Assembly Language Programming

Course Title: Computer Organization and Architecture

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Content

- **1. Creating, Assembling and executing assembly language program.**

- **2. By the end of this lesson we will be able to write simple but interesting assembly program.**

Overview

Four Steps

1. Learn Syntax
2. Variable declarations
3. Introduction of basic data movement
4. Program organization: Code, Data and stack

- Assembly language instructions are so basic. So, I/O is much harder unlike high-level languages.
- We Use DOS functions for I/O as they are easy to invoke and faster
- A program is must be converted to machine language before execution

Assembly Language Syntax

- Assembly language is **not case sensitive**, however, we use upper case to differentiate code from rest of the text.

➢ **Statements:**

- Programs consist of statements (one per line)
- Each statement can be any of following types:
  - Instruction that are translated into machine code
  - Assembler directives that instruct the assemble to perform some specific task:
    - ➢ Allocating memory space for variables
    - ➢ Creating procedure

Fields

- Instructions and directives can have up to **four fields**:

Name Operation Operand(s) comment

START MOV CX,5 ; initialize counter

****[Fields must appear in this order]**

MAIN PROC [creates a Procedure]

- At least one **blank** or **tab** character must separate the fields

Name Field

- **Name**: it is used for instruction levels, procedure names and variable names.
  - The assembler translates names into variable names.
  - Can be 1 to 31 characters long and consists of letter , digit and special characters.
  - Embedded blanks are not allowed.
  - Names may not begin with number.
  - **UPPERCASE** and **lowercase** in name are same.
  - **Examples: COUNTER1, $1000, Done?, .TEST**
    - **Illegal names TWO WORD, 2AB, A45.28, ME &YOU**

Solve the Following

- **Which of the following names are legal in IBM PC assembly language?**

TWO_WORDS

TwoWOrDs

?1

.@?

$145

LET'S_GO

T = .

Operation Field

- Operation field contains a symbolic operation code (opcode).
- The assembler translates a symbolic opcode into a machine language.
- Opcode symbols often describe the **operations function** (e.g. **MOV, ADD, SUM** etc..).
- In assembler directive, the operation field contains pseudo operation code (pseudo-ops).
- Pseudo-ops are NOT translated into machine code. they simply **tell** the assembler to do something.
  - e.g. **PROC** pseudo-op is used to create procedure.

Operand Field(cont'd...)

- Operand field species the data that are to be **acted on** by the operation.
- An instruction may have zero, one or two operands. e.g.

NOP	**No operands; does nothing**
INC AX	**Adds one to the contents of AX**
ADD WORD1,2	**Add 2 to the contents of WORD1**

- First operand is **Destination** (i.e. register or Memory location)
  - some instruction do not store any result
- Second operand is **Source** and its not usually modified by instruction

Comment Field

- **Comment:** put instruction into the context of program.
- Comment field of a statement is used to say something about what the statement does?
- **Semicolon (;) marks in the beginning of this field**
- Assembler ignores anything typed after " ; "

** Comment is very important in assembly language and it is almost impossible to understand assembly code without comment.

** Commenting is considered as good programming practice

Program Data

- Processor operates only on **binary** data.
- So, the assembler MUST **translate** all data representation into binary numbers.
- In assembly program, we may express data as **binary**, **decimal** or **hex** numbers and even characters.

➢ **Numbers:**

- **Binary:** a binary number is written as bit string followed by the letter **B** or **b** (e.g. 1010**B**)
- **Decimal:** A decimal number is a string of decimal digits. It ends with optional "D" or "d" (e.g. 1234).
- **Hex:** A hex number begins with a decimal digit and ends with the letter **H** or **h (e.g.** 12AB**h**).

➢ **Characters:**

Character strings must be enclosed with single or double quotes.

- **e.g. 'A' or "hello" is translated into ASCII by assembler. So, there is no difference between 'A' or 41h or 65d.**

Solve the Following

- **Which of the following are legal numbers? if they are legal tell whether they are Binary, decimal or hex numbers?**
  - **246**
  - **246h**
  - **1001**
  - **1,001**
  - **2A3h**
  - **FFFEh**
  - **0Ah**
  - **Bh**
  - **1110b**

Variables

- We use a variable to store values temporarily.
- Each variable has a data type and is assigned a memory address by the program.
- We will mostly use DB (define byte) and DW(define word) variables.

➢ **Byte Variables:** In the following , the directive **associates a memory byte to ALPHA and initialize it to 4.** A **"?"** mark can be used for uninitialized byte. The range of values in a byte is **2^8 or 256**

```
Name     DB   Initial_value

ALPHA   DB    4
```

➢ **Word Variables:** Similar to byte variable and the range of initial values is **2^16 or 65536.**

```
Name     DW   Initial_value

WRD      DW     -2
```

Array

- Array is just a **sequence** of bytes or words.
- i.e. to define a three-byte array, we write

B_ARRAY DB 10h, 20h, 30h

Name B_ARRAY is associated with first byte, B_ARRAY+1 with second and B_ARRAY+2 with third.

B_ARRAY	**200**	**10h**
B_ARRAY+1	**201**	**20h**
B_ARRAY+2	**202**	**30h**

Array Exercise

- **Create a word array (named MY_W_ARRAY) table of which the starting address is 500 and values are 2000,323,4000 and 1000.**

Solution

MY_W_ARRAY DW 2000,323,4000,1000

MY_W_ARRAY	500	2000
MY_W_ARRAY+2	502	323
MY_W_ARRAY+4	504	4000
MY_W_ARRAY +6	506	1000

Array (Cont.)

- **High and Low bytes of Word:** Sometimes we may need to refer to the high and **low bytes** of a word variable. i.e. if we define,

  WORD1 DW 1234H

  the **low byte** of WORD1 contains 34h (symbolic address: WORD1) and **High byte** contains 12h (symbolic address: WORD1+1).

- **Character string:** An array of ASCII codes.

  - LETTER DB 'ABC'
  - LETTER DB 41h,42h,43h [UPPERCASE]
  - MSG DB `HELLO', 0Ah, 0Dh, '$' [combination is also possible]
  - MSG DB 48h,45h,4Ch,4Ch,4Fh,0Ah,0Dh,24h

Named Constant

- Using a symbolic name for constant quantity make the assembly code much easier.

➢ **EQU (Equates):** Assign a name to a constant

e.g. LF EQU 0Ah [LF= 0Ah]

(LF=0Ah is applicable to whole code after assigning)

- **PROMPT EQU 'Type Your Name'**

No memory is allocated for EQU names

Instructions: MOV

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

- **Syntax:** **MOV destination, source**

MOV AX, WORD1 [reads Move WORD1 to AX]

Before	After
0006	0008
AX	AX
0008	0008
WORD1	WORD1

**Copy of WORD is sent to AX

Legal Combinations of Operands for MOV

Source Operand	General Register	Segment Register	Memory location	Constant
General Register	Yes	Yes	Yes	No
Segment Register	Yes	No	Yes	No
Memory location	Yes	Yes	No illegal: MOV W1,W2	No
Constant	Yes	No	Yes	No

Solve the Following

- What is the value of BX and A after MOV BX,A ?[assume value of A is 24h]
- Using previous values, find the value of AX and BX from MOV AX, BX
- Tell us whether the following instructions are legal or illegal?

MOV DS,AX

MOV DS,1000h

MOV CS,ES

MOV W1,DS

MOV W1,B1

Instructions: XCHG

- MOV is used to **exchange** the contents between two registers or register and memory-location.

- Syntax: **XCHG destination, source**

XCHG AH, BL

[reads exchange value of AH with BL]

Before		After	
1A	00	05	00
AH	AL	AH	AL
00	05	00	1A
BH	BL	BH	BL

Legal combinations of operands for XCHG

Source Operand	General Register	Memory location
General Register	Yes	Yes
Memory location	Yes	No illegal: XCHG W1,W2

Solve the following

- What is the value of BX and A after XCHG BX,A?[assume value of A is 15h].
- Also find, AX and A after MOV AX,A ?
- Using previous values, find the value of AX and BX from XCHG AX, BX?
- Tell us whether the following instructions are legal or illegal?

XCHG W1,W2

XCHG AX,W1

Solution

- **XCHG or MOV operation is not allowed between memory locations. So, What could be the way out?**

- Using Register,

```
MOV AX, W2
XCHG  AX,W2
MOV W1, AX
```

Instructions: ADD

- **ADD** is used to **add** content of two registers, register and memory-location or add a number to register or memory location.

- **Syntax: ADD destination, source**

ADD WORD1,AX [reads Add AX to WORD1]

Before	After
01BC	01BC
AX	AX
0523	06DF
WORD1	WORD1

**Copy of WORD1 is added with content of AX and stored in WORD1

Legal Combinations of Operands for ADD

Source Operand	General Register	Memory location
General Register	Yes	Yes
Memory location	Yes	No illegal: ADD W1,W2
Constant	Yes	Yes

Solve the Following

- What is the value of BX and A after ADD BX,A ?[assume value of BX is 5h and A is 9h]
- using previous values[AX=9h], find the value of AX and BX from ADD AX, BX
- Tell us whether the following instructions are legal or illegal?

ADD B1,B2

ADD AL,56H

Instructions: SUB

- **SUB** is used to **subtract** content of two registers, register and memory-location or subtract a number from register or memory location.

- **Syntax: SUB destination, source**

SUB AX,DX [reads Subtract DX from AX]

Before	After
0000	FFFF
AX	AX
0001	0001
DX	DX

**Subtracts the content of DX from AX and stored in AX.

Legal Combinations of Operands for ADD

Source Operand	General Register	Memory location
General Register	Yes	Yes
Memory location	Yes	No illegal: SUB W1,W2
Constant	Yes	Yes

Solve the Following

- What is the value of BX and A after SUB BX,A ?[assume value of BX is F and A is 9h]
- Using previous values[AX=9h], find the value of AX and BX from SUB AX, BX
- Tell us whether the following instructions are legal or illegal?

SUB B1,B2

SUB AL,56H

Instructions: INC

- **INC** is used to **add 1** to the contents of a register or memory-location.
- **Syntax: INC destination**

INC WORD1 [reads Add 1 to WORD1]

Before	After
0002	0003
WORD1	WORD1

** **1** is added to WORD1 and result is stored in WORD1

Solve the Following

- **What is the value of BX and A?[assume BX=3h and A=9h]**
  - **INC BX**
  - **INC A**

Instructions: DEC

- **DEC** is used to **subtract 1** from the contents of a register or memory-location.

- **Syntax: DEC destination**

DEC WORD1 [reads subtract 1 from WORD1]

Before	After
FFFE	FFFD
WORD1	WORD1

** **1** is subtracted from BYTE1 and result is stored in BYTE1

Solve the Following

- **What is the value of BX and A?[assume BX=3h and A=9h]**
  - **DEC BX**
  - **DEC A**

Instructions: NEG

- **NEG** is used to **negate** the contents of the destination

NEG does this by replacing the contents by its two's complement.

- **Syntax: NEG destination**

NEG BX [reads negate the contents of BX]

Before	After
0002	FFFE
BX	BX

** The content of BX is replaced with its two's complement

Solve the Following

- **What is the value of BX and A? [assume BX=3h and A=9h]**
  - **NEG BX**
  - **NEG A**

Agreement of Operator

- The operand of the preceding two-operand instruction MUST be same type. (i.e. both bytes or words). Thus,
- **MOV AX,BYTE1 ; its illegal**
- **MOV AH,'A' ; legal**
- **MOV AX,'A' ; legal if source is a word**

Translation of High-Level Language to Assembly Language

Statement	Translation

B = A	MOV AX,A
	MOV B,AX
	** A direct memory move in illegal

A = 5-A	MOV AX,5
	SUB AX,A
	MOV A,AX
	or
	NEG A
	ADD A,5

A=B-2*A	MOV AX,B
	SUB AX,A
	SUB AX,A
	MOV A,AX

Program Structure

- A program Consist of
  - **Stack**
  - **Data**
  - **Code**
- Each part occupies memory segments. Program segment is **translated** into memory segment by assembler.
- The size of code and data of a program can be specified by **memory model** using **.MODEL** directive

  .MODEL Memory_model

  .MODEL SMALL [Code in ONE segment and Data in one segment]

Stack Segment

- Allocate a block of memory (stack area) to store the stack.
- The stack area should be big enough to contain the stack at its maximum size.
- **Declaration:**

.STACK size

.STACK 100H

** Allocates 100 bytes for stack area reasonable size for most applications

** If size is omitted 1KB is allocated for stack area.

Data Segment

- Contains all the **variable** definitions and sometimes Constant definitions (constant does not take any memory).
- To declare data segment **.DATA** directive is used followed by variable and constant declaration.

```
.DATA

WORD1     DW   2

BYTE1     DB   1

MSG       DB   'THIS IS A MESSAGE'

MASK      EQU  10010001B
```

Code Segment

- Contains the program's instructions
- **Declaration:**
- **.CODE** name [name is optional]

  There is no need of **name** in SMALL program
- Inside a code segment, instructions are organized as procedures.

  name PROC

  ; body of the procedure

  name ENDP
- Here name = name of the procedure. PROC and ENDP are pseudo-ops

Program Structure


```
.MODEL      SMALL

.STACK      100H

.DATA

; data definitions here

.CODE MAIN

    MAIN PROC

        ;instructions go here

    MAIN ENDP

;other procedures go here

END MAIN
```

*** The last line of the program should be the END directive, followed by the name of main

Instruction: INT (Appendix C)

- **INT**: Interrupt option stops the continuous progress of an activity or process.
- **Syntax:**

INT interrupt_number

***A particular function is requested by placing a function number in the **AH** register and **invoking INT 21h** .

*** **INT 21h** functions expect input values to be in certain registers and return output values to other registers

Function Number	Routine	Input	Output
1	single-key input	AH=1	AL = 0 if no input or ASCII of character
2	single-character output	AH=2	DL=ASCII of display char AL= ASCII of display char
9	character-string output	AH=9	

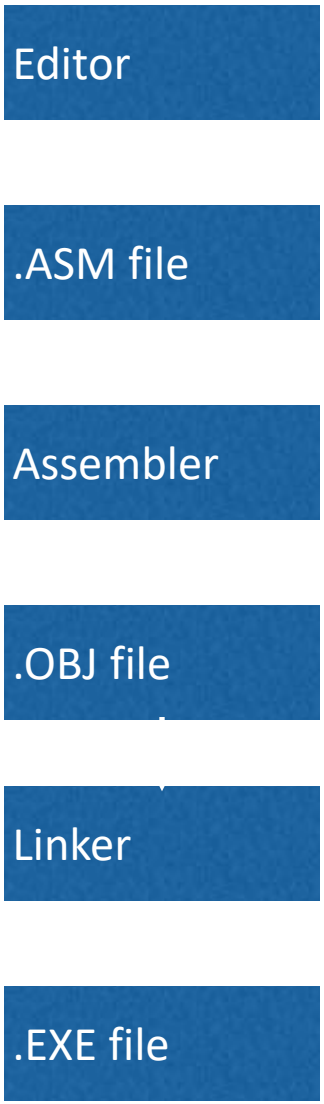
The First Program

- **Task: Write a program to read a character from the keyboard and display the same at the beginning of next line.**
- **Lets start by displaying a question (“?”) mark for the user input**

The Solution

```
.MODEL      SMALL
.STACK      100H
.CODE
 MAIN PROC
; display prompt to the user
 MOV AH, 2 ; display character function
 MOV DL, '?' ; character is '?'
 INT 21H     ; display the DL char (?)
;input a character
 MOV AH, 1   ; read character function
 INT 21H     ; character is in AL
 MOV BL, AL ; save input to BL reg
;go to new line
 MOV AH, 2       ; display character function
 MOV DL, 0Dh    ; carriage return
 INT 21H        ; execute carriage return
 MOV DL, 0Ah    ; line feed to display
 INT 21h        ; execute Line feed
; display character
 MOV DL, BL      ; retrieve character
 INT 21h
;return to DOS
 MOV AH, 4Ch  ; terminate the currant process and   transfer
                control to invoking process
 INT 21h         ; termination the execution of program
              return control to DOS
MAIN ENDP
END MAIN
```

Programming Steps



Create source program

Assemble source program

Link Object program

Instruction: LEA

- LEA: Load Effective address

  LEA destination, source
- LEA puts copy of the source offset address into the destination.

  i.e. LEA DX, MSG ; will load address of MSG to DX

Program Segment Prefix (PSP)

- PSP contains information about the program to facilitate the **program access** in this area
- DOS places its segment number in both DS and ES before program execution
- Usually, DS does not contain the segment number of the data segment.
- Thus, a program with data segment will start with these two instruction

MOV AX,@DATA [name of data segment define in .DATA]

MOV DS,AX

HW: Solve the Following

1. **Write a program to print HELLO! on the screen**
2. **Write a program that can convert the user input character in UPPERCASE like below**

   Example:
   ENTER A LOWER-CASE LETTER: a
   IN UPPERCASE IT IS: A

References

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