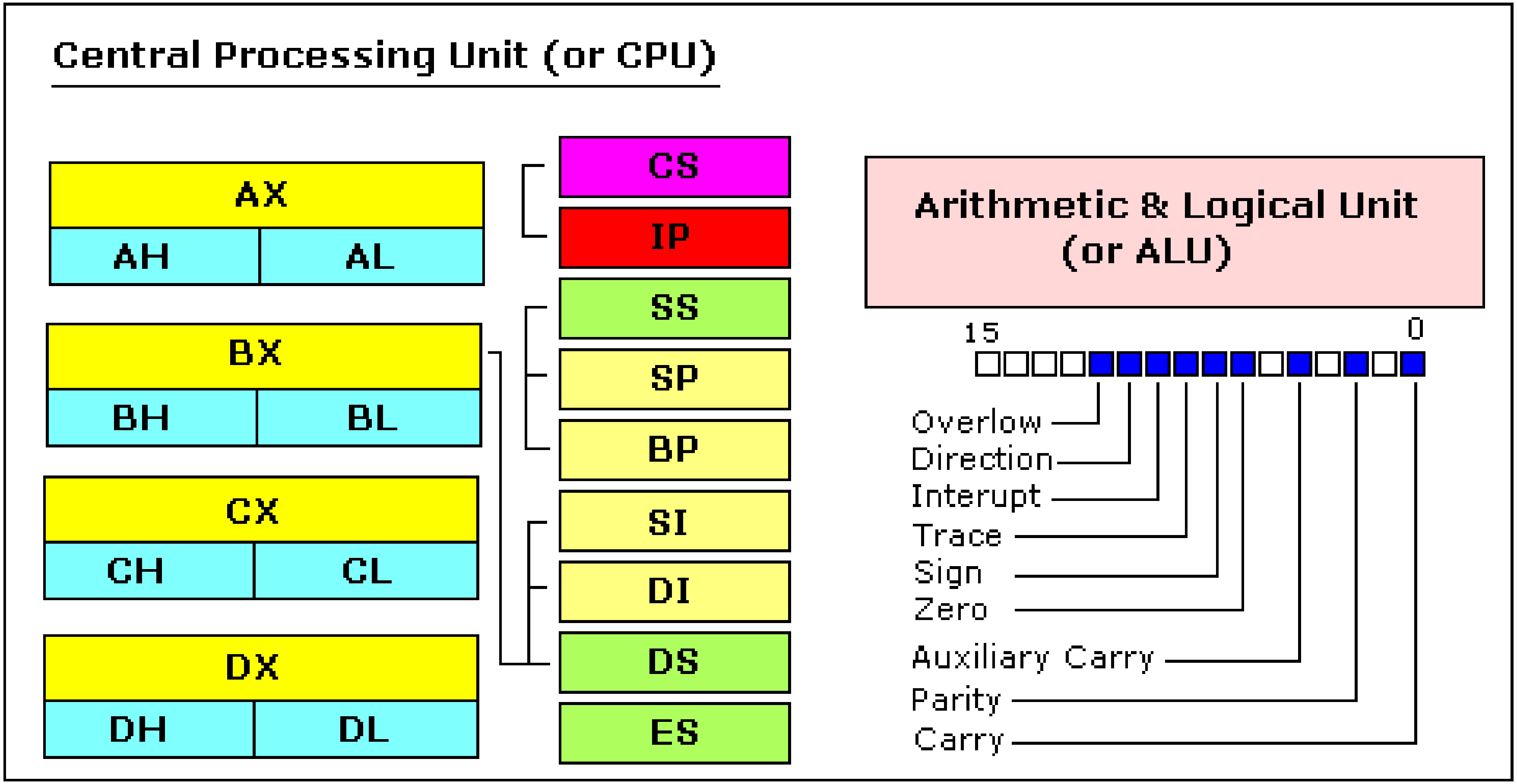
Lecture 3

Addressing Modes and Assembly Language

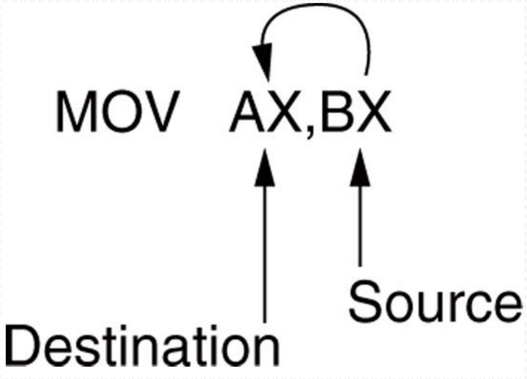
8086 Components



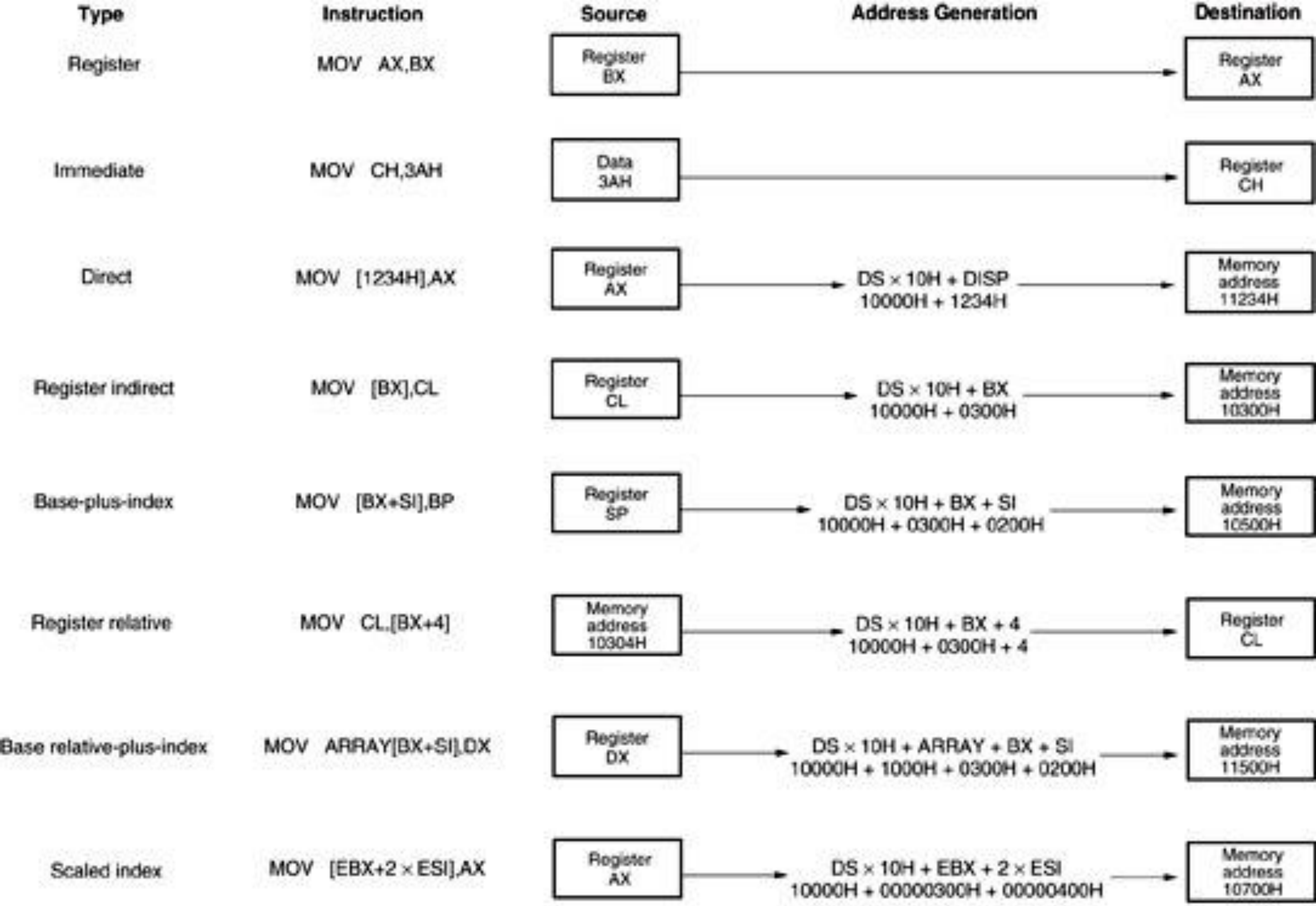
Introduction

- Efficient software development for the microprocessor requires a complete familiarity with the addressing modes employed by each instruction.

Data Addressing Modes



- MOV instruction is a common and flexible instruction.
  - provides a basis for explanation of data-addressing modes
- **Source** is to the right and **destination** the left, next to the opcode MOV.
  - an **opcode**, or operation code, tells the microprocessor which operation to perform



Notes: EBX = 00000300H, ESI = 00000200H, ARRAY = 1000H, and DS = 1000H

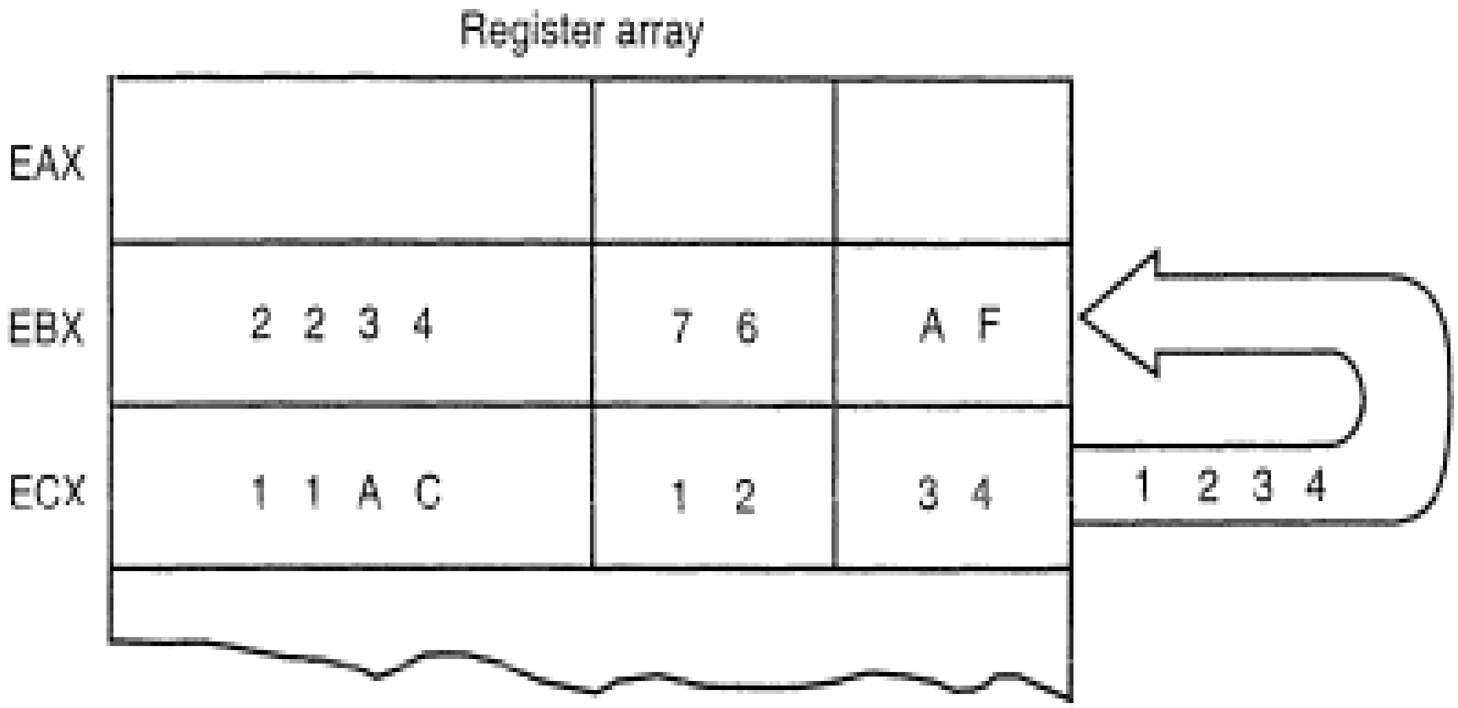
Addressing Mode

- An addressing mode specifies how to calculate the ***effective memory address*** of an ***operand*** by using information held in registers and/or constants contained within a machine instruction or elsewhere.

1. Register Addressing

- In this mode the source operand, destination operand or both are to be contained in the 8086 register.
  - MOV DX, CX
  - MOV CL, DL
- 8-bit registers: AH, AL, BH, BL, CH, CL, DH, and DL.
- 16-bit registers: AX, BX, CX, DX, SP, BP, SI, and DI.
- *never* mix an 8-bit \with a 16-bit register.

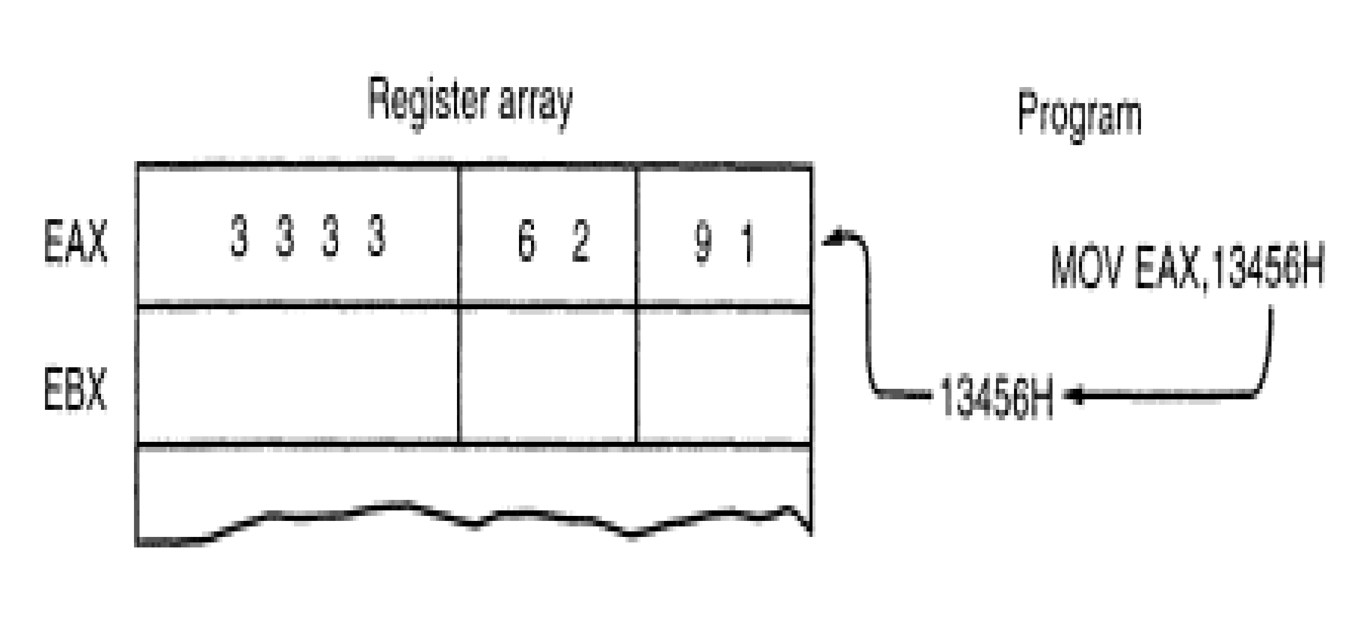
Register Addressing (continued)



2. Immediate Addressing

- Transfers the source-immediate byte or word of data into the destination register or memory location.
  - MOV CL, 03H
  - MOV DX, 0502H
- Term *immediate* implies that data immediately follow the hexadecimal opcode in the memory.
  - immediate data are constant data
  - data transferred from a register or memory location are variable data

Immediate Addressing



Immediate Addressing (continued)

- The letter **H** appends hexadecimal data.
- If hexadecimal data begin with a letter, the assembler requires the data start with a **0**.
  - to represent a hexadecimal F2, 0F2H is used in assembly language
- Decimal data are represented as is and require no special codes or adjustments.
  - an example is the 100 decimal in the MOV AL,100 instruction

An Assembly Program

```
DATA1    DB 23H      ;define DATA1 as a byte of 23H
DATA2    DW 1000H    ;define DATA2 as a word of 1000H

START:   MOV AL,BL   ;copy BL into AL
         MOV BH,AL   ;copy AL into BH
         MOV CX,200  ;copy 200 decimal into CX
```

Assembly Programs

- Each statement in an assembly language program consists of four parts or fields.
- The leftmost field is called the **label**.
  - used to store a symbolic name for the memory location it represents
  - All labels must begin with a letter or one of the following special characters: @, $, -, or ?.
  - a label may any length from 1 to 35 characters
  - The label appears in a program to identify the name of a memory location for storing data and for other purposes.

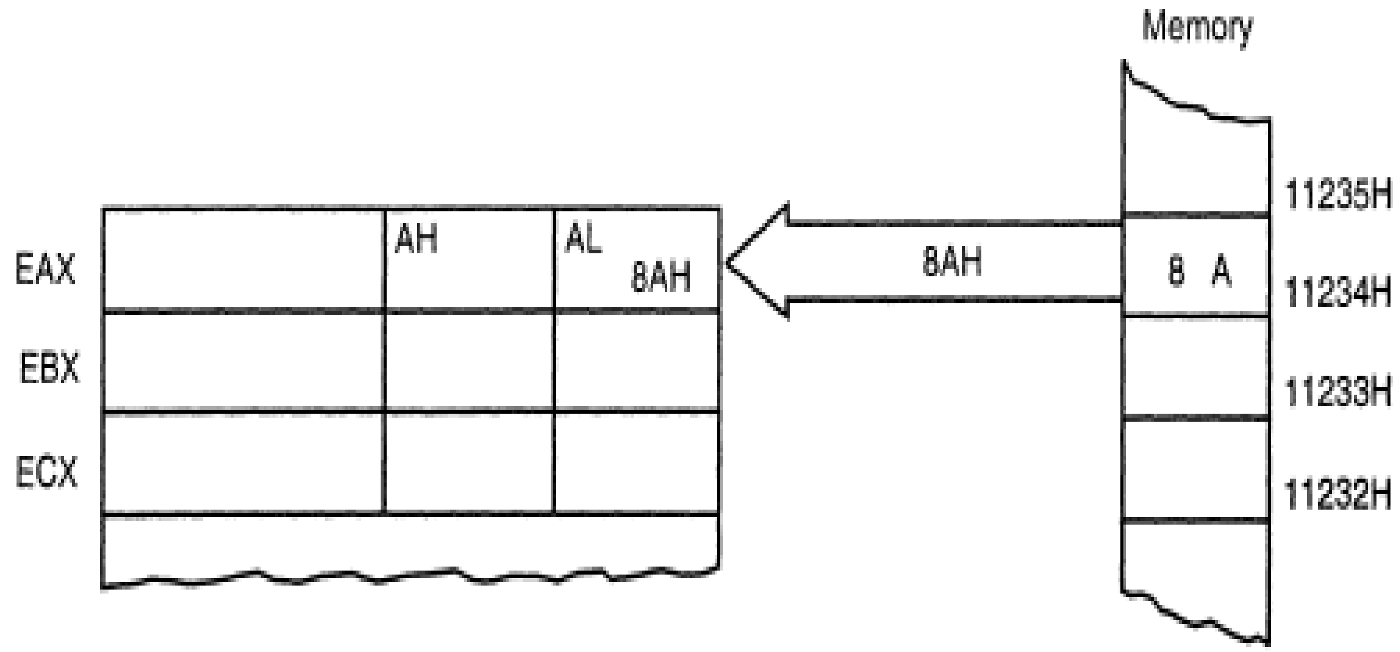
Assembly Language (continued)

- The next field to the right is the **opcode** field.
  - designed to hold the instruction, or opcode
  - the MOV part of the move data instruction is an example of an opcode
- Right of the opcode field is the **operand** field.
  - contains information used by the opcode
  - the MOV AL,BL instruction has the opcode MOV and operands AL and BL
- The **comment** field, the final field, contains a comment about the instruction(s).
  - comments always begin with a semicolon (;)

3. Direct Addressing

- Moves a byte or word between a memory location and a register. The instruction set does not support a memory-to-memory transfer, except for the MOVS instruction.
- **Examples:**
  - MOV CX,START
  - MOV START,BL
  - START can be defined as an address by using the assembler DB(Define Byte) or DW(Define Word) pseudo instructions.

Direct Addressing



4. Register Indirect Addressing

- Transfers a byte or word between a register and a memory location addressed by an index or base register. The index and base registers are BP, BX, DI, and SI.
- Example: **MOV AX,[BX]** instruction copies the word-sized data from the data segment offset address indexed by BX into register AX.

Register Indirect Addressing

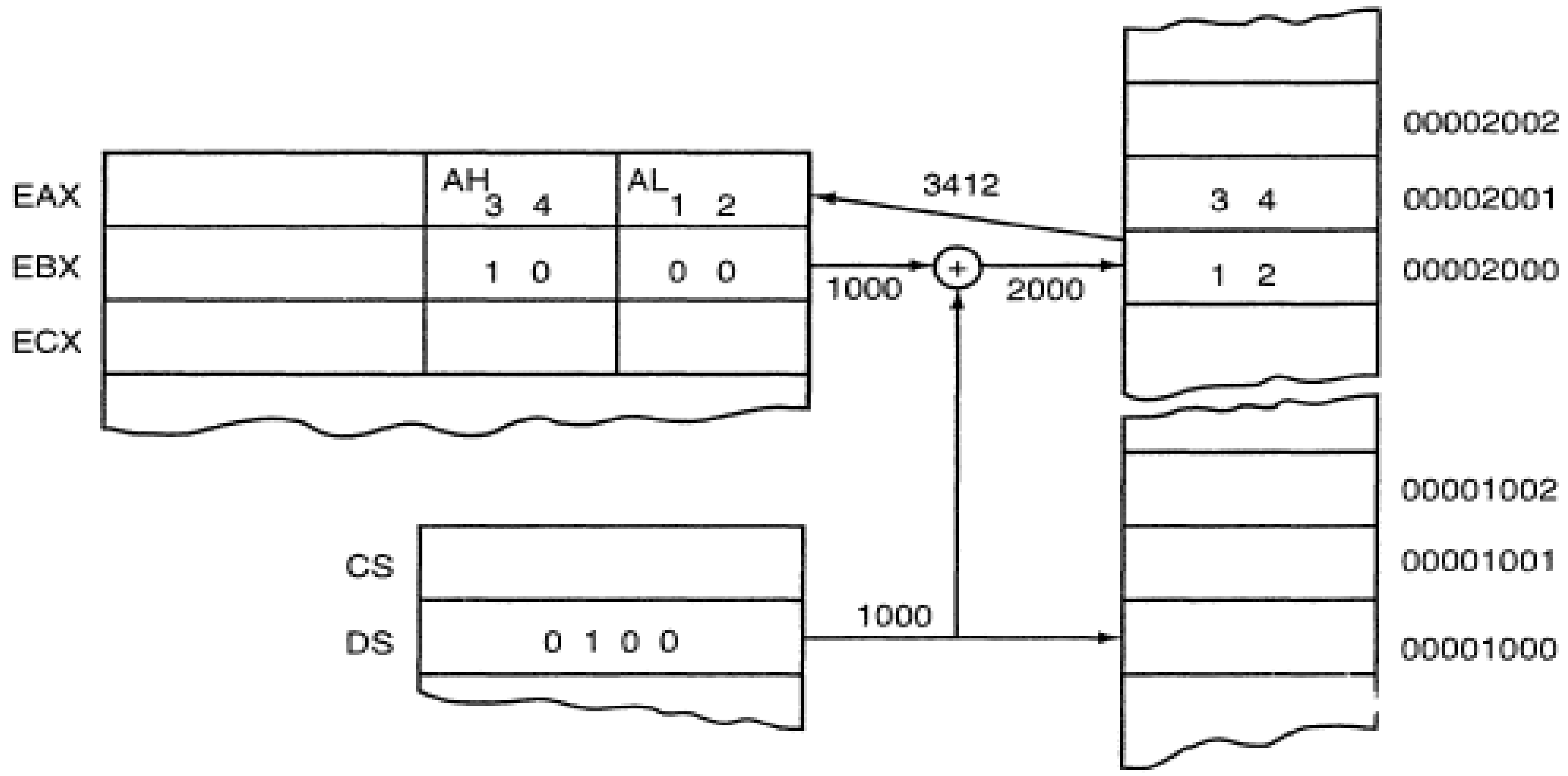
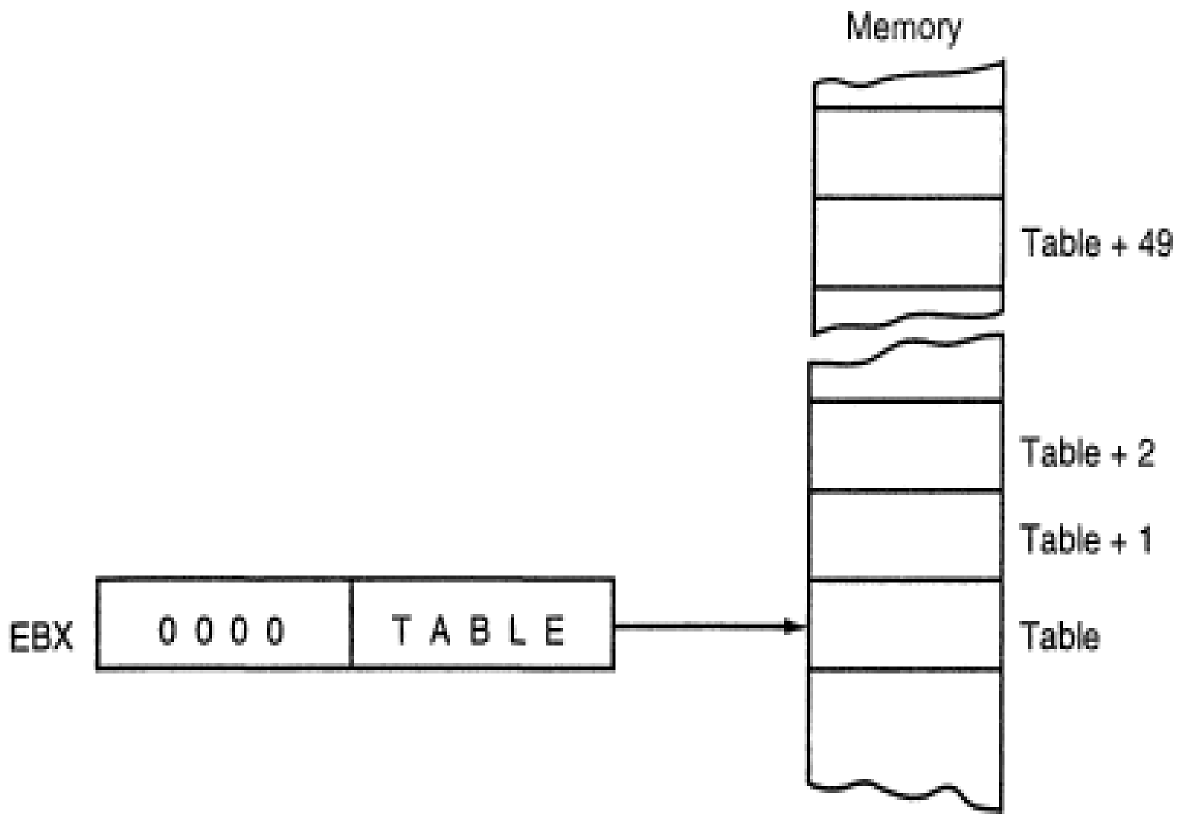


FIGURE 3–6 The operation of the MOV AX,[BX] instruction when BX = 1000H and DS = 0100H. Note that this instruction is shown after the contents of memory are transferred to AX.

Register Indirect Addressing

FIGURE 3–7 An array (TABLE) containing 50 bytes that are indirectly addressed through register BX



5. Base-plus-index Addressing

- Transfers a byte or word between a register and the memory location addressed by a base register (BP or BX) plus an index register (DI or SI).
- Example: **MOV [BX+DI],CL** instruction copies the byte-sized contents of register CL into the data segment memory location addressed by BX+DI.

Base-plus-index Addressing

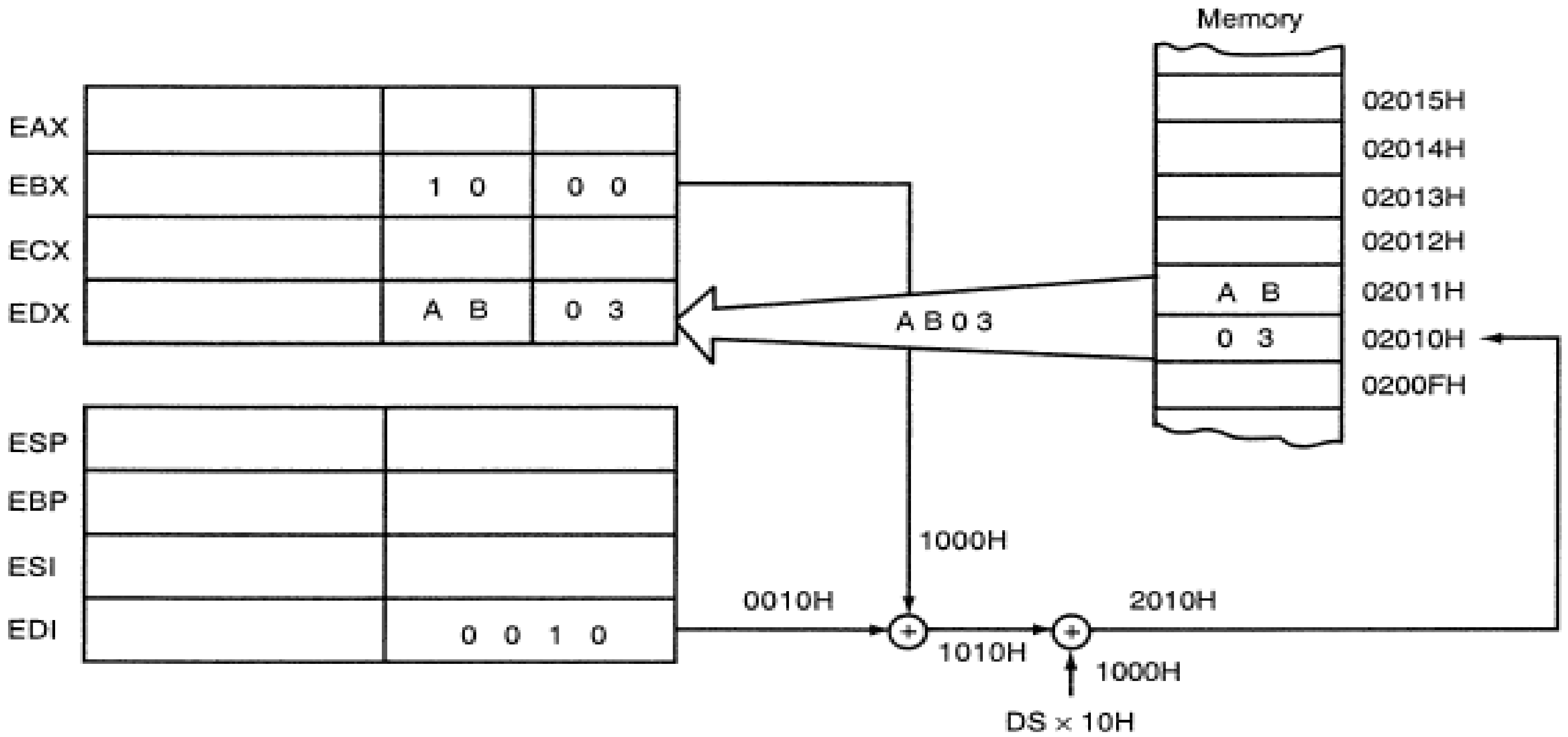


FIGURE 3–8 An example showing how the base-plus-index addressing mode functions for the MOV DX,[BX+DI] instruction. Notice that memory address 02010H is accessed because DS = 0100H, BX = 100H, and DI = 0010H.

Base-plus-index Addressing

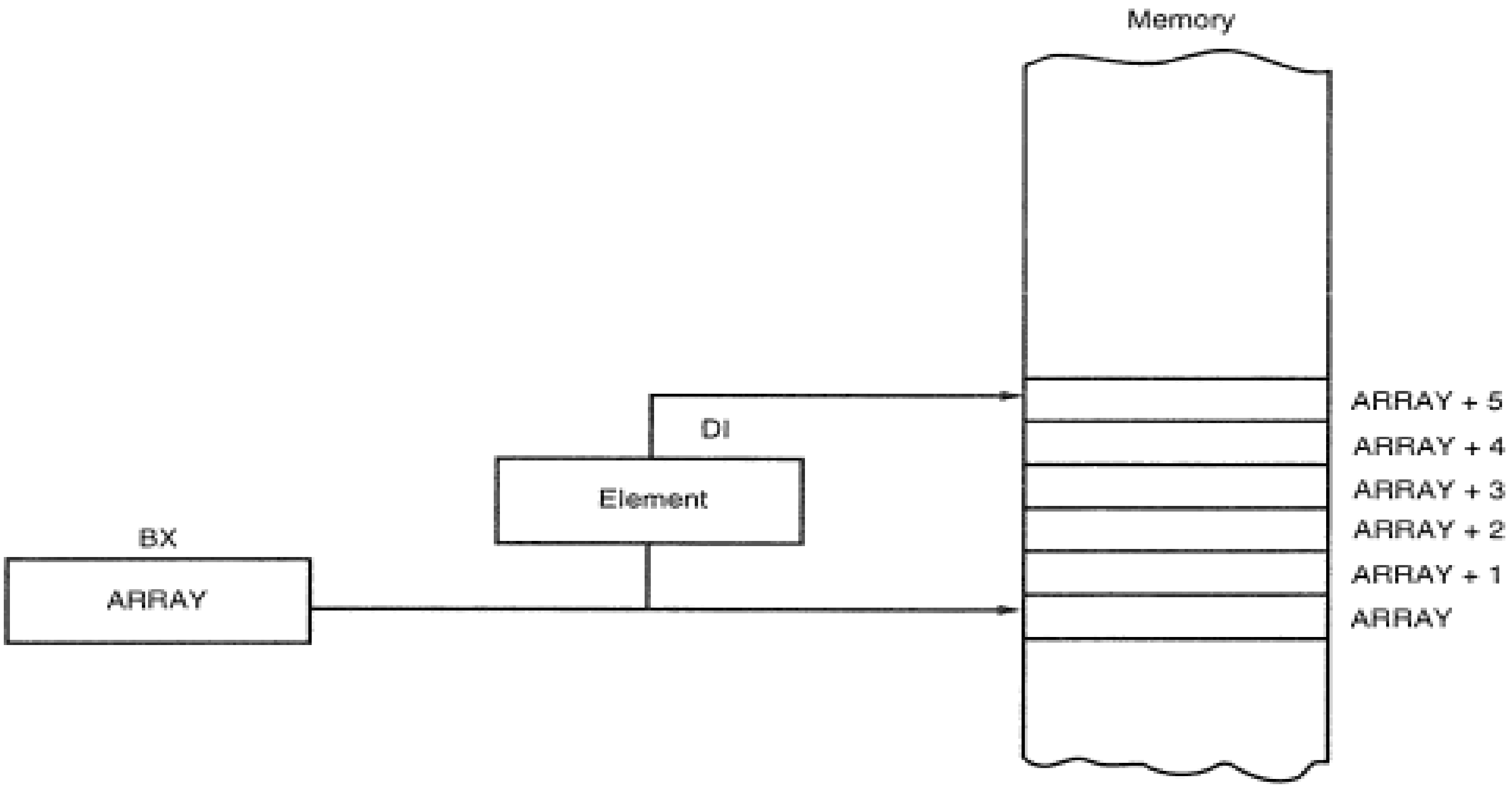


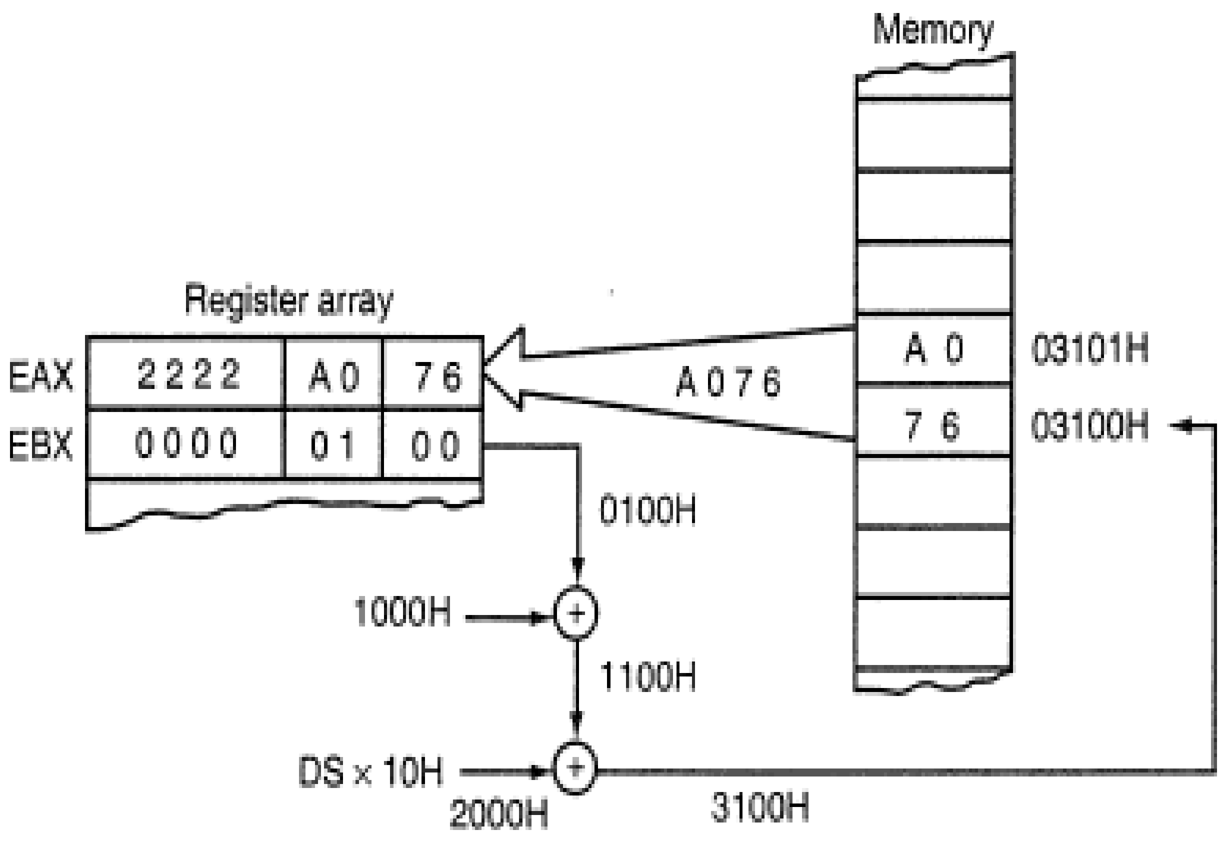
FIGURE 3–9 An example of the base-plus-index addressing mode. Here an element (DI) of an ARRAY (BX) is addressed.

6. Register Relative Addressing

- Moves a byte or word between a register and the memory location addressed by an index or base register plus a displacement.
- Examples:
  - **MOV AX,[BX+4]**
  - **MOV AX,ARRAY[BX]**

Register Relative Addressing

FIGURE 3–10 The operation of the MOV AX,[BX+1000H] instruction, when BX = 0100H and DS = 0200H



Register Relative Addressing

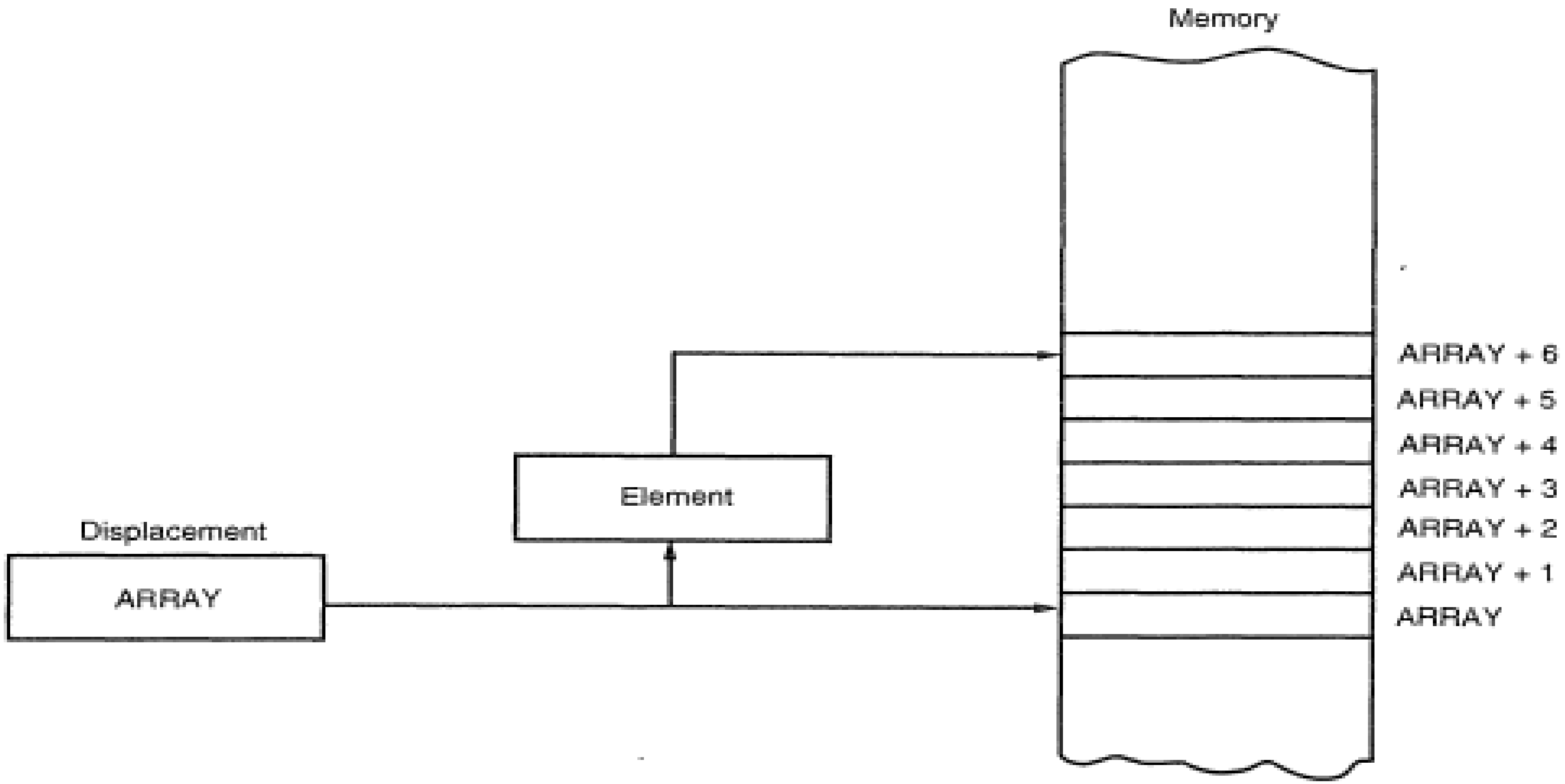


FIGURE 3–11 Register relative addressing used to address an element of ARRAY. The displacement addresses the start of ARRAY, and DI accesses an element.

7. Base Relative-Plus-Index Addressing

- Transfers a byte or word between a register and the memory location addressed by a base and an index register plus a displacement.
- Examples:
  - **MOV AX,ARRAY[BX+DI]**
  - **MOV AX,[BX+DI+4]**

Base Relative-Plus-Index Addressing

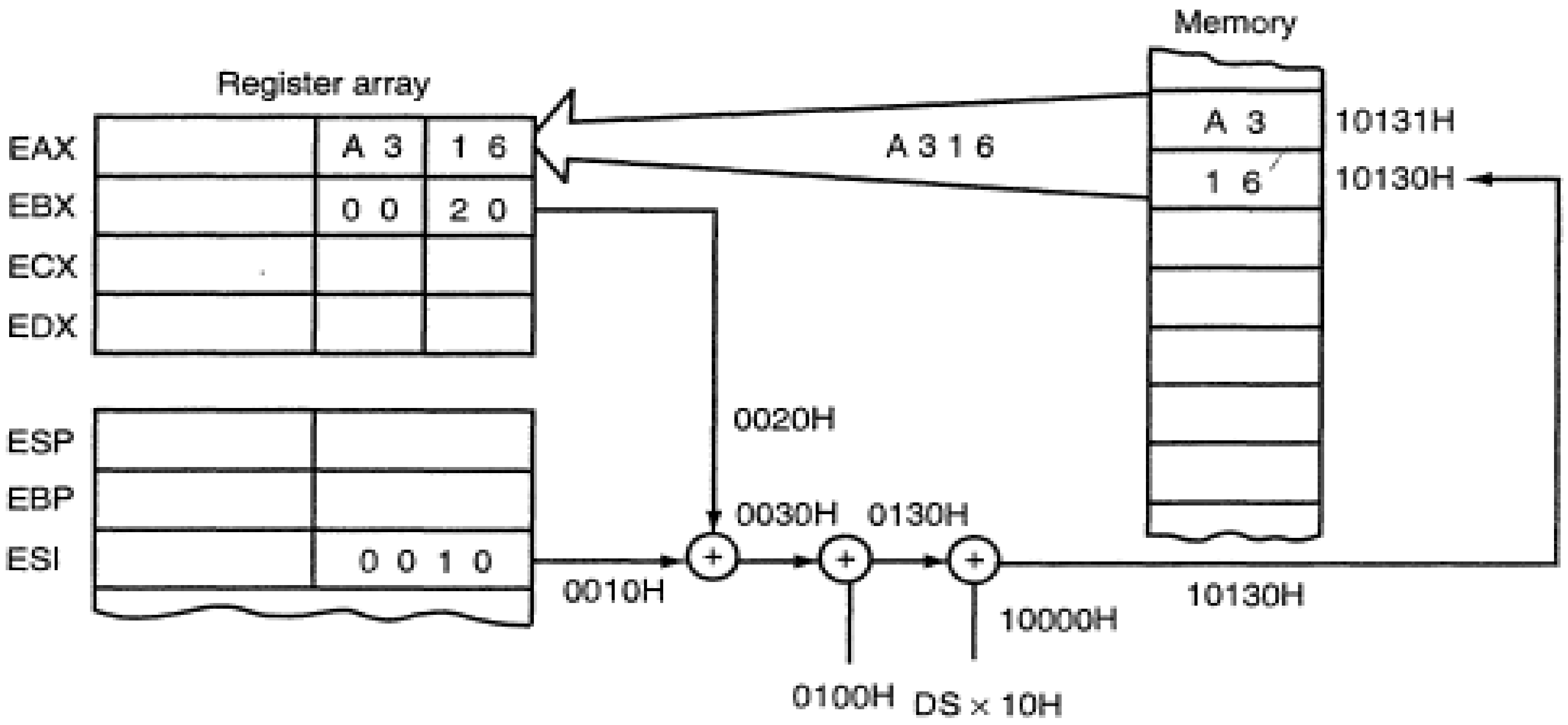
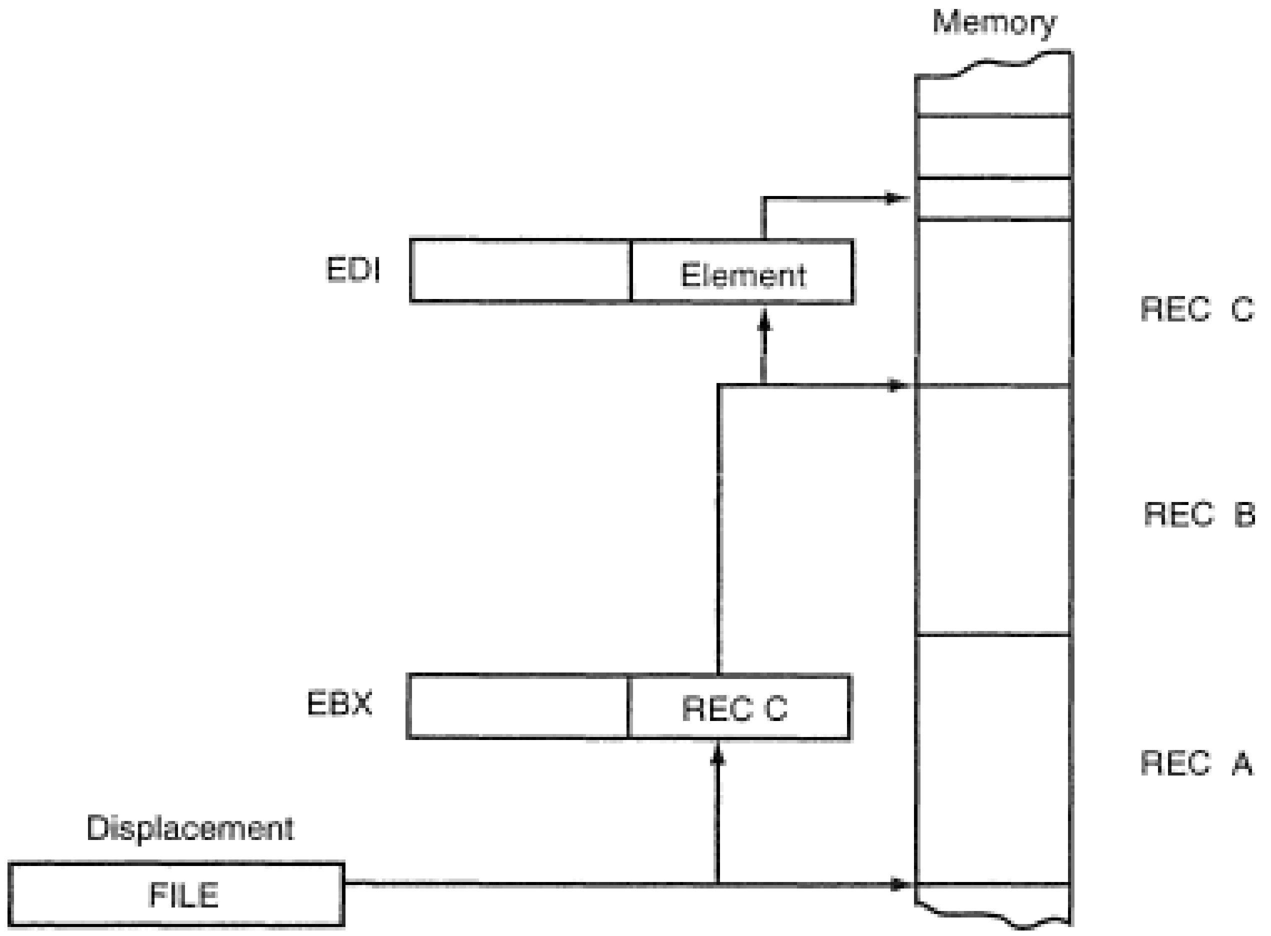


FIGURE 3–12 An example of base relative-plus-index addressing using a MOV AX,[BX+SI+100H] instruction. Note: DS = 1000H.

Base Relative-Plus-Index Addressing

FIGURE 3–13 Base relative-plus-index addressing used to access a FILE that contains multiple records (REC)



8. Relative Addressing

- In this mode, the operand is specified as a signed 8 bit displacement, relative to PC (Program Counter).
- Example: **JMP START**
  - PC is loaded with current PC contents plus the 8 bit signed value of START, otherwise the next instruction is executed.

9. Implied Addressing

- Instructions using this mode have no operands.
- Example: **CLC**
  - This clears the carry flag to zero.

Exercises

- Find the addressing modes of the following statements:
  - MOV DH,[BX+DI+20H]
  - MOV AL,BL
  - JMP LABEL1
  - MOV SP,BP
  - MOV AX,WATER
  - MOV CH,[BP+SI]
  - MOV AX,FILE[BX+DI]
  - MOV [DI],BH
  - MOV AX,44H
  - MOV [BX+SI],SP
  - MOV AL,NUMBER
  - MOV AX,[DI+100H]
  - MOV BL,44
  - MOV ARRAY[SI],BL
  - MOV LIST[SI+2],CL
  - MOV CX,[BX]
  - CLI

PUSH POP Instructions

- The PUSH POP instructions are important instructions that store and retrive the data from a LIFO (Last In First Out) stack memory

Push Instruction

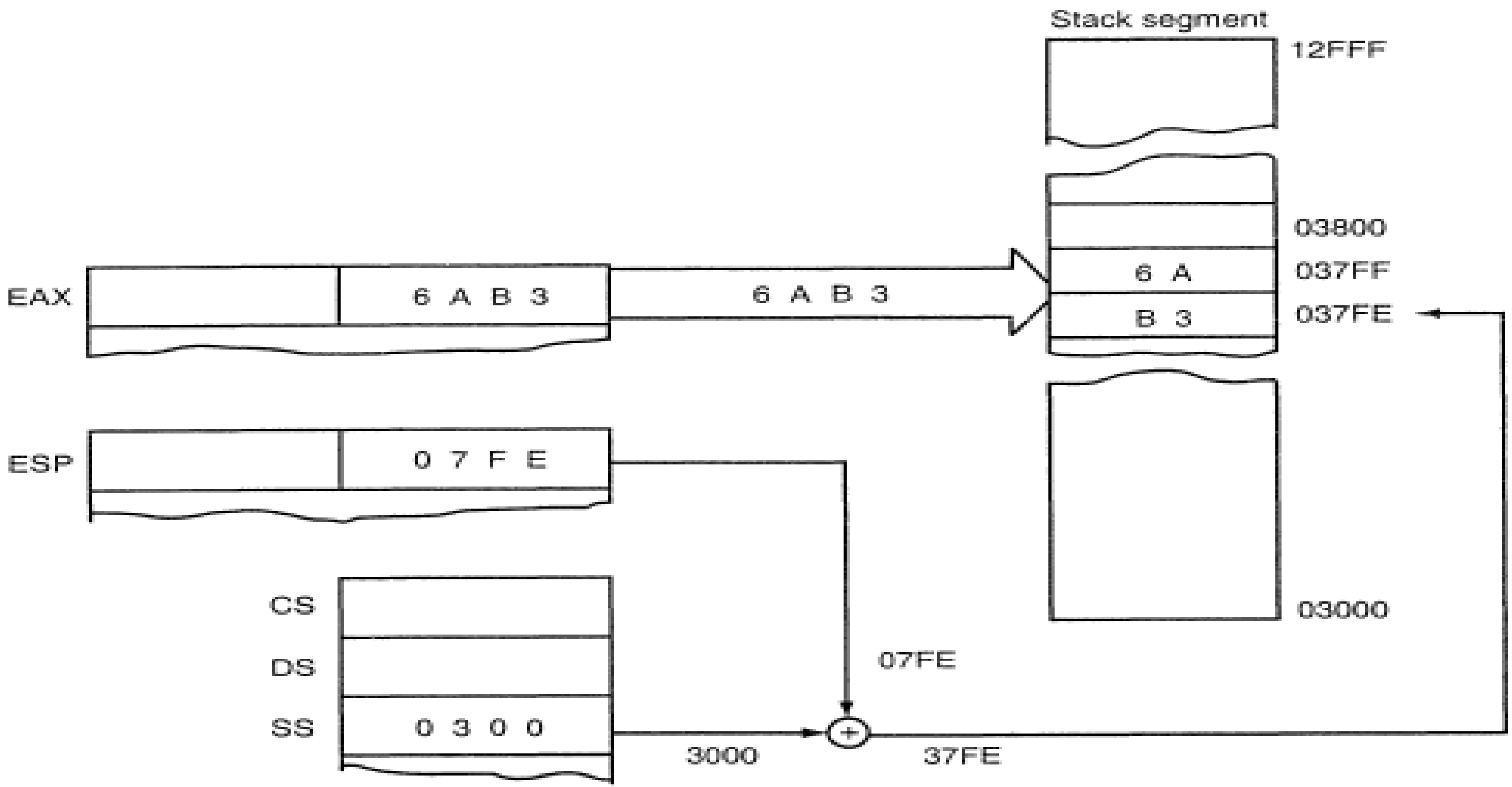


FIGURE 4–11 The effect of the PUSH AX instruction on ESP and stack memory location 37FFH and 37FEH. This instruction is shown at the point after execution.

Pop Instruction

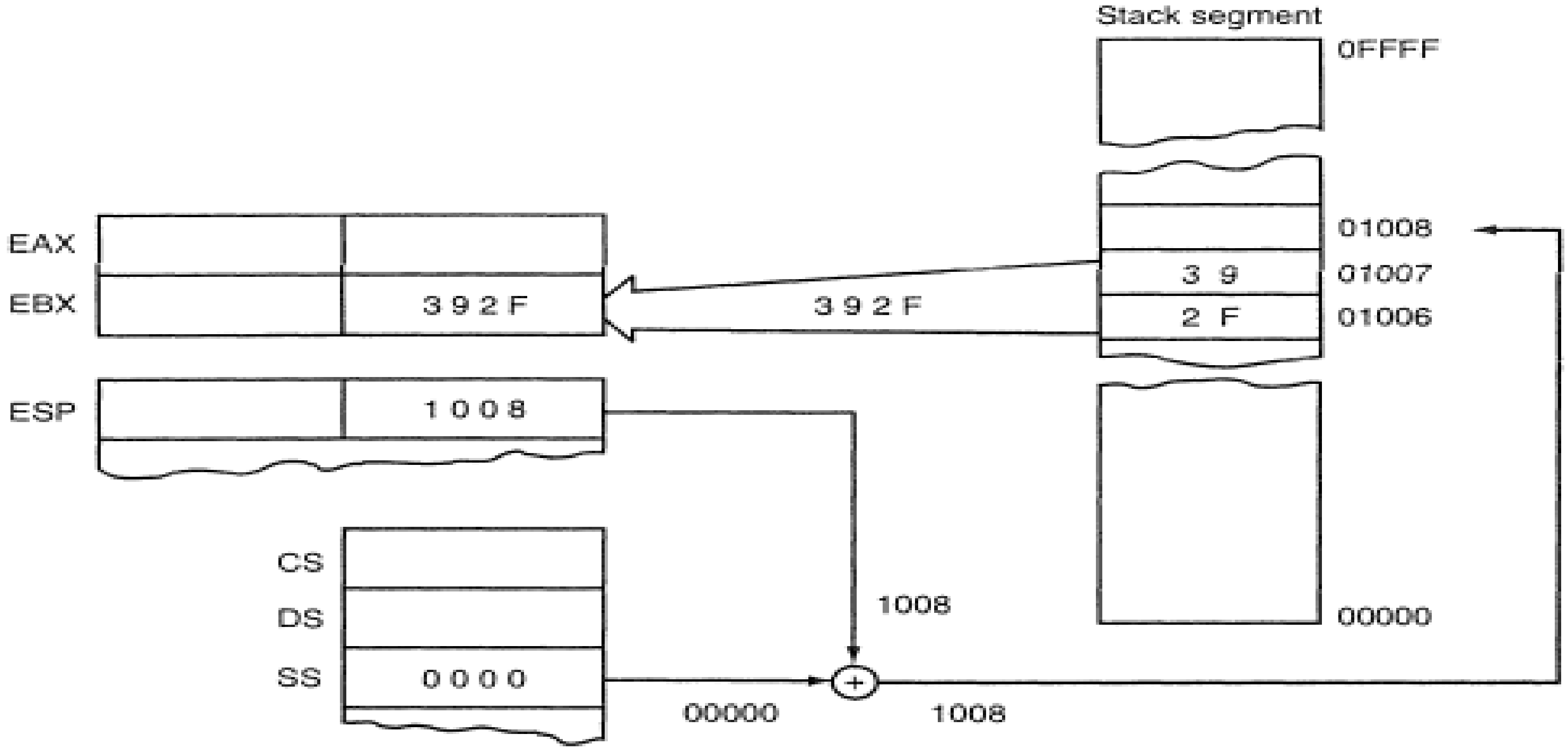


FIGURE 4–13 The POP BX instruction, showing how data are removed from the stack. This instruction is shown after execution.

Memory Access

- To access memory we can use these four registers: **BX**, **SI**, **DI**, **BP**.
- Combining these registers inside [ ] symbols, we can get different memory locations.

[BX+SI] [BX+DI] [BP+SI] [BP+DI]	[SI] [DI] d16 (variable offset only) [BX]	[BX+SI+d8] [BX+DI+d8] [BP+SI+d8] [BP+DI+d8]
[SI + d8] [DI + d8] [BP + d8] [BX + d8]	[BX + SI + d16] [BX + DI + d16] [BP + SI + d16] [BP + DI + d16]	[SI + d16] [DI + d16] [BP + d16] [BX + d16]

Displacements

- **d8** - stays for 8 bit signed immediate displacement (for example: 22, 55h, -1, etc...)
- **d16** - stays for 16 bit signed immediate displacement (for example: 300, 5517h, -259, etc...).
- Displacement can be an immediate value or offset of a variable, or even both (If there are several values, assembler evaluates all values and calculates a single immediate value).
- Displacement can be inside or outside of the [ ] symbols, assembler generates the same machine code for both ways.
- Displacement is a **signed** value, so it can be both positive or negative.
- Generally the compiler takes care about difference between **d8** and **d16**, and generates the required machine code.

Example

- Let's assume that **DS = 100**, **BX = 30**, **SI = 70**.
- **[BX + SI] + 25** is calculated by processor to this physical address: **100 * 16 + 30 + 70 + 25 = 1725**.
- *(note that all addresses are in decimal form, not hexadecimal, so DS is multiplied by 16=10H)*

Data Types

- In order to say the compiler about data type, these prefixes should be used:
  - **BYTE PTR** - for byte.
  - **WORD PTR** - for word (two bytes)
- Examples:
  - **MOV AL, BYTE PTR [BX]** ; byte access
  - **MOV CX, WORD PTR [BX]** ; word access
- Assembler supports shorter prefixes as well:
  - **B.** - for **BYTE PTR**
  - **W.** - for **WORD PTR**
- In certain cases the assembler can calculate the data type automatically.

MOV Instruction

- Copies the **second operand** (source) to the **first operand** (destination).
- The source operand can be an immediate value, general-purpose register or memory location.
- The destination register can be a general-purpose register, or memory location.
- Both operands must be the same size, which can be a byte or a word.
- the **MOV** instruction cannot be used to set the value of the **CS** and **IP** registers.

Operands of MOV

- These types of operands are supported:
  - MOV REG, memory
  - MOV memory, REG
  - MOV REG, REG
  - MOV memory, immediate
  - MOV REG, immediate
- **REG**: AX, BX, CX, DX, AH, AL, BL, BH, CH, CL, DH, DL, DI, SI, BP, SP.
- **memory**: [BX], [BX+SI+7], variable, etc.
- **immediate**: 5, -24, 3Fh, 10001101b, etc.

Segment Register Operands

- For segment registers only these types of **MOV** are supported:
  - MOV SREG, memory
  - MOV memory, SREG
  - MOV REG, SREG
  - MOV SREG, REG
- **SREG**: DS, ES, SS, and only as second operand: CS.
- **REG**: AX, BX, CX, DX, AH, AL, BL, BH, CH, CL, DH, DL, DI, SI, BP, SP.
- **memory**: [BX], [BX+SI+7], variable, etc.

MOV Example

ORG 100h ; this directive required for a simple 1 segment .com program.

MOV AX, 0B800h ; set AX to hexadecimal value of B800h.

MOV DS, AX ; copy value of AX to DS.

MOV CL, 'A' ; set CL to ASCII code of 'A', it is 41h.

MOV CH, 11011111b ; set CH to binary value.

MOV BX, 15Eh ; set BX to 15Eh.

MOV [BX], CX ; copy contents of CX to memory at B800:015E

RET ; returns to operating system.

Variables

- Syntax for a variable declaration:
  - *name* **DB** *value*
  - *name* **DW** *value*
- **DB** - stays for Define Byte.
- **DW** - stays for Define Word.
- *name* - can be any letter or digit combination, though it should start with a letter. It's possible to declare unnamed variables by not specifying the name (this variable will have an address but no name).
- *value* - can be any numeric value in any supported numbering system (hexadecimal, binary, or decimal), or "**?**" symbol for variables that are not initialized.

Example

```
ORG 100h
MOV AL, var1
MOV BX, var2
RET ; stops the program.
var1    DB      7
var2    DW    1234H
```

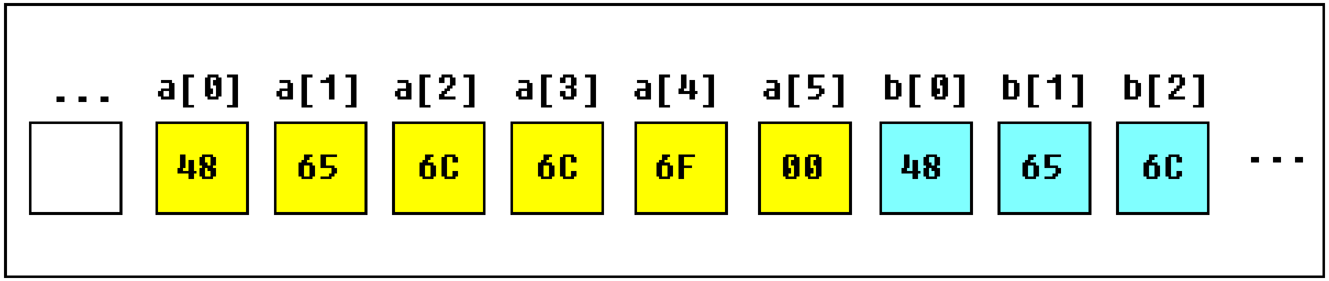
ORG Directive

- **ORG 100h** is a compiler directive (it tells compiler how to handle the source code).
- It tells compiler that the executable file will be loaded at the **offset** of 100h (256 bytes), so compiler should calculate the correct address for all variables when it replaces the variable names with their **offsets**.
- Directives are never converted to any real **machine code**.
- Operating system keeps some data about the program in the first 256 bytes of the **CS** (code segment), such as command line parameters and etc.

Arrays

- Arrays can be seen as chains of variables.
- A text string is an example of a byte array, each character is presented as an ASCII code value (0..255).
- Examples:
  - **a DB 48h, 65h, 6Ch, 6Ch, 6Fh, 00h**
  - **b DB 'Hello', 0**
- **b** is an exact copy of the **a** array, when compiler sees a string inside quotes it automatically converts it to set of bytes.

Accessing Array Elements



- You can access the value of any element in array using square brackets, for example:
  - MOV AL, a[3]
- You can also use any of the memory index registers **BX**, **SI**, **DI**, **BP**, for example:
  - MOV SI, 3
  - MOV AL, a[SI]

Declaring Large Arrays

- If you need to declare a large array you can use **DUP** operator.
- The syntax for **DUP**:
  - number DUP (value(s))
  - number - number of duplicate to make (any constant value).
  - value - expression that DUP will duplicate.
- Example:

  c DB 5 DUP(9)

  is an alternative way of declaring:

  c DB 9, 9, 9, 9, 9

Declaring Large Arrays

- One more example:

  d DB 5 DUP(1, 2)

  is an alternative way of declaring:

  d DB 1, 2, 1, 2, 1, 2, 1, 2, 1, 2

Getting the Address of a Variable

- The **LEA** instruction and the **OFFSET** operator can be used to get the offset address of a variable.
- **LEA** is more powerful because it also allows you to get the address of an indexed variables.
- Getting the address of the variable can be very useful in some situations, for example when you need to pass parameters to a procedure.

Example 1

```
ORG 100h
MOV AL, VAR1 ; check value of VAR1 by moving it to AL.
LEA BX, VAR1     ; get address of VAR1 in BX.
MOV BYTE PTR [BX], 44h ; modify the contents of
   VAR1.
MOV AL, VAR1 ; check value of VAR1 by moving it to AL.
RET
VAR1 DB 22h
END
```

Example 2

```
ORG 100h
MOV AL, VAR1 ; check value of VAR1 by moving it to AL.
MOV BX, OFFSET VAR1 ; get address of VAR1 in BX.
MOV BYTE PTR [BX], 44h ; modify the contents of
   VAR1.
MOV AL, VAR1 ; check value of VAR1 by moving it to AL.
RET
VAR1 DB 22h
END
```

About the Examples…

- Both examples have the same functionality.
- These lines:
  LEA BX, VAR1
  MOV BX, OFFSET VAR1
  are even compiled into the same machine code: **MOV BX, num**
  where **num** is a 16 bit value of the variable offset.

Constants

- Constants are just like variables, but they exist only until your program is compiled (assembled).
- After definition of a constant its value cannot be changed.
- To define constants **EQU** directive is used:

  name EQU < any expression >
- Example:

  k EQU 5

  MOV AX, k
- The above example is functionally identical to code:

  MOV AX, 5

Arithmetic and Logic Instructions

- Most arithmetic instructions affect the **FLAGS** register.
- **Carry Flag (C)**
- **Zero Flag (Z)**
- **Sign Flag (S)**
- **Overflow Flag (O)**
- **Parity Flag (P)**
- **Interrupt enable Flag (I)**
- **Direction Flag (D)**

1st group: ADD, SUB,CMP, AND, TEST, OR, XOR

- These types of operands are supported:
  - REG, memory
  - memory, REG
  - REG, REG
  - memory, immediate
  - REG, immediate
- **REG**: AX, BX, CX, DX, AH, AL, BL, BH, CH, CL, DH, DL, DI, SI, BP, SP.
- **memory**: [BX], [BX+SI+7], variable, etc.
- **immediate**: 5, -24, 3Fh, 10001101b, etc.

ADD, SUB,CMP, AND, TEST, OR, XOR (cont)

- After operation between operands, result is always stored in first operand. **CMP** and **TEST** instructions affect flags only and do not store a result (these instruction are used to make decisions during program execution).
- These instructions affect these flags only:
  - **C**, **Z**, **S**, **O**, **P**, **A**.

ADD, SUB,CMP, AND, TEST, OR, XOR (cont)

- **ADD** - add second operand to the first.
- **SUB** - Subtract second operand from the first.
- **CMP** - Subtract second operand from first **for flags only**.
- **AND** - Logical AND between all bits of two operands.
- **TEST** - The same as **AND** but **for flags only**.
- **OR** - Logical OR between all bits of two operands.
- **XOR** - Logical XOR (exclusive OR) between all bits of two operands.

More About AND, OR, XOR

- AND operator gives 1 only if both operands are 1.
- OR operator gives 1 if at least one operand is 1.
- XOR operator gives 1 only if the operands are different.

2nd Group: MUL, IMUL, DIV, IDIV

- These types of operands are supported:
  - REG
  - Memory
  - **REG**: AX, BX, CX, DX, AH, AL, BL, BH, CH, CL, DH, DL, DI, SI, BP, SP.
  - **memory**: [BX], [BX+SI+7], variable, etc.
- **MUL** and **IMUL** instructions affect these flags only:
  - **C**, **O**
- When result is over operand size these flags are set to **1**, when result fits in operand size these flags are set to **0**.
- For **DIV** and **IDIV** flags are undefined.

MUL and IMUL

- **MUL** - Unsigned multiply
  - When operand is a **byte**: AX = AL * operand.
  - When operand is a **word**: (DX AX) = AX * operand.
- **IMUL** - Signed multiply
  - When operand is a **byte**: AX = AL * operand.
  - When operand is a **word**: (DX AX) = AX * operand.

DIV and IDIV

- **DIV** - Unsigned divide
  - When operand is a **byte**:
    - AL = AX / operand and AH = remainder (modulus).
  - When operand is a **word**:
    - AX = (DX AX) / operand and DX = remainder (modulus)
- **IDIV** - Signed divide
  - When operand is a **byte**:
    - AL = AX / operand and AH = remainder (modulus)
  - When operand is a **word**:
    - AX = (DX AX) / operand and DX = remainder (modulus)

3rd Group: INC, DEC, NOT, NEG

- These types of operands are supported:
  - REG
  - Memory
  - **REG**: AX, BX, CX, DX, AH, AL, BL, BH, CH, CL, DH, DL, DI, SI, BP, SP.
  - **memory**: [BX], [BX+SI+7], variable, etc.

INC and DEC

- **INC:** Increments the operand by 1.
- **DEC:** Decrements the operand by 1.
- **INC**, **DEC** instructions affect these flags only:
  - **Z**, **S**, **O**, **P**, **A**

NOT and NEG

- **NOT** - Reverse each bit of operand.
- **NEG** - Make operand negative (two's complement). Actually it reverses each bit of operand and then adds 1 to it. For example 5 will become -5, and -2 will become 2
- **NOT** instruction does not affect any flags.
- **NEG** instruction affects these flags only:
  - **C**, **Z**, **S**, **O**, **P**, **A**

Negative Numbers

- There are three conventions used to negate a number:
  1. Sign and Magnitude
     - Make the first bit 1
  2. One's Complement
     - Complement each bit
  3. Two's Complement
     - Complement each bit and add 1
     - This convention is used in 8086.

Two's Complement

- To find the representation of 5 is the following:
  - Represent 5: **00000101**
  - Reverse each bit: **11111010**
  - Add 1: **11111011**
  - So, **-5** is represented as **11111011** in two's complement convention.

Summary

- Addressing modes
- Data movement Instructions
- Arithmetic Instructions
- Logic Instructions
- Assembly Language Programming

Course Completed

- Chapter 3 4 and 5 Completed.