

Microprocessor Based Systems

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Outline

- ❑ 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.
- ❑ In this course we will use the 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
- ❑ If a period is used it should be the first character

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

- ❑ 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

- ❑ 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

- ❑ 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.)

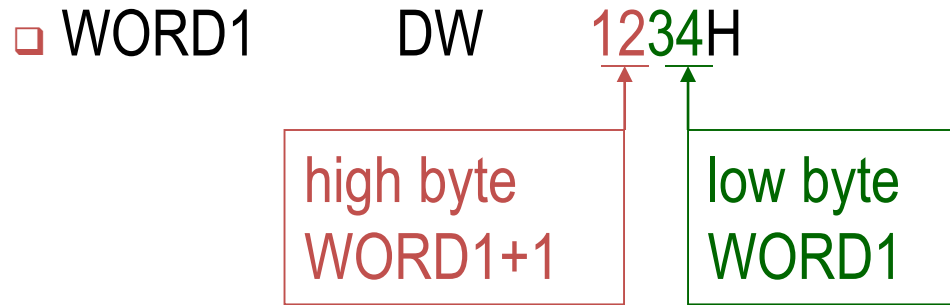
Number	Type
11011	
1101B	
64223	
-21843D	
1,234	
1BADH	
1B4D	
FFFFH	
0FFFFH	

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, '$'`

Byte Variables

name	DB	initial_value
ALPHA	DB	4
BYT	DB	?

- -128 to 127 for signed interpretation
- 0 to 255 for unsigned interpretation

Word Variables

name	DW	initial_value
-------------	-----------	----------------------

WRD	DW	-2
-----	----	----

- -32768 to 32767 for signed interpretation
- 0 to 65535 for unsigned interpretation

Arrays

- B_ARRAY DB 10H, 20H, 30H

Symbol	Address	Contents
B_ARRAY	0200h	10h
B_ARRAY+1	0201h	20h
B_ARRAY+2	0202h	30h


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	No	Constant can be source but not Destination
Segment Register	Yes	No	Yes	No	
Memory Location	Yes	Yes	No	No	
Constant	Yes	No	Yes	No	

Source Operand	Destination Operand	
	General Register	Memory Location
General Register	Yes	Yes
Memory Location	Yes	No

MOV Segment, Segment

MOV Segment, Constant

MOV Memory, Memory --> these 3 operations are invalid

Restrictions on MOV and XCHG

ILLEGAL: MOV WORD1, WORD2

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

```
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	No

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 16h**
 - 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

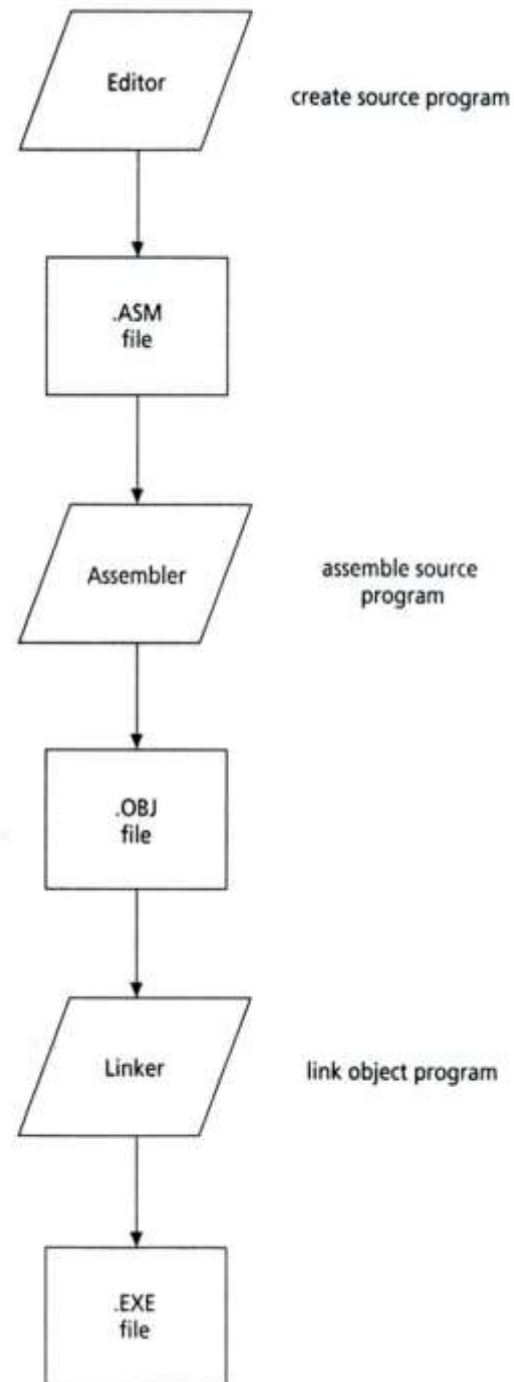
```
; go to a new line
MOV AH, 2          ; display character function
MOV DL, 0DH        ; carriage return
INT 21H           ; execute carriage return
MOV DL, 0AH        ; line feed
INT 21H           ; execute line feed

; 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 prefaces 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**