

# Microprocessor Based Systems

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# Outline

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- ❑ From Book: Chapter 4
- ❑ Assembly language syntax
  - Name Field
  - Operation Field
  - Operand Field
  - Comment Field
- ❑ Program Data
- ❑ Variables

# Assembly language Syntax

- ❑ Assembly language programs are translated into machine language instructions by an assembler, so they must be written to conform to the assembler's specifications.
- ❑ One of the most popular assembler is Microsoft Macro Assembler (MASM).
- ❑ Programs consist of statements, one per line
- ❑ Each statement is either an:
  - Instruction, which the assembler translates into machine code.
  - Assembler directive, which instructs the assembler to perform some specific task (ex. Allocating memory space for a variable or creating a procedure).

# Syntax (Cont.)

- ❑ Both instructions and directives have up to four fields:

**[name]**      **operation**      **[operand(s)]**      **[comment]**

- ❑ [Fields are optional]
- ❑ At least one blank or tab character must separate the fields
- ❑ The fields do not have to be aligned in a particular column, but they must appear in the above order.
- ❑ An example of an instruction:  
**START:**      **MOV**      **CX,5**      **; initialize counter**
- ❑ An example of an assembler directive:  
**MAIN**      **PROC**

# Name Field

- ❑ The name field is used for:
  - Instruction labels.
  - Procedure names.
  - Variable names Ex. Table look-up instruction XLAT (used for translation)
- ❑ The assembler translates names into memory addresses.
- ❑ Names:
  - Can be from 1 to 31 characters long (not case sensitive).
  - May consist of letters, digits, and the special characters
  - ? . @ \_ \$ % (Thus, embedded blanks are not allowed).
- ❑ Names may not begin with a digit
- ❑ Uppercase and lowercase considered as same.

# Name Field Examples

COUNTER1



2abc



Begins with a digit

@CHARACTER



A45. 28



. Not first character

TWO WORDS



Contains a blank

STD\_NUM



.TEST



YOU&ME



Contains an illegal character

# Operation Field

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- ❑ For an instruction, the operation field contains a symbolic **operation code (opcode)**
- ❑ The assembler translates a symbolic opcode into a machine language opcode
- ❑ Opcode symbols often describe the operation's function (ex. MOV, ADD, SUB)

# Operation Field

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- ❑ In an assembler directive, the operation field contains a **pseudo-operation** code (**pseudo-op**).
- ❑ Pseudo-ops are not translated into machine code, rather, they simply tell the assembler to do something (ex. The PROC pseudo-op is used to create a procedure).



# Operand Field

- ❑ For an instruction, the operand field specifies the data that are needed to be acted on by the operation.
- ❑ An instruction may have zero, one, or two operands
- ❑ Examples:
  - ❑ NOP ; no operands... does nothing
  - ❑ INC AX ; one operand... adds 1 to the contents of AX
  - ❑ ADD WORD1,2 ; two operands... adds 2 to the contents of memory word WORD1

**Destination operand**  
register or memory location  
where the result is stored  
(note:some instructions  
don't store the result)

**Source operand**  
usually not modified  
by the instruction

# Comment Field

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- ❑ The comment field of a statement is used by the programmer to say something about what the statement does
- ❑ A semicolon marks the beginning of this field, and the assembler ignores anything typed after the semicolon.
- ❑ It is almost impossible to understand an assembly language program without comments.
- ❑ Good programming practice dictates a comment on almost every line.

# Comment Field (Cont.)


## Examples:


MOV CX, 0 ; move 0 to CX



MOV CX, 0 ; CX counts terms, initially 0



 Thus, comments are used to put the instruction into the context of the program

 It is permissible to make an entire line a comment, and to use them to create space in a program.

# Program Data

- ❑ In an assembly language program we may express data as:
  - **Binary:** bit string followed by 'B' or 'b'
  - **Decimal:** string of decimal digits followed by an optional 'D' or 'd'
  - **Hex:** begins with a decimal digit and ends with 'H' or 'h'
  - **Characters & Character strings:** enclosed in a single or double quotes or by their ASCII codes.
- ❑ Any number may have an optional sign.

# Program Data (Cont.)

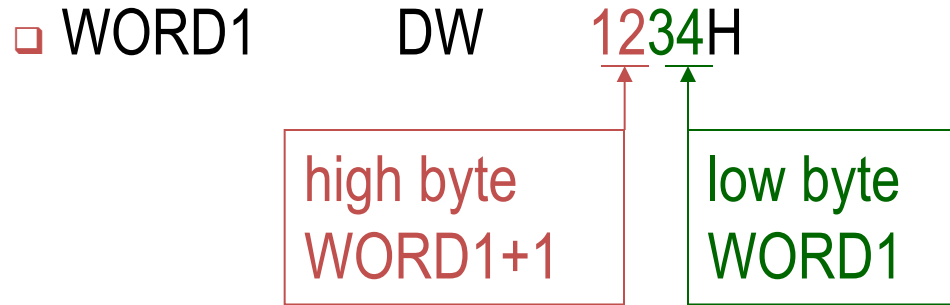
Number	Type
11011	
1101B	
64223	
-21843D	
1,234	
1BADH	
1B4D	
FFFFH	
0FFFFH	

# Variables

- ❑ Variables play the same role in assembly language that they do in HLL
- ❑ Each variable has a data type and is assigned a memory address by the program
- ❑ The table below shows the assembler directives that are used to define the variables

Pseudo-op	Stands for
DB	Define Byte
DW	Define Word
DD	Define Double Word
DQ	Define Quote
DT	Define Ten bytes

# Bytes of the Words



# Variables – Byte & Word

## ❑ Syntax:

name      DB   initial\_value

## ❑ Example:

- ALPHA      DB      4      a memory byte is associated with the name ALPHA, and initialized to 4.
  - BYT          DB   ?      a memory byte is associated with the name BYT, and uninitialized.
  - WRD      DW -2      a memory word is associated with the name WRD, and initialized to -2.
- ## ❑ The decimal range is:
- Unsigned representation: 0 to 255
  - Signed representation: -128 to 127



# Variables - Arrays

❑ an array is a sequence of memory bytes or words.

❑ Example:

```
B_ARRAY      DB  10H,20H,30H
```

Symbol	Address	Contents
B_ARRAY	200H	10H
B_ARRAY+1	201H	20H
B_ARRAY+2	202H	30H

# Variables – Array (words)

❑ Example:

```
W_ARRAY DW 1000,40,29887,329
```

Symbol	Address	Contents
W_ARRAY	0300H	1000D
W_ARRAY+2	0302H	40D
W_ARRAY+4	0304H	29887D
W_ARRAY+6	0306H	329D

# The DUP Operator

- It is possible to define arrays whose elements share a common initial value by using the DUP (duplicate) operator.

- Syntax:

repeat\_count DUP (value)

- Example:

DELTA DB 212 DUP (?) creates an array of 212  
uninitialized bytes.

GAMMA DW 100 DUP (0) set up an array of 100  
words, with each entry  
initialized to 0.

# Character String

- ❑ Any array of ASCII codes can be initialized with a string of characters.

- ❑ Example:

  - `LETTERS DB 'ABC'`

=

`LETTERS DB 41H,42H,43H`

- ❑ Inside a string, the assembler differentiates between upper and lowercase.

- ❑ It is possible to combine characters and numbers in one definition:

- ❑ Example: `MSG DB 'HELLO',0AH,0DH, '$'`


# Character Strings

- `LETTERS DB 'ABC'`
- `LETTER DB 41H, 42H, 43H`
- `MSG DB 'HELLO', 0AH, 0DH, '$'`
- `MSG DB 48H, 45H, 4CH, 4CH, 4FH, 0AH, 0DH, 24H`

# EQU

- The EQU (equates) pseudo-op is used to assign a name to a constant.

name	EQU	constant
• LF	EQU	0AH
– MOV	DL, 0AH	
– MOV	DL, LF	
• PROMPT	EQU	'TYPE YOUR NAME'
– MSG	DB	'TYPE YOUR NAME'
– MSG	DB	PROMPT



**No memory is allocated for EQU Names**

# Few Basic Instructions

- Over a hundred Instructions for 8086
- Some specially designed instructions for advanced processors
- We discuss six of most useful instructions

# MOV

- The MOV instruction is used to transfer data between registers, between a register and a memory location, or to move a number directly into a register or memory location.
- **MOV      destination, source**

MOV      AX,   WORD1

MOV      AX,   BX

MOV      AH,   'A'



# XCHG

- The XCHG operation is used to exchange the contents of two registers, or a register, and a memory location.
- **XCHG      destination, source**  
XCHG    AH,   BL  
XCHG    AX,   WORD1

# Legal Combinations of Operands for MOV and XCHG

Source Operand	Destination Operand			
	General Register	Segment Register	Memory Location	Constant
General Register	Yes	Yes	Yes	<b>No</b>
Segment Register	Yes	<b>No</b>	Yes	<b>No</b>
Memory Location	Yes	Yes	<b>No</b>	<b>No</b>
Constant	Yes	<b>No</b>	Yes	<b>No</b>

Source Operand	Destination Operand	
	General Register	Memory Location
General Register	Yes	Yes
Memory Location	Yes	<b>No</b>

# Restrictions on MOV and XCHG

ILLEGAL:      MOV WORD1, WORD2

But we can overcome this problem in  
the following lines

```
MOV      AX, WORD2
```

```
MOV      WORD1, AX
```

# ADD and SUB

- The ADD and SUB instructions are used to add or subtract the contents of two registers, a register and a memory location, or to add (subtract) a number to (from) a register or memory location.

**ADD destination, source**

**SUB destination, source**

```
ADD    WORD1,  AX
```

```
SUB    AX,  DX
```

```
ADD    BL,  5
```

# Restrictions on ADD and SUB

ILLEGAL: `ADD BYTE1, BYTE2`

We can solve using the following lines

```
MOV  AL, BYTE2      ; AX gets BYTE2
ADD  BYTE1, AL       ; add it to BYTE1
```

# Legal Combinations of Operands for ADD and SUB

Source Operand	Destination Operand	
	General Register	Memory Location
General Register	Yes	Yes
Memory Location	Yes	<b>No</b>

# INC and DEC

- INC (increment) is used to add 1 to the contents of a register or memory location and DEC (decrement) subtracts 1 from a register or memory location.

**INC destination**

**DEC destination**

INC WORD1

DEC BYTE1

# NEG

- NEG is used to negate the contents of the destination.
- NEG does this by replacing the contents by its **two's complement**.

**NEG destination**

NEG BX



# Type Agreement of Operands

```
MOV AX, BYTE1          ; illegal
MOV AH, 'A'
MOV AX, 'A'             ; move 0041h into AX
```

# Translation of high-Level Language to Assembly Language

**Statement**

**Translation**

B = A

MOV AX, A; move A into AX

MOV B, AX; and then into B

# Translation of high-Level Language to Assembly Language

## Statement

## Translation

$A = 5 - A$

MOV AX, 5; put 5 in AX

SUB AX, A; AX contains  $5 - A$

MOV A, AX; put it in A

$A = 5 - A$

NEG A ;  $A = -A$

ADD A, 5 ;  $A = 5 - A$

# Translation of high-Level Language to Assembly Language

**Statement**

**Translation**

$A = B - 2 \times A$

**MOV AX, B; AX has B**

**SUB AX, A; AX has B - A**

**SUB AX, A; AX has B - 2 x A**

**MOV A, AX; move result to A**

# PROGRAM STRUCTURE

- Assembly language program occupies code, data and stack segment in memory
- Same organization reflected in assembly language programs as well
- Code data and stack are structured as **program segments**
- **Program segments** are translated to **memory segments** by **assembler**

# MEMORY MODELS

Size of code and data, a program can have is determined by specifying a memory model using **.MODEL** directive

**.MODEL**      `memory_model`

Model	Description
SMALL	code in one segment data in one segment
MEDIUM	code in more than one segment data in one segment
COMPACT	code in one segment data in more than one segment
LARGE	code in more than one segment data in more than one segment no array larger than 64k bytes
HUGE	code in more than one segment data in more than one segment arrays may be larger than 64k bytes

# DATA SEGMENT

- A program's data segment contains all the variable definitions.
  - Constant definitions are often made here as well, but they may be placed elsewhere in the program since no memory allocation is involved.
- .data** directive to declare a data segment

```
.DATA  
WORD1          DW  2  
WORD2          DW  5  
MSG            DB  'THIS IS A MESSAGE'  
MASK           EQU 10010111B
```

# STACK SEGMENT

- The purpose of the stack segment declaration is to set aside a block of memory (the stack area) to store the stack.
- The stack area should be big enough to contain the stack at its maximum size.

```
.STACK      100H
```

- If size is omitted, by default 1kB is set aside



# CODE SEGMENT

- The code segment contains a program's instructions.

**.CODE name**

- Inside a code segment, instructions are organized as procedures.

**name PROC**

**; body of the procedure**

**name ENDP**

- The last line in the program should be the END directive, followed by name of the main procedure.

```
MAIN          PROC
; instructions go here
MAIN          ENDP
; other procedures go here
```

# PUTTING IT TOGETHER

```
.MODEL      SMALL
.STACK      100H
.DATA
; data definitions go here
.CODE
MAIN        PROC
; instructions go here
MAIN        ENDP
; other procedures go here
END         MAIN
```

# INPUT AND OUTPUT INSTRUCTIONS

- CPU communicates with the peripherals through **IO ports**
  - **IN and OUT instructions to access the ports directly**
    - Used when fast IO is essential
    - Seldom used as
      - Port address varies among computer models
      - Easier to program IO with service routine

# IO SERVICE ROUTINES

IO Service  
routines

# INT

- I/O service routines
  - The **B**asic **I**nput/**O**utput **S**ystem (BIOS) routines
  - The DOS routines
- The **INT (interrupt)** instruction is used to invoke a DOS or BIOS routine.
- `INT 21h`
  - invokes a BIOS routine that performs keyboard input.

# INT 21H

- INT 21h may be used to invoke a large number of DOS functions.
- A particular function is requested by placing a function number in the AH register and invoking INT 21h.

# FUNCTION 1: SINGLE-KEY INPUT

Input:

AH = 1

Output:

AL = ASCII code if character key is pressed  
= 0 if non-character key is pressed



# FUNCTION 1: SINGLE-KEY INPUT

```
MOV    AH, 1           ; input key function
INT    21h             ; ASCII code in AL
```

## FUNCTION 2: DISPLAY A CHARACTER OR EXECUTE A CONTROL FUNCTION

Input:

AH = 2

DL = ASCII code of the display character or  
control character

Output:

AL = ASCII code of the display character or  
control character

## FUNCTION 2: DISPLAY A CHARACTER OR EXECUTE A CONTROL FUNCTION

- |     |         |                              |
|-----|---------|------------------------------|
| MOV | AH, 2   | ; display character function |
| MOV | DL, '?' | ; character is '?'           |
| INT | 21h     | ; display character          |

# PRINCIPAL CONTROL CAHARCTERS

ASCII Code HEX	Symbol	Function
7	BEL	beep
8	BS	backspace
9	HT	tab
A	LF	line feed (new line)
D	CR	carriage return (start of current line)

# A FIRST PROGRAM

- ECH.ASM will read a character from the keyboard and display it at the beginning of the next line.
- The data segment was omitted because no variables were used.
- When a program terminates, it should return control to DOS.
- This can be accomplished by executing INT 21h, function 4Ch.

# ASSEMBLY CODE

```
TITLE ECHO PROGRAM
```

```
.MODEL SMALL
```

```
.STACK 100H
```

```
.CODE
```

```
MAIN PROC
```

```
; display prompt
```

```
MOV AH, 2 ; display character function
```

```
MOV DL, '?' ; character is '?'
```

```
INT21H ; display it
```

```
; input a character
```

```
MOV AH, 1 ; read character function
```

```
INT 21H ; character in AL
```

```
MOV BL, AL ; save it in BL
```

# ASSEMBLY CODE

```
; go to a new line
MOV AH, 2          ; display character function
MOV DL, 0DH        ; carriage return
INT 21H           ; execute carriage return
MOV DL, 0AH        ; line feed
INT 21H           ; execute line feed

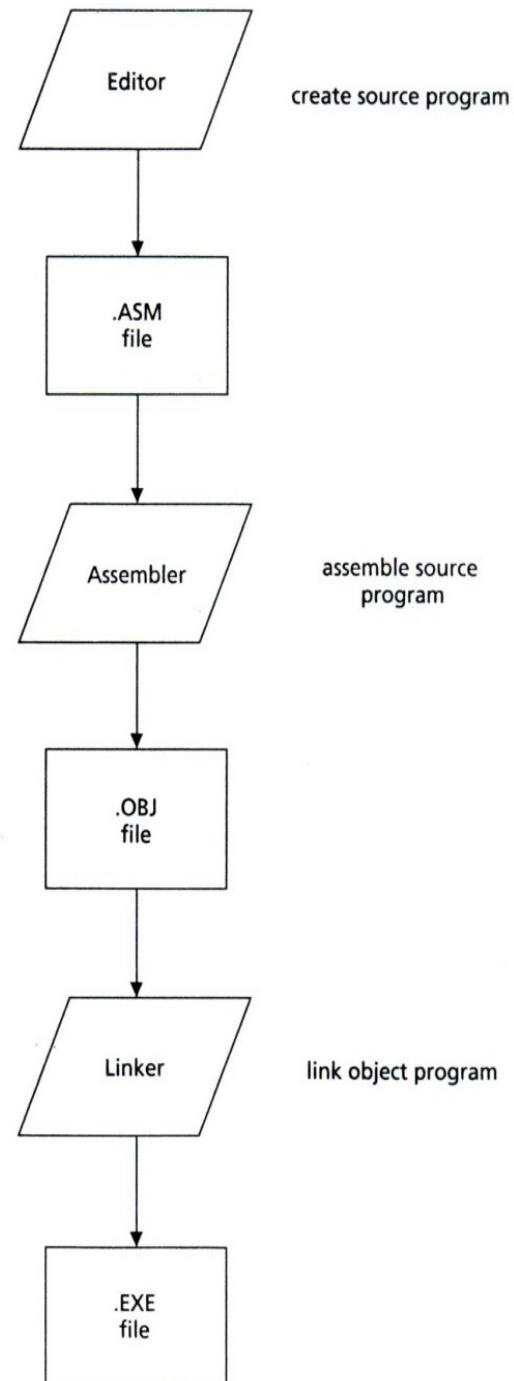
; display character
MOV DL, BL         ; retrieve character
INT 21H           ; and display it

; return to DOS
MOV AH, 4CH        ; DOS exit function
INT 21H           ; exit to DOS

MAIN ENDP

END MAIN
```

# PROGRAMMING STEPS





# STEP 1. CREATE THE SOURCE PROGRAM FILE

- An editor is used to create the preceding program.
- The .ASM is the conventional extension used to identify an assembly language source file.

## STEP 2. ASSEMBLE THE PROGRAM

- The Microsoft Macro Assembler (MASM) is used to translate the source file (.ASM file) into a machine language object file (.OBJ file).
- MASM checks the source file for syntax errors.
- If it finds any, it will display the line number of each error and a short description.
- `C:\>MASM File_Name;`

## STEP 3. LINK THE PROGRAM

- The Link program takes one or more object files, fills in any missing addresses, and combines the object files into a single executable file (.EXE file)
- This file can be loaded into memory and run.
- C:\>LINK *File\_Name*;

## STEP 4. RUN THE PROGRAM

- To run it, just type the run file name.
- `C:\>File_Name`

# INT 21H, FUNCTION 9: DISPLAY A STRING

Input:

DX = offset address of string.

The string must end with a '\$' character.

# LEA

- LEA is used to load effective address of a character string.
- **LEA        destination, source**
- MSG        DB        'HELLO!\$'
- LEA        DX, MSG        ; get message
- MOV        AH, 9        ; display string function
- INT        21h        ; display string

# PROGRAM SEGMENT PREFIX

- When a program is loaded into memory, DOS prefates it 256 byte PSP which contains information about the program
- DOS places segment no of PSP in DS and ES before executing the program
- To correct this, a program containing a data segment must start with these instructions;

```
MOV AX, @DATA
```

```
MOV DS, AX
```

```

.MODEL          SMALL
.STACK          100H
.DATA
MSG    DB       'HELLO!$'

```

# Print String Program

```

.CODE
MAIN  PROC
; initialize DS
    MOV AX, @DATA
    MOV DS, AX                ; initialize DS
; display message
    LEA DX, MSG                ; get message
    MOV AH, 9                  ; display string function
    INT 21H                    ; display message
; return to DOS
    MOV AH, 4CH
    INT 21H                    ; DOS exit
MAIN  ENDP
      END MAIN

```



# A CASE CONVERSION PROGRAM

- CASE.ASM begins by prompting the user to enter a lowercase letter, and on the next line displays another message with the letter in uppercase.
- The lowercase letters begin at 61h and the uppercase letters start at 41h, so subtraction of 20h from the contents of AL does the conversion.

# CASE CONVERSION PROGRAM

```
.MODEL      SMALL
.STACK 100H
.DATA
CREQU0DH
LF EQU0AH
MSG1 DB      'ENTER A LOWER CASE LETTER: $'
MSG2 DB      CR, LF, 'IN UPPER CASE IT IS: '
CHAR DB      '?, '$'
.CODE
MAIN PROC
; intialize DS
    MOV      AX, @DATA    ; get data segment
    MOV      DS, AX       ; intialize DS
; print user prompt
    LEA DX, MSG1          ; get first message
    MOV      AH, 9         ; display string function
    INT 21H               ; display first message
```

```

; input a character and convert to upper case
MOV      AH, 1          ; read character function
INT 21H          ; read a small letter into AL
SUB      AL, 20H        ; convert it to upper case
MOV      CHAR, AL      ; and store it
; display on the next line
LEA DX, MSG2      ; get second message
MOV      AH, 9          ; display string function
INT 21H          ; display message and upper case
letter in front
; DOS exit
MOV      AH, 4CH
INT 21H          ; DOS exit
MAIN ENDP
END MAIN

```

**CASE  
CONVERSION  
PROGRAM**