EM78P153K

8-Bit Microcontroller with OTP ROM

Product Specification

DOC. VERSION 1.3

ELAN MICROELECTRONICS CORP.

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Specification Revision History

Doc. Version	Revision Description	Date
1.0	Official original Specification	2011/11/22
1.1	1. Added Ordering and Manufacturing Information 2. Modified the Instruction Table, not the Instruction Set 3. Added diagram of Voltage to Frequency Curve in Section 7.3 *Device Characteristics* 4. Modified the part number 5. Modified the description about POR and LVR in the Features section	2012/05/28
1.2	1. Fixed up the part number issues 2. Added 10-Pin SSOP Package	2012/08/07
1.3	Added diagrams of Temperature relative measurements	2012/10/23

1 General Description

The EM78P153K is an 8-bit microprocessor designed and developed with low-power and high-speed CMOS technology. The device has an on-chip 1024×13-bit Electrical One Time Programmable Read Only Memory (OTP-ROM). It provides a protection bit to prevent intrusion of user's OTP memory code. Fifteen Code option bits are also available to meet user's requirements.

With enhanced OTP-ROM features, the EM78P153K 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
  - 32×8 bits on-chip registers (SRAM, general purpose)
  - 5-level stacks for subroutine nesting
  - Less than 1.5 mA at 5V / 4 MHz
  - Typically 15 µA at 3V / 32kHz
  - Typically 1 µA during Sleep mode
- I/O port configuration
  - 2 bidirectional I/O ports : P5, P6
  - 12 I/O pins
  - Wake-up port : P6
  - 6 Programmable pull-down I/O pins
  - 7 programmable pull-high I/O pins
  - 7 programmable open-drain I/O pins
  - External interrupt : 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):
  - IRC mode:

Internal RC Freq.	Drift Rate			
	Temp. (-40~85°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%

  - Crystal mode:
    DC ~ 20 MHz / 2clks @ 5V
    DC ~ 8 MHz / 2clks @ 3V
    DC ~ 4MHz / 2clks @ 2.1V
  - ERC mode:
    DC ~ 2 MHz / 2clks @ 2.1V
- Peripheral configuration
  - 8-bit Real Time Clock/Counter (TCC) with selective signal sources, trigger edges, and overflow interrupt
  - Power-on reset and 3 programmable level voltage reset
    POR: 1.8V (Default), LVR: 4.0, 3.5, 2.7V
  - 2-/ 4 clocks per instruction cycle selected by code option
  - High EFT immunity
- Three available interrupts:
  - TCC overflow interrupt
  - Input-port status changed interrupt (wake-up from sleep mode)
  - External interrupt
- Special features
  - Programmable free running Watchdog Timer
  - Power saving sleep mode
  - Selectable oscillation mode
  - Programmable prescaler of oscillator set-up time
- Package type:
  - 14-pin DIP 300mil : EM78P153KD14J
  - 14-pin SOP 150mil : EM78P153KSO14J
  - 10-pin SSOP 150mil : EM78P153KSS10J
  - 10-pin SSOP 150mil : EM78P153KASS10J

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

3 Pin Assignment

14-Pin DIP/SOP

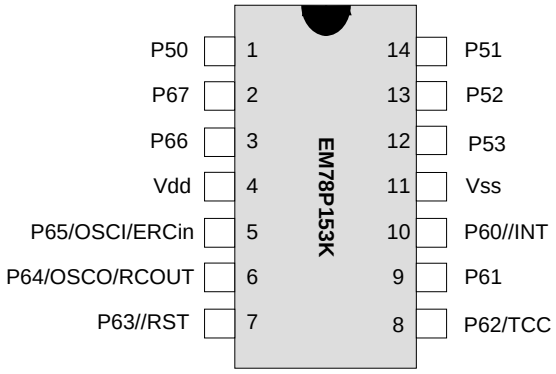


Figure 3-1 EM78P153KD14J/SO14J

10-Pin SSOP 1

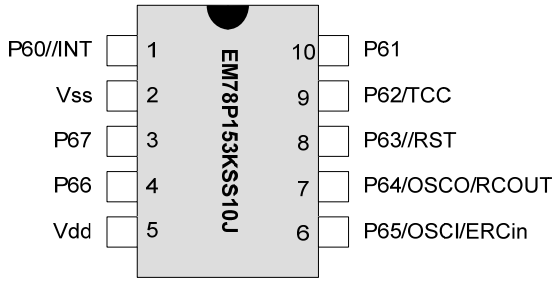


Figure 3-2 EM78P153KSS10J

10-Pin SSOP 2

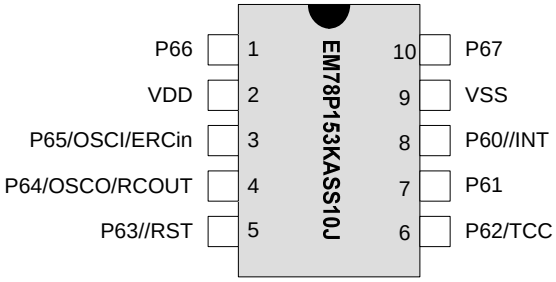


Figure 3-2 EM78P153KASS10J

4 Pin Description

Name	Function	Input Type	Output Type	Description
P53	P53	ST	CMOS	Bidirectional I/O pin
P52 P51 P50	P52 P51 P50	ST	CMOS	Bidirectional I/O pin with programmable pull-low
P67 P66	P67 P66	ST	CMOS	Bidirectional I/O pin with programmable pull-high, open-drain and wake-up pin from sleep mode when the pin status changes.
P65/OSCI	P65	ST	CMOS	Bidirectional I/O pin with programmable pull-high, open-drain and wake-up pin from sleep mode when the pin status changes.
	OSCI	XTAL	–	Clock input of crystal/ resonator oscillator
P64/OSCO	P64	ST	CMOS	Bidirectional I/O pin with programmable pull-high, open-drain and wake-up pin from sleep mode when the pin status changes.
	OSCO	–	XTAL	Clock output of crystal/ resonator oscillator
P63//RESET	P63	ST	–	Input pin and wake-up pin from sleep mode when the pin status changes.
	/RESET	ST	–	Reset Pin, Active Low.
P62/TCC	P62	ST	CMOS	Bidirectional I/O pin with programmable pull-high, pull-low, open-drain and wake-up pin from sleep mode when the pin status changes.
	TCC	ST	–	TCC External Input
P61	P61	ST	CMOS	Bidirectional I/O pin with programmable pull-high, pull-low, open-drain and wake-up pin from sleep mode when the pin status changes.
P60/INT	P60	ST	CMOS	Bidirectional I/O pin with programmable pull-high, pull-low, open-drain and wake-up pin from sleep mode when the pin status changes.
	/INT	ST	–	External interrupt pin triggered by a falling edge
VDD	VDD	Power	–	IC Power supply
VSS	VSS	Power	–	Ground for the IC

5 Functional Description

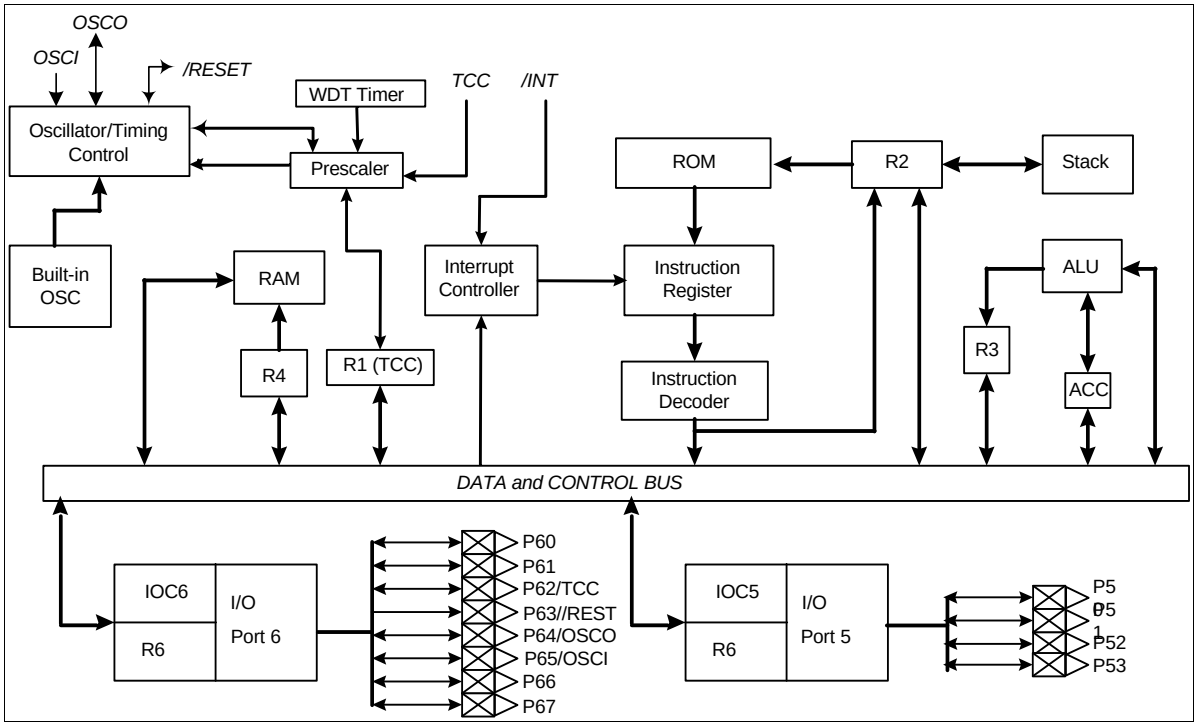


Figure 5-1 EM78P153K Functional Block Diagram

5.1 Operational Registers

5.1.1 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).

5.1.2 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.

5.1.3 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.

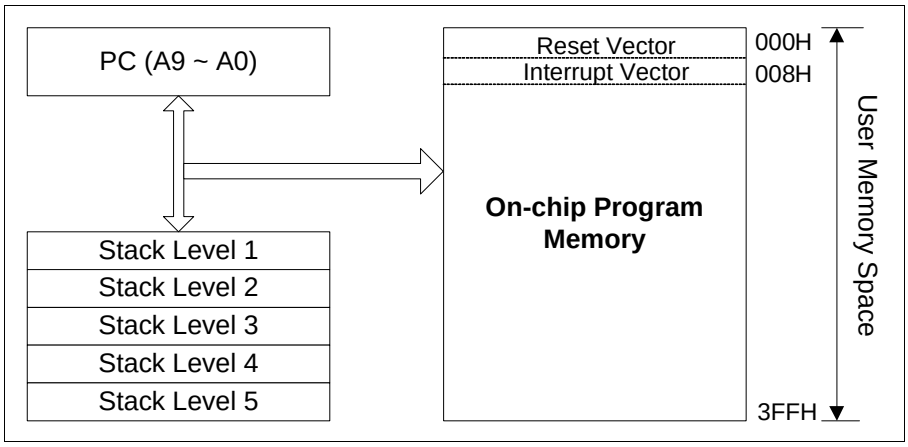


Figure 5-2 Program Counter Organization

- 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 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.
- Any instruction written to R2 (e.g. “ADD R2, A”, "MOV R2, A", "BC R2, 6",···) will cause the ninth bit and the tenth bit (A8 ~ A9) of the PC to be cleared. Hence, the computed jump is limited to the first 256 locations of a page.
- 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.

■ The Data Memory Configuration is as follows:

Address	R PAGE Registers	IOC PAGE Registers
00	R0 (IAR)	Reserve
01	R1 (TCC)	CONT (Control Register)
02	R2 (PC)	Reserve
03	R3 (Status)	Reserve
04	R4 (RSR)	Reserve
05	R5 (Port 5)	IOC5 (I/O Port Control Register)
06	R6 (Port 6)	IOC6 (I/O Port Control Register)
07	Reserve	Reserve
08	Reserve	Reserve
09	Reserve	Reserve
0A	Reserve	Reserve
0B	Reserve	IOCB (Pull-down Register)
0C	Reserve	IOCC (Open-drain Control)
0D	Reserve	IOCD (Pull-high Control Register)
0E	Reserve	IOCE (WDT Control Register)
0F	RF (Interrupt Status)	IOCF (Interrupt Mask Register)
10 : 2F	General Registers	

Figure 5-3 Data Memory Configuration

5.1.4 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

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

5.1.5 R4 (RAM Select Register)

- Bits 7 ~ 6 are not used (Read only).
- Bits 7 ~ 6 set to “1” at all time.
- Bits 5 ~ 0 are used to select registers (Address: 0x00 ~ 0x06, 0x0F ~ 0x2F) in indirect addressing mode.
- See the Data Memory Configuration in Figure 5-3.

5.1.6 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 are fixed to “0”.

P63 is input only.

5.1.7 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 change 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.

5.1.8 R10 ~ R2F

These are all 8-bit general-purpose registers.

5.2 Special Function Registers

5.2.1 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.

5.2.2 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

Bits 2 ~ 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.

5.2.3 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.

IOC5 and IOC6 registers are both readable and writable.

5.2.4 IOCB (Pull-down Control Register)

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

Bit 7: Not used. Set to "1" at all time.

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.

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.

5.2.5 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.

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.

5.2.6 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.

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.

5.2.7 IOCE (WDT Control Register)

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

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

0: Disable WDT

1: Enable WDT

WDTE is both readable and writable.

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. In this case, the I/O control bit of P60 (Bit 0 of IOC6) must be set to "1."

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 5-6 under Section 5.4 for reference.

EIS is both readable and writable.

Bits 5 ~ 0: Not used. Set to “0” at all time.

5.2.8 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.

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.

5.3 TCC/WDT and Prescaler

There is an 8-bit counter available as prescaler for the TCC or WDT. The prescaler is available for the TCC only or the WDT only 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 the 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 5-4 depicts the circuit diagram of TCC / WDT.

- 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, TCC will be incremented by 1 at every instruction cycle (without prescaler). Referring to Figure 5-4, CLK=Fosc / 2 or CLK=Fosc / 4, depends on the Code Option bit CLK. CLK=Fosc / 2 is used if CLK bit is "0", and CLK=Fosc / 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 ms[1] (default).

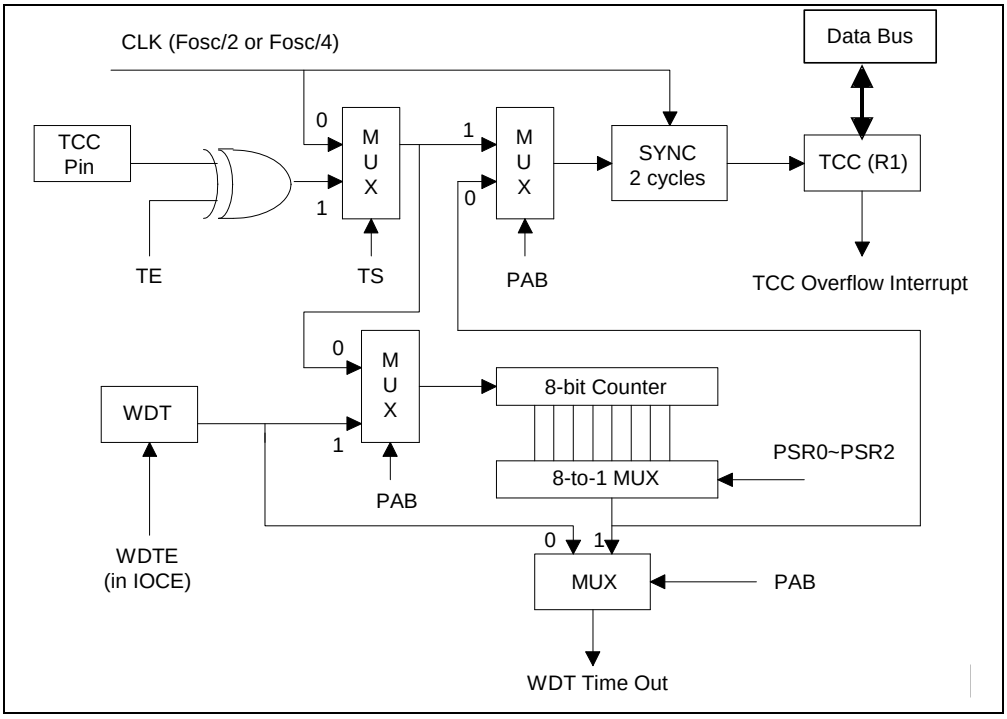
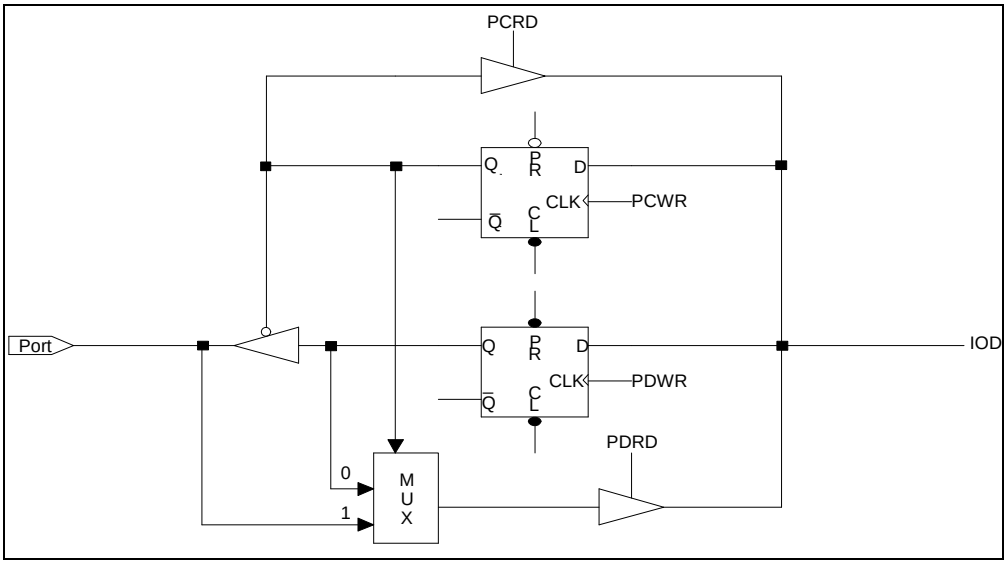


Figure 5-4 TCC and WDT Block Diagram

5.4 I/O Ports

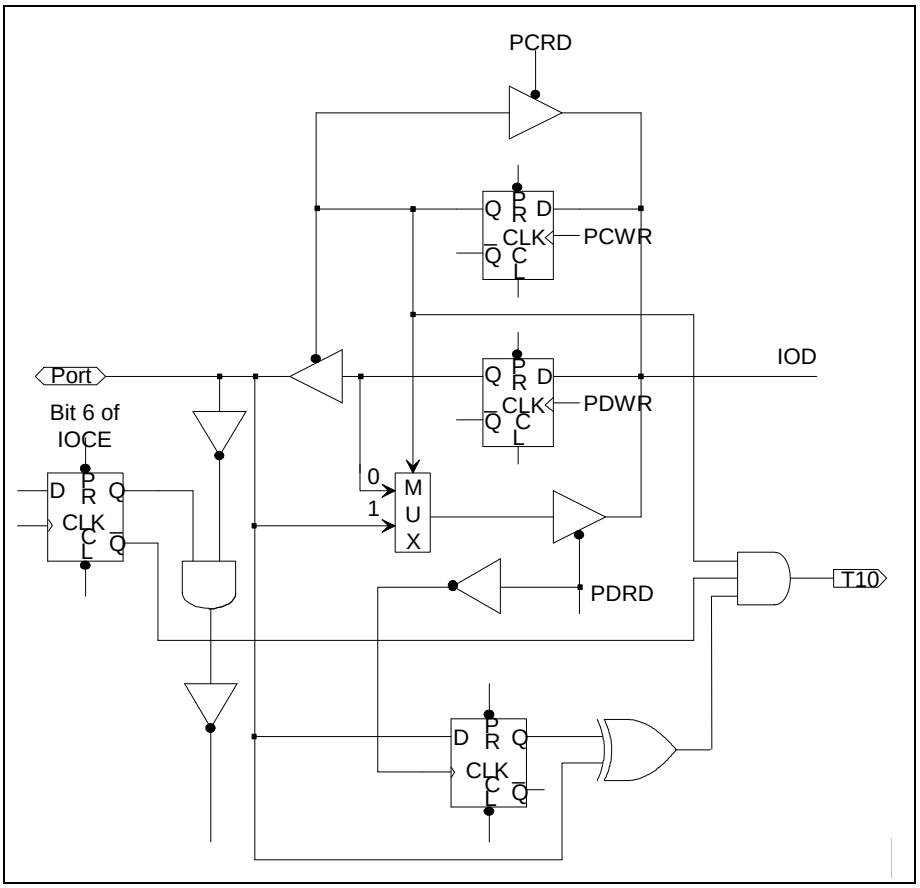
The I/O registers, both Port 5 and Port 6, are bidirectional tri-state I/O ports. Port 6 can be pulled-high internally by software except P63. In addition, Port 6 can also have open-drain output by software except P63. Input status changed interrupt (or wake-up) function is available from Port 6. P50 ~ P52 and P60 ~ P62 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) except P63. 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 5-5 ~ Figure 5-7 respectively.

[1] Vdd = 5V, set up time period = 16.5ms ± 30% at 25°C
Vdd = 3V, set up time period = 18ms ± 30% at 25°C



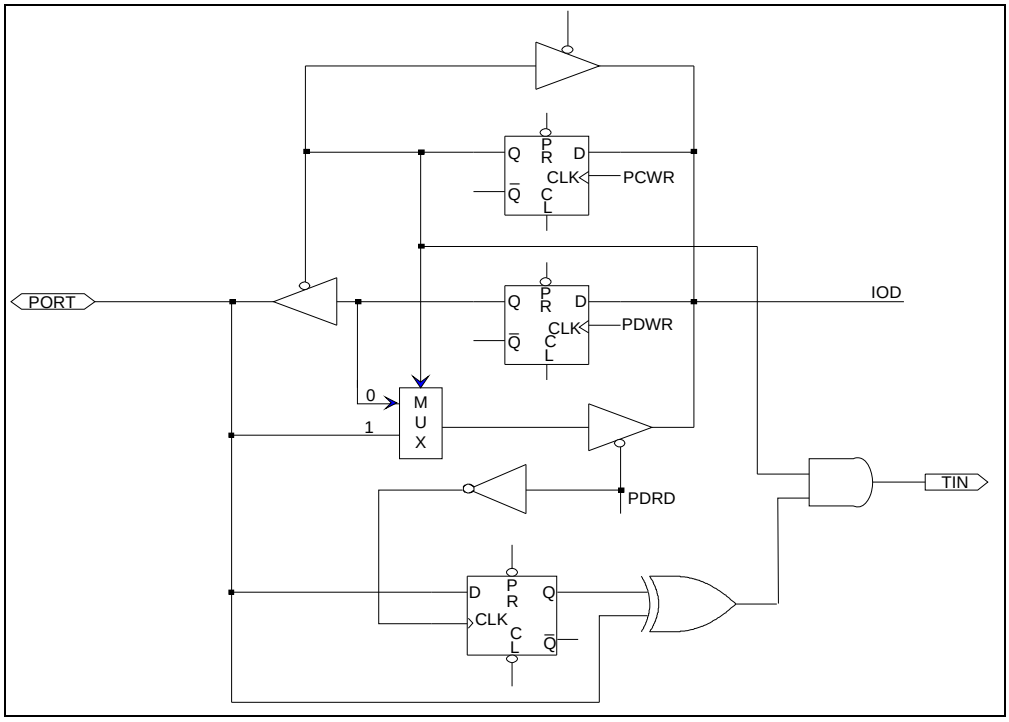
Note: *Pull-down is not shown in the figure.*

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



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

Figure 5-6 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 5-7 I/O Port and I/O Control Register Circuit for P61~P67

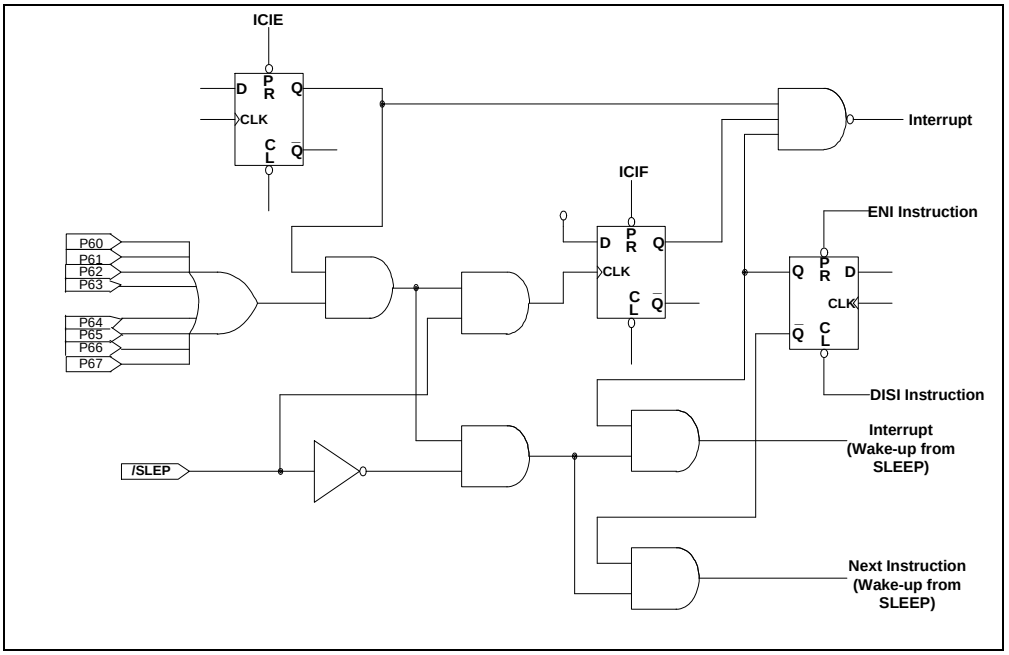


Figure 5-8 Block Diagram of I/O Port 6 with input change interrupt/wake-up

Table 5-1 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 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 1. IF "ENI" → Interrupt vector (008H) 2. IF "DISI" → Next instruction	(II) Port 6 Input Status Change Interrupt 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)

5.5 Reset and Wake-up

5.5.1 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 18ms[2] (one oscillator start-up timer period) after a reset is detected. Once a Reset occurs, the following functions are performed:

- 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 Bits 4 and 6 are cleared.
- Bits 0 ~ 2 of RF and Bits 0 ~ 2 of IOCF registers are cleared.

[2] Vdd = 5V, set up time period = 16.8ms ± 30%
Vdd = 3V, set up time period = 18ms ± 30%

Sleep (power down) mode is asserted by executing the “SLEP” instruction. While entering Sleep mode, WDT (if enabled) is cleared but keeps on running.

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)

The first two cases will cause the EM78P153K 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 a 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.

Only one of Cases 2 and 3 can be enabled before going into the Sleep mode. That is,

[a] If Port 6 Input Status Change Interrupt is enabled before SLEP, WDT must be disabled by software. Hence, the EM78P153K can be awakened only by Case 1 or Case 3.

[b] If WDT is enabled before SLEP, Port 6 Input Status Change Interrupt must be disabled. Hence, the EM78P153K can be awakened only by Case 1 or Case 2. For further details, refer to Section 5.6, *Interrupt*.

If Port 6 Input Status Change Interrupt is used to wake-up the EM78P153K (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, @0xxxxxxxb     ; 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.*

5.5.2 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
0×00	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
0×01	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
0×02	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							
0×03	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
0×04	R4 (RSR)	Bit Name	GP1	GP0	-	-	-	-	-	-
		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
0×05	P5	Bit Name	×	×	×	×	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

Address	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0×06	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
0×0F	RF (ISR)	Bit Name	×	×	×	×	×	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	N	P
N/A	CONT	Bit Name	×	/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	0	P	P	P	P	P	P
0×05	IOC5	Bit Name	×	×	×	×	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	0	0	0	0	P	P	P	P
0×06	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
0×0B	IOCB	Bit Name	×	/PD66	/PD65	/PD64	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
0×0C	IOCC	Bit Name	OD67	OD66	OD65	OD64	×	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
0×0D	IOCD	Bit Name	/PH67	/PH66	/PH65	/PH64	×	/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

Address	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0×0E	IOCE	Bit Name	WDTE	EIS	×	×	×	×	×	×
		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	1	1	1	1	1	1
0×0F	IOCF	Bit Name	×	×	×	×	×	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
0×10~ 0×2F	R10~R2F	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 5.5.3).*

5.5.3 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 5-2 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 5-3 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*

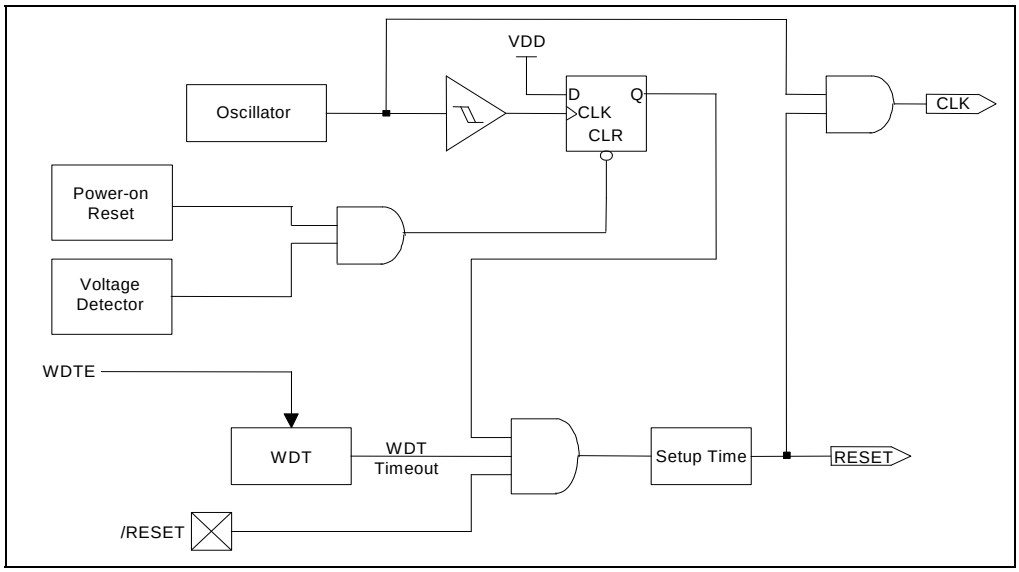


Figure 5-9 Controller Reset Block Diagram

5.6 Interrupt

The EM78P153K has three falling-edge interrupts as listed herewith:

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

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 EM78P153K from Sleep mode if Port 6 is enabled prior to going into Sleep mode by executing SLEP 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 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 5-10). The RETI instruction ends the interrupt routine and enables the global interrupt (the execution of ENI).

When an interrupt is generated by the INT instruction (enabled), the next instruction will be fetched from Address 001H.

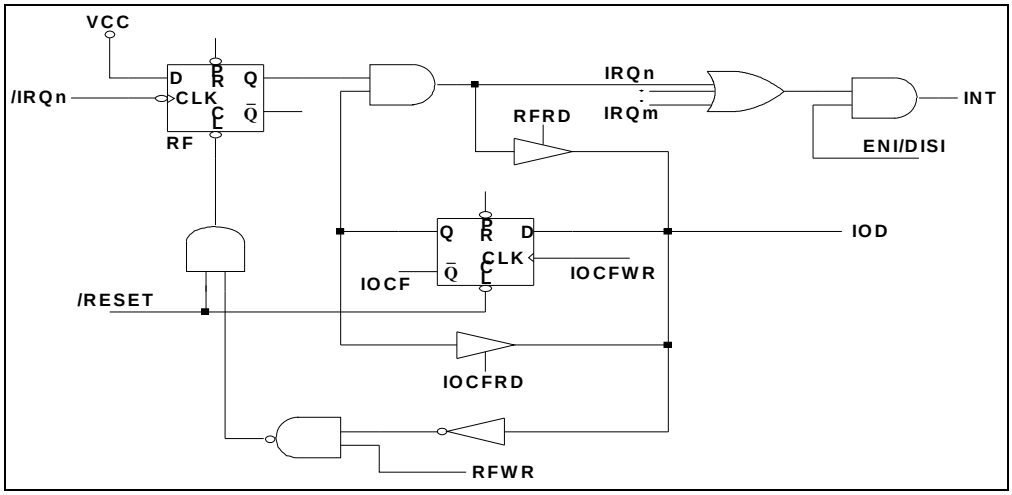


Figure 5-10 Interrupt Input Circuit

5.7 Oscillator

5.7.1 Oscillator Modes

The EM78P153K 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 ~ OSC0 in the Code Option register. Table 5-4 describes how these four oscillator modes are defined.

Table 5-4 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 1 MHz ~ 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, P64 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; OSCI and OSCO 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 5-5 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

5.7.2 Crystal Oscillator/Ceramic Resonators (Crystal)

The EM78P153K can be driven by an external clock signal through the OSCI pin as shown in the following figure.

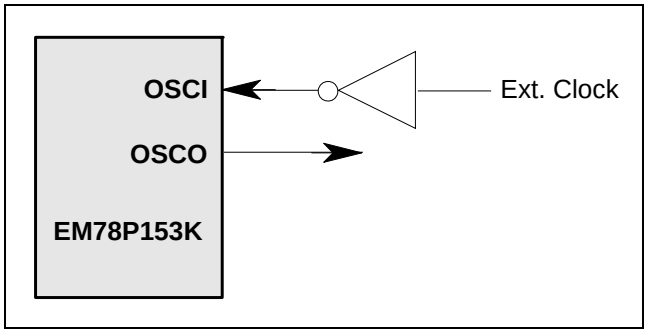


Figure 5-11 Circuit for External Clock Input

In most applications, pin OSCI and pin OSCO can be connected with a crystal or ceramic resonator to generate oscillation. Figure 5-12 depicts such a circuit. The same thing applies whether it is in the HXT mode or in the LXT mode.

In Figure 5-12-1, when the connected resonator in OSCI and OSCO is used in applications, the 1 MΩ R1 needs to be shunted with a resonator.

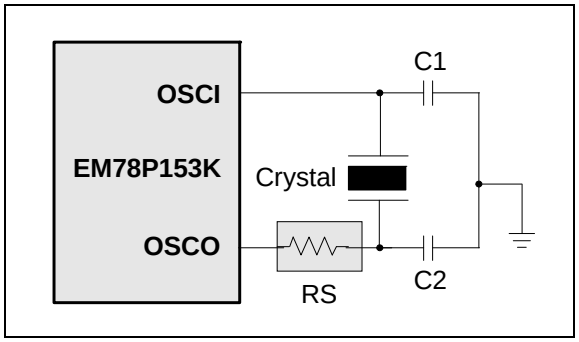


Figure 5-12 Circuit for Crystal/Resonator

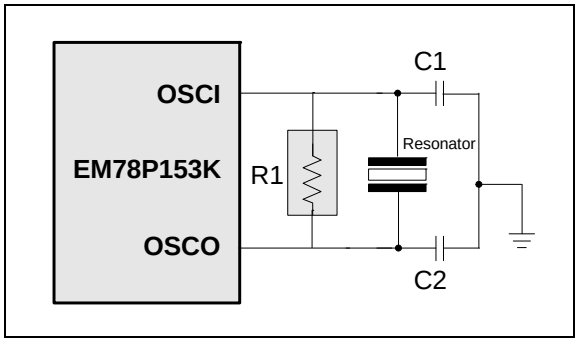


Figure 5-12-1 Circuit for Crystal/Resonator

Table 5-6 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. A serial resistor RS, may be necessary for AT strip cut crystal or low frequency mode.

Table 5-6 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
		12.0 MHz	30pF	30pF
	HXT1 (12 ~ 20 MHz)	12.0 MHz	30pF	30pF
		16.0 MHz	20pF	20pF
		20.0 MHz	15pF	15pF

5.7.3 External RC Oscillator Mode

For some applications that do not require a very precise timing calculation, the RC oscillator (Figure 5-13) 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 (Rext), the capacitor (Cext), 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 Cext should not be lesser than 20pF, and the value of Rext should not be greater than 1 MΩ. If they cannot be kept in this range, the frequency can be easily affected by noise, humidity, and leakage.

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

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 laid out, will affect the system frequency.

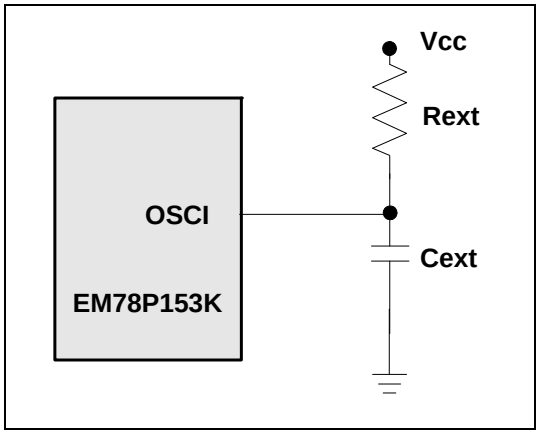


Figure 5-13 External RC Oscillator Mode Circuit

Table 5-7 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 ± 30%

5.7.4 Internal RC Oscillator Mode

EM78P153K 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. The table below describes the EM78P153K internal RC drift with variation of voltage, temperature, and process.

Table 5-8 Internal RC Drift Rate (Ta=25°C, VDD=5V, VSS=0V)

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

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

5.8 Code Option Register

The EM78P153K 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

5.8.1 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	Bit 2~0
Mnemonic	RESETEN	ENWDT	CLKS	LVR1	LVR0	–	WDTPS1	WDTPS0	ID10	ID9	Protect
1	Disable	Disable	4 clocks	High	High	–	High	High	High	High	Disable
0	Enable	Enable	2 clocks	Low	Low	–	Low	Low	Low	Low	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: Not used. Set to "1" at all time.

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

Table 5-9 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*

Bits 4 ~ 3: Bit 10 and 9 of Customer's ID code

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

Protect Bits	Protect
0	Enable
1	Disable (Default)

5.8.2 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	–	C4	C3	C2	C1	C0	RCM1	RCM0	OSC3	OSC2	OSC1	OSC0	–
1	–	High	High	High	High	High	High	High	High	High	High	High	–
0	–	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	–

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

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

Bits 6 ~ 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 1 MHz~100 kHz)	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 32.768 kHz)	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, P64 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; OSCI and OSCO are used as oscillator pins. These pins cannot and should not be defined as normal I/O pins.

Bit 0: Not used. Set to "1" at all time.

5.8.3 Code Option 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	ID12	ID11	–	–	ID8	ID7	ID6	ID5	ID4	ID3	ID2	ID1	ID0
1	High	High	–	–	High	High	High	High	High	High	High	High	High
0	Low	Low	–	–	Low	Low	Low	Low	Low	Low	Low	Low	Low

Bits 12 ~ 11: Bit 12 and Bit 11 of the Customer's ID code

Bits 10 ~ 9: Not used. Set to "1" at all time.

Bits 8 ~ 0: Bits 8 ~ 0 of the Customer's ID code

5.9 Power-on Considerations

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, Vdd must drop to below 1.8V and remains OFF for 10 μs before power can be switched ON again. This way, the EM78P153K will reset and operate normally. The extra external reset circuit will work well if Vdd can rise at a 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.

5.10 Programmable Oscillator Set-up Time

The Option word contains SUT0 and SUT1 which can be used to define the oscillator set-up time. Theoretically, the range is from 4.5 ms to 72 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 Set-up Time.

5.11 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 Vdd to reach minimum operation voltage. This circuit is used when the power supply has a slow rise time.

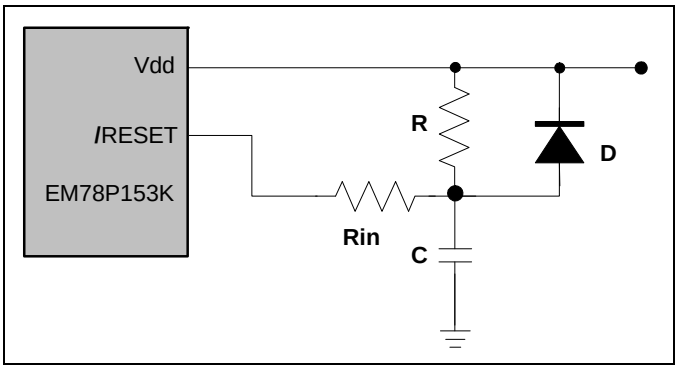


Figure 5-14 External Power-up Reset Circuit

Since the current leakage from the /RESET pin is ± 5 μA, 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. The current-limited resistor, Rin, will prevent high current or ESD (electrostatic discharge) from flowing to pin /RESET.

5.12 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 EM78P153K.

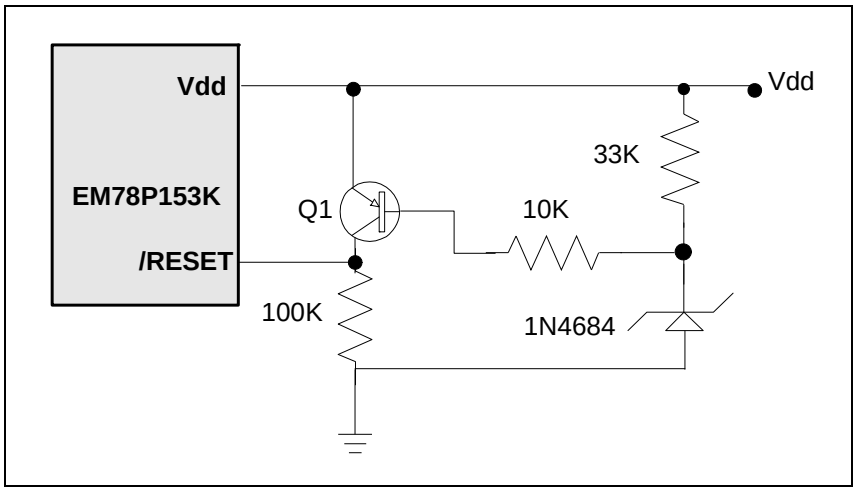


Figure 5-15 Residue Voltage Protection Circuit 1

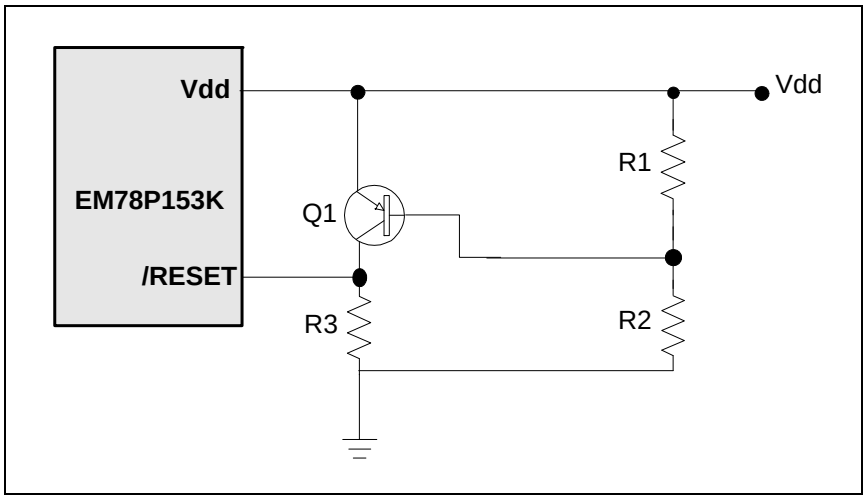


Figure 5-16 Residue Voltage Protection Circuit 2

Note

Figure 5-15 and Figure 5-16 should be designed to ensure that the voltage of the /RESET pin is larger than VIH (min).

5.13 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",). In this case, the execution takes two instruction cycles.

If for some reasons, the specification of the instruction cycle is not suitable for certain applications, try to modify 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 two instruction cycles. The instructions that are written to the program counter also take two instruction cycles.

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=Fosc/4, instead of Fosc/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 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.*

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*

Mnemonic	Operation	Status Affected
NOP	No Operation	None
DAA	Decimal Adjust A	C
CONTW	A → CONT	None
SLEP	0 → WDT, Stop oscillator	T, P
WDTC	0 → WDT	T, P

(Continuation)

Mnemonic	Operation	Status Affected
IOW R	A → IOCR	None [1]
ENI	Enable Interrupt	None
DISI	Disable Interrupt	None
RET	[Top of Stack] → PC	None
RETI	[Top of Stack] → PC, Enable Interrupt	None
CONTR	CONT → A	None
IOR R	IOCR → A	None [1]
MOV R, A	A → R	None
CLRA	0 → A	Z
CLR R	0 → R	Z
SUB A, R	R - A → A	Z, C, DC
SUB R, A	R - A → R	Z, C, DC
DECA R	R - 1 → A	Z
DEC R	R - 1 → R	Z
OR A, R	A ∨ R → A	Z
OR R, A	A ∨ R → R	Z
AND A, R	A & R → A	Z
AND R, A	A & R → R	Z
XOR A, R	A ⊕ R → A	Z
XOR R, A	A ⊕ R → R	Z
ADD A, R	A + R → A	Z, C, DC
ADD R, A	A + R → R	Z, C, DC
MOV A, R	R → A	Z
MOV R, R	R → R	Z
COMA R	/R → A	Z
COM R	/R → R	Z
INCA R	R + 1 → A	Z
INC R	R + 1 → R	Z
DJZA R	R - 1 → A, skip if zero	None
DJZ R	R - 1 → R, skip if zero	None

Note: *[1] This instruction is applicable to IOC5~IOC6, IOCB ~ IOCF only.*

(Continuation)

Mnemonic	Operation	Status Affected
RRCA R	R(n) → A(n - 1), R(0) → C, C → A(7)	C
RRC R	R(n) → R(n - 1), R(0) → C, C → R(7)	C
RLCA R	R(n) → A(n + 1), R(7) → C, C → A(0)	C
RLC R	R(n) → R(n + 1), R(7) → C, C → R(0)	C
SWAPA R	R(0 - 3) → A(4 - 7), R(4 - 7) → A(0 - 3)	None
SWAPR	R(0 - 3) ↔ R(4 - 7)	None
JZA R	R + 1 → A, skip if zero	None
JZ R	R + 1 → R, skip if zero	None
BC R, b	0 → R(b)	None [2]
BS R, b	1 → R(b)	None [3]
JBC R, b	if R(b) = 0, skip	None
JBS R, b	if R(b) = 1, skip	None
CALL k	PC + 1 → [SP], (Page, k) → PC	None
JMP k	(Page, k) → PC	None
MOV A, k	k → A	None
OR A, k	A ∨ k → A	Z
AND A, k	A & k → A	Z
XOR A, k	A ⊕ k → A	Z
RETL k	k → A, [Top of Stack] → PC	None
SUB A, k	K - A → A	Z, C,DC
INT	PC + 1 → [SP], 001H → PC	None
ADD A, k	K + A → A	Z, C, DC

Note: *[2]This instruction is not recommended for RF operation.*

[3]This instruction cannot operate under RF.

6 Absolute Maximum Ratings

Items	Rating		
Temperature under bias	-40°C	to	85°C
Storage temperature	-65°C	to	150°C
Input voltage	Vss-0.3V	to	Vdd+0.5V
Output voltage	Vss-0.3V	to	Vdd+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.*

7 Electrical Characteristics

7.1 DC Characteristics

Ta=25°C, VDD=5V, VSS=0V

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
FXT	Crystal: VDD to 2.3V	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	VIN = VDD, VSS	–	–	±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
VIHX1	Clock Input High Voltage (VDD=5V)	OSCI	2.5	–	Vdd+0.3	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

(Continuation)

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
IOH1	High Drive Current (Ports 5 and 6)	VOH = 2.4V	-8.5	-12	-	mA
IOL1	Low Sink Current (Ports 5 & 6)	VOL = 0.4V	11.5	16	-	mA
IOL2	Low Sink Current (P64, P65)	VOL = 0.4V	11.5	16	-	mA
IOL3	Low Sink Current (P63)	VOL = 0.4V	17.5	25	-	mA
IPH	Pull-high current	Pull-high active, input pin at VSS	–60	–75	–90	μA
IPL	Pull-low current	Pull-down active, input pin at VDD	20	35	50	μA
ICC1	Operating supply current at two clocks (VDD=3V)	/RESET= 'High', Fosc=32kHz (Crystal type, CLKS="0"), Output pin floating, WDT disabled	-	15	30	μA
ICC2	Operating supply current at two clocks (VDD=3V)	/RESET= 'High', Fosc=32kHz (Crystal type, CLKS="0"), Output pin floating, WDT enabled	-	19	35	μA
ICC3	Operating supply current at two clocks (VDD=5.0V)	/RESET= 'High', Fosc=4 MHz (Crystal type, CLKS="0"), Output pin floating	-	-	2.0	mA
ICC4	Operating supply current at two clocks (VDD=5.0V)	/RESET= 'High', Fosc=10 MHz (Crystal type, CLKS="0"), Output pin floating	-	-	4.0	mA
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

Note: **These parameters are theoretical values and have not been tested.*

■ **Internal RC Electrical Characteristics (T_A = 25°C, V_{DD} = 5 V, V_{SS} = 0V)**

Internal RC Selected Band	Drift Rate				
	Temperature	Operating 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	0.98 MHz	1 MHz	1.02 MHz

■ **Internal RC Electrical Characteristics (Process, Voltage and Temperature Deviation)**

Internal RC Selected Band	Drift Rate (Process & Operating Voltage and Temperature Variation)				
	Temperature	Operating 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	16 MHz	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	1 MHz	1.06 MHz

7.2 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	TXAL, SUT1, SUT0=1, 1	17.6-30%	17.6	17.6+30%	ms
Trst	/RESET pulse width	-	2000	-	-	ns
*Twdt1	Watchdog timer period	SUT1, SUT0=1,1	17.6~30%	17.6	17.6+30%	ms
*Twdt2	Watchdog timer period	SUT1, SUT0=1,0	4.5+30%	4.5	4.5+30%	ms
*Twdt3	Watchdog timer period	SUT1, SUT0=0,1	288~30%	288	288+30%	ms
*Twdt4	Watchdog timer period	SUT1, SUT0=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 Option Code (Bit 6, Bit 5)

**N = selected prescaler ratio*

**Twdt1: The Option word (SUT1, SUT0) is used to define the oscillator set-up time. In Crystal mode the WDT time-out length is the same as the set-up time (18 ms).*

**Twdt2: The Option word (SUT1, SUT0) is used to define the oscillator set-up time. In Crystal mode the WDT time-out length is the same as the set-up time (4.5 ms).*

**Twdt3: The Option word (SUT1, SUT0) is used to define the oscillator set-up time. In Crystal mode the WDT time-out length is the same as the set-up time (288 ms).*

**Twdt4: The Option word (SUT1, SUT0) is used to define the oscillator set-up time. In Crystal mode the WDT time-out length is the same as the set-up time (72 ms).*

7.3 Device Characteristics

The graphs provided in the following pages were derived based on a limited number of samples and are shown here for reference only. The device characteristics illustrated herein are not guaranteed for its accuracy. In some graphs, the data may be out of the specified warranted operating range.

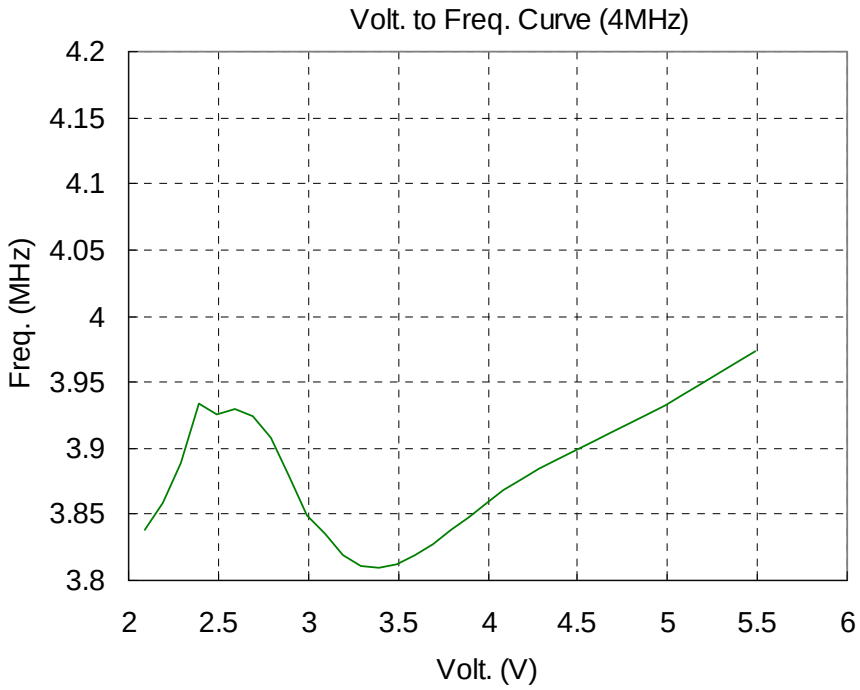


Figure 8-1 IRC Deviation (4MHz)

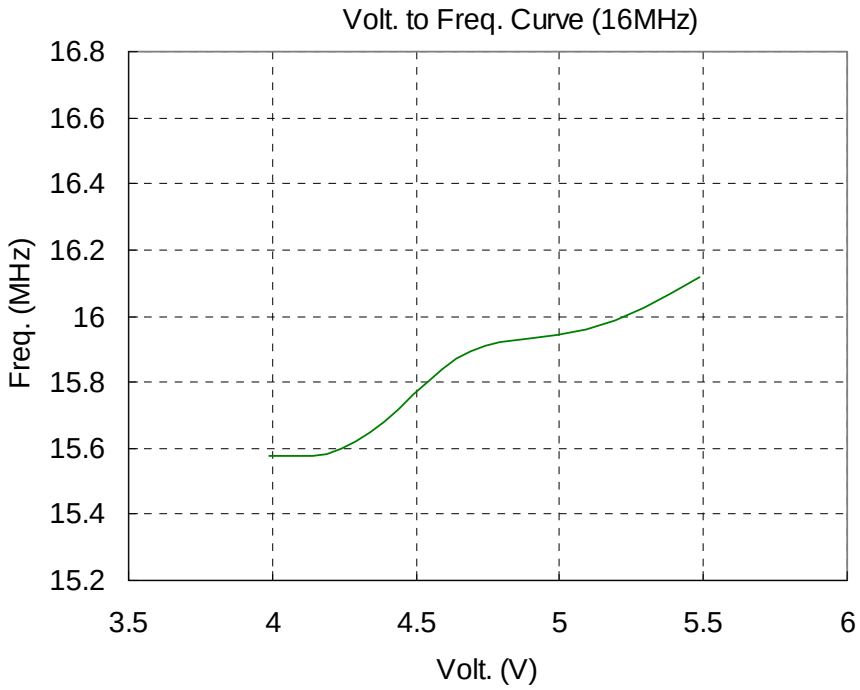


Figure 8-2 IRC Deviation (16 MHz)

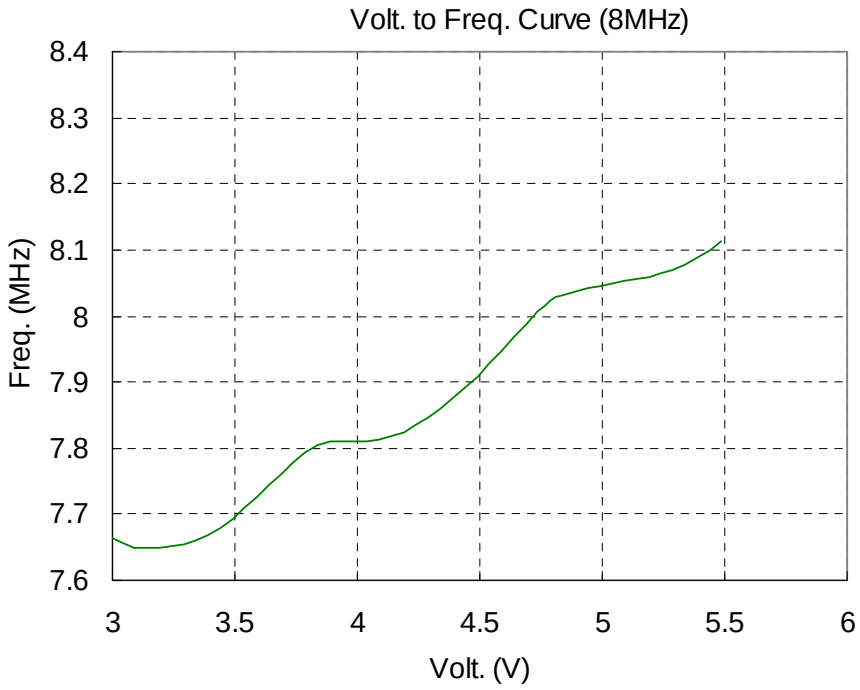


Figure 8-3 IRC Deviation (8 MHz)

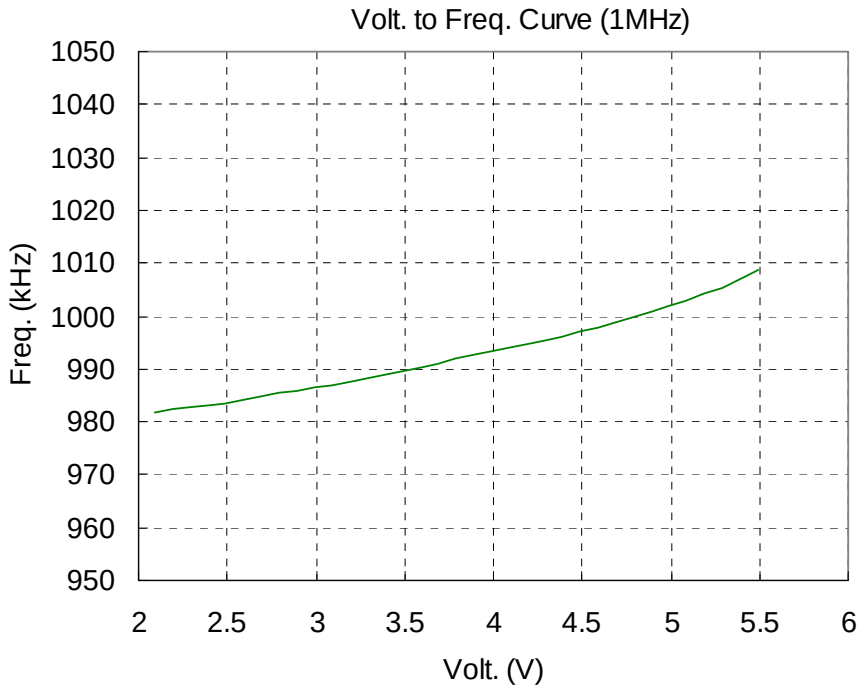


Figure 8-4 IRC Deviation (1 MHz)

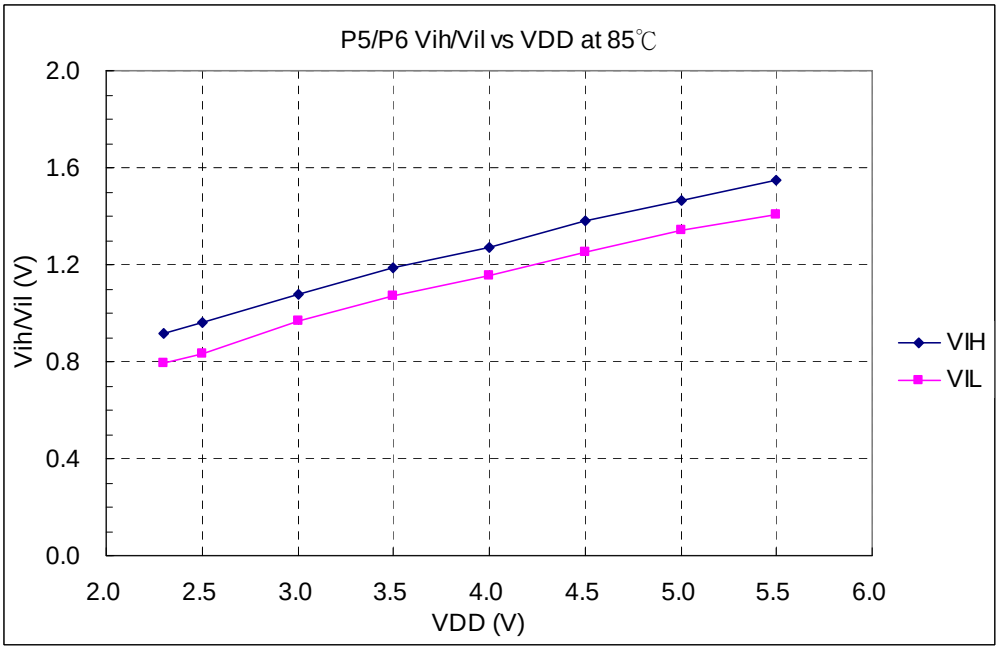


Figure 8-5 VIH/VIL vs. VDD (85°C)

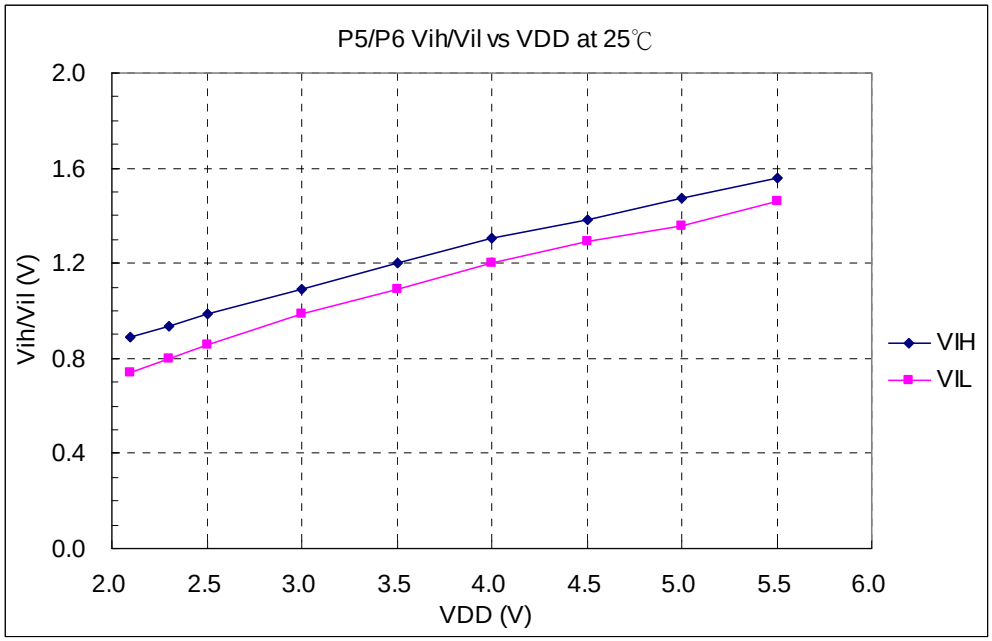


Figure 8-6 VIH/VIL vs. VDD (25°C)

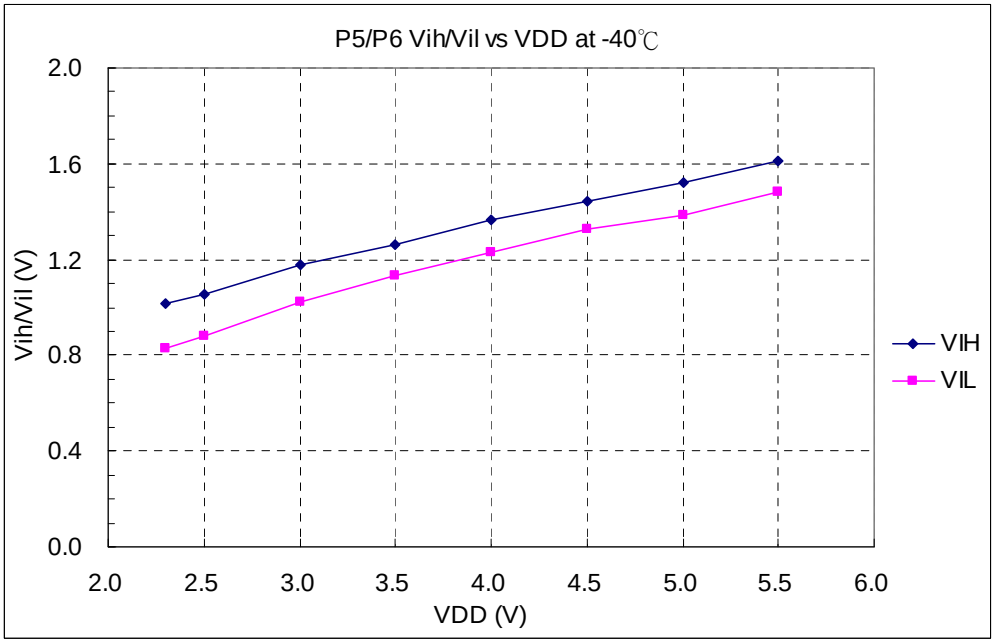


Figure 8-7 VIH/VIL vs. VDD (-40°C)

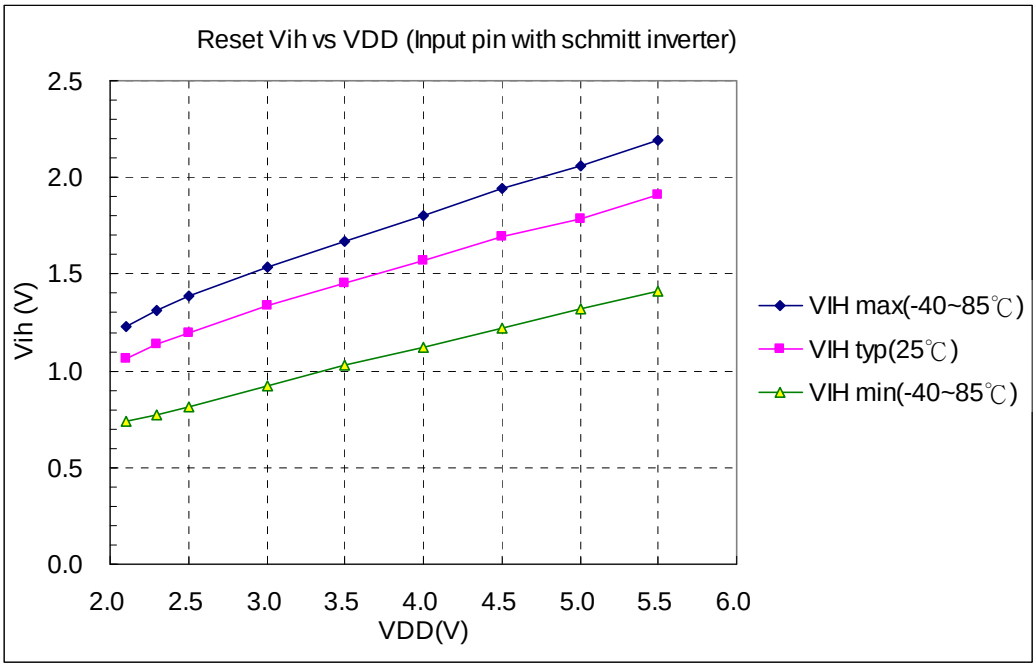


Figure 8-8 VIH of RESET Pin vs. VDD

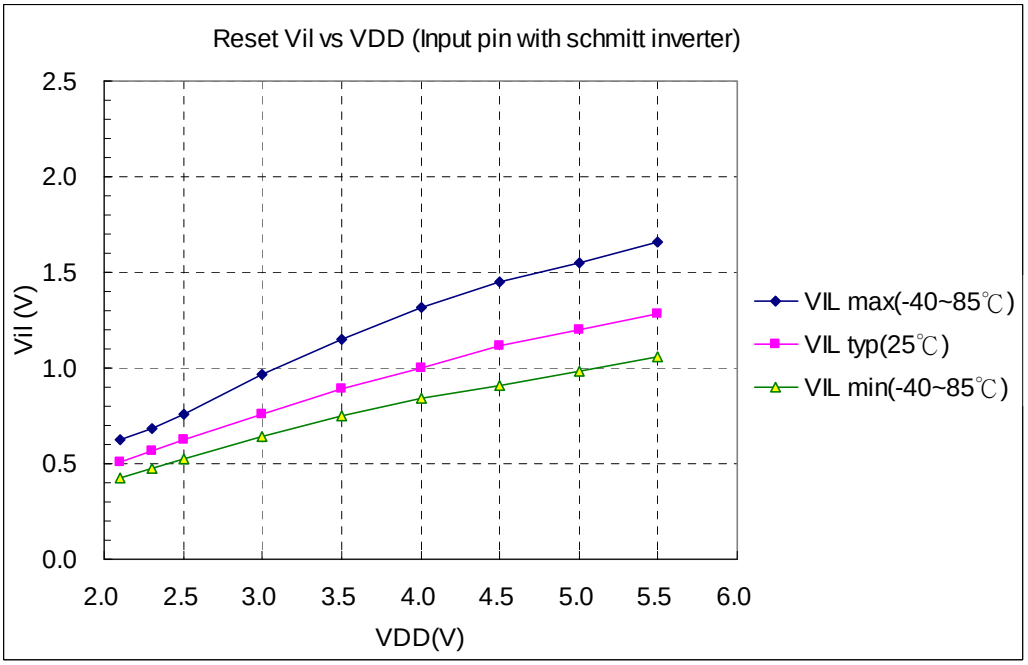


Figure 8-9 VIL of RESET Pin vs. VDD

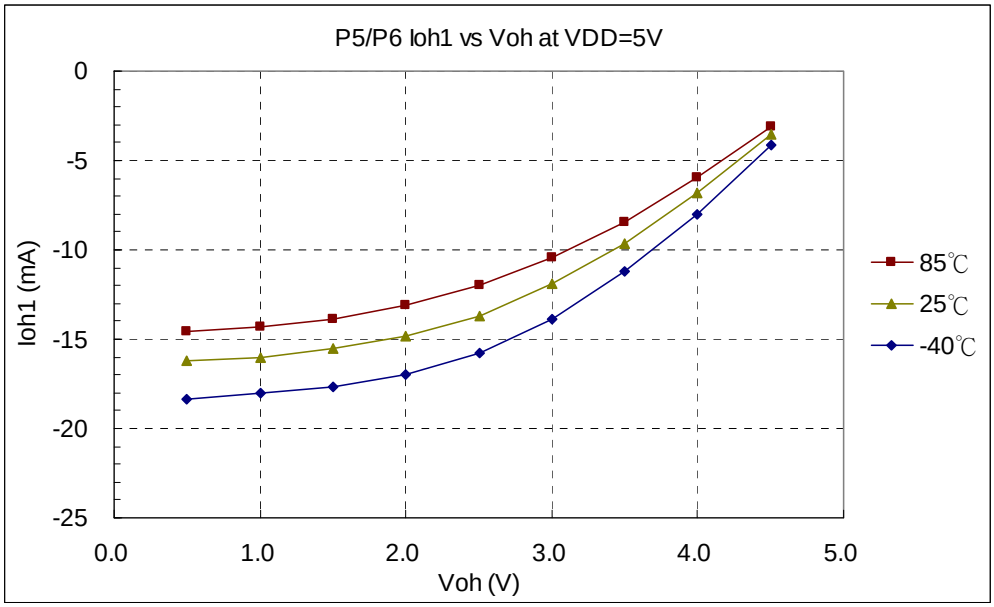


Figure 8-10 VOH vs. IOH, VDD=5V

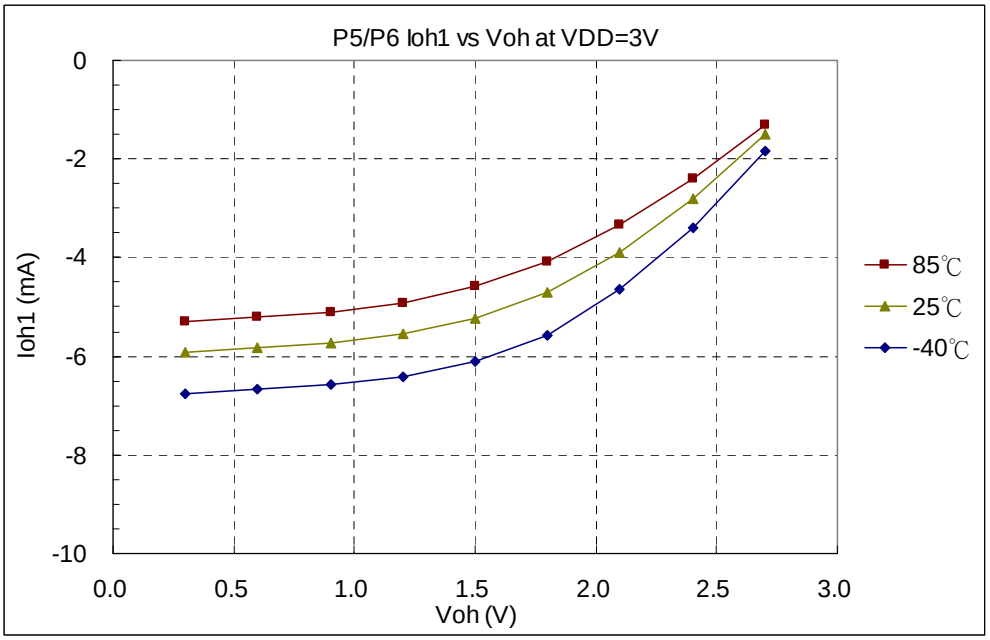


Figure 8-11 VOH vs. IOH, VDD=3V

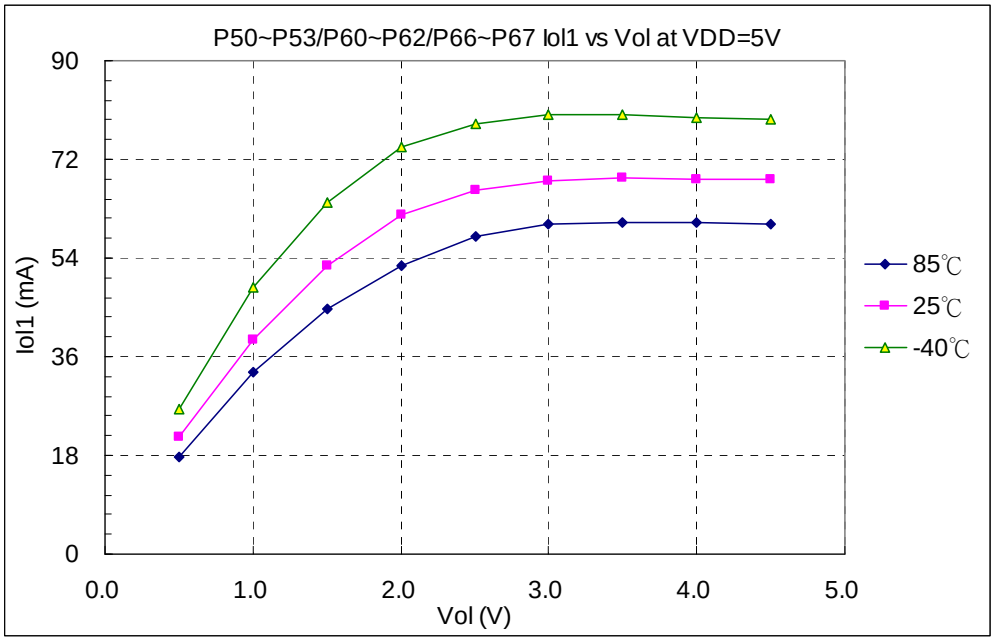


Figure 8-12 VOL vs. IOL, VDD=5V (Except P63~P65)

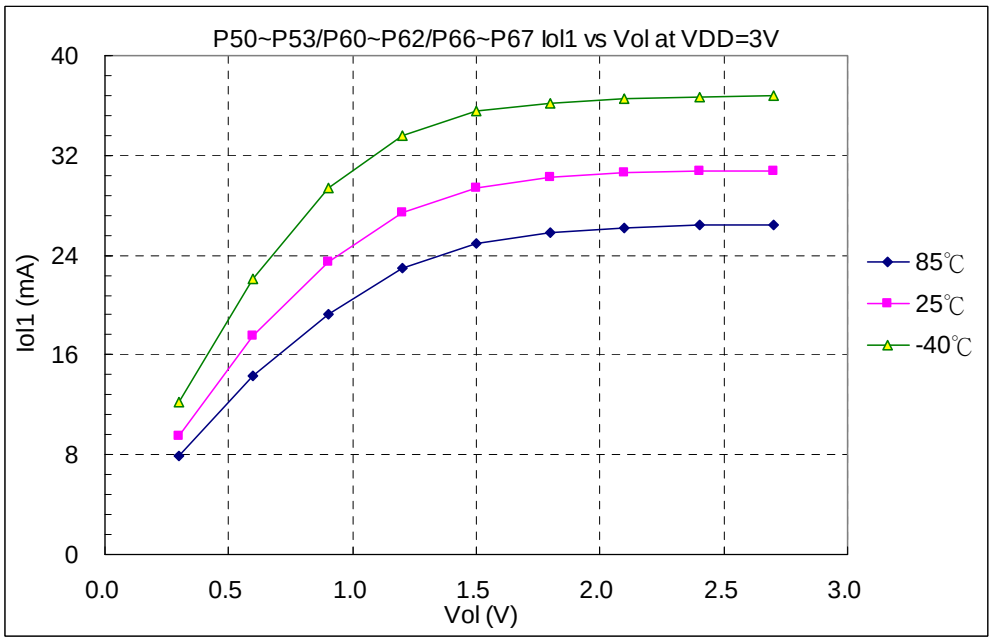


Figure 8-13 VOL vs. IOL, VDD=3V (Except P63~P65)

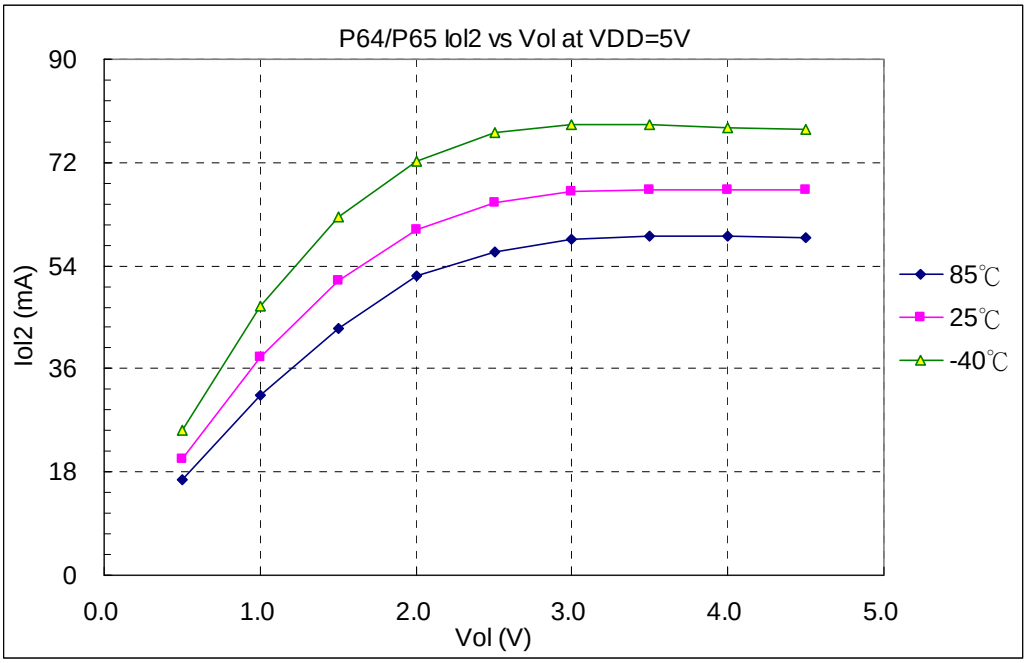


Figure 8-14 VOL of P64, P65 vs. IOL, VDD=5V

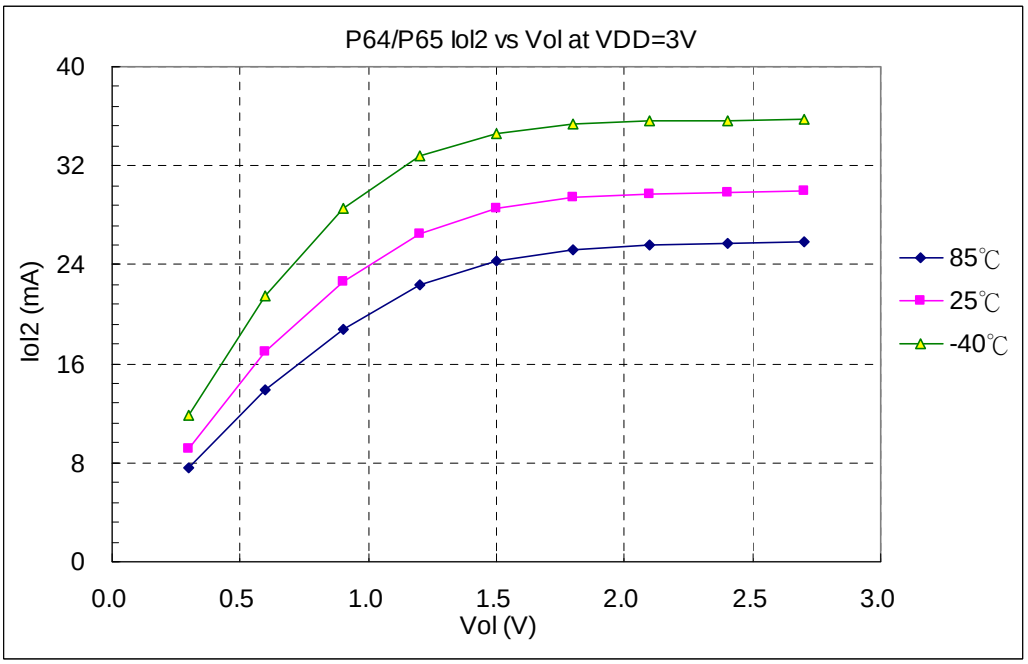


Figure 8-15 VOL of P64, P65 vs. IOL, VDD=3V

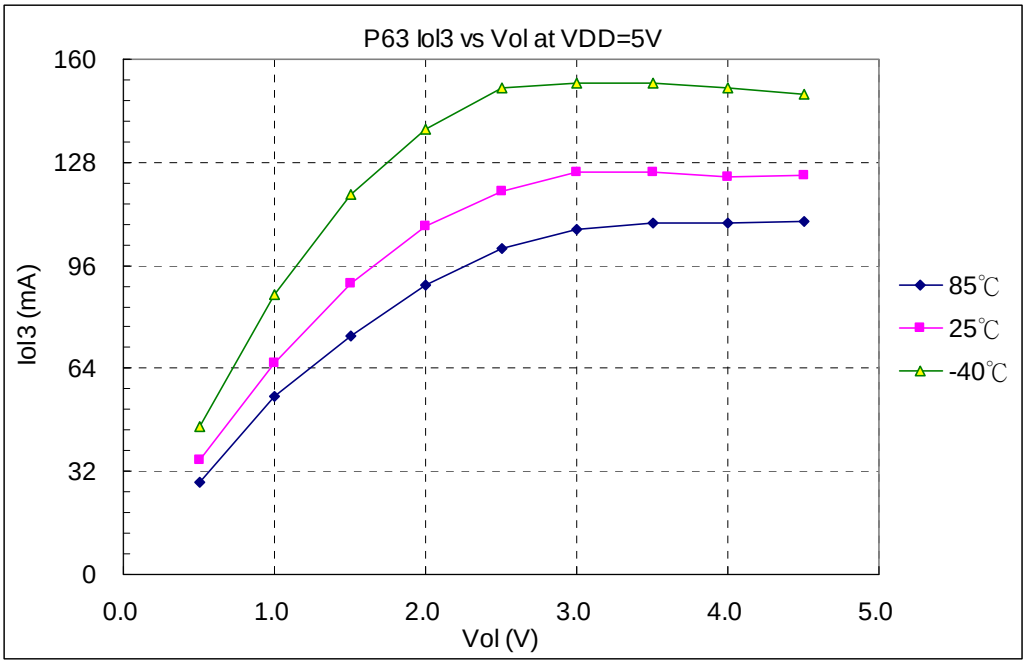


Figure 8-16 VOL of P63 vs. IOL, VDD=5V

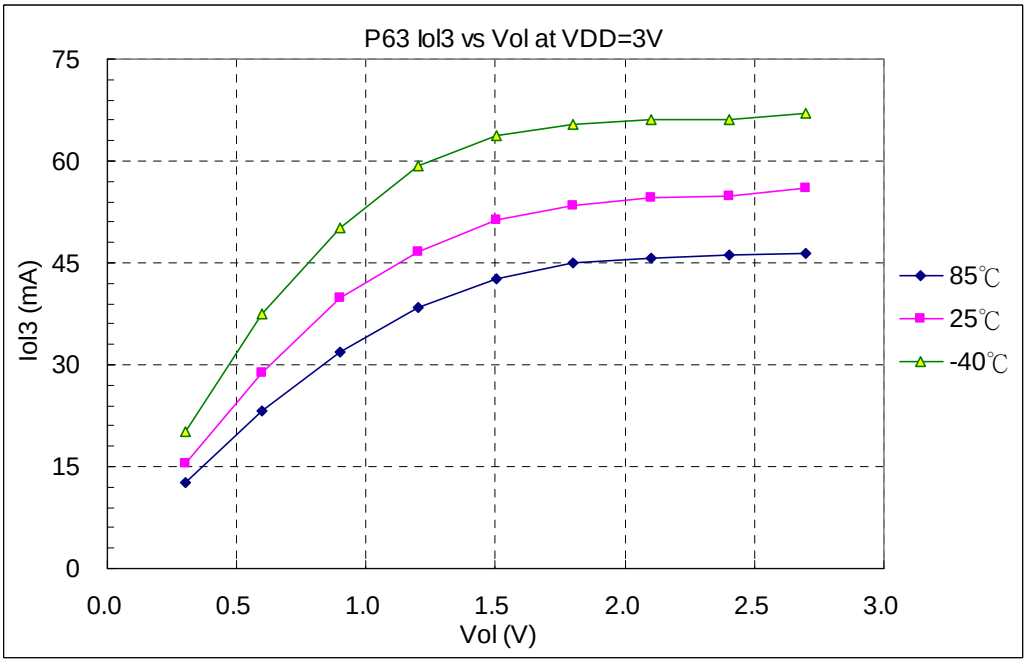


Figure 8-17 VOL of P63 vs. IOL, VDD=3V

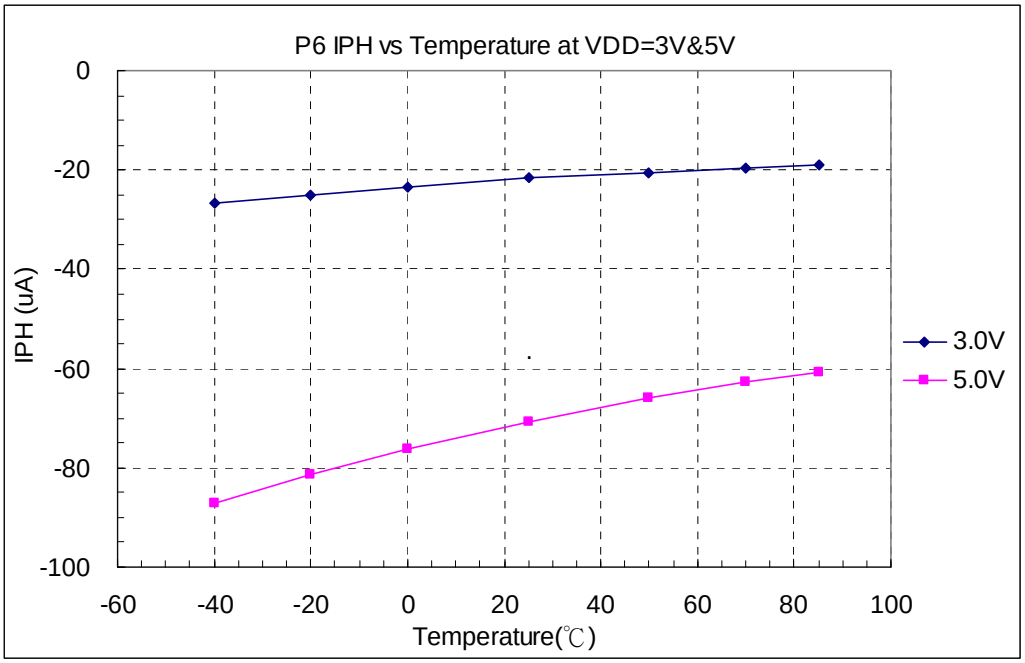


Figure 8-18 IPH of Port 6 vs. Temperature, VDD=3V & 5V

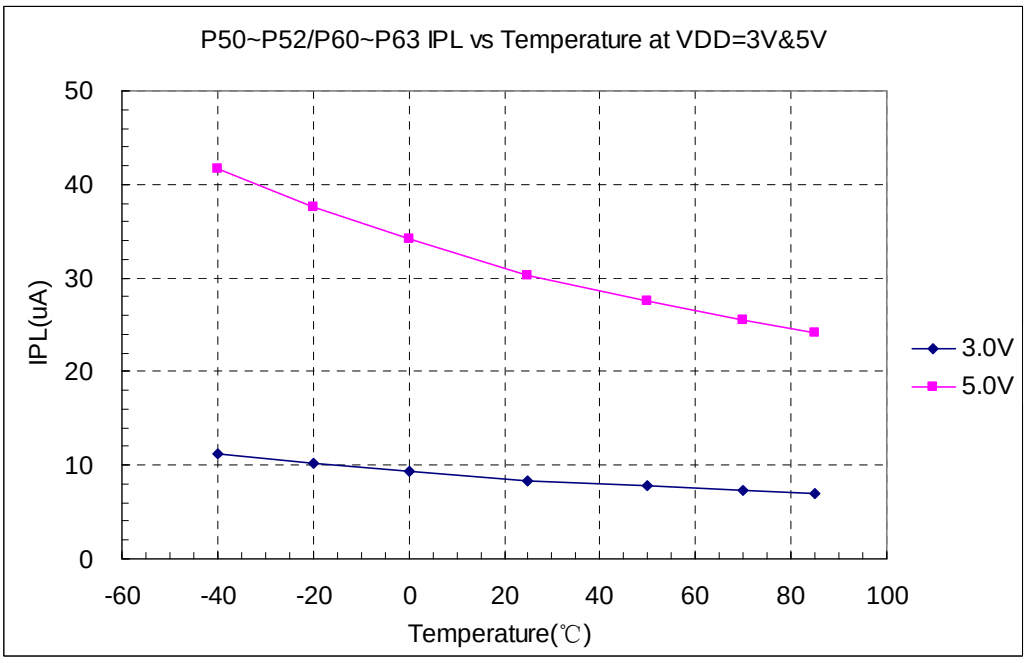


Figure 8-19 IPL of Ports 5 & 6 vs. Temperature, VDD=3V & 5V

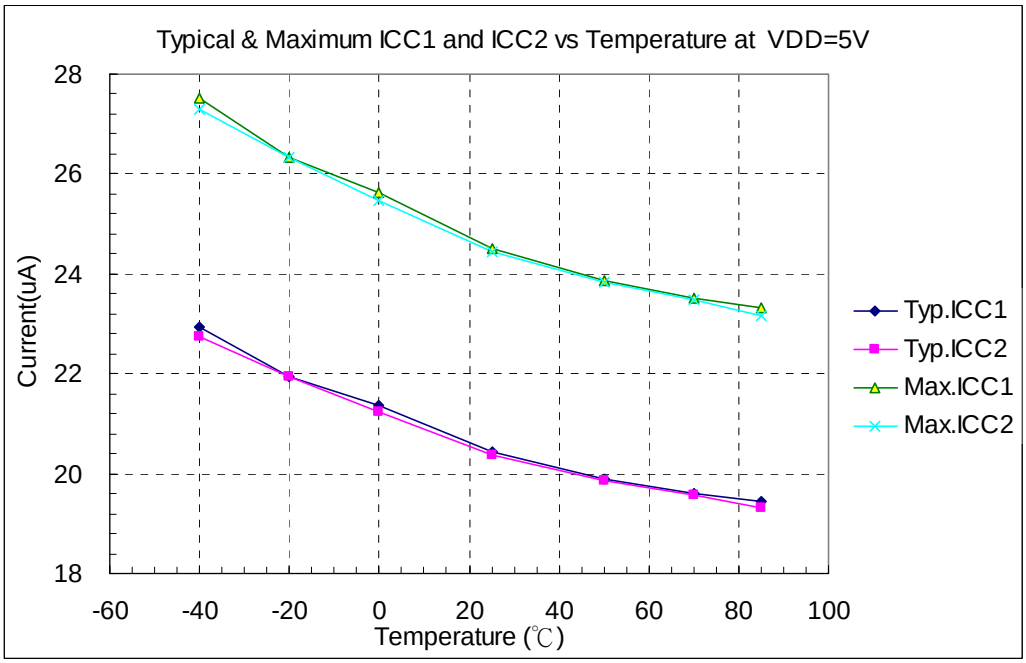


Figure 8-20 ICC1 and ICC2 vs. Temperature, VDD=5V

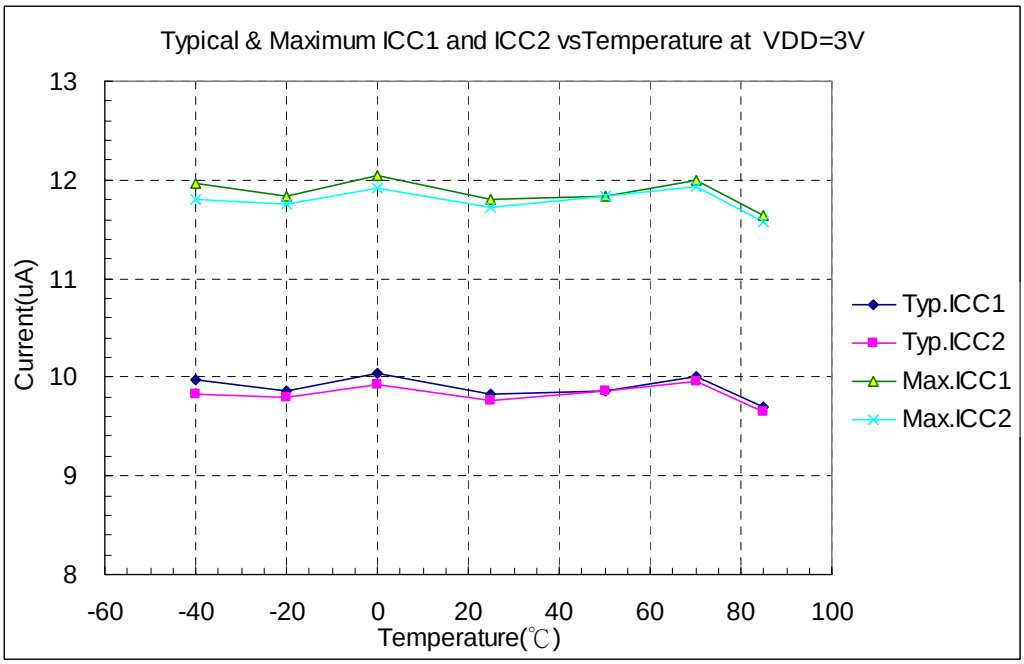


Figure 8-21 ICC1 and ICC2 vs. Temperature, VDD=3V

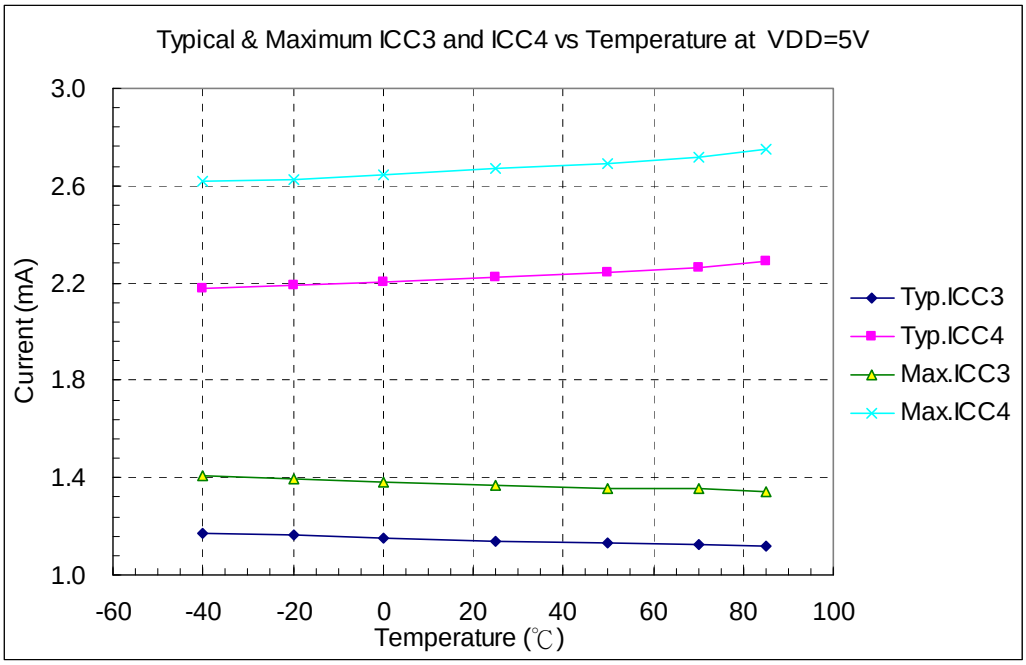


Figure 8-22 ICC3 and ICC4 vs. Temperature, VDD=5V

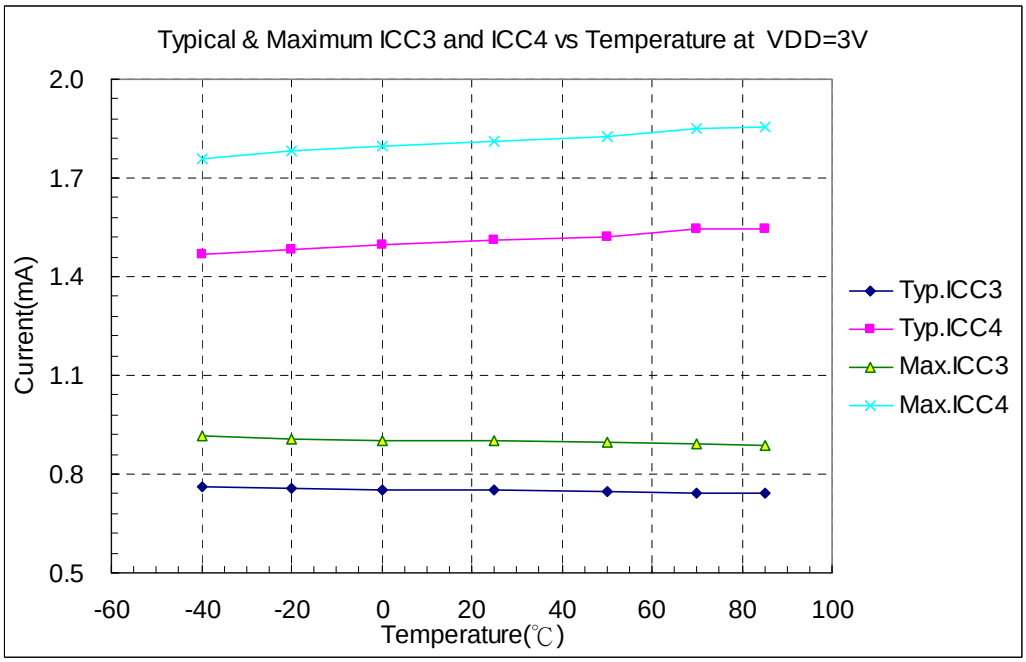


Figure 8-23 ICC3 and ICC4 vs. Temperature, VDD=3V

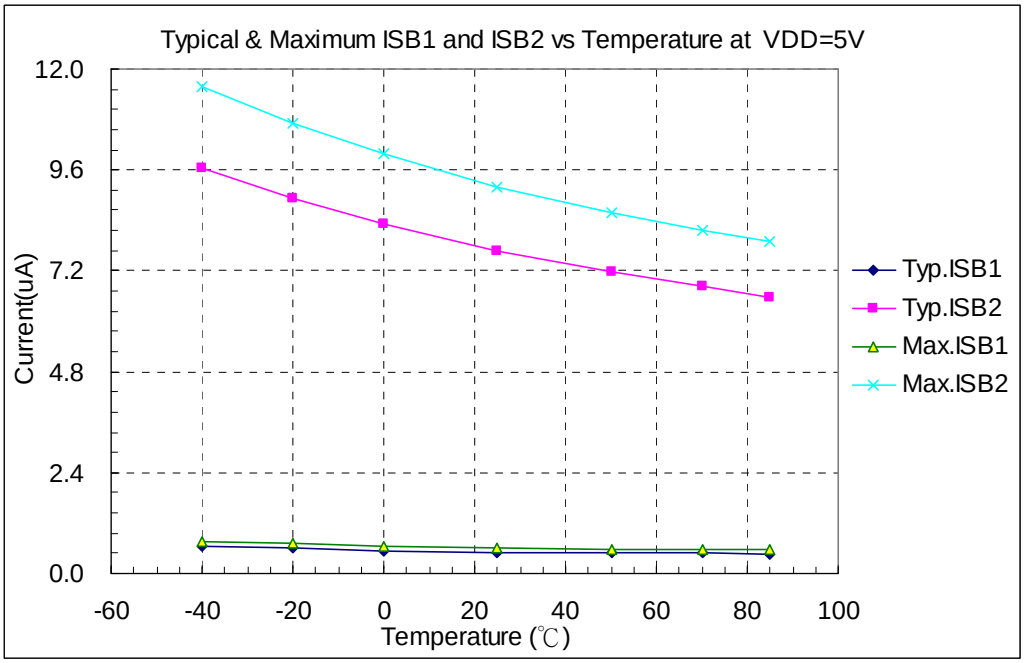


Figure 8-24 ISB1 and ISB2 vs. Temperature, VDD=5V

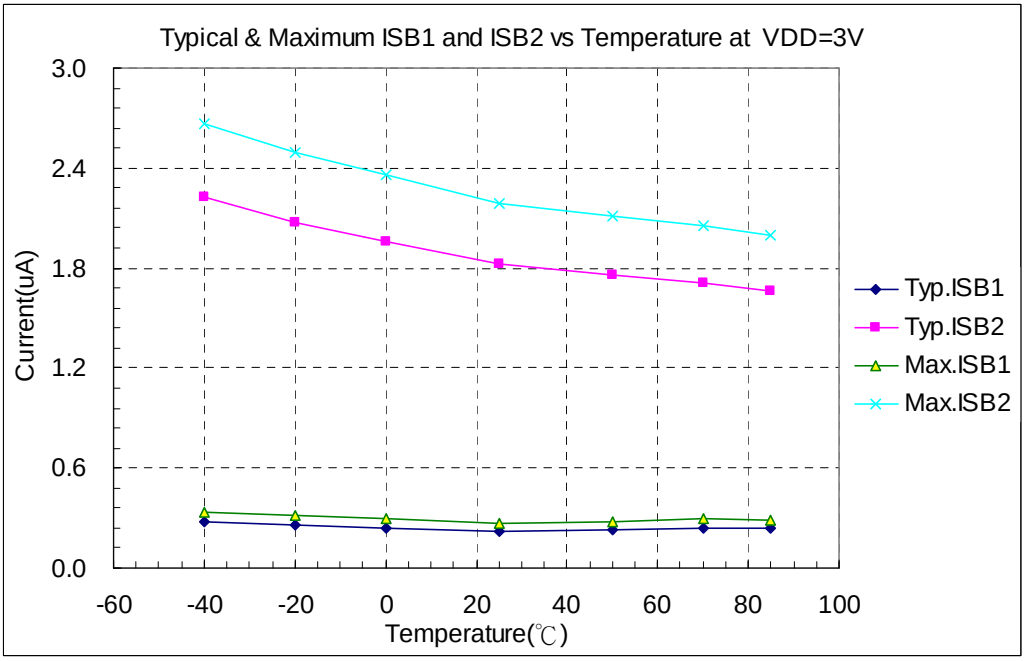


Figure 8-25 ISB1 and ISB2 vs. Temperature, VDD=3V

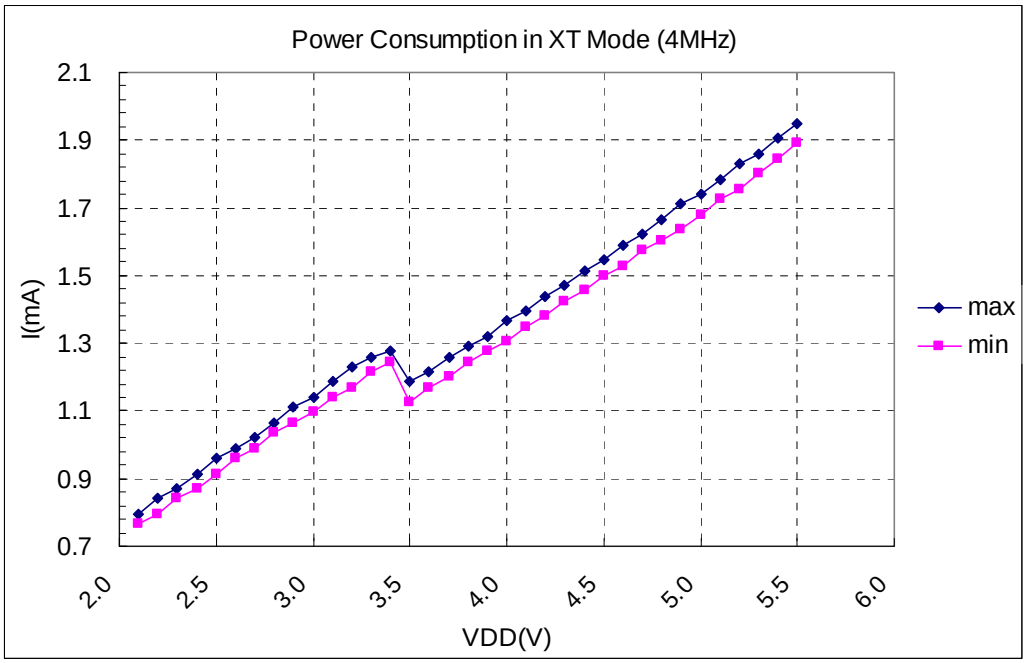


Figure 8-26 Power Consumption in HXT Mode (4MHz)

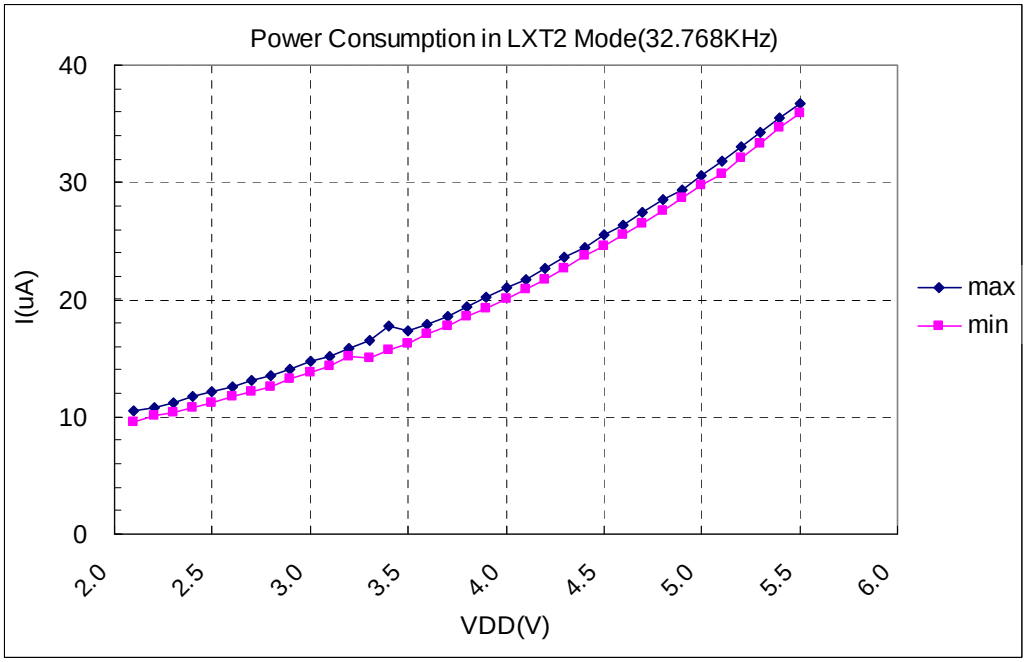


Figure 8-27 Power Consumption in LXT Mode (32765Hz)

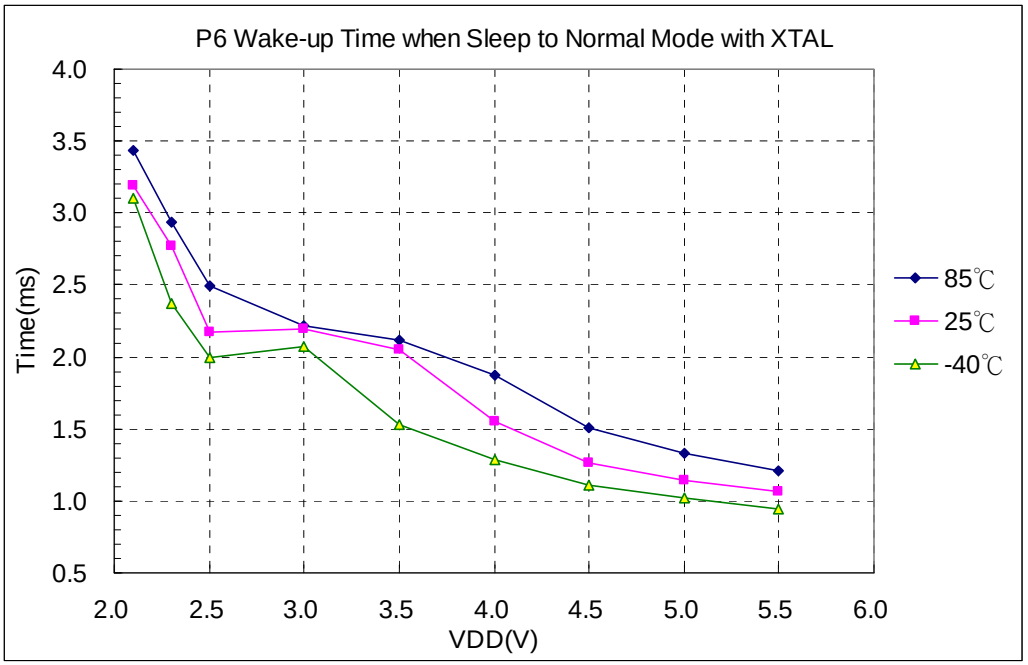


Figure 8-28 P6 Wake-up Time when Sleep to Normal, Crystal mode (Sub. Freq.=16kHz, 4 MHz)

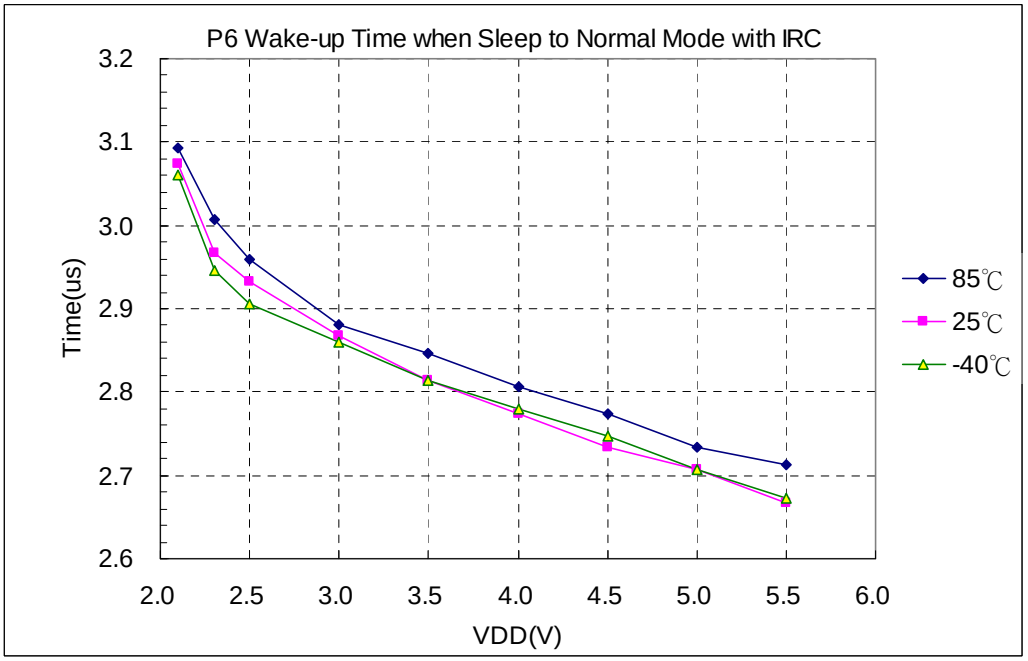


Figure 8-29 P6 Wake-up Time when Sleep to Normal, IRC mode (Sub. Freq.=16kHz, 4 MHz)

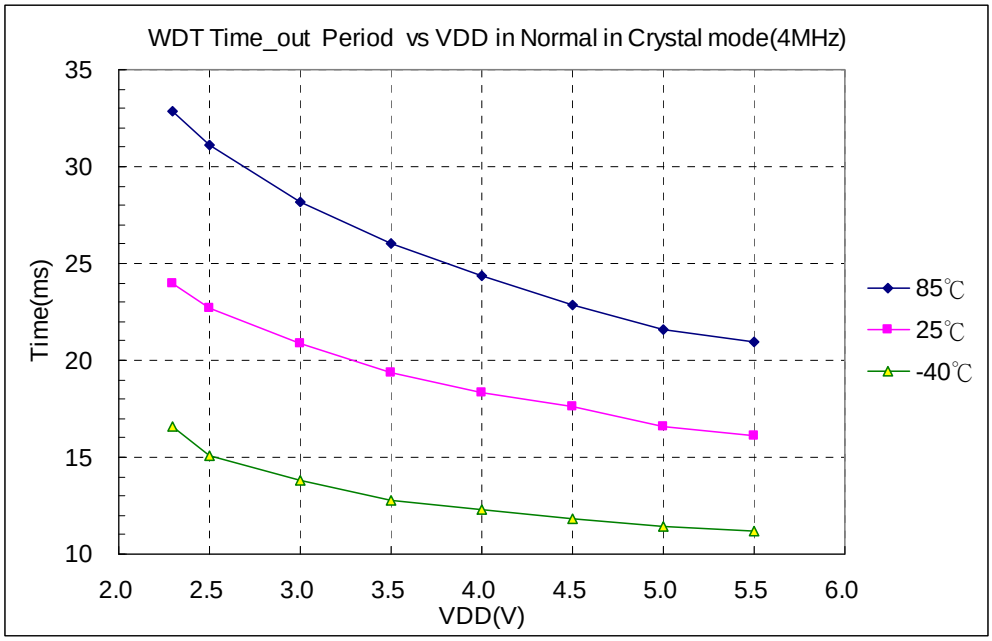


Figure 8-30 WDT Timer Time Out in Normal, Crystal Mode (Sub. Freq.=16kHz, 4 MHz)

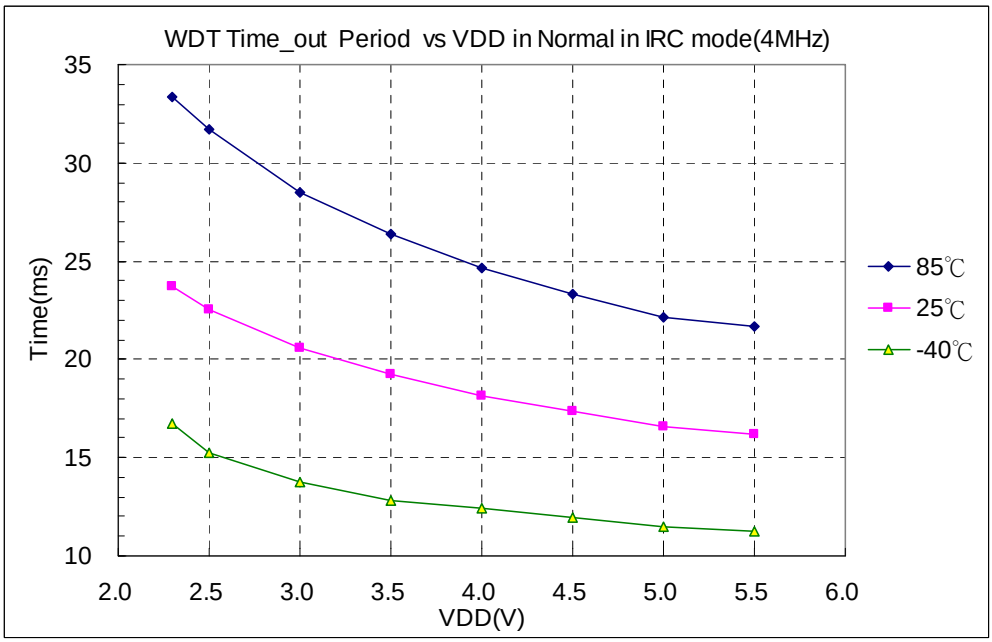


Figure 8-31 WDT Timer Time-out in Normal, IRC Mode (Sub. Freq.=16kHz, 4 MHz)

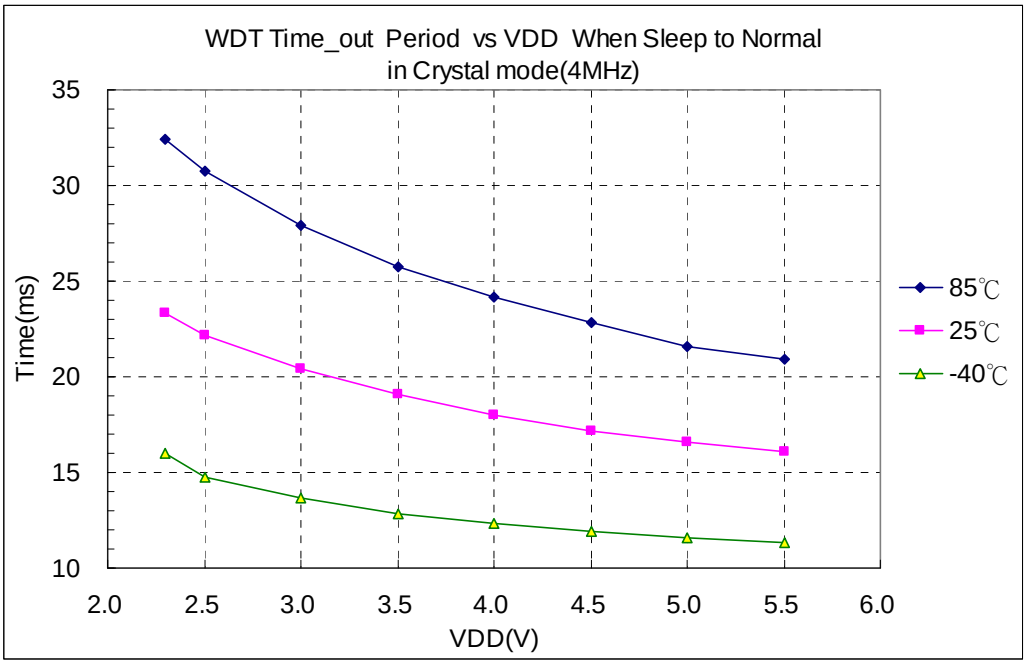


Figure 8-32 WDT Timer Time Out when Sleep to Normal, Crystal Mode (4MHz)

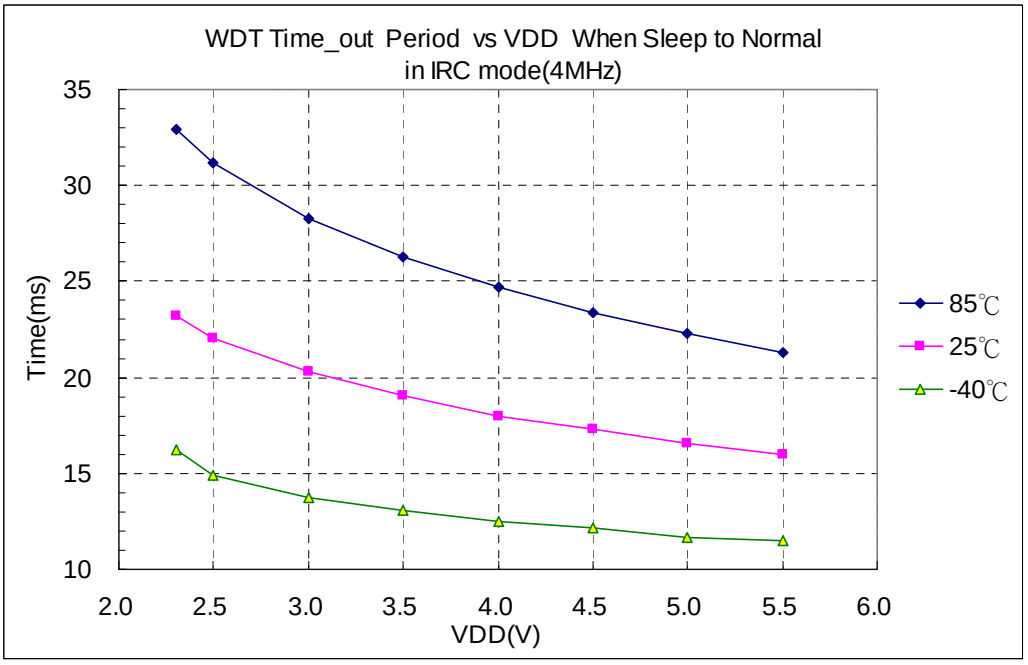


Figure 8-33 WDT Timer Time Out when Sleep to Normal, IRC Mode (4MHz)

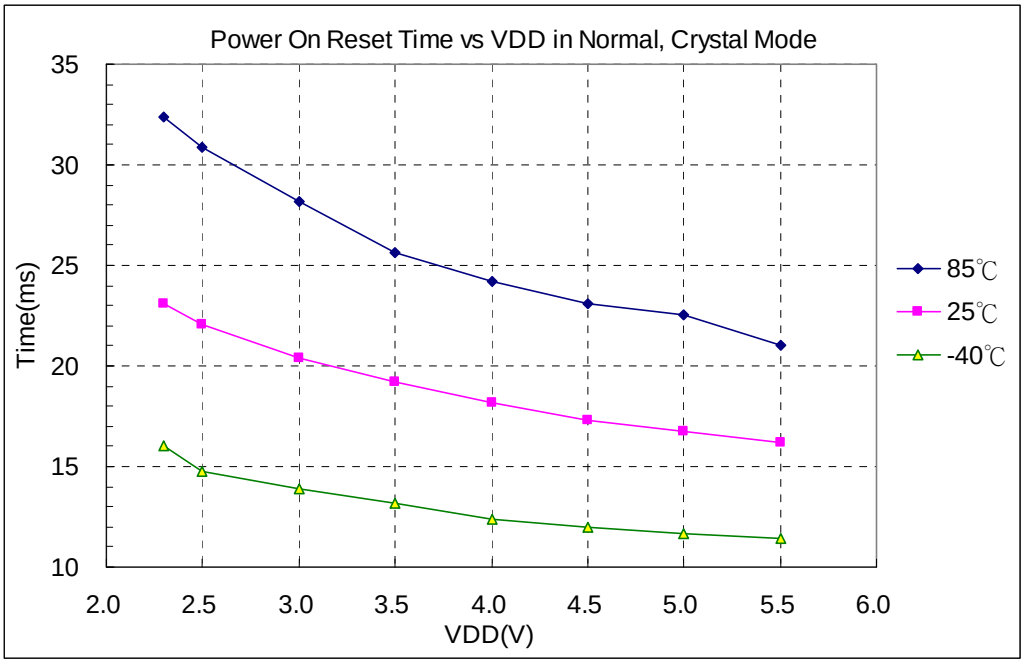


Figure 8-34 Power on Reset Time in Normal, Crystal Mode (Sub. Freq.=16kHz, 4 MHz)

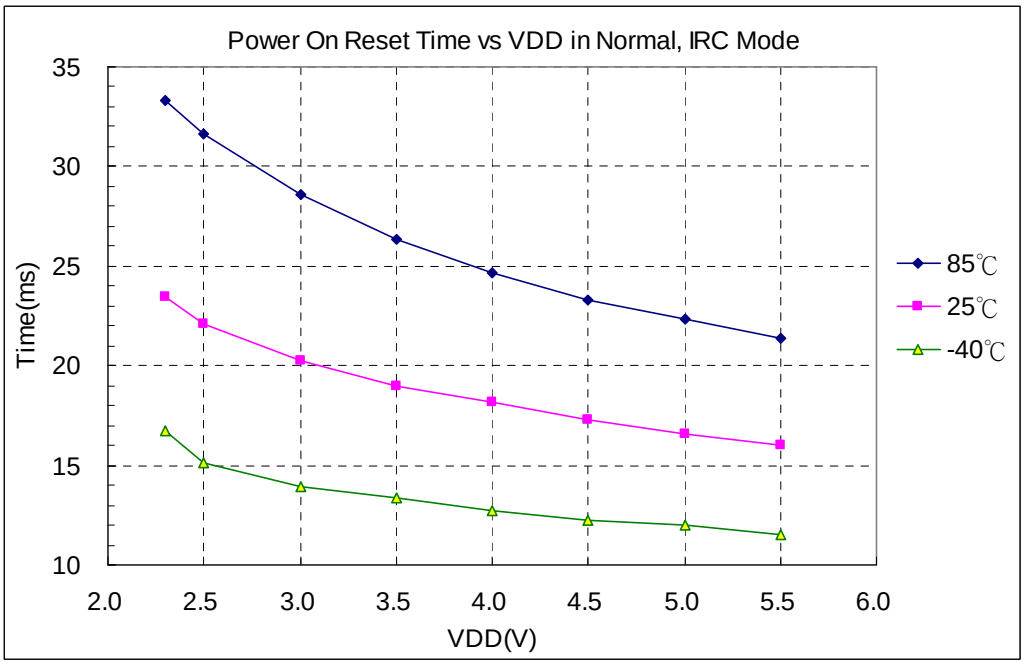


Figure 8-35 Power on Reset Time in Normal, IRC Mode (Sub. Freq.=16kHz, 4 MHz)

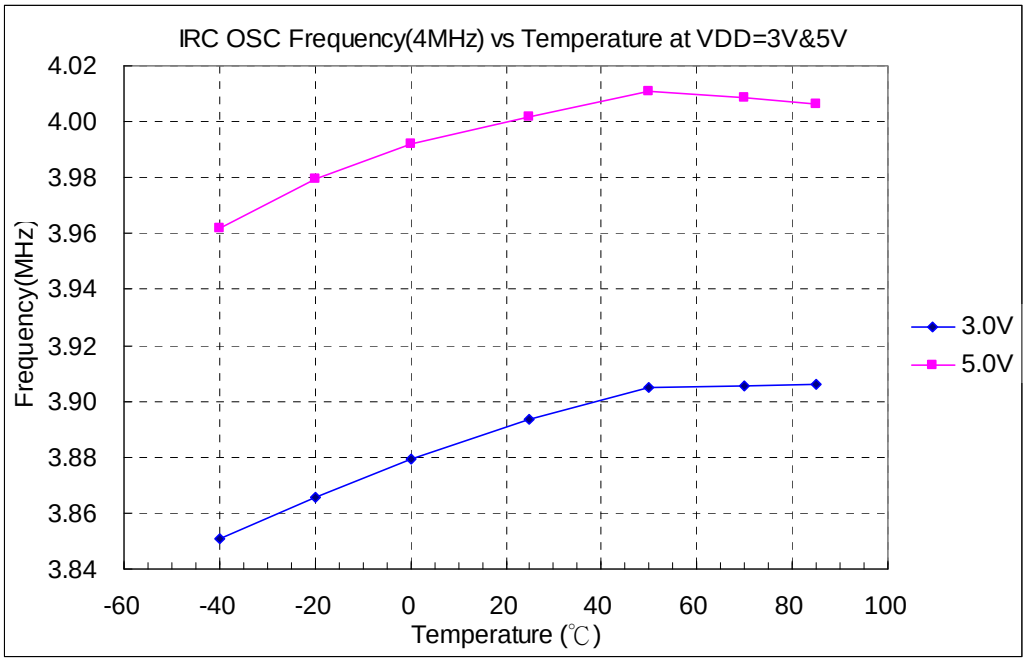


Figure 8-36 IRC OSC Freq, vs. Temp. (4MHz)

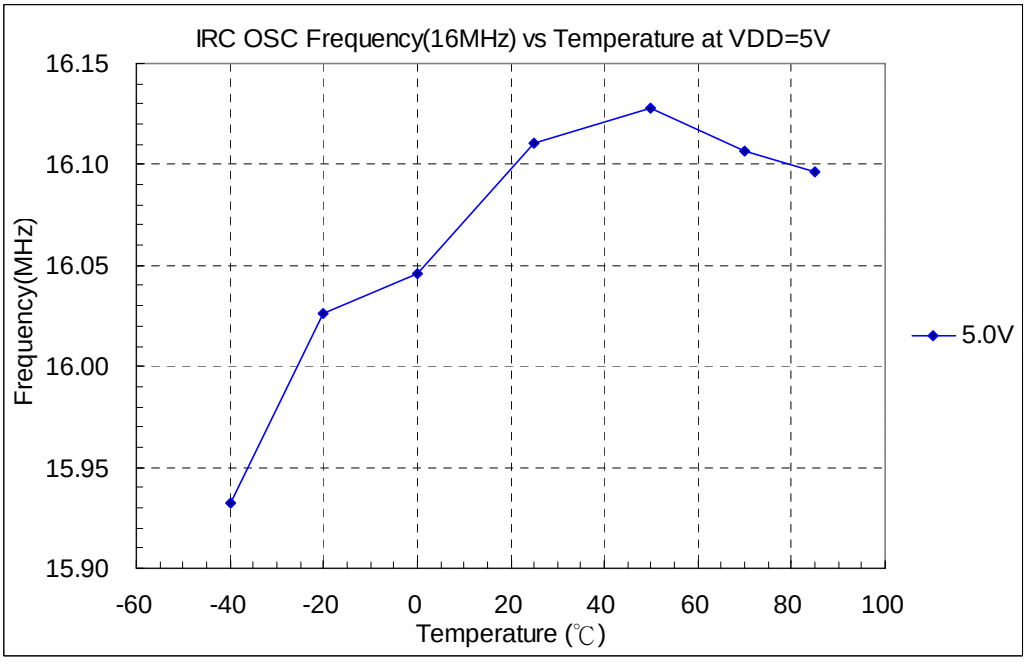


Figure 8-37 IRC OSC Freq, vs. Temp. (16MHz)

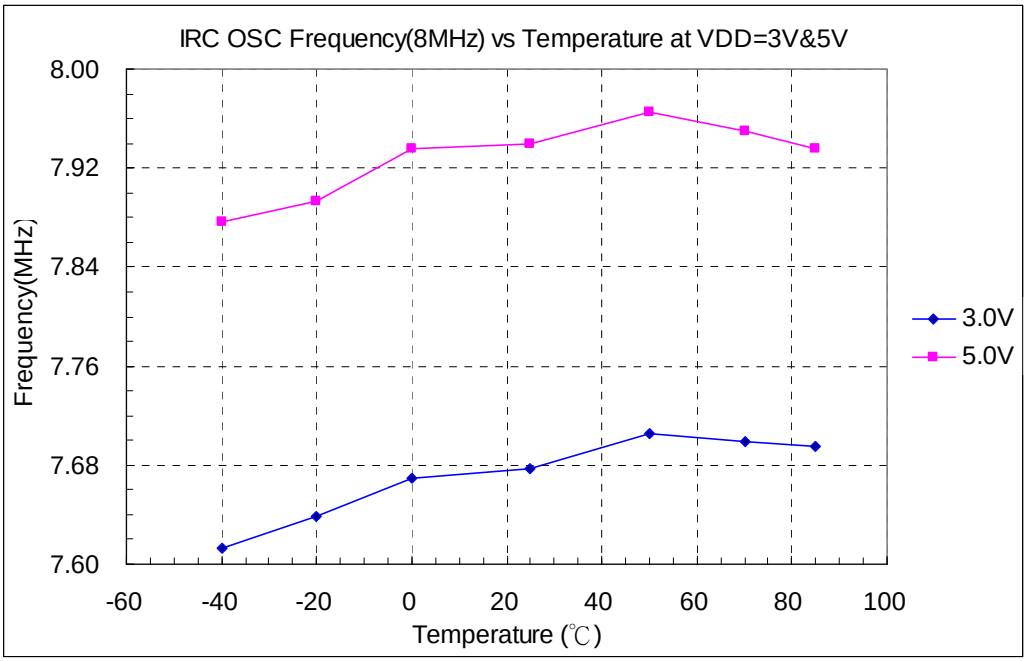


Figure 8-38 IRC OSC Freq, vs. Temp. (8MHz)

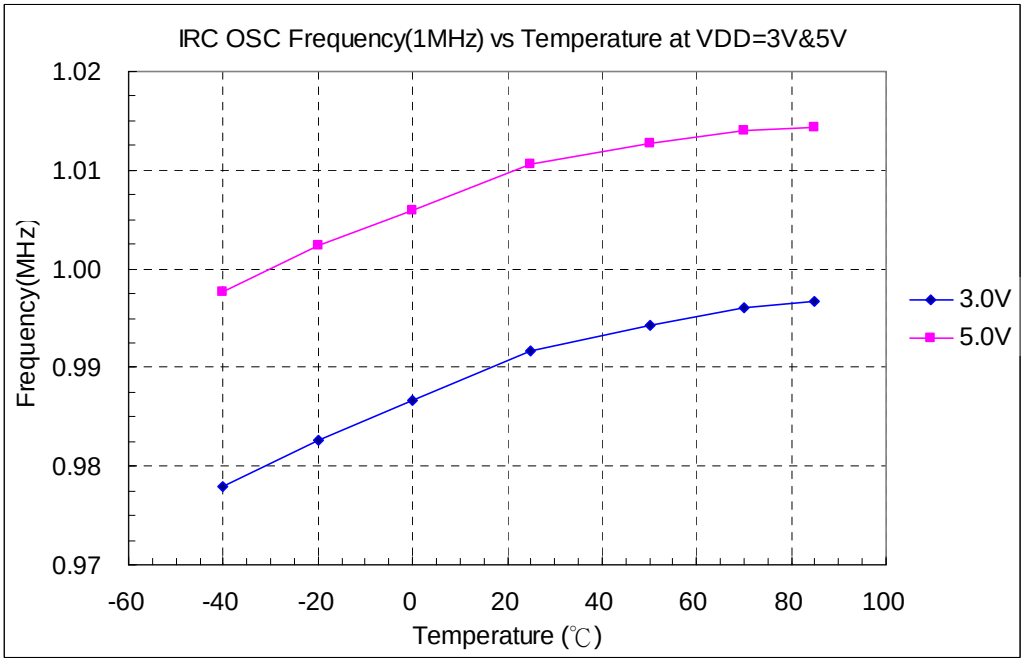


Figure 8-39 IRC OSC Freq, vs. Temp. (1 MHz)

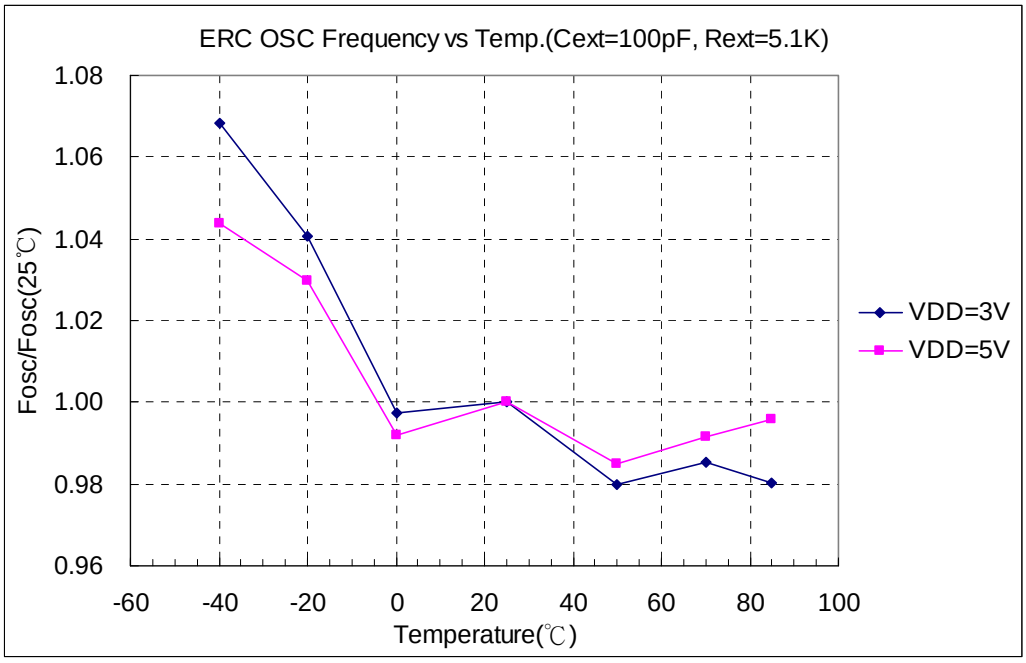


Figure 8-40 ERC OSC Frequency vs. Temp (C_{EXT}=100pf, R_{EXT}=5.1k)

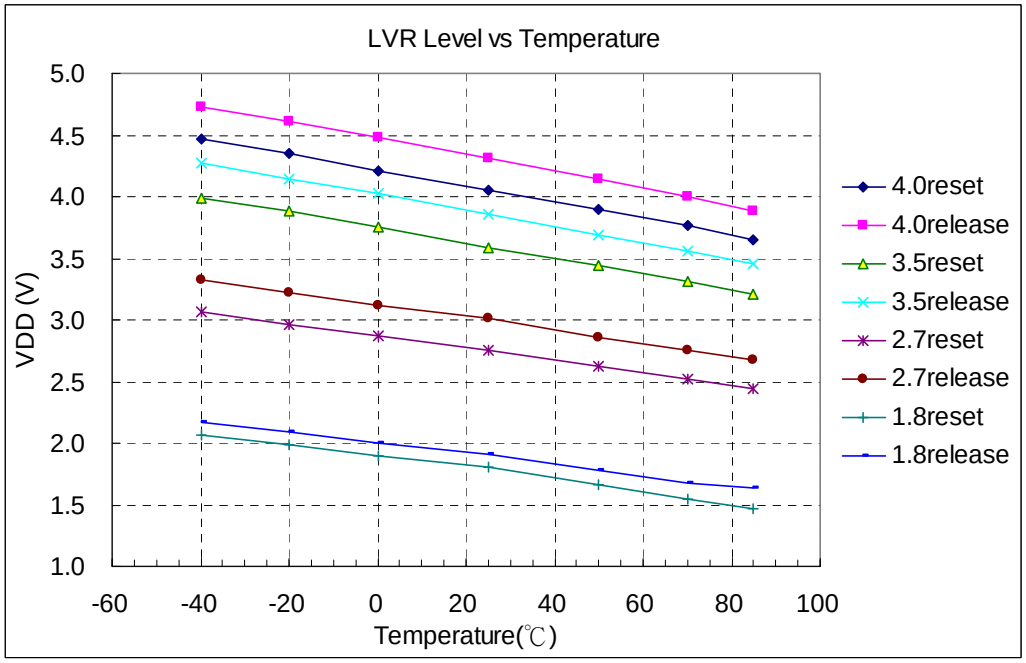
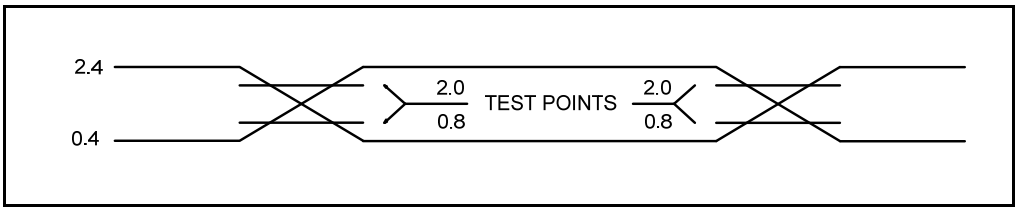


Figure 8-41 LVR Level vs Temperature

8 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 8-1a AC Test Input/Output Waveform Timing Diagram

Reset Timing (CLK = "0")

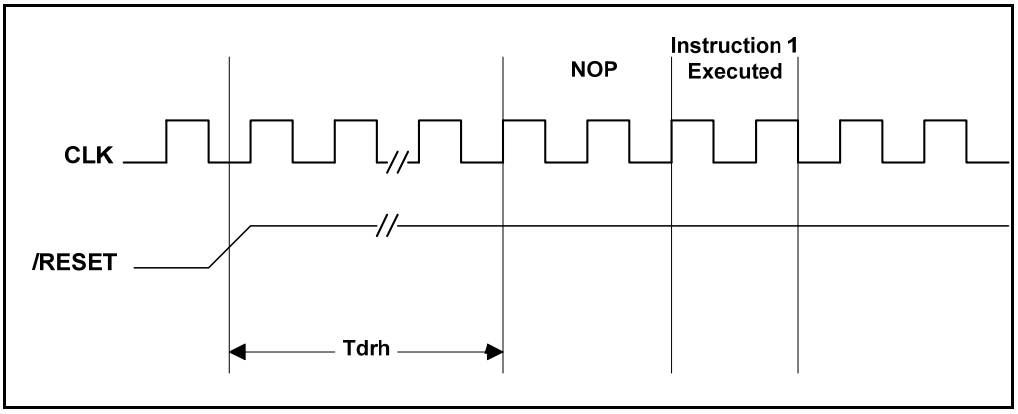


Figure 8-1b Reset Timing Diagram

TCC Input Timing (CLKS = "0")

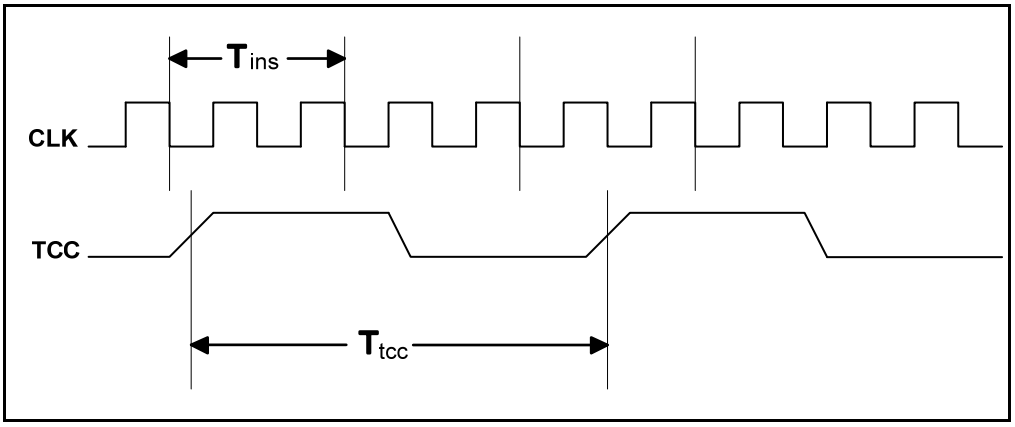
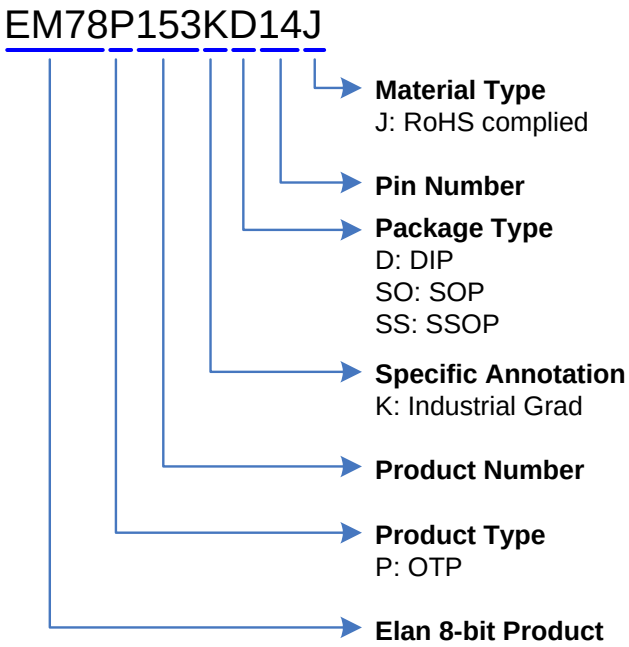


Figure 8-1c TCC Input Timing Diagram

APPENDIX

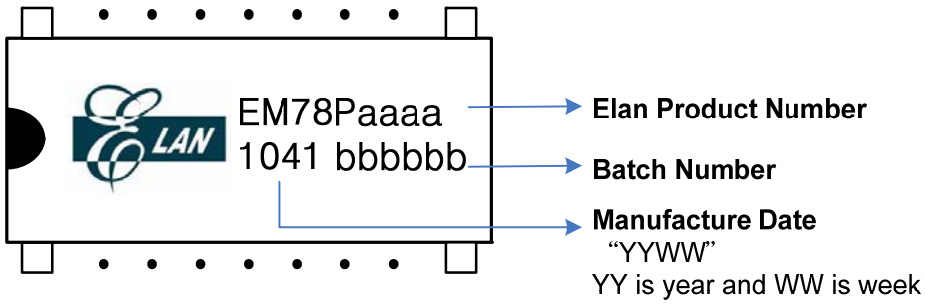
A Ordering and Manufacturing Information



For example:

EM78P153KSO14J

is EM78P153K with OTP program memory, industrial grade product, in 14-pin SOP 300mil package with RoHS complied



B Package Type

OTP MCU	Package Type	Pin Count	Package Size
EM78P153KD14J	DIP	14	300 mil
EM78P153KSO14J	SOP	14	150 mil
EM78P153KSS10J EM78P153KASS10J	SSOP	10	150 mil

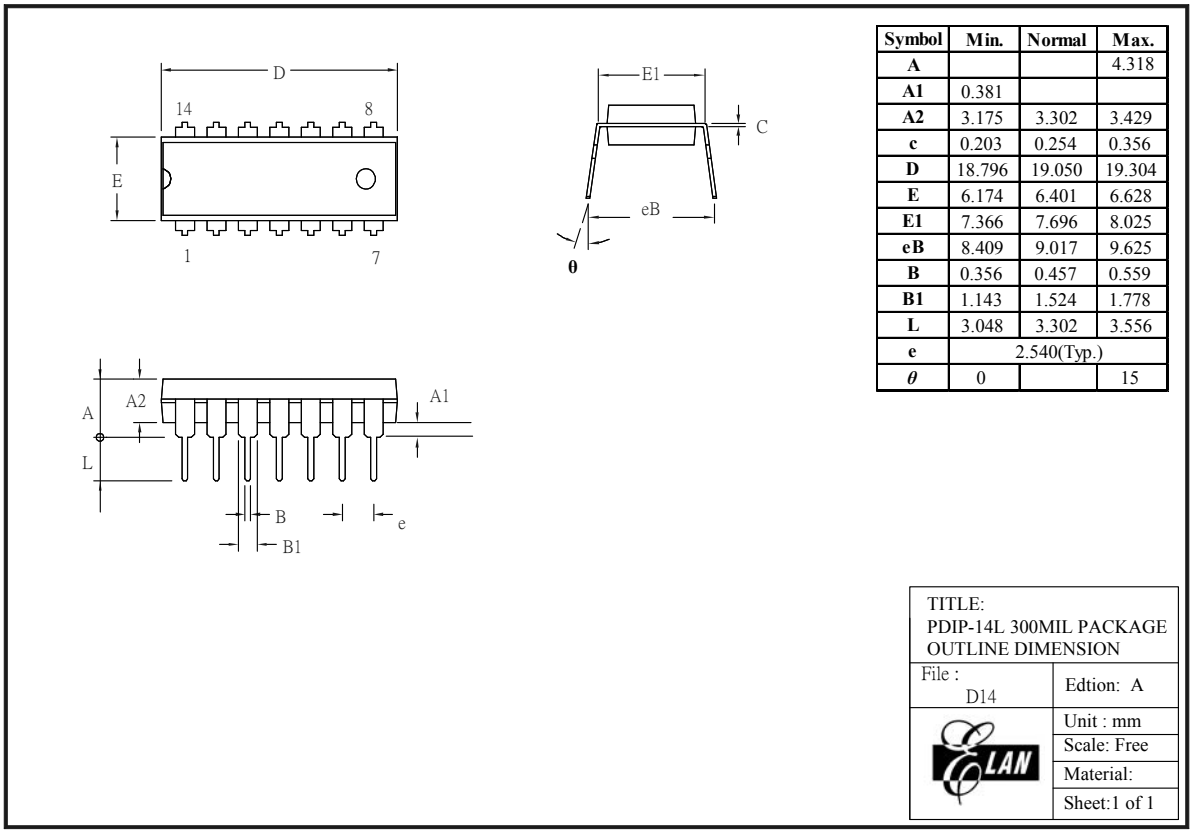
For product code "J".

These are Green products and comply with RoHS specifications.

Part No.	EM78P153KD14J/SO14J/SS10J/ASS10J
Electroplate type	Pure Tin
Ingredient (%)	Sn: 100%
Melting point (°C)	232°C
Electrical resistivity (μΩ-cm)	11.4
Hardness (hv)	8~10
Elongation (%)	>50%

C Package Information

■ **14-Lead Plastic Dual in-line (DIP) — 300 mil**

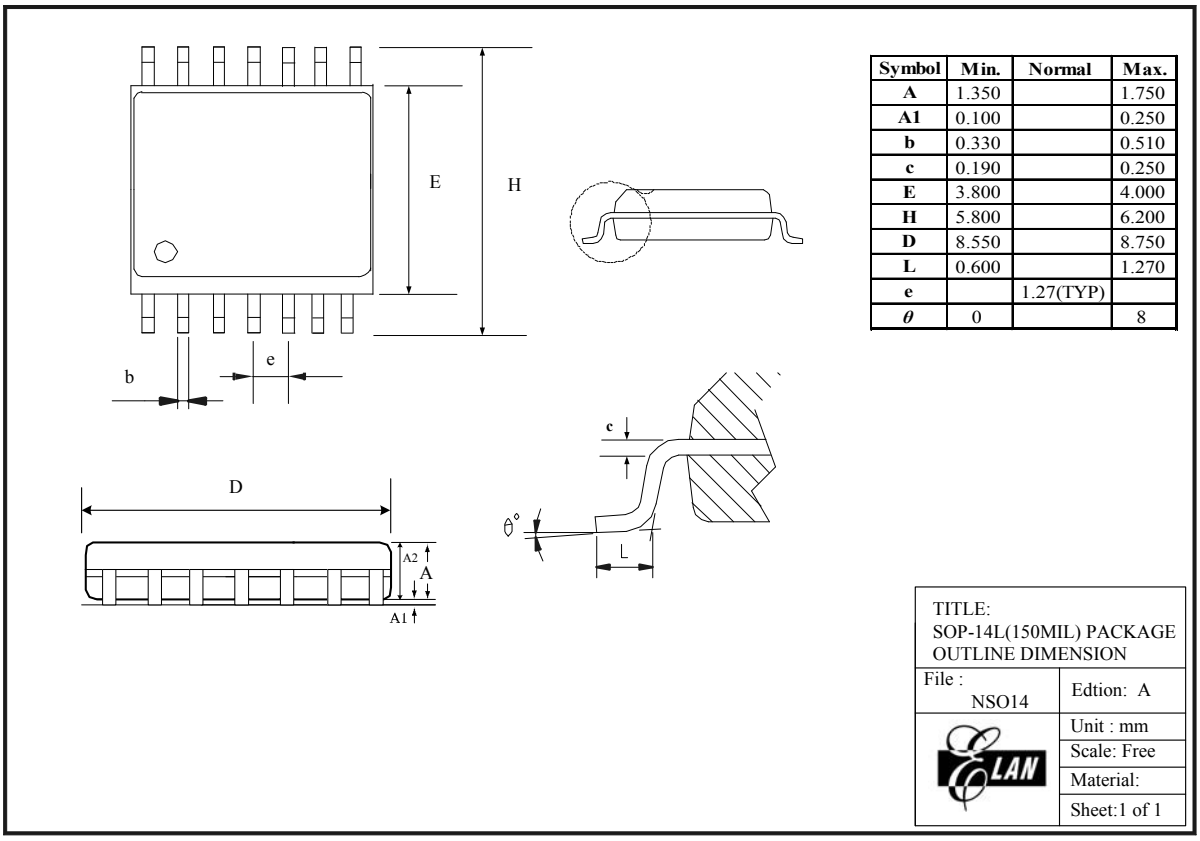


Symbol	Min.	Normal	Max.
A			4.318
A1	0.381		
A2	3.175	3.302	3.429
c	0.203	0.254	0.356
D	18.796	19.050	19.304
E	6.174	6.401	6.628
E1	7.366	7.696	8.025
eB	8.409	9.017	9.625
B	0.356	0.457	0.559
B1	1.143	1.524	1.778
L	3.048	3.302	3.556
e	2.540(Typ.)		
θ	0		15

TITLE: PDIP-14L 300MIL PACKAGE OUTLINE DIMENSION	
File : D14	Edtion: A
	Unit : mm
	Scale: Free
	Material:
	Sheet:1 of 1

Figure B-1a EM78P153K 14-Lead DIP Package Type

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

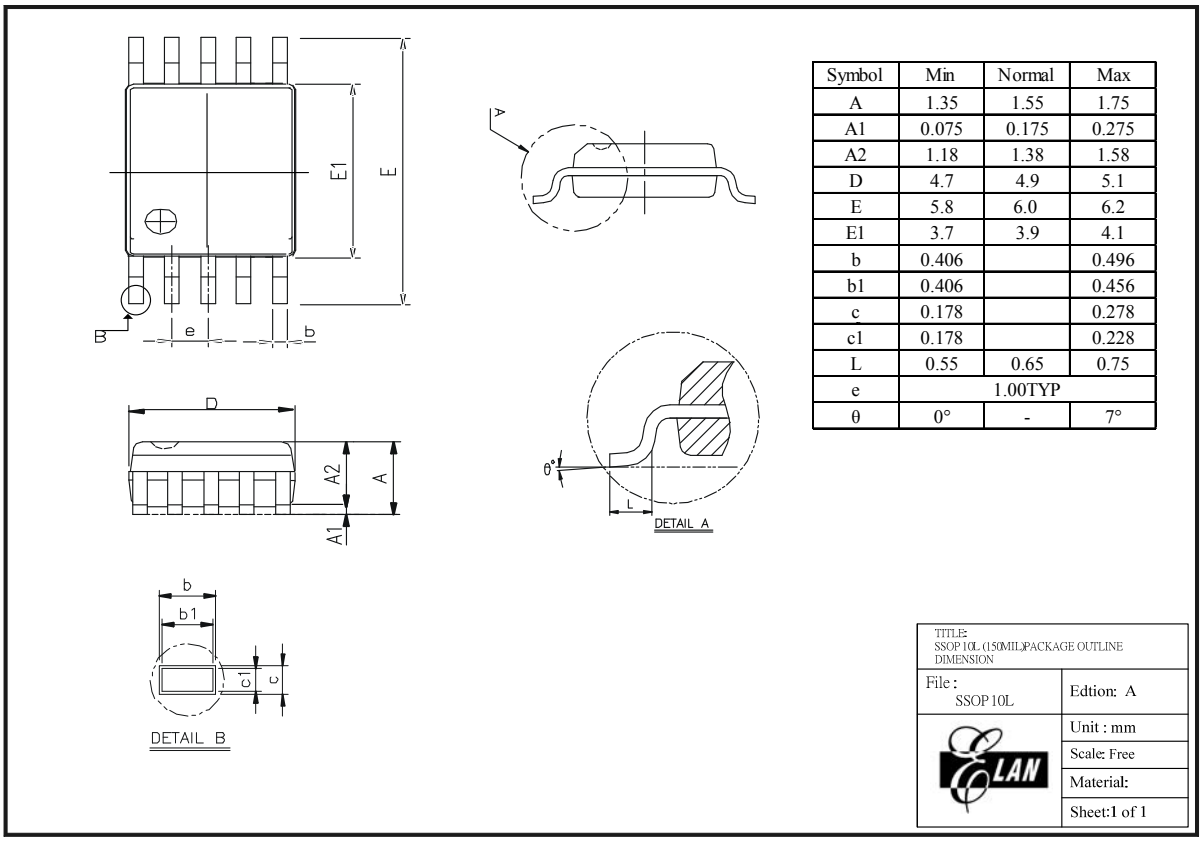


Symbol	Min.	Normal	Max.
A	1.350		1.750
A1	0.100		0.250
b	0.330		0.510
c	0.190		0.250
E	3.800		4.000
H	5.800		6.200
D	8.550		8.750
L	0.600		1.270
e		1.27(TYP)	
θ	0		8

TITLE: SOP-14L(150MIL) PACKAGE OUTLINE DIMENSION	
File : NSO14	Edtion: A
	Unit : mm
	Scale: Free
	Material:
	Sheet:1 of 1

Figure B-1b EM78P153K 14-Lead SOP Package Type

■ **10-Lead Shrink Small-Outline Package (SSOP) — 150 mil**



Symbol	Min	Normal	Max
A	1.35	1.55	1.75
A1	0.075	0.175	0.275
A2	1.18	1.38	1.58
D	4.7	4.9	5.1
E	5.8	6.0	6.2
E1	3.7	3.9	4.1
b	0.406		0.496
b1	0.406		0.456
c	0.178		0.278
c1	0.178		0.228
L	0.55	0.65	0.75
e	1.00TYP		
θ	0°	-	7°

Figure B-1c EM78P153K 10-Lead SSOP Package Type