Batch No.	Seat No.

Rashtreeya Sikshana Samithi Trust

R. V. COLLEGE OF ENGINEERING

[Autonomous Institution Affiliated to VTU, Belagavi]

Department of Computer Science & Engineering

Bengaluru-560059

IOT & Embedded Systems Lab

Subject Code: CS344AI

IV SEMESTER B.E.

LABORATORY RECORD

[Autonomous Scheme 2022]

2023-2024

Name of the Student:_____ **USN:** _____

Semester:_____**Section:**_____**Year:**_____

Rashtreeya Sikshana Samithi Trust

R. V. COLLEGE OF ENGINEERING

DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

IOT & EMBEDDED SYSTEMS LAB

(CS344AI)

2023 - 2024

IV SEMESTER B.E LABORATORY RECORD

[Autonomous Scheme 2022]

R.V. College of Engineering,Bangalore - 59

(Autonomous Institution affiliated to VTU, Belagavi)

Department of Computer Science & Engineering

LABORATORY CERTIFICATE

This is to certify that Mr. / Ms. _____

with USN _____ of IV semester has satisfactorily completedthe course of experiments in IOT and Embedded Systems Lab [CS344AI] prescribed by the department during the year 2023-2024.

Marks	
Maximum	**Obtained**
50	

Signature of the staff in-charge Head of the department

Date:

R. V. COLLEGE OF ENGINEERING

[Autonomous Institution Affiliated to VTU, Belagavi] Department of Computer Science & Engineering Bengaluru-560059

VISION

To achieve leadership in the field of Computer Science & Engineering by strengthening fundamentals and facilitating interdisciplinary sustainable research to meet the ever growing needs of the society.

MISSION

- To evolve continually as a Centre of excellence in quality education in computers and allied fields.
- To develop state-of-the-art infrastructure and create environment capable for interdisciplinary research and skill enhancement.
- To collaborate with industries and institutions at national and international levels to enhance research in emerging areas.
- To develop professionals having social concern to become leaders in top-notch industries and/or become entrepreneurs with good ethics.

Program Educational Objectives

PEO1: Develop Graduates capable of applying the principles of mathematics, science, core engineering and Computer Science to solve real-world problems in interdisciplinary domains.

PEO2: To develop the ability among graduates to analyze and understand current pedagogical techniques, industry accepted computing practices and state-of-art technology.

PEO3: To develop graduates who will exhibit cultural awareness, teamwork with professional ethics, effective communication skills and appropriately apply knowledge of societal impacts of computing technology.

PEO4: To prepare graduates with a capability to successfully get employed in the right role / become entrepreneurs to achieve higher career goals or take up higher education in pursuit of lifelong learning.

Program Outcomes

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization for the solution of complex engineering problems

PO2: Problem analysis: Identify, formulate, 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 public health and safety, and 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 the 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.

Program Specific Outcomes

PSO1: System Analysis and Design

The student will:

1. Recognize and understand the dynamic nature of developments in computer architecture, data organization and analytical methods.
2. Learn the applicability of various systems software elements for solving real-world design problems.
3. Identify the various analysis & design methodologies for facilitating development of high quality system software products with focus on performance optimization.
4. Display good team participation, communication, project management and document skills.

PSO2: Product Development

The student will:

1. Demonstrate knowledge of the ability to write programs and integrate them resulting in state-of –art hardware/software products in the domains of embedded systems, databases /data analytics, network/web systems and mobile products.
2. Participate in teams for planning and implementing solutions to cater to business – specific requirements displaying good team dynamics and professional ethics.
3. Employee state-of-art methodologies for product development and testing / validation with focus on optimization and quality related aspects

Course Outcomes

After completing the course, the student will be able to:

CO1: Acquire the knowledge of architecture of Microprocessors and Microcontrollers for the different applications.

CO2: Develop skill in simple program writing for micro controllers for applications in assembly level language and Embedded C.

CO3: Design system configuration for a given application.

CO4: Integrate, implement and test the design in applications.

Do's and Don'ts in the Laboratory

Do's……...

- Come prepared to the lab with the program logic.
- Use the computers and controller kit for academic purposes only.
- Following the lab exercise cycles as per the instructions given by the department.
- Keep the chairs back to their position before you leave.
- Handle the computer and the kits with care.
- Keep your lab clean.

Don'ts……...

- Coming late to the lab and leaving the lab early.
- Move around in the lab during the lab session.
- Download or install any software onto the computers.
- Tamper system files or try to access the server.
- Write record in lab.
- Change the system assigned to you without the notice of lab staff.
- Carrying CD's, Floppy's, Pen Drives and other storage devices into lab.
- Using others login id's.

PARTICULARS OF THE EXPERIMENT

Prog No.	Program	Page No	Marks Split as per rubrics					Marks (10)
			Execution			Viva		
			2	2	2	2	2	
1	Interface Logic Controller and write Embedded C programs to generate BCD up / down and Ring counters. Input is read from the DIP switch.	31						
2	Seven Segment Display Interface: Write a C program to display messages “FIRE” & “HELP” on 4 digit seven segment display alternately with a suitable delay.	34						
3	Stepper Motor Interface: Write an Embedded C program to rotate stepper motor in clockwise direction for “M” steps, anti-clock wise direction for “N” steps.	39						
4	DAC Interface : Write an Embedded C program to generate sine , full rectified ,triangular, sawtooth and square waveforms using DAC module	42						
5	Matrix Keyboard Interface : Write an mbedded C program to interface 4 X 4 matrix keyboard using lookup table and display the key pressed on the Terminal.	49						
6	DC Motor Interface: Write an Embedded C program to generate PWM wave to control speed of DC motor. Control the duty cycle by analog input.	53						
7	Character LCD Interface : Write an Embedded C program to display text messages on the multiple lines of the display.	57						
Total for 70 Marks								

LAB INTERNALS	
RECORD Marks	/ 20 Marks
Mini Project	/ 20 Marks
TEST	/ 10 Marks
TOTAL	/ 50 Marks

Lab Write-up and Execution Rubrics (Max: 6 marks)					
Sl no	**Criteria**	**Excellent**	**Good**	**Poor**	**Score**
1	**Understanding of problem and requirements (2 Marks) CO1**	Student exhibits thorough understanding of program requirements and applies ALP / Embedded C for ARM concepts. **(2M)**	Student has sufficient understanding of program requirements and applies ALP / Embedded C for ARM concepts. **(1.5M - 1M)**	Student does not have clear understanding of program requirements and is unable to apply ALP / Embedded C for ARM concepts. **(0M)**	
2	**Design & Execution (2Marks)** **CO 2, 3**	Student demonstrates the design & execution of the program with optimized code with all the modifications and test cases handled. **(2M)**	Student demonstrates the design & execution of the program without optimization of the code and handles only few modifications and few test cases. **(1.5M - 1M)**	Student has not executed the program. **(0M)**	
3	**Results and Documentation (2Marks) CO 1, 4**	Documentation with appropriate comments and output with observations is covered in manual. **(2M)**	Documentation with only few comments and only few output cases is covered in manual. **(1.5M - 1M)**	Documentation with no comments and no output cases covered in manual. **(0M)**	
Viva Voce Rubrics (Max: 4 marks)					
1	**Conceptual Understanding (2 Marks) CO 1**	Explains related architecture & Assembly language programming / Embedded C related concepts involved. **(2M)**	Adequately explains architecture & Assembly language programming / Embedded C related concepts involved. **(1.5-1M)**	Unable to explain the concepts. **(0M)**	
2	**Use of appropriate Design Techniques (2 Marks) CO 2, 3**	Insightful explanation of appropriate design techniques for the given problem to derive solution. **(2M)**	Sufficiently explains the use of appropriate design techniques for the given problem to derive solution. **(1.5M-0.5M)**	Unable to explain the design techniques for the given problem. **(0M)**	
Total Marks					
Staff Signature:					

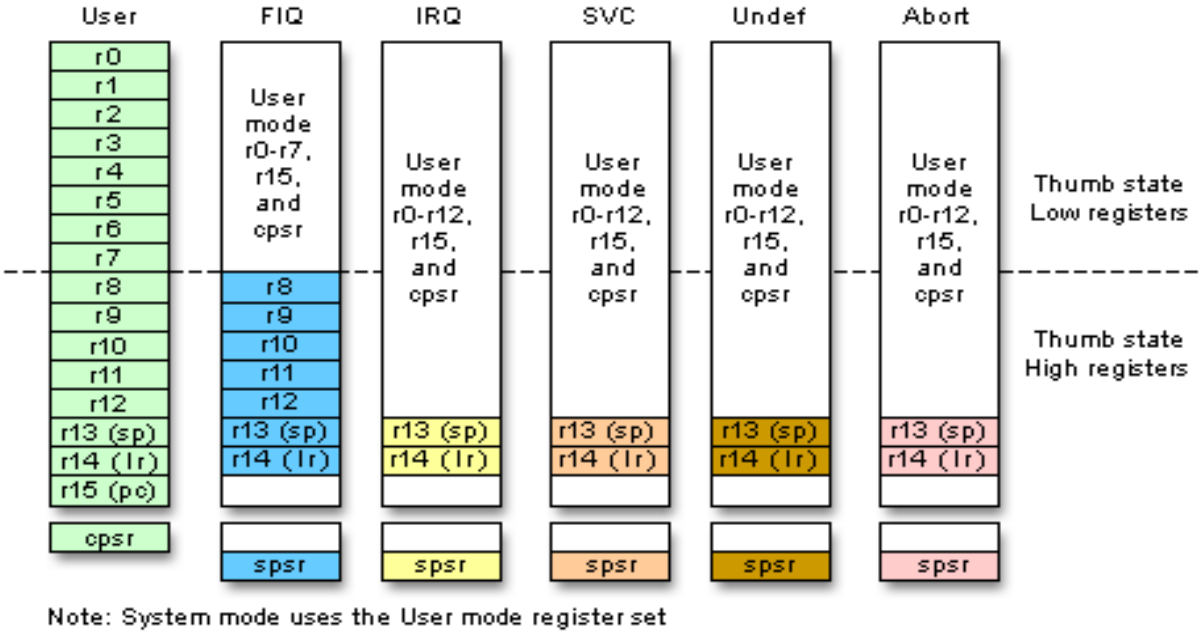
ARM Assembly Language Programs – Part A

ARM Architecture (Instruction Set Architecture – ISA)

ARM – stands for "**A**dvanced **R**ISC **M**achine" , ARM based microcontrollers are very popular in 32 bit embedded market, occupying the major share of the market. ARM7 was the first commercial success, used extensively in products like PDAs, IPods, hard disks, set-top boxex, mobile phones etc.

Operating Modes : ARM has seven operating modes, i.e it exists in any one of these modes when the processor is running,

i) User mode: simplest mode with least privileges (or also referred as Unprivileged mode), this is the mode under which most applications run, User mode is used for the execution of programs and applications.
ii) FIQ Mode (Fast interrupt request): Entered this mode on request from FIQ interrupts
iii) IRQ Mode (Interrupt Request): Entered this mode on IRQ request
iv) Supervisor: Entered on Reset and when a software interrupt instruction (SWI) is executed, and is generally the mode in which the operating system kernel operates in.
v) Abort: Used to handle memory access violations, Abort is entered after a failed memory access
vi) Undef: Used to handle undefined instructions, Undefined is entered if the instruction is not defined (invalid opcodes)
vii) System: This is highly privileged mode used by operating systems to manipulate and control the activities of the processor, System mode is a special version of user mode that allows full read write access to the CPSR



Note: System mode uses the User mode register set

Register Set: ARM has 37 registers of size 32bits each, they are

i) PC - 1 dedicated program counter

ii) CPSR – 1 dedicated program status register, (like flag register of 8086)

iii) 5 dedicated saved program status registers (SPSR)

iv) 30 general purpose registers

Overview of ARM Assembly Language Instructions.

Data/Register Transfer Instructions

Format: MOV REG, REG / IMM
MVN REG, REG / IMM

Example: MOV R1,R2 ; Move contents of R2 to R1
MOV R1,#3 ; Move the immediate 3 to R1

Shift and Rotate operations can be part of other Register Transfer / Arithmetic / Logic operations. One of the operand can be operated by shift/rotate operations using barrel shifter.

Example: MOV R1, R0 , LSL #1

; rotate R0, by operation Logical Left Shift & Put the value to R1, the second operand [R0 with LSL #1] is also called as shifter operand. Register can also be used to indicate the number of bits to be shifted, Ex- MOV R1, R0, LSL R2

Similar logical/rotate options :

LSR #n - Logical Shift Right
LSL #n - Logical Shift Left
ASR #n – Arithmetic Shift Right
ROR #n - Rotate Right
RRX #n - Rotate Right Extended (i.e with Carry)
(Rotate left ‘n’ bits is equivalent to rotate right by (32-n) bits)

Updating of Status Flags

Updation of status flags is possible by appending “S” to the instruction,

MOV**S** R0, #0

Conditional Execution : **Suffixing** condition codes is possible for any data processing and branch instructions, if condition code satisfies instruction works, else it is a NOP instruction. There are 15 such condition codes.

Ex: MOV**EQ** R0, #10 ; 10 is moved to R0, if Zero flag is set else it is a NOP
Other Commonly used Condition codes :
EQ Z=1 zero flag set
NE Z=0 zero flag clear
CS C=1 carry flag set
CC C=0 carry flag clear

MI N=1 Sign/Negative flag set (number is MINUS)
PL N=0 Sign/Negative flag is clear(number is POSITIVE)

ARITHMETIC INSTRUCTIONS

Format:
ADD REG, REG, (REG/IMM)
SUB REG, REG, (REG/IMM)
RSB REG, REG, (REG/IMM)

Ex : ADDS R2,R3,R4 ; R2 ← R3 + R4 and update the flags (because of suffix S)

LOGICAL INSTRUCTIONS

Format:
AND REG, REG, (REG/IMM)
EOR REG, REG, (REG/IMM)
ORR REG, REG, (REG/IMM)
BIC REG, REG, (REG/IMM)

Ex: **ANDS R5, R0 , R1** ; R5 ← R0 .AND. R1 (bit AND operation), S – updatde flags
Ex: **ORRS R5, R0 , R1** ; R5 ← R0 .OR. R1 (bit AND operation), S – updatde flags
Ex: **EORS R5, R0 , R1** ; R5 ← R0 .OR. R1 (bit AND operation), S – updatde flags

- BIC is used to clear selected bits of the Register

Ex: **BIC R5, R0 , R1** ; R5 ← R0 .AND. ~R1 (i.e R0. AND. NOT R1)

COMPARE instructions
The CPSR register contains four flags Negative(sign flag),Zero,Carry and Overflow flags, which are affected by the execution of following instructions. Flags are also affected by using suffix S to the other data processing instructions.

Format:
CMP REG, (REG/IMM)
TST REG, (REG/IMM)
TEQ REG, (REG/IMM)

- CMP R1 , R2 ; pseudo subtraction and updates the flags
- TEQ R1 , R2 ; R1. XOR . R2 pseudo XOR operation and updates the flags
- TST R1 , R2 ; R1. AND . R2 pseudo AND operation and updates the flags

MULTIPLICATION

Format:
MUL REG , REG, (REG/IMM)
MLA REG , REG, REG, REG

Examples:

MUL R1 , R2 , R3 - Multiply R1 ← R2 x R3
MLA R4 , R3 , R2 , R1 - Multiply and Accumulate; R4 ←(R3 x R2) + R1

BRANCH INSTRUCTIONS

1) **B LOOP ; branch to the address with label LOOP**
   BEQ LOOP ; branch only if Zero Flag is set
   BNE LOOP ; branch only if Zero Flag is not set (i.e clear)
   (used when executing conditional/unconditional branches**)**
2) **BL NEXT ; branch with LINK, copy the PC(address on next instruction i.e PC+4) contents to LR, then branch**
   (used when calling procedures)

Format of Procedure Calls:
Ex: BL PROC1 ; contents of PC is Copied to LR

Load & Store Instructions

Format:

LDR REG, [REG]
LDR REG, [REG,IMM]
LDR REG, [REG,REG]
LDR REG, [REG,REG,SHIFT IMM]

STR REG, [REG]
STR REG, [REG]
STR REG, [REG,IMM]
STR REG, [REG,REG]
STR REG, [REG,REG,SHIFT IMM]

Ex:

LDR R1, [R0] ;contents of memory(32 bit number – 4 bytes) pointed by R0 is loaded into R1

STR R1, [R0] ; contents of R1(32bit number-4 bytes) is stored in memory pointed by R0.

Sample Program No 1A (i):

AIM: Translate the following code in C to the ARM instruction set. Assume variables are 32bit integers represented in Registers.

A = B + C - D

```
        AREA   RESET, CODE
        ENTRY

        MOV  R0,#00 ; A
        MOV  R1,#NUM1 ; B
        MOV  R2,#NUM2 ; C
        MOV  R3,#NUM3; D

        ADD  R0,R2,R1
        SUB   R0,R0,R3

STOP    B   STOP
        END
```

A = 2 * A + B

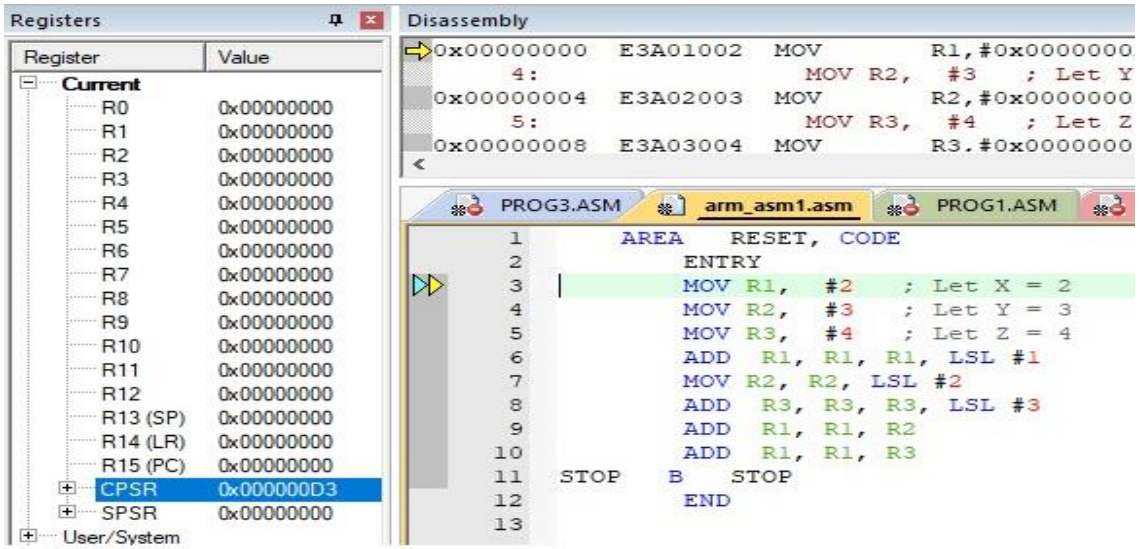
```
AREA   RESET, CODE
        ENTRY

        MOV  R0,#NUM1 ; A
        MOV  R1,#NUM2; B
        ADD  R0,R1,R0,LSL #2

STOP    B   STOP
        END
```

Sum of 3X + 4Y + 9Z, where X = 2, Y=3 and Z=4.

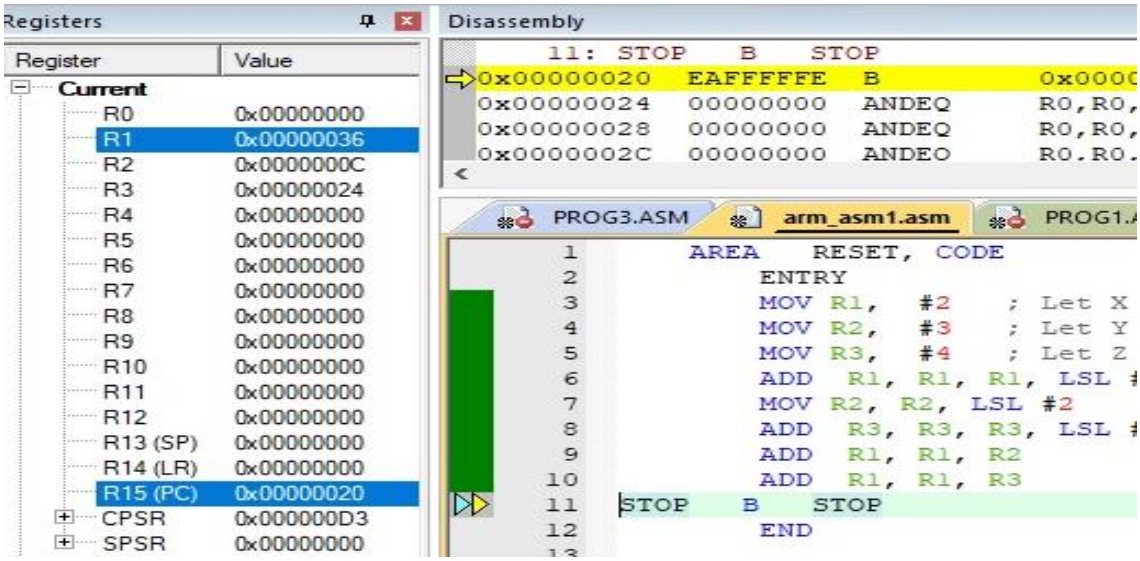
```
        AREA   RESET, CODE
        ENTRY
        MOV R1,  #2   ; Let X = 2
        MOV R2,  #3   ; Let Y = 3
        MOV R3,  #4   ; Let Z = 4
        ADD  R1, R1, R1, LSL #1
        MOV R2, R2, LSL #2
        ADD  R3, R3, R3, LSL #3
        ADD  R1, R1, R2
        ADD  R1, R1, R3
STOP   B   STOP
        END
```

Sample Output:

Before Execution



After Execution



Sample Program No 1A(ii):

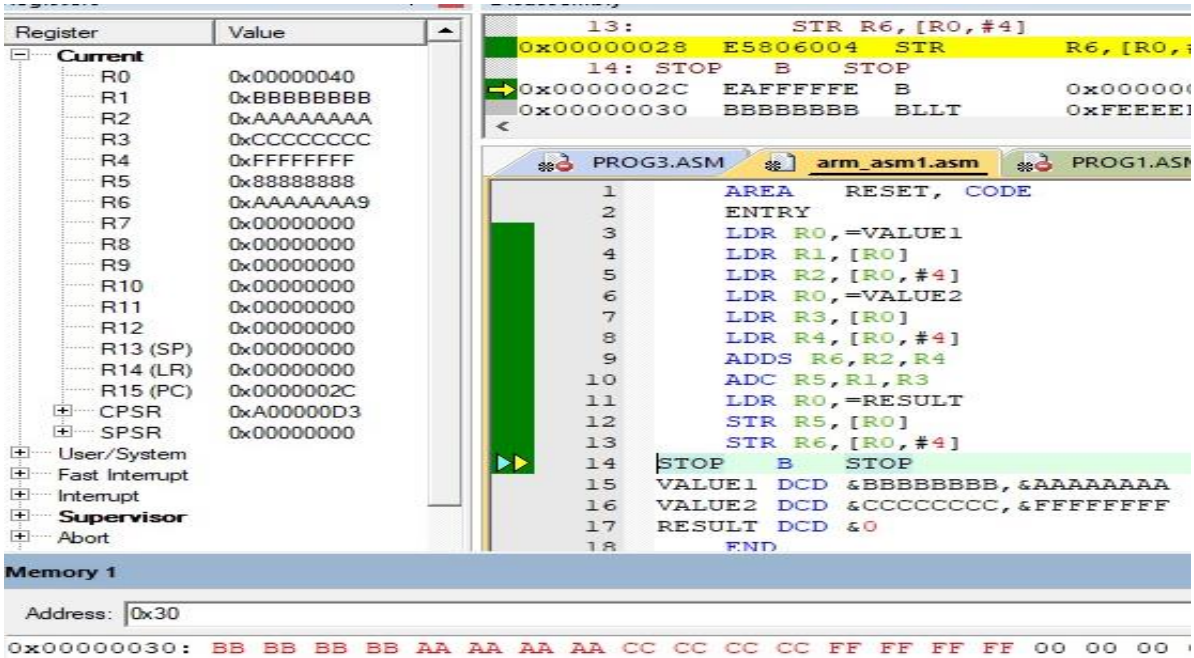
AIM: Write an ARM ALP to perform addition and subtraction of two 32-bit and 64bit numbers.

MSB:LSB
Value1 = R1 : R2
Value2 = R3 : R4
Result = R5 : R6

Program:

```
        AREA RESET, CODE
        ENTRY
        LDR R0,=VALUE1
        LDR R1,[R0]
        LDR R2,[R0,#4]
        LDR R0,=VALUE2
        LDR R3,[R0]
        LDR R4,[R0,#4]
        ADDS R5,R1,R3
        ADC R6,R2,R4
        LDR R0,=RESULT
        STR R5,[R0]
        STR R6,[R0,#4]
STOP  S   STOP

VALUE1  DCD  &BBBBBBBB,&AAAAAAAA
VALUE2  DCD  &CCCCCCCC,&FFFFFFFF

        AREA    MEMORY, DATA
RESULT  SPACE   4
        END
```

Sample Output:



Sample Program No 2A:

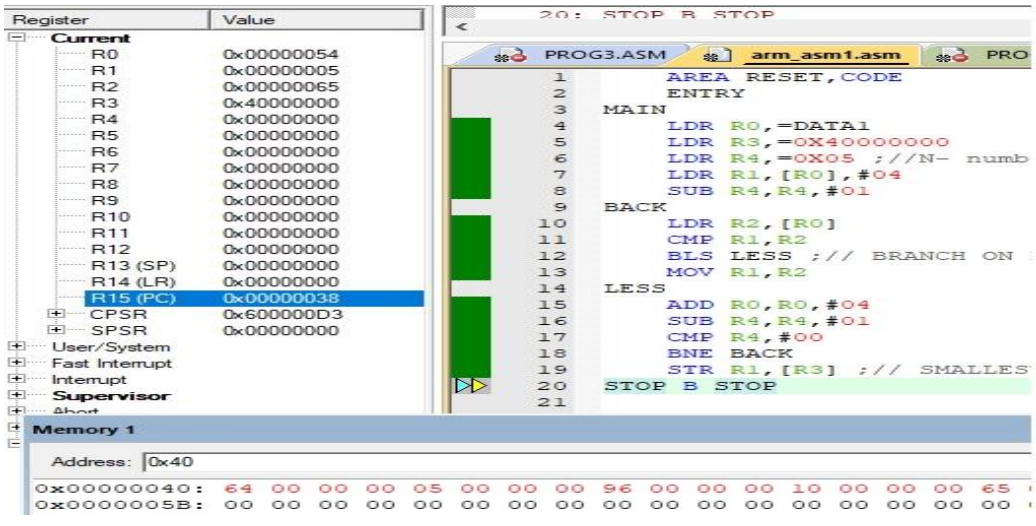
Algorithm:

1) Initialize first element as smallest [R1] and number of elements *n = n-1*
2) Loop through all the *n* [R4] elements. If the current element is smaller than *the smallest*, then update *smallest*.

AIM: Write an ARM ALP to find smallest and largest of N- 32 bit numbers.

```
        AREA RESET,CODE
        ENTRY
        LDR R0,=DATA1
        LDR R3,=0X40000000  ; memory location for storing answer
        MOV R4,#05   ; //N- number of elements
        LDR R1,[R0],#04; assume first no. as smaller no & increment R0 by 4
        SUB R4,R4,#01  ; compare with n-1 elements
BACK
        LDR R2,[R0]      ; get next number & compare with small
        CMP R1,R2
        BLS LESS   ;  // If R1 < R2 , BRANCH
        MOV R1,R2 ; update with new smaller no
LESS
        ADD R0, R0,#04   ; increment pointer to next number
        SUB  R4,R4,#01
        CMP  R4,#00
        BNE  BACK
        STR   R1, [R3]  ; // SMALLEST VALUE STORED IN MEMORY LOCATION
        STOP B STOP

        AREA DATA,CODE
DATA1  DCD &64,&05,&96,&10,&65
        END
```

Sample Output:



Sample Program No 3A:

AIM: Write an ARM ALP to compute Average of N-32 bit numbers

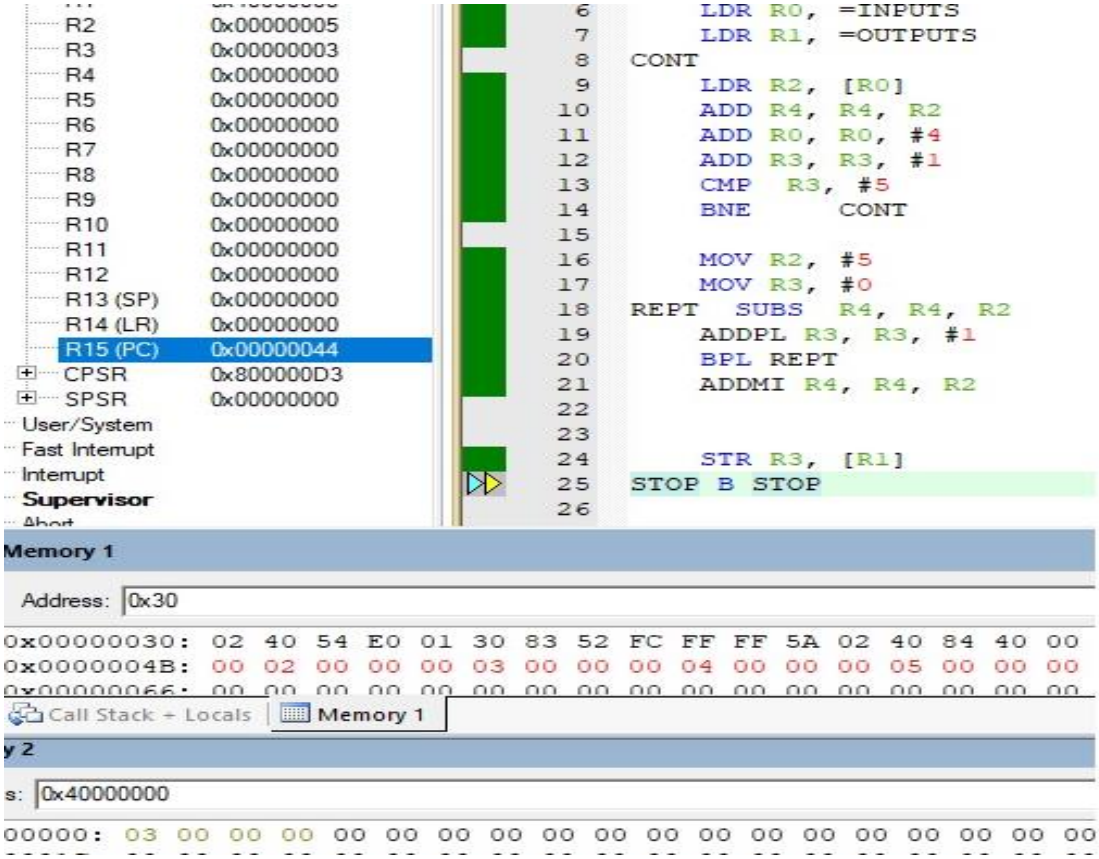
Algorithm:

1) Initialize *sum = 0*
2) Loop through all the *n* elements. Add the current element to *sum*.
3) Calculate *average = sum divide by n*

Program:

```
AREA RESET, CODE
        ENTRY

        MOV   R3,#0
        MOV   R4, #0
        LDR    R0, =INPUTS
        LDR    R1, =OUTPUTS
CONT
        LDR    R2, [R0]
        ADD R4, R4, R2
        ADD R0, R0, #4
        ADD R3, R3, #1
        CMP  R3, #5
        BNE  CONT
        MOV   R2, #5
        MOV   R3, #0
REPT   SUBS   R4, R4, R2
       ADDPL   R3, R3, #1
       BPL REPT
       ADDMI   R4, R4, R2
       STR  R3, [R1]

STOP  B  STOP

INPUTS        DCD    01,02,03,04,05

        AREA  MEMORY, DATA
OUTPUTS    SPACE    4

END
```

Sample Output:



Sample Program No 4A:

AIM: Write an ARM ALP to count the occurrences of the given 32-bit number in a List using Linear Search algorithm

Algorithm:

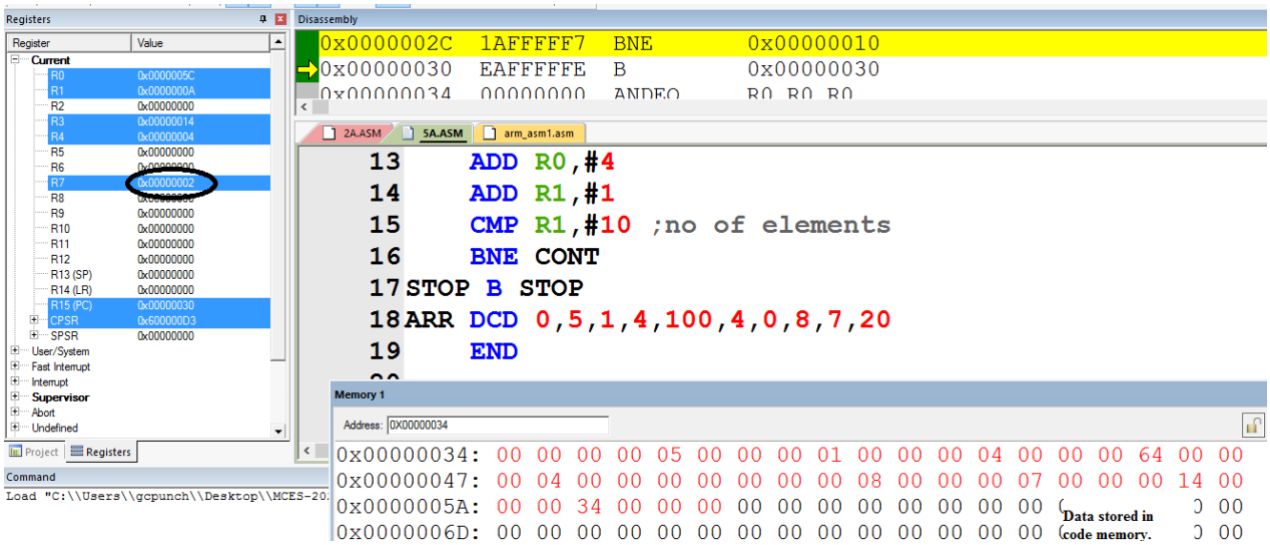
Linear Search (array A, key x)
{
  for i =0 to n
        if A[i] = x then
              increment element found count

}

Program:

```
        AREA RESET, CODE, READWRITE
        ENTRY
        LDR R0,=ARR
        MOV R1, #0    ; Loop Iterator
        MOV R7, #0    ; Number Of occurrences in The Array
        MOV R4, #4    ; key
CONT
        LDR R3,[R0]
        CMP R3, R4
        BNE SKIP
        ADD R7, R7,#1
SKIP
        ADD R0, #4
        ADD R1, #1
        CMP R1, #10   ; no of elements
        BNE  CONT
STOP  B STOP
ARR   DCD    0,5,1,4,100,4,0,8,7,20
END
```

Sample Output:



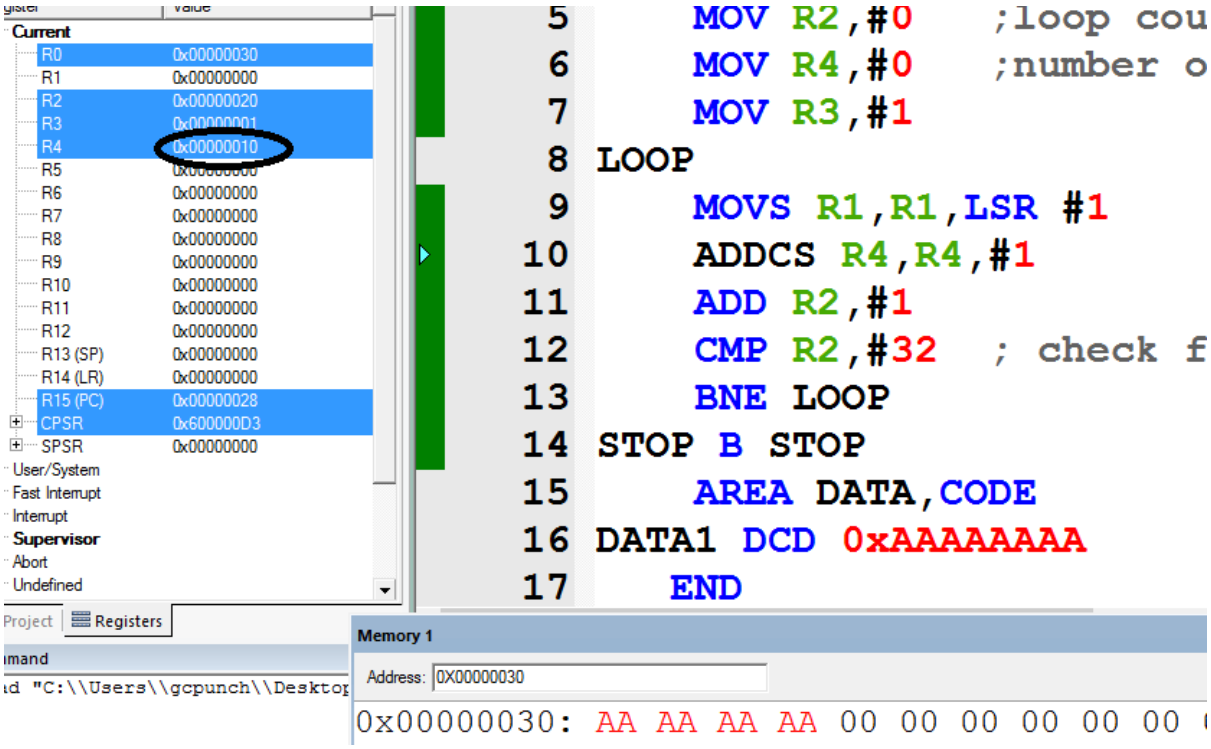
Sample Program No 5A(i):

AIM: Write an ARM ALP to compute number of 1's in a given 32 bit number and check the parity of the given number

Program:

```
        AREA  RESET,CODE
        ENTRY
        LDR R0,=DATA1
        LDR R1,[R0] ;Stores 32bit number-16 ones
        MOV R2,#0   ;loop counter, 32 times(32bits)
        MOV R4,#0   ;number of 1's counter
        MOV R3,#1
LOOP
        MOVS R1,R1,LSR #1
        ADDCS R4,R4,#1
        ADD R2,#1
        CMP R2,#32  ; check for 32 bits
        BNE LOOP
STOP B STOP
        AREA DATA,CODE
DATA1 DCD 0xAAAAAAAA
        END
```

Sample Output:



Sample Program No 5A(ii):

AIM: Write an ARM ALP to compute GCD of two given 32-bit numbers.

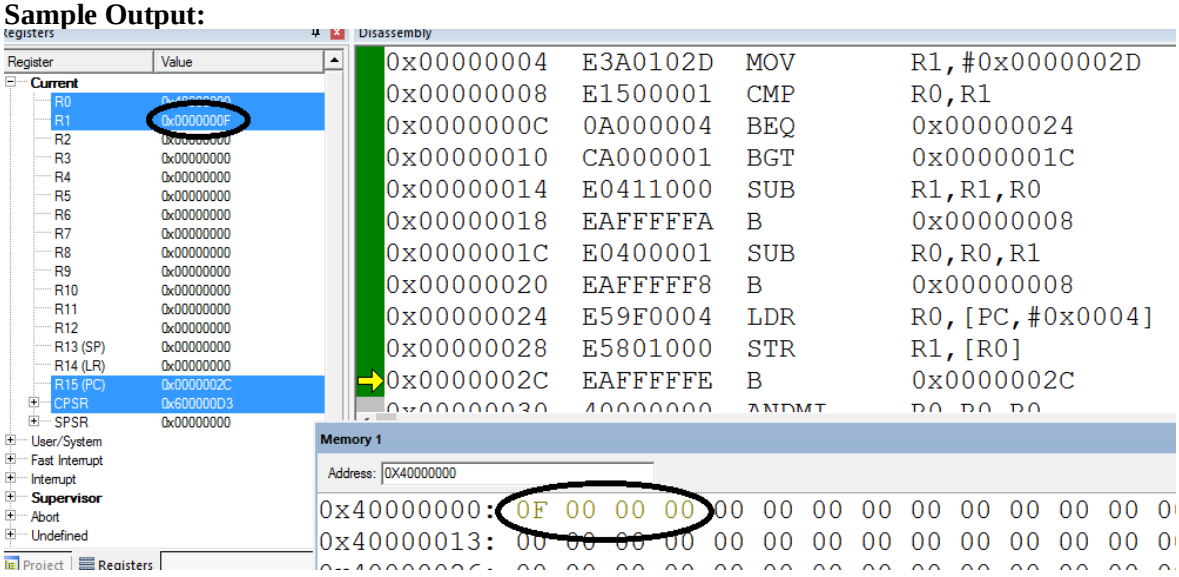
Algorithm:

```
int gcd(int x,int y){
  while(x!=y)
  {
    if(x>y)
      return gcd(x-y,y);
    else
      return gcd(x,y-x);
  }
  return x;
}
```

Program:

```
        AREA RESET,CODE
        ENTRY
        MOV R0,#30 ; test values
        MOV R1,#45 ; test values
LOOP    CMP R0,R1
        BEQ EXIT
        BGT COND1
        SUB R1,R0
        B LOOP
COND1   SUB R0,R1
        B LOOP
EXIT    LDR R0,=GCD
        STR R1,[R0]
STOP    B STOP
        AREA RESULT,DATA
GCD     SPACE 4
        END
```

Sample Output:



Sample Program No 6A:

AIM: Write an ARM ALP to compute the factorial of a given 32-bit number using procedure.

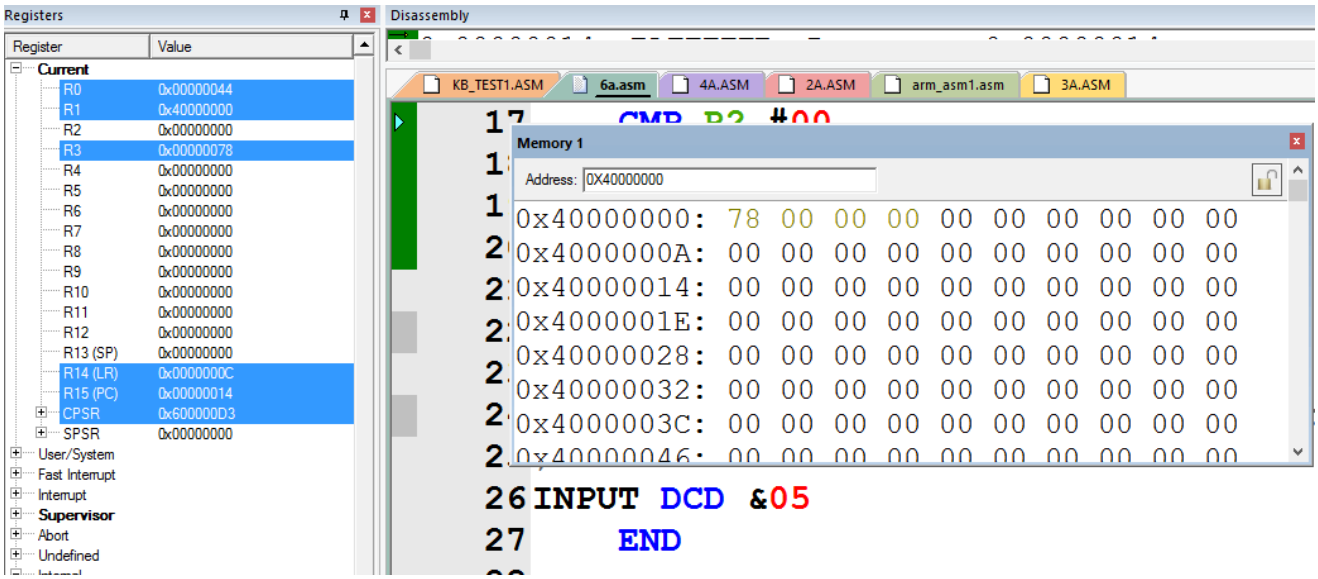
Algorithm:

```
fact(int n)
{
    Read number n.
    Initialize i =n and fact to 1.
    Repeat  while i is not equal to 0.
    {
        fact = fact * i
        i = i -1
    }
    Return fact
}
```

Program:

```
    AREA RESET,CODE
    ENTRY
    LDR R0,=INPUT
    BL FACT                 ;  CALL SUBROUTINE FACT
    LDR R1,=0X40000000   ;  RAM area
    STR R3,[R1]              ; store result in R3 to RAM
STOP B STOP

;subroutine-begin
FACT
    LDR R2,[R0]          ; get num in R2
    CMP R2,#00
    BEQ END1
    MOV R3,R2            ; result = num
LOOP
    SUB R2,#01           ; num = num - 1
    CMP R2,#00
    MULNE R3,R2,R3    ;result = result * num
    BNE LOOP
    MOV PC,LR
END1
    MOV R3,#01           ; return R3=1, if  num=0
END2
    MOV PC,LR ; return from subroutine
;subroutine-end

INPUT DCD &05
    END
```

Sample Output:



Sample Program No 7A:

AIM: Write an ARM ALP to sort the given list of 32-bit numbers using Bubble sort.

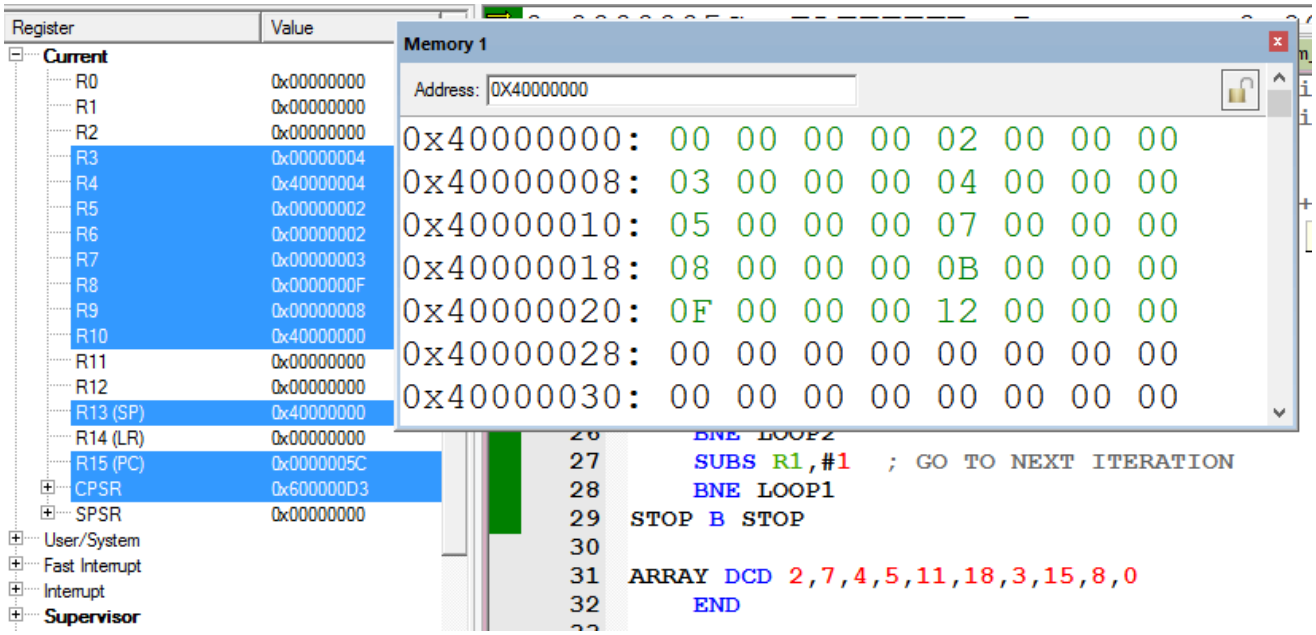
Algorithm:

```
bubbleSort(list of n elements)
{
  for all n elements
     n = n-1;
     for (i=0 to n, i++)
         if ( A[i] > A[i+1] )
            temp = A[i]
            A[i] = A[i+1]
            A[i+1] = temp
}
```

Program:

```
        AREA RESET, CODE
        ENTRY

        LDR   R0, =ARRAY
        LDMIA  R0, {R1-R10}        ;COPY FROM FLASH TO SRAM,USING REGISTERS
        MOV     SP,  #0X40000000
        STMIA  SP,  {R1-R10}
        MOV   R10,  #0X40000000   ; STARTING MEMORY ADDRESS OF ARRAY
        MOV   R1,  #10   ; TOTAL ELEMENTS
        SUB   R1,#1    ; TOTAL ITERATIONS = N-1
LOOP1
        MOV   R2, R1    ; NO OF COMPARISIONS IN A GIVEN PASS = NO OF PASSES LEFT
        MOV   R4, R10  ;  SET R4 = STARTING MEM ADDRESS,FOR EVERY PASS
LOOP2
        LDR   R0, [R4]   ; GET FIRST ELEMENT, ARR[i]
        LDR   R5, [R4, #4]  ;GET NEXT ELEMENT,ARR[i+1]
        CMP   R0, R5
        BLS   SKIP        ;IF ARR[i]<ARR[i+1], skip
        MOV   R6, R0   ;else, SWAP ARR[i] & ARR[i+1]
        MOV   R0, R5
        MOV   R5, R6
        STR   R0, [R4]
        STR   R5, [R4,#4]
SKIP
        ADD   R4,  #4
        SUBS  R2, #1  ; GO TO NEXT COMPARISION
        BNE   LOOP2
        SUBS   R1, #1  ; GO TO NEXT ITERATION

        BNE   LOOP1
    STOP   B   STOP

    ARRAY   DCD   2,7,4,5,11,18,3,15,8,0
        END
```

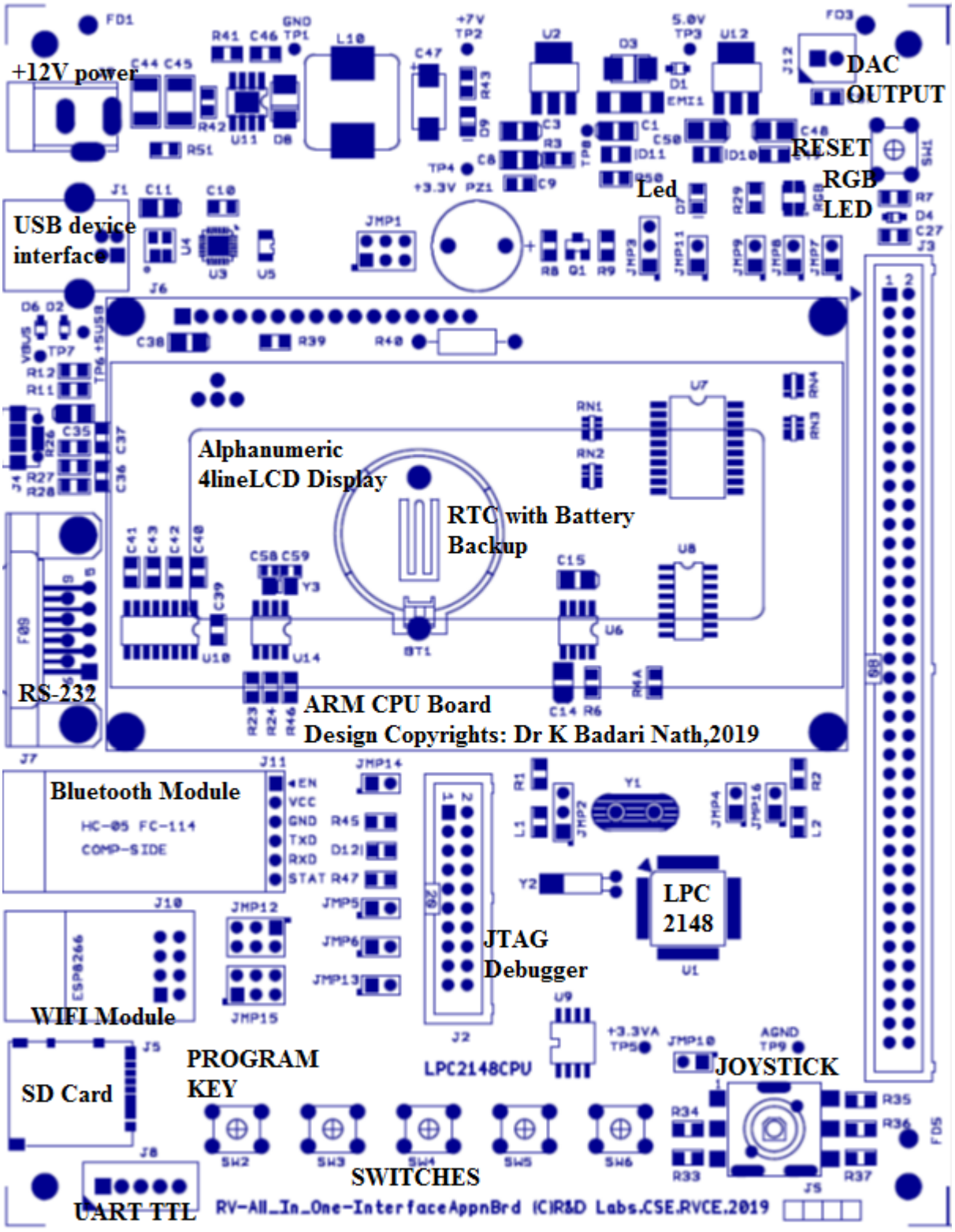
Sample Output:



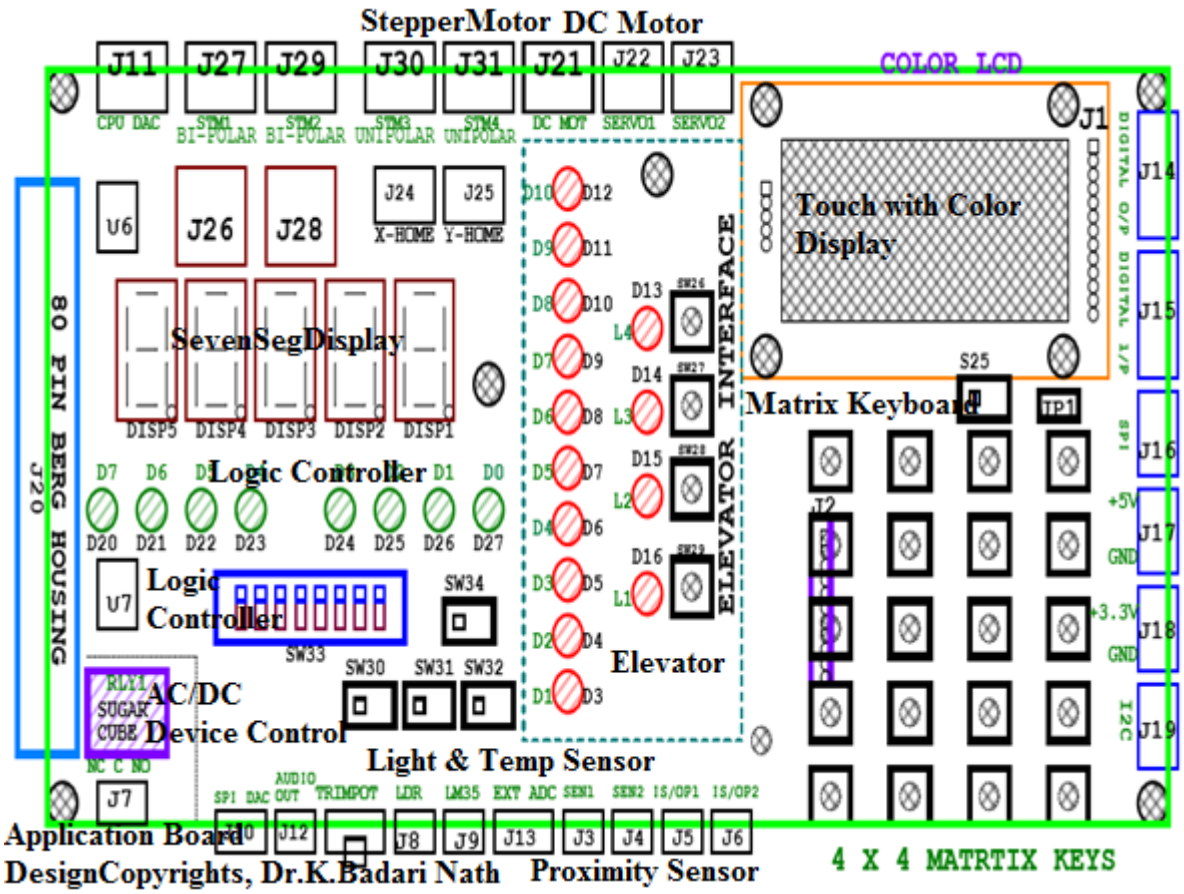
PART – A

Interfacing Programs using ARM LPC 2148

ARM CPU Board



ARM Application Board



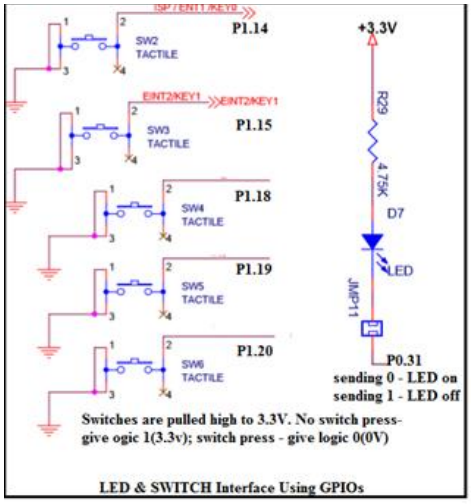
Board Specifications: Power : 12V, 1A

8 Bit DIP Switch (Toggle) 5 Application Switches 4 x 4 Matrix Keyboard Joystic Interface Touch Interface **Input Interfaces**	9 LEDs 5 Digit Common Anode seven segment display 20x4 Alphanumeric display RGB LED using PWM Color Touch Enabled Display **Output Interfaces**
Communication Interfaces 8 bit GPIO outputs RS-232 COM Port TTL Serial Port – UART USB Client Interface SPI Interface I2C Interface Wifi Interface Bluetooth Interface	Debugging & Programming Virtual COM Port JTAG Debugger 8LEDs & 5 Application Keys to support debugging of projects **Debugging & Programming Support** Storage Support Flash MemoryChip – 8MB SD Card Interface RTC with Battery Backup **Storage Support**

Board Specifications: RV - ARM AllInOne Board
ARM CPU Board & Application Board

Sample program : Interfacing LED and Switches

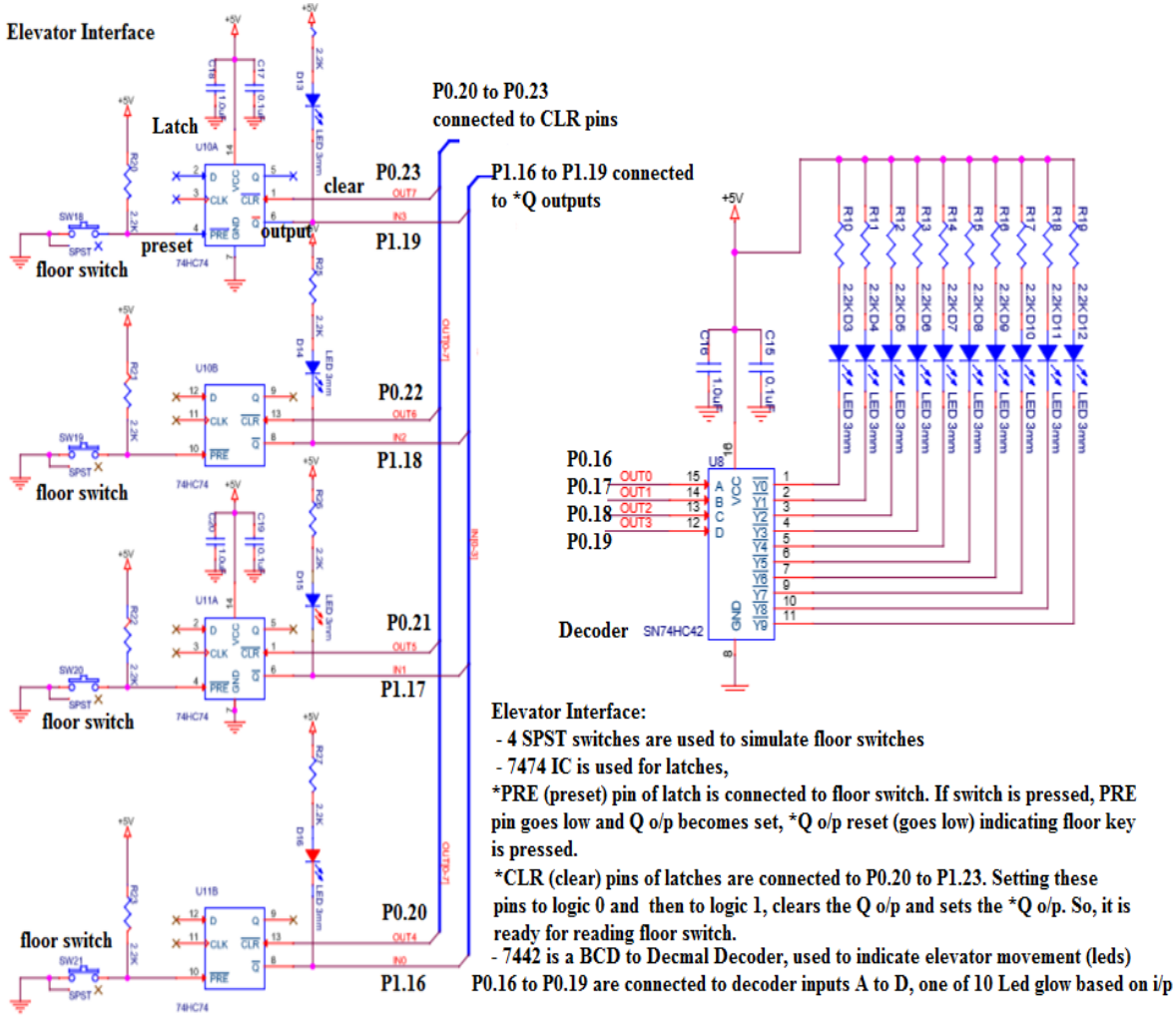
Interfacing Diagram




```
 //Sample Program 1:  Interfacing LED and Switch to LPC2148 using GPIO pins
   //P0.31 connected to LED - D7 in CPU board(common anode)
   //P1.14 connected to Switch - SW2 in CPU board
#include <lpc214x.h>
#define LED_OFF (IO0SET = 1U << 31)
#define LED_ON (IO0CLR = 1U << 31)
#define SW2 (IO0PIN & (1 << 14))
void delay_ms(unsigned int j);
int main( )
{
    IO0DIR = 1U << 31;
    IO0SET = 1U << 31;
    while(1)
     {
          if (!(IO0PIN & (1 << 14)))//(if(!SW2 )
           {
                    IO0CLR = 1U << 31; //LED_ON
                    delay_ms(250);
                    IO0SET = 1U << 31; //LED_OFF
                    delay_ms(250);
           }
      }
}
void delay_ms(unsigned int j)
{
  unsigned int x, i;
  for(i=0; i<j; i++)
   {
     for(x=0; x<10000; x++);    /* loop to generate 1 milisecond delay with CCLK = 60MHz */
   }
}
```

Program 1: Interface Logic Controller and write Embedded C programs to generate BCD up / down and Ring counters. Input is read from the DIP switch.

Interfacing Diagram



//Elevator Program:

// P0.16 - P0.19 are connected to decoder inputs, it makes one of the o/p LEDs 0 to 9 on

*// P0.20-P0.23 are connected to *CLR pins of latches: make it '0' and then '1' to clear*

*// elevator keys: *Q outputs of latches connected to P1.16 TO P1.19*

```
#include<lpc214x.h>
#define IS_ON(pin) (IO1PIN & (1U << (pin)))

void delay_ms(unsigned int x);
void reset_values(int y);

int contUP = 0;
int contDN = 99;
unsigned int rightSFT = 1U<<7;
unsigned int leftSFT = 1;
const int key0 = 16;
const int key1 = 17;
const int key2 = 18;
const int key3 = 19;

int main()
{
	IO0DIR |= 0xFF;

	while(1)
	{
		if(IS_ON(key0))
		{
			reset_values(0);
			IO0CLR = 0xFF<<16;
			IO0SET |= ((contUP/10)<<4 | (contUP%10))<<16;
			contUP++;
			if(contUP > 99) contUP = 0;
		}
		else if(IS_ON(key1))
		{
			reset_values(1);
			IO0CLR = 0xFF<<16;
			IO0SET |= ((contDN/10)<<4 | (contDN%10)) << 16;
			contDN--;
			if(contDN < 0) contDN = 99;
		}
		else if(IS_ON(key2))
		{
			reset_values(2);
			IO0CLR = 0xFF<<16;
			IO0SET |= leftSFT<<16;
			leftSFT<<=1;
			if(leftSFT > 1U<<7) leftSFT = 1;
		}
		else if(IS_ON(key3))
		{
			reset_values(3);
			IO0CLR = 0xFF<<16;
			IO0SET |= rightSFT<<16;
```

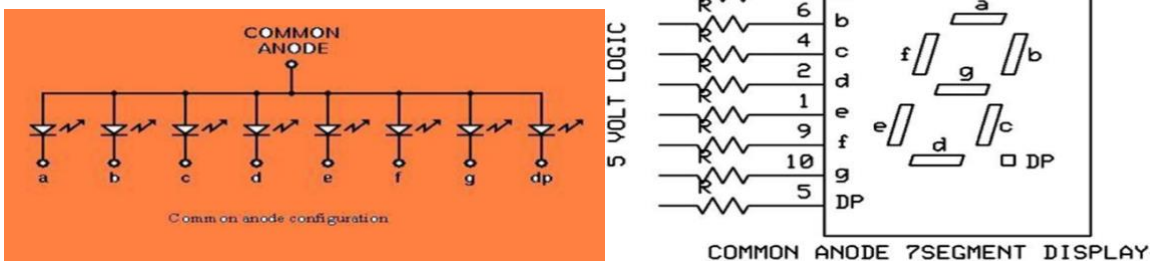
```
                rightSFT>>=1;
                if(rightSFT < 1) rightSFT = 1U<<7;
            }
            delay_ms(100);
        }
}

void reset_values(int y)
{
        switch(y)
        {
            case 0: contDN = 99;
                                    rightSFT = 1U<<7;
                                    leftSFT = 1;
                                    break;
            case 1: contUP = 0;
                                    rightSFT = 1U<<7;
                                    leftSFT = 1;
                                    break;
            case 2: contUP = 0;
                                    contDN = 99;
                                    rightSFT = 1U<<7;
                                    break;
            case 3: contUP = 0;
                                    contDN = 99;
                                    leftSFT = 1;
                                    break;
        }
}

void delay_ms(unsigned int ms) {
        for(int i = 0; i < ms; i++) {
            for(int x = 0; x < 10000; x++);
        }
}
```

Interfacing Circuit working Explanation:

Output Observation:

Program 2: Seven Segment Display Interface: Write a C program to display messages "FIRE" & "HELP" on 4 digit seven segment display alternately with a suitable delay.

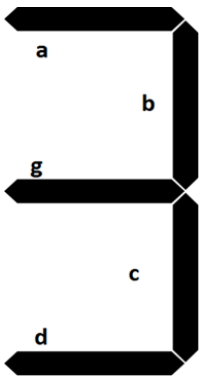
Serial In Parallel Out mode of Shift Register (74HC4094) is used to send 8 bits of data to seven segment display. Seven segment display used is of common anode type i.e. we have to send 0 to make corresponding segment ON and 1 to make it OFF.



To display 3, we have to send following bit pattern,

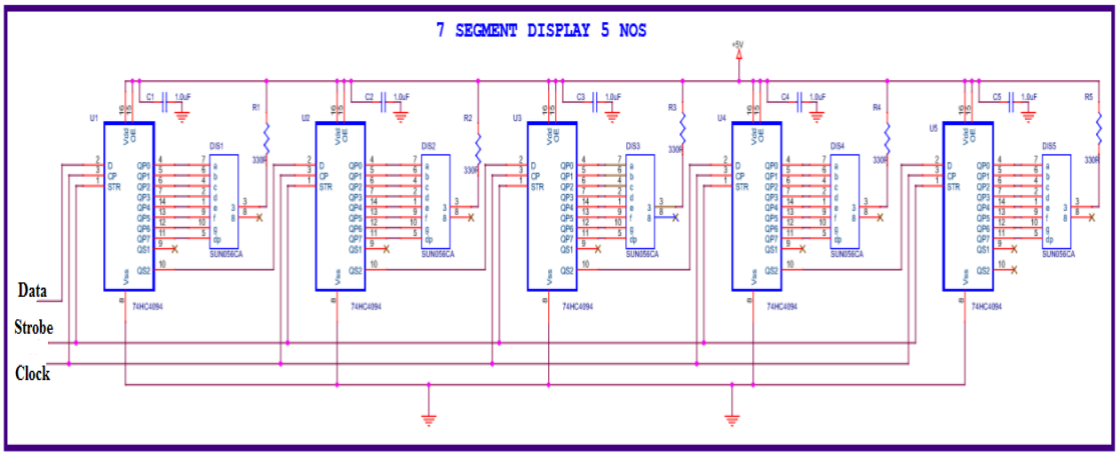
DP	G	f	e	d	c	b	a
1	0	1	1	0	0	0	0

This is B0 in hexadecimal. To send B0H we have to start sending the bits from MSB onwards i.e D7 first, D6 next and so on with D0 being the last



Clock pulses are required to clock in the data, 8 clock pulses for one byte of data. As shift registers are cascaded, 8*4=32 clocks are required to clock in 4 bytes of data. To send "12345", first we have to send '1', then '2','3' ,'4' and lastly '5'. All the shift registers are cascaded, the data is fed to the shift register using serial in parallel out method. Strobe is used to copy the shifted data to the output pins. STB is generated after shifting is comleted.

Interfacing Diagram




```
//Seven Segment Display Program:
//P0.19 Data pin of 1st shift register
//P0.20 Clock pin of shift registers, make 1 to 0
//P0.30 Strobe pin of shift registers: 1 to 0

#include <lpc214x.h>
#define LED_OFF (IO0SET = 1U << 31)
#define LED_ON (IO0CLR = 1U << 31)
#define PLOCK 0x00000400
void delay_ms(unsigned int j);
void SystemInit(void);
unsigned char getAlphaCode(unsigned char alphachar);
void alphadisp7SEG(char *buf);
int main()
{
      IO0DIR |= 1U << 31 | 1U << 19 | 1U << 20 | 1U << 30 ; // to set as o/ps
       LED_ON; // make D7 Led on .. just indicate the program is running
       SystemInit();
       while(1)
          {
            alphadisp7SEG("fire ");
            delay_ms(500);
            alphadisp7SEG("help ");
            delay_ms(500);
          }

}
```

```
unsigned char getAlphaCode(unsigned char alphachar)
{
  switch (alphachar)
            {
            // dp g f e d c b a - common anode: 0 segment on, 1 segment off
            case 'f': return 0x8e;
            case 'i': return 0xf9;
            case 'r': return 0xce;
            case 'e':return 0x86;  // 1000 0110
            case 'h':return 0x89;
            case 'l': return 0xc7;
            case 'p':return 0x8c;
            case ' ': return 0xff;
            //simmilarly add for other digit/characters
            default : break;
            }
  return 0xff;
}
void alphadisp7SEG(char *buf)
{
  unsigned char  i,j;
  unsigned char seg7_data,temp=0;
  for(i=0;i<5;i++) // because only 5 seven segment digits are present
    {
       seg7_data = getAlphaCode(*(buf+i));  //instead of this look up table can be used
        //to shift the segment data(8bits)to the hardware (shift registers) using Data,Clock,Strobe
            for (j=0 ; j<8; j++)
            {
                    //get one bit of data for serial sending
                    temp = seg7_data & 0x80;  // shift data from Most significan bit (D7)
                    if(temp == 0x80)
                            IOSET0 |= 1 << 19; //IOSET0 | 0x00080000;
                    else
                            IOCLR0 |= 1 << 19; //IOCLR0 | 0x00080000;
                    //send one clock pulse
                    IOSET0 |= 1 << 20;  //IOSET0 | 0x00100000;
                    delay_ms(1);
                    IOCLR0 |= 1 << 20;  //IOCLR0 | 0x00100000;
                    seg7_data = seg7_data << 1; // get next bit into D7 position
            }
    }
```

```
   // send the strobe signal
   IOSET0 |= 1 << 30; //IOSET0 | 0x40000000;
   delay_ms(1);      //nop();
   IOCLR0 |= 1 << 30;  //IOCLR0 | 0x40000000;
   return;
}
 void SystemInit(void)
 {
   PLL0CON = 0x01;
   PLL0CFG = 0x24;
   PLL0FEED = 0xAA;
   PLL0FEED = 0x55;
   while( !( PLL0STAT & PLOCK ))
   { ; }
   PLL0CON = 0x03;
   PLL0FEED = 0xAA;  // lock the PLL registers after setting the required PLL
   PLL0FEED = 0x55;
   VPBDIV = 0x01;      // PCLK is same as CCLK i.e 60Mhz
 }

 void delay_ms(unsigned int j)
 {
  unsigned int x,i;
  for(i=0;i<j;i++)
   {
     for(x=0; x<10000; x++);
   }
 }
```

// CODE to display an integer number/long integer number

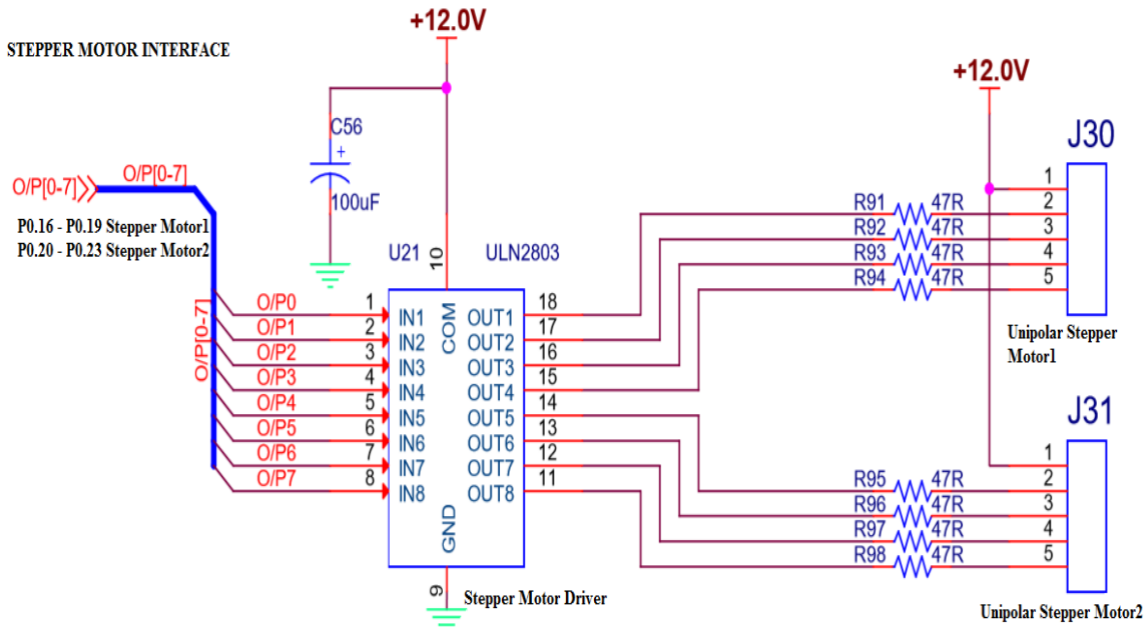
```
// long int dig_value;
// unsigned char buf[5];
// sprintf(buf,"%05lu",dig_value);
// alphadisp7SEG(&buf[0]);
```

Interfacing Circuit working Explanation:

Output Observation:

Program No.3: Stepper Motor Interface: Write an Embedded C program to rotate stepper motor in clockwise direction for "M" steps, anti-clock wise direction for "N" steps.

Interfacing circuit diagram



- Total number of steps for one revolution = 200 steps (200 teeth shaft)

  Step angle = 360°/200 = 1.8°
- Use appropriate delay in between consequent steps
- 2Phase, 4winding stepper motor is used, along with driver circuit(ULN 2803) built on the RV All-In- One Card, 12v power is used to drive the stepper motor. Digital input generated by the microcontroller, is used to drive and control the direction and rotation of stepper motors. If it is required to drive bigger/higher torque stepper motors only change is- use MOSFETS or higher power stepper driver ICs to drive motors

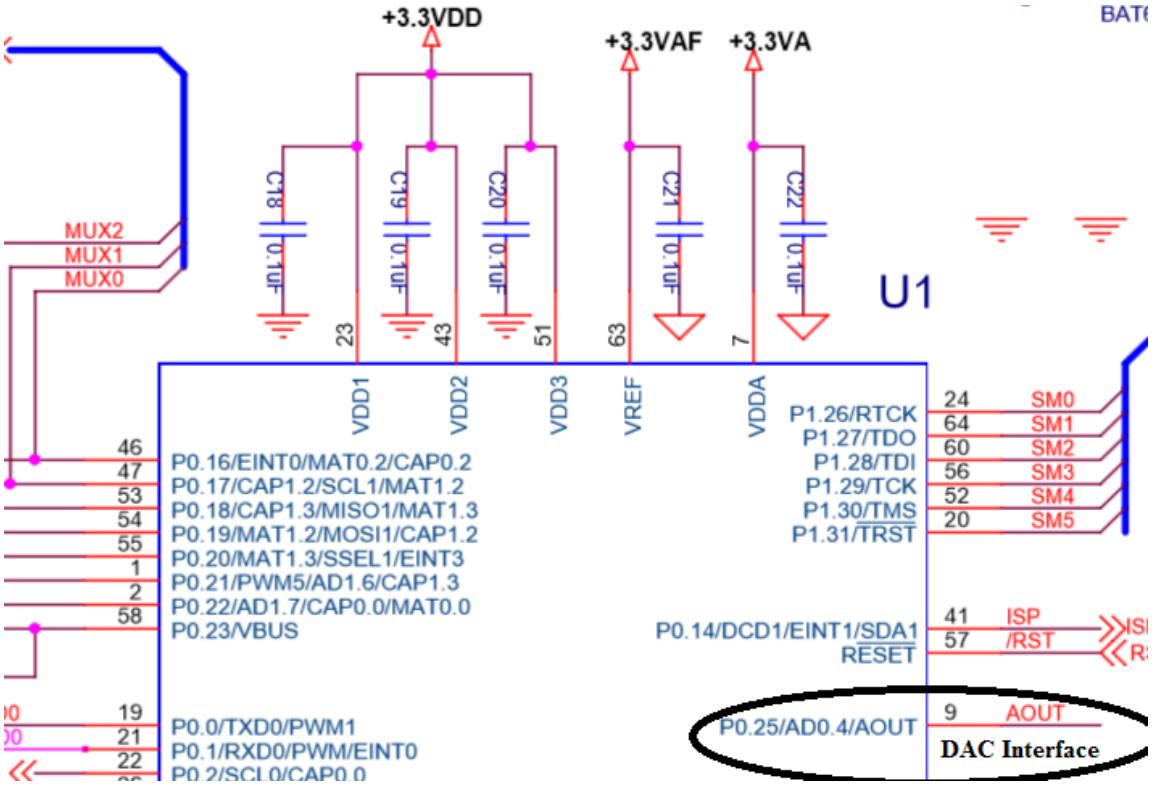
//Stepper Motor Program:
//P0.16 to P0.19 are connected to Windings of SMotor

```
#include <lpc214x.h>
#define LED_OFF (IO0SET = 1U << 31)
#define LED_ON (IO0CLR = 1U << 31)
#define PLOCK 0x00000400
void delay_ms(unsigned int j);
void SystemInit(void);

int main()
{
    unsigned int  no_of_steps_clk = 100, no_of_steps_aclk = 100;
    IO0DIR |= 1U << 31 | 0x00FF0000 | 1U << 30; // to set P0.16 to P0.23 as o/ps
    LED_ON; delay_ms(500);LED_OFF; // make D7 Led on .. just indicate the program is running
    SystemInit( );
   do{
   IO0CLR = 0X000F0000;IO0SET = 0X00010000;delay_ms(10);if(--no_of_steps_clk == 0) break;
   IO0CLR = 0X000F0000;IO0SET = 0X00020000;delay_ms(10);if(--no_of_steps_clk == 0) break;
   IO0CLR = 0X000F0000;IO0SET = 0X00040000;delay_ms(10);if(--no_of_steps_clk == 0) break;
   IO0CLR = 0X000F0000;IO0SET = 0X00080000;delay_ms(10);if(--no_of_steps_clk == 0) break;
   }while(1);
   do{
   IO0CLR = 0X000F0000;IO0SET = 0X00080000;delay_ms(10);if(--no_of_steps_aclk == 0) break;
   IO0CLR = 0X000F0000;IO0SET = 0X00040000;delay_ms(10);if(--no_of_steps_aclk == 0) break;
   IO0CLR = 0X000F0000;IO0SET = 0X00020000;delay_ms(10);if(--no_of_steps_aclk == 0) break;
   IO0CLR = 0X000F0000;IO0SET = 0X00010000;delay_ms(10);if(--no_of_steps_aclk == 0) break;
   }while(1);
   IO0CLR = 0X00FF0000;
   while(1);
}

void delay_ms(unsigned int j)
{
 unsigned int x,i;
 for(i=0;i<j;i++)
  {
    for(x=0; x<10000; x++);
  }
}
```

Interfacing Circuit working Explanation:

Output Observation:

Program No.4: DAC Interface : Write an Embedded C program to generate sine, full rectified sine, Triangular, Sawtooth and Square waveforms using DAC module



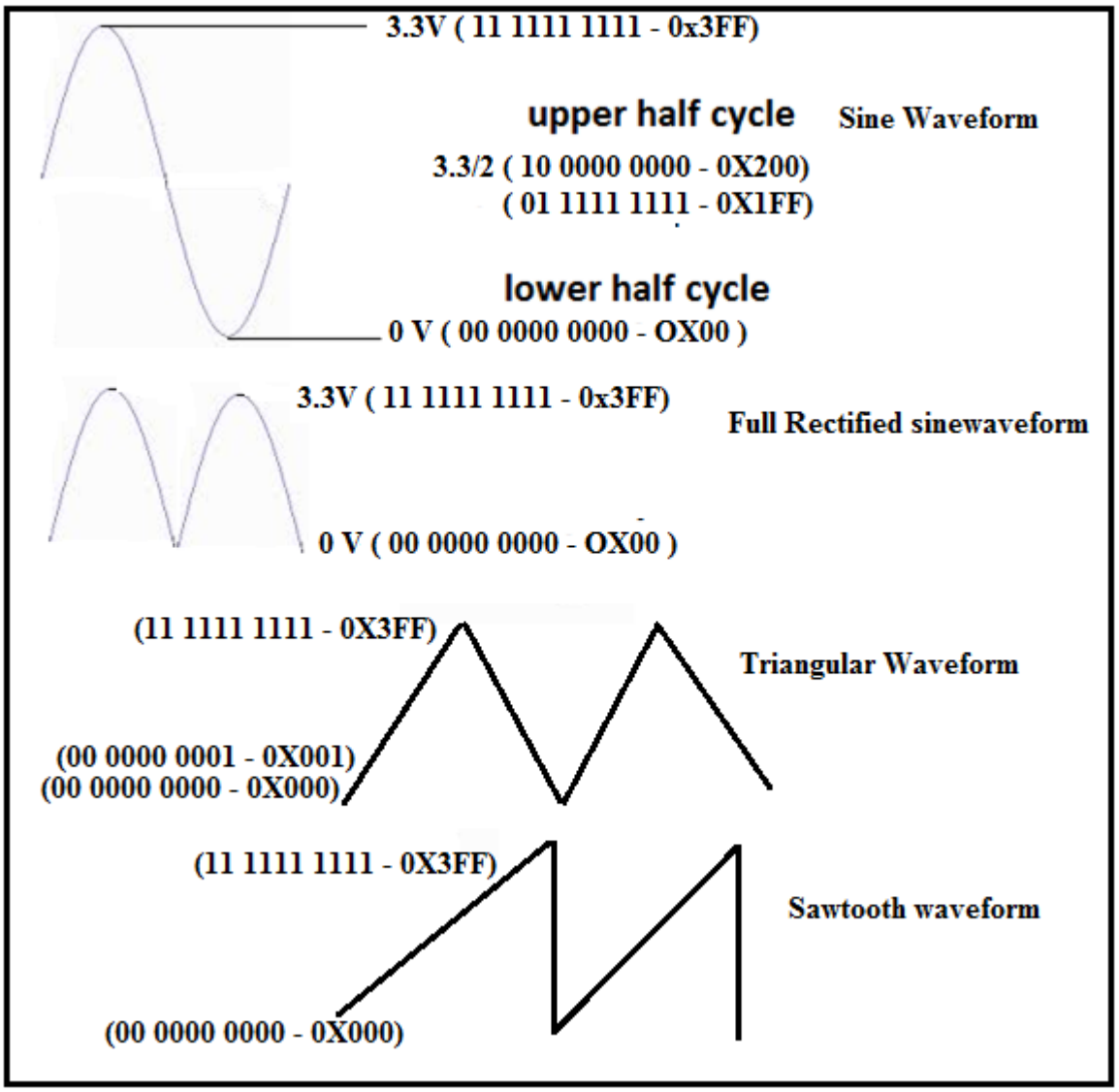
- DAC module of LPC 2148 is 10 bit Digital to Analog converter used to convert 10 bit Digital data to corresponding Analog voltage.
- Digital I/P : **000 to 3FF (0 to 1023)**, corresponding Analog O/P : **0V to 3.3V**
- Resolution = (3.3/1024) ≈ **3.2mili volts**

Look up Table Creation: Look up tables are used extensively in embedded systems, to store precomputed digital values, corresponding to analog voltages and used to generate different waveforms using DAC Module. Here the explanation about creating sine table is given.

Formula for calculation of the sine table entries: **512 + 511 x Sin Θ**
(512 Corresponds to 1FFh, i.e. 3.3/2 V, 511 x SIN 90 gives 511, so 512 + 511 = 1023 (for 3.3V). Calculate the digital values to be outputted to DAC for angles in the steps of 6º,

511 x sin 0 = 0	511 x sin 48 = 380
511 x sin 6 = 53	511 x sin 54 = 413
511 x sin 12 = 106	511 x sin 60 = 442
511 x sin 18 = 158	511 x sin 66 = 467
511 x sin 24 = 208	511 x sin 72 = 486
511 x sin 30 = 256	511 x sin 80 = 503
511 x sin 36 = 300	511 x sin 86 = 510
511 x sin 42 = 342	511 x sin 90 = 511

Output the above values in the reverse order to get other portion of the top half cycle, (add 512 for top half cycle, and subtract from 512 for the lower half cycle, refer the table declaration).




```
//Alpha-numeric LCD Interface (4Lines,20characters)
//Connected in 4bit nibble mode
//LCD handshaking:RS->P0.20,EN->P0.25 ,R/W -Gnd
//LCD data:D4,D5,D6,D7 -> P0.16,P0.17,P0.18,P0.19
```

```
#include <lpc214x.h>
#include <stdio.h>
#define PLOCK 0x00000400
#define LED_OFF (IO0SET = 1U << 31)
#define LED_ON  (IO0CLR = 1U << 31)
#define SW2 (IO0PIN & (1 << 14))
#define SW3 (IO0PIN & (1 << 15))
#define SW4 (IO1PIN & (1 << 18))
#define SW5 (IO1PIN & (1 << 19))
#define SW6 (IO1PIN & (1 << 20))
void SystemInit(void);
static void delay_ms(unsigned int j);//millisecond delay
short int sine_table[ ] =
{512+0,512+53,512+106,512+158,512+208,512+256,512+300,512+342,512+380,512+413,
512+442,512+467,512+486,512+503,512+510,512+511,
512+510,512+503,512+486,512+467,512+442,512+413,512+380,512+342,512+300,512+25
6,512+208,512+158,512+106,512+53,512+0,
512-53,512-106,512-158,512-208,512-256,512-300,512-342,512-380,512-413,512-442,512-
467,512-486,512-503,512-510,512-511,
512-510,512-503,512-486,512-467,512-442,512-413,512-380,512-342,512-300,512-
256,512-208,512-158,512-106,512-53};
short int sine_rect_table[ ] =
{512+0,512+53,512+106,512+158,512+208,512+256,512+300,512+342,512+380,512+413,
512+442,512+467,512+486,512+503,512+510,512+511,
512+510,512+503,512+486,512+467,512+442,512+413,512+380,512+342,512+300,512+25
6,512+208,512+158,512+106,512+53,512+0};

int main()
{
 short int value,i=0;
 SystemInit();
 PINSEL1 |= 0x00080000;      /* P0.25 as DAC output :option 3 - 10 (bits18,19)*/
 IO0DIR |= 1U << 31 | 0x00FF0000 ; // to set P0.16 to P0.23 as o/ps

 while(1)
         {
            if (!SW2)     /* If switch for sine wave is pressed */
              {
                    while (i!=60 )
                     {
                        value = sine_table[i++];
                        DACR = ( (1<<16) | (value<<6) );
                        delay_ms(1);
                     }
                    i=0;
               }
```

```
        else if (!SW3)
            {
                while ( i!=30 )
                 {
                   value = sine_rect_table[i++];
                   DACR = ( (1<<16) | (value<<6) );
                   delay_ms(1);
                 }
                i=0;
             }
        else if ( !SW4)          /* If switch for triangular wave is pressed */
             {
                value = 0;
                while ( value != 1023 )
                  {
                    DACR = ( (1<<16) | (value<<6) );
                    value++;
                  }
                while ( value != 0 )
                  {
                   DACR = ( (1<<16) | (value<<6) );
                   value--;
                 }
             }
        else if ( !SW5 )         /* If switch for sawtooth wave is pressed */
           {
                value = 0;
                while ( value != 1023 )
                  {
                   DACR = ( (1<<16) | (value<<6) );
                   value++;
                  }
           }
        else if ( !SW6 )         /* If switch for square wave is pressed */
          {
                value = 1023;
                DACR = ( (1<<16) | (value<<6) );
                delay_ms(1);
                value = 0;
                DACR = ( (1<<16) | (value<<6) );
                delay_ms(1);
          }
        else     /* If no switch is pressed, 3.3V DC */
         {
                value = 1023;
                DACR = ( (1<<16) | (value<<6) );
        }
    }
}
```

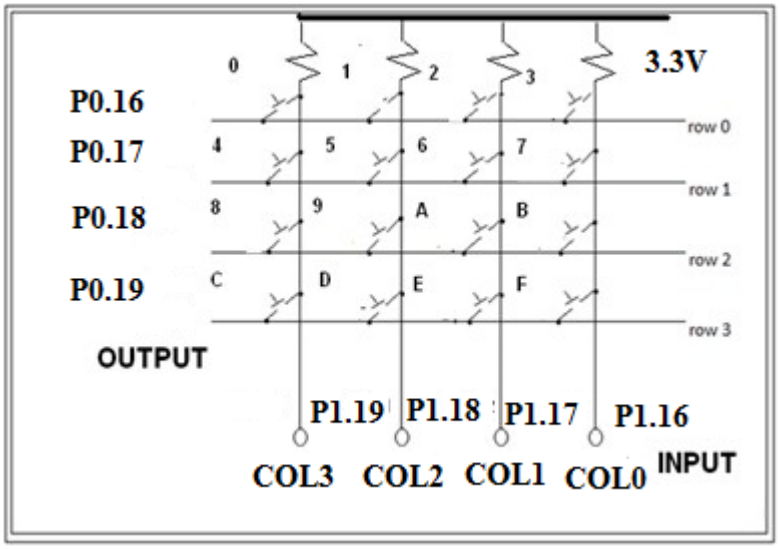
```
void SystemInit(void)
{
  PLL0CON = 0x01;
  PLL0CFG = 0x24;
  PLL0FEED = 0xAA;
  PLL0FEED = 0x55;
  while( !( PLL0STAT & PLOCK ))
  {  ;  }
  PLL0CON = 0x03;
  PLL0FEED = 0xAA;
  PLL0FEED = 0x55;
}
void delay_ms(unsigned int j)
{
 unsigned int x,i;
 for(i=0;i<j;i++)
  {
    for(x=0; x<10000; x++);
  }
}
```

Interfacing Circuit working Explanation:

Output Observation:

Program No.5: Matrix Keyboard Interface : Write an embedded C program to interface 4 X 4 matrix keyboard using lookup table and display the key pressed on the Terminal.

Interfacing Diagram



Working method:

- If no key is pressed, we will have on columns 0-3, '1111' on P1.16 to P1.19, as all the inputs are pulled up by pull up resistors.
- If we press any key, let '0' key be pressed, it will short row0 and col0 lines (P0.16 & P1.19), so whatever data (0 or 1) available at row0 (P0.16) is available at col0 (P1.19). Since already columns are pulled high, it is required to apply logic '0' to see change in col0 when the key is pressed.
- To identify which key is pressed,
  - Check for a key press in first row by out putting – '0111'on row's, check which column data is changed, if no key press go for next row
  - Check for a key press in second row by out putting – '1011'on row's, check which column data is changed, if no key press go for next row
  - Check for a key press in third row by out putting – '1101'on row's, check which column data is changed, if no key press go for next row
  - Check for a key press in last row by out putting – '1110'on row's, if no key is pressed go for the first row again
- Once the key press is found, use the row number and column number and look up table to convert the key position corresponding to ascii code. Use appropriate delay for debouncing.

```
//Matrix 4 x 4 Keyboard
//Columns & Rows are pulled to +5v,if dont press key, we receive '1' on columns
//Method: Sending '0' to a selected row, checking for '0' on each column
//ROWS - ROW0-ROW3 -> P0.16,P0.17,P0.18,P0.19
//COLS - COL0-COL3 -> P1.19,P1.18,P1.17,P1.16
#include <lpc214x.h>
#define PLOCK 0x00000400
#define LED_OFF (IO0SET = 1U << 31)
#define LED_ON  (IO0CLR = 1U << 31)
#define COL0 (IO1PIN & 1 <<19)
#define COL1 (IO1PIN & 1 <<18)
#define COL2 (IO1PIN & 1 <<17)
#define COL3 (IO1PIN & 1 <<16)
void SystemInit(void);
void delay_ms(unsigned int j);
void uart_init(void);
unsigned char lookup_table[4][4]={  {'0', '1', '2','3'},
                                    {'4', '5', '6','7'},
                                    {'8', '9', 'a','b'},
                                    {'c', 'd', 'e','f'}};
unsigned char rowsel=0,colsel=0;
int main( )
{
 SystemInit();
 uart_init();//initialize UART0 port
 IO0DIR |= 1U << 31 | 0x00FF0000; // to set P0.16 to P0.23 as o/ps
//make D7 Led on off for testing
 LED_ON; delay_ms(500);LED_OFF;delay_ms(500);
 do
   {
     while(1)
       {
        //check for keypress in row0,make row0 '0',row1=row2=row3='1'
        rowsel=0;IO0SET = 0X000F0000;IO0CLR = 1 << 16;
        if(COL0==0){colsel=0;break;};if(COL1==0){colsel=1;break;};
        if(COL2==0){colsel=2;break;};if(COL3==0){colsel=3;break;};
        //check for keypress in row1,make row1 '0'
        rowsel=1;IO0SET = 0X000F0000;IO0CLR = 1 << 17;
        if(COL0==0){colsel=0;break;};if(COL1==0){colsel=1;break;};
        if(COL2==0){colsel=2;break;};if(COL3==0){colsel=3;break;};
        //check for keypress in row2,make row2 '0'
        rowsel=2;IO0SET = 0X000F0000;IO0CLR = 1 << 18;//make row2 '0'
        if(COL0==0){colsel=0;break;};if(COL1==0){colsel=1;break;};
```

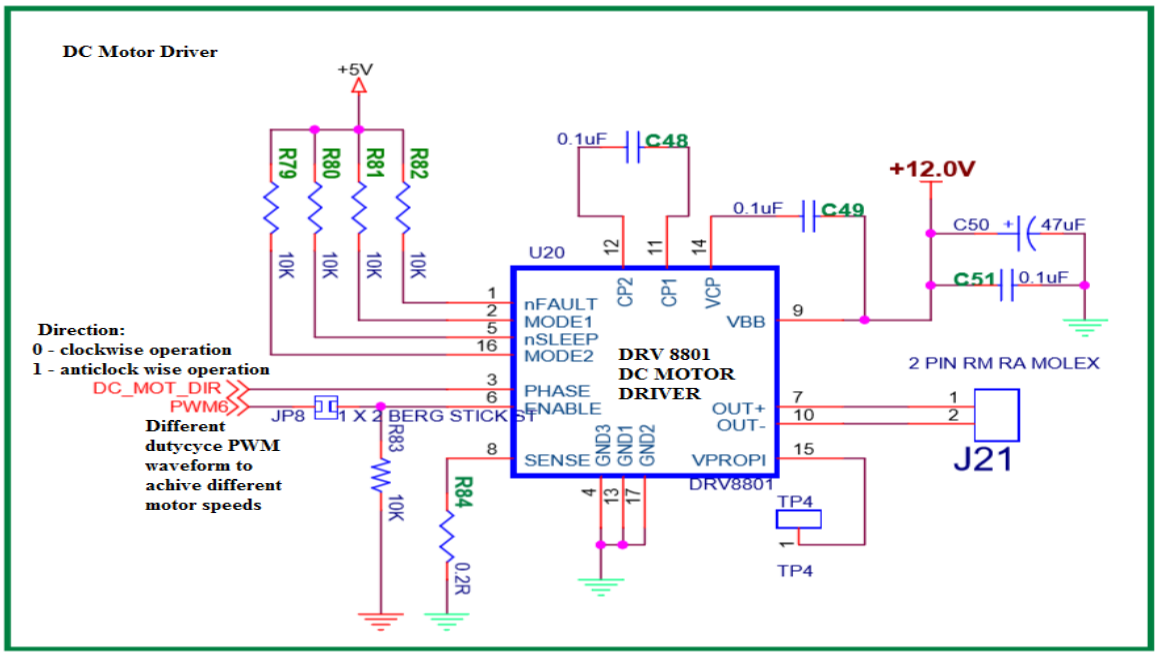
```
        if(COL2==0){colsel=2;break;};if(COL3==0){colsel=3;break;};
        //check for keypress in row3,make row3 '0'
        rowsel=3;IO0SET = 0X000F0000;IO0CLR = 1 << 19;//make row3 '0'
        if(COL0==0){colsel=0;break;};if(COL1==0){colsel=1;break;};
        if(COL2==0){colsel=2;break;};if(COL3==0){colsel=3;break;};
      };
  delay_ms(50);  //allow for key debouncing
  while(COL0==0 || COL1==0 || COL2==0 || COL3==0);//wait for key release
  delay_ms(50);   //allow for key debouncing
  IO0SET = 0X000F0000; //disable all the rows
  U0THR = lookup_table[rowsel][colsel];  //send to serial port(check on the terminal)
 }
 while(1);
}
void uart_init(void)
{
 //configurations to use serial port
 PINSEL0 |= 0x00000005;  // P0.0 & P0.1 ARE CONFIGURED AS TXD0 & RXD0
 U0LCR = 0x83;   /* 8 bits, no Parity, 1 Stop bit    */
 U0DLM = 0; U0DLL = 8; // 115200 baud rate
 U0LCR = 0x03;  /* DLAB = 0                   */
 U0FCR = 0x07;  /* Enable and reset TX and RX FIFO. */
}
void SystemInit(void)
{
  PLL0CON = 0x01;
  PLL0CFG = 0x24;
  PLL0FEED = 0xAA;
  PLL0FEED = 0x55;
  while( !( PLL0STAT & PLOCK ))
  { ; }
  PLL0CON = 0x03;
  PLL0FEED = 0xAA;  // lock the PLL registers after setting the required PLL
  PLL0FEED = 0x55;
  VPBDIV = 0x01;      // PCLK is same as CCLK i.e 60Mhz
}
void delay_ms(unsigned int j)
{
 unsigned int x,i;
 for(i=0;i<j;i++)
  {
    for(x=0; x<10000; x++);
  }
}
```

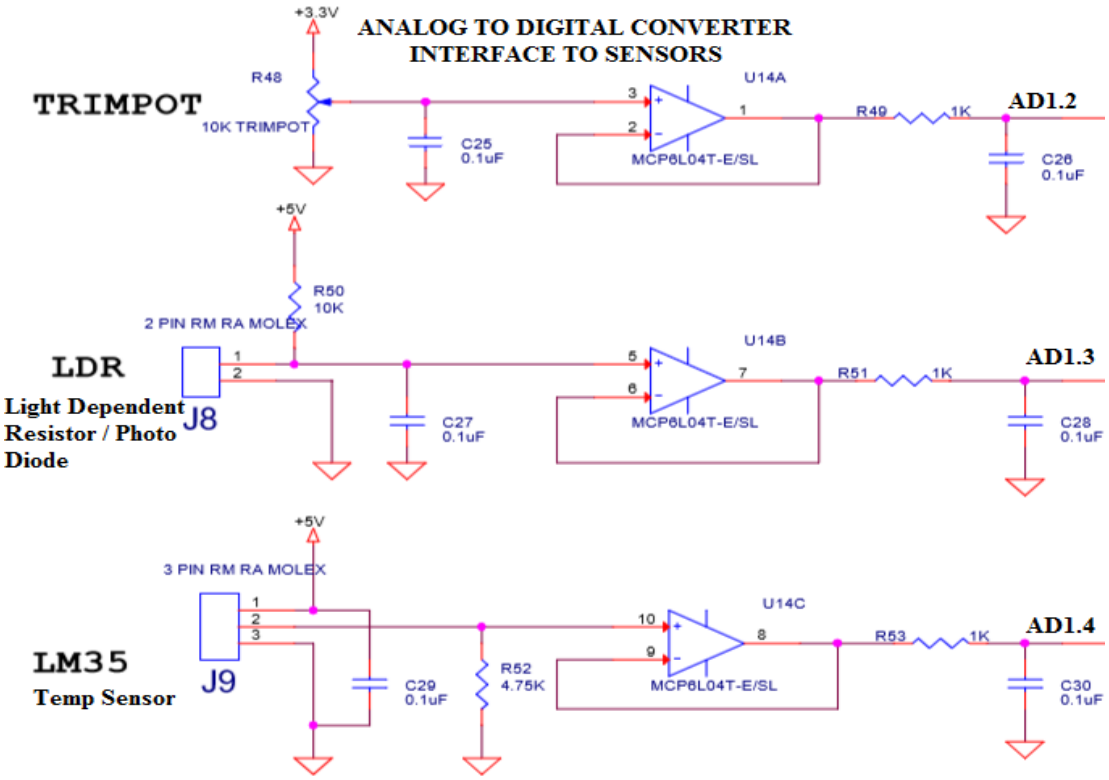
Interfacing Circuit working Explanation:

Output Observation:

Program No. 6: DC Motor Interface: Write an Embedded C program to generate PWM wave to control speed of DC motor. Control the duty cycle by analog input fed from potentiometer.

Interfacing Diagram





```
//DC Motor Speed Control
//P0.28 - used for direction control
//P0.9  - used for speed,generated by PWM6
//duty cycle - 0 to 100 controlled by PWM, fed from Potentiameter connected to ADC

#include <lpc214x.h>
#define LED_OFF (IO0SET = 1U << 31)
#define LED_ON (IO0CLR = 1U << 31)
#define PLOCK 0x00000400
void delay_ms(unsigned int j);
void SystemInit(void);
void runDCMotor(int direction,int dutycycle);
unsigned int adc(int no,int ch);

int main()
{
      int dig_val;
      IO0DIR |= 1U << 31 | 0x00FF0000 | 1U << 30; // to set P0.16 to P0.23 as o/ps
      LED_ON; delay_ms(500);LED_OFF; // make D7 Led on / off for program checking
      SystemInit( );
      do{
         dig_val = adc(1,2) / 10;
         if(dig_val > 100) dig_val =100;
         runDCMotor(2,dig_val); // run at 10% duty cycle
      }
      while(1);
}

void runDCMotor(int direction,int dutycycle)
{
        IO0DIR |= 1U << 28;     //set P0.28 as output pin
          PINSEL0 |= 2 << 18;   //select P0.9 as PWM6 (option 2)
        if (direction == 1)
                IO0SET = 1 << 28;   //set to 1, to choose anti-clockwise direction
         else
                IO0CLR = 1 << 28;  //set to 0, to choose clockwise direction

         PWMPCR = (1 << 14);  // enable PWM6
         PWMMR0 = 1000;   // set PULSE rate to value suitable for DC Motor operation
         PWMMR6 = (1000U*dutycycle)/100;  // set PULSE period
         PWMTCR = 0x00000009;  // bit D3 = 1 (enable  PWM), bit D0=1 (start the timer)
         PWMLER = 0X70;  // load the new values to PWMMR0 and PWMMR6 registers
}
```

```
unsigned int adc(int no,int ch)
{
        // adc(1,4) for temp sensor LM34, digital value will increase as temp increases
        // adc(1,3) for LDR - digival value will reduce as the light increases
        // adc(1,2) for trimpot - digital value changes as the pot rotation
        unsigned int val;
        PINSEL0 |=  0x0F300000;   /* Select the P0_13 AD1.4 for ADC function */
                                  /* Select the P0_12 AD1.3 for ADC function */
                                  /* Select the P0_10 AD1.2 for ADC function */
     switch (no)       //select adc
        {
          case 0: AD0CR=0x00200600|(1<<ch);      //select channel
                AD0CR|=(1<<24);                  //start conversion
                while((AD0GDR& (1U<<31))==0);
                val=AD0GDR;
                break;

          case 1: AD1CR=0x00200600|(1<<ch);      //select channel
                AD1CR|=(1<<24);                  //start conversion
                while((AD1GDR&(1U<<31))==0);
                val=AD1GDR;
                break;
        }
   val=(val >> 6) & 0x03FF;        // bit 6:15 is 10 bit AD value
   return val;
}

void SystemInit(void)
{
  PLL0CON = 0x01;
  PLL0CFG = 0x24;
  PLL0FEED = 0xAA;
  PLL0FEED = 0x55;
  while( !( PLL0STAT & PLOCK ))
  { ; }
  PLL0CON = 0x03;
  PLL0FEED = 0xAA;  // lock the PLL registers after setting the required PLL
  PLL0FEED = 0x55;
  VPBDIV = 0x01;      // PCLK is same as CCLK i.e 60Mhz
}
void delay_ms(unsigned int j)
{
 unsigned int x,i;
 for(i=0;i<j;i++)
  {
    for(x=0; x<10000; x++);
  }
}
```

Interfacing Circuit working Explanation:

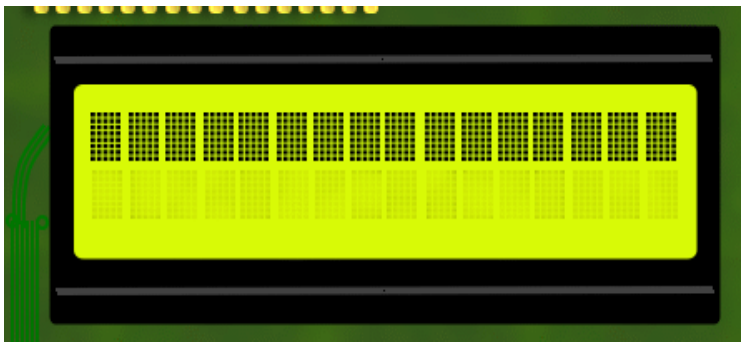
Output Observation:

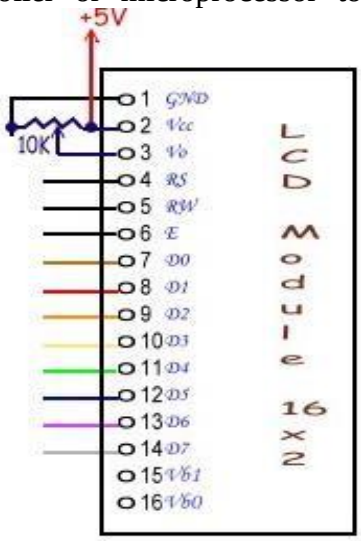
Program No.7: Alpha Numeric LCD Interface - Write an Embedded C program to display text messages on the multiple lines of the display.

LCD's are preferred to seven segment displays because of their versatility and capability to house more information.2 line (2 x 6) and 4 line (4x20) is the most popular, low cost character oriented LCD, suitable for understanding the working and programming of LCD. You have seen LCD modules used in many of the electronics devices like coin phone, billing machine and weighing machines. It is a powerful display options for stand-alone systems. Because of low power dissipation, high readability, flexibility for programmers, LCD modules are becoming popular.

LCD consists of DDRAM, CGROM, Shift registers, bit/pixel drivers, refreshing logics and lcd controller. The data to be displayed on lcd, is to be written on to the DDRAM-display data Ram using the ascii format. CGROM-Character generator rom, contains dot/pixel patterns for every character to be displayed (pre programmed). Shift registers are used to convert CGROM parallel data to serial data(serializing), drivers are required to drive (ON/OFF) the bits, refreshing logics are required to hold the display data, as the dots are displayed row by row basis continuously, like in CRT.

LCD provides many control pins, to enable the microcontroller or microprocessor to





communicate, whatever the data we write to LCD is of two types, either it is a command to the LCD(to configure) or ASCII code of character to be displayed on LCD (to DDRAM). RS signal is used for this,

RS (Register Select): 0 or 1

0 - writing command byte into command register of LCD

1 - writing data (ASCII code) into Data register of LCD

R/W : (Read/Write) (In our kit, R/W is grounded)

0- Write to LCD (Data/Command)

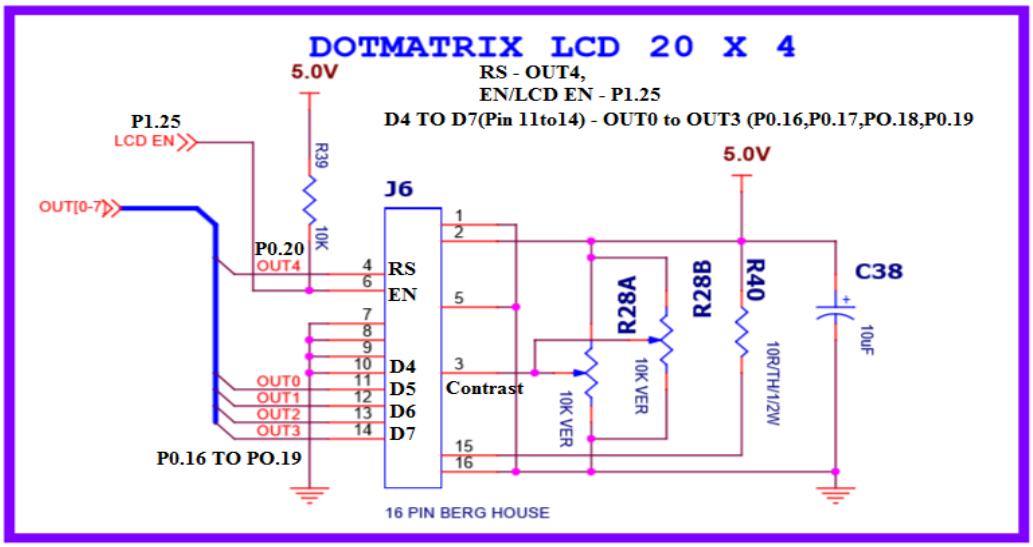
1- Read from the LCD

E (Enable) : 1 to 0 pulse

- Enable is required to perform the writing/reading to LCD, E – '1' (for 450nsec) & then '0' (High to Low Pulse)

D0-D7 - It is a bidirectional data bus, used to write data/command to LCD or reading status. In 4bit nibble mode, only lines D4 – D7 are used for communication.

Interfacing Diagram



LCD Command Table

Instruction	D7	D6	D5	D4	D3	D2	D1	D0	Description
Clear display	0	0	0	0	0	0	0	1	Clears Display and returns cursor to home position.
Cursor home	0	0	0	0	0	0	1	X	Returns cursor to home position. Also returns display being shifted to the original position.
Entry mode set	0	0	0	0	0	1	I/D	S	I/D = 0 - cursor is in decrement position. I/D = 1 - cursor is in increment position. S = 0 - Shift is invisible. S = 1 - Shift is visible
Display ON- OFF Control	0	0	0	0	1	D	C	B	D- Display, C- Cursor, B-Blinking cursor 0 - OFF 1 - ON
Cursor/ Display Shift	0	0	0	1	S/C	R/L	X	X	S/C = 0 - Move cursor. S/C = 1 - Shift display. R/L = 0 - Shift left. R/L = 1- Shift right.
Function Set	0	0	1	DL	N	F	X	X	DL = 0 - 4 bit interface. DL = 1 - 8 bit interface. N = 0 - 1/8 or 1/11 Duty (1 line). N = 1 - 1/16 Duty (2 lines). F = 0 - 5x7 dots. F = 1 - 5x10 dots.

Programming 4 x 20 alphanumeric LCD

Two steps are involved,

1. Configure the LCD for different parameters/settings, by writing series of commands (command bytes) like
    - Function set command(0x28)
    - Display On command(0x0C)
    - Clear display (0x01)

2. Writing actual string data to LCD, character by character, (by default characters are displayed from line1 first column position, we can issue DDRAM address command - 0x80 + char pos, for first line, 0xc0 + char pos, for second line,0x94+char pos, for third line, 0xD4+char pos, for fourth line).

```
//Alpha-numeric LCD Interface (4Lines,20characters)
//Connected in 4bit nibble mode
//LCD handshaking:RS->P0.20,EN->P0.25 ,R/W -Gnd
//LCD data:D4,D5,D6,D7 -> P0.16,P0.17,P0.18,P0.19

#include <lpc214x.h>
#define PLOCK 0x00000400
#define LED_OFF (IO0SET = 1U << 31)
#define LED_ON  (IO0CLR = 1U << 31)
#define RS_ON  (IO0SET =  1U << 20)
#define RS_OFF (IO0CLR = 1U << 20)
#define EN_ON  (IO1SET = 1U << 25)
#define EN_OFF (IO1CLR = 1U << 25)

void SystemInit(void);
static void delay_ms(unsigned int j);//millisecond delay
static void delay_us(unsigned int count);//microsecond delay
static void LCD_SendCmdSignals(void);
static void LCD_SendDataSignals(void);
static void LCD_SendHigherNibble(unsigned char dataByte);
static void LCD_CmdWrite( unsigned char cmdByte);
static void LCD_DataWrite( unsigned char dataByte);
static void LCD_Reset(void);
static void LCD_Init(void);
void LCD_DisplayString(const char *ptr_stringPointer_u8);

int main()
{
    SystemInit();
    IO0DIR |= 1U << 31 | 0x00FF0000 ; // to set P0.16 to P0.23 as o/ps
    IO1DIR |= 1U << 25;                 // to set P1.25 as o/p used for EN
                                        // make D7 Led on off for testing
    LED_ON; delay_ms(500);LED_OFF;delay_ms(500);
    LCD_Reset();
    LCD_Init();
    delay_ms(100);
```

```
    LCD_CmdWrite(0x80); LCD_DisplayString("RV College Of Engrng");
    LCD_CmdWrite(0xc0); LCD_DisplayString("   Computer Sciene");
    LCD_CmdWrite(0x94); LCD_DisplayString("    4th Semester");
    LCD_CmdWrite(0xD4); LCD_DisplayString("      B Section");
    while(1);
}
static void LCD_CmdWrite( unsigned char cmdByte)
{
   LCD_SendHigherNibble(cmdByte);
    LCD_SendCmdSignals();
    cmdByte = cmdByte << 4;
    LCD_SendHigherNibble(cmdByte);
    LCD_SendCmdSignals();
}
static void LCD_DataWrite( unsigned char dataByte)
{
    LCD_SendHigherNibble(dataByte);
    LCD_SendDataSignals();
    dataByte = dataByte  <<  4;
    LCD_SendHigherNibble(dataByte);
    LCD_SendDataSignals();
}
static void LCD_Reset(void)
{
 /* LCD reset sequence for 4-bit mode*/
   LCD_SendHigherNibble(0x30);
   LCD_SendCmdSignals();
   delay_ms(100);
   LCD_SendHigherNibble(0x30);
   LCD_SendCmdSignals();
   delay_us(200);
   LCD_SendHigherNibble(0x30);
   LCD_SendCmdSignals();
   delay_us(200);
   LCD_SendHigherNibble(0x20);
   LCD_SendCmdSignals();
   delay_us(200);
}

static void LCD_SendHigherNibble(unsigned char dataByte)
{
  //send the D7,6,5,D4(uppernibble) to P0.16 to P0.19
   IO0CLR = 0X000F0000;IO0SET = ((dataByte >>4) & 0x0f) << 16;
}
static void LCD_SendCmdSignals(void)
{
    RS_OFF;  // RS - 1
    EN_ON;delay_us(100);EN_OFF; // EN - 1 then 0
}
```

```
static void LCD_SendDataSignals(void)
{
    RS_ON;// RS - 1
    EN_ON;delay_us(100);EN_OFF; // EN - 1 then 0
}
static void LCD_Init(void)
{
          delay_ms(100);
          LCD_Reset();
          LCD_CmdWrite(0x28u);   //Initialize the LCD for 4-bit 5x7 matrix type
          LCD_CmdWrite(0x0Eu);  // Display ON cursor ON
          LCD_CmdWrite(0x01u);  //Clear the LCD
          LCD_CmdWrite(0x80u);  //go to First line First Position
}
void LCD_DisplayString(const char *ptr_string)
{
          // Loop through the string and display char by char
   while((*ptr_string)!=0)
      LCD_DataWrite(*ptr_string++);
}
static void delay_us(unsigned int count)
{
        unsigned int j=0,i=0;
        for(j=0;j<count;j++)
        {
          for(i=0;i<10;i++);
        }
}
void SystemInit(void)
{
  PLL0CON = 0x01;
  PLL0CFG = 0x24;
  PLL0FEED = 0xAA;
  PLL0FEED = 0x55;
  while( !( PLL0STAT & PLOCK ))
  { ; }
  PLL0CON = 0x03;
  PLL0FEED = 0xAA;  // lock the PLL registers after setting the required PLL
  PLL0FEED = 0x55;
  VPBDIV = 0x01;      // PCLK is same as CCLK i.e 60Mhz
}
void delay_ms(unsigned int j)
{
 unsigned int x,i;
 for(i=0;i<j;i++)
  {
    for(x=0; x<10000; x++);
  }
}
```

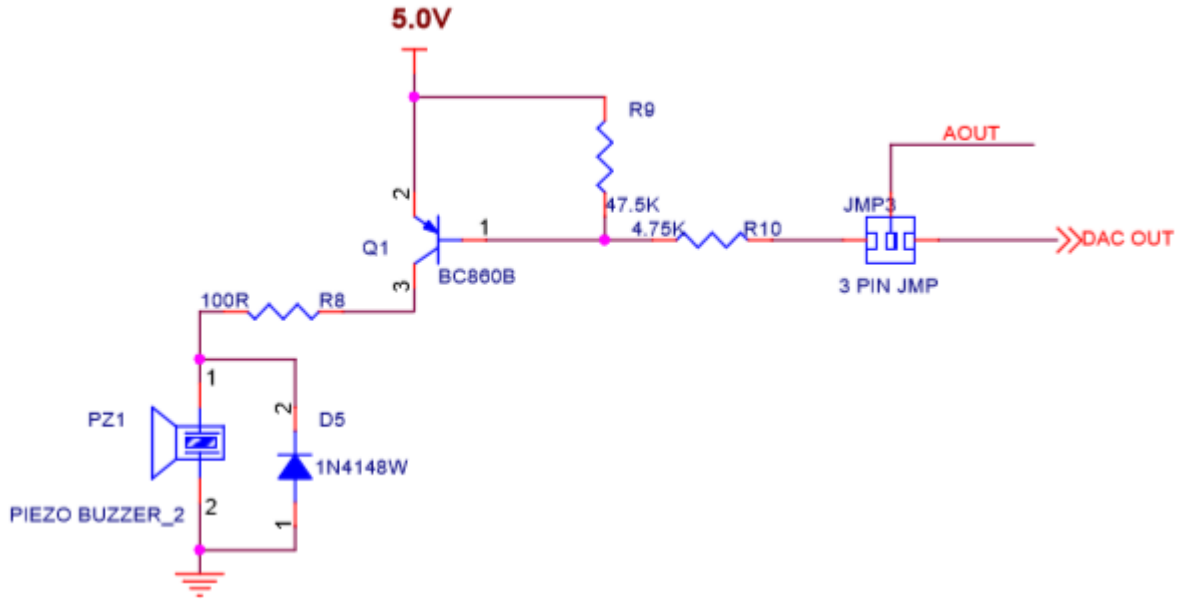
Interfacing Circuit working Explanation:

Output Observation:

Mini Project

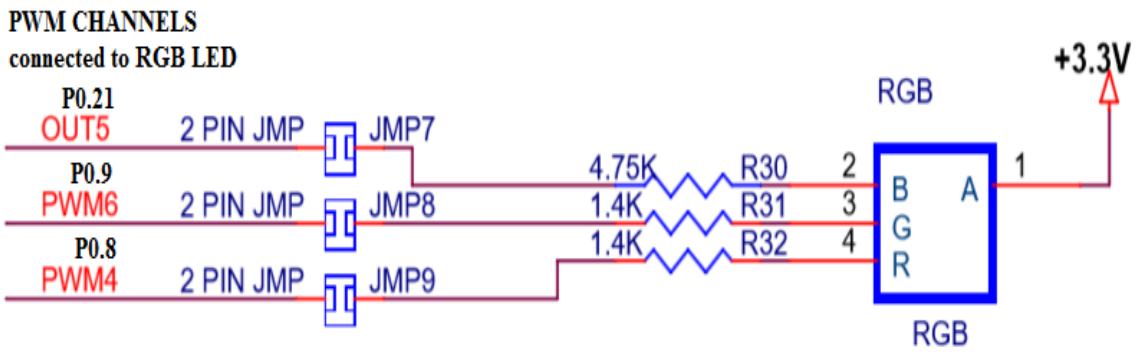
(Use Buzzer , Joystick, RGB LED, Logic Controller DIP Switch, Temperature Sensor, LDR, Proximity Sensor, Servomotor along with the earlier learned interfaces to develop the Mini project.)

BUZZER INTERFACE & SAMPLE PROGRAM



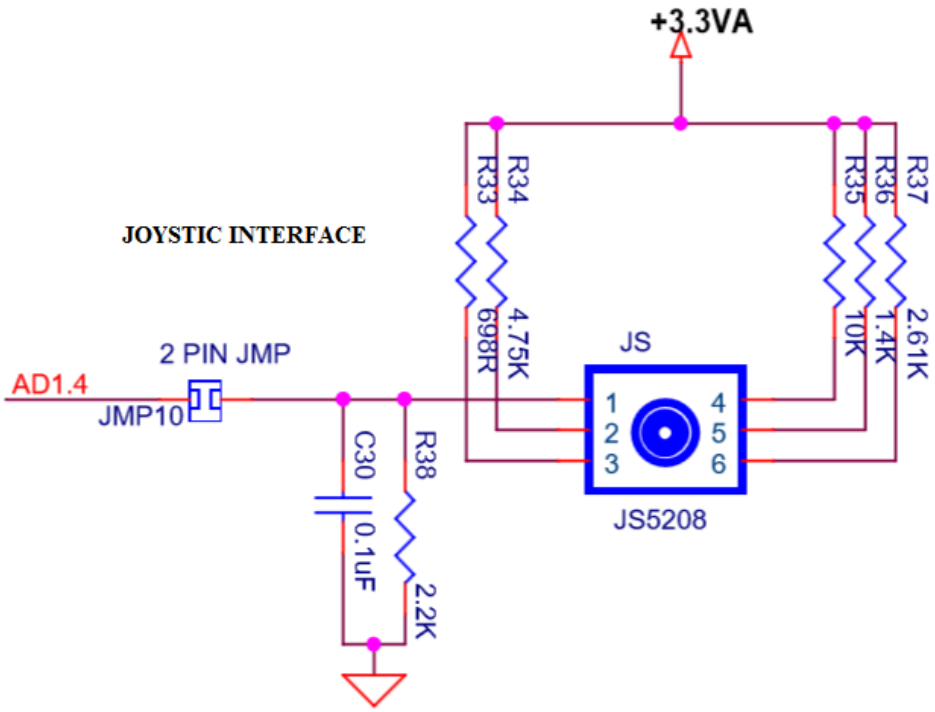

```
//DAC output - P0.25 (option 3:10) , JUM-3:selection for buzzer/CPU-DAC,
//JMP-A10:selection for audio/CPU DAC
//DAC Register - It is a 32 bit register, Bits:D15-D6 holds 10bit digital data; D16 - BIAS bit,
set //to 1
PINSEL1 |= 0x00080000;       /* P0.25 as DAC output :option 3 - 10 (bits18,19)*/
void beep(unsigned int val)
{
        //P0.25 used as AOUT - DAC output
        //val - 0 to 1023  : 10 bit DAC, P0.25 used as AOUT generates analog output
        DACR = ( (1<<16) | (val<<6) );
        delay_ms(500);
        DACR = ( (1<<16) | (1023<<6) );
        delay_ms(1);
}
```

RGB LED INTERFACE & SAMPLE PROGRAM



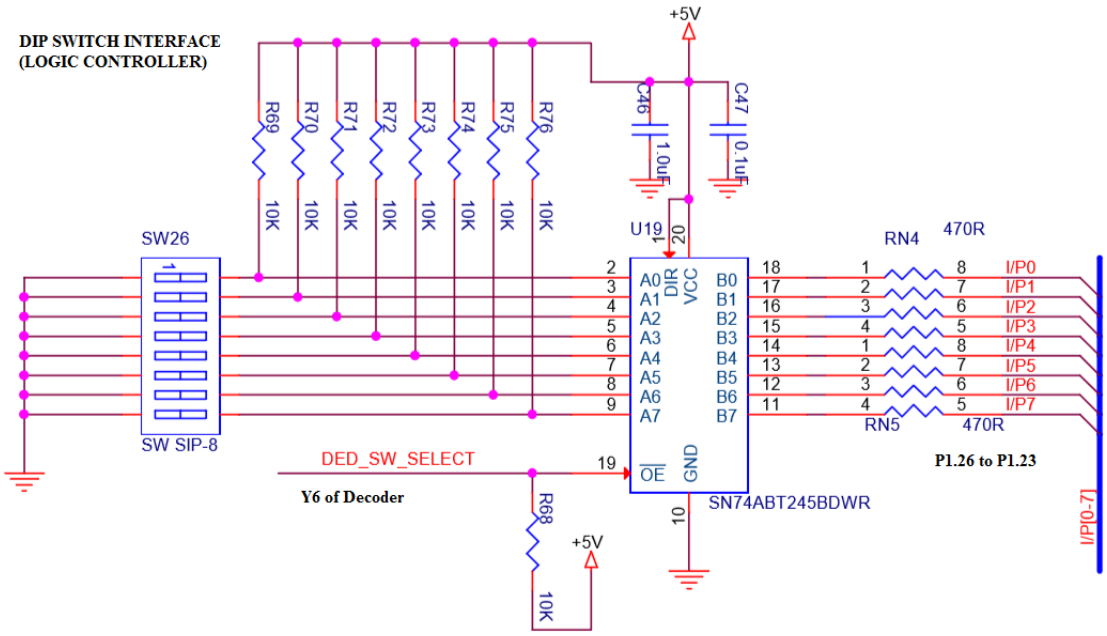

```
void PWM_RGBLed_test(void)
{
        unsigned int i;
        PWM_Init();
        for(i=0;i<=100;i=i+1)
        {
          PWMMR4 = 100; PWMMR5 = i; PWMMR6 = 100;
          PWMLER = 0X70; // to enable copy to Match registers from shadow regs. 1110000
          delay_ms(1000);
        }
        for(i=0;i<=100;i=i+1)
        {
          PWMMR4 = 100;  PWMMR5 = 100;          PWMMR6 = i;
          PWMLER = 0X70; //  to enable copy to Match registers from shadow regs. 1110000
          delay_ms(1000);
        }
        for(i=0;i<=100;i=i+1)
        {
          PWMMR4 = i PWMMR5 = 100;  PWMMR6 = 100;
          PWMLER = 0X70; //   to enable copy to Match registers from shadow regs. 1110000
          delay_ms(1000);
        }
}
void PWM_Init(void)
{
   PINSEL0 |= 2 << 18 | 2 << 16 ;
  //SELECT P0.8 PWM4 AND P0.9PWM6 AS 2ND OPTION FOR PWM OPERATION
   PINSEL1 |= 1 << 10; //SELECT P0.21 PWM5 AS OPTION 1 FOR PWM OPERATION
   PWMPCR =  (1 << 12 | 1 << 13 | 1 << 14); //Enable PWM4,PWM5 and PWM
   PWMMR0 = 100;    // load the value to MR0 to fix the pulse rate
   PWMTCR = 0x00000009;   // bit D3 = 1 (enable  PWM), bit D0=1 (start the timer)
}
```

Joystick Interface



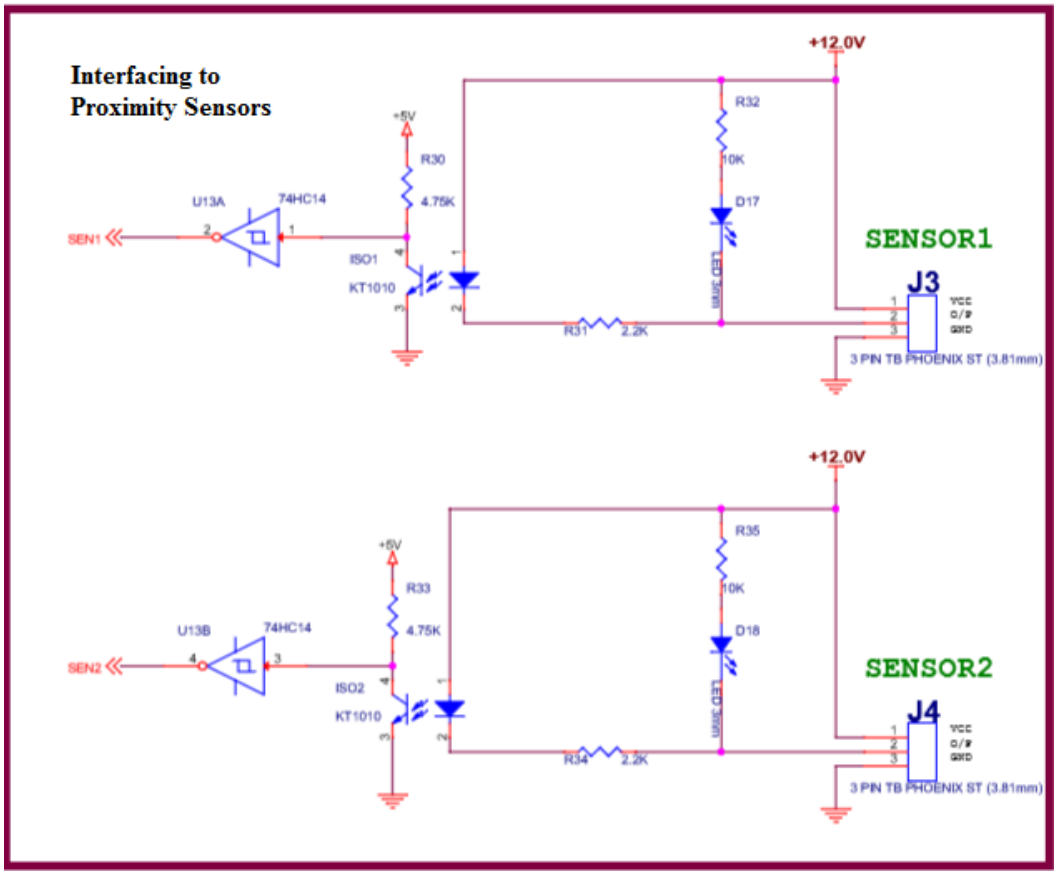

```
 char Joystick_position(void)
{
  // returns joystic position
  // Up , Left , Down, Right & Enter
   unsigned int adc_result=0;
    char res =6;
    PINSEL0|= 0x0C000000;  /* Select the P0_13 AD1.4 for ADC function */
    adc_result = adc(1,4);
    if(adc_result == 0 && adc_result < 5) res =6;
    else if(adc_result > 180 && adc_result < 185) res = 0; // Up
    else if(adc_result > 315 && adc_result < 325) res = 1; // Left
    else if(adc_result > 460 && adc_result < 470) res = 2; // Down
    else if(adc_result > 614 && adc_result < 624) res = 3; // Right
    else if(adc_result > 770 && adc_result < 800) res = 4; // Enter
    return res;

}
```

Logic controller 8 bit DIP Switch Interface.




```
unsigned long LC_readSW(void)
{
    unsigned long result;
    //select switch: Mux2:Mux1:Mux0(P0.18,P0.17,P0.16 - 110), Mux select:DEC_SEL : P0.7 - 0
    IO0SET = 1<<18|1<<17; IO0CLR = (1<<16)|(1<< 7);delay_ms(2);
    //read the switches: (SW1-8)IN7-0 -> P1.23-P1.16 REFER SW26 in CIRCUIT
    result = (IO1PIN >> 16) & 0X000000FF;delay_ms(2);
    //disable Mux: DEC_SEL(P0.7) - 1
    IO0SET = (1U << 7);delay_ms(2);
    //return 8 bit result, stored in the bits D7-D0
    return result;
}
```

Proximity Sensor Interface




```
int readSensor(int sen_no)
{
        int result=0;
        IO1DIR |= 1 << 24;
        IO1CLR = 1<< 24; // enable sensor logic: P1.24 - 0
        switch (sen_no)
        {
                case 1:  result = IO1PIN & (1<<22); //P1.22 connected to sensor1
                         break;
                case 2:  result = IO1PIN & (1<<23); //P1.23 connected to sensor2
                         break;
                default: result = 0;
        };
        IO1SET = 1<< 24; // disable sensor logic: P1.24
        return result;

}
```