Lecture 7

First Instructions II

"Hello
World"

Last Time

Five instructions

```
mov.w    src, dst
add.w    src, dst
rra.w    dst
jmp      label
nop
```

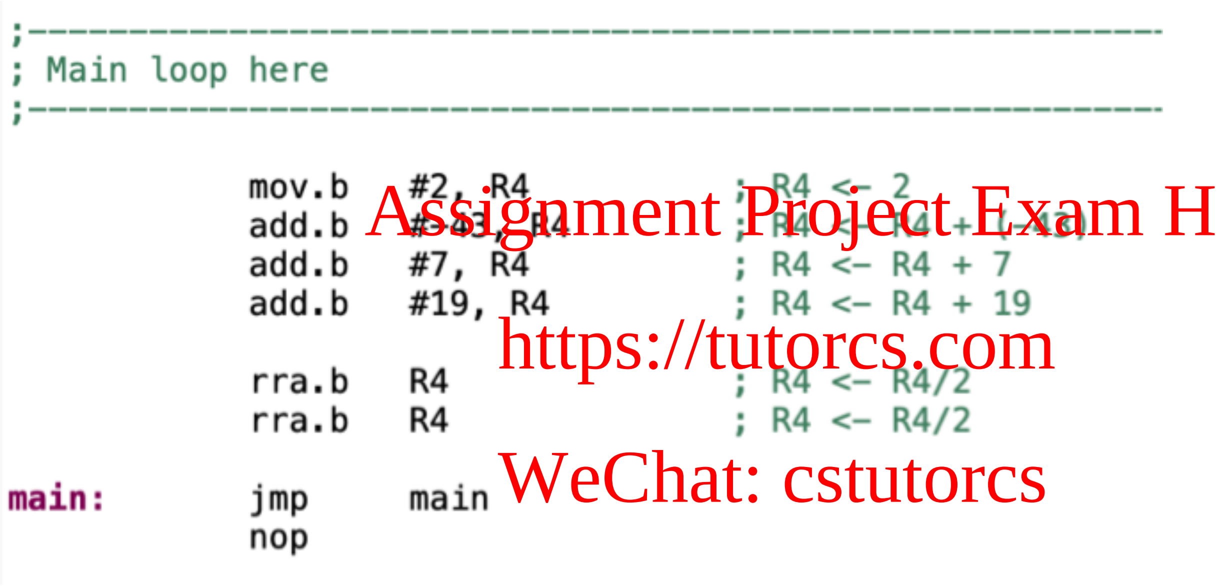
These instructions also have a byte version

Three addressing modes

- **Immediate data:** `src` is the value given after **#**
- **Absolute address:** the address of the `src` or `dst` is given after **&**
- **Register mode:** `src` or `dst` is one of the core registers **R**0 – **R**15

First Code

First task: Find the average value of the set of numbers {2, -43, 7, 19}



```
;-------------------------------------------------------------------
; Main loop here
;-------------------------------------------------------------------

            mov.b   #2, R4              ; R4 <- 2
            add.b   #-43, R4            ; R4 <- R4 + (-43)
            add.b   #7, R4              ; R4 <- R4 + 7
            add.b   #19, R4             ; R4 <- R4 + 19

            rra.b   R4                  ; R4 <- R4/2
            rra.b   R4                  ; R4 <- R4/2

main:       jmp     main
            nop
```

Today we will redo this

- Introducing assembler directives
- *Variables* and *arrays*
- More addressing modes

Assembler Directives

Assembler directives supply program data and control the assembly process

We will use them to

- Assemble code and data into specified sections

```
        .data    ; Everything after this goes to RAM
        .text    ; Everything after this goes to FRAM
```

- Reserve space in memory (initialized to zero)

```
        .space 6   ; Reserve 6 bytes of space
```

- Initialize memory to desired values

```
        .word 0xB, 0xC      ; initialize words
        .byte -1, 5, 3      ; initialize bytes
```

- Define global variables

```
array:      .word 0x1, 0x2, 0x3, 0x4
```

- Define symbolic constants – no memory reserved

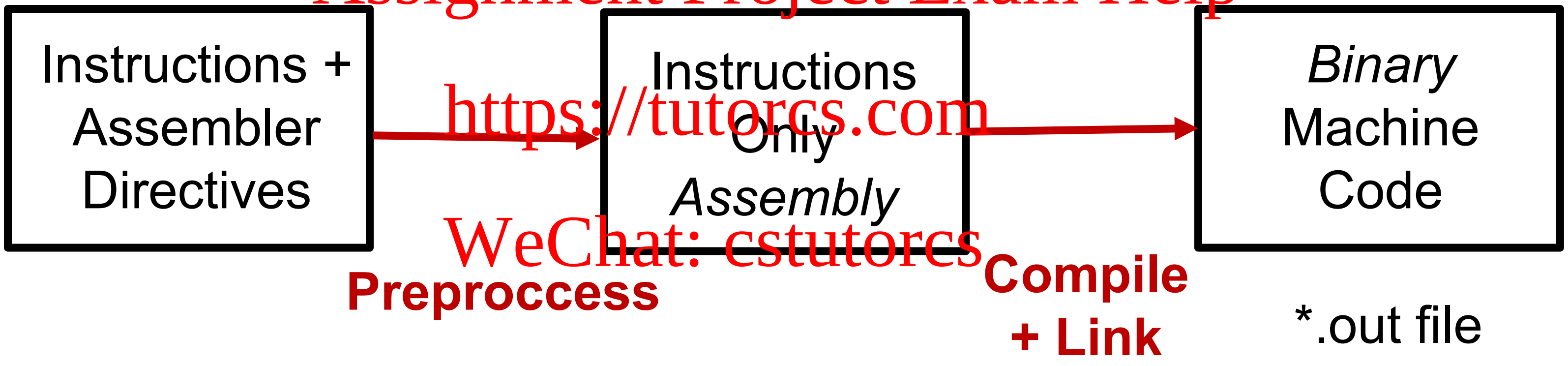
```
scon:       .set 4
```

Assembly to Machine Code

The hammer icon on CCS initiates the **build** of the code

Build = Preprocess + Compile + Link

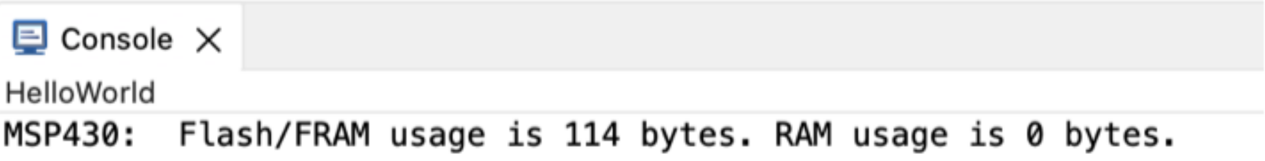
Simplified Picture


Instructions + Assembler Directives
Preproccess
Instructions Only *Assembly*
Compile + Link
Binary Machine Code
*.out file

The bug icon uploads the binary machine code to the FRAM and also initiates memory in RAM and FRAM (per preprocessor directions)

Assembly to Machine Code

Assembly Code	Machine Code	Address of Instruction
mov.w #__STACK_END,SP	4031 2400	0x4400
mov.w #WDTPW|WDTHOLD,&WDTCTL	40B2 5A80 015C	0x4404
mov.b #2, R4	4364	0x440a
add.b #-43, R4	5074 FFD5	0x440c
add.b #7, R4	5074 0007	0x4410
add.b #19, R4	5074 0013	0x4414
rra.b R4	1144	0x4418
rra.b R4	1144	0x441a
jmp main	3FFF	0x441c
nop	4303	0x441e



```
HelloWorld
MSP430:  Flash/FRAM usage is 114 bytes. RAM usage is 0 bytes.
```

Memory usage reported after code upload

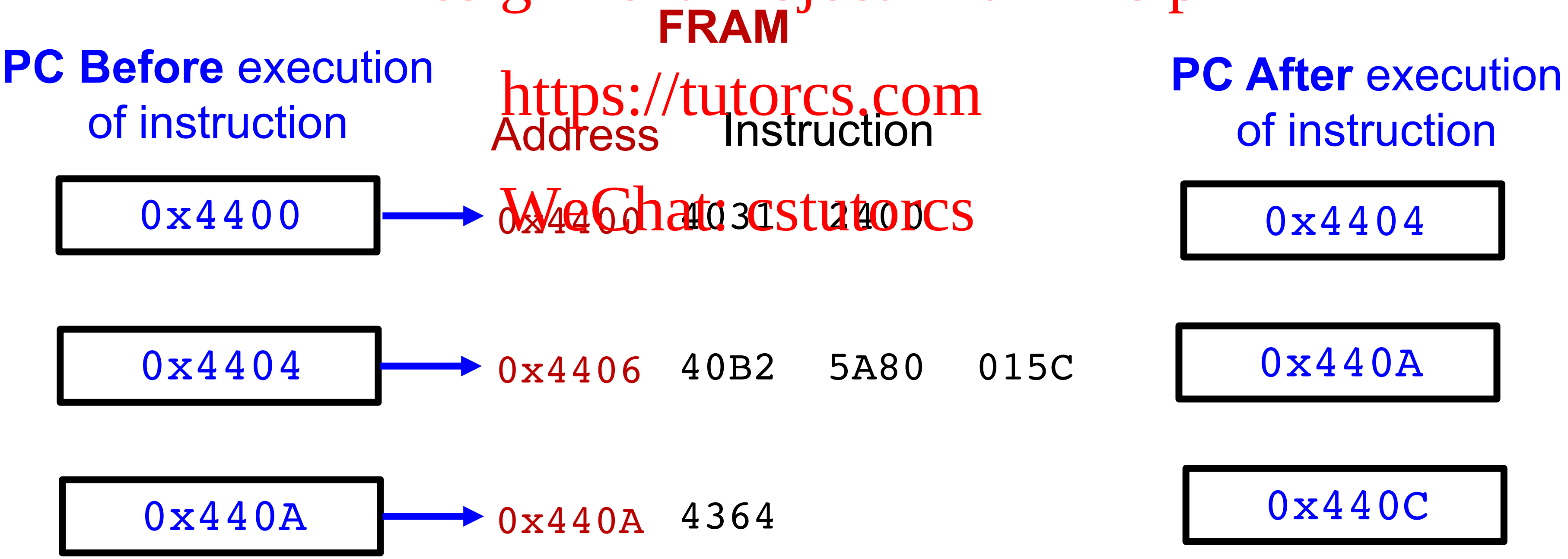
The Program Counter R0/PC

The core register R0 is the **Program Counter PC**

The **program counter points to the next instruction to be executed**

i.e.,

when we look into the PC register we see the address of the next instruction



PC Before execution of instruction	FRAM Address	Instruction	PC After execution of instruction
0x4400	0x4400	4031 2400	0x4404
0x4404	0x4406	40B2 5A80 015C	0x440A
0x440A	0x440A	4364	0x440C

Variables in MSP430 Assembly

We will use assembler directives to reserve and initialize data in memory

We will use labels to name *variables* and use **absolute address mode (&)** or **symbolic address mode**

Task: Define word variables x = 5 and y = 8 in RAM and reserve space for word variable sum

```
        .data
x:      .word    5
y:      .word    8
sum:    .space   2
```

A label is simply a name for an address

```
x = 0x1C00
y = 0x1C02
sum = 0x1C04
```

Symbolic address mode

```
mov.w   x, R4
add.w   y, R4
mov.w   R4, sum
```

Task: Add x and y and store in sum

Arrays in MSP430 Assembly

There is no actual array construct in assembly

We will emulate arrays using assembler directives and labels

```
               array1    array1+2    array1+4         address

array1: .word  0x0100,   0x0200,     0x0300
```

```
               array2    array2+1    array2+2         address

array2: .byte  0x01,     0x02,       0x03
```

We will have to be careful with byte and word arrays

Indexed Mode of Addressing

Syntax of **indexed mode**

```
array1: .word  0x0100,  0x0200,  0x0300

       mov.w  array1(R4), R5
```

e.g.:

```
       mov.w  #2, R4
       mov.w  array1(R4), R5
```

same as

```
       mov.w  &array1+2, R5
```

Indexed Mode and **Byte** Arrays

Rewrite our previous example using indexed mode

```
array2: .byte  0x10,   0x20,   0x30

        mov.b  &array2, R5
        add.b  &array2+1, R5
        add.b  &array2+2, R5
```

```
array2: .byte  0x10,   0x20,   0x30

        mov.w  #0, R4                ; R4 = 0 will be the index
        mov.b  array2(R4), R5        ; R5 = array2[R4]
        inc.w  R4                    ; R4++
        add.b  array2(R4), R5        ; R5 += array2[R4]
        inc.w  R4                    ; R4++
        add.b  array2(R4), R5        ; R5 += array2[R4]
```

Indexed Mode and **Word** Arrays

```
array1: .word  0x0100,  0x0200,  0x0300

        mov.w  &array1, R5
        add.w  &array1+2, R5
        add.w  &array1+4, R5
```

```
array1: .word  0x0100,  0x0200,  0x0300

        mov.w  #0, R4            ; R4 = 0 will be the index
        mov.w  array2(R4), R5    ; R5 = array2[R4]
        inc.w  R4                ; R4++
        inc.w  R4                ; R4++
        add.w  array2(R4), R5    ; R5 += array2[R4]
        inc.w  R4                ; R4++
        inc.w  R4                ; R4++
        add.w  array2(R4), R5    ; R5 += array2[R4]
```