



PADAUK

應廣科技

RapiDragon (**迅龙**)

PFS252

8bit MTP IO type MCU (FPPA™)

Data Sheet

Version 0.01

May 28, 2021

Copyright © 2021 by PADAUK Technology Co., Ltd., all rights reserved.

6F-6, No.1, Sec. 3, Gongdao 5th Rd., Hsinchu City 30069, Taiwan, R.O.C.

TEL: 886-3-572-8688  www.padauk.com.tw

IMPORTANT NOTICE

PADAUK Technology reserves the right to make changes to its products or to terminate production of its products at any time without notice. Customers are strongly recommended to contact PADAUK Technology for the latest information and verify whether the information is correct and complete before placing orders.

PADAUK Technology products are not warranted to be suitable for use in life-support applications or other critical applications. PADAUK Technology assumes no liability for such applications. Critical applications include, but are not limited to, those that may involve potential risks of death, personal injury, fire or severe property damage.

PADAUK Technology assumes no responsibility for any issue caused by a customer's product design. Customers should design and verify their products within the ranges guaranteed by PADAUK Technology. In order to minimize the risks in customers' products, customers should design a product with adequate operating safeguards.

Table of Contents

1. Features	8
1.1. Special Features	8
1.2. System Features	8
1.3. CPU Features	8
1.4. Package Information	8
2. General Description and Block Diagram	9
3. Pin Definition and Functional Description	10
4. Central Processing Unit (CPU)	12
4.1. Functional Description.....	12
4.1.1. Two FPPA Units	12
4.1.2. Single FPPA Unit.....	13
4.1.3. Program Counter	13
4.1.4. Program Structure	14
4.1.5. Arithmetic and Logic Unit.....	15
4.2. Storage Memory	15
4.2.1. Program Memory – ROM.....	15
4.2.2. Data Memory – SRAM.....	17
4.2.3. System Register	18
4.2.3.1. ACC Status Flag Register (FLAG), address = 0x00	19
4.2.3.2. FPPA unit Enable Register (FPPEN), address = 0x01	19
4.2.3.3. MISC Register (MISC), address = 0x1F.....	20
4.3. The Stack.....	20
4.3.1. Stack Pointer Register (<i>SP</i>), address = 0x02.....	21
4.4. Code Options	21
5. Oscillator and System Clock	23
5.1. Internal High RC Oscillator and Internal Low RC Oscillator	23
5.2. External Crystal Oscillator	23
5.2.1. External Oscillator Setting Register (<i>EOSCR</i>), address = 0x0A.....	24
5.2.2. Usages and Precautions of External Oscillator	24
5.3. System Clock and IHRC Calibration.....	25
5.3.1. System Clock.....	25
5.3.1.1. Clock Mode Register (<i>CLKMD</i>), address = 0x03.....	26
5.3.2. Frequency Calibration.....	26
5.3.2.1. Special Statement.....	27
5.3.3. System Clock Switching	28
6. Reset	28
6.1. Power On Reset – POR	28

6.2.	Low Voltage Reset – LVR	30
6.3.	Watch Dog Timeout Reset	31
6.4.	External Reset Pin – PRSTB.....	32
7.	System Operating Mode.....	33
7.1.	Power-Save Mode (“stopexe”).....	33
7.2.	Power-Down Mode (“stopsys”).....	34
7.3.	Wake-Up.....	35
8.	Interrupt.....	35
8.1.	Interrupt Enable Register (<i>INTEN</i>), address = 0x04	36
8.2.	Interrupt Request Register (<i>INTRQ</i>), address = 0x05.....	37
8.3.	Interrupt Edge Select Register (<i>INTEGS</i>), address = 0x0C	37
8.4.	Interrupt Work Flow.....	38
8.5.	General Steps to Interrupt.....	38
8.6.	Example for Using Interrupt.....	39
9.	I/O Port.....	40
9.1.	IO Related Registers.....	40
9.1.1.	Port A Digital Input Enable Register (<i>PADIER</i>), address = 0x0D	40
9.1.2.	Port B Digital Input Enable Register (<i>PBDIER</i>), address = 0x0E.....	40
9.1.3.	Port A Data Registers (<i>PA</i>), address = 0x10.....	40
9.1.4.	Port A Control Registers (<i>PAC</i>), address = 0x11	40
9.1.5.	Port A Pull-High Registers (<i>PAPH</i>), address = 0x12	41
9.1.6.	Port A Pull-Low Register (<i>PAPL</i>), address = 0x13	41
9.1.7.	Port B Data Registers (<i>PB</i>), address = 0x14.....	41
9.1.8.	Port B Control Registers (<i>PBC</i>), address = 0x15	41
9.1.9.	Port B Pull-High Registers (<i>PBPH</i>), address = 0x16	41
9.1.10.	Port B Pull-Low Register (<i>PBPL</i>), address = 0x17	41
9.2.	IO Structure and Functions	42
9.2.1.	IO Pin Structure	42
9.2.2.	IO Pin Functions	42
9.2.3.	IO Pin Usage and Setting	43
10.	Timer / PWM Counter	44
10.1.	16-bit Timer (Timer16)	44
10.1.1.	Timer16 Introduction.....	44
10.1.2.	Timer16 Time Out.....	45
10.1.3.	Timer16 Mode Register (<i>T16M</i>), address = 0x06.....	46
10.2.	8-bit Timer with PWM Generation (Timer2, Timer3)	46
10.2.1.	Timer2、Timer3 Related Registers.....	48
10.2.1.1.	Timer2 Bound Register (<i>TM2B</i>), address = 0x09.....	48

10.2.1.2.	Timer2 Counter Register (<i>TM2CT</i>), address = 0x1D	48
10.2.1.3.	Timer2 Scalar Register (<i>TM2S</i>), address = 0x1E.....	48
10.2.1.4.	Timer2 Control Register (<i>TM2C</i>), address = 0x1C.....	49
10.2.1.5.	Timer3 Counter Register (<i>TM3CT</i>), address = 0x33.....	49
10.2.1.6.	Timer3 Scalar Register (<i>TM3S</i>), address = 0x34.....	49
10.2.1.7.	Timer3 Bound Register (<i>TM3B</i>), address = 0x38.....	50
10.2.1.8.	Timer3 Control Register (<i>TM3C</i>), address = 0x32	50
10.2.2.	Using the Timer2 to Generate Periodical Waveform	51
10.2.3.	Using the Timer2 to Generate 8-bit PWM Waveform	52
10.2.4.	Using the Timer2 to Generate 6-bit PWM Waveform	53
10.3.	11-bit PWM Generation.....	53
10.3.1.	PWM Waveform	53
10.3.2.	Hardware and Timing Diagram	54
10.3.3.	Equations for 11-bit PWM Generator	55
10.3.4.	11bit PWM Related Registers.....	56
10.3.4.1.	PWMG0 control Register (<i>PWMG0C</i>), address = 0x20.....	56
10.3.4.2.	PWMG0 Scalar Register (<i>PWMG0S</i>), address = 0x21	56
10.3.4.3.	PWMG0 Duty Value High Register (<i>PWMG0DTH</i>), address = 0x22.....	56
10.3.4.4.	PWMG0 Duty Value Low Register (<i>PWMG0DTL</i>), address = 0x23	56
10.3.4.5.	PWMG0 Counter Upper Bound High Register, address = 0x24.....	57
10.3.4.6.	PWMG0 Counter Upper Bound Low Register, address = 0x25.....	57
10.3.4.7.	PWMG1 Control Register (<i>PWMG1C</i>), address = 0x26.....	57
10.3.4.8.	PWMG1 Scalar Register (<i>PWMG1S</i>), address = 0x27	57
10.3.4.9.	PWMG1 Duty Value High Register (<i>PWMG1DTH</i>), address = 0x28	58
10.3.4.10.	PWMG1 Duty Value Low Register (<i>PWMG1DTL</i>), address = 0x29	58
10.3.4.11.	PWMG1 Counter Upper Bound High Register, address = 0x2A	58
10.3.4.12.	PWMG1 Counter Upper Bound Low Register, address = 0x2B	58
10.3.4.13.	PWMG2 Control Register (<i>PWMG2C</i>), address = 0x2C	58
10.3.4.14.	PWMG2 Scalar Register (<i>PWMG2S</i>), address = 0x2D.....	59
10.3.4.15.	PWMG2 Duty Value High Register (<i>PWMG2DTH</i>), address = 0x2E.....	59
10.3.4.16.	PWMG2 Duty Value Low Register (<i>PWMG2DTL</i>), address = 0x2F	59
10.3.4.17.	PWMG2 Counter Upper Bound High Register, address = 0x30.....	59
10.3.4.18.	PWMG2 Counter Upper Bound Low Register, address = 0x31.....	59
10.3.5.	Examples of PWM Waveforms with Complementary Dead Zones.....	60
11.	Special Functions	62
11.1.	Comparator.....	62
11.1.1.	Comparator Control Register (<i>GPCC</i>), address = 0x18	63
11.1.2.	Comparator Selection Register (<i>GPCS</i>), address = 0x19	63
11.1.3.	Internal Reference Voltage ($V_{\text{internal R}}$).....	64
11.1.4.	Using the Comparator.....	66
11.1.5.	Using the Comparator and Bandgap 1.20V	67
11.2.	VDD/2 Bias Voltage Generator.....	68

11.3. Operational Amplifier (OPA) module	69
11.3.1. OPA Comparator Mode	69
11.3.2. OPA Amplifier Mode	69
11.3.3. OPA Control Register (<i>OPAC</i>), address = 0x1A	70
11.3.4. OPA Offset Register (<i>OPAOFS</i>), address = 0x07	70
11.4. Multiplier	71
11.4.1. Multiplier Operand Register (<i>MULOP</i>), address = 0x08	71
11.4.2. Multiplier Result High Byte Register (<i>MULRH</i>), address = 0x09.....	71
12. Notes for Emulation.....	72
13. Program Writing.....	73
13.1. Normal Programming Mode	73
13.2. Limited-Voltage Programming Mode	73
13.3. On-Board Writing	74
14. Device Characteristics	75
14.1. Absolute Maximum Ratings.....	75
14.2. DC/AC Characteristics	75
14.3. Typical ILRC frequency vs. VDD	77
14.4. Typical IHRC frequency deviation vs. VDD(calibrated to 16MHz).....	77
14.5. Typical ILRC Frequency vs. Temperature	78
14.6. Typical IHRC Frequency vs. Temperature (calibrated to 16MHz).....	78
14.7. Typical operating current vs. VDD @ system clock = ILRC/n	79
14.8. Typical operating current vs. VDD @ system clock = IHRC/n.....	79
14.9. Typical operating current vs. VDD @ system clock = 32KHz EOSC / n.....	80
14.10. Typical operating current vs. VDD @ system clock = 1MHz EOSC / n.....	80
14.11. Typical operating current vs. VDD @ system clock = 4MHz EOSC / n.....	81
14.12. Typical IO driving current (I_{OH}) and sink current (I_{OL})	81
14.13. Typical IO input high/low threshold voltage (V_{IH}/V_{IL})	82
14.14. Typical resistance of IO pull high/low device	83
14.15. Typical power down current (I_{PD}) and power save current (I_{PS}).....	84
15. Instructions	85
15.1. Instruction Table	86

Revision History:

Revision	Date	Description
0.00	2020/10/23	Preliminary version
0.01	2021/05/28	1. Amend Chapter 8 2. Amend Section 1.1, 4.2.3.1, 4.2.3.3, 6.2, 7.1, 11.1.1 3. Amend Fig. 7, Table 8, Fig. 32

Warning

User must read all application notes of the IC by detail before using it. Please download the related application notes from the following link:

<http://www.padauk.com.tw/cn/technical/index.aspx>

1. Features

1.1. Special Features

- ◆ Not supposed to use in AC RC step-down powered or high EFT requirement applications.
PADAUK assumes no liability if such kind of applications can not pass the safety regulation tests.
- ◆ Operating temperature range: -20°C ~ 70°C
- ◆ ESD > 4 KV

1.2. System Features

- ◆ 2KW MTP program memory for both FPPA units (programming cycle at least 1,000 times)
- ◆ 128 Bytes data RAM for both FPPA units
- ◆ One hardware 16-bit timer
- ◆ Two hardware 8-bit timers with PWM generation
- ◆ Three hardware 11-bit PWM generators (PWMG0, PWMG1 & PWMG2)
- ◆ Provide one hardware comparator
- ◆ Provide one OP Amplifier (OPA)
- ◆ Provide 1T 8x8 hardware multiplier
- ◆ 14 IO pins with optional pull-high / pull-low resistor
- ◆ Every IO pin can be configured to enable wake-up function
- ◆ For every wake-up enabled IO, two optional wake-up speed are supported: normal and fast
- ◆ Bandgap circuit to provide 1.20V reference voltage
- ◆ Clock sources: internal high RC oscillator, internal low RC oscillator and external crystal oscillator
- ◆ Built-in VDD/2 bias voltage generator to provide maximum 5x9 dots LCD display
- ◆ 8 selectable levels of LVR reset from 1.8V to 4.5V
- ◆ Four selectable external interrupt pins

1.3. CPU Features

- ◆ Operating modes: Two processing units FPPA™ mode or Traditional one processing unit mode
- ◆ 89 powerful instructions
- ◆ Most instructions are 1T execution cycle
- ◆ Programmable stack pointer and 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
- ◆ Register space, memory space and MTP space are independent

1.4. Package Information

- ◆ PFS252-S08: SOP8 (150mil);
- ◆ PFS252-S14: SOP14 (150mil);
- ◆ PFS252-S16: SOP16 (150mil);

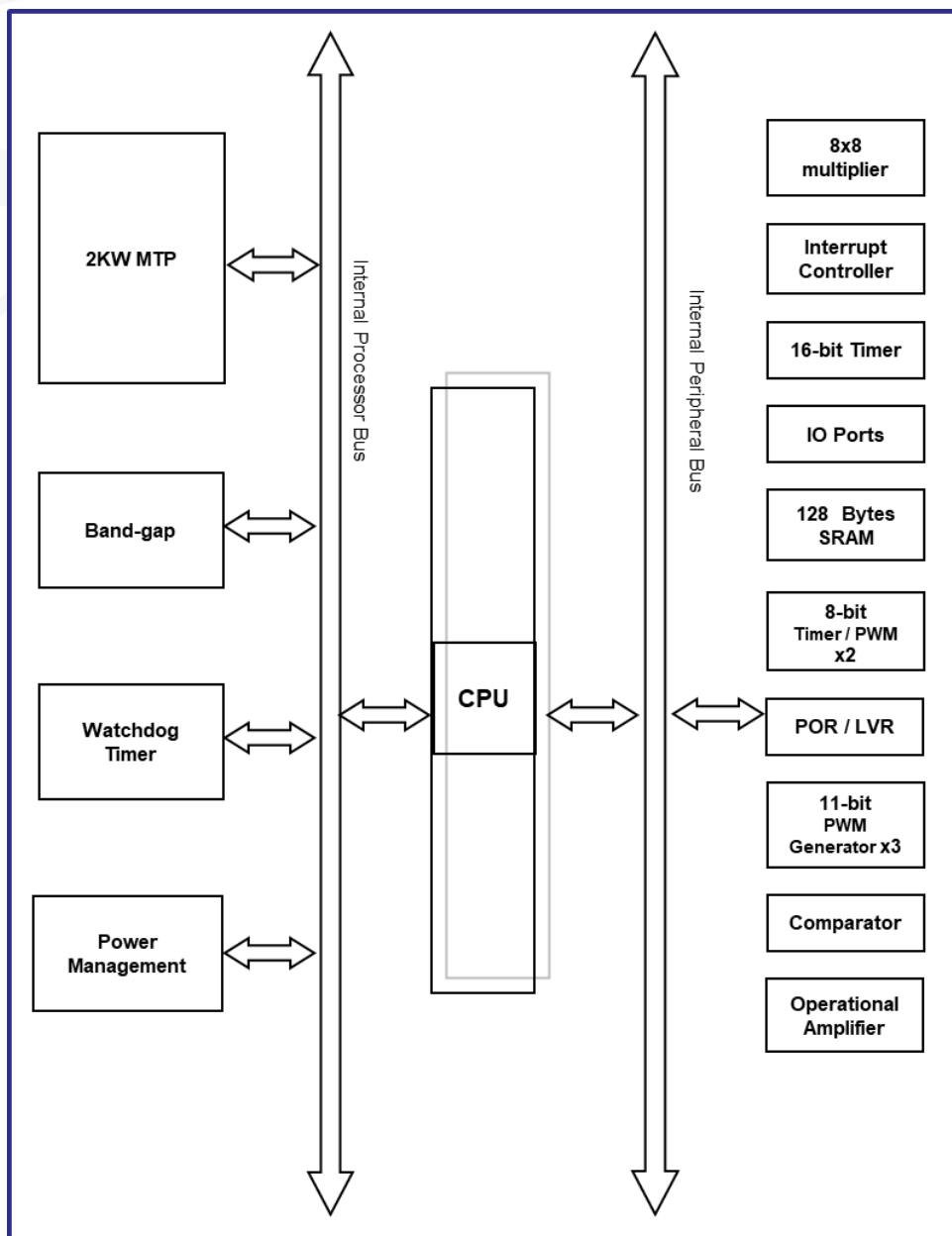
2. General Description and Block Diagram

The PFS252 family is a parallel processing, fully static, MTP-based CMOS 8 bit*2 processor array that can execute two peripheral functions in parallel. It employs RISC architecture based on patent pending FPPA™ (Field Programmable Processor Array) technology and all the instructions are executed in one cycle except that some instructions are two cycles that handle indirect memory access.

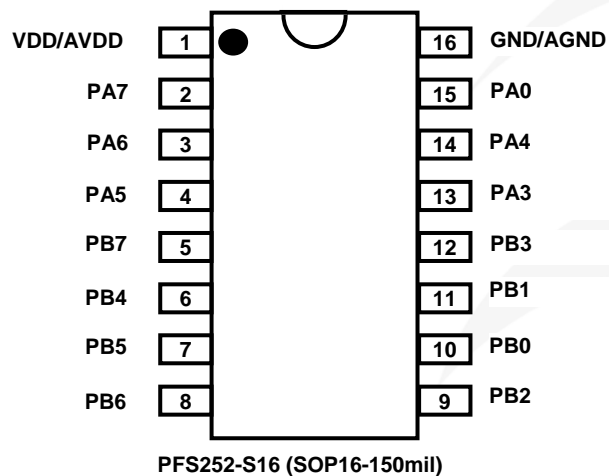
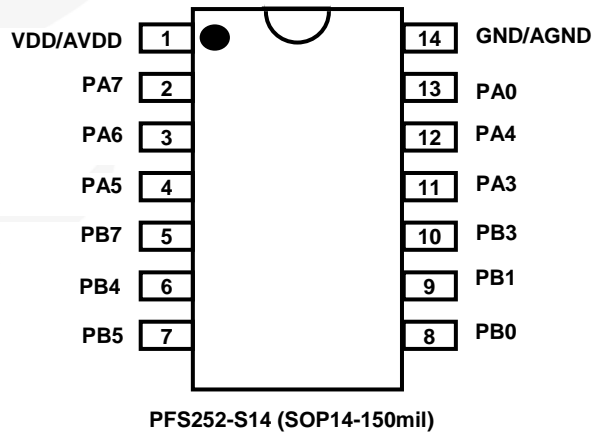
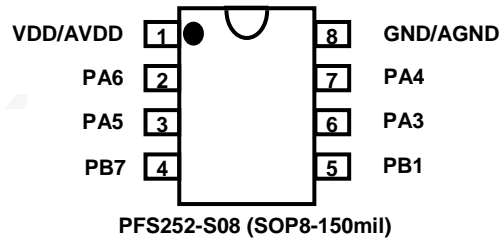
2KW MTP program memory and 128 bytes data SRAM are inside for two FPPA units using.

PFS252 provides a hardware 16-bit timer, two hardware 8-bit timers with PWM generation (Timer2, Timer3) and Three hardware 11-bit timers with PWM generation (PWMG0, PWMG1, PWMG2).

PFS252 also supports an Operational Amplifier (OPA) and a hardware comparator, plus one VDD/2 bias voltage generator for LCD display application and one 8x8 hardware multiplier to enhance hardware capability in arithmetic function.



3. Pin Definition and Functional Description



Caution: The pin assignment of PFS252 is NOT compatible with PMC232/PMS232.

PFS252

8bit MTP IO type MCU

Pin Name	Input / output				Special Functions							
	I / O	Pull High	Pull Low	Wake Up	Crystal	Comparator	PWM	VDD/2	OPA	External Interrupt	External Reset	Program
PA0	√	√	√	√		CO CIN- CIN+	PG0PWM	COM2	OPO	INT0		
PA3	√	√	√	√		CIN-	TM2PWM PG2PWM	COM4	OPIN-			√
PA4	√	√	√	√		CIN+ CIN-	PG1PWM	COM3	OPIN+ OPIN-	INT1A		
PA5	√	√	√	√			PG2PWM				√	√
PA6	√	√	√	√	√							√
PA7	√	√	√	√	√							
PB0	√	√	√	√				COM1		INT1		
PB1	√	√	√	√								
PB2	√	√	√	√			TM2PWM PG2PWM					
PB3	√	√	√	√			PG2PWM	COM5				
PB4	√	√	√	√			TM2PWM PG0PWM					
PB5	√	√	√	√			TM3PWM PG0PWM			INT0A		
PB6	√	√	√	√		CIN-	TM3PWM PG1PWM		OPIN-			
PB7	√	√	√	√		CIN-	TM3PWM PG1PWM		OPIN-			
VDD AVDD												√
GND AGND												√
Notice	<ol style="list-style-type: none"> 1. All the I/O pins have: Schmitt Trigger input and CMOS voltage level. 2. IO function is automatically deactivated when a pin is used as PWM output port. 3. Please put 33Ω resistor in series to have high noise immunity when PA5 is in input mode. 4. ICE doesn't support the function PG2PWM output to PA5. 5. VDD is the IC power supply while AVDD is the Analog positive power supply. AVDD and VDD are double bonding internally and they have the same external pin. 6. GND is the IC ground pin while AGND is the Analog negative ground pin. AGND and GND are double bonding internally and they have the same external pin. 											

4. Central Processing Unit (CPU)

4.1. Functional Description

There are two processing units (FPPA0 and FPPA1) inside the chip of PFS252. In each processing unit, it includes:

- a. its own Program Counter to control the program execution sequence
- b. its own Stack Pointer to store or restore the program counter for program execution
- c. its own accumulator
- d. status Flag to record the status of program execution.

Each FPPA unit has its own program counter and accumulator for program execution, flag register to record the status, and stack pointer for jump operation. Based on such architecture, FPPA unit can execute its own program independently, thus parallel processing can be expected.

4.1.1. Two FPPA Units

These two FPPA units share the same 2K words MTP program memory, 128 bytes data SRAM and all the IO ports, these two FPPA units are operated at mutual exclusive clock cycles to avoid interference. One task switch is built inside the chip to decide which FPPA unit should be active for the corresponding cycle. The hardware diagram and basic timing diagram of FPPA units are illustrated in Fig. 1. For FPPA0 unit, its program will be executed in sequence every other system clock, shown as (M-1)th, Mth and (M+1)th instructions. For FPPA1 unit, its program will be also executed in sequence every other system clock, shown as (N-1)th, Nth and (N+1)th instructions.

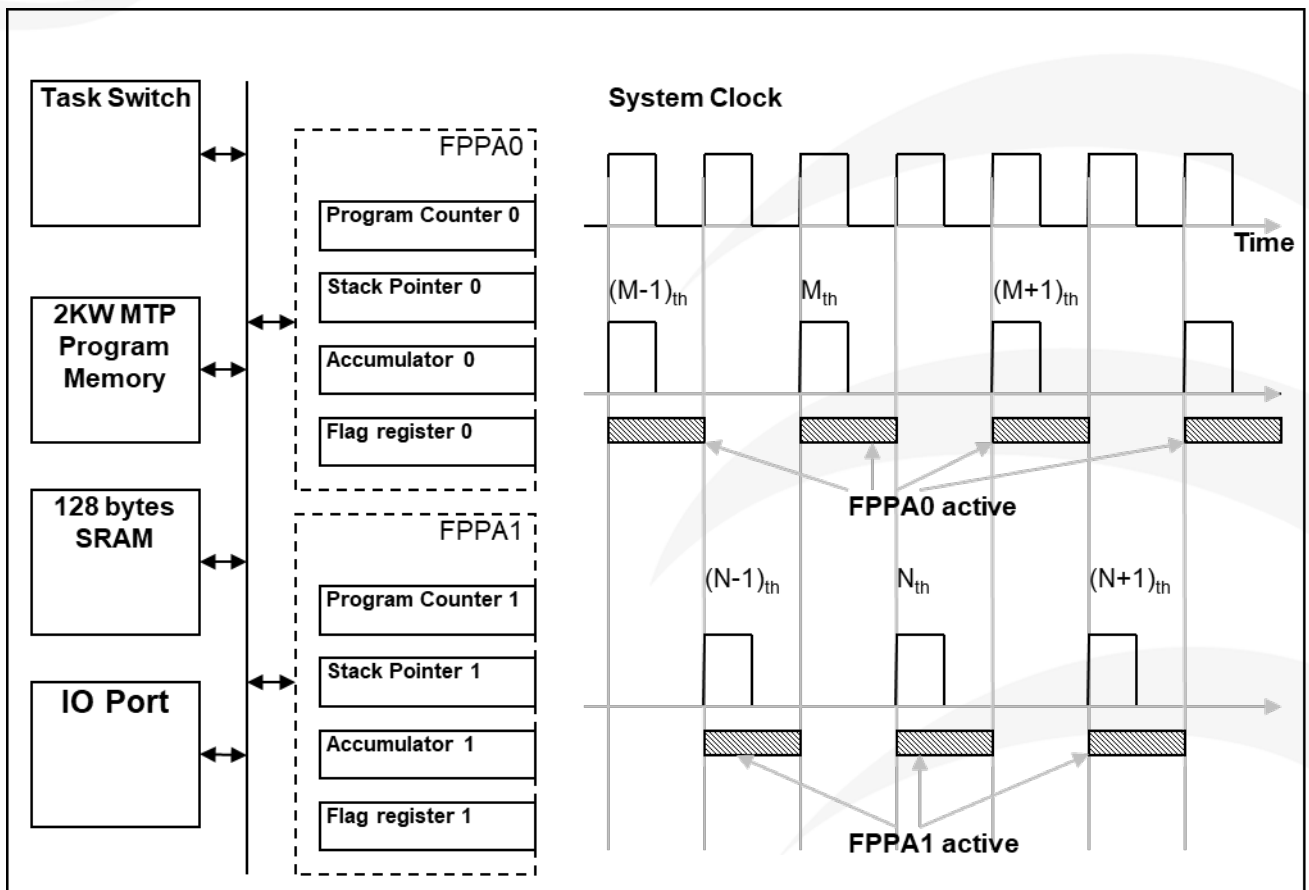


Fig. 1: Hardware and Timing Diagram of FPPA unit

Each FPPA unit has half computing power of whole system; for example, FPPA0 and FPPA1 will be operated at 4MHz if system clock is 8MHz. The FPPA unit can be enabled or disabled by programming the FPPA unit Enable Register, and only FPPA0 is enabled after power-on reset. The system initialization will be started from FPPA0 and FPPA1 unit can be enabled by user's program if necessary. Both FPPA0 and FPPA1 can be enabled or disabled by using any one FPPA unit.

4.1.2. Single FPPA Unit

For traditional MCU user who does not need parallel processing capability, PFS252 provides single FPPA mode optional to behave as traditional MCU. After single FPPA mode is selected, FPPA1 is always disabled and only FPPA0 is active. Fig.2 shows the timing diagram for each FPPA unit, FPPA1 is always disabled and only FPPA0 active.

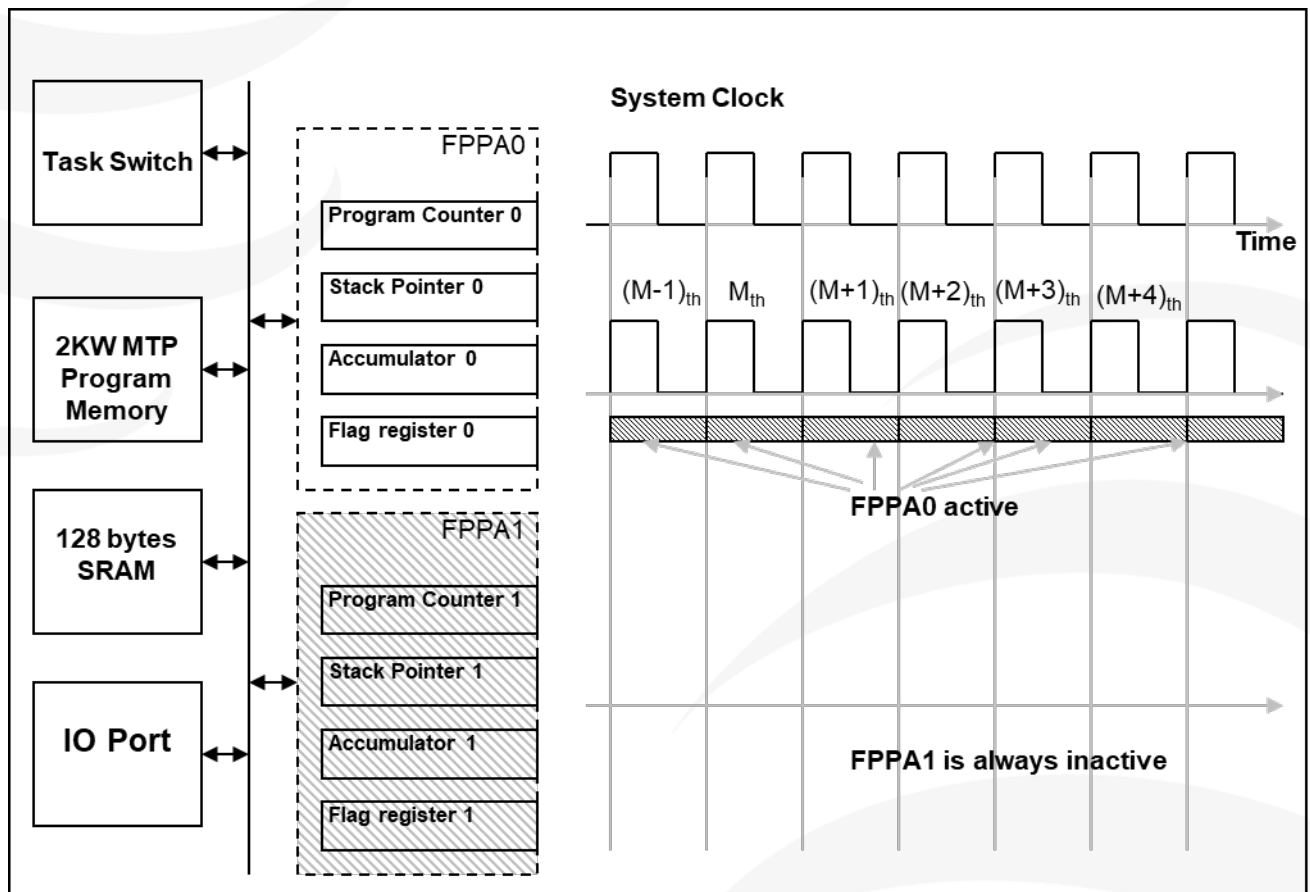


Fig. 2: Timing Diagram of single FPPA mode

4.1.3. Program Counter

Program Counter (PC) is the unit that contains the address of an instruction to be executed next. The program counter is automatically incremented at each instruction cycle so that instructions are retrieved sequentially from the program memory. Certain instructions, such as branches and subroutine calls, interrupt the sequence by placing a new value in the program counter. The bit length of the program counter is 11 for PFS252. The program counter of FPPA0 is 0 after hardware reset and 1 for FPPA1. Whenever an interrupt happens in FPPA0, the program counter will jump to 0x10 for interrupt service routine. Each FPPA unit has its own program counter to control the program execution sequence.

4.1.4. Program Structure

Program structure of two FPPA units mode

After power-up, the program starting address of FPPA0 is 0x000 and 0x001 for FPPA1. The 0x010 is the entry address of interrupt service routine, which belongs to FPPA0 only. The basic firmware structure for PFS252 is shown as Fig. 3, the program codes of two FPPA units are placed in one whole program space. Except for the initial addresses of processing units and entry address of interrupt, the memory location is not specially specified; the program codes of processing unit can be resided at any location no matter what the processing unit is. After power-up, the FPPA0Boot will be executed first, which will include the system initialization and other FPPA units enabled.

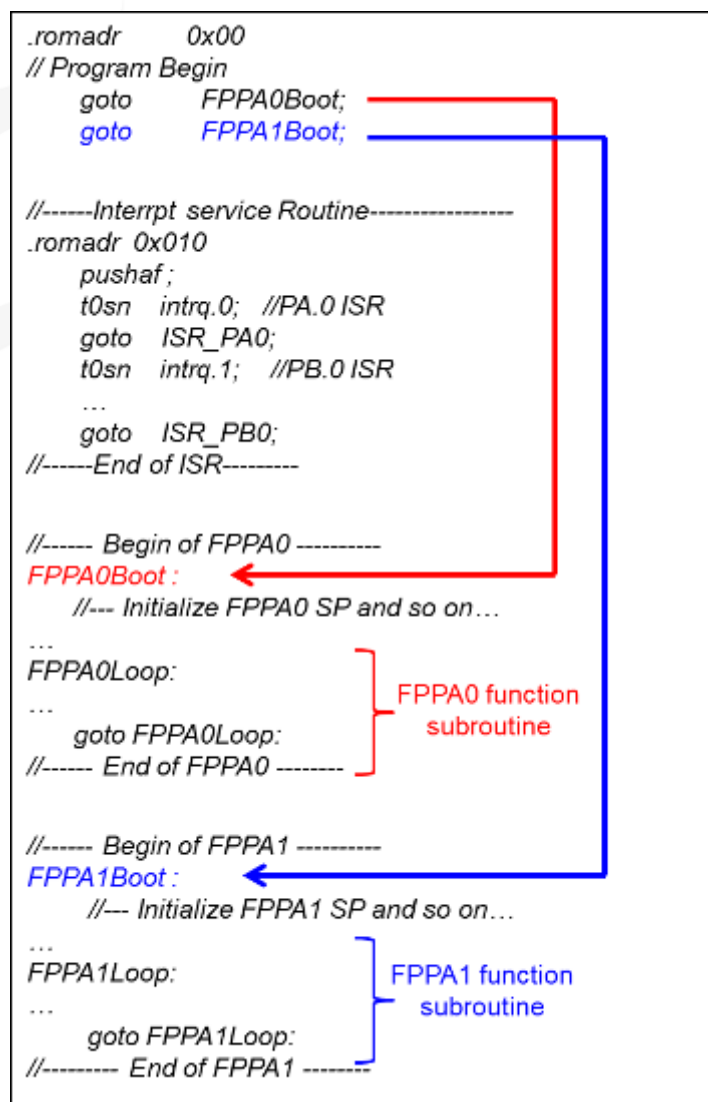


Fig. 3: Program Structure

Program structure of single FPPA mode

After power-up, the program starting address of FPPA0 is 0x000, 0x010 is the entry address of interrupt service routine. For single FPPA unit mode, the firmware structure is same as traditional MCU. After power-up, the program will be executed from address 0x000, then continuing the program sequence.

4.1.5. Arithmetic and Logic Unit

Arithmetic and Logic Unit (ALU) is the computation element to operate integer arithmetic, logic, shift and other specialized operations. The operation data can be from instruction, accumulator or SRAM data memory. Computation result could be written into accumulator or SRAM. FPPA0 and FPPA1 will share ALU for its corresponding operation.

4.2. Storage Memory

4.2.1. Program Memory – ROM

The PFS252 program memory is MTP (Multiple Time Programmable), used to store data (including: data, tables and interrupt entry) and program instructions to be executed. All program codes for each FPPA unit are stored in this MTP memory for both FPPA0 and FPPA1. The MTP program memory for PFS252 is 2K words that is partitioned as Table 1.

After reset, the initial address for FPPA0 is 0x000 and 0x001 for FPPA1. The interrupt entry is 0x010 if used and interrupt function is for FPPA0 only.

The MTP memory from address 0x7E0 to 0x7FF are for system using, address space from 0x001 to 0x00F and from 0x011 to 0x7DF are user program spaces. And the address 0x001 is the FPPA1 initial address for two FPPA units mode and user program for single FPPA unit mode.

The last 32 addresses are reserved for system using, like checksum, serial number, etc.

Address	Function
0x000	FPPA0 reset – <i>goto</i> instruction
0x001	FPPA1 reset – <i>goto</i> instruction
0x002	User program
•	•
0x00F	User program
0x010	Interrupt entry address
0x011	User program
•	•
0x7DF	User program
0x7E0	System Using
•	•
0x7FF	System Using

Table 1: Program Memory Organization

Example of Using Program Memory for Two FPPA mode

Table 2 shows one example of using program memory which two FPPA units are active.

Address	Function
0x000	FPPA0 reset – <i>goto</i> instruction (<i>goto</i> 0x020)
0x001	Begin of FPPA1 program
•	•
0x00F	<i>goto</i> 0x1A1 to continue FPPA1 program
0x010	Interrupt entry address (FPPA0 only)
•	•
0x01F	End of ISR (depend on user code size)
0x020	Begin of FPPA0 user program
•	•
0x1A0	End of FPPA0 user program
0x1A1	Continuing FPPA1 program
•	•
0x7DF	End of FPPA1 program
0x7E0	System Using
•	•
0x7FF	System Using

Table 2: Example of using Program Memory for two FPPA units mode

Example of Using Program Memory for Single FPPA mode

The entire user's program memory can be assigned to FPPA0 when single FPPA mode is selected. Table 3 shows the example of program memory using for single FPPA unit mode.

Address	Function
0x000	FPPA0 reset
0x001	Begin of FPPA0 program
0x002	user program
•	•
0x00F	<i>goto</i> instruction (<i>goto</i> 0x020)
0x010	Interrupt entry address
0x011	ISR
•	•
0x01F	End of ISR (depend on user code size)
0x020	user program
•	•
•	•
0x7DF	user program
0x7E0	System Using
•	•
0x7FF	System Using

Table 3: Example of using Program Memory for single FPPA mode

4.2.2. Data Memory – SRAM

Fig. 4 shows the SRAM data memory organization of PFS252, all the SRAM data memory could be accessed by FPPA0 and FPPA1 directly with 1T clock cycle. 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 for all FPPA units.

The stack memory for each processing unit should be independent from each other, and defined in the data memory. The stack pointer is defined in the stack pointer register of each processing unit; 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 128 bytes data memory of PFS252 can be accessed by indirect access mechanism.

Bit defined: Only addressed at 0x00 ~ 0x3F.

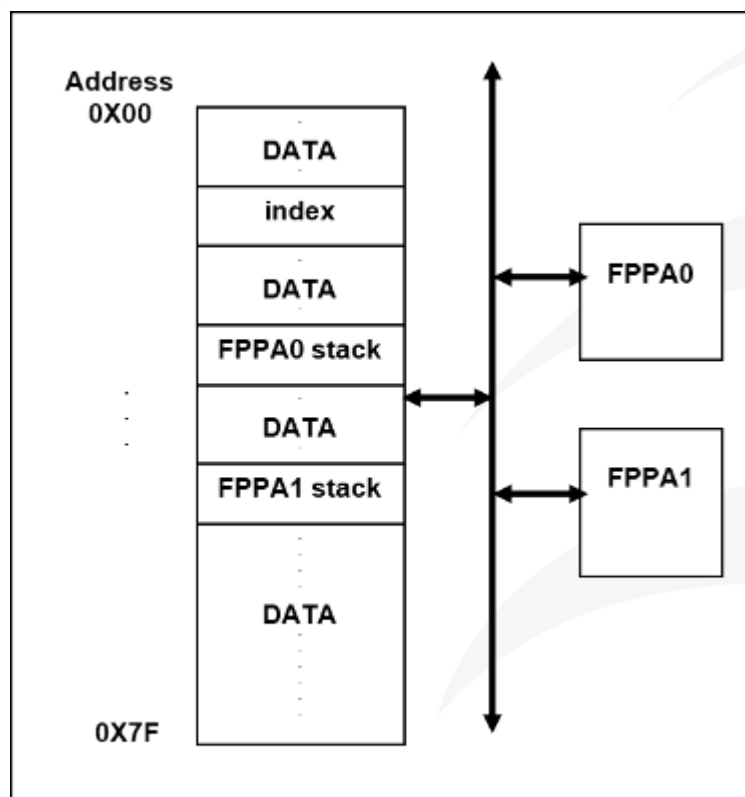


Fig. 4: Data Memory Organization

4.2.3. System Register

The register space of PFS252 is independent of SRAM space and MTP space.

The following is the PFS252 register address and brief description:

	+0	+1	+2	+3	+4	+5	+6	+7
0x00	<i>FLAG</i>	<i>FPPEN</i>	<i>SP</i>	<i>CLKMD</i>	<i>INTEN</i>	<i>INTRQ</i>	<i>T16M</i>	<i>OPAOFS</i>
0x08	<i>MULOP</i>	<i>MULRH / TM2B</i>	<i>EOSCR</i>	-	<i>INTEGS</i>	<i>PADIER</i>	<i>PBDIER</i>	-
0x10	<i>PA</i>	<i>PAC</i>	<i>PAPH</i>	<i>PAPL</i>	<i>PB</i>	<i>PBC</i>	<i>PBPH</i>	<i>PBPL</i>
0x18	<i>GPCC</i>	<i>GPCS</i>	<i>OPAC</i>	-	<i>TM2C</i>	<i>TM2CT</i>	<i>TM2S</i>	<i>MISC</i>
0x20	<i>PWMG0C</i>	<i>PWMG0S</i>	<i>PWMG0-DTH</i>	<i>PWMG0-DTL</i>	<i>PWMG0-CUBH</i>	<i>PWMG0-CUBL</i>	<i>PWMG1C</i>	<i>PWMG1S</i>
0x28	<i>PWMG1DTH</i>	<i>PWMG1DTL</i>	<i>PWMG1-CUBH</i>	<i>PWMG1-CUBL</i>	<i>PWMG2C</i>	<i>PWMG2S</i>	<i>PWMG2-DTH</i>	<i>PWMG2-DTL</i>
0x30	<i>PWMG2CUBH</i>	<i>PWMG2CUBL</i>	<i>TM3C</i>	<i>TM3CT</i>	<i>TM3S</i>	-	-	-
0x38	<i>TM3B</i>	-	-	-	-	-	-	-

FLAG: ACC Status Flag Register

FPPEN: FPP unit Enable Register

SP: Stack Pointer Register

CLKMD: Clock Mode Register

INTEN: Interrupt Enable Register

INTRQ: Interrupt Request Register

T16M: Timer 16 mode Register

OPAOFS: OPA Offset Register

MULOP: Multiplier Operand Register

MULRH: Multiplier Result High Byte Register

TM2B / TM3B: Timer2 / Timer3 Bound Register

EOSCR: External Oscillator setting Register

INTEGS: Interrupt Edge Select Register

PADIER: Port A Digital Input Enable Register

PBDIER: Port B Digital Input Enable Register

PA: Port A Data Registers

PAC: Port A Control Registers

PAPH: Port A Pull-High Registers

PAPL: Port A Pull-Low Registers

PB: Port B Data Registers

PBC: Port B Control Registers

PBPH: Port B Pull-High Registers

PBPL: Port B Pull-Low Registers

GPCC: Comparator Control Register

GPCS: Comparator Selection Register

OPAC: OPA Control Register

TM2C / TM3C: Timer2 / Timer3 Control Register

TM2CT / TM3CT: Timer2 / Timer3 Counter Register

TM2S / TM3S: Timer2 / Timer3 Scalar Register

MISC: MISC Register

PWMG0C / PWMG1C / PWMG2C:

PWMG0 / PWMG1 / PWMG2 control Register

PWMG0S / PWMG1S / PWMG2S:

PWMG0 / PWMG1 / PWMG2 Scalar Register

PWMG0DTH / PWMG1DTH / PWMG2DTH:

PWMG0 / PWMG1 / PWMG2 Duty Value High Register

PWMG0DTL / PWMG1DTL / PWMG2DTL:

PWMG0 / PWMG1 / PWMG2 Duty Value Low Register

PWMG0CUBH / PWMG1CUBH / PWMG2CUBH:

PWMG0 / PWMG1 / PWMG2 Counter Upper Bound High Register

PWMG0CUBL / PWMG1CUBL / PWMG2CUBL:

PWMG0 / PWMG1 / PWMG2 Counter Upper Bound

Low Register

4.2.3.1.ACC Status Flag Register (*FLAG*), address = 0x00

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

4.2.3.2.FPPA unit Enable Register (*FPPEN*), address = 0x01

Bit	Reset	R/W	Description
7 - 2	-	-	Reserved. Please keep 0 for future compatibility.
1	0	R/W	FPPA1 enable. This bit is used to enable FPPA1. 0 / 1: disable / enable
0	1	R/W	FPPA0 enable. This bit is used to enable FPPA0. 0 / 1: disable / enable

4.2.3.3. MISC Register (*MISC*), address = 0x1F

Bit	Reset	R/W	Description
7 – 6	-	-	Reserved. (keep 0 for future compatibility)
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	0	WO	Enable VDD/2 bias voltage generator 0 / 1 : Disable / Enable (ICE cannot be dynamically switched)
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

4.3. The Stack

The stack pointer in each processing unit is used to point the top of the stack area where the local variables and parameters to subroutines are stored; the stack pointer register (*SP*) is located in register address 0x02. The bit number of stack pointer is 8 bit; the stack memory cannot be accessed over 128 bytes and should be defined within 128 bytes from 0x00 address. The stack memory of PFS252 for each FPPA unit can be assigned by user via stack pointer register, means that the depth of stack pointer for each FPPA unit is adjustable in order to optimize system performance. The following example shows how to define the stack in the ASM (assembly language) project:

```

.ROMADR0
GOTO      FPPA0
GOTO      FPPA1
...
.RAMADR0      // Address must be less than 0x100
WORD      Stack0 [1] // one WORD
WORD      Stack1 [2] // two WORD
...
FPPA0:
SP =      Stack0;      // assign Stack0 for FPPA0,
                        // one level call because of Stack0[1]
...
call      function1
...
FPPA1:
SP =      Stack1;      // assign Stack1 for FPPA1,
                        // two level call because of Stack1[2]

```

```
...
call    function2
...
```

In Mini-C project, the stack calculation is done by system software, user will not have effort on it, and the example is shown as below:

```
void    FPPA0 (void)
{
    ...
}
```

User can check the stack assignment in the window of program disassembling, Fig. 5 shows that the status of stack before FPPA0 execution, system has calculated the required stack space and has reserved for the program.

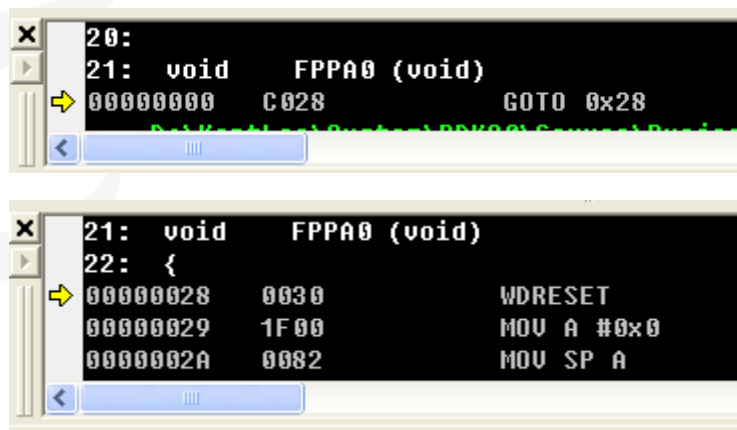


Fig. 5: Stack Assignment in Mini-C project

4.3.1. Stack Pointer Register (SP), address = 0x02

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

4.4. Code Options

Option	Selection	Description
Security	Enable	MTP content is protected 7/8 words
	Disable(default)	MTP content is not protected so program can be read back
LVR	4.0V	Select LVR = 4.0V
	3.75V	Select LVR = 3.75V
	3.0V	Select LVR = 3.0V
	2.7V	Select LVR = 2.7V
	2.5V(default)	Select LVR = 2.5V
	2.2V	Select LVR = 2.2V
	2.0V	Select LVR = 2.0V

Option	Selection	Description
	1.8V	Select LVR = 1.8V
GPC_P_In	PA.4(default)	Comparator plus input is from PA.4
	PA.0	Comparator plus input is from PA.0
GPC_PWM	Disable(default)	GPC / PWM are independent
	Enable	GPC output control PWM output (ICE does NOT Support.)
OPA_PWM	Disable(default)	OPA / PWM are independent
	Enable	OPA output control PWM output (ICE does NOT Support.)
Comparator_Edge	All_Edge(default)	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
Interrupt Src0	PA.0(default)	<i>INTEN/ INTRQ</i> .Bit0 is from PA.0
	PB.5	<i>INTEN/ INTRQ</i> .Bit0 is from PB.5
Interrupt Src1	PB.0(default)	<i>INTEN/ INTRQ</i> .Bit1 is from PB.0
	PA.4	<i>INTEN/ INTRQ</i> .Bit1 is from PA.4
PB4_PB7_Drive	Normal	PB4 & PB7 Drive / Sink Current is Normal
	Strong(default)	PB4 & PB7 Drive / Sink Current is Strong
PWM_Source	16MHZ(default)	When <i>PWMG0C.0</i> = 1, PWMG0 clock source = IHRC = 16MHZ When <i>PWMG1C.0</i> = 1, PWMG1 clock source = IHRC = 16MHZ When <i>PWMG2C.0</i> = 1, PWMG2 clock source = IHRC = 16MHZ
	32MHZ	When <i>PWMG0C.0</i> = 1, PWMG0 clock source = IHRC*2 = 32MHZ When <i>PWMG1C.0</i> = 1, PWMG1 clock source = IHRC*2 = 32MHZ When <i>PWMG2C.0</i> = 1, PWMG2 clock source = IHRC*2 = 32MHZ (ICE does NOT Support.)
TMx_Source	16MHZ(default)	When <i>TM2C[7:4]</i> = 0010, TM2 clock source = IHRC = 16MHZ When <i>TM3C[7:4]</i> = 0010, TM3 clock source = IHRC = 16MHZ
	32MHZ	When <i>TM2C[7:4]</i> = 0010, TM2 clock source = IHRC*2 = 32MHZ When <i>TM3C[7:4]</i> = 0010, TM3 clock source = IHRC*2 = 32MHZ (ICE does NOT Support.)
TMx_Bit	6 Bit(default)	When <i>TM2S.7</i> =1, TM2 PWM resolution is 6 Bit When <i>TM3S.7</i> =1, TM3 PWM resolution is 6 Bit
	7 Bit	When <i>TM2S.7</i> =1, TM2 PWM resolution is 7 Bit When <i>TM3S.7</i> =1, TM3 PWM resolution is 7 Bit (ICE does NOT Support.)
EMI	Disable(default)	Disable EMI optimize option
	Enable	The system clock will be slightly vibrated for better EMI performance
FPPA	1-FPPA(default)	Single FPPA unit mode
	2-FPPA	Two FPPA units mode

5. Oscillator and System Clock

There are three oscillator circuits provided by PFS252: external crystal oscillator (EOSC), internal high RC oscillator (IHRC) and internal low RC oscillator (ILRC).

These three oscillators are enabled or disabled by registers *EOSCR.7*, *CLKMD.4* and *CLKMD.2* independently. User can choose one of these three 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
EOSC	<i>EOSCR.7</i>
IHRC	<i>CLKMD.4</i>
ILRC	<i>CLKMD.2</i>

Table 4: Three Oscillator Circuits provided by PFS252

5.1. Internal High RC Oscillator and Internal Low RC Oscillator

The frequency of IHRC / ILRC will vary by process, supply voltage and temperature. Please refer to the measurement chart for IHRC / ILRC frequency verse V_{DD} and IHRC / ILRC frequency verse temperature.

The PFS252 writer tool provides IHRC frequency calibration (usually up to 16MHz) to eliminate frequency drift caused by factory production. ILRC has no calibration operation. For applications that require accurate timing, please do not use the ILRC clock as a reference time.

5.2. External Crystal Oscillator

The range of operating frequency of crystal oscillator can be from 32 KHz to 4MHz, depending on the crystal placed on; higher frequency oscillator than 4MHz is NOT supported. Fig. 6 shows the hardware connection under this application.

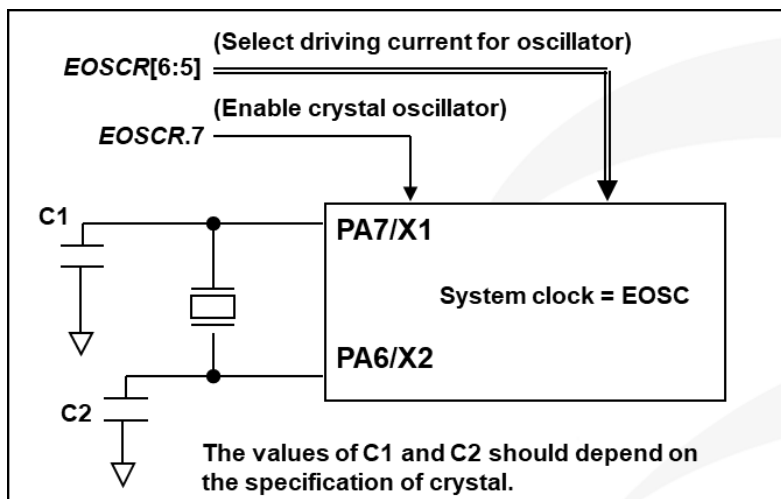


Fig. 6: Connection of crystal oscillator

5.2.1. External Oscillator Setting Register (*EOSCR*), address = 0x0A

Bit	Reset	R/W	Description
7	0	WO	Enable external crystal oscillator. 0 / 1 : Disable / Enable
6 – 5	00	WO	External crystal oscillator selection. 00 : reserved 01 : Low driving capability, for lower frequency, ex: 32KHz crystal oscillator 10 : Middle driving capability, for middle frequency, ex: 1MHz crystal oscillator 11 : High driving capability, for higher frequency, ex: 4MHz crystal oscillator
4 – 0	-	-	Reserved. Please keep 0 for future compatibility.

5.2.2. Usages and Precautions of External Oscillator

Besides crystal, external capacitor and options of PFS252 should be fine tuned in *EOSCR* register to have good sinusoidal waveform. The *EOSCR.7* is used to enable crystal oscillator module. *EOSCR.6* and *EOSCR.5* are used to set the different driving current to meet the requirement of different frequency of crystal oscillator.

Table 5 shows the recommended values of C1 and C2 for different crystal oscillator; the measured start-up time under its corresponding conditions is also shown. Since the crystal or resonator had its own characteristic, the capacitors and start-up time may be slightly different for different type of crystal or resonator, please refer to its specification for proper values of C1 and C2.

Frequency	C1	C2	Measured Start-up time	Conditions
4MHz	4.7pF	4.7pF	6ms	(<i>EOSCR</i> [6:5]=11)
1MHz	10pF	10pF	11ms	(<i>EOSCR</i> [6:5]=10)
32KHz	22pF	22pF	450ms	(<i>EOSCR</i> [6:5]=01)

Table 5: Recommend values of C1 and C2 for crystal and resonator oscillators

Configuration of PA7 and PA6 when using crystal oscillator:

- (1) PA7 and PA6 are set as input;
- (2) PA7 and PA6 internal pull-high resistors are set to close;
- (3) Set PA6 and PA7 as analog inputs with the *PADIER* register to prevent power leakage.

Note: Please read the PMC-APN013 carefully. According to PMC-APN013, the crystal oscillator should be used reasonably. If the following situations happen to cause IC start-up slowly or non-startup, PADAUK Technology is not responsible for this: the quality of the user's crystal oscillator is not good, the usage conditions are unreasonable, the PCB cleaner leakage current, or the PCB layouts are unreasonable.

When using the crystal oscillator, user must pay attention to the stable time of oscillator after enabling it. The stable time of oscillator will depend on frequency, crystal type, external capacitor and supply voltage. Before switching the system to the crystal oscillator, user must make sure the oscillator is stable. The reference program is shown as below:

```

void  FPPA0 (void)
{
    . ADJUST_IC  SYSCLK=IHRC/16, IHRC=16MHz, VDD=5V
    ...
    $ EOSCR Enable, 4Mhz;           // EOSCR = 0b110_00000;
    $ T16M  EOSC, /1, BIT13;       // while T16.Bit13 0 => 1, Intrq.T16 => 1
                                    // suppose crystal eoscr. is stable

    WORD    count    = 0;
    stt16    count;
    Intrq.T16 = 0;
    while (! Intrq.T16) NULL;      // count from 0x0000 to 0x2000, then trigger INTRQ.T16
    CLKMD = 0xB4;                 // switch system clock to EOSC;
    CLKMD.4 = 0;                  // disable IHRC
    ...
}

```

Please notice that the crystal oscillator should be fully turned off before entering the Power-Down mode, in order to avoid unexpected wake-up event.

5.3. System Clock and IHRC Calibration

5.3.1. System Clock

The clock source of system clock comes from IHRC, ILRC or EOSC, the hardware diagram of system clock in the PFS252 is shown as Fig. 7.

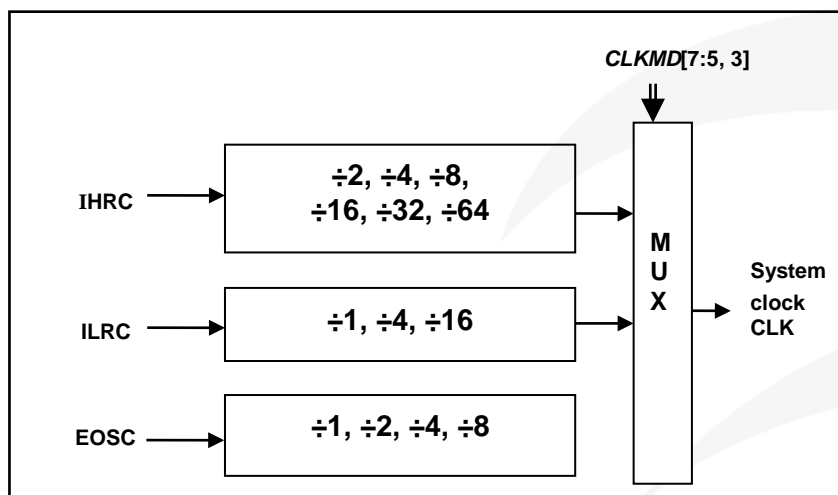


Fig. 7: Options of System Clock

5.3.1.1. Clock Mode Register (*CLKMD*), address = 0x03

Bit	Reset	R/W	Description	
System clock selection				
			Type 0, <i>CLKMD</i> [3]=0	Type 1, <i>CLKMD</i> [3]=1
7 – 5	111	R/W	000: IHRC/4 001: IHRC/2 010: reserved 011: EOSC/4 100: EOSC/2 101: EOSC 110: ILRC/4 111: ILRC (default)	000: IHRC/16 001: IHRC/8 010: ILRC/16 (ICE does NOT Support.) 011: IHRC/32 100: IHRC/64 101: EOSC/8 Others: reserved
4	1	R/W	IHRC oscillator Enable. 0 / 1: disable / enable	
3	0	R/W	Clock Type Select. This bit is used to select the clock type in bit [7:5]. 0 / 1: Type 0 / Type 1	
2	1	R/W	ILRC Enable. 0 / 1: disable / enable If ILRC is disabled, watchdog timer is also disabled.	
1	1	R/W	Watch Dog Enable. 0 / 1: disable / enable	
0	0	R/W	Pin PA5/PRSTB function. 0 / 1: PA5 / PRSTB	

5.3.2. Frequency Calibration

The IHRC frequency and Bandgap reference voltage may be different chip by chip due to manufacturing variation, PFS252 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, VDD=(p3)V
```

Where,

p1=2, 4, 8, 16, 32; In order to provide different system clock.

p2=16 ~ 18; In order to calibrate the chip to different frequency, 16MHz is the usually one.

p3=2.2 ~ 5.5; In order to calibrate the chip under different supply voltage.

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 MTP 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. As shown in table 6:

SYCLK	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, Bandgap OFF

Table 6: Options for IHRC Frequency Calibration

The following shows the different states of PFS252 under different options:

(1) .ADJUST_IC SYCLK=IHRC/4, IHRC=16MHz, V_{DD}=5V

After boot, CLKMD = 0x14:

- a. IHRC frequency is calibrated to 16MHz@V_{DD}=5V and IHRC module is enabled
- b. System CLK = IHRC/4 = 4MHz
- c. Watchdog timer is disabled, ILRC is enabled, PA5 is in input mode

(2) .ADJUST_IC SYCLK=IHRC/8, IHRC=16MHz, V_{DD}=2.5V

After boot, CLKMD = 0x3C:

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

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

After boot, CLKMD = 0xE4:

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

(4) .ADJUST_IC DISABLE

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

- a. IHRC is not calibrated.
- b. System CLK = ILRC or IHRC/64
- c. Watchdog timer is enabled, ILRC is enabled, PA5 is in input mode

5.3.2.1.Special Statement

- (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.

5.3.3. System Clock Switching

After IHRC calibration, the system clock of PFS252 can be switched among IHRC, ILRC and EOSC by setting the *CLKMD* register at any time, **but please notice that the original clock module can NOT be turned off at the same time as writing command to *CLKMD* register**. For example, when switching from A clock source to B clock source, you should first switch the system clock source to B and then close the A clock source. 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/4

```

... // system clock is ILRC
CLKMD.4 = 1; // turn on IHRC first to improve anti-interference ability
CLKMD = 0x14; // switch to IHRC/4, 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/4 to EOSC

```

... // system clock is IHRC/4
CLKMD = 0xB0; // switch to EOSC, IHRC CAN NOT be disabled here
CLKMD.4 = 0; // IHRC CAN be disabled at this time
...

```

Case 3: Switching system clock from IHRC/8 to IHRC/4

```

... // system clock is IHRC/8, 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 = 0x10; // CAN NOT switch clock from ILRC to IHRC/4 and turn off
// ILRC oscillator at the same time
...

```

6. Reset

PFS252 reset can be caused by four factors: power-on reset, LVR reset, watchdog timeout overflow reset, and PRSTB pin reset. After the reset, the system will restart. The program counter will jump to address 0x000 and most of all the registers in PFS252 will be set to the default values.

6.1. Power On Reset - POR

POR (Power-On-Reset) is used to reset PFS252 when power up. Time for boot-up is about 3000 ILRC clock cycles. The power up sequence is shown in the Fig. 8. Customer must ensure the stability of supply voltage after power up no matter which option is chosen.

The PFS252 data memory is in an uncertain state when the power on reset occurs.

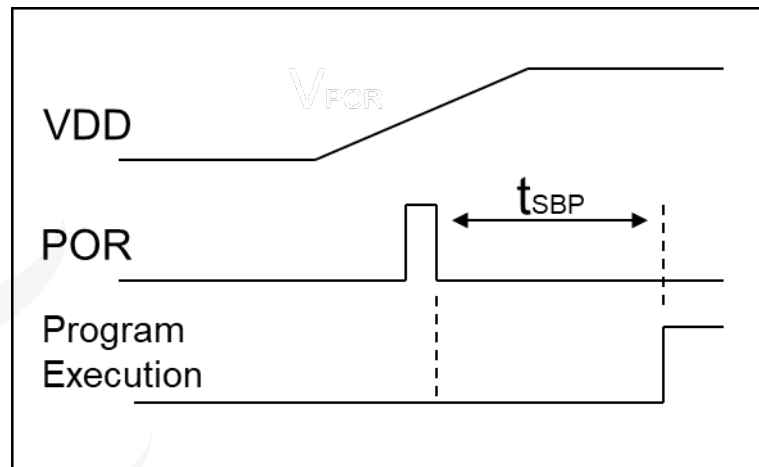


Fig. 8: Power Up Sequence

Fig. 9 shows the typical program flow after boot up. Please notice that the FPPA1 is disabled after reset and recommend NOT enabling FPPA1 before system and FPPA0 initialization.

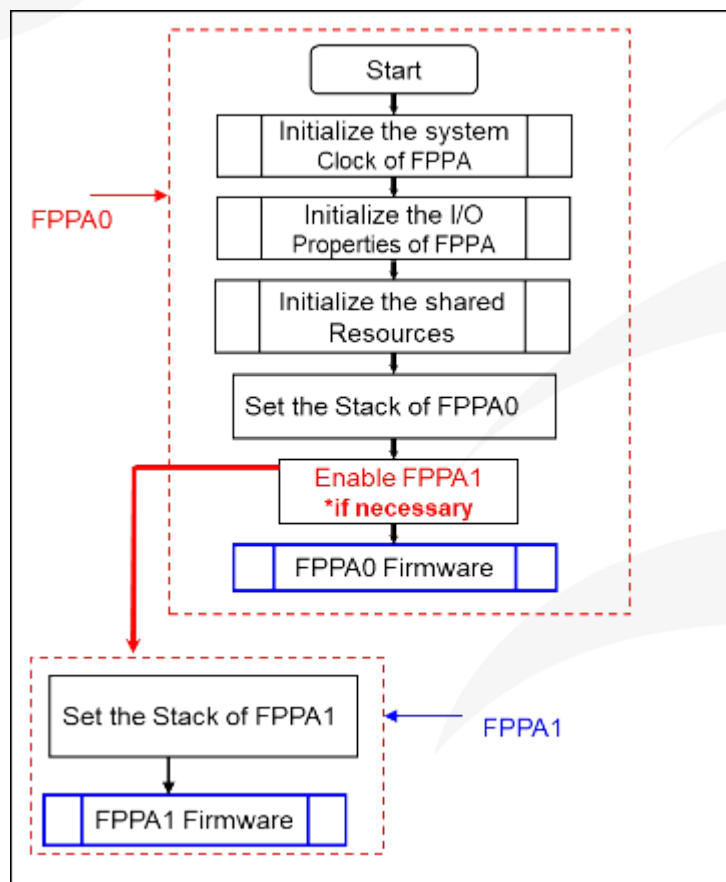


Fig. 9: Boot Procedure

6.2. Low Voltage Reset - LVR

If VDD drops below the Voltage level of LVR (Low Voltage Reset), LVR Reset will occur in the system. The LVR reset timing diagram is shown in figure 10. After LVR reset, the SRAM data will be kept when $VDD > VDR$ (SRAM data retention voltage). However, if SRAM is cleared after power-on again, the data cannot be kept, the data memory is in an uncertain state when $VDD < VDR$.

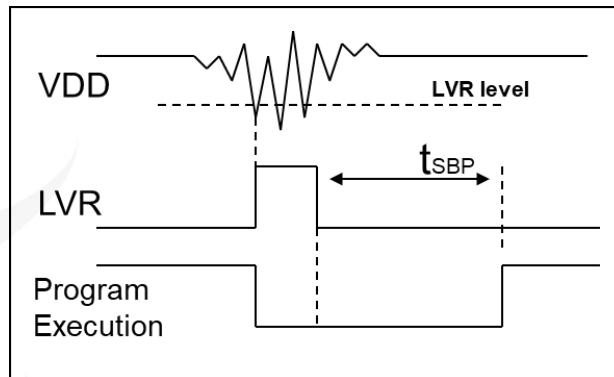


Fig. 10: Low Voltage Reset Sequence

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	VDD	LVR
8MHz	$\geq 3.75V$	3.75V
4MHz	$\geq 2.5V$	2.5V
2MHz	$\geq 2.2V$	2.2V

Table 7: LVR setting for reference

- (1) The setting of LVR (1.8V ~ 4.5V) will be valid just after successful power-on process.
- (2) User can set MISC.2 as "1" to disable LVR. However, V_{DD} must be kept as exceeding the lowest working voltage of chip; Otherwise IC may work abnormally.
- (3) The LVR function will be invalid when IC in stopexe or stopsys mode.

MISC Register (MISC), address = 0x1F			
Bit	Reset	R/W	Description
7 – 5	-	-	Reserved. (keep 0 for future compatibility)
4	0	WO	Enable VDD/2 bias voltage generator 0 / 1 : Disable / Enable
3	-	-	Reserved. (keep 0 for future compatibility)
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

6.3. Watch Dog Timeout Reset

The watchdog timer (WDT) is a counter with clock coming from ILRC, so it will be invalid if ILRC is off. The frequency of ILRC may drift a lot due to the variation of manufacture, supply voltage and temperature. User should reserve guard band for safe operation.

Besides, the watchdog period will also be shorter than expected after Reset or Wakeup events. It is suggested to clear WDT by *wdreset* command after these events to ensure enough clock periods before WDT timeout.

To ensure the watchdog is cleared before the timeout overflow, the instruction *wdreset* can be used to clear the WDT within a safe time. WDT can be cleared by power-on-reset or by command *wdreset* at any time.

When WDT is timeout, PFS252 will be reset to restart the program execution. The relative timing diagram of watchdog timer is shown as Fig. 11.

The PFS252 data memory will be reserved when the WDT reset occurs.

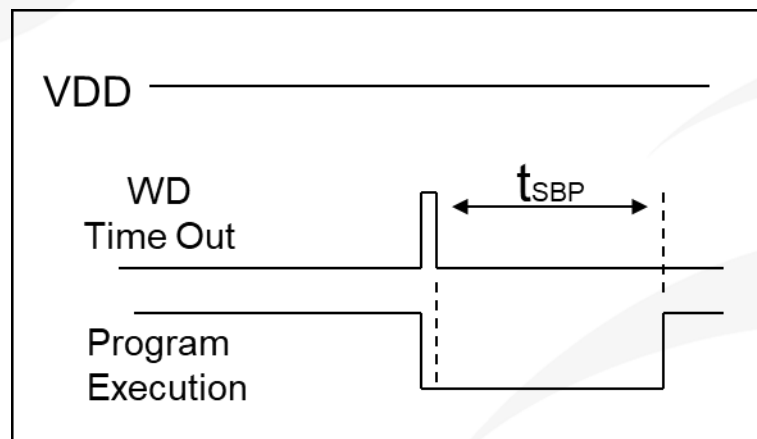


Fig. 11: Sequence of Watch Dog Timeout reset

There are four different timeout periods of watchdog timer can be chosen by setting the *MISC[1:0]*. And watchdog timer can be disabled by *CLKMD.1*.

Clock Mode Register (<i>CLKMD</i>), address = 0x03			
Bit	Reset	R/W	Description
7 – 5	111	R/W	System clock selection
4	1	R/W	IHRC oscillator Enable. 0 / 1: disable / enable
3	0	R/W	Clock Type Select.
2	1	R/W	ILRC Enable. 0 / 1: disable / enable If ILRC is disabled, watchdog timer is also disabled.
1	1	R/W	Watch Dog Enable. 0 / 1: disable / enable
0	0	R/W	Pin PA5/PRSTB function. 0 / 1: PA5 / PRSTB

6.4. External Reset Pin - PRSTB

The PFS252 supports external reset and its external reset pin shares the same IO port with PA5. Using external reset function requires:

- (1) Set PA5 as input;
- (2) Set *CLKMD.0* = 1 to make PA5 as the external PRSTB input pin.

When the PRSTB pin is high, the system is in normal working state. Once the reset pin detects a low level, the system will be reset. The timing diagram of PRSTB reset is shown in figure 6.

The PFS252 data memory will be reserved when the PRSTB reset occurs.

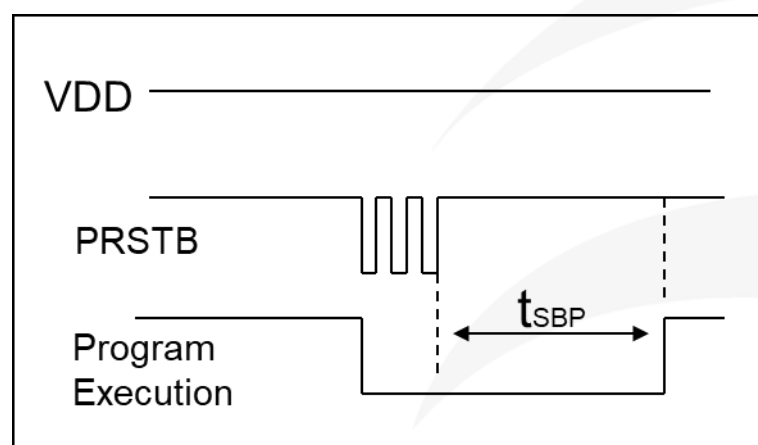


Fig. 12: Sequence of PRSTB reset

7. System Operating Mode

There are three operational modes defined by hardware:

- (1) ON mode
- (2) Power-Save mode
- (3) Power-Down mode

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 periodically and Power-Down mode is used in the system which needs power down deeply with seldom wake-up.

7.1. Power-Save Mode (“*stopexe*”)

Using *stopexe* instruction to enter the Power-Save mode, only system clock is disabled, remaining all the oscillator modules be active. So only the CPU stops executing instructions. Wake-up from input pins can be considered as a continuation of normal execution.

The detail information for Power-Save mode shown below:

- (1) IHRC and oscillator modules: No change, keep active if it was enabled
- (2) ILRC oscillator modules: must remain enabled, need to start with ILRC when waking up
- (3) System clock: Disable, therefore, CPU stops execution
- (4) MTP memory is turned off.
- (5) 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, TM3, PWMG0, PWMG1, PWMG2.)
- (6) Wake-up sources:
 - a. IO toggle wake-up: IO toggling in digital input mode (*PxC* bit is 1 and *PxDIER* 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. 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.

7.2. 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 recommend to set *GPCC.7=0* to disable the comparator before the command *stopsys*.

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 following shows the internal status of PFS252 in detail when *stopsys* command is issued:

- (1) All the oscillator modules are turned off
- (2) MTP memory is turned off
- (3) The contents of SRAM and registers remain unchanged
- (4) Wake-up sources: IO toggle in digital mode (*PxDIER* bit is 1)

The reference sample program for power down mode is shown as below:

```
CMKMD = 0xF4;           // Change clock from IHRC to ILRC, disable watchdog timer
CLKMD.4 = 0;           // disable IHRC
...
while (1)
{
    STOPSYS;           // enter Power-Down mode
    if (...) break;    // if wake-up happen and check OK, then return to high speed,
                        // else stay in Power-Down mode again.
}
CLKMD = 0x14;       // Change clock from ILRC to IHRC/4
```

7.3. Wake-Up

After entering the Power-Down or Power-Save modes, the PFS252 can be resumed to normal operation by toggling IO pins. Wake-up from timer are available for Power-Save mode ONLY. Table 8 shows the differences in wake-up sources between *stopsys* and *stopexe*.

Differences in wake-up sources between <i>stopsys</i> and <i>stopexe</i>			
	IO Toggle	Timer wake-up	Comparator wake-up
<i>stopsys</i>	Yes	No	No
<i>stopexe</i>	Yes	Yes	Yes

Table 8: Differences in wake-up sources between Power-Save mode and Power-Down mode

When using the IO pins to wake-up the PFS252, registers *PxDIER* 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
<i>stopexe</i> suspend or <i>stopsys</i> suspend	Fast wake-up	$45 * T_{ILRC}$, Where T_{ILRC} is the time period of ILRC
<i>stopexe</i> suspend or <i>stopsys</i> suspend	Normal wake-up	$3000 * T_{ILRC}$, Where T_{ILRC} is the clock period of ILRC

8. Interrupt

There are seven interrupt lines for PFS252:

- ◆ External interrupt PA0/PB5
- ◆ External interrupt PB0/PA4
- ◆ GPC interrupt
- ◆ Timer16 interrupt
- ◆ Timer2 interrupt
- ◆ Timer3 interrupt
- ◆ PWMG0 interrupt

Every interrupt request line to CPU has its own corresponding interrupt control bit to enable or disable it. The hardware diagram of interrupt controller is shown as Fig. 13. 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.

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

Note: the external interrupt source can be switched through Interrupt Src0 or Interrupt Src1 in the Code Option.

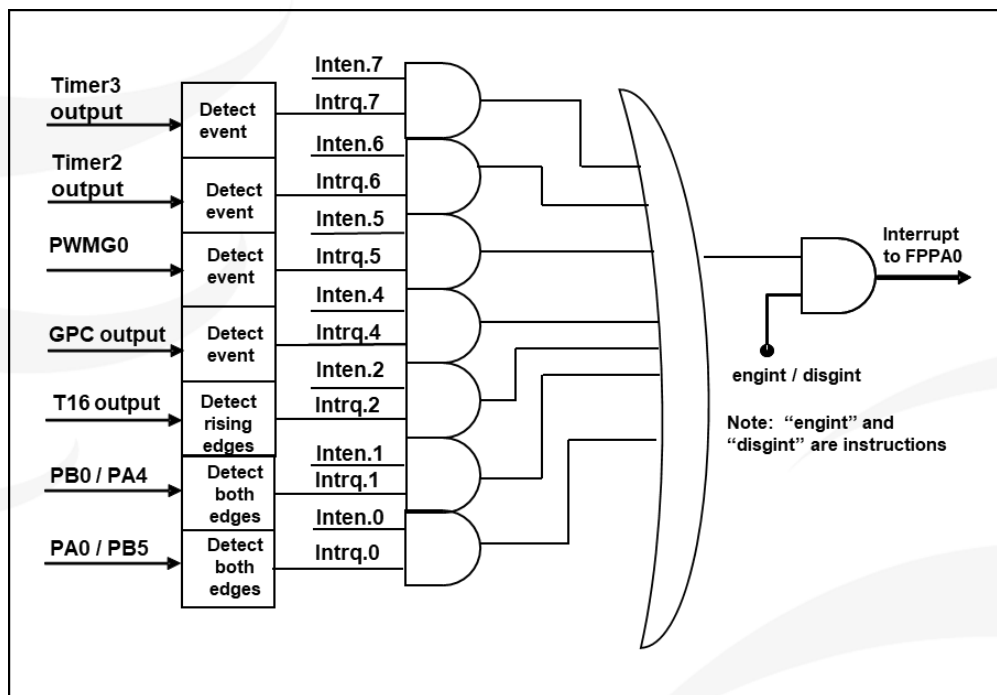


Fig. 13: Hardware diagram of Interrupt controller

8.1. Interrupt Enable Register (*INTEN*), address = 0x04

Bit	Reset	R/W	Description
7	0	R/W	Enable interrupt from Timer3. 0 / 1: disable / enable.
6	0	R/W	Enable interrupt from Timer2. 0 / 1: disable / enable.
5	0	R/W	Enable interrupt from PWMG0. 0 / 1: disable / enable.
4	0	R/W	Enable interrupt from comparator. 0 / 1: disable / enable.
3	-	-	Reserved
2	0	R/W	Enable interrupt from Timer16 overflow. 0 / 1: disable / enable.
1	0	R/W	Enable interrupt from PB0/PA4. 0 / 1: disable / enable. (by code option Interrupt Src1)
0	0	R/W	Enable interrupt from PA0/PB5. 0 / 1: disable / enable. (by code option Interrupt Src0)

8.2. Interrupt Request Register (*INTRQ*), address = 0x05

Bit	Reset	R/W	Description
7	-	R/W	Interrupt Request from Timer3, this bit is set by hardware and cleared by software. 0 / 1: No request / Request
6	-	R/W	Interrupt Request from Timer2, this bit is set by hardware and cleared by software. 0 / 1: No request / Request
5	-	R/W	Interrupt Request from PWMG0, 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	-	-	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 PB0/PA4, this bit is set by hardware and cleared by software. 0 / 1: No request / Request
0	-	R/W	Interrupt Request from pin PA0/PB5, this bit is set by hardware and cleared by software. 0 / 1: No Request / request

8.3. Interrupt Edge Select Register (*INTEGS*), address = 0x0C

Bit	Reset	R/W	Description
7 - 5	-	-	Reserved.
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	00	WO	PB0/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/PB5 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.

Note:

- (1) *INTEN* and *INTRQ* have no initial values. Please set required value before enabling interrupt function. Even if *INTEN*=0, *INTRQ* will be still triggered by the interrupt source.
- (2) PA4 and PB5 can be used as external interrupt pins. When using the PA4 as external interrupt pin, the setting method of *INTEN* / *INTRQ* / *INTEGS* registers are same as that of PB0, the only difference is to choose PB0 or PA4 as source of interrupt_Src1 in CODE_OPTION. Similarly, when using the PB5 as external interrupt pin, the setting method of *INTEN* / *INTRQ* / *INTEGS* registers are same as that of PA0, the only difference is to choose PA0 or PB5 as source of interrupt_Src0 in CODE_OPTION.

8.4. Interrupt Work Flow

Once the interrupt occurs, its operation will be:

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

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

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

8.5. General Steps to Interrupt

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.

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
```

* Use *disgint* in the main program can disable all interrupts.

8.6. Example for Using Interrupt

User must reserve enough stack memory for interrupt, two bytes stack memory for one level interrupt and four bytes for two levels interrupt.

For interrupt operation, the following sample program shows how to handle the interrupt, noticing that it needs four bytes stack memory to handle interrupt and *pushaf*.

```

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

void Interrupt (void) // interrupt service routine
{
    PUSHAF // store ALU and FLAG register

    // If 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
}

```

9. I/O Port

9.1. IO Related Registers

9.1.1. Port A Digital Input Enable Register (*PADIER*), address = 0x0D

Bit	Reset	R/W	Description
7 - 6	11	WO	Enable PA7~PA6 digital input and wake-up event. 1 / 0 : enable / disable. These bits should be set to low to prevent leakage current when external crystal oscillator is used.
5	1	WO	Enable PA5 digital input and wake-up event. 1 / 0 : enable / disable.
4	1	WO	Enable PA4 digital input and wake-up event and interrupt request. 1 / 0 : enable / disable.
3	1	WO	Enable PA3 digital input and wake-up event. 1 / 0 : enable / disable.
2 - 1	1	WO	Reserved.
0	1	WO	Enable PA0 digital input and wake-up event and interrupt request. 1 / 0: enable / disable.

9.1.2. Port B Digital Input Enable Register (*PBDIER*), address = 0x0E

Bit	Reset	R/W	Description
7 - 6	11	WO	Enable PB7~PB6 digital input and wake up event. 1 / 0: enable / disable.
5	1	WO	Enable PB5 digital input and wake-up event and interrupt request. 1 / 0: enable / disable.
4 - 1	1111	WO	Enable PB4~PB1 digital input and wake up event. 1 / 0: enable / disable.
0	1	WO	Enable PB0 digital input and wake-up event and interrupt request. 1 / 0: enable / disable.

9.1.3. Port A Data Registers (*PA*), address = 0x10

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

9.1.4. Port A Control Registers (*PAC*), 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.

9.1.5. Port A Pull-High Registers (*PAPH*), address = 0x12

Bit	Reset	R/W	Description
7 – 3	00000	R/W	Port PA7 ~ PA3 pull-high registers. This register is used to enable the internal pull-high device on each corresponding pin of port A. 0 / 1 : disable / enable
2 – 1	-	-	Reserved. Please keep 0 for future compatibility.
0	0	R/W	Port PA0 pull-high registers. This register is used to enable the internal pull-high device on each corresponding pin of port A. 0 / 1 : disable / enable

9.1.6. Port A Pull-Low Register (*PAPL*), address = 0x13

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

9.1.7. Port B Data Registers (*PB*), address = 0x14

Bit	Reset	R/W	Description
7 – 0	0x00	R/W	Data registers for Port B.

9.1.8. Port B Control Registers (*PBC*), address = 0x15

Bit	Reset	R/W	Description
7 – 0	0x00	R/W	Port B control registers. This register is used to define input mode or output mode for each corresponding pin of port B. 0 / 1: input / output.

9.1.9. Port B Pull-High Registers (*PBPH*), address = 0x16

Bit	Reset	R/W	Description
7 – 0	0x00	R/W	Port B pull-high registers. This register is used to enable the internal pull-high device on each corresponding pin of port B. 0 / 1 : disable / enable

9.1.10. Port B Pull-Low Register (*PBPL*), address = 0x17

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

9.2. IO Structure and Functions

9.2.1. IO Pin Structure

All the IO pins of PFS252 have the same structure. The hardware diagram of IO buffer is shown as Fig. 14.

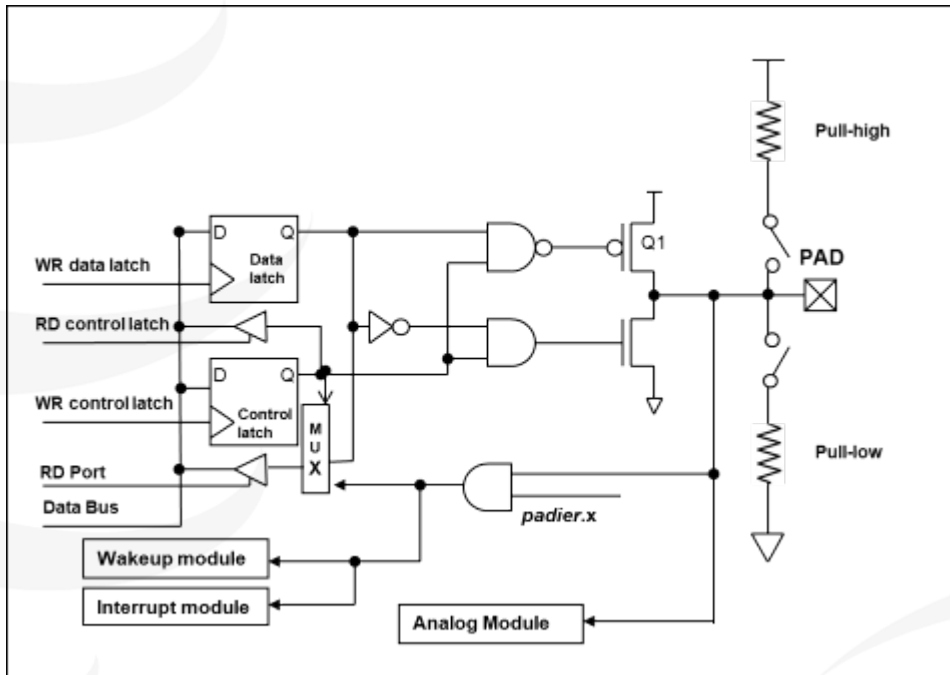


Fig. 14: Hardware diagram of IO buffer

9.2.2. IO Pin Functions

(1) Input / output function:

PFS252 all the pins can be independently set into digital input, analog input, output low, output high.

Each IO pin can be independently configured for different state by configuring the data registers (*PA/PB*), control registers (*PAC/PBC*), pull-high registers (*PAPH/PBPH*) and pull-low registers (*PAPL/PBPL*).

The corresponding bits in registers *PxDIER* should be set to low to prevent leakage current for those pins are selected to be analog function. When it is set to output mode, the pull-high / pull-low 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 9 shows the configuration table of bit 0 of port A.

<i>PA.0</i>	<i>PAC.0</i>	<i>PAPH.0</i>	<i>PAPL.0</i>	Description
X	0	0	0	Input without pull-high / pull-low resistor
X	0	1	0	Input with pull-high resistor
X	0	0	1	Input with pull-low resistor
X	0	1	1	Input with pull-low / pull-high resistor
0	1	X	X	Output low without pull-high / pull-low resistor
1	1	X	X	Output high without pull-high / pull-low resistor

Table 9: PA0 Configuration Table

(2)Wake-up function:

When PFS252 put in Power-Down or Power-Save mode, every IO 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 *PxDIER* to high.

(3)External interrupt function:

When the IO acts as an external interrupt pin, the corresponding bit of *PxDIER* should be set to high. For example, *PADIER.0* should be set to high when PA0 is used as external interrupt pin.

(4)Drive capability optional:

PB4 and PB7 can adjust their drive and sink current by code option *PB4_PB7_Drive*.

9.2.3. IO Pin Usage and Setting

(1) IO pin as digital input

- ◆ When IO is set as digital input, the level of V_{ih} and V_{il} would changes with the voltage and temperature. Please follow the minimum value of V_{ih} and the maximum value of V_{il} .
- ◆ The value of internal pull high resistor would also changes with the voltage, temperature and pin voltage. It is not the fixed value.

(2) If IO pin is set to be digital input and enable wake-up function

- ◆ Configure IO pin as input mode by *PxC* register.
- ◆ 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 >10Ω resistor in between PA5 and the long wire.
- ◆ Avoid using PA5 as input in such application.

10. Timer / PWM Counter

10.1. 16-bit Timer (Timer16)

10.1.1. Timer16 Introduction

PFS252 provide a 16-bit hardware timer (Timer16/T16) and its block diagram is shown in Fig. 15.

The clock source of timer16 is selected by register $T16M[7:5]$. Before sending clock to the 16-bit counter (counter16), a pre-scaling logic with divided-by-1, 4, 16 or 64 is selected by $T16M[4:3]$ for wide range counting.

$T16M[2:0]$ is used to select the interrupt request. The interrupt request from Timer16 will be triggered by the selected bit which comes from bit[15:8] of this 16-bit counter. Rising edge or falling edge can be optional chosen by register $INTEGS.4$.

The 16-bit counter performs up-counting operation only, the counter initial values can be stored from data memory by issuing the $stt16$ instruction and the counting values can be loaded to data memory by issuing the $ldt16$ instruction.

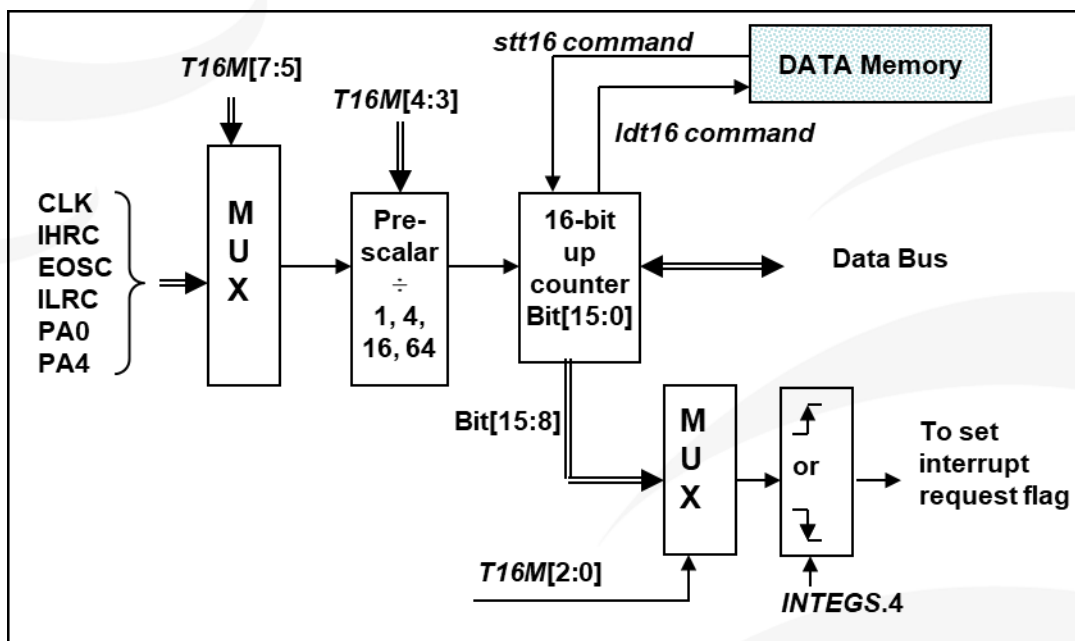


Fig. 15: Hardware diagram of Timer16

There are three parameters to define the Timer16 using; 1st parameter is used to define the clock source of Timer16, 2nd parameter is used to define the pre-scaler and the 3rd one is to define the interrupt source.

```

T16M      IO_RW  0x06
$ 7~5:   STOP, SYSCLK, X, PA4_F, IHRC, EOSC, ILRC, PA0_F // 1st par.
$ 4~3:   /1, /4, /16, /64 // 2nd par.
$ 2~0:   BIT8, BIT9, BIT10, BIT11, BIT12, BIT13, BIT14, BIT15 // 3rd par.
    
```

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

```

$ T16M SYCLK, /64, BIT15;
// choose (SYCLK/64) as clock source, every 2^16 clock to set INTRQ.2=1
// if system clock SYCLK = IHRC / 4 = 4 MHz
// SYCLK/64 = 4 MHz/64 = 16 uS, about every 1 S to generate INTRQ.2=1

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

$ T16M STOP;
// stop Timer16 counting

```

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

$$F_{\text{INTRQ_T16M}} = F_{\text{clock source}} \div P \div 2^{n+1}$$

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 nth bit selected to request interrupt service, for example: n=10 if bit 10 is selected.

10.1.2. Timer16 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.

10.1.3. Timer16 Mode Register (*T16M*), address = 0x06

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

10.2. 8-bit Timer with PWM Generation (Timer2, Timer3)

Two 8-bit hardware timers (Timer2/TM2, Timer3/TM3) with PWM generation are implemented in the PFS252. Timer2 is used as the example to describe its function due to these two 8-bit timers are the same. Fig. 16 shows the Timer2 hardware diagram.

Bit[7:4] of register *TM2C* are used to select the clock source of Timer2. And the output of Timer2 is selected by *TM2C*[3:2]. The clock frequency divide module is controlled by bit [6:5] of *TM2S* register. *TM2B* register controls the upper bound of 8-bit counter. It will be clear to zero automatically when the counter values reach for upper bound register. The counter values can be set or read back by *TM2CT* register.

PFS252

8bit MTP IO type MCU

There are two operating modes for Timer2: period mode and PWM mode. Period mode is used to generate periodical output waveform or interrupt event, and PWM mode is used to generate PWM output waveform with optional 6-bit ~ 8-bit PWM resolution.

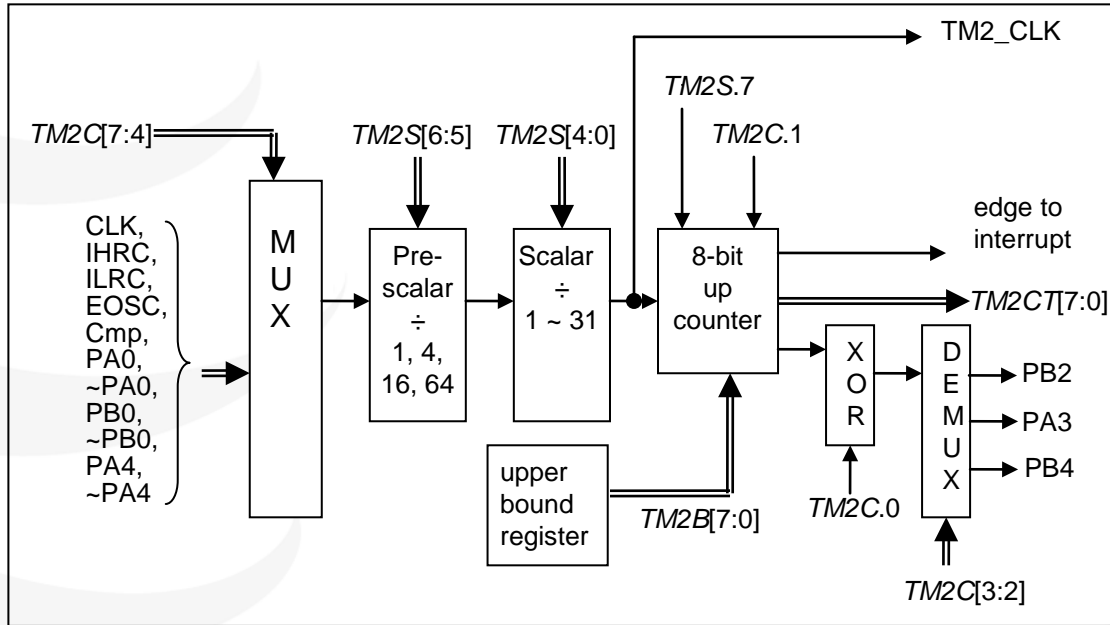


Fig. 16: Timer2 hardware diagram

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

Fig. 17 shows the timing diagram of Timer2 for both period mode and PWM mode.

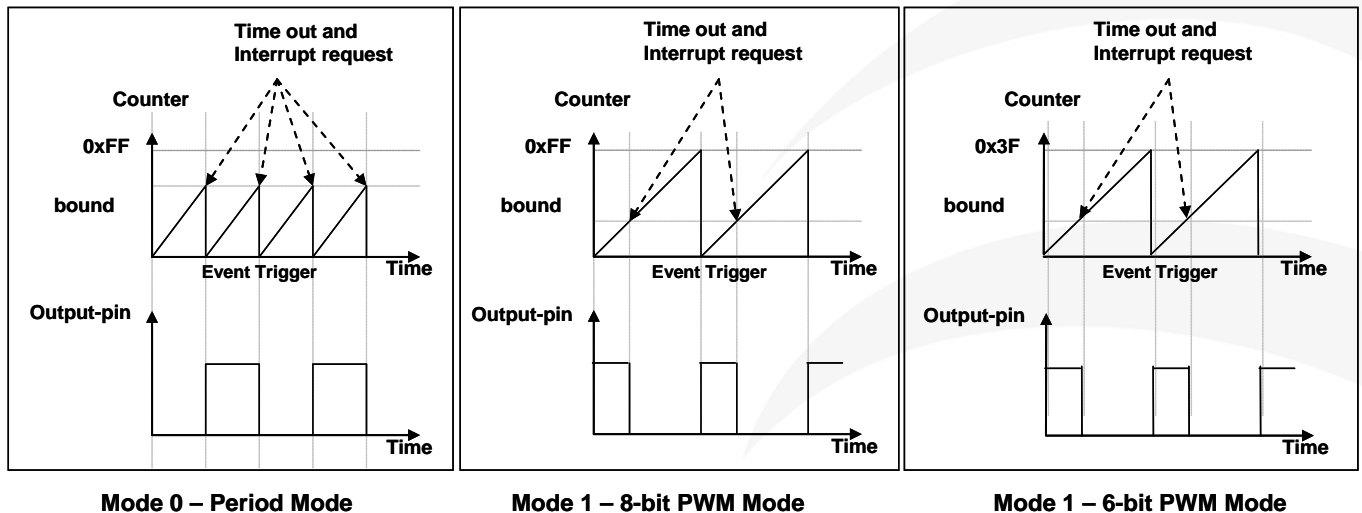


Fig. 17: Timing diagram of Timer2 in period mode and PWM mode ($TM2C.1=1$)

Code Options GPC_PWM and OPA_PWM are for the applications which need the generated PWM waveform to be controlled by the comparator result. If the Code Option GPC_PWM or OPA_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. 18.

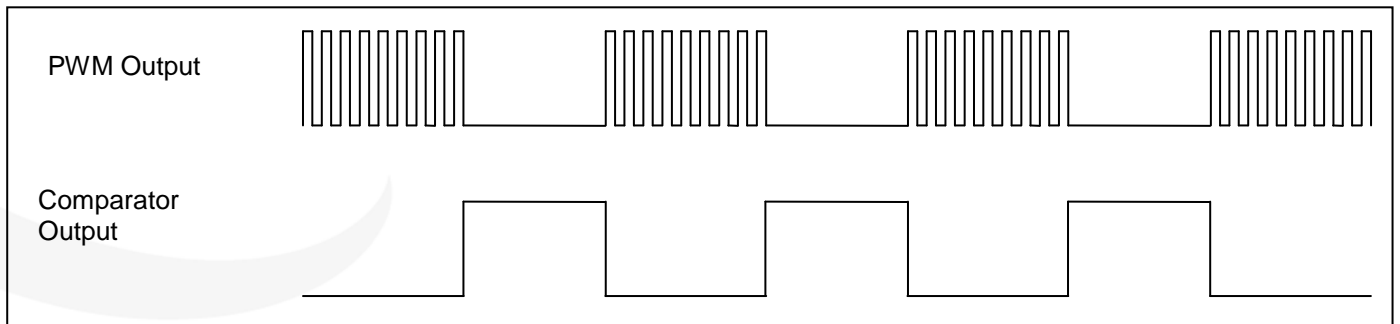


Fig.18: Comparator controls the output of PWM waveform

10.2.1. Timer2、Timer3 Related Registers

10.2.1.1. Timer2 Bound Register (*TM2B*), address = 0x09

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

10.2.1.2. Timer2 Counter Register (*TM2CT*), address = 0x1D

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

10.2.1.3. Timer2 Scalar Register (*TM2S*), address = 0x1E

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

10.2.1.4. Timer2 Control Register (*TM2C*), address = 0x1C

Bit	Reset	R/W	Description
7 – 4	0000	R/W	Timer2 clock selection. 0000 : disable 0001 : CLK 0010 : IHRC or IHRC *2 (by code option TMx_source) 0011 : EOSC 0100 : ILRC 0101 : comparator output 0110 : OPA (Comparator mode) compare output 1000 : PA0 (rising edge) 1001 : ~PA0 (falling edge) 1010 : PB0 (rising edge) 1011 : ~PB0 (falling edge) 1100 : PA4 (rising edge) 1101 : ~PA4 (falling edge) Others: reserved Notice: In ICE mode and IHRC is selected for Timer2 clock, the clock sent to Timer2 does NOT be stopped, Timer2 will keep counting when ICE is in halt state.
3 – 2	00	R/W	Timer2 output selection. 00 : disable 01 : PB2 10 : PA3 11 : PB4
1	0	R/W	Timer2 mode selection. 0 / 1 : period mode / PWM mode
0	0	R/W	Enable to inverse the polarity of Timer2 output. 0 / 1: disable / enable

10.2.1.5. Timer3 Counter Register (*TM3CT*), address = 0x33

Bit	Reset	R/W	Description
7 – 0	0x00	R/W	Bit [7:0] of Timer3 counter register.

10.2.1.6. Timer3 Scalar Register (*TM3S*), address = 0x34

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

10.2.1.7. Timer3 Bound Register (*TM3B*), address = 0x38

Bit	Reset	R/W	Description
7 – 0	0x00	WO	Timer3 bound register.

10.2.1.8. Timer3 Control Register (*TM3C*), address = 0x32

Bit	Reset	R/W	Description
7 – 4	0000	R/W	Timer3 clock selection. 0000 : disable 0001 : CLK 0010 : IHRC or IHRC *2 (by code option TMx_source) 0011 : EOSC 0100 : ILRC 0101 : comparator output 0110 : OPA (Comparator mode) compare output 1000 : PA0 (rising edge) 1001 : ~PA0 (falling edge) 1010 : PB0 (rising edge) 1011 : ~PB0 (falling edge) 1100 : PA4 (rising edge) 1101 : ~PA4 (falling edge) Others: reserved Notice: In ICE mode and IHRC is selected for Timer3 clock, the clock sent to Timer3 does NOT be stopped, Timer3 will keep counting when ICE is in halt state.
3 – 2	00	R/W	Timer3 output selection. 00 : disable 01 : PB5 10 : PB6 11 : PB7
1	0	R/W	Timer3 mode selection. 0 / 1 : period mode / PWM mode
0	0	R/W	Enable to inverse the polarity of Timer3 output. 0 / 1: disable / enable

10.2.2. 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:

$$\text{Frequency of Output} = Y \div [2 \times (K+1) \times S1 \times (S2+1)]$$

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_1100, Y=4MHz

TM2B = 0b0111_1111, K=127

TM2S = 0b0_00_00000, S1=1, S2=0

frequency of output = 4MHz ÷ [2 × (127+1) × 1 × (0+1)] = 15.625KHz

Example 2:

TM2C = 0b0001_1000, Y=4MHz

TM2B = 0b0000_0001, K=1

TM2S = 0b0_00_00000, S1=1, S2=0

frequency = 4MHz ÷ [2 × (1+1) × 1 × (0+1)] = 1MHz

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

```

void FPPA0 (void)
{
    . ADJUST_IC    SYSCLK=IHRC/4, IHRC=16MHz, VDD=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;
    }
}

```

10.2.3. 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:

$$\text{Frequency of Output} = Y \div [256 \times S1 \times (S2+1)]$$

$$\text{Duty of Output} = [(K+1) \div 256] \times 100\%$$

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 ($S2 = 0 \sim 31$)

Example 1:

$TM2C = 0b0001_1010$, $Y=4MHz$

$TM2B = 0b0111_1111$, $K=127$

$TM2S = 0b0_00_00000$, $S1=1$, $S2=0$

frequency of output = $4MHz \div (256 \times 1 \times (0+1)) = 15.625KHz$

duty of output = $[(127+1) \div 256] \times 100\% = 50\%$

Example 2:

$TM2C = 0b0001_1010$, $Y=4MHz$

$TM2B = 0b0000_1001$, $K = 9$

$TM2S = 0b0_00_00000$, $S1=1$, $S2=0$

frequency of output = $4MHz \div (256 \times 1 \times (0+1)) = 15.625KHz$

duty of output = $[(9+1) \div 256] \times 100\% = 3.9\%$

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

```

void FPPA0(void)
{
    .ADJUST_IC SYSCLK=IHRC/4, IHRC=16MHz, VDD=5V
    wreset;
    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;
    }
}

```

10.2.4. 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:

$$\text{Frequency of Output} = Y \div [64 \times S1 \times (S2+1)]$$

$$\text{Duty of Output} = [(K+1) \div 64] \times 100\%$$

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 ($S2 = 0 \sim 31$)

Example 1:

$TM2C = 0b0001_1010$, $Y=4\text{MHz}$

$TM2B = 0b0011_1111$, $K=63$

$TM2S = 0b1_00_00000$, $S1=1$, $S2=0$

frequency of output = $4\text{MHz} \div (64 \times 1 \times (0+1)) = 62.5\text{KHz}$

duty of output = $[(63+1) \div 64] \times 100\% = 100\%$

Example 2:

$TM2C = 0b0001_1010$, $Y=4\text{MHz}$

$TM2B = 0b0000_0000$, $K=0$

$TM2S = 0b1_00_00000$, $S1=1$, $S2=0$

Frequency = $4\text{MHz} \div (64 \times 1 \times (0+1)) = 62.5\text{KHz}$

Duty = $[(0+1) \div 64] \times 100\% = 1.5\%$

10.3. 11-bit PWM Generation

Three 11-bit hardware PWM generators (PWMG0, PWMG1 & PWMG2) are implemented in the PFS252. PWMG0 is used as the example to describe its functions due to all of them are almost the same. Their individual outputs are listed as below:

- (1) PWMG0 – PA0, PB4, PB5
- (2) PWMG1 – PA4, PB6, PB7
- (3) PWMG2 – PA3, PB2, PB3, PA5 (Only PA5 ICE does not support)

10.3.1. PWM Waveform

A PWM output waveform (Fig. 19) has a time-base ($T_{\text{Period}} = \text{Time of Period}$) and a time with output high level (Duty Cycle). The frequency of the PWM output is the inverse of the period ($f_{\text{PWM}} = 1/T_{\text{Period}}$), the resolution of the PWM is the clock count numbers for one period (N bits resolution, $2^N \times T_{\text{clock}} = T_{\text{Period}}$).

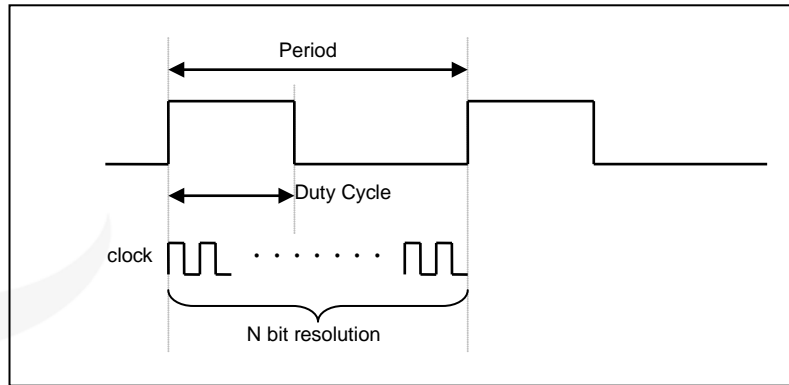


Fig. 19: PWM Output Waveform

10.3.2. Hardware and Timing Diagram

Fig. 20 shows the hardware diagram of 11-bit Timer. The clock source can be IHRC or system clock. The PWM output pin is selected by register *PWMG0C*. The period of PWM waveform is defined in the PWM upper bond high and low registers (*PWMG0CUBH* and *PWMG0CUBL*), the duty cycle of PWM waveform is defined in the PWM duty high and low registers (*PWMG0DTH* and *PWMG0DTL*).

Selecting code option GPC_PWM can also control the generated PWM waveform by the comparator result. Please refer the section of Timer2 for further information.

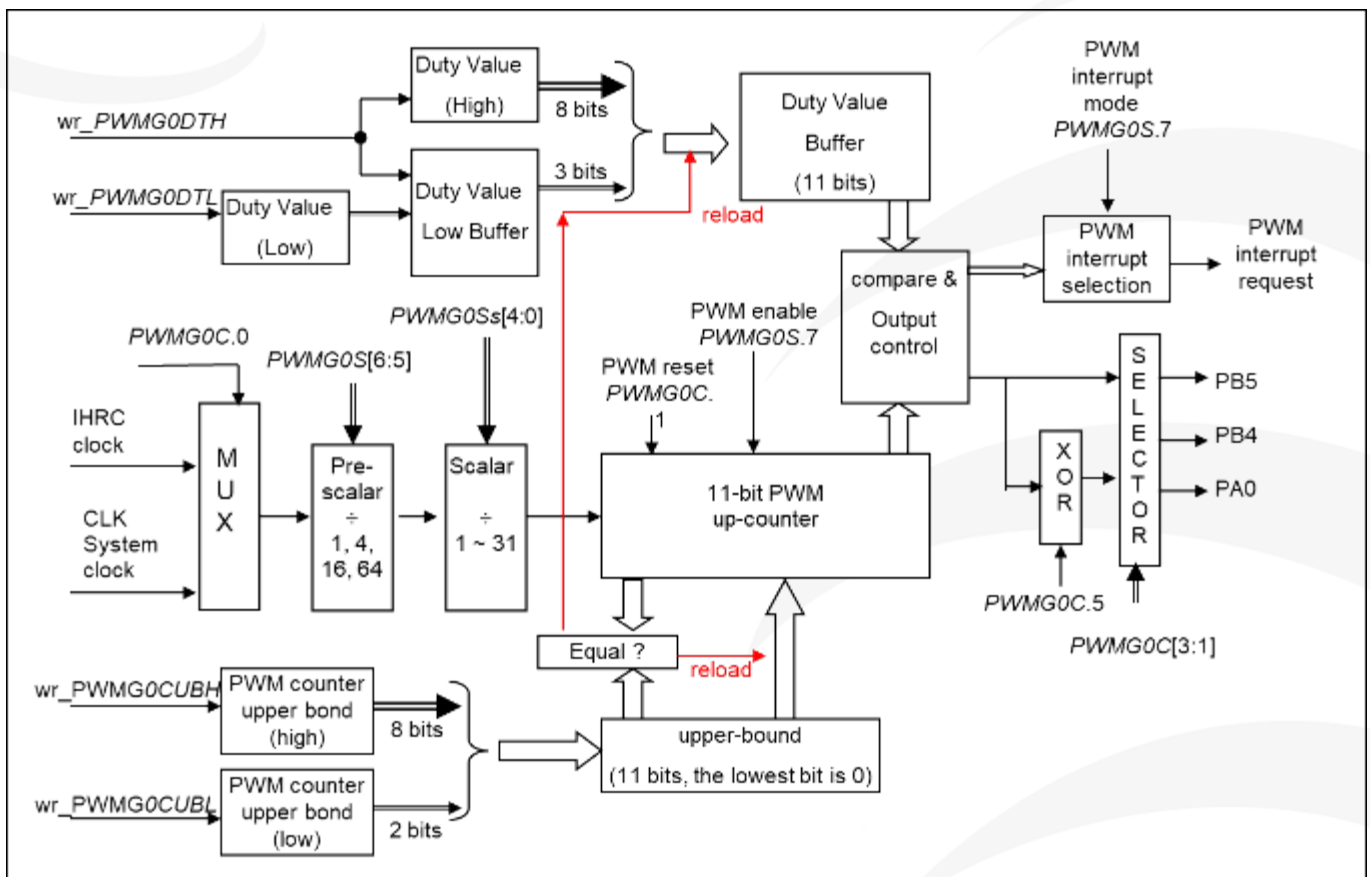


Fig. 20: Hardware Diagram of 11-bit PWM Generator 0 (PWMG0)

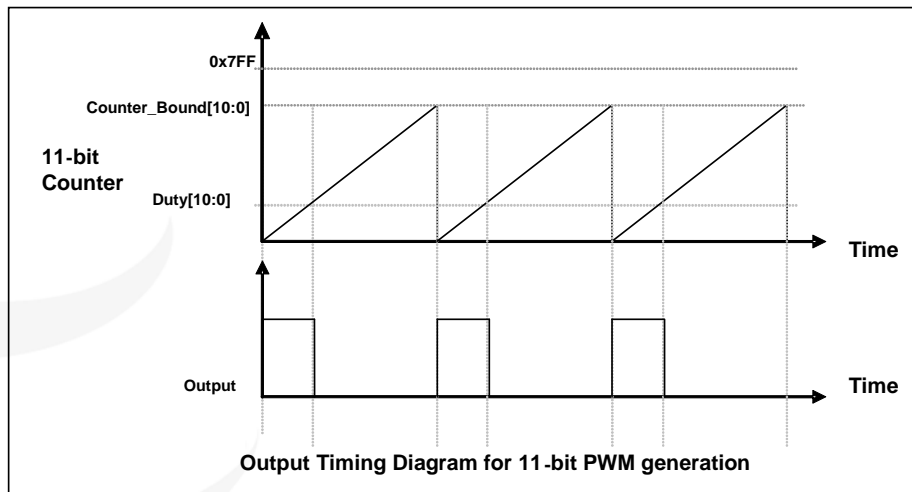


Fig. 21: Output Timing Diagram of 11-bit PWM Generator

10.3.3. Equations for 11-bit PWM Generator

The frequency and duty cycle of 11bit PWM can be obtained from the following formula:

$$\text{PWM Frequency } F_{\text{PWM}} = F_{\text{clock source}} \div [P \times (K + 1) \times (\text{CB10_1} + 1)]$$

$$\text{PWM Duty(in time)} = (1 / F_{\text{PWM}}) \times (\text{DB10_1} + \text{DB0} \times 0.5 + 0.5) \div (\text{CB10_1} + 1)$$

$$\text{PWM Duty(in percentage)} = (\text{DB10_1} + \text{DB0} \times 0.5 + 0.5) \div (\text{CB10_1} + 1) \times 100\%$$

Where,

P = *PWMGxS* [6:5] : pre-scalar (**P** = 1, 4, 16, 64)

K = *PWMGxS* [4:0] : scalar in decimal (**K** =0 ~ 31)

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

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

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

10.3.4. 11bit PWM Related Registers

10.3.4.1. PWMG0 control Register (*PWMG0C*), address = 0x20

Bit	Reset	R/W	Description
7	0	R/W	Enable PWMG0 generator. 0 / 1: disable / enable
6	-	RO	Output status of PWMG0 generator.
5	0	R/W	Enable to inverse the polarity of PWMG0 generator output. 0 / 1: disable / enable.
4	0	R/W	PWMG0 counter reset. Writing "1" to clear PWMG0 counter and this bit will be self clear to 0 after counter reset.
3 – 1	000	R/W	Select PWM output pin for PWMG0. 000: none 001: PB5 011: PA0 100: PB4 Others: reserved
0	0	R/W	Clock source of PWMG0 generator. 0: CLK, 1: IHRC or IHRC*2 (by code option PWM_source)

10.3.4.2. PWMG0 Scalar Register (*PWMG0S*), address = 0x21

Bit	Reset	R/W	Description
7	0	WO	PWMG0 interrupt mode 0: Generate interrupt when counter matches the duty value 1: Generate interrupt when counter is 0
6 – 5	00	WO	PWMG0 clock pre-scalar 00 : ÷1 01 : ÷4 10 : ÷16 11 : ÷64
4 – 0	00000	WO	PWMG0 clock divider

10.3.4.3. PWMG0 Duty Value High Register (*PWMG0DTH*), address = 0x22

Bit	Reset	R/W	Description
7 – 0	-	WO	Duty values bit[10:3] of PWMG0.

10.3.4.4. PWMG0 Duty Value Low Register (*PWMG0DTL*), address = 0x23

Bit	Reset	R/W	Description
7 – 5	-	WO	Duty values bit [2:0] of PWMG0.
4 – 0	-	-	Reserved

Note: It's necessary to write *PWMG0DTL* Register before writing *PWMG0DTH* Register.

10.3.4.5. PWMG0 Counter Upper Bound High Register (*PWMG0CUBH*), address = 0x24

Bit	Reset	R/W	Description
7 – 0	-	WO	Bit[10:3] of PWMG0 counter upper bound.

10.3.4.6. PWMG0 Counter Upper Bound Low Register (*PWMG0CUBL*), address = 0x25

Bit	Reset	R/W	Description
7 – 6	-	WO	Bit[2:1] of PWMG0 counter upper bound.
5	-	WO	Bit[0] of PWMG0 counter upper bound.
4 – 0	-	-	Reserved

10.3.4.7. PWMG1 Control Register (*PWMG1C*), address = 0x26

Bit	Reset	R/W	Description
7	0	R/W	Enable PWMG1. 0 / 1: disable / enable
6	-	RO	Output of PWMG1.
5	0	R/W	Enable to inverse the polarity of PWMG1 output. 0 / 1 : disable / enable.
4	0	R/W	PWMG1 counter reset. Writing “1” to clear PWMG1 counter and this bit will be self clear to 0 after counter reset.
3 – 1	0	R/W	Select PWMG1 output pin. 000: none 001: PB6 011: PA4 100: PB7 Others: reserved
0	0	R/W	Clock source of PWMG1. 0: CLK, 1: IHRC or IHRC*2 (by code option PWM_source)

10.3.4.8. PWMG1 Scalar Register (*PWMG1S*), address = 0x27

Bit	Reset	R/W	Description
7	0	WO	PWMG1 interrupt mode. 0: Generate interrupt when counter matches the duty value 1: Generate interrupt when counter is 0
6 – 5	00	WO	PWMG1 clock pre-scalar. 00 : ÷1 01 : ÷4 10 : ÷16 11 : ÷64
4 – 0	00000	WO	PWMG1 clock divider.

10.3.4.9. PWMG1 Duty Value High Register (*PWMG1DTH*), address = 0x28

Bit	Reset	R/W	Description
7 – 0	0x00	WO	Duty values bit[10:3] of PWMG1.

10.3.4.10. PWMG1 Duty Value Low Register (*PWMG1DTL*), address = 0x29

Bit	Reset	R/W	Description
7 – 5	000	WO	Duty values bit[2:0] of PWMG1.
4 – 0	-	-	Reserved

Note: It's necessary to write *PWMG1DTL* Register before writing *PWMG1DTH* Register.

10.3.4.11. PWMG1 Counter Upper Bound High Register (*PWMG1CUBH*), address = 0x2A

Bit	Reset	R/W	Description
7 – 0	0x00	WO	Bit[10:3] of PWMG1 counter upper bound.

10.3.4.12. PWMG1 Counter Upper Bound Low Register (*PWMG1CUBL*), address = 0x2B

Bit	Reset	R/W	Description
7 – 6	00	WO	Bit[2:1] of PWMG1 counter upper bound.
5	0	WO	Bit[0] of PWMG1 counter upper bound.
4 – 0	-	-	Reserved

10.3.4.13. PWMG2 Control Register (*PWMG2C*), address = 0x2C

Bit	Reset	R/W	Description
7	0	R/W	Enable PWMG2. 0 / 1: disable / enable.
6	-	RO	Output of PWMG2.
5	0	R/W	Enable to inverse the polarity of PWMG2 output. 0 / 1: disable / enable.
4	0	R/W	PWMG2 counter reset. Writing "1" to clear PWMG2 counter and this bit will be self clear to 0 after counter reset.
3 – 1	000	R/W	Select PWMG2 output pin. 000: disable 001: PB3 011: PA3 100: PB2 101: PA5 (ICE does NOT Support.) Others: reserved
0	0	R/W	Clock source of PWMG2. 0: CLK, 1: IHRC or IHRC*2 (by code option PWM_source)

10.3.4.14. PWMG2 Scalar Register (*PWMG2S*), address = 0x2D

Bit	Reset	R/W	Description
7	0	RO	PWMG2 interrupt mode. 0: Generate interrupt when counter matches the duty value 1: Generate interrupt when counter is 0.
6 – 5	00	RO	PWMG2 clock pre-scalar. 00 : ÷1 01 : ÷4 10 : ÷16 11 : ÷64
4 – 0	00000	RO	PWMG2 clock divider.

10.3.4.15. PWMG2 Duty Value High Register (*PWMG2DTH*), address = 0x2E

Bit	Reset	R/W	Description
7 – 0	0x00	WO	Duty values bit[10:3] of PWMG2.

10.3.4.16. PWMG2 Duty Value Low Register (*PWMG2DTL*), address = 0x2F

Bit	Reset	R/W	Description
7 – 5	000	WO	Duty values bit[2:0] of PWMG2.
4 – 0	-	-	Reserved

Note: It's necessary to write *PWMG2DTL* Register before writing *PWMG2DTH* Register.

10.3.4.17. PWMG2 Counter Upper Bound High Register (*PWMG2CUBH*), address = 0x30

Bit	Reset	R/W	Description
7 – 0	0x00	WO	Bit[10:3] of PWMG2 counter upper bound.

10.3.4.18. PWMG2 Counter Upper Bound Low Register (*PWMG2CUBL*), address = 0x31

Bit	Reset	R/W	Description
7 – 6	00	WO	Bit[2:1] of PWMG2 counter upper bound.
5	0	WO	Bit[0] of PWMG2 counter upper bound.
4 – 0	-	-	Reserved

10.3.5. Examples of PWM Waveforms with Complementary Dead Zones

Users can use two 11bit PWM generators to output two complementary PWM waveforms with dead zones. Take PWMG0 output PWM0, PWMG1 output PWM1 as an example, the program reference is as follows.

In addition, Timer2 and Timer3 can also output 8-bit PWM waveforms with complementary dead zones of two bands. The principle is similar to this, and it will not be described in detail.

```

#define dead_zone_R 2           // Control dead-time before rising edge of PWM1
#define dead_zone_F 3           // Control dead-time after falling edge of PWM1

void FPPA0 (void)
{
    .ADJUST_IC    SYSCLK=IHRC/16, IHRC=16MHz, VDD=5V;
    //.....
    Byte duty     = 60;           // Represents the duty cycle of PWM0
    Byte _duty    = 100 - duty; // Represents the duty cycle of PWM1

    //***** Set the counter upper bound and duty cycle *****
    PWMG0DTL     = 0x00;
    PWMG0DTH     = _duty;
    PWMG0CUBL    = 0x00;
    PWMG0CUBH    = 100;

    PWMG1DTL     = 0x00;
    PWMG1DTH     = _duty - dead_zone_F;
    //Use duty cycle to adjust the dead-time after the falling edge of PWM1
    PWMG1CUBL    = 0x00;
    PWMG1CUBH    = 100; // The above values are assigned before enable PWM output

    //***** PWM out control *****
    $ PWMG0C Enable,Inverse,PA0,SYSCLK; // PWMG0 output the PWM0 waveform to PA0
    $ PWMG0S INTR_AT_DUTY,/1,/1;

    .delay dead_zone_R; // Use delay to adjust the dead-time before the rising edge of PWM1

    $ PWMG1C Enable, PA4, SYSCLK; // PWMG1 output the PWM1 waveform to PA4
    $ PWMG1S INTR_AT_DUTY, /1, /1;

    //**** Note: for the output control part of the program, the code sequence can not be moved ****//

    While(1)
        { nop; }
}

```

The PWM0 / PWM1 waveform obtained by the above program is shown in Fig. 22.

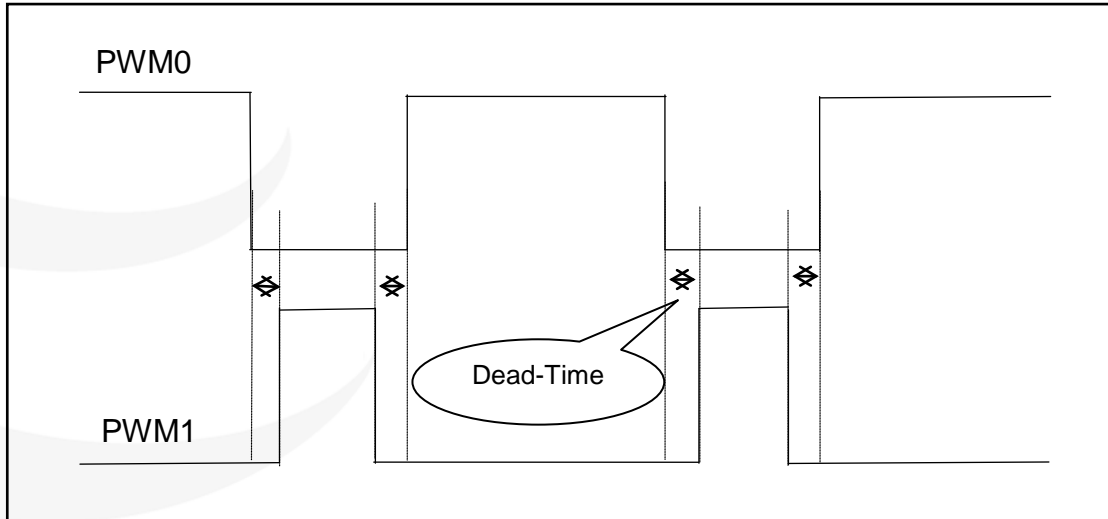


Fig. 22: Two complementary PWM waveforms with dead zones

Users can modify the **dead_zone_R** and **dead_zone_F** values in the program to adjust the dead-time. Table 10 provides data corresponding to different dead-time for users' reference. Where, if dead-time = 4us, then there are dead zones of 4us before and after PWM1 high level.

dead-time (us)	dead_zone_R	dead_zone_F
4 (minimum)	0	2
6	2	3
8	4	4
10	6	5
12	8	6
14	10	7

Table 10: The value of dead-time for reference

Dead_zone_R and **dead_zone_F** need to work together to get an ideal dead-time. If user wants to adjust other dead-time, please note that **dead_zone_R** and **dead_zone_F** need to meet the following criteria:

dead_zone_R	dead_zone_F
1 / 2 / 3	> 1
4 / 5 / 6 / 7	> 2
8 / 9	> 3
...	...

11. Special Functions

11.1. Comparator

One hardware comparator is built inside the PFS252; Fig. 23 shows its hardware diagram. It can compare signals between two input pins. The two signals to be compared, one is the plus input and the other one is the minus input. The plus input pin is selected by register *GPCC.0*, and the minus input pin is selected by *GPCC[3:1]*.

The output result can be:

- (1) read back by *GPCC.6*;
- (2) inversed the polarity by *GPCC.4*;
- (3) sampled by Time2 clock (TM2_CLK) which comes from *GPCC.5*;
- (4) enabled to output to PA0 directly by *GPCS.7*;
- (5) used to request interrupt service.

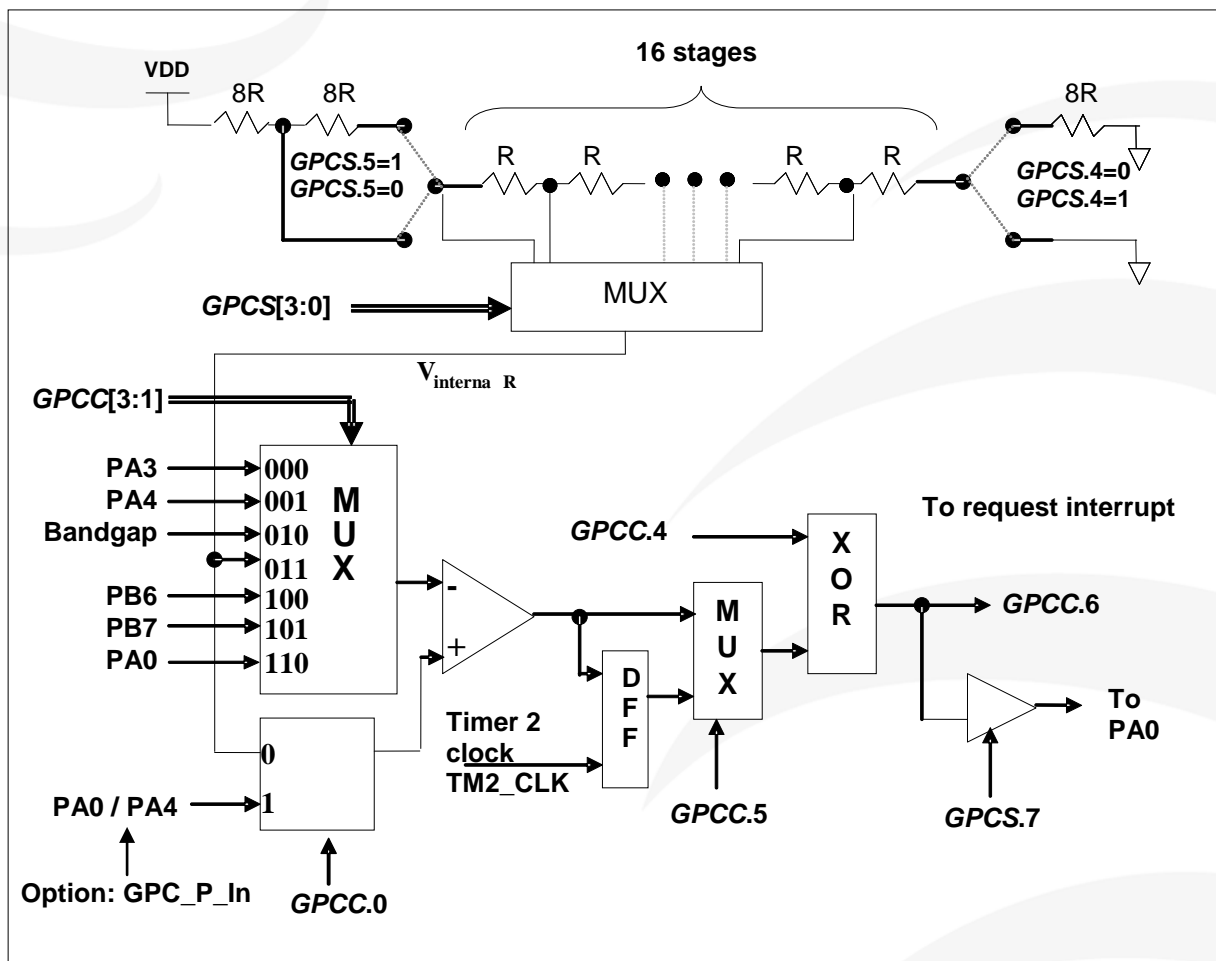


Fig. 23: Hardware diagram of comparator

11.1.1. Comparator Control Register (GPCC), 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 input pins to be digital disable to prevent IO leakage.
6	-	RO	Comparator result. 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: $V_{\text{internal R}}$ 100: PB6 101: PB7 110 : PA0 111: reserved
0	0	R/W	Selection the plus input (+) of comparator. 0 : $V_{\text{internal R}}$ 1 : PA4 or PA0 (by code option GPC_P_In)

11.1.2. Comparator Selection Register (GPCS), address = 0x19

Bit	Reset	R/W	Description
7	0	WO	Comparator output enable (to PA0). 0 / 1 : disable / enable Before setting this bit to enable the comparator, please make sure the OPA is not enabled to prevent signal fighting at PA0.
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)

11.1.3. Internal Reference Voltage ($V_{\text{internal R}}$)

The internal reference voltage $V_{\text{internal R}}$ 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 $V_{\text{internal R}}$ and bit [3:0] of $GPCS$ register are used to select one of the voltage level which is divided-by-16 from the defined maximum level to minimum level. By setting the $GPCS$ register, the internal reference voltage $V_{\text{internal R}}$ can be ranged from $(1/32)*V_{DD}$ to $(3/4)*V_{DD}$.

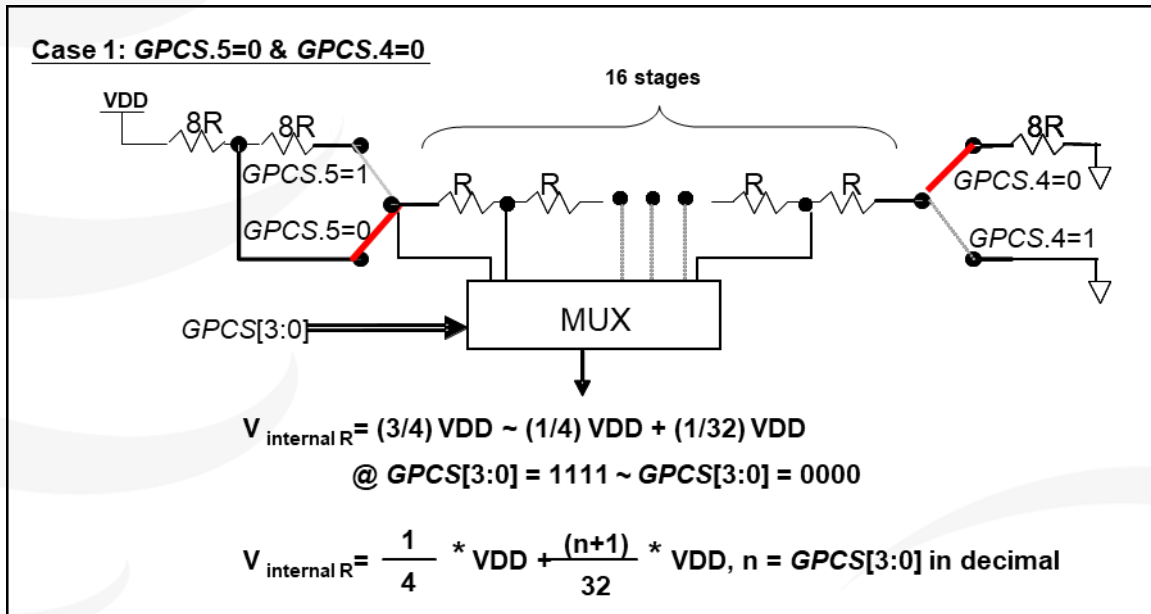


Fig. 24: $V_{\text{internal R}}$ hardware connection if $GPCS.5=0$ and $GPCS.4=0$

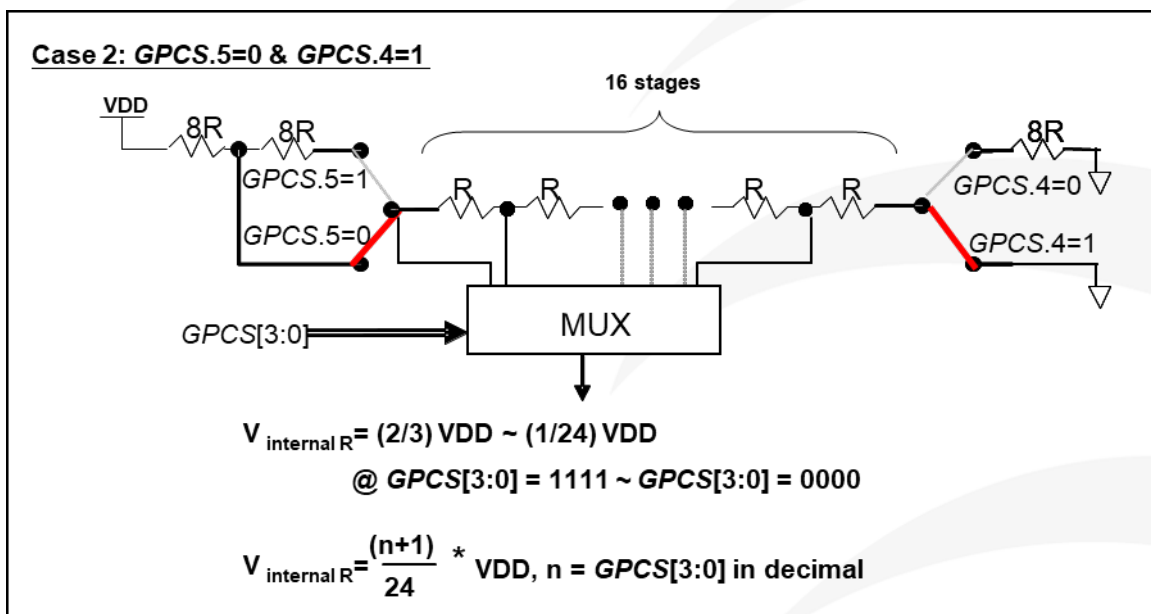


Fig. 25: $V_{\text{internal R}}$ hardware connection if $GPCS.5=0$ and $GPCS.4=1$

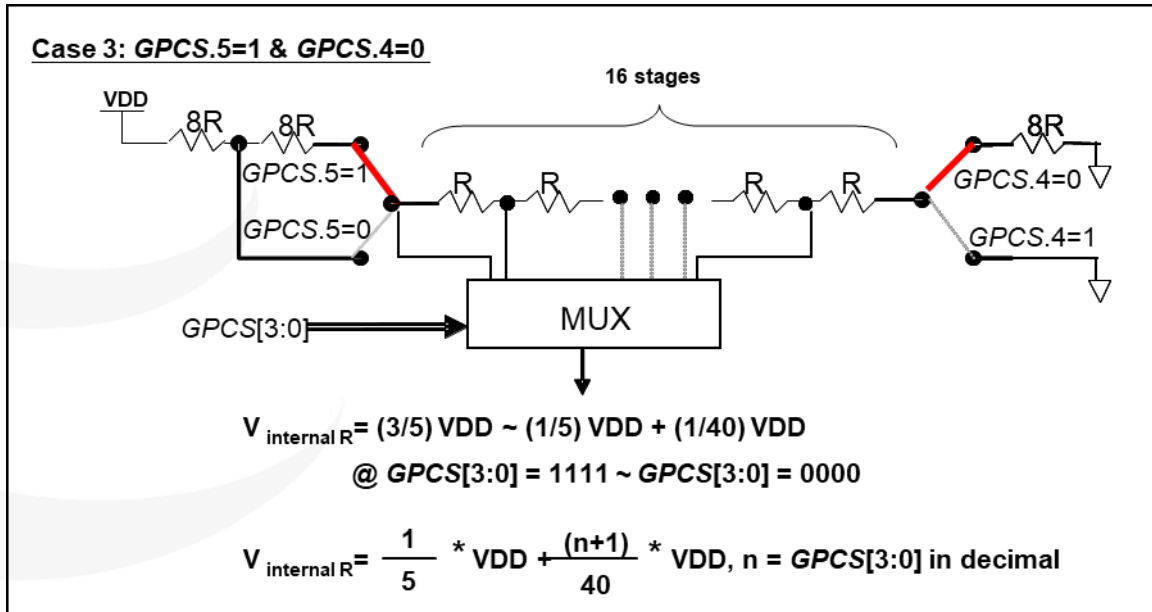


Fig. 26: $V_{internal R}$ hardware connection if $GPCS.5=1$ and $GPCS.4=0$

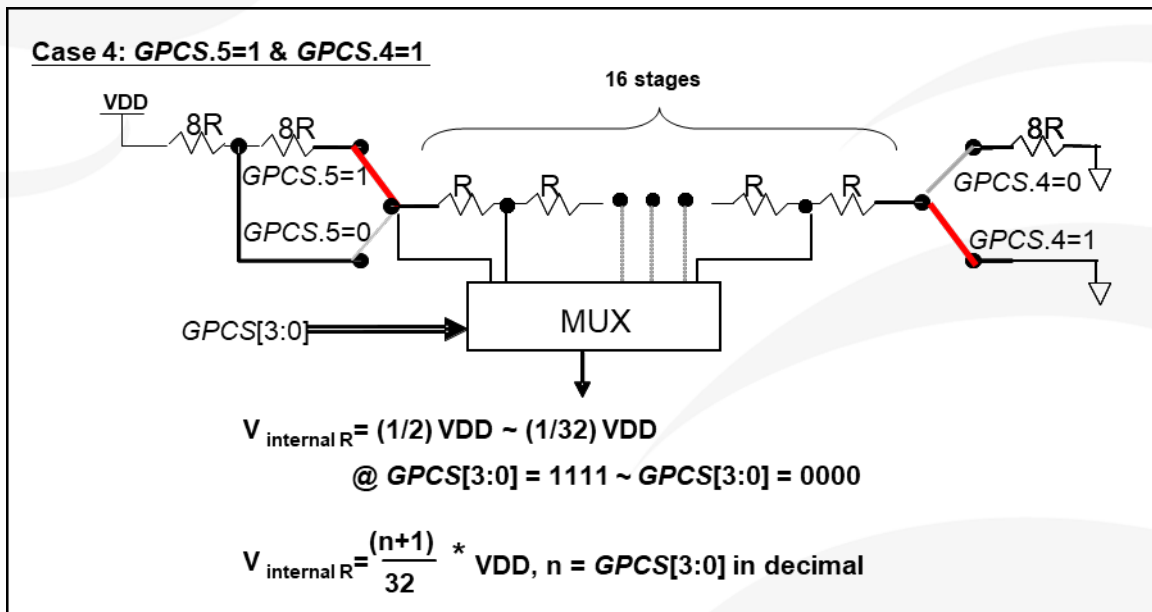


Fig. 27: $V_{internal R}$ hardware connection if $GPCS.5=1$ and $GPCS.4=1$

11.1.4. Using the Comparator

Case 1:

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

```
GPCS = 0b0_0_00_1001; // Vinternal R = VDD*(18/32)
GPCC = 0b1_0_0_0_000_0; // enable comp, - input: PA3, + input: Vinternal R
PADIER = 0bxxxx_0_xxx; // disable PA3 digital input to prevent leakage current
```

or

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

Case 2:

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

```
GPCS = 0b1_0_10_1101; // output to PA0, Vinternal R = VDD*(22/40)
GPCC = 0b1_0_0_1_011_1; // Inverse output, - input: Vinternal R, + input: PA4
PADIER = 0bxxxx_0_xxx; // disable PA4 digital input to prevent leakage current
```

or

```
$ GPCS Output, VDD*22/40;
$ GPCC Enable, Inverse, N_R, P_PA4; // - input: N_R(Vinternal 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.

11.1.5. Using the Comparator and Bandgap 1.20V

The internal Bandgap module provides a stable 1.20V output, and it can be used to measure the external supply voltage level. The Bandgap 1.20V is selected as minus input of comparator and $V_{\text{internal R}}$ is selected as plus input, the supply voltage of $V_{\text{internal R}}$ is VDD, the VDD voltage level can be detected by adjusting the voltage level of $V_{\text{internal R}}$ to compare with Bandgap.

If N ($GPCS[3:0]$ in decimal) is the number to let $V_{\text{internal R}}$ closest to Bandgap 1.20 volt, the supply voltage VDD can be calculated by using the following equations:

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

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

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

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

Case 1:

```

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

```

11.2. VDD/2 Bias Voltage Generator

The five pins of PFS252: PA0, PA3, PA4, PB0 and PB3, can generate VDD/2 as the COM function when driving the LCD display. This function can be enabled by setting the register *MISC.4* as 1.

MISC Register (<i>MISC</i>), address = 0x1F			
Bit	Reset	R/W	Description
7 – 5	-	-	Reserved. (keep 0 for future compatibility)
4	0	WO	Enable VDD/2 bias voltage generator 0 / 1 : Disable / Enable (ICE cannot be dynamically switched)
3	-	-	Reserved.
2	0	WO	Disable LVR function. 0 / 1 : Enable / Disable
1 – 0	00	WO	Watch dog time out period

The COM port can generate VDD/2 by switching it to input mode (*PAC.x / PBC.x=0*). However, keep in mind to turn off the pull-high / pull-low resistor (*PxPH.x / PxPL.x=0*) and digital input from *PADIER.x / PBDIER.x* register to prevent the output voltage level from disturbing. Fig.28 shows how to use this function.

The output function of COM port is the same as other normal IO.

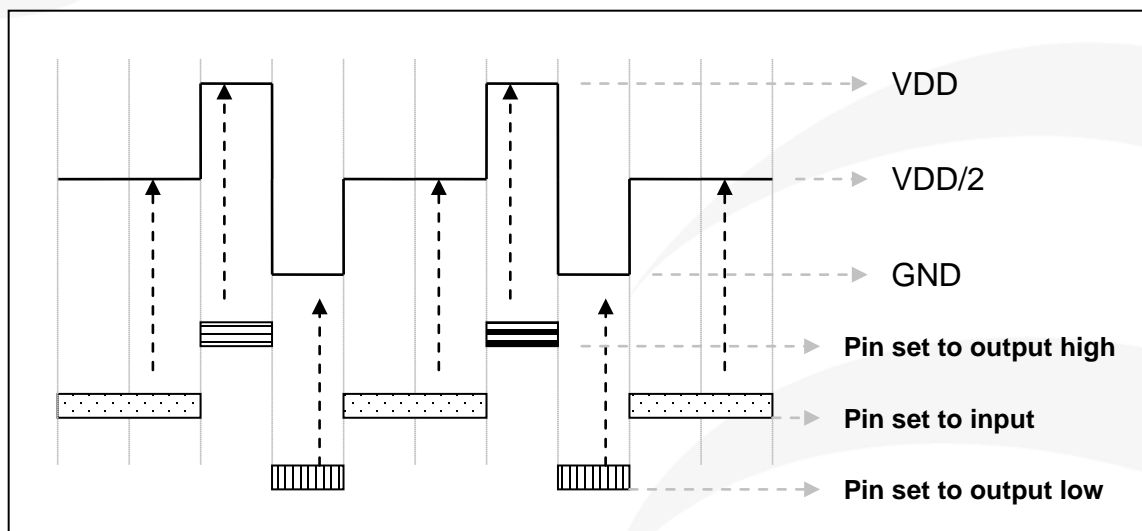


Fig. 28: Using VDD/2 bias voltage generator

Note: ICE does NOT support VDD/2 function of PB3.

11.3. Operational Amplifier (OPA) module

An Operational Amplifier (OPA) is built-in in the PFS252, the basic configuration is shown in the following diagram. There are 2 different configurations, one is called OPA Comparator mode and the other is Amplifier mode.

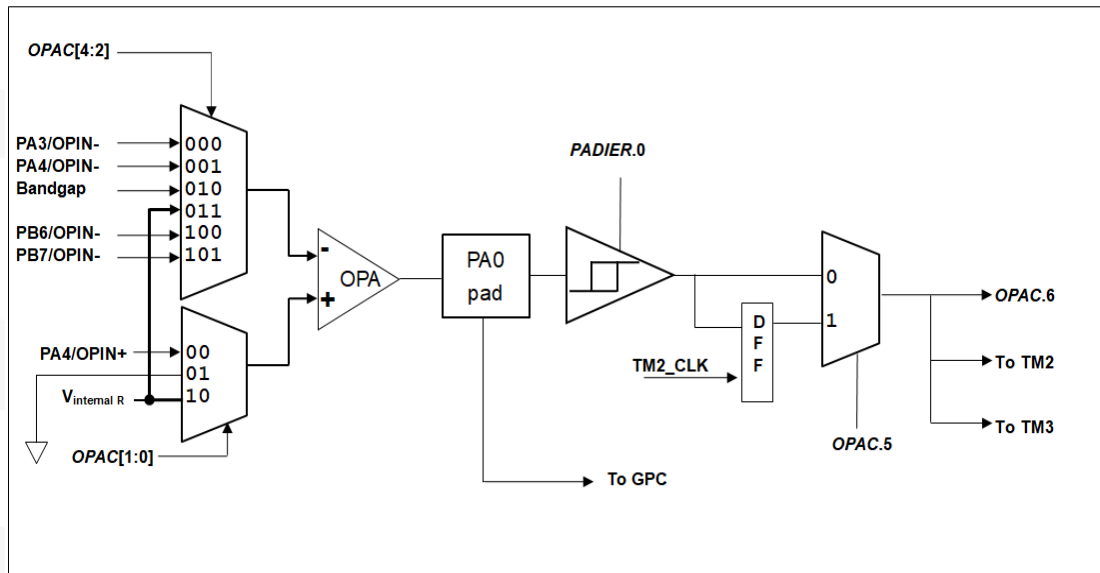


Fig.29: Hardware diagram of OPA

When user turns on the OPA by enabling the *OPAC.7*, the IO port PA0 turns to be the output of OPA. User can measure the analog PA0 voltage by GPC in Amplifier mode, or read the digital OPA compare result from PA0 directly in Comparator mode.

Note: ICE does NOT support OPA.

11.3.1. OPA Comparator Mode

The open-loop configuration shown in the above diagram is called OPA Comparator mode. There is no feedback path between input and output (PA0) of OPA. In this mode, user can enable *PADIER.0* to read the compare result from *OPAC.6*.

Like the comparator (GPC), the compare result of OPA can also be the counting source of TM2 or TM3. Also like GPC, the OPA compare result can also be used to control generated PWM waveform by enable code option *OPA_PWM*.

Moreover, user can select the internal reference voltage $V_{\text{internal R}}$ which generated in GPC as one of the plus or minus input of OPA as the compare reference voltage.

11.3.2. OPA Amplifier Mode

Another configuration is called Amplifier mode, which needs some external components to make a feedback amplifier. When it is configured as a feedback amplifier, PA0 becomes an analog output pad. Always keep in mind to disable *PADIER.0* to prevent it from current leakage.

PA0 can be selected as the input of comparator (GPC), therefore the output voltage of OPA can be compared by GPC.

11.3.3. OPA Control Register (*OPAC*), address = 0x1A

Bit	Reset	R/W	Description
7	0	R/W	Enable OPA. 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. Please note PA0 will be assigned to the output of OPA when it is enabled.
6	-	RO	Compare result of OPA in Comparator mode. 0: plus input < minus input 1: plus input > minus input
5	0	R/W	Select whether the compare result of OPA output is sampled by TM2_CLK? 0: result output NOT sampled by TM2_CLK 1: result output sampled by TM2_CLK
4 - 2	000	R/W	Selection the minus input (-) of OPA. 000 : PA3 001 : PA4 010 : Internal 1.20 volt Bandgap reference voltage 011 : $V_{\text{internal R}}$ 100 : PB6 101 : PB7 11X: reserved
1-0	00	R/W	Selection the plus input (+) of OPA. 00 : PA4 01 : GND 10 : $V_{\text{internal R}}$ from the comparator (refer to <i>GPCS</i> register) 11 : reserved

11.3.4. OPA Offset Register (*OPAofs*), address = 0x07

Bit	Reset	R/W	Description
7 - 4	-	-	Reserved
3 - 0	0000	R/W	Select the offset level of OPA. 0000 : +1mV 0001 : +2mV 0010 : +5mV 0011 : +10mV 0100 : +15mV 0101 : +20mV 0110 : +25mV 0111 : +30mV 1000 : -1mV 1001 : -2mV 1010 : -5mV 1011 : -10mV 1100 : -15mV 1101 : -20mV 1110 : -25mV 1111 : -30mV

11.4. Multiplier

There is an 8x8 multiplier on-chip to enhance hardware capability in arithmetic function, its multiplication is an 8 x 8 unsigned operation and can be finished in one clock cycle. Before issuing the *mul* command, both multiplicand and multiplier must be put on *ACC* and register *MULOP* (0x08); After *mul* command, the high byte result will be put on register *MULRH* (0x09) and low byte result on *ACC*. The hardware diagram of this multiplier is shown as Fig.31.

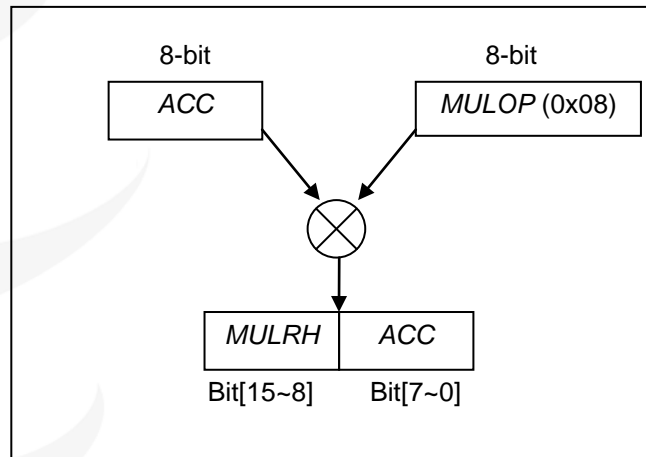


Fig.31: Block diagram of hardware multiplier

11.4.1. Multiplier Operand Register (*MULOP*), address = 0x08

Bit	Reset	R/W	Description
7 - 0	-	R/W	Operand for hardware multiplication operation.

11.4.2. Multiplier Result High Byte Register (*MULRH*), address = 0x09

Bit	Reset	R/W	Description
7 - 0	-	RO	High byte result of multiplication operation (read only).

12. Notes for Emulation

It is recommended to use PDK5S-I-S01/2(B) for emulation of PFS252. Please notice the following items while simulating:

- (1) PDK5S-I-S01/2(B) is a single-core emulator, so it can only simulate the prime core (FPPA0) function, and does NOT support the multi-core simulation.
- (2) PDK5S-I-S01/2(B) doesn't support the instruction *nadd, comp*.
- (3) PDK5S-I-S01/2(B) doesn't support $SYSCCLK=ILRC/16$.
- (4) PDK5S-I-S01/2(B) doesn't support the function *TM2C.GPCRS/TM3C.GPCRS*.
- (5) PDK5S-I-S01/2(B) doesn't support the OPA.
- (6) PDK5S-I-S01/2(B) doesn't support the function *PAPL/PBPL*.
- (7) PDK5S-I-S01/2(B) doesn't support the function *GPCC.P_PA0*.
- (8) PDK5S-I-S01/2(B) doesn't support the dynamic setting of function *MISC.4* (Only fix to 0 or 1).
- (9) PDK5S-I-S01/2(B) doesn't support the function *PWMG2C.PA5*.
- (10) PDK5S-I-S01/2(B) doesn't support the code options: *PB4_PB7_Drive, GPC_P_In, OPA_PWM, GPC_PWM, PWM_Source, TMx_Source* and *TMx_bit*.
- (11) The ILRC frequency of the PDK5S-I-S01/2(B) simulator is different from the actual IC and is uncalibrated, with a frequency range of about 34K~38KHz.
- (12) PDK5S-I-S01/2(B) doesn't support VDD/2 function of PB3.
- (13) The PA3 output function will be affected when *GPCS* selects output to PA0 output.
- (14) Fast Wakeup time is different from PDK5S-I-S01/2(B): 128 SYSCCLK, PFS252: 45 ILRC
- (15) Watch dog time out period is different from PDK5S-I-S01/2(B):

WDT period	PDK5S-I-S01/2(B)	PFS252
<i>MISC</i> [1:0]=00	2048 * T_{ILRC}	8192 * T_{ILRC}
<i>MISC</i> [1:0]=01	4096 * T_{ILRC}	16384 * T_{ILRC}
<i>MISC</i> [1:0]=10	16384 * T_{ILRC}	65536 * T_{ILRC}
<i>MISC</i> [1:0]=11	256 * T_{ILRC}	262144 * T_{ILRC}

13. Program Writing

Please use PDK5S-P-003 to program. PDK3S-P-002 or older versions do not support programming PFS252.

Jumper connection: Please follow the instruction inside the writer software to connect the jumper.

Please select the following program mode according to the actual situation.

13.1. Normal Programming Mode

Range of application:

- Single-Chip-Package IC with programming at the writer IC socket or on the handler.
- Multi-Chip-Package(MCP) with PFS252. Be sure its connected IC and devices will not be damaged by the following voltages, and will not clam the following voltages.

The voltage conditions in normal programming mode:

- (1) VDD is 7.5V, and the maximum supply current is up to about 20mA.
- (2) PA5 is 5.5V.
- (3) The voltages of other program pins (except GND) are the same as VDD.

Important Cautions:

- You MUST follow the instructions on APN004 and APN011 for programming IC on the handler.
- Connecting a 0.01uF capacitor between VDD 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 mode may be fail.

13.2. Limited-Voltage Programming Mode

Range of application:

- On-Board writing. Its peripheral circuits and devices will not be damaged by the following voltages, and will not clam the following voltages. Please refer to Chapter 13.3 for more details about On-Board Writing.
- Multi-Chip-Package(MCP) with PFS252. Please be sure that its connected IC and devices will not be damaged by the following voltages, and will not clam the following voltages.

The voltage conditions in Limited-Voltage programming mode:

- (1) VDD is 5.0V, and the maximum supply current is up to about 20mA.
- (2) PA5 is 5.0V.
- (3) The voltage of other program pins (except GND) is the same as VDD.

Please select "MTP On-Board VDD Limitation" or "On-Board Program" on the writer screen to enable the limited-voltage programming mode. (Please refer to the file of Writer "PDK5S-P-003 UM").

13.3. On-Board Writing

PFS252 can support On-board writing. On-Board Writing is known as the situation that the IC have to be programmed when the IC itself and other peripheral circuits and devices have already been mounted on the PCB. Five wires of PDK5S-P-003 are used for On-Board Writing: ICPCCK, ICPDA, VDD, GND and ICPVPP. They are used to connect PA3, PA6, VDD, GND and PA5 of the IC correspondingly.

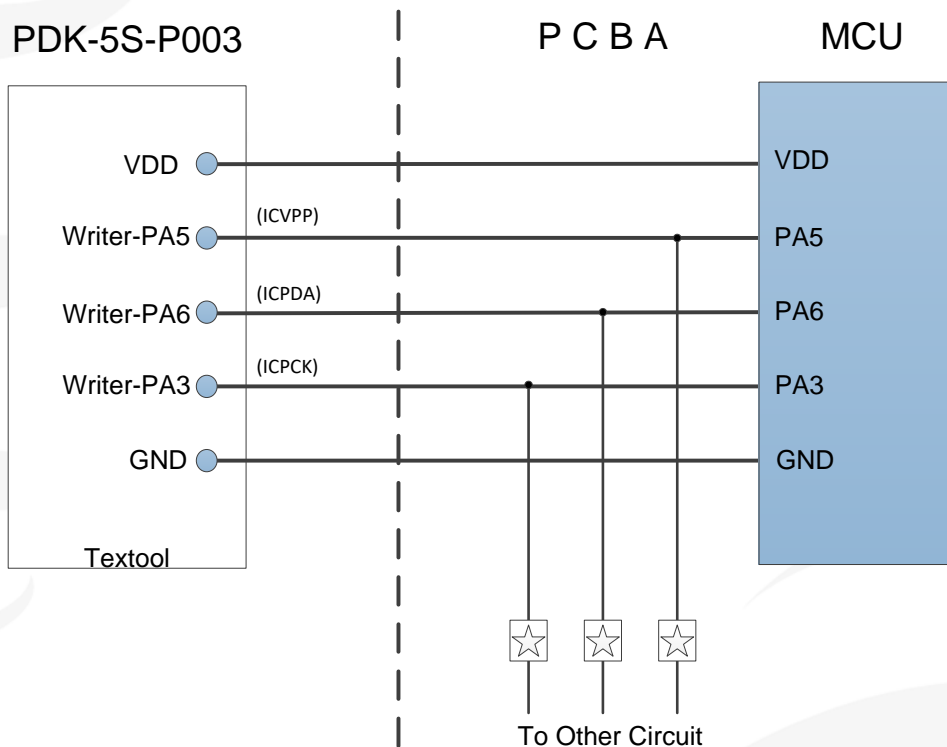


Fig. 32: Schematic Diagram of On-Board Wiring

The symbol ☆ on Fig. 32 can be either resistors or capacitors. They are used to isolate the programming signal wires from the peripheral circuit. it should be $\geq 10K \Omega$ for resistance while $\leq 220pF$ for capacitance.

Notice:

- In general, the limited-voltage programming mode is used in On-board Writing, Please refers to the 13.2 for more detail about limited-voltage programming mode.
- Any zener diode $\leq 5.0V$, or any circuitry which clam the 5.0V to be created SHOULD NOT be connected between VDD and GND of the PCB.
- Any capacitor $\geq 500uF$ SHOULD NOT be connected between VDD and GND of the PCB.
- In general, the writing signal pins PA3, PA5 and PA6 SHOULD NOT be considered as strong output pins.

14. Device Characteristics

14.1. Absolute Maximum Ratings

Name	Min	Typ.	Max	Unit	Notes
Supply Voltage (VDD)	2.2		5.5	V	Exceed the maximum rating may cause permanent damage !!
Input Voltage	-0.3		V _{DD} + 0.3	V	
Operating Temperature	-40		85	°C	
Storage Temperature	-50		125	°C	
Junction Temperature		150		°C	

14.2. DC/AC Characteristics

All data are acquired under the conditions of V_{DD}=5.0V, f_{SYS} =2MHz unless noted.

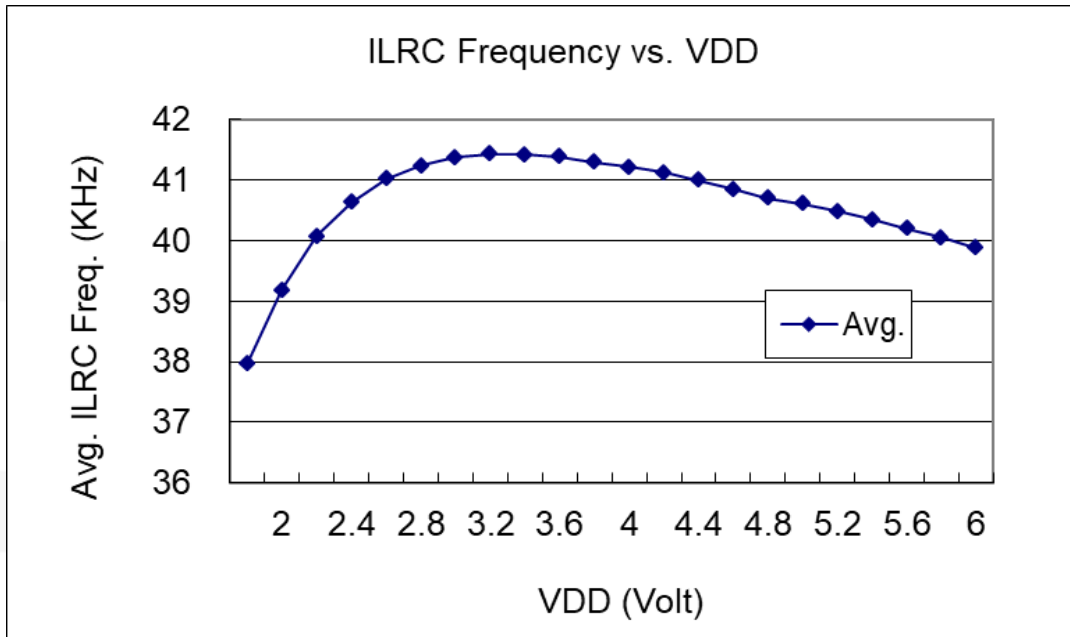
Symbol	Description	Min	Typ	Max	Unit	Conditions (Ta=25°C)
V _{DD}	Operating Voltage	2.2	5.0	5.5	V	* Subject to LVR tolerance
LVR%	Low Voltage Reset Tolerance	-5		5	%	
f _{SYS}	System clock (CLK)* = IHRC/2 IHRC/4 IHRC/8 ILRC	0 0 0	 44K	8M 4M 2M	Hz	V _{DD} ≥ 3.75V V _{DD} ≥ 2.5V V _{DD} ≥ 2.2V V _{DD} =5V
P _{cycle}	Program cycle	1000			cycles	
I _{OP}	Operating Current		1 65		mA uA	f _{SYS} =IHRC/16=1MIPS@5V f _{SYS} =ILRC=44KHz@5V
I _{PD}	Power Down Current (by <i>stopsys</i> command)		1		uA	f _{SYS} = 0Hz, V _{DD} =5V
I _{PS}	Power Save Current (by <i>stopexe</i> command)		3		uA	V _{DD} =5V; f _{SYS} = ILRC Only ILRC module is enabled.
V _{IL}	Input low voltage for IO lines	0		0.1 V _{DD}	V	
V _{IH}	Input high voltage for IO lines	0.7 V _{DD}		V _{DD}	V	
I _{OL}	IO lines sink current PA0, PA3, PA4, PB2 PA5, PA6, PA7, PB0, PB1, PB3, PB5, PB6 PB4, PB7 (Strong) PB4, PB7 (Normal)		23 17 23 37 23		mA	V _{DD} =5V, V _{OL} =0.5V
I _{OH}	IO lines drive current PB4, PB7 (Strong) PB4, PB7 (Normal) Others IO		-26 -10 -10		mA	V _{DD} =5V, V _{OH} =4.5V
V _{IN}	Input voltage	-0.3		V _{DD} +0.3	V	
I _{INJ} (PIN)	Injected current on pin		1		uA	V _{DD} +0.3 ≥ V _{IN} ≥ -0.3

Symbol	Description	Min	Typ	Max	Unit	Conditions (Ta=25°C)
R _{PH}	Pull-high Resistance		82		KΩ	V _{DD} =5V
R _{PL}	Pull-low Resistance		82		KΩ	V _{DD} =5V
V _{BG}	Bandgap Reference Voltage	1.145*	1.20*	1.255*	V	V _{DD} =2.2V ~ 5.5V -40°C < Ta < 85°C*
f _{IHRC}	Frequency of IHRC after calibration *	15.84*	16*	16.16*	MHz	V _{DD} =5V, Ta=25 °C
		15.20*	16*	16.80*		V _{DD} =2.2V~5.5V, -40 °C <Ta<85 °C *
t _{INT}	Interrupt pulse width	30			ns	V _{DD} = 5V
V _{DR}	RAM data retention voltage*	1.5			V	in power-down 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 normal wake-up		3000			
t _{SBP}	System boot-up period from power-on		72		ms	V _{DD} =5V
t _{RST}	External reset pulse width	120			us	V _{DD} =5V
CP _{os}	Comparator offset*	-	±10	±20	mV	
CP _{cm}	Comparator input common mode*	0		V _{DD} -1.5	V	
CP _{spt}	Comparator response time**		100	500	ns	Both Rising and Falling
CP _{mc}	Stable time to change comparator mode		2.5	7.5	us	
CP _{cs}	Comparator current consumption		20		uA	V _{DD} = 3.3V
OPA _{cm}	OPA input common mode*	0		V _{DD} -1.3	V	
OPA _{os}	OPA offset*		±10		mV	V _{DD} =5V
I _{OPA}	OPA output current*	200			uA	
OPA _{gain}	OPA DC gain*		80		dB	

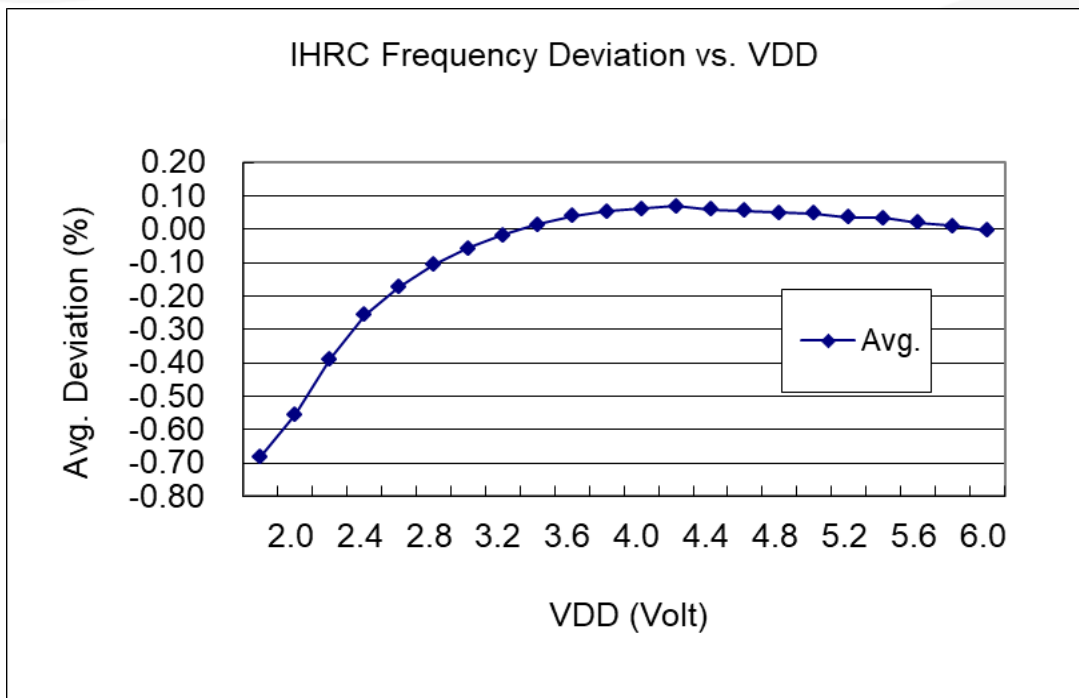
*These parameters are for design reference, not tested for every chip.

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.

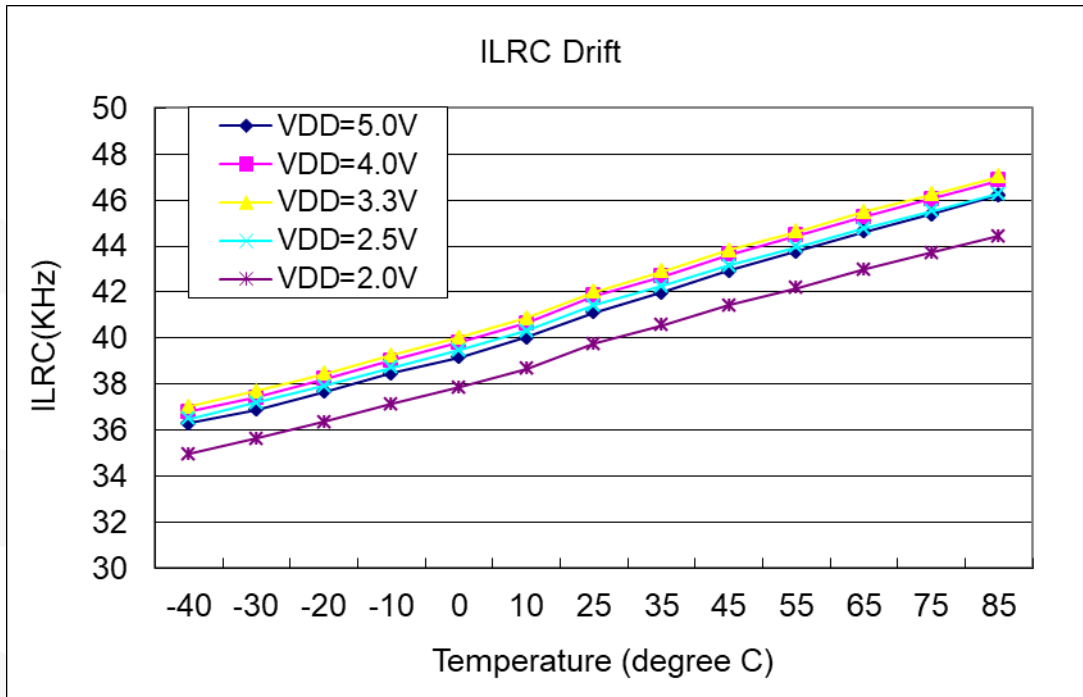
14.3. Typical ILRC frequency vs. VDD



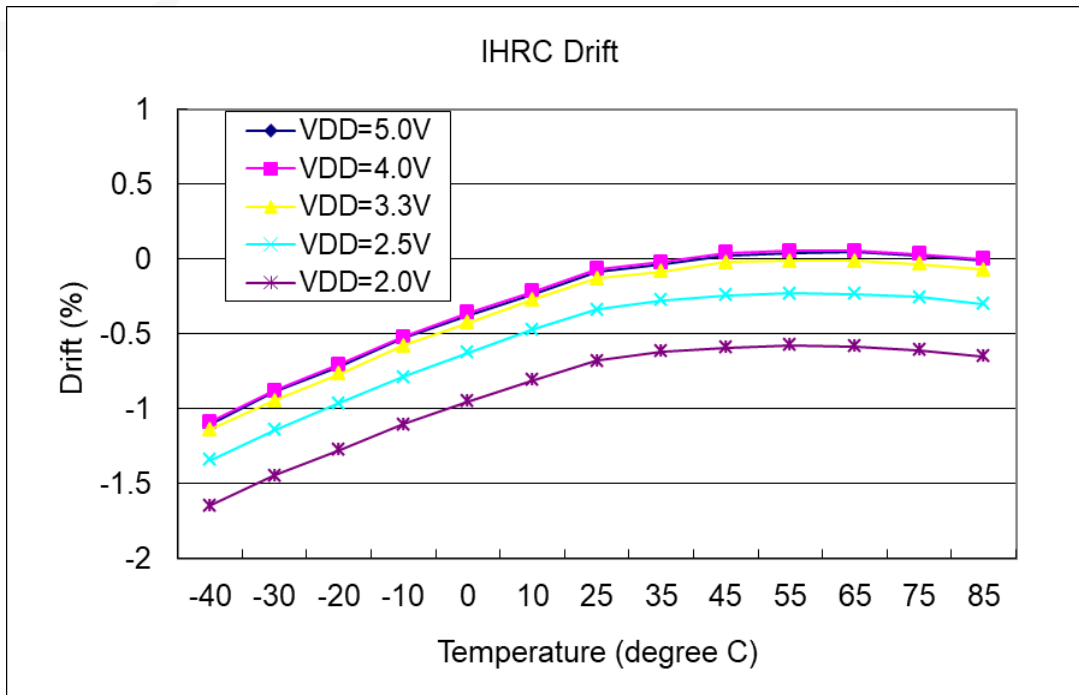
14.4. Typical IHRC frequency deviation vs. VDD(calibrated to 16MHz)



14.5. Typical ILRC Frequency vs. Temperature



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



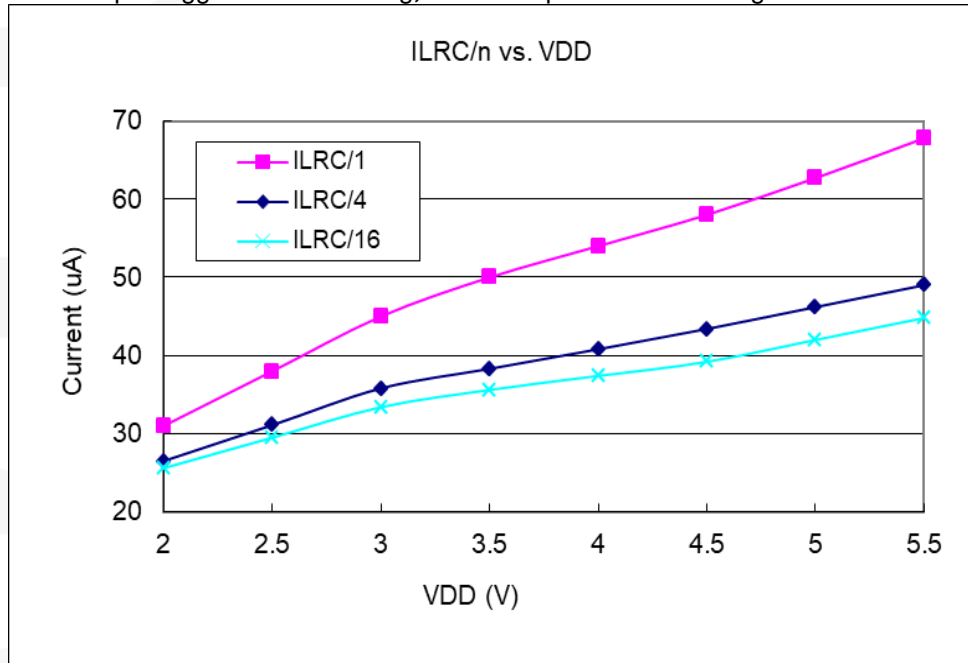
14.7. Typical operating current vs. VDD @ system clock = ILRC/n

Conditions:

2-FPPA (FPPA0: tog PA0, FPPA1: idle)

ON: ILRC, Bandgap, LVR; **OFF:** IHRC, EOSC, T16, TM2, TM3;

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



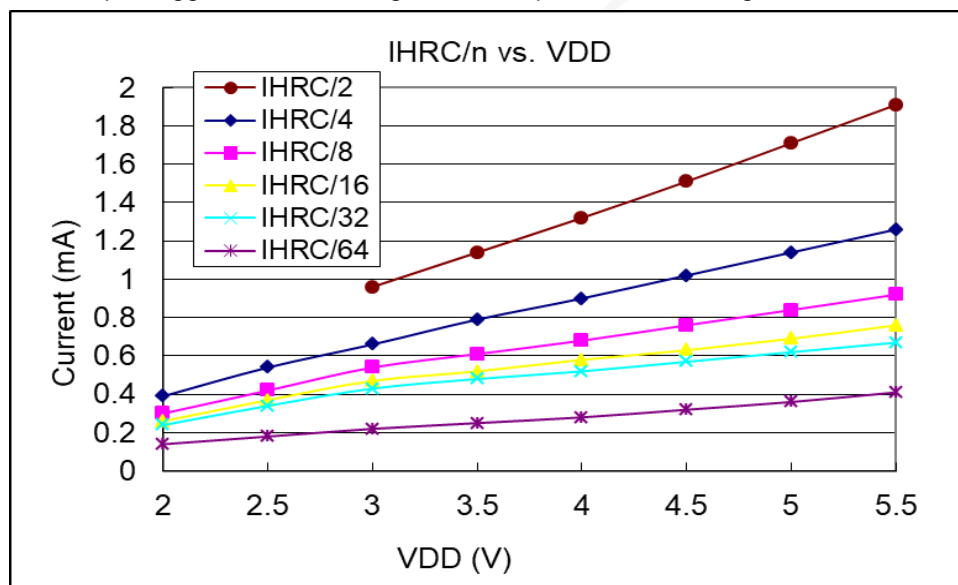
14.8. Typical operating current vs. VDD @ system clock = IHRC/n

Conditions:

2-FPPA (FPPA0: tog PA0, FPPA1: idle)

ON: Bandgap, LVR, IHRC; **OFF:** ILRC, EOSC, LVR, T16, TM2, TM3;

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

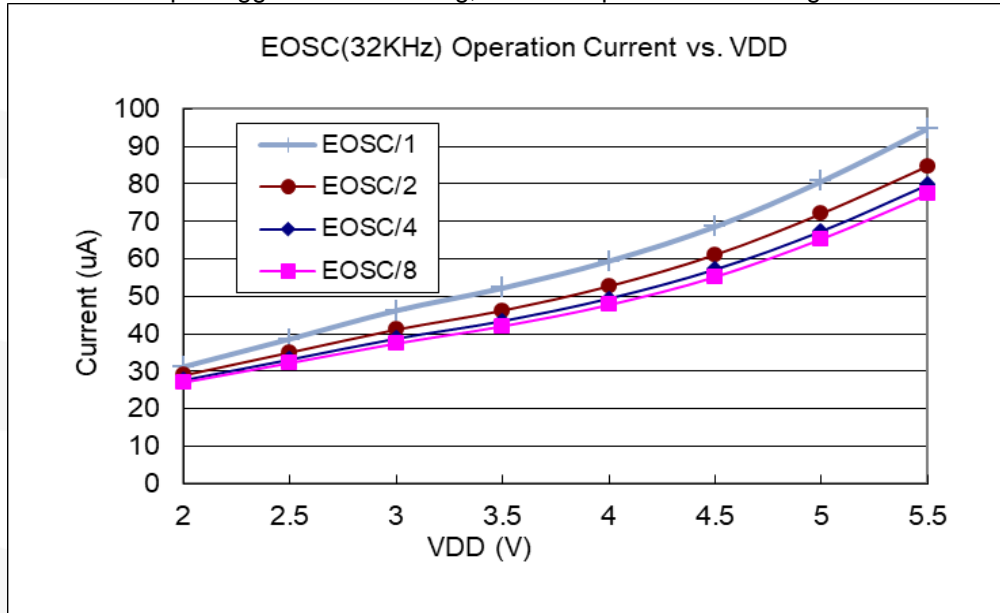


14.9. Typical operating current vs. VDD @ system clock = 32KHz EOSC / n

Conditions:

ON: EOSC, MISC.6 = 1, Bandgap, LVR; **OFF:** IHRC, ILRC, T16, TM2, TM3;

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

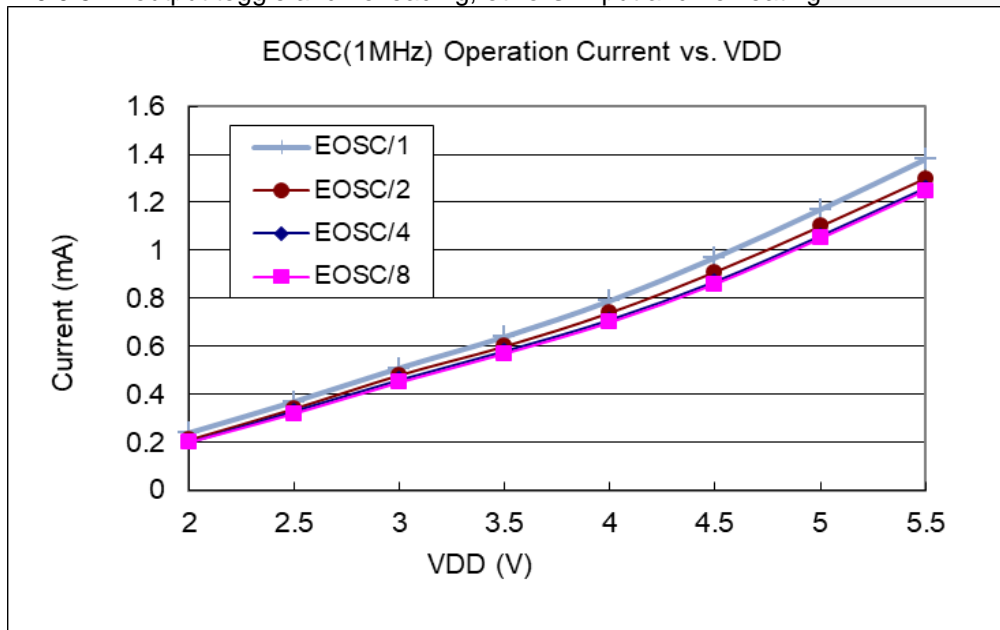


14.10. Typical operating current vs. VDD @ system clock = 1MHz EOSC / n

Conditions:

ON: EOSC, MISC.6 = 1, Bandgap, LVR; **OFF:** IHRC, ILRC, T16, TM2, TM3;

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

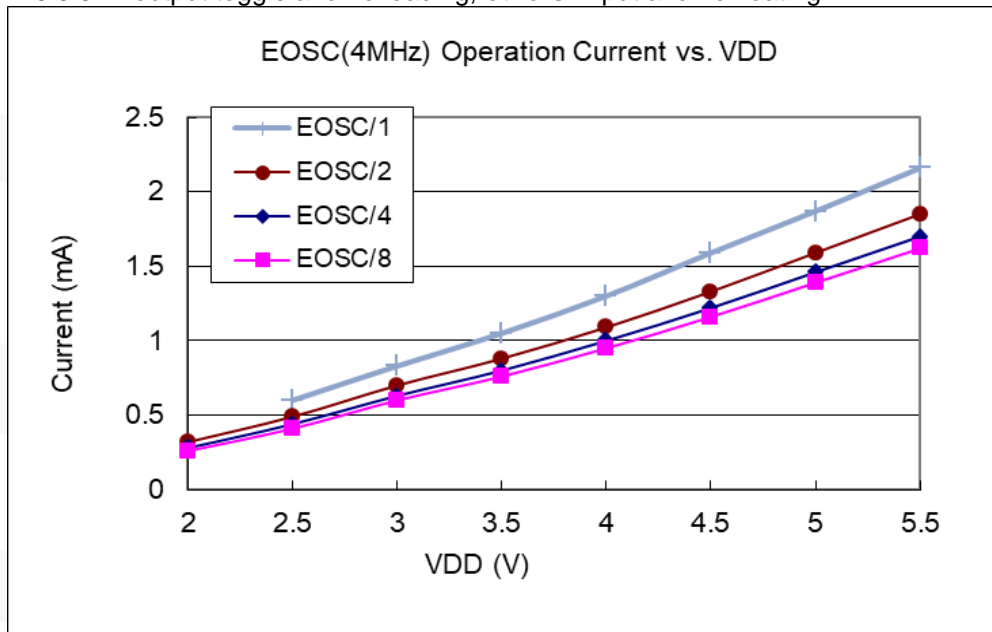


14.11. Typical operating current vs. VDD @ system clock = 4MHz EOSC / n

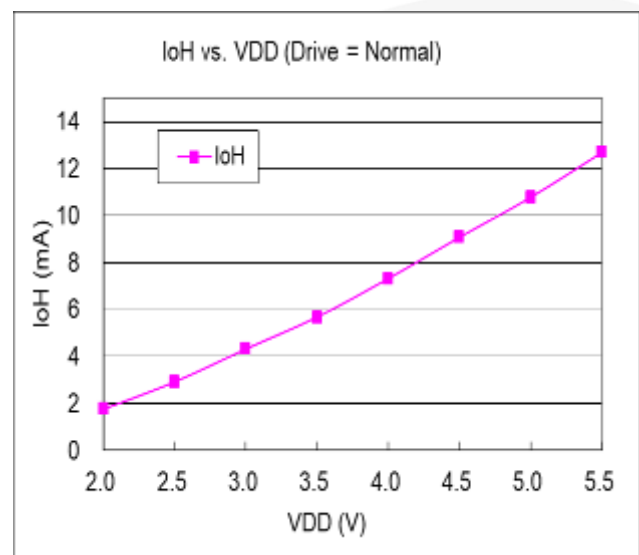
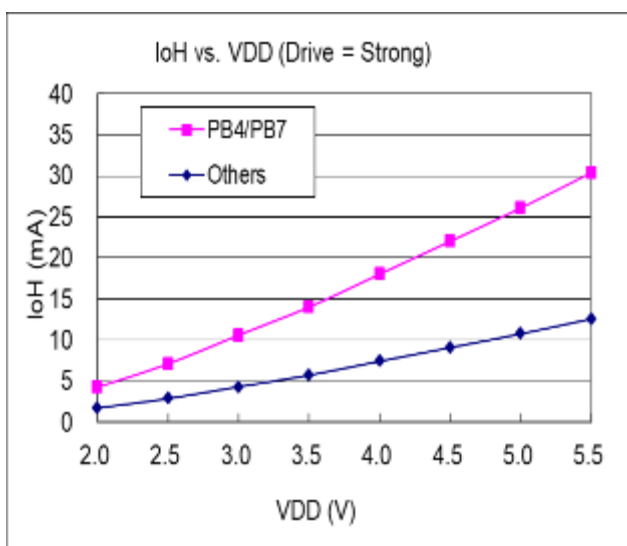
Conditions:

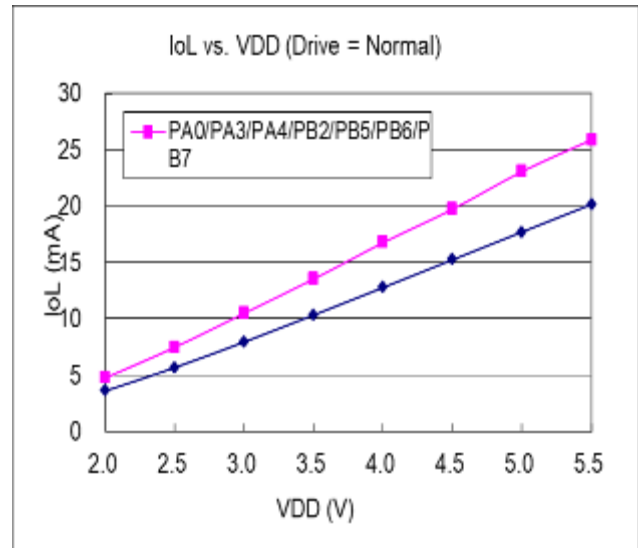
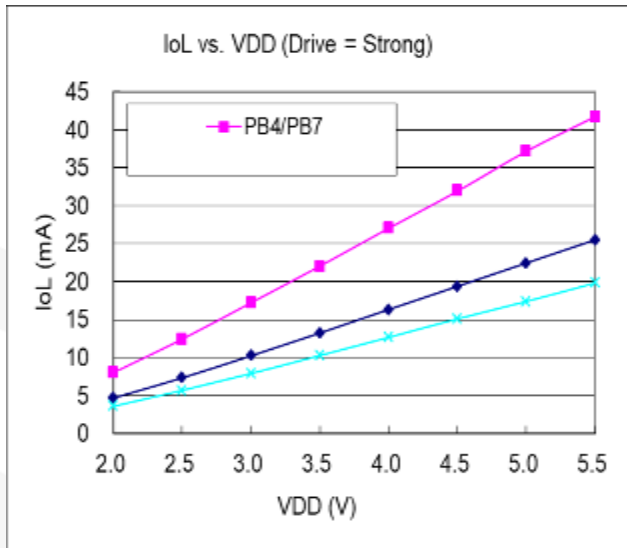
ON: EOSC, MISC.6 = 1, Bandgap, LVR; **OFF:** IHRC, ILRC, T16, TM2, TM3;

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

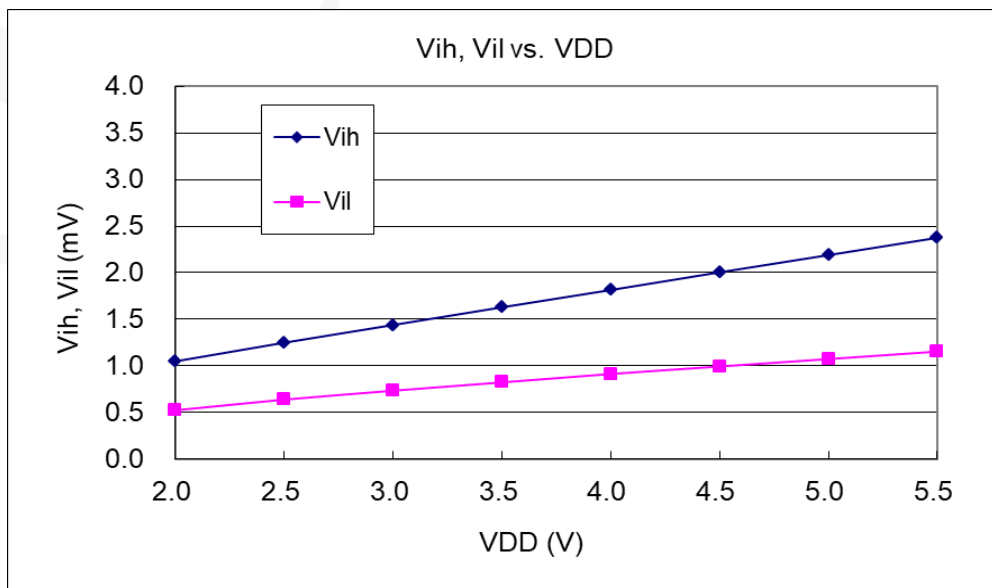


14.12. Typical IO driving current (I_{OH}) and sink current (I_{OL}) ($V_{OH}=0.9 \cdot V_{DD}$, $V_{OL}=0.1 \cdot V_{DD}$)

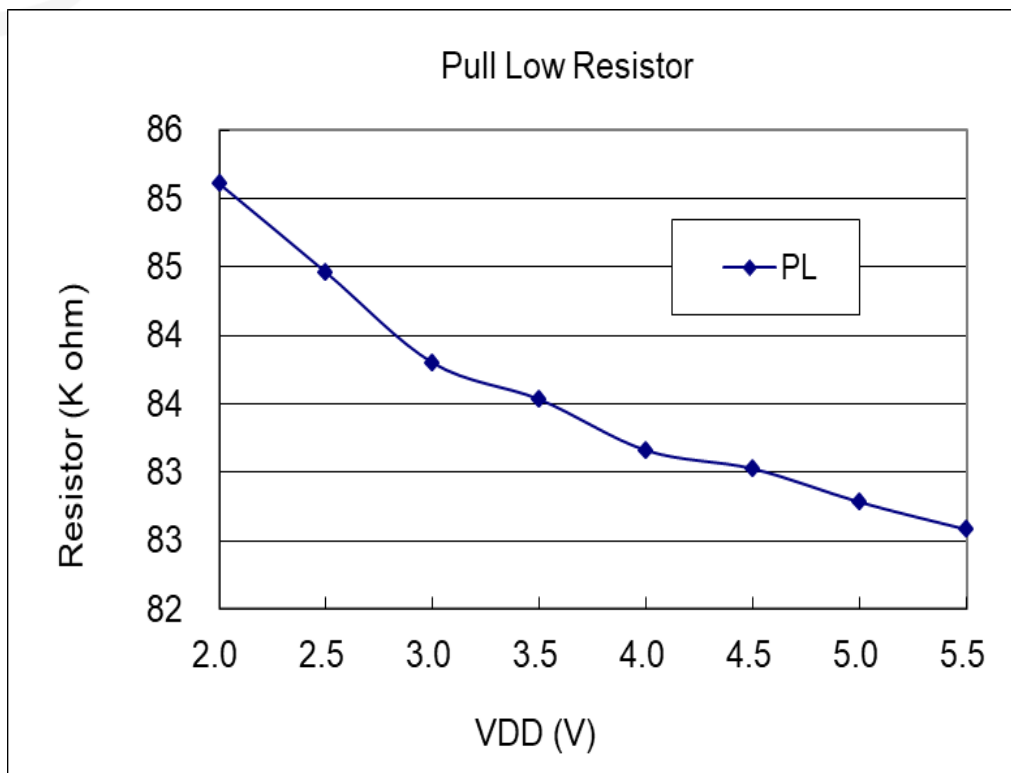
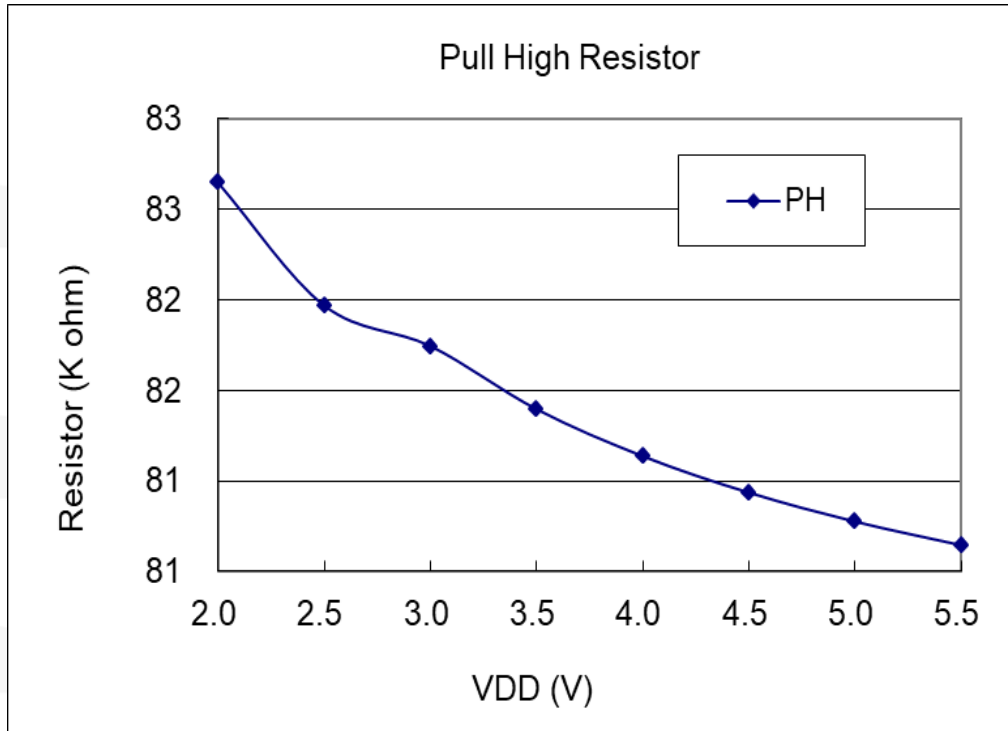




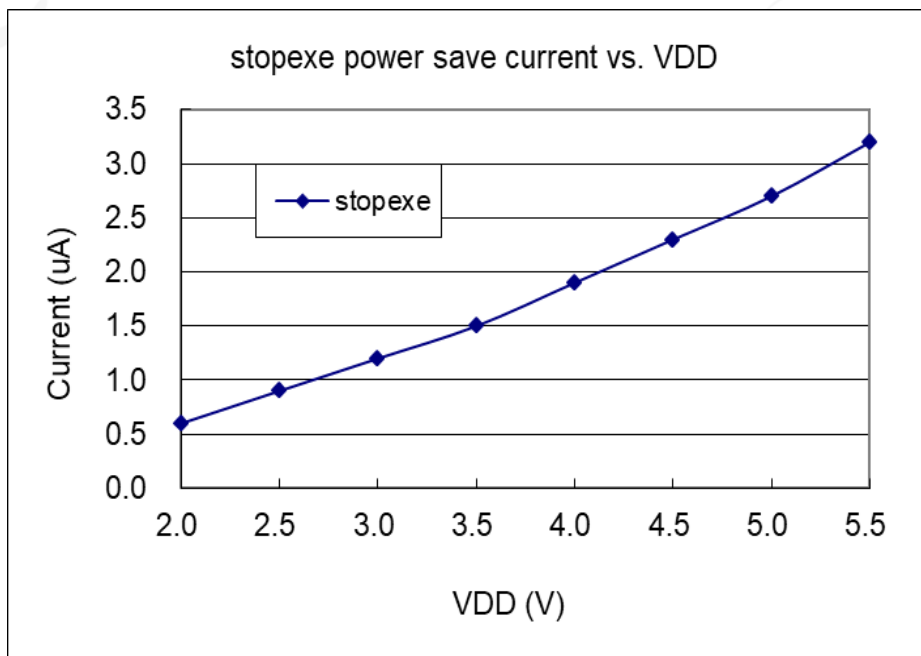
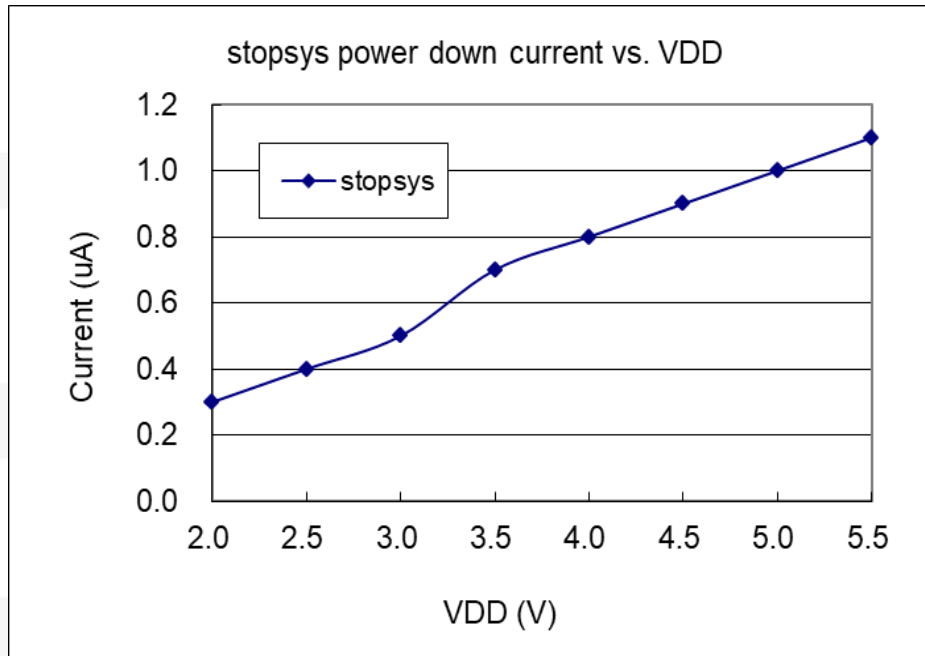
14.13. Typical IO input high/low threshold voltage (V_{IH}/V_{IL})



14.14. Typical resistance of IO pull high/low device



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



15. 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 <i>ALU</i> 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 <i>ALU</i> operation, this bit is set to 1)
IO.n	The bit of register
M.n	Only addressed in 0~0x3F (0~63) is allowed

15.1. Instruction Table

Instructions	Function	Cycles	Z	C	AC	OV
Data Transfer and Arithmetic Operation Instructions						
<i>mov</i> a, l	<i>mov</i> a, 0x0f; $a \leftarrow 0fh$;	1	-	-	-	-
<i>mov</i> M, a	<i>mov</i> MEM, a; $MEM \leftarrow a$	1	-	-	-	-
<i>mov</i> a, M	<i>mov</i> a, MEM; $a \leftarrow MEM$; Flag Z is set when MEM is zero.	1	Y	-	-	-
<i>mov</i> a, IO	<i>mov</i> a, pa; $a \leftarrow pa$; Flag Z is set when pa is zero.	1	Y	-	-	-
<i>mov</i> IO, a	<i>mov</i> pb, a; $pb \leftarrow a$;	1	-	-	-	-
<i>ldt16</i> word	<i>ldt16</i> word; $word \leftarrow$ 16-bit timer	1	-	-	-	-
<i>stt16</i> word	<i>stt16</i> word; 16-bit timer \leftarrow word	1	-	-	-	-
<i>ldtabh</i> index	<i>ldtabh</i> index; $a \leftarrow$ {bit 15~8 of MTP [index]};	2	-	-	-	-
<i>ldtabl</i> index	<i>ldtabl</i> index; $a \leftarrow$ {bit7~0 of MTP [index]};	2	-	-	-	-
<i>idxm</i> a, index	<i>idxm</i> a, index; $a \leftarrow$ [index], where index is declared by word.	2	-	-	-	-
<i>idxm</i> index, a	<i>idxm</i> index, a; [index] \leftarrow a; where index is declared by word.	2	-	-	-	-
<i>xch</i> M	<i>xch</i> MEM; $MEM \leftarrow a$, $a \leftarrow MEM$	1	-	-	-	-
<i>pushaf</i>	<i>pushaf</i> ; [sp] \leftarrow {flag, ACC}; $sp \leftarrow sp + 2$;	1	-	-	-	-
<i>popaf</i>	<i>popaf</i> ; $sp \leftarrow sp - 2$; {Flag, ACC} \leftarrow [sp];	1	Y	Y	Y	Y
<i>add</i> a, l	<i>add</i> a, 0x0f; $a \leftarrow a + 0fh$	1	Y	Y	Y	Y
<i>add</i> a, M	<i>add</i> a, MEM; $a \leftarrow a + MEM$	1	Y	Y	Y	Y
<i>add</i> M, a	<i>add</i> MEM, a; $MEM \leftarrow a + MEM$	1	Y	Y	Y	Y
<i>addc</i> a, M	<i>addc</i> a, MEM; $a \leftarrow a + MEM + C$	1	Y	Y	Y	Y
<i>addc</i> M, a	<i>addc</i> MEM, a; $MEM \leftarrow a + MEM + C$	1	Y	Y	Y	Y
<i>addc</i> a	<i>addc</i> a; $a \leftarrow a + C$	1	Y	Y	Y	Y
<i>addc</i> M	<i>addc</i> MEM; $MEM \leftarrow MEM + C$	1	Y	Y	Y	Y
<i>nadd</i> a, M	<i>nadd</i> a, MEM; $a \leftarrow \bar{a} + MEM$	1	Y	Y	Y	Y
<i>nadd</i> M, a	<i>nadd</i> MEM, a; $MEM \leftarrow \bar{MEM} + a$	1	Y	Y	Y	Y
<i>sub</i> a, l	<i>sub</i> a, 0x0f; $a \leftarrow a - 0fh$ ($a + [2$'s complement of 0fh])	1	Y	Y	Y	Y
<i>sub</i> a, M	<i>sub</i> a, MEM; $a \leftarrow a - MEM$ ($a + [2$'s complement of M])	1	Y	Y	Y	Y
<i>sub</i> M, a	<i>sub</i> MEM, a; $MEM \leftarrow MEM - a$ ($MEM + [2$'s complement of a])	1	Y	Y	Y	Y
<i>subc</i> a, M	<i>subc</i> MEM, a; $a \leftarrow a - MEM - C$	1	Y	Y	Y	Y
<i>subc</i> M, a	<i>subc</i> MEM, a; $MEM \leftarrow MEM - a - C$	1	Y	Y	Y	Y
<i>subc</i> a	<i>subc</i> a; $a \leftarrow a - C$	1	Y	Y	Y	Y
<i>subc</i> M	<i>subc</i> MEM; $MEM \leftarrow MEM - C$	1	Y	Y	Y	Y
<i>inc</i> M	<i>inc</i> MEM; $MEM \leftarrow MEM + 1$	1	Y	Y	Y	Y
<i>dec</i> M	<i>dec</i> MEM; $MEM \leftarrow MEM - 1$	1	Y	Y	Y	Y
<i>clear</i> M	<i>clear</i> MEM; $MEM \leftarrow 0$	1	-	-	-	-
<i>mul</i>	<i>mul</i> ; {MulRH,ACC} \leftarrow ACC * MulOp	1	-	-	-	-

Instructions	Function	Cycle	Z	C	AC	OV
Shift Operation Instructions						
<i>sr a</i>	<i>sr a</i> ; $a(0,b7,b6,b5,b4,b3,b2,b1) \leftarrow a(b7,b6,b5,b4,b3,b2,b1,b0)$, $C \leftarrow a(b0)$	1	-	Y	-	-
<i>src a</i>	<i>src a</i> ; $a(c,b7,b6,b5,b4,b3,b2,b1) \leftarrow a(b7,b6,b5,b4,b3,b2,b1,b0)$, $C \leftarrow a(b0)$	1	-	Y	-	-
<i>sr M</i>	<i>sr MEM</i> ; $MEM(0,b7,b6,b5,b4,b3,b2,b1) \leftarrow MEM(b7,b6,b5,b4,b3,b2,b1,b0)$, $C \leftarrow MEM(b0)$	1	-	Y	-	-
<i>src M</i>	<i>src MEM</i> ; $MEM(c,b7,b6,b5,b4,b3,b2,b1) \leftarrow MEM(b7,b6,b5,b4,b3,b2,b1,b0)$, $C \leftarrow MEM(b0)$	1	-	Y	-	-
<i>sl a</i>	<i>sl a</i> ; $a(b6,b5,b4,b3,b2,b1,b0,0) \leftarrow a(b7,b6,b5,b4,b3,b2,b1,b0)$, $C \leftarrow a(b7)$	1	-	Y	-	-
<i>slc a</i>	<i>slc a</i> ; $a(b6,b5,b4,b3,b2,b1,b0,c) \leftarrow a(b7,b6,b5,b4,b3,b2,b1,b0)$, $C \leftarrow a(b7)$	1	-	Y	-	-
<i>sl M</i>	<i>sl MEM</i> ; $MEM(b6,b5,b4,b3,b2,b1,b0,0) \leftarrow MEM(b7,b6,b5,b4,b3,b2,b1,b0)$, $C \leftarrow MEM(b7)$	1	-	Y	-	-
<i>slc M</i>	<i>slc MEM</i> ; $MEM(b6,b5,b4,b3,b2,b1,b0,C) \leftarrow MEM(b7,b6,b5,b4,b3,b2,b1,b0)$, $C \leftarrow MEM(b7)$	1	-	Y	-	-
<i>swap a</i>	<i>swap a</i> ; $a(b3,b2,b1,b0,b7,b6,b5,b4) \leftarrow a(b7,b6,b5,b4,b3,b2,b1,b0)$	1	-	-	-	-
Logic Operation Instructions						
<i>and a, l</i>	<i>and a, 0x0f</i> ; $a \leftarrow a \& 0fh$	1	Y	-	-	-
<i>and a, M</i>	<i>and a, RAM10</i> ; $a \leftarrow a \& RAM10$	1	Y	-	-	-
<i>and M, a</i>	<i>and MEM, a</i> ; $MEM \leftarrow a \& MEM$	1	Y	-	-	-
<i>or a, l</i>	<i>or a, 0x0f</i> ; $a \leftarrow a 0fh$	1	Y	-	-	-
<i>or a, M</i>	<i>or a, MEM</i> ; $a \leftarrow a MEM$	1	Y	-	-	-
<i>or M, a</i>	<i>or MEM, a</i> ; $MEM \leftarrow a MEM$	1	Y	-	-	-
<i>xor a, l</i>	<i>xor a, 0x0f</i> ; $a \leftarrow a \wedge 0fh$	1	Y	-	-	-
<i>xor IO, a</i>	<i>xor pa, a</i> ; $pa \leftarrow a \wedge pa$;	1	-	-	-	-
<i>xor a, M</i>	<i>xor a, MEM</i> ; $a \leftarrow a \wedge RAM10$	1	Y	-	-	-
<i>xor M, a</i>	<i>xor MEM, a</i> ; $MEM \leftarrow a \wedge MEM$	1	Y	-	-	-
<i>not a</i>	<i>not a</i> ; $a \leftarrow \sim a$	1	Y	-	-	-
<i>not M</i>	<i>not MEM</i> ; $MEM \leftarrow \sim MEM$	1	Y	-	-	-
<i>neg a</i>	<i>neg a</i> ; $a \leftarrow \bar{a}$	1	Y	-	-	-
<i>neg M</i>	<i>neg MEM</i> ; $MEM \leftarrow \bar{MEM}$	1	Y	-	-	-
<i>comp a, M</i>	<i>comp a, MEM</i> ; Flag will be changed by regarding as ($a - MEM$)	1	Y	Y	Y	Y
<i>comp M, a</i>	<i>comp MEM, a</i> ; Flag will be changed by regarding as ($MEM - a$)	1	Y	Y	Y	Y

Instructions	Function	Cycles	Z	C	AC	OV
Bit Operation Instructions						
<i>set0</i> IO.n	<i>set0</i> pa.5 ; PA5=0	1	-	-	-	-
<i>set1</i> IO.n	<i>set1</i> pb.5 ; PB5=1	1	-	-	-	-
<i>set0</i> M.n	<i>set0</i> MEM.5 ; set bit 5 of MEM to low	1	-	-	-	-
<i>set1</i> M.n	<i>set1</i> MEM.5 ; set bit 5 of MEM to high	1	-	-	-	-
<i>swapc</i> IO.n	<i>swapc</i> IO.0; 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;	1	-	Y	-	-
Conditional Operation Instructions						
<i>ceqsn</i> a, l	<i>ceqsn</i> a, 0x55 ; <i>inc</i> MEM ; <i>goto</i> error ; If a=0x55, then “goto error”; otherwise, “inc MEM”.	1 / 2	Y	Y	Y	Y
<i>ceqsn</i> a, M	<i>ceqsn</i> a, MEM; If a=MEM, skip next instruction	1 / 2	Y	Y	Y	Y
<i>cneqsn</i> a, M	<i>cneqsn</i> a, MEM; If a≠MEM, skip next instruction	1 / 2	Y	Y	Y	Y
<i>cneqsn</i> a, l	<i>cneqsn</i> a, 0x55 ; <i>inc</i> MEM ; <i>goto</i> error ; If a≠0x55, then “goto error”; Otherwise, “inc MEM”	1 / 2	Y	Y	Y	Y
<i>t0sn</i> IO.n	<i>t0sn</i> pa.5; If bit 5 of port A is low, skip next instruction	1 / 2	-	-	-	-
<i>t1sn</i> IO.n	<i>t1sn</i> pa.5; If bit 5 of port A is high, skip next instruction	1 / 2	-	-	-	-
<i>t0sn</i> M.n	<i>t0sn</i> MEM.5 ; If bit 5 of MEM is low, then skip next instruction	1 / 2	-	-	-	-
<i>t1sn</i> M.n	<i>t1sn</i> MEM.5 ; If bit 5 of MEM is high, then skip next instruction	1 / 2	-	-	-	-
<i>izsn</i> a	<i>izsn</i> a; a ← a + 1, skip next instruction if a = 0	1 / 2	Y	Y	Y	Y
<i>dzsn</i> a	<i>dzsn</i> a; a ← a - 1, skip next instruction if a = 0	1 / 2	Y	Y	Y	Y
<i>izsn</i> M	<i>izsn</i> MEM; MEM ← MEM + 1, skip next instruction if MEM= 0	1 / 2	Y	Y	Y	Y
<i>dzsn</i> M	<i>dzsn</i> MEM; MEM ← MEM - 1, skip next instruction if MEM= 0	1 / 2	Y	Y	Y	Y
System Control Instructions						
<i>call</i> label	<i>call</i> function1; [sp] ← pc + 1, pc ← function1, sp ← sp + 2	2	-	-	-	-
<i>goto</i> label	<i>goto</i> routine1; Go to routine1 and execute program.	2	-	-	-	-
<i>ret</i> l	<i>ret</i> 0x55; A ← 55h ret ;	2	-	-	-	-
<i>ret</i>	<i>ret</i> ; sp ← sp - 2 pc ← [sp]	2	-	-	-	-
<i>reti</i>	<i>reti</i> ; Return to program that is interrupt service routine. After this command is executed, global interrupt is enabled automatically.	2	-	-	-	-
<i>nop</i>	<i>nop</i> ; Nothing changed.	1	-	-	-	-
<i>pcadd</i> a	<i>pcadd</i> a; pc ← pc + a	2	-	-	-	-
<i>engint</i>	<i>engint</i> ; Interrupt request can be sent to FPPA0	1	-	-	-	-
<i>disgint</i>	<i>disgint</i> ; Interrupt request is blocked from FPPA0	1	-	-	-	-
<i>stopsys</i>	<i>stopsys</i> ; Stop the system clocks and halt the system	1	-	-	-	-
<i>stopexe</i>	<i>stopexe</i> ; Stop the system clocks and keep oscillator modules active.	1	-	-	-	-
<i>reset</i>	<i>reset</i> ; Reset the whole chip.	1	-	-	-	-
<i>wdreset</i>	<i>wdreset</i> ; Reset Watchdog timer.	1	-	-	-	-