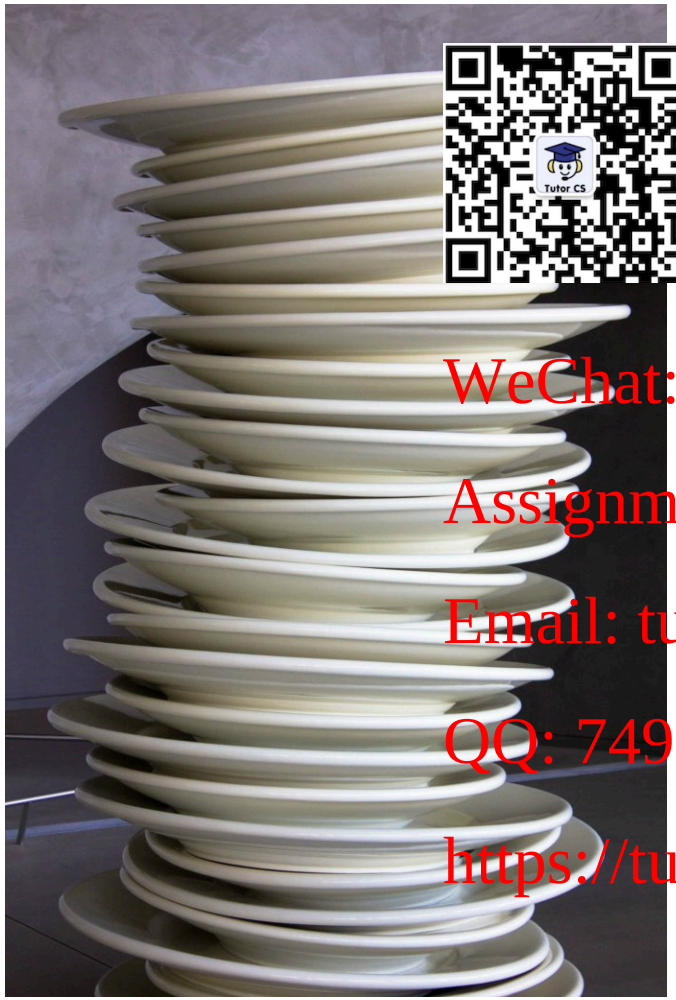


Lecture 14

The Stack

Last Time: Subroutine Calling Sequence

Sequence o events after

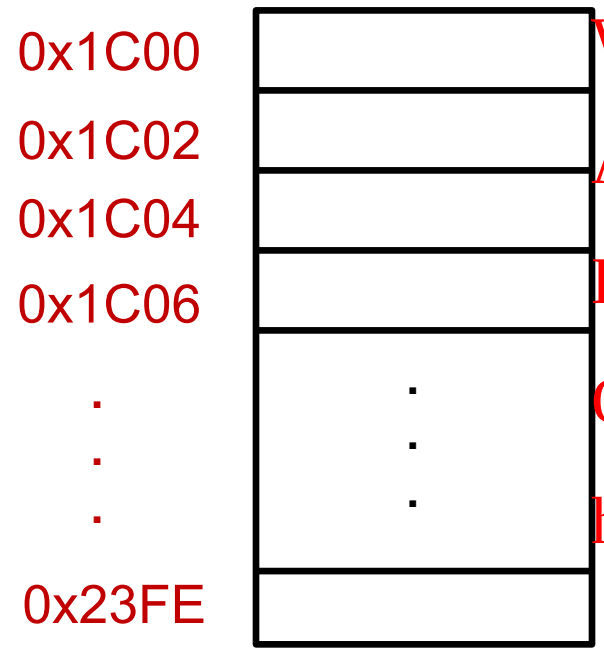
`call` `#div_by_16`

- Current PC is **saved o[illegible]ck**
- This will be the **return address**
- The address of the subroutine is loaded into the PC
- The subroutine is executed
- With **`ret`**, the return address is **restored from the stack** into PC
- Execution continues from this point in the calling function

```
;-------------------------------------------------
; 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
```

Static vs. Dynamic Allocation

So far we have used the RAM for storing program data initialized or reserved at compilation time – using assembler directives **`.word`** **`.byte`** **`.space`**



Assembler directives allocate data at the **top of the RAM**

e.g.

```
.data
.retain
.retainrefs
array_1:    .word  1, 2, 3, 4, 5, 6, 7, 8, 9,
array_2:    .space  24
```

This allocation is **static** – it does *not* change during runtime

⇒ **Static allocation**

The Stack

The **stack** is a data structure that is managed at the end of the RAM

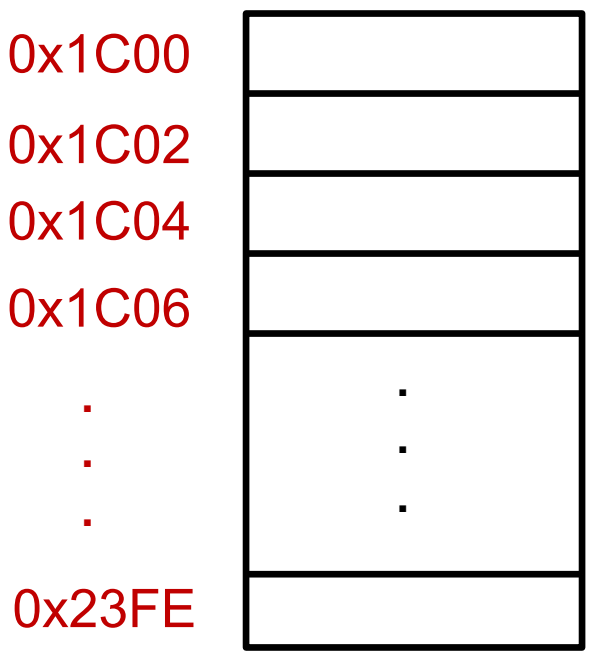
ed using `SP`, `push` and `pop`

tine calls and interrupts use the stack critical registers (`PC` and `SR`) before execution and restore these with `ret/reti`

We can use the stack to save/restore additional registers (R4 – R15) during subroutine calls and interrupts

We can create variables during runtime without initializing/reserving them at compile time

The stack enables **dynamic data allocation**



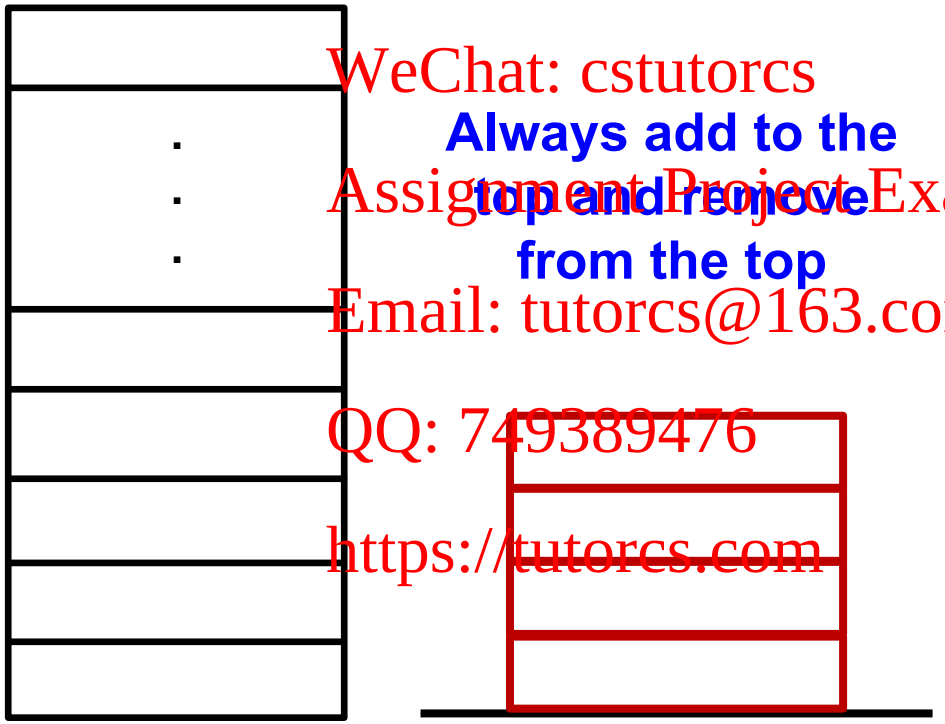

```
mov.w   #__STACK_END,SP     ; Initialize stackpointer
```

`0x2400`

The Stack

The **stack** starts empty and is managed dynamically during runtime

i.e., we can add new data to the stack and remove it



Stack – Adding and Removing Data

To add data onto the stack we use `push.w src`

To remove data from the `pop.w dst`

Address **RAM**

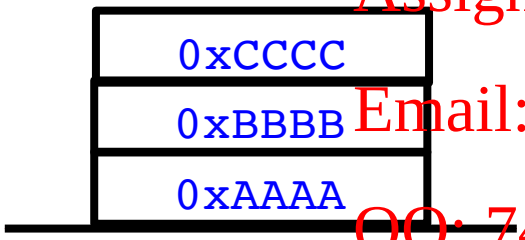
0x23F6

0x23F8

0x23FA

0x23FC

0x23FE




```
push.w   #0xAAAA
push.w   #0xBBBB
push.w   #0xCCCC

pop.w    R4
pop.w    R5
pop.w    R6
```


The stack is a last-in first-out data structure: the last element that is added onto the stack (i.e., **push**ed) is the first element removed (i.e., **pop**ped)

Top of Stack – Stack Pointer (SP)

New elements are added onto the top of stack and removed from there

To manage the stack we  to know the address of the **top of stack**

Core register R1 is dedica[illegible]s task: **Stack Pointer (SP)**

At the beginning of each program the stack pointer is initialized

```
RESET       mov.w   #__STACK_END,SP         ; Initialize stackpointer
                    #0x2400
```


0x23F8

0x23FA

0x23FC

0x23FE

0x2400 – not in RAM !

The stack pointer is always aligned with **even addresses**

`SP = 0x2400`

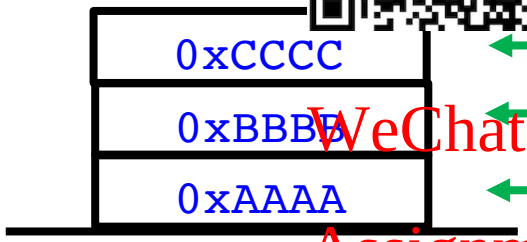
← `SP` points here

Top of Stack – Stack Pointer (SP)

The stack pointer SP is **decremented** as we `push` elements onto stack

incremented as we `pop` elements from stack

The SP operates using a **pre-decrement, post-increment** scheme




```
push.w   #0xAAAA        SP = 0x23FE
push.w   #0xBBBB        SP = 0x23FC
push.w   #0xCCCC        SP = 0x23FA

pop.w    R4             SP = 0x23FC      R4 = 0xCCCC
pop.w    R5             SP = 0x23FE      R5 = 0xBBBB
pop.w    R6             SP = 0x2400      R6 = 0xAAAA
```

Saving/Restoring Registers using the Stack

Often subroutine contracts have restrictions on using core registers

```
;-------------------------------------------------------------------------
; Subroutine: x_Tim
; Inputs: unsigned        x in R5 -- returned unchanged
;         unsigned        y in R6 -- returned unchanged
;
; Output: unsigned        r in R12 -- R12 = R5 * R6
;
; All other core registers in R4-R15 unchanged
;-------------------------------------------------------------------------
```


We will use the stack to save core registers at the beginning of a subroutine and restore them before returning


```
x_times_y:

        push    R5
        push    R6

        ; Compute R5*R6 by repeatedly adding R5 -- R6 times

        pop     R6
        pop     R5

        ret
```

mind the order of `push` and `pop`!

Not so efficient x_times_y


```
;-------------------------------------------------------------------------------
; Subroutine: x_Times_y
; Inputs: unsigned 8-bit nu                    -- returned unchanged
;         unsigned 8-bit nu                    -- returned unchanged
;
; Output: unsigned 16-bit n                    -- R12 = R5 * R6
;
; All other core registers in R4-R15 unchanged
; Does not access any addressed memory
;-------------------------------------------------------------------------------
x_times_y:
; Compute R5*R6 by repeatedly adding R5 -- R6 times

            push    R6          ; save R6 on stack

            clr.w   R12         ; start with R12=0 before adding

check_R6:   tst.w   R6          ; R6 could be zero to start with, check before 1st add
            jz      ret_from_x_times_y

            add.w   R5, R12     ; R6 not zero, continue adding R5
            dec.w   R6          ; account for added R5 by decreasing R6
            jnz     check_R6

ret_from_x_times_y:
            pop     R6      ; restore R6 from stack
            ret
```