
EM78P173N

**8-Bit Microcontroller
with OTP ROM**

**Product
Specification**

DOC. VERSION 1.1


ELAN MICROELECTRONICS CORP.

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ELAN MICROELECTRONICS CORPORATION

Headquarters:

No. 12, Innovation 1st Road
Hsinchu Science Park
Hsinchu, TAIWAN 30076
Tel: +886 3 563-9977
Fax: +886 3 563-9966
webmaster@emc.com.tw
<http://www.emc.com.tw>

Hong Kong:

Elan (HK) Microelectronics Corporation, Ltd.
Flat A, 19F., World Tech Centre 95
How Ming Street, Kwun Tong
Kowloon, HONG KONG
Tel: +852 2723-3376
Fax: +852 2723-7780

USA:

Elan Information Technology Group (U.S.A.)
PO Box 601
Cupertino, CA 95015
U.S.A.
Tel: +1 408 366-8225
Fax: +1 408 366-8225

Korea:

Elan Korea Electronics Company, Ltd.
301 Dong-A Building
632 Kojan-Dong, Namdong-ku
Incheon City, KOREA
Tel: +82 32 814-7730
Fax: +82 32 813-7730

Shenzhen:

Elan Microelectronics Shenzhen, Ltd.
3F, SSMEC Bldg., Gaoxin S. Ave. I
Shenzhen Hi-tech Industrial Park
(South Area), Shenzhen
CHINA 518057
Tel: +86 755 2601-0565
Fax: +86 755 2601-0500
elan-sz@elanic.com.cn

Shanghai:

ELAN Microelectronics Shanghai, Ltd.
Rm101, #3 Lane 289, Bisheng Rd..
Zhangjiang Hi-Tech Park
Pudong New Area, Shanghai,
CHINA 201204
Tel: +86 21 5080-3866
Fax: +86 21 5080-0273
elan-sh@elanic.com.cn

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Specification Revision History

Doc. Version	Revision Description	Date
0.9	Preliminary version	2010/03/24
1.0	Initial version	2010/04/20
1.1	Modified the Electrical Characteristics	2011/07/08

1 General Description

The EM78P173N is an 8-bit microprocessor designed and developed with low-power and high-speed CMOS technology. It has an on-chip 1K×13-bit Electrical One Time Programmable Read Only Memory (OTP-ROM). This device provides a protection bit to prevent intrusion of user's OTP memory code. Three Code option words are also available to meet user's requirements.

With its enhanced OTP-ROM features, the EM78P173N provides a convenient way of developing and verifying user's programs. Moreover, this OTP device offers the advantages of easy and effective program updates, using development and programming tools. Users can avail of the ELAN Writer to easily program their development code.

2 Features

- CPU configuration
 - 1K×13 bits on-chip ROM
 - 48×8 bits on-chip registers (SRAM, General purpose)
 - 5-level stacks for subroutine nesting
 - 4 programmable level voltage detector
LVD : 4.5, 4.0, 3.3, 2.2V
 - 3 programmable level voltage reset
LVR : 4.0, 3.5, 2.7V
 - Less than 1.5mA at 5V/4 MHz
 - Typically 15 μ A, at 3V/32kHz
 - Typically 1 μ A, during Sleep mode
- I/O port configuration
 - 2 bidirectional I/O ports : P5, P6
 - 12 I/O pins
 - Wake-up port : P6
 - 7 Programmable pull-down I/O pins
 - 7 programmable pull-high I/O pins
 - 7 programmable open-drain I/O pins
 - External interrupt with wake-up: P60
- Operating voltage range:
 - 2.1V~5.5V at 0~70°C (Commercial)
 - 2.3V~5.5V at -40~85°C (Industrial)
- Operating frequency range (base on 2 clocks):
 - Crystal mode:
DC~20MHz/2clks @ 5V
DC~8MHz/2clks @ 3V
DC~4MHz/2clks @ 2.1V
 - ERC mode:
DC~2 MHz/2clks @ 2.1V

- IRC mode:

Internal RC Frequency	Drift Rate			
	Temperature (-40°C ~85°C)	Voltage	Process	Total
4 MHz	$\pm 1\%$	$\pm 3\%$ *(2.1~5.5V)	$\pm 2\%$	$\pm 6\%$
16 MHz	$\pm 1\%$	$\pm 1\%$ *(4.0~5.5V)	$\pm 2\%$	$\pm 4\%$
8 MHz	$\pm 1\%$	$\pm 2\%$ *(3.0~5.5V)	$\pm 2\%$	$\pm 5\%$
1 MHz	$\pm 1\%$	$\pm 3\%$ *(2.1~5.5V)	$\pm 2\%$	$\pm 6\%$

- * Operating Voltage Range

- Peripheral configuration
 - 8-bit real time clock/counter (TCC) with selective signal sources, trigger edges, and overflow interrupt
 - External interrupt input pin
 - 2/4 clocks per instruction cycle selected by code option
 - Power down (Sleep) mode
 - High EFT immunity
- Four available interrupts:
 - TCC overflow interrupt
 - Input-port status changed interrupt
 - External interrupt
 - Low voltage detect interrupt
- Special features
 - Programmable free running watchdog timer
 - Power-on voltage detector available
- Package type:
 - 14-pin DIP 300mil : EM78P173ND14J/S
 - 14-pin SOP 150mil : EM78P173NSO14J/S
 - 10-pin MSOP 118mil : EM78P173NMS10J/S

Note: These are all Green products which do not contain hazardous substances.

3 Pin Assignment

(1) 14-Pin DIP/SOP

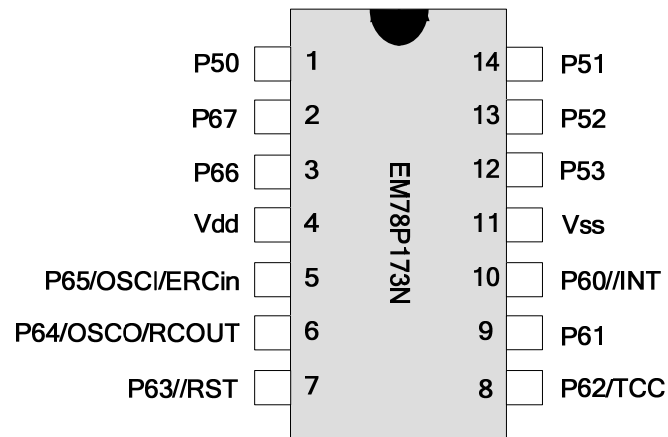


Figure 3-1 14-pin EM78P173N

(2) 10-Pin MSOP

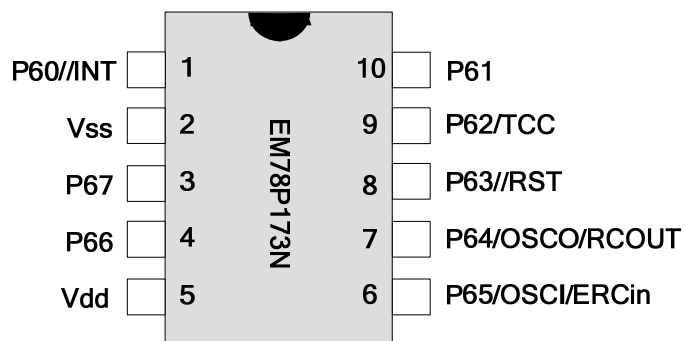


Figure 3-2 10-pin EM78P173N

4 Pin Description

4.1 EM78P173N-14PIN

Name	Function	Input Type	Output Type	Description
P50~P52	P50~P52	ST	CMOS	Bidirectional I/O pin with programmable pull-down.
P53	P53	ST	CMOS	Bidirectional I/O pin
P60//INT	P60	ST	CMOS	Bidirectional I/O pin with programmable pull-down, open-drain, pull-high and pin change wake-up.
	/INT	ST	–	External interrupt pin
P61	P61	ST	CMOS	Bidirectional I/O pin with programmable pull-down, open-drain, pull-high and pin change wake-up.
P62/TCC	P62	ST	CMOS	Bidirectional I/O pin with programmable pull-down, open-drain, pull-high and pin change wake-up.
	TCC	ST	–	Real Time Clock/Counter clock input
P63//RESET	P63	ST	CMOS	Bidirectional I/O pin with programmable pull-down and pin change wake-up. (open-drain)
	/RESET	ST	–	External pull-high reset pin
P64/OSCO/RCOUT	P64	ST	CMOS	Bidirectional I/O pin with programmable open-drain, pull-high and pin change wake-up.
	OSCO	–	XTAL	Clock output of crystal/ resonator oscillator
	RCOUT	–	CMOS	Clock output of internal RC oscillator Clock output of external RC oscillator (open-drain)
P65/OSCI/ERCin	P65	ST	CMOS	Bidirectional I/O pin with programmable open-drain, pull-high and pin change wake-up
	OSCI	XTAL	–	Clock input of crystal/resonator oscillator
	ERCin	AN	–	External RC input pin
P66~P67	P66~P67	ST	CMOS	Bidirectional I/O pin with programmable open-drain, pull-high and pin change wake-up
VDD	VDD	Power	–	Power
VSS	VSS	Power	–	Ground

Legend: ST: Schmitt Trigger input
AN: analog pin

CMOS: CMOS output
XTAL: oscillation pin for crystal / resonator

4.2 EM78P173N-10PIN

Name	Function	Input Type	Output Type	Description
P60//INT	P60	ST	CMOS	Bidirectional I/O pin with programmable pull-down, open-drain, pull-high and pin change wake-up.
	/INT	ST	–	External interrupt pin
P61	P61	ST	CMOS	Bidirectional I/O pin with programmable pull-down, open-drain, pull-high and pin change wake-up.
P62//TCC	P62	ST	CMOS	Bidirectional I/O pin with programmable pull-down, open-drain, pull-high and pin change wake-up.
	TCC	ST	–	Real Time Clock/Counter clock input
P63//RESET	P63	ST	CMOS	Bidirectional I/O pin with programmable pull-down and pin change wake-up. (open-drain)
	/RESET	ST	–	External pull-high reset pin
P64//OSCO/RCOUT	P64	ST	CMOS	Bidirectional I/O pin with programmable open-drain, pull-high and pin change wake-up.
	OSCO	–	XTAL	Clock output of crystal/ resonator oscillator
	RCOUT	–	CMOS	Clock output of internal RC oscillator Clock output of external RC oscillator (open-drain)
P65//OSCI/ERCin	P65	ST	CMOS	Bidirectional I/O pin with programmable open-drain, pull-high and pin change wake-up.
	OSCI	XTAL	–	Clock input of crystal/resonator oscillator
	ERCin	AN	–	External RC input pin
P66~P67	P66~P67	ST	CMOS	Bidirectional I/O pin with programmable open-drain, pull-high and pin change wake-up.
VDD	VDD	Power	–	Power
VSS	VSS	Power	–	Ground

Legend: ST: Schmitt Trigger input
AN: analog pin

CMOS: CMOS output
XTAL: oscillation pin for crystal / resonator

5 Block Diagram

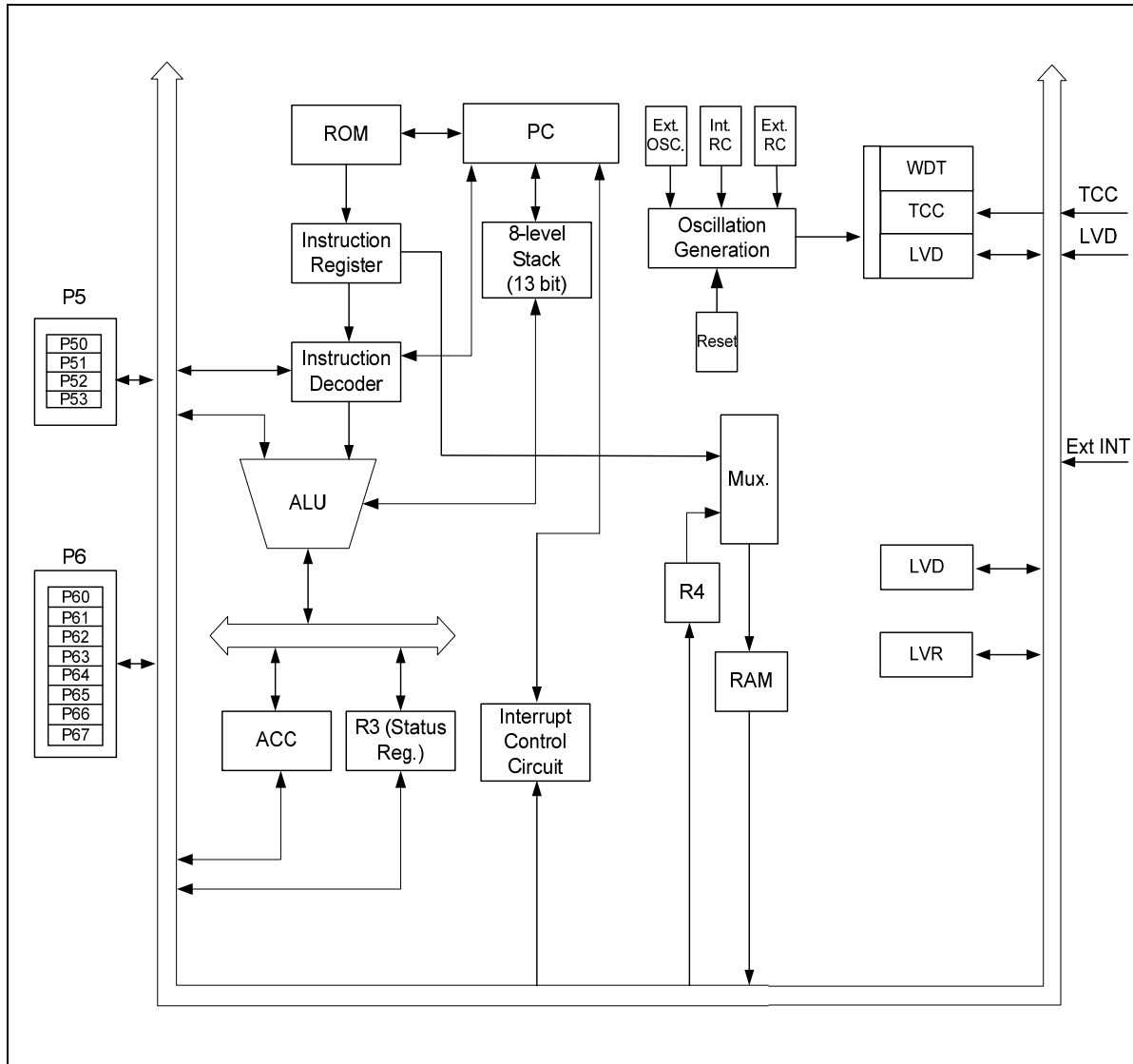


Figure 5-1 EM78P173N Functional Block Diagram

6 Functional Description

6.1 Operational Registers

6.1.1 R0 (Indirect Addressing Register)

R0 is not a physically implemented register. It is used as an indirect addressing pointer. Any instruction using R0 as a pointer actually accesses data pointed by the RAM Select Register (R4).

6.1.2 R1 (Timer Clock/Counter)

- Incremented by an external signal edge, which is defined by TE bit (CONT-4) through the TCC pin, or by the instruction cycle clock.
- Writable and readable as any other registers.
- Defined by resetting PAB (CONT-3).
- The prescaler is assigned to TCC, if the PAB bit (CONT-3) is reset.
- The contents of the prescaler counter will be cleared only when the TCC register is written with a value.

6.1.3 R2 (Program Counter and Stack)

- Depending on the device type, R2 and hardware stack are 10-bit wide. The structure is depicted in the following figure.

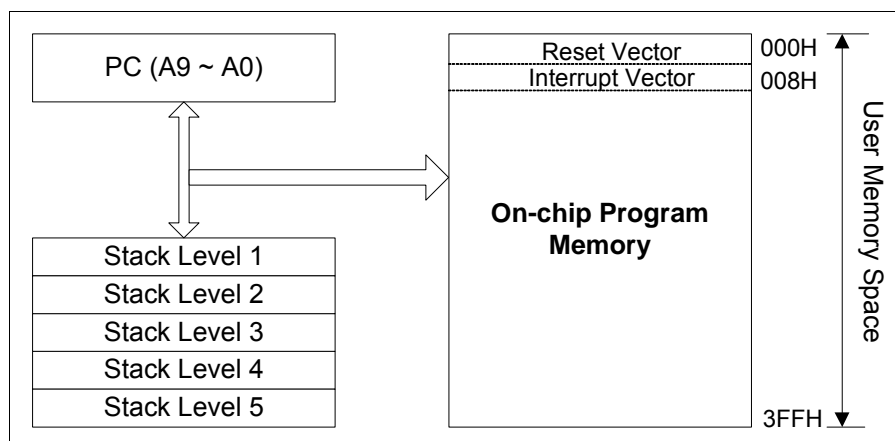


Figure 6-1 Program Counter Organization

- When ICE300N tries to simulate the stack of EM78P173N, and when the simulated stacks exceed 5 levels, the simulated result will be inconsistent with the EM78P173N.
- The configuration structure generates 1024×13 bits on-chip OTP ROM addresses to the relative programming instruction codes. One program page is 1024 words long.
- R2 is set as all "0" when under Reset condition.

- "JMP" instruction allows direct loading of the lower 10 program counter bits. Thus, "JMP" allows the PC to go to any location within a page.
 - "CALL" instruction loads the lower 10 bits of the PC, and then PC+1 are pushed onto the stack. Thus, the subroutine entry address can be located anywhere within a page.
 - "RET" ("RETLK", "RETI") instruction loads the program counter with the contents of the top-level stack.
 - "ADD R2, A" allows a relative address to be added to the current PC, and the ninth and tenth bits of the PC will increase progressively.
 - "MOV R2, A" allows loading of an address from the "A" register to the lower 8 bits of the PC, and the ninth and tenth bits (A8 ~ A9) of the PC will remain unchanged.
- Any instruction (except "ADD R2,A") that is written to R2 (e.g., "MOV R2, A", "BC R2, 6" etc.) will cause the ninth bit and above bits of the PC to remain unchanged.
- All instructions are single instruction cycle (fclk/2 or fclk/4) except for instructions that would change the contents of R2. Such instructions will need one more instruction cycle.

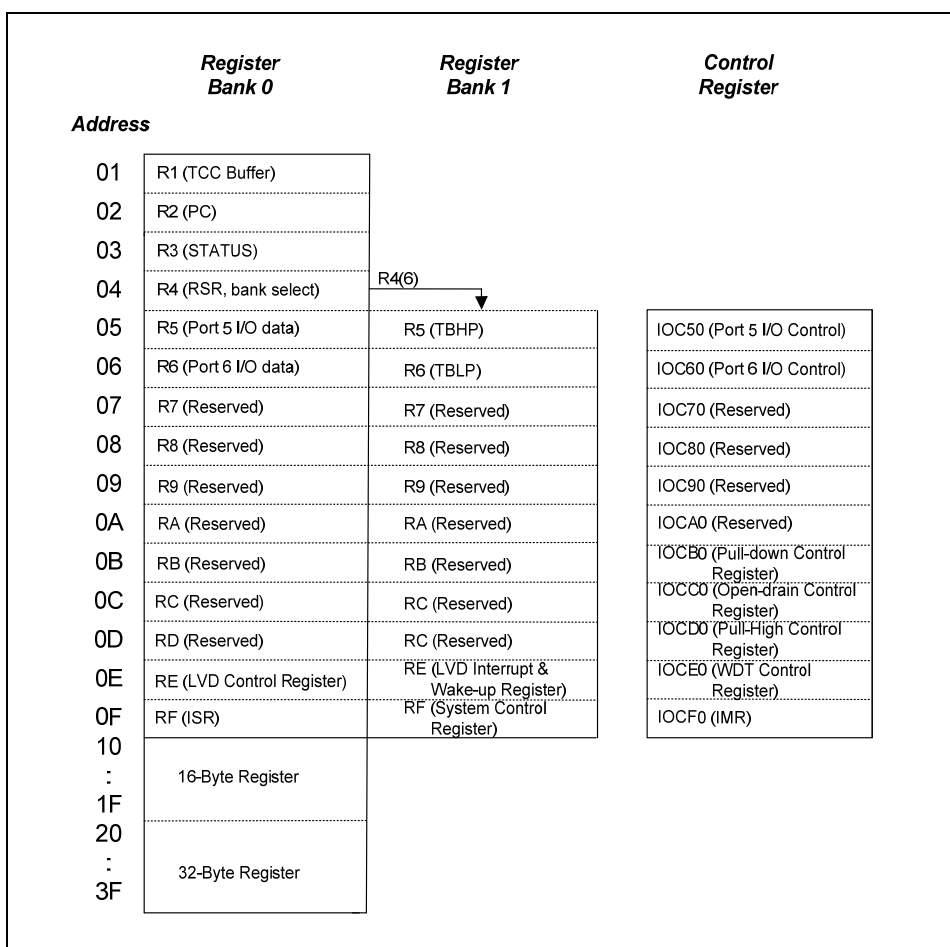


Figure 6-2 Data Memory Configuration

6.1.4 R3 (Status Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RST	GP1	GP0	T	P	Z	DC	C

Bit 7 (RST): Bit for reset type

0 : Set to 0 if the device wakes up from other reset type

1 : Set to 1 if the device wakes up from sleep mode on a pin change, external interrupt or low voltage detector interrupt.

Bits 6 ~ 5 (GP1 ~ GP0): General-purpose read/write bits

Bit 4 (T): Time-out bit

Set to "1" with the "SLEP" and "WDTC" commands, or during power up; and reset to "0" by WDT time-out.

Bit 3 (P): Power down bit

Set to "1" during power on or by a "WDTC" command; and reset to "0" by a "SLEP" command.

Bit 2 (Z): Zero flag

Set to "1" if the result of an arithmetic or logic operation is zero.

Bit 1 (DC): Auxiliary carry flag

Bit 0 (C): Carry flag

6.1.5 R4 (RAM Select Register)

Bit 7: General-purpose read/write bits

Bit 6: Used to select Banks 0~1

See the Data Memory Configuration in Figure 6-2.

6.1.6 R5 ~ R6 (Port 5 ~ Port 6)

R5 and R6 are I/O registers.

Only the lower 4 bits of R5 are available.

The upper 4 bits of R5 can be R/W.

6.1.7 Bank 0 RE (LVD Control Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
/LVD	LVDIF	-	-	-	-	-	LVDWE

Bit 7 (/LVD): Low voltage Detector state.

When the VDD pin voltage is lower than LVD voltage interrupt level (selected by LVD1 and LVD0), this bit will be cleared.

0: Low voltage is detected

1: Low voltage is not detected or LVD function is disabled

Bit 6 (LVDIF): LVD Interrupt Flag bit.

0: No interrupt occurs

1: With interrupt request

Bits 5 ~ 1: Not used. Set to "0" at all time.

Bit 0 (LVDWE): Low Voltage Detect wake-up.

0: Disable Low Voltage Detect wake-up

1: Enable Low Voltage Detect wake-up

6.1.8 Bank 0 RF (Interrupt Status Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	-	EXIF	ICIF	TCIF

NOTE

" 1 " means with interrupt request " 0 " means no interrupt occurs

Bits 7 ~ 3: Not used. Set to "0" at all time.

Bit 2 (EXIF): External Interrupt Flag. Set by a falling edge on the /INT pin, reset by software.

Bit 1 (ICIF): Port 6 input status changed interrupt flag. Set when Port 6 input changes, reset by software.

Bit 0 (TCIF): TCC Overflow Interrupt Flag. Set when TCC overflows, reset by software.

RF can be cleared by instruction but cannot be set.

IOCF is the interrupt mask register.

NOTE

The result of reading RF is the "logic AND" of RF and IOCF.

6.1.9 Bank 1 R5 (TBHP: Table Point Register for Instruction TBRD)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
MLB	-	-	-	-	-	RBit9	RBit8

Bit 7 (MLB): Chooses the MSB or LSB machine code to move into the register.

The machine code is pointed by TBLP and TBHP register.

Bits 6 ~ 2: Not used. Set to "0" at all time.

Bits 1 ~ 0: These are the most 2 significant bits of address for program code

6.1.10 Bank 1 R6 (TBLP: Table Point Register for Instruction TBRD)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
RBit7	RBit6	RBit5	RBit4	RBit3	RBit2	RBit1	RBit0

Bits 7 ~ 0: These are the least 8 significant bits of address for program code.

6.1.11 Bank 1 RE (LVD Interrupt and Wake-up Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
LVDIE	LVDEN	LVD1	LVD0	-	-	-	EXWE

Bit 7 (LVDIE): Low voltage detector interrupt enable bit

0: Disable the low voltage detector interrupt

1: Enable the low voltage detector interrupt

Bit 6 (LVDEN): Low voltage detector enable bit

0: Disable Low voltage detector function

1: Enable Low voltage detector function

Bits 5 ~ 4: Low voltage detector level bits

LVDEN	LVD1, LVD0	LVD Voltage Interrupt Level	/LVD
1	11	$V_{dd} \leq 2.2V$	0
		$V_{dd} > 2.2V$	1
1	10	$V_{dd} \leq 3.3V$	0
		$V_{dd} > 3.3V$	1
1	01	$V_{dd} \leq 4.0V$	0
		$V_{dd} > 4.0V$	1
1	00	$V_{dd} \leq 4.5V$	0
		$V_{dd} > 4.5V$	1
0	xx	N/A	1

NOTE

IF V_{dd} has crossover at LVD voltage in interrupt level as V_{DD} varies, LVD interrupt will occur.

Bits 3 ~ 1: Not used. Set to "0" at all time.

Bit 0 (EXWE): External /INT wake-up enable bit

0: Disable External /INT pin wake-up

1: Enable External /INT pin wake-up

6.1.12 Bank 1 RF (System Control Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	TIMERSC	CPUS	IDLE	-	-	RCM1	RCM0

Bits 7, 3 ~ 2: not used, fixed to "0" at all time.

Bit 6 (TIMERSC): TCC clock source select

0 : Fs is used as Fc

1 : Fm is used as Fm/2 or Fm/4 (default)

Bit 5 (CPUS): CPU Oscillator Source Select

0 : Fs : sub frequency for WDT internal RC time base 16kHz

1 : Fm : Main oscillator (Fm) (default)

When CPUS=0, the CPU oscillator selects the sub-oscillator and the main oscillator is stopped.

Bit 4 (IDLE): Idle Mode Enable Bit

From SLEP instruction, this bit will determine as to which mode to choose.

0 : IDLE = '0' + SLEP instruction → sleep mode (default)

1 : IDLE = '1' + SLEP instruction → idle mode

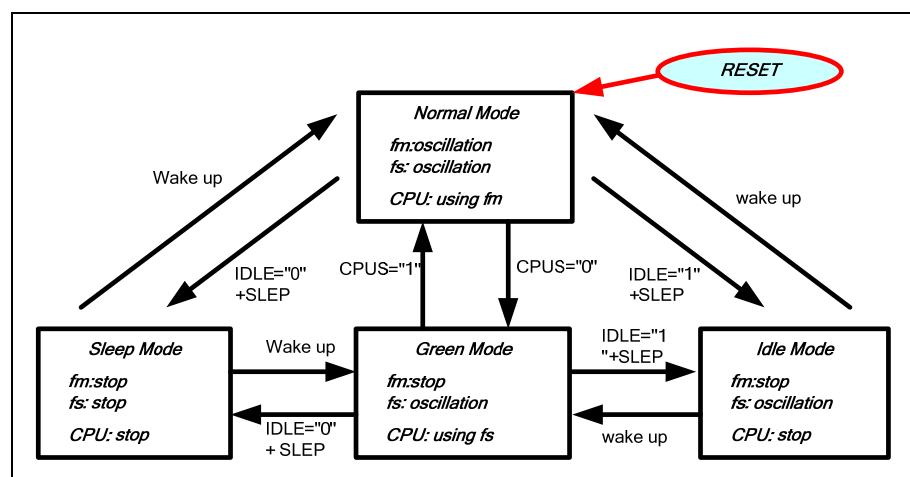


Figure 6-3 CPU Operation Mode Diagram

Oscillator (Normal Mode Source)	CPU Mode Status	Oscillator Stable Time (S) ¹	Count from Normal/Green (CLK) ²
Crystal 1M ~ 20 MHz	Sleep/Idle → Normal	0.5 ms ~ 2 ms	510 CLK
	Green → Normal		510 CLK
	Sleep/Idle → Green	< 100 μs	8 CLK
ERC 2 MHz	Sleep/Idle → Normal	< 5 μs	8 CLK
	Green → Normal		
	Sleep/Idle → Green	< 100 μs	
IRC 1M, 4M, 8M, 16 MHz	Sleep/Idle → Normal	< 2 μs	8 CLK
	Green → Normal		
	Sleep/Idle → Green	< 100 μs	

NOTE

- ¹ The oscillator stable time depends on the oscillator characteristics.
- ² After the oscillator has stabilized, the CPU will count 510/8 CLK in Normal/Green mode and continue to work in Normal/Green mode.
Ex 1 : The 4 MHz IRC wakes-up from Sleep mode to Normal mode, the total wake-up time is 2 μs + 8 CLK @ 4 MHz.
Ex 2 : The 4 MHz IRC wakes-up from Sleep mode to Green mode, the total wake-up time is 100 μs + 8 CLK @ 16kHz.

Bits 1 ~ 0 (RCM1 ~ RCM0): IRC mode select bits.

RCM 1	RCM 0	Frequency (MHz)
1	1	4
1	0	16
0	1	8
0	0	1

Bank 1 RF<1, 0> will be enabled.

Writer Trim IRC	Bank 1 RF<1, 0>		Frequency	Operating Voltage Range	Stable Time
	RCM1	RCM0			
4 MHz	1	1	4 MHz ± 2%	2.1V ~ 5.5V	< 5 μs
	1	0	16 MHz ± 10%	4.5V ~ 5.5V	< 1.5 μs
	0	1	8 MHz ± 10%	3.0V ~ 5.5V	< 3 μs
	0	0	1 MHz ± 10%	2.1V ~ 5.5V	< 24 μs
16 MHz	1	1	4 MHz ± 10%	2.1V ~ 5.5V	< 6 μs
	1	0	16 MHz ± 2%	4.5V ~ 5.5V	< 1.25 μs
	0	1	8 MHz ± 10%	3.0V ~ 5.5V	< 3 μs
	0	0	1 MHz ± 10%	2.1V ~ 5.5V	< 24 μs
8 MHz	1	1	4 MHz ± 10%	2.1V ~ 5.5V	< 6 μs
	1	0	16 MHz ± 10%	4.5V ~ 5.5V	< 1.5 μs
	0	1	8 MHz ± 2%	3.0V ~ 5.5V	< 2.5 μs
	0	0	1 MHz ± 10%	2.1V ~ 5.5V	< 24 μs
1 MHz	1	1	4 MHz ± 10%	2.1V ~ 5.5V	< 6 μs
	1	0	16 MHz ± 10%	4.5V ~ 5.5V	< 1.5 μs
	0	1	8 MHz ± 10%	3.0V ~ 5.5V	< 3 μs
	0	0	1 MHz ± 2%	2.1V ~ 5.5V	< 20 μs

NOTE

- The initial values of Bank 1 RF<1,0> will be kept the same as Word 1<6,5>.
- If user changes the IRC frequency from A-frequency to B-frequency, the MCU needs to wait for some time for it to work. The waiting time corresponds to the B-frequency.

For Example:

1st step When user selects the 4 MHz at the Writer, the initial values of Bank 1 RF<1,0> would be “11”, the same as the value of Word 1<6,5> which is “11”.

If the MCU is free-running, it will work at 4 MHz ± 2%. Refer to the table below.

Writer Trim IRC	Bank 1 RF<1, 0>		Frequency	Operating Voltage Range	Stable Time
	RCM1	RCM0			
4 MHz	1	1	4 MHz ± 2%	2.1V ~ 5.5V	< 5 μs
	1	0	16 MHz ± 10%	4.5V ~ 5.5V	< 1.5 μs
	0	1	8 MHz ± 10%	3.0V ~ 5.5V	< 3 μs
	0	0	1MHz ± 10%	2.1V ~ 5.5V	< 24 μs

2nd step If it is desired to set Bank 1 RF<1, 0> = “10” while the MCU is working at 4 MHz \pm 2%, the MCU needs to hold for 1.5 μ s, then it will continue to work at 16 MHz \pm 10%.

Writer Trim IRC	Bank 1 RF<1, 0>		Frequency	Operating Voltage Range	Stable Time
	RCM1	RCM0			
4 MHz	1	1	4 MHz \pm 2%	2.1V ~ 5.5V	< 5 μ s
	1	0	16 MHz \pm 10%	4.5V ~ 5.5V	< 1.5 μ s
	0	1	8 MHz \pm 10%	3.0V ~ 5.5V	< 3 μ s
	0	0	1 MHz \pm 10%	2.1V ~ 5.5V	< 24 μ s

3rd step If it is desired to set Bank 1 RF<1, 0> = “00” while the MCU is working at 16 MHz \pm 10%, the MCU needs to hold for 24 μ s, then it will continue to work at 1 MHz \pm 10%.

Writer Trim IRC	Bank 1 RF<1, 0>		Frequency	Operating Voltage Range	Stable Time
	RCM1	RCM0			
4 MHz	1	1	4 MHz \pm 2%	2.1V ~ 5.5V	< 5 μ s
	1	0	16 MHz \pm 10%	4.5V ~ 5.5V	< 1.5 μ s
	0	1	8 MHz \pm 10%	3.0V ~ 5.5V	< 3 μ s
	0	0	1 MHz \pm 10%	2.1V ~ 5.5V	< 24 μ s

4th step If it is desired to set Bank 1 RF<1, 0> = “11” while the MCU is working at 1 MHz \pm 10%, the MCU needs to hold for 5 μ s, then it will continue to work at 4 MHz \pm 2%.

Writer Trim IRC	Bank 1 RF<1, 0>		Frequency	Operating Voltage Range	Stable Time
	RCM1	RCM0			
4 MHz	1	1	4 MHz \pm 2%	2.1V ~ 5.5V	< 5 μ s
	1	0	16 MHz \pm 10%	4.5V ~ 5.5V	< 1.5 μ s
	0	1	8 MHz \pm 10%	3.0V ~ 5.5V	< 3 μ s
	0	0	1 MHz \pm 10%	2.1V ~ 5.5V	< 24 μ s

6.1.13 R10 ~ R3F

These are all 8-bit general-purpose registers.

6.2 Special Function Registers

6.2.1 A (Accumulator)

Internal data transfer operation, or instruction operand holding usually involves the temporary storage function of the Accumulator, which is not an addressable register.

6.2.2 CONT (Control Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GP	INT	TS	TE	PAB	PSR2	PSR1	PSR0

Bit 7 (GP): General purpose register.

Bit 6 (INT): Interrupt Enable flag

0 : Masked by DISI or hardware interrupt

1 : Enabled by ENI/RETI instructions

Bit 5 (TS): TCC signal source

0 : Internal instruction cycle clock, P62 is a bidirectional I/O pin

1 : Transition on the TCC pin

Bit 4 (TE): TCC Signal Edge

0 : Increment if the transition from low to high takes place on the TCC pin

1 : Increment if the transition from high to low takes place on the TCC pin

Bit 3 (PAB): Prescaler Assigned Bit

0 : TCC

1 : WDT

Bit 2 ~ Bit 0 (PSR2 ~ PSR0): TCC/WDT prescaler bits

PSR2	PSR1	PSR0	TCC Rate	WDT Rate
0	0	0	1:2	1:1
0	0	1	1:4	1:2
0	1	0	1:8	1:4
0	1	1	1:16	1:8
1	0	0	1:32	1:16
1	0	1	1:64	1:32
1	1	0	1:128	1:64
1	1	1	1:256	1:128

The CONT register is both readable and writable.



6.2.3 IOC5 ~ IOC6 (I/O Port Control Register)

0 : defines the relative I/O pin as output

1 : puts the relative I/O pin into high impedance

Only the lower 4 bits of IOC5 are available to be defined, IOC54~57 registers are fixed to "0"

6.2.4 IOCB (Pull-down Control Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
/PD63	/PD62	/PD61	/PD60	-	/PD52	/PD51	/PD50

Bit 7(/PD63): Control bit used to enable pull-down of the P63 pin.

0 : Enable internal pull-down

1 : Disable internal pull-down

Bit 6 (/PD62): Control bit used to enable pull-down of the P62 pin.

Bit 5 (/PD61): Control bit used to enable pull-down of the P61 pin.

Bit 4 (/PD60): Control bit used to enable pull-down of the P60 pin.

Bit 3: Not used. Set to "1" at all time (R/W).

Bit 2 (/PD52): Control bit used to enable pull-down of the P52 pin.

Bit 1 (/PD51): Control bit used to enable pull-down of the P51 pin.

Bit 0 (/PD50): Control bit used to enable pull-down of the P50 pin.

The IOCB Register is both readable and writable.

6.2.5 IOCC (Open-drain Control Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
OD67	OD66	OD65	OD64	-	OD62	OD61	OD60

Bit 7 (OD67): Control bit used to enable open-drain of the P67 pin.

0 : Disable open-drain output

1 : Enable open-drain output

Bit 6 (OD66): Control bit used to enable open-drain of the P66 pin.

Bit 5 (OD65): Control bit used to enable open-drain of the P65 pin.

Bit 4 (OD64): Control bit used to enable open-drain of the P64 pin.

Bit 3: Not used. Set to "0" at all time (R/W).

Bit 2 (OD62): Control bit used to enable open-drain of the P62 pin.

Bit 1 (OD61): Control bit used to enable open-drain of the P61 pin.

Bit 0 (OD60): Control bit used to enable open-drain of the P60 pin.

The IOCC Register is both readable and writable.

6.2.6 IOCD (Pull-high Control Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
/PH67	/PH66	/PH65	/PH64	-	/PH62	/PH61	/PH60

Bit 7 (/PH67): Control bit is used to enable pull-high of the P67 pin.

0 : Enable internal pull-high

1 : Disable internal pull-high

Bit 6 (/PH66): Control bit used to enable pull-high of the P66 pin.

Bit 5 (/PH65): Control bit used to enable pull-high of the P65 pin.

Bit 4 (/PH64): Control bit used to enable pull-high of the P64 pin.

Bit 3: Not used. Set to "1" at all time (R/W).

Bit 2 (/PH62): Control bit used to enable pull-high of the P62 pin.

Bit 1 (/PH61): Control bit used to enable pull-high of the P61 pin.

Bit 0 (/PH60): Control bit used to enable pull-high of the P60 pin.

The IOCD Register is both readable and writable.

6.2.7 IOCE (WDT Control Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
WDTE	EIS	GP	GP	GP	GP	GP	GP

Bit 7 (WDTE): Control bit used to enable the Watchdog timer.

0 : Disable WDT

1 : Enable WDT

Bit 6 (EIS): Control bit is used to define the function of P60 (/INT) pin.

0 : P60, bidirectional I/O pin.

1 : /INT, external interrupt pin.

When EIS is "0," the path of /INT is masked. When EIS is "1," the status of /INT pin can also be read by way of reading Port 6 (R6).

See Figure 6-6 under Section 6.4 for reference.

EIS is both readable and writable.

WDTE is both readable and writable.

Bits 5 ~ 0: General purpose register.



6.2.8 IOCF (Interrupt Mask Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	-	EXIE	ICIE	TCIE

Bits 7 ~ 3: Not used. Set to "1" at all time.

Individual interrupt is enabled by setting its associated control bit in the IOCF to "1".

Global interrupt is enabled by the ENI instruction and is disabled by the DISI instruction. Refer to Figure 6-10.

Bit 2 (EXIE): EXIF interrupt enable bit

0 : disable EXIF interrupt

1 : enable EXIF interrupt

Bit 1 (ICIE): ICIF interrupt enable bit

0 : disable ICIF interrupt

1 : enable ICIF interrupt

Bit 0 (TCIE): TCIF interrupt enable bit

0 : disable TCIF interrupt

1 : enable TCIF interrupt

The IOCF register is both readable and writable.

6.3 TCC/WDT and Prescaler

An 8-bit counter is available as prescaler for the TCC or WDT. The prescaler is available for the TCC only or the WDT only, one at a time and the PAB bit of the CONT register is used to determine the prescaler assignment. The PSR0 ~ PSR2 bits determine the ratio. The prescaler is cleared each time an instruction is written to TCC under TCC mode. The WDT and prescaler, when assigned to WDT mode, are cleared by the "WDTC" or "SLEP" instructions. Figure 6-4 depicts the TCC / WDT circuit diagram.

- R1 (TCC) is an 8-bit timer/counter. The TCC clock source can be internal or external clock input (edge selectable from TCC pin). If the TCC signal source is from an internal clock, the TCC will be incremented by 1 at $F_m/2$ or $F_m/4$ (without prescaler). Referring to Figure 6-4, $CLK=F_m/2$ or $CLK=F_m/4$, depends on the Code Option bit CLK. $CLK=F_m/2$ is used if CLK bit is "0", and $CLK=F_m/4$ is used if CLK bit is "1". If the TCC signal source is from an external clock input, TCC is incremented by 1 at every falling edge or rising edge of the TCC pin.

- The watchdog timer is a free running on-chip RC oscillator. The WDT will keep running even when the oscillator driver has been turned off (i.e. in sleep mode). During normal operation or sleep mode, a WDT time-out (if enabled) will cause the device to reset. The WDT can be enabled or disabled any time during normal mode by software programming. Refer to WDTE bit of the IOCE register. Without prescaler, the WDT time-out period is approximately 18 ms¹ (default).

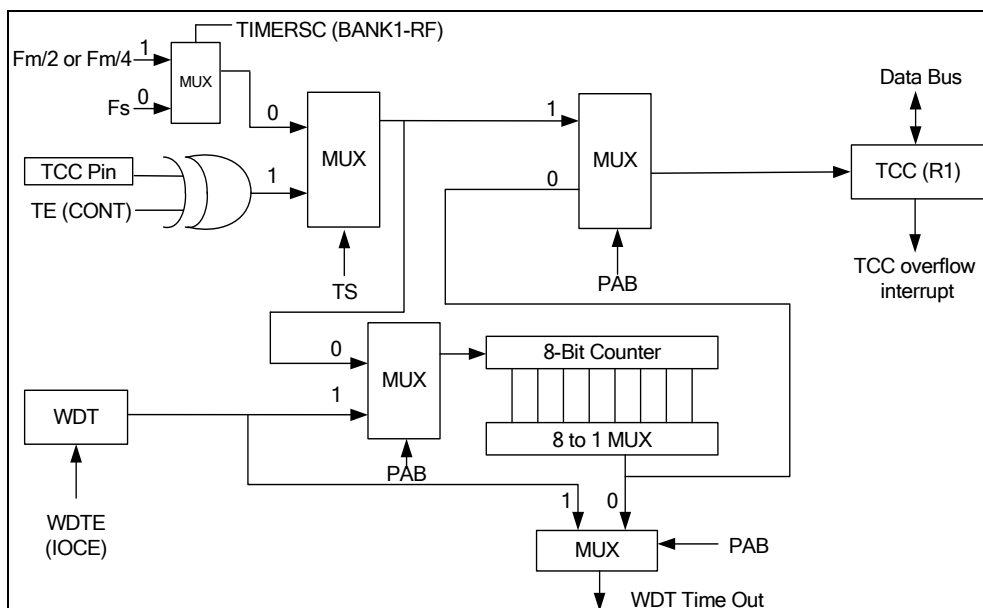
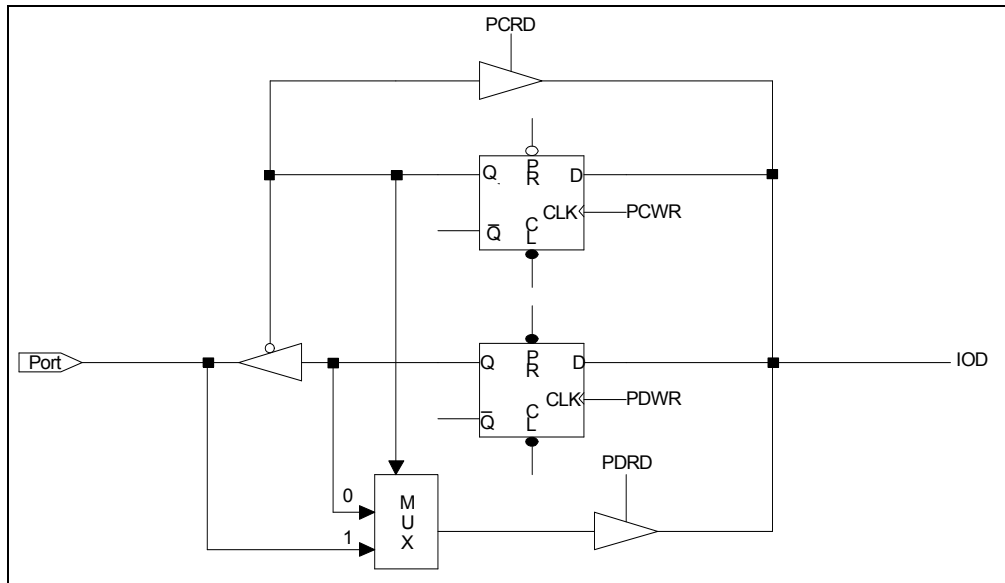


Figure 6-4 TCC and WDT Block Diagram

6.4 I/O Ports

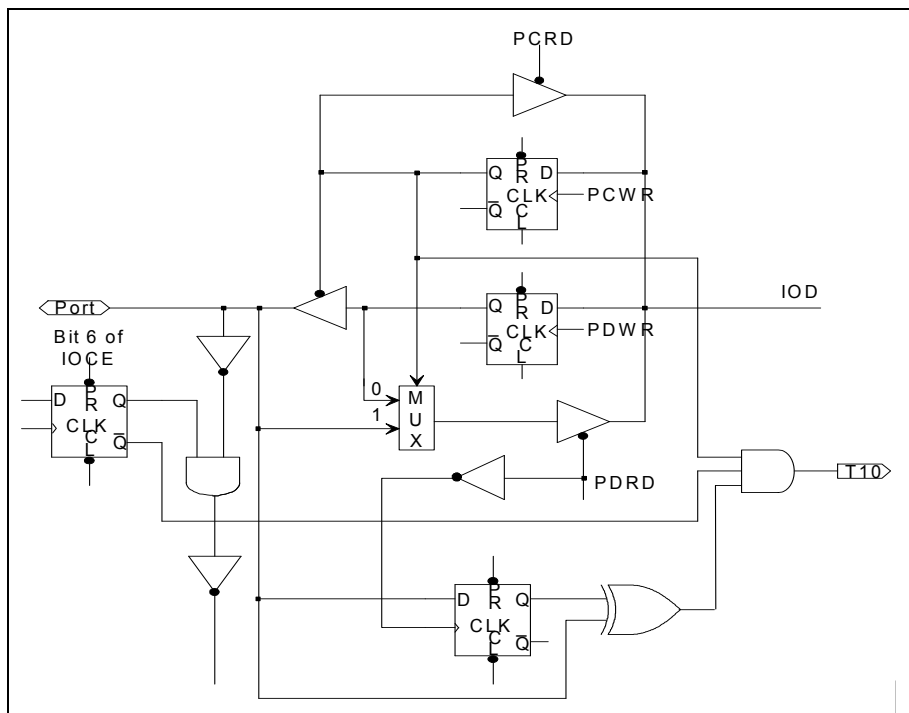
The I/O registers, both Port 5 and Port 6, are bidirectional tri-state I/O ports. Port 6 can be pulled-high internally by software except P63. In addition, Port 6 can also have open-drain output by software except P63. Input status changed interrupt (or wake-up) function is available from Port 6. P50 ~ P52 and P60 ~ P63 pins can be pulled-down by software. Each I/O pin can be defined as "input" or "output" pin by the I/O control register (IOC5 ~ IOC6). The I/O registers and I/O control registers are both readable and writable. The I/O interface circuits for Port 5 and Port 6 are shown in Figure 6-5, Figure 6-6 and Figure 6-7 respectively.

¹ Vdd = 5V, WDT time-out period = 16.8ms ± 30% at 25°C
Vdd = 3V, WDT time-out period = 18ms ± 30% at 25°C



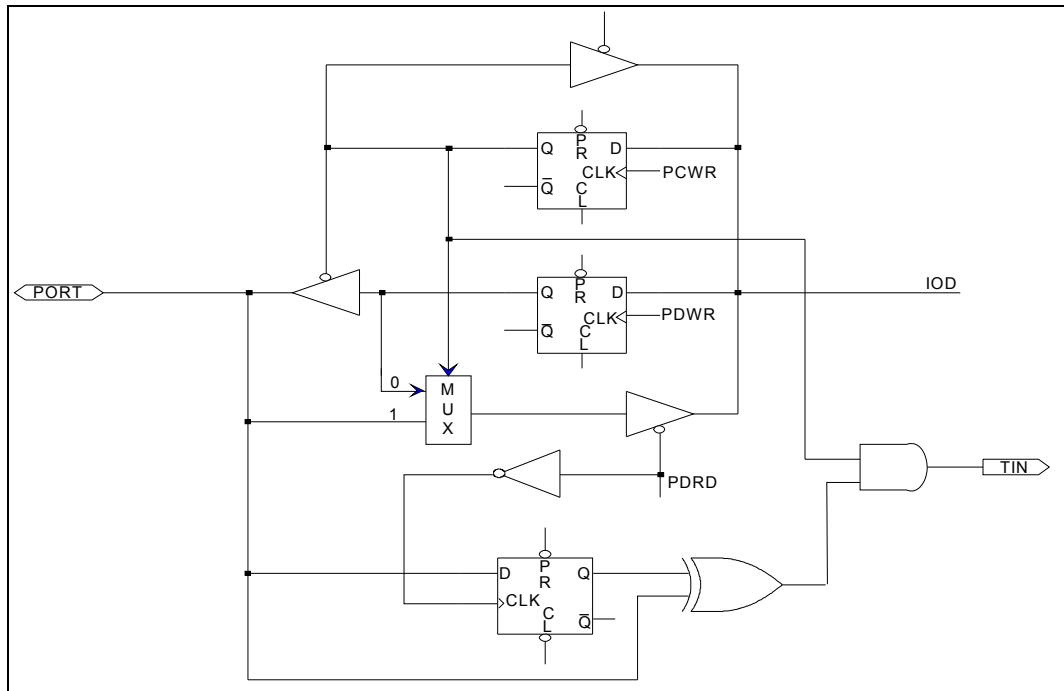
Note: Pull-down is not shown in the figure.

Figure 6-5 I/O Port and I/O Control Register Circuit for Port 5, 6



Note: Pull-high (down) and open-drain are not shown in the figure.

Figure 6-6 I/O Port and I/O Control Register Circuit for P60 (/INT)



Note: Pull-high (down) and open-drain are not shown in the figure.

Figure 6-7 I/O Port and I/O Control Register Circuit for P61~P67

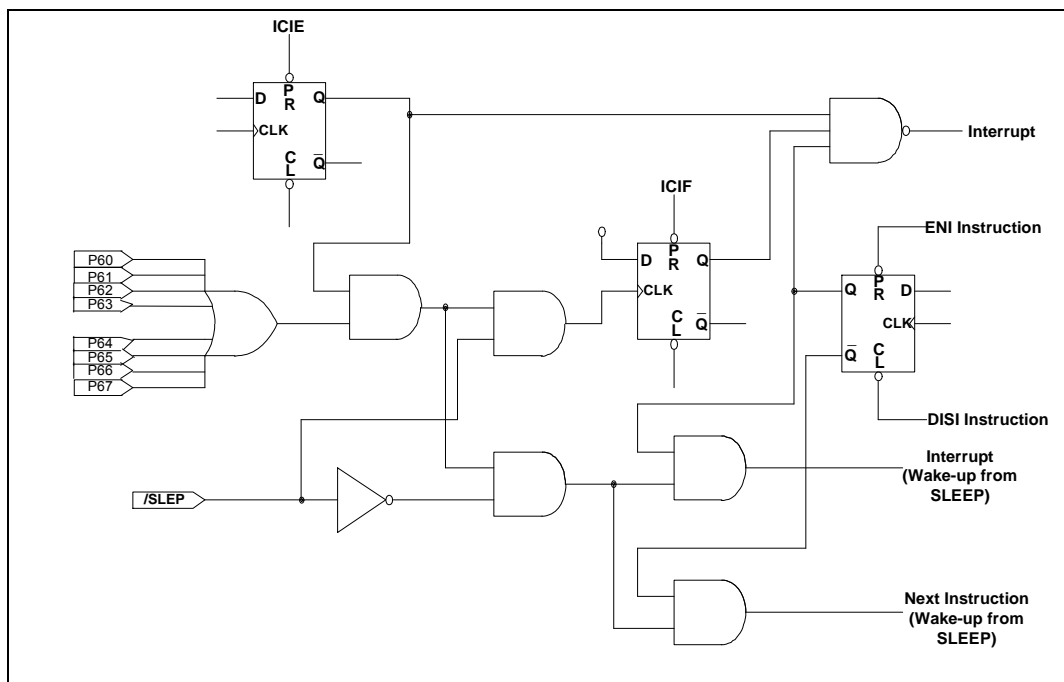


Figure 6-8 Block Diagram of I/O Port 6 with Input Change Interrupt/Wake-up



Table 6-1 Usage of Port 6 Input Change Wake-up/Interrupt Function

Usage of Port 6 Input Status Change Wake-up/Interrupt	
(I) Wake-up from Port 6 Input Status Change (a) Before Sleep <ol style="list-style-type: none"> 1. Disable WDT 2. Read I/O Port 6 (MOV R6,R6) 3. Execute "ENI" or "DISI" 4. Enable interrupt (Set IOCF.1) 5. Execute "SLEP" instruction (b) After Wake-up <ol style="list-style-type: none"> 1. IF "ENI" → Interrupt Vector (008H) 2. IF "DISI" → Next instruction 	(II) Port 6 Input Status Change Interrupt <ol style="list-style-type: none"> 1. Read I/O Port 6 (MOV R6,R6) 2. Execute "ENI" 3. Enable interrupt (Set IOCF.1) 4. IF Port 6 change (interrupt) → Interrupt Vector (008H)

6.5 Reset and Wake-up

6.5.1 Reset

A Reset is initiated by one of the following events:

- 1) Power-on reset
- 2) /RESET pin input "low"
- 3) WDT time-out (if enabled).
- 4) Low Voltage Reset

The device is kept under reset condition for a period of approximately 18 ms or 150 μ s (Events 1 and 4 are approximately 18 ms and Events 2, 3 are approximately 150 μ s) after a reset is detected.

- The oscillator is running, or will be started.
- The Program Counter (R2) is set to all "0."
- All I/O port pins are configured as input mode (high-impedance state)
- The Watchdog timer and prescaler are cleared.
- When power is switched on, the upper 3 bits of R3 are cleared.
- The bits of the CONT register are set to all "1" except for Bit 6 (INT flag).
- The bits of the IOCB register are set to all "1."
- The IOCC register is cleared.
- The bits of the IOCD register are set to all "1."
- Bit 7 of the IOCE register is set to "1," and Bit 6 is cleared.
- Bits 0 ~ 2 of RF and Bits 0 ~ 2 of IOCF registers are cleared.

Sleep (power down) mode is asserted by executing the "SLEP" instruction. While entering Sleep mode, WDT (if enabled) is cleared but keeps on running. After a wake-up in IRC mode (IRC 4 MHz / 5V), wake-up time is 1.5 μ s, XT mode (4 MHz / 5V) wake-up time is 1.5 ms.

The controller can be awakened by:

- 1) External reset input on /RESET pin
- 2) WDT time-out (if enabled)
- 3) Port 6 Input Status changed (if enabled)
- 4) External (P60, /INT) pin changes (if EXWE is enabled)
- 5) Low voltage detector (if LVDWE is enabled)

The first two cases will cause the EM78P173N to reset. The T and P flags of R3 are used to determine the source of the reset (wake-up). The last case is considered the continuation of program execution and the global interrupt ("ENI" or "DISI" being executed) determines whether or not the controller branches to the interrupt vector following a wake-up. If ENI is executed before SLEP, the instruction will begin to execute from Address 008H after wake-up. If DISI is executed before SLEP, the operation will restart from the succeeding instruction right next to SLEP after a wake-up. After a wake-up in IRC mode (IRC 4MHz / 5V), the wake-up time is 1.5 μ s, XT mode (4 MHz / 5V) wake-up time is 1.5 ms.

One or more of Cases 2 and 5 can be enabled before going into Sleep mode. That is,

- [a]** if WDT is enabled before SLEP, Port 6 Input Status Change Interrupt must be disabled. Hence, the EM78P173N can be awakened only by Case 1 or Case 2. Refer to Section 6.6, *Interrupt* for further details.
- [b]** if Port 6 Input Status Change Interrupt is enabled before SLEP, WDT must be disabled. However, the EM78P173N can be awakened only by Case 3.
- [c]** if External (P60, INT) pin change is used to wake-up the EM78P173N and the EXWE bit of the Bank 1-RE register is enabled before SLEP, the WDT must be disabled. Hence, the EM78P173N can be waken-up only by Case 4.
- [d]** if Low voltage detector is used to wake up the EM78P173N and the LVDWE bit of the Bank 0-RE register is enabled before SLEP, the WDT must be disabled by software. Hence, the EM78P173N can be awakened only by Case 5.

If Port 6 Input Status Change Interrupt is used to wake-up the EM78P173N (Case [a] above), the following instructions must be executed before SLEP:

```

MOV A, @xxxx1110b      ; Select the WDT prescaler, it must be
                        ; set over 1:1

CONTW
WDTC                    ; Clear WDT and prescaler
MOV A, @0xxxxxxxxb     ; Disable WDT
IOW RE
MOV R6, R6              ; Read Port 6
MOV A, @00000x1xb     ; Enable Port 6 input change interrupt
IOW RF
ENI (or DISI)          ; Enable (or disable) global interrupt
SLEP                   ; Sleep

```

NOTE

1. After waking up from sleep mode, WDT is automatically enabled. The WDT enable/disable operation after waking up from sleep mode should be appropriately defined in the software.
2. To avoid a reset from occurring when the Port 6 Input Status Changed Interrupt enters into interrupt vector or is used to wake-up the MCU, the WDT prescaler must be set above the 1:1 ratio.

6.5.2 Wake-up and Interrupt Modes Operation Summary

The controller can be awakened from sleep mode and idle mode. The wake-up signals are listed as follows.

Wake-up Signal	Condition Signal	Sleep Mode		Idle Mode		Green Mode		Normal Mode	
		DISI	ENI	DISI	ENI	DISI	ENI	DISI	ENI
External INT	EXWE = 0 EXIE = 0	Wake-up is invalid		Wake-up is invalid		Interrupt is invalid		Interrupt is invalid	
	EXWE = 0 EXIE = 1	Wake-up is invalid		Wake-up is invalid		Next Instruction	Interrupt + Interrupt Vector	Next Instruction	Interrupt + Interrupt Vector
	EXWE = 1 EXIE = 0	Wake up + Next Instruction		Wake up + Next Instruction		Interrupt is invalid		Interrupt is invalid	
	EXWE = 1 EXIE = 1	Wake up + Next Instruction	Wake up + Interrupt Vector	Wake up + Next Instruction	Wake up + Interrupt Vector	Next Instruction	Interrupt + Interrupt Vector	Next Instruction	Interrupt + Interrupt Vector
Port 6 Pin Change	ICIE = 0	Wake-up is invalid		Wake-up is invalid		Interrupt is invalid		Interrupt is invalid	
	ICIE = 1	Wake up + Next Instruction	Wake up + Interrupt Vector	Wake up + Next Instruction	Wake up + Interrupt Vector	Next Instruction	Interrupt + Interrupt Vector	Next Instruction	Interrupt + Interrupt Vector
TCC Overflow	TCIE = 0	Wake-up is invalid		Wake-up is invalid		Interrupt is invalid		Interrupt is invalid	
	TCIE = 1	Wake-up is invalid		Wake up + Next Instruction	Wake up + Interrupt Vector	Next Instruction	Interrupt + Interrupt Vector	Next Instruction	Interrupt + Interrupt Vector
Low Voltage Detector	LVDWE = 0 LVDIE = 0	Wake-up is invalid		Wake-up is invalid		Interrupt is invalid		Interrupt is invalid	
	LVDWE = 0 LVDIE = 1	Wake-up is invalid		Wake-up is invalid		Next Instruction	Interrupt + Interrupt Vector	Next Instruction	Interrupt + Interrupt Vector
	LVDWE = 1 LVDIE = 0	Wake up + Next Instruction		Wake up + Next Instruction		Interrupt is invalid		Interrupt is invalid	
	LVDWE = 1 LVDIE = 1	Wake up + Next Instruction	Wake up + Interrupt Vector	Wake up + Next Instruction	Wake up + Interrupt Vector	Next Instruction	Interrupt + Interrupt Vector	Next Instruction	Interrupt + Interrupt Vector

6.5.3 Summary of Registers Initialized Values

Address	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
N/A	IOC5	Bit Name	x	x	x	x	C53	C52	C51	C50
		Power-on	0	0	0	0	1	1	1	1
		/RESET and WDT	0	0	0	0	1	1	1	1
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
N/A	IOC6	Bit Name	C67	C66	C65	C64	C63	C62	C61	C60
		Power-on	1	1	1	1	1	1	1	1
		/RESET and WDT	1	1	1	1	1	1	1	1
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x05	P5	Bit Name	x	x	x	x	P53	P52	P51	P50
		Power-on	1	1	1	1	1	1	1	1
		/RESET and WDT	P	P	P	P	P	P	P	P
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x06	P6	Bit Name	P67	P66	P65	P64	P63	P62	P61	P60
		Power-on	1	1	1	1	1	1	1	1
		/RESET and WDT	P	P	P	P	P	P	P	P
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
N/A	CONT	Bit Name	GP	INT	TS	TE	PAB	PSR2	PSR1	PSR0
		Power-on	1	0	1	1	1	1	1	1
		/RESET and WDT	1	0	1	1	1	1	1	1
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x00	R0 (IAR)	Bit Name	-	-	-	-	-	-	-	-
		Power-on	U	U	U	U	U	U	U	U
		/RESET and WDT	P	P	P	P	P	P	P	P
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x01	R1 (TCC)	Bit Name	-	-	-	-	-	-	-	-
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x02	R2 (PC)	Bit Name	-	-	-	-	-	-	-	-
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Pin Change	Jump to Address 0x08 or continue to execute next instruction.							



Address	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x03	R3 (SR)	Bit Name	RST	GP1	GP0	T	P	Z	DC	C
		Power-on	0	0	0	1	1	U	U	U
		/RESET and WDT	0	0	0	*	*	P	P	P
		Wake-up from Pin Change	1	P	P	*	*	P	P	P
0x04	R4 (RSR)	Bit Name	GP	Bank 0	-	-	-	-	-	-
		Power-on	0	0	U	U	U	U	U	U
		/RESET and WDT	0	0	P	P	P	P	P	P
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x0E	Bank 0 RE (LVDCR)	Bit Name	/LVD	LVDIF	x	x	x	x	x	LVDWE
		Power-on	1	0	0	0	0	0	0	0
		/RESET and WDT	1	0	0	0	0	0	0	0
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x0F	Bank 0 RF (ISR)	Bit Name	x	x	x	x	x	EXIF	ICIF	TCIF
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Pin Change	0	0	0	0	0	P	P	P
0x05	Bank 1 R5 (TBHP)	Bit Name	MLB	x	x	x	x	x	RBit 9	RBit 8
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x06	Bank 1 R6 (TBLP)	Bit Name	RBit7	RBit 6	RBit 5	RBit 4	RBit 3	RBit 2	RBit 1	RBit 0
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x0E	Bank 1 RE (LVD ICR)	Bit Name	LVDIE	LVDEN	LVD1	LVD0	x	x	x	EXWE
		Power-on	0	0	1	1	0	0	0	0
		/RESET and WDT	0	0	1	1	0	0	0	0
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x0F	Bank 1 RF (SC and COCR)	Bit Name	x	TIMERSC	CPUS	IDLE	x	x	RCM1	RCM0
		Power-on	0	1	1	0	0	0	Word 1 <6,5>	
		/RESET and WDT	0	1	1	0	0	0		
		Wake-up from Pin Change	P	P	P	P	P	P	P	P

Address	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x0B	IOCB	Bit Name	/PD63	/PD62	/PD61	/PD60	x	/PD52	/PD51	/PD50
		Power-on	1	1	1	1	1	1	1	1
		/RESET and WDT	1	1	1	1	1	1	1	1
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x0C	IOCC	Bit Name	OD67	OD66	OD65	OD64	x	OD62	OD61	OD60
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x0D	IOCD	Bit Name	/PH67	/PH66	/PH65	/PH64	x	/PH62	/PH61	/PH60
		Power-on	1	1	1	1	1	1	1	1
		/RESET and WDT	1	1	1	1	1	1	1	1
		Wake-up from Pin Change	P	P	P	P	P	P	P	P
0x0E	IOCE	Bit Name	WDTE	EIS	GP	GP	GP	GP	GP	GP
		Power-on	1	0	1	1	1	1	1	1
		/RESET and WDT	1	0	1	1	1	1	1	1
		Wake-up from Pin Change	1	P	P	P	P	P	P	P
0x0F	IOCF	Bit Name	x	x	x	x	x	EXIE	ICIE	TCIE
		Power-on	1	1	1	1	1	0	0	0
		/RESET and WDT	1	1	1	1	1	0	0	0
		Wake-up from Pin Change	1	1	1	1	1	P	P	P
0x10 ~ 0x3F	R10~R3F	Bit Name	-	-	-	-	-	-	-	-
		Power-on	U	U	U	U	U	U	U	U
		/RESET and WDT	P	P	P	P	P	P	P	P
		Wake-up from Pin Change	P	P	P	P	P	P	P	P

Legend: x: Not used U: Unknown or don't care P: Previous value before reset

* Refer to the tables provided in the next section (Section 6.5.4).

6.5.4 Status of RST, T, and P of the Status Register

A Reset condition is initiated by the following events

- 1) A power-on condition
- 2) A high-low-high pulse on /RESET pin
- 3) Watchdog timer time-out

The values of T and P listed in the table below are used to check how the processor wakes up.

Table 6-2 Values of RST, T, and P after a Reset

Reset Type	RST	T	P
Power on	0	1	1
/RESET during Operation mode	0	*P	*P
/RESET wake-up during Sleep mode	0	1	0
WDT during Operation mode	0	0	*P
WDT wake-up during Sleep mode	0	0	0
Wake-up on pin change during Sleep mode	1	1	0

* P: Previous status before reset

The following table shows the events that may affect the status of T and P.

Table 6-3 Status of T and P Being Affected by Events

Event	RST	T	P
Power on	0	1	1
WDTC instruction	*P	1	1
WDT time-out	0	0	*P
SLEP instruction	*P	1	0
Wake-up on pin change during Sleep mode	1	1	0

* P: Previous status before reset

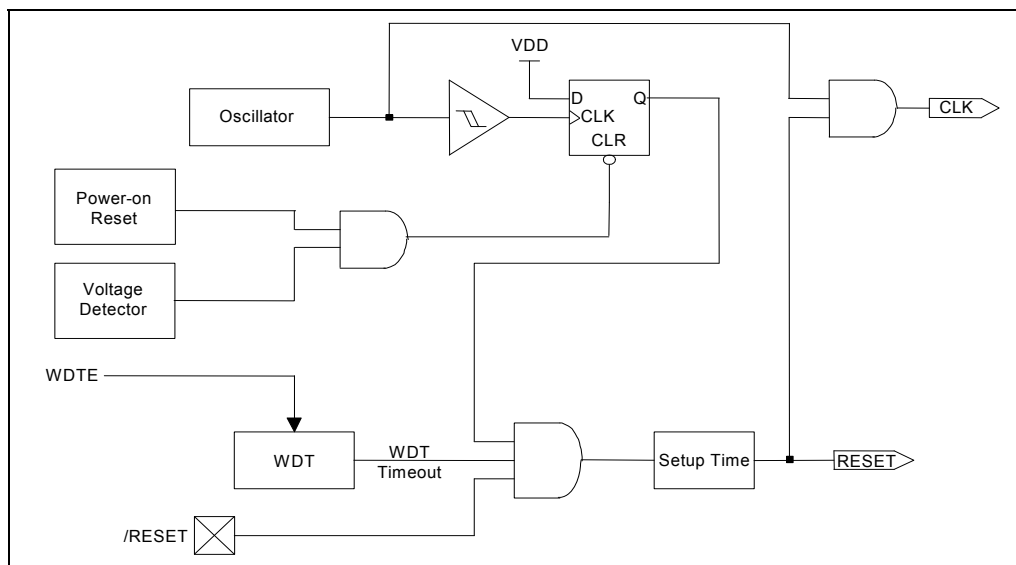


Figure 6-9 Controller Reset Block Diagram

6.6 Interrupt

The EM78P173N has four interrupts as listed below:

- 1) TCC overflow interrupt
- 2) Port 6 Input Status Change Interrupt
- 3) External interrupt [(P60, /INT) pin]
- 4) Low Voltage Detect Interrupt

Before the Port 6 Input Status Changed Interrupt is enabled, reading Port 6 (e.g. "MOV R6,R6") is necessary. Each pin of Port 6 will have this feature if its status changes. Any pin configured as output or P60 pin configured as /INT is excluded from this function. The Port 6 Input Status Changed Interrupt can wake up the EM78P173N from Sleep mode if Port 6 is enabled prior to going into Sleep mode by executing SLEEP instruction. When the chip wakes-up, the controller will continue to execute the program in-line if the global interrupt is disabled. If the global interrupt is enabled, it will branch to the Interrupt Vector 008H.

RF is the interrupt status register that records the interrupt requests in the relative flags/bits. IOCF is an interrupt mask register. The global interrupt is enabled by the ENI instruction and is disabled by the DISI instruction. When one of the interrupts (enabled) occurs, the next instruction will be fetched from Address 008H. Once in the interrupt service routine, the source of an interrupt can be determined by polling the flag bits in RF. The interrupt flag bit must be cleared by instructions before leaving the interrupt service routine and before interrupts are enabled to avoid recursive interrupts.

The flag (except ICIF bit) in the Interrupt Status Register (RF) is set regardless of the status of its mask bit or the execution of ENI. Note that the outcome of RF will be the logic AND of RF and IOCF (refer to Figure 6-10). The RETI instruction ends the interrupt routine and enables the global interrupt (the execution of ENI).

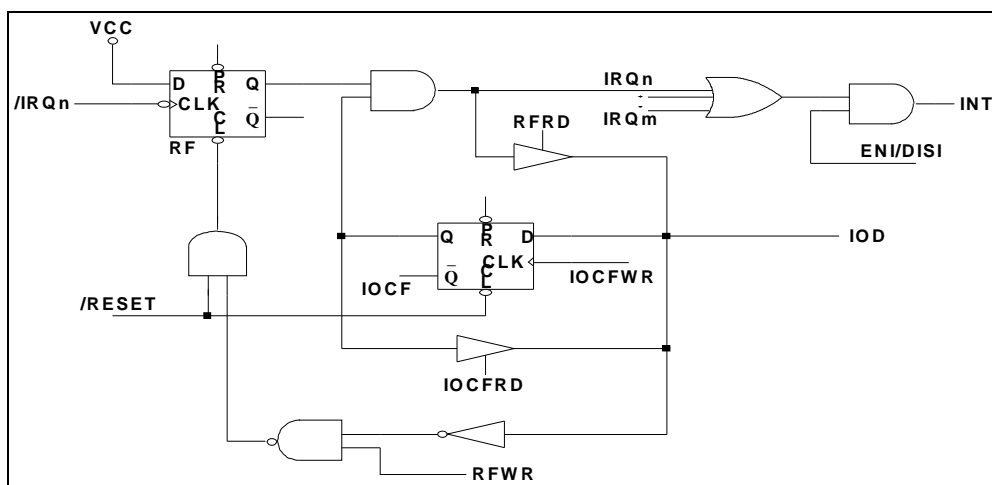


Figure 6-10 Interrupt Input Circuit

Before an interrupt subroutine is executed, the contents of ACC and the R3 and R4 registers will be saved by the hardware. If another interrupt occurs, the ACC, R3, and R4 will be replaced by the new interrupt. After the interrupt service routine is completed, the ACC, R3, and R4 registers are restored.

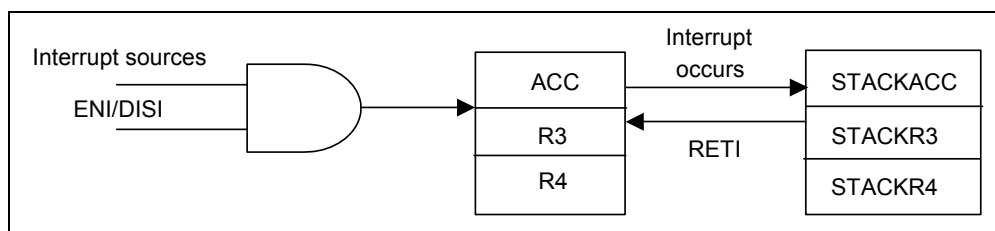


Figure 6-11 Interrupt Backup Diagram

6.7 Oscillator

6.7.1 Oscillator Modes

The EM78P173N can be operated in four different oscillator modes, such as External RC oscillator mode (ERC), Internal RC oscillator mode (IRC), High Crystal oscillator mode (XT, HXT1,2), and Low Crystal oscillator mode (LXT1, 2). The desired mode can be selected by programming OSC3, OSC2, OSC1, and OSC0 in the Code Option register. Table 6-4 describes how these four oscillator modes are defined.

Table 6-4 Oscillator Modes Defined by OSC

Oscillator Modes	OSC3	OSC2	OSC1	OSC0
ERC ¹ (External RC oscillator mode); P64/RCOUT act as P64	0	0	0	0
ERC ¹ (External RC oscillator mode); P64/RCOUT act as RCOUT	0	0	0	1
IRC ² (Internal RC oscillator mode); P64/RCOUT act as P64	0	0	1	0
IRC ² (Internal RC oscillator mode); P64/RCOUT act as RCOUT	0	0	1	1
LXT1 ³ (Frequency range of LXT1 mode is 1MHz~100kHz)	0	1	0	0
HXT1 ³ (Frequency range of HXT1 mode is 20 MHz~12 MHz)	0	1	0	1
LXT2 ³ (Frequency range of LXT2 mode is 32.768kHz)	0	1	1	0
HXT2 ³ (Frequency range of HXT2 mode is 12 MHz~6 MHz)	0	1	1	1
XT (Frequency range of XT mode is 6 MHz~1 MHz) (default)	1	1	1	1

¹ In ERC mode, ERCin is used as oscillator pin. RCOUT/P64 is defined by code option Word 1 Bit 4 ~ Bit 1.

² In IRC mode, P65 is normal I/O pin. RCOUT/P64 is defined by code option Word 1 Bit 4 ~ Bit 1.

³ In LXT1, LXT2, HXT1, HXT2 and XT modes; OSC1 and OSC0 are used as oscillator pins. These pins cannot and should not be defined as normal I/O pins.

The maximum operational frequency of the crystal/resonator under different VDD is listed below.

Table 6-5 Summary of Maximum Operating Speeds

Conditions	VDD	Max Freq. (MHz)
Two cycles with two clocks	2.1	4.0
	3.0	8.0
	5.0	20.0

6.7.2 Crystal Oscillator/Ceramic Resonators (Crystal)

The EM78P173N can be driven by an external clock signal through the OSC1 pin as shown in the following figure.

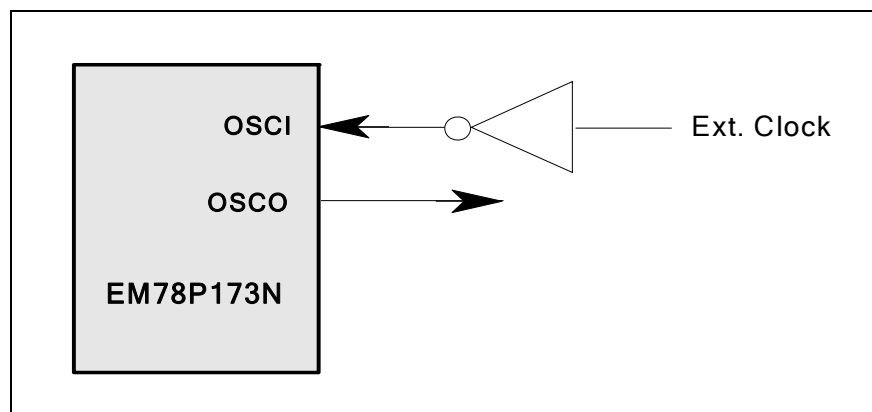


Figure 6-12 Circuit for External Clock Input

In most applications, Pin OSCI and Pin OSCO can be connected with a crystal or ceramic resonator to generate oscillation. Figure 6-13 depicts such a circuit. The same thing applies whether it is in the HXT mode or in the LXT mode.

In Figure 6-14, when the connected resonator in OSCI and OSCO is used in applications, the 1 M Ω R1 needs to be shunted with resonator.

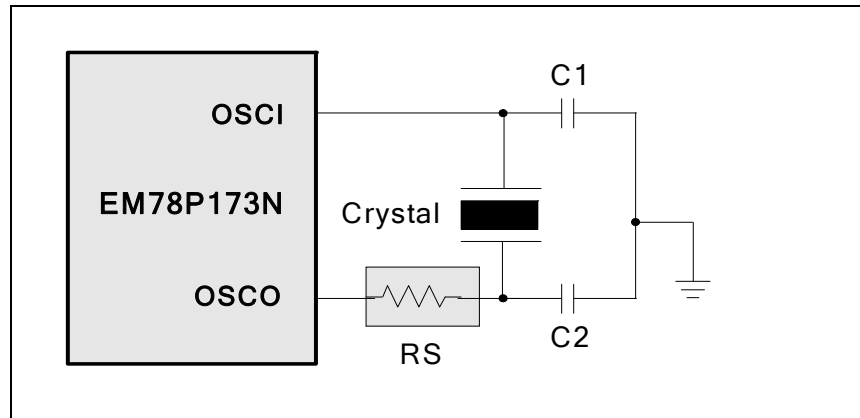


Figure 6-13 Circuit for Crystal/Resonator

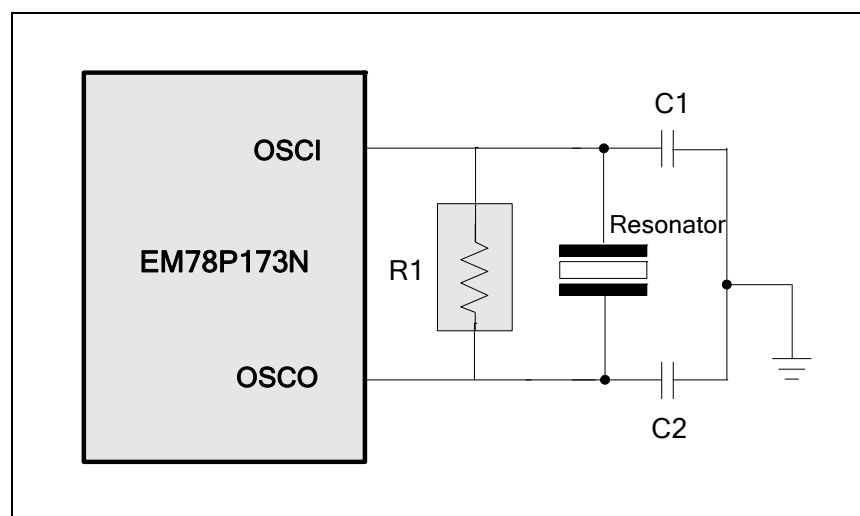


Figure 6-14 Circuit for Crystal/Resonator

Table 6-6 provides the recommended values of C1 and C2. Since each resonator has its own attribute, refer to its specification for appropriate values of C1 and C2. RS, a serial resistor, may be necessary for AT strip cut crystal or low frequency mode.

Table 6-6 Capacitor Selection Guide for Crystal Oscillator or Ceramic Resonator

Oscillator Type	Frequency Mode	Frequency	C1 (pF)	C2 (pF)
Ceramic Resonators	LXT1 (100K~1 MHz)	100kHz	60pF	60pF
		200kHz	60pF	60pF
		455kHz	40pF	40pF
		1 MHz	30pF	30pF
	XT (1M~6 MHz)	1.0 MHz	30pF	30pF
		2.0 MHz	30pF	30pF
4.0 MHz		20pF	20pF	
Crystal Oscillator	LXT2 (32.768kHz)	32.768kHz	40pF	40pF
	LXT1 (100K~1 MHz)	100kHz	60pF	60pF
		200kHz	60pF	60pF
		455kHz	40pF	40pF
		1 MHz	30pF	30pF
	XT (1~6 MHz)	455kHz	30pF	30pF
		1.0 MHz	30pF	30pF
		2.0 MHz	30pF	30pF
		4.0 MHz	20pF	20pF
		6.0 MHz	30pF	30pF
	HXT2 (6~12 MHz)	6.0 MHz	30pF	30pF
		8.0 MHz	20pF	20pF
		10.0 MHz	30pF	30pF
	HXT1 (12~20 MHz)	12.0 MHz	30pF	30pF
		16.0 MHz	20pF	20pF
20.0 MHz		15pF	15pF	

6.7.3 External RC Oscillator Mode

For some applications that do not require a very precise timing calculation, the RC oscillator (Figure 6-15) offers a cost-effective oscillator configuration. Nevertheless, it should be noted that the frequency of the RC oscillator is influenced by the supply voltage, the values of the resistor (R_{ext}), the capacitor (C_{ext}), and even by the operation temperature. Moreover, the frequency also changes slightly from one chip to another due to manufacturing process variations.

In order to maintain a stable system frequency, the values of the C_{ext} should not be less than 20pF, and that the value of R_{ext} should not be greater than 1 M Ω . If they cannot be kept in this range, the frequency can be easily affected by noise, humidity, and leakage.

The smaller the R_{ext} in the RC oscillator is, the faster its frequency will be. On the contrary, for very low R_{ext} values, for instance, 1 K Ω , the oscillator becomes unstable because the NMOS cannot discharge the current of the capacitance correctly.

Based on the above reasons, it must be kept in mind that all of the supply voltage, the operation temperature, the components of the RC oscillator, the package types, the way the PCB is layout, will affect the system frequency.

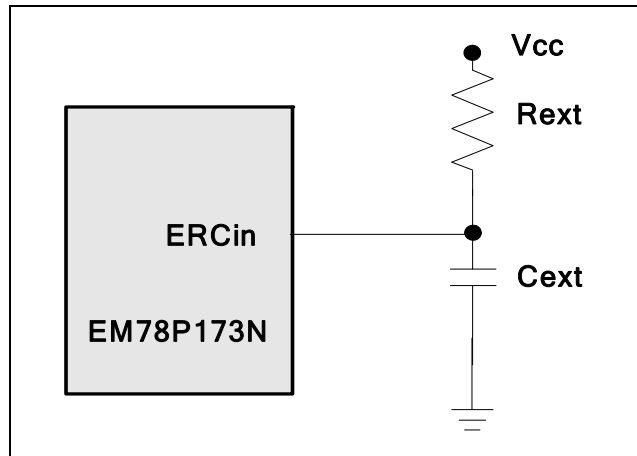


Figure 6-15 External RC Oscillator Mode Circuit

Table 6-7 RC Oscillator Frequencies

Cext	Rext	Average Fosc 5V, 25°C	Average Fosc 3V, 25°C
20pF	3.3k	2.064 MHz	1.901 MHz
	5.1k	1.403 MHz	1.316 MHz
	10k	750kHz	719.7kHz
	100k	81.45kHz	81.33kHz
100pF	3.3k	647.3kHz	615.1 MHz
	5.1k	430.8kHz	414.3kHz
	10k	225.8kHz	219.8kHz
	100k	23.88kHz	23.96kHz
300pF	3.3k	256.6kHz	245.3kHz
	5.1k	169.5kHz	163.0kHz
	10k	88.53kHz	86.14kHz
	100k	9.283kHz	9.255kHz

- Note:** 1. These are measured in DIP packages
 2. The values are for design reference only
 3. The frequency drift is $\pm 30\%$

6.7.4 Internal RC Oscillator Mode

EM78P173N offers a versatile internal RC mode with default frequency value of 4 MHz. The Internal RC oscillator mode has other frequencies (1 MHz, 8 MHz, and 16 MHz) that can be set by Code Option (Word 1), RCM1, and RCM0. All these four main frequencies can be calibrated by programming the Option Bits C0 ~ C4. Table 6-8 describes the EM78P173N internal RC drift with variation of voltage, temperature, and process.

Table 6-8 Internal RC Drift Rate

Internal RC	Drift Rate			
	Temperature (-40°C~85°C)	Voltage	Process	Total
4 MHz	± 1%	± 3% (2.1~5.5V)	± 2%	± 6%
16 MHz	± 1%	± 1% (4.0~5.5V)	± 2%	± 4%
8 MHz	± 1%	± 2% (3.0~5.5V)	± 2%	± 5%
1 MHz	± 1%	± 3% (2.1~5.5V)	± 2%	± 6%

Note: These are theoretical values provided for reference only. Actual values may vary depending on the actual process.

6.8 Code Option Register

The EM78P173N has a Code Option word that is not part of the normal program memory. The option bits cannot be accessed during normal program execution.

■ Code Option Register and Customer ID Register Arrangement Distribution:

Word 0	Word 1	Word 2
Bit 12 ~ Bit 0	Bit 12 ~ Bit 0	Bit 12 ~ Bit 0

6.8.1 Code Option Register (Word 0)

Word 0											
Bit	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bits 2~ 0
Mnemonic	RESETEN	ENWDT	CLKS	LVR1	LVR0	–	WDTPS1	WDTPS0	NRHL	NRE	Protect
1	Disable	Disable	4 clocks	High	High	–	High	High	32/fc	Enable	Disable
0	Enable	Enable	2 clocks	Low	Low	–	Low	Low	8/fc	Disable	Enable

Bit 12 (RESETEN): Define Pin 63 as a reset pin

0 : /RESET enable

1 : /RESET disable

Bit 11 (ENWDT): Watchdog timer enable bit

0 : Enable

1 : Disable

Bit 10 (CLKS): Instruction period option bit.

0 : two oscillator periods

1 : four oscillator periods

Refer to the Instruction Set section.



Bits 9 ~ 8 (LVR1 ~ LVR0): Low Voltage Reset control bits

LVR1, LVR0	VDD Reset Level	VDD Release Level
11	NA (Power-on Reset) (default)	
10	2.7V	2.9V
01	3.5V	3.7V
00	4.0V	4.0V

Bit 7: Set to “1” at all time.

Bit 6 and Bit 5 (WDTPS1 and WDTPS0): WDT Time-out Period of device bits.

Table 6-9 WDT Time-out Period of Device Programming

WDTPS1	WDTPS0	*WDT Time-out Period
1	1	18 ms
1	0	4.5 ms
0	1	288 ms
0	0	72 ms

* These are theoretical values, provided for reference only

Bit 4 (NRHL): Noise rejection high/low pulse define bit. The INT pin has a falling edge trigger.

0 : Pulses equal to $8/f_c$ is regarded as signal

1 : Pulses equal to $32/f_c$ is regarded as signal (Default)

Bit 3 (NRE): Noise rejection enable

0 : disable noise rejection

1 : enable noise rejection (default). However in Low Crystal oscillator (LXT2) mode, the noise rejection circuit is always disabled.

Bits 2 ~ 0 (Protect): Protect Bits. Each protect status is as follows:

Protect Bits	Protect
0	Enable
1	Disable (Default)

6.8.2 Code Option Register (Word 1)

Word 1													
Bit	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Mnemonic	HLP	C4	C3	C2	C1	C0	RCM1	RCM0	OSC3	OSC2	OSC1	OSC0	RCOUT
1	High	High	High	High	High	High	High	High	High	High	High	High	System-clock
0	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Open-drain

Bit 12 (HLP): power consumption mode

0 : Low power consumption mode, applies to operating frequency at 400kHz or below 400kHz

1 : High power consumption mode, applies to operating frequency above 400kHz (default)

Bits 11 ~ 7 (C4 ~ C0): Internal RC mode Calibration bits. These bits must always be set to “1” only (auto calibration).

Bit 6 and Bit 5 (RCM1, RCM0): RC mode selection bits

RCM 1	RCM 0	*Frequency (MHz)
1	1	4
1	0	16
0	1	8
0	0	1

* Theoretical values, for reference only

Bits 4 ~ 1 (OSC3, OSC2, OSC1 and OSC0): Oscillator Mode Select bits

Oscillator Modes	OSC3	OSC2	OSC1	OSC0
ERC ¹ (External RC oscillator mode); P64/RCOUT act as P64	0	0	0	0
ERC ¹ (External RC oscillator mode); P64/RCOUT act as RCOUT	0	0	0	1
IRC ² (Internal RC oscillator mode); P64/RCOUT act as P64	0	0	1	0
IRC ² (Internal RC oscillator mode); P64/RCOUT act as RCOUT	0	0	1	1
LXT1 ³ (Frequency range of LXT1 mode is 1MHz~100kHz)	0	1	0	0
HXT1 ³ (Frequency range of HXT1 mode is 20 MHz~12 MHz)	0	1	0	1
LXT2 ³ (Frequency range of LXT2 mode is 32.768kHz)	0	1	1	0
HXT2 ³ (Frequency range of HXT2 mode is 12 MHz~6 MHz)	0	1	1	1
XT (Frequency range of XT mode is 6 MHz~1 MHz) (default)	1	1	1	1

¹ In ERC mode, ERCin is used as oscillator pin. RCOUT/P64 is defined by Code Option Word 1 Bit 4 ~ Bit 1.

² In IRC mode, P65 is normal I/O pin. RCOUT/P64 is defined by Code Option Word 1 Bit 4 ~ Bit 1.

³ In LXT1, LXT2, HXT1, HXT2 and XT modes; OSC1 and OSC0 are used as oscillator pins. These pins cannot and should not be defined as normal I/O pins.

Bit 0 (RCOUT): System clock or open-drain enable bit in IRC or ERC mode

0 : RCOUT pin is open drain

1 : RCOUT output System clock (**Default**)

6.8.3 Customer ID Register (Word 2)

Word 2													
Bit	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Mnemonic	–	SFS	TYPE	ID9	ID8	ID7	ID6	ID5	ID4	ID3	ID2	ID1	ID0
1	–	16K	14 PIN	High	High	High	High	High	High	High	High	High	High
0	–	128K	10 PIN	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

Bit 12: Not used. Set to “1” at all time.

Bit 11 (SFS): Sub Frequency Select for Green mode.

(Not included WDT time-out and POR release setup-up time)

0 : 128kHz

1 : 16kHz (default)

Bit 10 (TYPE): Type selection for EM78P173N

Type	MCU Type
0	EM78P173N-10Pin
1	EM78P173N-14Pin (Default)

Bits 9 ~ 0: Customer’s ID code

6.9 Power-on Consideration

Any microcontroller is not guaranteed to start to operate properly before the power supply stabilizes at its steady state. Under customer application, when power is OFF, V_{DD} must drop to below 1.8V and remains OFF for 10 μs before power can be switched ON again. This way, the EM78P173N will reset and operate normally. The extra external reset circuit will work well if V_{DD} can rise at very fast speed (50 ms or less). However, under most cases where critical applications are involved, extra devices are required to assist in solving the power-up problems.

6.10 Programmable Oscillator WDT Time-out Period

The Option word contains WDTPS0 and WDTPS1 which can be used to define the oscillator WDT time-out Period. Theoretically, the range is from 4.5 ms to 288 ms. For most of crystal or ceramic resonators, the lower the operation frequency, the longer the set-up time may be required. Table 12 describes the values of the Oscillator WDT Time.

6.11 External Power-on Reset Circuits

The circuitry in the figure implements an external RC to produce the reset pulse. The pulse width (time constant) should be kept long enough for V_{dd} to reach minimum operation voltage. This circuit is used when the power supply has a slow rise time.

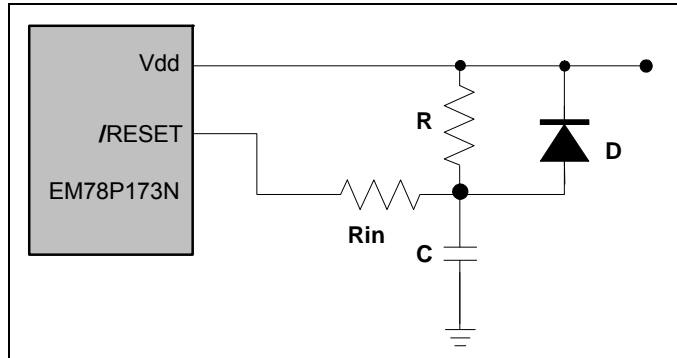


Figure 6-16 External Power-up Reset Circuit

Since the current leakage from the /RESET pin is $\pm 5 \mu\text{A}$, it is recommended that R should not be greater than 40K. In this way, the /RESET pin voltage is held below 0.2V. The diode (D) acts as a short circuit at the moment of power down. The capacitor C will discharge rapidly and fully. Rin, the current-limited resistor, will prevent high current or ESD (electrostatic discharge) from flowing to pin /RESET.

6.12 Residue-Voltage Protection

When the battery is replaced, the device power (Vdd) is cut off but residue-voltage remains. The residue-voltage may trip below the minimum Vdd, but not to zero. This condition may cause a poor power-on reset. The following figures illustrate two recommended methods on how to build a residue-voltage protection circuit for the EM78P173N.

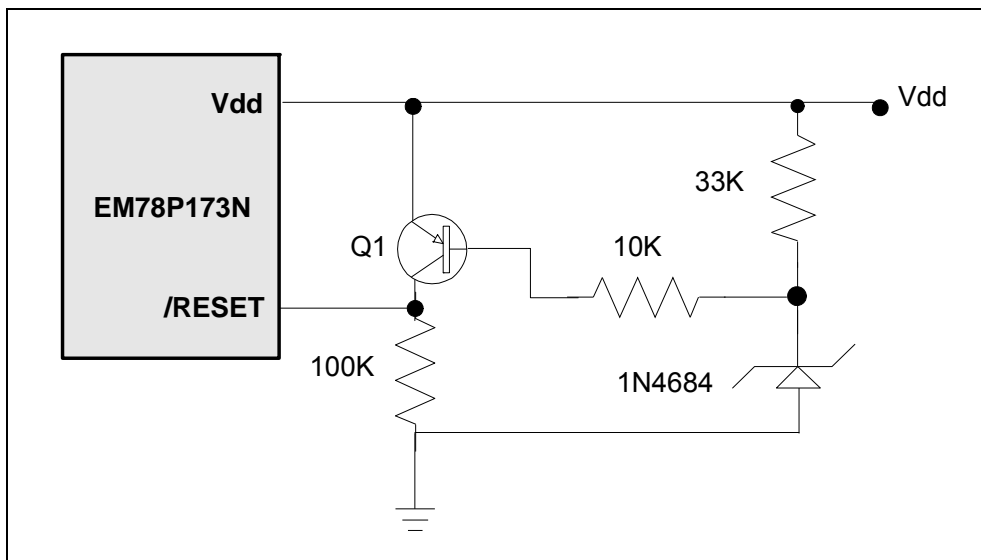


Figure 6-17 Residue Voltage Protection Circuit 1

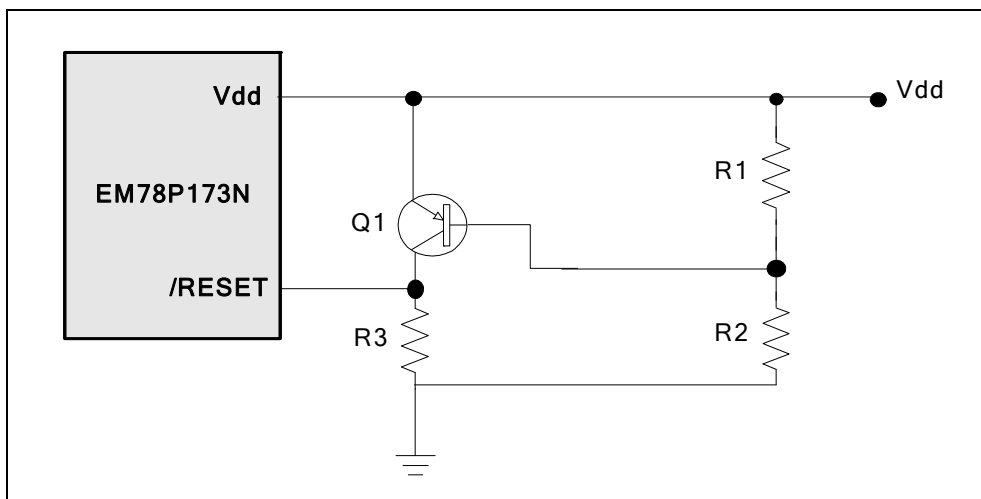


Figure 6-18 Residue Voltage Protection Circuit 2

NOTE

Figure 6-17 and Figure 6-18 should be designed to ensure that the voltage of the /RESET pin is larger than $V_{IH}(\min)$.

6.13 Low Voltage Detector

When an unstable power source condition occurs, such as external power noise interference or EMS test condition, a violent power vibration is generated. At the same time, the V_{DD} becomes unstable as it could be operating below the working voltage. When the system supply voltage (V_{DD}) is below the operating voltage, the IC kernel will automatically keep all register status.

6.13.1 Low Voltage Reset (LVR)

LVR property is set at Bits 9 and 8 of Code Option Word 0. Detailed operation mode is as follows:

Word 0										
Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2 ~ Bit 0
RESETE _N	ENWDT	CLKS	LVR1	LVR0	-	WDTPS1	WDTPS0	NRHL	NRE	Protect

Bits 9 ~ 8 (LVR1 ~ LVR0): Low Voltage Reset enable bits

LVR1, LVR0	VDD Reset Level	VDD Release Level
11	N/A (Power-on Reset)	
10	2.7V	2.9V
01	3.5V	3.7V
00	4.0V	4.2V

6.13.2 Low Voltage Detector (LVD)

LVD property is set at Registers Bank 0-RE and Bank 1-RE. Detailed operation mode is explained below.

6.13.2.1 Bank 0 RE (LVD Control Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
/LVD	LVDIF	-	-	-	-	-	LVDWE

Bit 7 (/LVD): Low voltage Detector state. This is a read only bit. When the V_{DD} pin voltage is lower than the LVD voltage interrupt level (selected by LVD1 and LVD0), this bit will be cleared.

0: Low voltage is detected.

1: Low voltage is not detected or LVD function is disabled.

Bit 6 (LVDIF): Low Voltage Detector Interrupt Flag

LVDIF is reset to "0" by software or hardware

"1" means there's interrupt request

"0" means no interrupt occurs

Bit 0 (LVDWE): Low Voltage Detect wake-up enable bit

0: Disable Low Voltage Detect wake-up

1: Enable Low Voltage Detect wake-up



When the Low Voltage Detect is used to enter an interrupt vector or to wake-up the IC from Sleep/Idle mode with the Low Voltage Detect running, the LVDWE bit must be set to "Enable."

6.13.2.2 Bank 1 RE (LVD Interrupt and Wake-up Register)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
LVDIE	LVDEN	LVD1	LVD0	-	-	-	EXWE

NOTE

- The Bank 1-RE <7> register is both readable and writable.
- Individual interrupt is enabled by setting its associated control bit in the Bank 1-RE<7> to "1."
- Global interrupt is enabled by the ENI instruction and is disabled by the DISI instruction. Refer to Figure 6-10
- (Interrupt Input Circuit) in Section 6.6 (Interrupt).

Bit 7 (LVDIE): Low voltage Detector interrupt enable bit

- 0: Disable Low Voltage Detector interrupt
- 1: Enable Low Voltage Detector interrupt

When a detected low level voltage state is used to enter an interrupt vector or enter the next instruction, the LVDIE bit must be set to "Enable."

Bit 6 (LVDEN): Low Voltage Detector enable bit

- 0: Disable Low voltage detector
- 1: Enable Low voltage detector

Bits 5 ~ 4 (LVD1 ~ 0): Low Voltage Detector level bits

LVDEN	LVD1, LVD0	LVD Voltage Interrupt Level	/LVD
1	11	Vdd ≤ 2.2V	0
		Vdd > 2.2V	1
1	10	Vdd ≤ 3.3V	0
		Vdd > 3.3V	1
1	01	Vdd ≤ 4.0V	0
		Vdd > 4.0V	1
1	00	Vdd ≤ 4.5V	0
		Vdd > 4.5V	1
0	xx	NA	1

NOTE

IF Vdd has crossover at LVD voltage in interrupt level as VDD varies, LVD interrupt will occur.

6.13.3 Programming Process

Follow these steps to obtain data from the LVD:

1. Write to the two bits (LVD1: LVD0) on the Bank 1-RE (LVDCR) register to define the LVD level
2. Set the LVDWE bit if the wake-up function is in use.
3. Set the LVDIE bit if the interrupt function is in use.
4. Write "ENI" instruction if the interrupt function is in use.
5. Set LVDEN bit to "1"
6. Write "SLEP" instruction or Polling /LVD bit
7. Clear the interrupt flag bit (LVDIF) when Low Voltage Detect occurs.

NOTE

- The internal LVD module uses an internal circuit, and when the code option is set to enable the LVD module, the current consumption will increase to about 5 μ A.
- During Sleep mode, the LVD module continues to operate. If the device voltage drops slowly and crosses the detection point, the LVDIF bit will be set and the device will wake up from Sleep mode. The LVD interrupt flag will remain set at priority status.
- When the system resets, the LVD flag is cleared.

The following figure shows the LVD module detection point in an external voltage condition.

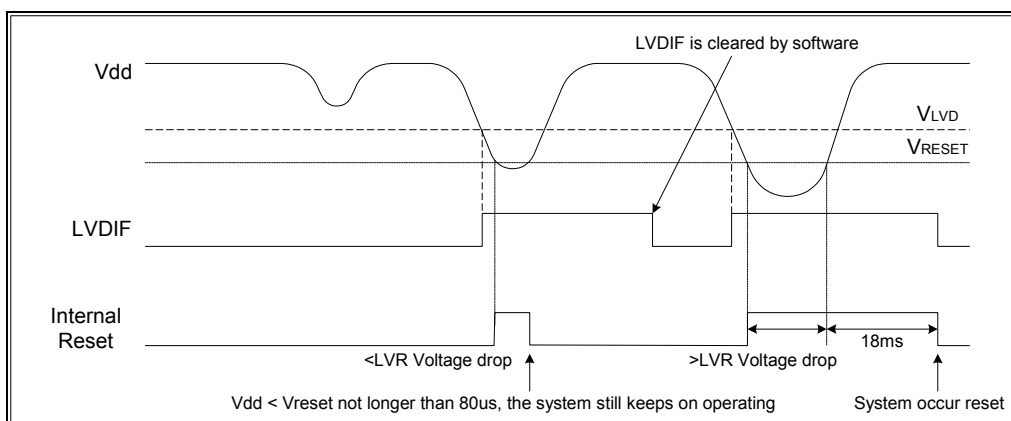


Figure 6-19 LVD/LVR Waveform with the Detection Point in an External Voltage Condition

- When Vdd drops, but above VLVD, the LVDIF is kept at "0".
- When Vdd drops below VLVD, the LVDIF is set to "1". If global ENI is enabled, the LVDIF is also set to "1" and the next instruction will branch to an interrupt vector. The LVD interrupt flag is cleared to "0" by software.



- When V_{dds} drops below V_{RESET} at less than 80 μs, the system will keep all the registers' status and halts its operation, but the oscillation remains active.
- When V_{dd} drops below V_{RESET} at more than 80 μs, a system reset will occur. Refer to Section 6.5.1 *Reset and Wake-up Operation*, for detailed Reset description.

6.14 Instruction Set

Each instruction in the instruction set is a 13-bit word divided into an OP code and one or more operands. Normally, all instructions are executed within one single instruction cycle (one instruction consists of two oscillator periods), unless the program counter is changed by instruction "MOV R2,A", "ADD R2,A", or by instructions of arithmetic or logic operation on R2 (e.g., "SUB R2,A", "BS(C) R2,6", "CLR R2", etc.). In this case, execution takes two instruction cycles.

If for some reasons, the specification of the instruction cycle is not suitable for certain applications, try modifying the instruction as follows:

- A) Modify one instruction cycle to consist of four oscillator periods.
- B) "JMP", "CALL", "RET", "RETL", "RETI" or the conditional skip ("JBS", "JBC", "JZ", "JZA", "DJZ", "DJZA") commands which were tested to be true, are executed within one instruction cycle. The instructions that are written to the program counter also take one instruction cycle.

Case (A) is selected by the Code Option bit, called CLK. One instruction cycle consists of two oscillator clocks if CLK is low; and four oscillator clocks if CLK is high.

Note that once the four oscillator periods within one instruction cycle is selected as in Case (A), the internal clock source to TCC should be CLK=F_{osc}/4, instead of F_{osc}/2.

Moreover, the instruction set has the following features:

- 1) Every bit of any register can be set, cleared, or tested directly.
- 2) The I/O register can be regarded as general register. That is, the same instruction can operate on the I/O register.

The following symbols are used in the Instruction Set table:

Convention:

R = Register designator that specifies which one of the registers (including operation and general purpose registers) is to be utilized by the instruction.

Bit 6 in R4 determine the selected register bank.

b = Bit field designator that selects the value for the bit located in the register *R* and which affects the operation.

k = 8 or 10-bit constant or literal value

Binary Instruction	Hex	Mnemonic	Operation	Status Affected
0 0000 0000 0000	0000	NOP	No Operation	None
0 0000 0000 0001	0001	DAA	Decimal Adjust A	C
0 0000 0000 0010	0002	CONTW	A → CONT	None
0 0000 0000 0011	0003	SLEP	0 → WDT, Stop oscillator	T, P
0 0000 0000 0100	0004	WDTC	0 → WDT	T, P
0 0000 0000 rrrr	000r	IOW R	A → IOCR	None ¹
0 0000 0001 0000	0010	ENI	Enable Interrupt	None
0 0000 0001 0001	0011	DISI	Disable Interrupt	None
0 0000 0001 0010	0012	RET	[Top of Stack] → PC	None
0 0000 0001 0011	0013	RETI	[Top of Stack] → PC, Enable Interrupt	None
0 0000 0001 0100	0014	CONTR	CONT → A	None
0 0000 0001 rrrr	001r	IOR R	IOCR → A	None ¹
0 0000 01rr rrrr	00rr	MOV R,A	A → R	None
0 0000 1000 0000	0080	CLRA	0 → A	Z
0 0000 11rr rrrr	00rr	CLR R	0 → R	Z
0 0001 00rr rrrr	01rr	SUB A,R	R-A → A	Z, C, DC
0 0001 01rr rrrr	01rr	SUB R,A	R-A → R	Z, C, DC
0 0001 10rr rrrr	01rr	DECA R	R-1 → A	Z
0 0001 11rr rrrr	01rr	DEC R	R-1 → R	Z
0 0010 00rr rrrr	02rr	OR A,R	A ∨ R → A	Z
0 0010 01rr rrrr	02rr	OR R,A	A ∨ R → R	Z
0 0010 10rr rrrr	02rr	AND A,R	A & R → A	Z
0 0010 11rr rrrr	02rr	AND R,A	A & R → R	Z
0 0011 00rr rrrr	03rr	XOR A,R	A ⊕ R → A	Z
0 0011 01rr rrrr	03rr	XOR R,A	A ⊕ R → R	Z
0 0011 10rr rrrr	03rr	ADD A,R	A + R → A	Z, C, DC
0 0011 11rr rrrr	03rr	ADD R,A	A + R → R	Z, C, DC

¹ This instruction is applicable to IOC5~IOC6, IOCB ~ IOCF only.

(Continuation)

Binary Instruction	Hex	Mnemonic	Operation	Status Affected
0 0100 00rr rrrr	04rr	MOV A,R	$R \rightarrow A$	Z
0 0100 01rr rrrr	04rr	MOV R,R	$R \rightarrow R$	Z
0 0100 10rr rrrr	04rr	COMA R	$\neg R \rightarrow A$	Z
0 0100 11rr rrrr	04rr	COM R	$\neg R \rightarrow R$	Z
0 0101 00rr rrrr	05rr	INCA R	$R+1 \rightarrow A$	Z
0 0101 01rr rrrr	05rr	INC R	$R+1 \rightarrow R$	Z
0 0101 10rr rrrr	05rr	DJZA R	$R-1 \rightarrow A$, skip if zero	None
0 0101 11rr rrrr	05rr	DJZ R	$R-1 \rightarrow R$, skip if zero	None
0 0110 00rr rrrr	06rr	RRCA R	$R(n) \rightarrow A(n-1)$, $R(0) \rightarrow C$, $C \rightarrow A(7)$	C
0 0110 01rr rrrr	06rr	RRC R	$R(n) \rightarrow R(n-1)$, $R(0) \rightarrow C$, $C \rightarrow R(7)$	C
0 0110 10rr rrrr	06rr	RLCA R	$R(n) \rightarrow A(n+1)$, $R(7) \rightarrow C$, $C \rightarrow A(0)$	C
0 0110 11rr rrrr	06rr	RLC R	$R(n) \rightarrow R(n+1)$, $R(7) \rightarrow C$, $C \rightarrow R(0)$	C
0 0111 00rr rrrr	07rr	SWAPA R	$R(0-3) \rightarrow A(4-7)$, $R(4-7) \rightarrow A(0-3)$	None
0 0111 01rr rrrr	07rr	SWAP R	$R(0-3) \leftrightarrow R(4-7)$	None
0 0111 10rr rrrr	07rr	JZA R	$R+1 \rightarrow A$, skip if zero	None
0 0111 11rr rrrr	07rr	JZ R	$R+1 \rightarrow R$, skip if zero	None
0 100b brrr rrrr	0xxx	BC R,b	$0 \rightarrow R(b)$	None ²
0 101b brrr rrrr	0xxx	BS R,b	$1 \rightarrow R(b)$	None ³
0 110b brrr rrrr	0xxx	JBC R,b	if $R(b)=0$, skip	None
0 111b brrr rrrr	0xxx	JBS R,b	if $R(b)=1$, skip	None
1 00kk kkkk kkkk	1kkk	CALL k	$PC+1 \rightarrow [SP]$, $(Page, k) \rightarrow PC$	None
1 01kk kkkk kkkk	1kkk	JMP k	$(Page, k) \rightarrow PC$	None
1 1000 kkkk kkkk	18kk	MOV A,k	$k \rightarrow A$	None
1 1001 kkkk kkkk	19kk	OR A,k	$A \vee k \rightarrow A$	Z
1 1010 kkkk kkkk	1Akk	AND A,k	$A \& k \rightarrow A$	Z
1 1011 kkkk kkkk	1Bkk	XOR A,k	$A \oplus k \rightarrow A$	Z
1 1100 kkkk kkkk	1Ckk	RETL k	$k \rightarrow A$, $[Top\ of\ Stack] \rightarrow PC$	None
1 1101 kkkk kkkk	1Dkk	SUB A,k	$k-A \rightarrow A$	Z, C, DC
1 1111 kkkk kkkk	1Fkk	ADD A,k	$k+A \rightarrow A$	Z, C, DC
1 1110 1001 kkkk	1E9k	BANK k	$k \rightarrow R4(6)$	None

Note: ² This instruction is not recommended for interrupt status register operation.

³ This instruction cannot operate under interrupt status register.

(Continuation)

Binary Instruction	Hex	Mnemonic	Operation	Status Affected
1 1110 11rr rrrr	1Err	TBRD R	If Bank 1 R5.7=0, machine code(7:0) → R Else Bank 1 R5.7 = 1 Machine Code (12:8) → R(4:0), R(7:5)=(0,0,0)	None

7 Absolute Maximum Ratings

■ EM78P173N

Items	Rating		
Temperature under bias	-40°C	to	85°C
Storage temperature	-65°C	to	150°C
Input voltage	V _{ss} -0.3V	to	V _{dd} +0.5V
Output voltage	V _{ss} -0.3V	to	V _{dd} +0.5V
Working Voltage	2.1V	to	5.5V
Working Frequency	DC	to	20 MHz

NOTE

These parameters are theoretical values and have not been tested.

8 Electrical Characteristics

8.1 DC Characteristics

T_a=25°C, V_{DD}=5V, V_{SS}=0V

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
FXT	Crystal: VDD to 2.1V	Two cycles with two clocks	DC	–	4.0	MHz
	Crystal: VDD to 3V	Two cycles with two clocks	DC	–	8.0	MHz
	Crystal: VDD to 5V	Two cycles with two clocks	DC	–	20.0	MHz
ERC	ERC: VDD to 5V	R: 5KΩ, C: 39pF	F±30%	1500	F±30%	kHz
IIL	Input Leakage Current for input pins	V _{IN} = V _{DD} , V _{SS}	–	–	±1	μA
VIH1	Input High Voltage (VDD=5V)	Ports 5, 6	2.0	–	–	V
VIL1	Input Low Voltage (VDD=5V)	Ports 5, 6	–	–	0.8	V
VIHT1	Input High Threshold Voltage (VDD=5V)	/RESET, TCC (Schmitt trigger)	2.0	–	–	V
VILT1	Input Low Threshold Voltage (VDD=5V)	/RESET, TCC (Schmitt trigger)	–	–	0.8	V

(Continuation)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
VIHX1	Clock Input High Voltage (VDD=5V)	OSCI	2.5	–	–	V
VILX1	Clock Input Low Voltage (VDD=5V)	OSCI	–	–	1.0	V
VIH2	Input High Voltage (VDD=3V)	Ports 5, 6	1.5	–	–	V
VIL2	Input Low Voltage (VDD=3V)	Ports 5, 6	–	–	0.4	V
VIHT2	Input High Threshold Voltage (VDD=3V)	/RESET, TCC (Schmitt trigger)	1.5	–	–	V
VILT2	Input Low Threshold Voltage (VDD=3V)	/RESET, TCC (Schmitt trigger)	–	–	0.4	V
VIHX2	Clock Input High Voltage (VDD=3V)	OSCI	1.5	–	–	V
VILX2	Clock Input Low Voltage (VDD=3V)	OSCI	–	–	0.6	V
VOH1	Output High Voltage (Ports 5, Ports 6)	IOH = -12mA	2.4	–	–	V
VOL1	Output Low Voltage (P50~P53, P60~P62, P66~P67 are Schmitt trigger)	IOL = 12mA	–	–	0.4	V
VOL2	Output Low Voltage (P64, P65)	IOL = 16.0mA	–	–	0.4	V
VOL3	Output Low Voltage (P63)	IOL = 20mA	–	–	0.4	V
IPH	Pull-high current	Pull-high active, input pin at VSS	–	70	–	μA
IPD	Pull-down current	Pull-down active, input pin at VDD	–	30	–	μA
ISB1	Power down current	All input and I/O pins at VDD, Output pin floating, WDT disabled	–	–	1	μA
ISB2	Power down current	All input and I/O pins at VDD, Output pin floating, WDT enabled	–	–	10	μA
ICC1	Operating supply current at two clocks (VDD=3V)	/RESET= 'High', Fosc=32kHz (Crystal type, CLKS="0"), Output pin floating, WDT disabled	–	15	20	μA
ICC2	Operating supply current at two clocks (VDD=3V)	/RESET= 'High', Fosc=32kHz (Crystal type, CLKS="0"), Output pin floating, WDT enabled	–	15	25	μA
ICC3	Operating supply current at two clocks (VDD=5.0V)	/RESET= 'High', Fosc=4 MHz (Crystal type, CLKS="0"), Output pin floating	–	–	1.5	mA
ICC4	Operating supply current at two clocks (VDD=5.0V)	/RESET= 'High', Fosc=10 MHz (Crystal type, CLKS="0"), Output pin floating	–	–	2.8	mA

NOTE

These parameters are theoretical values and have not been tested.

■ Internal RC Electrical Characteristics (Ta=25°C, VDD=5 V, VSS=0V)

Internal RC	Drift Rate				
	Temperature	Voltage	Min.	Typ.	Max.
4 MHz	25°C	5V	3.92 MHz	4 MHz	4.08 MHz
16 MHz	25°C	5V	15.68 MHz	16 MHz	16.32 MHz
8 MHz	25°C	5V	7.84 MHz	8 MHz	8.16 MHz
1 MHz	25°C	5V	0.98MHz	1MHz	1.02MHz

■ Internal RC Electrical Characteristics (Ta= -40 ~85°C)

Internal RC	Drift Rate				
	Temperature	Voltage	Min.	Typ.	Max.
4 MHz	-40 ~ 85°C	2.1V~5.5V	3.76 MHz	4 MHz	4.24 MHz
16 MHz	-40 ~ 85°C	4.0V~5.5V	15.36 MHz	16MHz	16.64 MHz
8 MHz	-40 ~ 85°C	3.0V~5.5V	7.60 MHz	8 MHz	8.40 MHz
1 MHz	-40 ~ 85°C	2.1V~5.5V	0.94 MHz	1MHz	1.06 MHz

8.2 AC Characteristics

Ta=25°C, VDD=5V, VSS=0V

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Dclk	Input CLK duty cycle	–	45	50	55	%
Tins	Instruction cycle time (CLKS="0")	Crystal type	100	–	DC	ns
		RC type	500	–	DC	ns
Ttcc	TCC input period	–	(Tins+20)/N*	–	–	ns
Tdrh	Device reset hold time	Ta = 25°C, XTAL, WDTPS1, WDTPS0=1, 1	16.8-30%	16.8	16.8+30%	ms
Trst	/RESET pulse width	Ta = 25°C	2000	–	–	ns
*Twdt1	Watchdog timer period	Ta = 25°C WDTPS1, WDTPS0=1,1	16.8-30%	17.6	16.8+30%	ms
*Twdt2	Watchdog timer period	Ta = 25°C WDTPS1, WDTPS0=1,0	4.5-30%	4.5	4.5+30%	ms
*Twdt3	Watchdog timer period	Ta = 25°C WDTPS1, WDTPS0=0,1	288-30%	288	288+30%	ms
*Twdt4	Watchdog timer period	Ta = 25°C WDTPS1, WDTPS0=0,0	72-30%	72	72+30%	ms
Tset	Input pin setup time	–	–	0	–	ns
Thold	Input pin hold time	–	–	20	–	ns
Tdelay	Output pin delay time	Cload=20pF	–	50	–	ns



NOTE

These parameters are theoretical values and have not been tested.

The Watchdog Timer duration is determined by Code Option (Bit 6, Bit 5)

**N = selected prescaler ratio*

**Twdt1: The Option Word (WDTPS1, WDTPS0) is used to define the oscillator WDT time. In Crystal mode the WDT time-out length is the same as 18 ms.*

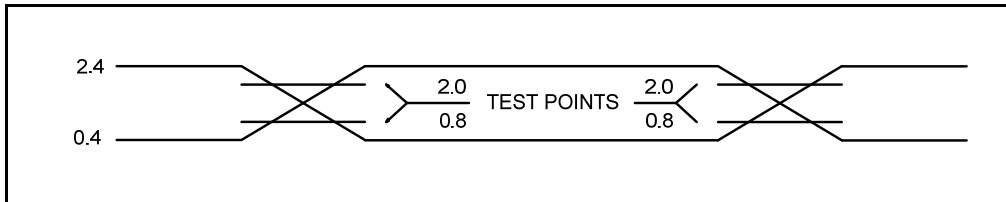
**Twdt2: The Option Word (WDTPS1, WDTPS0) is used to define the oscillator WDT time. In Crystal mode the WDT time-out length is the same as 4.5 ms.*

**Twdt3: The Option Word (WDTPS1, WDTPS0) is used to define the oscillator WDT time. In Crystal mode the WDT time-out length is the same as 288 ms.*

**Twdt4: The Option Word (WDTPS1, WDTPS0) is used to define the oscillator WDT time. In Crystal mode the WDT time-out length is the same as 72 ms.*

9 Timing Diagrams

AC Test Input/Output Waveform



Note: AC Testing: Input are driven at 2.4V for logic "1", and 0.4V for logic "0"
Timing measurements are made at 2.0V for logic "1", and 0.8V for logic "0"

Figure 9-1a AC Test Input/Output Waveform Timing Diagram

Reset Timing (CLK = "0")

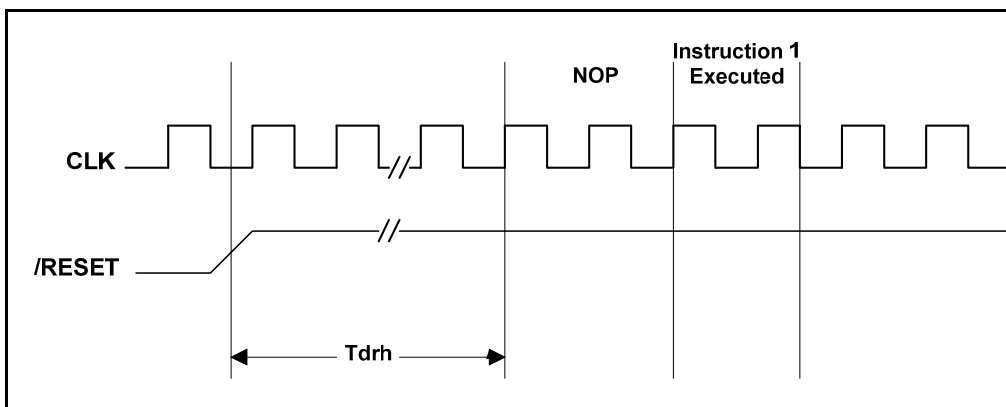


Figure 9-1b Reset Timing Diagram

TCC Input Timing (CLKS = "0")

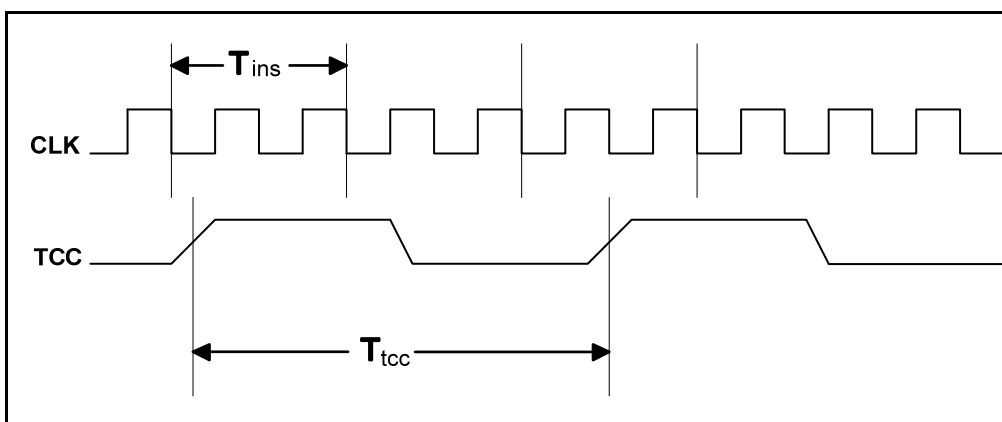


Figure 9-1c TCC Input Timing Diagram



APPENDIX

A Package Type

OTP MCU	Package Type	Pin Count	Package Size
EM78P173ND14J/S	DIP	14	300 mil
EM78P173NSO14J/S	SOP	14	150 mil
EM78P173NMS10J/S	MSOP	10	118 mil

These are Green products which do not contain hazardous substances and comply with the third edition of Sony SS-00259 standard.

Pb content is less than 100ppm and complies with Sony specifications.

Part No.	EM78P173N
Electroplate type	Pure Tin
Ingredient (%)	Sn: 100%
Melting point (°C)	232°C
Electrical resistivity ($\mu\Omega$ -cm)	11.4
Hardness (hv)	8~10
Elongation (%)	>50%

B Package Information

■ 14-Lead Plastic Dual In-line Package (PDIP) — 300 mil

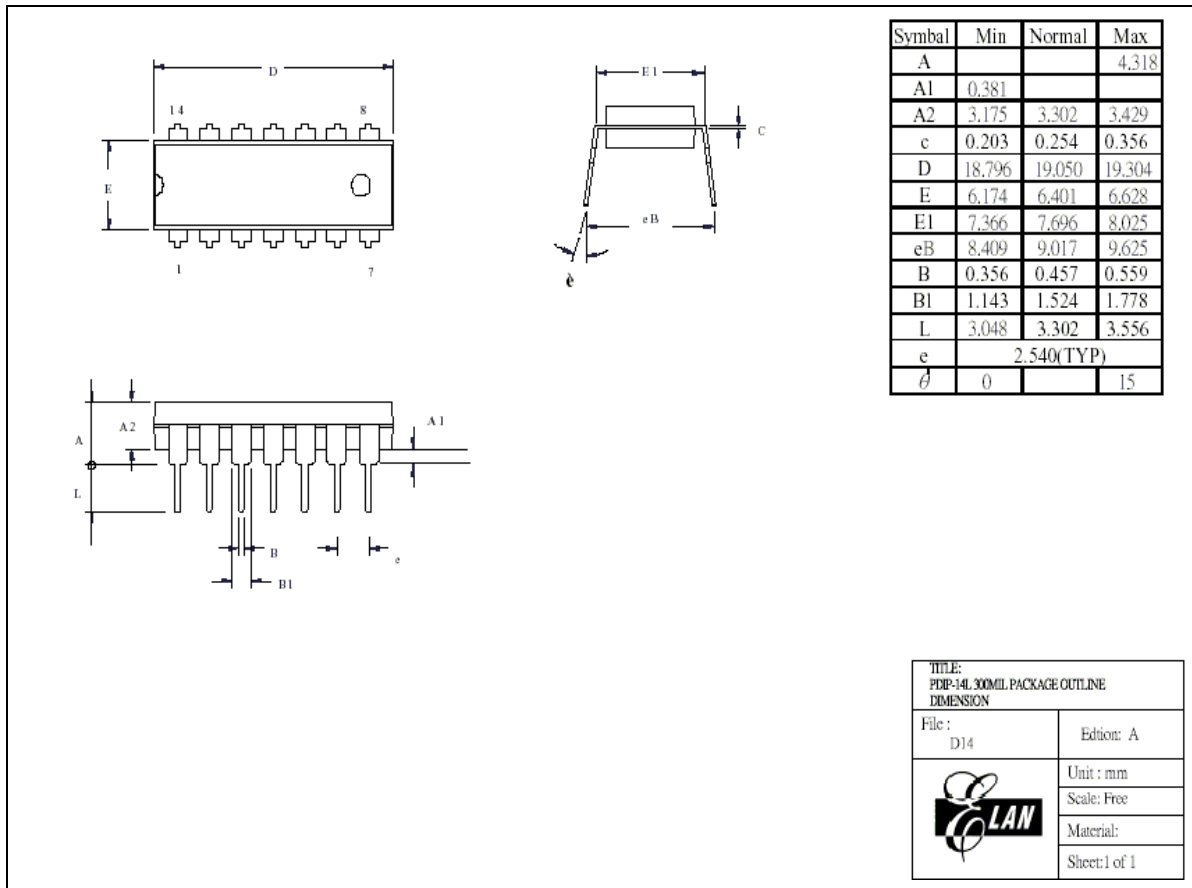


Figure B-1a EM78P173N 14-Lead PDIP Package Type

■ **14-Lead Small Outline Package (SOP) — 150 mil**

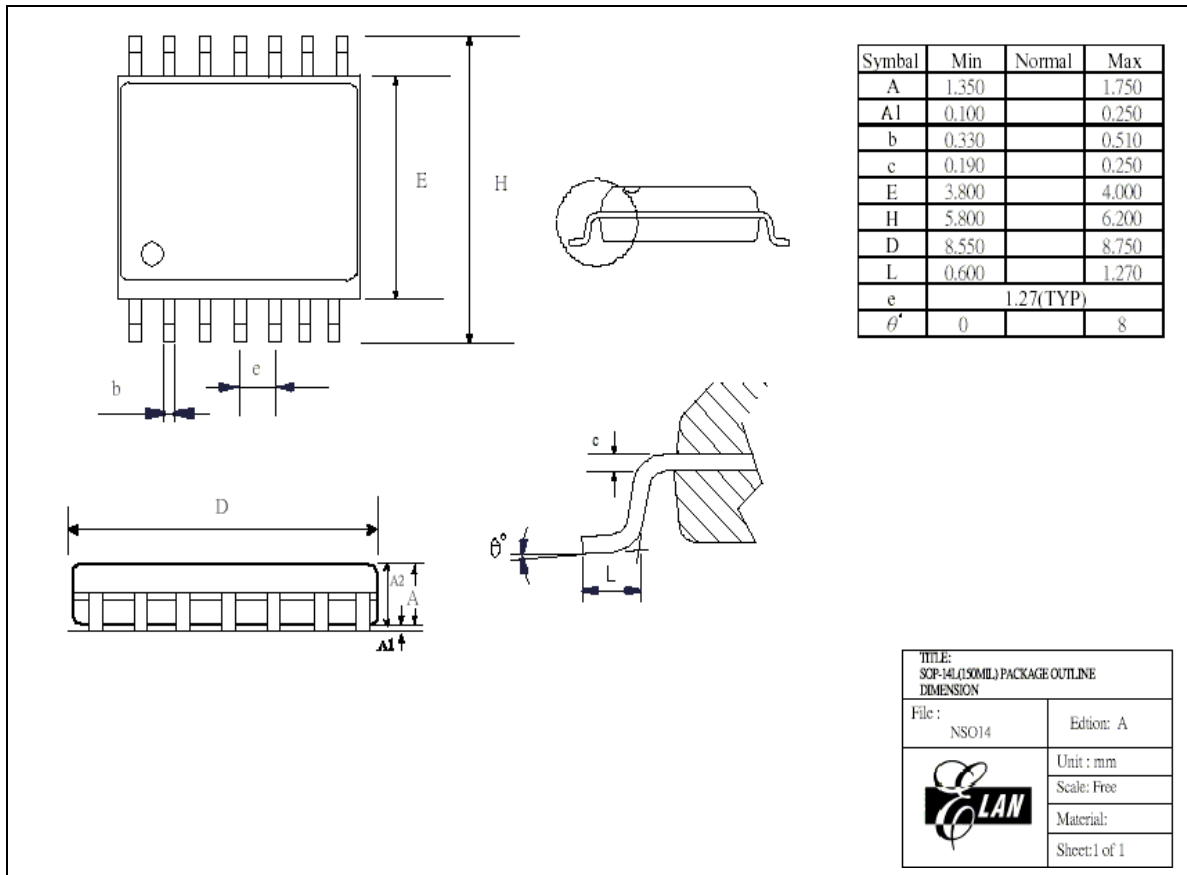


Figure B-1b EM78P173N 14-Lead SOP Package Type

■ **10-Lead Micro Small Outline Package (MSOP) — 118 mil**

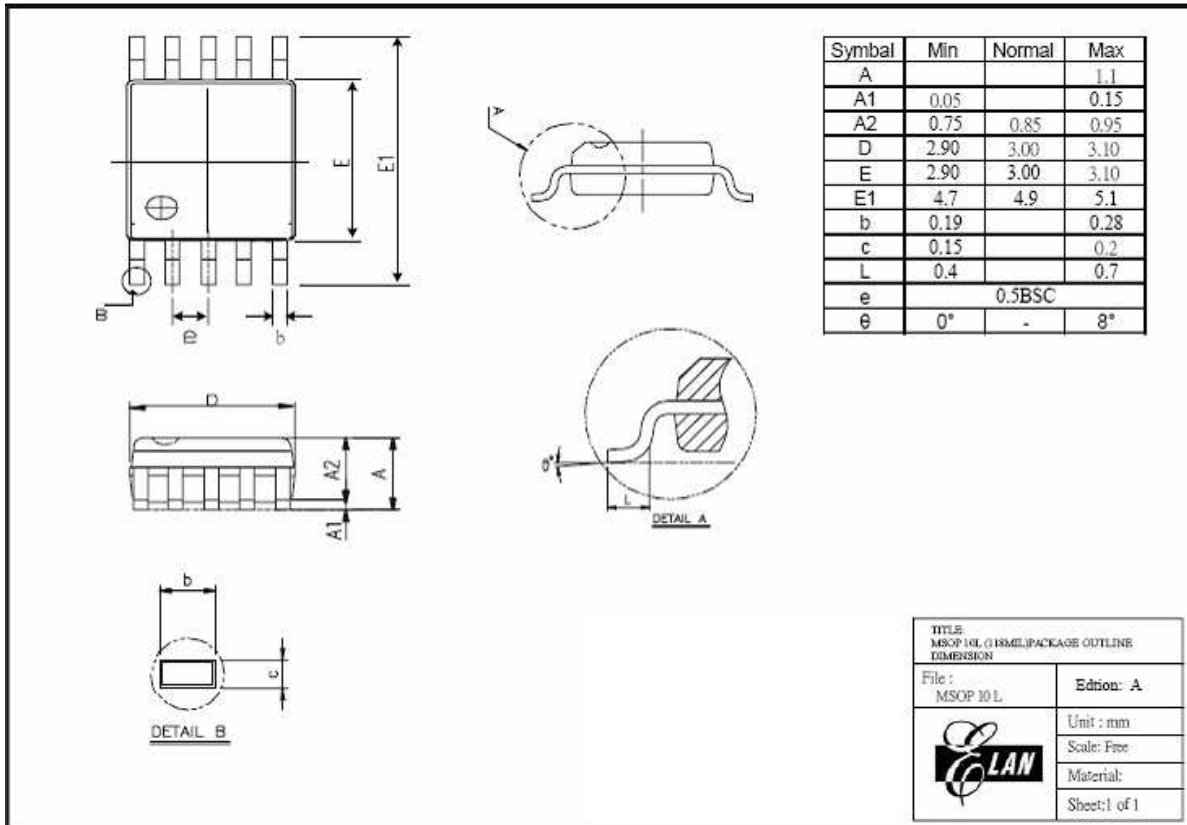


Figure B-1c EM78P173N 10-Lead MSOP Package Type

C Quality Assurance and Reliability

Test Category	Test Conditions	Remarks
Solderability	Solder temperature = $245 \pm 5^{\circ}\text{C}$, for 5 seconds up to the stopper using a rosin-type flux	–
Pre-condition	Step 1: TCT, 65°C (15 min)~ 150°C (15 min), 10 cycles	For SMD IC (such as SOP, QFP, SOJ, etc)
	Step 2: Bake at 125°C , TD (endurance) = 24 hrs	
	Step 3: Soak at $30^{\circ}\text{C}/60\%$, TD (endurance) = 192 hrs	
	Step 4: IR flow 3 cycles (Pkg thickness $\geq 2.5\text{mm}$ or Pkg volume $\geq 350\text{ mm}^3$ ---- $225 \pm 5^{\circ}\text{C}$) (Pkg thickness $\leq 2.5\text{ mm}$ or Pkg volume $\leq 350\text{ mm}^3$ ---- $240 \pm 5^{\circ}\text{C}$)	
Temperature cycle test	-65°C (15 min) ~ 150°C (15 min), 200 cycles	–
Pressure cooker test	TA = 121°C , RH = 100%, pressure = 2 atm, TD (endurance) = 96 hrs	–
High temperature / High humidity test	TA = 85°C , RH = 85%, TD (endurance) = 168 , 500 hrs	–
High-temperature storage life	TA = 150°C , TD (endurance) = 500, 1000 hrs	–
High-temperature operating life	TA = 125°C , VCC = Max. operating voltage, TD (endurance) = 168, 500, 1000 hrs	–
Latch-up	TA = 25°C , VCC = Max. operating voltage, 800mA/40V	–
ESD (HBM)	TA = 25°C , $\geq \pm 4\text{KV} $	IP_ND,OP_ND,IO_ND IP_NS,OP_NS,IO_NS IP_PD,OP_PD,IO_PD,
ESD (MM)	TA = 25°C , $\geq \pm 400\text{V} $	IP_PS,OP_PS,IO_PS, VDD-VSS(+),VDD_VSS (-) mode

C.1 Address Trap Detect

An address trap detect is one of the MCU embedded fail-safe functions that detects MCU malfunction caused by noise or the like. Whenever the MCU attempts to fetch an instruction from a certain section of ROM, an internal recovery circuit is auto started. If a noise-caused address error is detected, the MCU will repeat execution of the program until the noise is eliminated. The MCU will then continue to execute the next program.