Week 3

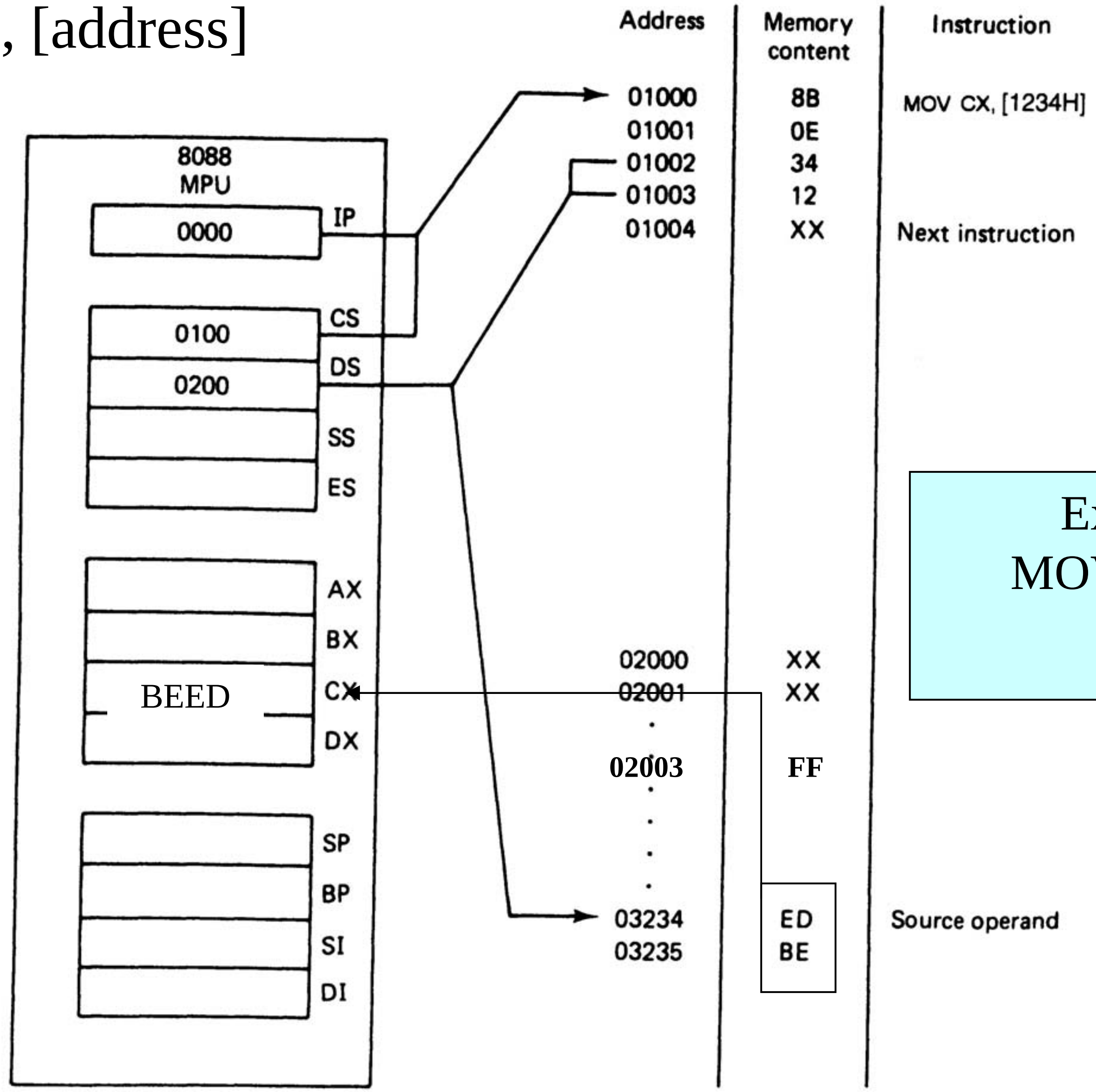
8086/8088 Addressing Modes, Instruction Set & Machine Codes

Addressing Modes

- When the 8088 executes an instruction, it performs the specified function on data
- These data, called operands,
  - May be a part of the instruction
  - May reside in one of the internal registers of the microprocessor
  - May be stored at an address in memory
- **Register Addressing Mode**
  - MOV AX, BX
  - MOV ES,AX
  - MOV AL,BH
- **Immediate Addressing Mode**
  - MOV AL,15h
  - MOV AX,2550h
  - MOV CX,625

Direct Addressing Mode

MOV CX, [address]



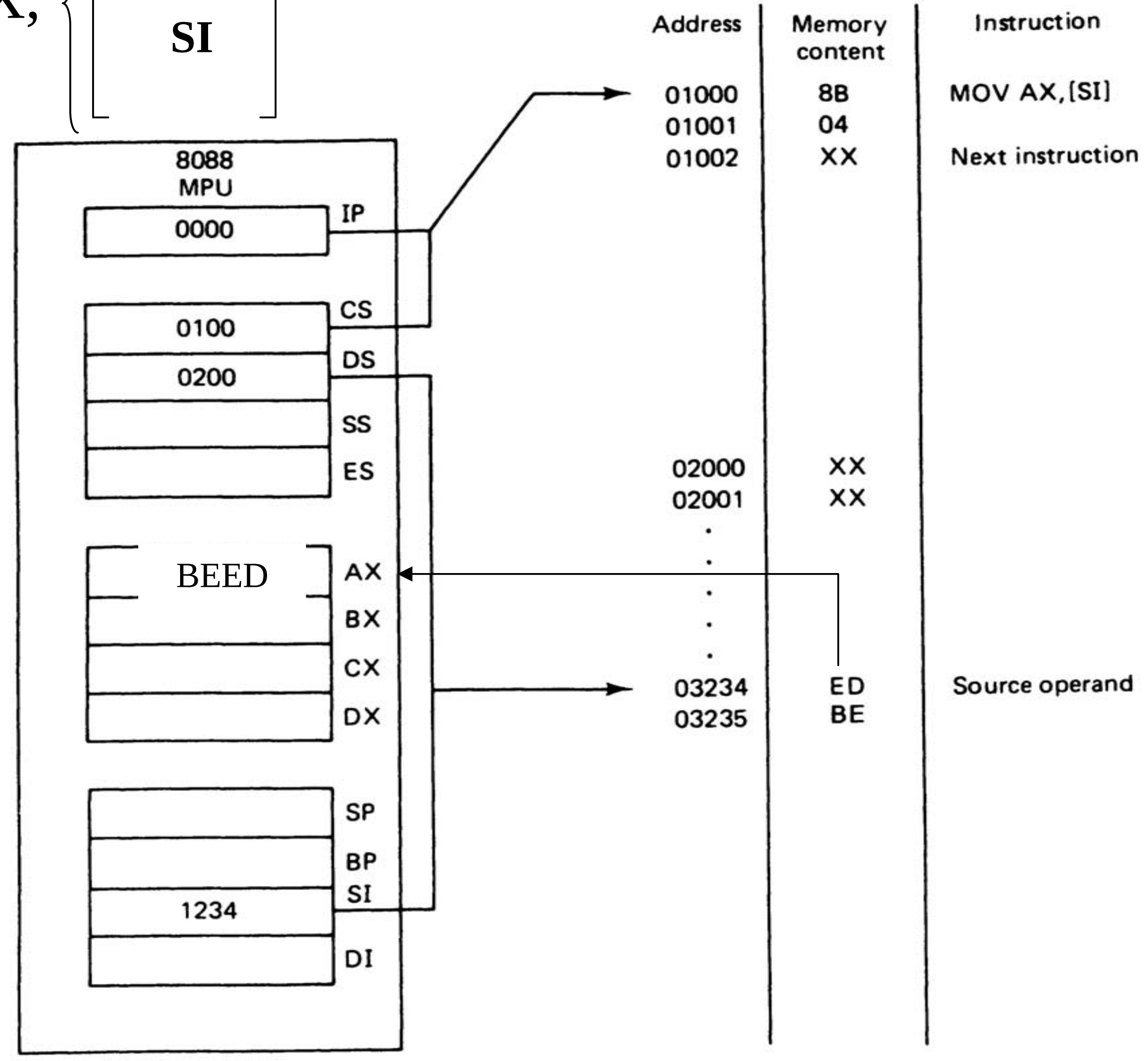
Address	Memory content	Instruction
01000	8B	MOV CX, [1234H]
01001	0E	
01002	34	
01003	12	
01004	XX	Next instruction
02000	XX	
02001	XX	
02003	FF	
03234	ED	Source operand
03235	BE	

Example:
MOV AL,[03]

AL=?

Register Indirect Addressing Mode

$$\text{MOV AX,} \left\{ \begin{bmatrix} \textbf{BX} \\ \textbf{DI} \\ \textbf{SI} \end{bmatrix} \right.$$



Address	Memory content	Instruction
01000	8B	MOV AX,[SI]
01001	04	
01002	XX	Next instruction
02000	XX	
02001	XX	
.		
.		
.		
.		
.		
03234	ED	Source operand
03235	BE	

Example for Register Indirect Addressing

- Assume that DS=1120, SI=2498 and AX=17FE show the memory locations after the execution of:

MOV [SI],AX

DS (Shifted Left) + SI = 13698.

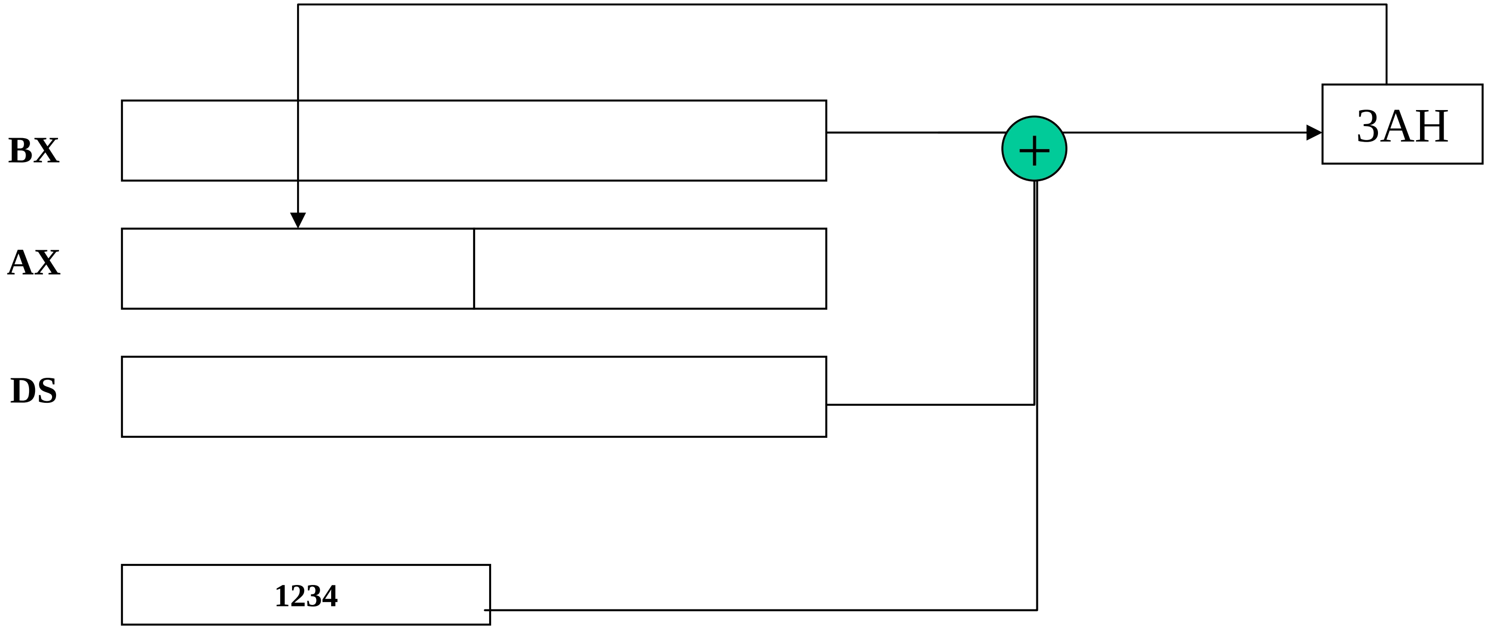
With little endian convention:

Low address 13698 → FE

High Address 13699 → 17

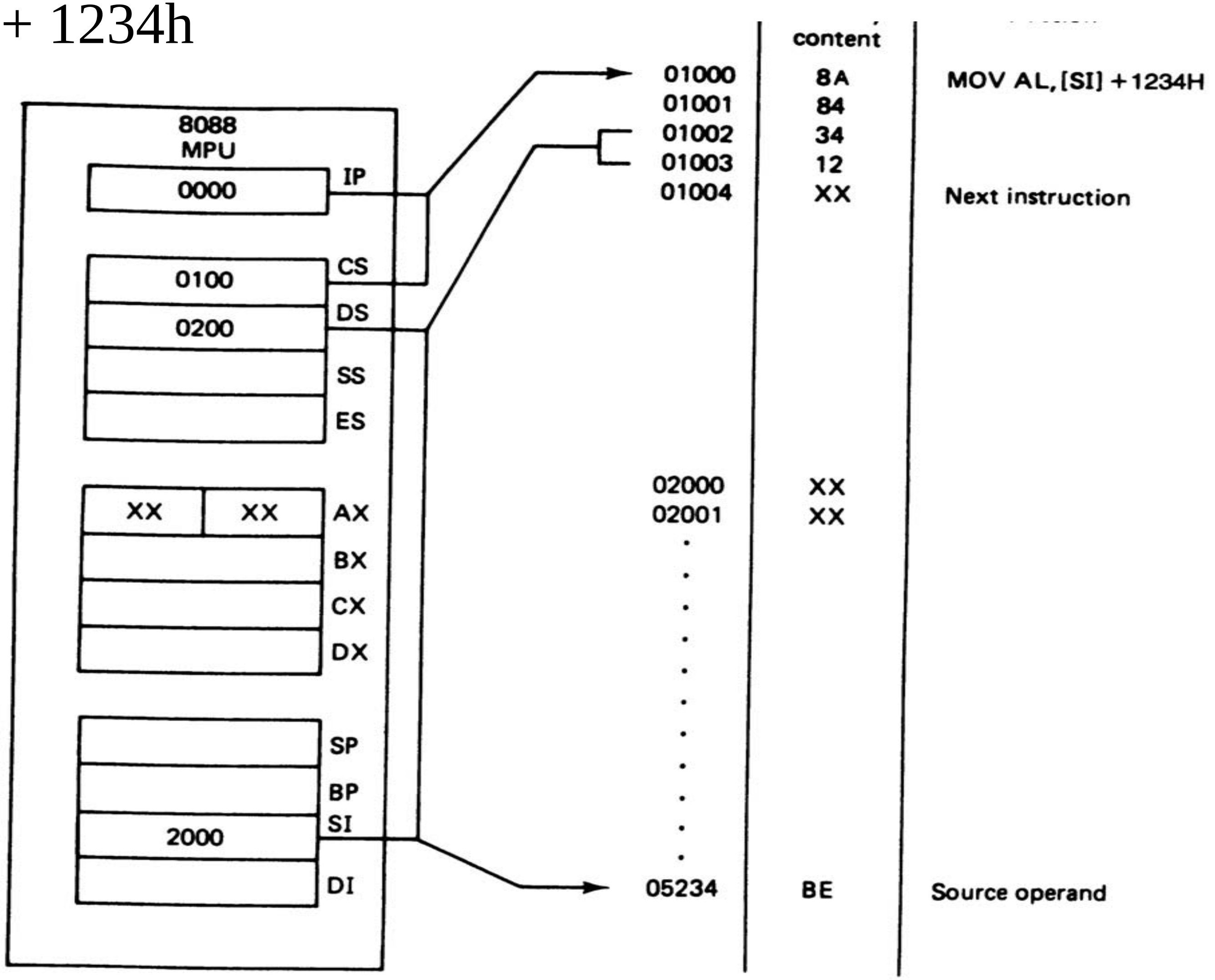
Based-Relative Addressing Mode

MOV AH, [$\begin{matrix}\textbf{DS:BX}\\ \textbf{SS:BP}\end{matrix}$] + 1234h



Indexed Relative Addressing Mode

MOV AH, [$\substack{\textbf{SI}\\\textbf{DI}}$] + 1234h



Example: What is the physical address MOV [DI-8],BL if DS=200 & DI=30h ?
DS:200 shift left once 2000 + DI + -8 = 2028

Based-Indexed Relative Addressing Mode

- Based Relative + Indexed Relative
- We must calculate the PA (physical address)

$$\text{PA} = \boxed{\begin{matrix}\text{CS}\\ \text{SS}\\ \text{DS}\\ \text{ES}\end{matrix}} : \boxed{\begin{matrix}\text{BX}\\ \text{BP}\end{matrix}} + \boxed{\begin{matrix}\text{SI}\\ \text{DI}\end{matrix}} + \boxed{\begin{matrix}\text{8 bit displacement}\\ \text{16 bit displacement}\end{matrix}}$$

$$\left.\begin{array}{c}\text{MOV AH,[BP+SI+29]}\\ \text{or}\\ \text{MOV AH,[SI+29+BP]}\\ \text{or}\\ \text{MOV AH,[SI][BP]+29}\end{array}\right\}\ \begin{array}{c}\text{The}\\ \text{register}\\ \text{order does}\\ \text{not matter}\end{array}$$

Based-Indexed Addressing Mode

```
MOV BX, 0600h
MOV SI, 0010h ; 4 records, 4 elements each.
MOV AL, [BX + SI + 3]
```

OR

```
MOV BX, 0600h
MOV AX, 004h ;
MOV CX,04;
MUL CX
MOV SI, AX
MOV AL, [BX + SI + 3]
```

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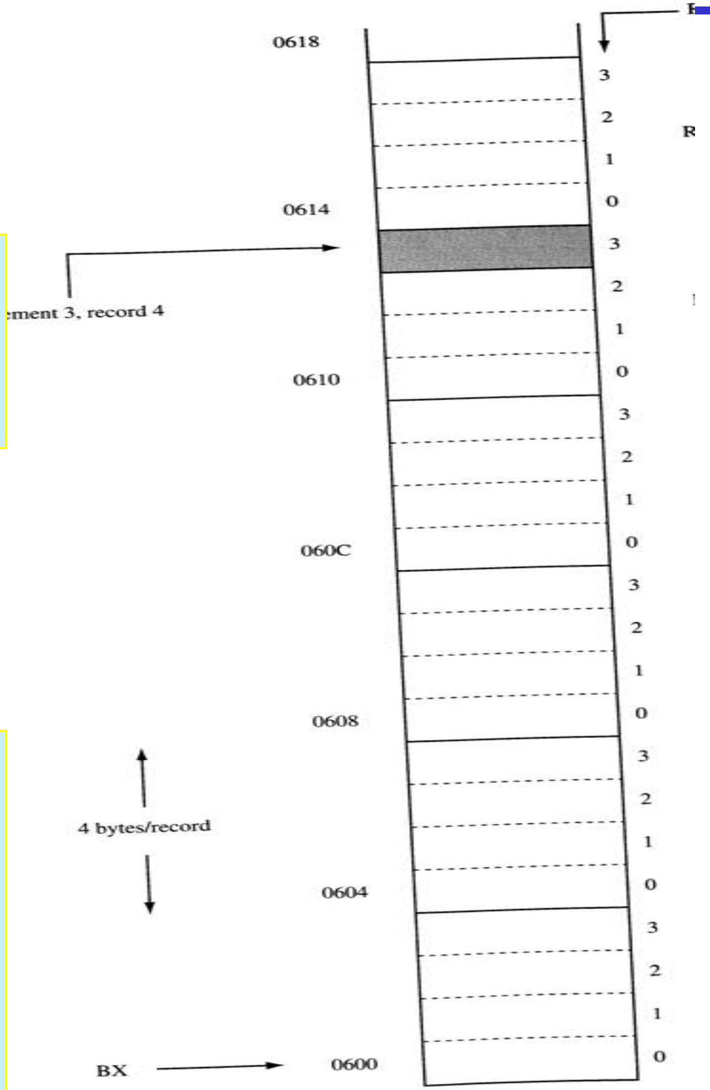
e base + index + placement dressing mode can used to access a rticular element in a rticular record of an ray.



Summary of the addressing modes

Addressing Mode	Operand	Default Segment
Register	Reg	None
Immediate	Data	None
Direct	[offset]	DS
Register Indirect	[BX] [SI] [DI]	DS DS DS
Based Relative	[BX]+disp [BP]+disp	DS SS
Indexed Relative	[DI]+disp [SI]+disp	DS DS
Based Indexed Relative	[BX][SI or DI]+disp [BP][SI or DI]+disp	DS SS

16 bit Segment Register Assignments

Type of Memory Reference	Default Segment	Alternate Segment	Offset
Instruction Fetch	CS	none	IP
Stack Operations	SS	none	SP,BP
General Data	DS	CS,ES,SS	BX, address
String Source	DS	CS,ES,SS	SI, DI, address
String Destination	ES	None	DI

Brey

Segment override

Segment Registers	CS	DS	ES	SS
Offset Register	IP	SI,DI,BX	SI,DI,BX	SP,BP

Instruction Examples	Override Segment Used	Default Segment
MOV AX,CS:[BP]	CS:BP	SS:BP
MOV DX,SS:[SI]	SS:SI	DS:SI
MOV AX,DS:[BP]	DS:BP	SS:BP
MOV CX,ES:[BX]+12	ES:BX+12	DS:BX+12
MOV SS:[BX][DI]+32,AX	SS:BX+DI+32	DS:BX+DI+32

Example for default segments

- The following registers are used as offsets. Assuming that the default segment used to get the logical address, give the segment register associated?

a) BP b)DI c)IP d)SI, e)SP, f) BX

- Show the contents of the related memory locations after the execution of this instruction

  MOV [BP][SI]+10,DX

  if DS=2000, SS=3000,CS=1000,SI=4000,BP=7000,DX=1299 (all hex)

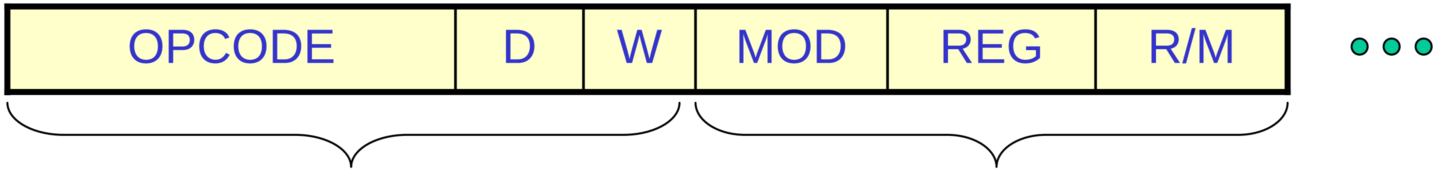
Assembly Language

- There is a one-to-one relationship between assembly and machine language instructions
- What is found is that a compiled machine code implementation of a program written in a high-level language results in inefficient code
  - More machine language instructions than an assembled version of an equivalent handwritten assembly language program
- Two key benefits of assembly language programming
  - It takes up less memory
  - It executes much faster

Languages in terms of applications

- One of the most beneficial uses of assembly language programming is **real-time applications**.
- Real time means the task required by the application must be completed before any other input to the program that will alter its operation can occur
- For example the device service routine which controls the operation of the floppy disk drive is a good example that is usually written in assembly language
- Assembly language not only good for controlling hardware devices but also **performing pure software operations**
  - searching through a large table of data for a special string of characters
  - Code translation from ASCII to EBCDIC
  - Table sort routines
  - Mathematical routines
- Assembly language: perform real-time operations
- High-level languages: Those operations mostly not critical in time.

Converting Assembly Language Instructions to Machine Code



OPCODE	D	W	MOD	REG	R/M	• • •

- An instruction can be coded with 1 to 6 bytes
- **Byte 1 contains three kinds of information:**
  - Opcode field (6 bits) specifies the operation such as add, subtract, or move
  - Register Direction Bit (D bit)
    - Tells the register operand in REG field in byte 2 is source or destination operand
      - 1:Data flow to the REG field from R/M
      - 0: Data flow from the REG field to the R/M
  - Data Size Bit (W bit)
    - Specifies whether the operation will be performed on 8-bit or 16-bit data
      - 0: 8 bits
      - 1: 16 bits
- **Byte 2 has two fields:**
  - Mode field (MOD) – 2 bits
  - Register field (REG) - 3 bits
  - Register/memory field (R/M field) – 2 bits

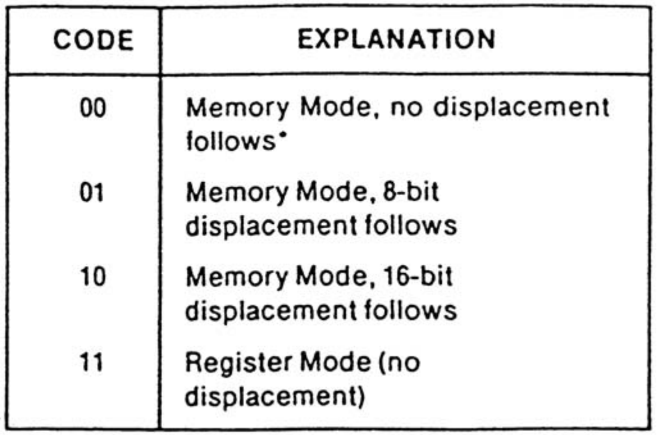
Continued

- **REG field is used to identify the register for the first operand**

REG	**W = 0**	**W = 1**
000	AL	AX
001	CL	CX
010	DL	DX
011	BL	BX
100	AH	SP
101	CH	BP
110	DH	SI
111	BH	DI

Continued

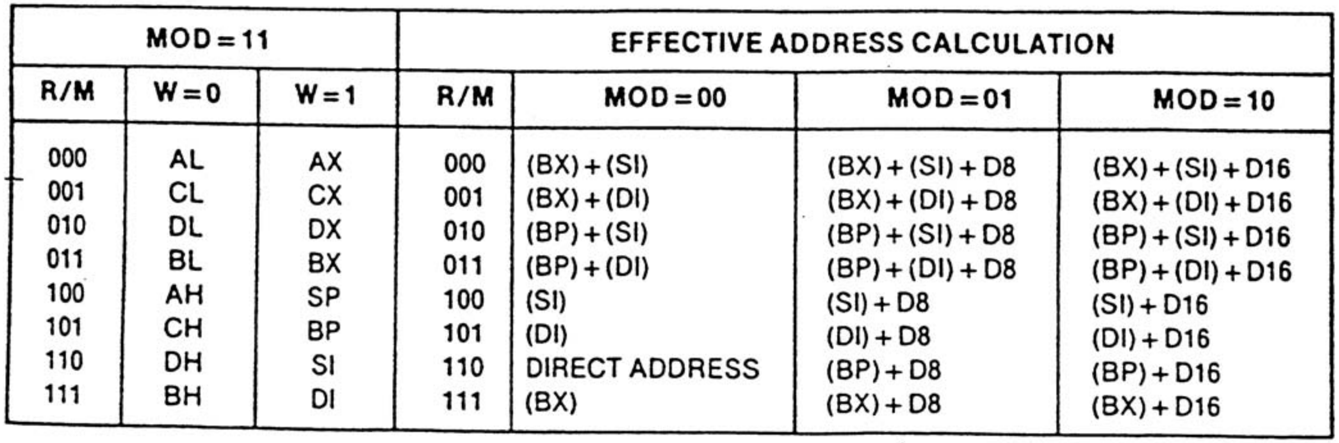
- 2-bit MOD field and 3-bit R/M field together specify the second operand



CODE	EXPLANATION
00	Memory Mode, no displacement follows*
01	Memory Mode, 8-bit displacement follows
10	Memory Mode, 16-bit displacement follows
11	Register Mode (no displacement)

*Except when R/M = 110, then 16-bit displacement follows

(a)



MOD = 11			EFFECTIVE ADDRESS CALCULATION			
R/M	W = 0	W = 1	R/M	MOD = 00	MOD = 01	MOD = 10
000	AL	AX	000	(BX) + (SI)	(BX) + (SI) + D8	(BX) + (SI) + D16
001	CL	CX	001	(BX) + (DI)	(BX) + (DI) + D8	(BX) + (DI) + D16
010	DL	DX	010	(BP) + (SI)	(BP) + (SI) + D8	(BP) + (SI) + D16
011	BL	BX	011	(BP) + (DI)	(BP) + (DI) + D8	(BP) + (DI) + D16
100	AH	SP	100	(SI)	(SI) + D8	(SI) + D16
101	CH	BP	101	(DI)	(DI) + D8	(DI) + D16
110	DH	SI	110	DIRECT ADDRESS	(BP) + D8	(BP) + D16
111	BH	DI	111	(BX)	(BX) + D8	(BX) + D16

(b)

Examples

- MOV BL,AL
- Opcode for MOV = 100010
- We’ll encode AL so
  - D = 0 (AL source operand)
- W bit = 0 (8-bits)
- MOD = 11 (register mode)
- REG = 000 (code for AL)
- R/M = 011

OPCODE	D	W	MOD	REG	R/M
100010	0	0	11	000	011

MOV BL,AL => 10001000 11000011 = 88 C3h

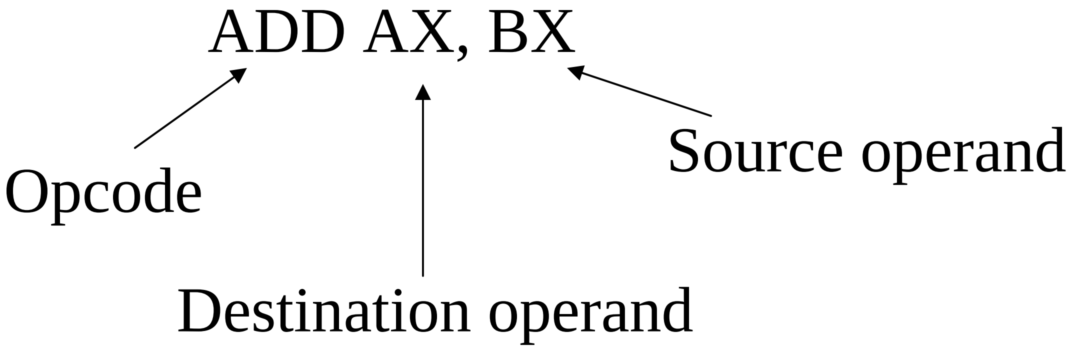
ADD AX,[SI] => 00000011 00000100 = 03 04 h

ADD [BX][DI] + 1234h, AX => 00000001 10000001 __ __ h

=> 01 81 34 12 h

Software

- The sequence of commands used to tell a microcomputer what to do is called a **program**
- Each command in a program is called an **instruction**
- 8088 understands and performs operations for **117 basic instructions**
- The native language of the **IBM PC** is the machine language of the 8088
- A program written in machine code is referred to as **machine code**
- In 8088 assembly language, each of the operations is described by alphanumeric symbols instead of just 0s or 1s.



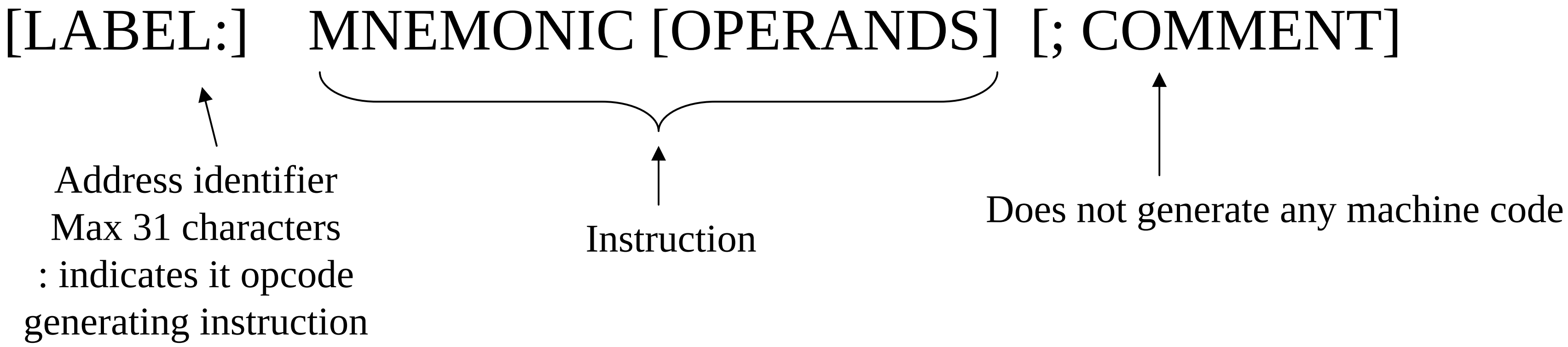
ADD AX, BX

Opcode

Destination operand

Source operand

Instructions



[LABEL:] MNEMONIC [OPERANDS] [; COMMENT]

Address identifier
Max 31 characters
: indicates it opcode
generating instruction

Instruction

Does not generate any machine code

Ex. START: MOV AX,BX ; copy BX into AX

DEBUG program instruction set (page 825 mzd)

- Debug instructions
- List of commands
  - a Assemble [address] you can type in code this way
  - c range address ; compare c 100 105 200
  - d [range] ; Dump d 150 15A
  - e address [list] ; Enter e 100
  - f Fill range list F 100 500 ‘ ‘
  - g Go [=address] addresses runs the program
  - h Value1 Value2 ; addition and subtraction H 1A 10
  - i Input port I 3F8
  - r Show & change registers Appears to show the same thing as t, but doesn't cause any code to be executed.
  - t Trace either from the starting address or current location.
  - u UnAssemble

Some examples with debug

```
0100 mov ax,24b6
0103 mov di, 85c2
0106 mov dx,5f93
0109 mov sp,1236
010c push ax
010d push di
010e int 3
```

Display the stack contents after execution.

```
-D 1230 123F
```

Some examples with DEBUG

- 0100 mov al,9c
- 0102 mov dh,64
- 0104 add al,dh
- 0109 int 3

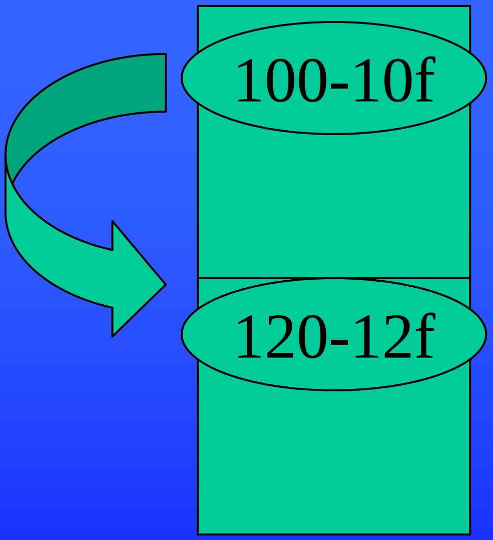
trace these three commands and observe the flags

- After the code has been entered with the A command
- Use CX to store data indicating number of bytes to save. BX is the high word.
- Use N filename.com
- Then W command to write to file.
- L loads this file.

Example

Copy the contents of a block of memory (16 bytes) starting at location 20100h to another block of memory starting at 20120h

```
        MOV AX,2000
        MOV DS,AX
        MOV SI, 100
        MOV DI, 120
        MOV CX, 10
NXTPT:  MOV AH, [SI]
        MOV [DI], AH
        INC SI
        INC DI
        DEC CX
        JNZ  NXTPT
```



Assembler Directives

.MODEL SMALL ; selects the size of the memory model usually sufficient max 64K code 64K data

```
.STACK  ; beginning of the stack segment
.DATA    ; beginning of the data segment
.CODE   ; beginning of the code segment
```

Ex: .DATA

```
DATAW           DW      213FH
DATA1           DB      52H
SUM             DB      ?  ; nothing stored but a storage is assigned
```

Ex: .CODE

```
PROGRAMNAME  PROC;  Every program needs a name
                …. ; program statements
PROGRAMNAME  ENDP
                  END PROGRAMNAME
```

Sample Program

```
title Hello World Program         (hello.asm)
; This program displays "Hello, world!"
.model small
.stack 100h
.data
message db "Hello, world!",0dh,0ah,'$‘ ;newline+eoc
.code
main proc
    mov  ax,@data ; address of data
    mov  ds,ax
    mov  ah,9
    mov  dx,offset message ;disp.msg.starting at 0
    int  21h   ; or LEA dx,message will do!
    mov  ax,4C00h ; halt the program and return
    int  21h
main endp
end main
```

The PTR Operator

- INC [20h] ; is this byte/word/dword? or
- MOV [SI],5
  - Is this byte 05?
  - Is this word 0005?
  - Or is it double word 00000005?
- Byte or word or doubleword?

- To clarify we use the PTR operator
  - INC BYTE PTR [20h]
  - INC WORD PTR [20h]
  - INC DWORD PTR [20h]
- or for the mov example:
  - MOV byte ptr [SI],5
  - MOV word ptr[SI],5

The PTR Operator

- Would we need to use the PTR operator in each of the following?

```
MOV AL,BVAL
MOV DL,[BX]
SUB [BX],2
MOV CL,WVAL
ADD AL,BVAL+1

.data
BVAL DB 10H,20H
WVAL DW 1000H
```

```
MOV AL,BVAL
MOV DL,byte ptr [BX]
SUB [BX],byte ptr 2
MOV CL,byte ptr WVAL
ADD AL,BVAL+1
```