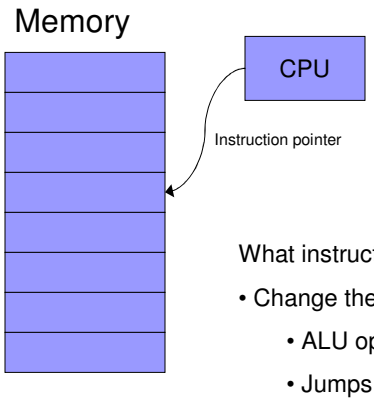
X86 assembly quick tutorial (real mode)

Wei Dong

The State Machine



The CPU program:

```
while (TRUE)
{
        fetch the instruction
        execute the instruction
        (update the instruction pointer)
}
```

What instructions do:

- Change the state of CPU
  - ALU operation
  - Jumps
- Read data from memory
- Write data to memory

CPU State: Register Set

General-purpose registers 16bit 32bit

	AH	AL	AX	EAX
	BH	BL	BX	EBX
	CH	CL	CX	ECX
	DH	DL	DX	EDX
	BP			EBP
	SI			ESI
	DI			EDI
	SP			ESP

Segment registers (16bit)

CS
DS
SS
ES
FS
GS

Flags (32bit)

EFLAGS

Instruction Pointer (32bit)

EIP

Address the register by: %ax, %ebx, etc

A little bit on EFLAGS

Function of EFLAGS:

- Control the behavior of CPU
- Save the status of last instruction

Bit	Name	Comment
0	CF: carry flag	
6	ZF: zero flag	
7	SF: sign flag	
9	IF: interrupt	sti; cli;
10	DF: direction	std; cld;
11	OF: overflow	

Memory Addressing

Format:

segment:displacement(base, index)

Offset = Base + Index + Displacement

Address = (Segment << 4) + Offset

Displacement: constant

Base: %bx, %bp

Index: %si, %di

Segment: %cs, %ds, %ss, %es

Memory Addressing (data)

segment:displacement(base, index)

- The components are all optional
- Default segment:
  - %bp: %ss
  - %bx, %si, %di: %ds
- Examples

  100
  (%si) = %ds:(%si)
  (%bp) = %ss:(%bp)
  (%bx,%si) = %ds:(%bx,%si)
  -10(%bp) = %ss:-10(%bp)
  %ds:-10(%bx, %si)

Instructions: arithmetic & logic

- add/sub{l,w,b} source, dest
- inc/dec/neg{l,w,b} dest
- cmp{l,w,b} source, dest
- and/or/xor{l,w,b} source, dest

…

- Restrictions
  - No more than one memory operand

Instructions: Data Transfer

- mov{lwb} source, dest
- xchg{lwb} source, dest
  - Segment registers can only appear with registers
- movsb
  - movb %ds:(%si) %es:(%di)
  - %si ← %si + inc
  - %di ← %di + inc
  - %cx ← %cx – 1

  If DF = 0 then inc = 1

  else inc = -1
  - Often used with %cx to move a number of bytes

Example

- Move 0x200 bytes from 0x0100:0x0000 to 0x0080:0x0000

```
    movw $0x0100, %ax
    movw %ax, %ds          /* setup %ds */
    movw $0x0080, %ax
    movw %ax, %es          /* setup %es */
    movw $0, %ax
    movw %ax, %si          /* setup %si */
    movw %ax, %di          /* setup %di */
    movw $0x200, %cx
    cld                    /* setup direction flag */
repeat:
    movsb
    cmp $0, %cx
    jnz repeat
```

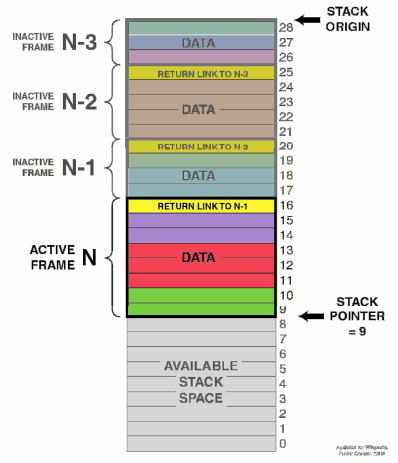
Example (cont.)

- Move 0x200 bytes from 0x0100:0x0000 to 0x0080:0x0000

```
    movw $0x0100, %ax
    movw %ax, %ds          /* setup %ds */
    movw $0x0080, %ax
    movw %ax, %es          /* setup %es */
    movw $0, %ax
    movw %ax, %si          /* setup %si */
    movw %ax, %di          /* setup %di */
    movw $0x200, %cx
    cld                    /* setup direction flag */
    rep
    movsb
```

Instructions: stack access

- pushw source
  - %sp ← %sp – 2
  - %ss:(%sp) ← source
- popw dest
  - dest ← %ss:(%sp), dest
  - %sp ← %sp + 2
- Setup up the stack before you actually use it



Instructions: unconditional jump

- jmp label
  - %ip ← label
- ljmp NEW_CS, offset
  - %ip ←label; %cs ← NEW_CS
- call label
  - push %ip + ? (address of call instruction)
  - %ip ← label
- ret
  - pop %ip
- Also lcall and lret

Instructions: conditional jump

- j* label: jump to label if flag * is 1
- jn* label: jump to label if flag * is 0
- *: bits of %eflags

  Examples: js, jz, jc, jns, jnz, jnc, …

BIOS Service

- Use BIOS service through interruption
  - Store the parameters to the registers
  - Call the interruption
- int INT_NUM

Example: BIOS INT 0x13 Function 2

- ah = 2
- al = number of sectors to read
- ch = cylinder number bits 0-8
- cl, bits 6&7 = cylinder number bits 8-9.
- bits 0-5 = starting sector number, 1 to 63
- dh = starting head number, 0 to 255
- dl = drive number
- es:bx = pointer where to place information read from diskette

- Returns:
- ah = return status (0 if successful)
- carry = 0 successful, = 1 if error occurred

Note for project 1

- In our project, the bootloader is working in real mode (16 bits).
- Bootloader code is loaded by BIOS, so it did not have %ds, %ss, %sp setup properly when it is loaded.
- In bootloader, all the code and data share the same 512 bytes. So data will have the same segment as code.