

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 completed the 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:					

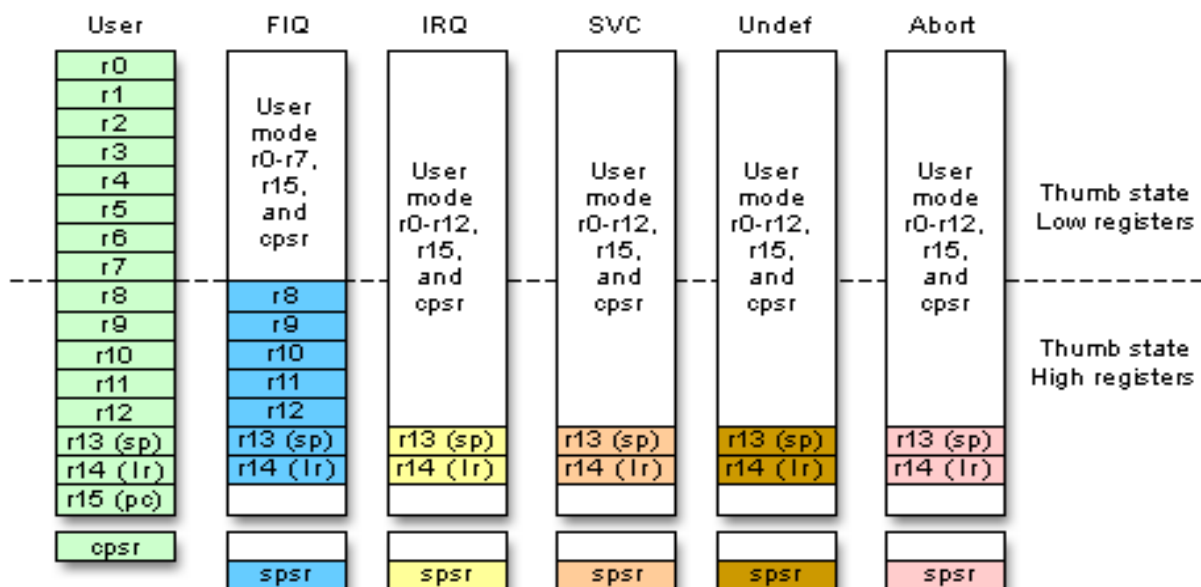
ARM Assembly Language Programs – Part A

ARM Architecture (Instruction Set Architecture – ISA)

ARM – stands for “Advanced RISC Machine”, 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 boxes, 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,

- 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.
- FIQ Mode (Fast interrupt request): Entered this mode on request from FIQ interrupts
- IRQ Mode (Interrupt Request): Entered this mode on IRQ request
- 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.
- Abort: Used to handle memory access violations, Abort is entered after a failed memory access
- Undef: Used to handle undefined instructions, Undefined is entered if the instruction is not defined (invalid opcodes)
- 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,

MOVS 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: MOVEQ 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 ; $R2 \leftarrow R3 + R4$ 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** ; $R5 \leftarrow R0 \text{ .AND. } R1$ (bit AND operation), S – updatde flags

Ex: **ORRS R5, R0 , R1** ; $R5 \leftarrow R0 \text{ .OR. } R1$ (bit AND operation), S – updatde flags

Ex: **EORS R5, R0 , R1** ; $R5 \leftarrow R0 \text{ .OR. } R1$ (bit AND operation), S – updatde flags

- BIC is used to clear selected bits of the Register

Ex: **BIC R5, R0 , R1** ; $R5 \leftarrow R0 \text{ .AND. } \sim R1$ (i.e $R0 \text{ .AND. NOT } R1$)

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 ; $R1 \text{ .XOR. } R2$ pseudo XOR operation and updates the flags
- TST R1 , R2 ; $R1 \text{ .AND. } R2$ 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 $R1 \leftarrow R2 \times R3$

MLA R4 , R3 , R2 , R1 - Multiply and Accumulate; $R4 \leftarrow (R3 \times R2) + R1$

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.

$$\underline{A = B + C - D}$$

```
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
```

$$\underline{A = 2 * A + B}$$

```
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

The screenshot shows the Keil uVision IDE with the 'Registers' window on the left and the 'Disassembly' window on the right. The 'Registers' window displays the current values of all 16 registers, with R0 through R15 all set to 0x00000000. The CPSR register is 0x000000D3 and the SPSR register is 0x00000000. The 'Disassembly' window shows the assembly code for 'arm_asm1.asm', starting with an AREA directive for the RESET vector and an ENTRY point. The first three instructions are MOV R1, #2; MOV R2, #3; and MOV R3, #4, which are highlighted in green. The program then continues with several ADD and LSL instructions before reaching a STOP instruction at address 0x00000011.

Register	Value
R0	0x00000000
R1	0x00000000
R2	0x00000000
R3	0x00000000
R4	0x00000000
R5	0x00000000
R6	0x00000000
R7	0x00000000
R8	0x00000000
R9	0x00000000
R10	0x00000000
R11	0x00000000
R12	0x00000000
R13 (SP)	0x00000000
R14 (LR)	0x00000000
R15 (PC)	0x00000000
CPSR	0x000000D3
SPSR	0x00000000

```

0x00000000 E3A01002 MOV R1, #0x00000000
4:          MOV R2, #3 ; Let Y
0x00000004 E3A02003 MOV R2, #0x00000000
5:          MOV R3, #4 ; Let Z
0x00000008 E3A03004 MOV R3, #0x00000000

1 AREA RESET, CODE
2 ENTRY
3 MOV R1, #2 ; Let X = 2
4 MOV R2, #3 ; Let Y = 3
5 MOV R3, #4 ; Let Z = 4
6 ADD R1, R1, R1, LSL #1
7 MOV R2, R2, LSL #2
8 ADD R3, R3, R3, LSL #3
9 ADD R1, R1, R2
10 ADD R1, R1, R3
11 STOP B STOP
12 END
13

```

After Execution

The screenshot shows the Keil uVision IDE after execution. The 'Registers' window shows that R1 has been updated to 0x00000036, R15 (PC) to 0x00000020, and the CPSR register to 0x000000D3. The 'Disassembly' window shows the execution has reached the STOP instruction at address 0x00000011. The assembly code is the same as in the 'Before Execution' screenshot, but the execution pointer (yellow arrow) is now at the STOP instruction. The instructions from MOV R1, #2 to ADD R1, R1, R3 are highlighted in green, indicating they have been executed.

Register	Value
R0	0x00000000
R1	0x00000036
R2	0x0000000C
R3	0x00000024
R4	0x00000000
R5	0x00000000
R6	0x00000000
R7	0x00000000
R8	0x00000000
R9	0x00000000
R10	0x00000000
R11	0x00000000
R12	0x00000000
R13 (SP)	0x00000000
R14 (LR)	0x00000000
R15 (PC)	0x00000020
CPSR	0x000000D3
SPSR	0x00000000

```

11: STOP B STOP
0x00000020 EAFFFFFE B 0x00000000
0x00000024 00000000 ANDEQ R0, R0, #0
0x00000028 00000000 ANDEQ R0, R0, #0
0x0000002C 00000000 ANDEQ R0, R0, #0

1 AREA RESET, CODE
2 ENTRY
3 MOV R1, #2 ; Let X
4 MOV R2, #3 ; Let Y
5 MOV R3, #4 ; Let Z
6 ADD R1, R1, R1, LSL #1
7 MOV R2, R2, LSL #2
8 ADD R3, R3, R3, LSL #3
9 ADD R1, R1, R2
10 ADD R1, R1, R3
11 STOP B STOP
12 END
13

```

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:

The screenshot displays the ARM assembler interface. On the left, the 'Register' pane shows the current values of registers R0 through R15, CPSR, and SPSR. On the right, the 'PROG3.ASM' pane shows the assembly code being executed. The current instruction is highlighted in yellow.

Register	Value
R0	0x00000040
R1	0xBFFFFFFF
R2	0xAAAAAAAA
R3	0xCCCCCCCC
R4	0xFFFFFFFF
R5	0x88888888
R6	0xAAAAAAAA9
R7	0x00000000
R8	0x00000000
R9	0x00000000
R10	0x00000000
R11	0x00000000
R12	0x00000000
R13 (SP)	0x00000000
R14 (LR)	0x00000000
R15 (PC)	0x0000002C
CPSR	0xA00000D3
SPSR	0x00000000

The assembly code shown is:

```

1  AREA RESET, CODE
2  ENTRY
3  LDR R0,=VALUE1
4  LDR R1,[R0]
5  LDR R2,[R0,#4]
6  LDR R0,=VALUE2
7  LDR R3,[R0]
8  LDR R4,[R0,#4]
9  ADDS R5,R1,R3
10 ADC R6,R2,R4
11 LDR R0,=RESULT
12 STR R5,[R0]
13 STR R6,[R0,#4]
14 STOP B STOP
15 VALUE1 DCD &BBBBBBBB,&AAAAAAAA
16 VALUE2 DCD &CCCCCCCC,&FFFFFFFF
17 RESULT DCD &0
18 END

```

The memory address 0x00000030 is shown with the following data: BB BB BB BB AA AA AA AA CC CC CC CC FF FF FF FF 00 00 00 00.

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.

```

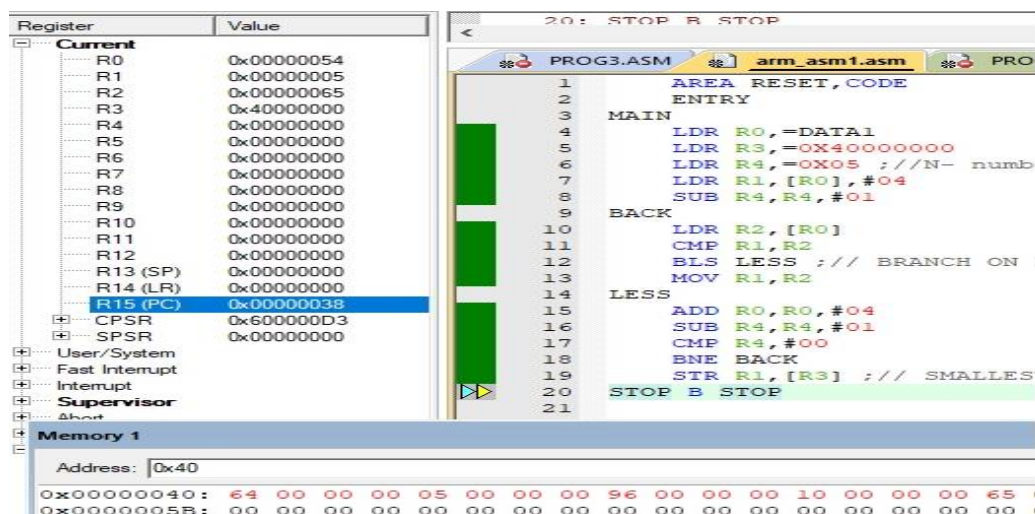
AREA RESET, CODE
ENTRY
LDR R0, =DATA1
LDR R3, =0X40000000 ; memory location for storing answer
MOV R4, #05 ; //N- number of elements
LDR R1, [R0], #04; assume first no. as smaller no & increment R0 by 4
SUB R4, R4, #01 ; compare with n-1 elements

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 $average = sum \text{ divide by } n$

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:

The screenshot displays a debugger interface with the following components:

- Register Window:** Shows registers R2 through R15 (PC), CPSR, and SPSR. R15 (PC) is highlighted with the value 0x00000044.
- Assembly Window:** Displays assembly code from address 6 to 26. The code includes instructions like LDR, ADD, CMP, BNE, MOV, SUBS, ADDPL, BPL, STR, and STOP. A green highlight is under the STOP instruction at address 25.
- Memory Window (Memory 1):** Shows a memory dump starting at address 0x00000030. The first three lines of memory are visible, showing hexadecimal values.
- Call Stack / Locals Window:** Shows a single entry for 'Memory 1' at address 0x40000000.

Register Values:

Register	Value
R2	0x00000005
R3	0x00000003
R4	0x00000000
R5	0x00000000
R6	0x00000000
R7	0x00000000
R8	0x00000000
R9	0x00000000
R10	0x00000000
R11	0x00000000
R12	0x00000000
R13 (SP)	0x00000000
R14 (LR)	0x00000000
R15 (PC)	0x00000044
CPSR	0x800000D3
SPSR	0x00000000

Assembly Code:

```

6      LDR R0, =INPUTS
7      LDR R1, =OUTPUTS
8      CONT
9      LDR R2, [R0]
10     ADD R4, R4, R2
11     ADD R0, R0, #4
12     ADD R3, R3, #1
13     CMP R3, #5
14     BNE CONT
15
16     MOV R2, #5
17     MOV R3, #0
18     REPT SUBS R4, R4, R2
19     ADDPL R3, R3, #1
20     BPL REPT
21     ADDMI R4, R4, R2
22
23
24     STR R3, [R1]
25     STOP B STOP
26

```

Memory Dump (Memory 1):

Address	0x00000030	0x0000004B	0x00000066
Hex	02 40 54 E0 01 30 83 52 FC FF FF 5A 02 40 84 40 00	00 02 00 00 00 03 00 00 00 04 00 00 00 05 00 00	00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

Call Stack / Locals:

Address	0x40000000
Hex	03 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00

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:

The screenshot displays the ARM assembler interface. On the left, the 'Registers' window shows the current state of registers, with R7 highlighted and its value 0x00000002 circled. The 'Disassembly' window on the right shows the assembly code with line numbers 13 to 19. The code includes instructions for adding the loop counter and the number of elements, comparing the current element with the key, and branching to the next iteration or stopping. The 'Memory' window at the bottom shows the data stored in code memory, with addresses 0x00000034 to 0x0000006D and their corresponding values in hexadecimal and decimal.

```

13  ADD R0, #4
14  ADD R1, #1
15  CMP R1, #10 ;no of elements
16  BNE CONT
17  STOP B STOP
18  ARR DCD 0,5,1,4,100,4,0,8,7,20
19  END

```

Memory 1

Address: 0x00000034

0x00000034:	00	00	00	00	05	00	00	00	01	00	00	00	04	00	00	00	64	00	00
0x00000047:	00	04	00	00	00	00	00	00	00	08	00	00	00	07	00	00	00	14	00
0x0000005A:	00	00	34	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00
0x0000006D:	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

Data stored in code memory.

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:

The screenshot displays an ARM assembler simulator interface. On the left, a 'Registers' window shows the current state of 16 registers (R0-R15), CPSR, and SPSR. Register R4 is highlighted with a black circle, showing a value of 0x00000010. The main window shows assembly code with line numbers 5 through 17. The code is as follows:

```

5      MOV R2, #0      ; loop cou
6      MOV R4, #0      ; number o
7      MOV R3, #1
8  LOOP
9      MOVS R1, R1, LSR #1
10     ADDCS R4, R4, #1
11     ADD R2, #1
12     CMP R2, #32     ; check f
13     BNE LOOP
14 STOP B STOP
15     AREA DATA, CODE
16 DATA1 DCD 0xAAAAAAAA
17     END

```

At the bottom, a 'Memory 1' window shows the memory address 0x00000030 with the value 0x00000030, followed by a sequence of bytes: AA AA AA AA 00 00 00 00 00 00 00 00.

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:

The screenshot displays the ARM Disassembler interface. On the left, the 'Registers' window shows the current state of registers: R0 is 0x00000000 and R1 is 0x0000000F. The main window shows the disassembly of the program, with instructions such as MOV R1, #0x0000002D, CMP R0, R1, BEQ 0x00000024, BGT 0x0000001C, SUB R1, R1, R0, B 0x00000008, SUB R0, R0, R1, B 0x00000008, LDR R0, [PC, #0x0004], STR R1, [R0], and B 0x0000002C. The 'Memory' window at the bottom shows the value 0F 00 00 00 at address 0x40000000, which is circled in red.

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:

The screenshot displays a disassembler interface with two main panels. The left panel, titled 'Registers', shows a list of registers and their current values. The right panel, titled 'Disassembly', shows the assembly code and a memory dump for a specific address.

Registers Window:

Register	Value
R0	0x00000044
R1	0x40000000
R2	0x00000000
R3	0x00000078
R4	0x00000000
R5	0x00000000
R6	0x00000000
R7	0x00000000
R8	0x00000000
R9	0x00000000
R10	0x00000000
R11	0x00000000
R12	0x00000000
R13 (SP)	0x00000000
R14 (LR)	0x0000000C
R15 (PC)	0x00000014
CPSR	0x80000003
SPSR	0x00000000

Disassembly Window:

Assembly code is shown with line numbers 17, 26, and 27. Line 17 is highlighted, showing the instruction `CMP R2, #00`. Below the code, a memory dump for address `0x40000000` is displayed, showing hexadecimal values and their corresponding byte representations.

Memory 1
Address: 0x40000000

Address	Hex	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8	Byte 9	Byte 10
0x40000000	78	00	00	00	00	00	00	00	00	00	00
0x4000000A	00	00	00	00	00	00	00	00	00	00	00
0x40000014	00	00	00	00	00	00	00	00	00	00	00
0x4000001E	00	00	00	00	00	00	00	00	00	00	00
0x40000028	00	00	00	00	00	00	00	00	00	00	00
0x40000032	00	00	00	00	00	00	00	00	00	00	00
0x4000003C	00	00	00	00	00	00	00	00	00	00	00
0x40000046	00	00	00	00	00	00	00	00	00	00	00

26 INPUT DCD &05
27 END

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 COMPARISONS 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 COMPARISON
        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:

The screenshot displays a debugger interface with two main panels. The left panel shows the 'Current' register set, and the right panel shows a 'Memory 1' dump.

Register Window:

Register	Value
R0	0x00000000
R1	0x00000000
R2	0x00000000
R3	0x00000004
R4	0x40000004
R5	0x00000002
R6	0x00000002
R7	0x00000003
R8	0x0000000F
R9	0x00000008
R10	0x40000000
R11	0x00000000
R12	0x00000000
R13 (SP)	0x40000000
R14 (LR)	0x00000000
R15 (PC)	0x0000005C
CPSR	0x600000D3
SPSR	0x00000000

Below the registers, there are expandable sections for 'User/System', 'Fast Interrupt', 'Interrupt', and 'Supervisor'.

Memory 1 Window:

Address: 0x40000000

0x40000000:	00	00	00	00	02	00	00	00
0x40000008:	03	00	00	00	04	00	00	00
0x40000010:	05	00	00	00	07	00	00	00
0x40000018:	08	00	00	00	0B	00	00	00
0x40000020:	0F	00	00	00	12	00	00	00
0x40000028:	00	00	00	00	00	00	00	00
0x40000030:	00	00	00	00	00	00	00	00

Assembly Code Window:

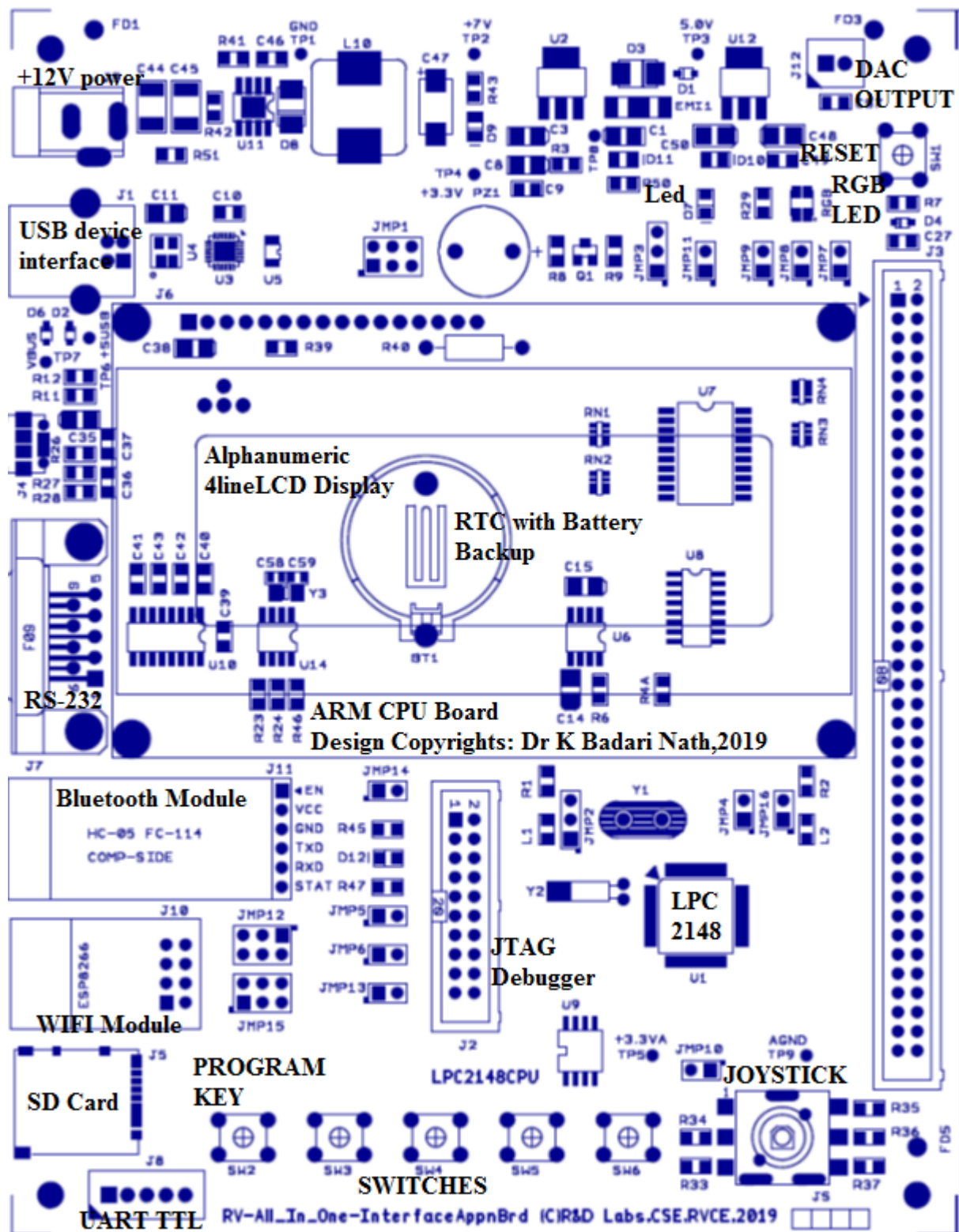
```

26      BNE LOOP2
27      SUBS R1, #1 ; GO TO NEXT ITERATION
28      BNE LOOP1
29      STOP B STOP
30
31      ARRAY DCD 2,7,4,5,11,18,3,15,8,0
32      END
  
```

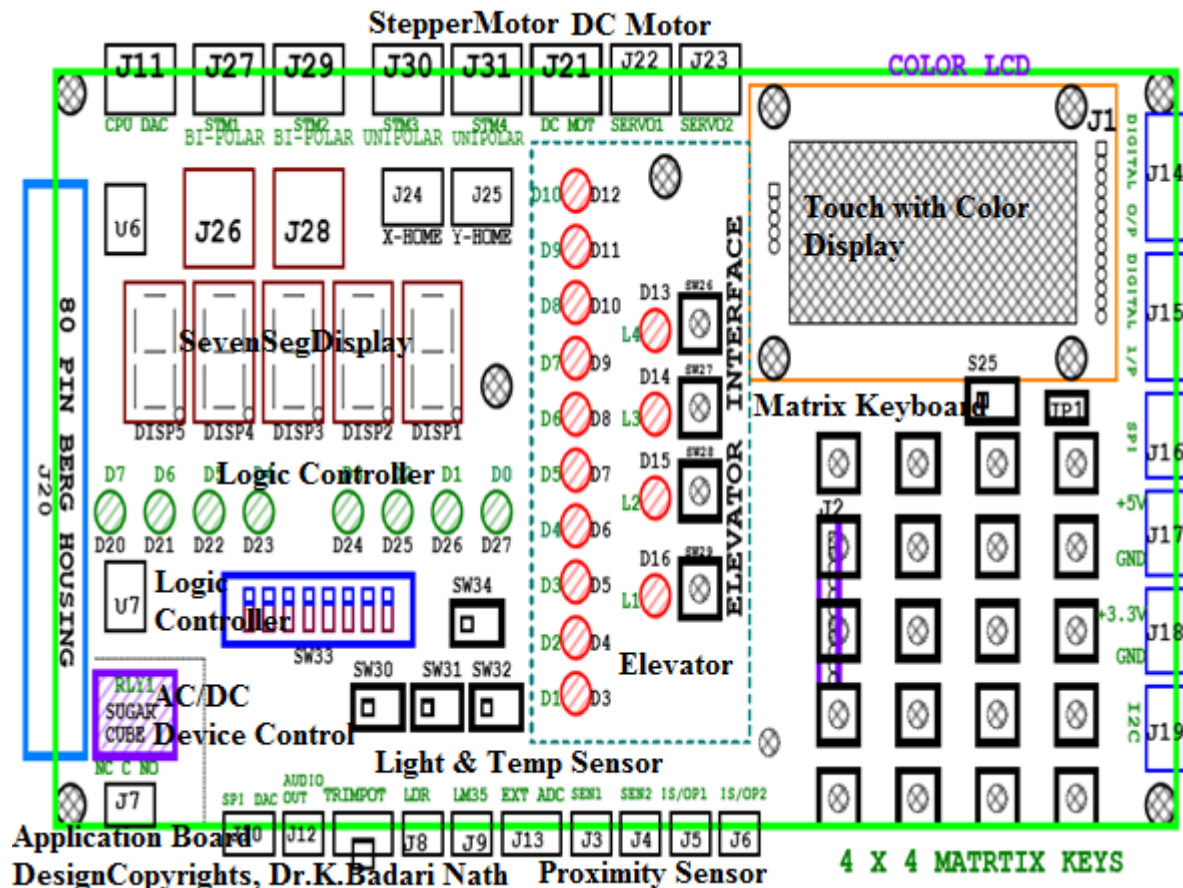
PART – A

Interfacing Programs using ARM LPC 2148

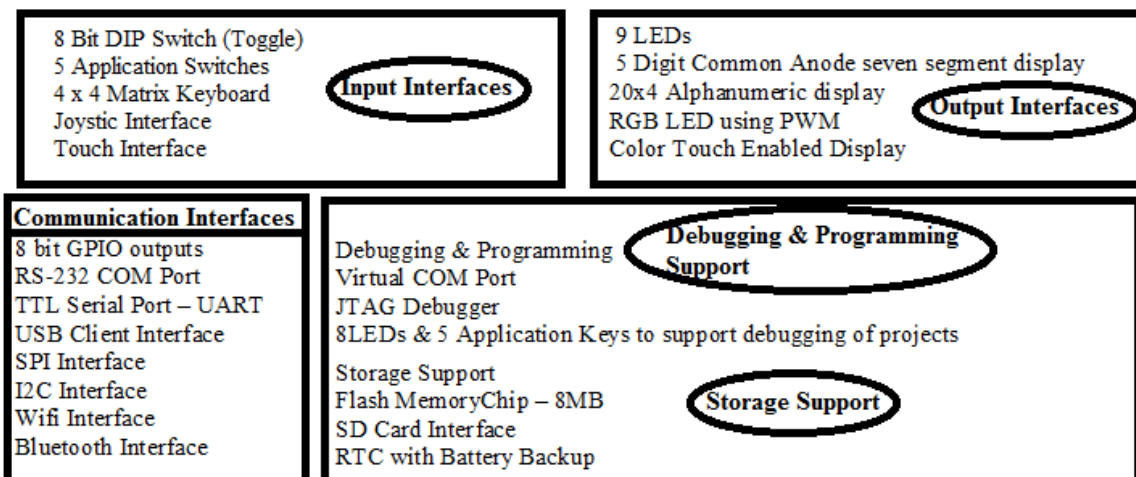
ARM CPU Board



ARM Application Board



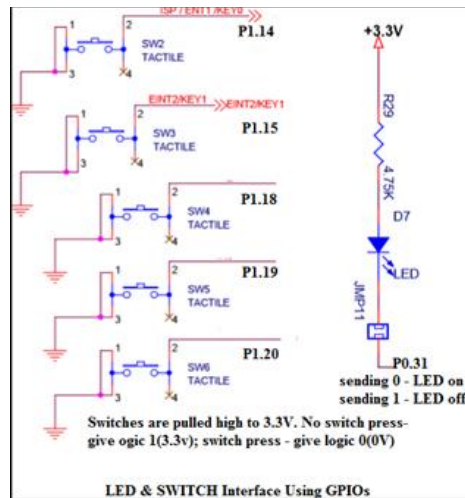
Board Specifications: Power : 12V, 1A



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)

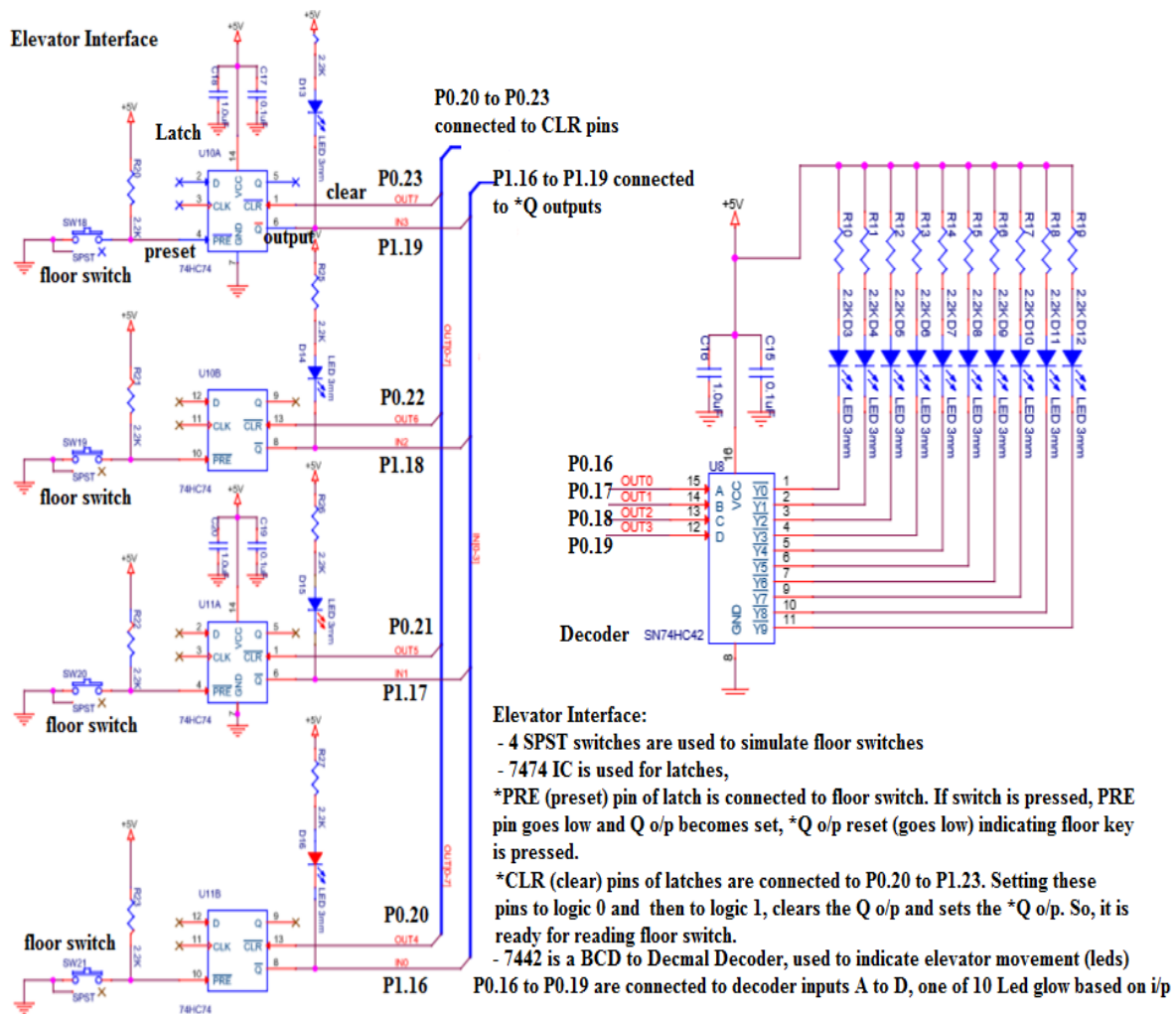
//P1.14 connected to Switch - SW2 in CPU board

```
#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;
    }
}

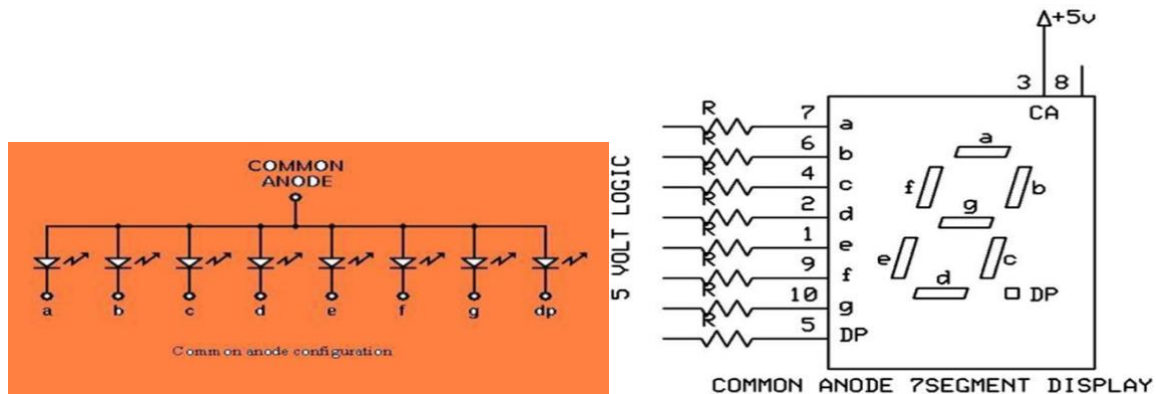
void delay_ms(unsigned int ms) {
    for(int i = 0; i < ms; i++) {
        for(int x = 0; x < 10000; x++);
    }
}
```

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.

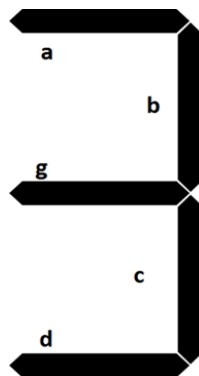
Serial In Parallel Out mode of Shift Register (74HC4094) is used to send 8 bits of data to seven segment display. Seven segment display used is of common anode type i.e. we have to send 0 to make corresponding segment ON and 1 to make it OFF.



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

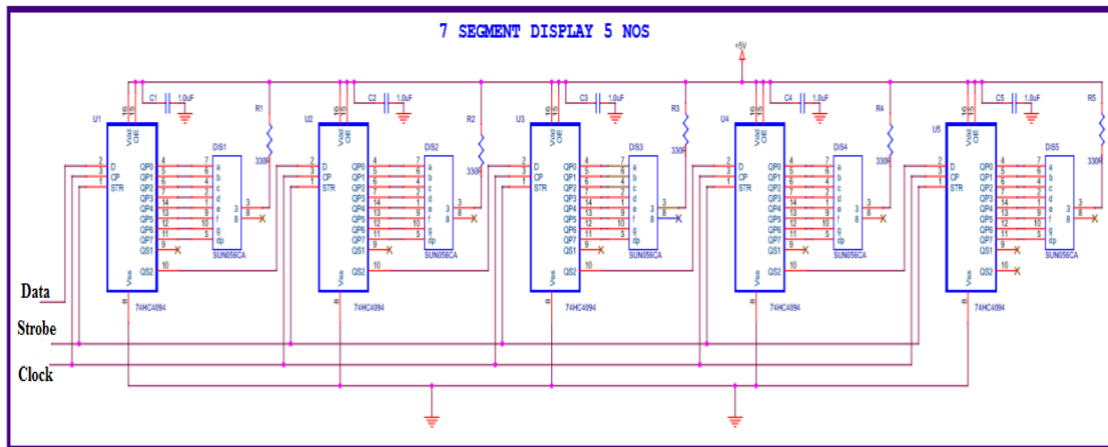
DP	G	f	e	d	c	b	a
1	0	1	1	0	0	0	0

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, $8 \times 4 = 32$ 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 completed.

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/p
    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;
        //similarly 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 significant 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++);
    }
}

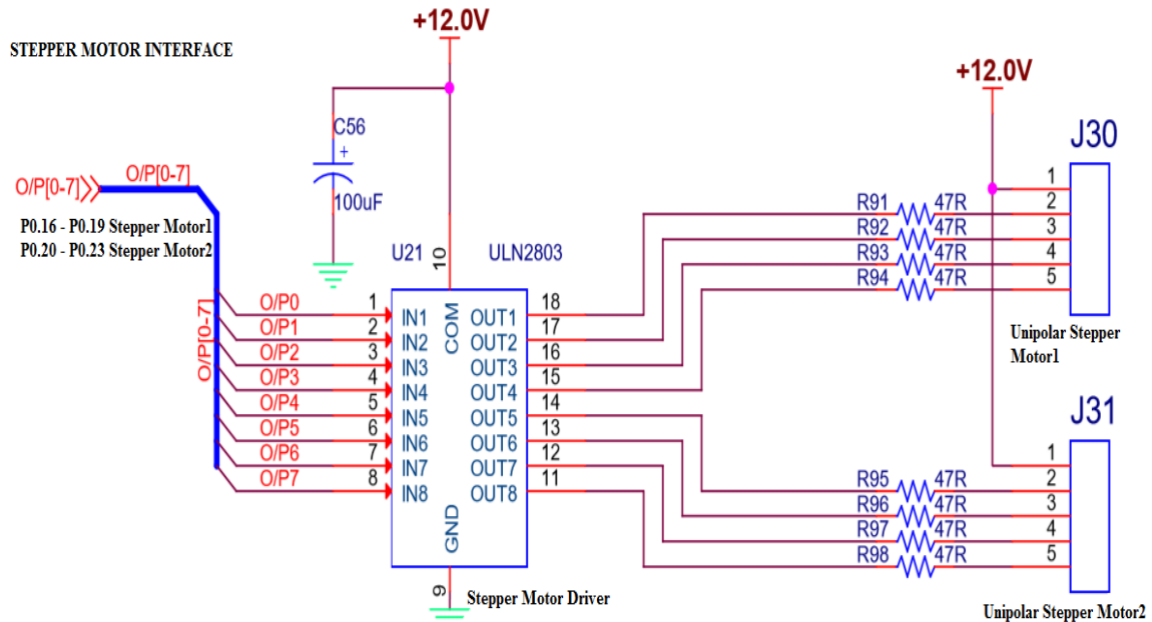
// CODE to display an integer number/long integer number
// long int dig_value;
// unsigned char buf[5];
// sprintf(buf,"%05lu",dig_value);
// alphadis7SEG(&buf[0]);
```

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)

$$\text{Step angle} = 360^\circ / 200 = 1.8^\circ$$

- 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);

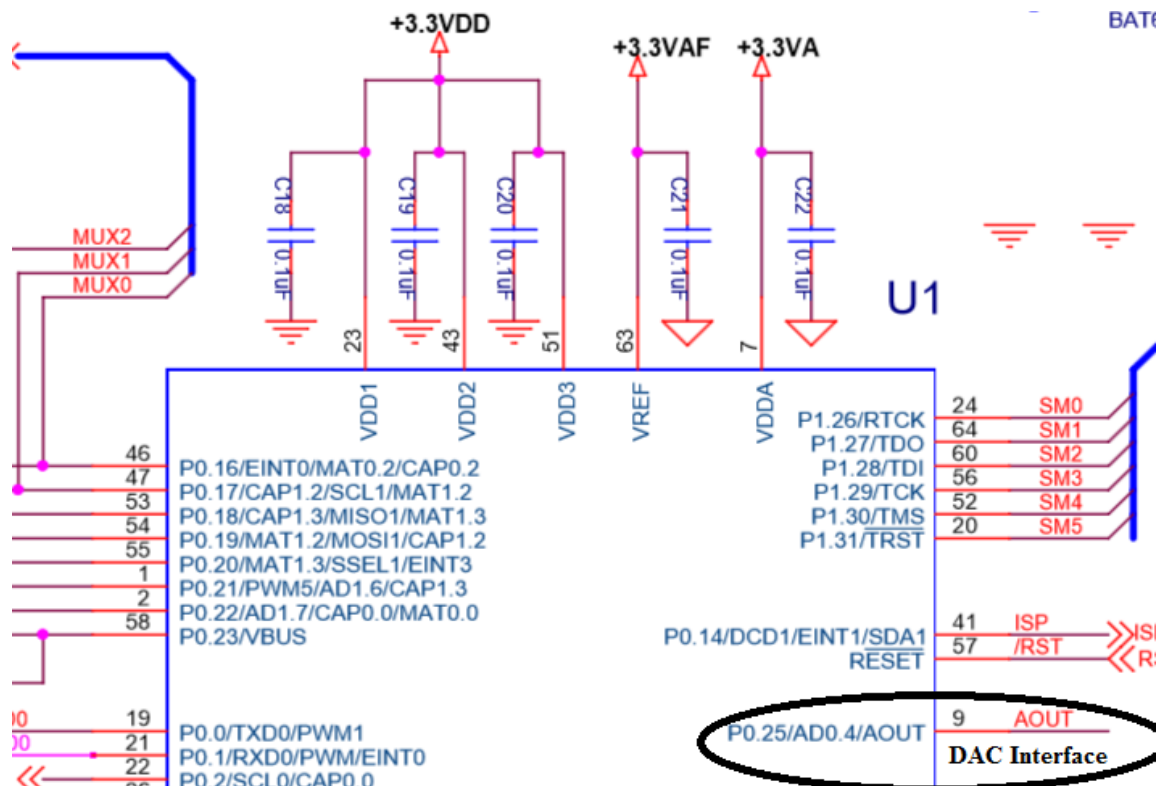
int main()
{
    unsigned int no_of_steps_clk = 100, no_of_steps_aclk = 100;
    IO0DIR |= 1U << 31 | 0x00FF0000 | 1U << 30; // to set P0.16 to P0.23 as o/ps
    LED_ON; delay_ms(500); LED_OFF; // make D7 Led on .. just indicate the program is running
    SystemInit( );
    do{
        IO0CLR = 0X000F0000; 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++);
    }
}
```

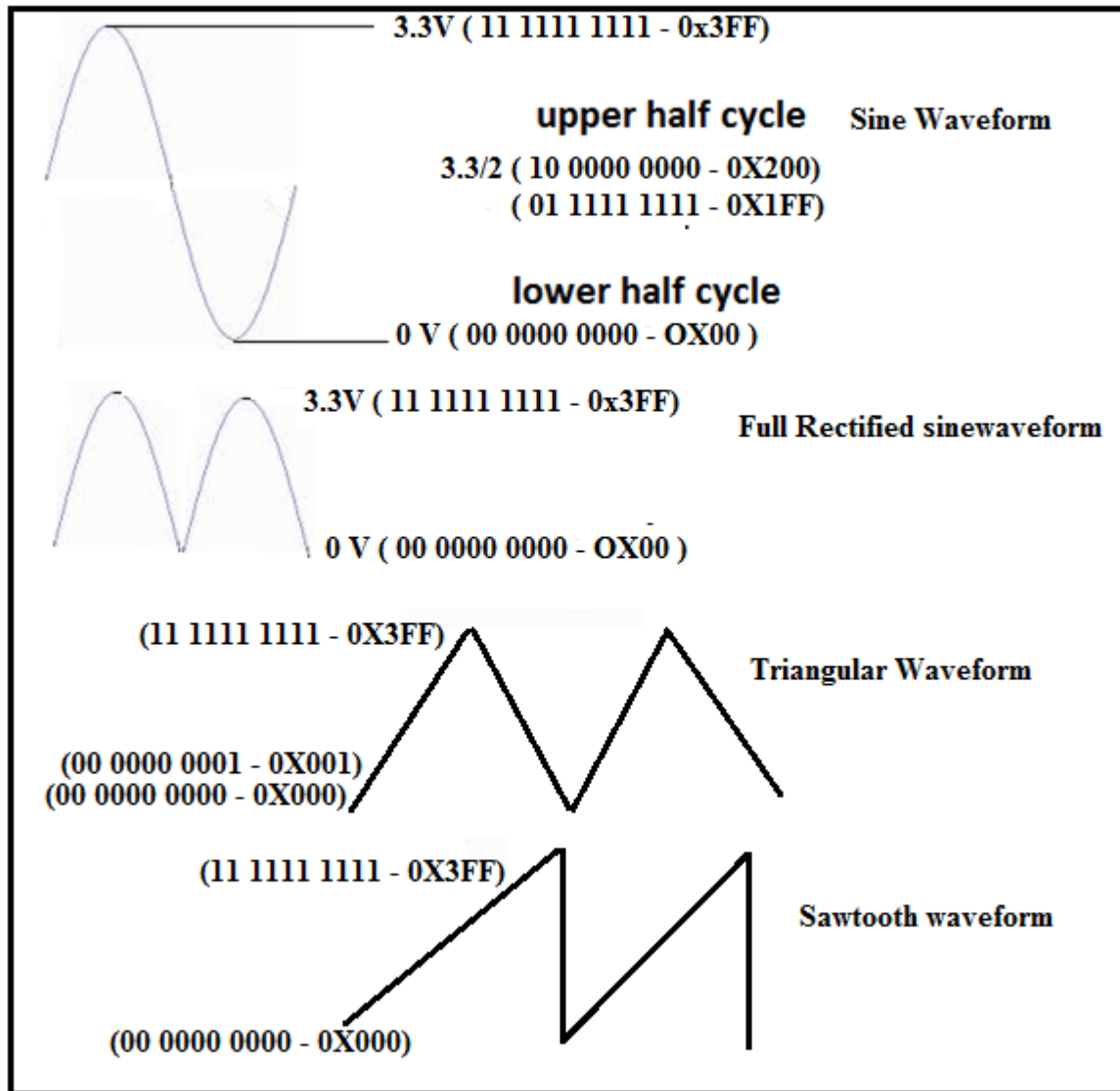
Interfacing Circuit working Explanation:

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



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+256,
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+256,
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) );
}
}
}
```

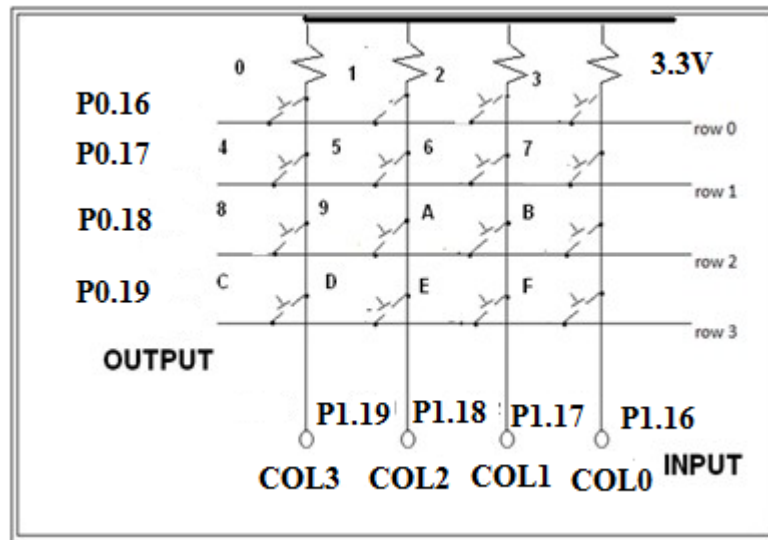
```
void SystemInit(void)
{
    PLL0CON = 0x01;
    PLL0CFG = 0x24;
    PLL0FEED = 0xAA;
    PLL0FEED = 0x55;
    while( !( PLL0STAT & PLOCK ))
    { ; }
    PLL0CON = 0x03;
    PLL0FEED = 0xAA;
    PLL0FEED = 0x55;
}
void delay_ms(unsigned int j)
{
    unsigned int x,i;
    for(i=0;i<j;i++)
    {
        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,colssel=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){colssel=0;break;};if(COL1==0){colssel=1;break;};
            if(COL2==0){colssel=2;break;};if(COL3==0){colssel=3;break;};
            //check for keypress in row1,make row1 '0'
            rowsel=1;IO0SET = 0X000F0000;IO0CLR = 1 << 17;
            if(COL0==0){colssel=0;break;};if(COL1==0){colssel=1;break;};
            if(COL2==0){colssel=2;break;};if(COL3==0){colssel=3;break;};
            //check for keypress in row2,make row2 '0'
            rowsel=2;IO0SET = 0X000F0000;IO0CLR = 1 << 18;//make row2 '0'
            if(COL0==0){colssel=0;break;};if(COL1==0){colssel=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++);
    }
}

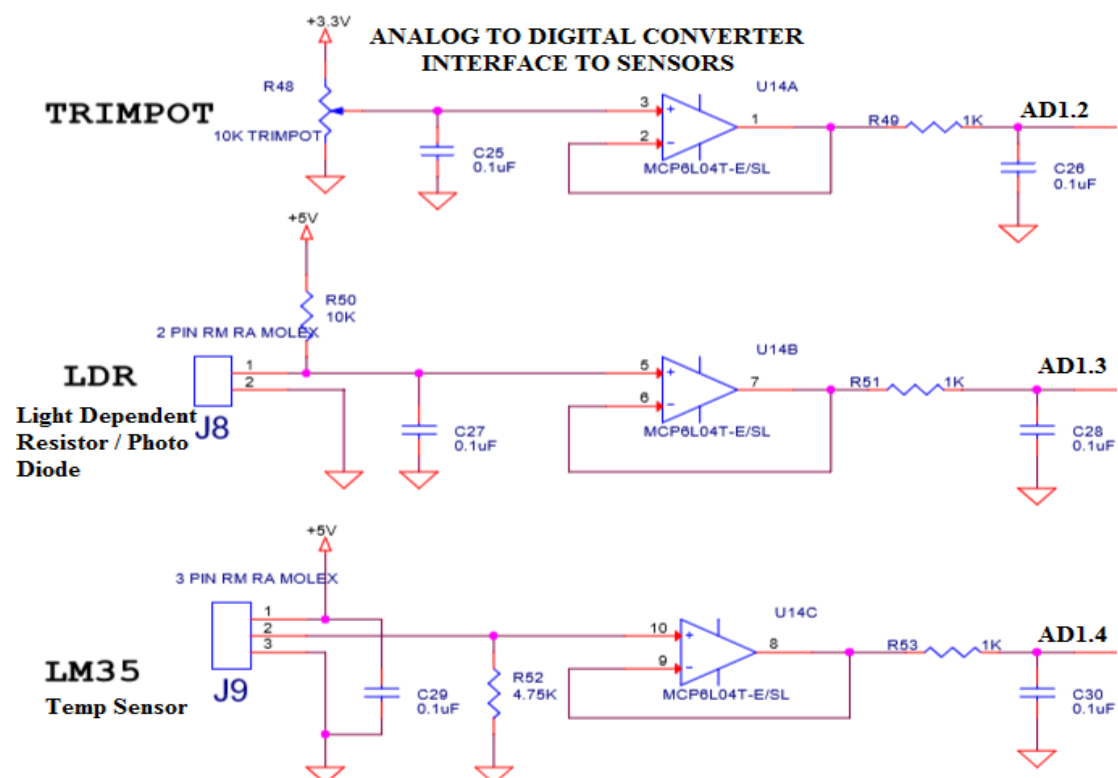
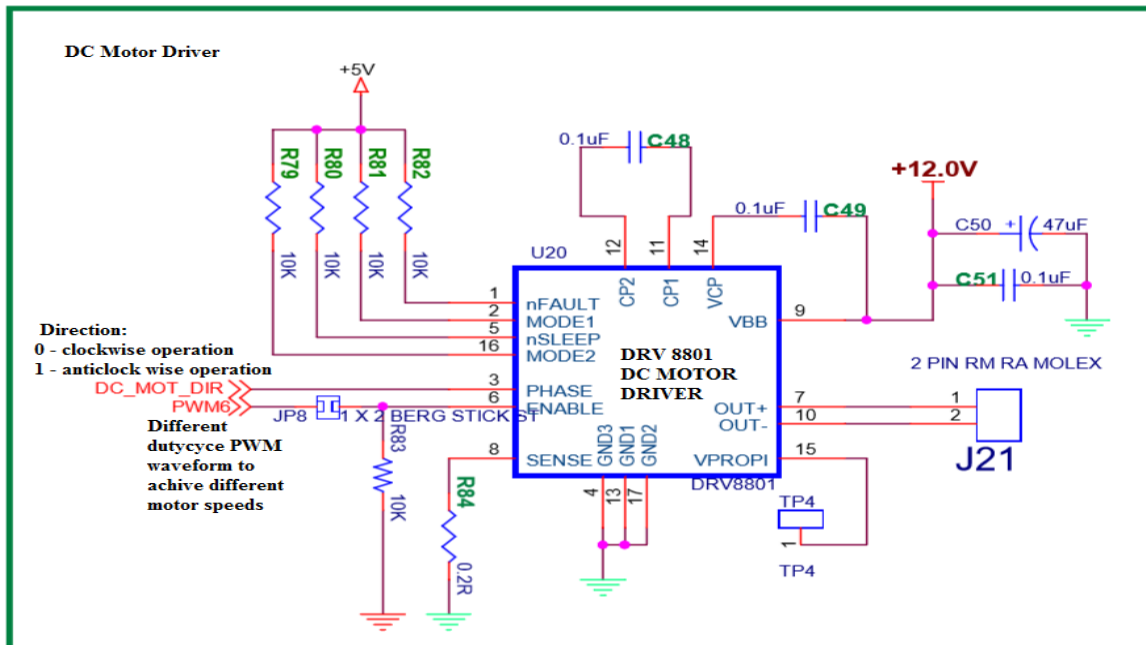
```

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 Potentiometer 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 - digital 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:

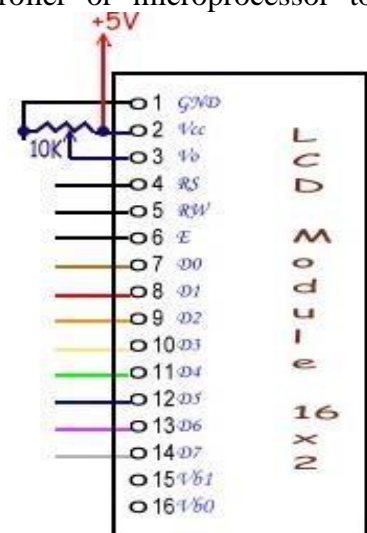
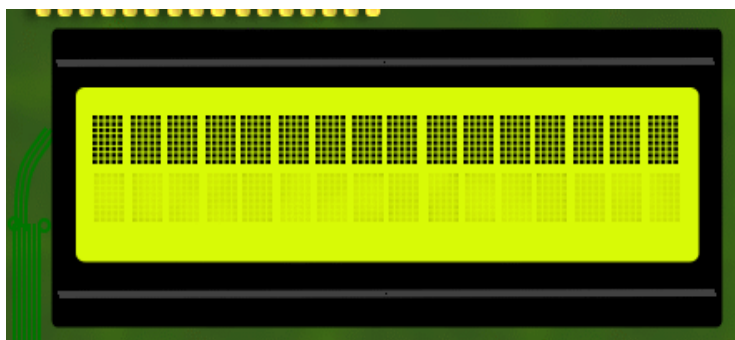
Output Observation:

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 16) 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)

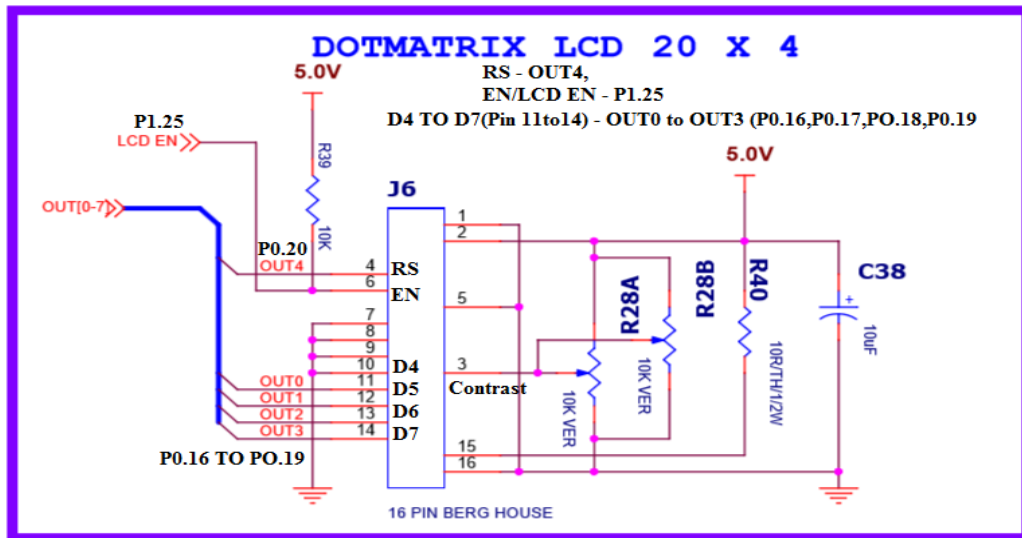
- 0- Write to LCD (Data/Command)
- 1- Read from the LCD

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(upper nibble) 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++);
    }
}
```

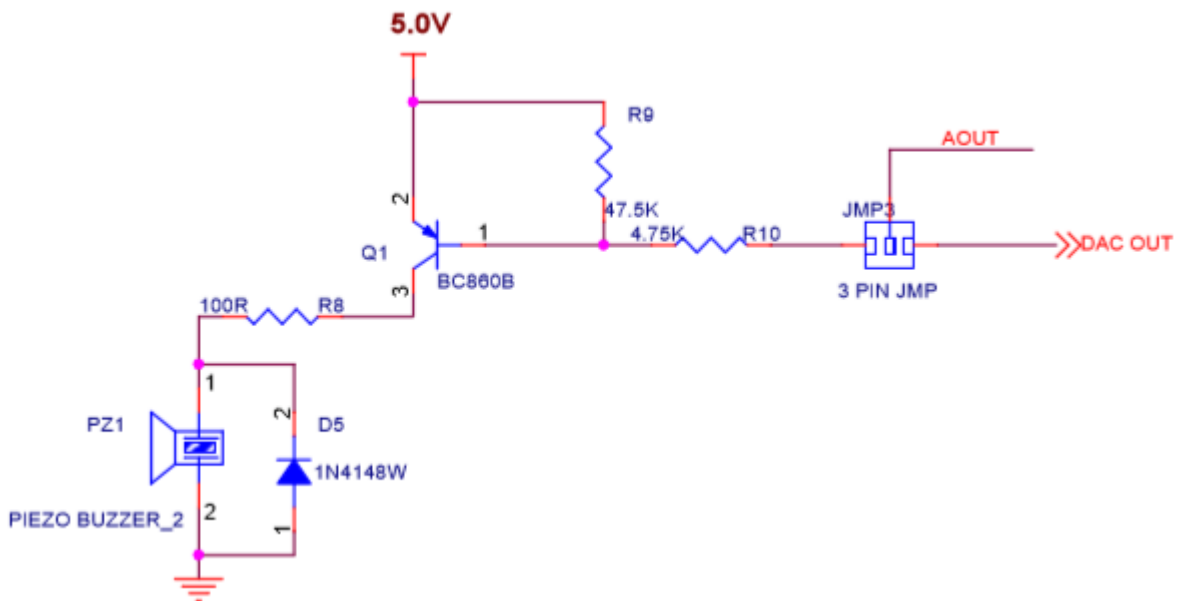
Interfacing Circuit working Explanation:

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));

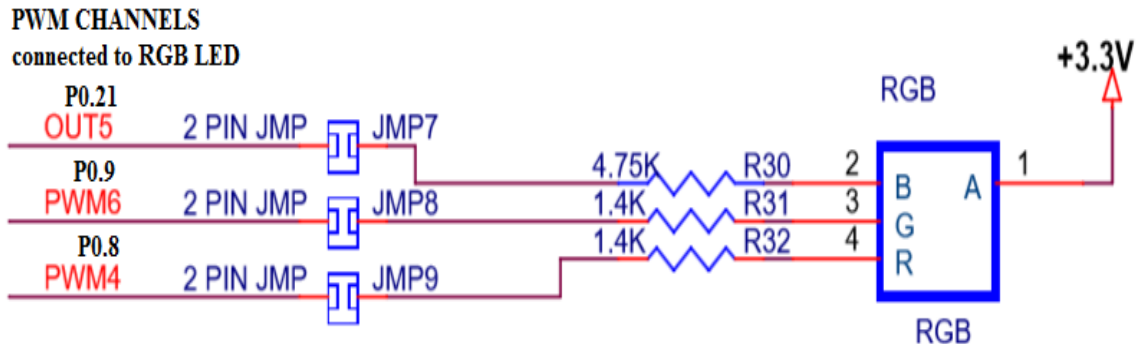
 delay_ms(500);

 DACR = ((1<<16) | (1023<<6));

 delay_ms(1);

}

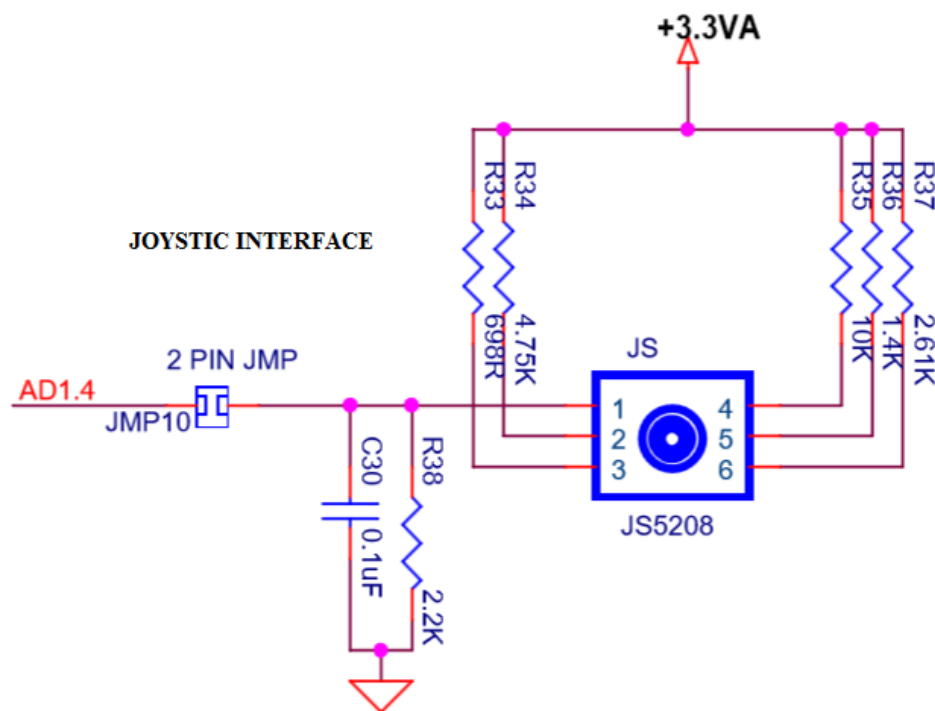
RGB LED INTERFACE & SAMPLE PROGRAM



```
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

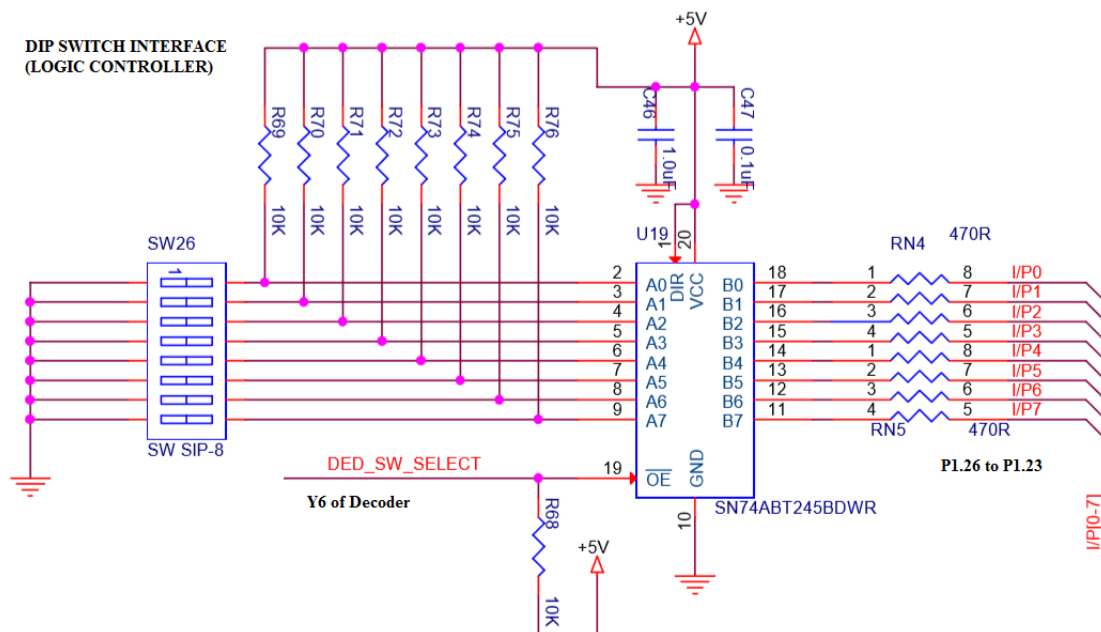


```

char Joystick_position(void)
{
    // returns joystick 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.

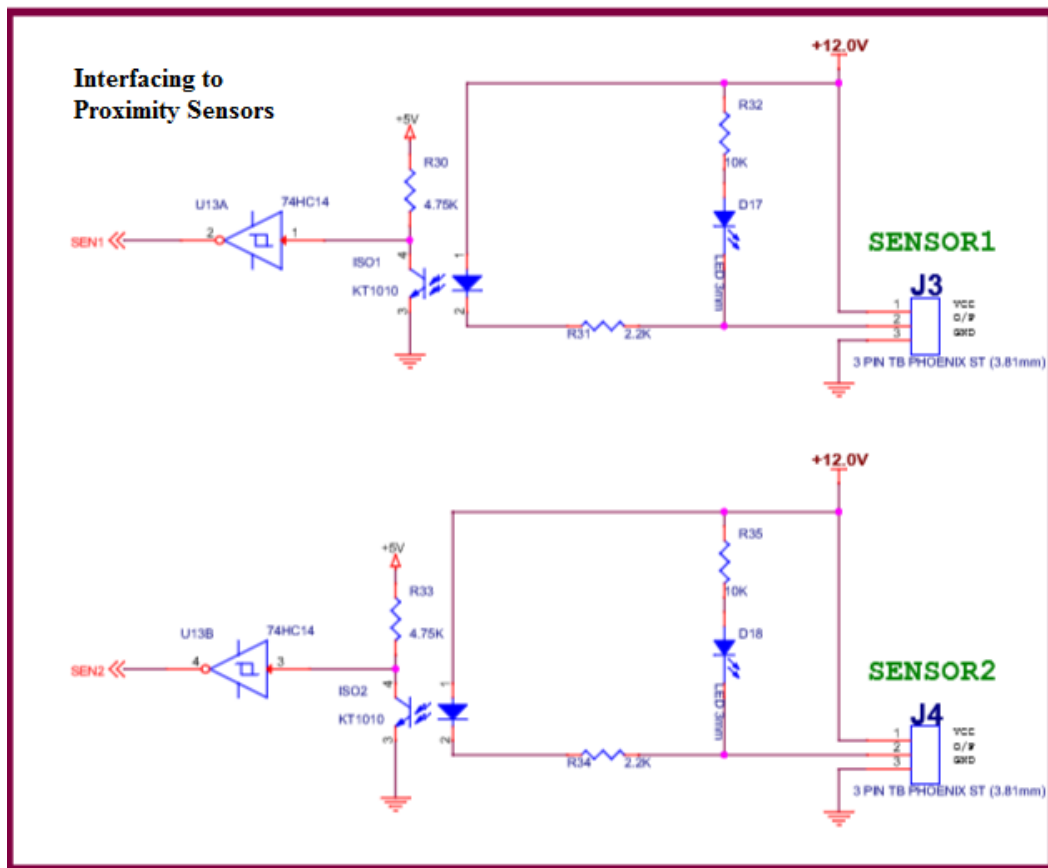


```

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;
}
```