x86 branches & subroutines

CMSC 313

Raphael Elspas

Flags review

- The EFLAGS register is a 32 bit register that stores flags bit by bit.
- The relevant ones in this class are:
  - OF – overflow, 1 if the previous operation produces an overflow (POS+POS=NEG or NEG+NEG=POS). This flag is only triggered on signed operations
  - CF – carry, 1 if the previous operation produces a carry out bit = 1. This flag is only triggered on unsigned operations
  - ZF – zero, 1 if the previous operation produced a zero
  - SF – sign, 1 if the previous operation produced a negative number (first bit is zero).

Flags cont.

- Operations may set, clear, modify, or test (view) a flag
- Some operations do not affect any flags
- RFLAGS is the 64 bit version of EFLAGS (32 bit)

Branch/Jump instructions

- x86 refers to all jumps and branches as **jump** instructions
- Unconditional jump is **JMP**
- Conditional jumps are called **Jcc**, which stands for “Jump condition”**. cc** represents that there may be two letters as part of the conditional jump command such as **JGL** or **JLE**

x86 jump (jcc)

Inst		Sign
JL	<	Signed
JLE	<=	Signed
JB	<	Unsigned
JBE	<=	Unsigned
JG	>	Signed
JGE	>=	Signed
JA	>	Unsigned
JAE	>=	Unsigned

Inst	
JE	==
JNE	!=
JZ	Previous == 0
JNZ	Previous != 0
JS	Previous < 0
JNS	Preivious >= 0

More located here:
https://www.felixcloutier.com/x86/jcc

Compare

- X86 provides a way of testing if values are greater, less than or equal to another without modifying either of the values. This is called a compare or **CMP**.
- CMP computes the difference between the operands, like a SUB instruction, but does not store the difference in a register. Instead, only the EFLAGS register is updated with new flag values.

CMP example

```
MOV eax, 10
MOV ebx, 20
CMP eax, ebx ; Compare the values in EAX and EBX
             ; eax – ebx is computed
             ; SF = 1, ZF = 0, CF = 0, OF = 0
jle happy    ; Jump to ‘happy’ if EAX <= EBX (ZF = 1 or SF != OF)
             ; branch taken
```

7E cb	JLE rel8	D	Valid	Valid	Jump short if less or equal (ZF=1 or SF≠ OF).

From https://www.felixcloutier.com/x86/jcc

JMP addressing

- Jumps can use **absolute** addressing or **relative** addressing
- An **absolute** address is a specific address
  - The value can be a label or in a register
  - Actual number is computed by the assembler
- A **relative** address is a displacement off of the value in the RIP register
  - Assembler computes address from offset

JMP addressing example

```
section .data
    absolute_data dd 42      ; Absolute data value stored in a 4-byte integer

section .text
main:
    ; Relative addressing
    mov eax, [ebp - 4]       ; Load the value stored at [ebp - 4] into eax
                             ; This is an example of relative addressing,
                             ; accessing data relative to the base pointer (ebp)

    ; Absolute addressing
    mov ebx, absolute_data   ; Load the address of absolute_data into ebx
    mov ecx, [ebx]           ; Load the value stored at the address in ebx into ecx
                             ; This is an example of absolute addressing,
                             ; accessing data directly via its memory address
```

if/else example

- Convert the following to

```
if ( x < y ) {
    columbus_sailed();
} else {
    the_ocean_blue();
}
```

```
section .data
        ;declare x and y
section .text
        MOV RAX, [x]
        MOV RBX, [y]
        CMP RAX, RBX
        JGE else
        columbus_sailed
        JMP done
else:   the_ocean_blue
done:
```

Note: the “if” will run if x < y. The “else” will run if x >= y. therefore, since we want to jump to the else block, we will use the condition x >= y

While loop

- Convert the following to

```
while ( i > 0 ) {
    foo;
}
```

```
section .data
      ;declare i
section .text
loop: MOV RAX, [i]
      CMP RAX, 0
      JLE done
      foo
      JMP loop
done:
```

Note: We need an exit condition so that we can leave the loop. In the case of this program, although we have a jump instruction to done, we never reach it since “i” doesn’t change.

Loop over array

- You can declare an array of values by using commas in the .data section
- There is something wrong with this code. Use gdb to figure out what is wrong and suggest a fix
- **loop** keyword automatically decrements rcx by 1 and will jump to given address as long as rcx != 0

```
section .data
        arr dw 2,3,4,5
        len equ ($ - arr)/2
section .bss
        buffer resb 1
section .text
        global main
main:   mov  rbx, arr       ; Load address of the message
        mov  ecx, len       ; load value of length
loop_print:
        ; convert from int to ascii
        mov  ax, word [rbx]
        add  al, '0'
        mov  [buffer], al

        ; setup syscall
        mov  rsi, buffer            ; address of ascii char
        mov  rdi, 1                 ; File descriptor 1 (stdout)
        mov  rdx, 1                 ; Length of the element
        mov  rax, 1                 ; Syscall number for sys_write
        syscall                     ; Invoke syscall to write the message

        ; handle loop iteration
        add  rbx, 2
        loop loop_print

        ; exit syscall
        mov rax, 60
        mov rdi, 0
        syscall
```

UMBC

Loop over array

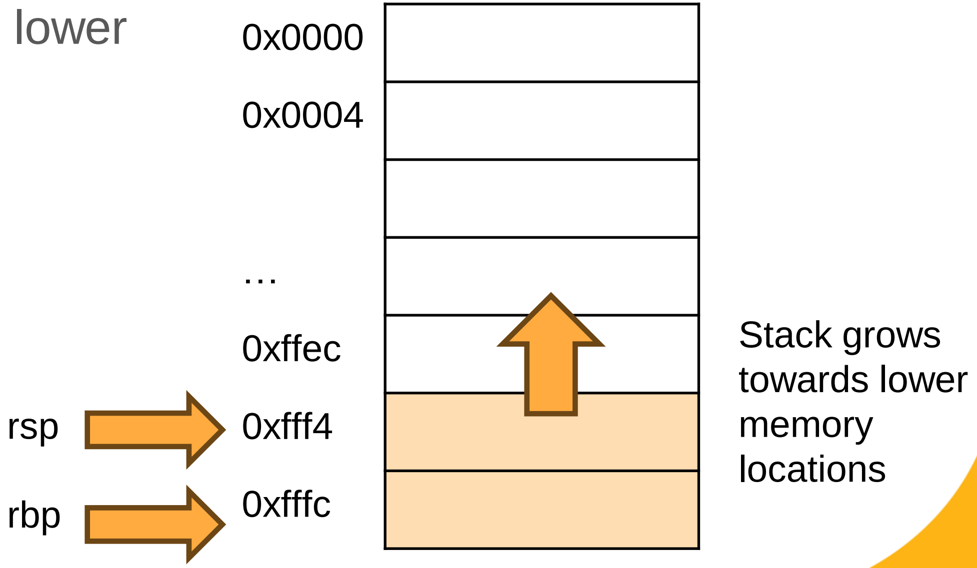
- The rcx register gets **clobbered** (trash valued) by the write syscall
- We need to store rcx before syscall and then reintroduce it after.
- We can use **push** and **pop** to store rcx and then retrieve it later

```
section .data
      arr dw 2,3,4,5
      len equ ($ - arr)/2
section .bss
      buffer resb 1
section .text
      global main
main: mov  rbx, arr       ; Load address of the message
      mov  ecx, len       ; load value of length
loop_print :
      ; convert from int to ascii
      mov  ax, word [rbx]
      add  al, '0'
      mov  [buffer], al

      ; setup syscall
      push rcx
      mov  rsi, buffer          ; address of ascii char
      mov  rdi, 1               ; File descriptor 1 (stdout)
      mov  rdx, 1               ; Length of the element
      mov  rax, 1               ; Syscall number for sys_write
      syscall                   ; Invoke syscall to write the message
      pop rcx

      ; handle loop iteration
      add  rbx, 2
      loop loop_print

      ; exit syscall
      mov rax, 60
      mov rdi, 0
      syscall
```


```
mov  rsi, buffer
mov  rdi, 1
mov  rdx, 1
mov  rax, 1
syscall

rcx ; ?? clobbered
```

Stack

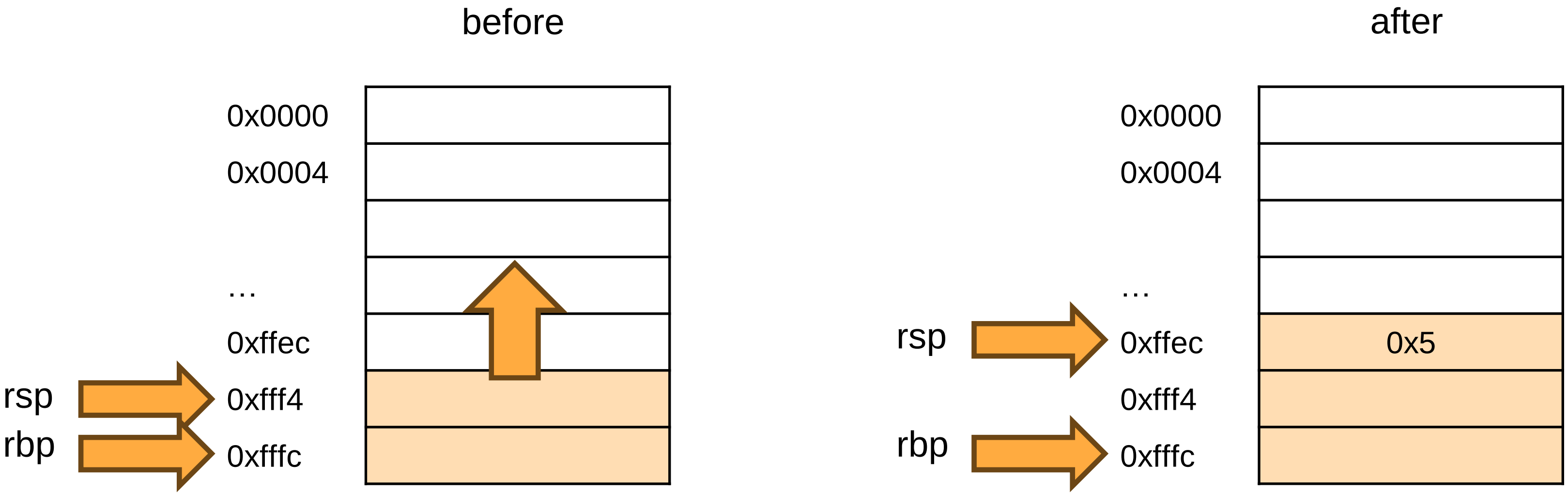
- The stack is a memory data structure to store data as needed
- Follows LIFO pattern: Last in, first out
- The top of the stack grows towards lower memory addresses
- RBP points to base of stack
- RSP points to top of stack



Push operation

- RSP gets decremented by the size of the operand
- Operand is copied into [RSP]

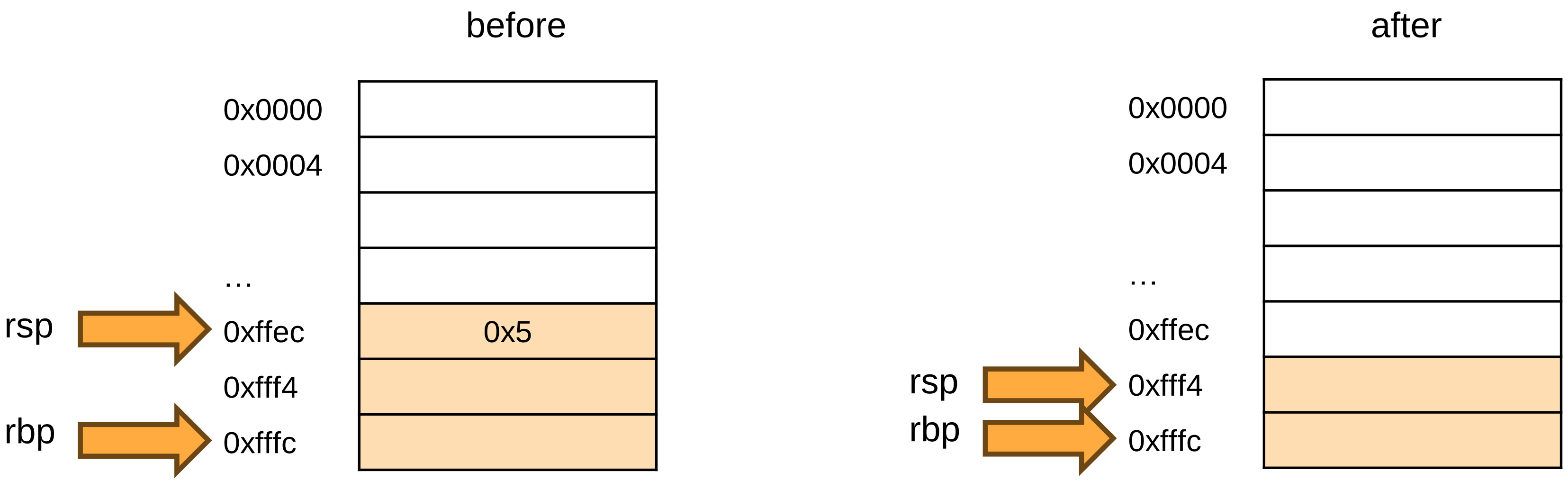
```
push rax ; rax = 0x5
```



Pop operation

- Opposite of Push operation
- [RSP] is copied into operand
- RSP is incremented by the size of the operand

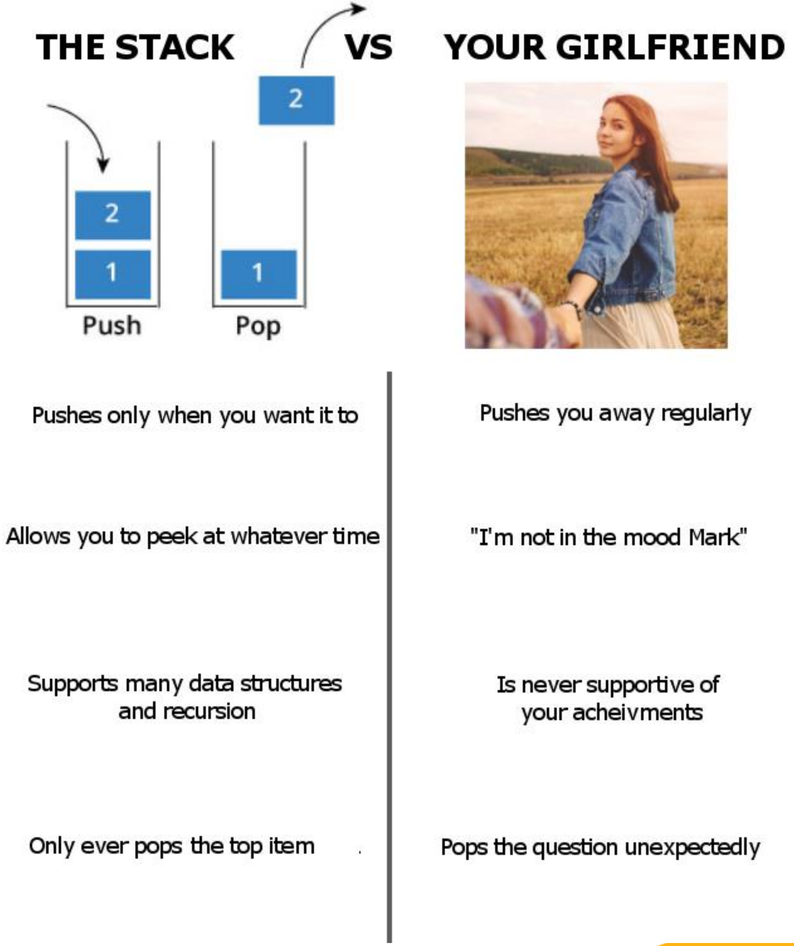
```
pop rax ; rax = <random>
; rax = 0x5
```



Push and Pop

- You don’t always have to push and pop values into the same register

```
push rax
; do something
pop rsi
```



Subroutine instructions

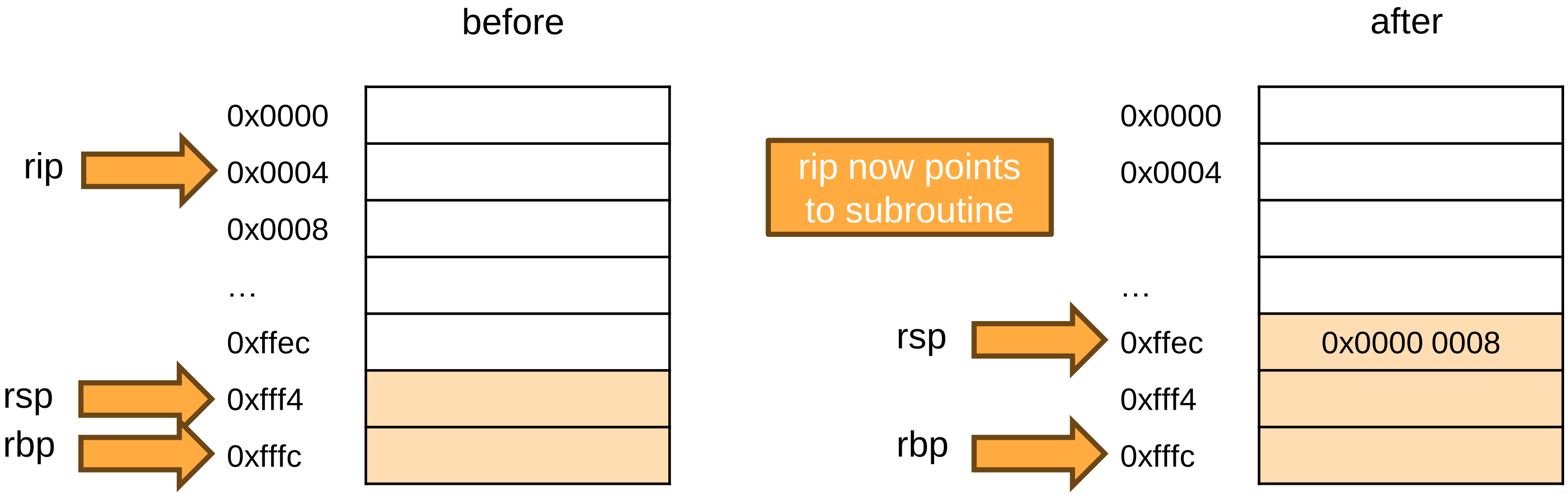
- CALL label is used to call subroutine
  - Increments RIP
  - PUSHes RIP onto the stack
  - Jumps to the label
- RET returns from a subroutine
  - POPs the top of the stack into RIP
  - Execution proceeds from the location saved at RIP

A subroutine that is CALLed Always needs a RET!

```
foo: ; this is just a label
     mov rax, 5

bar: ; this is a subroutine
     mov rax, 5
     ret
```

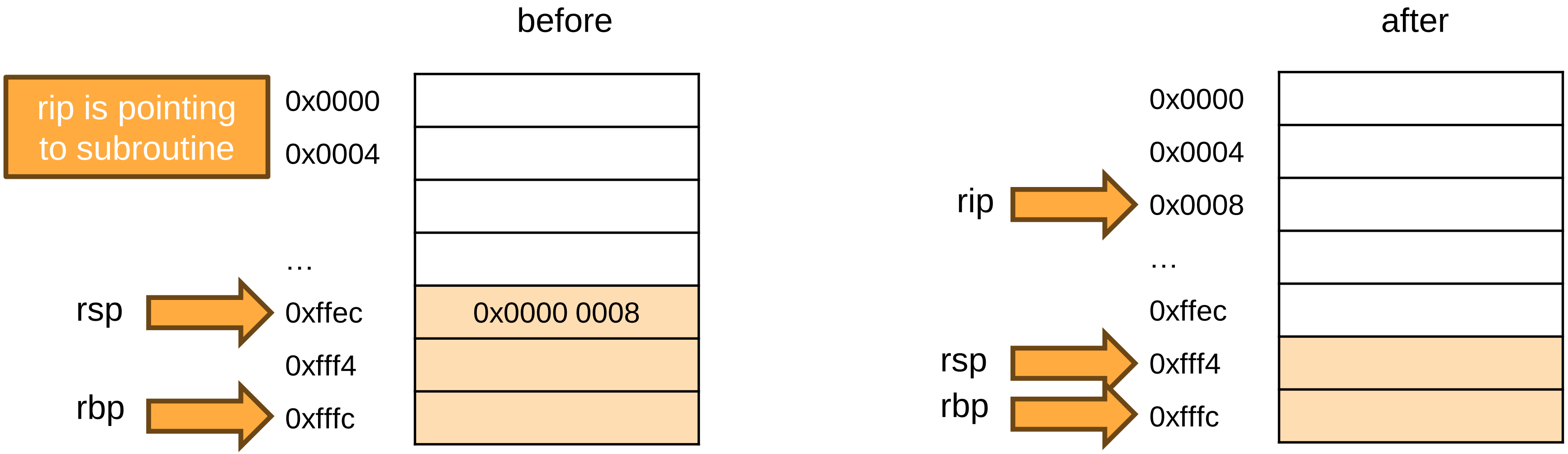
Subroutine stack during CALL

- Instruction after rip is saved on stack during a subroutine call
- Addresses are 64bit, so 8 bytes will be pushed on the stack



Subroutine stack during ret

- After RET, execution continues with where the head of the stack is pointing and rsp is incremented by the address size (64 bits)



References

- Ivan Sekyonda's slides
- https://en.wikipedia.org/wiki/FLAGS_register
- http://asmdebugger.com/