# MANIPAL INSTITUTE OF TECHNOLOGY
# Manipal – 576 104

## DEPARTMENT OF INFORMATION & COMMUNICATION TECHNOLOGY


**CERTIFICATE**

This is to certify that Ms./Mr. ……...…… Reg. No. …..…… Section: …… Roll No: ……... has satisfactorily completed the lab exercises prescribed for Embedded System Lab [ICT-3111 ] of Third Year B. Tech (IT) Degree at MIT, Manipal, in the academic year 2017-2018**.**

Date: …….....

Signature of the faculty

# CONTENTS

**Course Objectives**

- To gain knowledge in assembly language and Embedded C programming
- To implement the programs using various instructions from the instruction set of microcontroller.
- To understand various interfacing circuits necessary for various applications and programming using ARM.

**Course Outcomes**

At the end of this course, students will be able to

- To gain knowledge about simulator for an embedded system.
- To comprehend the software development for ARM cortex-M microcontroller using assembly language.
- To comprehend the software development for ARM cortex-M microcontroller using embedded C language
- To design real world systems using ARM cortex-M embedded system.

**Evaluation plan**

| **Split up of 60 marks for Regular Lab Evaluation** |
|---|
| Four regular evaluations will be carried out once in every three weeks. Each evaluation is for 10 marks with following split up:<br>Record : 4 Marks<br>Evaluation: 4 Marks<br>Execution: 2 Marks<br>Total = 10 Marks<br>Total Regular Evaluation Marks: 4 * 10 =40 Marks |
| Students are required to carry out a mini project in Embedded System using ARM LPC1768 Controller and ALS evaluation board<br>Output and work done: 10 Marks<br>Report: 5 Marks<br>Viva a: 5 Marks<br>Total mini project marks: 20 Marks |
| **Total Internal Marks : Total Regular Evaluation Marks+ Total Mini project Marks: 40+20=60 Marks** |
| **End Semester Lab evaluation: 40 marks (Duration 2 Hrs)** |

## INSTRUCTIONS TO THE STUDENTS

### Pre- Lab Session Instructions

1. Students should carry the Lab Manual Book and the required stationery to every lab session
2. Be in time and follow the institution dress code
3. Must sign in the log register provided
4. Make sure to occupy the allotted seat and answer the attendance
5. Adhere to the rules and maintain the decorum

### In- Lab Session Instructions

- Follow the instructions on the allotted exercises
- Show the program and results to the instructors on completion of experiments
- On receiving approval from the instructor, copy the program and results in the Lab record
- Prescribed textbooks and class notes can be kept ready for reference if required

### General Instructions for the exercises in Lab

- Implement the given exercise individually as well as group.
- The programs should meet the following criteria:
    - Programs should be interactive with appropriate prompt messages, error messages if any, and descriptive messages for outputs.
    - Comments should be used to give the statement of the problem.
    - Statements within the program should be properly indented.
- Plagiarism (copying from others) is strictly prohibited and would invite severe penalty during evaluation.
- The exercises for each lab is divided under three sets:
    - Solved exercise
    - Lab exercises - to be completed during lab hours
    - Additional Exercises - to be completed outside the lab or in the lab to enhance the skill
- In case a student misses a lab class, he/ she must ensure that the experiment is completed during the repetition class with the permission of the faculty concerned but credit will be given only to one day's experiment(s).

LAB1:

# Start up Keil uVision4

## Objectives:

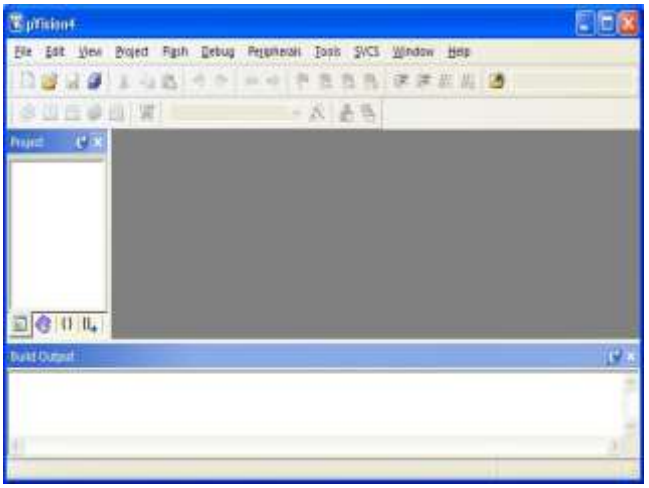
Aim: Understand the usage of Keil u Vision 4 software for assembly language.

Before you start up, you are recommended that you create a folder to hold all your project files. For example: you can create a folder "FirstARM-Project" ready before hand.

**Step1:**

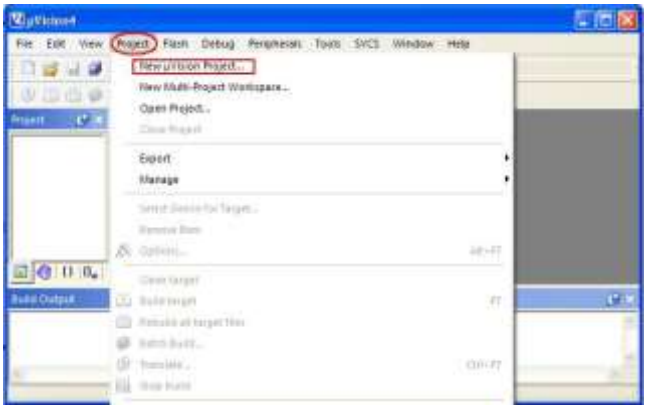
You can start up uVision4 by clicking on the icon 

from the desktop or from the "Start" menu or "All Programs" on a lab PC. You will see the following screen.



**Step2:** Create a project

To create a project, click on the "Project" menu from the uVision4 screen and select "New uVision Project...".

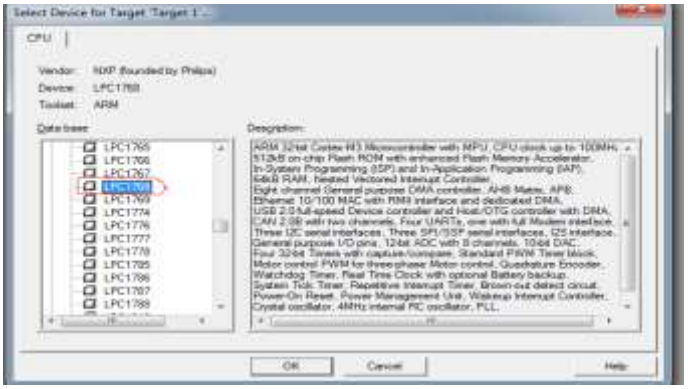



Then, select a folder, give project a name and save.

From the "Select Device for Target" window, select "NXP" as the vendor. In that select LPC1768 ARM controller , then click on OK button

**Caution**

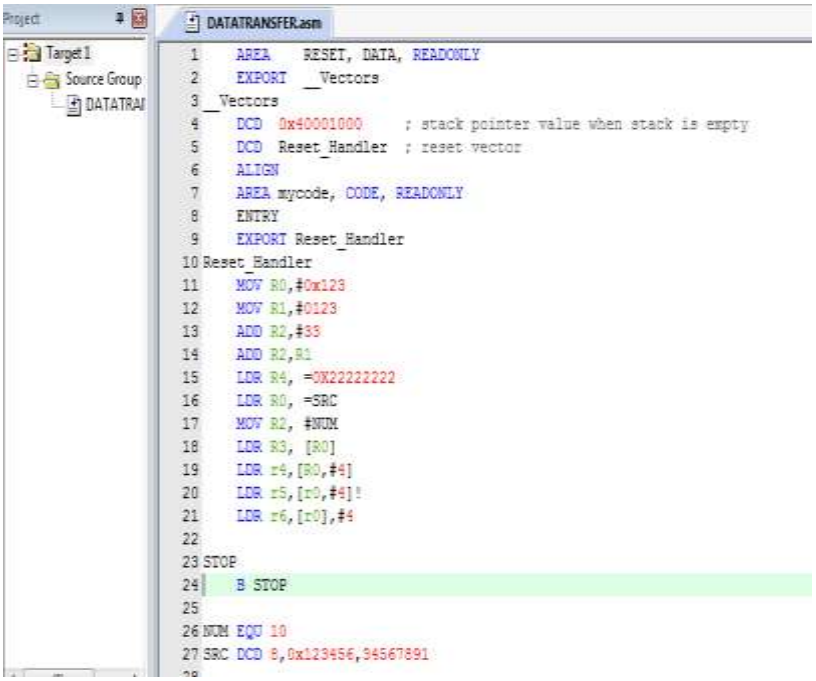
When you choose the chip some general information of the chip is shown in the ***Description*** box.




Make sure you click on "NO" for the following pop up window.

## Step3: Create Source File

From the "File" menu, select "New", you will see the "Text1*" text edit window. That is the place you will write your ARM assembly language program. You can write the program into this window. (Note: give a tab space at the beginning)

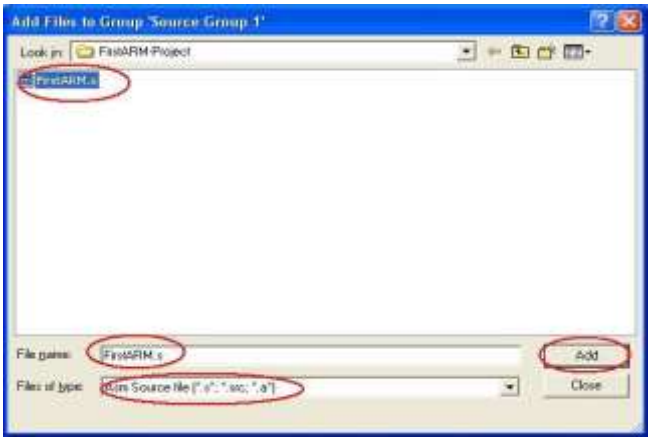



Save the program by clicking on the "Save" or "Save As" from the "File" menu and give it a name.


## Add Source File to the Project

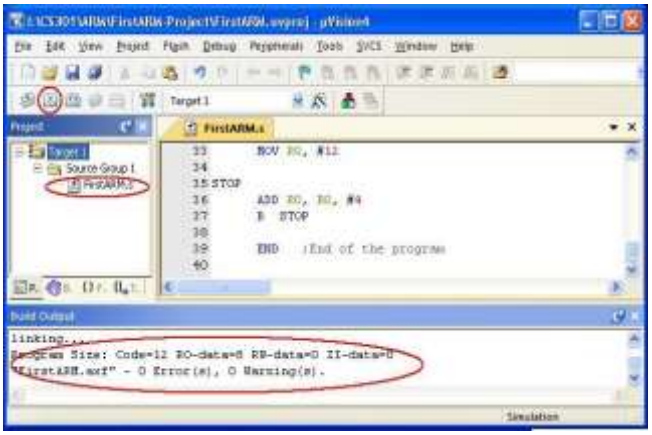
Right click on the "Source Group 1", select "Add Files to Group 'Source Group 1'".


Select "Files of type" as "asm Source file (*.s*;*.src*;*.a*), then select the file "FirstARM.s" for example. Click on "Add", and then click on "Close".



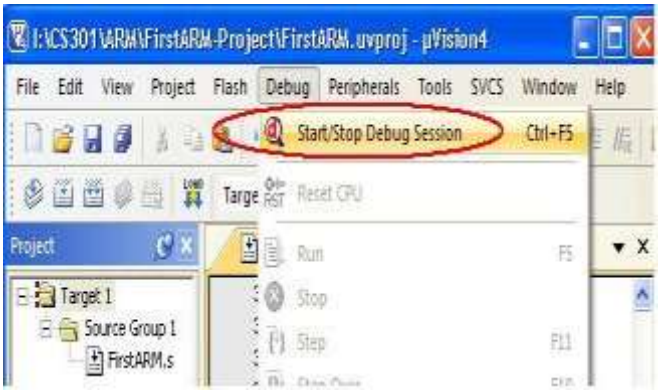

## Step4: Build your project

Click on the "+" beside the "Source Group 1", you will see the program "FirstARM.s". Click on the "Build" button or from the "Project" menu, you will see the following screen.



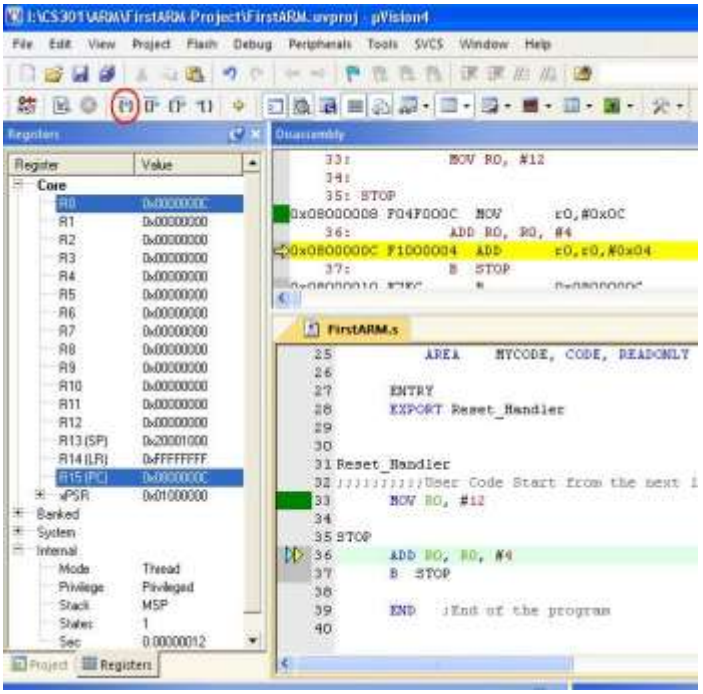
## Run the program in your project

Run the program through "Debug" menu.

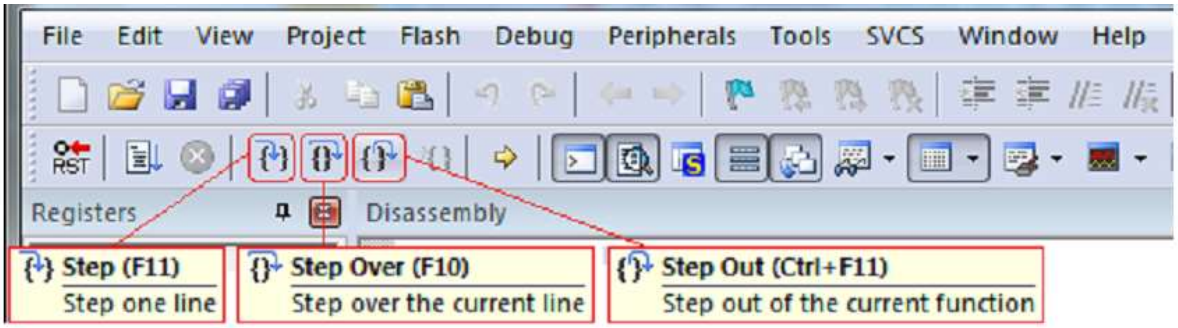



Click on "OK" for the pop up window showing "EVALUATION MODE, Running with Code Size Limit: 32K".

Open uVision4 to full screen to have a better and complete view. The left hand side window shows the registers and the right side window shows the program code. There are some other windows open. Adjust the size of them to have better view. Run the program step by step; observe the change of the values in the registers.




To trace the program use the **Step Over** button or click on **Step Over** from the Debug menu. It executes the instructions of the program one after another. To trace the program one can use the **Step** button, as well. The difference between the **Step Over** and **Step** is in executing functions. While **Step** goes into the function and executes its instructions one by one, **Step Over** executes the function completely and goes to the instruction next to the function. To see the difference between them, trace the program once with **Step Over** and then with **Step**. When PC is executing the function, if you want the function to be executed completely you can use **Step Out**. In this case, the instructions of the function will be executed, it returns from the function, and goes to the instruction which is next to the function call.




Click on the "**Start/Stop Debug** Session" again to stop execution of the program.

## An example ARM assembly language module

An ARM assembly language module has several constituent parts.

These are:

- Extensible Linking Format (ELF) sections (defined by the AREA directive).
- Application entry (defined by the ENTRY directive).
- Application execution.
- Program end (defined by the END directive).

Consider the following example

```
AREA     mycode, CODE, READONLY
                                ; Name this block of code is mycode
          ENTRY                 ; Mark first instruction to execute
start
          MOV       r0, #10     ; Set up parameters
          MOV       r1, #3
          ADD       r0, r0, r1  ; r0 = r0 + r1
          END                   ; Mark end of file
```

**Application entry**

The ENTRY directive declares an entry point to the program. It marks the first instruction to be executed. In applications using the C library, an entry point is also contained within the C library initialization code. Initialization code and exception handlers also contain entry points.

**Application execution**

The application code begins executing at the label start, where it loads the decimal values 10 and 3 into registers R0 and R1. These registers are added together and the result is placed in R0.

**Program end**

The END directive instructs the assembler to stop processing the source file. Every assembly language source module must finish with an END directive on a last line. Any line following the END directive is ignored by the assembler.

LAB NO: 1

**Title:** Data transfer

**Aim:** Familiarization of ARM data transfer instructions.

**Introduction to ARM addressing modes:** Data can be transferred into and out of ARM controller using different addressing modes. There are different ways to specify the address of the operands for any given operations such as load, add or branch. The different ways of determining the address of the operands are called addressing modes. In this lab, we are going to explore different data transfer instructions of ARM processor and learn how all instructions can fit into a single word (32 bits).

**Question:** Write a ARM assembly language program to copy a 32 bit binary number from code memory to data memory.

Input : SRC = 0X00000008 at location pointed by R0

Output : DST = 0X00000008 at location pointed by R1

```
        AREA    RESET, DATA, READONLY
        EXPORT  __Vectors

__Vectors
        DCD  0x10001000     ; stack pointer value when stack is empty
        DCD  Reset_Handler  ; reset vector

        ALIGN

        AREA mycode, CODE, READONLY
        ENTRY
        EXPORT Reset_Handler

Reset_Handler
        LDR R0, =SRC;       Load address of SRC into R0
        LDR R1, =DST;       Load the address of DST onto R1
        LDR R3, [R0];       Load data pointed by R0 into R3
        STR R3,[R1]  ;      Store data from R3 into the address pointed by R1
```

```
STOP
    B STOP

SRC DCD 0x00000008

    AREA mydata, DATA, READWRITE

DST DCD 0

    END
```

**Observations to be made**

1. **Data storage into the memory:** Click on Memory window and select the Memory1 option and type the address pointed by R0 in address space. Observe how the data is stored in the memory.
2. **Data movement from one memory to another memory:** Click on Memory window and select the Memory2 option and type address pointed by R1 in address space. Observe data movement to another location before execution and after execution.

**Exercise questions**

1. Write an ARM assembly language program to transfer block of TEN 32- bit binary numbers from data memory to data memory.
    a. When the source and destination blocks are non-overlapping
    b. When the source and destination blocks are overlapping

   Hint: Use Register indirect addressing mode or indexed addressing mode

2. Reverse an array of TEN 32- bit binary numbers available in the data memory.

**LAB 2:**

**Title:** Arithmetic Operations.

**Aim**: Familiarization of Arithmetic operations - addition and subtraction

**Question:** Write a program to add two 32- bit numbers.

```
        AREA    RESET, DATA, READONLY
        EXPORT  __Vectors

__Vectors
        DCD  0x10001000     ; stack pointer value when stack is empty
        DCD  Reset_Handler  ; reset vector

        ALIGN
AREA mycode, CODE, READONLY
        ENTRY
        EXPORT Reset_Handler

Reset_Handler
        LDR R0, =VALUE1     ;pointer to the first value1
        LDR R1,[R0]         ;load the first value into R1
        LDR R0,=VALU2       ;pointer to the second value
        LDR R3, [R0]        ;load  second number into r3
        ADDS R6, R1,R3      ;add two numbers and store the result in r6
        LDR R2, =RESULT
        STR R6,[R2]
STOP
        B STOP
VALUE1 DCD 0X12345678       ; First 32 bit number
VALUE2 DCD 0XABCDEF12       ; Second 32 bit number
        AREA mydata, DATA, READWRITE
RESULT DCD 0
```

**Exercise questions**

1. Write a program to add two 128- bit numbers available in the code memory and store the result in the data memory.
2. Write a program to subtract two 32- bit numbers available in the code memory and store the result in the data memory.
3. Write a program to subtract two 128 -bit numbers available in the code memory and store the result in the data memory.
4. Write a program to add TEN 32-bit binary numbers available in the code memory and store the result in the data memory.

**LAB 3**

**Title:** Arithmetic Operations.

**Aim:** Familiarization of Arithmetic operations – multiplication, division, GCD, LCM and BCD arithmetic.

**Question:** Write an assembly program to multiply two 32- bit binary numbers

```
        AREA    RESET, DATA, READONLY
        EXPORT  __Vectors

__Vectors
        DCD  0x10001000     ; stack pointer value when stack is empty
        DCD  Reset_Handler  ; reset vector

        ALIGN

        AREA mycode, CODE, READONLY
        ENTRY
        EXPORT Reset_Handler

Reset_Handler
                LDR R0, =VALUE1     ;pointer to the first value
                LDRH R1,[R0]        ;load the first value into r1
                LDR R0,=VALU2       ;pointer to the second value
                LDRH R3, [R0]       ;load  second number into r3
                MUL R6, R1,R3       ;Multiply the values from R1 and R3 and store
                                    ;least significant 32 bit number into R6.
                LDR R2, =RESULT
                STR R6,[R2]         ; store result in r6
        STOP
                B STOP
        VALUE1 DCD 0X1234; First 32 bit number
        VALUE2 DCD 0X5678; Second 32 bit number
                AREA mydata, DATA, READWRITE
        RESULT DCD 0
```

**Note: If the result is more than 32 bits, use UMULL instruction.**

Question: Write a program to divide a 32 bit number by 16 bit number

- . We follow repetitive subtraction method to divide two numbers.

```
        AREA    RESET, DATA, READONLY
        EXPORT  __Vectors

__Vectors
        DCD  0x10001000     ; stack pointer value when stack is empty
        DCD  Reset_Handler  ; reset vector

        ALIGN
        AREA mycode, CODE, READONLY
        ENTRY
        EXPORT Reset_Handler

Reset_Handler
                MOV R2,#0
                LDR R0, =VALUE1     ;pointer to the first value
                LDR R1,[R0]         ;load the first value into r1
                LDR R0,=VALUE2      ;pointer to the second value
                LDR R3, [R0]        ;load  second number into r3
        up      SUB  R1, R3         ;Subtract two numbers
                ADD R2,#01          ;increment a counter
                CMP R1,R3           ;compare two numbers
                BCS up              ;check r1 is greater than r3 or not, if yes loop
                LDR R6, =RESULT     ;Quotient
                STR R2,[R6,#4]
                STR R1,[R6]         ;Store remainder.
        STOP
                B STOP
        VALUE1 DCD 0x12345678   ;First 32 bit number
        VALUE2 DCD 0x00001A1B   ;Second 16 bit number
                AREA mydata, DATA, READWRITE
        RESULT DCD 0,0
```

**Exercise questions**

1. Write a program to multiply two 32 bit numbers using repetitive addition
   Hint: If two numbers are in R0 and R1 registers then use following algorithm

```
Sum=0;
do { sum=sum+R0; R1--;   ;Use ADS instruction for addition and use  ADD
                         ;instruction to increment a register by 1
if carry then
R2++;                    ;Increment carry value by one.
 } while(R1!=0);         ;Use Compare instruction to check greater
                         ;than or not. And Brach instructions for loop
Result= R2 and R0
```

2. Repeat the above program for BCD multiplication
3. Write a program two subtract two 8-digit BCD numbers.
4. Find the sum of 'n' natural numbers using MLA instruction.
5. Write an assembly language program to find GCD of two numbers
   Hint:

```
While(a!=b)
{
        If(a>b)
        a=a-b;
        else
        b=b-a;

} Return (a);
```

6. Write an assembly language program to find LCM of two numbers
   Hint: i=1

```
        do{
        remainder= i*a mod  b;
        If (remainder==0)
        Exit;
        Else
           i++;
          } while(remainder!=0);
        Return (i*a);
```

LAB 4:

**Title:** Code conversion**.**

**Aim:** Familiarization of logical instructions and code conversion programs.

**Question:** Write an assembly program to convert a 2- digit hexadecimal number into unpacked ASCII.

```
        AREA    RESET, DATA, READONLY
        EXPORT  __Vectors

__Vectors
        DCD  0x10001000     ; stack pointer value when stack is empty
        DCD  Reset_Handler  ; reset vector
        ALIGN
        AREA mycode, CODE, READONLY
        ENTRY
        EXPORT Reset_Handler

Reset_Handler

                LDR R0,=NUM
                LDR R3,=RESULT
                LDRB R1,[R0]          ; load hex number into register R1
                AND R2,R1,#0x0F       ; mask upper 4 bits
                CMP R2,#09            ; compare  the digit with 09
                BLO DOWN              ; if it is lower than 9 then jump to DOWN
                                      ; label
                ADD R2,#07            ;else add 07 to that number
        DOWN
                ADD R2,#0x30          ; Add 30H to the number, ASCII value of first
                STRB R2,[R3]          ; digit
                AND R4,R1,#0xF0       ; Mask the second digit
                MOV R4,R4,LSR#04      ; Shift right by 4 bits
                CMP R4,#09            ; check for >9 or not
                BLO DOWN1
                ADD R3,#07
        DOWN1
```

```
        ADD R4,#0x30        ; Ascii value of second digit
        STRB R4,[R3,#01]
NUM DCD 0x000003A
        AREA mydata, DATA, READWRITE
RESULT DCD 0
        END
```

**Exercise programs**

1. Write an assembly language program to convert a 32-bit hexadecimal number into unpacked form.
2. Write an assembly language program to covert 8-digit hexadecimal number in unpacked ASCII form into packed form.
3. Write an assembly language program to convert an 8-digit hexadecimal number in the unpacked form into packed form.
4. Write an assembly language program to convert an 8-digit BCD number into hexadecimal.
5. Write an assembly language program to convert an 8-digit hexadecimal number into BCD.

**LAB 5:**
**Title: Sorting, searching and stack**

**Aim:** To understand the logic of looping and sorting.
**Question:** Write an assembly language program to sort an array using bubble sort.

```
                AREA    RESET, DATA, READONLY
                EXPORT  __Vectors

__Vectors
                DCD  0x10001000     ; stack pointer value when stack is empty
                DCD  Reset_Handler  ; reset vector

                ALIGN
                AREA mycode, CODE,READONLY
                ENTRY
        Reset_Handler
                mov r4,#0
                mov r1,#10
                ldr r0, =list
                ldr r2, =result
        up      ldr r3, [r0,r4]
                str r3, [r2,r4]
                add r4, #04
                sub r1,#01
                cmp r1,#00
                bhi up
                ldr r0, =result
                                        ; inner loop counter
                mov r3, #10
                sub r3, r3, #1
                mov r9, r3              ; R9 contains no. of passes
                                        ; outer loop counter
        outer_loop
                mov r5, r0
                mov r4, r3              ; R4- no. of comparisons in a pass
        inner_loop
```

```
        ldr r6, [r5], #4
        ldr r7, [r5]
        cmp r7, r6

        strls r7, [r5, #-4]

        subs r4, r4, #1
        bne inner_loop
        sub r3, #1
        subs r9, r9, #1
        bne outer_loop


list dcd 0x10,0x05,0x33,0x24,0x56,0x77,0x21,0x04,0x87,0x01
      AREA mydata, DATA, READWRITE
result DCW 0,0,0,0,0,0,0,0,0,0
        end
```

**Exercise questions**:

1. Write an assembly program to sort an array using selection sort.
2. Write an assembly program to find the factorial of a unsigned number using recursion
3. Write an assembly program to search an element in an array of ten 32 bit numbers using linear search.
4. Assume that ten 32 bit numbers are stored in registers R1-R10. Sort these numbers in the fully ascending stack using selection sort and store the sorted array back into the registers. Use STM and LDMDB instructions wherever necessary.
5. Repeat the above question (4) for fully descending stack using STMDB and LDM instruction wherever necessary.

**Lab 6**

**Title:** Interfacing LED.

**Aim:** Interface LEDs to the LPC1768 microcontroller using ALS interfacing board.

**Steps to be followed**

**Project Creation in Keil uvision4 IDE:**

- Create a project folder before creating NEW project.
- Use separate folder for each project.
- Open Keil uVision4 IDE software by double clicking on "Keil Uvision4" icon.
- Select "Project" then to "New Project" and save it with a name in the respective Project folder, which is already you created.
- Select the device as "NXP (founded by Philips)" Select "LPC1768" then Press "OK" and then press "YES" button to add "system_LPC17xx.s" file.
- Go to "File", select "New" to open an editor window. Create a source file and use the header file "LPC17xx.h" in the source file and save the file. Color syntax highlighting will be enabled once the file is saved with a Recognized extension such as ".C ".
- Right click on "Source Group 1" and select the option "Add Files to Group 'Source Group 1' "add the. C source file(s) to the group.
- Again right click on Source Group 1 and select the option "Add Files to Group 'Source Group 1' "add the file - C:Keil\ARM\startup\NXP\LPC17xx\system_LPC17xx.c.
- Any changes made to this file at current project will directly change the source system_LPC17xx.C file. As a result other project settings may get altered. So, it is recommended to copy the file. C:Keil\ARM\startup\NXP\LPC17xx\system_LPC17xx.c to the project folder and add to the source group.
- **Important: This file should be added during each project creation.**
- Select "Project" then select "Translate" to compile the File (s).
- Select "Project" , select "Build Target" for building all source files such as ".C","ASM", ".h", files, etc…This will create the hex file if there are no warnings & no errors.

**Sample program to turn ON and OFF LED serially.**

**Note: Before writing the program please check GPIO port pins available in the kit (Refer Appendix A.)**

```
#include <LPC17xx.h>

unsigned int i,j;
unsigned long LED = 0x00000010;

int main(void)
{
 SystemInit()              ;Add these two function for its

                           ;internal operation

 SystemCoreClockUpdate();

 LPC_PINCON->PINSEL0 &= 0xFF0000FF

                           ;Configure  Port0 pins  P0.4-P0.11
                           ;as GPIO

 LPC_GPIO0->FIODIR |= 0x00000FF0;
                           ;Configure P0.4-P0.11 as output

 while(1)
     {
          LED = 0x00000010; Initial value on LED
          for(i=1;i<9;i++)      //ON the LED's serially
          {
           LPC_GPIO0->FIOSET = LED;

                           ; Turn ON LED at LSB(LED

                           ;connected to p0.4)

           for(j=0;j<10000;j++);a random delay
            LED <<= 1; Shift the LED to the left by one
```

```
                                ;unit.

                }                       ; loop  9 times

                LED = 0x00000010;

                for(i=1;i<9;i++)   //OFF the LED's serially
                {
                        LPC_GPIO0->FIOCLR = LED;
                                        ;Turn OFF LED at LSB(LED is
                                        ;connected to p0.4)
                        for(j=0;j<10000;j++);
                        LED <<= 1;
                }

        }
}
```

**Some Settings to be done in KEIL UV4 for Executing C programs :**

- In Project Window Right click "TARGET1" and select "options for target 'TARGET1'. Select the option "Target". Set following values:
    1. XTAL 12.0MHz
    2. Select IROM1 (starting 0×0 size 0×8000).
    3. Select IRAM1 (starting 0×10000000 size 0×8000).
- Then go to option "Output"
  Select "Create Hex file".
- Then go to option "Linker"
  Select use memory layout from target dialog

**Settings to be done at configuration wizard of system_LPC17xx.c file**

- There are three clock sources for CPU. Select Oscillator clock out of three. This selection is done by CLKSRCSEL register.

- If we disable the PLL0 System, clock will be bypassed directly into CPU clock divider register.
- Use CCLKCFG register for choosing the division factor of 4 to get 3 MHz out of 12 MHz Oscillator frequency
- For any other peripherals use the PCLK same as CCLK.

**Follow the steps specified below to carry out the settings.**

- Double click on system_LPC17xx.c file at project window
- Select the configuration wizard at the bottom
- Expand the icons
- Select Clock configuration
- Under System controls and Status registers
  OSCRANGE: Main Oscillator range select 1MHz to 20MHz
  OSCEN: Main oscillator enable √
- Under Clock source select register (CLKSRCSEL)
  CLKSRC: PLL clock source selection Main oscillator
- Disable PLL0 configuration and PLL1 configuration
- Under CPU Clock Configuration register(CCLKCFG)
  CCLKSEL: Divide value for CPU clock for PLL0 4
- Under USB Clock configuration register (USBCLKCFG)
  USBSEL: Divide value for USB clock for PLL0 4
- Under Peripheral clock selection register 0 (PCLKSEL0) and 1 (PCLKSEL1) select Pclk = Cclk for all.
- Under Power control for peripherals (PCONP)
  Enable the power for required peripherals
- If CLKOUT to be studied configure the Clock output configuration register as
  below
  CLKOUTSEL : Main Oscillator
  CLKOUTDIV : 1
  CLKOUT_EN : √

- Call the functions
  SystemInit();

SystemCoreClockUpdate(); at the beginning of the main function. These functions are defined in system_LPC17xx.c where the actual clock and other system control registers are configured.

- A small change is required in the file system_LPC17xx.c after installation. Go to text editor:
  #define PLL0_SETUP 0
  #define PLL1_SETUP 0
  if the above #defines are 1 then make 0

**Components required**

- ALS-SDA-ARMCTXM3-01 : 1 No.
- Power supply (+5V) : 1 No.
- Cross cable for programming and serial communication : 1 No
- One working USB port in the host computer system and PC for downloading the software.
- 10 core FRC cables of 8 inch length 2 No
- USB to B type cable 1 No

**Some Settings for downloading the program in FLASH MAGIC:**

Step1.Connect 9 pin DSUB cross cable from PC to CN9 at the board.

Step2.On the 2 way dip switch SW21. Short jumper JP3.

Step3.Open flash magic 6.01

Step4.Make following setting in Flash magic(Only once)

**a. Communications:**

Device: LPC1768
Com Port: COM1
Baud Rate: 9600
Interface: None(ISP)
Oscillator: 12MHz

b. ERASE:

Select “Erase Blocks Used By Hex File”.

c. Hex file:

Browse and select the Hex file which you want to download.

d. Options:

Select "Verify After Programming".

**Go to Options -> Advanced Options->communications**

Do not select High Speed Communications, keep baud rate 115200.

**Options -> Advanced Options->Hardware config**

Select Use DTR & RTS to control RST & ISP Pin.

Select Keep RTS asserted while COM Port open.

T1 = 50ms. T2 = 100ms.

Step5.Start:

Click "Start" to download the hex file to the controller.

Step6. Connect one end of 10 pin FRC cable to CNA1, Short other end to CNA

Step7. Press reset controller switch SW1 and Check output on the LEDs connected to CNA1.

**Exercise Questions:**

1. Write a C program to display 8-bit binary up counter on the LEDs.
2. Write a C program to read a key and display an 8-bit up/down counter on the LEDs.
   **Hint:** Use key SW2(if SW2=1, up counter else down counter), which is available at CNB1 pin 7. Connect CNB1 to any connector like CNB, CNC etc. Configure corresponding port pin as GPIO using corresponding PINSEL register and input pin using corresponding FIODIR register.
3. Write a program to simulate an 8- bit ring counter with a key press (SW2).

LAB 7.

**Title**: Multiplexed seven segment display

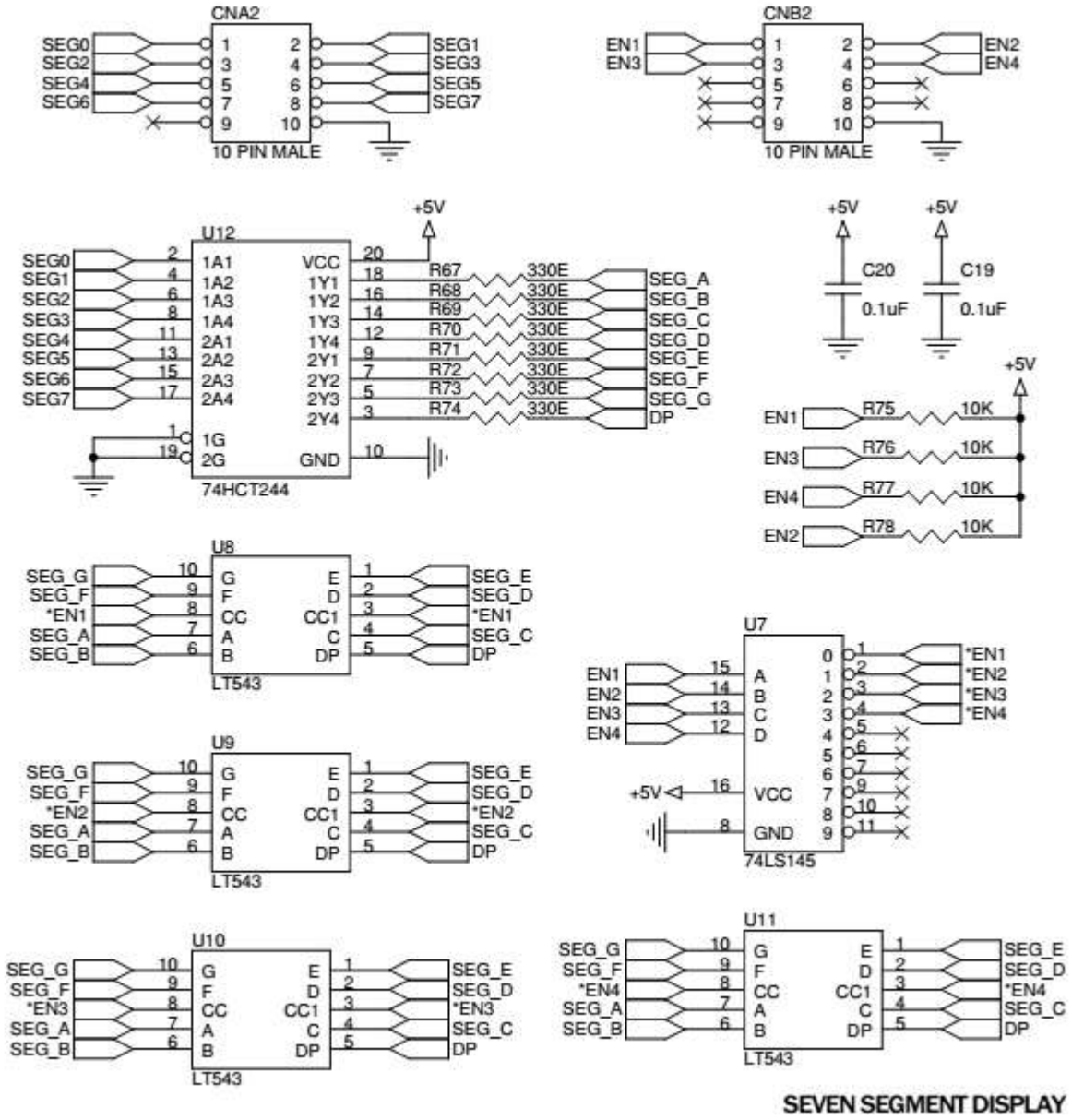
**Aim:** To interface and understand the working of multiplexed seven segments display

**Introduction:**

There are four multiplexed 7-segment display units (U8, U9, U10 and U11) on the board. Each display has 8-inputs SEG_A (Pin-7), SEG_B (Pin-6), SEG_C (Pin-4), SEG_D (Pin-2), SEG_E (Pin-1), SEG_F (Pin-9), SEG_G (Pin-10) and SEG_H (Pin-5) and the remaining pins pin-3 & pin-8 are Common Cathode CC. These segments are common cathode type hence active high devices.

At power on all the segments are pulled up. A four-bit input through CNB2 is used for multiplexing operation. A 4-10 Decoder/Driver U7 is used to accept BCD inputs and provide appropriate outputs for enabling the required display.

Eight-bit data is provided in this block using CNA2. All the data lines are buffered at U12 before giving to the displays.




At controller end any 2 connectors are required for interfacing this block.

```
Lookup Table for displaying 0 to 9


   value= h g f e d c b a  On 7-SEG U8,U9,U10 & U11.
 * 0x3F = 0 0 1 1 1 1 1 1   -> Displaying '0'
 * 0x06 = 0 0 0 0 0 1 1 0   -> Displaying '1'
 * 0x5B = 0 1 0 1 1 0 1 1   -> Displaying '2'
 * 0x4F = 0 1 0 0 1 1 1 1   -> Displaying '3'
 * 0x66 = 0 1 1 0 0 1 1 0   -> Displaying '4'
 * 0x6D = 0 1 1 0 1 1 0 1   -> Displaying '5'
 * 0x7D = 0 1 1 1 1 1 0 1   -> Displaying '6'
 * 0x07 = 0 0 0 0 0 1 1 1   -> Displaying '7'
 * 0x7F = 0 1 1 1 1 1 1 1   -> Displaying '8'
 * 0x6F = 0 1 1 0 1 1 1 1   -> Displaying '9'
```

**Sample program** : To simulate 4-digit BCD up counter on the multiplexed seven segment display.

```
 #include <LPC17xx.h>
 #include <stdio.h>

 #define   FIRST_SEG  0xF87FFFFF
 #define   SECOND_SEG 0xF8FFFFFF
 #define   THIRD_SEG  0xF97FFFFF
 #define   FOURTH_SEG 0xF9FFFFFF
 #define   DISABLE_ALL 0xFA7FFFFF

 unsigned int dig1=0x00,dig2=0x00,dig3=0x00,dig4=0x00;
 unsigned int count = 0x00,dig_count=0x00,temp1=0x00;
 unsigned char
array_dec[10]={0x3F,0x06,0x5B,0x4F,0x66,0x6D,0x7D,0x07,0x7F,0x6F
};
 unsigned char tmr0_flg = 0x00,one_sec_flg = 0x00;
 unsigned long int temp2 = 0x00000000,i=0;
 unsigned int temp3=0x00;
 void delay(void);
 void display(void);

 int main(void)
 {
     SystemInit();
     SystemCoreClockUpdate();
```

```
      LPC_PINCON->PINSEL0 & = 0xFF0000FF;     //P0.4 to P0.11
                                              //GPIO data lines
      LPC_PINCON->PINSEL3 & = 0xFFC03FFF;    //P1.23 to P1.26
                                             //GPIO enable lines

      LPC_GPIO0->FIODIR | = 0x00000FF0;      //P0.4 to P0.11
output
      LPC_GPIO1->FIODIR | = 0x07800000;      //P1.23 to P1.26
output


      while(1)
      {
            Delay();
            dig_count +=1;
            if(dig_count == 0x05)
                  { dig_count = 0x00;
                        one_sec_flg =0xFF;
                  }
            if(one_sec_flg == 0xFF)
            {
                  one_sec_flg = 0x00;
                  dig1 +=1;

                  if(dig1 == 0x0A)
                  {
                        dig1 = 0;
                        dig2 +=1;

                        if(dig2 == 0x0A)
                        {
                              dig2 = 0;
                              dig3+=1;

                              if(dig3 == 0x0A)
                              {
                                    dig3 = 0;
                                    dig4 += 1;

                                    if(dig4 == 0x0A)
                                    {
                                          dig4 = 0;
                                    } //end of dig4
```

```
                              } //end of dig3

                         } //end of dig2

                    }  //end of dig1

          }   //end of one_sec if

          Display();

     } //end of while(1)

}//end of main

void Display(void)      //To Display on 7-segments
{


     if(dig_count == 0x01)       // For Segment U8
     {
          temp1 = dig1;
          LPC_GPIO1->FIOPIN = FIRST_SEG;

     }

     else if(dig_count == 0x02)  // For Segment U9
     {
          temp1 = dig2;
          LPC_GPIO1->FIOPIN = SECOND_SEG;

     }

     else if(dig_count == 0x03)  // For Segment U10
     {
          temp1 = dig3;
          LPC_GPIO1->FIOPIN = THIRD_SEG;
     }
     else if(dig_count == 0x04)  // For Segment U11
     {
          temp1 = dig4;
          LPC_GPIO1->FIOPIN = FOURTH_SEG;

     }
     temp1 &= 0x0F;
```

```
      temp2 = array_dec[temp1];  // Decoding to 7-segment
      temp2 = temp2 << 4;
      LPC_GPIO0->FIOPIN = temp2; // Taking Data Lines for 7-Seg
      for(i=0;i<500;i++);
      LPC_GPIO0->FIOCLR = 0x00000FF0;
//    LPC_GPIO1->FIOPIN = DISABLE_ALL;//disable all the segments
 }
Void delay(void)
 {  unsigned int i;
      for(i=0;i<1000;i++);
      if(count ==1000)     //multiplied by 1000x1msec for
                                 //1 Sec
      {
            one_sec_flg = 0xFF;
            count = 0x00;
      }
      else count += 1;

}
```

**Components required**

- ALS-SDA-ARMCTXM3-01 : 1 No.
- Power supply (+5V) : 1 No.
- Cross cable for programming and serial communication : 1 No
- One working USB in the host computer system and PC for downloading the software.
- 10 core FRC cables of 8 inch length 2 No
- USB to B type cable 1 No

**Hardware setup:** Connect a 10 core FRC cable from CNA to CNA2 and CNB to CNB2.

**Working procedure:** After software download and hardware setup, press the reset, Observe the count from 0000 to 9999 on the display.

**Exercise Questions:**

1. Write a C program to simulate a 4- digit BCD down counter.
2. Write a C program for 4- digit BCD up/down counter on seven segment using a switch. Use timer for delay of 1-second between each count.
3. Write a program for 4- digit hexadecimal up/down counter on seven segment using a switch. Use timer for a delay of 1-second between each count.
4. Write a program for 4-bit binary up/down counter on seven segment using a switch. Use timer for a delay of 1-second between each count.
5. Write a program to simulate a digital clock (Hour.Minute)

LAB 8:

**Title:** Liquid Crystal Display (LCD) and Keyboard interfacing

**Aim:** To interface and understand the working of LCD and matrix keyboard.

**Introduction:**

**LCD**: A 16×2 alphanumeric LCD can be used to display the message from controller.

16 pin small LCD has to be mounted to the connector CN11. 10 pin connector CNAD is used to interface this LCD from controller. Only higher 4 data lines are used among the 8 LCD data lines. Use POT3 for contrast adjustment and short the jumper JP16 to use this LCD. LCD connector CN11 is described in this table. CN11 is single row 16 pin female berg.

| Pin no CN11 | Description |
|---|---|
| 1 | Ground |
| 2 | +5V |
| 3 | LCD contrast |
| 4 | RS |
| 5,7,8,9,10 | NC |
| 6 | En |
| 11 to 14 | Data 4 to 7 |
| 15 | Back light anode |
| 16 | Back light cathode |

**Connection from CNAD to LCD connector CN11 is shown below**

| Pin no at CNAD | Description | Pin no at CN11 |
|---|---|---|
| 1 | L0 – Data line 4 of LCD | 11 |
| 2 | L1 – Data line 5 of LCD | 12 |
| 3 | L2 – Data line 6 of LCD | 13 |
| 4 | L3 – Data line 7 of LCD | 14 |
| 5 | L5 – Command line of LCD | 4 |
| 6 | L5 – Enable line of LCD | 6 |

| Instruction | Code RS | R/W | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 | Description | Execution Time (max) (when $f_{cp}$ or $f_{OSC}$ is 270 kHz) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Write data to CG or DDRAM | 1 | 0 | Write data | | | | | | | | Writes data into DDRAM or CGRAM. | 37 µs<br>$t_{ADD}$ = 4 µs* |
| Read data from CG or DDRAM | 1 | 1 | Read data | | | | | | | | Reads data from DDRAM or CGRAM. | 37 µs<br>$t_{ADD}$ = 4 µs* |
| | I/D = 1: Increment<br>I/D = 0: Decrement<br>S = 1: Accompanies display shift<br>S/C = 1: Display shift<br>S/C = 0: Cursor move<br>R/L = 1: Shift to the right<br>R/L = 0: Shift to the left<br>DL = 1: 8 bits, DL = 0: 4 bits<br>N = 1: 2 lines, N = 0: 1 line<br>F = 1: 5 × 10 dots, F = 0: 5 × 8 dots<br>BF = 1: Internally operating<br>BF = 0: Instructions acceptable | | | | | | | | | | DDRAM: Display data RAM<br>CGRAM: Character generator RAM<br>ACG: CGRAM address<br>ADD: DDRAM address (corresponds to cursor address)<br>AC: Address counter used for both DD and CGRAM addresses | Execution time changes when frequency changes<br>Example:<br>When $f_{cp}$ or $f_{OSC}$ is 250 kHz,<br>$37\ \mu s \times \frac{270}{250} = 40\ \mu s$ |

Note: — indicates no effect.

* After execution of the CGRAM/DDRAM data write or read instruction, the RAM address counter is incremented or decremented by 1. The RAM address counter is updated after the busy flag turns off. In Figure 10, $t_{ADD}$ is the time elapsed after the busy flag turns off until the address counter is updated.

| Instruction | Code RS | R/W | DB7 | DB6 | DB5 | DB4 | DB3 | DB2 | DB1 | DB0 | Description | Execution Time (max) (when $f_{cp}$ or $f_{osc}$ is 270 kHz) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Clear display | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | Clears entire display and sets DDRAM address 0 in address counter. | |
| Return home | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | — | Sets DDRAM address 0 in address counter. Also returns display from being shifted to original position. DDRAM contents remain unchanged. | 1.52 ms |
| Entry mode set | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | I/D | S | Sets cursor move direction and specifies display shift. These operations are performed during data write and read. | 37 µs |
| Display on/off control | 0 | 0 | 0 | 0 | 0 | 0 | 1 | D | C | B | Sets entire display (D) on/off, cursor on/off (C), and blinking of cursor position character (B). | 37 µs |
| Cursor or display shift | 0 | 0 | 0 | 0 | 0 | 1 | S/C | R/L | — | — | Moves cursor and shifts display without changing DDRAM contents. | 37 µs |
| Function set | 0 | 0 | 0 | 0 | 1 | DL | N | F | — | — | Sets interface data length (DL), number of display lines (N), and character font (F). | 37 µs |
| Set CGRAM address | 0 | 0 | 0 | 1 | ACG | ACG | ACG | ACG | ACG | ACG | Sets CGRAM address. CGRAM data is sent and received after this setting. | 37 µs |
| Set DDRAM address | 0 | 0 | 1 | ADD | ADD | ADD | ADD | ADD | ADD | ADD | Sets DDRAM address. DDRAM data is sent and received after this setting. | 37 µs |
| Read busy flag & address | 0 | 1 | BF | AC | AC | AC | AC | AC | AC | AC | Reads busy flag (BF) indicating internal operation is being performed and reads address counter contents. | 0 µs |

**Sample program: To display message on LCD**

```
#include <lpc17xx.h>

#define RS_CTRL  0x08000000  //P0.27
#define EN_CTRL  0x10000000  //P0.28
#define DT_CTRL  0x07800000  //P0.23 to P0.26 data lines

void lcd_init(void);
void wr_cn(void);
void clr_disp(void);
void delay_lcd(unsigned int);
void lcd_com(void);
void wr_dn(void);
void lcd_data(void);
void clear_ports(void);
void lcd_puts(unsigned char *);

extern unsigned long int temp1 , temp2;

unsigned long int temp1=0, temp2=0 ;

int main(void)
{
      unsigned int i;
      unsigned char Msg3[] = {"MIT Diamond"};
      unsigned char Msg4[] = {"Jubilee Year"};

      SystemInit();
      SystemCoreClockUpdate();
      lcd_init();
      temp1 = 0x80;
            lcd_com();
            delay_lcd(800);
            lcd_puts(&Msg3[0]);

            temp1 = 0xC0;
            lcd_com();
            delay_lcd(800);
            lcd_puts(&Msg4[0]);
      }
//lcd initialization
 void lcd_init()
```

```
{
    /* Ports initialized as GPIO */
   LPC_PINCON->PINSEL3 &= 0xFC003FFF;  //P0.23 to P0.28

    /* Setting the directions as output */
     LPC_GPIO0->FIODIR |= DT_CTRL;
    LPC_GPIO0->FIODIR |= RS_CTRL;
    LPC_GPIO0->FIODIR |= EN_CTRL;

     clear_ports();
    delay_lcd(3200);

    temp2 = (0x30<<19);
    wr_cn();
    delay_lcd(30000);

    temp2 = (0x30<<19);
    wr_cn();
    delay_lcd(30000);

    temp2 = (0x30<<19);
    wr_cn();
    delay_lcd(30000);

    temp2 = (0x20<<19);
    wr_cn();
    delay_lcd(30000);

    temp1 = 0x28;
    lcd_com();
    delay_lcd(30000);

    temp1 = 0x0c;
    lcd_com();
    delay_lcd(800);

    temp1 = 0x06;
    lcd_com();
    delay_lcd(800);

    temp1 = 0x01;
    lcd_com();
    delay_lcd(10000);
```

```
     temp1 = 0x80;
     lcd_com();
     delay_lcd(800);
    return;
}

void lcd_com(void)
{
     temp2 = temp1 & 0xf0;//move data (26-8+1) times : 26 - HN
                          //place, 4 - Bits
     temp2 = temp2 << 19; //data lines from 23 to 26
     wr_cn();
     temp2 = temp1 & 0x0f; //26-4+1
     temp2 = temp2 << 23;
     wr_cn();
     delay_lcd(1000);
    return;
}

// command nibble o/p routine
void wr_cn(void)                          //write command reg
{
     clear_ports();
     LPC_GPIO0->FIOPIN = temp2; // Assign the value to the data
                               //lines
    LPC_GPIO0->FIOCLR = RS_CTRL;       // clear bit RS
     LPC_GPIO0->FIOSET = EN_CTRL;      // EN=1
     delay_lcd(25);
     LPC_GPIO0->FIOCLR  = EN_CTRL;     // EN =0
    return;

}

// data o/p routine which also outputs high nibble first
// and lower nibble next
void lcd_data(void)
{
    temp2 = temp1 & 0xf0;
    temp2 = temp2 << 19;
    wr_dn();
    temp2= temp1 & 0x0f;
    temp2= temp2 << 23;
    wr_dn();
    delay_lcd(1000);
```

```
   return;
}

// data nibble o/p routine
void wr_dn(void)
{
     clear_ports();

     LPC_GPIO0->FIOPIN = temp2;       // Assign the value to the
                                      //data lines
     LPC_GPIO0->FIOSET = RS_CTRL;     // set bit  RS
     LPC_GPIO0->FIOSET = EN_CTRL;     // EN=1
     delay_lcd(25);
     LPC_GPIO0->FIOCLR = EN_CTRL;     // EN =0
   return;
}

void delay_lcd(unsigned int r1)
{
     unsigned int r;
     for(r=0;r<r1;r++);
   return;
}

void clr_disp(void)
{
     temp1 = 0x01;
     lcd_com();
     delay_lcd(10000);
   return;
}
void clear_ports(void)
{
   /* Clearing the lines at power on */
     LPC_GPIO0->FIOCLR = DT_CTRL; //Clearing data lines
     LPC_GPIO0->FIOCLR = RS_CTRL;  //Clearing RS line
     LPC_GPIO0->FIOCLR = EN_CTRL; //Clearing Enable line

   return;
}

void lcd_puts(unsigned char *buf1)
{
   unsigned int i=0;
```

```
   while(buf1[i]!='\0')
   {
       temp1 = buf1[i];
    lcd_data();
          i++;
       if(i==16)
          {
                temp1 = 0xc0;
                lcd_com();
          }

      }
   return;
}
```

**Components required**

- ALS-SDA-ARMCTXM3-01 : 1 No.
- Power supply (+5V) : 1 No.
- Cross cable for programming and serial communication: 1 No
- One working USB port in the host computer system and PC for downloading the software.
- 10 core FRC cables of 8 inch length 2 No
- USB to B type cable 1 No

**Hardware setup:**

Connect 10 pin FRC cable from CND to CNAD. Short the jumper JP16 & JP5. Use POT3 for contrast adjustment.

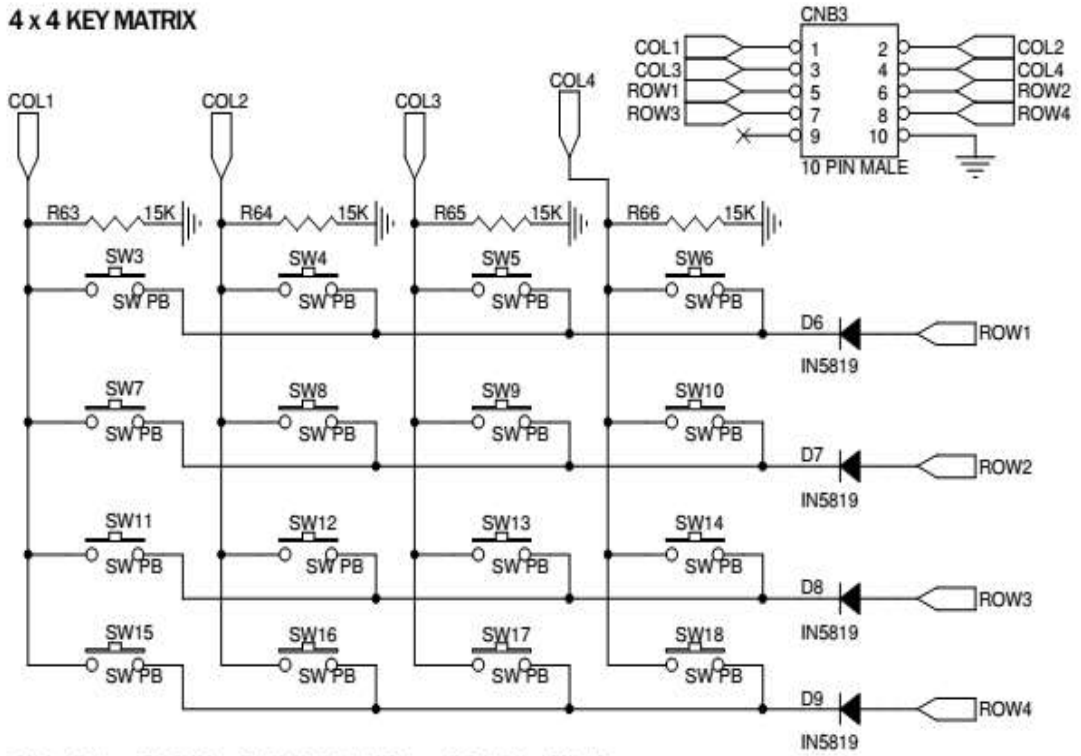
**Working procedure:** After software download and hardware setup, press the reset. A fixed message will display on LCD.

**Exercise Questions:**

1. Simulate DIE tossing on LCD.
   Hint: Program reads the external interrupt using the key SW2. A random number between 0-6 should be displayed on the LCD upon keypress.
2. Simulate a digital clock on LCD (Hour:Minute:Seconds)

**Keyboard connection**: The switches SW3 to SW18 are organized as 4 rows X 4 columns matrix. One end of all the switches are configured as columns. The other end of the matrix configured as rows. A row line will be always an output from the controller. Column lines are pulled to ground. A high level sent from the row will appear at column end if the switch is pressed.

Connector CNB3 is used for interfacing this block with controller. At the controller end any connector can be used to interact this connector CNB3.



**Sample program:** To read a key from the matrix keyboard and display its key code on the LCD.

```
  #include <LPC17xx.h>
     void scan(void);
     unsigned char col,row,var,flag,key,*ptr;
     unsigned long int i,var1,temp,temp3;
int main(void)
 {
     SystemInit();
     SystemCoreClockUpdate();

     LPC_PINCON->PINSEL3 &= 0xFFC03FFF; //P1.23 to P1.26 MADE
                                         //GPIO
     LPC_PINCON->PINSEL3 &= 0xF00FFFFF; //P2.10 t P2.13 made
                                         //GPIO
     LPC_GPIO2->FIODIR |= 0x00003C00; //made output P2.10 to
                                       //P2.13 (rows)
     LPC_GPIO1->FIODIR &= 0xF87FFFFF; //made input P1.23 to
                                      //P1.26 (cols)
   while(1)
     {
          while(1)
          {
               for(row=0;row<4;row++)
               {
                    if(row == 0)
                    var1 = 0x00000400;
                    else if(row == 1)
                    var1 = 0x00000800;
                    else if(row == 2)
                    var1 = 0x00001000;
                    else if(row == 3)
                    var1 = 0x00002000;

                    temp = var1;

                    LPC_GPIO2->FIOCLR = 0x00003C00;
                    LPC_GPIO2->FIOSET = var1;

                    flag = 0;
                    scan();
                    if(flag == 1)
```

```
                        {
                        LCD_display(row,col);
                        break;
                        }

                  } //end for(row=1;row<5;row++)

                  if(flag == 1)
                  break;

            } //2nd while(1)

void scan(void)
      {
            unsigned long temp3;

            temp3 = LPC_GPIO0->FIOPIN;
            temp3 &= 0x07800000;
            if(temp3 != 0x00000000)
            {
                        flag = 1;
                  if (temp3 ==0x00800000)
                        col=0;
                  else if (temp3==0x01000000)
                        col=1;
                  else if (temp3==0x02000000)
                        col=2;
                  else if (temp3==0x04000000)
                        col=3;

            }//1st if(temp3 != 0x00000000)
      }//end scan
```

**Components required**

- ALS-SDA-ARMCTXM3-01 : 1 No.
- Power supply (+5V) : 1 No.
- Cross cable for programming and serial communication : 1 No
- One working USB port in the host computer system and PC for downloading the software.
- 10 core FRC cables of 8 inch length 2 No
- USB to B type cable 1 No

**Hardware setup:** Connect 10 core FRC cable from CNB to CNB3, short JP4(1, 2)

Connect another 10 core FRC cable from CND to CNAD, Short the jumper JP16 & JP5. Use POT3 for contrast.

**Working procedure:** After software download and hardware setup, use the reset. Identity of key pressed (0 to F) will be displayed on LCD.

**Exercise question:**

1. Write a program to input an expression of the type A operator B =, from the key board, where A and B are the single digit BCD numbers and operator may be + or - . Display the result on the LCD.

Lab 9.

**Title:** Analog to Digital Converter

**Aim:** To understand the working of a 12 bit internal Analog-to-Digital Converter (ADC)

**Introduction:** The LPC1768 contains a single 12-bit successive approximation ADC with eight channels and DMA support. 12-bit ADC with input multiplexing among eight pins, conversion rates up to 200 kHz, and multiple result registers. The 12-bit ADC can be used with the GPDMA controller. On board there are two interfaces for internal ADC's. AD0.5 (pin P1.31) of controller is used to convert the analog input voltage varied using POT1 to digital value. AD0.4(Pin 1.30) used convert the analog voltage varied using POT4. Input voltage range of 0 to 3.3V is accepted. 000 to FFF is the converted digital value range here. Short JP18 (2, 3) to use AD0.4.

**Sample program:** To configure and read analog data from ADC channel No. 5, and display the digital data on the LCD.

```
#include<LPC17xx.h>
#include<stdio.h>
#include"AN_LCD.h"
#define    Ref_Vtg          3.300
#define    Full_Scale 0xFFF           //12 bit ADC

int main(void)
    {
    unsigned long adc_temp;
    unsigned int i;
    float in_vtg;
    unsigned char vtg[7],dval[7];
    unsigned char Msg3[11] = {"ANALOG IP:"};
    unsigned char Msg4[12] = {"ADC OUTPUT:"};

    SystemInit();
    SystemCoreClockUpdate();

    LPC_SC->PCONP |= (1<<15); //Power for GPIO block
    lcd_init();
    LPC_PINCON->PINSEL3 |= 0xC0000000;    //P1.31 as AD0.5
    LPC_SC->PCONP |= (1<<12);  //enable the peripheral ADC

    SystemCoreClockUpdate();
```

```
      temp1 = 0x80;
      lcd_com();
      delay_lcd(800);
      lcd_puts(&Msg3[0]);

      temp1 = 0xC0;
      lcd_com();
      delay_lcd(800);
      lcd_puts(&Msg4[0]);

      while(1)
      {
            LPC_ADC->ADCR = (1<<5)|(1<<21)|(1<<24);//0x01200001;
      //ADC0.5, start conversion and operational
            //for(i=0;i<2000;i++);     //delay for conversion
            while((adc_temp = LPC_ADC->ADGDR) == 0x80000000);
     //wait till 'done' bit is 1, indicates conversion complete
            adc_temp = LPC_ADC->ADGDR;
            adc_temp >>= 4;
            adc_temp &= 0x00000FFF;               //12 bit ADC
            in_vtg = (((float)adc_temp *
(float)Ref_Vtg))/((float)Full_Scale); //calculating input analog
                                        //voltage
            sprintf(vtg,"%3.2fV",in_vtg);
//convert the readings into string to display on LCD
            sprintf(dval,"%x",adc_temp);
            for(i=0;i<2000;i++);
            temp1 = 0x8A;
            lcd_com();
            delay_lcd(800);
            lcd_puts(&vtg[0]);

            temp1 = 0xCB;
            lcd_com();
            delay_lcd(800);
            lcd_puts(&dval[0]);

           for(i=0;i<200000;i++);
            for(i=0;i<7;i++)
           vtg[i] = dval[i] = 0x00;
            adc_temp = 0;
            in_vtg = 0;
      }
}
```

**Components required**

- ALS-SDA-ARMCTXM3-01 : 1 No.
- Power supply (+5V) : 1 No.
- Cross cable for programming and serial communication : 1 No
- One working COM port (Ex: COM1) in the host computer system and PC for downloading the software.
- 10 core FRC cables of 8 inch length 2 No
- USB to B type cable 1 No

**Hardware Setup**: Do the setup related to LCD

**Working procedure:** Vary POT1 and observe the corresponding analog volatage and digital values on LCD.

**Exercise question**

1. Write a c program to display the digital value representing the difference in analog voltages at ADC channel 4 and channel 5 on LCD using BURST and Software mode.

Lab 10:

**Title:** Digital to Analog Convertor (DAC)

**Aim:** To understand the working of a 10 bit DAC and check the waveform on Cathode Ray Oscilloscope (CRO).

**Introduction:** LPC1768 has 10 bit internal DAC with dedicated conversion timer and DMA support. The DAC allows to generate a variable analog output. The maximum output voltage of the DAC is VREFP. The equation to calculate output voltage is given as below.

AOUT = DACR value x ((VREFP - VREFN)/1024) + VREFN

An analog output from the controller can be observed in this block at TP8. Open JP5 to use this feature and use CRO to watch analog output value.

**Sample program:** To generate a sawtooth waveform using DAC and display it on CRO.

```
#include <lpc17xx.h>

#define DAC_BIAS (0x1<<16)  //maximum update rate of 400KHz
#define DATA_LENGTH 0x400     //Maximum value is 0xCFF in 10 bit DAC

void DAC_Init(void);

int main (void)
{
    unsigned int m,i=0;
    SystemInit();
    SystemCoreClockUpdate();
     LPC_PINCON->PINSEL1 = 0x00200000;  /* set p0.26 to DAC output */

    /* Initialize DAC  */
    DAC_Init();

    while ( 1 )
    {
            LPC_DAC->DACR = (i << 6) ;
//| DAC_BIAS;   // AOUT = DACR value x ((VREFP - VREFN)/1024) + VREFN
```

```
            i=i+50;
            for(m = 100; m > 1; m--);
            if ( i == DATA_LENGTH )    //Maximum value is 0xCFF in 10 bit DAC
            {
                  i = 0;
            }
      }
}

void DAC_Init( void )
{
/* Note that the DAC does not have a control bit in the PCONP register.
      To enable the DAC, its output must be selected to appear on the
      related pin, P0.26, by configuring the PINSEL1 register */

      /* setup the related pin to DAC output */

      LPC_DAC->DACCNTVAL = 0x00FF;
      LPC_DAC->DACCTRL = (0x1<<1)|(0x1<<2);
      return;
}
```

**Components required**

- ALS-SDA-ARMCTXM3-01 : 1 No.
- Power supply (+5V) : 1 No.
- Cross cable for programming and serial communication : 1 No
- One working USB port in the host computer system and PC for downloading the software.
- 10 core FRC cables of 8 inch length 2 No
- USB to B type cable 1 No

**Hardware setup:**

Open the jumper JP5

Connect TP8 pin to CRO positive wire and TP3 to CRO negative wire. Scale the CRO to the proper display

**Working procedure**: Reset the controller and observe the analog output waveform on CRO.

**Exercise questions**

1. Using DAC generate a triangular waveform with maximum possible peak-peak amplitude.
2. Using DAC, generate a variable frequency sine waveform. Use ROW-0 of keyboard for frequency variation.

LAB 11:

**Title:** Pulse Width Modulation (PWM)

**Aim:** To interface and understand the working of PWM.

**Introduction:** The PWM is based on the standard Timer block and inherits all of its features, although only the PWM function is pinned out on theLPC1768. The Timer is designed to count cycles of the system derived clock and optionally switch pins, generate interrupts or perform other actions when the specified timer values occur, based on seven match registers. The PWM function is in addition to these features, and is based on match register events. A PWM output from the controller can be observed as an intensity variation of the LED LD10.

**Sample program:** To vary the intensity of an LED using PWM.

```
#include <LPC17xx.H>
 void pwm_init(void);
 void PWM1_IRQHandler(void);

 unsigned long int i;
 unsigned char flag;

 int main(void)
 {
        SystemInit();
        SystemCoreClockUpdate();
        pwm_init();

        while(1)
        {
        for(i=0;i<=1000;i++);   // delay
   }//end of while

 }//end of main
```

```
void pwm_init(void)
{
        LPC_SC->PCONP |= (1<<6);           //PWM1 is powered
        LPC_PINCON->PINSEL3 &= ~(0x0000C000);       //cleared if any other
                                                    //functions are enabled
        LPC_PINCON->PINSEL3 |= 0x00008000;  //pwm1.4 is selected for the pin
                                            //P1.23

        LPC_PWM1->PR  = 0x00000000;      //Count frequency : Fpclk
        LPC_PWM1->PCR = 0x00001000;      //select PWM1 single edge
        LPC_PWM1->MCR = 0x00000003;      //Reset and interrupt on PWMMR0
        LPC_PWM1->MR0 = 30000;           //setup match register 0 count
        LPC_PWM1->MR4 = 0x00000100;      //setup match register MR1
        LPC_PWM1->LER = 0x000000FF;      //enable shadow copy register
        LPC_PWM1->TCR = 0x00000002;    //RESET COUNTER AND PRESCALER
        LPC_PWM1->TCR = 0x00000009;      //enable PWM and counter

        NVIC_EnableIRQ(PWM1_IRQn);
        return;
}

void PWM1_IRQHandler(void)
{
        LPC_PWM1->IR = 0xff; //clear the interrupts

        if(flag == 0x00)
          {
                LPC_PWM1->MR4 += 100;
                LPC_PWM1->LER = 0x000000FF;

                if(LPC_PWM1->MR4 >= 29500)
                {
                  flag = 0xff;
```

```
        LPC_PWM1->LER = 0x000000FF;
                }
        }
         else if(flag == 0xff)
          {
                LPC_PWM1->MR4 -= 100;
                LPC_PWM1->LER = 0x000000FF;

                if(LPC_PWM1->MR4 <= 500)
                {
                        flag  = 0x00;
                        LPC_PWM1->LER = 0X000000FF;
                }
        }
}
```

**Hardware setup**: Connect 10 pin FRC cable from CNB to CNB1.

Working procedure: As the pulse width varies, intensity of LED LD10 varies. Observe the pulses at TP5. Observe the amplitude level at TP6.

**Exercise question:**

1. Write a program to set the following intensity levels to the LED connected to PWM output. Use ROW-0 of keyboard for intensity variation

| Intensity level | Key pressed |
|---|---|
| 10% | 0 |
| 25% | 1 |
| 50% | 2 |
| 75% | 3 |

LAB 12

**Title:** Stepper motor

**Aim :** To interface and understand the working of stepper motor

**Introduction:** The Stepper motor can be interfaced to the board by connecting it to the Power Mate PM1. The direction of the rotation can be changed through software. The DC Motor can also be interfaced to the board by connecting it to the Reliamate RM5. The direction of the rotation can be changed through software.

The Relay K2 is switched between ON and OFF state. The LED L12 will toggle for every relay switch over. The contact of NO & NC of the relay can be checked at the MKDSN connector CN12 pins 1 & 2 using a CRO– these contacts can be connected to external devices. Using connector CNA5 micro controller can interface with this block.

Description of the connector pins are given in below table.

| Pin @ CNA5 | Description |
|---|---|
| 1 to 4 | Buffered from U13 used for stepper motor control |
| 5 | Buffered from U13 and connected to relay k2 coil. coil other end is connected to +5V |
| 6 | Connected to both 1 & 2 of U13; corresponding outputs of U13 are taken to NO and NC contacts of relay K1 |
| 7 | One end of coil of relay K1 |
| 8 | Controls the buzzer |

PM1– it's a 5 pin straight male power mate. PIN descriptions are as given below.

| Pin no | Description |
|---|---|
| 1 | +5v supply |
| 2 | Phase A |
| 3 | Phase B |
| 4 | Phase C |
| 5 | Phase D |

Pin 2 to 5 are phase A to D output for the stepper motor respectively.

**Sample program:** To rotate the stepper motor in clockwise and anticlockwise direction at a particular speed continuously.

```
#include <LPC17xx.H>
 void clock_wise(void);
 void anti_clock_wise(void);
 unsigned long int var1,var2;
 unsigned int i=0,j=0,k=0;

 int main(void)
 {
     SystemInit();
     SystemCoreClockUpdate();

     LPC_PINCON->PINSEL0 = 0xFFFF00FF;  //P0.4 to P0.7 GPIO
     LPC_GPIO0->FIODIR = 0x000000F0;        //P0.4 to P0.7 output

     while(1)
     {
             for(j=0;j<50;j++)          // 20 times in Clock wise Rotation
                     clock_wise();

             for(k=0;k<65000;k++);       // Delay to show  anti_clock Rotation

             for(j=0;j<50;j++)          // 20 times in  Anti Clock wise Rotation
                     anti_clock_wise();

             for(k=0;k<65000;k++);       // Delay to show clock Rotation

     } // End of while(1)

 } // End of main
```

```
void clock_wise(void)
{
     var1 = 0x00000008;         //For Clockwise
  for(i=0;i<=3;i++)         // for A B C D Stepping
     {
               var1 = var1<<1;        //For Clockwise
               var2 = ~var1;
               var2 = var2 & 0x000000F0;

               LPC_GPIO0->FIOPIN = ~var1;
               //LPC_GPIO0->FIOSET = var1;
     //LPC_GPIO0->FIOCLR = var2;

      for(k=0;k<3000;k++); //for step speed variation
    }

}

void anti_clock_wise(void)
{
     var1 = 0x00000100;      //For Anticlockwise
   for(i=0;i<=3;i++)       // for A B C D Stepping
    {
      var1 = var1>>1;      //For Anticlockwise
      var2 = ~var1;
      var2 = var2 & 0x000000F0;

       LPC_GPIO0->FIOPIN = ~var1;
      //LPC_GPIO0->FIOSET = var1;
      //LPC_GPIO0->FIOSET = var2;
      for(k=0;k<3000;k++); //for step speed variation
       }
}
```

**Components required**

- ALS-SDA-ARMCTXM3-01 : 1 No.
- Power supply (+5V) : 1 No.
- Cross cable for programming and serial communication: 1 No
- Stepper motor 1 No
- One working USB port in the host computer system and PC for downloading the software.
- 10 core FRC cables of 8 inch length 2 No
- USB to B type cable 1 No

**Hardware setup:** Connect 10 pin FRC cable from CNA to CNA5. Connect the stepper motor to PM1.

**Working procedure:** Stepper motor will rotate clockwise and in anti-clock wise direction automatically after reset.

**Exercise question**

Write a C program to rotate the stepper motor in the clockwise direction when SW2 is high and anticlockwise direction when SW2 is low.

# APPENDIX A

## GPIO extension connectors:

There are four 10 pin FRC type male connectors, they extends the controllers general purpose port lines for the use of user requirements. Details on each connector is given below:

**CNA** –10 pin male box type FRC connector. Port lines P0.4 to P0.11 from controller are terminated in this connector. They can be extended to interface few on board or external peripherals. The pins mentioned in the above table are configured to work as a GPIO's at power on. Other alternate functions on those pins needs to be selected using respective PINSEL registers.

| Pin CNA | PIN LPC1768 | Description |
|---|---|---|
| 1 | 81 | P0.4/I2SRX_CLK/RD2/CAP2.0 |
| 2 | 80 | P0.5/I2SRX_WS/TD2/CAP2.1 |
| 3 | 79 | P0.6/I2SRX_SDA/SSEL1/MAT2.0 |
| 4 | 78 | P0.7/I2STX_CLK/SCK1//MAT2.1 |
| 5 | 77 | P0.8/I2STX_WS/MISO1/MAT2.2 |
| 6 | 76 | P0.9/I2STX_SDA/MOSI1/MAT2.3 |
| 7 | 48 | P0.10/TXD2/SDA2/MAT3.0 |
| 8 | 49 | P0.11/RXD2/SCL2/MAT3.1 |
| 9 | - | No connection |
| 10 | - | Ground |

**CNB** – 10 pin male box type FRC connector. Port lines fromP1.23 to P1.26 and P2.10 to

P2.13 are terminated in this connector.

Description of the connector **CNB:**

| Pin CNB | Pin LPC1768 | Description |
|---|---|---|
| 1 | 37 | P1.23/MCI1/PWM1.4/MISO0 |
| 2 | 38 | P1.24/MCI2/PWM1.5/MOSI0 |
| 3 | 39 | P1.25/MCOA1/MAT1.1 |
| 4 | 40 | P1.26/MCOB1/PWM1.6/CAP0.0 |
| 5 | 53 | P2.10/EINT0/NMI |
| 6 | 52 | P2.11/EINT1/I2STX_CLK |
| 7 | 51 | P2.12/EINT2/I2STX_WS |
| 8 | 50 | P2.13/EINT3/I2STX_SDA |
| 9 | - | No connection |
| 10 | - | Ground |

**CNC** – 10 pin male box type FRC connector. Port lines fromP0.15 to P0.22 and P2.13 are terminated in this connector.

| Pin CNC | Pin LPC1768 | Description |
|---|---|---|
| 1 | 62 | P0.15/TXD1/SCK0/SCK |
| 2 | 63 | P0.16/RXD1/SSEL0/SSEL |
| 3 | 61 | P0.17/CTS1/MISO0/MISO |
| 4 | 60 | P0.18/DCD1/MOSI0/MOSI |
| 5 | 59 | P0.19/DSR1/SDA1 |
| 6 | 58 | P0.20/DTR1/SCL1 |
| 7 | 57 | P0.21/RI1/RD1 |
| 8 | 56 | P0.22/RTS1/TD1 |
| 9 | 50 | P2.13/I2STX_SDA |
| 10 | - | Ground |

**CND** – 10 pin male box type FRC connector. Port lines fromP0.23 to P0.28 and P2.0 to P2.1 are terminated in this connector.

| Pin CND | Pin LPC1768 | Description |
|---|---|---|
| 1 | 9 | P0.23/AD0.0/I2SRX_CLK/CAP3.0 |
| 2 | 8 | P0.24/AD0.1/I2SRX_WS/CAP3.1 |
| 3 | 7 | P0.25/AD0.2/I2SRX_SDA/TXD3 |
| 4 | 6 | P0.26/AD0.3/AOUT/RXD3 |
| 5 | 25 | P0.27/SDA0/USB/SDA |
| 6 | 24 | P0.28/SCL0/USB_SCL |
| 7 | 75 | P2.0/PWM1.1/TXD1 |
| 8 | 74 | P2.1/PWM1.2/RXD1 |
| 9 | - | No connection |
| 10 | - | Ground |