Memory, Register and Debugging

Jingtong Hu

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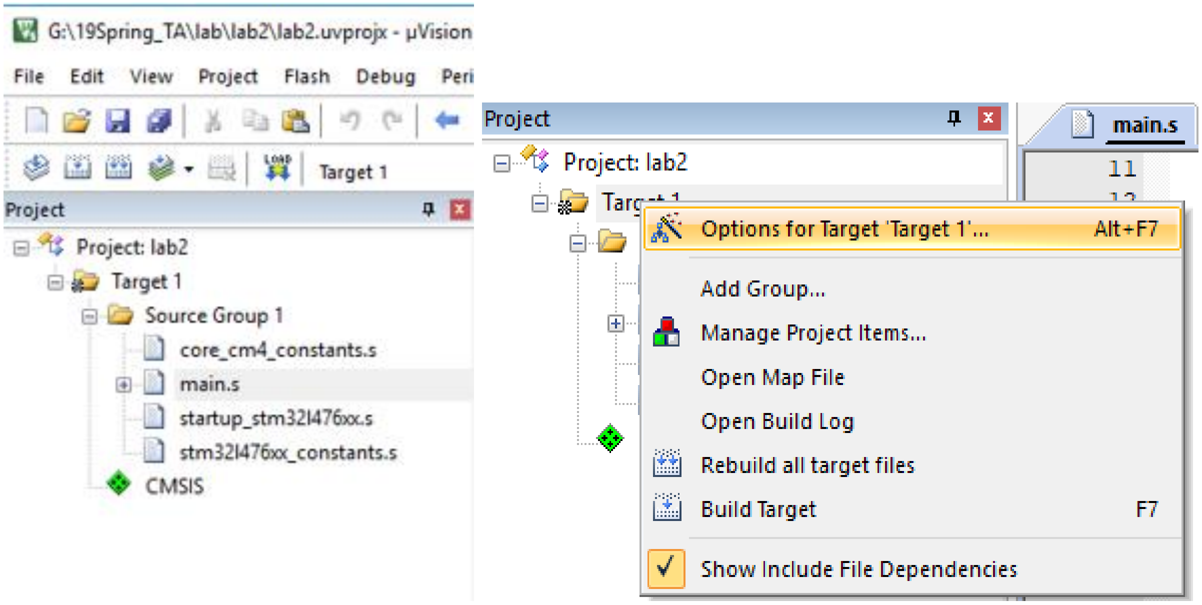
Step 1: Project Creation

Create a new program as you did in the lab1 with the provided files in the Courseweb. **Remember to set the options of target (as you did in the lab1)** . And then build it and load it to your board.

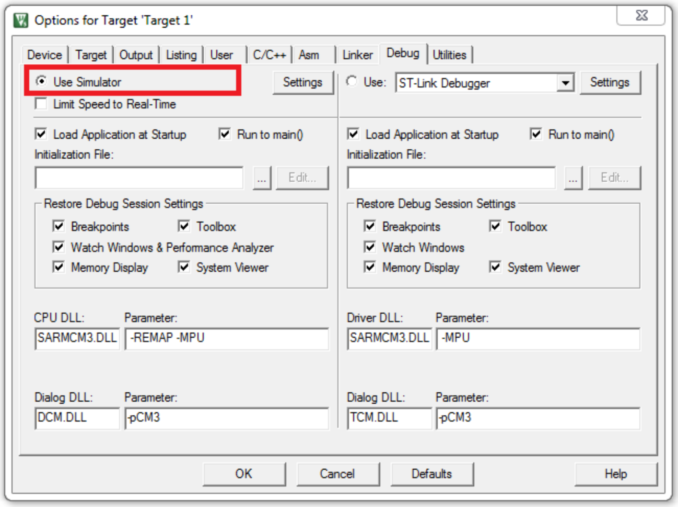


Step 2: Debugging

If you want to monitor the memory and register, you need to get into the debugging mode. The following is some basic knowledge of debugging.

Software *vs* Hardware Debug

There are two methods to debug your program: software debug and hardware debug. By using the software debug, you do not have to have the hardware board to debug a software program. However, the hardware debug requires you to connect the board to the computer. **In lab2, we will use hardware debug**.


Options for Target 'Target 1'

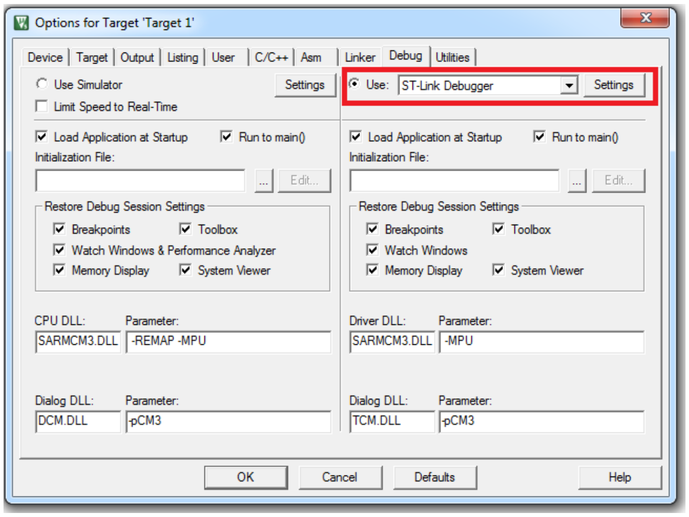
Device | Target | Output | Listing | User | C/C++ | Asm | Linker | Debug | Utilities

● Use Simulator — Settings
□ Limit Speed to Real-Time
☑ Load Application at Startup ☑ Run to main()
Initialization File:
Restore Debug Session Settings: ☑ Breakpoints ☑ Toolbox ☑ Watch Windows & Performance Analyzer ☑ Memory Display ☑ System Viewer
CPU DLL: SARMCM3.DLL Parameter: -REMAP -MPU
Dialog DLL: DCM.DLL Parameter: -pCM3

○ Use: ST-Link Debugger — Settings
☑ Load Application at Startup ☑ Run to main()
Initialization File:
Restore Debug Session Settings: ☑ Breakpoints ☑ Toolbox ☑ Watch Windows ☑ Memory Display ☑ System Viewer
Driver DLL: SARMCM3.DLL Parameter: -MPU
Dialog DLL: TCM.DLL Parameter: -pCM3

OK | Cancel | Defaults | Help

Selecting **software** debug


Options for Target 'Target 1'

Device | Target | Output | Listing | User | C/C++ | Asm | Linker | Debug | Utilities

○ Use Simulator — Settings
□ Limit Speed to Real-Time
☑ Load Application at Startup ☑ Run to main()
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CPU DLL: SARMCM3.DLL Parameter: -REMAP -MPU
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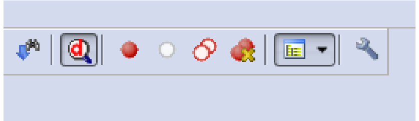
● Use: ST-Link Debugger — Settings
☑ Load Application at Startup ☑ Run to main()
Initialization File:
Restore Debug Session Settings: ☑ Breakpoints ☑ Toolbox ☑ Watch Windows ☑ Memory Display ☑ System Viewer
Driver DLL: SARMCM3.DLL Parameter: -MPU
Dialog DLL: TCM.DLL Parameter: -pCM3

OK | Cancel | Defaults | Help

Selecting **hardware** debug

Debug Control

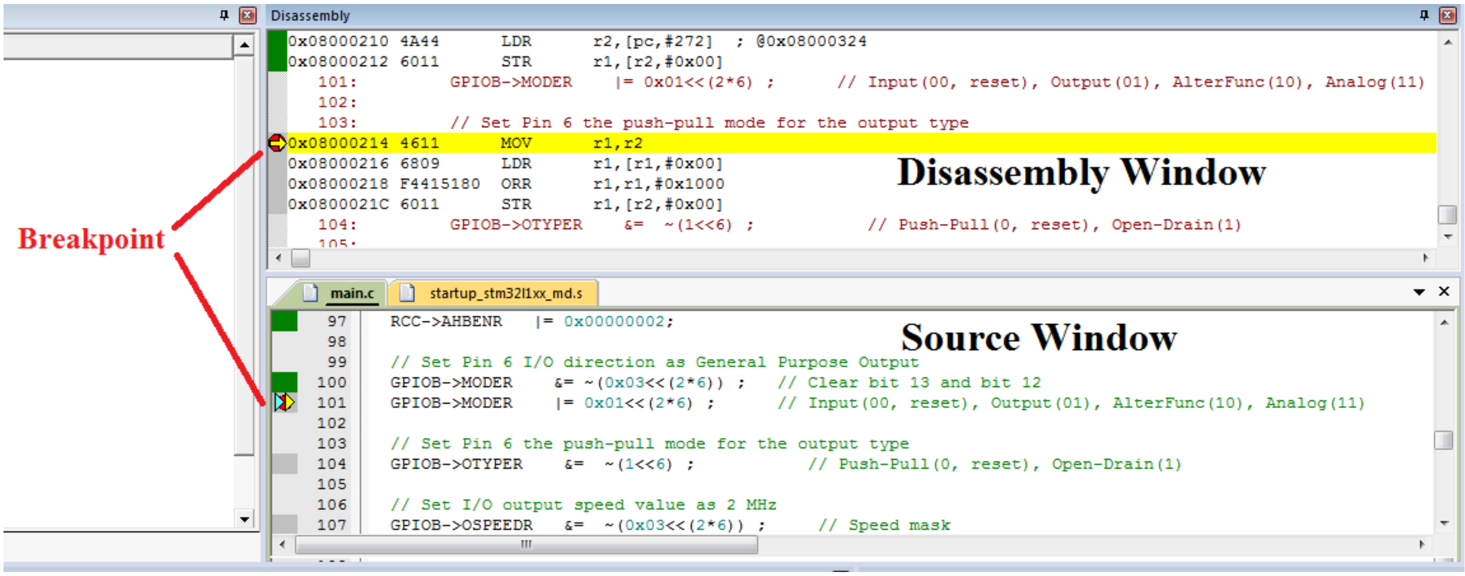
- You can program the STM32 flash by clicking the LOAD button (You need to do it on step 1).
- Click the debug button to start the debug and click it again to exit the debug. You can use the breakpoint button ● to set a break point in either disassembly or source windows.
- STM32 allows up to six breakpoints during hardware debugging. When a program stops at a breakpoint, the corresponding instruction has not been executed yet.
- **If the disassembly window is in focus, the debugger executes assembly instructions step by step. If the source window is focused, the debugger then steps through the source lines instead.**



The following table summarizes commonly used debug control buttons.

Start Debug	Set a Breakpoint	Run	Stop Debug	Step In	Step Over	Step Out

- **Run**: Continues the execution from the current position until you click ***Stop*** or the program is paused by a breakpoint.
- **Step In**: Execute one step and enter the function if the current step calls a function.
- **Step Over**: Execute one step and run the function all at once if the current step calls a function.
- **Step Out**: Execute until the current function returns.



```
0x08000210 4A44      LDR      r2,[pc,#272]  ; @0x08000324
0x08000212 6011      STR      r1,[r2,#0x00]
   101:          GPIOB->MODER    |= 0x01<<(2*6) ;      // Input(00, reset), Output(01), AlterFunc(10), Analog(11)
   102:
   103:          // Set Pin 6 the push-pull mode for the output type
0x08000214 4611      MOV      r1,r2
0x08000216 6809      LDR      r1,[r1,#0x00]
0x08000218 F4415180  ORR      r1,r1,#0x1000
0x0800021C 6011      STR      r1,[r2,#0x00]
   104:          GPIOB->OTYPER    &=  ~(1<<6) ;          // Push-Pull(0, reset), Open-Drain(1)
   105:
```

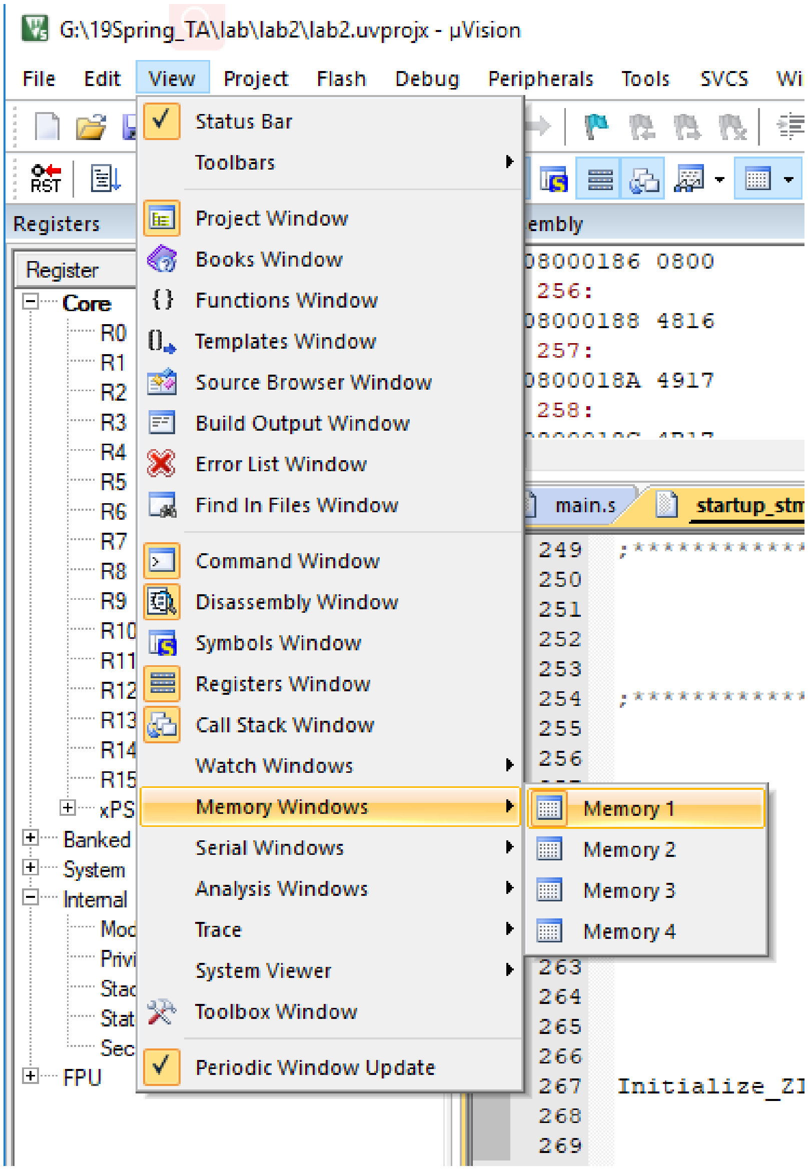
```
RCC->AHBENR   |= 0x00000002;

// Set Pin 6 I/O direction as General Purpose Output
GPIOB->MODER    &= ~(0x03<<(2*6)) ;   // Clear bit 13 and bit 12
GPIOB->MODER    |= 0x01<<(2*6) ;      // Input(00, reset), Output(01), AlterFunc(10), Analog(11)

// Set Pin 6 the push-pull mode for the output type
GPIOB->OTYPER    &=  ~(1<<6) ;          // Push-Pull(0, reset), Open-Drain(1)

// Set I/O output speed value as 2 MHz
GPIOB->OSPEEDR   &=  ~(0x03<<(2*6)) ;     // Speed mask
```

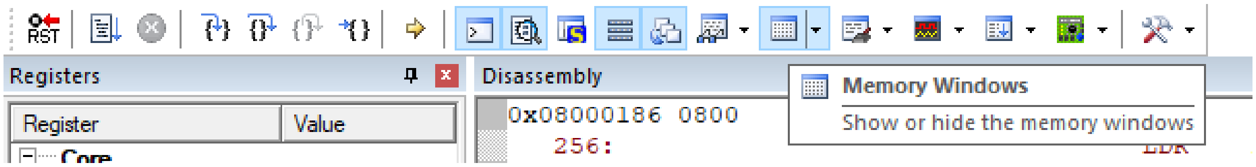
In step 2, Click the debug button to get into debugging mode.

Step3: Monitoring Memory

Memory Window

The memory window is used to view the memory content in real time. The memory window can be found from menu View->Memory Windows->Memory 1 or you can find the memory window button in the toolbar.





By default, the address of data memory (RAM) starts at `0x2000_0000`. This is specified in the scatter-loading file (*.sct).

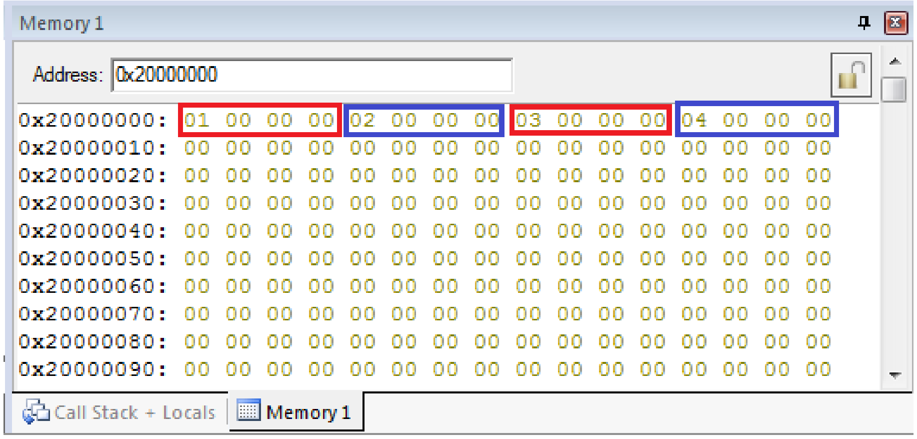
The following assembly program (main.s) defines and allocates an array of four words, and write the result of addition to memory (**the address of variable value**).

```
    INCLUDE core_cm4_constants.s        ; Load Constant Definitions
```

```
      INCLUDE stm32l476xx_constants.s
      AREA    main, CODE, READONLY
      EXPORT      __main                        ; make __main visible to linker
      ENTRY
__main      PROC
      MOVS r1, #0x01
      MOVS r2, #0x02
      ADDS r3, r1, r2
      LDR r0, =value
      STR r3, [r0]
stop  B           stop              ; dead loop & program hangs here
      ENDP

      ALIGN
      AREA    myData, DATA, READWRITE
      ALIGN
array DCD   1, 2, 3, 4
value DCD     0
      END
```

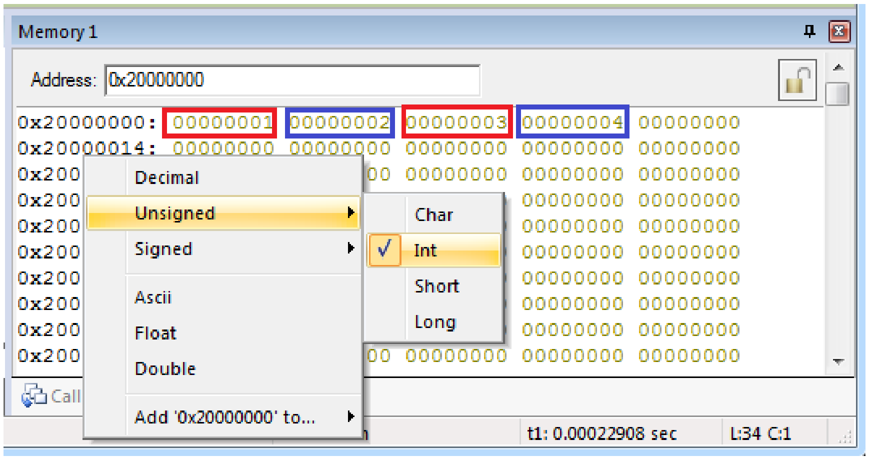
(1) Watch memory content before execution

Set a breakpoint in the line “MOVS r1, #0x01”, and click “Run” to execute until this line. When we type the memory address 0x20000000, we can see the content. **The memory content is displayed in bytes (Char) by default**.



```
0x20000000: 01 00 00 00 02 00 00 00 03 00 00 00 04 00 00 00
0x20000010: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000020: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000030: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000040: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000050: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000060: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000070: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000080: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0x20000090: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
```

By right click, we can select different display format. For example, we can show the content as unsigned integers.



```
0x20000000: 00000001 00000002 00000003 00000004 00000000
0x20000014: 00000000 00000000 00000000 00000000 00000000
0x200                               00 00000000 00000000 00000000
0x200                                           00000000 00000000
0x200                                           00000000 00000000
0x200                                           00000000 00000000
0x200                                           00000000 00000000
0x200                                           00000000 00000000
0x200                                           00000000 00000000
0x200                               00 00000000 00000000 00000000
```

The value of variable “value” is shown at address 0x20000010. Before execution, the value of this variable is 0.

(2) Watch memory content after execution

Set another breakpoint in the line “MOVS r0, #0x01”, and click “Run” to execute until this line. After execution, the result of “1+2” is written to variable “value” (0x20000000), and the value of corresponding address is changed from 0 to 3.

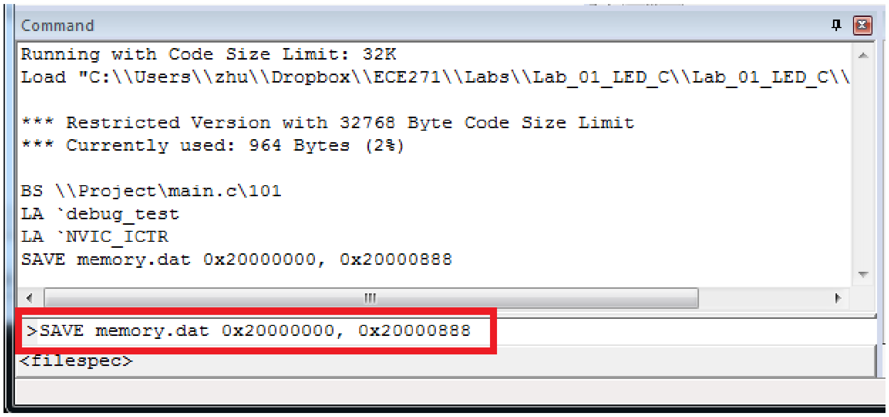
(3)Save Memory Content to a File

In the debug environment, run the following command in the Command Window:

```
SAVE <filename> <start address>, <end address>
```

This allows you to perform data analysis in other software tools, such as Microsoft Excel and Matlab. The output is saved in Intel HEX format (the location of this file is under your project directory by default).

For example, `SAVE memory.dat 0x20000000, 0x20000888`



```
Running with Code Size Limit: 32K
Load "C:\\Users\\zhu\\Dropbox\\ECE271\\Labs\\Lab_01_LED_C\\Lab_01_LED_C\\

*** Restricted Version with 32768 Byte Code Size Limit
*** Currently used: 964 Bytes (2%)

BS \\Project\main.c\101
LA `debug_test
LA `NVIC_ICTR
SAVE memory.dat 0x20000000, 0x20000888
```

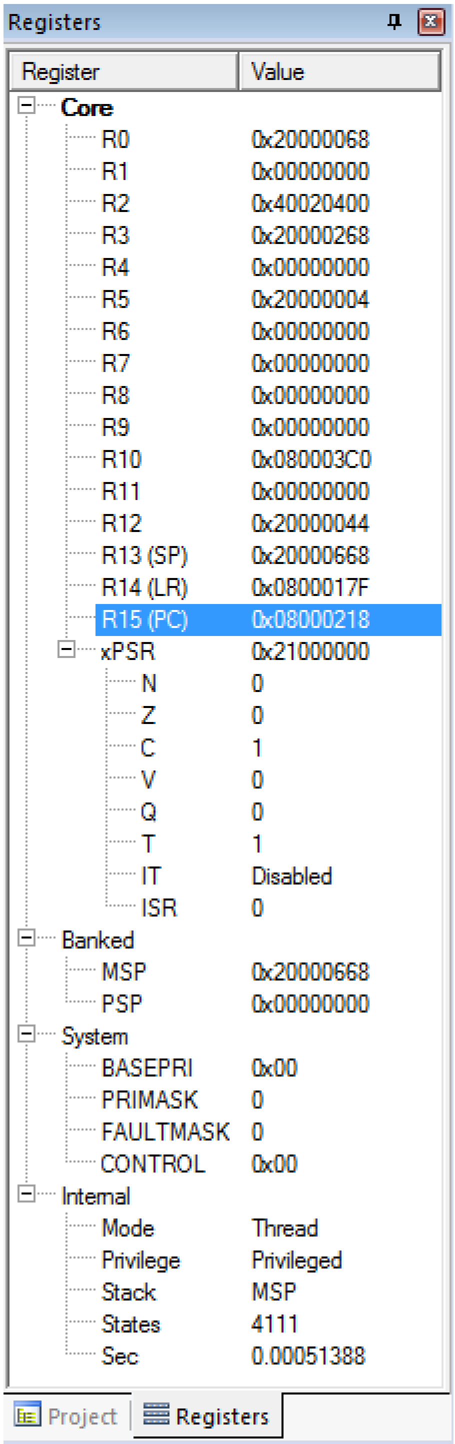
```
>SAVE memory.dat 0x20000000, 0x20000888
<filespec>
```

Exercise

In previous step, the value of variable “value” in memory 0x20000010 has been changed to 3. **Save memory content to the file memory.dat after execution, and upload it to Courseweb.**

Step 4: Monitoring Processor Registers

Before monitoring the processor register, you need to learn some basic knowledge about processor register (you can refer to the content in the next page). In lab2, you need to monitor the NZCV flags in xPSR register in the debugging mode with the codes provided (main.s).



Register	Value
Core	
R0	0x20000068
R1	0x00000000
R2	0x40020400
R3	0x20000268
R4	0x00000000
R5	0x20000004
R6	0x00000000
R7	0x00000000
R8	0x00000000
R9	0x00000000
R10	0x080003C0
R11	0x00000000
R12	0x20000044
R13 (SP)	0x20000668
R14 (LR)	0x0800017F
R15 (PC)	0x08000218
xPSR	0x21000000
N	0
Z	0
C	1
V	0
Q	0
T	1
IT	Disabled
ISR	0
Banked	
MSP	0x20000668
PSP	0x00000000
System	
BASEPRI	0x00
PRIMASK	0
FAULTMASK	0
CONTROL	0x00
Internal	
Mode	Thread
Privilege	Privileged
Stack	MSP
States	4111
Sec	0.00051388

Core Registers:

- Program counter (PC) r15 holds the memory address (location in memory) of the next instruction to be fetched from the instruction memory.
- Stack point (SP) r13 holds a memory address that points to the top of the stack. SP is a shadow of either MSP or PSP.
- xPSR (Special-purpose program status registers) is a combination of the following three processor status registers:
  - Application PSR
  - Interrupt PSR
  - Execution PSR

N	Negative or less than flag (1 = result negative)
Z	Zero flag (1 = result 0)
C	Carry or borrow flag (1 = Carry true or borrow false)
V	Overflow flag (1 = overflow)
Q	Q Sticky saturation flag
T	Thumb state bit
IT	If-Then bits
ISR	ISR Number (6 bits)

System:

- Base priority mask register (BASEPRI) defines the minimum priority for exception processing.
- Priority mask register (PRIMASK) is used to disable all interrupts excluding hard faults and non-maskable interrupts (NMI). If an interrupt is masked, this interrupt is ignored (i.e. disabled) by the processor.
- Control register (CONTROL) sets the choice of main stack or process stack, and the choice of privileged or unprivileged mode.
- Fault mask register (FAULTMASK) is used to disable all interrupts excluding non-maskable interrupts (NMI).

(1) Watch C (Carry) flag

In the part of monitoring memory, you have got into debugging mode. Now click debug button again to exit. Delete the breakpoints you set before and Set some new breakpoints. The locations of these breakpoints are as follows:

1. line21: MOV r1, #0xFFFFFFFF
2. line 25: MOV r1, #0xFFFFFFFF
3. line 29: MOV r1, #0x7FFFFFFF
4. line 32: stop B   stop

After finishing setting the new breakpoints, click debug button to get into debugging mode. Click run to execute until line 21. Note that at this moment, the NZCV flags are all cleared (value is 0). Click run to execute until line 25 and you can see the C flag is set.

(2) Watch Z (Zero) flag

Click run to execute until line 29 and you can see the Z flag is set.

(3) Watch V (Overflow) and N (Negative) flags

Click run to execute until line 32 and you can see the V and N flags are set.