

# MPSL2019

## Lab0

# Lab hardware

# 實驗硬體

# STM32 Nucleo Board L476RG

- STM32L476RG
- An ARM Cortex-M4 development board
- Built in a ST-LINK as debugger
- Arduino pin compatible
- One user button
- One LED



# Hardware Block

Figure 2. Hardware block diagram

ST-LINK part

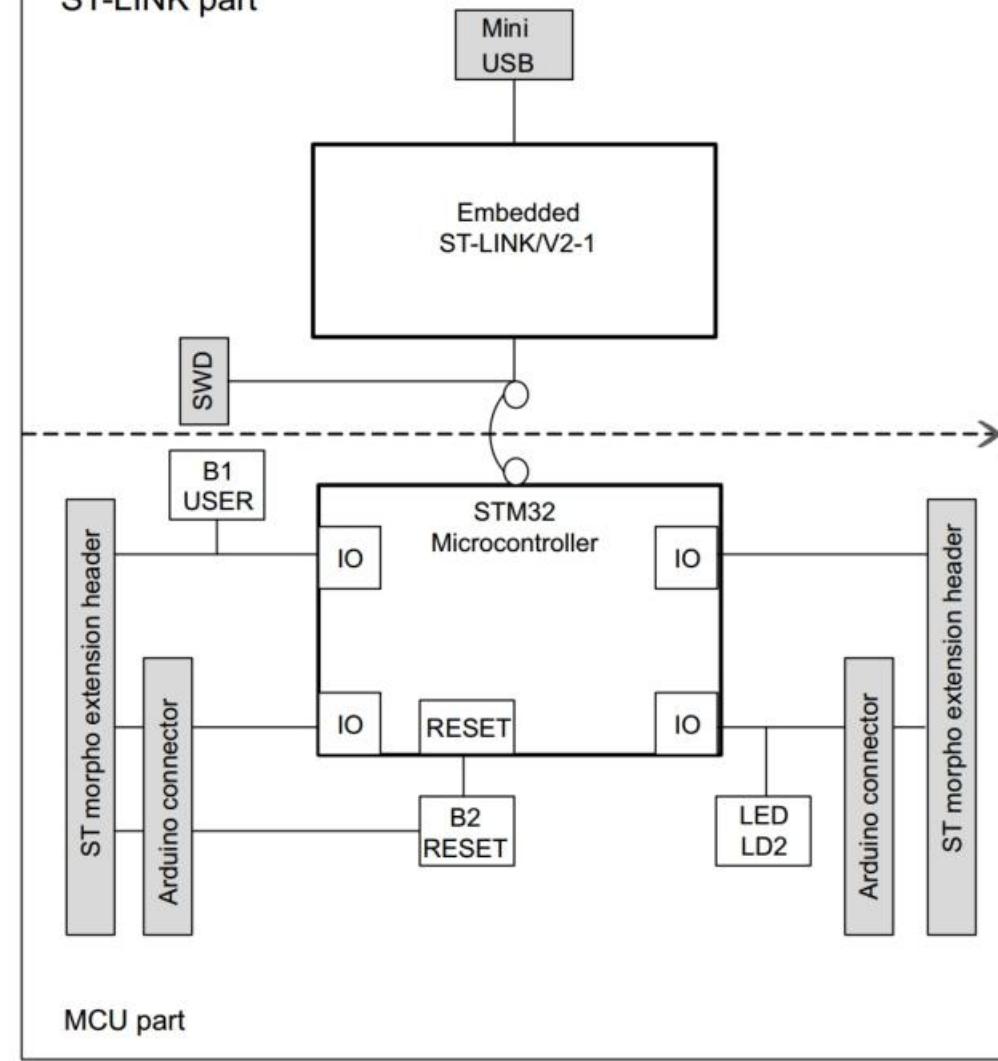
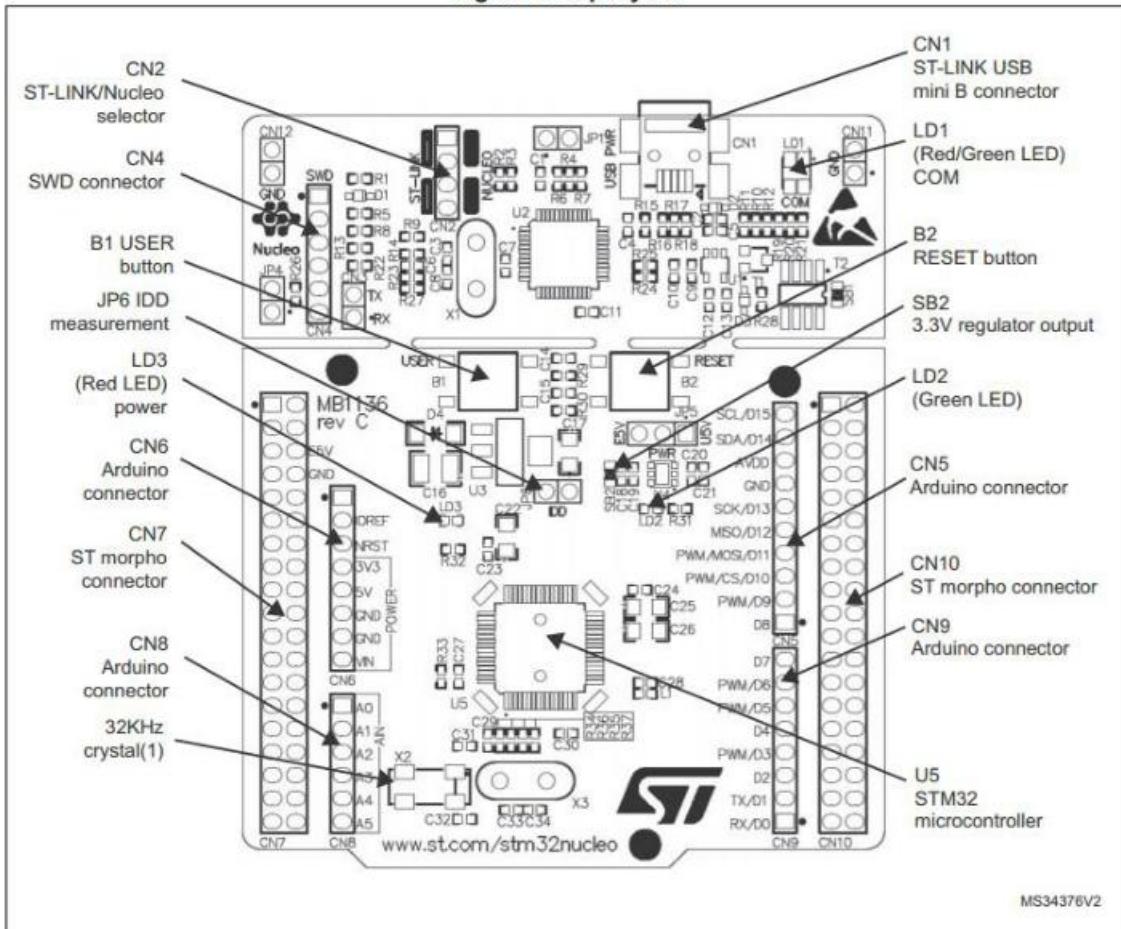
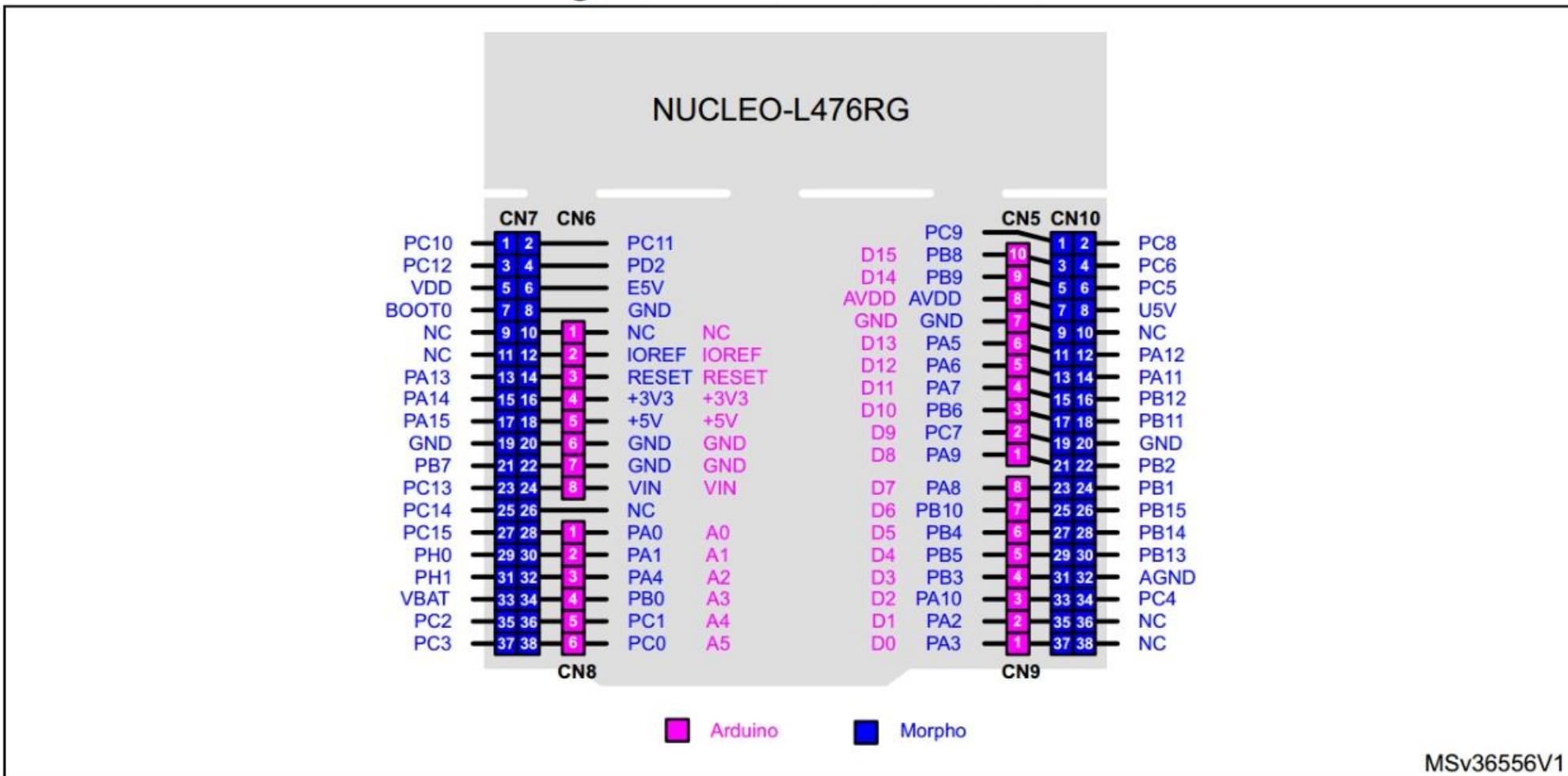


Figure 3. Top layout



# Pin Map

Figure 22. NUCLEO-L476RG



# Lab software

# 實驗軟體

# Development Environment

- We use SW4STM32 which is a **eclipse based STM32 IDE tool**
  - STM32 Devices database and libraries
  - Source code editor
  - Linker script generator
  - Building tools (GCC-based cross compiler, assembler, linker)
  - Debugging tools (OpenOCD, GDB)
  - Flash programing tools
  - <http://www.openstm32.org/HomePage>

# SW4STM32 IDE

- [Download Page](#)
- Maybe need JRE7 or Later
- Windows 7 or Windows 10
  - [http://www.ac6-tools.com/downloads/SW4STM32/install\\_sw4stm32\\_win\\_64bits-latest.exe](http://www.ac6-tools.com/downloads/SW4STM32/install_sw4stm32_win_64bits-latest.exe)
- Linux
  - [http://www.ac6-tools.com/downloads/SW4STM32/install\\_sw4stm32\\_linux\\_64bits-latest.run](http://www.ac6-tools.com/downloads/SW4STM32/install_sw4stm32_linux_64bits-latest.run)
  - Dependence
    - Need some library
      - libc6:i386 lib32ncurses5
- MacOS
  - [http://www.ac6-tools.com/downloads/SW4STM32/install\\_sw4stm32\\_macos\\_64bits-latest.run](http://www.ac6-tools.com/downloads/SW4STM32/install_sw4stm32_macos_64bits-latest.run)

# Install note for Linux & MacOS

- Open a terminal session to Installer file and Run chmod +x For instance

e.g. \$ chmod +x install\_sw4stm32\_linux\_64bits-latest.run

e.g. \$ chmod +x install\_sw4stm32\_macos\_64bits-latest.run

- Execute the installer by running the installation file.

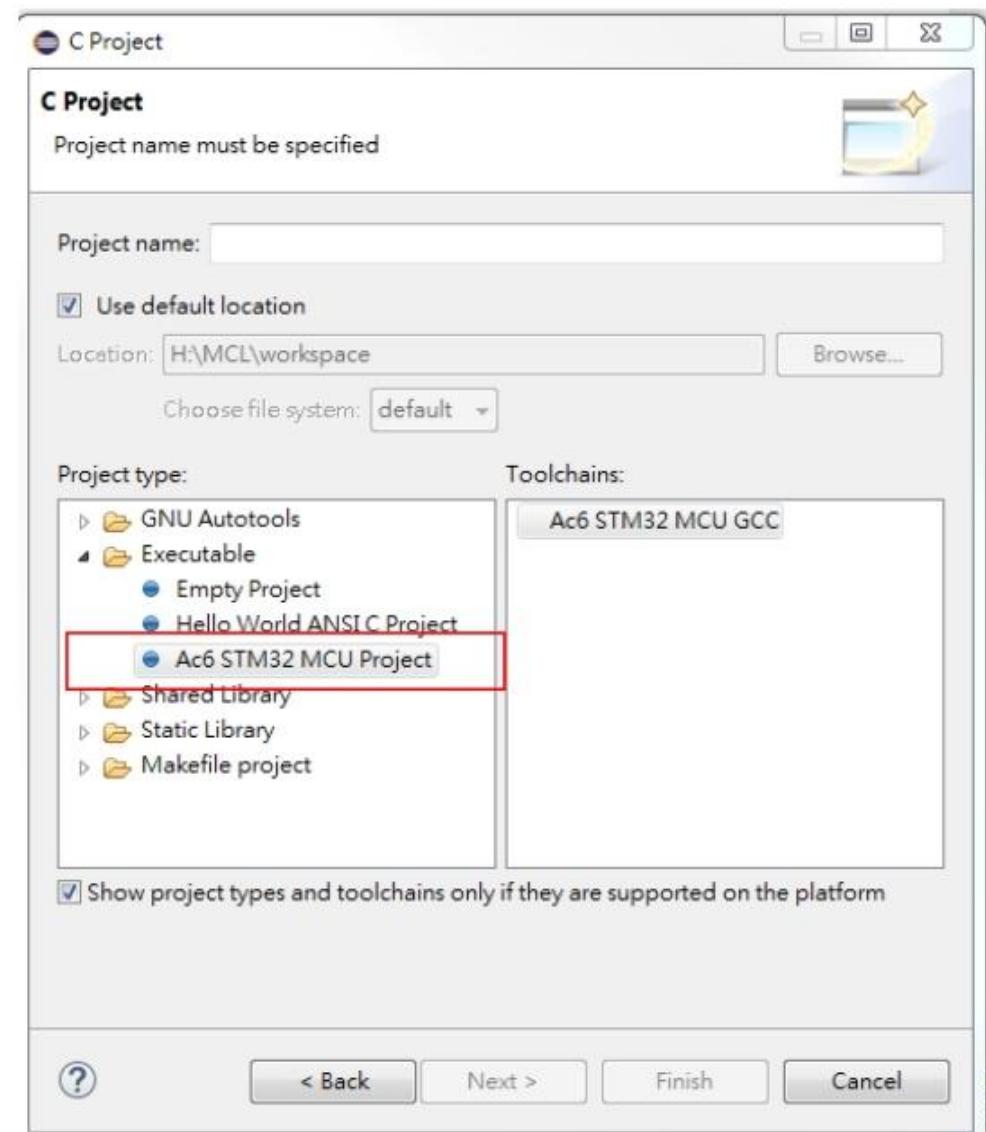
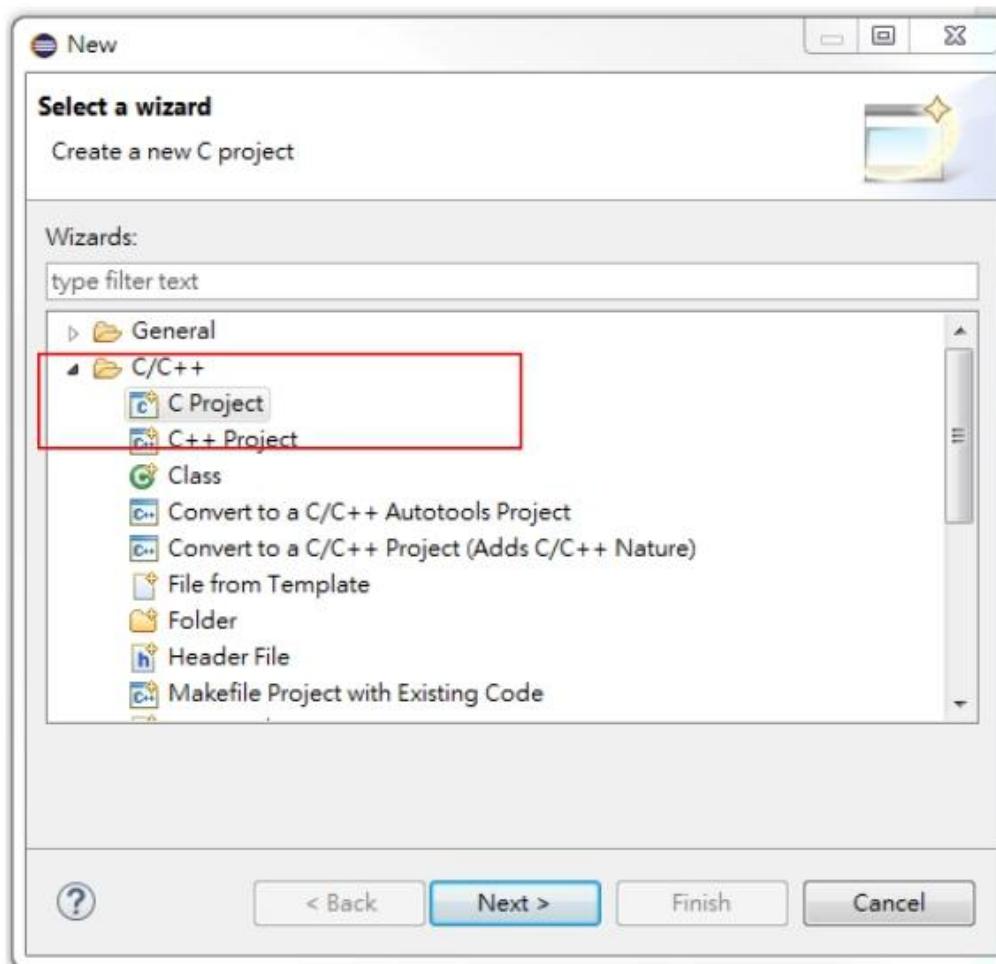
e.g. ./install\_sw4stm32\_linux\_64bits-latest.run

e.g. ./install\_sw4stm32\_macos\_64bits-latest.run

# **SW4STM32 Getting Started Guide**

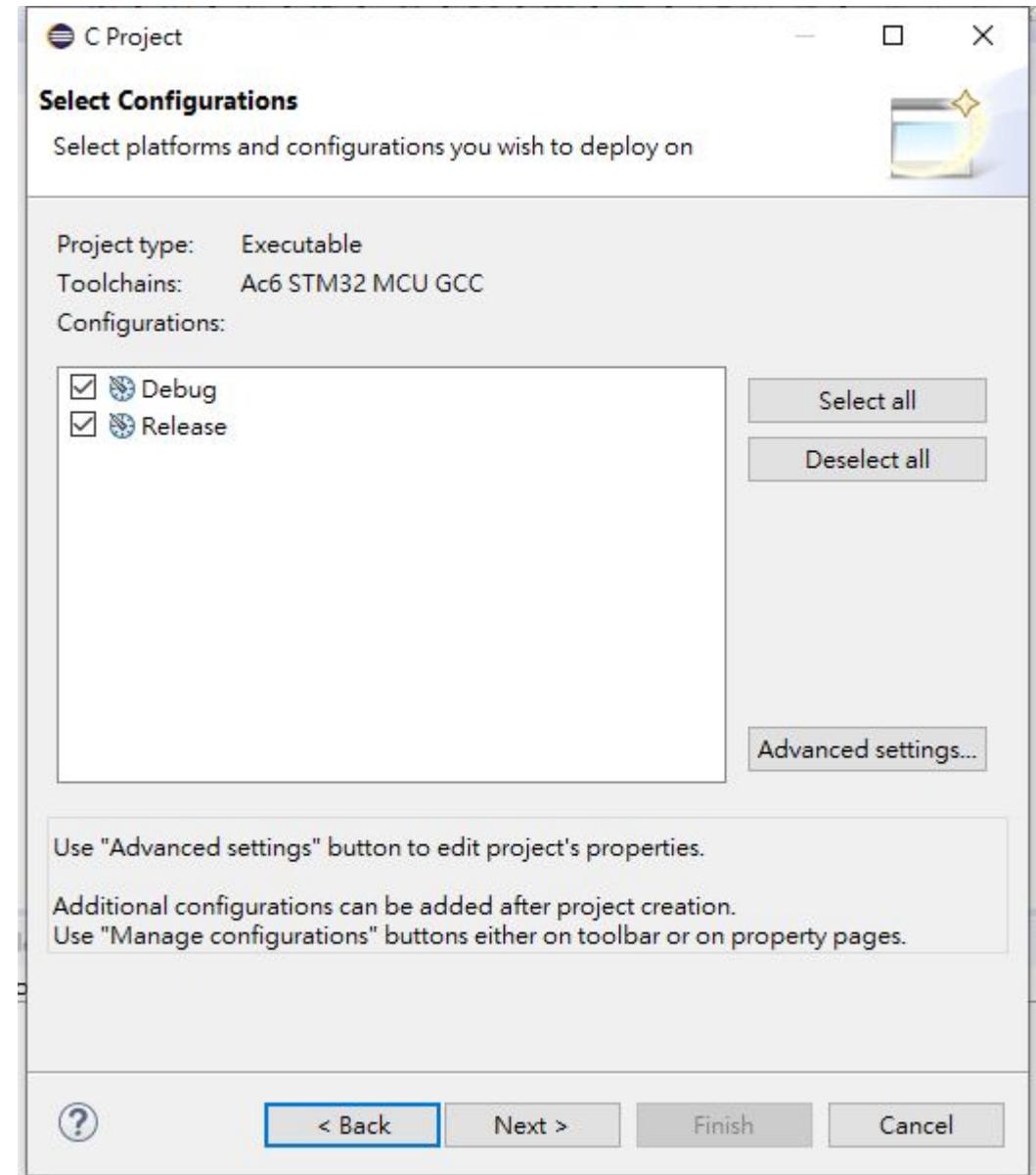
# Create Project

File -> New -> Other



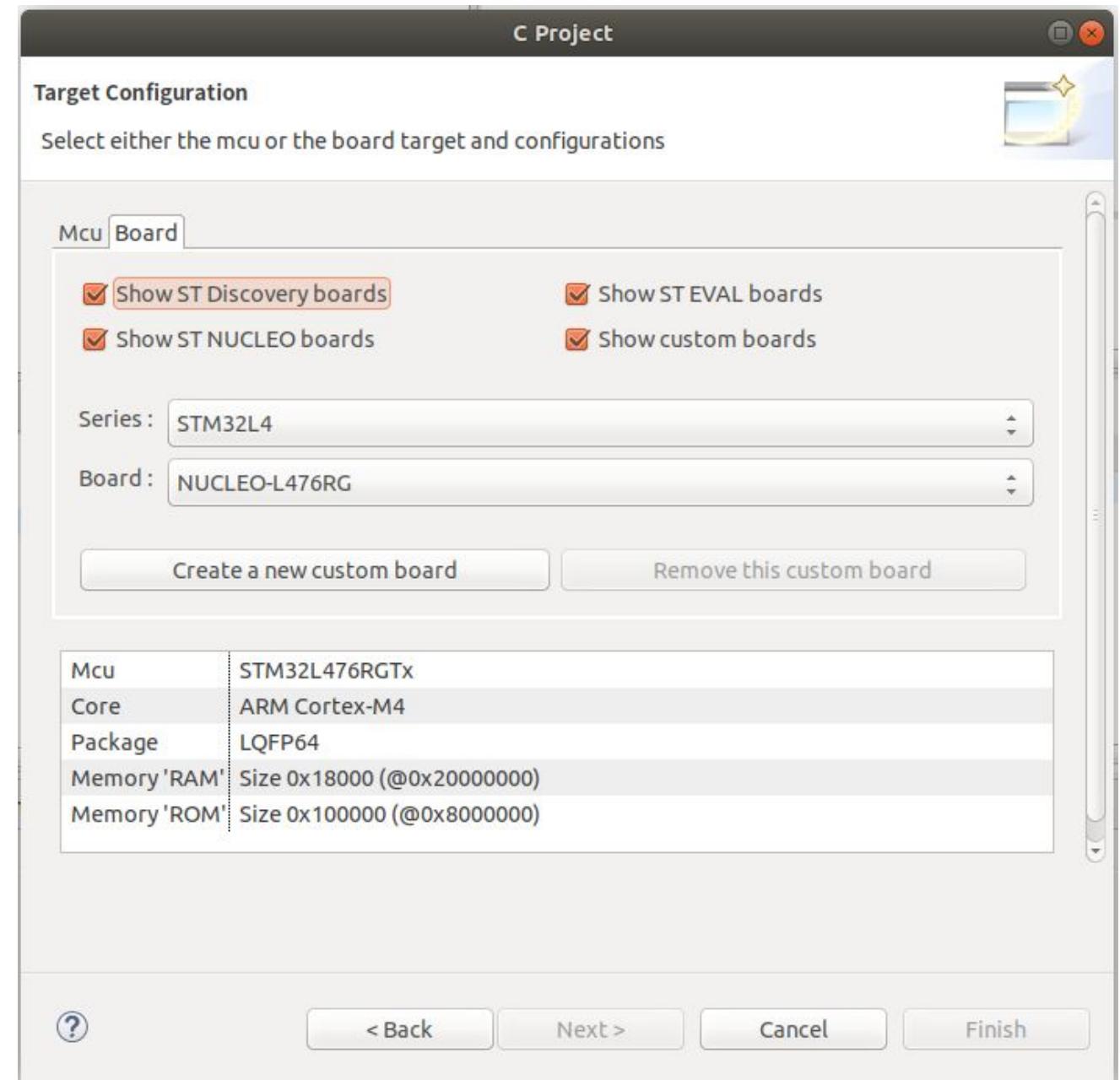
# Create Project (cont.)

Next

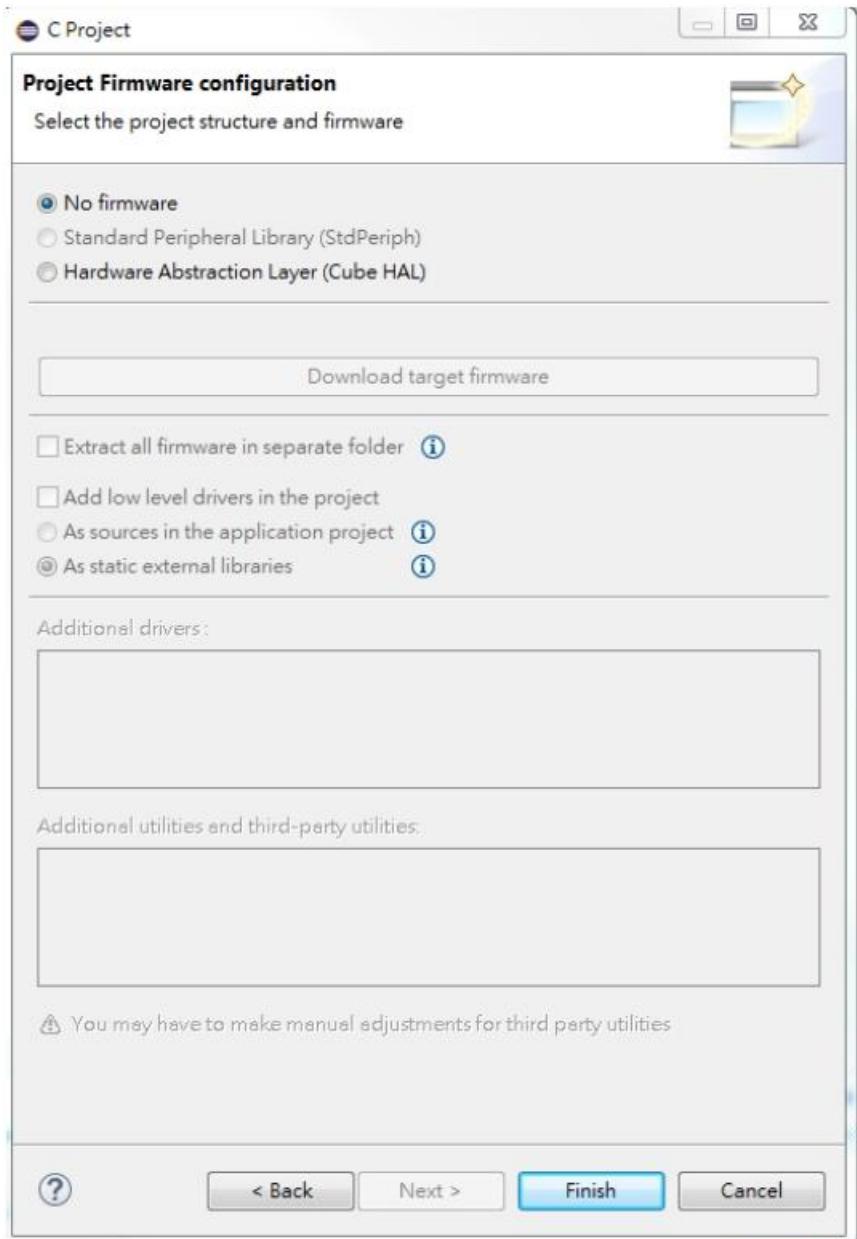


# MCU Configuration

- Series select STM32L4
- Board select NUCLEO-L476RG



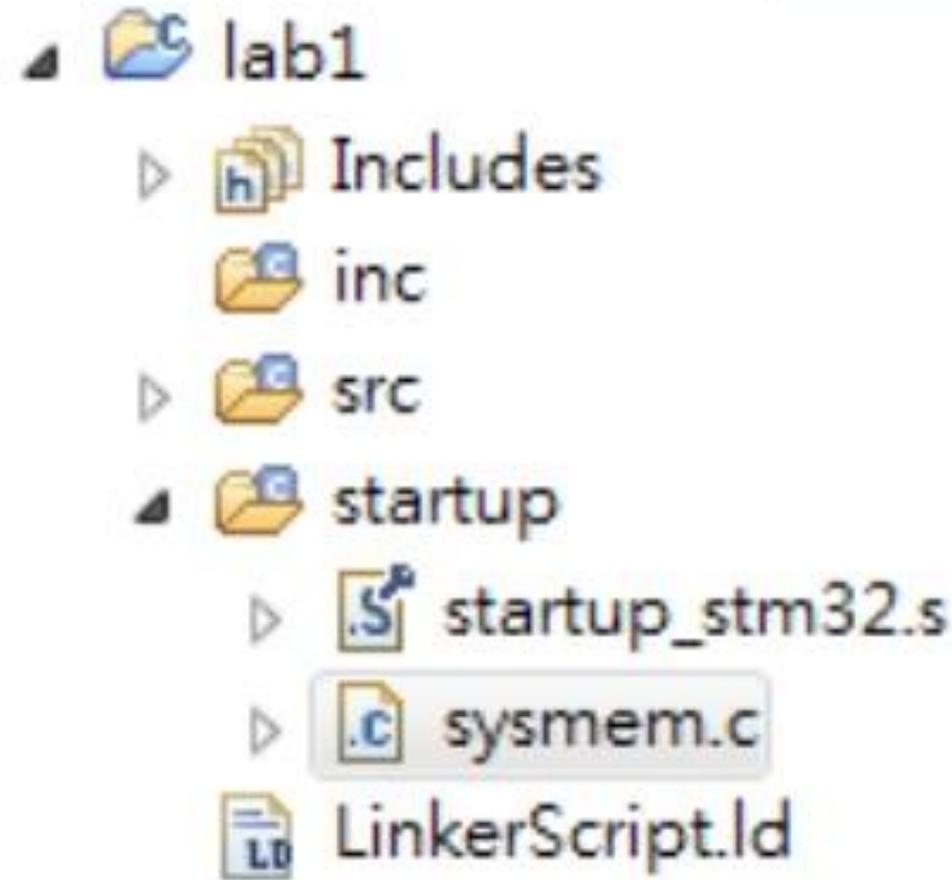
- Choose No firmware
- Then press Finish



# Project Files

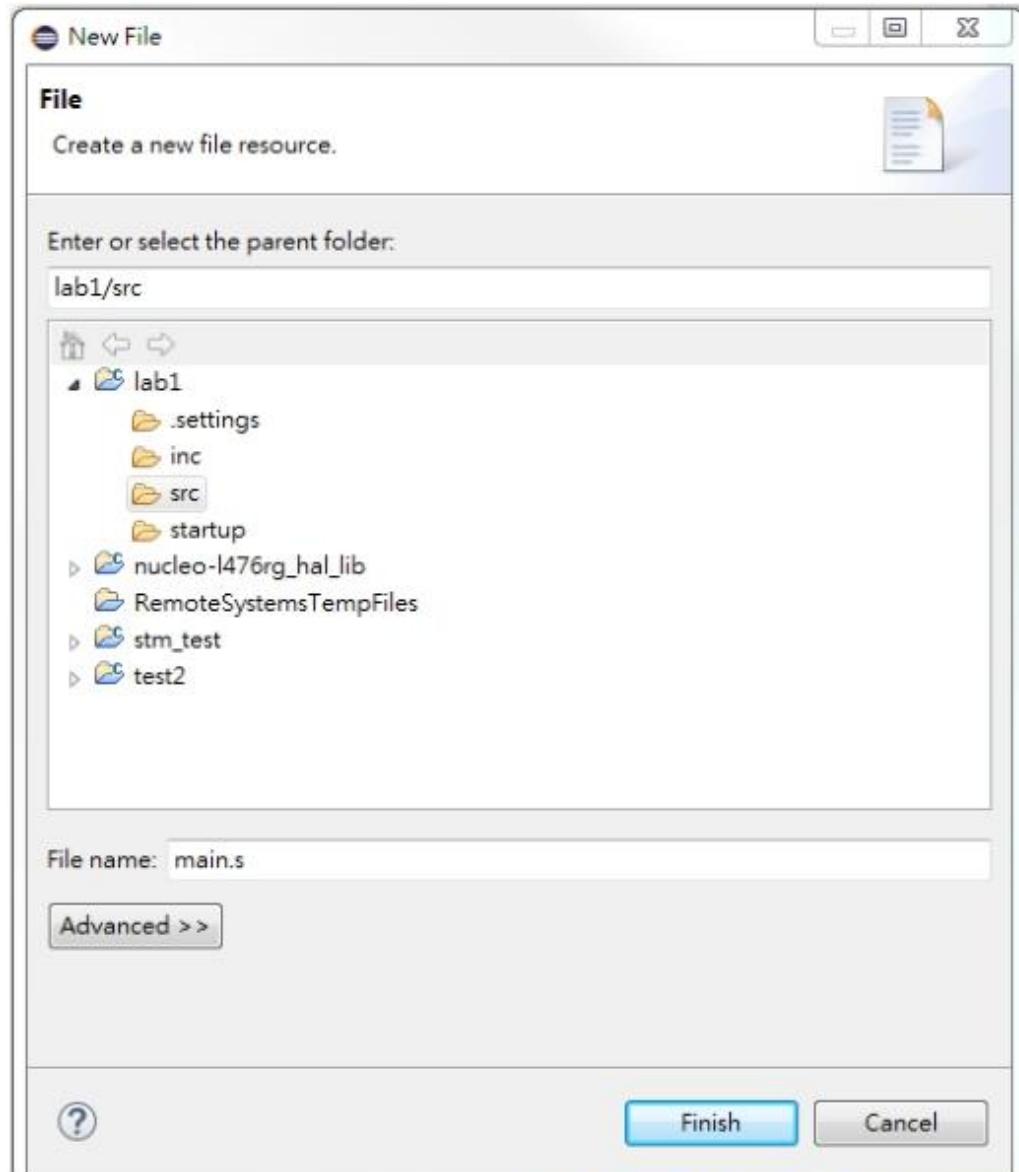
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- Then you can see the project files in the Project Explorer list
- It contain the board startup code `startup_stm32.s` and linker script `LinkerScript.ld`
- This about practice 1



# Create File

- Right click the **src** folder
- Select New -> File
- Create a file call **main.s**



# Write Your First Code

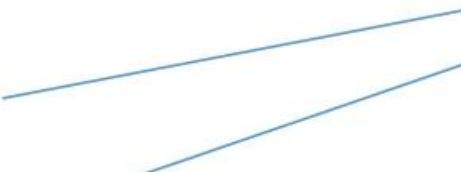
Use UAL syntax



Text section start point



Define global symbol



Define a constant symbol AA

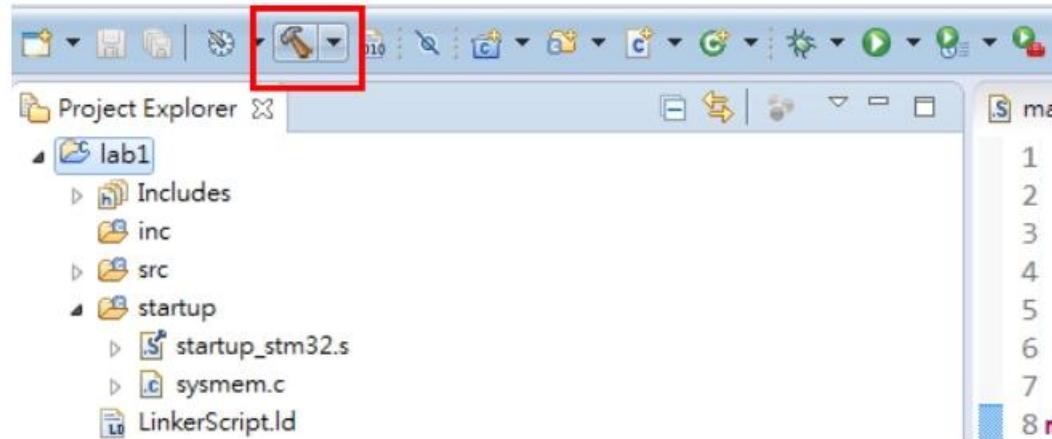


```
1 .syntax unified
2 .cpu cortex-m4
3 .thumb
4 .text
5 .global main
6 .equ AA,0x5566 // How about 0x1000 ?
7
8 main:
9     movs r0, #AA
10    movs r1, #20
11    adds r2,r0,r1
12    b main
13
```

main.s

# Build Code

- Write your first code
- Project->Build all



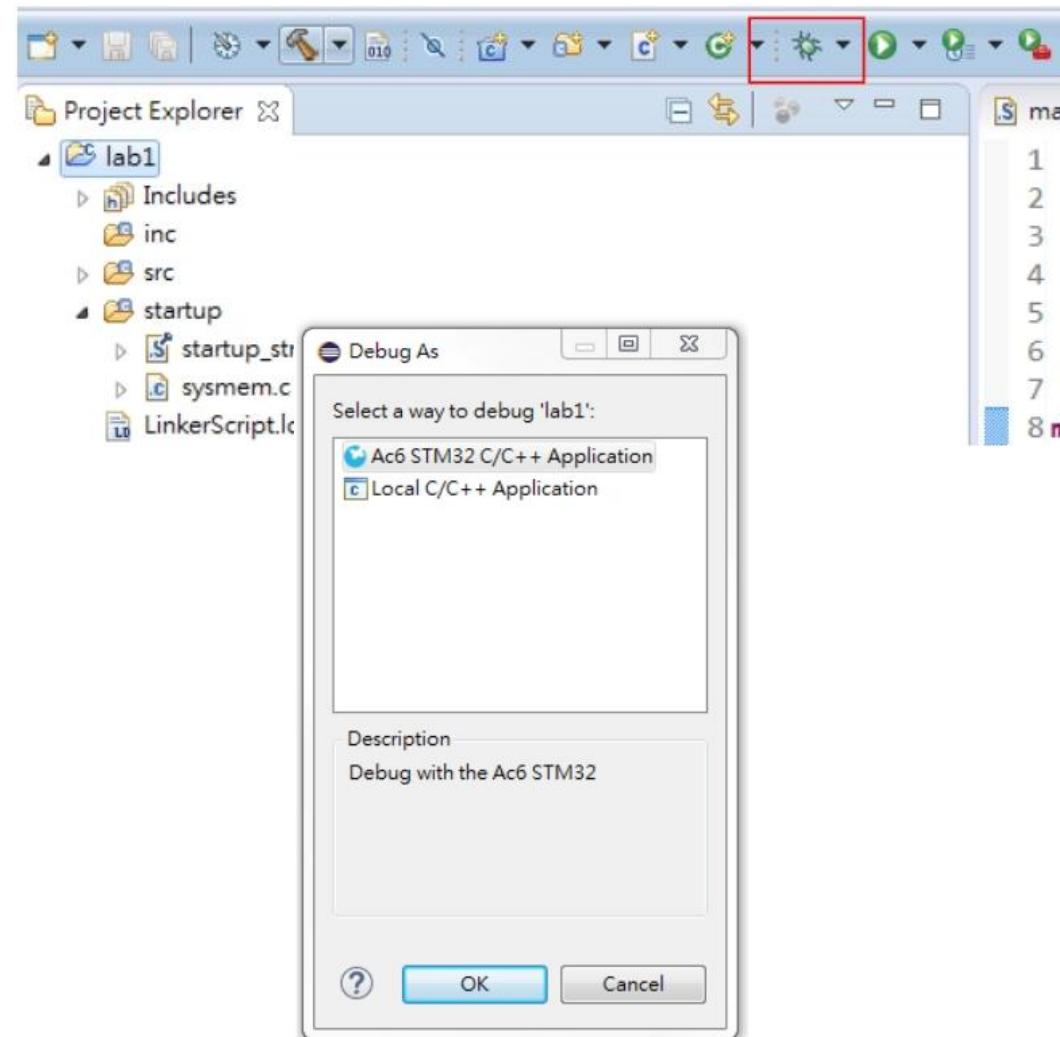
## Build result

```
'Building target: lab1.elf'
'Invoking: MCU GCC Linker'
arm-none-eabi-gcc -mcpu=cortex-m4 -mthumb -mfloating-point-abi=hard -mfpu=fpv4-sp-d16
'Finished building target: lab1.elf'
'
make --no-print-directory post-build
'Generating binary and Printing size information:'
arm-none-eabi-objcopy -O binary "lab1.elf" "lab1.bin"
arm-none-eabi-size "lab1.elf"
      text      data      bss      dec      hex filename
      992       1080     1056     3128      c38 lab1.elf
'
```

Create the target image file

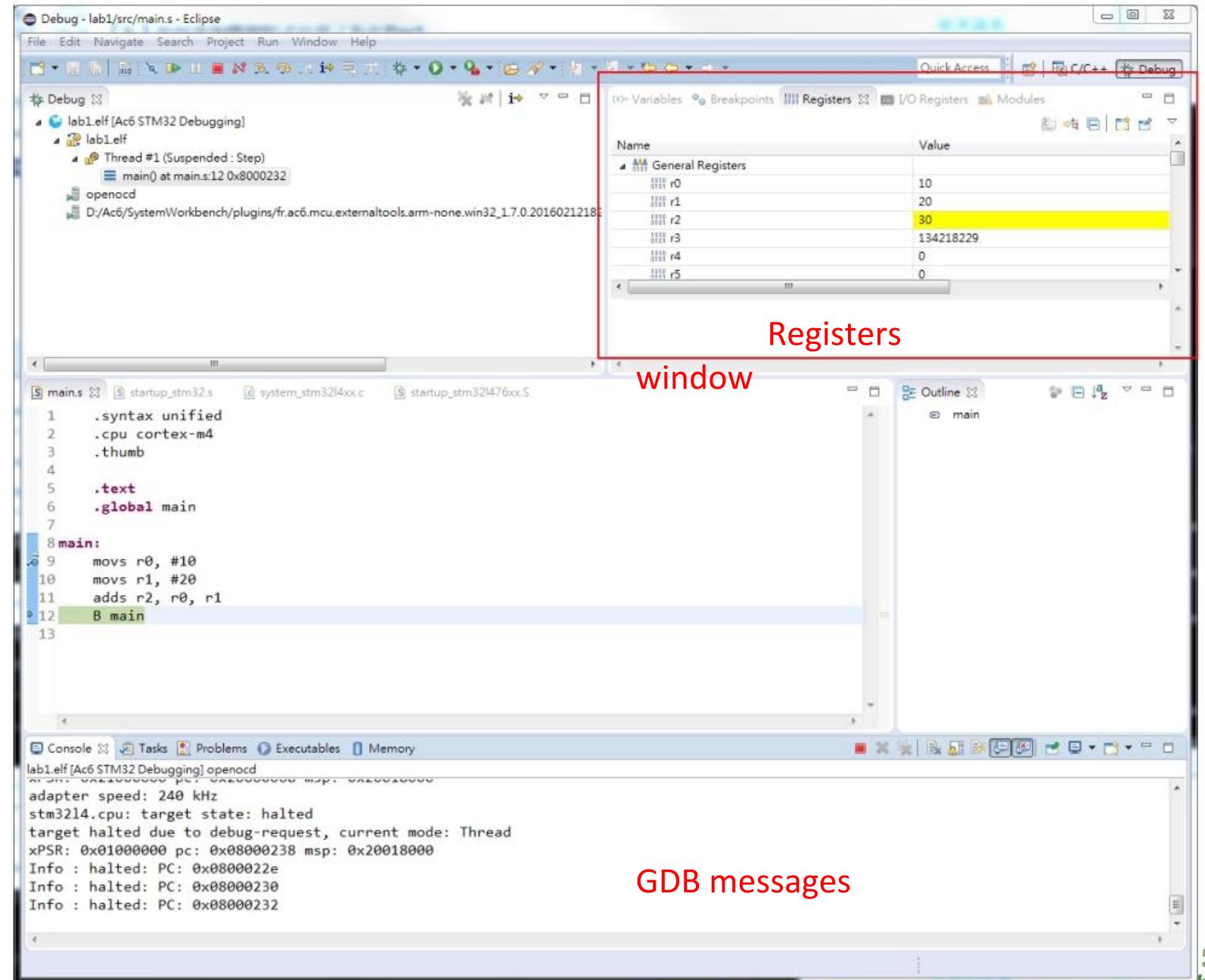
# Debug your Code on board

- Run->Debug
- Debug as AC6 STM32 C/C++ Application



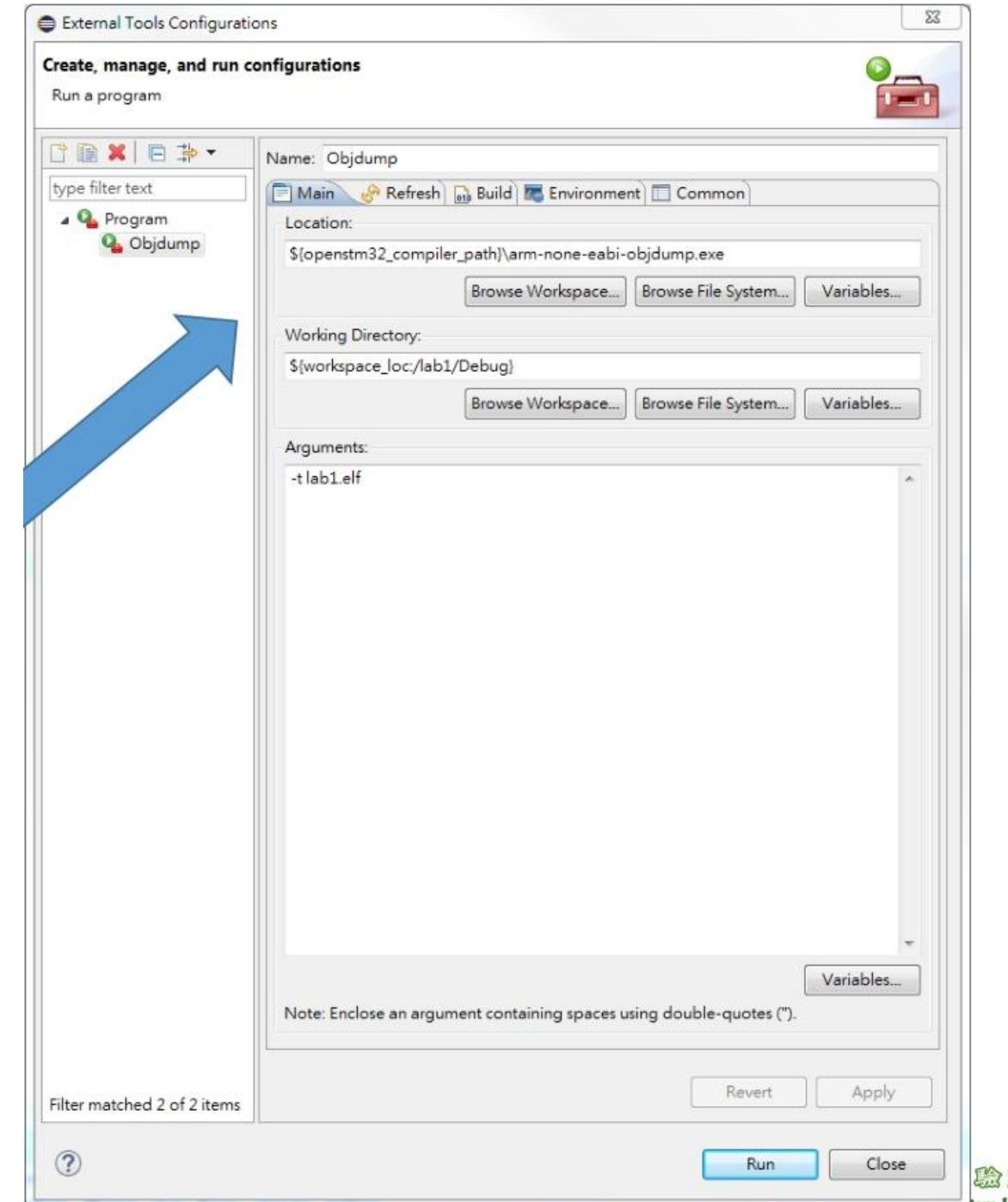
# Debug Guide

- By default the GDB will set the first breakpoint at main
- Press Step into button or F5 will debug your code step by step
- You can use IDE to inspect registers, I/O registers, memory on board



# Object Dump

- This tool can help you show the program's symbol table
- Run -> External Tool -> External Tool Configurations
  - Set a new program Objdump with the same settings
- Objdump usage guide
  - <https://sourceware.org/binutils/docs/binutils/objdump.html>
- Remove .exe suffix where Linux and MacOS



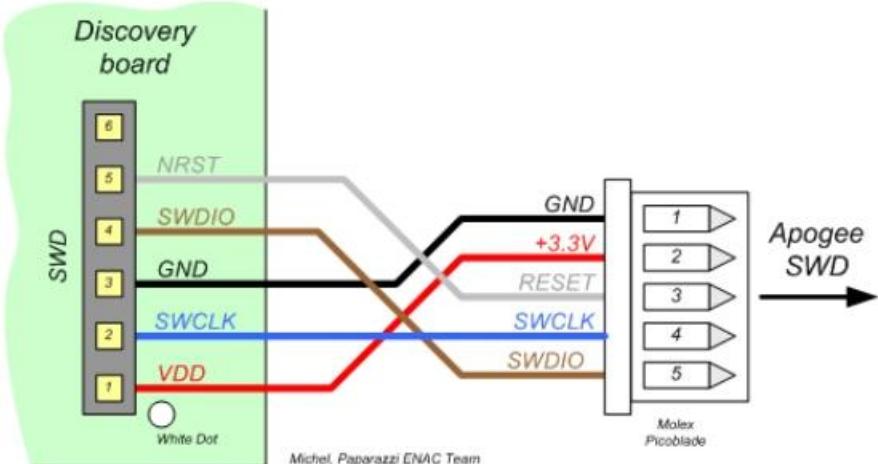
# Symbol Table

Symbol address	Section locate	Symbol name
080001a8	F .text	register_tm_clones
080001cc	F .text	_do_global_dtors_aux
20000400	.bss	completed.6516
080003f8	O .fini_array	00000000 __do_global_dtors_aux_fini_array_entry
080001f4	F .text	frame_dummy
20000444	.bss	object.6521
080003f4	O .init_array	00000000 __frame_dummy_init_array_entry
00000000	df *ABS*	src/main.o
20000000	.data	X
20000004	.data	str
00000055	*ABS*	AA
0800023a	.text	L
00000000	df *ABS*	init.c
00000000	df *ABS*	__call_atexit.c
080002e0	F .text	register_fini
00000000	df *ABS*	atexit.c
00000000	df *ABS*	fini.c
00000000	df *ABS*	__atexit.c

# Debug architecture

# Debug Interface

- JTAG(Joint Test Action Group)
  - A standard ASICs hardware debug interface
- SWD(Serial Wire Debug)
  - Only use 5 wires from part of JTAG interface

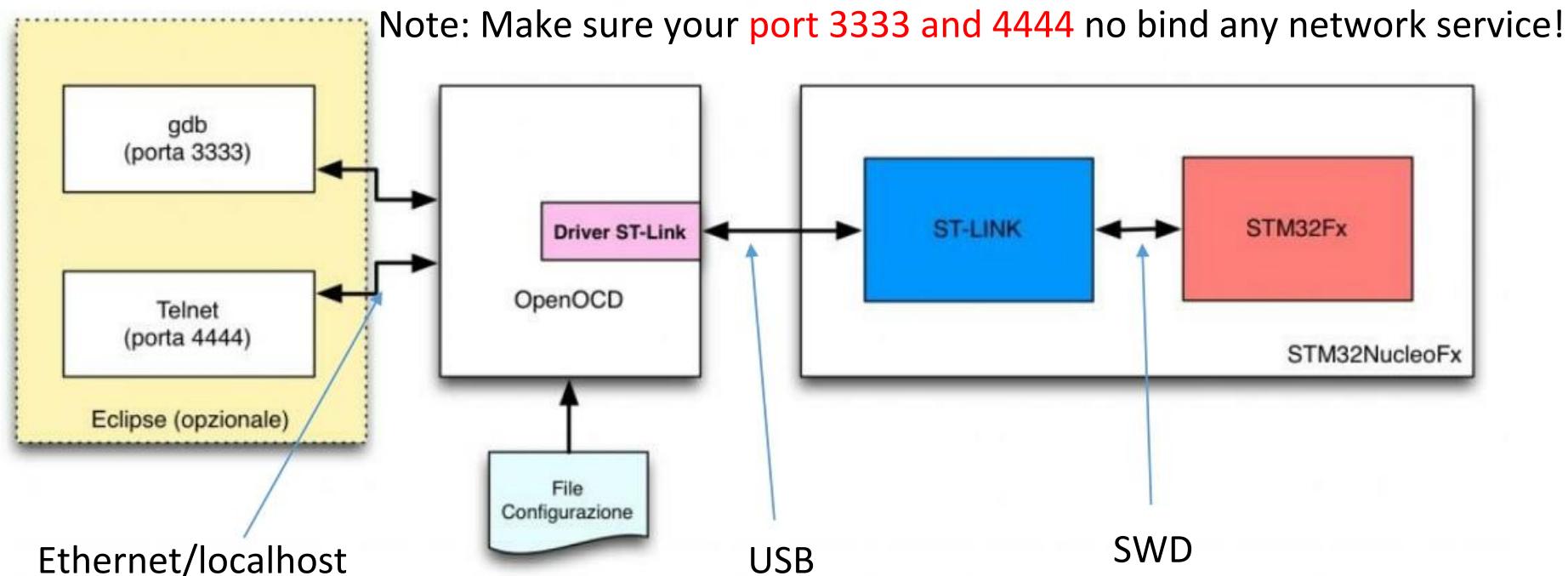


ARM Standard JTAG  
20-pin Connector

VCC 1	□	□	2 VCC(Optional)
TRST 3	□	□	4 GND
NC/TDI 5	□	□	6 GND
SWDIO/TMS 7	□	□	8 GND
SWDCLK/TCLK 9	□	□	10 GND
RTCK 11	□	□	12 GND
SWO/TDO 13	□	□	14 GND
RESET 15	□	□	16 GND
N/C 17	□	□	18 GND
N/C 19	□	□	20 GND

# Debug on board

- ST-Link: A STM32 hardware flasher and debugger
- OpenOCD: An open source GDB server



# Memory Guide

# Memory Access

- Define data variable
- Direct access
- Indirect read access

Write the data register into memory

```
1 .syntax unified
2 .cpu cortex-m4
3 .thumb
4
5 .data           ← Data section start point
6 |   X: .word 100
7 |   Y: .asciz "Hello World!"
8 .text
9 .global main
10 .equ AA, 0x55
11
12 main:
13 |   ldr r1, =X
14 |   ldr r0, [r1]
15 |   movs r2, #AA
16 |   adds r2, r2, r0
17 |   str r2, [r1]
18
19 |   ldr r1, =Y
20 |   ldr r2, [r1]
21
22 L: B L
```

# Memory Monitors

- That can help you watch the memory content

The screenshot shows a software interface for monitoring memory. At the top, there's a navigation bar with tabs: Console, Tasks, Problems, Executables, Memory, and Monitors. The 'Monitors' tab is selected. Below the tabs, there's a section titled 'Monitors' containing a single entry: '0x20000000'. To the right of this section is a toolbar with three icons: a green plus sign, a red minus sign, and a grey cross. An orange arrow points from the text 'Press it to add a memory monitor' to the green plus sign icon.

Below the monitors section is a table titled '0x20000000 : 0x20000000 <Hex>'. The table has columns labeled 'Address' and 'Value'. The first row of data is:

Address	0 - 3	4 - 7	8 - B	C - F
20000000	64000000	48656C6C	6F20576F	726C6421
20000010	00000000	00000000	00000000	04030020
20000020	6C030020	D4030020	00000000	00000000
20000030	00000000	00000000	00000000	00000000
20000040	00000000	00000000	00000000	E8030008
20000050	00000000	00000000	00000000	00000000
20000060	00000000	00000000	00000000	00000000

An orange arrow points from the text 'Press “New Renderings” can change the display format' to a button labeled 'New Renderings...' located at the top of the table area.

# Document Guide

- About ARM programming
  - PM0204-Cortex-M4-Programming-Manual
- About C call ASM or ASM call C
  - Procedure-Call-Standard-For-ARM-Arch
- About I/O, timer, power .....
- All on internet or E3, They are useful for lab and midterm exam.

# Practice

# 練習

# Practice 1

Create a STM32 eclipse project according to Getting started guide.  
Add a "main.s" code as right and observe program execution result through debugger.

請依照 Getting started guide, 建立一個 STM32 eclipse project , 新增一個程式碼如右的 main.s 並透過 debugger 觀察程式執行結果。

Q: What is the R2 value after the program is executed ? How to observe ?

問: 程式執行結束後 R2 值為多少？如何觀察？

- .syntax unified
- .cpu cortex-m4
- .thumb

- .text
- .global main
- .equ AA, 0x55

main:

```
    movs r0, #AA  
    movs r1, #20  
    adds r2, r0, r1
```

L: B L

# Practice 2

Q1: Where is the initial value of the variables X and Y initialized by whom?

問1: 變數 X 與 Y 的初始值是由誰在何處初始化的？

Q2: What happens the program execution result if I change the X declaration to the text section?

問2: 若將 X 宣告改在 text section 對其程式執行結果會有何改變？

Q3: What is the difference between the r2 content and the Y string in the first 4 bytes of memory after the program is executed? How to load first byte 'H' in variable Y ?

問3: 執行完畢後 r2 內容與 Y 字串在 memory 前4個byte呈現內容有何差異？怎麼讀取第一個 byte 'H' 在變數 Y 中？

Q4: The variable Y "Hello World!" Is there any other way to declare? If there is one, please explain one of them.

問4: 變數 Y "Hello World!" 有無其他種宣告方式？

```
.syntax unified  
.cpu cortex-m4  
.thumb  
  
.data  
    X: .word 100  
    Y: .asciz "Hello  
World!"  
.text  
.global main  
.equ AA, 0x55
```

```
main:  
    ldr r1, =X  
    ldr r0, [r1]  
    movs r2, #AA  
    adds r2, r2, r0  
    str r2, [r1]
```

```
    ldr r1, =Y  
    ldr r2, [r1]
```

# Practice 3

This part of the practice requires students to declare three X, Y, and Z variables of length 4 bytes in the data section and calculate the following formula using the ARM assembly language. Find the memory address of these variables and observe the program execution results.

這部分練習需要在 data section 中宣告三個 X, Y, Z 長度為 4 byte 的變數並利用 ARM 組合語言計算以下式子。找出這些變數的memory address並觀察程式執行結果。

$$X = 5$$

$$Y = 10$$

$$X = X * 10 + Y$$

$$Z = Y - X$$

# Appendix

# Reference

- Getting started with STM32 Nucleo board software development tools
  - [http://www.st.com/content/ccc/resource/technical/document/user\\_manual/1b/03/1b/b4/88/20/4e/cd/DM00105928.pdf/files/DM00105928.pdf/jcr:content/translations/en.DM00105928.pdf](http://www.st.com/content/ccc/resource/technical/document/user_manual/1b/03/1b/b4/88/20/4e/cd/DM00105928.pdf/files/DM00105928.pdf/jcr:content/translations/en.DM00105928.pdf)
- STM32 Nucleo-64 boards user manual
  - [https://www.st.com/content/ccc/resource/technical/document/user\\_manual/98/2e/fa/4b/e0/82/43/b7/DM00105823.pdf/files/DM00105823.pdf/jcr:content/translations/en.DM00105823.pdf](https://www.st.com/content/ccc/resource/technical/document/user_manual/98/2e/fa/4b/e0/82/43/b7/DM00105823.pdf/files/DM00105823.pdf/jcr:content/translations/en.DM00105823.pdf)
- Linker Script
  - [https://www.math.utah.edu/docs/info/Id\\_toc.html#SEC4](https://www.math.utah.edu/docs/info/Id_toc.html#SEC4)