PMB180(B)

8bit OTP with Charge IC

Datasheet

Version 0.09 – January 29, 2026

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Table of content

Revision History

Revision	Date	Description
0.07	2025/05/12	1. Update the illustration references for the official website. 2. Add description for Code Option
0.08	2025/10/31	1. Delete the description “PMB180(B)_not supported” in Section 6.34. 2. Modify the read value of the PMB180B charging status register in Section 6.35.
0.09	2026/01/29	1. Modify Section 5.5: change the register CHG_CTRL to CHG_Temp.

Usage Warning

User must read all application notes of the IC by detail before using it.

Please visit the official website to download and view the latest APN information associated with it.

http://www.padauk.com.tw/en/product/show.aspx?num=174&kw=PMB180(B)

(The following picture are for reference only.)

PMB180(B)

- General purpose series
- Operating temperature : -40°C ~ 85°C

Feature Documents Software &Tools Application Note

Content	Description	Download (CN)	Download (EN)
APN002	Over voltage protection		
APN003	Over voltage protection		
APN004	Semi-Automatic writing handler		
APN007	Setting up LVR level		
APN011	Semi-Automatic writing Handler improve writing stability		
APN019	E-PAD PCB layout guideline		

Major Differences between PMB180 and PMB180B

Item	Function	PMB180	PMB180B
1	register of chg_temp.1 function	OTP_100 (The new version of IDE does not support)	Added charging completion indicator bit (Charging current is less than 1/10, turn off charging)
2	leakage when Vcc_Pin is in a floating state	Vcc_Pin cannot be left floating and a resistor and capacitor must be added. (Please refer to APN-021)	No problem Vcc_Pin leakage problem has been fixed

1. Features

1.1. Special Features

- General purpose series
- Operating temperature range: -40°C ~ 85°C

1.2. System Features

- 1.25KW OTP program memory
- 64 Bytes data RAM
- One hardware 16-bit timer
- One hardware 8-bit timers with 6/7/8-bit PWM generation
- One set triple 11bit PWM generators and timers
- One hardware comparator
- 7 IO pins with optional pull-high / pull-low resistor
- Every IO pin can be configured to enable wake-up function
- Clock sources: IHRC & ILRC
- For every wake-up enabled IO, two optional wake-up speed are supported: normal and fast
- LVR Range 1.8V ~ 4.5V
- External interrupt pins: PA0, PA4
- Bandgap circuit to provide 1.20V reference voltage
- One low-power clock (NILRC) wake-up stopsys regularly.
- VCC input range:4.3V~6.5V
- Programmable Charge Current Up to 500mA
- No MOSFET, Sense Resistor or Blocking Diode Required
- Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate Without Risk of Overheating
- Preset 4.2V Charge Voltage with ±1% Accuracy
- Automatic Recharge
- C/10 Charge Termination
- 2.9V Trickle Charge Threshold
- Standby power dissipation 57uA (VCC) in charging mode

1.3. CPU Features

- One processing unit operating mode
- 86 powerful instructions
- Most instructions are 1T execution cycle
- Programmable stack pointer to provide adjustable stack level
- Direct and indirect addressing modes for data access. Data memories are available for use as an index pointer of Indirect addressing mode
- IO space and memory space are independent

1.4. Ordering/ Package Information

- PMB180(B)-ES08: ESOP8 (150mil)
- PMB180(B)-EY10: ESSOP10 (150mil)

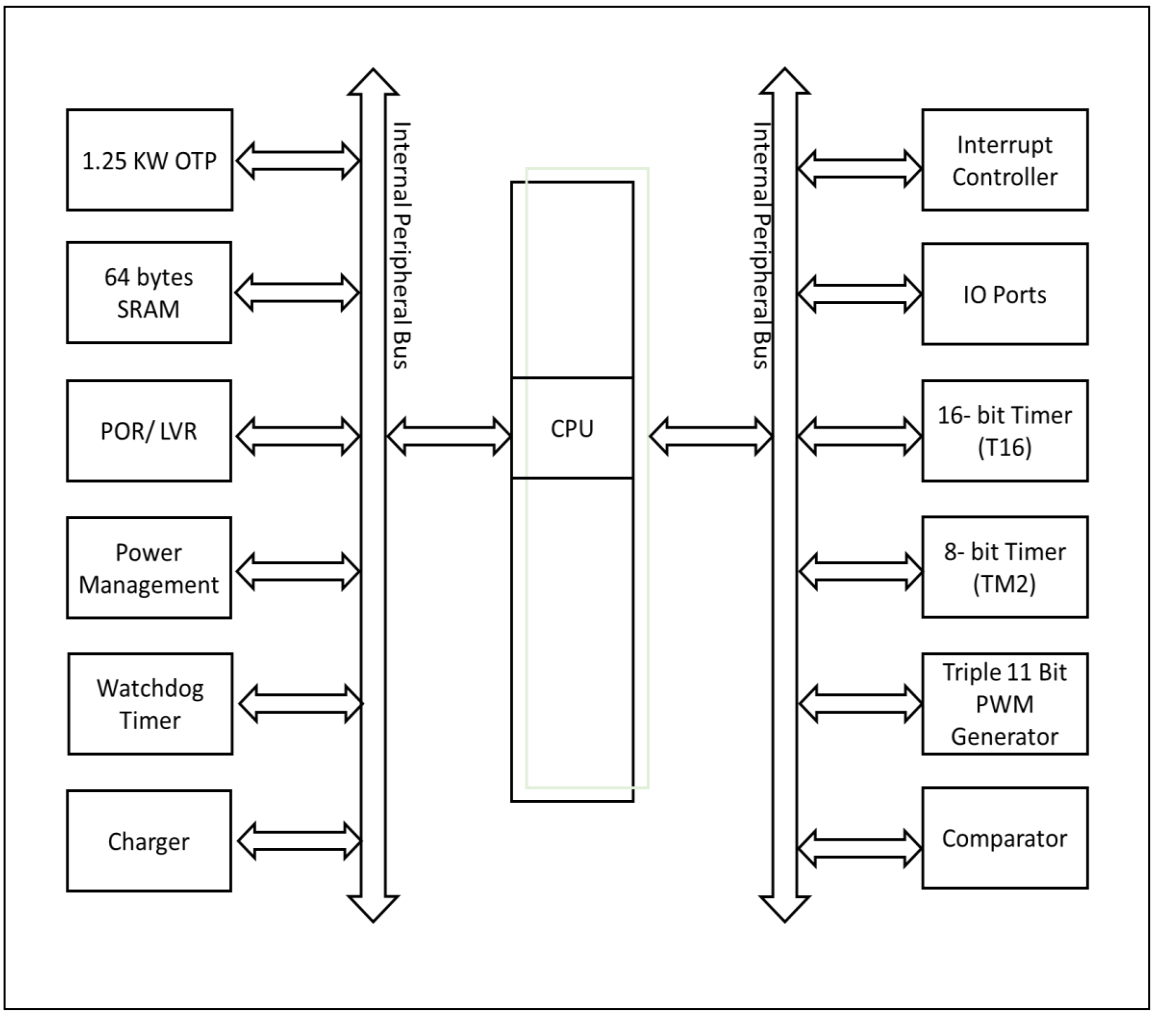
- Please refer to the official website file for package size information：”Package information “

2. General Description and Block Diagram

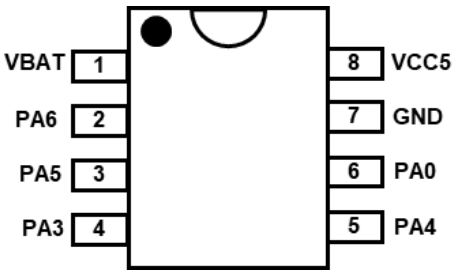
The PMB180(B) family is an IO-Type, fully static, OTP-based CMOS 8-bit microcontroller. It employs RISC architecture and all the instructions are executed in one cycle except that some instructions are two cycles that handle indirect memory access.

1.25KW bits OTP program memory and 64 bytes data SRAM are inside; one hardware comparator is built inside the chip to compare signal between two pin or with either internal reference voltage $V_{internalR}$ or internal bandgap reference voltage. PMB180(B) also provides three hardware timers: one 16-bit timer, one 8-bit timer with PWM generation, and one new triple 11-bit timer with PWM generation (LPWMG0, LPWMG1 & LPWMG2) are included.

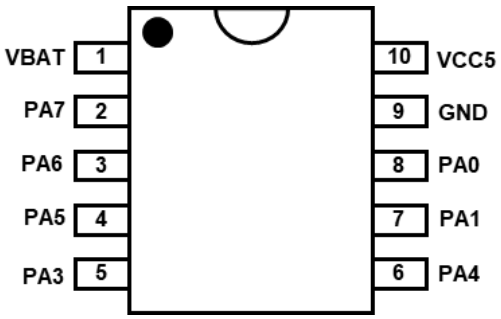
The charger in PMB180(B) is a constant current/constant voltage charger for single cell Li-Ion batteries and is designed to work within USB power specifications. An internal block regulates the current when the junction temperature increases, in order to protect the device when it operates in high power or high ambient temperature. The charge voltage is fixed at 4.2V, and the charge current limitation can be programmed by the registers without the external resistor and the current up to 500mA. The charge cycle is automatically terminated when the current flowing to the battery is lower than 1/10 of the programmed value. If the external adaptor is removed, the charger turned off and a less 2μA current can flow from the battery to the device.



3. Pin Definition and Functional Description



PMB180(B)-ES08: ESOP8 (150mil)



PMB180(B)-EY10: ESSOP10 (150mil)

Pin Name	Pin Type & Buffer Type	Description
PA7 / CIN5-	IO ST / CMOS	The functions of this pin can be: (1) Bit 7 of port A. It can be configured as digital input or two-state output, with pull-high resistor / pull-low resistor. (2) Minus input source 5 of comparator If this pin is used for crystal oscillator, bit 7 of ***padier*** register must be programmed "0" to avoid leakage current. This pin can be used to wake-up system during sleep mode; however, wake-up function is also disabled if bit 7 of ***padier*** register is "0".
PA6 / LPG1PWM / CIN4-	IO ST / CMOS	The functions of this pin can be: (1) Bit 6 of port A. It can be configured as digital input or two-state output, with pull-high resistor / pull-low resistor. (2) Output of 11-bit PWM generator LPWMG1. (3) Minus input source 4 of comparator If this pin is used for crystal oscillator, bit 6 of ***padier*** register must be programmed "0" to avoid leakage current. This pin can be used to wake-up system during sleep mode; however, wake-up function is also disabled if bit 6 of ***padier*** register is "0".
PA5 / PRSTB / LPG2PWM / LPG0PWM	IO ST / CMOS	The functions of this pin can be: (1) Bit 5 of port A. It can be configured as digital input or output, with pull-high resistor / pull-low resistor. (2) Hardware reset. (3) Output of 11-bit PWM generator LPWMG2. (4) Output of 11-bit PWM generator LPWMG0. This pin can be used to wake-up system during sleep mode; however, wake-up function is also disabled if bit 5 of ***padier*** register is "0". Please put 33Ω resistor in series to have high noise immunity when this pin is in input mode.

Pin Name	Pin Type & Buffer Type	Description
PA4 / CIN+ / CIN1- / TM2PWM / LPG1PWM / INT1	IO ST / CMOS / Analog	The functions of this pin can be: (1) Bit 4 of port A. It can be configured as digital input or two-state output, with pull-high resistor / pull-low resistor. (2) Plus input source of comparator. (3) Minus input source 1 of comparator. (4) PWM output from Timer2. (5) Output of 11-bit PWM generator LPWMG1. (6) External interrupt line 1. Both rising edge and falling edge are accepted to request interrupt service and configurable by register setting When this pin is configured as analog input, please use bit 4 of register ***padier*** to disable the digital input to prevent current leakage. The bit 4 of ***padier*** register can be set to "0" to disable digital input; wake-up from power-down by toggling this pin is also disabled.
PA3 / CIN0- / TM2PWM / LPG2PWM	IO ST / CMOS / Analog	The functions of this pin can be: (1) Bit 3 of port A. It can be configured as digital input or two-state output, with pull-high resistor / pull-low resistor. (2) Minus input source 0 of comparator. (3) PWM output from Timer2. (4) Output of 11-bit PWM generator LPWMG2. When this pin is configured as analog input, please use bit 3 of register ***padier*** to disable the digital input to prevent current leakage. The bit 3 of ***padier*** register can be set to "0" to disable digital input; wake-up from power-down by toggling this pin is also disabled.
PA1/ LPG0PWM	IO/ ST/ CMOS	The functions of this pin can be: (1) Bit 1 of port A. It can be configured as digital input or two-state output, with pull-high resistor / pull-low resistor. (2) Output of 11-bit PWM generator LPWMG0. When this pin is configured as analog input, please use bit 1 of register ***padier*** to disable the digital input to prevent current leakage. The bit 1 of ***padier*** register can be set to "0" to disable digital input; wake-up from power-down by toggling this pin is also disabled.

Pin Name	Pin Type & Buffer Type	Description
PA0 / CO / LPG0PWM / INT0	IO ST / CMOS	The functions of this pin can be: (1) Bit 0 of port A. It can be configured as digital input or two-state output, with pull-high resistor / pull-low resistor. (2) Output of comparator. (3) Output of 11-bit PWM generator LPWMG0. (4) External interrupt line 0. Both rising edge and falling edge are accepted to request interrupt service and configurable by register setting. The bit 0 of ***padier*** register can be set to "0" to disable wake-up from power-down by toggling this pin.
VBAT	VBAT	Positive power for Charger. Positive power for MCU.
VCC5	VCC	When VCC is connected, can charge Battery.
GND	GND	Ground.
Notes: **IO**: Input/Output; **ST**: Schmitt Trigger input; **OD**: Open Drain; **Analog**: Analog input pin; **CMOS**: CMOS voltage level		

4. Device Characteristics

4.1. AC/DC Device Characteristics

All data are acquired under the conditions of Ta= -40 °C ~ 85 °C, V_{BAT} =5.0V, f_{SYS} =2MHz unless noted.

Symbol	Description	Min	Typ	Max	Unit	Conditions (Ta=25°C)
V_{BAT}	Operating Voltage	1.8#	5.0	5.5	V	# Subject to LVR tolerance
LVR%	Low Voltage Reset Tolerance	-5		5	%	
f_{SYS}	System clock (CLK)* = IHRC/2 IHRC/4 IHRC/8 ILRC	 0 0 0	 100K	 8M 4M 2M	Hz	 $V_{BAT} \geqq$ 2.7V $V_{BAT} \geqq$ 2.2V $V_{BAT} \geqq$ 1.8V V_{BAT} = 3.0V
V_{POR}	Power On Reset Voltage		1.8*		V	* Subject to LVR tolerance
I_{OP}	Operating Current		0.55 85		mA uA	f_{SYS}=IHRC/16=1MIPS@5.0V f_{SYS}=ILRC=90KHz@5.0V
I_{PD}	Power Down Current (by ***stopsys*** command)		1 0.6		uA uA	f_{SYS}= 0Hz, V_{BAT} =5.0V f_{SYS}= 0Hz, V_{BAT} =3.3V
I_{PS}	Power Save Current (by ***stopexe*** command)		3		uA	V_{BAT}=5.0V ; f_{SYS}= ILRC Only ILRC module is enabled.
V_{IL}	Input low voltage for IO lines	0		0.2 V_{BAT}	V	
V_{IH}	Input high voltage for IO lines	0.7 V_{BAT}		V_{BAT}	V	
I_{OL}	IO lines sink current					
	All IO		18		mA	V_{BAT} =5.0V, V_{OL}=0.5V
I_{OH}	IO lines drive current					
	All IO		-16		mA	V_{BAT} =5.0V, V_{OH}=4.5V
V_{IN}	Input voltage	-0.3		V_{BAT} +0.3	V	
$I_{INJ\ (PIN)}$	Injected current on pin			1	mA	V_{BAT} +0.3$\geqq V_{IN} \geqq$ -0.3
R_{PH}	Pull-high Resistance		91		KΩ	V_{BAT} =5.0V
R_{PL}	Pull-low Resistance		91		KΩ	V_{BAT} =5.0V
V_{BG}	Bandgap Reference Voltage	1.145*	1.20*	1.255*	V	V_{BAT} =2.2V ~ 5.5V -40°C <Ta< 85°C*
f_{IHRC}	Frequency of IHRC after calibration *	15.76*	16*	16.24*	MHz	25°C, V_{BAT} =2.2V~5.5V
		15.20*	16*	16.80*		V_{BAT} =2.2V~5.5V, -40°C <Ta< 85°C*
		13.60*	16*	18.40*		V_{BAT} =1.8V~5.5V, -40°C <Ta< 85°C
f_{ILRC}	Frequency of ILRC *		100		KHz	V_{BAT} = 5.0V
f_{NILRC}	Frequency of NILRC *		17		KHz	V_{BAT} = 5.0V
t_{INT}	Interrupt pulse width	30			ns	V_{BAT} = 5.0V

Symbol	Description	Min	Typ	Max	Unit	Conditions (Ta=25°C)
V_{DR}	RAM data retention voltage*	1.5			V	in stop mode
t_{WDT}	Watchdog timeout period		8k		T_{ILRC}	misc[1:0]=00 (default)
			16k			misc[1:0]=01
			64k			misc[1:0]=10
			256k			misc[1:0]=11
t_{WUP}	Wake-up time period for fast wake-up		45		T_{ILRC}	Where T_{ILRC} is the time period of ILRC
	Wake-up time period for slow wake-up		3000			
t_{SBP}	System boot-up period from power-on for Slow boot-up		30		ms	V_{BAT} = 5V
t_{RST}	External reset pulse width	120			us	@ V_{BAT} = 5V
CPos	Comparator offset*		±10	±20	mV	
CPcm	Comparator input normal mode*	0		V_{BAT}-1.5	V	
CPspt	Comparator response time**		100	500	ns	Both Rising and Falling
CPmc	Stable time to change comparator mode		2.5	7.5	us	
CPcs	Comparator current consumption		20		uA	V_{BAT} = 3.3V
VCC	Charger Input Supply Voltage	4.3	5	6.5	V	
I_{VCC}	Charger Input Supply Current		200	500	μA	Charge mode
			57		μA	Standby mode
			38		μA	Shutdown mode
			0		μA	Sleep mode
I_{CCM}	Constant Current Mode Charge Current	-15%	50	+15%	mA	@VCC = 5V
			100		mA	
			200		mA	
			250		mA	
			300		mA	
			350		mA	
			400		mA	
			500		mA	
I_{TRKL}	Trickle Charge Current		1/10		I_{CCI}	V_{BAT} <V_{TRKL}
V_{FLOAT}	Float Voltage	-1%	4.2	+1%	V	@VCC = 5V
V_{TRKL}	Trickle-Charge Threshold Voltage		2.9		V	V_{BAT} rising
V_{TRHYS}	Trickle Voltage Hysteresis Voltage		100		mV	
V_{UV}	UnderVoltage Lockout threshold		3.7		V	VCC rising

Symbol	Description	Min	Typ	Max	Unit	Conditions (Ta=25°C)
V_{UVHYS}	UnderVoltage Lockout Hysteresis		200		mV	
V_{ASD}	VCC-V_{BAT} lockout threshold voltage		100		mV	VCC rising
			30		mV	VCC falling
t_{RECHA}	Recharge Comparator Filter Time		2		mS	V_{BAT} High to Low
t_{TERM}	Termination Comparator Filter Time		1		mS	I_{CCM} is less than 1/10
I_{TERM}	C/10 termination current threshold		0.1		mA	
$\triangle V_{RECHA}$	Recharge Battery Threshold Voltage		150		mV	
T_{LIM}	Junction Temperature In Constant Temperature Mode		90		℃	

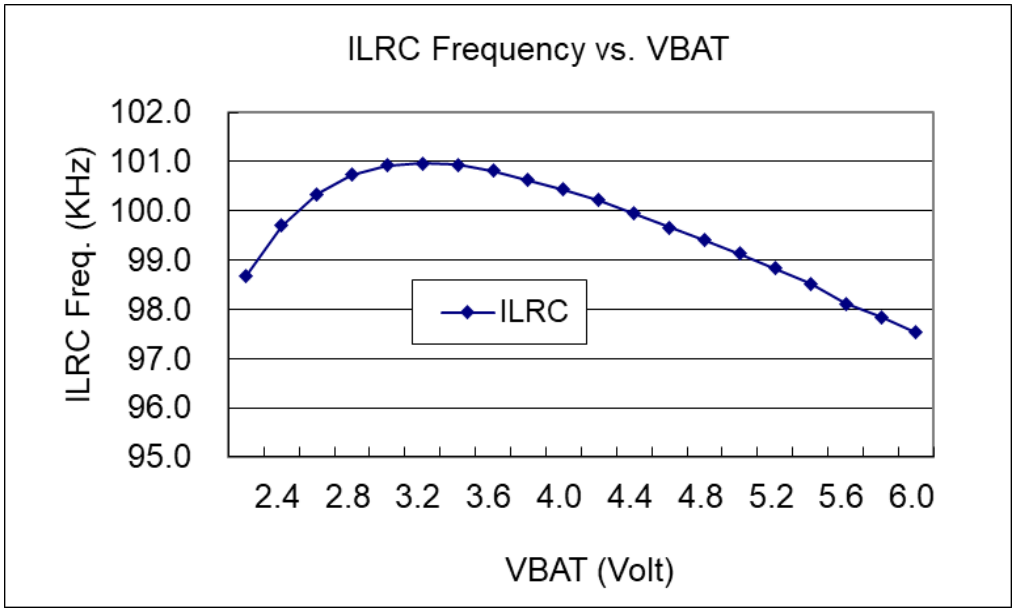
*These parameters are for design reference, not tested for each chip.

**The characteristic diagrams are the actual measured values. Considering the influence of production drift and other factors, the data in the table are within the safety range of the actual measured values.

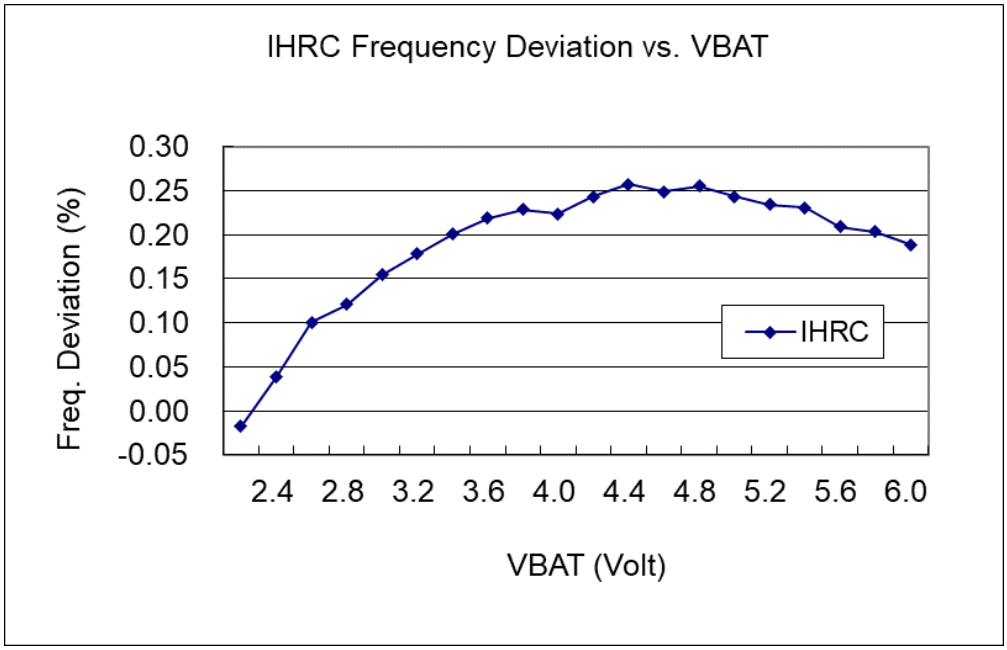
4.2. Absolute Maximum Ratings

Parameter	Maximum Rating	Notes
Supply Voltage	1.8V ~ 5.5V (Maximum Rating: 5.5V)	*If V_{BAT} is over the maximum rating, it may lead to a permanent damage of IC.
Input Voltage	-0.3V ~ V_{BAT} + 0.3V	
Operating Temperature	-40°C ~ 85°C	
Storage Temperature	-50°C ~ 125°C	
Junction Temperature	150°C	

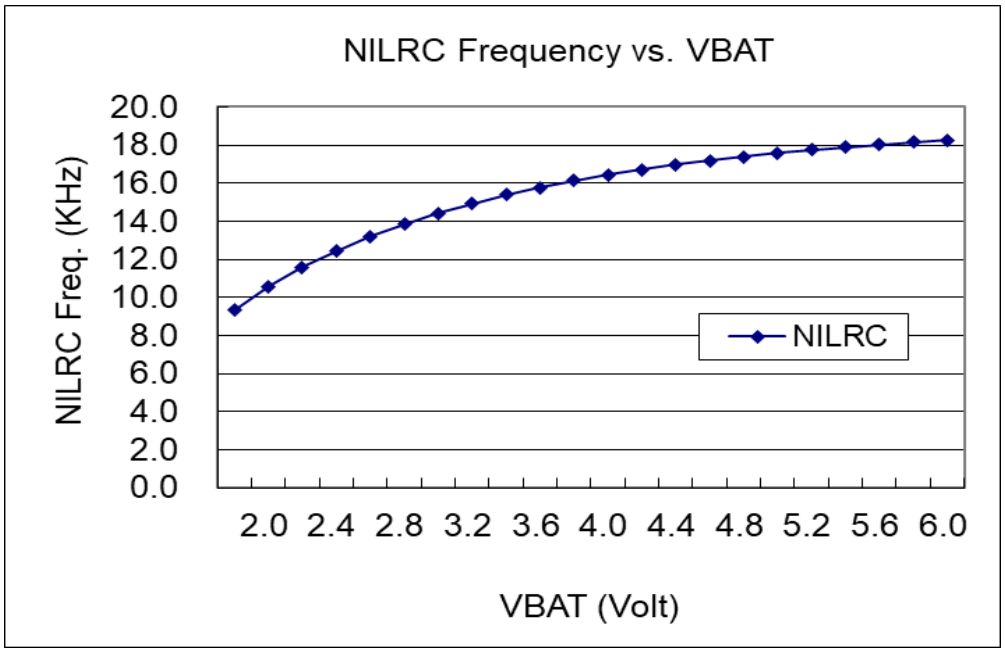
4.3. Typical ILRC frequency vs. V_{BAT}



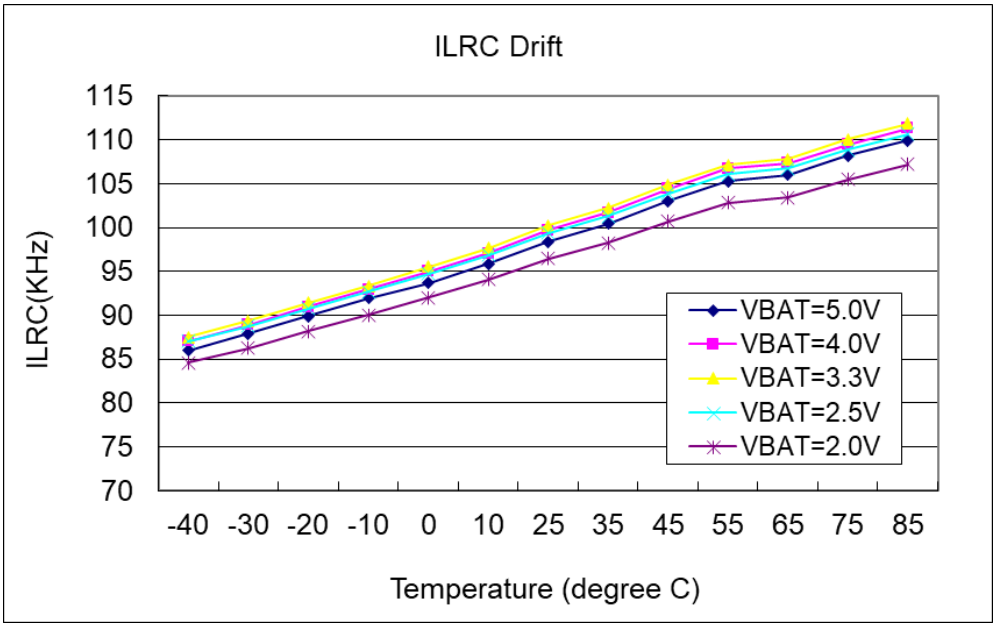
4.4. Typical IHRC frequency deviation vs. V_{BAT} (calibrated to 16MHz)



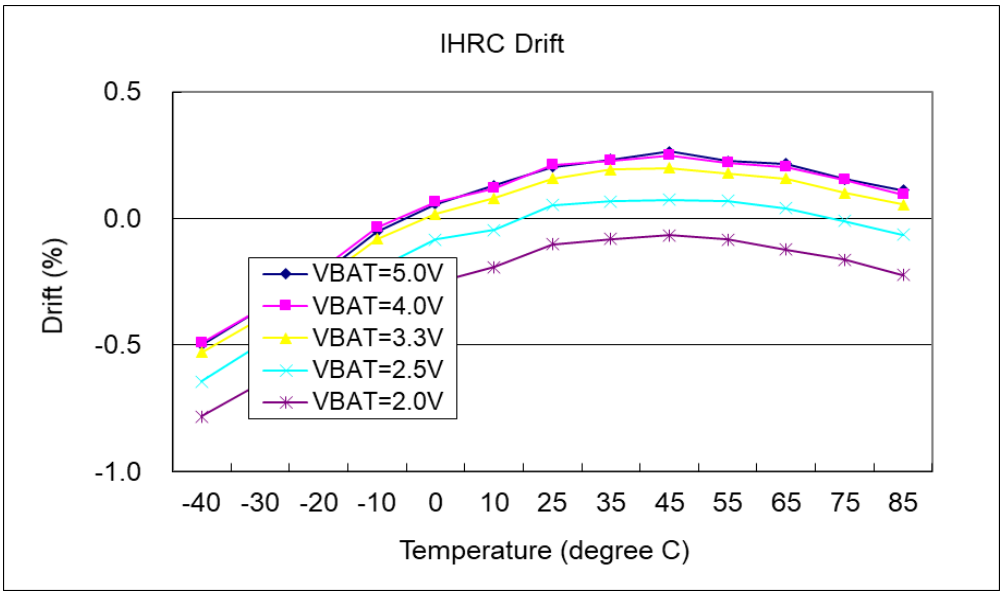
4.5. Typical NILRC Frequency vs. V_{BAT}



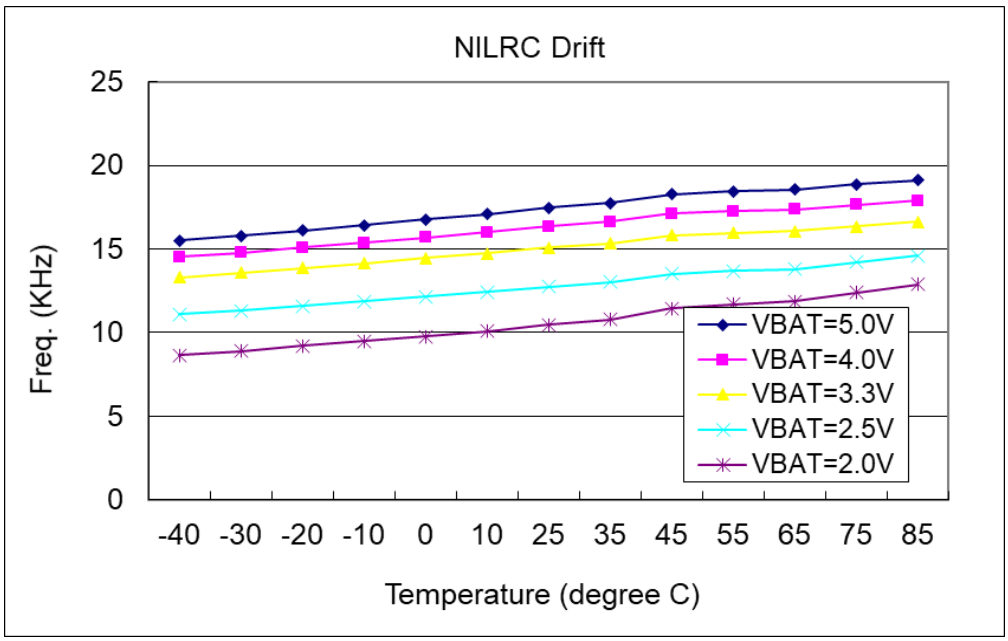
4.6. Typical ILRC Frequency vs. Temperature



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



4.8. Typical NILRC Frequency vs. Temperature

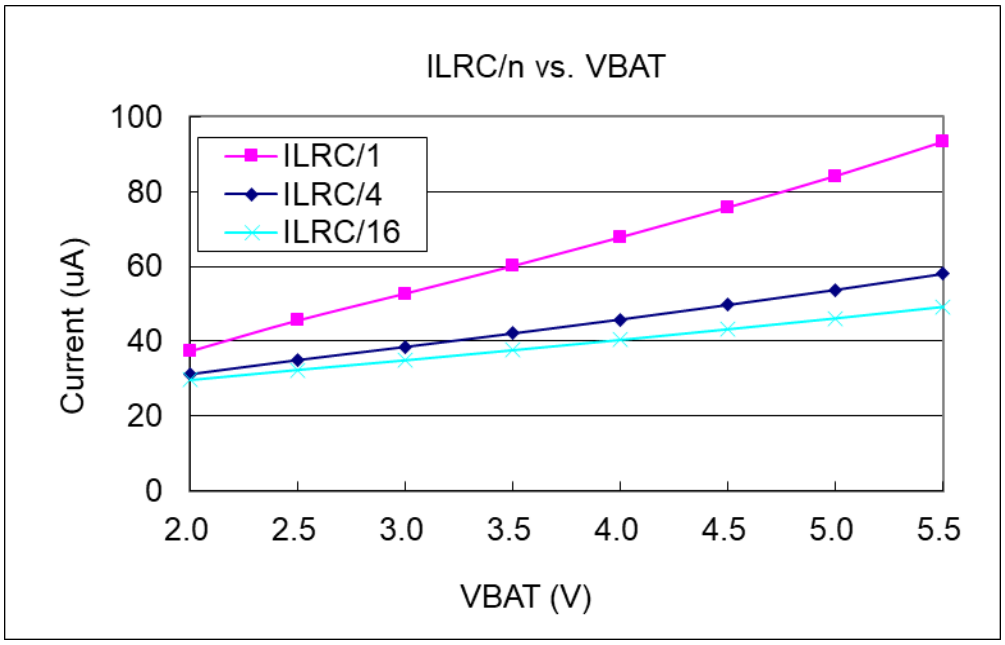


4.9. Typical operating current vs. V_{BAT} @ system clock = ILRC/n

Conditions:

ON: Bandgap, LVR, ILRC; **OFF**: IHRC, EOSC, T16, TM2;

IO: PA0:0.5Hz output toggle and no loading, **others**: input and no floating

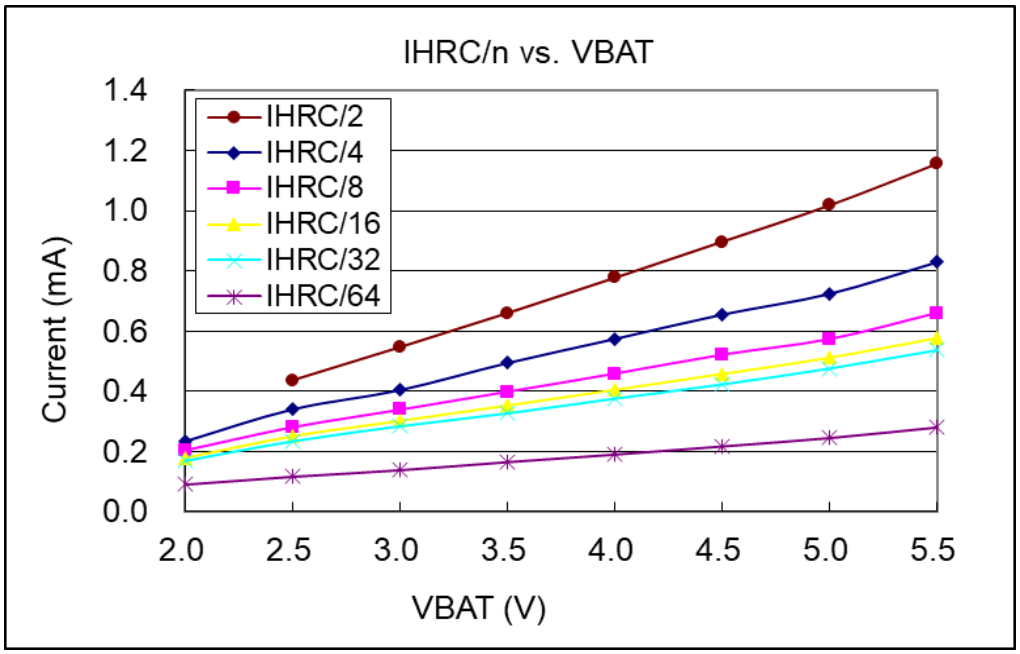


4.10. Typical operating current vs. V_{BAT} @ system clock = IHRC/n

Conditions:

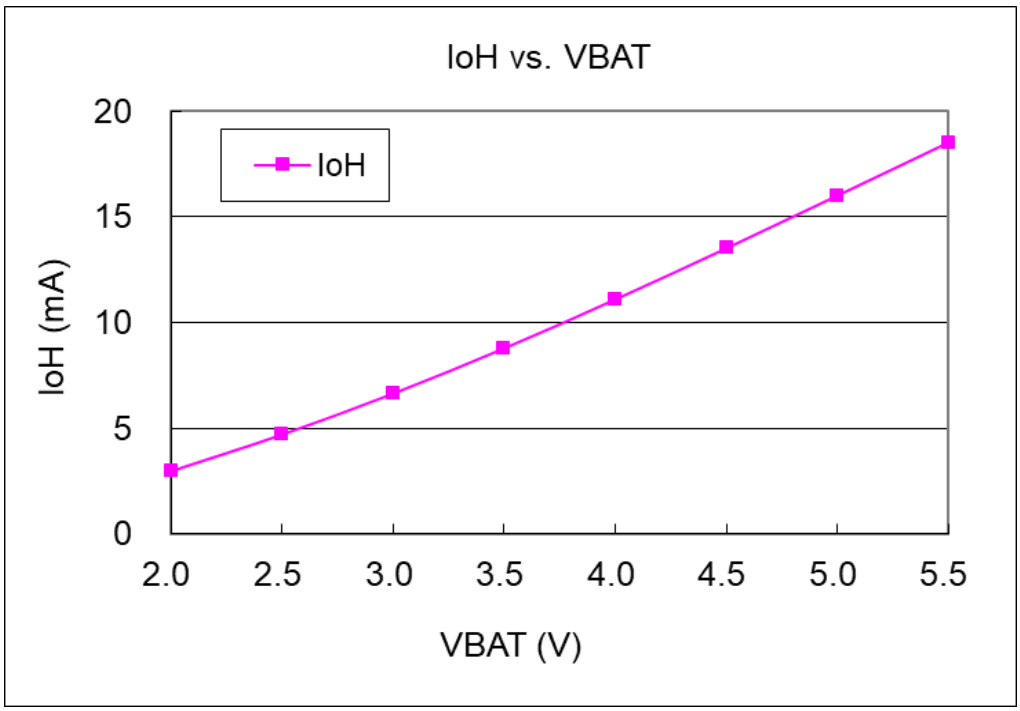
ON: Bandgap, LVR, IHRC; **OFF**: ILRC, EOSC, T16, TM2;

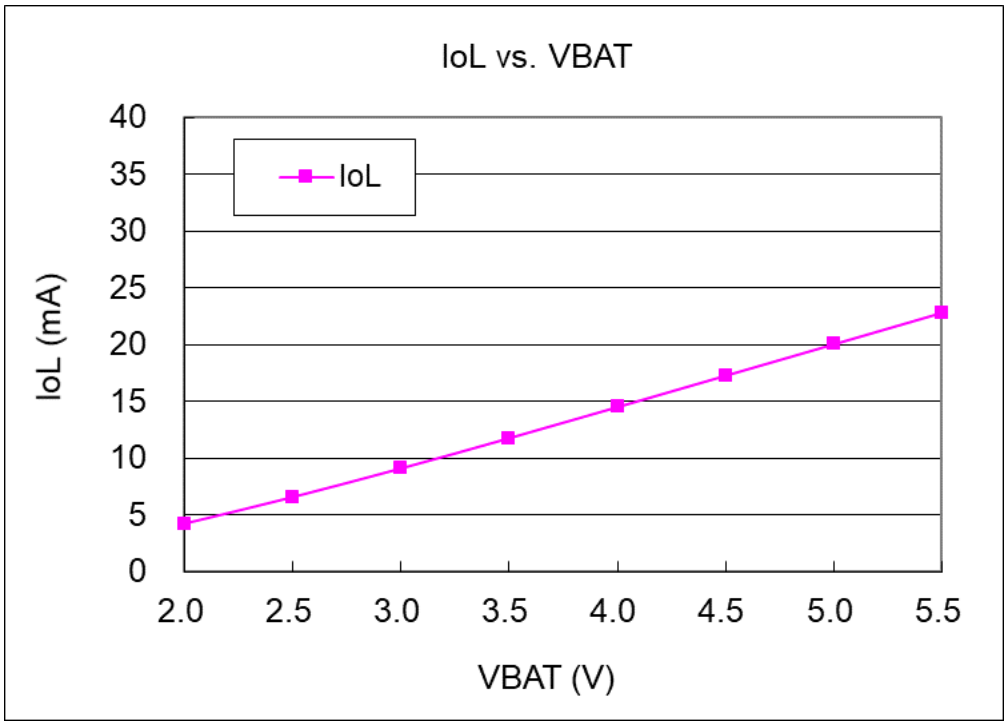
IO: PA0:0.5Hz output toggle and no loading, **others**: input and no floating



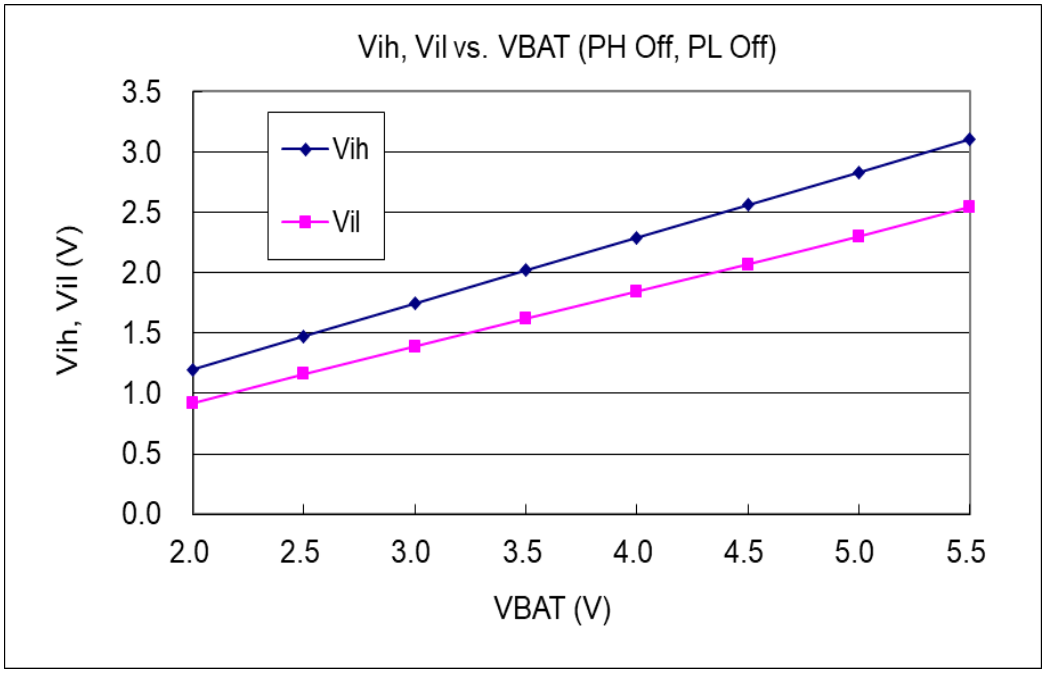
4.11. Typical IO driving current (I_{OH}) and sink current (I_{OL})

(VOH=0.9* V_{BAT}, VOL=0.1* V_{BAT})

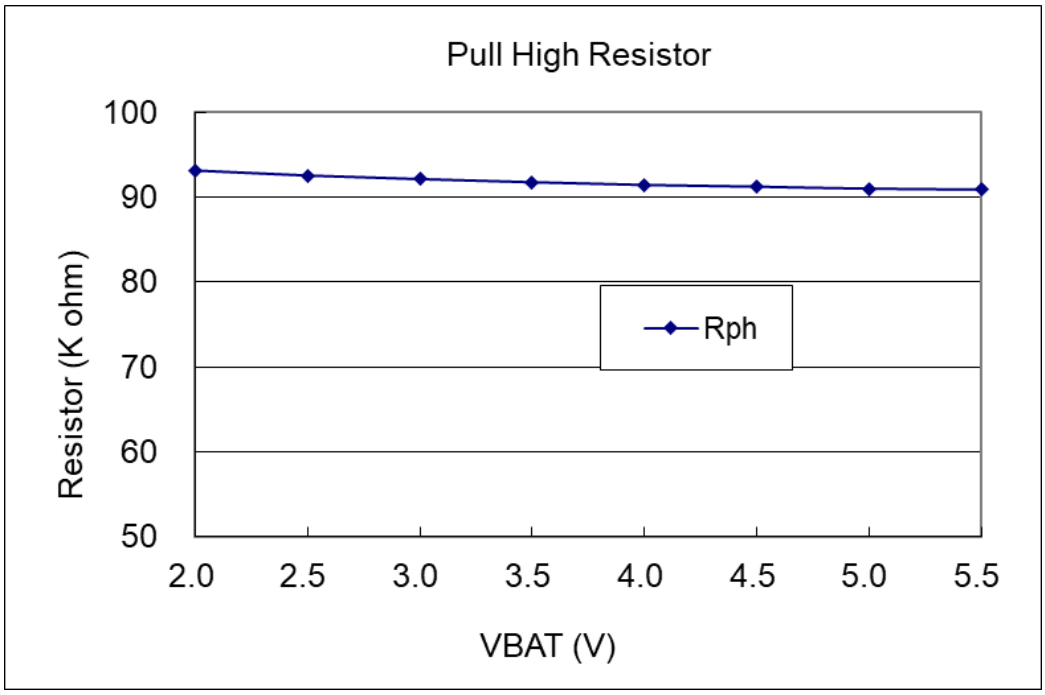


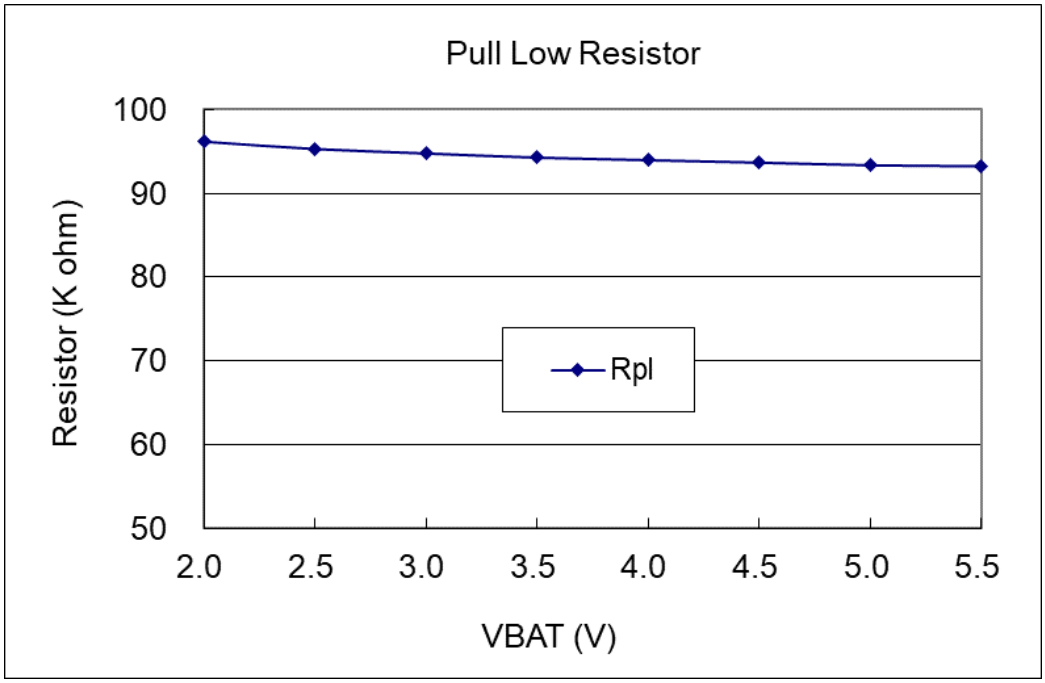


4.12. Typical IO input high/low threshold voltage (V_{IH}/V_{IL})

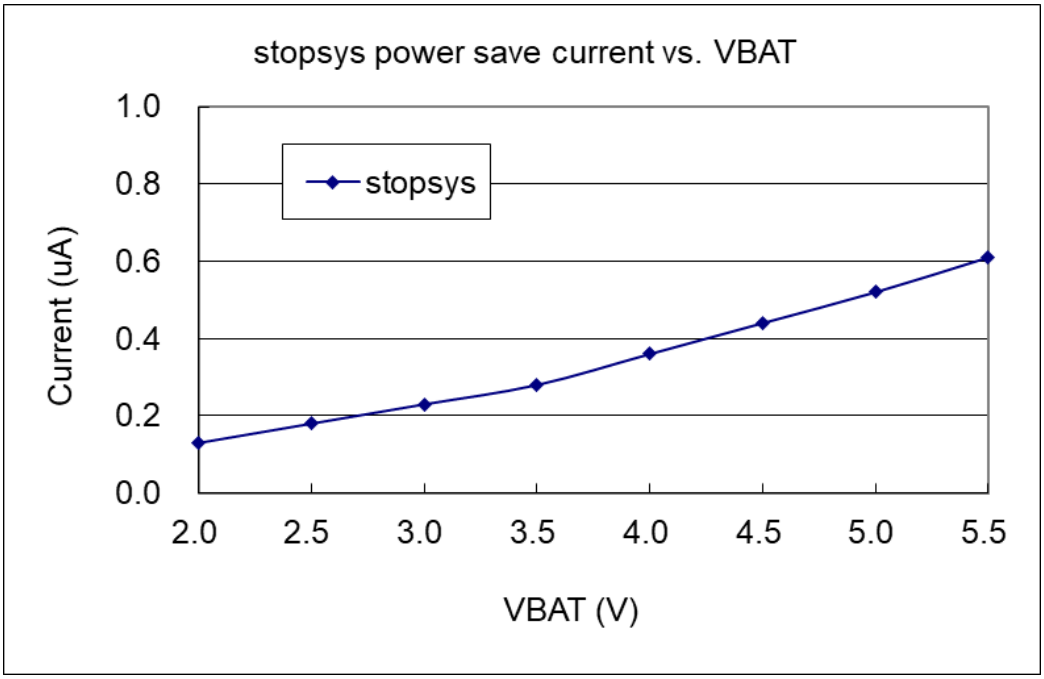


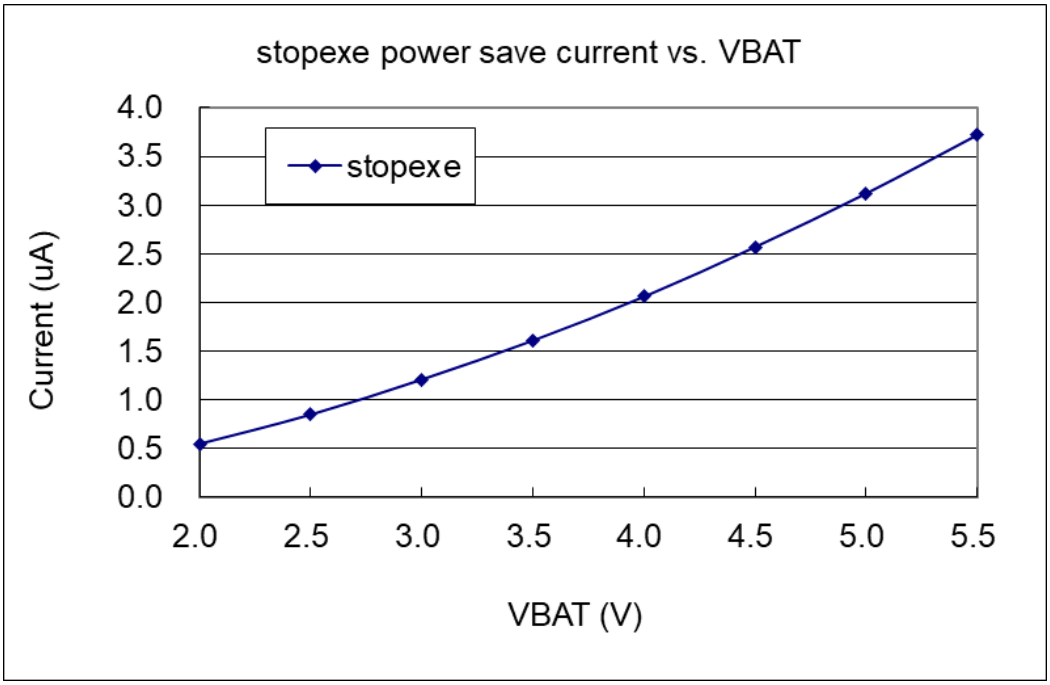
4.13. Typical resistance of IO pull high/low device





4.14. Typical power down current (IPD) and power save current (IPS)





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 contain the data, tables and interrupt entry. After reset, the program will start from 0x000 which is GOTO FPPA0 instruction usually. The interrupt entry is 0x010 if used, the last 16 addresses are reserved for system using, like checksum, serial number, etc. The OTP program memory for PMB180(B) is 1.25KW that is partitioned as Table 1. The OTP memory from address '0x4F0 to 0x4FF is for system using, address space from0x001 to 0x00F and from 0x011 to 0x4EF are user program spaces.

Address	Function
0x000	GOTO FPPA0 instruction
0x001	User program
•	•
0x00F	User program
0x010	Interrupt entry address
0x011	User program
•	•
0x4EF	User program
0x4F0	System Using
•	•
0x4FF	System Using

Table 1: Program Memory Organization

5.2. Boot Procedure

POR (Power-On-Reset) is used to reset PMB180(B) when power up. The boot up time is 3000 ILRC clock cycles Customer must ensure the stability of supply voltage after power up no matter which option is chosen, the power up sequence is shown in the Fig. 1 and t_{SBP} is the boot up time.

Please noted, during Power-On-Reset, the V_{BAT} must go higher than V_{POR} to boot-up the MCU.

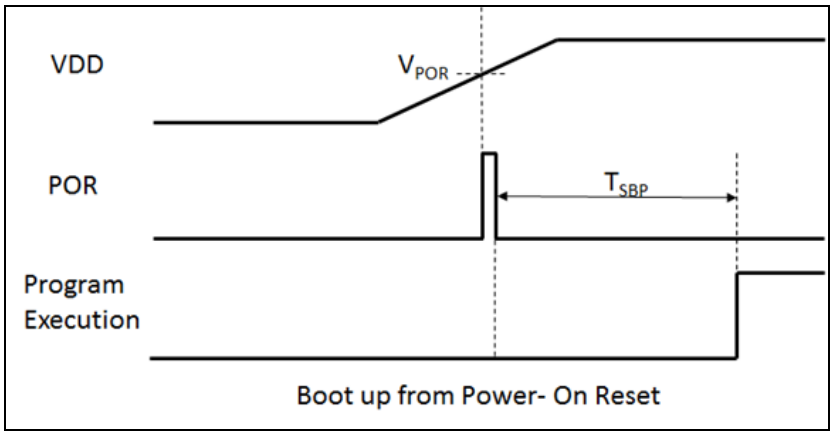
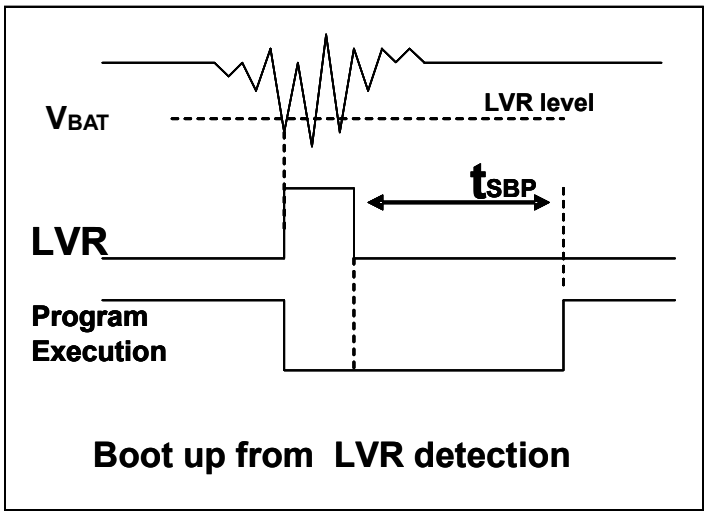
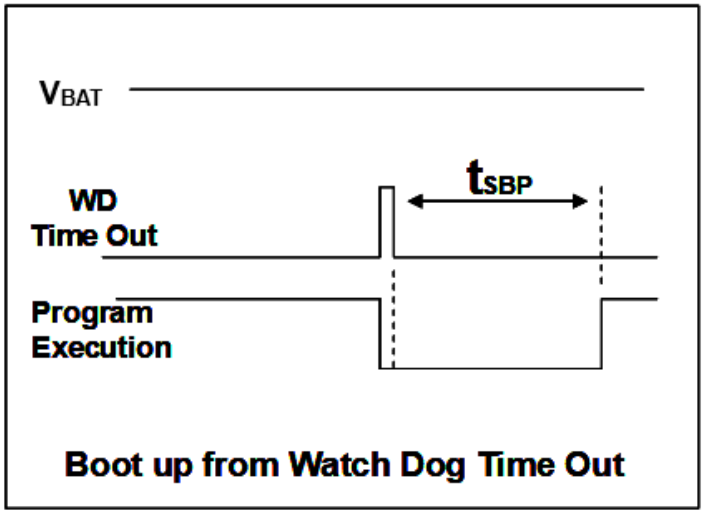
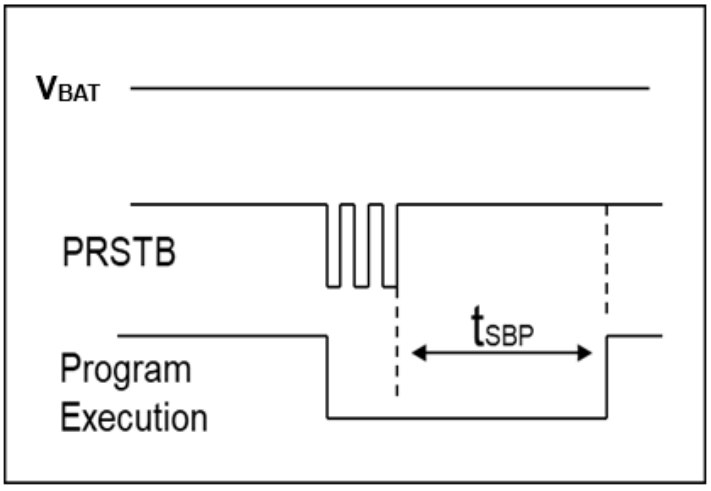


Fig.1: Power-Up Sequence

5.2.1. Timing charts for reset conditions







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. Since the data width is 8-bit, all the 64 bytes data memory of PMB180(B) can be accessed by indirect access mechanism.

5.4. Oscillator and Clock

There are two oscillator circuits provided by PMB180(B): 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 applications.

Oscillator Module	Enable/Disable
IHRC	**clkmd**.4
ILRC	**clkmd**.2

Table 2: Two oscillation circuits

5.4.1. Internal High RC oscillator and Internal Low RC oscillator

After boot-up, the IHRC and ILRC oscillators are enabled. The frequency of IHRC can be calibrated to eliminate process variation by ***ihrcr*** register; normally it is calibrated to 16MHz. Please refer to the measurement chart for IHRC frequency verse V_{BAT} and IHRC frequency verse temperature.

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

5.4.2. Chip calibration

The IHRC frequency and bandgap reference voltage may be different chip by chip due to manufacturing variation, PMB180(B) 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_{BAT} =(**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=1.8 ~ 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 starting 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 PMB180(B) for different option:

(1) .ADJUST_IC SYSCLK=IHRC/2, IHRC=16MHz, VDD=5V

After boot up, CLKMD = 0x34：

- IHRC frequency is calibrated to 16MHz@ VDD =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, VDD =3.3V

After boot up, CLKMD = 0x14：

- IHRC frequency is calibrated to 16MHz@ VDD =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, VDD =2.5V

After boot up, CLKMD = 0x3C：

- IHRC frequency is calibrated to 16MHz@ VDD =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, VDD =2.5V

After boot up, CLKMD = 0x1C：

- IHRC frequency is calibrated to 16MHz@ VDD =2.5V 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, VDD =5V

After boot up, CLKMD = 0x7C：

- IHRC frequency is calibrated to 16MHz@ VDD =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, VDD =5V

After boot up, CLKMD = 0XE4：

- IHRC frequency is calibrated to 16MHz@ VDD =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 up, CLKMD is not changed (Do nothing)：

- IHRC is not calibrated
- System CLK = ILRC or IHRC/64 (by Boot-up_Time)
- Watchdog timer is enabled, ILRC is enabled, PA5 is in input mode,

5.4.4. System Clock and LVR level

The clock source of system clock comes from IHRC and ILRC, the hardware diagram of system clock in the PMB180(B) is shown as Fig.2.

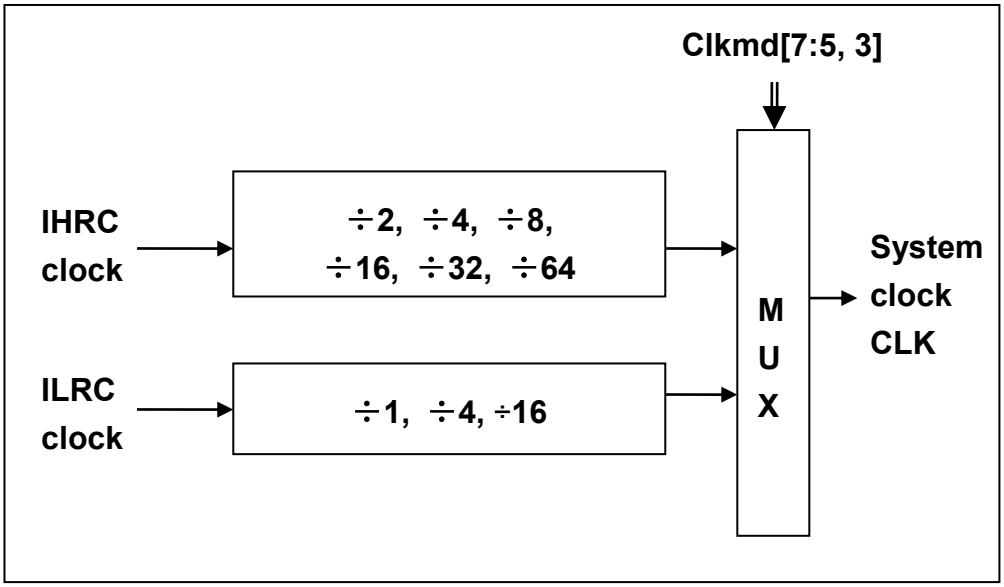


Fig.2: Options of System Clock

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 PMB180(B) 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

```
...
CLKMD.4     =   1;      //  turn on IHRC first to improve anti-interference ability
CLKMD       =   0x34;   //  switch to IHRC/2, ILRC CAN NOT be disabled here
//  CLKMD.2 =   0;      //  if need, ILRC CAN be disabled at this time
...
```

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

```
...
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. Charger

The PMB180(B) has a built-in hardware charger. This charger is fully constant current/constant voltage linear charging for single cell Li-ion battery charge management. Due to the internal MOSFET structure, there is no need for external sense resistors or blocking diodes, and the maximum charging current is up to 500 mA. The charger works automatically when power is supplied, and does not require the MCU program to make the startup settings, which means that it can manage the battery charging in the hardware default state.

Users can set or adjust the charging current through the three Bits of CHG_CTRL[7:5].

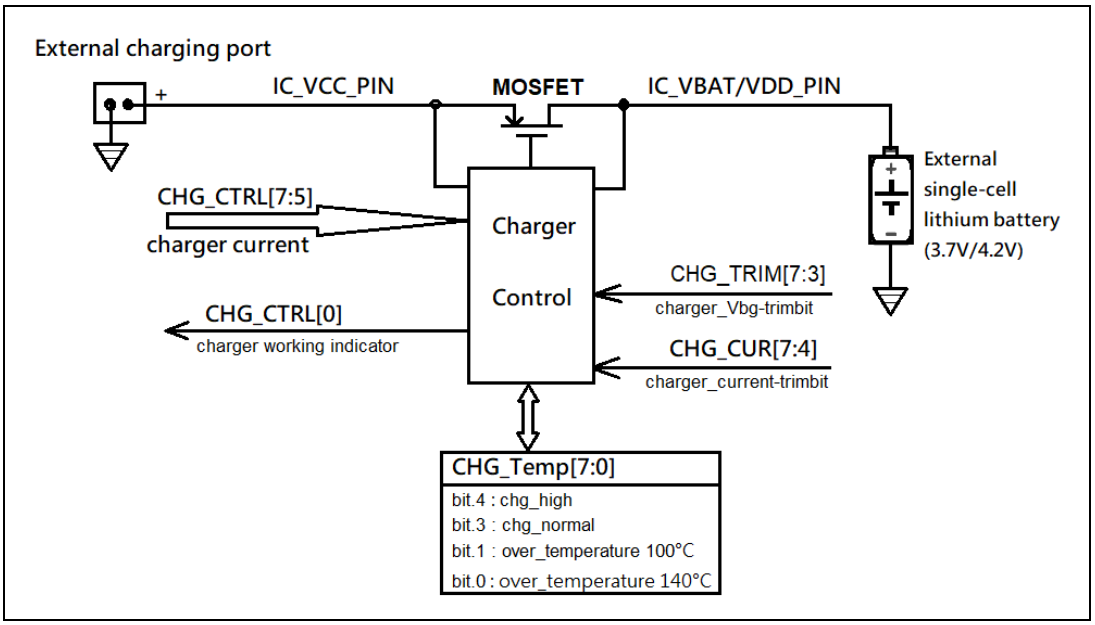
There are 8 groups of charging current can be set, maximum 500mA, minimum 50mA.

MCU program can read register CHG_CTRL[0] to judge the charger working status. The MCU program can read register CHG_Temp[4] to determine if the charging Vcc voltage is greater than Vbat. Read register CHG_Temp[3] to determine if the charging Vcc voltage is too low to make the charger shut down automatically. When CHG_Temp [4:3] = 0b11 it can be judged that the charging interface is connected and the charging voltage is normal.

The charger also integrates a charging over-temperature protection circuit, and the charging over-temperature protection has two options: 100°C and 140°C. The charging over-temperature protection can be controlled by writing CHG_Temp[1:0], and reading CHG_Temp[1:0] can determine whether charging over-temperature is triggered or not.

The charging voltage and current of the PMB180(B) charger have been calibrated at the factory and the calibration values are written into the system parameter protection area. When the MCU is successfully powered on and executes the ".Adjust_IC" macro instruction, the voltage/current factory calibration value of the charger will be filled into the CHG_Trim / CHG_CUR registers, and then the charging voltage and current of the charger will be measured as the factory calibration value, the charging voltage and current of the charger will be uncalibrated when the OTP of the MCU is blank and no program or the power-on failure. CHG_Trim / CHG_CUR registers are not recommended to be rewritten by users. When using "Adjust_IC Disable" or write assembly code can be discussed with FAE. If you want to fine tune the charging voltage and current of the charger, you can use "ReLoad_Vbat BGTRIM" and "ReLoad_ChargerCURTRIM" macros.

The PMB180(B) detects the battery voltage Vbat by comparing the built-in comparator's Bandgap 1.20V with the VintR voltage divider. The Vbat battery voltage can then be calculated. For more information on how to use the comparator, please refer to the Comparator section.



The charger charging voltage is fixed at 4.2V and the charging current can be set by register CHG_CTRL[7:5]. When the final constant charge voltage is reached, the charging current will automatically drop to 1/10 of the programmed value set in registers CHG_CTRL[7:5], and the charger will automatically stop the current charging cycle.

After removing the input power (wall outlet or USB power), the PMB180(B) charger IP automatically enters a low current state that reduces the battery leakage current to less than 2uA.

The charger is also designed with other features such as undervoltage lockout, automatic charging and trickle charge mode.

5.5.1. Thermal Limiting

The charger has thermal feedback to regulate the charging current to limit it to high power operation or high ambient temperatures. When the internal temperature of the PMB180(B) IC rises above a preset value of approximately 90°C, the internal thermal feedback loop will reduce the programmed charge current. This feature protects the PMB180(B) from excessive temperatures and allows the user to push the limits of the power handling capability of a given board without damaging the PMB180(B). The charging current can be set based on typical (non-worst case) ambient temperatures, ensuring that the charger automatically reduces the current in worst case scenarios.

5.5.2. Power Dissipation

The conditions that cause the PMB180(B) to reduce charge current through thermal feedback can be approximated by considering the power dissipated in the IC. Nearly all of this power dissipation is generated by the internal MOSFET—this is calculated to be approximately:

$P_D = (VCC - VBAT) \bullet I_{VBAT}$

where P_D is the power dissipated, V_{VCC} is the input supply voltage, V_{VBAT} is the battery voltage and I_{VBAT} is the charge current. The approximate ambient temperature at which the thermal feedback begins to protect the IC is:

$T_A = 120°C - P_D\theta_{JA}$
$T_A = 120°C - (V_{VCC} - V_{VBAT}) \bullet I_{VBAT} \bullet \theta_{JA}$

Example: The PMB180(B) operating from a 5V USB supply is programmed to supply 400mA full-scale current to a discharged Li-Ion battery with a voltage of 3.75V. Assuming θ_{JA} is 150°C/W (see Board Layout Considerations), the ambient temperature at which the PMB180(B) will begin to reduce the charge current is approximately:

$T_A = 90°C - (5V - 3.75V) \bullet (400mA) \bullet 150°C/W$
$T_A = 90°C - 0.5W \bullet 150°C/W = 90°C - 75°C$
$T_A = 15°C$

The PMB180(B) can be used above 15°C ambient, but the charge current will be reduced from 400mA. The approximate current at a given ambient temperature can be approximated by:

$$I_{VBAT} = \frac{90°C - T_A}{(V_{VCC} - V_{VBAT}) \cdot \theta_{JA}}$$

Using the previous example with an ambient temperature of 60°C, the charge current will be reduced to approximately:

$$I_{VBAT} = \frac{90°C - 60°C}{(5V - 3.75V) \cdot 150\,°C/W} = \frac{30°C}{187.5\,°C/A}$$

$$I_{VBAT} = 160mA$$

It is important to remember that PMB180(B) applications do not need to be designed for worst-case thermal conditions since the IC will automatically reduce power dissipation when the junction temperature reaches approximately 90°C.

5.5.3. Thermal Considerations

Because of the small size package, it is very important to use a good thermal PC board layout to maximize the available charge current. The thermal path for the heat generated by the IC is from the die to the copper lead frame, through the package leads, (especially the ground lead) to the PC board copper. The PC board copper is the heat sink. The footprint copper pads should be as wide as possible and expand out to larger copper areas to spread and dissipate the heat to the surrounding ambient. The feed through vias to inner or backside copper layers are also useful in improving the overall thermal performance of the charger. Other heat sources on the board, not related to the charger, must also be considered when designing a PC board layout because they will affect overall temperature rise and the maximum charge current.

The following table lists thermal resistance for several different board sizes and copper areas. All measurements were taken in still air on 3/32" FR-4 board with the device mounted on topside.

COPPER AREA		BOARD AREA	THERMAL RESISTANCE JUNCTION-TO-AMBIENT
TOPSIDE	BACKSIDE		
2500mm^2	2500mm^2	2500mm^2	125°C/W
1000mm^2	2500mm^2	2500mm^2	125°C/W
225mm^2	2500mm^2	2500mm^2	130°C/W
100mm^2	2500mm^2	2500mm^2	135°C/W
50mm^2	2500mm^2	2500mm^2	150°C/W

Table4: Measured Thermal Resistance (2-Layer Board)

5.5.4. EPAD

The PCB layout alignment should ensure that the package pins GND and EPAD have a sufficient number of thermal paths to make the thermal paths effective.

5.6. Comparator

One hardware comparator is built inside the PMB180(B); Fig.3 shows its hardware diagram. It can compare signals between two pins or with either internal reference voltage $V_{internal\ R}$ or internal bandgap 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 bandgap 1.20 volt, PA6, PA7 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.

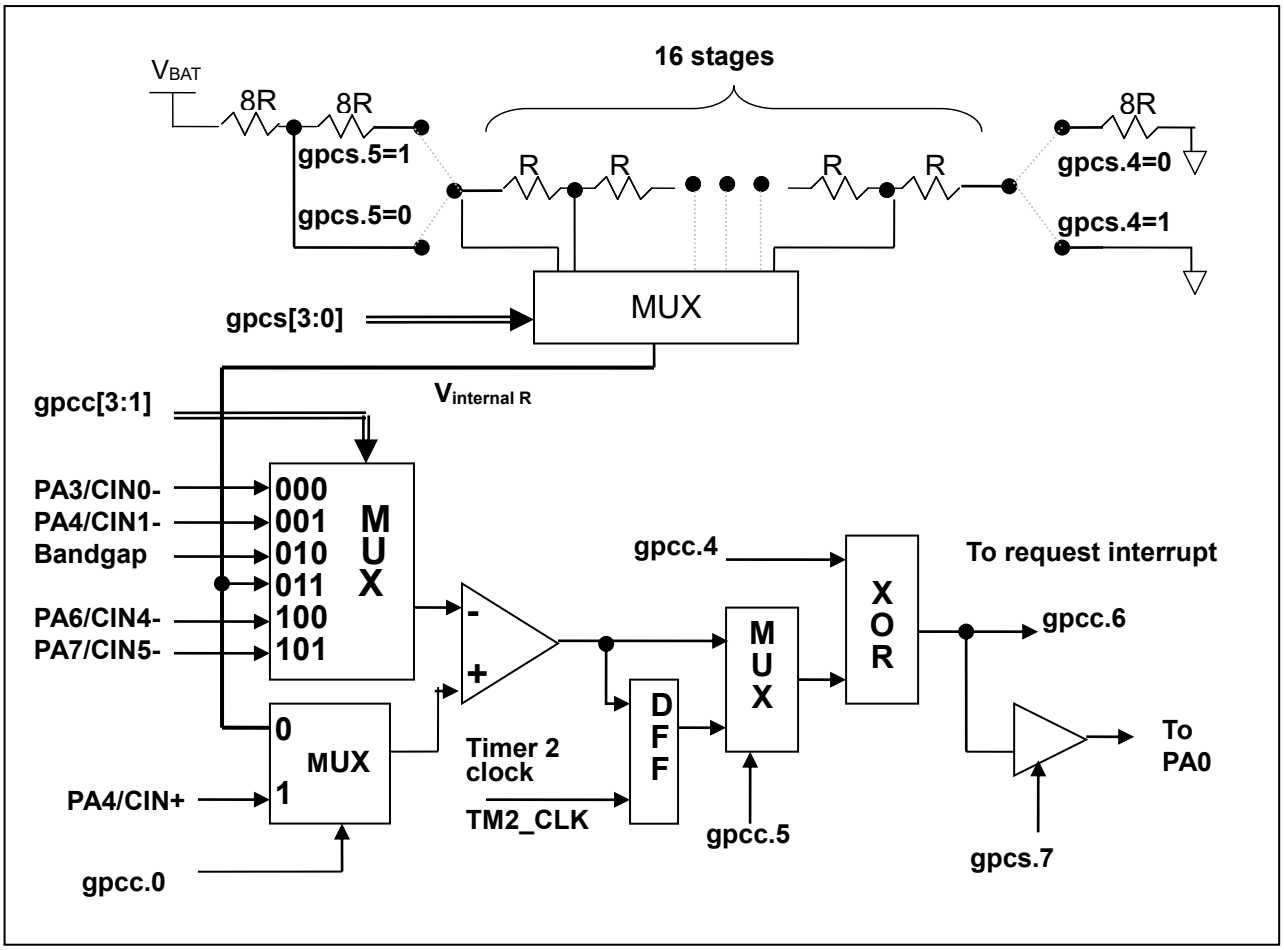


Fig.3: Hardware diagram of comparator

5.6.1. 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.4 to Fig.7 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_{BAT} to (3/4)* V_{BAT}.

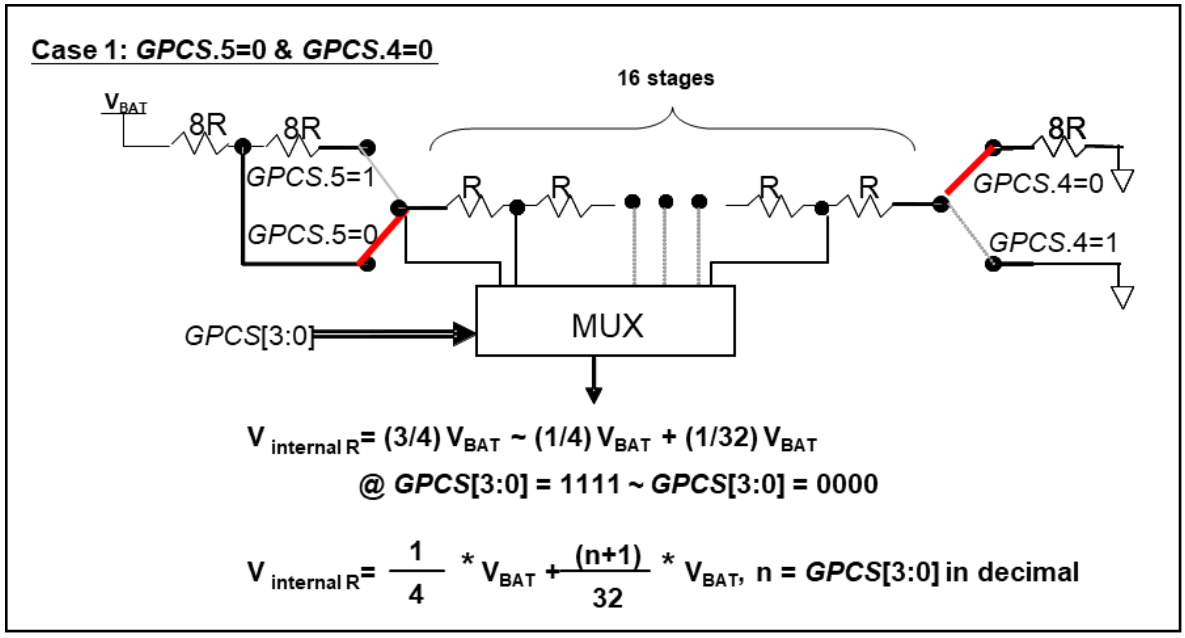


Fig.4: $V_{internal\ R}$ hardware connection if gpcs.5=0 and gpcs.4=0

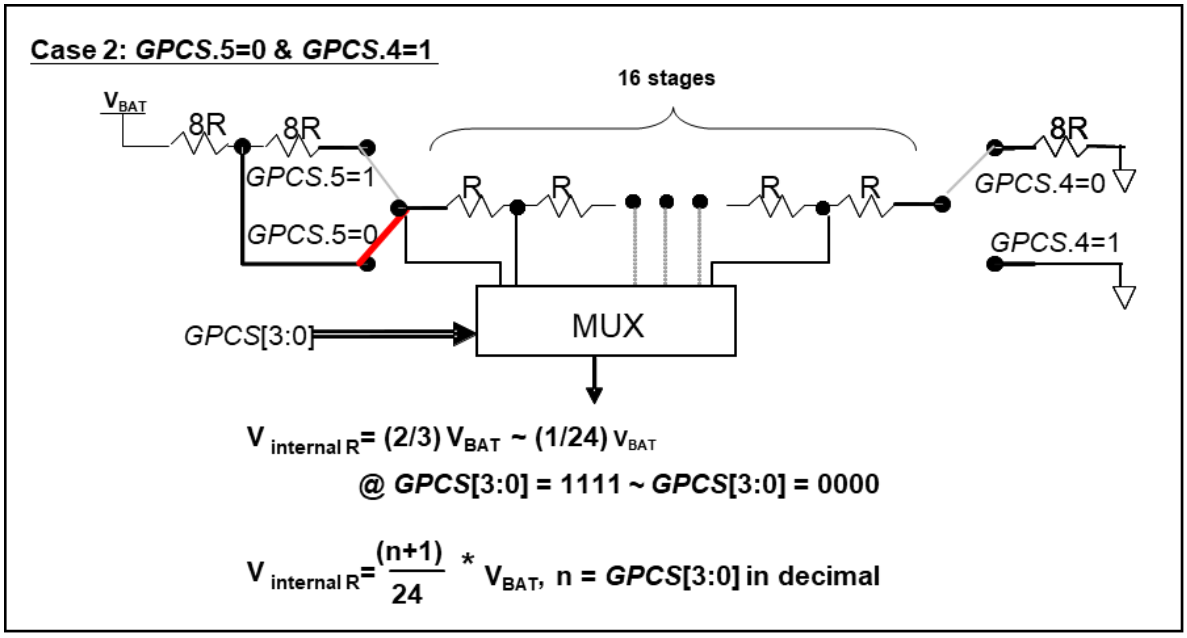


Fig.5: $V_{internal\ R}$ hardware connection if gpcs.5=0 and gpcs.4=1

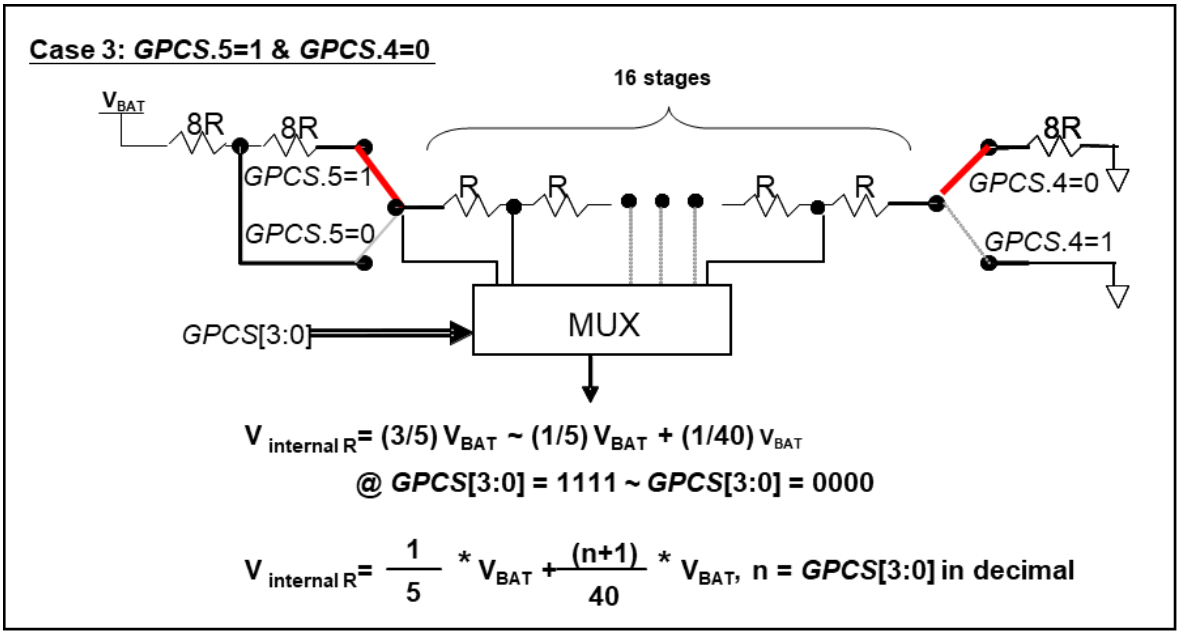


Fig.6: $V_{internal\ R}$ hardware connection if gpcs.5=1 and gpcs.4=0

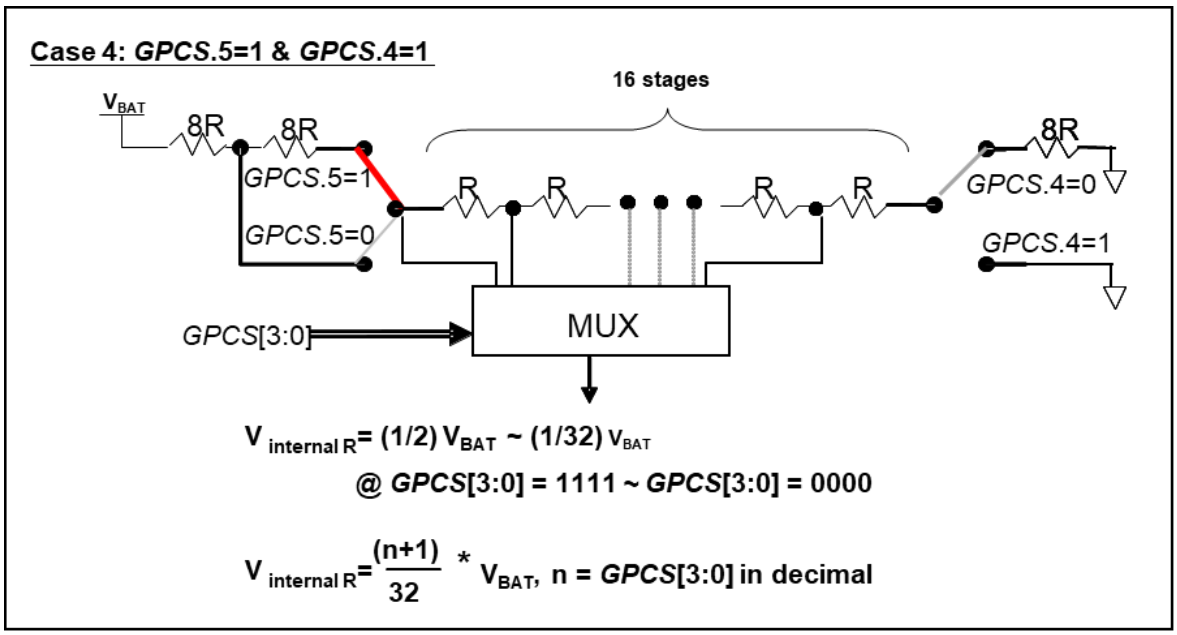


Fig.7: $V_{internal\ R}$ hardware connection if gpcs.5=1 and gpcs.4=1

5.6.2. Using the comparator

Case 1:

Choosing PA3 as minus input and $V_{internal\ R}$ with (18/32)*VBAT voltage level as plus input. $V_{internal\ R}$ is configured as the above Figure "gpcs[5:4] = 2b'00" and gpcs [3:0] = 4b'1001 (n=9) to have $V_{internal\ R}$ = (1/4)* V_{BAT} + [(9+1)/32]*V_{BAT} = [(9+9)/32]* V_{BAT} = (18/32)* V_{BAT}.

```
gpcs    = 0b0_0_00_1001;        // V_internal R = V_BAT *(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
```

or

```
$ GPCS      V_BAT *18/32;
$ GPCC      Enable, N_PA3, P_R;     // - input: N_xx，+ input: P_R(V_internal R)
PADIER = 0bxxxx_0_xxx;
```

Case 2:

Choosing $V_{internal\ R}$ as minus input with (22/40)* V_{BAT} voltage level and PA4 as plus input, the comparator result will be inversed and then output to PA0. $V_{internal\ R}$ is configured as the above Figure "gpcs[5:4] = 2b'10" and gpcs [3:0] = 4b'1101 (n=13) to have $V_{internal\ R}$ = (1/5)* V_{BAT} + [(13+1)/40]* V_{BAT} = [(13+9)/40]* V_{BAT} = (22/40)* V_{BAT}.

```
gpcs    = 0b1_0_10_1101;        // output to PA0, V_internal R = V_BAT *(22/40)
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
```

or

```
$ GPCS      Output, V_BAT *22/40;
$ GPCC      Enable, Inverse, N_R, P_PA4;    // - input: N_R(V_internal R)，+ input: P_xx
PADIER = 0bxxx_0_xxxx;
```

Note: When selecting output to PA0 output, GPCS will affect the PA3 output function in ICE. Though the IC is fine, be careful to avoid this error during emulation.

5.6.3. Using the comparator and bandgap 1.20V

The internal bandgap module can provide 1.20 volt; it can measure the external supply voltage level. The bandgap 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_{BAT}, the V_{BAT} voltage level can be detected by adjusting the voltage level of $V_{internal\ R}$ to compare with bandgap. If N (gpcs[3:0] in decimal) is the number to let $V_{internal\ R}$ closest to bandgap 1.20 volt, the supply voltage V_{BAT} can be calculated by using the following equations:

For using Case 1: V_{BAT} = [32 / (N+9)] * 1.20 volt ;

For using Case 2: V_{BAT} = [24 / (N+1)] * 1.20 volt ;

For using Case 3: V_{BAT} = [40 / (N+9)] * 1.20 volt ;

For using Case 4: V_{BAT} = [32 / (N+1)] * 1.20 volt ;

Case 1:

```
$ GPCS VBAT *12/40;                 //  4.0V * 12/40 = 1.2V
$ GPCC Enable, BANDGAP, P_R;        //  - input: BANDGAP, + input: P_R(Vinternal R)
....
if   (GPC_Out)                      //  or GPCC.6
{                                   //  when VBAT > 4V
}
else
{                                   //  when VBAT < 4V
}
```

5.7. 16-bit Timer (Timer16)

A 16-bit hardware timer (Timer16) is implemented in the PMB180(B), the clock sources of Timer16 may come from system clock (CLK), internal high RC oscillator (IHRC), internal low RC oscillator (ILRC), PA4 and PA0, a multiplex is used to select clock output for the clock source. Before sending clock to the counter16, a pre-scaling logic with divided-by-1, 4, 16, and 64 is used for wide range counting. The 16-bit counter performs up-counting operation only, the counter initial values can be stored from memory by *stt16* instruction and the counting values can be loaded to memory by *ldt16* instruction. A selector is used to select the interrupt condition of Timer16, whenever overflow occurs, the Timer16 interrupt can be triggered. The hardware diagram of Timer16 is shown as Fig.8. The interrupt source of Timer16 comes from one of bit 8 to 15 of 16-bit counter, and the interrupt type can be rising edge trigger or falling edge trigger which is specified in the bit 5 of ***integs.4*** register (address 0x0C).

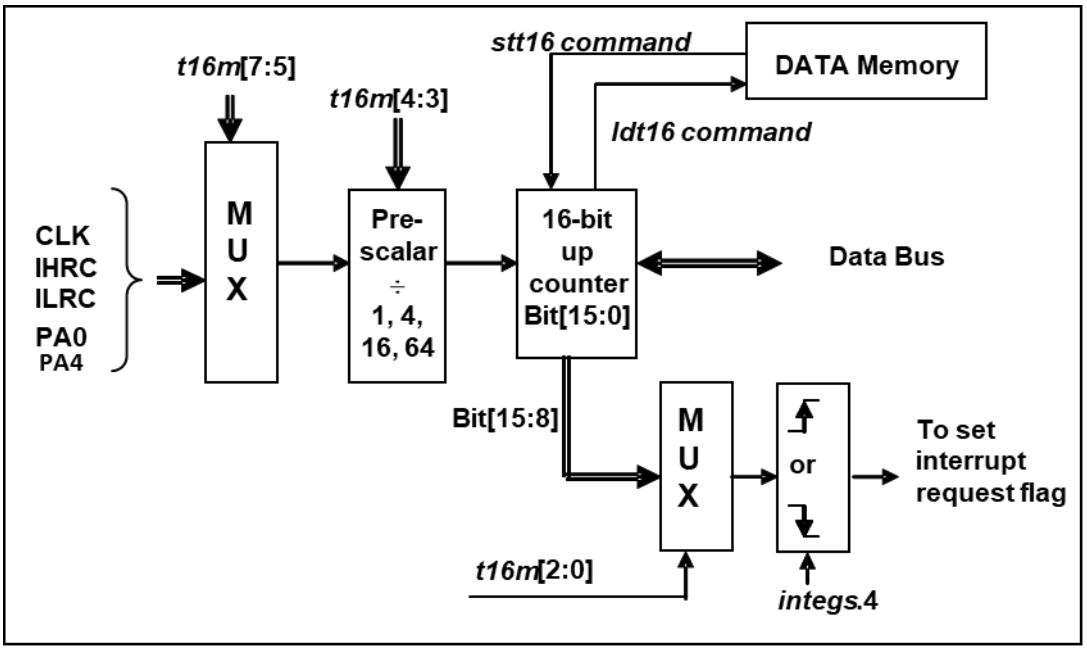


Fig.8: Hardware diagram of Timer16

When using the Timer16, the syntax for Timer16 has been defined in the .INC file. There are three parameters to define the Timer16; 1st parameter is used to define the clock source of Timer16, 2nd parameter is used to define the pre-scalar and the last one is to define the interrupt source. The detail description is shown as below:

```
T16M        IO_RW       0x06
$ 7~5:      STOP, SYSCLK, X, PA4_F, IHRC, 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 define the parameters of T16M based on system requirement, some examples are shown below and more examples please refer to "Help → Application Note → IC Introduction → Register Introduction → T16M" in IDE utility.

```
$ T16M SYSCLK, /64, BIT15;
    // choose (SYSCLK/64) as clock source, every 2^16 clock to set INTRQ.2=1
    // if using System Clock = IHRC / 2 = 8 MHz
    // SYSCLK/64 = 8 MHz/64 = 125KHz, about every 512 mS to generate INTRQ.2=1

$ T16M PA0_F, /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
```

If Timer16 is operated at free running, the frequency of interrupt can be described as below:

$$F_{INTRQ\_T16M} = F_{clock\ source} \div P \div 2^{n+1}$$

Where, F is the frequency of selected clock source to Timer16;
P is the selection of t16m [4:3]; (1, 4, 16, 64)
N is the n^{th} bit selected to request interrupt service, for example: n=10 if bit 10 is selected.

5.8. 8-bit Timer (Timer2) with PWM generation

An 8-bit hardware timer (Timer2) with PWM generation is implemented in the PMB180(B). Please refer to Fig.9 shown the hardware diagram of Timer2, the clock sources of Timer2 may come from system clock, internal high RC oscillator (IHRC), internal low RC oscillator (ILRC), NILRC, PA0, PA4 and comparator. Bit [7:4] of register tm2c are used to select the clock of Timer2. 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 or PA4, 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-1~32 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 in period mode. 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, 7-bit or 8-bit PWM resolution, Fig.10 shows the timing diagram of Timer2 for both period mode and PWM mode.

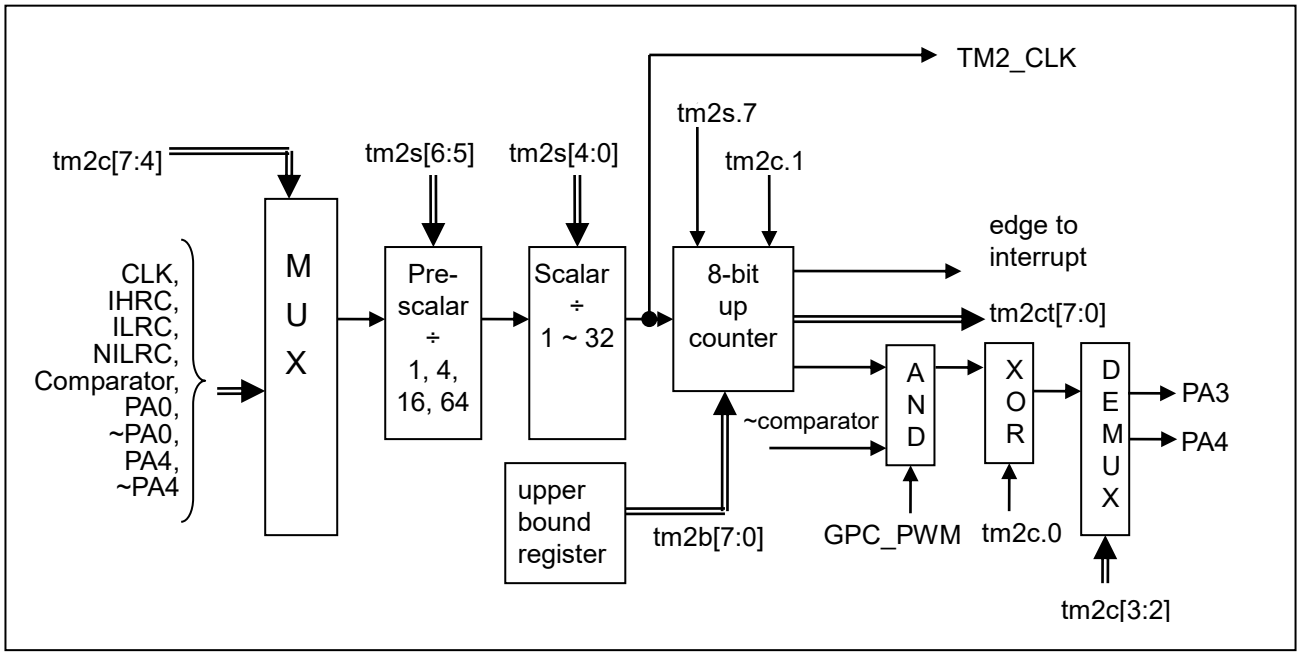
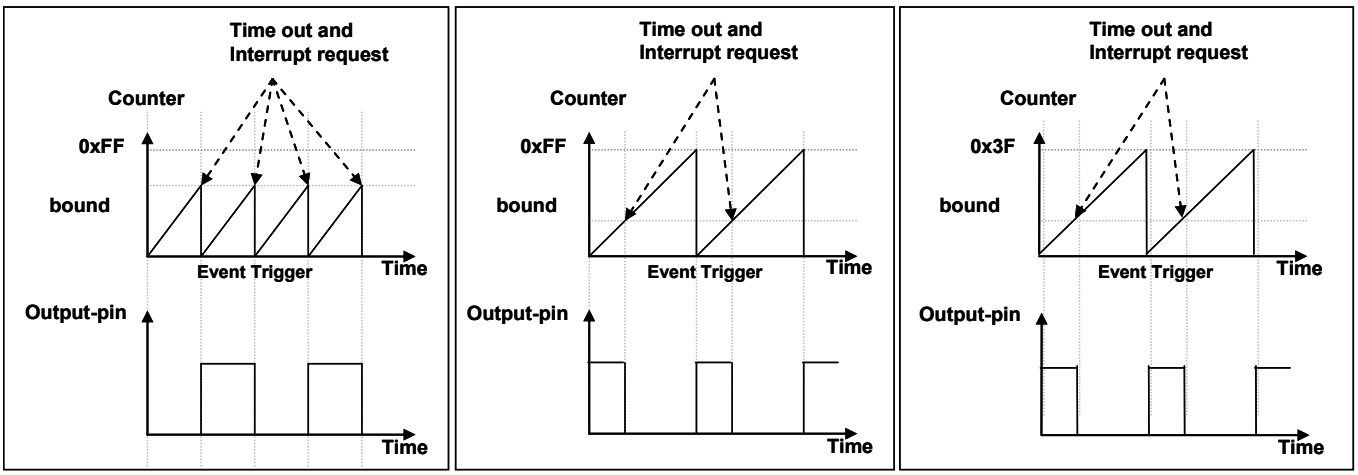


Fig.9: Timer2 hardware diagram



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

Fig.10: Timing diagram of Timer2 in period mode and PWM mode (tm2c.1=1)

A Code Option GPC_PWM is for the applications which need the generated PWM waveform to be controlled by the comparator result. If the Code Option GPC_PWM is selected, the PWM output stops while the comparator output is 1 and then the PWM output turns on while the comparator output goes back to 0, as shown in Fig. 11.

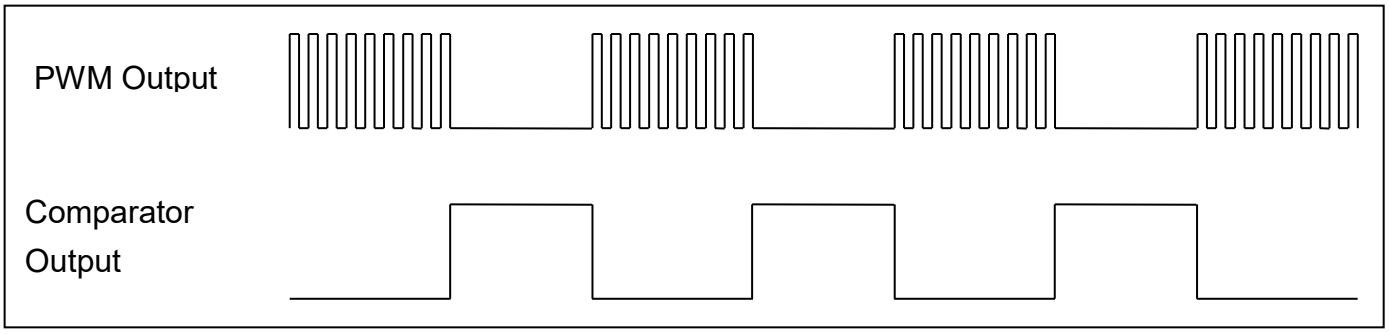


Fig.11：Comparator controls the output of PWM waveform

5.8.1. 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 (S1=1, 4, 16, 64)
S2 = tm2s[4:0] : scalar register in decimal (S2=0 ~ 31)

Example 1:

tm2c = 0b0001_1000, Y=8MHz
tm2b = 0b0111_1111, K=127
tm2s = 0b0000_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] = 0b0111_11111, S1=64 , S2 = 31
➔ frequency of output = 8MHz ÷ (2 × (127+1) × 64 × (31+1)) =15.25Hz

Example 3:

tm2c = 0b0001_1000, Y=8MHz
tm2b = 0b0000_1111, K=15
tm2s = 0b0000_00000, S1=1, S2=0
➔ frequency of output = 8MHz ÷ (2 × (15+1) × 1 × (0+1)) = 250KHz

Example 4:

tm2c = 0b0001_1000, Y=8MHz

tm2b = 0b0000_0001, K=1

tm2s = 0b0000_00000, S1=1, S2=0

➔ frequency of output = 8MHz ÷ (2 × (1+1) × 1 × (0+1)) =2MHz

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

```
Void   FPPA0 (void)
{
    . ADJUST_IC    SYSCLK=IHRC/2, IHRC=16MHz, VBAT =5V
    …
    tm2ct = 0x00;
    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;
    }
}
```

5.8.2. 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]×100%

Where, Y = tm2c[7:4] : frequency of selected clock source

K = tm2b[7:0] : bound register in decimal

S1= tm2s[6:5] : pre-scalar (S1=1, 4, 16, 64)

S2 = tm2s[4:0] : scalar register in decimal (S2=0 ~ 31)

Example 1:

tm2c = 0b0001_1010, Y=8MHz

tm2b = 0b0111_1111, K=127

tm2s = 0b0000_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 = 0b0111_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 = 0b0000_00000, S1=1, S2=0

➔ PWM output keep high

➔ duty of output = [(255+1) ÷ 256] × 100% = 100%

Example 4:

tm2c = 0b0001_1010, Y=8MHz

tm2b = 0b0000_1001, K = 9

tm2s = 0b0000_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, VBAT =5V
    wdreset;
    tm2ct = 0x00;
    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;
    }
}
```

5.8.3. 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 (S1=1, 4, 16, 64)
tm2s[4:0] = S2 : scalar register in decimal (S2=0 ~ 31)

Users can set Timer2 to be 7-bit PWM mode instead of 6-bit mode by using ***TM2_Bit*** code option. At that time, the calculation factors of the above equations become 128 instead of 64.

Example 1:

tm2c = 0b0001_1010, Y=8MHz
tm2b = 0b0001_1111, K=31
tm2s = 0b1000_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 = 0b1111_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 = 0b1000_00000, S1=1, S2=0
➔ PWM output keep high
➔ duty of output = [(63+1) ÷ 64] × 100% = 100%

Example 4:

tm2c = 0b0001_1010, Y=8MHz
tm2b = 0b0000_0000, K=0
tm2s = 0b1000_00000, S1=1, S2=0
➔ frequency = 8MHz ÷ (64 × 1 × (0+1)) = 125KHz
➔ duty = [(0+1) ÷ 64] × 100% =1.5%

5.9. 11-bit PWM Generators

One set of triple 11-bit SuLED (Super LED) hardware PWM generator is implemented in the PMB180(B). It consists of three PWM generators (LPWMG0, LPWMG1 & LPWMG2). Their individual outputs are listed as below:

- LPWMG0 – PA0, PA1, PA5
- LPWMG1 – PA4, PA6
- LPWMG2 – PA3, PA5

Note: 5S-I-S01/2(B) doesn't support the function of the set of 11-bit SuLED hardware PWM generators.

5.9.1. PWM Waveform

A PWM output waveform (Fig.12) has a time-base (T_{Period} = Time of Period) and a time with output high level (Duty Cycle). The frequency of the PWM output is the inverse of the period ($f_{PWM} = 1/T_{Period}$).

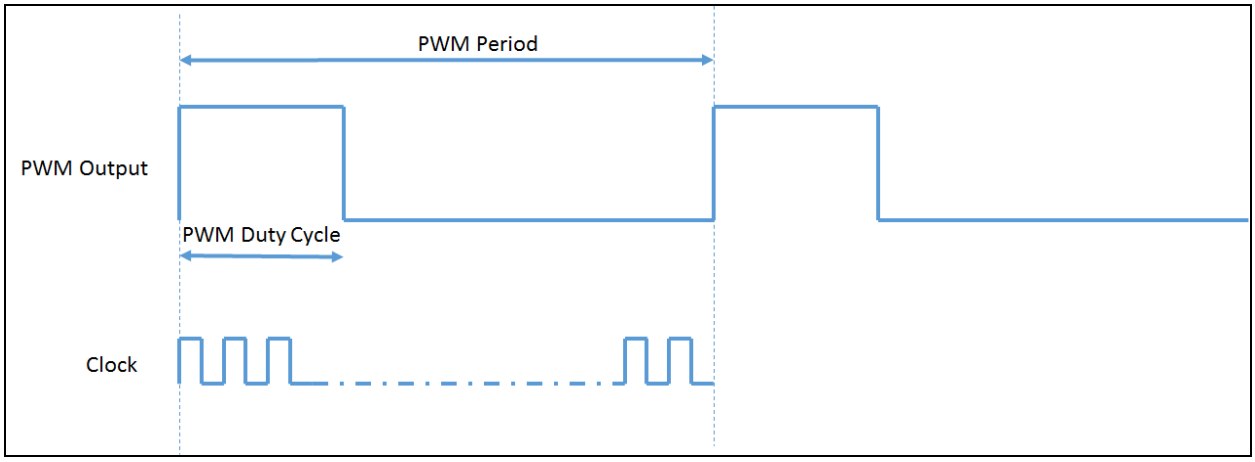


Fig.12: PWM Output Waveform

5.9.2. Hardware Diagram

Fig.13 shows the hardware diagram of the whole set of SuLED 11-bit hardware PWM generators. Those three PWM generators use a common Up-Counter and clock source selector to create the time base, and so the start points (the rising edge) of the PWM cycle are synchronized. The clock source can be IHRC or system clock. The PWM signal output pins that can be selected via ***lpwmgxc[3:1]*** register selection. The PWM output Enable are control by GPC, that can be selected via ***lpwmgxc.7***. The period of PWM waveform is defined by the common PWM upper bound high and low registers, and the duty cycle of individual PWM waveform is defined by the individual set in the PWM duty high and low registers.

The additional OR and XOR logic of LPWMG0 channel is used to create the complementary switching waveforms with dead zone control. Selecting code option GPC_TMx_LPWM can also control the generated PWM waveform by the comparator result.

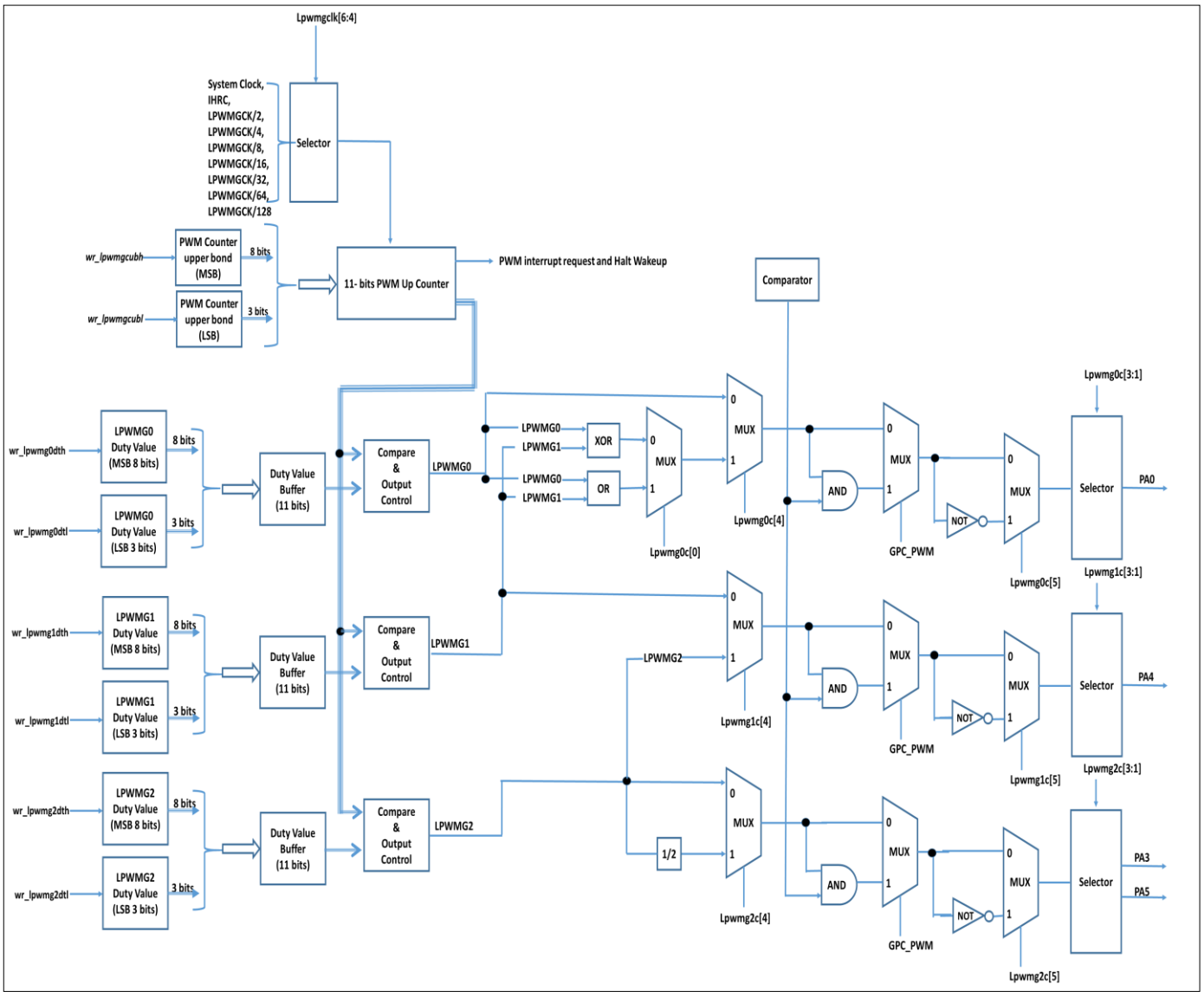


Fig.13: Hardware diagram of whole set of triple SuLED 11-bit PWM generators

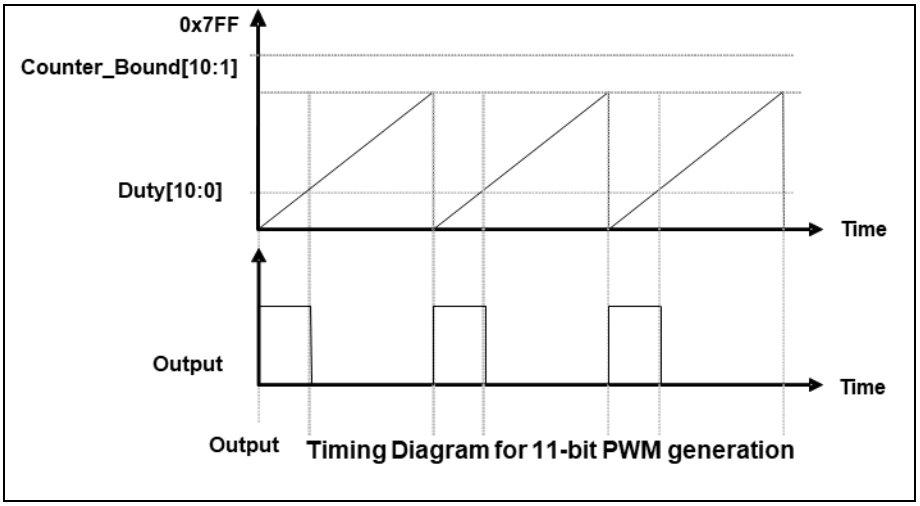


Fig.14: Output Timing Diagram of 11-bit PWM Generator

5.9.3. Equations for 11-bit PWM Generator

PWM Frequency F_{PWM} = F $_{clock\ source}$ ÷ [P × (CB10_1 + 1)]

PWM Duty(in time) = (1 / F_{PWM}) × (DB10_1 + DB0 × 0.5 + 0.5) ÷ (CB10_1 + 1)

PWM Duty(in percentage) = (DB10_1 + DB0 × 0.5 + 0.5) ÷ (CB10_1 + 1) × 100%

Where,

P = *LPWMGCLK* [6:4]; pre-scalar **P**=1,2,4,8,16,32,64,128

DB10_1 = Duty_Bound[10:1] = {*LPWMGxDTH[7:0], LPWMGxDTL[7:6]*}, duty bound

DB0 = Duty_Bound[0] = *LPWMGxDTL[5]*

CB10_1 = Counter_Bound[10:1] = {*LPWMGCUBH[7:0], LPWMGCUBL[7:6]*}, counter bound

5.9.4. PWM Waveforms with Complementary Dead Zones

Based on the specific 11 bit PWM architecture of PMB180(B), here we employ PWM2 output and PWM0 inverse output after PWM0 xor PWM1 to generate two PWM waveforms with complementary dead zones.

Example program is as follows:

```
#define   dead_zone      10      //   dead time = 10% * (1/PWM_Frequency) us
#define   PWM_Pulse      50      //   set 50% as PWM duty cycle

#define   PWM_Pulse_1    35      //   set 35% as PWM duty cycle
#define   PWM_Pulse_2    60      //   set 60% as PWM duty cycle
#define   switch_time    400*2   //   adjusting switch time

// Note: To avoid noise, switch_time must be a multiple of PWM period. In this example PWM period = 400us,
// so switch_time = 400*2 us.
void FPPA0 (void)
{
```

```
.ADJUST_IC      SYSCLK=IHRC/16, IHRC=16MHz, VBAT =5V;
//******* Generating fixed duty cycle waveform  ************************
//------  Set the counter upper bound and duty cycle -----------------
LPWMG0DTL     =     0x00;
LPWMG0DTH     =     PWM_Pulse + dead_zone;

LPWMG1DTL     =     0x00;
LPWMG1DTH     =     dead_zone;        // After LPWMG0 xor LPWMG, PWM duty cycle=PWM_Pulse%

LPWMG2DTL       =     0x00;
LPWMG2DTH     =     PWM_Pulse + dead_zone*2;

LPWMGCUBL     =     0x00;
LPWMGCUBH     =     100;
//---- Configure clock and pre-scalar ------------------
$ LPWMGCLK      Enable, /1, sysclk;
//------- Output control -----------------------------
$ LPWMG0C       Enable,Inverse,LPWM_Gen,PA0,gen_xor;   //      After LPWMG0 xor LPWMG1,
                                                       //      output the inversed waveform through PA0
$ LPWMG1C       Enable, LPWMG1,disable;                //      disable LPWMG1 output
$ LPWMG2C      Enable, PA3;                            //      output LPWMG2 waveform through PA3

while(1)
{
    //******** Switching duty cycle *********************************
    // To avoid the possible instant disappearance of dead zone, user should comply with the following
    // instruction sequence.
    // When increase the duty cycle:   50%/60%   →   35%
    LPWMG0DTL     =     0x00;
    LPWMG0DTH     =     PWM_Pulse_1 + dead_zone;
    LPWMG2DTL     =     0x00;
    LPWMG2DTH     =     PWM_Pulse_1 + dead_zone*2;
    .delay      switch_time
    // When decrease the duty cycle:   35% → 60%
    LPWMG2DTL     =     0x00;
    LPWMG2DTH     =     PWM_Pulse_2 + dead_zone*2;
    LPWMG0DTL     =     0x00;
    LPWMG0DTH     =     PWM_Pulse_2 + dead_zone;
    .delay      switch_time
}
}
```

The following figures show the waveforms at different condition.

1. The PWM waveform in a fixed-duty cycle:

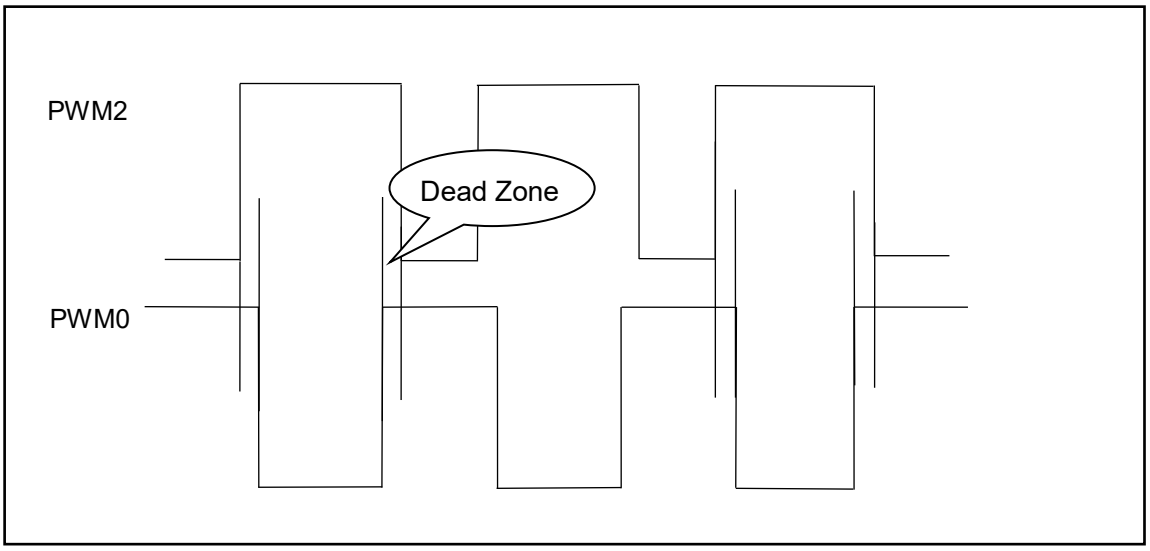


Fig.15: Complementary PWM waveform with dead zones

2. PWM waveform when switching two duty cycles:

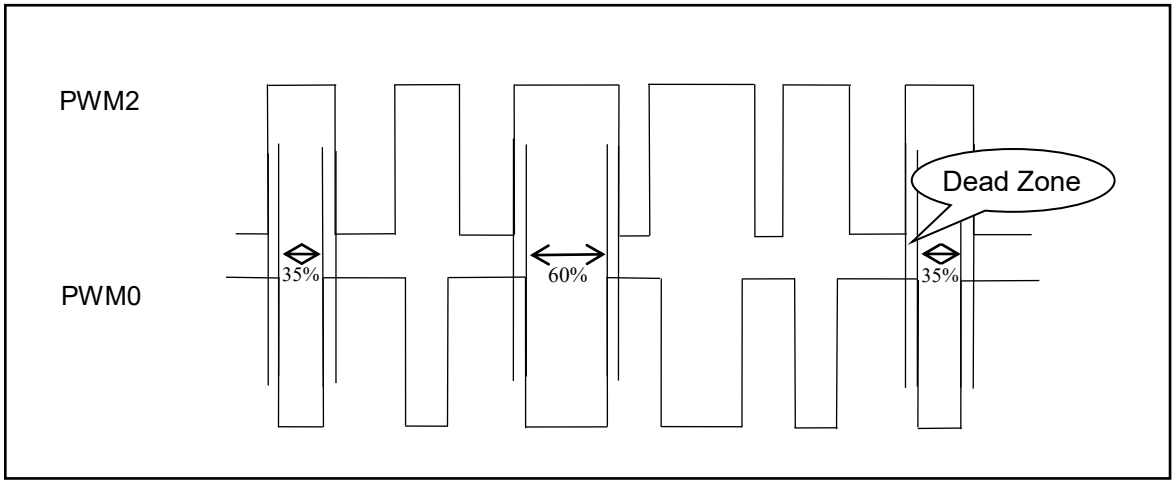


Fig.16: Complementary PWM waveform with dead zones

User can find that above example only provides dead zone where PWM are both in high. If need dead zone where PWM are both in low, you can realize it by resetting each control register's Inverse like:

$ LPWMG0C Enable,LPWM_Gen,PA0,gen_xor;

$ LPWMG2C Enable, Inverse, PA3;.

5.10.WatchDog Timer

The watchdog timer (WDT) is a counter with clock coming from ILRC. WDT can be cleared by power-on-reset or by command ***wdreset*** at any time. There are four different timeout periods of watchdog timer to 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 save 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, PMB180(B) will be reset to restart the program execution. The relative timing diagram of watchdog timer is shown as Fig.17.

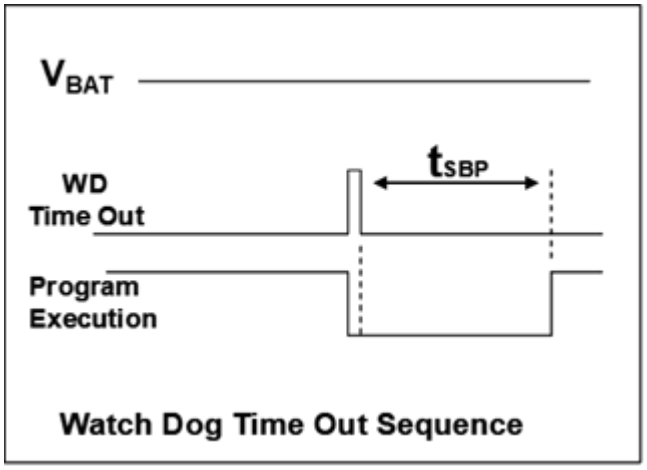


Fig.17: Sequence of Watch Dog Time Out

5.11. Interrupt

There are 6 interrupt lines for PMB180(B):

- External interrupt PA0
- External interrupt PA4
- Timer16 interrupt
- GPC interrupt
- LPWMG interrupt
- Timer2 interrupt

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.18. 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, the stack position and level are arranged by the compiler in Mini-C project. When defining the stack level in ASM project, users should arrange their locations carefully to prevent address conflicts.

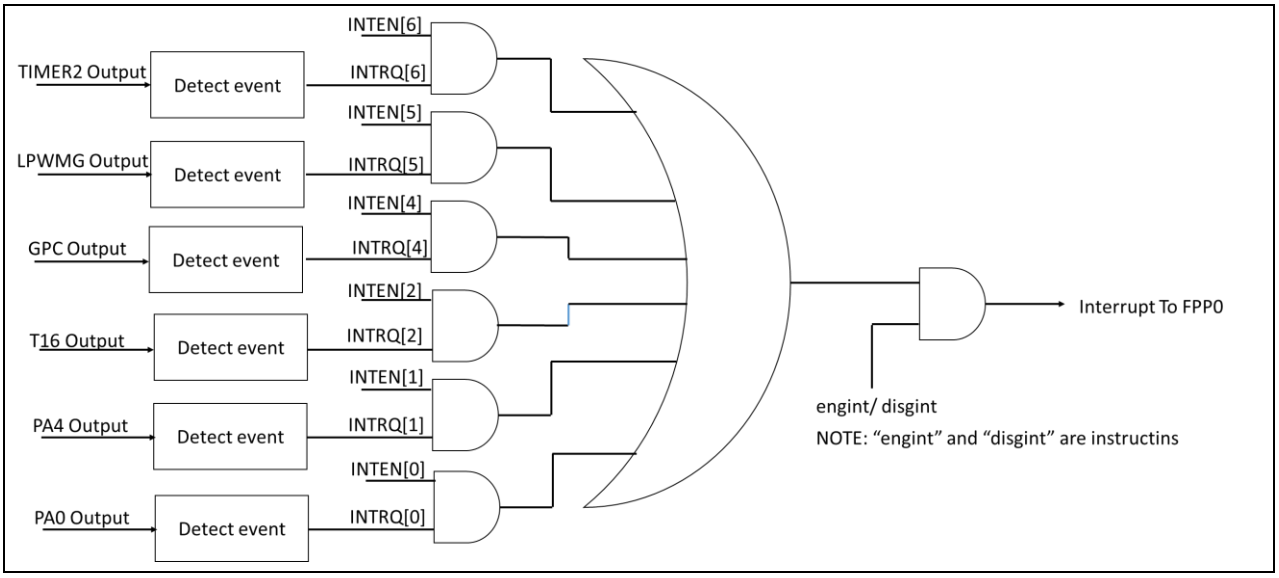


Fig.18: Hardware diagram of interrupt controller

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.
Note: Even if INTEN=0, INTRQ will be still triggered by the interrupt source.

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. And so on, two bytes stack memory is for ***pushaf***. For interrupt operation, the following sample program shows how to handle the interrupt, noticing that it needs four bytes stack memory to handle one level 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 INTEN.PA0 will be opened and closed dynamically,
    // user can judge whether INTEN.PA0 =1 or not.
    // Example:   If (INTEN.PA0 && INTRQ.PA0)   {…}

    // If INTEN.PA0 is always enable,
    // user can omit the INTEN.PA0 judgement to speed up interrupt service routine.

  If (INTRQ.PA0)
  {                              // Here for PA0 interrupt service routine
            INTRQ.PA0 = 0;       // Delete corresponding bit (take PA0 for example)
        ...
  }
    ...
    // X : INTRQ = 0;          // It is not recommended to use INTRQ = 0 to clear all at the end of the
                               // interrupt service routine.
                               // It may accidentally clear out the interrupts that have just occurred
                               // and are not yet processed.
POPAF                     // restore ALU and FLAG register
 }
```

5.12. 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 5 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	NILRC
STOPSYS	Stop	Stop	No Change
STOPEXE	No Change	No Change	No Change

Table 5: Differences in oscillator modules between STOPSYS and STOPEXE

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

Using "***stopexe***" instruction to enter the Power-Save mode, only system clock is disabled, remaining all the oscillator modules 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, NILRC wake-up of TM2C or wake-up by comparator when setting GPCC.7=1 and GPCS.6=1 to enable the comparator wake-up function at the same time. Wake-up from input pins can be considered as a continuation of normal execution, the detail information for Power-Save mode shows below:

- IHRC oscillator modules: No change, keep active if it was enabled.
- ILRC oscillator modules: must remain enabled, need to start with ILRC when be wakening up.
- System clock: Disable, therefore, CPU stops execution.
- OTP memory is turned off.
- Timer counter: Stop counting if its clock source is system clock or the corresponding oscillator module is disabled; otherwise, it keeps counting. (The Timer contains TM16, TM2, LPWMG0, LPWMG1, LPWMG2.)
- Wake-up sources:
  - **a.** IO toggle wake-up: IO toggling in digital input mode (*PAC* bit is 1 and *PADIER* bit is 1)
  - **b.** Timer wake-up: If the clock source of Timer is not the SYSCLK, the system will be awakened when the Timer counter reaches the set value.
  - **c.** TM2C wake up with NILRC clock source:
  - **d.** Comparator wake-up: It need setting *GPCC*.7=1 and *GPCS*.6=1 to enable the comparator wake-up function at the same time. Please note: the internal 1.20V bandgap reference voltage is not suitable for the comparator wake-up function.

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

```
$ T16M      ILRC, /1, BIT8              // Timer16 setting
…
WORD        count =     0;
STT16       count;
stopexe;
…
```

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

5.12.2. 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. It is recommending to set GPCC.7=0 to disable the comparator before the command "stopsys". The following shows the internal status of PMB180(B) 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: IO toggle in digital mode (PADIER bit is 1)

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:

```
CLKMD       =       0xF4;       //      Change clock from IHRC to ILRC
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
```

5.12.3. Wake-up

After entering the Power-Down or Power-Save modes, the PMB180(B) can be resumed to normal operation by toggling IO pins or NILRC wake-up of TM2C. Wake-up from timer are available for Power-Save mode ONLY. Table 6 shows the differences in wake-up sources between STOPSYS and STOPEXE.

Differences in wake-up sources between STOPSYS and STOPEXE			
	IO Toggle	NILRC wake-up of TM2C	Timer16/Comparator wake-up
STOPSYS	Yes	Yes	No
STOPEXE	Yes	Yes	Yes

Table 6: Differences in wake-up sources between Power-Save mode and Power-Down mode

When using the IO pins to wake-up the PMB180(B), registers ***padier*** should be properly set to enable the wake-up function for every corresponding pin. The time for normal wake-up is about 3000 ILRC clocks counting from wake-up event; fast wake-up can be selected to reduce the wake-up time by ***misc*** register, and the time for fast wake-up is about 45 ILRC clocks from IO toggling.

Suspend mode	Wake-up mode	Wake-up time (t_{WUP}) from IO toggle
STOPEXE suspend or STOPSYS suspend	Fast wake-up	45 * T_{ILRC}, Where T_{ILRC} is the time period of ILRC
STOPEXE suspend or STOPSYS suspend	Normal wake-up	3000 * T_{ILRC}, Where T_{ILRC} is the clock period of ILRC

Table 7: Differences in wake-up time between Fast/Normal wake-up

Please notice that when Code Option is set to Fast boot-up, no matter which wake-up mode is selected in **misc.**5, the wake-up mode will be forced to be FAST. If Normal boot-up is selected, the wake-up mode is determined by **misc.**5.

5.13. IO Pins

All the pins can be independently set into two states output or input by configuring the data registers (***pa***), control registers (***pac***) and pull-high/pull-low resistor (***paph/papl***). All these pins have Schmitt-trigger input buffer and output driver with CMOS level. When it is set to output low, the pull- high 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 8 shows the configuration table of bit 0 of port A. The hardware diagram of IO buffer is also shown as Fig.19.

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

Table 8: PA0 Configuration Table

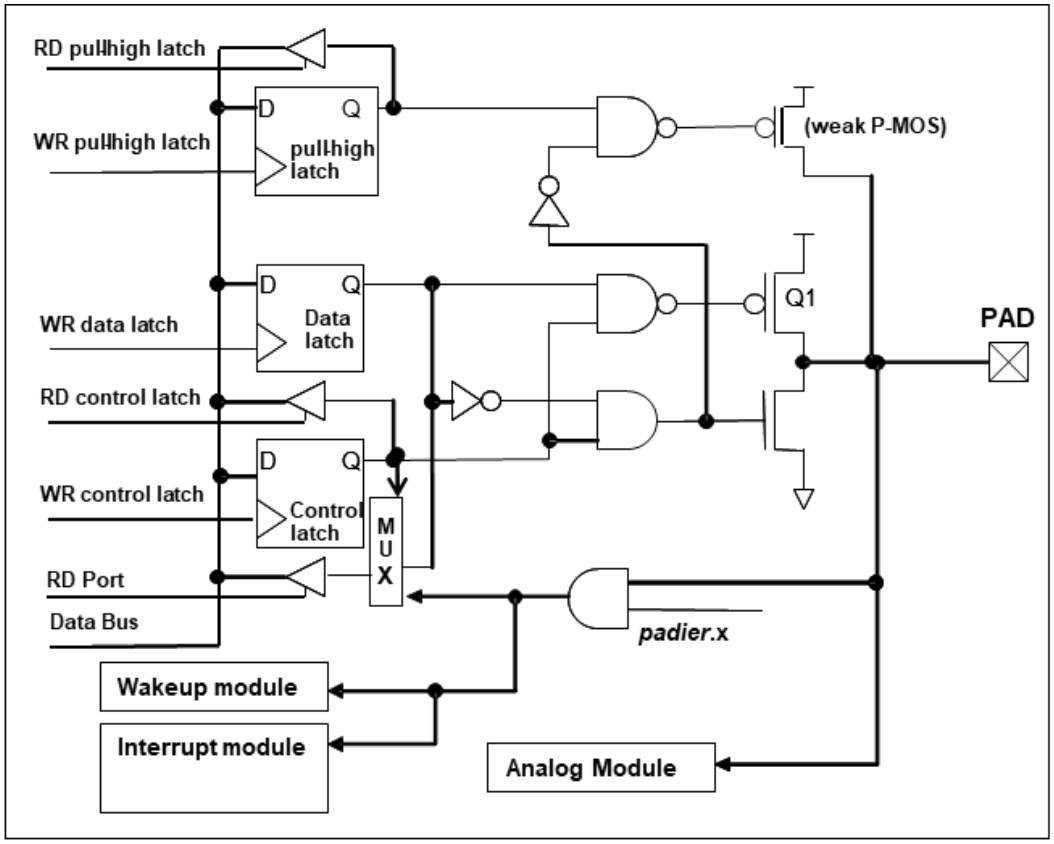


Fig.19: Hardware diagram of IO buffer

All the IO pins have the same structure. The corresponding bits in registers ***padier*** should be set to low to prevent leakage current for those pins are selected to be analog function. When PMB180(B) 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 high when PA0 is used as external interrupt pin.

5.14. Reset, LVR and LVD

5.14.1. Reset

There are many causes to reset the PMB180(B), once reset is asserted, most of all the registers in PMB180(B) will be set to default values, system should be restarted once abnormal cases happen, or by jumping program counter to address 0x00.

After a power-on reset or LVR reset occurs, if VDD is greater than VDR (data storage voltage), the value of the data memory will be retained, but if the SRAM is cleared after re-power, the data cannot be retained; if VDD is less than VDR, the data the value of the memory will be turned into an unknown state that is in an indeterminate state.

If a reset occurs, and there is an instruction or syntax to clear SRAM in the program, the previous data will be cleared during program initialization and cannot be retained.

The content will be kept when reset comes from PRSTB pin or WDT timeout.

5.14.2. LVR reset

By code option, there are 8 different levels of LVR from 1.8V to 4.0V for reset. Usually, user selects LVR reset level to be in conjunction with operating frequency and supply voltage.

5.14.3. LVD

By code option, user can use LVDC[7:2] select different levels of LVD from 1.85V to 5V, LVD can provide more accurate voltage for user confirm the voltage level.

6. IO Registers

6.1. ACC Status Flag Register (*flag*), IO address = 0x00

Bit	Reset	R/W	Description
7 - 4	-	-	Reserved. These 4 read "1".
3	0	R/W	OV (Overflow Flag). This bit is set to be 1 whenever the sign operation is overflow.
2	0	R/W	AC (Auxiliary Carry Flag). 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	0	R/W	C (Carry Flag). 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	0	R/W	Z (Zero Flag). 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.

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 (CLK) 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>010: reserved</td><td>010: ILRC÷16 (ICE does NOT Support.)</td></tr>
<tr><td>011: reserved</td><td>011: IHRC÷32</td></tr>
<tr><td>10X: reserved</td><td>100: IHRC÷64</td></tr>
<tr><td>110: ILRC÷4</td><td>110: reserved</td></tr>
<tr><td>111: ILRC (default)</td><td>11X: reserved</td></tr>
<tr><td>4</td><td>1</td><td>R/W</td><td colspan="2">Internal High RC 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">Internal Low RC 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/PRSTB function. 0 / 1: PA5 / PRSTB</td></tr>
</table>

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

Bit	Reset	R/W	Description
7	0	R/W	Reserved.
6	0	R/W	Enable interrupt from Timer2. 0 / 1: disable / enable
5	0	R/W	Enable interrupt from LPWMG. 0 / 1: disable / enable
4	0	R/W	Enable interrupt from comparator. 0 / 1: disable / enable
3	0	R/W	Reserved
2	0	R/W	Enable interrupt from Timer16 overflow. 0 / 1: disable / enable
1	0	R/W	Enable interrupt from PA4. 0 / 1: disable / enable
0	0	R/W	Enable interrupt from PA0. 0 / 1: disable / enable

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

Bit	Reset	R/W	Description
7	-	R/W	Reserved.
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 LPWM, this bit is set by hardware and cleared by software. 0 / 1: No request / Request
4	-	R/W	Interrupt Request from comparator, this bit is set by hardware and cleared by software. 0 / 1: No request / Request
3	-	R/W	Reserved
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 PA4, this bit is set by hardware and cleared by software. 0 / 1: No Request / request
0	-	R/W	Interrupt Request from pin PA0, this bit is set by hardware and cleared by software. 0 / 1: No Request / request

6.6. Timer16 mode Register (*t16m*), IO address = 0x06

Bit	Reset	R/W	Description
7 - 5	000	R/W	Timer16 Clock source selection. 000: disable 001: CLK (system clock) 010: reserved 011: PA4 falling edge (from external pin) 100: IHRC 101: EOSC 110: ILRC 111: PA0 falling edge (from external pin)
4 - 3	00	R/W	Timer16 clock pre-divider. 00: ÷1 01: ÷4 10: ÷16 11: ÷64
2 - 0	000	R/W	Interrupt source selection. Interrupt event happens when the selected bit status 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 - 6	-	-	Reserved.
5	0	WO	Enable fast Wake up. Fast wake-up is NOT supported when EOSC is enabled. 0: Normal wake up. The wake-up time is 3000 ILRC clocks (Not for fast boot-up) 1: Fast wake up. The wake-up time is 45 ILRC clocks.
4	-	-	Reserved.
3	-	-	Reserved.
2	0	WO	Disable LVR function. 0 / 1 : Enable / Disable
1 - 0	00	WO	Watch dog 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*), IO address = 0x0a

Bit	Reset	R/W	Description
7 - 1	-	-	Reserved.
0	0	WO	Power-down the Bandgap and LVR/LVD hardware modules. 0 / 1: normal / power-down. **Note:** If bandgap be disabled, there will only ILRC/T16/TM2 and I/O function can be used.

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

Bit	Reset	R/W	Description
7 - 5	-	-	Reserved. write 0.
4	0	WO	Timer16 edge selection: 0: rising edge of the selected bit to trigger interrupt 1: falling edge of the selected bit to trigger interrupt
3 - 2	-	-	PA4 edge selection: 00: both rising edge and falling edge of the selected bit to trigger interrupt 01: rising edge of the selected bit to trigger interrupt 10: falling edge of the selected bit to trigger interrupt 11: reserved.
1 - 0	00	WO	PA0 edge selection: 00: both rising edge and falling edge of the selected bit to trigger interrupt 01: rising edge of the selected bit to trigger interrupt 10: falling edge of the selected bit to trigger interrupt 11: reserved.

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

Bit	Reset	R/W	Description
7	0	WO	Enable PA7 digital input and wake-up event. 1 / 0: enable / disable. If this bit is set to low, PA7 is analog input and can NOT be used to wake-up the system.
6	0	WO	Enable PA6 digital input and wake-up event. 1 / 0: enable / disable. If this bit is set to low, PA6 is analog input and can NOT be used to wake-up the system.
5	0	WO	Enable PA5 digital input and wake-up event. 1 / 0: enable / disable. If this bit is set to low, PA5 is analog input and can NOT be used to wake-up the system.
4 - 3	00	WO	Enable PA4-PA3 digital input and wake-up event. 1 / 0: enable / disable. This bit should be set to low when PA4 is assigned as comparator input to prevent leakage current. If these bits are set to low, PA4-PA3 are analog input and can NOT be used to wake-up the system.
2	-	-	Reserved. (Please keep 00 for future compatibility)
0 - 1	00	WO	Enable PA0-PA1 digital input, wake-up event and interrupt request. 1 / 0: enable / disable. This bit can be set low to disable wake-up from PA0 toggling and interrupt request from this pin. If this bit is set to low, PA0-PA1 is analog input and can NOT be used to wake-up the system, interrupt from this pin is also disabled.

6.11.Port A Data Register (*pa*), IO address = 0x10

Bit	Reset	R/W	Description
7 - 0	0x00	R/W	Data register for Port A.

6.12. Port A Control Register (*pac*), IO address = 0x11

Bit	Reset	R/W	Description
7 - 0	0x00	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

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

Bit	Reset	R/W	Description
7 - 0	0x00	R/W	Port A pull-high register. This register is used to enable the internal pull-high device on each corresponding pin of port A and this pull high function is active only for input mode. 0 / 1 : disable / enable

6.14. Port A Pull-Low Register (*papl*), IO address = 0x0E

Bit	Reset	R/W	Description
7 - 0	0x00	R/W	Port A pull-low register. This register is used to enable the internal pull-low device on each corresponding pin of port A and this pull low function is active only for input mode. 0 / 1 : disable / enable

6.15. 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 bandgap reference voltage (not suitable for the comparator wake-up function) 011 : $V_{internal\ R}$ 100 : PA6 101 : PA7 11X: reserved
0	0	R/W	Selection the plus input (+) of comparator. 0 : $V_{internal\ R}$ 1 : PA4

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

Bit	Reset	R/W	Description
7	0	WO	Comparator output enable (to PA0). 0 / 1 : disable / enable (Please avoid this situation: GPCS will affect the PA3 output function when selecting output to PA0 output in ICE.)
6	0	WO	Wakeup by comparator enable. (The comparator wakeup effectively when gpcc.6 electrical level changed) 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)

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

Bit	Reset	R/W	Description
7 - 4	0000	R/W	Timer2 clock selection. 0000 : disable 0001 : CLK (system clock) 0010 : IHRC or IHRC *2 (by code option TM2_source) (ICE doesn't support IHRC *2.) 0011 : reserved 0100 : ILRC 0101 : comparator output 0110 : NILRC 0111 : reserved 1000 : PA0 (rising edge) 1001 : ~PA0 (falling edge) 1010 : Reserved 1011 : Reserved 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 : Reserved 10 : PA3 11 : PA4
1	0	R/W	TM2 Mode 0: Period Mode 1: PWM Mode
0	0	R/W	Inverse the polarity of result output of TM2. 0: polarity is NOT inversed. 1: polarity is inversed.

6.18. 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 TM2_bit) (ICE doesn't support 7-bit.)
6 - 5	00	WO	Timer2 clock pre-scalar. 00 : ÷ 1 01 : ÷ 4 10 : ÷ 16 11 : ÷ 64
4 - 0	00000	WO	Timer2 clock scalar.

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

Bit	Reset	R/W	Description
7 - 0	0x00	R/W	Bit [7:0] of Timer2 counter register.

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

Bit	Reset	R/W	Description
7 - 0	0x00	WO	Timer2 bound register.

6.21. Low Voltage Detect Control Register (*lvdc*), IO address = 0x1e

Bit	Reset	R/W	Description
7 - 2	000000	WO	Set LVD level: in the range of 1.85~5V, increment by 0.05V
1	-	-	Reserved
0	0	RO	The detect result between LVD & V_{BAT} 0: V_{BAT} > LVD level 1: V_{BAT} < LVD level

6.22. LPWMG0 control Register (*lpwmg0c*), IO address = 0x20

Bit	Reset	R/W	Description
7	0	R/W	GPC control lpwmg0 output. 0 / 1: Disable / Enable
6	-	RO	Output status of LPWMG0 generator.
5	0	WO	Enable to inverse the polarity of LPWMG0 generator output. 0 / 1: disable / enable.
4	0	R/W	LPWMG0 output selection. 0: LPWMG0 Output 1: LPWMG0 XOR LPWMG1 or LPWMG0 OR LPWMG1 (by lpwmg0c.0)
3 - 1	000	R/W	LPWMG0 Output Port Selection 000: LPWMG0 Output Disable 001: LPWMG0 Output to PA1 010: LPWMG0 Output to PA5 011: LPWMG0 Output to PA0 1xx: Reserved.
0	0	R/W	LPWMG0 output pre- selection. 0: LPWMG0 XOR LPWMG1 1: LPWMG0 OR LPWMG1

6.23. LPWMG Clock Register (*lpwmgclk*), IO address = 0x21

Bit	Reset	R/W	Description
7	0	WO	LPWMG Disable/ Enable 0: LPWMG Disable 1: LPWMG Enable
6 - 4	000	WO	LPWMG clock pre-scalar. 000: ÷1 001: ÷2 010: ÷4 011: ÷8 100: ÷16 101: ÷32 110: ÷64 111: ÷128
3 - 1	-	-	Reserved
0	0	WO	LPWMG clock source selection. 0: System Clock 1: IHRC or IHRC*2 (by code option PWM_Source)

6.24. LPWMG0 Duty Value High Register (*lpwmg0dth*), IO address = 0x22

Bit	Reset	R/W	Description
7 - 0	-	WO	Bit[10:3] of LPWMG0 Duty.

6.25. LPWMG0 Duty Value Low Register (*lpwmg0dtl*), IO address = 0x23

Bit	Reset	R/W	Description
7 - 5	-	WO	Bit[2:0] of LPWMG0 Duty.
4 - 0	-	-	Reserved.

Note: It's necessary to write LPWMG0 Duty_Value Low Register before writing LPWMG0 Duty_Value High Register.

6.26. LPWMG Counter Upper Bound High Register (*lpwmgcubh*), IO address = 0x24

Bit	Reset	R/W	Description
7 - 0	-	WO	Bit[10:3] of LPWMG Counter Bound.

6.27. LPWMG Counter Upper Bound Low Register (*lpwmgcubl*), IO address = 0x25

Bit	Reset	R/W	Description
7 - 6	-	WO	Bit[2:1] of LPWMG Counter Bound.
5 - 0	-	-	Reserved.

6.28. LPWMG1 control Register (*lpwmg1c*), IO address = 0x26

Bit	Reset	R/W	Description
7	0	R/W	GPC control lpwmg1 output. 0 / 1: Disable / Enable
6	-	RO	Output status of LPWMG1 generator.
5	0	R/W	Lpwmg1 output. 0 / 1: Buffered / Inverted
4	0	R/W	LPWMG1 output selection: 0: LPWMG1 1: LPWMG2
3 - 1	000	R/W	LPWMG1 Output Port Selection: 000: LPWMG1 Output Disable 001: LPWMG1 Output to PA6 010: Reserved 011: LPWMG1 Output to PA4 1xx: Reserved
0	-	R/W	Reserved.

6.29. LPWMG1 Duty Value High Register (*lpwmg1dth*), IO address = 0x28

Bit	Reset	R/W	Description
7 - 0	-	WO	Bit[10:3] of LPWMG1 Duty.

6.30. LPWMG1 Duty Value Low Register (*lpwmg1dtl*), IO address = 0x29

Bit	Reset	R/W	Description
7 - 5	-	WO	Bit[2:0] of LPWMG1 Duty.
4 - 0	-	-	Reserved

Note: It's necessary to write LPWMG1 Duty_Value Low Register before writing LPWMG1 Duty_Value High Register.

6.31. LPWMG2 Duty Value High Register (*lpwmg2dth*), IO address = 0x2E

Bit	Reset	R/W	Description
7 - 0	-	WO	Bit[10:3] of LPWMG2 Duty.

6.32. LPWMG2 Duty Value Low Register (*lpwmg2dtl*), IO address = 0x2F

Bit	Reset	R/W	Description
7 - 5	-	WO	Bit[2:0] of LPWMG2 Duty.
4 - 0	-	-	Reserved

Note: It's necessary to write LPWMG2 Duty_Value Low Register before writing LPWMG2 Duty_Value High Register.

6.33. LPWMG2 control Register (*lpwmg2c*), IO address = 0x2C

Bit	Reset	R/W	Description
7	0	R/W	GPC control lpwmg2 output. 0 / 1: Disable / Enable
6	-	RO	Output status of LPWMG2 generator.
5	0	R/W	LPWMG2 output. 0 / 1: Buffered / Inverted
4	0	R/W	LPWMG2 output selection: 0: LPWMG2 1: LPWMG2 ÷2
3 - 1	000	R/W	LPWMG2 Output Port Selection: 000: LPWMG2 Output Disable 001: Reserved 010: Reserved 011: LPWMG2 Output to PA3 100: Reserved 101: LPWMG2 Output to PA5 1xx: Reserved
0	-	R/W	Reserved

6.34. Charger Current Control (*chg_ctrl*), IO address = 0x34

Bit	Reset	R/W	Description
7 - 5	011	R/W	000 : 500mA 001 : 400mA 010 : 350mA 011 : 300mA 100 : 250mA 101 : 200mA 110 : 100mA 111 : 50mA
4 - 1	-	-	Reserved
0	0	RO	Charging module working indicator. When reading “0”, the charger starts charging. 0: Start charging or charging 1: Charging completed or stopped

6.35. Charger Current Control (*chg_temp*), IO address = 0x35

Bit	Reset	R/W	Description
7 - 5	-	-	Reserved.
4	-	RO	The status indicator bit of Vcc voltage source. It can be used to judge the status of charging Vcc 1: Vcc > V_{BAT} 0: Vcc < V_{BAT}
3	-	RO	Charging action indicator bit. 1: Vcc is normal 0: Charging in progress. Vcc is too low and charger shutdown.
2	-	-	Reserved.
1	-	R/W	**PMB180：** Reserved, only be set to 0. (The new version of IDE does not support OTP_100 settings) **PMB180B：** Charging completion indicator bit (this function is only available for PMB180B) (When the charging current drops below 1/10, charging is turned off and chg_temp.1 is automatically set to 1) Read "0"：Charging completion indicator. (Charging current is less than 1/10, charging is turned off) Read "1" ：Charging in progress. **only be set to 0**
0	-	R/W	Over temperature charging protection bit (Temperature less than 140) Write 1 read "0" to trigger the over-temperature protection, and read "1" to be normal.

6.36. Charger Charge Voltage Calibration Register (*chg_trim*), IO address = 0x32

Bit	Reset	R/W	Description
7 - 3	0XF	WO	Charger charging voltage calibration bit. 0b_1111_1:Vbat=max ； 0b_0000_0:Vbat=min The “.Adust_IC” macro command will automatically fill in the value of the calibration parameter after execution, and it is not recommended that users change it arbitrarily by themselves.
2	0	WO	Charger CV Mode Vbat Voltage Output 0 / 1: Disable / Enable (For verification test use only, VCC >= +5V, user modification is not recommended.)
1	0	WO	Reserved, write value needs to be 0
0	0	RO	Reserved, write value needs to be 0

Note:

(1) Users who want to dynamically micro-adjust the charging voltage of the charger in the program, or rewrite the chg_trim to the value of the calibration parameter, can use the macro instruction “ReLoad_VbatBGTRIM”.

(2) Using the macro command “Charger_CVMode”, the charger will switch to CV Mode, which is only for the VBAT pin to measure the final constant charge voltage value when the battery is empty and not connected to the Li-ion battery.

(3) Using the macro instruction “Charger_CCMode” or “ReLoad_VbatBGTRIM”, the charger will switch back to CC Mode.

(4) The macro instruction “.Adjust_IC” supports micro-adjustment of charger charging voltage correction parameters, just add the following command "REG:CHG_TRIM = -0x08";

//chg_cur[7:0] = CP_TrimParameter - 0x08;

Example.

.ADJUST_IC SYSCLK=ILRC (IHRC/16), IHRC=16MHz, VDD=4.2V O_WDRST, X_FIRST, REG:CHG_CUR = -0x08;

(5) If the charger trim value (chg_trim) is changed by the user, the message "The charger trim value of this PDK file has been modified" will appear in the pop-up window when Write downloads the PDK.

6.37. Charger Charge Current Calibration Register (*chg_cur*), IO address = 0x33

Bit	Reset	R/W	Description
7 - 4	0X8	WO	Charger charging voltage calibration bit. 0b_1111:Vbat = min ； 0b_0000: Vbat = max The “.Adust_IC” macro command will automatically fill in the value of the calibration parameter after execution, and it is not recommended that users change it arbitrarily by themselves.
3-0	0	WO	Reserved, write value needs to be 0

Note:

(1) Users who want to dynamically micro-adjust the charging current of the charger in the program, or rewrite chg_cur to the value of the calibration parameter, can use the macro instruction ReLoad_ChargerCURTRIM.

(2) The macro instruction “.Adjust_IC” supports micro-adjustment of the charger charge current correction parameter by simply adding the following command "REG:CHG_CUR = -0x10";

//chg_cur[7:0] = CP_TrimParameter - 0x10.

Example.

.ADJUST_IC SYSCLK=ILRC (IHRC/16), IHRC=16MHz, VDD=4.2V O_WDRST, X_FIRST, REG:CHG_CUR = -0x10;

(3) If the charger trim value (chg_cur) is changed by the user, the message "The charger trim value of this PDK file has been modified" will appear when Writer downloads the PDK.

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)
M.n	Only addressed in 0~0x3F (0~63) is allowed
IO.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 ; // mov 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 ; // mov 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
nadd a, M	Add negative logic (2's complement) of ACC with memory Example: *nadd a, MEM ;* Result: a ← ∓a + MEM Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV
nadd M, a	Add negative logic (2's complement) of memory with ACC Example: *nadd MEM, a ;* Result: MEM ← ∓MEM + a 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 ---

comp a, M	Compare ACC with the content of memory Example: *comp a, MEM;* Result: Flag will be changed by regarding as (a - MEM) Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV Application Example: --- *mov a, 0x38 ;* *mov mem, a ;* *comp a, mem ; // Z flag is set as 1* *mov a, 0x42 ;* *mov mem, a ;* *mov a, 0x38 ;* *comp a, mem ; // C flag is set as 1* ---
comp M, a	Compare ACC with the content of memory Example: comp MEM, a; Result: Flag will be changed by regarding as (MEM - a) Affected flags: 『Y』Z 『Y』C 『Y』AC 『Y』OV

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 B to high Affected flags: 『N』Z 『N』C 『N』AC 『N』OV
swapc IO.n	Swap the bit n 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 ... ---
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

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 EX: *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 from 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 CPU 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, idxm, pcadd, ret, reti*
2T	Condition is fulfilled	*ceqsn,* cneqsn,*t0sn, t1sn, dzsn, izsn*
1T	Condition is not fulfilled	
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	-	-	-	-	*nadd M, a*	Y	Y	Y	Y	*cneqsn a, I*	Y	Y	Y	Y
cneqsn a, M	Y	Y	Y	Y	*comp a, M*	Y	Y	Y	Y	*nadd a, M*	Y	Y	Y	Y
comp M, a	Y	Y	Y	Y	*swapc IO.n*	-	Y	-	-					

7.10. BIT definition

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

8. Code Options

Option	Selection	Description
Security	Enable	OTP content is protected and program cannot be read back
	Disable	OTP content is not protected so program can be read back
LVR	4.0V	Select LVR = 4.0V
	3.5V	Select LVR = 3.5V
	3.0V	Select LVR = 3.0V
	2.7V	Select LVR = 2.7V
	2.5V	Select LVR = 2.5V
	2.2V	Select LVR = 2.2V
	2.0V	Select LVR = 2.0V
	1.8V	Select LVR = 1.8V
GPC_TM2	Disable	Comparator does not control TM2 output
	Enable	Comparator controls TM2 output (ICE does NOT Support.)
LPWM_Source	16MHZ	When Lpwmgclk.0= 1, LPWMG clock source = IHRC = 16MHZ
	32MHZ	When Lpwmgclk.0= 1, LPWMG clock source = IHRC*2 = 32MHZ (ICE does NOT Support.)
TM2_Source	16MHZ	When tm2c[7:4]= 0010, TM2 clock source = IHRC = 16MHZ
	32MHZ	When tm2c[7:4]= 0010, TM2 clock source = IHRC*2 = 32MHZ (ICE does NOT Support.)
TM2_Bit	6 Bit	When tm2s.7=1, TM2 PWM resolution is 6 Bit
	7 Bit	When tm2s.7=1, TM2 PWM resolution is 7 Bit (ICE does NOT Support.)
Comparator_Edge	All_Edge	The comparator will trigger an interrupt on the rising edge or falling edge.
	Rising_Edge	The comparator will trigger an interrupt on the rising edge.
	Falling_Edge	The comparator will trigger an interrupt on the falling edge.
CheckROM_Enhancement	Newer (Default)	Added a verification mechanism in the programmer after data is written. Requires use with IDE / Writer software version V1.03A5 or later for programming. (Note: The checksum may differ from that of older compiled versions)
	Older	Compatible with older versions (prior to IDE / Writer V1.03A5)

9. Special Notes

This chapter is to remind user who use PMB180(B) series IC in order to avoid frequent errors upon operation.

9.1. Using IC

9.1.1. Charger Use and Setting

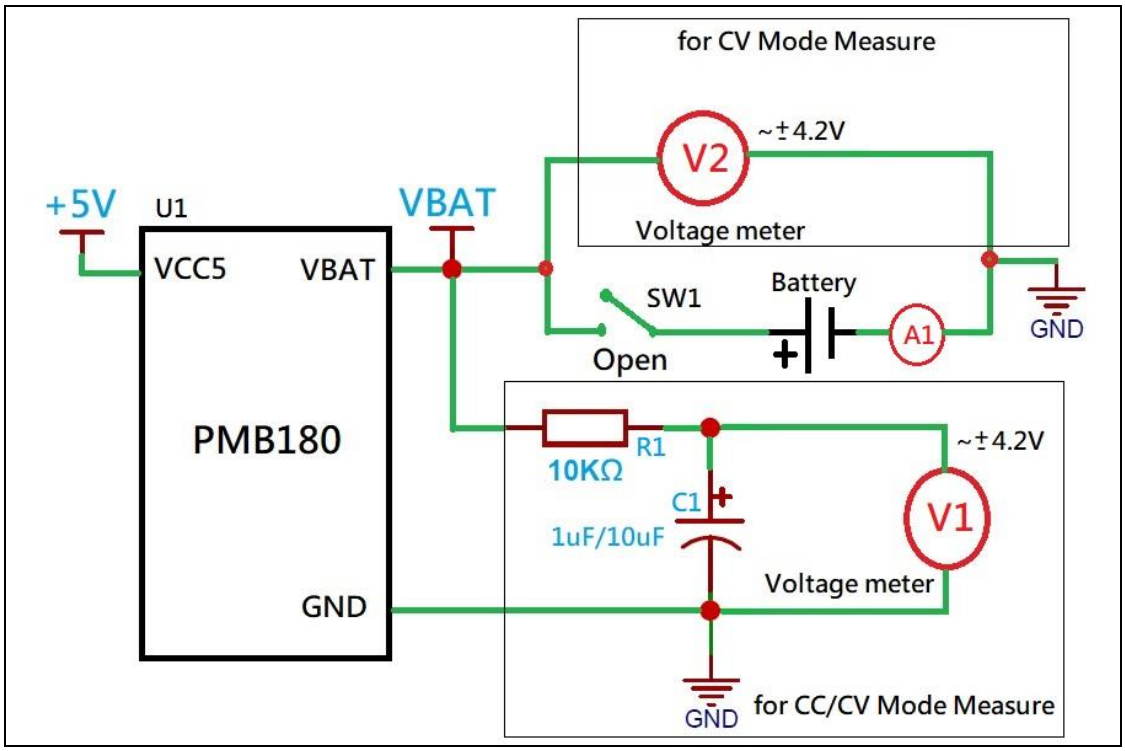
(1) Charging voltage and current measurement

◆ The PMB180(B) charger and the MCU execution program work independently of each other, and the MCU reset does not affect the charging action.

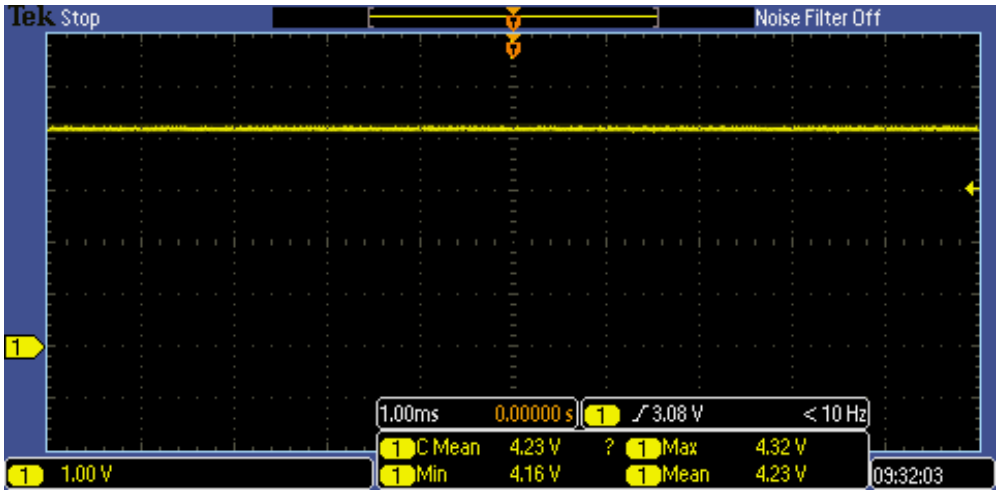
◆ Measuring the charging voltage and current of the PMB180(B) chip that has not been programmed will obtain the uncalibrated charging voltage and current. (Because the voltage and current calibration registers of the charger were not filled with accurate calibration parameters)

◆ The PMB180(B) will write calibration parameters for the charger after the program has started working properly, at which time the PMB180(B)'s charger can be electrically measured.

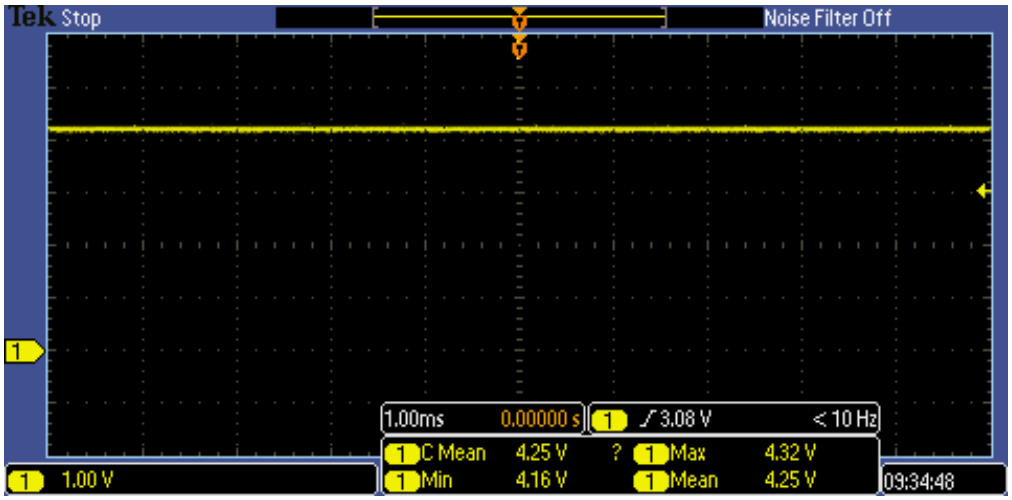
◆ The wiring diagram for measuring the charging voltage of the PMB180(B) charger is shown as follows: in CC Mode, you need to connect an RC circuit in series at the VBAT pin (to simulate the equivalent circuit of the battery's internal resistance), and the voltmeter V1 is connected in parallel to the capacitor C1, while in CV Mode, you can connect the voltmeter V2 in parallel to the VBAT pin.



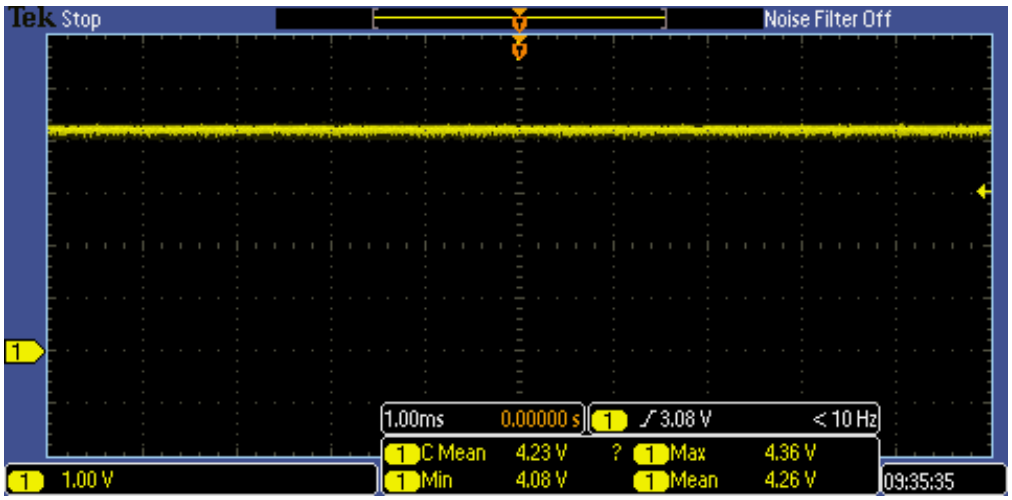
V1 Voltage waveform: (CC Mode, R1 = 10Kohm, C1 = 1uF)



V1 voltage waveform: (CV Mode, R1 = 10Kohm, C1 = 1uF)

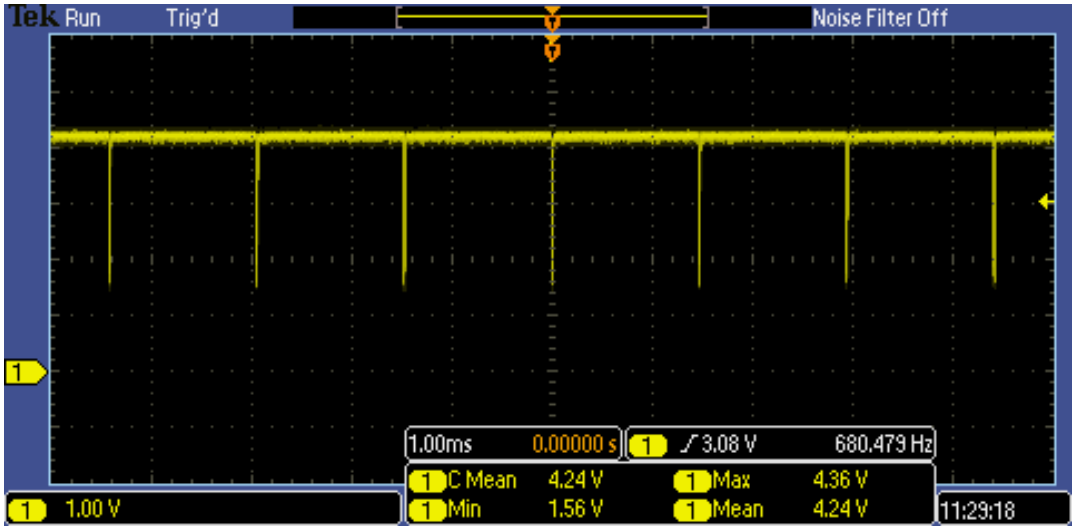


V2 voltage waveform: (CV Mode, No R1 and C1)

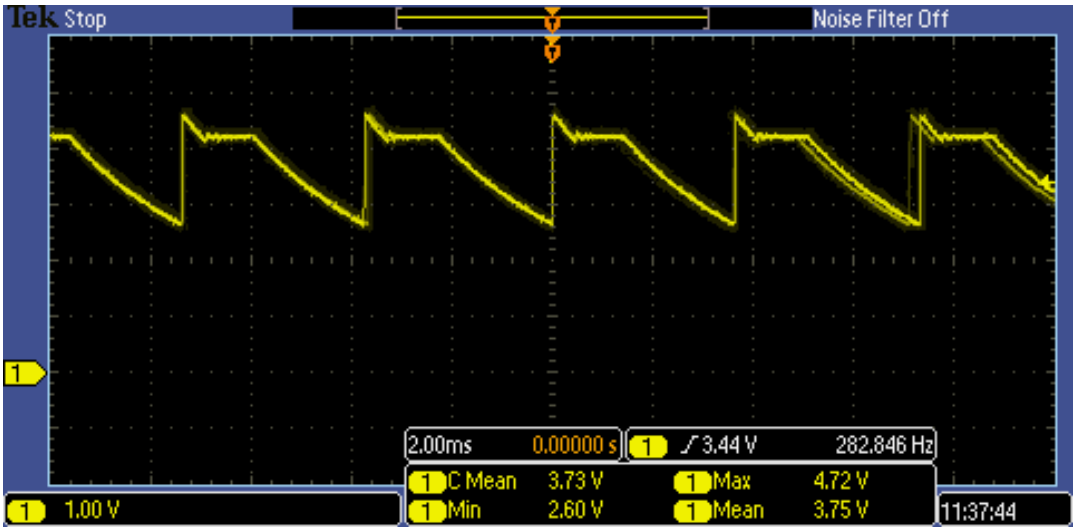


- In CC Mode, if the VBAT pin is empty or only the filtering capacitor / electrolytic capacitor is connected, the measured voltage may be lower due to the charging and discharging effect of the charger on the external capacitor. The interval cycle charging time of the charger after charging to 4.2V full charge is about 1-3ms. At this time, if VBAT pin is not connected to battery or only connected to capacitor, the average voltage measured by voltmeter will be lower due to the discharge time. For example, when using a voltmeter to directly measure the VBAT pin voltage, and the VBAT pin only has a 1uF capacitor connected in parallel, it will cause a measurement error (much lower than the target value) because the discharge time will become longer, causing the voltmeter to measure a lower voltage value. The Vbat voltage waveform is as shown below.

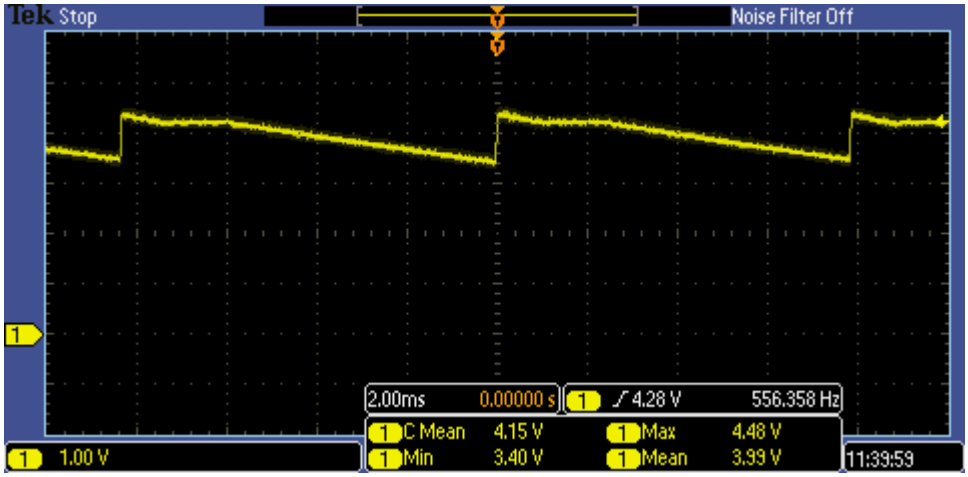
V2 voltage waveform: (CC Mode, No R1 and C1)



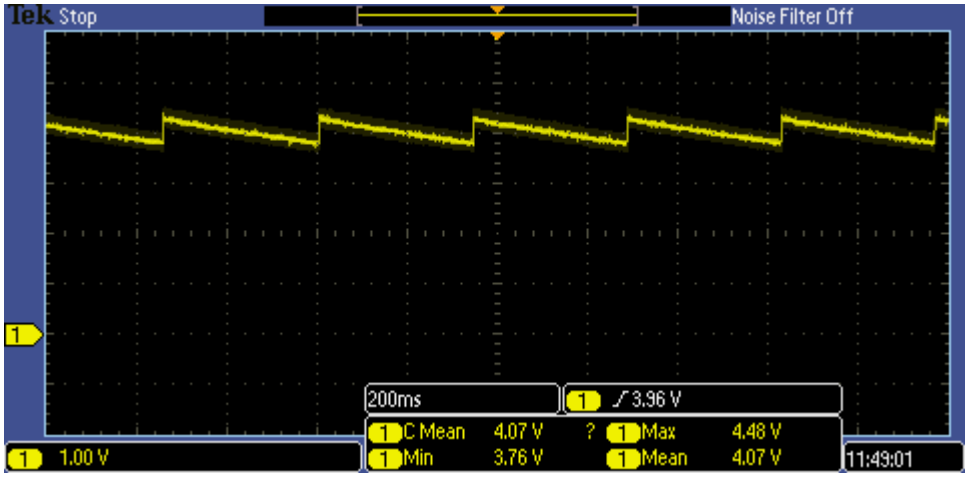
V2 voltage waveform: (CC Mode, R1 = 0R , C1 = 1uF)



V2 voltage waveform: (CC Mode, R1 = 0R , C1 = 4.7uF)



V2 voltage waveform: (CC Mode, R1 = 0R , C1 = 470uF)



- The versions of IDE 0.99D8 and later provide several advanced macro commands to modify the charger calibration parameters, which are not recommended to be changed by users. If you have any concerns, please consult the technical engineers of the original manufacturer or distributor. If the charger trim value is changed by the user, a message "The charger trim value of this PDK file has been modified" will appear when Writer downloads the burned file.

9.1.2. IO pin usage and setting

(1) IO pin is set to be digital input

- ◆ When IO is set 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 change with the voltage, temperature and pin voltage. It is not the fixed value.

(2) IO pin as digital input and enable wakeup function

- ◆ Configure IO pin as input
- ◆ Set corresponding bit to “1” in PXDIER
- ◆ For those IO pins of PA that are not used, PADIER[1:2] should be set low in order to prevent them from leakage.

(3) PA5 is set to be PRSTB input pin

- ◆ Configure PA5 as input
- ◆ Set CLKMD.0=1 to enable PA5 as PRSTB input pin

(4) 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.

9.1.3. 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.

9.1.4. 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.

- Example : 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
```

9.1.5. Watchdog

Watchdog is open by default, but when the program executes ADJUST_IC, the watchdog will be closed. To use the watchdog, you need to reconfigure the open. Watchdog will be inactive once ILRC is disabled.

9.1.6. TIMER time out

When select $ INTEGS BIT_R (default value) and T16M counter BIT8 to generate interrupt, if T16M counts from 0, 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.

If select $ INTEGS BIT_F(BIT triggers from 1 to 0) and T16M counter BIT8 to generate interrupt, the T16M counter changes to an interrupt every 0x200/0x400/0x600/. Please pay attention to two differences with setting INTEGS methods.

9.1.7. 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.

9.1.8. LVR

LVR level selection is done at compile time. User must select LVR based on the system working frequency and power supply voltage to make the MCU work stably.

The following are Suggestions for setting operating frequency, power supply voltage and LVR level:

SYSCLK	V_{BAT}	LVR
2MHz	≧ 1.8V	≧ 1.8V
4MHz	≧ 2.2V	≧ 2.2V
8MHz	≧ 2.7V	≧ 2.7V

Table 9: LVR setting for reference

(1) The setting of LVR (1.8V ~ 4.0V) will be valid just after successful power-on process.
(2) User can set MISC as "1" to disable LVR. However, V_{BAT} must be kept as exceeding the lowest working voltage of chip; Otherwise IC may work abnormally.
(3) The LVR function will be invalid when IC in stopexe or stopsys mode.

9.1.9. Programming Writing

There are 4 pins for using the writer to program: PA4, PA6, V_{BAT} and GND.

Please use 5S-P-003x or later version to program PMB180(B) real chip. (3S-P-002 or elder versions do not support programming PMB180(B))

- Special notes about voltage and current while Multi-Chip-Package(MCP) or On-Board Programming

(1) V_{BAT} may be higher than 9.5V, and its maximum current may reach about 20mA.
(2) All other signal pins level (except GND) are the same as V_{BAT}.

User should confirm when using this product in MCP or On-Board Programming, the peripheral components or circuit will not be damaged by the above voltages, and will not clam the above voltages.

Important Cautions：

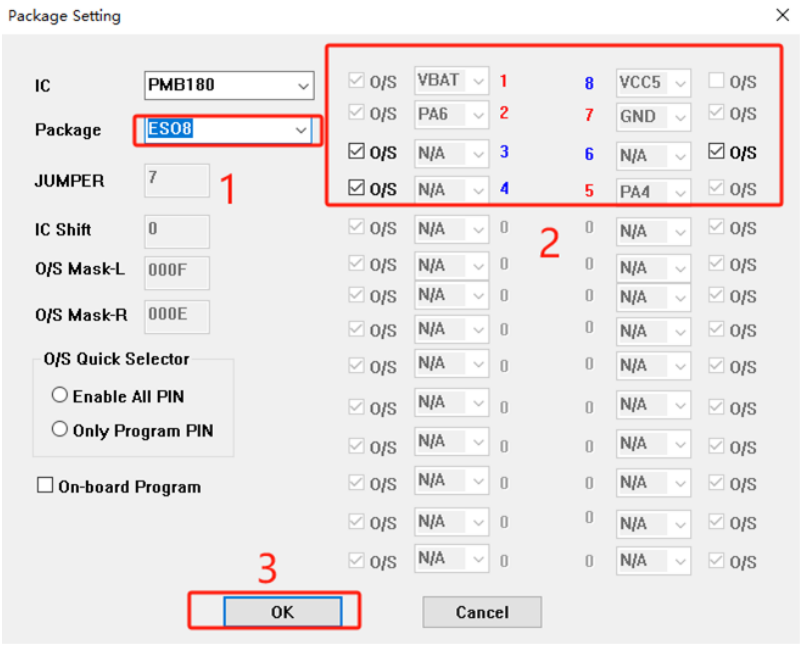
- **You MUST follow the instructions on APN004 and APN011 for programming IC on the handler.**
- **Connecting a 0.01uF capacitor between V_{BAT} and GND at the handler port to the IC is always good for suppressing disturbance. But please DO NOT connect with ＞0.01uF capacitor, otherwise, programming may be fail.**

9.1.9.1. Using 5S-P-003B to write PMB180(B)

For 5S-P-003B to write PMB180(B), Use jumper7 to adapt program signal connection. The connection of signal depends on the IC package. Please refer to. Chapter 5 of the Writer user manual to find example and make the jumper-7 adaptive board for target IC package. User can get the user manual from the following linker web page.

http://www.padauk.com.tw/en/technical/index.aspx?kind=27

Load PDK from GUI, insert JP7 and then input IC on the socket without shift. After LCDM displays IC ready, it can be written.



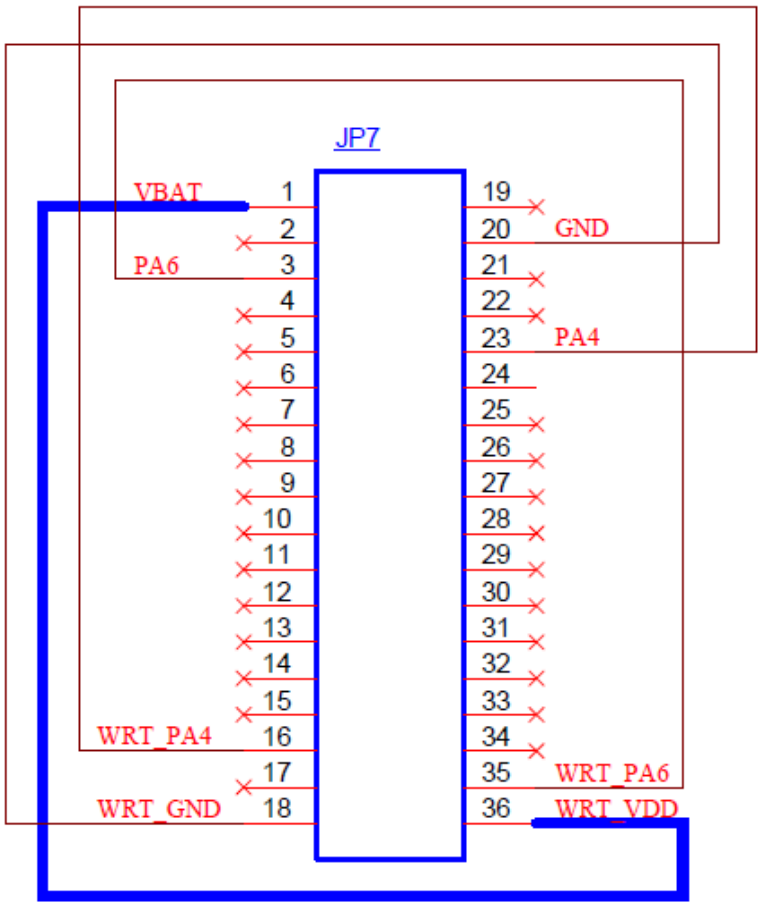
Note: O/S Test for VCC5 pins is not supported on Program Write

In addition, the information of Convert PDK can also be directly defined in the program, as follows:

```
//////////////////////////////
// program pin for ESOP10
//////////////////////////////
//   VBAT  1    10  VCC5
//         2    9   GND
//   PA6   3    8
//         4    7
//         5    6   PA4
//////////////////////////////

// package      pin_cnt   vbat pa0 pa3 pa4 pa5 pa6 pa7 gnd vcc5  agnd   mask1  mask2  shift  option
.writer package 10,         1,  0,  0,  6,  0,  3,  0,  9,  10,   0,     0x1F,  0x1E,  0,     0
```

For example, make JP7 writer signal connection of ESSOP-10, as the following.



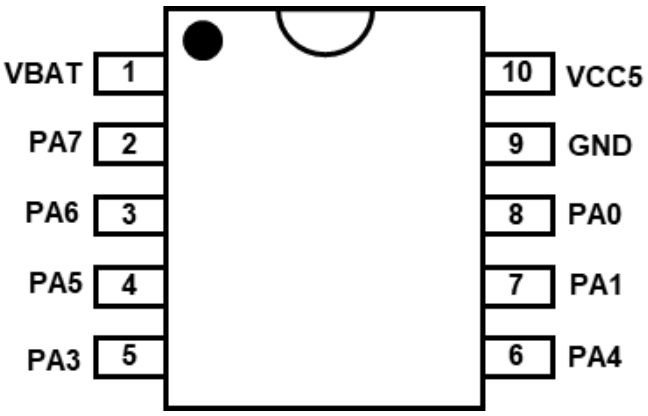


Fig. 20: schematic diagram of Jumper7 for P003B

Insert JP7 and input IC on the socket without shift. After LCDM displays IC ready, it can be written.

9.1.9.2. Using 5S-P-003 to write PMB180(B)

5S-P-003 and 5S-P-003B writing PMB180(B) in the likely way. But user should be take care the following thing.

1. Convert the PDK file from GUI

   Enter the writing interface from the IDE, then click “Convert” -> “To Package”. In the “Package Setting” interface, select the package with the suffix [P003] (as shown in Figure.21), then click “V_{BAT} /PA5 Swap on JP7 adapter”. After confirming information about the IC pin, save and use the newly generated PDK file. Please refer to Figure 21 and Figure 22 for specific operation steps.

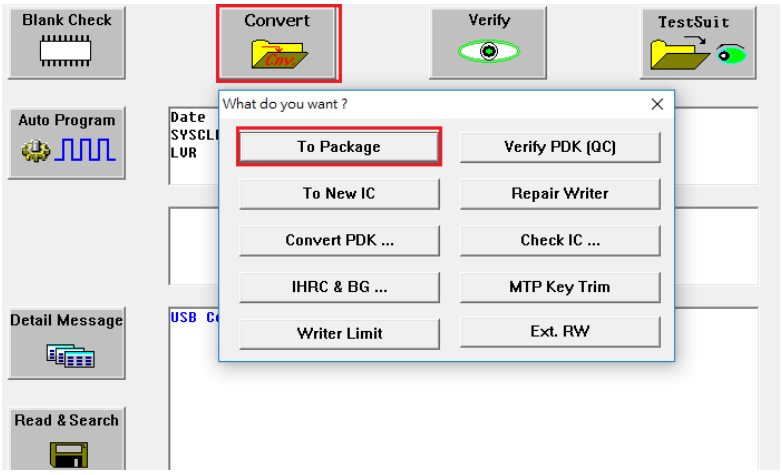


Fig.21: convert the PDK file

Note: O/S Test for VCC5 pins is not supported on Program Write

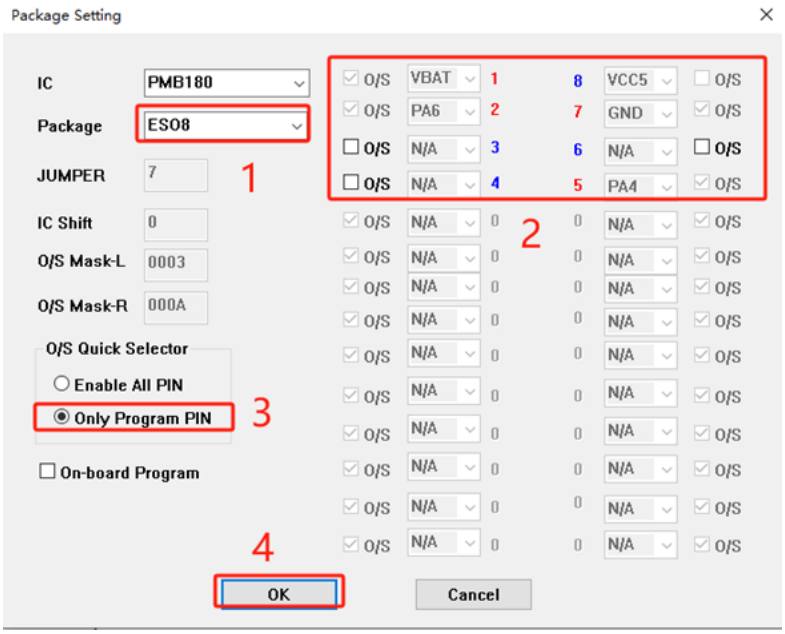


Fig.22: package setting

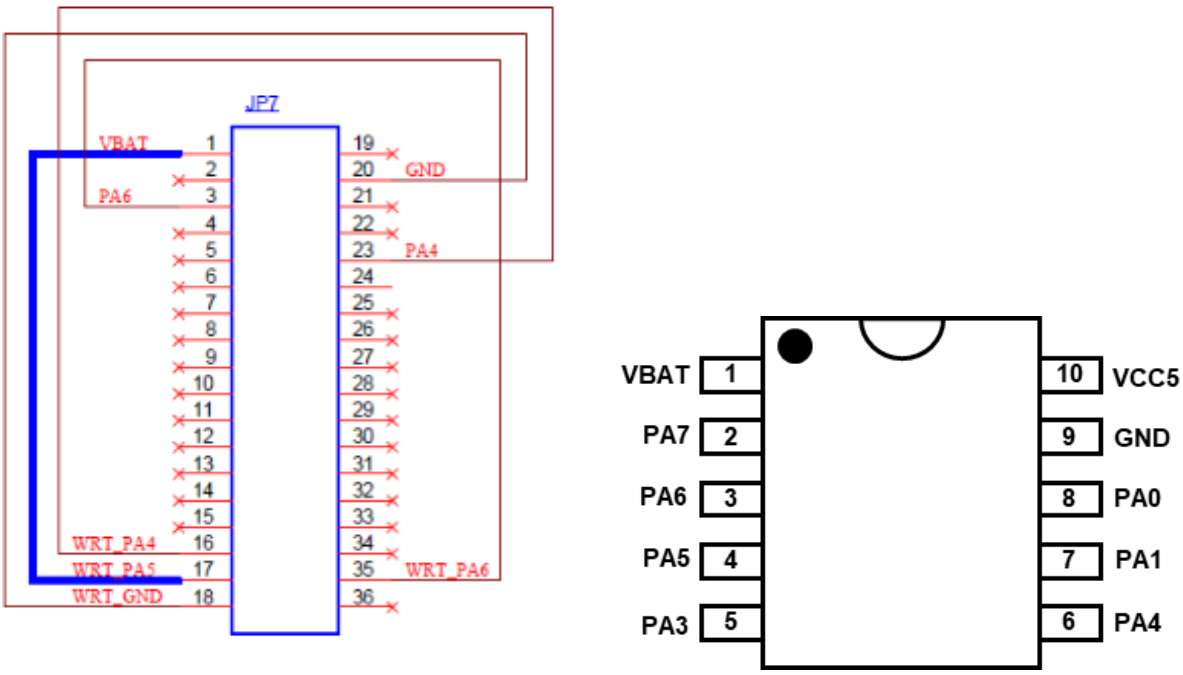
In addition, the information of Convert PDK can also be directly defined in the program, as follows

```
//////////////////////////////
// program pin for ESOP10
//////////////////////////////
//   VBAT  1    10  VCC5
//         2    9   GND
//   PA6   3    8
//         4    7
//         5    6   PA4
//////////////////////////////

// package      pin_cnt   vbat pa0 pa3 pa4 pa5 pa6 pa7 gnd vcc5  agnd   mask1  mask2  shift  option
.writer package 10,         1,  0,  0,  6,  0,  3,  0,  9,  10,   0,     0x05,  0x12,  0,     0x10

// option
//    bit2 - onboard
//    bit4 - vbat/vpp swap
//  others - reserved
```

As shown in figure 23, it is the Jumper7 connection method. (using ESSOP10 as example)



Note: Writer PA5-PIN MUST connect to IC-V_{BAT}

Fig.23: schematic diagram of Jumper7 for P003

2. Insert JP7 and input IC on the socket without shift. After LCDM displays IC ready, it can be written.

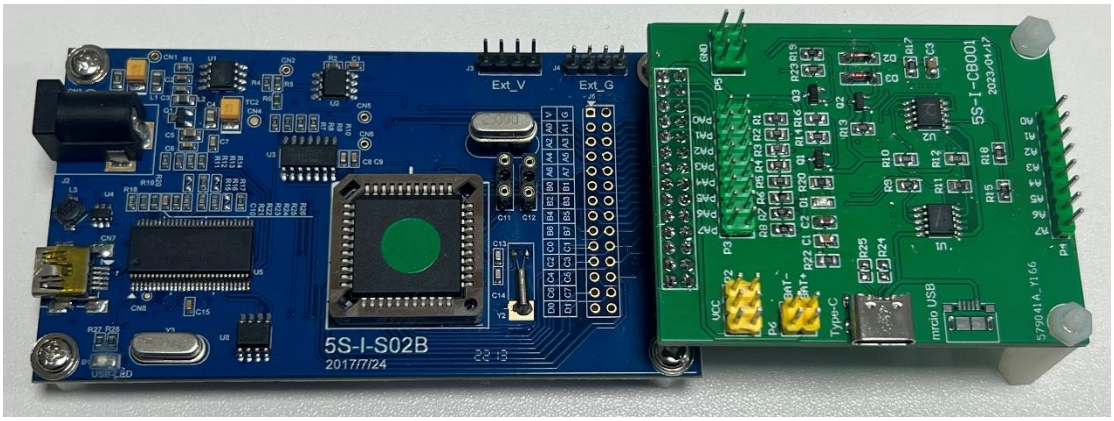
5S-P-003 writing PMB180(B) other package of IC in the same way, and both use the V_{BAT} /PA5 swap method. The principle and steps are similar to 5S-P-003 writing PMB180(B)-EY10. Please pay attention to changing the package setting and jumper7 connect method to correspond to another package, which will not be repeated here.

9.1.10. Application Manual

For more precautions on the use of the charger, refer to the APN-021 documentation instructions.

9.2. Using ICE

5S-I-CB001 is a simulation tool launched by PADAUK Technology for PMB180(B). It needs to be used with PADAUK Technology's IDE software for online simulation. When using 5S-I-CB001, it needs to be used with 5S-I-S01/2 (B). Refer to the following pictures:



5S-I-CB001 Simulation Notes:

(1) 5S-I-CB001 must be matched with 5S-I-S01/2 (B) series emulators to simulate functions such as PAPL/LPWM/CHARGE

(2) 5S-I-CB001 power supply by 5S-I-S01/2 (B) In order to stabilize the power supply, please connect 5S-I-S01/S02 (B) to the DC9V power adapter.

(3) IDE version 0.97E4 starts supporting emulation of 5S-I-CB001.

(4) When simulating charging, LPWM and PxPL related functions, the 5S-I-S01/2 (B) will communicate with the simulation board 5S-I-CB001, so the simulation may be slightly slower than the actual IC, which mainly affects the following register ： configurations: INTRQ/PAPL/LVDC/CHGC/CHGS/LPWMGCLK/ LPWMGCUBH/LPWMGCUBL/LPWMGxC, LPWMGxDTH, LPWMGxDTL and so on.

(5) During simulation, the communication between ICE and 5S-I-CB001 will delay the trigger of the interrupt, and the delay time is about 0~ 335us.

(6) Using interrupt timing such as T16/TM2/TM3, the interrupt timing is inaccurate. ICE and 5S-I-CB001 communication will switch the system clock and delay the trigger of the interrupt. This phenomenon often occurs when the timer clock source selects SYSCLK or when the timing time is short. Therefore, it is recommended that a single timing interrupt period ≥ 10ms during simulation.

(7) The communication between ICE and 5S-I-CB001 requires interrupts during simulation, so it is not supported to rewrite 7 times for functional simulation.

(8) During simulation, ICE and 5S-I-CB001 do not support the charger CV_Mode switching, charging voltage correction parameter and charging current correction parameter dynamic adjustment function.

5S-I-S01/2 (B) supports PMB180(B) 1-FPPA MCU emulation work, the following items should be noted when using 5S-I-S01/2(B) to emulate PMB180(B):

(1) 5S-I-S01/2(B) doesn't support the function of the set of 11-bit SuLED hardware PWM generators.
(2) 5S-I-S01/2(B) doesn't support the instruction NADD/COMP of PMB180(B).
(3) 5S-I-S01/2 (B) doesn't support SYSCLK=ILRC/16 of PMB180(B).
(4) 5S-I-S01/2 (B) doesn't support the function ***Tm2C.gpcrs, PA4*** of PMB180(B).
(5) 5S-I-S01/2 (B) doesn't support EOSCR Build-in Capacitor.
(6) 5S-I-S01/2 (B) doesn't support GPCC.N_PA6/N_PA7
(7) 5S-I-S01/2 (B) doesn't support LVDC and OPR3.
(8) 5S-I-S01/2 (B) doesn't support TM2 with NILRC clock source.
(9) The PA3 output function will be affected when GPCS selects output to PA0 output.
(10) When simulating PWM waveform, please check the waveform during program running. When the ICE is suspended or single-step running, its waveform may be inconsistent with the reality.
(11) The ILRC frequency of the 5S-I-S01/2(B) simulator is different from the actual IC and is not calibrated, with a frequency range of about 34K~38KHz.
(12) The power-down command Stopsys does not support the comparator wake-up function. When using 5S-I-S01/2(B), it should be noted that the comparator enable should be set to the off state before entering the power-down mode. If the enable state is turned on, the comparator will be mistakenly awakened.
(13) Fast Wakeup time is different from 5S-I-S01/2(B): 128 SysClk, PMB180(B): 45 ILRC.
(14) Watch dog time out period is different from 5S-I-S01/2:

WDT period	5S-I-S01/2(B)	PMB180(B)
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}

9.3. Typical Application

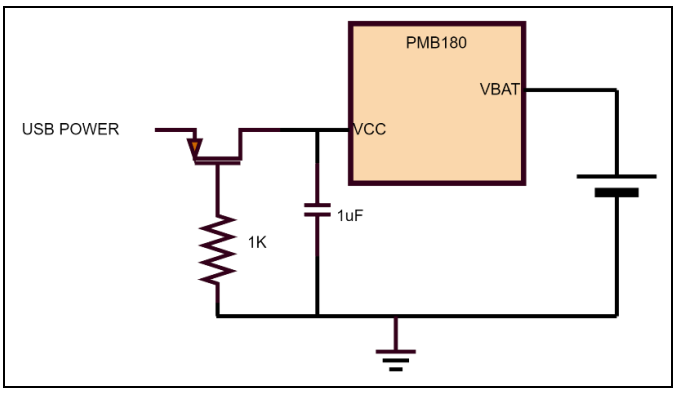


Fig.24: Basic Li-Ion Charger with Reverse Polarity Input Protection

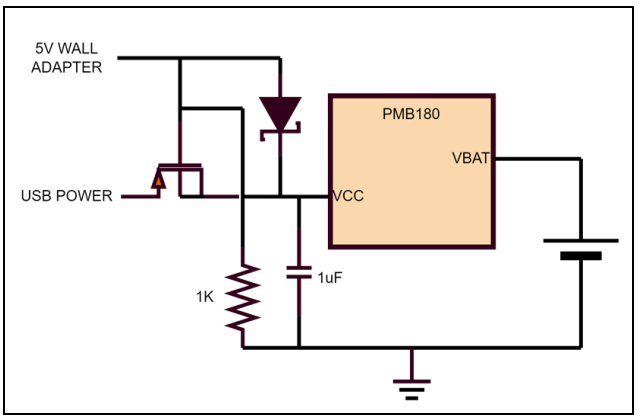


Fig.25: USB/Wall Adapter Power Li-Ion Charger

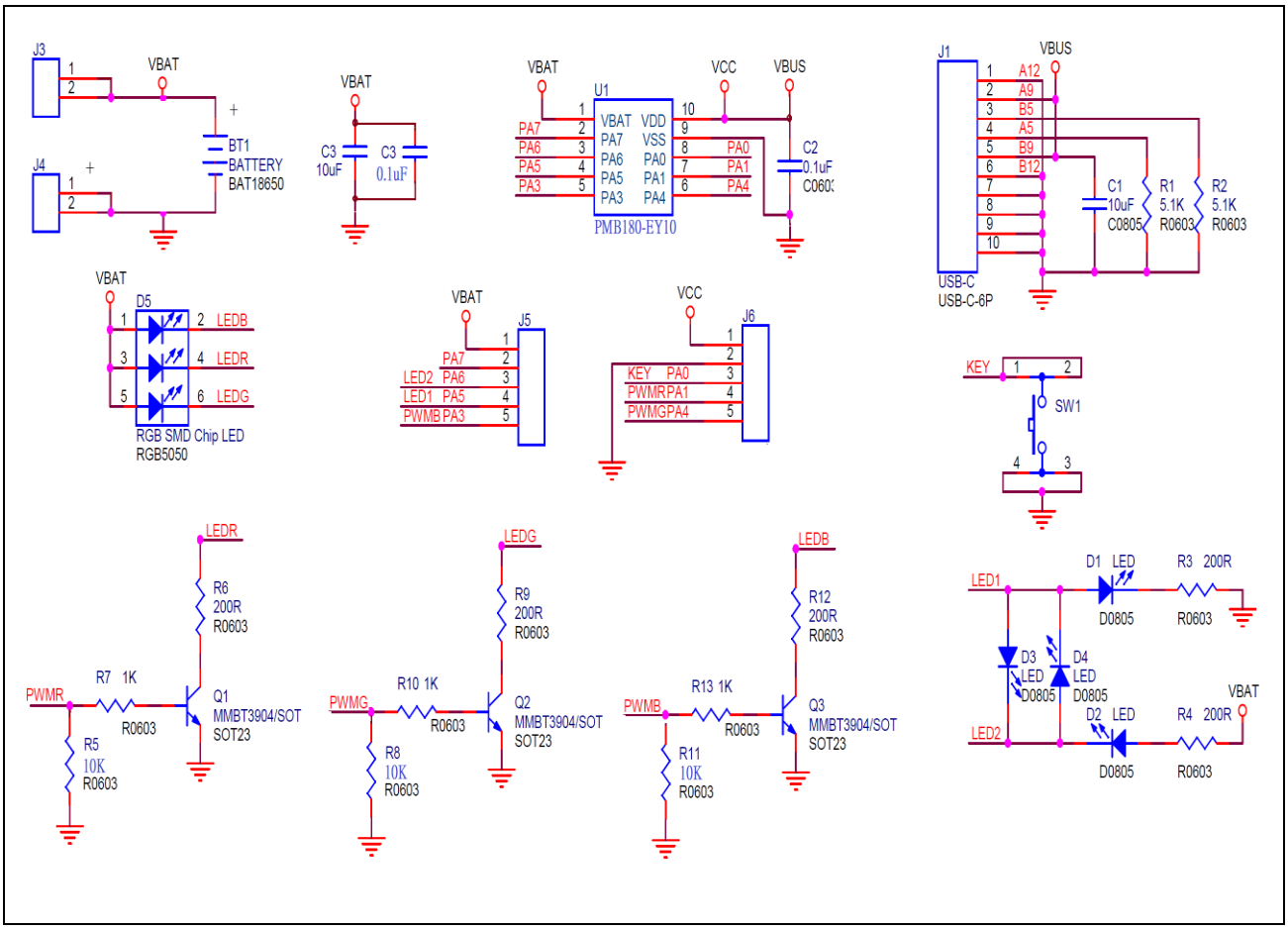


Fig.26: Schematic Diagram of Light Control with Li-Ion Charge

9.4. Improve the stability of the PMB180(B) chip during power on and startup

During the manufacturing process of PMB180(B) application boards, there is often a need to connect the Li-ion battery electrode pads with the application boards through spot welding process. This will cause the power supply on the application board to be unstable, resulting in jittery interference in the PMB180(B) power-up waveform. This process may last for tens to hundreds of milliseconds, which is a harsh challenge for the chip to power on and off, and may cause the chip to crash, the program to run away, abnormal functions, and system parameters to be messed up...and so on. To address this situation, the following settings can be used in the program to enhance the stability of the PMB180(B) IC during power-on and power jitter.

(1) CodeOption setting:

- CodeOption Boot speed selection "**Slow**". (If the chip has support for this function)

(2) The power-up program prioritizes the IO output low and delay settings before .Adjust_IC:

- The power-on startup program executes IO output low with ILRC priority (before .Adjust_IC).
- After IO output low, execute delay with ILRC system frequency (before .Adjust_IC).
- Add x_first to the parameters of .Adjust_IC.
- It is recommended to power on with a delay of 100ms ~ 200ms before entering Stopexe Mode.

(3) System frequency:

- It is recommended to keep the system frequency for ILRC operation after the IC is powered on and turned on until it enters the Stopexe / Stopsys mode.
- It is recommended to switch the system frequency to high frequency operation only after Stopexe / Stopsys wake up.
- It is recommended to set the system clock frequency below 1MHz (inclusive) to improve stability.
- It is recommended that the ILRC can always be enabled, so that it can be switched directly when switching from high frequency to low frequency.
- When switching the system main frequency from ILRC to IHRC, it is necessary to enable IHRC first and wait for the running time of two or more instructions before switching. Avoid doing Enable IHRC and switching frequency in one line of instruction.

```
//------------------------------------------------------------
// Macro Name: PowerOn_Delay
// Parameter: none
//
//------------------------------------------------------------
byte pndt;
PowerOn_Delay  macro          // delay 2048 ILRC period = 20.48ms
    PA = 0x00;
    PAC = 0xFF;               // change to Output Mode
    pndt = 0xFF;
    do
     {      nop; nop; nop; nop; nop;   }
    while(pndt--);
    PAC = 0x00;                // change to Intput Mode
endm

 void    FPPA0 (void)
{
 #if     _SYS(AT_EV)
   $ MISC WDT_64K;             // 64K*ILRC = 640ms
 #endif
   PowerOn_Delay               //delay 20ms
   .ADJUST_IC      SYSCLK=ILRC (IHRC/16), IHRC=16MHz, VDD=4.2V, O_WDRST, X_FIRST;
   .wdreset;
   .delay 7000         // delay 70ms for VDD = 5V
 //---- ReLoad_All_Param
   ReLoad_IHRC                 //Reload IHRCR Parameter
   ReLoad_ChargerCURTRIM       //Reload Charger Current Trim Bits
   ReLoad_VbatBGTRIM           //Reload Charger Vbat Trim Bits
```

```
    $ MISC WDT_64K;                    // 64K*ILRC = 640ms
     .wdreset;
     $ CLKMD IHRC/16, En_IHRC, En_ILRC, En_WatchDog;

     while(1)
     {
        .delay 10000;
        $ PA.6 Out, High;
        .delay 10000;
        $ PA.6 Out, Low;
     }
}
```

(4) **Watchdog**:

- Keeps the watchdog as Enable and does not turn off the watchdog. Add the **"O_WDRST"** string parameter to the Adjust-IC macro instruction.
- The watchdog does not need to be turned off when entering Stopexe Mode, the chip hardware will automatically turn off the watchdog and re-enable the watchdog after wakeup, and the watchdog counter will be cleared as well.
- It is recommended that the execution cycle of the watchdog clear instruction is not too intensive. It is recommended to execute it once in the main program.
- If interrupts are used, it is not recommended to add the watchdog clear instruction in the interrupt program.
- When switching the system frequency, it is necessary to pay attention to keep the watchdog on to avoid shutting down the watchdog by mistake.
- It is recommended to set the watchdog time to 64K ILRC, which is about 640ms. considering the frequency drift error of ILRC, the recommended cleaning watchdog period is about 320ms.

(5) Stopexe/Stopsys Wakeup

- It is recommended that the **ReLoad_IHRC / ReLoad_ChargerCURTRIM / ReLoad_VbatBGTRIM** macros can be executed after stopexe/Stopsys wake up to rewrite the system calibration parameter registers once again.