TOSHIBA

8 Bit Microcontroller

TLCS-870/C Series

TMP86CP27AFG

TOSHIBA CORPORATION

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Revision History

Date	Revision	
2006/9/6	1	First Release
2006/9/12	2	Contents Revised
2006/12/18	3	Contents Revised

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TMP86CP27AFG

9. 8-Bit TimerCounter (TC3, TC4)

10. Real-Time Clock

11. Asynchronous Serial interface (UART)

12. Synchronous Serial Interface (SIO)

13. 10-bit AD Converter (ADC)

14. Key-on Wakeup (KWU)

15. LCD Driver

16. Input/Output Circuitry

17. Electrical Characteristics

18. Package Dimensions

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

TMP86CP27AFG

Product No.	ROM (MaskROM)	RAM	Package	FLASH MCU	Emulation Chip
TMP86CP27AFG	49152 bytes	1024 bytes	P-QFP80-1420-0.80B	TMP86FS27FG	TMP86C927XB

1.1 Features

1. 8-bit single chip microcomputer TLCS-870/C series
   - Instruction execution time :

     0.25 μs (at 16 MHz)

     122 μs (at 32.768 kHz)
   - 132 types & 731 basic instructions
2. 20interrupt sources (External : 7 Internal : 13)
3. Input / Output ports (55 pins)

   Large current output: 8pins (Typ. 20mA), LED direct drive
4. Prescaler
   - Time base timer
   - Divider output function
5. Watchdog Timer
6. 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

   Emargency stop pin
7. 8-bit timer counter : 2 ch
   - Timer, Event counter, Programmable divider output (PDO),

Pulse width modulation (PWM) output,

Programmable pulse generation (PPG) modes

8. 8-bit UART : 1 ch
9. 8-bit SIO: 1 ch
10. 10-bit successive approximation type AD converter
    - Analog input: 8 ch
11. Key-on wakeup : 4 ch
12. LCD driver/controller

    Built-in voltage booster for LCD driver With display memory
    LCD direct drive capability (MAX 40 seg × 4 com)
    1/4,1/3,1/2duties or static drive are programmably selectable
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 TBTCR<TBTCK>.

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

    IDLE2 mode: CPU stops and peripherals operate using high and low frequency clock. Release by interruputs. (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 TBTCR<TBTCK>.

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

    SLEEP2 mode: CPU stops and peripherals operate using high and low frequency clock. Release by interruput.
15. Wide operation voltage:

    4.5 V to 5.5 V at 16MHz /32.768 kHz

    2.7 V to 5.5 V at 8 MHz /32.768 kHz

1.2 Pin Assignment

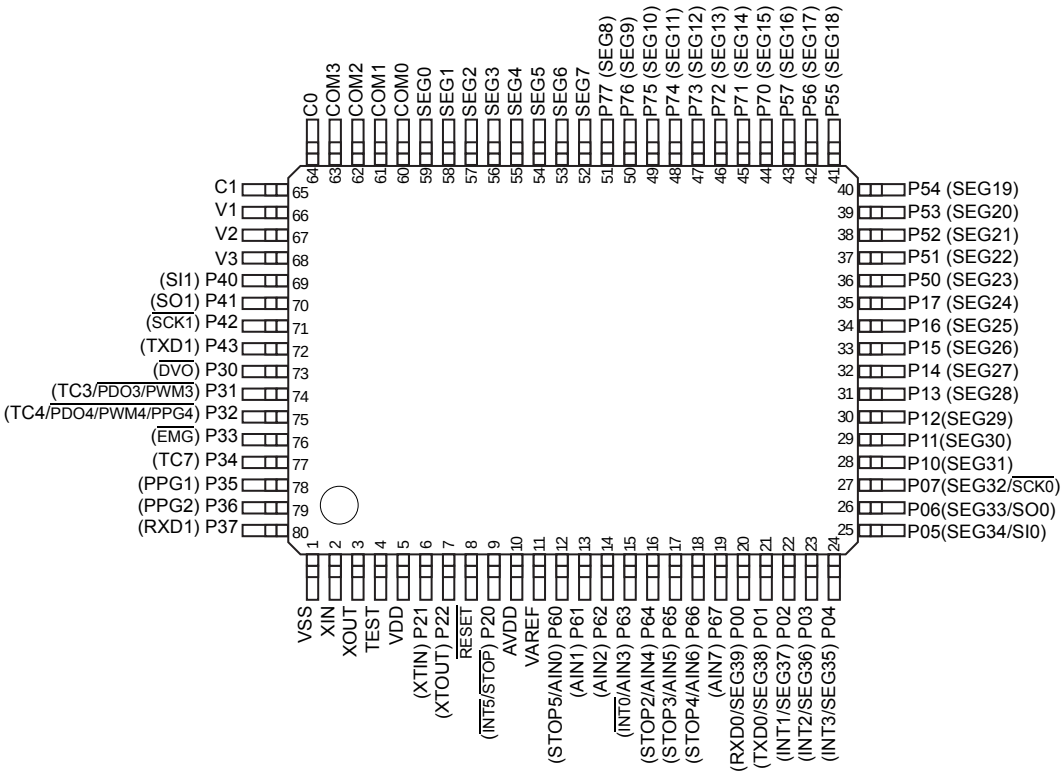


Figure 1-1 Pin Assignment

1.3 Block Diagram

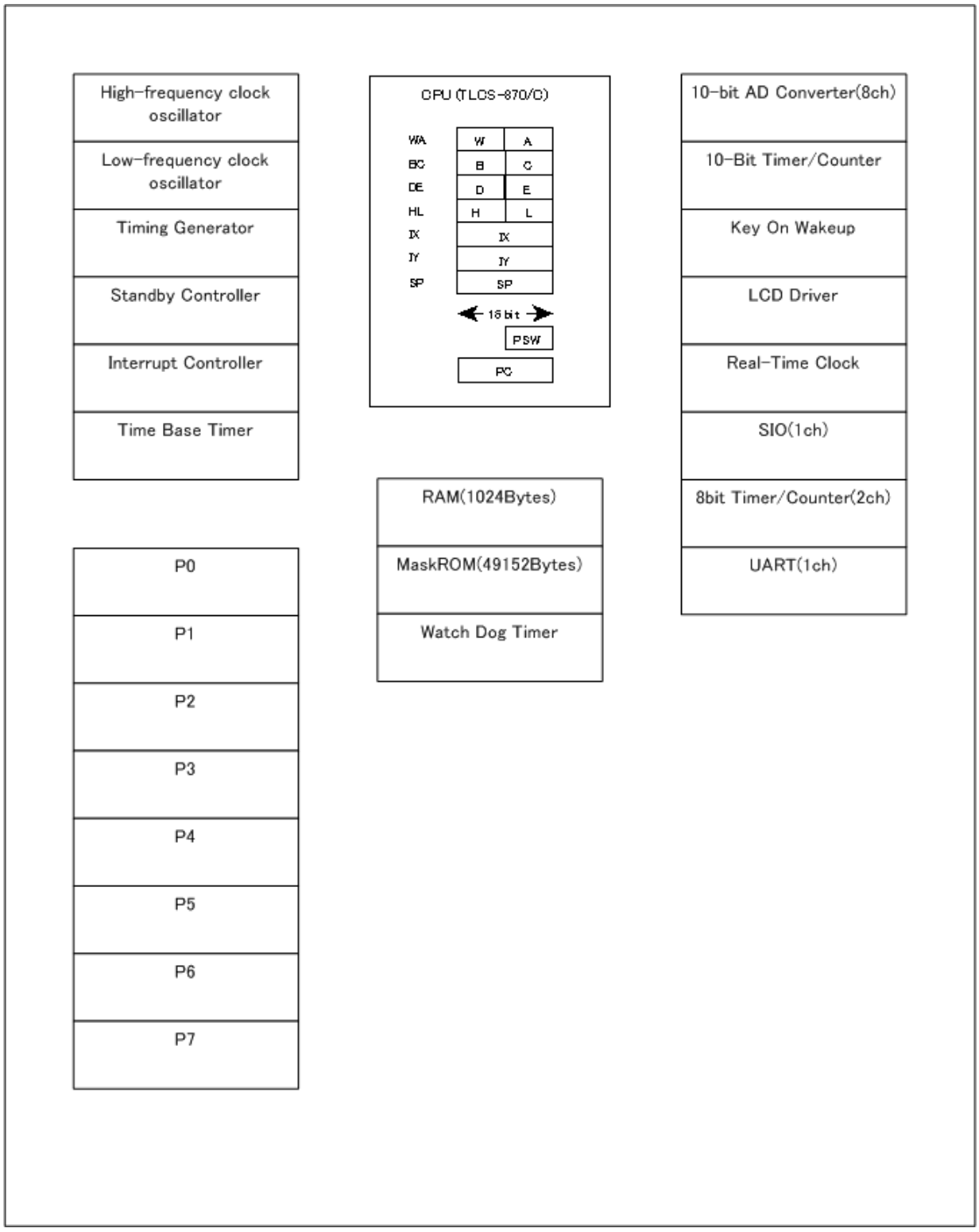


Figure 1-2 Block Diagram

1.4 Pin Names and Functions

Table 1-1 Pin Names and Functions(1/4)

Pin Name	Pin Number	Input/Output	Functions
P07 SEG32 $\overline{SCK0}$	27	IO O IO	PORT07 LCD segment output 32 Serial Clock I/O 0
P06 SEG33 SO0	26	IO O O	PORT06 LCD segment output 33 Serial Data Output 0
P05 SEG34 SI0	25	IO O I	PORT05 LCD segment output 34 Serial Data Input 0
P04 SEG35 INT3	24	IO O I	PORT04 LCD segment output 35 External interrupt 3 input
P03 SEG36 INT2	23	IO O I	PORT03 LCD segment output 36 External interrupt 2 input
P02 SEG37 INT1	22	IO O I	PORT02 LCD segment output 37 External interrupt 1 input
P01 SEG38 TXD0	21	IO O O	PORT01 LCD segment output 38 UART data output 0
P00 SEG39 RXD0	20	IO O I	PORT00 LCD segment output 39 UART data input 0
P17 SEG24	35	IO O	PORT17 LCD segment output 24
P16 SEG25	34	IO O	PORT16 LCD segment output 25
P15 SEG26	33	IO O	PORT15 LCD segment output 26
P14 SEG27	32	IO O	PORT14 LCD segment output 27
P13 SEG28	31	IO O	PORT13 LCD segment output 28
P12 SEG29	30	IO O	PORT12 LCD segment output 29
P11 SEG30	29	IO O	PORT11 LCD segment output 30
P10 SEG31	28	IO O	PORT10 LCD segment output 31
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

Table 1-1 Pin Names and Functions(2/4)

Pin Name	Pin Number	Input/Output	Functions
P20 $\overline{\text{STOP}}$ $\overline{\text{INT5}}$	9	IO I I	PORT20 STOP mode release signal input External interrupt 5 input
P37 RXD1	80	IO I	PORT37 UART data input 1
P36 PPG2	79	IO O	PORT36 Timer counter 7 PPG2 output
P35 PPG1	78	IO O	PORT35 Timer counter 7 PPG1 output
P34 TC7	77	IO I	PORT34 Timer counter 7 input
P33 $\overline{\text{EMG}}$	76	IO I	PORT33 Timer counter 7 Emergency stop input
P32 $\overline{\text{PDO4/PWM4/PPG4}}$ TC4	75	IO O I	PORT32 PDO4/PWM4/PPG4 output TC4 input
P31 $\overline{\text{PDO3/PWM3}}$ TC3	74	IO O I	PORT31 PDO3/PWM3 output TC3 input
P30 $\overline{\text{DVO}}$	73	IO O	PORT30 Divider Output
P43 TXD1	72	IO O	PORT43 UART data output 1
P42 $\overline{\text{SCK1}}$	71	IO IO	PORT42 Serial Clock I/O 1
P41 SO1	70	IO O	PORT41 Serial Data Output 1
P40 SI1	69	IO I	PORT40 Serial Data Input 1
P57 SEG16	43	IO O	PORT57 LCD segment output 16
P56 SEG17	42	IO O	PORT56 LCD segment output 17
P55 SEG18	41	IO O	PORT55 LCD segment output 18
P54 SEG19	40	IO O	PORT54 LCD segment output 19
P53 SEG20	39	IO O	PORT53 LCD segment output 20
P52 SEG21	38	IO O	PORT52 LCD segment output 21
P51 SEG22	37	IO O	PORT51 LCD segment output 22
P50 SEG23	36	IO O	PORT50 LCD segment output 23
P67 AIN7	19	IO I	PORT67 Analog Input7

Table 1-1 Pin Names and Functions(3/4)

Pin Name	Pin Number	Input/Output	Functions
P66 AIN6 STOP4	18	IO I I	PORT66 Analog Input6 STOP4 input
P65 AIN5 STOP3	17	IO I I	PORT65 Analog Input5 STOP3 input
P64 AIN4 STOP2	16	IO I I	PORT64 Analog Input4 STOP2 input
P63 AIN3 $\overline{\text{INT0}}$	15	IO I I	PORT63 Analog Input3 External interrupt 0 input
P62 AIN2	14	IO I	PORT62 Analog Input2
P61 AIN1	13	IO I	PORT61 Analog Input1
P60 AIN0 STOP5	12	IO I I	PORT60 Analog Input0 STOP5 input
P77 SEG8	51	IO O	PORT77 LCD segment output 8
P76 SEG9	50	IO O	PORT76 LCD segment output 9
P75 SEG10	49	IO O	PORT75 LCD segment output 10
P74 SEG11	48	IO O	PORT74 LCD segment output 11
P73 SEG12	47	IO O	PORT73 LCD segment output 12
P72 SEG13	46	IO O	PORT72 LCD segment output 13
P71 SEG14	45	IO O	PORT71 LCD segment output 14
P70 SEG15	44	IO O	PORT70 LCD segment output 15
SEG7	52	O	LCD segment output 7
SEG6	53	O	LCD segment output 6
SEG5	54	O	LCD segment output 5
SEG4	55	O	LCD segment output 4
SEG3	56	O	LCD segment output 3
SEG2	57	O	LCD segment output 2
SEG1	58	O	LCD segment output 1
SEG0	59	O	LCD segment output 0
COM3	63	O	LCD common output 3
COM2	62	O	LCD common output 2

Table 1-1 Pin Names and Functions(4/4)

Pin Name	Pin Number	Input/Output	Functions
COM1	61	O	LCD common output 1
COM0	60	O	LCD common output 0
V3	68	I	LCD voltage booster pin
V2	67	I	LCD voltage booster pin
V1	66	I	LCD voltage booster pin
C1	65	I	LCD voltage booster pin
C0	64	I	LCD voltage booster pin
XIN	2	I	Resonator connecting pins for high-frequency clock
XOUT	3	O	Resonator connecting pins for high-frequency clock
$\overline{\text{RESET}}$	8	I	Reset signal
TEST	4	I	Test pin for out-going test. Normally, be fixed to low.
VAREF	11	I	Analog Base Voltage Input Pin for A/D Conversion
AVDD	10	I	Analog Power Supply
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 TMP86CP27AFG 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 TMP86CP27AFG memory address map.

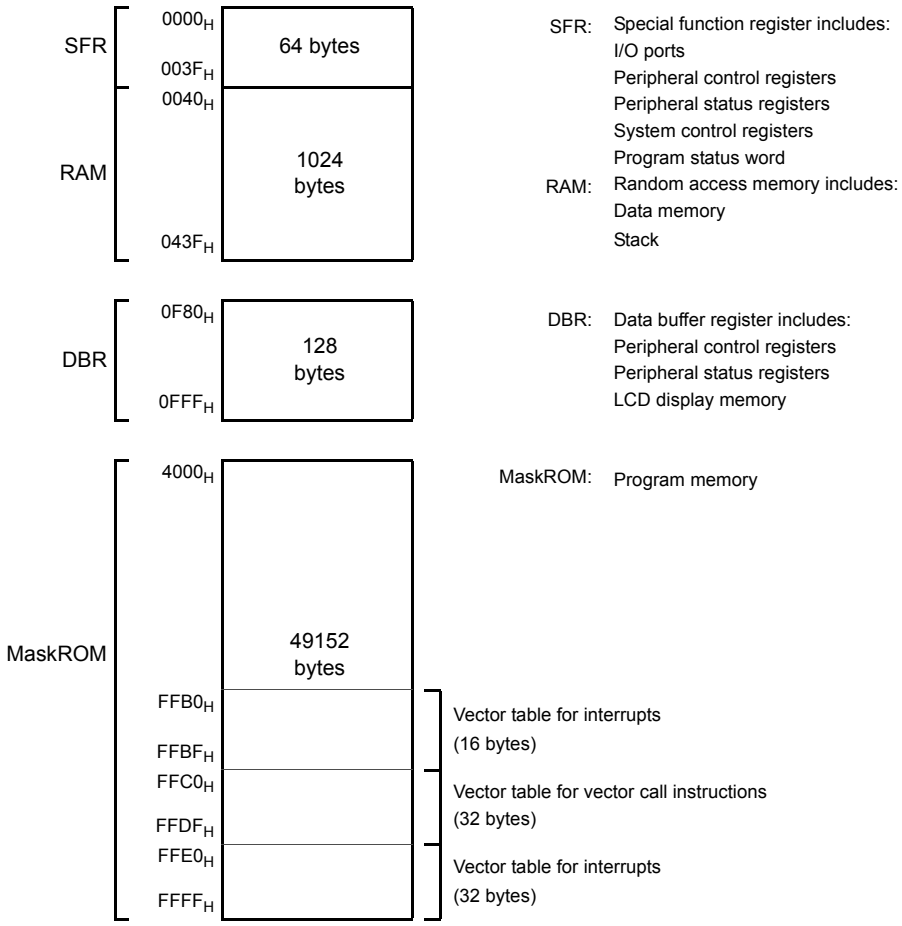


Figure 2-1 Memory Address Map

2.1.2 Program Memory (MaskROM)

The TMP86CP27AFG has a 49152 bytes (Address 4000H to FFFFH) of program memory (MaskROM).

2.1.3 Data Memory (RAM)

The TMP86CP27AFG has 1024bytes (Address 0040H to 043FH) 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”. (TMP86CP27AFG)

```
        LD      HL, 0040H       ; Start address setup
        LD      A, H            ; Initial value (00H) setup
        LD      BC, 03FFH
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.

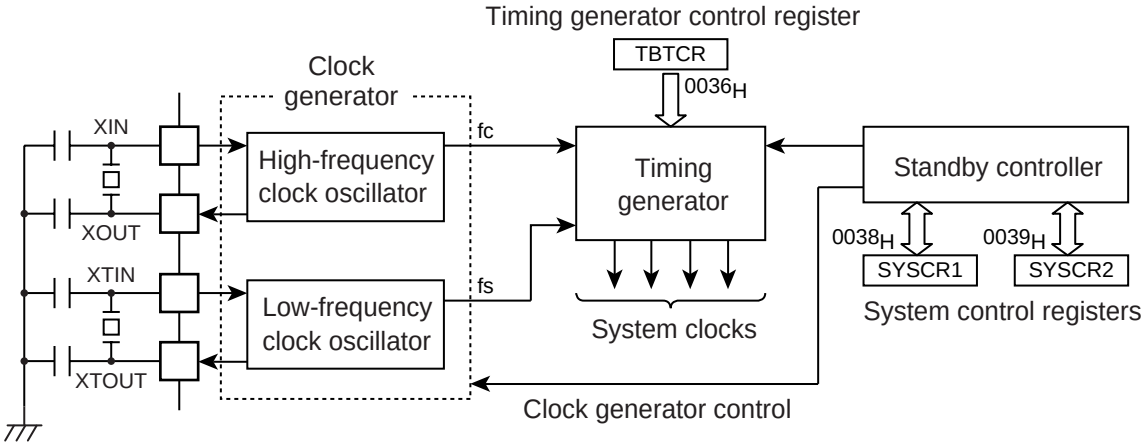


Figure 2-2 System Colck Control

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.

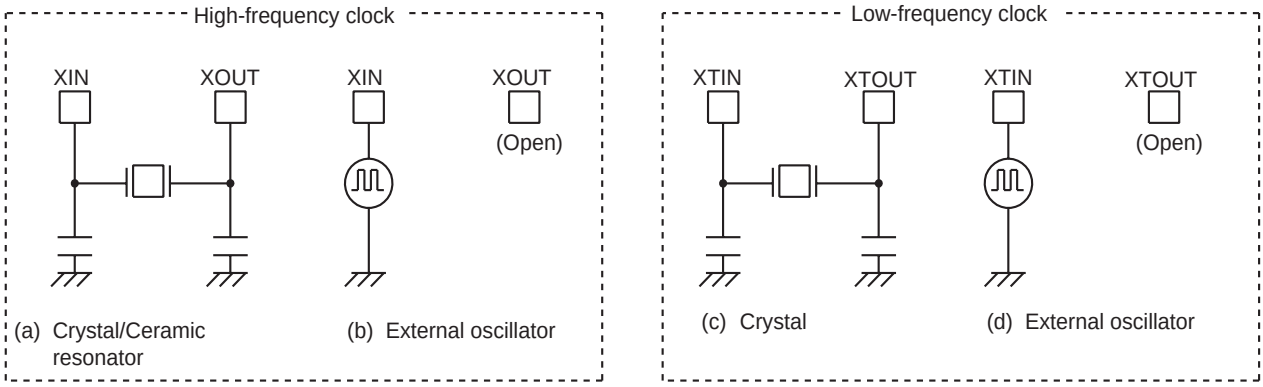


Figure 2-3 Examples of Resonator Connection

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 (fc or fs). 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
7. LCD

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”.

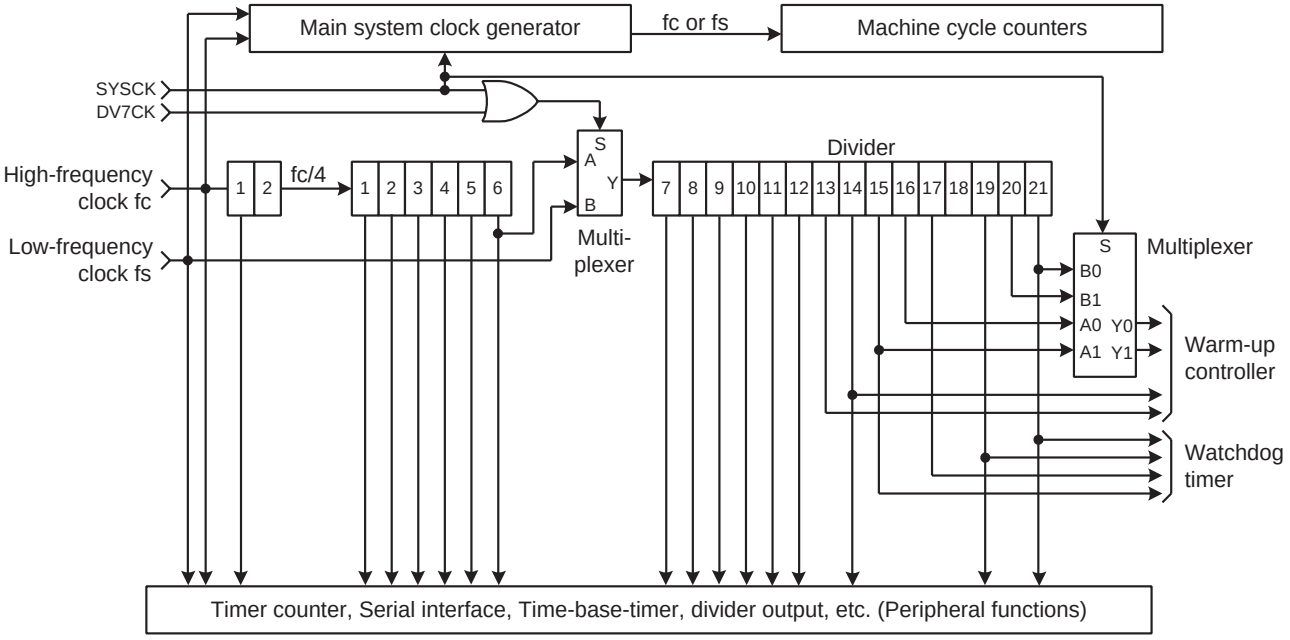


Figure 2-4 Configuration of Timing Generator

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 an "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.

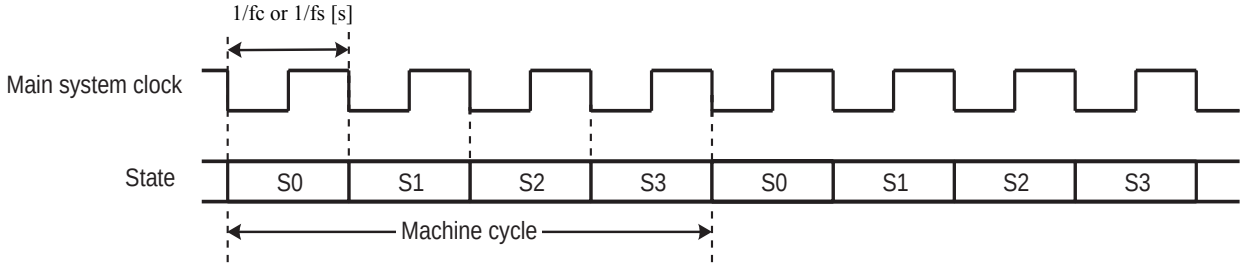


Figure 2-5 Machine Cycle

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 TMP86CP27AFG 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”, EF7 (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/fc [s] in the NORMAL2 and IDLE2 modes, and 4/fs [s] (122 μs at fs = 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>.

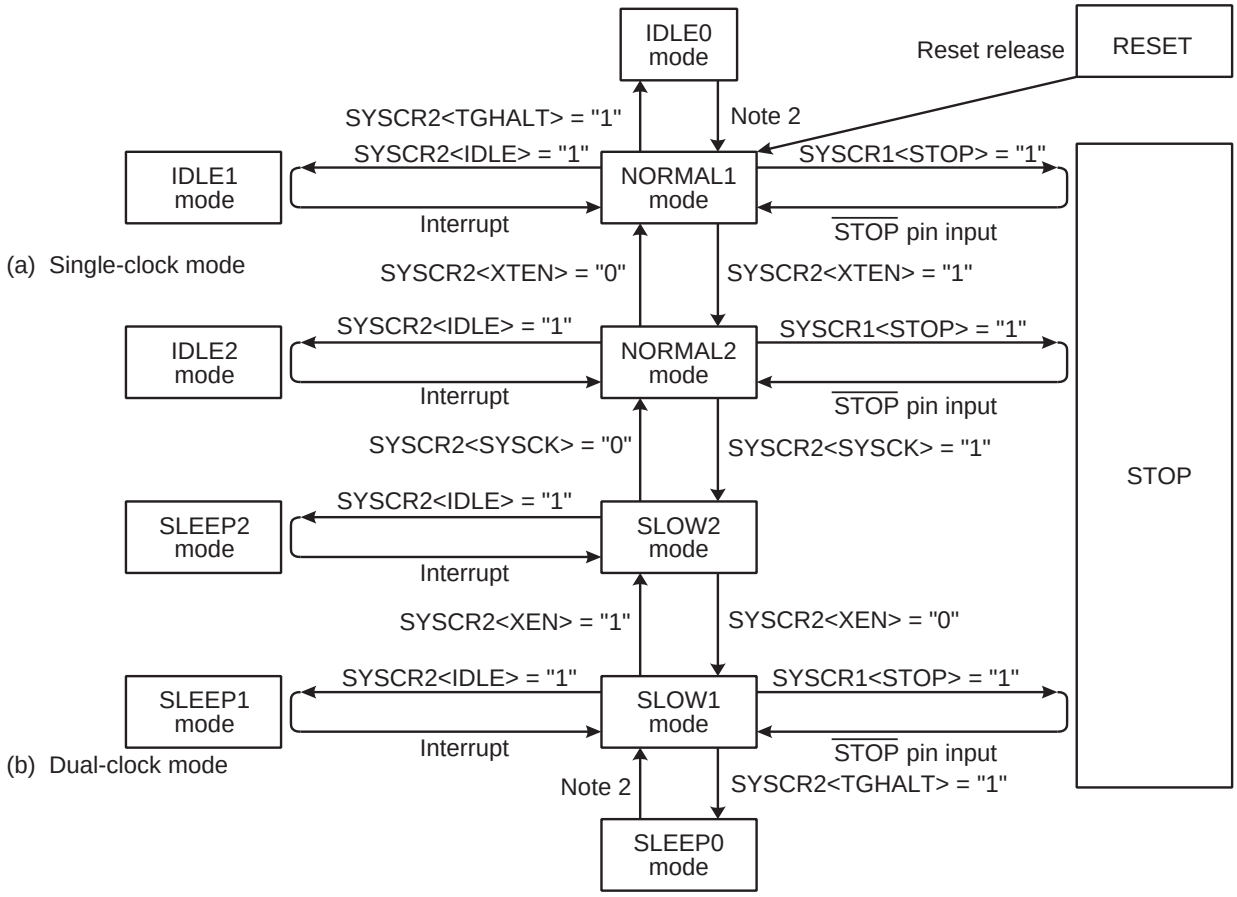
When SLEEP0 mode starts, the CPU stops and the timing generator stops feeding the clock to the peripheral circuits other than TBT. Then, upon detecting the falling edge of the source clock selected with TBTCR<TBTCK>, the timing generator starts feeding the clock to all peripheral circuits.

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”, EF7 (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 TBTCR<TBTCK> 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			
	IDLE0					Halt	
	STOP	Stop			Halt		–
Dual clock	NORMAL2	Oscillation	Oscillation	Operate with high frequency	Operate	Operate	4/fc [s]
	IDLE2			Halt			
	SLOW2			Operate with low frequency			4/fs [s]
	SLEEP2			Halt			
	SLOW1	Stop		Operate with low frequency			
	SLEEP1			Halt			
	SLEEP0					Halt	
	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	3×2^{16}/fc	3×2^{13}/fs	
		01	2^{16}/fc	2^{13}/fs	
		10	3×2^{14}/fc	3×2^{6}/fs	
		11	2^{14}/fc	2^{6}/fs	

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: fc: High-frequency clock [Hz], fs: 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 TBTCR<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 $\overline{STOP}$ pin input and key-on wakeup input (STOP5 to STOP2) which is controlled by the STOP mode release control register (STOPCR).
The $\overline{STOP}$ pin is also used both as a port P20 and an $\overline{INT5}$ (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 (STOP5 to STOP2) 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 (STOP5 to STOP2). 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 $\overline{STOP}$ pin high or setting the STOP5 to STOP2 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 $\overline{STOP}$ pin input is high or STOP5 to STOP2 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 $\overline{STOP}$ pin input is low or STOP5 to STOP2 input is high. The following two methods can be used for confirmation.

1. Testing a port.
2. Using an external interrupt input $\overline{INT5}$ ($\overline{INT5}$ 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 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
```

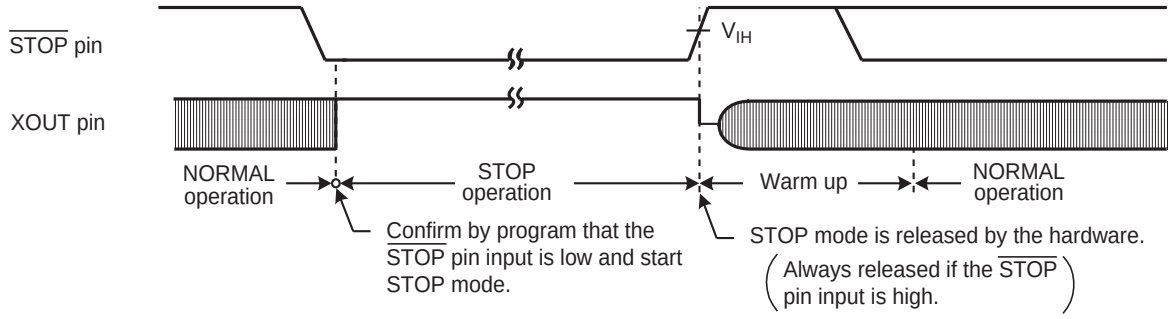


Figure 2-7 Level-sensitive Release Mode

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 STOP5 to STOP2 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
```

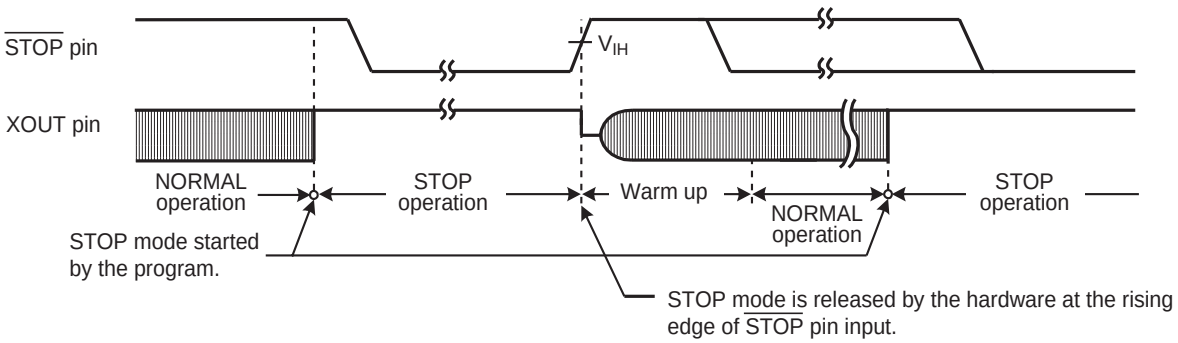


Figure 2-8 Edge-sensitive Release Mode

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 fc = 16.0 MHz, fs = 32.768 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.

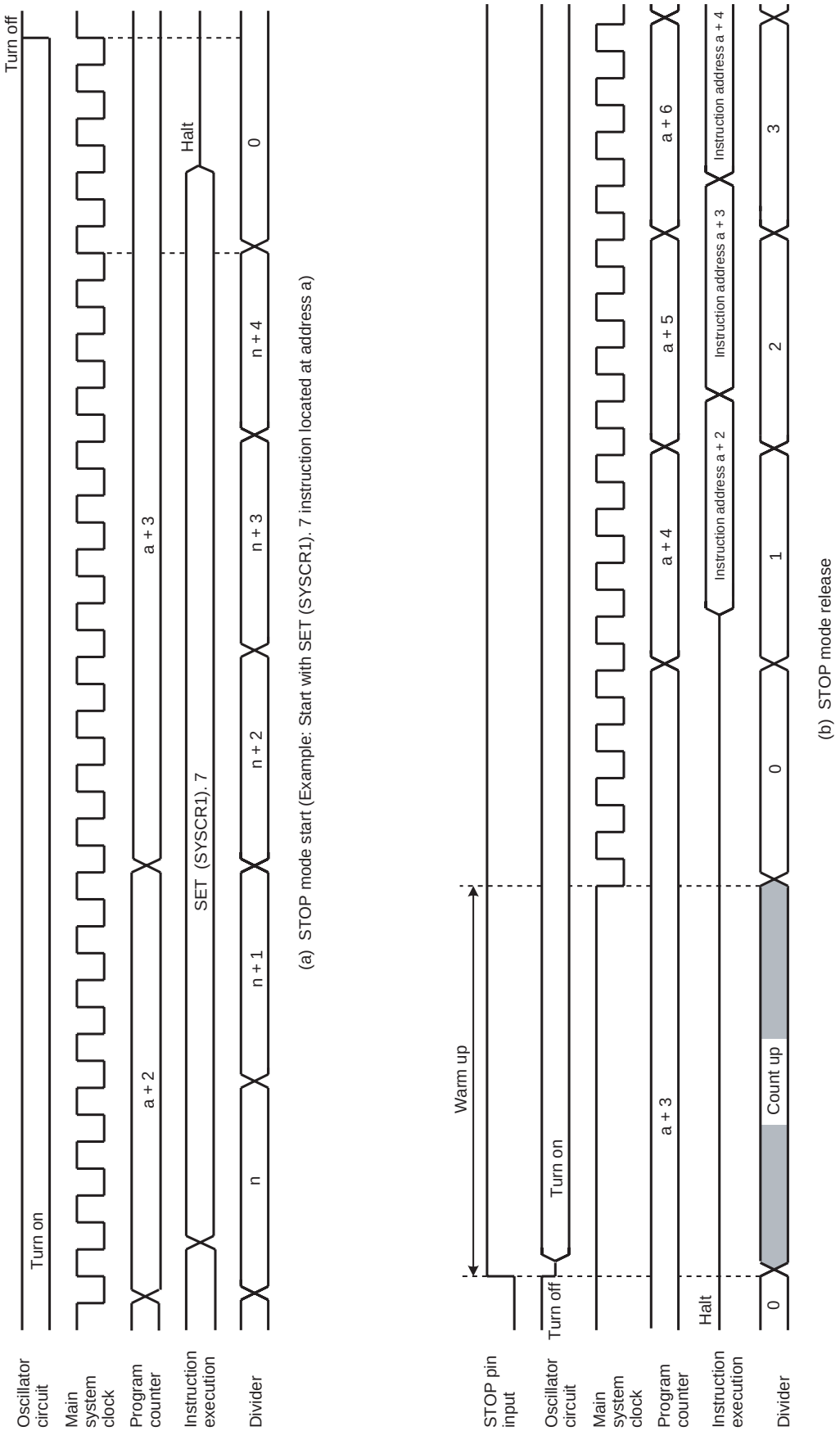


Figure 2-9 STOP Mode Start/Release

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.

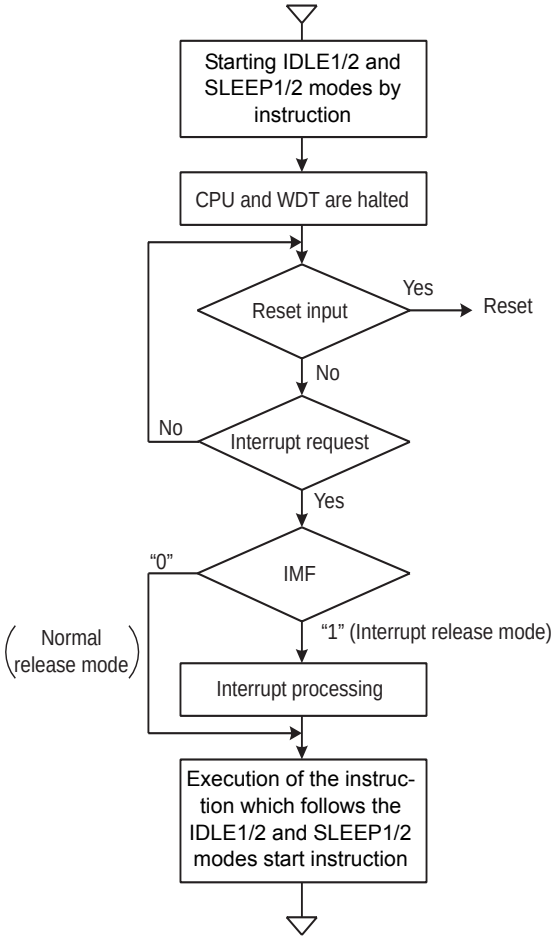


Figure 2-10 IDLE1/2 and SLEEP1/2 Modes

- 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.

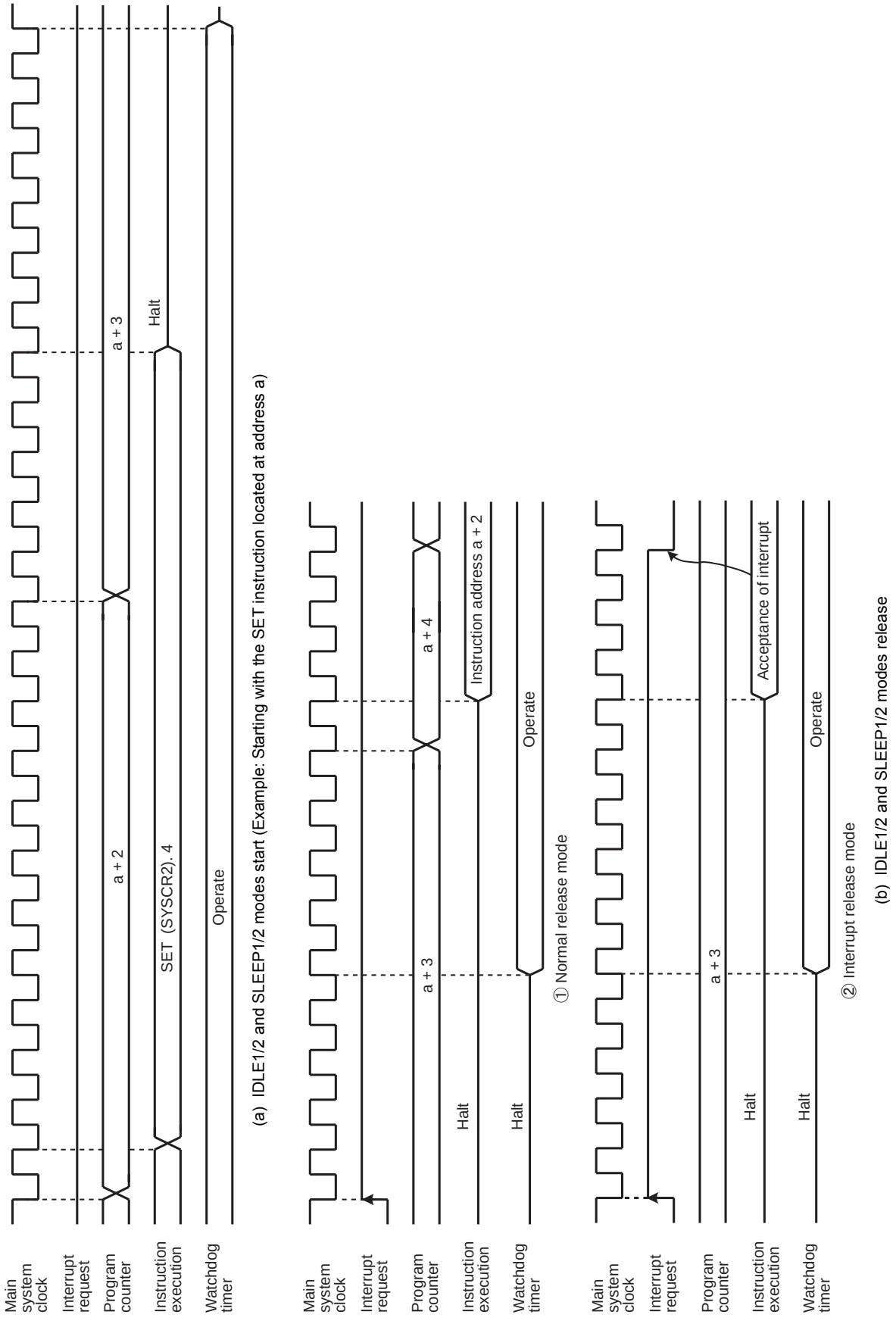


Figure 2-11 IDLE1/2 and SLEEP1/2 Modes Start/Release

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 (TBTCR). 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.

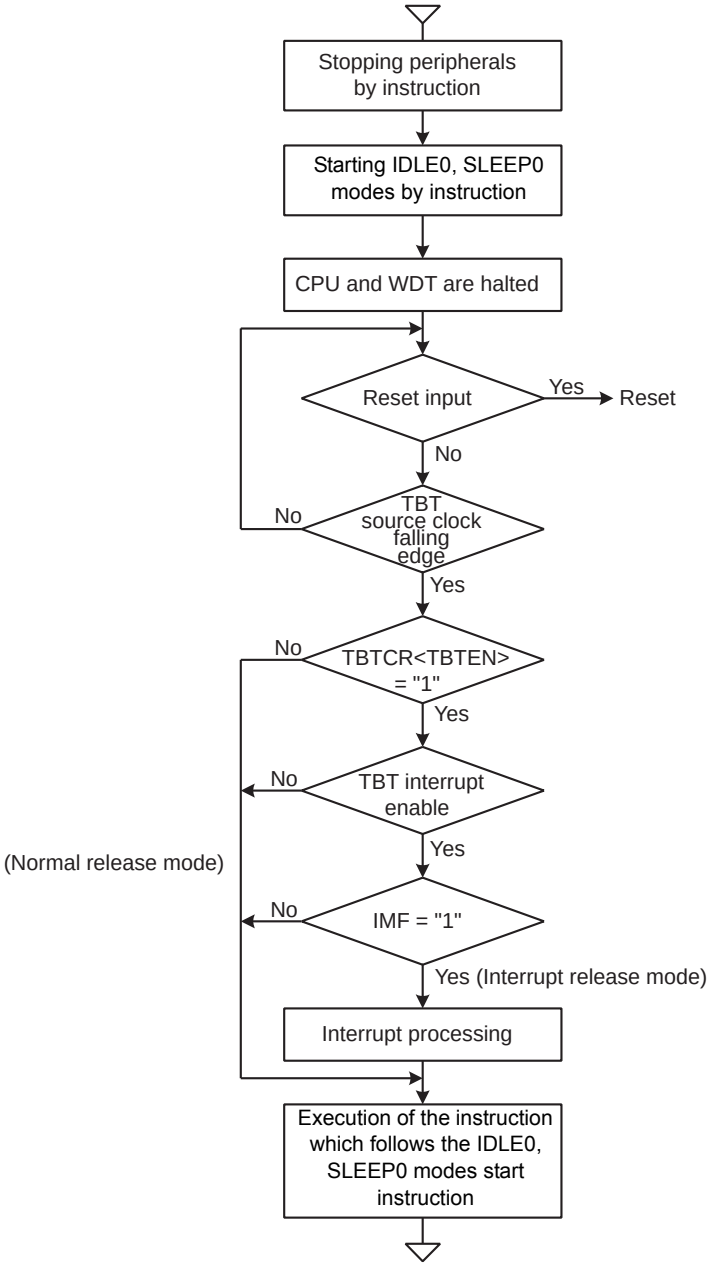


Figure 2-12 IDLE0 and SLEEP0 Modes

- 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•EF7•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•EF7•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.

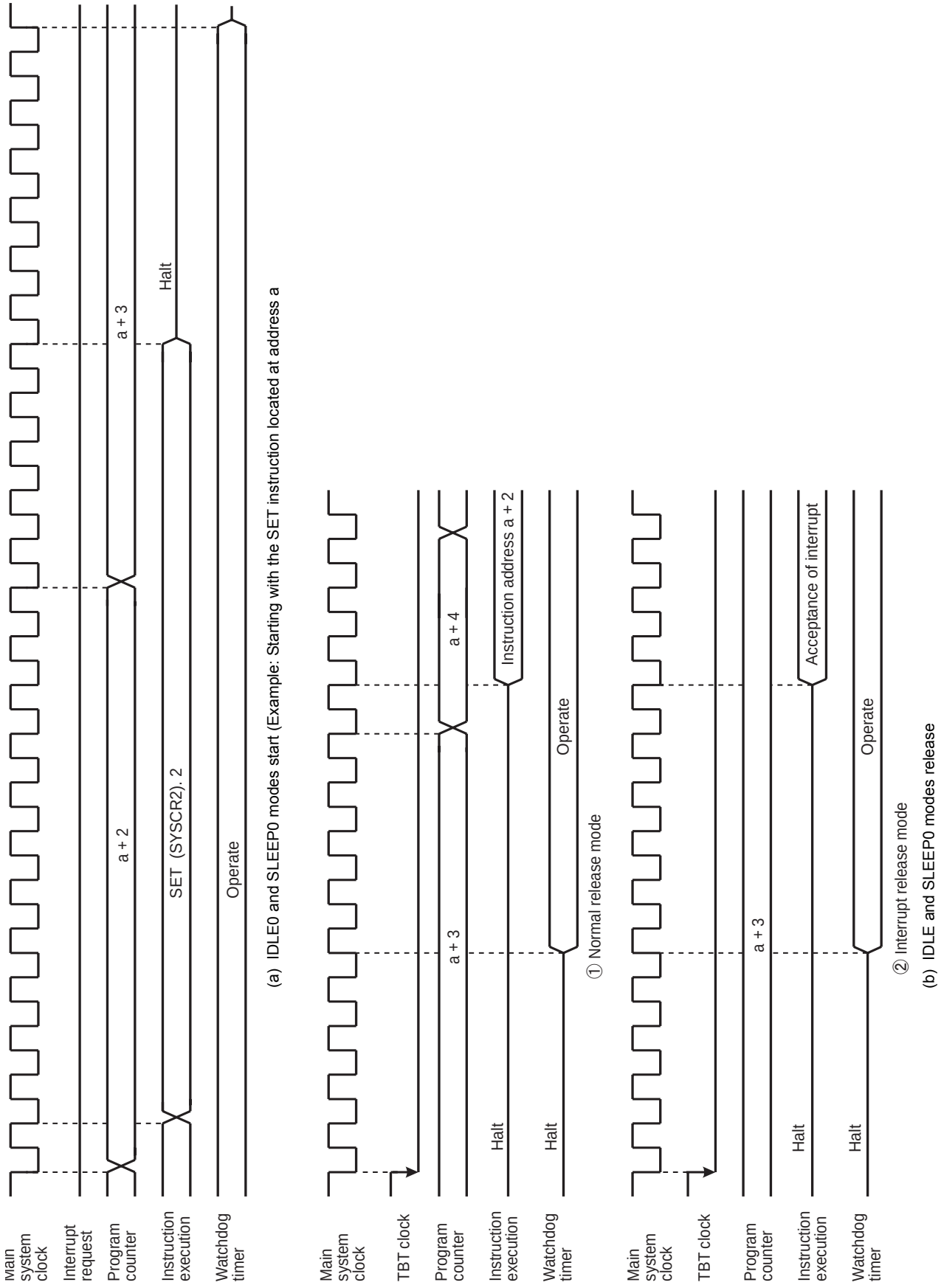


Figure 2-13 IDLE0 and SLEEP0 Modes Start/Release

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)
```

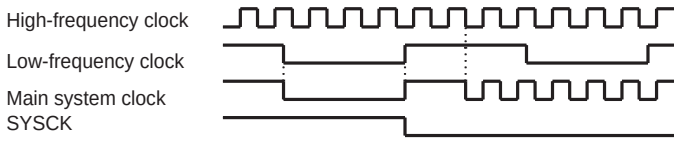
Example 2 :Switching to the SLOW1 mode after low-frequency clock has stabilized.

```
        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
```

(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 continiued 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 (fc = 16 MHz, warm-up time is 4.0 ms).

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

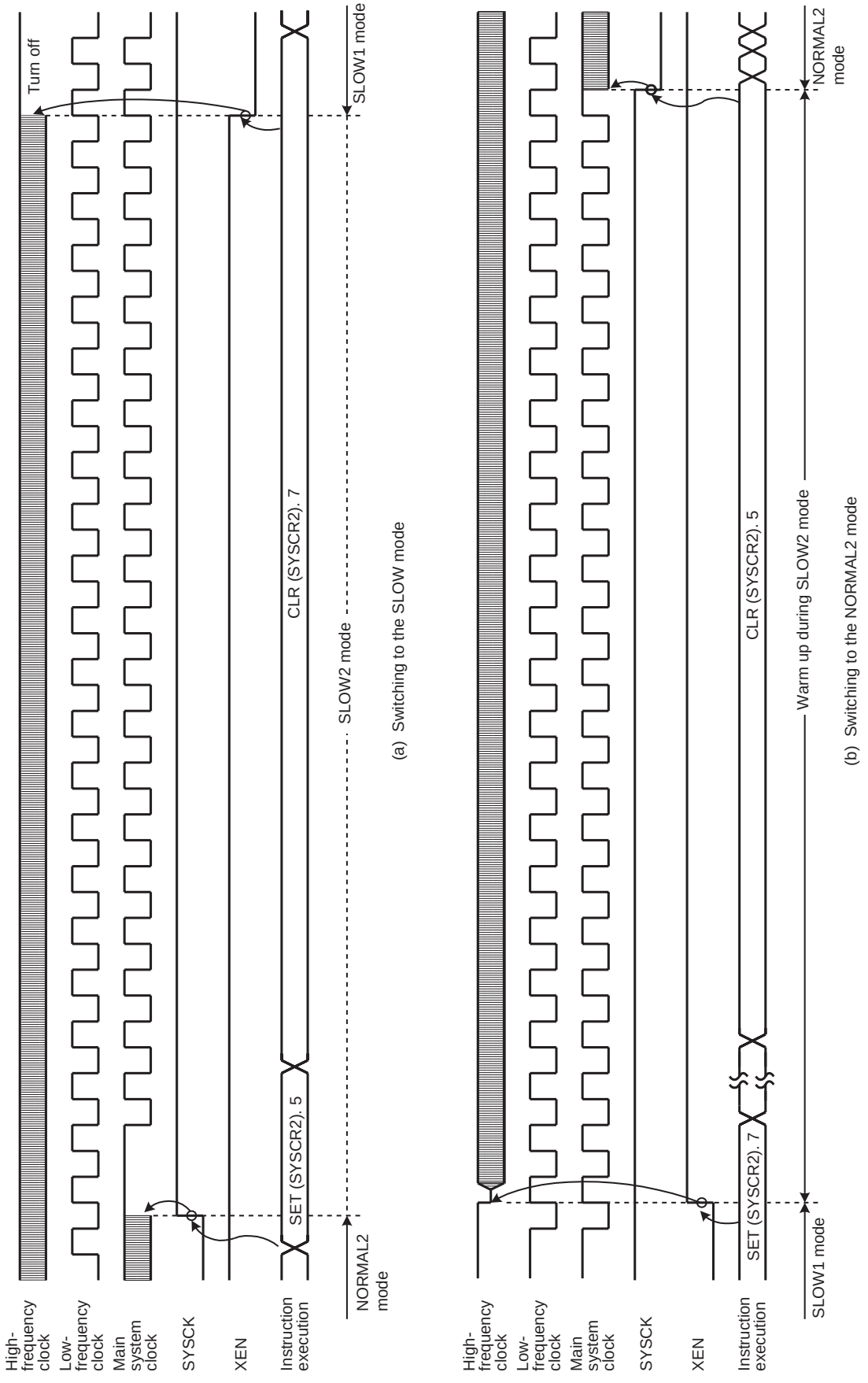


Figure 2-14 Switching between the NORMAL2 and SLOW Modes

2.3 Reset Circuit

The TMP86CP27AFG 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/fc[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/fc[s] (1.5μs 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		
Interrupt individual enable flags (EF)	0	Control registers	Refer to each of control register
Interrupt latches (IL)	0		
		LCD data buffer	Not initialized
		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/fc [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.

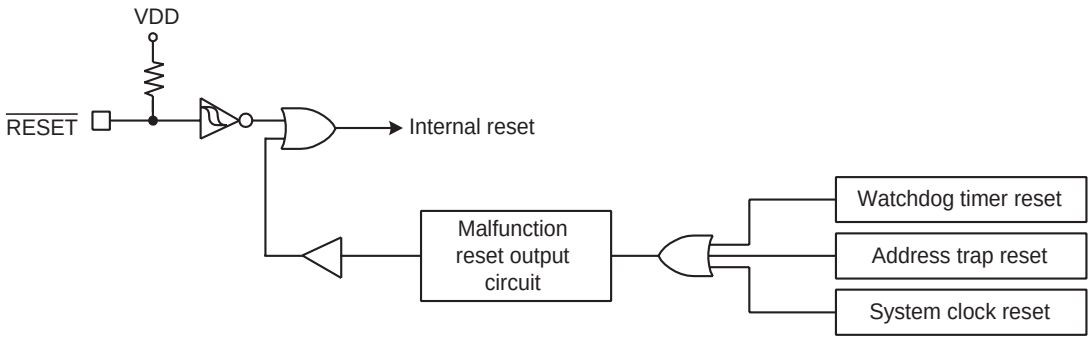
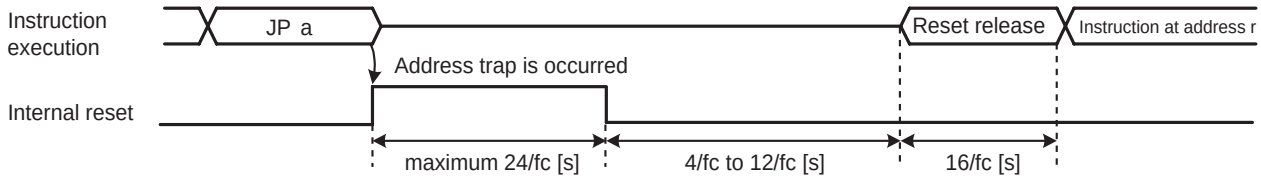


Figure 2-15 Reset Circuit

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/fc[s] (1.5μs 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/fc (1.5 μs at 16.0 MHz).

3. Interrupt Control Circuit

The TMP86CP27AFG has a total of 20 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
External	INTEMG	IMF• EF4 = 1	IL4	FFF6	5
External	$\overline{\text{INT0}}$	IMF• EF5 = 1, INT0EN = 1	IL5	FFF4	6
External	INT1	IMF• EF6 = 1	IL6	FFF2	7
Internal	INTTBT	IMF• EF7 = 1	IL7	FFF0	8
External	INT2	IMF• EF8 = 1	IL8	FFEE	9
External	INTTC7T	IMF• EF9 = 1	IL9	FFEC	10
Internal	INTRXD	IMF• EF10 = 1	IL10	FFEA	11
Internal	INTSIO	IMF• EF11 = 1	IL11	FFE8	12
Internal	INTTXD	IMF• EF12 = 1	IL12	FFE6	13
Internal	INTTC4	IMF• EF13 = 1	IL13	FFE4	14
Internal	INTTC7P	IMF• EF14 = 1	IL14	FFE2	15
Internal	INTADC	IMF• EF15 = 1	IL15	FFE0	16
External	INT3	IMF• EF16 = 1	IL16	FFBE	17
Internal	INTTC3	IMF• EF17 = 1	IL17	FFBC	18
Internal	INTRTC	IMF• EF18 = 1	IL18	FFBA	19
External	INT5	IMF• EF19 = 1	IL19	FFB8	20
-	Reserved	IMF• EF20 = 1	IL20	FFB6	21
-	Reserved	IMF• EF21 = 1	IL21	FFB4	22
-	Reserved	IMF• EF22 = 1	IL22	FFB2	23
-	Reserved	IMF• EF23 = 1	IL23	FFB0	24

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<WDTOUT> to "0" (It is set for the "Reset request" after reset is released). For details, see "Watchdog Timer".

Note 3: If an INTADC interrupt request is generated while an interrupt with priority lower than the interrupt latch IL15 (INTADC) is being accepted, the INTADC interrupt latch may be cleared without the INTADC interrupt being processed. For details, refer to the corresponding notes in the chapter on the AD converter.

3.1 Interrupt latches (IL19 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, 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 latchess

```
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, 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 (EF19 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 (EF19 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: 00000000 000000**)

ILH,ILL (003DH, 003CH)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IL15	IL14	IL13	IL12	IL11	IL10	IL9	IL8	IL7	IL6	IL5	IL4	IL3	IL2		

ILH (003DH) ILL (003CH)

(Initial value: ****0000)

ILE (002EH)

7	6	5	4	3	2	1	0
–	–	–	–	IL19	IL18	IL17	IL16

ILE (002EH)

		at RD	at WR	
IL19 to IL2	Interrupt latches	0: No interrupt request 1: Interrupt request	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: 00000000 0000***0)

EIRH,EIRL (003BH, 003AH)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EF15	EF14	EF13	EF12	EF11	EF10	EF9	EF8	EF7	EF6	EF5	EF4				IMF

EIRH (003BH) EIRL (003AH)

(Initial value: ****0000)

EIRE (002CH)

7	6	5	4	3	2	1	0
–	–	–	–	EF19	EF18	EF17	EF16

EIRE (002CH)

EF19 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".

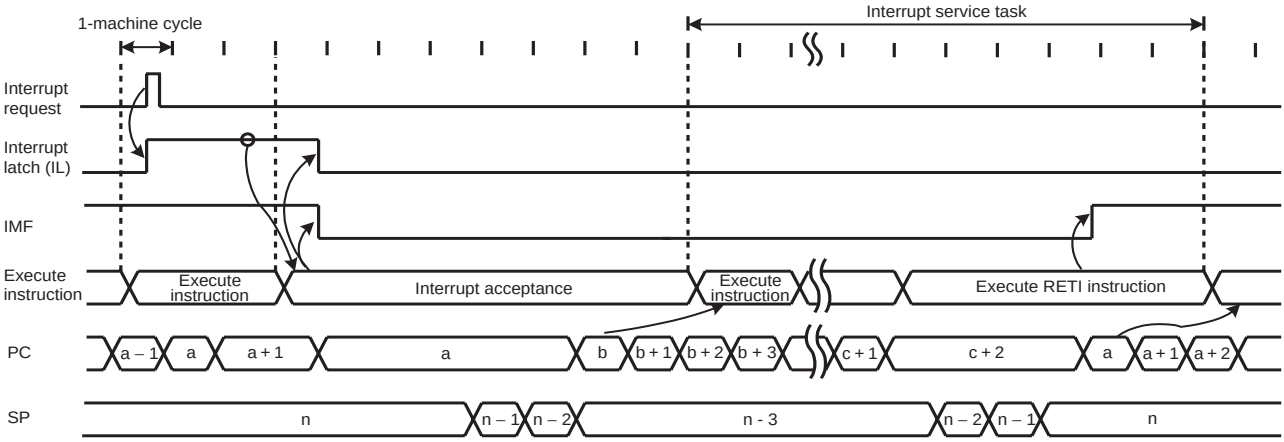
3.3 Interrupt Sequence

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 μs @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.

a. The interrupt master enable flag (IMF) is cleared to "0" in order to disable the acceptance of any following interrupt.
b. The interrupt latch (IL) for the interrupt source accepted is cleared to "0".
c. 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.
d. The entry address (Interrupt vector) of the corresponding interrupt service program, loaded on the vector table, is transferred to the program counter.
e. 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

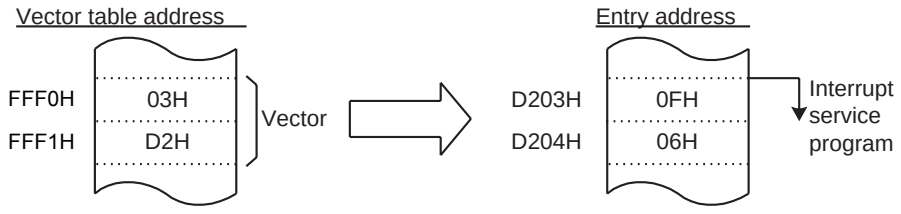


Figure 3-2 Vector table address,Entry address

A maskable interrupt is not accepted until the IMF is set to “1” even if the maskable interrupt higher than the level of current servicing interrupt is requested.

In order to utilize nested interrupt service, the IMF is set to “1” in the interrupt service program. In this case, acceptable interrupt sources are selectively enabled by the individual interrupt enable flags.

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.

3.3.2 Saving/restoring general-purpose registers

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.

3.3.2.1 Using PUSH and POP instructions

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.

Example :Save/store register using PUSH and POP instructions

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

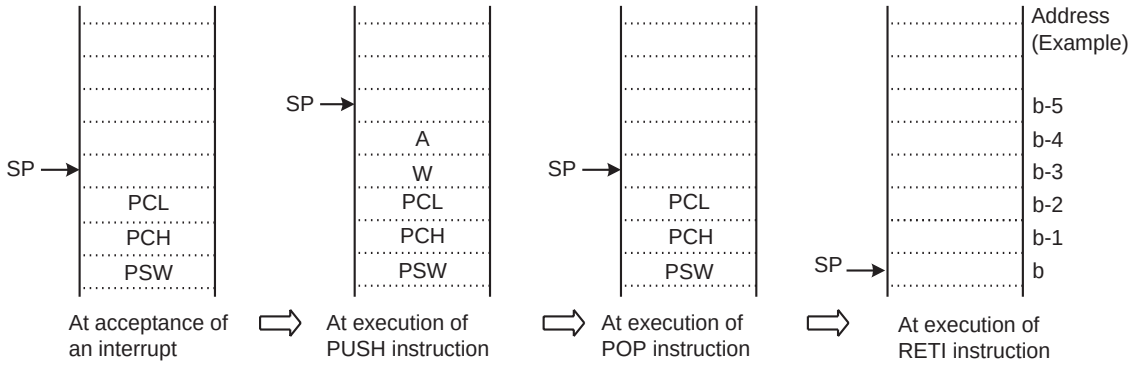


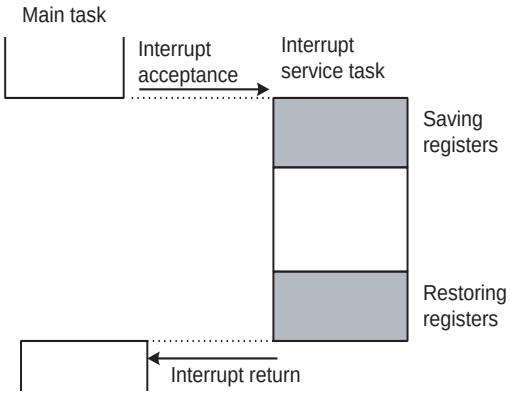
Figure 3-3 Save/store register using PUSH and POP instructions

3.3.2.2 Using data transfer instructions

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 TMP86CP27AFG has 7 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 INT3. The $\overline{\text{INT0}}$/P63 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 $\overline{\text{INT0}}$/P63 pin function selection are performed by the external interrupt control register (EINTCR).

Source	Pin	Enable Conditions	Release Edge	Digital Noise Reject
INT0	$\overline{\text{INT0}}$	IMF • EF5 • 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	IMF • EF6 = 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	IMF • EF8 = 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	IMF • EF16 = 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.
INT5	$\overline{\text{INT5}}$	IMF • EF19 = 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", IL5 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	-	-	INT3ES	INT2ES	INT1ES		(Initial value: 00** 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	P63/$\overline{INT0}$ pin configuration	0: P63 input/output port 1: $\overline{INT0}$ pin (Port P63 should be set to an input mode)	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.

4. Special Function Register (SFR)

The TMP86CP27AFG 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 TMP86CP27AFG.

4.1 SFR

Address	Read	Write
0000H	P0DR	
0001H	P1DR	
0002H	P2DR	
0003H	P3DR	
0004H	P4DR	
0005H	P5DR	
0006H	P6DR	
0007H	P7DR	
0008H	TC7DRAL	
0009H	TC7DRAH	
000AH	TC7DRBL	
000BH	TC7DRBH	
000CH	TC7DRCL	
000DH	TC7DRCH	
000EH	ADCCR1	
000FH	ADCCR2	
0010H	P0CR	
0011H	P1CR	
0012H	P3OUTCR	
0013H	P4OUTCR	
0014H	P6CR1	
0015H	P6CR2	
0016H	P2PRD	-
0017H	P3PRD	-
0018H	TC3CR	
0019H	TC4CR	
001AH	PWREG3	
001BH	PWREG4	
001CH	TTREG3	
001DH	TTREG4	
001EH	Reserved	
001FH	Reserved	
0020H	ADCDR2	-
0021H	ADCDR1	-
0022H	P4PRD	-
0023H	P5PRD	-
0024H	P7PRD	-
0025H	UARTSR	UARTCR1

Address	Read	Write
0026H	-	UARTCR2
0027H	Reserved	
0028H	LCDCR	
0029H	TC7CR1	
002AH	TC7CR2	
002BH	TC7CR3	
002CH	EIRE	
002DH	RTCCR	
002EH	ILE	
002FH	Reserved	
0030H	Reserved	
0031H	Reserved	
0032H	Reserved	
0033H	Reserved	
0034H	-	WDTCR1
0035H	-	WDTCR2
0036H	TBTCR	
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	SEG1/0	
0F81H	SEG3/2	
0F82H	SEG5/4	
0F83H	SEG7/6	
0F84H	SEG9/8	
0F85H	SEG11/10	
0F86H	SEG13/12	
0F87H	SEG15/14	
0F88H	SEG17/16	
0F89H	SEG19/18	
0F8AH	SEG21/20	
0F8BH	SEG23/22	
0F8CH	SEG25/24	
0F8DH	SEG27/26	
0F8EH	SEG29/28	
0F8FH	SEG31/30	
0F90H	SEG33/32	
0F91H	SEG35/34	
0F92H	SEG37/36	
0F93H	SEG39/38	
0F94H	Reserved	
0F95H	Reserved	
0F96H	Reserved	
0F97H	Reserved	
0F98H	Reserved	
0F99H	Reserved	
0F9AH	Reserved	
0F9BH	Reserved	
0F9CH	Reserved	
0F9DH	Reserved	
0F9EH	Reserved	
0F9FH	Reserved	

Address	Read	Write
0FA0H	SIOBR0	
0FA1H	SIOBR1	
0FA2H	SIOBR2	
0FA3H	SIOBR3	
0FA4H	SIOBR4	
0FA5H	SIOBR5	
0FA6H	SIOBR6	
0FA7H	SIOBR7	
0FA8H	-	SIOCR1
0FA9H	SIOSR	SIOCR2
0FAAH	-	STOPCR
0FABH	RDBUF	TDBUF
0FACH	P0LCR	
0FADH	P1LCR	
0FAEH	P5LCR	
0FAFH	P7LCR	
0FB0H	TC7DRDL	
0FB1H	TC7DRDH	
0FB2H	TC7DREL	
0FB3H	TC7DREH	
0FB4H	TC7CAPAL	-
0FB5H	TC7CAPAH	-
0FB6H	TC7CAPBL	-
0FB7H	TC7CAPBH	-
0FB8H	Reserved	
0FB9H	Reserved	
0FBAH	Reserved	
0FBBH	MULSEL	
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

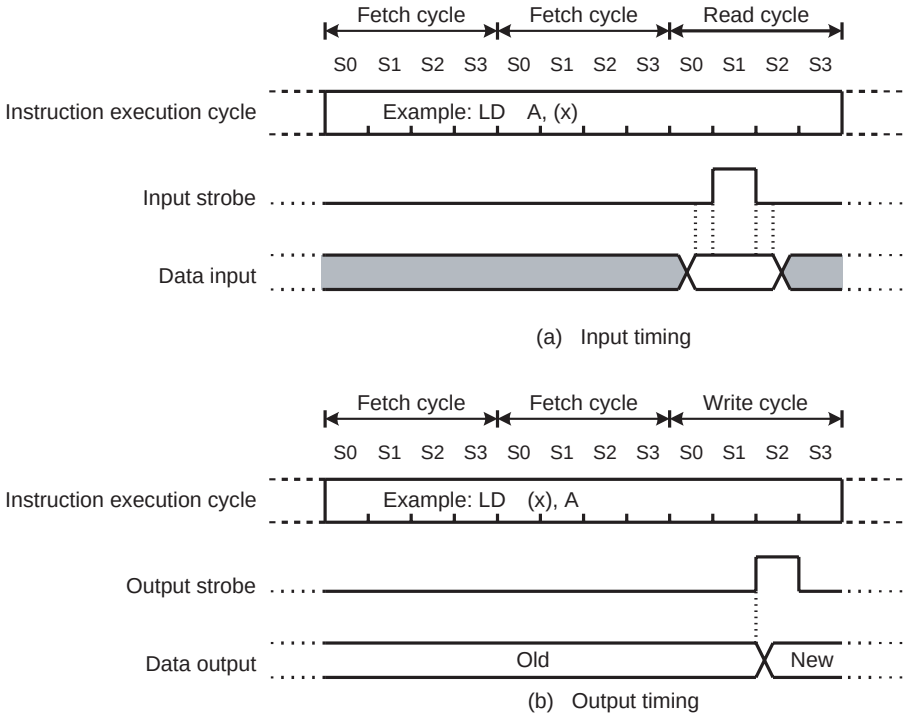
The TMP86CP27AFG have 8 parallel input/output ports (55 pins) as follows.

	Primary Function	Secondary Functions
Port P0	8-bit I/O port	LCD segment output. External interrupt, serial interface input/output and UART input/output.
Port P1	8-bit I/O port	LCD segment 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	Timer/counter input/output, UART input and divider output.
Port P4	4-bit I/O port	Serial interface input/output and UART output.
Port P5	8-bit I/O port	LCD segment output.
Port P6	8-bit I/O port	Analog input, external interrupt input and STOP mode release signal input.
Port P7	8-bit I/O port	LCD segment output.

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 which can be configured as an input or an output in 1-bit unit. Port P0 is also used as a UART input/output, an external interrupt input, serial interface input/output and segment output of LCD. Input/output mode is specified by the P0 control register (P0CR).

When used as an input port or a secondary function input pins (UART input, external interrupt input or serial interface input), the corresponding bit of P0CR and P0LCR should be cleared to "0".

When used as an output port, the corresponding bit of P0CR should be set to "1", and the respective P0LCR bit should be cleared to "0". When used as an UART output pin, or serial interface output pin, the corresponding bit of P0CR and the output latch (P0DR) should be set to "1", and the respective P0LCR bit should be cleared to "0".

When used as a segment pins of LCD, the respective bit of P0LCR should be set to "1".

During reset, the P0DR, P0CR and P0LCR are initialized to "0".

When the bit of P0CR and P0LCR is "0", the corresponding bit data by read instruction is a terminal input data.

When the bit of P0CR is "0" and that of P0LCR is "1", the corresponding bit data by read instruction is always "0".

When the bit of P0CR is "1", the corresponding bit data by read instruction is the value of P0DR.

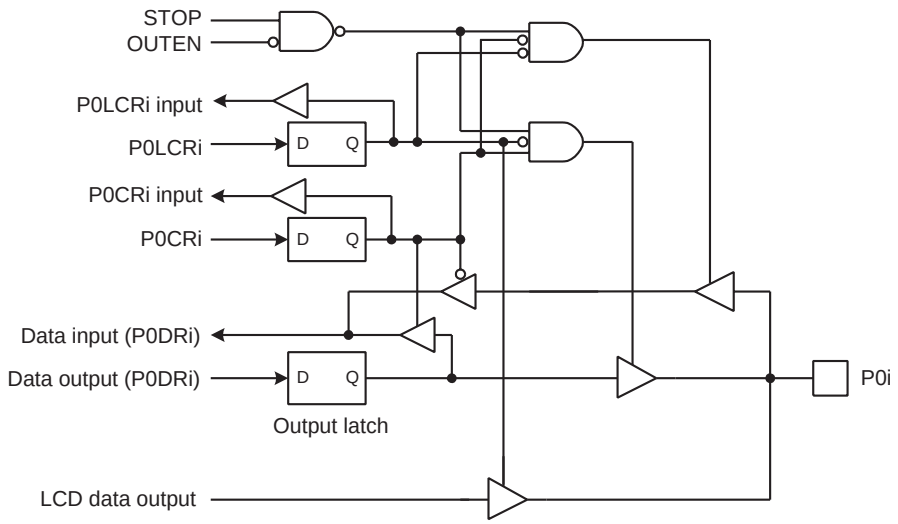
Table 5-1 Register Programming for Multi-function Ports

Function	Programmed Value		
	P0DR	P0CR	P0LCR
Port input, UART input, serial interface input, and external interrupt input	*	"0"	"0"
Port "0" output	"0"	"1"	"0"
Port "1" output, UART output and serial interface output	"1"	"1"	"0"
LCD segment output	*	*	"1"

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

Table 5-2 Values Read from P0DR and Register Programming

Conditions		Values Read from P0DR
P0CR	P0LCR	
"0"	"0"	Terminal input data
"0"	"1"	"0"
"1"	"0"	Output latch contents
	"1"	



Note: i = 7 to 0

Figure 5-2 Port 0

	7	6	5	4	3	2	1	0	
P0DR (0000H) R/W	P07 SEG32 $\overline{SCK0}$	P06 SEG33 SO0	P05 SEG34 SI0	P04 SEG35 INT3	P03 SEG36 INT2	P02 SEG37 INT1	P01 SEG38 TXD0	P00 SEG39 RXD0	(Initial value: 0000 0000)
P0LCR (0FACH)									(Initial value: 0000 0000)

P0LCR	Port P0/segment output control (Set for each bit individually)	0:P0 input/output port or secondary function (excect for segment) 1: LCD segment output	R/W

	7	6	5	4	3	2	1	0	
P0CR (0010H)									(Initial value: 0000 0000)

P0CR	P0 port input/output control (Set for each bit individually)	0: Input mode 1: Output mode	R/W

Note: 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.

Multi function register

	7	6	5	4	3	2	1	0	
MULSEL (0FBBH)							SIOSEL	UARTSEL	(Initial value: **** **00)

SIOSEL	SIO function pins select	0: P05(SI0), P06(SO0), P07(SCK0) 1: P40(SI1), P41(SO1), P42(SCK1)	R/W
UARTSEL	UART function pins select	0: P01(TXD0), P00(RXD0) 1: P43(TXD1), P37(RXD1)	

Note 1: Do not change a terminal during operation.

Note 2: Perform the setting terminal of a port after performing a setup by MULSEL, when changing a terminal.

5.2 Port P1 (P17 to P10)

Port P1 is an 8-bit input/output port which can be configured as an input or an output in 1-bit unit. Port P1 is also used as a segment output of LCD. Input/output mode is specified by the P1 control register (P1CR).

When used as an input port, the corresponding bit of P1CR and P1LCR should be cleared to "0".

When used as an output port, the corresponding bit of P1CR should be set to "1", and the respective P1LCR bit should be cleared to "0".

When used as a segment pins of LCD, the respective bit of P1LCR should be set to "1".

During reset, the output latch (P1DR), P1CR and P1LCR are initialized to "0".

When the bit of P1CR and P1LCR is "0", the corresponding bit data by read instruction is a terminal input data.

When the bit of P1CR is "0" and that of P1LCR is "1", the corresponding bit data by read instruction is always "0".

When the bit of P1CR is "1", the corresponding bit data by read instruction is the value of P1DR.

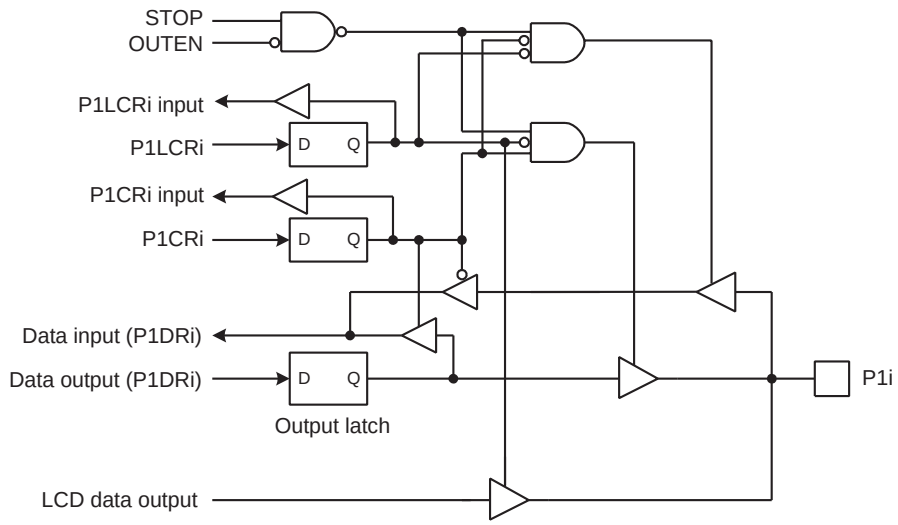
Table 5-3 Register Programming for Multi-function Ports

Function	Programmed Value		
	P1DR	P1CR	P1LCR
Port input	*	"0"	"0"
Port "0" output	"0"	"1"	"0"
Port "1" output	"1"	"1"	"0"
LCD segment output	*	*	"1"

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

Table 5-4 Values Read from P1DR and Register Programming

Conditions		Values Read from P1DR
P1CR	P1LCR	
"0"	"0"	Terminal input data
"0"	"1"	"0"
"1"	"0"	Output latch contents
	"1"	



Note: i = 7 to 0

Figure 5-3 Port 1

P1DR (0001H) R/W

7	6	5	4	3	2	1	0
P17 SEG24	P16 SEG25	P15 SEG26	P14 SEG27	P13 SEG28	P12 SEG29	P11 SEG30	P10 SEG31

(Initial value: 0000 0000)

P1LCR (0FADH)

(Initial value: 0000 0000)

P1LCR	Port P1/segment output control (Set for each bit individually)	0: P1 input/output port 1: LCD segment output	R/W

P1CR (0011H)

(Initial value: 0000 0000)

P1CR	P1 port input/output control (Set for each bit individually)	0: Input mode 1: Output mode	R/W

Note: 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.

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.

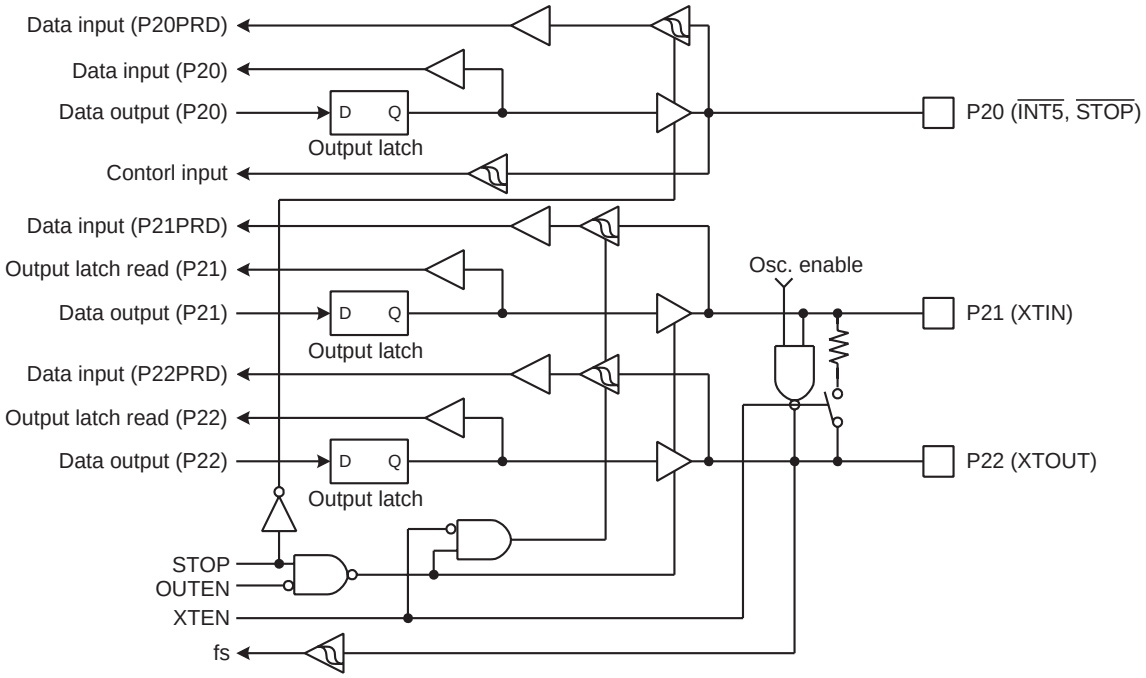


Figure 5-4 Port 2

	7	6	5	4	3	2	1	0	
P2DR (0002H) R/W						P22 XTOUT	P21 XTIN	P20 INT5 STOP	(Initial value: **** *111)
P2PRD (0F9CH) Read only						P22	P21	P20	

Note: Port P20 is used as $\overline{STOP}$ 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 P30)

Port P3 is a 8-bit input/output port.

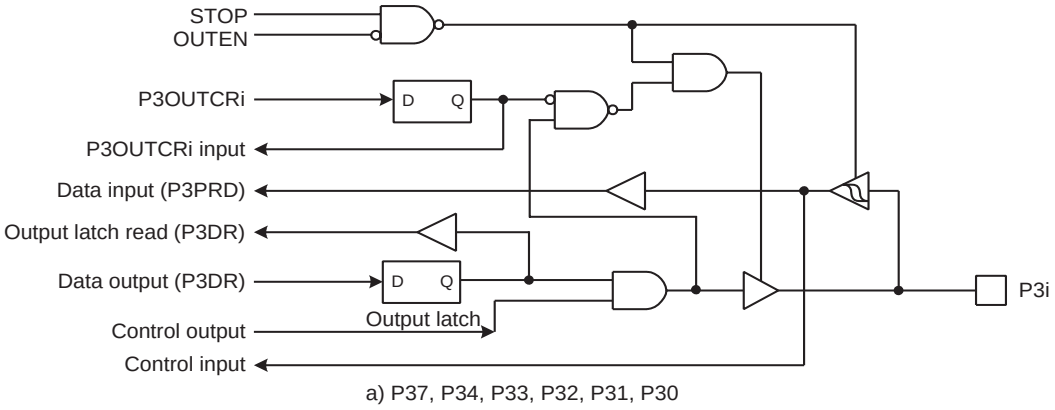
It is also used as a timer/counter input/output or divider output.

When used as a timer/counter output or divider output, respective output latch (P3DR) should be set to “1”.

It can be selected whether output circuit of port P3 is C-MOS output or a sink open drain individually, by setting P3OUTCR. When a corresponding bit of P3OUTCR is “0”, the output circuit is selected to a sink open drain and when a corresponding bit of P3OUTCR is “1”, the output circuit is selected to a C-MOS output. When used as an input port or timer/counter input, respective output control (P3OUTCR) should be set to “0” after P3DR is set to “1”. When using this port as a PPG1 and/or PPG2 output, set the output latch (P3DR) and then set the P3OUTCR to “1”. 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 (P3DR) should be set to the same value as the PPG output initial value (PPG1INI, PPG2INI). During reset, the P3DR is initialized to “1”, and the P3OUTCR is initialized to “0”.

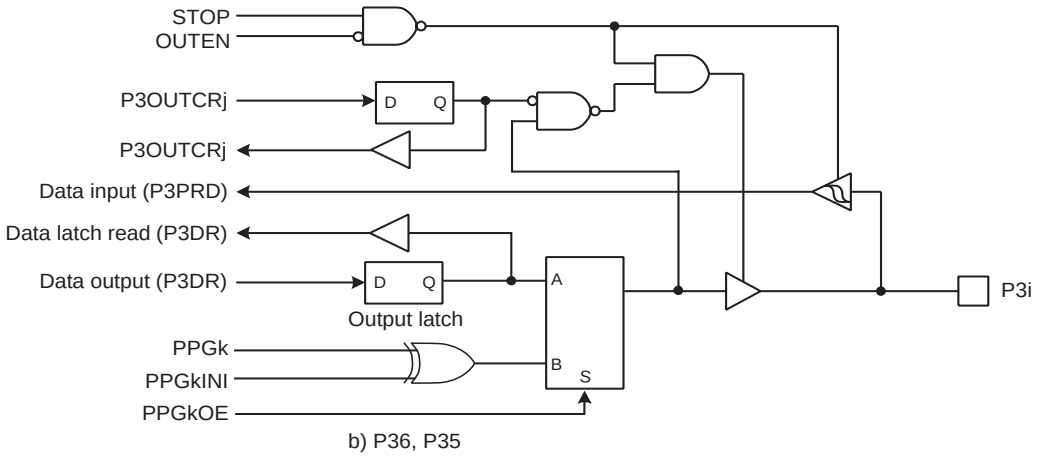
P3 port output latch (P3DR) and P3 port terminal input (P3PRD) are located on their respective address.

When read the output latch data, the P3DR should be read and when read the terminal input data, the P3PRD register should be read.



a) P37, P34, P33, P32, P31, P30

Note: i = 4 to 0 and 7



b) P36, P35

Note: j = 6, 5 k = 2, 1

Figure 5-5 Port 3

	7	6	5	4	3	2	1	0	
P3DR (0003H) R/W	P37 RXD1	P36 PPG2	P35 PPG1	P34 TC7	P33 $\overline{\text{EMG}}$	P32 $\overline{\text{PWM4}}$ $\overline{\text{PDO4}}$ $\overline{\text{PPG4}}$ TC4	P31 $\overline{\text{PWM3}}$ $\overline{\text{PDO3}}$ TC3	P30 $\overline{\text{DVO}}$	(Initial value: 1111 1111)
P3OUTCR (0012H)									(Initial value: 0000 0000)

P3OUTCR	Port P3 output circuit control (Set for each bit individually)	0: Sink open-drain output 1: C-MOS output	R/W

P3PRD (0017H) Read only	P37	P36	P35	P34	P33	P32	P31	P30

Multi function register

	7	6	5	4	3	2	1	0	
MULSEL (0FBBH)							SIOSEL	UARTSEL	(Initial value: **** **00)

SIOSEL	SIO function pins select	0: P05(SI0), P06(SO0), P07(SCK0) 1: P40(SI1), P41(SO1), P42(SCK1)	R/W
UARTSEL	UART function pins select	0: P01(TXD0), P00(RXD0) 1: P43(TXD1), P37(RXD1)	

Note 1: Do not change a terminal during operation.

Note 2: Perform the setting terminal of a port after performing a setup by MULSEL, when changing a terminal.

5.5 Port P4 (P43 to P40)

Port P4 is a 4-bit input/output port.

It is also used as a UART output or serial interface input/output.

When used as a UART output or serial interface output, respective output latch (P4DR) should be set to “1”.

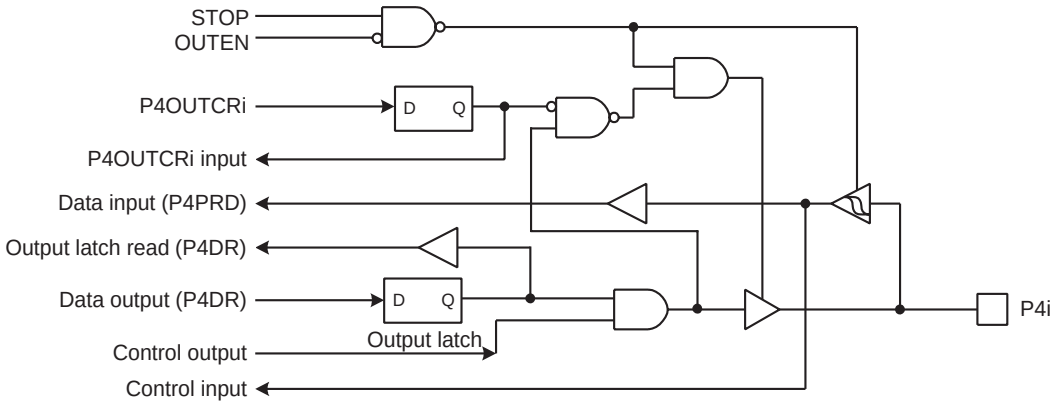
It can be selected whether output circuit of port P4 is C-MOS output or a sink open drain individually, by setting P4OUTCR. When a corresponding bit of P4OUTCR is “0”, the output circuit is selected to a sink open drain and when a corresponding bit of P4OUTCR is “1”, the output circuit is selected to a C-MOS output. When used as an input port or serial interface input, respective output control (P4OUTCR) should be set to “0” after P4DR is set to “1”. During reset, the P4DR is initialized to “1”, and the P4OUTCR is initialized to “0”.

P4 port output latch (P4DR) and P4 port terminal input (P4PRD) are located on their respective address.

When read the output latch data, the P4DR should be read and when read the terminal input data, the P4PRD register should be read. If a read instruction is executed for the P4PRD, P4DR and the P4OUTCR, read data of bits 7 to 5 are unstable.

Table 5-5 Register Programming for Multi-function Ports (P43 to P40)

Function	Programmed Value	
	P4DR	P4OUTCR
Port input or timer counter input	“1”	“0”
Port “0” output	“0”	Programming for each applications
Port “1” output or timer counter output	“1”	



Note: i = 4 to 0

Figure 5-6 Port 4

P4DR (0004H) R/W

7	6	5	4	3	2	1	0
				P43 TXD1	P42 $\overline{SCK1}$	P41 SO1	P40 SI1

(Initial value: **** 1111)

P4OUTCR (0013H)

(Initial value: **** 0000)

P4OUTCR	Port P4 output circuit control (Set for each bit individually)	0: Sink open-drain output 1: C-MOS output	R/W

P4PRD (0022H) Read only

				P43	P42	P41	P40

Multi function register

MULSEL (0FBBH)

7	6	5	4	3	2	1	0
						SIOSEL	UARTSEL

(Initial value: **** **00)

SIOSEL	SIO function pins select	0: P05(SI0), P06(SO0), P07(SCK0) 1: P40(SI1), P41(SO1), P42(SCK1)	R/W
UARTSEL	UART function pins select	0: P01(TXD0), P00(RXD0) 1: P43(TXD1), P37(RXD1)	

Note 1: Do not change a terminal during operation.

Note 2: Perform the setting terminal of a port after performing a setup by MULSEL, when changing a terminal.

5.6 Port P5 (P57 to P50)

Port P5 is an 8-bit input/output port which can be configured as an input or an output in 1-bit unit. Port P5 is also used as a segment output of LCD.

When used as an input port, the corresponding bit of P5LCR should be cleared to “0”, and the respective P5DR bit should be set to “1”.

When used as an output port, the respective P5LCR bit should be cleared to “0”.

When used as a segment pins of LCD, the respective bit of P5LCR should be set to “1”.

During reset, the output latch (P5DR) are intialized to “1”, and P5LCR are initialized to “0”.

P5 port output latch (P5DR) and P5 port terminal input (P5PRD) are located on their respective address.

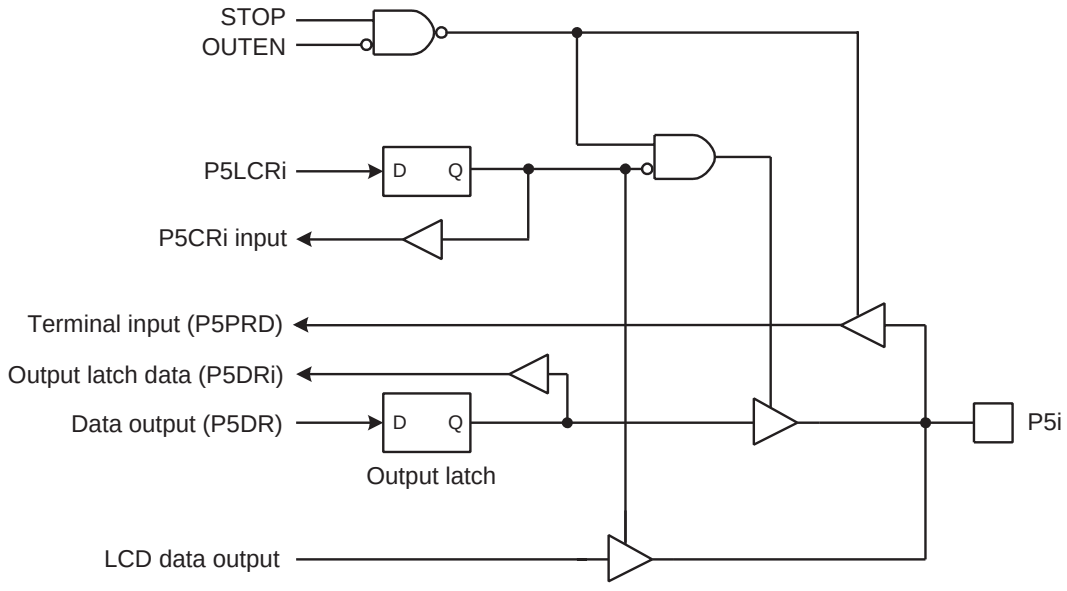
When read the output latch data, the P5DR should be read and when read the terminal input data, the P5PRD register should be read.

If the terminal input data which is configured as LCD segment output is read, unstable data is read.

Table 5-6 Register Programming for Multi-function Ports

Function	Programmed Value	
	P5DR	P5LCR
Port input	“1”	“0”
Port “0” output	“0”	“0”
LCD segment output	*	“1”

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



Note: i = 7 to 0

Figure 5-7 Port 5

P5DR (0005H) R/W

7	6	5	4	3	2	1	0
P57 SEG16	P56 SEG17	P55 SEG18	P54 SEG19	P53 SEG20	P52 SEG21	P51 SEG22	P50 SEG23

(Initial value: 1111 1111)

P5LCR (0FAEH)

(Initial value: 0000 0000)

P5LCR	Port P5/segment output control (Set for each bit individually)	0: P5 input/output port 1: LCD segment output	R/W

P5PRD (0023H) Read only

P57	P56	P55	P54	P53	P52	P51	P50

5.7 Port P6 (P67 to P60)

Port P6 is an 8-bit input/output port which can be configured as an input or an output in 1-bit unit. Port P6 is also used as an analog input, key-on wakeup input and external interrupt input. Input/output mode is specified by the P6 control register (P6CR1) and input control register (P6CR2).

When used as an output port, the corresponding bit of P6CR1 should be set to “1”.

When used as an input port, key-on wakeup input or an external interrupt input, the corresponding bit of P6CR1 should be cleared to “0”, and then, the corresponding bit of P6CR2 should be set to “1”.

When used as an analog input, the corresponding bit of P6CR1 should be cleared to “0”, and then, the corresponding bit of P6CR2 should be cleared to “0”.

During reset, the output latch (P6DR) and P6CR1 are initialized to “0”, P6CR2 is initialized to “1”.

When the bit of P6CR1 and P6CR2 is “0”, the corresponding bit data by read instruction is always “0”.

When the bit of P6CR1 is “0” and that of P6CR2 is “1”, the corresponding bit data by read instruction is a terminal input data.

When the bit of P6CR1 is “1”, the corresponding bit data by read instruction is the value of P6DR.

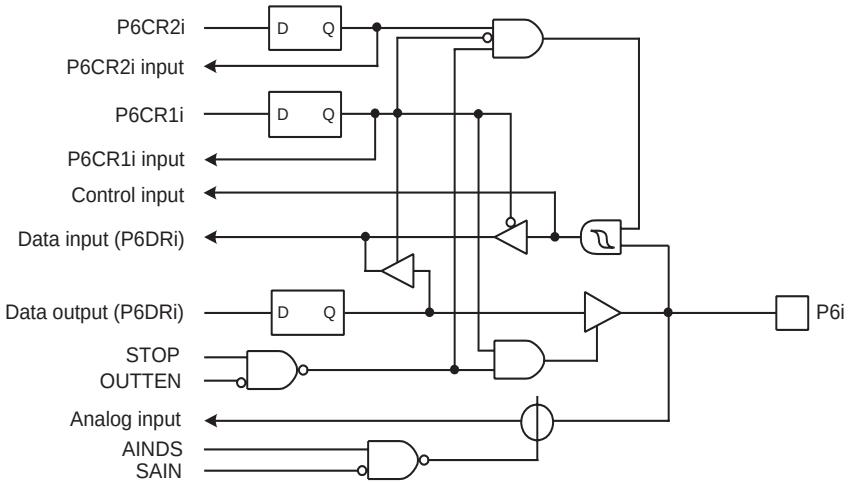
Table 5-7 Register Programming for Multi-function Ports

Function	Programmed Value		
	P6DR	P6CR1	P6CR2
Port input external interrupt input or key-on wakeup input	*	“0”	“1”
Analog input	*	“0”	“0”
Port “0” output	“0”	“1”	*
Port “1” output	“1”	“1”	*

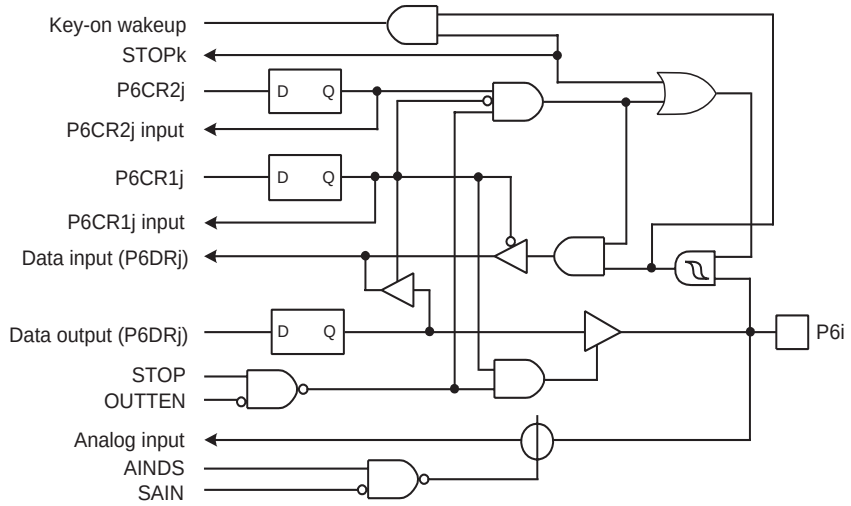
Note: Asterisk (*) indicates “1” or “0” either of which can be selected.

Table 5-8 Values Read from P6DR and Register Programming

Conditions		Values Read from P6DR
P6CR1	P6CR2	
“0”	“0”	“0”
“0”	“1”	Terminal input data
“1”	“0”	Output latch contents
	“1”	



a) P67, P63, P62, P61



b) P66, P65, P64, P60

Note 1: i = 1 to 3 and 7, j = 4 to 6 and 0, k = 2 to 5

Note 2: STOP is bit7 in SYSCR1.

Note 3: SAIN is AD input select signal.

Note 4: STOPk is input select signal in a key-on wakeup.

Figure 5-8 Port 6

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 P6CR2 to disable the port input.

Note 3: Do not set the output mode (P6CR1 = “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.

P6DR (0006H) R/W

7	6	5	4	3	2	1	0
P67 AIN7	P66 AIN6 STOP4	P65 AIN5 STOP3	P64 AIN4 STOP2	P63 AIN3 $\overline{\text{INT0}}$	P62 AIN2	P61 AIN1	P60 AIN0 STOP5

(Initial value: 0000 0000)

P6CR1 (0014H)

7	6	5	4	3	2	1	0

(Initial value: 0000 0000)

P6CR1	I/O control for port P6 (Specified for each bit)	0: Input mode 1: Output mode	R/W

P6CR2 (0015H)

7	6	5	4	3	2	1	0

(Initial value: 1111 1111)

P6CR2	P6 port input control (Specified for each bit)	0: Analog input 1: Port input, external interrupt input or key-on wakeup input	R/W

5.8 Port P7 (P77 to P70)

Port P7 is an 8-bit input/output port which can be configured as an input or an output in one-bit unit. Port P7 is also used as a segment output of LCD.

When used as an input port, the corresponding bit of P7LCR should be cleared to “0”, and the respective P7DR bit should be set to “1”.

When used as an output port, the respective P7LCR bit should be cleared to “0”.

When used as a segment pins of LCD, the respective bit of P7LCR should be set to “1”.

During reset, the output latch (P7DR) are initialized to “1”, and P7LCR are initialized to “0”.

P7 port output latch (P7DR) and P7 port terminal input (P7PRD) are located on their respective address.

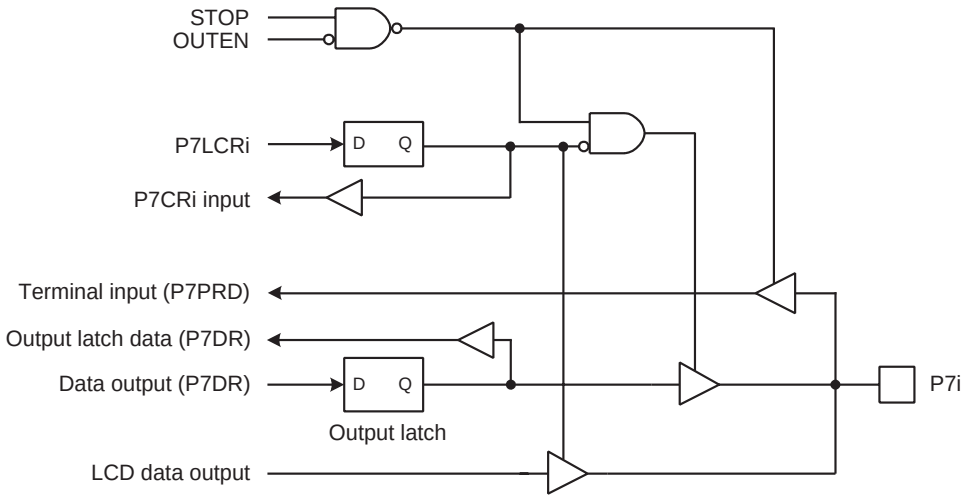
When read the output latch data, the P7DR should be read and when read the terminal input data, the P7PRD register should be read.

If the terminal input data which is configured as LCD segment output is read, unstable data is read.

Table 5-9 Register Programming for Multi-function Ports

Function	Programmed Value	
	P7DR	P7LCR
Port input	“1”	“0”
Port “0” output	“0”	“0”
LCD segment outputt	*	“1”

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



Note: i = 7 to 0

Figure 5-9 Port 7

P7DR (0007H) R/W

7	6	5	4	3	2	1	0
P77 SEG8	P76 SEG9	P75 SEG10	P74 SEG11	P73 SEG12	P72 SEG13	P71 SEG14	P70 SEG15

(Initial value: 1111 1111)

P7LCR (0FAFH)

(Initial value: 0000 0000)

P7LCR	Port P7/segment output control (Set for each bit individually)	0: P7 input/output port 1: Segment output	R/W

P7PRD (0024H) Read only

P77	P76	P75	P74	P73	P72	P71	P70

(Initial value: 0000 0000)

6. 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).

6.1 Time Base Timer

6.1.1 Configuration

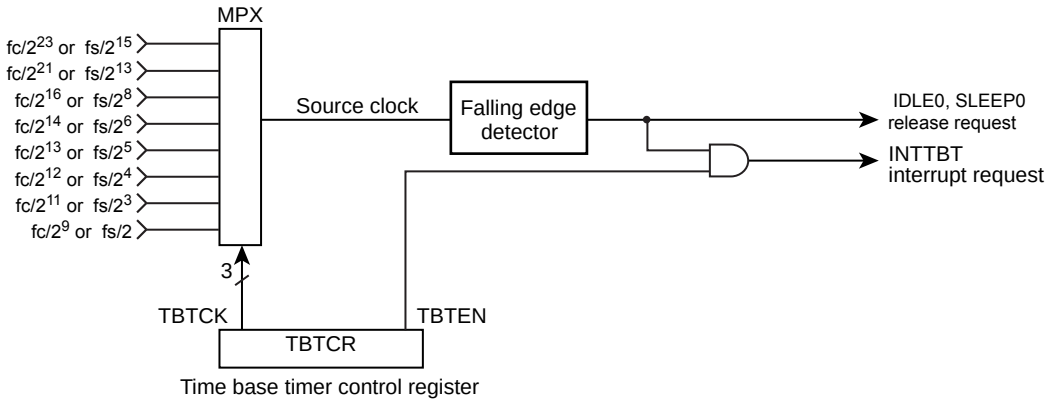


Figure 6-1 Time Base Timer configuration

6.1.2 Control

Time Base Timer is controled by Time Base Timer control register (TBTCR).

Time Base Timer Control Register

	7	6	5	4	3	2	1	0	
TBTCR (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]		NORMAL1/2, IDLE1/2 Mode		SLOW1/2 SLEEP1/2 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 fc/2^{16} [Hz] and enable an INTTBT interrupt.

```
LD      (TBTCR) ,  00000010B        ; TBTCK ← 010
LD      (TBTCR) ,  00001010B        ; TBTEN ← 1
DI                                  ; IMF ← 0
SET     (EIRL) . 7
```

Table 6-1 Time Base Timer Interrupt Frequency (Example : fc = 16.0 MHz, fs = 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	–

6.1.3 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 6-2).

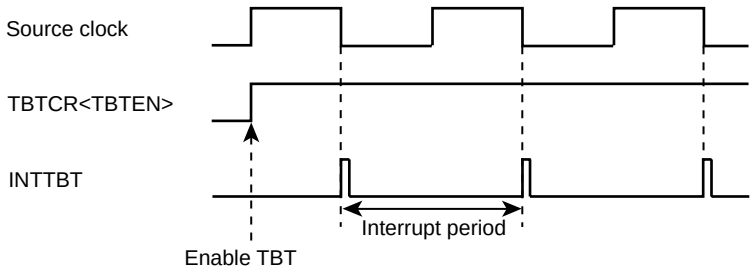


Figure 6-2 Time Base Timer Interrupt

6.2 Divider Output ($\overline{DVO}$)

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

6.2.1 Configuration

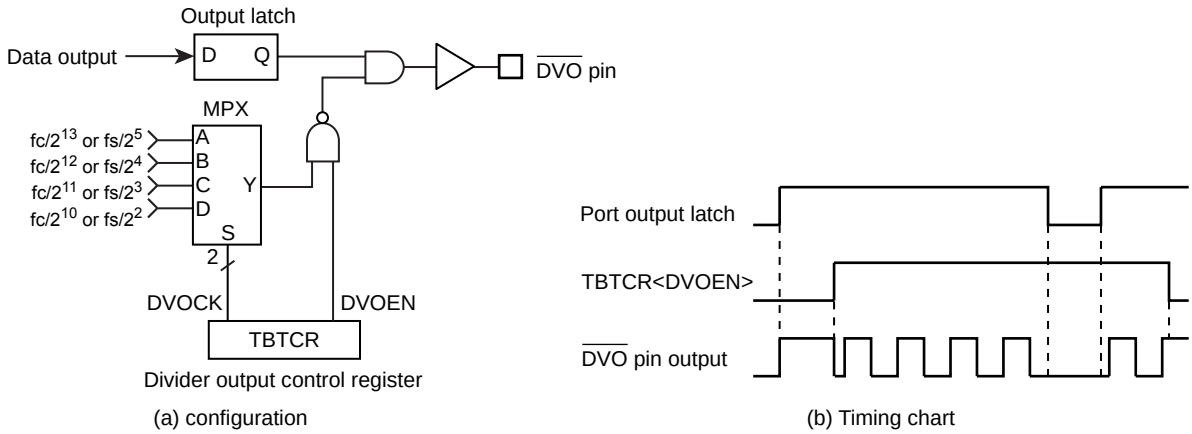


Figure 6-3 Divider Output

6.2.2 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 ($\overline{DVO}$) frequency selection: [Hz]		NORMAL1/2, IDLE1/2 Mode		SLOW1/2 SLEEP1/2 Mode	R/W
			DV7CK = 0	DV7CK = 1		
		00	fc/2^{13}	fs/2^5	fs/2^5	
		01	fc/2^{12}	fs/2^4	fs/2^4	
		10	fc/2^{11}	fs/2^3	fs/2^3	
		11	fc/2^{10}	fs/2^2	fs/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 disable(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 6-2 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

7. 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.

7.1 Watchdog Timer Configuration

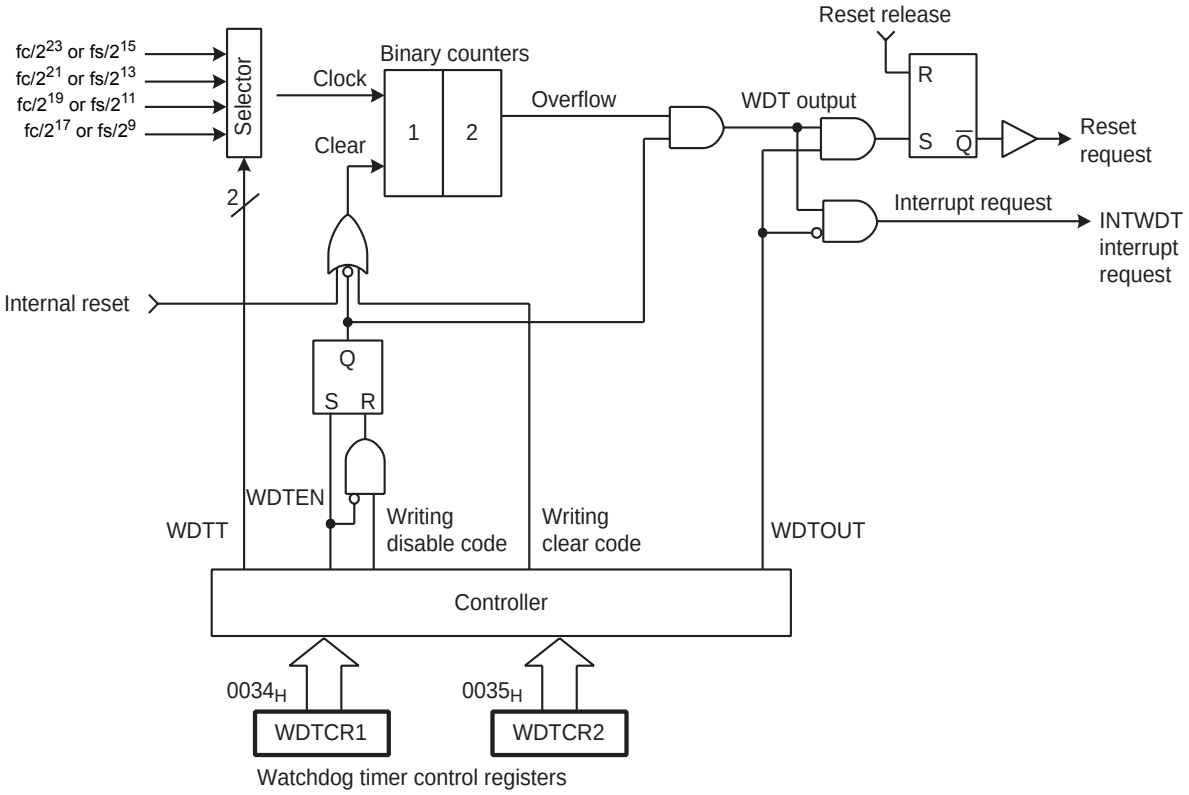


Figure 7-1 Watchdog Timer Configuration

7.2 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.

7.2.1 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}/fc [s], and resetting the CPU malfunction detection

```
        LD      (WDTCR2), 4EH       : Clears the binary counters.
        LD      (WDTCR1), 00001101B : WDTT ← 10, WDTOUT ← 1
        LD      (WDTCR2), 4EH       : Clears the binary counters (always clears immediately before and
                                      after changing WDTT).
Within  :
3/4 of  :
WDT
detect  LD      (WDTCR2), 4EH       : Clears the binary counters.
time
        :
Within  :
3/4 of
WDT     LD      (WDTCR2), 4EH       : Clears the binary counters.
detect
time
```

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]		NORMAL1/2 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 WDTEN, 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>.

7.2.2 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.

7.2.3 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 7-1 Watchdog Timer Detection Time (Example: fc = 16.0 MHz, fs = 32.768 kHz)

WDTT	Watchdog Timer Detection Time[s]		
	NORMAL1/2 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

7.2.4 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, 043FH           : Sets the stack pointer
LD      (WDTCR1), 00001000B : WDTOUT ← 0
```

7.2.5 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/fc [s] (1.5 μs @ fc = 16.0 MHz).

Note: When a watchdog timer reset is generated in the SLOW1 mode, the reset time is maximum 24/fc (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.

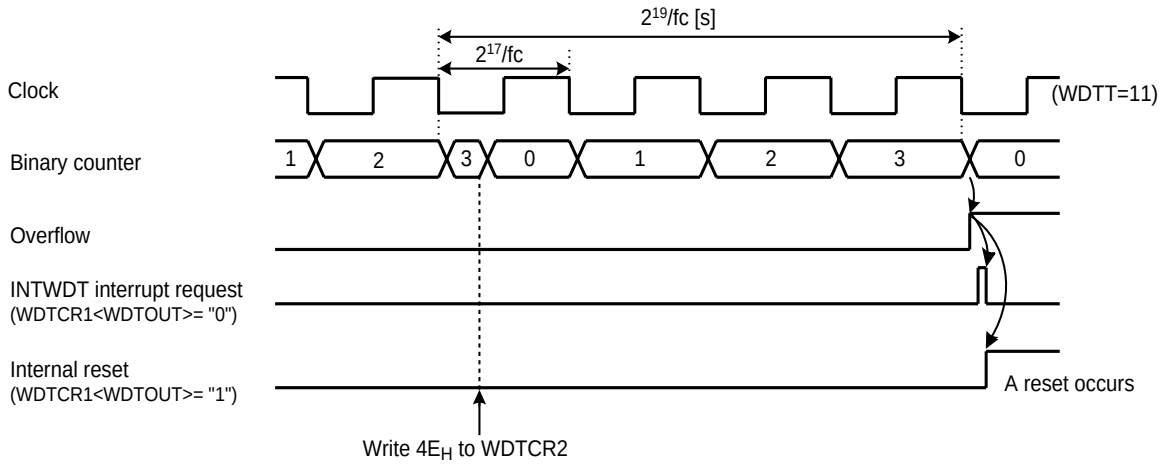


Figure 7-2 Watchdog Timer Interrupt

7.3 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 reguired)	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

7.3.1 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>.

7.3.2 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>.

7.3.3 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.

7.3.4 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/fc [s] (1.5 μs @ fc = 16.0 MHz).

Note: When an address trap reset is generated in the SLOW1 mode, the reset time is maximum 24/fc (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.

8. 10-Bit Timer/Counter (TC7)

8.1 Configuration

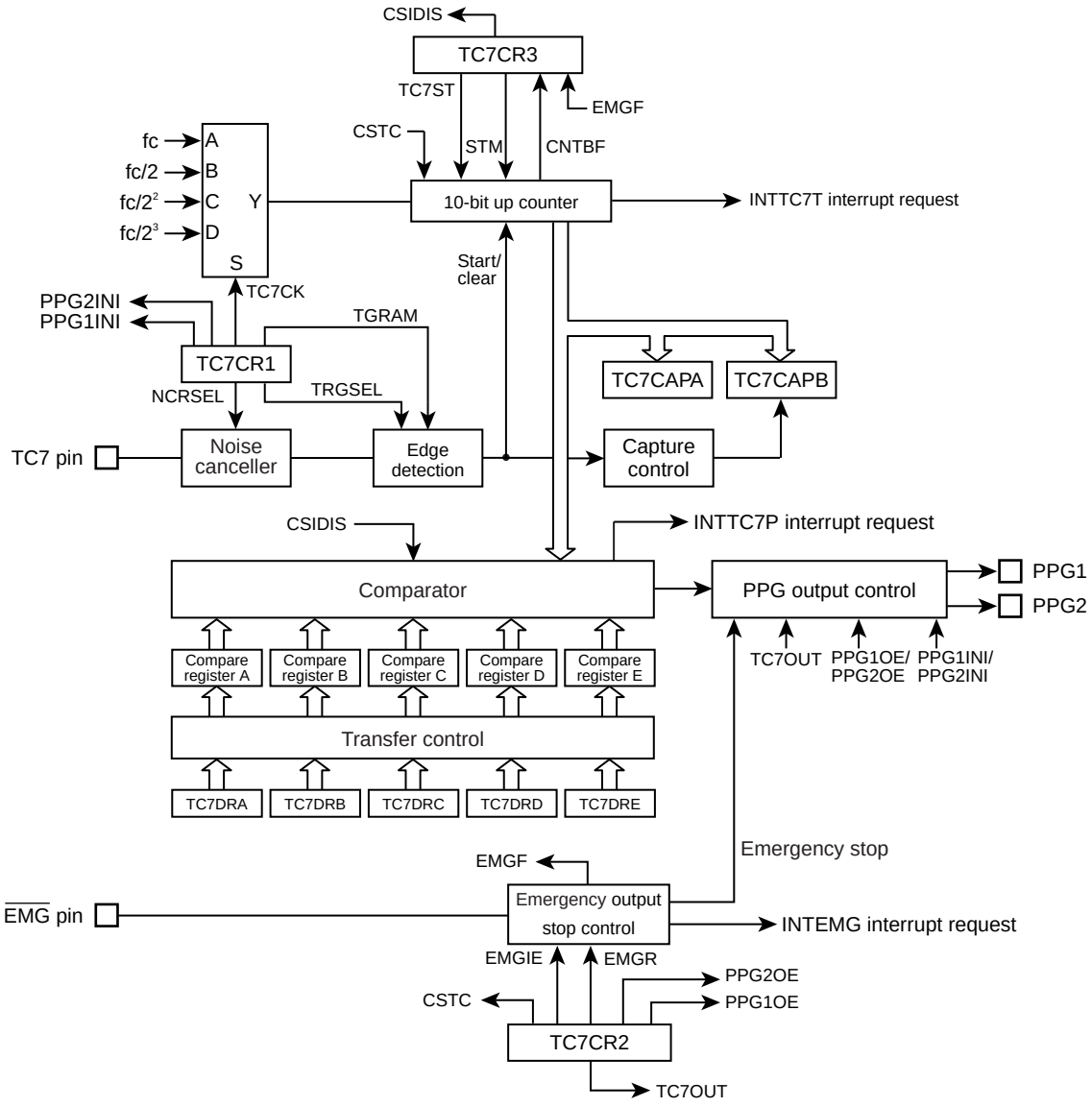


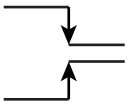
Figure 8-1 10-Bit Timer/Counter 7

8.2 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/fc 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)

TC7ST	Start/stop the timer.	0: Stop 1: Start		R/W
STM	Select the state when stopped. Select continuous or one-time output.	TC7ST = 0	TC7ST = 1	
		00: Immediately stop and clear the counter with the output initialized.	Continuous output	
		01: Immediately stop and clear the counter with the output maintained.	Continuous output	
		10: Stop the counter after completing output in the current period.	One-time output	
		11: -	–	
CSIDIS	Disable the first interrupt at upon a command start.	0: Allow a periodic interrupt (INTTC7P) to occur in the first period upon a command start. 1: Do not allow a periodic interrupt (INTTC7P) to occur in the first period upon a command start.		
CNTBF	Counting status flag	0: Counting stopped 1: Counting in progress		Read only
EMGF	Emergency output stop flag	0: Operating normally 1: Output stopped in emergency		

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.

Dead Time 1 Setup Register

	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)

Pulse Width 1 Setup Register

	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)

Period Setup Register

	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.

8.3 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.

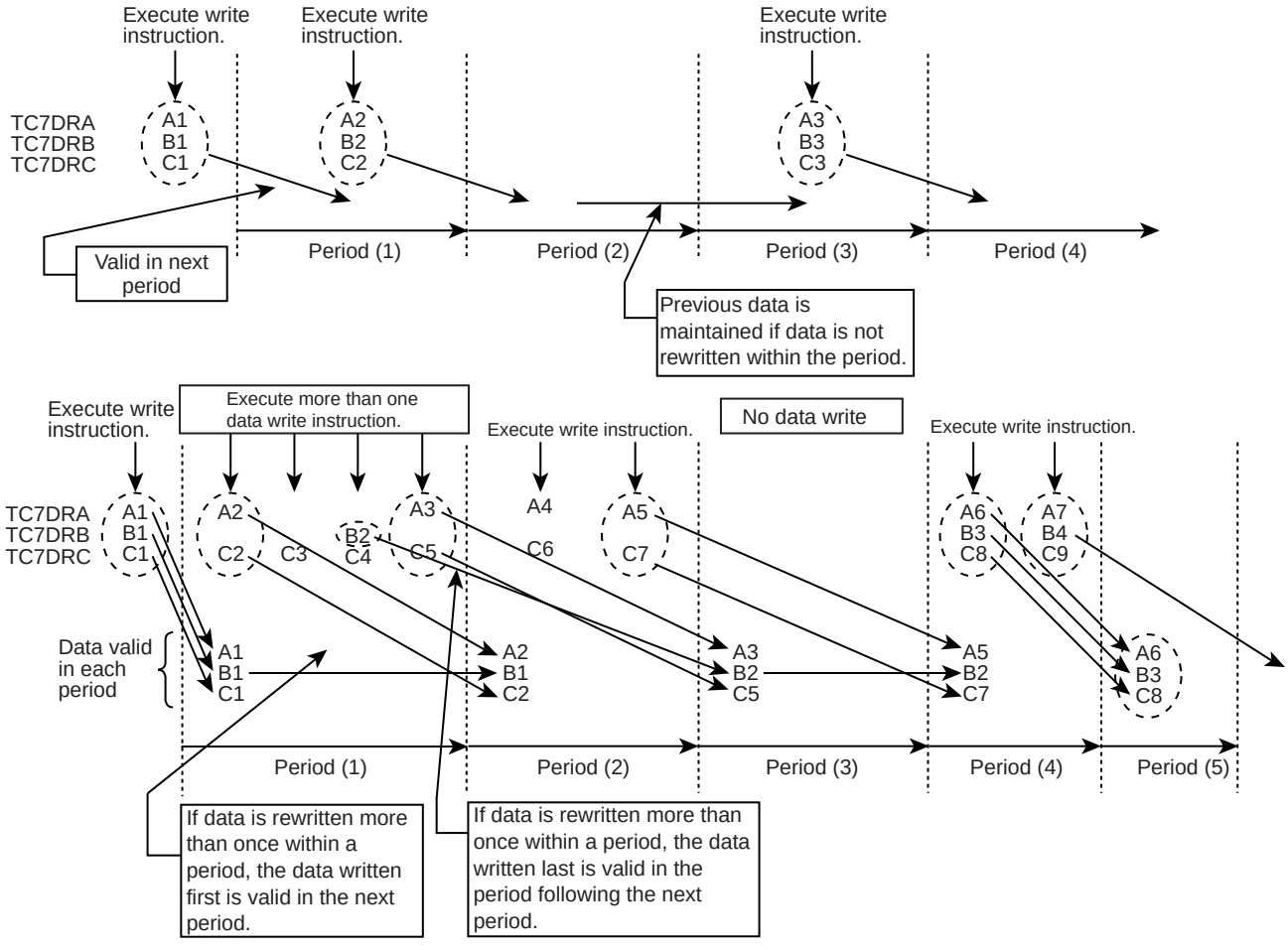


Figure 8-2 Example Configuration of Control/data Registers (1)

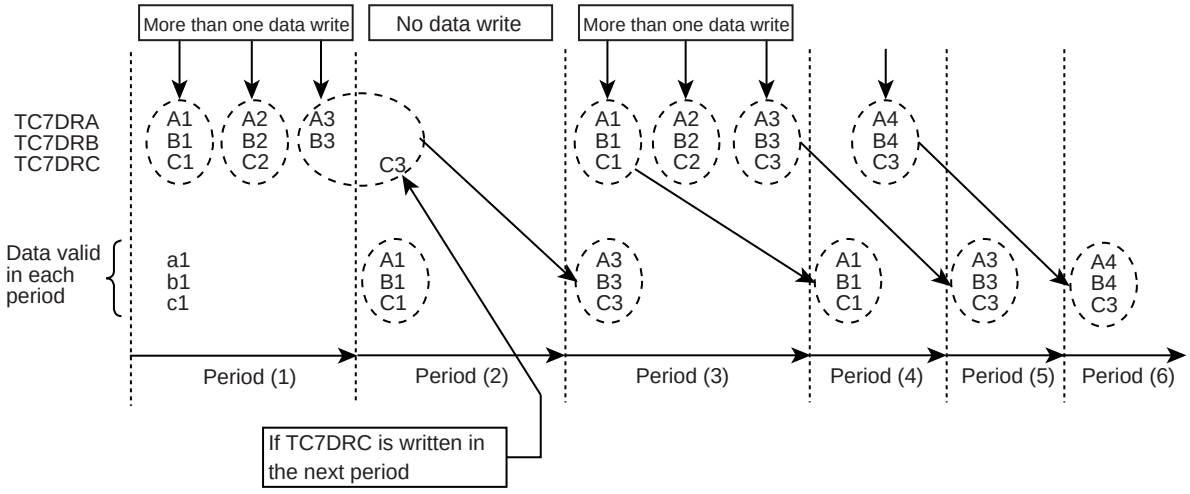


Figure 8-3 Example Configuration of Control/data Registers (2)

8.4 Features

8.4.1 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.

8.4.1.1 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 ≤ TC7DRA < TC7DRC/2

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

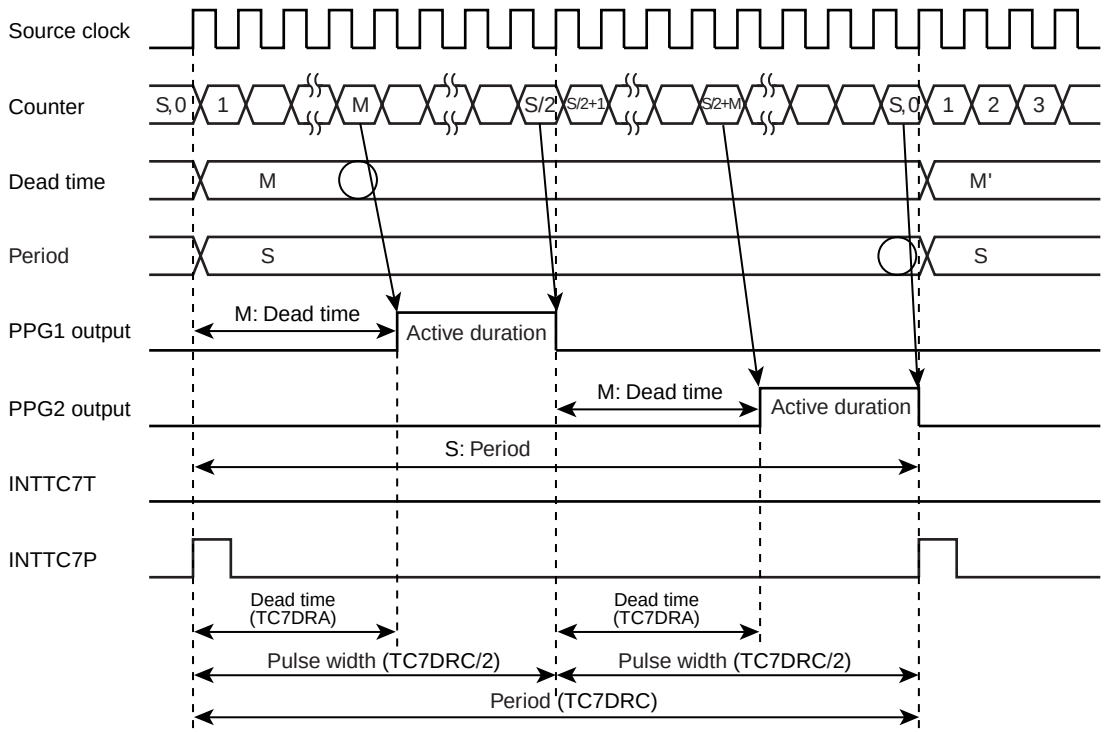


Figure 8-4 Example operation in 50% duty mode: Command and capture start, positive logic, continuous output

8.4.1.2 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 ≤ TC7DRB + TC7DRA < TC7DRC ≤ 400H

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

(b) Pulse width:

001H ≤ TC7DRB < TC7DRC

(c) Dead time:

000H ≤ TC7DRA < TC7DRB, 000H ≤ TC7DRA < (TC7DRC – TC7DRB)

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

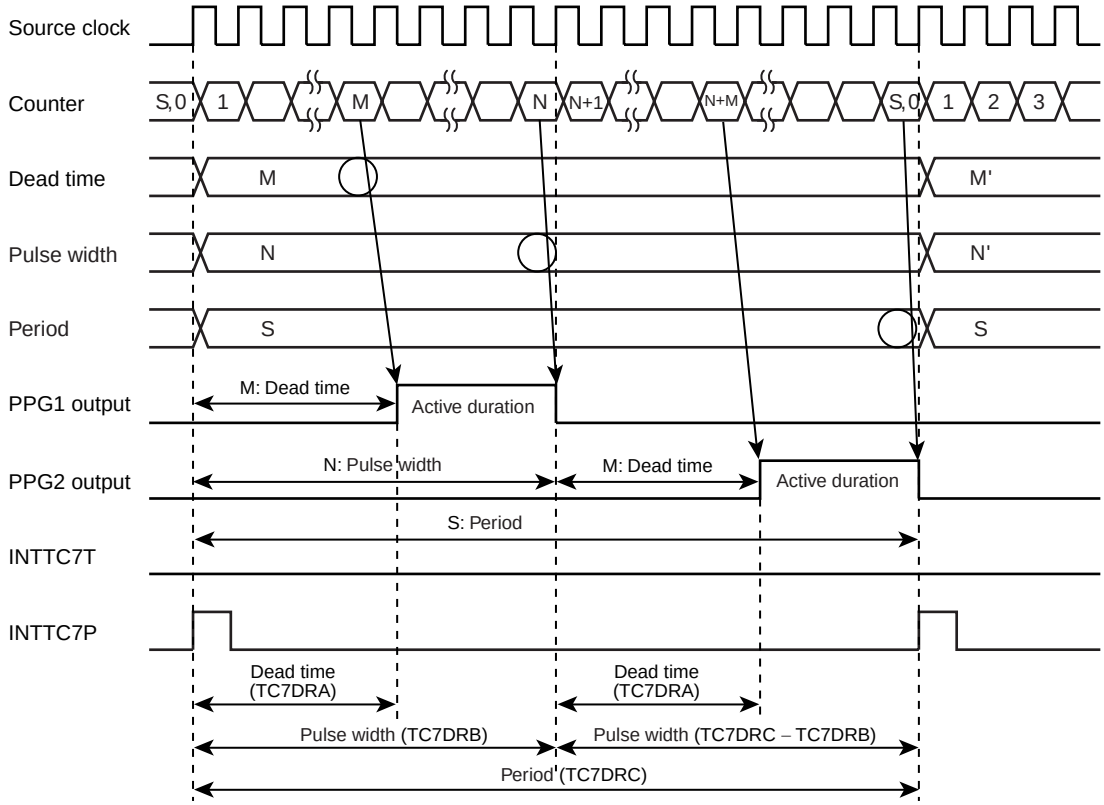


Figure 8-5 Example Operation in Variable Duty Mode: Command and Capture Start, Positive Logic, Continuous Output

8.4.1.3 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 ≤ TC7DRC ≤ 400H

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

(b) Pulse width:

001H ≤ TC7DRB ≤ 400H

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

001H ≤ TC7DRE ≤ 400H

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

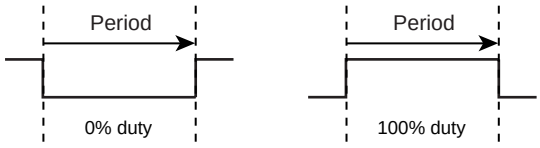
(c) Dead time:

000H ≤ TC7DRA ≤ 3FFH, where TC7DRA < TC7DRB ≤ TC7DRC

000H ≤ TC7DRD ≤ 3FFH, where TC7DRD < TC7DRE ≤ TC7DRC

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

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



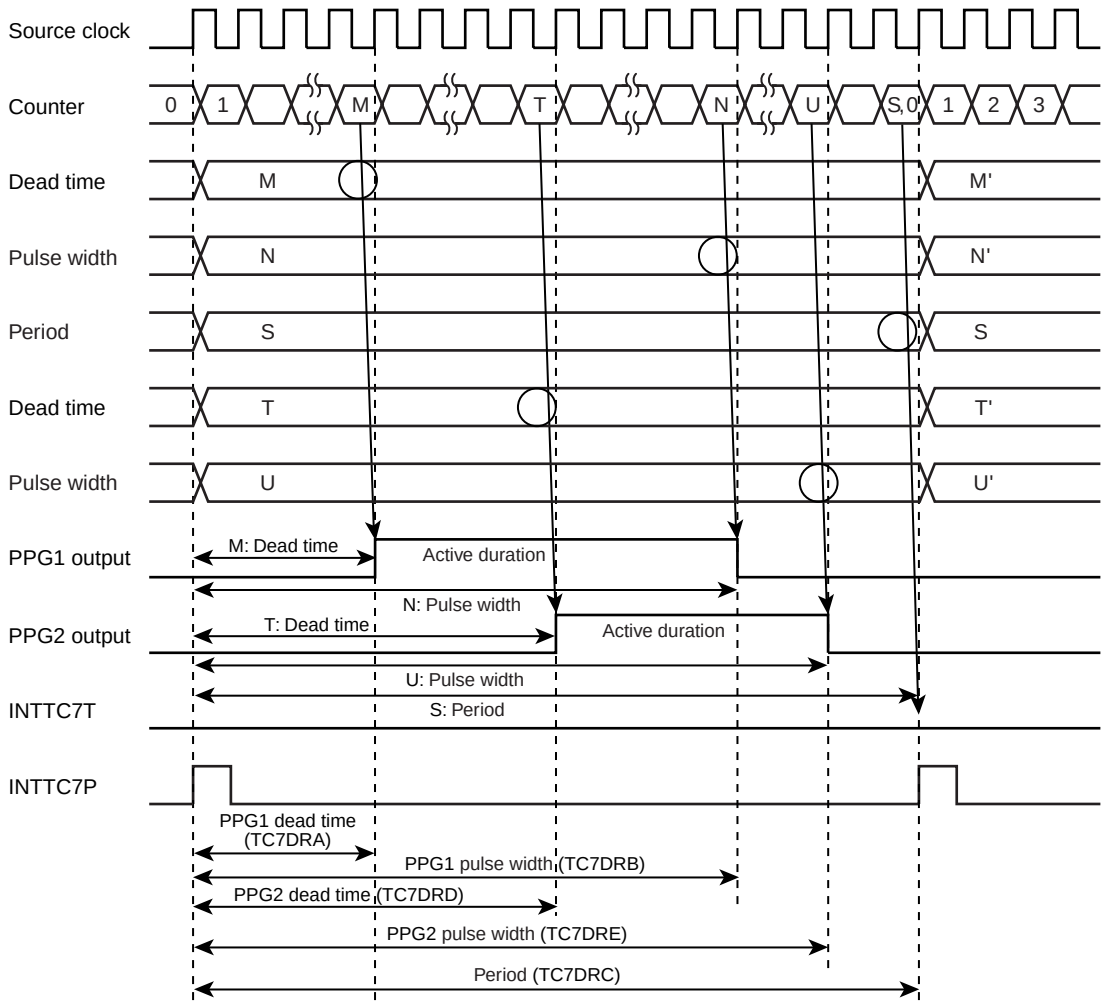


Figure 8-6 Example Operation in PPG1/PPG2 Independent Mode: Command and Capture Start, Positive Logic, Continuous Output

8.4.2 Starting a count

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

8.4.2.1 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

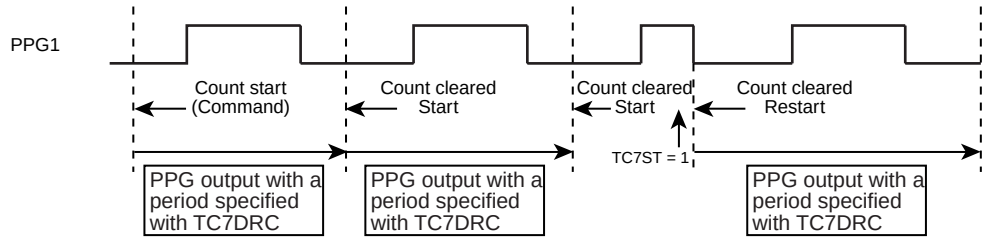


Figure 8-7 Example Operation in Command Start and Capture Mode

8.4.2.2 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 8.4.2.5 “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

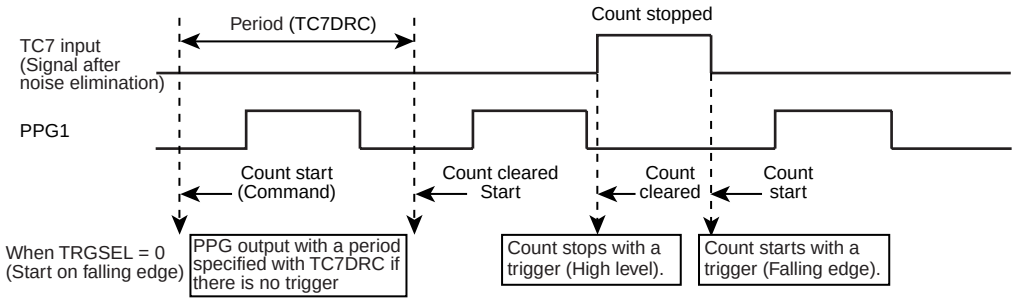


Figure 8-8 Example Operation in Command Start and Trigger Start Mode

8.4.2.3 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 8.4.2.5 “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

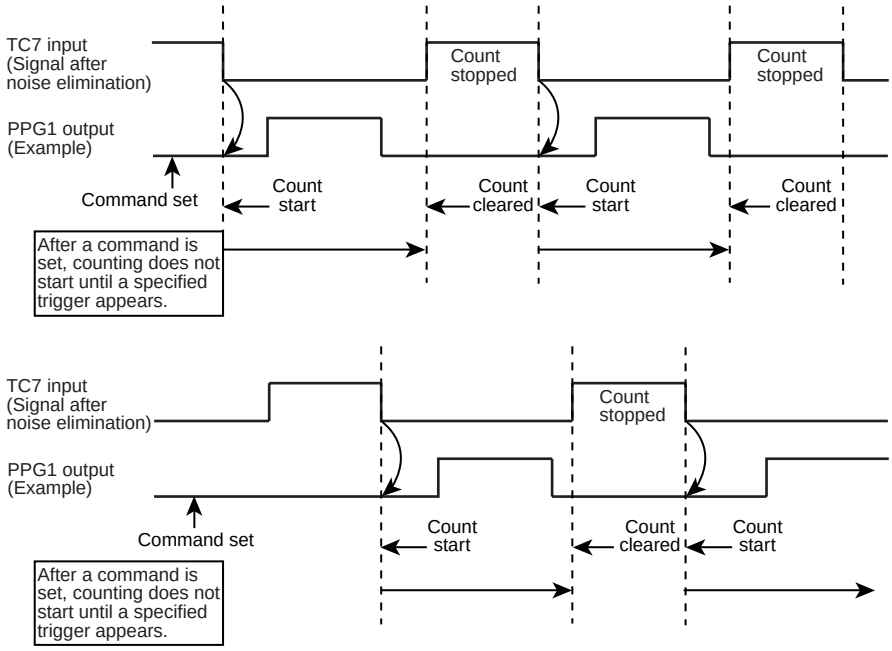


Figure 8-9 Example Operation in Trigger Start Mode

8.4.2.4 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

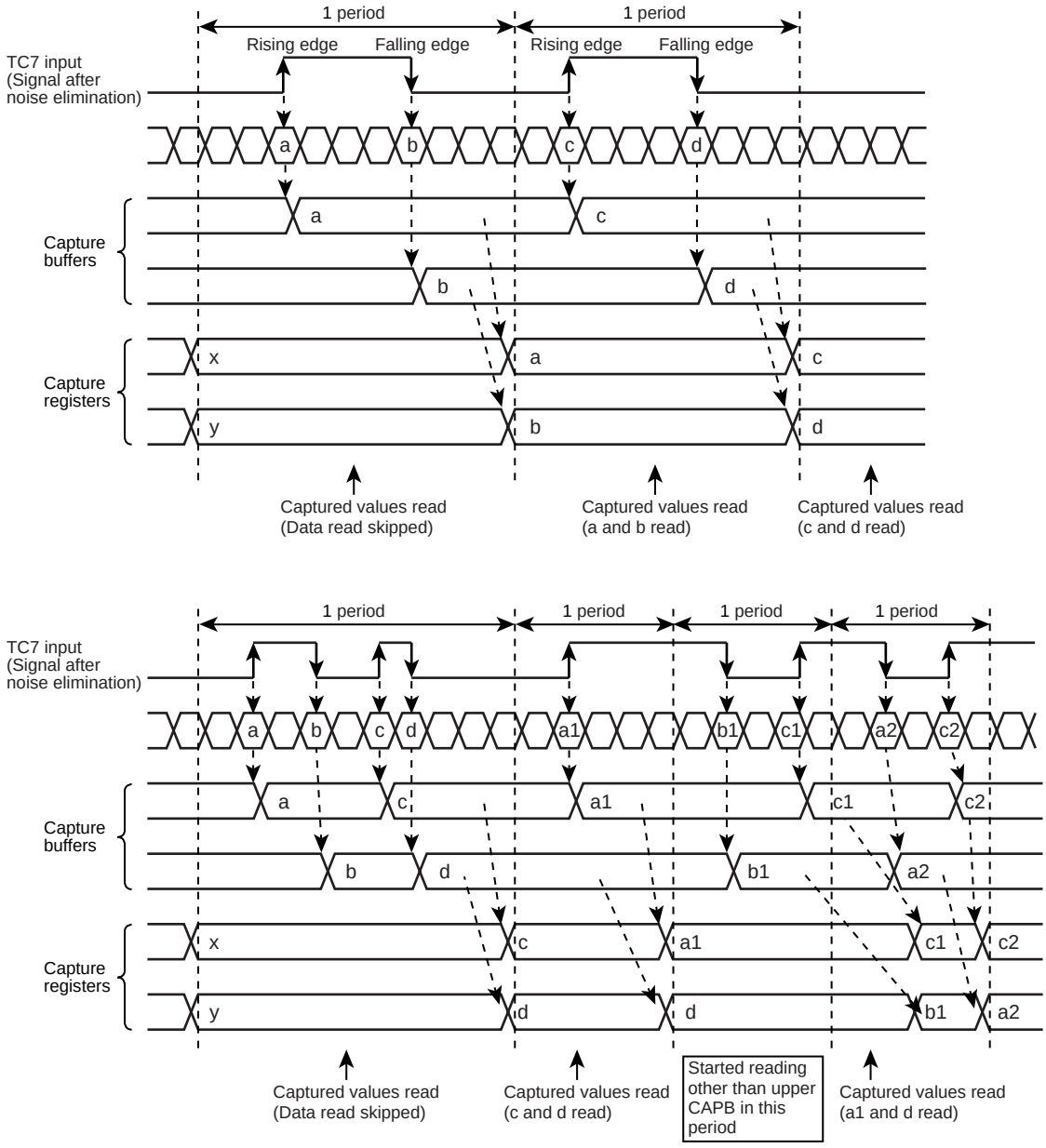


Figure 8-10 Example Operation in Trigger Capture Mode

8.4.2.5 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.

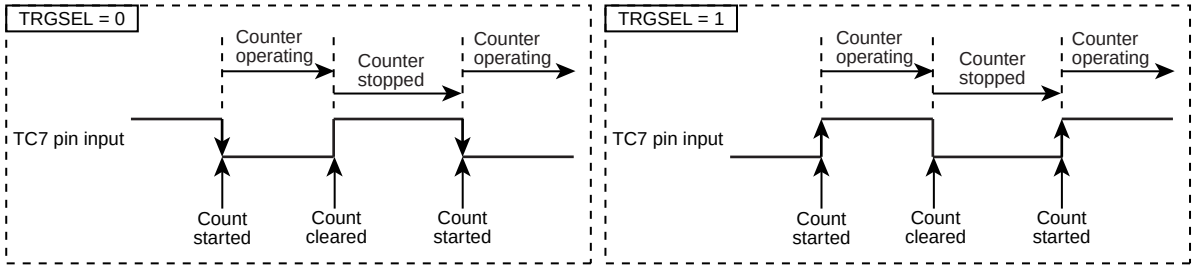
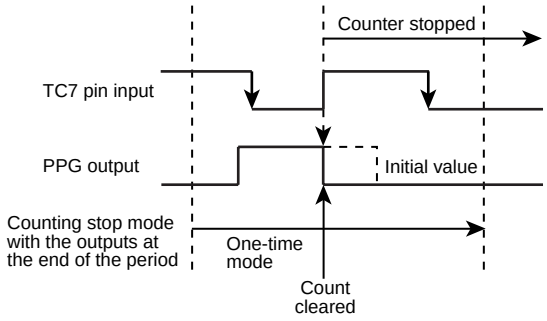


Figure 8-11 Trigger Input Signal

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.

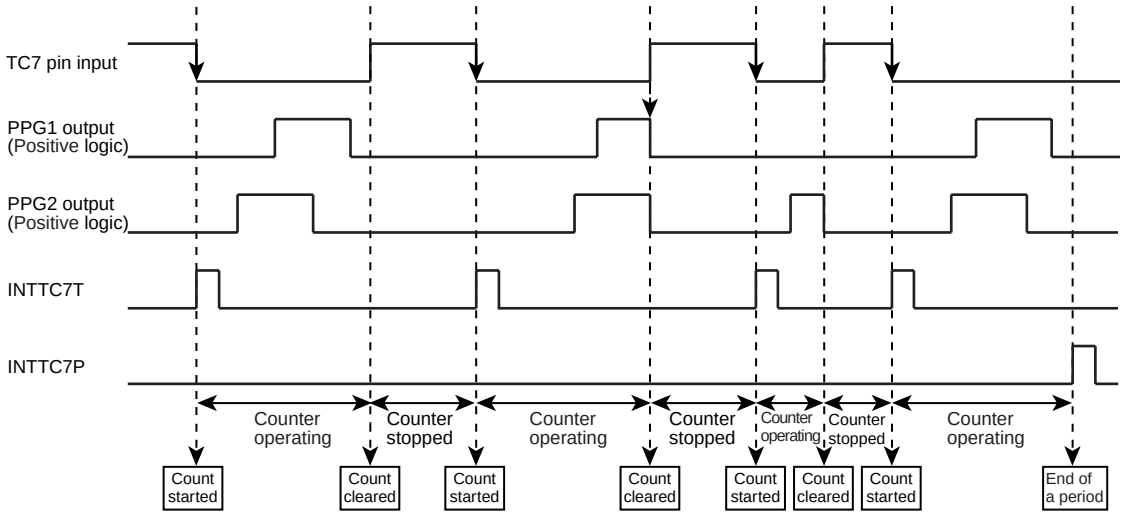


Figure 8-12 Start and Clear/stop Triggers on the TC7 Pin: Falling-edge Trigger (Counting stopped at high level), Triggers Always Accepted

(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.

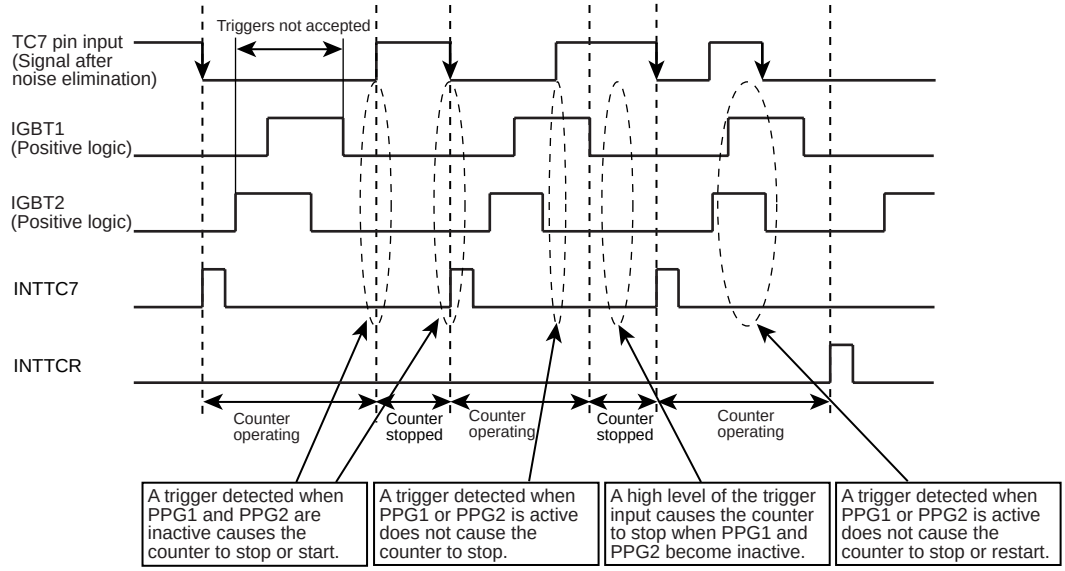


Figure 8-13 Start Triggers on the TC7 Pin: Falling-edge Trigger (Counting stopped at high level), Triggers Ignored when PPG Outputs are Active

8.4.3 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.

8.4.3.1 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.

8.4.3.2 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.

8.4.3.3 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.

8.4.4 One-time/continuous output mode

8.4.4.1 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.

8.4.4.2 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.

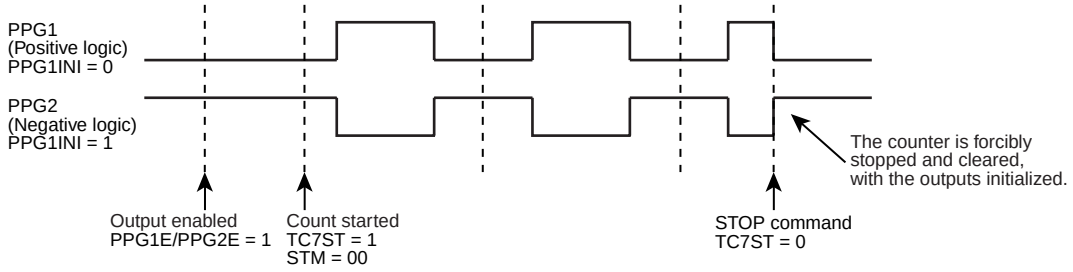


Figure 8-14 Immediately Stopping and Clearing the Counter with the Outputs Initialized (STM = 00)

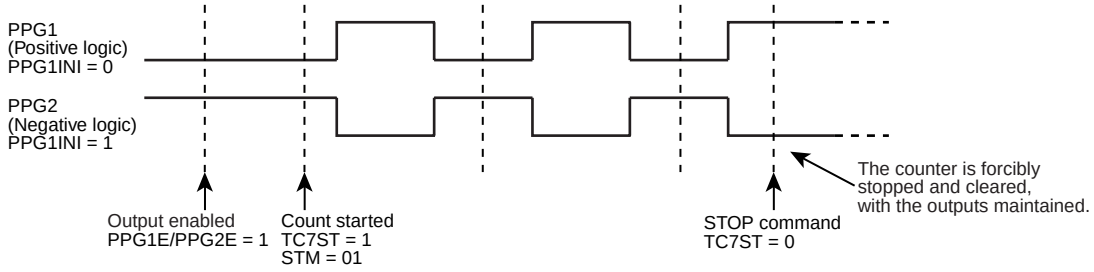


Figure 8-15 Immediately Stopping and Clearing the Counter with the Outputs Maintained (STM = 01)

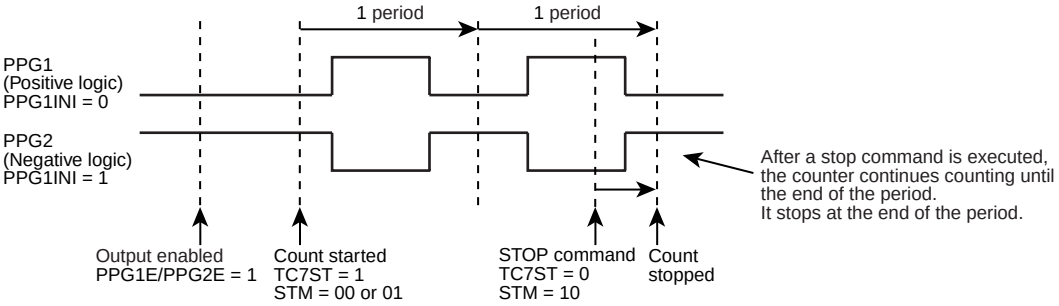


Figure 8-16 Stopping the Counter at the End of the Period (STM = 10)

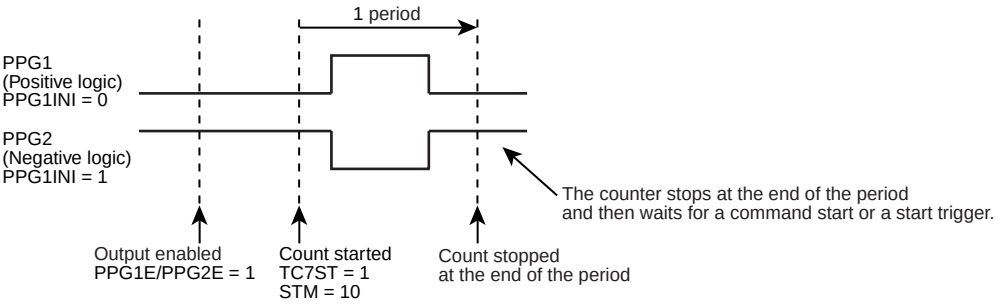


Figure 8-17 Stopping the Counter at the End of the Period (STM = 10): TC7ST = 1, One-time Output Mode

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

8.4.5.1 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.

8.4.5.2 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.

8.4.5.3 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.

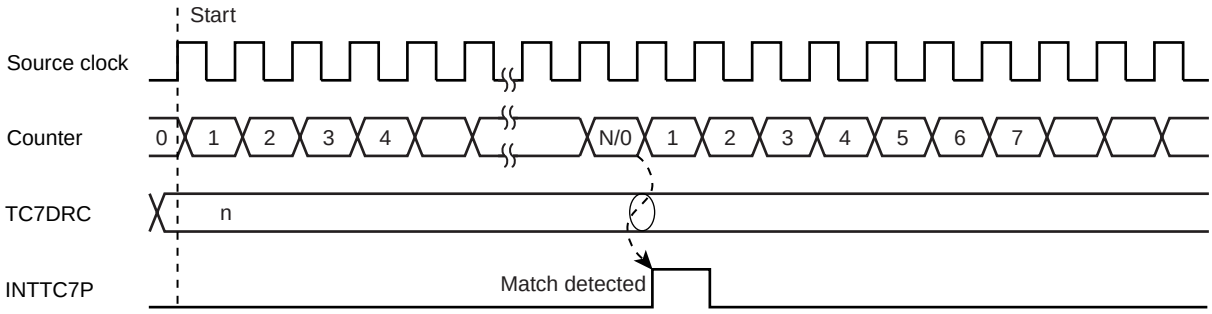


Figure 8-18 Using the TC7 as a Normal Timer/Counter

8.4.6 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 fc/4, fc/2 or fc, 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 8-1 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	fc/4 (5)	16/fc [s]	2 [ms]	1 [ms]	20/fc [s]	2.5 [ms]	1.25 [ms]
01	fc/2 (5)	8/fc [s]	1 [ms]	500 [ns]	10/fc [s]	1.25 [ms]	0.625 [ms]
10	fc (5)	4/fc [s]	0.5 [ms]	250 [ns]	5/fc [s]	0.625 [ms]	0.3125 [ms]
11	(None)	None	–	–	(1/fc)		

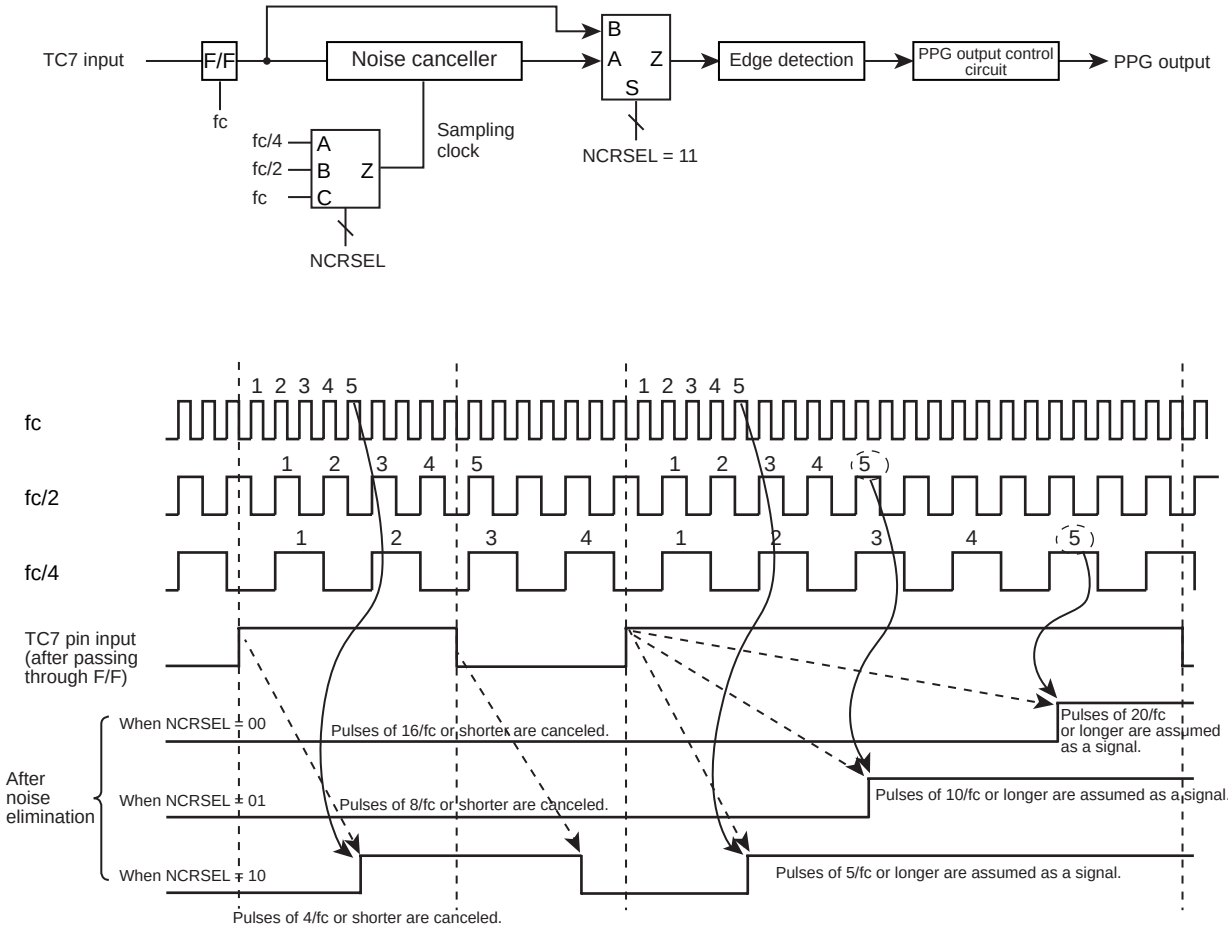


Figure 8-19 Noise Canceller Operation

- When NCRSEL = 00, a TC7 input level after passing through the F/F is always canceled if its duration is 16/fc [s] or less and always assumed as a signal if its duration is 20/fc [s] or greater. After the input signal supplied on the TC7 pin passes through the F/F, there is a delay between 21/fc [s] and 24/fc [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/fc [s] or less and always assumed as a signal if its duration is 10/fc [s] or greater. After the input signal supplied on the TC7 pin passes through the F/F, there is a delay between 13/fc [s] and 14/fc [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/fc [s] or less and always assumed as a signal if its duration is 5/fc [s] or greater. After the input signal supplied on the TC7 pin passes through the F/F, there is a delay of 5/fc [s] before the PPG outputs vary.
- When NCRSEL = 11, a pulse shorter than 1/fc 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/fc. After the input signal supplied on the TC7 pin passes through the F/F, there is a delay of 4/fc [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/fc [s] or less to pass through the F/F.

8.4.7 Interrupts

The TC7 supports three interrupt sources.

8.4.7.1 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.

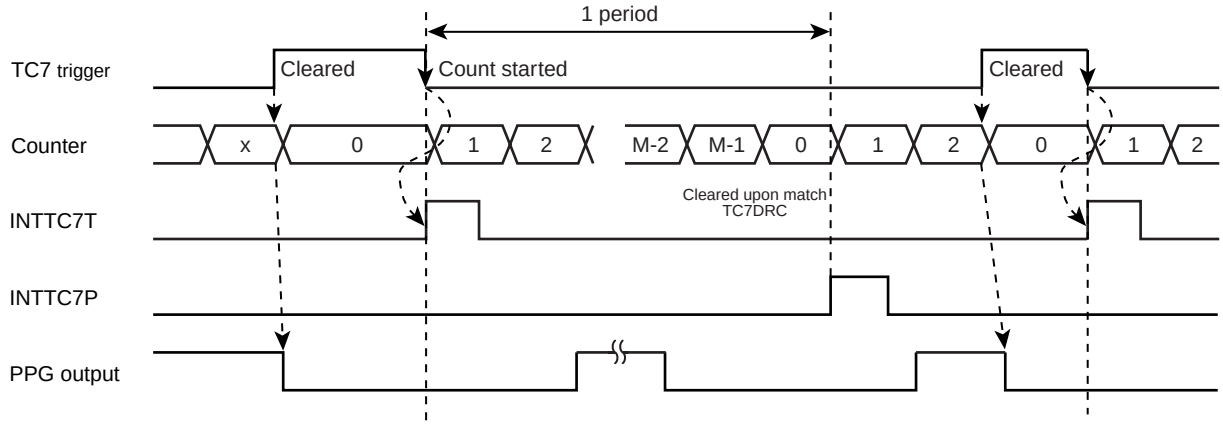


Figure 8-20 Trigger Start Interrupt

8.4.7.2 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.

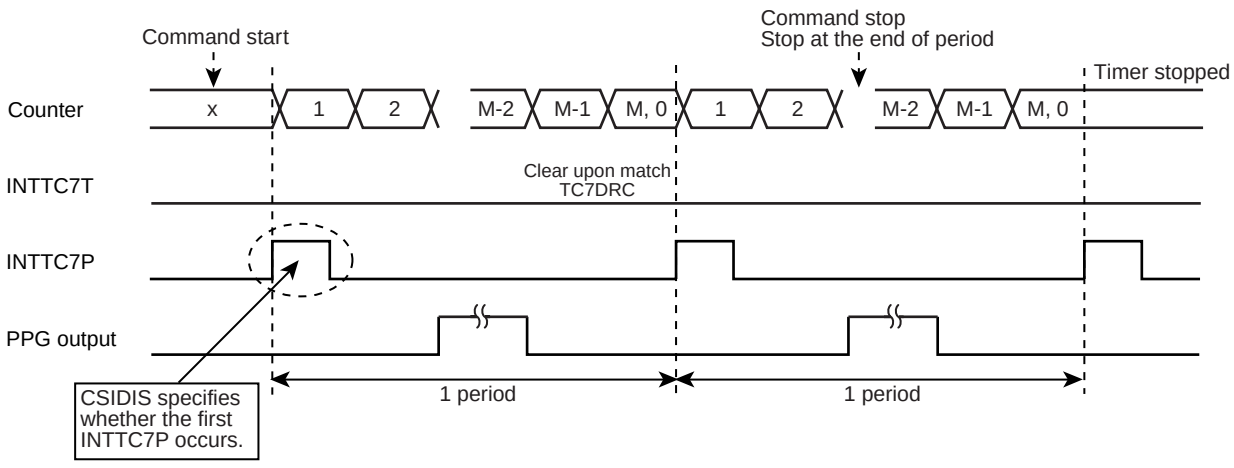


Figure 8-21 Period Interrupt

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.

8.4.7.3 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.

8.4.8 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/fc [s]. The emergency PPG output stop feature may not operate normally with a low level shorter than 4/fc [s].

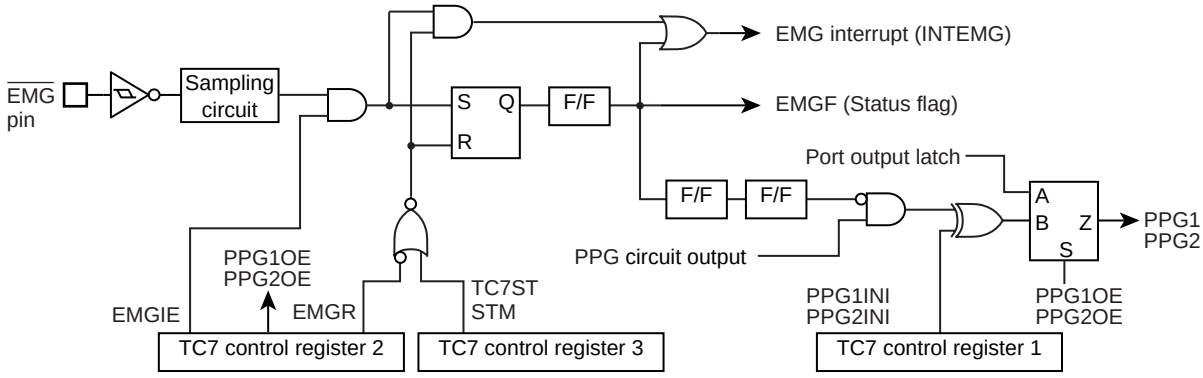


Figure 8-22 EMG Pin

8.4.8.1 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.

8.4.8.2 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.

8.4.8.3 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.

8.4.8.4 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.

8.4.8.5 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.

8.4.8.6 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/fc [s].

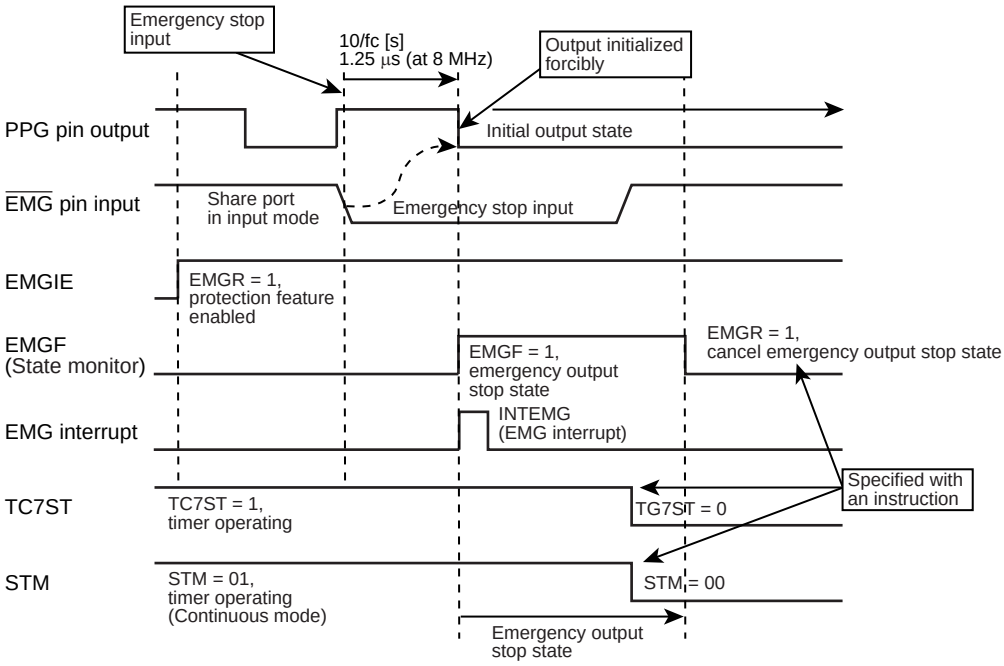


Figure 8-23 Timing between $\overline{\text{EMG}}$ Pin Input being Detected and PPG Outputs being Disabled

8.4.9 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.

9. 8-Bit TimerCounter (TC3, TC4)

9.1 Configuration

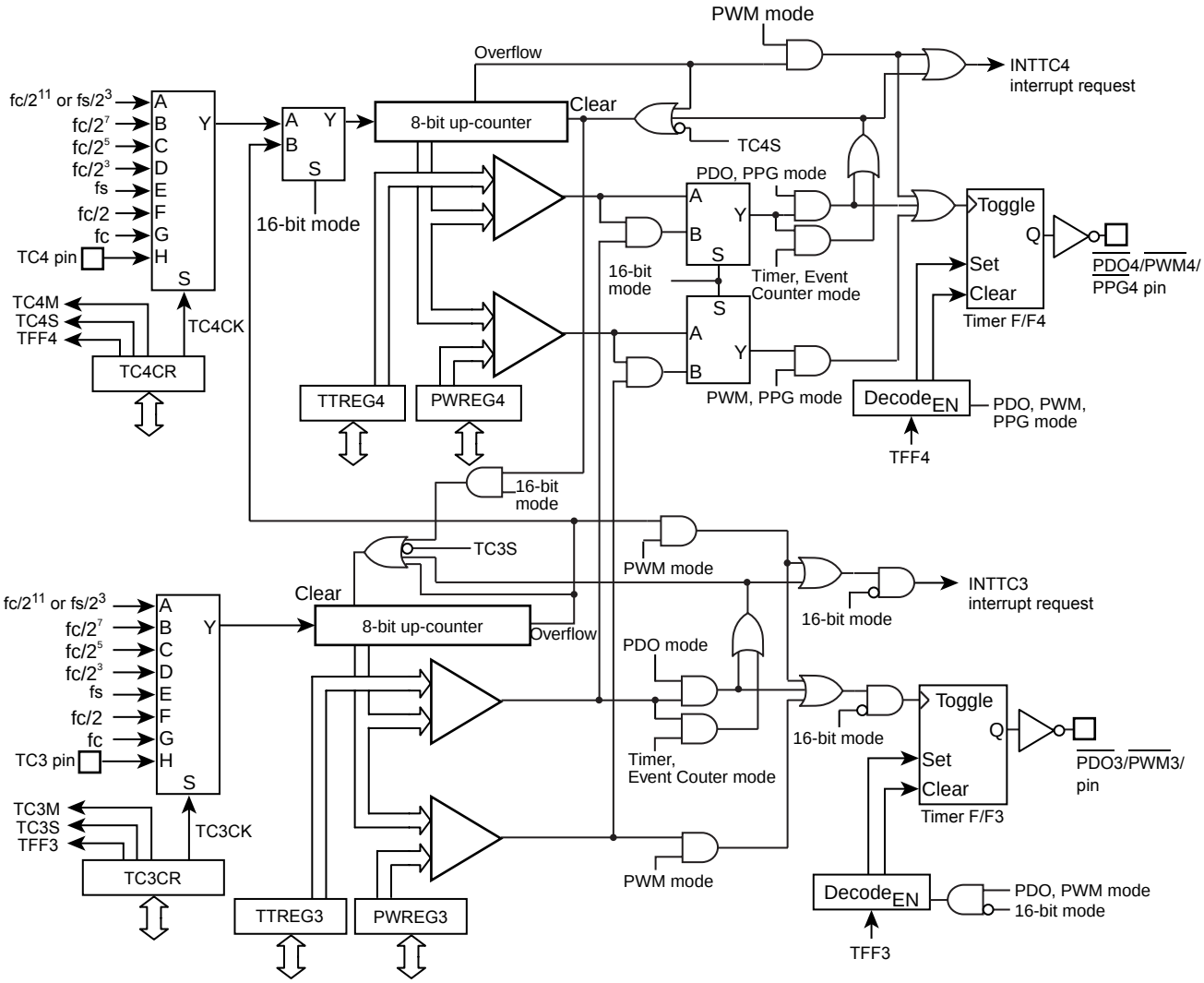


Figure 9-1 8-Bit TimerCouter 3, 4

9.2 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

	7	6	5	4	3	2	1	0	
TTREG3 (001CH) R/W									(Initial value: 1111 1111)
PWREG3 (001AH) R/W									(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 (0018H)	7	6	5	4	3	2	1	0	
	TFF3	TC3CK			TC3S	TC3M			(Initial value: 0000 0000)

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 9-1 and Table 9-2.

Note 7: The timer register settings are limited depending on the timer operating mode. For the detailed descriptions, see Table 9-3.

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

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

	7	6	5	4	3	2	1	0	
TTREG4 (001DH) R/W									(Initial value: 1111 1111)
PWREG4 (001BH) R/W									(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 (0019H)	7	6	5	4	3	2	1	0	
	TFF4	TC4CK			TC4S	TC4M			(Initial value: 0000 0000)

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 9-1 and Table 9-2.

Note 8: The timer register settings are limited depending on the timer operating mode. For the detailed descriptions, see Table 9-3.

Table 9-1 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 9-2 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 9-3 Constraints on Register Values Being Compared

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

Note: n = 3 to 4

9.3 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.

9.3.1 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 (TTREGj) value is detected, an INTTCj 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 $\overline{\text{PDOj, PWMj}}$ and $\overline{\text{PPGj}}$ pins may output pulses.

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 the programming. Therefore, if TTREGi is changed while the timer is running, an expected operation may not be obtained.

Note 3: j = 3, 4

Table 9-4 Source Clock for TimerCounter 3, 4 (Internal Clock)

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 μs	244.14 μs	32.6 ms	62.3 ms
$fc/2^7$	$fc/2^7$	–	8 μs	–	2.0 ms	–
$fc/2^5$	$fc/2^5$	–	2 μs	–	510 μs	–
$fc/2^3$	$fc/2^3$	–	500 ns	–	127.5 μs	–

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

```
LD      (TTREG4), 0AH          : Sets the timer register (80 μs÷2^7/fc = 0AH).
DI
SET     (EIRH). 5              : Enables INTTC4 interrupt.
EI
LD      (TC4CR), 00010000B     : Sets the operating cock to fc/2^7, and 8-bit timer mode.
LD      (TC4CR), 00011000B     : Starts TC4.
```

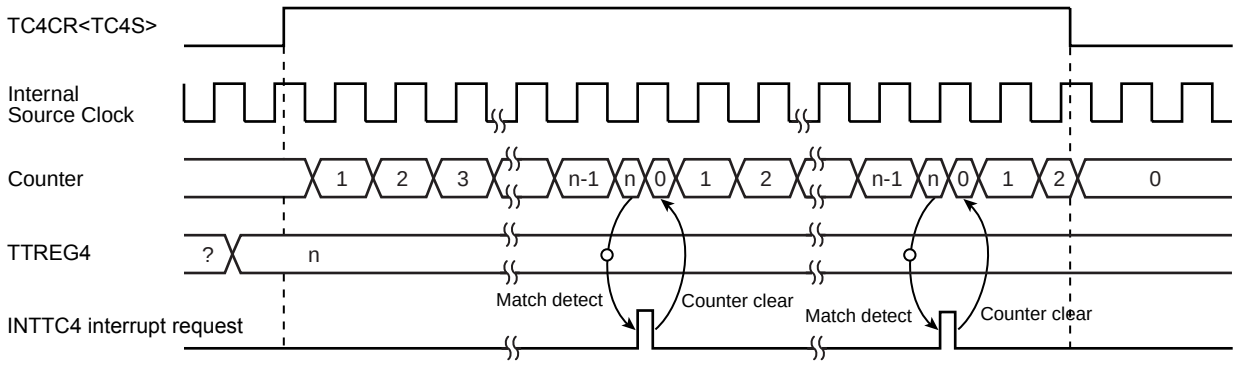


Figure 9-2 8-Bit Timer Mode Timing Chart (TC4)

9.3.2 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 $\overline{\text{PDOj, PWMj}}$ and $\overline{\text{PPGj}}$ 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 TTREGi is changed while the timer is running, an expected operation may not be obtained.

Note 3: j = 3, 4

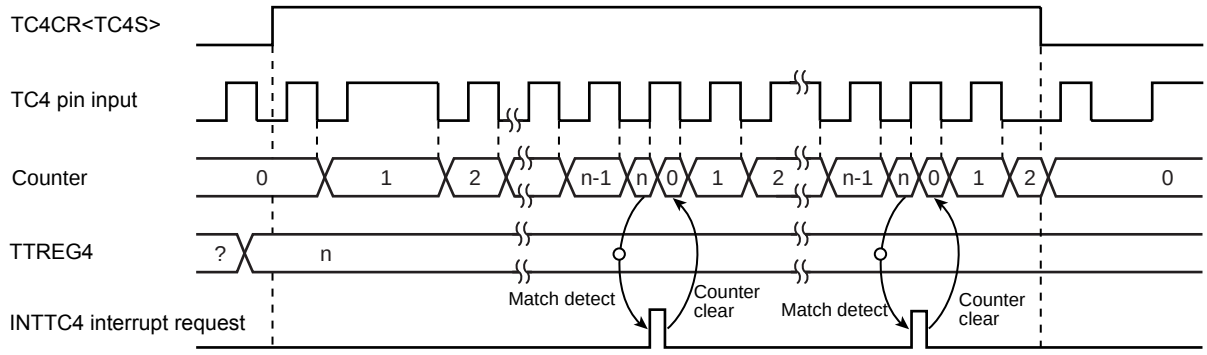


Figure 9-3 8-Bit Event Counter Mode Timing Chart (TC4)

9.3.3 8-Bit Programmable Divider Output (PDO) Mode (TC3, 4)

This mode is used to generate a pulse with a 50% duty cycle from the $\overline{\text{PDOj}}$ 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 $\overline{\text{PDOj}}$ 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 $\overline{\text{PDOj}}$ 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 (fc = 16.0 MHz)

```
                Setting port
LD      (TTREG4),  3DH          : 1/1024÷2^7/fc÷2 = 3DH
LD      (TC4CR),   00010001B    : Sets the operating clock to fc/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

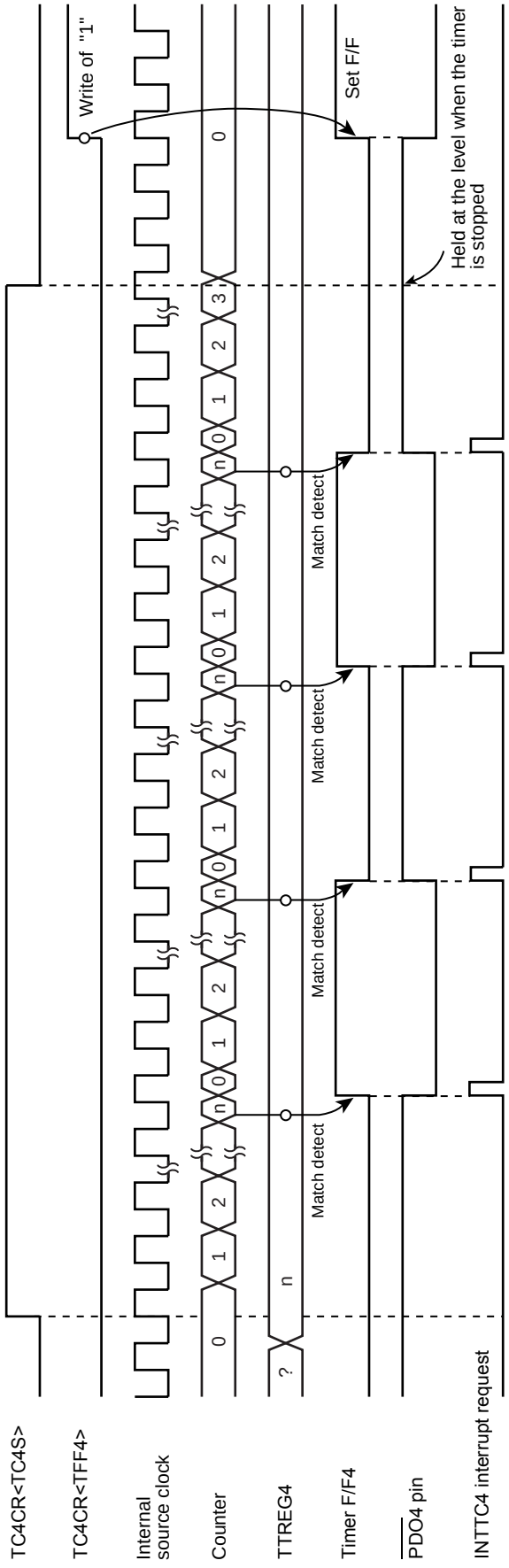


Figure 9-4 8-Bit PDO Mode Timing Chart (TC4)

9.3.4 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 9-5 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 μs	244.14 μs	32.8 ms	62.5 ms
$fc/2^7$	$fc/2^7$	–	8 μs	–	2.05 ms	–
$fc/2^5$	$fc/2^5$	–	2 μs	–	512 μs	–
$fc/2^3$	$fc/2^3$	–	500 ns	–	128 μs	–
fs	fs	fs	30.5 μs	30.5 μs	7.81 ms	7.81 ms
fc/2	fc/2	–	125 ns	–	32 μs	–
fc	fc	–	62.5 ns	–	16 μs	–

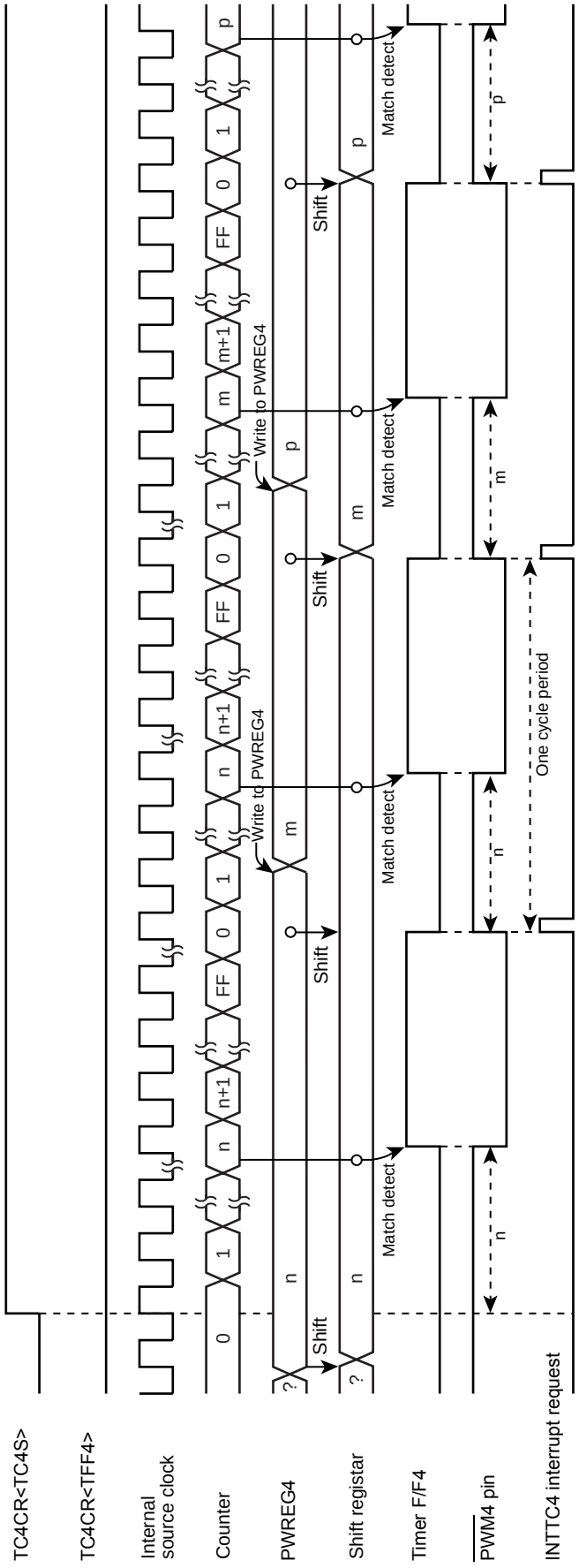


Figure 9-5 8-Bit PWM Mode Timing Chart (TC4)

9.3.5 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 cascadable 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 $\overline{PDOj}$, $\overline{PWMj}$, and $\overline{PPGj}$ 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 9-6 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 $fc/2^7$ Hz, and generating an interrupt 300 ms later (fc = 16.0 MHz)

```
LDW     (TTREG3), 927CH     : Sets the timer register (300 ms÷2^7/fc = 927CH).
DI
SET     (EIRH). 5           : Enables INTTC4 interrupt.
EI
LD      (TC3CR), 13H        :Sets the operating cock to fc/2^7, and 16-bit timer mode
                             (lower byte).
LD      (TC4CR), 04H        : Sets the 16-bit timer mode (upper byte).
LD      (TC4CR), 0CH        : Starts the timer.
```

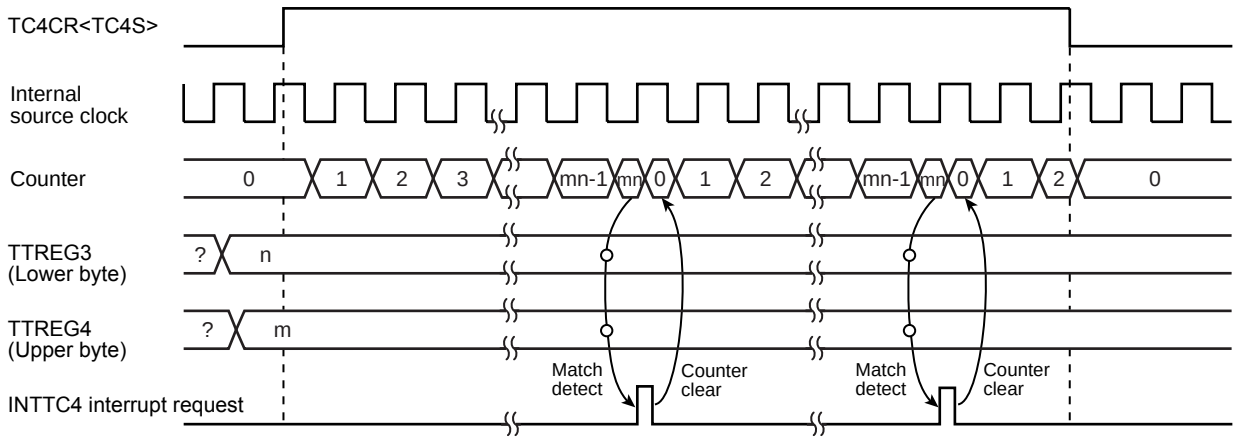


Figure 9-6 16-Bit Timer Mode Timing Chart (TC3 and TC4)

9.3.6 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 $fc/2^4$ Hz in the NORMAL1 or IDLE1 mode, and $fs/2^4$ 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 $\overline{PDOj, PWMj}$ 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

9.3.7 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 $fc/2^4$ Hz in the NORMAL1 or IDLE1 mode, and $fs/2^4$ 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 $\overline{PWM}4$ 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 $\overline{PWM}4$ 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$\overline{PWM}4$ pin to the high level when the TimerCounter is stopped

CLR (TC4CR).3: Stops the timer.
CLR (TC4CR).7 : Sets the $\overline{PWM4}$ 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 fc, fc/2 or fs is selected as the source clock, a pulse is output from the $\overline{PWM4}$ pin during the warm-up period time after exiting the STOP mode.

Table 9-7 16-Bit 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					
$fc/2^{11}$	$fs/2^3$ [Hz]	$fs/2^3$ [Hz]	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	–
$fc/2^3$	$fc/2^3$	–	500ns	–	32.8 ms	–
fs	fs	fs	30.5 μs	30.5 μs	2 s	2 s
fc/2	fc/2	–	125 ns	–	8.2 ms	–
fc	fc	–	62.5 ns	–	4.1 ms	–

Example :Generating a pulse with 1-ms high-level width and a period of 32.768 ms (fc = 16.0 MHz)

```
        Setting ports
LDW     (PWREG3), 07D0H     : Sets the pulse width.
LD      (TC3CR), 33H        : Sets the operating clock to fc/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.
```

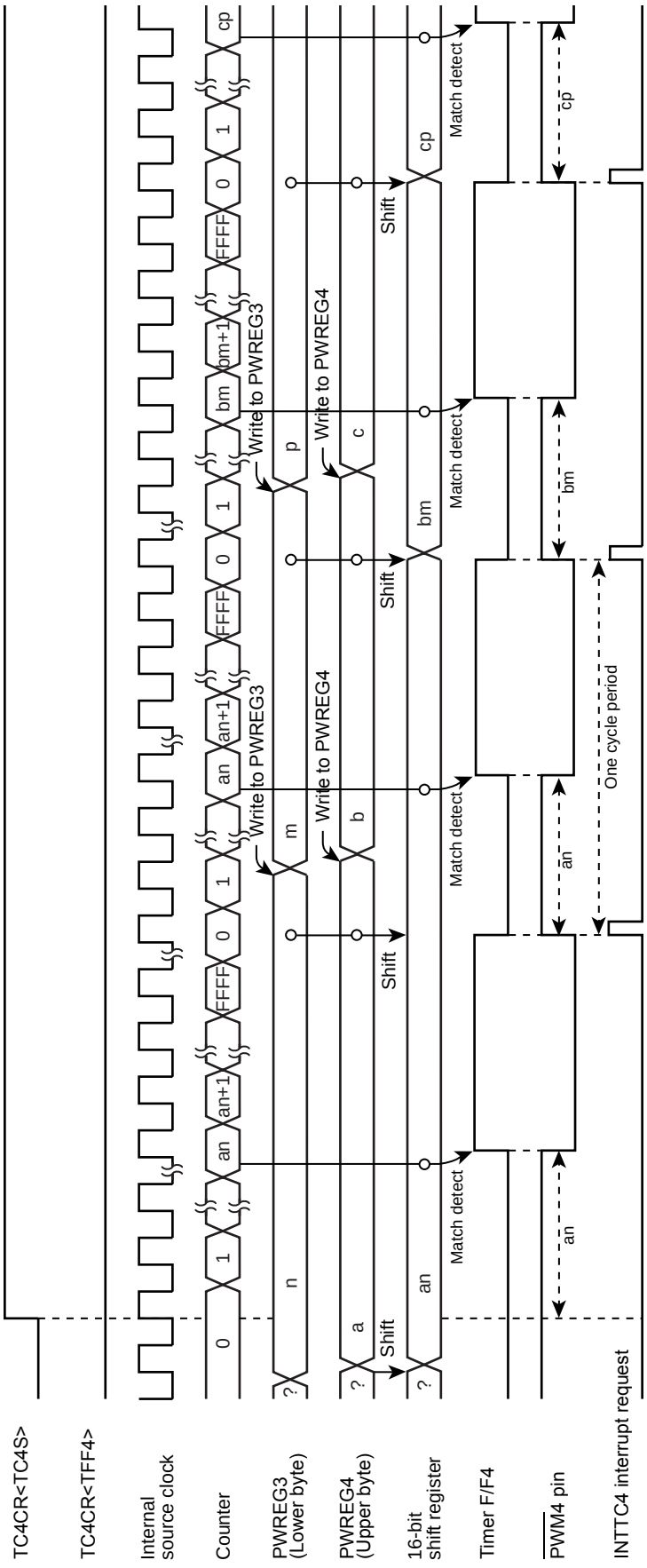


Figure 9-7 16-Bit PWM Mode Timing Chart (TC3 and TC4)

9.3.8 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 cascadable 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 $fc/2^4$ Hz in the NORMAL1 or IDLE1 mode, and $fc/2^4$ 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{PPG}$4 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 (fc = 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 fc/2^3, and16-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{PPG}$4 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{PPG}$4 pin to the high level when the TimerCounter is stopped
CLR (TC4CR).3: Stops the timer
CLR (TC4CR).7: Sets the $\overline{PPG}$4 pin to the high level

Note 3: i = 3, 4

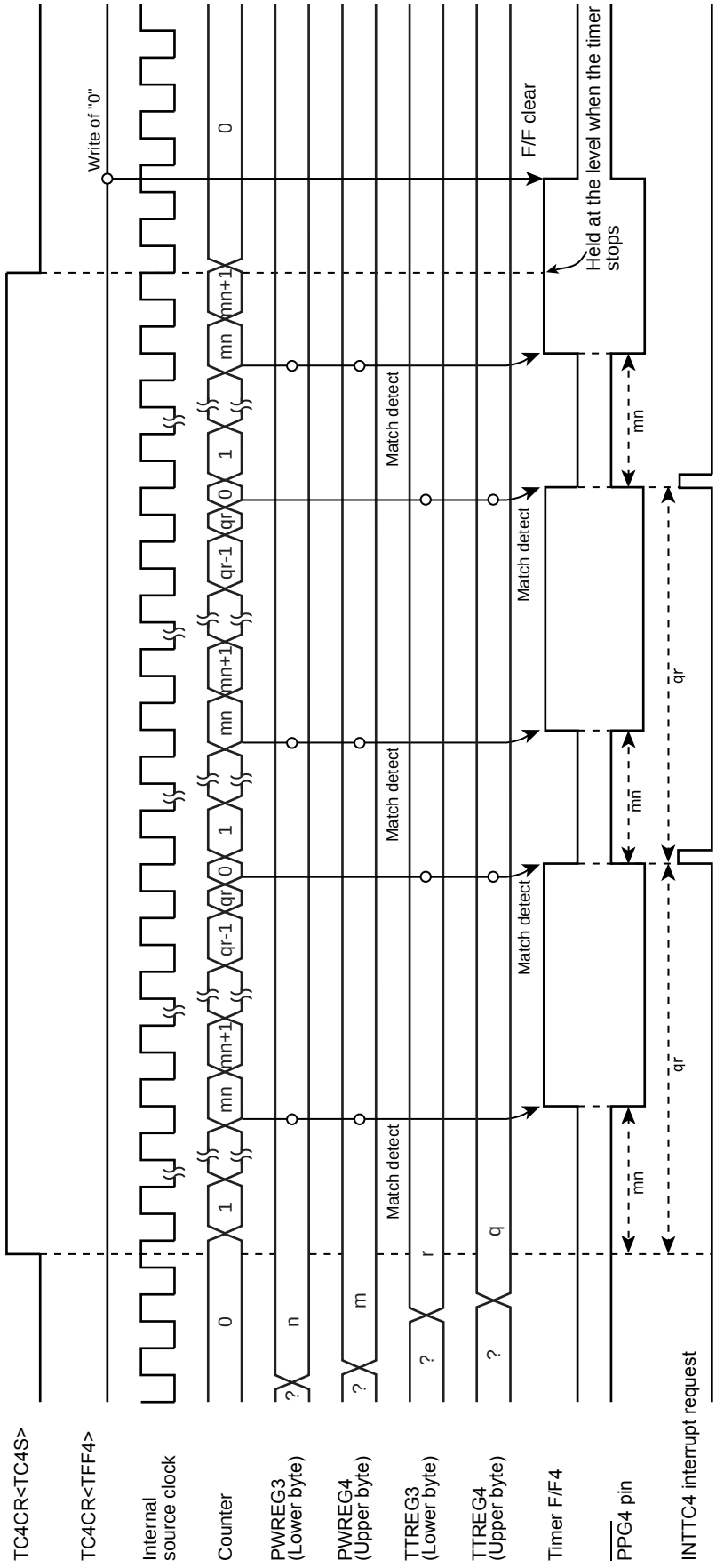


Figure 9-8 16-Bit PPG Mode Timing Chart (TC3 and TC40)

9.3.9 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 TimerCouter. 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 $\overline{\text{PDOi}}$, $\overline{\text{PWMi}}$ and $\overline{\text{PPGi}}$ 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

9.3.9.1 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 9-8 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
```

9.3.9.2 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 fc 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 9-9 Setting Time in High-Frequency Warm-Up Counter Mode

Minimum time (TTREG4, 3 = 0100H)	Maximum time (TTREG4, 3 = FF00H)
16 μs	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> ← 1
                LD      (TC3CR), 63H        : Sets TFF3=0, source clock fs, 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 ← 0
                SET     (EIRH). 5           : Enables the INTTC4.
                EI                          : IMF ← 1
                SET     (TC4CR).3           : Starts the TC4 and 3.
                 :          :
PINTTC4:        CLR     (TC4CR).3           : Stops the TC4 and 3.
                CLR     (SYSCR2).5          : SYSCR2<SYSCK> ← 0
                                              (Switches the system clock to the high-frequency clock.)
                CLR     (SYSCR2).6          : SYSCR2<XTEN> ← 0
                                              (Stops the low-frequency clock.)
                RETI
                 :          :
VINTTC4:        DW      PINTTC4             : INTTC4 vector table
```

10. Real-Time Clock

The TMP86CP27AFG 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).

10.1 Configuration

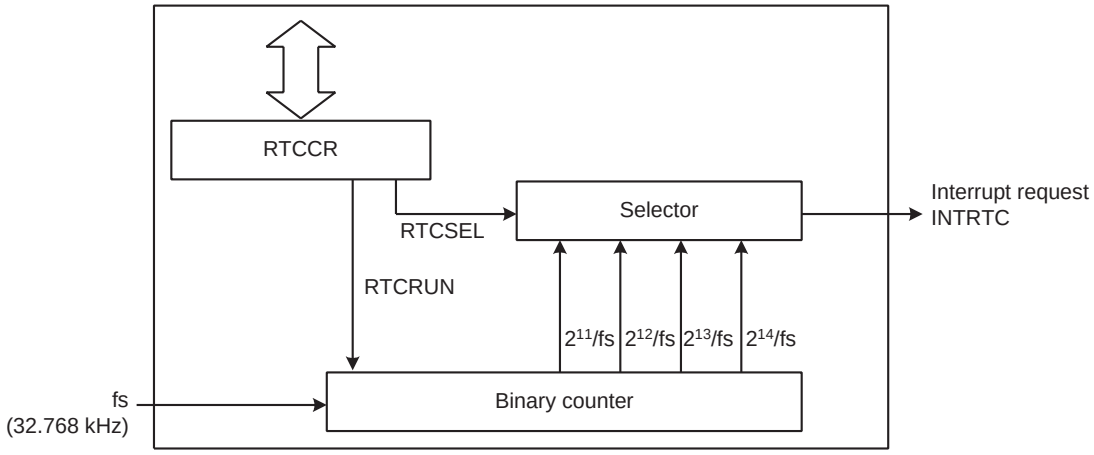


Figure 10-1 Configuration of the RTC

10.2 Control of the RTC

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

RTC Control Register

RTCCR (002DH)

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 TMP86CP27AFG 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.

10.3 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.

11. Asynchronous Serial interface (UART)

11.1 Configuration

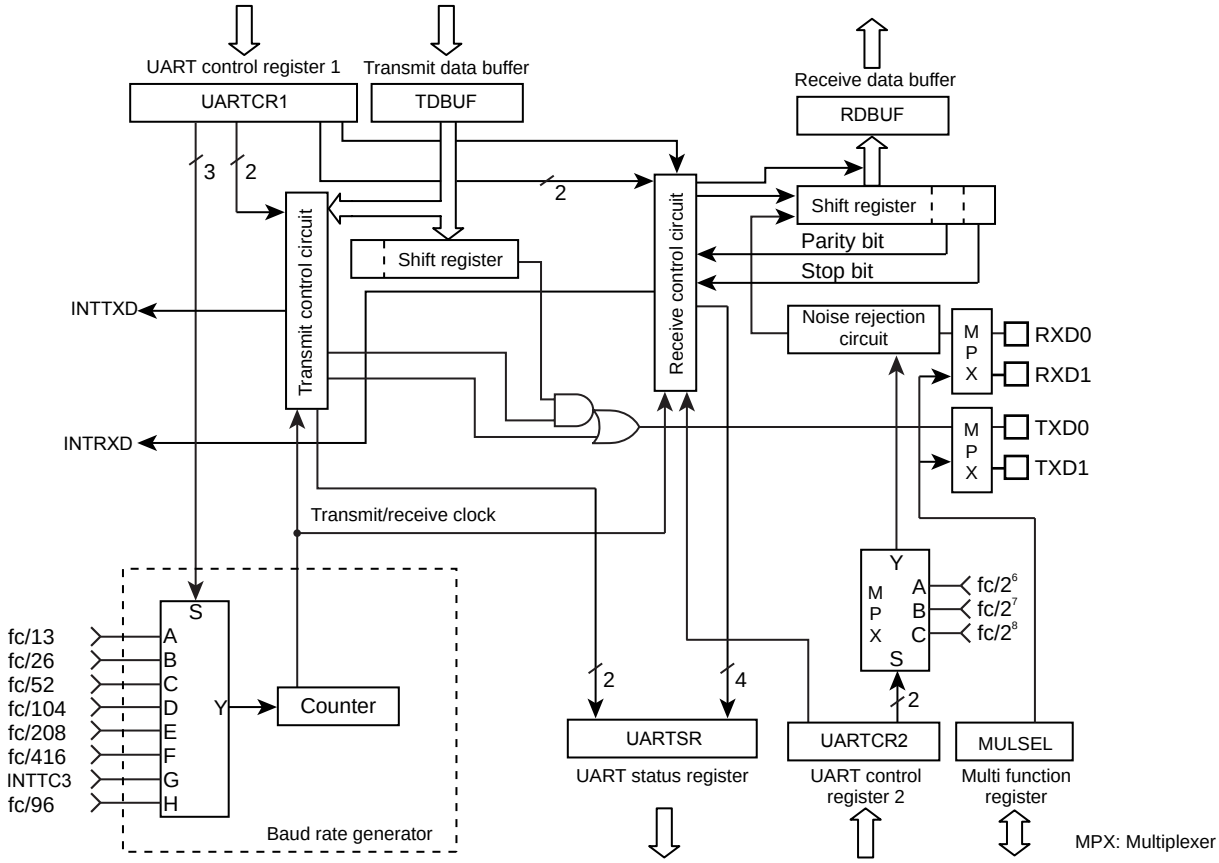


Figure 11-1 UART (Asynchronous Serial Interface)

11.2 Control

UART is controlled by the UART Control Registers (UARTCR1, UARTCR2). The operating status can be monitored using the UART status register (UARTSR).

TXD pin and RXD pin can be selected a port assignment by Multi Function Register (MULSEL).

UART Control Register1

UARTCR1 (0025H)

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 (0026H)

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 (0025H)

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

RDBUF (0FABH)

7	6	5	4	3	2	1	0

Read only

(Initial value: 0000 0000)

UART Transmit Data Buffer

TDBUF (0FABH)

7	6	5	4	3	2	1	0

Write only

(Initial value: 0000 0000)

Multi Function Register

MULSEL (0FBBH)

7	6	5	4	3	2	1	0
						(SIO SEL)	UART SEL

(Initial value: **** **00)

UARTSEL	UART function pins select	0: P01 (TXD0), P00 (RXD0) 1: P43 (TXD1), P37 (RXD1)	R/W

Note 1: Do not change MULSEL<UARTSEL> during UART operation.

Note 2: Set MULSEL register before performing the setting terminal of a I/O port when changing a terminal.

11.3 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.

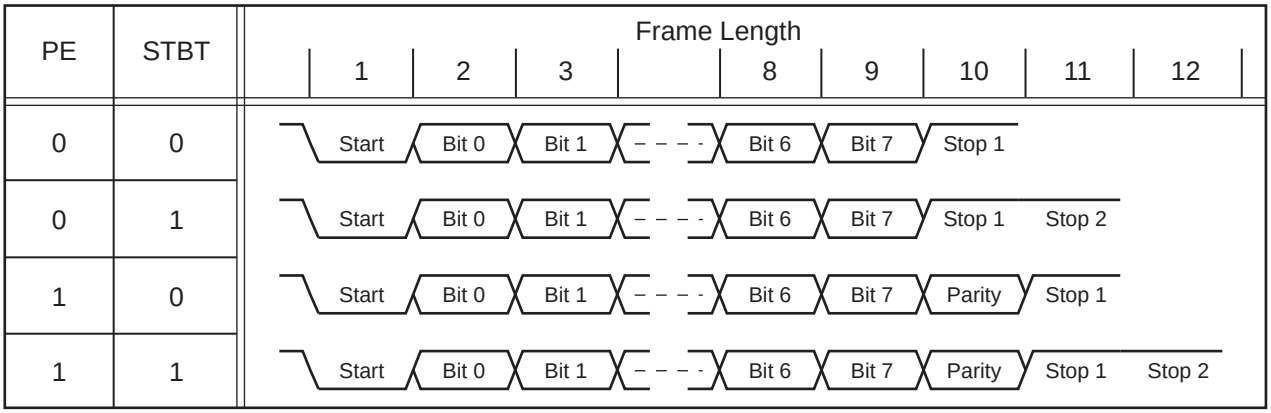


Figure 11-2 Transfer Data Format

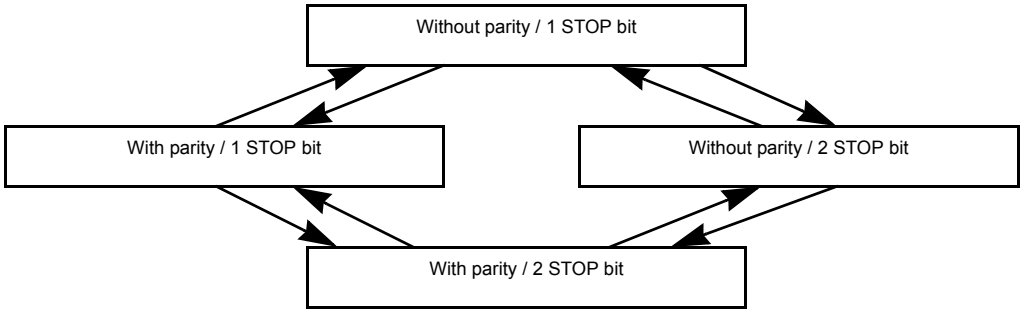


Figure 11-3 Caution on Changing Transfer Data Format

Note: In order to switch the transfer data format, perform transmit operations in the above Figure 11-3 sequence except for the initial setting.

11.4 Transfer Rate

The baud rate of UART is set of UARTCR1<BRG>. The example of the baud rate are shown as follows.

Table 11-1 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:

Transfer clock [Hz] = TC3 source clock [Hz] / TTREG3 setting value

Transfer Rate [baud] = Transfer clock [Hz] / 16

11.5 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).

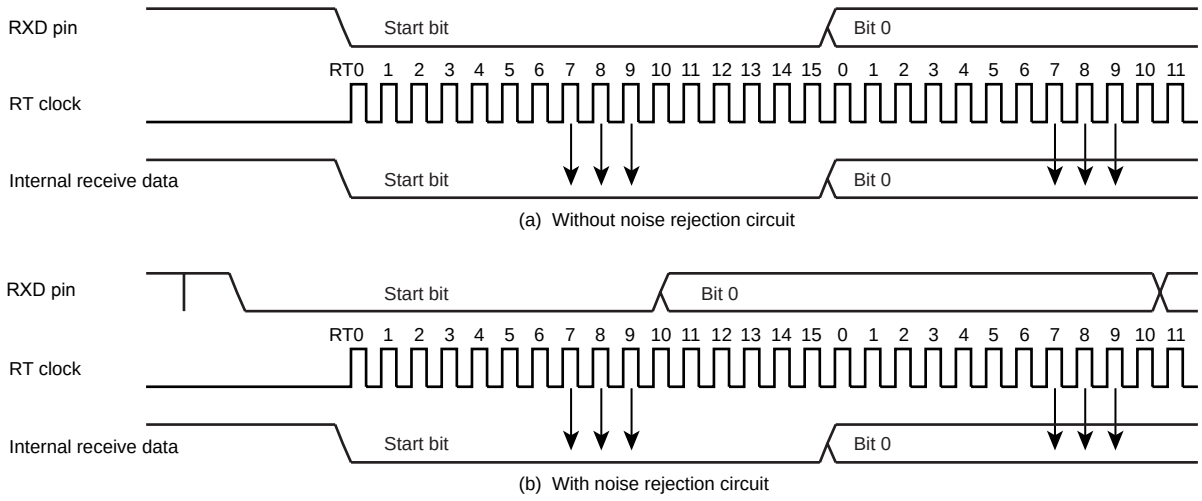


Figure 11-4 Data Sampling Method

11.6 STOP Bit Length

Select a transmit stop bit length (1 bit or 2 bits) by UARTCR1<STBT>.

11.7 Parity

Set parity / no parity by UARTCR1<PE> and set parity type (Odd- or Even-numbered) by UARTCR1<EVEN>.

11.8 Transmit/Receive Operation

11.8.1 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.

11.8.2 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.

11.9 Status Flag

11.9.1 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.

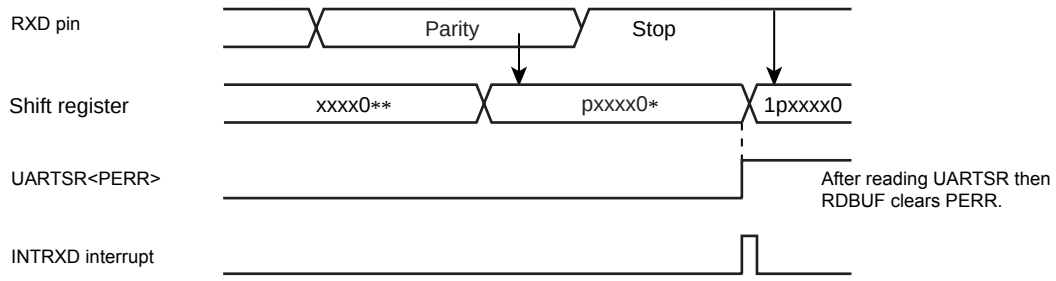


Figure 11-5 Generation of Parity Error

11.9.2 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.

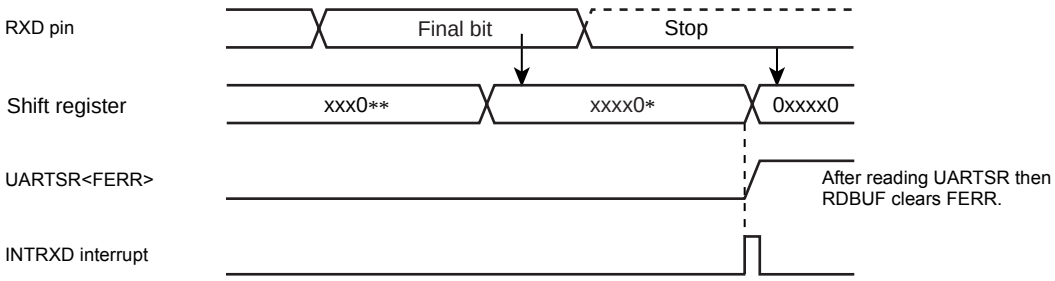


Figure 11-6 Generation of Framing Error

11.9.3 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.

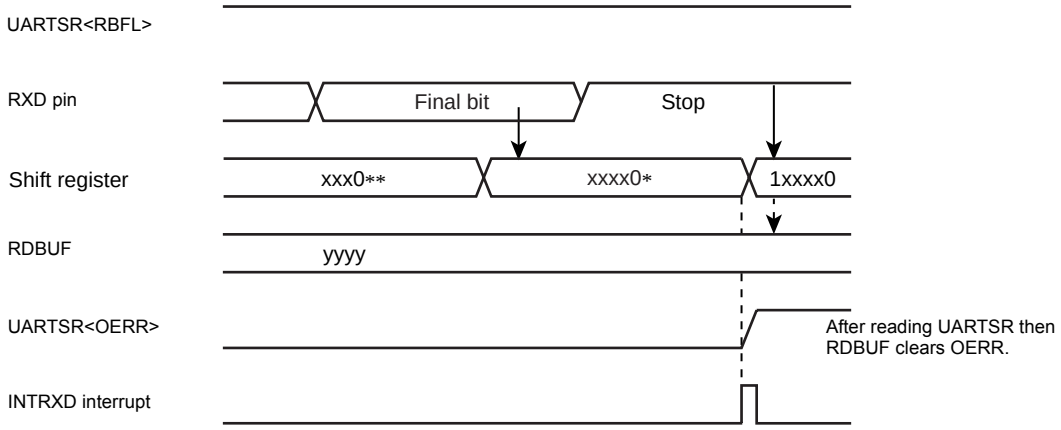


Figure 11-7 Generation of Overrun Error

Note: Receive operations are disabled until the overrun error flag UARTSR<OERR> is cleared.

11.9.4 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.

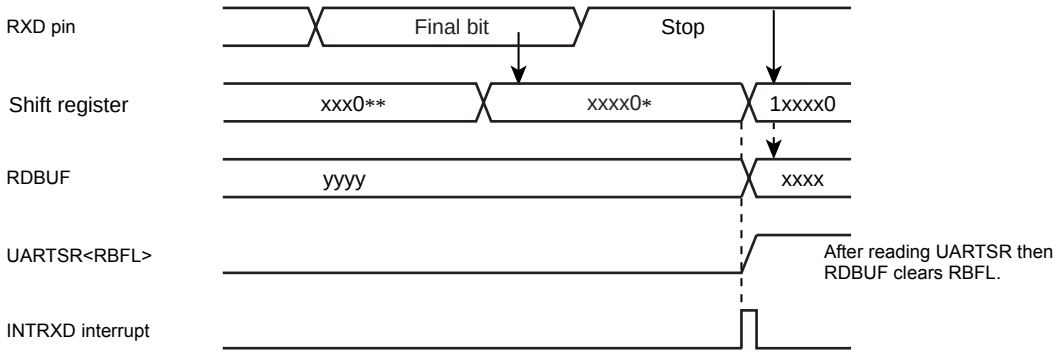


Figure 11-8 Generation of Receive Data Buffer Full

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.

11.9.5 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.

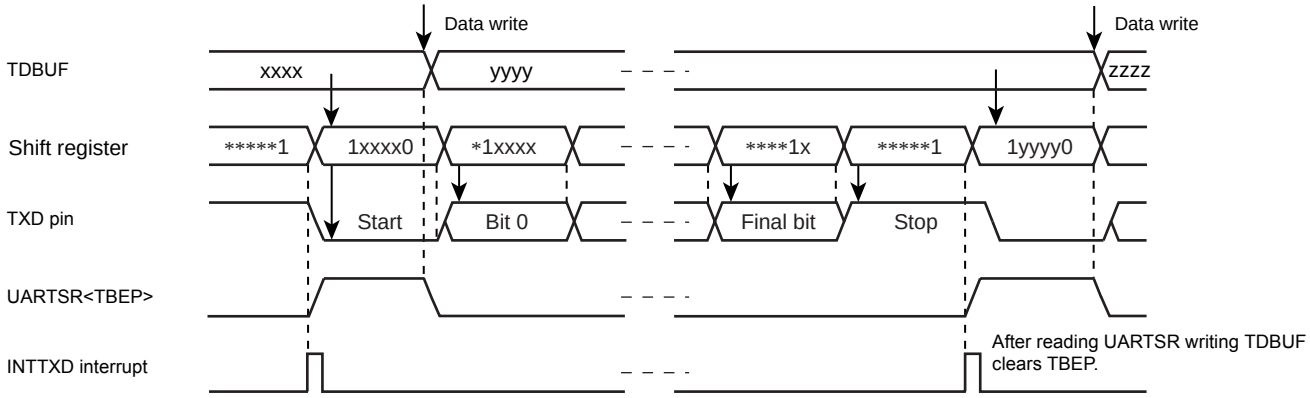


Figure 11-9 Generation of Transmit Data Buffer Empty

11.9.6 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.

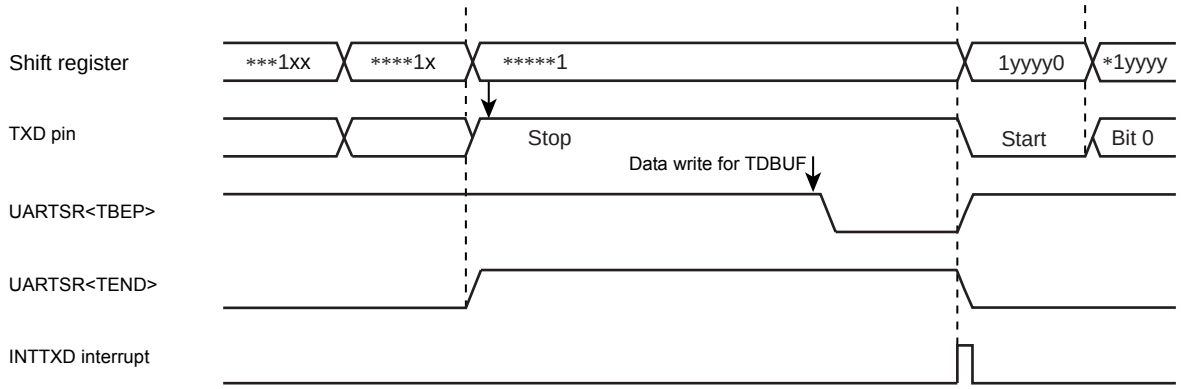


Figure 11-10 Generation of Transmit End Flag and Transmit Data Buffer Empty

12. Synchronous Serial Interface (SIO)

The TMP86CP27AFG 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 peripherl devices via SO, SI, SCK port.

12.1 Configuration

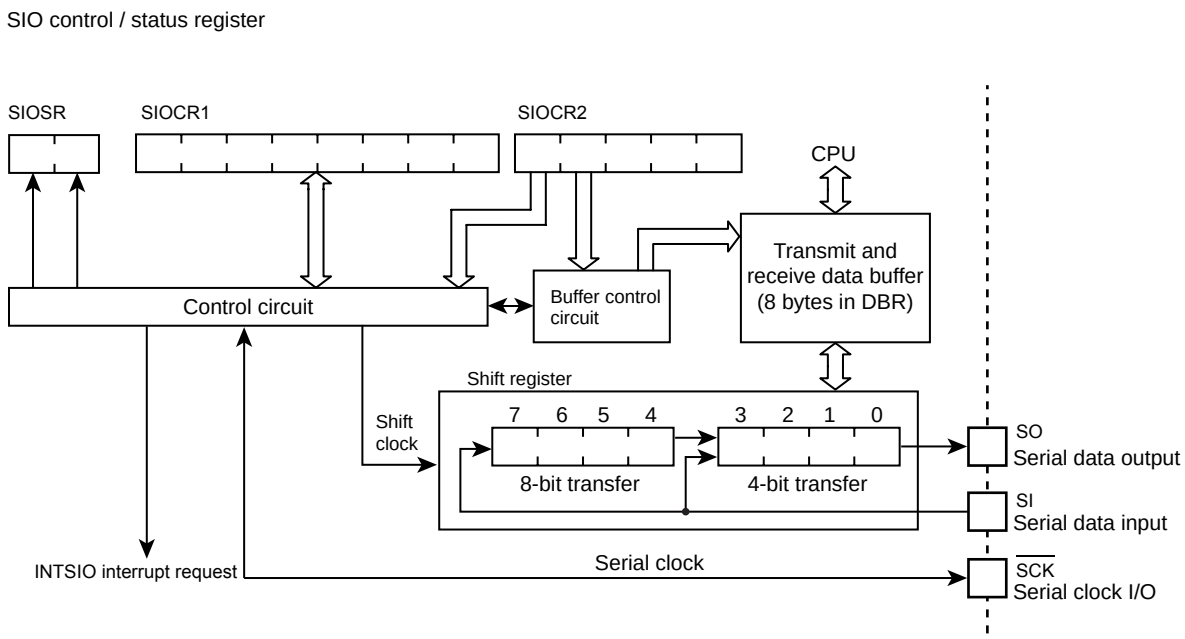


Figure 12-1 Serial Interface

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 0FA0H to 0FA7H 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	
(0FA8H)	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	
(0FA9H)				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 0FA0H 001: 2 words transfer 0FA0H ~ 0FA1H 010: 3 words transfer 0FA0H ~ 0FA2H 011: 4 words transfer 0FA0H ~ 0FA3H 100: 5 words transfer 0FA0H ~ 0FA4H 101: 6 words transfer 0FA0H ~ 0FA5H 110: 7 words transfer 0FA0H ~ 0FA6H 111: 8 words transfer 0FA0H ~ 0FA7H	

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 0FA0H).

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
(0FA9H)	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".

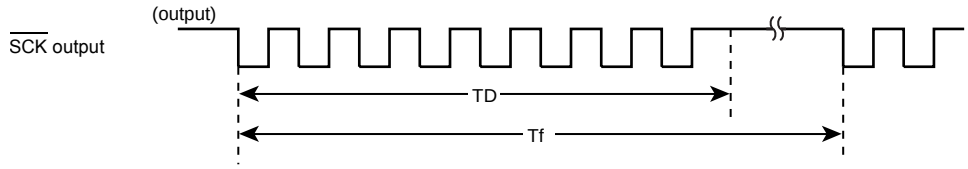


Figure 12-2 Frame time (T_f) and Data transfer time (T_D)

Multi Function Register

MULSEL	7	6	5	4	3	2	1	0
(0FBBH)							SIOSEL	(UART-SEL)

(Initial value: **** **00)

SIOSEL	SIO function pins select	0: P05 (SI0), P06 (SO0), P07 (SCK0) 1: P40 (SI1), P41 (SO1), P42 (SCK1)	R/W

Note 1: Do not change MULSEL<SIOSEL> during SIO operation.

Note 2: Set MULSEL register before performing the setting terminal of a I/O port when changing a terminal.

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

	NORMAL1/2, 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 (fc = 16 MHz, fs = 32.768 kHz)

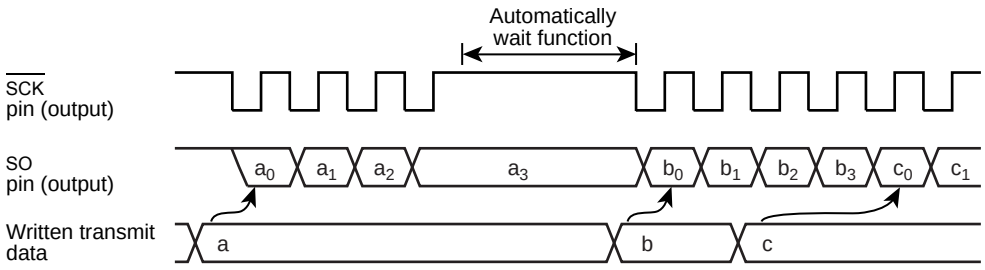


Figure 12-3 Automatic Wait Function (at 4-bit transmit mode)

12.3.1.2 External clock

An external clock connected to the $\overline{SCK}$ 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. Therfore, maximum transfer frequency will be 488.3K bit/sec (at fc=16MHz).

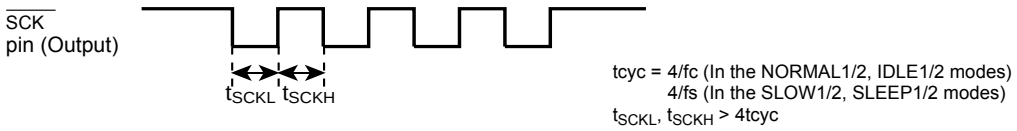


Figure 12-4 External clock pulse width

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 $\overline{SCK}$ 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 $\overline{SCK}$ pin input/output).

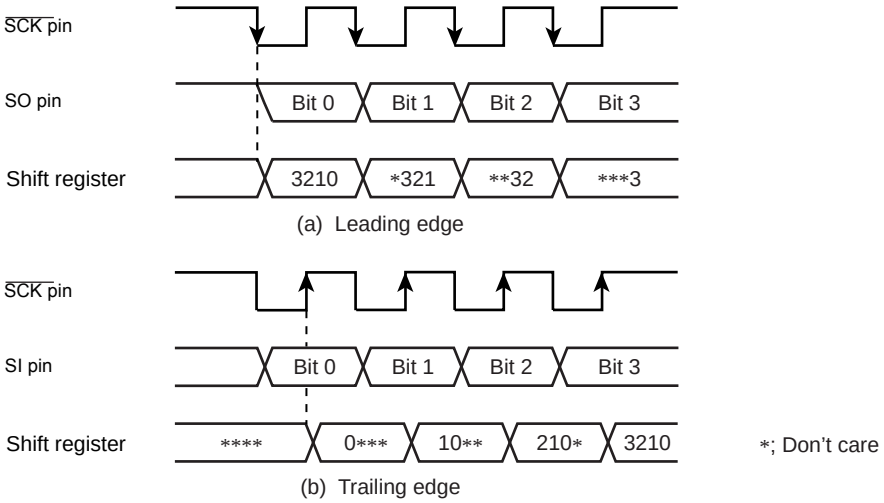


Figure 12-5 Shift edge

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.

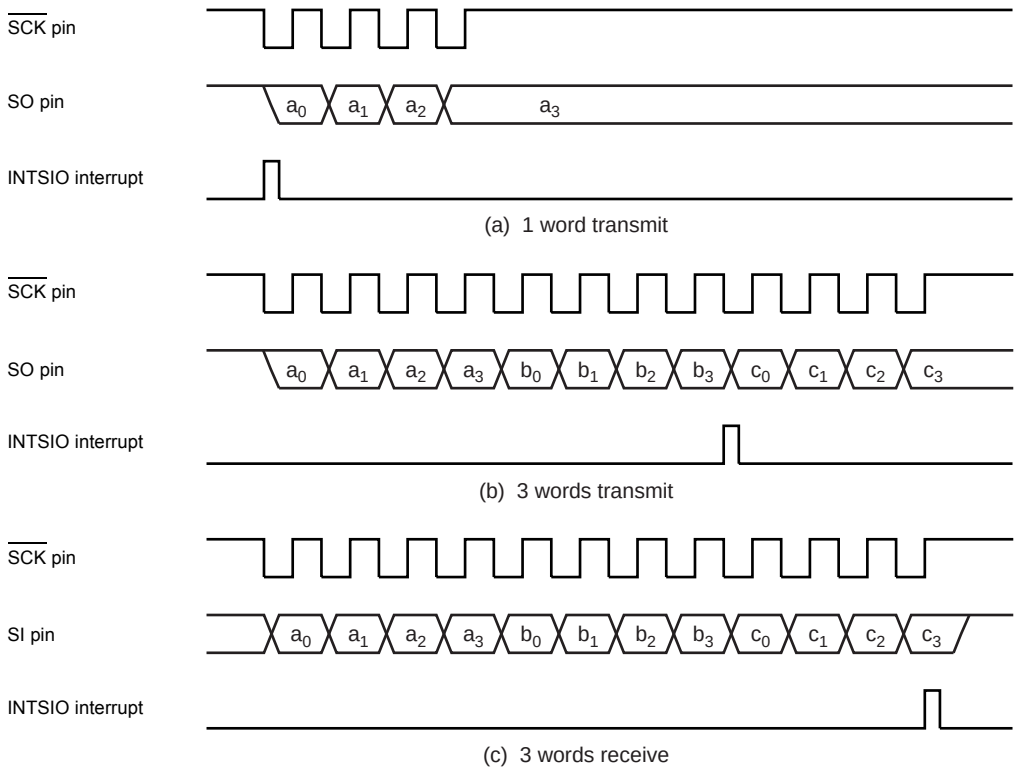


Figure 12-6 Number of words to transfer (Example: 1word = 4bit)

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".

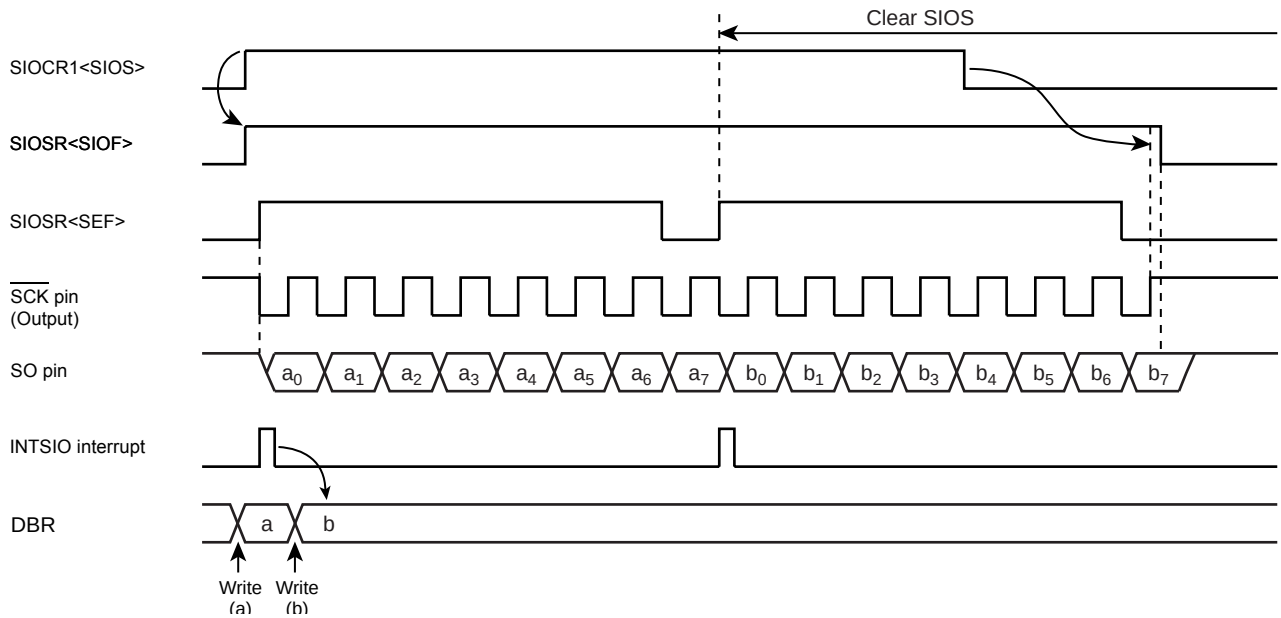


Figure 12-7 Transfer Mode (Example: 8bit, 1word transfer, Internal clock)

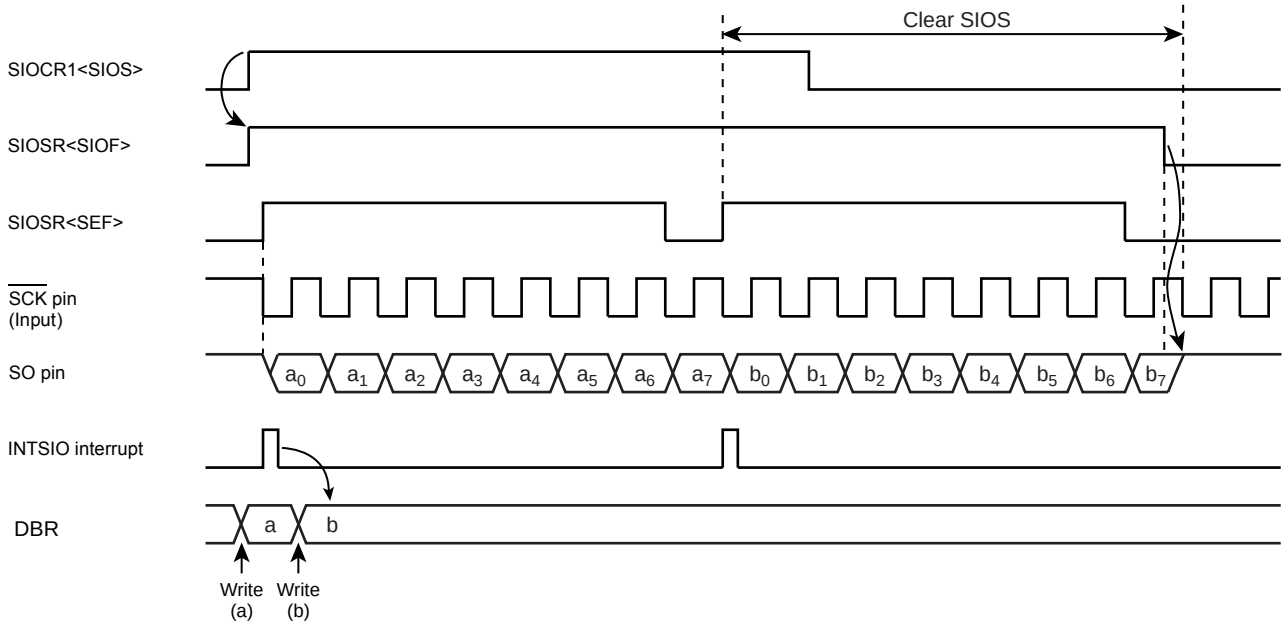


Figure 12-8 Transfer Mode (Example: 8bit, 1word transfer, External clock)

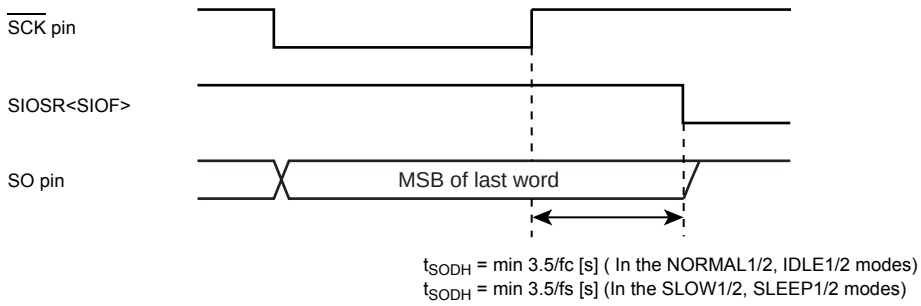


Figure 12-9 Transmiiied Data Hold Time at End of Transfer

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.

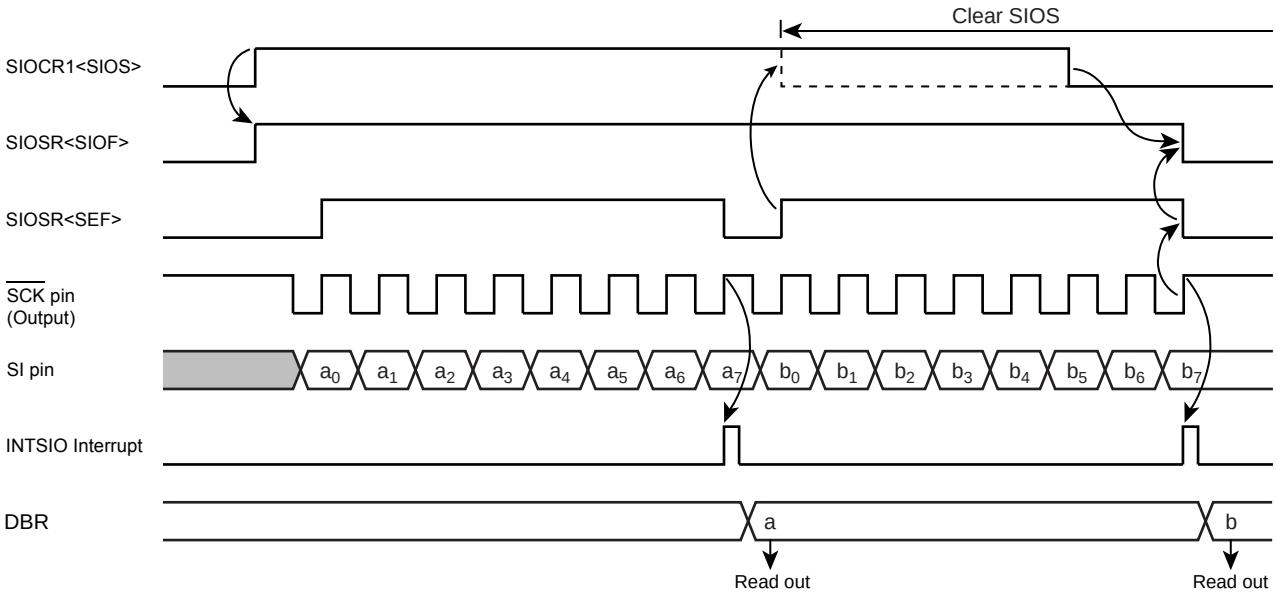


Figure 12-10 Receive Mode (Example: 8bit, 1word transfer, Internal clock)

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.

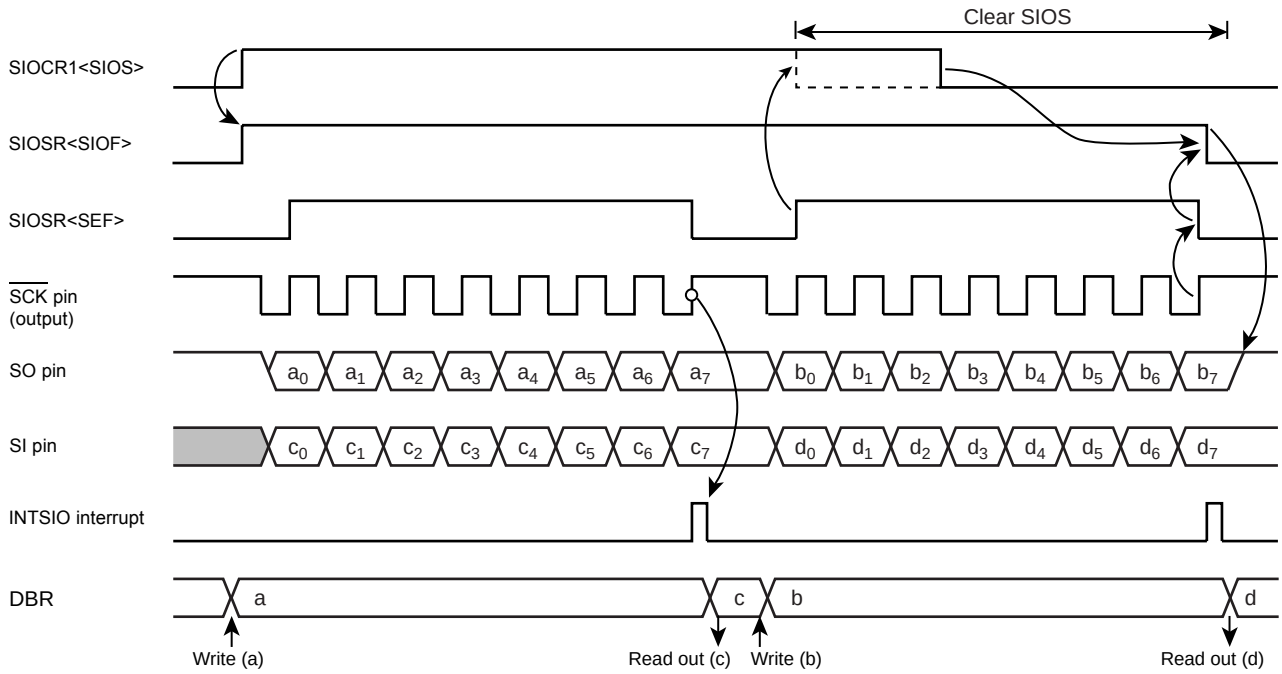


Figure 12-11 Transfer / Receive Mode (Example: 8bit, 1word transfer, Internal clock)

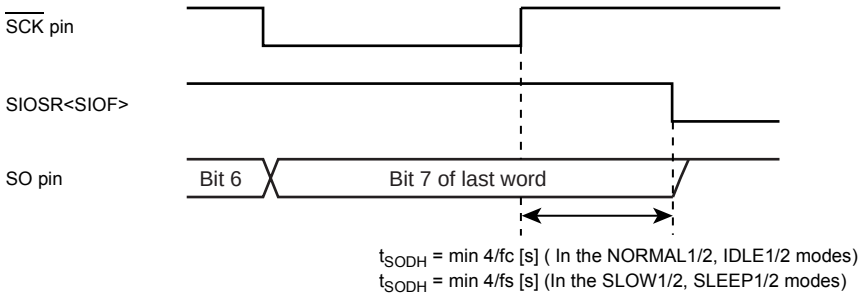


Figure 12-12 Transmitted Data Hold Time at End of Transfer / Receive

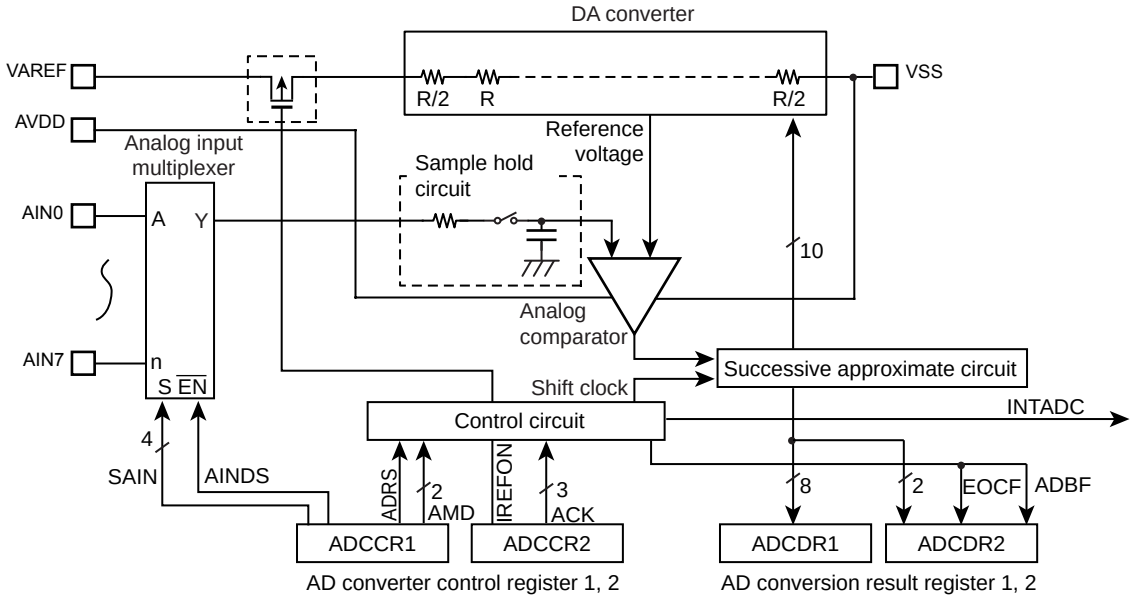
13. 10-bit AD Converter (ADC)

The TMP86CP27AFG have a 10-bit successive approximation type AD converter.

13.1 Configuration

The circuit configuration of the 10-bit AD converter is shown in Figure 13-1.

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 conbining a analog input port. For details, see the section on "I/O ports".

Figure 13-1 10-bit AD Converter

13.2 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 (000EH)

7	6	5	4	3	2	1	0
ADRS	AMD		AINDS	SAIN			

(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 (ADCDR2<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. Therfore, to use AD converter again, set the ADCCR1 newly after returning to NORMAL1 or NORMAL2 mode.

AD Converter Control Register 2

ADCCR2 (000FH)	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. Therfore, to use AD converter again, set the ADCCR2 newly after returning to NORMAL1 or NORMAL2 mode.

Table 13-1 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 μs	-	-	15.6 μs
001	Reserved							
010	78/fc	-	-	19.5 μs	39.0 μs	-	15.6 μs	31.2 μs
011	156/fc	-	19.5 μs	39.0 μs	78.0 μs	15.6 μs	31.2 μs	62.4 μs
100	312/fc	19.5 μs	39.0 μs	78.0 μs	156.0 μs	31.2 μs	62.4 μs	124.8 μs
101	624/fc	39.0 μs	78.0 μs	156.0 μs	-	62.4 μs	124.8 μs	-
110	1248/fc	78.0 μs	156.0 μs	-	-	124.8 μs	-	-
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 Analog reference voltage (VAREF) .

- VAREF = 4.5 to 5.5 V 15.6 μs and more
- VAREF = 2.7 to 5.5 V 31.2 μs and more

AD Converted value Register 1

ADCDR1 (0021H)	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 (0020H)	7	6	5	4	3	2	1	0	
	AD01	AD00	EOCF	ADBF					(Initial value: 0000 ****)

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. Therfore, 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.

13.3 Function

13.3.1 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).

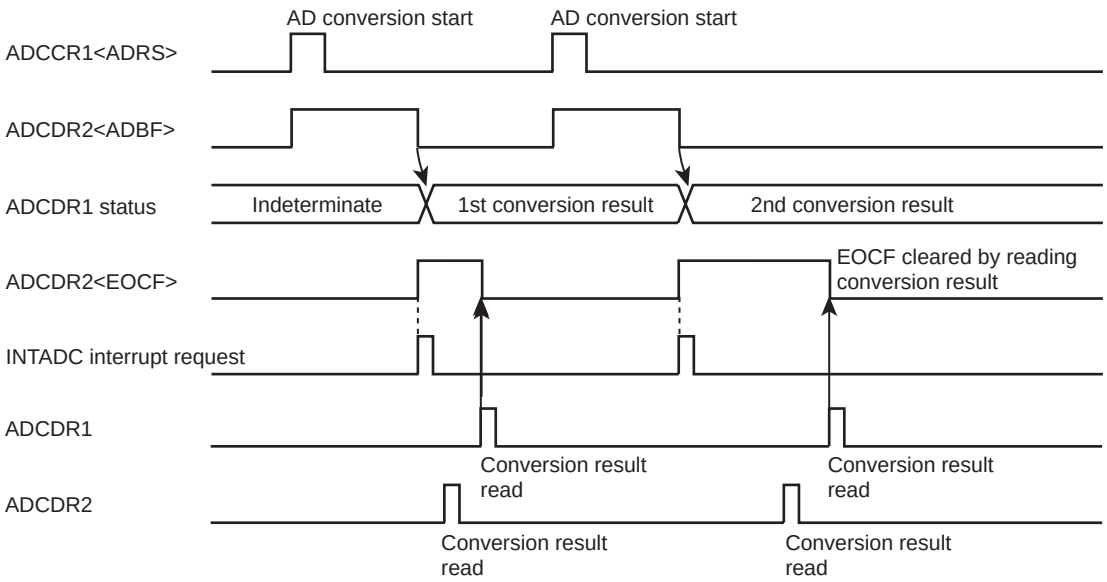


Figure 13-2 Software Start Mode

13.3.2 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.

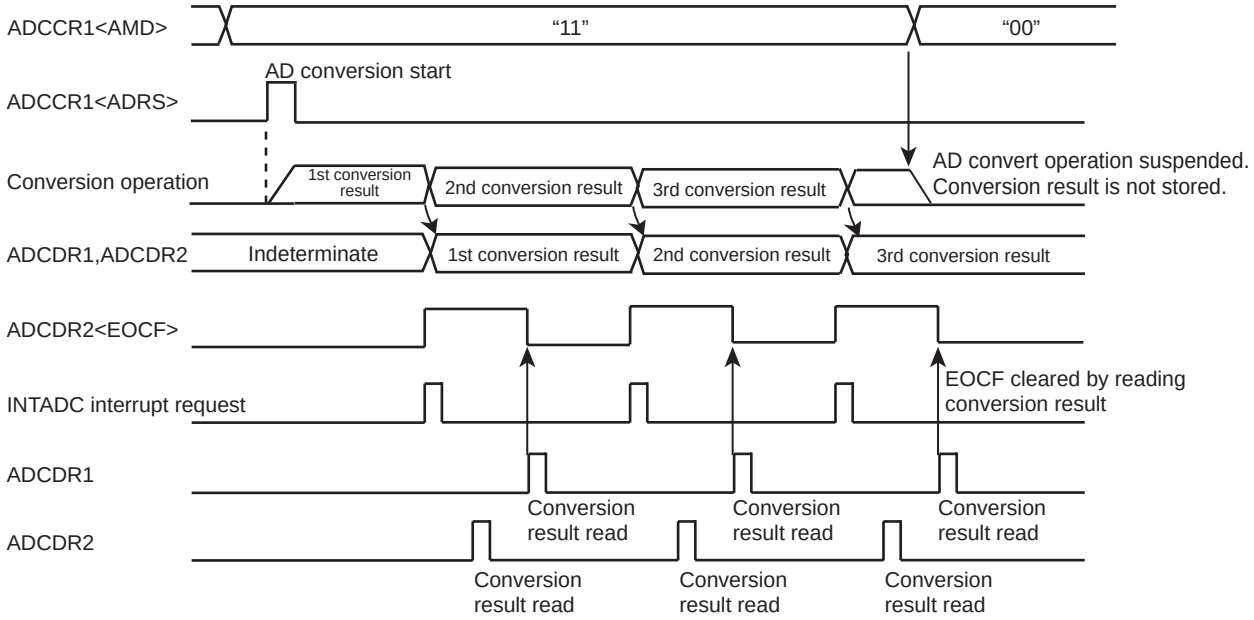


Figure 13-3 Repeat Mode

13.3.3 Register Setting

1. 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).
2. 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 13-1 and AD converter control register 2.
   - Choose IREFON for DA converter control.
3. 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.
4. 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.
5. 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 μs 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 nd store the upper 8 bits in address 0009FH in RAM. The operation mode is software start mode.

```
                : (port setting)      :                      ;Set port register approrriately 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
```

13.4 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.

13.5 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 13-4.

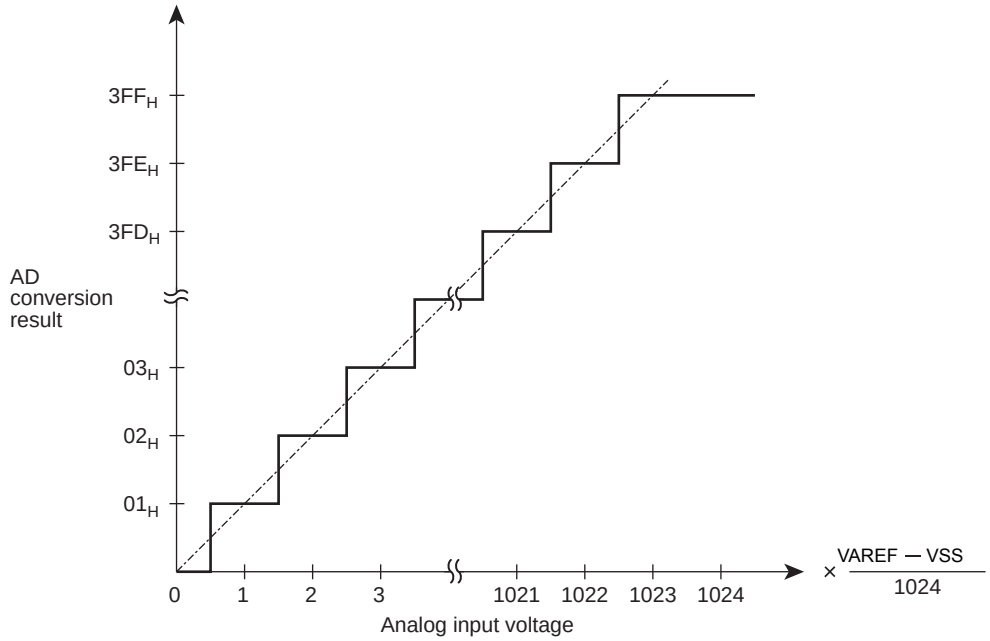


Figure 13-4 Analog Input Voltage and AD Conversion Result (Typ.)

13.6 Precautions about AD Converter

13.6.1 Restrictions for AD Conversion interrupt (INTADC) usage

When an AD interrupt is used, it may not be processed depending on program composition. For example, if an INTADC interrupt request is generated while an interrupt with priority lower than the interrupt latch IL15 (INTADC) is being accepted, the INTADC interrupt latch may be cleared without the INTADC interrupt being processed.

The completion of AD conversion can be detected by the following methods:

(1) Method not using the AD conversion end interrupt

Whether or not AD conversion is completed can be detected by monitoring the AD conversion end flag (EOCF) by software. This can be done by polling EOCF or monitoring EOCF at regular intervals after start of AD conversion.

(2) Method for detecting AD conversion end while a lower-priority interrupt is being processed

While an interrupt with priority lower than INTADC is being processed, check the AD conversion end flag (EOCF) and interrupt latch IL15. If IL15 = 0 and EOCF = 1, call the AD conversion end interrupt processing routine with consideration given to PUSH/POP operations. At this time, if an interrupt request with priority higher than INTADC has been set, the AD conversion end interrupt processing routine will be executed first against the specified priority. If necessary, we recommend that the AD conversion end interrupt processing routine be called after checking whether or not an interrupt request with priority higher than INTADC has been set.

13.6.2 Analog input pin voltage range

Make sure the analog input pins (AIN0 to AIN7) are used at voltages within VAREF 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.

13.6.3 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.

13.6.4 Noise Countermeasure

The internal equivalent circuit of the analog input pins is shown in Figure 13-5. 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 kΩ or less. Toshiba also recommends attaching a capacitor external to the chip.

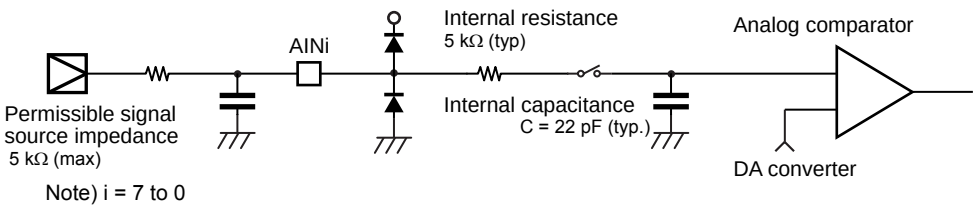


Figure 13-5 Analog Input Equivalent Circuit and Example of Input Pin Processing

14. Key-on Wakeup (KWU)

In the TMP86CP27AFG, the STOP mode is released by not only P20($\overline{INT5}$/$\overline{STOP}$) pin but also four (STOP2 to STOP5) pins.

When the STOP mode is released by STOP2 to STOP5 pins, the $\overline{STOP}$ pin needs to be used.
In details, refer to the following section " 14.2 Control ".

14.1 Configuration

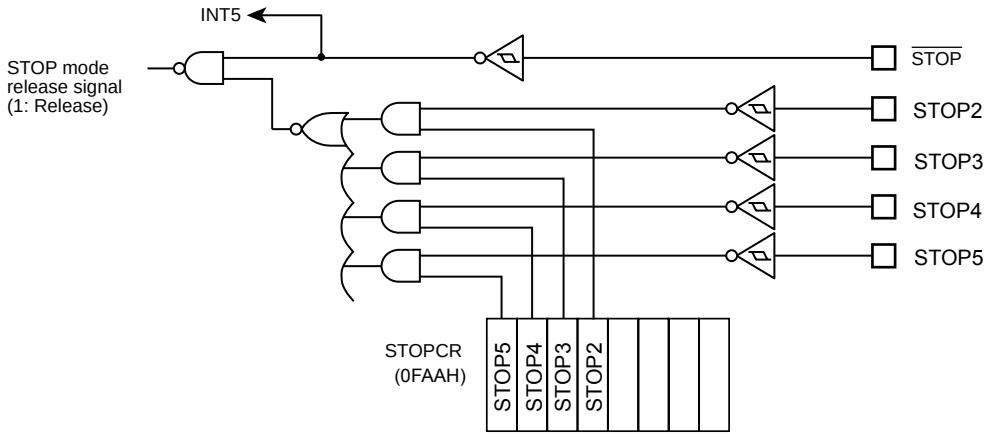


Figure 14-1 Key-on Wakeup Circuit

14.2 Control

STOP2 to STOP5 pins can 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	
(0FAAH)	STOP5	STOP4	STOP3	STOP2					(Initial value: 0000 ****)

STOP5	STOP mode released by STOP5	0:Disable 1:Enable	Write only
STOP4	STOP mode released by STOP4	0:Disable 1:Enable	Write only
STOP3	STOP mode released by STOP3	0:Disable 1:Enable	Write only
STOP2	STOP mode released by STOP2	0:Disable 1:Enable	Write only

14.3 Function

Stop mode can be entered by setting up the System Control Register (SYSCR1), and can be exited by detecting the "L" level on STOP2 to STOP5 pins, which are enabled by STOPCR, for releasing STOP mode (Note1).

Also, each level of the STOP2 to STOP5 pins can be confirmed by reading corresponding I/O port data register, check all STOP2 to STOP5 pins "H" that is enabled by STOPCR before the STOP mode is startd (Note2,3).

Note 1: When the STOP mode released by the edge release mode (SYSCR1<RELM> = “0”), inhibit input from STOP2 to STOP5 pins by Key-on Wakeup Control Register (STOPCR) or must be set "H" level into STOP2 to STOP5 pins that are available input during STOP mode.

Note 2: When the $\overline{\text{STOP}}$ pin input is high or STOP2 to STOP5 pins inputwhich is enabled by STOPCR 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: The input circuit of Key-on Wakeup input and Port input is separatedÅAso each input voltage threshold value is diffrent. Therefore, a value comes from port input before STOP mode start may be diffrent from a value which is detected by Key-on Wakeup input (Figure 14-2).

Note 4: $\overline{\text{STOP}}$ pin doesn’t have the control register such as STOPCR, so when STOP mode is released by STOP2 to STOP5 pins, $\overline{\text{STOP}}$ pin also should be used as STOP mode release function.

Note 5: In STOP mode, Key-on Wakeup pin which is enabled as input mode (for releasing STOP mode) by Key-on Wakeup Control Register (STOPCR) may genarate the penetration current, so the said pin must be disabled AD conversion input (analog voltage input).

Note 6: When the STOP mode is released by STOP2 to STOP5 pins, the level of $\overline{\text{STOP}}$ pin should hold "L" level (Figure 14-3).

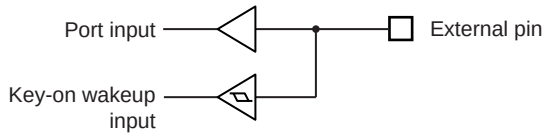


Figure 14-2 Key-on Wakeup Input and Port Input

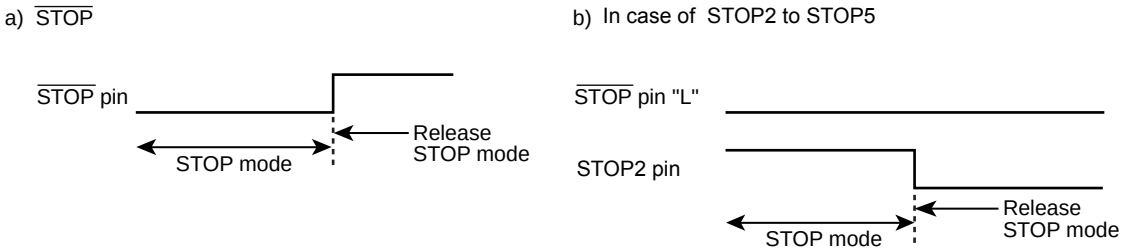


Figure 14-3 Priority of STOP pin and STOP2 to STOP5 pins

Table 14-1 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
STOP2	"L" level	Don’t use (Note1)
STOP3	"L" level	Don’t use (Note1)
STOP4	"L" level	Don’t use (Note1)
STOP5	"L" level	Don’t use (Note1)

15. LCD Driver

The TMP86CP27AFG has a driver and control circuit to directly drive the liquid crystal device (LCD). The pins to be connected to LCD are as follows:

1. Segment output port 40 pins (SEG39 to SEG0)
2. Common output port4 pins (COM3 to COM0)

In addition, C0, C1, V1, V2, V3 pin are provided for the LCD driver's booster circuit.

The devices that can be directly driven is selectable from LCD of the following drive methods:

1. 1/4 Duty (1/3 Bias) LCD Max 160 Segments(8 segments × 20 digits)
2. 1/3 Duty (1/3 Bias) LCD Max 120 Segments(8 segments × 15 digits)
3. 1/2 Duty (1/2 Bias) LCD Max 80 Segments(8 segments × 10 digits)
4. Static LCD Max 40 Segments(8 segments × 5 digits)

15.1 Configuration

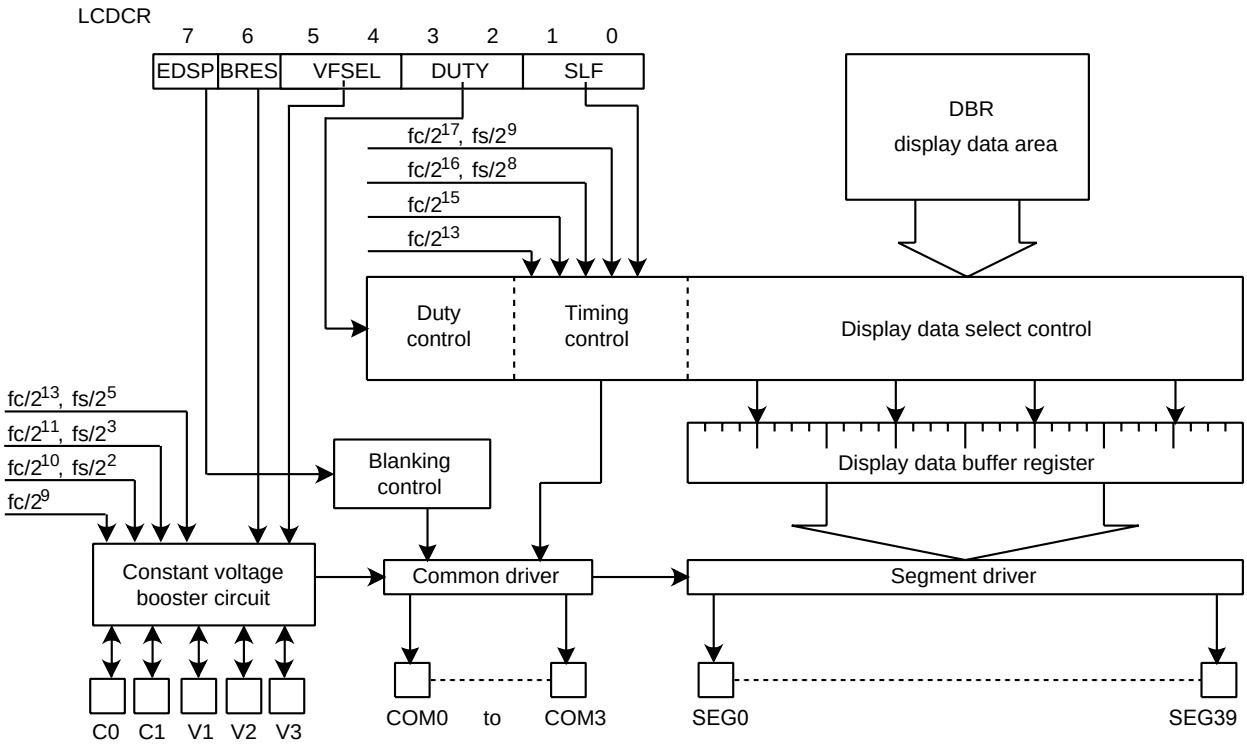


Figure 15-1 LCD Driver

Note: The LCD driver incorporates a dedicated divider circuit. Therefore, the break function of a debugger (development tool) will not stop LCD driver output.

15.2 Control

The LCD driver is controlled using the LCD control register (LCDCR). The LCD driver's display is enabled using the EDSP.

LCD Driver Control Register

LCDCR (0028H)

7	6	5	4	3	2	1	0
EDSP	BRES	VFSEL		DUTY		SLF	

(Initial value: 0000 0000)

EDSP	LCD Display Control	0: Blanking 1: Enables LCD display (Blanking is released)			R/W
BRES	Booster circuit control	0: Disable (use divider resistance) 1: Enable			
VFSEL	Selection of boost frequency		NORMAL1/2, IDLE/1/2 mode	SLOW1/2, SLEEP0/1/2 mode	
			DV7CK = 0	DV7CK = 1	
		00	$fc/2^{13}$	$fs/2^5$	$fs/2^5$
		01	$fc/2^{11}$	$fs/2^3$	$fs/2^3$
		10	$fc/2^{10}$	$fs/2^2$	$fs/2^2$
		11	$fc/2^9$	$fc/2^9$	–
DUTY	Selection of driving methods	00: 1/4 Duty (1/3 Bias) 01: 1/3 Duty (1/3 Bias) 10: 1/2 Duty (1/2 Bias) 11: Static			
SLF	Selection of LCD frame frequency		NORMAL1/2, IDLE/1/2 mode	SLOW1/2, SLEEP0/1/2 mode	
			DV7CK = 0	DV7CK = 1	
		00	$fc/2^{17}$	$fs/2^9$	$fs/2^9$
		01	$fc/2^{16}$	fs/28	$fs/2^8$
		10	$fc/2^{15}$	$fc/2^{15}$	–
		11	$fc/2^{13}$	$fc/2^{13}$	–

Note 1: When <BRES>(Booster circuit control) is set to "0", $V_{DD} \geq V3 \geq V2 \geq V1 \geq V_{SS}$ should be satisfied.
When <BRES> is set to "1", 5.5 [V] $\geq V3 \geq V_{DD}$ should be satisfied.
If these conditions are not satisfied, it not only affects the quality of LCD display but also may damage the device due to over voltage of the port.

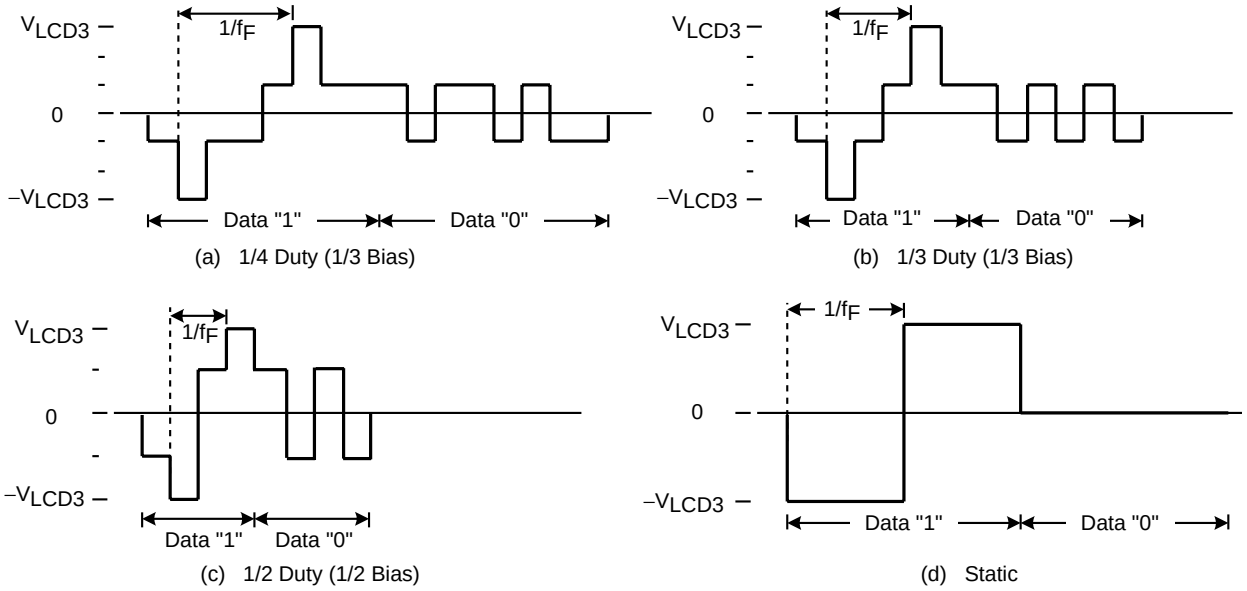
Note 2: When used as the booster circuit, bias should be composed to 1/3. Therefore, do not set LCDCR<DUTY> to "10" or "11" when the booster circuit is enable.

Note 3: Do not set SLF to "10" or "11" in SLOW1/2 modes.

Note 4: Do not set VFSEL to "11" SLOW1/2 modes.

15.2.1 LCD driving methods

As for LCD driving method, 4 types can be selected by LCDCR<DUTY>. The driving method is initialized in the initial program according to the LCD used.



Note 1: f_F: Frame frequency

Note 2: V_{LCD3}: LCD drive voltage

Figure 15-2 LCD Drive Waveform (COM-SEG pins)

15.2.2 Frame frequency

Frame frequency (f_F) is set according to driving method and base frequency as shown in the following Table 15-1. The base frequency is selected by LCDCR<SLF> according to the frequency fc and fs of the basic clock to be used.

Table 15-1 Setting of LCD Frame Frequency

(a) At the single clock mode. At the dual clock mode (DV7CK = 0).

SLF	Base frequency [Hz]	Frame frequency [Hz]			
		1/4 Duty	1/3 Duty	1/2 Duty	Static
00	$\frac{fc}{2^{17}}$	$\frac{fc}{2^{17}}$	$\frac{4}{3}\bullet\frac{fc}{2^{17}}$	$\frac{4}{2}\bullet\frac{fc}{2^{17}}$	$\frac{fc}{2^{17}}$
	(fc = 16 MHz)	122	163	244	122
	(fc = 8 MHz)	61	81	122	61
01	$\frac{fc}{2^{16}}$	$\frac{fc}{2^{16}}$	$\frac{4}{3}\bullet\frac{fc}{2^{16}}$	$\frac{4}{2}\bullet\frac{fc}{2^{16}}$	$\frac{fc}{2^{16}}$
	(fc = 8 MHz)	122	163	244	122
	(fc = 4 MHz)	61	81	122	61
10	$\frac{fc}{2^{15}}$	$\frac{fc}{2^{15}}$	$\frac{4}{3}\bullet\frac{fc}{2^{15}}$	$\frac{4}{2}\bullet\frac{fc}{2^{15}}$	$\frac{fc}{2^{15}}$
	(fc = 4 MHz)	122	163	244	122
	(fc = 2 MHz)	61	81	122	61
11	$\frac{fc}{2^{13}}$	$\frac{fc}{2^{13}}$	$\frac{4}{3}\bullet\frac{fc}{2^{13}}$	$\frac{4}{2}\bullet\frac{fc}{2^{13}}$	$\frac{fc}{2^{13}}$
	(fc = 1 MHz)	122	163	244	122

Note: fc: High-frequency clock [Hz]

Table 15-2

(b) At the dual clock mode (DV7CK = 1 or SYSCK = 1)

SLF	Base frequency [Hz]	Frame frequency [Hz]			
		1/4 Duty	1/3 Duty	1/2 Duty	Static
00	$\frac{fs}{2^{9}}$	$\frac{fs}{2^{9}}$	$\frac{4}{3}\bullet\frac{fs}{2^{9}}$	$\frac{4}{2}\bullet\frac{fs}{2^{9}}$	$\frac{fs}{2^{9}}$
	(fs = 32.768 kHz)	64	85	128	64
01	$\frac{fs}{2^{8}}$	$\frac{fs}{2^{8}}$	$\frac{4}{3}\bullet\frac{fs}{2^{8}}$	$\frac{4}{2}\bullet\frac{fs}{2^{8}}$	$\frac{fs}{2^{8}}$
	(fs = 32.768 kHz)	128	171	256	128

Note: fs: Low-frequency clock [Hz]

15.2.3 Driving method for LCD driver

In the TMP86CP27AFG, LCD driving voltages can be generated using either an internal booster circuit or an external resistor divider. This selection is made in LCDCR<BRES>.

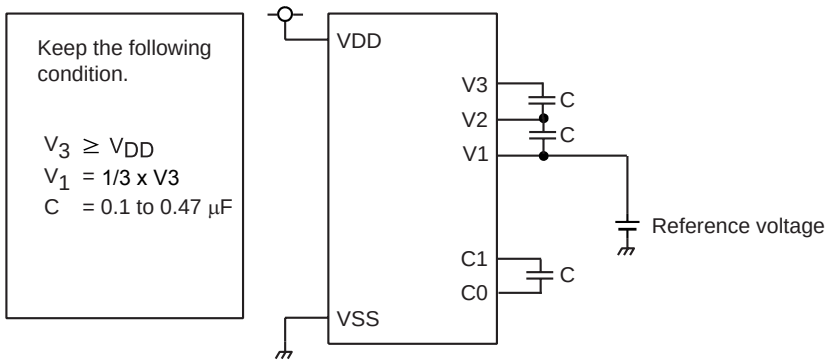
15.2.3.1 When using the booster circuit (LCDCR<BRES>="1")

When the reference voltage is connected to the V1 pin, the booster circuit boosts the reference voltage twofold (V2) or threefold (V3) to generate the output voltages for segment/common signals. When the reference voltage is connected to the V2 pin, it is reduced to 1/2 (V1) or boosted to 3/2 (V3). When the reference voltage is connected to the V3 pin, it is reduced to 1/3 (V1) or 2/3 (V2).

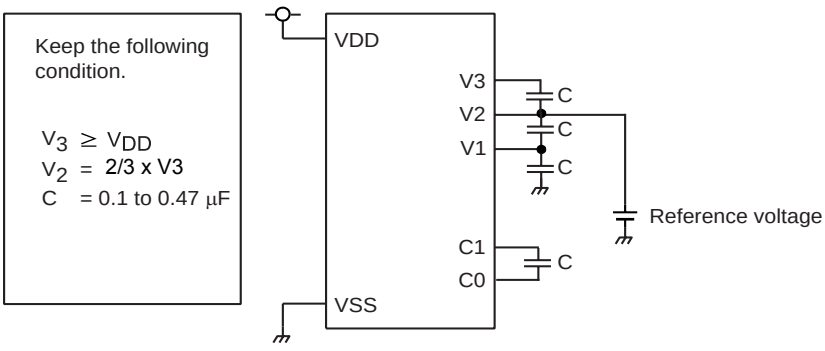
LCDCR<VFSEL> is used to select the reference frequency in the booster circuit. The faster the boosting frequency, the higher the segment/common drive capability, but power consumption is increased. Conversely, the slower the boosting frequency, the lower the segment/common drive capability, but power consumption is reduced. If the drive capability is insufficient, the LCD may not be displayed clearly. Therefore, select an optimum boosting frequency for the LCD panel to be used.

Table 15-3 shows the V3 pin current capacity and boosting frequency.

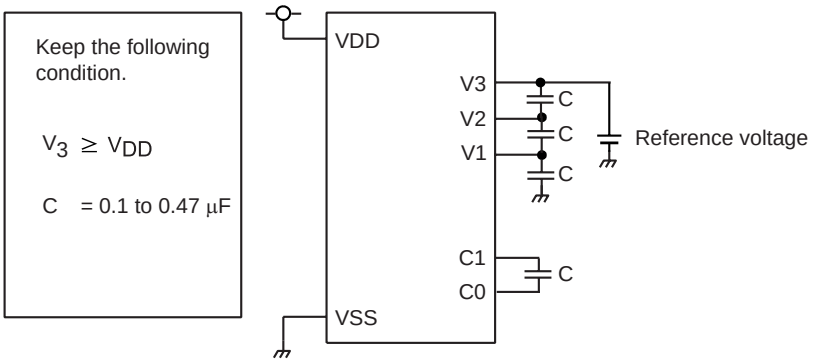
Note: When used as the booster circuit, bias should be composed to 1/3. Therefore, do not set LCDCR<DUTY> to "10" or "11" when the booster circuit is enable (LCDCR<BRES>="1").



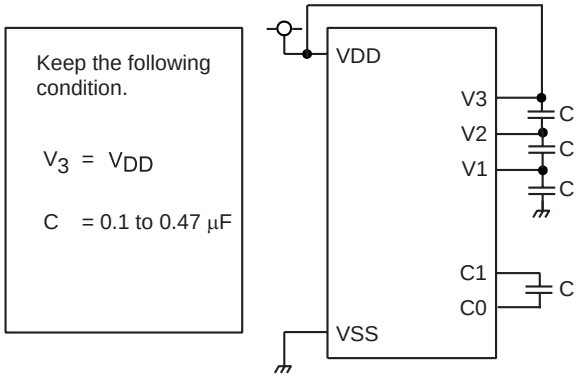
a) Reference pin = V1



b) Reference pin = V2



c) Reference pin = V3



d) Reference pin = V3

Note 1: When the TMP86CP27AFG uses the booster circuit to drive the LCD, the power supply and capacitor for the booster circuit should be connected as shown above.

Note 2: When the reference voltage is connected to a pin other than V1, add a capacitor between V1 and GND.

Note 3: The connection examples shown above are different from those shown in the datasheets of the existing mask or OTP products. Since the above connection method enhances the boosting characteristics, it is recommended that new boards be designed using the above connection method. (Using the existing connection method does not affect LCD display.)

Figure 15-3 Connection Examples When Using the Booster Circuit (LCDCR<BRES> = “1”)

Table 15-3 V3 Pin Current Capacity and Boosting Frequency (typ.)

VFSEL	Boosting frequency	fc = 16 MHz	fc = 8 MHz	fc = 4 MHz	fc = 32.768 MHz
00	$fc/2^{13}$ or $fs/2^5$	−37 mV/ μA	−80 mV/ μA	−138 mV/ μA	−76 mV/ μA
01	$fc/2^{11}$ or $fs/2^3$	−19 mV/ μA	−24 mV/ μA	−37 mV/ μA	−23 mV/ μA
10	$fc/2^{10}$ or $fs/2^2$	−17 mV/ μA	−19 mV/ μA	−24 mV/ μA	−18 mV/ μA
11	$fc/2^9$	−16 mV/ μA	−17 mV/ μA	−19 mV/ μA	–

Note 1: The current capacity is the amount of voltage that falls per 1μA.

Note 2: The boosting frequency should be selected depending on your LCD panel.

Note 3: For the reference pin V1 or V2, a current capacity ten times larger than the above is recommended to ensure stable operation.

For example, when the boosting frequency is $fc/2^9$ (at fc = 8 MHz), −1.7 mV/ μA or more is recommended for the current capacity of the reference pin V1.

15.2.3.2 When using an external resistor divider (LCDCR<BRES>="0")

When an external resistor divider is used, the voltage of an external power supply is divided and input on V1, V2, and V3 to generate the output voltages for segment/common signals.

The smaller the external resistor value, the higher the segment/common drive capability, but power consumption is increased. Conversely, the larger the external resistor value, the lower the segment/common drive capability, but power consumption is reduced. If the drive capability is insufficient, the LCD may not be displayed clearly. Therefore, select an optimum resistor value for the LCD panel to be used.

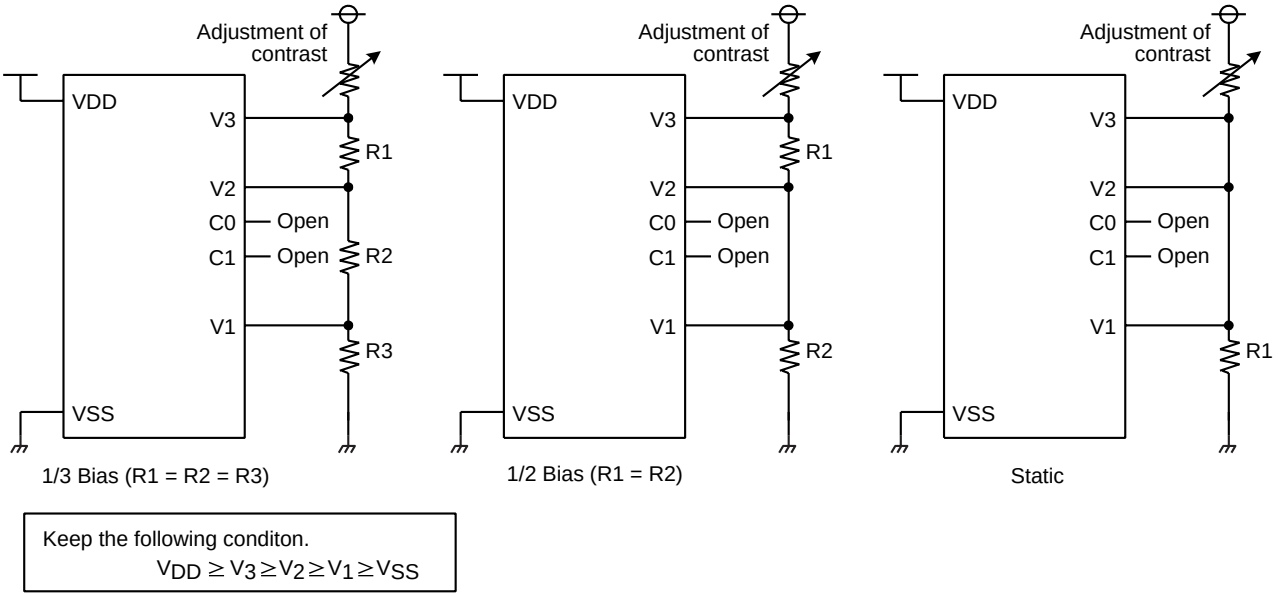


Figure 15-4 Connection Examples When Using an External Resistor Divider (LCDCR<BRES> = “0”)

15.3 LCD Display Operation

15.3.1 Display data setting

Display data is stored to the display data area (assigned to address 0F80H to 0F93H, 20bytes) in the DBR. The display data which are stored in the display data area is automatically read out and sent to the LCD driver by the hardware. The LCD driver generates the segment signal and common signal according to the display data and driving method. Therefore, display patterns can be changed by only over writing the contents of display data area by the program. Table 15-5 shows the correspondence between the display data area and SEG/COM pins.

LCD light when display data is “1” and turn off when “0”. According to the driving method of LCD, the number of pixels which can be driven becomes different, and the number of bits in the display data area which is used to store display data also becomes different.

Therefore, the bits which are not used to store display data as well as the data buffer which corresponds to the addresses not connected to LCD can be used to store general user process data (see Table 15-4).

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

Table 15-4 Driving Method and Bit for Display Data

Driving methods	Bit 7/3	Bit 6/2	Bit 5/1	Bit 4/0
1/4 Duty	COM3	COM2	COM1	COM0
1/3 Duty	–	COM2	COM1	COM0
1/2 Duty	–	–	COM1	COM0
Static	–	–	–	COM0

Note: –: This bit is not used for display data

Table 15-5 LCD Display Data Area (DBR)

Address	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0F80H	SEG1				SEG0			
0F81H	SEG3				SEG2			
0F82H	SEG5				SEG4			
0F83H	SEG7				SEG6			
0F84H	SEG9				SEG8			
0F85H	SEG11				SEG10			
0F86H	SEG13				SEG12			
0F87H	SEG15				SEG14			
0F88H	SEG17				SEG16			
0F89H	SEG19				SEG18			
0F8AH	SEG21				SEG20			
0F8BH	SEG23				SEG22			
0F8CH	SEG25				SEG24			
0F8DH	SEG27				SEG26			
0F8EH	SEG29				SEG28			
0F8FH	SEG31				SEG30			
0F90H	SEG33				SEG32			
0F91H	SEG35				SEG34			
0F92H	SEG37				SEG36			
0F93H	SEG39				SEG38			
	COM3	COM2	COM1	COM0	COM3	COM2	COM1	COM0

15.3.2 Blanking

Blanking is enabled when EDSP is cleared to “0”.

Blanking turns off LCD through outputting a GND level to SEG/COM pin.

When in STOP mode, EDSP is cleared to “0” and automatically blanked. To redisplay ICD after exiting STOP mode, it is necessary to set EDSP back to “1”.

Note: During reset, the LCD segment outputs and LCD common outputs are fixed “0” level. But the multiplex terminal of input/output port and LCD segment output becomes high impedance. Therefore, when the reset input is long remarkably, ghost problem may appear in LCD display.

15.4 Control Method of LCD Driver

15.4.1 Initial setting

Figure 15-5 shows the flowchart of initialization.

Example : To operate a 1/4 duty LCD of 40 segments × 4 com-mons at frame frequency fc/2^{16} [Hz], and booster frequency fc/2^{13} [Hz]

```
LD      (LCDCR), 01000001B      ; Sets LCD driving method and frame frequency. Boost frequency
LD      (P*LCR), 0FFH           ; Sets segment output control register. (*; Port No.)
 :       :
 :       :                      ; Sets the initial value of display data.
LD      (LCDCR), 11000001B      ; Display enable
```

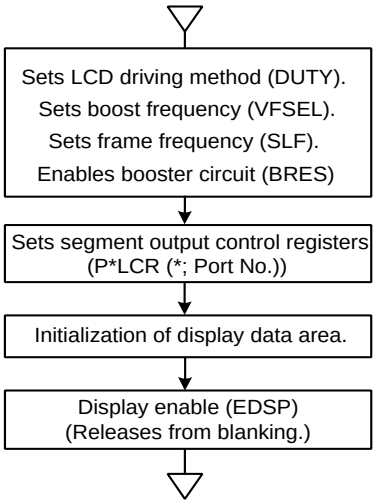


Figure 15-5 Initial Setting of LCD Driver

15.4.2 Store of display data

Generally, display data are prepared as fixed data in program memory (ROM) and stored in display data area by load command.

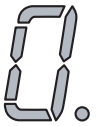
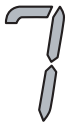
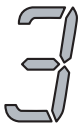
Example : To display using 1/4 duty LCD a numerical value which corresponds to the LCD data stored in data memory at address 80H (when pins COM and SEG are connected to LCD as in Figure 15-6), display data become as shown in Table 15-6.

```
        LD      A, (80H)
        ADD     A, TABLE-$-7
        LD      HL, 0F80H
        LD      W, (PC + A)
        LD      (HL), W
        RET
TABLE:  DB      11011111B, 00000110B,
                11100011B, 10100111B,
                00110110B, 10110101B,
                11110101B, 00010111B,
                11110111B, 10110111B
```

Note: DB is a byte data difinition instruction.

Figure 15-6 Example of COM, SEG Pin Connection (1/4 Duty)

Table 15-6 Example of Display Data (1/4 Duty)

No.	display	Display data	No.	display	Display data
0		11011111	5		10110101
1		00000110	6		11110101
2		11100011	7		00000111
3		10100111	8		11110111
4		00110110	9		10110111

Example 2: Table 15-6 shows an example of display data which are displayed using 1/2 duty LCD in the same way as Table 15-7. The connection between pins COM and SEG are the same as shown in Figure 15-7.

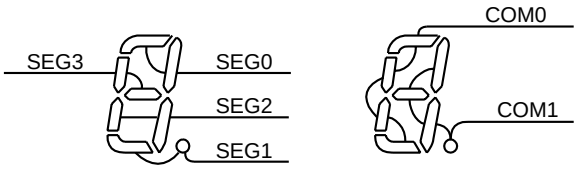


Figure 15-7 Example of COM, SEG Pin Connection

Table 15-7 Example of Display Data (1/2 Duty)

Number	Display data		Number	Display data	
	High order address	Low order address		High order address	Low order address
0	**01**11	**01**11	5	**11**10	**01**01
1	**00**10	**00**10	6	**11**11	**01**01
2	**10**01	**01**11	7	**01**10	**00**11
3	**10**10	**01**11	8	**11**11	**01**11
4	**11**10	**00**10	9	**11**10	**01**11

Note: *: Don't care

15.4.3 Example of LCD drive output

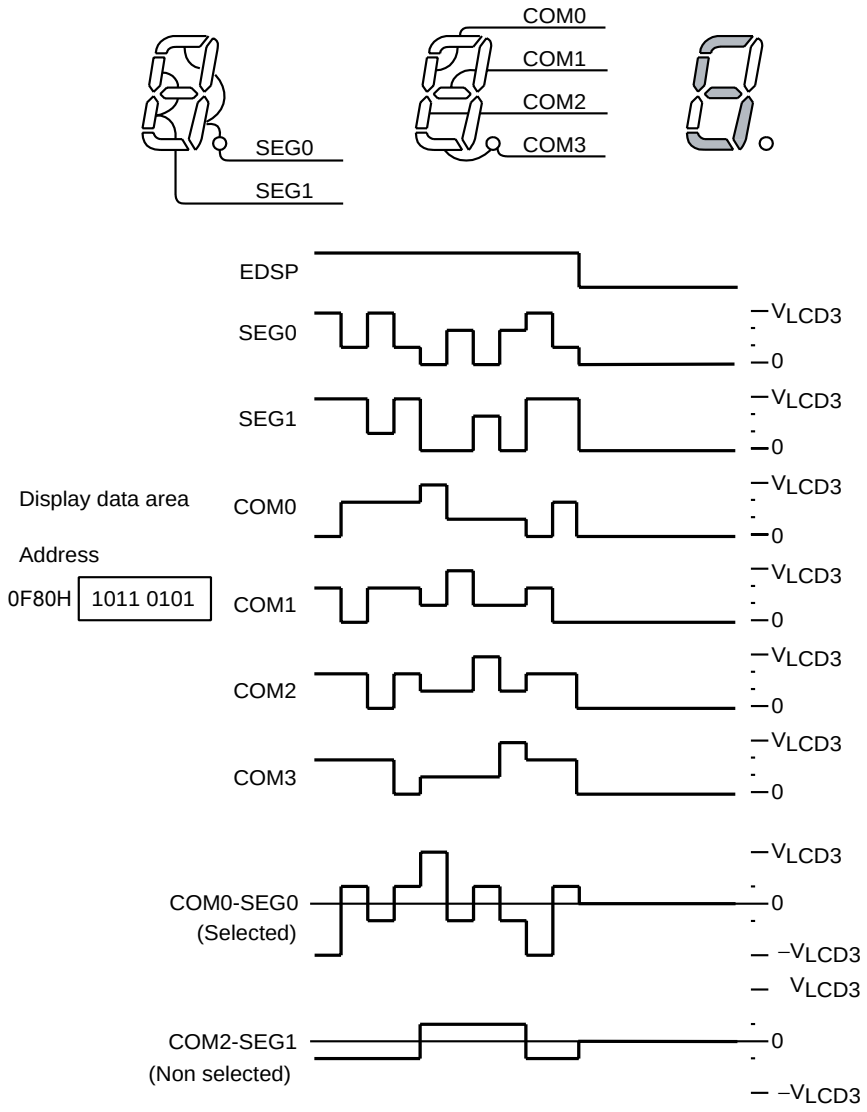


Figure 15-8 1/4 Duty (1/3 bias) Drive

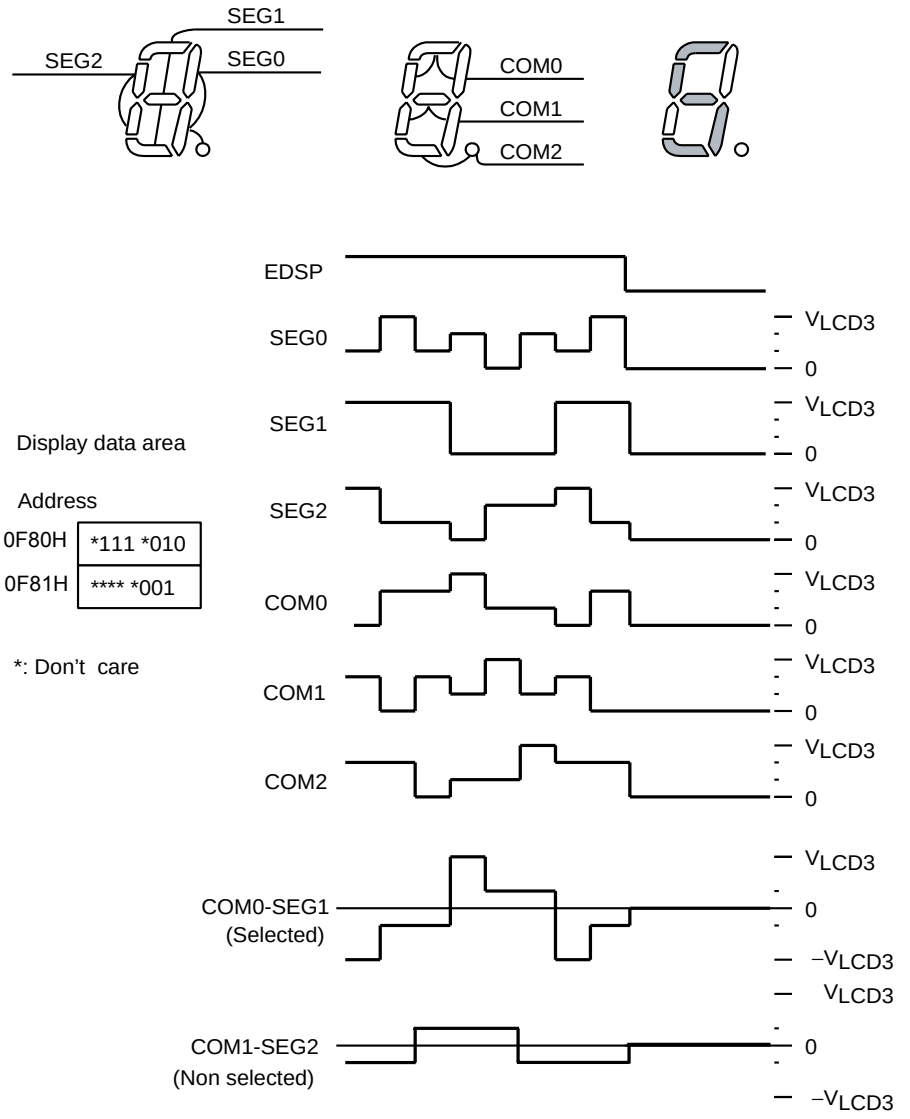


Figure 15-9 1/3 Duty (1/3 bias) Drive

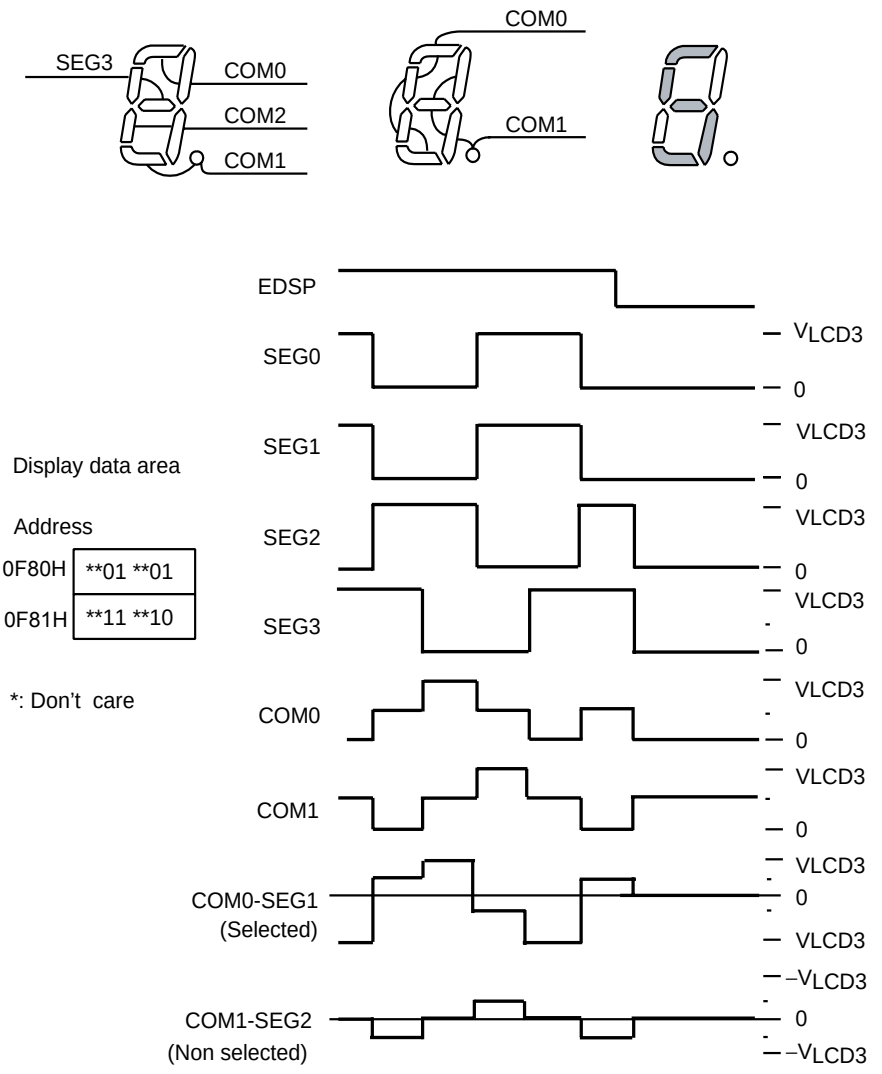


Figure 15-10 1/2 Duty (1/2 bias) Drive

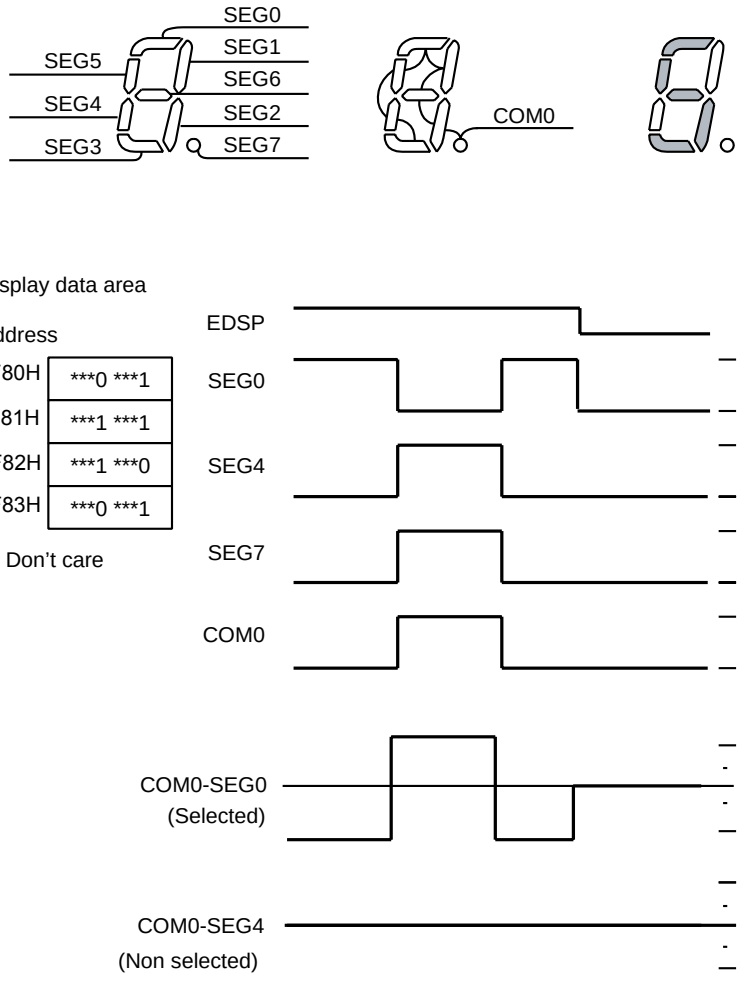
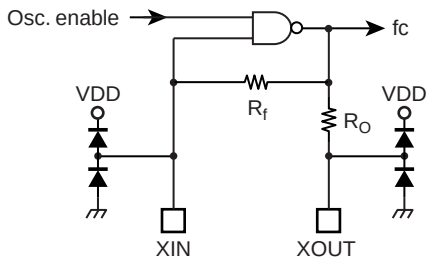
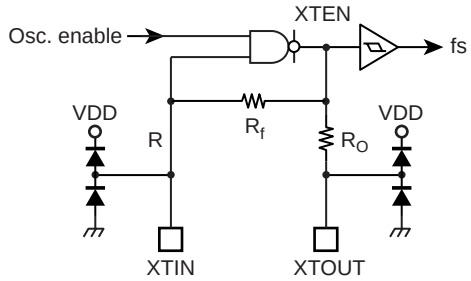
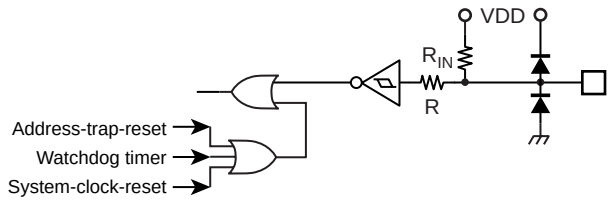
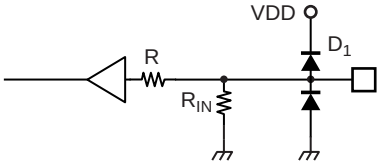


Figure 15-11 Static Drive

16. Input/Output Circuitry

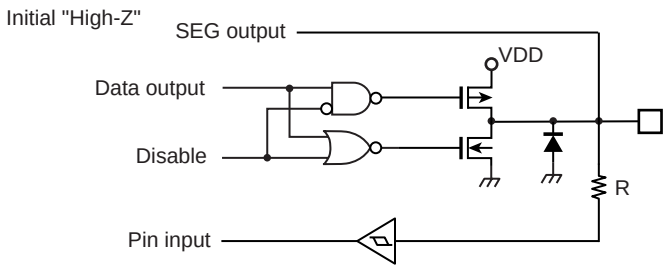
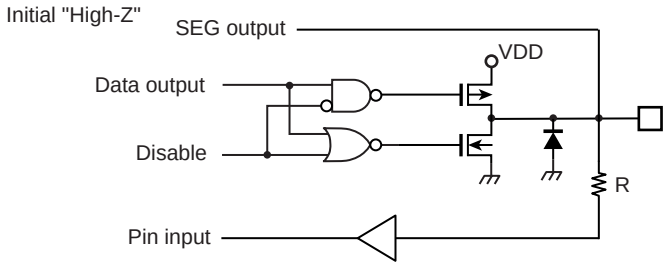
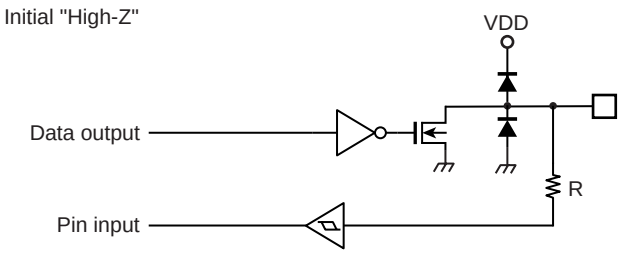
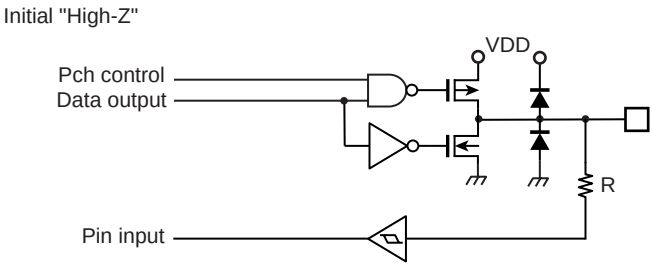
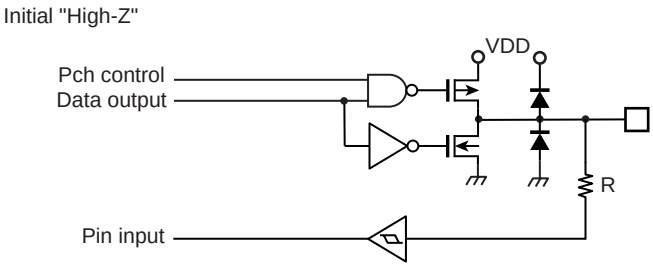
16.1 Control Pins

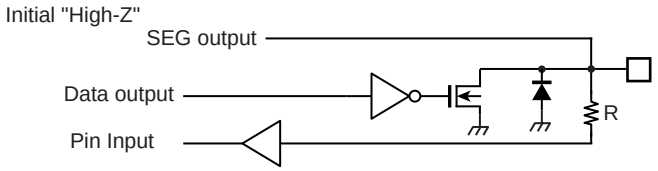
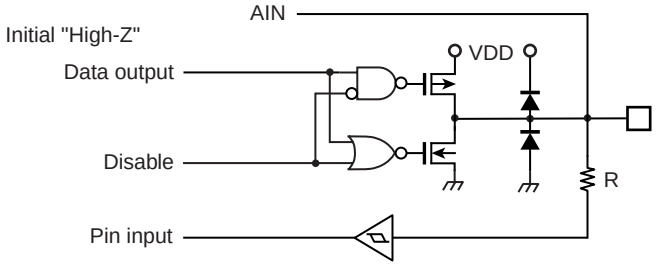
The input/output circuitries of the TMP86CP27AFG control pins are shown below.

Control Pin	I/O	Input/Output Circuitry	Remarks
XIN XOUT	Input Output		Resonator connecting pins (High frequency) R_f = 1.2 MΩ (Typ.) R_O = 0.5 kΩ (Typ.)
XTIN XTOUT	Input Output		Resonator connecting pins (Low frequency) R_f = 6 MΩ(Typ.) R_O = 220 kΩ (Typ.)
$\overline{\text{RESET}}$	Input		Hysteresis input Pull-up resistor R_{IN} = 220 kΩ (Typ.) R = 100 Ω(Typ.)
TEST	Input		Pull-down resistor R_{IN} = 70 kΩ (Typ.) R = 100 Ω (Typ.)

Note: The TEST pin of the TMP86PS27 does not have a pull-down resistor(R) and protect diode (D_1). Fix the TEST pin at low level.

16.2 Input/Output Ports

Port	I/O	Input/Output Circuitry	Remarks
P0	I/O		Tri-state output Hysteresis input R = 100 Ω (Typ.) LCD segment output
P1	I/O		Tri-state output R = 100 Ω (Typ.) LCD segment output
P2	I/O		Sink open drain output Hysteresis input R = 100 Ω (Typ.)
P3	I/O		Sink open drain output or C-MOS output Hysteresis input High current output (N-ch) R = 100 Ω (typ.)
P4	I/O		Sink open drain output or C-MOS output Hysteresis input R = 100 Ω (typ.)

Port	I/O	Input/Output Circuitry	Remarks
P5, P7	I/O		Sink open drain output LCD segment output R = 100 Ω (typ.)
P6	I/O		Tri-state I/O Hysteresis input AIN input R = 100 Ω (typ.)

Note: The absolute maximum ratings of P0, P1, P5 and P7 port input voltage should be used in −0.3 to V_{DD} + 0.3 volts.

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 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, P4, P6 port	−1.8	mA
	I_{OUT2}	P0, P1, P2, P4, P5, P6, P7 port	3.2	
	I_{OUT3}	P3 port	30	
Output current (Total)	ΣI_{OUT1}	P0, P1, P3, P4, P6 port	−30	
	ΣI_{OUT2}	P0, P1, P2, P4, P5, P6, P7 port	60	
	ΣI_{OUT3}	P3 Port	80	
Power dissipation [Topr = 85°C]	PD		250	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 V, Topr = –40 to 85°C)

Parameter	Symbol	Pins	Condition		Min	Max	Unit
Supply voltage	V_{DD}		fc = 16 MHz	NORMAL1, 2 modes	4.5	5.5	V
				IDLE0, 1, 2 modes			
			fc = 8 MHz	NORMAL1, 2 modes	2.7		
				IDLE0, 1, 2 modes			
			fs = 32.768 kHz	SLOW1, 2 modes			
				SLEEP0, 1, 2 modes			
				STOP mode	2.0		
Input high level	V_{IH1}	Except hysteresis input	$V_{DD} \geq 4.5$ V		$V_{DD} \times 0.70$	V_{DD}	
	V_{IH2}	Hysteresis input			$V_{DD} \times 0.75$		
	V_{IH3}		$V_{DD} < 4.5$ V		$V_{DD} \times 0.90$		
Input low level	V_{IL1}	Except hysteresis input	$V_{DD} \geq 4.5$ V		0	$V_{DD} \times 0.30$	
	V_{IL2}	Hysteresis input				$V_{DD} \times 0.25$	
	V_{IL3}		$V_{DD} < 4.5$ V			$V_{DD} \times 0.10$	
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			30.0	34.0	kHz

17.3 DC Characteristics

(V_{SS} = 0 V, Topr = −40 to 85°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 V, V_{IN} = 5.5 V/0 V	–	–	±2	μA
	I_{IN2}	Sink open drain, Tri-state					
	I_{IN3}	$\overline{RESET}$, $\overline{STOP}$					
Input resistance	R_{IN1}	TEST pull down		–	70	–	kΩ
	R_{IN2}	$\overline{RESET}$ pull up		100	220	450	
High frequency feedback resistor	Rfx	XIN-XOUT		–	1.2	–	MΩ
LOW frequency feedback resistor	Rfxt	XTIN-XTOUT		–	6	–	
Output leakage current	I_{LO1}	Sink open drain port	V_{DD} = 5.5 V, V_{OUT} = 5.5 V	–	–	2	μA
	I_{LO2}	Tri-state port	V_{DD} = 5.5 V, V_{OUT} = 5.5 V/0V	–	–	±2	
Output high voltage	V_{OH}	Tri-state port	V_{DD} = 4.5 V, I_{OH} = -0.7 mA	4.1	-	–	V
Output low voltage	V_{OL}	Except XOUT, XTOUT and P3 port	V_{DD} = 4.5 V, I_{OL} = 1.6 mA	-	–	0.4	
Output low current	I_{OL1}	Except XOUT, XTOUT and P3 port	V_{DD} = 4.5 V V_{OL} = 0.4V	-	1.6	–	mA
	I_{OL2}	High current port (P3 port)	V_{DD} = 4.5 V, V_{OL} = 1.0 V	–	20	–	
Supply current in NORMAL1, 2 modes	I_{DD}		V_{DD} = 5.5 V V_{IN} = 5.3 V/0.2 V fc = 16 MHz fs = 32.768 kHz	–	9.5	12	
Supply current in IDLE0, 1, 2 modes				–	7	8.5	
Supply current in SLOW1 mode			V_{DD} = 3.0 V V_{IN} = 2.8 V/0.2 V fs = 32.768 kHz	–	9	12	μA
Supply current in SLEEP1 mode				–	7	11	
Supply current in SLEEP0 mode				–	5	9	
Supply current in STOP mode			V_{DD} = 5.5 V V_{IN} = 5.3 V/0.2 V	–	0.5	10	

Note 1: Typical values show those at Topr = 25°C, V_{DD} = 5 V

Note 2: Input current (I_{IN1}, I_{IN2}): The current through pull-up or pull-down resistor is not included.

Note 3: I_{DD} does not include I_{REF} current.

Note 4: The supply currents of SLOW2 and SLEEP2 modes are equivalent to IDLE0, 1, 2.

17.4 AD Conversion Characteristics

(V_{SS} = 0.0 V, 4.5 V ≤ V_{DD} ≤ 5.5 V, Topr = –40 to 85°C)

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Analog reference voltage	V_{AREF}		A_{VDD} – 1.0	–	A_{VDD}	V
Power supply voltage of analog control circuit	A_{VDD}		V_{DD}			
	A_{VSS}		V_{SS}			
Analog reference voltage range	ΔV_{AREF}	V_{AREF} - A_{VSS}	3.5	-	V_{DD}	
Analog input voltage	V_{AIN}		V_{SS}	-	V_{AREF}	
Power supply current of analog reference voltage	I_{REF}	V_{DD} = A_{VDD} = V_{AREF} = 5.5 V V_{SS} = A_{VSS} = 0.0 V	–	0.6	1.0	mA
Non linearity error		V_{DD} = A_{VDD} = 5.0 V, V_{SS} = A_{VSS} = 0.0 V V_{AREF} = 5.0 V	–	-	±2	LSB
Zero point error			–	-	±2	
Full scale error			–	-	±2	
Total error			–	-	±4	

(V_{SS} = 0.0 V, 2.7 V ≤ V_{DD} < 4.5 V, Topr = –40 to 85°C)

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Analog reference voltage	V_{AREF}		A_{VDD} – 1.0	–	A_{VDD}	V
Power supply voltage of analog control circuit	A_{VDD}		V_{DD}			
	A_{VSS}		V_{SS}			
Analog reference voltage range	DV_{AREF}	V_{AREF} - A_{VSS}	2.5	–	V_{DD}	
Analog input voltage	V_{AIN}		V_{SS}	–	V_{AREF}	
Power supply current of analog reference voltage	I_{REF}	V_{DD} = A_{VDD} = V_{AREF} = 4.5 V V_{SS} = A_{VSS} = 0.0 V	–	0.5	0.8	mA
Non linearity error		V_{DD} = A_{VDD} = 2.7 V, V_{SS} = A_{VSS} = 0.0 V V_{AREF} = 2.7 V	–	-	±2	LSB
Zero point error			–	–	±2	
Full scale error			–	–	±2	
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 “Register Configuration of 10-Bit Timer/Counter”.

Note 3: Please use input voltage to AIN input Pin in limit of V_{AREF} - V_{SS}.
When voltage of range outside is input, conversion value becomes unsettled and gives affect to other channel conversion value.

Note 4: Analog reference voltage range: ΔV_{AREF} = V_{AREF} - A_{VSS}.

Note 5: The A_{VDD} pin should be fixed on the V_{DD} level even though AD convertor is not used.

17.5 AC Characteristics

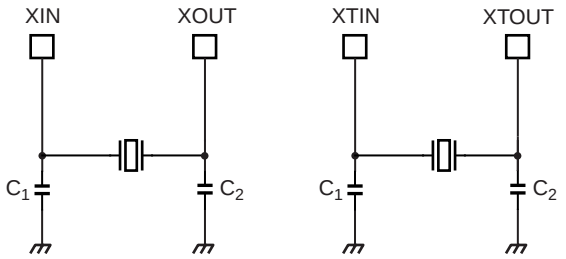
(V_{SS} = 0 V, V_{DD} = 4.5 to 5.5 V, Topr = –40 to 85°C)

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Machine cycle time	tcy	NORMAL1, 2 modes	0.25	–	4	μs
		IDLE1, 2 modes				
		SLOW1, 2 modes	117.6	–	133.3	
		SLEEP1, 2 modes				
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					

(VSS = 0 V, VDD = 2.7 to 4.5 V, Topr = -40 to 85°C)

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Machine cycle time	tcy	NORMAL1, 2 modes	0.5	-	4	μs
		IDLE1, 2 modes				
		SLOW1, 2 modes	117.6	-	133.3	
		SLEEP1, 2 modes				
High-level clock pulse width	twcH	For external clock operation (XIN input) fc = 8 MHz	-	62.5	-	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					

17.6 Recommended Oscillating Conditions



(1) High-frequency Oscillation (2) Low-frequency Oscillation

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.co.jp

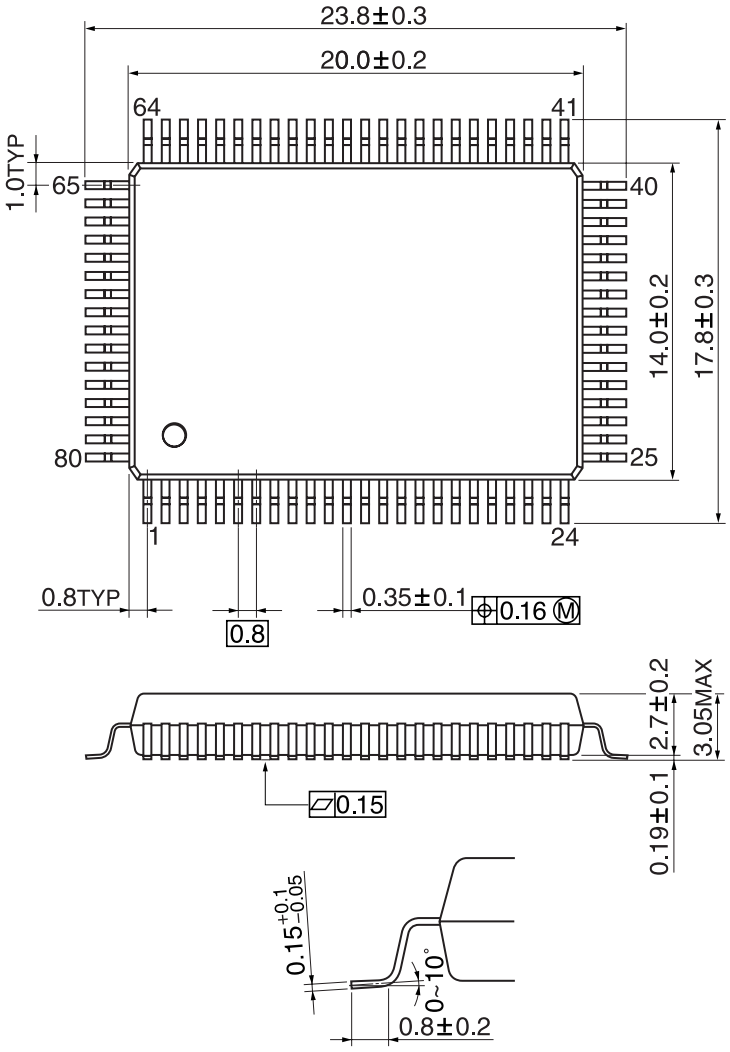
17.7 Handling Precaution

- 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 criteron of the above test is as follows:
  Solderability rate until forming ≥ 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 Dimensions

P-QFP80-1420-0.80B 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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