| 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 Computing - Laboratory

**Subject Code: CS344AI**

**IV SEMESTER B.E.**

**CS,CS(CY),CS(CD)**

**LABORATORY RECORD**

**[Autonomous Scheme 2022]**

**2024-2025**

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

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

Rashtreeya Sikshana Samithi Trust

# R. V. COLLEGE OF ENGINEERING

## DEPARTMENT OF COMPUTER SCIENCE & ENGINEERING

# IOT & EMBEDDED COMPUTING LAB

## (CS344AI)

## 2024 - 2025

## 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 Computing Lab [CS344AI] prescribed by the department during the year 2024-2025.

| 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.

## KNOWLEDGE & ATTITUDE PROFILE

**WK1:** A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social sciences.

**WK2:** Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline.

**WK3:** A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline.

**WK4:** Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline.

**WK5:** Knowledge, including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts, that supports engineering design and operations in a practice area.

**WK6:** Knowledge of engineering practice (technology) in the practice areas in the engineering discipline.

**WK7:** Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline, such as the professional responsibility of an engineer to public safety and sustainable development.

**WK8:** Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues.

**WK9:** Ethics, inclusive behaviour and conduct. Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability etc. with mutual understanding and respect, and of inclusive attitudes

# 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:** Apply Embedded System and IoT fundamentals and formulate sustainable societal relevant cost-effective solutions.

**CO2:** Demonstrate the development of software programs using Embedded C, using Microcontrollers and different sensors and peripherals to build embedded system applications .

**CO3:** Design smart systems using various I/O peripherals, Sensors, embedded protocols like UART,I2C,SPI using modern tools like Keil IDE software for various domains like Healthcare, automation, agriculture, smart cities and others.

**CO4:** Indulge in developing Novel multi-disciplinary IoT projects using prototype boards, with effective oral & written communication skills and working in teams.

**CO5**: Engage in Lifelong Learning by investigating and executing real world societal problems using engineering tools – Cross compilers, debuggers and simulators, emerging processor and controller-based hardware platforms, IOT cloud infrastructure & protocols.

# 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 EXPERIMENTS

## Part A

Laboratory Experiments using RV-ARM-Board (LPC 2148 ARM Microcontroller) comprises of,

| Prog No. | Program | Page No | Marks Split as per rubrics | | | | | Marks (10) |
|---|---|---|---|---|---|---|---|---|
| | | | Execution | | | Viva | | |
| | | | 2 | 2 | 2 | 2 | 2 | |
| 1 | Assembly Programs | 5 | | | | | | |
| 2 | Programming with LED and Switches<br>Simulation: Elevator Interface using switches and LEDs | 17 | | | | | | |
| 3 | Seven Segment Display Interface: Write a C program to display messages “FIRE” & “HELP” on 4-digit seven segment display alternately with a suitable delay. | 24 | | | | | | |
| 4 | 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. | 29 | | | | | | |
| 5 | DAC Interface: Write an Embedded C program to generate sine, full rectified, triangular, sawtooth and square waveforms using DAC module | 33 | | | | | | |
| 6 | 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. | 40 | | | | | | |
| 7 | 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. | 45 | | | | | | |
| **Total for 70 Marks** | | | | | | | | |

**PART-B**

Design & Develop IOT based Solutions, using RasberryPie / RV-IOT-Board, Use ThingSpeak /AWS cloud services, Use Web Application Frameworks like Django/Mobile App using C/C++/ Phython coding and relevant libraries/APIs

| Project No. | Program | Page No | Marks Split as per rubrics | | | | | Marks (10) |
|---|---|---|---|---|---|---|---|---|
| | | | Execution | | | Viva | | |
| | | | 2 | 2 | 2 | 2 | 2 | |
| 1 | Project 1:<br>Smart Lighting (Using ESP32 & BLYNK CLOUD) | 58 | | | | | | |
| 2 | Project 2:<br>Weather Monitoring and Reporting Bot (Using ESP32 & ThingSpeak Cloud) | 60 | | | | | | |
| 3 | Project3:<br>Smart Parking (Using RasberryPie & Google Firebase) | 62 | | | | | | |
| **Total for 30 Marks** | | | | | | | | |

| **LAB INTERNALS (CIE Evaluation)** | |
|---|---|
| **RECORD Marks (Part A & Part B)** | / 30 Marks |
| **TEST** | / 10 Marks |
| **Productathon /IOT Hackathon/ Skill Labs /SEE Project Evaluation** | / 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 Embedded C for ARM concepts. **(2M)** | Student has sufficient understanding of program requirements and applies Embedded C for ARM concepts. **(1.5M - 1M)** | Student does not have clear understanding of program requirements and is unable to apply 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 & Embedded C related concepts involved. **(2M)** | Adequately explains architecture & 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:** | | | | | |

# Conduction of Semester End Examination (SEE) for Lab

1. Prescribed experiments as per the scheme are conducted throughout the semester and evaluated for **CIE only.**
2. Students **undertake a project** encompassing the concepts of the exercises / experiments during the semester as an **open-ended exercise** related to the **course (both theory and lab).**
3. The problem statement of the project is proposed by the students using their skill set and creativity, and the student's team up in **group of TWO** to execute the project. All the student groups are from the **same lab batches and the Program**.
4. The Lab SEE will be the final presentation and full working demonstration of the prototype of the project.
5. The students are required to submit duly signed Report, having system block diagram with methodology, schematic circuit diagrams, algorithms, full code and documentation of results.

**Evaluation Scheme for Lab SEE:**

| Sl No | Particulars | Marks |
|---|---|---|
| 1 | Design and development of project | 20 Marks |
| 2 | Demonstration of the Working Prototype with all Use cases | 20 Marks |
| 3 | Viva Voce | 10 Marks |
| 4 | **TOTAL** | **50 Marks** |

**Rubrics: Design and development of the Solution (20 marks): CO1, CO2, CO3**

| Criteria | Excellent | Good | Poor |
|---|---|---|---|
| **Understanding of problem and requirements 05 marks** | Selects the most suitable relevant problem, Understands fully and bringing out best requirements **(5 M)** | Selects suitable problem but requirements are not fully done **(2 - 4 M)** | No proper understanding of problem, requirements not complete **(0 - 1 M)** |
| **Understanding Architecture & Effective Usage of Microcontroller/Board Used 05 marks** | Uses Most suitable Board and used all the features of the board effectively **(5 M)** | Used are appropriate but may not be optimal. **(2 - 4 M)** | Uses inefficient or inappropriate board and not effectively used the features. **(0 - 1 M)** |
| **Block Diagram of project, Schematic Diagrams, Specifications of all Components, Final Product specifications 05 marks** | Provides Detailed and accurate Information with proper justification. **(5 M)** | Information is included but lacks depth or contains minor errors. **(2 - 4 M)** | Not complete or incorrect. **(0 - 1 M)** |
| **Hardware & Software Integration: Inbuilt functions used, Procedures developed, Methodology, Novelty 05 Marks** | Code is correct, best integration is done with HW, code is optimized, and efficiently implemented the methodology and novelty element is present. **(5 M)** | Integration & Code is mostly correct but may contain inefficiencies or minor bugs. No novelty **(2 – 4 M)** | Integration & Code is incorrect, inefficient, or does not execute properly. **(0 -1 M)** |

**Rubrics: Demonstration of the Solution / Prototype / Working Model (20 marks): CO4, CO5**

| Criteria | Excellent | Good | Poor |
|---|---|---|---|
| **Explanation of all Connections, Components**<br><br>**03 marks** | Clearly Demonstrates all the connections, Identifies all the components with I/Os<br>**(3M)** | **Partially** Demonstrates all the connections, Identifies all the components with I/Os<br>**(1-2M)** | **No understanding of** connections, Identifies wrongly the components<br>**(0-0.5M)** |
| **Demonstration of Working Prototype**<br><br>**10 marks** | Fully Demonstrates the working model, with all use cases<br>**(7-10M)** | Partial Demonstration of working model with few use cases<br>**(4-6M)** | Not Proper working of the model<br>**(0-3M)** |
| **Demonstration of Cloud and Web/Mobile Interface**<br><br>**05 marks** | Fully implemented the web app/mobile app with full working demonstration<br>**(5M)** | Partial implemented the web app/mobile app with full working demonstration<br>**(2-4M)** | Not implemented the web app/mobile app<br>**(0-1M)** |
| **Documentation: Project Report**<br><br>**02 marks** | Well-structured report with clear explanations, figures, and references.<br>**(2 M)** | Report is mostly clear but lacks some details or organization.<br><br>**(1 M)** | Poorly structured report with missing explanations and references.<br>**(0.5 M)** |

***Sample open-ended experiment ideas for SEE Lab component of the course "*** **IOT & Embedded Computing *".*** **Use ARM Microcontroller / ESP32 / RasberrypiePico-Wifi / RasberryPie Zero / RasberryPie to develop the product. All projects should accompany associated Mobile/Web App Interface with IoT cloud enablement for data logging and visualization.**

- Microcontroller based Industrial Data logger with IOT enablement
- Microcontroller based Industrial Timer
- Smart Home Automation Using IoT
- IoT-Based Weather Monitoring System
- RFID-Based Smart Attendance System
- IoT-Based Smart Dustbin
- IoT-Enabled Soil Moisture Monitoring for Smart Irrigation
- IoT-Based Smart Door Lock System
- Smart Energy Meter with IoT Monitoring
- IoT-Based Smart Parking System
- IoT-Based Gas Leakage Detection System
- IoT-Based Health Monitoring System
- IoT-Based Home Security System
- IoT-Based Smart Lighting
- Embedded System for Attendence Management System
- Embedded System for instant non-invasive monitoring/measurement of blood pressure and glucose level
- Smart Real time Pest Detection for crops
- Smart System for Water Quality Monitoring in food production
- Wearable Health Monitoring System
- Autonomous IoT based Drone System

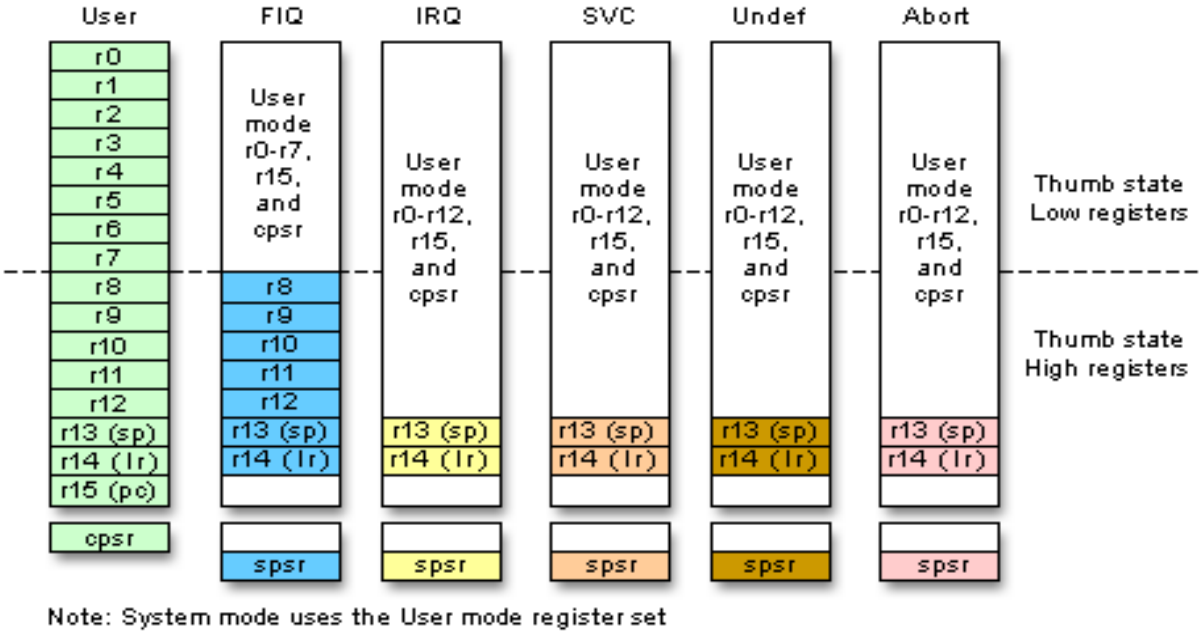
# Part A- ARM Fundamentals

## 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.

**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,#0x25 ; B
        MOV  R2,#0x34 ; C
        MOV  R3,#0x72; D

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

STOP    B   STOP
        END
```

**A = 4* A + B**

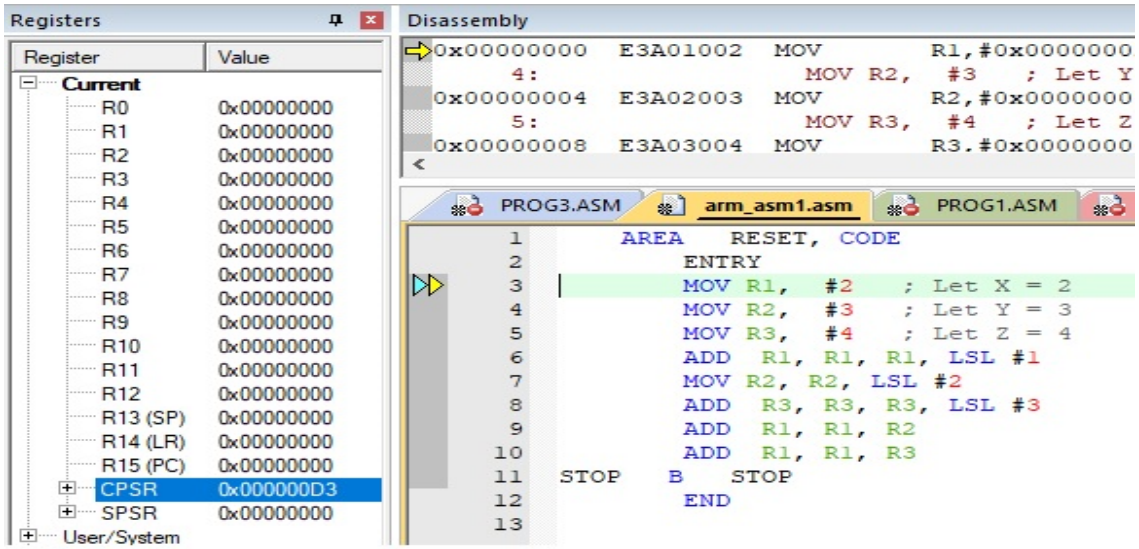
```
AREA   RESET, CODE
        ENTRY

        MOV  R0,#0X25 ; A
        MOV  R1,#0X34; B
        ADD  R0,R1,R0,LSL #2

STOP    B   STOP
        END
```

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

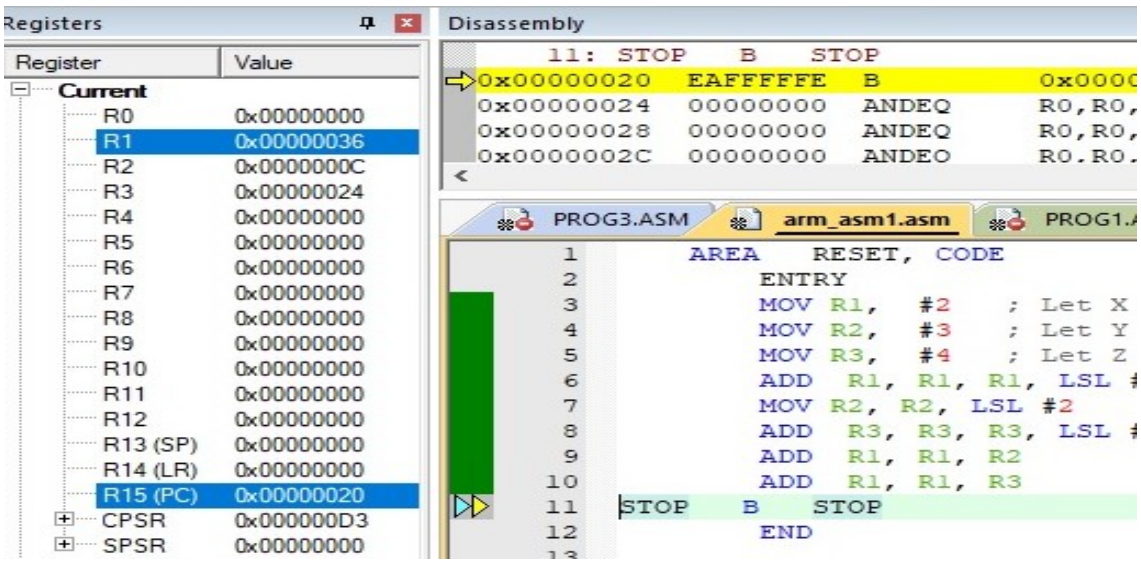
```
        AREA   RESET, CODE
        ENTRY
        MOV R1,  #2   ; Let X = 2
        MOV R2,  #3   ; Let Y = 3
        MOV R3,  #4   ; Let Z = 4
        ADD  R1, R1, R1, LSL #1
        MOV R2, R2, LSL #2
        ADD  R3, R3, R3, LSL #3
        ADD  R1, R1, R2
        ADD  R1, R1, R3
STOP   B   STOP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

**Sample Output:**

Before Execution




After Execution



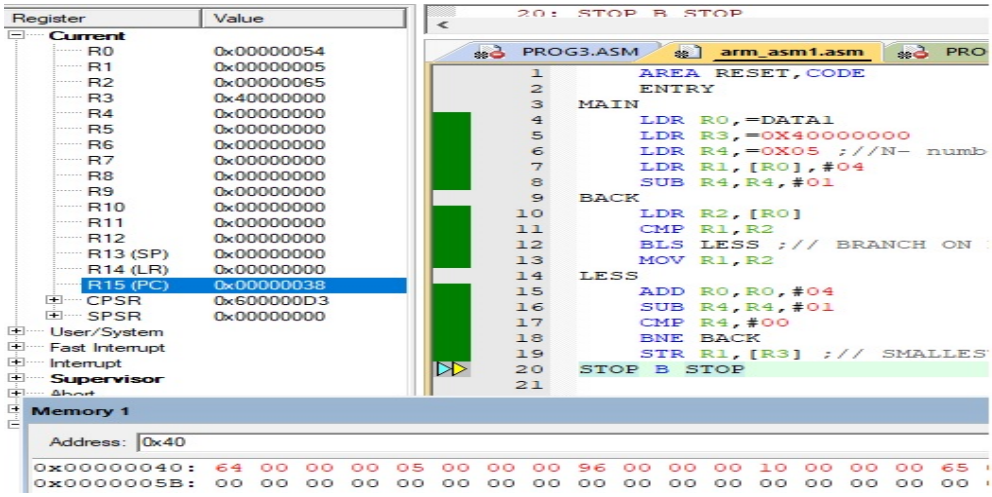
**AIM: Write an ARM ALP to find smallest and largest of N- 32 bit numbers.**

**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*.

```
        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

DATA1  DCD &64,&05,&96,&10,&65
        END
```

**Sample Output:**




**Note: Modify the program, to find both Smallest and Largest and use conditional execution instructions.**

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

**Algorithm:**

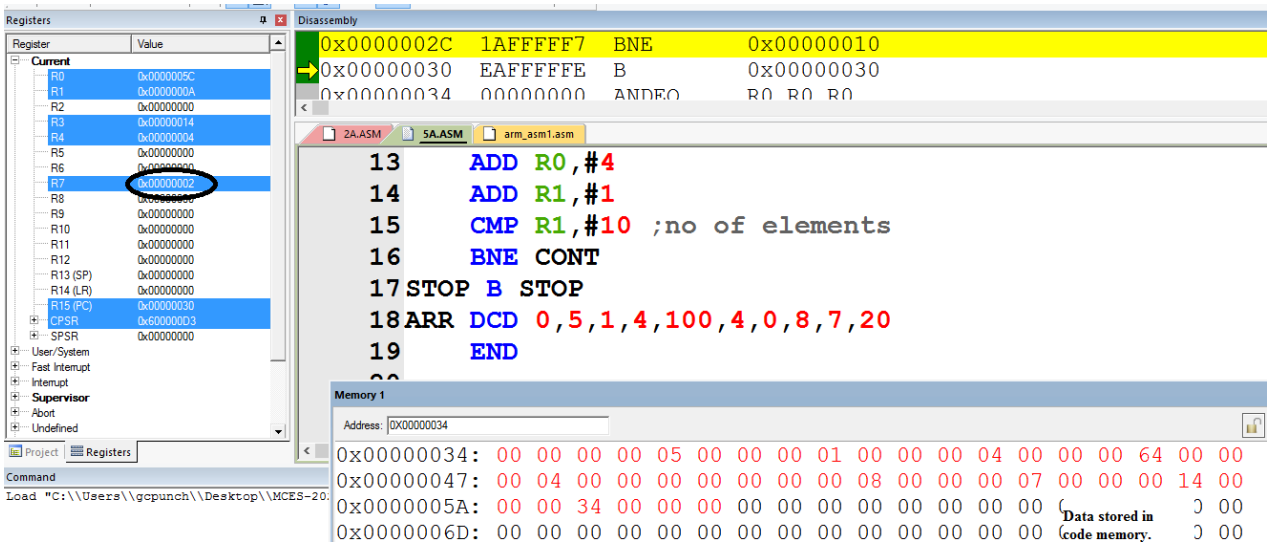
Linear Search ( array A, key x)
{
for i =0 to n
if A[i] = x then
increment element found count

}

**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:**



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

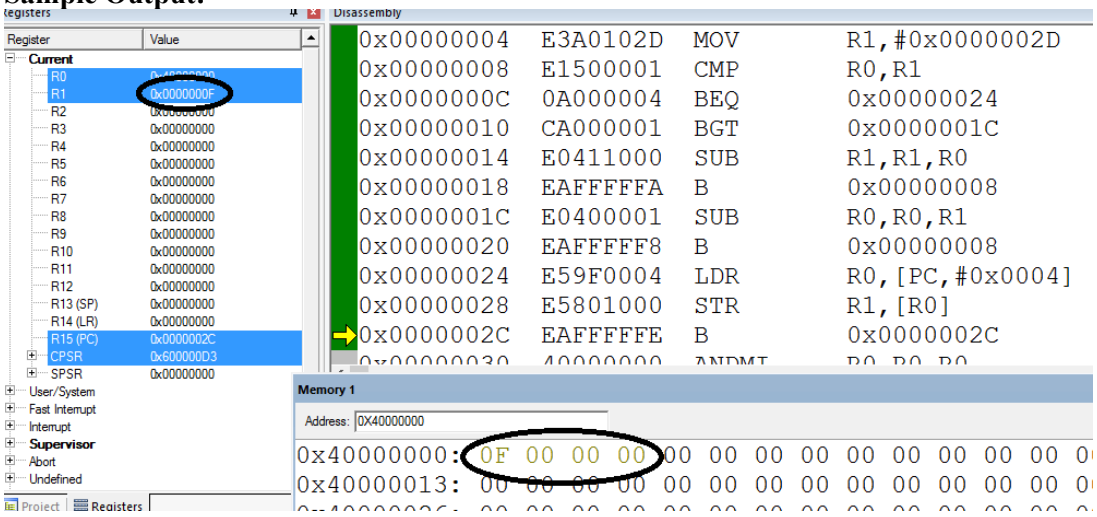
**Algorithm:**

```
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:**

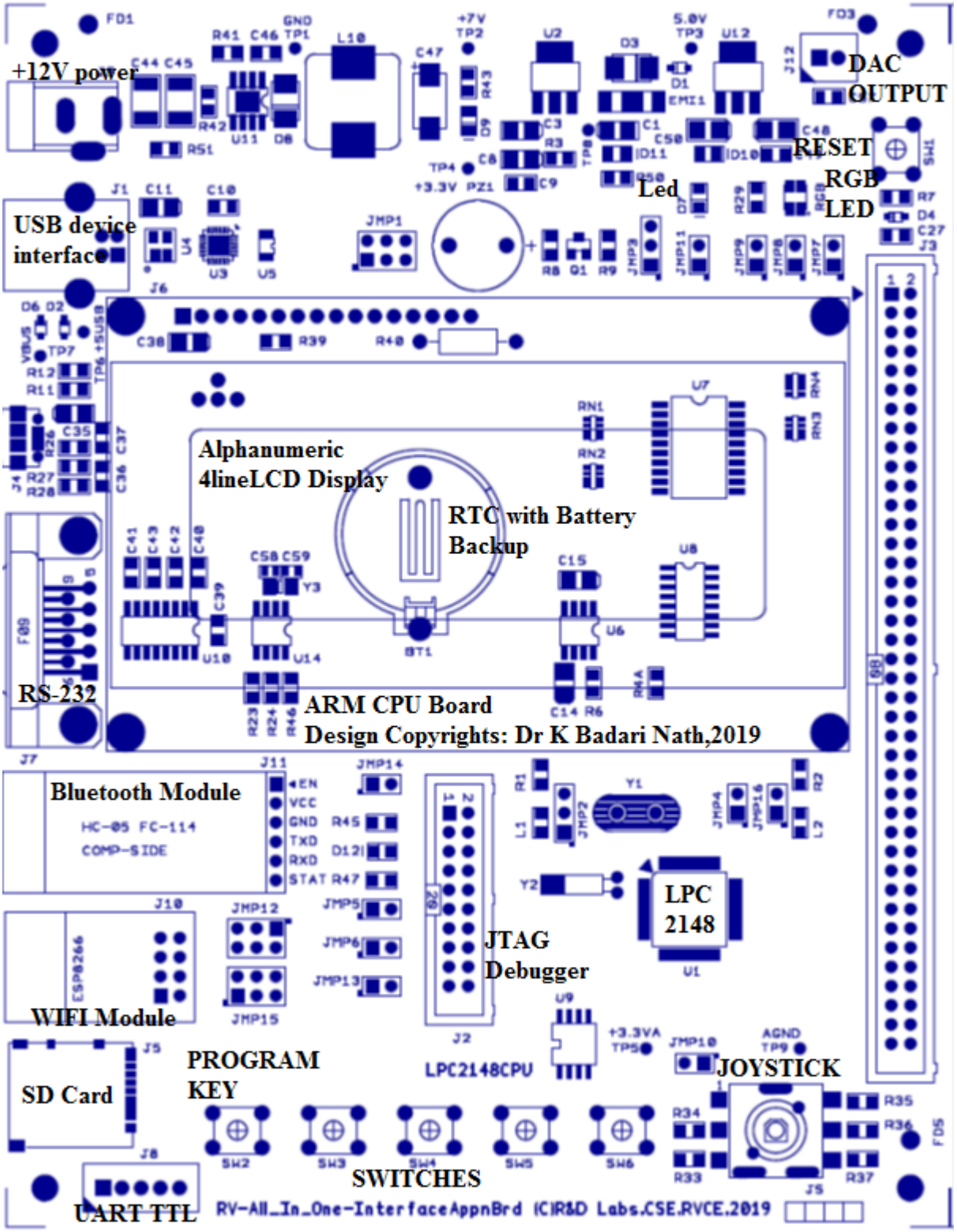



**Note: Modify the program, using the Condition Execution Instructions**

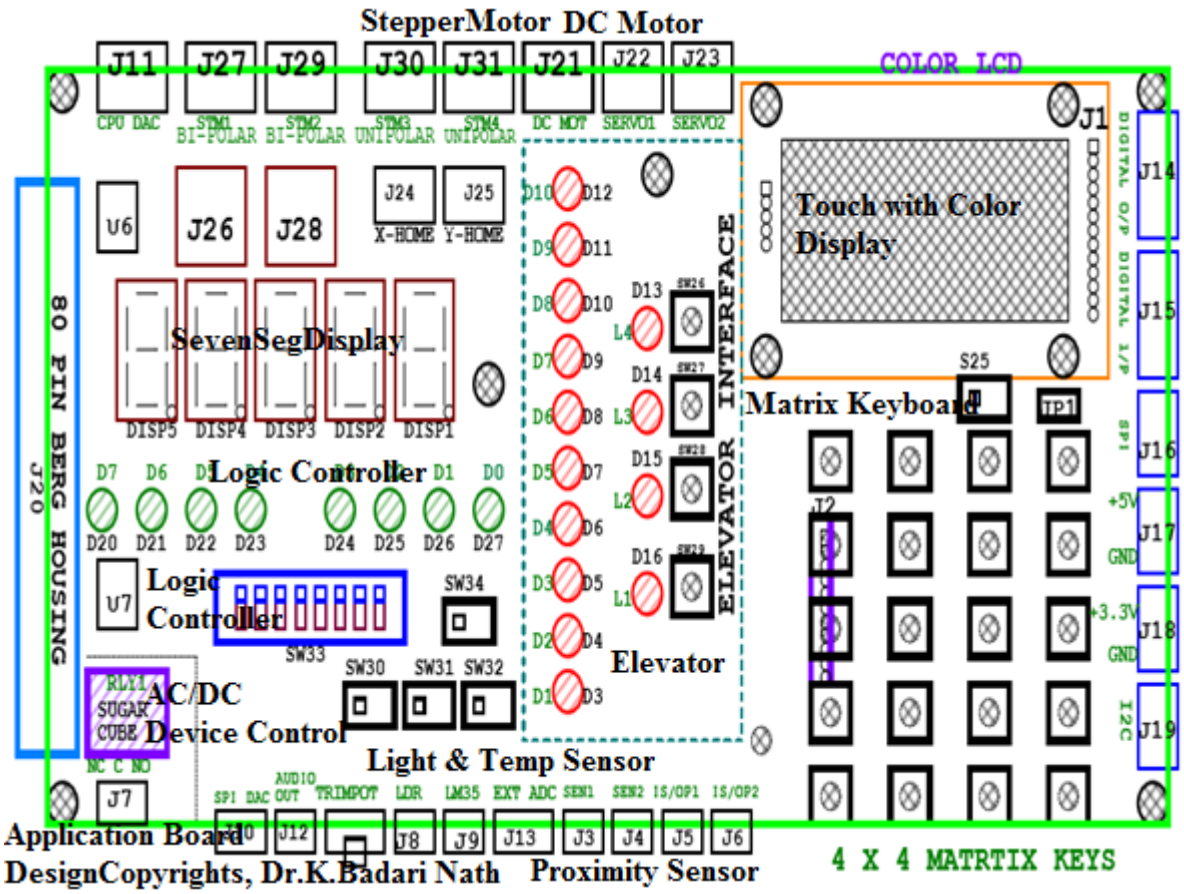
# PART – A

# Interfacing Programs using ARM LPC 2148

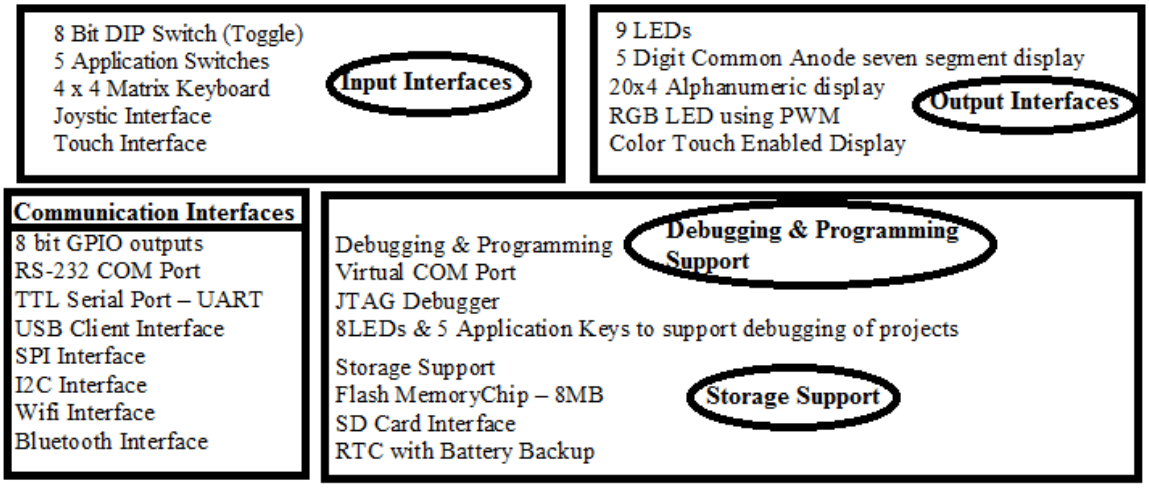
# ARM CPU Board



# ARM Application Board




Board Specifications: Power : 12V, 1A

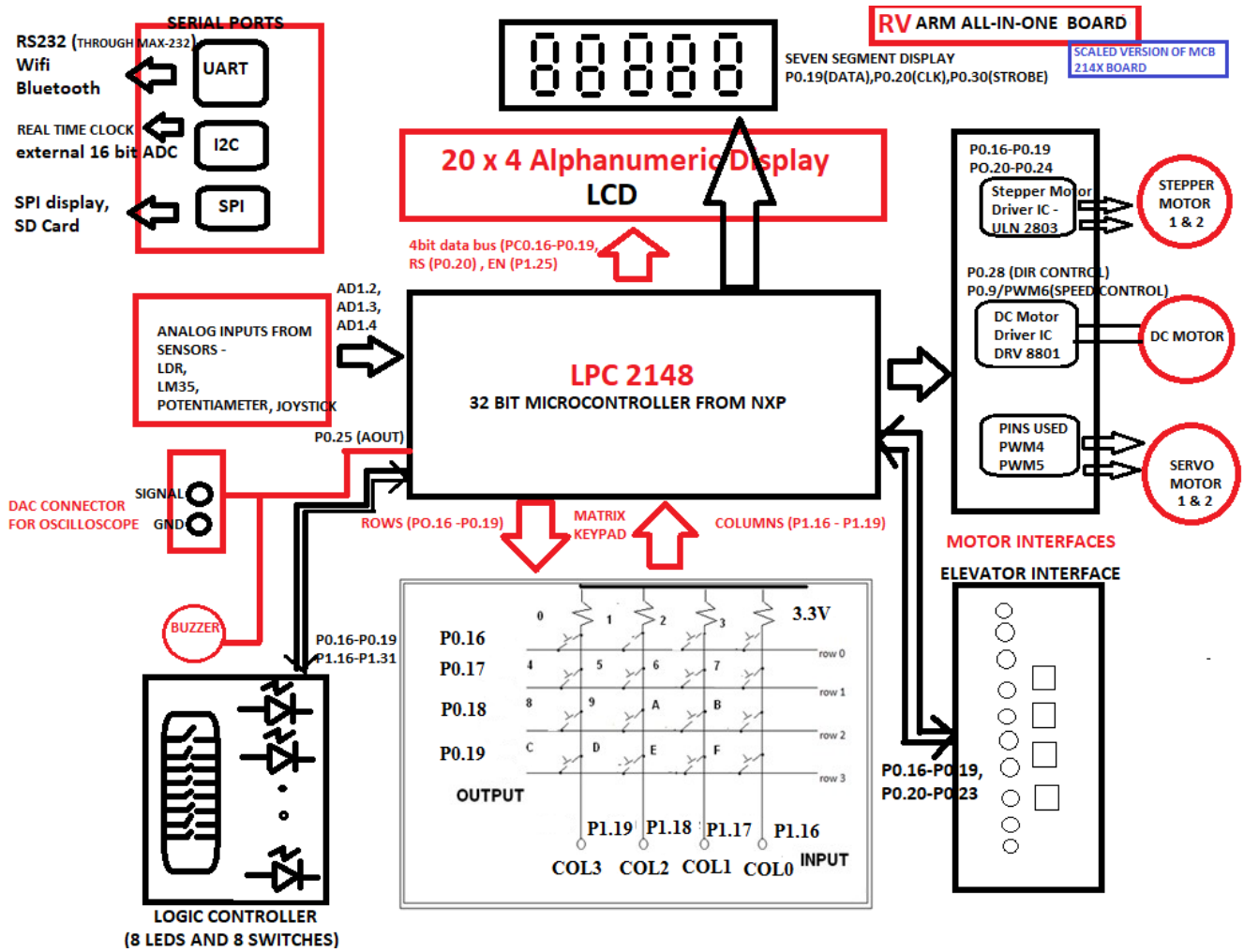


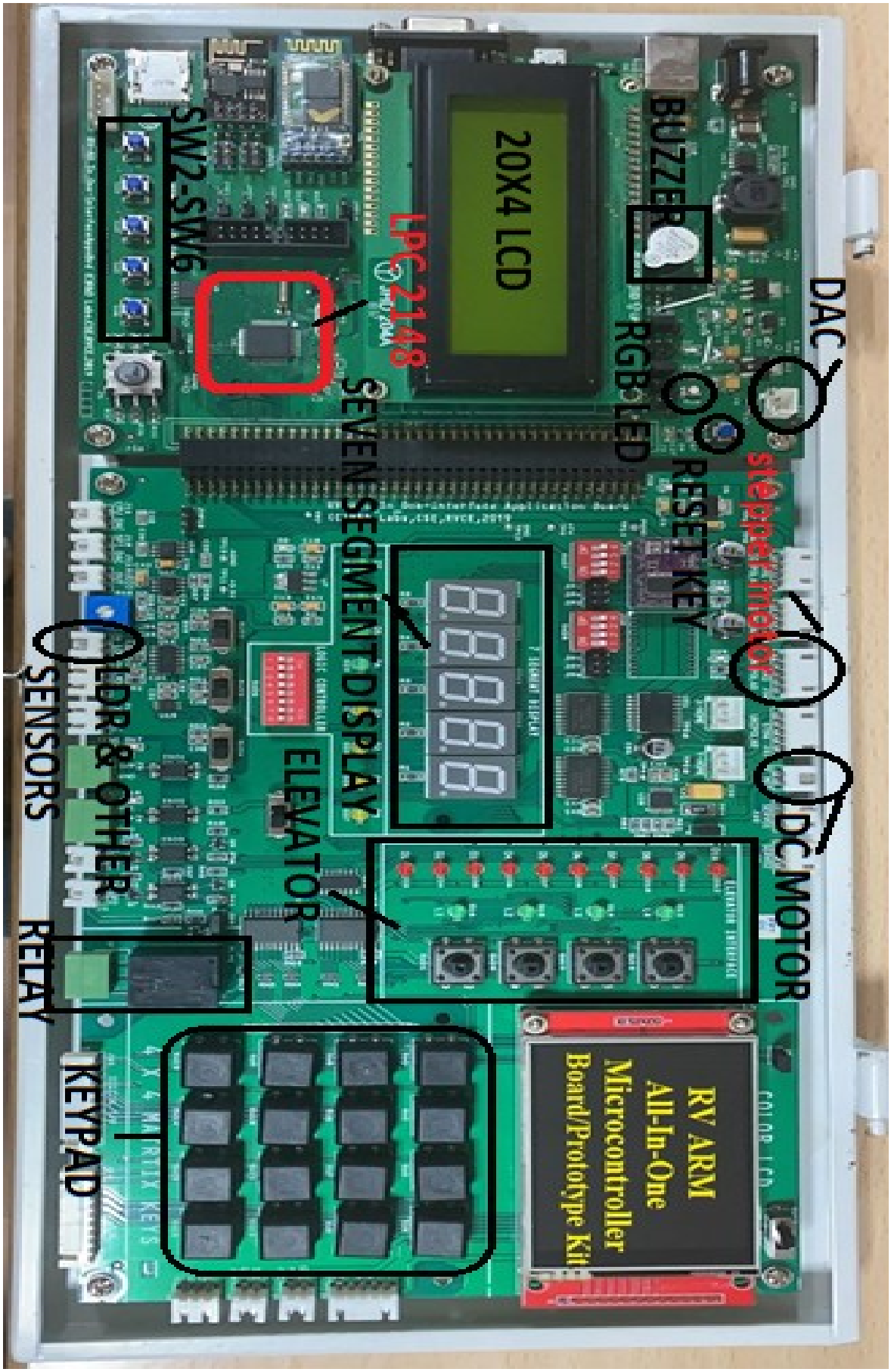

**Board Specifications: RV - ARM AllInOne Board**
**ARM CPU Board & Application Board**

## MCB 214X BOARD / RV-ARM ALL IN ONE BOARD

Due to their tiny size and low power consumption, LPC 2148 is ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. Serial communications interfaces ranging from a USB 2.0 Full-speed device, multiple UARTs, SPI, SSP to I2C-bus and on-chip SRAM of 8 kB up to 40 kB, make these devices very well suited for communication gateways and protocol converters, soft modems, voice recognition and low-end imaging, providing both large buffer size and high processing power. Various 32-bit timers, single or dual 10-bit ADC(s), 10-bit DAC, PWM channels and 45 fast GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers suitable for industrial control and medical systems.

The MCB214X Evaluation Board ships with an LPC2148 device. The Board contains all the necessary hardware components required in a single-chip LPC2148 based embedded system. The Keil MCB214X Evaluation Board allows one to generate and test application programs for the NXP LPC2148 microcontroller family. With this hands-on process, one can determine the hardware and software requirements for current and future product development.
RV-All In-One board is developed in similar lines with MCB2140 with additional peripherals and facilities. The following diagram of RV-All In-One board, summarizes the features,



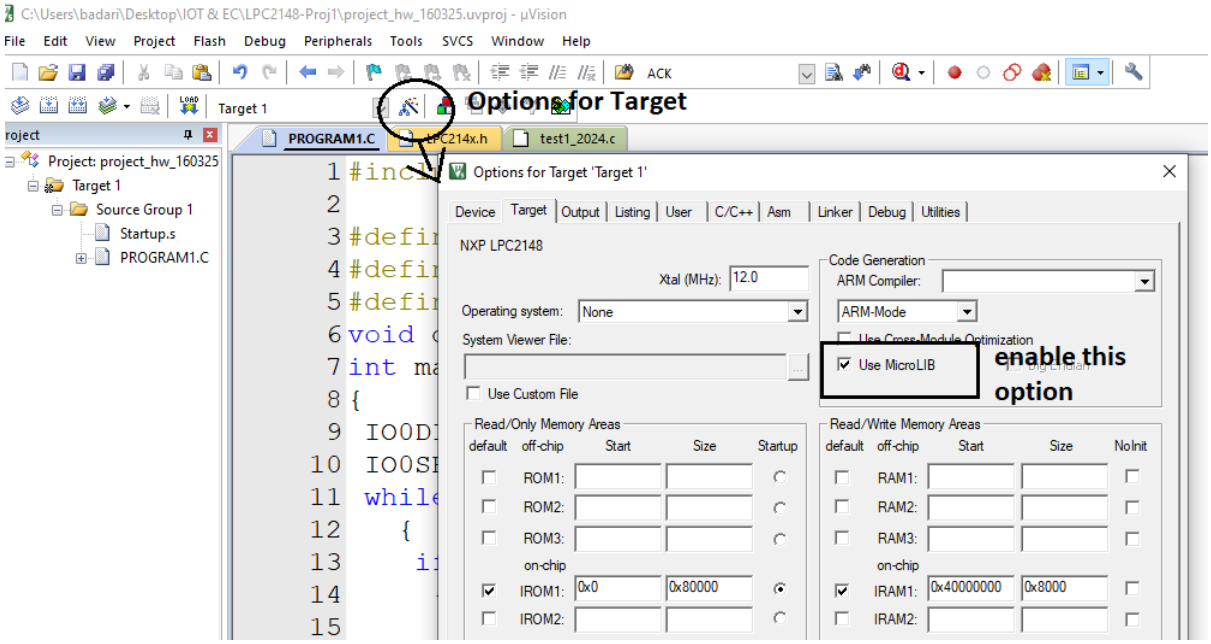

20X4 LCD
LPC 2148
SW2-SW6
BUZZER
RGB LED
RESET KEY
DAC
stepper motor
DC MOTOR
SEVEN SEGMENT DISPLAY
ELEVATOR
LDR & OTHER SENSORS
RELAY
KEYPAD
RV ARM
All-In-One
Microcontroller
Board/Prototype Kit

# Procedure to Create Embedded C Projects

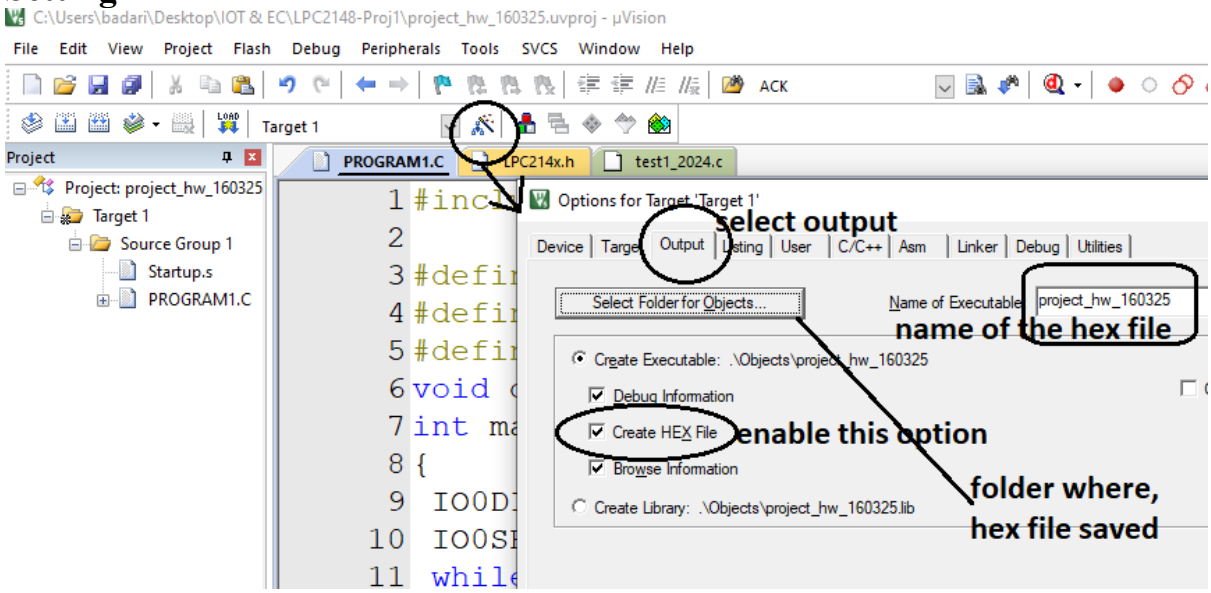
1. While creating the project include **“setup.s”.**

2. After creating the project, do following settings in the Keil IDE. (using the button “Options for Target”)

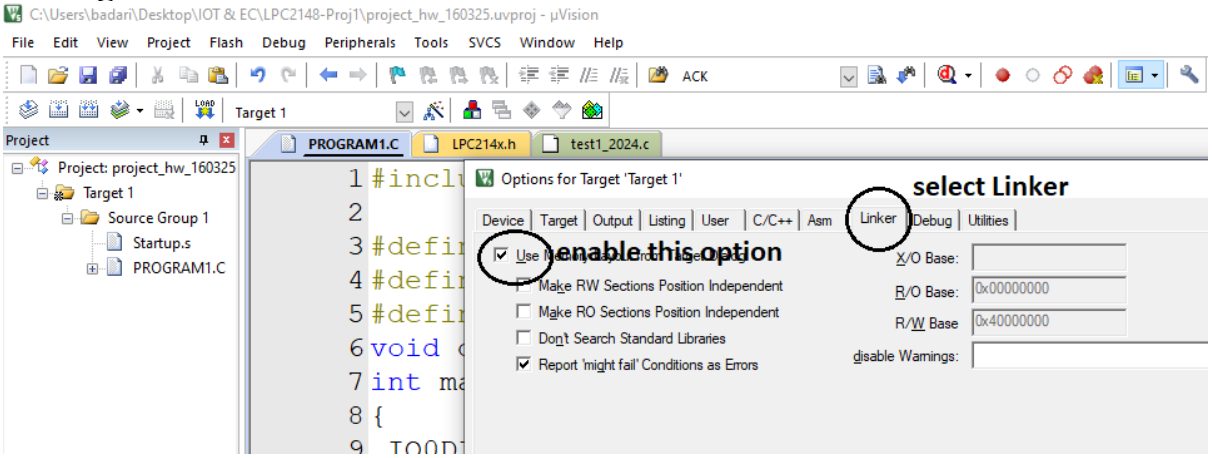
## Setting #1




## Setting #2



## Setting #3

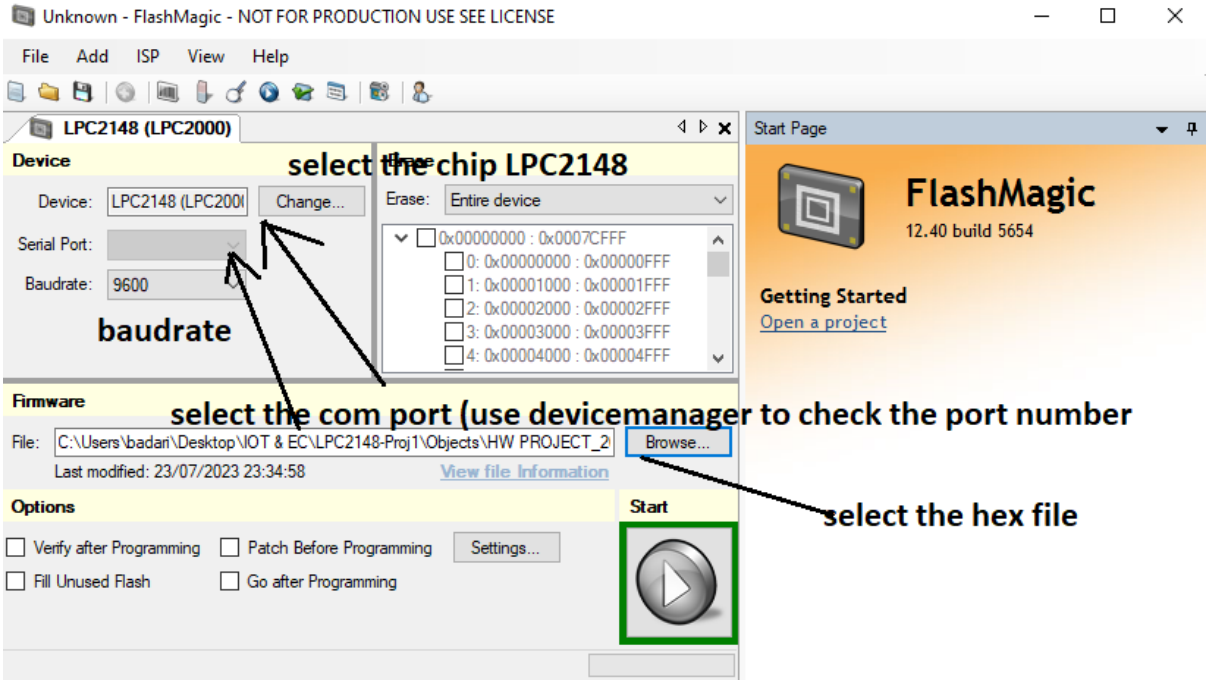



3. Create .c file and add to the project

4. **# include <lpc214x.h>** (add this line in the beginning, it is present in the keil folder under INC ->ARM->philips). This header file contains all **address definitions** of all the Registers of different peripheral blocks of LPC2148.

5. After the program is compiled (without any errors), hex file is created and stored in the OBJECTS directory of your project. (verify once). The name of the hex file is name of the project, unless changed by the user in the option settings.

6. This hex file is used to download to the RV-ARM kit, using the software Flash Magic. Make sure USB cable is connect to PC and kit. Power supply adapter is connected to the kit. Any errors while downloading, check the selection of chip, proper serial port is selected, proper baudrate is selected.




7. After successful downloading of the program, press the RESET button on the kit to run the program. By using reset button, program can be re-run multiple times( down loading is required only once). If any changes done to the program, then re compile and download the program again. Don't close the flashmagic application.

**Program 1: Interfacing LED and Switches : -** *Program to control the blinking of LED through Swtiches, Using GPIO Registers*

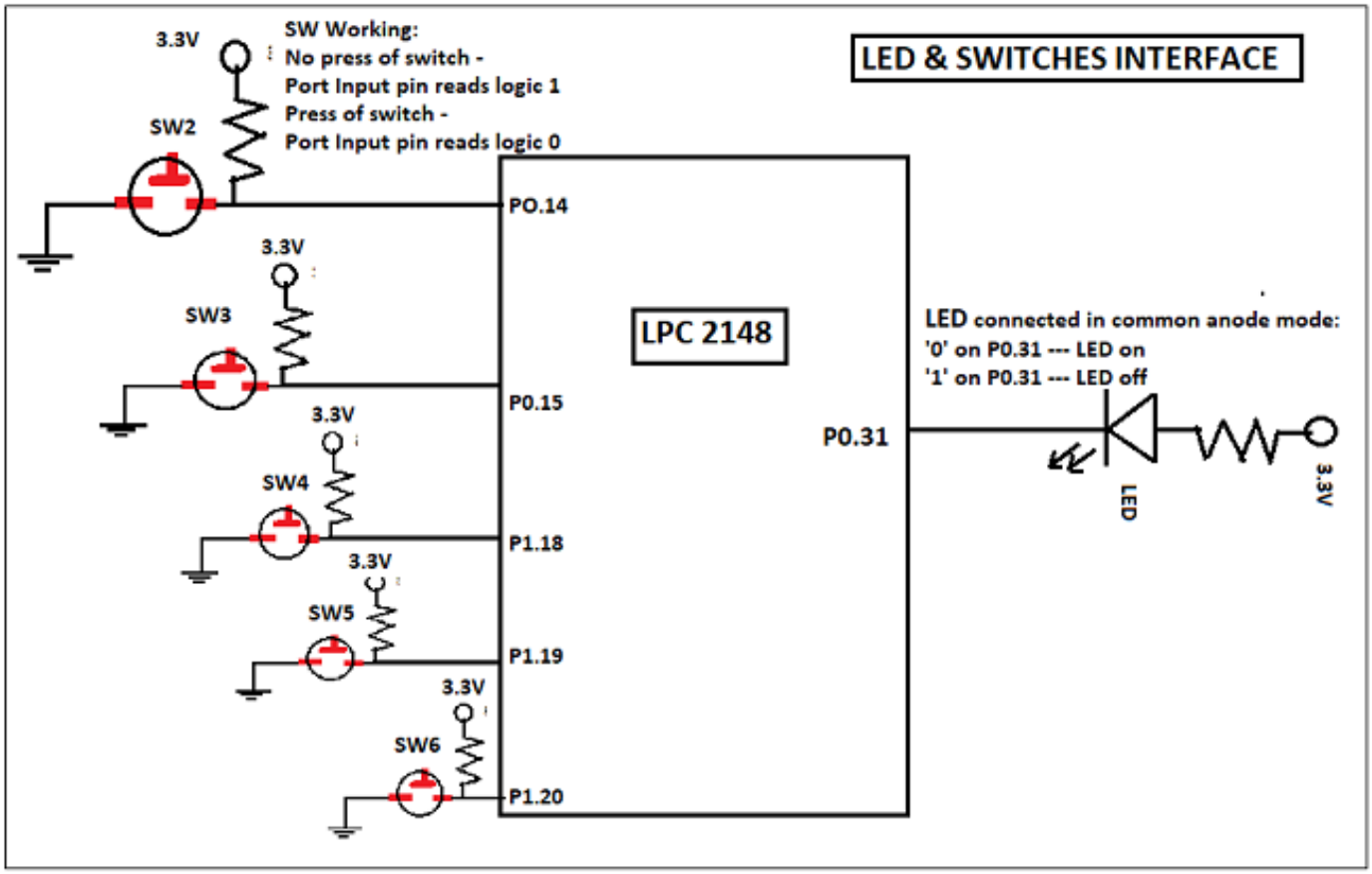
## GPIO Registers Used in the Programming:

**IODIR :** GPIO Port Direction control register. This register individually controls the direction of each port pin.

**IOSET :** GPIO Port Output Set register. This register controls the state of output pins in conjunction with the IOCLR register. Writing ones produces highs at the corresponding port pins. Writing zeroes has no effect.

**IOCLR** : GPIO Port Output Clear register. This register controls the state of output pins. Writing ones produces lows at the corresponding port pins and clears the corresponding bits in the IOSET register. Writing zeroes has no effect.

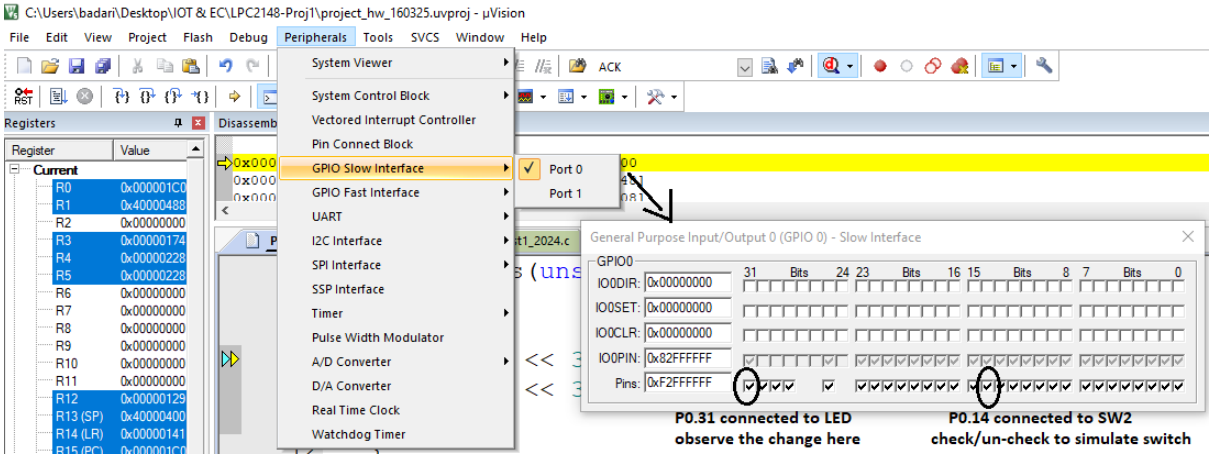
Interfacing Diagram



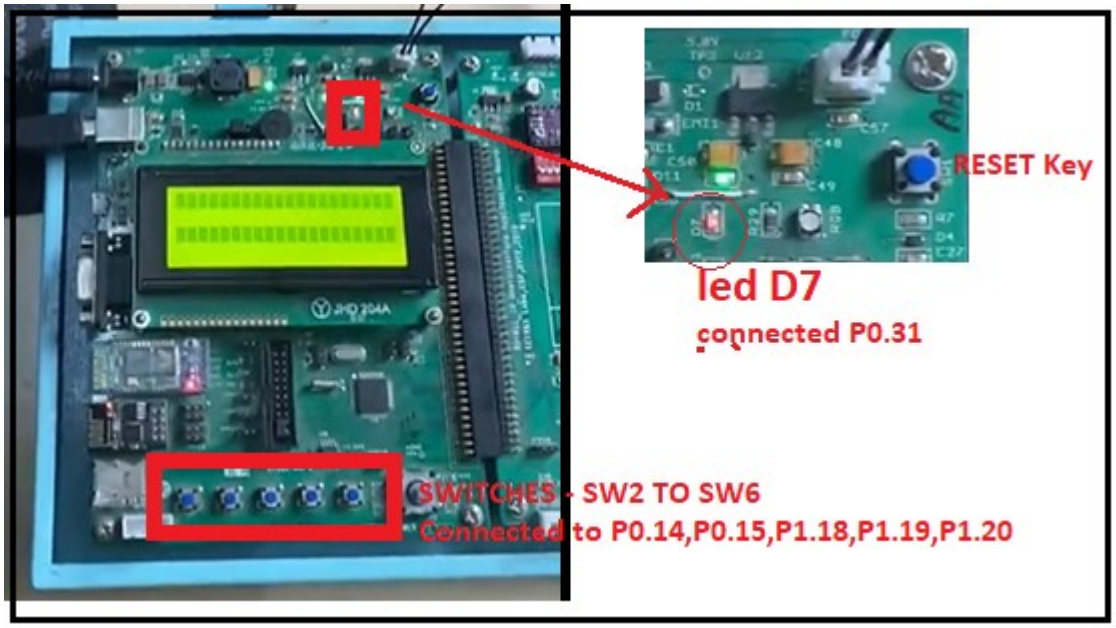
```
 //Sample Program 1:  Interfacing LED and Switch to LPC2148 using GPIO pins
//P0.31 connected to LED - D7 in CPU board(common anode)
//P1.14 connected to Switch - SW2 in CPU board

#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);
          }
     }
}

  /* loop to generate 1 milisecond delay with CCLK = 60MHz */

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

# RESULT:
# When you press the SW2, LED blinking is observed

## Observe the result in Simulator:




## Observe the Result in the Kit (after downloading the program)




## //***Note: Do following changes***//

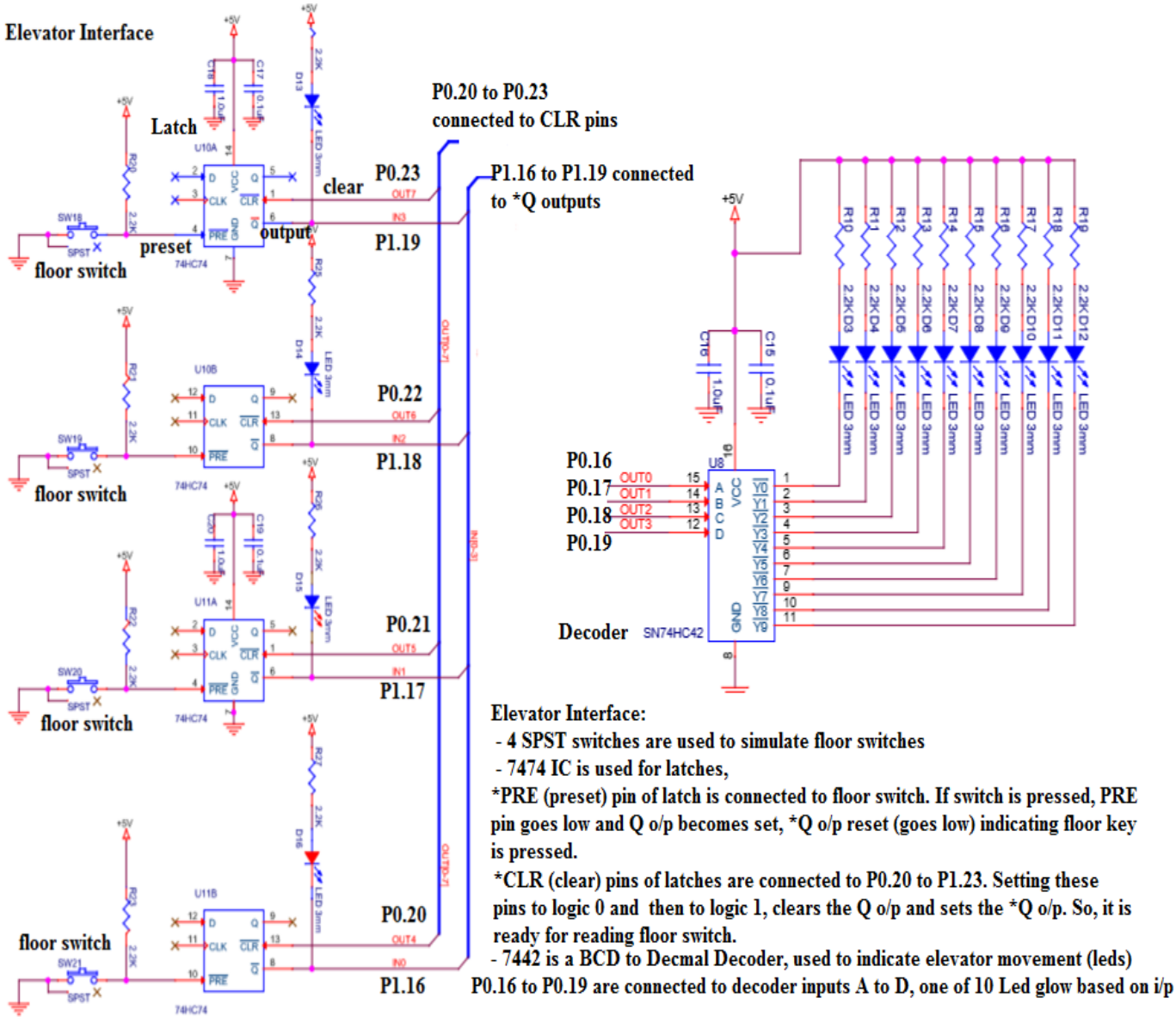
**Change1.** Now, modify the program with #define statements LED_ON and LED_OFF and SW2 and run the program. It simplifies understanding of the program.
**Change2**. Now, modify the program using SW3 on the board to control the LED. SW3 is connected P0.15. (SW4,5,6 are respectively connected to P1.18, P1.19 and P1.20.
**Change3.** Now, Use SW2 to start toggling of LEDs and SW3 to stop toggling.
**Change4**. Now, same as Change3, but introduce SW4 to increase toggle speed and SW5 to decrease toggle speed.

Note: Attach Data sheets containing the program executed with all modifications, with comments.

**Observation & Inference:**

**Program : Elevator Interface: Write an Embedded C program to read the elevator switches and simulate elevator up and down movements.**

## 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*

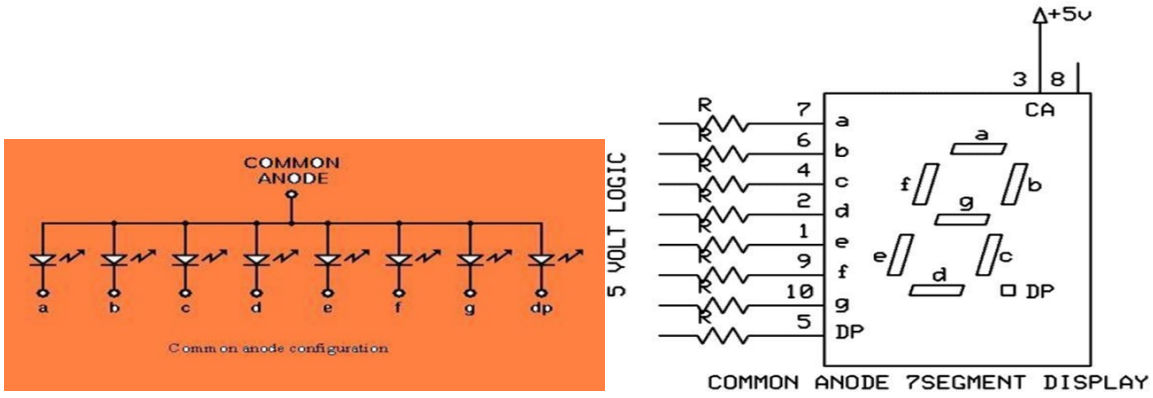
```
#include <lpc214x.h>
#define LED_OFF (IO0SET = 1U << 31)
#define LED_ON (IO0CLR = 1U << 31)
void delay_ms(unsigned int j);
void elevator_run(void);
int main()
{
        IO0DIR |= 1U << 31 | 0XFF << 16; // to set P0.31 & P1.20 to P1.23 as outputs
        IO1DIR |= 1 << 24; // to set P1.24 as output
        LED_ON; // make D7 Led on .. just to indicate the program is running
        elevator_run( );
        while(1);
}
void elevator_run(void)
{
         int i,val;
         unsigned int counter;
         IO1CLR = 1 << 24; // enable elevator section in the application board : 0 to enable
         IO0CLR = 0X000F0000; //to set the  elevator led for grnd floor
         do{
                  // clear all the latches *CLR
                  IO0CLR = 0X00F00000;IO0SET = 0X00F00000;
                  //waiting for floor key
                  do{
                    counter = (IO1PIN >> 16) & 0X0000000F ; // wait for any lift/elevator key press
                  }while(counter == 0x0F);
                  if(counter == 0x0e)      val=3;      //1110 - floor 1 key pressed
                  else if(counter == 0x0d) val=6;    //1101 - floor 2 key pressed
                  else if(counter == 0x0b) val=8;    //1011 - floor 3 key pressed
                  else if(counter == 0x07) val=10;  //0111- floor 4 key pressed
                  //elevator movement-UP
                  for(i=0 ; i<val ; i++)
                  {
                           IO0CLR = 0X000F0000;IO0SET = i << 16;
                           delay_ms(250);
                  }
                  //elevator movement-DN
                  for(i=val-1;i>=0;i--)
                  {
                           IO0CLR = 0X000F0000;IO0SET = i << 16;
                           delay_ms(250);
                  }
         } while(1);
}
```

**Interfacing Circuit working Explanation:**

**Output Observation:**

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

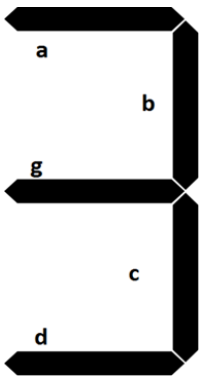
Serial In Parallel Out mode of Shift Register (74HC4094) is used to send 8 bits of data to seven segment display. Seven segment display used is of common anode type i.e. we have to send 0 to make corresponding segment ON and 1 to make it OFF.




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

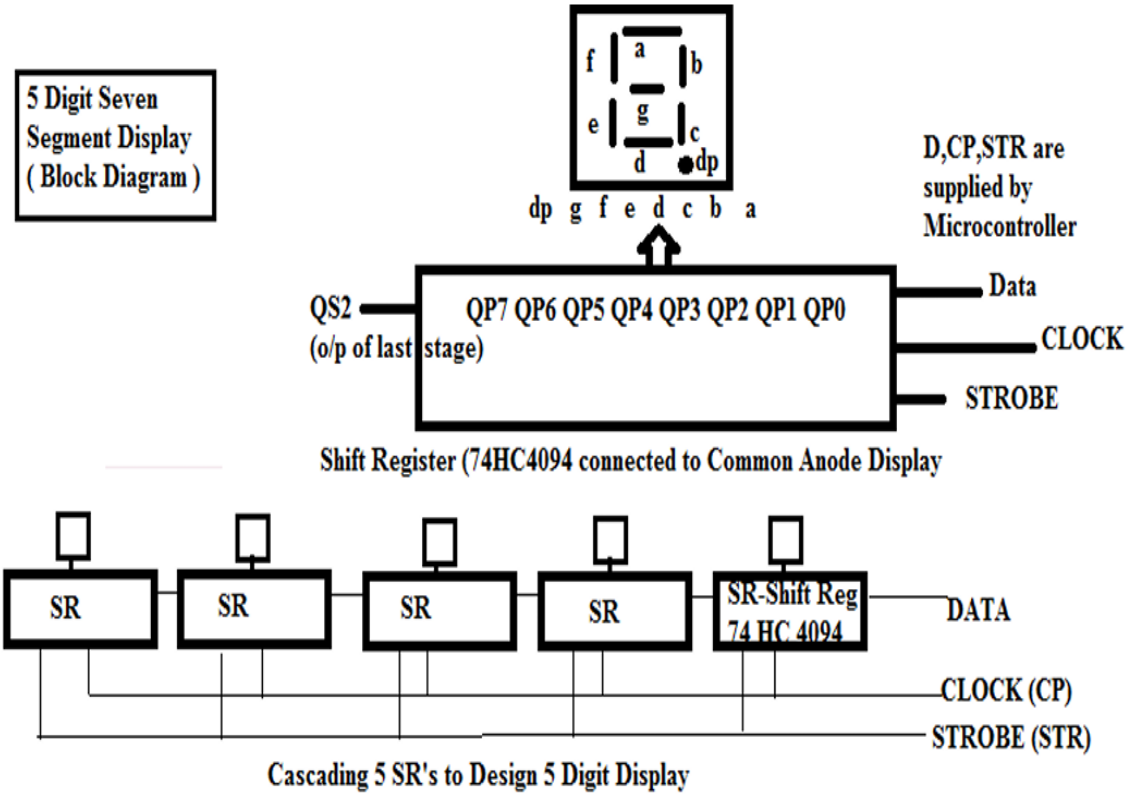
| DP | G | f | E | d | c | b | a |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |

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 completed.

## Interfacing Diagram




74HC4094 is a 8bit Serial-Input Shift Register with Latched 3 state outputs. It consists of an 8 bit shift register and 8bit D-type latch with 3 state parallel outputs. Data is shifted serially through the shift register on the positive going transition of the clock input signal. Shift register require Clock pulses to clock in the data serially through 'Data' pin, 8 clock pulses require for one byte of data. The data of each stage of the shift register is provided with a latch, which latches the data on negative going transition of the strobe input signal. Strobe signal is generated once all the 8 bits of data representing one digit is serially shifted. The outputs of the latches are connected to three state buffers, which is enabled by making output enable pin high. (Here, in the circuit we have connected Output Enable permanently to high, tied to Vcc.). The output of the last stage QS1/QS2' is used to cascade multiple shift registers, so that they appear to work as one unit. Microcontroller generates Shift register 3 inputs: CLOCK (CP), DATA (D) and STROBE(STR). The pins assignments are,

*//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)
void delay_ms(unsigned int j);
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
      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;
}
```

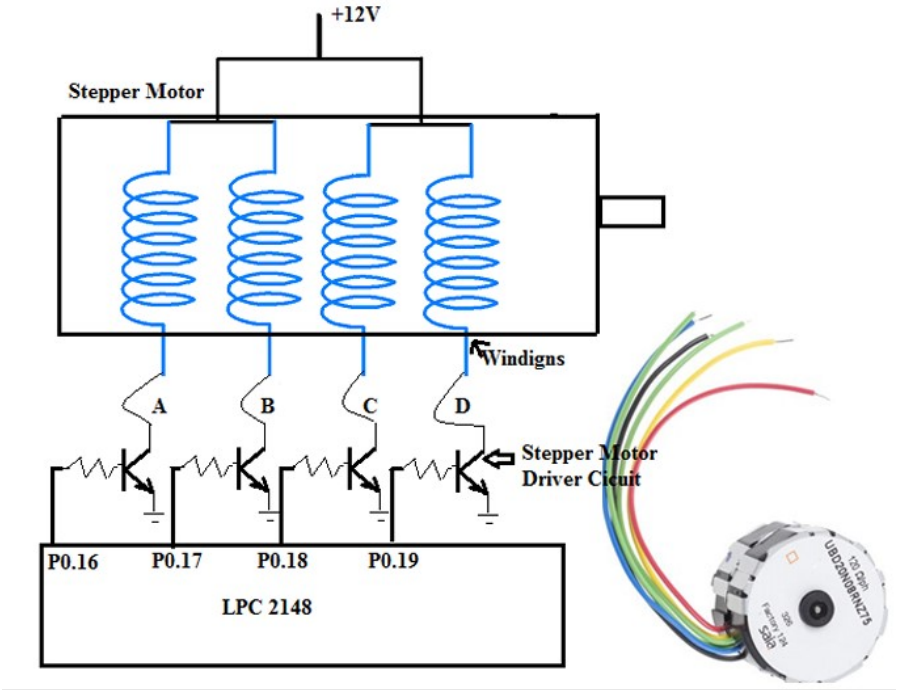
```
void alphadisp7SEG(char *buf)
{
  unsigned char  i,j;
  unsigned char seg7_data,temp=0;
  for(i=0;i<5;i++) // because only 5 seven segment digits are present
    {
       seg7_data = getAlphaCode(*(buf+i));  //instead of this look up table can be used
      //to shift the segment data(8bits)to the 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 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:**

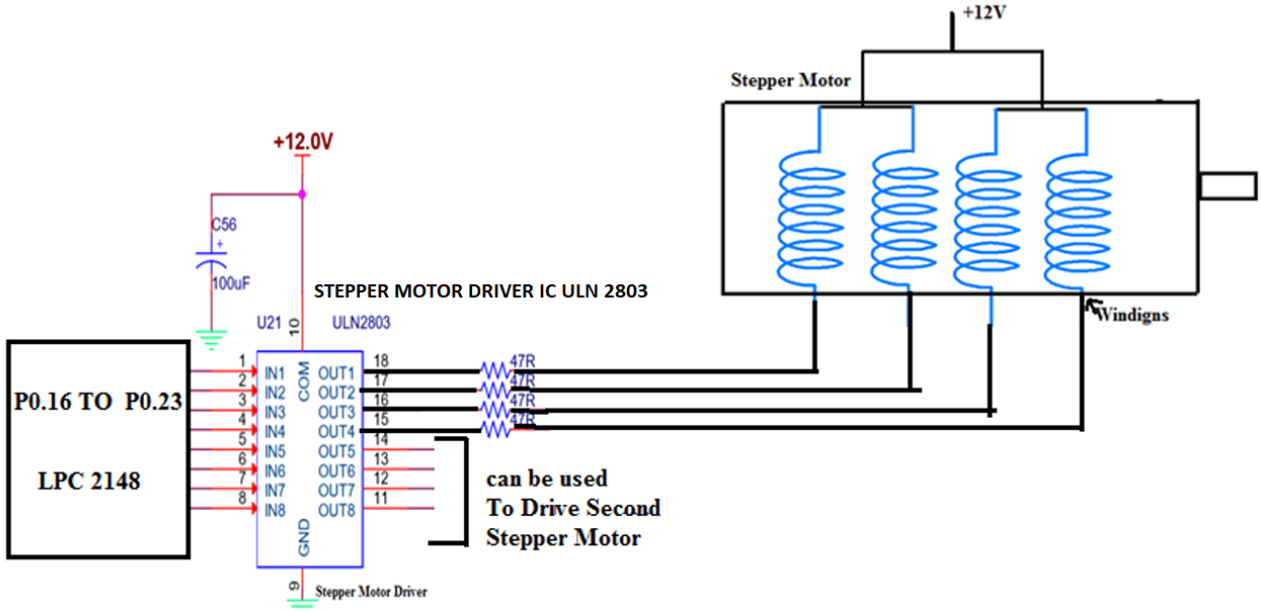
**Output Observation:**

## Program: 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.

Commonly available (2Phase, 4winding stepper motors) comes with 5/6 wire connector, 4 for windings, namely A,B,C,D and one/two connections for Power as shown in the figure below. As Microcontroller ports do not drive the current required for windings, transistors are used to derive the required current.




Now stepper motor driving circuit IC's are commonly available. ULN2803 has 8 inbuilt transistor's, which is used in the following circuit to interface two stepper motors.




**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

**Excitation sequence :** Following table indicates the sequence in which, windings are to be energized to achieve clock wise and anticlockwise direction. Each sequence drives the motor one step (i.e 1.8degree), after 4 steps repeat the sequence to continue rotation in the same direction.

Energizing or Driving a winding, means making the current flow in the winding. Applying logic '1' to the input of ULN2803 driver, switches on the transistor present inside the driver and the current flows through the corresponding winding, from the +12V supply.

| $A\ B\ C\ D$ | $A\ B\ C\ D$ | | $A\ B\ C\ D$ |
|---|---|---|---|
| 1 0 0 0 | 0 0 0 1 | | 1 0 0 1 |
| 0 1 0 0 | 0 0 1 0 | Note : Full drive sequence | 1 1 0 0 |
| 0 0 0 1 | 0 1 0 0 | | 0 1 1 0 |
| | 1 0 0 0 | | 0 0 1 1 |
| → clockwise | ← anticlock wise | | |

(energising the windings one by one; 1 – energise the winding, 0 – winding not energised)

*//Stepper Motor Program:*

***//P0.16 to P0.19 are connected to Windings of SMotor***

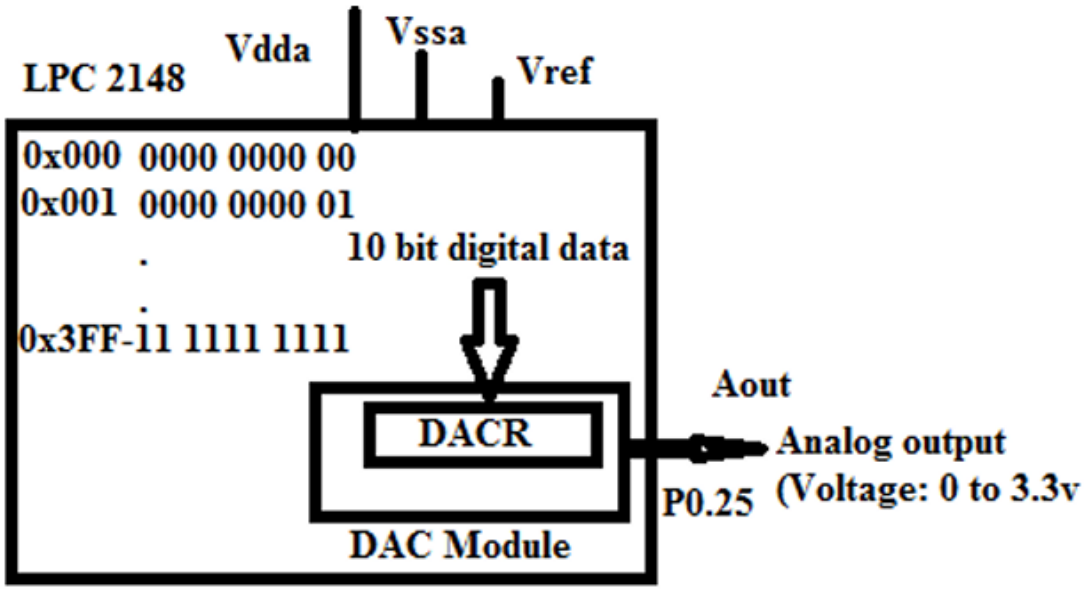
```
#include <lpc214x.h>
#define LED_OFF (IO0SET = 1U << 31)
#define LED_ON (IO0CLR = 1U << 31)
void delay_ms(unsigned int j);

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

   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++);
  }
}
```

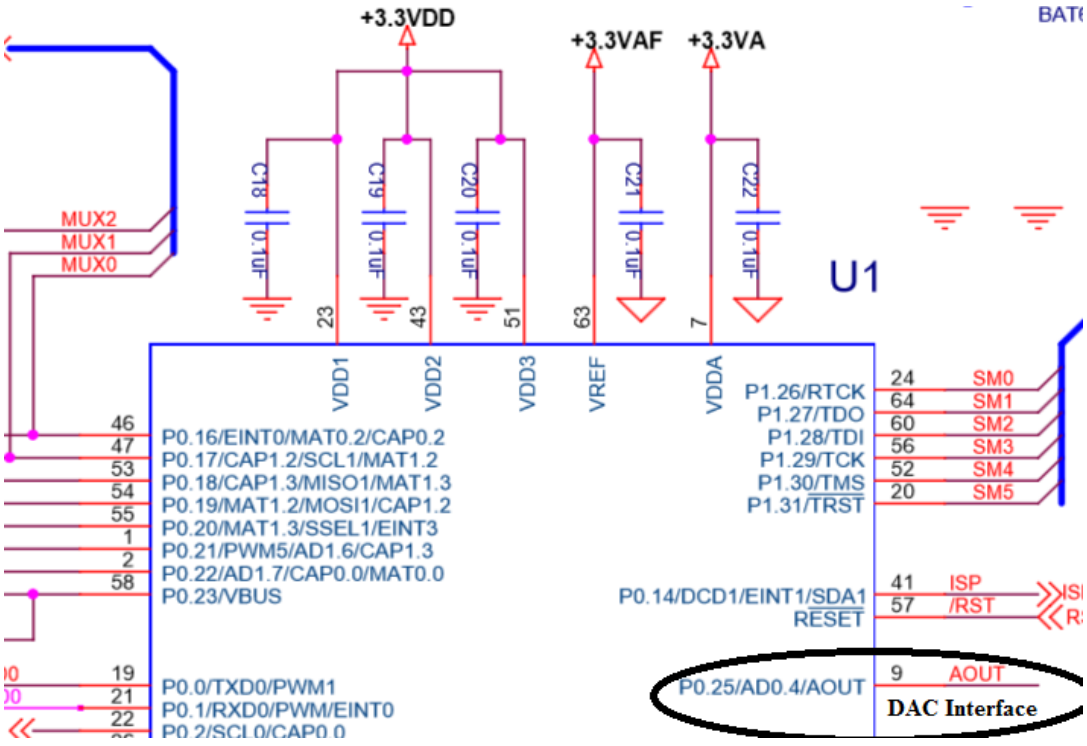
**Interfacing Circuit working Explanation:**

**Output Observation:**

**Program : 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**




**Interfacing with DAC**

DAC Programming: Programming DAC, meaning generating required analog output voltage, involves following steps.

1. Configuring P0.25 as AOUT: Bits 19:18 of the PINSEL1 register control whether the DAC is enabled and controlling the state of the pin P0.25/AD0.4/AOUT. When these bits are "10" , the DAC is powered on and active.

   **PINSEL1 |= 0x00080000; /* P0.25 as DAC output : option 3 -> 10 (bits18,19)*/**

2. Writing 10bit digital data to DACR ( DAC register) : DACR is a 32 bit register, where the bits D15:6 (10bits) representing VALUE is used to write digital data to the DAC module. Example writing the value to the DACR. (Here, 16$^{th}$ bit is referred as BIAS, setting this bit. The "value" is shifted to left by 6 bits, as D15 to D6 represent 10 bits of DAC.

   **DACR = ( (1<<16) | (value<<6) );**

**Waveform Generation Using DAC Module:**

Different waveforms like square,triangular,sawtooth,sine can be generated using DAC module, by producing different analog voltages with reference to time. This is achieve using two methods.

1. Using the program to compute analog voltage at run time. Ex: by executing the following code, we will be outputting 000 (Ov) and 3FF (3.3V) continuously and generating the square waveform

```
while(1)
{
value = 0x000;
DACR =  (value << 6) ; // bits D15-D6 refers to 10 bit data
value = 0x3FF;
DACR =  (value << 6) ;
}
```

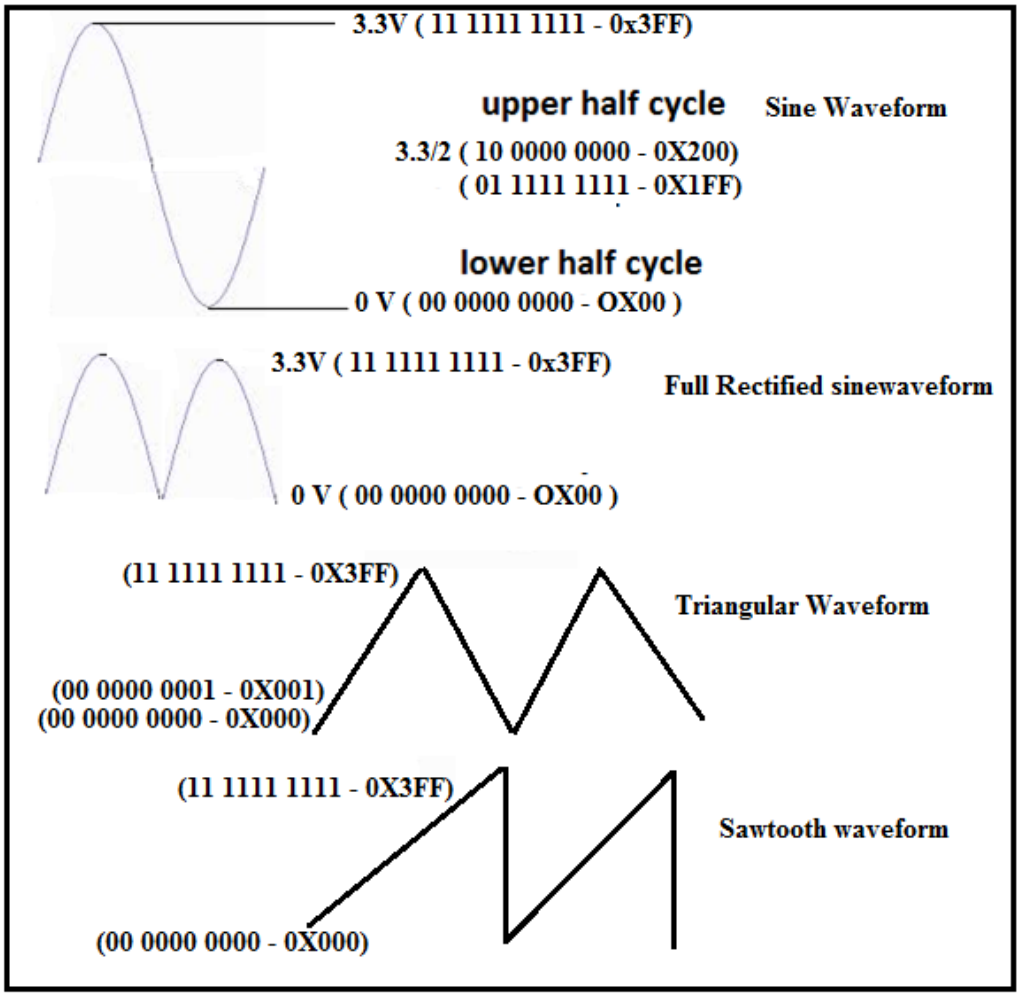
2. When we have to produce complex waveforms like sine, we require functions like sin( ) to compute the values, at run time. Since embedded system are not compute capable and requirement of real time data, the pre-computed values for different sine angles are stored in program/code memory are used to generate waveforms. This technique is called as look-up table method of generating the waveforms.

**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).



```
#include <lpc214x.h>
#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))
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;
 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) );
        }
    }
}
```

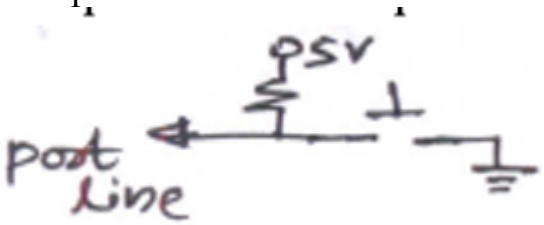
```
void delay_ms(unsigned int j)
{
  unsigned int x,i;
  for(i=0;i<j;i++)
   {
      for(x=0; x<10000; x++);
   }
}
```

**Interfacing Circuit working Explanation:**

**Output Observation:**

**Program: 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.**

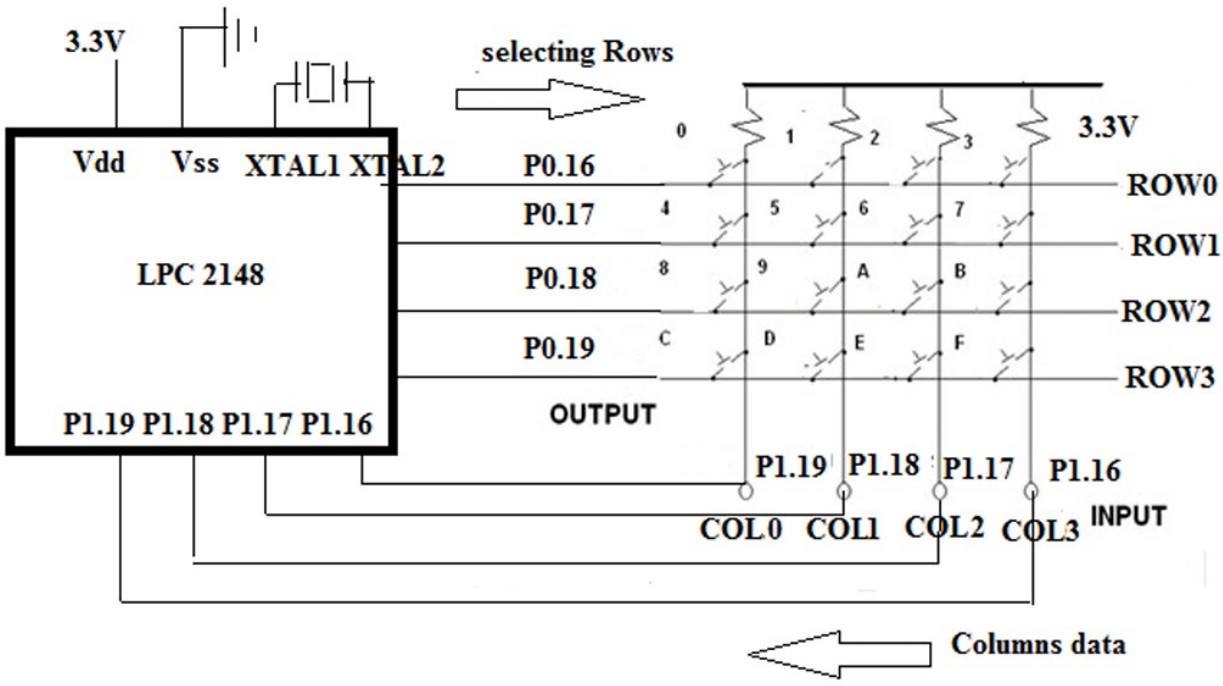
Every embedded product available in the market, do provide matrix keyboards to feed numbers and text. This is the common user interface (UI) to achieve size and cost optimization.




One port line is required to interface one key [when key is not pressed, port line carries logic 1, ∵it is pulled upto 5V, when key is pressed, port line gets grounded, hence logic ∅ is applied].

When number of keys increases, requirement of no. of port lines increases, hence concept of matrix arrangement of keys (matrix keyboard) are used. The layout is shown below, to build 4x4 matrix keyboard (16Keys).

## 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.

**Embedded C Program…**

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

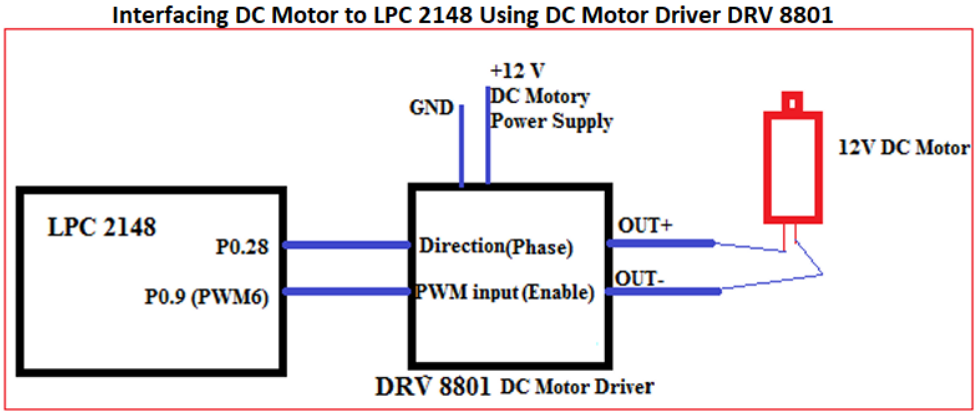
**Interfacing Circuit working Explanation:**

**Output Observation:**

## Program: 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.

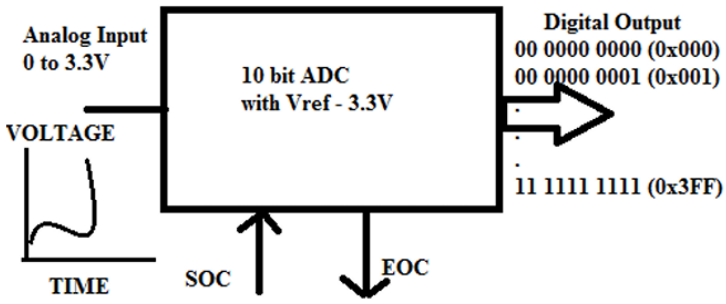
In this experiment, PWM and ADC modules of LPC 2148 are used, PWM module (PWM6) is used to control DC Motor. Since, controller do not have the power to drive directly the motor, Motor driver is used to drive the 12V dc motor, as shown in the figure.

**P0.28 is used to control the direction of rotation,**
**P0.9 (PWM6) is used to drive the motor through PWM waveform**




ADC Module is used to read the Potentiometer (AD1.2) /LDR (AD1.3) value, which is used to control the speed of the DC motor.

A typical ADC has, has analog input (one which is varying with time), and corresponding digital output, as shown below.




SOC – Start of conversion, indicates initiation of conversion process.
EOC – End of Conversion signal, indicates conversion of analog input to digital data is completed. Some older embedded systems.

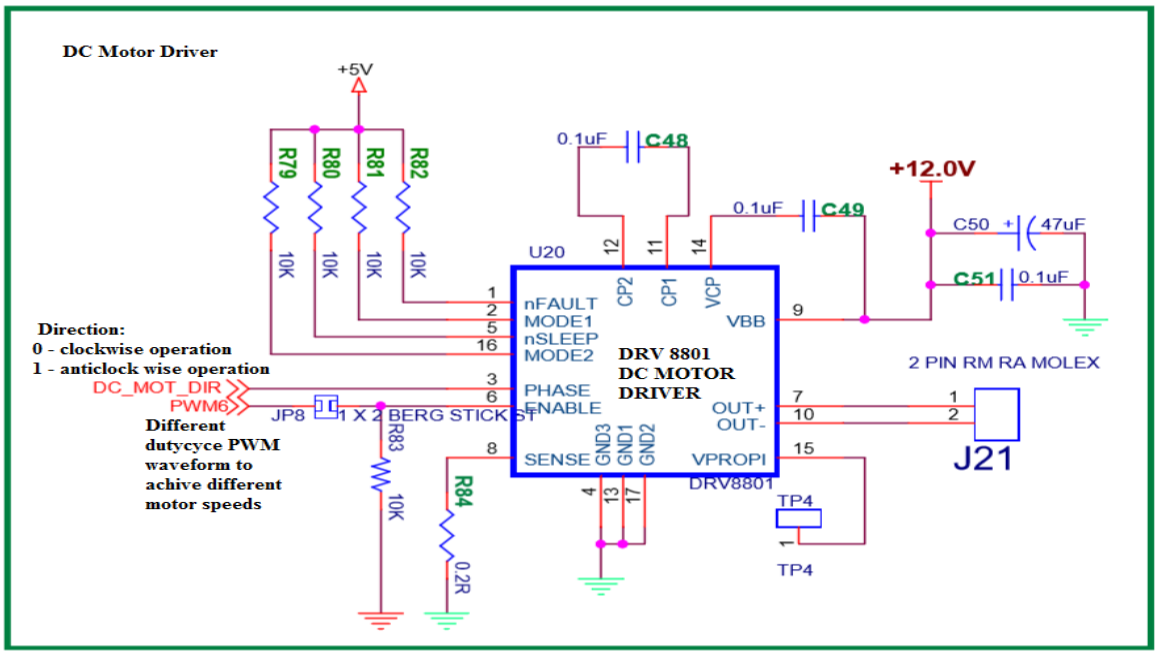
For 10 bit ADC of LPC 2148,
digital input – 000 to 3FF, analog output – 0 to 3.3v
Resolution = 3.3 V / 210 = 3.2 mv (appr), that means minimum of 3.2 mv is required to produce 1 bit change at the output.

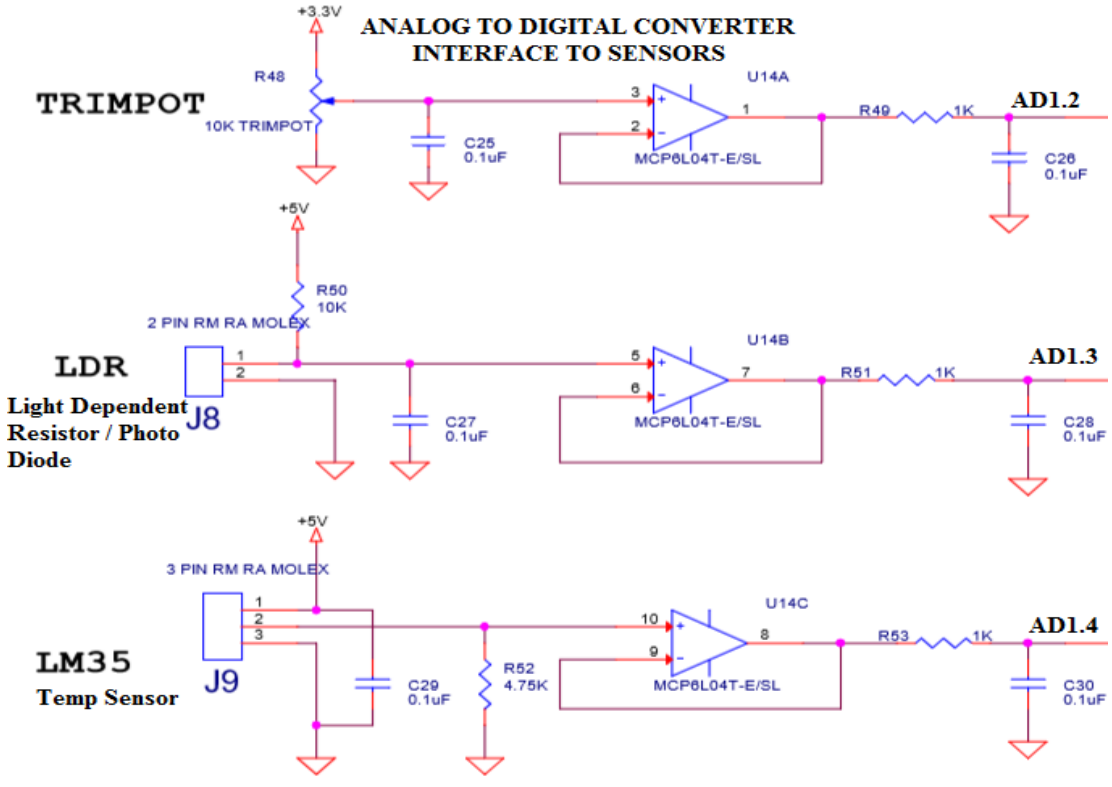
**For a given analog input,**

**digital_value = (input / 3.3) x 1024 [ = analog_input / resolution ]**

LPC 2148 provides two ADC's / Analog channels: ADC0 & ADC1. ADC0 provides 6 analog inputs (AD0.1 to AD0.7), ADC1 provides 8 analog inputs (AD1.0 to AD1.7).

# 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)
void delay_ms(unsigned int j);
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
    do{
      dig_val = adc(1,2) / 10;
      if(dig_val > 100) dig_val =100;
      runDCMotor(2,dig_val);
    }
    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 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:

# PART - B

# Internet Of Things

The Internet of Things (IoT) is a network where objects, equipped with sensors and other technologies, connect to the internet to exchange data and communicate. Its goal is to enhance intelligence, efficiency, and decision-making by enabling devices to collect and share data.

**Key components of IoT include:**

- Devices/Objects: Physical entities embedded with sensors, actuators, and technologies like LDR sensors, Potentiometers, and RTC modules for data collection and transmission.
- Connectivity: IoT devices utilize various communication protocols such as cellular networks, Bluetooth, Wi-Fi, and Zigbee to connect to the internet, enabling interaction between devices and the cloud.
- Data Processing: Data collected from sensors is processed locally on chips or in the cloud using algorithms to extract valuable insights, essential for decision-making and device actions.
- Cloud Computing: Cloud platforms store and process the vast amounts of data generated by IoT devices, offering scalability, flexibility, and accessibility for applications and services.
- Applications: IoT applications span across industries like smart homes, healthcare, agriculture, manufacturing, and transportation, revolutionizing various sectors.
- Security: Securing IoT devices and the data they generate is crucial, involving measures like encryption, authentication, and secure update mechanisms to counter cyber threats.

IoT has the potential to revolutionize human interactions with the world, creating more connected, automated, and efficient systems. However, it also poses challenges related to privacy, security, and data management. As technology advances, IoT's impact and utilization are expected to grow across different societal and industrial domains.

# IOT Cloud : Working of ThingSpeak IOT Cloud

ThingSpeak functions as an open-source platform for the Internet of Things (IoT), allowing users to collect, analyze, and display data from their IoT devices. It simplifies the process of storing and accessing data from connected devices and offers tools for real-time analysis and presentation.

**Steps for Using ThingSpeak Cloud**

- Channel Creation: In ThingSpeak, a "channel" serves as a crucial component. It acts as a virtual storage space where users can organize and retain data from their IoT devices. Upon creating a channel, users specify parameters such as field numbers, names, and data formats.

- API Key Acquisition: Each ThingSpeak channel is associated with API keys. These keys are essential for authenticating and authorizing access to the channel. Users can find their API keys in their ThingSpeak account settings.

- IoT Device Configuration: IoT devices need to be configured to send data to the designated ThingSpeak channel. This typically involves programming the devices to utilize the ThingSpeak API and providing the correct API key for the assigned channel. Devices can use various communication protocols like HTTP, MQTT, or others supported by ThingSpeak.

- Data Transmission to ThingSpeak: IoT devices regularly send data to the designated ThingSpeak channel using the API key. The data is organized according to the predefined fields within the channel, with each field representing a distinct parameter or sensor reading.

- Data Storage: ThingSpeak stores the incoming data within the channel, making it available for historical analysis. Users can set up the platform to retain data for a specified period.

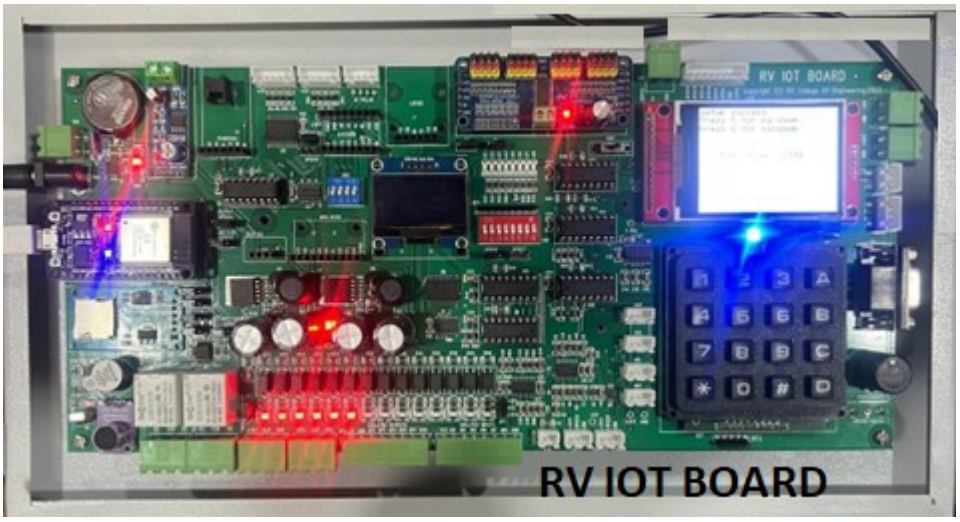
- Analysis and Presentation of Data: ThingSpeak provides integrated tools for users to analyze and present the collected data. Users can create MATLAB-like scripts, known as "ThingSpeak MATLAB Analysis," to perform custom analyses on the data. Additionally, the platform supports the creation of charts, graphs, and maps to visualize data trends.

- Response to Data with ThingSpeak React: Users can define predefined actions or alerts based on the received data. ThingSpeak React allows users to trigger actions when specific conditions are met, enabling a level of automation.

## The RV IoT Board

This unique and indigenous board, meticulously crafted and developed by the Department of Computer Science and Engineering at RV College of Engineering, offers a seamless platform for the creation of sophisticated IoT applications tailored for industrial use. At its core lies the ESP-32 Development Board, a microcontroller renowned for its capability to interconnect various sensors integrated onto the chip.

An All-In-One IoT board offers benefits such as a simplified and convenient development platform by integrating various Hardware components, reducing complexity and saving time. It reduces the physical footprint, accelerates Prototyping, and ensures compatibility and reliability of integrated parts. These boards are power-efficient, cost-effective in the long run, and aid in easier debugging and troubleshooting. They facilitate rapid iteration, making them ideal for educational purposes and streamlined deployment, catering to a range of IoT project's needs while considering convenience and integration.




All-in-one IoT boards find diverse applications across industries, including Home automation, Wearables, Environmental monitoring, Industrial automation, Agriculture, Smart cities, Healthcare, Retail, Energy management, Education, and Prototyping. These integrated boards facilitate rapid prototyping of smart devices, systems, and solutions for purposes like real-time data collection, remote monitoring, energy efficiency, and personalized control, making them valuable tools for creating efficient, connected, and innovative IoT applications in various domains.

The IoT board under consideration is built around an ESP32 core-based microcontroller, featuring peripherals like an SD card interface, TFT display, Audio modules, Keypad interface, I2S communication, Microphone input, Motor control interfaces, and an array of sensors, enhancing its versatility and functionality. It provides communication channels such as I2C, SPI, UART which enhance the usability of the All-in-one IoT board.

**SOCKET I2C_ADDS PERIPHERAL Details.....**

| | | A2 A1 A0 | |
|---|---|---|---|
| U3 | 0X38 | 000 | PCF8574-ULN2804 STEPPER-UNIPOLOAR |
| U4 | 0X39 | 001 | PCF8574-A4988 STEPPER-BIPOLAR |
| U11 | 0X3A | 010 | PCF8574-OPTO ISOLATED INPUTS, PROXIMITY SENSORS |
| U9 | 0X3B | 011 | PCF8574-OPTO IOSLATED OUTPUS, RELAYS |
| U12 | 0X3D | 101 | PCF8574-KEY MATRIX |
| U13 | 0X3E | 110 | PCF8574-LOGIC CONTROLLER - 8 LED ARRAY |
| U14 | 0X3F | 111 | PCF8574-LOGIC CONTROLLER - 8 DIP SWITCH |
| U2 | 0X48 | | ADS1115 (16 BIT I2C ADC) |
| U18 | 0X68 | | RTC MODULE DS1307 |
| MPU9250 | 0X69 | | ACCELEROMETER-GYROSCOPE- MPU9250 |
| PCA9685 | 0X40 | | SERVO MOTOR MODULE - PCA9685 |
| LCD2 | 0X3C | | OLED (64X128) |

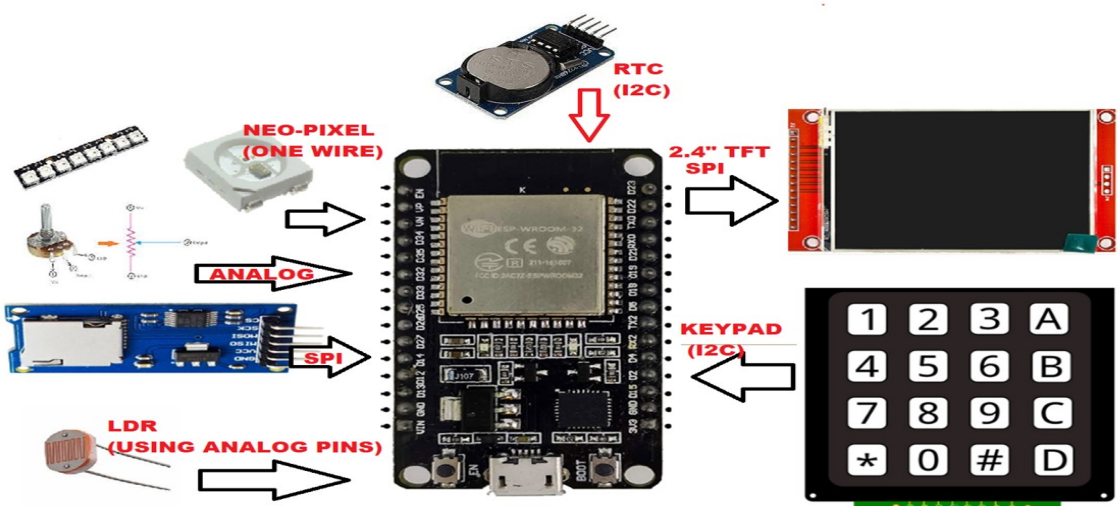
**SPI Connections...**

VSPI - SDCARD/FLASH MEM(W25Q64BV)
GPIO5 (SS),GPIO18(SCK),GPIO23(MOSI),GPIO19(MISO)
(NOTE: 4 jumpers are provided, to select SD(left)/Flash(right)

HSPI - TFT LCD / EXTERNAL CONNECTOR-HSPI
GPIO12 (MISO/SDO),GPIO14(SCK),GPIO13(MOSI/SDI),GPIO15(CS)
(for display, GPIO2-DC, GPIO4-RESET are used)
(NOTE: SW3 to used to switch on the TFT display)

# Sample Data Logger Application Using RV-IOT-Board

The Detailed block diagram of the system as shown in the below figure, indicates the peripherals used in the application.




**Features of the System:** The sample application serves as a prototype for IoT systems, demonstrating the seamless integration of multiple sensors and peripherals with the ESP32 microcontroller board.

**Display of Sensor Values and RTC Information on TFT Display:**

- Application featured a TFT display that provided real-time updates of sensor values, including LDR and Potentiometer readings.
- The display showcased RTC information, displaying the current date, time, and day of the week based on the Real-Time Clock (RTC) module.
- NeoPixel can be used for status indications.

**Real-time Data Streams from Sensors to ThingSpeak Cloud**

- Application facilitated the seamless transmission of real-time sensor data streams, including readings from the Light Dependent Resistor (LDR) and Potentiometer, to the ThingSpeak cloud platform, over WiFi.
- This ensures that the system could continuously monitor environmental conditions and provide timely insights for analysis and decision-making.

```
// Include the libraries
#include <WiFi.h>
#include "ThingSpeak.h"
#include <SPI.h>
#include <TFT_eSPI.h>
#include <Wire.h>
#include "RTClib.h"
#include <Adafruit_NeoPixel.h>
//Define Pin numbers for LDR, Microphone/Potentiameter
const int ldrPin = 39; // Analog pin connected to the LDR output
const int micPin = 36; // Analog pin connected to the microphone output
int  ldrValue = 0, micValue = 0, counter = 0;
// Define WiFi and ThingSpeak Cloud Constants
#define SECRET_SSID "xxxxxxxx"
#define SECRET_PASS "yyyyyyyy"
#define SECRET_CH_ID xxxxxxx
#define SECRET_WRITE_APIKEY "wwwwwwwwwwww"
#define PIN_WS2812B 17  ; Pin No used to connect NeoPixel
// Create Objects of TFT display, WiFi, RTC and NeoPixel
TFT_eSPI tft = TFT_eSPI();
RTC_DS1307 rtc;
Adafruit_NeoPixel ws2812b(1, PIN_WS2812B, NEO_GRB +NEO_KHZ800);
WiFiClient client;
char ssid[] = SECRET_SSID;
char pass[] = SECRET_PASS;
unsigned long myChannelNumber = SECRET_CH_ID;
const char * myWriteAPIKey = SECRET_WRITE_APIKEY;
```

## // Defining setup function

```
void setup() {
pinMode(ldrPin, INPUT); pinMode(micPin, INPUT);//Configure Input Pins
Serial.begin(115200); //Initialize Serial Port
   while (!Serial) {; }// wait for serial port to connect.
Wire.begin(); WiFi.mode(WIFI_STA); // Initialize I2C,Wifi
ThingSpeak.begin(client); // Initialize ThingSpeak
tft.init(); tft.setRotation(3); Serial.println("Connecting to TFT...");
tft.fillScreen(TFT_WHITE);tft.setTextColor(TFT_BLACK);tft.setTextSize(2);
if (! rtc.begin()) {
  Serial.println("Couldn't find RTC"); while (1);
}
if (!rtc.isrunning()) {
  Serial.println("RTC is NOT running, let's set the time!");
  rtc.adjust(DateTime(F(_DATE), F(TIME_)));
}
rtc.writeSqwPinMode(DS1307_SquareWave1HZ);
ws2812b.begin();ws2812b.setBrightness(100);
}
```

```
void loop() {  // Connect or reconnect to WiFi
// Connect to the Wifi
if (WiFi.status() != WL_CONNECTED) {
   Serial.print("Attempting to connect to SSID: ");
   Serial.println(SECRET_SSID);
   while (WiFi.status() != WL_CONNECTED) {
      WiFi.begin(ssid, pass);
      Serial.print(".");
      delay(5000);
    }
   Serial.println("\nConnected.");
}
// Read Date & Time from RTC and Update on the TFT
DateTime now = rtc.now();
tft.setTextSize(2); tft.setCursor(2, 4); tft.print(" ");tft.setCursor(2, 4); tft.print(now.hour());
tft.print(":");tft.print(now.minute()); tft.print(":"); tft.print(now.second());
tft.setCursor(2,7); tft.print(" "); tft.print(now.day()); tft.print("-");
tft.print(now.month()); tft.print("-");tft.print(now.year());
// Capture the Values from the Sensors and Display on the TFT
ldrValue = analogRead(ldrPin);
micValue = analogRead(micPin);
tft.setCursor(50, 100); tft.setTextSize(2); tft.print("LDR:"); tft.print(ldrValue);
tft.setCursor(50, 150); tft.print("Mic:");tft.print(micValue);
// Show the Alarming Values using NeoPixel
ws2812b.clear();
if (ldrValue > 2000) {   // If LDR value exceeds…show a change in color in NeoPixel
  ws2812b.setPixelColor(0, ws2812b.Color(255, 0, 0));
  ws2812b.show();
}
else {
  ws2812b.setPixelColor(0, ws2812b.Color(0, 255, 0));
  ws2812b.show();
}
//Update the Cloud as per the time constraints of ThingSpeak Cloud
if (counter % 80 == 0) {  // after a certain time elapse… Update the cloud
   ThingSpeak.setField(1, ldrValue);
   ThingSpeak.setField(2, micValue);

   int x = ThingSpeak.writeFields(myChannelNumber, myWriteAPIKey);
   if (x == 200)     Serial.println("Channel update successful.");
   else   Serial.println("Problem updating channel. HTTP error code " + String(x));
}
counter++;  delay(500);
// Clear the Display and Repeat the operations
tft.fillScreen(TFT_WHITE); tft.setTextColor(TFT_BLACK);tft.setTextSize(2);
}
```

# IOT Design Methodology

**Follow the following IOT Design Methodology steps, in documenting every project.**

Step 1: Purpose & Requirements Specification

Step 2: Process Specification

Step 3: Domain Model Specification

Step 4: Information Model Specification

Step 5: Service Specifications

Step 6: IOT Level Specification

Step 7: Functional View Specification

Step 8: Operational View Specification

Step 9: Device & Component Integration

Step 10 : Application Development

**Use the appropriate modules present in the RV IOT Board to realize the following projects.**

| IOT Projects |
|---|
| Project1: Smart Lighting (Use ESP32 and the Blynk Cloud) |
| Project2: Weather Monitoring and Weather Reporting Bot (Use ESP 32 and ThingSpeak Cloud) |
| Project3: Smart Parking (Use RasberryPie and Google cloud / Firebase) |

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