start)
SLOOP :	TEST	(ADCDR2) . 5		; EOCF= 1 ?
	JRS	T, SLOOP		
	LD	A , (ADCDR2)		; Read result data
	LD	(9EH) , A		
	LD	A , (ADCDR1)		; Read result data
	LD	(9FH), A		

14.4 STOP/SLOW Modes during AD Conversion

When standby mode (STOP or SLOW mode) is entered forcibly during AD conversion, the AD convert operation is suspended and the AD converter is initialized (ADCCR1 and ADCCR2 are initialized to initial value). Also, the conversion result is indeterminate. (Conversion results up to the previous operation are cleared, so be sure to read the conversion results before entering standby mode (STOP or SLOW mode).) When restored from standby mode (STOP or SLOW mode), AD conversion is not automatically restarted, so it is necessary to restart AD conversion. Note that since the analog reference voltage is automatically disconnected, there is no possibility of current flowing into the analog reference voltage.

14.5 Analog Input Voltage and AD Conversion Result

The analog input voltage is corresponded to the 10-bit digital value converted by the AD as shown in Figure 14-4.

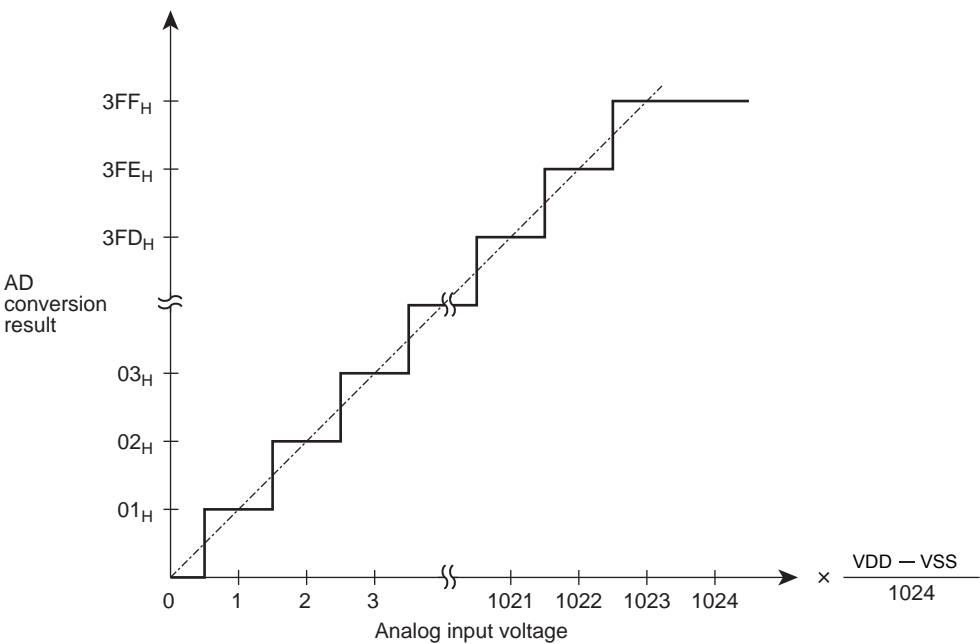


Figure 14-4 Analog Input Voltage and AD Conversion Result (Typ.)

14.6 Precautions about AD Converter

14.6.1 Analog input pin voltage range

Make sure the analog input pins (AIN0 to AIN7) are used at voltages within VDD to VSS. If any voltage outside this range is applied to one of the analog input pins, the converted value on that pin becomes uncertain. The other analog input pins also are affected by that.

14.6.2 Analog input shared pins

The analog input pins (AIN0 to AIN7) are shared with input/output ports. When using any of the analog inputs to execute AD conversion, do not execute input/output instructions for all other ports. This is necessary to prevent the accuracy of AD conversion from degrading. Not only these analog input shared pins, some other pins may also be affected by noise arising from input/output to and from adjacent pins.

14.6.3 Noise Countermeasure

The internal equivalent circuit of the analog input pins is shown in Figure 14-5. The higher the output impedance of the analog input source, more easily they are susceptible to noise. Therefore, make sure the output impedance of the signal source in your design is 5 k Ω or less. Toshiba also recommends attaching a capacitor external to the chip.

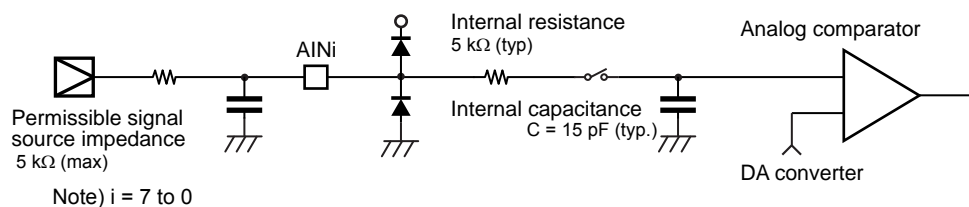


Figure 14-5 Analog Input Equivalent Circuit and Example of Input Pin Processing

15. Key-on Wakeup (KWU)

In the TMP86CH12MG, the STOP mode is released by not only P20($\overline{\text{INT5}}/\overline{\text{STOP}}$) pin but also four (STOP0 to STOP3) pins.

When the STOP mode is released by STOP0 to STOP3 pins, the $\overline{\text{STOP}}$ pin needs to be used. In details, refer to the following section " 15.2 Control ".

15.1 Configuration

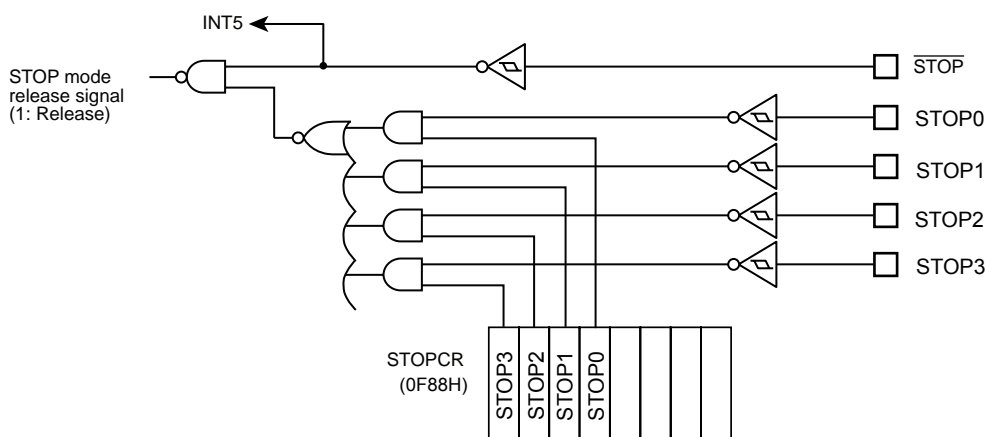


Figure 15-1 Key-on Wakeup Circuit

15.2 Control

STOP0 to STOP3 pins can be controlled by Key-on Wakeup Control Register (STOPCR). It can be configured as enable/disable in 1-bit unit. When those pins are used for STOP mode release, configure corresponding I/O pins to input mode by I/O port register beforehand.

Key-on Wakeup Control Register

STOPCR	7	6	5	4	3	2	1	0	
(0F88H)	STOP3	STOP2	STOP1	STOP0					(Initial value: 0000 ****)

STOP3	STOP mode released by STOP3	0: Disable 1: Enable	Write only
STOP2	STOP mode released by STOP2	0: Disable 1: Enable	Write only
STOP1	STOP mode released by STOP1	0: Disable 1: Enable	Write only
STOP0	STOP mode released by STOP0	0: Disable 1: Enable	Write only

15.3 Function

Stop mode can be entered by setting up the System Control Register (SYSCR1), and can be exited by detecting the "L" level on STOP0 to STOP3 pins, which are enabled by STOPCR, for releasing STOP mode (Note1).

Also, each level of the STOP0 to STOP3 pins can be confirmed by reading corresponding I/O port data register, check all STOP0 to STOP3 pins "H" that is enabled by STOPPCR before the STOP mode is started (Note2).

- Note 1: When the STOP mode released by the edge release mode (SYSCR1<RELM> = "0"), inhibit input from STOP0 to STOP3 pins by Key-on Wakeup Control Register (STOPPCR) or must be set "H" level into STOP0 to STOP3 pins that are available input during STOP mode.
- Note 2: When the $\overline{\text{STOP}}$ pin input is high or STOP0 to STOP3 pins input which is enabled by STOPPCR is low, executing an instruction which starts STOP mode will not place in STOP mode but instead will immediately start the release sequence (Warm up).
- Note 3: $\overline{\text{STOP}}$ pin doesn't have the control register such as STOPPCR, so when STOP mode is released by STOP0 to STOP3 pins, $\overline{\text{STOP}}$ pin also should be used as STOP mode release function.
- Note 4: In STOP mode, Key-on Wakeup pin which is enabled as input mode (for releasing STOP mode) by Key-on Wakeup Control Register (STOPPCR) may generate the penetration current, so the said pin must be disabled AD conversion input (analog voltage input).
- Note 5: When the STOP mode is released by STOP0 to STOP3 pins, the level of $\overline{\text{STOP}}$ pin should hold "L" level (Figure 15-2).

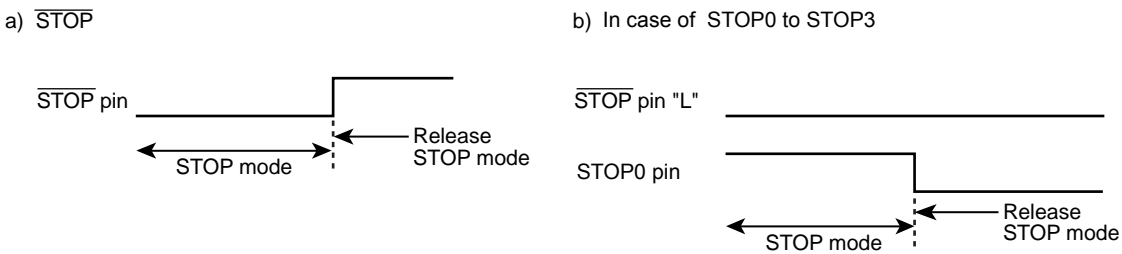


Figure 15-2 Priority of STOP pin and STOP0 to STOP3 pins

Table 15-1 Release level (edge) of STOP mode

Pin name	Release level (edge)	
	SYSCR1<RELM>="1" (Note2)	SYSCR1<RELM>="0"
$\overline{\text{STOP}}$	"H" level	Rising edge
STOP0	"L" level	Don't use (Note1)
STOP1	"L" level	Don't use (Note1)
STOP2	"L" level	Don't use (Note1)
STOP3	"L" level	Don't use (Note1)

16. Input/Output Circuit

16.1 Control pins

The input/output circuitries of the TMP86CH12MG control pins are shown below.

Control Pin	I/O	Input/Output Circuitry	Remarks
XIN XOUT	Input Output		Resonator connecting pins (high frequency) $R_f = 1.2 \text{ M}\Omega$ (typ.) $R_O = 0.5 \text{ k}\Omega$ (typ.)
XTIN XTOUT	Input Output		Resonator connecting pins (Low frequency) $R_f = 6 \text{ M}\Omega$ (typ.) $R_O = 220 \text{ k}\Omega$ (typ.)
$\overline{\text{RESET}}$	Input		Hysteresis input Pull-up resistor $R_{IN} = 220 \text{ k}\Omega$ (typ.) $R = 100 \Omega$ (typ.)
TEST	Input		Pull-down resistor $R_{IN} = 70 \text{ k}\Omega$ (typ.) $R = 100 \Omega$ (typ.)

16.2 Input/Output Ports

Port	I/O	Input/Output Circuitry	Remarks
P0	I/O	<p>Initial "High-Z"</p>	Sink open drain output or Tri-state output Hysteresis input High current output R = 100 Ω (typ.)
P1	I/O	<p>Initial "High-Z"</p>	Tri-state I/O R = 100 Ω (typ.)
P2	I/O	<p>Initial "High-Z"</p>	Sink open drain output Hysteresis input R = 100 Ω (typ.)
P3	I/O	<p>Initial "High-Z"</p>	Tri-state I/O Hysteresis input R = 100 Ω (typ.)

17. Electrical Characteristics

17.1 Absolute Maximum Ratings

The absolute maximum ratings are rated values, which must not be exceeded during operation, even for an instant. Any one of the ratings must not be exceeded. If any absolute maximum rating is exceeded, a device may break down or its performance may be degraded, causing it to catch fire or explode resulting in injury to the user. Thus, when designing products which include this device, ensure that no absolute maximum rating value will ever be exceeded.

($V_{SS} = 0\text{ V}$)

Parameter	Symbol	Pins	Rating	Unit
Supply Voltage	V_{DD}		-0.3 to 6.5	V
Input Voltage	V_{IN}		-0.3 to $V_{DD} + 0.3$	
Output Voltage	V_{OUT}		-0.3 to $V_{DD} + 0.3$	
Output Current (Per 1 pin)	I_{OUT1}	P0, P1, P3 ports	-1.8	mA
	I_{OUT2}	P1, P2, P3 ports	3.2	
	I_{OUT3}	P0 ports	30	
Output Current (Total)	ΣI_{OUT1}	P0, P1, P3 ports	-30	
	ΣI_{OUT2}	P1, P2, P3 ports	60	
	ΣI_{OUT3}	P0 ports	80	
Power Dissipation [Topr = 85°C]	P_D		145	mW
Soldering Temperature (Time)	Tsld		260 (10 s)	°C
Storage Temperature	Tstg		-55 to 125	
Operating Temperature	Topr		-40 to 85	

17.2 Recommended Operating Condition

The recommended operating conditions for a device are operating conditions under which it can be guaranteed that the device will operate as specified. If the device is used under operating conditions other than the recommended operating conditions (supply voltage, operating temperature range, specified AC/DC values etc.), malfunction may occur. Thus, when designing products which include this device, ensure that the recommended operating conditions for the device are always adhered to.

($V_{SS} = 0\text{ V}$, Topr = -40 to 85°C)

Parameter	Symbol	Pins	Condition		Min	Max	Unit
Supply Voltage	V _{DD}		fc = 16 MHz	NORMAL1, 2 mode IDLE0, 1, 2 mode	4.5	5.5	V
			fc = 8 MHz	NORMAL1, 2 mode IDLE0, 1, 2 mode	2.7		
			fs = 32.768 kHz	SLOW1, 2 mode SLEEP0, 1, 2 mode			
			STOP mode				
Input high Level	V _{IH1}	Except Hysteresis input	V _{DD} ≥ 4.5 V	V _{DD} ×0.70	V _{DD}		
	V _{IH2}	Hysteresis input		V _{DD} ×0.75			
	V _{IH3}		V _{DD} < 4.5 V	V _{DD} ×0.90			
Input low Level	V _{IL1}	Except Hysteresis input	V _{DD} ≥ 4.5 V	0	V _{DD} ×0.30		
	V _{IL2}	Hysteresis input			V _{DD} ×0.25		
	V _{IL3}		V _{DD} < 4.5 V		V _{DD} ×0.10		
Clock Frequency	fc	XIN, XOUT	V _{DD} = 2.7 to 5.5 V	1.0	8.0	MHz	
			V _{DD} = 4.5 to 5.5 V		16.0		
	fs	XTIN, XTOUT	V _{DD} = 2.7 to 5.5 V	30.0	34.0	kHz	

17.3 DC Characteristics

($V_{SS} = 0.0\text{ V}$, $T_{opr} = -40\text{ to }85^{\circ}\text{C}$)

Parameter	Symbol	Pins	Condition	Min	Typ.	Max	Unit
Hysteresis Voltage	V_{HS}	Hysteresis input		–	0.9	–	V
Input Current	I_{IN1}	TEST	$V_{DD} = 5.5\text{ V}$, $V_{IN} = 5.5\text{ V}/0\text{ V}$	–	–	± 2	μA
	I_{IN2}	Sink Open-drain, Tri-state					
	I_{IN3}	$\overline{\text{RESET}}$					
Input Resistance	R_{IN1}	TEST Pull-Down	$V_{DD} = 5.5\text{ V}$, $V_{IN} = 5.5\text{ V}$	–	70	–	$\text{k}\Omega$
	R_{IN2}	$\overline{\text{RESET}}$ Pull-Up	$V_{DD} = 5.5\text{ V}$, $V_{IN} = 0\text{ V}$	100	220	450	
Output leakage current	I_{LO1}	Sink open drain port	$V_{DD} = 5.5\text{ V}$, $V_{OUT} = 5.5\text{ V}$	–	–	2	μA
	I_{LO2}	Tri-state port	$V_{DD} = 5.5\text{ V}$, $V_{OUT} = 5.5\text{ V}/0\text{ V}$	–	–	± 2	
Output High Voltage	V_{OH}	Tri-state Port	$V_{DD} = 4.5\text{ V}$, $I_{OH} = -0.7\text{ mA}$	4.1	–	–	V
Output Low Voltage	V_{OL}	Except X_{OUT} , P0 Port	$V_{DD} = 4.5\text{ V}$, $I_{OL} = 1.6\text{ mA}$	–	–	0.4	
Output Low Current	I_{OL}	High Current Port (P0 Port)	$V_{DD} = 4.5\text{ V}$, $V_{OL} = 1.0\text{ V}$	–	20	–	mA
Supply Current in NORMAL1, 2 mode	I_{DD}		$V_{DD} = 5.5\text{ V}$ $V_{IN} = 5.3/0.2\text{ V}$ $f_c = 16\text{ MHz}$ $f_s = 32.768\text{ kHz}$	–	10	13	
Supply Current in IDLE0, 1, 2 mode				–	6.5	10	μA
Supply Current in SLOW1 mode			$V_{DD} = 3.0\text{ V}$ $V_{IN} = 2.8\text{ V}/0.2\text{ V}$ $f_s = 32.768\text{ kHz}$	–	8	18	
Supply Current in SLEEP1 mode				–	5	15	
Supply Current in SLEEP0 mode				–	4	12	
Supply Current in STOP mode			$V_{DD} = 5.5\text{ V}$ $V_{IN} = 5.3\text{ V}/0.2\text{ V}$	–	0.5	10	

Note 1: Typical values show those at $T_{opr} = 25^{\circ}\text{C}$, $V_{DD} = 5\text{ V}$

Note 2: Input current (I_{IN1} , I_{IN3}); The current through pull-up or pull-down resistor is not included.

Note 3: The supply current in SLOW 2 and SLEEP 2 mode are similar with the supply current in IDLE0, 1, 2 mode.

17.4 AD Conversion Characteristics

(V_{SS} = 0.0 V, 4.5 V ≤ V_{DD} ≤ 5.5 V, T_{opr} = −40 to 85°C)

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Analog Input Voltage	V _{AIN}		V _{SS}	–	V _{DD}	V
Non linearity Error		V _{DD} = 5.0 V V _{SS} = 0.0 V	–	–	±4	LSB
Zero Point Error			–	–	±4	
Full Scale Error			–	–	±4	
Total Error			–	–	±4	

(V_{SS} = 0.0 V, 2.7 V ≤ V_{DD} < 4.5 V, T_{opr} = −40 to 85°C)

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Analog Input Voltage	V _{AIN}		V _{SS}	–	V _{DD}	V
Non linearity Error		V _{DD} = 3.0 V V _{SS} = 0.0 V	–	–	±4	LSB
Zero Point Error			–	–	±4	
Full Scale Error			–	–	±4	
Total Error			–	–	±4	

Note 1: The total error includes all errors except a quantization error, and is defined as a maximum deviation from the ideal conversion line.

Note 2: Conversion time is different in recommended value by power supply voltage.
About conversion time, please refer to “10-bit AD converter (ADC)”.

Note 3: Please use input voltage to AIN input Pin in limit of V_{DD} – V_{SS}.

When voltage of range outside is input, conversion value becomes unsettled and gives affect to other channel conversion value.

17.5 AC Characteristics

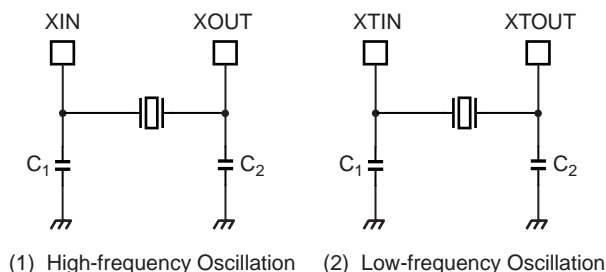
(V_{SS} = 0 V, 4.5 V ≤ V_{DD} ≤ 5.5 V, T_{opr} = −40 to 85°C)

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Machine Cycle Time	tcy	NORMAL1, 2 mode	0.25	–	4	μs
		IDLE0, 1, 2 mode				
		SLOW1, 2 mode	117.6	–	133.3	
		SLEEP0, 1, 2 mode				
High Level Clock Pulse Width	tWCH	For external clock operation (XIN input) fc = 16 MHz	–	31.25	–	ns
Low Level Clock Pulse Width	tWCL					
High Level Clock Pulse Width	tWSH	For external clock operation (XTIN input) fs = 32.768 kHz	–	15.26	–	μs
Low Level Clock Pulse Width	tWSL					

(V_{SS} = 0 V, 2.7 V ≤ V_{DD} < 4.5 V, T_{opr} = −40 to 85°C)

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Machine Cycle Time	t _{cy}	NORMAL1, 2 mode	0.5	–	4	μs
		IDLE0, 1, 2 mode				
		SLOW1, 2 mode	117.6	–	133.3	
		SLEEP0, 1, 2 mode				
High Level Clock Pulse Width	t _{WCH}	For external clock operation (XIN input) f _c = 4.2 MHz	–	62.5	–	ns
Low Level Clock Pulse Width	t _{WCL}					
High Level Clock Pulse Width	t _{WSH}	For external clock operation (XTIN input) f _s = 32.768 kHz	–	15.26	–	μs
Low Level Clock Pulse Width	t _{WSL}					

17.6 Recommended Oscillating Conditions



Note 1: To ensure stable oscillation, the resonator position, load capacitance, etc. must be appropriate. Because these factors are greatly affected by board patterns, please be sure to evaluate operation on the board on which the device will actually be mounted.

Note 2: For the resonators to be used with Toshiba microcontrollers, we recommend ceramic resonators manufactured by Murata Manufacturing Co., Ltd.

For details, please visit the website of Murata at the following URL:
<http://www.murata.com>

17.7 Handling Precaution

- The solderability test conditions for lead-free products (indicated by the suffix G in product name) are shown below.
 1. When using the Sn-37Pb solder bath
 - Solder bath temperature = 230 °C
 - Dipping time = 5 seconds
 - Number of times = once
 - R-type flux used
 2. When using the Sn-3.0Ag-0.5Cu solder bath
 - Solder bath temperature = 245 °C
 - Dipping time = 5 seconds
 - Number of times = once
 - R-type flux used

Note: The pass criterion of the above test is as follows:

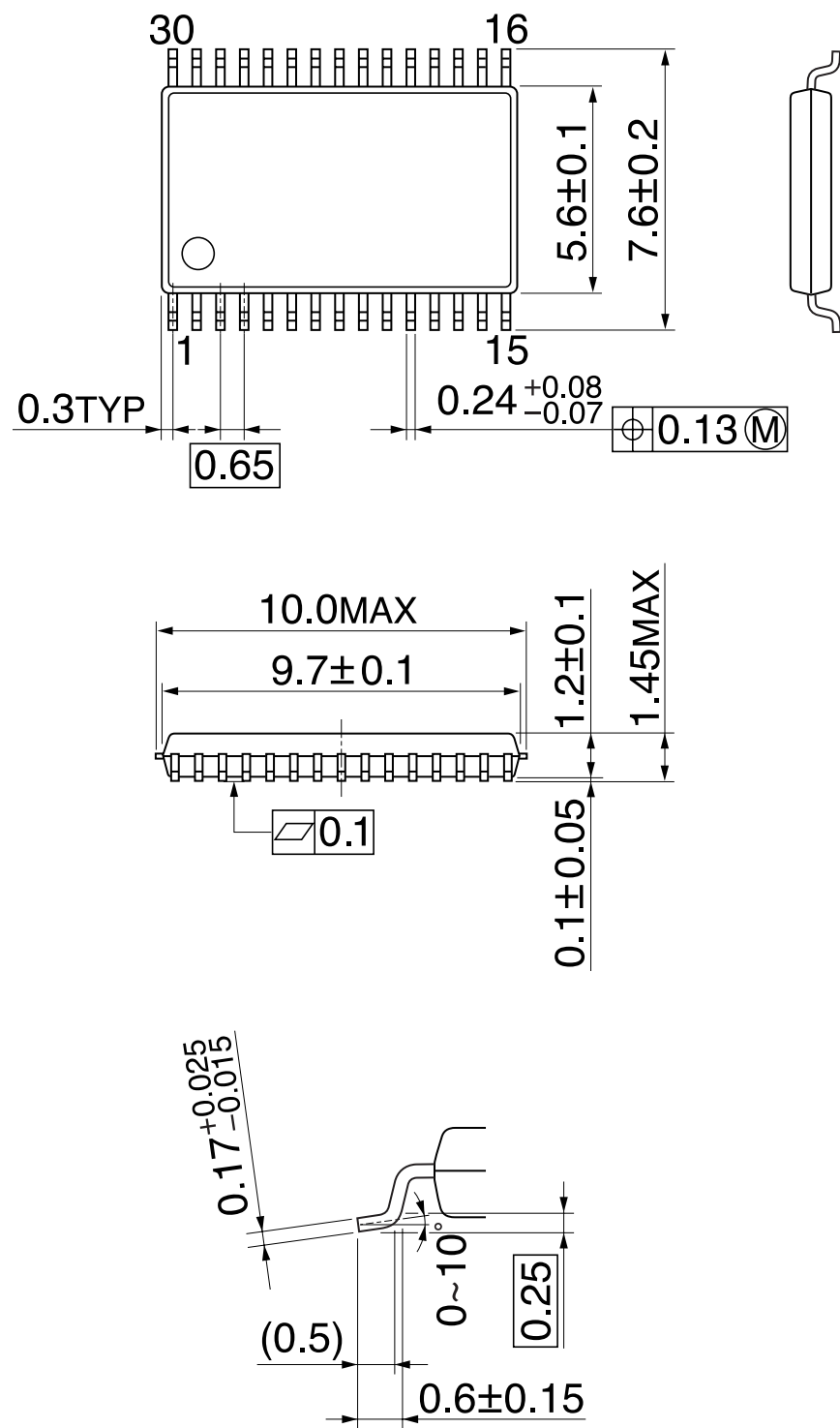
Solderability rate until forming $\geq 95\%$

- When using the device (oscillator) in places exposed to high electric fields such as cathode-ray tubes, we recommend electrically shielding the package in order to maintain normal operating condition.

18. Package Dimension

P-SSOP30-56-0.65

Unit: mm





This is a technical document that describes the operating functions and electrical specifications of the 8-bit microcontroller series TLCS-870/C (LSI).

Toshiba provides a variety of development tools and basic software to enable efficient software development.

These development tools have specifications that support advances in microcomputer hardware (LSI) and can be used extensively. Both the hardware and software are supported continuously with version updates.

The recent advances in CMOS LSI production technology have been phenomenal and microcomputer systems for LSI design are constantly being improved. The products described in this document may also be revised in the future. Be sure to check the latest specifications before using.

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