جامعة بيرزيت
BIRZEIT UNIVERSITY

Electrical and Computer Engineering

Computer Design Lab – ENCS4110

Introduction to ARM Assembly Language and Keil uVision5

Objectives

1. Introduce some of the ARM architecture to students.
2. Begin to use the lab tool - Keil uVision 5.
3. The students will create a project and write an ARM assembly language program based on a simulated target.

The ARM (Advanced RISC Machine) architecture is introduced in the class (also see **http://www.arm.com**.) Keil MDK-ARM is a complete software development toolkit for ARM processor-based microcontrollers. Keil uVision5 will be used in the lab. The ARM Cortex-M3 processor will be examined with the STM32VLDISCOVERY board. The following is some important information for you.

Important Information

1. In the lab room Masri207, computers are running the operating system Windows 10 Pro, and ARM Software Microcontroller Development Kit Version 5.21a (Keil uVision5) is installed.
2. To install it in your home computer, you can download the following files:
   ~ftp/pub/class/301/ftp/uVision5/MDK521a.EXE
   ~ftp/pub/class/301/ftp/uVision5/Keil.STM32F1xx_DFP.2.1.0.pack

   Here is the Link to Keil Tools.
3. To know more about Keil, visit http://www.keil.com/
4. To see STM32VLDISCOVERY board, visit STM32VLDISCOVERY Board.
5. To see The Cortex-M3 Instruction Set, visit Cortex-M3 Devices Generic User Guide.

```
6.      To see more references of Cortex-M3, visit the following:
```

[Cortex-M3 Technical Reference Manual - ARM Information Center]
[Cortex-M3 programming manual]

Create an ARM Assembly Language Program

To create an assembly language program, you need to use a text editor such as **NotePad** in Microsoft Windows environment. There is a text edit in the Keil uVision5 for you to use too. The file name must have a **.s** at the end. Let's look at the following program called **FirstArm.s** on a PC. The file **FirstArm.s** contains the source code of the program to load registers and demonstrate a few other operations. We will use Keil uVision5 to create a project and execute this program so that you can get a feel of how Keil uVision5 works.

```
;The semicolon is used to lead an inline documentation.
;This is the first ARM Assembly language program you see in the lab.
;This program skeleton was from Dave Duguid and Trevor Douglas in summer 2013.
;When you write your program, you could have your info at the top document block.
;For Example:  Your Name, Student Number, what the program is for, and what it does
etc.

;;; Directives
          PRESERVE8
          THUMB

; Vector Table Mapped to Address 0 at Reset
; Linker requires __Vectors to be exported

          AREA    RESET, DATA, READONLY
          EXPORT  __Vectors

__Vectors
        DCD  0x20001000     ; stack pointer value when stack is empty
                     ;The processor uses a full descending stack.
                     ;This means the stack pointer holds the address of the last
                     ;stacked item in memory. When the processor pushes a new item
                     ;onto the stack, it decrements the stack pointer and then
                     ;writes the item to the new memory location.

          DCD  Reset_Handler  ; reset vector

          ALIGN

; The program
; Linker requires Reset_Handler
```

```
          AREA    MYCODE, CODE, READONLY

        ENTRY
        EXPORT Reset_Handler


Reset_Handler
;;;;;;;;;;User Code Starts from the next line;;;;;;;;;;;;

        MOV R0, #12

STOP
        ADD R0, R0, #4
        B  STOP

          END;End of the program
```

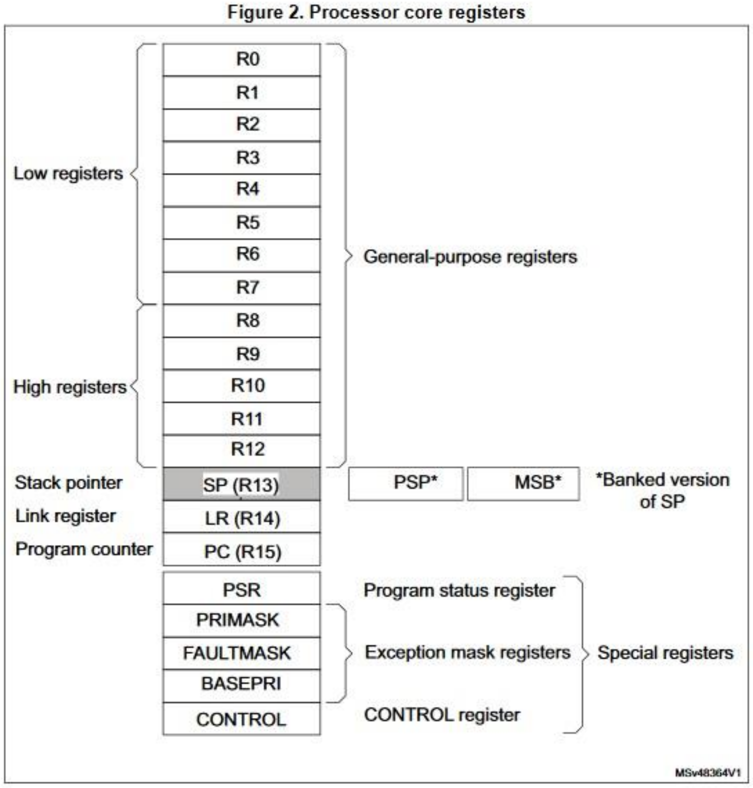
References:

1. A complete list of DIRECTIVES from ARM Information Center
2. Cortex-M3 Devices Generic User Guide
3. Cortex-M3 Programming Manual

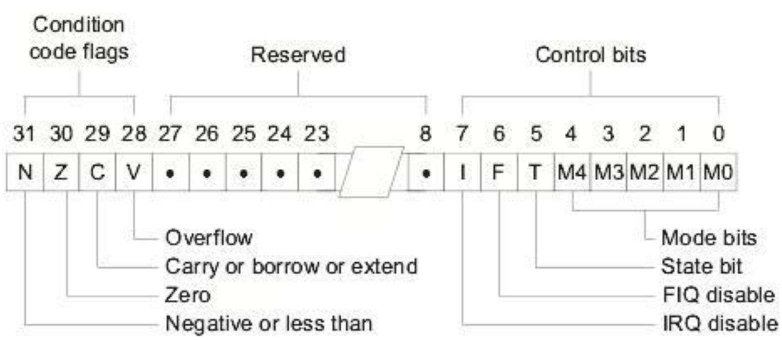
ARM Cortex-M3 Core Registers

2.1.3 Core registers

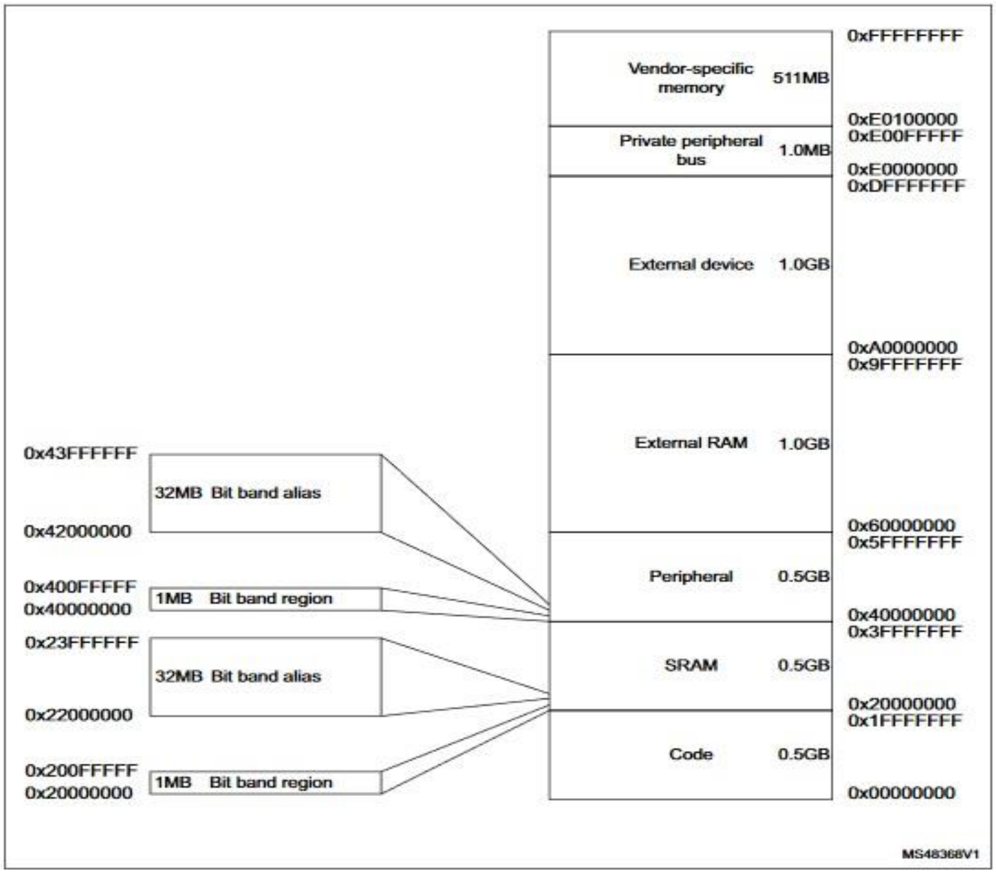
Figure 2. Processor core registers



Here is the Program Status Register Format:



ARM Cortex-M3 Memory Map



STM32F100xB Memory Map

[STM32F100xB Memory Map]

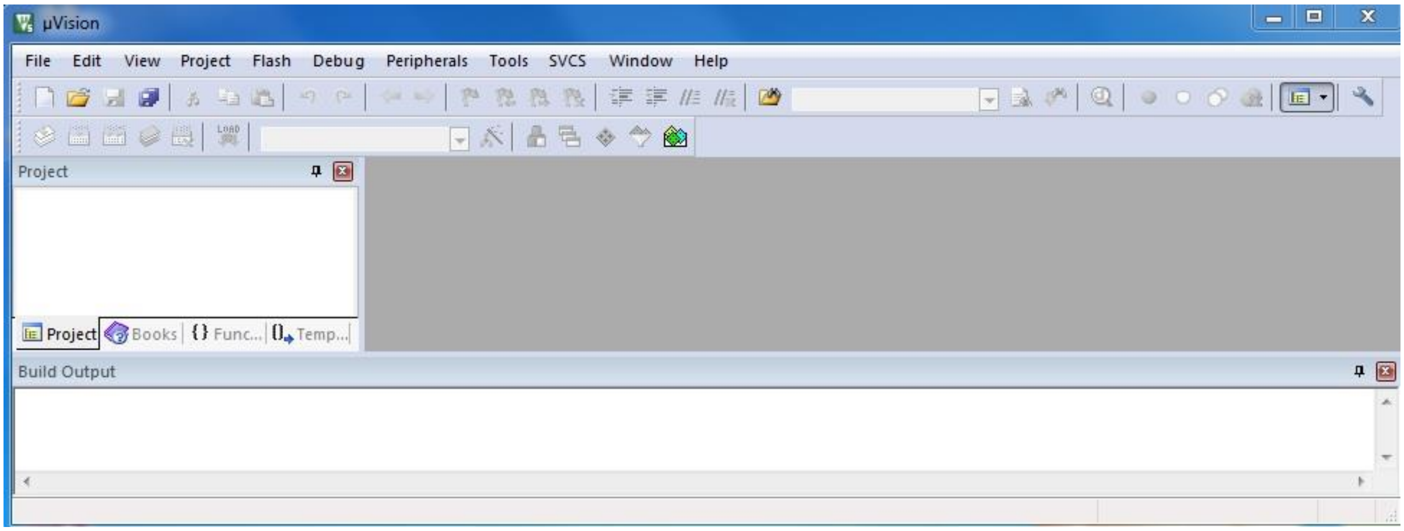
[STM32F100RB Datasheet]

Start up Keil uVision5

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

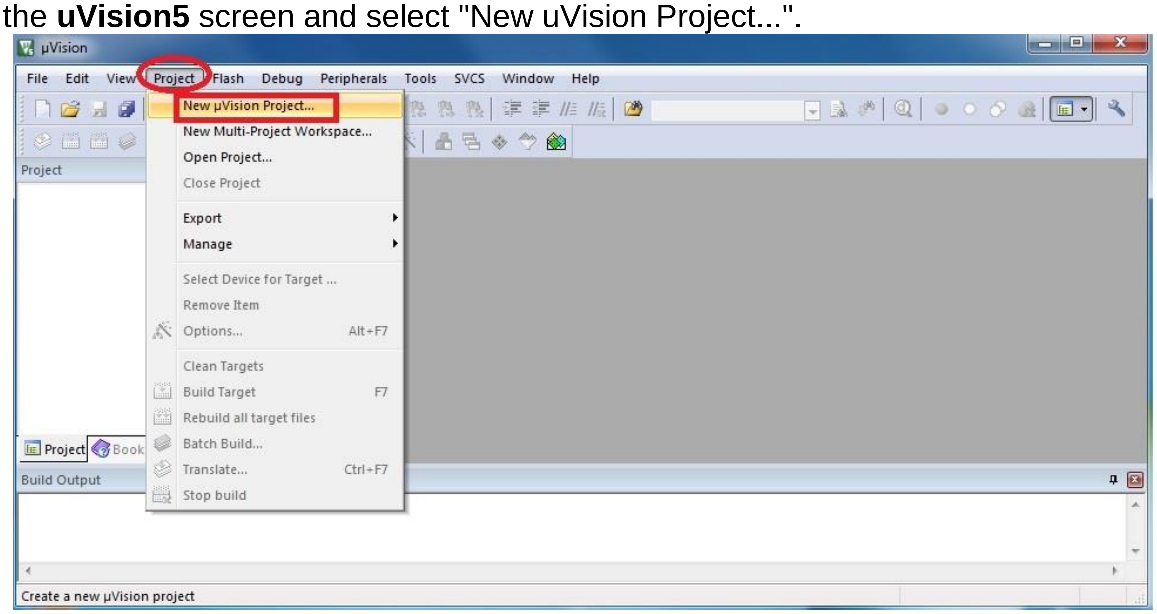
You can start up **uVision5** by clicking on the icon 

from the desktop or from the "Start" menu or "All Programs" on a lab PC.
The following screen is what you will see.

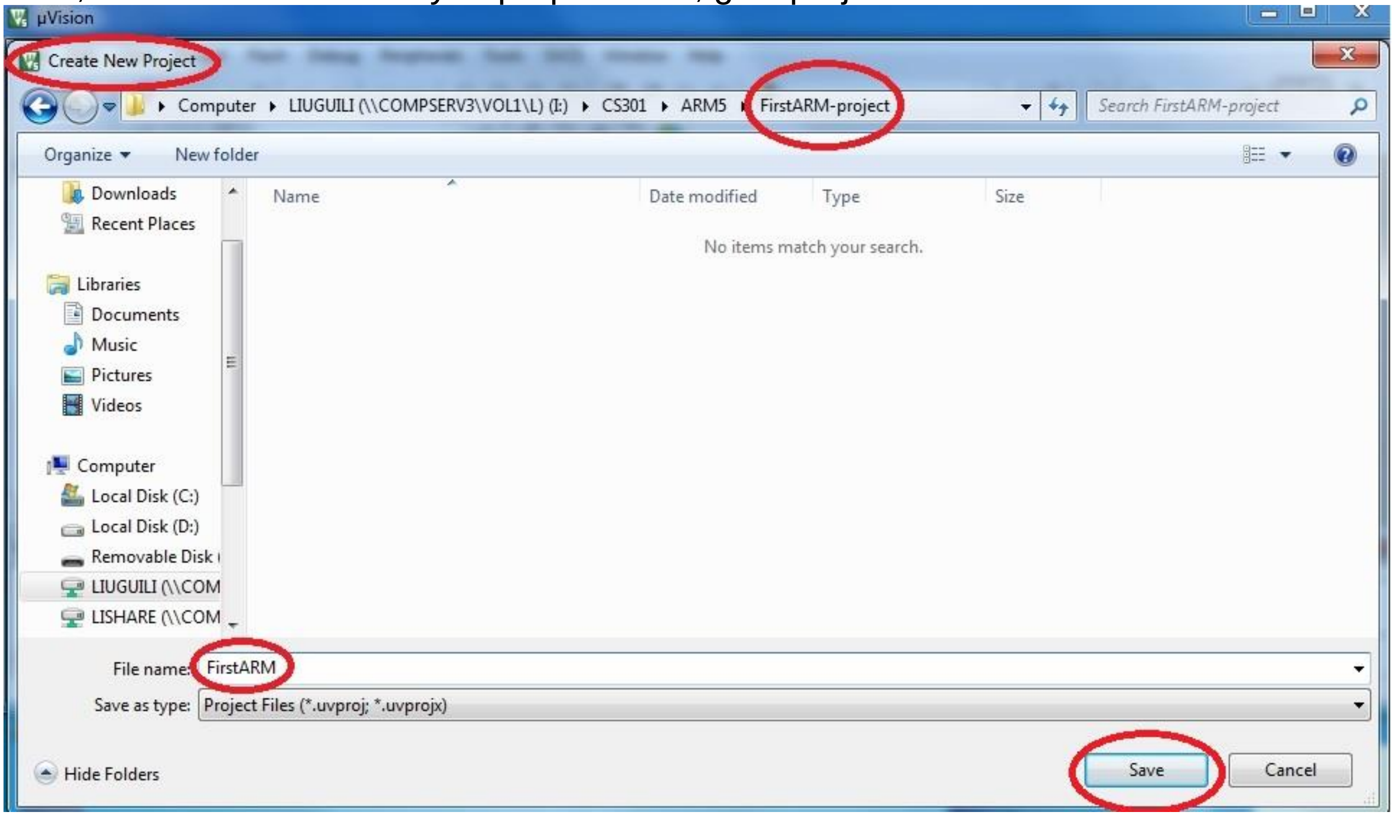


Create a project

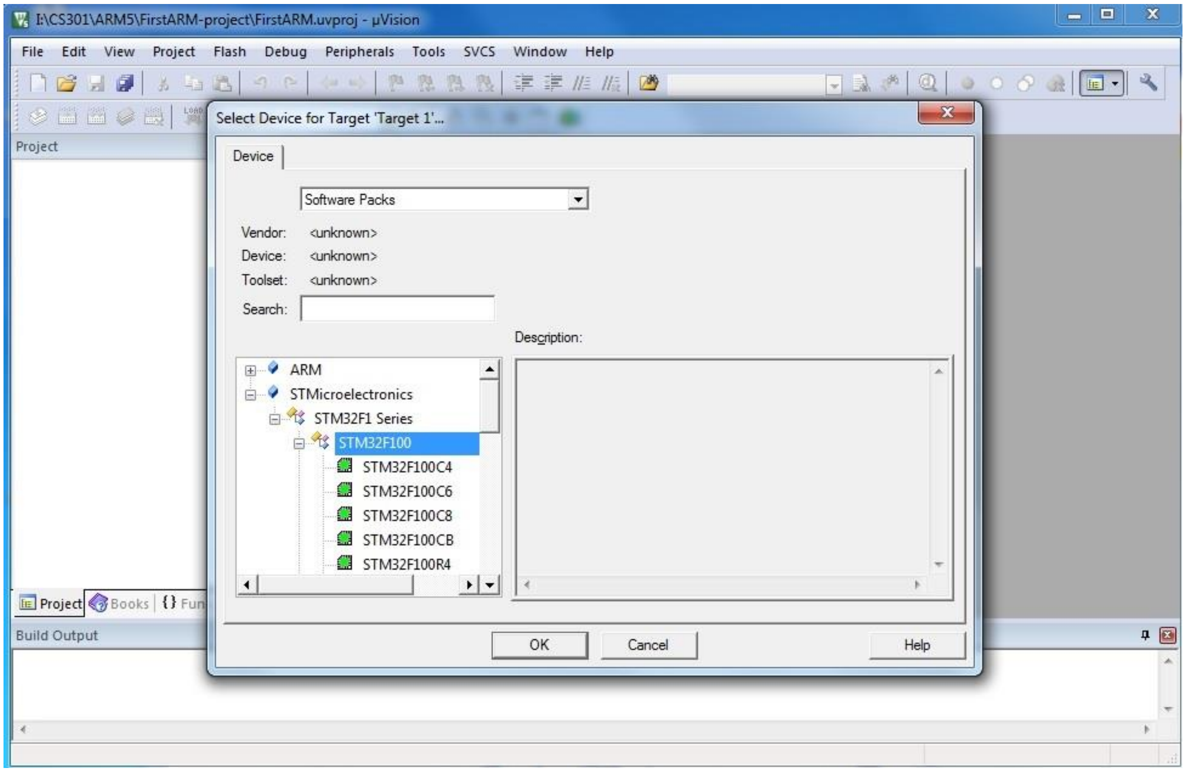
Let's create our first ARM **uVision5** project now. To create a project, click on the "Project" menu from the **uVision5** screen and select "New uVision Project...".



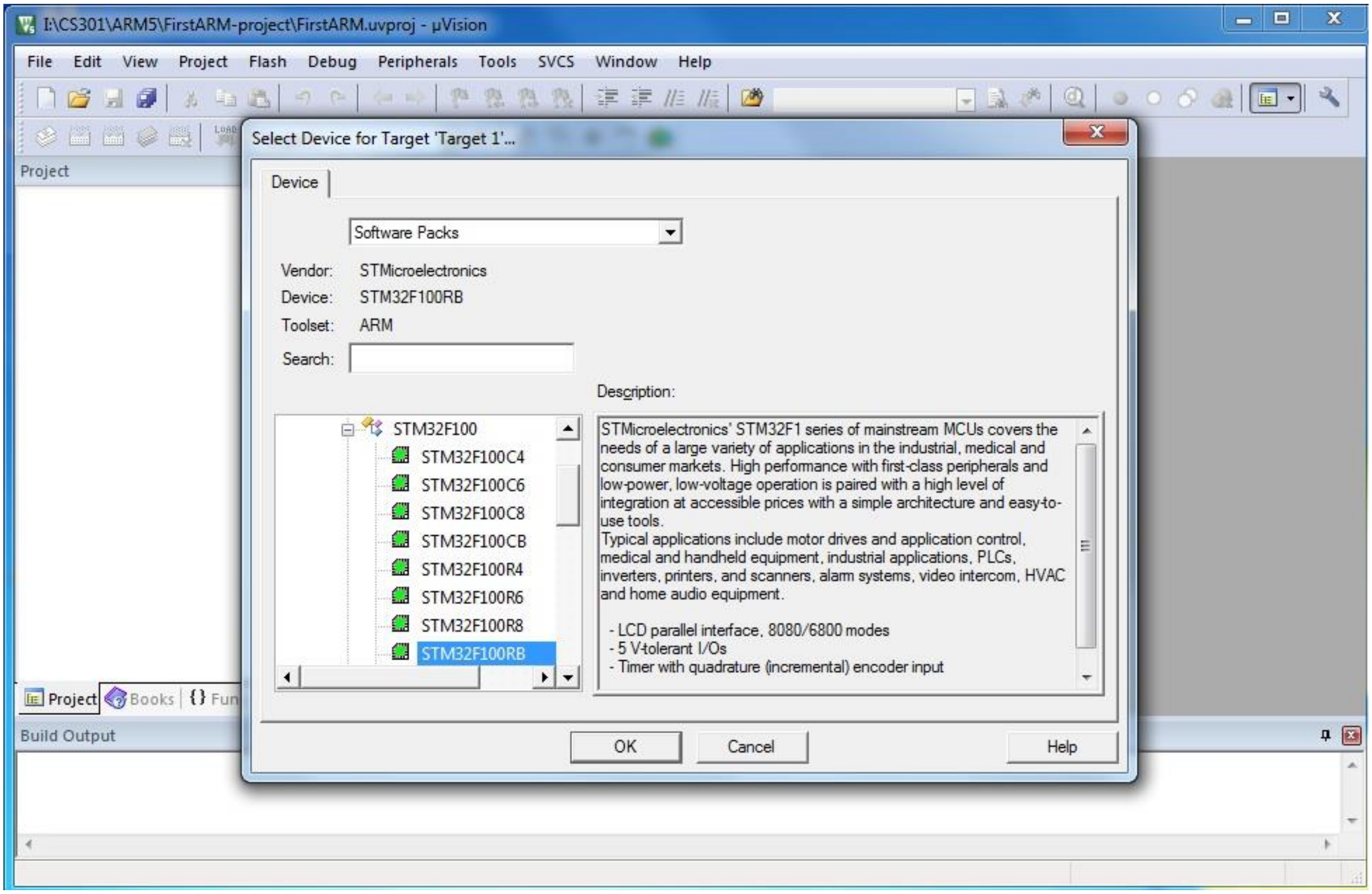
Then, select the folder that you prepared for, give project a name and save it.



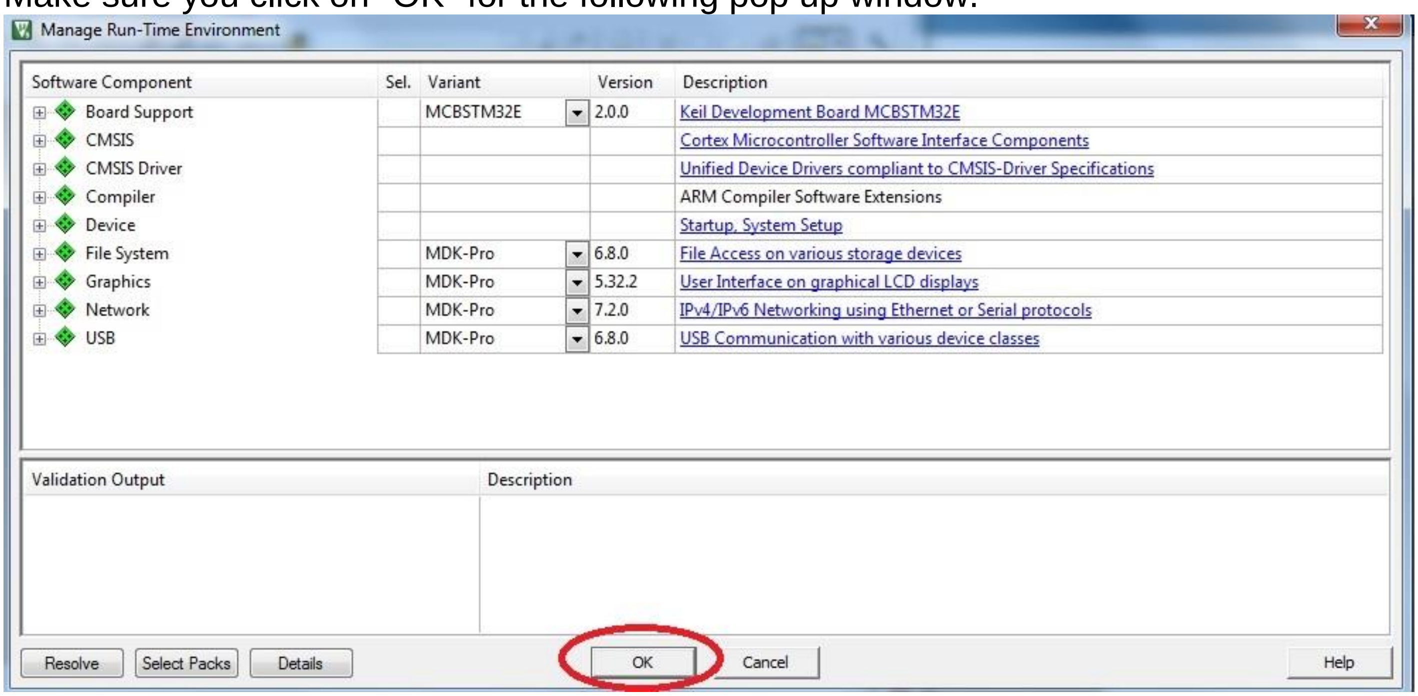
From the "Select Device for Target" window, select "STMicroelectronics" and then "STM32F1 Series".



click on "+" beside "STM32F100" and then select "STM32F100RB" and click on "OK".

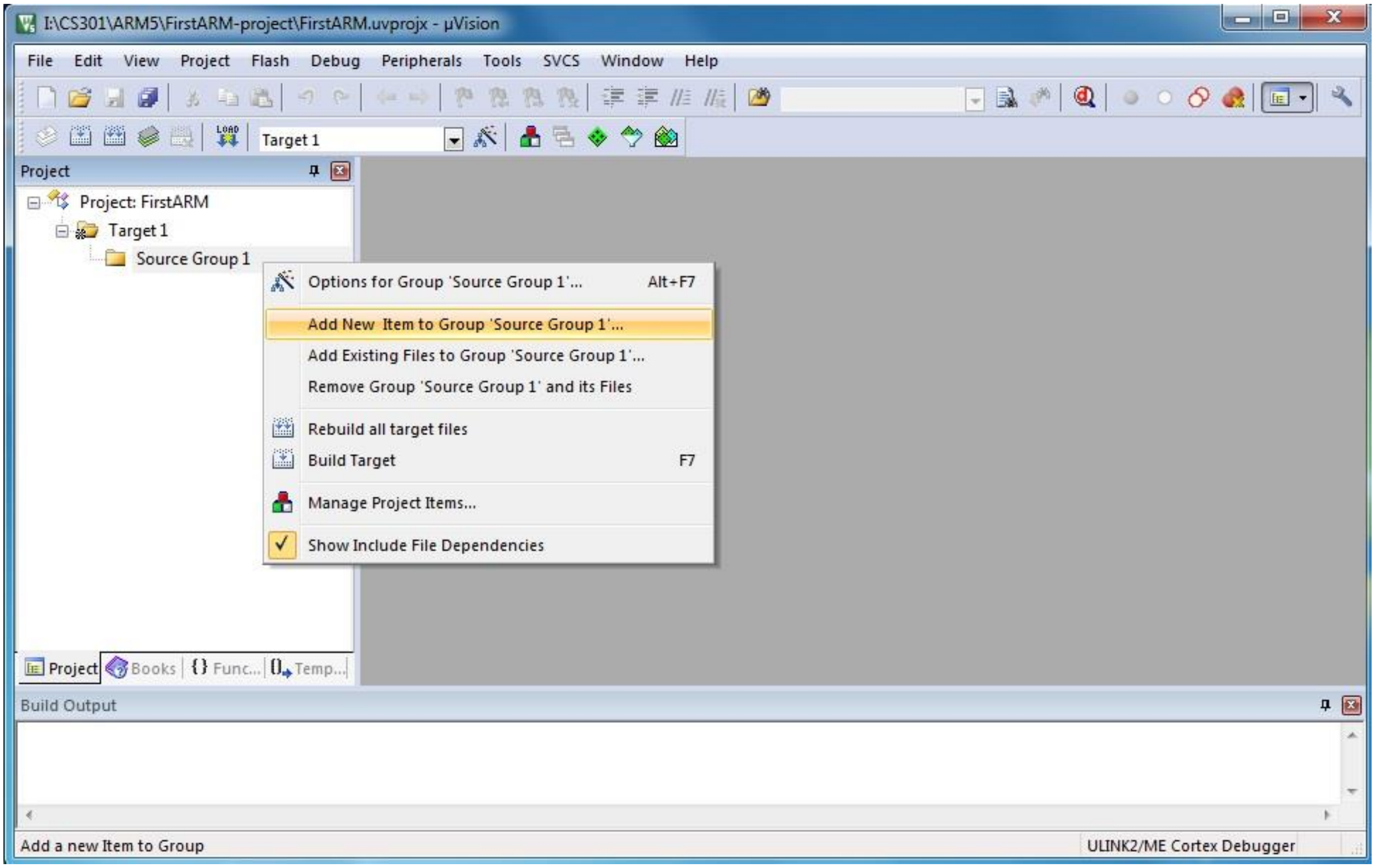


Make sure you click on "OK" for the following pop up window.

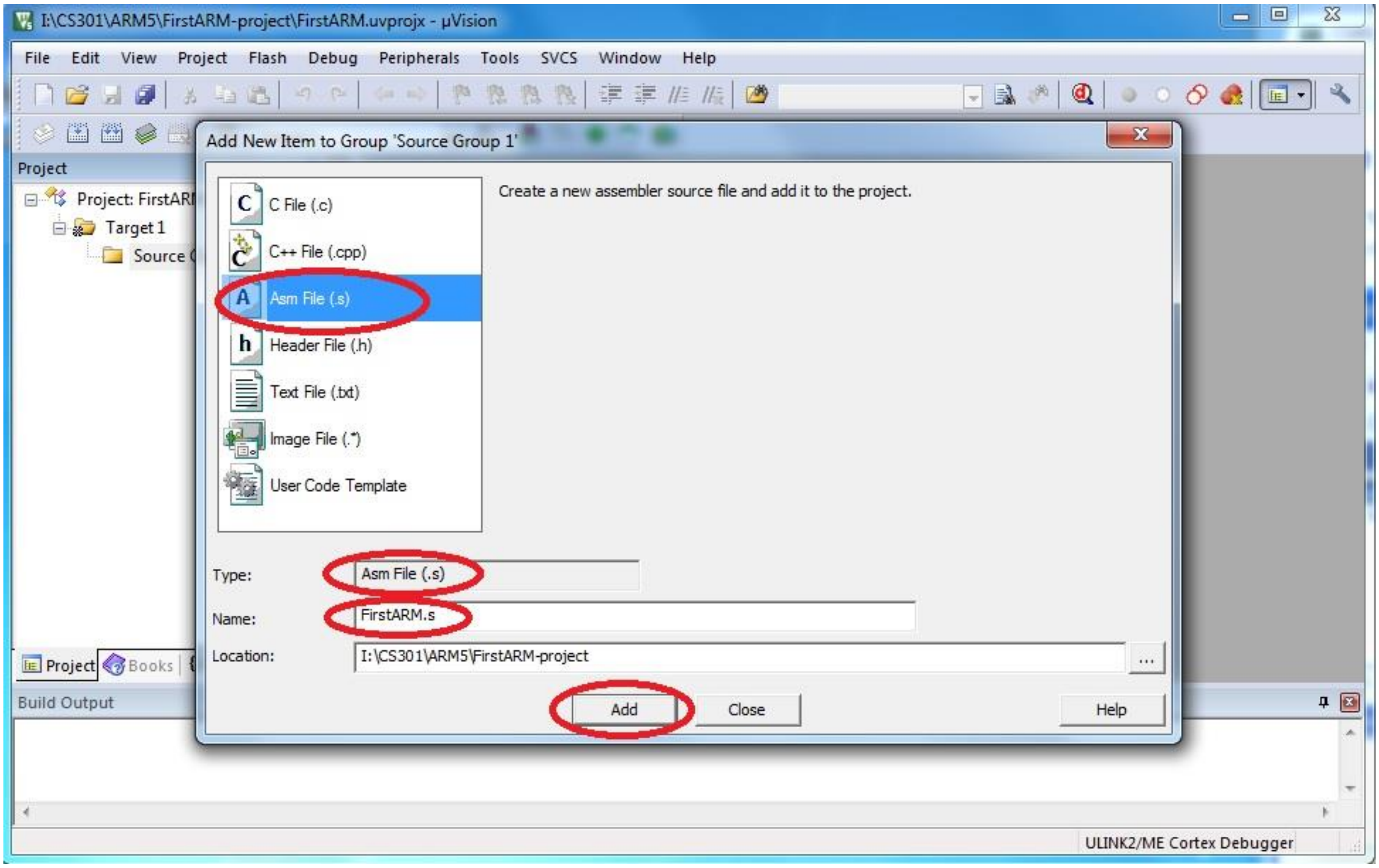


Create Source File and Add Source File to the Project

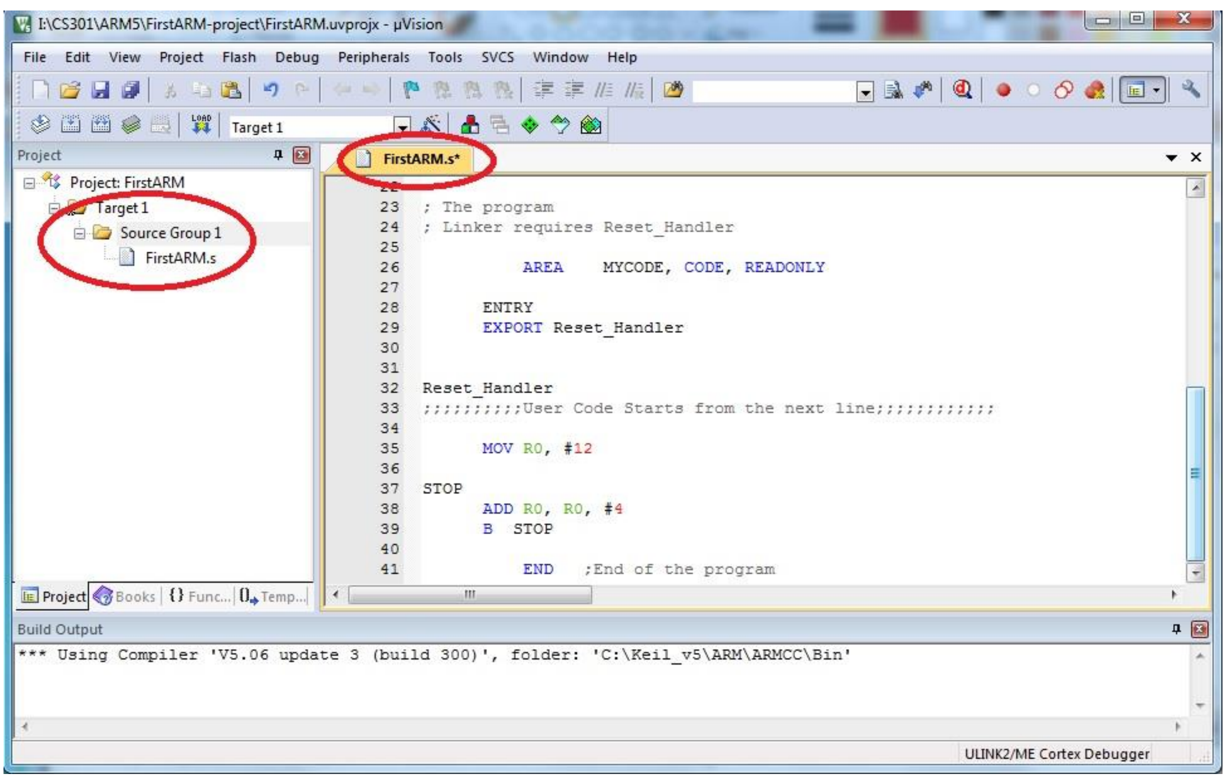
Right click on "Source Group 1" and then select "Add New Item to Group 'Source Group 1'...".



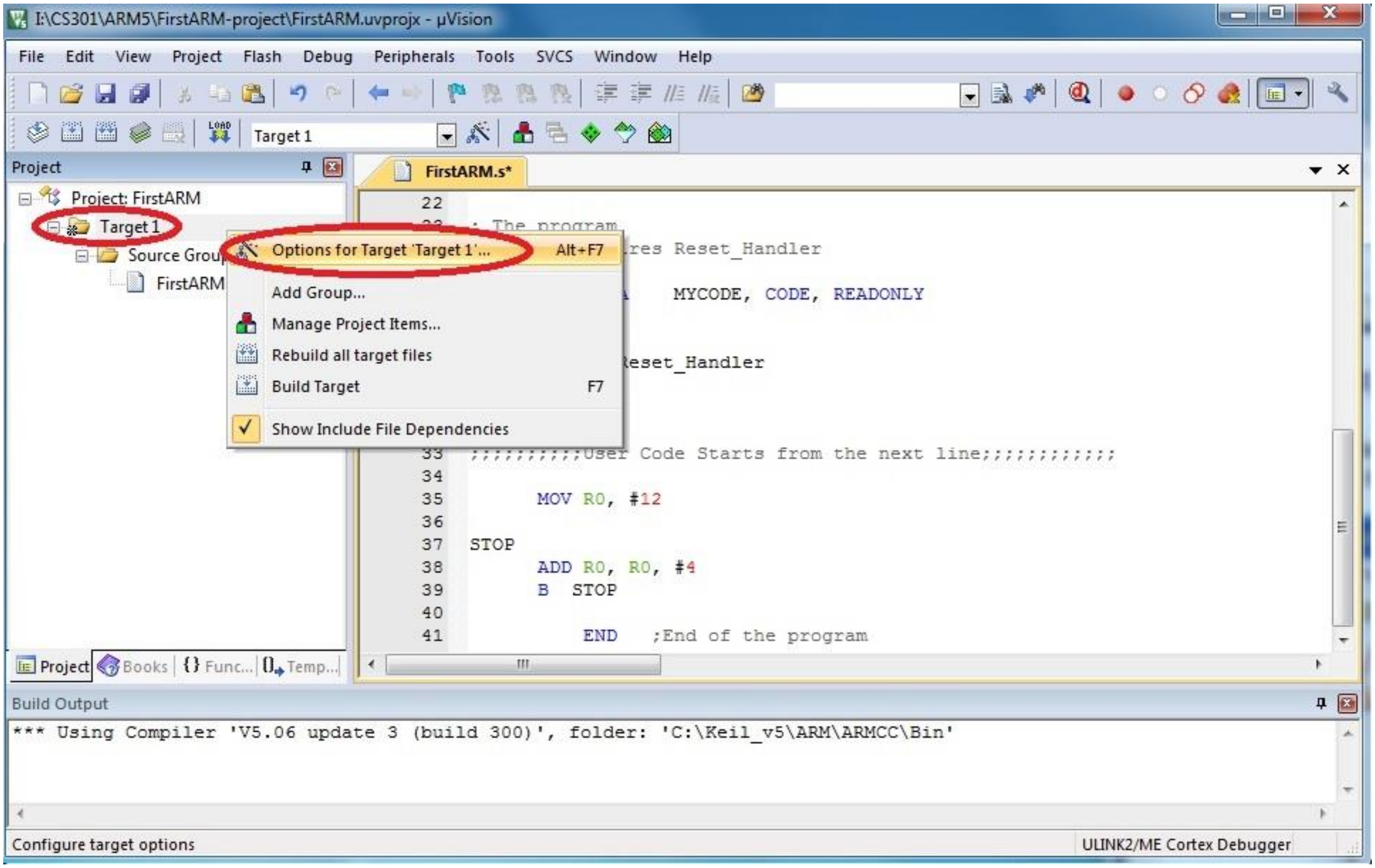
You will see the following window and make the suggested selections to proceed.



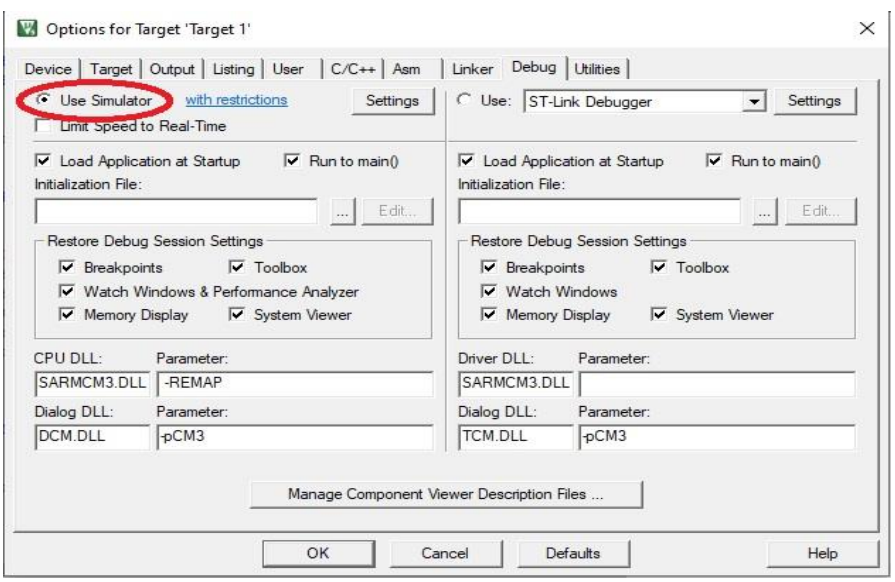
You will see the "FirstARM.s*" text edit window. That is the place you will write your ARM Assembly language program. For a test, you can copy and paste the example program into this window. You can click on the "save" buttom to save your project.



You can right click on "Target 1" and then select "options for Target 'Target 1'..." the same as the following screen.

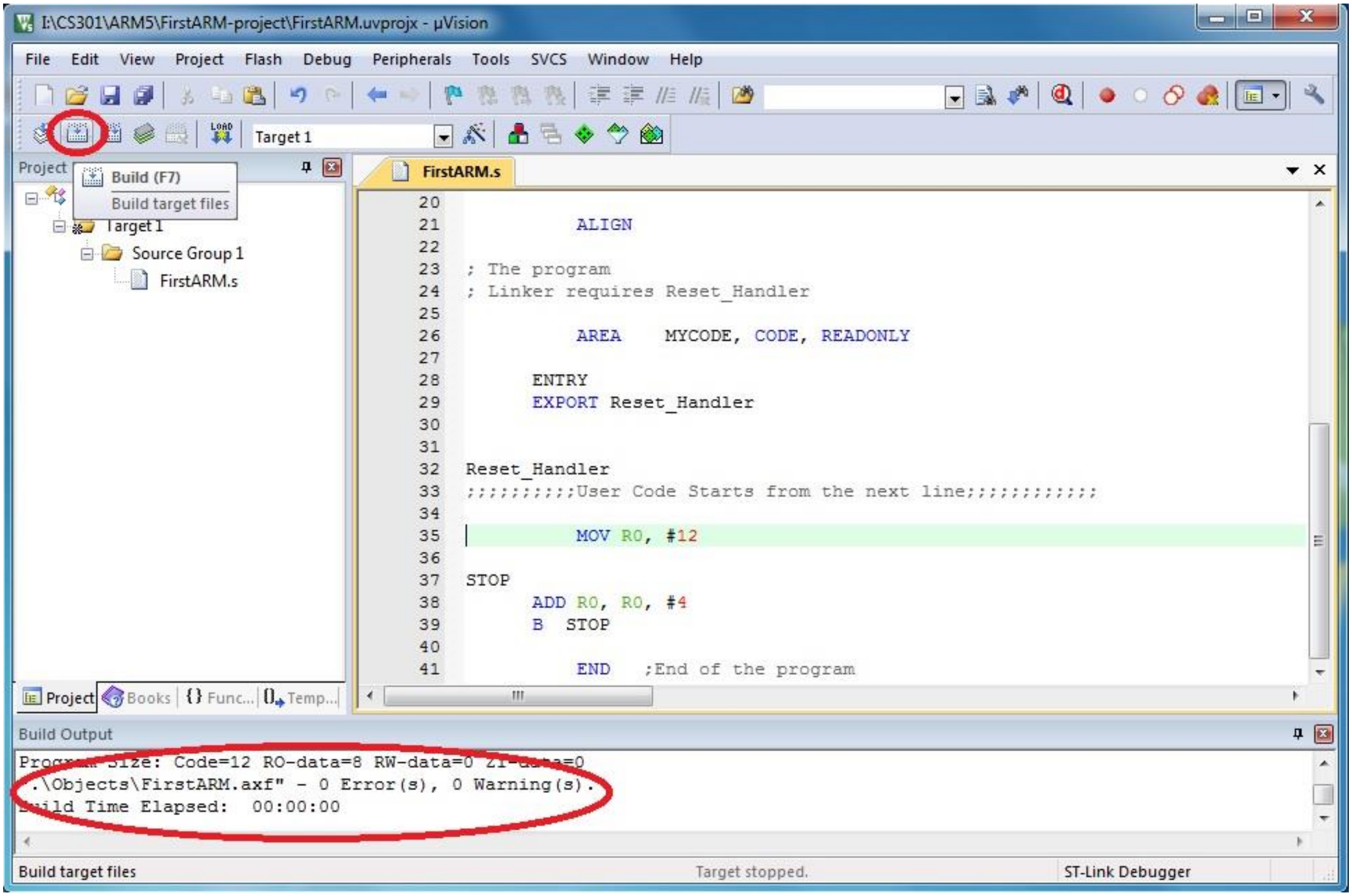


Please click on "Debug" and then select "Use Simulator".



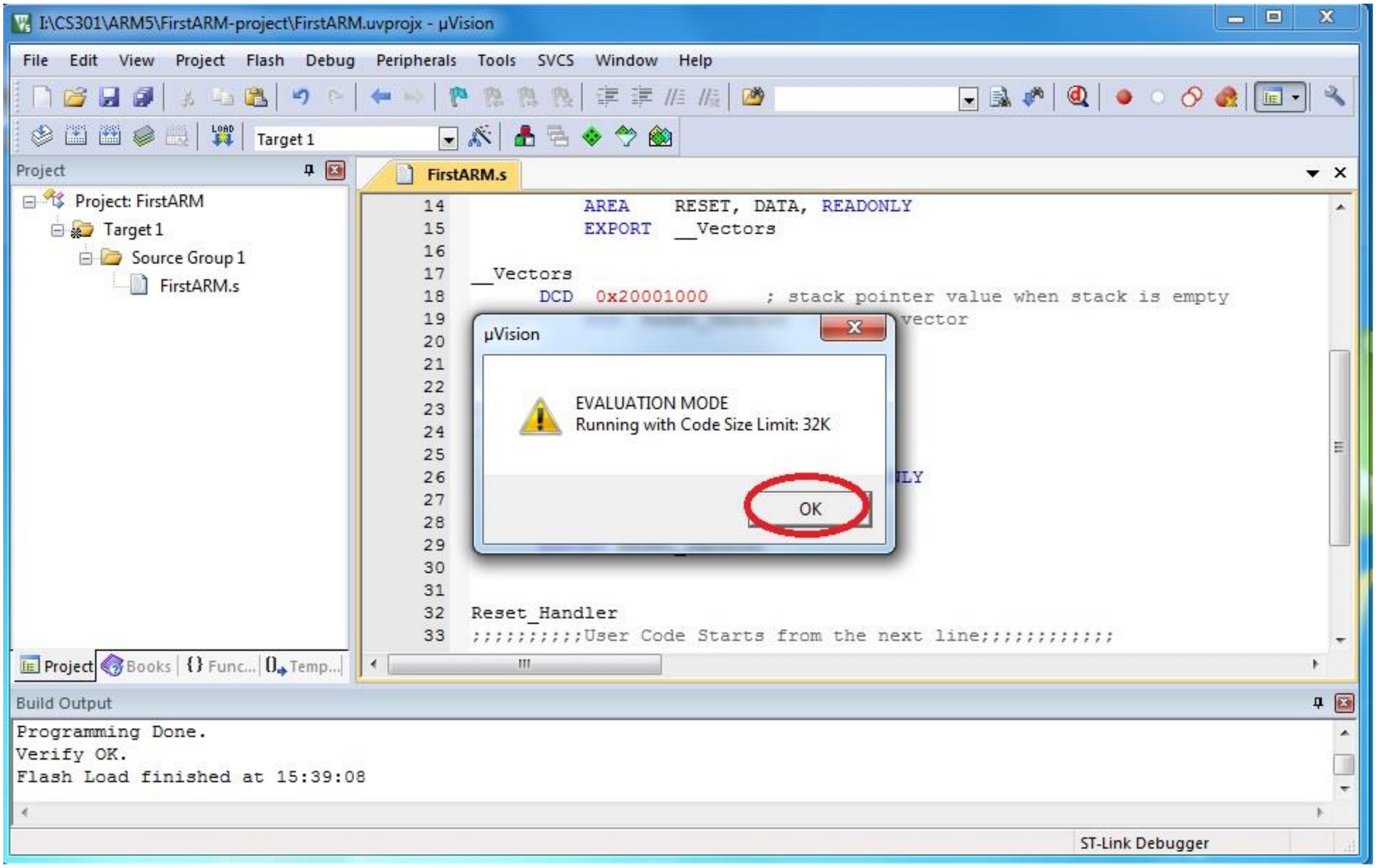
Build your project

Click on the "Build" button or from the "Project" menu, you will see the following screen.



Run the program in your project

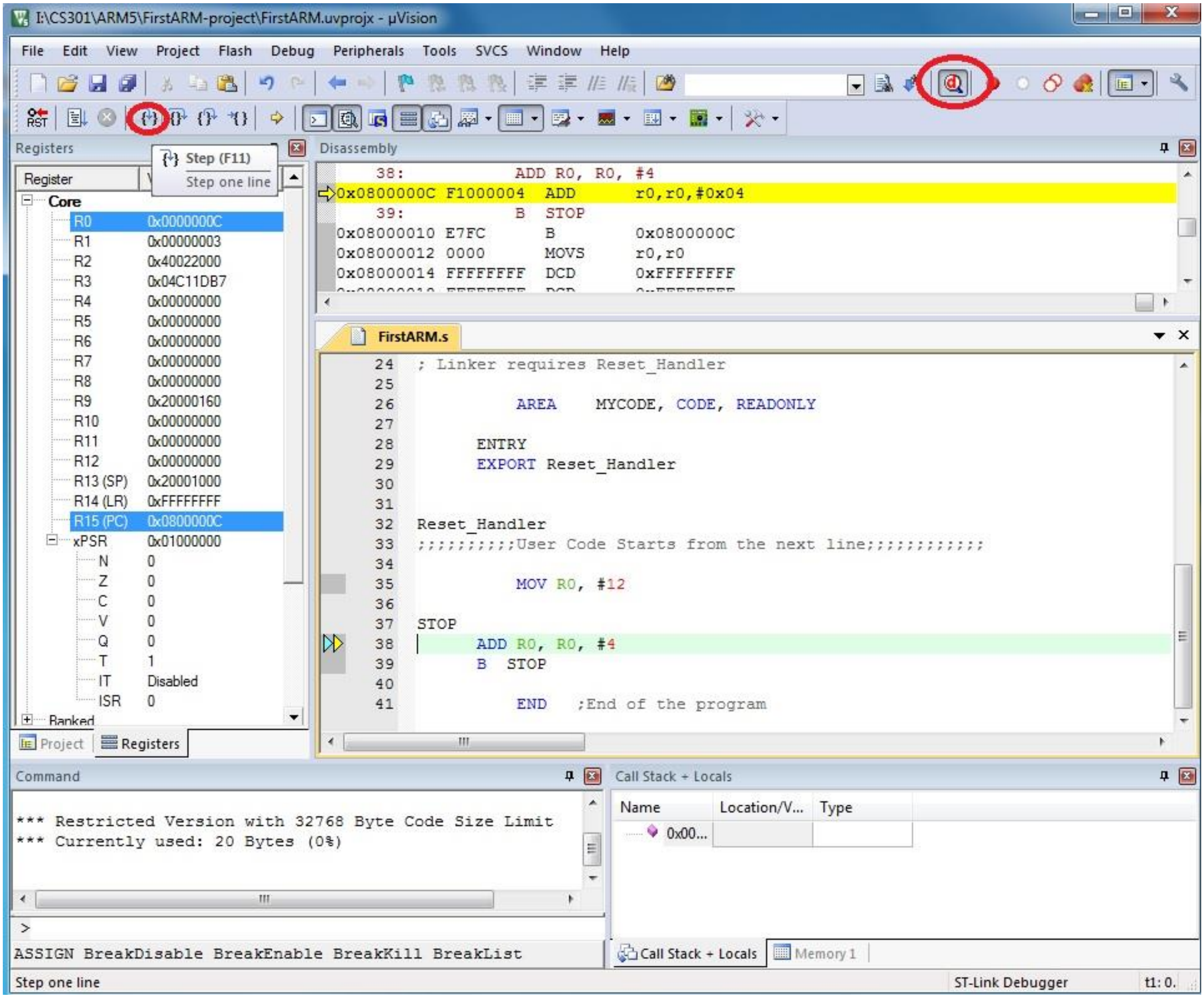
When the assembler is happy with the program, we can run the program by selecting "Start/Stop Debug Session" from the "Debug" menu or clicking on the debug button.



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

Open your uVision5 to full screen to have a better and complete view. The left hand side window shows you the registers and the right side window shows the program code. There are some other windows open. You may adjust the size of them to see better.

Run the program step by step, you can observe the change of the values in the registers.



Click on the "Start/Stop Debug Session" from the "Debug" menu or click on the debug button to stop executing the program.

We will analyze the program and see how it works.

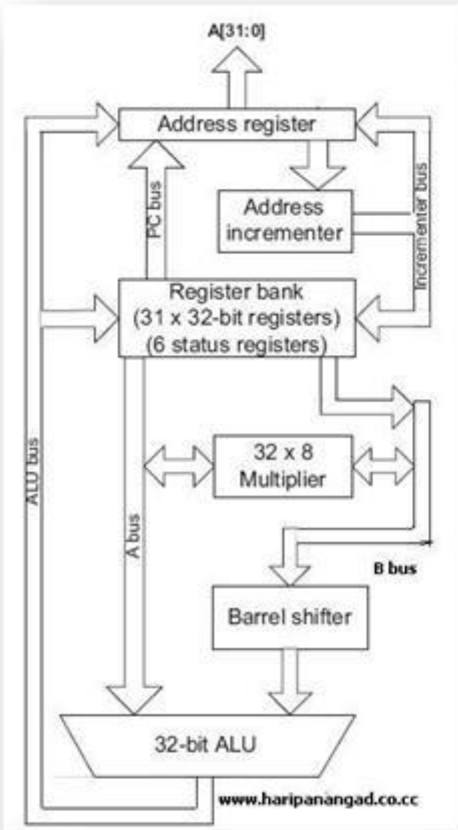
It works with both the simulated target and the real circuit board STM32VLDISCOVERY Board.

We will demonstrate it in the lab for you.

ARM Architecture

ARM processors are mainly used for low-power and low cost applications such as mobile phones, communication modems, automotive engine management systems, and hand-held digital systems.

Here is a diagram of the ARM architecture for your reference.




```
ARM Architecture is an Enhanced RISC Architecture.
It has large uniform Register file and uses Load Store Architecture.
   i.e. operations operate on registers and not in memory locations.

ARM Architecture instructions are of uniform and fixed length.
It is a 32 bit processor.
It also has 16 bit variant called THUMB.
   i.e. it can be used as 32 bit and as 16 bit processor.
```

ARM cores are licensed to partners/manufacturers so as to develop and fabricate new microcontrollers around same processor cores. A microcontroller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals.

The ARM Cortex-M3 microcontroller will be used in the lab with the STM32VLDISCOVERY board. For more information, visit **STM32VLDISCOVERY Board**.

ARM Registers

Here is the Register Organization in ARM State.

ARM-state general registers and program counter

	System and User	FIQ	Supervisor	Abort	IRQ	Undefined
General registers	r0	r0	r0	r0	r0	r0
	r1	r1	r1	r1	r1	r1
	r2	r2	r2	r2	r2	r2
	r3	r3	r3	r3	r3	r3
	r4	r4	r4	r4	r4	r4
	r5	r5	r5	r5	r5	r5
	r6	r6	r6	r6	r6	r6
	r7	r7	r7	r7	r7	r7
	r8	r8_fiq	r8	r8	r8	r8
	r9	r9_fiq	r9	r9	r9	r9
	r10	r10_fiq	r10	r10	r10	r10
	r11	r11_fiq	r11	r11	r11	r11
	r12	r12_fiq	r12	r12	r12	r12
	r13	r13_fiq	r13_svc	r13_abt	r13_irq	r13_und
	r14	r14_fiq	r14_svc	r14_abt	r14_irq	r14_und
Program counter	r15 (PC)	r15 (PC)	r15 (PC)	r15 (PC)	r15 (PC)	r15 (PC)
Program status registers	CPSR	CPSR	CPSR	CPSR	CPSR	CPSR
		SPSR_fiq	SPSR_svc	SPSR_abt	SPSR_irq	SPSR_und

ARM-state program status registers

◺ = *banked register*

Here is the Register Organization in THUMB State.

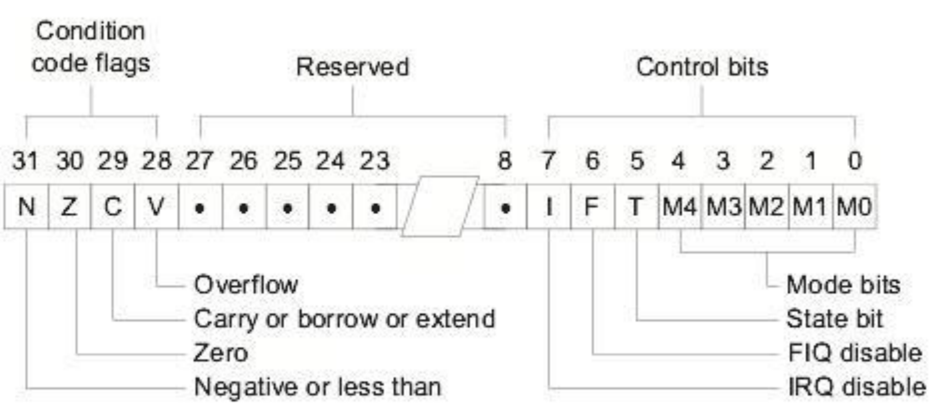
Thumb state general registers and program counter

System and User	FIQ	Supervisor	Abort	IRQ	Undefined
r0	r0	r0	r0	r0	r0
r1	r1	r1	r1	r1	r1
r2	r2	r2	r2	r2	r2
r3	r3	r3	r3	r3	r3
r4	r4	r4	r4	r4	r4
r5	r5	r5	r5	r5	r5
r6	r6	r6	r6	r6	r6
r7	r7	r7	r7	r7	r7
SP	SP_fiq	SP_svc	SP_abt	SP_irq	SP_und
LR	LR_fiq	LR_svc	LR_abt	LR_irq	LR_und
PC	PC	PC	PC	PC	PC
CPSR	CPSR	CPSR	CPSR	CPSR	CPSR
	SPSR_fiq	SPSR_svc	SPSR_abt	SPSR_irq	SPSR_und

Thumb state program status registers

= *banked register*

Here is the Program Status Register Format:




```
In ARM State, there are 16 general purpose registers;
              one or more status registers are accessible at any one time.

In  THUMB State, there are 8 general purpose registers;
                 PC, SP, LR and CPSR are accessible.

Conditonion code flags in CPSR:
N - Negative or less than flag
Z - Zero flag
C - Carry or bowrrow or extended flag
V - Overflow flag
```

ARM Instructions

Here are a few sample ARM Instructions for you to test out for this lab:

```
MOV     R2, #0x76
; Move the 8-bit Hex number 76 to the low portion of R2

MOV     R2, #0x7654
; Move the 16-bit Hex number 7654 to the low portion of R2

MOVT    R2, #0x7654
; Move the 16-bit Hex number 7654 to the high portion of R2

MOV32   R2, #0x76543210        ; Move the 32-bit Hex number 76543210 to the R2

LDR     R2, = 0x76543210       ; Load R2 with the 32-bit Hex number 76543210

ADD     R1, R2, R3             ; R1 = R2 + R3

ADDS    R1, R2, R3             ; R1 = R2 + R3, and FLAGs are updated

SUB     R1, R2, R3             ; R1 = R2 - R3

SUBS    R1, R2, R3             ; R1 = R2 - R3, and FLAGs are updated

B       LABEL                  ; Branch to LABEL
```

The entire list of the Instructions can be found in the **Cortex-M3 Devices Generic User Guide.**
OR see The Cortex-M3 Instruction Set in **Cortex-M3 Devices Generic User Guide**, in Chapter 3: The Cortex-M3 Instruction Set.

Lab work:

Write your first ARM assembly language program **MyFirstARM.s**.
The program will execute the following instructions. You will run the program step by step, observe and answer the question after each statement.

```
MOV     R2,     #0x01           ; R2 = ?
MOV     R3,     #0x02           ; R3 = ?

;Other examples to move immediate values
MOV     R5,     #0x3210         ; R5 = ?

MOVT    R5,     #0x7654         ; R5 = ?

MOV32   R6,     #0x87654321     ; R6 = ?

LDR     R7,     = 0x87654321     ; R7 = ?


ADD     R1,R2,R3                ; R1 = ?
MOV32    R3,    #0xFFFFFFFF     ; R3 = ?
ADDS    R1,R2,R3                ; R1 = ?
                                ; specify Condition Code updates

SUBS    R1,R2,R3                ; R1 = ?
                                ; specify Condition Code updates

MOV     R4,     #0xFFFFFFFF     ; R4 = ?
ADD     R1,R2,R4                ; R1 = ?
                        ; How did that operation affect the flags in CPSR?

ADDS    R1,R2,R4        ; R1 = ?
                        ; Please specify Condition Code updates
                        ; and now what happened to the flags in the CPSR?


MOV     R2,     #0x00000002     ; R2 = ?
ADDS    R1,R2,R4                ; R1 = ?
                                ; again, what happened to the flags?

MOV     R2,     #0x00000001     ; R2 = ?
MOV     R3,     #0x00000002     ; R3 = ?
ADDS    R1,R2,R3                ; R1 = ?
                                ; Add some small numbers again
                                ; and check the flags again......

; Add numbers that will create an overflow
MOV      R2,    #0x7FFFFFFF     ; R2 = ?
MOV     R3,     #0x7FFFFFFF     ; R3 = ?

ADDS     R1,R2,R3               ; R1 = ?
                                ; Check the flags in the CPSR?
```

You will hand in the following:

1. The screenshot of the program successfully built in Keil uVision.
2. The source code in the file **MyFirstARM.s** with the answers.