Lecture 13

Subroutines I

YOU KILLED OUR ROBOT.
HE HAD IT COMING.
ARE YOU AWARE THAT IT UPLOADED ITS PERSONALITY TO THE INTERNET BEFORE YOU VIOLENTLY DECOMMISSIONED IT?
WHAT?
DID YOU KNOW IT HAD SUBROUTINES FOR HAUNTING, REVENGE, AND BEING A JERK?
WHAT?
WE MEET AGAIN.
Dilbert.com DilbertCartoonist@gmail.com
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Announcements

Midterm #1 was due today – 4:10 pm

Will post solutions next w ng will take time – 140+ students

BUT one submission alre d:

OpenAI

ChatGPT receives 0/100 – **zero**!

- The code does not compile
- Not MSP430 assembly: incorrect instructions and incorrect syntax
- Even after fixing those issues: incorrect logic

Upcoming assignments:

Posted a graded anonymous survey: Mid-Semester Class Feedback

Will post Quiz #4 tonight/tomorrow – a short subroutine

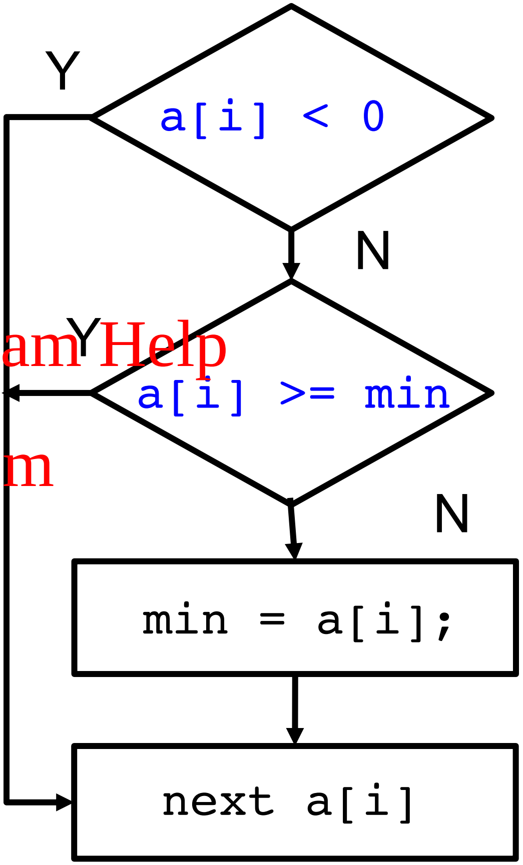
both due Wednesday March 1

Last Time: Compound Conditionals

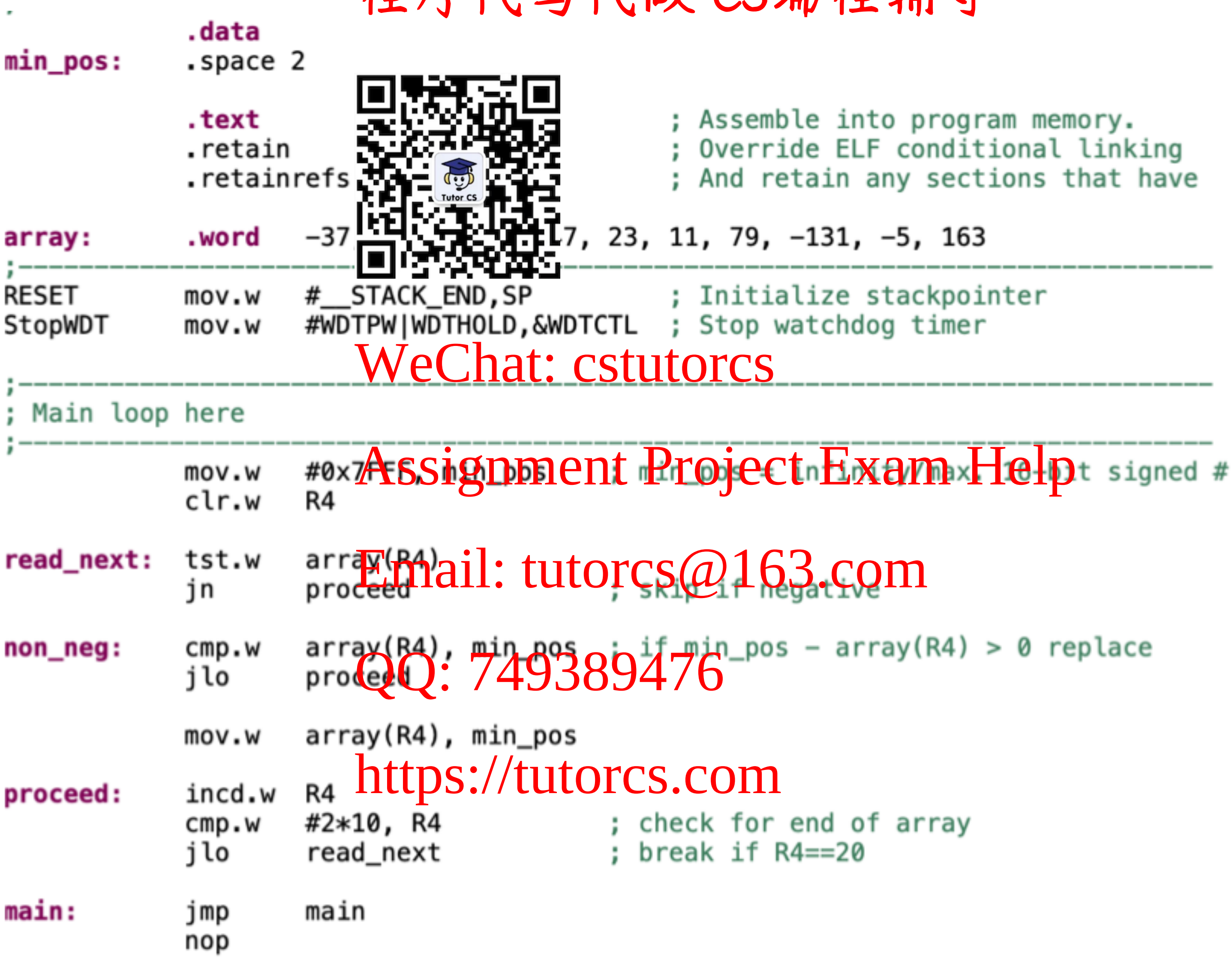
Task: Given an array of ten signed integers, find the min. nonnegative value

Easy in a high level langu we have a loop that finds the minimum

```
min = infinity;
for (ii = 0; i < length; i++) {
    if ( (a[i] >= 0 &&
         (a[i] < min_pos) )
        min = a[i];
}
```



One Solution



```
;
            .data
min_pos:    .space 2

            .text                           ; Assemble into program memory.
            .retain                         ; Override ELF conditional linking
            .retainrefs                     ; And retain any sections that have

array:      .word   -37 [illegible]7, 23, 11, 79, -131, -5, 163
;-------------------------------------------------------------------------------
RESET       mov.w   #__STACK_END,SP         ; Initialize stackpointer
StopWDT     mov.w   #WDTPW|WDTHOLD,&WDTCTL  ; Stop watchdog timer

;-------------------------------------------------------------------------------
; Main loop here
;-------------------------------------------------------------------------------
            mov.w   #0x7FFF, min_pos    ; min_pos = Infinity/max 16-bit signed #
            clr.w   R4

read_next:  tst.w   array(R4)
            jn      proceed             ; skip if negative

non_neg:    cmp.w   array(R4), min_pos  ; if min_pos - array(R4) > 0 replace
            jlo     proceed

            mov.w   array(R4), min_pos

proceed:    incd.w  R4
            cmp.w   #2*10, R4           ; check for end of array
            jlo     read_next           ; break if R4==20

main:       jmp     main
            nop
```

How to Solve a Problem?

Before jumping to the solution …

… take the time to study t n and understand it well

Let’s have a look at 16-bi umbers

0000	0	0
0001	1	1
...		
7FFE	32766	32766
7FFF	32767	32767
8000	-32768	32768
8001	-32767	32769
...		
FFFE	-2	65534
FFFF	-1	65535

Key Observation:

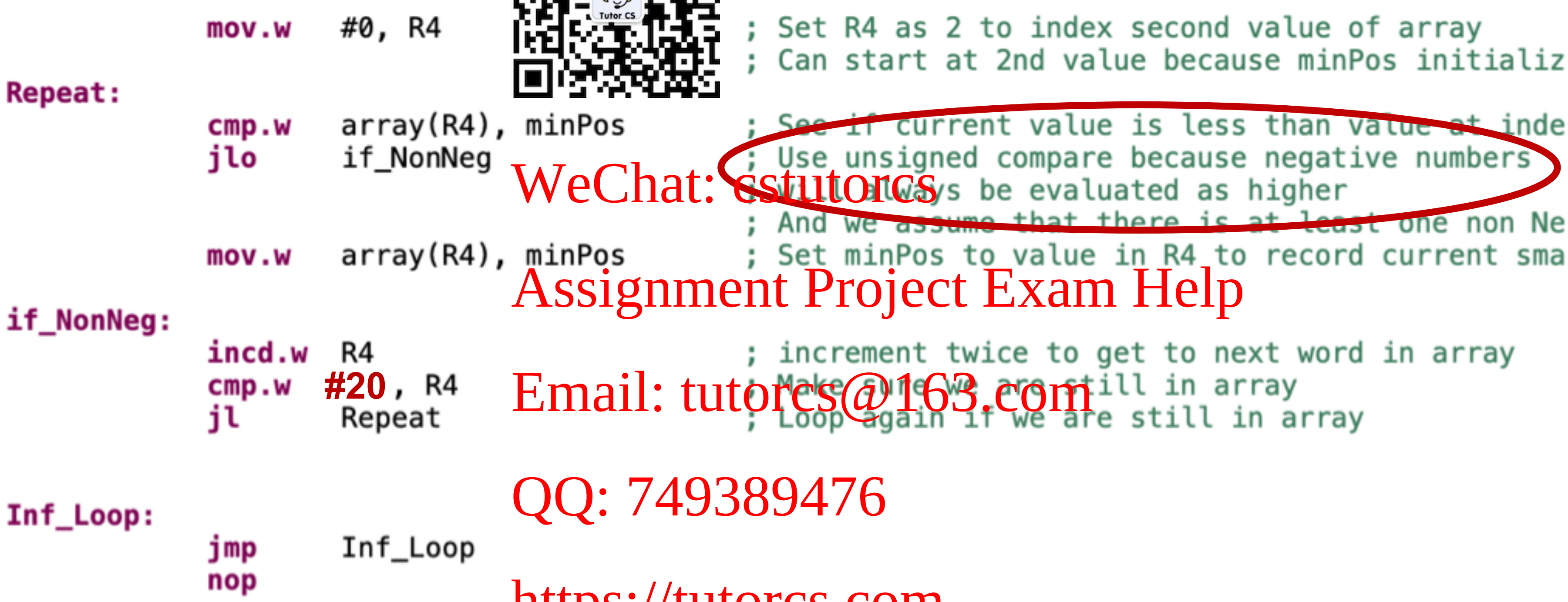
Every negative number is larger than every positive number if we do unsigned comparison

⇒ Minimum nonnegative value in array is the minimum value

⇒ No need to check for sign

Better Solution

Use unsigned compare, start with `min_pos = 0xFFFF`



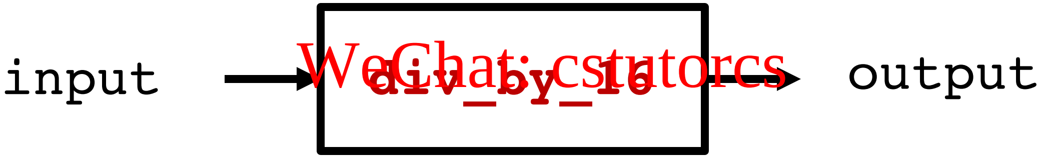
```
        mov.w   #0, R4                  ; Set R4 as 2 to index second value of array
                                        ; Can start at 2nd value because minPos initializ
Repeat:
        cmp.w   array(R4), minPos       ; See if current value is less than value at inde
        jlo     if_NonNeg               ; Use unsigned compare because negative numbers
                                        ; will always be evaluated as higher
                                        ; And we assume that there is at least one non Ne
        mov.w   array(R4), minPos       ; Set minPos to value in R4 to record current sma

if_NonNeg:
        incd.w  R4                      ; increment twice to get to next word in array
        cmp.w  #20, R4                  ; Make sure we are still in array
        jl      Repeat                  ; Loop again if we are still in array

Inf_Loop:
        jmp     Inf_Loop
        nop
```

A Simple Subroutine

In Midterm #1 you had to divide by 16 twice in the code

Do we really need to write [illegible] code twice? No!

We can write a simple **su**[illegible] to divide by 16



input

div_by_16

output

```
output= floor(input/16)
```

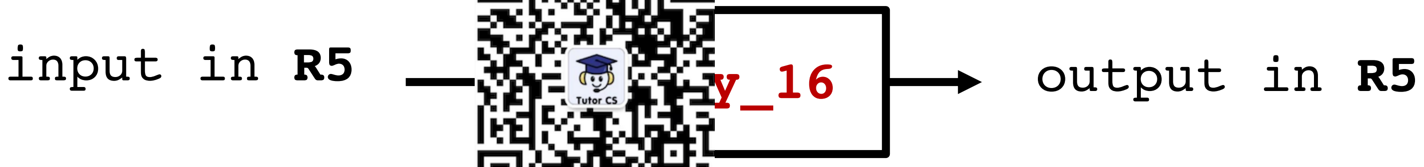
We can call this subroutine every time we need to divide by 16

- Allows us to reuse code
- Makes it easier to write, test, and maintain code
- Enables the use of libraries

Good code is _________ . **defect-free** **efficient** **modular**

A Simple Subroutine

Task: Write a simple subroutine **`div_by_16`** to divide a *given input* by 16

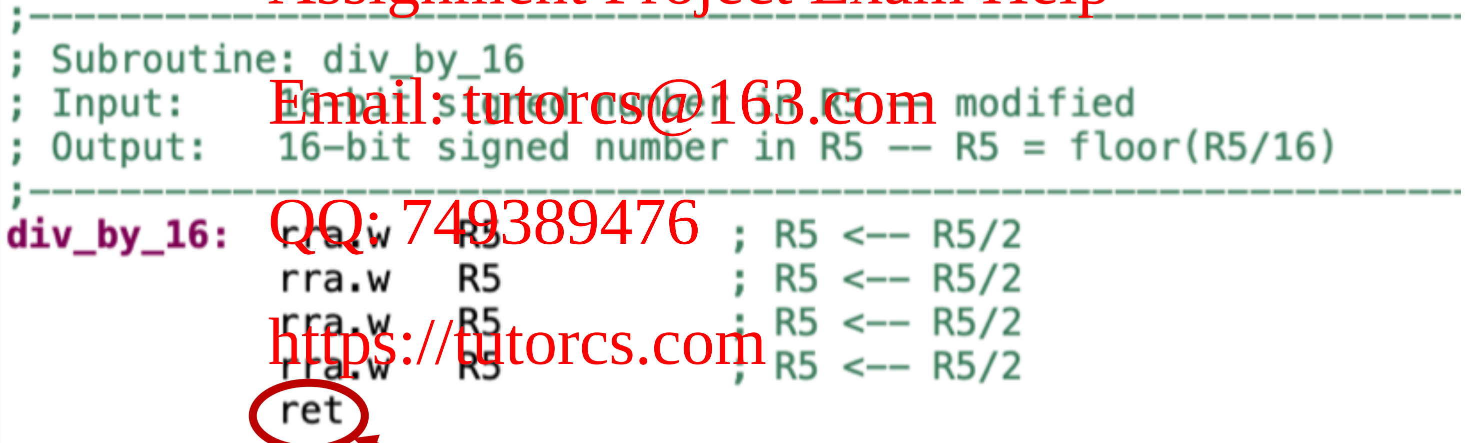


R5 = floor(R5/16)

What registers are affected by subroutine – if any?

What is the input, output, functionality?

Contract



```
;-------------------------------------------------------------------------
; Subroutine: div_by_16
; Input:      16-bit signed number in R5 -- modified
; Output:     16-bit signed number in R5 -- R5 = floor(R5/16)
;-------------------------------------------------------------------------
div_by_16:    rra.w   R5            ; R5 <-- R5/2
              rra.w   R5            ; R5 <-- R5/2
              rra.w   R5            ; R5 <-- R5/2
              rra.w   R5            ; R5 <-- R5/2
              ret
```

Label to identify the subroutine

`ret` – return to exit from subroutine

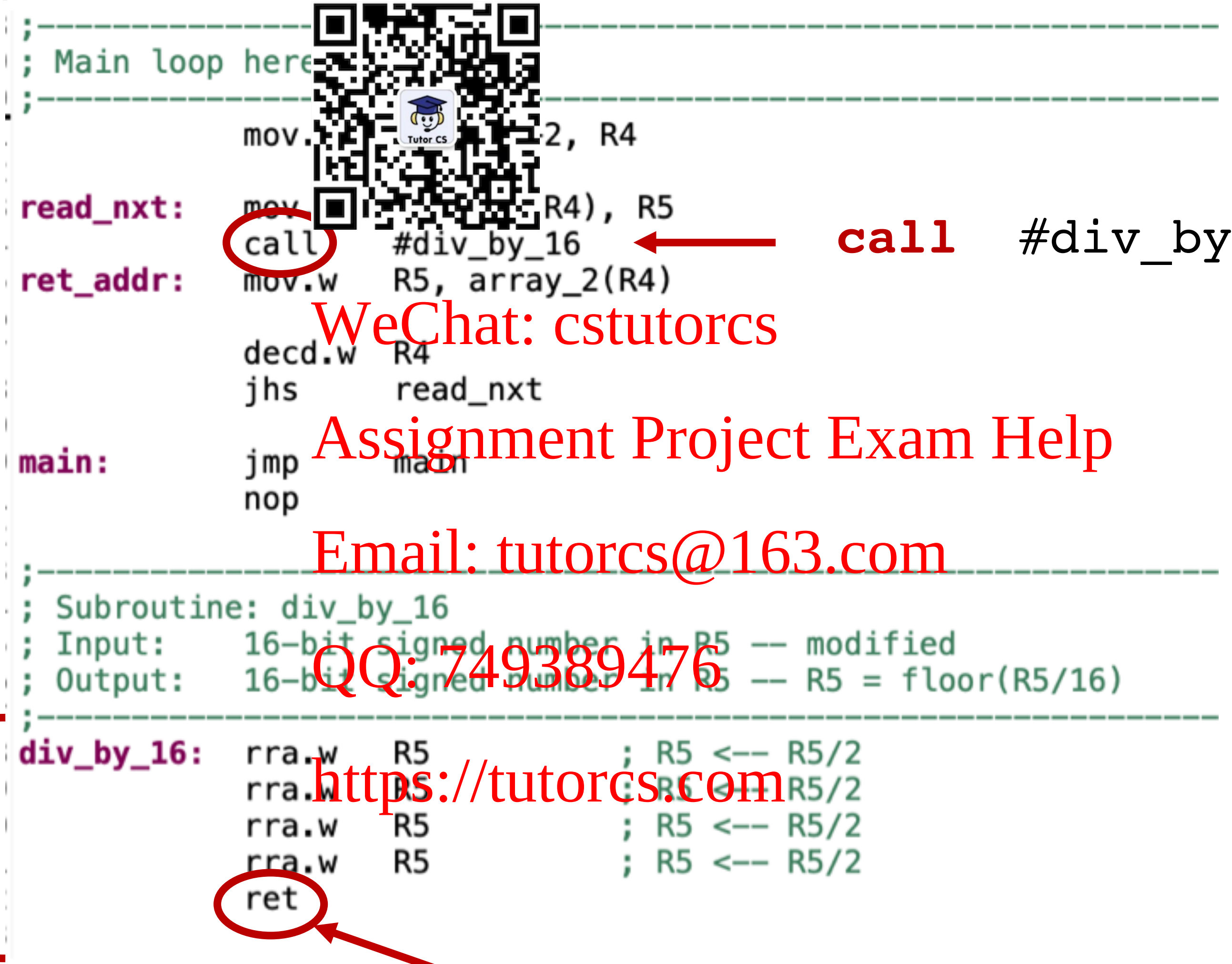
A Simple Subroutine

The bigger picture

Main loop

After the ∞-loop

sub-routine



```
;-----------------------------------------------------------------------
; Main loop here
;-----------------------------------------------------------------------
            mov.[illegible]2, R4

read_nxt:   mov[illegible]R4), R5
            call    #div_by_16
ret_addr:   mov.w   R5, array_2(R4)

            decd.w  R4
            jhs     read_nxt

main:       jmp     main
            nop

;-----------------------------------------------------------------------
; Subroutine: div_by_16
; Input:      16-bit signed number in R5 -- modified
; Output:     16-bit signed number in R5 -- R5 = floor(R5/16)
;-----------------------------------------------------------------------
div_by_16:  rra.w   R5              ; R5 <-- R5/2
            rra.w   R5              ; R5 <-- R5/2
            rra.w   R5              ; R5 <-- R5/2
            rra.w   R5              ; R5 <-- R5/2
            ret
```

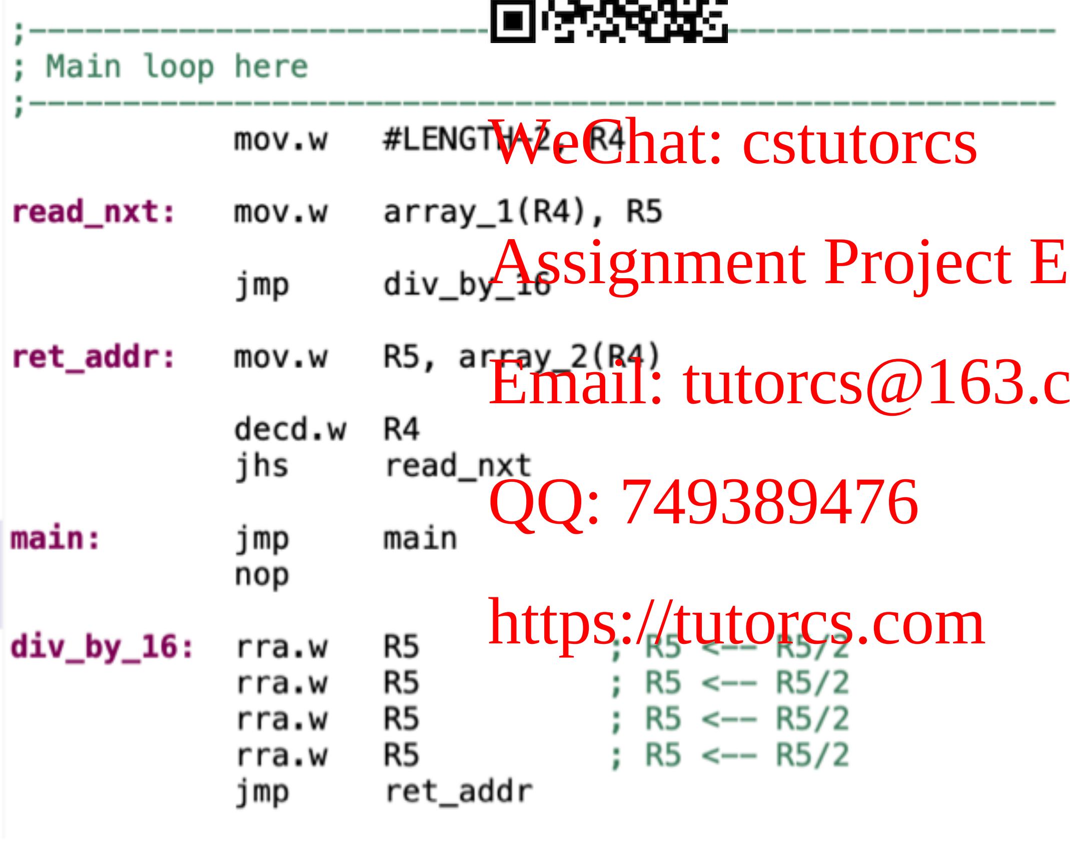
call #div_by_16

ret – return to exit from subroutine

Jumps vs `call`

With a jump:

- The program counter (PC) is updated to the address of the label
- Execution proceeds from the label



```
;-------------------------------------------------------------------
; Main loop here
;-------------------------------------------------------------------
            mov.w   #LENGTH-2,R4

read_nxt:   mov.w   array_1(R4), R5

            jmp     div_by_16

ret_addr:   mov.w   R5, array_2(R4)

            decd.w  R4
            jhs     read_nxt

main:       jmp     main
            nop

div_by_16:  rra.w   R5              ; R5 <-- R5/2
            rra.w   R5              ; R5 <-- R5/2
            rra.w   R5              ; R5 <-- R5/2
            rra.w   R5              ; R5 <-- R5/2
            jmp     ret_addr
```

Awful coding practice!

For demonstration purposes only!

DO NOT REPLICATE

Jumps vs `call`

With a **`call`** there is more

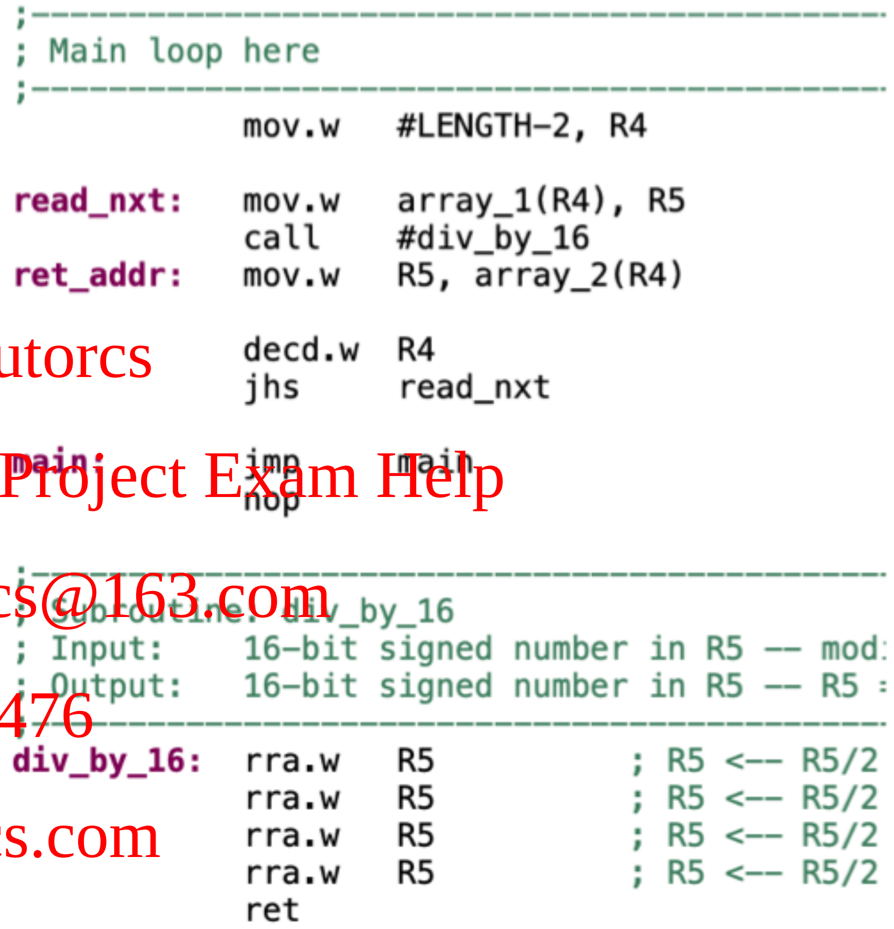
- The address of the next instruction in the calling program

⇒ **Return address**

- The address of the subroutine is loaded into the PC
- The subroutine is executed
- After the **`ret`** instruction, the return address is **restored** into the PC
- Execution continues from this point in the calling function

Where is the return address saved?

The Stack



```
;-------------------------------------------------------
; Main loop here
;-------------------------------------------------------
                mov.w   #LENGTH-2, R4

read_nxt:       mov.w   array_1(R4), R5
                call    #div_by_16
ret_addr:       mov.w   R5, array_2(R4)

                decd.w  R4
                jhs     read_nxt

main:           jmp     main
                nop

;-------------------------------------------------------
; Subroutine: div_by_16
; Input:        16-bit signed number in R5 -- mod:
; Output:       16-bit signed number in R5 -- R5 :
;-------------------------------------------------------
div_by_16:      rra.w   R5                  ; R5 <-- R5/2
                rra.w   R5                  ; R5 <-- R5/2
                rra.w   R5                  ; R5 <-- R5/2
                rra.w   R5                  ; R5 <-- R5/2
                ret
```

Shift and Rotate Instructions

Processors often offer three types of shifts and rotations

- **Logical Shift:** Inserts [illegible] both right and left shifts

  Divide/Multiply by 2 f[illegible]ned numbers

No Instruction in MSP430

- **Arithmetic Shift:** Insert zeros for left shifts

  Repeat the most significant bit for right shifts

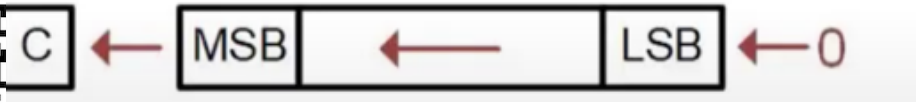
  Divide/Multiply by 2 for signed numbers

- **Bit Rotation:** No bits inserted or lost – bits are moved out of one end of the register and passed around to the other end

Shift and Rotate Instructions

Arithmetic Shift/Roll Left

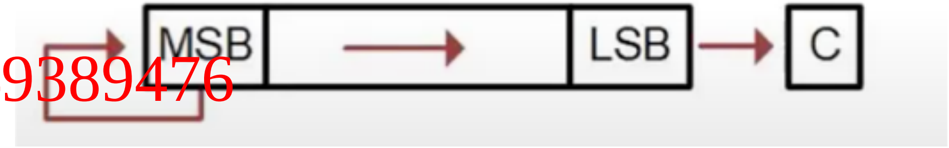
```
        rla.w   dst        ift all bits left, insert 0
```



- You can use **`rla.w`** to multiply a signed/unsigned number by 2

Arithmetic Shift/Roll Right

```
        rra.w   dst        ; shift all bits right, insert msb
```

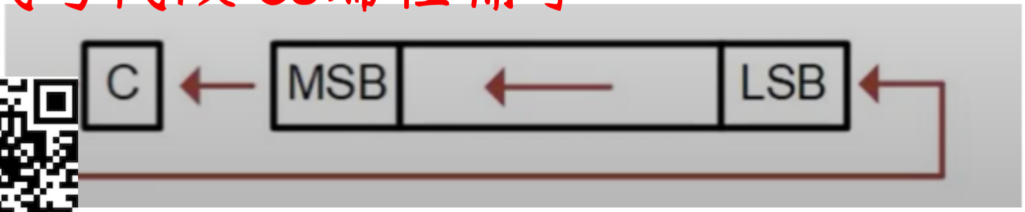


- You can use **`rra.w`** to divide **a signed number** by 2
- Does not work with unsigned numbers!!

Shift and Rotate Instructions

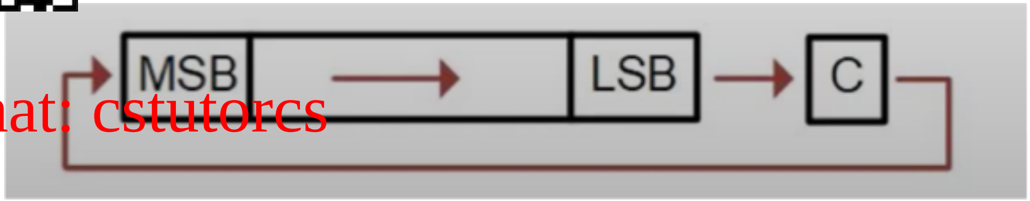
Rotate Left Through Carry

```
rlc.w   dst
```



Rotate Right Through Carry

```
rrc.w   dst
```



Shift and Rotate Instructions

```
rla.w   dst       ; arithmetic shift left
rra.w   dst       ; arithmetic shift right
rlc.w   dst       ; rotate left through carry
rrc.w   dst       ; rotate right through carry
```

Syntax: These instructions have one operand

Even More Instructions

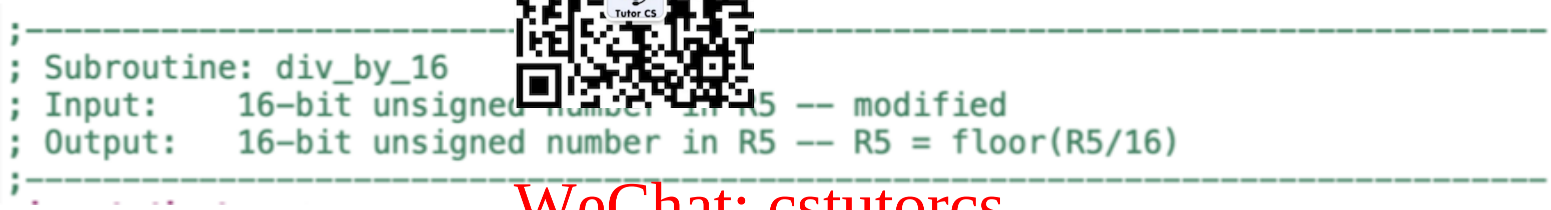
Operations on Bits in St[illegible]ister

```
clrc          ; [illegible]rry bit                   C = 0
clrn          ; [illegible]gative bit                N = 0
clrz          ; clear zero bit                       Z = 0
setc          ; set carry bit                        C = 1
setn          ; set negative bit                     N = 1
setz          ; set zero bit                         Z = 1
dint          ; disable general interrupts           GIE = 0
eint          ; enable general interrupts            GIE = 1
```

Syntax: These instructions do not have operands. They act on the specific status bits in SR = R2

Coding Task

Task: Write a subroutine that performs unsigned division by 16 with following contract



```
;-------------------------------------------------------------------------
; Subroutine: div_by_16
; Input:     16-bit unsigned number in R5 -- modified
; Output:    16-bit unsigned number in R5 -- R5 = floor(R5/16)
;-------------------------------------------------------------------------
```

You can download Lecture_13.asm from Carmen and add your code