EMBEDDED SYSTEMS LABORATORY

LAB MANUAL

Year	**:**	**2017 - 2018**
Course Code	**:**	BES102
Regulations	**:**	**IARE - R16**
Semester	**:**	**II**
Branch	**:**	**ECE**
Class	**:**	**M.TECH I Yr. II Sem**

Prepared by

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INSTITUTE OF AERONAUTICAL ENGINEERING
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Dundigal – 500 043, Hyderabad

1. PROGRAM OUTCOMES:

M.TECH - PROGRAM OUTCOMES (POS)	
PO1	**Engineering Knowledge :** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems
PO2	**Problem Analysis :** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences
PO3	**Design/Development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations
PO4	**Conduct Investigations of Complex Problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions
PO5	**Modern Tool Usage** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations
PO6	**The Engineer And Society** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice
PO7	**Environment and sustainability** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development
PO8	**Ethics** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice
PO9	**Individual and Team Work** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings
PO10	**Communication** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions
PO11	**Project management and finance** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments
PO12	**Life-long learning** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

2. PROGRAM SPECIFIC OUTCOMES

PROGRAM SPECIFIC OUTCOMES (PSO's)	
PSO-1	**Professional Skills:** The ability to research, understand and implement computer programs in the areas related to algorithms, system software, multimedia, web design, big data analytics, and networking for efficient analysis and design of computer-based systems of varying complexity.
PSO-2	**Problem-Solving Skills:** The ability to apply standard practices and strategies in software project development using open-ended programming environments to deliver a quality product for business success.
PSO-3	**Successful Career and Entrepreneurship:** The ability to employ modern computer languages, environments, and platforms in creating innovative career paths, to be an entrepreneur, and a zest for higher studies.

INSTITUTE OF AERONAUTICAL ENGINEERING

(Aproved by AICTE, New Delhi, Accreditated by NBA, New Delhi & Affliated to JNTU, Hyderabad)

Dundigal, Hyderabad -500 043.

EMBEDDED SYSTEMS – Lab Programs List	
Submission – 1	
Week – 1	Write a program to toggle all the led to port and with some time delay using ARM7
Week – 2	Write a program to interface LCD with ARM7
Week – 3	Write a program to interface 4*4 matrix keypad with ARM7
Week – 4	Write a program for interfacing LED and PWM and to verify the output in the ARM7
Week - 5	Write a program to interface Stepper motor with ARM7
Week – 6	Write a program for interfacing of DC motor with ARM7
Submission – 2	
Week – 7	Write a program to study and characteristics of the programmable gain amplifier (PGA)
Week – 8	Write a Program realization of low pass, high pass and band pass filters and their characteristics
Week – 9	Write a program to interface ADC and DAC with PSOC
Week - 10	Write a program for digital function implementation using digital blocks A. Counter for blinking LED B. PWW C. Digital buffer and digital inverter
Week – 11	Write a program to verify Timer operation in different modes
Week - 12	Write a Program to interface stepper motor with PSOC

3. ATTAINMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Exp. No.	Experiment	Program Outcomes Attained	Program Specific Outcomes Attained
1	Write a program to toggle all the led to port and with some time delay using ARM7	PO1, PO2	PSO1
2	Write a program to interface LCD with ARM7	PO1, PO2	PSO1
3	Write a program to interface 4*4 matrix keypad with ARM7	PO1, PO2	PSO1
4	Write a program for interfacing LED and PWM and to verify the output in the ARM7	PO1, PO2	PSO1
5	Write a program to interface Stepper motor with ARM7	PO1, PO2, PO3	PSO1, PSO2
6	Write a program for interfacing of DC motor with ARM7	PO1, PO2, PO3	PSO1
7	Write a program to study and characteristics of the programmable gain amplifier (PGA)	PO1, PO2	PSO1
8	Write a Program realization of low pass, high pass and band pass filters and their characteristics	PO5, PO6	PSO1
9	Write a program to interface ADC and DAC with PSOC	PO5, PO6, PO7	PSO1
10	Digital function implementation using digital blocks A. Counter for blinking LED B. PWW C. Digital buffer and digital inverter	PO5, PO6, PO8	PSO1, PSO2
11	Write a program to verify Timer operation in different modes	PO5, PO6	PSO2
12	Write a Program to interface stepper motor with PSOC	PO5, PO6, PO8	PSO2

4. MAPPING COURSE OBJECTIVES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES:

Course Objectives	Program Outcomes												Program Specific Outcomes		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11	PO 12	PSO1	PSO2	PSO3
I		√	√									√	√		
II		√	√									√	√		

EMBEDDED SYSTEMS LABORATORY

II Semester: ECE

Course Code	Category	Hours / Week			Credits	Maximum Marks		
		L	T	P	C	CIA	SEE	Total
BES102	Core	-	-	3	2	30	70	100
Contact Classes: Nil	Tutorial Classes: Nil	Practical Classes: 36				Total Classes: 36		

OBJECTIVES:

The course should enable the students to:

I. Use embedded C for reading data from port pins.

II. Understand the interfacing of data I/O devices with microcontroller.

III. Understand serial communication, port RTOS on microcontroller.

LIST OF EXPERIMENTS

WEEK-1	**LED BLINKING**
Write a program to toggle all the led to port and with some time delay using ARM7	
WEEK-2	**INTERFACING OF LCD**
Write a program to interface LCD with ARM7	
WEEK-3	**INTERFACING OF KEYPAD**
Write a program to interface 4*4 matrix keypad with ARM7	
WEEK-4	**INTERFACING OF LED**
Write a program for interfacing LED and PWM and to verify the output in the ARM7	
WEEK-5	**INTERFACING OF STEPPER MOTOR**
Write a program to interface Stepper motor with ARM7	
WEEK-6	**INTERFACING OF DC MOTOR**
Write a program for interfacing of DC motor with ARM7	
WEEK-7	**PROGRAMMABLE GAIN AMPLIFIER**
Write a program to study and characteristics of the programmable gain amplifier (PGA)	
WEEK-8	**FILTERS**
Write a Program realization of low pass, high pass and band pass filters and their characteristics	
WEEK-9	**ADC AND DAC**

Write a program to interface ADC and DAC with PSOC	
WEEK-10	**DIGITAL FUNCTION IMPLEMENTATION**
Digital function implementation using digital blocks A. Counter for blinking LED B. PWW Digital buffer and digital inverter	
WEEK-11	**ALU OPERATIONS**
Write a program to verify Timer operation in different modes	
WEEK-12	**TIMER**
Write a Program to interface stepper motor with PSOC	
Reference Books:	
1. Michael J. Pont, "Embedded C", Pearson Education, 2nd Edition, 2008. 2. Nigel Gardner, "The Microchip PIC in CCS C". Ccs Inc, 2nd Revision Edition, 2002.	
SOFTWARE AND HARDWARE REQUIREMENTS FOR A BATCH OF 18 STUDENTS: **SOFTWARE:** System Software: Microsoft windows/ Linux. Programming Languages: Keil Embedded C. **HARDWARE:** Dot matrix Printers: 02	

Introduction to ARM7

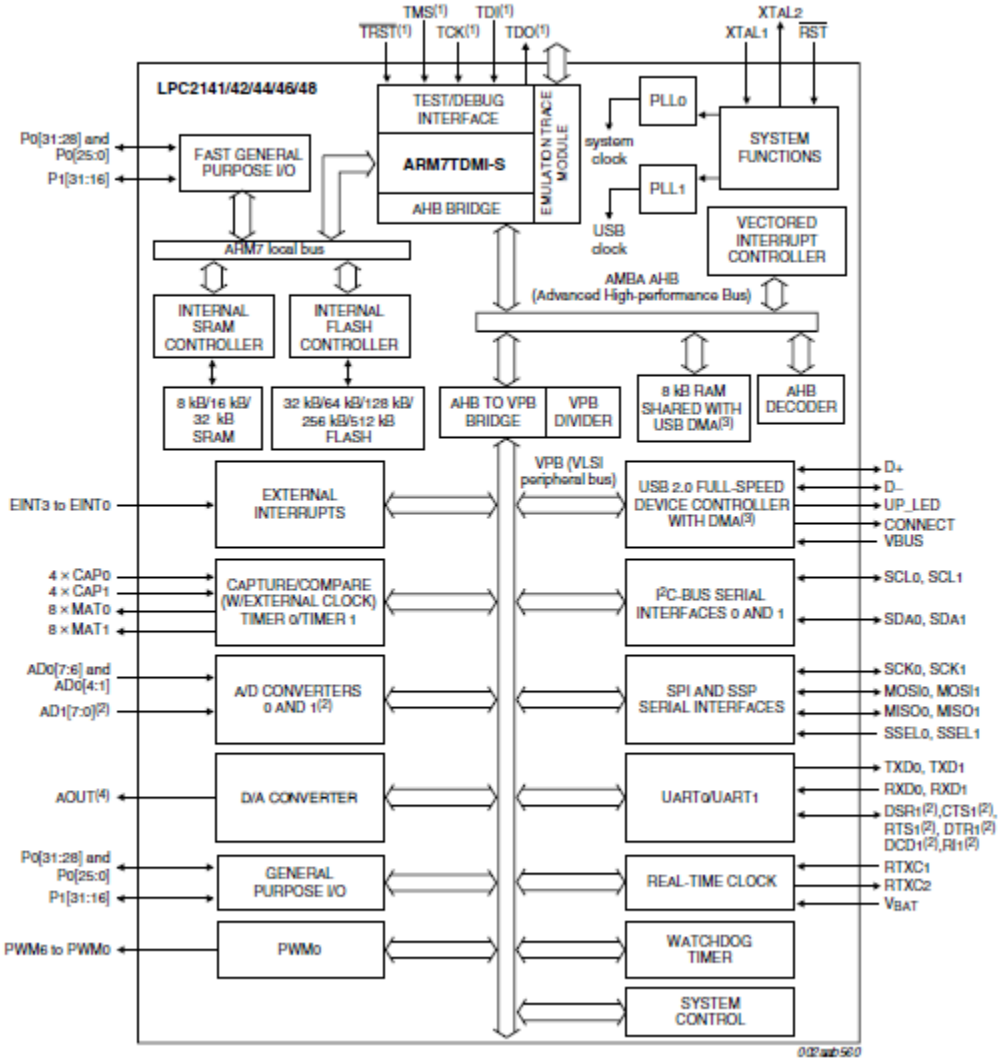
The LPC2141/42/44/46/48 microcontrollers are based on a 16-bit/32-bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combine microcontroller with embedded high speed flash memory ranging from 32 kB to 512 kB. A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical code size applications, the alternative 16-bit Thumbmode reduces code by more than 30 % with minimal performance penalty. Due to their tiny size and low power consumption, LPC2141/42/44/46/48 are ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. Serial communications interfaces ranging from a USB 2.0 Full-speed device,multiple UARTs, SPI, SSP to I2C-bus and on-chip SRAM of 8 kB up to 40 kB, make these devices very well suited for communication gateways and protocol converters, soft modems, voice recognition and low end imaging, providing both large buffer size and high processing power. Various 32-bit timers, single or dual 10-bit ADC(s), 10-bit DAC, PWM channels and 45 fast GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers suitable for industrial control and medical systems.

Features

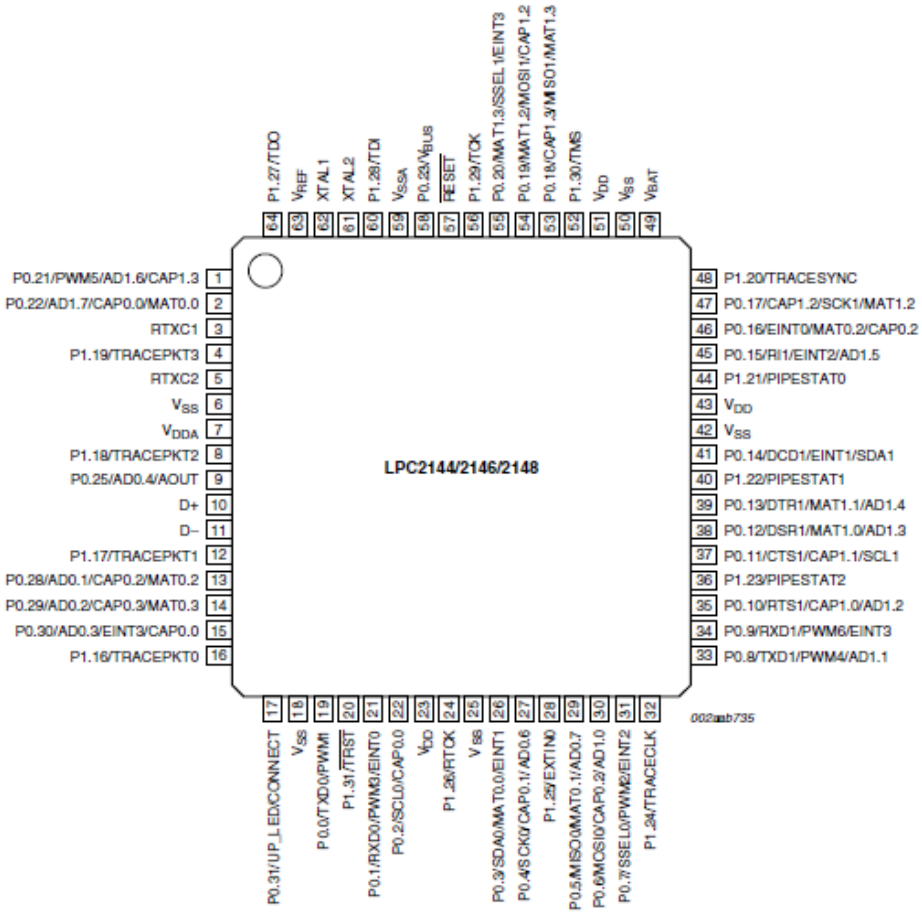
- 16-bit/32-bit ARM7TDMI-S microcontroller in a tiny LQFP64 package.
- 8 kB to 40 kB of on-chip static RAM and 32 kB to 512 kB of on-chip flash memory.
- 128-bit wide interface/accelerator enables high-speed 60 MHz operation.
- In-System Programming/In-Application Programming (ISP/IAP) via on-chip boot loader software. Single flash sector or full chip erase in 400 ms and programming of
- 256 bytes in 1 ms.
- EmbeddedICE RT and Embedded Trace interfaces offer real-time debugging with the on-chip RealMonitor software and high-speed tracing of instruction execution.
  USB 2.0 Full-speed compliant device controller with 2 kB of endpoint RAM. In addition, the LPC2146/48 provides 8 kB of on-chip RAM accessible to USB by DMA.
- One or two (LPC2141/42 vs. LPC2144/46/48) 10-bit ADCs provide a total of 6/14 analog inputs, with conversion times as low as 2.44 μs per channel.
- Single 10-bit DAC provides variable analog output (LPC2142/44/46/48 only).
- Two 32-bit timers/external event counters (with four capture and four compare
- channels each), PWM unit (six outputs) and watchdog.
- Low power Real-Time Clock (RTC) with independent power and 32 kHz clock input.
- Multiple serial interfaces including two UARTs (16C550), two Fast I2C-bus (400 kbit/s),
- SPI and SSP with buffering and variable data length capabilities.
- Vectored Interrupt Controller (VIC) with configurable priorities and vector addresses.
- Up to 45 of 5 V tolerant fast general purpose I/O pins in a tiny LQFP64 package.
- Up to 21 external interrupt pins available.
- 60 MHz maximum CPU clock available from programmable on-chip PLL with settling
- time of 100 μs.

- On-chip integrated oscillator operates with an external crystal from 1 MHz to 25 MHz.
- Power saving modes include Idle and Power-down.
- Individual enable/disable of peripheral functions as well as peripheral clock scaling for additional power optimization.
- Processor wake-up from Power-down mode via external interrupt or BOD.
- Single power supply chip with POR and BOD circuits:
- CPU operating voltage range of 3.0 V to 3.6 V (3.3 V ± 10 %) with 5 V tolerant I/O pads.

Architecture of ARM7 (LPC2148)



Pin Diagram



Introduction to PSoC

When developing more complex projects, there is often a need for additional peripheral units, such as operational and instrument amplifiers, filters, timers, digital logic circuits, AD and DA convertors, etc. As a general rule, implementation of the extra peripherals brings in additional difficulties: new components takespace, require additional attention during production of a printed circuit board, increase power consumption...All of these factors can significantly affect the price and development cycle of the project.

The introduction of PSoC microcontrollers has made many engineers' dream come true of having all their project needs covered in one chip.

PSoC: Programmable System on Chip

PSoC (Programmable System on Chip) represents a whole new concept in microcontroller evelopment. In addition to all the standard elements of 8-bit microcontrollers, PSoC chips feature digital and analog Programmable blocks, which themselves allow implementation of large number of peripherals.

Digital blocks consist of smaller programmable blocks that can be configured to allow different developmentoptions. Analog blocks are used for development of analog elements, such as analog filters, comparators, intrumentational (non–) inverting amplifiers, as well as AD and DA

convertors.There's a number of different PSoC families you can base your project upon, depending on the projectrequirements. Basic difference between PSoC families is the number of available programmable blocks and the number of input/output pins.Number of components that can be devised is primarily a function of the available programmable blocks.
Depending on the microcontroller family, PSoC chips have 4–16 digital blocks, and 3–12 analog Programmable blocks.

Characteristics of PSoC microcontrollers

Some of the most prominent features of PSoC microcontrollers are:

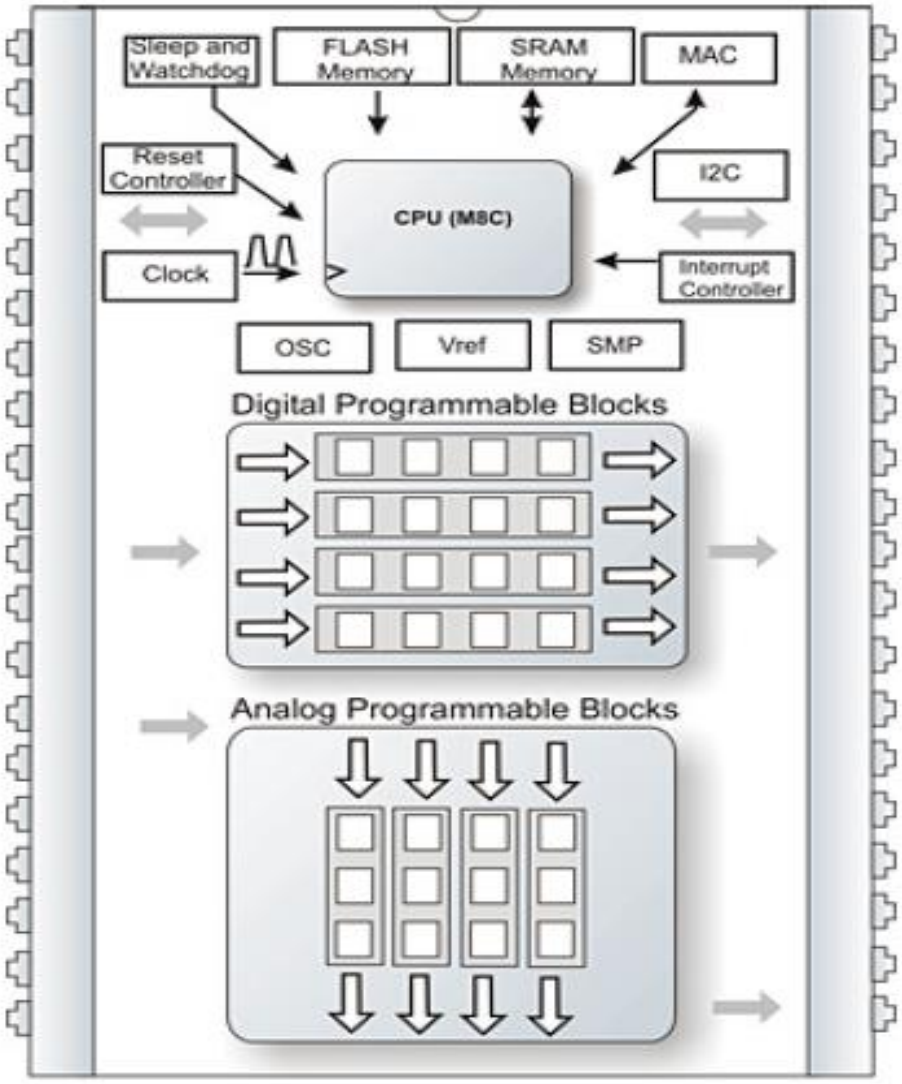
- MAC unit, hardware 8x8 multiplication, with result stored in 32-bit accumulator,
- Changeable working voltage, 3.3V or 5V
- Possibility of small voltage supply, to 1V
- Programmable frequency choice.

Programmable blocks allow you to devise:

- 16K bytes of programmable memory
- 256 bytes of RAM
- AD convertors with maximum resolution af 14 bits
- DA convertors with maximum resolution of 9 bits
- Programmable voltage amplifier
- Programmable filters and comparators
- Timers and counters of 8, 16, and 32 bits
- Pseudorandom sequences and CRC code generators
- Two Full-Duplex UART's
- Multiple SPI devices
- Option for connection on all output pins
- Option for block combining
- Option for programming only the specified memory regions and write protection
- For every pin there is an option of Pull up, Pull down, High Z, Strong, or Open pin state
- Possibility of interrupt generation during change of state on any input/output pin
- I2C Slave or Master and Multi-Master up to speed of 400KH
- Integrated Supervisory Circuit
- Built-in precise voltage reference

System overview

- PSoC microcontrollers are based on 8-bit CISC architecture. Their general structure with basic blocks is
- presented in the following image



CPU unit is the main part of a microcontroller whose purpose is to execute program instructions and controlworkflow of other blocks.

Frequency generator facilitates signals necessary for CPU to work, as well as an array of frequencies thatare used by programmable blocks. These signals could be based on internal or external referent oscillator.

Reset controller enables microcontroller start action and brings a microcontroller to regular state in the caseof irregular events.

Watch Dog timer is used to detect software dead-loops.

Sleep timer can periodically wake up microcontroller from power saving modes. It could be also used as aregular timer.

Input-Output pins enable communication between the CPU unit, digital and analog programmable blocksand outside world.

Digital programmable blocks are used to configure digital programmable components which are selected by user.

Analog programmable blocks are used to configure analog components, like AD and DA converters, filters,and DTMF receivers, programmable, instrumental, inverting, non-inverting and operational amplifiers.

Interrupt controller handles necessary operations in the case of interrupts.

I2C controller Enables hardware realization of an I2C communication.

Voltage reference is vital for the work of analog components that reside inside of analog programmableblocks.

MAC unit is used for operations of hardware signed multiplication of 8-bit numbers.

SMP is a system which can be used as a part of a voltage regulator. For example, it is possible to supplypower to a PSoC microcontroller from a single 1.5V battery.

WEEK-1

Experiment 1

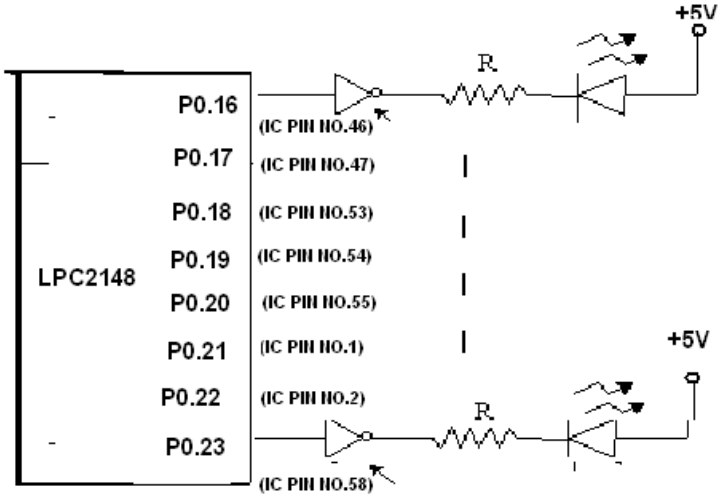
Aim:Write an Embedded C program to toggle LED‘s with some time delayusingARM-LPC2148.

Apparatus:1. ARM7-LPC2148 Trainer kit

2. 5V Adapter

3. RS-232 Cable

Interface Circuit:



Program:

```
#include<lpc21xx.h>
void delay(unsigned long val);

int main()
{
        IO1DIR = 0x00ff0000;                    /* Port1 16-23 as output*/
        while(1)                                        /* Infinite loop          */
        {
                IO1SET = 0x00ff0000;            /* Port1 16-23 High    */
                delay(100000);                          /* A delay of 100ms   */
                IO1CLR = 0x00ff0000;            /* Port1 16-23 low      */
                delay(100000);
        }
}
void delay(unsigned long val)
{
        while(val>0)
        {
                val--;
```

```
        }
}
```

Output: You can see the all led's blinking

‘

WEEK-2

Experiment No. 2:

Aim **:** Write an embedded C program to interface LCD with ARM7

Apparatus: 1. ARM7-LPC2148 Trainer kit

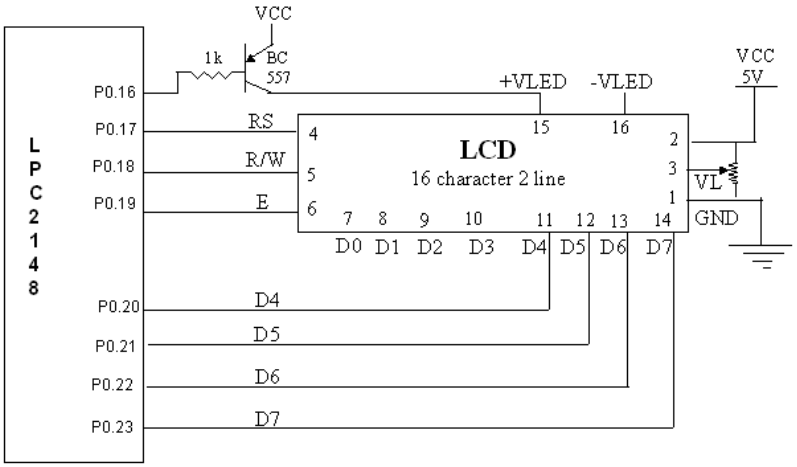
2. 5V Adapter

3. RS-232 Cable

4. 16*2 LCD Modules

Theory: Write theory related to LDC Interfacing with ARM Processors.

Interfacing Circuit:



Source Code:

```
#include <LPC214X.H>

voiddisplay_lcd_string(unsigned char *);
voidinit_lcd(void);

voidwr_data(unsigned char);

voidwr_cmd(unsigned char);
void wr_cmd0(unsigned char);

voiddelay_ms(unsigned int );

//=====================================================

unsigned char key_ready,key_code,nkp;
unsigned char dcount,krcount,scan_no;
```

```
unsignedintkrl;

unsigned char lut[] = {"0123456789ABCDEF"};
//=====================================================

int main()
  {
        VPBDIV  = 0x00;  //60/4=15mhz
        PINSEL0 = 0x00000005;
        PINSEL1 = 0x00000000;
        PINSEL2 = 0x00000000;

        IO0DIR  = 0xffffffff;     //p0.0 to p0.31 as output...
        IO1DIR  = 0xff0fffff; //P1.20 to p1.23 as input...rest as output...

        init_lcd();


while(1)
        {
display_lcd_string(" THIS IS ");
delay_ms(300);

        display_lcd_string(" NEW CREATION ");
        delay_ms(300);

        display_lcd_string(" EMBEDDED WORLD ");

                delay_ms(300);
        }

}//end of main...

/*=====================================================================
=============


================================================*/

voidinit_lcd()
{
        delay_ms(15);
        wr_cmd0(0x30);
        wr_cmd0(0x30);
        wr_cmd0(0x30);
        wr_cmd0(0x20); //4 bit mode

        wr_cmd(0x28);
        wr_cmd(0x0e);
```

```
	wr_cmd(0x06);
	wr_cmd(0x01); //clear lcd

	IO0CLR = 0x00010000;		//bacllight on...

}//end of init_lcd...

void wr_cmd0(unsigned char ch)
{
	delay_ms(10);

	IO0CLR = 0x00ff0000;		//clear all port pins p0.16 to p0.23...
	IO0SET = (ch& 0xf0) << 16;	//map ch with d4,d5,d6,d7

	IO0SET = 0x00080000;		//e = 1;
	delay_ms(1);
	IO0CLR = 0x00080000;		//e = 0;

}//end of wr_cmd0...

voidwr_cmd(unsigned char ch)
{
	delay_ms(10);

	IO0CLR = 0x00ff0000;		//clear all port pins p0.16 to p0.23...
	IO0SET = (ch& 0xf0) << 16;		//map ch with d4,d5,d6,d7

	IO0SET = 0x00080000;		//e = 1;
	delay_ms(1);
	IO0CLR = 0x00080000;		//e = 0;

	IO0CLR = 0x00ff0000;		//clear all port pins p0.16 to p0.23...
	IO0SET = (ch& 0x0f) << 20;	//map ch with d4,d5,d6,d7

	IO0SET = 0x00080000;		//e = 1;
	delay_ms(1);
	IO0CLR = 0x00080000;		//e = 0;


}//end of wr_cmd0...


voidwr_data(unsigned char ch)
{
	delay_ms(10);

	IO0CLR = 0x00ff0000;		//clear all port pins p0.16 to p0.23...
	IO0SET = 0x00020000;		//rs = 1;
```

```
	IO0CLR = 0x00f00000;		//clear all port pins p0.16 to p0.23...
	IO0SET = (ch& 0xf0) << 16;		//map ch with d4,d5,d6,d7

	IO0SET = 0x00080000;		//e = 1;
	delay_ms(1);
	IO0CLR = 0x00080000;		//e = 0;

	IO0CLR = 0x00f00000;		//clear all port pins p0.16 to p0.23...
	IO0SET = (ch& 0x0f) << 20;		//map ch with d4,d5,d6,d7

	IO0SET = 0x00080000;		//e = 1;
	delay_ms(1);
	IO0CLR = 0x00080000;		//e = 0;


}//end of wr_cmd0...


voiddisplay_lcd_string(unsigned char *ch)
{
unsigned char cnt = 0;

	wr_cmd(0x01);//clear lcd

	while((*ch) != '\0')
	{
		wr_data(*ch);
		ch++;
		cnt++;
		if(cnt == 16)
			wr_cmd(0xc0);		//next row

	}

}//end of display_lcd_string...

voiddelay_ms(unsigned int i)
{

	unsignedintj,k;

	for(j = 0; j <= i; j++)
	{
		for(k = 0; k <= 15000; k++)
		{}
	}
}//end of delay_ms...
```

Output: You can see the message on LCD.If required reset the board.

WEEK-3

Experiment No.3

Aim : Write an embedded C program to interface 4*4 matrix keyboard to ARM7

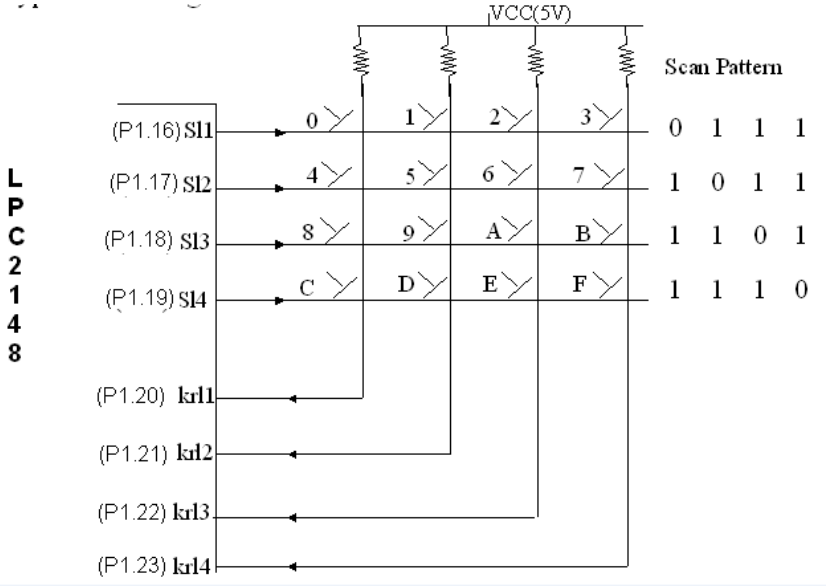
Apparatus: 1. ARM7-LPC2148 Trainer kit

2. 5V Adapter

3. RS-232 Cable

4. 4*4 Matrix keypad

Interfacing circuit:



Source Code:

```
#include <LPC214X.H>

/*-------------------------------------------------------------
 LCD PINS:
      P0.16-BL,  P0.17-RS, P0.18-RW, P0.19-ENABLE,
      P0.20-D4, P0.21-D5, P0.22-D6, P0.23-D7
 ============================================================

 ROWS N 7-SEGMENT:
      P1.16-SL1, P1.17-SL2, P1.18-SL3, P1.19-SL4

column- P1.20-KRL1, P1.21-KRL2, P1.22-KRL3, P1.23(KRL4)
 -------------------------------------------------------------*/

voiddisplay_lcd_string(unsigned char *);

voidinit_lcd(void);
voidwr_data(unsigned char);
```

```
voidwr_cmd(unsigned char);
void wr_cmd0(unsigned char);
voiddelay_ms(unsigned int );
//-------------------------------------

voidget_key(void);
voidkey_process(void);
voidkey_release(void);

voidinit_timer(void);
void scanner(void);
void k(void);
voidinit_key(void);

unsigned char key_ready,key_code,nkp;
unsigned char dcount,krcount,scan_no;
unsignedintkrl;

unsigned char lut[] = {"0123456789ABCDEF"};
//=====================================================

__irq void isr_t0()
{

        T0IR = 0x01;  //clearing interrupt register...
        init_timer();
        scanner();

        VICVectAddr = 0x00; //acknowledging VIC controller...

}//end of isr...

int main()
{

        VPBDIV  = 0x00;        //60/4=15MHZ
        PINSEL0 = 0x00000005; //uart
        PINSEL1 = 0x00000000; //gpio
        PINSEL2 = 0x00000000; //gpio

        IO0DIR  = 0xffffffff;  //p0.0 to p0.31 as output...
        IO1DIR  = 0xff0fffff;

        //P1.20 to p1.23 as input...rest as output...


        init_key();
        init_timer();
        init_lcd();
```

```
	VICIntSelect  = 0x00000000;
	//Interrupt IRQ selected...

	VICIntEnable  = 0x00000010;
	//timer interrupt enable...

	VICVectAddr0  = (unsigned long)isr_t0;

	VICVectCntl0  = (0x00000020)|4;
	//slot enable and interrupt no. is 4...

	display_lcd_string(" Welcome ");
	//while(1);
	delay_ms(2000);

	display_lcd_string(" Press any key ");
	delay_ms(2000);

	while(1)
	{
		get_key();
		key_process();
	}//end of while...

}//end of main...

voidinit_key()
{
	dcount = 33;
	krcount = 32;
	scan_no = 0;
	key_ready = nkp = 0;

}//end of init_key...

void scanner()
{
	switch(scan_no)
	{

		case 0:
					IO1SET = 0x000f0000;
					IO1CLR = 0x00010000;
	//select 1st row...

					krl    = IO1PIN;
					krl    = krl>> 20;
```

```
                k();

                scan_no++;
                break;

        case 1:
                krl    = IO1PIN;
                krl    = krl>> 21;
                k();

                scan_no++;
                break;
        case 2:

                krl    = IO1PIN;
                krl    = krl>> 22;
                k();

                scan_no++;
                break;
        case 3:
                krl    = IO1PIN;
                krl    = krl>> 23;
                k();
                scan_no++;
                break;


        case 4:
                IO1SET = 0x000f0000;
                IO1CLR = 0x00020000;        //select 2nd row...

                krl    = IO1PIN;
                krl    = krl>> 20;
                k();

                scan_no++;
                break;

        case 5:
                krl    = IO1PIN;
                krl    = krl>> 21;
                k();

                scan_no++;
                break;
        case 6:

                krl    = IO1PIN;
```

```
                krl    = krl>> 22;
                k();

                scan_no++;
                break;
        case 7:
                krl    = IO1PIN;
                krl    = krl>> 23;
                k();
                scan_no++;
                break;

        case 8:
                IO1SET = 0x000f0000;
                IO1CLR = 0x00040000;        //select 3rd row...

                krl    = IO1PIN;
                krl    = krl>> 20;
                k();

                scan_no++;
                break;

        case 9:
                krl    = IO1PIN;
                krl    = krl>> 21;
                k();

                scan_no++;
                break;
        case 10:

                krl    = IO1PIN;
                krl    = krl>> 22;
                k();

                scan_no++;
                break;
        case 11:
                krl    = IO1PIN;
                krl    = krl>> 23;
                k();
                scan_no++;
                break;

        case 12:
                IO1SET = 0x000f0000;
                IO1CLR = 0x00080000;        //select 4th row...
```

```
                                        krl    = IO1PIN;
                                        krl    = krl>> 20;
                                        k();

                                        scan_no++;
                                        break;

                case 13:
                                        krl    = IO1PIN;
                                        krl    = krl>> 21;
                                        k();

                                        scan_no++;
                                        break;
                case 14:

                                        krl    = IO1PIN;
                                        krl    = krl>> 22;
                                        k();

                                        scan_no++;
                                        break;
                case 15:
                                        krl    = IO1PIN;
                                        krl    = krl>> 23;
                                        k();
                                        scan_no = 0;
                                        break;

        }//end of switch case...

}//end of scanner...


void k()
{
        if(key_ready == 0)
        {
                if(dcount == 33)
                {
                        if((krl& 0x00000001) == 0)
                        {
                                key_code = scan_no;
                                dcount--;
                        }

                }//end of if dcount == 33...
                else
                {
```

```
                        dcount--;
                        if(dcount == 0)
                        {
                                if((krl& 0x00000001) == 0)
                                        key_ready = 1;
                                dcount = 33;

                        }
                }

        }//end of if key_ready == 0....
        else
        {
                if((krl& 0x00000001) != 0)
                {
                        krcount--;
                        if(krcount == 0)
                        {
                                nkp = 1;
                                krcount = 32;
                        }
                }
                else
                        krcount = 32;
        }

}//end of k...



voidinit_timer()
{
        T0CTCR = 0x00;                  //mode selection timer as timer
        T0TC   = 0x00000000;            //timer register, value inside this will increase...
        T0MR0  = 0x00003b2f;            //calulation for 1ms...
                        //1m/c = (Peripheral / 1) = (15Mhz / 1) = 15Mhz...
                        //1 M/c time = 1 / 15Mhz = 0.066us
                        //thus 1000us = (1000 / 0.066) = 15151.51 = 3b2f...
        T0MCR  = 0x0007;  //when tc will match MR0, timer will stop, it will
                        //reset Tc and generate interrupt signal...
        T0TCR  = 0x01;                  //run timer...


}//end of init_timer...


voidinit_lcd()
{
        delay_ms(15);
```

```
	wr_cmd0(0x30);
	wr_cmd0(0x30);
	wr_cmd0(0x30);
	wr_cmd0(0x20);//4 bit mode lcd

	wr_cmd(0x28);
	wr_cmd(0x0e);
	wr_cmd(0x06);
	wr_cmd(0x01);

	IO0CLR = 0x00010000;		//bacllight on...

}//end of init_lcd...

void wr_cmd0(unsigned char ch)
{
	delay_ms(10);

	IO0CLR = 0x00ff0000;
		//clear all port pins p0.16 to p0.23...
	IO0SET = (ch& 0xf0) << 16;
			//map ch with d4,d5,d6,d7

	IO0SET = 0x00080000;		//e = 1;
	delay_ms(1);
	IO0CLR = 0x00080000;		//e = 0;

}//end of wr_cmd0...

voidwr_cmd(unsigned char ch)
{
	delay_ms(10);

	IO0CLR = 0x00ff0000;		//clear all port pins p0.16 to p0.23...
	IO0SET = (ch& 0xf0) << 16;		//map ch with d4,d5,d6,d7

	IO0SET = 0x00080000;		//e = 1;
	delay_ms(1);
	IO0CLR = 0x00080000;		//e = 0;

	IO0CLR = 0x00ff0000;		//clear all port pins p0.16 to p0.23...
	IO0SET = (ch& 0x0f) << 20;		//map ch with d4,d5,d6,d7

	IO0SET = 0x00080000;		//e = 1;
	delay_ms(1);
	IO0CLR = 0x00080000;		//e = 0;


}//end of wr_cmd...
```

```
voidwr_data(unsigned char ch)
{
        delay_ms(10);

        IO0CLR = 0x00ff0000;            //clear all port pins p0.16 to p0.23...
        IO0SET = 0x00020000;            //rs = 1;

        IO0CLR = 0x00f00000;            //clear all port pins p0.16 to p0.23...
        IO0SET = (ch& 0xf0) << 16;              //map ch with d4,d5,d6,d7

        IO0SET = 0x00080000;            //e = 1;
        delay_ms(1);
        IO0CLR = 0x00080000;            //e = 0;

        IO0CLR = 0x00f00000;
        //clear all port pins p0.16 to p0.23...

        IO0SET = (ch& 0x0f) << 20;
   //map ch with d4,d5,d6,d7

        IO0SET = 0x00080000;            //e = 1;
        delay_ms(1);
        IO0CLR = 0x00080000;            //e = 0;


}//end of wr_cmd0...


voiddisplay_lcd_string(unsigned char *ch)
{

unsigned char cnt = 0;

        wr_cmd(0x01);

        while((*ch) != '\0')
        {
                wr_data(*ch);
                ch++;
                cnt++;
                if(cnt == 16)
                        wr_cmd(0xc0);

        }

}//end of display_lcd_string...
```

```
voiddelay_ms(unsigned int i)
{

        unsignedintj,k;

        for(j = 0; j <= i; j++)
        {
                for(k = 0; k <= 15000; k++)
                {}
        }
}//end of delay_ms...

voidget_key()
{
        while(key_ready == 0);
        key_code = lut[key_code];

}//end of get_key...

voidkey_process()
{
        wr_cmd(0xc0);
        wr_data(key_code);
        key_release();
}//end of key_process...

voidkey_release()
{
        while(nkp == 0);
        nkp = key_ready = 0;

}//end of key_release...
```

Output: *Inthis program after pressing any ,its code is send to serial port using UART0.Youcan see output on display*

WEEK-4

Experiment No.4

Aim : To write an embedded C program for **interfacing LED and PWM** and to verify the output in the ARM kit

Apparatus: 1. ARM7-LPC2148 Trainer kit

2. 5V Adapter

3. RS-232 Cable

Source code:

```
#include "LPC214x.H"                        // LPC214x definitions
#include "string.h"
voidInitializePWM(void);
voidDisplayPWMData(intdat);
voidDisplayLCD(char LineNumber,char *Message);
voidInitializeLCD();
voidConvertHextoBCD(unsigned int a);
int main (void)
{
      intval=900;
      InitializeLCD();                      // Initialize LCD
      DisplayLCD(0,"  PWM Testing ");       // Display Message
      DisplayLCD(1,"PWM Data:0900  ");
      InitializePWM();                              // Initialize PWM
      IODIR0 &= 0xffffff7d;
      while (1)
      {
            if((IOPIN0 & 0x02) == 0)
            {                                       // Increment switch pressed
                  if((IOPIN0 & 0x02) == 0)
                  {
                        if(val> 50)
                        val -= 50;          // Decrement PWM value
                        ConvertHextoBCD(val);
PWMMR4 = val;                                                   // Set value to PWM 4
                                                                        register
                        PWMMR5 = 950;       // Set value for PWM 5 register
                        PWMLER = 0x30;      // Latch the value
                        PWMTCR = 0x00000002;        // Reset counter and prescaler
                        PWMTCR = 0x00000009;                    }
                  while((IOPIN0 & 0x02) == 0);
            }
            if((IOPIN0 & 0x80) == 0)
            { // Decrement
```

```
                    if((IOPIN0 & 0x80) == 0)

                    {
                        if(val<900)
                            val += 50;
                        ConvertHextoBCD(val);
                        PWMMR4 = val;                    // Set value to PWM 4
                        register
                        PWMMR5 = 950;            // Set value for PWM 5 register
                        PWMLER = 0x30;           // Latch the value
                        PWMTCR = 0x00000002;     // Reset counter and prescaler
                        PWMTCR = 0x00000009;
                      }
                    while((IOPIN0 & 0x80) == 0);
                }
        }
}
voidInitializePWM (void)
{
    PINSEL1 = 0x00000400;                        // Enable P0.21 - PWM5
    PWMPR  = 0x00000000;            // Load prescaler
    PWMPCR = 0x00002020;             // PWM channel 5 output enabled, double edge control
    PWMMCR = 0x00010000;            // On match with timer reset the counter
    PWMMR0 = 1000;            // set cycle rate to sixteen ticks
    PWMMR4 = 900;
    PWMMR5 = 950;
    PWMLER = 0x30;            // enable shadow latch for match 5
    PWMTCR = 0x00000002;            // Reset counter and prescaler
    PWMTCR = 0x00000009;            // enable counter and PWM, release counter from reset
}
voidConvertHextoBCD(unsigned int a)
{
    unsigned char t[20]="PWM
            Data:0000"; t[9] = '0';
            t[10] = a/100
            + '0'; a -=
            (a/100) *
            100; t[11] =
            a/10 + '0';
            t[12] = a%10
            + '0';
            DisplayLCD(
            1,t);
}
void __gccmain()
{

}
```

RESULT:

Thus the Embedded C program for **interfacing LED and PWM** is written and executed. The output is verified in the ARM kit.

WEEK-5

Experiment No.5

Aim **:** Write an embedded C program to interface Stepper motor to ARM7

Apparatus: 1. ARM7-LPC2148 Trainer kit

2. 5V Adapter
3. RS-232 Cable
4. Stepper Motor

Source Code:

```
#include <LPC214X.H>
void delay_1sec(void);
int main()
{
        VPBDIV      = 0x00000000;                   //this is a reset value we can even
change the vaule
                                                    //VPB clock is 1/4th of
Processor clock

        PINSEL0 = 0x00000000;                   // p0.0 to p0.15 made as GPIO
        PINSEL1 = 0x00000000;                   //p0.16 to p0.31 made as GPIO

        IO0DIR  = 0xffffffff;               //all port pins(p0.0 to p0.31) made as output


        while(1)

        {

                IO0SET      = 0x40000040;                   //EN1,2 = p0.6 =1 and En3,4
= p0.30 =1

                IO0PIN  = 0x40000060;                   //en1,2 =en3,4
=i/p1=1,,,i/p2=i/p3=i/p4=0

                delay_1sec();

                IO0PIN  = 0x40000042;                   //en1,2 =en3,4
=i/p2=1,,,i/p1=i/p3=i/p4=0

                delay_1sec();
```

```
                IO0PIN  = 0x50000040;                  //en1,2 =en3,4
=i/p3=1,,,i/p2=i/p1=i/p4=0

                delay_1sec();

                IO0PIN  = 0x40400040;                  //en1,2 =en3,4
=i/p4=1,,,i/p2=i/p3=i/p1=0

                delay_1sec();

        }
}

void delay_1sec()
{
        register unsigned int i;
        for(i=0;i<=12000;i++) ;
}
```

Output: You can see stepper motor moving in particular direction and corresponding phasechanges

WEEK-6

Experiment No.6

Aim **:** Write an embedded C program to interface DC motor to ARM7

Apparatus: 1. ARM7-LPC2148 Trainer kit

2. 5V Adapter
3. RS-232 Cable
4. DC Motor

Source Code:

```
#include <LPC214X.H>
voiddelay_sec(unsigned int a);
int main()
{
        VPBDIV      = 0x00000000;                   //reset value we can change the vaule
                                                    //VPB clock is same as 1/4th
of Processor clock

        PINSEL0 = 0x00000000;                   // p0.0 to p0.15 made as GPIO
        PINSEL1 = 0x00000000;                   //p0.16 to p0.31 made as GPIO

        IO0DIR  = 0xffffffff;               //all port pins(p0.0 to p0.31) made as output


        while(1)

        {

                IO0SET      = 0x50000042;                   //EN1,2 and En3,4 and i/p1
and i/p3 = 1

                IO0CLR  = 0x00400020;               //i/p2 and i/p4 =0


                delay_sec(1);


                IO0SET      = 0x40400060;                   //EN1,2 and En3,4 and i/p1
and i/p3 = 1

                IO0CLR  = 0x10000002;               //i/p2 and i/p4 =0

                delay_sec(1);
```

```
        }
}

voiddelay_sec(unsigned int a)
{
        register unsigned int i;
        a*=12000000;
        for(i=0;i<=a;i++) ;
}
```

Output: You can see stepper motor moving in particular direction

WEEK-7

Experiment No.7

Aim **:** Study and characteristics of the Programmable Gain Amplifier (PGA).

Apparatus: 1. PSOC Board

2. 5V Adapter
3. Parallel Cable
4. PSOC designer

Source code:

```
#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules

void main()
{
   PGA_1_SetGain(PGA_1_G2_00);
   PGA_1_Start(PGA_1_MEDPOWER);

}
```

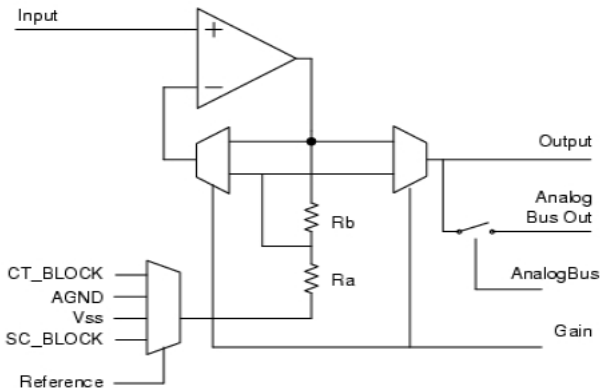


Fig: PGA Block Diagram

Fundamentals:

PGA is an OP-AMP based non-inverting amplifier with user programmable gain. This has high input impedance, wide bandwidth and selectable reference. It amplifies an internally or externally applied signal.

WEEK-8

Experiment No.8

Aim : Realization of low pass, high pass and band pass filters and their characteristics

Apparatus: 1. PSOC Board

2. 5V Adapter

3. Parallel Cable

4. PSOC designer

5. CRO

Source code:

Low pass filter:

```
#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules
void main()
{
    PGA_1_SetGain(PGA_1_G1_00);
   PGA_1_Start(PGA_1_MEDPOWER);
     LPF2_1_Start(LPF2_1_HIGHPOWER);
}
```

Band pass filter:

```
#include <m8c.h>
#include "PSoCAPI.h"
void main()
{
PGA_1_SetPower(PGA_1_HIGHPOWER);

   PGA_1_SetGain(PGA_1_G1_00);

  BPF2_1_Start(BPF2_1_HIGHPOWER );
while(1);
```

WEEK-9

Experiment No.9

Aim **:** Write a program for ADC and DAC

Apparatus: 1. PSOC Board

2. 5V Adapter

3. Parallel Cable

4. PSOC designer

5. CRO

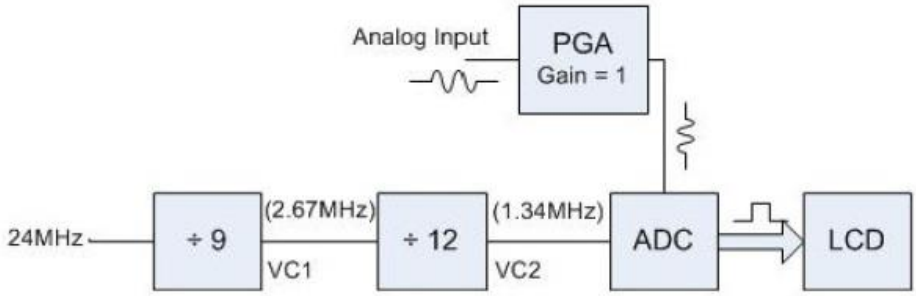


Fig: ADC Configuration Block Diagram

Source codeADC:

```
#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules
void main()
{
intiData;
  M8C_EnableGInt;
  PGA_1_SetGain(PGA_1_G1_00);
  PGA_1_Start(PGA_1_MEDPOWER);
  ADCINC14_1_Start(ADCINC14_1_HIGHPOWER);          //turn on analog section
  ADCINC14_1_GetSamples(0);                        //start adc to read
continuously
  LCD_1_Start();
```

```
for(;;)
  {
        while(ADCINC14_1_fIsDataAvailable()==0);        //wait for data to be ready
              iData=ADCINC14_1_iGetData();
              ADCINC14_1_ClearFlag();                                  //Get data
              LCD_1_Position(0,5);                                  //Place LCD cursor at
row 0,column 5
              LCD_1_PrHexInt(iData);                                  //print "PSOC
LCD" on the LCd
        }
}
```

Source codeDAC :

```
#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules

voiddelay_sec(int);
void main()
{

        int count;
        LCD_1_Start();
        DAC9_1_Start(DAC9_1_FULLPOWER);
        while(1)
        {
              for(count=0;count<=512;)
              {
                    LCD_1_Position(0,6);
                    LCD_1_PrHexInt(count);
                    //DAC9_1_WriteStall(count);
                    DAC9_1_WriteBlind(count);
                    delay_sec(5);
                    count=count+10;
```

```
                }
        }
}


voiddelay_sec(int sec)
{
        inti,j,secd;
        for(secd=0;secd<=sec;secd++)
        for(i=0;i<=2;i++)
                for(j=0;j<=20480;j++)
                {
                }
}
```

Fundamentals:

An ADC is a circuit that converts analog signals to 8/16/32 bit digitalsignals. We can use the digital data for another digital communication block.Example given below shows the design of ADC. We will make the ADC designby using a PGA, ADC and LCD user module. The block diagram for this design is as shown in the figure above.

WEEK-10

Experiment No.10

Aim **:** Write a program for digital function implementation using digital blocks

Apparatus: 1. PSOC Board

2. 5V Adapter

3. Parallel Cable

4. PSOC designer

Source code:

a) Counter for blinking LED:

```
#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules


void main()
{
   PRT2DR = 0x00;
   M8C_EnableGInt;                  /* enable global interrupts */
   Counter16_1_EnableInt();             /* disable the interrupt    */
   Counter16_1_Start();              /* start the counter        */
}
```

b) PWM:

```
#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules


void main()
{
  PWM16_1_Start();
  PWM16_2_Start();
}
```

c) Inverter:

```
#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules


void main()
{
```

```
        DigInv_1_Start();

    }
```

d) Buffer:

```
#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules


void main()
{
        BYTE temp;
   DigBuf_1_Start();
   CMPPRG_1_SetRef(CMPPRG_1_REF0_500 );          //set ref value
   CMPPRG_1_Start(CMPPRG_1_MEDPOWER);            //set power level and turn it on

}
```

WEEK-11

Experiment No.11

Aim **:** Write a program to verify timer operation

Apparatus: 1. PSOC Board

2. 5V Adapter

3. Parallel Cable

4. PSOC designer

Source code:

```
#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules


#pragma interrupt_handler Timer16_ISR_C

charbC_OpCounter;


//-------------------------------------------------------------------------
//  FUNCTION NAME: Mainc
//
//  DESCRIPTION:
//     Main function. Performs system initialization and loops infinitely.
//
//-------------------------------------------------------------------------
//
//  ARGUMENTS:       None
//
//  RETURNS:         None.
//
//  SIDE EFFECTS:    None.
//
//  THEORY of OPERATION or PROCEDURE:
//    1) Start the user modules
//    2) Loop Infinitely
//
void main()
{
   //Enable the Global Interrupt
   M8C_EnableGInt;

   //Enable the Timer interrupt and Start the UM
   Timer16_1_EnableInt();
   Timer16_1_Start();
```

```
//infinteloop.Processing done only at Timer_ISR.
while(1);
}

//-------------------------------------------------------------------------
//  FUNCTION NAME: Timer16_ISR_C
//
//  DESCRIPTION:
//      Interrupt Service routine of Timer16 usermodule written in C.
//      The _Timer16_ISR subroutine In the Timer16INT.asm file,
//      redirects the flow to this subroutine.
//-------------------------------------------------------------------------
//
//  ARGUMENTS:       None
//  RETURNS:         None.
//  SIDE EFFECTS:    None.
//
//  THEORY of OPERATION or PROCEDURE:
//       A Terminal Count interrupt occurs at an interval of 1 second and this ISR is serviced
//       A variable is incremented. The variable is reset to zero once its value
//       reaches 0x10(ie.,16).  The variable is written to Port2.
//
void Timer16_ISR_C()
{
bC_OpCounter++;

if (bC_OpCounter>= 0x10) {
bC_OpCounter = 0;
   }

   PRT2DR = bC_OpCounter;
}
```

WEEK-12

Experiment No.12

Aim **:** Write a program to interface stepper motor

Apparatus: 1. PSOC Board

2. 5V Adapter

3. Parallel Cable

4. PSOC designer

Source code:

```
#include <m8c.h>        // part specific constants and macros
#include "PSoCAPI.h"    // PSoC API definitions for all User Modules
#pragma interrupt_handler RX8_1_ISR_C

// in this code default mode is normal_sequence_forward is repersents the charcter 'a'
voidmotor_delay(int);
voidnormal_sequence_forward(void);
voidnormal_sequence_reverse(void);

int flag=1;
BYTE receiver_data;
int ds=15;      //ds means default speed
chardefault_mode='a';
chardefault_direction='f';

voiddelay_sec(int sec)
{
inti,j,secd;
for (secd=0;secd<=sec;secd++)
for(i=0;i<=2;i++)
for (j= 0;j<=20480;j++)
   {
   }
}

voidmotor_delay(int sec)
{
inti,j,secd;

for (secd=0;secd<=sec;secd++)
for(i=0;i<=4;i++)
                for (j= 0;j<=400;j++)
                        {
                        }
```

```
}
//-------------------------------------------------------------------------------//
voidnormal_sequence_reverse(){
        while(1){
        if(flag){
           PRT0DR=0x05;
        motor_delay(ds);
           PRT0DR=0x09;
        motor_delay(ds);
           PRT0DR=0x0a;
        motor_delay(ds);
           PRT0DR=0x06;
        motor_delay(ds);
           }

        else
        break;
          }
}

//-------------------------------------------------------------------------------//
voidnormal_sequence_forward(){
        while(1){
        if(flag){
           PRT0DR=0x05;
        motor_delay(ds);
           PRT0DR=0x06;
        motor_delay(ds);
           PRT0DR=0x0a;
        motor_delay(ds);
           PRT0DR=0x09;
        motor_delay(ds);
           }

        else
        break;
          }
}


void main()
{
inti,j;

M8C_EnableGInt;     // enable Globale interrupts
RX8_1_EnableInt();
RX8_1_Start(RX8_1_PARITY_NONE);
TX8_1_Start(TX8_PARITY_NONE);
```

```
LCD_1_Start();

    TX8_1_CPutString("\r\n This is tha Stepper Motor interfacing program");
    TX8_1_CPutString("\r\n Read the follwoinhinstrcutions:\r\n");
    TX8_1_CPutString("\r\n 1.  Normal sequence     = 'a'");
    TX8_1_CPutString("\r\n 4.  Forward directiom   = 'f'");
    TX8_1_CPutString("\r\n 5.  Reverse directiom   = 'r'");
    TX8_1_CPutString("\r\n 8.  Stop the motor      = 'd'");

    TX8_1_CPutString("\r\n\r\n ----------------------------------------------\r\n\r\n");

while(1){

if(receiver_data=='f' || receiver_data=='r')
default_direction=receiver_data;

else if(receiver_data=='a' || receiver_data=='d' )
default_mode=receiver_data;

flag=1;

switch(default_mode){

case 'a': LCD_1_Position(0,0);
            LCD_1_PrCString("Normal Sequence");
            LCD_1_Position(1,0);
          if(default_direction=='f'){
            LCD_1_PrCString("Forward mode");
            TX8_1_CPutString("\r\n This is the Normal Sequence Forward Mode\r\n");
          normal_sequence_forward();
            }
          else if(default_direction=='r'){
            LCD_1_PrCString("Reverse mode");
            TX8_1_CPutString("\r\n This is the Normal Sequence Reverse Mode\r\n");
          normal_sequence_reverse();
            }
break;


case 'd': LCD_1_Control(0x01);
                    LCD_1_Position(0,0);
                    TX8_1_CPutString("\r\n The system is stop mode\r\n");
                            LCD_1_PrCString("System stop");
while(1){
if(flag)
            PRT0DR=0x00;

          else
```

```
        break;
            }

break;

        }

  }

}
//RX8 Interrupr service routine
void RX8_1_ISR_C()
{
flag=0;
receiver_data = RX8_1_bReadRxData();
return;
}
```