TOSHIBA

TENTATIVE

TOSHIBA ORIGINAL CMOS 8-BIT MICROCONTROLLER

TLCS—870/X SERIES

TMP88CP38AN/AF , TMP88CM38AN/AF

DATA BOOK

1st Edition (2000-11-07)

TOSHIBA CORPORATION

ROM corrective function <add note> 3-38-33

Note3: RAM area which is used for ROM correction circuit in TMP88CM/P38A can use address from 00140H to 0063FH, but RAM area which is used for ROM correction circuit in OTP(TMP88PS38) can use address from 00140H to 0083FH. Therefore, when using ROM correction circuit in TMP88CM/P38A, load address for patch program code and jump vector must be changed after debugging a program by OTP.

On-Screen Display (OSD) Circuit <add note>

1) 3-38A-136

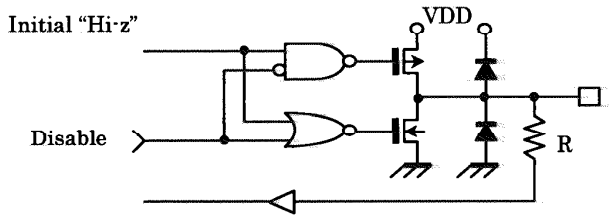
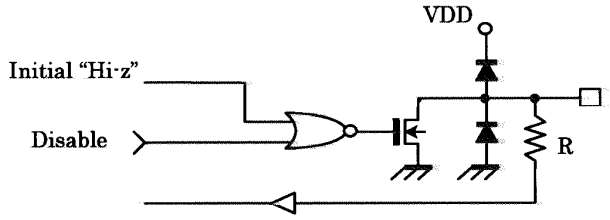
Note : The contents of OSD control registers except PIDS, P67S to P64S are initialized in STOP mode. Then Clock generation for OSD display dose not stop. Clock generation for OSD display stop when ORCLKC register writes 00H data.

2) 3-38A-168

Note4: Clock generation for OSD display dose not stop in STOP mode. Clock generation for OSD display stop when ORCLKC register writes 00H data.

Amend The Contents

1) 3-38A-195

P62 (@CSOUT)	I/O		Tri-state I/O R=1kΩ (typ.) High current output I_{OL}=20mA (typ.)
P62, P63	I/O		Sink open drain output High current output I_{OL}=20mA (typ.) R=1kΩ (typ.)

CMOS 8-Bit Microcontroller

TMP88CM38AN/F, TMP88CP38AN/F

The TMP88CM38A/P38A are the high speed and high performance 8-bit single chip microcomputers. This MCU contain CPU core, ROM, RAM, input / output ports, four Multi-function timer / counters, serial bus interface, on-screen display, PWM output, 8-bit AD converter, and remote control signal preprocessor on chip.

Part No.	ROM	RAM	Package	OTP MCU
TMP88CP38AN	48 Kbytes	1.5 Kbytes	P-SDIP42-600-1.78	TMP88PS38N
TMP88CP38AF			P-QFP44-1414-0.80D	TMP88PS38F
TMP88CM38AN	32 Kbytes		P-SDIP42-600-1.78	TMP88PS38N
TMP88CM38AF			P-QFP44-1414-0.80D	TMP88PS38F

Features

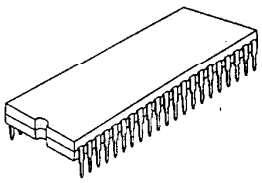
- 8-bit single chip microcomputer TLCS-870/X Series
- Instruction execution time: 0.25 μs (at 16 MHz)
- 842 basic instructions
  - Multiplication and Division (8 bits X 8 bits, 16 bits X 8 bits, 16 bits / 8 bits)
  - Bit manipulations (Set/Clear/Complement/Move/Test/Exclusive or)
  - 16-bit data and 20-bit data operations
  - 1-byte jump/subroutine-call(Short relative jump/Vector call)
- I/O Ports: Maximum 33 (High current output: 4)
- 16 interrupt sources: External 5, Internal 11
  - All sources have independent latches each, and nested interrupt control is available.
  - Edge-selectable external interrupts with noise reject
  - High-speed task switching by register bank changeover
- ROM Corrective Function
- Two 16-bit Timer / Counters: TC1, TC2
  - Timer, Event-counter, Pulse width measurement, External trigger timer, Window modes
- Two 8-bit Timer / Counters: TC3, TC4
  - Timer, Event counter, Capture (Pulse width/duty measurement) mode

Purchase of TOSHIBA I² C components conveys a license under the Philips I² C Patent Rights to use these components in an I² C system, provided that the system conforms to the I² C Standard Specification as defined by Philips.

- Time Base Timer (Interrupt frequency: 0.95 Hz to 31250 Hz)
- Watchdog Timer
  - Interrupt sourse / reset output
- Serial Bus Interface
  - I^2C bus, 8-bit SIO mode (Selectable two I/O channels)
- On-screen display circuit
  - Font ROM characters: 384 characters
  - Characters display: 32 columns X 12 lines
  - Composition: 16 X 18 dots
  - Size of character: 3 kinds (line by line)
  - Color of character: 8 or 15 kinds (character by character)
  - Variable display position: Horizontal 256 steps, Vertical 512 steps
  - Fringing, Smoothing, Slant, Underline , Blinking function
- Jitter Elimination
- Data slicer circuit 1ch
- DA conversion (Pulse Width Modulation) outputs
  - 14/12-bit resolution (2 channels)
  - 12-bit resolution (2 channels)
  - 7-bit resolution (6 channels)
- 8-bit successive approximate type AD converter with sample and hold
- Remote control signal preprocessor
- Two Power saving operating modes
  - STOP mode: Oscillation stops. Battery / Capacitor back-up. Port output hold/high-impedance.
  - IDLE mode: CPU stops, and Peripherals operate using high-frequency clock. Release by interrupts.
- Emulation POD: BM88CM38A/P38AN0A

Package

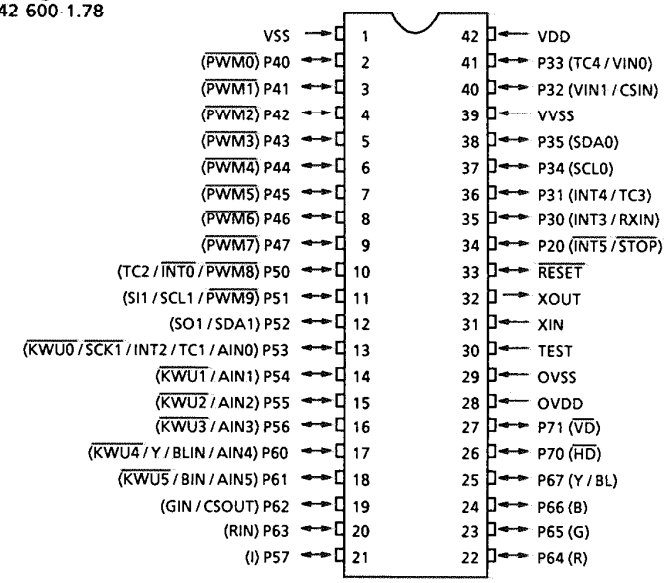
P-SDIP42-600-1.78



TMP88CM38AN
TMP88CP38AN

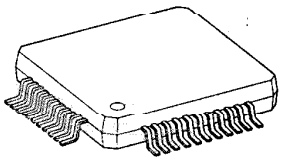
Pin Assignments

P-SDIP42-600-1.78



Package

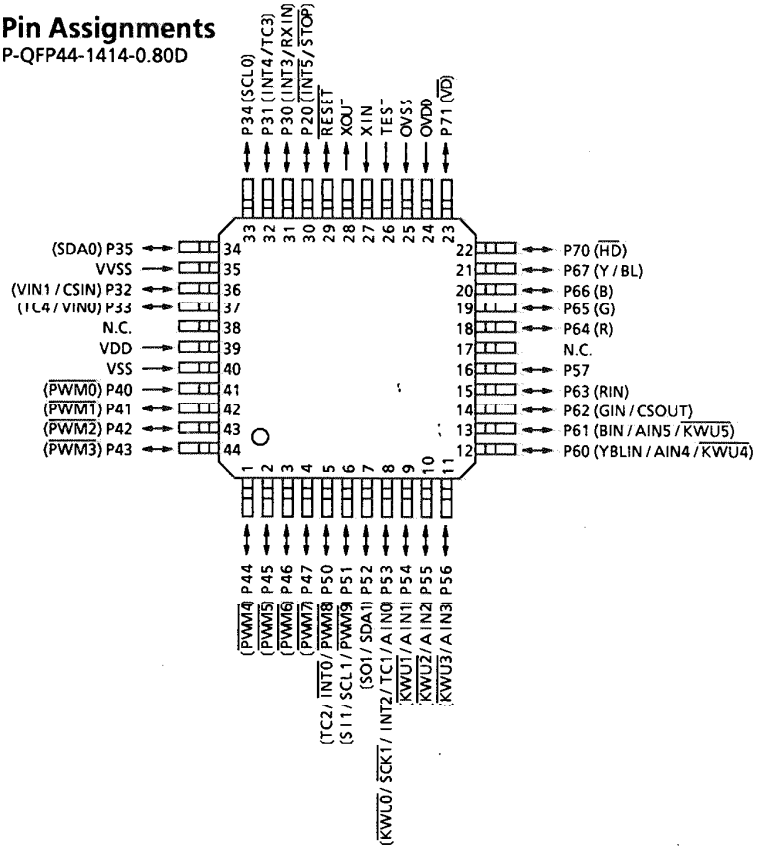
P-QFP44-1414-0.80D



TMP88CM38AF
TMP88CP38AF

Pin Assignments

P-QFP44-1414-0.80D



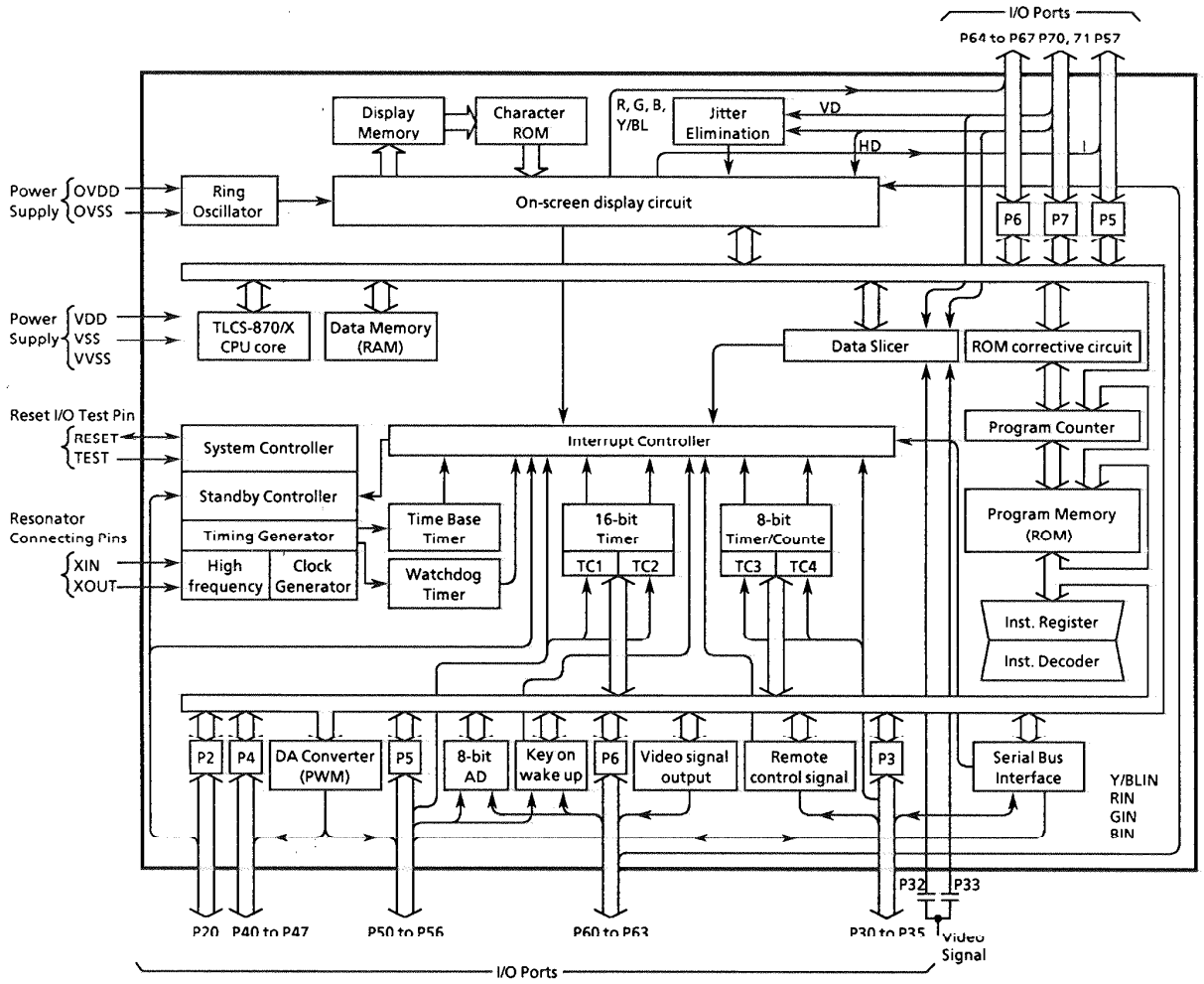
Pin Function

Pin Name	I/O	Function	
P20 ($\overline{INT5}$/$\overline{STOP}$)	I/O (Input)	1-bit input / output port with latch. When used as an input port, the latch must be set to "1".	External interrupt input 5 or STOP mode release signal input
P35 (SDA0)	I/O (Input/Output)	6-bit programmable input / output port. Each bit of these ports can be individually configured as an input or an output under software control. During reset, all bits are configured as inputs. When used as a serial bus interface input / output, the latch must be set to "1".	I^2C bus serial data input / output 0
P34 (SCL0)	I/O (Input/Output)		I^2C bus serial clock input / output 0
P33 (TC4/VIN0)	I/O (Input)		Timer / Counter input 4 or Video signal Input 0
P32 (VIN1 / CSIN)	I/O (Input)		Video signal input 1 or Composite sync input
P31 (INT4/TC3)	I/O (Input)		External interrupt input 4 or Timer / Counter input 3
P30 (INT3/RXIN)	I/O (Input)		External interrupt input 3 or Remote control signal preprocessor input
P47 ($\overline{PWM7}$)	I/O (Output)	8-bit programmable input / output port. Each bit of these ports can be individually configured as an input or an output under software control. During reset, all bits are configured as inputs. When used as a PWM output, the latch must be set to "1".	7-bit DA conversion (PWM) outputs
P46 ($\overline{PWM6}$)	I/O (Output)		
P45 ($\overline{PWM5}$)	I/O (Output)		
P44 ($\overline{PWM4}$)	I/O (Output)		
P43 ($\overline{PWM3}$)	I/O (Output)		12-bit DA conversion (PWM) outputs
P42 ($\overline{PWM2}$)	I/O (Output)		
P41($\overline{PWM1}$)	I/O (Output)		14/12-bit DA conversion (PWM) outputs
P40 ($\overline{PWM0}$)	I/O (Output)		
P57 (I)	I/O (Output)	8-bit programmable input / output port. Each bit of these ports can be individually configured as an input or an output under software control. During reset, all bits are configured as inputs. When used as a PWM output, a serial bus interface input / output, the latch must be set to "1".	Translucent signal output
P56 ($\overline{KWU3}$/AIN3)	I/O (Input)		Key on wake-up inputs or AD converter analog inputs
P55 ($\overline{KWU2}$/AIN2)	I/O (Input)		
P54 ($\overline{KWU1}$/AIN1)	I/O (Input)		
P53 ($\overline{KWU0}$/AIN0/TC1 /$\overline{INT2}$/SCK1)	I/O (Input /Input/Input /Input/Output)		Key on wake-up input or AD converter analog input or Timer / counter input 1 or External interrupt input 2 or SIO serial clock input /output 1
P52 (SDA1/SO1)	I/O (Input/Output /Output)		I^2C bus serial data Input / Output 1 or SIO serial data output 1
P51 ($\overline{PWM9}$/SCL1/SI1)	I/O (Output/Input/ Output/Input)		7-bit DA conversion (PWM) output or I^2C bus serial data input / Output 1 or SIO serial data input 1
P50 ($\overline{PWM8}$/TC2/$\overline{INT0}$)	I/O (Output/Input /Input)		7-bit DA conversion (PWM) output or Timer / Counter input 2 or External interrupt input 0
P67 (Y/BL)	I/O (Output)	8-bit programmable input / output port. (P67 to 64 : Tri-State, P63 to 60 : High current output) Each bit of these ports can be individually configured as an input or an output under software control. During reset, all bits are configured as inputs. When used P64 to P67 as port , each bit of the P6 port data selection register (bit 7 to 4 in ORP6S) must be set to "1".	Y or BL output
P66 (B)	I/O (Output)		R / G / B outputs
P65 (G)	I/O (Output)		
P64 (R)	I/O (Output)		
P63 (RIN)	I/O (Input)		R input
P62 (GIN/CSOUT)	I/O (Input/Output)		G input or TEST Video Singal output
P61 ($\overline{KWU5}$/BIN/AIN5)	I/O (Input)		Key on wake-up input 5 or B input or AD converter analog input 5
P60 ($\overline{KWU4}$/YBLIN/AIN4)	I/O (Input)		Key on wake-up input 4 or Y/BL input or AD converter analog input 4

Pin Function

Pin Name	I/O	Function	
P71 ($\overline{VD}$)	I/O (Input)	2-bit programmable input / output port. Each bit of these ports can be individually configured as an input or an output under software control. During reset, all bits are configured as inputs.	Vertical synchronous signal input
P70 ($\overline{HD}$)	I/O (Input)		Horizontal synchronous signal input
XIN, XOUT	Input, Output	Resonator connecting pins. For inputting external clock, XIN is used and XOUT is opened.	
RESET	I/O	Reset signal input or watchdog timer output / address-trap-reset output / system-clock-rest output	
TEST	Input	Test pin for out-going test. Be tied to low.	
OVDD, OVSS	Power Supply	+ 5 V, 0 V (GND) for oscillator circuit	
VDD, VSS, VVSS	Power Supply	+ 5 V, 0 V (GND)	

Block Diagram



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 TMP88CM38A/P38A memory consists of four blocks: ROM, RAM, SFR (Special Function Register), and DBR (Data Buffer Register). They are all mapped to a 1 Mbyte address space. Figure 1.1.1 shows the TMP88CM38A/P38A memory address map. There are 16 banks of the general-purpose register. The register banks are also assigned to the RAM address space.

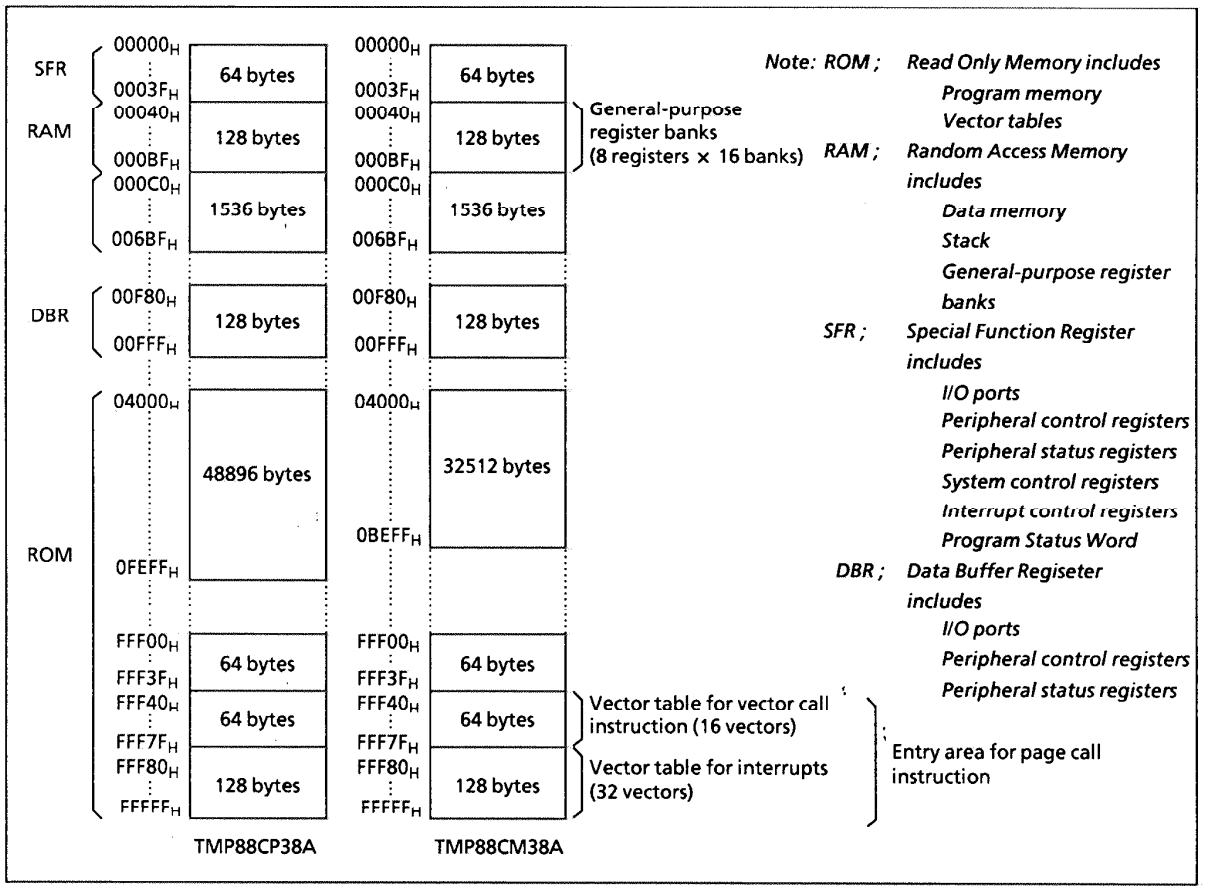


Figure 1.1.1 Memory Address Maps

1.2 Program Memory (ROM)

The TMP88CM38A/P38A can address up to 1 Mbyte of external program memory space except the SFR area, the internal RAM, and the DBR area. In addition, the TMP88CM38A contains a 32-Kbyte program memory (mask ROM) at address from 04000_H to $0BEFF_H$ and $FFF00_H$ to $FFFFF_H$. The TMP88CM38A contains a 48-Kbyte program memory (mask ROM) at address from 04000_H to $0FEFF_H$ and $FFF00_H$ to $FFFFF_H$.

1.3 Data Memory (RAM)

The TMP88CM38A/P38A have a 1.5 Kbytes (addresses 00040_H to $006BF_H$) of data memory. General-purpose register banks (8 registers x 16 banks) are also assigned to the 128 bytes of addresses 00040_H to $000BF_H$.

The general-purpuse registers are mapped in the RAM ; therefore, do not clear RAM at the current bank addresses.

Example: Clears RAM to "00_H" except the bank 0 (TMP88CM38A):

```
        LD    HL, 0048H      ;  Sets start address to HL register pair
        LD    A, H           ;  Sets initial data (00H) to A register
        LD    BC, 0677H      ;  Sets number of byte to BC register pair
SRAMCLR: LD   (HL+), A
        DEC   BC
        JRS   F, SRAMCLR
```

Note: The data memory contents become unstable when the power supply is turned on ; therefore, the data memory should be initialized by an initialization routine. Note that the general-purpose registers are mapped in the RAM ; therefore, do not clear RAM at the current bank addresses.

1.4 System Clock Controller

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

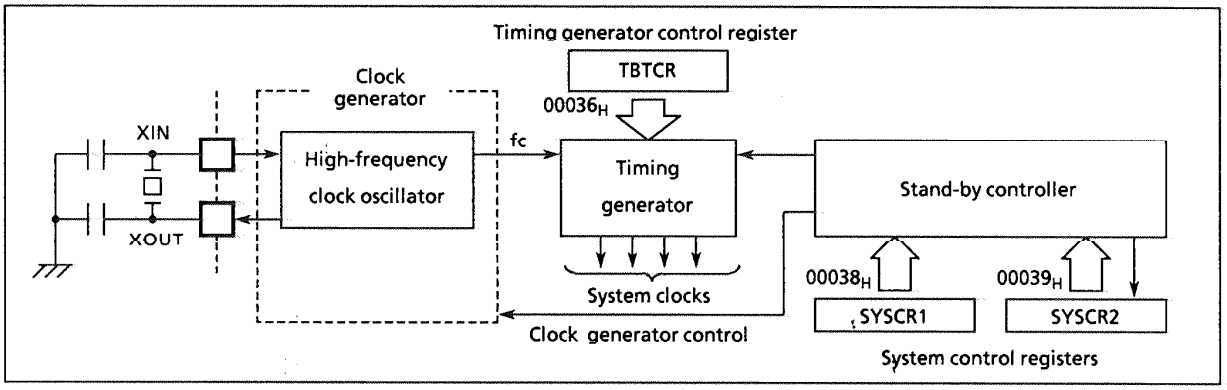


Figure 1.4.1 System Clock Controller

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 oscillation circuit: one for the high-frequency clock.

The high-frequency (fc) clock can be easily obtained by connecting a resonator between the XIN / XOUT pin, respectively. Clock input from an external oscillator is also possible. In this case, external clock is applied to the XIN / XTIN pin not connected. The TMP88CM38A/P38A is not provided an RC oscillation.

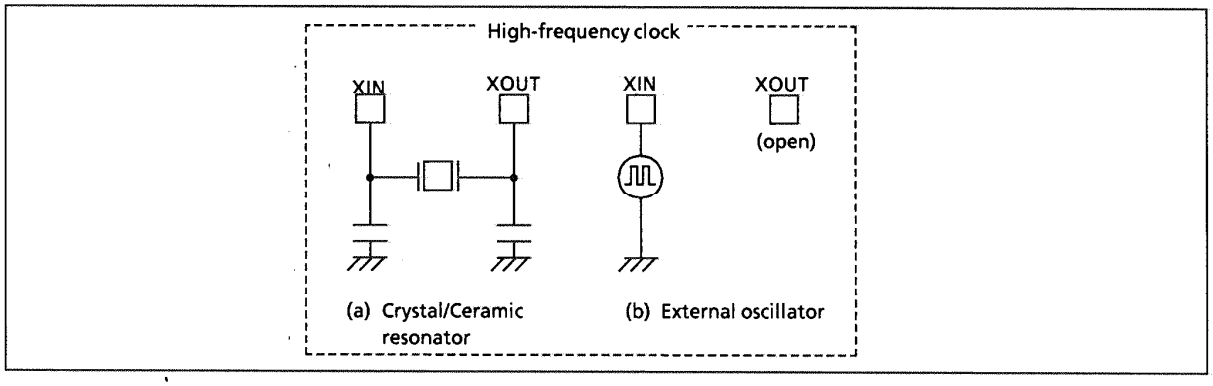


Figure 1.4.2 Examples of Resonator Connection

Note: Accurate Adjustment of the Oscillation Frequency:
Although hardware to externally and directly monitor the basic clock pulse is not provided, the oscillation frequency can be adjusted by making the program to output fixed frequency pulses to the port while disabling all interrupts and monitoring this pulse. With a system requiring adjustment of the oscillation frequency, the adjusting program must be created beforehand.

1.4.2 Timing Generator

The timing generator generates from the basic clock the various system clocks supplied to the CPU core and peripheral hardware. The timing generator provides the following functions:

① Generation of main system clock
② Generation of source clocks for time base timer
③ Generation of source clocks for watchdog timer
④ Generation of internal source clocks for timer / counters TC1 – TC4
⑤ Generation of warm-up clocks for releasing STOP mode
⑥ Generation of a clock for releasing reset output

(1) Configuration of Timing Generator

The timing generator consists of a 21-stage divider with a divided-by-3 prescaler, a main system clock generator, and machine cycle counters.
During reset and at releasing STOP mode, the prescaler and the divider are cleared to "0", however, the prescaler is not cleared.
An input clock to the 7th stage of the divider depends on the operating mode.
A divided-by-256 of high-frequency clock ($fc/2^8$) is input to the 7th stage of the divider.

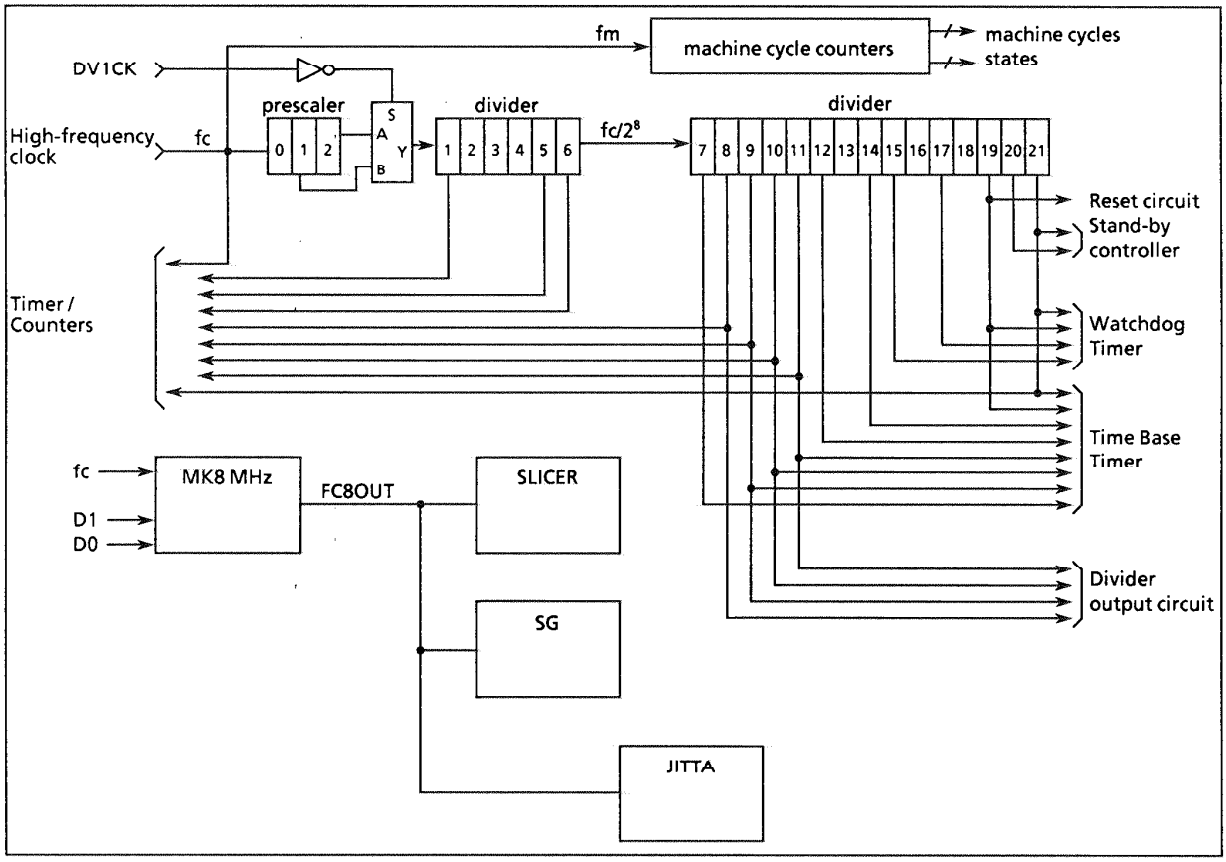


Figure 1.4.3 Configuration of Timing Generator

CGCR (00030_H)

"0"	"0"	DV1CK	"0"	"0"	"0"	"0"	"0"

(Initial value: 0000 0000)

DV1CK	Selection of input clock to the 1'st stage of the divider.	0: fc/4 1: fc/8	Write only

Note 1: fc ; high-frequency clock [Hz] ** ; Don't care*

Note 2: The all bits except DV1CK are cleared to "0".

Figure 1.4.4 DIVIDER Control Register

FC8CR ($00FEE_H$)

						D1	D0

(Initial value: 0000 0010)

D1	D0	FC8OUT
1	0	1/2 fc
0	0	1/1 fc

Figure 1.4.5 FC8 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 a "machine cycle". There are a total of 10 different types of instructions for the TLCS-870/X Series: ranging from 1-cycle instructions which require one machine cycle for execution to 15-cycle instructions which require 15 machine cycles for execution.

A machine cycle consists of 4 states (S0 to S3), and each state consists of one main system clock.

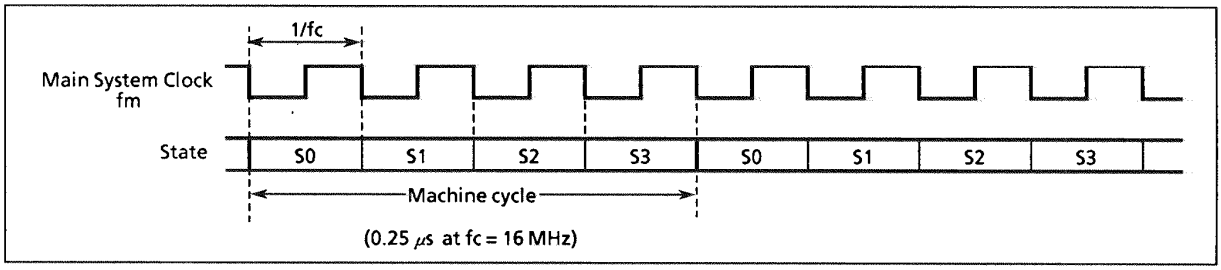


Figure 1.4.6 Machine Cycle

1.4.3 Stand-by Controller

The stand-by controller starts and stops the switches the main system clock. These modes are controlled by the system control registers (SYSCR1, SYSCR2).

Figure 1.4.6 shows the operating mode transition diagram and Figure 1.4.7 shows the system control registers.

Single-clock mode

In the single-clock mode, the machine cycle time is 4/fc [s] (0.25 μs at fc = 16 MHz).

① NORMAL mode

In this mode, both the CPU core and on-chip peripherals operate using the high-frequency clock.

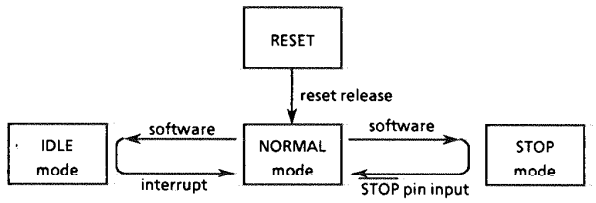
② IDLE mode

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). IDLE mode is started by setting IDLE bit in the system control register 2 (SYSCR2), and IDLE1 mode is released to NORMAL mode by an interrupt request from on-chip peripherals or external interrupt inputs. When IMF (interrupt master enable flag) is "1" (interrupt enable), the execution will resume upon acceptance of the interrupt, and the operation will return to normal after the interrupt service is completed. When IMF is "0" (interrupt disable), the execution will resume with the instruction which follows IDLE mode start instruction.

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 the lowest power consumption during this mode.

STOP mode is started by setting STOP bit in the system control register 1 (SYSCR1), and STOP mode is released by an input (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 next instruction which follows the STOP mode start instruction.



(a) Single-clock mode

Note: NORMAL mode is generically called NORMAL; STOP mode is called STOP; and IDLE mode is called IDLE.

Operating mode		Frequency		CPU core	On-chip Peripherals	Machine cycle time
		High-frequency	Low-frequency			
Single-Clock	RESET	turning on oscillation	turning off oscillation	reset	reset	4/fc [s]
	NORMAL			operate	operate	
	IDLE			halt		
	STOP	turning off oscillation			halt	–

Figure 1.4.7 Operating Mode Transition Diagram

System Control Register 1

SYSCR1 (00038_H)

7	6	5	4	3	2	1	0
STOP	RELM	"0"	"1"	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 (Rising Edge) 1: Level-sensitive release ("H" Level)			
WUT	Warming-up time at releasing STOP mode		Return to NORMAL mode		
			DV1CK = 0	DV1CK = 1	
		00	3×2^{16} / fc	3×2^{17} / fc	
		01	2^{16} / fc	2^{17} / fc	
		10	3×2^{14} / fc	3×2^{15} / fc	
		11	2^{14} / fc	2^{15} / fc	

Note 1: Always set bit 5 in SYSCR1 to "0".

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

Note 3: fc ; High-frequency clock [Hz]

** ; Don't care*

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

Note 5: Always set bit 4 in SYSCR1 to "1" when STOP mode is started.

System Control Register 2

SYSCR2 (00039_H)

7	6	5	4	3	2	1	0
"1"	"0"	"0"	IDLE				

(Initial value: 1000 ****)

IDLE	IDLE mode start	0: CPU and watchdog timer remain active 1: CPU and watchdog timer are stopped (start IDLE mode)	R/W

*Note: * ; Don't care*

Figure 1.4.8 System Control Registers

1.4.4 Operating Mode Control

(1) STOP mode

STOP mode is controlled by the system control register 1 (SYSCR1) and the $\overline{STOP}$ pin input. 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 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 of the instruction following the instruction which started the STOP mode.

STOP mode includes a level-sensitive release mode and an edge-sensitive release mode, either of which can be selected with RELM (bit 6 in SYSCR1).

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

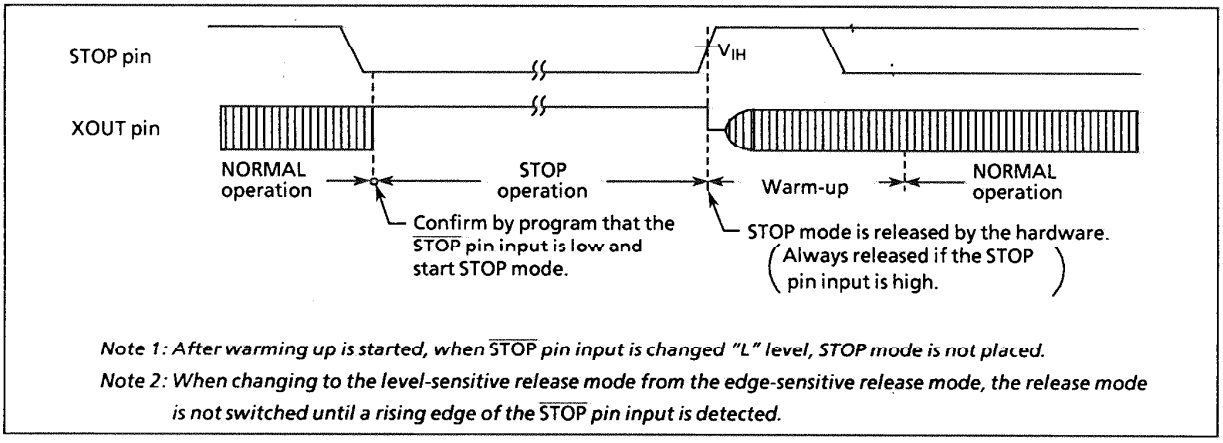
In this mode, STOP mode is released by setting the $\overline{STOP}$ pin high. This mode is used for capacitor back-up when the main power supply is cut off and long term battery back-up.

When the $\overline{STOP}$ pin input is high, executing an instruction which starts the 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. The following method can be used for confirmation:

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

Exampl: Starting STOP mode with an INT5 interrupt.

```
PINT5:  TEST  (P2) . 0                ;  To reject noise, the 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
        LDW   (IL), 1110011101010111B ;  IL12, 11, 7, 5, 3 ← 0 (Clears interrupt latches)
SINT5:  RETI
```



Note 1: After warming up is started, when $\overline{STOP}$ pin input is changed "L" level, STOP mode is not placed.

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

Figure 1.4.9 Level-sensitive Release Mode

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

In this mode, STOP mode is released by a rising edge of the $\overline{STOP}$ pin input. This is used in applications where a relatively short program is executed repeatedly at periodic intervals. This periodic signal (for example, a clock from a low-power consumption oscillator) is input to the $\overline{STOP}$ pin.

In the edge-sensitive release mode, STOP mode is started even when the $\overline{STOP}$ pin input is high.

Example: Starting STOP mode from NORMAL mode

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

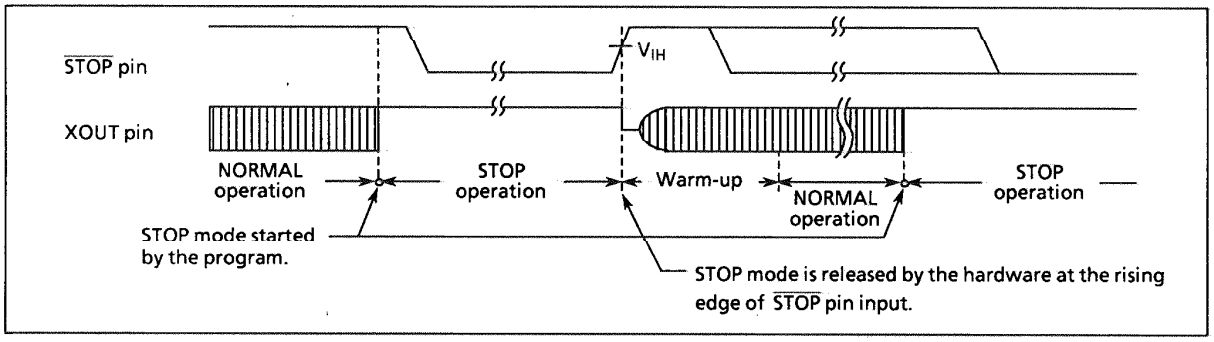


Figure 1.4.10 Edge-sensitive Release Mode

STOP mode is released by the following sequence:

① When returning to NORMAL, clock oscillator is turned on.

② A warming-up period is inserted to allow oscillation time to stabilize. During warm-up, all internal operations remain halted. Two different warming-up times can be selected with WUT (bits 2 and 3 in SYSCR1) as determined by the resonator characteristics.

③ When the warming-up time has elapsed, normal operation resumes with the instruction following the STOP mode start instruction (e.g. [SET (SYSCR1). 7]). The start is made after the divider of the timing generator is cleared to "0".

Table 1.4.1 Warming-up Time Example

WUT	Warming-up Time [ms]	
	Return to NORMAL mode	
	DV1CK = 0	DV1CK = 1
00	3×2^{16}/fc (12.29 m)	3×2^{17}/fc (24.58 m)
01	2^{16}/fc (4.10 m)	2^{17}/fc (8.20 m)
10	3×2^{14}/fc (3.07 m)	3×2^{15}/fc (6.14 m)
11	2^{14}/fc (1.02 m)	2^{15}/fc (2.05 m)

Note: The warming-up time is obtained by dividing the basic clock by the divider: therefore, the warming-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 warming-up time must be considered an approximate value.

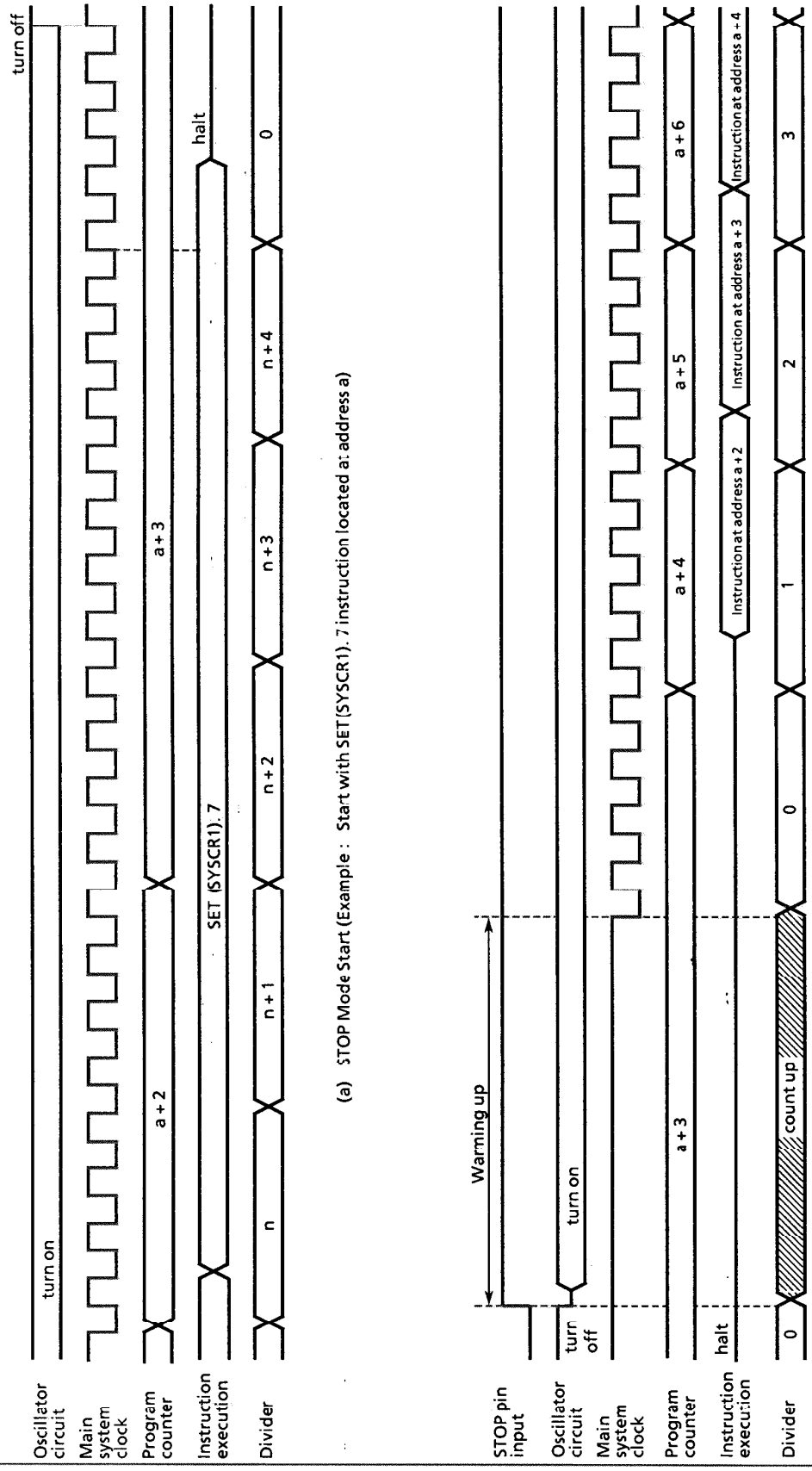


Figure 1.4.11 STOP Mode Start / Release

STOP mode can also be released by setting the $\overline{\text{RESET}}$ pin low, 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 high, 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 rate 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).

(2) IDLE mode

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

① Operation of the CPU and watchdog timer is halted. On-chip peripherals continue to operate.
② The data memory, CPU registers and port output latches are all held in the status in effect before IDLE mode was entered.
③ The program counter holds the address of the instruction following the instruction which started IDLE mode.

Example: Starting IDLE mode.

```
SET   (SYSCR2).4 ;   IDLE ← 1
```

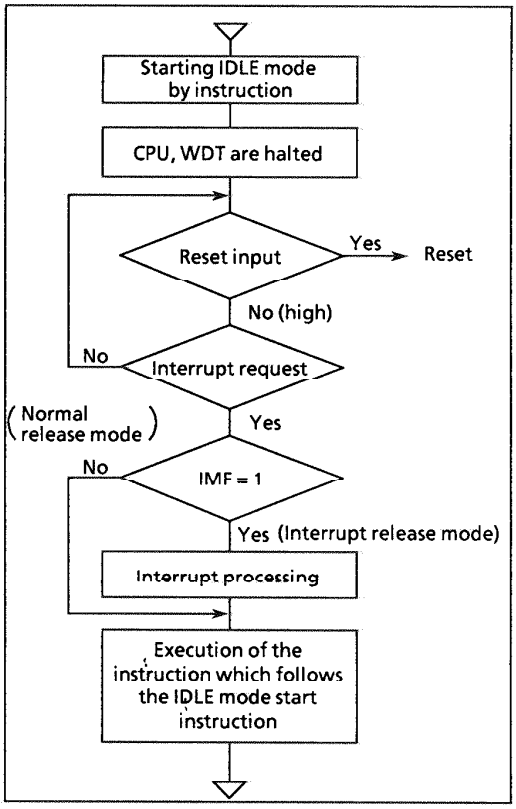


Figure 1.4.12 IDLE Mode

IDLE mode includes a normal release mode and an interrupt release mode. Selection is made with the interrupt master enable flag (IMF). Releasing the IDLE mode returns from IDLE to NORMAL.

a. Normal release mode (IMF = "0")
IDLE mode is released by any interrupt source enabled by the individual interrupt enable flag (EF) or an external interrupt 0 ($\overline{\text{INT0}}$ pin) request. Execution resumes with the instruction following the IDLE mode start instruction (e.g. [SET (SYSCR2).4]). Normally, IL (Interrupt Latch) of interrupt source to release IDLE mode must be cleared by load instructions.

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) or an external interrupt 0 ($\overline{\text{INT0}}$ pin) request. After the interrupt is processed, the execution resumes from the instruction following the instruction which started IDLE mode.

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

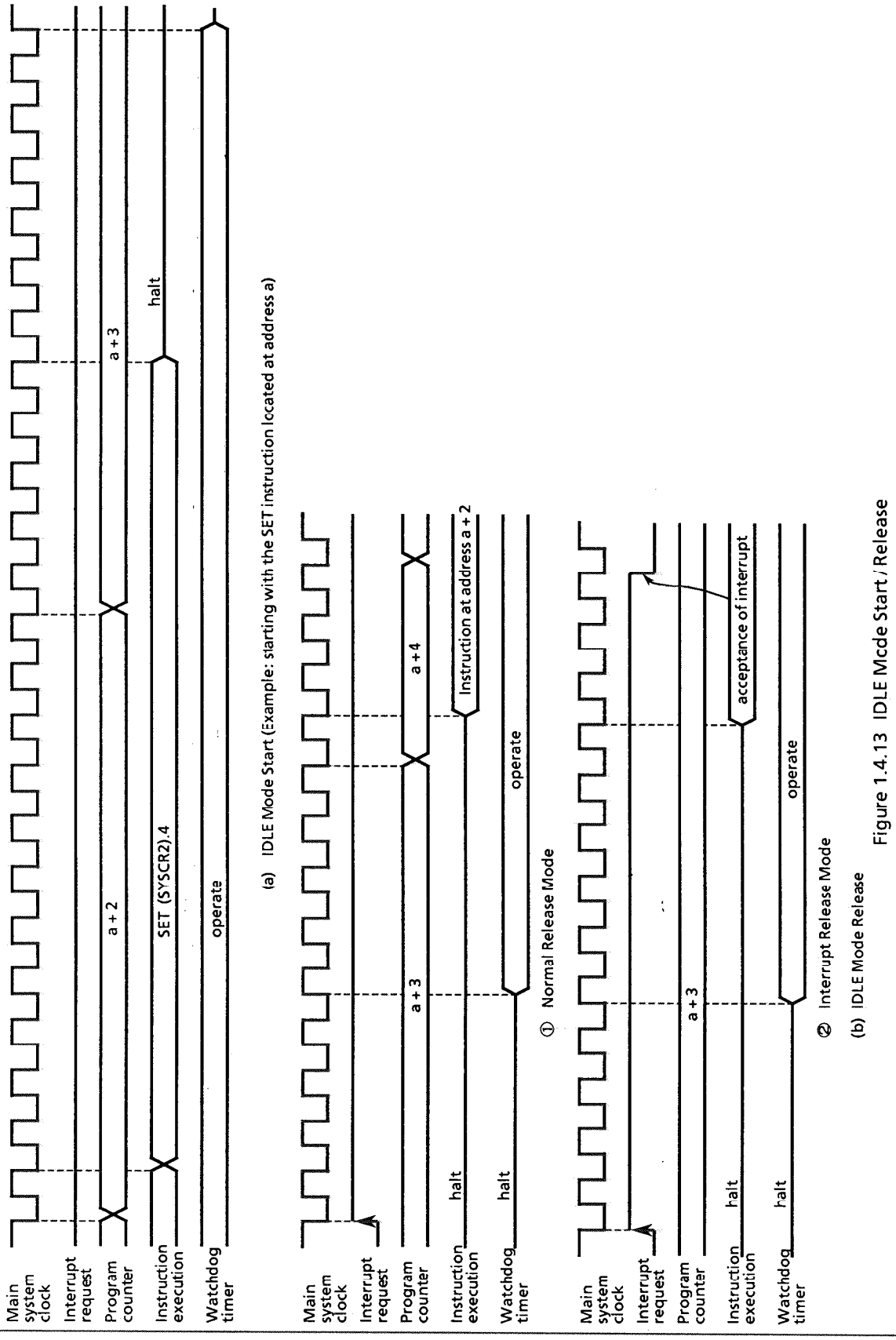


Figure 1.4.13 IDLE Mode Start / Release

IDLE mode can also be released by setting the $\overline{\text{RESET}}$ pin low, which immediately performs the reset operation. After reset, the TMP88CM38A/P38A is placed in NORMAL mode.

1.5 Interrupt Controller

The TMP88CM38A/P38A has a total of 17 interrupt sources. Multiple interrupts with priorities are also possible. Two of the internal sources are pseudo non-maskable interrupts; the remainder are all maskable interrupts.

Table 1.5.1 Interrupt Sources

Interrupt source			Enable condition	Interrupt latch	Vector table address	Priority
Internal / External	(Reset)		Non-Maskable	—	$FFFFC_H$	High 0
Internal	INTSW	(Software interrupt)	Pseudo non-maskable	—	$FFFF8_H$	1
Internal	INTWDT	(Watchdog timer interrupt)		IL_2	$FFFF4_H$	2
External	INT0	(External interrupt 0)	IMF · EF_3 = 1, INT0EN = 1	IL_3	$FFFF0_H$	3
Internal	INTTC1	(16-bit TC1 interrupt)	IMF · EF_4 = 1	IL_4	$FFFEC_H$	4
External	INTKWU	(Key-On-Wake-Up)	IMF · EF_5 = 1	IL_5	$FFFE8_H$	5
Internal	INTTBT	(Time base timer interrupt)	IMF · EF_6 = 1	IL_6	$FFFE4_H$	6
External	INT2	(External interrupt 2)	IMF · EF_7 = 1	IL_7	$FFFE0_H$	7
Internal	INTTC3	(8-bit TC3 interrupt)	IMF · EF_8 = 1	IL_8	$FFFDC_H$	8
Internal	INTTSBI	(SBI interrupt)	IMF · EF_9 = 1	IL_9	$FFFD8_H$	9
Internal	INTTC4	(8-bit TC4 interrupt)	IMF · EF_{10} = 1	IL_{10}	$FFFD4_H$	10
Internal	INT3	(External interrupt 3)	IMF · EF_{11} = 1	IL_{11}	$FFFD0_H$	11
Internal	INT4	(External interrupt 4)	IMF · EF_{12} = 1	IL_{12}	$FFFCC_H$	12
Internal	INTADC	(AD Converter interrupt)	IMF · EF_{13} = 1	IL_{13}	$FFFC8_H$	13
Internal	INTTC2	(16-bit TC2 interrupt)	IMF · EF_{14} = 1	IL_{14}	$FFFC4_H$	14
External	INT5	(External interrupt 5)	IMF · EF_{15} = 1	IL_{15}	$FFFC0_H$	15
Internal	INTOSD	(OSD interrupt)	IMF · EF_{16} = 1	IL_{16}	$FFFBC_H$	16
Internal	INTSLI	(Slicer interrupt)	IMF · EF_{17} = 1	IL_{17}	$FFFB8_H$	17
		reserved	IMF · EF_{18} = 1	IL_{18}	$FFFB4_H$	18
		reserved	IMF · EF_{19} = 1	IL_{19}	$FFFB0_H$	19
		reserved	IMF · EF_{20} = 1	IL_{20}	$FFFAC_H$	20
		reserved	IMF · EF_{21} = 1	IL_{21}	$FFFA8_H$	21
		reserved	IMF · EF_{22} = 1	IL_{22}	$FFFA4_H$	22
		reserved	IMF · EF_{23} = 1	IL_{23}	$FFFA0_H$	23
		reserved	IMF · EF_{24} = 1	IL_{24}	$FFF9C_H$	24
		reserved	IMF · EF_{25} = 1	IL_{25}	$FFF98_H$	25
		reserved	IMF · EF_{26} = 1	IL_{26}	$FFF94_H$	26
		reserved	IMF · EF_{27} = 1	IL_{27}	$FFF90_H$	27
		reserved	IMF · EF_{28} = 1	IL_{28}	$FFF8C_H$	28
		reserved	IMF · EF_{29} = 1	IL_{29}	$FFF88_H$	29
		reserved	IMF · EF_{30} = 1	IL_{30}	$FFF84_H$	30
		reserved	IMF · EF_{31} = 1	IL_{31}	$FFF80_H$	Low 31

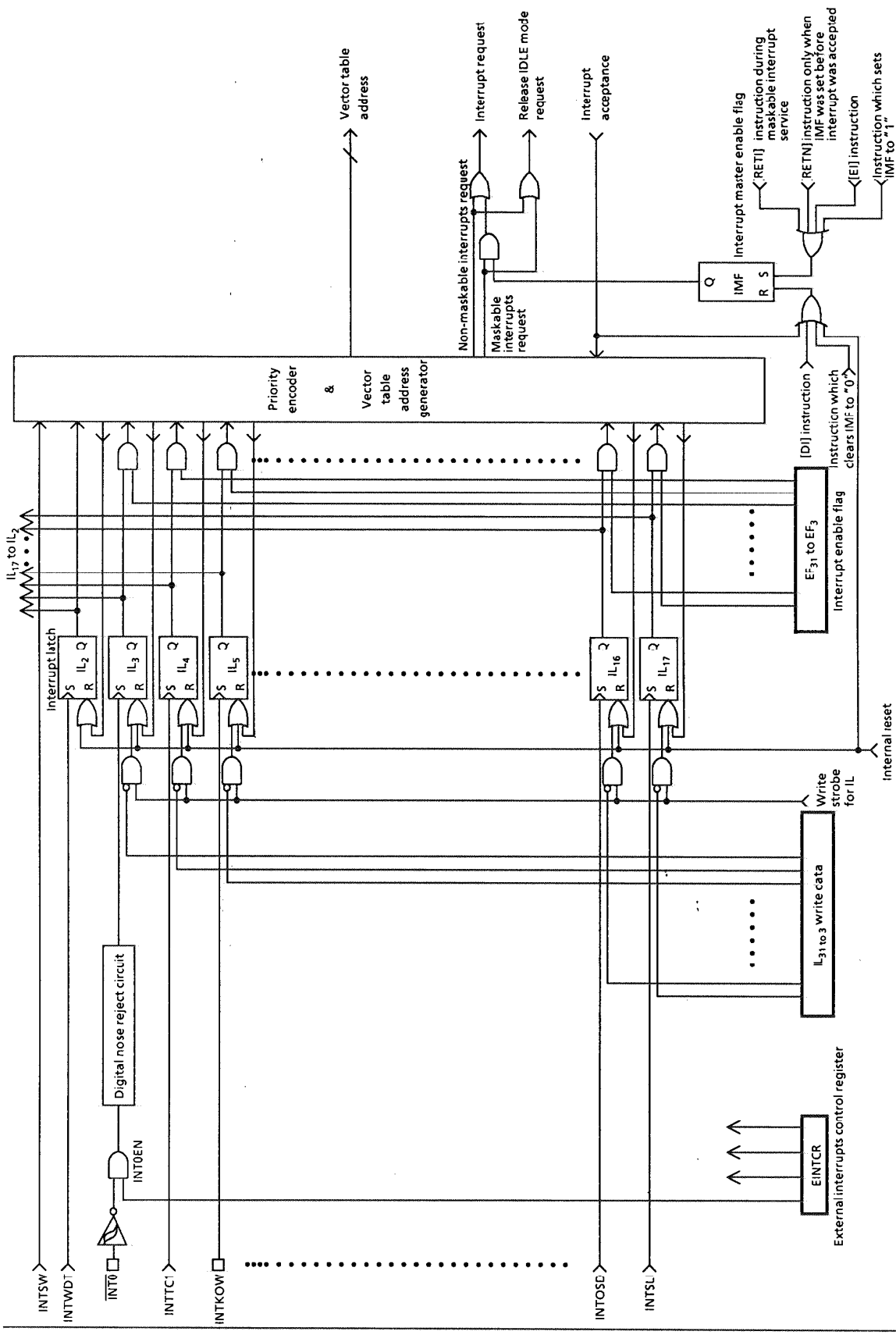


Figure 1.5.1 Interrupt Cortroller Block Diagram

Interrupt latches (IL) that hold the interrupt requests are provided for interrupt sources. Each interrupt vector is independent.
The interrupt latch is set to "1" when an interrupt request is generated, and requests the CPU to accept the interrupt. The acceptance of maskable interrupts can be selectively enabled and disabled by program using the interrupt master enable flag (IMF) and the individual interrupt enable flags (EF). When two or more interrupts are generated simultaneously, the interrupt is accepted in the highest priority order as determined by the hardware. Figure 1.5.1 shows the interrupt controller.

(1) Interrupt Latches (IL_{31} to IL_2)
Interrupt latches are provided for each source, except for a software interrupt. The latch is set to "1" when an interrupt request is generated, and requests the CPU to accept the interrupt. The latch is cleared to "0" just after the interrupt is accepted. All interrupt latches are initialized to "0" during reset.
The interrupt latches are assigned to addresses $0003C_H$, $0003D_H$, $0002E_H$ and $0002F_H$ in the SFR. Except for IL_2, each latch can be cleared to "0" individually by an instruction ; however, the read-modify-write instruction such as bit manipulation or operation instructions cannot be used. When interrupt occurred during order execution, the reason is because interrupt request is cleared. Thus, interrupt requests can be canceled and initialized by the program. Note that request the interrupt latches cannot be set to "1" by an instruction. For example, it may be that each latch is cleared even if an interrupt request is generated during instruction exection.
The contents of interrupt latches can be read out by an instruction. Therefore, testing interrupt request by software is possible.

Example 1: Clears interrupt latches

```
LDW  (ILL), 1110100000111111B   ;  IL12, IL10 to IL6 ← 0
```

Example 2: Reads interrupt latches

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

Example 3: Tests an interrupt latch

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

(2) Interrupt Enable Register (EIR)
The interrupt enable register (EIR) enables and disables the acceptance of interrupts, except for the pseudo non-maskable interrupts (software and watchdog timer interrupts). Pseudo non-maskable interrupts are accepted regardless of the contents of the EIR; however, the pseudo non-maskable interrupt cannot be nested more than once at the same time.
The EIR consists of an interrupt master enable flag (IMF) and the individual interrupt enable flags (EF). These registers are assigned to addresses $0003A_H$, $0003B_H$, $0002C_H$ and $0002D_H$ in the SFR, and can be read and written by an instruction (including read-modify-write instruction such as bit manipulation instructions).

Note: Do not use the read-modify-write instruction for the EIRL (address 0003AH) during pseudo non-maskable interrupt service task. If the read-modify-write instruction is used, the IMF is not set to "1" after RETN.

① Interrupt Master enable Flag (IMF)

The interrupt master enable flag (IMF) enables and disables the acceptance of all maskable interrupts. Clearing this flag to "0" disables the acceptance of all maskable interrupts. Setting to "1" enables the acceptance of interrupts.

When an interrupt is accepted, this flag is cleared to "0" to temporarily disable the acceptance of other maskable interrupts. After execution of the interrupt service program, this flag is set to "1" by the maskable interrupt return instruction [RETI] to again enable the acceptance of interrupts. If an interrupt request has already been occurred, interrupt service starts immediately after execution of the [RETI] instruction.

Pseudo non-maskable interrupts are returned by the [RETN] instruction. In this case, the IMF is set to "1" only when pseudo non-maskable interrupt service is started with interrupt acceptance enabled (IMF = 1). Note that the IMF remains "0" when cleared by the interrupt service program.

The IMF is assigned to bit 0 at address $0003A_H$ in the SFR, and can be read and written by an instruction. The IMF is normally set and cleared by the [EI] and [DI] instructions, and the IMF is initialized to "0" during reset.

② Individual interrupt Enable Flags (EF_{17} to EF_3)

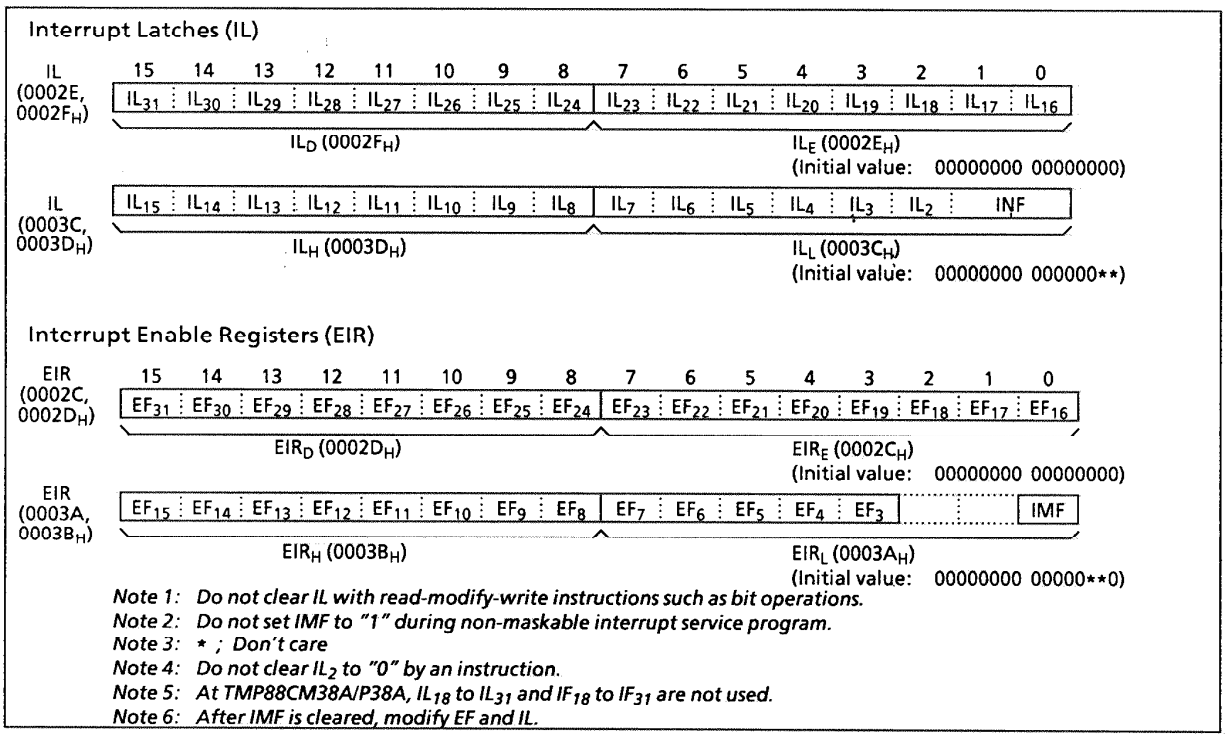
These flags enable and disable the acceptance of individual maskable interrupts, except for an external interrupt 0. Setting the corresponding bit of an individual interrupt enable flag to "1" enables acceptance of an interrupt, setting the bit to "0" disables acceptance.

Example 1: Sets EF for individual interrupt enable, and sets IMF to "1".

```
LD    (EIRE), 00000001B            ;  EF16 ← 1
LDW   (EIRL), 1110100010100001B    ;  EF15 to EF13, EF11, EF7, EF5, IMF ← 1
```

Example 2: Sets an individual interrupt enable flag to "1".

```
SET   (EIRH). 4                    ;  EF12 ← 1
```



Note 1: Do not clear IL with read-modify-write instructions such as bit operations.
Note 2: Do not set IMF to "1" during non-maskable interrupt service program.
*Note 3: * ; Don't care*
Note 4: Do not clear IL_2 to "0" by an instruction.
Note 5: At TMP88CM38A/P38A, IL_{18} to IL_{31} and IF_{18} to IF_{31} are not used.
Note 6: After IMF is cleared, modify EF and IL.

Figure 1.5.2 Interrupt Latches (IL) and Interrupt Enable Registers (EIR)

1.5.1 Interrupt Sequence

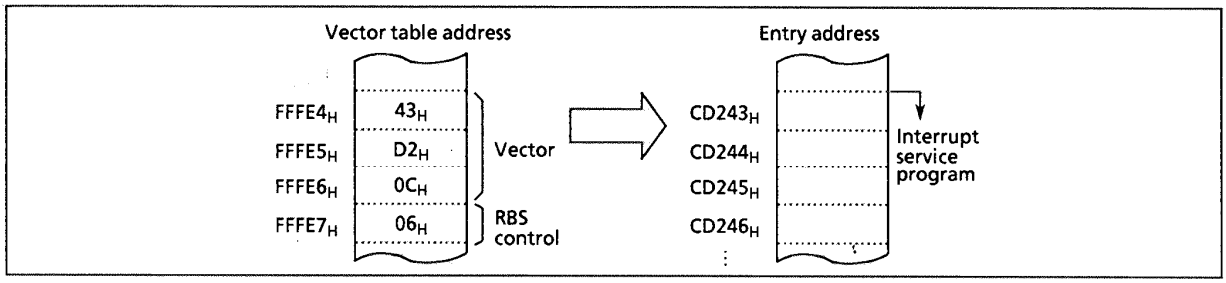
An interrupt request is held until the interrupt is accepted or the interrupt latch is cleared to "0" by a reset or an instruction. Interrupt acceptance sequence requires 12 machine cycles (3 μs at fc = 16 MHz in the NORMAL mode) after the completion of the current instruction execution. The interrupt service task terminates upon execution of an interrupt return instruction [RETI] (for maskable interrupts) or [RETN] (for pseudo non-maskable interrupts). Figure 1.5.3 shows the timing chart of interrupt acceptance processing.

(1) Interrupt acceptance

Interrupt acceptance processing is as follows.

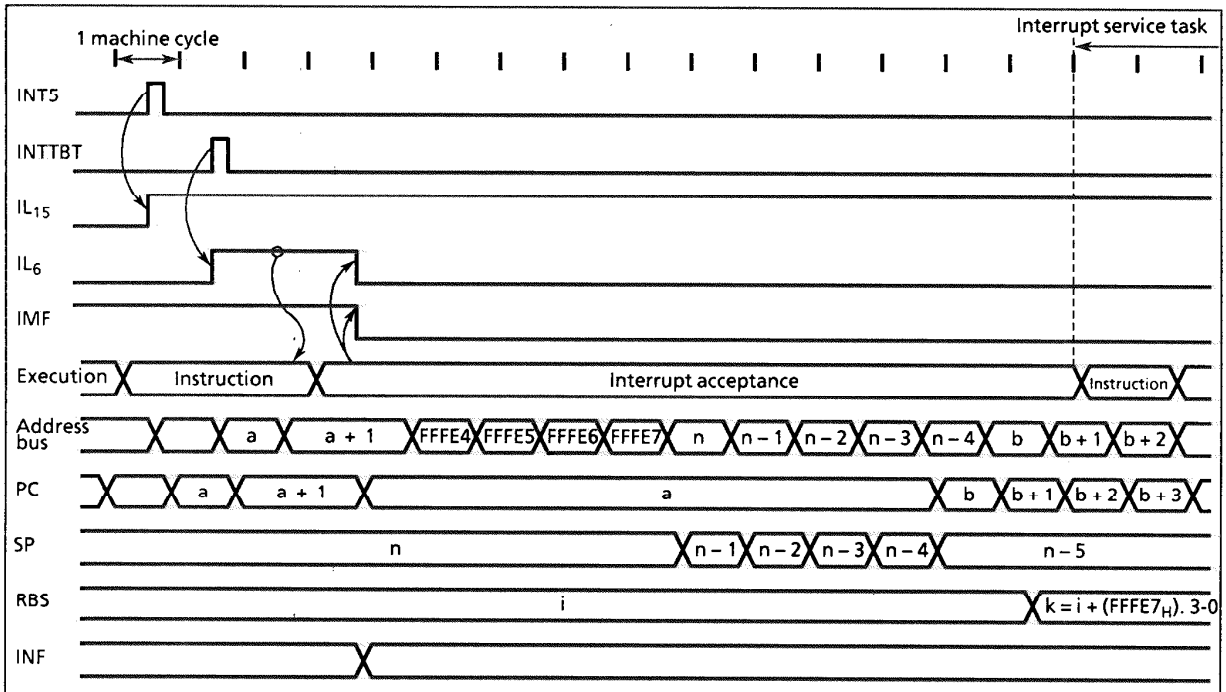
① The interrupt master enable flag (IMF) is cleared to "0" to temporarily disable the acceptance of any following maskable interrupts. When a non-maskable interrupt is accepted, the acceptance of any following interrupts is temporarily disabled.
② The interrupt latch (IL) for the interrupt source accepted is cleared to "0".
③ The contents of the program counter (PC) and the program status word (PSW) are saved (pushed) on the stack in sequence of PSW_H, PSW_L, PC_E, PC_H, PC_L. The stack pointer (SP) is decremented five times.
④ The entry address of the interrupt service program is read from the vector table, and set to the program counter.
⑤ The RBS control code is read from the vector table. The lower 4-bit of this code is added to the RBS.
⑥ The instruction stored at the entry address of the interrupt service program is executed.

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

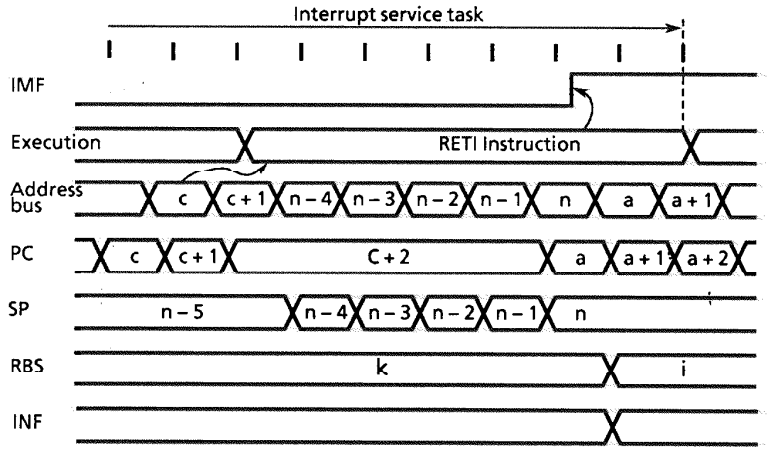


A maskable interrupt is not accepted until the IMF is set to "1" even if the maskable interrupt higher than the level of current servicing interrupt is occurred.
When nested interrupt service is necessary, the IMF is set to "1" in the interrupt service program. In this case, acceptable interrupt sources are selectively enabled by the individual interrupt enable flags.

Note: Do not use the read-modify-write instruction for the EIRL (address 0003A$_H$) during pseudo non-maskable interrupt service task.



(a) Interrupt acceptance



(b) Return from interrupt instruction

Note 1: a ; return address, b ; entry address, c ; address which the RETI instruction is stored
Note 2: The maximum response time from when an IL is set until an interrupt acceptance processing starts is 62/fc [s] with interrupt enabled.

Figure 1.5.3 Timing Chart of Interrupt Acceptance and Interrupt Return Instruction

(2) Saving / Restoring general-purpose registers

During interrupt acceptance processing, the program counter (PC) and the program status word (PSW) are automatically saved on the stack, but not the accumulator and other registers. These registers are saved by the program if necessary. Also, when nesting multiple interrupt services, it is necessary to avoid using the same data memory area for saving registers.

The following method is used to save / restore the general-purpose registers.

① General-purpose register save / restore by automatic register bank changeover

The general-purpose registers can be saved at high-speed by switching to a register bank that is not in use. Normally, the bank 0 is used for the main task and the banks 1 to 15 are assigned to interrupt service tasks. To increase the efficiency of data memory utilization, the same bank is assigned for interrupt sources which are not nested.

The switched bank is automatically restored by executing an interrupt return instruction [RETI] or [RETN]. Therefore, it is not necessary for a program to save the RBS.

Example: Register bank changeover

```
PINTxx:  interrupt processing
         RETI

VINTxx:  DP    PINTxx
         DB    1              ;  RBS ← RBS + 1
```

② General-purpose register save / restore by register bank changeover

The general-purpose registers can be saved at high-speed by switching to a register bank that is not in use. Normally, the bank 0 is used for the main task and the banks 1 to 15 are assigned to interrupt service tasks.

Example: Register bank changeover

```
PINTxx:  LD RBS, n
         interrupt processing
         RETI                  ;  Restores bank and Returns

VINTxx:  DP    PINTxx          ;  Interrupt service routine entry address
         DB    0
```

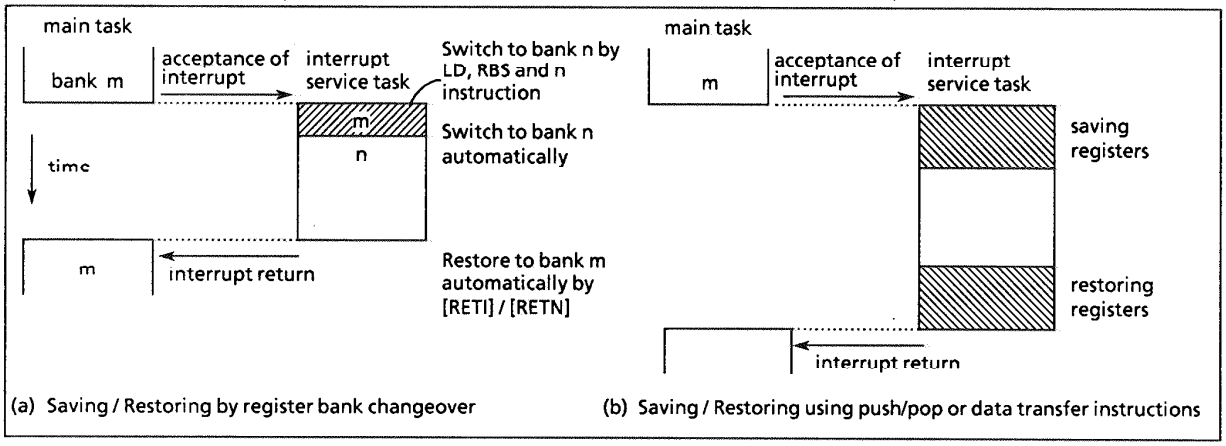
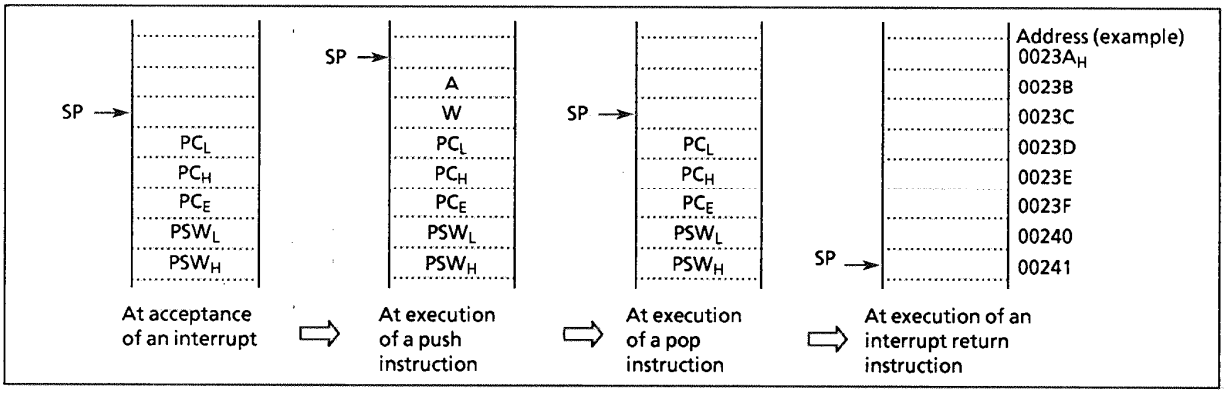


Figure 1.5.4 Saving / Restoring General-purpose Registers

③ General-purpose registers save / restore using push and pop instructions
To save only a specific register, and when the same interrupt source occurs more than once, the general-purpose registers can be saved / restored using the push / pop instructions.

Example: Register save / restore using push and pop instructions

```
PINTxx: PUSH WA              ; Save WA register pair
        interrupt processing
        POP  WA              ; Restore WA register pair
        RETI                 ; Return
```



④ General-purpose registers save / restore using data transfer instructions
Data transfer instruction can be used to save only a specific general-purpose register during processing of single interrupt.

Example: Saving / restoring a register using data transfer instructions

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

(3) Interrupt return

The interrupt return instructions [RETI] / [RETN] perform the following operations.

[RETI] Maskable interrupt return	[RETN] Non-maskable interrupt return
① The contents of the program counter and the program status word are restored from the stack.	① The contents of the program counter and program status word are restored from the stack.
② The stack pointer is incremented 5 times.	② The stack pointer is incremented 5 times.
③ The interrupt master enable flag is set to "1".	③ The interrupt master enable flag is set to "1" only when a non-maskable interrupt is accepted in interrupt enable status. However, the interrupt master enable flag remains at "0" when so clear by an interrupt service program.
④ The interrupt nesting counter is decremented, and the interrupt nesting flag is changed.	④ The interrupt nesting counter is decremented, and the interrupt nesting flag is changed.

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). However, if processing of a non-maskable interrupt is already underway, executing the SWI instruction will not generate a software interrupt but will result in the same operation as the [NOP] instruction.

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. 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, SFR or DBR areas.

② Debugging

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

1.5.3 External Interrupts

The TMP88CM38A/P38A each have five external interrupt inputs (INT0, INT2, INT3, INT4, and $\overline{INT5}$). Three of these are equipped with digital noise rejection circuits (pulse inputs of less than a certain time are eliminated as noise). Edge selection is also possible with INT2, INT3 and INT4.

The $\overline{INT0}$ / P50 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.

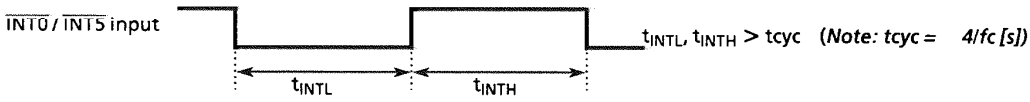
Edge selection, noise rejection control except INT3 pin input and $\overline{INT0}$ / P50 pin function selection are performed by the external interrupt control register (EINTCR). Edge selecting and noise rejection control for INT3 pin input are preformed by the Remote control signal preprocessor control registers. (refer to the section of the Remote control signal preprocessor.) When INT0EN = 0, the IL_3 will not be set even if the falling edge of $\overline{INT0}$ pin input is detected.

Table 1.5.2 External Interrupts

Source	Pin	Secondary function pin	Enable conditions	Edge	Digital noise rejection
INT0	$\overline{INT0}$	P50 / TC2 / $\overline{PWM8}$	IMF = 1, INT0EN = 1, EF_3 = 1	falling edge	— (hysteresis input)
INT2	INT2	P53 / TC1 / $\overline{SCK1}$ / AIN0 / $\overline{KWU0}$	IMF · EF_7 = 1	falling edge or rising edge	Pulses of less than 7/fc [s] are eliminated as noise. Pulses equal to or more than 24/fc [s] are regarded as signals.
INT3	INT3	P30/RXIN	IMF · EF_{11} = 1	falling edge, rising edge or falling / rising edge	Refer to the section of the Remote control preprocessor
INT4	INT4	P31 / TC3	IMF · EF_{12} = 1	falling edge or rising edge	Pulses of less than 7/fc [s] are eliminated as noise. Pulses of 24/fc [s] or more are considered to be signals.
INT5	$\overline{INT5}$	P20 / $\overline{STOP}$	IMF · EF_{15} = 1	falling edge	— (hysteresis input)

Note 1: The noise rejection function is also affected for timer/counter input (TC1 pin).

Note 2: The pulse width (both "H" and "L" level) for input to the $\overline{INT0}$ and $\overline{INT5}$ pins must be over 2 machine cycle.



Note 3: If a noiseless signal is input to the external interrupt pin in the NORMAL or IDLE mode, the maximum time from the edge of input signal until the IL is set is as follows:

① INT2,INT4 pins 25/fc [s]

② INT3 pin Refer to the section of the Remote control preprocessor.

Note 4: When high-impedance is specified for port output in stop mode, port input is forcibly fixed to low level internally. Thus, interrupt latches of external interrupt inputs except P20 ($\overline{INT5}$/$\overline{STOP}$) which are also used as ports may be set to "1". To specify high-impedance for port output in stop mode, first disable interrupt service (IMF = 0), activate stop mode. After releasing stop mode, clear interrupt latches using load instruction, then, enable interrupt service.

EINTCR (00037_H)

7	6	5	4	3	2	1	0
"0"	INT0 EN	–	INT4 ES	–	INT2 ES	"0"	–

(Initial value: 00*0 *00*)

INT0EN	P50 / $\overline{INT0}$ pin configuration	0 : P50 input / output port 1 : $\overline{INT0}$ pin (Port P50 should be set to an input mode)	write only
INT4 ES INT2 ES	INT4 and INT2 edge select	0 : Rising edge 1 : Falling edge	

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

Note 2: Edge detection during switching edge selection is invalid.

Note 3: Do not change EINTCR when IMF = 1. After changing EINTCR, interrupt latches of external interrupt inputs must be cleared to "0" using load instruction.

Note 4: In order to change of external interrupt input by rewriting the contents of INT2ES and INT4ES during NORMAL mode, clear interrupt latches of external interrupt inputs (INT2 and INT4) after 8 machine cycles from the time of rewriting.

*Note 5: In order to change an edge of timer counter input by rewriting the contents of INT2ES during NORMAL mode, rewrite the contents after timer counter is stopped (TC*s = 0), that is, interrupt disable state. Then, clear a interrupt lach of external interrupt input (INT2) after 8 machine cycles from the time of rewriting to change to interrupt enable state. Finally, start timer counter.*

Example : When changing TC1 pin inputs edge in external trigger timer mode from rising edge to falling edge.

```
                LD (TC1CR),01001000B    ; TC1S ← 00 (stops TC1)
                DI                      ; IMF ← 0 (disables interrupt service)
                LD (EINTCR),00000100B   ; INT2ES ← 1 (change edge selection)
                NOP
  8 machine     to
    cycles      NOP
                LD (ILL),01111111B      ; IL7 ← 0 (clears interrupt latch)
                EI                      ; IMF ← 1 (enables interrupt service)
                LD (TC1CR),01111000B    ; TC1S ← 11 (starts TC1)
```

Figure 1.5.5 External Interrupt Control Register

1.6 Reset Circuit

The TMP88CM38A/P38A has 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 1.6.1 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 MHz) when power is turned on.

Table 1.6.1 Initializing Internal Status by Reset Action

On-chip hardware	Initial value	On-chip hardware	Initial value
Program counter (PC)	($FFFFE_H$ to $FFFFC_H$)	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		
Register bank selector (RBS)	0	Watchdog timer	Enable
Jump status flag (JF)	1		
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/fc [s]) with the power supply voltage within the operating voltage range and oscillation stable, a reset is applied and the internal state is initialized.

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

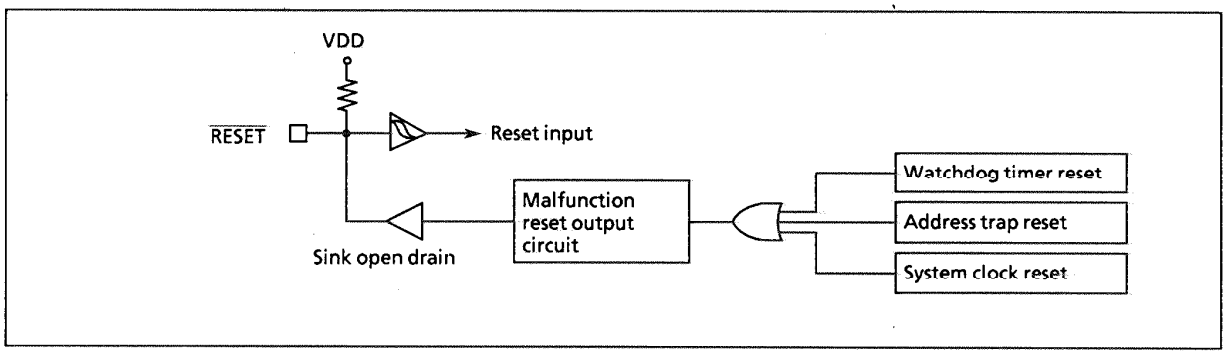
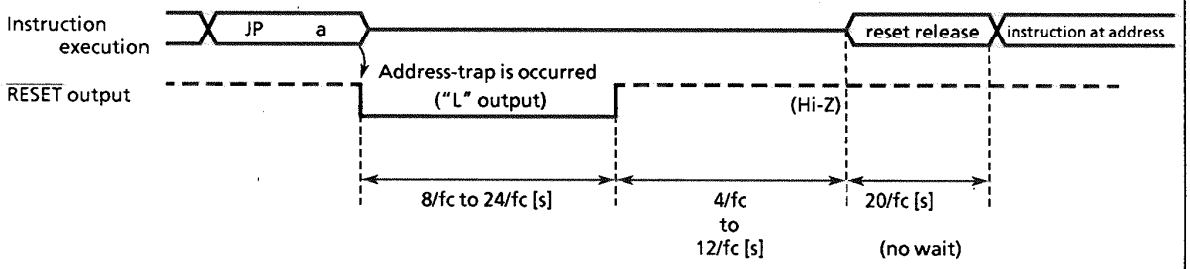


Figure 1.6.1 Reset Circuit

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, DBR 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 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.

Figure 1.6.2 Address-Trap-Reset

1.6.3 Watchdog Timer Reset

Refer to Section "2.4 Watchdog Timer".

1.6.4 System-Clock-Reset

Clearing XEN (bits 7 in SYSCR2) to "0", clearing XEN to "0" when SYSCK = 0 stops system clock, and causes the microcomputer to deadlock. This can be prevented by automatically generating a reset signal whenever XEN = 0, XEN = SYSCK = 0 is detected to continue the oscillation. The, the 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 MHz).

1.7 ROM Corrective Function

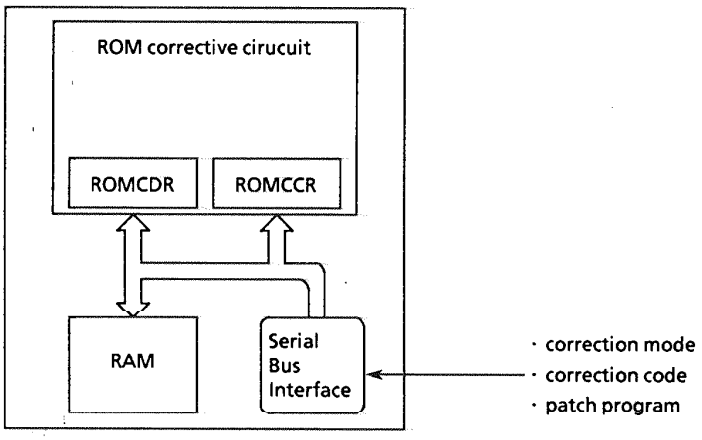
The ROM corrective function can patch the part (s) of on-chip ROM with some bugs.

The ROM corrective function have two modes. One is to replaced the instruction on a certain address in the ROM with the jump instruction to branch into the RAM area where the patched codes (Program Jump Mode). The other is to replace a bye or a word (2 or 3 byte) length data in the ROM with the patched data (Data Replacement Mode). When the ROM corrective function is enabled, the address-trap-reset is automatically disabled on the RAM area from 002C0H where the patched program is running.

Four independent location can be patched.

Note 1:	*When use ROM corrective circuit, it is necessary to contain a program which operates to load patched program and / or replacement data from external memory into an internal data RAM in an initial routine.*
Note 2:	*The address of a instruction for IDLE mode can not be specificated as start address of corrective area.*

Example:



1.7.1 Configuration

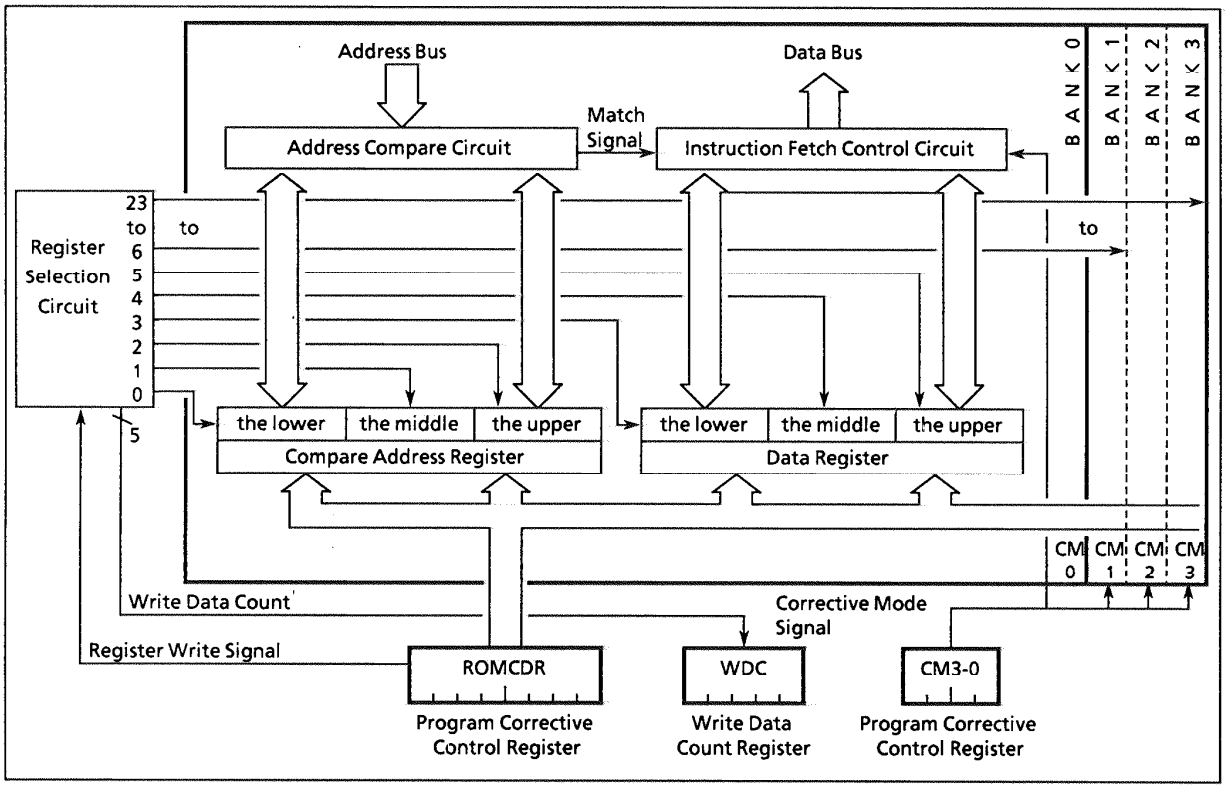


Figure 1.7.1 ROM Corrective Circuit

1.7.2 Control

The ROM corrective function is controlled by ROM corrective control register (ROMCCR) and ROM corrective data register (ROMCDR).

ROM Corrective Control Register

ROMCCR ($00FE0_H$)

7	6	5	4	3	2	1	0
–	–	–	–	CM3	CM2	CM1	CM0

(Initial Value: **** 0000)

CM3	Corrective mode setting (BANK3)	0: Program jump mode 1: Data replacement mode	R/W
CM2	Corrective mode setting (BANK2)		
CM1	Corrective mode setting (BANK1)		
CM0	Corrective mode setting (BANK0)		

ROM Corrective Status Register

ROMCC ($00FE1_H$)

7	6	5	4	3	2	1	0
–	–	–	WDC				

(Initial Value: ***0 0000)

WDC	Write data counter	Counting the number of the byte written in ROMCDR	Read only

ROM Corrective Data Register

ROMCDR ($00FE2_H$)

7	6	5	4	3	2	1	0

(Initial Value: 0000 0000)

ROMC	ROM Corrective data register		Write only

Figure 1.7.2 ROM Corrective Control Register, Status Register and ROM Corrective Data Register

(1) Enable and disable

The ROM corrective function is disabled after releasing reset. It is enabled after setting the data for one bank into ROMCDR. And the address-trap-reset is not generated when fetching an instruction from the RAM area except the address $002C0_H$ to $006BF_H$.

After the ROM corrective function is enabled, it is neccesary to reset the micro controller in order to disable it.

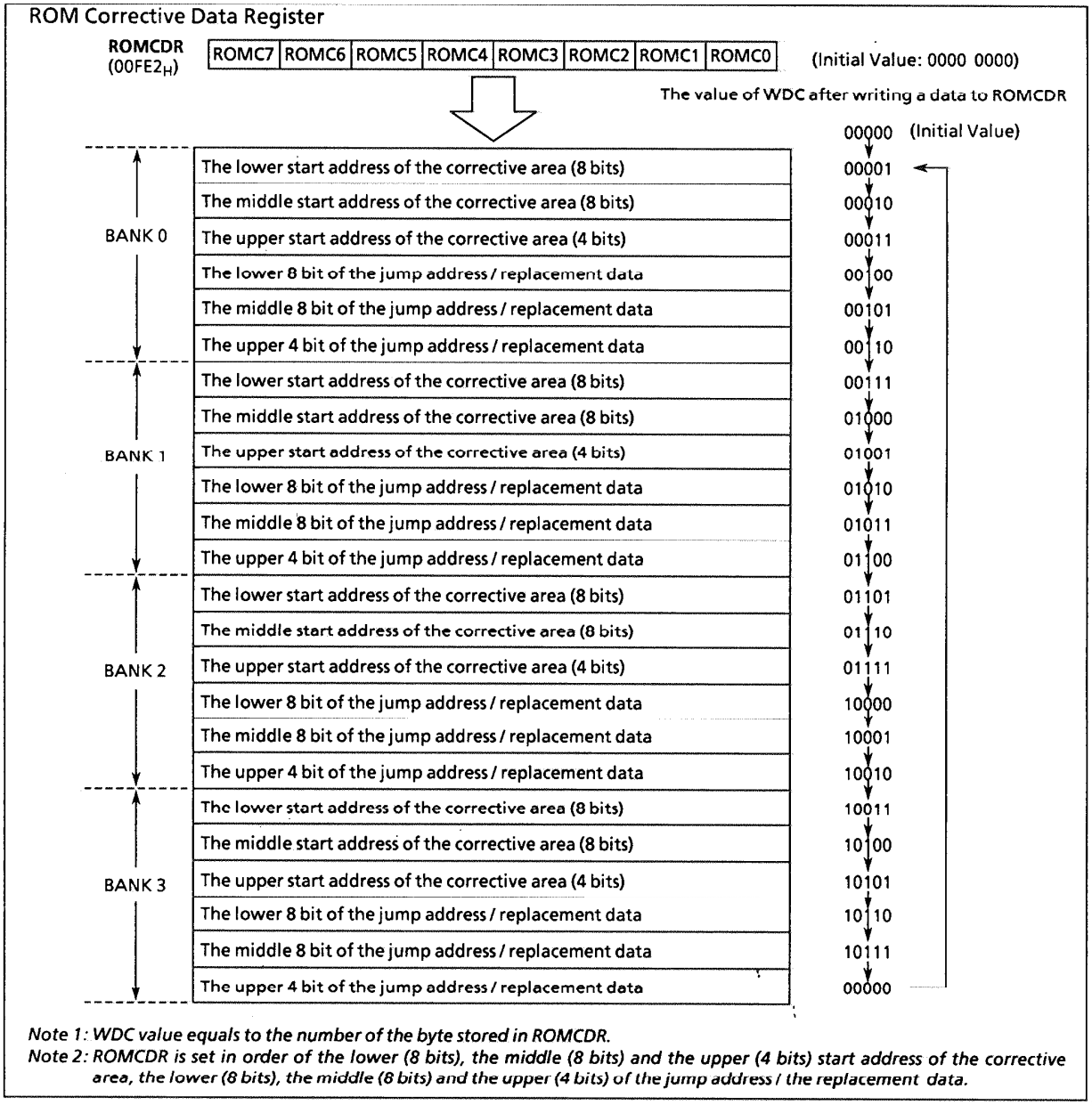
(2) Data replacement mode

The ROM corrective function has the program jump mode and the data replacement mode.

By setting CMx (x: 0 to 3) in ROMCCR, the data replacement mode is selected.

(3) The ROM corrective data register writing

The ROM corrective data register has four banks corresponding to four independent locations to patch. The write data counter (WDC) points each bank set. (Figure 1.7.2)



Note 1: WDC value equals to the number of the byte stored in ROMCDR.
Note 2: ROMCDR is set in order of the lower (8 bits), the middle (8 bits) and the upper (4 bits) start address of the corrective area, the lower (8 bits), the middle (8 bits) and the upper (4 bits) of the jump address / the replacement data.

Figure 1.7.3 Banks and WDC Value of the Program Corrective Data Register

Whenever ROMCDR is written, WDC is incremented to indicate what data is writen via ROMCDR. During reset, WDC is intialized to "0".

(1) The lower start address of the corrective area (8 bits)
(2) The middle start address of the corrective area (8 bits)
(3) The upper start address of the corrective area (4 bits)
(4) The lower jump address / replacement data (8 bits)
(5) The middle jump address / replacement data (8 bits)
(6) The upper jump address (4 bits) / replacement data

Note 1: Corrective addresses must have over five addresses each other.
Note 2: The address of a instruction for IDLE mode can not be specificated as start address of corrective area.

1.7.3 Functions

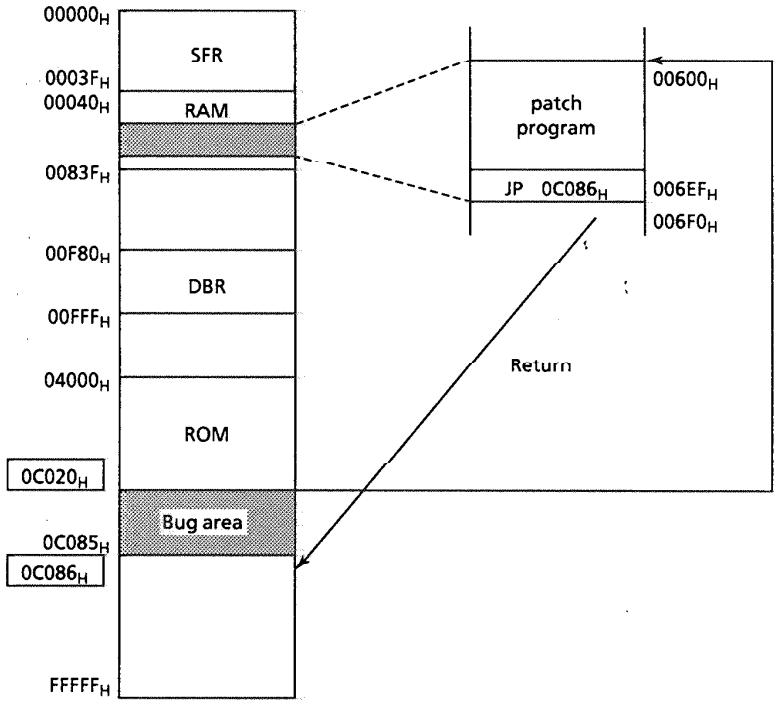
The ROM corrective function can correct maximum four ROM areas with their corresponding four banks of ROM corrective registers. Either program jump mode or data replacement mode is selected for each bank by CM0 to CM3 respectively.

(1) Program jump mode

The program jump mode is to execute the program in the RAM area to correct the bug (s) in the ROM. The start address of ROM that should be patched and the jump vector pointing the RAM area are specified by ROMCDR. When the program is about to run on the code at this start address, the jump instruction is issued, the program branches into the RAM at the jump vector, and the subsequent program codes primarily loaded into this RAM area are excuted. After this patch program execution, the program must be returned to the ROM area by any of the jump instructions at the end of this RAM area. By doing these, the correction of the bug is completed. The program jump mode can be selected at CMn = 0 (n = 0 to 3 for each bank) . The start address must point the 1 st byte of the instruction codes (Op-Code) .

Example : There is bugs on the locations from $0C020_H$ to $0C085_H$

The corrective address, the jump vector, the program patch codes and other information to patch the ROM with the bugs must be read out from any of memory storage that holds them during initial program routine. CMn = 0 specifies the program jump mode. Subsequently, the patch program codes are loaded into RAM (00600_H to $006EF_H$) . The start address ($0C020_H$) of the ROM necessary to patch is written to the corrective ROM address registers, and the start address (00600_H) of the RAM area to patch is loaded onto the jump address registers. When the instruction at $0C020_H$ is fetched, the instruction to jump into 00600_H is unconditionally executed instead of the instruction at $0C020_H$, and the subsequent patch program codes are executed. The jump instruction at the end of the patch program codes returns to the ROM at $0C086_H$.



Note: Corrective address must be assigned to 1st byte of instruction codes on the program jump mode.

(2) Data replacement mode

The data replacement mode is to directly replace a single byte or word (2 or 3 byte) length data with the replacement data which are written via ROMCDR.

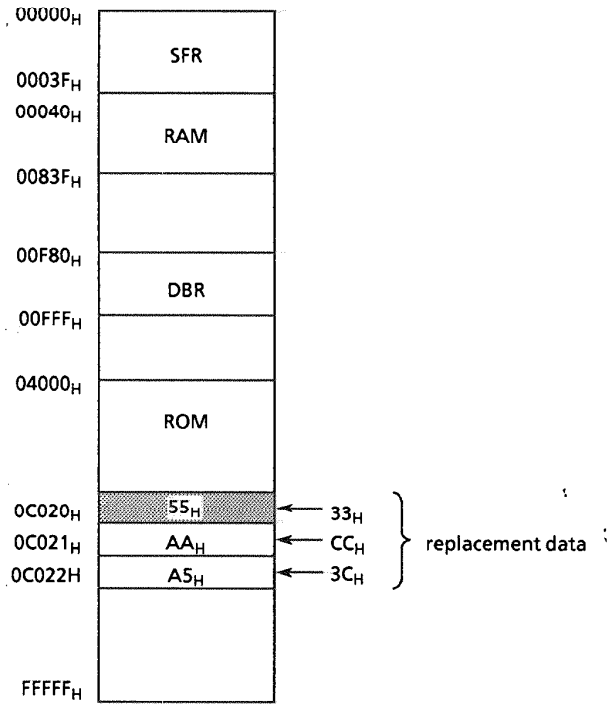
The program jump mode can work as the equivalent data replacement mode. However, when many instructions refer a certain data in the ROM which must be patched, the program jump mode consumes the same number of banks as that of the instructions referring this (these) data. ROM data replace mode reduces this kind of bank consumption.

Note: The instruction that gains access to an only byte is replaced to an only start byte.

By setting CMn to 1, the data replacement mode is selected. The start address of ROM data is set to the corrective ROM address, and two bytes replacement data is set to the patch data register via ROMCDR. The corrective address must point the constant data in the data replacement mode. It is impossible to replace opecode and operand in the data replacement mode.

Example:

The start address is set to $0C020_H$ as the location of the replaced data. Three bytes of the patch data are set 33_H for $0C020_H$, CC_H for $0C021_H$, 3CH for $0C022_H$.



1. At HL = $0C020_H$, Executing LD A, (HL) loads 33_H in A. (Data replacement)
2. At HL = $0C021_H$, Executing LD A, (HL) loads AA_H in A. (No data replacement)
3. At HL = $0C020_H$, Executing LD WA, (HL) loads $CC33_H$ in WA. (Data replacement)
4. At HL = $0C020_H$, Executing LD IX, (HL) loads $CCC33_H$ in IX. (Data replacement)

Note 1: Corrective address must be assigned to constant data area on the data replacement mode. (Ope-code and Ope-rand can't be replaced by ROM correction circuit.)

Note 2: Instructions which includes "(HL+)" or "(−HL)" operation can't be replaced by ROM corrective circuit on the data replace ment mode.

2. On-Chip Peripheral Functions

2.1 Special Function Registers (SFR) and Data Buffer Registers (DBR)

The TLCS 870/X series uses the memory mapped I/O system and all peripheral control and data transfers are performed through the special function registers (SFR) and data buffer registers (DBR).

The SFR are mapped to addresses 00000_H to $0003F_H$, and DBR are mapped to address $00F80_H$ to $00FFF_H$.

Figure 2.1.1 shows the list of the TMP88CM38A/P38A SFRs and-DBRs.

Address	Read	Write
00000 H	reserved	
00001	reserved	
00002	P2 port	
00003	P3 port	
00004	P4 port	
00005	P5 port	
00006	P6 port	
00007	P7 port	
00008	–	P5CR1 (P5 port I/O control1)
00009	–	P7CR (P7 port I/O control)
0000A	reserved	
0000B	reserved	
0000C	–	P4CR (P4 port I/O control)
0000D	–	P6CR (P6 port I/O control)
0000E	ADCCRA (AD converter controlA)	
0000F	ADCCRB (AD converter controlB)	
00010	–	$TC1DRA_L$ (Timer register 1A)
00011	–	$TC1DRA_H$
00012	$TC1DRB_L$ (Timer register1B)	
00013	$TC1DRB_H$	
00014	TC1CR (TC1 control)	
00015	–	TC2CR (TC2 control)
00016	–	$TC2DR_L$ (Timer register 2)
00017	–	$TC2DR_H$
00018	TC3DRA (Timer register 3A)	
00019	TC3DRB (Timer register 3B)	–
0001A	–	TC3CR (TC3 control)
0001B	–	TC4DR (Timer register 4)
0001C	–	TC4CR (TC4 control)
0001D	ORDSN (OSD control)	
0001E	$ORCRA_L$ (OSD control)	
0001F	$ORCRA_H$ (OSD control)	

Address	Read	Write
00020 H	SBISRA (SBI statusA)	SBICRA (SBI control registerA)
00021	SBIDBR (SBI Data buffer)	
00022	–	I²CAR (I²CBus address)
00023	SBISRB (SBI statusB)	SBICRB (SBI control registerB)
00024	–	$ORDMA_L$ (OSD control)
00025	–	$ORDMA_H$ (OSD control)
00026	RCSR (TC3 status)	RCCR (TC3 control)
00027	–	PMPXCR (Port control)
00028	–	PWMCR1A (PWM control1A)
00029	–	PWMCR1B (PWM control1B)
0002A	–	PWMDBR1 (PWMDBR1)
0002B	–	P3CR1 (P3 I/O control)
0002C	EIR_E (Interrupt enable register)	
0002D	EIR_D	
0002E	IL_E (Interrupt latch)	
0002F	IL_D	
00030	CGCR (Divider control)	
00031	ADCDR1 (AD conversion result)	
00032	ADCDR2 (AD conversion result)	
00033	reserved	
00034	–	WDTCR1 (Watch-dog timer control)
00035	–	WDTCR2
00036	TBTCR (TBT / TG control)	
00037	EINTCR (External interrupt control)	
00038	SYSCR1 (System control)	
00039	SYSCR2	
0003A	EIR_L (Interrupt enable register)	
0003B	EIR_H	
0003C	IL_L (Interrupt latch)	
0003D	IL_H	
0003E	PSW_L (Program status word)	
0003F	PSW_H	

(a) Special function registers

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

Note 2: - ; Cannot be accessed.

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

Note 4: When defining address $0003F_H$ with assembler symbols, use GRBS.

Address $0003E_H$ must be GPSW/GFLAG.

Figure 2.1.1 (a) SFR

Address	Read	Write
$00F80_H$	ORDON (OSD Control)	
81	–	OSD Control Register
≈	–	OSD Control Register ≈
A1	ORCLKC (OSD Clock Status)	ORCLKF (OSD Clock Control)
A2	–	OSD Control Register
≈	–	OSD Control Register ≈
B9	ORIRC (OSD Display Counter)	ORIRC (OSD Interrupt Control)
BA	–	OSD Control Register
≈	–	OSD Control Register ≈
C0	reserved	
≈	reserved	≈
D0	IDLEINV (Key-on Wake-up Status)	IDLECR (Key-on Wake-up Control)
D1	reserved	
≈	reserved	≈
D8	SINTCR (Data Slicer Interrupt Control)	
D9	–	DACLCR (Sync. Tip Slice Level Setting)
DA	SLVLCR (Slice Level Control)	
DB	SIFDR1 (Caption Data 1st Byte)	–
DC	SIFDR2 (Caption Data 2nd Byte)	–
DD	SIFSR (Data Slicer Status)	–
DE	–	–
DF	SIFS1R (Data Slicer Status2)	SIFSMS1 (Data Slicer Mode Setting)
E0	ROMCCR (ROM Correctiove Control)	
E1	ROMCC (ROM Corrective Status)	–
E2	–	ROMCDR (ROM Corrective Data)
E3	reserved	
E4	JECR (Jitter Elimination Control)	
E5	JESR (Jitter Elimination Status)	–
E6	–	TVSCR (Test Video Signal Output)
E7	reserved	
E8	RXCR1 (Remote Control Receive Control2)	
E9	RXCR2 (Remote Control Receive Control1)	
EA	RXCTR (Remote Control Receive Counter)	–
EB	RXDBR (Remote Control Receive Data buffer)	–
EC	RXSR (Remote Control Status)	–
ED	reserved	
EE	FC8CR (FC8 Control)	
EF	reserved	
F0	SCCRA (Source Clock Select Control)	
F1	SCCRB (Serial Clock Source Control)	SCSR (Serial Clock Source Status)
F2	reserved	
F3	reserved	
F4	reserved	
F5	–	PWMCR2A (PWM Control 2A)
F6	–	PWMCR2B (PWM Control 2B)
F7	–	PWMDBR2 (PWM Data buffer)
F8	reserved	
≈	reserved	≈
FE	–	PSELCR (P3, P5 Control2)
FF	reserved	

(b) Data butter register

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

Note 2: - ; Cannot be accessed.

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

Figure 2.1.1 (b) DBR

2.2 I/O Ports

The TMP88CM38A/P38A have 6 parallel input / output ports (33 pins) as follows:

	Primary Function	Secondary Functions
Port P2	1 bit I/O port	External interrupt input, and STOP mode release signal input
Port P3	6 bit I/O port	External interrupt input, remote control signal input, data slicer analog input, timer / counter input, serial bus interface input / output and data slicer input
Port P4	8 bit I/O port	Pulse width modulation output
Port P5	8 bit I/O port	Pulse width modulation output external interrupt input, timer / counter input, key-on wake-up input, serial bus interface input / output, analog input and I output from OSD circuitry.
Port P6	8 bit I/O port	R, G, B and Y / BL output from OSD circuitry, R.G.B and Y / BL input, analog input, test video signal output and key-on wake-up input
Port P7	2 bit I/O port	Horizontal synchronous pulse input and vertical synchronous pulse input to OSD circuitry

Each output port contains a latch, which holds the output data. All input ports do not have latches, so the external input data should either be held externally until read or reading should be performed several times before processing. Figure 2.2.1 shows input / output timing examples.

External data is read from an I/O port in the S1 state of the read cycle during execution of the read instruction. This timing can not 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.

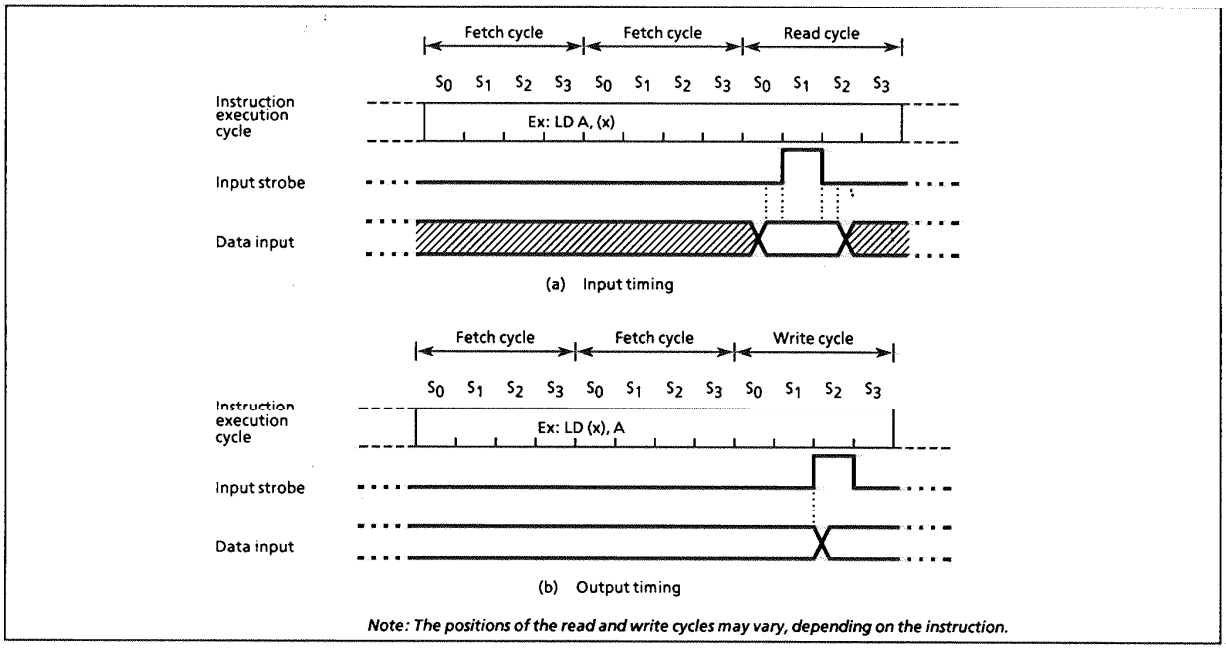


Figure 2.2.1 Input / Output Timing (Example)

When reading an I/O port except programmable I/O ports, whether the pin input data or the output latch contents are read depends on the instructions, as shown below:

(1) Instructions that read the output latch contents

① XCH r, (src)
② SET / CLR / CPL (src).b
③ SET / CLR / CPL (pp).g
④ LD (src).b, CF
⑤ LD (pp).b, CF
⑥ ADD / ADDC / SUB / SUBB / AND / OR / XOR (src), n
⑦ (src) side of ADD / ADDC / SUB / SUBB / AND / OR / XOR (src), (HL)

(2) Instructions that read the pin input data

① Instructions other than the above (1)
② (HL) side of ADD / ADDC / SUB / SUBB / AND / OR / XOR (src), (HL)

2.2.1 Port P2 (P20)

Port P2 is a 1bit input / output port. It is also used as an external interrupt input, and a STOP mode release signal input. When used as an input port, or a secondary function pin, the output latch should be set to "1". During reset, the output latch is initialized to "1".
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 used as an output port, the interrupt latch is set on the falling edge of the P20 output pulse.
When a read instruction for port P2 is executed, bits 7 to 1 in P2 are read in as undefined data.

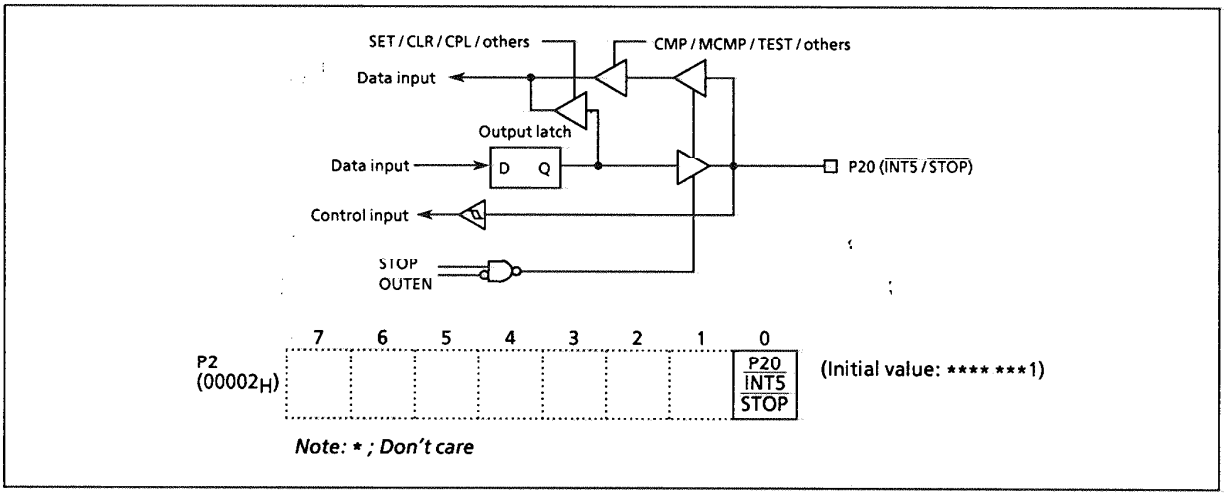


Figure 2.2.2 Port P2

2.2.2 Port P3 (P35 to P30)

Port P3 is an 6bit input / output port which can be configured as an input or an output in one-bit unit under software control. Input / output mode is specified by the corresponding bit in the port P3 input / output control register 1 (P3CR1). Port P3 is configured as an input if its corresponding P3CR1 bit is cleared to "0", and as an output if its corresponding P3CR1 bit is set to "1". During reset, P3CR1 is initialized to "0", which configures port P3 as an input. The P3 output latches are also initialized to "1". Data is written into the output latch regardless of the P3CR1 contents. Therefore initial output data should be written into the output latch before setting P3CR1.

Port P3 is also used as an external interrupt input, Remote-control signal input a timer / counter input, data slicer input and serial bus interface input / output. When used as a secondary function input pin except I^2C bus interface input / output, the input pins should be set to the input mode. When used as a secondary function output pin except I^2C bus interface input / output, the output pins should be set to the output mode and beforehand the output latch should be set to "1". When P34 and P35 are used as I^2C bus interface input / output, P3CR2 bits should be set to the sink open drain mode, the output latches should be set to "1", and the output pins should be set to the output mode.

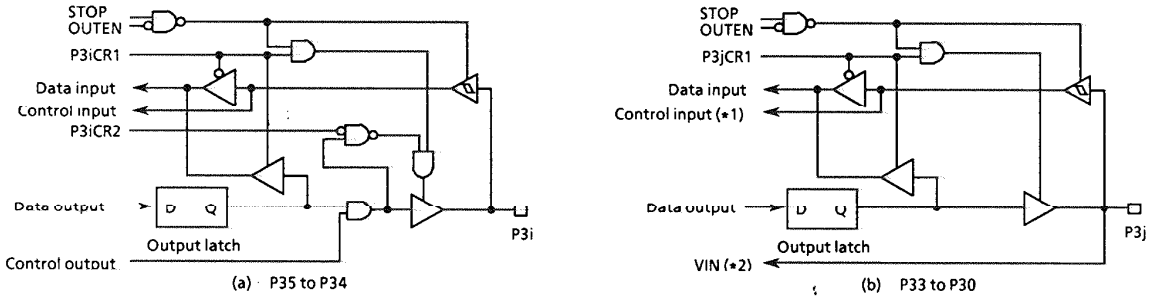
Note: Input mode port is read the state of input pin. When input / output mode is used mixed, the contents of output latch setting input mode may be changed by executing bit manipulation instructions.

Example 1: Outputs an immediate data $5A_H$ to port P3.

```
LD    (P3), 5AH        ; P3 ← 5AH
```

Example 2: Inverts the output of the lower 4 bits (P33 to P30) in port P3.

```
XOR   (P3), 00001111B  ; P33 to P30 ← P33 to P30
```



P3 (00003_H)

7	6	5	4	3	2	1	0
		P35 SDA0	P34 SCL0	P33 VIN0 TC4	P32 VIN1 CSIN	P31 INT4 TC3	P30 INT3 RXIN

(Initial Value: **11 1111)

P3CR1 ($0002B_H$)

7	6	5	4	3	2	1	0

(Initial Value: **00 0000)

P3CR1	I/O control for P3	0: Input mode 1: Output mode	Write only

PSELCR ($0FFE_H$)

7	6	5	4	3	2	1	0
0	0	P35CR2	P34CR2	0	P52CR2	P51CR2	0

(Initial value: 0*00 *00*)

P3CR2	I/O Control for P3	0: Sink open drain 1: Tri-state	Write only

(*1) only P33, P31
(*2) only P33, P32

*Note 1: * ; Don't care, i = 5 to 4, j = 3 to 0*
Note 2: P3CR1 cannot used the read-modify-write instructions.
(Bit manipulation instructions such as SET, CLR, etc. and logical operation such as AND, OR, etc.)
Note 3: Clear bit 7 to "0" in PSELCR.

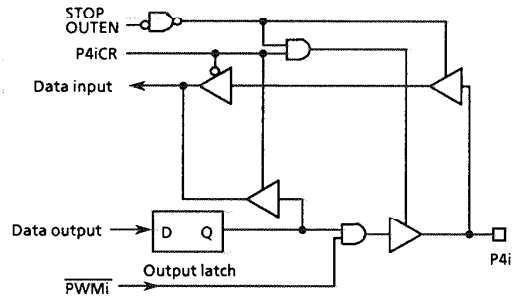
Figure 2.2.3 Port P3 and P3CR

2.2.3 Port P4 (P47 to P40)

Port P4 is an 8 bit input / output port which can be configured as an input or an output in one-bit unit under software control. Input / output mode is specified by the corresponding bit in the port P4 input / output control register (P4CR). Port P4 is configured as an input if its corresponding P4CR bit is cleared to "0", and as an output if its corresponding P4CR bit is set to "1". During reset, P4CR is initialized to "0", which configures port P4 as an input. The P4 output latches are also initialized to "1". Data is written into the output latch regardless of the P4CR contents. Therefore initial output data should be written into the output latch before setting P4CR.

Port P4 is also used as a pulse width modulation (PWM) output. When used as a PWM output pin, the output pins should be set to the output mode and beforehand the output latch should be set to "1".

Note: Input mode port is read the state of input pin. When input / output mode is used mixed, the contents of output latch setting input mode may be changed by executing bit manipulation instructions.



P4 (00004_H)

7	6	5	4	3	2	1	0
P47 / PWM7	P46 / PWM6	P45 / PWM5	P44 / PWM4	P43 / PWM3	P42 / PWM2	P41 / PWM1	P40 / PWM0

(Initial value: 1111 1111)

P4CR ($0000C_H$)

7	6	5	4	3	2	1	0

(Initial value: 0000 0000)

P4CR	I/O control for port P4	0: Input mode 1: Output mode	Write only

Note 1: i = 7 to 0

Note 2: P4CR cannot be used with the read-modify-write instructions.
(Bit manipulation instructions such as SET, CLR, etc. and logical operation such as AND, OR, etc.)

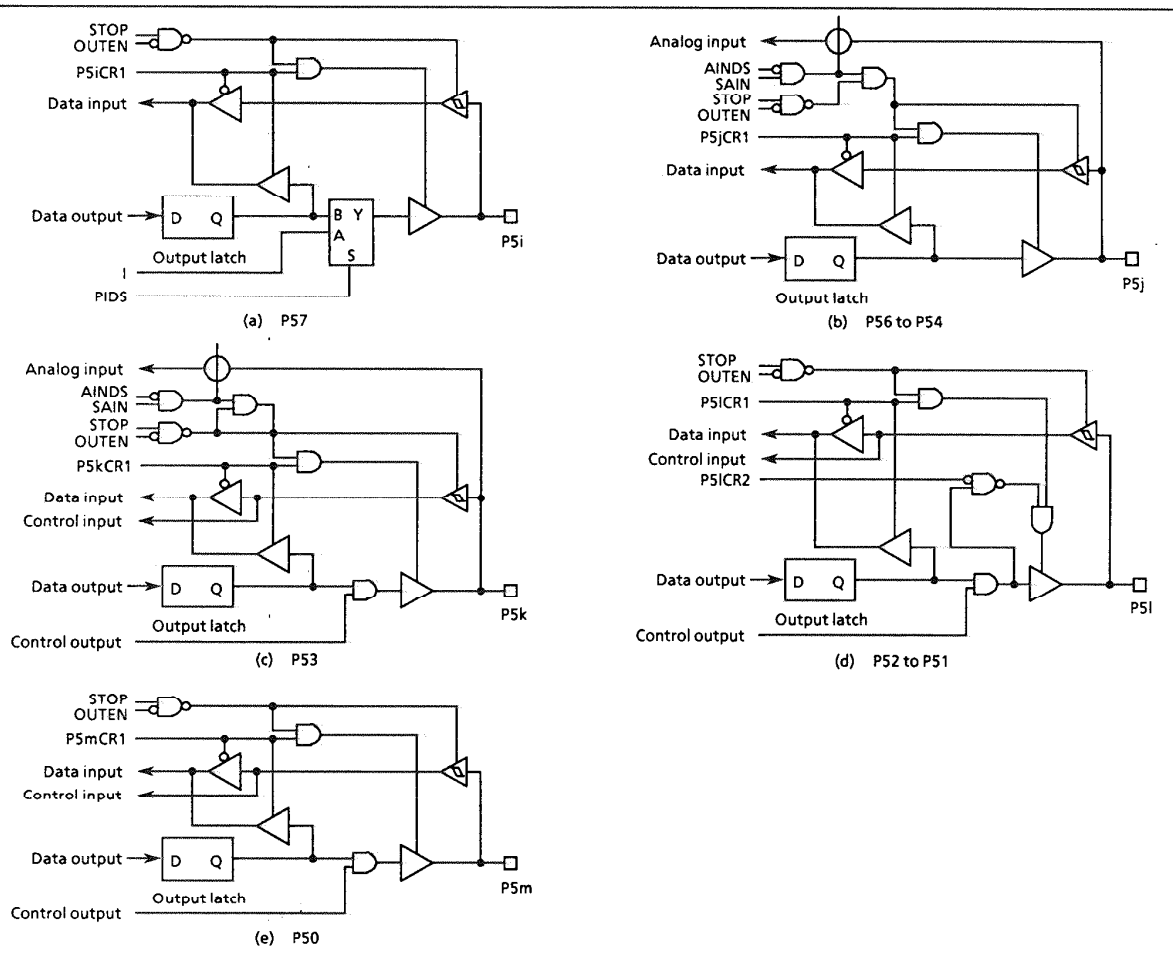
Figure 2.2.4 Ports P4 and P4CR

2.2.4 Port P5 (P57 to P50)

Port P5 is an 8 bit input / output port which can be configured as an input or an output in one-bit unit under software control. Input / output mode is specified by the corresponding bit in the port P5 input / output control register 1 (P5CR1). Port P5 is configured as an input if its corresponding P5CR1 bit is cleared to "0", and as an output if its corresponding P5CR1 bit is set to "1". During reset, P5CR1 is initialized to "0", which configures port P5 as an input. The P5 output latches are also initialized to "1". Data is written into the output latch regardless of the P5CR1 contents. Therefore initial output data should be written into the output latch before setting P5CR1.

Port P5 is also used as is also used as AD converter analog input, a pulse width modulation (PWM) output external interrupt input, timer / counter input, serial bus interface input / output, and an on screen display (OSD) output (I signal). When used as a secondary function input pin except I^2C bus interface input / output, the input pins should be set to the input mode. When used as a secondary function output pin except I^2C bus interface input / output, the output pins should be set to the output mode and beforehand the output latch should be set to "1". When P52 and P51 are used as I^2C bus interface input / output, P5CR2 bits should be set to the sink open drain mode, the output latches should be set to "1", and the output pins should be set to the output mode. When P57 is used as an OSD output pin, the output pin should be set to the output mode and beforehand the port 6 data selection register (PIDS) should be clear to "0". When used as port P5, the port 6 data selection register (PIDS) should be set to "1".

Note: Input mode port is read the state of input pin. When input / output mode is used mixed, the contents of output latch setting input mode may be changed by executing bit manipulation instructions.



P5 (00005H)

7	6	5	4	3	2	1	0
P57 I	P56 AIN3	P55 AIN2	P54 AIN1	P53 INT2 TC1 SCK1 AIN0	P52 SO1 SDA1	P51 PWM9 SI1 SCL1	P50 PWM8 INT0 TC2

(Initial Value: 1111 1111)

P5CR1 (00008H)

7	6	5	4	3	2	1	0

(Initial value: 0000 0000)

P5CR1	I/O control for P5	0: Input mode 1: Output mode	Write only

PSELCR (00FFEH)

7	6	5	4	3	2	1	0
"0"		P35CR2	P34CR2		P52CR2	P51CR2	

(Initial value: 0*00 *00*)

P5CR2	I/O Control for P5	0: Sink open drain 1: Tri-state	Write only

ORP6S (00FBAH)

7	6	5	4	3	2	1	0
P67S	P66S	P65S	P64S	PIDS	YBLCS	MPXS	

(Initial value: 0000 0000)

PIDS	Selection of the output data for port P57	0: The OSD output (I) 1: Port P57 output latch	Write only

*Note 1: * ; Don't care, i = 7, j = 6 to 4, k = 3, l = 2 to 1, m = 0*

Note 2: P5CR1 cannot be used with the read-modify-write instructions.
(Bit manipulation instructions such as SET, CLR, etc. and logical operation such as AND, OR, etc.)

Note 3: Clear bit 7 to "0" in PSELCR.

Figure 2.2.5 Ports P5

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 under software control. Input / output mode is selected by the corresponding bit in the port P6 input / output control register (P6CR). Port P6 is configured as an input if its corresponding P6CR bit is cleared to "0", and as an output if its corresponding P6CR bit is set to "1" and P6nS bit is set to "1". P63 to P60 are sink open drain ports. During reset, P6CR is initialized to "0", which configures port P6 as an input. The P6 output latches are also initialized to "1".

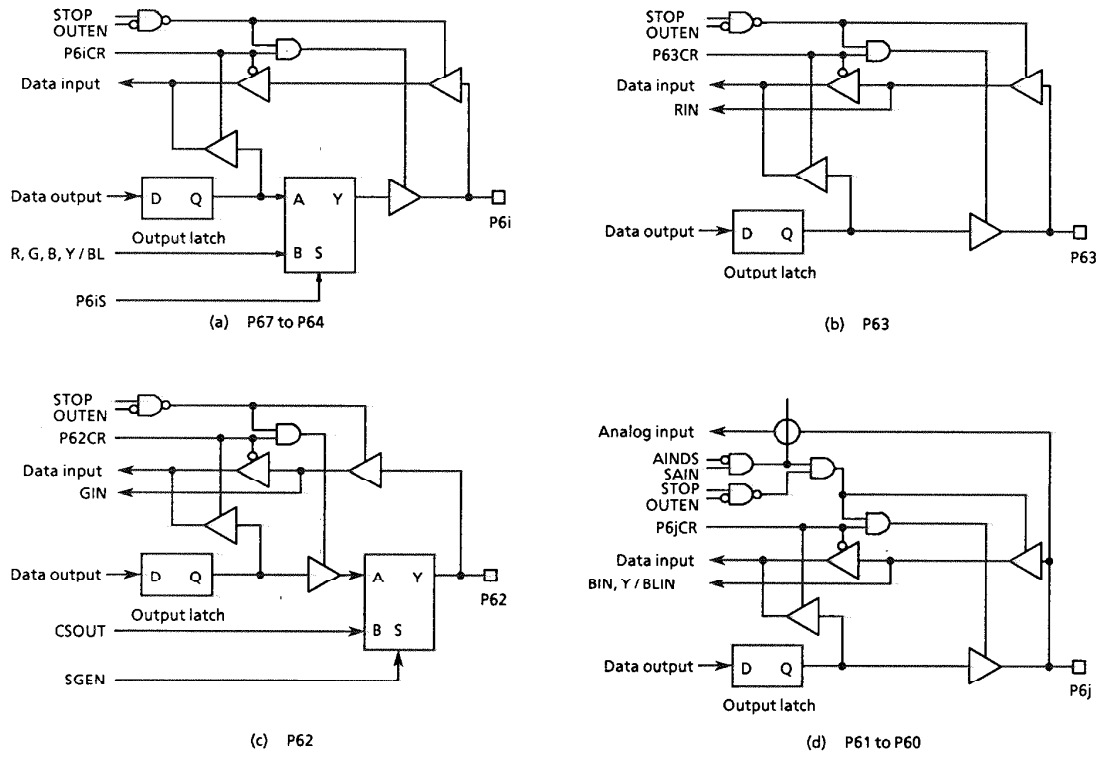
Data is written into the output latch regardless of the P6CR contents. Therefore initial output data should be written into the output latch before setting P6CR.

Port P6 is used as an on screen display (OSD) output (R, G, B, and Y / BL signal) / input (RIN, GIN BIN, Y / BLIN signal), a test video signal output and AD converter analog input. When used as a test video signal output pin, the output pins should be set to the output mode and beforehand the signal control register (SGEN) should be set to "1". When used as a secondary function input, the input pins should be set to the input mode. When used as an OSD output pin, the output pins should be set to the output mode and beforehand the port P6 data selection register (P67S to P64S) should be clear to "0". When used as port P6, the signal control register (P67 to P64) should be set to "1".

Note: Input mode port is read the state of input pin. When input / output mode is used mixed, the contents of output latch setting input mode may be changed by executing bit manipulation instructions.

Example: Sets the lower 4 bits (P63 to P60) in port P6 to the output mode, and the other bit to the input mode.

```
LD    (P6CR), 0FH  ;  P6CR ← 00001111B
```



P6 (00006H)

7	6	5	4	3	2	1	0
P67 Y / BL	P66 B	P65 G	P64 R	P63 RIN	P62 GIN CSOUT	P61 BIN AIN5	P60 Y / BLIN AIN4

(Initial value: 1111 1111)

P6CR (0000DH)

7	6	5	4	3	2	1	0

(Initial value: 0000 0000)

P6CR	I/O control for port P6	0: Input mode 1: Output mode	Write only

SGCR (00FE6H)

7	6	5	4	3	2	1	0
SGEN	SGVBLK	SGPAL	SGIV	SGCHS		SGPAT	

(Initial value: 0000 0000)

SGEN	Function selection	0: Disable 1: Enable	Write only

ORP6S (00FBAH)

7	6	5	4	3	2	1	0
P67S	P66S	P65S	P64S	PIDS	YBLCS	MPXS	

(Initial value: 0000 0000)

P67S to P64S	Selection of the output data for port P6i	0: The OSD output (R, G, B, Y / BL) 1: Port P6i output latch	Write only

*Note 1: * ; Don't care, i = 7 to 4, j = 1 to 0*
Note 2: P6CR and ORP6S cannot be used with the read-modify-write instructions. (Bit manipulations such as SET, CLR, etc. and logical operation such as AND, OR, etc.)

Figure 2.2.6 Ports P6, P6CR, and P67S to P64S

2.2.6 Port P7 (P71 to P70)

Port P7 is a 2bit input / output port, and is also used as a vertical synchronous signal ($\overline{VD}$) input and a horizontal synchronous signal ($\overline{HD}$) input for the on screen display (OSD) circuitry.

The output latches, are initialized to "1" during reset. When used as an input port or a secondary function pin, the output latch should be set to "1".

When a read instruction for port P7 is executed, bits 7 to 2 in P7 are read in as undefined data.

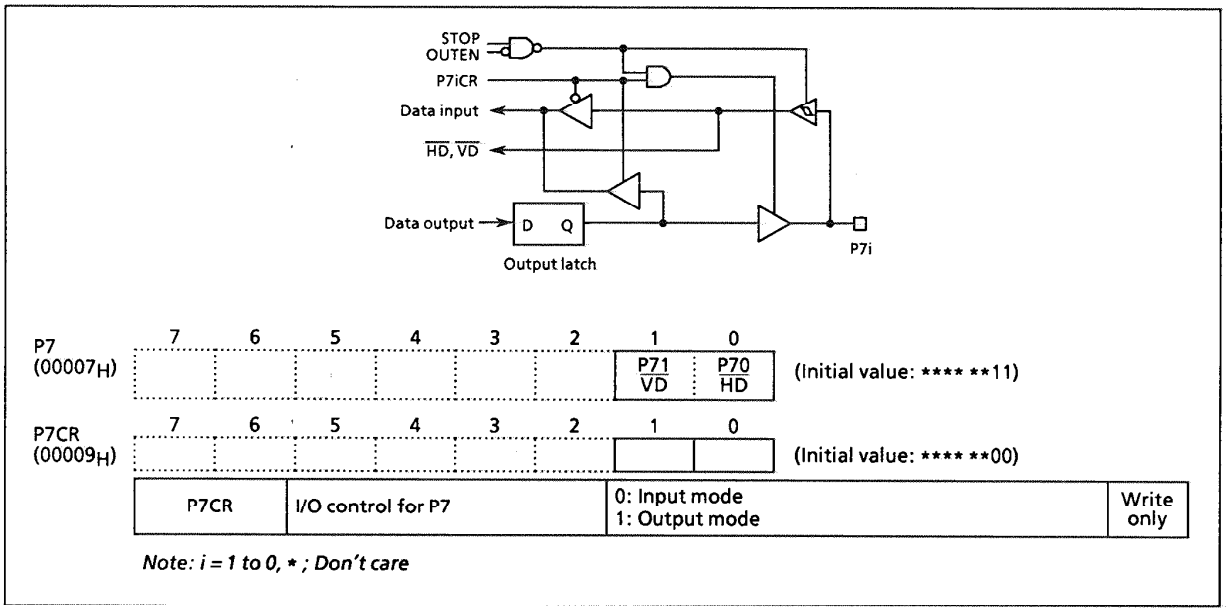


Figure 2.2.7 Ports P7

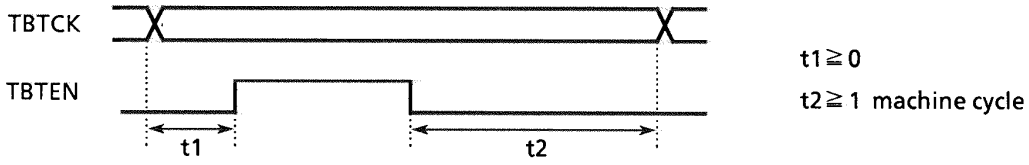
2.3 Time Base Timer (TBT)

The time base timer generates time base for key scanning, dynamic displaying, etc. It also provides a time base timer interrupt (INTTBT). The time base timer is controlled by a control register (TBTCR) shown in Figure 2.3.1.

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.

The interrupt frequency (TBTCK) must be selected with the time base timer disabled (When the time base timer is changed from enabling to disabling, the interrupt frequency can't be changed.)

Both frequency selection and enabling can be performed simultaneously.



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

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

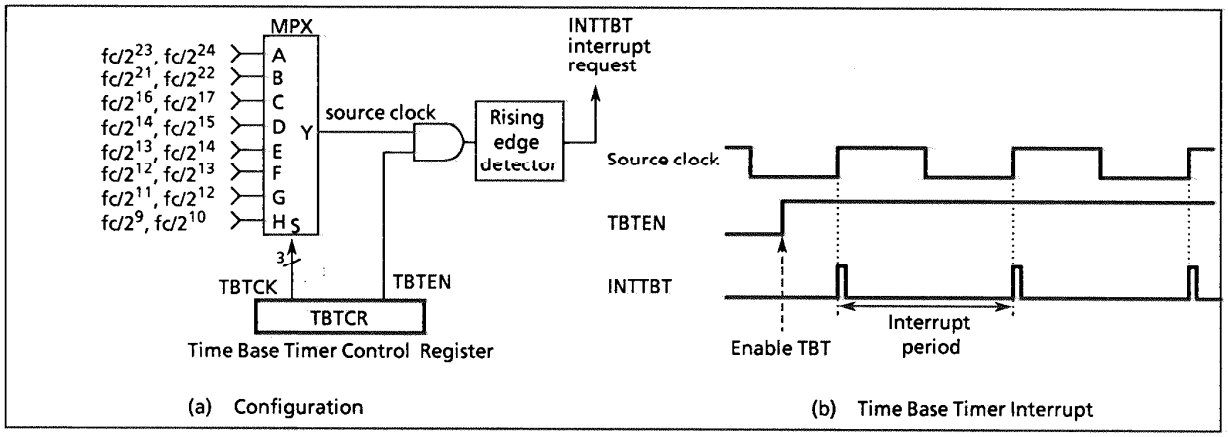


Figure 2.3.1 Time Base Timer

	7	6	5	4	3	2	1	0	
TBTCR (00036_H)	"0"	–	–	"0"	TBTEN	TBTCK			(Initial value: 0**0 0***)

			NORMAL, IDLE mode		
			DV7CK = 0		
			DV1CK = 0	DV1CK = 1	
TBTEN	Time base timer enable/disable	0: Disable 1: Enable			Write only
TBTCK	Time base timer interrupt frequency select	000	$fc/2^{23}$ [Hz]	$fc/2^{24}$ [Hz]	
		001	$fc/2^{21}$	$fc/2^{22}$	
		010	$fc/2^{16}$	$fc/2^{17}$	
		011	$fc/2^{14}$	$fc/2^{15}$	
		100	$fc/2^{13}$	$fc/2^{14}$	
		101	$fc/2^{12}$	$fc/2^{13}$	
		110	$fc/2^{11}$	$fc/2^{12}$	
		111	$fc/2^{9}$	$fc/2^{10}$	

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

Note 2: TBTCR is a write-only register and must not be used with any of read-modify-write instructions.

Note 3: Set bit 7 and 6 in TBTCR to "0".

Figure 2.3.2 Time Base Timer and Divider Output Control Register

Table 2.3.1 Time Base Timer Interrupt Frequency
(Example: at fc = 16MHz)

TBTCK	Time Base Timer Interrupt Frequency [Hz]	
	NORMAL, IDLE mode	
	DV1CK = 0	DV1CK = 1
000	1.90	0.95
001	7.62	3.81
010	244.14	122.07
011	976.56	488.28
100	1953.12	976.56
101	3906.25	1953.12
110	7812.50	3906.25
111	31250	15625

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 pseudo 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

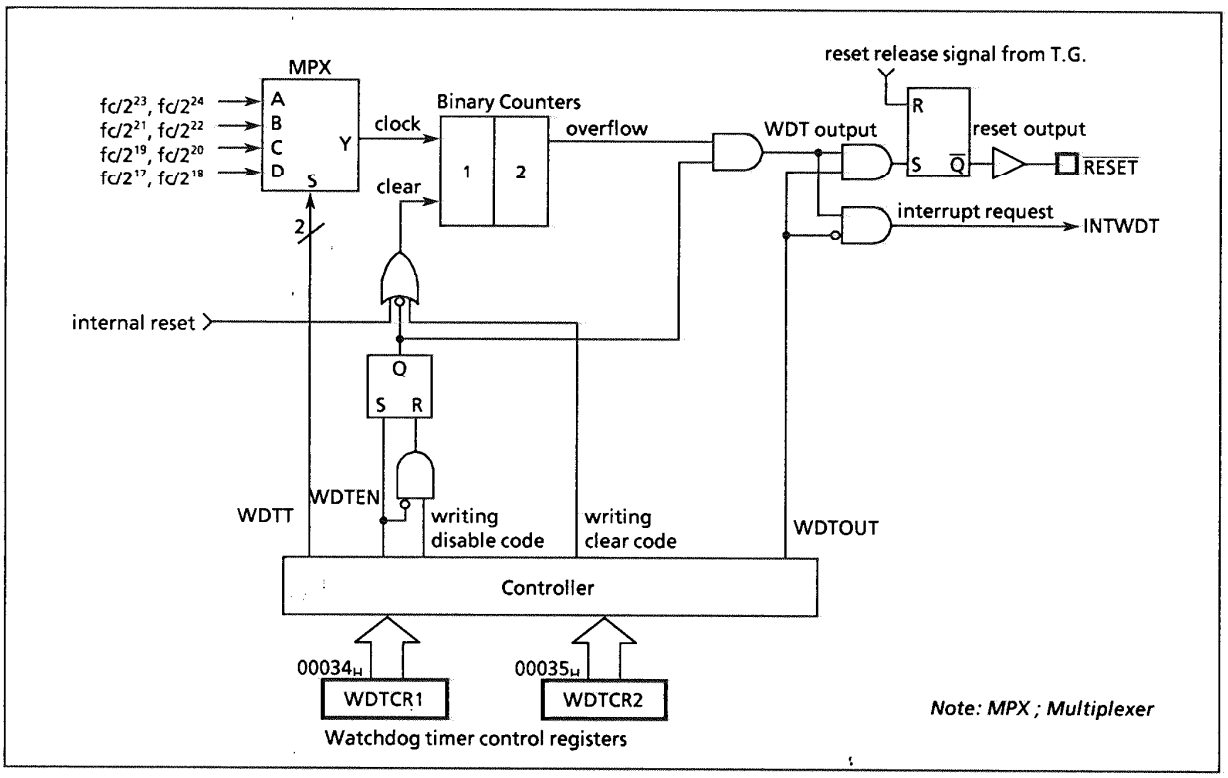


Figure 2.4.1 Watchdog Timer Configuration

2.4.2 Watchdog Timer Control

Figure 2.4.2 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
Within 3/4 of WDT
detection time
        LD   (WDTCR2), 4EH        ;  Clears the binary counters
                                     (always clear immediately before and
                                     after changing WDTT)
Within 3/4 of WDT
detection time
        LD   (WDTCR2), 4EH        ;  Clears the binary counters
        LD   (WDTCR2), 4EH        ;  Clears the binary counters
```

Watchdog Timer Register 1

WDTCR1 (00034_H)

7	6	5	4	3	2	1	0
				WDTEN	WDTT		WDTOUT

(Initial value: **** 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]		NORMAL mode		
			DV1CK = 0	DV1CK = 1	
		00	2^{25}/fc	2^{26}/fc	
		01	2^{23}/fc	2^{24}/fc	
		10	2^{21}/fc	2^{22}/fc	
		11	2^{19}/fc	2^{20}/fc	
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], *; 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 (00035_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) 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
Note 5: The watchdog timer counter must be disabled by writing the disable code ($B1_H$) to WDTCR2 after writing WDTCR2 to "$4E_H$"

Figure 2.4.2 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.

Example: Disables watchdog timer

```
LDW  (WDTCR1), 00001000B      ;  WDTEN ← 1
```

(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".

Table 2.4.1 Watchdog Timer Detection Time (Example: fc = 16 MHz)

WDTT	Watchdog timer detection time [s]	
	NORMAL mode	
	DV1CK = 0	DV1CK = 1
00	2.097	4.194
01	524.2 m	1.048
10	131.0 m	262.1 m
11	32.8 m	65.5 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, 006BFH                ;  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, fc = fc/16).

Note: If there is any fluctuation in the oscillation frequency at the start of clock oscillation, the reset time includes error. Thus, regard the reset time as an approximate value.

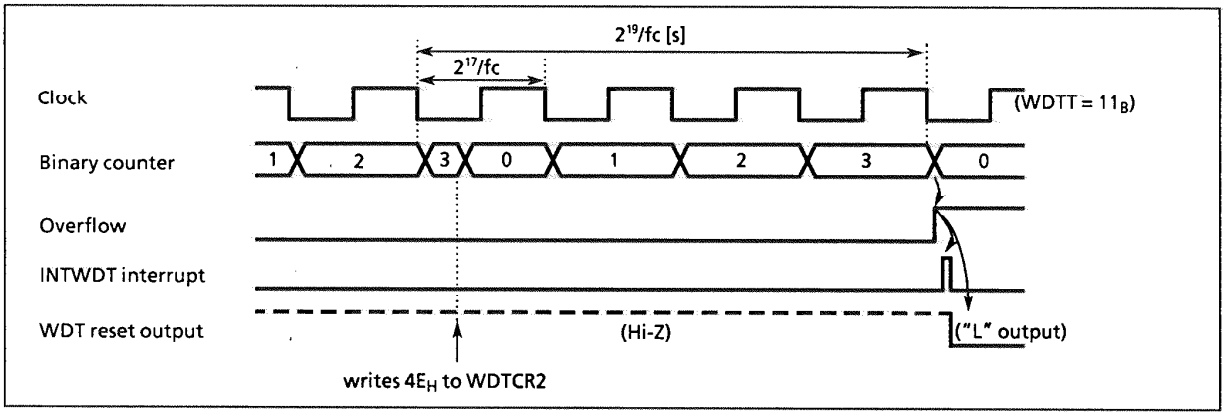


Figure 2.4.3 Watchdog Timer Interrupt / Reset

2.5 16-bit Timer / Counter 1 (TC1A)

2.5.1 Configuration

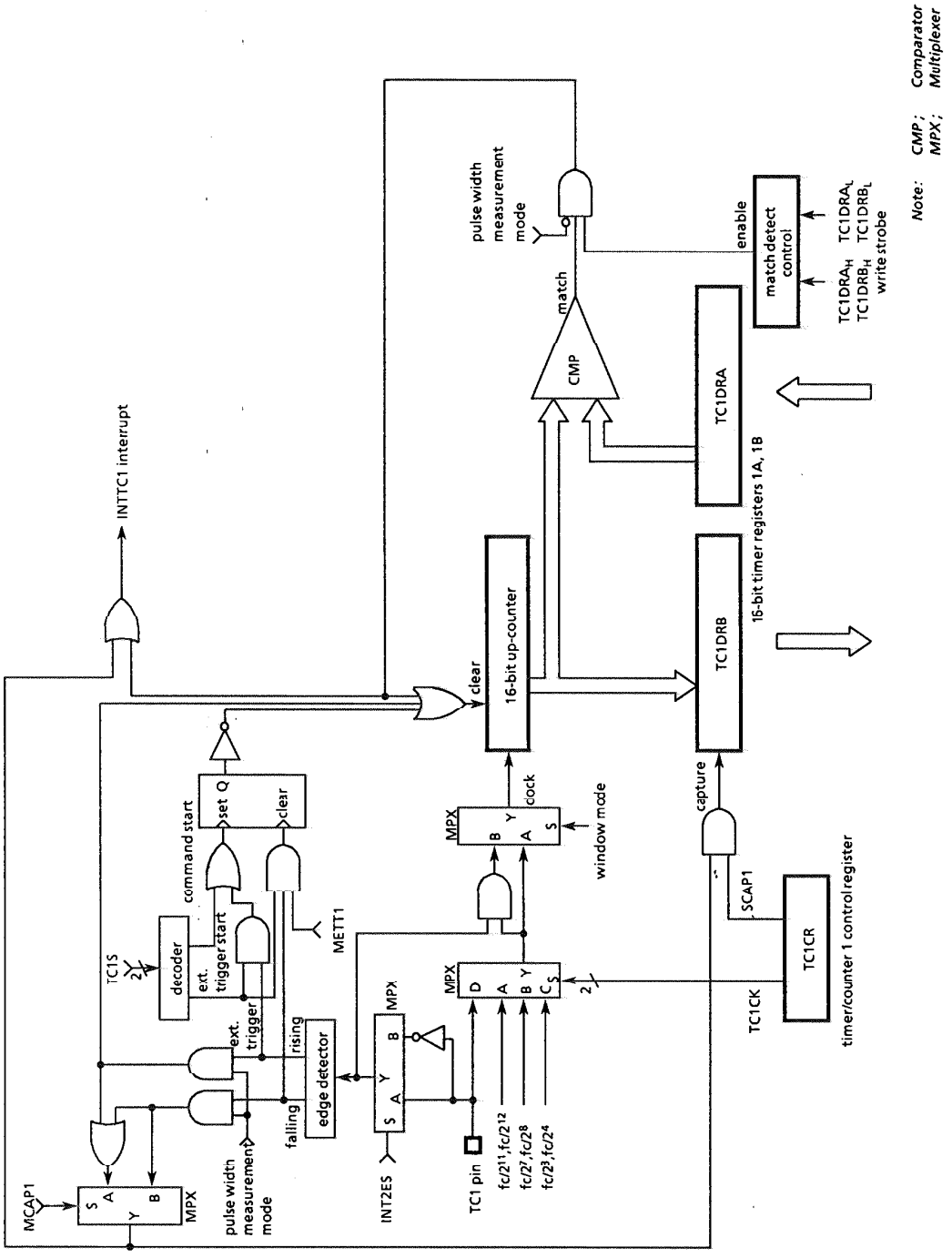


Figure 2.5.1 Timer/Counter 1

2.5.2 Control

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

TC1DRA (00010, 00011$_H$)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TC1DRA$_H$ (00011$_H$)								TC1DRA$_L$ (00010$_H$)							

Write only

TC1DRB (00012, 00013$_H$)

TC1DRB$_H$ (00013$_H$)								TC1DRB$_L$ (00012$_H$)							

Read only

TC1CR (00014$_H$)

7	6	5	4	3	2	1	0
"0"	ACPAP1 MCAP1 METT1	TC1S		TC1CK		TC1M	

(Initial value: 0000 0000)

TC1M	TC1 operating mode select	00: Timer / external trigger timer / event counter mode 01: Window mode 10: Pulse width measurement mode 11: reserved									R/W
TC1CK	TC1 source clock select [Hz]		NORMAL, IDLE mode								
			DV1CK = 0		DV1CK = 1						
		00	fc/2^{11}		fc/2^{12}						
		01	fc/2^{7}		fc/2^{8}						
		10	fc/2^{3}		fc/2^{4}						
		11	External clock (TC1 pin input)								
TC1S	TC1 start control	00: Stop & counter clear 01: Command start 10: External trigger start at the rising edge 11: External trigger start at the falling edge				Timer	Extend	Event	Window	Pulse	PPG
						○	○	○	○	○	○
						○	×	×	×	×	○
						×	○	○	○	○	○
						×	○	○	○	○	○
ACAP1	Auto capture control	0: Auto-capture disable		1: Auto-capture enable							
MCAP1	Pulse width measurement mode control	0: Double edge capture		1: Single edge capture							
METT1	External trigger timer mode control	0: Trigger start		1: Trigger start & stop							

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

Note 2: Writing to the lower byte of the timer registers (TC1DRA$_L$, TC1DRB$_L$), the comparison is inhibited until the upper byte (TC1DRA$_H$, TC1DRB$_H$) is written. Only the lower byte of the timer registers can not be changed. After writing to the upper byte, any match during 1 machine cycle (instruction execution cycle) is ignored.

Note 3: Set the mode, source clock when TC1 stops (TC1S – "00").

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

Note 5: Values to be loaded to timer registers must satisfy the following condition.
TC1DRA > "0" (others)

Note 6: Always write "0" to bit 7 in TC1CR.

Note 7: When STOP mode is started, timer counter is stopped and cleared. Set TC1S to "1" after STOP mode is released for restarting timer counter.

Figure 2.5.2 Timer registers and TC1 Control Register

2.5.3 Function

Timer / counter 1 has five operating modes: timer, external trigger timer, event counter, window, pulse width measurement.

(1) Timer mode

In this mode, counting up is performed using the internal clock. The contents of TC1DRA are compared with the contents of up-counter. If a match is found, an INTTC1 interrupt is generated, and the counter is cleared to "0". Counting up resumes after the counter is cleared. The current contents of up-counter can be transferred to TC1DRB by setting ACAP1 (bit 6 in TC1CR) to "1" (software capture function). (Auto-cpture function)

Table 2.5.1 Source Clock (internal clock) for Timer / Counter 1 (Example: at fc = 16.0 MHz)

TC1CK	NORMAL, IDLE mode			
	DV1CK = 0		DV1CK = 1	
	Resolution [μs]	Maximum time setting [s]	Resolution [μs]	Maximum time setting [s]
00	128.0	8.39	256.0	16.78
01	8.0	0.524	16.0	1.049
10	0.5	32.77 m	1.0	65.54 m

Example 1: Sets the timer mode with source clock $fc/2^{11}$ [Hz] and generates an interrupt 1 later (at fc = 16 MHz)

```
LDW  (TC1DRA), 1E84H  ;  Sets the timer register (1 s ÷ 2^11/fc = 1E84H)
SET  (EIRL). EF4      ;  Enable INTTC1
EI
LD (TC1CR), 00010000B ;  Starts TC1
```

Example 2: Auto-capture

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

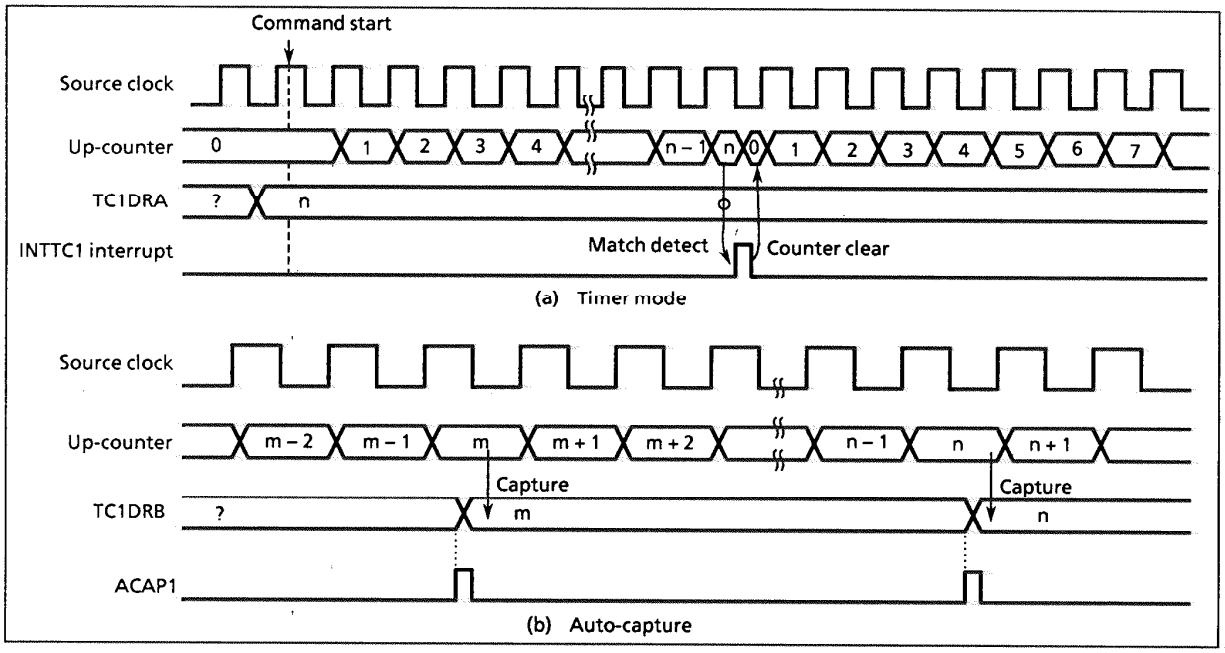


Figure 2.5.3 Timer Mode Timing Chart

(2) External trigger timer mode

In this mode, counting up is started by an external trigger. This trigger is the edge of the TC1 pin input. Either the rising or falling edge can be selected with TC1S. Source clock is an internal clock. The contents of TC1DRA is compared with the contents of up-counter. If a match is found, an INTTC1 interrupt is generated, and the counter is cleared to "0" and halted. The counter is restarted by the selected edge of the TC1 pin input.

When METT1 (bit 6 in TC1CR) is "1", inputting the edge to the reverse direction of the trigger edge to start counting clears the counter, and the counter is stopped. Inputting a constant pulse width can generate interrupts. When METT1 is "0", the reverse directive edge input is ignored. The TC1 pin input edge before a match detection is also ignored.

The TC1 pin input has the noise rejection; therefore, pulses of 7/fc [s] or less are rejected as noise. A pulse width of 24/fc [s] or more is required for edge detection in NORMAL or IDLE mode.

Example 1: Detects rising edge in TC1 pin input and generates an interrupt 100 μs later. (at fc = 16.0 MHz, DV1CK = 1)

```
LDW  (TC1DRA), 004EH     ;  100 μs ÷ 2^4/fc = 64H
SET  (EIRL). EF4         ;  INTTC1 interrupt enable
EI
LD   (TC1CR), 00101000B  ;  TC1 external trigger start, METT1 = 0
```

Example 2: Generates an interrupt, inputting "L" level pulse (pulse width: 4 ms or more) to the TC1 pin. (at fc = 16.0 MHz, DV1CK = 1)

```
LDW  (TC1DRA), 00FAH     ;  4 ms ÷ 2^8/fc = 00FAH
SET  (EIRL). EF4         ;  INTTC1 interrupt enable
EI
LD   (TC1CR), 01110100B  ;  TC1 external trigger start, METT1 = 1
```

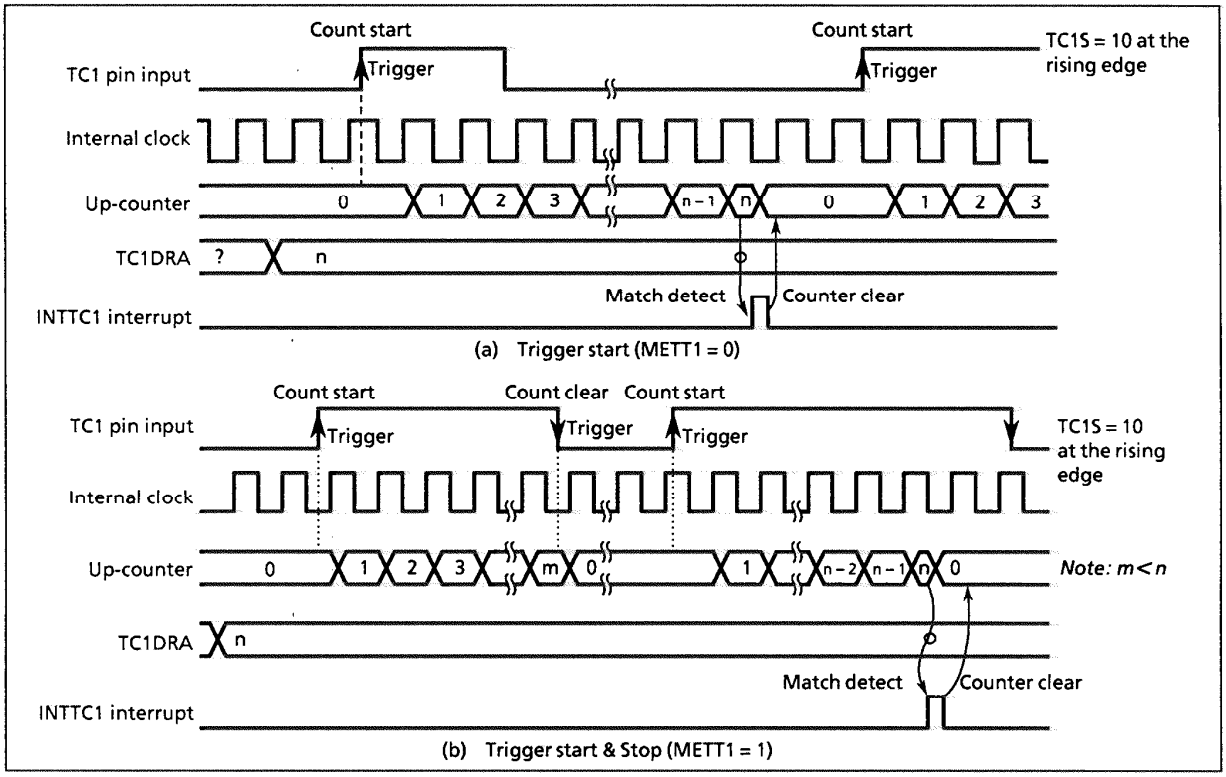


Figure 2.5.4 External Trigger Timer Mode Timing Chart

(3) Event counter mode

In this mode, events are counted at the edge of the TC1 pin input and bit 4 or 5 in TC1CR. Either the rising or falling edge can be selected with the external trigger. The contents of TC1DRA are compared with the contents of up-counter. If a match is found, an INTTC1 interrupt is generated, and the counter is cleared.

Match detect is executed on other edge of count-up. A match can not be detected and INTTC1 is not generated when the pulse is still in same state.

Setting ACAP1 to "1" transfers the current contents of up-counter to TC1DRB (Auto-capture function).

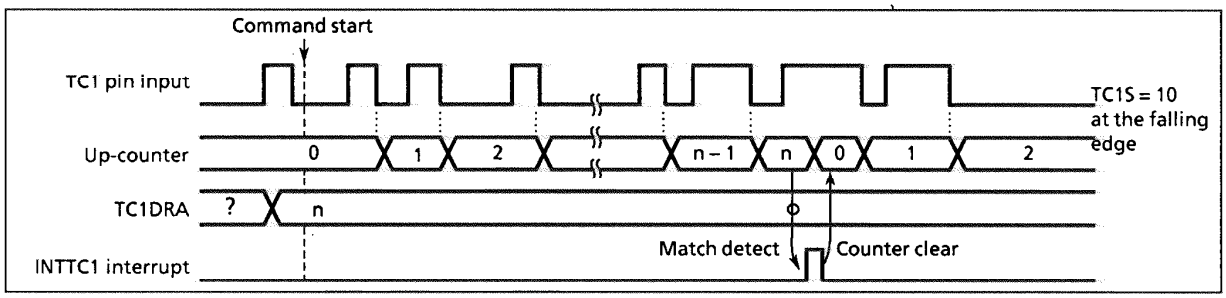


Figure 2.5.5 Event Counter Mode Timing Chart

(4) Window mode

Counting up is performed on the rising edge of the pulse that is the logical AND-ed product of the TC1 pin input (window pulse) and an internal clock. The contents of TC1DRA are compared with the contents of up-counter. If a match is found, an INTTC1 interrupt is generated, and the counter is cleared. Positive or negative logic for the TC1 pin input can be selected with bit4 or 5 in TC1CR.
It is necessary that the maximum applied frequency be such that the counter value can be analyzed by the program. That is ; the frequency must be considerably slower than the selected internal clock.

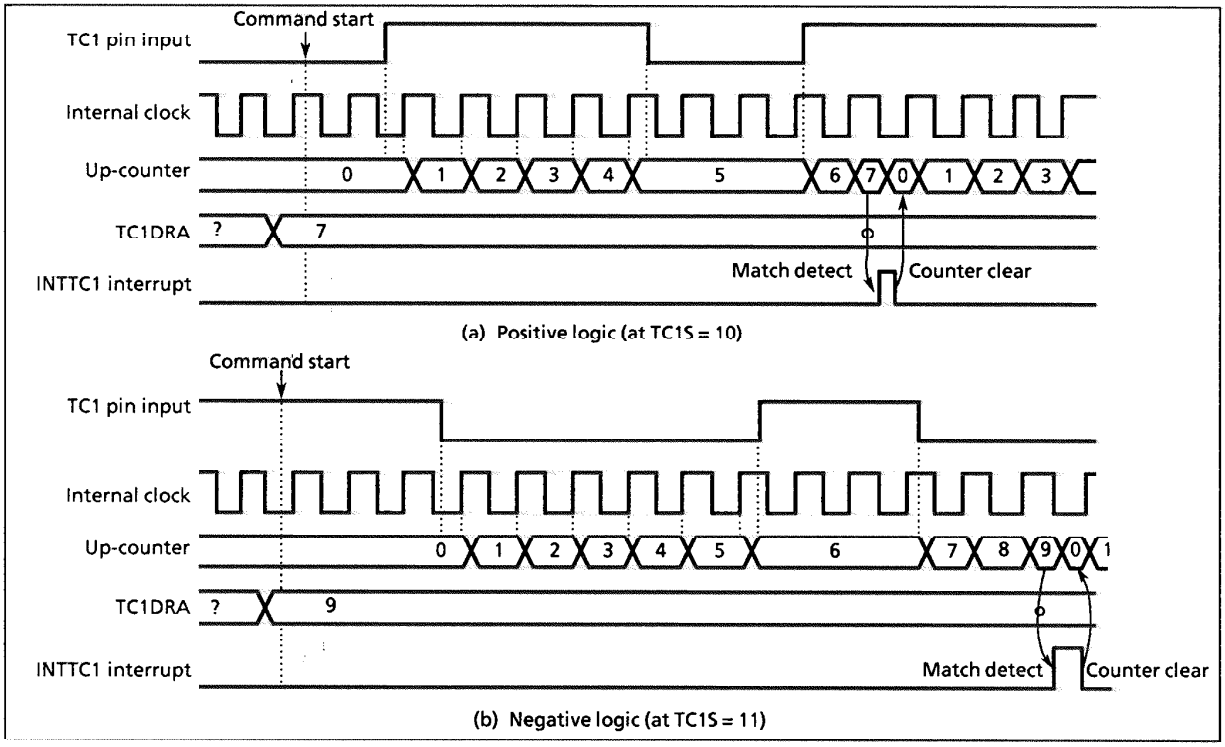


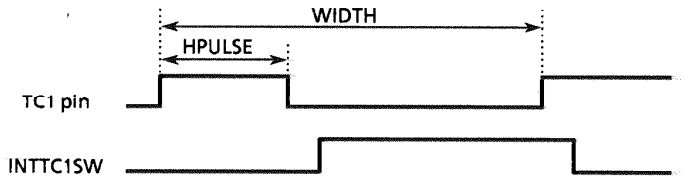
Figure 2.5.6 Window Mode Timing Chart

(5) Pulse width measurement mode

Counting is started by the external trigger (set to external trigger start by TC1CR). The trigger can be selected either the rising or falling edge of the TC1 pin input. the source clock is used an internal clock. On the next falling (rising) edge, the counter contents are transferred to TC1DRB and an INTTC1 interrupt is generated. The counter is cleared when the single edge capture mode is set. When double edge capture is set, the counter continues and, at the next rising (falling) edge, the counter contents are again transferred to TC1DRB. If a falling (rising) edge capture value is required, it is necessary to read out TC1DRB contents until a rising (falling) edge is detected. Falling or rising edge is selected with the external trigger (bit4 or 5 in TC1CR), and single edge or double edge is selected with MCAP1 (bit 6 in TC1CR).

Example: Duty measurement (resolution $fc/2^7$ [Hz] DV1CK = 0)

```
        CLR   (INTTC1SW). 0          ;  INTTC1 service switch initial setting
        LD (TC1CR), 00000110B        ;  Sets the TC1 mode and source clock
        SET   (EIRL). EF4            ;  Enables INTTC1
        EI
        LD (TC1CR), 00100110B        ;  Starts TC1 with an external trigger at MCAP1 = 0
        :
PINTTC1: CPL  (INTTC1SW). 0          ;  Complements INTTC1 service switch
        JRS   F, SINTTC1
        LD (HPULSE), (TC1DRBL)       ;  Reads TC1DRB ("H" level pulse width)
        LD (HPULSE + 1), (TC1DRBH)
        RETI
SINTTC1: LD (WIDTH), (TC1DRBL)       ;  Reads TC1DRB (Period)
        LD (WIDTH + 1), (TC1DRBH)
        :                            ;  Duty calculation
        RETI
        :
VINTTC1: DL PINTTC1
```



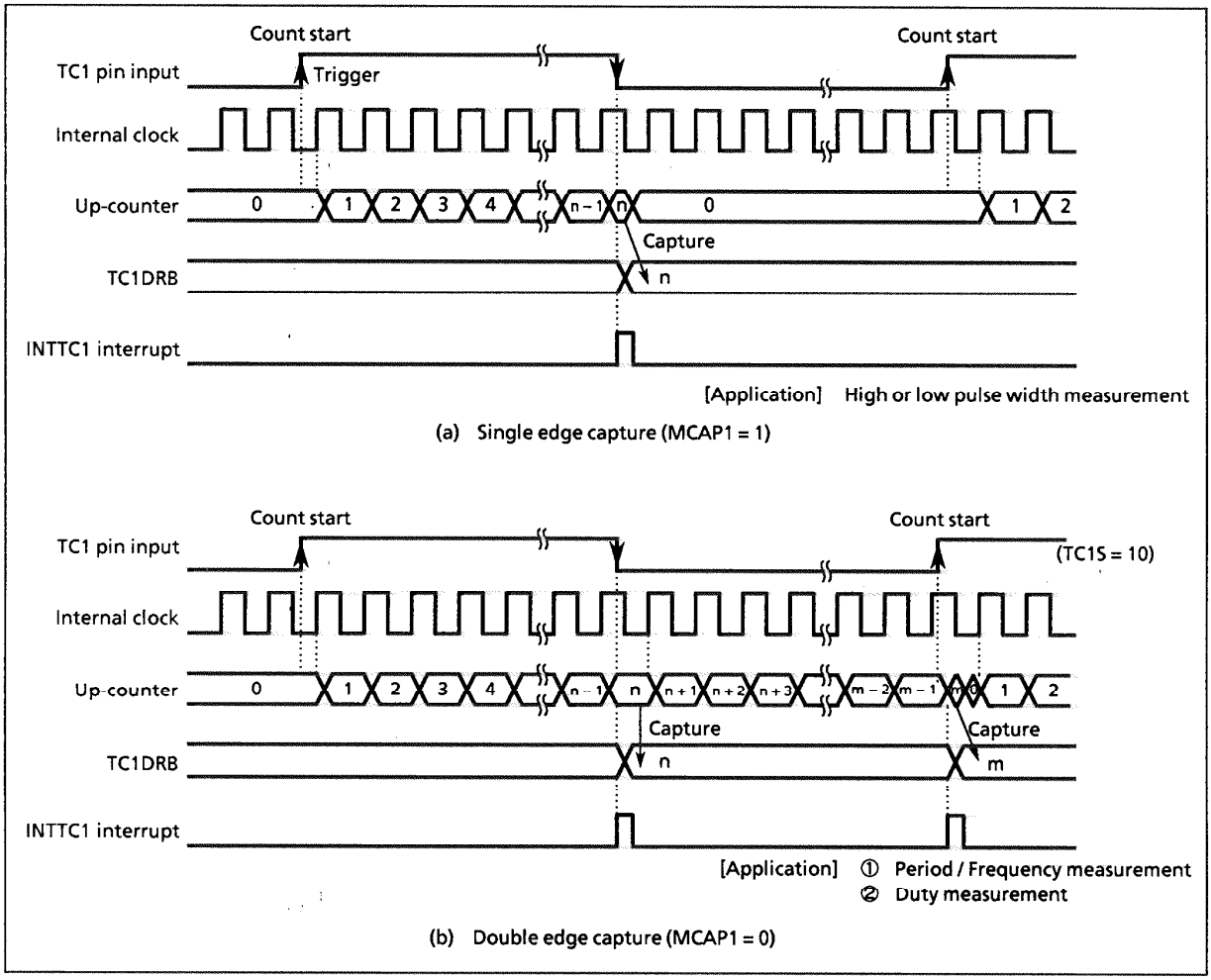


Figure 2.5.7 Pulse Measurement Mode Timing Chart

2.6 16-bit Timer / Counter 2 (TC2A)

2.6.1 Configuration

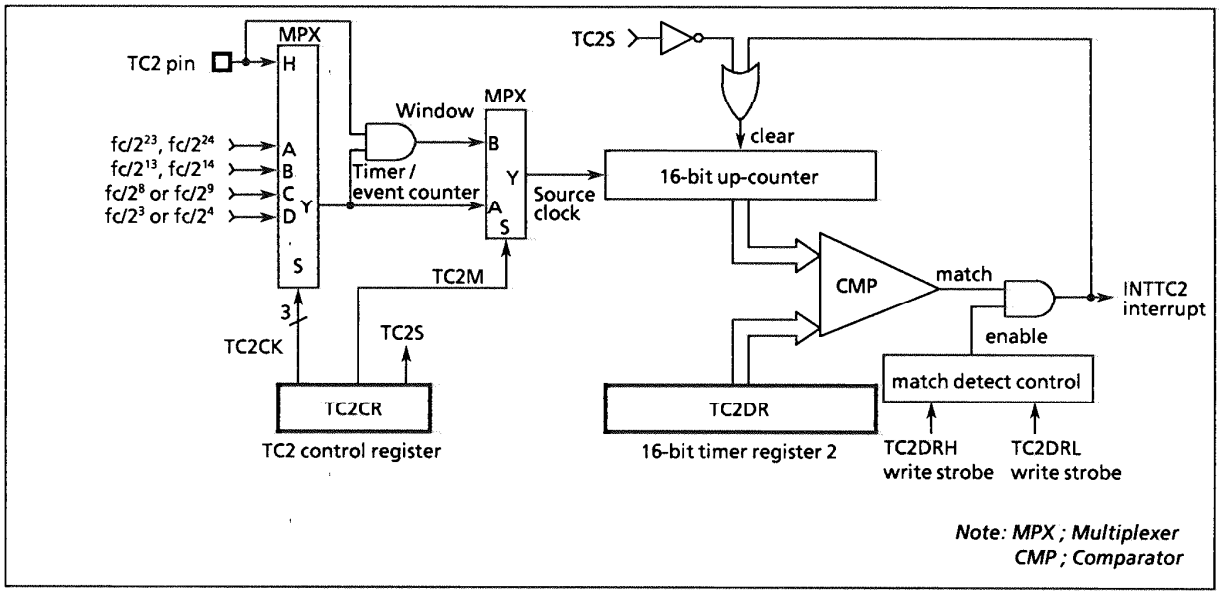


Figure 2.6.1 Timer / Counter 2 (TC2A)

2.6.2 Control

The timer / counter 2 is controlled by a timer / counter 2 control register (TC2CR) and a 16-bit timer register 2 (TC2DR). Reset does not affect TC2DR.

TC2DR (00016, 00017_H)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
$TC2DR_H$ (00017_H)								$TC2DR_L$ (00016_H)							

Write only

TC2CR (00015_H)

7	6	5	4	3	2	1	0
		TC2S	TC2CK				TC2M

(Initial value: **00 00*0)

TC2M	TC2 operating mode select	0: Timer / event counter mode 1: Windou mode			Write only
TC2CK	TC2 source clock select [Hz]		NORMAL, IDLE mode		
			DV1CK = 0	DV1CK = 1	
		000	$fc/2^{23}$	$fc/2^{24}$	
		001	$fc/2^{13}$	$fc/2^{14}$	
		010	$fc/2^{8}$	$fc/2^{9}$	
		011	$fc/2^{3}$	$fc/2^{4}$	
		100	reserved		
		101	reserved		
		110	reserved		
		111	External clock (TC2 pin input)		
TC2S	TC2 start control	0: Stop and counter clear 1: Start			

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

Note 2: Writing to the lower byte of timer register 2 ($TC2DR_L$), the comparison is inhibited until the upper byte ($TC2DR_H$) is written. After writing to the upper byte, any match during 1 machine cycle (instructon execution cycle) is ignored.

Note 3: Set the mode and source clock when the TC2 stops (TC2S = 0).

Note 4: Values to be loaded to the timer register must satisfy the following condition.
$TC2DR > 0$ ($TC2DR_{15\ to\ 11} > 0$ at warm-up)

Note 5: TC2CR are write-only registers and must not be used with any of the read-modify-write instructions.

Note 6: When STOP mode is started, timer counter is stopped and cleared. Set TC2S to "1" after STOP mode is released for restarting timer counter

Figure 2.6.2 Timer Register 2 and TC2 Control Register

2.6.3 Function

The timer / counter 2 has three operating modes: timer, event counter and window modes.

(1) Timer mode

In this mode, the internal clock is used for counting up. The contents of TC2DR are compared with the contents of up-counter. If a match is found, a timer / counter 2 interrupt (INTTC2) is generated, and the counter is cleared. Counting up is resumed after the counter is cleared.

Table 2.6.1 Source Clock (internal clock) for Timer / Counter 2 (at fc = 16.0 MHz)

TC2CK	NORMAL, IDLE mode			
	DV1CK = 0		DV1CK = 1	
	Resolution	Maximum time setting	Resolution	Maximum time setting
000	525 [ms]	9.55 [h]	1.05 [s]	19.1 [h]
001	510 [μs]	33.4 [s]	1.02 [ms]	1.1 [min]
010	16 [μs]	1.04 [s]	32.0 [μs]	2.1 [s]
011	0.5 [μs]	32.7 [ms]	1.0 [μs]	65.5 [ms]

Example: Sets the source clock $fc/2^3$ [Hz] and generates an interrupt event 25 ms (at fc = 16 MHz, DV1CK = 1)

```
LDW  (TC2DR), 61A8H    ;  Sets TC2DR
SET  (EIRH).EF14       ;  Enable INTTC2 interrupt
EI
LD   (TC2CR), 00101100B ;  Starts TC2
```

(2) Event counter mode

In this mode, events are counted on the rising edge of the TC2 pin input. The contents of TC2DR are compared with the contents of the up-counter. If a match is found, an INTTC2 interrupt is generated, and the counter is cleared. The maximum frequency applied to the TC2 pin is shown in Table 2.6.2. Two or more machine cycles are required for both the "H" and "L" levels of the pulse width. Match detect is executed on the falling edge of the TC2 pin. A match can not be detected and INTTC2 is not generated when the pulse is still in a falling state.

Example: Sets the event counter mode and generates an INTTC2 interrupt 640 counts later.

```
LDW  (TC2DR), 280H     ;  Sets TC2DR
SET  (EIRH). EF14      ;  Enables INTTC2 interrupt
EI
LD   (TC2CR), 00111100B ;  Starts TC2
```

Table 2.6.2 Timer / Counter 2 External Clock Source

Maximum applied frequency [Hz]
NORMAL, IDLE mode
$fc / 2^4$

(3) Window mode

In this mode, counting up performed on the rising edge of an internal clock during TC2 external pin input (window pulse) is "H" level. The contents of TC2DR are compared with the contents of up-counter. If a match found, an INTTC2 interrupt is generated, and the up-counter is cleared.
The maximum applied frequency (TC2 input) must be considerably slower than the selected internal clock.

Example: Generates an interrupt, inputting "H" level pulse width of 120 ms or more.
(at fc = 16.0 MHz, DV1CK = 1)

```
LDW  (TC2DR), 0075H      ;  Sets TC2DR (120 ms ÷ 2^14/fc = 0075H)
SET  (EIRH). EF14        ;  Enables INTTC2 interrupt
EI
LD   (TC2CR), 00100101B  ;  Starts TC2
```

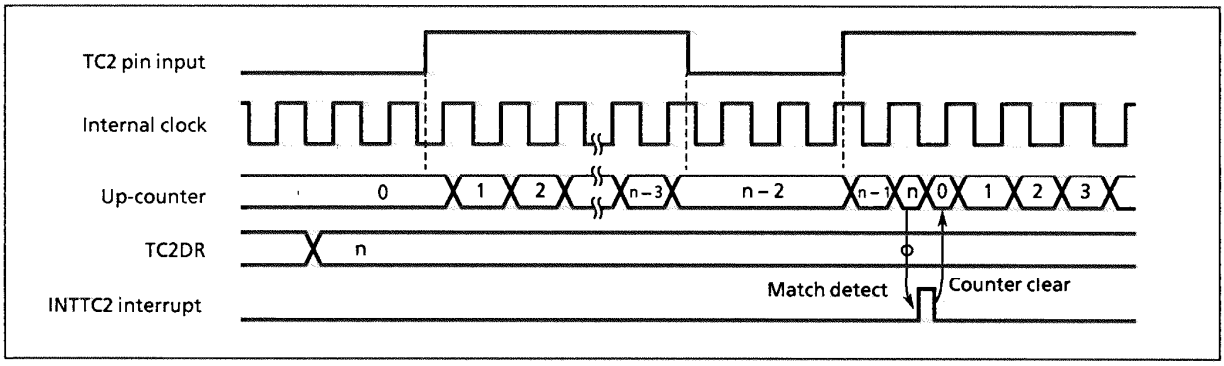


Figure 2.6.3 Window Mode Timing Chart

2.7 8-bit Timer / Counter 3 (TC3B)

2.7.1 Configuration

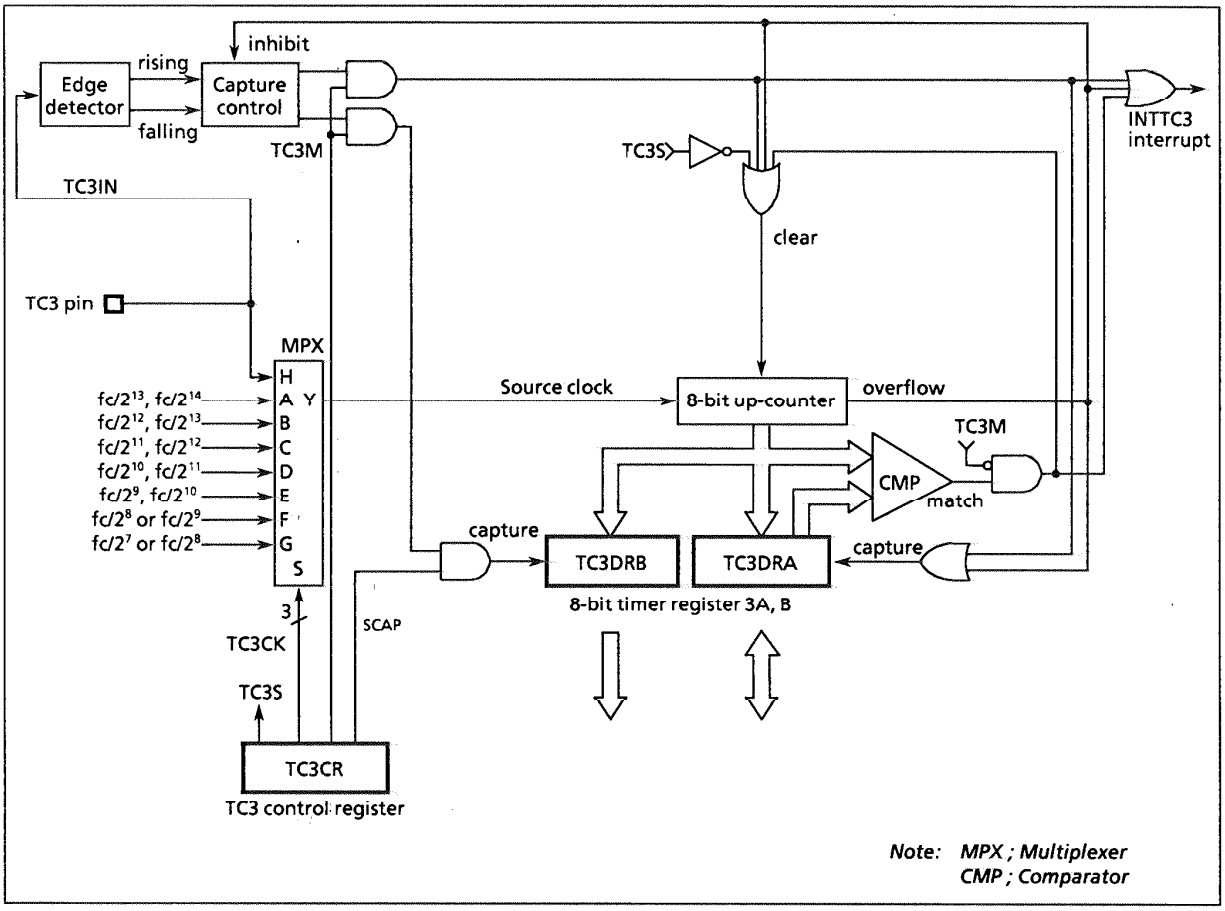


Figure 2.7.1 Timer / Counter 3 (TC3B)

2.7.2 Control

The timer / counter 3 is controlled by a timer / counter 3 control register (TC3CR) and two 8-bit timer registers (TC3DRA and TC3DRB) and port multiplex control register (PMPXCR).

TC3DRA (00018_H) — Read / Write

TC3DRB (00019_H) — Read only

TC3CR ($0001A_H$) — (Initial value: *0*0 0000)

TC3M	TC3 operation mode set	0: Timer / event counter 1: Capture	Write only
TC3CK	TC3 source clock select [Hz]	NORMAL, IDLE mode DV1CK = 0 / DV1CK = 1 000: $fc/2^{13}$ / $fc/2^{14}$ 001: $fc/2^{12}$ / $fc/2^{13}$ 010: $fc/2^{11}$ / $fc/2^{12}$ 011: $fc/2^{10}$ / $fc/2^{11}$ 100: $fc/2^{9}$ / $fc/2^{10}$ 101: $fc/2^{8}$ / $fc/2^{9}$ 110: $fc/2^{7}$ / $fc/2^{8}$ 111: External clock (TC3 pin input)	
TC3S	TC3 start select	0: Stop & clear 1: Start	
ACAP	Auto-capture control	0: Auto-capture disable 1: Auto-capture enable	

PMPXCR (00027_H) — (Initial value: 00** **00)

TC3ES	TC3 edge select	0: Rising edge 1: Falling edge	Write only

*Note 1: fc: High-frequency clock [Hz], * : Don't care*
Note 2: Set the mode and the source clock when the TC3 stops (TC3S = 0).
Note 3: Values to be loaded into timer register 3A must satisfy the following condition.
TC3DRA > 0 (in the timer and event counter mode)
Note 4: Auto-capture can be used only in the timer and event counter mode.
Note 5: TC3CR, TCESCR is a write-only register and must not be used with any of read-modify-write instructions.
Note 6: When STOP mode is started, timer counter is stopped and cleared. Set TC3S to "1" after STOP mode is released for restarting timer counter.
Note 7: Always write "0" to bit 7 in PMPXCR.

Figure 2.7.2 Timer Register 3 and TC3 Control Register

2.7.3 Function

The timer / counter 3 has three operating modes: timer, event counter, and capture mode.
When it is used in the capture mode, the noise rejection time of TC3 pin input can be set by remote control receive control register.

(1) Timer mode

In this mode, the internal clock is used for counting up. The contents of TC3DRA are compared with the contents of up-counter. If a match is found, a timer / counter 3 interrupt (INTTC3) is generated, and the up-counter is cleared. The current contents of up-counter are loaded into TC3DRB by setting ACAP (bit6 in TC3CR) to "1" (Auto-capture function).
The contents of up-counter can be easily confirmed by executing the read instruction (RD instruction) of TC3DRB. Loading the contents of up-counter is not synchronized with counting up. The contents of over flow (FF_H) and 00H can not be loaded correctly. It is necessary to consider the count cycle.

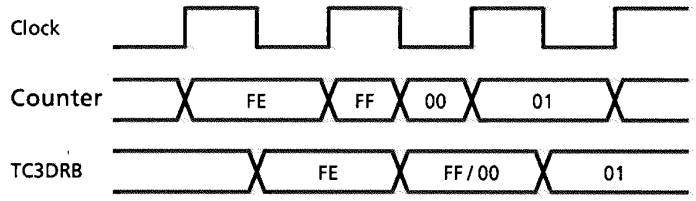


Table 2.7.1 Source Clock (internal clock) for Timer / Counter 3 (Example: at fc = 16.0 MHz)

TC3CK	NORMAL, IDLE mode			
	DV1CK = 0		DV1CK = 1	
	Resolution [μs]	Maximumsetting time[ms]	Resolution [μs]	Maximumsetting time[ms]
000	512	130.6	1024	261.1
001	256	65.3	512	130.6
010	128	32.6	256	65.3
011	64.0	16.3	128	32.6
100	32.0	8.2	64.0	16.3
101	16.0	4.1	32.0	8.2
110	8.0	2.0	16.0	4.1

(2) Event counter mode

In this mode, the TC3 pin input pulses are used for counting up Either the rising on falling edge can be selected with TC3ES (bit 0 in PMPXCR). The contents of TC3DRA are compared with the contents of the up-counter. If a match is found, an INTTC3 interrupt is generated and the counter is cleared. Match detect is executed on the falling edge of the TC3 pin. A match can not be detected, and INTTC3 is not generated when the pulse is still in a falling state.

The maximum applied frequency is shown in table 2.7.2. Two or more machine cycles are required for both the high and low levels of the pulse width.

The current contents of up-counter are loaded into TC3DRB by setting ACAP (bit 6 in TC3CR) to "1" (Auto-capture funcion).

The contents of up-counter can be easily confirmed by executing the read instruction (RD instruction) of TC3DRB. Loading the contents of up-counter is not synchronized with counting up. The contents of over flow (FFH) and 00H can not be loaded correctly. It is necessary to consider the count cycle.

Example: Generates an interrupt every 0.5 s, inputting 50 Hz pulses to the TC3 pin.

```
LD    (TC3CR), 00001110B   ;  Sets TC3 mode and source clock
LD    (TC3DRA), 19H        ;  0.5 s ÷ 1/50 = 25 = 19H
LD    (TC3CR), 00011100B   ;  Starts TC3
```

Table 2.7.2 Source Clock (External Clock) for Timer / Counter

Maximum applied frequency [Hz]
NORMAL, IDLE mode
$fc/2^4$

(3) Capture mode

The pulse width, period and duty of the TC3 pin input are measured in this mode, which can be used in decoding the remote control signals or distinguishing AC 50/60 Hz, etc. The counter is free running by the internal clock. On the rising (falling) edge of the TC3 pin input, the current contents of counter is loaded into TC3DRA, then the up-counter is cleared to "0" and an INTTC3 interrupt is generated. On the falling (rising) edge of the TC3 pin input, the current contents of the counter is loaded into TC3DRB. In this case, counting continues. On the next rising (falling) edge of the TC3 pin input, the current contents of counter are loaded into TC3DRA, then the counter is cleared again and an interrupt is generated. If the counter overflows before the edge is detected, FF_H is set into TC3DRA, and the counter is cleared and an INTTC3 interrupt is generated. During interrupt processing, it can be determined whether or not there is an overflow by checking whether or not the TC3DRA value is FF_H. Also, after an interrupt (capture to TC3DRA, or overflow detection) is generated, capture and overflow detection are halted until TC3DRA has been read out ; however, the counter continues. As reading out TC3DRA resumes capture / overflow detection, TC3DRB must be beforehand read out.

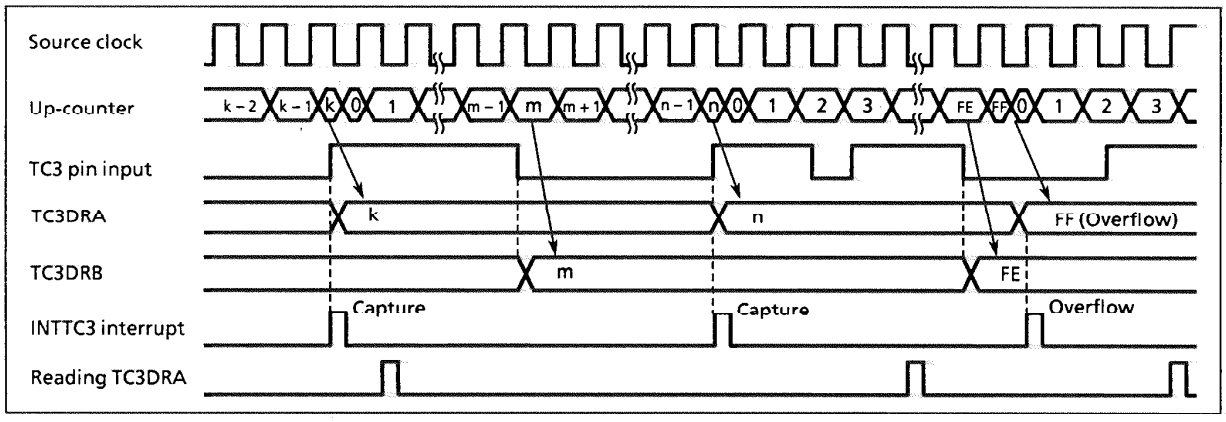


Figure 2.7.3 Capture Mode Timing Chart

The edge of TC3 pin input is detected in the remote control receive circuit with noize rejection. The remote control receive circuit is controlled by the remote control receive control register (RCCR). The romote control receive status register (RCSR) can monitor the porality selection and noize rejection circuit.

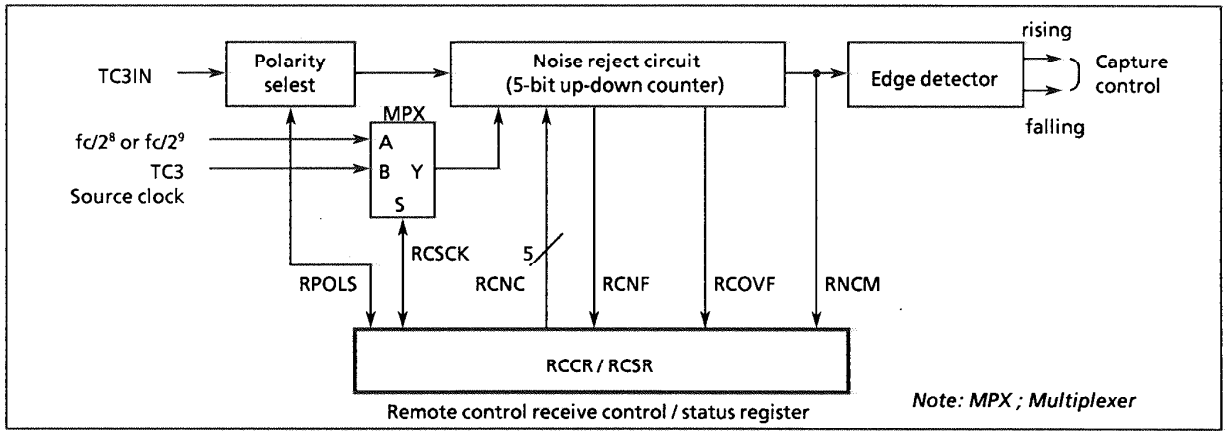


Figure 2.7.4 Remote Control Receiving Circuit

RCCR (00026H)

RCEN	RPOLS	RCSCK	RCNC	(Initial value: 0001 1111)

					Write / R/W
RCNC	Noise reject time select $02_H \leqq RCNC \leqq 1F_H$	(Source clock) × (RCNC−1) [s]			Write only
RCSCK	Noise reject circuit Source clock select		NORMAL, IDLE mode		R/W
			DV1CK = 0	DV1CK = 1	
		0	2^8/fc	2^9/fc	
		1	TC3CK Note2		
RPOLS	Remote control signal polarity select	0: Positive 1: Negative			R/W
RCEN	Remote control receive circuit operation control	0: Disable 1: Enable			Write only

Note 1: Set RPOLS and RCSCK when the timer / counter stops (TC3S = 0)
Note 2: Source clock of timer / counter 3
*Note 3: fc ; High-frequency clock [Hz], * ; Don't care*
Note 4: RCCR includes a write-only register and must not be used with any of read-modify-write instructions.
Note 5: Values to be loaded to RCNC must satisfy the following condition. 02≦ RCNC≦ 1F

RCSR (00026_H)

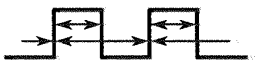
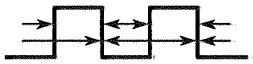
RCNF	RPOLS	RCSCK	RCOVF	RNCM				(Initial value: 0000 0***)

					Read / R/W
RNCM	Remote control signal monitor after noise rejecter	0: Low level 1: High level			Read only
RCOVF	Noise reject circuit Overflow flag	0: Signal and definition by overwriting the noise reject time RCNC 1: Other than above			Read only
RCSCK	Noise reject circuit Source clock select		NORMAL, IDLE mode		R/W
			DV1CK = 0	DV1CK = 1	
		00	2^8/fc	2^9/fc	
		11	TC3CK Note2		
RPOLS	Remote control signal polarity select	0: Positive 1: Negative			R/W
RCNF	Remote control signal monitor after noise rejecter	0: Without noise 1: With noise			Read only

Note 1: Reading out the register RCSR resets RCNF and RCOVF.
Note 2: Source clock of timer / counter 3
Note 3: When a 5-bit up-down counter counts down to "0" after counting up, the RCNF defines to be noise.
*Note 4: fc; High-frequency clock [Hz], * ; Don't care*

Figure 2.7.5 Remote Control Receive Control Register and Remote Control Receive Status Register

Table 2.7.3 Combination between The Porality and The Edge Selection

RPOLS	TC3 pin input pulse (Interrupt occurrence is shown as allow.)	Measuremont
0		
1		

Note: When TC3CK is used in RCSCK, do not select an external clock to the TC3CK.

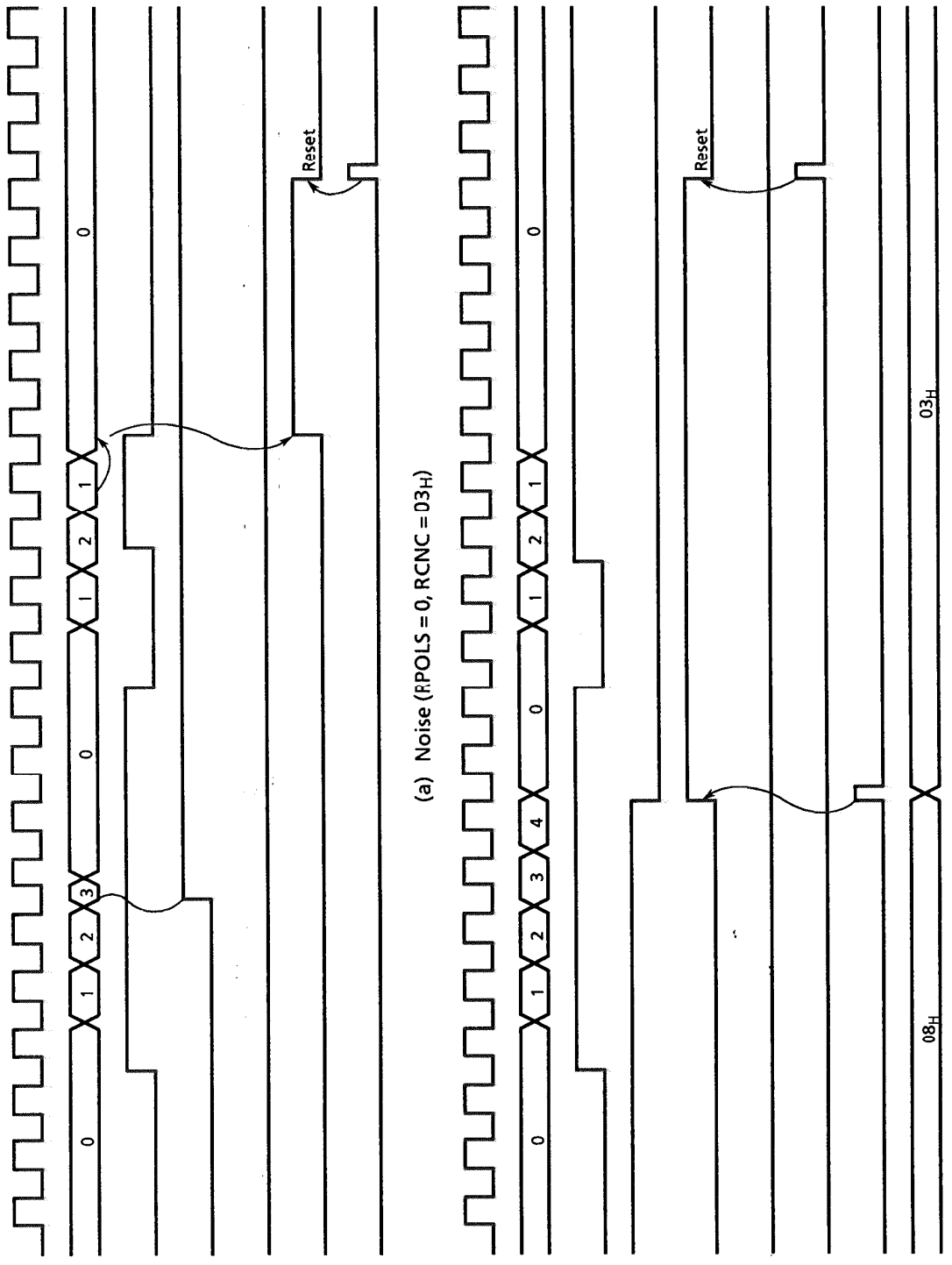


Figure 2.7.6 Remote Control Receive Circuit Timing Chart

2.8 8-bit Timer / Counter 4 (TC5A)

2.8.1 Configuration

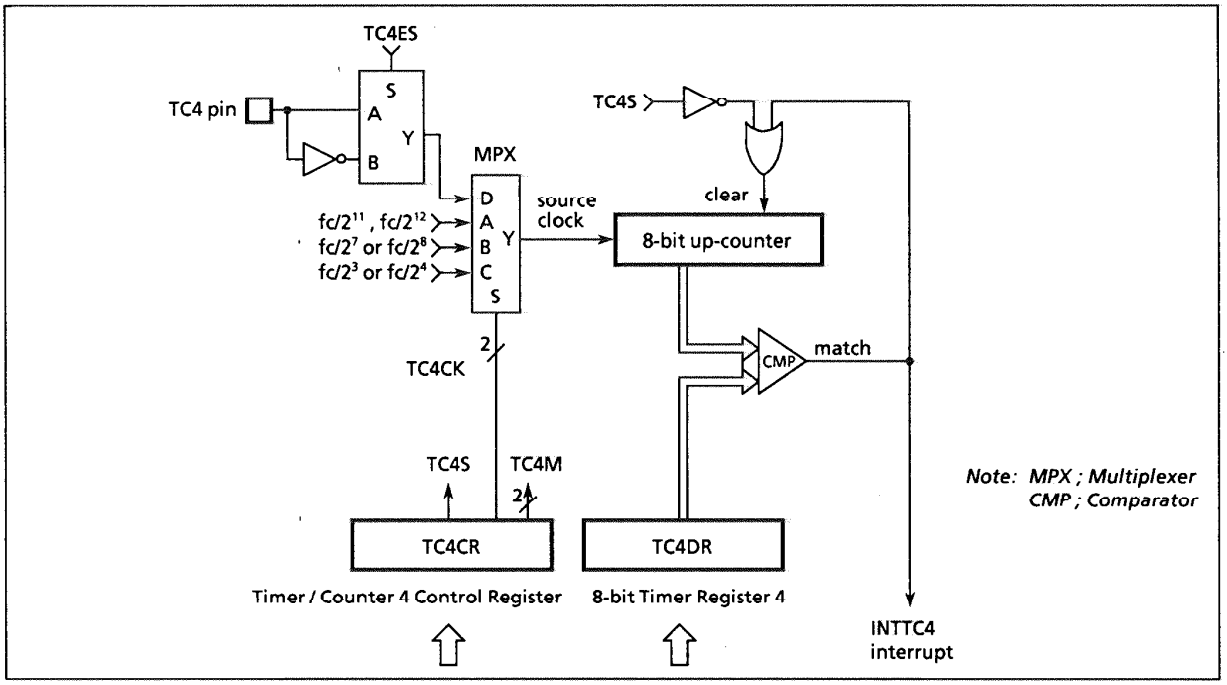


Figure 2.8.1 Timer / Counter 4 (TC5A)

2.8.2 Control

The timer / counter 4 is controlled by a timer / counter 4 control register (TC4CR) and an 8-bit timer register 4 (TC4DR). Reset does not affect TC4DR.

TC4DR ($0001B_H$)

7	6	5	4	3	2	1	0

Write only

TC4CR ($0001C_H$)

7	6	5	4	3	2	1	0
		TC4S	TC4CK			TC4M	

(Initial value: **00 0000)

TC4M	TC4 operating mode select	00: Timer / event counter mode 01: reserved 10: reserved 11: reserved			Write only
TC4CK	TC4 source clock select [Hz]		NORMAL, IDLE mode		
			DV1CK = 0	DV1CK = 1	
		000	$fc/2^{11}$	$fc/2^{12}$	
		001	$fc/2^{7}$	$fc/2^{8}$	
		010	$fc/2^{5}$	$fc/2^{6}$	
		011	$fc/2^{3}$	$fc/2^{4}$	
		100	reserved	reserved	
		101	reserved	reserved	
		110	reserved	reserved	
		111	External clock (TC4 pin input)		
TC4S	TC4 start control	0: Stop & counter clear 1: Start			

PMPXCR (00027_H)

7	6	5	4	3	2	1	0
"0"	CHS					TC4ES	(TC3ES)

(Initial value: 00** **00)

TC4ES	TC4 edge select	0: Rising edge 1: Falling edge	Write only

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

Note 2: Values to be loaded to the timer register must satisfy the following condition. 0<TC4DR

Note 3: Set the operating mode and the source clock selection when the TC4 stops (TC4ES ='0)

Note 4: Available source clocks for each operation mode is referred to the following table.

Note 5: TC4CR, TC4DR and the PMPXCR are write only register and must not be used with any of the read-modify-write instructions such as SET, CLR, etc.

Note 6: Always write "0" to bit 7 in PMPXCR.

Note 7: When STOP mode is started, timer counter is stopped and cleared. Set TC4S to "1" after STOP mode is released for restarting timer counter.

Figure 2.8.2 Timer Register 4 and TC4 Control Register

2.8.3 Function

The timer / counter 4 has two operating modes: timer, event counter mode.

(1) Timer mode

In this mode, the internal clock is used for counting up. The contents of TC4DR are compared with the contents of up-counter. If a match is found, an INTTC4 interrupt is generated and the up-counter is cleared to "0". Counting up resumes after the up-counter is cleared.

Table 2.8.1 Source Clock (internal clock) for Timer / Counter 4 (Example: at fc = 16.0 MHz)

TC4CK	NORMAL, IDLE mode			
	DV1CK = 0		DV1CK = 1	
	Resolution [μs]	Maximum setting time [s]	Resolution [μs]	Maximum setting time [s]
000	128	32.6 m	256	65.3 m
001	8.0	2.0 m	16.0	4.1 m
010	2.0	510 μ	4.0	1.0 m
100	0.5	127.5 μ	1.0	255 μ

(2) Event counter mode

In this mode, the TC4 pin input (external clock) pulse is used for counting up. Either the rising or falling edge can be selected with TC4ES (bit 1 PMPXCR). The contents of TC4DR are compared with the contents of the up-counter. If a match is found, an INTTC4 interrupt is generated and the counter is cleared. The maximum applied frequency is shown Table 2.8.2. Two or more machine cycles are required for both the high and low level of the pulse width.

Table 2.8.2 Timer / Counter 4 External Clock Source

Maximum applied frequency [Hz]
NORMAL, IDEL mode
$fc/2^4$

2.9 Serial Bus Interface (SBI-ver. D)

The TMP88CM38A/P38A have a 1-channel serial bus interface which employs a clocked-synchronous 8-bit serial bus interface and an I²C bus (a bus system by Philips).

The serial interface is connected to external devices through P35 (SDA0) / P52 (SDA1) and P34 (SCL0) / P51 (SCL1) in the I²C bus mode ; and through P53 ($\overline{SCK1}$), P52 (SO1) and P51 (SI1) in the clocked-synchronous 8-bit SIO mode.

The serial bus interface pins are also used for the P3 / P5 port. When used for serial bus interface pins, set the P3 / P5 output latches of these pins to "1". When not used as serial bus interface pins, the P3 / P5 port is used as a normal I/O port.

2.9.1 Configuration

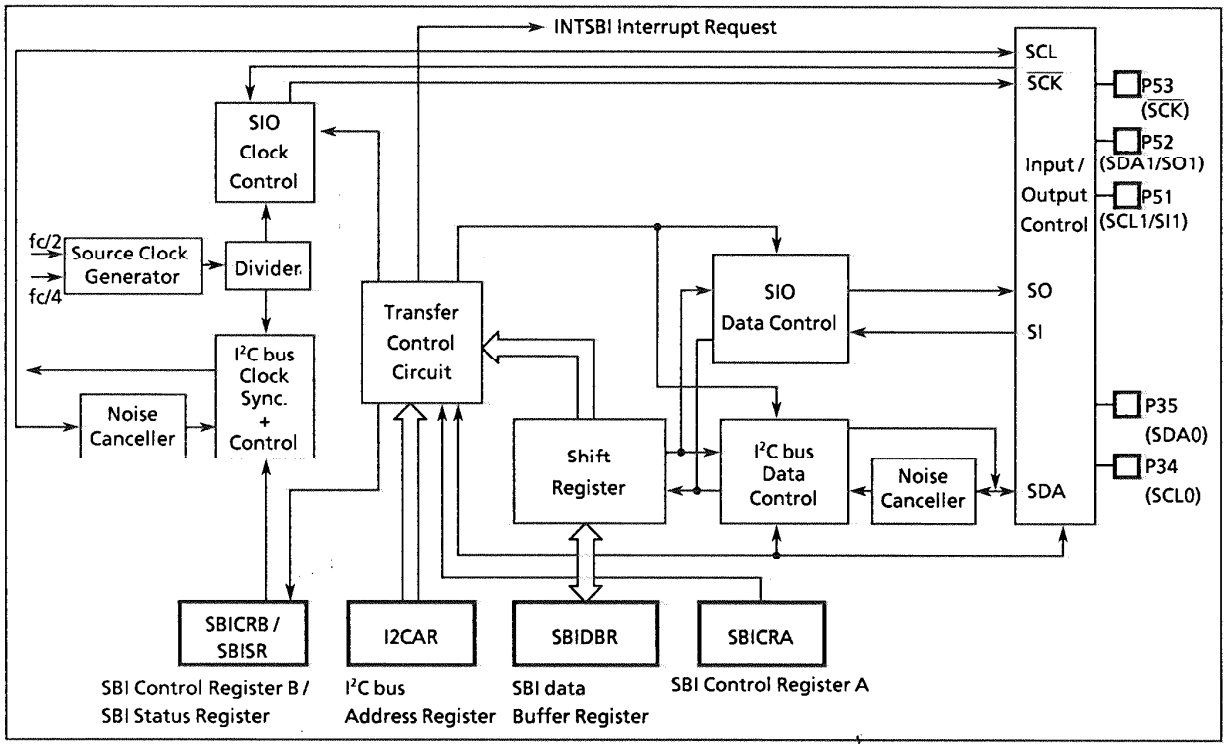


Figure 2.9.1 Serial Bus Interface (SBI)

2.9.2 Control

The following registers are used for control the serial bus interface and monitor the operation status.

- Serial bus interface control register A (SBICRA)
- Serial bus interface control register B (SBICRB)
- Serial bus interface data buffer register (SBIDBR)
- I²C bus address register (I²CAR)
- Serial bus interface status register A (SBISRA)
- Serial bus interface status register B (SBISRB)
- Serial clock source control register (SCCRB)
- Serial clock control status register (SCSR)

The above registers differ depending on a mode to be used. Refer to Section "2.9.7 I²C bus mode control" and "2.9.9 Clocked-synchronous 8-bit SIO mode control".

2.9.3 Serial Clock Source Control

A serial bus interface circuit can reduce the power consumption by stopping a serial clock generater.

Serial Clock Source Control Register

SCCRB ($00FF1_H$)

7	6	5	4	3	2	1	0
SCEN							

(Initial Value: 0*** ****)

SCEN	Serial clock source control	0: Do not generate source clock 1: Generate source clock	Write only

Note: When SCRQ and SCEN are "1", SCEN cannot be cleared to "0". When SCRQ is "0", SCEN is cleared to "0".

Serial Clock Control Status Register

SCSR ($00FF1_H$)

7	6	5	4	3	2	1	0
SCRQ							

(Initial Value: 0*** ****)

SCRQ	Serial clock source request	0: No source clock request from serial bus interface 1: Souce clock request from serial bus interface	Read only

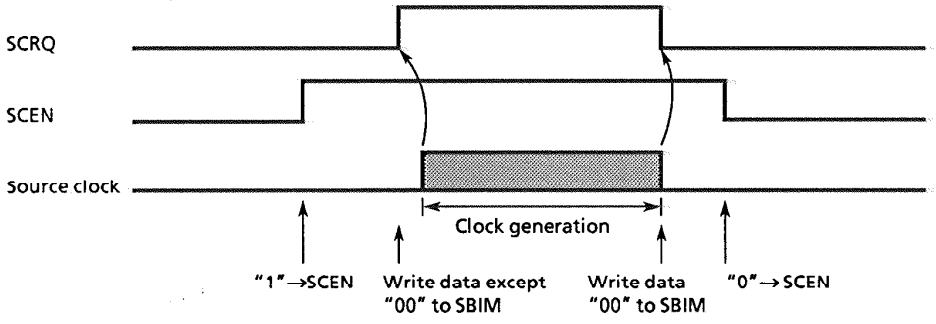


Figure 2.9.2 Serial Clock Souse

2.9.4 Channel Select

A serial bus interface circuit can select I/O pin when a serial bus interface is used for I²C bus mode.

Port Switching register

PMPXCR (00027H)

7	6	5	4	3	2	1	0
"0"	CHS					TC4ES	TC3ES

(Initial value: 00** **00)

CHS	I²C bus Channel Select	0: Channel 0 1: Channel 1	R/W

Note 1: When SIO mode, don't use channel 0. Therefore, set to "1" in PMPXCR at SIO mode.
Note 2: Always write "0" to bit 7 in PMPXCR.
*Note 3: * ; Don't care*

Figure 2.9.3 Channel Select

2.9.5 Software Reset

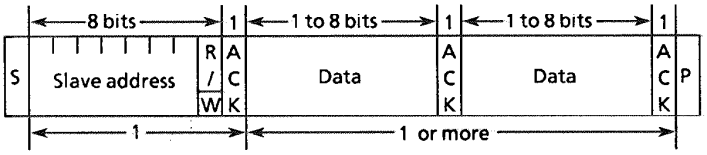
A serial bus interface circuit has a software reset function, when a serial bus interface circuit is locked by an external noise, etc.

To occur software reset, write "01", "10" into the SWRST (bit 1, 0 in SBICRB). During software reset, the SWRMON is clear to "0".

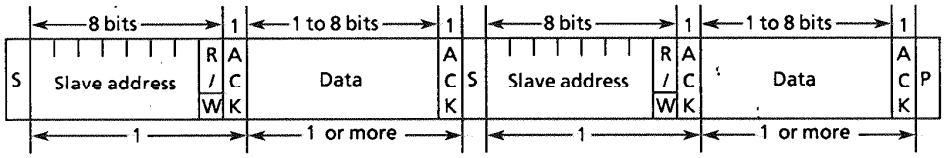
2.9.6 The Data Format in The I²C bus Mode

The data format when using the TMP88CM38A/P38A in the I²C bus mode are shown in as below.

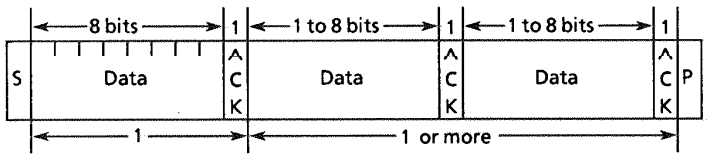
(a) Addrressing format



(b) Addrressing format (with restart)



(c) Free data format



Notes: S: Start condition
R/W: Direction bit
ACK: Acknowledge bit
P: Stop condition

Figure 2.9.4 Data Format in I²C bus Mode

2.9.7 I^2C bus Mode Control

The following registers are used to control the serial bus interface (SBI) and monitor the operation status in the I^2C bus mode.

Serial Bus Interface Control Register A

SBICRA (00020H)

7	6	5	4	3	2	1	0
BC			ACK		SCK		

(Initial value: 0000 *000)

		BC	ACK = 0		ACK = 1		
			Number of Clock	Bits	Number of Clock	Bits	
BC	Number of transferred bits	000	8	8	9	8	Write only
		001	1	1	2	1	
		010	2	2	3	2	
		011	3	3	4	3	
		100	4	4	5	4	
		101	5	5	6	5	
		110	6	6	7	6	
		111	7	7	8	7	
ACK	Acknowledgement mode specification	0: Do not generate a clock pulse for an acknowledgemet. (Master mode) / Do not count a clock pulse for an acknowledgement. (Slave mode) 1: Generate a clock pulse for an acknowledgement. (Master mode) / Count a clock pulse for an acknowledgement. (Slave mode)					R/W
SCK	Serial clock selection (At fc = 16 MHz, Output on SCL pin)	When DV1CK is "0"			When DV1CK is "1"		Write only
		000: 400.0 kHz 001: 222.2 kHz 010: 117.6 kHz 011: 60.6 kHz 100: 30.7 kHz 101: 15.5 kHz 110: 7.8 kHz 111: reserved			000: 200.0 kHz 001: 111.1 kHz 010: 58.8 kHz 011: 30.3 kHz 100: 15.4 kHz 101: 7.7 kHz 110: 3.9 kHz 111: reserved		

*Note 1: fc ; High-frequency clock [Hz], * ; Don't care*
Note 2: Set the BC to "000" before switching to 8-bit SIO mode.
Note 3: SBICRA cannot be used with any of read-modify-write instructions such as bit manipulation, etc.

Serial Bus Interface Data Buffer Register

SBIDBR (00021H)

7	6	5	4	3	2	1	0

(Initial Value: **** ****) R/W

Note 1: For writing transmitted data, start from the MSB (bit 7).
Note 2: The data which was written into SBIDBR can not be read, since a write data buffer and a read buffer are independent in SBIDBR. Therefore, SBIDBR cannot be used with any of read-modify-write instructions such as bit manipulation, etc.
Note 3: The data which was written into SBIDBR is cleared to "0" when INTSBI is generated.
*Note 4: * ; Don't care*

I^2C bus Address Register

I2CAR (00022H)

7	6	5	4	3	2	1	0
Slave address							ALS
SA6	SA5	SA4	SA3	SA2	SA1	SA0	

(Initial value: 0000 0000)

SA	TMP88CM38A/P38A slave address selection		Write only
ALS	Address recognition mode specification	0: Slave address recognition 1: Non slave address recognition	

Note: I^2CAR is a write-only register and cannot be used with any of read-modify-write instructions such as bit manipulation, etc.

Figure 2.9.5 Serial Bus Interface Control Register 1, Serial Bus Interface Data Buffer Register and I^2C bus Address Register In The I^2C bus Mode

Serial Bus Interface Control Register B

SBICRB (00023_H)

7	6	5	4	3	2	1	0
MST	TRX	BB	PIN	SBIM		SWRST1	SWRST0

(Initial value: 0001 0000)

MST	Master / Slave selection	0: Slave 1: Master	Write only
TRX	Transmitter / receiver selection	0: Receiver 1: Transmitter	
BB	Start / stop generation	0: Generate a stop condition when MST, TRX and PIN are "1". 1: Generate a start condition when MST, TRX and PIN are "1".	
PIN	Cancel interrupt service request	0: – 1: Cancel interrupt service request	
SBIM	Serial bus interface operating mode selection	00: Port mode (Serial bus interface output disable) 01: SIO mode 10: I^2C bus mode 11: Reserved	
SWRST1 SWRST0	Software reset start bit	Software reset starts by first writing "10" and next writing "01".	

*Note 1: * ; Don't care*

Note 2: Switch a mode to port after confirming that the bus is free.

Note 3: Switch a mode to I^2C bus mode or clock synchronous 8-bit SIO mode after confirming that the port is high-level.

Note 4: SBICRB is a write-only register and must not be used with any of read-modify-write instructions such as bit manipulation, etc.

Note 5: When the SWRST (bit 1, 0 in SBICRB) is written to "01", "10", software reset is occurred.
This time, control the serial bus interface and monitor the operation status registers except the SBIM (bit 3, 2 in SBICRB) and the CHS (bit 6 in PMPXCR) are reseted.
Control the serial bus interface and monitor the operation status registers are SBICRA, SBICRB, SBIDBR, I2CAR, SBISRA, SBISRB, SCCRA, SCCRB and SCSR.

Serial Bus Interface Status Register A

SBISRA (00020_H)

7	6	5	4	3	2	1	0
							SWR MON

(Initial Value: **** ***1)

SWRMON	Software reset monitor	0: During software reset 1: – (Initial)	Read only

Serial Bus Interface Status Register B

SBISRB (00023_H)

7	6	5	4	3	2	1	0
MST	TRX	BB	PIN	AL	AAS	AD0	LRB

(Initial Value: 0001 0000)

MST	Master / Slave selection status monitor	0: Slave 1: Master	Read only
TRX	Transmitter / Receiver selection status monitor	0: Receiver 1: Transmitter	
BB	Bus status monitor	0: Bus free 1: Bus busy	
PIN	Interrupt service requests status monitor	0: Requesting interrupt service 1: Releasing interrupt service request	
AL	Arbitration lost detection monitor	0: – 1: Arbitration lost detected	
AAS	Slave address match detection monitor	0: Do not detect slave address match or "GENERAL CALL" 1: Detect slave address match or "GENERAL CALL"	
AD0	"GENERAL CALL" detection monitor	0: Do not detect "GENERAL CALL" 1: Detect "GENERAL CALL"	
LRB	Last Received bit monitor	0: Last receive bit is "0" 1: Last receive bit is "1"	

Figure 2.9.6 Serial Bus Interface Control Register 2 and Serial Bus Interface Status Register A/B in the I^2C bus Mode

(1) Acknowledgement mode specification

Set the ACK (bit4 in SBICRA) to "1" for operation in acknowledgment mode. When a serial bus interface circuit is a master mode, an additional clock pulse is generated for an acknowledge signal. In a transmitter mode during this additional clock pulse cycle, the SDA pin is released in order to receive an acknowledge signal from the receiver. In the receiver mode during this additional clock pulse cycle, the SDA pin is set to low level generation an acknowledge signal.

Clear the ACK to "0" for operation in a non-acknowledgement mode. When a serial bus interface circuit is a master mode, a clock pulse for an acknowledge signal is not generated.

In an acknowledgement mode, when a serial bus interface circuit is a slave mode, a clock is counted for the acknowledge signal. During a clock for the acknowledge signal, when a received slave address matches to a slave address which is set to the I2CAR or a "GENERAL CALL" is received, the SDA pin is set to low level generating an acknowledge signal.

After a received slave address matches to a slave address which is set to the I^2CAR and a "GENERAL CALL" is received, in a transmitter mode during a clock for an acknowledge signal, the SDA pin is released in order to receive an acknowledge signal from a receiver. In a receiver mode, the SDA pin is set to low level generating an acknowledge signal.

In the non-acknowledgement mode, when a serial bus interface circuit is a slave mode, a clock for a acknowledge signal is not counted.

(2) Number of transfer bits

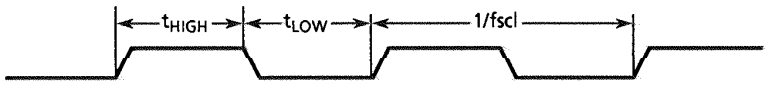
The BC (bits 7 to 5 in SBICRA) is used to select a number of bits for next transmitting and receiving data.

Since the BC is cleared to "000" as a start condition, a slave address and direction bit transmissions are always executed in 8 bits. Other than these, the BC retains a specified value.

(3) Serial clock

a. Clock source

The SCK (bits 2 to 0 in SBICRA) is used to select a maximum transfer frequency output from the SCL pin in the master mode.



$t_{LOW} = 2^n/fc$

$t_{HIGH} = 2^n/fc + 8/fc$

$fscl = 1/(t_{LOW} + t_{HIGH})$

SCK (bits 2 to 0 in the SBICR1)	n	
	When DV1CK is "0"	When DV1CK is "1"
000	4	5
001	5	6
010	6	7
011	7	8
100	8	9
101	9	10
110	10	11

Note: fc ; High-frequency clock

Figure 2.9.7 Clock Source

b. Clock synchronization

The I^2C bus has a clock synchronization function to meet the transfer speed to a slow processing device when a transfer is performed between the devices which have different process speed.

The example explains clock synchronization procedures when two masters simultaneously exist on a bus.

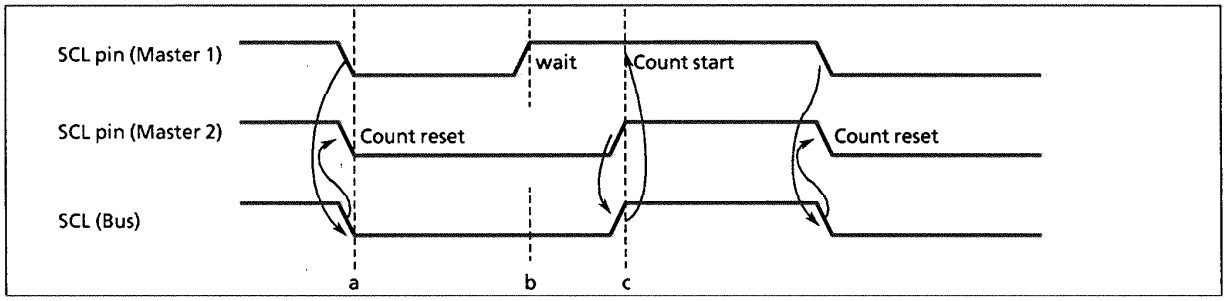


Figure 2.9.8 Clock Synchronization

As Master 1 pulls down the SCL pin to the low level at point "a", the SCL line of the bus becomes the low level. After detecting this situation, Master 2 resets counting a clock pulse in the high level and sets the SCL pin to the low level.
Master 1 finishes counting a clock pulse in the low level at point "b" and sets the SCL pin to the high level. Since Master 2 holds the SCL line of the bus at the low level, Master 1 waits for counting a clock pulse in the high level. After Master 2 sets a clock pulse to the high level at point "c" and detects the SCL line of the bus at the high level, Master 1 starts counting a clock pulse in the high level.
The clock pulse on the bus is deteminded by the master device with the shortest high-level period and the master device with the longest low-level period from among those master devices connected to the bus.

(4) Slave address and address recognition mode specification
When the serial bus interface circuit is used with an addressing format to recognize the slave address, clear the ALS (bit 0 in I2CAR) to "0", and set the SA (bits 7 to 1 in I2CAR) to the slave address.
When the serial bus interface circuit is used with a free data format not to recognize the slave address, set the ALS to "1". With a free data format, the slave address and the direction bit are not recognized, and they are processed as data from immediately after start condition.

(5) Master / slave selection
Set the MST (bit 7 in SBICRB) to "1" for operating a serial bus interface circuit as a master device.
Clear the MST for operation as a slave device. The MST is cleared to "0" by the hardware after a stop condition on the bus is detected or arbitration is lost.

(6) Transmitter / receiver selection
Set the TRX (bit 6 in SBICRB) to "1" for operating a serial bus interface circuit as a transmitter. Clear the TRX for operation as a receiver. When data with an addressing format is transferred in the slave mode, the TRX is set to "1" by a hardware if the direction bit (R/$\overline{W}$) sent from the master device is "1", and is cleared to "0" by a hardware if the bit is "0". In the master mode, after an acknowledge signal is returned from the slave device, the TRX is cleared to "0" by a hardware if a transmitted direction bit is "1", and is set to "1" by a hardware if it is "0". When an acknowledge signal is not returned, the current condition is maintained.
The TRX is cleared to "0" by the hardware after a stop condition on the bus is detected or arbitration is lost.
The following table shows TRX changing conditions in each mode and TRX value after changing.

Mode	Direction bit	Conditions	TRX after changing
Slave mode	"0"	A received slave address is the same	"0"
	"1"	value set to I2CAR	"1"
Master mode	"0"	ACK signal is returned	"1"
	"1"		"0"

When a serial bus interface circuit operates in the free data format, a slave address and a direction bit are not recognized. They are handled as data just after generating a start condition. The TRX is not changed by a hardware.

(7) Start / Stop condition generation

When the BB (bit 5 in SBICRB) is "0", a slave address and a direction bit which are set to the SBIDBR are output on a bus after generating a start condition by writing "1" to the MST, TRX, BB and PIN. It is necessary to set transmitted data to the data buffer register (SBIDBR) and set "1" to ACK beforehand.

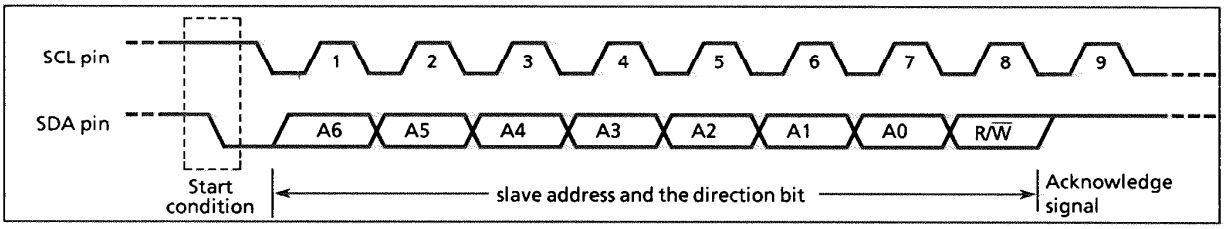


Figure 2.9.9 Start Condition Generation and Slave Address Generation

When the BB is "1", sequence of generating a stop condition is started by writeng "1" to the MST, TRX and PIN, and "0" to the BB. Do not modify the contents of MST, TRX, BB and PIN until a stop condition is generated on a bus.

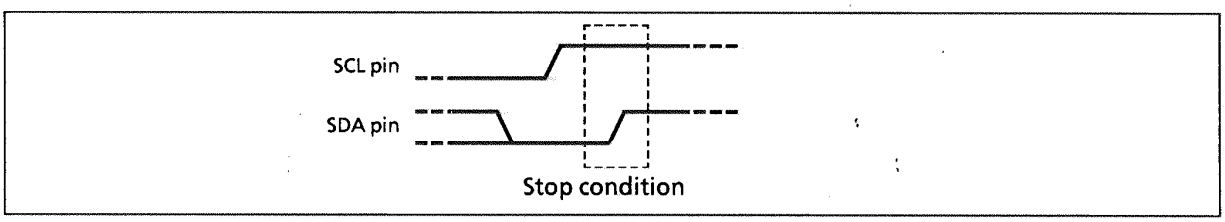


Figure 2.9.10 Stop Condition Generation

When a stop condition is generated and the SCL line on a bus is pulled-down to low level by another device, a stop condition is generated after releasing the SCL line.

The bus condition can be indicated by reading the contents of the BB (bit 5 in SBISRB). The BB is set to "1" when a start condition on a bus is detected and is cleared to "0" when a stop condition is detected.

(8) Interrupt service request and cancel

When a serial bus interface circuit is a master mode and transferring a number of clocks set by the BC and the ACK is complete, a serial bus interface interrupt request (INTSBI) is generated.

In a slave mode, the INTSBI is generated when the received slave address is the same as the value set to the I2CAR and an acknowledge signal is output, when a "GENERAL CALL" is received and an acknowledge signal is output, or when transferring or receiving data is complete after the received slave address is the same as the value set to the I2CAR and a "GENERAL CALL" is received.

When a serial bus interface interrupt request occurs, the PIN (bit 4 in SBISRB) is cleared to "0". During the time that the PIN is "0", the SCL pin is pulled-down to low level.

Either writing or reading data to or from the SBIDBR sets the PIN to "1".

The time from the PIN being set to "1" until the SCL pin is released takes t_{LOW}.

Although the PIN (bit 4 in SBICRB) can be set to "1" by the program, the PIN is not cleared to "0" when it is written "0".

(9) Serial bus interface operating mode selection

The SBIM (bit 3 and 2 in SBICRB) is used to specify a serial bus interface operation mode.

Set the SBIM to "10" in order to change a operation mode to I^2C bus mode. Before changing operation mode, confirm serial bus interface pins in a high level. And switch a mode to port after confirming that a bus is free.

(10) Arbitration lost detection monitor

Since more than one master device can exist simultaneously on a bus in the I^2C bus mode, a bus arbitration procedure is implemented in order to guarantee the contents of transferred data.

Data on the SDA line is used for bus arbitration of the I^2C bus.

The following shows an example of a bus arbitration procedure when two master devices exist simultaneously on a bus. Master 1 and Master 2 output the same data until point "a". After Master 1 outputs "1" and Master 2, "0", the SDA line of a bus is wired AND and the SDA line is pulled-down to the low level by Master 2. When the SCL line of a bus is pulled-up at point "b", the slave device reads data on the SDA line, that is data in Master 2. Data transmitted from Master 1 becomes invalid. The state in Master 1 is called "arbitration lost". A master device which loses arbitration releases the SDA pin and the SCL pin in order not to effect data transmitted from other masters with arbitration. When more than one master sends the same data at the first word, arbitration occurs continuously after the second word.

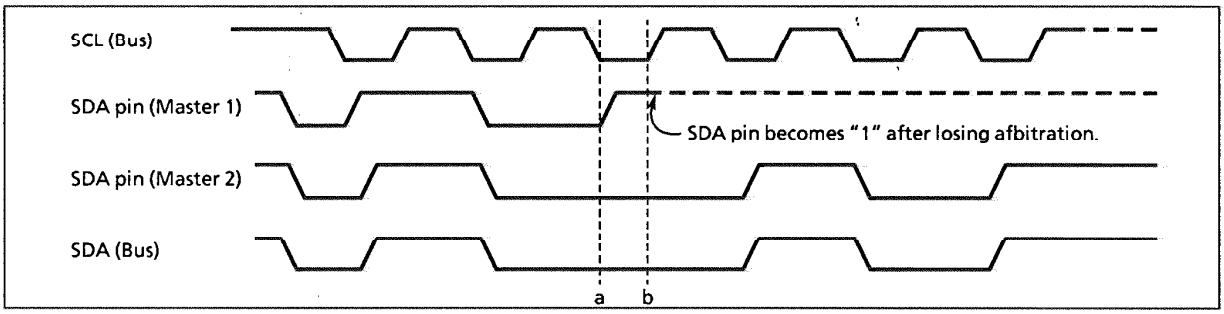


Figure 2.9.11 Arbitration Lost

The serial bus interface circuit compares levels of a SDA line of a bus with its those SDA pin at the rising edge of the SCL line. If the levels are unmatched, arbitration is lost and the AL (bit 3 in SBISRA) is set to "1".
When the AL is set to "1", the MST and TRX are cleared to "0" and the mode is switched to a slave receiver mode.
The AL is cleared to "0" by writing or reading data to or from the SBIDBR or writing data to the SBICRB.

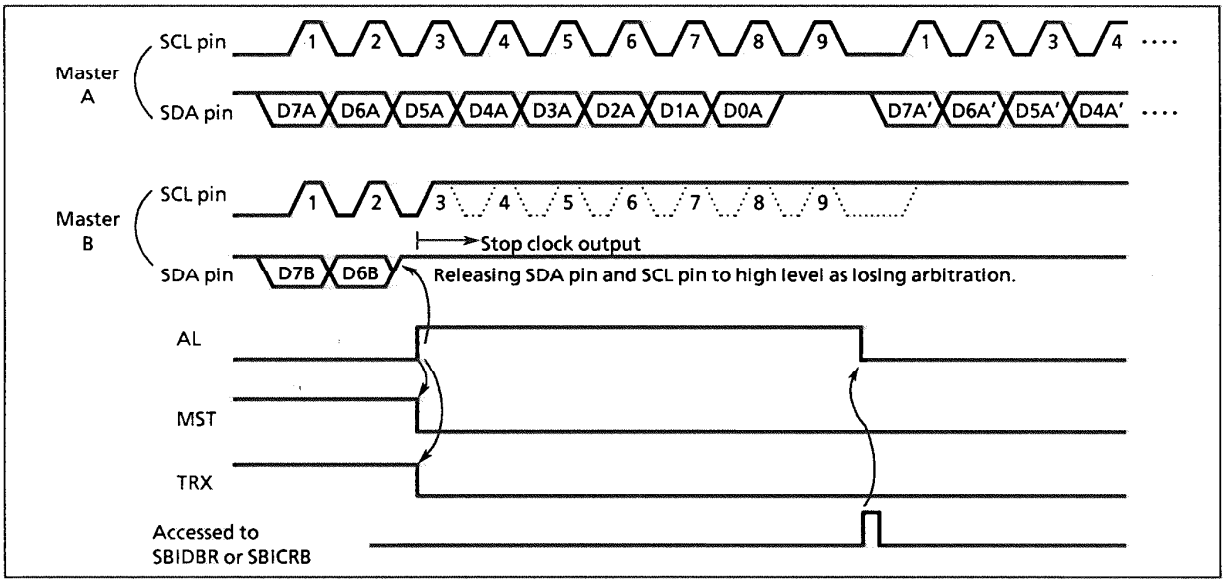


Figure 2.9.12 Example when a serial bus interface circuit is a Master B

(11) Slave address match detection monitor
The AAS (bit 2 in SBISRB) is set to "1" in a slave mode, in an address recognition mode (ALS = 0), when receiving "GENERAL CALL" or a slave address with the same value that is set to the I2CAR. When the ALS is "1", the AAS is set to "1" after receiving the first 1 word of data. The AAS is cleared to "0" by writing or reading data to or from a data buffer register.

(12) GENERAL CALL detection monitor
The AD0 (bit 1 in SBISR) is set to "1" in a slave mode, when all 8-bit received data is "0" immediately after a start condition. The AD0 is cleared to "0" when a start or stop condition is detected on a bus.

(13) Last received bit monitor
The SDA value stored at the rising edge of the SCL is set to the LRB (bit0 in SBISRB). In the acknowledge mode, immediately after an INTSBI interrupt request is generated, an acknowledge signal is read by reading the contents of the LRB.

2.9.8 Data Transfer in I^2C bus Mode

(1) Device Initialization

Set the ACK in SBICRA to "1", the BC to "000". Specify the data length to 8 bits to count clocks for an acknowledge signal. Set a transfer frequency to the SCK in SBICRA.

Next, set the slave address to the SA in I2CAR and clear the ALS to "0" to set an addressing format.

After confirming that the serial bus interface pin is high-level, for specifying the default setting to a slave receiver mode, clear "0" to the MST, TRX and BB in SBICRB, set "1" to the PIN, "10" to the SBIM, and "0" to bits 1 and 0.

Note: The initialization of a serial bus interface circuit must be complete within the time from all devices which are connected to a bus have initialized to and device does not generate a start condition. If not, there is a possibility that another device starts transferring before an end of the initialization of a serial bus interface circuit. Data cannot be received correctly.

(2) Start Condition and Slave Address Generation

Confirm a bus free status (when BB = 0).

Set the ACK to "1" and specify a slave address and a direction bit to be transmitted to the SBIDBR.

When the BB is "0", the start condition is generated and the slave address and the direction bit which are set to the SBIDBR are output on a bus by writing "1" to the MST, TRX, BB, and PIN. An INTSBI interrupt request occurs at the 9th falling edge of a SCL clock cycle, and the PIN is cleared to "0". The SCL pin is pulled-down to the low level while the PIN is "0". When an interrupt request occurs, the TRX changes by the hardware according to the direction bit only when an acknowledge signal is returned from the slave device.

Note 1: Do not write a slave address to be output to the SBIDBR while data is transferred. If data is written to the SBIDBR, data to been outputting may be destroyed.

Note 2: The bus free must be confirmed by software within 98.0 μs (the shortest transmitting time according to the I^2C bus standard) after setting of the slave address to be output. Only when the bus free is confirmed, set "1" to the MST, TRX, BB, and PIN to generate the start conditions. If the start conditions are generated without writing "1" to them, transferring may be executed by other masters between the time when the slave address to be output to the SBIDBR is written and the time when "1" is written to the MST, TRX, BB, and PIN in the SBICRB. Thus, the slave address may be corrupted.

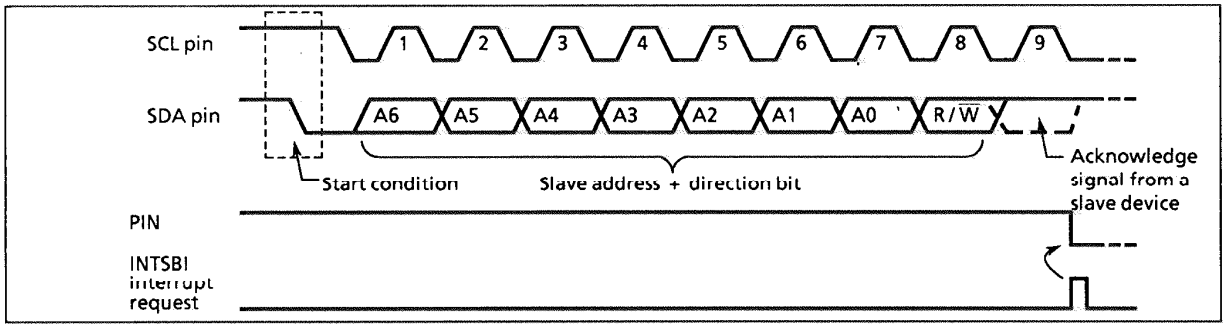


Figure 2.9.13 Start Condition Generation and Slave Address Transfer

(3) 1-word Data Transfer

Check the MST by the INTSBI interrupt process after an 1-word data transfer is completed, and determine whether the mode is a master or slave.

a. When the MST is "1" (Master mode)

Check the TRX and determine whether the mode is a transmitter or receiver.

① When the TRX is "1" (Transmitter mode)

Test the LRB. When the LRB is "1", a receiver does not request data. Implement the process to generate a stop condition (described later) and terminate data transfer.

When the LRB is "0", the receiver requests new data. When the next transmitted data is other than 8 bits, set the BC, set the ACK to "1", and write the transmitted data to the SBIDBR. After writing the data, the PIN becomes "1", a serial clock pulse is generated for transferring a new 1-word of data from the SCL pin, and then the 1-word data is transmitted. After the data is transmitted, and an INTSBI interrupt request occurs. The PIN become "0" and the SCL pin is set to low level. If the data to be transferred is more than one word in length, repeat the procedure from the LRB test above.

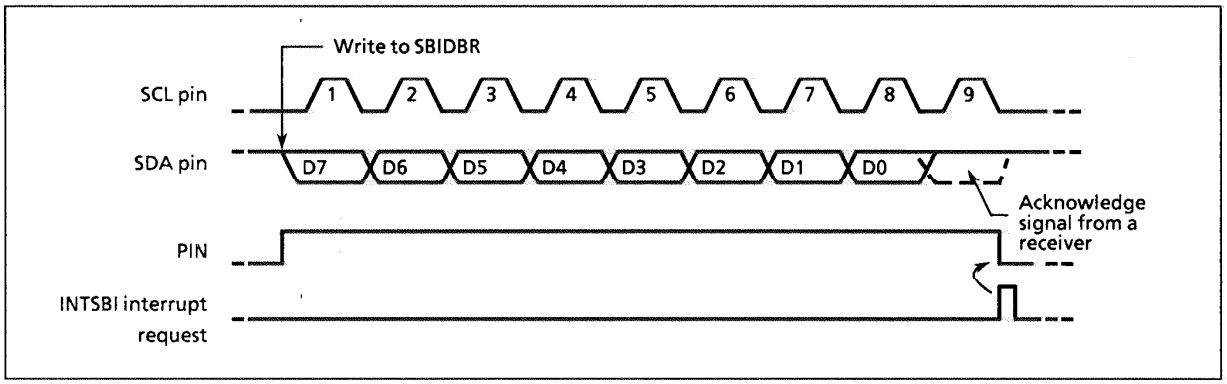


Figure 2.9.14 Example of when BC = "000", ACK = "1"

② When the TRX is "0" (Receiver mode)

When the next transmitted data is other than of 8 bits, set the BC again. Set the ACK to "1" and read the received data from the SBIDBR (reading data is undefined immediately after a slave address is sent). After the data is read, the PIN becomes "1". A serial bus interface circuit outputs a serial clock pulse to the SCL to transfer new 1-word of data and sets the SDA pin to "0" at the acknowledge signal timing.

An INTSBI interrupt request occurs and the PIN becomes "0". Then a serial bus interface circuit outputs a clock pulse for 1-word of data transfer and the acknowledge signal each time that received data is read from the SBIDBR.

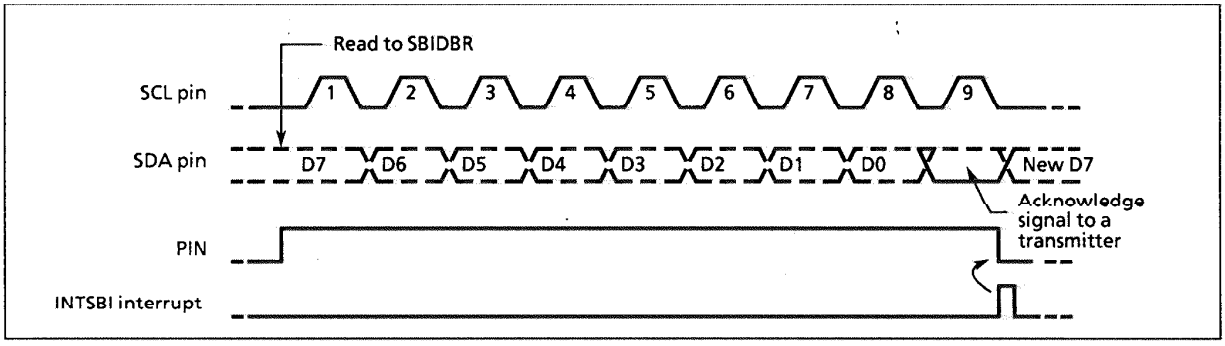


Figure 2.9.15 Example of when BC = "000", ACK = "1"

When a transmitter receives the negative-acknowledge signal, it must terminate transmitting data. Clear the ACK to "0" before reading data which is 1-word before the last data to be received. A serial bus interface circuit does not generate a clock pulse for the acknowledge signal. After the data transmitted and an interrupt request has occurred, set the BC to "001" and read the data. A serial bus interface circuit generates a clock pulse for a 1-bit data transfer. Since the master device is a receiver, the SDA line on a bus keeps the high-level. The transmitter receives the high-level signal as an ACK signal. The receiver indicates to the transmitter that data transfer is complete.
After 1-bit data is received and an interrupt request has occurred, a serial bus interface circuit generates a stop condition and terminates data transfer.

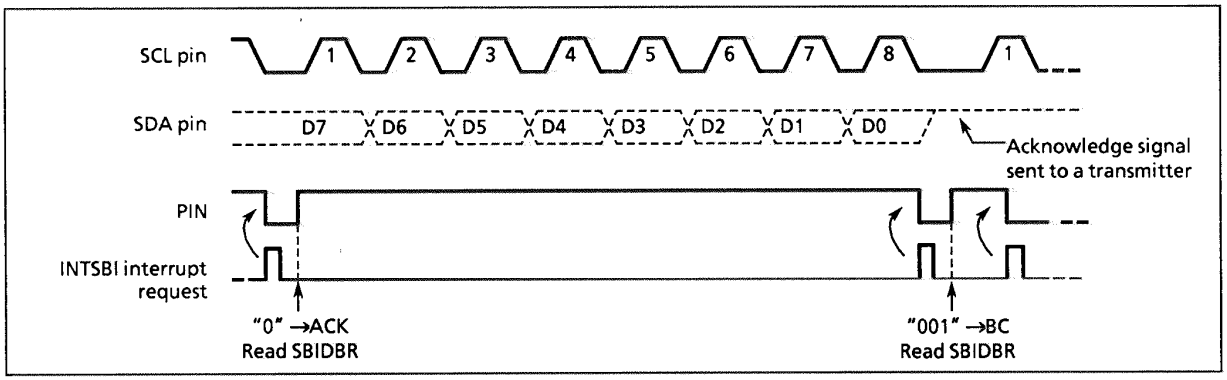


Figure 2.9.16 Termination of Data Transfer in Master Receiver Mode

b. When the MST is "0" (Slave mode)

In the slave mode, a serial bus interface circuit operates either in normal slave mode or in slave mode after losing arbitration.

In a slave mode, an INTSBI interrupt request occurs when a serial bus interface circuit receives a slave address or a "GENERAL CALL" from a master device, or when a "GENERAL CALL" is received and data transfer is complete after matching a received slave address. A serial bus interface circuit changes to a slave mode if it is losing arbitration in the master mode. And an INTSBI interrupt request occurs when word data transfer terminates after losing arbitration. When an INTSBI interrupt request occurs, the PIN (bit 4 in the SBICRB) is reset, and the SCL pin is pulled-down to the low-level. Either reading or writing from or to the SBIDBR or setting the PIN to "1", releases the SCL pin after taking t_{LOW} time.

Check the AL (bit 3 in the SBISRB), the TRX (bit 6 in the SBISRB), the AAS (bit 2 in the SBISRB), and the AD0 (bit 1 in the SBISRB) and implements processes according to conditions listed in the next table.

Table 2.9.1 Operation in The Slave Mode

TRX	AL	AAS	AD0	Conditions	Process
1	1	1	0	A serial bus interface circuit loses arbitration when transmitting a slave address and receives a slave address of which the value of the direction bit sent from another master is "1".	Set the number of bits in 1 word to the BC and write transmitted data to the SBIDBR.
	0	1	1	In the slave receiver mode, a serial bus interface circuit receives a slave address of which the value of the direction bit sent from the master is "1".	
		0	0	In the slave transmitter mode, 1-word data is transmitted.	Test the LRB. If the LRB is set to "1", set the PIN to "1" since the receiver does not request next data. Then, reset the TRX to release the bus. If the LRB is set to "0", set the number of bits in 1-word to the BC and write transmitted data to the SBIDBR since the receiver requests next data.
0	1	1	1/0	A serial bus interface circuit loses arbitration when transmitting a slave address and receives a slave address or a "GENERAL CALL" of which the value of the direction bit sent from another master is "0".	Read the SBIDBR for setting the PIN to "1" (reading dummy data) or write "1" to the PIIN.
		0	0	A serial bus interface circuit loses arbitration when transmitting a slave address or data and terminates transferring word data.	
	0	1	1/0	In the slave receiver mode, a serial bus interface circuit receives a slave address or "GENERAL CALL" of which the value of the direction bit sent from the master is "0".	
		0	1/0	In the slave receiver mode, a serial bus interface circuit terminates receiving of 1-word data.	Set the number of bits in 1-word to the BC and read received data from the SBIDBR.

(4) Stop Condition Generation

When the BB is "1", a sequence of generating a stop condition is started by setting "1" to the MST, TRX, and PIN, and clear "0" to the BB. Do not modify the contents of the MST, TRX, BB, PIN until a stop condition is generated on a bus.

When a SCL line on a bus is pulled-down by other devices, a serial bus interface circuit generates a stop condition after they release a SCL line.

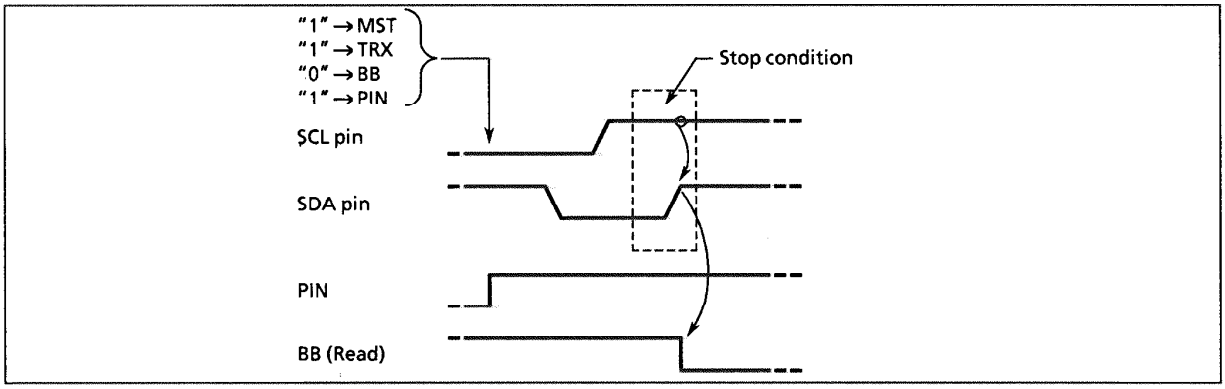


Figure 2.9.17 Stop Condition Generation

(5) Restart

Restart is used to change the direction of data transfer between a master device and a slave device during transferring data. The following explains how to restart a serial bus interface circuit.

Clear "0" to the MST, TRX and BB and set "1" to the PIN. The SDA pin retains the high-level and the SCL pin is released. Since a stop condition is not generated on a bus, a bus is assumed to be in a busy state from other devices. Test the BB until it becomes "0" to check that the SCL pin a serial bus interface circuit is released. Test the LRB until it becomes "1" to check that the SCL line on a bus is not pulled-down to the low-level by other devices. After confirming that a bus stays in a free state, generate a start condition with procedure (2).

In order to meet setup time when restarting, take at least 4.7 μs of waiting time by software from the time of restarting to confirm that a bus is free until the time to generate a start condition.

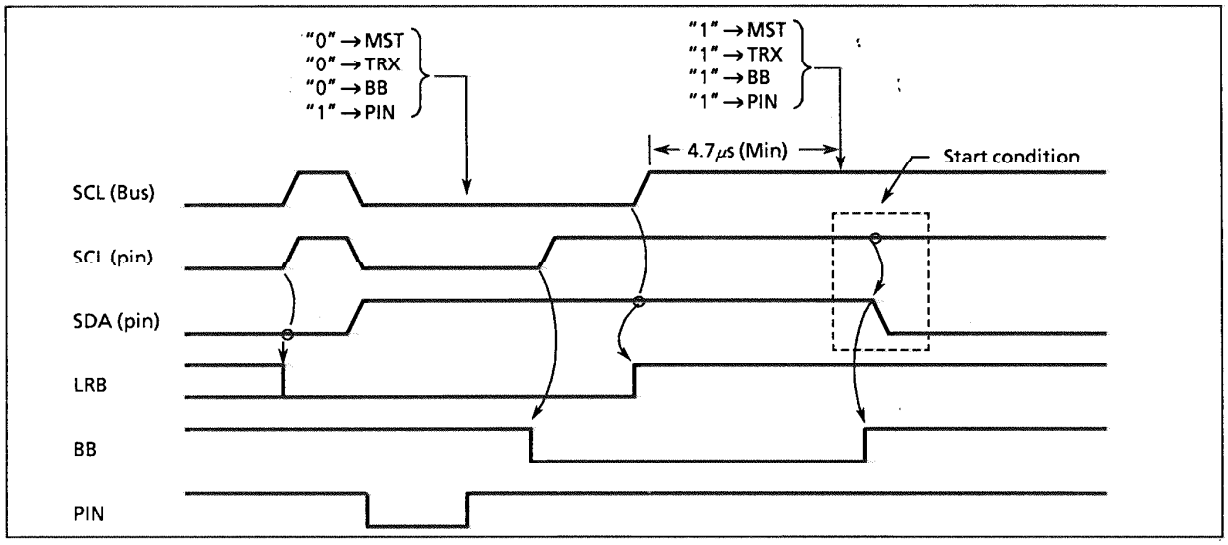


Figure 2.9.18 Timing Diagram when Restarting The TMP88CM38A/P38A

2.9.9 Clocked-synchronous 8-bit SIO Mode Control

The following registers are used to control the serial bus interface (SBI) and monitor the operation in the clocked-synchronous 8-bit SIO mode.

Serial Bus Interface Control Register A

SBICRA (00020_H)

7	6	5	4	3	2	1	0
SIOS	SIOINH	SIOM		"0"	SCK		

(Initial value: 0000 *000)

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	00: 8-bit transmit mode 01: reserved 10: 8-bit transmit / receive mode 11: 8-bit receive mode	
SCK	Serial clock selection (At fc = 16 MHz, Output on $\overline{SCK}$ pin)	When DV1CK is "0" 000: 1000.0 kHz 001: 500.0 kHz 010: 250.0 kHz 011: 125.0 kHz 100: 62.5 kHz 101: 31.2 kHz 110: 15.6 kHz 111: External clock (Input from $\overline{SCK}$ pin)	When DV1CK is "1" 000: 500.0 kHz 001: 250.0 kHz 010: 125.0 kHz 011: 62.5 kHz 100: 31.2 kHz 101: 15.6 kHz 110: 7.8 kHz 111: External clock (Input from $\overline{SCK}$ pin)	

*Note 1: fc ; High-frequency clock [Hz], * ; Don't care*
Note 2: Clear the SIOS to "0" and set the SIOINH to "1" when setting the transfer mode and serial clock.
Note 3: SBICRA is a write-only register and cannot be used with any of read-modify-write instructions such as bit manipulation, etc.
Note 4: When the SWRST (bit 1, 0 in SBICRB) is written to "01", "10", software reset is occurred.
This time, control the serial bus interface and monitor the operation status registers except the SBIM (bit 3, 2 in SBICRB) and the CHS (bit 6 in PMPXCR) are reseted.
Control the serial bus interface and monitor the operation status registers are SBICRA, SBICRB, SBIDBR, I2CAR, SBISRA, SBISRB, SCCRA, SCCRB and SCSR.

Serial Bus Interface Data Register

SBIDBR (00021_H)

7	6	5	4	3	2	1	0

(Initial Value: **** ****) R/W

Note 1: The data which was written into SBIDBR can not be read, since a write buffer and a read buffer are independent in SBIDBR. Therefore, SBIDBR cannot be used with any of read-modify-write instructions such as bit manipulation, etc.
*Note 2: * ; Don't care*

Serial Bus Interface Control Register B

SBICRB (00023_H)

7	6	5	4	3	2	1	0
"0"	"0"	"0"	"1"	SBIM		SWRST1	SWRST0

(Initial value: **** 0000)

SBIM	Serial bus interface operation mode selection	00: Port mode (serial bus interface output disable) 01: SIO mode 10: I²C bus mode 11: reserved	Write only
SWRST1 SWRST0	Software reset start bit	Software reset starts by first writing "10" and next writing "01".	

*Note 1: * ; Don't care*
Note 2: Switch a mode to port after data transfer is complete.
Note 3: Switch a mode to I²C bus mode or clock synchronous 8-bit SIO mode after confirming that the port is high-level.
Note 4: SBICRB is a write-only register and cannot be used with any of read-modify-write instructions such as bit manipulation, etc.
Note 5: Clear bit 7 to 5 in SBICR2 to "0", and set bit 4 to "1".

Figure 2.9.19 Control Register / Data Buffer Register / Status Register in SIO Mode (1)

Serial Bus Interface Status Register A

SBISRA (00020_H)

7	6	5	4	3	2	1	0
							SWR MON

(Initial Value: **** ***1)

SWRMON	Software reset monitor	0: During software reset 1: – (Initial)	Read only

Serial Bus Interface Status Register B

SBISRB (00023_H)

7	6	5	4	3	2	1	0
"1"	"1"	"1"	"1"	SIOF	SEF	"1"	"1"

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 2.9.20 Control Register / Data Buffer Register / Status Register in SIO Mode (2)

(1) Serial clock

a. Clock source

The SCK (bits 2 to 0 in SBICR1) is used to select the following functions.

① Internal clock

In an internal clock mode, any of seven frequencies can be selected. The serial clock is output to the outside on the $\overline{SCK}$ pin. The $\overline{SCK}$ pin becomes a high-level when data transfer starts. When writing (in the transmit mode) or reading (in the receive mode) data cannot follow the serial clock rate, an automatic-wait function is executed to stop the serial clock automatically and hold the next shift operation until reading or writing is complete.

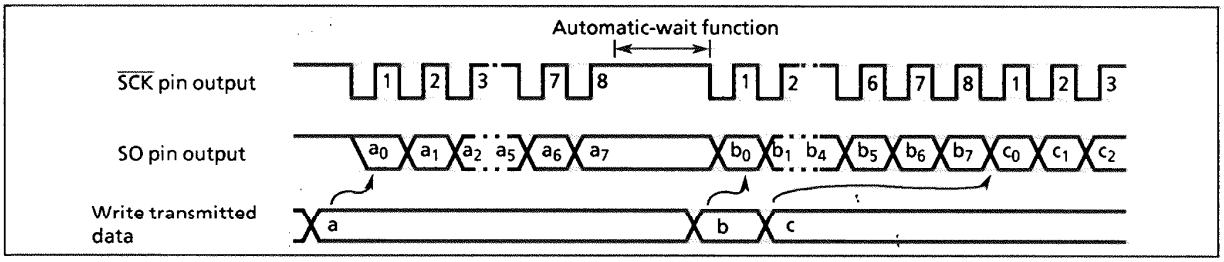


Figure 2.9.21 Automatic Wait Function

② External (SCK = "111")

An external clock supplied to the $\overline{SCK}$ pin is used as the serial clock. In order to ensure shift operation, a pulse width of at least 2 machine cycles is required for both high and low levels in the serial clock. The maximum data transfer frequency is 1 MHz (fc = 16.0 MHz).

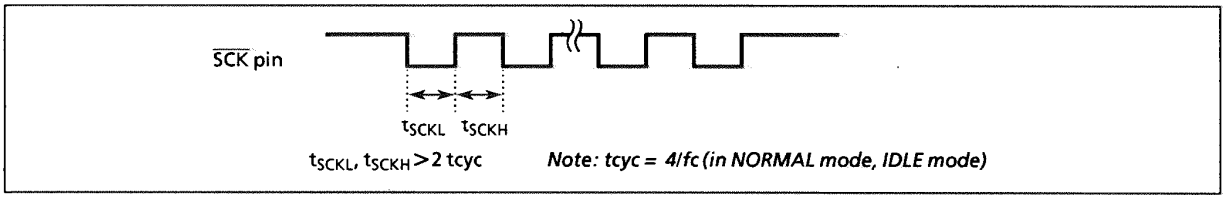


Figure 2.9.22 The Maximum Data Transfer Frequency in The External Clock Input

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

① Leading edge
Data is shifted on the leading edge of the serial clock (at a falling edge of the $\overline{SCK}$ pin input / output).

② Trailing edge
Data is shifted on the trailing edge of the serial clock (at a rising edge of the $\overline{SCK}$ pin input / output).

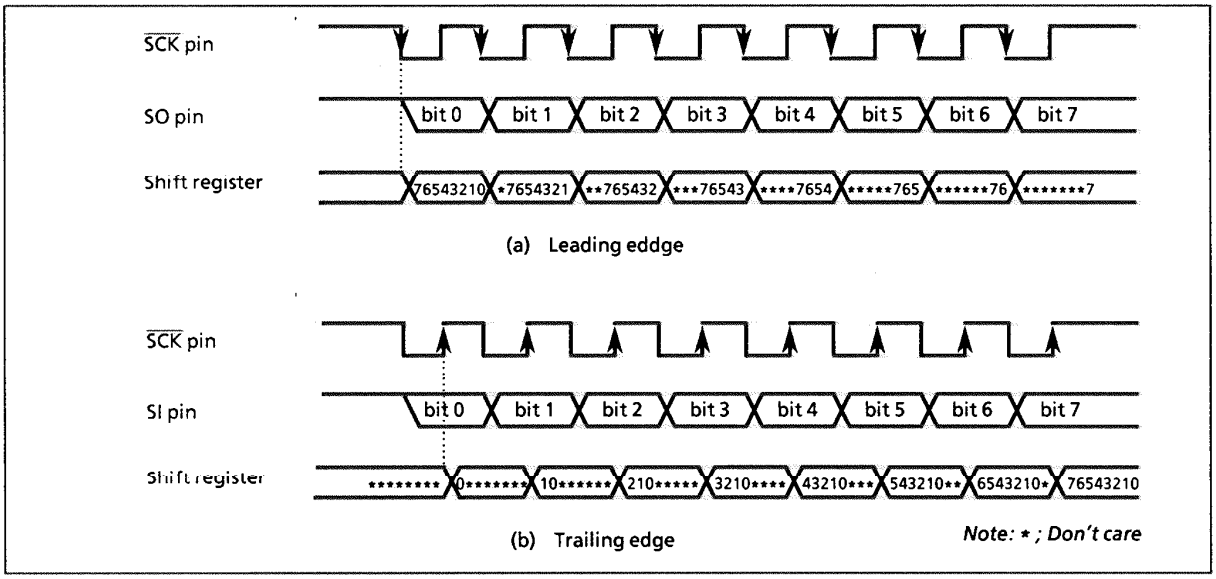


Figure 2.9.23 Shift Edge

(2) Transfer mode
The SIOM (bits 5 and 4 in SBICRA) is used to select a transmit, receive, or transmit / receive mode.

a. 8-bit transmit mode
Set a control register to a transmit mode and write transmit data to the SBIDBR.
After the transmit data is written, set the SIOS to "1" to start data transfer. The transmitted data is transferred from the SBIDBR to the shift register and output to the SO pin in synchronous with the serial clock, starting from the least significant bit (LSB). When the transmit data is transferred to the shift register, the SBIDBR becomes empty. The INTSBI (buffer empty) interrupt request is generated to request new data.
When the internal clock is used, the serial clock will stop and automatic-wait function will be initiated if new data is not loaded to the data buffer register after the specified 8-bit data is transmitted. When transmit new data is written, automatic-wait function is canceled.
When the external clock is used, data should be written to the SBIDBR before new data is shifted. The transfer speed is determined by the maximum delay time between the time when an interrupt request is generated and the time when data is written to the SBIDBR by the interrupt service program.

Transmitting data is ended by cleaning the SIOS to "0" by the buffer empty interrupt service program or setting the SIOINH to "1". When the SIOS is cleared, the transmitted mode ends when all data is output. In order to confirm if data is surely transmitted by the program, set the SIOF (bit 3 in the SBISR) to be sensed. The SIOF is cleared to "0" when transmitting is complete. When the SIOINH is set, transmitting data stops. The SIOF turns "0".
When the external clock is used, it is also necessary to clear the SIOS to "0" before new data is shifted ; otherwise, dummy data is transmitted and operation ends.

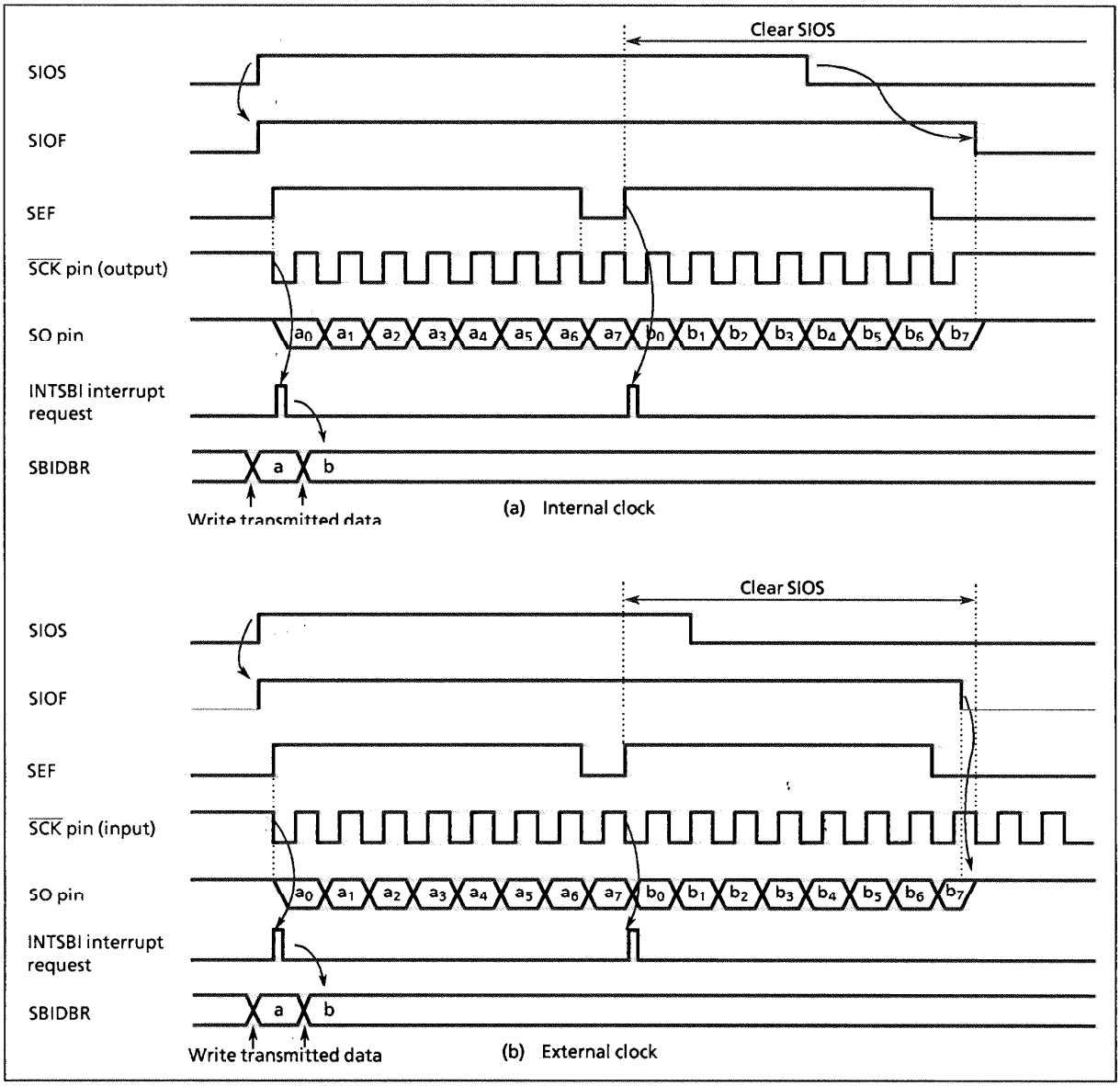


Figure 2.9.24 Transfer Mode

Example: Program to stop transmitting data. (When external clock is used)

```
STEST1:  TEST   (SBISRB) . SEF          ;  If SEF = 1 then  loop
         JRS    F, STEST1
STEST2:  TEST   (P5) . 3                ;  If SCK = 0 then  loop
         JRS    T, STEST2
         LD     (SBICRA) , 00000111B    ;  SIOS ← 0
```

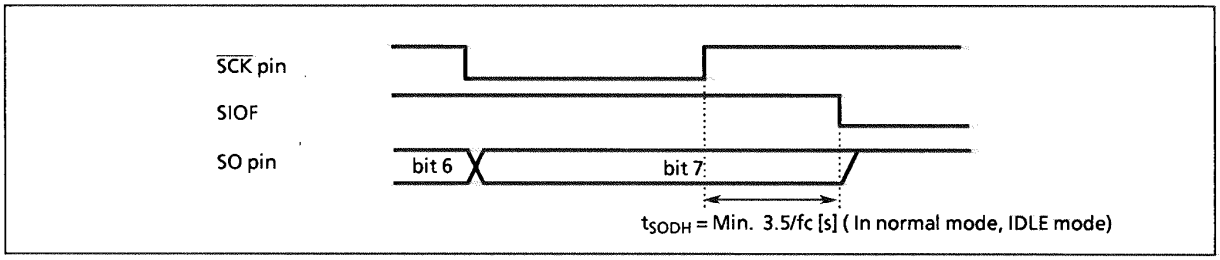


Figure 2.9.25 Transmitted Data Hold Time at End of Transmit

b. 8-bit receive mode

Set a control register to a receive mode and the SIOS to "1" for switching to a receive mode.
Data is received from the SI pin to the shift register in synchronous with the serial clock, starting from the least significant bit (LSB). When the 8-bit data is received, the data is transferred from the shift register to the SBIDBR. The INTSBI (buffer full) interrupt request is generated to request of reading the received data. The data is read from the SBIDBR by the interrupt service program.
When the external clock is used, since shift operation is synchronized with the clock pulse provided externally, the received data should be read from SBIDBR before next serial clock is input. If the received data is not read, further data to be received is canceled. The maximum transfer speed when the external clock is used is determined by the delay time between the time when an interrupt request is generated and the time when received data is read.
Receiving data is ended by clearing the SIOS to "0" by the buffer full interrupt service program or setting the SIOINH to "1". When the SIOS is cleared, received data is transferred to the SBIDBR in complete blocks. The received mode ends when the transfer is complete. In order to confirm if data is surely received by the program, set the SIOF (bit 3 in SBIDBR) to be sensed. The SIOF is cleared to "0" when receiving is complete. After confirming that receiving has ended, the last data is read. When the SIOINH is set, receiving data stops. The SIOF turns "0" (the received data becomes invalid, therefore no need to read it).

Note: When the transfer mode is switched, the SBIDBR contents are lost. In case that the mode needs to be switched, receiving data is concluded by clearing the SIOS to "0", read the last data, and then switch the mode.

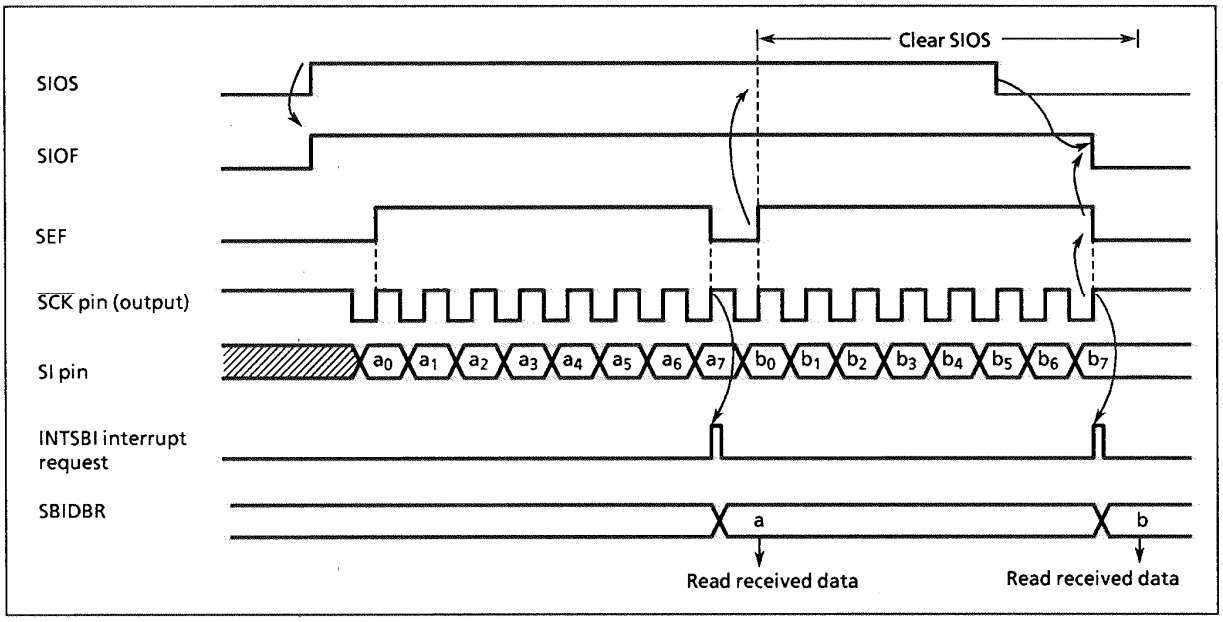


Figure 2.9.26 Receive Mode (Example: Internal clock)

c. 8-bit transmit / receive mode

Set a control register to a transmit / receive mode and write data to the SBIDBR. After the data is written, set the SIOS to "1" to start transmitting / receiving. When transmitting, the data is output from the SO pin on the leading edges in synchronous with the serial clock, starting from the least significant bit (LSB). When receiving, the data is input to the SI pin on the trailing edges of the serial clock. 8-bit data is transferred from the shift register to the SBIDBR, and the INTSBI interrupt request occurs. The interrupt service program reads the received data from the data buffer register and writes data to be transmitted. The SBIDBR is used for both transmitting and receiving. Transmitted data should always be written after received data is read.

When the internal clock is used, automatic-wait function is initiated until received data is read and next data is written.

When the external clock is used, since the shift operation is synchronized with the external clock, received data is read and transmitted data is written before new shift operation is executed. The maximum transfer speed when the external clock is used is determined by the delay time between the time when an interrupt request is generated and the time when received data is read and transmitted data is written.

Transmitting / receiving data is ended by cleaning the SIOS to "0" by the INTSBI interrupt service program or setting the SIONH to "1". When the SIOS is cleared, received data is transferred to the SBIDBR in complete blocks. The transmit / receive mode ends when the transfer is complete. In order to confirm if data is surely transmitted / received by the program, set the SIOF (bit 3 in SBISRB) to be sensed. The SIOF becomes "0" after transmitting / receiving is complete. When the SIONH is set, transmitting / receiving data stops. The SIOF turns "0".

Note: When the transfer mode is switched, the SBIDBR contents are lost. In case that the mode needs to be switched, conclude transmitting / receiving data by clearing the SIOS to "0", read the last data, and then switch the transfer mode.

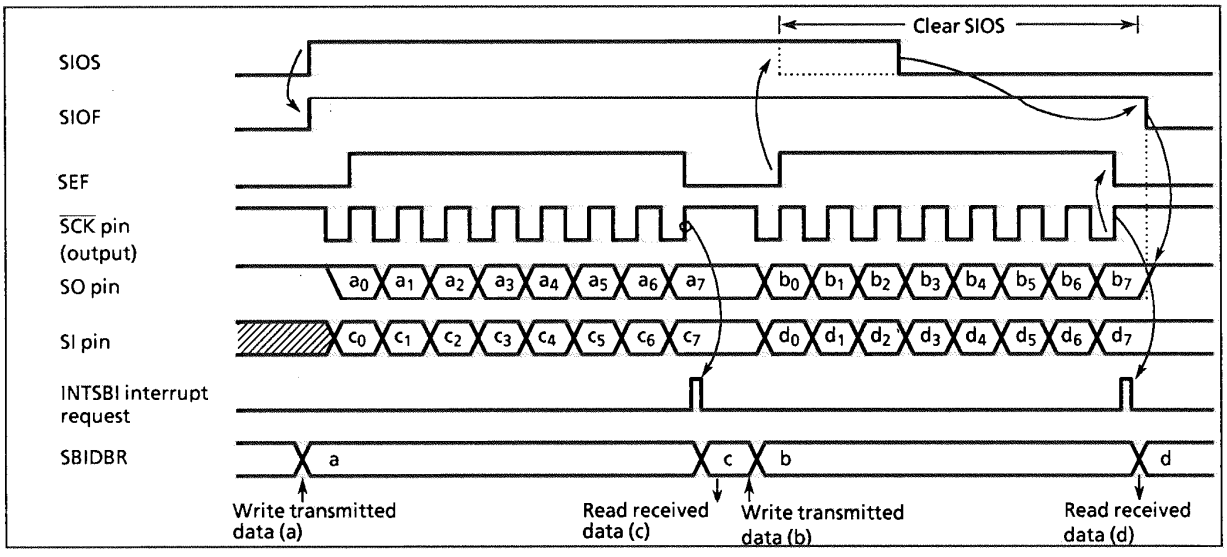


Figure 2.9.27 Transmit / Receive Mode (Example: Internal clock)

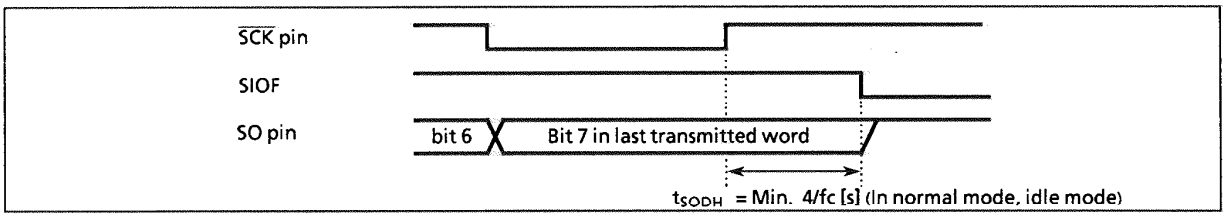


Figure 2.9.28 Transmitted data hold time at end of transmit / receive

2.10 Remote Control Signal Preprocessor / External Interrupt 3 Input Pin

The remote control signal waveform can be determined by inputting the remote control signal waveform from which the carrier wave was eliminated by the receive circuit to P30 (INT3 / RXIN) pin. When the remote control signal preprocessor / external interrupt 3 pin is also used as the P30 port, set the P30 port output latch to "1". When it is not used as the remote control signal preprocessor/external interrupt 3 input pin, it can be used for normal port.

2.10.1 Configuration

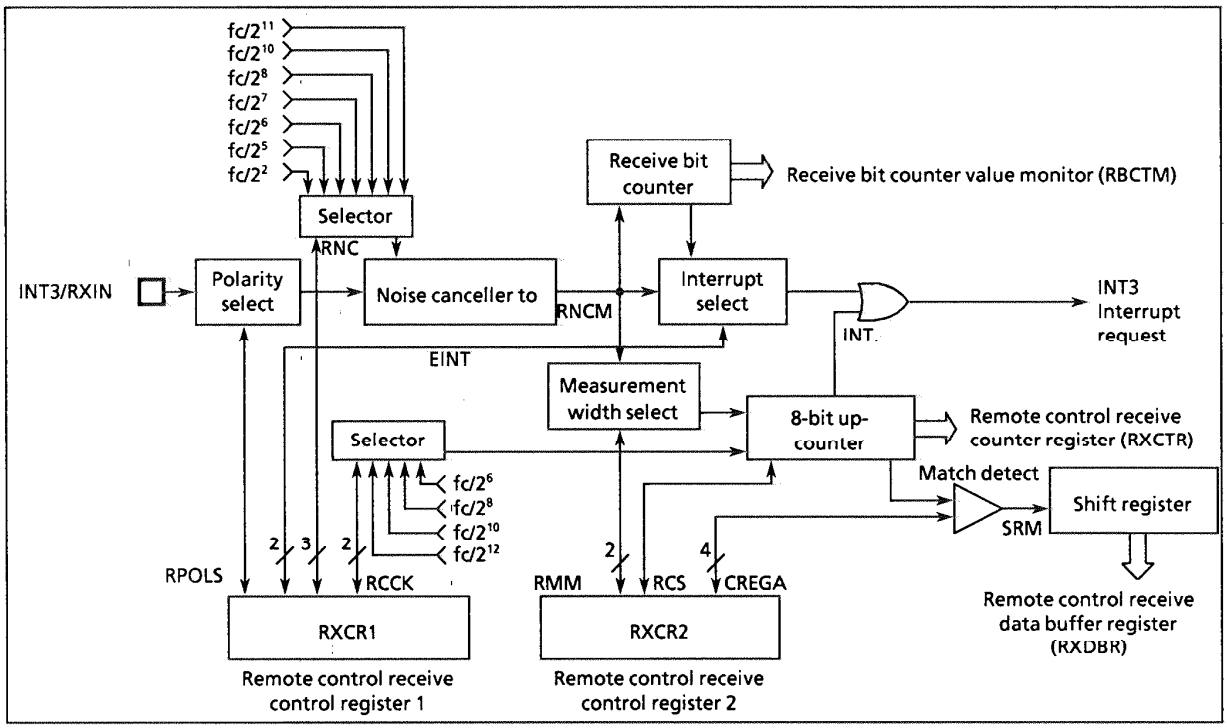


Figure 2.10.1 Remote control signal preprocessor

2.10.2 Remote control signal preprocessor control

When the remote control signal preprocessor is used, operating states are controlled and monitored by the following registers. Interrupt requests also use the remote control signal preprocessor / external interrupt 3 input pin.

- Remote control receive control register 1 (RXCR1)
- Remote control receive control register 2 (RXCR2)
- Remote control receive counter register (RXCTR)
- Remote control receive data buffer register (RXDBR)
- Remote control receive status register (RXSR)

When this pin is used for the external interrupt 3 input, set EINT in RXCR1 to other than "11".

Remote control receive control register 1

RXCR1 (00FE8$_H$)

7	6	5	4	3	2	1	0
RCCK		RPOLS	EINT		RNC		

(Initial value: 0000 0000)

RCCK	8-bit up-counter source clock select	00: fc/2^6 (Hz) 01: fc/2^8 10: fc/2^{10} 11: fc/2^{12}	R/W
RPOLS	Remote control signal polarity select	0: Positive 1: Negative	
EINT	Interrupt source select	00: Rising edge 01: Falling edge 10: Rising / Falling edge 11: 8-bit receive end	
RNC	Noise canceler noise eliminating time select	001: 2^2/fc × 7 – 1/fc (s) 010: 2^5/fc × 7 – 1/fc 011: 2^6/fc × 7 – 1/fc 100: 2^7/fc × 7 – 1/fc 101: 2^8/fc × 7 – 1/fc 110: 2^{10}/fc × 7 – 1/fc 111: 2^{11}/fc × 7 – 1/fc 000: Noise canceler disable	

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

Note 2: After reset, RPOLS do not change the set value in the receiving remote control signal. For setting interrupt edge and measurement data, use EINT and RMM.

Remote control receive control register 2

RXCR2 (00FE9$_H$)

7	6	5	4	3	2	1	0
CREGA				RCS	RMCEN	RMM	

(Initial value: 0000 0000)

CREGA	Setting of detect time for match with 8-bit up-counter upper 4 bits	Match detect time (Tth) = 16 × CREGA / RCCK [s] CREGA = 0_H to F_H Example: CREGA = 2_H, RCCK = fc/2^6 [Hz] ,at fc = 16 MHz, DV1CK = 0 Tth = 128 [μs]	R/W
RCS	8-bit up-counter start control	0: Stop and counter clear 1: Start	
RMCEN	Remote control signal preprocesser Enable / Disable	0: Disable 1: Enabl	
RMM	Measurement mode select (invalid when EINT = "10")	00: 01: 10: 11: Refer to Table 2.10.1	

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

Note 2: When an interrupt source is set for rising / falling edge, low and high widths are forcibly measured separately.

Note 3: Set CREGA (0_H to F_H) before EINT sets to 8-bit receive end.

Figure 2.10.2 Remote control receive control register 1, 2

Remote control receive counter register

RXCTR ($00FEA_H$)

7	6	5	4	3	2	1	0

Read Only
(Initial value: 0000 0000)

Remote control receive data buffer register

RXDBR ($00FEB_H$)

7	6	5	4	3	2	1	0

Read Only
(Initial value: 0000 0000)

Remote control receive status register

RXSR ($00FEC_H$)

7	6	5	4	3	2	1	0
RBCTM					OVFF	SRM	RNCM

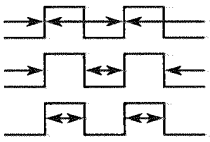
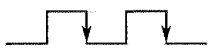
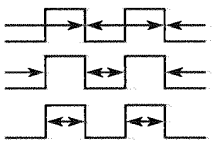
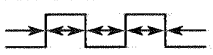
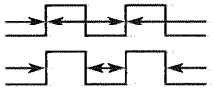
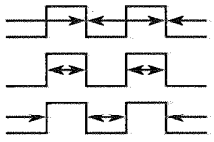
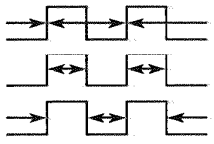
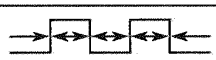
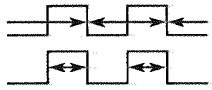
(Initial value: 0000 * 000)

RBCTM	Receive bit counter value monitor		Read Only
OVFF	8-bit up-counter overflow flag	0: No overflow 1: Overflow	
SRM	Data buffer register input monitor	0: Upper 4 bits of 8-bit up-counter < CREGA 1: Upper 4 bits of 8-bit up-counter ≧ CREGA	
RNCM	Remote control signal monitor after passing through noise canceler		

*Note: * ; Don't care*

Figure 2.10.3 Remote control receive counter register, data buffer register, status register

Table 2.10.1 Combination of interrupt source and measurement mode

RPOLS	EINT	RMM	Interrupt source	Measurement mode
0	00	00 10 11		
	01	01 10 11		
	10	—		
	11	00 10	Receive end	
1	00	00 10 11		
	01	01 10 11		
	10	—		
	11	00 10	Receive end	

2.10.3 Noise elimination time setting

The remote control receive circuit has a noise canceler. By setting RNC in RXCR1, input signals shorter than the fixed time can be eliminated as noise.

Table 2.10.2 Noise elimination time setting (fc = 16 MHz)

RNC	Minimum signal pulse width (s)	Maximum noise width to be eliminated (s)
000	-	-
001	$(2^5 + 5) / fc$ (2.31 μ)	$(2^2 \times 7 - 1) / fc$ (1.69 μ)
010	$(2^8 + 5) / fc$ (16.31 μ)	$(2^5 \times 7 - 1) / fc$ (13.88 μ)
011	$(2^9 + 5) / fc$ (32.31 μ)	$(2^6 \times 7 - 1) / fc$ (27.88 μ)
100	$(2^{10} + 5) / fc$ (64.31 μ)	$(2^7 \times 7 - 1) / fc$ (55.88 μ)
101	$(2^{11} + 5) / fc$ (128.3 μ)	$(2^8 \times 7 - 1) / fc$ (111.9 μ)
110	$(2^{13} + 5) / fc$ (512.3 μ)	$(2^{10} \times 7 - 1) / fc$ (447.9 μ)
111	$(2^{14} + 5) / fc$ (1.024 m)	$(2^{11} \times 7 - 1) / fc$ (895.9 μ)

2.10.4 Operation

(1) interrupts at rising, falling, or rising / falling edge, and measurement modes

First set EINT and RMM. Next, set RCS to "1" ; the 8-bit up-counter is counted up by the internal clock. After measurement, the 8-bit up-counter value is saved in RXCTR. Then, the 8-bit up-counter is cleared, an INT3 request is generated, and the 8-bit up-counter resumes counting.

If the 8-bit up-counter overflows (FF_H) before measurement is completed, an INT3 request is generated and the overflow flag (OVFF) is set to "1". Then, the 8-bit up-counter is cleared. An overflow can be detected by reading OVFF by the interrupt processing. To restart the 8-bit up-counter, set RCS to "1".

Setting RCS to "1" zero-clears OVFF.

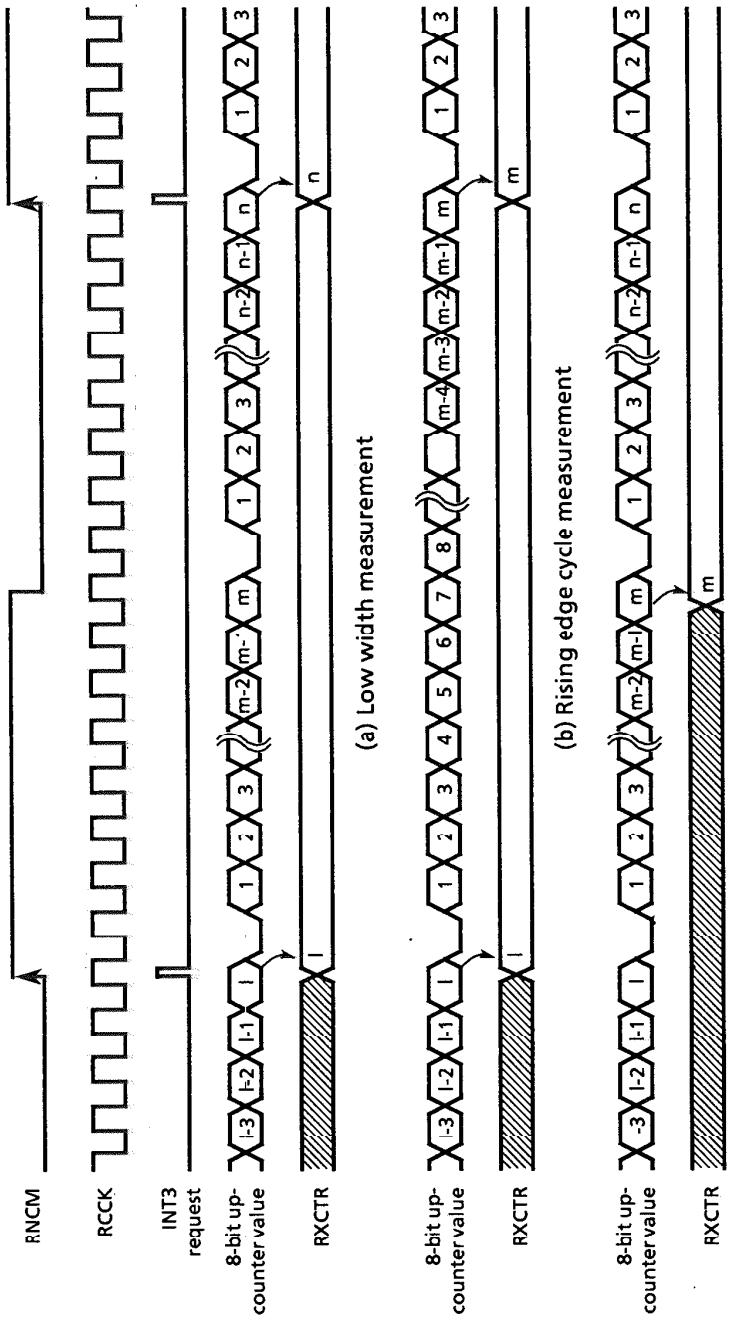


Figure 2.10.4 Rising edge interrupt timing chart (RPOLS = 0)

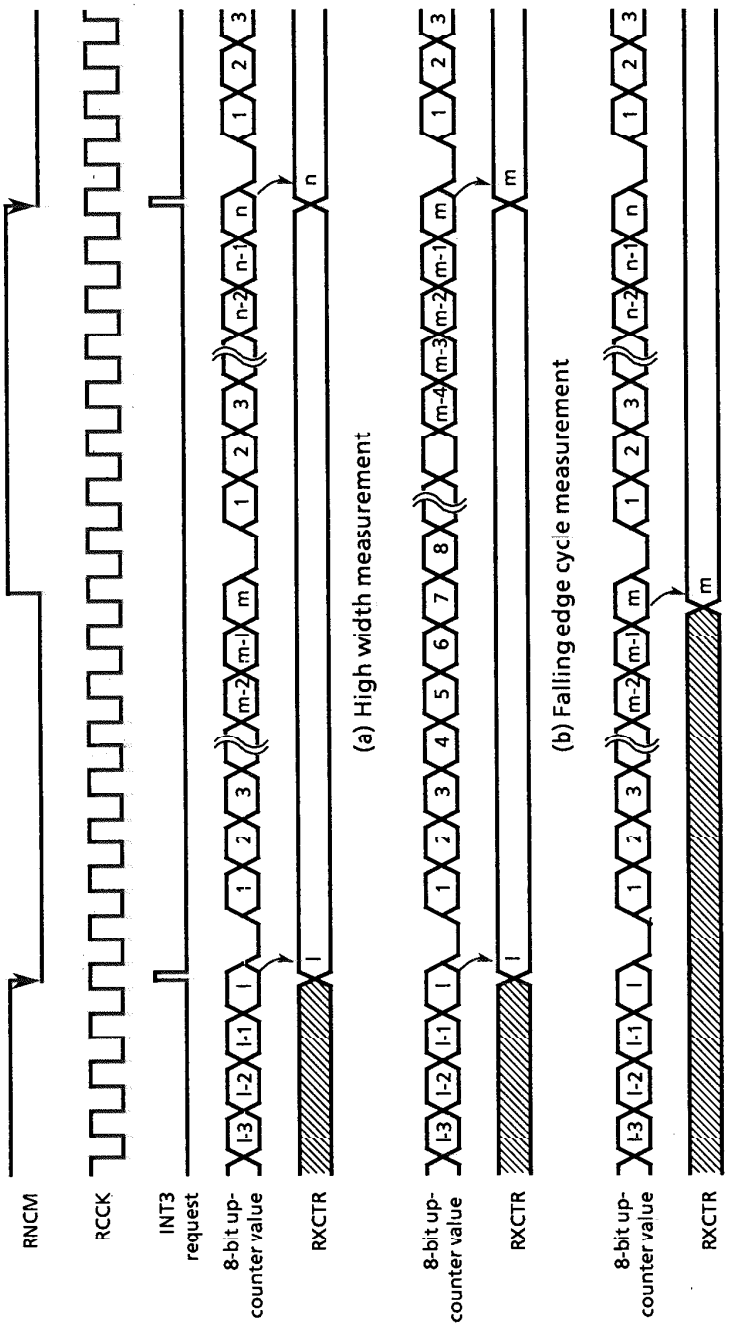
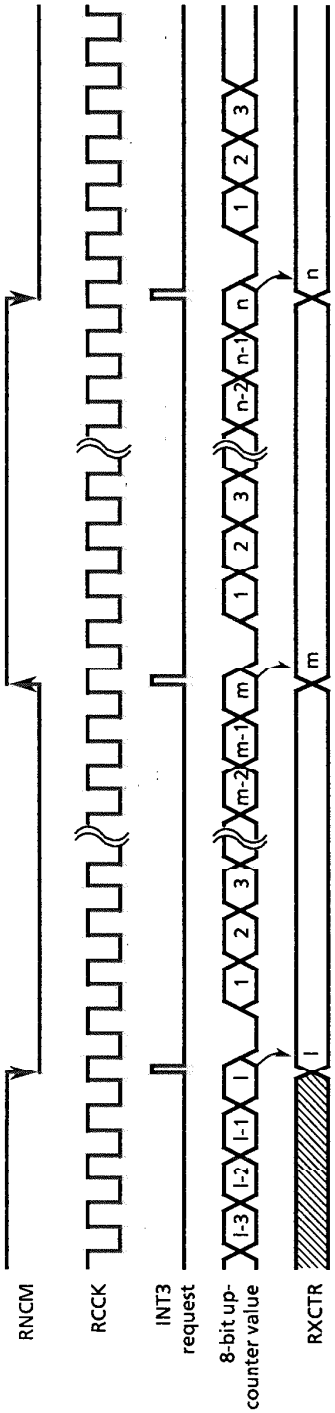


Figure 2.10.5 Falling edge interrupt timing chart (RPOLS = 0)



(a) High and low width measurement

Figure 2.10.6 Rising / falling edge interrupt timing chart

(2) 8-bit receive end interrupts and measurement modes

By determining one-cycle remote control signal as one-bit data set to "0" or one-pulse width remote control signal as one-bit data set to "1", an INT3 request is generated after 8-bit data is received. When "0" is determined, this means the upper four bits in the 8-bit up-counter have not reached the CREGA value. When "1" is determined, this means the upper four bits in the 8-bit up-counter have reached or exceeded the CREGA value. The 8-bit up-counter value is saved in RXCTR after one bit is determined. The determined data is saved, bit by bit, in RXDBR at the rising edge of the remote control signal (when RPOLS = 1, falling edge). The number of bits saved in RXDBR is counted by the receive bit counter and saved in RBCTM. RBCTM is set to "0001B" at the rising edge of the input (when RPOLS = 1, falling edge) after the INT3 request is generated.

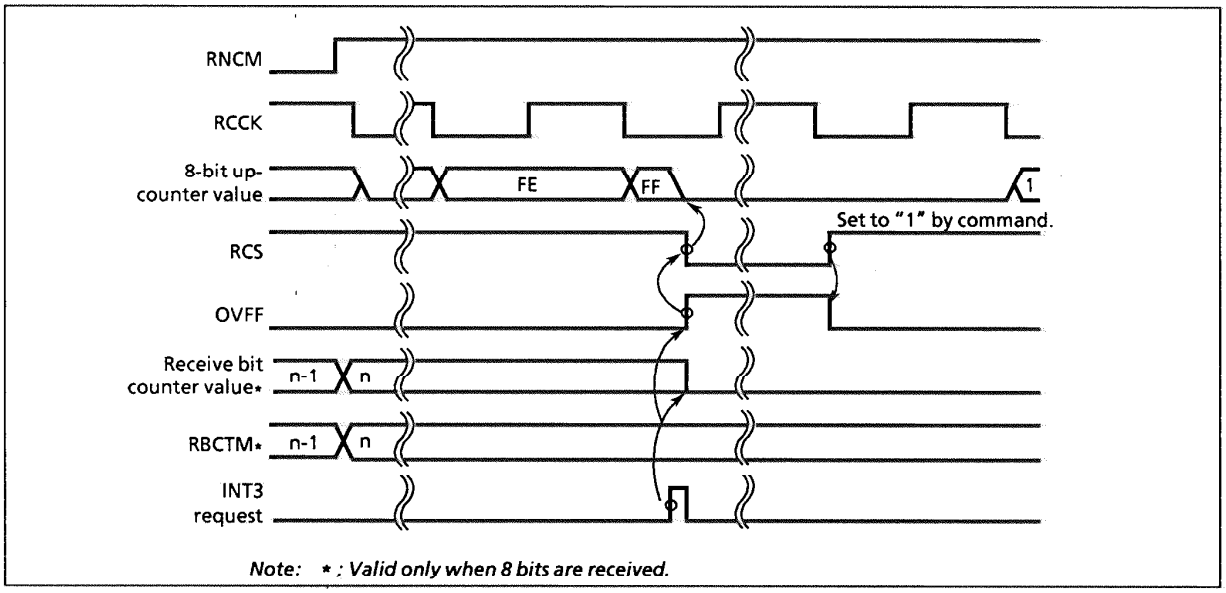


Figure 2.10.7 Overflow interrupt timing chart

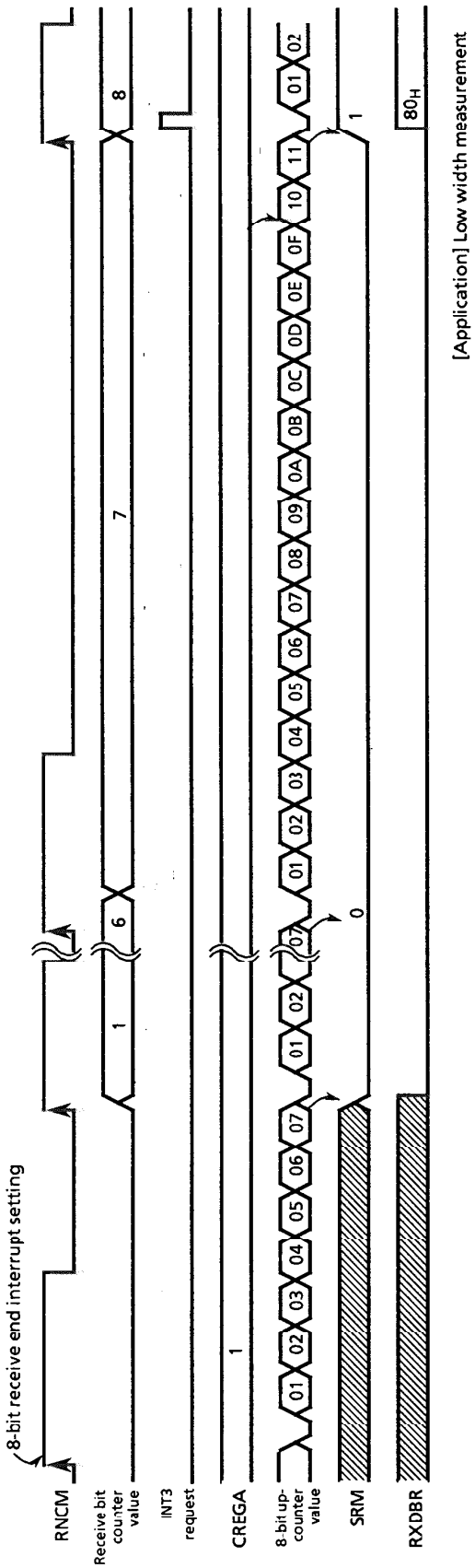


Figure 2.10.8 8-bit receive end interrupt timing chart (RPOLS = 0)

Table 2.10.3 Count clock for remote control preprocessor circuit (at fc = 16 MHz)

Count clock (RCCK)	Resolution [μs]	Maximum setting time [ms]
00	256	65.53
01	64	16.38
10	16	4.096
11	4	1.024

2.11 8-bit AD Converter (ADC)

The TMP88CM38A/P38A have a 8-bit successive approximation type AD converter.

2.11.1 Configuration

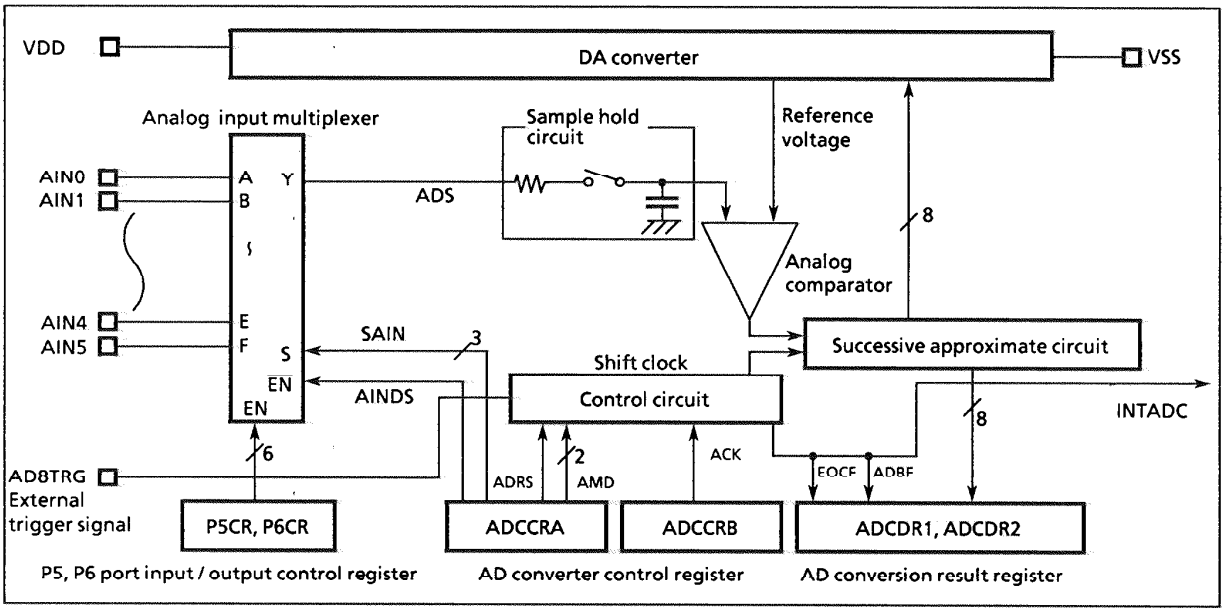


Figure 2.11.1 AD Converter (ADC)

2.11.2 Control register

The following register are used foe AD converter.

- AD converter control register 1 (ADCCRA)
- AD converter control register 2 (ADCCRB)
- AD conversion result register

(1) AD converter control register 1

ADCCRA control AD conversion start, AD operation mode select, analog input control and analog input channel select.

(2) AD converter control register 2

ADCCRB control AD conversion time select.

(3) AD conversion result register

AD conversion result is stored after end of conversion.

(4) AD conversion result register

For monitoring status of conversion.

Figure 2.11.2 and Figure 2.11.3 show AD converter control register.

AD Converter Control Register 1

ADCCRA ($000E_H$)

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

(Initial value: 0001 0000)

ADRS	AD conversion start	The ADRS bit is automatically cleared after starting AD conversion. During AD conversion, setting ADRS to "1" initializes the ADRS bit and resets conversion. 0: – 1: AD conversion restart	R/W
AMD	AD Operating mode select	00: STOP mode 01: Single mode 10: Trigger start mode 11: reserved	
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: – 111: –	

Note 1: Select analog input when AD 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 ADCCRA to "0"

AD Converter Control Register 2

ADCCRB ($000F_H$)

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

(Initial value: **0* 000*)

		ACK	Conversion time	DV1CK = 0		DV1CK = 1		
				fc = 16 MHz	fc = 8 MHz	fc = 16 MHz	fc = 8 MHz	
ACK	AD conversion time select	000	reserved					R/W
		011	156/fc [s]	–	19.5	–	39	
		100	312/fc [s]	19.5	39.0	39	78	
		101	624/fc [s]	39.0	78.0	78	156	
		110	1248/fc [s]	78.0	–	156	–	
		111	reserved					

Note 1: Do not use setting except the above list.
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)
Note 3: Always set bit 0 in ADCCRB to "0" and set bit 4 in ADCCRB to "1".
Note 4: When a read instruction for ADCCRB, bit 6 to 7 in ADCCRB read in as undefined data.
Note 5: fc ; High-frequency clock [Hz]
Note 6: During conversion, don't set to bit 7 in ADCCRA. For resting to ADRS, confirm end of conversion to read EOCF or after INTADC generation.
Note 7: In trigger start mode, any trigger can't be accepted after starting by first trigger. For restart trigger mode, clear bit 6 and 5 in ADCCRA to "00"after end of conversion

Figure 2.11.2 AD Converter Control Register

AD Conversion Result Register

	7	6	5	4	3	2	1	0	
ADCDR1 (0031_H)	AD07	AD06	AD05	AD04	AD03	AD02	AD01	AD00	(Initial value: 0000 0000)
ADCDR2 (0032_H)	—	—	EOCF	ADBF	—	—	—	—	(Initial value: **00 ****)

EOCF	AD conversion end flag	0: Under conversion or Before conversion 1: End of conversion	Read only
ADBF	AD conversion busy flag	0: During stop of AD conversion 1: During AD conversion	

Note 1: The EOCF is cleared to "0" when reading the ADCDR2.
Therefore, the AD conversion result should be read to ADCDR1 more first than ADCDR2.
Note 2: ADBF is set to "1" by starting AD conversion and cleared to "0" by end of AD conversion. Additionally, ADBF is cleared to "0" by setting AMD = "00" in ADCCR2 or entering to the STOP mode.

Figure 2.11.3 AD Converter Result Register

2.11.3 AD Converter Operation

The high side of an analog reference voltage is applied to VDD, and the low side is applied to VSS pin. Dividing a reference voltage between VDD and VSS to the voltage corresponding to a bit by a rudder resistance and comparing it with the analog input voltage converts the AD.

Table 2.11.1 AD Converter Operation mode

Mode	Function
AD converter disable mode	AD converter stop mode. This mode is always used to change modes.
Single mode	Single AD conversion of the specified 1 channel.
Trigger start mode	Single AD conversion of 1 channel which specifies input (AD8TRG) from Key-On-Wake-Up circuit as a trigger.

2.11.4 Interrupt

Interrupt occur at the timing when the EOCF bit is set to "1".

2.11.5 AD Converter Operation Modes

When the MCU places in the STOP mode during the AD conversion, the conversion is stopped and the ADCDR2 content becomes indefinite. After returning from the STOP mode, the EOCF and INTADC does not occur. Therefore, the AD conversion must be restarted after returning from the STOP mode.

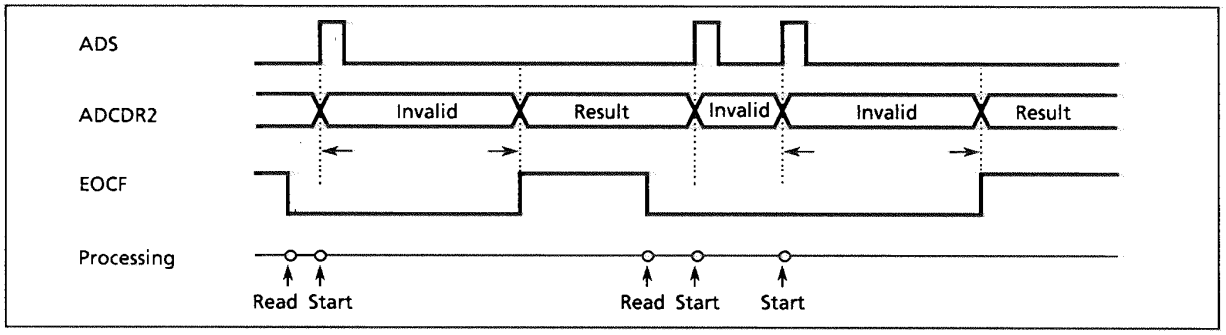


Figure 2.11.4 AD Conversion Timing chart

(1) AD conversion in STOP mode

When the AD converter stop mode is specified during AD conversion, the AD conversion is stopped immediately. The AD conversion is not implemented, so the undefined value is not written to the AD conversion result register. The AD conversion start commands which occur is the AD converter stop mode are ignored.

This mode is automatically selected by reset.

This mode is used to change the AD converter operation mode.

(2) Single mode

When the AMD (bit 6, 5 to in ADCCRA) set to "01", the AD conversion signal mode

This mode does AD conversion of single channel, and conversion result is stored in ADCDR1. The EOCF (bit 5 in ADCDR2) is set to "1" at end of one conversion, and an intcrrupt request signal occurs. The EOCF is cleared to "0" by reading the AD conversion registers.

But when the AD conversion is restarted before the ADCDR is read, the EOCF is cleared to "0" and the last AD conversion result is maintained till next conversion end.

During conversion, when the ADRS (bit 7 ADCCRA) set to "1", the AD conversion is breaking and the AD conversion is restarted.

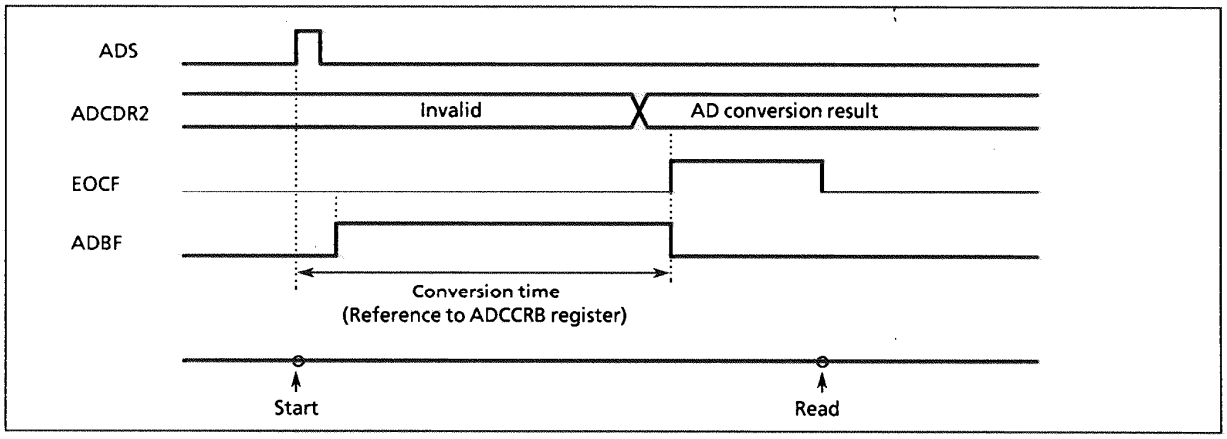


Figure 2.11.5 Single Mode

Example: The AD conversion starts after 19.5 μs (at fc = 16 MHz) and AIN4 pin are selected as the conversion time and the analog input channel. Confirming the EOCF, the converted value is read out, and the 8 bits data is stored to address 009FH in RAM. The operation mode is a signal mode.

```
    ; AIN SELECT
    LD      (P5), 00000000B
    LD      (P5CR1), 00000000B
    LD      (P6), 00000000B
    LD      (P6CR), 00000000B
    LD      (ADCCRA), 00000100B   ;  Selects AIN4
    LD      (ADCCRB), 11011000B   ;  Selects the conversion time and the operation
                                      mode.
    ; AD CONVERT START
    SET     (ADCCRA) . 7          ;  ADRS = 1
SLOOP: TEST (ADCCR2) . 5          ;  EOCF = 1 ?
    JRS     T, SLOOP
    ; RESULT DATA READ
    LD      (0x9E), (ADCDR1)
```

(3) Trigger start mode

The AD conversion of a specified single channel is executed when input (AD8TRG) from Key-On-Wake-Up circuit is set as trigger, the conversion result is stored in the ADCDRH.

The EOCF (bit 5 in ADCCR2) is set to "1" at end of one conversion, and an interrupt request signal occurs.

It needs to be set the STOP mode by bit 5 to 6 in ADCCRA before the AD conversion is executed again.

The analog input voltage is corresponded to the 8-bit digital value converted by the AD as shown in Figure 2.11.6.

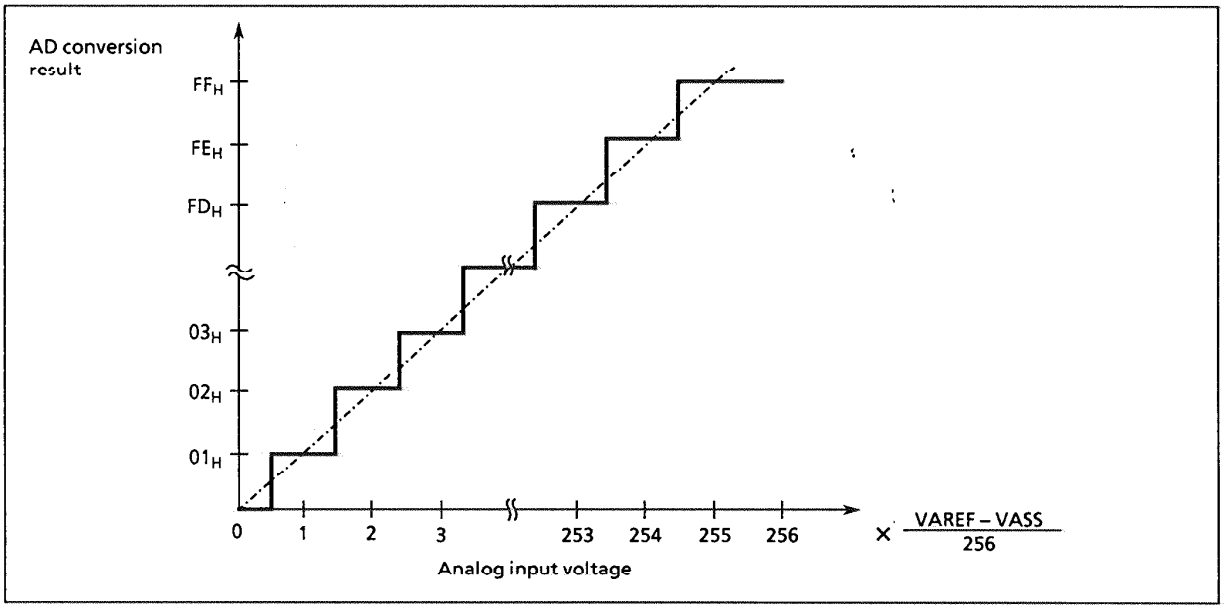


Figure 2.11.7 Analog Input Voltage and AD Conversion Result (typ.)

2.11.6 Notice of AD converter

(1) Analog input voltage range
Voltage range of analog input (AIN0 to AIN5) must be forced from V_{SS} to V_{DD}. If input voltage of which out of range is forced to analog input pin, AD conversion result to unknown. Also, this cause other analog input pin unstable.

(2) I/O port with analog input
Analog input pins (AIN0 to AIN5) are also I/O port. During AD conversion using any analog input pin, don't operate other I/O port with analog input. Because, AD accuracy would be worse a. Also , other electrically swinging port without analog input may cause noise to near analog input pin.

(3) Reduce to noise
Figure 2.11.6 is shown as internal equivalent circuit of analog input pin.
Increasing output impedance of analog input supply, cause noise or other non-good condition.
Therefore, output impedance of analog input supply must be less than 5kΩ.
And we recommend to connect capacitance to analog input pin.

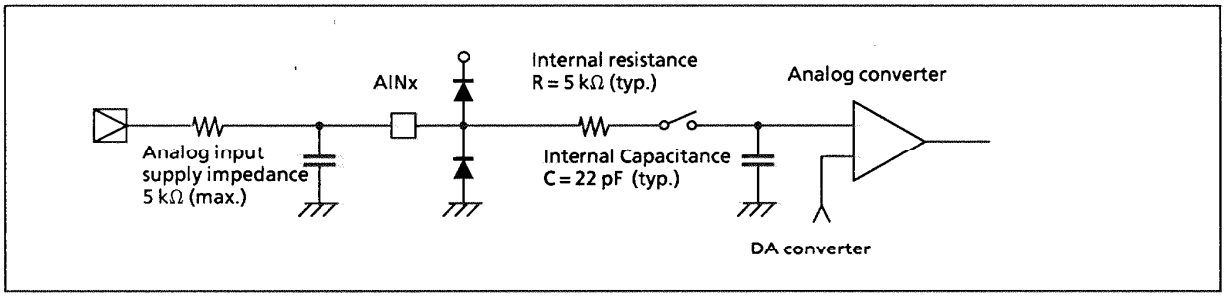


Figure 2.11.6 Analog input equivalent circuit and analog input pin

2.12 Key-On-Wake-Up

In this MCU the IDLE mode is also released by Low active port inputs. The low input voltage is regulated higher than the other normal ports. Therefore the ports can be enabled by analog input level.

2.12.1 Configuration

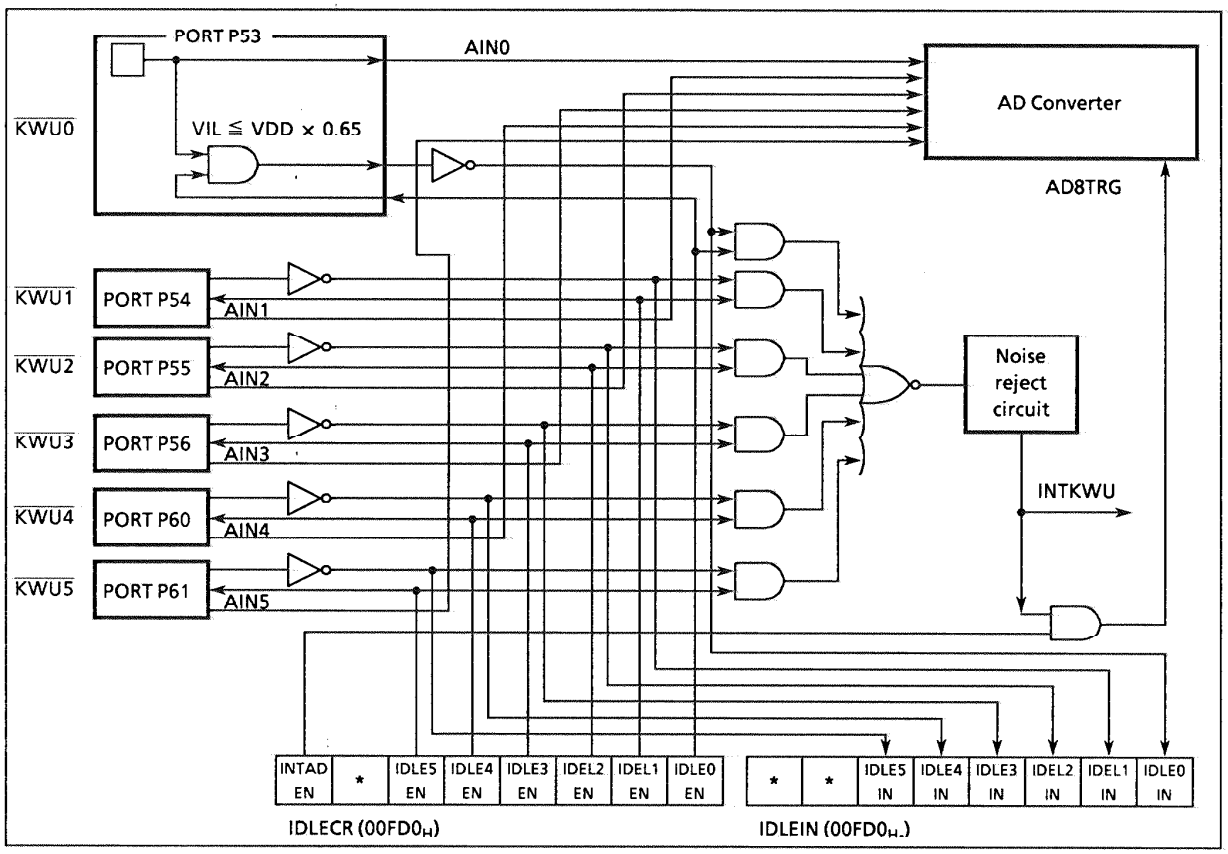


Figure 2.12.1 Key-On-Wake-Up control circuit

2.12.2 Control

P53 to P56 and P60, P61 ports can be controlled by IDLE control register (IDLECR).

It can be configured as enable/disable in one-bit unit. When those pins are used by IDLE mode release, those pins must be set input mode (P5CR1, P5, P6CR, P6, ADCCRA).

IDLE mode is controlled by system control register 2 (SYSCR2) and maskable interrupts. After the individual enable flag (EF5) is set to "1", the IDLE mode must starts. When enabled port input generates INTKWU interrupt, the IDLE mode is released. Low level input voltage in those ports is regulated to less than VDD × 0.65 (V).

IDLE port monitorring register (IDLEIN) can be used to check state of ports.

INTADEN can enable to generate AD8TRG, which is used as trigger of AD converter trigger start mode.

Noise reject circuit eliminate noise, which is less than 24 μs period.

IDLE control register

IDLECR ($00FD0_H$)

7	6	5	4	3	2	1	0
INTAD EN	*	IDLE5 EN	IDLE4 EN	IDLE3 EN	IDLE2 EN	IDLE1 EN	IDLE0 EN

(Initial value: 0*00 0000)

INTADEN	Setting for $\overline{AD8TRG}$	0: disable 1: enable	Write only
IDLE5EN	Setting for $\overline{KWU5}$	0: disable 1: enable	
IDLE4EN	Setting for $\overline{KWU4}$	0: disable 1: enable	
IDLE3EN	Setting for $\overline{KWU3}$	0: disable 1: enable	
IDLE2EN	Setting for $\overline{KWU2}$	0: disable 1: enable	
IDLE1EN	Setting for $\overline{KWU1}$	0: disable 1: enable	
IDLE0EN	Setting for $\overline{KWU0}$	0: disable 1: enable	

*Note: * ; Don't care*

IDLE port monitorring register

IDLEIN ($00FD0_H$)

7	6	5	4	3	2	1	0
*	*	IDLE5 IN	IDLE4 IN	IDLE3 IN	IDLE2 IN	IDLE1 IN	IDLE0 IN

(Initial value: **00 0000)

IDLE5IN	Input level of $\overline{KWU5}$	0: "0" detect 1: "1" detect	Read only
IDLE4IN	Input level of $\overline{KWU4}$	0: "0" detect 1: "1" detect	
IDLE3IN	Input level of $\overline{KWU3}$	0: "0" detect 1: "1" detect	
IDLE2IN	Input level of $\overline{KWU2}$	0: "0" detect 1: "1" detect	
IDLE1IN	Input level of $\overline{KWU1}$	0: "0" detect 1: "1" detect	
IDLE0IN	Input level of $\overline{KWU0}$	0: "0" detect 1: "1" detect	

*Note: * ; Don't care*

Figure 2.12.2 Key-On-Wake-Up control register

2.13 Pulse Width Modulation Circuit Output

The TMP88CM38A/P38A have four 12-bit resolution PWM output channels including two 14-bit resolution selectable and six 7-bit resolution PWM output channels.
DA converter output can easily be obtained by connecting an external low-pass filter. PWM outputs are multiplexed with general purpose I/O ports as; P40 ($\overline{PWM0}$) to P47 ($\overline{PWM7}$), P50 ($\overline{PWM8}$), P51 ($\overline{PWM9}$). When these ports are used PWM outputs, the corresponding bits of P4, P5 output latches and input / output control latches should be set to "1".
In STOP mode, PWM output pin keeps high-level. When operation mode is changed from STOP mode to NORMAL mode, PWMCR1A, PWMCR2A, PWMCR1B, PWMCR2B are initialized.

2.13.1 Configuration

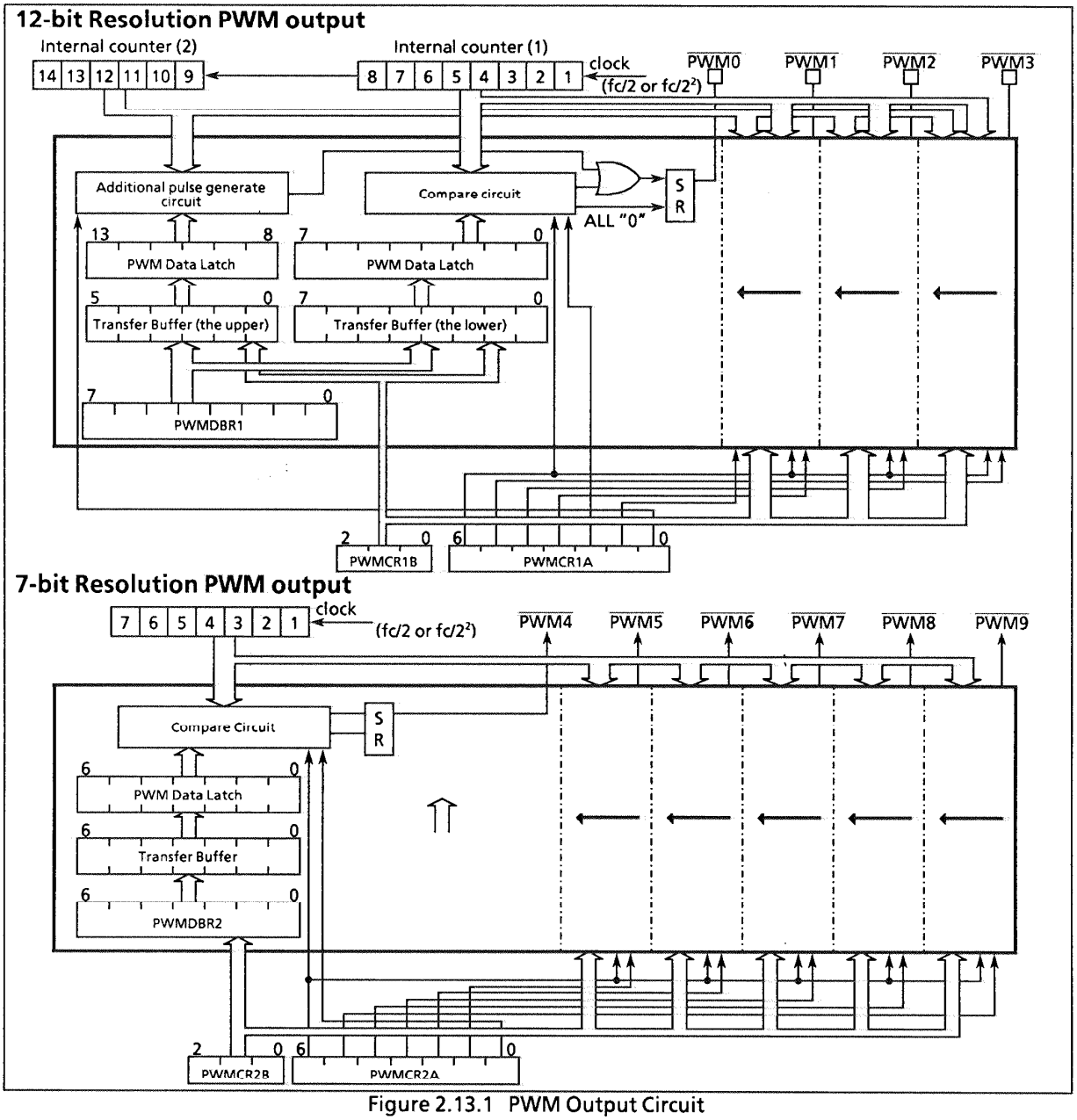


Figure 2.13.1 PWM Output Circuit

2.13.2 PWM Output Wave Form

(1) $\overline{PWM0}$ to $\overline{PWM1}$ Outputs

$\overline{PWM0}$ and $\overline{PWM1}$ output can be selected 12-bit or 14-bit resolution PWM outputs.

① 12-bit Resolution PWM Output

When these are used as 12-bit PWM output, one period is $T_M = 2^{13}/fc$ [s] (When DV1CK = 0) and $T_M = 2^{14}/fc$ [s] (When DV1CK = 1) and sub-period is $T_S = T_M/16$.

The lower 8-bit of the PWM data latch controls the low level pulse width with a cycle of T_S. The lower 8-bit of the PWM data latch is n (n = 1 to 255), the low level pulse width with a cycle becomes n x t_0 [s] (t_0 = 2/fc [s] when DV1CK = 0, t_0 = 4/fc [s] when DV1CK = 1).

The upper 4-bit of the PWM data latch controls a position to output the additional pulses. When the upper 4-bit of the PWM data latch is m, the additional pulses are generated in each of m periods out of 16 periods contained in a T_M period.

The relationship between the 4-bit data and the position of T_S period where the additional pulses are generated is shown in Table 2.13.1.

Table 2.13.1 The addition pulse (12 bit mode)

	Bit position of the lower 4 bits of PWMDRxH				Relative position of T_S in T_M period where the additional pulse is generated. (Number of $T_{S(I)}$ is listed)
	bit 11	bit 10	bit 9	bit 8	
a)	0	0	0	0	No additional pulse
b)	0	0	0	1	8
c)	0	0	1	0	4, 12
d)	0	1	0	0	2, 6, 10, 14
e)	1	0	0	0	1, 3, 5, 7, 9, 11, 13, 15

Note: The bit positions of a) to e) can be combined.

② 14-bit Resolution PWM Output

When these are used as 14-bit PWM output, one period is $T_M = 2^{15}/fc$ [s] (When DV1CK = 0) and $T_M = 2^{16}/fc$ [s] (When DV1CK = 1) and sub-period is $T_S = T_M/64$.

The lower 8-bit of the PWM data latch controls the low level pulse width with a cycle of T_S. The lower 8-bit of the PWM data latch is n (n = 1 to 255), the low level pulse width with a cycle becomes n x t_0 [s] (t_0 = 2/fc [s] when DV1CK = 0, t_0 = 4/fc [s] when DV1CK = 1).

The upper 6-bit of the PWM data latch controls a position to output the additional pulses. When the upper 6-bit of the PWM data latch is m, the additional pulses are generated in each of m periods out of 64 periods contained in a T_M period.

The relationship between the 6-bit data and the position of T_S period where the additional pulses are generated is shown in Table 2.13.2.

Table 2.13.2 The addition pulse (14 bit mode)

	Bit position of the lower 6 bits of PWMDRxH						Relative position of T_S in T_M period where the additional pulse is generated. (Number of $T_{S(I)}$ is listed)
	bit 13	bit 12	bit 11	bit 10	bit 9	bit 8	
a)	0	0	0	0	0	0	No additional pulse
b)	0	0	0	0	0	1	32
c)	0	0	0	0	1	0	16, 48
d)	0	0	0	1	0	0	8, 24, 40, 56
e)	0	0	1	0	0	0	4, 12, 20, 28, 36, 44, 52, 60
f)	0	1	0	0	0	0	2, 6, 10, 14, 18, 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62
g)	1	0	0	0	0	0	1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, 47, 49, 51, 53, 55, 57, 59, 61, 63

Note: The bit positions of a) to g) can be combined.

(2) $\overline{PWM2}$ to $\overline{PWM3}$ Outputs

$\overline{PWM2}$ and $\overline{PWM3}$ output are 12-bit resolution PWM outputs.

One period is $T_M = 2^{13}/fc$ [s] (When DV1CK = 0) and $T_M = 2^{14}/fc$ [s] (When DV1CK = 1) and sub-period is $T_S = T_M/16$.

The lower 8-bit of the PWM data latch controls the low level pulse width with a cycle of T_S. The lower 8-bit of the PWM data latch is n (n = 1 to 255), the low level pulse width with a cycle becomes n x t_0 [s] ($t_0 = 2/fc$ [s] when DV1CK = 0, $t_0 = 4/fc$ [s] when DV1CK = 1).

The upper 4-bit of the PWM data latch controls a position to output the additional pulses. When the upper 4-bit of the PWM data latch is m, the additional pulses are generated in each of m periods out of 16 periods contained in a T_M period.

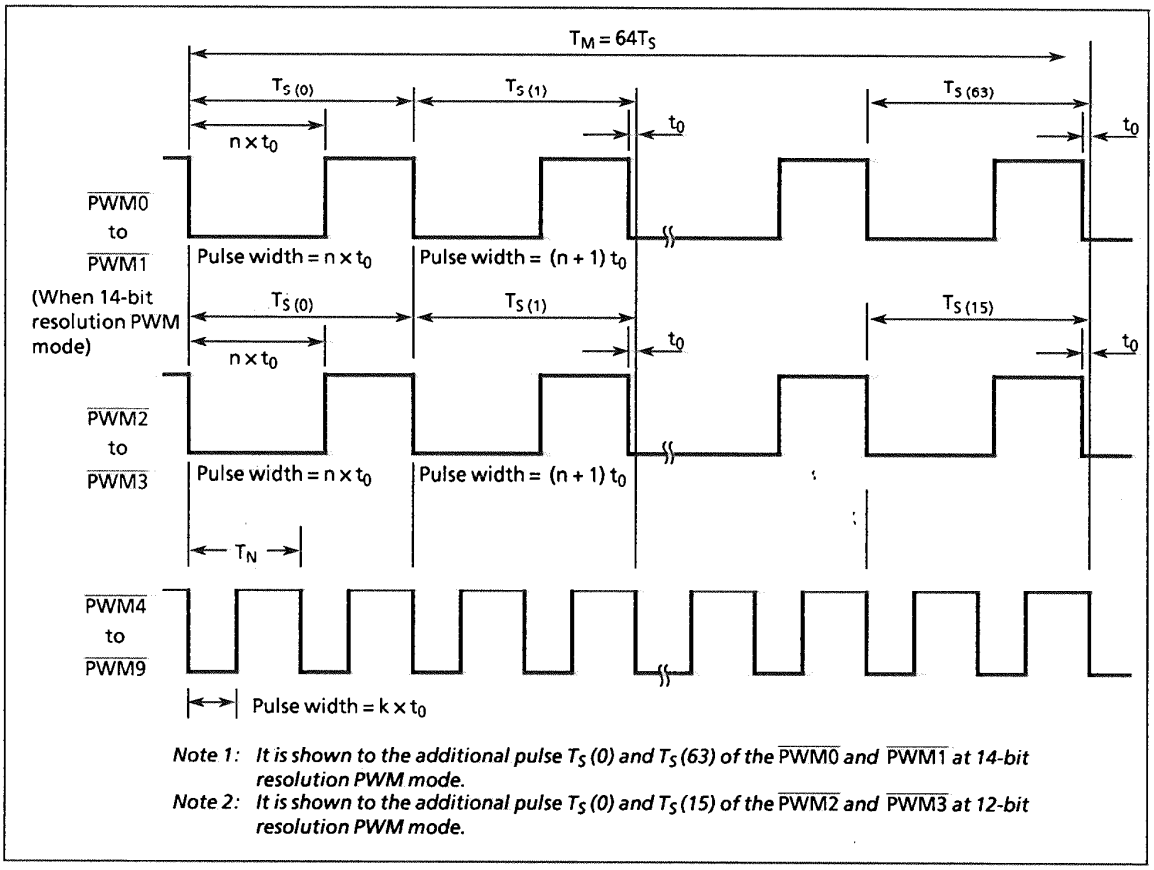
The relationship between the 4-bit data and the position of T_S period where the additional pulses are generated is shown in Table 2.13.1.

(3) $\overline{PWM4}$ to $\overline{PMW9}$ Outputs

These are 7-bit resolution PWM outputs.

One period is $T_N = 2^8/fc$ [s] (When DV1CK = 0) and $T_N = 2^9/fc$ [s] (When DV1CK = 1) .

The 7-bit of the PWM data latch controls the low level pulse width with a cycle of T_N. The lower 7-bit of the PWM data latch is k (k = 1 to 127), the low level pulse width with a cycle becomes k x t_0 [s] ($t_0 = 2/fc$ [s] when DV1CK = 0, $t_0 = 4/fc$ [s] when DV1CK = 1).



Note 1: It is shown to the additional pulse T_S (0) and T_S (63) of the $\overline{PWM0}$ and $\overline{PWM1}$ at 14-bit resolution PWM mode.

Note 2: It is shown to the additional pulse T_S (0) and T_S (15) of the $\overline{PWM2}$ and $\overline{PWM3}$ at 12-bit resolution PWM mode.

Figure 2.13.2 PWM output wave form

2.13.3 Control

PWM output is controlled by PWM Control Register (PWMCR1A, PWMCR1B, PWMCR2A, PWMCR2B) and PWM Data Buffer Register (PWMDBR1, PWMDBR2).

PWM Control Register 1A

PWMCR1A (00028_H)

7	6	5	4	3	2	1	0
–	ABORT1	START3	START2	START1	START0	RESOLUTION 1	RESOLUTION 0

(Initial value: *000 0000)

ABORT1	Abort PWM operation of channel 3 to 0	0: Operation 1: PWM Abort (PWM outputs are fixed to a high-level.)	Write only
START3	Start channel 3	0: Stop $\overline{PWM3}$ 1: Start $\overline{PWM3}$	
START2	Start channel 2	0: Stop $\overline{PWM2}$ 1: Start $\overline{PWM2}$	
START1	Start channel 1	0: Stop $\overline{PWM1}$ 1: Start $\overline{PWM1}$	
START0	Start channel 0	0: Stop $\overline{PWM0}$ 1: Start $\overline{PWM0}$	
RESOLUTION1	Select channel 1 resolution	0: 14-bit resolution 1: 12-bit resolution	
RESOLUTION0	Select channel 0 resolution	0: 14-bit resolution 1: 12-bit resolution	

*Note 1: * ; Don't care*
Note 2: The ABORT1 is cleared to "0" automatically.
Note 3: PWMCR1A is write-only register and cannot be used with any of the read-modify-write instructions such as SET, CLR, etc.

PWM Control Register 1B

PWMCR1B (00029_H)

7	6	5	4	3	2	1	0
					PWMCHS1		PWMHL

(Initial value: **** *000)

PWMCHS1	Select the PWM data latch of 12-bit PWM channels	00: Channel 0 01: Channel 1 10: Channel 2 11: Channel 3	Write only
PWMHL	Select upper or lower data transfer buffer	0: lower 8-bit 1: upper 4-bit or 6-bit	

*Note 1: * ; Don't care*
Note 2: PWMCR1B is write-only register and cannot be used with any of the read-modify-write instructions such as SET, CLR, etc.

PWM Data Buffer Register 1

PWMDBR1 ($0002A_H$)

7	6	5	4	3	2	1	0

(Initial value: 0000 0000)

Write only

Note 1: PWMDBR1 is write-only register and cannot be used with any of the read-modify-write instructions such as SET, CLR, etc.
Note 2: When operation mode is changed from STOP mode to NORMAL mode, PWMCR1A, PWMCR1B are initialized.

Figure 2.13.3 PWM Control Register 1A/1B and PWM Data Buffer Register 1

PWM Control Register 2A

PWMCR2A (00FF5H)

7	6	5	4	3	2	1	0
–	ABORT2	START9	START8	START7	START6	START5	START4

(Initial value: *000 0000)

ABORT2	Abort PWM operation of channel 9 to 4	0: Operation 1: PWM Abort	Write only
START9	Start channel 9	0: Stop $\overline{PWM9}$ 1: Start $\overline{PWM9}$	
START8	Start channel 8	0: Stop $\overline{PWM8}$ 1: Start $\overline{PWM8}$	
START7	Start channel 7	0: Stop $\overline{PWM7}$ 1: Start $\overline{PWM7}$	
START6	Start channel 6	0: Stop $\overline{PWM6}$ 1: Start $\overline{PWM6}$	
START5	Start channel 5	0: Stop $\overline{PWM5}$ 1: Start $\overline{PWM5}$	
START4	Start channel 4	0: Stop $\overline{PWM4}$ 1: Start $\overline{PWM4}$	

*Note 1: * ; Don't care*
Note 2: The ABORT2 is cleared to "0" automatically.
Note 3: PWMCR2A is write-only register and cannot be used with any of the read-modify-write instructions such as SET, CLR, etc.

PWM Control Register 2B

PWMCR2B (00FF6H)

7	6	5	4	3	2	1	0
					PWMCHS2		

(Initial value: **** *000)

PWMCHS2	Select the PWM data latch of 7-bit PWM channels	000: Channel 4 001: Channel 5 010: Channel 6 011: Channel 7 100: Channel 8 101: Channel 9 110: reserved 111: reserved	Write only

*Note 1: * ; Don't care*
Note 2: PWMCR2B is write-only register and cannot be used with any of the read-modify-write instructions such as SET, CLR, etc.

PWM Data Buffer Register 2

PWMDBR2 (00FF7H)

7	6	5	4	3	2	1	0

(Initial value: *000 0000)

Write only

*Note 1: * ; Don't care*
Note 2: PWMDBR2 is write-only register and cannot be used with any of the read-modify-write instructions such as SET, CLR, etc.
Note 3: When operation mode is changed from STOP mode to NORMAL mode, RWMCR2A, PWMCR2B are initialized.

Figure 2.13.4 PWM Control Register 2A/2B and PWM Data Buffer Register 2

Binary Counter Control Register

	7	6	5	4	3	2	1	0	
CGCR (00030_H)	–	–	DV1CK	–	"0"	"0"	"0"	"0"	(Initial value: **0* 0000)

DV1CK	Selection of input clock to 1st divider	0: fc/4 1: fc/8

R/W

*Note 1: * ; Don't care*

Note 2: Clear bit 3 to 0.

Figure 2.13.5 Binary Counter Control Register

(1) Internal Counter

The internal counter of PWM outputs is a free running counter. The all bits of counter are set to "1" and are not counted up at one of the following conditions.

① During reset
② The operation mode is changed to STOP or SLOW or SLEEP mode.
③ Setting ABORTx (x: 1, 2) to "1".
④ The START3 to 0 are "0" in 12-bit PWM outputs. The START9 to 4 are "0" in 7-bit PWM outputs.
⑤ The lower 8-bit of PWM data latch in 12-bit PWM outputs is "00_H". The PWM data latch in 7-bit PWM outputs is "00_H".

(2) Outputs control and Programming of PWM data

The PWM outputs are fixed to a high-level immediately when the ABORTx (x: 1, 2) is set to "1". The PWM outputs starts the operation when the STARTx (x: 0 to 9) is set to "1".

The data from the transfer buffer to a PWM data latch is transferred when the all bits of internal counter are set to "1". Therefore, the data is transferred to a PWM data latch immediately when the internal counter is initialized. And the data is transferred to a PWM data latch at the beginning of the next cycle when all bits of the internal counter are not set to "1".

The sequence of writing the output data to PWM data latches is shown as follows;

① $\overline{PWM0}$ to $\overline{PWM1}$

1. Write the channel number of PWM data latch to PWMCHS1 and clear PWMHL to "0".
2. Write the lower 8-bit PWM output data to PWMDBR1.
3. Write the channel number of PWM data latch to PWMCHS1 and set PWMHL to "1".
4. Write the upper 4-bit or 6-bit PWM output data to PWMDBR1.
5. Select the resolution of PWM output to RESOLUTIONx (x: 0, 1) and set STARTx (x: 0, 1) to "1".

Note: The upper 4-bit PWM output data of data and the lower 8-bit PWM output data must be write to PWMDBR1 even if the one of them is not changed (Except when lower 8-bit PWM output data is "00_H".).

② $\overline{PWM2}$ to $\overline{PWM3}$

1. Write the channel number of PWM data latch to PWMCHS1 and clear PWMHL to "0".
2. Write the lower 8-bit PWM output data to PWMDBR1.
3. Write the channel number of PWM data latch to PWMCHS1 and set PWMHL to "1".
4. Write the upper 4-bit PWM output data to PWMDBR1.
5. Set STARTx (x: 2, 3) to "1".

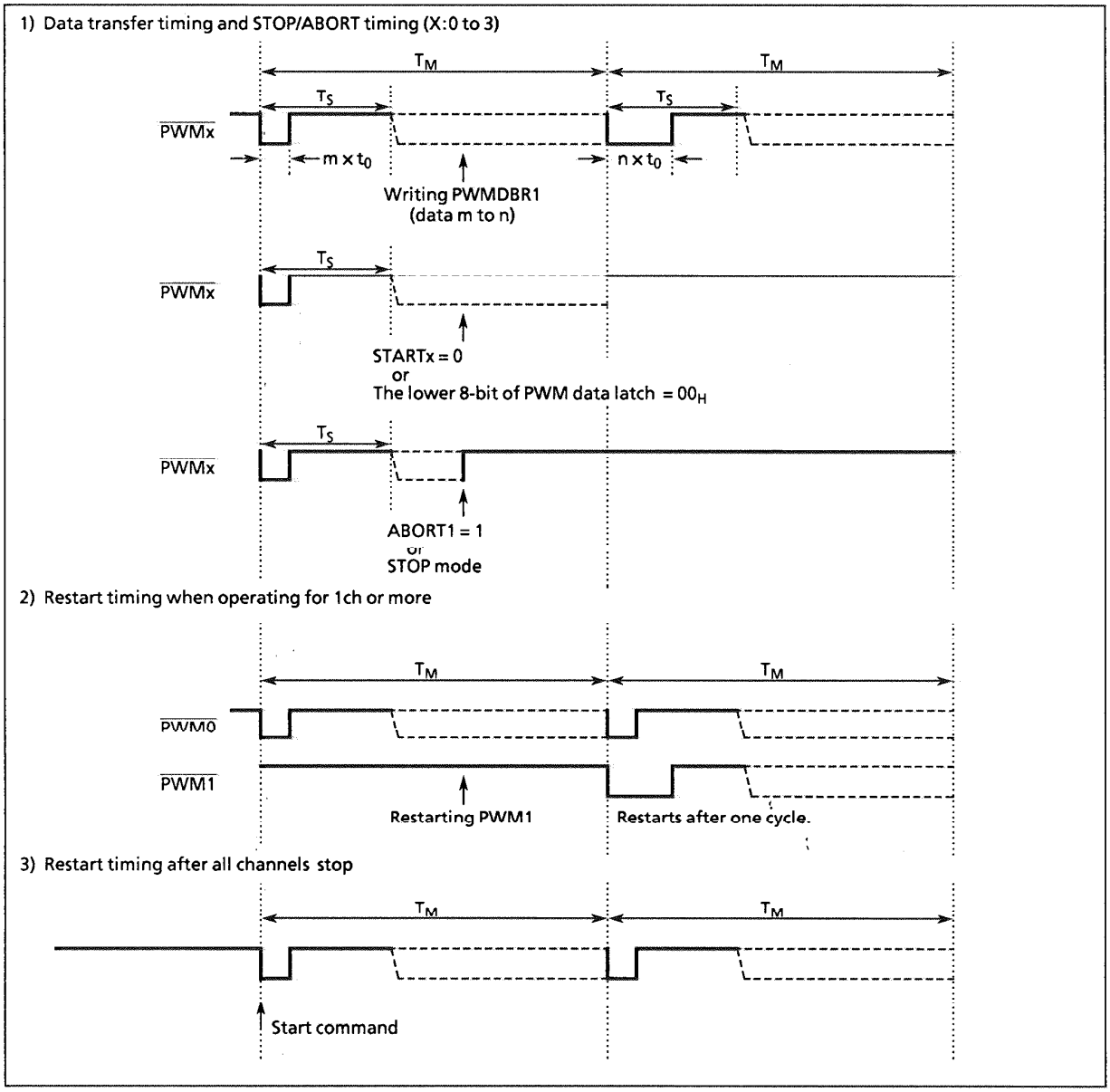


Figure 2.13.6 Wave form of $\overline{PWM0}$ to $\overline{PWM3}$

Note: The upper 4-bit PWM output data of data and the lower 8-bit PWM output data must be write to PWMDBR1 even if the one of them is not changed (Except when lower 8-bit PWM output data is "00_H".).

③ $\overline{PWM4}$ to $\overline{PWM9}$

1. Write the channel number of PWM data latch to PWMCHS2.
2. Write the lower 7-bit PWM output data to PWMDBR2.
3. Set STARTx (x: 4 to 9) to "1".

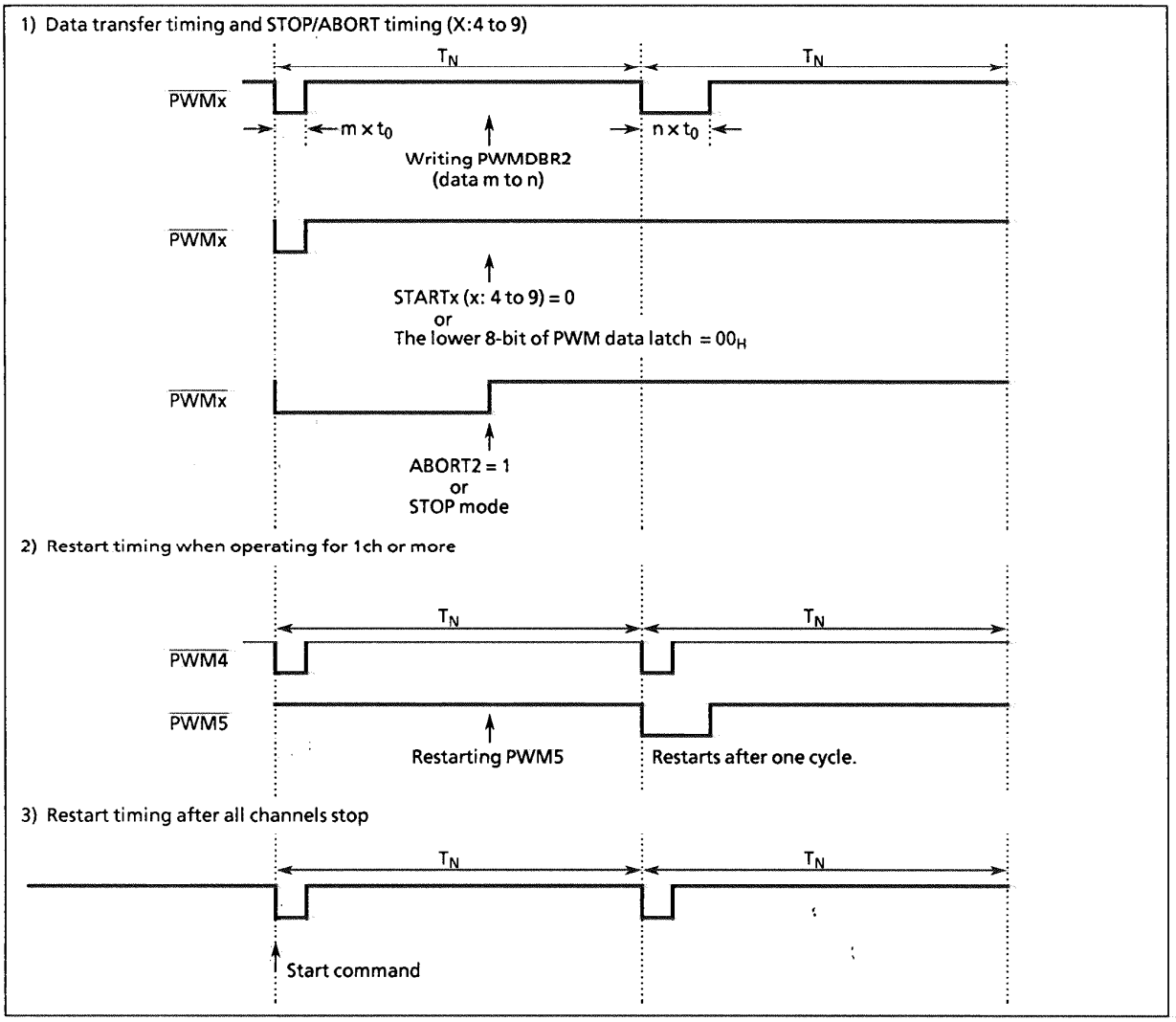


Figure 2.13.7 Wave form of $\overline{PWM4}$ to $\overline{PWM9}$

Example: At fc = 16MHz, DV1CK = 0

$\overline{PWM0}$ pin outputs a 14-bit resolution PWM wave form with a low-level of 16 μs width and additional pulse ($T_{S(16)}$, $T_{S(32)}$, $T_{S(48)}$).
$\overline{PWM1}$ pin outputs a 12-bit resolution PWM wave form with a low-level of 8 μs width and no additional pulse.
$\overline{PWM4}$ pin outputs a PWM wave form with a low-level of 4 μs width.

```
LD (CGCR),00H       ; DV1CK = 0

LD (PWMCR1B),00H    ; Select the lower 8-bit of PWM0 output data latch
LD (PWMDBR1),80H    ; 16 μs ÷ 2/fc = 80H
LD (PWMCR1B),01H    ; Select the upper 6-bit of PWM0 output data latch
LD (PWMDBR1),03H    ; Additional pulse (TS(16), TS(32), TS(48))
LD (PWMCR1B),02H    ; Select the lower 8-bit of PWM1 output data latch
LD (PWMDBR1),40H    ; 8 μs ÷ 2/fc = 40H
LD (PWMCR1B),03H    ; Select the upper 4-bit of PWM1 output data latch
LD (PWMDBR1),00H    ; No additional pulse
LD (PWMCR1A),0DH    ; Start PWM0 and PWM1,
                      PWM0: 14-bit resolution, PWM1: 12-bit resolution

LD (PWMCR2B),00H    ; Select PWM4 output data latch
LD (PWMDBR2),20H    ; 4 μs ÷ 2/fc = 20H
LD (PWMCR2A),01H    ; Start PWM4
```

2.14 Test Video Signal Output for Adjusting TV Screen

The TMP88CM38A/P38A have a built-in video signal output circuit to output necessary signal for TV screen adjustment.

Picture pattern: Total eight types, Monochromatic inversion possible
Output format: Three states (H, L, Hi-Z) output

Comp.Sync duration time	L output
Black level / Pedestal duration time	Hi-Z output
White level duration time	H output

2.14.1 Configuration

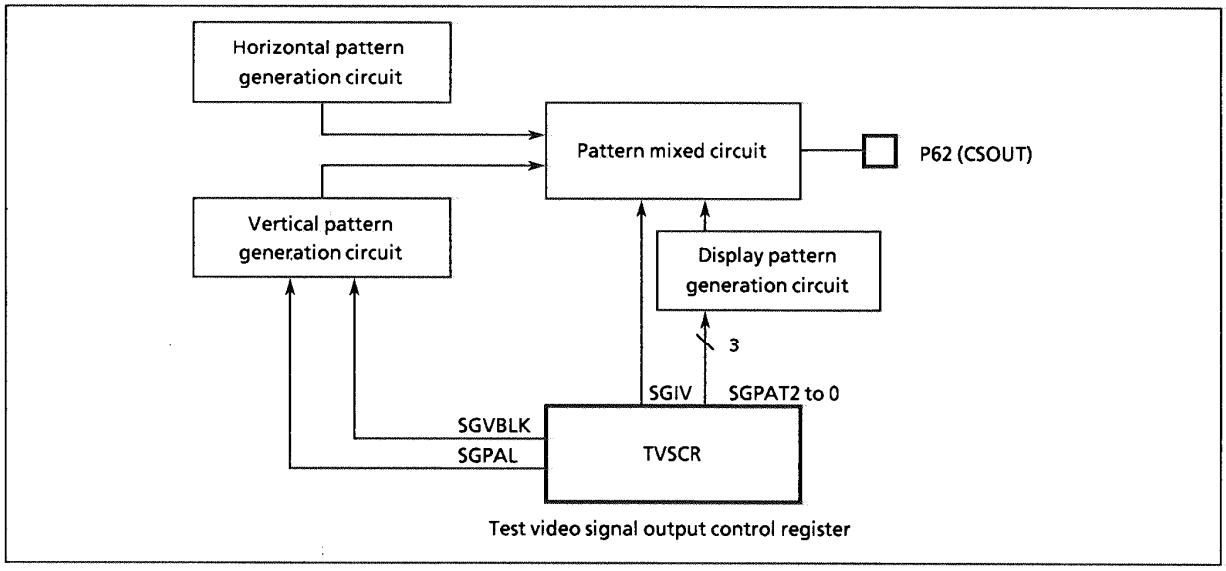


Figure 2.14.1 Test video signal output circuit

2.14.2 Control

The test video signal output circuit can be controlled with the test video signal control register.

TVSCR ($00FE6_H$)

7	6	5	4	3	2	1	0
SGEN	SGVBLK	SGPAL	SGIV	SGCHS		SGPAT	

(Initial Value: 0000 0000)

SGEN	SG function selection	0: disable 1: enable	Write only
SGVBLK	Picture signal for VBLK duration time	0: Output 1: No output	
SGPAL	PAL/NTSC selection	0: NTSC 1: PAL	
SGIV	Pattern monochromatic inversion	0: No inversion 1: Inversion	
SGCHS	OSD synchronous signal selection	0: Port 1: Pseudo signal circuit	
SGPAT	Display pattern	000: Black on the whole screen 001: White on the whole screen 010: Cross hatch 011: Cross dot pattern 100: Cross bar 101: White on the upper side / Black on the lower side 110: H signal pattern 111: H resolution pattern	

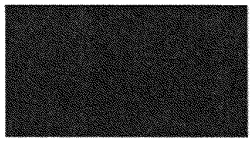
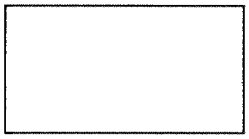
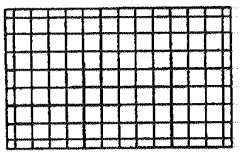
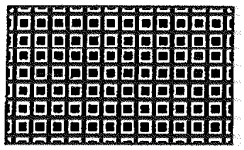
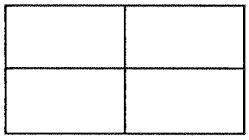
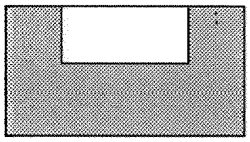
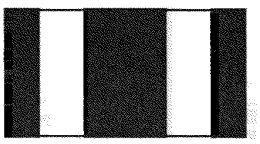
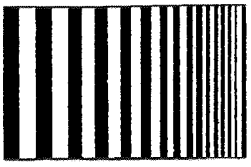
Note: Test video signal output function does work correctly when fc is not 16 MHz.

Figure 2.14.2 Test video signal control register

2.14.3 Functions

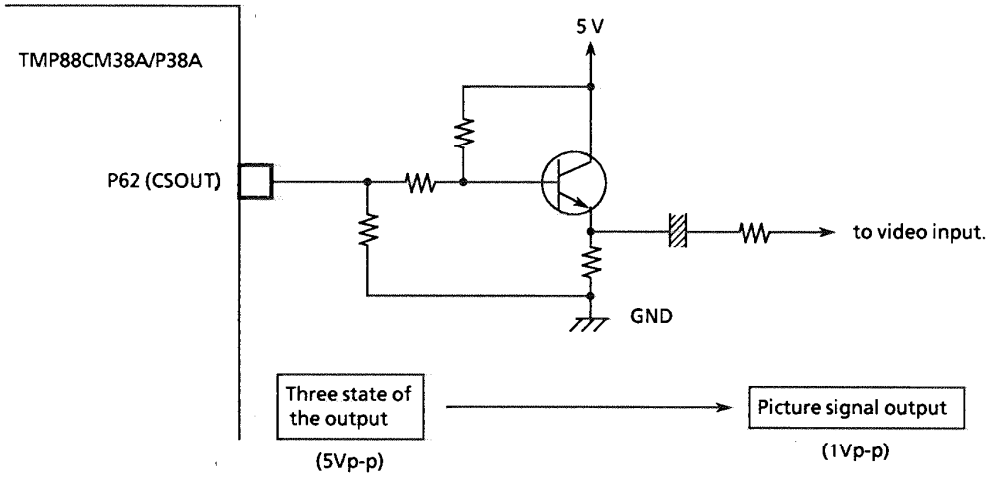
Video signal output is to generate monochromatic picture signal output to take easily the necessary tests such as TV screen white adjustment and screen distortion amplitude adjustment implemented on the final manufacturing process of a TV receiver set.

Table 2.14.1 Display pattern and TV screen

Display pattern	TV screen
000 (Black on the whole surface)	
001 (White on the whole surface)	
010 (Cross hatch)	
011 (Cross dot)	
100 (Cross bar)	
101 (White on the upper side / Black on the lower side)	
110 (H signal pattern)	
111 (H resolution pattern)	

There are three states of the output to generate picture signal with the external circuit of the resistance divided voltage.

Example of picture output generation)



2.15 On-Screen Display (OSD) Circuit

The TMP88CM38A/P38A features a built-in on-screen display circuit used to display characters and symbols on the TV screen. There are 384 characters and any characters can be displayed in an area of 32 columns × 12 lines. With an OSD interrupt, additional lines can be displayed. The functions of the OSD circuit meet the requirements of on-screen display functions of closed caption decoders based on FCC standards.

OSD circuit functions are as follows :

① Number of character fonts : 384
② Number of display characters : 384 (32 columns × 12 lines).
③ Composition of character : 16 × 18 dots
④ Character sizes : 3 (Selectable line by line)
⑤ Fringing function : for large, middle and small characters
⑥ Smoothing function : for large and middle characters
⑦ Slant function (Italics)
⑧ Blinking function
⑨ Underline
⑩ Solid space
⑪ Area plane function : 2 planes
⑫ Full-raster blanking function
⑬ Display colors
  Character colors : 8 or 15 colors (selectable character by character)
  Fringe color : 8 or 15 colors (selectable page by page)
  Background color : 8 or 15 colors (selectable page by page)
  Area plane color : 8 or 15 colors (selectable each of 2 planes)
  Raster color : 8 or 15 colors (selectable page by page)
⑭ Display position : 256 horizontal steps and 512 vertical steps for code plane
  : 512 horizontal steps and 512 vertical steps for Area plane
⑮ Window function : 512 vertical steps
⑯ Half transparency output function

The TMP88CM38A/P38A outputs OSD through 3 planes; code, area, and raster. 3 planes function independently. In addition, they are displayed simultaneously. There is the priority among these 3 planes, so OSDs are displayed on a screen according to the priority.

Code > Area > Raster

① Code plane

Usually, OSD character is displayed on the code plane. The code plane functions as a row displayed on a screen.

The code plane consists of 32 characters × 1 row and a total of 12 planes. The 12 planes have the priority such as code 1 > code 2 > ··· > code 11 > code 12.

On the code plane, characters of 16 × 18 dots is displayed. These fonts are called characters, and read from character ROM and display memory through the character code on the display memory.

② Area plane

The area on a screen is displayed on the area plane.

The area plane can display 2 square areas of any size by specifying coordinates. The 2 planes have the priority such as area plane 1 > area plane 2.

2.15.1 Configuration

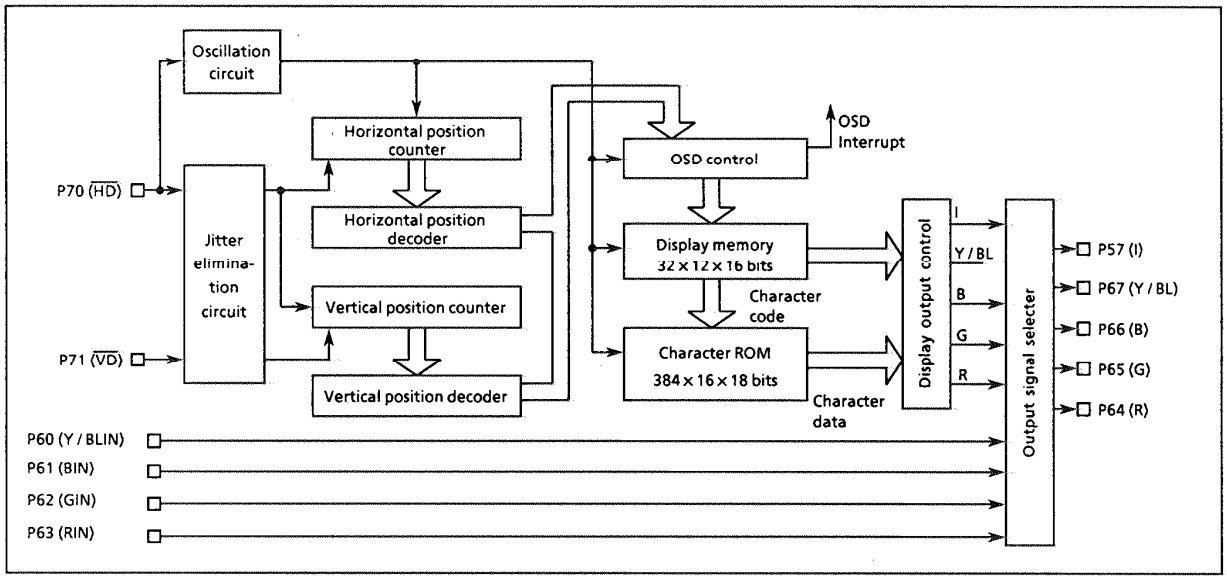


Figure 2.15.1 OSD Circuit

2.15.2 Character ROM and display memory

(1) Character ROM

The character ROM contains 384 character fonts. The user can set fonts as desired. The character ROM consists of 384 characters in 16 x 18 dots (character codes 000_H to $17F_H$). Each dot corresponds to one bit in the character ROM. When a bit in the character ROM is set to "1", the corresponding dot is displayed; if set to "0", the dot is not displayed. The start address in the character ROM corresponding to a character code is determined by the following expression:

$$\text{Start address in character ROM} = CRA \times 40_H + 20000_H$$

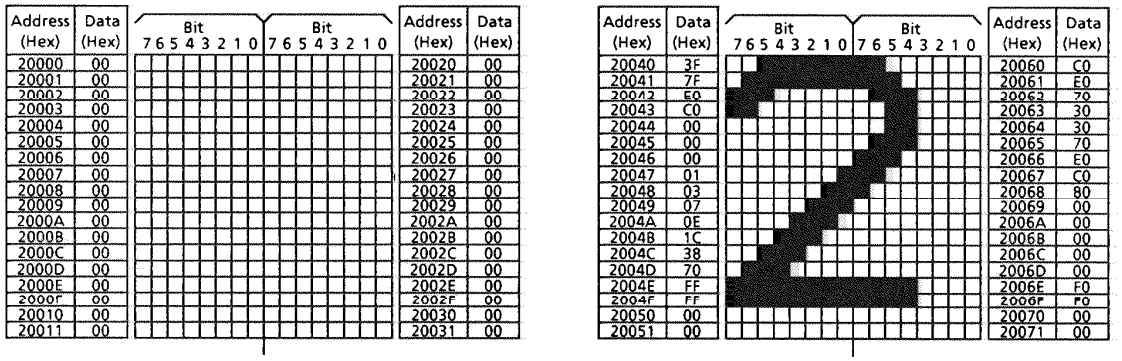
Since character code 000_H is used as blank character, the character font for this character code cannot be changed. Write "0" in the data of character code 000_H.

Write the data "FF_H" to all unused address (5th bit of an address is "1" and also the lower 4-bits of an address are 2_H to F_H) in character ROM.

Figure 2.15.2 (a) shows an example of the character font configuration for the character code 000_H and 001_H, together with the ROM addresses and data.

Figure 2.15.2 (b) shows the character ROM dump list for these 2 character fonts.

Note 1: CRA ; Character code (000_H to $17F_H$).
Note 2: A data can not be read from character ROM by software.
Note 3: When ordering a mask, load the data to character ROM at addresses 20000_H to $25FFF_H$. And the data in unused are of character ROM are must be specified to FF_H.



(a) Character font configuration

```
20000/ 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
20010/ 00 00 FF FF FF FF FF FF FF FF FF FF FF FF FF FF
20020/ 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
20030/ 00 00 FF FF FF FF FF FF FF FF FF FF FF FF FF FF
20040/ 3F 7F E0 C0 00 00 00 01 03 07 0E 1C 38 70 FF FF
20050/ 00 00 FF FF FF FF FF FF FF FF FF FF FF FF FF FF
20060/ C0 E0 70 30 30 70 E0 C0 80 00 00 00 00 00 F0 F0
20070/ 00 00 FF FF FF FF FF FF FF FF FF FF FF FF FF FF
```

(b) ROM dump list

Figure 2.15.2 Character font configuration and ROM dump list

(2) Display memory

Each character of the 384 characters displayed in 32 columns x 12 lines consists of 16 bits in the display memory. Five data items are written to the display memory: character code, color data, blinking specification, underline enable, and slant enable.

There are two modes for writing display data to the display memory. One mode is used for writing all display data (character code, color data, blinking specification, underline enable, and slant enable) simultaneously. The other mode is used for changing either character codes or the remaining data items (color data, blinking specification, underline enable, and slant enable). How to write display data to the display memory is described in section 2.15.5.7 (1).

Note: The display memory is in an unknown state at reset.

Display memory configuration

- Character code specification register (9 bits) ..... CRA8 to CRA0
- Color data specification register (4 bits) ..... IDT / RDT / GDT / BDT
- Blinking specification register (1 bit) ..... BLF
- Underline enable register (1 bit) ..... EUL
- Slant enable register (1 bit) ..... SLNT

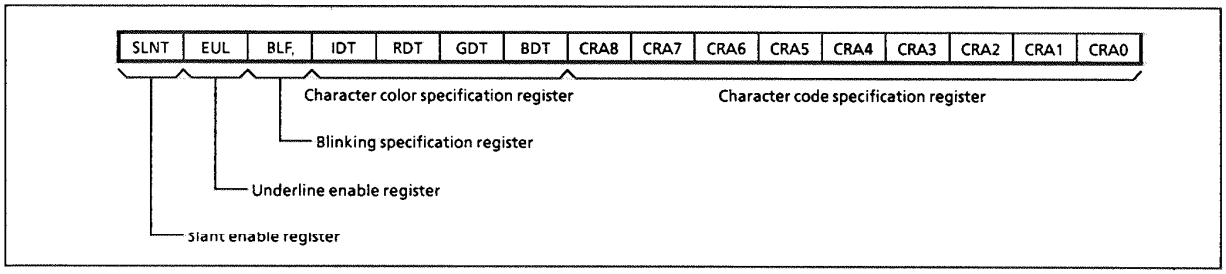


Figure 2.15.3 Display Memory Bit Configuration

Line \ Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	000	001	002	003	004	005	006	007	008	009	00A	00B	00C	00D	00E	00F	010	011	012	013	014	015	016	017	018	019	01A	01B	01C	01D	01E	01F
2	020	021	022	023	024	025	026	027	028	029	02A	02B	02C	02D	02E	02F	030	031	032	033	034	035	036	037	038	039	03A	03B	03C	03D	03E	03F
3	040																															
4	060																															
5	080																															
6	0A0																															
7	0C0																															
8	0E0																															
9	100																															
10	120																															
11	140																															
12	160																															17F

Note. Numerals in the table indicate (hexadecimal) addresses in the display memory.

Figure 2.15.4 Display Memory Address Configuration

2.15.3 OSD Circuit Control

The OSD circuit performs control functions using the OSD control registers which reside in addreses $0001D_H$ to $0001F_H$ and 00024_H to 00025_H in the special function registers (SFR), and in addresses $00F80_H$ to $00FC1_H$ in the data buffer register (DBR). Section 2.15.5.9 shows the OSD control registers. To write data to the OSD control registers, use the normal data buffer register access method. The OSD control registers are used to set display start position, display character designs (that is, fringing, smoothing, color data, character size, and etc.), display memory addresses, and character codes.

Setting the display on-off control bit, DON, (bit 0 in ORDON) to "1" enables display (starts display). Setting DON to "0" disables display (halts display).

Note: The contents of OSD control registers except PIDS, P67S to P64S are initialized in STOP mode.

2.15.4 OSD Control Register Write / Read

The addresses of the OSD control registers are assigned to the SFR and DBR register.

For writing data to or reading data from the OSD control registers, access the SFR and DBR register in the normal way.

If RGWR register is set to "1" the written data is transferred to the OSD circuit and become valid.

However, while the display line is being scanned, the data written after the display line is scanned is transferred to the OSD circuit and becomes valid.

The registers for writing data to display memory become valid, when its data is written. (VDSMD, PISEL, BKMF, ESMZ, MFYWR, MBK, RDWRV, SVD, ISDC, P67S to P64S, PIDS, YBLCS, MPXS, VDPOL, HDPOL, YBLII, RGBII, YIV, BLIV, RGBIV, IIV, DMA8 to 0, SLNT, EUL, BLF, IDT, RDT, GDT, BDT, CRA8 to 0, and RGWR)

Written data transfer register (1 bit) ..... RGWR (Bit 2 in ORDON)

"0" ..... Initialized state

"1" ..... Transfers written data to OSD circuit.
(After transfer, RGWR is reset to 0.)

Note: Don't write "0" to RGWR.

<RGWR timing>

(1) RGWR system

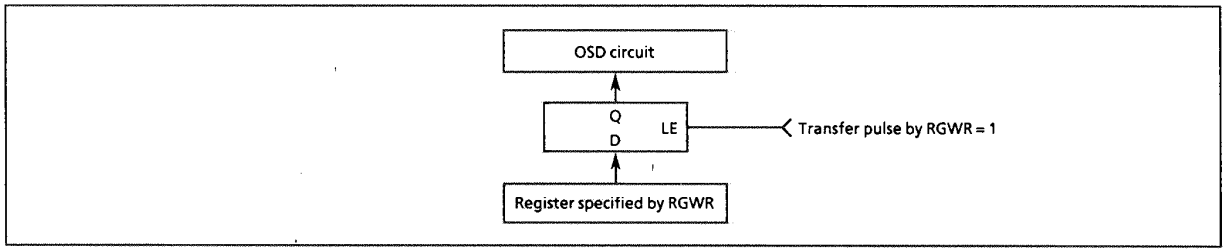


Figure 2.15.5 RGWR System

(2) Transfer timing

① No display area
When having set RGWR to "1" during no display area, the timing OSD register can be transferred is at the falling edge of $\overline{HD}$ signal.

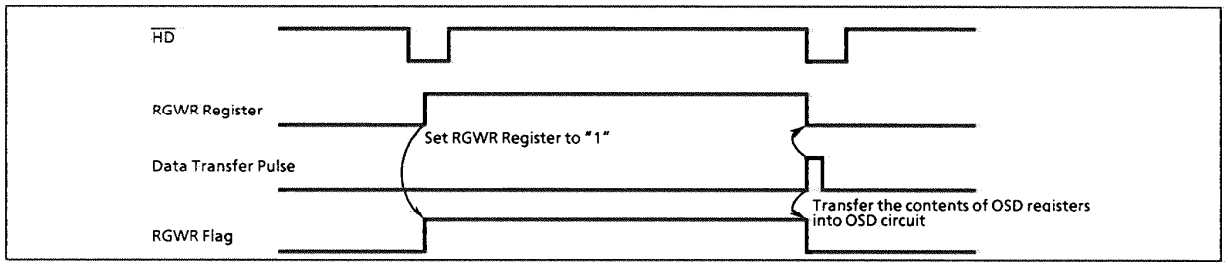


Figure 2.15.6 Data Transfer Timing in No Display Area

② Display area (including any lines specified as display off by character size)
When having set RGWR to "1" during display area, the timing OSD register can be transferred is at the falling edge of $\overline{HD}$ signal when the display line has been finished.

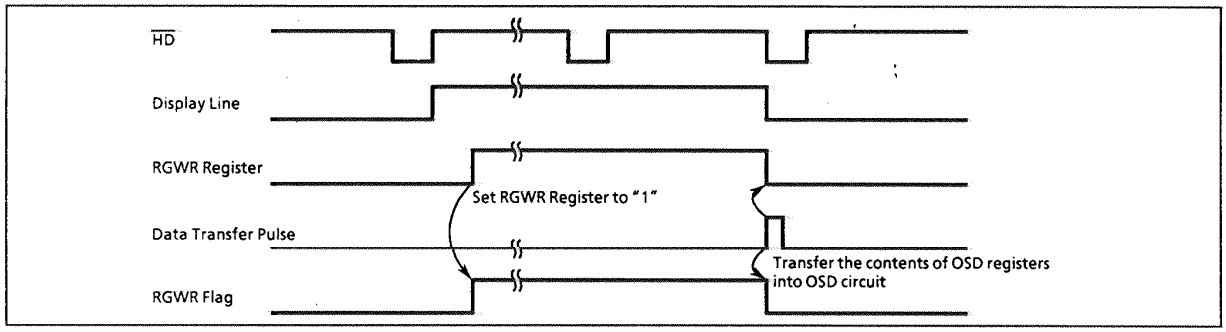


Figure 2.15.7 Data Tranfer Timing in Display Area

(3) Flag
RGWR flag is set to "1" during the period from the timing having set RGWR register to "1" to the timing data transfer pulse is generated.
When RGWR flag becomes "0", the data of OSD register can be available. After setting RGWR register to "1", it is possible to write OSD registers even RGWR flag is "1".

2.15.5 OSD function

2.15.5.1 Signal control (Port I/O)

(1) P6 port output select function
This function is used to select whether the contents of port P57, P67 to P64 will be output or I, R, G, B, Y/BL signals of the OSD circuit will be output on pins P57, P67 to P64.

P57 port output select registers (1 bits): PIDS (bit 3 in ORP6S)

	PIDS = 0	PIDS = 1
P57	I	Port

P67 to P64 port output select registers (4 bits): P67S, P66S, P65S, P64S, (bit 7 to 4 in ORP6S)

	P6nS = 0	P6nS = 1
P64	R	Port
P65	G	
P66	B	
P67	Y/BL	

(2) OSD pin output polarity control function
This function is used to select the polarity of the OSD outputs for RGB, I and Y/BL.

Output polarity control register (4 bits) ··· BLIV, YIV, RGBIV, IIV (bit 3 to 0 in ORIV)

Table 2.15.1 Control of OSD Output Polarity

Symbol	Output port	Data "0"	Data "1"
BLIV	BL	Active High	Active Low
YIV	Y	Active High	Active Low
RGBIV	RGB	Active High	Active Low
IIV	I	Active High	Active Low

(3) OSD pin input polarity control

Input polarity control
Input polarity control register of RIN / GIN / BIN / Y / BLIN (2 bits)
For Y / BLIN ..... YBLII (Bit 5 in ORIV)
For RIN, GIN, and BIN ..... RGBII (Bit 4 in ORIV)
Input polarity control
**II
"0" ..... Active high
"1" ..... Active low
Input polarity control register of $\overline{HD}$ / $\overline{VD}$ (2 bits)
For $\overline{VD}$ ..... VDPOL (Bit 7 in ORIV)
For $\overline{HD}$ ..... HDPOL (Bit 6 in ORIV)
Input polarity control
**POL
"0" ..... Not invert input signal
"1" ..... Invert input signal

(4) Y/BL signal select function
This function is used to select either Y or BL signal output from the Y/BL pin.

Y/BL signal select register (1 bit) ··· YBLCS (bit 7 in ORP6S)
"0" ··· Y signal output
"1" ··· BL signal output

Y signal ··· Output in all OSD areas (Logical OR for R, G, B, Character data, Fringing data, area data, etc.)
BL signal ··· When EXBL is "0":
Output in all display character areas
(except for character code 000_H: blank character)
When EXBL is "1":
Output in the whole page

(5) I signal function select
When PISEL (bit 6 in ORETC) is set to "1" and PIDS (bit 3 in ORP6S) is set to "0", Port 57 (I pin) can be used as Half Transparency / Half Tone through an extra circuit.
At Half Transparency / Half Tone function, contents of IDT (bit 3 in ORDSN) is make no sense. Therefore character color are limited to 8 colors.
Similarly background color, fringing color, raster plane color and area plane color are limited to 8 colors.
When PISEL (bit 6 in ORETC) sets to "0" and, PIDS (bit 3 in ORP6S) set to "0", 15 colors to be selectable.

(6) R, G, B, Y / BL Internal / external signal select.
Selects either R, G, B, and Y / BL signals from the internal OSD circuit, or RIN, GIN, BIN, and Y / BLIN signals from external input.

R, G, B, Y / BL signal select registers (2 bits) ..... MPXS1 / MPXS0
(Bits 1 and 0 in ORP6S)
"00" ..... Simultaneous output (Signal from the OSD circuit has higher priority.)
"01" ..... Output of signal from internal OSD circuit
"10" ..... Output of signal from external input
"11" ..... Simultaneous output (External input signal has higher priority.)

2.15.5.2 OSD data output format control

(1) Scan mode

The double scan mode is used to handle non-interlaced scanning TV. When double scan mode is enabled, the vertical display counter increases every 2 scan lines and a vertical size of a dot is double. This function is enabled by setting VDSMD (bit 7 in ORETC) in the OSD control register to "1".

Scan mode select register (1 bit) ··· VDSMD (bit 7 in ORETC)
"0" ··· Normal mode
"1" ··· Double scan mode

Note 1: The data written to those control register is transferred to the OSD circuit and become valid when the data is written.
Note 2: When OSD circuit is used on an interlace scanning TV, a jitter elimination circuit must be enabled and set AFLD to "1" in JECR.

Table 2.15.2 The difference of 2 types of scan mode

	Normal mode	Double scan mode
Specification Unit of vertical display start position	1 scan line	2 scan lines
1 dot height	—	Normal mode height × 2

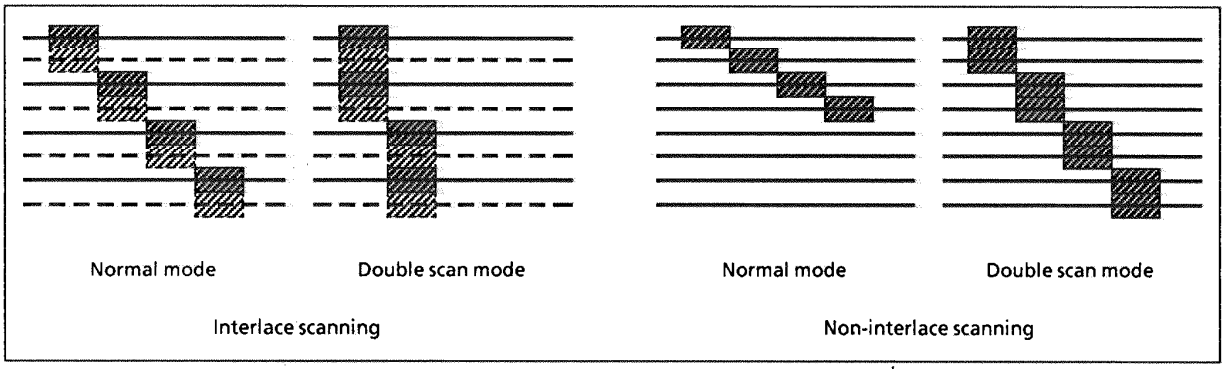


Figure 2.15.8 Scan mode

2.15.5.3 Display position control

(1) Code display position setting

① Horizontal display start position

The horizontal display start position can be set in 256 steps by writing to OSD control registers HS17 to HS10 (bit 7 to 0 in ORHS1). The value is in common with all lines.

Specification unit: 2 T_{OSC}

Specification steps: 256

Specification horizontal display start position: Line 1 to 12: HS17 to HS10 (ORHS1)

HS1 = (HS17 to HS10) $_H \times 2T_{OSC} + 20T_{OSC}$ (Line1 to 12)

Note 1: T_{OSC} ; One cycle of OSD oscillation (normal mode) or $\frac{1}{2}$ cycle of OSD oscillation (double speed mode).

Note 2: The data written to these control registers is transmitted to OSD circuit by setting RGWR (bit 2 in ORDON) to "1".

② Vertical display start position

The vertical display start position can be specified for each display line using 512 steps by writing to VSn8 to VSn0 (in ORVSn (n;1 to 12)).

Specification unit: 1 scan line (Normal mode)

Specification steps: 512

Specification vertical display start position: Line1: VS18 to VS10 (ORVS 1)
Line2: VS28 to VS20 (ORVS 2)
⋮
Line12: VS128 to VS120 (ORVS 12)

Line n: VSn = (VSn8 to VSn0) $_H \times 1T_{HD}$ (n : 1 to 12)

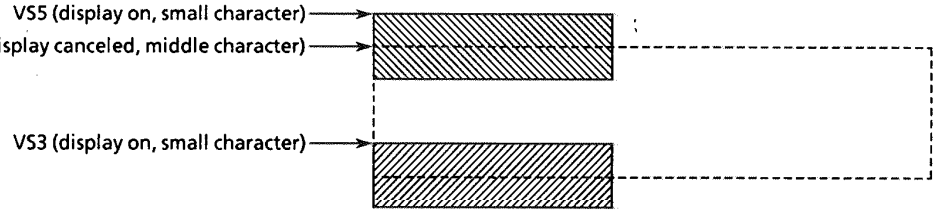
Note1: T_{HD} ; One cycle of $\overline{HD}$ signal (normal mode) or two cycle of $\overline{HD}$ signal (double scan mode).

Note2: The data written to these control registers is transmitted to OSD circuit by setting RGWR (bit 2 in ORDON) to "1".

Note3: If display lines are overlapped each other, previous display line is enabled and next line is disabled. If vertical display start positions of two or more lines are set on same value, high priority line is enabled. Lines of OSD (VS1 to VS12) are fixed priority levels as follows:

VS1 > VS2 > VS3 > ····· > VS12

Set the vertical display start position not to overlap display lines.



Occasion of overlapping

Note4: The line which is displayed off is managed as a small size character line.

Note5: Transfer the contents of vertical display start positon registers into OSD circuit before the position of the scanning line coincides with their own vertical display start position.

(2) Area display position setting

The planes have the priority such as Code plane > Area plane 1 > Area plane 2 > Raster plane.

① Horizontal display start position

The horizontal display start position can be set in 512 steps by writing to OSD control registers AHSn8 to AHSn0 (bit 8 to 0 in ORAHSn). And also display stop position is correspond to AHEn8 to AHEn0 (bit 8 to 0 in ORAHEn). (n; 1 to 2)

Horizontal display start position

$AHSn = (AHSn8 \text{ to } AHSn0)_H \times 2T_{OSC}$

$AHEn = (AHEn8 \text{ to } AHEn0)_H \times 2T_{OSC}$

Note: T_{OSC}; One cycle of OSD oscillation.

② Vertical display start position

The vertical display start position can be set in 512 steps by writing to OSD control registers AVSn8to AVSn0 (bit 8 to 0 ORAVSn). And also display stop position is correspond to AVEn8 to AVEn0 (bit 8 to 0 in ORAVEn). (n; 1 to 2)

Vertical display start position

$AVSn = (AVSn8 \text{ to } AVSn0)_H \times T_{HD}$

$AVEn = (AVEn8 \text{ to } AVEn0)_H \times T_{HD}$

Note: T_{HD}; One cycle of $\overline{HD}$ signal.

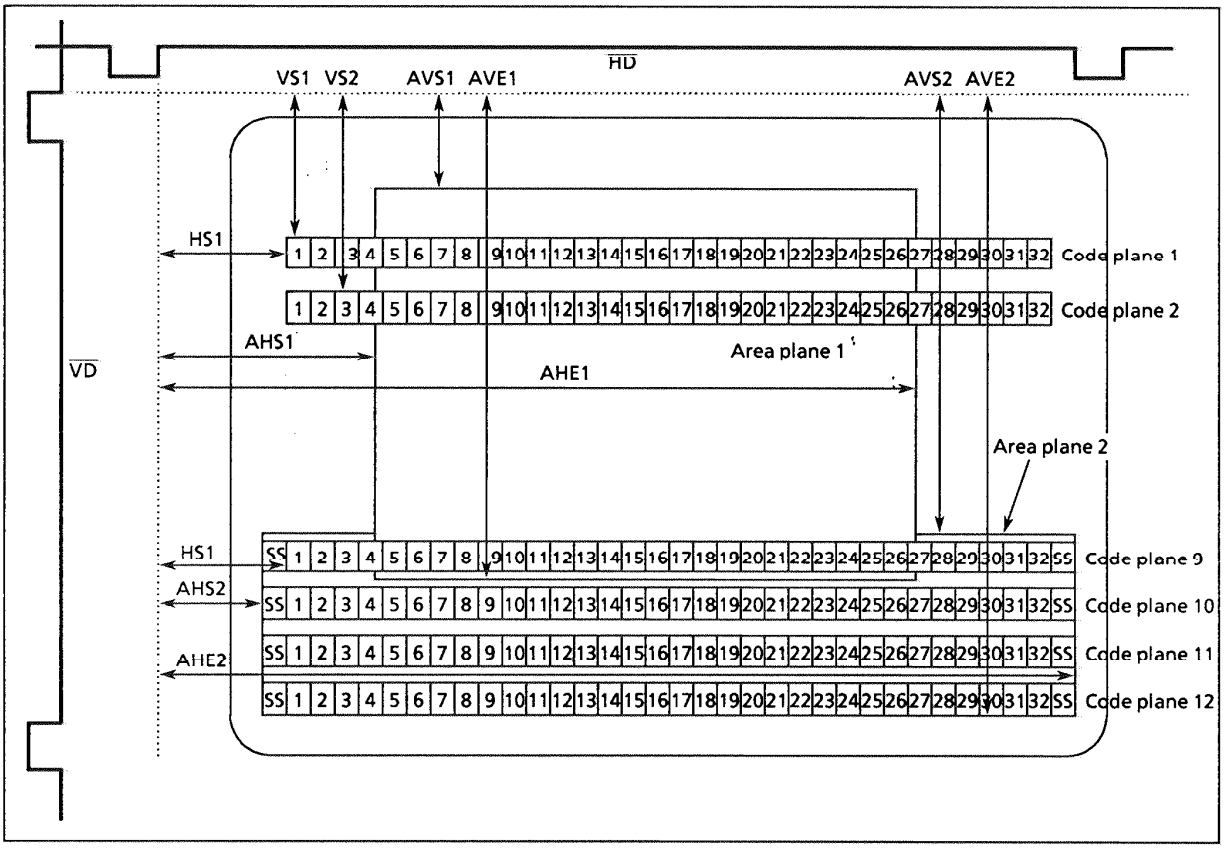


Figure 2.15.9 TV scan image

2.15.5.4 Character ornamentation control

(1) Character sizes

Character size can be selected line by line from 3 sizes. And display on / off also can be set line by line. Small, middle and large character size and display on / off can be set with OSD control registers CSn (n = 1 to 12, ORCS4, ORCS8, ORCS12) in the OSD control registers.

Character sizes : 3 sizes (Small, middle and large)
Character size and display on / off specification unit: Line
Character size select/display on / off register (2 bits x 12)
Line 1: CS1
Line 2: CS2
: :
Line 12: CS12

Table 2.15.3 Character size and display on / off specifications (n;1 to 12)

CSn (Upper bit)	CSn (Lower bit)	Character size	Display on/off
1	1	Small	On
1	0	Middle	On
0	1	Large	On
0	0	–	Off

Note 1: The display off line operates like the width of small character size line thought the character is not displayed.
Note 2: The data written to these control registers is transmitted to OSD circuit by setting RGWR (bit 2 in ORDON) to "1".
Note 3: When OSD circuit is used on an interlace scanning TV, a jitter elimination circuit must be enabled and set AFLD to "1" in JECR.
Note 4: When VDSMD and AFLD are "0", only character of even display dot is displayed. (refer to 2.16 a jitter elimination circuit)

Table 2.15.4 Dot and character sizes

		VDSMD = 0 (Normal mode)			VDSMD = 1 (Double scan mode)		
		Dot size	Character size		Dot size	Character size	
			EFRn = 0 (Fringe OFF)	EFRn = 1 (Fringe ON)		EFRn = 0 (Fringe OFF)	EFRn = 1 (Fringe ON)
EULAn = 0 (Underline OFF)	Small	$1T_{OSC} \times 0.5T_{HD}$	$16T_{OSC} \times 9T_{HD}$	$16T_{OSC} \times 11T_{HD}$	$1T_{OSC} \times 1T_{HD}$	$16T_{OSC} \times 18T_{HD}$	$16T_{OSC} \times 20T_{HD}$
	Middle	$2T_{OSC} \times 1T_{HD}$	$32T_{OSC} \times 18T_{HD}$	$32T_{OSC} \times 20T_{HD}$	$2T_{OSC} \times 2T_{HD}$	$32T_{OSC} \times 36T_{HD}$	$32T_{OSC} \times 40T_{HD}$
	Large	$4T_{OSC} \times 2T_{HD}$	$64T_{OSC} \times 36T_{HD}$	$64T_{OSC} \times 40T_{HD}$	$4T_{OSC} \times 4T_{HD}$	$64T_{OSC} \times 72T_{HD}$	$64T_{OSC} \times 80T_{HD}$
EULAn = 1 (Underline ON)	Small	$1T_{OSC} \times 0.5T_{HD}$	$16T_{OSC} \times 12T_{HD}$	$16T_{OSC} \times 13T_{HD}$	$1T_{OSC} \times 1T_{HD}$	$16T_{OSC} \times 24T_{HD}$	$16T_{OSC} \times 25T_{HD}$
	Middle	$2T_{OSC} \times 1T_{HD}$	$32T_{OSC} \times 24T_{HD}$	$32T_{OSC} \times 25T_{HD}$	$2T_{OSC} \times 2T_{HD}$	$32T_{OSC} \times 48T_{HD}$	$32T_{OSC} \times 50T_{HD}$
	Large	$4T_{OSC} \times 2T_{HD}$	$64T_{OSC} \times 48T_{HD}$	$64T_{OSC} \times 50T_{HD}$	$4T_{OSC} \times 4T_{HD}$	$64T_{OSC} \times 96T_{HD}$	$64T_{OSC} \times 100T_{HD}$

Note: T_{OSC}; One cycle of OSD oscillation T_{HD}; One cycle of $\overline{HD}$ signal

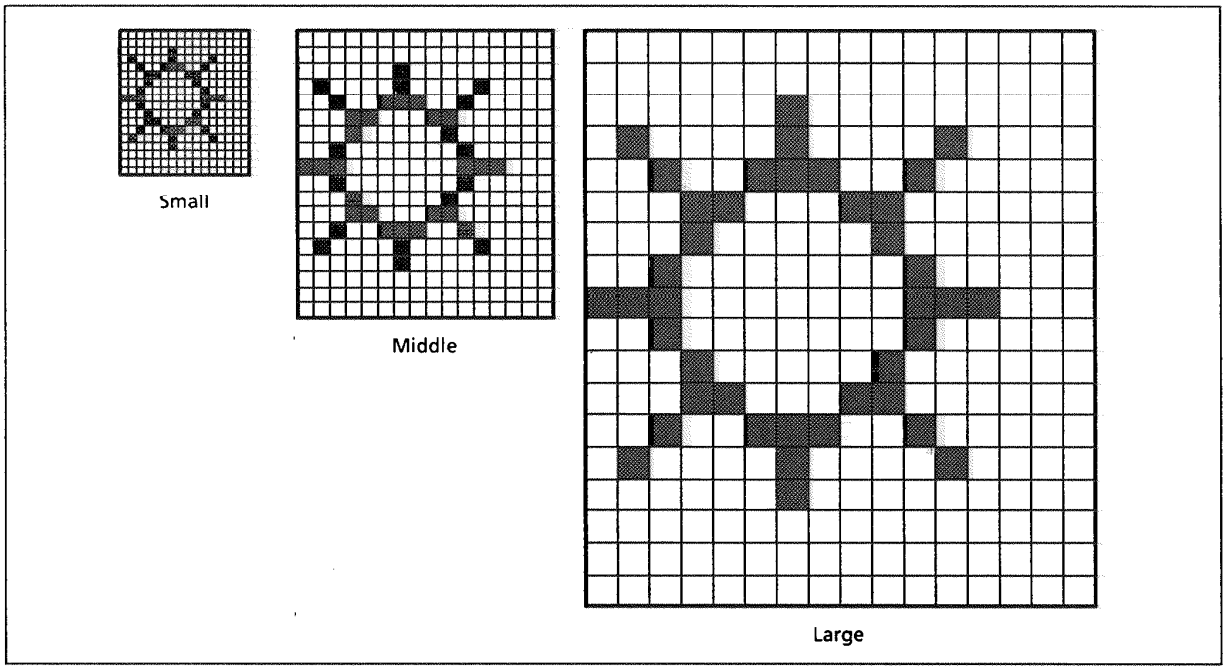


Figure 2.15.10 Character size

(2) Smoothing function

The smoothing function is used to make characters look smooth. Enabling smoothing displays 1/4 dot between two dots connecting corner to corner within a character. Small size character can not be enabled smoothing. Smoothing is enabled by setting ESMZ (bit 4 in ORETC) in the OSD control register to "1".

Smoothing specification unit: Display page
Smoothing specification register (1 bit) ··· ESMZ (bit 4 in ORETC)
"0" ··· Disable smoothing
"1" ··· Enable smoothing

Note: Data of the register is transferred to the OSD circuit and become valid when the data is written.

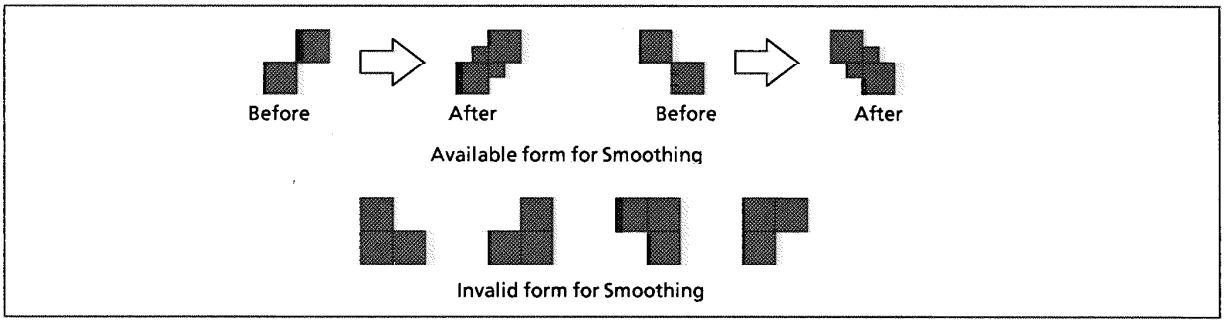


Figure 2.15.11 Available form and Invalid form for Smoothing

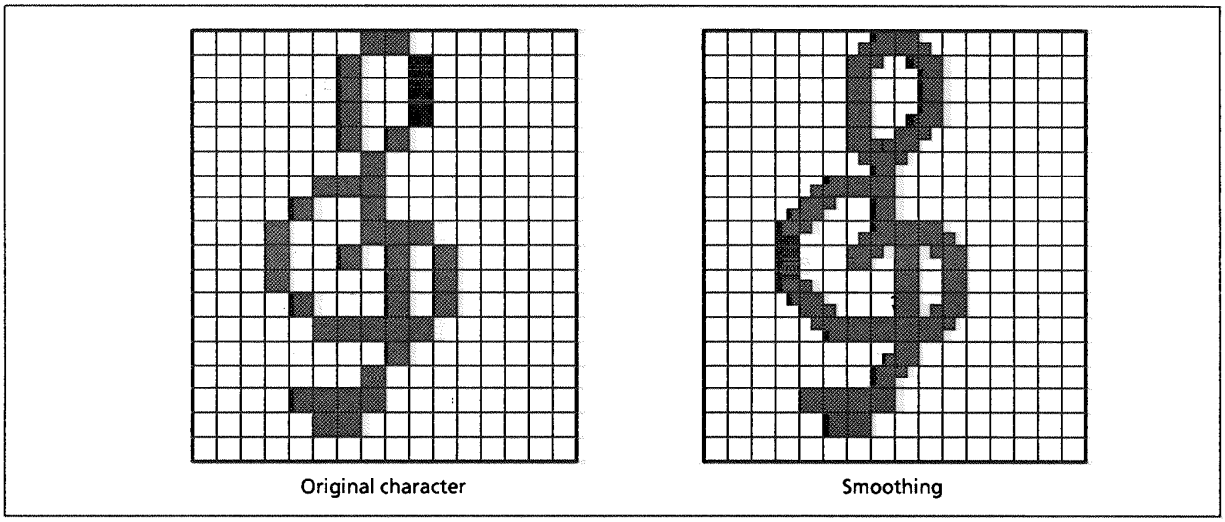


Figure 2.15.12 Smoothing example

(3) Fringing function

The fringing function is used to display a character with a fringe width is 1 dot in a different color from that of the character. When a character is displayed with the maximum of 18 vertical dots and 16 horizontal dots, the fringe exceeds right and left, top, and bottom of the character display area. If there is an adjacent character that outer dot is active, then this dot will overrule the fringe in the horizontal direction. Underlines are not fringed.

Fringing is enabled for each line by setting EFR1 to EFR8 (OREFR8) and EFR9 to EFR12 (OREFR12) in the OSD control register to "1".

A color for fringe is specified common to all lines using OSD control registers, IFDT, RFDT, GFDT, and BFDT (bit 3 to 0 in ORBK).

Fringing specification unit: Line

Fringing enable register (1 bit x 12) ··· EFRn (n ; 1 to 8) (OREFR8), EFRn (n;9 to 12) (OREFR12)

"0" ··· Disable fringing

"1" ··· Enable fringing

Fringe colors: 8 or 15

Fringe color specification unit: Display page

Fringe color register (4 bits) ··· IFDT, RFDT, GFDT, BFDT (bit 3 to 0 in ORBK)

I signal function select: PISEL (bit 6 in ORETC)

"0" ··· 15 colors specification

I pin can be used to make a half level of R, G, B signal (dark color) through an extra circuit.

"1" ··· 8 colors specification

Contents of IDT register is disregarded.

I pin can be used as Half Transparency / Half Tone through an extra circuit.

Table 2.15.5 Fringe color (15 colors)

IFDT	RFDT	GFDT	BFDT	Figure color
0	0	0	0	Black
	0	0	1	Blue
	0	1	0	Green
	0	1	1	Cyan
	1	0	0	Red
	1	0	1	Magenta
	1	1	0	Yellow
	1	1	1	White
1	0	0	0	Black
	0	0	1	Dark Blue
	0	1	0	Dark Green
	0	1	1	Dark Cyan
	1	0	0	Dark Red
	1	0	1	Dark Magenta
	1	1	0	Dark Yellow
	1	1	1	Gray

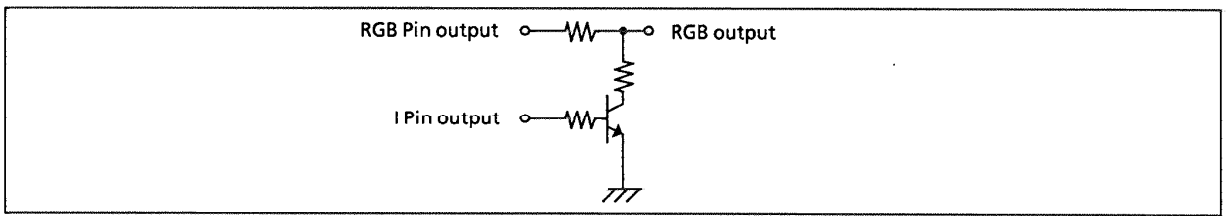


Figure 2.15.13 Example circuit for 15 colors by I pin.

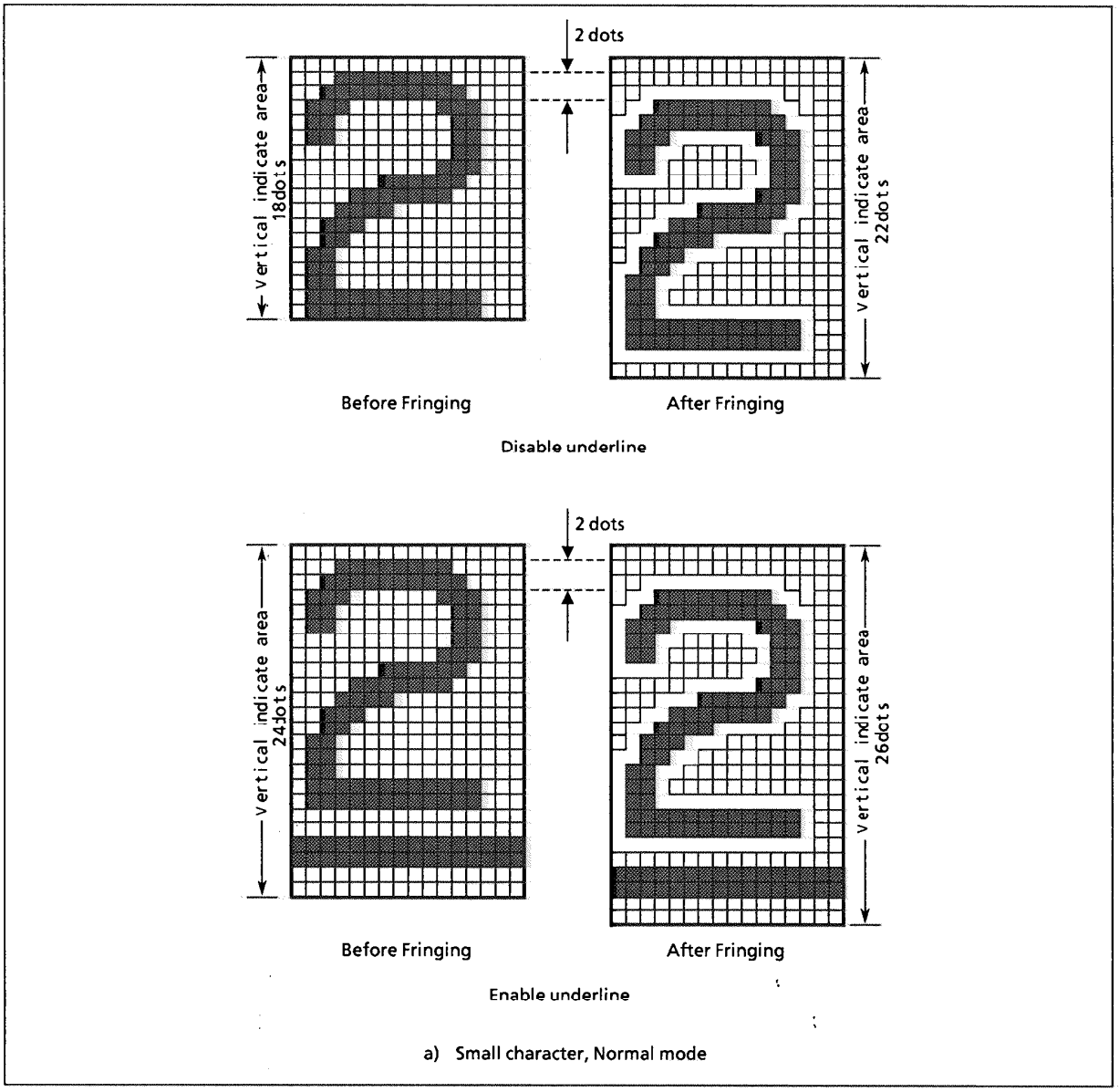


Figure 2.15.14 (a) Fringing example

Note: The fringe of 1st column character does not exceed left, and the fringe of 32th character does not exceed right.

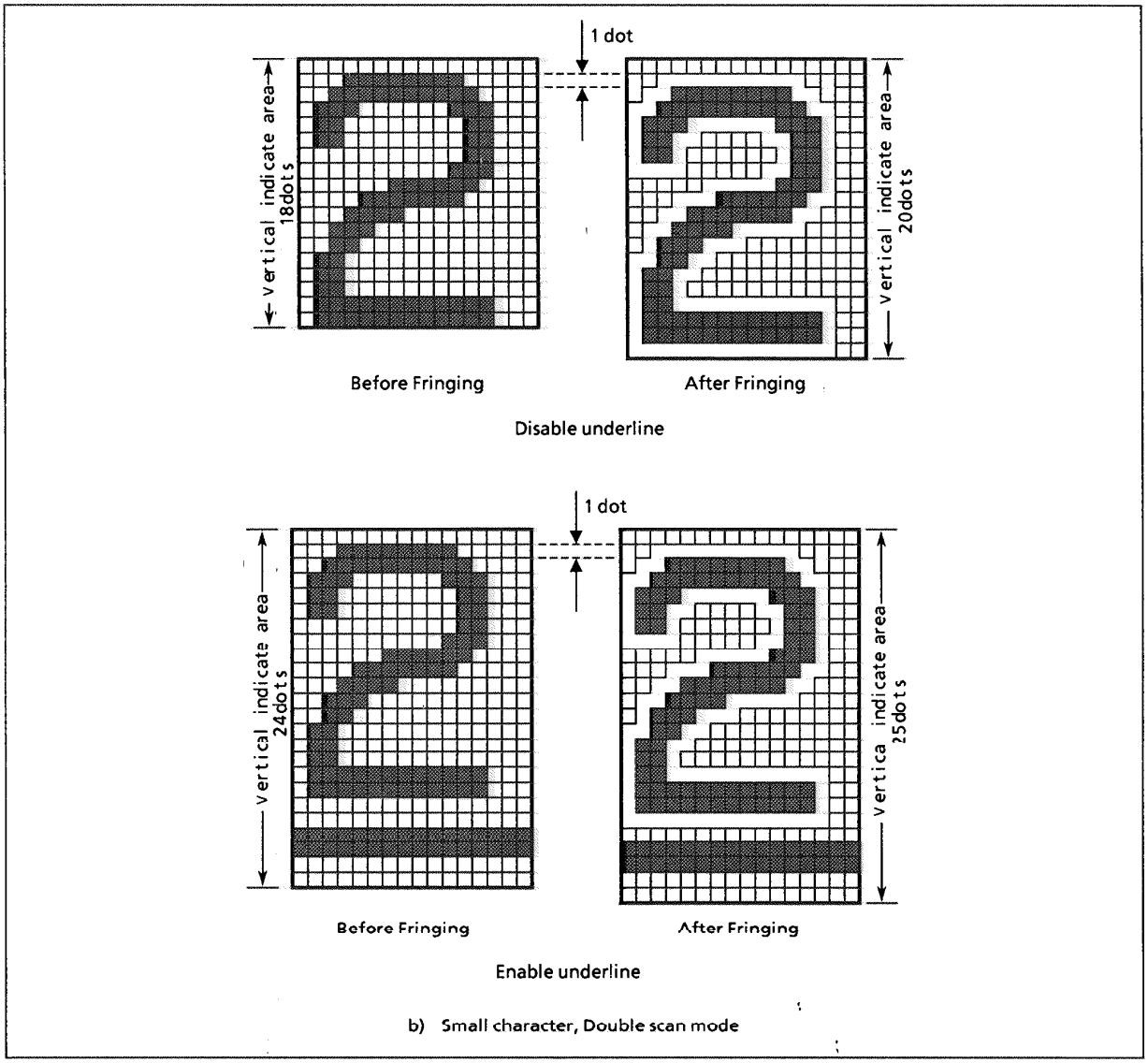


Figure 2.15.14 (b) Fringing example

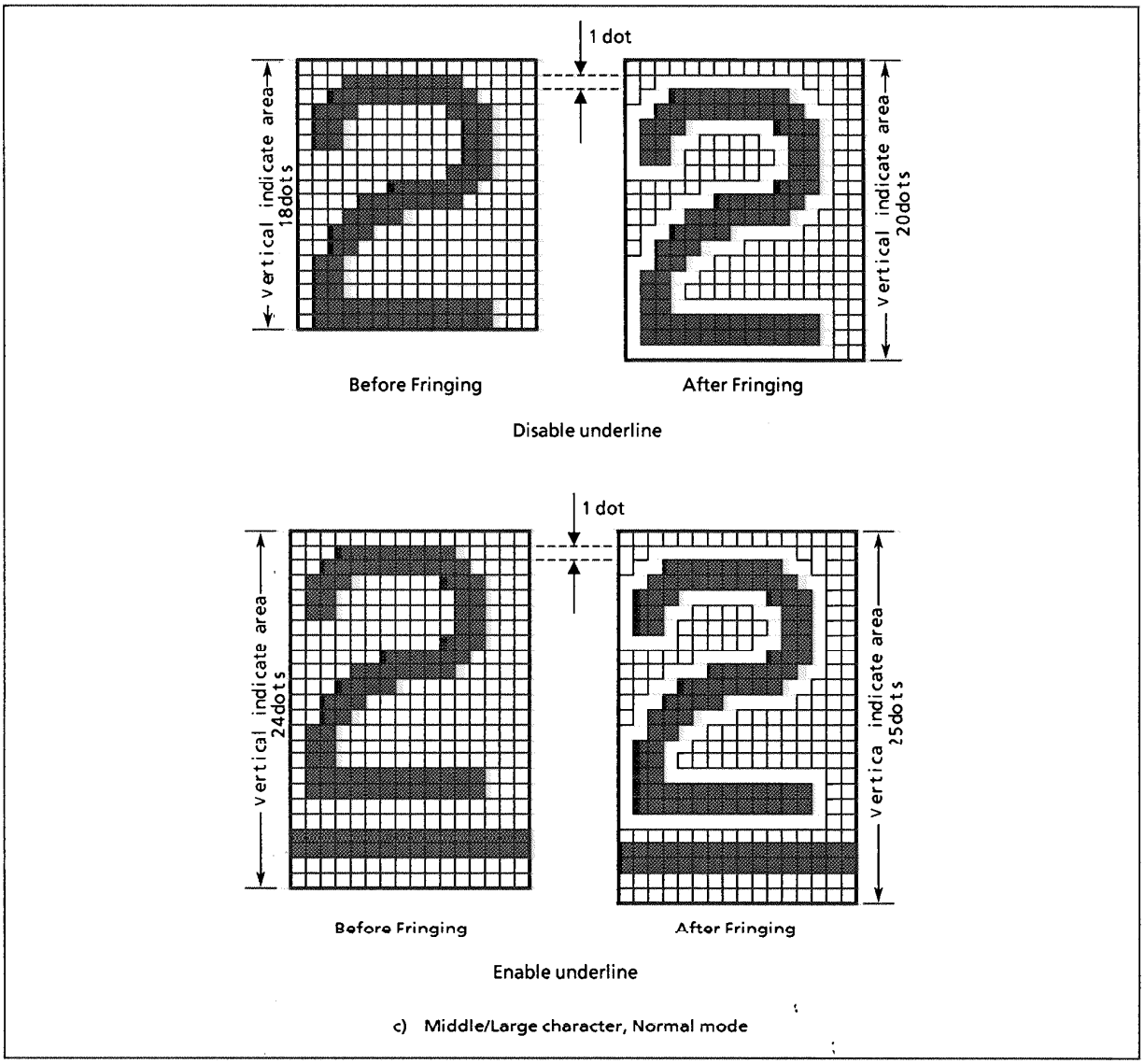


Figure 2.15.14 (c) Fringing example

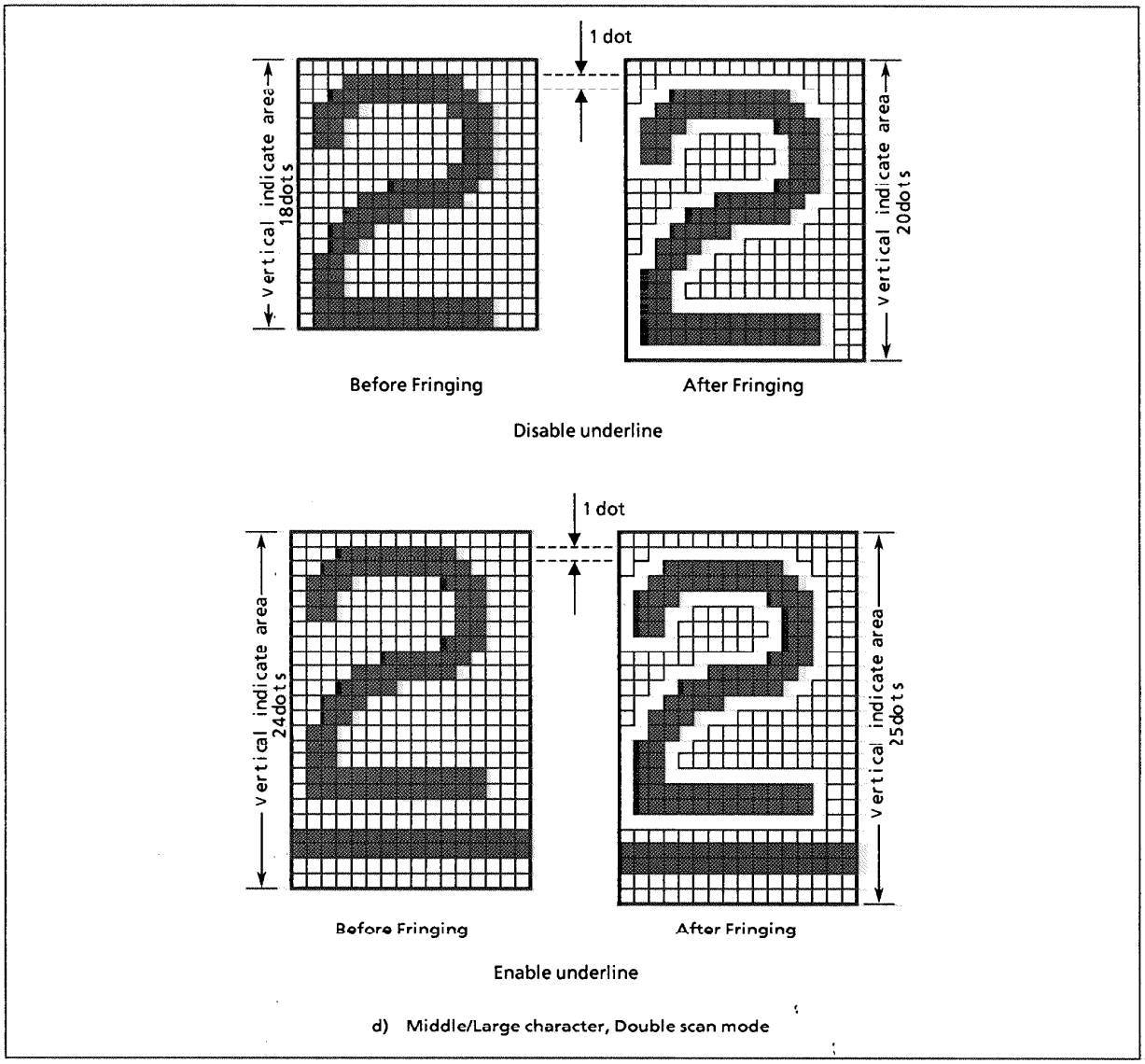


Figure 2.15.14 (d) Fringing example

(4) Background function

Background color function is used to color the entire background for the character area (refer to Table 2.15.4). Except the character area whose character code is 000_H

This function is specified for each display page by setting EBKGD (bit 7 in ORRCL) in the OSD control register to "1".

A background color is specified for each display page by setting IBDT, RBDT, GBDT, and BBDT (bit 7 to 4 in ORBK) in the OSD control registers. A color specification is same as them for full-raster blanking.

Background specification unit: Display page

Background enable register (1 bit) ··· EBKGD (bit 7 in ORRCL)

"0" ··· Disable background

"1" ··· Enable background

Background color specification unit: Display page

Background color specification registers (4 bits) ··· IBDT, RBDT, GBDT, BBDT (bit 7 to 4 in ORBK)

I signal function select: PISEL (bit 6 in ORETC)

"0" ··· 15 colors specification

I pin can be used to make a half level of R, G, B signal (dark color) through an extra circuit.

"1" ··· 8 colors specification

Contents of IDT register is disregarded.

I pin can be used as Half Transparency / Half Tone through an extra circuit.

Table 2.15.6 Background color (15 colors)

IBDT	RBDT	GBDT	BBDT	Background color
0	0	0	0	Black
	0	0	1	Blue
	0	1	0	Green
	0	1	1	Cyan
	1	0	0	Red
	1	0	1	Magenta
	1	1	0	Yellow
	1	1	1	White
1	0	0	0	Black
	0	0	1	Dark Blue
	0	1	0	Dark Green
	0	1	1	Dark Cyan
	1	0	0	Dark Red
	1	0	1	Dark Magenta
	1	1	0	Dark Yellow
	1	1	1	Gray

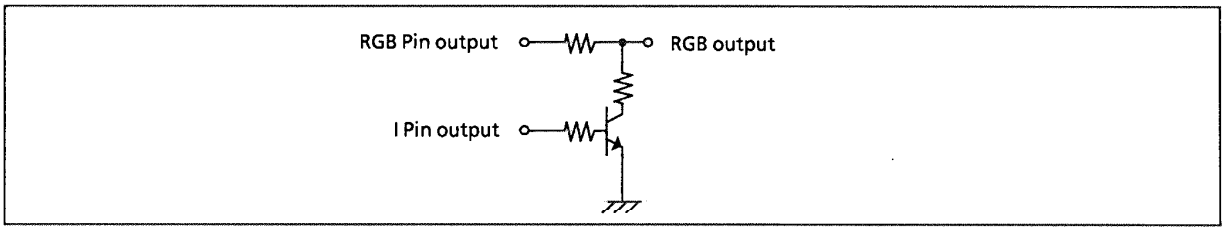


Figure 2.15.15 Example circuit for 15 colors by I pin.

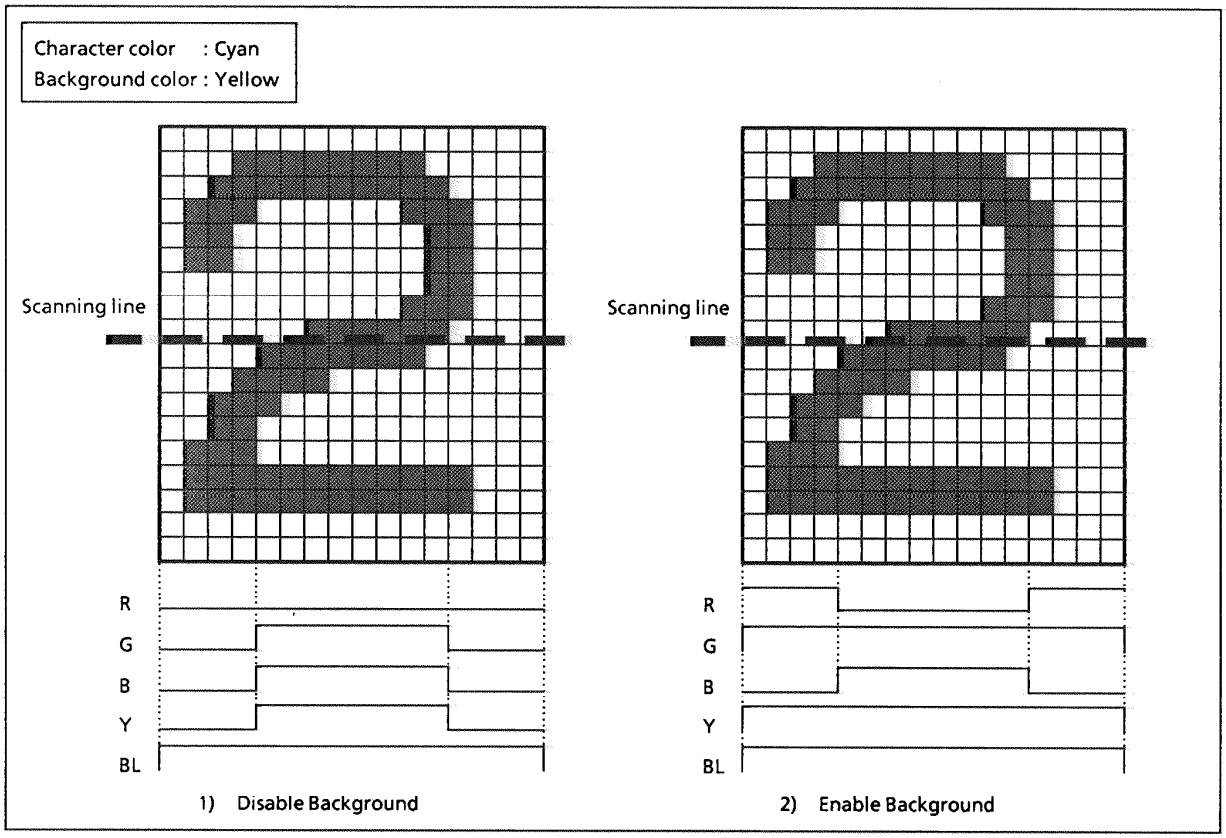


Figure 2.15.16 Background Function

2.15.5.5 OSD display screeen control

(1) Display on / off

This function is used to display characters specified for on / off display.

Display on / off specification unit: Display page
Display on / off specification register (1 bit) ··· DON (bit 0 in ORDON)
"0" ··· Disable display
"1" ··· Enable display

Note: Do not start STOP mode during display is enable.

(2) Window function

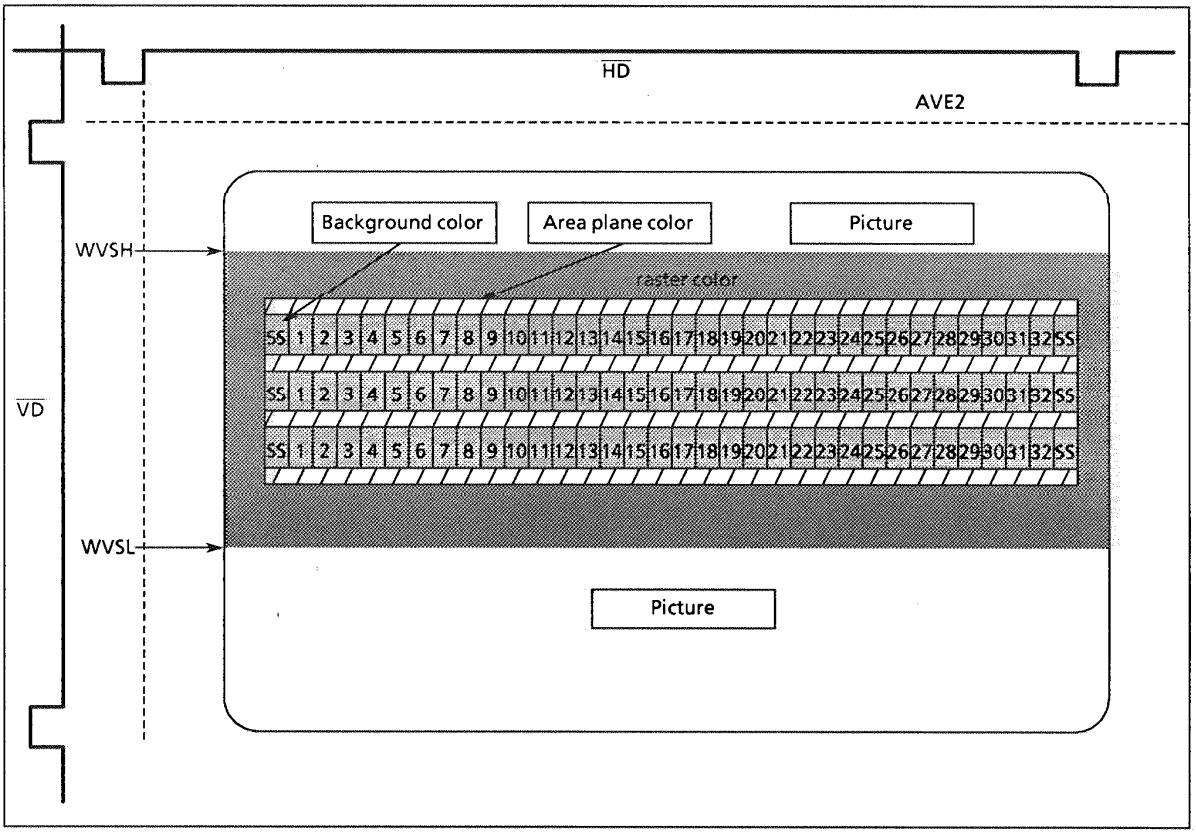
This function is used to set upper and lower limit of display page. Window upper limit is specified by WVSH (ORWVSH). Window lower limit is specified by WVSL (ORWVSL). This function is enabled by setting EWDW (bit 1 in ORDON) in the OSD control register to 1.

Window specification unit: Display page
Window function enable specification register (1 bit) ··· EWDW (bit 1 in ORDON)
"0" ··· Disable window function
"1" ··· Enable window function

Window upper limit specification register (9 bits) ··· WVSH8 to 0 (ORWVSH)
Window lower limit specification register (9 bits) ··· WVSL8 to 0 (ORWVSL)
Window upper and lower limit position ···
When VDSMD is "0" (Normal mode):
WVSH = (WVSH8 to WVSH0)$_H \times T_{HD}$
WVSL = (WVSL8 to WVSL0)$_H \times T_{HD}$
When VDSMD is "1" (Double scan mode):
WVSH = (WVSH8 to WVSH0)$_H \times 2T_{HD}$
WVSL = (WVSL8 to WVSL0)$_H \times 2T_{HD}$

Note 1: T_{HD} ; One cycle of $\overline{HD}$ signal
Note 2: WVSL > WVSH ≧ "1"
Note 3: Modify the value of window upper and lower limit register as follows:
1. *When $WVSH_{NEW} \leqq WVSH_{OLD}$*
   Finish to transfer the new value, during $\overline{VD}$ signal is low or before the position of the scanning line coincides with $WVSH_{NEW}$.
2. *When $WVSL > WVSH_{NEW} > WVSH_{OLD}$*
   Finish to transfer the new value, during $\overline{VD}$ signal is low or before the position of the scanning line coincides with $WVSH_{OLD}$.
3. *When $WVSL_{NEW} \leqq WVSL_{OLD}$*
   Finish to transfer the new value, during $\overline{VD}$ signal is low or before the position of the scanning line coincides with $WVSL_{NEW}$.
4. *When $WVSL_{NEW} > WVSL_{OLD}$*
   Finish to transfer the new value, during $\overline{VD}$ signal is low or before the position of the scanning line coincides with $WVSL_{OLD}$.

Note 4: It is recommendable that the window function is always enabled (EWDW = "1") and set WVSH to "01_H", WVSL to "$1FE_H$". When the window function should be set to disable, clear EWDW to "0" independent of the value which this register has been set from detecting the rising edge of $\overline{HD}$ signal by software until the falling edge of $\overline{HD}$ signal.



Correspond to closed caption

Widow display: ON, Area plane display: ON, Background color display: ON, Raster plane display: ON

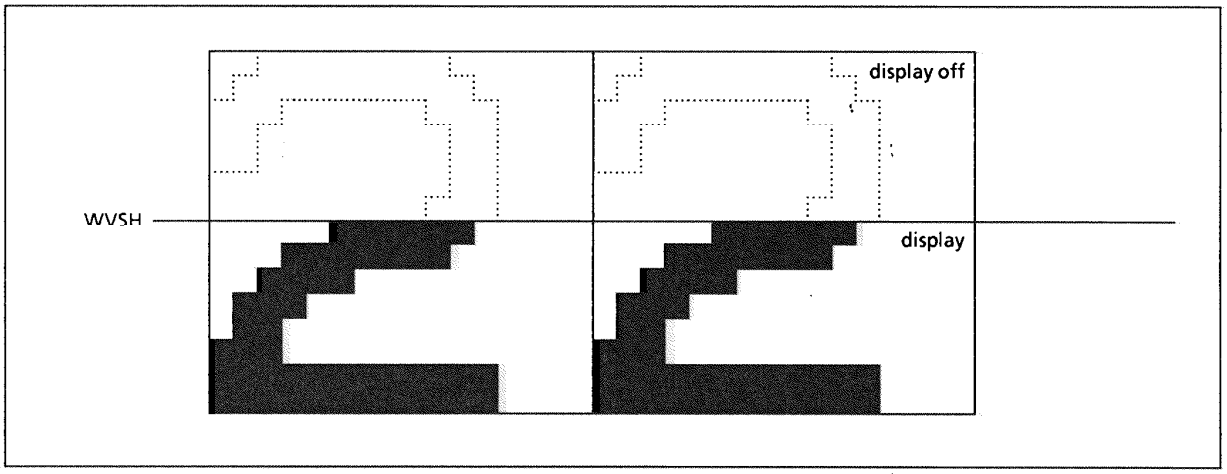


Figure 2.15.17 If WVSH is on a code plane

(3) Full-raster blanking function

Full-raster blanking function is used to color the entire background for the display area (TV screen). When using the full-raster blanking function, set YBLCS (bit 2 in ORP6S) to "1", output BL signal from Y/BL pin, because Y signal cannot delete whole display page from video signal.
This function is specified for each display page by setting EXBL (bit 6 in ORBK) in the OSD register to "1". Color specification is same as them for background color.

Full-raster blanking specification unit: Display page
Full-raster blanking enable register (1 bit) ··· EXBL (bit 6 in ORRCL)
"0" ··· Disable full-raster blanking
"1" ··· Enable full-raster blanking

Full-raster blanking color specification registers (4 bits) ··· RCLI, RCLR, RCLG, RCLB (bit 3 to 0 in ORRCL)

I signal function select: PISEL (bit 6 in ORETC)
"0" ··· 15 colors specification
I pin can be used to make a half level of R, G, B signal (dark color) through an extra circuit.
"1" ··· 8 colors specification
Contents of IDT register is disregarded.
I pin can be used as Half Transparency / Half Tone through an extra circuit.

Table 2.15.7 Raster plane color (15 colors)

RCLI	RCLR	RCLG	RCLB	Raster plane color
0	0	0	0	Black
	0	0	1	Blue
	0	1	0	Green
	0	1	1	Cyan
	1	0	0	Red
	1	0	1	Magenta
	1	1	0	Yellow
	1	1	1	White
1	0	0	0	Black
	0	0	1	Dark Blue
	0	1	0	Dark Green
	0	1	1	Dark Cyan
	1	0	0	Dark Red
	1	0	1	Dark Magenta
	1	1	0	Dark Yellow
	1	1	1	Gray

(4) Area plane function

Area plane function is used to display square area to two points on a screen.
Two planes operate independently. They are displayed according to the priority (area plane 1 > area plane 2).
See area plane display position setting in section 2.12.5.3 (2) how to set display positions for each area.
Each area plane is set to ON or OFF by AON2 and AON1 (bit 5 and bit 4 in ORRCL).
Area plane colors are set by ACLIx, ACLRx, ACLGx, ACLBx (bit 7 to bit 0 in ORACL, x = 1, 2).

Area plane colors: 8 or 15
Area plane specification unit: plane
Area plane color specification register (8 bit)
Area plane 1: ACLI1 / ACLR1 / ACLG1 / ACLB1 (bit 3 to 0 in ORACL)
Area plane 2: ACLI2 / ACLR2 / ACLG2 / ACLB2 (bit 7 to 4 in ORACL)

I signal function select: PISEL (bit 6 in ORETC)
"0" ··· 15 colors specification
I pin can be used to make a half level of R, G, B signal (dark color) through an extra circuit.
"1" ··· 8 colors specification
Contents of IDT register is disregarded.
I pin can be used as Half Transparency / Half Tone through an extra circuit.

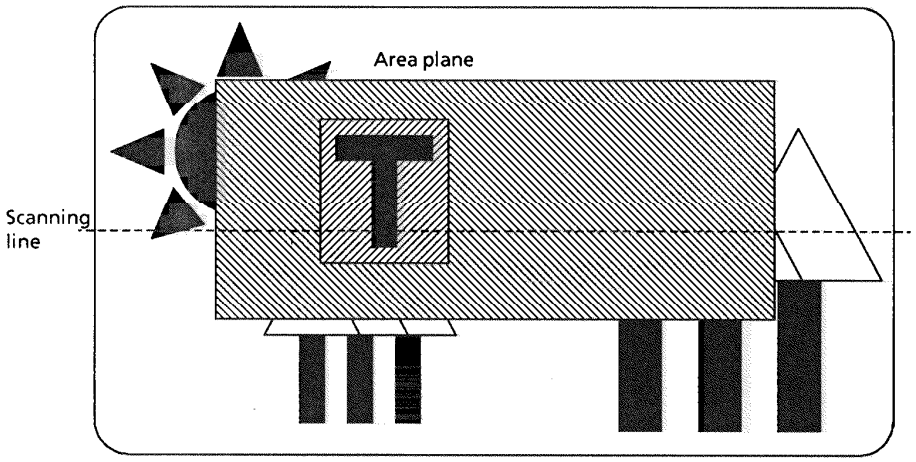
Table 2.15.8 Area plane color (15 colors)

ACLIx	ACLRx	ACLGx	ACLBx	Area plane color
0	0	0	0	Black
	0	0	1	Blue
	0	1	0	Green
	0	1	1	Cyan
	1	0	0	Red
	1	0	1	Magenta
	1	1	0	Yellow
	1	1	1	White
1	0	0	0	Black
	0	0	1	Dark Blue
	0	1	0	Dark Green
	0	1	1	Dark Cyan
	1	0	0	Dark Red
	1	0	1	Dark Magenta
	1	1	0	Dark Yellow
	1	1	1	Gray

(x = 1, 2)

I signal function select

① Using for 15 colors (PISEL = 0)



Example color

	I = 0	I = 1
Character color	Red	Dark Red
Character Background color	Green	Dark Green
Area plane color	Blue	Dark Blue

Raster plane: off
Character background: ON
YBLCS: 0 (Y select)

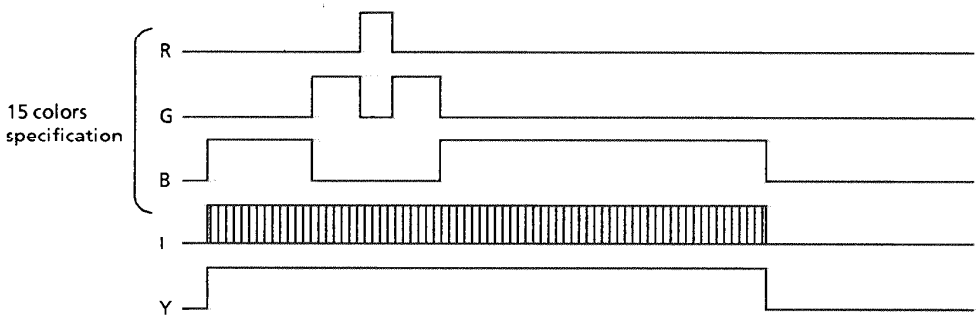


Figure 2.15.18 TV display and OSD signals (PISEL = 0)

② Using for Half transparency / Half Tone (PISEL = 1)

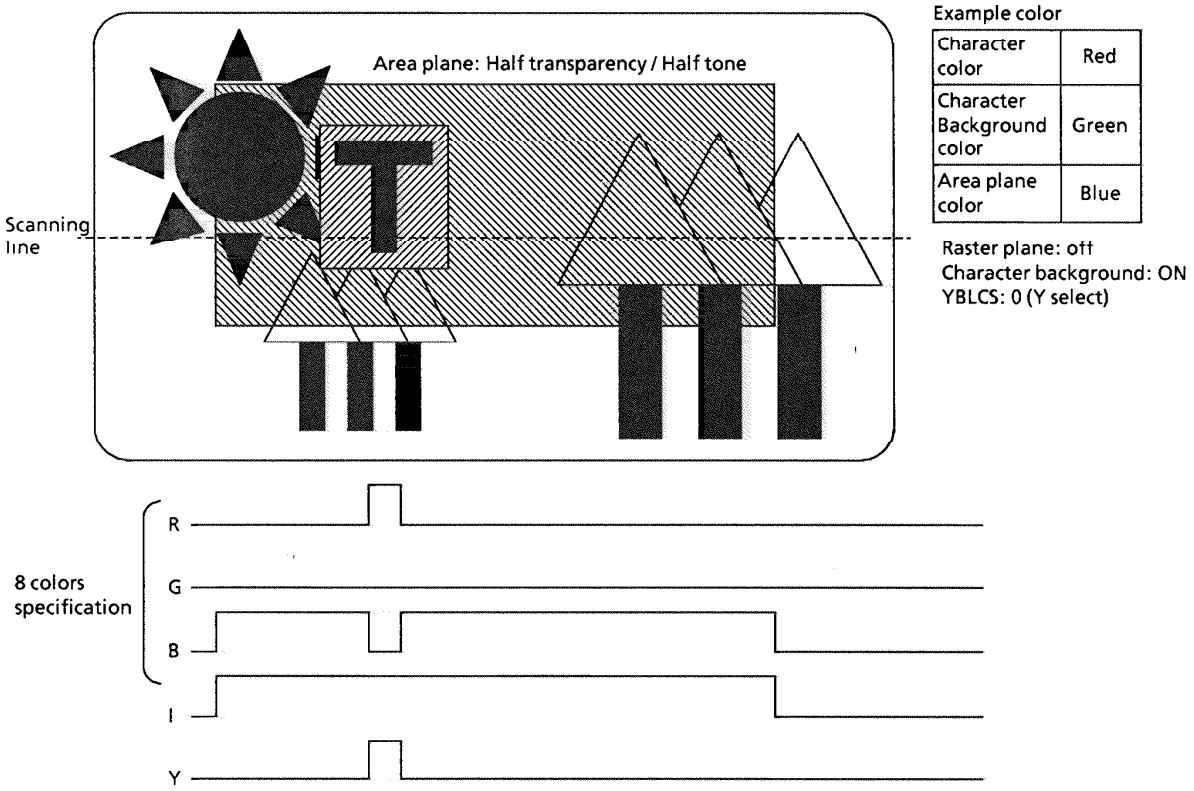


Figure 2.15.19 TV display and OSD signals (PISEL = 1)

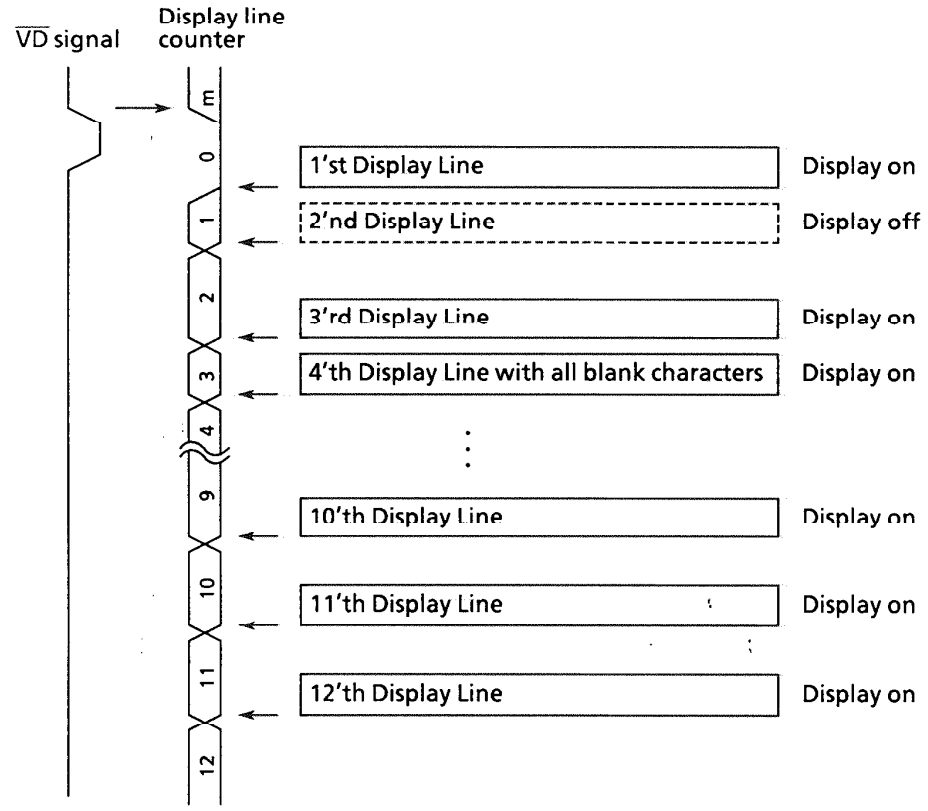
2.15.5.6 Interrupt control

(1) Display line counter

The display line counter indicates number of display line (s) by OSD circuit on the TV screen. The display line counter is a 4-bit counter which is initialized to "0" by the falling edge of the $\overline{VD}$ signal and which increments when last scanning of each display line is completed (falling edge of the $\overline{HD}$ signal). It is necessary to be read out display line counter several times, because it does not synchronize CPU clock.

Display line counter register (4 bits) ··· DCTR (bit 3 to 0 in ORIRC)

"0000" ··· No display line is completed.
"0001" ··· 1'st display line is completed.
"0010" ··· 2'nd display line is completed.
to to
"1111" ··· 15'th display line is completed.



Note: The display line counter also increments when a line with all blank characters or a line with display off is specified.

Figure 2.15.20 Display line counter

(2) Interrupt generator circuit

An interrupt request is generated when a falling edge of $\overline{VD}$ signal or when line counter (DCTR) is counted to the certain value specified by ISDC.

Interrupt source select register (1 bit) ··· SVD (bit4 in ORIRC)

"0" ··· Interrupt request generated when the display line counter (DCTR) is counted to the certain value which is specified by ISDC.

"1" ··· Interrupt request is generated when a falling edge of $\overline{VD}$ signal.

Interrupt generation line specification register (4 bits) ··· ISDC (bit 3 to 0 in ORIRC)

"0000" ··· Interrupt request generated when the display line counter is cleared.

"0001" ··· Interrupt request generated at end points of the last scanning line of the first display line

"0010" ··· Interrupt request generated at end points of the last scanning line of the 2'nd display line

to

"1111" ··· Interrupt request generated at end points of the last scanning line of the 15'th display line

2.15.5.7 Display memory access

(1) Display memory

The display memory is accessed for two purposes, one for writing data to the display memory, and one for reading data from the display memory.

Display memory address specification registers (9 bits) ··· DMA8 to MDA0 (ORDMA)

Display memory data write registers

Character code write register (9 bits) ··· CRA8 to CRA0 (ORCRA)

Character ornamentation data write registers (7 bits) ··· SLNT, EUL, BLF, IDT, RDT, GDT, and BDT (ORDSN)

Display memory bank select register MBK (ORETC bit 1)

"0" ··· When writing either character code or character ornamentation data

"1" ··· When writing both character code and character ornamentation data

Note 1: These control registers have a characteristic that immediately when a value is written to the register, the content of the register is transferred as valid data to the OSD circuit/display memory.

Note 2: The data written to the display memory takes effect at the same time it is written. When character code or character ornamentation data is written to the display memory while it is displaying some character, the character may not be displayed correctly. When writing data to the display memory, make sure no character is being displayed in the memory location where you are going to write data.

Note 3: When writing data to or reading data from the display memory, do not use two-byte transfer instructions such as "LDW(HL),mn LD rr, (pp)." Otherwise, erroneous data may be written to the display memory or data may be written to an incorrect address.

Note 4: Allow for at least two instruction cycles between a display memory address write instruction and a data write or read instruction. Also, when continuous writing data to or reading data from the display memory, allow for at least two instruction cycles between one write or read instruction and the next. Otherwise, erroneous data may be written to the display memory or data may be written to an incorrect address.

Note 5: When setting display memory addresses, always be sure to write all of 9 address bits sequentially in order of DMA8 and DMA7 to DMA0.

1. Normal mode

In normal mode, the display memory addresses are automatically incremented each time data is read from or written to the memory. Because addresses are automatically incremented, this mode may be used for reading from or writing data to multiple continuous addresses simultaneously.

<Display memory write sequence in normal mode>

(a) When writing either character code or character ornamentation data

(1) Set MFYWR, MBK, and RDWRV all to 0.

(2) Write the most significant address bit of the display memory to DMA8. Go on and write the 8 low-order address bits of the display memory to DMA7 to DMA0.

(3) Writing character code or character ornamentation data

- Writing character code
  Write the most significant bit of character code to CRA8. Go on and write the 8 low-order bits of character code to CRA7 through CRA0. At this point in time, the 9 bits of character code written are transferred to the display memory, and DMA8 to DMA0 are automatically incremented.
- Writing character ornamentation data
  Write character ornamentation data to SLNT, EUL, BLF, IDT, RDT, GDT, and BDT. At this point in time, the character ornamentation data written are transferred to the display memory, and DMA8 to DMA0 are automatically incremented.

(4) To write data (character code or character ornamentation data) to continuous addresses, repeat step (3).

(b) When writing character code and character ornamentation data at a time

(1) Set MFYWR to 0, MBK to 1, and RDWRV to 0.

(2) Write the most significant address bit of the display memory to DMA8. Go on and write the 8 low-order address bits of the display memory to DMA7 to DMA0.

(3) Write character ornamentation data to SLNT, EUL, BLF, IDT, RDT, GDT, and BDT. At this point in time, the character ornamentation written are transferred to the display memory.

(4) Write the most significant bit of character code to CRA8. Go on and write the 8 low-order bits of character code to CRA7 to CRA0. At this point in time, the 9 bits of character code written and the character ornamentation data written in step (3) are transferred to the display memory, and DMA8 to DMA0 are automatically incremented.

(5) To write data to continuous addresses, repeat steps (3) and (4).

<Display memory read sequence in normal mode>

(a) When reading either character code or character ornamentation data

(1) Set MFYWR to 0, MBK to 0, and RDWRV to 1.

(2) Write the most significant address bit of the display memory to DMA8. Go on and write the 8 low-order address bits of the display memory to DMA7 to DMA0.

(3) Reading character code or character ornamentation data

- Reading character code
  Read CRA8. Next, Read CRA7 to CRA0. At this point in time, DMA8 to DMA0 are automatically incremented.
- Reading character ornamentation data
  Read character ornamentation data SLNT, EUL, BLF, IDT, RDT, GDT, and BDT. At this point in time, DMA8 through DMA0 are automatically incremented.

(4) To read data (character code or character ornamentation data) from continuous addresses, repeat step (3).

(b) When reading character code and character ornamentation data at a time

(1) Set MFYWR to 0, MBK to 1, and RDWRV to 1.

(2) Write the most significant address bit of the display memory to DMA8. Go on and write the 8 low-order address bits of the display memory to DMA7 to DMA0.

(3) Read character ornamentation data SLNT, EUL, BLF, IDT, RDT, GDT, and BDT.

(4) Read CRA8. Read the 8 low-order bits of character code, CRA7 through CRA0. At this point in time, DMA8 through DMA0 are automatically incremented.

(5) To read data from continuous addresses, repeat steps (3) and (4).

2. Read-modify-write mode

When writing data in read-modify-write mode, the display memory addresses are automatically incremented as in normal mode, but when reading data in this mode, the memory addresses are not automatically incremented.
Therefore, immediately after executing a read from some display memory address, you can execute a write to the same display memory address. After executing a write, the display memory addresses are automatically incremented.

(a) Reading/writing either character code or character ornamentation data in read-modify-write mode

(1) Set MFYWR to 1 and MBK to 0.

(2) Write the most significant address bit of the display memory to DMA8. Go on and write the 8 low-order address bits of the display memory to DMA7 to DMA0.

(3) Reading character code or character ornamentation data

- Reading character code
  Read CRA8. Read the 8 low-order bits of character code, CRA7 to CRA0. DMA8 to DMA0 are not incremented.
- Reading character ornamentation data
  Read character ornamentation data SLNT, EUL, BLF, IDT, RDT, GDT, and BDT. DMA8 to DMA0 are not incremented.

(4) Writing character code or character ornamentation data

- Writing character code
  Write the most significant bit of character code to CRA8. Go on and write the 8 low-order bits of character code to CRA7 to CRA0. At this point in time, the 9 bits of character code written are transferred to the display memory, and DMA8 to DMA0 are automatically incremented.
- Writing character ornamentation data
  Write character ornamentation data to SLNT, EUL, BLF, IDT, RDT, GDT, and BDT. At this point in time, the character ornamentation data written are transferred to the display memory, and DMA8 to DMA0 are automatically incremented.

(5) To continue executing read-modify-write operations, repeat steps (2), (3), and (4). To read/write data (character code or character ornamentation data). To continue executing read modify-write mode from continuous addresses, repeat steps (3) and (4).

(b) Reading/writing both character code and character modification data in read-modify-write mode

(1) Set MFYWR to 1, MBK to 1.

(2) Write the most significant address bit of the display memory to DMA8. Go on and write the 8 low-order address bits of the display memory to DMA7 to DMA0.

(3) Read character ornamentation data SLNT, EUL, BLF, IDT, RDT, GDT, and BDT. DMA8 to DMA0 are not incremented.

(4) Read CRA8. Read the 8 low-order bits of character code, CRA7 to CRA0. DMA8 to DMA0 are not incremented.

(5) Write character ornamentation data to SLNT, EUL, BLF, IDT, RDT, GDT, and BDT. At this point in time, the character ornamentation data written is transferred to the display memory.

(6) Write the most significant bit of character code to CRA8. Go on and write the 8 low-order bits of character code to CRA7 to CRA0. At this point in time, the 9 bits of character code written and the character ornamentation data written in step (5) are transferred to the display memory, and DMA8 to DMA0 are automatically incremented.

(7) To continue executing read-modify-write operations, repeat steps (2), (6). (To read/write data to and from continuous addresses in read-modify-write mode, repeat steps (3) to (6).)

Table 2.15.9 Address increment

		RD		WR	
		Character ornamentation	Character code	Character ornamentation	Character code
MFYWR = 0	MBK = 0	INC	INC	INC	INC
	MBK = 1	–	INC	–	INC
MFYWR = 1	MBK = 0	–	–	INC	INC
	MBK = 1	–	–	–	INC

INC: Automatic address increment at read or write.

– : No address change at data read or write.

Example: Setting a character code (020_H) to the display memory (Address: 120_H) and setting a character ornamentation (001_H) for character code 020_H and display memory address 120_H.

① MBK = 0

```
; Set display memory
LD    (0x25),  0x01
LD    (0x24),  0x20
; Set character code
LD    (0x1F),  0x00
LD    (0x1E),  0x20
; Set display memory again
LD    (0x25),  0x01
LD    (0x24),  0x20
; Set character ornamentation
LD    (0x1D),  0X01
```

② MBK = 1

```
; Set display memory
LD    (0x25),  0x01
LD    (0x24),  0x20
; Set character ornamentation
LD    (0x1D),  0X01
; Set character code
LD    (0x1F),  0x00
LD    (0x1E),  0x20
```

Note: Transfer the contents of display memory which affect displaying characters into OSD circuit, before the position of scanning line coincides with their own vertical display start position.

(2) Character

Characters: 384 (including blank character)

Character specification register (9 bits) ··· CRA8 to CRA0 (bit 8 to 0 in ORCRA)

Character code "000_H" ··· Blank character

Character code "001_H" to "$017F_H$" ··· User programmable by character ROM

(3) Character color

Character colors: 8 or 15

Character color specification unit: Character

Character color specification register (4 bits): RDT / GDT / BDT / IDT (bit3 to 0 in ORDSN)

I signal function select: PISEL (bit 6 in ORETC)

"0" ··· 15 colors specification

I pin can be used to make a half level of R, G, B signal (dark color) through an extra circuit.

"1" ··· 8 colors specification

Contents of IDT register is disregarded.

I pin can be used as Half Transparency / Half Tone through an extra circuit.

Table 2.15.10 Character color (15 colors)

IDT	RDT	GDT	BDT	Character color
0	0	0	0	Black
	0	0	1	Blue
	0	1	0	Green
	0	1	1	Cyan
	1	0	0	Red
	1	0	1	Magenta
	1	1	0	Yellow
	1	1	1	White
1	0	0	0	Black
	0	0	1	Dark Blue
	0	1	0	Dark Green
	0	1	1	Dark Cyan
	1	0	0	Dark Red
	1	0	1	Dark Magenta
	1	1	0	Dark Yellow
	1	1	1	Gray

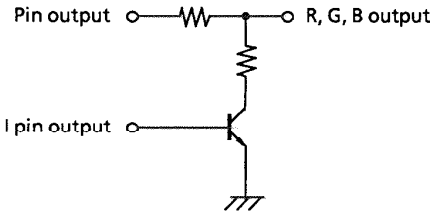


Figure 2.15.21 Example of circuit for 15 color by I pin

(4) Blinking function

Blinking function is used to blink display characters.

When BKMF is "1", characters specified for blinking by BLF are not displayed. (If the background color function is used, the background color is not disappeared.)

Blinking specification unit: Character

Blinking specification register (1 bit) ··· BLF (bit 4 in ORDSN)

"0" ··· No blinking

"1" ··· Blinking

Blinking master specification register (1 bit) ··· BKMF (bit 5 in ORETC)

"0" ··· Disable blinking

"1" ··· Enable blinking (Characters whose BLF are set to "1" are not displayed.)

Note: Regarding the extra dot of the left and/or right character by fringing function, it is not enabled as blink.

(5) Underline function

Underline function is used to add a line under a display character. The underline is same color as that of character.

Underline specification unit: Character
Underline enable register (1 bit) ··· EUL (Bit 5 in ORDSN)
"0" ··· No underline
"1" ··· Underline
Underline colors: 8 or 15
Underline color specification registers (4 bits) ··· RDT, GDT, BDT, IDT (Bit 3 to 0 in ORDSN)
(refer to Table 2.15.10)

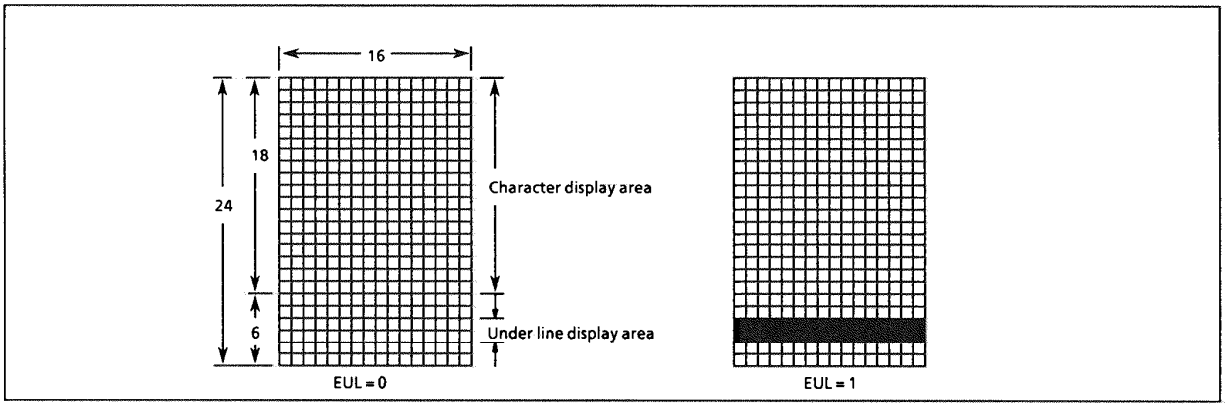


Figure 2.15.22 Underline

(6) Solid space control

Solid space control is used to display one column of solid space to the left and right of 32 columns. Solid space control is used to delete the Video signal in the areas where solid spaces are located in the original display page, then add color to them.

Solid space specification unit: line
Solid space specification register (24 bits)
For line 1 SOL11 and SOL10 (Bits 1 and 0 in ORSOL4)
For line 2 SOL21 and SOL20 (Bits 3 and 2 in ORSOL4)
⋮ ⋮
For line 12 SOL121 and SOL120 (Bits 7 and 6 in ORSOL12)

Solid space specification
The solid space control functions as follows:
SOL × 1 / SOL × 0 (x = 1 to 12)
"00" ..... No solid space display
"01" ..... Solid space display left for 32 columns
"10" ..... Solid space display right for 32 columns
"11" ..... Solid space display left and right for 32 columns
Solid space color specification registers (3 bits)
..... RBDT, GBDT, BBDT, IBDT (Bits 3 to 0 in ORBK)
(Same color as that of background)

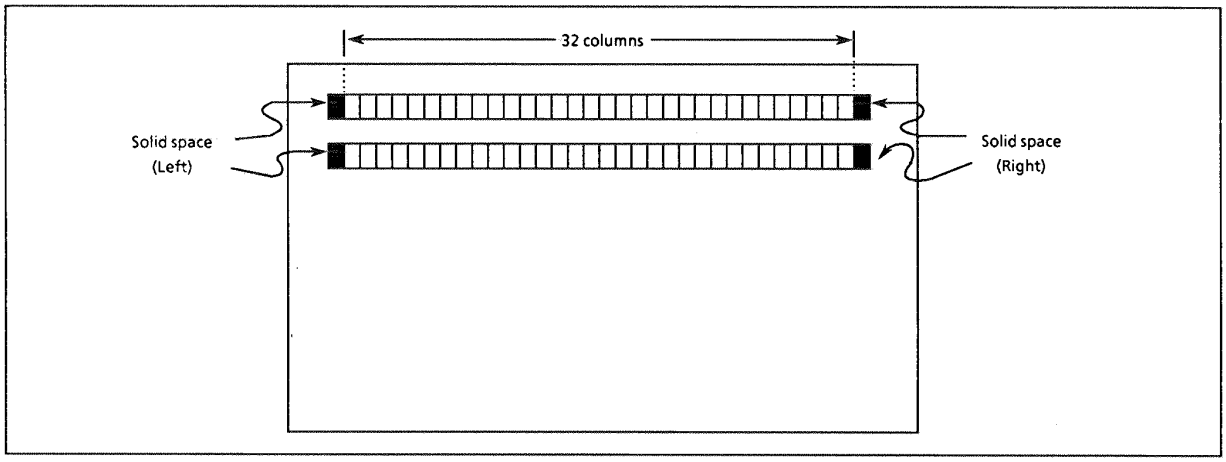


Figure 2.15.23 Solid Space

(7) Slant function

Slant function is used to slant characters for italics.

Slant specification unit: Character

Slant enable register (1 bits) ..... SLNT (Bit 6 in ORDSN)

"0" ..... No slant

"1" ..... Slant

Note: SLANT function is enabled each characters, and therefore, in case of using background function, this color of the Background is enable as slant. Regarding the extra dots of the left and / or right character by fringing function, it is not enabled as slant.

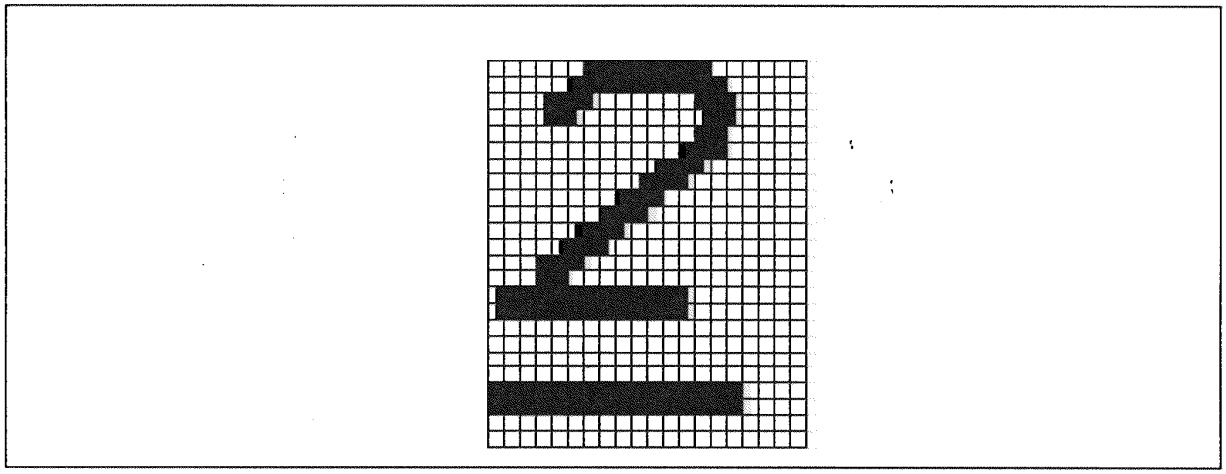


Figure 2.15.24 Slant

2.15.5.8 Clock generation for OSD display

The TMP88CM38A/P38A have clock generator for OSD display. It can generate a clock from 8 MHz to 24 MHz. The frequency of display clock is specified by ORCLKC and is monitored by ORCLKF.

Display clock frequency specification register: ORCLKC (8 bit)

$f_{OSD} = ORCLKC \times 8/T_{Hdhigh}$ (T_{Hdhigh}: High period of $\overline{HD}$ signal)

Display clock frequency locked monitor: ORCLKF (8 bit)

0: unmatched

1: matched

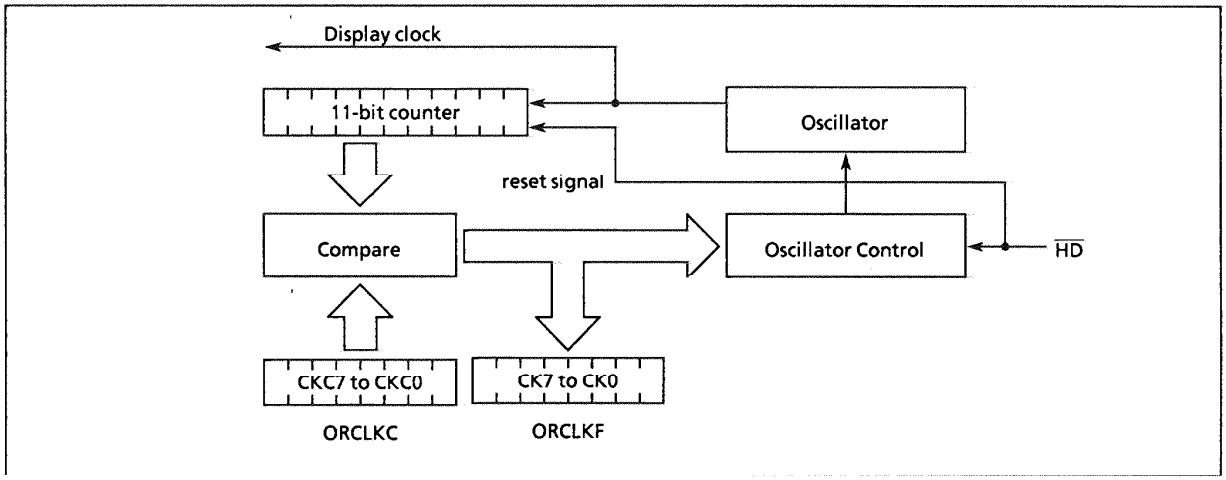


Figure 2.15.25 Clock Generation For OSD Display Control

Note 1: The ORCLKC is compared with the higher 8-bit of 11-bit binary counter. Therefore, the frequency of display clock contains the tolerance of 3-bit (0 to 2).

Note 2: The ORCLKC and the higher 8-bit of 11-bit binary counter are not compared after they were matched. The frequency of display clock is drifted by the temperature and voltage and so on. Therefore, The ORCLKC must be rewrite by program for monitoring the ORCLKF.

Note 3: When the ORCLKC and the contents of the higher 8-bit of 11-bit binary counter are matched, the higher 4-bit of ORCLKF is sequentially setted to "1" from bit 7. After that, the higher 4-bit of ORCLKF is setted to "1". The lower 4-bit of ORCLKF is unfixed.

2.15.5.9 OSD control registers

Can not access all OSD control registers in any of read-modify-write instructions such as bit operation, etc.

	7	6	5	4	3	2	1	0	
ORVS1									
(00F82$_H$)	VS17	VS16	VS15	VS14	VS13	VS12	VS11	VS10	(Initial value: 0000 0000)
(00F83$_H$)	–	–	–	–	–	–	–	VS18	(Initial value: **** ***0)
ORVS2									
(00F84$_H$)	VS27	VS26	VS25	VS24	VS23	VS22	VS21	VS20	(Initial value: 0000 0000)
(00F85$_H$)	–	–	–	–	–	–	–	VS28	(Initial value: **** ***0)
ORVS3									
(00F86$_H$)	VS37	VS36	VS35	VS34	VS33	VS32	VS31	VS30	(Initial value: 0000 0000)
(00F87$_H$)	–	–	–	–	–	–	–	VS38	(Initial value: **** ***0)
ORVS4									
(00F88$_H$)	VS47	VS46	VS45	VS44	VS43	VS42	VS41	VS40	(Initial value: 0000 0000)
(00F89$_H$)	–	–	–	–	–	–	–	VS48	(Initial value: **** ***0)
ORVS5									
(00F8A$_H$)	VS57	VS56	VS55	VS54	VS53	VS52	VS51	VS50	(Initial value: 0000 0000)
(00F8B$_H$)	–	–	–	–	–	–	–	VS58	(Initial value: **** ***0)
ORVS6									
(00F8C$_H$)	VS67	VS66	VS65	VS64	VS63	VS62	VS61	VS60	(Initial value: 0000 0000)
(00F8D$_H$)	–	–	–	–	–	–	–	VS68	(Initial value: **** ***0)
ORVS7									
(00F8E$_H$)	VS77	VS76	VS75	VS74	VS73	VS72	VS71	VS70	(Initial value: 0000 0000)
(00F8F$_H$)	–	–	–	–	–	–	–	VS78	(Initial value: **** ***0)
ORVS8									
(00F90$_H$)	VS87	VS86	VS85	VS84	VS83	VS82	VS81	VS80	(Initial value: 0000 0000)
(00F91$_H$)	–	–	–	–	–	–	–	VS88	(Initial value: **** ***0)
ORVS9									
(00F92$_H$)	VS97	VS96	VS95	VS94	VS93	VS92	VS91	VS90	(Initial value: 0000 0000)
(00F93$_H$)	–	–	–	–	–	–	–	VS98	(Initial value: **** ***0)
ORVS10									
(00F94$_H$)	VS107	VS106	VS105	VS104	VS103	VS102	VS101	VS100	(Initial value: 0000 0000)
(00F95$_H$)	–	–	–	–	–	–	–	VS108	(Initial value: **** ***0)
ORVS11									
(00F96$_H$)	VS117	VS116	VS115	VS114	VS113	VS112	VS111	VS110	(Initial value: 0000 0000)
(00F97$_H$)	–	–	–	–	–	–	–	VS118	(Initial value: **** ***0)
ORVS12									
(00F97$_H$)	VS127	VS126	VS125	VS124	VS123	VS122	VS121	VS120	(Initial value: 0000 0000)
(00F98$_H$)	–	–	–	–	–	–	–	VS128	(Initial value: **** ***0)

VSn8 to 0	Vertical display start position for line n	Write only

(n; 1 to 12)

Note 1: If display lines are overlapped each other, previous display line is enabled and next line is disabled. Set the vertical display start position not to overlap display lines.

Note 2: Transfer the contents of vertical display start position registers into OSD circuit before a position of the scanning line coincides with their own vertical display start position.

	7	6	5	4	3	2	1	0	
ORCS4 ($00F9A_H$)	CS4		CS3		CS2		CS1		(Initial value: 0000 0000)
ORCS8 ($00F9B_H$)	CS8		CS7		CS6		CS5		(Initial value: 0000 0000)
ORCS12 ($00F9C_H$)	CS12		CS11		CS10		CS9		(Initial value: 0000 0000)

CSn	Character size and display on/off for line n	00: Display off 01: Large size 10: Middle size 11: Small size	Write only

(n; 1 to 12)

	7	6	5	4	3	2	1	0	
OREULA8 ($00F9D_H$)	EULA8	EULA7	EULA6	EULA5	EULA4	EULA3	EULA2	EULA1	(Initial value: 0000 0000)
OREULA12 ($00F9E_H$)					EULA12	EULA11	EULA10	EULA9	(Initial value: **** 0000)

EULAn	Underline for display line for line n	0: Display off 1: Display on	

(n; 1 to 12)

	7	6	5	4	3	2	1	0	
OREFR ($00F9F_H$) ($00FA0_H$)	EFR8	EFR7	EFR6	EFR5	EFR4	EFR3	EFR2	EFR1	(Initial value: 0000 0000)
					EFR12	EFR11	EFR10	EFR9	(Initial value: **** 0000)

EFRn	Fringing enable specification register for line n	0: Disable fringing 1: Enable fringing	Write only

(n; 1 to 12)

Note: When a display line is enabled fringing function, its vertical size is increased by one dot (by two dots when its character size is small) independent of its character font. Therefore, when a vertical display start position is specified to no space between the lines, the display line which is overlapped with increasing dot(s) is canceled.

	7	6	5	4	3	2	1	0	
ORCLKF ($00FA1_H$)	CK7	CK6	CK5	CK4	CK3	CK2	CK1	CK0	(Initial value: 0000 0000)
ORCLKC ($00FA1_H$)	CKC7	CKC6	CKC5	CKC4	CKC3	CKC2	CKC1	CKC0	(Initial value: 0000 0000)

CKn	Display clock frequency locked monitor	Read only
CKCn	Display clock frequency specification register	Write only

(n; 0 to 7)

ORSLO4 ($00FA2_H$)	SLO4	SLO3	SLO2	SLO1	(Initial value: 0000 0000)
ORSLO8 ($00FA3_H$)	SLO8	SLO7	SLO6	SLO5	(Initial value: 0000 0000)
ORSLO12 ($00FA4_H$)	SLO12	SLO11	SLO10	SLO9	(Initial value: 0000 0000)

SLOn	Solid space for line n	00: No solid space display 01: Solid space display left of 32 columns 10: Solid space display right of 32 columns 11: Solid space display left and right for 32 columns	Write only

(n; 0 to 12)

ORBK ($00FA5_H$)

7	6	5	4	3	2	1	0
IBTD	RBDT	GBDT	BBDT	IFDT	RFDT	GFDT	BFDT

(Initial value: 0000 0000)

IBDT/ RBDT/ GBDT/ BBDT	Background color select	0000: Black 0001: Blue 0010: Green 0011: Cyan 0100: Red 0101: Magenta 0110: Yellow 0111: White 1000: Black 1001: Dark blue 1010: Dark green 1011: Dark cyan 1100: Dark red 1101: Dark magenta 1110: Dark yellow 1111: Gray	Write only
IFDT/ RFDT/ GFDT/ BFDT	Fringing color select	0000: Black 0001: Blue 0010: Green 0011: Cyan 0100: Red 0101: Magenta 0110: Yellow 0111: White 1000: Black 1001: Dark blue 1010: Dark green 1011: Dark cyan 1100: Dark red 1101: Dark magenta 1110: Dark yellow 1111: Gray	

Note: Set IBDT and IFDT to 1 when PISEL (bit 6 in ORETC) sets to 1. Then background color select and fringing color select are 8 variety.

ORACL ($00FA6_H$)

7	6	5	4	3	2	1	0
ACLI2	ACLR2	ACLG2	ACLB2	ACLI1	ACLR1	ACLG1	ACLB1

(Initial value: 0000 0000)

ACLI2/ ACLR2/ ACLG2/ ACLB2	Area 2 plan color select	0000: Black 0001: Blue 0010: Green 0011: Cyan 0100: Red 0101: Magenta 0110: Yellow 0111: White 1000: Black 1001: Dark blue 1010: Dark green 1011: Dark cyan 1100: Dark red 1101: Dark magenta 1110: Dark yellow 1111: Gray	Write only
ACLI1/ ACLR1/ ACLG1/ ACLB1	Area 1 plan color select	0000: Black 0001: Blue 0010: Green 0011: Cyan 0100: Red 0101: Magenta 0110: Yellow 0111: White 1000: Black 1001: Dark blue 1010: Dark green 1011: Dark cyan 1100: Dark red 1101: Dark magenta 1110: Dark yellow 1111: Gray	
ACLI2		0: Not assign half transparency for area 2 plane 1: Assign half transparency for area 2 plane	
ACLI1		0: Not assign half transparency for area 1 plane 1: Assign half transparency for area 1 plane	

Note: Set ACLI2 and ACLI1 to 1 when PISEL (bit 6 in ORETC) sets to 1. Then area 2 plane color select and area 1 plane color selct are 8 varity.

ORIV ($00FBB_H$)

7	6	5	4	3	2	1	0
VDPOL	HDPOL	YBLII	RGBII	YIV	BLIV	RGBIV	IIV

(Initial value: 0000 0000)

VDPOL	$\overline{VD}$ input polarity select	0: Non-invert input signal 1: Invert input signal	Write only
HDPOL	$\overline{HD}$ input polarity select	0: Non-invert input signal 1: Invert input signal	
YBLII	Y/BLIN input polarity select	0: Active high 1: Active low	
RGBII	RIN, GIN, BIN input polarity select	0: Active high 1: Active low	
YIV	Y output polarity select	0: Active high 1: Active low	
BLIV	BL output polarity select	0: Active high 1: Active low	
RGBIV	R, G, B output polarity select	0: Active high 1: Active low	
IIV	I output polarity select	0: Active high 1: Active low	

ORDMA

(00024_H)

7	6	5	4	3	2	1	0
DMA7	DMA6	DMA5	DMA4	DMA3	DMA2	DMA1	DMA0

(Initial value: 0000 0000)

(00025_H)

7	6	5	4	3	2	1	0
–	–	–	–	–	–	–	DMA8

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

DMAn	Display memory address	Write only

(n; 0 to 8)

Note. It is necessary to write all bits of display memory address, writting DMA7 to DMA0 after DMA8, when writing display address.

ORDSN ($0001D_H$)

7	6	5	4	3	2	1	0
	SLNT	EUL	BLF	IDT	RDT	GDT	BDT

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

SLNT	Slant enable specification register	0: Disable slant 1: Enable slant	Read/ Write
EUL	Underline enable specification register	0: Disable underline 1: Enable underline	
BLF	Blinking enable specification register	0: Disable blinking 1: Enable blinking	
IDT/ RDT/ GDT/ BDT	Character color select	0000: Black 0001: Blue 0010: Green 0011: Cyan 0100: Red 0101: Magenta 0110: Yellow 0111: White 1000: Black 1001: Dark blue 1010: Dark green 1011: Dark cyan 1100: Dark red 1101: Dark magenta 1110: Dark yellow 1111: Gray	

Note: Set IDT to 1 when PISEL (bit 6 in ORETC) sets to 1. Then character color select is 8 variety.

ORCRA
($0001E_H$)
($0001F_H$)

7	6	5	4	3	2	1	0	
CRA7	CRA6	CRA5	CRA4	CRA3	CRA2	CRA1	CRA0	(Initial value: **** ****)
–	–	–	–	–	–	–	CRA8	(Initial value: **** ****)

CRAn	Character code	Read/ Write

(n; 0 to 8)

Note: Write or Read CRA8. And write or read CRA7 to CRA0.

ORWVSH
($00FBC_H$)
($00FBD_H$)

7	6	5	4	3	2	1	0	
WVSH7	WVSH6	WVSH5	WVSH4	WVSH3	WVSH2	WVSH1	WVSH0	(Initial value: 0000 0000)
–	–	–	–	–	–	–	WVSH8	(Initial value: **** ***0)

WVSLn	Window upper limit position	Write only

(n; 0 to 8)

ORWVSL
($00FBE_H$)
($00FBF_H$)

7	6	5	4	3	2	1	0	
WVSL7	WVSL6	WVSL5	WVSL4	WVSL3	WVSL2	WVSL1	WVSL0	(Initial value: 0000 0000)
–	–	–	–	–	–	–	WVSL8	(Initial value: **** ***0)

WVSLn	Window lower limit position	Write only

(n; 0 to 8)

ORDON
($00F80_H$)

7	6	5	4	3	2	1	0	
–	–	–	–	–	RGWR	EWDW	DON	(Initial value: **** *000)

RGWR	Written data transfer control	0: (Initial state) 1: Transfers written data to OSD circuit. (After transfer, RGWR is reset to 0.)	Read/ Write
EWDW	Window enable specification register	0: Disable window function 1: Enable window function	
DON	Display on / off select	0: Disable display 1: Enable display	

*Note 1: * ; Don't care*

Note 2: All OSD control registers cannot use the read-modify-write instructions. (Bit manipulation instructions such as SET, CLR, etc. and logical operation such as AND, OR, etc.)

ORRCL ($00FA7_H$)

7	6	5	4	3	2	1	0
EBKGD	EXBL	AON2	AON1	RCLI	RCLR	RCLG	RCLB

(Initial value: 0000 0000)

EBKGD	Background function enable specification register	0: No background function 1: Background function enable	Write only
EXBL	Full-raster blanking enable specification register	0: No Full-raster blanking 1: Full-raster blanking	
AON2	Area 2 plane display enable specification register	0: No area 2 plane display 1: Area 2 plane display enable	
AON1	Area 1 plane display enable specification register	0: No area 1 plane display 1: Area 1 plane display enable	
RCLI/ RCLR/ RCLG/ RCLB	Raster plane color select	0000: Black 0001: Blue 0010: Green 0011: Cyan 0100: Red 0101: Magenta 0110: Yellow 0111: White 1000: Black 1001: Dark blue 1010: Dark green 1011: Dark cyan 1100: Dark red 1101: Dark magenta 1110: Dark yellow 1111: Gray	

Note: Set RCLI to 1 when PISEL (bit 6 in ORETC) sets to 1. Then raster plane select is 8 variety.

ORAHS1

	7	6	5	4	3	2	1	0	
(00FA8H)	AHS17	AHS16	AHS15	AHS14	AHS13	AHS12	AHS11	AHS10	(Initial value: 0000 0000)
(00FA9H)	–	–	–	–	–	–	–	AHS18	(Initial value: **** ***0)

ORAHE1

(00FAAH)	AHE17	AHE16	AHE15	AHE14	AHE13	AHE12	AHE11	AHE10	(Initial value: 0000 0000)
(00FABH)	–	–	–	–	–	–	–	AHE18	(Initial value: **** ***0)

AHS1n	Horizontal start point for area 1 plane	Write only
AHE1n	Horizontal end point for area 1 plane	

(n; 0 to 8)

ORAVS1

(00FACH)	AVS17	AVS16	AVS15	AVS14	AVS13	AVS12	AVS11	AVS10	(Initial value: 0000 0000)
(00FADH)	–	–	–	–	–	–	–	AVS18	(Initial value: **** ***0)

ORAVE1

(00FAEH)	AVE17	AVE16	AVE15	AVE14	AVE13	AVE12	AVE11	AVE10	(Initial value: 0000 0000)
(00FAFH)	–	–	–	–	–	–	–	VES18	(Initial value: **** ***0)

AVS1n	Vertical start point for area 1 plane	Write only
AVE1n	Vertical end point for area 1 plane	

(n; 0 to 8)

ORAHS2

(00FB0H)	AHS27	AHS26	AHS25	AHS24	AHS23	AHS22	AHS21	AHS20
(00FB1H)	–	–	–	–	–	–	–	AHS28

ORAHE2

(00FB2H)	AHE27	AHE26	AHE25	AHE24	AHE23	AHE22	AHE21	AHE20	(Initial value: 0000 0000)
(00FB3H)	–	–	–	–	–	–	–	AHE28	(Initial value: **** ***0)

AHS2n	Horizontal start point for area 2 plane	Write only
AHE2n	Horizontal end point for area 2 plane	

(n; 0 to 8)

ORAVS2

(00FB4H)	AVS27	AVS26	AVS25	AVS24	AVS23	AVS22	AVS21	AVS20	(Initial value: 0000 0000)
(00FB5H)	–	–	–	–	–	–	–	AVS28	(Initial value: **** ***0)

ORAVE2

(00FB6H)	AVE27	AVE26	AVE25	AVE24	AVE23	AVE22	AVE21	AVE20	(Initial value: 0000 0000)
(00FB7H)	–	–	–	–	–	–	–	AVE28	(Initial value: **** ***0)

AVS2n	Vertical start point for area 2 plane	Write only
AVE2n	Vertical end point for area 2 plane	

(n; 0 to 8)

ORP6S (00FBA$_H$)

7	6	5	4	3	2	1	0
P67S	P66S	P65S	P64S	PIDS	YBLCS	MPXS	

(Initial value: 0000 0000)

P67S to P64S	P6 port output select	0: R, G, B, Y/BL signal output 1: Port contents output	Write only
PIDS	I pin output select	0: I signal output 1: Port contents output	
YBLCS	Y/BL signal select	0: Y signal output 1: BL signal output	
MPXS	R, G, B, Y/BL signal select	00: Simultaneous output (Signal from the OSD circuit has higher priority.) 01: Output of signal from internal OSD circuit 10: Output of signal from externally input 11: Simultaneous output (Externally input signal has higher priority.)	

ORETC (00FB8$_H$)

7	6	5	4	3	2	1	0
VDSMD	PISEL	BKMF	ESMZ	"0"	MFYWR	MBK	RDWRV

(Initial value: 0000 0000)

VDSMD	Scan mode select	0: Normal mode 1: Double scan mode	Write only
PISEL	I pin function select	0: 15 colors 1: Half transparency / Half tone	
BKMF	Blinking master	0: Disable blinking 1: Enable blinking	
ESMZ	Smoothing enable specification register	0: Disable smoothing 1: Enable smoothing	
MFYWR	Display memory read mode select	0: Normal mode 1: Read-modify-write- mode	
MBK	Display memory bank switching	0: Access to either character code or character display options 1: Access both character code and character display option	
RDWRV	Read / write mode select at normal mode	0: Data write mode for display memory 1: Data read mode for display memory	

Note: Clear "0" to bit 3 in ORETC.

ORIRC (00FB9$_H$)

7	6	5	4	3	2	1	0
–	–	–	SDV	ISDC			

(Initial value: ***0 0000)

SVD	Interrupt source select	0: Interrup request by ISDC value 1: Interrupt request at falling edge of $\overline{VD}$ signal	Write only
ISDC	Interrupt genaration line select		

ORIRC (00FB9$_H$)

7	6	5	4	3	2	1	0
–	–	–	–	DCTR			

(Initial value: **** 0000)

DCTR	Display line counter	Read only

Note: The display line counter also increments when a line with all blank data or a line with display off is specified.

OSD control register list (1/2)

Register Address	Register Name	Register bit configuration								Bit contents
		bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	
00F81	ORHS1	HS17	HS16	HS15	HS14	HS13	HS12	HS11	HS10	HS17 to 10: Code horizontal display base position setting
00F82, 00F83 to 00F98, 00F99	ORVSn	VSn7	VSn6	VSn5	VSn4	VSn3	VSn2	VSn1	VSn0	VSn8 to 0: Code vertical display position setting (n; 0 to 12)
		–	–	–	–	–	–	–	VSn8	
00F9A	ORCS4	CS4		CS3		CS2		CS1		CSn: Character size (n; 1 to 12)
00F9B	ORCS8	CS8		CS7		CS6		CS5		00: Display off 10: Middle size
00F9C	ORCS12	CS12		CS11		CS10		CS9		01: Large size 11: Small size
00F9D	OREULA8	EULA8	EULA7	EULA6	EULA5	EULA4	EULA3	EULA2	EULA1	EULAn: Underline display setting for line n (n; 0 to 12)
00F9E	OREULA12	–	–	–	–	EULA12	EULA11	EULA10	EULA9	
00F9F	OREFR8	EFR8	EFR7	EFR6	EFR5	EFR4	EFR3	EFR2	EFR1	EFRn: Fringing setting for line n (n; 0 to 12)
00FA0	OREFR12	–	–	–	–	EFR12	EFR11	EFR10	EFR9	
00FA1	ORCLKF	CK7	CK6	CK5	CK4	CK3	CK2	CK1	CK0	CKx: Display clock frequency monitor (x; 0 to 7)
00FA1	ORCLKC	CKC7	CKC6	CKC5	CKC4	CKC3	CKC2	CKC1	CKC0	CKCx: Display clock frequency (x; 0 to 7)
00FA2	ORSOL4	SOL4		SOL3		SOL2		SOL1		SOLn: Solid space display setting for line n (n; 0 to 12)
00FA3	ORSOL8	SOL8		SOL7		SOL6		SOL5		00: No solid space 10: Right
00FA4	ORSOL12	SOL12		SOL11		SOL10		SOL9		01: Left 11: Left and right
00FA5	ORBK	IBDT	RBDT	GBDT	BBDT	IFDT	RFDT	GFDT	BFDT	IBDT, RBDT, GBDT: Background color setting IFDT, RFDT, GFDT, BFDT: Fringing color setting
00FA6	ORACL	ACLI2	ACLR2	ACLG2	ACLB2	ACLI1	ACLR1	ACLG1	ACLB1	ACLI2 / ACLR2 / ACLG2 / ACLB2: Area 2 plane color ACLI1 / ACLR1 / ACLG1 / ACLB1: Area 1 plane color Set ACLI2 and ACLI1 to 1, when PISEL; 1.
00FA7	CRRCL	EBKGD	EXBL	AON2	AON1	RCLI	RCLR	RCLG	RCLB	EBKGD: Background function EXBL: Full-rasterblanking AON2: Area 2 plane display AON1: Area 1 plane display RCLI / R / G / B: Raster plane color Set RCLI to 1, when PISEL; 1.
00FA8	ORAHS1	AHS17	AHS16	AHS15	AHS14	AHS13	AHS12	AHS11	AHS10	AHSx: Area 1 plane horizontal start position (n; 0 to 8)
00FA9		–	–	–	–	–	–	–	AHS18	
00FAA	ORAHE1	AHE17	AHE16	AHE15	AHE14	AHE13	AHE12	AHE11	AHE10	AHE1x: Area 1 plane horizontal end position (n; 0 to 8)
00FAB		–	–	–		–	–	–	AHE18	
00FAC	ORAVS1	AVS17	AVS16	AVS15	AVS14	AVS13	AVS12	AVS11	AVS10	AVS1x: Area 1 plane vertical start position (n; 0 to 8)
00FAD		–	–	–	–	–	–	–	AVS18	
00FAE	ORAVE1	AVE17	AVE16	AVE15	AVE14	AVE13	AVE12	AVE11	AVE10	AVE1x: Area 1 plane vertical end position (n; 0 to 8)
00FAF		–	–	–	–	–	–	–	AVE18	
00FB0	ORAHS2	AHS27	AHS26	AHS25	AHS24	AHS23	AHS22	AHS21	AHS20	AHS2x: Area 2 plane horizontal start position (n; 0 to 8)
00FB1		–	–	–	–	–	–	–	AHS28	
00FB2	ORAHE2	AHE27	AHE26	AHE25	AHE24	AHE23	AHE22	AHE21	AHE20	AHE2x: Area 2 plane horizontal end position (n; 0 to 8)
00FB3		–	–	–	–	–	–	–	AHE28	
00FB4	ORSVS2	AVS27	AVS26	AVS25	AVS24	AVS23	AVS22	AVS21	AVS20	AVS2x: Area 2 plane vertical start position (n; 0 to 8)
00FB5		–	–	–	–	–	–	–	AVS28	
00FB6	ORAVE2	AVE27	AVE26	AVE25	AVE24	AVE23	AVE22	AVE21	AVE20	AVE2x: Area 2 plane vertical end position (n; 0 to 8)
00FB7		–	–	–	–	–	–	–	AVE28	
00FB8	ORETC	VDSMD	PISEL	BKMF	ESMZ	"0"	MFYWR	MBK	RDWRV	VDSMD: Scan mode select PISEL: I pin function select BKMF: Blinking master ESMZ: Smoothing MFYWR: Display memory read mode select MBK: Display memory bank switching select RDWRV: Read / write mode select at normal mode
00FB9	ORIRC	–	–	–	SVD	ISDC				SVD: Interrupt source select ISDC: Interrupt generation line select
00FB9	ORIRC	–	–	–	–	DCTR				DCTR: Display line counter
00FBA	ORP6S	P67S	P66S	P65S	P64S	PIDS	YBLCS	MPXS		P6xS: P6 port output select (x; 4 to 7) PIDS: I pin output select YBLCS: Y/BL signal select MPXS: R, G, B, Y/BL single select

OSD control register list (2/2)

Register Address	Register Name	Register bit configuration								Bit contents
		bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	
00FBB	ORIV	VDPOL	HDPOL	YBLII	RGBII	YIV	BLIV	RGBIV	IIV	VDPOL: VD input polarity select HDPOL: HD INPUT polarity select YBLII: Y/BLIN input polarity select RGBII: RIN, GIN, BIN input select YIV: Y output polarity select BLIV: BL output polarity select RGBIV: R, G, B output polarity select IIV: I pin polarity select
00024	ORDMA	DMA7	DMA6	DMA5	DMA4	DMA3	DMA2	DMA1	DMA0	DMAx: Display memory address setting (x; 0 to 8)
00025		–	–	–	–	–	–	–	DMA8	
0001D	ORCSN	–	SLNT	EUL	BLF	IDT	RDT	GDT	BDT	SLNT: Slant EUL: Underline BLF: Blinking IDT / RDT / CDT / BDT: Character color
0001E	ORCRA	CRA7	CRA6	CRA5	CRA4	CRA3	CRA2	CRA1	CRA0	CRAx: Character code (x; 0 to 0)
0001F		–	–	–	–	–	–	–	CRA8	
00FBC	ORWVSH	WVSH7	WVSH6	WVSH5	WVSH4	WVSH3	WVSH2	WVSH1	WVSH0	WVSHx: Window upper limit position (x; 0 to 8)
00FBD		–	–	–	–	–	–	–	WVSH8	
00FBE	ORWVSL	WVSL7	WVSL6	WVSL5	WVSL4	WVSL3	WVSL2	WVSL1	WVSL0	WVSL: Window lower limit position (x; 0 to 8)
00FBF		–	–	–	–	–	–	–	WVSL8	
00F80	ORDON	–	–	–	–	–	RGWR	EWDW	DON	RGWR: Writing data transfer control EWDW: Window enable DON: OSD display ON/OFF

Note 1: Except the meshed registers are changed by RGWR.

Note 2: Only lower 2 bits of the register in address $00F80_H$ are changed by RGWR (The register in address $00F80_H$ must not be used with any of the read-modify-write instructions as SET, CLR, etc.).

2.16 Jitter Elimination Circuit

The TMP88CM38A/P38A have a built-in jitter elimination circuit which maintains the vertical stability of the OSD even when input of the vertical signal fluctuates.

And the field decision information for the OSD circuit is detected by using jitter elimination circuit.

2.16.1 Configuration

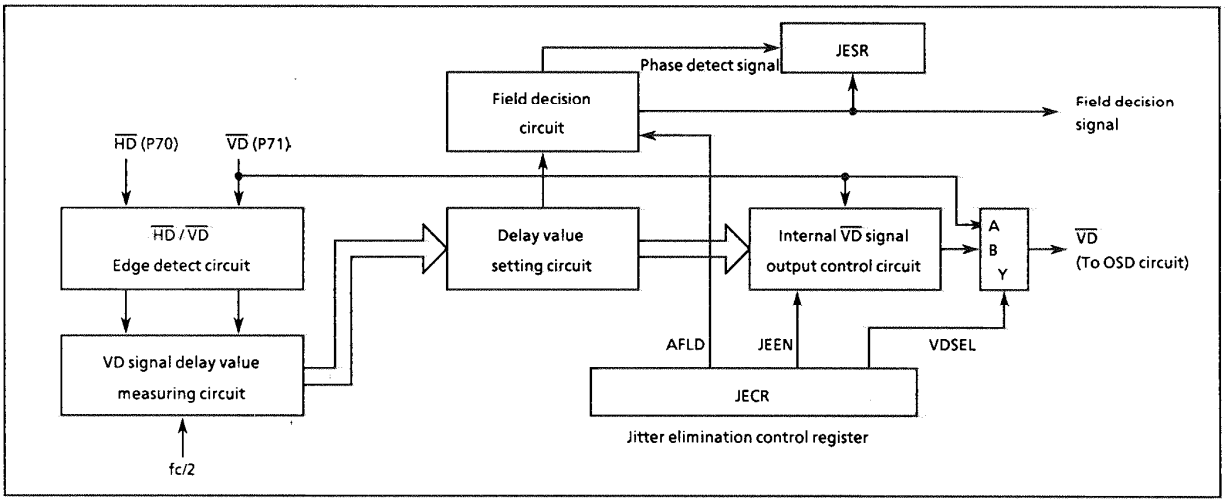


Figure 2.16.1 Jitter Elimination Circuit

2.16.2 Jitter Elimination Mode

The jitter elimination circuit is to identify the phase of the falling edges of the external $\overline{VD}$ signal and $\overline{HD}$ signal. When $\overline{VD}$ signal is falling within $\overline{HD}$ signal falling +/−1/4HD, the jitter is automatically eliminated and internal $\overline{VD}$ signal is set to the stable location.

This function is enabled by setting JEEN (bit2 in JECR) in the jitter elimination control register to "1".

2.16.3 Control

Jitter elimination circuit is controlled by the jitter elimination control register (JECR).

Jitter elimination control register

JECR ($00FE4_H$)

7	6	5	4	3	2	1	0
			VDSEL	AFLD	JEEN	"0"	"0"

(Initial value : ***0 0000)

VDSEL	VD select	0: $\overline{VD}$ from P71 1: $\overline{VD}$ from jitter elimination circuit	Write only
AFLD	Automatic field decision	0: Automatic field decision disabled 1: Automatic field decision enabled	
JEEN	Jitter elimination enable specification	0: Jitter elimination disabled 1: Jitter elimination enabled	

Note 1: Clear the AFLD to "0" to disable jitter elimination circuit.
Note 2: Always clear "0" to bit 1 and 0 of JECR.
Note 3: Clear "0" to AFLD and VDSEL if there is no phase shift in the vertical and horizontal sync. signals every other time, such as with non-interlaced TV.
*Note 4: * ; Don't care*

Jitter elemination status register

JESR ($00FE5_H$)

7	6	5	4	3	2	1	0
FDSF	PDF1	PDF0					PDF2

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

FDSF	Field deetect status flag	0: A position of a scanning line exists in the field which has a second display dot of character on an interlace TV screen. 1: A position of a scanning line exists in the field which has a first display dot of character on an interlace TV screen.	Read only
PDF2, 1, 0	Phase detect flag between $\overline{HD}$ and $\overline{VD}$	000: Phase 0 001: Phase 1 010: Phase 2 011: Phase 3 100: Phase 4 101: Phase 5 110: Phase 6 111: Phase 7	

Note 1: FDSF is different from the 1st and the 2nd field. It is a uique filed decided for OSD display.
*Note 2: *: Don't care*
Note 3:

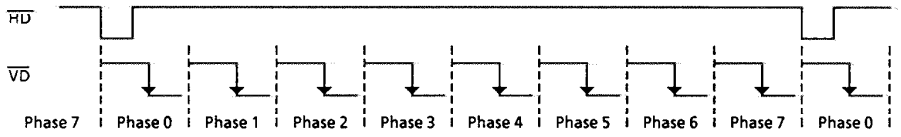


Figure 2.16.2 Jitter Elimination Control Register and Jitter Elimination Status Register

2.16.4 Auto Field Line Decision

The internal vertical and horizontal sync. signals corrected by the jitter elimination circuit generate the field line decision signals used in the OSD.

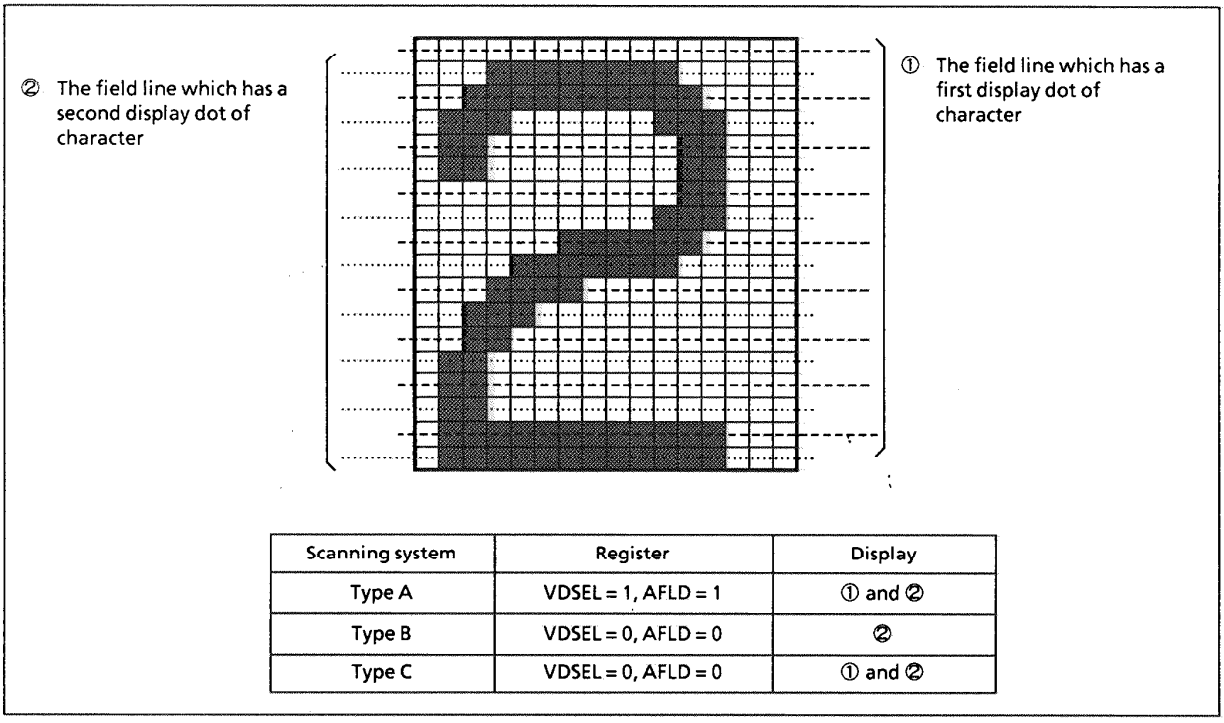
The OSD display in normal mode

Type A) When the OSD circuit is used on the TV system which has a phase shift in the vertical and horizontal sync. Signals every other filed such as the interlace TV, enable jitter elimination circuit and set "1" to AFLD and VDSEL. At this time, the field lines which have first and second display dot of character are displayed.

Type B) When the OSD circuit is used on the TV system which has no phase shift in the vertical and horizontal sync. Signals every other filed such as the non-interlace TV, enable jitter elimination circuit and clear "0" to AFLD and VDSEL. At this time, the field line which has a second display dot of character is only displayed.

The OSD display in double scan mode

Type C) Disable jitter elimination circuit and clear "0" to AFLD and VDSEL. At this time, the field lines which have first and second display dot of character are displayed.



Scanning system	Register	Display
Type A	VDSEL = 1, AFLD = 1	① and ②
Type B	VDSEL = 0, AFLD = 0	②
Type C	VDSEL = 0, AFLD = 0	① and ②

Figure 2.16.3 Relation with field line and VDSEL, AFLD

2.17 Data Slicer

The TMP88CM38A/P38A contain the data slicer to decode the caption data which multiplied during vertical flyback time of the composite video signal.

The composite video signal inputs to the data slicer circuit through P32 (V_{IN1}) and P33 (V_{IN0}). The caption data is decoded from the video signal. The composite video signal including negative sync-tip inputs to V_{IN0} and V_{IN1} pins. The data slicer can comply with the copy guard signal and special signals, and receive accurately the caption data under the condition of a weak electrical field or a ghost.

Note: When the data slicer is used at fc = 16 MHz, set to "02_H" in FC8CR.
When the data slicer is used at fc = 8 MHz, set to "00_H" in EC8CR (refer to Table 2.15.4).

2.17.1 Configuration

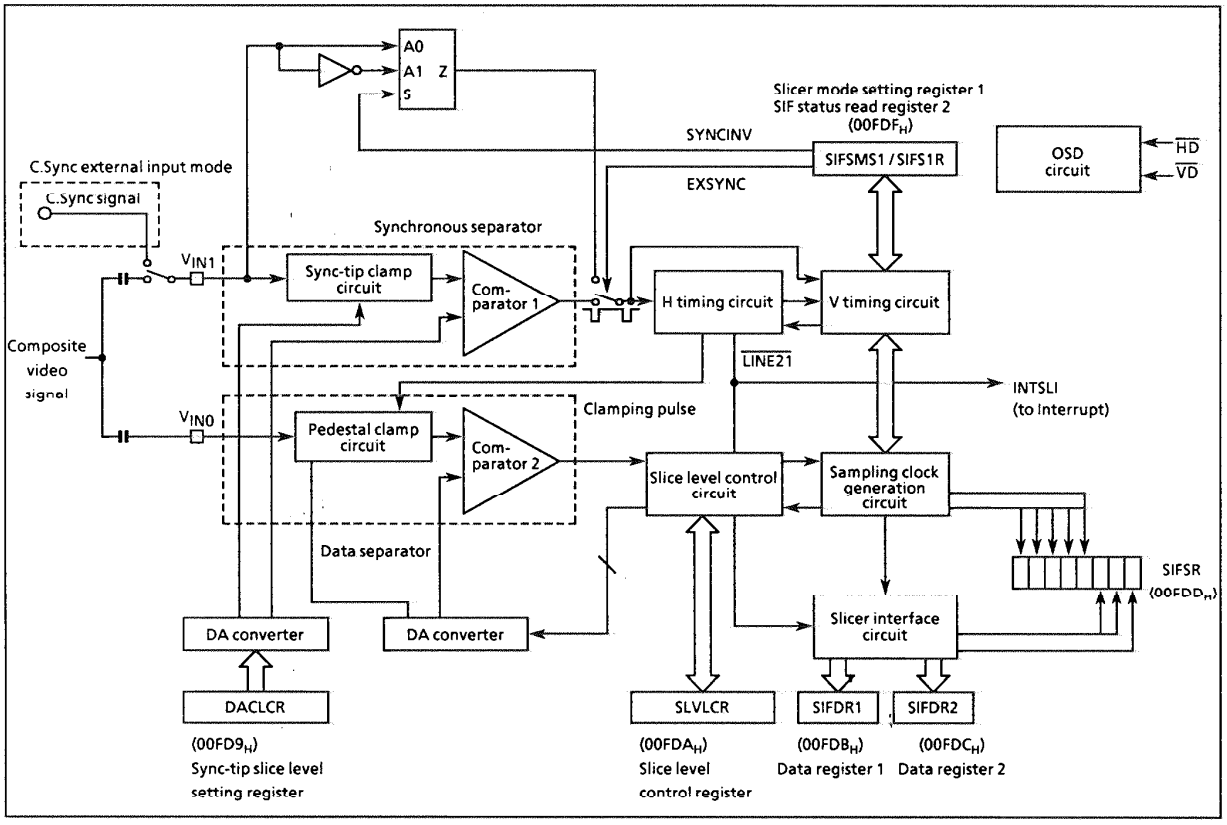


Figure 2.17.1 Data Slicer

2.17.2 Functions

(1) Video signal input
A low pass filter, a voltage amplifier and a condenser of about 0.1μF are connected between the video signal and the video signal input pin of V_{IN1} and V_{IN0} pins, that is shown as Figure 2.17.9. The low pass filter functions to reduce noise and color burst from the video signal, passes the amplifier and inputs the video signal to both V_{IN1} and V_{IN0} pins.

(2) Synchronous separator
This circuit is to separate the synchronous signal from the video signal. When DACL7 to 0 of DACLCR are set for the synchronous separation, the sync slice level is capable of setting. DACL7 to 4 set the slice level at the rising edge of the sync signal clamped data, and DACL3 to 0 set the slice level at the falling edge of the sync-tip clamped data. (Refer to section 2.14.5)

(3) Data separator
The data separator replaces the caption data piled on the video signal with the digital signal.
When SLVL5 to 0 of SLVLCR are set to get the digital signal, the Initial value: of the caption data slice level is capable of setting. (Refer to section 2.14.5)

(4) Sync-tip clamp circuit
The sync-tip level is clamped to the specified value.

(5) Pedestal clamp circuit
The video signal is set to the specified voltage with the clamp pulse generated from the H/V timing part, which is called as a pedestal clamp.

(6) DA converter
This converter gets the DA changed slice level of the clamp circuit to the comparator.

(7) Comparator
This comparator replaces the composite video signal with the digital value while inputting to the comparator.

(8) H timing circuit
This circuit detects the horizontal synchronous signal from C.Sync signal separated synchornously from the video signal, and generates the clamp pulse to clamp the video signal and provides it to the pedestal clamp circuit. In addition, the circuit detects the change of H frequency and provides the data to the sampling clock generation part.

(9) V timing circuit
This circuit detects the horizontal synchronous signal from C.Sync signal separated synchornously from the video signal, and provides line 21 detection signal to take out caption signal to the slice level control part.

(10) Slice level control circuit
This circuit detects CRI (clock run in) signal from VIDEO signal with line 21 detection signal generated at H/V timing part after slicing, and controls to the most suitable slice level and takes out the caption data.

(11) Sampling clock generation circuit
This circuit generates the sampling clock which is phase-locked to CRI signal with CRI signal detected at the slice level control part. In addition, the circuit revises the location where the sampling clock generates with H frequency variable data generated at H timing generation part.

(12) Slicer interface circuit
This is a 16 bit serial interface to receive the serial data.

(13) Interrupt generation circuit
Interrupts are generated by a rise in the caption line detection signal.

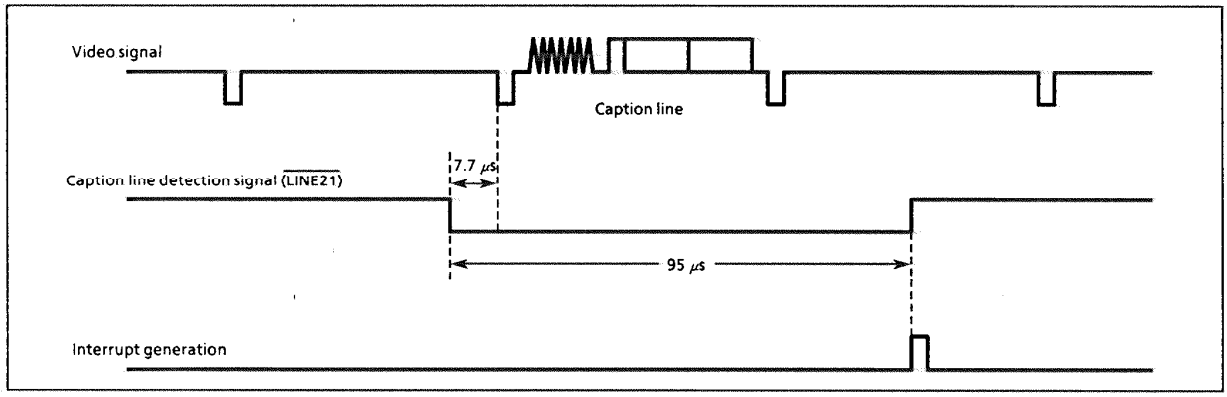


Figure 2.17.2 Interrupt Generation Timing

See the description of the on-screen display circuit interrupt vectors for details of interrupt vectors.

(14) C.Sync external input mode
The external C.Sync signal can be used internally by setting EXSYNC (SIFSMS1 bit 5) to "1".
As shown in Figure 2.17.3 (b), insert a low-pass filter (f_T = 503 kHz), voltage amplifier (x 2 voltage amplification), and a capacitor of approximately 0.1 μF between the video signal and the video signal input pin V_{IN1} and input an external C.Sync signal to V_{IN0}.
The polarity of the C.Sync signal is selected by SYNCINV (SIFSMS1 bit 6). (Internally used as $\overline{\text{C.Sync}}$.)

CSIN (P32)	SYNCINV
$\overline{\text{C.Sync}}$ (⊓_⊓)	"0"
C.Sync (_⊓_⊓_)	"1"

2.17.3 Video Signal Connection

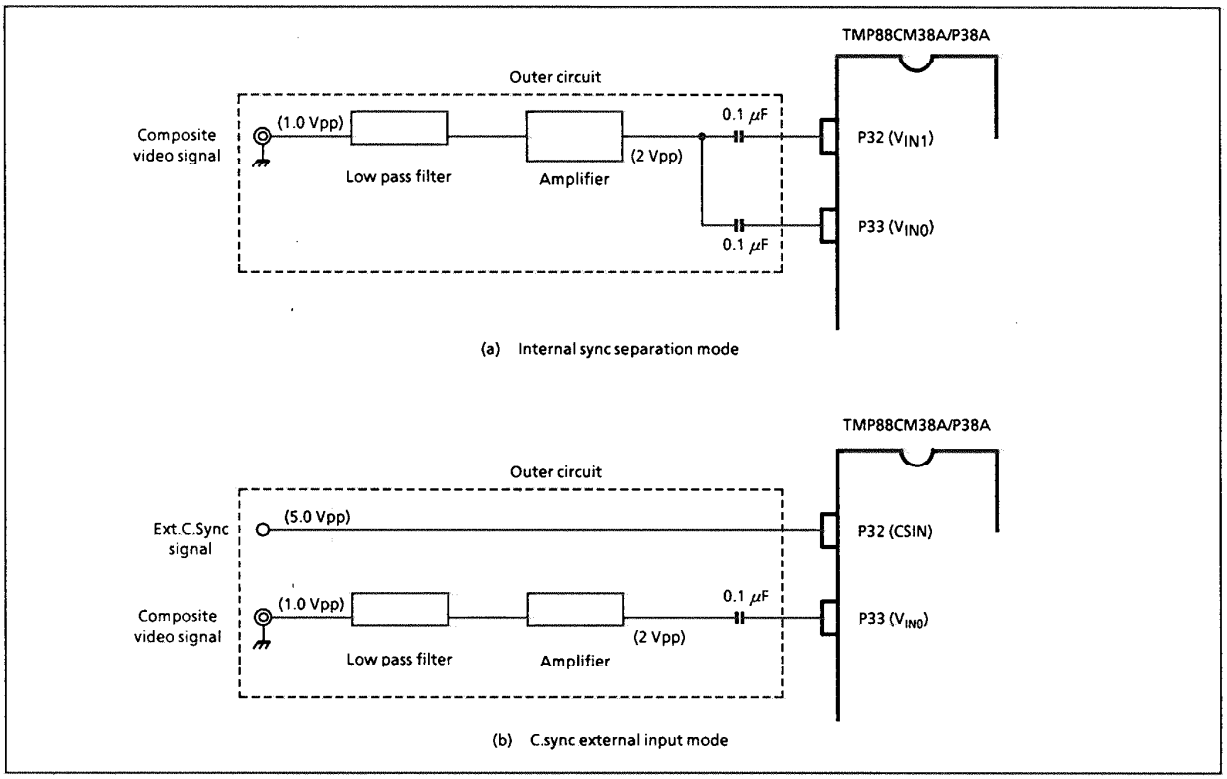


Figure 2.17.3 Video Signal Connection

Data Slicer Control Register

SINTCR ($00FD8_H$)

7	6	5	4	3	2	1	0
–	–	–	–	SLON	SLCR	–	–

(Initial value: 0000 00**)

SLON	Data Slicer Enable / Disable	1: Enable 0: Disable	Write only
SCLR	Data Slicer Interrupt Control	1: Enable Interrupt 0: Disable Interrupt	

Data Slicer Interrupt Status Register

SINTCR ($00FD8_H$)

7	6	5	4	3	2	1	0
–	–	–	SLIS	–	–	–	–

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

SLCR	Data Slicer Interrupt Status	0: – 1: Interrupt Request	Read only

Note 1: For setting SCLR to "1", write "1" after SLON is set to "1".
Note 2: SLIS is cleared to "0" after reading SINTCR.

Example: LD (SINTCR), 00001000B
LD (SINTCR), 00001100B

Figure 2.17.4 Data Slicer Control (I)

SIF data register 1 (Caption data 1st byte read register) (Read Only)

SIFDR1 ($00FD8_H$)

7	6	5	4	3	2	1	0
D1ST7	D1ST6	D1ST5	D1ST4	D1ST3	D1ST2	D1ST1	D1ST0

DIST7-0	Caption data 1st byte read register		Read only

SIF data register 2 (Caption data 2nd byte read register) (Read Only)

SIFDR2 ($00FDC_H$)

7	6	5	4	3	2	1	0
D2ND7	D2ND6	D2ND5	D2ND4	D2ND3	D2ND2	D2ND1	D2ND0

D2ND7-0	Caption data 2nd byte read register		Read only

SIF status register (Read Only)

SIFSR ($00FDD_H$)

7	6	5	4	3	2	1	0
STCRI	CRIN3	CRIN2	CRIN1	CRIN0	STFLD	STSB	STDE

STCRI	Clock run in detection	1: Clock run in detection 0: No clock run in detection	Read only
CRIN	CRI number -1	Actual CRI number-1	
STFLD	Field identification	1: 2nd field 0: 1st field	
STSB	Start bit identification flag	1: From detection of start bit until fall in / VD 0: Other times	
STDE	16 bit data receive end identification flag	1: From end of 16 bit data reception until fall in / VD 0: Other times	

Figure 2.17.5 Data Slicer Control (II)

Slicer mode setting register 1 (Write Only)

SIFSMS1 ($00FDF_H$)

7	6	5	4	3	2	1	0
"0"	SYNC INV	EXSYNC	"1"	CLINE3	CLINE2	CLINE1	CLINE0

(Initial value: 0001 1011)

SYNCINV	Sync signal input inversion	0: No inversion 1: Inversion of C.Sync external input signal	Write only
EXSYNC	Sync signal selection	0: Internal sync separation 1: External C.Sync input	
CLINE	Setting lines piled on caption data	0000: 10 line 0001: 11 line 0010: 12 line 0011: 13 line 0100: 14 line 0101: 15 line 0110: 16 line 0111: 17 line 1000: 18 line 1001: 19 line 1010: 20 line 1011: 21 line 1100: 22 line 1101: 23 line 1110: 24 line 1111: 25 line	

Note: Always write "0" to bit 7 of SIFSMS1 and "1" to bit 4 when writing to SIFSMS1.

Figure 2.17.6 Data Slicer Control (III)

SIF status read register 2

	7	6	5	4	3	2	1	0
SIFS1R ($00FDF_H$)			GOODV	FLINE4	FLINE3	FLINE2	FLINE1	FLINE0

GOODV	Monitor signal of synchronization	0: Out of synchronization (One or more) 1: V timing synchronizing	Read only
FLINE	Field scanning line (Standard 262.5 = − 1) Two's complement	00000: 0 263.5 00001: 1 264.5 00010: 2 00011: 3 00100: 4 00101: 5 00110: 6 00111: 7 01000: 8 01001: 9 01010: 10 01011: 11 01100: 12 01101: 13 01110: 14 01111: 15 278.5 10000: V synchronizing adjustment 10001: −15 248.5 10010: −14 10011: −13 10100: −12 10101: −11 10110: −10 10111: −9 11000: −8 11001: −7 11010: −6 11011: −5 11100: −4 11101: −3 11110: −2 261.5 11111: −1 262.5	

Figure 2.17.7 Data Slicer Control (Ⅳ)

The explanation of the monitor signals (GOODV, FLINE) are as follows.

① GOODV 0: Data slicer can not synchronize video signal.
1: Data slicer can synchronize video signal.

② FLINE The number of field signal scanning line which the data slicer is detecting or monitor flag of detecting state.

Example: FLINE = $1F_H$: NTSC Signal
FLINE = 10_H: V synchronizing adjustment

Caption data slice level control register (Write / Read)

SLVLCR ($00FDA_H$)

7	6	5	4	3	2	1	0
		SLVL5	SLVL4	SLVL3	SLVL2	SLVL1	SLVL0

(Initial value: **00 1010)

SLVL	Slice level (Initial value:) setting Slice level setting	000000: VPCLAMP + (1 / 256) V_{DD} 000001: VPCLAMP + (2 / 256) V_{DD} 000010: VPCLAMP + (3 / 256) V_{DD} 000011: VPCLAMP + (4 / 256) V_{DD} 000100: VPCLAMP + (5 / 256) V_{DD} ⋮ ⋮ 111101: VPCLAMP + (62 / 256) V_{DD} 111110: VPCLAMP + (63 / 256) V_{DD} 111111: VPCLAMP + (64 / 256) V_{DD}	Write
SLVL	Slice level (Final value)		Read

Note 1: VPCLAMP (Pedestal clamp) = (1 / 2) V_{DD}

Note 2: The SLVLCR has different write buffer and read buffer, and cannot be read write-buffer data. The SBIDBR cannot be used with any read-modify-write instructions. (Bit manipulation instructions such as SET, CLR, etc. and logical operation such as AND, OR, etc.)

Sync-tip slice level setting register (Write Only)

DACLCR ($00FD9_H$)

7	6	5	4	3	2	1	0
DACL7	DACL6	DACL5	DACL4	DACL3	DACL2	DACL1	DACL0

(Initial value: 0100 0010)

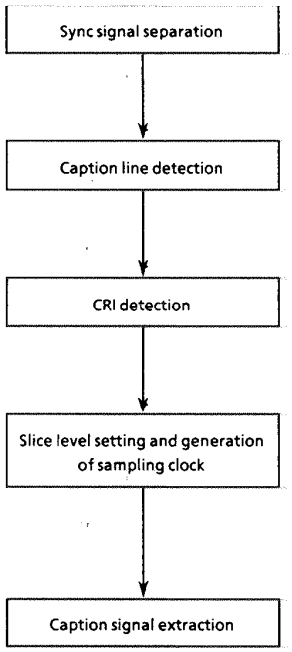
DACL	DACL7 to 4: Slice level Lower limit setting DACL3 to 0: Slice level Upper limit setting	0000: VSCLAMP + (3 / 512) V_{DD} 0001: VSCLAMP + (6 / 512) V_{DD} 0010: VSCLAMP + (9 / 512) V_{DD} 0011: VSCLAMP + (12 / 512) V_{DD} ⋮ ⋮ 1101: VSCLAMP + (42 / 512) V_{DD} 1110: VSCLAMP + (45 / 512) V_{DD} 1111: VSCLAMP + (48 / 512) V_{DD}	Write only

Note: VSCLAMP (Sync-tip clamp) = (204 / 512) V_{DD}

Figure 2.17.8 Data Slicer Control (V)

2.17.5 Clamp and Data Slicer Operation

The slicer uses the following steps to obtain the caption signals:



The composite video signal input via V_{IN1} (pin 40) is clamped by the sync tip clamp circuit and the HD and VD sync signals separated by the sync separation circuit.

Field decision and caption line detection are effected using the HD and VD sync signals.

The CRI signal of the caption line interval is detected from the pedestal clamped video signal at V_{IN0} (pin 41).

The slice level is controlled during the CRI signal interval, detected by the slice level control block, to obtain the optimum level.
To determine the timing for extracting the caption data, a sampling clock is generated that is phase-locked to the CRI.

The caption data is extracted at the selected slice level using sampling clock, which is locked to the caption data.

The data slicer has two separation circuits:

a. Sync signal (sync tip clamp + sync signal slice) separation.
b. Caption data (pedestal clamp + data slice) separation.

The two circuits are described briefly below.

a. Sync signal (sync tip clamp + sync signal slice)

a-1 Sync tip clamp (pin 40) ..... The sync tip is clamped at (204 / 512) V_{DD} [V] as shown in Figure 2.17.9.

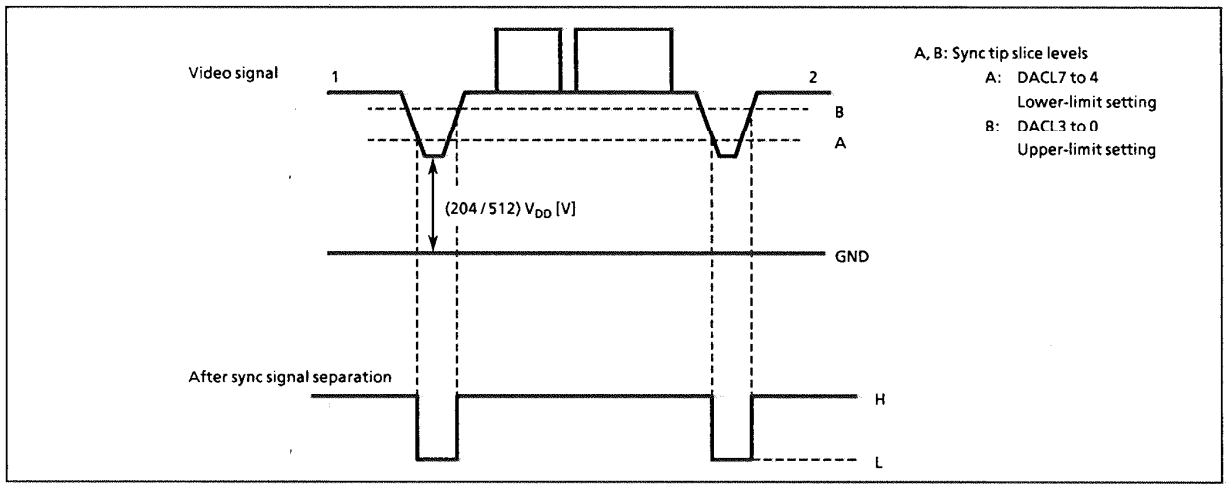


Figure 2.17.9 Sync Signal Slice

a-2 Method of sync signal slice

The sync signal is separated as shown in Figure 2.17.9.

Sync signal separation is accomplished by comparing the voltage of the sync tip-clamped video signal with the sync tip slice level. For a 1 → 2 video signal change, if the sync signal after separation is high, the slice level A is selected ; if low, the slice level B is selected.

(Sync tip slice level)

Slice level = VSCLAMP + {(3 + 3X) / 512} V_{DD}

V_{DD}: power supply voltage

VSCLAMP: sync tip clamp voltage = (204 / 512) V_{DD}

X: setup data (4 bits)

b. Caption data (pedestal clamp + data slice)

b-1 Pedestal clamp (pin 41) ..... Clamped at (1 / 2) V_{DD} [V] as shown in Figure 2.17.10.

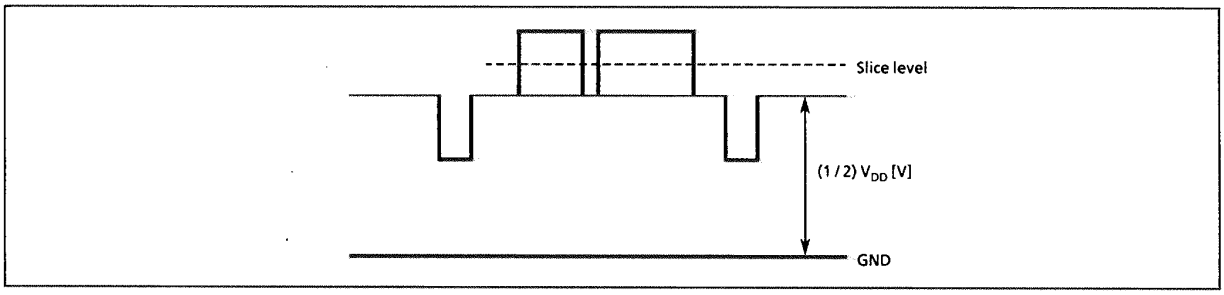


Figure 2.17.10 Pedestal Clamp

b-2 Method of data slice

The data slice level constitutes a level at which the CCD data is differentiated.
The slice level's setup value is indicated by the following:

Slice level = VPCLAMP + (X / 256) V_{DD} [V]
V_{DD}: power supply voltage
VPCLAMP: pedestal clamp voltage = (1 / 2) V_{DD}
X: setup data (6 bits)

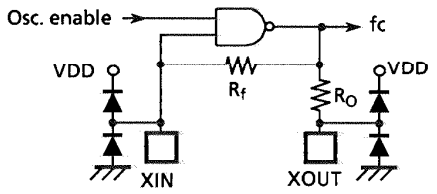
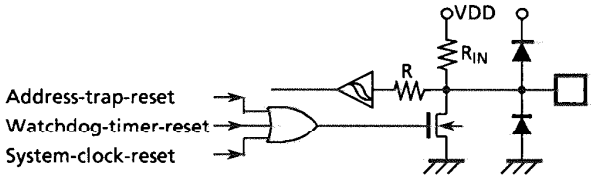
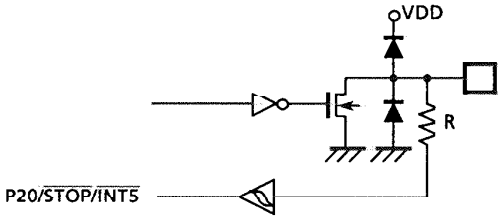
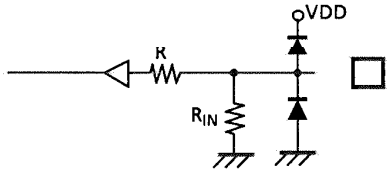
b-3 Automatic slice level correction circuit

The slice level is corrected to the appropriate value during the CRI period.
Slice level correction always begins with the setup value of SLVL (bits 5 to 0 of SLVLCR).
If you want the last value to become the initial value of the next slice level, set it to SLVL (bits 5 to 0 of SLVLCR).

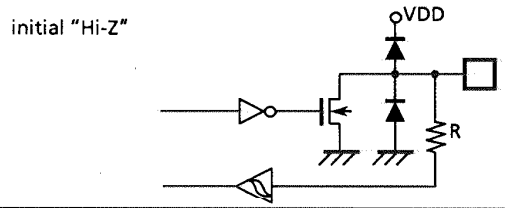
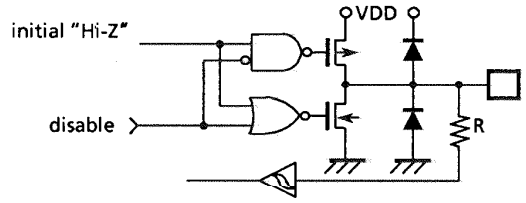
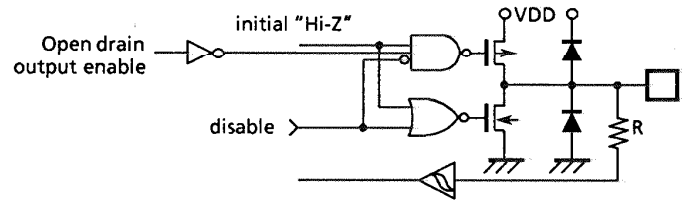
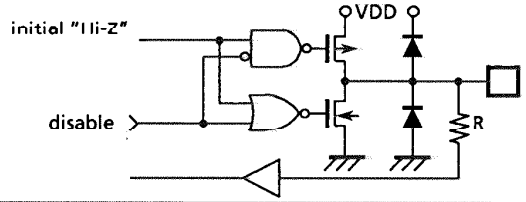
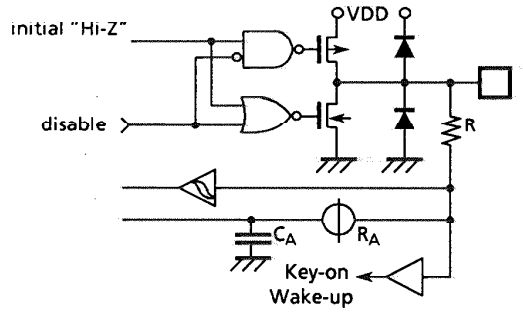
Input / Output Circuit

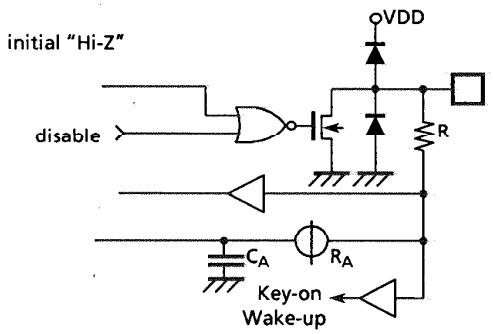
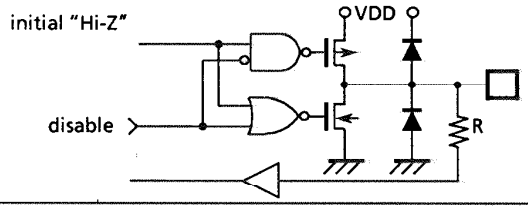
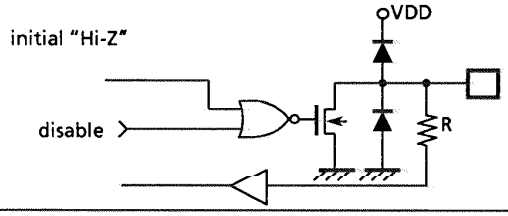
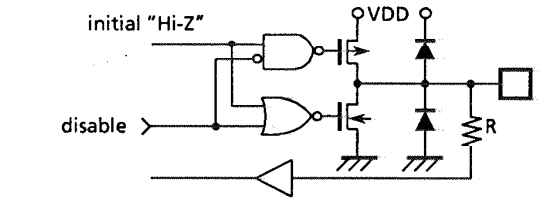
(1) Control pins

The input / output circuitries of the TMP88CM38A/P38A control pins are shown below.

Control Pin	I/O	Input / Output Circuitry	Remarks
XIN XOUT	I/O		Resonator connecting pins (high-frequency) R_f = 1.2 MΩ (typ.) R_O = 0.5 kΩ (typ.)
$\overline{\text{RESET}}$	I/O		Sink open drain output Hysteresis input Pull-up resistor R_{IN} = 220 kΩ (typ.) R = 1 kΩ (typ.)
$\overline{\text{STOP/INT5}}$ (P20)	Input		Hysteresis input R = 1 kΩ (typ.)
TEST	Input		R = 1 kΩ (typ.) Pull-down resistor R_{IN} = 70 kΩ (typ.)

(2) Input / output ports

Port	I/O	Input / Output Circuitry	Remarks
P20	I/O		Sink open drain output Hysteresis input R = 1 kΩ (typ.)
P30 to P33 P50, P57 P70, P71	I/O		Tri-state I/O Hysteresis input R = 1 kΩ (typ.)
P34, P35, P51, P52	I/O		Tri-state I/O or Open drain output programmable Hysteresis input R = 1 kΩ (typ.)
P40 to P47	I/O		Tri-state I/O R = 1 kΩ (typ.)
P53 to P56	I/O		Tri-state I/O Hysteresis input Key on wake up input ($V_{IL4} = 0.65 \times V_{DD}$) R = 1 kΩ (typ.) R_A = 5 kΩ (typ.) C_A = 22 pF (typ.)

Port	I/O	Input / Output Circuitry	Remarks
P60, P61	I/O		Sink open drain output High current output I_A = 20 mA (typ.) R = 1 kΩ (typ.) R_A = 5 kΩ (typ.) C_A = 22 pF (typ.) Key on wake up input (V_{IL4} = 0.65 × V_{DD})
P62	I/O		Tri-state I/O R = 1 kΩ (typ.) High current output I_{OL} = 20 mA (typ.)
P63	I/O		Sink open drain output High current output I_{OL} = 20 mA (typ.) R = 1 kΩ (typ.)
P64 to P67	I/O		Tri-state I/O R = 1 kΩ (typ.)

Electrical Characteristics

Absolute maximum ratings (V_{SS} = 0 V)

Parameter	Symbol	Pins	Ratings	Unit
Supply Voltage	V_{DD}	—	− 0.3 to 6.5	V
Input Voltage	V_{IN}	—	− 0.3 to V_{DD} + 0.3	V
Output Voltage	V_{OUT1}	—	− 0.3 to V_{DD} + 0.3	V
Output Current (Per 1 pin)	I_{OUT1}	Ports P2, P3, P4, P5, P64 to P67, P7	3.2	mA
	I_{OUT2}	Ports P60 to P63	30	
Output Current (Total)	Σ I_{OUT1}	Ports P2, P3, P4, P5, P64 to P67, P7	120	mA
	Σ I_{OUT2}	Ports P60 to P63	120	
Power Dissipation [Topr = 70°C]	PD	—	400	mW
Soldering Temperature (time)	Tsld	—	260 (10 s)	°C
Storage Temperature	Tstg	—	− 55 to 125	°C
Operating Temperature	Topr	—	− 30 to 70	°C

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 conditions (V_{SS} = 0 V, Topr = −30 to 70°C)

Parameter	Symbol	Pins	Conditions		Min	Max	Unit
Supply Voltage	V_{DD}		fc = 16 MHz	NORMAL mode	4.5	5.5	V
			fc = 16 MHz	IDLE mode			
				STOP mode	2.0		
Input High Voltage	V_{IH1}	Except hysteresis input	V_{DD} = 4.5 to 5.5 V		V_{DD} × 0.70	V_{DD}	V
	V_{IH2}	Hysteresis input			V_{DD} × 0.75		
	V_{IH3}		V_{DD} < 4.5 V		V_{DD} × 0.90		
Input Low Voltage	V_{IL1}	Except hysteresis input	V_{DD} = 4.5 to 5.5 V		0	V_{DD} × 0.30	V
	V_{IL2}	Hysteresis input				V_{DD} × 0.25	
	V_{IL3}		V_{DD} < 4.5 V			V_{DD} × 0.10	
	V_{IL4}	Key-on Wake-up input	V_{DD} = 4.5 to 5.5 V			V_{DD} × 0.65	
Clock Frequency	fc	XIN, XOUT	V_{DD} = 4.5 to 5.5 V		8.0	16.0	MHz
	f_{OSC}	Internal clock	V_{DD} = 4.5 to 5.5 V	fc = 8 MHz	8.0	12.0	
				fc = 16 MHz	16.0	24.0	

Note 1: 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.

Note 2: Clock frequency fc ; Supply voltage range is specified in NORMAL mode and IDLE mode.

Note 3: Smaller value is alternatively specified as the maximum value.

DC Characteristics

(V_{SS} = 0 V, Topr = − 30 to 70°C)

Parameter	Symbol	Pins	Conditions	Min	Typ.	Max	Unit
Hysteresis Voltage	V_{HS}	Hysteresis inputs		−	0.9	−	V
Input Current	I_{IN1}	TEST	V_{DD} = 5.5 V, V_{IN} = 5.5 V / 0 V	−	−	± 2	μA
	I_{IN2}	Open drain ports	V_{DD} = 5.5 V, V_{IN} = 5.5 V / 0 V	−	−	± 2	
	I_{IN3}	Tri-state ports	V_{DD} = 5.5 V, V_{IN} = 5.5 V / 0 V	−	−	± 2	
	I_{IN4}	$\overline{RESET}$, $\overline{STOP}$	V_{DD} = 5.5 V, V_{IN} = 5.5 V / 0 V	−	−	± 2	
Input Resistance	R_{IN2}	$\overline{RESET}$		100	220	450	kΩ
Output Leakage Current	I_{LO1}	Sink open drain ports	V_{DD} = 5.5 V, V_{OUT} = 5.5 V	−	−	2	μA
	I_{LO2}	Tri-state ports	V_{DD} = 5.5 V, V_{OUT} = 5.5 V / 0 V	−	−	± 2	
Output High Voltage	V_{OH2}	Tri-state ports	V_{DD} = 4.5 V, I_{OH} = − 0.7 mA	4.1	−	−	V
Output Low Voltage	V_{OL}	Except XOUT and ports P60 to P63	V_{DD} = 4.5 V, I_{OL} = 1.6 mA	−	−	0.4	V
Output Low current	I_{OL3}	Port P60 to P63	V_{DD} = 4.5 V, V_{OL} = 1.0 V	−	20	−	mA
Supply Current in NORMAL mode	I_{DD}	—	V_{DD} = 5.5 V fc = 16 MHz (Note3) V_{IN} = 5.3 V / 0.2 V	−	25	30	mA
Supply Current in IDLE mode				−	20	25	mA
Supply Current in STOP mode			V_{DD} = 5.5 V V_{IN} = 5.3 V / 0.2 V	−	0.5	10	μA

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

Note 2 : Input Current I_{IN3} ; The current through resistor is not included.

Note 3 : Supply Current I_{DD} ; The current (Typ. 0.5 mA) through ladder resistors of ADC is included in NORMAL mode and IDLE mode.

AD Conversion Characteristics

(V_{SS} = 0 V, V_{DD} = 4.5 V to 5.5 V, Topr = − 30 to 70°C)

Parameter	Symbol	Conditions	Min	Typ.	Max	Unit
Analog Reference Voltage	V_{AREF}	supplied from V_{DD} pin.	−	V_{DD}	−	V
	V_{ASS}	supplied from V_{SS} pin.	−	0	−	
Analog Reference Voltage Range	$\triangle V_{AREF}$	= V_{DD} − V_{SS}	−	V_{DD}	−	
Analog Input Voltage	V_{AIN}		V_{SS}	−	V_{DD}	
Nonlinearity Error		V_{DD} = 5.0 V	−	−	± 1	LSB
Zero Point Error			−	−	± 2	
Full Scale Error			−	−	± 2	
Total Error			−	−	± 3	

Note: The total error means all error except quanting error.

AC characteristics

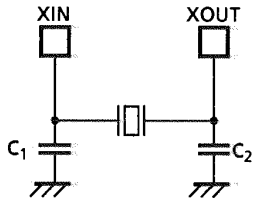
(V_{SS} = 0 V, V_{DD} = 4.5 to 5.5 V, Topr = −30 to 70°C)

Parameter	Symbol	Conditions	Min	Typ.	Max	Unit
Machine Cycle Time	t_{cy}	In NORMAL mode	0.5	–	1.0	μs
		In IDLE mode				
High Level Clock Pulse Width	t_{WCH}	For external clock operation (XIN input), fc = 16 MHz	31.25	–	–	ns
Low Level Clock Pulse Width	t_{WCL}					

Recommended oscillating conditions

(V_{SS} = 0 V, V_{DD} = 4.5 to 5.5 V, Topr = −30 to 70°C)

Parameter	Oscillator	Oscillation Frequency	Recommended Oscillator	Recommended Constant	
				C_1	C_2
High-frequency Osillation	Ceramic Resonator	8 MHz	Murata CSA8.00MTZ	30 pF	30 pF
		16 MHz	Murata CSA16.00MXZ040	5 pF	5 pF



High-frequency Oscillation

Note: To keep reliable operation, shield the device electrically with the metal plate on its package mold surface against the high electric field, for example, by CRT (Cathode Ray Tube).