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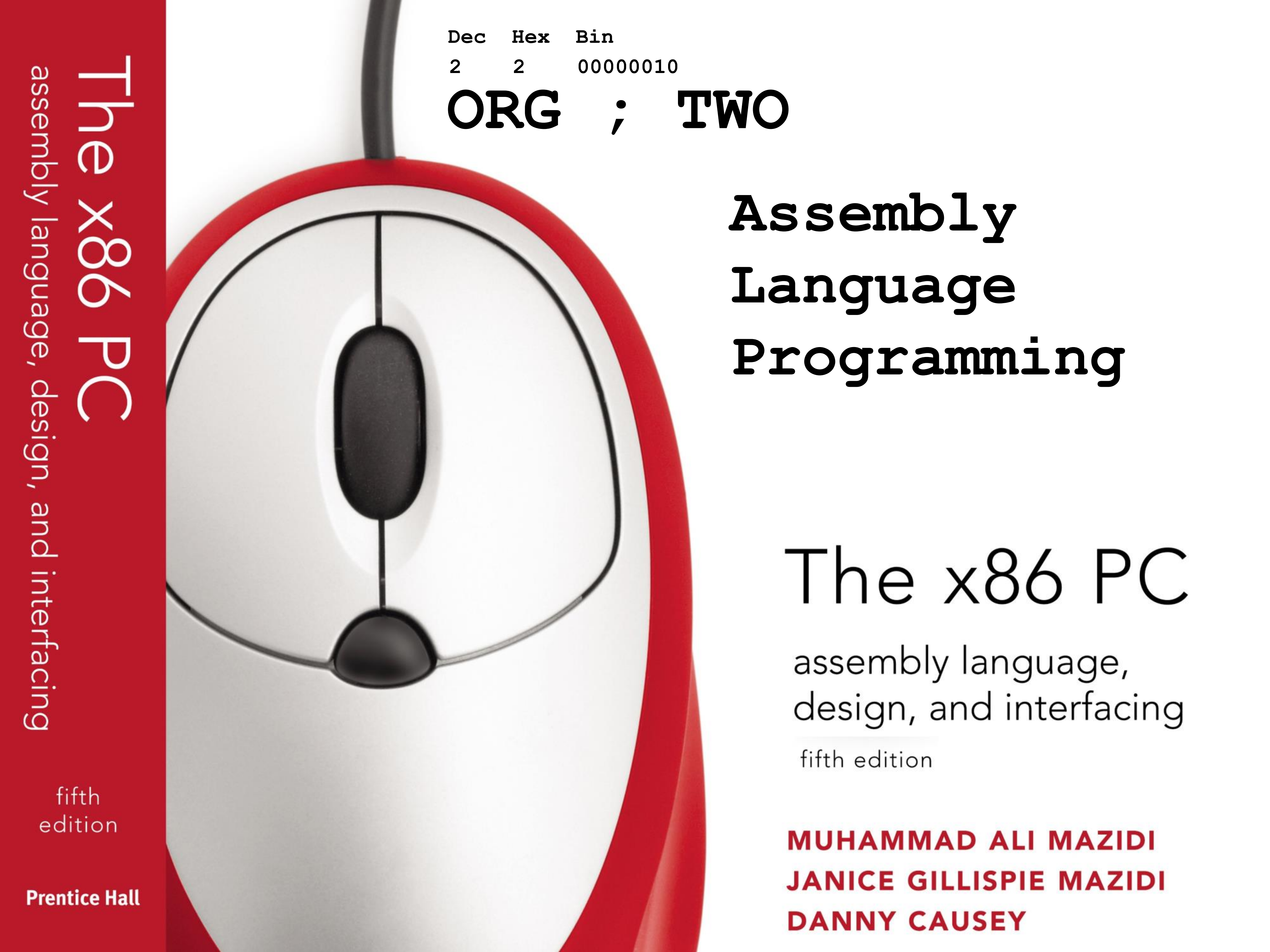
ORG ; TWO

Assembly Language Programming



OBJECTIVES
this chapter enables the student to:

- Explain the difference between Assembly language instructions and pseudo-instructions.
- Identify the segments of an Assembly language program.
- Code simple Assembly language instructions.
- Assemble, link, and run a simple Assembly language program.
- Code control transfer instructions such as conditional and unconditional jumps and call instructions.

OBJECTIVES (*cont*)

this chapter enables the student to:

- Code Assembly language data directives for binary, hex, decimal, or ASCII data.
- Write an Assembly language program using either the simplified segment definition or the full segment definition.
- Explore the use of the MASM and emu8086 assemblers.

2.0: ASSEMBLY LANGUAGE

- An Assembly language program is a series of statements, or lines.
  - Either Assembly language instructions, or statements called *directives*.
    - Directives (pseudo-instructions) give directions to the assembler about how it should translate the Assembly language instructions into machine code.
- Assembly language instructions consist of four fields:

`[label:] mnemonic [operands][;comment]`

  - Brackets indicate that the field is optional.
    - Do not type in the brackets.

2.1: DIRECTIVES AND A SAMPLE PROGRAM
assembly language instructions

```
[label:] mnemonic [operands][;comment]
```

- The label field allows the program to refer to a line of code by name.
  - The label field cannot exceed 31 characters.
    - A label must end with a colon when it refers to an opcode generating instruction.

2.1: DIRECTIVES AND A SAMPLE PROGRAM assembly language instructions

```
[label:] mnemonic [operands][;comment]
```

- The mnemonic (instruction) and operand(s) fields together accomplish the tasks for which the program was written.

```
ADD    AL,BL
MOV    AX,6764
```

  - The mnemonic opcodes are **ADD** and **MOV**.
  - "**AL,BL**" and "**AX,6764**" are the operands.
    - Instead of a mnemonic and operand, these fields could contain assembler pseudo-instructions, or *directives*.
    - Directives do not generate machine code and are used only by the assembler as opposed to instructions.

2.1: DIRECTIVES AND A SAMPLE PROGRAM
assembly language instructions

[label:] mnemonic [operands] [;comment]

- Examples of directives are **DB**, **END**, and **ENDP**.

```
;THE FORM OF AN ASSEMBLY LANGUAGE PROGRAM
;NOTE: USING SIMPLIFIED SEGMENT DEFINITION
            .MODEL SMALL
            .STACK 64
            .DATA
DATA1       DB     52H
DATA2       DB     29H
SUM         DB     ?
            .CODE
MAIN        PROC   FAR          ;this is the program entry point
            MOV    AX,@DATA     ;load the data segment address
            MOV    DS,AX        ;assign value to DS
            MOV    AL,DATA1     ;get the first operand
            MOV    BL,DATA2     ;get the second operand
            ADD    AL,BL        ;add the operands
            MOV    SUM,AL       ;store the result in location SUM
            MOV    AH,4CH       ;set up to return to OS
            INT    21H          ;
MAIN        ENDP
            END    MAIN         ;this is the program exit point
```

2.1: DIRECTIVES AND A SAMPLE PROGRAM
assembly language instructions

```
[label:] mnemonic [operands][;comment]
```

- The comment field begins with a ";" and may be at the end of a line or on a line by themselves.
  - The assembler ignores comments.
    - Comments are optional, but highly recommended to make it easier to read and understand the program.

2.1: DIRECTIVES AND A SAMPLE PROGRAM
model definition

- After the first two comments is the MODEL directive.
  - This directive selects the size of the memory model.

```
;THE FORM OF AN ASSEMBLY LANGUAGE PROGRAM
;NOTE: USING SIMPLIFIED SEGMENT DEFINITION
            .MODEL SMALL
            .STACK 64
            .DATA
DATA1       DB     52H
DATA2       DB     29H
SUM         DB     ?
            .CODE
MAIN        PROC   FAR          ;this is the program entry point
            MOV    AX,@DATA     ;load the data segment address
            MOV    DS,AX        ;assign value to DS
            MOV    AL,DATA1     ;get the first operand
            MOV    BL,DATA2     ;get the second operand
            ADD    AL,BL        ;add the operands
            MOV    SUM,AL       ;store the result in location SUM
            MOV    AH,4CH       ;set up to return to OS
            INT    21H          ;
MAIN        ENDP
            END    MAIN         ;this is the program exit point
```

2.1: DIRECTIVES AND A SAMPLE PROGRAM
model definition

- Among the options for the memory model are SMALL, MEDIUM, COMPACT, and LARGE.

```
.MODEL SMALL     ;this directive defines the model as small
.MODEL MEDIUM    ;the data must fit into 64K bytes
                 ;but the code can exceed 64K bytes of memory
.MODEL COMPACT   ;the data can exceed 64K bytes
                 ;but the code cannot exceed 64K bytes
.MODEL LARGE     ;both data and code can exceed 64K
                 ;but no single set of data should exceed 64K
.MODEL HUGE      ;both code and data can exceed 64K
                 ;data items (such as arrays) can exceed 64K
.MODEL TINY      ;used with COM files in which data and code
                 ;must fit into 64K bytes
```

2.1: DIRECTIVES AND A SAMPLE PROGRAM
segment definition

- Every line of an Assembly language program must correspond to one an x86 CPU segment register.
  - CS (code segment); DS (data segment).
  - SS (stack segment); ES (extra segment).
- The simplified segment definition format uses three simple directives: "**.CODE**" "**.DATA**" "**.STACK**"
  - Which correspond to the CS, DS, and SS registers.

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

  - The stack segment defines storage for the stack.
  - The data segment defines the data the program will use.
  - The code segment contains Assembly language instructions.

2.1: DIRECTIVES AND A SAMPLE PROGRAM
stack segment

- This directive reserves 64 bytes of memory for the stack:

```
;THE FORM OF AN ASSEMBLY LANGUAGE PROGRAM
;NOTE: USING SIMPLIFIED SEGMENT DEFINITION
            .MODEL SMALL
            .STACK 64
            .DATA
DATA1       DB    52H
DATA2       DB    29H
SUM         DB    ?
            .CODE
MAIN        PROC  FAR         ;this is the program entry point
            MOV   AX,@DATA    ;load the data segment address
            MOV   DS,AX       ;assign value to DS
            MOV   AL,DATA1    ;get the first operand
            MOV   BL,DATA2    ;get the second operand
            ADD   AL,BL       ;add the operands
            MOV   SUM,AL      ;store the result in location SUM
            MOV   AH,4CH      ;set up to return to OS
            INT   21H         ;
MAIN        ENDP
            END   MAIN        ;this is the program exit point
```

2.1: DIRECTIVES AND A SAMPLE PROGRAM
data segment

- The data segment defines three data items:
  - DATA1, DATA2, and SUM.

```
;THE FORM OF AN ASSEMBLY LANGUAGE PROGRAM
;NOTE: USING SIMPLIFIED SEGMENT DEFINITION
            .MODEL SMALL
            .STACK 64
            .DATA
DATA1       DB     52H
DATA2       DB     29H
SUM         DB     ?
            .CODE
MAIN        PROC   FAR          ;this is the program entry point
            MOV    AX,@DATA     ;load the data segment address
            MOV    DS,AX        ;assign value to DS
            MOV    AL,DATA1     ;get the first operand
            MOV    BL,DATA2     ;get the second operand
            ADD    AL,BL        ;add the operands
            MOV    SUM,AL       ;store the result in location SUM
            MOV    AH,4CH       ;set up to return to OS
            INT    21H          ;
MAIN        ENDP
            END    MAIN         ;this is the program exit point
```

2.1: DIRECTIVES AND A SAMPLE PROGRAM
data segment

- The DB directive is used by the assembler to allocate memory in byte-sized chunks.
  - Each is defined as DB (define byte).
    - Memory can be allocated in different sizes.
  - Data items defined in the data segment will be accessed in the code segment by their labels.
- DATA1 and DATA2 are given initial values in the data section.
- SUM is not given an initial value.
  - But storage is set aside for it.

2.1: DIRECTIVES AND A SAMPLE PROGRAM
code segment definition

- The first line of the segment after the .CODE directive is the PROC directive.

```
;THE FORM OF AN ASSEMBLY LANGUAGE PROGRAM
;NOTE: USING SIMPLIFIED SEGMENT DEFINITION
            .MODEL SMALL
            .STACK 64
            .DATA
DATA1       DB     52H
DATA2       DB     29H
SUM         DB     ?
            .CODE
MAIN        PROC   FAR          ;this is the program entry point
            MOV    AX,@DATA     ;load the data segment address
            MOV    DS,AX        ;assign value to DS
            MOV    AL,DATA1     ;get the first operand
            MOV    BL,DATA2     ;get the second operand
            ADD    AL,BL        ;add the operands
            MOV    SUM,AL       ;store the result in location SUM
            MOV    AH,4CH       ;set up to return to OS
            INT    21H          ;
MAIN        ENDP
            END    MAIN         ;this is the program exit point
```

2.1: DIRECTIVES AND A SAMPLE PROGRAM
code segment definition

- *A procedure* is a group of instructions designed to accomplish a specific function.
  - A code segment is organized into several small procedures to make the program more structured.
- Every procedure must have a name defined by the PROC directive.
  - Followed by the assembly language instructions, and closed by the ENDP directive.
    - The PROC and ENDP statements must have the same label.
  - The PROC directive may have the option FAR or NEAR.
    - The OS requires the entry point to the user program to be a FAR procedure.

code segment definition

- Before the OS passes control to the program so it may execute, it assigns segment registers values.
  - When the program begins executing, only CS and SS have the proper values.
    - DS (and ES) values are initialized by the program.

```
MOV AX,@DATA ;DATA refers to the start of the data segment
MOV DS,AX
```

2.1: DIRECTIVES AND A SAMPLE PROGRAM code segment definition

- The program loads **AL** & **BL** with **DATA1** & **DATA2**, ADDs them together, and stores the result in **SUM**.

```
;THE FORM OF AN ASSEMBLY LANGUAGE PROGRAM
;NOTE: USING SIMPLIFIED SEGMENT DEFINITION
            .MODEL SMALL
            .STACK 64
            .DATA
DATA1       DB     52H
DATA2       DB     29H
SUM         DB     ?
            .CODE
MAIN        PROC   FAR          ;this is the program entry point
            MOV    AX,@DATA     ;load the data segment address
            MOV    DS,AX        ;assign value to DS
            MOV    AL,DATA1     ;get the first operand
            MOV    BL,DATA2     ;get the second operand
            ADD    AL,BL        ;add the operands
            MOV    SUM,AL       ;store the result in location SUM
            MOV    AH,4CH       ;set up to return to OS
            INT    21H          ;
MAIN        ENDP
            END    MAIN         ;this is the program exit point
```

code segment definition

- The last instructions, "**MOV AH,4CH**" & "**INT 21H**" return control to the operating system.

```
;THE FORM OF AN ASSEMBLY LANGUAGE PROGRAM
;NOTE: USING SIMPLIFIED SEGMENT DEFINITION
            .MODEL SMALL
            .STACK 64
            .DATA
DATA1       DB     52H
DATA2       DB     29H
SUM         DB     ?
            .CODE
MAIN        PROC   FAR          ;this is the program entry point
            MOV    AX,@DATA     ;load the data segment address
            MOV    DS,AX        ;assign value to DS
            MOV    AL,DATA1     ;get the first operand
            MOV    BL,DATA2     ;get the second operand
            ADD    AL,BL        ;add the operands
            MOV    SUM,AL       ;store the result in location SUM
            MOV    AH,4CH       ;set up to return to OS
            INT    21H          ;
MAIN        ENDP
            END    MAIN         ;this is the program exit point
```

2.1: DIRECTIVES AND A SAMPLE PROGRAM
code segment definition

- The last two lines end the procedure & program.
  - The label for **ENDP (MAIN)** matches the label for **PROC**.

```
;THE FORM OF AN ASSEMBLY LANGUAGE PROGRAM
;NOTE: USING SIMPLIFIED SEGMENT DEFINITION
            .MODEL SMALL
            .STACK 64
            .DATA
DATA1       DB     52H
DATA2       DB     29H
SUM         DB     ?
            .CODE
MAIN        PROC   FAR          ;this is the program entry point
            MOV    AX,@DATA     ;load the data segment address
            MOV    DS,AX        ;assign value to DS
            MOV    AL,DATA1     ;get the first operand
            MOV    BL,DATA2     ;get the second operand
            ADD    AL,BL        ;add the operands
            MOV    SUM,AL       ;store the result in location SUM
            MOV    AH,4CH       ;set up to return to OS
            INT    21H          ;
MAIN        ENDP
            END    MAIN         ;this is the program exit point
```

2.1: DIRECTIVES AND A SAMPLE PROGRAM
code segment definition

- It is handy to keep a sample shell & fill it in with the instructions and data for your program.

```
;THE FORM OF AN ASSEMBLY LANGUAGE PROGRAM
; USING SIMPLIFIED SEGMENT DEFINITION
            .MODEL SMALL
            .STACK 64
            .DATA
            ;
            ;place data definitions here
            ;
            .CODE
MAIN        PROC   FAR          ;this is the program entry point
            MOV    AX,@DATA     ;load the data segment address
            MOV    DS,AX        ;assign value to DS
            ;
            ;place code here
            ;
            MOV    AH,4CH       ;set up to
            INT    21H          ;return to OS
MAIN        ENDP
            END    MAIN         ;this is the program exit point
```

2.2: ASSEMBLE, LINK, AND RUN A PROGRAM

- MASM & LINK are the assembler & linker programs.
  - Many editors or word processors can be used to create and/or edit the program, and produce an ASCII file.
  - The steps to create an executable Assembly language program are as follows:

Step	Input	Program	Output
1. Edit the program	keyboard	editor	myfile.asm
2. Assemble the program	myfile.asm	MASM or TASM	myfile.obj
3. Link the program	myfile.obj	LINK or TLINK	myfile.exe

- Program 2-1, and the list file generated when the program was assembled.

Write, run, and analyze a program that adds 5 bytes of data and saves the result. The data should be the following hex numbers: 25, 12, 15, 1F, and 2B.

```
        PAGE      60,132
        TITLE     PROG2-1   (EXE)   PURPOSE: ADDS 5 BYTES OF DATA
                  .MODEL SMALL
                  .STACK 64
;-----------------
                  .DATA
DATA_IN           DB              25H,12H,15H,1FH,2BH
SUM               DB              ?
;-----------------
                  .CODE
MAIN              PROC    FAR
                  MOV     AX,@DATA
                  MOV     DS,AX
                  MOV     CX,05               ;set up loop counter CX=5
                  MOV     BX,OFFSET DATA_IN   ;set up data pointer BX
                  MOV     AL,0                ;initialize AL
AGAIN:            ADD     AL,[BX]                    data item to AL
```

See the entire program listing on page 63 of your textbook.

2.3: MORE SAMPLE PROGRAMS
analysis of Program 2-1

- Program 2-1, explained instruction by instruction:
  - "**`MOV CX,05`**" will load the value 05 into the CX register.
    - Used by the program as a counter for iteration (looping).
  - "**`MOV BX,OFFSET DATA_IN`**" will load into BX the offset address assigned to DATA.
    - The assembler starts at offset 0000 and uses memory for the data, then assigns the next available offset memory for SUM (in this case, 0005).
  - "**`ADD AL,[BX]`**" adds the contents of the memory location pointed at by the register BX to AL.
    - Note that [BX] is a pointer to a memory location.
  - "**`INC BX`**" increments the pointer by adding 1 to BX.
    - This will cause BX to point to the next data item. (next byte)

2.3: MORE SAMPLE PROGRAMS
analysis of Program 2-1

- Program 2-1, explained instruction by instruction:
  - "**`DEC CX`**" will decrement (subtract 1 from) the CX counter and set the zero flag high if CX becomes zero.
  - "**`JNZ AGAIN`**" will jump back to the label AGAIN as long as the zero flag is indicating that CX is not zero.
    - "**`JNZ AGAIN`**" will *not* jump only after the zero flag has been set high by the "DEC CX" instruction (CX becomes zero).
  - When CX becomes zero, this means that the loop is completed and all five numbers have been added to AL.

2.3: MORE SAMPLE PROGRAMS
various approaches to Program 2-1

- Variations of Program 2-1 clarify use of addressing modes, and show that the x86 can use any general-purpose register for arithmetic and logic operations.

```
;from the data segment:
DATA1   DB 25H
DATA2   DB 12H
DATA3   DB 15H
DATA4   DB 1FH
DATA5   DB 2BH
SUM   DB   ?
;from the code segment:
MOV   AL,DATA1        ;MOVE DATA1 INTO AL
ADD   AL,DATA2        ;ADD DATA2 TO AL
ADD   AL,DATA3
ADD   AL,DATA4
ADD   AL,DATA5
MOV   SUM,AL          ;SAVE AL IN SUM
```

2.3: MORE SAMPLE PROGRAMS
analysis of Program 2-2

- The 16-bit data (a word) is stored with the low-order byte first, referred to as "little endian."

Write and run a program that adds four words of data and saves the result. The values will be 234DH, 1DE6H, 3BC7H, and 566AH. Use DEBUG to verify the sum is D364.

```
TITLE       PROG2-2   (EXE)   PURPOSE: ADDS 4 WORDS OF DATA
PAGE   60,132
            .MODEL SMALL
            .STACK 64
;------------------
            .DATA
DATA_IN     DW          234DH,1DE6H,3BC7H,566AH
            ORG    10H
SUM         DW          ?
;------------------
            .CODE
MAIN        PROC        FAR
            MOV    AX,@DATA
            MOV    DS,AX
            MOV    CX,04                ;set up loop counter CX=4
            MOV    DI,OFFSET DATA_IN    ;set up data pointer DI
            MOV    BX,00
```

See the entire program listing on page 66 of your textbook.

2.3: MORE SAMPLE PROGRAMS
analysis of Program 2-2

- The address pointer is incremented twice, since the operand being accessed is a word (two bytes).
  - The program could have used "**ADD DI,2**" instead of using "**INC DI**" twice.
- "**MOV SI,OFFSET SUM**" was used to load the pointer for the memory allocated for the label SUM.
- "**MOV [SI],BX**" moves the contents of register BX to memory locations with offsets 0010 and 0011.
- Program 2-2 uses the ORG directive to set the offset addresses for data items.
  - This caused SUM to be stored at DS:0010.

analysis of Program 2-3

- Program 2-3 shows the data segment being dumped before and after the program was run.

Write and run a program that transfers 6 bytes of data from memory locations with offset of 0010H to memory locations with offset of 0028H.

```
TITLE        PROG2-3   (EXE)    PURPOSE: TRANSFERS 6 BYTES OF DATA
PAGE   60,132
             .MODEL SMALL
             .STACK 64
             .DATA
             ORG    10H
DATA_IN      DB          25H,4FH,85H,1FH,2BH,0C4H
             ORG    28H
COPY         DB          6 DUP(?)
;--------------
             .CODE
MAIN         PROC        FAR
             MOV    AX,@DATA
             MOV    DS,AX
             MOV    SI,OFFSET DATA_IN ;SI points to data to be copied
             MOV    DI,OFFSET COPY    ;DI points to copy of data
             MOV    CX,06H            ;loop counter = 6
MOV_LOOP:    MOV    AL,[SI]         ;move the next byte from DATA area to AL
```

See the entire program listing on page 67 of your textbook.

2.3: MORE SAMPLE PROGRAMS
analysis of Program 2-3

- C4 was coded in the data segments as 0C4.
  - Indicating that C is a hex number and not a letter.
    - Required if the first digit is a hex digit A through F.
- This program uses registers SI & DI as pointers to the data items being manipulated.
  - The first is a pointer to the data item to be copied.
  - The second points to the location the data is copied to.
- With each iteration of the loop, both data pointers are incremented to point to the next byte.

2.4: CONTROL TRANSFER INSTRUCTIONS conditional jumps

- Conditional jumps have mnemonics such as JNZ (jump not zero) and JC (jump if carry).
  - In the conditional jump, control is transferred to a new location if a certain condition is met.
  - The flag register indicates the current condition.
- For example, with "JNZ label", the processor looks at the zero flag to see if it is raised.
  - If not, the CPU starts to fetch and execute instructions from the address of the label.
  - If ZF = 1, it will not jump but will execute the next instruction below the JNZ.

2.4: CONTROL TRANSFER INSTRUCTIONS conditional jumps

Table 2-1: 8086 Conditional Jump Instructions

Mnemonic	Condition Tested	"Jump IF ..."
JA/JNBE	(CF = 0) and (ZF = 0)	above/not below nor zero
JAE/JNB	CF = 0	above or equal/not below
JB/JNAE	CF = 1	below/not above nor equal
JBE/JNA	(CF or ZF) = 1	below or equal/not above
JC	CF = 1	carry
JE/JZ	ZF = 1	equal/zero
JG/JNLE	((SF xor OF) or ZF) = 0	greater/not less nor equal
JGE/JNL	(SF xor OF) = 0	greater or equal/not less
JL/JNGE	(SF xor OR) = 1	less/not greater nor equal
JLE/JNG	((SF xor OF) or ZF) = 1	less or equal/not greater
JNC	CF = 0	not carry
JNE/JNZ	ZF = 0	not equal/not zero
JNO	OF = 0	not overflow
JNP/JPO	PF = 0	not parity/parity odd
JNS	SF = 0	not sign
JO	OF = 1	overflow
JP/JPE	PF = 1	parity/parity equal
JS	SF = 1	sign

Note: "Above" and "below" refer to the relationship of two unsigned values; "greater" and "less" refer to the relationship of two signed values.

2.4: CONTROL TRANSFER INSTRUCTIONS
CALL statements

- The CALL instruction is used to call a procedure, to perform tasks that need to be performed frequently.
  - The target address could be in the current segment, in which case it will be a NEAR call or outside the current CS segment, which is a FAR call.
- The microprocessor saves the address of the instruction following the call on the stack.
  - To know where to return, after executing the subroutine.
    - In the NEAR call only the IP is saved on the stack.
    - In a FAR call both CS and IP are saved.

2.4: CONTROL TRANSFER INSTRUCTIONS
assembly language subroutines

```
                .CODE
MAIN            PROC   FAR          ;THIS IS THE ENTRY POINT FOR OS
                MOV    AX,@DATA
                MOV    DS,AX
                CALL   SUBR1
                CALL   SUBR2
                CALL   SUBR3
                MOV    AH,4CH
                INT    21H
MAIN            ENDP
;---------------------------------
SUBR1           PROC
                ...
                ...
                RET
SUBR1           ENDP
;---------------------------------
SUBR2           PROC
                ...
                ...
                RET
SUBR2           ENDP
;---------------------------------
SUBR3           PROC
                ...
                ...
                RET
SUBR3           ENDP
;---------------------------------
                END         MAIN    ;THIS IS THE EXIT POINT
```

It is common to have one main program and many subroutines to be called from the main.

Each subroutine can be a separate module, tested separately, then brought together.

If there is no specific mention of FAR after the directive PROC, it defaults to NEAR.

2.4: CONTROL TRANSFER INSTRUCTIONS
rules for names in Assembly language

- The names used for labels in Assembly language programming consist of…
  - Alphabetic letters in both upper- and lowercase.
  - The digits 0 through 9.
  - Question mark (?); Period (.); At (@)
  - Underline (_); Dollar sign ($)
- Each label name must be unique.
  - They may be up to 31 characters long.
- The first character must be an alphabetic or special character.
  - It cannot be a digit.

2.4: CONTROL TRANSFER INSTRUCTIONS rules for names in Assembly language

- The period can only be used as the first character.
  - This is not recommended since later versions of MASM have several reserved words that begin with a period.

x86 data types

- The 8088/86 processor supports many data types.
  - Data types can be 8- or 16-bit, positive or negative.
    - The programmer must break down data larger than 16 bits (0000 to FFFFH, or 0 to 65535 in decimal).
  - A number less than 8 bits wide must be coded as an 8-bit register with the higher digits as zero.
    - A number is less than 16 bits wide must use all 16 bits.

2.5: DATA TYPES AND DATA DEFINITION
ORG origin

- ORG is used to indicate the beginning of the offset address.
  - The number after ORG can be either in hex or in decimal.
    - If the number is *not* followed by H, it is decimal and the assembler will convert it to hex.

DB define byte

- One of the most widely used data directives, it allows allocation of memory in byte-sized chunks.
  - This is the smallest allocation unit permitted.
  - DB can define numbers in decimal, binary, hex, & ASCII.
    - **D** after the decimal number is optional.
    - **B** (binary) and **H** (hexadecimal) is required.
    - To indicate ASCII, place the string in single quotation marks.
- DB is the only directive that can be used to define ASCII strings larger than two characters.
  - It should be used for all ASCII data definitions.

2.5: DATA TYPES AND DATA DEFINITION
DB define byte

- Some DB examples:

```
DATA1      DB     25                  ;DECIMAL
DATA2      DB     10001001B           ;BINARY
DATA3      DB     12H                 ;HEX
                  ORG    0010H
DATA4      DB     '2591'              ;ASCII NUMBERS
                  ORG         0018H
DATA5      DB     ?                   ;SET ASIDE A BYTE
                  ORG    0020H
DATA6      DB     My name is Joe'     ;ASCII CHARACTERS
```

  – **Single** or **double** quotes can be used around ASCII strings.
    - Useful for strings, which should contain a single quote, such as "O'Leary".

2.5: DATA TYPES AND DATA DEFINITION
DB define byte

- List file for DB examples.

```
0000 19                      DATA1  DB    25                 ;DECIMAL
0001 89                      DATA2  DB    10001001B          ;BINARY
0002 12                      DATA3  DB    12H                ;HEX
0010                                ORG   0010H
0010 32 35 39 31             DATA4  DB    '2591'             ;ASCII NUMBERS
0018                                ORG   0018H
0018 00                      DATA5  DB    ?                  ;SET ASIDE A BYTE
0020                                ORG   0020H
0020 4D 79 20 6E 61 6D       DATA6  DB 'My name is Joe'      ;ASCII CHARACTERS
     65 20 69 73 20 4A
     6F 65
```

2.5: DATA TYPES AND DATA DEFINITION
DUP duplicate

- DUP will duplicate a given number of characters.

```
      ORG 0030H
DATA7 DB  0FFH,0FFH,0FFH,0FFH,0FFH,0FFH ;FILL 6 BYTES WITH FF
      ORG 38H
DATA8 DB 6 DUP(0FFH)        ;FILL 6 BYTES WITH FF
; the following reserves 32 bytes of memory with no initial
; value given
      ORG 40H
DATA9 DB 32 DUP (?)         ;SET ASIDE 32 BYTES
;DUP can be used inside another DUP
; the following fills 10 bytes with 99
DATA10 DB 5 DUP (2 DUP (99)) ;FILL 10 BYTES WITH 99
```

  – Two methods of filling six memory locations with FFH.

2.5: DATA TYPES AND DATA DEFINITION

DUP duplicate

- List file for DUP examples.

```
0030                                 ORG    0030H
0030  FF FF FF FF FF FF      DATA7   DB     0FFH,0FFH,0FFH,0FFH,0FFH,0FFH  ; 6 FF
0038                                 ORG    38H
0038  0006[                  DATA8   DB     6 DUP(0FFH)      ;FILL 6 BYTES WITH FF
            FF
                 ]
0040                                 ORG    40H
0040 0020 [                  DATA9   DB     32 DUP (?)       ;SET ASIDE 32 BYTES
        ??
                 ]
0060                                 ORG    60H
0060 0005[                   DATA10  DB     5 DUP (2 DUP (99))     ;FILL 10 BYTES WITH 99
            0002[
                 63
                      ]
                 ]
```

2.5: DATA TYPES AND DATA DEFINITION
DW define word

- DW is used to allocate memory 2 bytes (one word) at a time:

```
                ORG     70H
DATA11          DW       954                        ;DECIMAL
DATA12          DW       100101010100B              ;BINARY
DATA13          DW       253FH                      ;HEX
                         ORG     78H
DATA14          DW       9,2,7,0CH,00100000B,5,'HI'  ;MISC. DATA
DATA15          DW       8 DUP (?)                ;SET ASIDE 8 WORDS
```

- List file for DW examples.

```
0070                               ORG     70H
0070  03BA                  DATA11  DW     954                 ;DECIMAL
0072  0954                  DATA12  DW     100101010100B       ;BINARY
0074  253F                  DATA13  DW     253FH               ;HEX
0078                               ORG     78H
0078 0009 0002 0007 000C    DATA14  DW     9,2,7,0CH,00100000B,5,'HI'   ;MISC. DATA
     0020 0005 4849
0086 0008[                  DATA15  DW     8 DUP (?)           ;SET ASIDE 8 WORDS
          ????        ]
```

2.5: DATA TYPES AND DATA DEFINITION
EQU equate

- EQU associates a constant value with a data label.
  - When the label appears in the program, its constant value will be substituted for the label.
  - Defines a constant without occupying a memory location.
- EQU for the counter constant in the immediate addressing mode:

```
COUNT   EQU  25
```

- When executing the instructions "**`MOV CX,COUNT`**", the register CX will be loaded with the value 25.
  - In contrast to using DB:

```
COUNT   DB  25
```

2.5: DATA TYPES AND DATA DEFINITION
EQU equate

- When executing the same instruction "MOV CX,COUNT" it will be in the direct addressing mode.
  - EQU can also be used in the data segment:

```
COUNT           EQU         25
COUNTER1    DB          COUNT
COUNTER2    DB          COUNT
```

  - Assume a constant (a fixed value) used in many different places in the data and code segments.
    - By use of EQU, one can change it once and the assembler will change all of them.

2.5: DATA TYPES AND DATA DEFINITION
DD define doubleword

- The DD directive is used to allocate memory locations that are 4 bytes (two words) in size.
  - Data is converted to hex & placed in memory locations
    - Low byte to low address and high byte to high address.

```
                ORG   00A0H
DATA16          DD      1023                              ;DECIMAL
DATA17          DD      10001001011001011100B             ;BINARY
DATA18          DD      5C2A57F2H                         ;HEX
DATA19          DD      23H,34789H,65533
```

- List file for DD examples.

```
00A0                                ORG  00A0H
00A0  000003FF             DATA16   DD   1023                      ;DECIMAL
00A4  0008965C             DATA17   DD   10001001011001011100B     ;BINARY
00A8  5C2A57F2             DATA18   DD    5C2A57F2H                ;HEX
00AC 00000023 00034789     DATA19   DD    23H,34789H,65533
     0000FFFD
```

2.5: DATA TYPES AND DATA DEFINITION
DQ define quadword

- DQ is used to allocate memory 8 bytes (four words) in size, to represent any variable up to 64 bits wide:

```
              ORG    00C0H
DATA20        DQ      4523C2H                 ;HEX
DATA21        DQ      'HI'                            ;ASCII CHARACTERS
DATA22        DQ      ?                               ;NOTHING
```

- List file for DQ examples.

```
00C0                             ORG  00C0H
00C0  C223450000000000     DATA20    DQ    4523C2H       ;HEX
00C8  4948000000000000     DATA21    DQ    'HI'          ;ASCII CHARACTERS
00D0  0000000000000000     DATA22    DQ    ?             ;NOTHING
```

2.5: DATA TYPES AND DATA DEFINITION
DT define ten bytes

- DT is used for memory allocation of packed BCD numbers.
  - This directive allocates 10 bytes.
    - A maximum of 18 digits can be entered.
  - The "**H**" after the data is not needed.

```
              ORG   00E0H
DATA23        DT     867943569829     ;BCD
DATA24        DT     ?                ;NOTHING
```

- List file for DT examples.

```
00E0                          ORG 00E0H
00E0  299856437986000000   DATA23  DT    867943569829       ;BCD
       00
00EA  000000000000000000   DATA24  DT    ?                  ;NOTHING
       00
```

2.5: DATA TYPES AND DATA DEFINITION
DQ define ten bytes

- DT can also be used to allocate 10-byte integers by using the "D" option:

```
DEC    DT    65535d   ;the assembler will convert the
                      ;decimal number to hex and store it
```

2.5: DATA TYPES AND DATA DEFINITION directives

- Figure 2-7 shows the memory dump of the data section, including all the examples in this section.
  - It is essential to understand the way operands are stored in memory.

```
-D 1066:0 100
1066:0000 19 89 12 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:0010 32 35 39 31 00 00 00 00-00 00 00 00 00 00 00 00 2591............
1066:0020 4D 79 20 6E 61 6D 65 20-69 73 20 4A 6F 65 00 00 My name is Joe..
1066:0030 FF FF FF FF FF FF 00 00-FF FF FF FF FF FF 00 00 ................
1066:0040 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:0060 63 63 63 63 63 63 63 63-63 63 00 00 00 00 00 00 cccccccccc......
1066:0070 BA 03 54 09 3F 25 00 00-09 00 02 00 07 00 0C 00 :.T.?%..........
1066:0080 20 00 05 00 4F 48 00 00-00 00 00 00 00 00 00 00 ...OH...........
1066:0090 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:00A0 FF 03 00 00 5C 96 08 00-F2 57 2A 5C 23 00 00 00 ....\...rW*\#...
1066:00B0 89 47 03 00 FD FF 00 00-00 00 00 00 00 00 00 00 B#E......IH.....
1066:00C0 C2 23 45 00 00 00 00 00-49 48 00 00 00 00 00 00 ................
1066:00D0 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:00E0 29 98 56 43 79 86 00 00-00 00 00 00 00 00 00 00 9.VCy6..........
```

2.5: DATA TYPES AND DATA DEFINITION directives

- All of the data directives use the little endian format.
  - For ASCII data, only DB can define data of any length.
    - Use of DD, DQ, or DT directives for ASCII strings of more than 2 bytes gives an assembly error.

```
-D 1066:0 100
1066:0000 19 89 12 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:0010 32 35 39 31 00 00 00 00-00 00 00 00 00 00 00 00 2591............
1066:0020 4D 79 20 6E 61 6D 65 20-69 73 20 4A 6F 65 00 00 My name is Joe..
1066:0030 FF FF FF FF FF FF 00 00-FF FF FF FF FF FF 00 00 ................
1066:0040 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:0060 63 63 63 63 63 63 63 63-63 63 00 00 00 00 00 00 cccccccccc......
1066:0070 BA 03 54 09 3F 25 00 00-09 00 02 00 07 00 0C 00 :.T.?%..........
1066:0080 20 00 05 00 4F 48 00 00-00 00 00 00 00 00 00 00 ...OH...........
1066:0090 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:00A0 FF 03 00 00 5C 96 08 00-F2 57 2A 5C 23 00 00 00 ....\...rW*\#...
1066:00B0 89 47 03 00 FD FF 00 00-00 00 00 00 00 00 00 00 B#E......IH.....
1066:00C0 C2 23 45 00 00 00 00 00-49 48 00 00 00 00 00 00 ................
1066:00D0 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:00E0 29 98 56 43 79 86 00 00-00 00 00 00 00 00 00 00 9.VCy6..........
```

2.5: DATA TYPES AND DATA DEFINITION directives

- Review "**DATA20 DQ 4523C2**", residing in memory starting at offset 00C0H.
  - **C2**, the least significant byte, is in location **00C0**, with **23** in 00C1, and **45**, the most significant byte, in 00C2.

```
-D 1066:0 100
1066:0000 19 89 12 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:0010 32 35 39 31 00 00 00 00-00 00 00 00 00 00 00 00 2591............
1066:0020 4D 79 20 6E 61 6D 65 20-69 73 20 4A 6F 65 00 00 My name is Joe..
1066:0030 FF FF FF FF FF FF 00 00-FF FF FF FF FF FF 00 00 ................
1066:0040 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:0060 63 63 63 63 63 63 63 63-63 63 00 00 00 00 00 00 cccccccccc......
1066:0070 BA 03 54 09 3F 25 00 00-09 00 02 00 07 00 0C 00 :.T.?%..........
1066:0080 20 00 05 00 4F 48 00 00-00 00 00 00 00 00 00 00 ...OH...........
1066:0090 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:00A0 FF 03 00 00 5C 96 08 00-F2 57 2A 5C 23 00 00 00 ....\...rW*\#...
1066:00B0 89 47 03 00 FD FF 00 00-00 00 00 00 00 00 00 00 B#E......IH.....
1066:00C0 C2 23 45 00 00 00 00 00-49 48 00 00 00 00 00 00 ................
1066:00D0 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:00E0 29 98 56 43 79 86 00 00-00 00 00 00 00 00 00 00 9.VCy6..........
```

2.5: DATA TYPES AND DATA DEFINITION directives

- When DB is used for ASCII numbers, it places them backwards in memory.
  - Review "**DATA4 DB '2591'**" at origin **10H:32**,
    - ASCII for 2, is in memory location 10H;35; for 5, in 11H; etc.

```
-D 1066:0 100
1066:0000 19 89 12 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:0010 32 35 39 31 00 00 00 00-00 00 00 00 00 00 00 00 2591............
1066:0020 4D 79 20 6E 61 6D 65 20-69 73 20 4A 6F 65 00 00 My name is Joe..
1066:0030 FF FF FF FF FF FF 00 00-FF FF FF FF FF FF 00 00 ................
1066:0040 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:0060 63 63 63 63 63 63 63 63-63 63 00 00 00 00 00 00 cccccccccc......
1066:0070 BA 03 54 09 3F 25 00 00-09 00 02 00 07 00 0C 00 :.T.?%..........
1066:0080 20 00 05 00 4F 48 00 00-00 00 00 00 00 00 00 00 ...OH...........
1066:0090 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:00A0 FF 03 00 00 5C 96 08 00-F2 57 2A 5C 23 00 00 00 ....\...rW*\#...
1066:00B0 89 47 03 00 FD FF 00 00-00 00 00 00 00 00 00 00 B#E......IH.....
1066:00C0 C2 23 45 00 00 00 00 00-49 48 00 00 00 00 00 00 ................
1066:00D0 00 00 00 00 00 00 00 00-00 00 00 00 00 00 00 00 ................
1066:00E0 29 98 56 43 79 86 00 00-00 00 00 00 00 00 00 00 9.VCy6..........
```

Dec	Hex	Bin
2	2	00000010

ENDS ; TWO