§2.2 x86 Architecture Details (Part 2)
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§3.1 Basics of Assembly Language

§2.2
x86 Architecture Details (Part 2)

x86 Registers (Review)

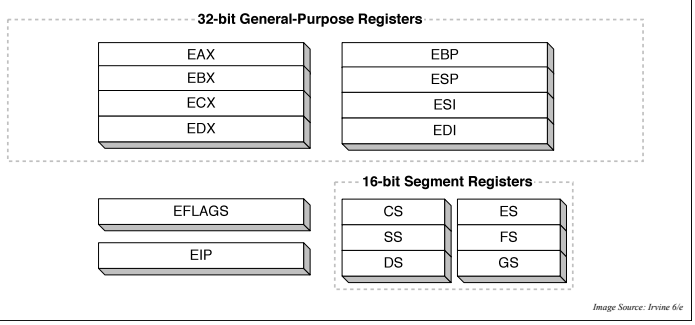


Image Source: Irvine 6/e

x86 Registers (Review)

- **32-bit general-purpose registers:**
  - EAX (Extended) Accumulator
  - EBX Base
  - ECX Count
  - EDX Data
  - ESI Source Index
  - EDI Destination Index
  - ESP Stack Pointer
  - EBP Base Pointer

Names are based on historical or special uses.

Do not use ESP or EBP for arithmetic/data transfer; they have special uses (Chapter 8)

x86 Registers (Review)

- General-purpose registers (except EBP, ESP) can be used more or less arbitrarily, but some instructions use them for special purposes, e.g.,
  - The **`mul`** (multiplication) instruction requires one operand to be in EAX (Chapter 7)
  - EBP is used to access function parameters and local variables in procedures (Chapter 8)
  - ESI and EDI are used by high-speed memory transfer instructions, e.g., **`movsb`** (Chapter 9)

x86 Registers

- **16-bit segment registers:**
  - CS Code Segment
  - SS Stack Segment
  - DS Data Segment
  - ES Extra Segment
  - FS F Segment (Extra Segment)
  - GS G Segment (Extra Segment)
- Used when accessing memory
- Important in real-mode programming and when writing an OS; we won't need them in this course

x86 Registers

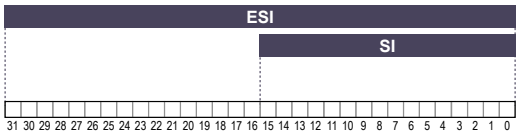
- **EFLAGS – Extended Flags**
  - Each bit has a different purpose
  - Some bits are *control flags*
    - Setting/clearing these bits changes the CPU's operation
    - E.g., enter protected mode
    - E.g., break after each instruction (for debugging)
  - Other bits are *status flags*
    - E.g., Carry flag: is set to 1 when unsigned arithmetic operation produces a result too large to fit in 32 bits
    - E.g., Zero flag: becomes set to 1 when an arithmetic or logical operation results in a 0 value

x86 Registers

- **EIP – Extended Instruction Pointer**
  - Contains the memory address of the next instruction to be executed
  - Recall that the instruction pointer is incremented as part of the fetch-decode-execute cycle
  - Other instructions (e.g., `jmp`) change the instruction pointer

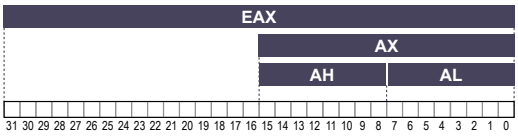
Accessing Parts of Registers

- Parts of some registers can be accessed by other names
  - ESI: Low 16 bits are called SI
  - EDI: Low 16 bits are called DI
  - EBP: Low 16 bits are called BP
  - ESP: Low 16 bits are called SP

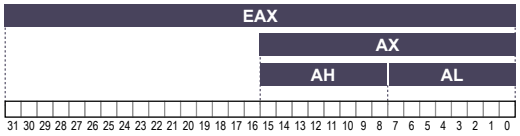


Accessing Parts of Registers

- Parts of some registers can be accessed by other names
  - EAX: bits 0–15 are AX, bits 8–15 are AH, bits 0–7 are AL
  - EBX, BX, BH, BL
  - ECX, CX, CH, CL
  - EDX, DX, DH, DL

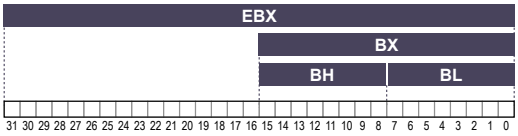


Accessing Parts of Registers



	EAX Contains
`mov eax, AAAAAAAAh`	AAAAAAAAh
`mov ax, BBBBh`	AAAABBBBh
`mov ah, CCh`	AAAACCBBh
`mov al, DDh`	AAAACCDDh

Accessing Parts of Registers



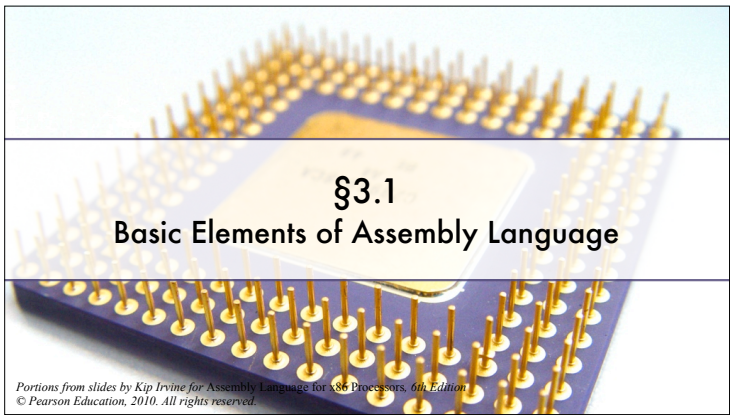
	EBX	BX	BH	BL
`mov ebx, 12345678h`	12345678h	5678h	56h	78h
`mov bx, 0ABCDh`	1234ABCDh	ABCDh	ABh	CDh
`mov bh, 0h`	123400CDh	00CDh	00h	CDh
`mov bl, 0FEh`	123400FEh	00FEh	00h	FEh

x86 Registers

- Registers discussed so far are the *basic program execution registers*
  - EAX, EBX, ECX, EDX,
    EBP, ESP, ESI, EDI,
    EFLAGS, EIP,
    CS, SS, DS, ES, FS, GS
- Processor contains many more registers
  - Several for the floating-point unit (Chapter 12)
  - Others we won't use in this course

x86 Registers

- Activity 4 (front side)



§3.1
Basic Elements of Assembly Language

Important References

- Textbook Appendix A (p. 598): MASM Reference
- Textbook Appendix B (p. 620): The x86 Instruction Set
- Microsoft Macro Assembler Reference, VS2010
  http://msdn.microsoft.com/en-us/library/afzk3475(v=vs.100).aspx
- Intel 64 and IA-32 Architectures
  Software Developer Manuals
  Note: Volume 2 is the instruction set reference
  http://www.intel.com/content/www/us/en/processors/architectures-software-developer-manuals.html

Basic Elements of Assembly Language

To be discussed:

- Instructions
- Mnemonics and Operands
- Reserved words and identifiers
- Labels
- Integer constants and integer expressions
- Character and string constants
- Directives
- Comments

Instructions (1) – JMP

- Instructions you saw in Lab 1: **`mov`** **`add`** **`sub`** **`call`**
- A new instruction: **`jmp`** (*unconditional jump*)
  - Like a "goto" statement – go to the instruction with a given label
  - Prefix any instruction with *label*: – then you can `jmp` to *label*

Example 1

```
        mov eax, 2
        jmp write
        mov eax, 1
write:  call WriteDec
```

Skips over mov eax, 1 and displays 2

Example 2

```
start:  mov eax, 0
        jmp start
```

Infinite loop: keep setting EAX to 0

Example 3

```
top:    call ReadDec
        call WriteDec
        jmp top
```

Infinite loop: read unsigned integer, then display it

Instructions (2)

- Assembled into machine code by assembler
- Executed at runtime by the CPU
- We use the Intel IA-32 instruction set
- An instruction contains:

```
something: mov  bl, 0FEh   ; Hello
```

  - Label (optional)
  - Mnemonic (required)
  - Operand(s) (depends on the instruction)
  - Comment (optional)

Mnemonics & Operands

Instruction Mnemonics

- memory aid
- examples: MOV, ADD, SUB, CALL, JMP

Instructions can take different types of operands

- constant `mov eax, 4000`
- constant expression `mov eax, (8*1000)/2`
- register `mov eax, 4000`
- memory (data label) *(you'll see examples of this later)*

Constants and constant expressions are often called *immediate values*

Instruction Format Examples

- No operands
  - stc ; set Carry flag
- One operand
  - inc eax ; register
  - inc myByte ; memory
- Two operands
  - add ebx, ecx ; register, register
  - sub myByte, 25 ; memory, constant
  - add eax, 36 * 25 ; register, constant-expression

Reserved Words & Identifiers

- Reserved words cannot be used as identifiers
  - Instruction mnemonics, directives, type attributes, operators, predefined symbols
  - See MASM reference in Appendix A
- Identifiers
  - 1–247 characters, including digits
  - Case *insensitive*
  - first character must be a letter, _, @, ?, or $

Labels

- Act as place markers
  - marks the address (offset) of code and data
- Follow identifier rules
- Data label
  - must be unique
  - example: **msg** (not followed by colon)
- Code label
  - target of instructions like **jmp**
  - example: **done:** (followed by colon)

Example

```
INCLUDE Irvine32.inc

.data
msg BYTE "Hello", 0

.code
main PROC
      mov edx, offset msg
      call WriteString
      jmp done
done: exit
main ENDP
END main
```

Comments

- Comments are good!
  - Summarize the contents of a file or procedure
  - Explain tricky coding techniques
  - Don't just re-state what each instruction does
- Single-line comments begin with semicolon (;)
- Multi-line comments begin with COMMENT directive and a programmer-chosen character; end with the same programmer-chosen character

Integer Constants

- Optional leading + or – sign
- Binary, decimal, hexadecimal, or octal digits
- Common radix characters:
  - h – hexadecimal
  - d – decimal
  - b – binary
  - r – encoded real

Examples: 30d, 6Ah, 42, 1101b

```
mov  bl, 0FEh
```

Hexadecimal beginning with letter: 0A5h – **must** prefix with 0!

Integer Expressions (1)

- Anywhere you can use an integer constant, you can use an integer *expression*
- Operators and precedence levels:

Operator	Name	Precedence Level
( )	parentheses	1
+,-	unary plus, minus	2
*,/	multiply, divide	3
MOD	modulus	3
+,-	add, subtract	4

- Examples:

Expression	Value
16 / 5	3
-(3 + 4) * (6 - 1)	-35
-3 + 4 * 6 - 1	20
25 mod 3	1

Integer Expressions (2)

- Anywhere you can use an integer constant, you can use an integer *expression*
- Only *constant* expressions are permitted – can't contain register names, etc.
  - **Q.** Which of the following are permitted?

In .data:
```
something BYTE 93-1
```
✔

In .data:
```
five BYTE 5
six  BYTE five+1
```
✘ (five is a label – not constant-valued)

In .code:
```
mov eax, 3*100+3
```
✔

In .code:
```
mov eax, 5
mov ebx, eax+1
```
✘ (eax is a register – not constant-valued)

Character & String Constants

- Enclose character in single or double quotes
  - 'A', "x"
  - ASCII character = 1 byte
- Enclose strings in single or double quotes
  - "ABC"
  - 'xyz'
  - Each character occupies a single byte
- Embedded quotes:
  - 'Say "Goodnight," Gracie'

Directives

- Commands that are recognized and acted upon by the assembler
  - Not part of the Intel instruction set
  - Used to declare code, data areas, select memory model, declare procedures, etc.
  - Case *insensitive*
- Different assemblers have different directives
  - NASM not the same as MASM, for example

Homework

- **Homework 1** due in Canvas by Friday at 2:00 p.m. – come by office hours for help
- For next class (Friday, September 5):
  - Read **Section 3.1** (6/e pp. 58–66, 7/3 pp. 54–63) - mostly covered today
  - Read **Section 3.2** (6/e pp. 66–70, 7/e pp. 63–70) - *not covered in any lectures*
    - Goal: understand the sample program so you can read Section 3.4 later on
    - Sample program changed slightly from 6th edition to 7th edition; read either one