National University of Computer & Emerging Sciences, Karachi

EL-213: Computer Organization & Assembly Language Lab

Lab 2: Assembly Language Fundamentals	**Session:** Fall 2019
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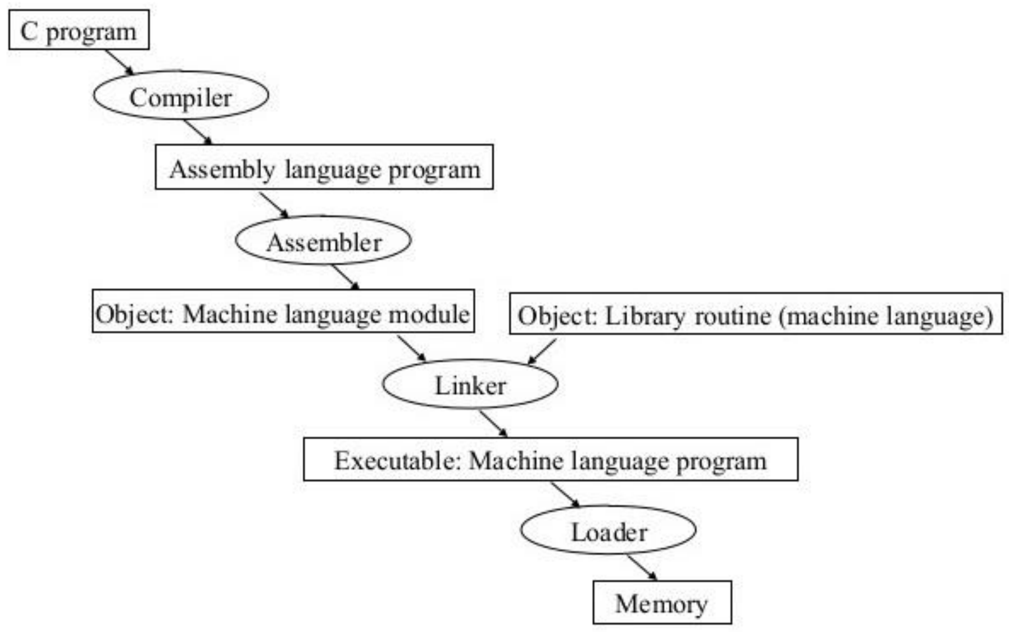
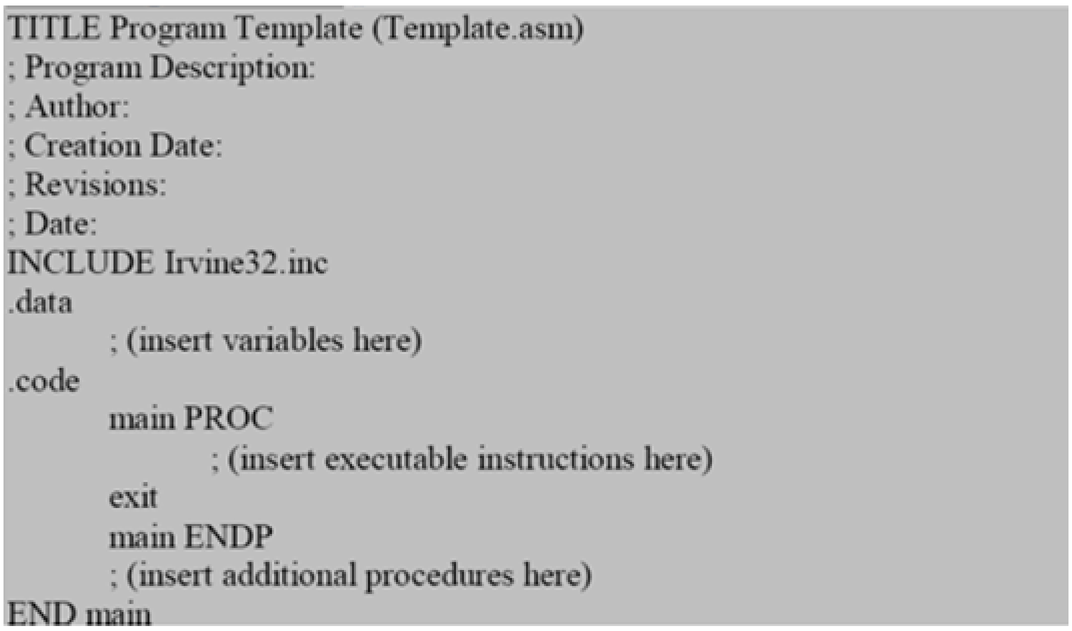
Steps in creating & running code


C program
Compiler
Assembly language program
Assembler
Object: Machine language module
Object: Library routine (machine language)
Linker
Executable: Machine language program
Loader
Memory

Program Template



```
TITLE Program Template (Template.asm)
; Program Description:
; Author:
; Creation Date:
; Revisions:
; Date:
INCLUDE Irvine32.inc
.data
        ; (insert variables here)
.code
        main PROC
                ; (insert executable instructions here)
        exit
        main ENDP
        ; (insert additional procedures here)
END main
```

Integer Constant

Integer constants are made up of an optional leading sign, one or more digits and an optional suffix character.

Format:
[{+ | -}] digits radix

Examples:

26	for decimal
26d	for decimal
10111110b	for binary
42o	for octal
1Ah	for Hexadecimal
0A3h	for Hexadecimal

Character Constant

Character constants are made up of a single character enclosed in either single or double quotes.

Example:
'A'
"d"

String Constant

A string of characters enclosed in either single or double quotes.

Example:
"Hello World"

Identifiers

An identifier is a programmer-defined name of a variable, procedure or code label.

Format:
They may contain between 1 and 247 characters.
They are not case sensitive.
The first character must be a letter (A..Z, a..z), underscore (_), @ , ?, or $. Subsequent characters may also be digits.
An identifier cannot be the same as an assembler reserved word.

Examples:
myVar
_abc
hello2

Data Types

MASM defines intrinsic data types, each of which describes a set of values that can be assigned to variables and expressions of the given type.

BYTE	8-bit unsigned integer
SBYTE	8-bit signed integer. S stands for signed
WORD	16-bit unsigned integer
SWORD	16-bit signed integer

DWORD	32-bit unsigned. D stands for double
QWORD	64-bit integer. Q stands for quad
TBYTE	80-bit integer. T stands for ten

Examples:

value1 **BYTE** 'A'	; character constant
value2 **BYTE** 0	; smallest unsigned byte
value3 **BYTE** 255	; largest unsigned byte
value4 **SBYTE** −128	; smallest signed byte
value5 **SBYTE** +127	; largest signed byte
greeting1 **BYTE** "Good afternoon”, 0	; String constant
greeting2 **BYTE** 'Good night'	; String constant
list **BYTE** 10,20,30,40	; Multiple initializers

Note: A question mark (?) initializer leaves the variable uninitialized, implying it will be assigned a value at runtime:

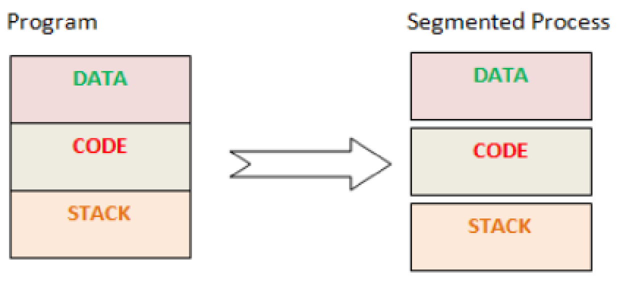
value6 **BYTE** ?

Activity:
Write a data declaration for an 8-bit unsigned integer and store 10 in it. Move this value to AL and add 40 to it.

Memory Segments

A segmented memory model divides the system memory into groups of independent segments referenced by pointers located in the segment registers. Each segment defines the area of our program that contains data variables, code and stack, respectively.

Data segment: It is the memory region, where data elements are stored for the program. This section cannot be expanded after the data elements are declared, and it remains static throughout the program.



Code segment: This section defines an area in memory that stores the instruction codes. This is also a fixed area.

Stack segment: This segment contains data values passed to procedures within the program.

Directives

A *directive* is a command embedded in the source code that is recognized and acted upon by the assembler. Directives do not execute at runtime. They can assign names to memory segments. In MASM, directives are case insensitive. For example, it recognizes .data, .DATA and .Data as equivalent.

Let us see what different directives we can use to define segments of our program:

The **.DATA** directive identifies the area of a program containing variables:
Syntax: .data

The **.CODE** directive identifies the area of a program containing executable instructions:
Syntax: .code

The **.STACK** directive identifies the area of a program holding the runtime stack, setting its size:
Syntax: .stack 100h

Instructions

An *instruction* is a statement that becomes executable when a program is assembled. Instructions are translated by the assembler into machine language bytes, which are loaded and executed by the CPU at runtime. An instruction contains four basic parts:

1. Label (optional)
2. Instruction mnemonic (required)
3. Operand(s) (usually required)
4. Comment (optional)

The basic syntax of an Assembly Language instruction is as:

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

where elements in square brackets are optional.

We will now see what each of these elements.

Label: A *label* is an identifier that acts as a place marker for instructions and data.

Operands: Assembly language instructions can have between zero and three operands, each of which can be a register, memory operand, constant expression, or input-output port.

Mnemonics: An instruction mnemonic is a short word that identifies an instruction to perform an operation. Following are examples of instruction mnemonics:

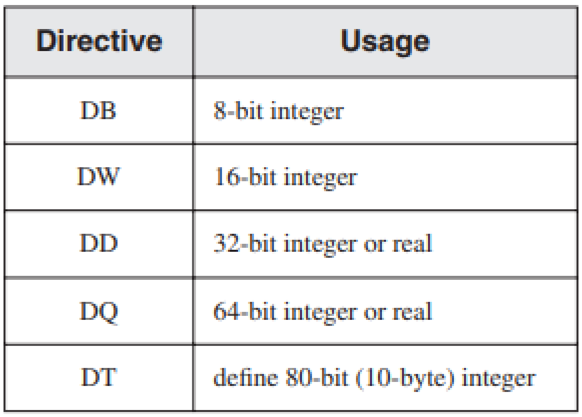
- **mov**: Moves (assigns) one value to another.
- **add**: Adds two values
- **sub**: Subtracts one value from another
- **mul**: Multiplies two values
- **jmp**: Jumps to a new location
- **call**: Calls a procedure

Activity:
Create an uninitialized data declaration for 64-bit integer

Legacy Data Directives

Following are some examples of using define directives:

```
choice        DB   'Y'
number        DW  12345
neg_number    DW  -12345
big_number    DQ 123456789
```



Directive	Usage
DB	8-bit integer
DW	16-bit integer
DD	32-bit integer or real
DQ	64-bit integer or real
DT	define 80-bit (10-byte) integer

DUP Operator

The DUP operator allocates storage for multiple data items, using a constant expression as a counter. It is particularly useful when allocating space for a string or array, and can be used with initialized or uninitialized data.

Examples:

```
v1    BYTE  20    DUP(0)           ; 20 bytes, all equal to zero
v2    BYTE  20    DUP(?)           ; 20 bytes, uninitialized
v3    BYTE  4     DUP("STACK")     ;20 bytes, "STACKSTACKSTACKSTACK"
```

Introduction to Registers

To speed up the processor operations, the processor includes some internal memory storage locations, called Registers. The registers store data elements for processing without having to access the memory.

There are ten 32-bit and six 16-bit processor registers in IA-32 architecture. The registers are grouped into three categories:

- General-Purpose registers,
- Control registers, and
- Segment registers

Furthermore, the general registers are further divided into the following groups:

- Data registers,
- Pointer registers &
- Index registers

Data Registers

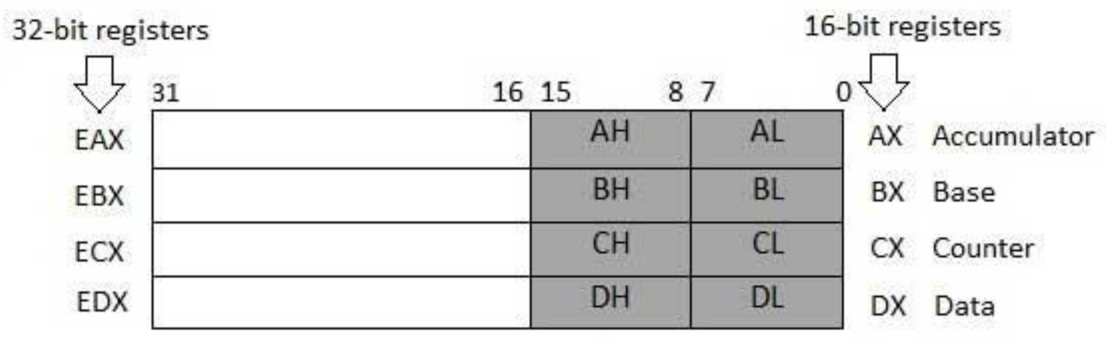
EAX (Accumulator register)
It is used in input/output and most arithmetic instructions. For example, in multiplication operation, one operand is stored in EAX or AX or AL register according to the size of the operand.

EBX (Base register)
It could be used in indexed addressing.

ECX (Counter register)
The ECX, CX registers store the loop count in iterative operations.

EDX (Data register)
It is also used in input/output operations. It is also used with AX register along with DX for multiply and division operations involving large values.

These four 32-bit registers are used for arithmetic, logical, and other operations.



Pointer Registers

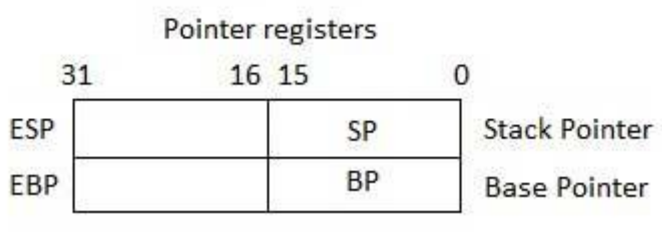
The pointer registers are 32-bit EIP, ESP, and EBP registers and their corresponding 16-bit portions IP, SP, and BP.

Extended Instruction Pointer (EIP)
The EIP register stores the offset address of the next instruction to be executed.

Extended Stack Pointer (ESP)

The ESP register provides the offset value within the program stack.

Extended Base Pointer (EBP)
The EBP register mainly helps in referencing the parameter variables passed to a subroutine.

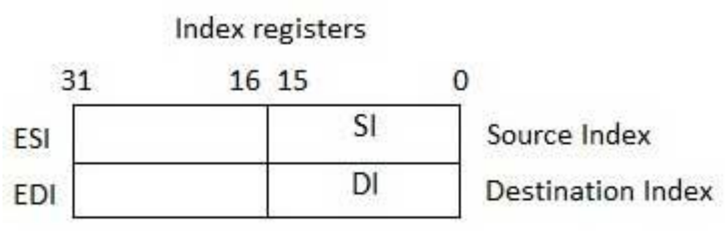


Index Registers

The 32-bit index registers, ESI and EDI, and their 16-bit rightmost portions. SI and DI, are used for indexed addressing and sometimes used in addition and subtraction.

Extended Source Index (ESI)
It is used as source index for string operations.

Extended Destination Index (EDI)
It is used as destination index for string operations.



Exercises:

1. Write an uninitialized data declaration for an 8-bit signed integer *val1* and also initialize another 8-bit signed integer *val2* with -10. Now use the value of *val2* to initialize *val1*.
2. Create an uninitialized data declaration for a 16-bit unsigned integer. Copy whatever is in the BX to this integer.
3. Declare a 32-bit signed integer *val3* and initialize it with the smallest possible negative decimal value.
4. Declare an unsigned 16-bit integer variable named **wArray** that uses three initializers
5. Declare a string variable containing the name of your favorite color. Initialize it as a null terminated string.
6. Initialize five 16-bit unsigned integers A, B, C, D & E with the following values: *12, 2, 13, 8, 14*. Create another uninitialized unsigned integer called *value*. Now write a program to evaluate the expression A - B + C + D – E and store the result in *value*.
(Note: For this example, expression should be resolved from left to right)