TOSHIBA

1999-9-17

TOSHIBA Original CMOS 8-bit Microcontroller

TLCS-870/C Series

TMP86C829U/F, TMP86CH29U/F, TMP86CM29U/F, TMP86PM29U/F

Databook

10th Edition

TOSHIBA CORPORATION

CMOS 8-Bit Microcontroller

TMP86C829U/F, TMP86CH29U/F, TMP86CM29U/F

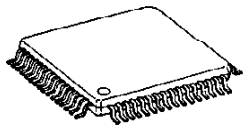
The 86C829/H29/M29 are the high-speed, high-performance and low power consumption 8-bit microcomputer, including large-capacity ROM, RAM, LCD driver, multi-function timer / counter, serial interface (UART/SIO), a 10-bit A/D converter and two clock generators on chip.

Part No.	ROM	RAM	Package	OTP MCU
TMP86C829U/F	8 K × 8-bit	512 × 8 bit	P-LQFP64-1010-0.50 P-QFP64-1414-0.80A	TMP86PM29U/F
TMP86CH29U/F	16 K × 8-bit	1.5 K × 8 bit		
TMP86CM29U/F	32 K × 8-bit			

Features

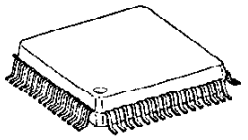
- 8-bit single chip microcomputer TLCS-870/C series
- Instruction execution time: 0.25 μs (at 16 MHz)
  122 μs (at 32.768 kHz)
- 132 types & 731 basic instructions
- 18 interrupt sources (External: 5, Internal: 13)
- Input / Output ports (39 pins)
- 18-bit timer counter: 1 ch
  - Timer, Event counter, Pulse width measurement, Frequencymeasurement modes
- 8-bit timer counter: 4 ch
  - Timer, Event counter, PWM output, Programmable Divider Output PPG modes
- Time Base Timer
- Divider output function
- Watchdog Timer
  - Interrupt source / reset output (programmable)
- Serial interface
  - 8-bit UART / SIO: 1ch
- 10-bit successive approximation type A/D converter
  - Analog input: 8 ch

P-LQFP64-1010-0.50



TMP86C829U
TMP86CH29U
TMP86CM29U

P-QFP64-1414-0.80A



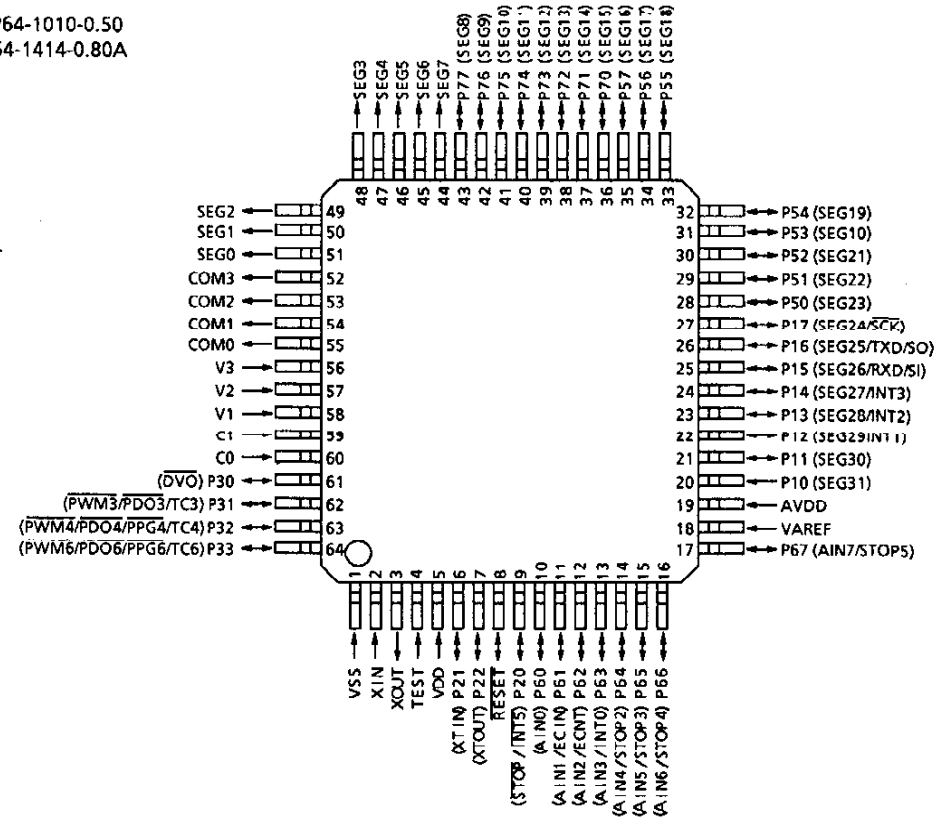
TMP86C829F
TMP86CH29F
TMP86CM29F

980910EBP1

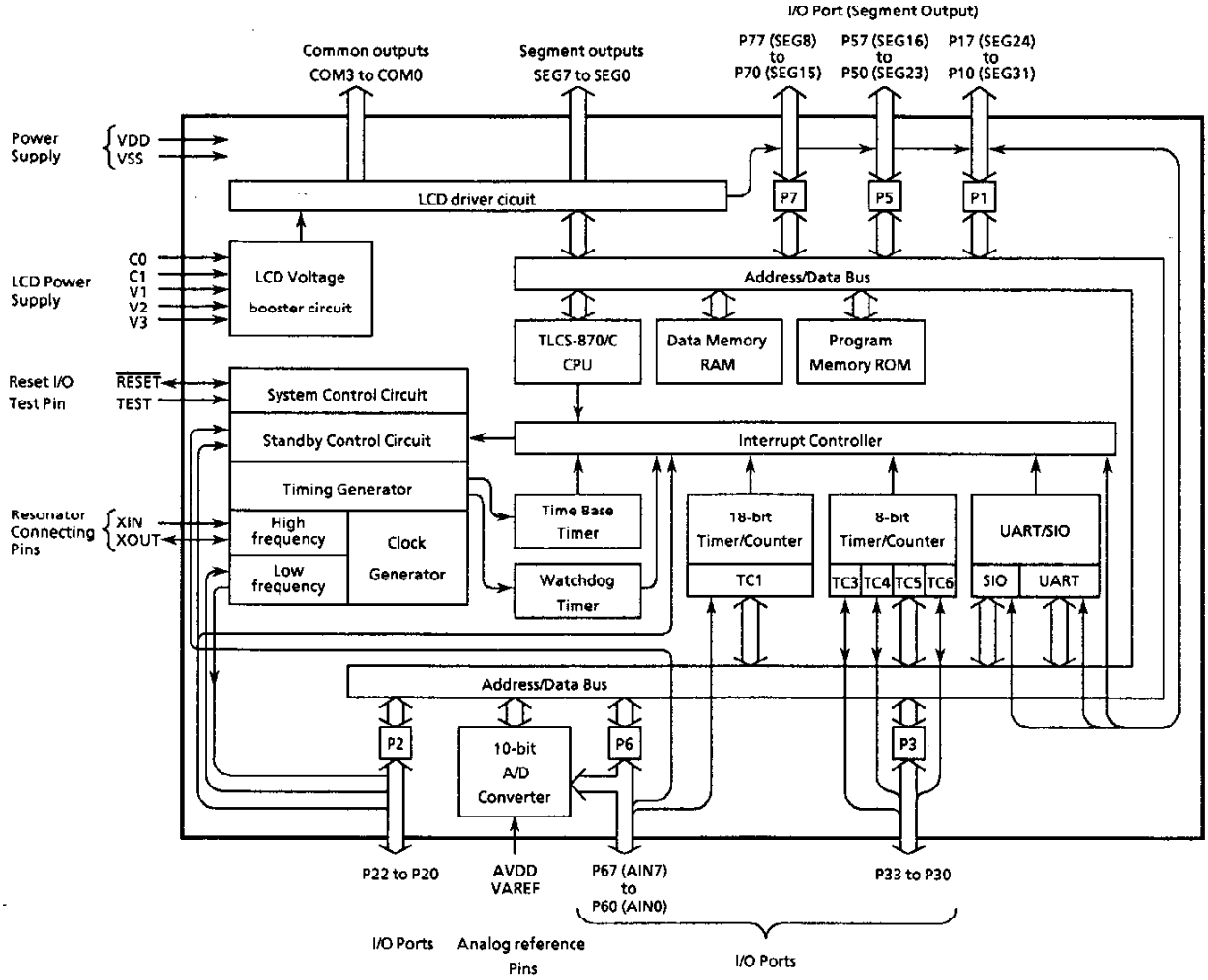
- Four Key On Wake Up pins
- LCD driver / controller
  - Built-in voltage booster for LCD driver
  - With displaymemory
  - LCD direct drive capability (Max 32 seg × 4 com)
  - 1/4, 1/3, 1/2duties or static drive are programmably selectable
- Dual clock operation
  - Single / Dual-clock mode
- Nine power saving operating modes
  - STOP mode: Oscillation stops. Battery / Capacitor back-up. Port output hold / High-impedance.
  - SLOW 1, 2 mode: Low power consumption operation using low-frequency clock (32.768 kHz)
  - IDLE 0 mode: CPU stops, and peripherals operate using high-frequency clock of Time-Base-Timer. Release by INTTBT interruput.
  - IDLE 1 mode: CPU stops, and peripherals operate using high-frequency clock. Release by interruputs.
  - IDLE 2 mode: CPU stops, and peripherals operate using high and low frequency clock. Release by interruputs.
  - SLEEP 0 mode: CPU stops, and peripherals operate using low-frequency clock of Time-Base-Timer. Release by INTTBT interruput.
  - SLEEP 1 mode: CPU stops, and peripherals operate using low-frequency clock. Release by interrupts.
  - SLEEP 2 mode: CPU stops, and peripherals operate using high and low frequency clock. Release by interrupts.
- Wide operating voltage: 1.8 to 5.5 V at 4.2 MHz / 32.768 kHz,
  2.7 to 5.5 V at 8 MHz / 32.768 kHz,
  4.5 to 5.5 V at 16 MHz / 32.768 kHz

Pin Assignments (Top View)

P-LQFP64-1010-0.50
P-QFP64-1414-0.80A



Block Diagram



Pin Function

Pin Name	Input / Output	Function		
P17 (SEG24, $\overline{SCK}$)	I/O (I/O)	8-bit input / output port with latch. When used as input port, an external interruput input, serial clock input / output, serial data input / output and UART data input / output, the latch must be set to "1". When used as a LCD segment output, the P1LCR must be set to "1".	Serial clock input / output	LCD segment outputs.
P16 (SEG25, TxD, SO)	I/O (I/O)		UART data output Serial data output	
P15 (SEG26, RxD, SI)	I/O (I/O)		UART data input Serial data input	
P14 (SEG27, INT3)	I/O (I/O)		External interrupt 3 input	
P13 (SEG28, INT2)	I/O (I/O)		External interrupt 2 input	
P12 (SEG29, INT1)	I/O (I/O)		External interrupt 1 input	
P11 (SEG30)	I/O (Output)			
P10 (SEG31)	I/O (Output)			
P22 (XTOUT)	I/O (Output)	3-bit input / output port with latch. When used as an input port, the latch must be set to "1".	Resonator connecting pins (32.768 kHz) For inputting external clock, XTIN is used and XOUT is opened.	
P21 (XTIN)	I/O (Input)			
P20 ($\overline{INT5}$, $\overline{STOP}$)	I/O (Input)		External interrupt input 5 or STOP mode release signal input	
P33 ($\overline{PWM6}$, $\overline{PDO6}$, $\overline{PPG6}$, TC6)	I/O(I/O)	4-bit programmable input / output ports (high current output). Each bit of these ports can be individually configured as an input or an output under software control. When used as a timer / conter input, timer / counter output, a divider output, the latch must be set to "1".	8-bit (16-bit) PWM output, 8 (16) bit programmable divider output, 8 (16) bit PPG output, Timercounter 6 input	
P32 ($\overline{PWM4}$, $\overline{PDO4}$, $\overline{PPG4}$, TC4)	I/O(I/O)		8-bit PWM output, 8-bit programmable divider output, 16-bit PPG output, Timer counter 4 input	
P31 (PWM3, PDO3, TC3)	I/O(I/O)		8-bit (16-bit) PWM output, 8 (16) programmable divider output, Timer counter 3 input	
P30 ($\overline{DVO}$)	I/O(Output)		Divider output	
P57 (SEG16) to P50 (SEG23)	I/O (Output)	8-bit input / output port with latch. When used as a LCD segment output, the P5LCR must be set to "1".	LCD segment outputs	
P67 (AIN7, STOP5)	I/O (Input)	8-bit programmable input / output ports (tri-state). Each bit of these ports can be individually configured as an input or an output under software control. When used as a key on wake up input, an external interrupt input and timer / counter input, the P6CR must be set to "1".	Key on wake up input 5	A/D converter analog inputs
P66 (AIN6, STOP4)	I/O (Input)		Key on wake up input 4	
P65 (AIN5, STOP3)	I/O (Input)		Key on wake up input 3	
P64 (AIN4, STOP2)	I/O (Input)		Key on wake up input 2	
P63 (AIN3, $\overline{INT0}$)	I/O (Input)		External interrupt input 0	
P62 (AIN2, ECNT)	I/O (Input)		Timer / counter 1 input	
P61 (AIN1, ECIN)	I/O (Input)			
P60 (AIN0)	I/O (Input)			
P77 (SEG8) to P70 (SEG15)	I/O (Output)	8-bit input / output port with latch. When used as a LCD segment output, the P7LCR must be set to "1".	LCD segment outputs	
SEG7 to SEG0	Output	LCD segment outputs		
COM3 to COM0		LCD common outputs		
V3 to V1 C1 to C0	LCD voltage booster pin	LCD voltage booster pin. Capacitors are required between C0 and C1 pin and V1/V2/V3 pin and GND.		
XIN, XOUT	Input Output	Resonator connecting pins for high-frequency clock. For inputting external clock, XIN is used and XOUT is opened.		
$\overline{RESET}$	I/O	Reset signal input or watchdog timer output / address-trap-reset output		
$\overline{TEST}$	Input	Test pin for out-going test. Be fixed to low.		
VDD, VSS	Power Supply	+ 5 V, 0 (GND)		
VAREF		Analog reference voltage inputs (High, Low)		
AVDD		+ 5 V, 0 (GND) A/D circuit power supply		

Operational Description

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, the external memory interface, and the reset circuit.

1.1 Memory Address Map

The TMP86C829/H29/M29 memory consist of 4 blocks: ROM, RAM, DBR (Data Buffer Register) and SFR (Special Function Register). They are all mapped in 64 Kbyte address space. Figure 1-1 shows the TMP86C829/H29/M29 memory address map. The general-purpose register banks are not assigned to the RAM address space.

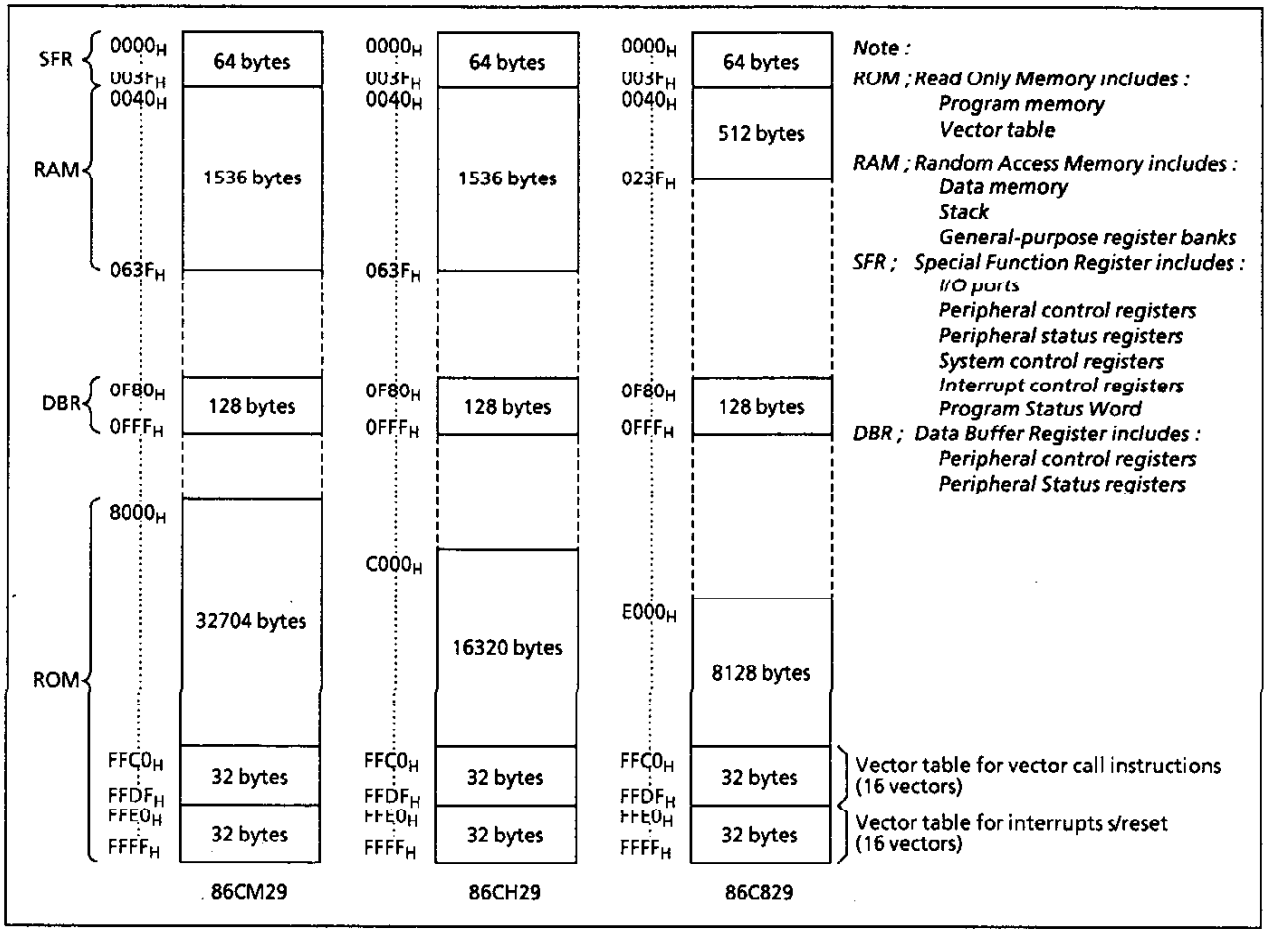


Figure 1-1. Memory Address Maps

1.2 Program Memory (ROM)

The TMP86C829/H29/M29 has a 8 K×8-bit (address $E000_H$ to $FFFF_H$), 86CH29 has a 16 K×8-bit (address $C000_H$ to $FFFF_H$), and the 87CM29 has a 32 K×8-bit (address 8000_H to $FFFF_H$) of program memory (mask programmed ROM). However, placing program memory on the internal RAM is deregulated if a certain procedure is executed (See 2.4.5 Address trap).

1.3 Data Memory (RAM)

The TLCS-870/C is available up to 64 Kbytes of data memory area. Data memory consists of internal data memory (internal ROM or RAM). The TMP86C829 has 512 bytes, the 86CH29/M29 have 1.5 Kbytes 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.

1.4 System Clock Controller

The system clock controller consists of a clock generator, a timing generator, and a stand-by controller.

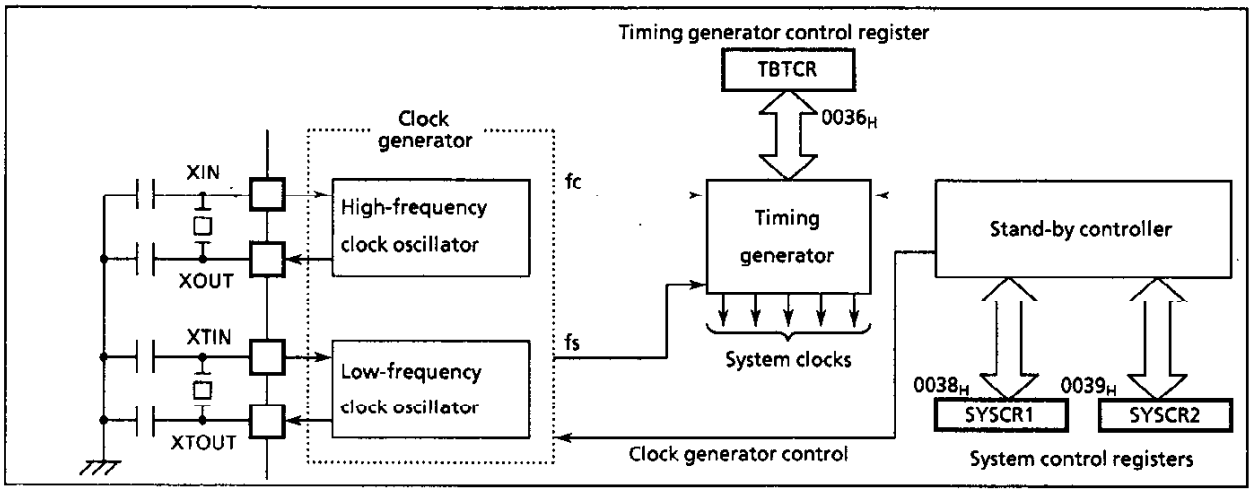


Figure 1-2. System Clock Control

1.4.1 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) and low-frequency (fs) clocks 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 / XOUT pin not connected.

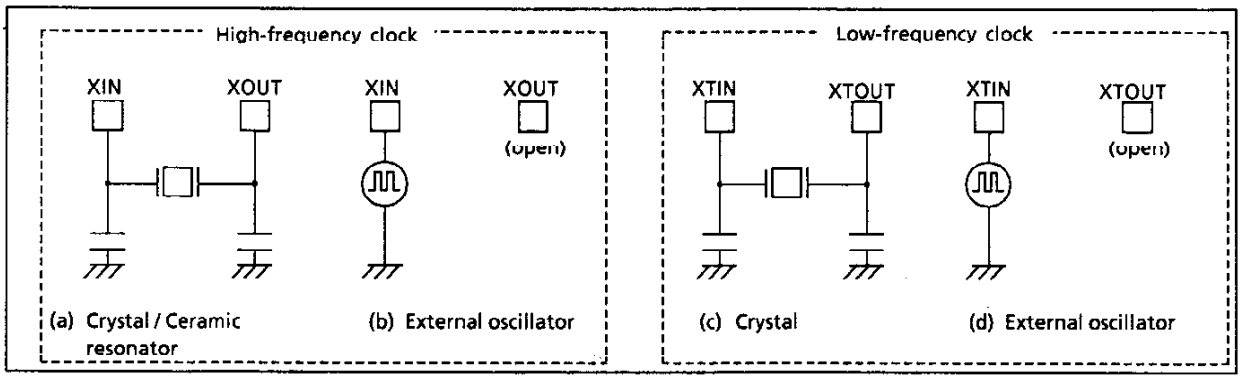


Figure 1-3. Examples of Resonator Connection

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.

1.4.2 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 (fm)
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 Generation of base clocks for LCD driver / controller

(1) Configuration of timing generator

The timing generator consists of a 3-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, DV7CK (bit 4 in TBTCR), that is shown in Figure 1-5. As reset and STOP mode started / canceled, the prescaler and the divider are cleared to "0".

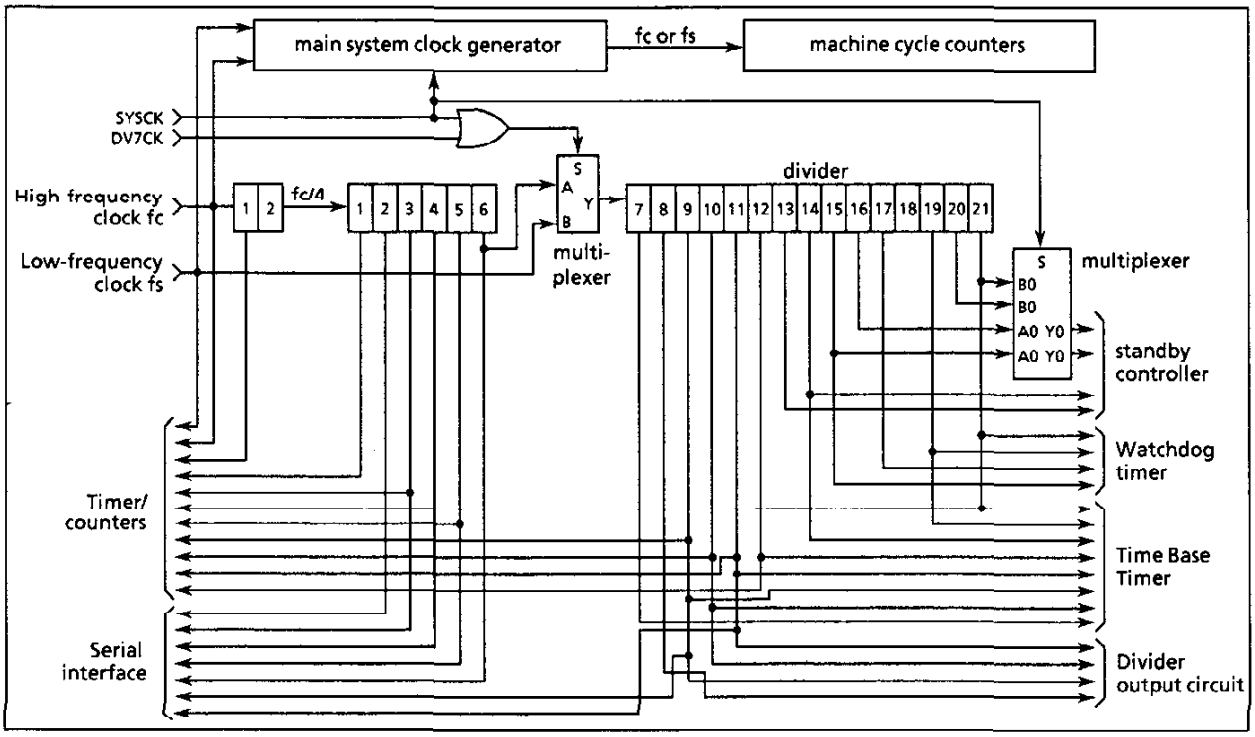


Figure 1-4. Configuration of Timing Generator

TBTCR (0036_H)

7	6	5	4	3	2	1	0
(DVOEN)	(DVOCK)		DV7CK	(TBTEN)	(TBTCK)		

(initial value: 0**0 0***)

DV7CK	Selection of input to the 7th stage of the divider	0: $fc/2^8$ [Hz] 1: fs	R/W

Note 1: Do not set "1" on DV7CK while the low-frequency clock is not operated stably.
*Note 2: fc ; High-frequency clock [Hz], fs ; Low-frequency clock [Hz], * ; Don't care*

Figure 1-5. Timing Generator Control Register

(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.

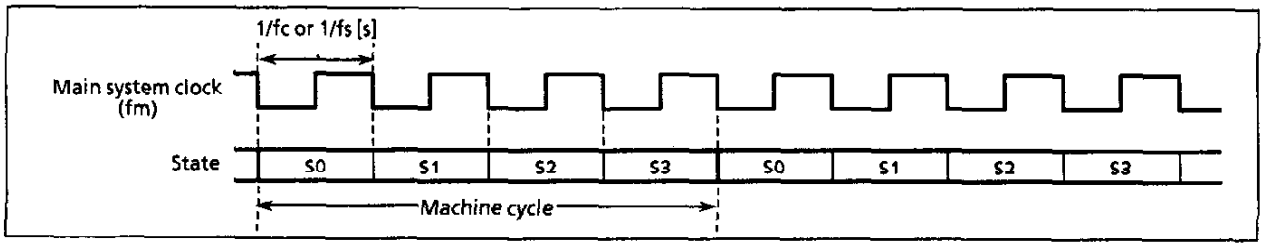


Figure 1-6. Machine Cycle

1.4.3 Standby Controller

The standby controller starts and stops the oscillation circuits for the high-frequency and low-frequency clocks, and switches the main system clock. There are two operating modes: single-clock and dual-clock. These modes are controlled by the system control registers (SYSCR1 and SYSCR2).
Figure 1-11 shows the operating mode transition diagram and Figure 1-12 shows the system control registers.

(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 86C829/H29/M29 are 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 the system control register 2 (SYSCR2), 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 setting "1" on bit TGHALT on the system control register 2 (SYSCR2). As IDLE0 mode is enabled, the timing generator halts (the system clock halts) and the CPU and other peripherals are stopped.
As IDLE0 mode is enabled, the count on the Time-Base-Timer is cleared and the Time-Base-Timer restart counting. When the count reaches the rate on TBTCR, SLEEP0 releasing signal, which restarts the timing generator, is generated and the hardware restores NORMAL1 mode.

(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. On-chip peripherals are triggered by the low-frequency clock. As the SYSCK on SYSCR2 becomes "0", the hardware changes into NORMAL2 mode. As the XEN on SYSCR2 becomes "0", the hardware changes into SLOW1 mode. Do not clear 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 XEN bit on the system control register 2 (SYSCR2). In SLOW1 and SLEEP mode, 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 SLOW mode. In SLOW and SLEEP mode, 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

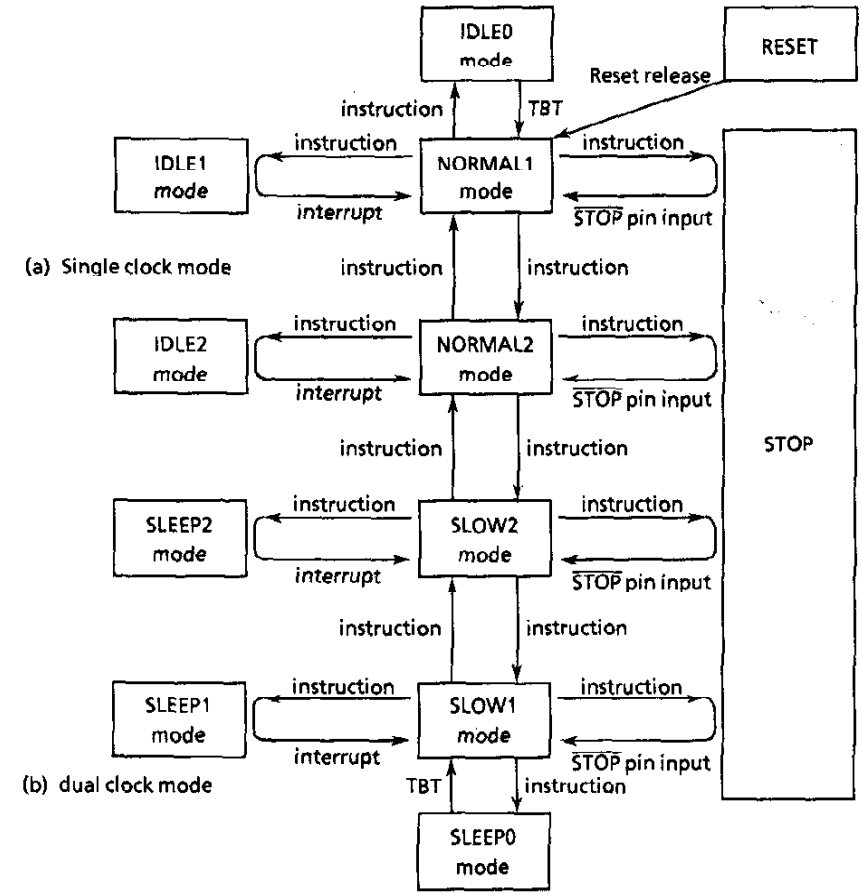
The SLEEP2 mode is the idle mode corresponding to the SLOW2 mode. The status under the SLEEP2 mode is same as that under the SLEEP1 mode, except for the oscillation circuit of the high-frequency clock.

⑦ SLEEP0 mode

In this mode, All the circuit, except oscillator and the Time-Base-Timer, stops operation.
This mode is enabled by setting "1" on bit TGHALT on the system control register2 (SYSCR2). As SLEEP0 mode is enabled, the timing generator halts (the system clock halts) and the CPU and other peripherals are stopped.
As SLEEP0 mode is enabled, the count on the Time-Base-Timer is cleared and the Time-Base-Timer restart counting. When the count reaches the rate on TBTCR, SLEEP0 releasing signal, which restarts the timing generator, is generated and the hardware restores SLOW1 mode.

(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 warming-up period is completed, the execution resumes with the instruction which follows the STOP mode start instruction.



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

Operating Mode		oscillator		CPU core	TBT	Other Peripherals	Machine Cycle Time
		High-freq.	Low-freq.				
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 Freq.	operate	operate	4 / fc [s]
	IDLE2			halt			
	SLOW2			operate with Low Freq.			4 / fs [s]
	SLEEP2			halt			
	SLOW1	Stop		operate with Low Freq.			
	SLEEP1			halt			
	SLEEP0					halt	
	STOP		Stop		halt		—

Figure 1-7. Operating Mode Transition Diagram

System Control Register 1

SYSCR1 (00038_H)

7	6	5	4	3	2	1	0
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		
RETM	Operating mode after STOP mode	0: Return to NORMAL mode 1: return to SLOW mode		
OUTEN	Port output during STOP mode	0: High Impedance 1: Output Kept		
WUT	Warming-up time at releasing STOP mode		Return to NORMAL mode	Return to SLOW mode
		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 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 interrupt request on account of falling edge.

Note 6: When the Key on wake-up is used, the edge release can not function according to some conditions. It is recommended to set the level release (RELM = "0").

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 Hi-Z mode.*

System Control Register 2

SYSCR2 (00039_H)

7	6	5	4	3	2	1	0
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 1: Low-frequency clock	
IDLE	IDLE mode start	0: CPU and watchdog timer remain active 1: CPU and watchdog timer are stopped (start IDLE mode)	
TGHALT	TG stops (SLEEP0, IDLE0 mode)	0: TG keeps its operation 1: TG stops (SLEEP0, IDLE0 mode)	

Note 1: XEN and SYSCK are automatically overwritten in accordance with the contents of RETM (bit 5 in SYSCR1) when STOP mode is released. But XTEN is not change.

RETM	operating mode after STOP mode	XEN	SYSCK
0	NORMAL 1/2 mode	1	0
1	SLOW mode	0	1

Note 2: A reset is applied ($\overline{\text{RESET}}$ *pin output goes low) 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 3: * ; Don't care*

Note 4: Bits 3, 1and 0 in SYSCR2 are always read as undefined value.

Figure 1-8. System Control Registers

1.4.4 Operating Mode Control

(1) STOP mode

STOP mode is controlled by the system control register 1, the $\overline{STOP}$ pin input and key wake-up input (STOP2 to STOP5) 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 STOP (bit 7 in SYSCR1) 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 RELM (bit 6 in SYSCR1). Do not use any STOPx (x ; 2to 5) pin input for releasing STOP mode in edge-sensitive mode.

Note: $\overline{STOP}$ pin doesn't have the control register such as STOPCR, so when STOP mode is relesed by STOPx (x ; 2 to 5), $\overline{STOP}$ pin should be fixed to low.

a. Level-sensitive release mode (RELM = "1")

In this mode, STOP mode is released by setting the $\overline{STOP}$ pin high or setting the STOPx (x ; 2 to 5) pin input which is enabled by STOPCR. This mode is used for capacitor back-up when the main power supply is cut off and long term battery back-up.
When the STOP pin input is high or STOPx (x ; 2 to 5) pin input which 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). 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 and STOPx (x ; 2 to 5) pin input which is enabled by STOPCR is high. The following two methods can be used for confirmation.

① Testing a port P20.

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  (P2DR). 0           ;  Wait until the STOP pin input goes low level
        JRS   F, SSTOPH
        SET   (SYSCR1). 7         ;  Starts STOP mode
```

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

```
PINT5:  TEST  (P2DR). 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.
        SET   (SYSCR1). 7         ;  Starts STOP mode
SINT5:  RETI
```

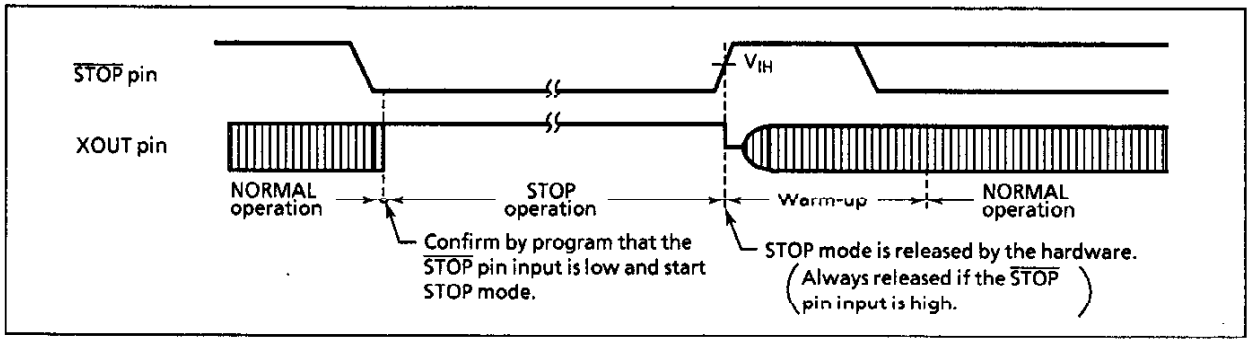


Figure 1-9. Level-sensitive release Mode

Note 1: Even if the STOP pin input is low or STOPx (x ; 2 to 5) pin input which is enabled by STOPCR is high after warming 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 STOP pin input is detected.

b. Edge-sensitive release mode (RELM = "0")

In this mode, STOP mode is released by a rising edge of the 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 STOP pin. In the edge-sensitive release mode, STOP mode is started even when the STOP pin input is high level. Do not use any STOPx (x ; 2 to 5) pin input for releasing STOP mode in edge-sensitive release mode.

Example: Starting STOP mode from NORMAL mode

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

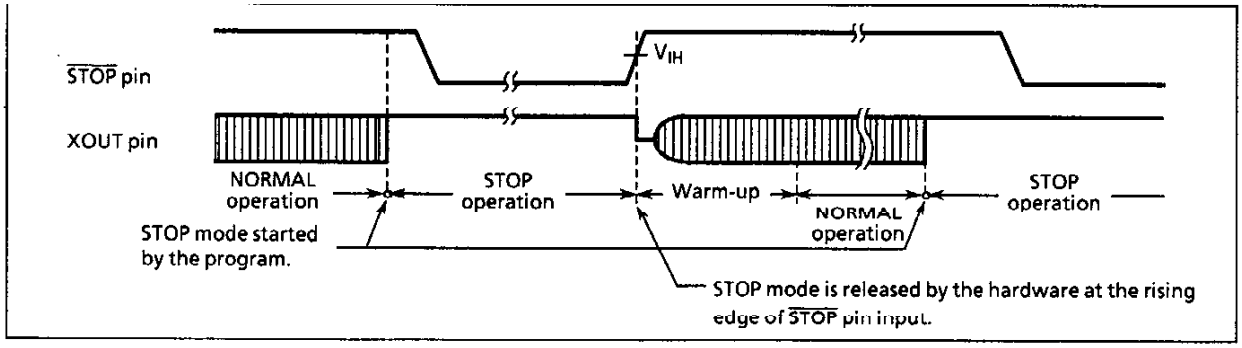


Figure 1-10. Edge-sensitive release Mode

STOP mode is released by the following sequence.

① In the dual-clock mode, when returning to NORMAL2 or SLOW2, 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 signal-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 WUT (bits 2 and 3 in SYSCR1) 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. The start is made after the prescaler and the divider of the timing generator are cleared to "0".

Table 1-1. 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: 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 an approximate value.

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

Note: 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).

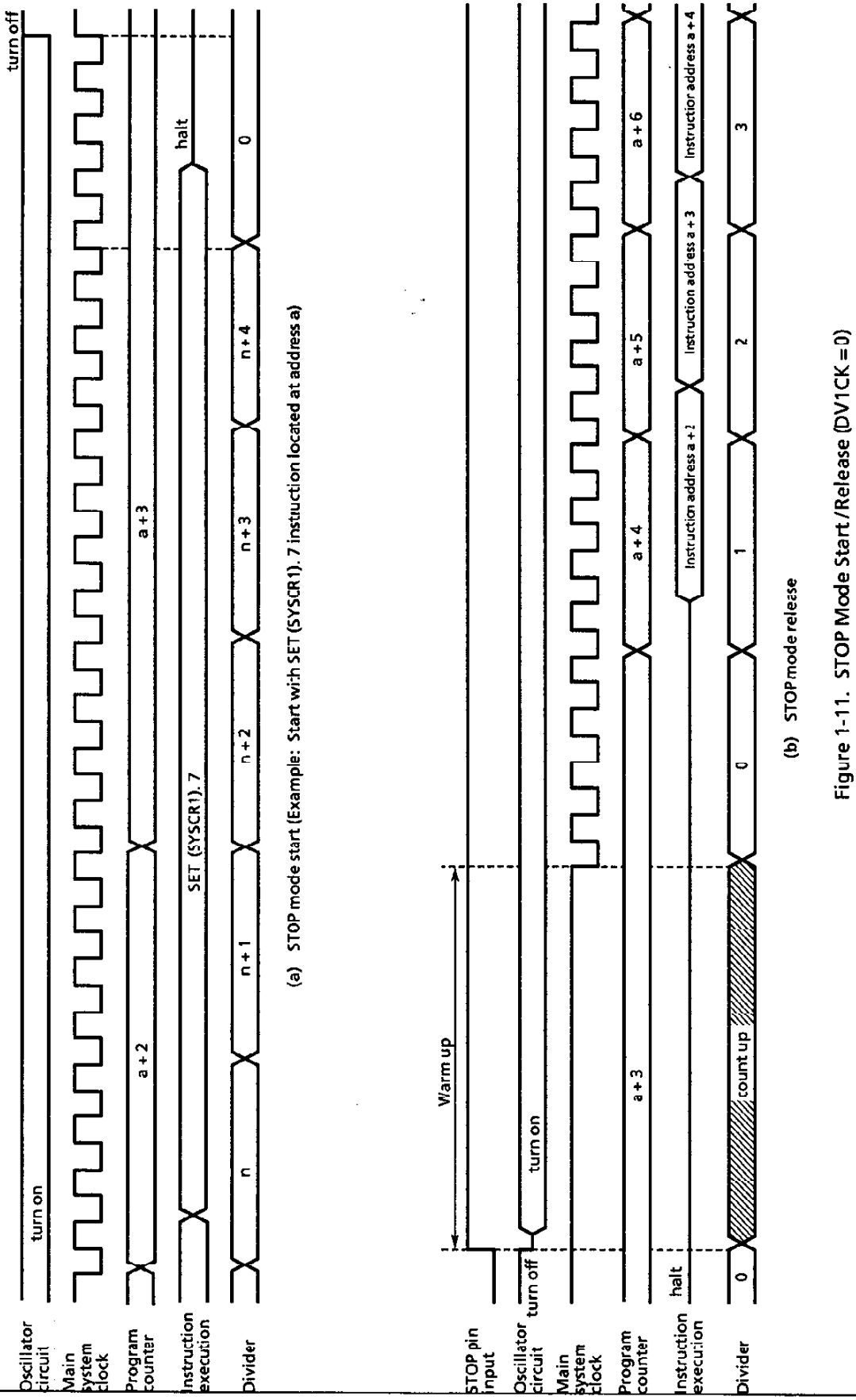


Figure 1-11. STOP Mode Start/Release (DV1CK = 0)

(2) IDLE mode (IDLE1, IDLE2, SLEEP1, SLEEP2)

IDLE mode is controlled by the system control register 2 (SYSCR2) and maskable interrupts. The following status is maintained during IDLE mode.

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 IDLE mode was entered.

③ The program counter holds the address 2 ahead of the instruction which starts IDLE mode.

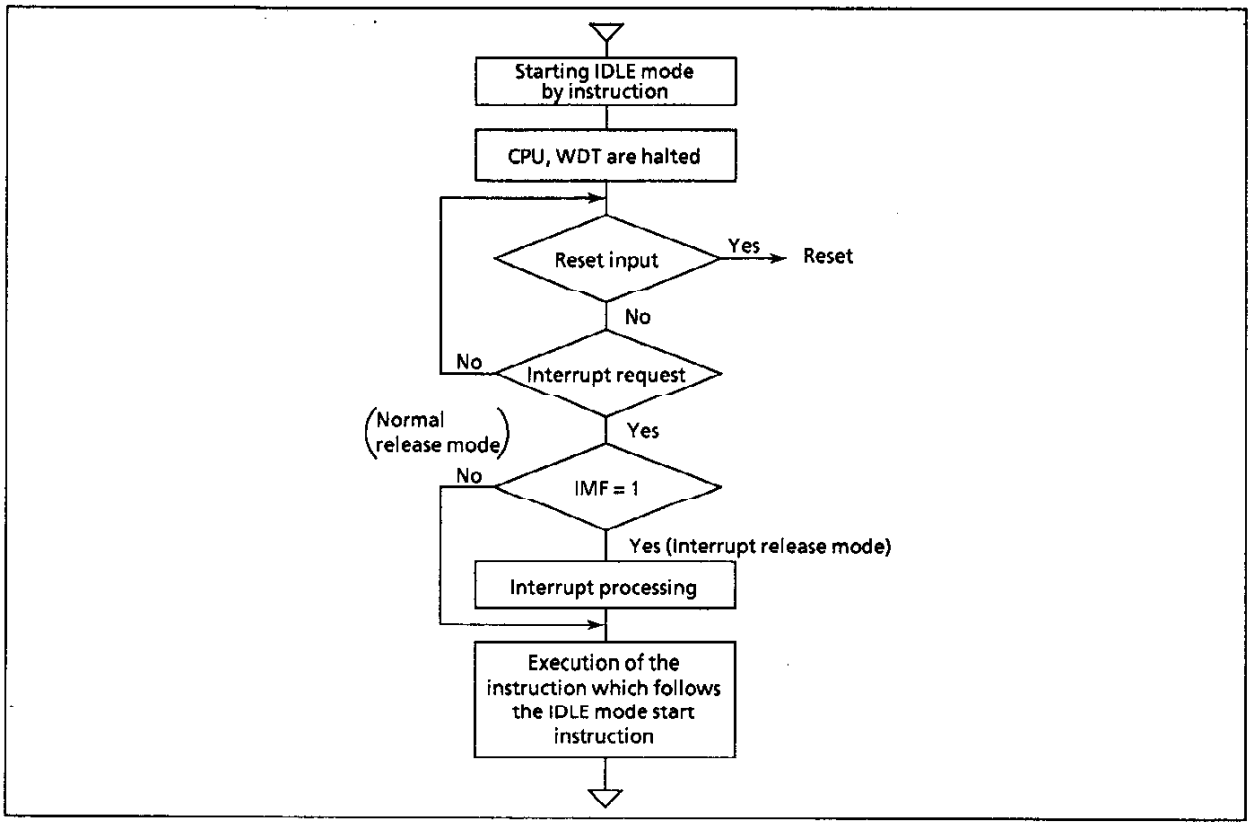


Figure 1-12. IDLE Mode

Example: Starting IDLE mode.

```
SET  (SYSCR2). 4    ; IDLE ← 1
```

IDLE mode includes a normal release mode and an interrupt release mode. Selection is made with the interrupt master enable flag (IMF). Releasing IDLE mode returns from IDLE1 to NORMAL1, from IDLE2 to NORMAL2, from SLEEP1 to SLOW mode, and from SLEEP2 to SLOW2 mode.

a. Normal release mode (IMF = "0")

IDLE mode is released by any interrupt source enabled by the individual interrupt enable flag (EF). Execution resumes with the instruction following the IDLE mode start instruction . The interrupt latches (IL) of the interrupt source used for releasing must be cleared to "0" by load instructions. However, only TBT interrupt can release IDLE0/SLEEP0 mode.

b. Interrupt release mode (IMF = "1")

IDLE mode is released and interrupt processing is started by any interrupt source enabled with the individual interrupt enable flag (EF). After the interrupt is processed, the execution resumes from the instruction following the instruction which starts IDLE mode. However, only TBT interrupt can release IDLE0/SLEEP0 mode.

IDLE mode can also be released by inputting low level on the $\overline{\text{RESET}}$ pin, which immediately performs the reset operation. After reset, the 86C829/H29/M29 is placed in NORMAL 1 mode.

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

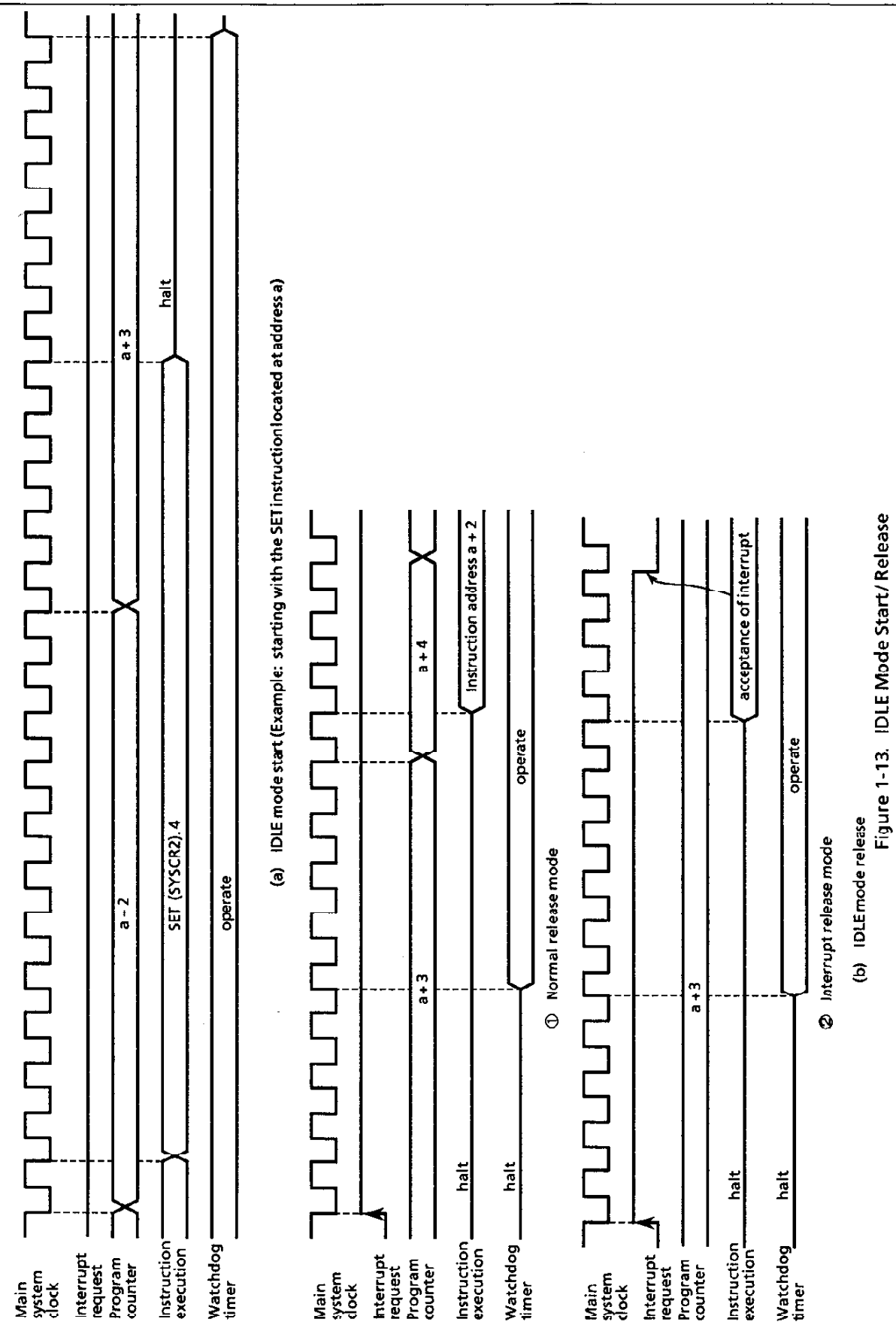


Figure 1-13. IDLE Mode Start/Release

(3) SLOW mode

SLOW mode is controlled by the system control register 2 (SYSCR2).
The following is the methods to switch the mode with the warming-up counter (TC4, 3).

a. Switching from NORMAL2 mode to SLOW1 mode

First, set SYSCK (bit 5 in SYSCR2) to switch the main system clock to the low-frequency clock for SLOW2 mode.
Next, clear XEN (bit 7 in SYSCR2) to turn off high-frequency oscillation.

Note: The high-frequency clock oscillation can be continued to return quickly to NORMAL2 mode.

When the low-frequency clock oscillation is unstable, wait until oscillation stabilizes before performing the above operations. The timer / counter 4, 3 (TC4, TC3) can conveniently be used to confirm that low-frequency clock oscillation has stabilized.

Example1: Switching from NORMAL2 mode to SLOW1 mode.

```
        SET  (SYSCR2). 5      ;  SYSCK ← 1
                                 (switches the main system clock to the low-frequency
                                 clock for SLOW2)
        CLR  (SYSCR2). 7      ;  XEN ← 0
                                 (turns off high-frequency oscillation)
```

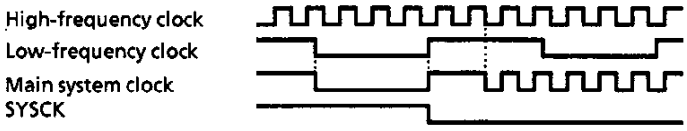
Example2: Switching to the SLOW1 mode after low-frequency clock has stabilized.

```
        LD   (TC3CR), 43H     ;  Sets mode for TC4, TC3 (16-bit TC, fs for source)
        LD   (TC4CR), 05H
        LDW  (TREG3A), 8000H  ;  Sets warming-up time
                                 (depend on oscillator accompanied)
        SET  (EIRH). 3        ;  Enables INTTC4
        EI
        SET  (TC4CR). 3       ;  Starts TC4, 3
          :
PINTTC1: CLR  (TC4CR). 3      ;  Stops TC4, 3
        SET  (SYSCR2). 5      ;  SYSCK ← 1 (Switches the main system clock to the
                                 low-frequency clock)
        CLR  (SYSCR2). 7      ;  XEN ← 0 (Turns off high-frequency oscillation)
        RETI
          :
VINTTC1: DW  PINTTC4          ;  INTTC4 vector table
```

b. Switching from SLOW1 mode to NORMAL2 mode

First, set XEN (bit 7 in SYSCR2) to turn on the high-frequency oscillation. When time for stabilization (warm-up) has been taken by the timer / counter 4, 3 (TC4, 3), clear SYSCK (bit 5 in SYSCR2) to switch the main system clock to the high-frequency clock.

Note 1: After SYSCK is cleared to "0", executing the instructions is continued by the low frequency clock for the period synchronized with low-frequency and high-frequency clocks.



Note 2: SLOW mode can also be released by inputting low level on the RESET pin, which immediately performs the reset operation. After reset, the 86C829/H29/M29 are placed in NORMAL1 mode.

Example: Switching from the SLOW1 mode to the NORMAL2 mode
(fc = 16 MHz, warm-up time is 4.0 ms).

```
        SET   (SYSCR2). 7      ;  XEN ← 1 (Starts high-frequency oscillation)
        LD    (TC3CR), 63H     ;  Sets mode for TC4, TC3 (16-bit TC, fc for source)
        LD    (TC4CR), 05H
        LD    (TREG4A), 0F8H   ;  Sets warming-up time
        SET   (EIRH). 3        ;  Enables INTTC4
        EI
        SET   (TC4CR). 3       ;  Starts TC4, 3
          :
PINTTC1: CLR  (TC4CR). 3       ;  Stops TC4, 3
        CLR   (SYSCR2). 5      ;  SYSCR ← 0 (Switches the main system clock to the
                                  high-frequency clock)
        RETI
          :
VINTTC1: DW   PINTTC4          ;  INTTC4 vector table
```

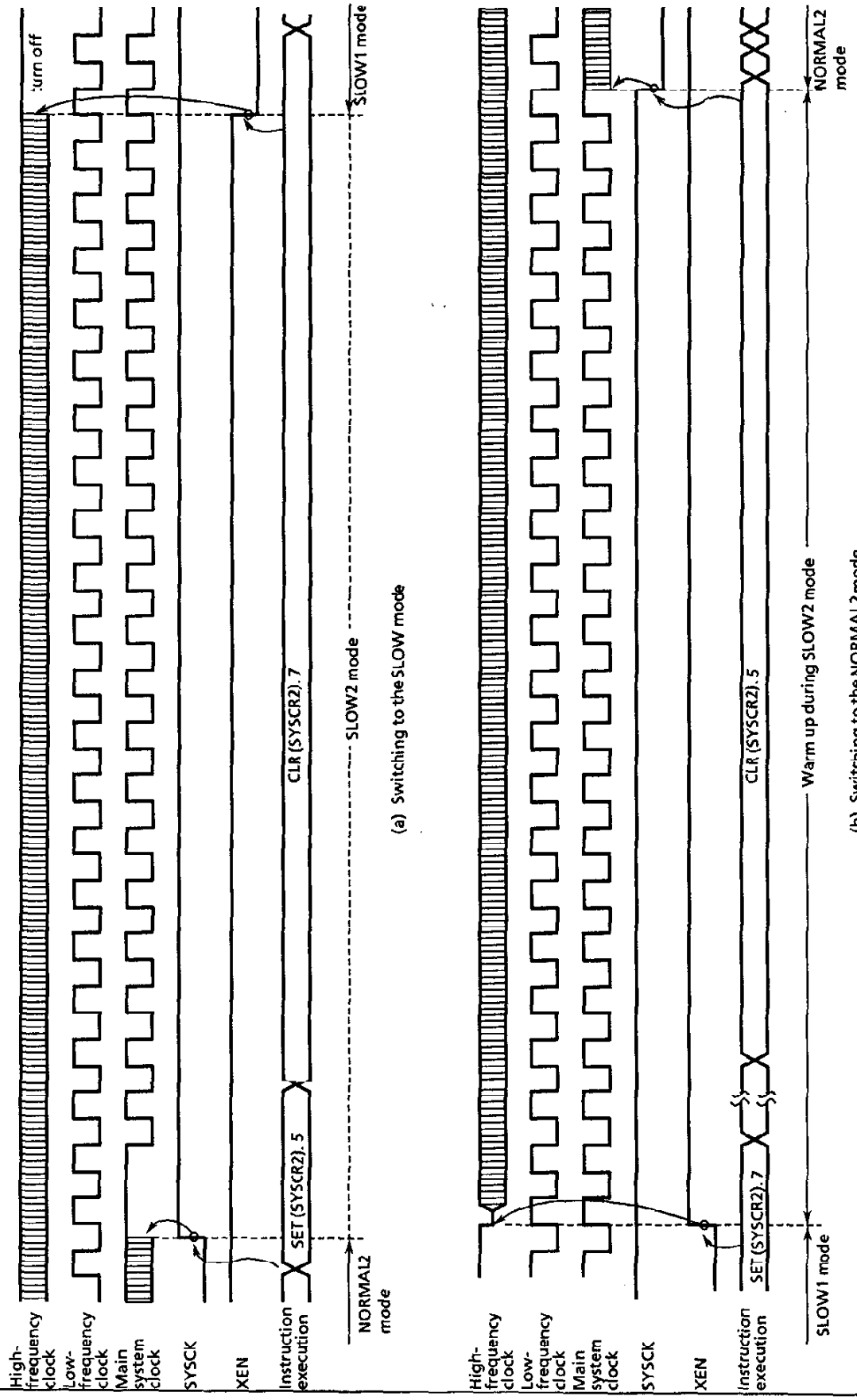


Figure 1-14. Switching between the NORMAL2 and SLOW Modes

1.5 Interrupt Control Circuit

The 86C829/H29/M29 are a total (Reset is excluded) of 15 interrupt sources for 19 interrupt factors; 3 of the sources are multiplexed. Multiple interrupt with priorities is available. 4 of the internal factors are non-maskable interrupts, and the rest of them are maskable interrupts.

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.

Table 1-2. Interrupt Sources

Interrupt Factors		Enable Condition	Interrupt Latch	Vector Address	Priority
Internal / External	(Reset)	non-maskable	—	$FFFE_H$	High 1
Internal	INTSWI (Software interrupt)	non-maskable	—	$FFFC_H$	2
Internal	INTUNDEF (Executed the Undefined Instruction interrupt)	non-maskable	—	$FFFC_H$	2
Internal	INTATRAP (Address Trap interrupt)	non-maskable	IL_2	$FFFA_H$	2
Internal	INTWDT (Watchdog Timer interrupt)	non-maskable	IL_3	$FFF8_H$	2
External	$\overline{INT0}$ (External interrupt 0)	IMF = 1, EF_4 = 1	IL_4	$FFF6_H$	5
External	INT1 (External interrupt 1)	IMF = 1, EF_5 = 1	IL_5	$FFF4_H$	6
Internal	INTTBT (Time Base Timer interrupt)	IMF = 1, EF_6 = 1	IL_6	$FFF2_H$	7
External	INT2 (External interrupt2)	IMF = 1, EF_7 = 1	IL_7	$FFF0_H$	8
Internal	INTTC1 (18 bit TC1 interrupt)	IMF = 1, EF_8 = 1	IL_8	$FFEE_H$	9
Internal	INTRxD (UART received interrupt)	IMF = 1, EF_9 = 1	IL_9	$FFEC_H$	10
Internal	INTSIO (SIO interrupt)				
Internal	INTTxD (UART transmitted interrupt)	IMF = 1, EF_{10} = 1	IL_{10}	$FFEA_H$	11
Internal	INTTC4 (TC4 interrupt)	IMF = 1, EF_{11} = 1	IL_{11}	$FFE8_H$	12
Internal	INTTC6 (TC6 interrupt)	IMF = 1, EF_{12} = 1	IL_{12}	$FFE6_H$	13
Internal	INTADC (A/D converter interrupt)	IMF = 1, EF_{13} = 1	IL_{13}	$FFE4_H$	14
External	INT3 (External interrupt 3)	IMF = 1, EF_{14} = 1	IL_{14}	$FFE2_H$	15
Internal	INTTC3 (TC3 interrupt)				
External	$\overline{INT5}$ (External interrupt 5)	IMF = 1, EF_{15} = 1	IL_{15}	$FFE0_H$	Low 16
Internal	INTTC5 (TC5 interrupt)				

Note 1: The following interrupt factors share their interrupt source; the factor is selected on the register INTSEL.

1) INTRXD and INTSIO share the source whose priority is 10.

2) INT3 and INTTC3 share the source whose priority is 15.

3) $\overline{INT5}$ and INTTC5 share the source whose priority is 16.

Note 2: 2 alternatives are to be chosen in case INTATRAP (address trap interrupt) is executed: interrupt or reset. (for detail, see 2.4.5 address trap interrupt (INTATRAP)

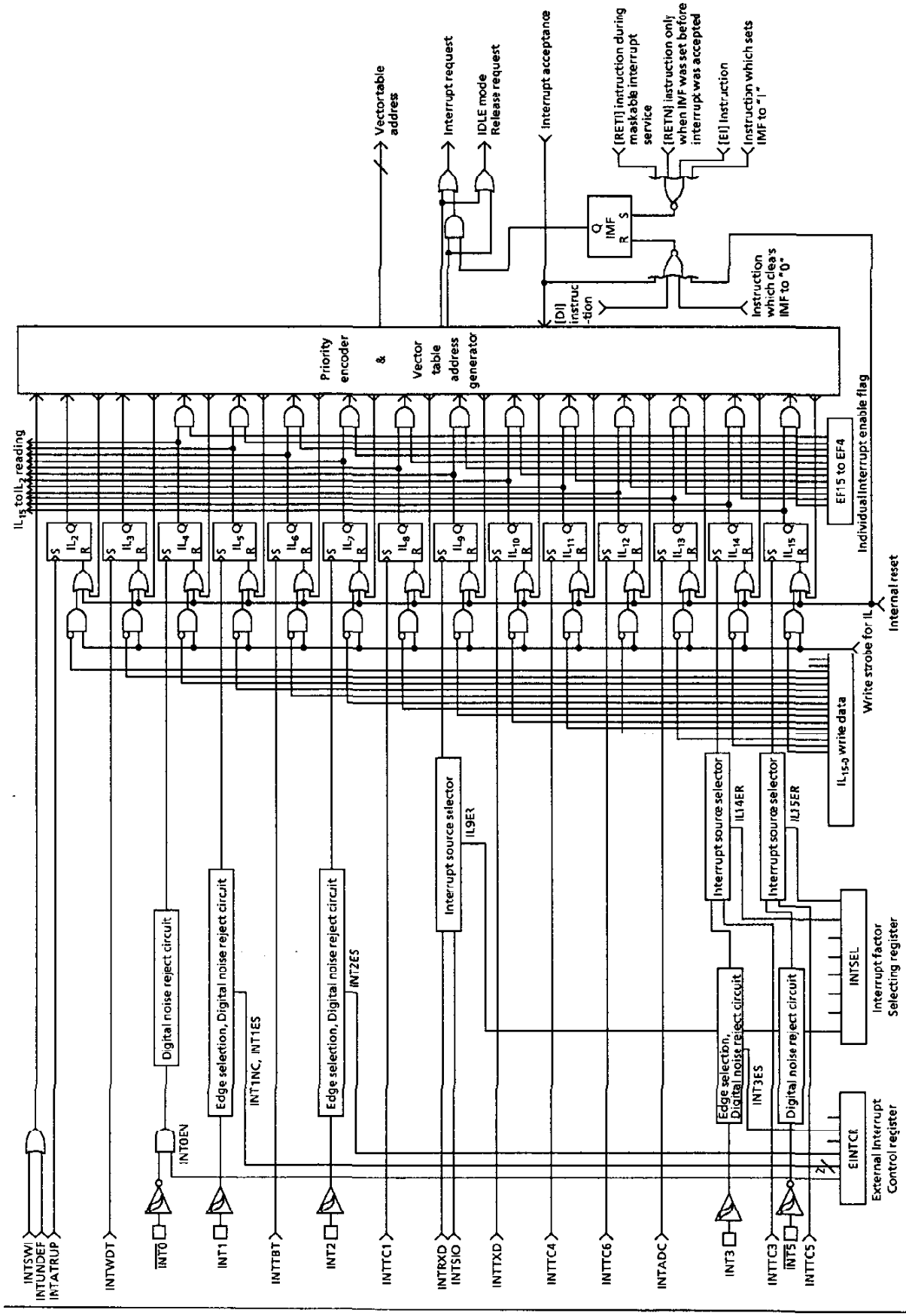


Figure 1-15. Interrupt Controller Block Diagram

(1) Interrupt Latches (IL_{15} to IL_2)

An interrupt latch is provided for each interrupt source, except for a software 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. All interrupt latches are initialized to "0" during reset.
The interrupt latches are located on address $003C_H$ and $003D_H$ in SFR area. Except for IL_3 and IL_2, each latch can be cleared to "0" individually by instruction (However, the read-modify-write instructions such as bit manipulation or operation instructions cannot be used. Interrupt request would be cleared inadequately if interrupt is requested while such instructions are executed.). Thus interrupt request can be canceled /initialized by software.
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.

Example 1: Clears interrupt latches

```
LDW (ILL), 1110100000111111B  ; IL12, IL10 to IL6 ← 0
LD  (ILH), 11111000B          ; IL10 to IL8 ← 0
```

Example 2: Reads interrupt latches

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

Example 3: Tests an interrupt latches

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

(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 $003C_H$ and $003D_H$ 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).

a) 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: $003A_H$ 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", and maskable interrupts are not accepted until it is set to "1".

b) Individual interrupt enable flags (EF_{15} to EF_4)

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. The individual interrupt enable flags (EF_{15} to EF_4) are located on EIRL to EIRH (address: $003A_H$ to $003B_H$ in SFR), and can be read and written by an instruction. During reset, all the individual interrupt enable flags (EF_{15} to EF_4) are initialized to "0" and all maskable interrupts are not accepted until they are set to "1".

Example 1: Enables interrupts individually and sets IMF

```
DI                                  ;  IMF ← 0
LDW (EIRL), 1110100010100000B       ;  EF15 to EF13, EF11, EF7, EF5 ← 1
        :                           ;  Note: IMF is not 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 (IL)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IL_{15}	IL_{14}	IL_{13}	IL_{12}	IL_{11}	IL_{10}	IL_9	IL_8	IL_7	IL_6	IL_5	IL_4	IL_3	IL_2		

IL_H ($003D_H$) IL_L ($003C_H$)

(Initial value: 00000000 000000**)

		at RD	at WR	
IL_{15} to IL_2	Interrupt Latches	0: no interrupt request 1: interrupt request	0: clears the interrupt request (Note 1) 1: (Interrupt Latch is not set.)	R/W

Note 1: IL2 and IL3 are prohibited from clearing.

Interrupt Enable Registers (EIR)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EF_{15}	EF_{14}	EF_{13}	EF_{12}	EF_{11}	EF_{10}	EF_9	EF_8	EF_7	EF_6	EF_5	EF_4				IMF

EIR_H ($003B_H$) EIR_L ($003A_H$)

(Initial value: 00000000 00000***)

Note 1: Do not clear IL with read-modify-write instructions such as bit operations.
*Note 2: * ; Don't care*
Note 3: When manipulating EF, clear IMF (to disable interrupts) beforehand.
Note 4: Do not set IMF to 1 simultaneously with EF.

Figure 1-16. Interrupt Latch (IL), Interrupt Enable Registers (EIR)

(3) Selecting interrupt factor (INTSEL)

Each interrupt factor, that shares its interrupt source with other factors, enables its interrupt latch (IL) only if it is selected on INTSEL. The interrupt controller does not hold the interrupt request, while the factor generates the interrupt request is not selected on INTSEL. Therefore, set INTSEL appropriately before interrupt factors arises.

Interrupt source selector

INTSEL ($003E_H$)

7	6	5	4	3	2	1	0
–	IL9ER	–	–	–	–	IL14ER	IL15ER

(Initial value: *0** **00)

IL9ER	alternative of INTRXD or INTSIO	0: INTRXD 1: INTSIO	R/W
IL14ER	alternative of INT3 or INTTC3	0: INT3 1: INTTC	
IL15ER	alternative of $\overline{INT5}$ or INTTC5	0: $\overline{INT5}$ 1: INTTC5	

Figure 1-17. Interrupt Source Selector

1.5.1 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 (4 μs at 8.0 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 1-18 shows the timing chart of interrupt acceptance processing.

(1) Interrupt acceptance processing is packaged as follows.

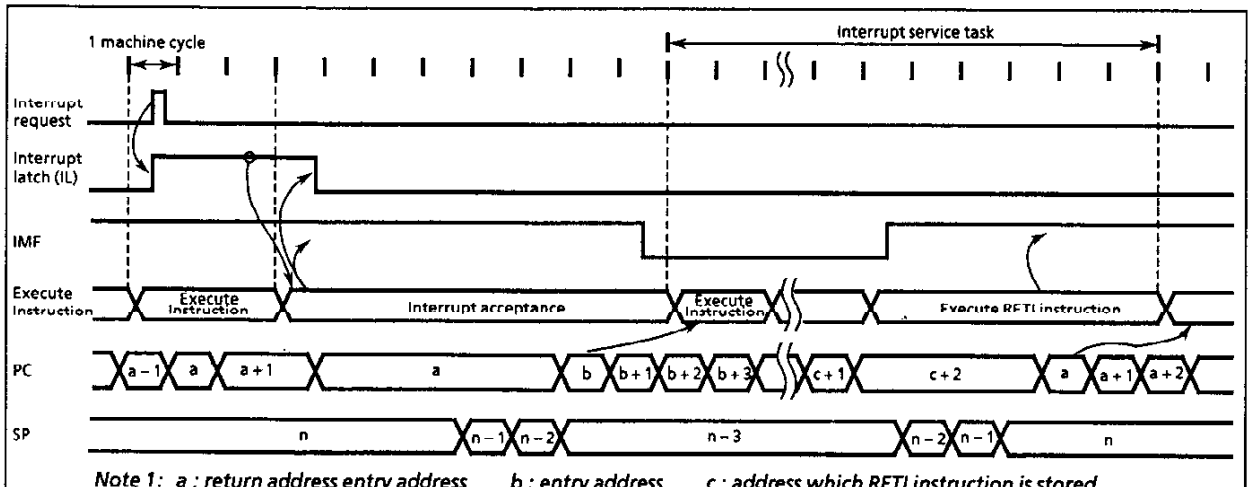
a) The interrupt latch (IL) for the interrupt source accepted is cleared to "0".

b) 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.

c) The interrupt master enable flag (IMF) is cleared to "0" in order to disable the acceptance of any following interrupt.

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.

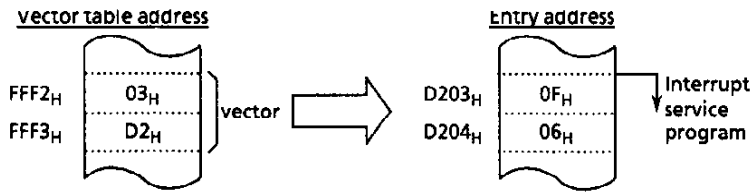


Note 1: a ; return address entry address b ; entry address c ; address which RETI instruction is stored

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 1-18. 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



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.

(2) Saving/Restoring general -purpose registers

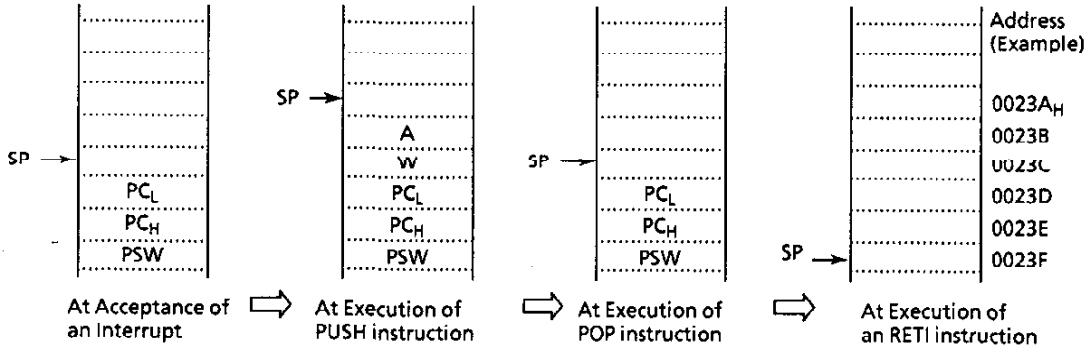
During interrupt acceptance processing, the program counter (PC) and the program status word (PSW, includes IMF) are automatically saved on the stack, but the accumulator and others are not. These registers are saved by software if necessary. When multiple interrupt services are nested, it is also necessary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

a) using PUSH and POP instructions

To save only a specific register, PUSH and POP instructions are available.

Example: save/store register using PUSH and POP instructions

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



b) 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
```

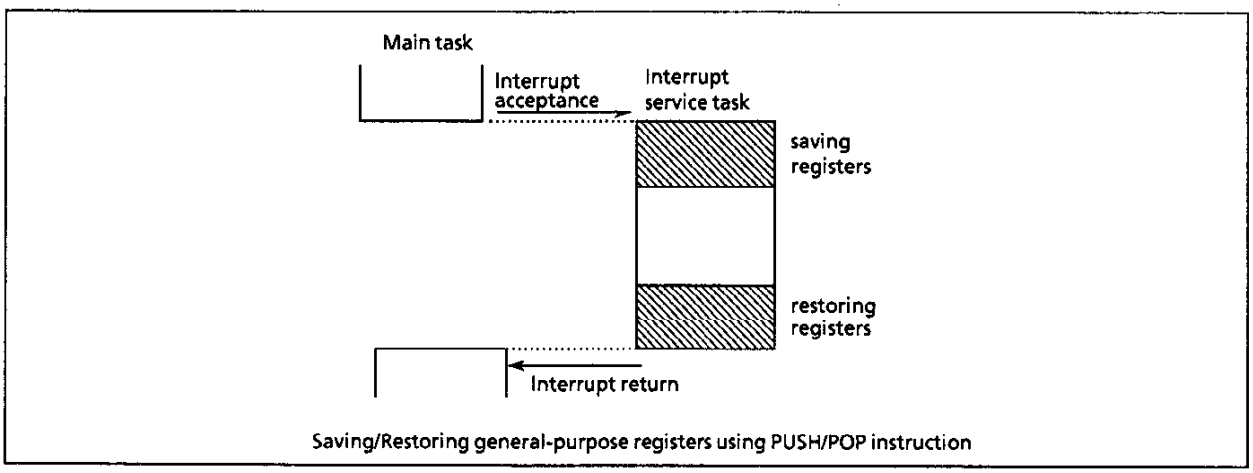


Figure 1-19. Saving/Restoring general-purpose registers under interrupt processing

(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 (INTARTAP), it is required to alter stacked data for program counter (PC) to restarting address, during interrupt service program. Otherwise returning interrupt causes INTATRAP again. When interrupt acceptance processing has completed, stacked data for PC_L and PC_H 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
```

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).

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: When the interrupt processing time is longer than the interrupt request generation time, the interrupt service task is performed but not the main task.

1.5.2 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.

① Address error detection

FF_H 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 FF_H 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 FF_H to unused areas of the program memory. Address-trap reset is generated in case that an instruction is fetched from RAM or SFR areas.

② Debugging

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

1.5.3 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.

1.5.4 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.
The address trapped area is alternative: SFR and RAM, or SFR only.

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

1.5.5 External Interrupts

The 86C829/H29/M29 have five 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 $\overline{INT0}$ / P10 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 $\overline{INT0}$ / P10 pin function selection are performed by the external interrupt control register (EINTCR).

Table 1-3. External Interrupts

Source	Pin	Secondary function pin	Enable conditions	Edge	Digital noise reject
INT0	$\overline{INT0}$	P63	IMF = 1, EF_4 = 1, INT0EN = 1	falling edge	Pulses of less than 2/fc [s] are eliminated as noise. Pulses of 6/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/fs [s] or more are considered to be signals.
INT1	INT1	P12	IMF · EF_5 = 1	falling edge or rising edge	Pulses of less than 15/fc or 63/fc [s] are eliminated as noise. Pulses of 48/fc or 192/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/fs [s] or more are considered to be signals.
INT2	INT2	P13/SEG28	IMF · EF_7 = 1		Pulses of less than 7/fc [s] are eliminated as noise. Pulses of 24/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/fs [s] or more are considered to be signals.
INT3	INT3	P14/SEG27	IMF · EF_{15} = 1 IL14ER = 0		
INT5	$\overline{INT5}$	P20/$\overline{STOP}$	IMF · EF_{15} = 1 IL1SER = 0	falling edge	Pulses of less than 2/fc [s] are eliminated as noise. Pulses of 6/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/fs [s] or more are considered to be signals.

Note 1: If a noiseless signal is input to the external interrupt pin in the NORMAL 1/2 or IDLE 1/2 mode, the maximum time from the edge of input signal until the IL is set is as follows :
① INT1 pin 49/fc [s] (INT1NC = 1), 193/fc [s] (INT1NC = 0)
② INT2, INT3 pin 25/fc [s]
Note 2: Even if the falling edge of $\overline{INT0}$ pin input is detected at INT0EN = 0, the interrupt latch IL_4 is not set.
Note 3: When data changed and did a change of I/O when used external interrupt ports as a normal ports, interrupt request signal occurs incorrectly. Handling of prohibition of interrupt enable register (EIR) is necessary.

EINTCR (00037_H)

7	6	5	4	3	2	1	0
INT1 NC	INT0 EN			INT3 ES	INT2 ES	INT1 ES	

(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	P10/$\overline{INT0}$ pin configuration	0: Pulses of less than 63/fc [s] are eliminated as noise 1: Pulses of less than 15/fc [s] are eliminated as noise	
INT3 ES INT2 ES INT1 ES	INT3 to INT1 edge select	0: Rising edge 1: Falling edge	

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

Figure 1-20. External Interrupt Control Register

1.6 Reset Circuit

The 86C829/H29/M29 have four types of reset generation procedures: an external reset input, an address trap reset output, a watchdog timer reset output and a system clock reset output. Table 1-7 shows on-chip hardware initialization by reset action.

The malfunction reset output circuit such as watchdog timer reset, address trap reset and system clock reset is not initialized when power is turned on. The $\overline{\text{RESET}}$ pin can output level "L" at the maximum 24/fc[s] (1.5 μs at 16.0 MHz) when power is turned on.

Table 1-4. Initializing Internal Status by Reset Action

On-chip hardware	Initial value	On-chip hardware	Initial value
Program counter (PC)	($FFFE_H$)	Prescaler and Divider of timing generator	0
Stack pointer (SP)	not initialized		
General-purpose registers (W, A, B, C, D, E, H, L)	not initialized		
Jump status flag (IF)	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		
		RAM	not initialized

1.6.1 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/fcgck [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 FFFE to $FFFF_H$.

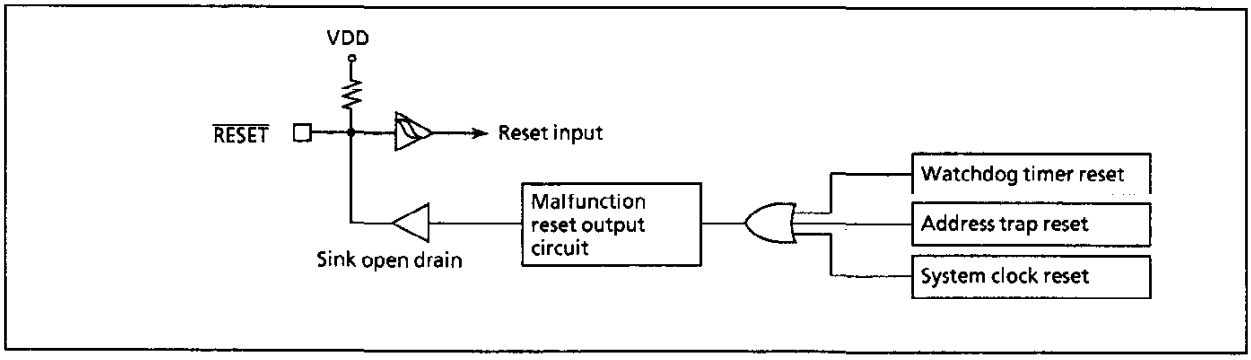
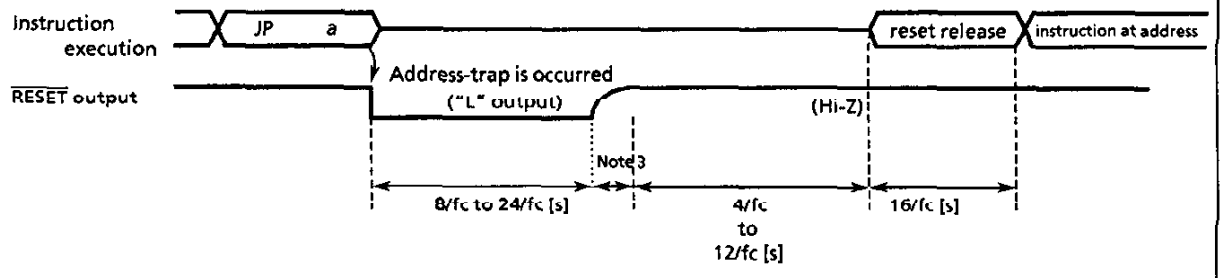


Figure 1-21. Reset Circuit

1.6.2 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 or the SFR area, address-trap-reset will be generated. Then, the $\overline{\text{RESET}}$ pin output will go low. The reset time is about 8/fc to 24/fc [s] (0.5 to 1.5 μs at 16.0 MHz).



Note 1: Address "a" is in the SFR or on-chip RAM space.
Note 2: During reset release, reset vector "r" is read out, and an instruction at address "r" is fetched and decoded.
Note 3: Varies on account of external condition: voltage or Capacitance

Figure 1-22. Address-Trap-Reset

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

1.6.3 Watchdog Timer Reset

Refer to Section "2.4 Watchdog Timer".

1.6.4 System-Clock-Reset

Clearing both XEN and XTEN (bits 7 and 6 in SYSCR2) to "0", clearing XEN to "0" when SYSCK = 0, or clearing XTEN to "0" when SYSCK = 1 stops system clock, and causes the microcomputer to deadlock. This can be prevented by automatically generating a reset signal whenever XEN = XTEN = 0, XEN = SYSCK = 0, or XTEN = 0 / SYSCK = 1 is detected to continue the oscillation. The, the $\overline{\text{RESET}}$ pin output goes low from high-impedance. The reset time is about 8/fc to 24/fc [s] (0.5 to 1.5 μs at 16.0 MHz).

2. On-Chip Peripherals Functions

2.1 Special Function Register (SFR)

The TMP86C829/H29/M29 adopt the memory mapped I/O system, and all peripheral control and data transfers are performed through the special function register (SFR). The SFR is mapped on address 0000_H to $003F_H$, DBR is mapped on address $0F80_H$ to $0FFF_H$.
Figure 2-1 (a) to 2-1 (c) indicate the special function register (SFR) and data buffer register (DBR) for TMP86C829/H29/M29.

Address	Read	Write
0000_H	reserved	
01	P1DR (P1 Port output latch)	
02	P2DR (P2 Port output latch)	
03	P3DR (P3 Port output latch)	
04	P3OUTCR (P3 Port output circuits select register)	
05	P5DR (P5 Port output latch)	
06	P6DR (P6 Port output latch)	
07	P7DR (P7 Port output latch)	
08	P1PRD (P1 Terminal input)	–
09	P2PRD (P2 Terminal input)	–
0A	P3PRD (P3 Terminal input)	–
0B	P5PRD (P5 Terminal input)	–
0C	P6CR (P6 Port input/output control)	
0D	P7PRD (P7 Terminal input)	–
0E	ADCCR1 (A/D control register A)	
0F	ADCCR2 (A/D control register B)	
10	$TREG1A_L$	
11	$TREG1A_M$ (Timer register 1 A)	
12	$TREG1A_H$	
13	TREG1B (Timer register1B)	
14	TC1CR1 (Timer Counter 1 control)	
15	TC1CR2 (Timer Counter 1 control)	
16	TC1SR (TC1 Status)	–
17	reserved	
18	TC3CR (Timer Counter 3 control)	
19	TC4CR (Timer Counter 4 control)	
1A	TC5CR (Timer Counter 5 control)	
1B	TC6CR (Timer Counter 6 control)	
1C	TTREG3 (Timer register 3)	
1D	TTREG4 (Timer register 4)	
1E	TTREG5 (Timer register 5)	
1F	TTREG6 (Timer register 6)	

Address	Read	Write
0020_H	ADCDR1 (A/D converter register 1)	–
21	ADCDR2 (A/D converter register 2)	–
22	reserved	
23	reserved	
24	reserved	
25	UARTSR (UART Status register)	UARTCR1 (UART control register 1)
26	–	UARTCR1 (UART control register 2)
27	reserved	
28	LCDCR (LCD Control register)	
29	P1LCR (P1 Control register)	
2A	P5LCR (P5 Control register)	
2B	P7LCR (P7 Control register)	
2C	PWREG3 (Timer register 3)	
2D	PWREG4 (Timer register 4)	
2E	PWREG5 (Timer register 5)	
2F	PWREG6 (Timer register 6)	
30	reserved	
31	reserved	
32	reserved	
33	reserved	
34	–	WDTCR1 (watch dog timer control)
35	–	WDTCR2 (watch dog timer control)
36	TBTCR (TBT/TG/DVO control)	
37	EINTCR (External interrupt control)	
38	SYSCR1 (System control 1)	
39	SYSCR2 (System control 2)	
3A	EIR_L (Interrupt enable register)	
3B	EIR_H (Interrupt enable register)	
3C	IL_L (Interrupt latch)	
3D	IL_H (Interrupt latch)	
3E	INTSEL (Interrupt source selector)	
3F	PSW (Program Status word)	

Figure 2-1 (a). The Special Function Register (SFR) for TMP86C829/H29/M29

Address	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
$0F80_H$	SEG1				SEG0			
81	SEG3				SEG2			
82	SEG5				SEG4			
83	SEG7				SEG6			
84	SEG9				SEG8			
85	SEG11				SEG10			
86	SEG13				SEG12			
87	SEG15				SEG14			
88	SEG17				SEG16			
89	SEG19				SEG18			
8A	SEG21				SEG20			
8B	SEG23				SEG22			
8C	SEG25				SEG24			
8D	SEG27				SEG26			
8E	SEG29				SEG28			
8F	SEG31				SEG30			

Address	Read	Write
0090_H	SIOBR0 (SIO Buffer 0)	
91	SIOBR1 (SIO Buffer 1)	
92	SIOBR2 (SIO Buffer 2)	
93	SIOBR3 (SIO Buffer 3)	
94	SIOBR4 (SIO Buffer 4)	
95	SIOBR5 (SIO Buffer 5)	
96	SIOBR6 (SIO Buffer 6)	
97	SIOBR7 (SIO Buffer 7)	
98	–	SIOCR1 (SIO Control register 1)
99	SIOSR (SIO Status register)	SIOCR2 (SIO Control register 2)
9A	–	STOPCR (Key On Wake Up Control register)
9B	RDBUF (uart received data buffer)	TDBUF (uart transmited data buffer)
9C	reserved	
9D	reserved	
9E	reserved	
0FFF	reserved	

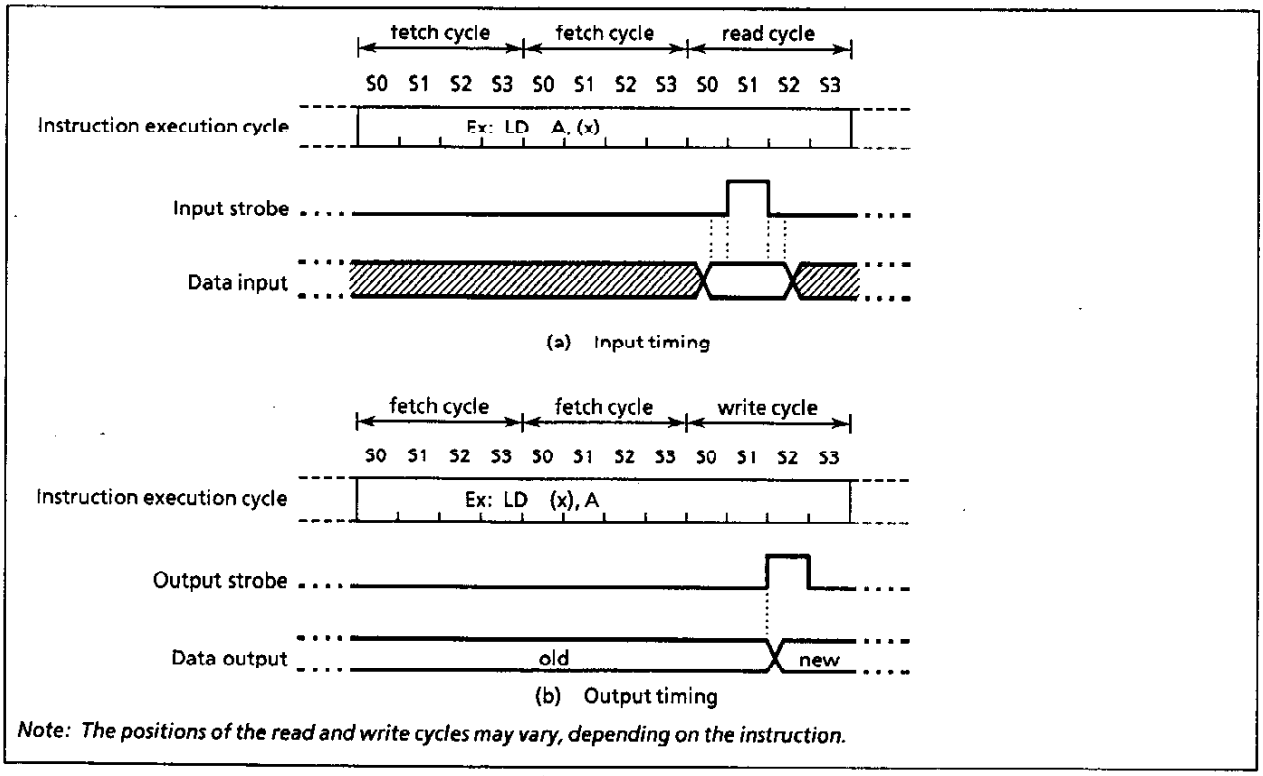
Figure 2-1 (c). The Data Buffer Register (DBR) for TMP86C829/H29/M29

2.2 I/O Ports

The 86C829/H29/M29 have 5 parallel input/output ports (39 pins) as follows.

	Primary Function	Secondary Functions
Port P1	8-bit I/O port	External interrupt input, serial interface input / output, UART input/output and segment output.
Port P2	3-bit I/O port	Low-frequency resonator connections, external interrupt input, STOP mode release signal input.
Port P3	4-bit I/O port	Timer / counter input / output and divider output.
Port P5	8-bit I/O port	Segment output.
Port P6	8-bit I/O port	Analog input, external interrupt input, timer/counter input and STOP mode release signal input.
Port P7	8-bit I/O port	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 2-2 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 2-2. Input / Output Timing (Example)

2.2.1 Port P1 (P17 to P10)

Port P1 is an 8-bit input/output port which is also used as an external interrupt input, serial interface input/output, UART input/output and segment output of LCD. When used as a segment pins of LCD, the respective bit of P1LCR should be set to "1".

When used as an input port or a secondary function (except for segment) pins, the respective output latch (P1DR) should be set to "1" and its corresponding P1LCR bit should be set to "0". When used as an output port, the respective P1LCR bit should be set to "0". During reset, the output latch is initialized to "1".

P1 port output latch (P1DR) and P1 port terminal input (P1PRD) are located on their respective address.

When read the output latch data, the P1DR should be read and when read the terminal input data, the P1PRD register should be read.

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

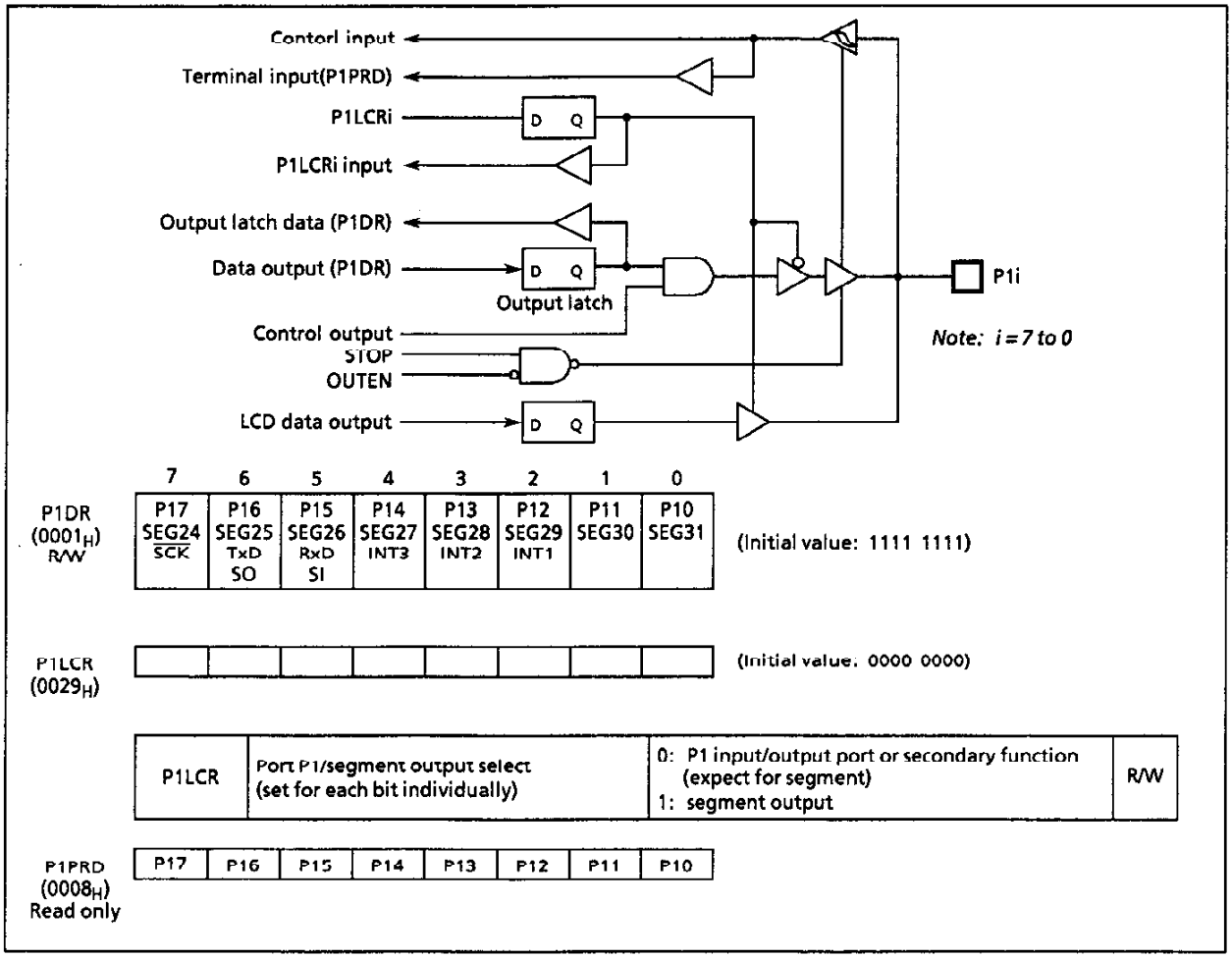


Figure 2-3. Port 1

2.2.2 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.

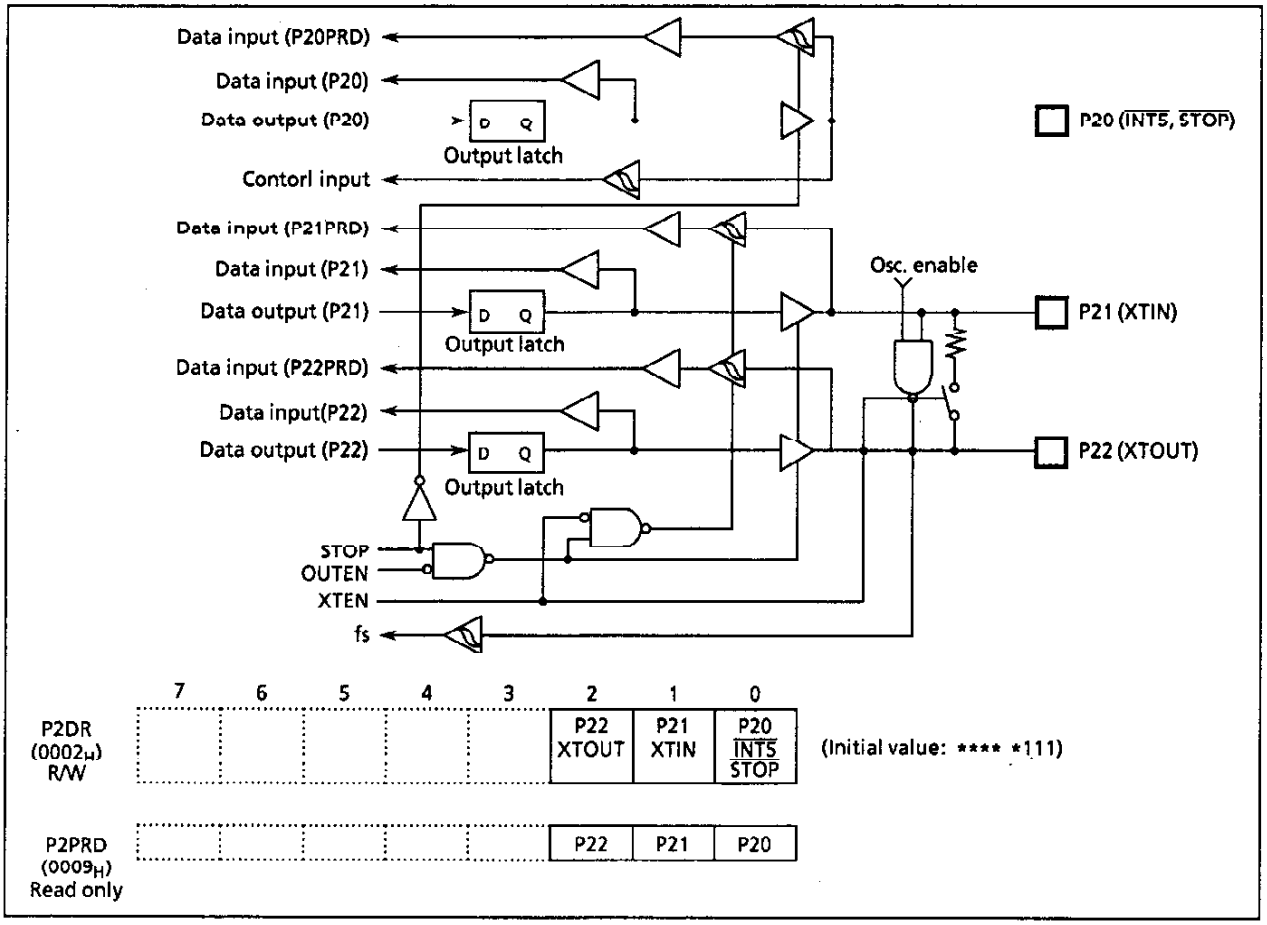


Figure 2-4. Port 2

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

2.2.3 Port P3 (P33 to P30)

Port P3 is a 4-bit input/output port.
It is also used as a timer/counter input/output, divider output output.
When used as an input port or a secondary function pins, respective output latch (P3DR) should be set to "1".
During reset, the P3DR is initialized to "1". It can be selected whether output circuit of P3 port is Push-pull port 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 push-pull output.
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. If a read instruction is executed for port P3, read data of bits 7 to 4 are unstable.

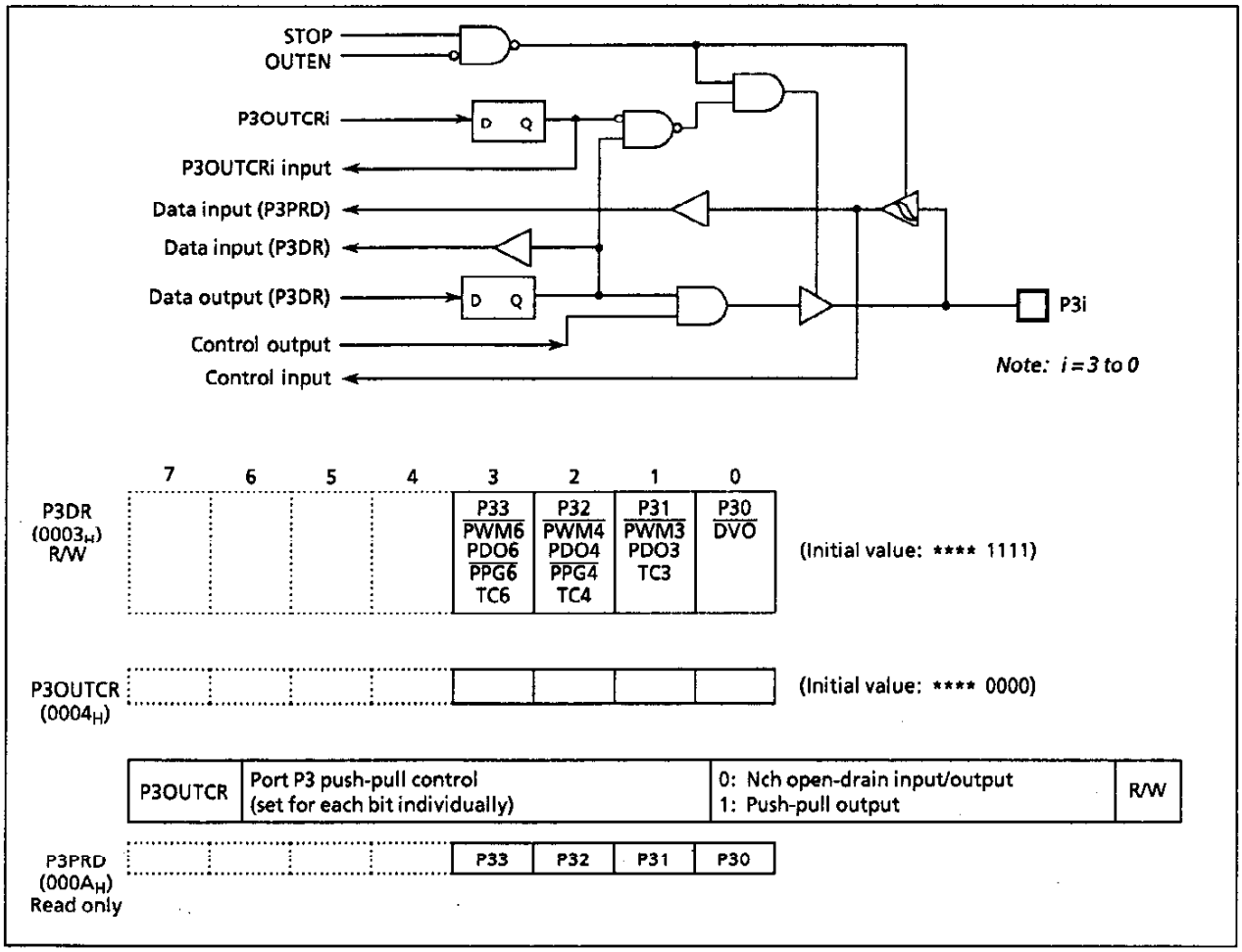


Figure 2-5. Port 3

2.2.4 Port P5 (P57 to P50)

Port P5 is an 8-bit input / output port which is also used as a segment pins of LCD.
When used as input port, the respective output latch (P5DR) should be set to "1".
During reset, the P5DR is initialized to "1".
When used as a segment pins of LCD, the respective bit of P5LCR should be set to "1" and its corresponding LCR bit should be set to "0". When used as an output port, the respective LCR bit should be set 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.

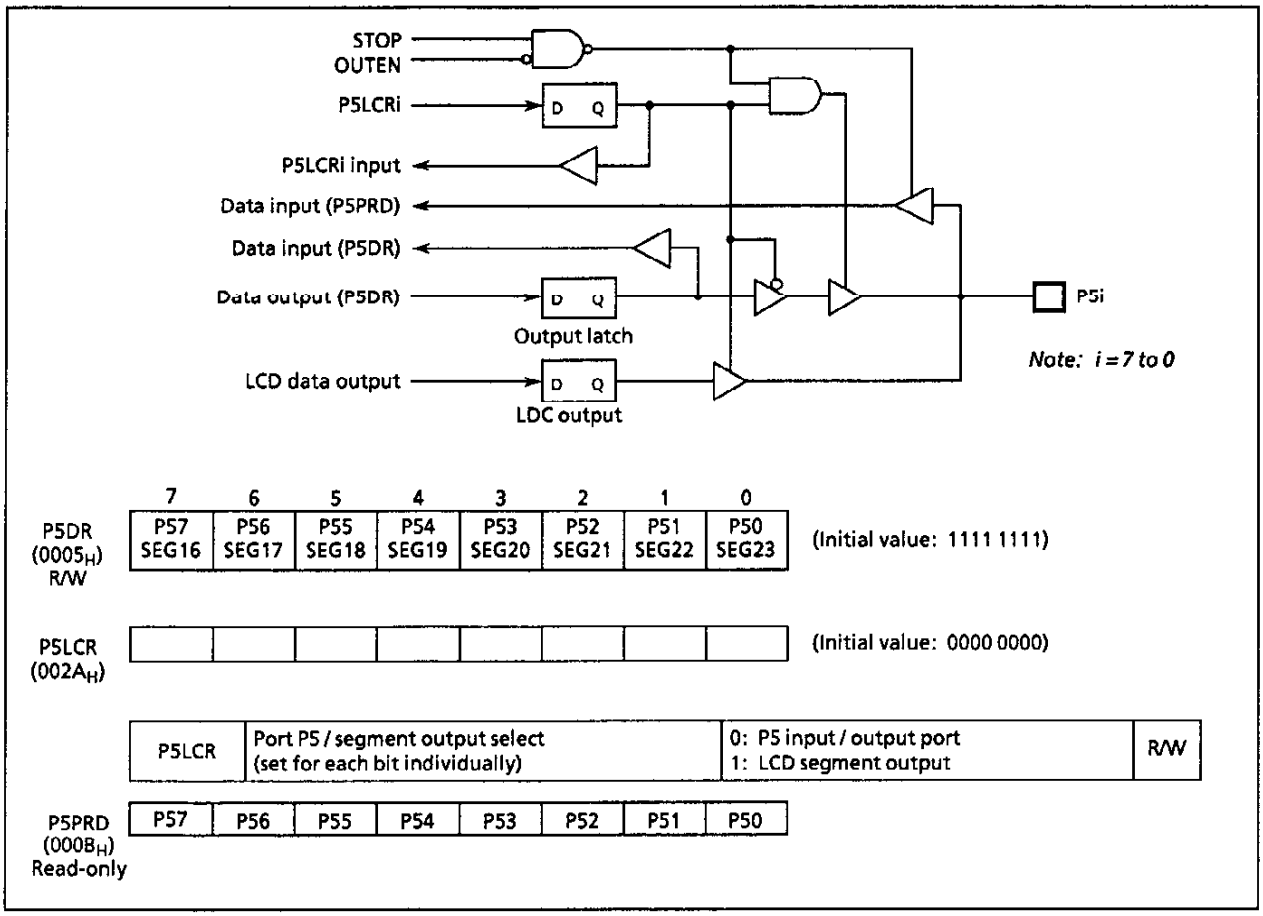


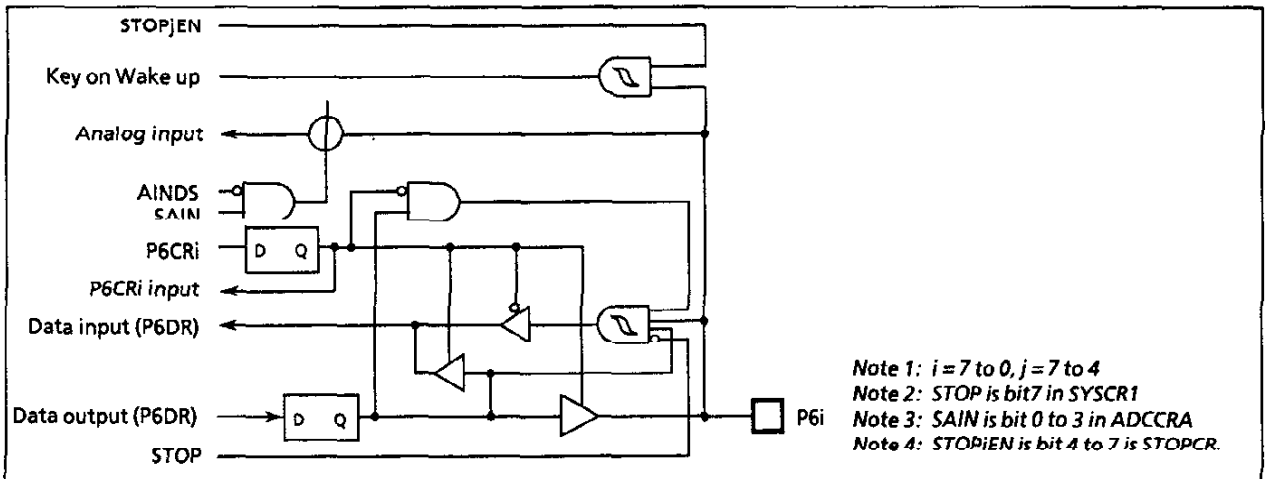
Figure 2-6. Port 5

2.2.5 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 one-bit unit. Port P6 is also used as an analog input, Key on Wake up input, Timer / counter input and external interrupt input. Input / output mode is specified by the P6 control register (P6CR), the P6 output latch (P6DR), and AINDS (bit 4 in ADCCR1). During reset, P6CR and P6DR are initialized to "0" and AINDS is set to "1". At the same time, pins P67 to P60 are fixed to "0" level. To use port P6 as an input port, set data of P6DR to "1" and P6CR to "0". To use it as an output port, set data of P6CR to "1". To use it as an analog input, set data of P6DR to "0" and P6CR to "0", and start the A/D. It is the penetration electric current measures by the analog voltage.

Pins not used for analog input can be used as I/O ports. During A/D 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 A/D conversion.

When the A/D converter is in use (P6DR=0), bits mentioned above are read as "0" by executing input instructions.



P6DR (0006_H) R/W

7	6	5	4	3	2	1	0
P67 AIN7 STOP5	P66 AIN6 STOP4	P65 AIN5 STOP3	P64 AIN4 STOP2	P63 AIN3 INT0	P62 AIN2 ECNT	P61 AIN1 ECIN	P60 AIN0

(Initial value: 0000 0000)

P6CR ($000C_H$)

7	6	5	4	3	2	1	0

(Initial value: 0000 0000)

P6CR	I/O control for port P6 (specified for each bit)		AINDS = 1 (A/D unused)		AINDS = 0 (A/D used)		R/W
			P6DR = "0"	P6DR = "1"	P6DR = "0"	P6DR = "1"	
		0	Input "0" fixed	Input mode	A/D input	Input mode	
		1	Output mode		Output mode		

Note 1: Port P6 can be set to the output mode even if it is used as an analog input. Note that a collision with external signals may occur.

Note 2: When used as an $\overline{INT0}$, ECNT and ECIN pins of a secondary function, the respective bit of P6CR should be set to "0" and the P6 should set to "1".

Note 3: When used as an STOP2 to STOP5 pins of Key on Wake up, the respective bit of P6CR should be set to "0".

Note 4: When a read instruction for port P6 is executed, the bit of Analog input mode becomes read data "0".

Figure 2-7. Port 6 and P6CR

Note: When used as Input or Analog input mode (case of these mode are used 1 bit or more), P6DR should not use Read-modify-write instruction.
Read-modify-write instruction writes the all data of 8-bit after data is read and modified. Because a bit setting Input mode read data of terminal, the output latch is changed by these instruction. So P6 port can not input data.

2.2.6 Port P7 (P77 to P70)

Port P7 is an 8-bit input / output port which is also used as a segment pins of LCD.
When used as input port, the respective output latch (P7DR) should be set to "1".
During reset, the P7DR is initialized to "1".
When used as a segment pins of LCD, the respective bit of P7LCR should be set to "1" and its corresponding P7LCR bit should be set to "0". When used as an output port, the respective P7LCR bit should be set 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.

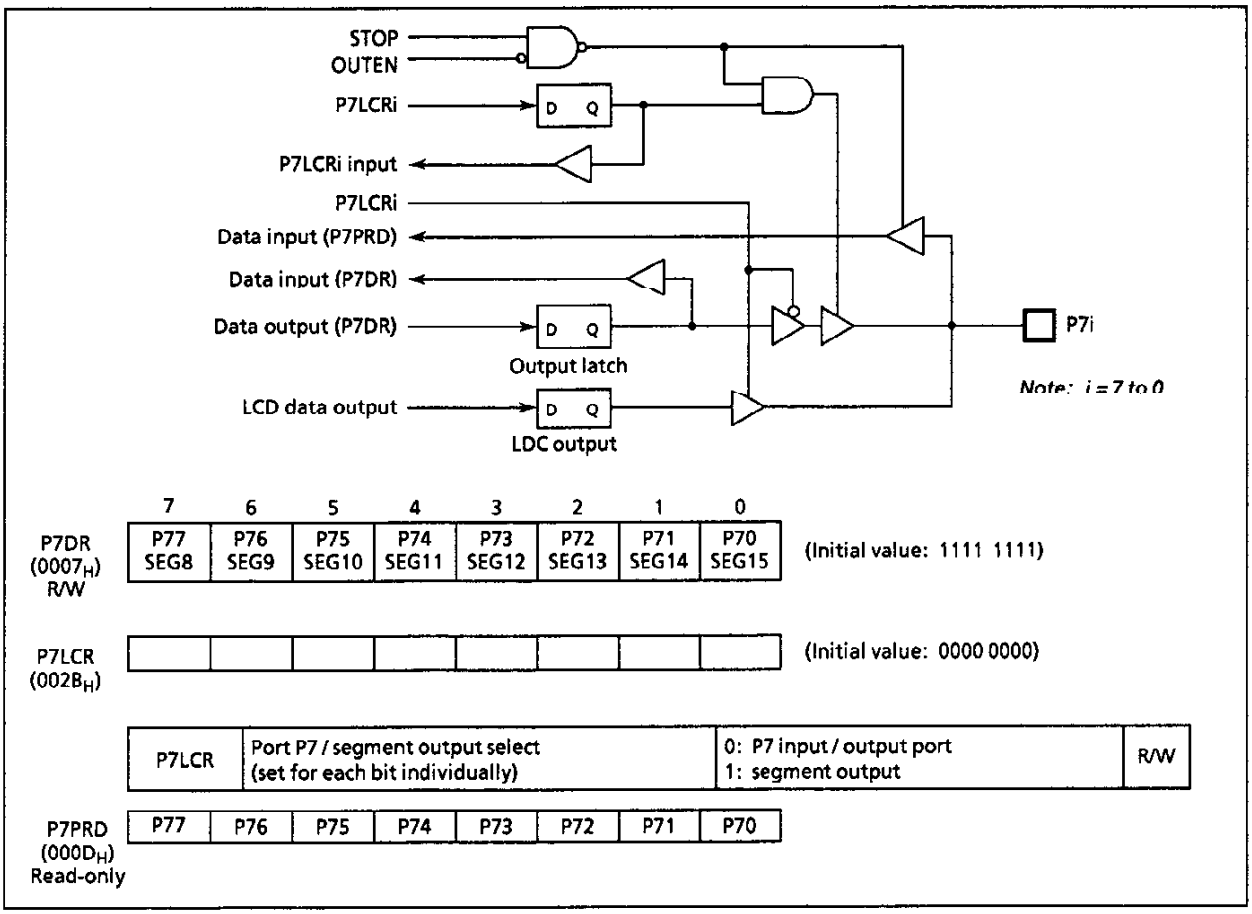


Figure 2-8. Port 7

2.3 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).

An INTTBT is generated on the first rising edge of source clock (the divider output of the timing generator) after the 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 2-9.(b)).

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

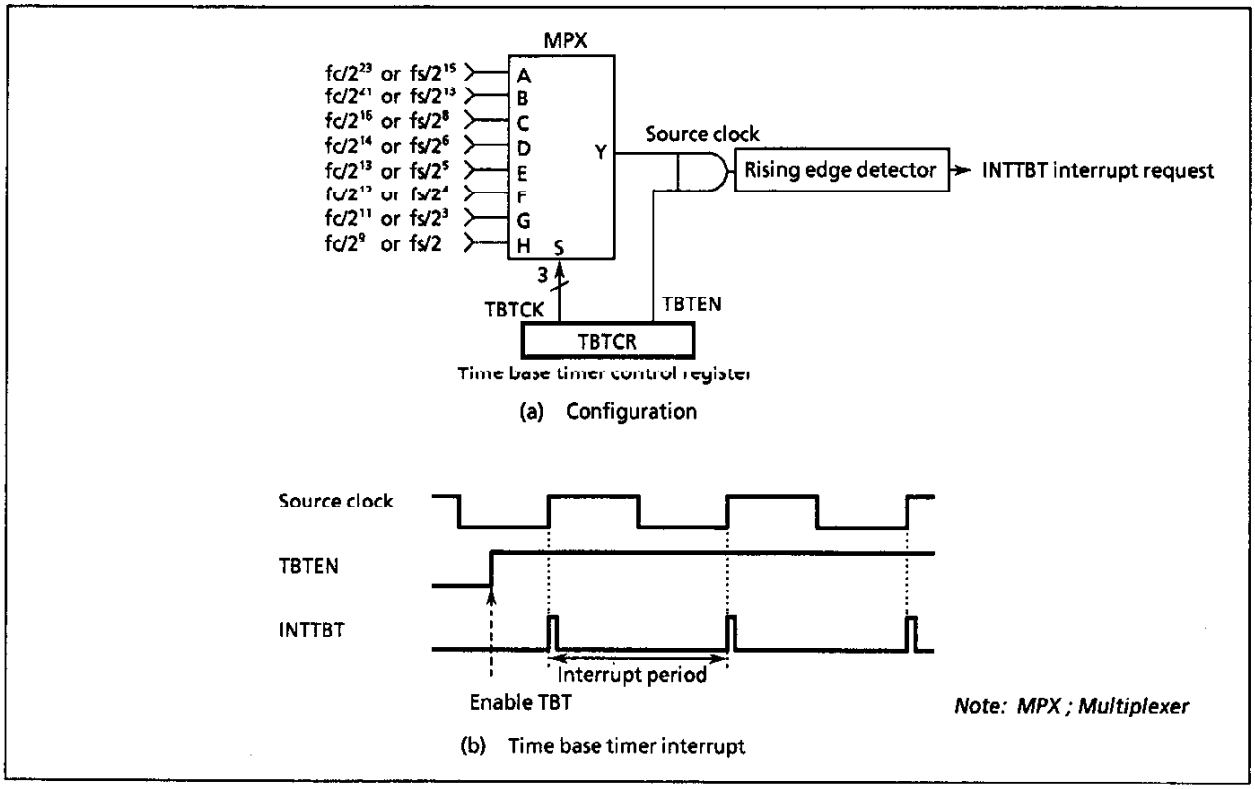


Figure 2-9. Time Base Timer

Example: Sets the time base timer frequency to fc/2^{16} [Hz] and enables an INTTBT interrupt.

```
LD    (TBTCR), 00001010B
SET   (EIRL). 6
```

TBTCR (00036_H)

7	6	5	4	3	2	1	0
(DVOEN)	(DVOCK)		(DV7CK)	TBTEN	TBTCK		

(Initial value: 0**0 0***)

TBTEN	Time base timer enable / disable	0: Disable 1: Enable			R/W
TBTCK	Time base timer interrupt frequency select [Hz]		NORMAL1/2, IDLE1/2 mode	SLOW, SLEEP mode	
			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: fc ; High-frequency clock [Hz], fs ; Low-frequency clock [Hz], * ; Don't care*

Figure 2-10. Time Base Timer Control Register

Table 2-1. 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		SLOW, SLEEP mode
	DV7CK = 0	DV7CK = 1	
000	2.38	1	1
001	9.54	4	4
010	305.18	128	–
011	1220.70	512	–
100	2441.41	1024	–
101	4882.81	2048	–
110	9765.63	4096	–
111	39062.50	16384	–

2.4 Watchdog Timer (WDT)

The watchdog timer is a fail-safe system to rapidly detect the CPU malfunctions such as endless looping caused by noise or the like, or deadlock and resume the CPU to the normal state.

The watchdog timer signal for detecting malfunction can be selected either a reset output or a non-maskable interrupt request. However, selection is possible only once after reset. At first the reset output is selected.

When the watchdog timer is not being used for malfunction detection, it can be used as a timer to generate an interrupt at fixed intervals.

2.4.1 Watchdog Timer Configuration

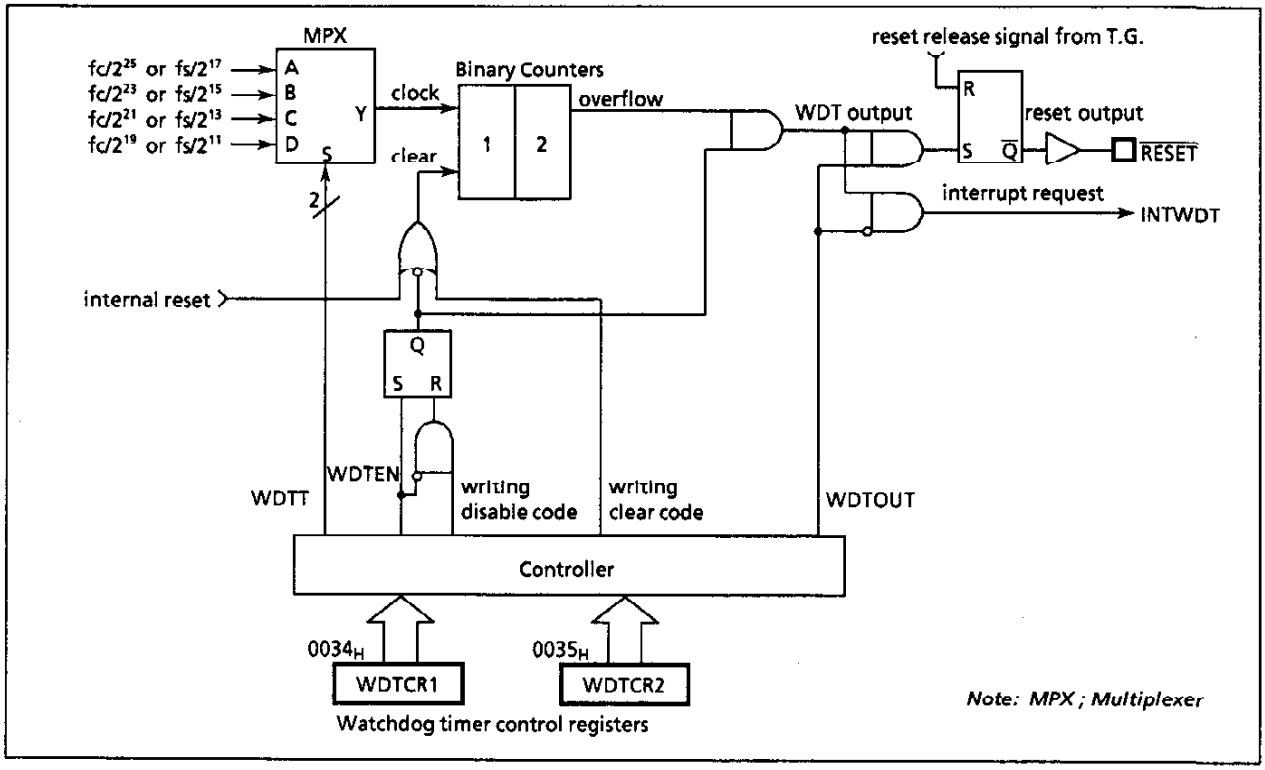


Figure 2-11. Watchdog Timer Configuration

2.4.2 Watchdog Timer Control

Figure 2-12 shows the watchdog timer control registers (WDTCR1, WDTCR2). The watchdog timer is automatically enabled after reset.

(1) *Malfunction detection methods using the watchdog timer*

The CPU malfunction is detected at follows.

① Setting the detection time, selecting output, and clearing the binary counter.

② Repeatedly clearing the binary counter within the setting detection time

> *Note: Clears the binary counter does not clear the source clock.*
> *It is recommended that the time to clear is set to 3/4 of the detecting time*

If the CPU malfunctions such as endless looping or deadlock occur for any cause, the watchdog timer output will become active at the rising of an overflow from the binary counters unless the binary counters are cleared. At this time, when WDTOUT = 1 a reset is generated, which drivers the $\overline{\text{RESET}}$ pin low to reset the internal hardware and the external circuit. When WDTOUT = 0, a watchdog timer interrupt (INTWDT) is generated.
The watchdog timer temporarily stops counting in STOP mode including warm-up or IDLE mode, and automatically restarts (continues counting) when the STOP / IDLE mode is released.

Example: Sets the watchdog timer detection time to 2^{21}/fc [s] and resets the CPU malfunction.

```
                LD(WDTCR2), 4EH          ; Clears the binary counters
                LD(WDTCR1), 00001101B    ; WDTT ← 10, WDTOUT ← 1
               ┌LD(WDTCR2), 4EH          ; Clears the binary counters
Within 3/4 of WDT                        (always clear immediately before and after
detection time │                         changing WDTT)
               └
               ┌LD(WDTCR2), 4EH          ; Clears the binary counters
Within 3/4 of WDT
detection time │
               └LD(WDTCR2), 4EH          ; Clears the binary counters
```

Watchdog Timer Register 1

WDTCR1 (0034_H)

7	6	5	4	3	2	1	0
		ATAS	ATOUT	WDT EN	WDTT		WDT OUT

(Initial value: **11 1001)

WDTEN	Watchdog timer enable / disable	0: Disable (It is necessary to write the disable code to WDTCR2) 1: Enable			Write-only
WDTT	Watchdog timer detection time [s]		NORMAL1/2 mode		SLOW mode
			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 output			

Note 1: WDTOUT cannot be set to "1" by program after clearing WDTOUT to "0".
*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.
Note 4: The watchdog timer must be disabled or the counter must be cleared immediately before entering to the STOP mode. When the counter is cleared, the counter must be cleared again immediately after releasing the STOP mode.

Watchdog Timer Register 2

WDTCR2 (0035_H)

7	6	5	4	3	2	1	0

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

WDTCR2	Watchdog timer control code write register	$4E_H$: Watchdog timer binary counter clear (clear code) $B1_H$: Watchdog timer disable (disable code) D2: Enable assigning address trap area Others: Invalid	Write-only

Note 1: The disable code is invalid unless written when 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: Clears the binary counter does not clear the source clock.
It is recommended that the time to clear is set to 3/4 of the detecting time

Figure 2-12. Watchdog Timer Control Registers

(2) Watchdog timer enable

The watchdog timer is enabled by setting WDTEN (bit 3 in WDTCR1) to "1". WDTEN is initialized to "1" during reset, so the watchdog timer operates immediately after reset is released.

(3) Watchdog timer disable

The watchdog timer is disabled by writing the disable code ($B1_H$) to WDTCR2 after clearing WDTEN (bit 3 in WDTCR1) to "0". The watchdog timer is not disabled if this procedure is reversed and the disable code is written to WDTCR2 before WDTEN is cleared to "0". During disabling the watchdog timer, the binary counters are cleared to "0".

Example: Disables watchdog timer

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

Table 2-2. 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	254.288 m	1	1
10	131.072 m	250 m	250 m
11	32.768 m	62.5 m	62.5 m

2.4.3 Watchdog Timer Interrupt (INTWDT)

This is a pseudo non-maskable interrupt which can be accepted regardless of the contents of the EIR. If a watchdog timer interrupt or a software interrupt is already accepted, however, the new watchdog timer interrupt waits until the previous interrupt processing is completed (the end of the [RETN] instruction execution).
The stack pointer (SP) should be initialized before using the watchdog timer output as an interrupt source with WDTOUT.

Example: Watchdog timer interrupt setting up

```
LD   SP, 0023FH              ;  Sets the stack pointer
LD   (WDTCR1), 00001000B     ;  WDTOUT ← 0
```

2.4.4 Watchdog Timer Reset

If the watchdog timer output becomes active, a reset is generated, which drivers the $\overline{\text{RESET}}$ pin (sink open drain input / output with pull-up) low to reset the internal hardware. The reset output time is about 8/fc to 24/fc [s] (0.5 to 1.5 μs at fc=16.0 MHz).

Note: The high-frequency clock oscillator also turns on when a watchdog timer reset is generated in SLOW mode. The reset output time is 8/fc to 24/fc [s]. Therefore, the reset time may include a certain amount of error if there is any fluctuation of the oscillation frequency at starting the high-frequency clock oscillation. Thus, the reset time must be considered an approximated value.

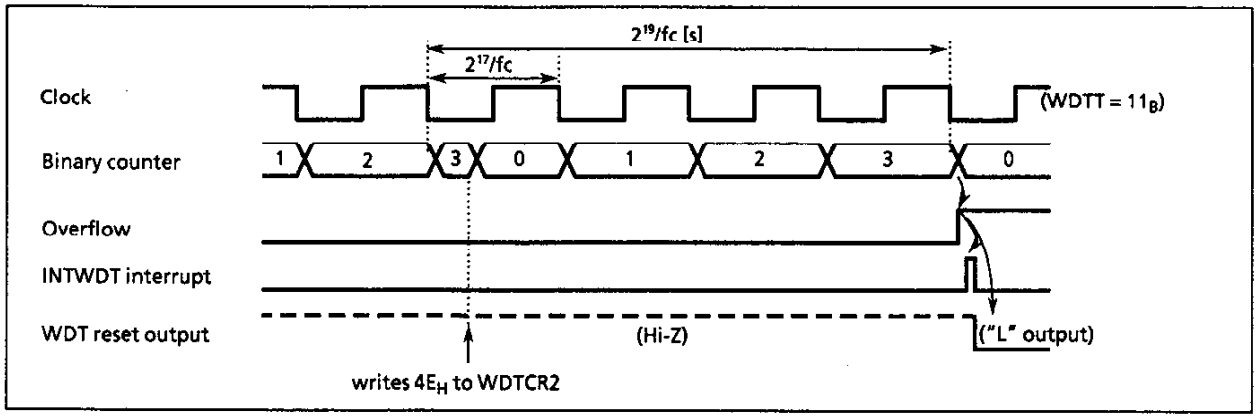


Figure 2-13. Watchdog Timer Interrupt / Reset

2.4.5 Address trap

The Watchdog Timer Control Register 1, 2 shares its addresses with the control registers in case of address trap. These control registers for address trap are shown on figure 1-16. Whether internal RAM area should be trapped or not is selected on bit ATAS on WDTCR1. The written data becomes valid after the control code D2H is written on WDTCR2. If the instructions are to be placed on internal RAM area, internal RAM area should be excepted from the area to be trapped before such instructions are executed.

The operating mode under address trapped, whether to be reset-output or interrupt processing, is selected on bit ATOUT on WDTCR1.

Example: Setting in order that the CPU normally executes instruction in internal RAM area and the address trap causes interrupt

```
LD    (WDTCR1), 0D200H
```

Watchdog Timer Control Register 1

WDTCR1 (0034_H)

7	6	5	4	3	2	1	0
-	-	ATAS	ATOUT	WDT EN	WDTT		WDT OUT

(Initial value: **11 1001)

ATAS	Area for address trap	0: SFR area only 1: SFR and RAM area (Valid if control code is written on WDTCR2)	Write-only
ATOUT	Operation in case of address trap	0: Interrupt 1: Reset	

Watchdog Timer Control Register 2

WDTCR2 (0035_H)

7	6	5	4	3	2	1	0

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

WDTCR2	Watchdog timer control code and Address trapped area control code	D2: Address trapped area valid to set (ATRAP control code) 4E: Watchdog timer binary counter clear (WDT clear code) $B1_H$: Watchdog timer disable (WDT disable code) Others: Invalid	Write-only

Figure 2-14. Watchdog Timer Control Registers

2.5 Divider Output (DVO)

Approximately 50% duty pulse can be output using the divider output circuit, which is useful for piezoelectric buzzer drive. Divider output is from pin P30 ($\overline{DVO}$). The P30 output latch should be set to "1".

TBTCR (0036_H)

7	6	5	4	3	2	1	0
DVOEN	DVOCK		(DV7CK)	(TBTEN)	(TBTCK)		

(Initial value: 0000 0000)

DVOEN	Divider output enable / disable	0: Disable (It is necessary to write the disable code to WDTCR2) 1: Enable			R/W
DVOCK	Divider output ($\overline{DVO}$) frequency selection [Hz]		NORMAL1/2 mode		SLOW, SLEEP mode
			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: fc; High-frequency clock [Hz], fs; Low-frequency clock [Hz], *; Don't care*

Figure 2-15. Divider Output Control Register

Example: 1.95 kHz pulse output (at fc = 16 MHz)

```
SET  (P3DR). 0                ;  P30 output latch ← 1
LD   (TBTCR), 10000000B       ;  DVOEN ← 1, DVOCK ← 00
```

Table 2-3. Divider Output Frequency (Example: at fc = 16.0 MHz, fs = 32.768 kHz)

DVOCK	Divider output frequency [Hz]		
	NORMAL1/2, IDLE1/2 mode		SLOW, SLEEP 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

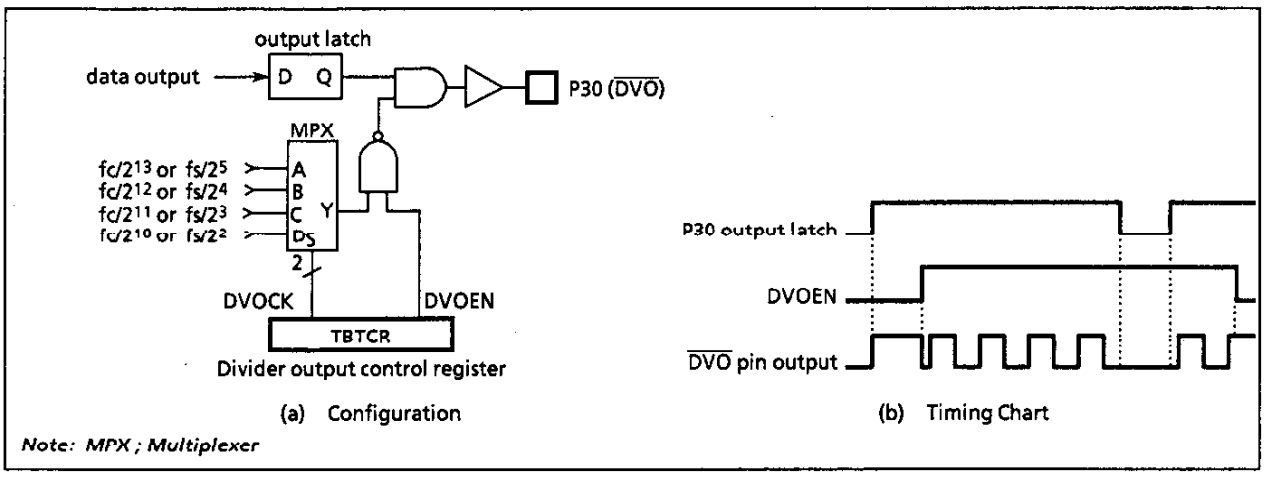


Figure 2-16. Divider Output

2.6 18-bit Timer / Counter (TC1)

2.6.1 Configuration

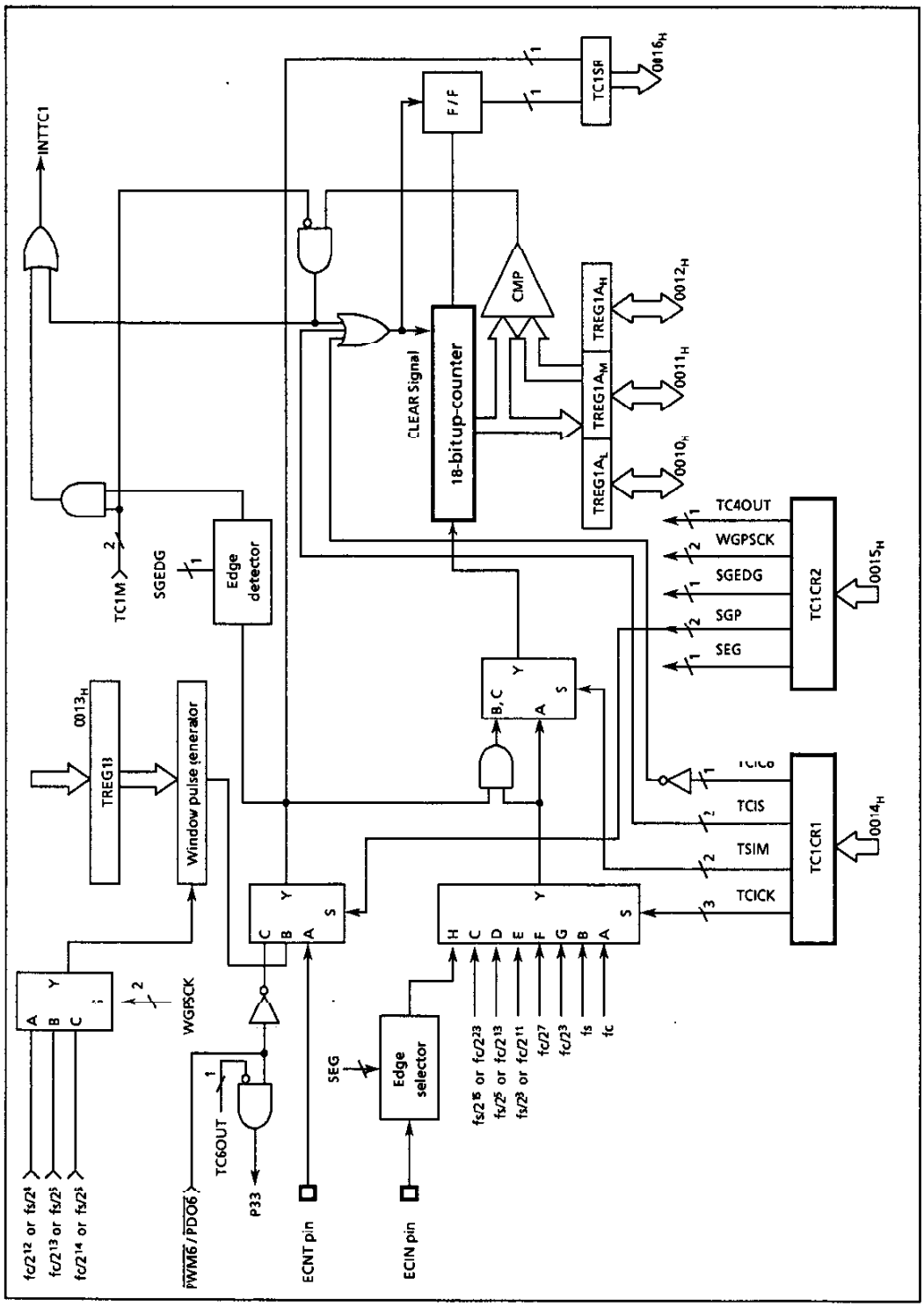


Figure 2-17. Timer / Counter 1

2.6.2 Control

The Timer/counter 1 is controlled by a timer / counter 1 control registers (TC1CR1 / TC1CR2), an 18-bit timer register (TREG1A), and an 8-bit internal window gate pulse setting register (TREG1B).

Timer register

TREG1A (0010_H, 0011_H, 0012_H)

17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$TREG1A_H$ (0012_H)		$TREG1A_M$ (0011_H)								$TREG1A_L$ (0010_H)							

Read/Write
(Initial value: 00 0000 0000 0000 0000)

Internal window gate pulse setting register

TREG1B (0013_H)

7	6	5	4	3	2	1	0
Tb				Ta			

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

Ta	Setting "H" level period of the window gate pulse	$(16 - Ta) \times 2^{13}/fc$ or $(16 - Ta) \times 2^5/fs$ [s]	R/W
Tb	Setting "L" level period of the window gate pulse	$(16 - Tb) \times 2^{13}/fc$ or $(16 - Tb) \times 2^5/fs$ [s]	

Note: WGPSCK = 01

Timer/counter 1 control register 1

TC1CR1 (0014_H)

7	6	5	4	3	2	1	0
TC1C	TC1S			TC1CK		TC1M	

(Initial value: 1001 1000)

TC1C		0: Counter / overflow flag clear request ("1" is automatically set after clearing.)	R/W
TC1S	TC1 start control	00: Stop & counter clear 10: Start *1: reserved	
TC1CK	TC1 source clock select	000: Internal clock fc [Hz] 001: Internal clock fs 010: Internal clock $fc/2^{23}$ or $fs/2^{15}$ 011: Internal clock $fc2^{13}$ or $fs/2^5$ 100: Internal clock $fc/2^{11}$ or $fs/2^3$ 101: Internal clock $fc/2^7$ 110: Internal clock $fc/2^3$ 111: External clock (ECIN pin input)	
TC1M	TC1 mode select	00: Timer / event counter mode 01: reserved 10: Pulse width measurement mode 11: Frequency measurement mode	

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

Note 2: Writing to the low-byte of the timer register 1A ($TREG1A_L$, $TREG1A_M$), the compare function is inhibited until the high-byte ($TREG1A_H$) is written.

Note 3: Set the mode, source clock, and edge (selection) when the TC1 stops (TC1S = 00).

Note 4: "fc" can be selected as the source clock only in the timer mode during SLOW mode and in the pulse width measurement mode during NORMAL 1/2 or IDLE 1/2 mode.

Figure 2-18. Timer Register / Window Gate Pulse Setting Register / Control Register of the TC1

Timer/counter 1 control register 2

TC1CR2 (0015_H)

7	6	5	4	3	2	1	0	
SEG	SGP		SGEDG	WGPSCK		TC6OUT		(Initial value: 0000 000*)

SEG	External input clock (ECIN) edge select	0: Counts at the falling edge 1: Counts at the falling / rising edges	R/W
SGP	Window gate pulse select	00: ECNT input 01: Internal window gate pulse (TREG1B) 10: $\overline{PWM6}$ / $\overline{PDO6}$ (TC6) output 11: reserved	
SGEDG	Window gate pulse interrupt edge select	0: Interrupts at the falling edge 1: Interrupts at the falling / rising edges	
WGPSCK	Window gate pulse source clock select	00: Select 2^{12}/fc or 2^4/fs 01: Select 2^{13}/fc or 2^5/fs 10: Select 2^{14}/fc or 2^6/fs 11: reserved	
TC6OUT	TC6 output (PWM6 / PDO6) external output select	0: Output to P33 1: No output to P33	

TC1 Status register

TC1SR (0016_H)

7	6	5	4	3	2	1	0	
HECF	HEOVF	"1"	"1"	"1"	"1"	"1"	"1"	(Initial value: 0011 1111)

HECF	Operating Status monitor	0: Stop (during Tb) or disable 1: Under counting (during Ta)	R/W
HEOVF	Counter overflow monitor	0: No overflow 1: Overflow status	

*Note 1: fc ; High-frequency clock [Hz] fs ; Low-frequency clock [Hz] * ; Don't care*
Note 2: Set the mode, source clock, and edge (selection) when the TC1 stops (TC1S = 00).
Note 3: If there is no need to use $\overline{PWM6}$ / $\overline{PDO6}$ as window gate pulse of TC1, always write "0" to TC6OUT.

Figure 2-19. Control Register of the TC1 / Status Register

2.6.3 Function

TC1 has four operating modes. The timer mode of the TC1 is used at warm-up when switching form SLOW mode to NORMAL2 mode.

(1) Timer mode

In this mode, counting up is performed using the internal clock. The contents of TREG1A are compared with the contents of up-counter. If a match is found, an INTTC1 interrupt is generated, and the counter is cleared. Counting up resumes after the counter is cleared.

Table 2-4. Source Clock (internal clock) of Timer / Counter 1

Source clock				Resolution		Maximum time setting	
NORMAL1/2, IDLE1/2 mode		SLOW mode	SLEEP mode	fc = 16 MHz	fs = 32.768 kHz	fc = 16 MHz	fs = 32.768 kHz
DV7CK = 0	DV7CK = 1						
$fc/2^{23}$ [Hz]	$fs/2^{15}$ [Hz]	$fs/2^{15}$ [Hz]	$fs/2^{15}$ [Hz]	0.52 s	1 s	38.2 h	72.8 h
$fc/2^{13}$	$fs/2^{5}$	$fs/2^{5}$	$fs/2^{5}$	512 μs	0.98 ms	2.2 min	4.3 min
$fc/2^{11}$	$fs/2^{3}$	$fs/2^{3}$	$fs/2^{3}$	128 μs	244 μs	0.5 min	1.07 min
$fc/2^{7}$	$fc/2^{7}$	—	—	8 μs	—	2.1 s	—
$fc/2^{3}$	$fc/2^{3}$	—	—	0.5 μs	—	131 ms	—
fc	fc	fc (Note)	—	62.5 ns	—	16.4 ms	—
fs	fs	—	—	—	30.5 μs	—	8 s

Note: fc can be used only in the timer mode (SLOW mode) and the pulse width measurement mode (NORMAL 1/2, IDLE 1/2 modes). When fc is selected for the source clock in SLOW mode, the lower bits 11 of TREG1A is invalid, and a match of the upper bits 7 makes interrupts.

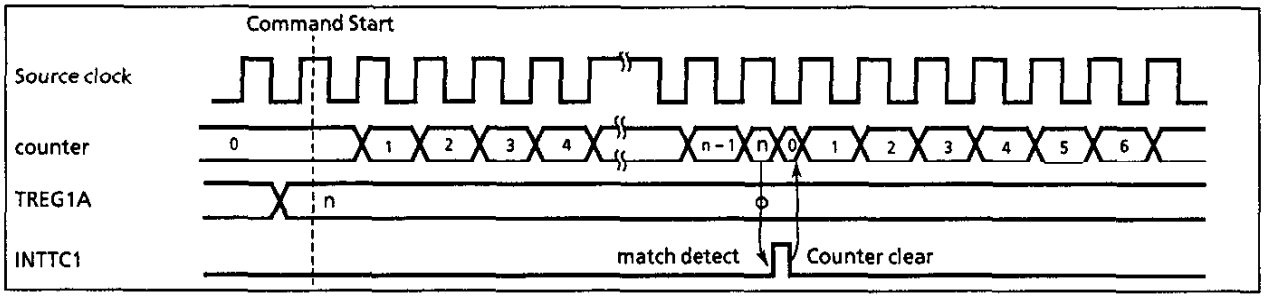


Figure 2-20. Timing Chart for Timer Mode

(2) Event Counter mode

It is a mode to count up at the falling edge of the ECIN pin input. Both edges can not be used. The countents of TREG1A are compared with the contents of up-counter. If a match is found, an INTTC1 interrupt is generated, and the counter is cleared. Counting up resums for ECIN pin input edge each after the counter is cleared. The maximum applied frequency is fc/2^4 [Hz] in NORMAL 1/2 or IDLE 1/2 mode and fs/2^4 [Hz] in SLOW or SLEEP mode.

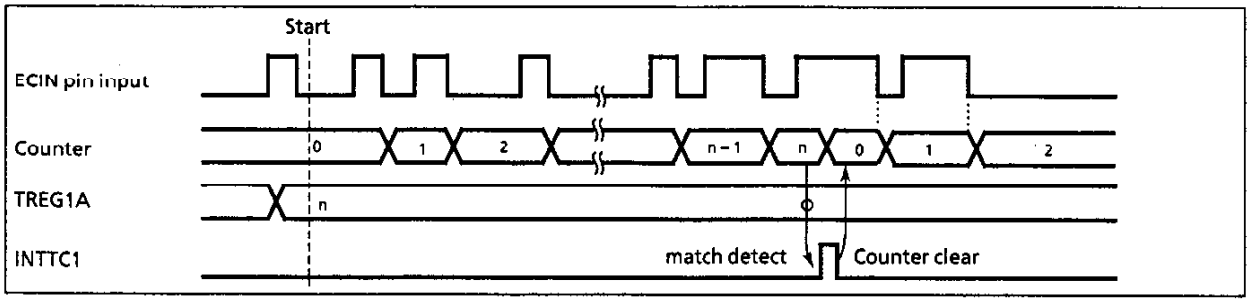


Figure 2-21. Event Counter Mode Timing Chart

(3) Pulse Width Measurement mode

In this mode, pulse widths are counted on the rising edge of logical AND-ed product between ECIN pin input (window pulse) and the internal clock. The internal clock is selected by TC1CK (bit 2, 3 and 4 in TC1CR1). An INTTC1 interrupt is generated at the falling edge of the window pulse or both rising and falling edges of the window pulse, that can be selected by SGEDG (bit 4 in TC1CR2). After reading out the contents of TREG1A by an interrupt service program, the counter is required to be cleared by TC1C (bit 7 in TC1CR1). When the counter is not cleared, counting up resumes by starting count-up. The window pulse status can be monitored by HECF (bit 7 in TC1SR) of the status register. HEOVF (bit 6 in TC1SR) of the status register can monitor whether the binary counter overflows or not. HEOVF remains the old data until the counter is required to be cleared by TC1C.

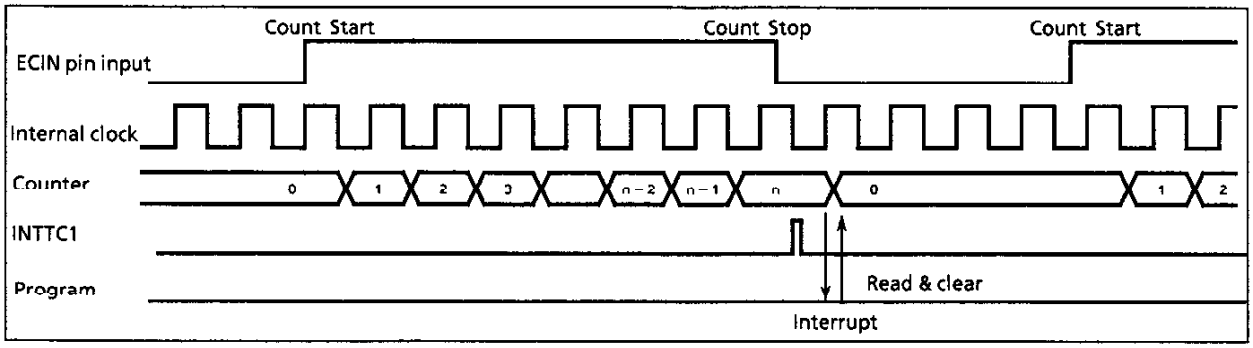


Figure 2-22. Pulse Width Measurement Mode Timing Chart

Note: INTTC1 interrupt occurs when ECIN input is "1" and TC1S of TC1CR1 is written to "00". According to the following step, when timer counter is stopped, INTTC1 interrupt latch should be cleared to "0".

```
TC1STOP:  ⋮
          DI                          ; Clear IMF
          CLR   (EIRH). EF8           ; Clear EF8
          LD    (TC1CR1), 0y00011110  ; Stop timer counter 1
          LD    (ILH), 0y11111110     ; Clear IL8
          SET   (EIRH). EF8           ; SET EF8
          EI                          ; SET IMF
```

(4) Frequency Measurement mode

In This mode, the frequency of ECIN pin input pulse is measured. TC1CK is required to be set to the external clock. The edge of the input pulse is counted during "H" level of the window gate pulse selected by SGP (bit 5 and 6 in TC1CR2). Whether the input pulse is counted on the falling edge or the both edges can be selected by SEG (bit 7 in TC1CR2). An INTTC1 interrupt is generated on the falling edge or both the rising / falling edges of the window gate pulse, that can be selected by SGEDG (bit 4 in TC1CR2). After reading out the contents of TREG1A by the interrupt service program, the counter is required be cleared by TC1C. When the counter is not cleared, counting up resumes by stating count-up. The window pulse status can be monitored by HECF of the status register. HEOVF of the status register can monitor whether the binary counter overflows or not. In the overflow flag status, a new data is not input until the counter clear requests.

- Using TC6 output ($\overline{PWM6}$ / $\overline{PDO6}$) for the window gate pulse can select whether $\overline{PWM6}$ / $\overline{PDO6}$ is output to the external port (P33) (initial output) in TC6OUT (bit 1 in TC1CR2).
- When the internal window gate pulse is selected, the window gate pulse is set as follows. The internal window gate pulse consists of "H" level period (Ta) that is counting time and "L" level period (Tb) that is counting stop time. Ta or Tb can be individually set by TREG1B. One cycle contains Ta + Tb.

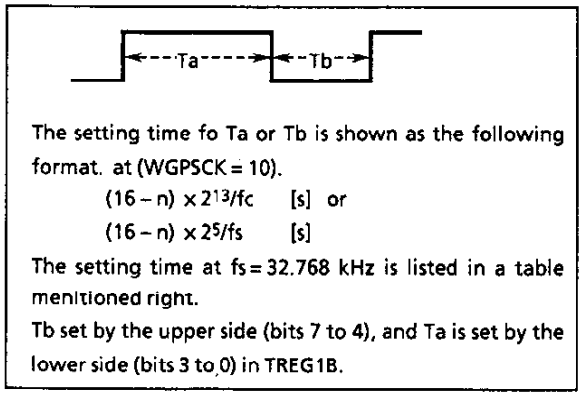


Figure 2-23. Window Gate Pulse Format

Tabale 2-5. Setting Ta and Tb

Setting value	Setting time	Setting value	Setting time
0	31.25 ms	8	15.63 ms
1	29.30 ms	9	13.67 ms
2	27.34 ms	A	11.72 ms
3	25.39 ms	B	9.77 ms
4	23.44 ms	C	7.81 ms
5	21.48 ms	D	5.86 ms
6	19.53 ms	E	3.91 ms
7	17.58 ms	F	1.95 ms

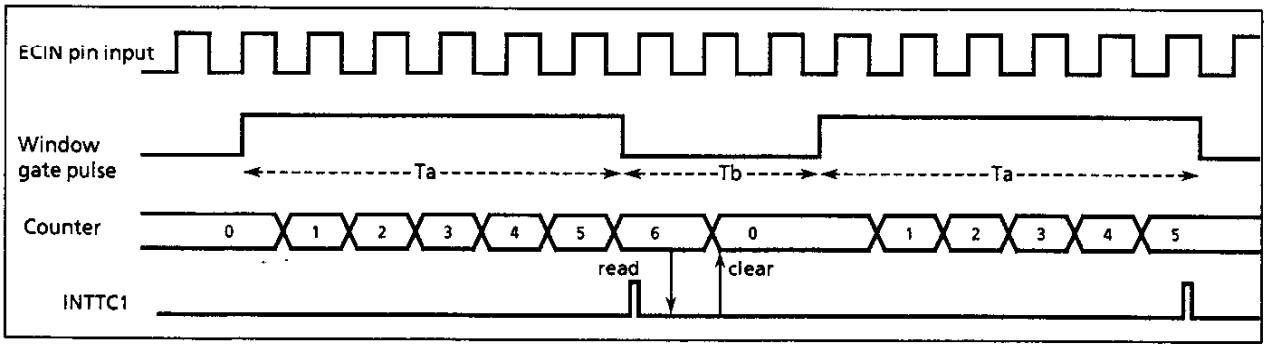


Figure 2-24. Timing Chart for the Frequency Measurement Mode (ECIN falling edge count, window gate pulse falling interrupt)

2.7 8-bit Timer / Counter (TC3, 4, 5, 6)

The 86C829/H29/M29 have four channels of 8-bit timer/counter (TC3, 4, 5, 6). These timer/counter are used as timer, event counter, PWM, PPG and PDO. These are also available as a 16-bit timer / counter by cascade connection.

2.7.1 Configuration

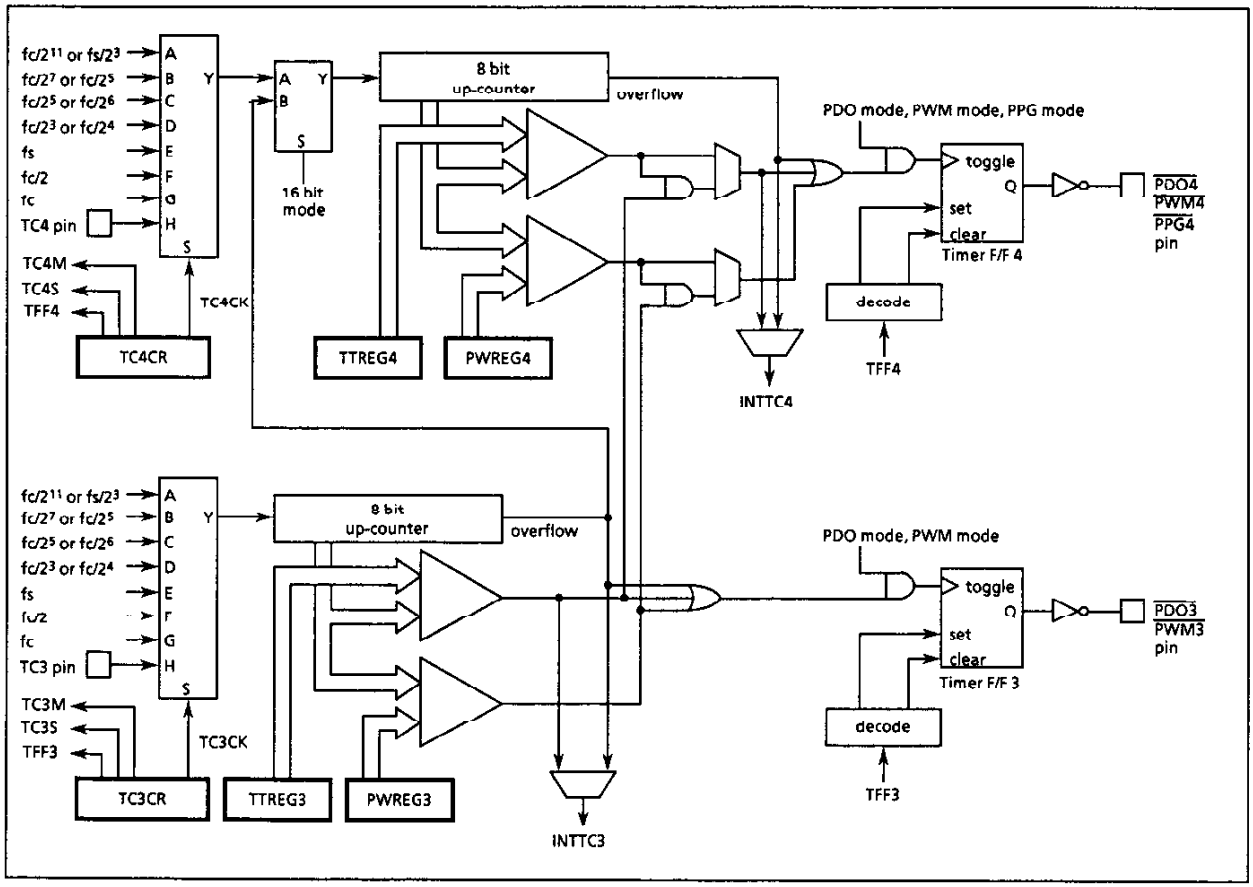


Figure 2-25. 8 bit Timer 3, 4

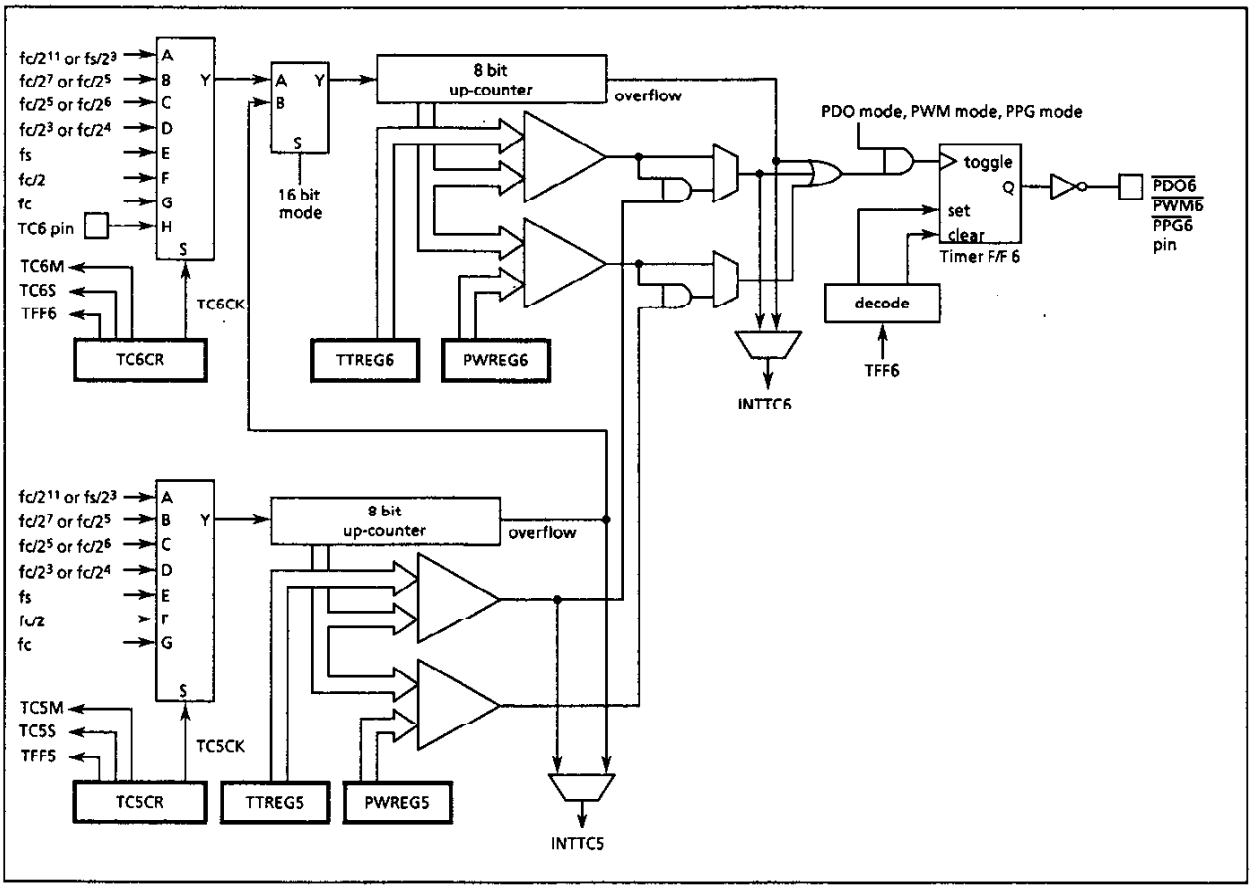


Figure 2-26. 8 bit Timer 5, 6

2.7.2 Control

The timer / counter 3 is controlled by a timer / counter 3 control register (TC3CR) and two 8-bit timer registers (TTREG3 and PWREG3).

Timer Register

	7	6	5	4	3	2	1	0	
TTREG3 ($001C_H$)									(Initial value: 1111 1111)
PWREG3 ($002C_H$)									(Initial value: 1111 1111)

Timer / counter 3 control register

	7	6	5	4	3	2	1	0	
TC3CR (0018_H)	TFF3		TC3CK		TC3S		TC3M		(Initial value: 0000 0000)

TFF3	Timer F/F3 contorl	0: clear 1: set				R/W
TC3CK	TC3 source clock select [Hz]		NORMAL1/2,IDLE1/2 mode		SLOW1/2, SLEEP1/2 mode	
			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 (Note9)	fs (Note9)	fs	
		101	fc/2	fc/2	–	
		110	fc	fc	fc (Note10)	
		111	TC3 pin input			
TC3S	TC3 start control	0: stop 1: command start				
TC3M	TC3 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) mode 011: 16 bit mode (Mode seleiction is controlled by TC4M) 1**: reserved				

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

Note 2: During TC3 operation, do not change TC3M, TC3CK and TFF3.

Note 3: When TC3 operation is stopped (TC3S = "1"→"0"), do not change TC3M, TC3CK and TFF3. But it is possible to change TC3M, TC3CK and TFF3 at the start timing (TC3S = "0" → "1").

Note 4: The value of TTREG3 which determines interrupt period has to be longer than the period of interrupt routine.

Note 5: When used as 16-bit mode,the operating mode is selected by TC4M (bit 2 to 0 in TC4CR), and TC3M should be set to "011".

Note 6: When used as 16-bit mode, only the source clock is selected by TC3CK, and start of operation and control of F/F are controlled by TC4S and TFF4 (bit 3 and 7 in TC4CR).

Note 7: Selecting source clock depends on the operating mode, refer to Table 2-6 and 2-7 for details.

Note 8: Value of timer register depends on the operating mode, refer to Table 2-8 for details.

Note 9: When used as the NORMAL1 and IDLE1 modes, the TC3 source clock can not use the "fs".

Note 10: When used as the SLOW and SLEEP modes, the "fs" of TC3 source clock can use only "fc warming-up counter " mode.

Figure 2-27. Timer 3 Register and Timer / Counter 3 Control Register

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

Timer Register

	7	6	5	4	3	2	1	0	
TTREG4 ($001D_H$)									(Initial value: 1111 1111)
PWREG4 ($002D_H$)									(Initial value: 1111 1111)

Timer / counter 4 control register

	7	6	5	4	3	2	1	0	
TC4CR (0019_H)	TFF4	TC4CK			TC4S	TC4M			(Initial value: 0000 0000)

TFF4	Timer F/F4 contorl	0: clear 1: set			R/W
TC4CK	TC4 source clock select [Hz]		NORMAL1/2,IDLE1/2 mode	SLOW1/2, SLEEP1/2 mode	
			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 (Note10)	fs (Note10)	fs
		101	fc/2	fc/2	–
		110	fc	fc	–
		111	TC4 pin input		
TC4S	TC4 start control	0: stop 1: command start			
TC4M	TC4 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) mode 011: reserved 100: 16 bit timer / event counter mode 101: 16 bit timer mode (for warming-up timer) 110: 16 bit programmable divider output (PDO) mode 111: 16 bit programmable pulse generate (PPG) output mode			

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

Note 2: During TC4 operation, do not change TC4M, TC4CK and TFF4.

Note 3: When TC4 operation is stopped (TC4S = "1" → "0"), do not change TC4M, TC4CK and TFF4. But it is possible to change TC4M, TC4CK and TFF4 at the start timing (TC4S = "0" → "1").

Note 4: The value of TTREG4 which determines interrupt period has to be longer than the period of interrupt routine.

*Note 5: When TC4M is selected to "1**" (16-bit mode), the source clock is automatically selected to the over-flowing signal of TC3 counter.*

Note 6: When used as 16-bit mode, the operating mode is selected by TC4M (bit 2 to 0 in TC4CR), and TC3M should be set to "011".

Note 7: When used as 16-bit mode, only the source clock is selected by TC3CK, and start of operation and control of F/F are controlled by TC4S and TFF4 (bit 3 and 7 in TC4CR).

Note 8: Selecting source clock depends on the operating mode, refer to Table 2-6 and 2-7 for details.

Note 9: Value of timer register depends on the operating mode, refer to Table 2-8 for details.

Note 10: When used as the NORMAL1 and IDLE1 modes, the TC4 source clock can not use the "fs".

Figure 2-28. Timer 4 Register and Timer / Counter 4 Control Register

The timer / counter 5 is controlled by a timer / counter 5 control register (TC5CR) and two 8-bit timer registers (TTREG5 and PWREG5).

Timer Register

	7	6	5	4	3	2	1	0	
TTREG5 ($001E_H$)									(Initial value: 1111 1111)
PWREG5 ($002E_H$)									(Initial value: 1111 1111)

Timer / counter 5 control register

	7	6	5	4	3	2	1	0	
TC5CR ($001A_H$)		TC5CK			TC5S	TC5M			(Initial value: *000 0000)

			NORMAL1/2,IDLE1/2 mode		SLOW1/2, SLEEP1/2 mode	
			DV7CK = 0	DV7CK = 1		
TC5CK	TC5 source clock select [Hz]	000	$fc/2^{11}$	$fs/2^3$	$fs/2^3$	R/W
		001	$fc/2^7$	$fc/2^7$	–	
		010	$fc/2^5$	$fc/2^5$	–	
		011	$fc/2^3$	$fc/2^3$	–	
		100	fs (Note9)	fs (Note9)	fs	
		101	fc/2	fc/2	–	
		110	fc	fc	fc (Note10)	
		111	reserved			
TC5S	TC5 start control	0: stop 1: command start				
TC5M	TC5 operating mode select	000: 8 bit timer / event counter mode 001: reserved 010: reserved 011: 16 bit mode (Mode selelction is controlled by TC6M) 1**: reserved				

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

Note 2: During TC5 operation, do not change TC5M and TC5CK .

Note 3: When TC5 operation is stopped (TC5S = "1"→"0"), do not change TC5M and TC5CK. But it is possible to change TC5M and TC5CK at the start timing (TC5S = "0"→"1").

Note 4: The value of TTREG5 which determines interrupt period has to be longer than the period of interrupt routine.

Note 5: When used as 16-bit mode,the operating mode is selected by TC6M (bit 2 to 0 in TC6CR), and TC5M should be set to "011".

Note 6: When used as 16-bit mode, only the source clock is selected by TC5CK, and start of operation and control of F/F are controlled by TC6S and TFF6 (bit 3 and 7 in TC6CR).

Note 7: Selecting source clock depends on the operating mode, refer to Table 2-6 and 2-7 for details.

Note 8: Value of timer register depends on the operating mode, refer to Table 2-8 for details.

Note 9: When used as the NORMAL1 and IDLE1 modes, the TC5 source clock can not use the "fs".

Note 10: When used as the SLOW and SLEEP modes, the "fs" of TC5 source clock can use only "fc warming-up counter " mode.

Figure 2-29. Timer 5 Register and Timer / Counter 5 Control Register

The timer / counter 6 is controlled by a timer / counter 6 control register (TC6CR) and two 8-bit timer registers (TTREG6 and PWREG6).

Timer Register

	7	6	5	4	3	2	1	0	
TTREG6 ($001F_H$)									(Initial value: 1111 1111)
PWREG6 ($002F_H$)									(Initial value: 1111 1111)

Timer / counter 6 control register

	7	6	5	4	3	2	1	0	
TC6CR ($001B_H$)	TFF6	TC6CK			TC6S	TC6M			(Initial value: 0000 0000)

TFF6	Timer F/F6 contorl	0: clear 1: set				R/W
TC6CK	TC6 source clock select [Hz]		NORMAL1/2,IDLE1/2 mode		SLOW1/2, SLEEP1/2 mode	
			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 (Note10)	fs (Note10)	fs	
		101	fc/2	fc/2	–	
		110	fc	fc	–	
		111	TC6 pin input			
TC6S	TC6 start control	0: stop 1: command start				
TC6M	TC6 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) mode 011: reserved 100: 16 bit timer / event counter mode 101: 16 bit timer mode (for warming-up timer) 110: 16 bit programmable divider output (PDO) mode 111: 16 bit programmable pulse generate (PPG) output mode				

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

Note 2: During TC6 operation, do not change TC6M, TC6CK and TFF6.

Note 3: When TC6 operation is stopped (TC6S = "1" → "0"), do not change TC6M, TC6CK and TFF6. But it is possible to change TC6M, TC6CK and TFF6 at the start timing (TC6S = "0" → "1").

Note 4: The value of TTREG6 which determines interrupt period has to be longer than the period of interrupt routine.

*Note 5: When TC6M is selected to "1**" (16-bit mode), the source clock is automatically selected to the over-flowing signal of TC5 counter.*

Note 6: When used as 16-bit mode,the operating mode is selected by TC6M (bit 2 to 0 in TC6CR), and TC5M should be set to "011".

Note 7: When used as 16-bit mode, only the source clock is selected by TC5CK, and start of operation and control of F/F are controlled by TC6S and TFF6 (bit 3 and 7 in TC6CR).

Note 8: Selecting source clock depends on the operating mode, refer to Table 2-6 and 2-7 for details.

Note 9: Value of timer register depends on the operating mode, refer to Table 2-8 for details.

Note 10: When used as the NORMAL1 and IDLE1 modes, the TC6 source clock can not use the "fs".

Figure 2-30. Timer 6 Register and Timer / Counter 6 Control Register

Table 2-6. Operating mode and available source clock (NORMAL1/2, IDLE1/2 mode)

Operating Mode	$fc/2^{11}$ or $fs/2^3$	$fc/2^7$	$fc/2^5$	$fc/2^3$	fs	fc/2	fc	TCi pin input
8-bit Timer	○	○	○	○	–	–	–	–
8-bit Event Counter	–	–	–	–	–	–	–	○
8-bit PDO	○	○	○	○	–	–	–	–
8-bit PWM	○	○	○	○	○	○	○	–
16-bit Timer	○	○	○	○	–	–	–	–
16-bit Event Counter	–	–	–	–	–	–	–	○
fs Warming-up Counter	–	–	–	–	○	–	–	–
16-bit PWM	○	○	○	○	○	○	○	○
16-bit PPG	○	○	○	○	–	–	–	○

Note 1: Foe 16-bit operation (16-bit Timer/Event Counter, fc Warming-up Counter, 16-bit PWM and 16-bit PPG), set its source clock on lower bits (TC3CK, TC5CK).

Note 2: i = 3, 4, 6, (8-bit mode)
i = 3 (16-bit mode)

Note 3: When used as the NORMAL1 and IDLE1 modes, the source clock can not use the "fs".

Table 2 7. Operating mode and available source clock (Under SLOW1/2 mode, SLEEP1/2 mode)

Operating Mode	$fc/2^{11}$ or $fs/2^3$	$fc/2^7$	$fc/2^5$	$fc/2^3$	fs	fc/2	fc	TCi pin input
8-bit Timer	○	–	–	–	–	–	–	–
8-bit Event Counter	–	–	–	–	–	–	–	○
8-bit PDO	○	–	–	–	–	–	–	–
8-bit PWM	○	–	–	–	○	–	–	–
16-bit Timer	○	–	–	–	–	–	–	–
16-bit Event Counter	–	–	–	–	–	–	–	○
fc Warming-up Counter	–	–	–	–	–	–	○	–
16-bit PWM	○	–	–	–	○	–	–	○
16-bit PPG	○	–	–	–	–	–	–	○

Note 1: Foe 16-bit operation (16-bit Timer/Event Counter, fc Warming-up Counter, 16-bit PWM and 16-bit PPG), set its source clock on lower bits (TC3CK, TC5CK).

Note 2: i = 3, 4, 6, (8-bit mode)
i = 3 (16-bit mode)

Table 2-8. Restriction against the Rate for Comparing Registers

Operating Mode	Authorized Rate for Register
8-bit Timer/Event Counter	$1 \leq$ (TTREGn) ≤ 255
8-bit PDO	$1 \leq$ (TTREGn) ≤ 255
8-bit PWM	$2 \leq$ (PWREGn) ≤ 254
16-bit Timer/Event Counter	$1 \leq$ (TTREG4, 3) ≤ 65535, $1 \leq$ (TTREG6, 5) ≤ 65535
fc Warming-up Counter	$256 \leq$ (TTREG4, 3) ≤ 65535, $256 \leq$ (TTREG6, 5) ≤ 65535
16-bit PWM	$2 \leq$ (PWREG4, 3) ≤ 65534, $2 \leq$ (PWREG6, 5) ≤ 65534
16-bit PPG	$1 \leq$ (PWREG4, 3) $<$ (TTREG4, 3) ≤ 65535, $1 \leq$ (PWREG6, 5) $<$ (TTREG6, 5) ≤ 65535

Note 1: n = 3 to 6

Note 2: When used as the "fc Warming-up counter" mod, the timer operating mode must use the 16-bit timer mode. That time, the timer register uses higher 8-bits and the lower 8-bits are ignored. But the timer register must be set both of high and low bits.

2.7.3 Function

Timer/Counter 3, 4, 5 and 6 have eight operating modes: 8-bit timer, 8-bit external trigger timer, 8-bit programmable divider output mode, 8-bit pulse width modulation output mode, 16-bit timer, 16-bit external trigger timer, 16-bit pulse width modulation output mode, 16-bit programmable pulse generator output mode.
16-bit timer mode can use Timer counter 3 and 4 (5 and 6) by cascade connection.

(1) 8-bit Timer Mode (Timer/Counter 3, 4, 5 and 6)

In this mode, counting up is performed using the internal clock. The contents of TTREGi are compared with the contents of up-counter. If a match is found, an INTTCi interrupt is generated, and the counter is cleared to "0". Counting up resumes after the counter is cleared.

Note: i = 3 to 6

Table 2-9. Timer/Counter 1 Source Clock (Internal Clock)

Source clock			Resolution		Maximum time setting	
NORMAL1/2, IDLE1/2 modes		SLOW1/2, SLEEP1/2 modes	At fc = 8 MHz	At fs = 32.768 kHz	At fc = 8 MHz	At 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	–	2.0 ms	–
$fc/2^5$	$fc/2^5$	–	2 μs	–	510 μs	–
$fc/2^3$	$fc/2^3$	–	500 ns	–	127.5 μs	–

Example: Sets the timer mode with source clock $fc/2^7$ [Hz] and generates an interrupt 80 μs later (at fc = 16 MHz).

```
LDW  (TTREG4), 0AH        ; Sets the timer register (80μs÷27/fc=0A_H)
SET  (EIRH). EF11         ; Enables INTTC4 interrupt
EI
LD   (TC4CR), 00011000B   ; Starts TC4
```

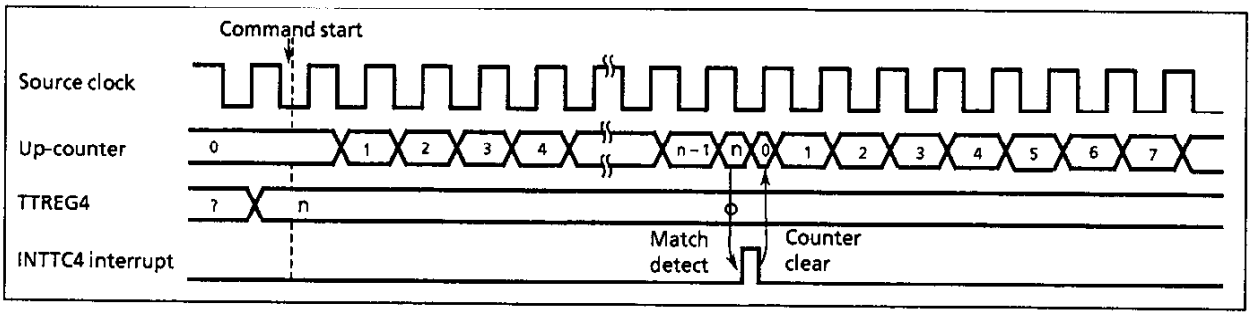


Figure 2-31. 8-bit Timer Mode Timing Chart (In Case of Timer/Counter 4)

(2) 8-bit Event Counter Mode (Timer/Counter 3, 4 and 6)

In this mode, events are counted on the falling edge of TCi pin input. The contents of TTREGi are compared with the contents of up-counter. If a match is found, an INTTCi interrupt is generated, and the counter is cleared. The maximum applied frequency is fc/2^3 [Hz] in NORMAL1/2 or IDLE1/2 mode and fs/2^3 [Hz] in SLOW or SLEEP mode.

Note: i = 3, 4, 6

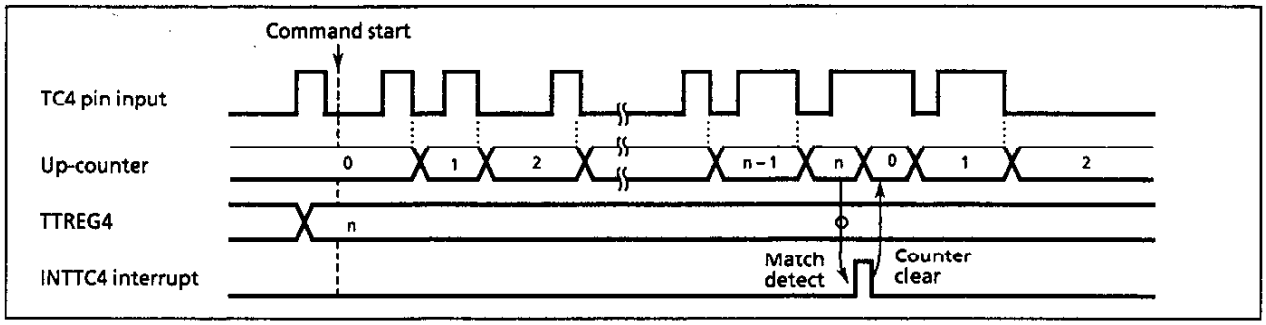


Figure 2-32. Event Counter Mode Timing Chart (In Case of Timer/Counter 4)

(3) Programmable Divider Output (PDO) Mode (Timer/Counter 3, 4 and 6)

The internal clock is used for counting up. The contents of TTREGi are compared with the contents of the up-counter. Timer F/F i output is toggled and the counter is cleared each time a match is found. Timer F/F i output is inverted and output to the $\overline{\text{PDOi}}$ pin. When used as a this mode, respective output latch should be set to "1". This mode can be used for 50 % duty pulse output. Timer F/F i can be initialized by program, and it is initialized to "0" during reset. An INTTCi interrupt is generated each time the $\overline{\text{PDOi}}$ output is toggled.

Note: i = 3, 4, 6

Example: Output a 1024 Hz pulse (at fc = 16 MHz, in case of TC4)

```
SET  (P3DR). 2              ;  P32 output latch ← 1
LD   (TTREG4), 7AH          ;  (1/1024÷27/fc)÷2=7AH
LD   (TC4CR), 00011001B     ;  Starts TC4
```

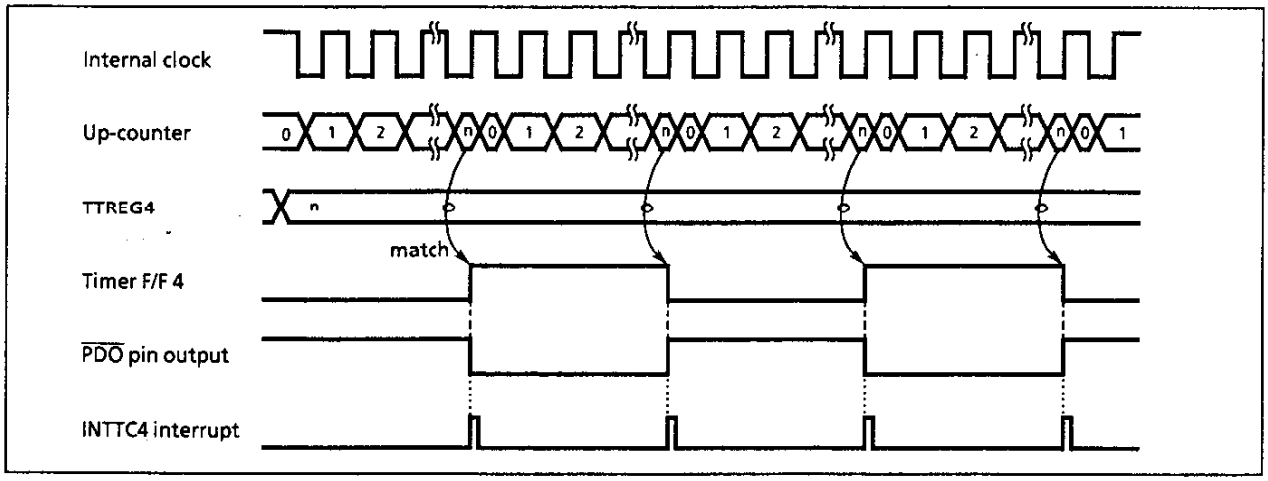


Figure 2-33. 8-bit Timing Chart for PDO Mode (In Case of Tmer/Counter 4)

(4) 8-bit Pulse Width Modulation (PWM) Output Mode (Timer/Counter 3, 4 and 6)

PWM output with a resolution of 8 bits is possible. The internal clock is used for counting up. The contents of PWREGi are compared with the contents of up-counter. If a match is found, the timer F/F i output is toggled. The counter continues counting. And, when an overflow occurs, the timer F/F i output is again toggled and the counter is cleared. Timer F/F i output is inverted and output to the $\overline{\text{PWM}}$ i pin. An INTTCi interrupt is generated when an overflow occurs.

PWREGi is configured a 2-stage shift register and, during output, will not switch until one output cycle is completed even if PWREGi is overwritten; therefore, output can be altered continuously. Also, the first time, PWREGi is shifted by setting TCiS (bit 4 in TCiCR) to "1" after data are loaded to PWREGi.

Note 1: Do not overwrite PWREGi only when an INTTCi interrupt is generated. Usually, PWREGi is overwriten in the routine of INTTCi interrupt service.

Note 2: i = 3, 4, 6

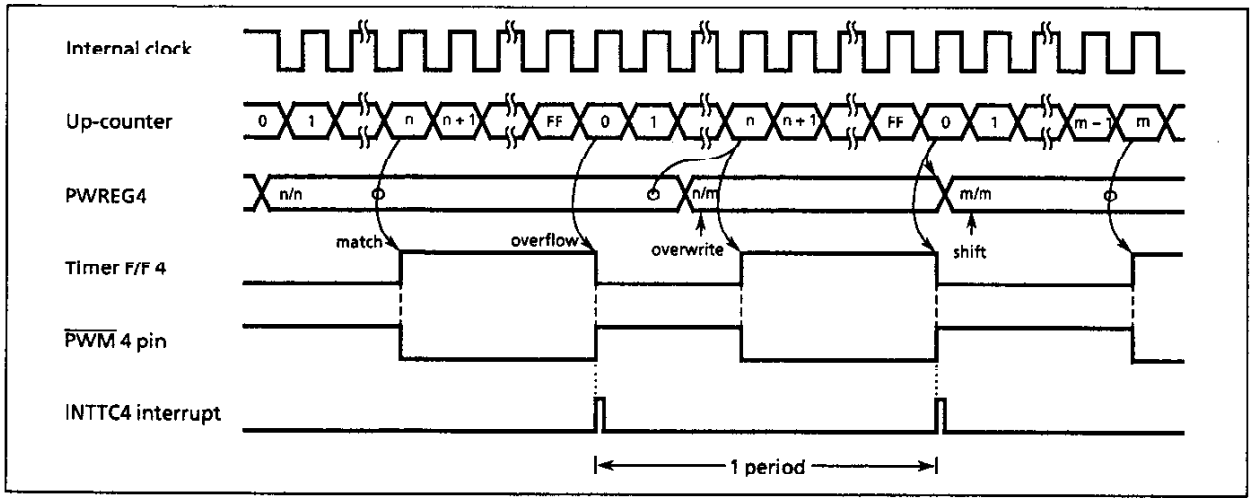


Figure 2-34. Timing Chart for PWM Mode (In Case of TC4)

Table 2-10. PWM Output Mode

Source clock			Resolution		Maximum setting time	
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	fcs	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	–

(5) 16-bit Timer Mode (Timer/counter 3 and 4, Timer/counter 5 and 6)

In this mode, counting up is performed using the internal clock.
Timer/counter 3 and 4 (5 and 6) are also available as a 16-bit timer mode by cascade connection.

a. 16 bit timer mode of Timer/counter 3 and 4

If a match is found, the INTTC4 interrupt is generated and the counter is cleared to "0". Counting up resumes after the counter is cleared. The timer register should write to the TTREG3 more first than TTREG4. The timer register must not write only either TTREG3 or TTREG4. When the TTREG4 is written during counter continuation, the timer register is changed by next falling edge of source clock at TTREG3 and TTREG4 same time. The timer/counter is counting by value of last timer register until the TTREG4 is written. Also, the first time, the timer register is changed by the TC4S (bit 3 in TC4CR) set to "1" after data are loaded to PWREG3/4.

b. 16 bit timer mode of Timer/counter 5 and 6

If a match is found, the INTTC6 interrupt is generated and the counter is cleared to "0". Counting up resumes after the counter is cleared. The timer register should write to the TTREG5 more first than TTREG6. The timer register must not write only either TTREG5 or TTREG6. When the TTREG6 is written during counter continuation, the timer register is changed by next falling edge of source clock at TTREG5 and TTREG6 same time. The timer/counter is counting by value of last timer register until the TTREG6 is written. Also, the first time, the timer register is changed by the TC6S (bit 3 in TC6CR) set to "1" after data are loaded to PWREG5/6.

Table 2-11. Source Clock of 16-bit Timer Mode

Source clock			Resolution		Maximum setting time	
NORMAL1/2, IDLE1/2 mode		SLOW1/2, SLEEP1/2 mode	At fc = 16 MHz	At fs = 32.768 kHz	At fc = 16 MHz	At fs = 32.768 kHz
DV7CK = 0	DV7CK = 1					
$fc/2^{11}$	$fs/2^3$ [Hz]	$fs/2^3$	128 μs	244.1 μs	8.38 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	–
–	–	–	–	–	–	–
fc/2	fc/2	–	125 ns	–	8.2 ms	–
fc	fc	–	62.5 ns	–	4.1 ms	–

Example: Set the 16-bit timer mode with source clock fc/27 [Hz] and generates an interruput 300 [ms] later (at fc = 16 [MHz])

```
LDW  (TTREG3), 927CH    ; Sets the timer register (300ms ÷ 27/fc = 927CH)
SET  (EIRH). EF11       ; Enable INTTC4 interrupt
EI
LD   (TC3CR), 13H       ; Sets the TC3 mode and source clock
LD   (TC4CR), 0CH       ; Starts timer/counter
```

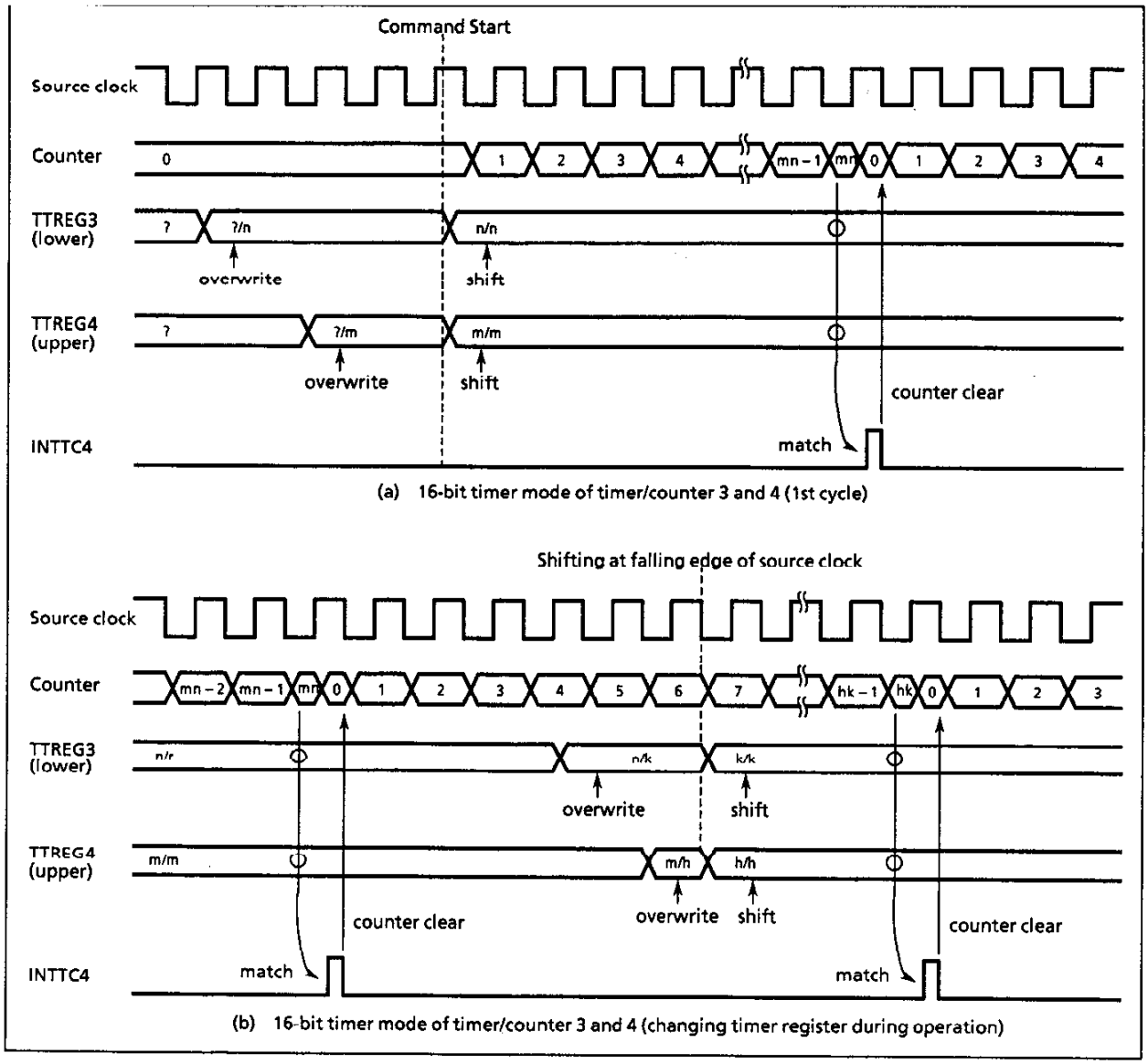


Figure 2-35. Timing Chart for 16-bit Timer Mode (Timer/Counter 3 and 4)

(6) 16-bit Event Counter Mode (Timer/counter 3 and 4)

In this mode, event are counted on the falling edge of the TC3 pin input. Timer/counter 5 and 6 are can not use a 16-bit Event Counter Mode. Timer/counter 3 and 4 are also available as a 16-bit Event counter mode by cascade connection.

a. 16 bit event counter mode of Timer/counter 3 and 4

If a match is found, the INTTC4 interrupt is generated and the counter is cleared to "0". After the counter is cleared, counting up resumes every falling edge of TC3 input. The timer register should write to the TTREG3 more first than TTREG4. The timer register must not write only either TTREG3 or TTREG4. When the TTREG4 is written during counter continuation, the timer register is changed by next falling edge of TC3 input at TTREG3 and TTREG4 same time. The timer/counter is counting by value of last timer register until the TTREG4 is written. Also, the first time, the timer register is changed by the TC4S (bit 3 in TC4CR) set to "1" after data are loaded to TTREG3/4.

(7) 16-bit Pulse Width Modulation (PWM) Output Mode (Timer/counter 3 and 4, Timer/counter 5 and 6)

PWM output with a resolution of 16 bits is possible. Timer/counter 3 and 4 (5 and 6) are also available as a 16-bit PWM output mode by cascade connection

a. 16 bit PWM output mode of Timer/counter 3 and 4

The contents of PWREG3/4 are compared with the contents of up-counter. If a match is found, the timer F/F 4 output is toggled. The counter continues counting. And, when an overflow occurs, the timer F/F 4 output is again toggled and the counter is cleared. Timer F/F 4 output is inverted and output to the $\overline{\text{PWM4}}$ pin. An INTTC4 interrupt is generated when an overflow occurs. When used as $\overline{\text{PWM4}}$ pin, respective output latch should be set to "1". PWREG3/4 are configured a 2-stage shift register and, during output, will not switch until one output cycle is completed even if PWREG3/4 are overwritten. Therefore, output can be altered continuously. Also, the first time, the timer register is changed by the TC4S (bit 3 in TC4CR) set to "1" after data are loaded to PWREG3/4.
The timer register should write to the PWREG3 more first than PWREG4. The timer register must not write only either PWREG3 or PWREG4.

b. 16 bit PWM output mode of Timer/counter 5 and 6

The contents of PWREG5/6 are compared with the contents of up-counter. If a match is found, the timer F/F 6 output is toggled. The counter continues counting. And, when an overflow occurs, the timer F/F 6 output is again toggled and the counter is cleared. Timer F/F 6 output is inverted and output to the $\overline{\text{PWM6}}$ pin. An INTTC6 interrupt is generated when an overflow occurs. When used as $\overline{\text{PWM6}}$ pin, respective output latch should be set to "1". PWREG5/6 are configured a 2-stage shift register and, during output, will not switch until one output cycle is completed even if PWREG5/6 are overwritten. Therefore, output can be altered continuously. Also, the first time, the timer register is changed by the TC6S (bit 3 in TC6CR) set to "1" after data are loaded to PWREG5/6.
The timer register should write to the PWREG5 more first than PWREG6. The timer register must not write only either PWREG5 or PWREG6.

Table 2-12. 16-bit PWM Output Mode

Source clock			Resolution		Maximum setting time	
NORMAL1/2, IDLE1/2 mode		SLOW, SLEEP mode	At fc = 16 MHz	At fs = 32.768 kHz	At fc = 16 MHz	At fs = 32.768 kHz
DV7CK = 0	DV7CK = 1					
$fc/2^{11}$	$fs/2^3$ [Hz]	$fs/2^3$	128 μs	244.1 μs	8.38 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	–
$fc/2^4$	$fc/2^3$	–	500 ns	–	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: Extract the pulse, whose term and "high" width is 32.768 ms and 1ms respectively, from P32 width 16-bit PWM mode (at fc = 16 MHz, DV7CK = 0)

```
SET  (P3DR). 2          ;  Sets P32 output data latch to "1"
LDW  (PWREG3), 07D0H    ;  Sets pulse width
LD   (TC3CR), 63H       ;  Sets the mode and source clock (fc/23)
LD   (TC4CR), DEH       ;  Sets the TFF4 to "1" and starts timer/counter
```

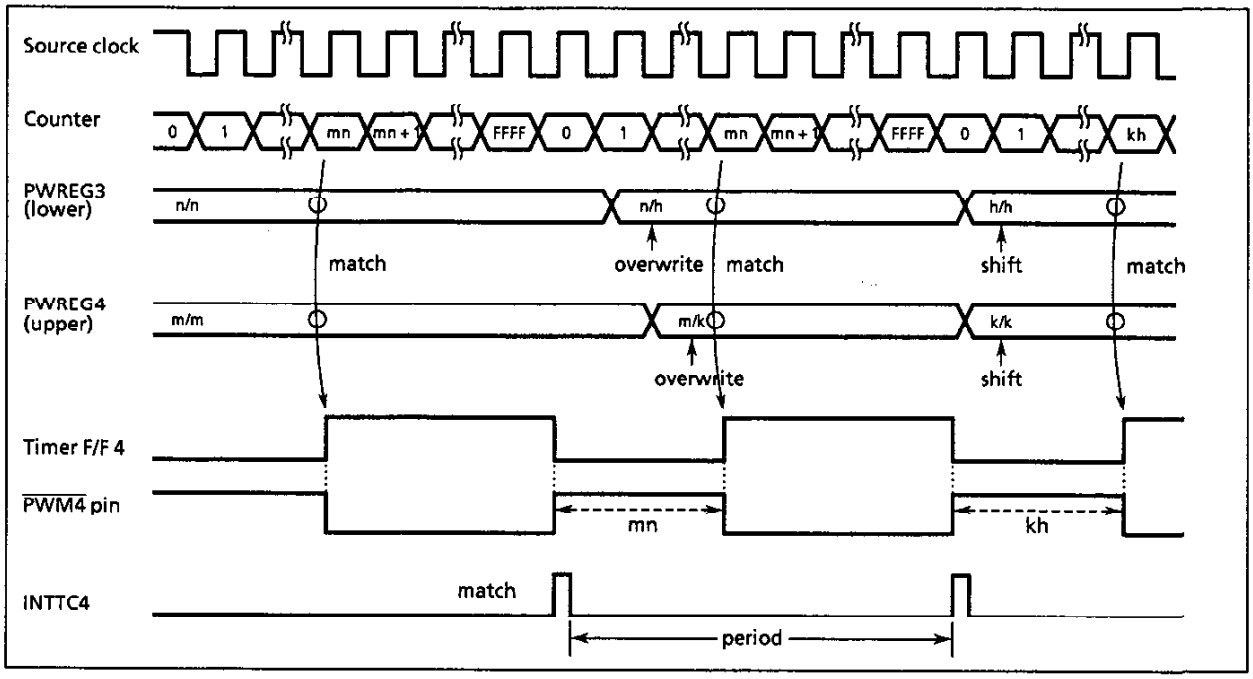


Figure 2-36. Timing Chart of 16-bit PWM Mode (Timer/Counter 3 and 4)

(8) 16-bit Programmable Pulse Generate (PPG) output mode
(Timer/counter 3 and 4, Timer/counter 5 and 6)

PPG output with a resolution of 16 bits is possible. Timer/counter 3 and 4 (5 and 6) are also available as a 16-bit PPG output mode by cascade connection.

a. 16 bit PPG output mode of Timer/counter 3 and 4

First, the contents of PWREG3/4 are compared with the contents of up-counter. If a match is found, the timer F/F 4 output is toggled. The INTTC4 interrupt is generated at this time. Next, timer F/F 4 is again toggled and the counter is cleared by matching with TTREG3/4. The INTTC4 interrupt is again generated when an overflow occurs.

When used as $\overline{PPG4}$ pin, respective output latch should be set to "1". During reset, the F/F 4 is initialized to "0".

The F/F 4 output is configured by TFF4 (bit 7 in TC4CR). Therefore, the $\overline{PPG4}$ can output either output high or output low at first time. The timer register should write to the PWREG3/TTREG3 more first than PWREG4/TTREG4. The timer register must not write only either PWREG3/TTREG3 or PWREG4 /TTREG4.

When the TTREG4/PWREG4 are written during counter continuation, the timer register is changed by next falling edge of source clock at PWREG3/TTREG3 and PWREG4/TTREG4 same time. The timer/counter is counting by value of last timer register until the PWREG4/TTREG4 is written.

b. 16 bit PPG output mode of Timer/counter 5 and 6

First, the contents of PWREG5/6 are compared with the contents of up-counter. If a match is found, the timer F/F 6 output is toggled. The INTTC6 interrupt is generated at this time. Next, timer F/F 6 is again toggled and the counter is cleared by matching with TTREG5/6. The INTTC6 interrupt is again generated when an overflow occurs.

When used as $\overline{PPG6}$ pin, respective output latch should be set to "1". During reset, the F/F 6 is initialized to "0".

The F/F 6 output is configured by TFF6 (bit 7 in TC6CR). Therefore, the $\overline{PPG6}$ can output either output high or output low at first time. The timer register should write to the PWREG5/TTREG5 more first than PWREG6/TTREG6. The timer register must not write only either PWREG5/TTREG5 or PWREG6/TTREG6.

When the TTREG6/PWREG6 are written during counter continuation, the timer register is changed by next falling edge of source clock at PWREG5/TTREG5 and PWREG6/TTREG6 same time. The timer/counter is counting by value of last timer register until the PWREG6/TTREG6 is written.

Example: Extract the pulse, whose term and "high" width is 16.385 ms and 1ms respectively, from P32 with 16-bit PPG mode (at fc = 16 MHz, DV7CK = 0)

```
SET  (P3DR). 2          ;  Sets P32 output data latch to "1"
LDW  (PWREG3), 07D0H    ;  Sets pulse width
LDW  (TTREG3), 8002H    ;  Sets pulse term
LD   (TC3CR), 63H       ;  Sets the mode and source clock (fc/2^3)
LD   (TC4CR), DFH       ;  Sets the TFF4 to "1" and starts timer/counter
```

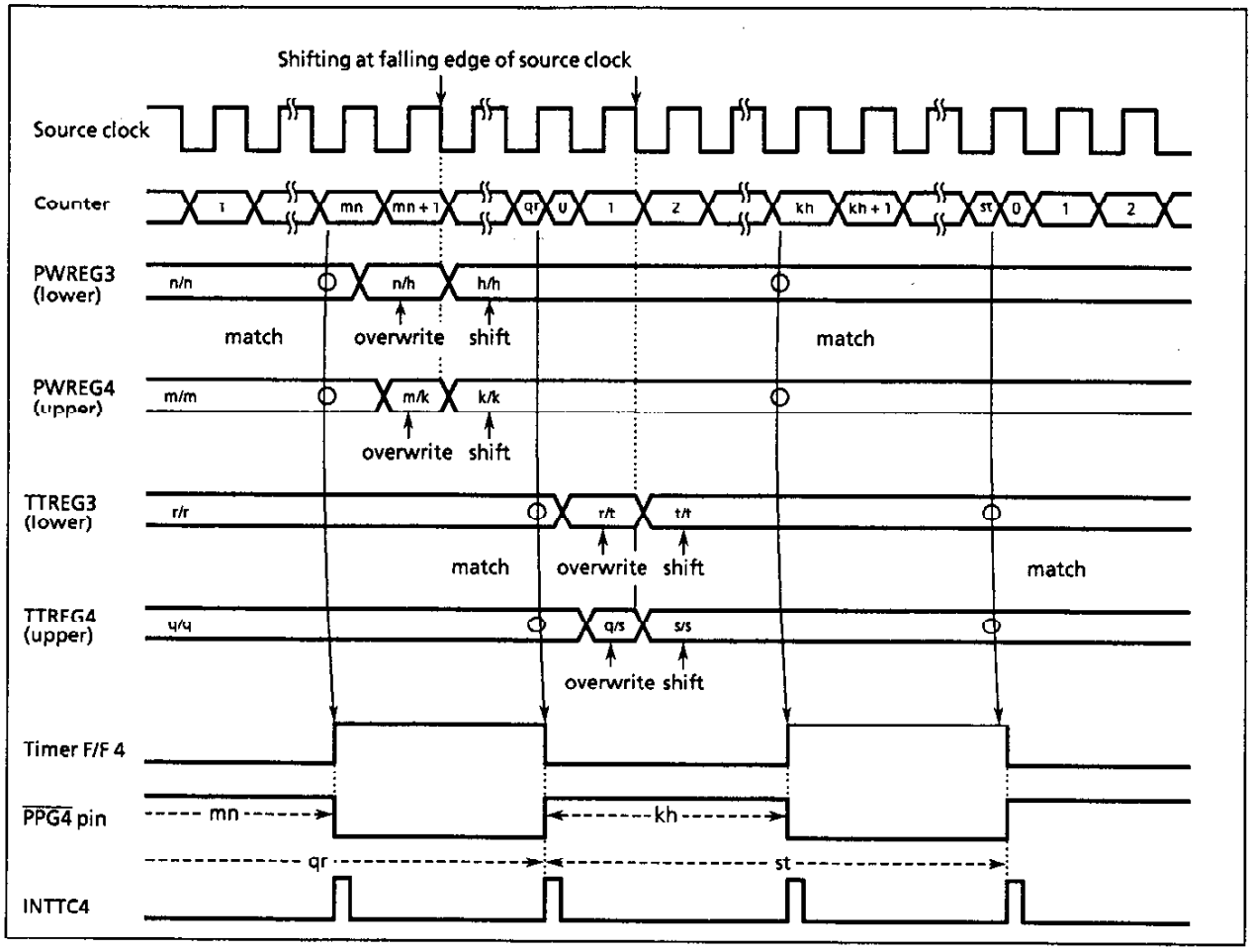


Figure 2-37. Timing Chart of 16-bit PPG Mode (Timer/Counter 3 and 4)

2.8 UART (Asynchronous serial interface)

The 86C829/H29/M29 have 1 channel of UART (asynchronous serial interface).
The UART is connected to external devices via RxD and TxD. RxD is also used as P15 ; TxD, as P16. To use P15 or P16 as the RxD or TxD pin, set P1 port output latches to 1.

2.8.1 Configuration

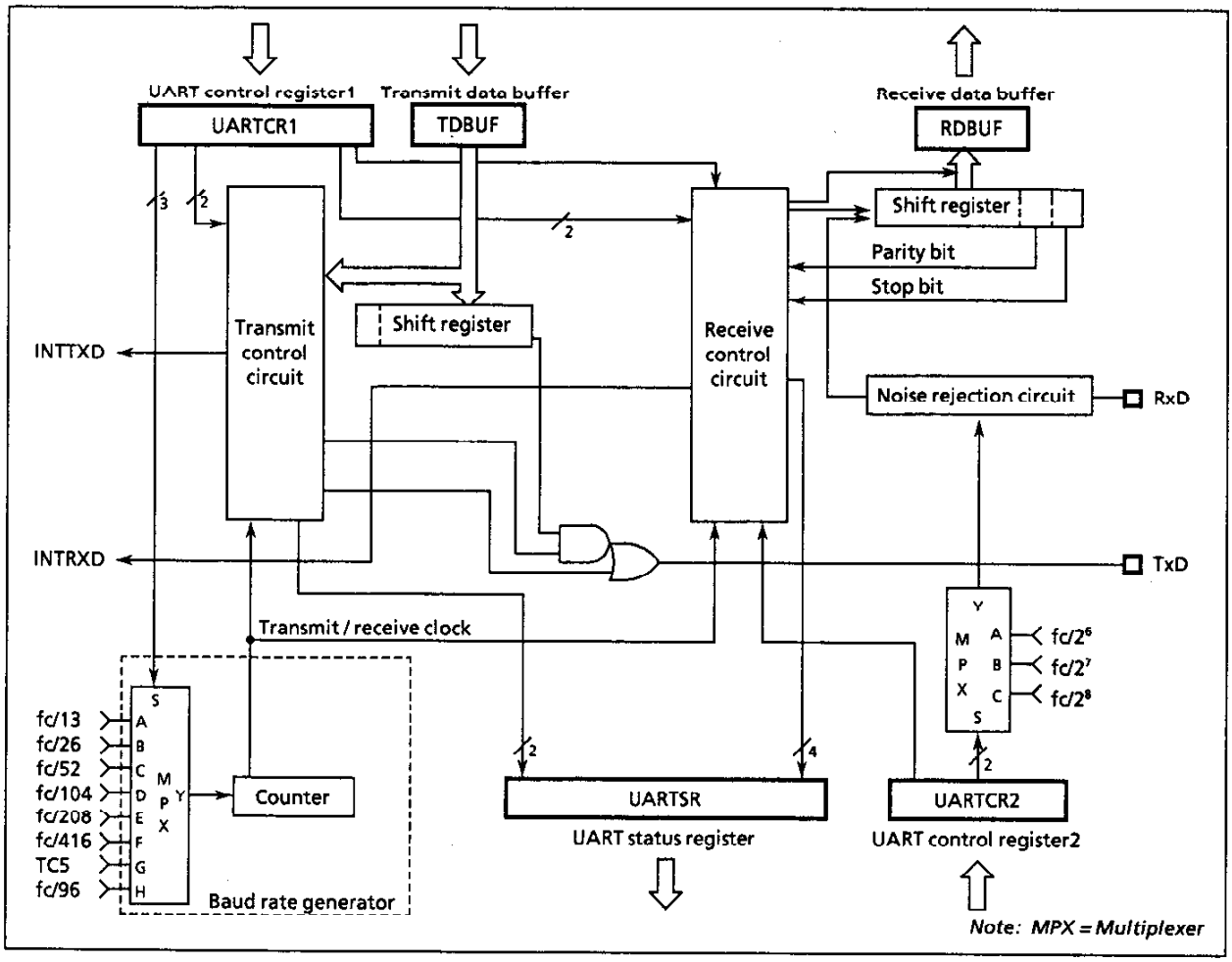


Figure 2-38. UART

2.8.2 Control

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

UART control register

UARTCR1 (0025_H)

7	6	5	4	3	2	1	0
TXE	RXE	STBT	EVEN	PE	BRG		

(Initial value: 0000 0000)

BRG	Transmit clock select	000: fc/13 [Hz] 001: fc/26 010: fc/52 011: fc/104 100: fc/208 101: fc/416 110: TC5 (INTTC5) 111: fc/96	Write-only
PE	Parity addition	0: No parity 1: Parity	
EVEN	Even-numbered parity	0: Odd-numbered parity 1: Even-numbered parity	
STBT	Transmit stop bit length	0: 1 bit 1: 2 bit	
RXE	Receive operation	0: Disable 1: Enable	
TXE	Transfer operation	0: Disable 1: Enable	

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.

UARTCR2 (0026_H)

7	6	5	4	3	2	1	0
					RXDNC		STOPBR

(Initial value: **** *000)

STOPBR	Receive stop bit length	0: 1 bit 1: 2 bit	Write-only
RxDNC	Selection of RxD input noise rejection 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	

Note 3: When RxDNC = 01, pulses longer than 96/fc [s] are always regarded as signals ; when RxDNC = 10, longer than 192/fc [s] ; and when RxDNC = 11, longer than 384/fc [s]

Figure 2-39. UART Control Register

UARTSR (0025_H)

7	6	5	4	3	2	1	0
PERR	FERR	OERR	RBFL	TEND	TBEP		

(Initial value: 0000 11**)

TBEP	Transmit data buffer empty flag	0: – 1: Transmit data buffer empty	Read-only
TEND	Transmit end flag	0: Transmitting 1: Transmit end	
RBFL	Receive data buffer full flag	0: – 1: Receive data buffer full	
OERR	Overrun error flag	0: No overrun error 1: Overrun error	
FERR	Framing error flag	0: No framing error 1: Framing error	
PERR	Parity error flag	0: No parity error 1: Parity error	

UART receive data buffer (Initial value: 0000 0000) Read-only

RDBUF ($0F9B_H$)

7	6	5	4	3	2	1	0

UART transmit data buffer (Initial value: 0000 0000) Write-only

TDBUF ($0F9B_H$)

7	6	5	4	3	2	1	0

Figure 2-40. UART status register and Data Buffer Registers

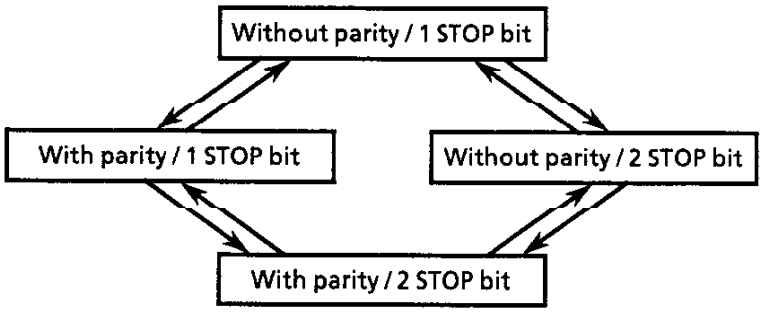
2.8.3 Transfer Data Format

In UART, a one-bit start bit (low level) , stop bit (bit length selectable at high level, by STBT), and parity (select parity in PE ; even-or odd-numbered parity by EVEN) are added to the transfer data. The transfer data formats are shown as follow.

Table 2-13. Transfer Data Format

PE	STBT	Frame length 1 | 2 | 3 |-------| 8 | 9 | 10 | 11 | 12
0	0	Start bit0 bit1 ----- bit6 bit7 Stop1
0	1	Start bit0 bit1 ----- bit6 bit7 Stop1 Stop2
1	0	Start bit0 bit1 ----- bit6 bit7 Parity Stop1
1	1	Start bit0 bit1 ----- bit6 bit7 Parity Stop1 Stop2

Note: In order to switch the transmit data format, perform transmit operations in the following sequence except for the initial setting.



2.8.4 Transfer Rate

The baud rate of UART is set of BRG (bit 0, 1, and 2 in UARTCR1) . The example of the baud rate shown as follows.

Table 2-14. Transfer Rate

BRG	Sourse 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 TC5 is used as the UART transfer rate (when BRG = 110), the transfer clock and transfer rate are detarmined as follows:

$$\text{Transfer clock} = \frac{\text{TC5 source clock}}{\text{TTREG5 set value}}$$

$$\text{Transfer rate} = \frac{\text{Transfer clock}}{16}$$

2.8.5 Data Sampling

The UART receiver keeps sampling input using the clock selected by BRG (bit 0, 1, and 2 in UARTCR1) until a start bit is detected in RxD pin input. RT clock starts at the falling edge 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) .

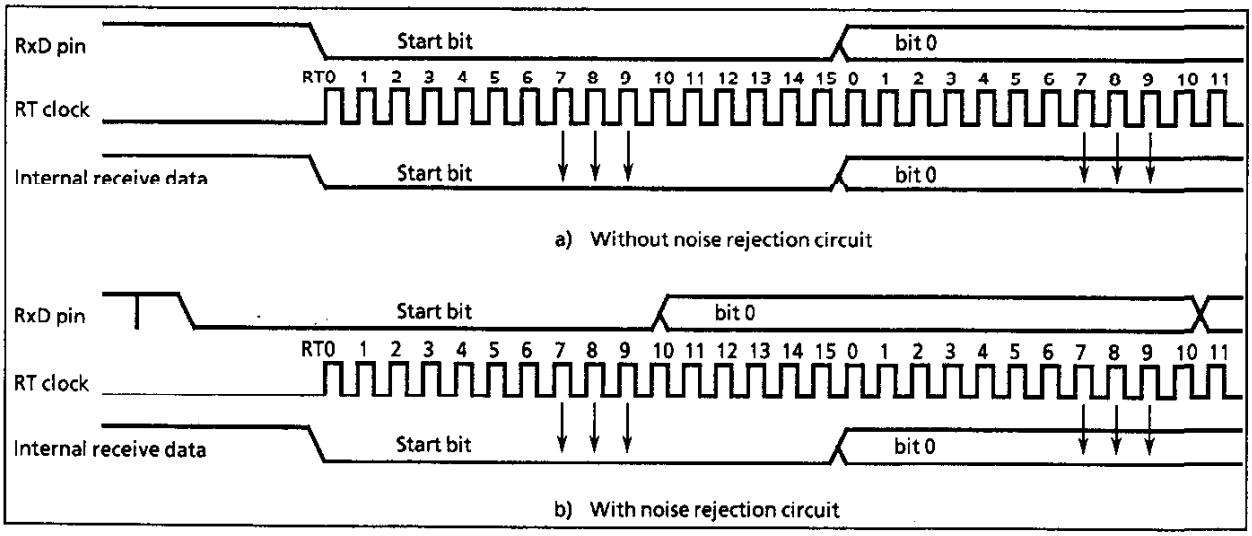


Figure 2-41. Data Samping

2.8.6 STOP Bit Length

Select a transmit stop bit length (1 or 2 bits) by STBT (bit 5 in UARTCR1)

2.8.7 Parity

Set parity / no parity by PE ; set parity type (odd-or even-numbered) by EVEN (bit 4 in UARTCR1).

2.8.8 Transmit / Receive

(1) Data transmit

Set TXE (bit 7 in UARTCR1) to 1. Read UARTSR to check TBEP=1, then write data in TDBUF (transmit data buffer). Writing data in TDBUF zero-clears 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 STDT (bit 5 in UARTCR1) and a parity bit if parity addition is specified. Select the data transfer baud rate using bits 0 to 2 in UARTCR1. When data transmit starts, transmit buffer empty flag TBEP is set to 1 and an INTTX interrupt is generated.
When transmitting data, first read UARTSR, then write data in TDBUF. Otherwise, TBEP is not zero-cleared and transmit does not start.

(2) Data receive

Set RXE (bit 6 in UARTCR1) 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 include 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 RBFL is set and an INTRX interrupt is generated. Select the data transfer baud rate using bits 0 to 2 in UARTCR1. 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 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.

2.8.9 Status Flag / Interrupt Signal

(1) Parity error

When parity determined using the receive data bits differs from the received parity bit, the parity error flag PERR is set in UARTSR. Reading UARTSR then RDBUF clears PERR.

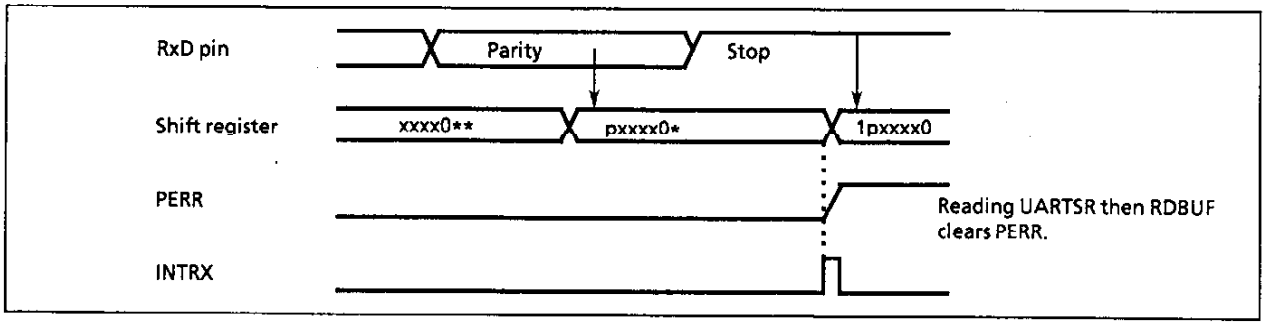


Figure 2-42. Generation of Parity Error

(2) Framing error

When 0 is sampled as the stop bit in the receive data, framing error flag FERR is set. Reading UARTSR then RDBUF clears FERR.

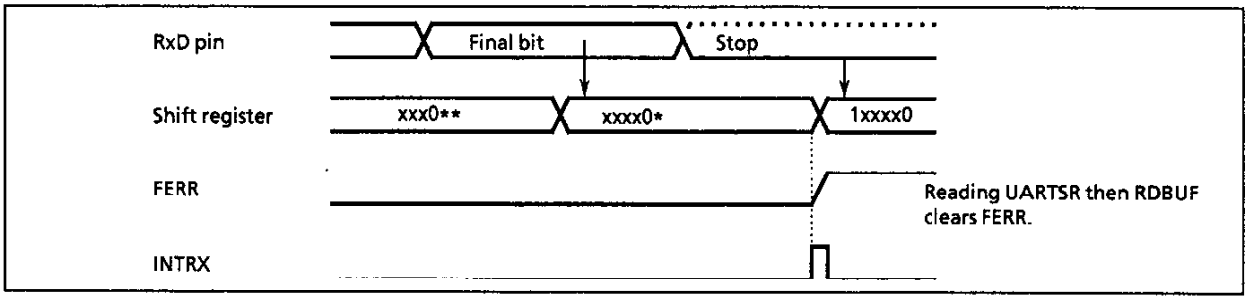


Figure 2-43. Generation of Framing Error

(3) Overrun error

When all bits in the next data are received while unread data are still in RDBUF, overrun error flag OERR is set. In this case, the receive data is discarded ; data in RDBUF are not affected. Reading UARTSR then RDBUF clears OERR.

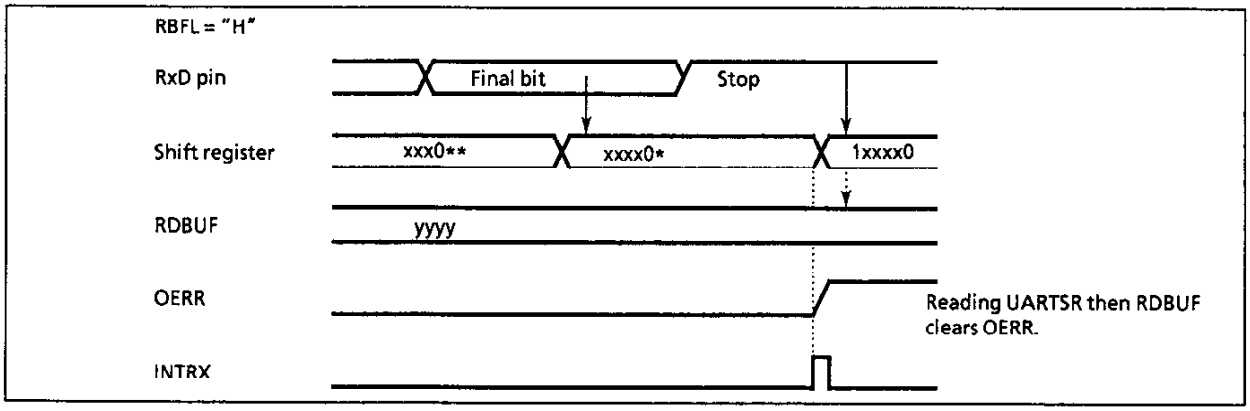


Figure 2-44. Generation of Overrun Error

(4) Receive data buffer full

Loading the received data in RDBUF sets receive data buffer full flag RBFL. Reading UARTSR then RDBUF clears the RBFL.

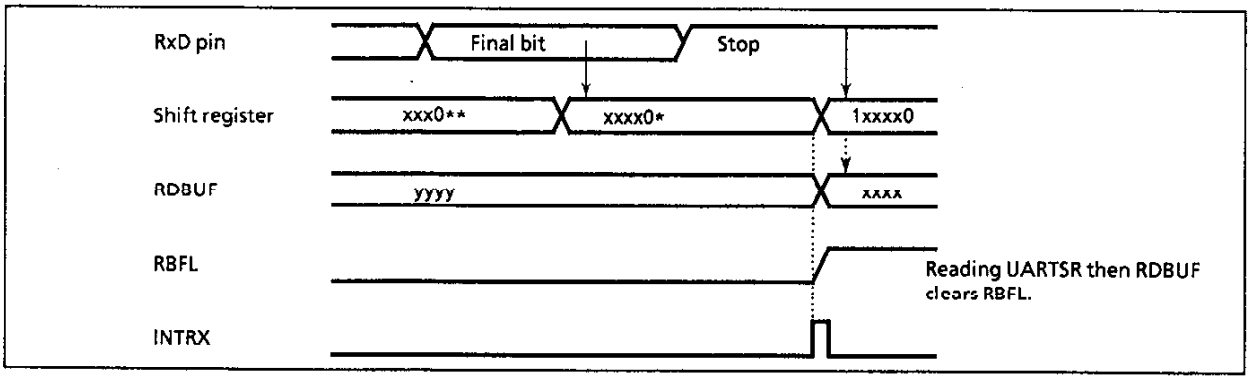


Figure 2-45. Generation of Receive Buffer Full

(5) Transmit data buffer empty

When no data is in the transmit buffer TDBUF, TBEP is set, that is, when data in TDBUF are transferred to the transmit shift register and data transmit starts, transmit data buffer empty flag TBEP is set. Reading UARTSR then writing the data to TDBUF clears TBEP.

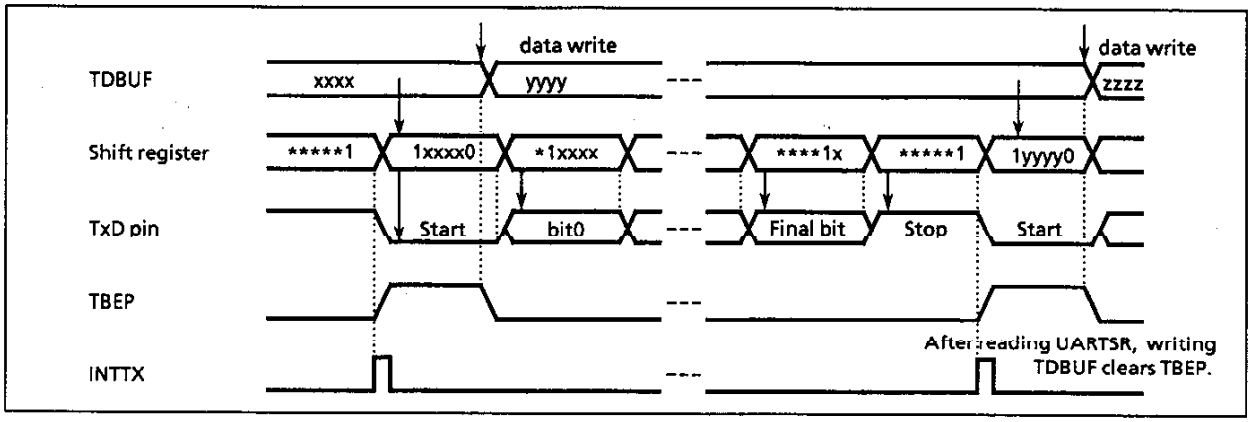


Figure 2-46. Generation of Transmit Buffer Empty

(6) Transmit end flag

When data are transmitted and no data is in TDBUF (TBEP = 1), transmit end flag TEND is set. Writing data to TDBUF then staring data transmit clears TEND.

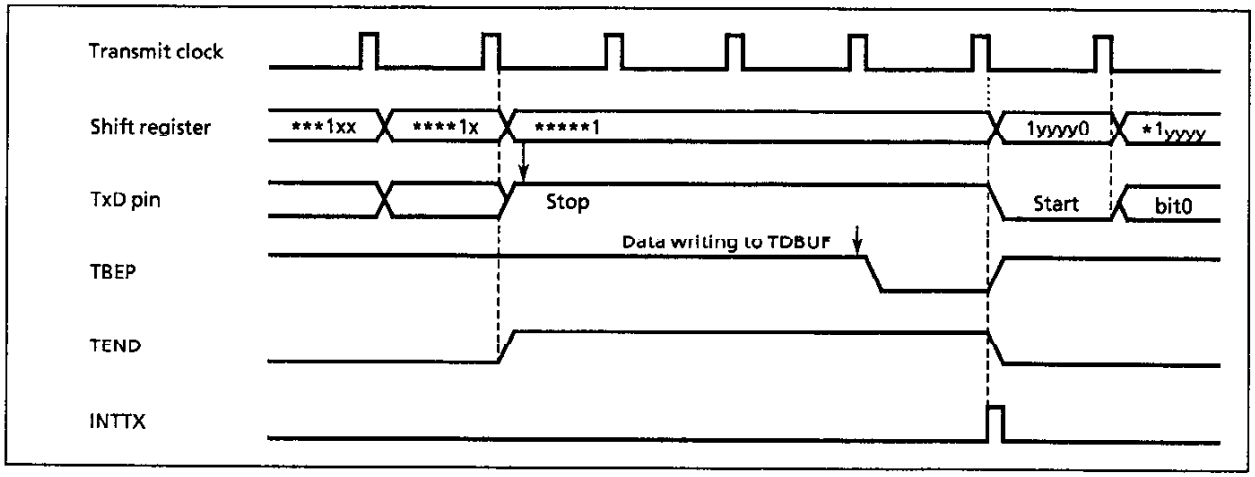


Figure 2-47. Generation of Transmit Buffer Empty

2.9 Serial Interface (SIO)

The 86C829/H29/M29 have one 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.

The serial interface is connected to external devices via pins P16 (SO), P15 (SI), P17 ($\overline{SCK}$). The serial interface pins are also used as port P1. When these pins are used as serial interface pins, the correspondence output latch should be set to "1". In the transmit mode, pin P15 can be used as normal I/O port, and in the receive mode, the pin P16 can be used as normal I/O ports.

2.9.1 Configuration

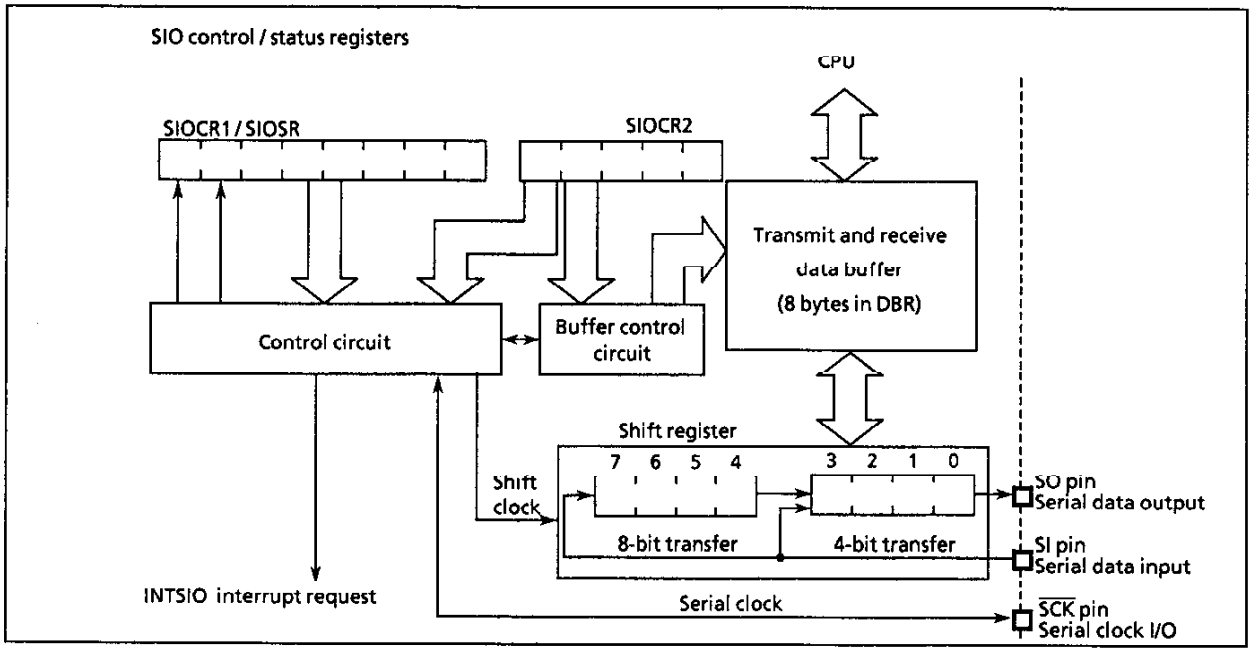


Figure 2-48. Serial Interfaces

2.9.2 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 BUF (bits 2-0 in SIOCR2). The data buffer is assigned to address $0F90_H$ to $0F97_H$ 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 WAIT (bits 4 and 3 in SIOCR2).

SIO Control Register 1

SIOCR1 ($0F98_H$)

7	6	5	4	3	2	1	0
SIOS	SIO INH	SIOM			SCK		

(Initial value: 0000 0000)

SIOS	Indicate transfer start / stop	0: Stop 1: Start			Write-only
SIOINH	Continue / abort transfer	0: Continue 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			
SCK	Serial clock select		NORMAL1/2,IDLE1/2 mode		SLOW, SLEEP mode
			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 Status Registers

SIOSR ($0F99_H$)

7	6	5	4	3	2	1	0
SIOF	SEF						

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

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	

Figure 2-49. SIO Control Register and Status Register (1/2)

SIO Control Register 2

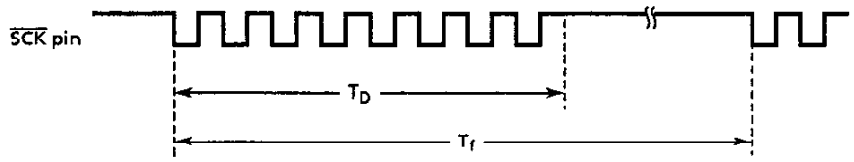
SIO1CR2 (0F99H)

7	6	5	4	3	2	1	0
			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: $T_f = 2T_D$ } 10: $T_f = 4T_D$ }(wait) 11: $T_f = 8T_D$ }	Write-only
BUF	Number of transfer words	Buffer address used 000: 1 word transfer 0F90H 001: 2 words transfer 0F90 to 0F91H 010: 3 words transfer 0F90 to 0F92H 011: 4 words transfer 0F90 to 0F93H 100: 5 words transfer 0F90 to 0F94H 101: 6 words transfer 0F90 to 0F95H 110: 7 words transfer 0F90 to 0F96H 111: 8 words transfer 0F90 to 0F97H	

Note 1: T_f; frame time, T_D; data transfer time



Note 2: The lower 4 bits of each buffer are used during 4-bit transfers. Zeros (0) are stored to the upper 4bits when receiving.

Note 3: Transmitting starts at the lowest address. Received data are also stored starting from the lowest address to the highest address. For example, in the case of SIO, the first buffer address transmitted is 0F90H.

Note 4: The value to be loaded to BUF is held after transfer is completed.

Note 5: SIOCR2 must be set when the serial interface is stopped (SIOF = 0).

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

*Note 7: * ; Don't care*

Figure 2-49. SIO Control Register and Status Register (2/2)

(1) Serial Clock

a. Clock Source

SCK (bits 2 - 0 in SIOCR) is able to select the following:

① Internal Clock

Any of four frequencies can be selected. The serial clock is output to the outside on the $\overline{SCK}$ pin. The $\overline{SCK}$ 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 2-15. Serial Clock Rate

Serial clock			Transfer rate	
NORMAL1/2, IDLE1/2 modes		SLOW, SLEEP modes	fc = 16 MHz	fs = 32.768 kHz
DV7CK = 0	DV7CK = 1			
$fc/2^{13}$ [Hz]	$fs/2^5$ [Hz]	$fs/2^5$ [Hz]	1.91 Kbit/s	1 Kbit/s
$fc/2^8$	$fc/2^8$	–	61.0 Kbit/s	–
$fc/2^7$	$fc/2^7$	–	122.1 Kbit/s	–
$fc/2^6$	$fs/2^6$	–	244.1 Kbit/s	–
$fc/2^5$	$fc/2^5$	–	488.3 Kbit/s	–
$fc/2^4$	$fc/2^4$	–	976.6 Kbit/s	

Note: 1 Kbit = 1024 bit

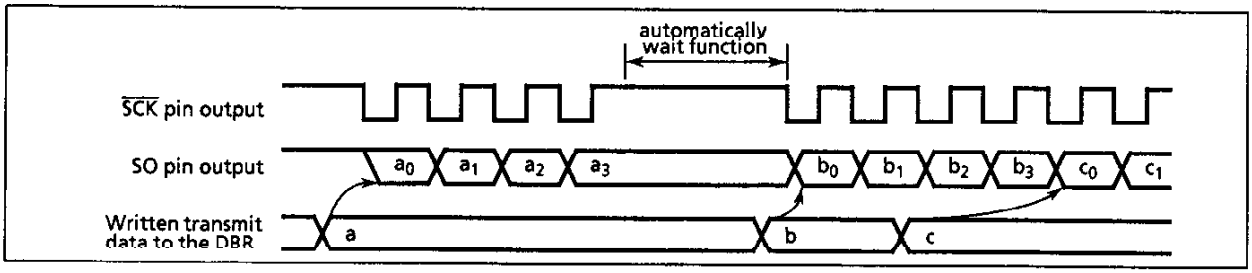
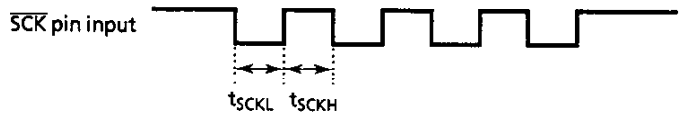


Figure 2-50. Clock Source (Internal Clock)

② External Clock

An external clock connected to the $\overline{SCK}$ pin is used as the serial clock. In this case, the P17 ($\overline{SCK}$) must be set to the input mode. 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.



t_{SCKL}, t_{SCKH} > 4 tcyc *Note: tcyc = 4/fc (In NORAML1/2, IDLE1/2 modes)*
4/fs (In SLOW, SLEEP modes)

b. Shift edge

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

① Leading Edge

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

② Trailing Edge

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

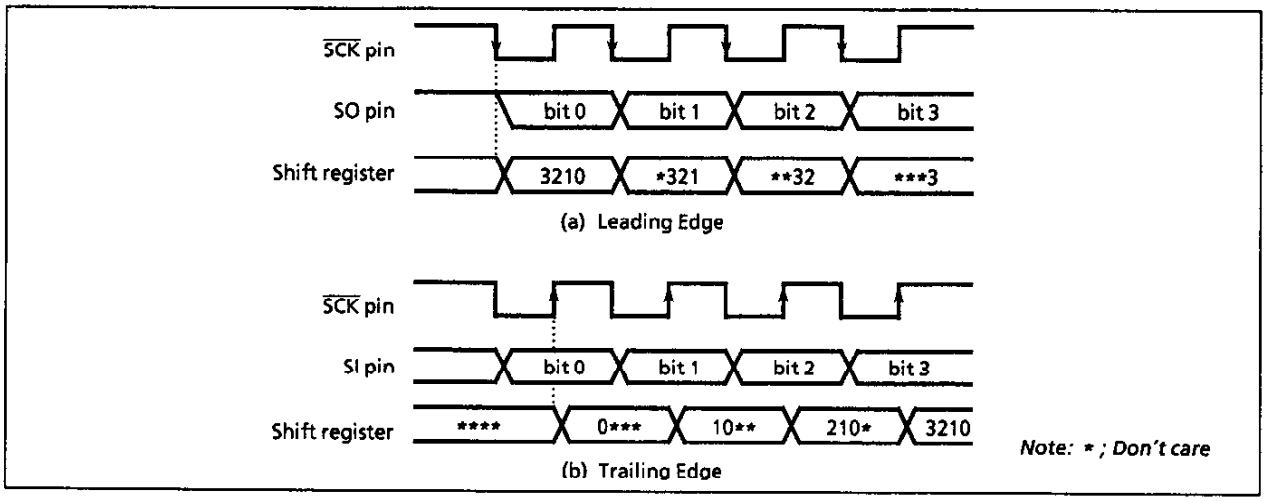


Figure 2-51. Shift Edge

(2) 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).

(3) 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 is loaded to 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.

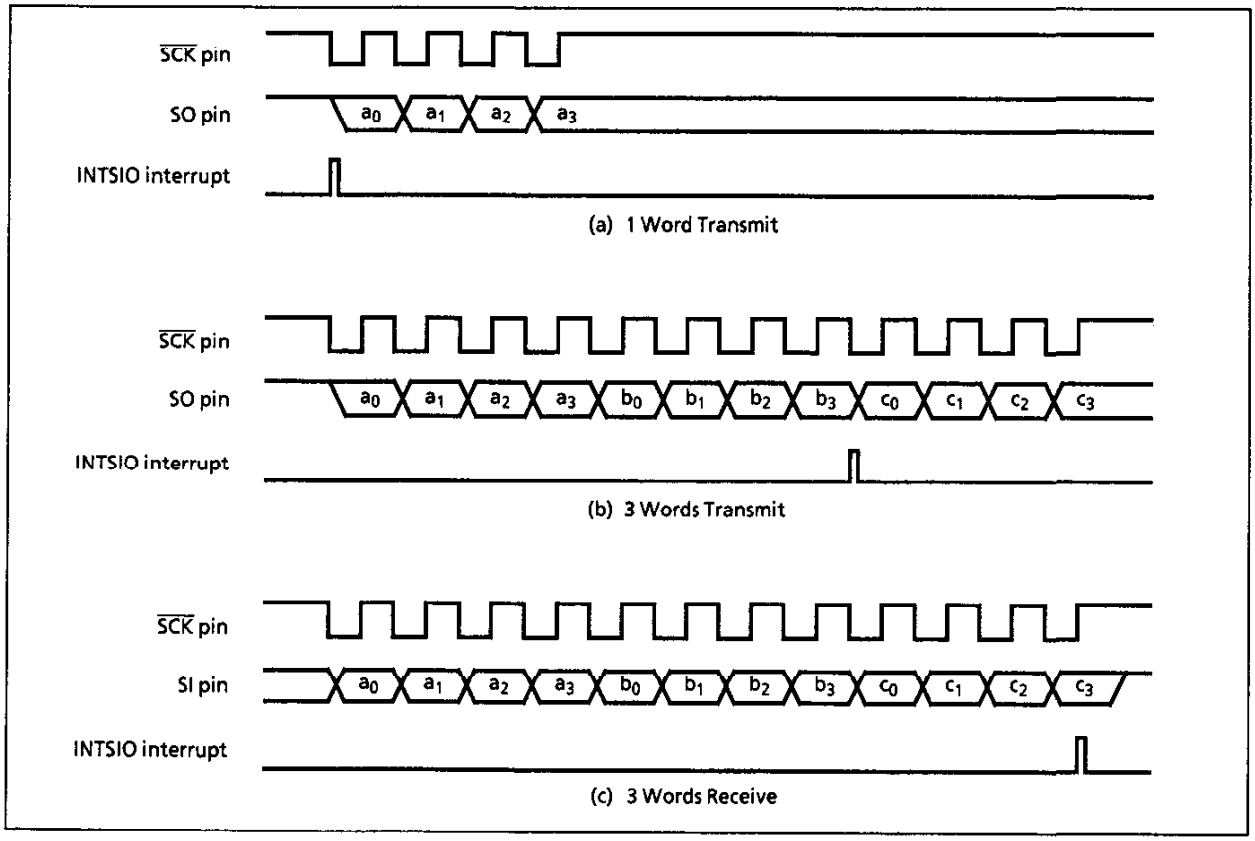


Figure 2-52. Number of Bits to Transfer (Example: 4-bit serial transfer)

2.9.3 Transfer Mode

SIOM (bits 5 to 3 in SIOCR1) is used to select the transmit, receive, or transmit/receive mode.

(1) 4-bit and 8-bit Transmit Modes

In these modes, the SIOCR1 is set to the transmit mode and then the data to be transmitted first are written to the data buffer registers (DBR). After the data are written, the transmission is started by setting 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 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.
When the transmit is started, after the SIOF goes "high" output from the SO pin holds final bit of the last data until falling edge of the SCK.
The transmission is ended by clearing SIOS to "0" or setting SIOINH to "1" in buffer empty interrupt service program. That the transmission has ended can be determined from the status of SIOF (bit 7 in SIOSR) because SIOF is cleared to "0" when a transfer is completed.
When SIOINH is set, the transmission is immediately ended and SIOF is cleared to "0".
When an external clock is used, it is also necessary to clear SIOS to "0" before shifting the next data; otherwise, dummy data will be transmitted and the operation will end.
If it is necessary to change the number of words, SIOS should be cleared to "0", then BUF must be rewritten after confirming that SIOF has been cleared to "0".

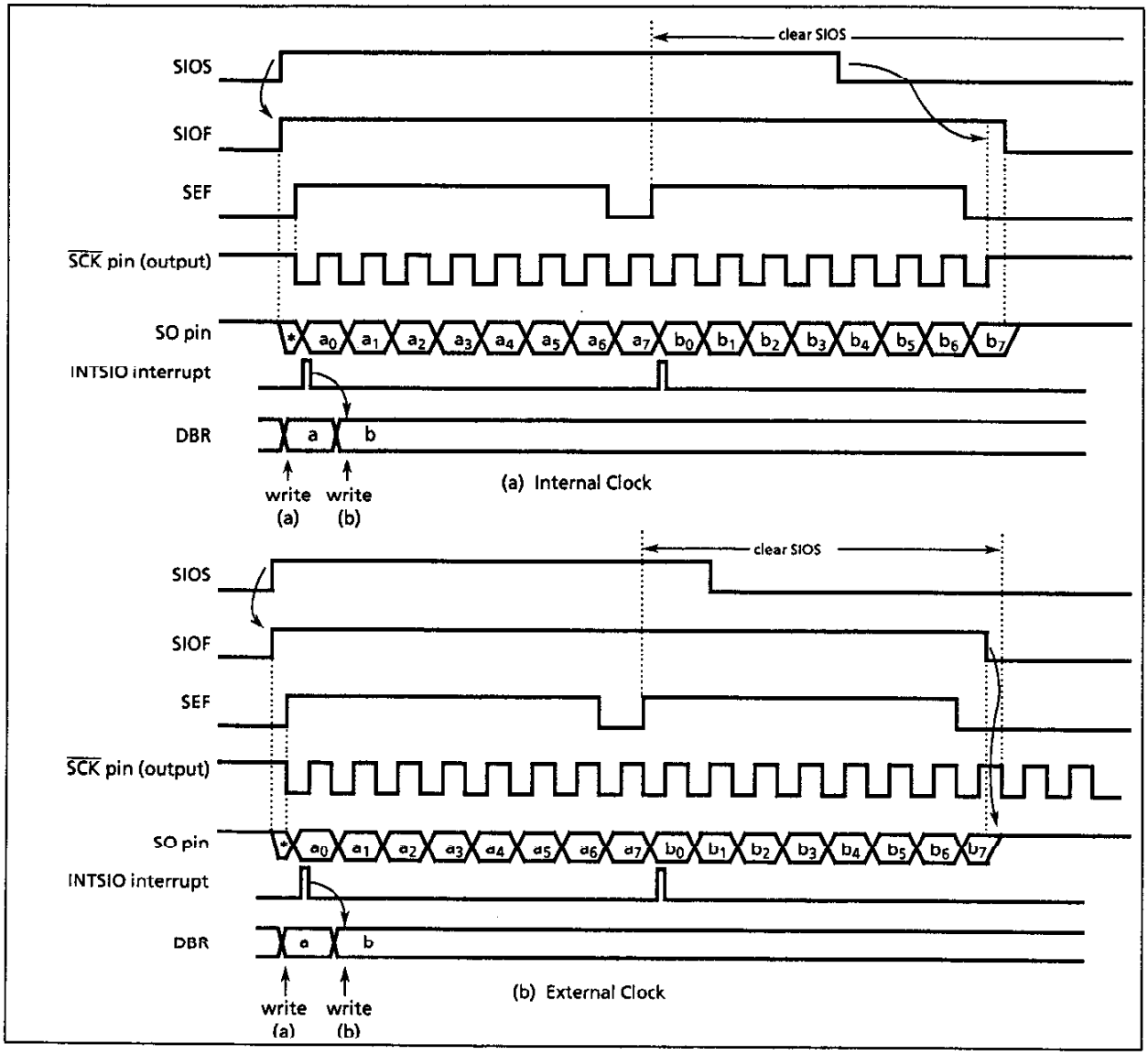


Figure 2-53. Transfer Mode (Example: 8-bit, 1 Word Transfer)

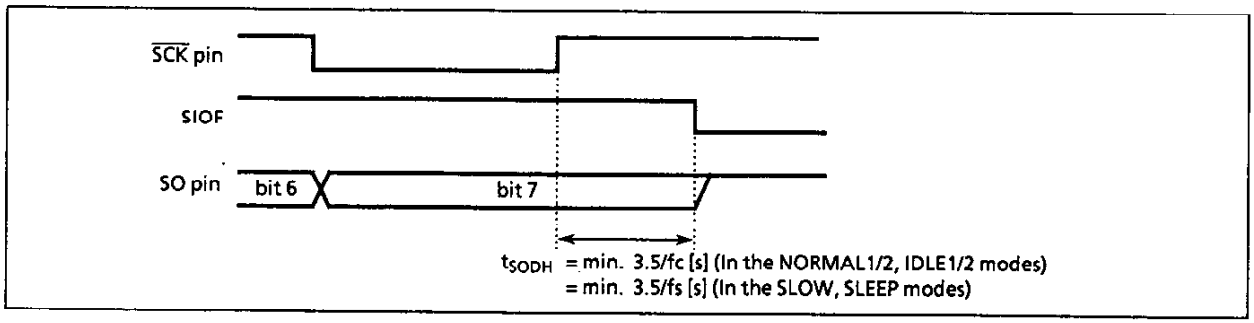


Figure 2-54. Transmitted Data Hold Time at End of Transmit

(2) 4-bit and 8-bit Receive Modes

After setting the control registers to the receive mode, set 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 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 SIOS to "0" or setting SIOINH to "1" in buffer full interrupt service program. When SIOS is cleared, the current data are transferred to the buffer. After 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 SIOF (bit 7 in SIOSR). SIOF is cleared to "0" when the receiving is ended. After confirmed the receiving termination, the final receiving data is read. When SIOINH is set, the receiving is immediately ended and 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, SIOS should be cleared to "0" then BUF must be rewritten after confirming that 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, 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 SIOS to "0", read the last data and then switch the transfer mode.

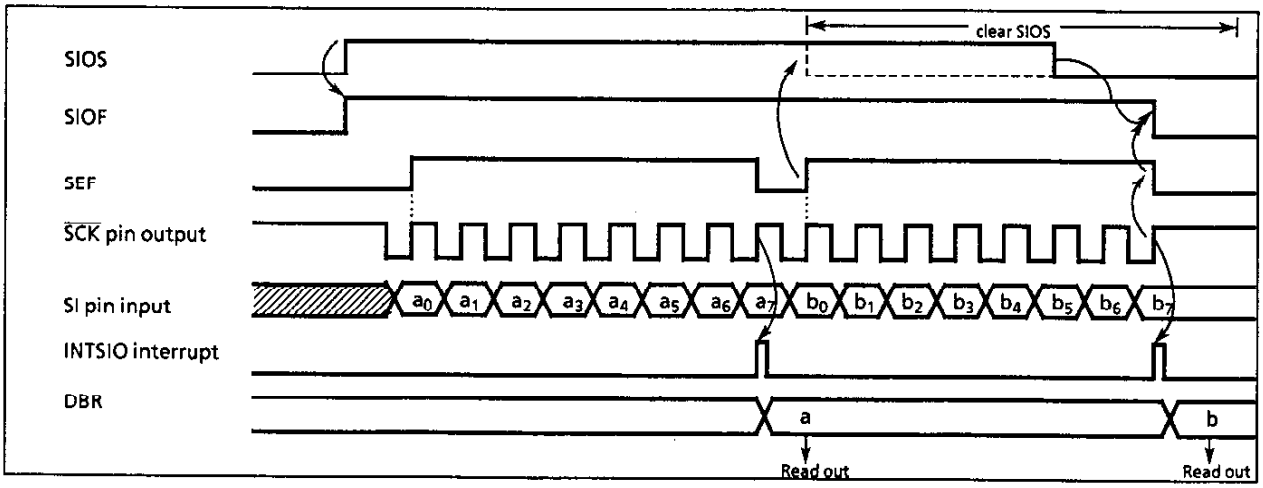


Figure 2-55. Receive Mode (Example: 8 bit, 1 word, internal clock)

(3) 8-bit Transmit / Receive Mode

After setting the control registers to the 8-bit transmit / receive mode, write the data to be transmitted first to the data buffer registers (DBR). After that, enable transceiving by setting 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. 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 BUF has been transferred. The interrupt service program reads the received data from the data buffer register and then writes the data to be transmitted. The data buffer register is used for both transmitting and receiving; therefore, always write the data to be transmitted after reading the received data.
When the internal clock is used, a wait is initiated until the received data are read and the next data are written. A wait will not be initiated if even one data word has been written.

Note: The wait is also canceld by writing to a DBR not being used as a transmit data buffer registers; 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, 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.
When the receive is started, after the SIOF goes "high"output from the SO pin holds final bit of the last data until falling edge of the $\overline{SCK}$.
The transmit / receive operation is ended by clearing SIOS to "0" or setting SIOINH to "1" in interrupt service program.
When SIOINH is set, the transmit / receive operation is immediately ended and SIOF is cleared to "0".
If it is necessary to change the number of words in external clock operation, SIOS should be cleared to "0", then BUF must be rewritten after confirming that 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, 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 SIOS to "0", read the last data and then switch the transfer mode.

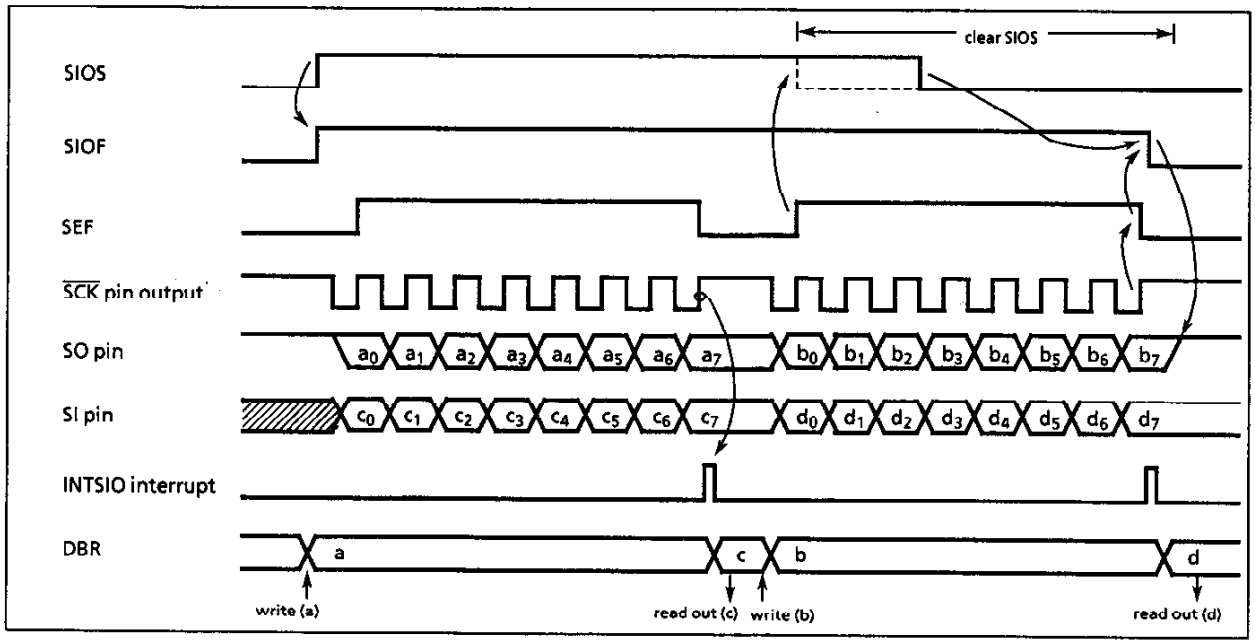


Figure 2-56. Transmit/Receive Mode (Example: 8-bit, 1word, internal clock)

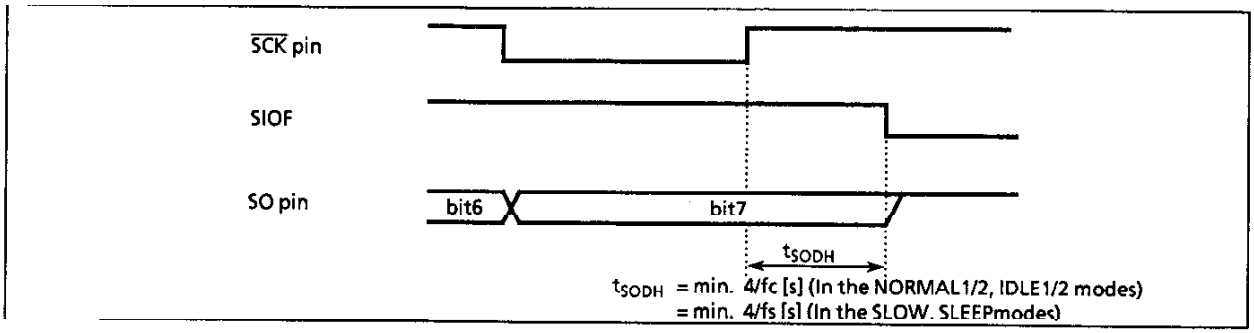


Figure 2-57. Transmitted Data Hold Time at End of Transmit/Receive

2.10 10-bit A/D Converter (ADC)

The 86C829/H29/M29 have a 10-bit successive approximation type A/D converter.

2.10.1 Configuration

The circuit configuration of the 10-bit A/D converter is shown in Figure 2-58.
It consists of control registers ADCCR1 and ADCCR2, converted value registers ADCDR1 and ADCDR2, a D/A converter, a sample-and-hold circuit, a comparator, and a successive comparison circuit.

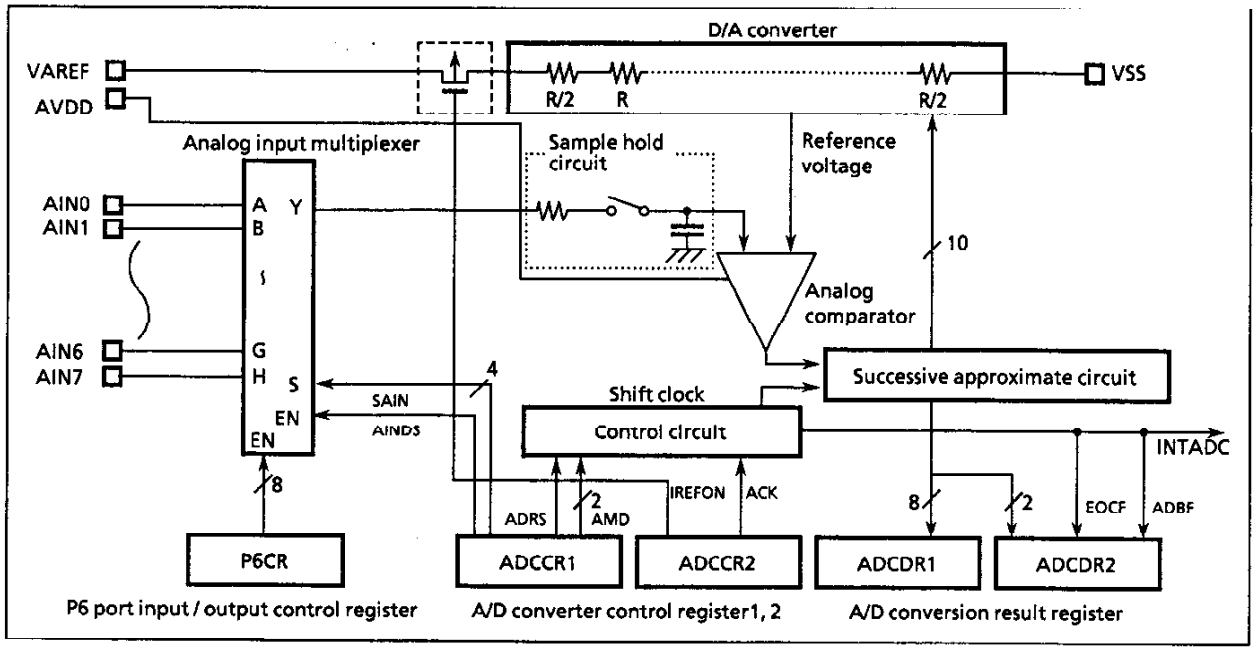


Figure 2-58. A/D Converter (ADC)

2.10.2 Register Configuration

The A/D converter consists of the following four registers:

- A/D converter control register 1 (ADCCR1)
- A/D converter control register 2 (ADCCR2)
- A/D converted value register H/L (ADCDR1/ADCDR2)

(1) A/D converter control register 1 (ADCCR1)
This register selects the analog channels and operation mode (software start or repeat) in which to perform A/D conversion and controls the A/D converter as it starts operating.

(2) A/D converter control register 2 (ADCCR2)
This register selects the A/D conversion time and controls the connection of the D/A converter (ladder resistor network).

(3) A/D converted value register (ADCDR1)
This register is used to store the digital value after being converted by the A/D converter.

(4) A/D converted value register (ADCDR2)
This register monitors the operating status of the A/D converter.

The A/D converter control register configurations are shown in Figures 2-59 and 2-60.

A/D Converter Control Register 1

ADCCR1 ($000E_H$)

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

(Initial value: 0001 0000)

ADRS	A/D conversion start	The ADRS bit is automatically cleared after starting A/D conversion. During A/D conversion, setting ADRS to "1" initializes the ADRS bit and resets conversion. 0: – 1: Start	R/W
AMD	A/D Operating mode	00: A/D 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	000: Selects AIN0 001: Selects AIN1 010: Selects AIN2 011: Selects AIN3 100: Selects AIN4 101: Selects AIN5 110: Selects AIN6 111: Selects AIN7	

Note 1: Select analog input when A/D converter stops.
Note 2: When the analog input is all use disabling, the AINDS should be set to "1".
Note 3: During conversion, do not perform output instruction to maintain a precision for all of the pins. And port near to analog input, do not input intense signaling of change.
Note 4: The ADRS is automatically cleared to "0" after starting conversion.
Note 5: Always set bit 3 in ADCCR1 to "0".
Note 6: Do not set ADRS (ADCCR1 bit 7) newly again during A/D conversion. Before you set ADRS newly again, check EOCF (ADCDR bit 5) to see that the conversion is completed or wait until the interrupt signal (INTADC) is generated (e.g., interrupt handling routine).

A/D Converter Control Register 2

ADCCR2 ($000F_H$)

7	6	5	4	3	2	1	0
		IREFON	"1"	ACK			"0"

(Initial value: **0* 000*)

IREFON	D/A converter (ladder resistor) connection control	Inputting current to the ladder resistor 0: Connected only during A/D conversion 1: Always connected						R/W
ACK	A/D conversion time select	ACK	Conversion time	fc = 16 MHz	fc = 8 MHz	fc = 4 MHz	fc = 2 MHz	
		000	39/fc [s]	–	–	–	19.5	
		001	reserved					
		010	78/fc [s]	–	–	19.5	39.0	
		011	156/fc [s]	–	19.5	39.0	156.0	
		100	312/fc [s]	19.5	39.0	156.0	–	
		101	624/fc [s]	39.0	78.0	–	–	
		110	1248/fc [s]	78.0	156.0	–	–	
		111	reserved					

Note 1: Settings for "–" in the above table are inhibited.
Note 2: Set conversion time by analog reference voltage (V_{AREF}) as follows.
V_{AREF} = 4.5 to 5.5 V (15.6 μ or more)
V_{AREF} = 2.7 to 5.5 V (31.2 μ or more)
V_{AREF} = 1.8 to 5.5 V (124.8 μ or more)
Note 3: Always set bit 0 in ADCCR2 to "0" and set bit 4 in ADCCR2 to "1".
Note 4: When a read instruction for ADCCR2, bit 6 to 7 in ADCCR2 read in as undefined data.
Note 5: fc ; High-frequency clock [Hz]
Note 6: The D/A converter is disconnected when in STOP mode. Therefore, set it newly again after exiting STOP mode.

Figure 2-59. A/D Converter Control Register

A/D Conversion Result Register

	7	6	5	4	3	2	1	0	
ADCDR1 (0020_H)	AD09	AD08	AD07	AD06	AD05	AD04	AD03	AD02	(Initial value: 0000 0000)
ADCDR2 (0021_H)	AD01	AD00	EOCF	ADBF					(Initial value: 0000 ****)

EOCF	A/D conversion end flag	0: Before or during conversion 1: Conversion completed	Read-only
ADBF	A/D conversion busy flag	0: During stop of A/D conversion 1: During A/D conversion	

Note 1: The EOCF is cleared to "0" when reading the ADCDR1.
Therefore, the A/D conversion result should be read to ADCDR2 more first than ADCDR1.
Note 2: ADBF is set to "1" when A/D conversion starts and cleared to "0" when the A/D conversion is finished.
It also is cleared upon entering standby mode (STOP or SLOW).

Figure 2-60. A/D Converter Result Register

2.10.3 A/D Converter Operation

(1) Set up the A/D converter control register 1 (ADCCR1) as follows:

- Choose the channel to A/D convert using A/D input channel select (SAIN).
- Specify analog input enable for analog input control (AINDS).
- Specify AMD for the A/D converter control operation mode (software or repeat mode).

(2) Set up the A/D converter control register 2 (ADCCR2) as follows:

- Set the A/D conversion time using A/D conversion time (ACK). For details on how to set the conversion time, refer to Note 2 for A/D converter control register 2.
- Choose IREFON for D/A converter control.

(3) After setting up (1) and (2) above, set AD conversion start (ADRS) of A/D converter control register 1 (ADCCR1) to "1". If software start mode has been selected, A/D conversion starts immediately.

(4) After an elapse of the specified A/D conversion time, the A/D converted value is stored in A/D converted value register 1 (ADCDR1) and the A/D conversion finished flag (EOCF) of A/D converted value register 2 (ADCDR2) is set to "1", upon which time A/D 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.

2.10.4 A/D Converter Operation Modes

There are following two A/D converter operation modes:

- Software start: A/D conversion is performed once by setting AMD to "01" and ADRS to "1".
- Repeat mode: A/D conversion is performed repeatedly by setting AMD to "11" and ADRS to "1".

(1) Software start mode

After setting AMD (ADCCR1 bits 5, 6) to "01" (software start mode), set ADRS (ADCCR1 bit 7) to "1". A/D conversion of the voltage at the analog input pin specified by SAIN (ADCCR1 bits 0-3) is thereby started.

After completion of the A/D conversion, the conversion result is stored in A/D converted value registers (ADCDR1, 2) and at the same time EOCF (ADCDR2 bit 5) is set to 1, the A/D conversion finished interrupt (INTADC) is generated.

ADRS is automatically cleared after A/D conversion has started. Do not set ADRS (ADCCR1 bit 7) newly again (restart) during A/D conversion. Before you set ADRS newly again, check EOCF (ADCDR bit 5) to see that the conversion is completed or wait until the interrupt signal (INTADC) is generated (e.g., interrupt handling routine).

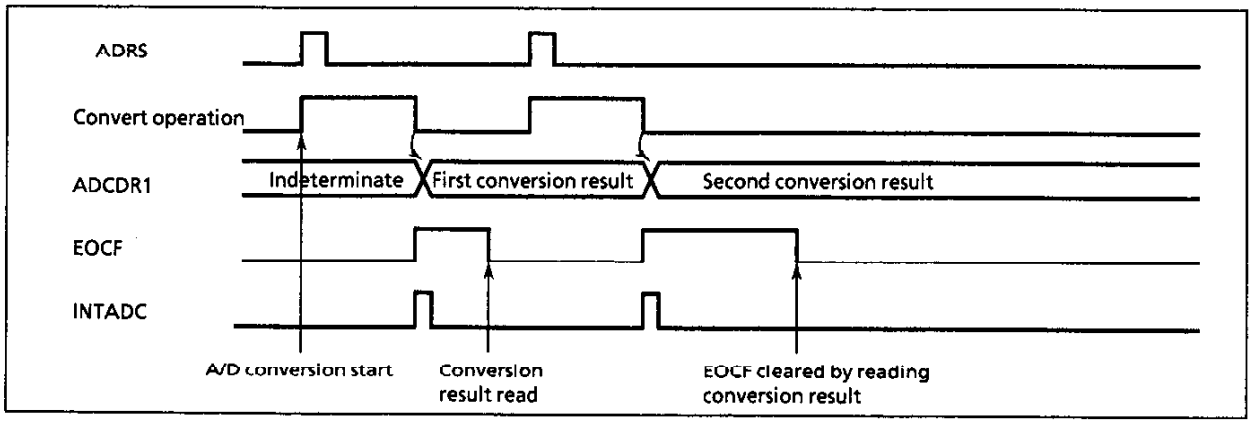


Figure 2-61. Operation in Software Start Mode

(2) Repeat mode

A/D conversion of the voltage at the analog input pin specified by SAIN (ADCCR1 bits 0 to 3) is performed repeatedly. In this mode, A/D conversion is started by setting ADRS (ADCCR1 bit 7) to "1" after setting AMD (ADCCR1 bits 5,6) to "11".

After completion of the A/D conversion, the conversion result is stored in A/D converted value registers (ADCDR1, 2) and at the same time EOCF (ADCDR2 bit 5) is set to 1, the A/D conversion finished interrupt (INTADC) is generated.

In repeat mode, each time one A/D conversion is completed, the next A/D conversion is started. To stop A/C conversion, set AMD (ADCCR1 bits 5, 6) to "00" (disable mode) by writing 0s. The A/D convert operation is stopped immediately. The converted value at this time is not stored in the A/D converted value register.

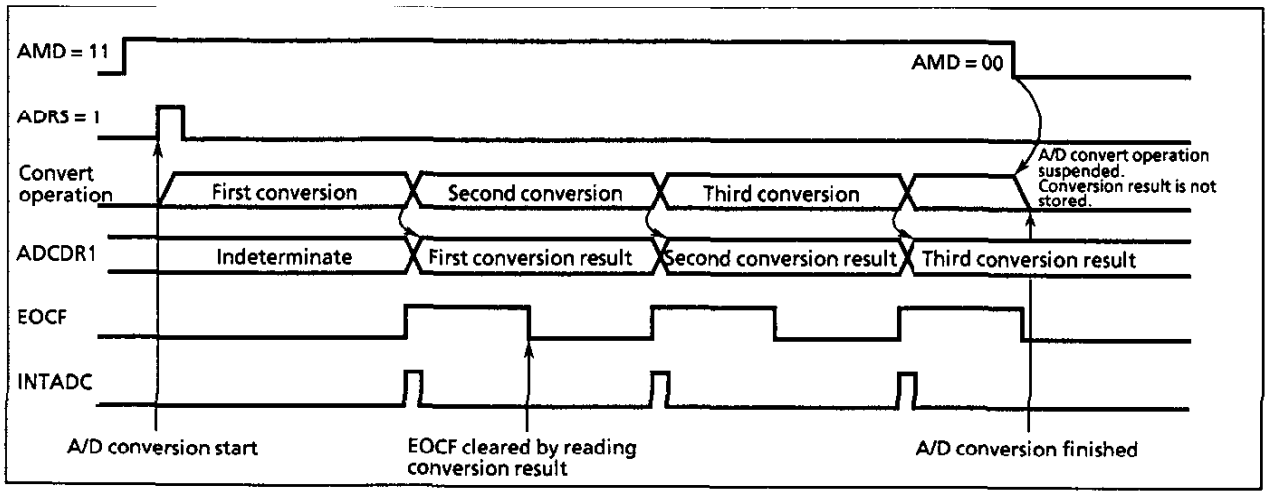


Figure 2-62. Operation in Repeat Mode

2.10.5 STOP and SLOW Modes during A/D Conversion

When standby mode (STOP or SLOW mode) is entered forcibly during A/D conversion, the A/D convert operation is suspended and the A/D converter is initialized. 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.) When restored from standby mode, A/D conversion is not automatically restarted, so you need to restart A/D conversion. Note that since the analog reference voltage is automatically disconnected, there is no possibility of current flowing into the analog reference voltage.

2.10.6 Precautions about A/D Converter

(1) Analog input pin voltage range

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

(2) Analog input shared pins

The analog input pins (AIN0 to AIN7) are shared with input/output ports. When using any of the analog inputs to execute A/D conversion, do not execute input/output instructions for all other ports. This is necessary to prevent the accuracy of A/D 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.

(3) Noise countermeasure

The internal equivalent circuit of the analog input pins is shown in Figure 2-63. 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.

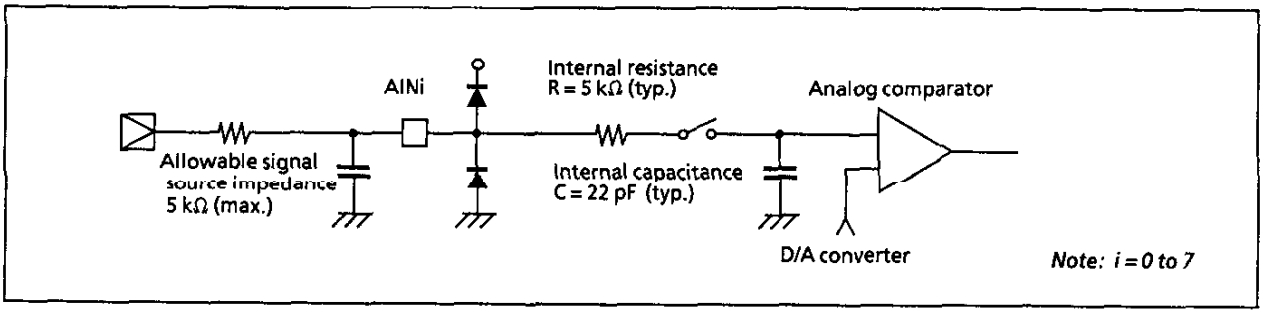


Figure 2-63. Analog Input Equivalent Circuit and Example of Input Pin Processing

2.11 Key-On Wake-Up (KWU)

In the TMP86C829/H29/M29, the STOP mode must be released by not only P20 ($\overline{INT5}$ / $\overline{STOP}$) pin but also P64 to P67 pins.
When the STOP mode is released by P64 to P67 pins, the P20 ($\overline{INT5}$ / $\overline{STOP}$) pin needs to be used.

2.11.1 Configuration

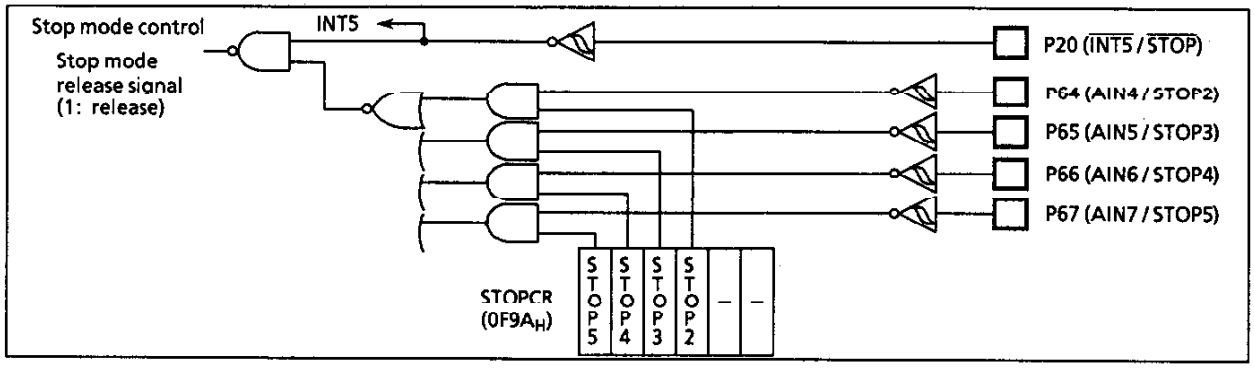
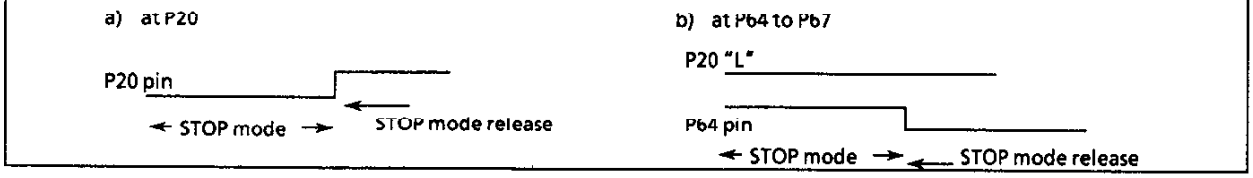


Figure 2-64. Stop Mode Control Circuit

Note: When STOP mode is released by P20 and P64 to P67, the most priority is P20.
When P64 to P67 pin used to release the STOP mode, then P20 must be input to "0" level.



2.11.2 Control

P64 to P67 (STOP2 to STOP5) pin can controlled by Key-On Wake-Up control register (STOPCR). It can be configured as enable /disable in one-bit unit. When those pins are used by STOP mode release, those pins must be set input mode (P6CR, P6DR, ADCCRA).
The STOP mode is set by SYSCR1 and release is the selected pin (STOPCR bit) to "0". When the STOP mode is released by inputting to P64 to P67 pins, the STOP mode (level mode) must be started by the system register 1 (SYSCR1). When the STOP mode, pleas check the level that P64 to P67 pin is high. When the STOP mode release, P20 pin must be use.

Note: When the STOP mode release by edge mode, do not use STOP2 to STOP5 or must be set "1" level into STOP2 to STOP5 pins.

Key On Wake Up control register

STOPCR (0F9AH)

7	6	5	4	3	2	1	0
STOP5	STOP4	STOP3	STOP2	–	–	–	–

(Initial value: 0000 ****)

STOP2	Stop mode released by P64 port	0: Disable 1: Enable	write-only
STOP3	Stop mode released by P65 port	0: Disable 1: Enable	
STOP4	Stop mode released by P66 port	0: Disable 1: Enable	
STOP5	Stop mode released by P67 port	0: Disable 1: Enable	

Figure 2-65. Key On Wake Up control register

2.12 LCD Driver

The 86C829/H29/M29 each have 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	8 pins (SEG7 to SEG0)
② Segment output or P1, P5, P7 input / output port	24 pins (SEG31 to SEG8)
③ Common output port	4 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 128 Segments (8-segment×16 digits)
② 1/3 Duty (1/3 Bias) LCD	Max 96 Segments (8-segment×12 digits)
③ 1/2 Duty (1/2 Bias) LCD	Max 64 Segments (8-segment× 8 digits)
④ Static LCD	Max 32 Segments (8-segment× 4 digits)

2.12.1 Configuration

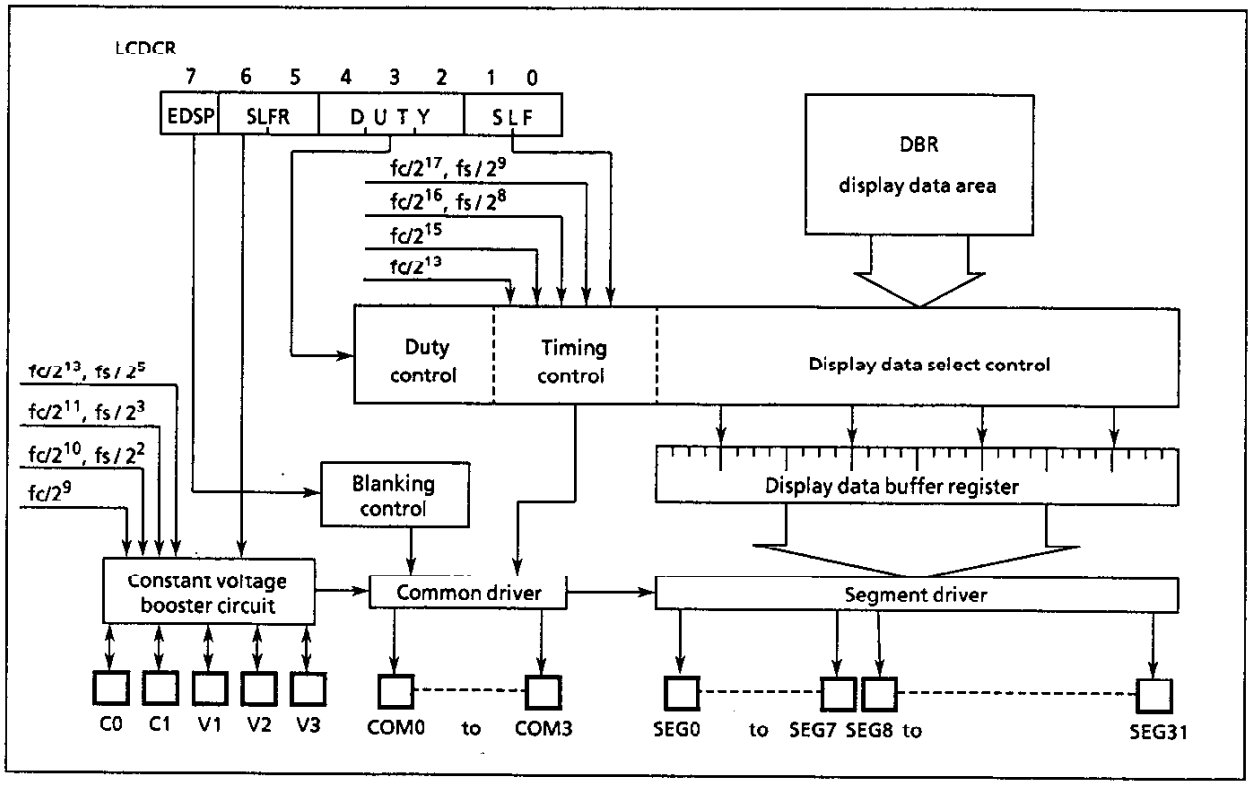


Figure 2-66. LCD Driver

2.12.2 Control

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

LCDCR (0028_H)

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

(Initial value: 0000 0000)

SLF	Selection of LCD frame frequency	00: $fc/2^{17}$ or $fs/2^9$ [Hz] 01: $fc/2^{16}$ or $fs/2^8$ 10: $fc/2^{15}$ 11: $fc/2^{13}$	R/W
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	
~~SLFR~~ VFSEL	Selection of boost frequency	00: $fc/2^{13}$ or $fs/2^5$ [Hz] 01: $fc/2^{11}$ or $fs/2^3$ 10: $fc/2^{10}$ or $fs/2^2$ 11: $fc/2^9$	
BRES	Booster circuit control	0: Disable (use divider resistance) 1: Enable	
EDSP	LCD Display Control	0: Blanking 1: Enables LCD display (Blanking is released)	

Figure 2-67. LCD Driver Control Register

(1) LCD driving methods

As for LCD driving method, 4 types can be selected by DUTY (bit 3 to bit 2 of LCDCR). The driving method is initialized in the initial program according to the LCD used.

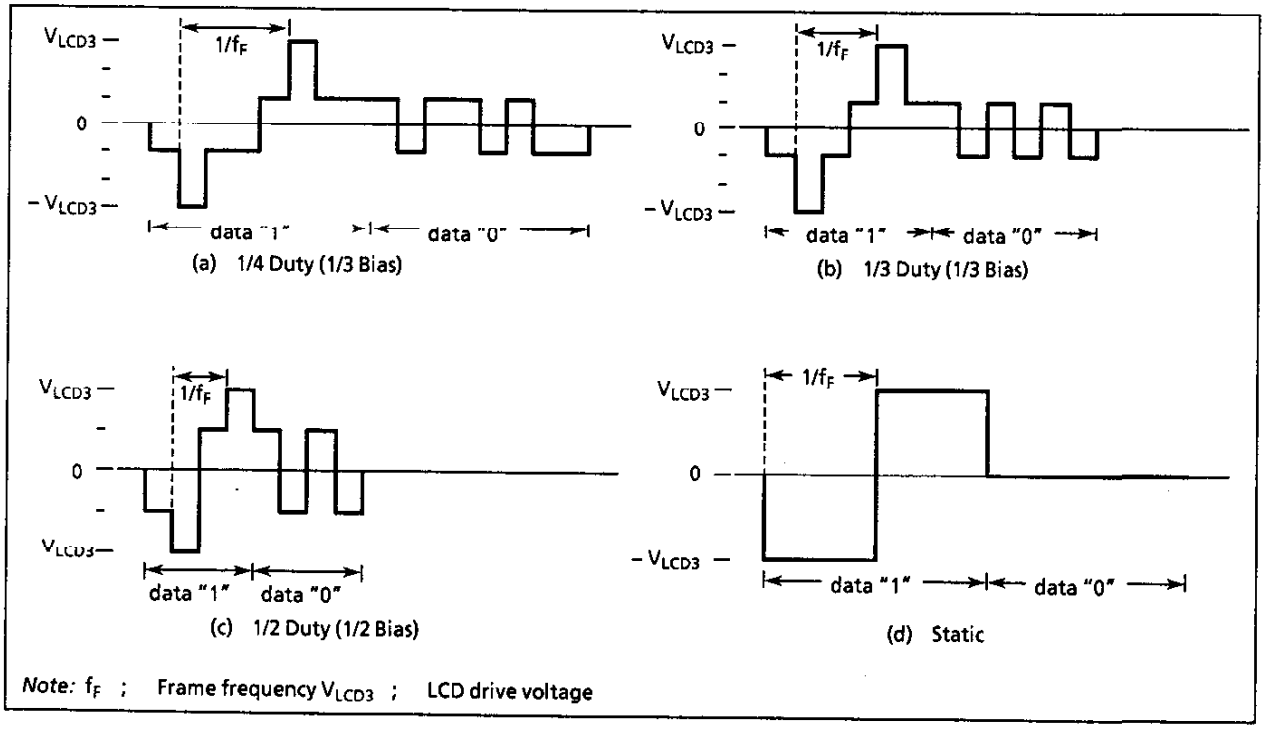


Figure 2-68. LCD Drive Waveform (COM – SEG pins)

(2) Frame frequency

Frame frequency (f_F) is set according to driving method and base frequency as shown in the following Table 2-16. The base frequency is selected by SLF (bit 1 and 0 of LCDCR) according to the frequency fc and fs of the basic clock to be used.

Table 2-16. 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	$\frac{fc}{2^{17}}$	$\frac{fc}{2^{17}}$	$\frac{4}{3}\cdot\frac{fc}{2^{17}}$	$\frac{4}{2}\cdot\frac{fc}{2^{17}}$	$\frac{fc}{2^{17}}$
	(fc = 16 MHz)	122	163	244	122
	(fc = 8 MHz)	61	81	122	61
01	$\frac{fc}{2^{16}}$	$\frac{fc}{2^{16}}$	$\frac{4}{3}\cdot\frac{fc}{2^{16}}$	$\frac{4}{2}\cdot\frac{fc}{2^{16}}$	$\frac{fc}{2^{16}}$
	(fc = 8 MHz)	122	163	244	122
	(fc = 4 MHz)	61	81	122	61
10	$\frac{fc}{2^{15}}$	$\frac{fc}{2^{15}}$	$\frac{4}{3}\cdot\frac{fc}{2^{15}}$	$\frac{4}{2}\cdot\frac{fc}{2^{15}}$	$\frac{fc}{2^{15}}$
	(fc = 4 MHz)	122	163	244	122
	(fc = 2 MHz)	61	81	122	61
11	$\frac{fc}{2^{15}}$	$\frac{fc}{2^{13}}$	$\frac{4}{3}\cdot\frac{fc}{2^{13}}$	$\frac{4}{2}\cdot\frac{fc}{2^{13}}$	$\frac{fc}{2^{13}}$
	(fc = 1 MHz)	122	163	244	122

Note: fc; High frequency clock [Hz]

(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	$\frac{fs}{2^{9}}$	$\frac{fs}{2^{9}}$	$\frac{4}{3}\cdot\frac{fs}{2^{9}}$	$\frac{4}{2}\cdot\frac{fs}{2^{9}}$	$\frac{fs}{2^{9}}$
	(fs = 32.768 kHz)	64	85	128	64
11	$\frac{fs}{2^{8}}$	$\frac{fs}{2^{8}}$	$\frac{4}{3}\cdot\frac{fs}{2^{8}}$	$\frac{4}{2}\cdot\frac{fs}{2^{8}}$	$\frac{fs}{2^{8}}$
	(fs = 32.768 kHz)	128	171	256	128

Note: fs; Low-frequency clock [Hz]

(3) Booster circuit for LCD driver

The LCD voltage booster pin can select the booster circuit or the divider resistance.
The booster circuit control is selected by BRES (bit 6 in LCDCR).
The booster circuit boosts the output voltage for the segment / common signal by double (V2) and triple (V3) in relation to the on-chip output voltage (1 V typ.).
When used as the divider resistance, the V1, V2 and V3 pins are input by divider voltage of external supply.
When used as the booster circuit, the VLCD setting should be composed to 1/3 bias.
The selection of boost frequency is selected by SLFR (bit 1 to 0 in LCDCR).
Selecting the fast frequency using the SLFR in the command register (LCDCR) raises the drive capability of segment/common.
Table 2-17. shows the reference frequency of the booster circuit.

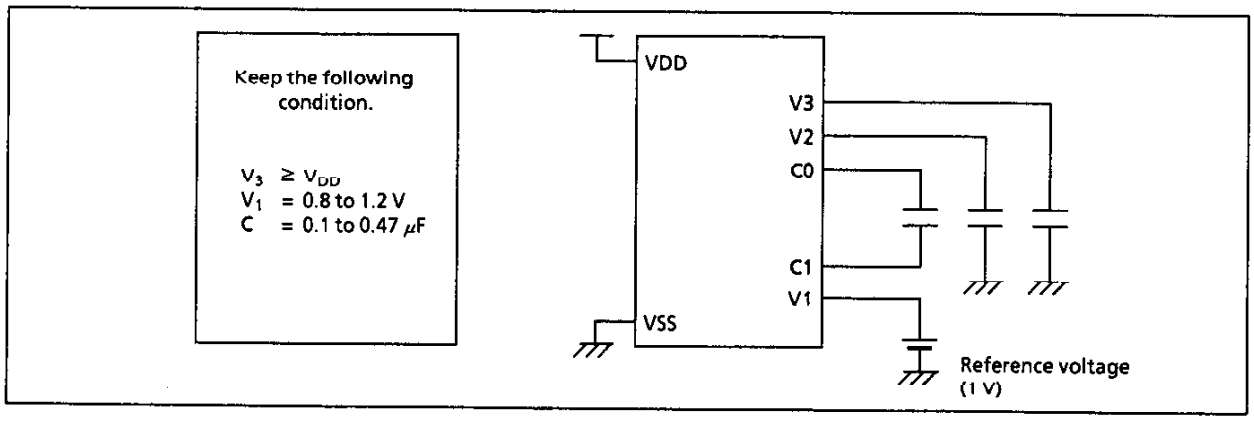


Figure 2-69. Example of a Booster Circuit

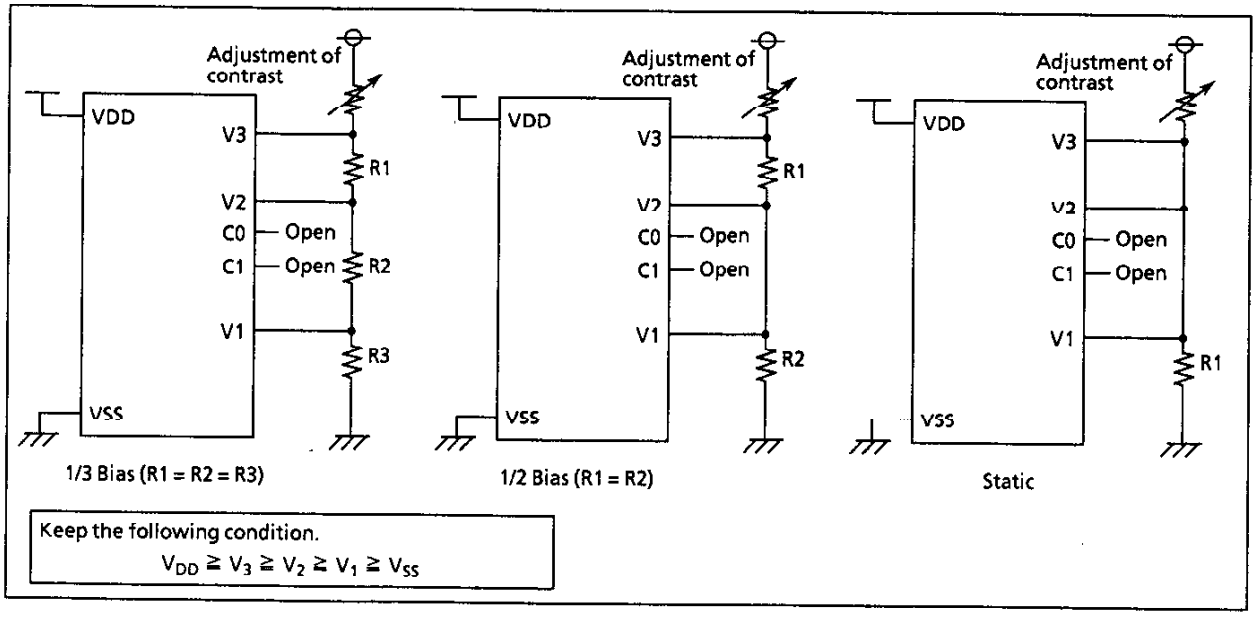


Figure 2-70. Example of Divider Registance

Table 2-17. Reference Frequency of the Booster Circuit

SLFR	frequency	fc = 2 MHz	fc = 4 MHz	fc = 8 MHz	fc = 16 MHz	fs = 32.768 kHz
00	$fc/2^{13}$ or $fs/2^5$	—	—	—	1.95 kHz	1.02 kHz
01	$fc/2^{11}$ or $fs/2^3$	—	1.95 kHz	3.91 kHz	7.81 kHz	4.09 kHz
10	$fc/2^{10}$ or $fs/2^2$	1.95 kHz	3.91 kHz	7.81 kHz	15.6 kHz	8.19 kHz
11	$fc/2^9$	3.91 kHz	7.81 kHz	15.6 kHz	31.3 kHz	—

Note: To fully drive the booster circuit, it must be operated with a boosting frequency of 1 kHz or above. Therefore, make sure SLFR is set to 1 kHz or above for any operating frequency used.

Table 2-18. Selection of V3 Boosting Frequency

Boosting frequency	fc = 16 MHz	fc = 8 MHz	fs = 32.768 MHz
$fc/2^{13}$ or $fs/2^5$	20 ms	40 ms	40 ms
$fc/2^{11}$ or $fs/2^3$	5 ms	10 ms	10 ms
$fc/2^{10}$ or $fs/2^4$	2.5 ms	5 ms	5 ms
$fc/2^9$	1.25 ms	2.5 ms	—

Note 1: Topr = 25°C, 0.1 μF ≦ C ≦ 0.47 μF
Note 2: V3 booting time at VDD is stable.

Notice of using LCD driver

The falling time and fluctuation of power supply voltage.

When LCD driver is used with the following condition, LCD may not be displayed temporarily, because the V1/V2/V3 pins output will be unstable by stopping of LCD booster circuit.
Therefore, please take an enough time by software, before enabling LCD.

a) When the falling time of power supply voltage is shorter than 1ms, within an operating voltage. (at ~~4.5~~ 1.8 V to ~~5.5~~ V_3 V, Topr = ~~-10~~ -40 to ~~70~~ 85c)

b) When the fluctuation of power supply within 1ms is bigger than 0.7 V.

2.12.3 LCD Display Operation

(1) Display data setting

Display data is stored to the display data area (assigned to address 0F80 to $0F8F_H$) 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. Figure 2-71. 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 2-19.)

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.

address	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
$0F80_H$	SEG1				SEG0			
81	SEG3				SEG2			
82	SEG5				SEG4			
83	SEG7				SEG6			
84	SEG9				SEG8			
85	SEG11				SEG10			
86	SEG13				SEG12			
87	SEG15				SEG14			
88	SEG17				SEG16			
89	SEG19				SEG18			
8A	SEG21				SEG20			
8B	SEG23				SEG22			
8C	SEG25				SEG24			
8D	SEG27				SEG26			
8E	SEG29				SEG28			
8F	SEG31				SEG30			
	COM3	COM2	COM1	COM0	COM3	COM2	COM1	COM0

Figure 2-71. LCD Display Data Area (DBR)

Table 2-19. 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

(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 (SEG0 to SEG7) and LCD common outputs are fixed "0" level. But the multiplex terminal (P1, P5 and P7 ports) 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.

2.12.4 Control Method of LCD Driver

(1) Initial setting

Figure 2-72. shows the flowchart of initialization.

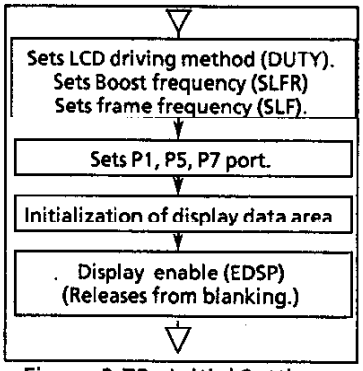


Figure 2-72. Initial Setting of LCD Driver

Example: To operate a 1/4 duty LCD of 32 segments × 4 com-mons at frame frequency $fc/2^{16}$ [Hz]

```
LD   (LCDCR), 00000001B ; Sets LCD driving method and frame frequency.
                          Boost frequency
LD   (P1LCR), 0FFH      ; Sets P1 port as segment output.
 :    :
                        ; Sets the initial value of display data.
LD   (LCDCR), 10000001B ; Display enable
```

(2) Store of display data

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

Example 1: To display using 1/4 duty LCD a numerical value which corresponds to the LCD data stored in data memory at address 80_H (when pins COM and SEG are connected to LCD as in Figure 2-73.), display data become as shown in Table 2-20.

```
      LD    A, (80H)
      ADD   A, TABLE-$-5
      LD    HL,0F80H
      LD    (HL), (PC+A)
      RET
TABLE: DB   11011111B, 00000110B,
            11100011B, 10100111B,
            00110110B, 10110101B,
            11110101B, 00010111B,
            11110111B, 10110111B
SNEXT:
```

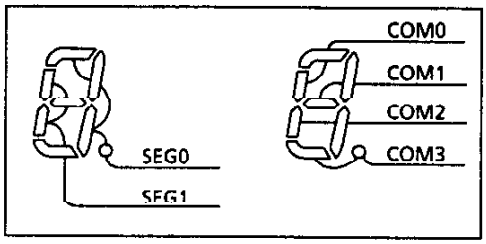


Figure 2-73. Example of COM, SEG Pin Connection (1/4 Duty)

Note: DB is a byte data difinition instruction.

Table 2-20. Example of Display Data (1/4 Duty)

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

Example 2: Table 2-20. shows an example of display data which are displayed using 1/2 duty LCD in the same way as Table 2-21. The connection between pins COM and SEG are the same as shown in Figure 2-74.

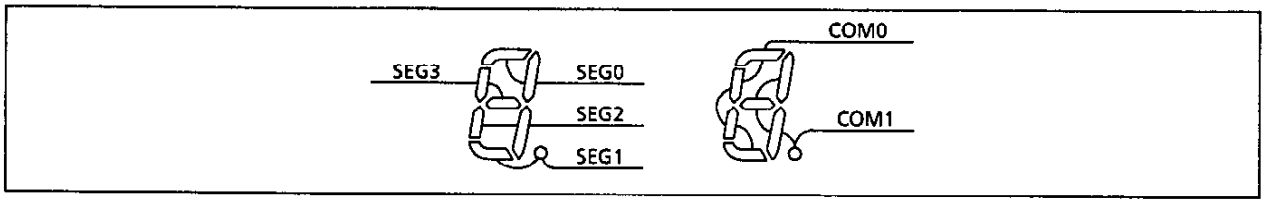


Figure 2-74. Example of COM, SEG Pin Connection

Table 2-21. 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*

(3) Example of LCD drive output

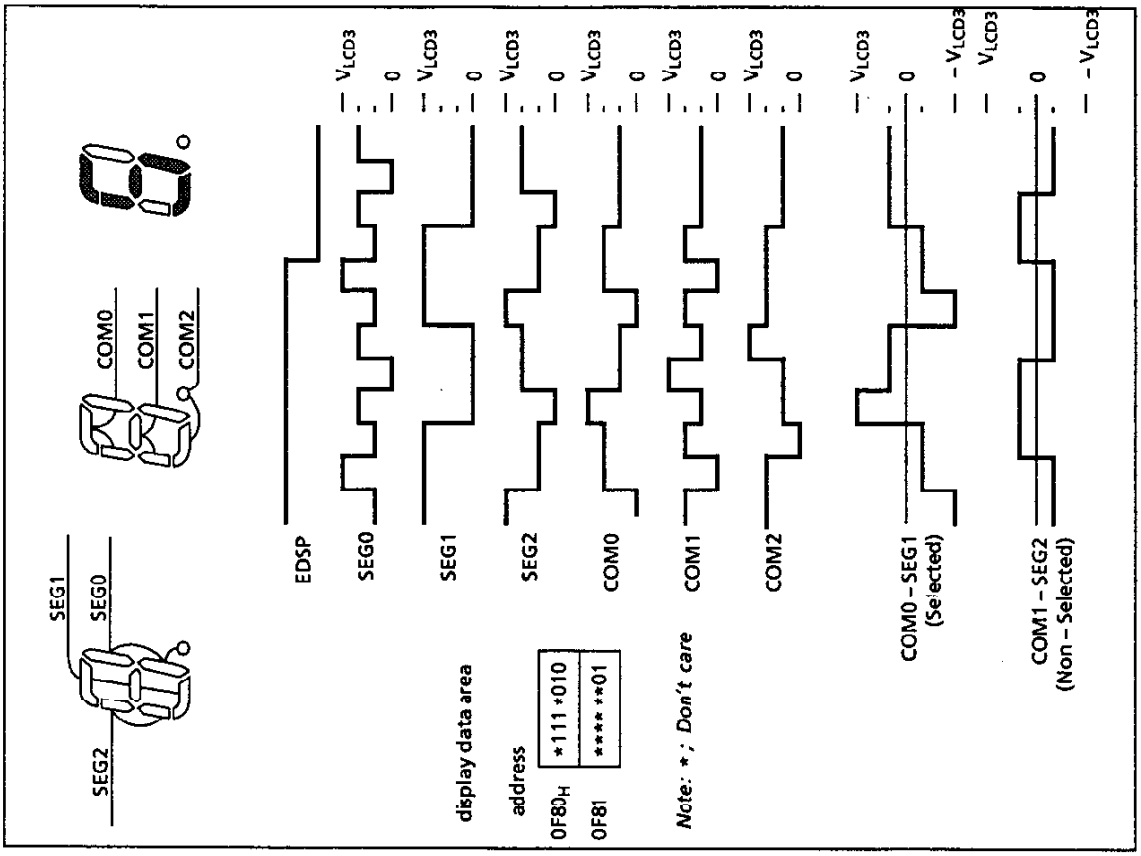


Figure 2-76. 1/3 Duty (1/3 Bias) Drive

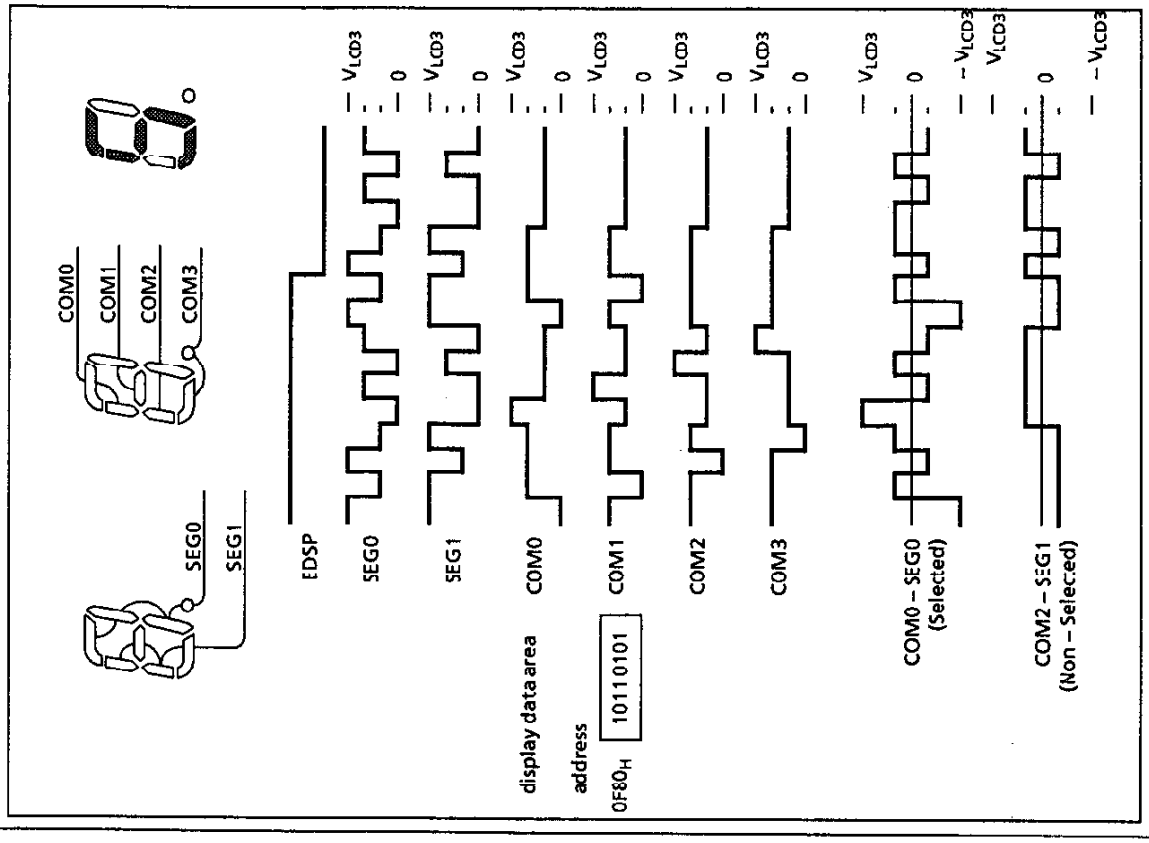


Figure 2-75. 1/4 Duty (1/3 Bias) Drive

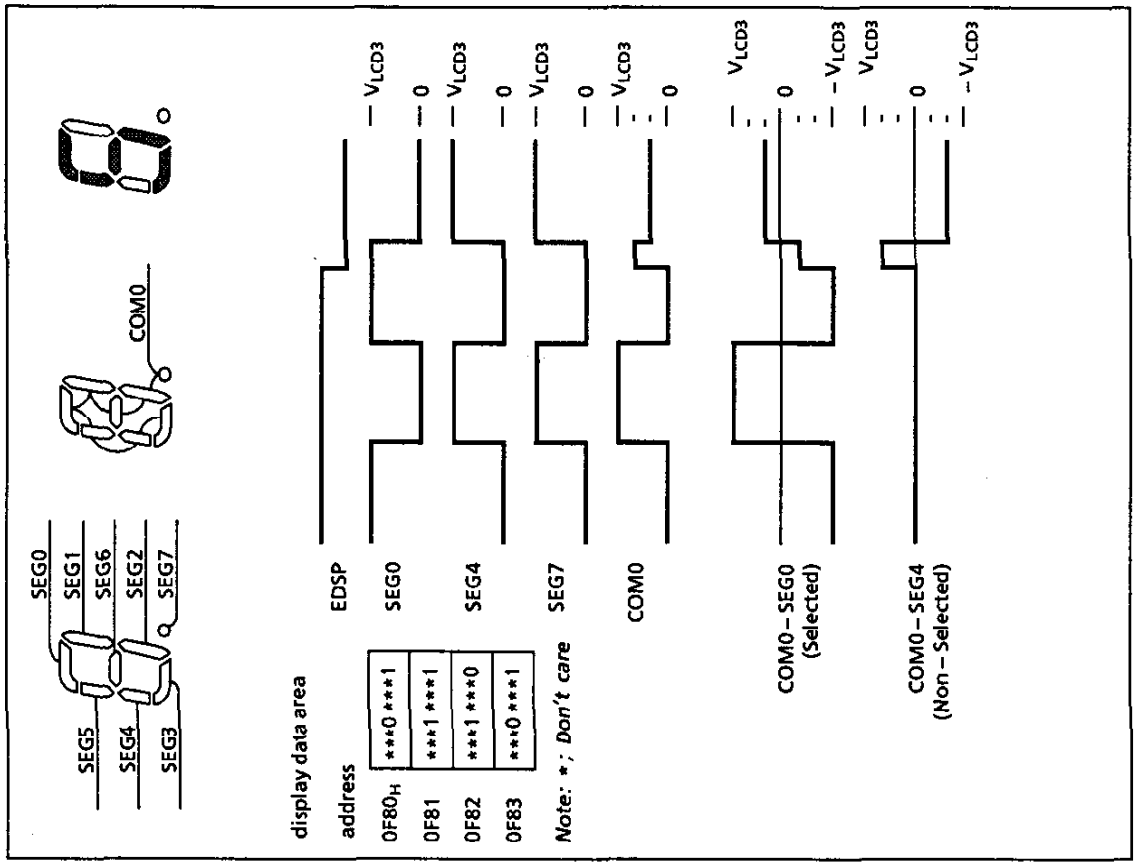


Figure 2-78. Static Drive

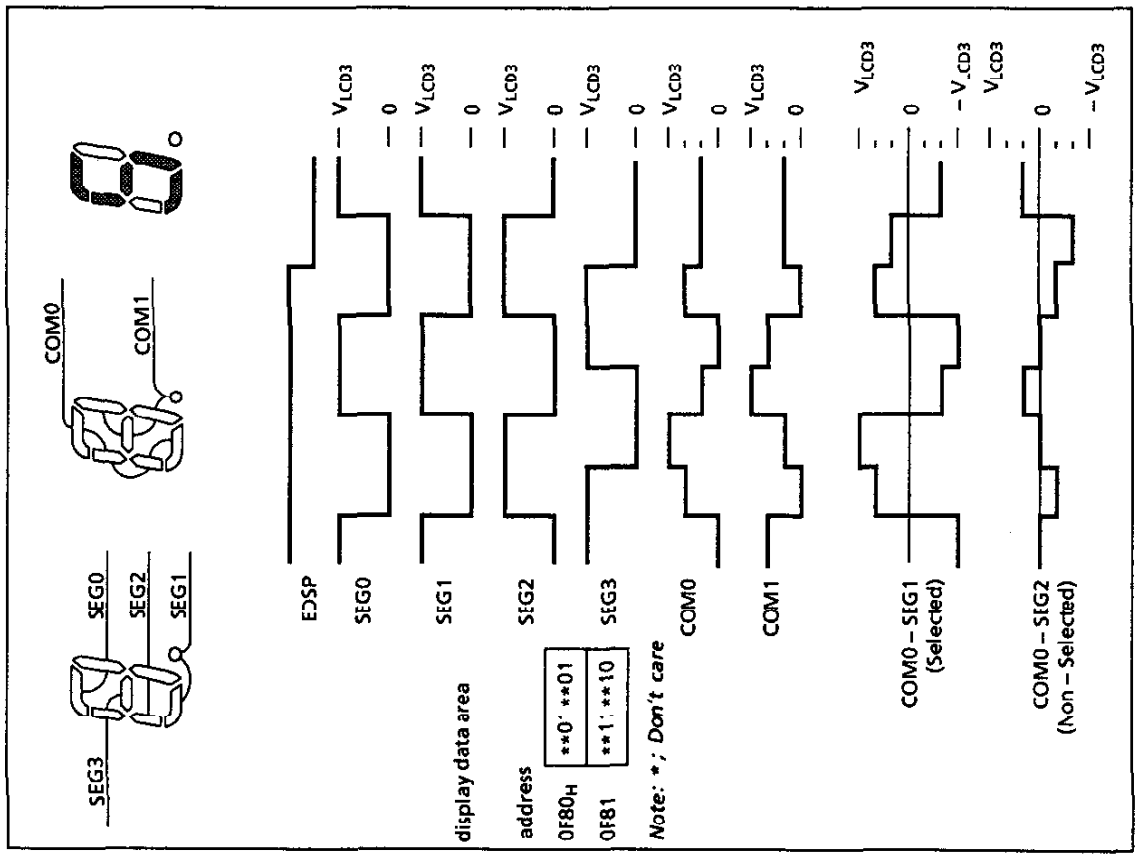
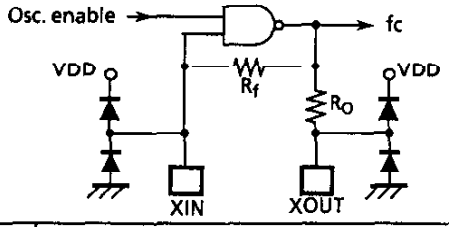
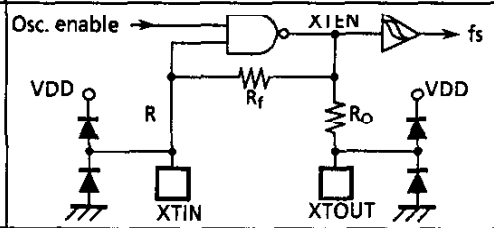
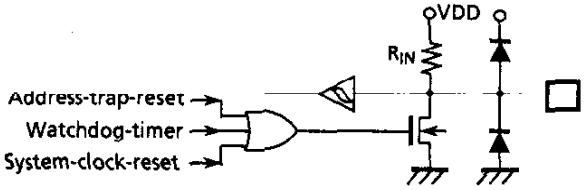
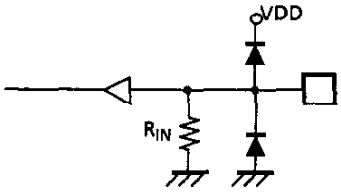


Figure 2-77. 1/2 Duty (1/3 Bias) Drive

Input / Output Circuitry

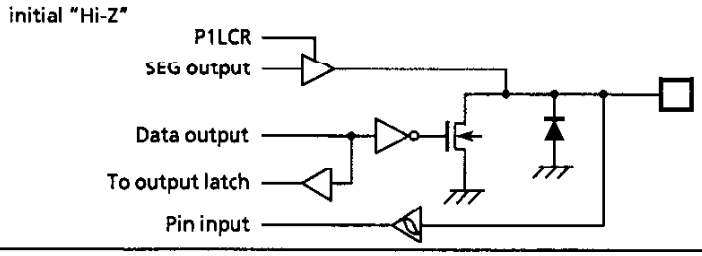
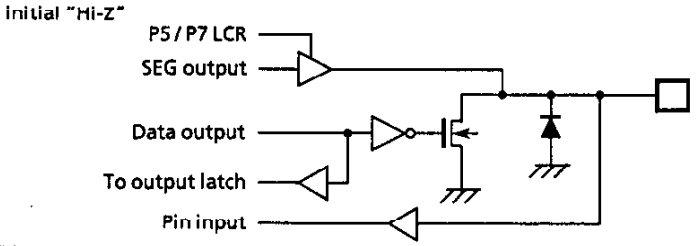
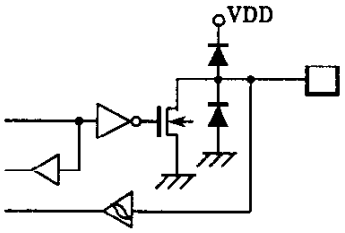
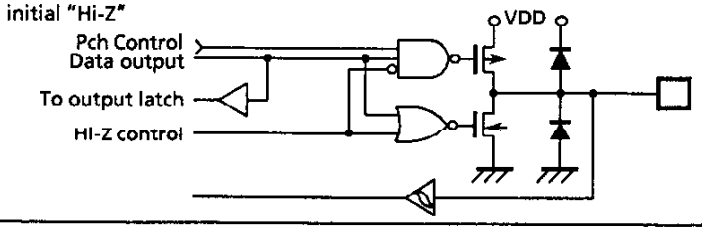
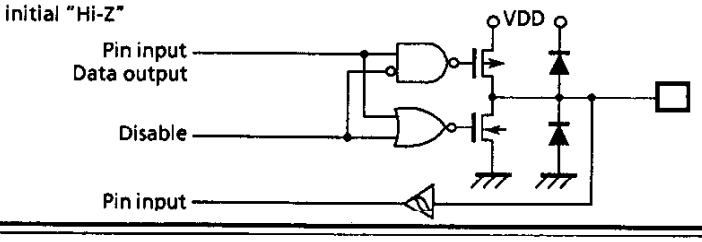
(1) Control Pins

The input / output circuitries of the TMP86C829/H29/M29 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 = 1.5 kΩ (typ.)
XTIN XTOUT	Input Output	NM1: Refer to port P2 NM2: 	Resonator connecting pins (Low-frequency) R_f = 6 MΩ (typ.) R_O = 220 kΩ (typ.)
$\overline{\text{RESET}}$	I/O		Sink open drain output Hysteresis input Pull-up resistor R_{IN} = 220 kΩ (typ.)
TEST	Input		Pull-down resistor R_{IN} = 70 kΩ (typ.)

Note: The TEST pin of the 86PM29 does not have a pull-down resistor. Fix the test pin at low-level.

(2) Input / Output Ports

Port	I/O	Input / Output Circuitry	Remarks
P1	I/O	initial "Hi-Z" 	Sink open drain output Hysteresis input
P5 P7	I/O	initial "Hi-Z" 	Sink open drain output
P2	I/O	initial "Hi-Z" 	Sink open drain output Hysteresis input
P3	I/O	initial "Hi-Z" 	Sink open drain or Push-pull output Hysteresis input High current output (Nch) (Programable port option)
P6	I/O	initial "Hi-Z" 	Tri-state I/O Hysteresis input

Note: Port P1, P5 and P7 are sink open drain output. But they are also used as a segment output of LCD. Therefore, absolute maximum ratings of port input voltage should be used in −0.3 to V_{DD} +0.3 volts

4. Electrical Characteristics

Absolute Maximum Ratings (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_{OUT1}	P21, P22, /RESET, Tri-state Port	− 0.3 to V_{DD} + 0.3	
Output Current (Per 1 pin)	I_{OUT1}	P3, P6 Port	− 1.8	mA
	I_{OUT2}	P1, P2, P5, P6, P7 Port	3.2	
	I_{OUT3}	P3 Port	30	
Output Current (Total)	ΣI_{OUT1}	P1, P2, P5, P6, P7 Port	60	
	ΣI_{OUT2}	P3 Port	80	
Power Dissipation [T_{opr} = 85°C]	PD		350	mW
Soldering Temperature (time)	Tsld		260 (10 s)	°C
Storage Temperature	Tstg		− 55 to 125	
Operating Temperature	Topr		− 40 to 85	

Note: 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.

Recommended Operating Condition (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 mode	4.5	5.5	V
				IDLE0, 1, 2 mode			
			fc = 8 MHz	NORMAL1, 2 mode	2.7		
				IDLE0, 1, 2 mode			
			fc = 4.2 MHz	NORMAL1, 2 mode	1.8		
				IDLE0, 1, 2 mode			
			fs = 32.768 kHz	SLOW1, 2 mode			
				SLEEP0, 1, 2 mode			
				STOP mode			
Input high Level	V_{IH1}	Except Hysteresis input	$V_{DD} \geq 4.5$ V		$V_{DD} \times 0.70$	V_{DD}	V
	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
	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} = 1.8 to 5.5 V		1.0	4.2	MHz
			V_{DD} = 2.7 to 5.5 V			8.0	
			V_{DD} = 4.5 to 5.5 V			16.0	
	fs	XTIN, XTOUT			30.0	34.0	kHz

Note: 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.

D.C. 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	
Output Leakage Current	I_{LO}	Sink Open Drain, Tri-state	V_{DD} = 5.5 V, V_{OUT} = 5.5 V / 0 V	−	−	±2	μA
Output High Voltage	V_{OH1}	Push-pull Port	V_{DD} = 4.5 V, I_{OH} = −200μA	2.4	−	−	V
	V_{OH2}	Tri-st Port	V_{DD} = 4.5 V, I_{OH} = −0.7 mA	4.1	−	−	
Output Low Voltage	V_{OL}	Except XOUT and P3 Port	V_{DD} = 4.5 V, I_{OL} = 1.6mA	−	−	0.4	V
Output Low Current	I_{OL}	High Current Port (P3 Port)	V_{DD} = 4.5 V, V_{OL} = 1.0 V	−	20	−	mA
Supply Current in NORMAL 1, 2 mode	I_{DD}		V_{DD} = 5.5 V V_{IN} = 5.3 / 0.2 V fc = 16 MHz fs = 32.768 kHz	−	7.5	9	mA
Supply Current in IDLE 0, 1, 2 mode				−	5.5	6.5	
Supply Current in SLOW 1 mode			V_{DD} = 3.0 V V_{IN} = 2.8 V / 0.2 V fs = 32.768 kHz LCD driver is not enable.	−	18	42	μA
Supply Current in SLEEP 1 mode				−	16	25	
Supply Current in SLEEP 0 mode				−	12	20	
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 SLOW 2 and SLEEP 2 modes are equivalent to IDLE 0, 1, 2.

A/D Conversion Characteristics

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

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Analog Reference Voltage	V_{AREF}		V_{DD}-1.5	–	V_{DD}	V
Power Supply Voltage of Analog Control Circuit	A_{VDD}			V_{DD}		V
Analog Reference Voltage Range	$\triangle V_{AREF}$		2.5	–	–	V
Analog Input Voltage	V_{AIN}		V_{SS}	–	V_{AREF}	V
Power Supply Current of Analog Reference Voltage	I_{REF}	$V_{DD} = A_{VDD} = V_{AREF}$ = 5.5 V V_{SS} = 0.0 V	–	0.6	1.0	mA
Non linearity Error		V_{DD} = 4.5 to 5.5 V, V_{SS} = 0.0 V $A_{VDD} = V_{AREF}$ = 5.0 V	–	–	±4	LSB
Zero Point Error			–	–	±4	
Full Scale Error			–	–	±4	
Total Error			–	–	±8	

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

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Analog Reference Voltage	V_{AREF}		V_{DD}-1.5	–	V_{DD}	V
Power Supply Voltage of Analog Control Circuit	A_{VDD}			V_{DD}		V
Analog Reference Voltage Range	$\triangle V_{AREF}$		2.5	–	–	V
Analog Input Voltage	V_{AIN}		V_{SS}	–	V_{AREF}	V
Power Supply Current of Analog Reference Voltage	I_{REF}	$V_{DD} = A_{VDD} = V_{AREF}$ = 4.5 V V_{SS} = 0.0 V	–	0.5	0.8	mA
Non linearity Error		V_{DD} = 2.7 to 4.5 V, V_{SS} = 0.0 V $A_{VDD} = V_{AREF}$ = 2.7 V	–	–	±4	LSB
Zero Point Error			–	–	±4	
Full Scale Error			–	–	±4	
Total Error			–	–	±8	

(V_{SS} = 0.0 V, V_{DD} = 1.8 to 2.7 V, Topr = – 40 to 85°C)

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Analog Reference Voltage	V_{AREF}		V_{DD}-0.9	–	V_{DD}	V
Power Supply Voltage of Analog Control Circuit	A_{VDD}			V_{DD}		V
Analog Reference Voltage Range	$\triangle V_{AREF}$		1.8	–	–	V
Analog Input Voltage	V_{AIN}		V_{SS}	–	V_{AREF}	V
Power Supply Current of Analog Reference Voltage	I_{REF}	$V_{DD} = A_{VDD} = V_{AREF}$ = 2.7 V V_{SS} = 0.0 V	–	03	0.5	mA
Non linearity Error		V_{DD} = 1.8 to 2.7 V, V_{SS} = 0.0 V $A_{VDD} = V_{AREF}$ = 1.8 V	–	–	±4	LSB
Zero Point Error			–	–	±4	
Full Scale Error			–	–	±4	
Total Error			–	–	±8	

Note 1: Total errors includes all errors, except quantization error.
Note 2: Conversion time is different in recommended value by power supply voltage. About conversion time, please refer to "2.10.2 Register Framing".
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.

A.C. 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	NORMAL 1, 2 mode	0.25	–	4	μs
		IDLE 0, 1, 2 mode				
		SLOW 1, 2 mode	117.6	–	133.3	
		SLEEP 0, 1, 2 mode				
High Level Clock Pulse Width	twcH	For external clock operation (XIN input) fc = 16 MHz	–	31.25	–	ns
Low Level Clock Pulse Width	twcL					
High Level Clock Pulse Width	twcH	For external clock operation (XTIN input) fc = 32.768 kHz	–	15.26	–	μs
Low Level Clock Pulse Width	twcL					

(V_{SS} = 0 V, V_{DD} = 2.7 to 4.5 V, Topr = −40 to 85°C)

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Machine Cycle Time	tcy	NORMAL 1, 2 mode	0.5	–	4	μs
		IDLE 0, 1, 2 mode				
		SLOW 1, 2 mode	117.6	–	133.3	
		SLEEP 0, 1, 2 mode				
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	twcH	For external clock operation (XTIN input) fc = 32.768 kHz	–	15.26	–	μs
Low Level Clock Pulse Width	twcL					

(V_{SS} = 0 V, V_{DD} = 1.8 to 2.7 V, Topr = −40 to 85°C)

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Machine Cycle Time	tcy	NORMAL 1, 2 mode	0.95	–	4	μs
		IDLE 0, 1, 2 mode				
		SLOW 1, 2 mode	117.6	–	133.3	
		SLEEP 0, 1, 2 mode				
High Level Clock Pulse Width	twcH	For external clock operation (XIN input) fc = 4.2 MHz	–	119.05	–	ns
Low Level Clock Pulse Width	twcL					
High Level Clock Pulse Width	twcH	For external clock operation (XTIN input) fc = 32.768 kHz	–	15.26	–	μs
Low Level Clock Pulse Width	twcL					

Timer Counter 1 input (ECIN) Characteristics

(V_{SS} = 0 V, Topr = −40 to 85°C)

Parameter	Symbol	Condition		Min	Typ.	Max	Unit
TC1 input (ECIN input)	t_{TC1}	Frequency measurement mode V_{DD} = 4.5 to 5.5 V	Single edge count	–	–	16	MHz
			Both edge count	–	–		
		Frequency measurement mode V_{DD} = 2.7 to 4.0 V	Single edge count	–	–	8	
			Both edge count	–	–		
		Frequency measurement mode V_{DD} = 1.8 to 2.7 V	Single edge count	–	–	4.2	
			Both edge count	–	–		