MCU391
Touch Controller

Datasheet

Version 0.01 – Mar. 15, 2018

Table of Contents

Revision History:

Revision	Date	Description
0.01	2018/03/15	1st version

MCU391
Touch Controller

1. Features

1.1. Special Features

- General purpose series
- Please don't apply to AC RC step-down powered, high power ripple or high EFT requirement application
- Operating temperature range: -20°C ~ 70°C

1.2. System Features

- 1.75KW OTP program memory
- 128 Bytes data RAM
- One hardware 16-bit timer
- Two hardware 8-bit timers with 6/7/8-bit PWM generation
- One hardware comparator
- 14 IO pins with optional pull-high resistor
- 12 IO pins can be selected as touch pad individually
- Band-gap circuit to provide 1.20V Band-gap voltage
- Clock sources: internal high RC oscillator and internal low RC oscillator
- Eight Levels of LVR reset ~ 4.0V, 3.5V, 3.0V, 2.75V, 2.5V, 2.2V, 2.0V, 1.8V
- Three selectable external interrupt pins

1.3. CPU Features

- Operating modes: One processing unit mode
- 82 powerful instructions
- Most instructions are 1T execution cycle
- Programmable stack pointer to provide adjustable stack level (Using 2 bytes SRAM for one stack level)
- Direct and indirect addressing modes for data and instructions
- All data memories are available for use as an index pointer
- Separated IO and memory space

1.4. Package Information

- **MCU391 Series**
  - MCU391-U06: SOT23-6 (60mil)
  - MCU391-S08: SOP8 (150mil)
  - MCU391-D08: DIP8 (300mil)
  - MCU391-M10: MSOP10 (118mil)
  - MCU391-S14: SOP14 (150mil)
  - MCU391-D14: DIP14 (300mil)
  - MCU391-S16: SOP16 (150mil)
  - MCU391-D16: DIP16 (300mil)
  - MCU391-1J16A: QFN3*3-16P (0.5pitch)

2. General Description and Block Diagram

The MCU391 is a fully static, OTP-based touch controller; it employs RISC architecture and most the instructions are executed in one cycle except that few instructions are two cycles that handle indirect memory access. Besides touch controller, 1.75KW bits OTP program memory and 128 bytes data SRAM are inside, one hardware 16-bit timer and two hardware 8-bit Timer2 & Timer3 with PWM generation are also provided in the MCU391.

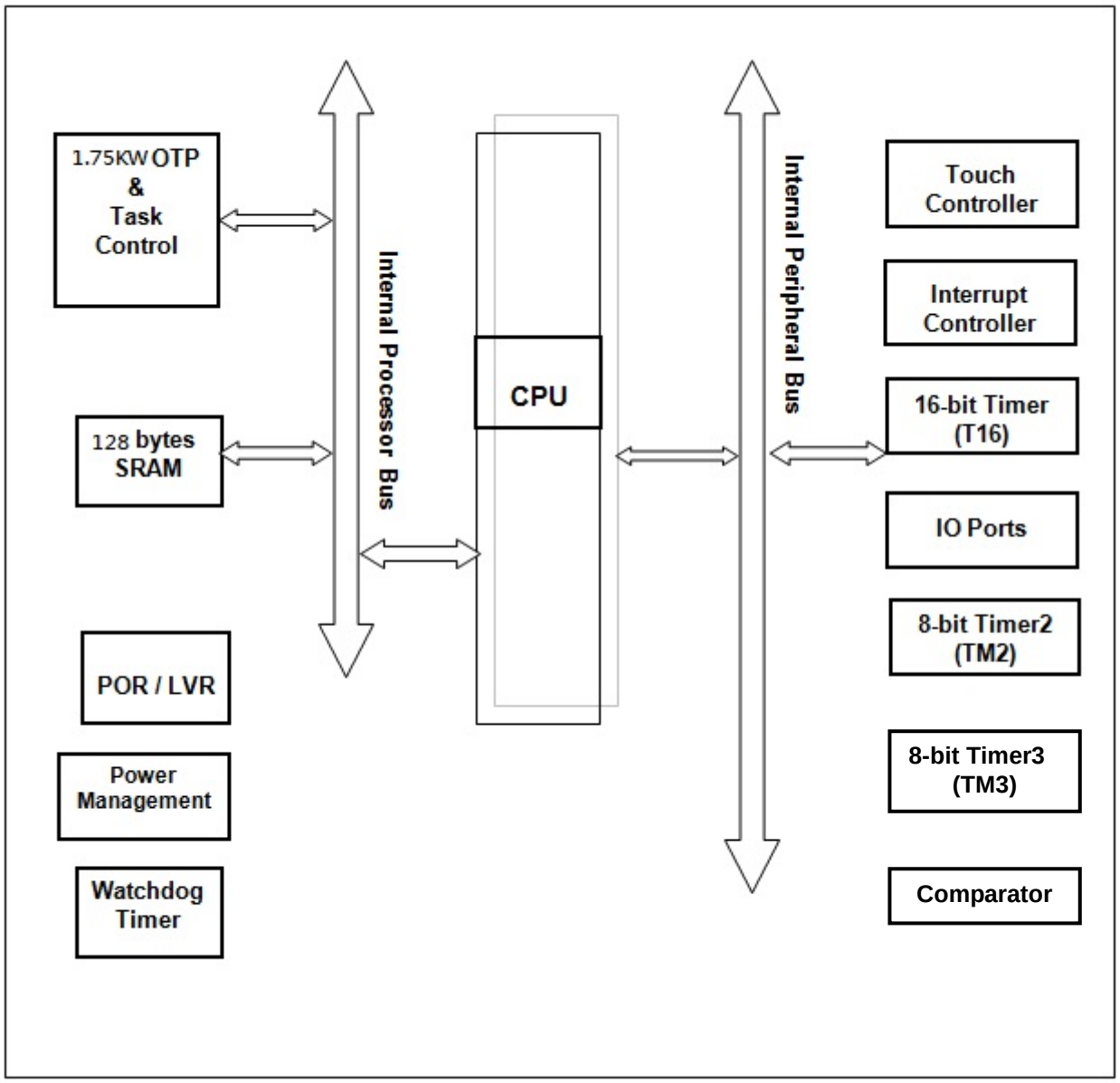
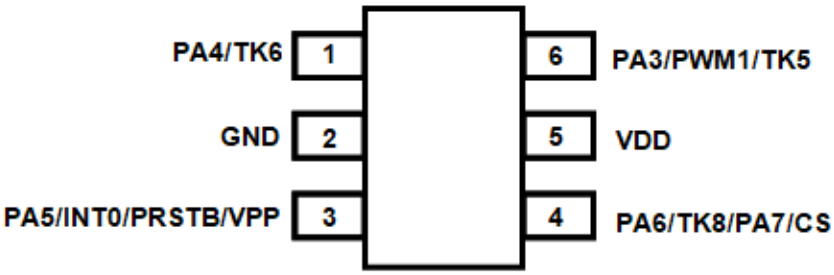
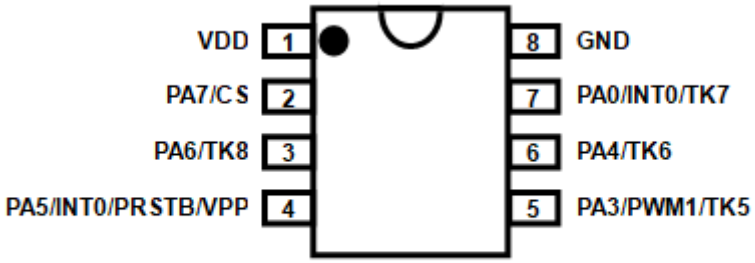


Fig. 1: MCU391 Block Diagram

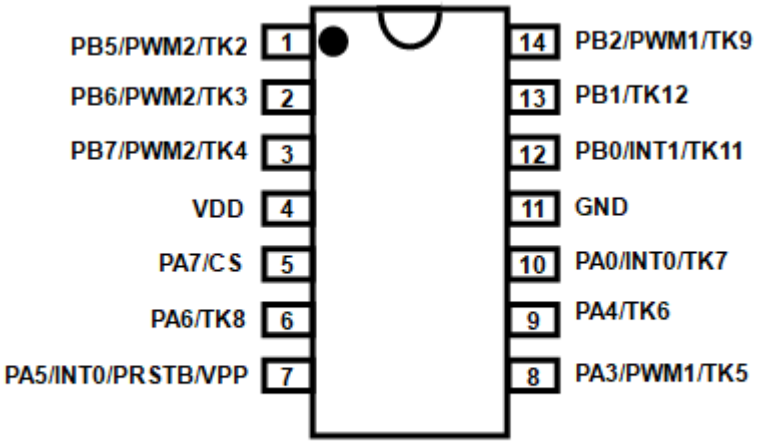
3. Pin Definition and Functional Description



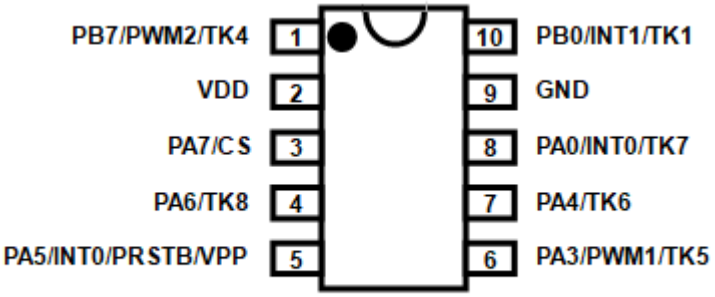
MCU391-U06 (SOT23-6 60mil)



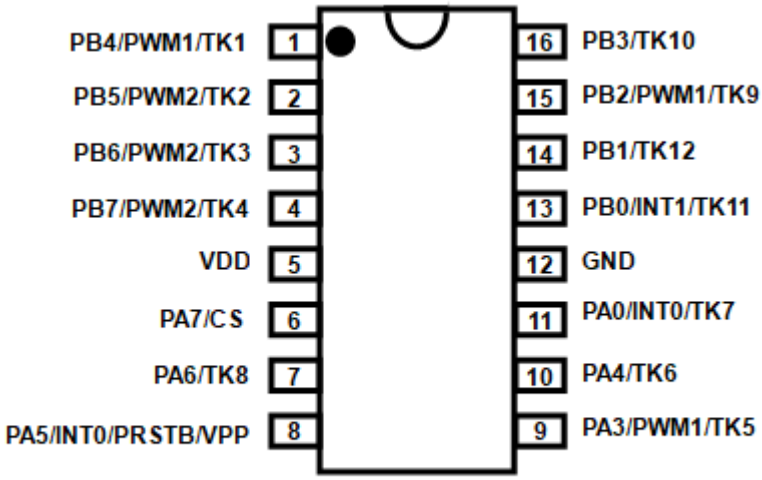
MCU391-S08 (SOP8-150mil)
MCU391-D08 (DIP8-300mil)



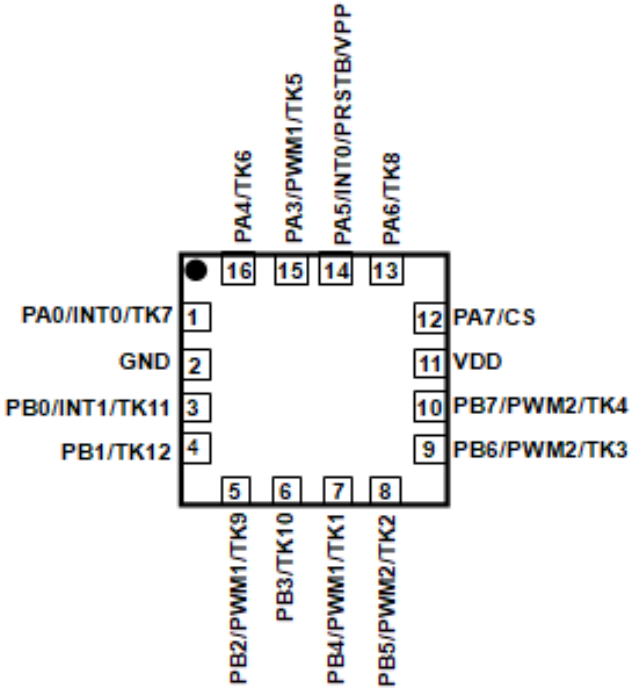
MCU391-S14 (SOP14-150mil)
MCU391-D14 (DIP14-300mil)



MCU391-M10 (MSOP10-118mil)



MCU391-S16 (SOP16-150mil)
MCU391-D16 (DIP16-300mil)



MCU391-1J16A (QFN3*3-16P-0.5pitch)

Pin Name	Pin & Buffer Type	Description
PA6 / TK8	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 6 of port A. It can be configured as digital input, two-state output with pull-up resistor by software independently. (2) Touch Key 8 When this pin is configured as analog input, please use bit 6 of register ***padier*** to disable the digital input to prevent leakage current.
PA5 / INT0 / PRSTB / VPP	IO ST / CMOS	This pin can be used as: (1) Bit 5 of port A. It can be configured as input with optional pull-up resistor or open-drain output pin. (2) Optional external interrupt line 0. Both rising edge and falling edge are accepted to request interrupt service. (3) External reset pin (4) VPP for OTP programming
PA4 / TK6	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 4 of port A. It can be configured as digital input, two-state output with pull-up resistor by software independently (2) Touch Key 6 When this pin is configured as analog input, please use bit 4 of register ***padier*** to disable the digital input to prevent leakage current.
PA3 / PWM1 / TK5	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 3 of port A. It can be configured as digital input, two-state output with pull-up resistor by software independently. (2) PWM output of Timer2 (3) Touch Key 5 When this pin is configured as analog input, please use bit 3 of register ***padier*** to disable the digital input to prevent leakage current.
PA0 / INT0 / TK7	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 0 of port A. It can be configured as digital input, two-state output with pull-up resistor by software independently. (2) Optional external interrupt line 0. Both rising edge and falling edge are accepted to request interrupt service. (3) Touch Key 7 When this pin is configured as analog input, please use bit 0 of register ***padier*** to disable the digital input to current leakage current.

Pin Name	Pin & Buffer Type	Description
PB0 / INT1 / TK11	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 0 of port B. It can be configured as digital input, two-state output with pull-up resistor by software independently. (2) External interrupt line 1. Both rising edge and falling edge are accepted to request interrupt service. (3) Touch Key 11 When this pin is configured as analog input, please use bit 0 of register ***pbdier*** to disable the digital input to current leakage current.
PB1 / TK12	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 1 of port B. It can be configured as digital input, two-state output with pull-up resistor by software independently. (2) Touch Key 12 When this pin is configured as analog input, please use bit 1 of register ***pbdier*** to disable the digital input to current leakage current.
PB2 / PWM1 / TK9	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 2 of port B. It can be configured as digital input, two-state output with pull-up resistor by software independently. (2) PWM output of Timer2 (3) Touch Key 9 When this pin is configured as analog input, please use bit 2 of register ***pbdier*** to disable the digital input to prevent leakage current.
PB3 / TK10	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 3 of port B. It can be configured as digital input, two-state output with pull-up resistor by software independently. (2) Touch Key 10 When this pin is configured as analog input, please use bit 3 of register ***pbdier*** to disable the digital input to prevent leakage current.
PB4 / PWM1 / TK1	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 4 of port B. It can be configured as digital input, two-state output with pull-up resistor by software independently. (2) PWM output of Timer2. (3) Touch Key 1 When this pin is configured as analog input, please use bit 4 of register ***pbdier*** to disable the digital input to prevent leakage current.

Pin Name	Pin & Buffer Type	Description
PB5 / PWM2 / TK2	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 5 of port B. It can be configured as digital input, two-state output with pull-up resistor by software independently. (2) PWM output of Timer3. (3) Touch Key 2 When this pin is configured as analog input, please use bit 5 of register pbdier to disable the digital input to prevent leakage current.
PB6 / PWM2 / TK3	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 6 of port B. It can be configured as digital input, two-state output with pull-up resistor by software independently. (2) PWM output of Timer3. (3) Touch Key 3 When this pin is configured as analog input, please use bit 6 of register pbdier to disable the digital input to prevent leakage current.
PB7 / PWM2 / TK4	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 7 of port B. It can be configured as digital input, two-state output with pull-up resistor by software independently. (2) PWM output of Timer3. (3) Touch Key 4 When this pin is configured as analog input, please use bit 7 of register pbdier to disable the digital input to prevent leakage current.
PA7 / CS	IO ST / CMOS / Analog	This pin can be used as: (1) Bit 7 of port A. It can be configured as digital input, two-state output with pull-up resistor by software independently. (2) External Capacitor When this pin is configured as CS, the input function of this pin is disabled to prevent leakage current regardless of the setting of the bit 7 of register padier.
VDD		Positive power
GND		Ground
Notes: IO: Input/Output; **ST**: Schmitt Trigger input; **Analog**: Analog input pin; **CMOS**: CMOS voltage level		

4. Device Characteristics

4.1. DC/AC Characteristics

Symbol	Description	Min.	Typ	Max.	Unit	Conditions
V_{DD}	Operating Voltage	2.0		5.5	V	* Subject to LVR tolerance
LVR%	Low Voltage Reset Tolerance	-5		5	%	
f_{SYS}	System clock (CLK)* =				Hz	
	IHRC/2	0		8M		$V_{DD} \geqq$ 3.5V
	IHRC/4	0		4M		$V_{DD} \geqq$ 2.5V
	IHRC/8	0		2M		$V_{DD} \geqq$ 2.0V
	ILRC		55K			V_{DD} =3V
I_{OP}	Operating Current		0.5		mA	f_{SYS}=IHRC/16=1MIPS@5.0V
			35		uA	f_{SYS}=ILRC=55KHz@3.3V
I_{PD}	Power Down Current		1.4		uA	V_{DD} =5V
	(by *stopsys* command)		1.0			V_{DD} =3.3V
I_{PS}	Power Save Current (by *stopexe* command) *Disable IHRC		5		uA	V_{DD} =3.3V
V_{IL}	Input low voltage for IO lines	0		0.1 V_{DD}	V	
V_{IH}	Input high voltage for IO lines	0.8 V_{DD}		V_{DD}	V	PA5
		0.7 V_{DD}		V_{DD}		Other IO
I_{OL}	IO lines sink current (Normal)				mA	V_{DD}=5.0V, V_{OL}=0.5V
	PB4/PB5		42			
	PA7		26			
	PA5		19			
	Others		14			
	IO lines sink current (Low)					
	PB4/PB5		8			
	PA7		9			
	PA5		19			
	Others		5			
I_{OH}	IO lines drive current (Normal)				mA	V_{DD}=5.0V, V_{OH}=4.5V
	PB5		30			
	PA7		19			
	PA5		0			
	Others		10			
	IO lines drive current (Low)					
	PA7		5			
	PA5		0			
	Others		3			
V_{IN}	Input voltage	-0.3		V_{DD}+0.3	V	
$I_{INJ\ (PIN)}$	Injected current on pin		1		uA	V_{DD} +0.3$\geqq V_{IN} \geqq$ -0.3
R_{PH}	Pull-high Resistance		110		KΩ	V_{DD}=5.0V
			200			V_{DD}=3.3V

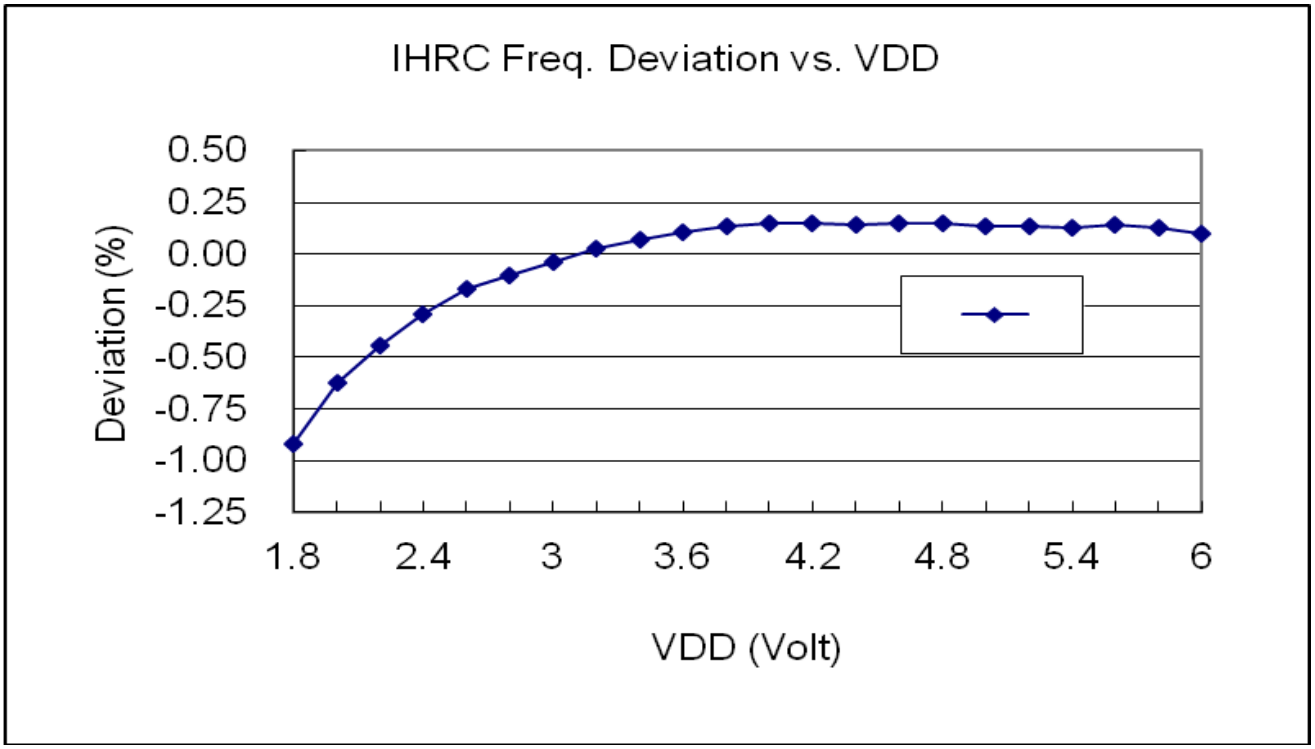
Symbol	Description	Min.	Typ	Max.	Unit	Conditions
f_{IHRC}	Frequency of IHRC after calibration *	15.76*	16*	16.24*	MHz	25°C, V_{DD} =2.2V~5.5V
		15.20*	16*	16.80*		V_{DD} =2.2V~5.5V, -20°C <Ta<70°C*
		13.60*	16*	18.40*		V_{DD} =2.0V~5.5V, -20°C <Ta<70°C
f_{ILRC}	Frequency of ILRC *		55		KHz	
t_{INT}	Interrupt pulse width	30			ns	V_{DD} = 5.0V
t_{WDT}	Watchdog timeout period		8192		ILRC clock period	misc[1:0]=00 (default)
			16384			misc[1:0]=01
			65536			misc[1:0]=10
			262144			misc[1:0]=11
t_{SBP}	System boot-up period from power-on		55		ms	@ V_{DD} =5V
t_{RST}	External reset pulse width	120			us	@ V_{DD} =5V

*These parameters are for design reference, not tested for every chip.

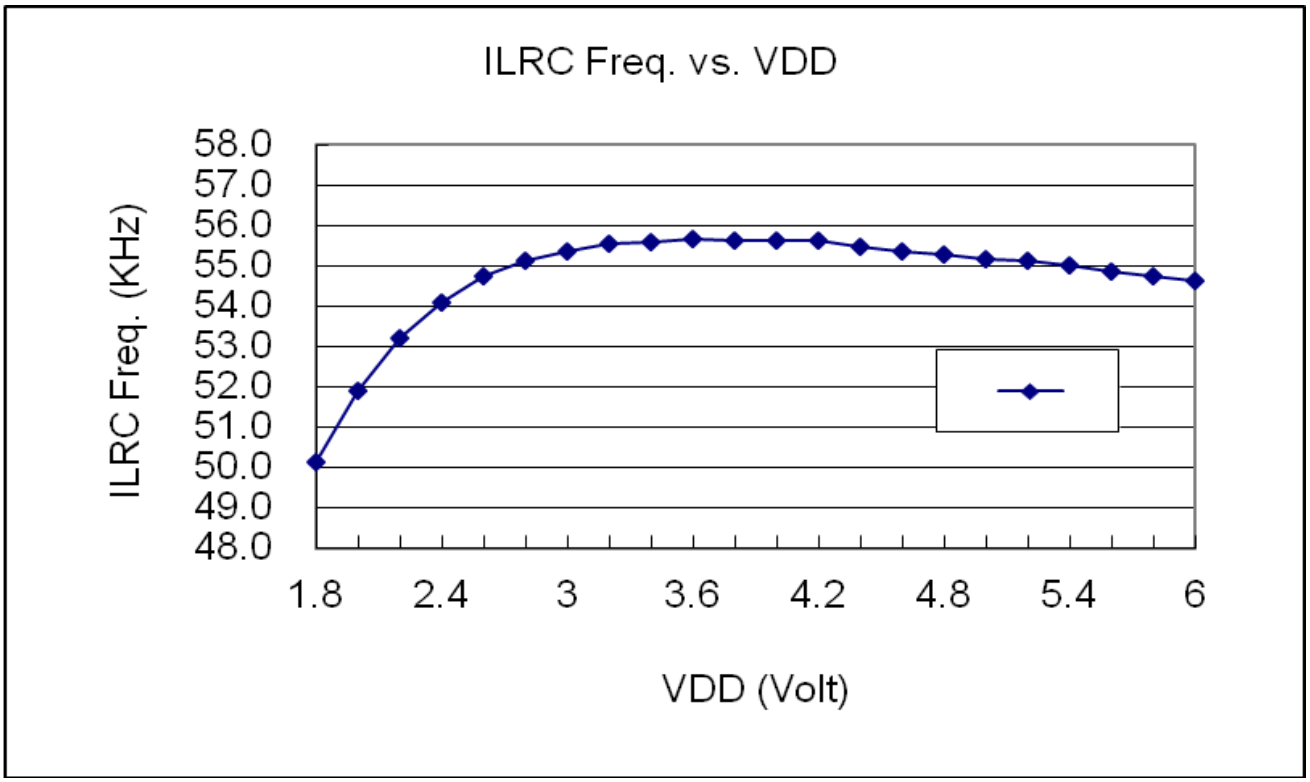
4.2. Absolute Maximum Ratings

- Operating Voltage …… 2.0V ~ 5.5V
- Input Voltage …….. -0.3V ~ V_{DD} + 0.3V
- Operating Temperature ……. -20°C ~ 70°C
- Storage Temperature ……. -50°C ~ 125°C
- Junction Temperature …….. 150°C

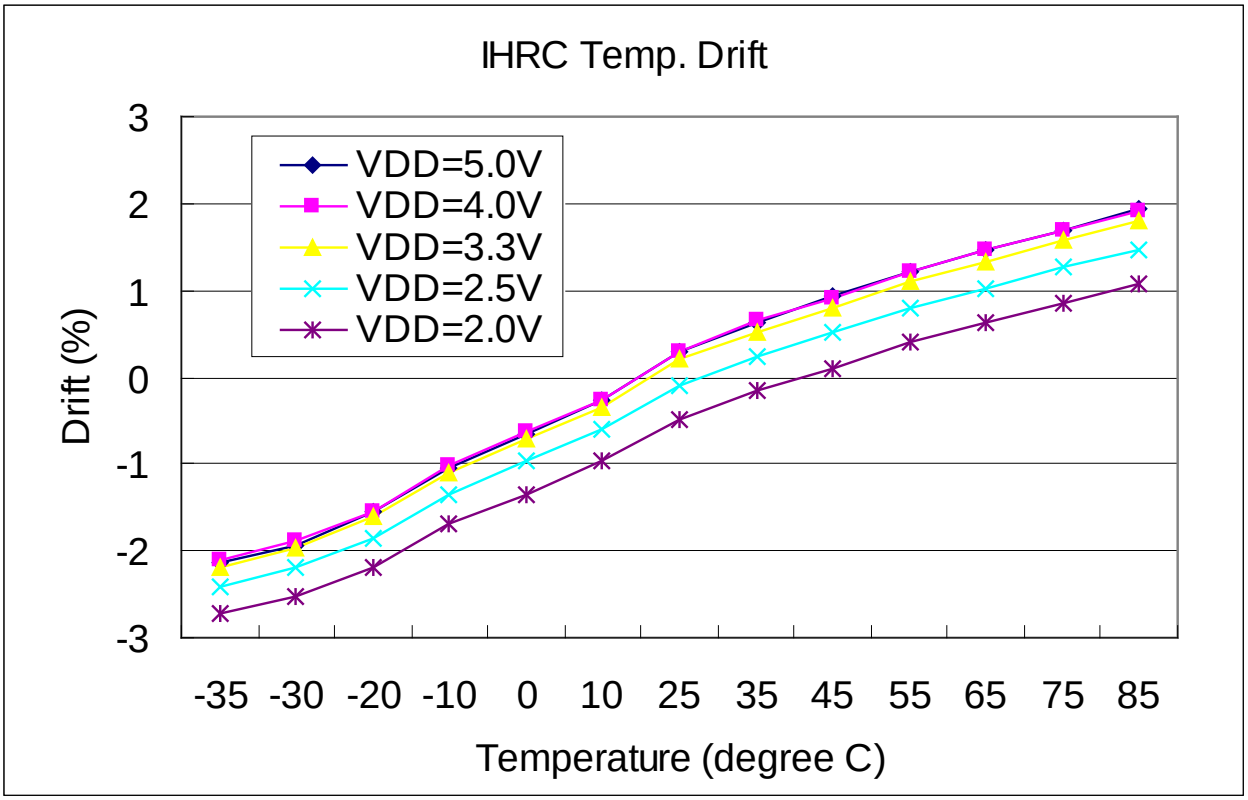
4.3. Typical IHRC Frequency vs. VDD (calibrated to 16MHz)



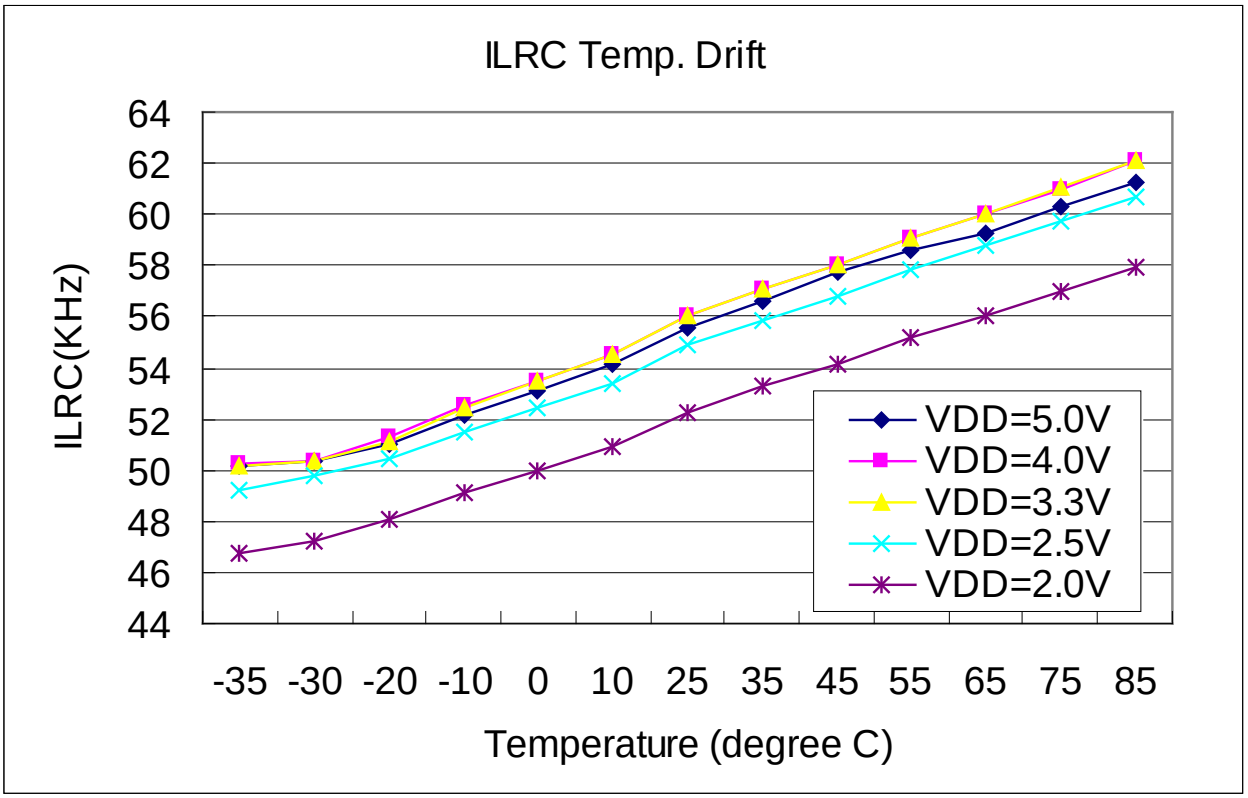
4.4. Typical ILRC Frequency vs. VDD



4.5. Typical IHRC Frequency vs. Temperature (calibrated to 16MHz)

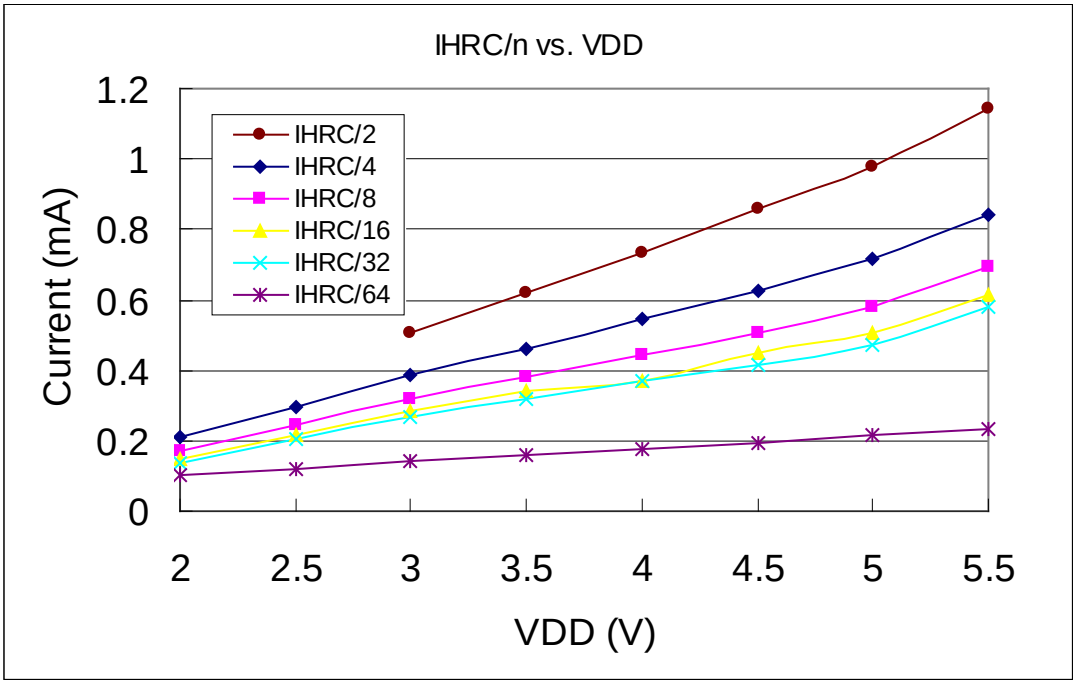


4.6. Typical ILRC Frequency vs. Temperature



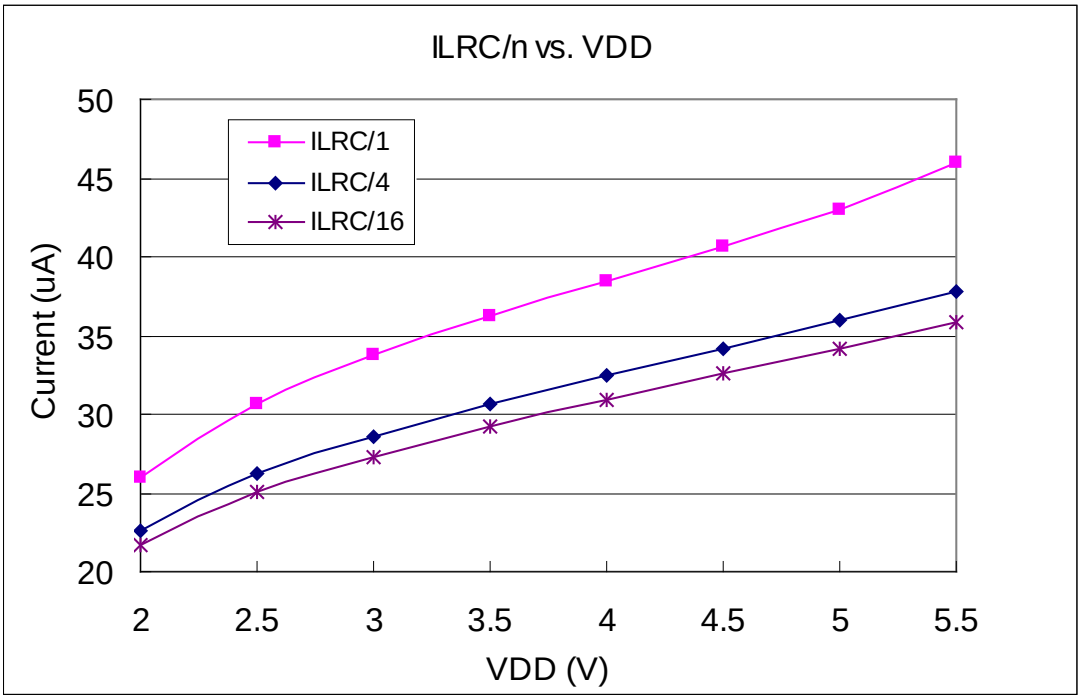
4.7. Typical Operating Current vs. VDD and CLK=IHRC/n

- Conditions:
  tog pa0(1s), **ON**: Band-gap, LVR, IHRC
  no t16m, no interrupt, no floating IO pins, disable ILRC, **Touch**: Disable

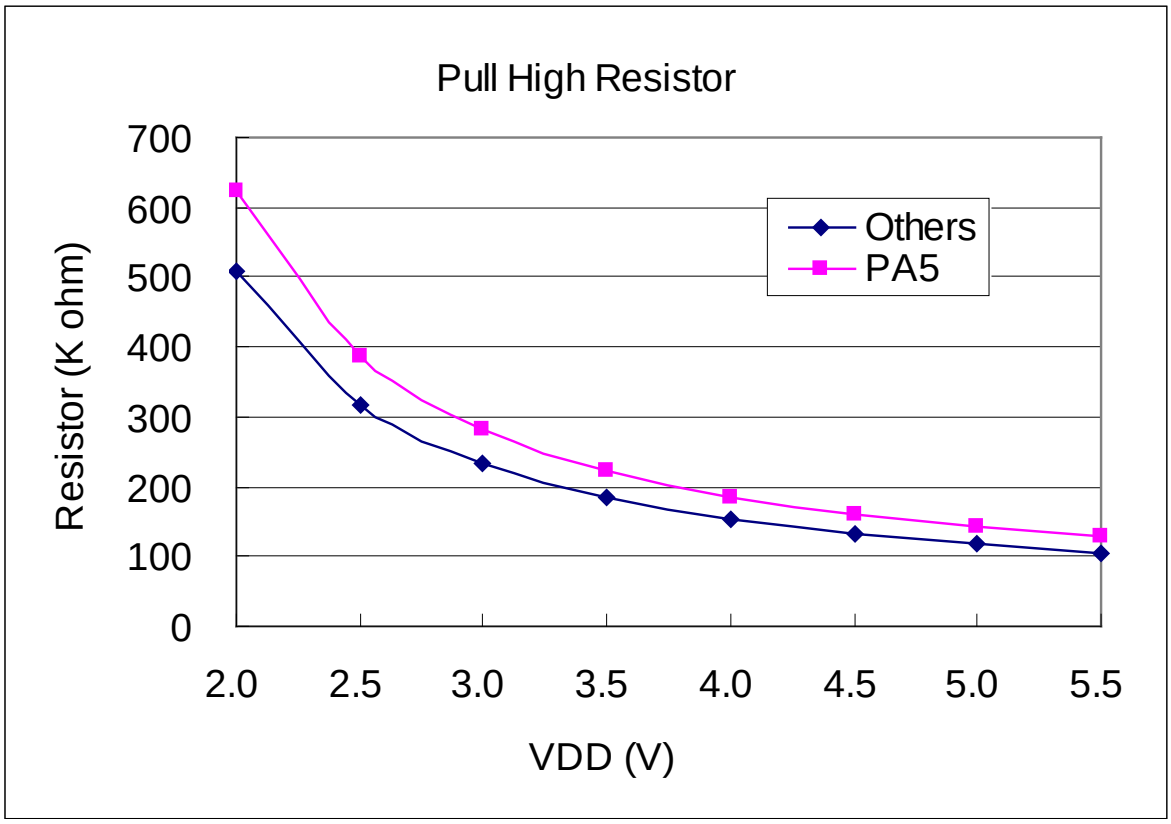


4.8. Typical Operating Current vs. VDD and CLK=ILRC/n

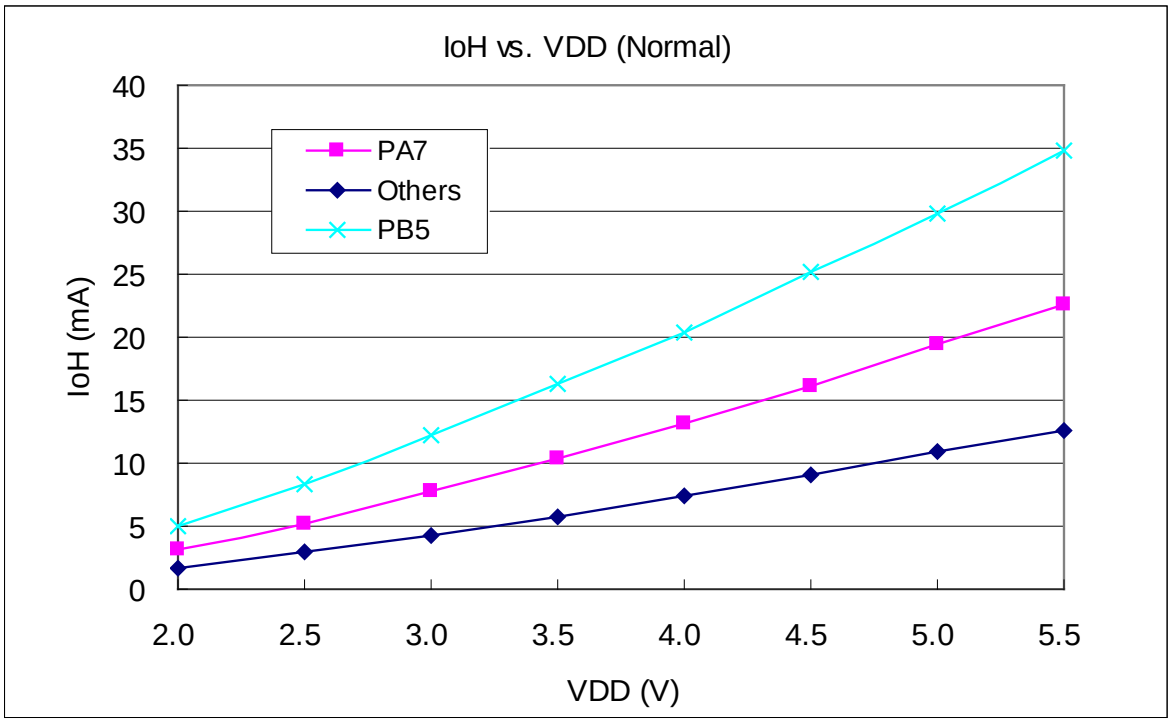
- Conditions:
  tog pa0(1s), **ON**: Band-gap, LVR, IHRC
  no t16m, no interrupt, no floating IO pins, disable ILRC, **Touch**: Disable

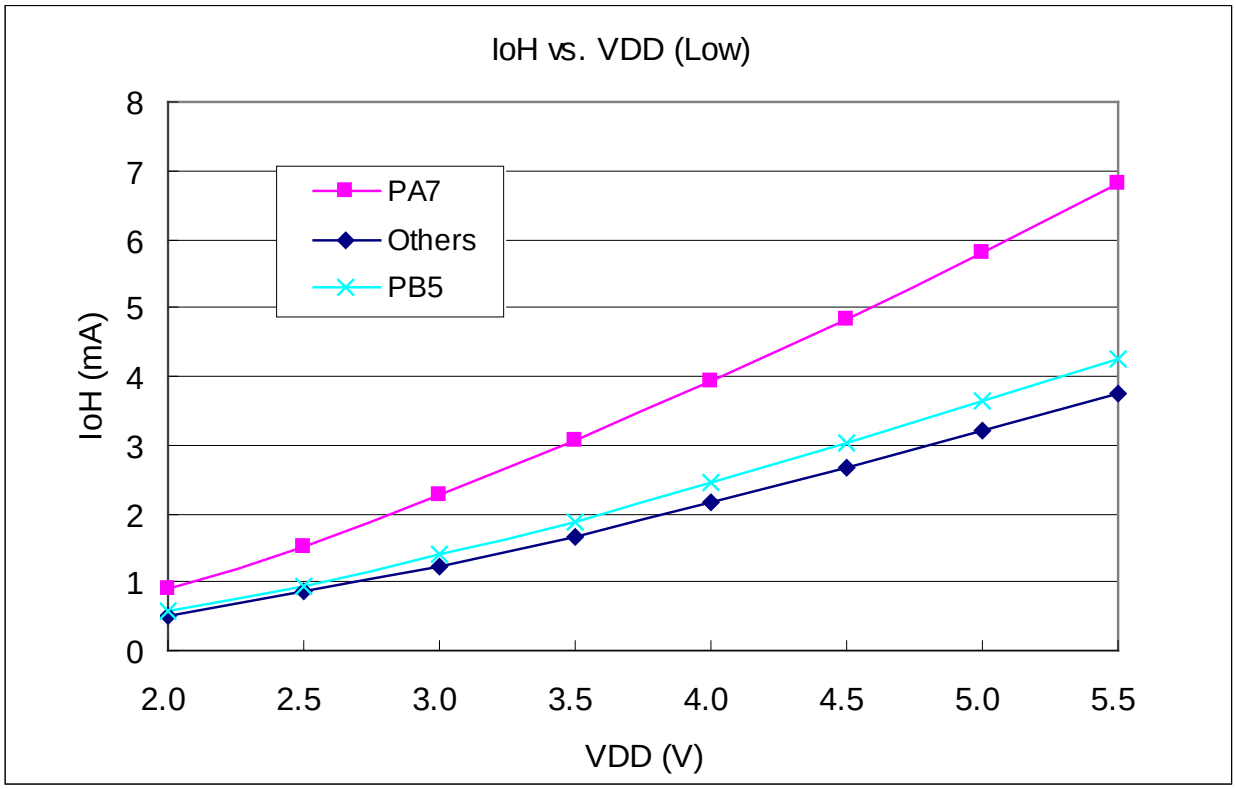


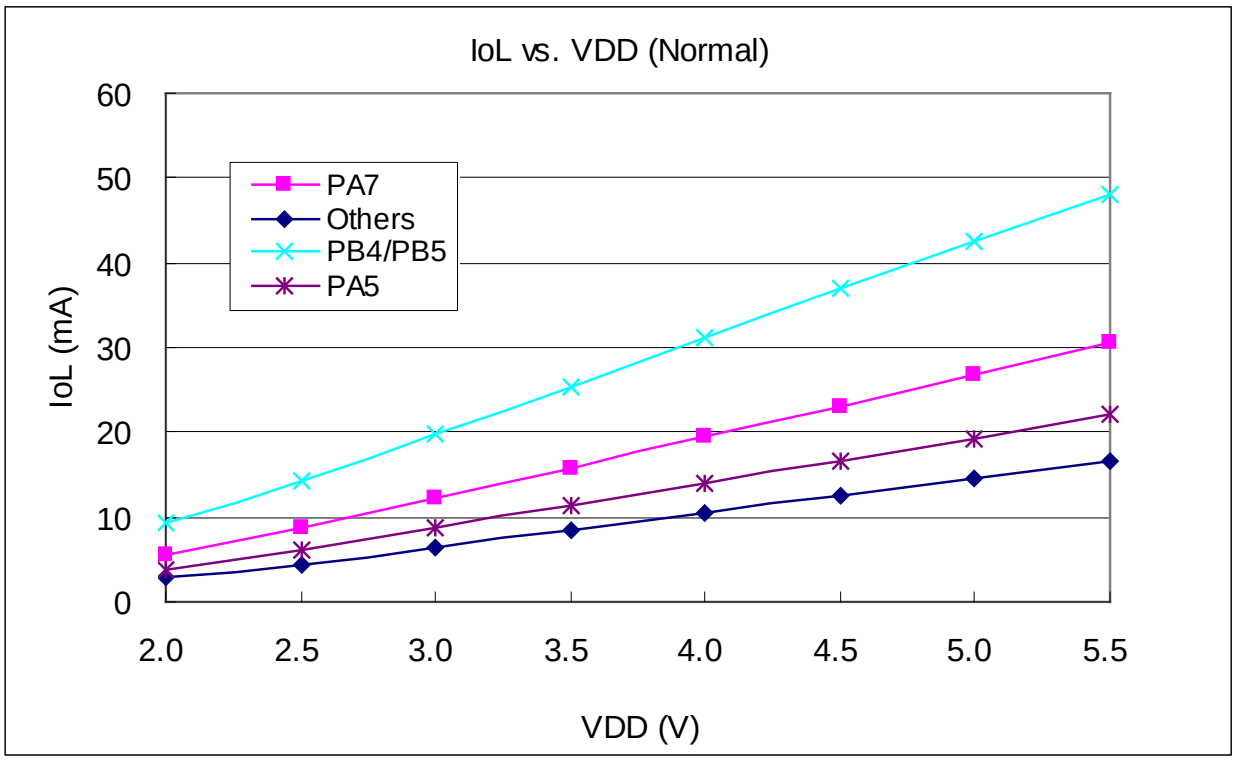
4.9. Typical IO pull high resistance



4.10. Typical IO driving current (I_{OH}) and sink current (I_{OL})




IoH vs. VDD (Low)
IoH (mA)
VDD (V)
PA7
Others
PB5
0
1
2
3
4
5
6
7
8
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5


IoL vs. VDD (Normal)
IoL (mA)
VDD (V)
PA7
Others
PB4/PB5
PA5
0
10
20
30
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50
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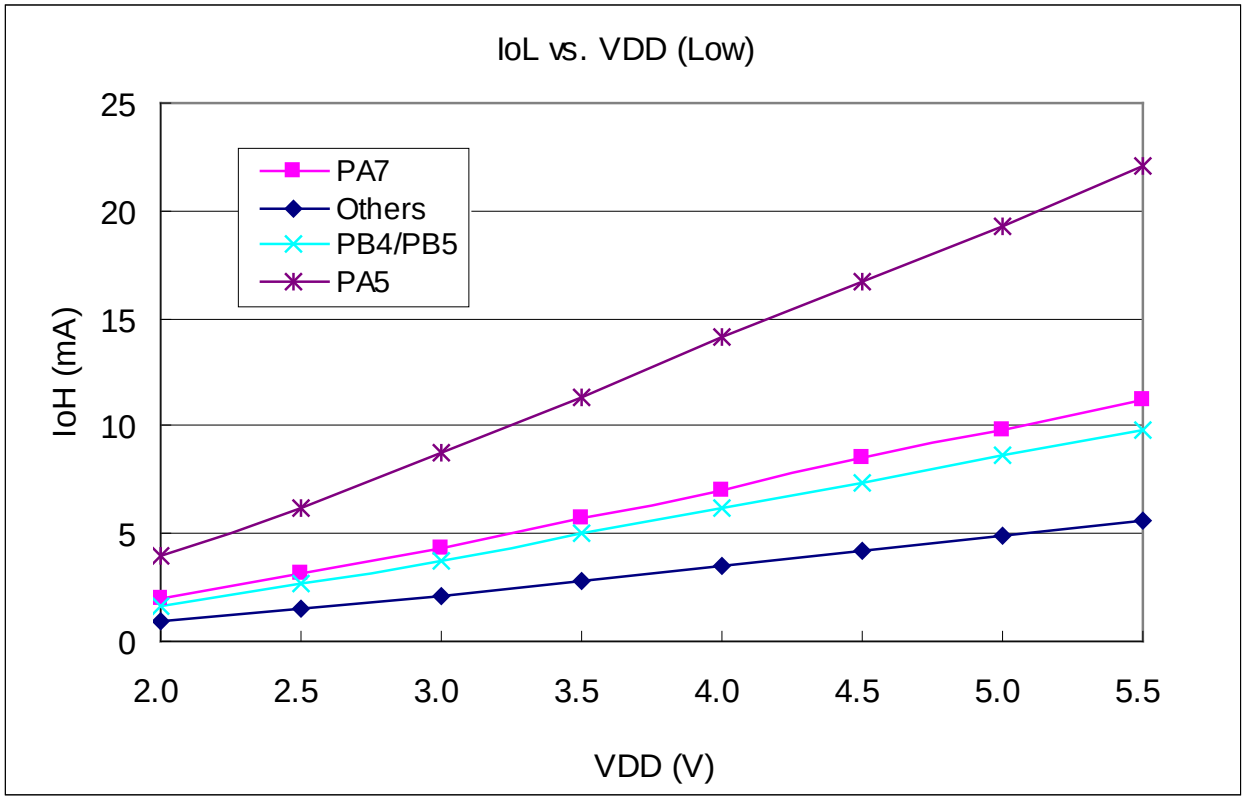
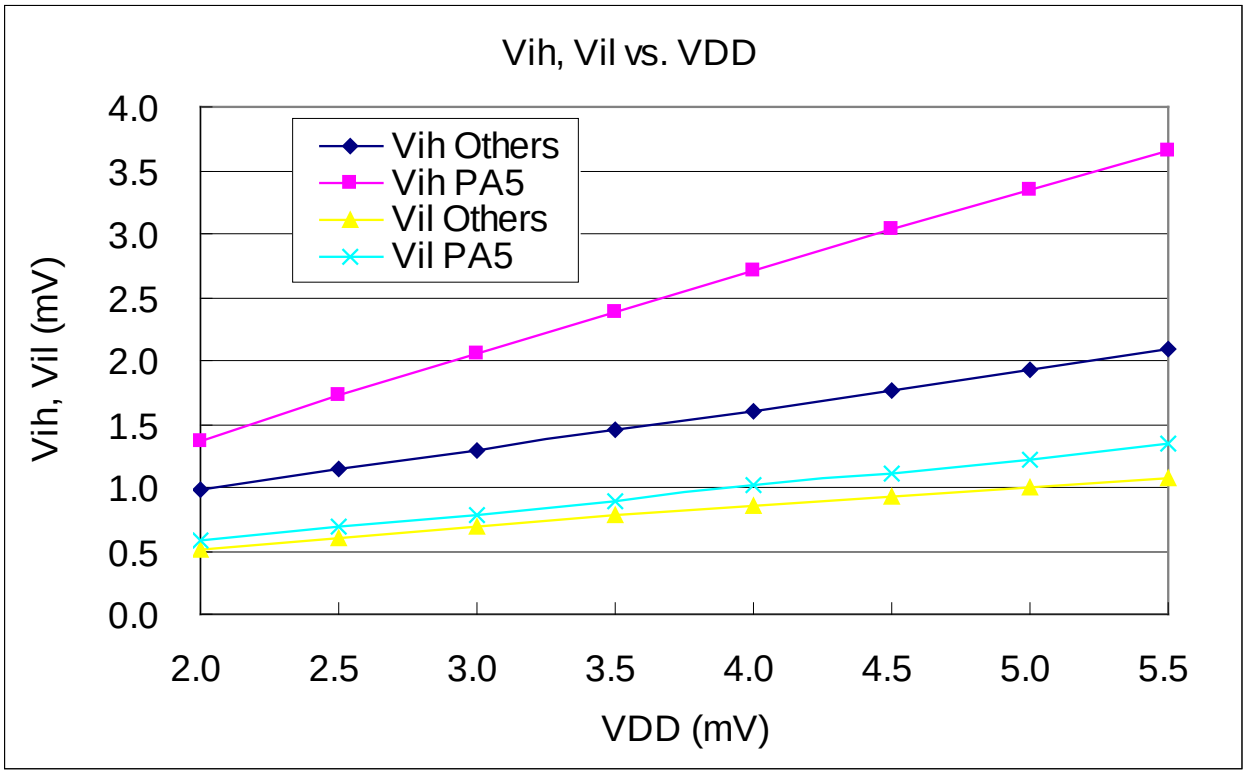
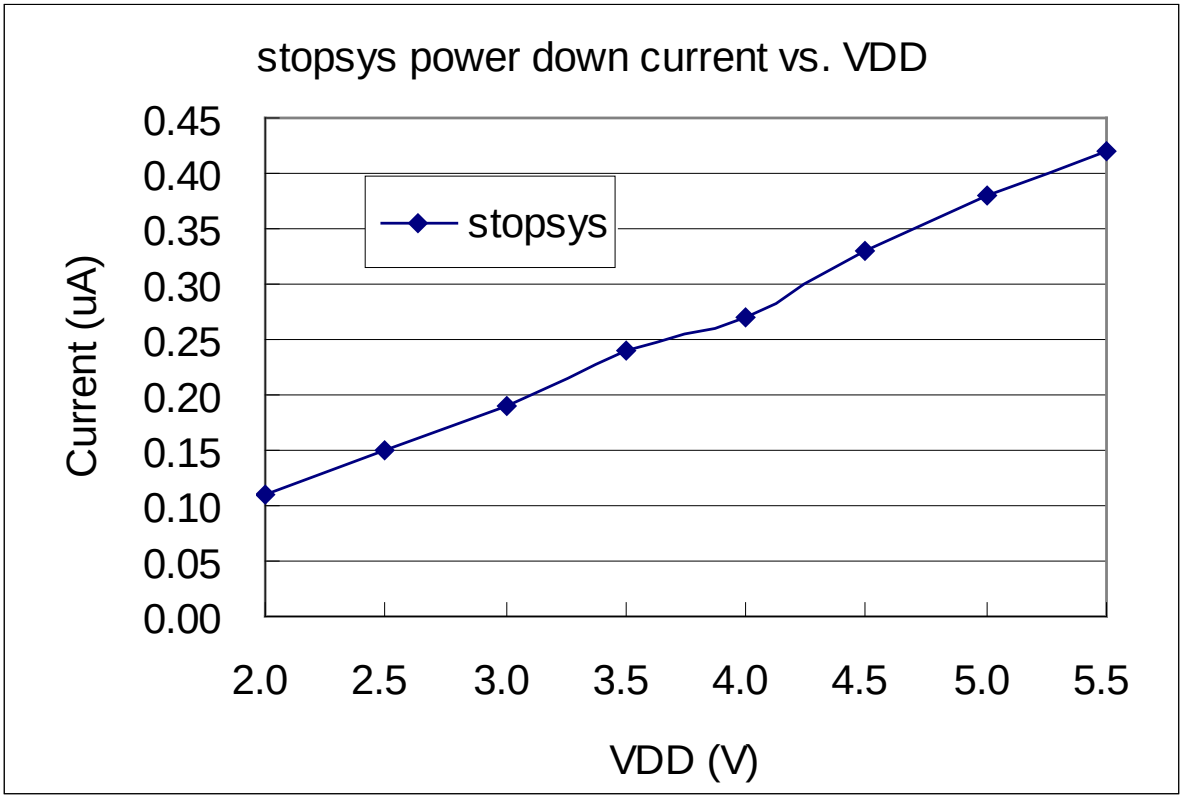
3.0
3.5
4.0
4.5
5.0
5.5

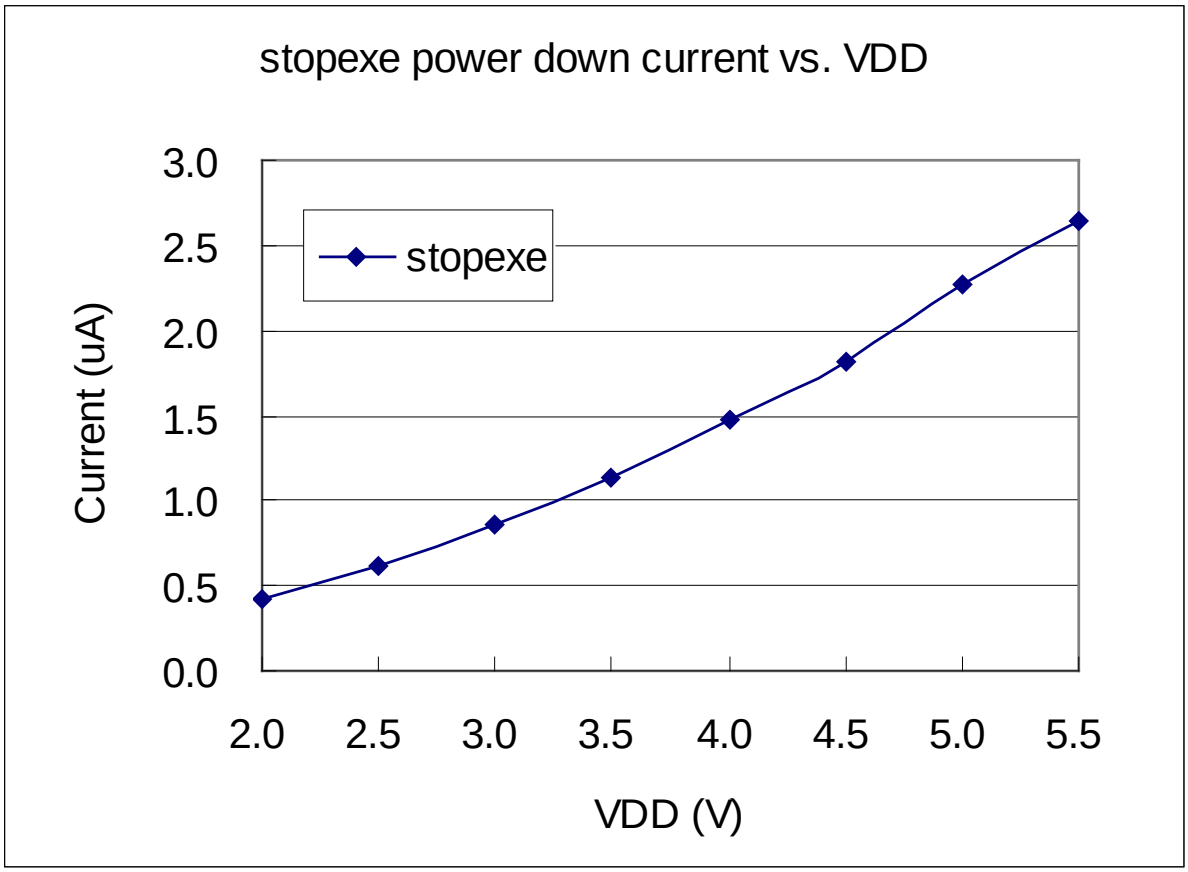


4.11. Typical IO input high/ low threshold voltage (V_{IH}/ V_{IL})



4.12. Typical power down current (I_{PD}) and power save current (I_{PS})





5. Functional Description

5.1. Program Memory – OTP

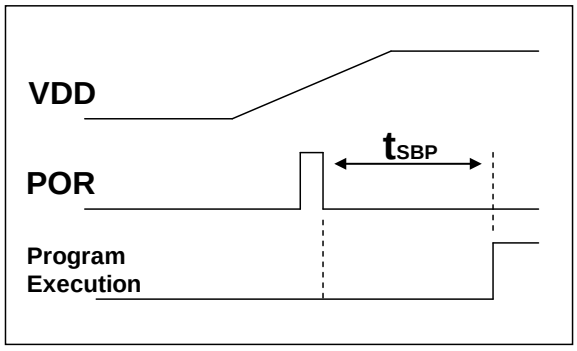
The OTP (One Time Programmable) program memory is used to store the program instructions to be executed. The OTP program memory may contains the data, tables and interrupt entry. After reset, the initial address for FPP0 is 0x000. The interrupt entry is 0x010 if used. The OTP program memory for MCU391 is a 1.75KW that is partitioned as Table 1. The OTP memory from address 0x700 to 0x7FF is for system using, address space from 0x001 to 0x00F and from 0x011 to 0x6FF is user program space.

Address	Function
0x000	FPP0 reset – goto instruction
0x001	User program
•	•
•	•
0x00F	User program
0x010	Interrupt entry address
0x011	User program
•	•
0x6FF	User program
0x700	System Using
•	•
0x7FF	System Using

Table 1: Program Memory Organization

5.2. Boot Up

POR (Power-On-Reset) is used to reset MCU391 when power up, the boot up time is about 2048 ILRC clock cycles. Customer must ensure the stability of supply voltage after power up, the power up sequence is shown in the Fig. 2 and t_{SBP} is the boot up time.



Boot up from Power-On Reset

Fig. 2: Power Up Sequence

5.3. Data Memory – SRAM

The access of data memory can be byte or bit operation. Besides data storage, the SRAM data memory is also served as data pointer of indirect access method and the stack memory.

The stack memory is defined in the data memory. The stack pointer is defined in the stack pointer register; the depth of stack memory of each processing unit is defined by the user. The arrangement of stack memory fully flexible and can be dynamically adjusted by the user.

For indirect memory access mechanism, the data memory is used as the data pointer to address the data byte. All the data memory could be the data pointer; it's quite flexible and useful to do the indirect memory access. All the 128 bytes data memory of MCU391 can be accessed by indirect access mechanism.

5.4. Oscillator and clock

There are two oscillator circuits provided by MCU391: internal high RC oscillator (IHRC) and internal low RC oscillator (ILRC), and these two oscillators are enabled or disabled by registers clkmd.4 and clkmd.2 independently. User can choose one of these two oscillators as system clock source and use ***clkmd*** register to target the desired frequency as system clock to meet different application.

Oscillator Module	Enable/Disable	Default after boot-up
IHRC	**clkmd**.4	Disabled
ILRC	**clkmd**.2	Enabled

Table 2: Oscillator Module

5.4.1. Internal High RC oscillator and Internal Low RC oscillator

After boot-up, only the ILRC oscillators are enabled. The frequency of IHRC can be calibrated to eliminate process variation by ***ihrcr*** register; normally it is calibrated to 16MHz. The frequency deviation can be within 2% normally after calibration and it still drifts slightly with supply voltage and operating temperature, the total drift rate is about ±5% for V_{DD}=2.2V~5.5V and -20^{o}C~70^{o}C operating conditions. Please refer to the measurement chart for IHRC frequency verse V_{DD} and IHRC frequency verse temperature.

The frequency of ILRC will vary by process, supply voltage and temperature, please refer to DC specification and do not use for accurate timing application.

5.4.2. IHRC calibration

The IHRC frequency may be different chip by chip due to manufacturing variation, MCU391 provide the IHRC frequency calibration to eliminate this variation, and this function can be selected when compiling user's program and the command will be inserted into user's program automatically. The calibration command is shown as below:

.ADJUST_IC SYSCLK=IHRC/(**p1**), IHRC=(**p2**)MHz, V_{DD}=(**p3**)V
Where,

p1=2, 4, 8, 16, 32; In order to provide different system clock.
p2=14 ~ 18; In order to calibrate the chip to different frequency, 16MHz is the usually one.
p3=2.3 ~ 5.5; In order to calibrate the chip under different supply voltage.

5.4.3. IHRC Frequency Calibration and System Clock

During compiling the user program, the options for IHRC calibration and system clock are shown as Table 3:

SYSCLK	CLKMD	IHRCR	Description
○ Set IHRC / 2	= 34h (IHRC / 2)	Calibrated	IHRC calibrated to 16MHz, CLK=8MHz (IHRC/2)
○ Set IHRC / 4	= 14h (IHRC / 4)	Calibrated	IHRC calibrated to 16MHz, CLK=4MHz (IHRC/4)
○ Set IHRC / 8	= 3Ch (IHRC / 8)	Calibrated	IHRC calibrated to 16MHz, CLK=2MHz (IHRC/8)
○ Set IHRC / 16	= 1Ch (IHRC / 16)	Calibrated	IHRC calibrated to 16MHz, CLK=1MHz (IHRC/16)
○ Set IHRC / 32	= 7Ch (IHRC / 32)	Calibrated	IHRC calibrated to 16MHz, CLK=0.5MHz (IHRC/32)
○ Set ILRC	= E4h (ILRC / 1)	Calibrated	IHRC calibrated to 16MHz, CLK=ILRC
○ Disable	No change	No Change	IHRC not calibrated, CLK not changed

Table 3: Options for IHRC Frequency Calibration

Usually, .ADJUST_IC will be the first command after boot up, in order to set the target operating frequency whenever stating the system. The program code for IHRC frequency calibration is executed only one time that occurs in writing the codes into OTP memory; after then, it will not be executed again. If the different option for IHRC calibration is chosen, the system status is also different after boot. The following shows the status of MCU391 for different option:

(1) **.**ADJUST_IC SYSCLK=IHRC/2, IHRC=16MHz, V_{DD}=5V

After boot up, CLKMD = 0x34:

- IHRC frequency is calibrated to 16MHz@V_{DD}=5V and IHRC module is enabled
- System CLK = IHRC/2 = 8MHz
- Watchdog timer is disabled, ILRC is enabled, PA5 is in input mode

(2) **.**ADJUST_IC SYSCLK=IHRC/4, IHRC=16MHz, V_{DD}=3.3V

After boot, CLKMD = 0x14:

- IHRC frequency is calibrated to 16MHz@V_{DD}=3.3V and IHRC module is enabled
- System CLK = IHRC/4 = 4MHz
- Watchdog timer is disabled, ILRC is enabled, PA5 is in input mode

(3) **.**ADJUST_IC SYSCLK=IHRC/8, IHRC=16MHz, V_{DD}=2.5V

After boot, CLKMD = 0x3C:

- IHRC frequency is calibrated to 16MHz@V_{DD}=2.5V and IHRC module is enabled
- System CLK = IHRC/8 = 2MHz
- Watchdog timer is disabled, ILRC is enabled, PA5 is in input mode

(4) **.**ADJUST_IC SYSCLK=IHRC/16, IHRC=16MHz, V_{DD}=2.3V

After boot, CLKMD = 0x1C:

- IHRC frequency is calibrated to 16MHz@V_{DD}=2.3V and IHRC module is enabled
- System CLK = IHRC/16 = 1MHz
- Watchdog timer is disabled, ILRC is enabled, PA5 is in input mode

(5) **.**ADJUST_IC SYSCLK=IHRC/32, IHRC=16MHz, V_{DD}=5V

After boot, CLKMD = 0x7C:

- IHRC frequency is calibrated to 16MHz@V_{DD}=5V and IHRC module is enabled
- System CLK = IHRC/32 = 500KHz
- Watchdog timer is disabled, ILRC is enabled, PA5 is in input mode

(6) .ADJUST_IC SYSCLK=ILRC, IHRC=16MHz, V_{DD}=5V

After boot, CLKMD = 0XE4:

- IHRC frequency is calibrated to 16MHz@V_{DD}=5V and IHRC module is disabled
- System CLK = ILRC
- Watchdog timer is disabled, ILRC is enabled, PA5 is input mode

(7) .ADJUST_IC DISABLE

After boot, CLKMD is not changed (Do nothing):

- IHRC is not calibrated and IHRC module is disabled
- System CLK = ILRC or IHRC/64
- Watchdog timer is enabled, ILRC is enabled, PA5 is input mode

5.4.4. System Clock and LVR levels

The clock source of system clock comes from IHRC or ILRC, the hardware diagram of system clock in the MCU391 is shown as Fig. 3.

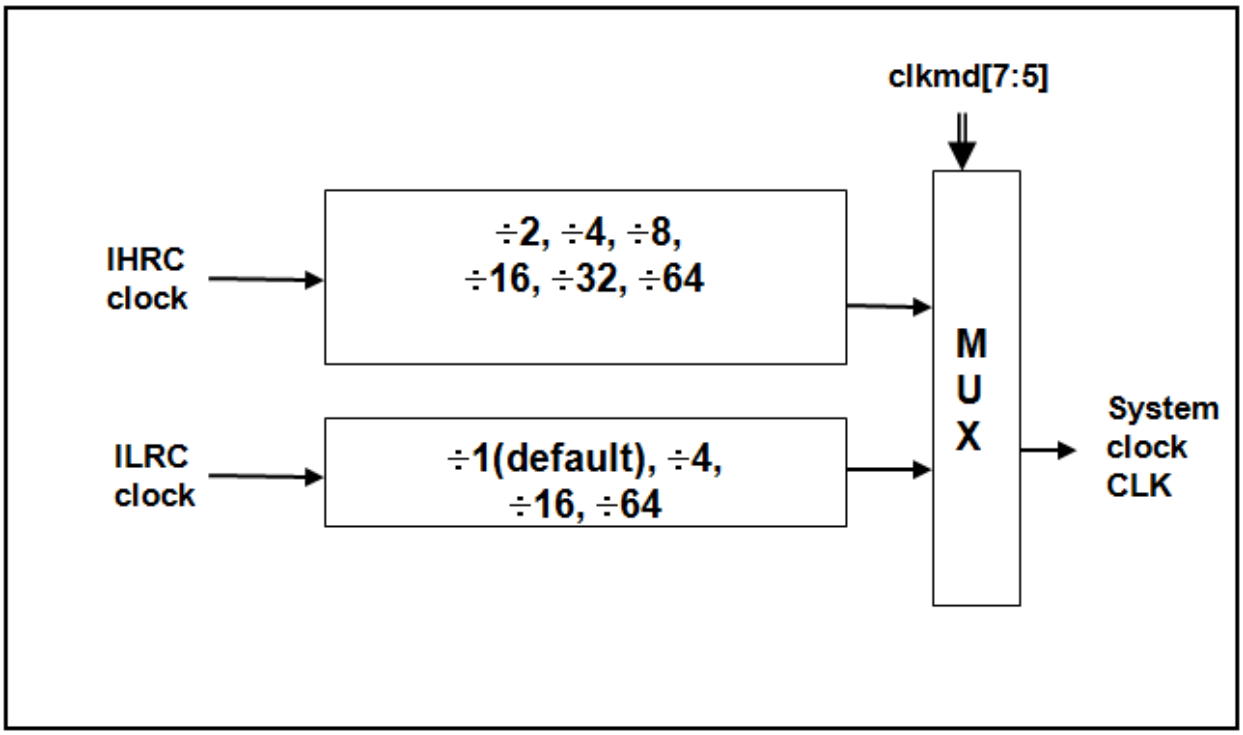


Fig. 3: Options of System Clock

User can choose different operating system clock depends on its requirement; the selected operating system clock should be combined with supply voltage and LVR level to make system stable. The LVR level will be selected during compilation. Please refer to Section 4.1.

5.4.5. System Clock Switching

After IHRC calibration, user may want to switch system clock to a new frequency or may switch system clock at any time to optimize the system performance and power consumption. Basically, the system clock of MCU391 can be switched among IHRC and ILRC by setting the ***clkmd*** register at any time; system clock will be the new one after writing to ***clkmd*** register immediately. Please notice that the original clock module can NOT be turned off at the same time as writing command to ***clkmd*** register. The examples are shown as below and more information about clock switching, please refer to the "Help" -> "Application Note" -> "IC Introduction" -> "Register Introduction" -> CLKMD".

Case 1: Switching system clock from ILRC to IHRC/2

```
...                          //  system clock is ILRC
CLKMD     =   0x34 ;         //  switch to IHRC/2 ，ILRC CAN NOT be disabled here
CLKMD.2   =   0 ;            //  ILRC CAN be disabled at this time
...
```

Case 2: Switching system clock from IHRC/2 to ILRC

```
...                          //  system clock is IHRC/2
CLKMD     =   0xF4 ;         //  switch to ILRC, IHRC CAN NOT be disabled here
CLKMD.4   =   0 ;            //  IHRC CAN be disabled at this time
...
```

Case 3: Switching system clock from IHRC/2 to IHRC/4

```
...                          //  system clock is IHRC/2, ILRC is enabled here
CLKMD     =   0X14 ;         //  switch to IHRC/4
...
```

Case 4: System may hang if it is to switch clock and turn off original oscillator at the same time

```
...                          //  system clock is ILRC
CLKMD     =   0x30 ;         //  CAN NOT switch clock from ILRC to IHRC/2 and turn off
                             //  ILRC oscillator at the same time
```

5.5. Comparator

One hardware comparator is built inside the MCU391; Fig.4 shows its hardware diagram. It can compare signals between two pins or with either internal reference voltage $V_{internal\ R}$ or internal band-gap reference voltage. The two signals to be compared, one is the plus input and the other one is the minus input. For the minus input of comparator can be PA3, PA4, Internal band-gap 1.20 volt, PB6, PB7 or $V_{internal\ R}$ selected by bit [3:1] of gpcc register, and the plus input of comparator can be PA4 or $V_{internal\ R}$ selected by bit 0 of gpcc register.

The output result can be enabled to output to PA0 directly, or sampled by Time2 clock (TM2_CLK) which comes from Timer2 module. The output can be also inversed the polarity by bit 4 of ***gpcc*** register, the comparator output can be used to request interrupt service.

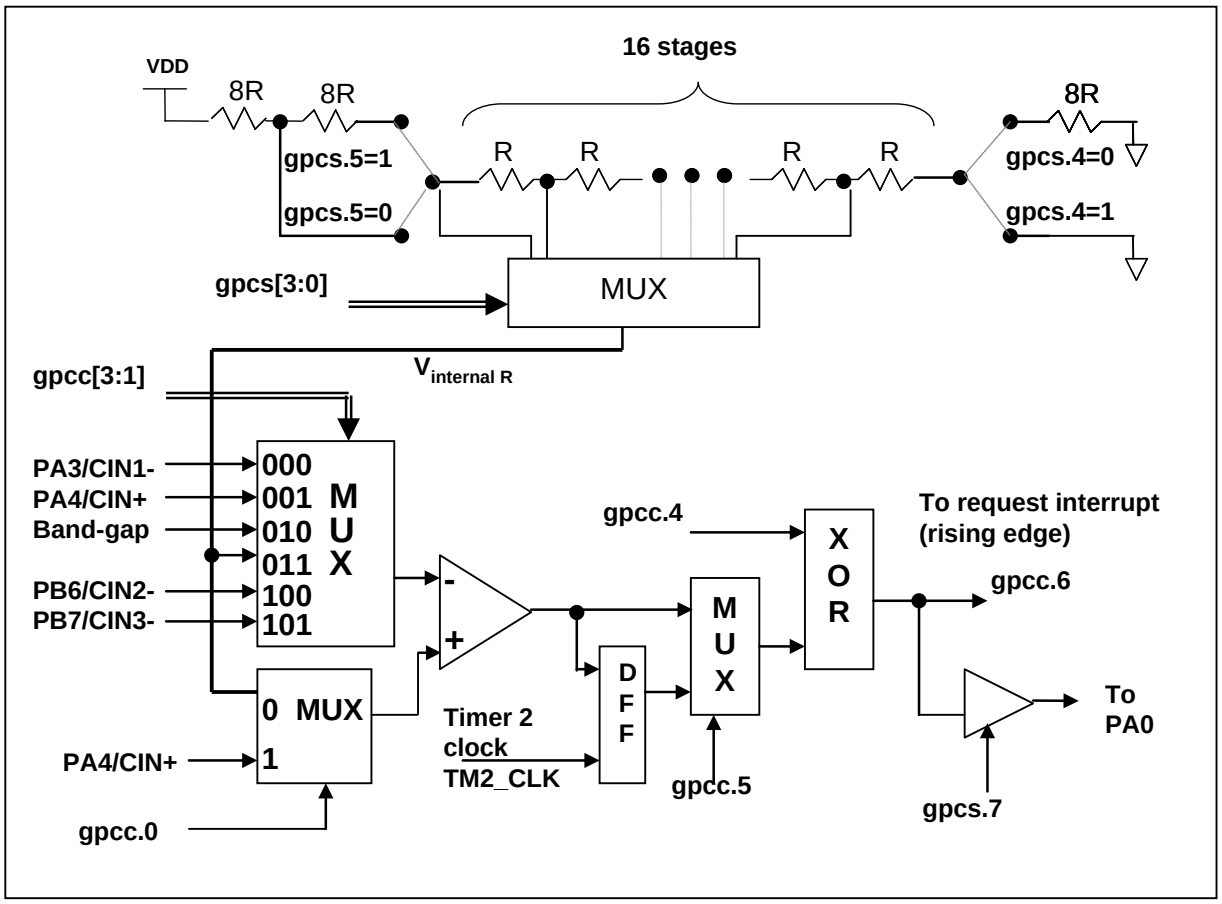


Fig.4: Hardware diagram of comparator

5.5.1. Internal reference voltage ($V_{internal\ R}$)

The internal reference voltage $V_{internal\ R}$ is built by series resistance to provide different level of reference voltage, bit 4 and bit 5 of ***gpcs*** register are used to select the maximum and minimum values of $V_{internal\ R}$ and bit [3:0] of ***gpcs*** register are used to select one of the voltage level which is deivided-by-16 from the defined maximum level to minimum level. Fig.5 to Fig.8 shows four conditions to have different reference voltage $V_{internal\ R}$. By setting the ***gpcs*** register, the internal reference voltage $V_{internal\ R}$ can be ranged from $(1/32)*V_{DD}$ to $(3/4)*V_{DD}$.

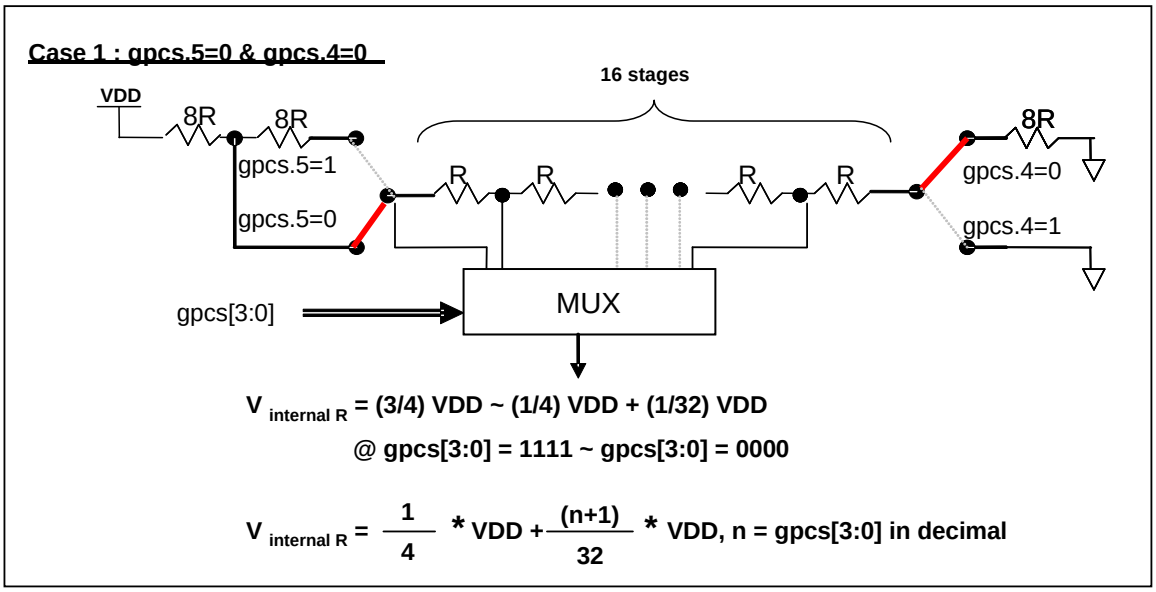


Fig.5: $V_{internal\ R}$ hardware connection if gpcs.5=0 and gpcs.4=0

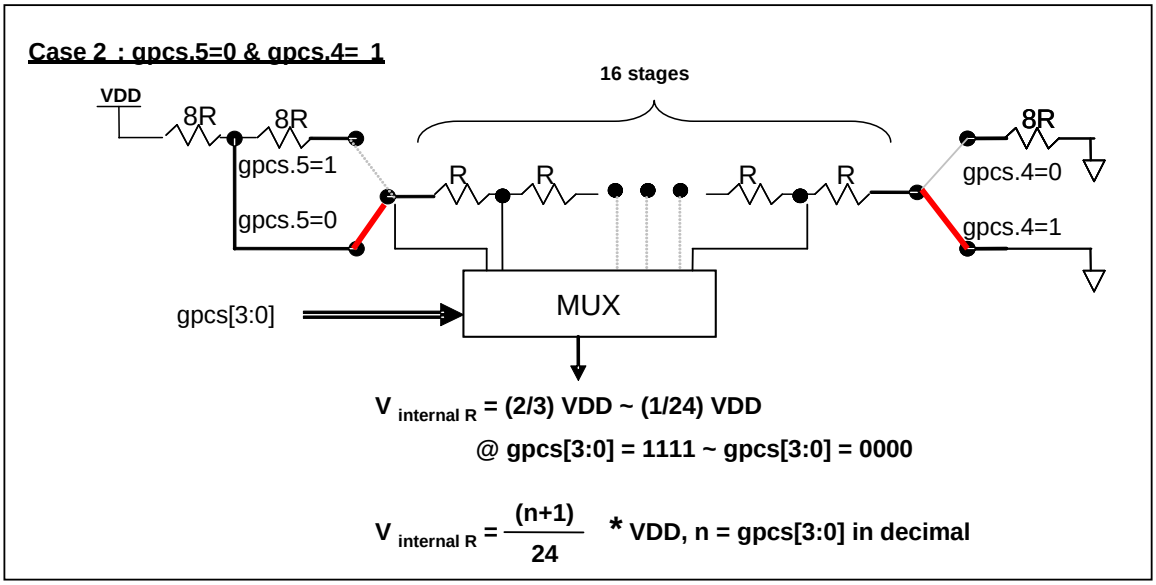


Fig.6: $V_{internal\ R}$ hardware connection if gpcs.5=0 and gpcs.4=1

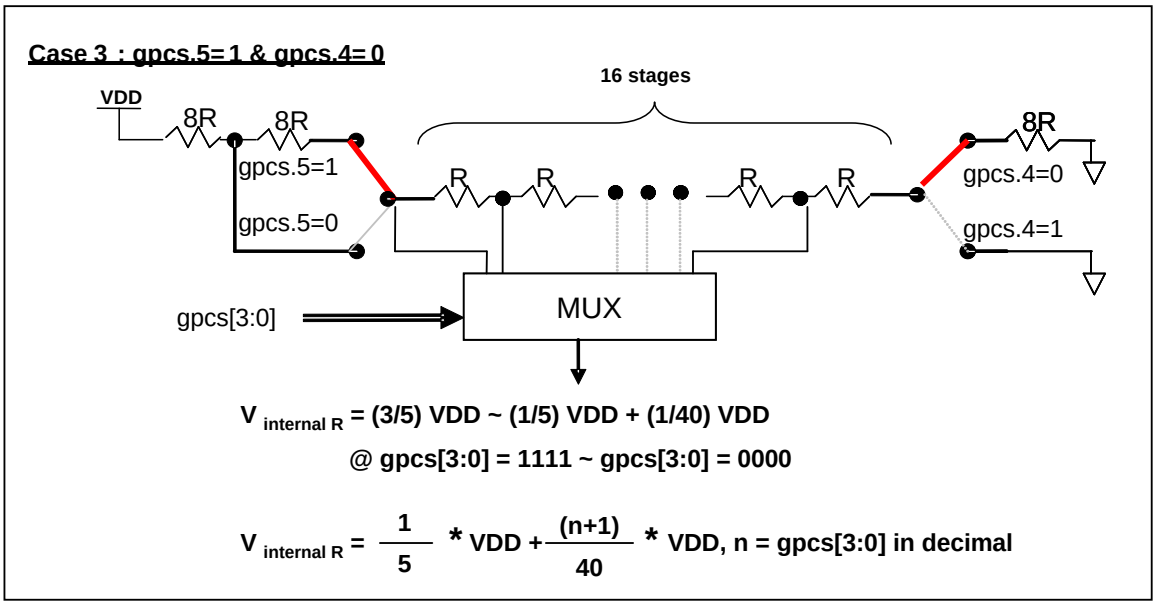


Fig.7: $V_{internal\ R}$ hardware connection if gpcs.5=1 and gpcs.4=0

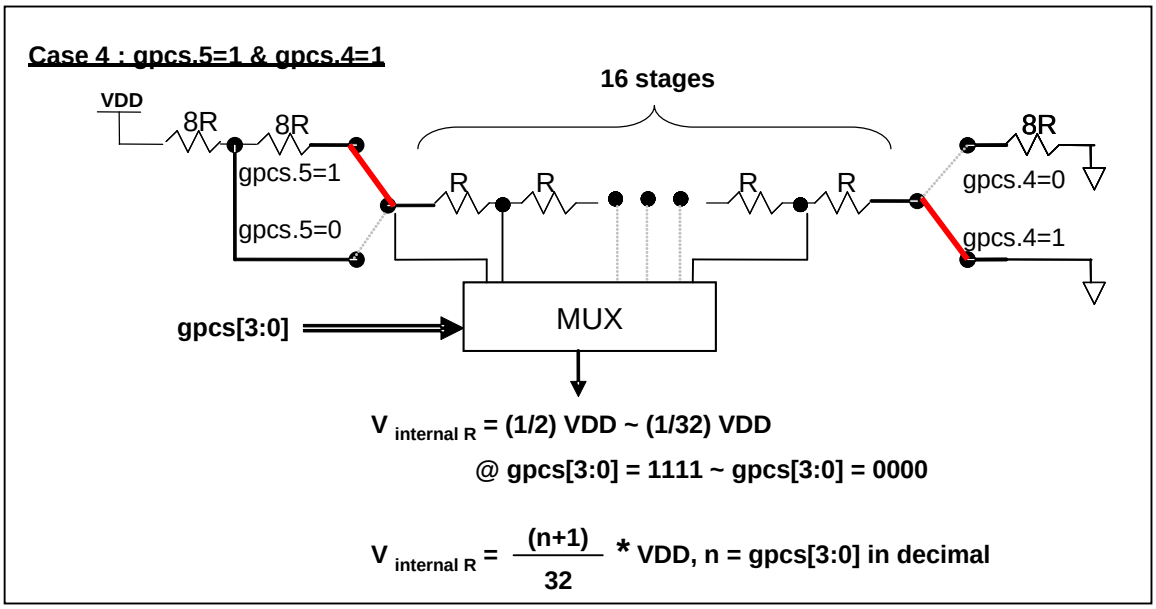


Fig.8: $V_{internal\ R}$ hardware connection if gpcs.5=1 and gpcs.4=1

5.5.2. Using the comparator

Case I:

Choosing PA3 as minus input and $V_{internal\ R}$ with (18/32)*V_{DD} voltage level as plus input, the comparator result will be output to PA0, the comparator result will be output to PA0. $V_{internal\ R}$ is configured as Fig. 10 and gpcs [3:0] = 4b'1001 (n=9) to have $V_{internal\ R}$ = (1/4)*V_{DD} + [(9+1)/32]*V_{DD} = (18/32)*V_{DD}.

```
gpcs    = 0b1_0_00_1001;      // output to PA0, V_internal R = V_DD*(18/32)
gpcc    = 0b1_0_0_0_000_0;    // enable comp, - input: PA3, + input: V_internal R
padier = 0bxxxx_0_xxx;        // disable PA3 digital input to prevent leakage current
```

Case 2:

Choosing $V_{internal\ R}$ as minus input with (14/32)*V_{DD} voltage level and PA4 as plus input, the comparator result will be inversed and then output to PA0. $V_{internal\ R}$ is configured as Fig. 11 and gpcs [3:0] = 4b'1101 (n=13) to have $V_{internal\ R}$ = [(13+1)/32]*V_{DD} = (14/32)*V_{DD}.

```
gpcs    = 0b1_1_1_1_1101;     // V_internal R = V_DD*(14/32)
gpcc    = 0b1_0_0_1_011_1;    // Inverse output, - input: V_internal R, + input: PA4
padier = 0bxxx_0_xxxx;        // disable PA4 digital input to prevent leakage current
```

5.5.3. Using the comparator and band-gap 1.20V

The internal band-gap module can provide 1.20 volt, it can measure the external supply voltage level. The band-gap 1.20 volt is selected as minus input of comparator and $V_{internal\ R}$ is selected as plus input, the supply voltage of $V_{internal\ R}$ is V_{DD}, the V_{DD} voltage level can be detected by adjusting the voltage level of $V_{internal\ R}$ to compare with band-gap. If N (gpcs[3:0] in decimal) is the number to let $V_{internal\ R}$ closest to band-gap 1.20 volt, the supply voltage V_{DD} can be calculated by using the following equations:

For using Case 1: V_{DD} = [32 / (N+9)] * 1.20 volt ;
For using Case 2: V_{DD} = [24 / (N+1)] * 1.20 volt ;
For using Case 3: V_{DD} = [40 / (N+9)] * 1.20 volt ;
For using Case 4: V_{DD} = [32 / (N+1)] * 1.20 volt ;

More information and sample code, please refer to IDE utility.

5.6. 16-bit Timer (Timer16)

MCU391 provide a 16-bit hardware timer (Timer16) and its clock source may come from system clock (CLK), internal high RC oscillator (IHRC), internal low RC oscillator (ILRC), PA0 or PA4. Before sending clock to the 16-bit counter, a pre-scaling logic with divided-by-1, 4, 16 or 64 is selectable for wide range counting. The 16-bit counter performs up-counting operation only, the counter initial values can be stored from data memory by issuing the ***stt16*** instruction and the counting values can be loaded to data memory by issuing the ***ldt16*** instruction. The interrupt request from Timer16 will be triggered by the selected bit which comes from bit[15:8] of this 16-bit counter, rising edge or falling edge can be optional chosen by register ***integs.4***. The hardware diagram of Timer16 is shown as Fig. 9.

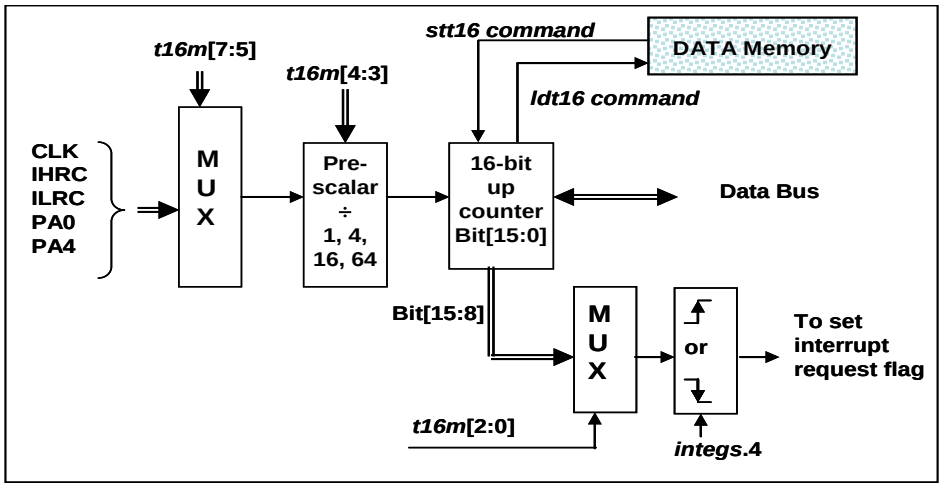


Fig. 9: Hardware diagram of Timer16

When using the Timer16, the syntax for Timer16 has been defined in the .INC file. There are three parameters to define the Timer16 using; 1st parameter is used to define the clock source of Timer16, 2nd parameter is used to define the pre-scalar and the 3rd one is to define the interrupt source.

```
T16M    IO_RW    0x06
$ 7~5:      STOP, SYSCLK, X, X, IHRC, X, ILRC, PA0_F          // 1st par.
$ 4~3:      /1, /4, /16, /64                                  // 2nd par.
$ 2~0:      BIT8, BIT9, BIT10, BIT11, BIT12, BIT13, BIT14, BIT15   // 3rd par.
```

User can choose the proper parameters of T16M to meet system requirement, examples as below:

```
$    T16M    SYSCLK, /64, BIT15;
     // choose (SYSCLK/64) as clock source, every 2^16 clock to set INTRQ.2=1
     // if system clock SYSCLK = IHRC / 2 = 8 MHz
     // SYSCLK/64 = 8 MHz/64 = 8 uS, about every 524 mS to generate INTRQ.2=1

$    T16M    PA0, /1, BIT8;
     // choose PA0 as clock source, every 2^9 to generate INTRQ.2=1
     // receiving every 512 times PA0 to generate INTRQ.2=1

$    T16M    STOP;
     // stop Timer16 counting
```

5.7. Watchdog Timer

The watchdog timer (WDT) is a counter with clock coming from ILRC and its frequency is about **55KHz**@5V. There are four different timeout periods of watchdog timer can be chosen by setting the ***misc*** register, it is:

- 8k ILRC clocks period if register misc[1:0]=00 (default)
- 16k ILRC clocks period if register misc[1:0]=01
- 64k ILRC clocks period if register misc[1:0]=10
- 256k ILRC clocks period if register misc[1:0]=11

The frequency of ILRC may drift a lot due to the variation of manufacture, supply voltage and temperature; user should reserve guard band for safe operation. Besides, the watchdog period will also be shorter than expected after Reset or Wakeup events. It is suggested to clear WDT by wdreset command after these events to ensure enough clock periods before WDT timeout.

When WDT is timeout, MCU391 will be reset to restart the program execution. The relative timing diagram of watchdog timer is shown as Fig.10.

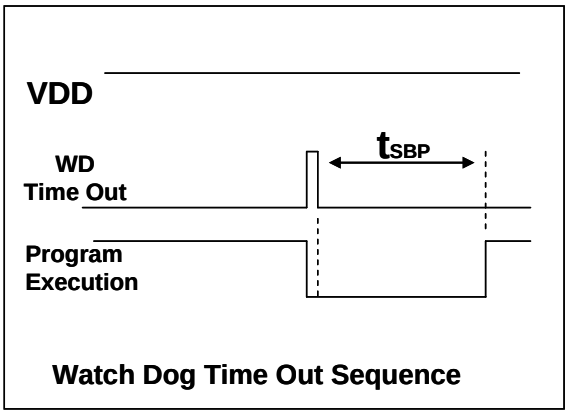


Fig. 10: Sequence of Watch Dog Time Out

5.8. Interrupt

There are eight interrupt lines for MCU391:

- External interrupt PA0 / PA5
- External interrupt PB0
- Timer16 interrupt
- Timer2 interrupt
- Timer3 interrupt
- GPC interrupt
- Two touch key interrupts (TK_OV and TK_END)

Every interrupt request line has its own corresponding interrupt control bit to enable or disable it; the hardware diagram of interrupt function is shown as Fig. 11. All the interrupt request flags are set by hardware and cleared by writing ***intrq*** register. When the request flags are set, it can be rising edge, falling edge or both, depending on the setting of register ***integs***. All the interrupt request lines are also controlled by ***engint*** instruction (enable global interrupt) to enable interrupt operation and ***disgint*** instruction (disable global interrupt) to disable it. The stack memory for interrupt is shared with data memory and its address is specified by stack register ***sp.*** Since the program counter is 16 bits width, the bit 0 of stack register ***sp*** should be kept 0.

Moreover, user can use ***pushaf*** / ***popaf*** instructions to store or restore the values of ***ACC*** and ***flag*** register ***to*** / ***from*** stack memory.

Since the stack memory is shared with data memory, user should manipulate the memory using carefully. By adjusting the memory location of stack point, the depth of stack pointer could be fully specified by user to achieve maximum flexibility of system.

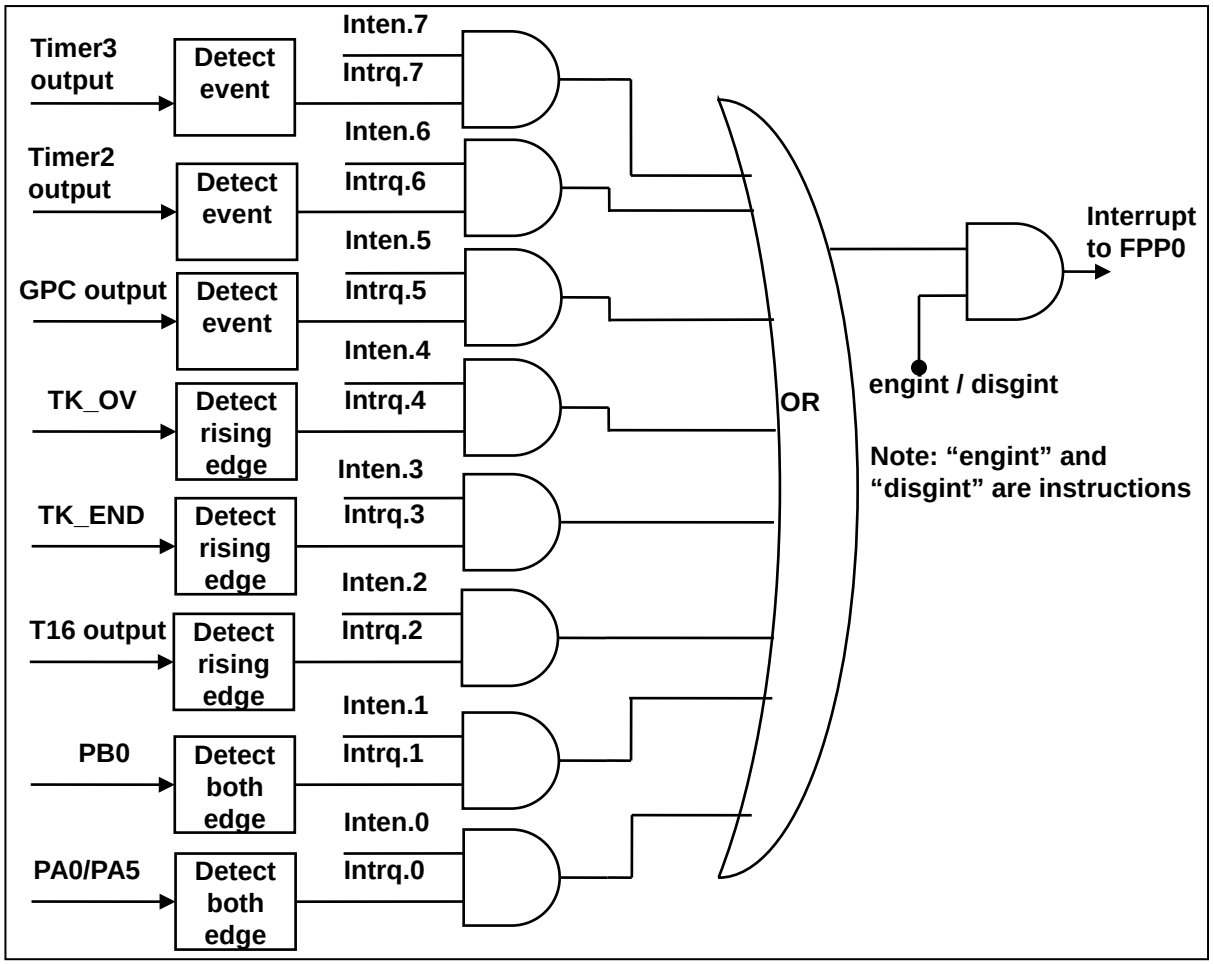


Fig. 11: Hardware diagram of Interrupt controller

Once the interrupt occurs, its operation will be:

- The program counter will be stored automatically to the stack memory specified by register ***sp.***
- New ***sp*** will be updated to ***sp+2.***
- Global interrupt will be disabled automatically.
- The next instruction will be fetched from address 0x010.

During the interrupt service routine, the interrupt source can be determined by reading the ***intrq*** register.

After finishing the interrupt service routine and issuing the ***reti*** instruction to return back, its operation will be:

- The program counter will be restored automatically from the stack memory specified by register *sp*.
- New ***sp*** will be updated to ***sp-2***.
- Global interrupt will be enabled automatically.
- The next instruction will be the original one before interrupt.

User must reserve enough stack memory for interrupt, two bytes stack memory for one level interrupt and four bytes for two levels interrupt. For interrupt operation, the following sample program shows how to handle the interrupt, noticing that it needs four bytes stack memory to handle interrupt and ***pushaf***.

```
void        FPPA0   (void)
{
    ...
    $  INTEN   PA0;          // INTEN =1; interrupt request when PA0 level changed
    INTRQ  =  0;             // clear INTRQ
    ENGINT                   // global interrupt enable
    ...
    DISGINT                  // global interrupt disable
    ...
}

void        Interrupt  (void)    // interrupt service routine
{
    PUSHAF                   // store ALU and FLAG register
    If    (INTRQ.0)
    {                        // Here for PA0 interrupt service routine
        // INTRQ  =  0;      // User can not use this instruction
        INTRQ.0  =  0;       // User is recommended to use this instruction
        ...
    }
    ...
    POPAF                    // restore ALU and FLAG register
}
```

5.9. Power-Save and Power-Down

There are three operational modes defined by hardware: ON mode, Power-Save mode and Power-Down modes. ON mode is the state of normal operation with all functions ON, Power-Save mode ("***stopexe***") is the state to reduce operating current and CPU keeps ready to continue, Power-Down mode ("***stopsys***") is used to save power deeply. Therefore, Power-Save mode is used in the system which needs low operating power with wake-up occasionally and Power-Down mode is used in the system which needs power down deeply with seldom wake-up. Table 4 shows the differences in oscillator modules between Power-Save mode ("***stopexe***") and Power-Down mode ("***stopsys***").

Differences in oscillator modules between STOPSYS and STOPEXE		
	IHRC	ILRC
STOPSYS	Stop	Stop
STOPEXE	No Change	No Change

Table 4: Differences in oscillator modules between STOPSYS and STOPEXE

5.9.1. Power-Save mode ("*stopexe*")

Using "***stopexe***" instruction to enter the Power-Save mode, only system clock is disabled, remaining all the oscillator modules be active. For CPU, it stops executing; however, for Timer16, counter keep counting if its clock source is not the system clock. The wake-up sources for "***stopexe***" can be IO-toggle or Timer16 counts to set values when the clock source of Timer16 is IHRC or ILRC modules. Wake-up from input pins can be considered as a continuation of normal execution, ***nop*** command is recommended to follow the ***stopexe*** command, the detail information for Power-Save mode shown below:

- IHRC and ILRC oscillator modules: No change, keep active if it was enabled

- System clock: Disable, therefore, CPU stops execution
- OTP memory is turned off
- Timer16: Stop counting if system clock is selected or the corresponding oscillator module is disabled; otherwise, it keeps counting.
- Wake-up sources: IO toggle or Timer16.

The watchdog timer must be disabled before issuing the "***stopexe***" command, the example is shown as below:

```
CLKMD.En_WatchDog    =    0;          // disable watchdog timer
stopexe;
nop;
....                                  // power saving
Wdreset;
CLKMD.En_WatchDog    =    1;          // enable watchdog timer
```

Another example shows how to use Timer16 to wake-up from "***stopexe***":

```
$ T16M    IHRC, /1, BIT8              // Timer16 setting
...
WORD      count      =    0;
STT16     count;
stopexe;
nop;
...
```

The initial counting value of Timer16 is zero and the system will be waken up after the Timer16 counts 256 IHRC clocks.

5.9.2. Power-Down mode ("*stopsys*")

Power-Down mode is the state of deeply power-saving with turning off all the oscillator modules. By using the "*stopsys*" instruction, this chip will be put on Power-Down mode directly. The following shows the internal status of MCU391 in detail when "***stopsys***" command is issued:

- All the oscillator modules are turned off
- OTP memory is turned off
- The contents of SRAM and registers remain unchanged
- Wake-up sources: ANY IO toggle.
- If PA is input mode and set to analog input by ***padier*** register, it can NOT be used to wake-up the system.

Wake-up from input pins can be considered as a continuation of normal execution. To minimize power consumption, all the I/O pins should be carefully manipulated before entering power-down mode. The reference sample program for power down is shown as below:

```
CMKMD   =    0xF4;     //    Change clock from IHRC to ILRC, disable watchdog timer
CLKMD.4 =    0;        //    disable IHRC
...
while (1)
{
      STOPSYS;         //    enter power-down
      if (...) break;  //    if wakeup happen and check OK, then return to high speed,
                       //    else stay in power-down mode again.
}
CLKMD   =    0x34;     //    Change clock from ILRC to IHRC/2
```

5.9.3. Wake-up

After entering the Power-Down or Power-Save modes, the MCU391 can be resumed to normal operation by toggling IO pins, Timer16 interrupt is available for Power-Save mode ONLY. Table 5 shows the differences in wake-up sources between STOPSYS and STOPEXE.

Differences in wake-up sources between STOPSYS and STOPEXE		
	IO Toggle	T16 Interrupt
STOPSYS	Yes	No
STOPEXE	Yes	Yes

Table 5: Differences in wake-up sources between Power-Save mode and Power-Down mode

When using the IO pins to wake-up the MCU391, registers ***padier and pbdier*** should be properly set to enable the wake-up function for every corresponding pin. The time for normal wake-up is about 2048 ILRC clocks counting from wake-up event.

Suspend mode	Wake-up mode	Wake-up time (t_{WUP}) from IO toggle
STOPEXE suspend	normal wake-up	2048 * T_{ILRC}, Where T_{ILRC} is the clock period of ILRC
STOPSYS suspend	normal wake-up	2048 * T_{ILRC}, Where T_{ILRC} is the clock period of ILRC

Table 6: Suspend mode / Wake-up mode / Wake-up time from IO toggle

5.10. IO Pins

Other than PA5, all the pins can be independently set into two states output or input by configuring the data registers (***pa, pb***), control registers (***pac, pbc***) and pull-high registers (***paph, pbph***). All these pins have Schmitt-trigger input buffer and output driver with CMOS level. When it is set to output low, the pull-up resistor is turned off automatically. If user wants to read the pin state, please notice that it should be set to input mode before reading the data port; if user reads the data port when it is set to output mode, the reading data comes from data register, NOT from IO pad. As an example, Table 7 shows the configuration table of bit 0 of port A. The hardware diagram of IO buffer is also shown as Fig. 12.

pa.0	*pac.0*	*paph.0*	Description
X	0	0	Input without pull-up resistor
X	0	1	Input with pull-up resistor
0	1	X	Output low without pull-up resistor
1	1	0	Output high without pull-up resistor
1	1	1	Output high with pull-up resistor

Table 7: PA0 Configuration Table

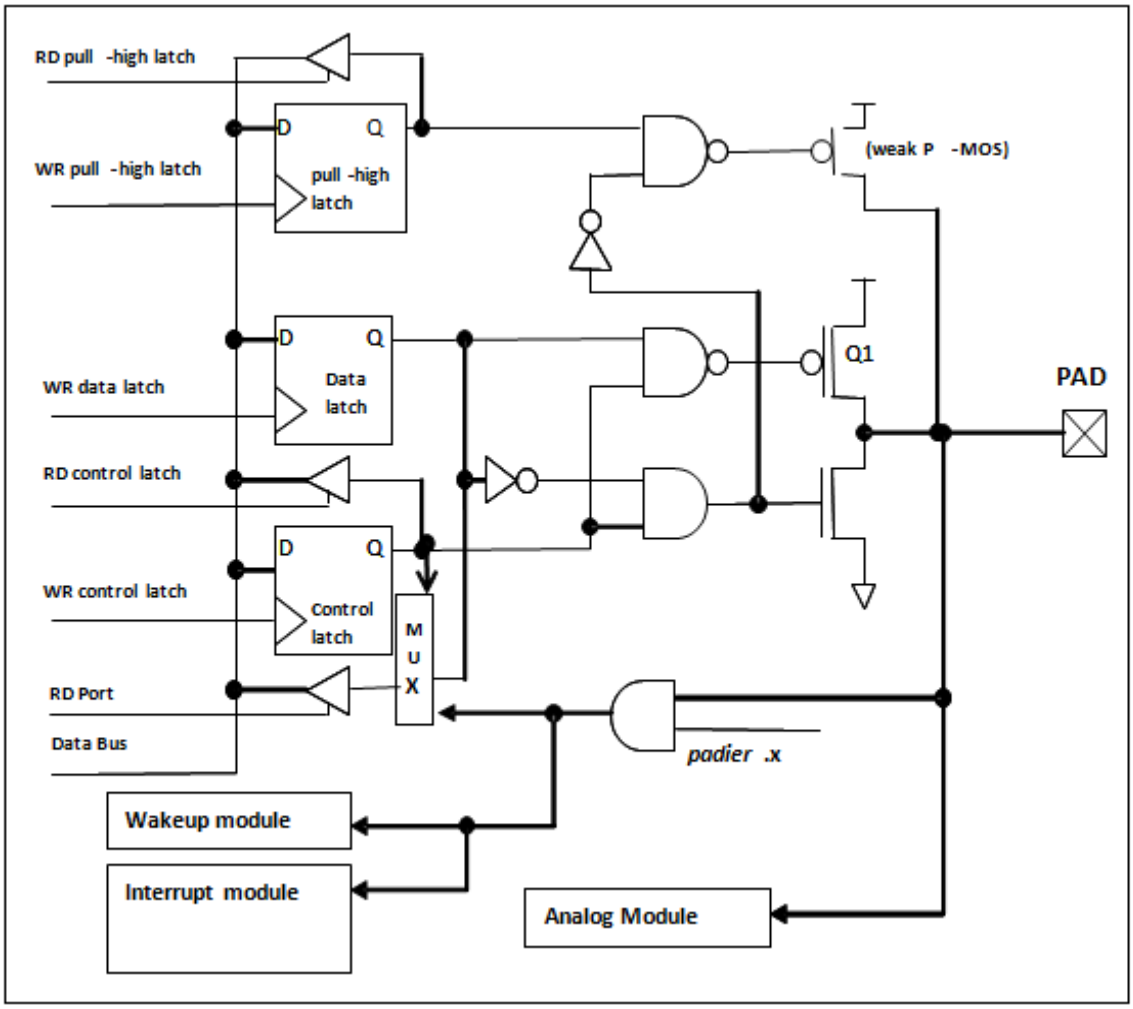


Fig. 12: Hardware diagram of IO buffer

Other than PA5, all the IO pins have the same structure; PA5 can be open-drain ONLY when setting to output mode (without Q1). When MCU391 is put in power-down or power-save mode, every pin can be used to wake-up system by toggling its state. Therefore, those pins needed to wake-up system must be set to input mode and set the corresponding bits of registers ***padier*** to high***.*** The same reason, ***padier***.0 should be set to high when PA0 is used as external interrupt pin.

5.11. Reset

There are many causes to reset the MCU391, once reset is asserted, all the registers in MCU391 will be set to default values, system should be restarted once abnormal cases happen, or by jumping program counter to address 'h0. The data memory is in uncertain state when reset comes from power-up and LVR; however, the content will be kept when reset comes from PRSTB pin or WDT timeout.

5.12. 8-bit Timer (Timer2/Timer3) with PWM generation

Two 8-bit hardware timers (Timer2 and Timer3) with PWM generation is implemented in the MCU391, The following descriptions thereinafter are for Timer2 only. It is because Timer3 have same structure with Timer2. Please refer to Fig. 13 shown its hardware diagram, the clock sources of Timer2 may come from system clock, internal high RC oscillator (IHRC), internal low RC oscillator (ILRC), comparator, PB0, PA0 and PA4, bit [7:4] of register tm2c are used to select the clock of Timer2. Please notice that if IHRC is selected for Timer2 clock source, the clock sent to Timer2 will keep running when using ICE in halt state. The output of Timer2 can be sent to pin PA3, PB2 or PB4, depending on bit [3-2] of tm2c register. A clock pre-scaling module is provided with divided-by-1, 4, 16, and 64 options, controlled by bit [6:5] of tm2s register; one scaling module with divided-by-1~31 is also provided and controlled by bit [4:0] of tm2s register. In conjunction of pre-scaling function and scaling function, the frequency of Timer2 clock (TM2_CLK) can be wide range and flexible.

The Timer2 counter performs 8-bit up-counting operation only; the counter values can be set or read back by tm2ct register. The 8-bit counter will be clear to zero automatically when its values reach for upper bound register, the upper bound register is used to define the period of timer or duty of PWM. There are two operating modes for Timer2: period mode and PWM mode; period mode is used to generate periodical output waveform or interrupt event; PWM mode is used to generate PWM output waveform with optional 6-bit to 8-bit PWM resolution, Fig. 14 shows the timing diagram of Timer2 for both period mode and PWM mode.

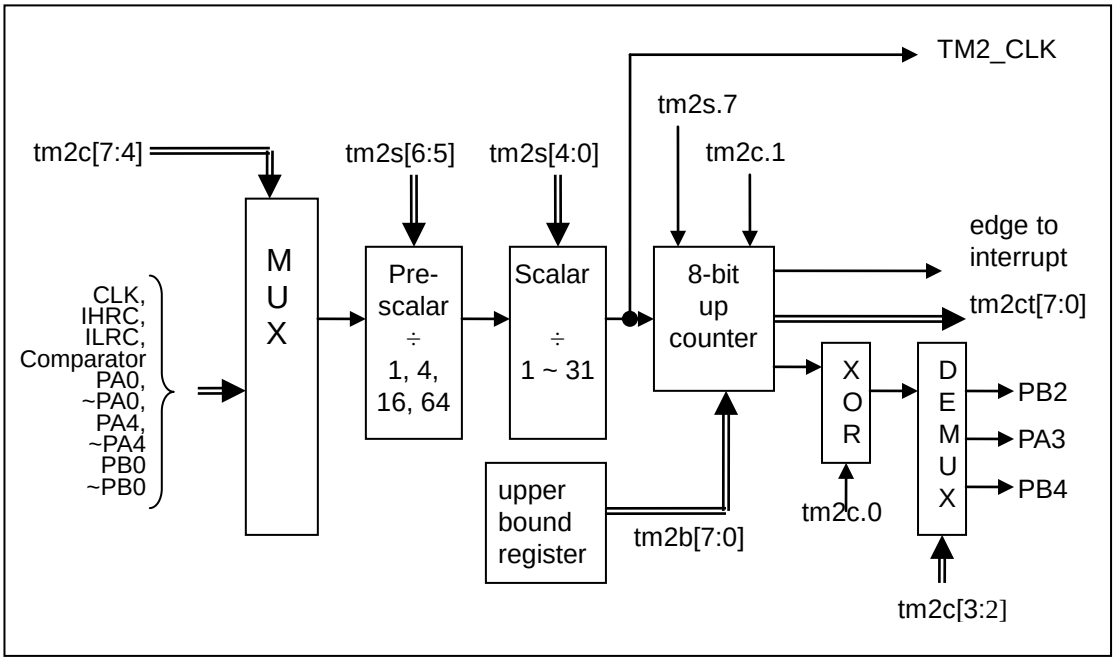
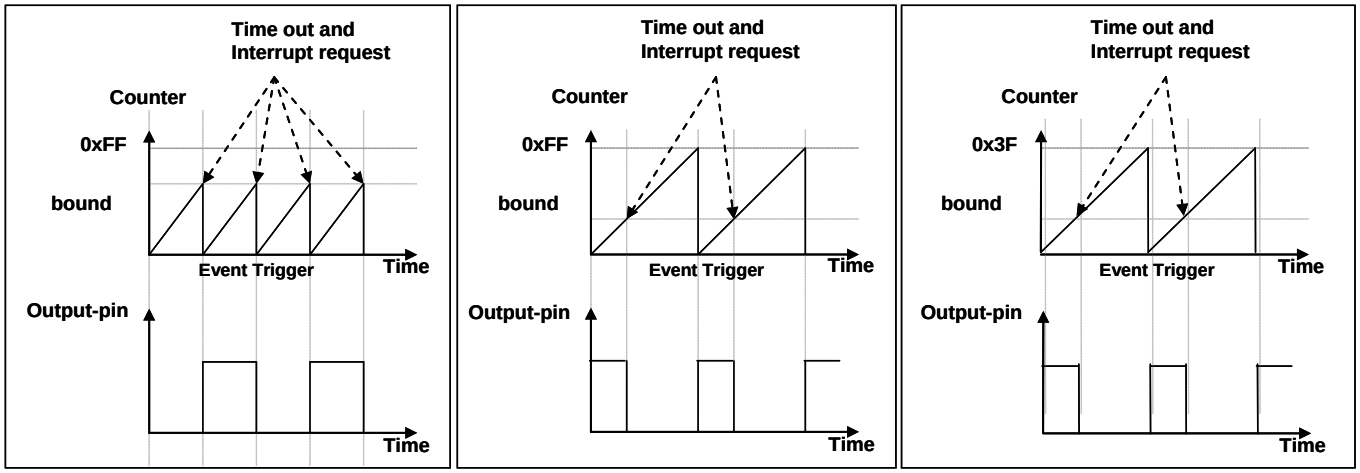


Fig. 13: Timer2 hardware diagram

The output of Timer3 can be sent to pin PB5, PB6 or PB7.



Mode 0 – Period Mode **Mode 1 – 8-bit PWM Mode** **Mode 1 – 6-bit PWM Mode**

Fig. 14: Timing diagram of Timer2 in period mode and PWM mode (tm2c.1=1)

5.12.1. Using the Timer2 to generate periodical waveform

If periodical mode is selected, the duty cycle of output is always 50%; its frequency can be summarized as below:

Frequency of Output = Y ÷ [2 × (K+1) × S1 × (S2+1)]

Where, Y = tm2c[7:4] : frequency of selected clock source
K = tm2b[7:0] : bound register in decimal
S1 = tm2s[6:5] : pre-scalar (1, 4, 16, 64)
S2 = tm2s[4:0] : scalar register in decimal (1 ~ 31)

Example 1:

tm2c = 0b0001_1000, Y=8MHz
tm2b = 0b0111_1111, K=127
tm2s = 0b0_00_00000, S1=1, S2=0
➔ frequency of output = 8MHz ÷ [2 × (127+1) × 1 × (0+1)] = 31.25kHz

Example 2:

tm2c = 0b0001_1000, Y=8MHz
tm2b = 0b0111_1111, K=127
tm2s[7:0] = 0b0_11_11111, S1=64 , S2 = 31
➔ frequency = 8MHz ÷ (2 × (127+1) × 64 × (31+1)) =15.25Hz

Example 3:

tm2c = 0b0001_1000, Y=8MHz
tm2b = 0b0000_1111, K=15
tm2s = 0b0_00_00000, S1=1, S2=0
➔ frequency = 8MHz ÷ (2 × (15+1) × 1 × (0+1)) = 250kHz

Example 4:

tm2c = 0b0001_1000, Y=8MHz
tm2b = 0b0000_0001, K=1
tm2s = 0b0_00_00000, S1=1, S2=0
➔ frequency = 8MHz ÷ (2 × (1+1) × 1 × (0+1)) =2MHz

The sample program for using the Timer2 to generate periodical waveform to PA3 is shown as below:

```
void    FPPA0 (void)
{
    . ADJUST_IC     SYSCLK=IHRC/2, IHRC=16MHz, VDD=5V
    …
    tm2ct = 0x0;
    tm2b = 0x7f;
    tm2s = 0b0_00_00001;            //  8-bit PWM, pre-scalar = 1, scalar = 2
    tm2c = 0b0001_10_0_0;           //  system clock, output=PA3, period mode
    while(1)
    {
        nop;
    }
}
```

5.12.2. Using the Timer2 to generate 8-bit PWM waveform

If 8-bit PWM mode is selected, it should set ***tm2c***[1]=1 and ***tm2s***[7]=0, the frequency and duty cycle of output waveform can be summarized as below:

Frequency of Output = Y ÷ [256 × S1 × (S2+1)]

Duty of Output = (K＋1) ÷ 256

Where, Y = tm2c[7:4] : frequency of selected clock source
K = tm2b[7:0] : bound register in decimal
S1= tm2s[6:5] : pre-scalar (1, 4, 16, 64)
S2 = tm2s[4:0] : scalar register in decimal (1 ~ 31)

Example 1:

tm2c = 0b0001_1010, Y=8MHz
tm2b = 0b0111_1111, K=127
tm2s = 0b0_00_00000, S1=1, S2=0
➔ frequency of output = 8MHz ÷ (256 × 1 × (0+1)) = 31.25kHz
➔ duty of output = [(127+1) ÷ 256] × 100% = 50%

Example 2:

tm2c = 0b0001_1010, Y=8MHz
tm2b = 0b0111_1111, K=127
tm2s = 0b0_11_11111, S1=64, S2=31
➔ frequency of output = 8MHz ÷ (256 × 64 × (31+1)) = 15.25Hz
➔ duty of output = [(127+1) ÷ 256] × 100% = 50%

Example 3:

tm2c = 0b0001_1010, Y=8MHz
tm2b = 0b1111_1111, K=255
tm2s = 0b0_00_00000, S1=1, S2=0
➔ frequency of output = 8MHz ÷ (256 × 1 × (0+1)) = 31.25kHz
➔ duty of output = [(255+1) ÷ 256] × 100% = 100%

Example 4:

tm2c = 0b0001_1010, Y=8MHz
tm2b = 0b0000_1001, K = 9
tm2s = 0b0_00_00000, S1=1, S2=0
➔ frequency of output = 8MHz ÷ (256 × 1 × (0+1)) = 31.25kHz
➔ duty of output = [(9+1) ÷ 256] × 100% = 3.9%

The sample program for using the Timer2 to generate PWM waveform from PA3 is shown as below:

```
void    FPPA0 (void)
{
    .ADJUST_IC    SYSCLK=IHRC/2, IHRC=16MHz, VDD=5V
    wdreset;
    tm2ct = 0x0;
    tm2b = 0x7f;
    tm2s = 0b0_00_00001;        //    8-bit PWM, pre-scalar = 1, scalar = 2
    tm2c = 0b0001_10_1_0;       //    system clock, output=PA3, PWM mode
    while(1)
    {
        nop;
    }
}
```

5.12.3. Using the Timer2 to generate 6-bit PWM waveform

If 6-bit PWM mode is selected, it should set ***tm2c***[1]=1 and ***tm2s***[7]=1, the frequency and duty cycle of output waveform can be summarized as below:

Frequency of Output = Y ÷ [64 × S1 × (S2+1)]

Duty of Output = [(K＋1) ÷ 64] × 100%

Where, tm2c[7:4] = Y : frequency of selected clock source
tm2b[7:0] = K : bound register in decimal
tm2s[6:5] = S1 : pre-scalar (1, 4, 16, 64)
tm2s[4:0] = S2 : scalar register in decimal (1 ~ 31)

Example 1:

tm2c = 0b0001_1010, Y=8MHz
tm2b = 0b0001_1111, K=31
tm2s = 0b1_00_00000, S1=1, S2=0
➔ frequency of output = 8MHz ÷ (64 × 1 × (0+1)) = 125kHz
➔ duty = [(31+1) ÷ 64] × 100% = 50%

Example 2:

tm2c = 0b0001_1010, Y=8MHz

tm2b = 0b0001_1111, K=31

tm2s = 0b1_11_11111, S1=64, S2=31

➔ frequency of output = 8MHz ÷ (64 × 64 × (31+1)) = 61.03 Hz

➔ duty of output = [(31+1) ÷ 64] × 100% = 50%

Example 3:

tm2c = 0b0001_1010, Y=8MHz

tm2b = 0b0011_1111, K=63

tm2s = 0b1_00_00000, S1=1, S2=0

➔ frequency of output = 8MHz ÷ (64 × 1 × (0+1)) = 125kHz

➔ duty of output = [(63+1) ÷ 64] × 100% = 100%

Example 4:

tm2c = 0b0001_1010, Y=8MHz

tm2b = 0b0000_0000, K=0

tm2s = 0b1_00_00000, S1=1, S2=0

➔ frequency = 8MHz ÷ (64 × 1 × (0+1)) = 125kHz

➔ duty = [(0+1) ÷ 64] × 100% =1.5%

5.13. Touch Function

Touch pads operate in one of several ways, including capacitive sensing and resistive touchscreen. The Touch detecting circuit in MCU391 is the method of capacitive sensing, detecting the capacitive virtual ground effect of a finger, or the capacitance between sensors.

An accurate, external capacitor CS is required to be applied between PA7/CS pad and power. In the mean time, user should set the code option PA7_Sel to be As CS to configure it as CS pad, instead of PA7.

Before the Touch converting progress starts, user selects the Touch pad to be measured by setting TKE1 & TKE2 registers. After user issues a Touch START command by writing “0x10” into TCC register, the capacitor CS will be fully discharged to VSS firstly, then it will be charged toward VCC clock by clock. The charging speed is determined by the capacitance value of the selected Touch pad. By reading the Touch Counter value from TKCH & TKCL registers, user can monitor the capacitance value change of the Touch pad.

The periodically charging progress will be stopped automatically when the voltage reach an internal generated VREF. The VREF voltage is selectable from 0.2*VCC, 0.3*VCC, 0.4*VCC and 0.5*VCC. The capacitor CS discharging time is also selectable from 32, 64 and 128 Touch clocks. The larger the capacitance value, the longer the discharge time is needed to fully discharge the capacitor to VSS.

There are also several frequency options selectable for Touch clock. However, in case the 128 Touch clocks are not long enough to fully discharge the CS capacitor, MCU391 supports a special manual discharge function. User can start this manual discharge progress by writing “0x30” into TCC register instead of “0x10”. After a certain discharge time controlled by the user, user can issue a Touch START (0x10) command to continue this touch conversion progress. Or user can also abort the conversion progress by writing “0x00” into TCC register.

The value reads from Touch Counter is related to the ratio of CS and CP, while CP represents the total capacitance that is the combination of PCB, wire and touch pad whose capacitance can be varied by human finger’s touch. Once the CP value is altered, the periods required to charge the CS to VREF shorten. By counting the discrepancy of clock periods, the circuitry can decide if the touch pad is enabled.

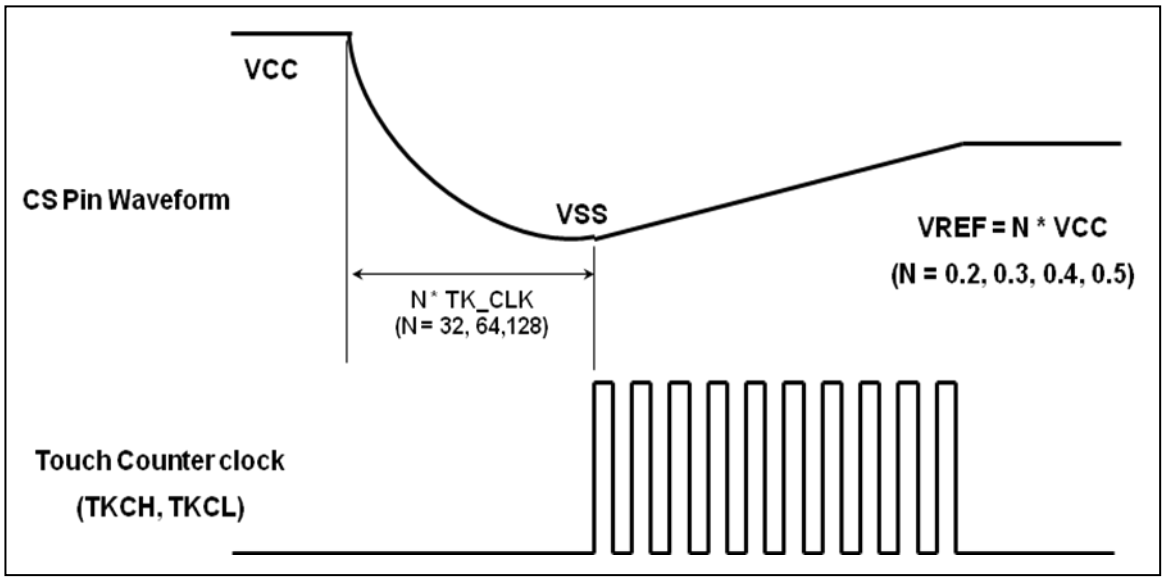


Fig. 15: Timing diagram of Touch converting progress

6. IO Registers

6.1. ACC Status Flag Register (*flag*), IO address = 0'h00

Bit	Reset	R/W	Description
7 - 4	-	-	Reserved[1]. These four bits are "1" when read.
3	-	R/W	OV (Overflow). This bit is set whenever the sign operation is overflow.
2	-	R/W	AC (Auxiliary Carry). There are two conditions to set this bit, the first one is carry out of low nibble in addition operation, and the other one is borrow from the high nibble into low nibble in subtraction operation.
1	-	R/W	C (Carry). There are two conditions to set this bit, the first one is carry out in addition operation, and the other one is borrow in subtraction operation. Carry is also affected by shift with carry instruction.
0	-	R/W	Z (Zero). This bit will be set when the result of arithmetic or logic operation is zero; Otherwise, it is cleared.

6.2. Stack Pointer Register (*sp*), IO address = 0x02

Bit	Reset	R/W	Description
7 - 0	-	R/W	Stack Pointer Register. Read out the current stack pointer, or write to change the stack pointer. Please notice that bit 0 should be kept 0 due to program counter is 16 bits.

6.3. Clock Mode Register (*clkmd*), IO address = 0x03

<table>
<tr><th>Bit</th><th>Reset</th><th>R/W</th><th colspan="2">Description</th></tr>
<tr><td rowspan="10">7 - 5</td><td rowspan="10">111</td><td rowspan="10">R/W</td><td colspan="2">System clock selection:</td></tr>
<tr><td>Type 0, clkmd[3]=0</td><td>Type 1, clkmd[3]=1</td></tr>
<tr><td>000: IHRC/4</td><td>000: IHRC/16</td></tr>
<tr><td>001: IHRC/2</td><td>001: IHRC/8</td></tr>
<tr><td>01x: reserved</td><td>010: ILRC/16 (ICE doesn't support)</td></tr>
<tr><td>100: reserved</td><td>011: IHRC/32</td></tr>
<tr><td>101: reserved</td><td>100: IHRC/64</td></tr>
<tr><td>110: ILRC/4</td><td>110: ILRC/64 (ICE doesn't support)</td></tr>
<tr><td>111: ILRC (default)</td><td>1x1: reserved.</td></tr>
<tr><td>4</td><td>0</td><td>R/W</td><td colspan="2">IHRC oscillator Enable. 0 / 1: disable / enable</td></tr>
<tr><td>3</td><td>0</td><td>R/W</td><td colspan="2">Clock Type Select. This bit is used to select the clock type in bit [7:5].
0 / 1: Type 0 / Type 1</td></tr>
<tr><td>2</td><td>1</td><td>R/W</td><td colspan="2">ILRC Enable. 0 / 1: disable / enable
If ILRC is disabled, watchdog timer is also disabled.</td></tr>
<tr><td>1</td><td>1</td><td>R/W</td><td colspan="2">Watch Dog Enable. 0 / 1: disable / enable</td></tr>
<tr><td>0</td><td>0</td><td>R/W</td><td colspan="2">Pin PA5/PRST# function. 0 / 1: PA5 / PRSTB</td></tr>
</table>

[1] Please contact our sales representative.

6.4. Interrupt Enable Register (inten), IO address = 0x04

Bit	Reset	R/W	Description
7	0	R/W	Enable interrupt from Timer3. 0 / 1: disable / enable
6	0	R/W	Enable interrupt from Timer2. 0 / 1: disable / enable
5	0	R/W	Enable interrupt from comparator. 0 / 1: disable / enable
4	0	R/W	Enable interrupt from Touch Key TK_OV. 0 / 1: disable / enable
3	0	R/W	Enable interrupt from Touch Key TK_END. 0 / 1: disable / enable
2	0	R/W	Enable interrupt from Timer16 overflow. 0 / 1: disable / enable
1	0	R/W	Enable interrupt from PB0. 0 / 1: disable / enable
0	0	R/W	Enable interrupt from PA0 / PA5. 0 / 1: disable / enable

6.5. Interrupt Request Register (*intrq*), IO address = 0x05

Bit	Reset	R/W	Description
7	-	R/W	Interrupt Request from Timer3, this bit is set by hardware and cleared by software. 0 / 1: No request / Request
6	-	R/W	Interrupt Request from Timer2, this bit is set by hardware and cleared by software. 0 / 1: No request / Request
5	-	R/W	Interrupt Request from comparator, this bit is set by hardware and cleared by software. 0 / 1: No request / Request
4	-	R/W	Interrupt Request from Touch Key TK_OV, this bit is set by hardware and cleared by software. 0 / 1: No request / Request
3	-	R/W	Interrupt Request from Touch Key TK_END, this bit is set by hardware and cleared by software. 0 / 1: No request / Request
2	-	R/W	Interrupt Request from Timer16, this bit is set by hardware and cleared by software. 0 / 1: No request / Request
1	-	R/W	Interrupt Request from pin PB0, this bit is set by hardware and cleared by software. 0 / 1: No request / Request
0	-	R/W	Interrupt Request from pin PA0 / PA5, this bit is set by hardware and cleared by software. 0 / 1: No request / Request

6.6. Timer 16 mode Register (*t16m*), IO address = 0x06

Bit	Reset	R/W	Description
7 - 5	000	R/W	Timer Clock source selection 000: Timer 16 is disabled 001: CLK (system clock) 010: reserved 011: PA4 falling edge (from external pin) 100: IHRC 101: reserved 110: ILRC 111: PA0 falling edge (from external pin)
4 - 3	00	R/W	Internal clock divider. 00: ÷1 01: ÷4 10: ÷16 11: ÷64
2 - 0	000	R/W	Interrupt source selection. Interrupt event happens when selected bit is changed. 0 : bit 8 of Timer16 1 : bit 9 of Timer16 2 : bit 10 of Timer16 3 : bit 11 of Timer16 4 : bit 12 of Timer16 5 : bit 13 of Timer16 6 : bit 14 of Timer16 7 : bit 15 of Timer16

6.7. MISC Register (*misc*), IO address = 0x08

Bit	Reset	R/W	Description
7 - 3	-	-	Reserved
2	0	WO	Disable LVR function. 0 / 1 : Enable / Disable
1 - 0	00	WO	Watchdog time out period 00: 8K ILRC clock period 01: 16K ILRC clock period 10: 64K ILRC clock period 11: 256K ILRC clock period

6.8. External Oscillator setting Register (*eoscr, write only*), IO address = 0x0a

Bit	Reset	R/W	Description
7 - 1	-	-	Reserved. Please keep 0.
0	0	WO	Power-down the LVR hardware modules. 0 / 1: normal / power-down.

6.9. Interrupt Edge Select Register (*integs*), IO address = 0x0c

Bit	Reset	R/W	Description
7 - 5	-	-	Reserved. Please keep 0.
4	0	WO	Timer16 edge selection. 0 : rising edge to trigger interrupt 1 : falling edge to trigger interrupt
3 - 2	00	WO	PB0 edge selection. 00 : both rising edge and falling edge to trigger interrupt 01 : rising edge to trigger interrupt 10 : falling edge to trigger interrupt 11 : reserved.
1 - 0	00	WO	PA0 / PA5 edge selection. 00 : both rising edge and falling edge to trigger interrupt 01 : rising edge to trigger interrupt 10 : falling edge to trigger interrupt 11 : reserved.

6.10. Port A Digital Input Enable Register (*padier*), IO address = 0x0d

Bit	Reset	R/W	Description
7 - 3	11111	WO	Enable PA7~PA3 wake up event. 1 / 0 : enable / disable These bits can be set to low to disable wake up from PA7~PA3 toggling.
2 - 1	-	-	Reserved.
0	1	WO	Enable PA0 wake up event and interrupt request. 1 / 0 : enable / disable This bit can be set to low to disable wake up from PA0 toggling and interrupt request from this pin.

6.11. Port B Digital Input Enable Register (*pbdier*), IO address = 0x0e

Bit	Reset	R/W	Description
7	1	WO	Enable PB7 digital input and wake-up event. 1 / 0 : enable / disable. This bit can be set to low to disable wake-up from PB7 toggling.
6	1	WO	Enable PB6 wake-up event. 1 / 0 : enable / disable. This bit can be set to low to disable wake-up from PB6 toggling.
5	1	WO	Enable PB5 wake-up event. 1 / 0 : enable / disable. This bit can be set to low to disable wake-up from PB5 toggling.
4	1	WO	Enable PB4 wake-up event. 1 / 0 : enable / disable. This bit can be set to low to disable wake-up from PB4 toggling.
3	1	WO	Enable PB3 digital input and wake-up event. 1 / 0 : enable / disable. This bit can be set to low to disable wake-up from PB3 toggling.
2	1	WO	Enable PB2 digital input and wake-up event. 1 / 0 : enable / disable. This bit can be set to low to disable wake-up from PB2 toggling.
1	1	WO	Enable PB1 digital input and wake-up event. 1 / 0 : enable / disable. This bit can be set to low to disable wake-up from PB1 toggling.
0	1	WO	Enable PB0 digital input, wake-up event and interrupt request. 1 / 0 : enable / disable. This bit can be set to low to disable wake up from PB0 toggling and interrupt request from this pin.

6.12. Port A Data Registers (*pa*), IO address = 0x10

Bit	Reset	R/W	Description
7 - 0	8'h00	R/W	Data registers for Port A.

6.13. Port A Control Registers (*pac*), IO address = 0x11

Bit	Reset	R/W	Description
7 - 0	8'h00	R/W	Port A control registers. This register is used to define input mode or output mode for each corresponding pin of port A. 0 / 1: input / output.

6.14. Port A Pull-High Registers (*paph*), IO address = 0x12

Bit	Reset	R/W	Description
7 - 0	8'h00	R/W	Port A pull-high registers. This register is used to enable the internal pull-high device on each corresponding pin of port A. 0 / 1 : disable / enable

6.15. Port B Data Registers (*pb*), IO address = 0x14

Bit	Reset	R/W	Description
7 - 0	0'h00	R/W	Data registers for Port B.

6.16. Port B Control Registers (*pbc*), IO address = 0x15

Bit	Reset	R/W	Description
7 - 0	0'h00	R/W	Port B control registers. This register is used to define input mode or output mode for each corresponding pin of port B. 0 / 1: input / output

6.17. Port B Pull-High Registers (*pbph*), IO address = 0x16

Bit	Reset	R/W	Description
7 - 0	8'h00	R/W	Port B pull-high registers. This register is used to enable the internal pull-high device on each corresponding pin of port B. 0 / 1 : disable / enable

6.18. Comparator Control Register (*gpcc*), IO address = 0x18

Bit	Reset	R/W	Description
7	0	R/W	Enable comparator. 0 / 1 : disable / enable When this bit is set to enable, please also set the corresponding analog input pins to be digital disable to prevent IO leakage.
6	-	RO	Comparator result of comparator. 0: plus input < minus input 1: plus input > minus input
5	0	R/W	Select whether the comparator result output will be sampled by TM2_CLK? 0: result output NOT sampled by TM2_CLK 1: result output sampled by TM2_CLK
4	0	R/W	Inverse the polarity of result output of comparator. 0: polarity is NOT inversed. 1: polarity is inversed.
3 - 1	000	R/W	Selection the minus input (-) of comparator. 000 : PA3 001 : PA4 010 : Internal 1.20 volt band-gap reference voltage 011 : $V_{internal\ R}$ 100 : PB6 (not for EV5) 101 : PB7 (not for EV5) 11X: reserved
0	0	R/W	Selection the plus input (+) of comparator. 0 : $V_{internal\ R}$ 1 : PA4

6.19. Comparator Selection Register (*gpcs*), IO address = 0x19

Bit	Reset	R/W	Description
7	0	WO	Comparator output enable (to PA0). 0 / 1 : disable / enable
6	0	WO	Wakeup by comparator output enable. 0 / 1 : disable / enable
5	0	WO	Selection of high range of comparator.
4	0	WO	Selection of low range of comparator.
3 - 0	0000	WO	Selection the voltage level of comparator. 0000 (lowest) ~ 1111 (highest)

6.20. Reset Status Register (*rstst*), IO address = 0x1b

Bit	Reset (POR only)	R/W	Description
7	0	R/W	MCU had been reset by Watch-Dog time-out? This bit is set to high whenever reset occurs from watch-dog time-out, and reset only when writing “0” to clear this bit or POR (power-on-reset) happens. 0 / 1 : No / Yes
6	0	R/W	MCU had been reset by invalid code? This bit is set to high whenever reset occurs from invalid instruction code, and reset only when writing “0” to clear this bit or POR (power-on-reset) happens. 0 / 1 : No / Yes
5	0	-	Reserved. Please keep 0.
4	-	-	Reserved. Please keep 1.
3	-	R/W	MCU reset from external reset pin (PA5)? This bit is set to high whenever reset occurs from PA5 pin, and reset only when writing “0” to clear this bit or POR (power-on-reset) happens. 0 / 1 : No / Yes
2	-	R/W	V_{DD} had been lower than 4V? This bit is set to high whenever VDD under 4V and reset only when writing “0” to clear this bit or POR (power-on-reset) happens. 0 / 1 : No / Yes
1	-	R/W	V_{DD} had been lower than 3V? This bit is set to high whenever VDD under 3V and reset only when writing “0” to clear this bit or POR (power-on-reset) happens. 0 / 1 : No / Yes
0	-	R/W	V_{DD} had been lower than 2V? This bit is set to high whenever VDD under 2V and reset only when writing “0” to clear this bit or POR (power-on-reset) happens. 0 / 1 : No / Yes

6.21. Timer2 Control Register (tm2c), IO address = 0x1c

Bit	Reset	R/W	Description
7 - 4	0000	R/W	Timer2 clock selection. 0000 : disable 0001 : system clock 0010 : internal high RC oscillator (IHRC) 0011 : reserved 0100 : ILRC 0101 : comparator output 011x : reserved 1000 : PA0 (rising edge) 1001 : ~PA0 (falling edge) 1010 : PB0 (rising edge) 1011 : ~PB0 (falling edge) 1100 : PA4 (rising edge) 1101 : ~PA4 (falling edge) Notice: In ICE mode and IHRC is selected for Timer2 clock, the clock sent to Timer2 does NOT be stopped, Timer2 will keep counting when ICE is in halt state.
3 - 2	00	R/W	Timer2 output selection. 00 : disable 01 : PB2 10 : PA3 11 : PB4
1	0	R/W	Timer2 mode selection. 0 / 1 : period mode / PWM mode
0	0	R/W	Enable to inverse the polarity of Timer2 output. 0 / 1: disable / enable

6.22. Timer2 Counter Register (tm2ct), IO address = 0x1d

Bit	Reset	R/W	Description
7 - 0	0'h00	RO	Bit [7:0] of Timer2 counter register.

Note: Timer2 is designed for PWM mode and Period mode, so do not read tm2ct register.

6.23. Timer2 Scalar Register (tm2s), IO address = 0x17

Bit	Reset	R/W	Description
7	0	WO	PWM resolution selection. 0 : 8-bit 1 : 6-bit or 7-bit (by code option TMx_bit)
6 - 5	00	WO	Timer2 clock pre-scalar. 00 : ÷ 1 01 : ÷ 4 10 : ÷ 16 11 : ÷ 64
4 - 0	00000	WO	Timer2 clock scalar.

6.24. Timer2 Bound Register (tm2b), IO address = 0x09

Bit	Reset	R/W	Description
7 - 0	0'h00	WO	Timer2 bound register.

6.25. Timer3 Control Register (tm3c), IO address = 0x32

Bit	Reset	R/W	Description
7 - 4	0000	R/W	Timer3 clock selection. 0000 : disable 0001 : system clock 0010 : internal high RC oscillator (IHRC) 0011 : reserved 0100 : ILRC 0101 : comparator output 011x : reserved 1000 : PA0 (rising edge) 1001 : ~PA0 (falling edge) 1010 : PB0 (rising edge) 1011 : ~PB0 (falling edge) 1100 : PA4 (rising edge) 1101 : ~PA4 (falling edge) Notice: In ICE mode and IHRC is selected for Timer3 clock, the clock sent to Timer3 does NOT be stopped, Timer3 will keep counting when ICE is in halt state.
3 - 2	00	R/W	Timer3 output selection. 00 : disable 01 : PB5 10 : PB6 11 : PB7
1	0	R/W	Timer3 mode selection. 0 / 1 : period mode / PWM mode
0	0	R/W	Enable to inverse the polarity of Timer3 output. 0 / 1: disable / enable

6.26. Timer3 Counter Register (tm3ct), IO address = 0x33

Bit	Reset	R/W	Description
7 - 0	0'h00	RO	Bit [7:0] of Timer3 counter register.

Note: Timer3 is designed for PWM mode and Period mode, so do not read tm3ct register.

6.27. Timer3 Scalar Register (tm3s), IO address = 0x34

Bit	Reset	R/W	Description
7	0	WO	PWM resolution selection. 0 : 8-bit 1 : 6-bit or 7-bit (by code option TMx_bit)
6 - 5	00	WO	Timer3 clock pre-scalar. 00 : ÷ 1 01 : ÷ 4 10 : ÷ 16 11 : ÷ 64
4 - 0	00000	WO	Timer3 clock scalar.

6.28. Timer3 Bound Register (tm3b), IO address = 0x35

Bit	Reset	R/W	Description
7 - 0	0'h00	WO	Timer3 bound register.

6.29. Touch Selection Register (ts), IO address = 0x20

Bit	Reset	R/W	Description
7 - 4	-	R/W	Touch clock selection (TK_CLK) 0000: reserved 0001: reserved 0010: IHRC/4 0011: IHRC/8 0100: IHRC/16 0101: IHRC/32 0110: IHRC/64 0111: IHRC/128 1000: ILRC Others: reserved
3 - 2	-	R/W	Touch VREF selection 00: 0.5 * VCC 01: 0.4 * VCC 10: 0.3 * VCC 11: 0.2 * VCC
1 - 0	-	R/W	Select the discharge time before starting the touch function (TK_DISCHG) 00: reserved 01: 32 * CLK 10: 64 * CLK 11: 128 * CLK

6.30. Touch Charge Control Register (tcc), IO address = 0x21

Bit	Reset	R/W	Description		
7	-	-	Reserved		
6 - 4	-	R/W	Touch control and status		
			Data	**Command (W)**	**Status (R)**
			000	TK_STOP (Touch module power down)	Ready / End
			001	TK_RUN	Running
			011	Discharge (Discharge CS capacitor)	Discharging
			Others	Reserved	Reserved
3 - 0	-	-	reserved		

6.31. Touch Key Enable 2 Register (tke2), IO address = 0x22

Bit	Reset	R/W	Description
7 - 5	-	-	Reserved
4	0	R/W	Enable TK12. 0/1: disable/enable
3	0	R/W	Enable TK11. 0/1: disable/enable
2	0	R/W	Enable TK10. 0/1: disable/enable
1	0	R/W	Enable TK9. 0/1: disable/enable
0	0	R/W	Enable TK8. 0/1: disable/enable

6.32. Touch Key Enable 1 Register (tke1), IO address = 0x24

Bit	Reset	R/W	Description
7	0	R/W	Enable TK7. 0/1: disable/enable
6	0	R/W	Enable TK6. 0/1: disable/enable
5	0	R/W	Enable TK5. 0/1: disable/enable
4	0	R/W	Enable TK4. 0/1: disable/enable
3	0	R/W	Enable TK3. 0/1: disable/enable
2	0	R/W	Enable TK2. 0/1: disable/enable
1	0	R/W	Enable TK1. 0/1: disable/enable
0	-	-	reserved

6.33. Touch Key Charge Counter High Register (tkch), IO address = 0x2B

Bit	Reset	R/W	Description
7 - 4	-	-	Reserved
3 - 0	-	RO	tkct[11:8] of touch key charge counter.

6.34. Touch Key Charge Counter Low Register (tkcl), IO address = 0x2C

Bit	Reset	R/W	Description
7 - 0	-	RO	tkct[7:0] of touch key charge counter.

7. Instructions

Symbol	Description
ACC	Accumulator (Abbreviation of accumulator)
a	Accumulator (Symbol of accumulator in program)
sp	Stack pointer
flag	ACC status flag register
I	Immediate data
&	Logical AND
|	Logical OR
←	Movement
^	Exclusive logic OR
+	Add
–	Subtraction
~	NOT (logical complement, 1's complement)
∓	NEG (2's complement)
OV	Overflow (The operational result is out of range in signed 2's complement number system)
Z	Zero (If the result of ALU operation is zero, this bit is set to 1)
C	Carry (The operational result is to have carry out for addition or to borrow carry for subtraction in unsigned number system)
AC	Auxiliary Carry (If there is a carry out from low nibble after the result of ALU operation, this bit is set to 1)
pc0	Program counter for FPP0
M.n,	Only addressed in 0~0x3F (0~63) is allowed

7.1. Data Transfer Instructions

mov a, I	Move immediate data into ACC. Example: *mov* a, 0x0f; Result: a ← 0fh; Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
mov M, a	Move data from ACC into memory Example: *mov* MEM, a; Result: MEM ← a Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
mov a, M	Move data from memory into ACC Example: *mov* a, MEM ; Result: a ← MEM; Flag Z is set when MEM is zero. Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
mov a, IO	Move data from IO into ACC Example: *mov* a, pa ; Result: a ← pa; Flag Z is set when pa is zero. Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
mov IO, a	Move data from ACC into IO Example: *mov* pa, a; Result: pa ← a Affected flags: 『N』Z 『N』C 『N』AC 『N』OV

ldt16 word	Move 16-bit counting values in Timer16 to memory in word.
	Example: ldt16 word;
	Result: word ← 16-bit timer
	Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
	
	Application Example:
	--- 	
	word T16val ; // declare a RAM word
	…
	clear lb@ T16val ; // clear T16val (LSB)
	clear hb@ T16val ; // clear T16val (MSB)
	stt16 T16val ; // initial T16 with 0
	…
	set1 t16m.5 ; // enable Timer16
	…
	set0 t16m.5 ; // disable Timer 16
	ldt16 T16val ; // save the T16 counting value to T16val
	….
	--- 	

stt16 word	Store 16-bit data from memory in word to Timer16.
	Example: *stt16* word;
	Result: 16-bit timer ←word
	Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
	Application Example:
	--- 	
	word T16val ; // declare a RAM word
	…
	mov a, 0x34 ;
	mov lb@ T16val , a ; // move 0x34 to T16val (LSB)
	mov a, 0x12 ;
	mov hb@ T16val , a ; // move 0x12 to T16val (MSB)
	stt16 T16val ; // initial T16 with 0x1234
	…
	--- 	

idxm a, index	Move data from specified memory to ACC by indirect method. It needs 2T to execute this instruction.
	Example: idxm a, index;
	Result: a ← [index], where index is declared by word.
	Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
	Application Example:
	--- 	
	word RAMIndex ; // declare a RAM pointer
	…
	mov a, 0x5B ; // assign pointer to an address (LSB)
	mov lb@RAMIndex, a ; // save pointer to RAM (LSB)
	mov a, 0x00 ; // assign 0x00 to an address (MSB), should be 0
	mov hb@RAMIndex, a ; // save pointer to RAM (MSB)
	…
	idxm a, RAMIndex ; // move memory data in address 0x5B to ACC
	--- 	

Idxm index, a	Move data from ACC to specified memory by indirect method. It needs 2T to execute this instruction.
	Example: *idxm* index, a;
	Result: [index] ← a; where index is declared by word.
	Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
	Application Example:
	--- 	
	word RAMIndex ; // declare a RAM pointer
	…
	mov a, 0x5B ; // assign pointer to an address (LSB)
	mov lb@RAMIndex, a ; // save pointer to RAM (LSB)
	mov a, 0x00 ; // assign 0x00 to an address (MSB), should be 0
	mov hb@RAMIndex, a ; // save pointer to RAM (MSB)
	…
	mov a, 0xA5 ;
	idxm RAMIndex, a ; // move 0xA5 to memory in address 0x5B
	--- 	

xch M	Exchange data between ACC and memory Example: xch MEM ; Result: MEM ← a , a ← MEM Affected flags: 『N』Z 『N』C 『N』AC 『N』OV

pushaf	Move the ACC and flag register to memory that address specified in the stack pointer.
	Example: pushaf;
	Result: [sp] ← {flag, ACC};
	sp ← sp + 2 ;
	Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
	
	Application Example:
	--- 	
	.romadr 0x10 ; // ISR entry address
	pushaf ; // put ACC and flag into stack memory
	… // ISR program
	… // ISR program
	popaf ; // restore ACC and flag from stack memory
	reti ;
	--- 	

popaf	Restore ACC and flag from the memory which address is specified in the stack pointer. Example: popaf; Result: sp ← sp - 2 ; {Flag, ACC} ← [sp] ; Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV

7.2. Arithmetic Operation Instructions

add a, I	Add immediate data with ACC, then put result into ACC Example: *add* a, 0x0f ; Result: a ← a + 0fh Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
add a, M	Add data in memory with ACC, then put result into ACC Example: *add* a, MEM ; Result: a ← a + MEM Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
add M, a	Add data in memory with ACC, then put result into memory Example: *add* MEM, a; Result: MEM ← a + MEM Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
addc a, M	Add data in memory with ACC and carry bit, then put result into ACC Example: *addc* a, MEM ; Result: a ← a + MEM + C Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
addc M, a	Add data in memory with ACC and carry bit, then put result into memory Example: *addc* MEM, a ; Result: MEM ← a + MEM + C Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
addc a	Add carry with ACC, then put result into ACC

	Example: *addc* a ; Result: a ← a + C Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
addc M	Add carry with memory, then put result into memory Example: *addc* MEM ; Result: MEM ← MEM + C Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
sub a, I	Subtraction immediate data from ACC, then put result into ACC. Example: *sub* a, 0x0f; Result: a ← a - 0fh (a + [2's complement of 0fh]) Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
sub a, M	Subtraction data in memory from ACC, then put result into ACC Example: *sub* a, MEM ; Result: a ← a - MEM (a + [2's complement of M]) Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
sub M, a	Subtraction data in ACC from memory, then put result into memory Example: *sub* MEM, a; Result: MEM ← MEM - a (MEM + [2's complement of a]) Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
subc a, M	Subtraction data in memory and carry from ACC, then put result into ACC Example: *subc* a, MEM; Result: a ← a – MEM - C Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
subc M, a	Subtraction ACC and carry bit from memory, then put result into memory Example: *subc* MEM, a ; Result: MEM ← MEM – a - C Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
subc a	Subtraction carry from ACC, then put result into ACC Example: *subc* a; Result: a ← a - C Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
subc M	Subtraction carry from the content of memory, then put result into memory Example: *subc* MEM; Result: MEM ← MEM - C Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
inc M	Increment the content of memory Example: *inc* MEM ; Result: MEM ← MEM + 1 Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
dec M	Decrement the content of memory Example: *dec* MEM; Result: MEM ← MEM - 1 Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
clear M	Clear the content of memory Example: *clear* MEM ; Result: MEM ← 0 Affected flags: 『N』Z 『N』C 『N』AC 『N』OV

7.3. Shift Operation Instructions

sr a	Shift right of ACC, shift 0 to bit 7 Example: *sr* a ; Result: a (0,b7,b6,b5,b4,b3,b2,b1) ← a (b7,b6,b5,b4,b3,b2,b1,b0), C ← a(b0) Affected flags: 『N』Z 『Y』C 『N』AC 『N』OV
src a	Shift right of ACC with carry bit 7 to flag Example: *src* a ; Result: a (c,b7,b6,b5,b4,b3,b2,b1) ← a (b7,b6,b5,b4,b3,b2,b1,b0), C ← a(b0) Affected flags: 『N』Z 『Y』C 『N』AC 『N』OV
sr M	Shift right the content of memory, shift 0 to bit 7 Example: *sr* MEM ; Result: MEM(0,b7,b6,b5,b4,b3,b2,b1) ← MEM(b7,b6,b5,b4,b3,b2,b1,b0), C ← MEM(b0) Affected flags: 『N』Z 『Y』C 『N』AC 『N』OV
src M	Shift right of memory with carry bit 7 to flag Example: *src* MEM ; Result: MEM(c,b7,b6,b5,b4,b3,b2,b1) ← MEM (b7,b6,b5,b4,b3,b2,b1,b0), C ← MEM(b0) Affected flags: 『N』Z 『Y』C 『N』AC 『N』OV
sl a	Shift left of ACC shift 0 to bit 0 Example: *sl* a ; Result: a (b6,b5,b4,b3,b2,b1,b0,0) ← a (b7,b6,b5,b4,b3,b2,b1,b0), C ← a (b7) Affected flags: 『N』Z 『Y』C 『N』AC 『N』OV
slc a	Shift left of ACC with carry bit 0 to flag Example: *slc* a ; Result: a (b6,b5,b4,b3,b2,b1,b0,c) ← a (b7,b6,b5,b4,b3,b2,b1,b0), C ← a(b7) Affected flags: 『N』Z 『Y』C 『N』AC 『N』OV
sl M	Shift left of memory, shift 0 to bit 0 Example: *sl* MEM ; Result: MEM (b6,b5,b4,b3,b2,b1,b0,0) ← MEM (b7,b6,b5,b4,b3,b2,b1,b0), C ← MEM(b7) Affected flags: 『N』Z 『Y』C 『N』AC 『N』OV
slc M	Shift left of memory with carry bit 0 to flag Example: *slc* MEM ; Result: MEM (b6,b5,b4,b3,b2,b1,b0,C) ← MEM (b7,b6,b5,b4,b3,b2,b1,b0), C ← MEM (b7) Affected flags: 『N』Z 『Y』C 『N』AC 『N』OV
swap a	Swap the high nibble and low nibble of ACC Example: *swap* a ; Result: a (b3,b2,b1,b0,b7,b6,b5,b4) ← a (b7,b6,b5,b4,b3,b2,b1,b0) Affected flags: 『N』Z 『N』C 『N』AC 『N』OV

7.4. Logic Operation Instructions

and a, I	Perform logic AND on ACC and immediate data, then put result into ACC Example: *and* a, 0x0f ; Result: a ← a & 0fh Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
and a, M	Perform logic AND on ACC and memory, then put result into ACC Example: *and* a, RAM10 ; Result: a ← a & RAM10 Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
and M, a	Perform logic AND on ACC and memory, then put result into memory Example: *and* MEM, a ; Result: MEM ← a & MEM Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
or a, I	Perform logic OR on ACC and immediate data, then put result into ACC Example: *or* a, 0x0f ; Result: a ← a | 0fh Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
or a, M	Perform logic OR on ACC and memory, then put result into ACC Example: *or* a, MEM ; Result: a ← a | MEM Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
or M, a	Perform logic OR on ACC and memory, then put result into memory Example: *or* MEM, a ; Result: MEM ← a | MEM Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
xor a, I	Perform logic XOR on ACC and immediate data, then put result into ACC Example: *xor* a, 0x0f ; Result: a ← a ^ 0fh Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV

xor IO, a	Perform logic XOR on ACC and IO register, then put result into IO register
	Example: *xor* *pa, a ;*
	Result: pa ← a ^ pa ; // pa is the data register of port A
	Affected flags: 『N』Z 『N』C 『N』AC 『N』OV

xor a, M	Perform logic XOR on ACC and memory, then put result into ACC Example: *xor* a, MEM ; Result: a ← a ^ RAM10 Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
xor M, a	Perform logic XOR on ACC and memory, then put result into memory Example: *xor* MEM, a ; Result: MEM ← a ^ MEM Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
not a	Perform 1's complement (logical complement) of ACC Example: *not* a ; Result: a ← ～a Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV Application Example: ----------

	mov a, 0x38 ; // ACC=0X38
	not a ; // ACC=0XC7
	---------- 	

not M	Perform 1's complement (logical complement) of memory
	Example: *not* MEM ;
	Result: MEM ← ～MEM
	Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
	
	Application Example:
	---------- 	
	mov a, 0x38 ;
	mov mem, a ; // mem = 0x38
	not mem ; // mem = 0xC7
	---------- 	

neg a	Perform 2's complement of ACC
	Example: *neg* a;
	Result: a ← 〒a
	Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
	
	Application Example:
	---------- 	
	mov a, 0x38 ; // ACC=0X38
	neg a ; // ACC=0XC8
	---------- 	

neg M	Perform 2's complement of memory
	Example: *neg* MEM;
	Result: MEM ← 〒MEM
	Affected flags: 『Y』Z 『N』C 『N』AC 『N』OV
	
	Application Example:
	---------- 	
	mov a, 0x38 ;
	mov mem, a ; // mem = 0x38
	not mem ; // mem = 0xC8
	---------- 	

7.5. Bit Operation Instructions

set0 IO.n	Set bit n of IO port to low Example: *set0* pa.5 ; Result: set bit 5 of port A to low Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
set1 IO.n	Set bit n of IO port to high Example: *set1* pa.5 ; Result: set bit 5 of port A to high Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
set0 M.n	Set bit n of memory to low Example: *set0* MEM.5 ; Result: set bit 5 of MEM to low Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
set1 M.n	Set bit n of memory to high Example: *set1* MEM.5 ; Result: set bit 5 of MEM to high Affected flags: 『N』Z 『N』C 『N』AC 『N』OV

swapc IO.n	Swap the nth bit of IO port with carry bit
	Example: swapc IO.0;
	Result: C ← IO.0 , IO.0 ← C
	When IO.0 is a port to output pin, carry C will be sent to IO.0;
	When IO.0 is a port from input pin, IO.0 will be sent to carry C;
	Affected flags: 『N』Z 『Y』C 『N』AC 『N』OV
	Application Example1 (serial output) :
	...
	set1 pac.0 ; // set PA.0 as output
	...
	set0 flag.1 ; // C=0
	swapc pa.0 ; // move C to PA.0 (bit operation), PA.0=0
	set1 flag.1 ; // C=1
	swapc pa.0 ; // move C to PA.0 (bit operation), PA.0=1
	...
	Application Example2 (serial input) :
	...
	set0 pac.0 ; // set PA.0 as input
	...
	swapc pa.0 ; // read PA.0 to C (bit operation)
	src a ; // shift C to bit 7 of ACC
	swapc pa.0 ; // read PA.0 to C (bit operation)
	src a ; // shift new C to bit 7, old C
	...
	---------- 	

7.6. Conditional Operation Instructions

ceqsn a, I	Compare ACC with immediate data and skip next instruction if both are equal. Flag will be changed like as (a ← a - I) Example: *ceqsn* a, 0x55 ; *inc* MEM ; *goto* error ; Result: If a=0x55, then “goto error”; otherwise, “inc MEM”. Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
ceqsn a, M	Compare ACC with memory and skip next instruction if both are equal. Flag will be changed like as (a ← a - M) Example: *ceqsn* a, MEM; Result: If a=MEM, skip next instruction Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
cneqsn a, M	Compare ACC with memory and skip next instruction if both are not equal. Flag will be changed like as (a ← a - M) Example: *cneqsn a, MEM;* Result: If a≠MEM, skip next instruction Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
cneqsn a, I	Compare ACC with immediate data and skip next instruction if both are no equal. Flag will be changed like as (a ← a - I) Example: *cneqsn a,0x55 ;* *inc MEM ;* *goto error ;* Result: If a≠0x55, then “goto error”; Otherwise, “inc MEM”. Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
t0sn IO.n	Check IO bit and skip next instruction if it’s low Example: *t0sn* pa.5; Result: If bit 5 of port A is low, skip next instruction Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
t1sn IO.n	Check IO bit and skip next instruction if it’s high Example: *t1sn* pa.5 ; Result: If bit 5 of port A is high, skip next instruction Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
t0sn M.n	Check memory bit and skip next instruction if it’s low Example: *t0sn* MEM.5 ; Result: If bit 5 of MEM is low, then skip next instruction Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
t1sn M.n	Check memory bit and skip next instruction if it’s high Example: *t1sn* MEM.5 ; Result: If bit 5 of MEM is high, then skip next instruction Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
izsn a	Increment ACC and skip next instruction if ACC is zero Example: *izsn* a; Result: a ← a + 1,skip next instruction if a = 0 Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV

dzsn a	Decrement ACC and skip next instruction if ACC is zero Example: *dzsn* a; Result: A ← A - 1,skip next instruction if a = 0 Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
izsn M	Increment memory and skip next instruction if memory is zero Example: *izsn* MEM; Result: MEM ← MEM + 1, skip next instruction if MEM= 0 Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
dzsn M	Decrement memory and skip next instruction if memory is zero Example: *dzsn* MEM; Result: MEM ← MEM - 1, skip next instruction if MEM = 0 Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV

7.7. System control Instructions

call label	Function call, address can be full range address space Example: *call* function1; Result: [sp] ← pc + 1 pc ← function1 sp ← sp + 2 Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
goto label	Go to specific address which can be full range address space Example: *goto* error; Result: Go to error and execute program. Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
ret I	Place immediate data to ACC, then return Example: *ret* 0x55; Result: A← 55h ret ; Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
ret	Return to program which had function call Example: ret; Result: sp ← sp - 2 pc ← [sp] Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
reti	Return to program that is interrupt service routine. After this command is executed, global interrupt is enabled automatically. Example: reti; Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
nop	No operation Example: nop; Result: nothing changed Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
pcadd a	Next program counter is current program counter plus ACC. Example: pcadd a; Result: pc ← pc + a Affected flags: 『N』Z 『N』C 『N』AC 『N』OV Application Example:

	--- 	
	…
	mov a, 0x02 ;
	pcadd a ; // PC <- PC+2
	goto err1 ;
	goto correct ; // jump here
	goto err2 ;
	goto err3 ;
	…
	correct: // jump here
	…
	--- 	

engint	Enable global interrupt enable Example: *engint*; Result: Interrupt request can be sent to FPP0 Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
disgint	Disable global interrupt enable Example: *disgint* ; Result: Interrupt request is blocked from FPP0 Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
stopsys	System halt. Example: stopsys; Result: Stop the system clocks and halt the system Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
stopexe	CPU halt. The oscillator module is still active to output clock, however, system clock is disabled to save power. Example: stopexe; Result: Stop the system clocks and keep oscillator modules active. Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
reset	Reset the whole chip, its operation will be same as hardware reset. Example: reset; Result: Reset the whole chip. Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
wdreset	Reset Watchdog timer. Example: wdreset ; Result: Reset Watchdog timer. Affected flags: 『N』Z 『N』C 『N』AC 『N』OV

7.8. Summary of Instructions Execution Cycle

2T	*goto, call, pcadd, ret, reti , idxm*
1T/2T	*ceqsn,cneqsn, t0sn, t1sn, dzsn, izsn*
1T	Others

7.9. Summary of affected flags by Instructions

Instruction	Z	C	AC	OV	Instruction	Z	C	AC	OV	Instruction	Z	C	AC	OV
mov a, I	-	-	-	-	*mov* M, a	-	-	-	-	*mov* a, M	Y	-	-	-
mov a, IO	Y	-	-	-	*mov* IO, a	-	-	-	-	*ldt16* word	-	-	-	-
stt16 word	-	-	-	-	*idxm* a, index	-	-	-	-	*idxm* index, a	-	-	-	-
xch M	-	-	-	-	*pushaf*	-	-	-	-	*popaf*	Y	Y	Y	Y
add a, I	Y	Y	Y	Y	*add* a, M	Y	Y	Y	Y	*add* M, a	Y	Y	Y	Y
addc a, M	Y	Y	Y	Y	*addc* M, a	Y	Y	Y	Y	*addc* a	Y	Y	Y	Y
addc M	Y	Y	Y	Y	*sub* a, I	Y	Y	Y	Y	*sub* a, M	Y	Y	Y	Y
sub M, a	Y	Y	Y	Y	*subc* a, M	Y	Y	Y	Y	*subc* M, a	Y	Y	Y	Y
subc a	Y	Y	Y	Y	*subc* M	Y	Y	Y	Y	*inc* M	Y	Y	Y	Y
dec M	Y	Y	Y	Y	*clear* M	-	-	-	-	*sr* a	-	Y	-	-
src a	-	Y	-	-	*sr* M	-	Y	-	-	*src* M	-	Y	-	-
sl a	-	Y	-	-	*slc* a	-	Y	-	-	*sl* M	-	Y	-	-
slc M	-	Y	-	-	*swap* a	-	-	-	-	*and* a, I	Y	-	-	-
and a, M	Y	-	-	-	*and* M, a	Y	-	-	-	*or* a, I	Y	-	-	-
or a, M	Y	-	-	-	*or* M, a	Y	-	-	-	*xor* a, I	Y	-	-	-
xor IO, a	-	-	-	-	*xor* a, M	Y	-	-	-	*xor* M, a	Y	-	-	-
not a	Y	-	-	-	*not* M	Y	-	-	-	*neg* a	Y	-	-	-
neg M	Y	-	-	-	*set0* IO.n	-	-	-	-	*set1* IO.n	-	-	-	-
set0 M.n	-	-	-	-	*set1* M.n	-	-	-	-	*ceqsn* a, I	Y	Y	Y	Y
ceqsn a, M	Y	Y	Y	Y	*t0sn* IO.n	-	-	-	-	*t1sn* IO.n	-	-	-	-
t0sn M.n	-	-	-	-	*t1sn* M.n	-	-	-	-	*izsn* a	Y	Y	Y	Y
dzsn a	Y	Y	Y	Y	*izsn* M	Y	Y	Y	Y	*dzsn* M	Y	Y	Y	Y
call label	-	-	-	-	*goto* label	-	-	-	-	*ret* I	-	-	-	-
ret	-	-	-	-	*reti*	-	-	-	-	*nop*	-	-	-	-
pcadd a	-	-	-	-	*engint*	-	-	-	-	*disgint*	-	-	-	-
stopsys	-	-	-	-	*stopexe*	-	-	-	-	*reset*	-	-	-	-
wdreset	-	-	-	-	*swapc IO.n*	-	Y	-	-	*ceqsn a, I*	Y	Y	Y	Y
cneqsn a, M	Y	Y	Y	Y										

8. Code Option Table

Option	Selection	Description
Security	Enable	Security 7/8 words Enable
	Disable	Security Disable
LVR	4.0V	LVR typical range 4.0V
	3.5V	LVR typical range 3.5V
	3.0V	LVR typical range 3.0V
	2.75V	LVR typical range 2.75V
	2.5V	LVR typical range 2.5V
	2.2V	LVR typical range 2.2V
	2.0V	LVR typical range 2.0V
	1.8V	LVR typical range 1.8V
Drive	Low	IO Drive/ Sink Current is Low
	Normal	IO Drive/ Sink Current is Normal
TMx_Source	16MHZ	When tm2c[7:4]= 0010, TM2 clock source = IHRC = 16MHZ When tm3c[7:4]= 0010, TM3 clock source = IHRC = 16MHZ
	32MHZ	When tm2c[7:4]= 0010, TM2 clock source = IHRC*2 = 32MHZ When tm3c[7:4]= 0010, TM3 clock source = IHRC*2 = 32MHZ (ICE doesn't support.)
TMx_Bit	6 Bit	When tm2s.7=1, TM2 PWM resolution is 6 Bit When tm3s.7=1, TM3 PWM resolution is 6 Bit
	7 Bit	When tm2s.7=1, TM2 PWM resolution is 7 Bit When tm3s.7=1, TM3 PWM resolution is 7 Bit (ICE doesn't support.)
Comparator Edge	All Edge	GPC INT both Rising & Falling edge trigger
	Rising Edge	GPC INT both Rising edge trigger
	Falling Edge	GPC INT both Falling edge trigger
GPC_PWM	Disable	Comparator does not control all PWM outputs
	Enable	Comparator controls all PWM outputs (ICE doesn't support.)
Interrupt Src0	PA.0	INTEN/INTRQ.Bit0 is from PA.0
	PA.5	INTEN/INTRQ.Bit0 is from PA.5 (ICE doesn't support.)
PA7_Sel	As_CS	Configure pad PA7/CS as CS pad of Touch
	As_IO	Configure pad PA7/CS as normal PA7 IO pad
EMI	Disable	Disable EMI optimize option
	Enable	The system clock will be slightly vibrated for better EMI performance

9. Special Notes

This chapter is to remind user who use MCU391 IC in order to avoid frequent errors upon operation.

9.1. Warning

User must read all application notes of the IC by detail before using it. Please download the related application notes from the following link:
http://www.padauk.com.tw/technical-application.php

9.2. Using IC

9.2.1. IO pin usage and setting

(1) IO pin is set to be digital input
- When IO is as digital input, the level of Vih and Vil would changes with the voltage and temperature. Please follow the minimum value of Vih and the maximum value of Vil.
- The value of internal pull high resistor would also changes with the voltage, temperature and pin voltage. It is not the fixed value.

(2) IO pin is set to be digital input and enable wakeup function
- Configure IO pin as input
- Set PADIER and PBDIER registers to set the corresponding bit to 1.

(3) PA5 is set to be output pin
- PA5 can be set to be Open-Drain output pin only, output high requires adding pull-up resistor.

(4) PA5 is set to be PRSTB input pin
- Configure PA5 as input
- Set CLKMD.0=1 to enable PA5 as PRSTB input pin

(5) PA5 is set to be input pin and to connect with a push button or a switch by a long wire
- Needs to put a >33Ω resistor in between PA5 and the long wire
- Avoid using PA5 as input in such application.

9.2.2. Interrupt

(1) When using the interrupt function, the procedure should be:
Step1: Set INTEN register, enable the interrupt control bit.
Step2: Clear INTRQ register.
Step3: In the main program, using ENGINT to enable CPU interrupt function.
Step4: Wait for interrupt. When interrupt occurs, enter to Interrupt Service Routine.
Step5: After the Interrupt Service Routine being executed, return to the main program.
*Use DISGINT in the main program to disable all interrupts.
*When interrupt service routine starts, use PUSHAF instruction to save ALU and FLAG register. POPAF instruction is to restore ALU and FLAG register before RETI as below:

```
void Interrupt (void)      // Once the interrupt occurs, jump to interrupt service routine
{                          // enter DISGINT status automatically, no more interrupt is accepted
```

```
        PUSHAF;
        …
        POPAF;
    }   // RETI will be added automatically. After RETI being executed, ENGINT status will be restored
```

(2) INTEN and INTRQ have no initial values. Please set required value before enabling interrupt function.

9.2.3. System clock switching

System clock can be switched by CLKMD register. Please notice that, NEVER switch the system clock and turn off the original clock source at the same time. For example: When switching from clock A to clock B, please switch to clock B first; and after that turn off the clock A oscillator through CLKMD.

- Switch system clock from ILRC to IHRC/2

```
CLKMD   =   0x36;           // switch to IHRC, ILRC can not be disabled here
CLKMD.2 =   0;              // ILRC can be disabled at this time
```

- **ERROR.** Switch ILRC to IHRC and turn off ILRC simultaneously

```
CLKMD   =   0x50;           // MCU will hang
```

9.2.4. Power down mode, wakeup and watchdog

Watchdog will be inactive once ILRC is disabled.

9.2.5. TIMER time out

When select T16M counter BIT8 as 1 to generate interrupt, the first interrupt will occur when the counter reaches to 0x100 (BIT8 from 0 to 1) and the second interrupt will occur when the counter reaches 0x300 (BIT8 from 0 to 1). Therefore, selecting BIT8 as 1 to generate interrupt means that the interrupt occurs every 512 counts. Please notice that if T16M counter is restarted, the next interrupt will occur once Bit8 turns from 0 to 1.

9.2.6. IHRC

(1) The IHRC frequency calibration is performed when IC is programmed by the writer.
(2) Because the characteristic of the Epoxy Molding Compound (EMC) would some degrees affects the IHRC frequency (either for package or COB), if the calibration is done before molding process, the actual IHRC frequency after molding may be deviated or becomes out of spec. Normally , the frequency is getting slower a bit.
(3) It usually happens in COB package or Quick Turnover Programming (QTP). And PADAUK would not take any responsibility for this situation.
(4) Users can make some compensatory adjustments according to their own experiences. For example, users can set IHRC frequency to be 0.5% ~ 1% higher and aim to get better re-targeting after molding.

9.2.7. LVR

User can set MISC.2 as “1” to disable LVR. However, V_{DD} must be kept as exceeding the lowest working voltage of chip; Otherwise IC may work abnormally.

9.2.8. Instructions

(1) MCU391 supports 82 instructions.

(2) The instruction execution cycle of MCU391 is shown as below:

Instruction	Condition	CPU
goto, call, pcadd, ret, reti		2T
ceqsn, cneqsn, t0sn, t1sn, dzsn, izsn	Condition is fulfilled	2T
	Condition is not fulfilled	1T
idxm		2T
Others		1T

9.2.9. BIT definition

Bit access of RAM is only available for address from 0x00 to 0x3F.

9.2.10. Programming Writing

Please use PDK5S-P-002 or above to program and put the jumper over the CN39 (P201CS/CD16A) location. If the package is 16 Pin, the front pin does not need to move; the front pin of 14 Pin package should move down a space; the front pin of 10 Pin package should move down three spaces; the front pin of 8 Pin package should move down four spaces.

9.3. Using ICE

(1) PDK5S-I-001 supports MCU391 MCU emulation, the following items should be noted when using PDK5S-I-001 to emulate MCU391:

- PDK5S-I-001 doesn't support SYSCLK=ILRC/16 and ILRC/64.
- PDK5S-I-001 doesn't support PA5 as the interrupt source.
- PDK5S-I-001 doesn't support the code options: GPC_PWM, TMx_source, TMx_bit.
- PDK5S-I-001 doesn't support ALL touch function.
- Fast Wakeup time is different from PDK5S-I-S01: 128 SysClk, PMS171: 45 ILRC.
- Watch dog time out period is different from PDK5S-I-001.

WDT period	PDK5S-I-S01	PMS171
misc[1:0]=00	2048 * T_{ILRC}	8192 * T_{ILRC}
misc[1:0]=01	4096 * T_{ILRC}	16384 * T_{ILRC}
misc[1:0]=10	16384 * T_{ILRC}	65536 * T_{ILRC}
misc[1:0]=11	256 * T_{ILRC}	262144 * T_{ILRC}