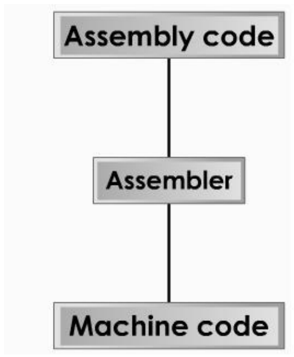
2 **The Art of Assembly Language Programming**

Assembler

An **assembler** is a program that converts **source-code** programs written in **assembly language** into **object files** in machine language.

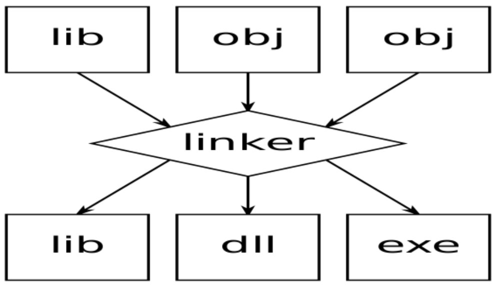
An Assembler is used to translate the assembly language mnemonics into machine language(i.e binary codes). When you run the assembler it reads the source file of your program from where you have saved it. The assembler generates two files . The first file is the Object file with the extension **.OBJ**. The object file consists of the binary codes for the instructions and information about the addresses of the instructions. After further processing, the contents of the file will be loaded in to memory and run. The second file is the assembler list file with the extension **.LST**.



Linker

A **linker** is a program that combines your program's **object file** created by the assembler with other object files and **link libraries**, and produces a single **executable program**. You need a linker utility to produce executable files. Two linkers: **LINK.EXE** and **LINK32.EXE** are provided with the MASM 6.15 distribution to link **16-bit real-address mode** and **32-bit protected-address mode** programs respectively.

: A linker is a program used to connect several object files into one large object file. While writing large programs it is better to divide the large program into smaller modules. Each module can be individually written, tested and debugged. Then all the object modules are linked together to form one, functioning program. These object modules can also be kept in library file and linked into other programs as needed. A linker produces a link file which contains the binary codes for all the combined modules. The linker also produces a link map file which contains the address information about the linked files. The linkers which come with TASM or MASM assemblers produce link files with the **.EXE** extension.



Locator : A locator is a program used to assign the specific addresses of where the segments of object code are to be loaded into memory. A locator program called EXE2BIN comes with the IBM PC Disk Operating System (DOS). EXE2BIN converts a .EXE file to a .BIN file which has physical addresses.

Debugger: A debugger is a program which allows to load your object code program into system memory, execute the program, and troubleshoot or debug it. The debugger allows to look into the contents of registers and memory locations after the program runs. We can also change the contents of registers and memory locations and rerun the program. Some debuggers allows to stop the program after each instruction so that you can check or alter memory and register contents. This is called single step debug. A debugger also allows to set a breakpoint at any point in the program. If we insert a break point , the debugger will run the program up to the instruction where the breakpoint is put and then stop the execution.

Editor

An Editor is a program which allows us to create a file containing the assembly language statements for the program. Examples of some editors are PC write Wordstar. As we type the program the editor stores the ACSII codes for the letters and numbers in successive RAM locations. If any typing mistake is done editor will alert us to correct it. If we leave out a program statement an editor will let you move everything down and insert a line. After typing all the program we have to save the program for a hard disk. This we call it as source file. The next step is to process the source file with an assembler. While using TASM or MASM we should give a file name and extension .ASM.

Ex: Sample. asm

Emulator: An emulator is a mixture of hard ware and software. It is usually used to test and debug the hardware and software of an external system such as the prototype of a microprocessor based instrument.

ASSEMBLER DIRECTIVES AND OPERATORS

ASSEMBLER DIRECTIVES :

Assembler directives are the directions to the assembler which indicate how an operand or section of the program is to be processed. These are also called pseudo operations which are not executable by the microprocessor. The various directives are explained below.

1. ASSUME : The ASSUME directive is used to inform the assembler the name of the logical segment it should use for a specified segment.

Ex: ASSUME DS: DATA tells the assembler that for any program instruction which refers to the data segment ,it should use the logical segment called DATA.

2.DB -Define byte. It is used to declare a byte variable or set aside one or more storage locations of type byte in memory.

For example, CURRENT_VALUE DB 36H tells the assembler to reserve 1 byte of memory for a variable named CURRENT_ VALUE and to put the value 36 H in that memory location when the program is loaded into RAM .

3. DW -Define word. It tells the assembler to define a variable of type word or to reserve storage locations of type word in memory.

4. **DD(define double word**) :This directive is used to declare a variable of type double word or restore memory locations which can be accessed as type double word.

5.DQ (define quadword) : This directive is used to tell the assembler to declare a variable 4 words in length or to reserve 4 words of storage in memory .

6.DT (define ten bytes): It is used to inform the assembler to define a variable which is **10** bytes in length or to reserve 10 bytes of storage in memory.

7. EQU –Equate It is used to give a name to some value or symbol**.** Every time the assembler finds the given name in the program, it will replace the name with the value or symbol we have equated with that name

8.ORG -**Originate** : The ORG statement changes the starting offset address of the data.

It allows to set the location counter to a desired value at any point in the program.For example the statement ORG 3000H tells the assembler to set the location counter to 3000H.

9 .PROC- Procedure: It is used to identify the start of a procedure. Or subroutine.

10. END- End program .This directive indicates the assembler that this is the end of the program module.The assembler ignores any statements after an END directive.

11. **ENDP**- End procedure: It indicates the end of the procedure (subroutine) to the assembler.

12.ENDS-End Segment: This directive is used with the name of the segment to indicate the end of that logical segment.

Ex: CODE SEGMENT : Start of logical segment containing code

CODE ENDS : End of the segment named CODE.

SEGMENT
The SEGMENT directive is used to indicate the start of a logical segment. Preceding the SEGMENT directive is the name you want to give the segment. For example, the statement CODE SEGMENT indicates to the assembler the start of a logical segment called CODE. The SEGMENT and ENDS directive are used to "bracket" a logical segment containing code of data.
Additional terms are often added to a SEGMENT directive statement to indicate some special way in which we want the assembler to treat the segment. The statement CODE SEGMENT WORD tells the assembler that we want the content of this segment located on the next available word (even address) when segments ate combined and given absolute addresses. Without this WORD addition, the segment will be located on the next available paragraph (16-byte) address, which might waste as much as 15 bytes of memory. The statement CODE SEGMENT PUBLIC tells the assembler that the segment may be put together with other segments named CODE from other assembly modules when the modules are linked together.

ENDS (END SEGMENT)
This directive is used with the name of a segment to indicate the end of that logical segment.

➢ CODE SEGMENT Start of logical segment containing code instruction statements

CODE ENDS End of segment named CODE

END (END PROCEDURE)
The END directive is put after the last statement of a program to tell the assembler that this is the end of the program module. The assembler will ignore any statements after an END directive, so you should make sure to use only one END directive at the very end of your program module. A carriage return is required after the END directive.

ASSUME
The ASSUME directive is used tell the assembler the name of the logical segment it should use for a specified segment. The statement ASSUME CS: CODE, for example, tells the assembler that the instructions for a program are in a logical segment named CODE. The statement ASSUME DS: DATA tells the assembler that for any program instruction, which refers to the data segment, it should use the logical segment called DATA.

DB (DEFINE BYTE)
The DB directive is used to declare a byte type variable, or a set aside one or more storage locations of type byte in memory.
➢ PRICES DB 49H, 98H, 29H Declare array of 3 bytes named PRICE and initialize them with specified values.
➢ NAMES DB "THOMAS" Declare array of 6 bytes and initialize with ASCII codes for the letters in THOMAS.

- TEMP DB 100 DUP (?) Set aside 100 bytes of storage in memory and give it the name TEMP. But leave the 100 bytes un-initialized.
- PRESSURE DB 20H DUP (0) Set aside 20H bytes of storage in memory, give it the name PRESSURE and put 0 in all 20H locations.

DD (DEFINE DOUBLE WORD)
The DD directive is used to declare a variable of type double word or to reserve memory locations, which can be accessed as type double word. The statement ARRAY DD 25629261H, for example, will define a double word named ARRAY and initialize the double word with the specified value when the program is loaded into memory to be run. The low word, 9261H, will be put in memory at a lower address than the high word.

DQ (DEFINE QUADWORD)
The DQ directive is used to tell the assembler to declare a variable 4 words in length or to reserve 4 words of storage in memory. The statement BIG_NUMBER DQ 243598740192A92BH, for example, will declare a variable named BIG_NUMBER and initialize the 4 words set aside with the specified number when the program is loaded into memory to be run.

DT (DEFINE TEN BYTES)
The DT directive is used to tell the assembler to declare a variable, which is 10 bytes in length or to reserve 10 bytes of storage in memory. The statement PACKED_BCD DT 11223344556677889900 will declare an array named PACKED_BCD, which is 10 bytes in length. It will initialize the 10 bytes with the values 11, 22, 33, 44, 55, 66, 77, 88, 99, and 00 when the program is loaded into memory to be run. The statement RESULT DT 20H DUP (0) will declare an array of 20H blocks of 10 bytes each and initialize all 320 bytes to 00 when the program is loaded into memory to be run.

DW (DEFINE WORD)
The DW directive is used to tell the assembler to define a variable of type word or to reserve storage locations of type word in memory. The statement MULTIPLIER DW 437AH, for example, declares a variable of type word named MULTIPLIER, and initialized with the value 437AH when the program is loaded into memory to be run.

- WORDS DW 1234H, 3456H Declare an array of 2 words and initialize them with the specified values.
- STORAGE DW 100 DUP (0) Reserve an array of 100 words of memory and initialize all 100 words with 0000. Array is named as STORAGE.
- STORAGE DW 100 DUP (?) Reserve 100 word of storage in memory and give it the name STORAGE, but leave the words un-initialized.

EQU (EQUATE)
EQU is used to give a name to some value or symbol. Each time the assembler finds the given name in the program, it replaces the name with the value or symbol you equated with that name. Suppose, for example, you write the statement FACTOR EQU 03H at the start of your program, and later in the program you write the instruction statement ADD AL, FACTOR. When the assembler codes this instruction statement, it will code it as if you had written the instruction ADD AL, 03H.

- CONTROL EQU 11000110 B Replacement
  MOV AL, CONTROL Assignment
- DECIMAL_ADJUST EQU DAA Create clearer mnemonic for DAA
  ADD AL, BL Add BCD numbers
  DECIMAL_ADJUST Keep result in BCD format

LENGTH

LENGTH is an operator, which tells the assembler to determine the number of elements in some named data item, such as a string or an array. When the assembler reads the statement MOV CX, LENGTH STRING1, for example, will determine the number of elements in STRING1 and load it into CX. If the string was declared as a string of bytes, LENGTH will produce the number of bytes in the string. If the string was declared as a word string, LENGTH will produce the number of words in the string.

OFFSET

OFFSET is an operator, which tells the assembler to determine the offset or displacement of a named data item (variable), a procedure from the start of the segment, which contains it. When the assembler reads the statement MOV BX, OFFSET PRICES, for example, it will determine the offset of the variable PRICES from the start of the segment in which PRICES is defined and will load this value into BX.

PTR (POINTER)

The PTR operator is used to assign a specific type to a variable or a label. It is necessary to do this in any instruction where the type of the operand is not clear. When the assembler reads the instruction INC [BX], for example, it will not know whether to increment the byte pointed to by BX. We use the PTR operator to clarify how we want the assembler to code the instruction. The statement INC BYTE PTR [BX] tells the assembler that we want to increment the byte pointed to by BX. The statement INC WORD PTR [BX] tells the assembler that we want to increment the word pointed to by BX. The PTR operator assigns the type specified before PTR to the variable specified after PTR.

We can also use the PTR operator to clarify our intentions when we use indirect Jump instructions. The statement JMP [BX], for example, does not tell the assembler whether to code the instruction for a near jump. If we want to do a near jump, we write the instruction as JMP WORD PTR [BX]. If we want to do a far jump, we write the instruction as JMP DWORD PTR [BX].

FAR PTR: This directive indicates the assembler that the label following **FAR PTR** is not available within the same segment and the address of the bit is of 32 bits i.e. 2 bytes offset followed by 2 bytes.

NEAR PTR: This directive indicates that the label following **NEAR PTR** is in the same segment and need only 16 bit i.e. 2 byte offset to address it. A **NEAR PTR** label is considered as default if a label is not preceded by NEAR PTR or FAR PTR.

EVEN (ALIGN ON EVEN MEMORY ADDRESS)

As an assembler assembles a section of data declaration or instruction statements, it uses a location counter to keep track of how many bytes it is from the start of a segment at any time. The EVEN directive tells the assembler to increment the location counter to the next even address, if it is not already at an even address. A NOP instruction will be inserted in the location incremented over.

- DATA SEGMENT

SALES DB 9 DUP (?) Location counter will point to 0009 after this instruction.
EVEN Increment location counter to 000AH
INVENTORY DW 100 DUP (0) Array of 100 words starting on even address for quicker read
DATA ENDS

PROC (PROCEDURE)

The PROC directive is used to identify the start of a procedure. The PROC directive follows a name you give the procedure. After the PROC directive, the term *near* or the term *far* is used to specify the type of the procedure. The statement DIVIDE PROC FAR, for example, identifies the start of a procedure named DIVIDE and tells the assembler that the procedure is far (in a segment with different name from the one that contains the instructions which calls the procedure). The PROC directive is used with the ENDP directive to “bracket” a procedure.

ENDP (END PROCEDURE)
The directive is used along with the name of the procedure to indicate the end of a procedure to the assembler. The directive, together with the procedure directive, PROC, is used to “bracket” a procedure.

- SQUARE_ROOT PROC Start of procedure.

  SQUARE_ROOT ENDP End of procedure.

ORG (ORIGIN)
As an assembler assembles a section of a data declarations or instruction statements, it uses a location counter to keep track of how many bytes it is from the start of a segment at any time. The location counter is automatically set to 0000 when assembler starts reading a segment. The ORG directive allows you to set the location counter to a desired value at any point in the program. The statement ORG 2000H tells the assembler to set the location counter to 2000H, for example.
A “$” it often used to symbolically represent the current value of the location counter, the $ actually represents the next available byte location where the assembler can put a data or code byte. The $ is often used in ORG statements to tell the assembler to make some change in the location counter relative to its current value. The statement ORG $ + 100 tells the assembler increment the value of the location counter by 100 from its current value.

NAME
The NAME directive is used to give a specific name to each assembly module when programs consisting of several modules are written.
LABEL
As an assembler assembles a section of a data declarations or instruction statements, it uses a location counter to be keep track of how many bytes it is from the start of a segment at any time. The LABEL directive is used to give a name to the current value in the location counter. The LABEL directive must be followed by a term that specifics the type you want to associate with that name. If the label is going to be used as the destination for a jump or a call, then the label must be specified as type *near* or type *far*. If the label is going to be used to reference a data item, then the label must be specified as type byte, type word, or type double word. Here’s how we use the LABEL directive for a jump address.

- ENTRY_POINT LABEL FAR Can jump to here from another segment

NEXT: MOV AL, BL Can not do a far jump directly to a label with a colon

The following example shows how we use the label directive for a data reference.

- STACK_SEG SEGMENT STACK

DW 100 DUP (0) Set aside 100 words for stack
STACK_TOP LABEL WORD Give name to next location after last word in stack
STACK_SEG ENDS
To initialize stack pointer, use MOV SP, OFFSET STACK_TOP.

EXTRN

The EXTRN directive is used to tell the assembler that the name or labels following the directive are in some other assembly module. For example, if you want to call a procedure, which in a program module assembled at a different time from that which contains the CALL instruction, you must tell the assembler that the procedure is external. The assembler will then put this information in the object code file so that the linker can connect the two modules together. For a reference to externally named variable, you must specify the type of the variable, as in the statement EXTRN DIVISOR: WORD. The statement EXTRN DIVIDE: FAR tells the assembler that DIVIDE is a label of type FAR in another assembler module. Name or labels referred to as external in one module must be declared public with the PUBLIC directive in the module in which they are defined.

- PROCEDURE SEGMENT

  EXTRN DIVIDE: FAR Found in segment PROCEDURES
  PROCEDURE ENDS

PUBLIC
Large program are usually written as several separate modules. Each module is individually assembled, tested, and debugged. When all the modules are working correctly, their object code files are linked together to form the complete program. In order for the modules to link together correctly, any variable name or label referred to in other modules must be declared PUBLIC in the module in which it is defined. The PUBLIC directive is used to tell the assembler that a specified name or label will be accessed from other modules. An example is the statement PUBLIC DIVISOR, DIVIDEND, which makes the two variables DIVISOR and DIVIDEND available to other assembly modules.

SHORT
The SHORT operator is used to tell the assembler that only a 1 byte displacement is needed to code a jump instruction in the program. The destination must in the range of –128 bytes to +127 bytes from the address of the instruction after the jump. The statement JMP SHORT NEARBY_LABEL is an example of the use of SHORT.

TYPE
The TYPE operator tells the assembler to determine the type of a specified variable. The assembler actually determines the number of bytes in the type of the variable. For a byte-type variable, the assembler will give a value of 1, for a word-type variable, the assembler will give a value of 2, and for a double word-type variable, it will give a value of 4. It can be used in instruction such as ADD BX, TYPE-WORD-ARRAY, where we want to increment BX to point to the next word in an array of words

GLOBAL (DECLARE SYMBOLS AS PUBLIC OR EXTRN)
The GLOBAL directive can be used in place of a PUBLIC directive or in place of an EXTRN directive. For a name or symbol defined in the current assembly module, the GLOBAL directive is used to make the symbol available to other modules. The statement GLOBAL DIVISOR, for example, makes the variable DIVISOR public so that it can be accessed from other assembly modules.

INCLUDE (INCLUDE SOURCE CODE FROM FILE)
This directive is used to tell the assembler to insert a block of source code from the named file into the current source module.