ವಿಶ್ವೇಶ್ವರಯ್ಯ ತಾಂತ್ರಿಕ ವಿಶ್ವವಿದ್ಯಾಲಯ, ಬೆಳಗಾವಿ

VISVESVARAYA TECHNOLOGICAL UNIVERSITY - BELAGAVI

BACHELOR OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

Course: COMPUTER ORGANIZATION &

ARM MICROCONTROLLERS

Semester: V

IPCC- WORK BOOK

(21EC52)

NAME OF THE STUDENT	
USN	
SEC.	

COURSE SUPERVISOR	**Ms.Nami Susan Kurian**
COURSE MODERATOR	**Dr.K.Chandrasekhar**

Department of Electronics and Communication Engineering
Jyothy Institute of Technology, Tataguni, off Kanakapura Road
Bengaluru, 560083

Academic Year 2023-24

Semester: V Year: 2023-2024 **Scheme**: 2021

Practical Component of IPCC

Course Objectives:

This course will enable students to:

1. Explain the basic organization of a computer system.
2. Demonstrate functioning of different sub systems, such as processor, Input/output, and memory.
3. Describe the architectural features and instructions of 32-bit microcontroller ARM Cortex M3.
4. Apply the knowledge gained for Programming ARM Cortex M3 for different applications.
5. Understand the basic hardware components and their selection method based on the characteristics and attributes of an embedded system.

Course Outcomes (Course Skill Set):

At the end of the course the student will be able to :

1. Explain the basic organization of a computer system.
2. Demonstrate functioning of different sub systems, such as processor, Input/output, and memory.
3. Describe the architectural features and instructions of 32-bit microcontroller ARM Cortex M3.
4. Apply the knowledge gained for Programming ARM Cortex M3 for different applications.

CIE for the Practical Component of IPCC:

1. On completion of every experiment/program in the laboratory, the students shall be evaluated and marks shall be awarded on the same day. The 15 marks are for conducting the experiment and preparation of the laboratory record, the other 05 marks shall be for the test conducted at the end of the semester.
2. The CIE marks awarded in the case of the Practical component shall be based on the continuous evaluation of the laboratory report. Each experiment report can be evaluated for 10 marks. Marks of all experiments' write-ups are added and scaled down to 15 marks.
3. The laboratory test (duration 03 hours) at the end of the 15th week of the semester /after completion of all the experiments (whichever is early) shall be conducted for 50 marks and scaled down to 05 marks. Scaled-down marks of write-up evaluations and tests added will be CIE marks for the laboratory component of IPCC for 20 marks

Total hours :13

Vision & Mission of the Institution

Vision

To be an Institution of Excellence in Engineering education, Innovation and Research and work towards evolving great leaders for the country's future and meeting global needs.

Mission

The Institution aims at providing a vibrant, intellectually and emotionally rich teaching learning environment with the State of the Art Infrastructure and recognizing and nurturing the potential of each individual to evolve into ones own self and contribute to the welfare of all.

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Vision & Mission of the Department

Vision

To be a department of excellence at a global level in Electronics and Communication Engineering education, incorporating Research & Innovation and leadership training components.

Mission

M1. The department will, strive to provide state of the art infrastructure in classrooms and laboratories.

M2. Enable all-round development with individual attention and innovative teaching-learning methodology.

M3. Impart leadership qualities into the students by exposing them to industry and research in the global Electronics and Communication Engineering domain

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Programme Education Objectives

PEO1. (Domain Knowledge) Graduates of electronics and communication Engineering will be able to utilize mathematics, science, engineering fundamentals, theoretical as well as laboratory-based experiences to identify, formulate and solve engineering problems and succeed in advanced engineering or other fields.

PEO2. (Professional Employment) Graduates of electronics and communication engineering will succeed in entry level engineering positions in VLSI, Communication and Fabrication industries in regional, national, or global industries.

PEO3. (Engineering Citizenship) Graduates of electronics and communication engineering will be prepared to communicate and work effectively on individual and team-based engineering projects while practicing the ethics of their profession consistent with a sense of social responsibility.

PEO4. (Lifelong learning) Graduates of electronics and communication engineering will be equipped to recognize the importance of, and have the skills for, continuous learning to become experts in their domain and enhance their professional attributes.

Programme Specific Outcomes

PSO1. (Knowledge/skills) Explore emerging technologies in the field of Electronics and Communication Engineering using the knowledge and skills gained.

PSO2. (Application/Analysis/Problem Solving) Apply techniques in different domains to create innovative products and services in the communication, VLSI, DSP and Networking.

PSO3. (value/Attribute) Work on various platforms as an individual/team member to develop useful and safe circuits, PCB, Power Management Systems are automation for the society and nation.

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Program Outcomes

PO1: Engineering Knowledge: Apply knowledge of mathematics, science, engineering fundamentals and an engineering specialization to 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 specified needs with appropriate consideration for public health and safety, cultural, societal and environmental considerations.
PO4: Conduct investigations of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data and synthesis of 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 modelling to complex engineering activities with an understanding of the limitations.
PO6: The Engineer and Society: Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to professional engineering practice.
PO7: Environment and Sustainability: Understand the impact of professional engineering solutions in societal and environmental contexts and demonstrate knowledge of and need for sustainable development.
PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice.

PO9: Individual and Team Work: Function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings.
PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations and give and receive clear instructions.
PO11: Project Management and Finance: Demonstrate knowledge and understanding of 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 changes

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List of Experiments

SI.No	Experiments
Practical Component of IPCC	Conduct the following experiments by writing Assembly Language Program (ALP) using ARM Cortex M3 Registers using an evaluation board/simulator and the required software tool.
1	Write an ALP to i) multiply two 16-bit binary numbers. ii) add two 64-bit numbers
2	Write an ALP to find the sum of first 10 integer numbers
3	Write an ALP to find factorial of a number.
4	Write an ALP to add an array of 16-bit numbers and store the 32-bit result in internal RAM
5	Write an ALP to find the square of a number (1 to 10) using look-up table.
6	Write an ALP to find the largest/smallest number in an array of 32 numbers.
7	Write an ALP to arrange a series of 32-bit numbers in ascending/descending order.
8	i) Write an ALP to count the number of ones and zeros in two consecutive memory locations ii)Write an ALP to Scan a series of 32-bit numbers to find how many are negative.
Demonstration Experiments (For CIE only not for SEE)	Conduct the following experiments on an ARM CORTEX M3 evaluation board using evaluation version of Embedded 'C' & Keil µvision-4 tool/compiler.
9	Interface a Stepper motor and rotate it in clockwise and anti-clockwise direction
10	Interface a DAC and generate Triangular and Square waveforms.
11	Display the Hex digits 0 to F on a 7-segment LED interface, with a suitable delay in between.
12	Interface a simple Switch and display its status through Relay, Buzzer and LED.
Content Beyond Syllabus	
13	Program to interface hex keypad with LPC1768 and display the characters on 16*2 lcd.

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Evaluation Sheet

Sl no	Program	Date of completion	RUBRICS			Marks obtained	Teacher's Signature
			Conduction and execution (5M)	Tabulation and Results(5M)	Viva-Voce (5M)		
1	(I)Program to multiply two 16-bit binary numbers. ii) Program to add two 64-bit numbers						
2	Program to find the sum of first 10 integer numbers						
3	Program to find factorial of a number.						
4	Program to add an array of 16-bit numbers and store the 32-bit result in internal RAM						
5	Program to find the square of a number (1 to 10) using look-up table.						
6	Program to find the largest/smallest number in an array of 32 numbers.						
7	Program to arrange a series of 32-bit numbers in ascending/descending order.						
8	i) Write an ALP to count the number of ones and zeros in two consecutive memory locations ii)Write an ALP to Scan a series of 32-bit numbers to find how many are negative.						

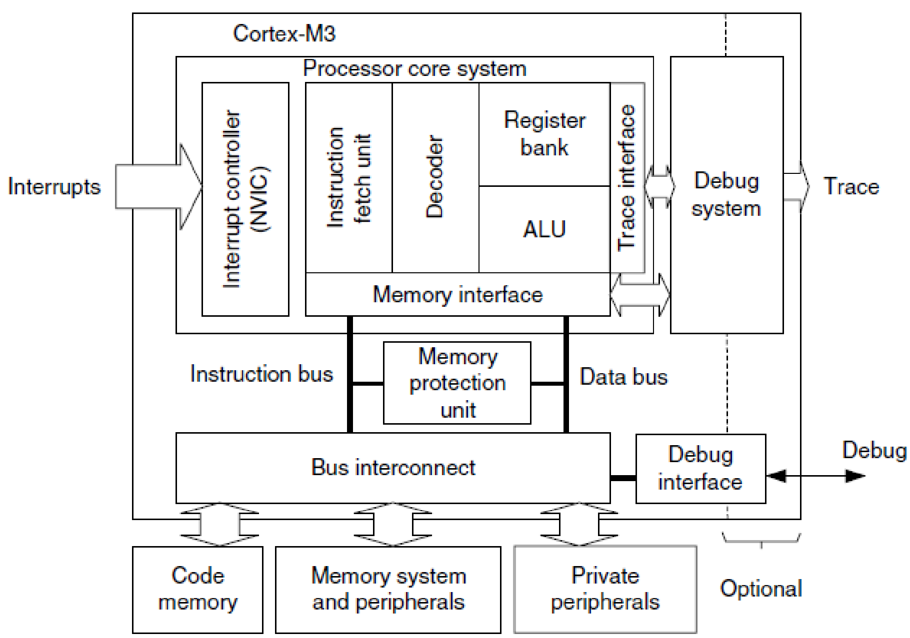
9	Program to interface a Stepper motor and rotate it in clockwise and anti-clockwise direction						
10	Program to interface a DAC and generate Triangular and Square waveforms.						
11	Program to display the Hex digits 0 to F on a 7-segment LED interface, with a suitable delay in between.						
12	Program to interface a simple Switch and display its status through Relay, Buzzer and LED.						
Average (15)							
Test (5)							
Total Marks (20) (Average + Test)							

Signature of faculty

HOD-ECE

INTRODUCTION TO ARM Cortex M3 PROCESSOR

The ARM Cortex-M3 is a general purpose 32-bit microprocessor, which offers high performance and very low power consumption. The Cortex-M3 offers many new features, including a Thumb 2 instruction set, low interrupt latency, hardware divide, interruptible/continuable multiple load and store instructions, automatic state save and restore for interrupts, tightly integrated interrupt controller with Wake-up Interrupt Controller and multiple core buses capable of simultaneous accesses. Pipeline techniques are employed so that all parts of the processing and memory systems can operate continuously. Typically, while one instruction is being executed, its successor is being decoded, and a third instruction is being fetched from memory. The processor has a Harvard architecture, which means that it has a separate instruction bus and data bus. This allows instructions and data accesses to take place at the same time, and as a result of this, the performance of the processor increases because data accesses do not affect the instruction pipeline. A simplified block diagram of the Cortex-m3 architecture is shown below



INTRODUCTION TO MICRO CONTROLLER LPC1768

Architectural Overview

The LPC1768FBD100 is an ARM Cortex-M3 based micro controller for embedded applications requiring a high level of integration and low power dissipation. The ARM Cortex-M3 is a next generation core that offers system enhancements such as modernized debug features and a higher level of support block integration. LPC1768 operate up to 100 MHz CPU frequency. The peripheral complement of the LPC1768 includes up to 512 kilo bytes of flash memory, up to 64KB of data memory, Ethernet MAC, a USB interface that can be configured as either Host, Device, or OTG, 8 channel general purpose DMA controller, 4 UARTs, 2 CAN channels, 2 SSP controllers, SPI interface, 3 I2C interfaces, 2-input plus 2-output I2S interface, 8 channel 12-bit ADC, 10-bit DAC, motor control PWM, Quadrature Encoder interface, 4 general purpose timers, 6-output general purpose PWM, ultra-low power RTC with separate battery supply, and up to 70 general purpose I/O pins.

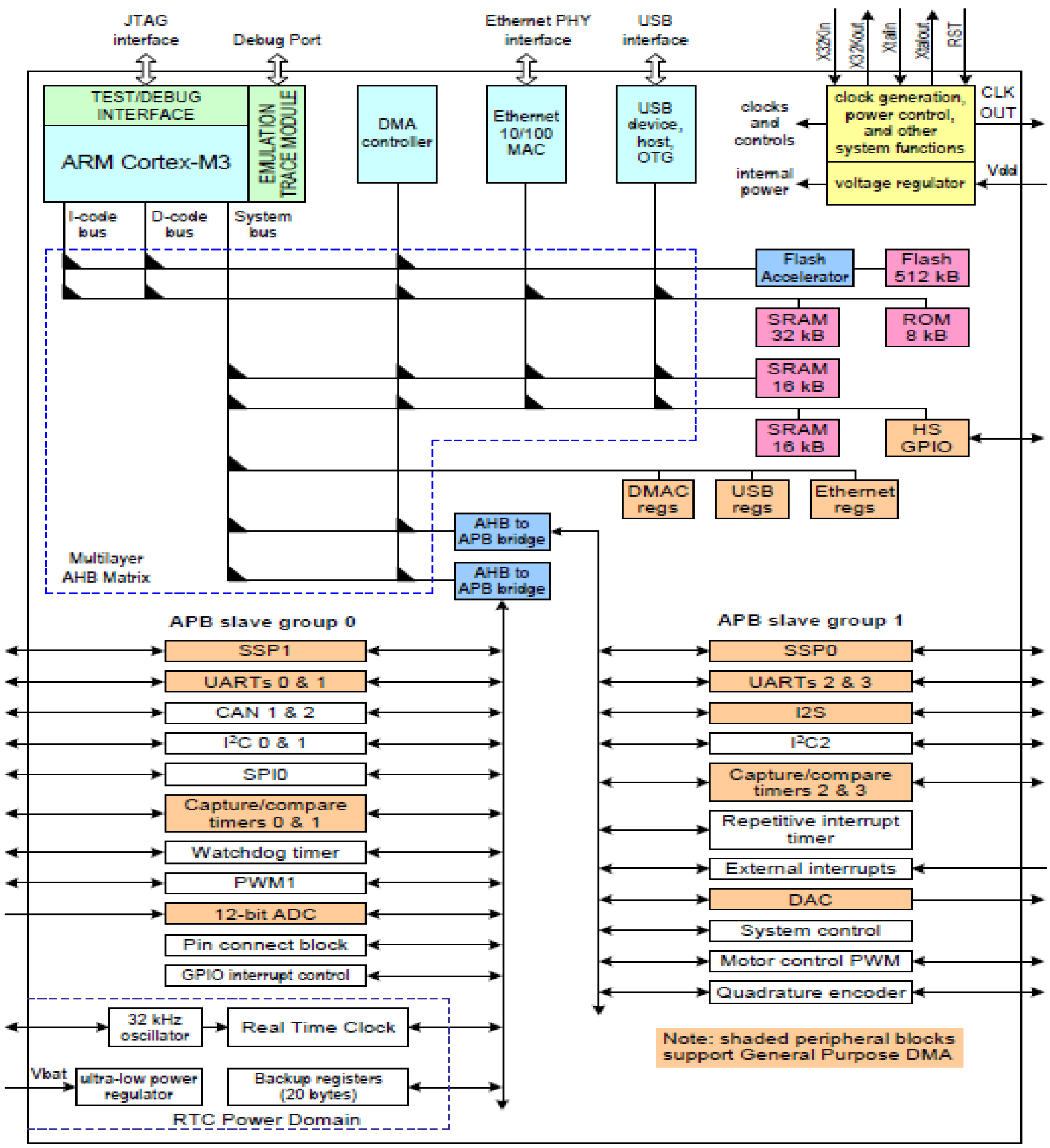
On-chip flash memory system

The LPC1768 contains up to 512 KB of on-chip flash memory. A flash memory accelerator maximizes performance for use with the two fast AHB Lite buses. This memory may be used for both code and data storage. Programming of the flash memory may be accomplished in several ways. It may be programmed In System via the serial port. The application program may also erase and/or program the flash while the application is running, allowing a great degree of flexibility for data storage field firmware upgrades, etc.

On-chip Static RAM

The LPC1768 contains up to 64 KB of on-chip static RAM memory. Up to 32 KB of SRAM, accessible by the CPU and all three DMA controllers are on a higher-speed bus. Devices containing more than 32 KB SRAM have two additional 16 KB SRAM blocks, each situated on separate slave ports on the AHB multilayer matrix. This architecture allows the possibility for CPU and DMA accesses to be separated in such a way that there are few or no delays for the bus masters.

Block Diagram of LPC1768



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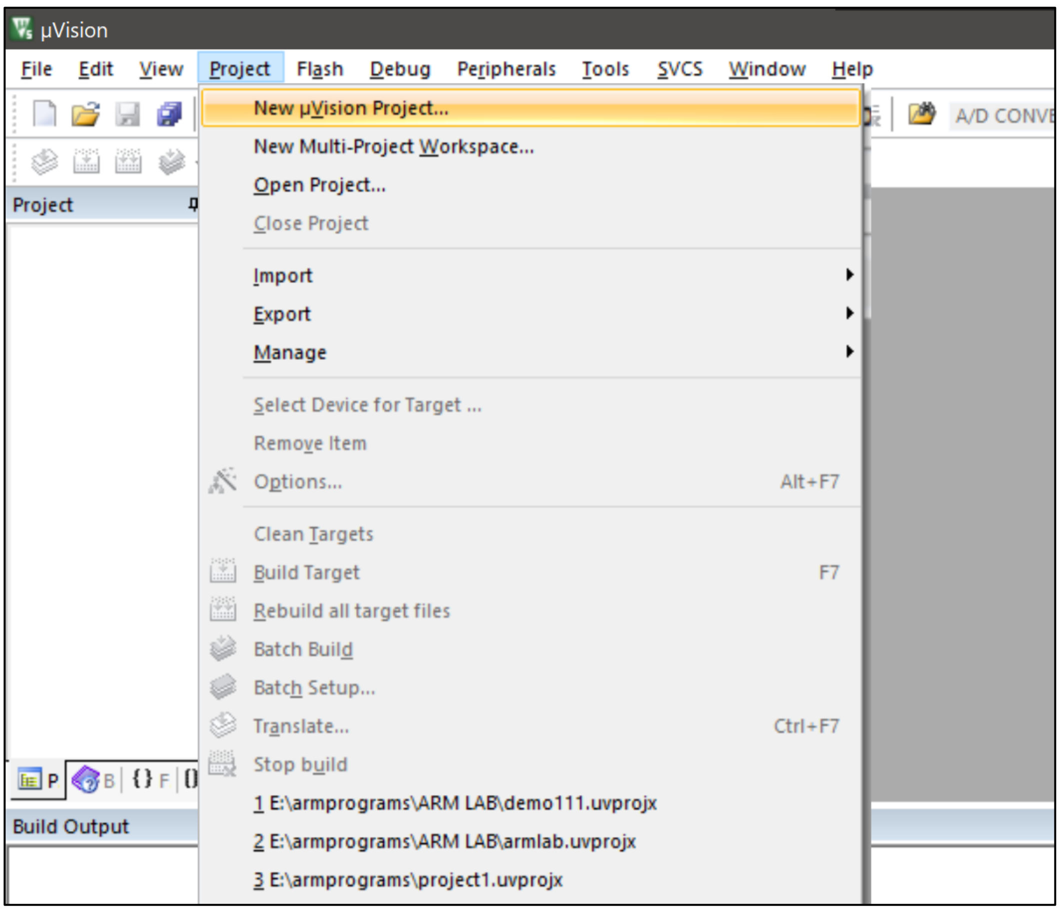
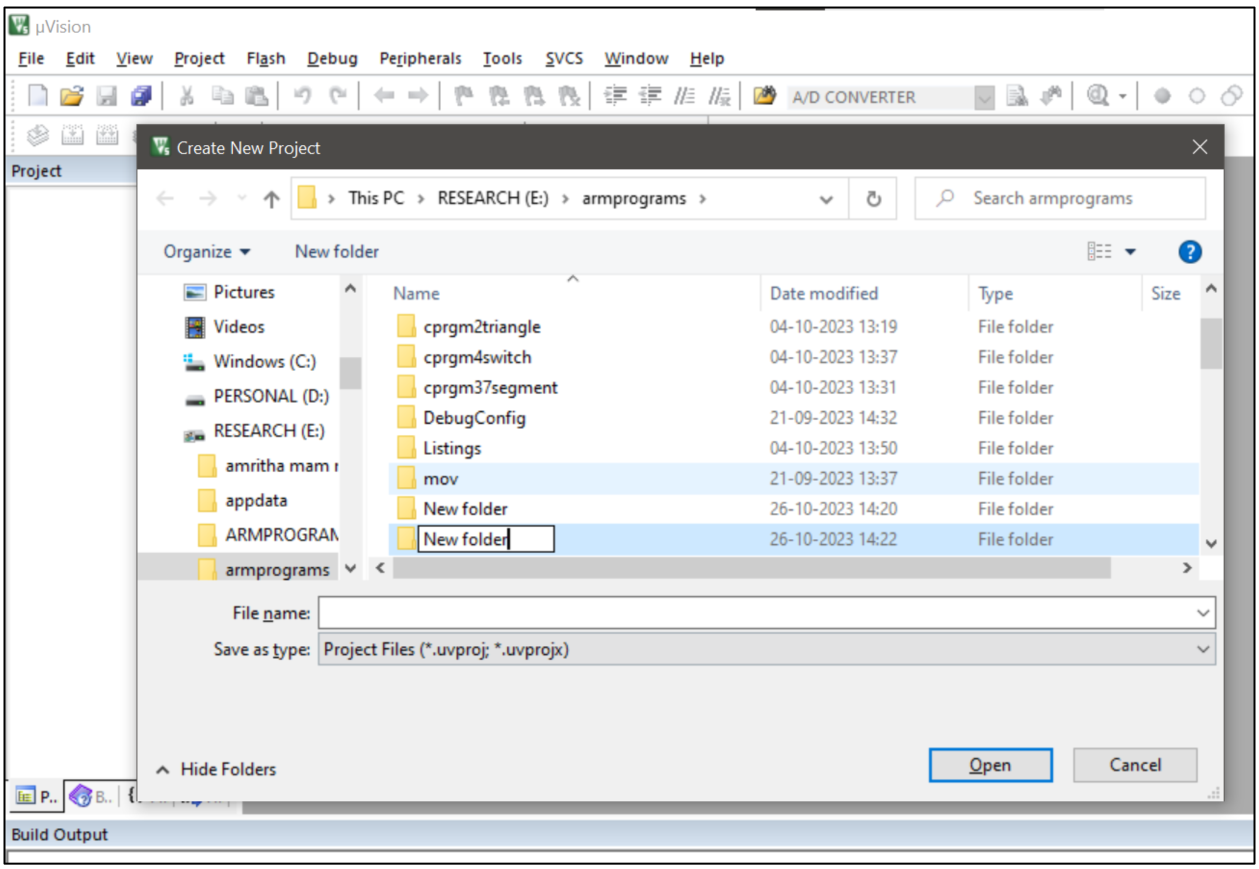
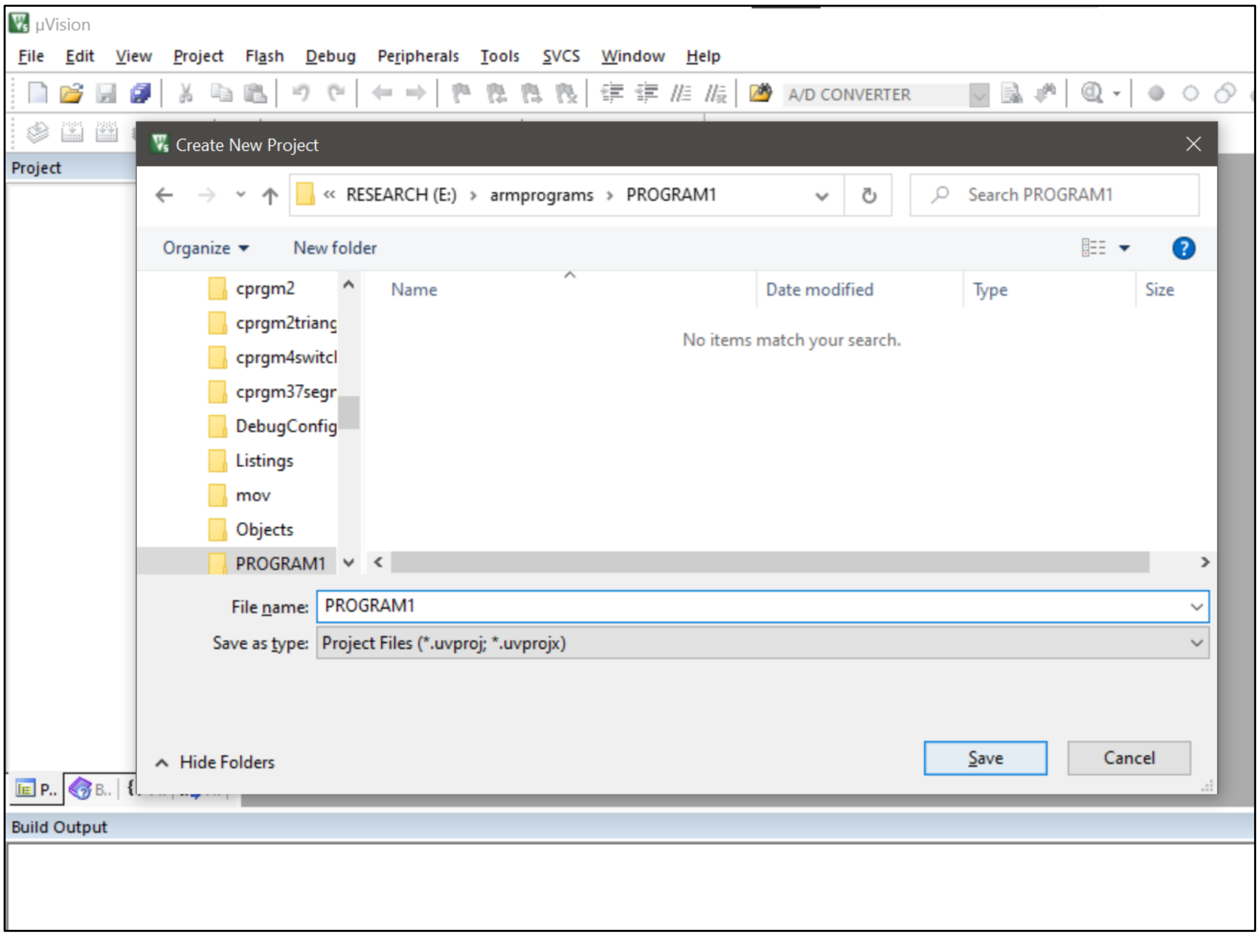
PROCEDURE TO RUN PROGRAM IN KEIL uVISION 5

Step 1 : Open the Keil uVision 5 software. Go to Project and select New uVision project

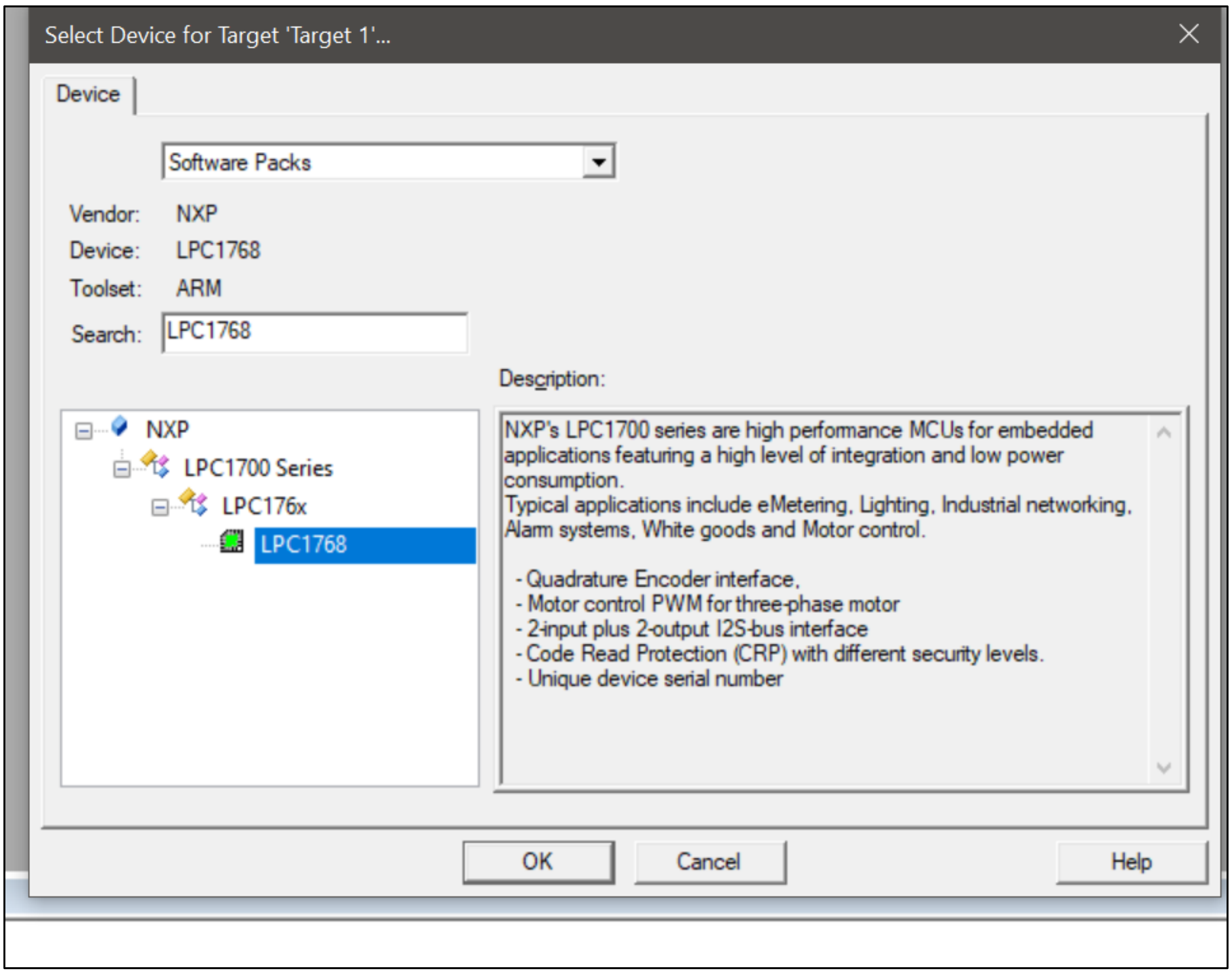


Step 2:Create a new folder by giving folder name and inside the folder create a new file and give a file name. Click at Save.




µVision
File Edit View Project Flash Debug Peripherals Tools SVCS Window Help
A/D CONVERTER
Project
Create New Project
RESEARCH (E:) › armprograms › PROGRAM1
Search PROGRAM1
Organize
New folder
cprgm2
cprgm2trianc
cprgm4switcl
cprgm37segr
DebugConfig
Listings
mov
Objects
PROGRAM1
Name
Date modified
Type
Size
No items match your search.
File name: PROGRAM1
Save as type: Project Files (*.uvproj; *.uvprojx)
Hide Folders
Save
Cancel
Build Output

Step 3: Search for the device by typing "lpc1768" and click on LPC1768 from the drop down menu. Then click ok



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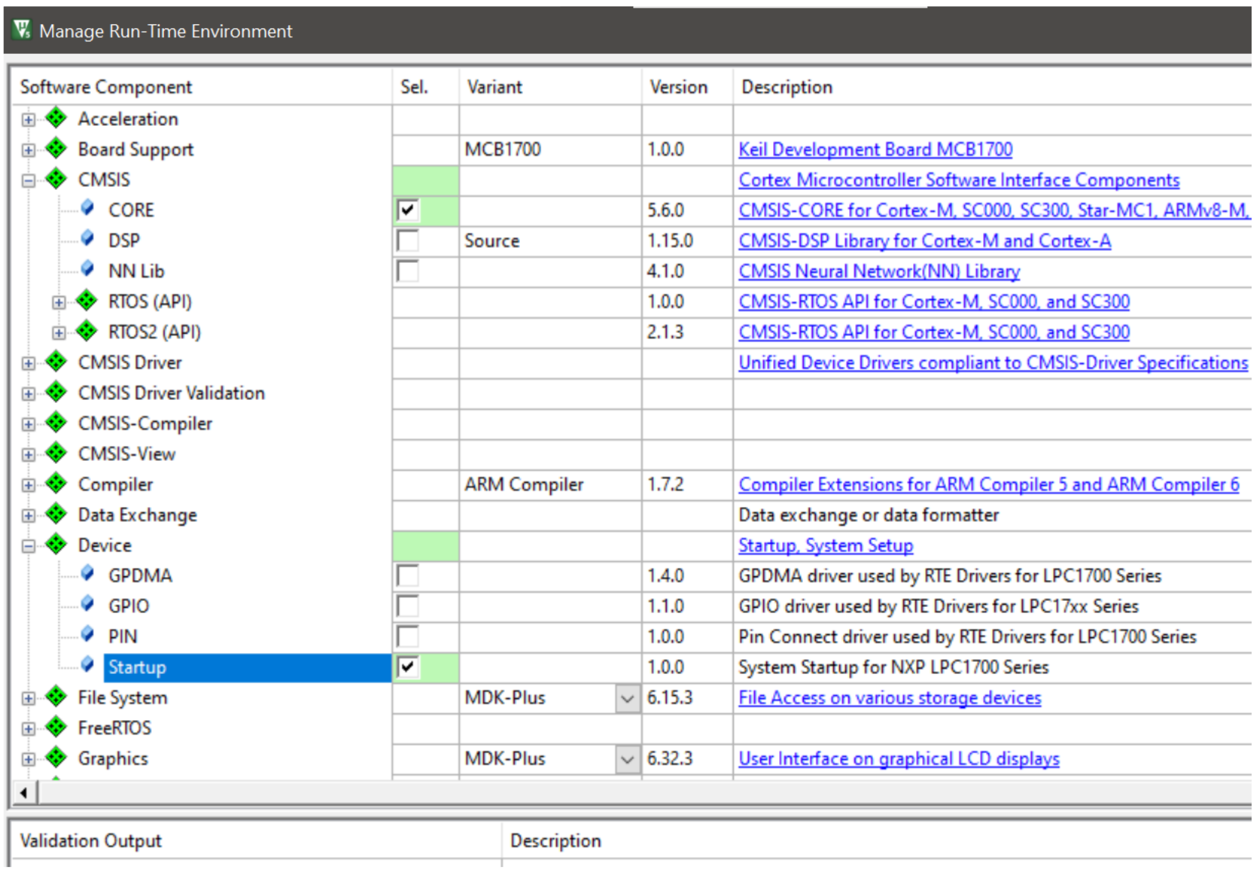
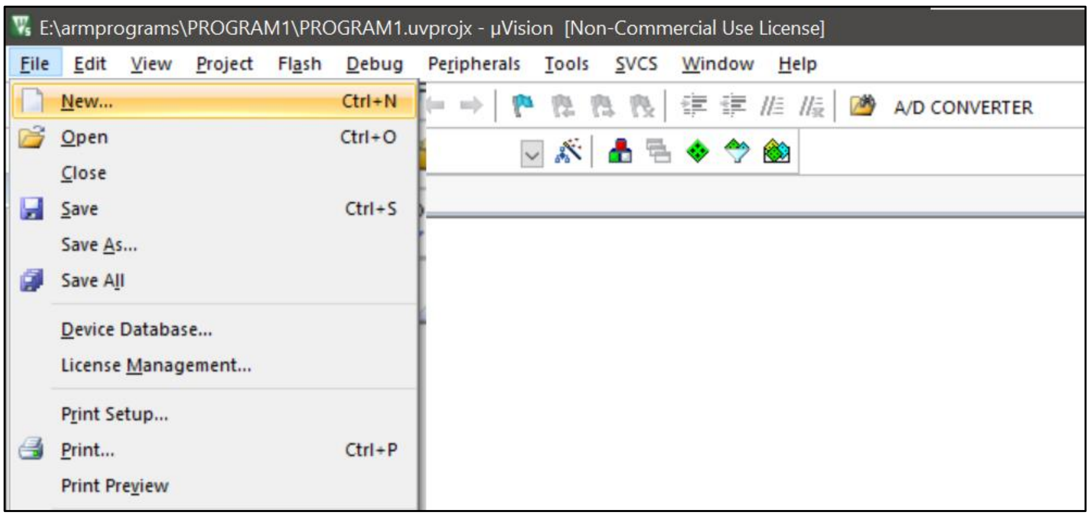
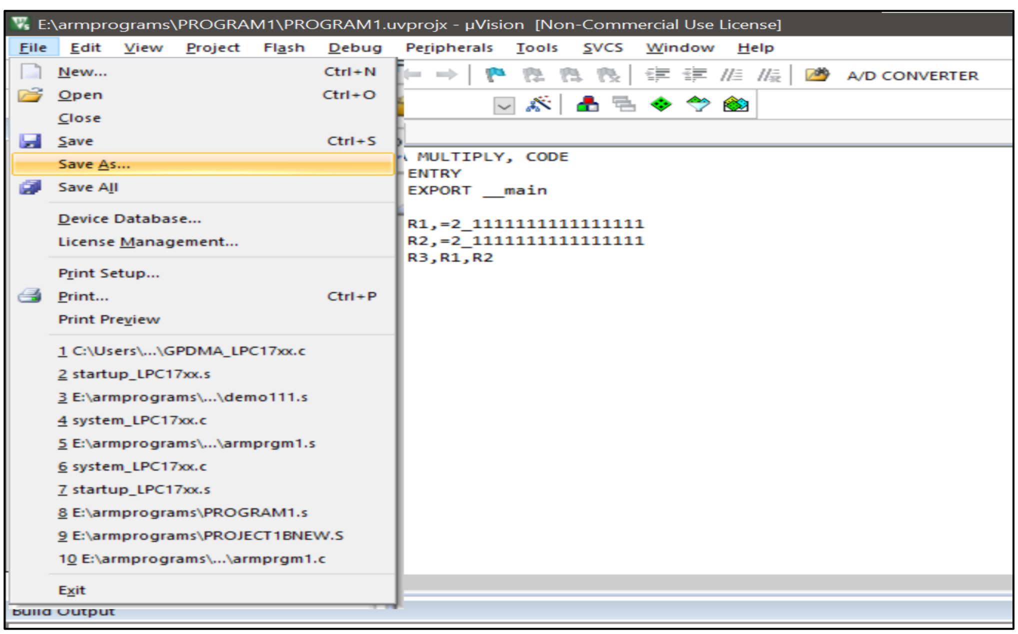
Step 4: Extend CMSIS and tick ✓ CORE .Extend Device and tick ✓ Startup. Click at OK.



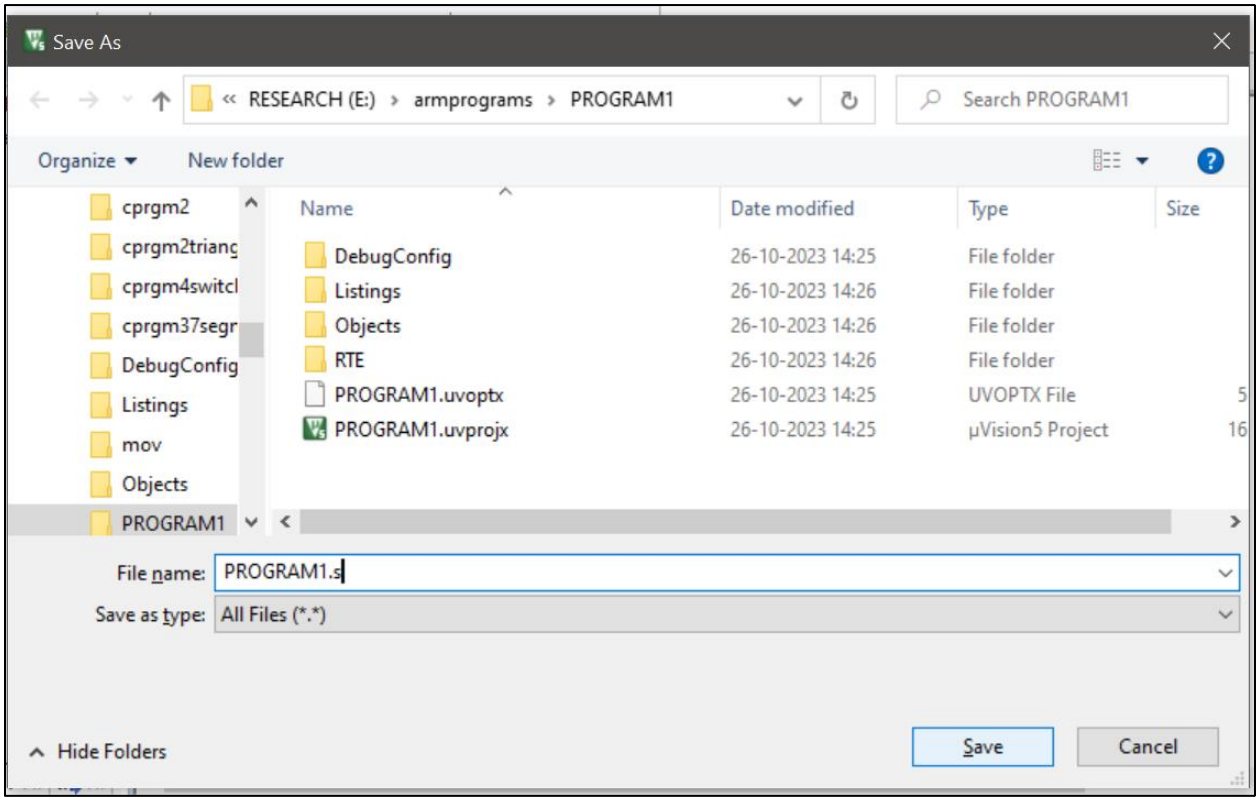
STEP 5: Click at File -> New. A new text file will be opened to type or paste the program



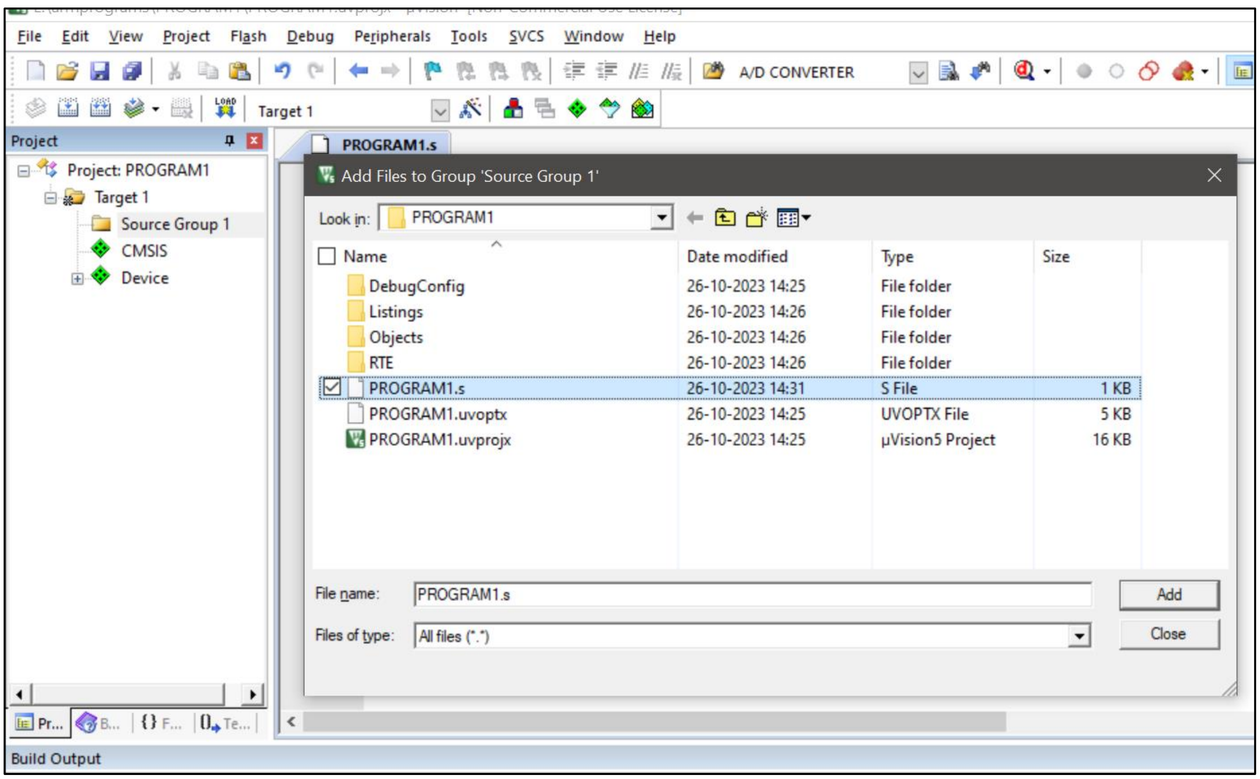
STEP 6: Type the program and click at Save As option.



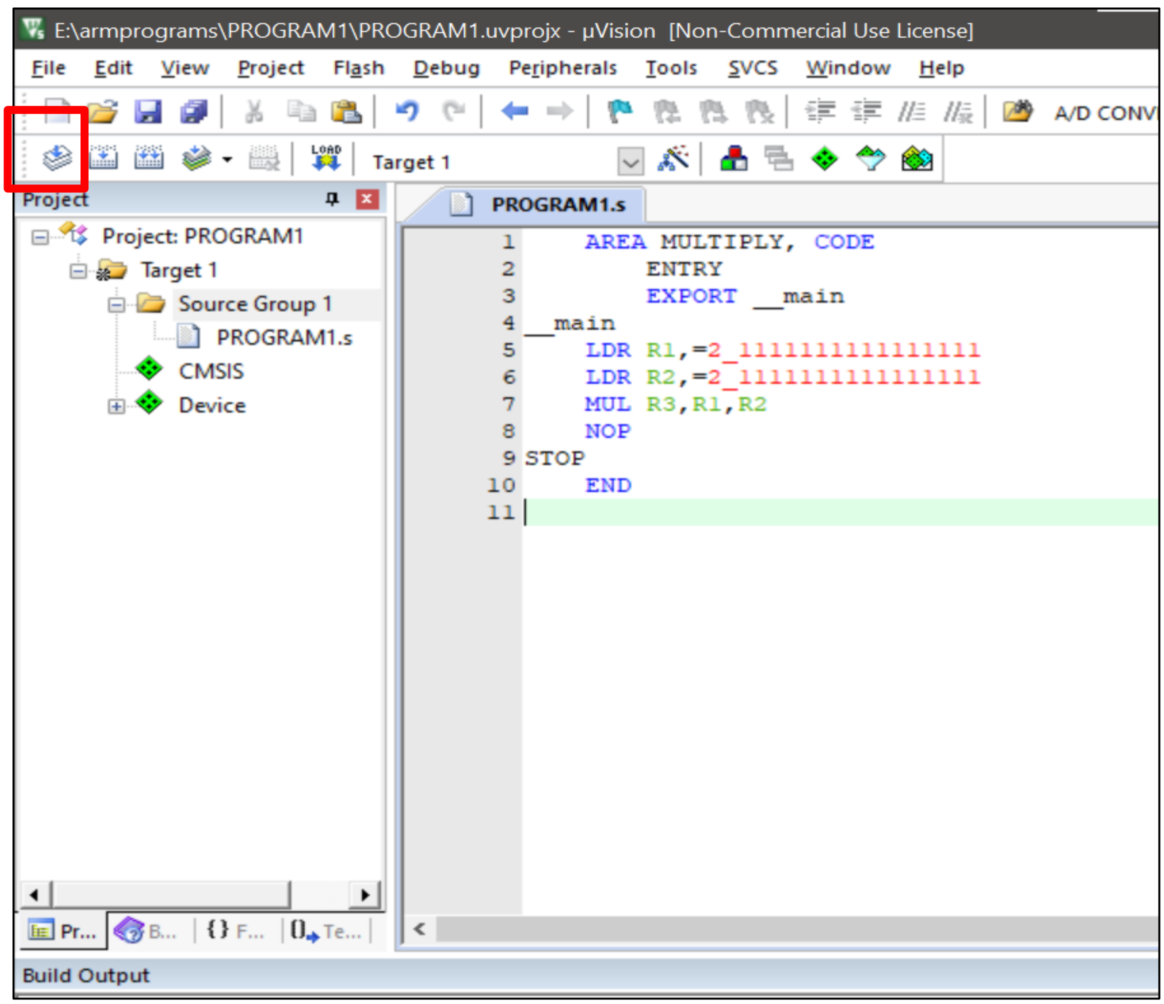
Step 7: Save the file in .s (for.eg: armprgm1.s) for ALP programming and .c for Embedded C programming. Click OK



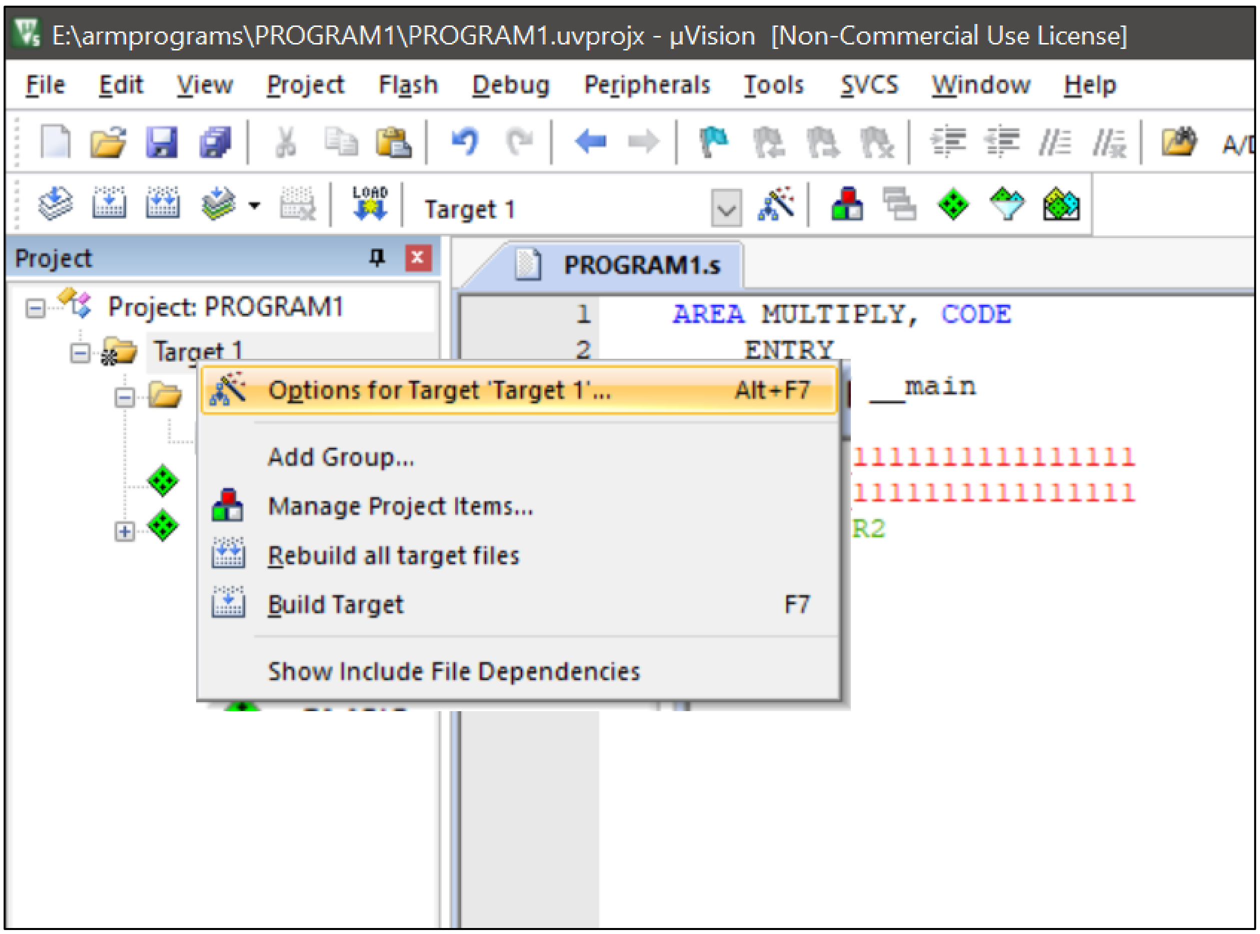
Step 8: Extend Target 1 by clicking at + symbol. Click at source Group. Search for the .s file you have saved (for eg: PROGRAM1.s). Click at Add. Then click at Close.



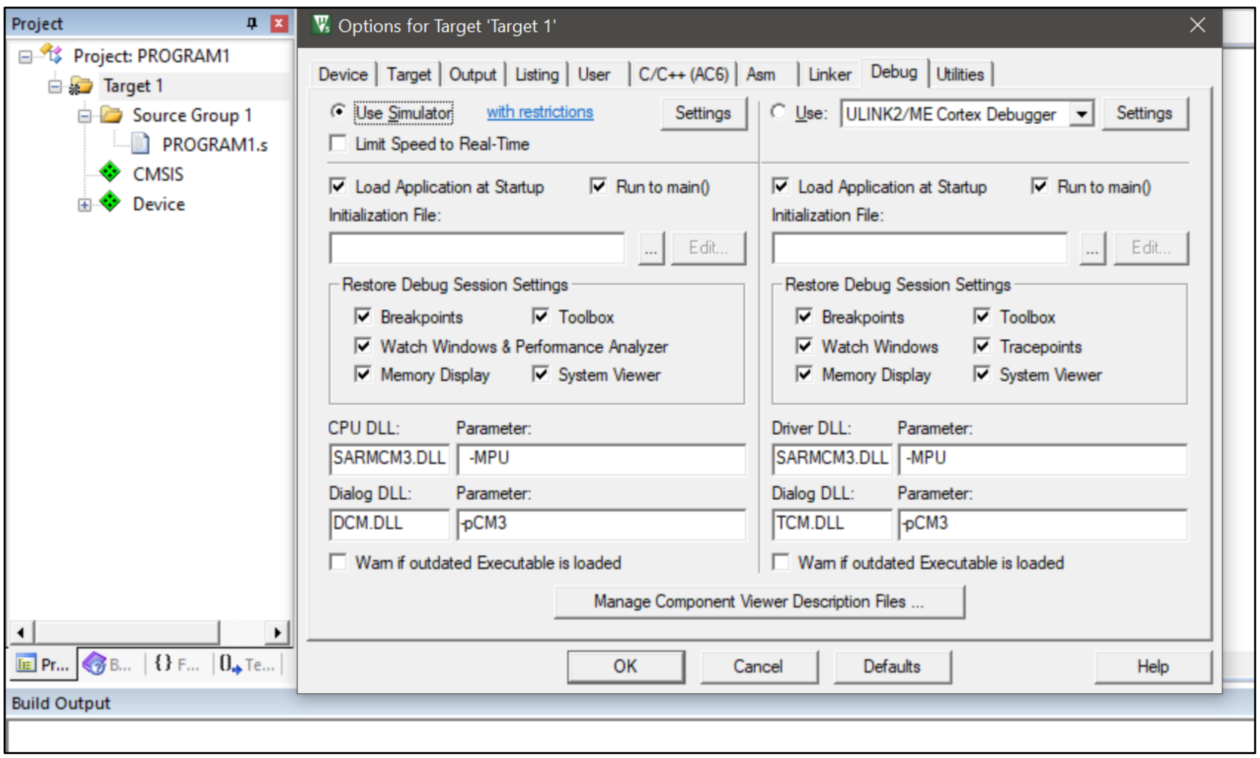
Step 9: Extend Source Group1 and check the file is added under that. Click at Translate and check for errors and warnings.



Step 10: Right click at Target 1 and select Options for Target Target 1.



Step 11: Click at Debug and choose the option "Use Simulator". Click at OK.



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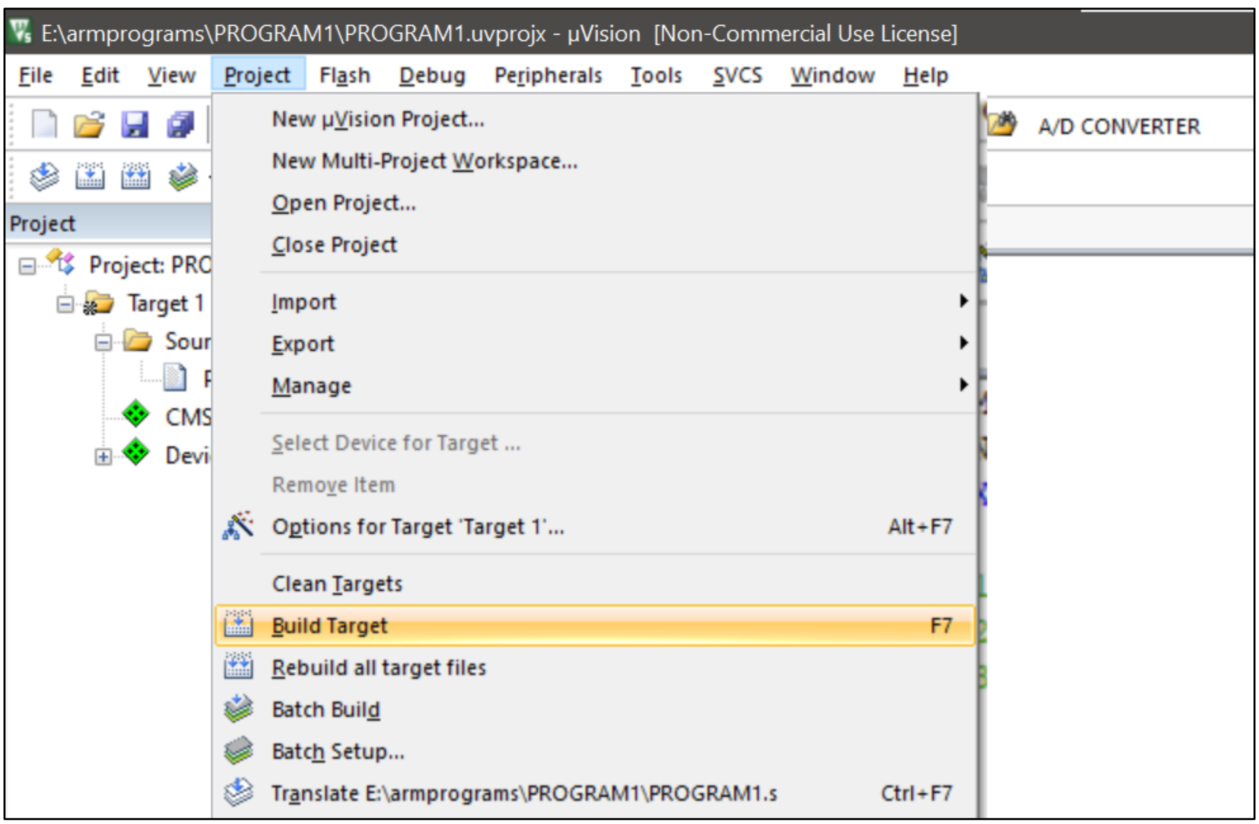
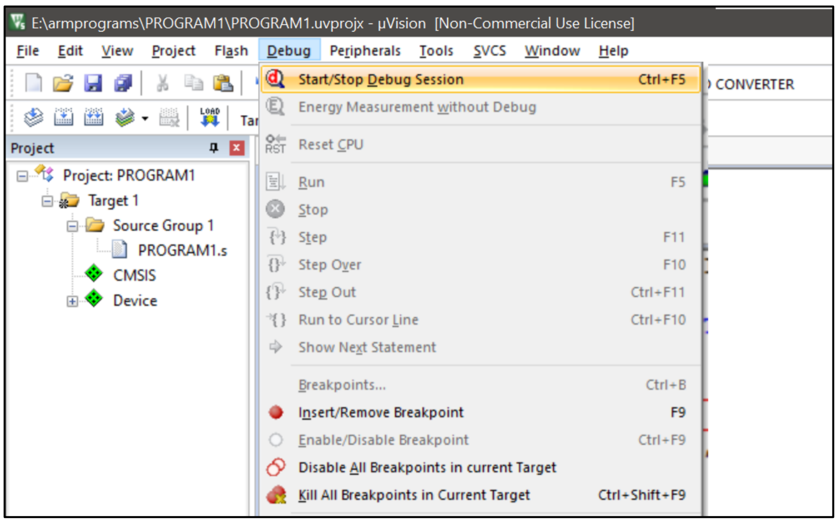
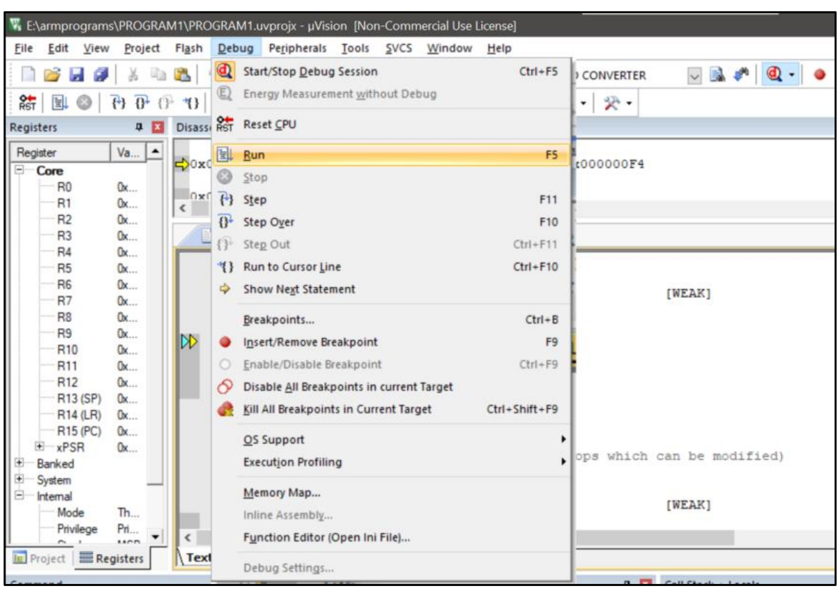
Step 12: Select Project from the Toolbar and Click at Built Target and check for errors



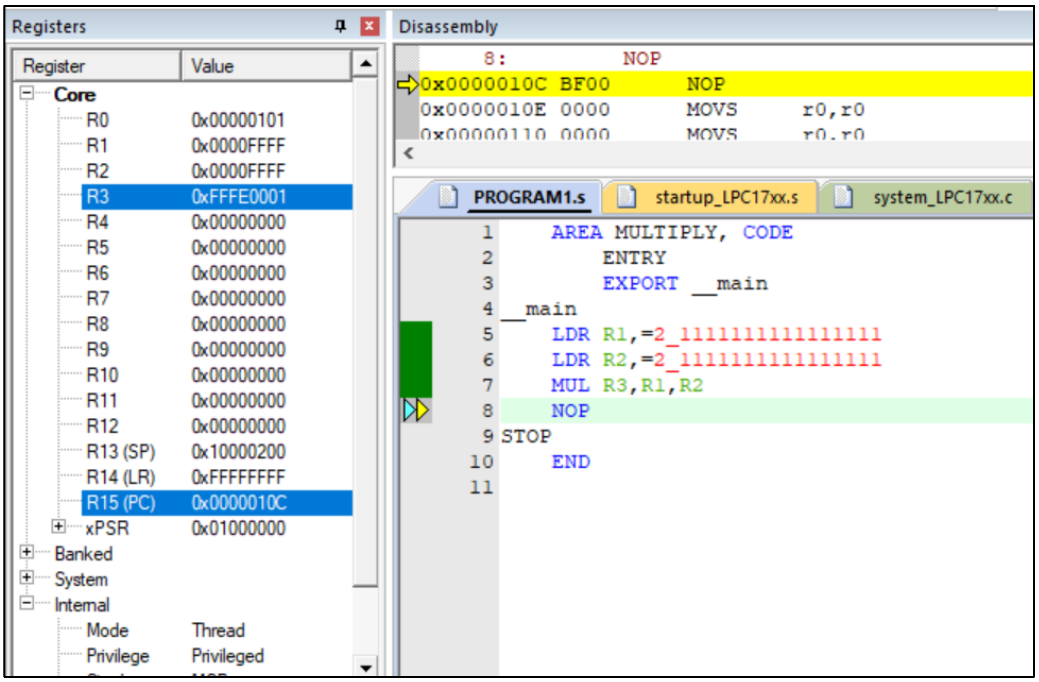
Step 13: Click at Debug from Toolbar and click at Start/Stop Debug Session. The program will start running.



Step 14: Click at Run and execute the program.



Step 15: Observe the output at the corresponding register.



Date:

Program 1.a. Program to multiply two 16-bit binary numbers.

```
        AREA MULTIPLY, CODE
                ENTRY                          ; start of execution
                EXPORT __main                  ; transfer the code to main
__main
        LDR R1,=2_1111111111111111             ; load the rgister R1
        LDR R2,=2_1111111111111111             ; load the rgister R2
        MUL R3,R1,R2                           ; Multiply & store result in R3
        NOP                                    ; No operation
STOP                                           ; end of execution
        END                                    ; end of program

        `       `
```

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Date:

Program 1.b. Program to add two 64 bit numbers

```
        AREA ADD, CODE
                ENTRY
                EXPORT __main
 __main
    LDR R0, =2_11111111111111110000000000000000    ;lower half of 1st number
    LDR R1, =2_00000000000000001111111111111111    ;upper half of 1st number
    LDR R2, =2_00000000000000000000000000000000    ;lower half of 2nd number
    LDR R3, =2_11111111111111110000000000000000    ;upper half of 2nd number
    ADDS R4,R0,R2           ;add the lower half and store the sum in R4
    ADC R5,R1,R3            ; add the upper half  with carry and store the result in R5
    NOP
STOP
        END
```

OBSERVATION SHEET

OBSERVATION SHEET

Faculty Signature

Date:

Program 2. Write an ALP to find the sum of first 10 integer numbers

```
    AREA MULTIPLY, CODE
        ENTRY
        EXPORT  __main
__main
        MOV R0,#10          ; Set the counter =10
        MOV R1,#0           ; Initialize a register to store result
        MOV R2,#1           ; Take the first number to add
L1      ADD R1,R1,R2        ; Add the numbers
        ADD R2,#1           ; Increment the integer
        SUBS R0,#1          ; Decrement counter
        BNE L1              ; Branch to  loop if not equal to zero
        NOP
STOP
        END
```

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Program 3. Write an ALP to find factorial of a number.

```
        AREA FACTORIAL, CODE
                ENTRY
                EXPORT __main
__main

        MOV R1,#1               ; Initialize a register to store result
        MOV R2,#5               ; Factorial number

L1      MUL R1,R2               ; Multiply R1*R2
        SUBS R2,#1              ; Decrement the number
        BNE L1                  ; Branch to loop if not equal to zero
        NOP                     ; No operation
STOP
        END
```

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Program 4. Write an ALP to add an array of 16-bit numbers and store the 32-bit result in internal RAM

```
        AREA SUM,CODE
                ENTRY
                EXPORT __main
__main

                LDR R0,=0X40000015      ; Load starting address of the array

                MOV R1,#4               ; Load array size (counter)

                LDRH R2,[R0]            ; Load first number

                ADD R1,#-1              ; Decrement counter

UP              ADD R0,R0,#2            ; Increment pointer by 2

                LDRH R3,[R0]            ; Load second number

                ADD R2,R3,R2            ; Add R3 and R2 and store in R2

NEXT            ADD R1,#-1              ; Decrement counter

                CMP R1,#0               ; Is counter=0?

                BNE    UP               ; If counter not equal to 0, Then repeat

                LDR R0,=0X4000002A      ; Result

                STRH R2,[R0]            ;Store the result

HERE            B HERE

                END
```

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Program 5. Write an ALP to find the square of a number (1 to 10) using look-up table.

```
        AREA SQUARE, CODE
                ENTRY
                EXPORT __main
__main
                LDR     R0,LOOKUP
                LDR     R2,RESULT
                LDRB    R1,[R0]
                ADD     R0,R0,R1
                LDRB    R3,[R0]
                STRB    R3,[R2]
HERE            B       HERE

LOOKUP          DCD  0X40000015
RESULT          DCD  0X4000002A
                NOP
STOP
                END
```

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Program 6. Write an ALP to find the largest/smallest **number in an array of 32 bit numbers.**

```
        AREA FILENAME, CODE
                ENTRY
                EXPORT __main
__main
                MOV R5,#5       ; counter =5, if n=6, counter = n-1
                LDR R0,A        ; Load the register R0 with the address of A
                LDR R2, [R0]    ;Load the value in the memory of R0 to R2
NEXT            ADD R0,#4       ;Increment the address
                LDR R3,[R0]     ;Load the value in the memory of R0 to R3
                CMP R2,R3       ;Comparison
                BHS LARGE       ;Branch to LARGE if higher or same (R2>=R3)
                MOV R2,R3       ; Move the content of R3 to R2
LARGE           SUBS R5,#1      ;Decrement the counter
                BNE NEXT        ;Branch of not equal to 0(R5 not equal to 0)
```

```
            LDR R1,RESULT       ; Load the address of Result to R1
            STR R2,[R1]         ;Store the value of R2 to the memory location
HERE        B   HERE

A           DCD 0X40000015
RESULT      DCD 0X4000003F
            NOP
STOP
            END
```

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Program 7. Write an ALP to arrange a series of 32-bit numbers in ascending/descending order.

```
        AREA FILENAME, CODE
                ENTRY
                EXPORT __main
__main
                        MOV   R5,#3           ;N-1 PASSES
NXTPASS                 LDR   R0,A
                        MOV   R4,R5           ;N-1 COMPARISON
NXTCOMP                 LDR   R2,[R0]         ;READ FIRST NO.
                        MOV   R1,R2           ;SAVE IT IN R1
                        ADD   R0,#4           ;UPDATE POINTER
                        LDR   R2,[R0]         ;READ SECOND NUMBER
                        CMP   R1,R2           ;COMPARE 1ST NO. WITH 2ND NO.
                        BLS   NOEXG           ;IF IST NO.<2ND NO. THEN EXC IS NOT REQ
                        STR   R1,[R0],#-4     ;EXCHANGE THE NO.
                        STR   R2,[R0],#4
```

```
NOEXG   SUBS  R4,#1       ;DECREMENT THE NUMBER OF PASSES
        BNE   NXTCOMP     ;BRANCH IF NOT EQUAL TO ZERO
        SUBS  R5,#1       ;DECREMENT R5
        BNE   NXTPASS     ;BRANCH IF NOT EQUAL TO ZERO
HERE    B     HERE
A       DCD   0X4000002A
        NOP
STOP
        END
```

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Program 8.a. Write an ALP to count the number of ones and zeros in two consecutive memory locations.

```
AREA FILENAME, CODE
            ENTRY
            EXPORT __main
__main
            LDR   R0,MEMORY       ;Load the address of the memory
            LDR   R1,[R0]         ;Load 32 bit number
            MOV   R4,#32          ;Load rotation count
ROTATE      RORS  R1,#1           ;Rotate right by 1 bit
            BCS   ONES            ;Branch if carry is set to 1
            ADD   R3,R3,1         ;Increment zero's counter
            B     NEXT            ;Branch the next rotation
ONES        ADD   R2,R2,#1        ;Increment one's counter
NEXT        ADD   R4,R4,#-1       ;Decrement the rotation count
            CMP   R4,#0           ;Is rotation count is =0
            BNE   ROTATE          ;If no, go to rotate
            ADD   R0,R0,#4        ;Load address of memory for no. of one's
```

```
        STRB R2,[R0]        ;Store no. of one's
        ADD  R0, R0,#1      ;Load address of memory for no. of zeros
        STRB R3,[R0]        ;Store no. of zeros
HERE    B    HERE
MEMORY  DCD  0X40000000     ;Memory address
STOP
        END
```

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Program 8.b. Write an ALP to Scan a series of 32-bit numbers to find how many are negative.

```
        AREA NEGATIVE , CODE
                ENTRY
                EXPORT __main
__main
                MOV   R5,#7           ; intialise counter to 7(i.e. n=7)
                MOV   R2,#0           ; counter
                LDR    R4,=VALUE      ; loads the address of first value
LOOP            LDR   R1,[R4],#4      ; word align to array element
                ANDS R1,R1,#1<<31     ; to check negative number
                BHI   FOUND           ; if the given number is negative goto FOUND
                B      LOOP1          ; if the given number is not negative goto LOOP1
FOUND           ADD   R2,R2,#1        ; increment the counter(negative number)
                B     LOOP1           ; goto LOOP1
LOOP1           SUBS  R5,R5,#1        ; decrement counter
                CMP   R5,#0           ; compare counter to 0
```

```
        BNE   LOOP           ; loop back till array ends
        NOP
        NOP

VALUE   DCD 0X12345678       ;array of 32 bit numbers(n=7)
        DCD 0X8D489867
        DCD 0X11111111
        DCD 0X33333333
        DCD 0XE605546C
        DCD   0XAAAAAAAA
        DCD 0X99999999 ;
STOP
        END                  ; Mark end of file
```

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Program 9: Interface a Stepper motor and rotate it in clockwise and anti-clockwise direction

```
//STEPPER-MOTOR DEMO
#include <LPC17xx.H>

void delay(unsigned int count)
{
  unsigned int j=0,i=0;
  for(j=0;j<count;j++)
  {
    for(i=0;i<12000;i++);
  }
}
//////////////////// MAIN //////////////////////////////////
int main (void)
{
        unsigned int del=10;
        LPC_GPIO1->FIODIR =  0x03C00000;//  stepper motor port P1.22 to P1.25
while(1)
{
        LPC_GPIO1->FIOPIN =0x02000000;
        delay(del);
        LPC_GPIO1->FIOPIN =0x01000000;
        delay(del);
```

```
        LPC_GPIO1->FIOPIN =0x00800000;
        delay(del);
        LPC_GPIO1->FIOPIN =0x00400000;
        delay(del);
    }
}
```

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Program 10: Interface a DAC and generate Triangular and Square waveforms.

Program 10.a. SQUARE WAVEFORM

```
#include <LPC17xx.H>
#include "lcd.h"

//(10bit = 1024 max = 3.3v)
#define voltage          1024
#define freq             120000

/*--------------------------------------------------------------------------
  Main Program
 *--------------------------------------------------------------------------*/
int main (void)
{
        uint32_t m;

        /* Initialize DAC  */
        LPC_PINCON->PINSEL1 |= (1<<21); //Select AOUT function for P0.26

  init_lcd();

 lcd_putstring16(0,"* DAC - SQUARE *");
 lcd_putstring16(1,"* LPC1768 DEMO *");
```

```
  while(1)
  {
        LPC_DAC->DACR = (voltage/2 << 6);
        for(m = freq; m > 1; m--);

        LPC_DAC->DACR = (voltage << 6);
        for(m = freq; m > 1; m--);
  }
}
```

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Program 10.b. TRIANGULAR WAVE

```
//Program DAC-Triangle wave

#include <LPC17xx.H>
#include "lcd.h"

#define voltage     1024 //(10bit = 1024 max = 3.3v)
#define       freq  10

/*------------------------------------------------------------------------
  Main Program
 *------------------------------------------------------------------------*/
int main (void)
{
        uint32_t i = 0;
        uint32_t m;

        /* Initialize DAC  */
        LPC_PINCON->PINSEL1 |= (1<<21); //Select AOUT function for P0.26
 init_lcd();

 lcd_putstring16(0," DAC - TRIANGLE ");
 lcd_putstring16(1,"* LPC1768 DEMO *");

  while(1)
  {
                for(i = 0; i < voltage; i++)
                 {
                        LPC_DAC->DACR = (i << 6);
```

```
                for(m = freq; m > 1; m--);
            }
            for(i = voltage; i > 0; i--)
            {
                LPC_DAC->DACR = (i << 6);
                for(m = freq; m > 1; m--);
            }
    }
  }
```

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Program 11. Display the Hex digits 0 to F on a 7-segment LED interface, with a suitable delay in between.

```
#include <LPC17xx.H>

////digits are created using bit patterns corresponding to the segments ////
unsigned char data7[] =
{0x88,0xeb,0x4c,0x49,0x2b,0x19,0x18,0xcb,0x8,0x9,0xa,0x38,0x9C,0x68,0x1c,0x1e};

/*-------------------------------------------------------------------------
  Main Program
 *-------------------------------------------------------------------------*/
int main (void)
{
        unsigned int i,j;
  unsigned int count=0;

        LPC_GPIO2->FIODIR = 0x000000FF;    /* Seven seg on PORT2 are output  */
        LPC_GPIO2->FIOPIN = 0x000000FF;    /* Display blank  */

        LPC_GPIO1->FIODIR = 0x3C000000;  /*Dig control on PORT1 are output  */
        LPC_GPIO1->FIOPIN = ~(0x3C000000); /* Display blank */

        while(1)
```

```
 {
        ++count;
        if (count > 0xF) count = 0;
                for (i=0; i < 90000; i++)  //change to inc/dec speed of count
                 {
                        LPC_GPIO2->FIOPIN = data7[count];
                        LPC_GPIO1->FIOSET = 0x04000000;  //digit1 enable
                        for (j=0;j<500;j++);        //change to inc/dec brightness of display
                        LPC_GPIO1->FIOCLR =0x04000000;  // digit1 enable
                 }
 }
}
```

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Program 12. Program to interface a simple Switch and display its status through Relay, Buzzer and LED.

//SWITCH DEMO

```
#include <LPC17xx.H>
#include "lcd.h"

#define KEY1 (1 << 14)//p1.14
#define KEY2 (1 << 15)//p1.15
#define KEY3 (1 << 16)//p1.16
#define LED   (1 << 4) //p0.4
#define RELAY(1 << 25)//p0.25
#define BUZZ (1 << 25)//p3.25

#define KEY_PIN    LPC_GPIO1->FIOPIN

/*----------------------------------------------------------------------------
  Main Program
 *----------------------------------------------------------------------------*/
int main (void)
{

        LPC_GPIO0->FIODIR |= LED;      /* LED on PORT0  output  */
        LPC_GPIO0->FIOCLR  = LED;      //LED off

        LPC_GPIO0->FIODIR |= RELAY;      /* RELAY on PORT0  output */
        LPC_GPIO0->FIOCLR  = RELAY;     //RELAY off
```

```
        LPC_GPIO3->FIODIR |= BUZZ;      /* BUZZER on PORT3 output      */
        LPC_GPIO3->FIOCLR  = BUZZ;      //BUZZER off

        LPC_GPIO1->FIODIR &= ~(KEY1 | KEY2 | KEY3); //keys input
        LPC_GPIO1->FIOSET = (KEY1 | KEY2 | KEY3);     //keys pullup

  init_lcd();

        lcd_putstring16(0,"#   KEY DEMO   #");
        lcd_putstring16(1,"1-LED 2-RLY 3-BZ");

        while(1)
  {
         if (!(KEY_PIN & KEY1))
                 LPC_GPIO0->FIOSET  = LED;
         else
                 LPC_GPIO0->FIOCLR  = LED;

         if (!(KEY_PIN & KEY2))
                 LPC_GPIO0->FIOSET  = RELAY;
         else
                 LPC_GPIO0->FIOCLR  = RELAY;

         if (!(KEY_PIN & KEY3))
                 LPC_GPIO3->FIOSET  = BUZZ;
         else
                 LPC_GPIO3->FIOCLR  = BUZZ;
  }
 }
```

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CONTENT BEYOND SYLLABYS

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Program 13. Program to interface hex keypad with LPC1768 and display the characters on 16*2 lcd.

```
#include <LPC17xx.H>                /* NXP LPC17xx definitions           */
#include "lcd.h"

//////////////////////////////////////////////
// Matrix Keypad Scanning Routine
//
// COL1 COL2 COL3 COL4
// 0    1    2    3    ROW 1
// 4    5    6    7    ROW 2
// 8    9    A    B    ROW 3
// C    D    E    F    ROW 4
//////////////////////////////////////////////

#define COL1        (1 << 14)
#define COL2        (1 << 15)
#define COL3        (1 << 16)
#define COL4        (1 << 17)

#define ROW1               (1 << 18)
#define ROW2               (1 << 19)
#define ROW3               (1 << 20)
#define ROW4               (1 << 21)

#define COLMASK            (COL1 | COL2 | COL3 | COL4)
#define ROWMASK            (ROW1 | ROW2 | ROW3 | ROW4)
```

```
#define KEY_DIR          LPC_GPIO1->FIODIR
#define KEY_SET          LPC_GPIO1->FIOSET
#define KEY_CLR          LPC_GPIO1->FIOCLR
#define KEY_PIN          LPC_GPIO1->FIOPIN

/////////////// COLUMN WRITE ////////////////////
void col_write( unsigned char data )
{
  unsigned int temp=0;

  temp=(data << 14) & COLMASK;

  KEY_CLR |= COLMASK;
  KEY_SET |= temp;
}

/////////////////////////////// MAIN  /////////////////////////////////////
int main (void)
{
unsigned char key, i;
unsigned char rval[] = {0x7,0xB,0xD,0xE,0x0};
unsigned char keyPadMatrix[] =
{
    'C','8','4','0',
    'D','9','5','1',
    'E','A','6','2',
    'F','B','7','3'
};

  init_lcd();
```

```
  KEY_DIR |= COLMASK;    //Set COLs as Outputs
  KEY_DIR &= ~(ROWMASK); //  Set ROW lines as Inputs

  lcd_putstring16(0,"Press HEX Keys..");
  lcd_putstring16(1,"Key Pressed =   ");

 while (1)
  {
    key = 0;
    for( i = 0; i < 4; i++ )
    {
      // turn on COL output one by one
                  col_write(rval[i]);

      // read rows - break when key press detected
      if (!(KEY_PIN & ROW1))
         break;

      key++;
      if (!(KEY_PIN & ROW2))
         break;

      key++;
      if (!(KEY_PIN & ROW3))
         break;

      key++;
                  if (!(KEY_PIN & ROW4))
         break;
```

```
        key++;
      }

        if (key == 0x10)
                lcd_putstring16(1,"Key Pressed =   ");
        else
                {
                        lcd_gotoxy(1,14);
                        lcd_putchar(keyPadMatrix[key]);
                }
   }

  }
```

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APPENDIX

A. FUNCTION DESCRIPTION

GPIO Registers in LPC1768

1) FIODIR : This is the GPIO direction control register. Setting a bit to 0 in this register will configure the corresponding pin to be used as an Input while setting it to 1 will configure it as Output.
2) FIOMASK : This gives masking mechanism for any pin i.e. it is used for Pin access control. Setting a bit to 0 means that the corresponding pin will be affected by changes to other registers like FIOPIN, FIOSET, FIOCLR. Writing a 1 means that the corresponding pin won't be affected by other registers.

3) FIOPIN **:** This register can be used to Read or Write values directly to the pins. Regardless of the direction set for the particular pins it gives the current start of the GPIO pin when read.

4) FIOSET **:** It is used to drive an 'output' configured pin to Logic 1 i.e HIGH. Writing Zero does NOT have any effect and hence it cannot be used to drive a pin to Logic 0 i.e LOW. For driving pins LOW FIOCLR is used which is explained below.

5) FIOCLR **:** It is used to drive an 'output' configured pin to Logic 0 i.e LOW. Writing Zero does NOT have any effect and hence it cannot be used to drive a pin to Logic 1.

INSTRUCTIONS

S.No	INSTRUCTION	DESCRIPTION
1.	LDR	Load memory word
2.	MUL	Multiply register values
3.	ADDS	Add the contents of two 32 bit registers and place the result in 32 bit destination register
4.	ADC	Add register value and C flag to register value
5.	SUB	Subtract the register values and store in destination register
6.	BNE	Branch on Not Equal
7.	STR	store a register value into memory
8.	ADD	Add register values and store the value in register
9.	MOV	copies data from one location to another
10.	LDRSH	Load Register Signed Halfword
11.	CMP	Compare registers
12.	STRH	Store register half word
13.	LDRB	Load Register Byte
14.	STRB	Store Register byte
15.	BHS	Branch on Higher than or Same
16.	BLS	Branch on Lower than or Same
17.	B	Brach conditional
18.	RORS	Rotate right
19.	BCS	Brach if carry is set to 1

B. SAMPLE VIVA QUESTIONS

1. Name the number of ports in ARM Cortex M3 lpc1768.

   The ARM Cortex M3 LPC1768 has five ports:

   - Port 0 (P0):
   - Port 1 (P1):
   - Port 2 (P2):
   - Port 3 (P3):
   - Port 4 (P4):
     Each port can be 32-bit wide, which means it can have a maximum of 32 pins. The pins in a port are named Px

2. Name the number of pins in ARM Cortex M3 LPC1768.
   LPC1768 consists of 100 pins. Almost 70 pins are used as GPIO pins, which are used to connect the external peripherals.

3. How to configure the ports as input and output ports
   To configure a microcontroller pin as an output, you can apply a logic zero (0) to the appropriate I/O port bit. This will connect the pin to ground (0V). To configure a microcontroller pin as an input, you can apply a logic one (1) to the appropriate port.

4. Name the important peripherals in ARM Cortex M3 LPC1768
   LPC1768 MCU consists of the following peripherals: 512 kB Flash, 64 kB RAM, USB

Interface, Ethernet MAC, 4 UARTs, 2 CANs, 3 I2C Interfaces, SPI, 2 SSP Controllers, 2-input 2-output I2S, 8-channel ADC with 12-bit resolution, 10-bit DAC, 4 Timers, 8-channel DMA, 6-channel PWM, Motor Control PWM, low-power RTC, Quadrature Encoder and 70 GPIO Pins.

5. Difference between 8086 and ARM.

   ARM uses Reduced Instruction Set Computing Architecture (RISC). x86 uses Complex Instruction Set Architecture (CISC).

6. What are the day to day applications of ARM?

- Washing machines
- Motor control systems
- Flight control systems
- Medical MRI machines
- Sensors
- Internet of things devices
- Data analytics
- Mobile applications
- Machine learning inferencing
- In-memory databases
- Web hosting
- Cloud native applications

7. What is the main function of watchdog timer?

   A watchdog timer (WDT) is a timer that monitors microcontroller (MCU) programs to see if they are out of control or have stopped operating. It acts as a "watchdog" watching over MCU operation.

8. What is RISC and CISC?

   RISC-Reduced Instruction Set Computer – Size of the instruction set is smaller – No. of instructions are less, hence high performance

   CISC – Complex Instruction Set Computer- Size of the instruction set is larger – No. of instructions are more and complex.

9. Define co-processor.

   A coprocessor is a supplementary processor unit that complements the central processing unit (CPU) of a computer. It's designed to offload processor-intensive tasks from the CPU.

10. What is called the register bank?

    The collection of general purpose registers is called as register banks, which accept one byte of data. The bank register is a part of the RAM memory in the embedded microcontrollers, and it is used to store the program instructions.

11. What are the execution stages of ARM Cortex M3?

    The Arm Cortex-M3 CPU incorporates a 3-stage pipeline (FETCH, DECODE,,EXECUTE) and uses a Harvard architecture with separate local instruction and data buses as well as a third bus for peripherals

12. What is the function of DMA controller?

    The primary function of a DMA controller is to transfer data between memory and an auxiliary device directly, without involving the CPU

13. What is interrupt handling?

    An interrupt is a signal to the processor emitted by hardware or software indicating an event that needs immediate attention. Whenever an interrupt occurs, the controller completes the execution of the current instruction and starts the execution of an Interrupt Service Routine (ISR) or Interrupt Handler.

14. What is the importance of link register inARM?

    The link register (LR) in ARM is used to store the return address when calling a function or subroutine.

15. What is Thumb instruction set?

    The Thumb instruction set consists of 16-bit instructions that act as a compact shorthand for a subset of the 32-bit instructions of the standard ARM.

C. APPLICATIONS

Data communication: The processor's low power and high efficiency, couples with thumb 2 instructions, make cortex m3 which is ideal for many communication applications.

Automotive: It has high-performance efficiency and low interrupt latency, allowing to be used in real time systems.

Industrial control: In industrial control applications simplicity, reliability and fast response are the key factors, Cortex M3 has the low interrupt latency so is best suited.

Low-cost microcontrollers: Ideally, it is well suited for low-cost microcontrollers, which is commonly utilizing in consumer products.
Consumer products: It is small, processor and is highly efficient, low in power and supports an MPU enabling complex software to execute while providing robust memory protection.

Advantages:

- Many instructions are single cycle.
- Simultaneous data and instruction access can be performed.
- Faster time to market and easier code maintenance.
- Higher code density and reduced memory requirements.
- Instruction fetches are 32bit. More bandwidth is available for data transfer.
- It has advanced interrupt handling features.