Introduction to NASM

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Muhammed Yazar

Chapter 1

Basics of Computer Organization

In order to program in assembly language it is necessary to have basic knowledge of Computer organization and processor architecture. This chapter gives you the basic idea of how a processor works, how it access data from main memory, how it reads or writes information from other I/O (Input / Output) devices etc.

The basic operational design of a computer is called architecture. 80X86 series of processors follow Von Newmann Architecture which is based on the stored program concept.

1. **Processor**
   Processor is the brain of the computer. It performs all mathematical, logical and control operations of a computer. It is that component of the computer which executes all the instructions given to it in the form of programs. It interacts with I/O devices, memory (RAM) and secondary storage devices and thus implements the instructions given by the user.

2. **Registers**
   Registers are the most immediately accessible memory units for the processor. They are the fastest among all the types of memory. They reside inside the processor and the processor can access the contents of any register in a single clock cycle. It is the working memory for a processor, i.e , if we want the processor to perform any task it needs the data to be present in any of its registers. The series of processors released on or after 80186 like 80186, 80286, 80386, Pentium etc are referred to as x86 or 80x86 processors. The processors released on or after 80386 are called I386 processors. They are 32 bit processors internally and externally. So their register sizes are generally 32 bit. In this section we will go through the I386 registers. Intel maintains

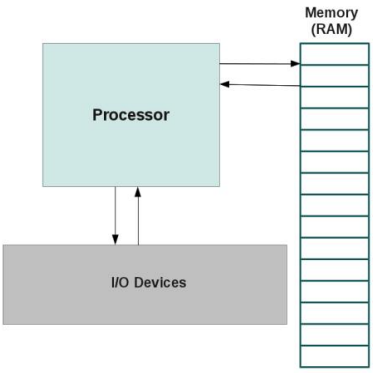


Figure 1.1: Basic Operation of a processor

its backward compatibility of instruction sets, i.e, we can run a program designed for an old 16 bit machine in a 32bit machine. That is the reason why we can install 32-bit OS in a 64 bit PC. The only problem is that, the program will not use the complete set of registers and other available resources and thus it will be less efficient.

(a) General Purpose Registers
There are eight general purpose registers. They are EAX, EBX, ECX, EDX, EBP, ESI, EDI, ESP. We can refer to the lower 8 and 16 bits of these registers (E.g.: AX, AH, AL) separately. This is to maintain the backward compatibility of instruction sets. These registers are also known as scratchpad area as they are used by the processor to store intermediate values in a calculation and also for storing address locations.

The General Purpose Registers are used for :

- EAX: Accumulator Register Contains the value of some operands in some operations (E.g.: multiplication).
- EBX: Base Register Pointer to some data in Data Segment.
- ECX: Counter Register Acts as loop counter, used in string operations etc.
- EDX: Used as pointer to I/O ports.
- ESI: Source Index Acts as source pointer in string operations. It can also act as a pointer in Data Segment (DS).
- EDI: Destination Index- Acts as destination pointer in string operations. It can also act as a pointer in Extra Segment (ES)

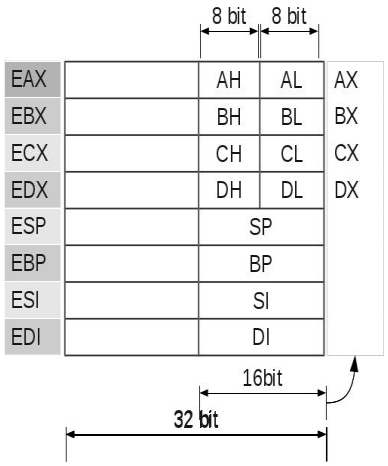


Figure 1.2: I-386 General Purpose Registers

- ESP: Stack Pointer Always points to the top of system stack.
- EBP: Base Pointer It points to the starting of system stack (ie. bottom/base of stack).

(b) Flags and EIP
FLAGS are special purpose registers inside the CPU that contains the status of CPU / the status of last operation executed by the CPU. Some of the bits in FLAGS need special mention:

- Carry Flag: When a processor do a calculation, if there is a carry then the Carry Flag will be set to 1.
- Zero Flag: If the result of the last operation was zero, Zero Flag will be set to 1, else it will be zero.
- Sign Flag : If the result of the last signed operation is negative then the Sign Flag is set to 1, else it will be zero.
- Parity Flag: If there are odd number of ones in the result of the last operation, parity flag will be set to 1.
- Interrupt Flag: If interrupt flag is set to 1, then only it will listen to external interrupts.

EIP:
EIP is the instruction pointer, it points to the next instruction to be executed. In memory there are basically two classes of things stored: (a) Data. (b)Program. When we start a program, it will be copied into the main memory and EIP is the pointer which points to the starting

of this program in memory and execute each instruction sequentially. Branch statements like JMP, RET, CALL, JNZ (we will see this in chapter 3) alter the value of EIP.

(c) Segment Registers

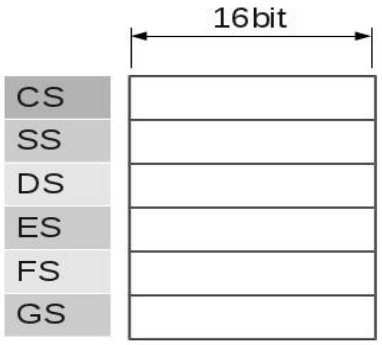


Figure 1.3: X System Flags, S Status Flags, C Control Flags

In x86 processors for accessing the memory basically there are two types of registers used Segment Register and Offset. Segment register contains the base address of a particular data section and Offset will contain how many bytes should be displaced from the segment register to access the particular data. CS contains the base address of Code Segment and EIP is the offset. It keeps on updating while executing each instruction. SS or Stack Segment contains the address of top most part of system stack. ESP and EBP will be the offset for that. Stack is a data structure that follows LIFO ie. Last-In-First-Out. There are two main operations associated with stack: push and pop. If we need to insert an element into a stack, we will push it and when we give the pop instruction, we will get the last value which we have pushed. Stack grows downward. So SP will always points to the top of stack and if we push an element, ESP (Stack Pointer) will get reduced by sufficient number of bytes and the data to be stored will be pushed over there. DS, ES, FS and GS acts as base registers for a lot of data operations like array addressing, string operations etc. ESI, EDI and EBX can act as offsets for them. Unlike other registers, Segment registers are still 16 bit wide in 32-bit processors.

In modern 32 bit processor the segment address will be just an entry into a descriptor table in memory and using the offset it will get the exact memory locations through some manipulations. This is called segmentation.
Here in the memory ,the Stack Segment starts from the memory location 122 and grows downwards. Here the Stack Pointer ESP is pointing to the location 119.
Now if we pop 1 byte of data from stack, we will get (01010101)2 and the ESP will get increased by one Now suppose we have (01101100 11001111)2 in the register ax and we execute the push command:

```
push ax
```

Then the ESP will get reduced by two units (because we need two store two bytes of data) and ax will be copied over there:

Here we can see that now ESP points to the lower byte of data from the 2 bytes data which we have pushed. In x86 architecture when we push or save some data in memory, the lower bytes of it will be addressed immediately and thus it is said to follow Little Endian Form. MIPS architecture follows Big Endian Form.

3. **Bus**
   Bus is a name given to any communication medium, that transfers data between two components. We can classify the buses associated with the processor into three:

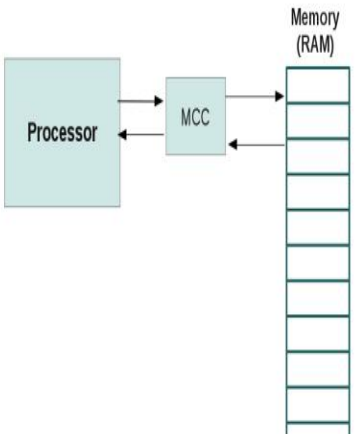
   (a) Data Bus
   It is the bus used to transfer data between the processor and memory or any other I/O devices (for both reading and writing). As the size of data bus increases, it can transfer more data in a single stretch. The size of data bus in common processors by Intel are given below:

Processor	Bus size
8088, 80188	8 bit
8086, 80816, 80286, 80386SX	16 bit
80386DX, 80486	32 bit
80586, Pentium Pro and later processors	64 bit

(b) Address Bus

RAM or random access memory is the working memory for a computer. It is a primary storage device, i.e. the data stored in RAM will be erased when the power is gone. All the instructions and data used by the computer is copied to RAM from other secondary storage devices like Hard Disk, Floppy drive, DVD drive etc. When we power on the PC the booting process will happen, which is the process of copying / loading Operating System from a secondary storage device to the main memory or RAM. When we start a program, the associated instructions and data are copied into RAM. Later on when processor needs the data from RAM it will copy that into its registers. RAM consists of contiguous storage units each of which is 8 bit wide (1 byte) and each location in RAM is given a location number starting from 0.

When processor wants to read some data from memory (RAM) or write data into some locations in the memory, it will first place the location in RAM from where the data is to be copied / written in the address bus. If it is a reading process, the data bus will have the data from that memory location. If it is a writing process, processor will place the data to be written into the data bus. Memory management Unit (MMU) or Memory Control Circuitry (MCC) or Memory Control Unit (MCU) is the set of electronic circuits present in the motherboard which helps the processor in reading or writing the data to or from a location in the RAM.



Address bus is also used for addressing the I/O devices as they can also be viewed as a source or destination of data. For these operations

control buses help a lot.
The maximum size of RAM which can be used in a PC is determined by the size of the address bus. If the size of address bus is n bits, it can address a maximum of 2n bytes of RAM. This is the reason why even if we add more than 4 G.B of RAM in a 32 bit PC, we cannot find more than 4G.B of available memory. There are also others factors which limit the maximum usable memory size (e.g. some locations are used for I/O addressing).

Processor	Address Bus Width	Maximum addressable RAM size
8088, 8086, 80186, 80286,80188	20	16 KB
80386SX, 80286	24	16 MB
80486, 80386DX, Pentium, Pentium Overdrive	32	4 GB
Pentium II, Pentium Pro	36	64 GB

(c) Control Bus :
Control bus contains information which controls the operations of processor or any other memory or I/O device. For example, the data bus is used for both reading and writing purpose and how is it that the Memory or MMU knows the data has to be written to a location or has to be read from a location, when it encounters an address in the address bus? This ambiguity is being cleared using read and write bits in the control bus. When the read bit is enabled, the data in the EDB (external data bus or simply data bus) will be written to that location. When the write bit is enabled, MMU will write the data in the EDB into the address location in the address bus.

There are also control bits for interrupts, clocking etc. We will see what an interrupt and clocking is in the coming pages.

4. **System Clock**

The basic component of a microprocessor or a microcontroller is logic gates. They are examples of digital circuits (i.e. they work in two voltage levels - high and low or 1 and 0). More specifically they are synchronous sequential circuits, i.e, their activities are synchronized with a common clock, which

will create square wave pulses at a constant rate. In the control bus, there is a bit for clocking. The processing cycle is divided into four: Fetch, Decode, Execute, Write.

Fetch : At first the processor will fetch the data and instructions to be manipulated from the EDB(External Data Bus)

Decode : It will then decode the binary instruction and decide what action(arithmetic / logic operation) to be done on the operands. In this stage, the values are read from the source registers.

Execute : It will perform the operations on the operands and manipulates the result.

Memory Access : The memory is accessed at this stage (read/ write).

Write : In this stage result is written back to the destination register.

How come the processor knows when to do each of these operations? How can the processor conclude that now the data to be fetched is there in the EDB....? All these issues are solved by clocking. During the first clock pulse the processor knows that it is time to take the data from the EDB. During the next cycle it will decode the binary instruction. In the succeeding cycle it will execute the operations on operands and then it will write the result into the EDB. So a single operation takes minimum of four clock pulses to complete. Some operation (especially decode) will take more than one clock cycle to complete. So we can say that, all the activities of a processor are synchronized by a common clocking.

Speed of a processor depends much on its clock speed. It is the maximum speed at which we can make a processor work. But motherboard will always use the processor at a speed lower than or equal to its clock speed and that speed is decided by the system crystals and it is known as System Bus Speed. In earlier days we need to have some jumper settings in motherboard to adjust the system bus speed to clock speed. Modern motherboards will communicate with the processor, get the clock speed and then automatically adjust the System Bus Speed. Nowadays some people use third party software and make the motherboard to use processor at a higher speed than its specified clock speed. This is known as overclocking. Clock speed of a processor is the highest clock rate at which it will work safely, without any problems. So if we overclock the processor, still it may work but there is a very high risk for the processor to burn off due to heat dissipation. So never go for overclocking.

5. **Interrupts:**

   Interrupts are the most critical routines executed by a processor. Interrupts may be triggered by external sources or due to internal operations. In linux based systems 80h is the interrupt number for OS generated interrupts and in windows based systems it is 21h. The Operating System Interrupt is used for implementing systems calls.

   Whenever an interrupt occurs, processor will stop its present work, preserve the values in registers into memory and then execute the ISR (Interrupt Service Routine) by referring to an interrupt vector table. ISR is the set of instructions to be executed when an interrupt occurs. By referring to the interrupt vector table, the processor can get which ISR it should execute for the given interrupt. After executing the ISR, processor will restore the registers to its previous state and continue the process that it was executing before. Almost all the I/O devices work by utilizing the interrupt requests.

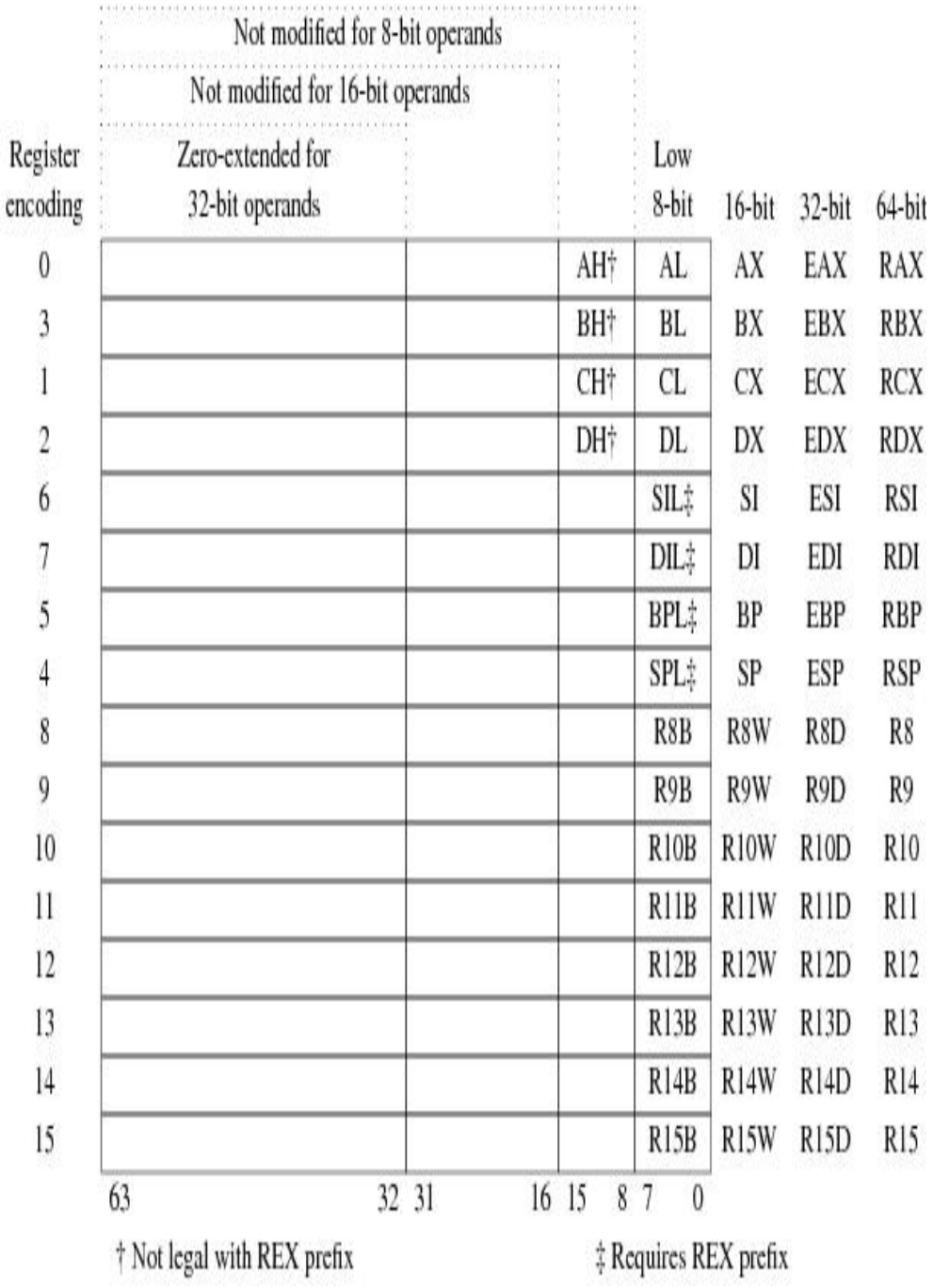


Figure 1.4: Registers in 64-bit architecture(Source: http://www.tortall.net/)

Chapter 2

How to Start

We can classify the programming languages into three categories :

- Machine Language : Machine language consists of instructions in the form of 0's and 1's. Every CPU has its own machine language. It is very difficult to write programs using the combination of 0's and 1's. So we rely upon either assembly language or high level language for writing programs.

- Assembly Language : Assembly language, when compared with machine language is in more human readable form. The general syntax of an assembly language instruction is:
  mnemonic operand(s)

  Eg:
  ```
  add eax, ebx
  mov al, ah
  inc byte[data1]
  ```

  Corresponding to each assembly language instruction, there will be a machine language instruction (ie. a hardware implementation). An assembler converts an assembly language code into machine language. We will be using the 'Netwide Assembler' (NASM). It is freely available on the internet. It works for both 32bit and 64bit PCs. It can be installed in Linux as well as Windows. Examples of other assemblers are Microsoft Assembler (MASM) and Borland Assembler(TASM).

- High Level Languages : They are in more human readable forms when compared to assembly language and machine language. They resemble natural languages like English very much. Eg: C, C++, Java, Perl, Fortan etc. A compiler or an interpreter converts a high level program into machine language.

Installing NASM

NASM is freely available on internet. You can visit :www.nasm.us . It's documentation is also available there.
In order to install NASM in windows you can download it as an installation package from the site and install it easily.
In Ubuntu Linux you can give the command : *sudo apt-get install nasm* and in fedora you can use the command: *su -c 'yum install nasm'* in a terminal and easily install nasm.

Why Assembly Language ?

- When you study assembly language, you will get a better idea of computer organization and how a program executes in a computer.
- A program written in assembly language will be more efficient than the same program written in a high level language. The code size will also be smaller. So it is preferred to program using assembly language for embedded systems, where memory is a great constraint.
- Some portions of Linux kernel and some system softwares are written in assembly language. In programming languages like C, C++ we can even embed assembly language instructions into it using functions like asm( );

First Program :

Now let us write our first program in NASM to print the message Hello World.

1. Go to the terminal.
2. If you are using gedit as your text editor type the following command:

```
gedit hello.asm
```

This will create a file hello.asm in the present working directory and open it in background. ie. you can still use the terminal for running some other commands,

without closing the gedit which we have opened. This happens since we put an ” sign at the end of our command.
3. Now type the following program into it :

```
;Program to print Hello World
;Section where we write our program
global _start:
_start:
mov eax, 4
mov ebx, 1
mov ecx, string
mov edx, length
int 80h

;System Call to exit
mov eax, 1
mov ebx, 0
int 80h

;Section to store uninitialized variables

section .data
string: db 'Hello World', 0Ah
length: equ 13

section .bss
var: resb 1
```

We will go through each portion of the above code in the next few chapters.

Executing a NASM program

1. Assembling the source file

   ```
   nasm -f elf filename.asm
   ```

   This creates an object file, filename.o in the current working directory.

2. Creating an executable file
   For a 32 bit machine

```
ld filename.o -o output_filename
```

For 64 bit machine

```
ld -melf_i386 filename
```

This creates an executable file of the name output_filename.

3. Program execution

```
./output_filename
```

For example, if the program to be run is test.asm

```
 nasm -f elf test.asm
ld test.o -o output
./output
```

Sections in NASM:

A typical NASM Program contain different sections. They are mainly:

`Section .text`: This is the part of a NASM Program which contains the executable code. It is the place from where the execution starts in NASM program, analogous to the main( ) function in C-Programming.

`section .bss` : This is the part of program used to declare variables without initialization

`section .data` : This is the part of program used to declare and initialize the variables in the program.

Eg:

```
section .data
var1: db  10
str1:  db Hello World!..
```

```
section .bss
var3: db resb 1
var4: db resq 1
```

- **RESx** directive is used to reserve just space in memory for a variable without giving any initial values.
- **Dx** directive is used for declaring space in the memory for any variable and also providing the initial values at that moment.

x	Meaning	Number of Bytes
b	BYTE	1
w	WORD	2
d	DOUBLE WORD	4
q	QUAD WORD	8
t	TEN BYTE	20

```
var1: resb  1     ;Reserves 1 byte for storing var1

var2: dw  25      ;Reserve 1 word in memory for storing var2 and initial value
                  ;of var2 = 25
```

NB:

- ; Semicolon is used to give comments in NASM.
- 011101b Represents a number (011101)2 Binary Number.
- 31h Represents a number (31)16 Hexadecimal Number.
- 23415o Represents a number (23415)8 Octal Number.

Decalring Multiple Elements Together(Arrays)

```
var: db         10,5,8,9        ;Reserves 4 bytes in memory for var and stores
                                 the values 10, 5, 8, 9 respectively in that.
```

Strings:

```
string:     db       Hello
string2:     db       H, e, l, l, o
```

Here both string and string2 are identical. They are 5 bytes long and stores the String Hello. Each character in the string will be first converted to ASCII Code and that numeric value will be stored in each byte location.

TIMES:

TIMES is used to create and initialize large arrays with a common initial value for all its elements.
Eg:

```
var: times 100  db 1            ; Creates an array of 100 bytes and each element
                                  will be initialized with the value 1
```

Dereferencing Mechanism in NASM:

In NASM if we have some operands in memory, we need the address of that memory location in some variables or in any of the general purpose registers. Let us assume that we have an address in the variable label. If we need to get the value at that address then we need to use the dereferencing operator [ ]
Eg:

```
mov eax, [label]      ;Value stored in the address location will be copied to eax
mov ebx, label        ;The address location will be copied to ebx reg.
```

We need to do the type casting operations to instructions for the operands for which the assembler wont be able to predict the number of memory locations to be dereferenced to get the data(like INC , MOV etc). For other instructions (like ADD, SUB etc) it is not mandatory. The directives used for specifying the data type are: BYTE, WORD, DWORD, QWORD, TWORD.

Eg:

```
MOV dword[ebx], 1
INC BYTE[label]
ADD eax, dword[label]
```

Chapter 3

X86 - Basic Instruction Set

In this chapter we will explore the syntax of basic instructions in NASM. We will see few examples of each instruction.

1. MOV Move/Copy
   Copy the content of one register/memory to another or change the value or a reg / memory variable to an immediate value.
   sy: mov dest, src

   - src should be a register / memory operand
   - Both src and dest cannot together be memory operands.

   Eg:

```
mov eax, ebx        ;Copy the content of ebx to eax
mov ecx, 109        ;Changes the value of ecx to 109
mov al, bl
mov byte[var1], al  ;Copy the content of al reg to the variable var in memory
mov word[var2], 200
mov eax, dword[var3]
```

2. MOVZX Move and Extend
   Copy and extend a variable from a lower spaced memory / reg location to a higher one
   sy:mov src, dest

   - size of dest should be $\geq$ size of src
   - src should be a register / memory operand

- Both src and dest cannot together be memory operands.
- Works only with signed numbers.

  Eg:
  ```
  movzx eax, ah
  movzx cx, al
  ```
- For extending signed numbers we use instructions like CBW (Convert Byte to Word), CWD (Convert Word to Double).
- CBW extends the AL reg to AX
- CWD extends the AX reg to DX:AX reg pair

3. ADD Addition
   sy :add dest, src
   dest = dest + src;
   Used to add the values of two reg / memory var and store the result in the first operand.

   - src should be a register / memory operand
   - Both src and dest cannot together be memory operands.
   - Both the operands should have the same size.

   Eg:

   ```
   add eax, ecx            ; eax = eax + ecx
   add al, ah              ; al = al + ah
   add ax, 5
   add edx, 31h
   ```

4. SUB - Subtraction
   sy: sub dest, src
   dest = dest - src;

   Used to subtract the values of two reg / memory var and store the result in the first operand.

   - src should be a register / memory operand
   - Both src and dest cannot together be memory operands.
   - Both the operands should have the same size.

Eg:

```
sub eax, ecx              ; eax = eax - ecx
sub al, ah                ; al = al - ah
sub ax, 5
sub edx, 31h
```

5. INC Increment operation
   Used to increment the value of a reg / memory variable by 1

   Eg:

```
INC eax                 ; eax++
INC byte[var]
INC al
```

6. DEC Decrement operation
   Used to decrement the value of a reg / memory variable by 1
   Eg:

```
DEC eax                ; eax--
DEC byte[var]
DEC al
```

7. MUL Multiplication
   sy: mul src
   Used to multiply the value of a reg / memory variable with the EAX / AX / AL reg. MUL works according to the following rules.

   - If src is 1 byte then AX = AL * src
   - If src is 1 word (2 bytes) then DX:AX = AX * src (ie. Upper 16 bits of the result will go to DX and the lower 16 bits will go to AX)
   - If src is 2 words long(32 bit) then EDX:EAX = EAX * src (ie. Upper 32 bits of the result will go to EDX and the lower 32 bits will go to EAX)

8. IMUL Multiplication of signed numbers
   IMUL instruction works with the multiplication of signed numbers. can be used mainly in three different forms.
   Sy:

   (a) imul src
   (b) imul dest, src
   (c) imul dest, src1, src2

   - If we use imul as in (a) then its working follows the same rules of MUL
   - If we use that in (b) form then dest = dest * src
   - If we use that in (c) form then dest = src1 * scr2

9. DIV Division
   Sy:div src
   Used to divide the value of EDX:EAX / DX:AX / AX reg with reg / memory variable with the. DIV works according to the following rules.

   - If src is 1 byte then AX will be divide by src, remainder will go to AH and quotient will go to AL.
   - If src is 1 word (2 bytes) then DX:AX will be divide by src, remainder will go to DX and quotient will go to AX
   - If src is 2 words long(32 bit) then EDX:EAX will be divide by src, remainder will go to EDX and quotient will go to EAX

10. NEG Negation of Signed numbers.
    Sy:NEG op1
    NEG Instruction negates a given reg / memory variable.

11. CLC - Clear Carry
    This instruction clears the carry flag bit in CPU FLAGS.

12. ADC Add with Carry
    sy: ADC dest, src
    ADC is used for the addition of large numbers. Suppose we want to add two 64 bit numbers. We keep the first number in EDX:EAX (ie. most significant 32 bits in EDX and the others in EAX) and the second number in EBX:ECX. Then we perform addition as follows

    Eg:

```
clc                 ; Clearing the carry FLAG
add eax, ecx        ; Normal addition of eax with ecx
adc edx, ebx        ; Adding with carry for the higher bits.
```

13. SBB Subtract with Borrow
    sy:SBB dest, src
    SBB is analogous to ADC and it is used for the subtraction of large numbers. Suppose we want to subtract two 64 bit numbers. We keep the first numbers in EDX:EAX and the second number in EBX:ECX. Then we perform subtraction as follows

    Eg:

```
clc                 ; Clearing the carry FLAG
sub eax, ecx        ; Normal subtraction of ecx from eax
sbb edx, ebx        ; Subtracting with carry for the higher bits.
```

Branching In NASM:

14. JMP Unconditionally Jump to label
    JMP is similar to the goto label statements in C / C++. It is used to jump control to any part of our program without checking any conditions.

15. CMP Compares the Operands
    sy:CMP op1, op2
    When we apply CMP instruction over two operands say op1 and op2 it will perform the operation op1 - op2 and will not store the result. Instead it will affect the CPU FLAGS. It is similar to the SUB operation, without saving the result. For example if $op1 \neq op2$ then the Zero Flag(ZF) will be set to 1.
    NB: For generating conditional jumps in NASM we will first perform the CMP operation between two reg / memory operands and then we use the following jump operations which checks the CPU FLAGS.

Conditional Jump Instructions:

Instruction	Working
JZ	Jump If Zero Flag is Set
JNZ	Jump If Zero Flag is Unset
JC	Jump If Carry Flag is Set
JNC	Jump If Carry Flag is Unset
JP	Jump If Parity Flag is Set
JNP	Jump If Parity Flag is Unset
JO	Jump If Overflow Flag is Set
JNO	Jump If Overflow Flag is Unset

Advanced Conditional Jump Instructions:
In 80x86 processors Intel has added some enhanced versions of the conditional operations which are much more easier to use compared to traditional Jump instructions. They are easy to perform comparison between two variables. First we need to use CMP op1, op2 before even using these set of Jump instructions. There is separate class for comparing the signed and unsigned numbers.

(a) For Unsigned numbers:

Instruction	Working
JE	Jump if op1 $=$ op2
JNE	Jump if op1 $\neq$ *op*2
JA (Jump if above)	Jump if op1 $>$ op2
JNA	Jump if op1 $\leq$ *op*2
JB (Jump if below)	Jump if op1 $<$ op2
JNB	Jump if op1 $\geq$ *op*2

(b) For Signed numbers:

Instruction	Working
JE	Jump if op1 $=$ op2
JNE	Jump if op1 $\neq$ *op*2
JG (Jump if greater)	Jump if op1 $>$ op2
JNG	Jump if op1 $\leq$ *op*2
JL (Jump if lesser)	Jump if op1 $<$ op2
JNL	Jump if op1 $\geq$ *op*2

16. LOOP Instruction
Sy:loop label
When we use Loop instruction ecx register acts as the loop variable. Loop instruction first decrements the value of ecx and then check if the new value

of $ecx \neq 0$. If so it will jump to the label following that instruction. Else control jumps to the very next statement.

Converting Standard C/C++ Control Structures to NASM:

```
(i) If-Else

// If-Else

if( eax <= 5 )
eax = eax + ebx;
else
ecx = ecx + ebx;

;NASM Statement
cmp eax, 5      ; Comparing
ja if

else:           ; Else Part
add ecx, ebx
jmp L2

if:             ; If Part
add eax, ebx

L2:

(ii) For Loop     //For Loop

eax = 0;
for(ebx = 1 to 10)
eax = eax + ebx;

;NASM Code

mov eax, 0
mov ebx, 1

for:
add eax, ebx
cmp ebx, 10
jbe for
```

```
--------
--------

(iii) While Loop          //While-Loop
sum = 0;
ecx = n;
while( ecx >= 0 )
sum = sum + ecx;

;NASM Code
mov dword[sum], 0
mov ecx, dword[n]

add:
add [sum], ecx
loop add               ; Decrements ecx and checks if ecx is not equal to 0 ,
```

Boolean Operators:

17. AND Bitwise Logical AND
    sy : AND op1, op1
    Performs bitwise logical ANDing of op1 and op2 , assign the result to op1.
    op1 = op1 & op2; //Equivalent C Statement
    Let x = 1010 1001b and y= 10110 010b be two 8-bit binary numbers.
    Then x & y

x	1	0	1	0	1	0	0	1
y	1	0	1	1	0	0	1	0
x AND y	1	0	1	0	0	0	0	0

18. OR Bitwise Logical OR
    sy: OR op1, op1
    Performs bitwise logical ORing of op1 and op2 , assign the result to op1.
    $op1 = op1 \| op2$; //Equivalent C Statement
    Let x = 1010 1001b and y= 10110 010b be two 8-bit binary numbers.
    Then x $\| y$

x	1	0	1	0	1	0	0	1
y	1	0	1	1	0	0	1	0
x OR y	1	0	1	1	1	0	1	1

19. XOR Bitwise Logical Exclusive OR
    sy: XOR op1, op1
    Performs bitwise logical XORing of op1 and op2 , assign the result to op1.
    op1 = op1 ôp2; //Equivalent C Statement
    Let x = 1010 1001b and y= 10110 010b be two 8-bit binary numbers.
    Then x ŷ

x	1	0	1	0	1	0	0	1
y	1	0	1	1	0	0	1	0
x XOR y	0	0	0	1	1	0	1	1

20. NOT Bitwise Logical Negation
    sy: NOT op1
    Performs bitwise logical NOT of op1 and assign the result to op1.
    op1 = õp1; //Equivalent C Statement
    Let x = 1010 1001b and y= 10110 010b be two 8-bit binary numbers.
    Then op1 = õp1;

x	1	0	1	0	1	0	0	1
x̃	0	1	0	1	0	1	1	0

21. TEST Logical AND, affects only CPU FLAGS

    sy: TEST op1, op2

    - It performs the bitwise logical AND of op1 and op2 but it wont save the result to any registers. Instead the result of the operation will affect CPU FLAGs.
    - It is similar to the CMP instruction in usage.

22. SHL Shift Left
    sy: SHL op1, op2
    $op1 = op1 \ll op2$; //Equivalent C Statement

    - SHL performs the bitwise left shift. op1 should be a reg / memory variable but op2 must be an immediate(constant) value.

- It will shift the bits of op1, op2 number of times towards the left and put the rightmost op2 number of bits to 0.

Eg:
shl eax, 5

al	1	0	1	0	1	0	0	1
$al \ll 3$	0	1	0	0	1	0	0	0

23. SHR Right Shift
sy: SHR op1, op2
$op1 = op1 \gg op2$; //Equivalent C Statement

- SHR performs the bitwise right shift. op1 should be a reg / memory variable but op2 must be an immediate(constant) value.
- It will shift the bits of op1, op2 number of times towards the right and put the leftmost op2 number of bits to 0.

Eg:
`shr eax, 5`

al	1	0	1	0	1	0	0	1
$al \gg 3$	0	0	0	1	0	1	0	1

24. ROL Rotate Left
sy: ROL op1, op2

- ROL performs the bitwise cyclic left shift. op1 could be a reg / memory variable but op2 must be an immediate(constant) value.

Eg: rol eax, 5

al	1	0	1	0	1	0	0	1
rol al, 3	0	1	0	0	1	1	0	1

25. ROR Rotate Right
sy: ROR op1, op2

- ROR performs the bitwise cyclic right shift. op1 could be a reg / memory variable but op2 must be an immediate(constant) value.

Eg:
ror eax, 5

al	1	0	1	0	1	0	0	1
ror al, 3	0	1	1	0	1	0	1	0

26. RCL Rotate Left with Carry
sy: RCL op1, op2

    - Its working is same as that of rotate left except it will consider the carry bit as its left most extra bit and then perform the left rotation.

27. RCR Rotate Right with Carry
sy: RCR op1, op2

    - Its working is same as that of rotate right except it will consider the carry bit as its left most extra bit and then perform the right rotation.

Stack Operations

28. PUSH Pushes a value into system stack
PUSH decreases the value of ESP and copies the value of a reg / constant into the system stack
sy: PUSH reg/const

    Eg:
```
PUSH ax ;ESP = ESP  2 and copies value of ax to [EBP]
PUSH eax ;ESP = ESP  4 and copies value of ax to [EBP]
PUSH ebx
PUSH dword 5
PUSH word 258
```

29. POP Pop off a value from the system stack
POP Instruction takes the vale stored in the top os system stack to a reg and then increases the value of ESP

    Eg:

```
POP bx ; ESP= ESP + 2
POP ebx ; ESP= ESP + 4
POP eax
```

30. PUSHA Pushes the value of all general purpose registers
    PUSHA is used to save the value of general purpose registers especially when calling some subprograms which will modify their values.

31. POPA POP off the value of all general purpose registers which we have pushed before using PUSHA instruction

32. PUSHF Pushes all the CPU FLAGS

33. POPF POP off and restore the values of all CPU Flags which have been pushed before using PUSHF instructions.

    NB: It is important to pop off the values pushed into the stack properly. Even a minute mistake in any of the PUSH / POP instruction could make the program not working.

34. Pre-processor Directives in NASM

    In NASM %define acts similar to the C's preprocessor directive define. This can be used to declare constants.

    Eg:

```
%define SIZE 100
```

Chapter 4

Basic I/O in NASM

The input from the standard input device (Keyboard) and Output to the standard output device (monitor) in a NASM Program is implemented using the Operating Systems read and write system call. Interrupt no: 80h is given to the software generated interrupt in Linux Systems. Applications implement the System Calls using this interrupt. When an application triggers int 80h, then OS will understand that it is a request for a system call and it will refer the general purpose registers to find out and execute the exact Interrupt Service Routine (ie. System Call here).The standard convention to use the software 80h interrupt is, we will put the system call no: in eax register and other parameters needed to implement the system calls in the other general purpose registers. Then we will trigger the 80h interrupt using the instruction INT 80h. Then OS will implement the system call.

(a) Exit System Call

- System call number for exit is 1, so it is copied to eax reg.
- Output of a program if the exit is successful is 0 and it is being passed as a parameter for exit( ) system call. We need to copy 0 to ebx reg.
- Then we will trigger INT 80h

```
mov eax, 1        ; System Call Number
mov ebx, 0        ; Parameter
int 80h           ; Triggering OS Interrupt
```

(b) Read System Call

- Using this we could read only string / character

- System Call Number for Read is 3. It is copied to eax.
- The standard Input device(keyboard) is having the reference number 0 and it must be copied to ebx reg.
- We need to copy the pointer in memory, to which we need to store the input string to ecx reg.
- We need to copy the number of characters in the string to edx reg.
- Then we will trigger INT 80h.
- We will get the string to the location which we copied to ecx reg.

```
mov eax, 3              ; Sys_call number for read
mov ebx, 0              ; Source Keyboard
mov ecx, var             ; Pointer to memory location
mov edx, dword[size]    ; Size of the string
int 80h                 ; Triggering OS Interrupt
```

- This method is also used for reading integers and it is a bit tricky. If we need to read a single digit, we will read it as a single character and then subtract 30h from it(ASCII of 0 = 30h). Then we will get the actual value of that number in that variable.

```
mov eax, 3
mov ebx, 0
mov ecx, digit1
mov edx, 1
int 80h

sub byte[digit1], 30h           ;Now we have the actual number in [var]

Reading a two digit number:

;Reading first digit
mov eax, 3
mov ebx, 0
mov ecx, digit1
mov edx, 1
int 80h

;Reading second digit
```

```
mov eax, 3
mov ebx, 0
mov ecx, digit2
mov edx, 2              ;Here we put 2 because we need to read and
int 80h                  omit enter key press as well

sub byte[digit1], 30h
sub byte[digit2], 30h

;Getting the number from ASCII
; num = (10* digit1) + digit2

mov al, byte[digit1]     ; Copying first digit to al
mov bl, 10
mul bl                   ; Multiplying al with 10
movzx bx, byte[digit2]   ; Copying digit2 to bx
add ax, bx

mov byte[num], al        ; We are sure that no less than 256, so we can
                           omit higher 8 bits of the result.
```

(c) Write System Call

- Using this we could write only string / character
- System Call Number for Write is 4. It is copied to eax.
- The standard Output device(Monitor) is having the reference number 1 and it must be copied to ebx reg.
- We need to copy the pointer in memory, where the output sting resides to ecx reg.
- We need to copy the number of characters in the string to edx reg.
- Then we will trigger INT 80h.
  Eg:

```
mov eax, 4          ;Sys_call number
mov ebx, 1          ;Standard Output device
mov ecx, msg1       ;Pointer to output string
mov edx, size1      ;Number of characters
int 80h             ;Triggering interrupt.
```

- This method is even used to output numbers. If we have a number we will break that into digits. Then we keep each of that digit in a variable of size 1 byte. Then we add 30h (ASCII of 0) to each, doing so we will get the ASCII of character to be print.

Sample Programs:

1. Hello World Program

```
section .text           ; Code Section
global _start:

_start:
mov eax, 4              ; Using int 80h to implement write() sys_call
mov ebx, 1
mov ecx, string
mov edx, length
int 80h

;Exit System Call
mov eax, 1
mov ebx, 0
int 80h

section .data                   ;For Storing Initialized Variables
string: db 'Hello World', 0Ah   ;String Hello World followed by a
                                 newline character
length: equ 13                  ; Length of the string stored to a constant.
```

NB: Using equ we declare constants, ie. their value wont change during execution.
$ -string will return the length of string variables in bytes (ie. number of characters)

2.Program to add two one two digit numbers

```
;Initialized variables

section .data
message: db "Enter a two digit number : "
```

```
message _length: equ $-message

;Un-initialized variables

section .bss
digit1: resb 1
digit2: resb 1
digit3: resb 1
digit4: resb 1
num: resb 1
num1: resb 1
num2: resb 1
sum: resw 1

section .text
global _start

_start:

;Printing prompt message
mov eax, 4
mov ebx, 1
mov ecx, message
mov edx, message _length
int 80h

;Reding first digit
mov eax, 3
mov ebx, 0
mov ecx, digit1
mov edx, 1
int 80h

;Reading second digit
mov eax, 3
mov ebx, 1
mov ecx, digit2
mov edx, 2 ;Read and ignore an extra character as the system will
int 80h          read enter press as well
```

```
;Calculating the number from digits
sub byte[digit1], 30h
sub byte[digit2], 30h

movzx ax, byte[digit1]
mov bl, 10
mul bl
movzx bx, byte[digit2]
add ax, bx
mov byte[num], al  ; We are sure that no less than 256...
mov word[sum], 0     ; Initializing sum to zero
movzx ecx, byte[num] ; Initializing loop variable(ecx) to number

;Loop for adding ecx to num

adding:
add word[sum], cx   ; Assuming maxium value in ecx will use only 16 bits

Loop adding

;The result could be maximum of 4 digits......
;In the remaining section of the code, we will break the
;number so as to print each digit one by one

;First splitting the number into two num1, num2 each
;having maximum 2 digits each
mov ax, word[sum]
mov bl, 100

div bl
mov byte[num1], al
mov byte[num2], ah

;Copying each digits to digit1, digit2, digit3 and digit4

movzx ax, byte[num1]
mov bl, 10
div bl
mov byte[digit4], al
mov byte[digit3], ah
```

```
movzx ax, byte[num2]
mov bl, 10
div bl
mov byte[digit2], al
mov byte[digit1], ah

;Converting the digit to its ASCII by adding 30h

add byte[digit1], 30h
add byte[digit2], 30h
add byte[digit3], 30h
add byte[digit4], 30h

Printing each digits.............
mov eax, 4
mov ebx, 1
mov ecx, digit4
mov edx, 1
int 80h

mov eax, 4
mov ebx, 1
mov ecx, digit3
mov edx, 1
int 80h

mov eax, 4
mov ebx, 1
mov ecx, digit2
mov edx, 1
int 80h

mov eax, 4
mov ebx, 1
mov ecx, digit1
mov edx, 1
int 80h

;Exit code
mov eax, 1
```

```
mov ebx, 0
int 80h
```

NB: Problem with the above code is we need to give the input as two digits. If we need to input 9 we need to give it as 09 Output will be printed in 4 digits. ie even if the sum is just 45 the output will be : 0045 We can correct this by reading each digits by pushing to a stack and the popping out when new line character is being encountered in the input. In your programs you are expected to use this method for reading and writing numbers.

The code snippet given below gives the sample code with subprograms for reading and printing a general 16 bit number stored in memory variable *num* by splitting the number using stack. This will be the better way for inputting / outputting a number.

```
section .bss
num:   resw 1      ; For storing a number, to be read of printed....
nod:   resb 1      ; For storing the number of digits....
temp:  resb  2

section .text
global _start

_start:
call read_num
call print_num

exit:
mov eax, 1
mov ebx, 0
int 80h

;Function to read a number from console and to store that in num
read_num:

pusha
mov word[num], 0
```

```
loop_read:
mov eax, 3
mov ebx, 0
mov ecx, temp
mov edx, 1
int 80h

cmp byte[temp], 10;       ASCII key for newline
je end_read

mov ax, word[num]
mov bx, 10
mul bx
mov bl, byte[temp]
sub bl, 30h
mov bh, 0
add ax, bx
mov word[num], ax
jmp loop_read

end_read:
popa

ret


;Function to print any number stored in num...
print_num:
pusha

extract_no:
cmp word[num], 0
je print_no
inc byte[nod]
mov dx, 0
mov ax, word[num]
mov bx, 10
div bx
push dx
mov word[num], ax
```

```
jmp extract_no

print_no:
cmp byte[nod], 0
je end_print
dec byte[nod]
pop dx
mov byte[temp], dl
add byte[temp], 30h


mov eax, 4
mov ebx, 1
mov ecx, temp
mov edx, 1
int 80h

jmp print_no

end_print:
popa

ret
```

Chapter 5

Subprograms

Subprograms are independent parts of the code which can be called at various parts of the main code. They are called functions in high level languages. They are used to group together redundant code and call them repeatedly.

CALL RET Statements:
In NASM subprograms are implemented using the CALL and RET instructions. The general systax is like this:

```
;main code.......
-------------
-------------

call func\underline{ }name
-------------
-------------

;Sub\underline{ }Program
func\underline{  }name:                ;Label for subprogram
----------
----------
----------
ret
```

- When we use the CALL instruction, address of the next instruction will be copied to the system stack and it will jump to the subprogram. ie.

ESP will be decreased by 4 units and address of the next instruction will go over there.

- When we call the ret towards the end of the sub-program then the address being pushed to the top of the stack will be restored and control will jump to that.

Calling Conventions:

The set of rules that the calling program and the subprogram should obey to pass parameters are called calling conventions. Calling conventions allow a subprogram to be called at various parts of the code with different data to operate on. The data may be passed using system registers / memory variables / system stack. If we are using system stack, parameters should be pushed to system stack before the CALL statement and remember to pop off, preserve and to push back the return address within the sub program which will be in the top of the stack.

Example program: Adding 10 numbers using sub-program

```
section .data

msg1:   db 0Ah,"Enter a number"
size1:  equ $-msg1
msg2:  db 0Ah,"the sum= "
size2:  equ $-msg2

section .bss

num:  resb 1
sum:  resb 1
digit1:  resb 1
digit0:  resb 1
digit2:  resb 1
temp:  resb 1

section .text

global _start

_start:
```

```
mov byte[temp],0
mov byte[sum],0

;using a loop to read 10 numbers
read:

mov eax,4
mov ebx,1
mov ecx,msg1
mov edx,size1
int 80h

;reading the first digit
mov eax,3
mov ebx,0
mov ecx,digit1
mov edx,1
int 80h

;reading the second digit
mov eax,3
mov ebx,0
mov ecx,digit0
mov edx,2
int 80h

;converting to numeric value
sub byte[digit1],30h
sub byte[digit0],30h

;calculating the number as digit1 * 10 +digit0
mov al,byte[digit1]
mov bl,10
mul bl
add al,byte[digit0]
mov byte[num],al

;calling the function add to add the number to the existing sum
call add
```

```
;loop condition checking
inc byte[temp]
cmp byte[temp],10
jl read

;printing the sum

;calculating digit0 as sum modulus 10
movzx ax,byte[sum]
mov bl,10
div bl
mov byte[temp],al
mov byte[digit0],ah

;calculating digit1 as (sum/10) modulus 10
;calculating digit2 as (sum/10)/10
movzx ax,byte[temp]
mov bl,10
div bl
mov byte[digit2],al
mov byte[digit1],ah

;converting to ascii value
add byte[digit2],30h
add byte[digit1],30h
add byte[digit0],30h

mov eax,4
mov ebx,1
mov ecx,msg2
mov edx,size2
int 80h

;printing the number
mov eax,4
mov ebx,1
mov ecx,digit2
mov edx,1
int 80h
```

```
mov eax,4
mov ebx,1
mov ecx,digit1
mov edx,1
int 80h

mov eax,4
mov ebx,1
mov ecx,digit0
mov edx,1
int 80h

;exit
mov eax,1
mov ebx,0
int 80h

 ;sub-program add to add a number to the existing sum
add:

mov al,byte[num]
add byte[sum],al

ret
```

Recursive Sub-routine:

A subprogram which calls itself again and again recursively to calculate the return value is called recursive sub-routine. We could implement recursive sub-routine for operations like calculating factorial of a number very easily in NASM.

Example program: Printing fibonacci series up to a number using recursive sub-progam

```
section .data

msg1:   db 0Ah,"Enter the number"
size1:  equ $-msg1
```

```
msg2:   db 0Ah,"fibonacci series = "
size2:  equ $-msg2
space:  db " "

section .bss

num:  resb 1
sum:  resb 1
digit1:  resb 1
digit0:  resb 1
fiboterm1:  resb 1
fiboterm2:  resb 1
temp:  resb 1

section .text

global _start

_start:

;Reading the number up to which fibonacci series has to be printed

mov eax,4
mov ebx,1
mov ecx,msg1
mov edx,size1
int 80h

mov eax,3
mov ebx,0
mov ecx,digit1
mov edx,1
int 80h

mov eax,3
mov ebx,0
mov ecx,digit0
mov edx,2
int 80h
```

```
sub byte[digit1],30h
sub byte[digit0],30h

mov al,byte[digit1]
mov bl,10
mul bl
add al,byte[digit0]
mov byte[num],al

mov byte[fiboterm1],0        ;first fibonacci term
mov byte[fiboterm2],1        ;second fibonacci term

mov eax,4
mov ebx,1
mov ecx,msg2
mov edx,size2
int 80h

;printing the first fibonacci term

movzx ax,byte[fiboterm1]
mov bl,10
div bl
mov byte[digit1],al
mov byte[digit0],ah

add byte[digit1],30h
add byte[digit0],30h

mov eax,4
mov ebx,1
mov ecx,digit1
mov edx,1
int 80h

mov eax,4
mov ebx,1
mov ecx,digit0
mov edx,1
int 80h
```

```
mov eax,4
mov ebx,1
mov ecx,space
mov edx,1
int 80h

;printing the second fibonacci term

movzx ax,byte[fiboterm2]
mov bl,10
div bl
mov byte[digit1],al
mov byte[digit0],ah

add byte[digit1],30h
add byte[digit0],30h

mov eax,4
mov ebx,1
mov ecx,digit1
mov edx,1
int 80h

mov eax,4
mov ebx,1
mov ecx,digit0
mov edx,1
int 80h

mov eax,4
mov ebx,1
mov ecx,space
mov edx,1
int 80h

;calling recursive sub-program fibo to print the series

call fibo
```

```
;exit
mov eax,1
mov ebx,0
int 80h

fibo:                          ;sub program to print fibonacci series

mov al,byte[fiboterm1]
mov bl,byte[fiboterm2]
add al,bl
mov byte[temp],al

cmp al,byte[num]
jng  contd

end:
ret

contd:

;printing the next fibonacci term

movzx ax,byte[temp]
mov bl,10
div bl
mov byte[digit1],al
mov byte[digit0],ah

add byte[digit1],30h
add byte[digit0],30h

mov eax,4
mov ebx,1
mov ecx,digit1
mov edx,1
int 80h

mov eax,4
mov ebx,1
mov ecx,digit0
```

```
mov edx,1
int 80h

mov eax,4
mov ebx,1
mov ecx,space
mov edx,1
int 80h

movzx ax,byte[fiboterm2]
mov byte[fiboterm1],al
movzx bx,byte[temp]
mov byte[fiboterm2],bl

call fibo

jmp end
```

Using C Library functions in NASM:

We can embed standard C library functions into our NASM Program especially for I/O operations. If we would like to use that then we have to follow Cs calling conventions given below:

- parameters are passed to the system stack from left to right order.
  Eg: `printf(%d,x)`
  Here value of x must be pushed to system stack and then the format string.

- C-Function wont pop out the parameters automatically, so it is our duty to restore the status of stack pointers(ESP and EBP) after the function being called.

Eg: `Reading an integer using the C-Functions...`

```
section .text
global main

;Declaring the external functions to be used in the program.......
```

```
extern scanf

extern printf

;Code to read an integer using the scanf function
getint:
push ebp                ;Steps to store the stack pointers
mov ebp , esp

;scanf(\%d,&x)
;Creating a space of 2 bytes on top of stack to store the int value

sub esp , 2
lea eax , [ ebp-2]
push eax                 ; Pushing the address of that location
push fmt1               ; Pushing format string
call scanf              ; Calling scanf function
mov ax, word [ebp-2]
mov word[num], ax

;Restoring the stack registers.
mov esp , ebp
pop ebp
ret

putint:
push ebp                 ; Steps to store the stack pointers
mov ebp , esp

;printf(%d,x)
sub esp , 2              ; Creating a space of 2 bytes and storing the int va
mov ax, word[num]
mov word[ebp-2], ax
push fmt2               ; Pushing pointer to format string
call printf             ; Calling printf( ) function
mov esp , ebp           ; Restoring stack to initial values
pop ebp
ret

main: ; Main( ) Function
```

```
mov eax, 4
mov ebx, 1
mov ecx, msg1
mov edx, size1
int 80h

call getint

mov ax, word[num]
mov bx, ax
mul bx
mov word[num], ax

call putint

exit:
mov ebx , 0
mov eax, 1
int 80h

section .data
fmt1 db "\%d",0
fmt2 db "Square of the number is : %\d",10
msg1: Enter an integer : "
size1: db $-msg1

section .bss
num: resw 1
```

NB: *Assembling and executing the code...*

- First we have to assemble the code to object code with NASM Assembler, then we have to use gcc compiler to make the executable code.
- nasm -f elf o int.o int.asm
- gcc int.o -o int
- ./int

Chapter 6

Arrays and Strings

An Array is a continuous storage block in memory. Each element of the array have the same size. We access each element of the array using:

i) Base address / address of the first element of the array.
ii) Size of each element of the array.
iii) Index of the element we want to access.

In NASM there is no array element accessing/dereferencing operator like [ ] in C / C++ / Java using which we can access each element. Here we compute the address of each element using an iterative control structure and traverse though the elements of the array.

Declaring / Initializing an array:

We can declare and initialize arrays in the data section using the normal notations and listing out each elements.

Eg:

```
array1: db 2, 5, 8, 10, 12, 15      ; An array of 6 bytes
array2: dw 191, 122, 165, 165       ; An array of 4 words
array3: dd 111, 111, 111            ; An array of 4 dwords and each
                                      having the same value
```

We can also use TIMES keyword to repeat each element with a given value and thus easily create array elements:
Eg:

```
array1:     TIMES       100 db      1       ; An array of 100 bytes
                                              with each element=1
array2:     TIMES       20  dw      2       ; An array of 20 dwords
```

We can declare array in .bss section using RESx keyword.Eg:

```
array1:     resb     100            ;An array of 100 bytes
array2:     resw      20
```

The label which we use to create array(eg: 'array1')acts as a pointer to the base address of the array and we can access each element by adding suitable offset to this base address and then dereferencing it.
Eg:

```
;Let array1 have elements of size 1 byte

mov al,byte[array1]          ; First element of the array copied to al reg
mov cl,byte[array1 + 5]      ; array1[5], ie. 6th element copied to cl reg

;Let array2 have elements of size 1 word(2bytes)
mov ax,word[array2]           ; First element of the array copied to ax reg
mov dx, word[array2 + 8]      ; array2[4], ie 5th element of the array
                                copied to dx reg.
```

The general syntax of using array offset is:

[basereg + factor *indexreg + constant]

basereg: It should be general purpose register containing the base address of the array.
factor: It can be 1, 2, 4 or 8.

indexreg: It can also be any of the general purpose registers.
constant: It should be an integer.

Eg:

```
byte[ebx+12]
word[ebp + 4 * esi]
dword[ebx - 12]
```

Sample Program - To search an array for an element(Traversal):

- First we read n, the number of elements.
- Then we store the base address of array to ebx reg.
- Iterate n times, read and keep the ith element to [ebx].
- Then read the number to be searched.
- Iterate through the array using the above method.
- Print success if the element is found.

```
section .bss
digit0: resb 1
digit1: resb 1
array: resb 50            ;Array to store 50 elements of 1 byte each.
element: resb 1
num: resb 1
pos: resb 1
temp: resb 1
ele: resb 1

section .data
msg1: db "Enter the number of elements : "
size1: equ $-msg1
msg2: db "Enter a number:"
size2: equ $-msg2
msg3: db "Enter the number to be searched : "
size3: equ $-msg3
msg_found: db "Element found at position : "
size_found: equ $-msg_found
msg_not: db "Element not found"
size_not: equ $-msg_not
```

```
section .text
global _start

_start:

;Printing the message to enter the number
mov eax, 4
mov ebx, 1
mov ecx, msg1
mov edx, size1
int 80h

;Reading the number
mov eax, 3
mov ebx, 0
mov ecx, digit1
mov edx, 1
int 80h

mov eax, 3
mov ebx, 0
mov ecx, digit0
mov edx, 1
int 80h

mov eax, 3
mov ebx, 0
mov ecx, temp
mov edx, 1
int 80h

sub byte[digit1], 30h
sub byte[digit0], 30h

mov al, byte[digit1]
mov dl, 10
mul dl
mov byte[num], al
mov al, byte[digit0]
```

```
add byte[num], al
mov al, byte[num]
mov byte[temp], al
mov ebx, array

reading:
push ebx              ;Preserving The value of ebx in stack

;Printing the message to enter each element
mov eax, 4
mov ebx, 1
mov ecx, msg2
mov edx, size2
int 80h

;Reading the number
mov eax, 3
mov ebx, 0
mov ecx, digit1
mov edx, 1
int 80h

mov eax, 3
mov ebx, 0
mov ecx, digit0
mov edx, 2
int 80h

sub byte[digit1], 30h
sub byte[digit0], 30h
mov al, byte[digit1]
mov dl, 10
mul dl
add al, byte[digit0]

;al now contains the number
pop ebx
mov byte[ebx], al
add ebx, 1
dec byte[temp]
```

```
cmp byte[temp], 0
jg reading

;Comparing loop variable

;Loop using branch statements

;Reading the number to be searched :.....
mov eax, 4
mov ebx, 1
mov ecx, msg3
mov edx, size3
int 80h

;Reading the number
mov eax, 3
mov ebx, 0
mov ecx, digit1
mov edx, 1
int 80h

mov eax, 3
mov ebx, 0
mov ecx, digit0
mov edx, 2
int 80h

sub byte[digit1], 30h
sub byte[digit0], 30h
mov al, byte[digit1]
mov dl, 10
mul dl
add al, byte[digit0]

;al now contains the number
pop ebx
mov byte[ebx], al
add ebx, 1
dec byte[temp]
cmp byte[temp], 0
```

```
jg reading

;Comparing loop variable

;Loop using branch statements

;Reading the number to be searched :.....
mov eax, 4
mov ebx, 1
mov ecx, msg3
mov edx, size3
int 80h

;Reading the number
mov eax, 3
mov ebx, 0
mov ecx, digit1
mov edx, 1
int 80h

mov eax, 3
mov ebx, 0
mov ecx, digit0
mov edx, 2
int 80h

sub byte[digit1], 30h
sub byte[digit0], 30h
mov al, byte[digit1]
mov dl, 10
mul dl
add al, byte[digit0]
mov byte[ele], al
movzx ecx, byte[num]
mov ebx, array
mov byte[pos], 1

searching:
push ecx
mov al , byte[ebx]
```

```
cmp al, byte[ele]
je found
add ebx, 1
pop ecx
add byte[pos], 1

loop searching
mov eax, 4
mov ebx, 1
mov ecx, msg_not
mov edx, size_not
int 80h

exit:
mov eax, 1
mov ebx, 0
int 80h

found:
mov eax, 4
mov ebx, 1
mov ecx, msg_found
mov edx, size_found
int 80h

movzx ax, byte[pos]
mov bl, 10
div bl
mov byte[digit1], al
mov byte[digit0], ah
add byte[digit0], 30h
add byte[digit1], 30h
mov eax, 4
mov ebx, 1
mov ecx, digit1
mov edx, 1
int 80h
mov eax, 4
mov ebx, 1
mov ecx, digit0
```

```
    mov edx, 1
    int 80h
    jmp exit
```

Strings:

Strings are stored in memory as array of characters. Each character in English alphabet has a 8-bit unique numeric representation called ASCII. When we read a string from the user, the user will give an enter key press at the end of the string. When we read that using the read system call, the enter press will be replaced with a new line character with ASCII code 10 . Thus we can detect the end of the string.

Sample Program - To count the number of each vowels in a string :

```
section .data
a_cnt:  db 0
e_cnt:  db 0
i_cnt:  db 0
o_cnt:  db 0
u_cnt:  db 0
string_len:  db 0
msg1:  db "Enter a string :  "
size1:  equ $-msg1
msg_a:  db 10 , "No:  of A : "
size_a:  equ $-msg_a
msg_e:  db 10, "No:  of E : "
size_e:  equ $-msg_e
msg_i:  db 10, "No:  of I : "
size_i:  equ $-msg_i
msg_o:  db 10, "No:  of O : "
size_o:  equ $-msg_o
msg_u:  db 10, "No:  of U : "
size_u:  equ $-msg_u

section .bss
string:  resb 50
temp:  resb 1

section .data
global_start
```

```
_start:
mov eax, 4
mov ebx, 1
mov ecx, msg1
mov edx, size1
int 80h
mov ebx, string

reading:
push ebx
mov eax, 3
mov ebx, 0
mov ecx, temp
mov edx, 1
int 80h
pop ebx
cmp byte[temp], 10
je end_reading
inc byte[string_len]
mov al,byte[temp]
mov byte[ebx], al
inc ebx
jmp reading

end_reading:
mov byte[ebx], 0
mov ebx, string

counting:
mov al, byte[ebx]
cmp al, 0
je end_counting
cmp al, 'a'
je inc_a
cmp al, 'e'
je inc_e
cmp al, 'i'
je inc_i
cmp al, 'o'
```

```
je inc_o
cmp al, 'u'
je inc_u
cmp al, 'A'
je inc_a
cmp al, 'E'
je inc_e
cmp al, 'I'
je inc_i
cmp al, 'O'
je inc_o
cmp al, 'U'
je inc_u

next:
inc ebx
jmp counting
end_counting:

;Printing the no of a
mov eax, 4
mov ebx, 1
mov ecx, msg_a
mov edx, size_a
int 80h
add byte[a_cnt], 30h
mov eax, 4
mov ebx, 1
mov ecx, a_cnt
mov edx, 1
int 80h

;Printing the no of e
mov eax, 4
mov ebx, 1
mov ecx, msg_e
mov edx, size_e
int 80h
add byte[e_cnt], 30h
mov eax, 4
```

```
mov ebx, 1
mov ecx, e_cnt
mov edx, 1
int 80h

;Printing the no of i
mov eax, 4
mov ebx, 1
mov ecx, msg_i
mov edx, size_i
int 80h
add byte[i_cnt], 30h
mov eax, 4
mov ebx, 1
mov ecx, i_cnt
mov edx, 1
int 80h

;Printing the no of o
mov eax, 4
mov ebx, 1
mov ecx, msg_o
mov edx, size_o
int 80h
add byte[o_cnt], 30h
mov eax, 4
mov ebx, 1
mov ecx, o_cnt
mov edx, 1
int 80h

;Printing the no of u
mov eax, 4
mov ebx, 1
mov ecx, msg_u
mov edx, size_u
int 80h
add byte[u_cnt], 30h
mov eax, 4
mov ebx, 1
```

```
mov ecx, u_cnt
mov edx, 1
int 80h

exit:
mov eax, 1
mov ebx, 0
int 80h

inc_a:
inc byte[a_cnt]
jmp next

inc_e:
inc byte[e_cnt]
jmp next

inc_i:
inc byte[i_cnt]
jmp next

inc_o:
inc byte[o_cnt]
jmp next

inc_u:
inc byte[u_cnt]
jmp next
```

Two / Multi-Dimensional Arrays:

Memory / RAM is a continuous storage unit in which we cannot directly store any 2-D Arrays/Matrices/Tables. 2-D Arrays are implemented in any programming language either in row major form or column major form. In row major form first we store the row1 then row 2 then row 3 and it goes on. In column major form we store column 1 first, then column 2 then column 3 and goes on till the last element of last column. For example if we have a 2 x 3 matrix say A of elements 1 byte each. Let the starting address of the array be 12340. Then the array will be stored in memory as:

a) Row Major Form

Address	Element
12340	A[0][0]
12341	A[0][1]
12342	A[0][2]
12343	A[1][0]
12344	A[1][1]
12345	A[1][2]

a) Column Major Form

Address	Element
12340	A[0][0]
12341	A[1][0]
12342	A[0][1]
12343	A[1][1]
12344	A[0][2]
12345	A[1][2]

Using this concept we can implement the 2-D array in NASM Programs.

Example program: reading and displaying an m x n matrix

```
section .bss
num: resw 1 ;For storing a number, to be read of printed....
nod: resb 1 ;For storing the number of digits....
temp: resb 2
matrix1: resw 200
m: resw 1
n: resw 1
i: resw 1
j: resw 1


section .data
msg1: db "Enter the number of rows in the matrix : "
msg_size1: equ $-msg1
msg2: db "Enter the elements one by one(row by row) : "
msg_size2: equ $-msg2
msg3: db "Enter the number of columns in the matrix : "
```

```
msg_size3: equ $-msg3
tab: db  9 ;ASCII for vertical tab
new_line: db 10 ;ASCII for new line

section .text
global _start

_start:
mov eax, 4
mov ebx, 1
mov ecx, msg1
mov edx, msg_size1
int 80h

mov ecx, 0

;calling sub function read num to read a number
call read_num
mov cx, word[num]
mov word[m], cx

mov eax, 4
mov ebx, 1
mov ecx, msg3
mov edx, msg_size3
int 80h

mov ecx, 0
call read_num
mov cx, word[num]
mov word[n], cx

mov eax, 4
mov ebx, 1
mov ecx, msg2
mov edx, msg_size2
int 80h

;Reading each element of the matrix........
mov eax, 0
```

```
mov ebx, matrix1

mov word[i], 0
mov word[j], 0

i_loop:
mov word[j], 0

j_loop:

call read_num
mov dx , word[num]

;eax will contain the array index and each element is 2 bytes(1 word) long
mov word[ebx + 2 * eax], dx
inc eax   ;Incrementing array index by one....

inc word[j]
mov cx, word[j]
cmp cx, word[n]
jb j_loop

inc word[i]
mov cx, word[i]
cmp cx, word[m]
jb i_loop

;Printing each element of the matrix
mov eax, 0
mov ebx, matrix1

mov word[i], 0
mov word[j], 0

i_loop2:
mov word[j], 0

j_loop2:

;eax will contain the array index and each element is 2 bytes(1 word) long
```

```
mov  dx, word[ebx + 2 * eax]   ;
mov word[num] , dx
call print_num

;Printing a space after each element.....
pusha
mov eax, 4
mov ebx, 1
mov ecx, tab
mov edx, 1
int 80h

popa

inc eax

inc word[j]
mov cx, word[j]
cmp cx, word[n]
jb j_loop2

pusha
mov eax, 4
mov ebx, 1
mov ecx, new_line
mov edx, 1
int 80h

popa

inc word[i]
mov cx, word[i]
cmp cx, word[m]

jb i_loop2

;Exit System Call.....
exit:
mov eax, 1
mov ebx, 0
```

```
int 80h

;Function to read a number from console and to store that in num

read_num:

pusha
mov word[num], 0

loop_read:
mov eax, 3
mov ebx, 0
mov ecx, temp
mov edx, 1
int 80h

cmp byte[temp], 10
je end_read

mov ax, word[num]
mov bx, 10
mul bx
mov bl, byte[temp]
sub bl, 30h
mov bh, 0
add ax, bx
mov word[num], ax
jmp loop_read
end_read:
popa

ret

;Function to print any number stored in num...
print_num:
pusha
extract_no:
cmp word[num], 0
je print_no
inc byte[nod]
```

```
mov dx, 0
mov ax, word[num]
mov bx, 10
div bx
push dx
mov word[num], ax
jmp extract_no

print_no:
cmp byte[nod], 0
je end_print
dec byte[nod]
pop dx
mov byte[temp], dl
add byte[temp], 30h


mov eax, 4
mov ebx, 1
mov ecx, temp
mov edx, 1
int 80h

jmp print_no

end_print:
popa
ret
```

Array / String Operations:

x86 Processors have a set of instructions designed specially to do array / string operations much easily compared with the traditional methods demonstrated above. They are called String Instructions. Even though it is termed as string instructions, it work well with general array manipulations as well. They use index registers(ESI EDI) and increments / decrements either one or both the registers after each operation. Depending on the value of Direction Flag(DF) it either increments or decrements the index register's value. The following instructions are used to set the value of DF manually:

i) CLD - Clears the Direction Flag. Then the string instruction will increment the values of index registers.

ii) STD - Sets the Direction Flag to 1. Then the string instructions will decrement the values of index registers.

NB: Always make sure to set the value of Direction Flags explicitly, else it may lead to unexpected errors.
For string operations we must make sure to have DS to be the segment base of Source string and ES to be the segment base of Destination String. As we are using the protected mode we need not set them manually. But in real mode we have to set the register values to the base address of the suitable segments properly.

(a) Reading an array element to reg(AL/AX/EAX):

LODSx: x = B / W / D - Load String Instruction

This instruction is used to copy one element from an array to the register. It can transfer an element of size 1 Byte / 1 Word / 4 Bytes at a time.

```
LODSB
AL = BYTE[DS:ESI]
ESI = ESI  1

LODSW
AX = WORD[DS:ESI]
ESI = ESI  2

LODSD
EAX= DWORD[DS:ESI]
ESI = ESI  4
```

(b) Storing a reg(AL/AX/EAX) to an array:

```
STOSx:  x = B / W / D - Load String Instruction

This instruction is used to copy one element from a register
to an array.  It can transfer an element of size 1 Byte / 1
Word / 4 Bytes at a time.
```

```
STOSB
byte[ES:EDI] = AL EDI = EDI  1

STOSW
word[ES:EDI] = AX
EDI = EDI  2

STOSD
dword[ES:EDI] = EAX
EDI = EDI  4
```

NB: ESI - Source Index reg is used when the array acts as a source ie. A value is copied from that EDI - Destination Index reg is used when the array acts as a destination ie. A value is copied to that.

Eg: Program to increment the value of all array elements by 1

```
section .data
array1:  db 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

section .text
global_start

_start:
CLD
;Clears the Direction Flag
mov esi, array1
;Copy Base address of array to index registers
mov edi, array1
mov ecx, 10
;No:  of element in the array

increment:
LODSB
INC al
STOSB
loop increment
.................................................
.................................................
.................................................
```

(c) Memory Move Instructions:
These instructions are used to copy the elements of one array/string to another.

MOVSx: x = B / W / D
- Move String Instruction

MOVSB
byte[ES:EDI] = byte[DS:ESI]
ESI = ESI 1
EDI = EDI 1

MOVSW
word[ES:EDI] = word[DS:ESI]
ESI = ESI 2
EDI = EDI 2

MOVSD
dword[ES:EDI] = dword[DS:ESI]
ESI = ESI 4
EDI = EDI 4
Eg: Program to copy elements of an array to another

```
section .data
array1: dd 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

section .bss
array2: resd 10

section .text
global _start

_start:
CLD               ;Clears the Direction Flag

mov  esi, array1    ;Copy Base address of array to index registers
mov edi, array2
mov ecx, 10       ;No: of element in the array
```

```
copy:
MOVSD
loop copy
.....................................................
.....................................................
.....................................................
```

(d) REP - Repeat String Instruction

REP 'string-instruction'

Repeats a string instruction. The number of times repeated is equal to the value of ecx register(just like loop instruction)

Eg: Previous program can also be written as follows using REP instruction:

```
section .data
array1:  dd 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

section .bss
array2:  resd 10

section .text
global_start

_start:
CLD ;Clears the Direction Flag

mov esi, array1
;Copy Base address of array to index registers
mov edi, array2
mov ecx, 10
;No:  of element in the array
REP MOVSD
.....................................................
.....................................................
.....................................................
```

(e) Compare Instructions

CMPSx : x = B / W / D - Compares two array elements and affects

the CPU Flags just like CMP instruction.

CMPSB
Compares byte[DS:ESI] with byte[ES:EDI]
ESI = ESI 1
EDI = EDI 1

CMPSW
Compares word[DS:ESI] with word[ES:EDI]
ESI = ESI 2
EDI = EDI 2

CMPSD
Compares dword[DS:ESI] with dword[ES:EDI]
ESI = ESI 4
EDI = EDI 4

(f) Scan Instructions
SCASx : x = B / W / D - Compares a register(AL/AX/EAX) with an array element and affects the CPU Flags just like CMP instruction.

SCASB
Compares value of AL with byte[ES:EDI]
EDI = EDI 1

SCASW
Compares value of AX with word[ES:EDI]
EDI = EDI 2

SCASD
Compares value of EAX with dword[ES:EDI]
EDI = EDI 4

Eg: Scanning an array for an element

```
section .data
array1:  db 1, 5, 8 , 12, 13, 15, 28 , 19, 9, 11

section .text
global_start
```

```
_start:
CLD ;Clears the Direction Flag
mov edi, array1
;Copy Base address of array to index registers
mov ecx, 10
;No:  of element in the array
mov al, 15
;Value to be searched
scan:
SCASB
je found
loop scan
jmp not_found
```

Floating Point Operations

As in the case of characters, floating point numbers also cannot be represented in memory easily. We need to have some conversion to have a unique numeric representation for all floating point numbers. For that we use the standard introduced by IEEE(Institute of Electrical and Electronics Engineers) called IEEE-754 Standard. In IEEE-754 standard a floating point number can be represented either in Single Precision(4 Bytes) or Double Precision(8 Bytes). There is also another representation called Extended Precision which uses 10 Bytes to represent a number. If we convert a double precision floating point number to a single precision number, the result won't go wrong but it will be less precise.

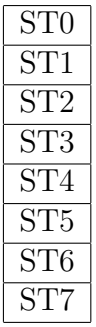
IEEE-754 Standard can be summarized as follows. For further details about this refer some books on Computer Organization / Architecture.

Single Precision	1 bit	8 bits	32bits
Double Precision	1 bit	11 bits	52bits
	S	Exponent	Fraction

S - Sign Bit. If the number is -ve then $S = 1$ else $S = 0$.
The number
$f = (-1)Sx(1 + 0.Fraction) \times 2Exponent - Bias$
$1.0 \leq |Significand| < 2.0$
Bias: 127 for Single Precision
1203 for Double Precision

Floating Point Hardware:
In the early intel microprocessors there were no built in floating point instructions. If we had to do some floating point operations then we had to do that using some software emulators(which will be about 100 times slower than direct hardware) or adding an extra chip to the PC's mother board called math coprocessor or floating

point coprocessor. For 8086 and 8088 the math coprocessor was 8087. For 80286 it was 80287 and for 80386 it was 80387. From 80486DX onwards intel started integrating the math co-processor into the main processor. But still it exists like a separate unit inside the main processor with a separate set of instructions, separate stack and status flags. There hardware for floating point operations are made for even doing operations in extended precision. But if we are using single / double precision numbers from memory it will be automatically converted while storing or loading. There are eight floating point registers called ST0, ST1, ST2....ST7. They are organized in the form of a stack with ST0 in the top. When we push or load a value to the stack, value of each registers is pushed downward by one register. Using these floating point registers we implement floating point operations. There is also a 1 word Status Flag for the floating point operations, which is analogous to the CPU Flags. It contains the status of the floating point operations.



Floating Point Stack

C15	C14	C13	C12	C11	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1	C0

Floating Point Control Word

Floating Point Instructions:

Load / Store Instructions:

FLD src : Loads the value of src on to the top of F.P stack(ie. ST0). src should be either a f.p register or a single precision / double precision / extended precision f.p number in memory.

ST0 = src

FILD src :Loads an integer from memory to ST0. src should be a word / double word / quad word in memory.

ST0 = (float) src

FLD1 :Stores 1 to the top of F.P Stack.

FLDZ :Stores 0 to the top of F.P Stack.

FST dest :Stores ST0 to dest and will not pop off the value from the stack. dest should be a coprocessor register or a single precision / double precision f.p number in memory.

dest = ST0 FSTP dest :Works

FSTP dest :Works similar to FST, it also pops off the value from ST0 after storing.

FIST dest :Converts the number present in the top of f.p stack to an integer and stores that into dest. dest should be a coprocessor register or a single precision / double precision f.p number in memory. The way the number is being rounded depend on the value of coprocessor flags. But default it will be set in such a way that the number in ST0 is being rounded to the nearest integer.

dest = (float)ST0

FISTP dest :Works similar to FIST and it will also pop off the value from top of the stack.

FXCH STn :The nth coprocessor register will be exchanged with ST0. $ST0 \longleftrightarrow STn$

FFREE STn :Frees up the nth coprocessor register and marks it as empty.

Arithmetic Operations:

FADD src : $ST0 = ST0 + src$, src should be a coprocessor register or a single precision / double precision f.p number in memory.

FIADD src :$ST0 = ST0 + (float)src$. This is used to add an integer with ST0. src should be word or dword in memory.

FSUB src : $ST0 = ST0 - src$, src should be a coprocessor register or a single precision/double precision f.p number in memory.

FSUBR src : $ST0 = src - ST0$, src should be a coprocessor register or a single precision /double precision f.p number in memory.

FISUB src :$ST0 = ST0 - (float)src$, this is used to subtract an integer from ST0. src should be word or dword in memory.

FISUBR src : $ST0 = (float)src - ST0$,

FMUL src : $ST0 = ST0 \times src$, src should be a coprocessor register or a single precision /double precision f.p number in memory.

FIMUL src :$ST0 = ST0imes(float)src$, src should be a coprocessor register or a single precision / double precision f.p number in memory.

FDIV src : $ST0 = ST0 \div src$, src should be a coprocessor register or a single precision /double precision f.p number in memory.

FDIVR src : $ST0 = src \div ST0$, src should be a coprocessor register or a single precision /double precision f.p number in memory.

FIDIV src : $ST0 = ST0 \div (float)src$, src should be a word or dword in memory.

FIDIVR src : $ST0 = (float)src \div ST0$, src should be a word or dword in memory.

Comparison Instructions:

The usual comparison instructions FCOM and FCOMP affects the coprocessors status word but the processor cannot execute direct jump instruction by checking these values. So we need to copy the coprocessor flag values to the CPU flags in order to implement a jump based on result of comparison. FSTSW instruction can be used to copy the value of coprocessor status word to AX and then we can use SAHF to copy the value from AL to CPU flags.

FCOM src :Compares src with ST0, src should be a coprocessor register or a single precision / double precision f.p number in memory.

FCOMP src :Works similar to FCOM, it will also pop off the value from ST0 after comparison.

FSTSW src :Stores co-processor status word to a dword in memory or to AX register.

SAHF :Stores AH to CPU Flags.

Eg:

```
fld dword[var1]
fcomp dword[var2]
fstsw
```

```
sahf
ja greater
```

In Pentium Pro and later processors(like Pentium II, III, IV etc) Intel added two other instructions FCOMI and FCOMIP which affects the CPU Flags directly after a floating point comparison. These instructions are comparatively easier than the trivial ones.

FCOMI src :Compares ST0 with src and affects the CPU Flags directly. src must be coprocessor register.

FCOMIP :Compares ST0 with src and affects the CPU Flags directly. It will then pop off the value in ST0. src must be a coprocessor register.

Miscellaneous Instructions:

FCHS : $ST0 = -(ST0)$

FABS : ST0 = —ST0—

FSQRT : $ST0 = \sqrt{ST0}$

FSIN : ST0 = sin(ST0)

FCOS : ST0 = cos(ST0)

FLDPI : Loads value of into ST0

NB: We use C-Functions to read or write floating point numbers from users. We cannot implement the read and write operations with 80h interrupt method easily.

Eg: Program to find the average of n floating point numbers:

```
section .text
global main
extern scanf
extern printf

print:
push ebp
```

```
mov ebp, esp
sub esp, 8
fst qword[ebp-8]
push format2
call printf
mov esp, ebp
pop ebp
ret

read:
push ebp
mov ebp, esp
sub esp, 8
lea eax, [esp]
push eax
push format1
call scanf
fld qword[ebp-8]
mov esp, ebp
pop ebp
ret


main:
mov eax, 4
mov ebx, 1
mov ecx, msg1
mov edx, len1
int 80h

mov eax, 3
mov ebx, 0
mov ecx, temp1
mov edx, 1
int 80h

mov eax, 3
mov ebx, 0
mov ecx, temp2
mov edx, 1
```

```
int 80h

mov eax, 3
mov ebx, 0
mov ecx, temp3
mov edx, 1
int 80h

sub byte[temp1], 30h
sub byte[temp2], 30h
mov al, byte[temp1]
mov bl, 10
mul bl
add al, byte[temp2]
mov byte[num], al
mov byte[ctr], al
mov ah, 0
mov word[num2], ax
fldz


reading:
call read
fadd ST1
dec byte[ctr]
cmp byte[ctr], 0
jne reading
fidiv word[num2]
call print


exit:
mov eax, 1
mov ebx, 0
int 80h

section .data
format1: db "%lf",0
format2: db "The average is : %lf",10
msg1: db "Enter the number of numbers : "
```

```
len1: equ $-msg1

section .bss
temp1: resb 1
temp2: resb 1
temp3: resb 1
num: resb 1
ctr: resb 1
num2: resw 1
```

Reference

(a) PC Assembly Language Tutorial - Dr. Paul Carter

www.drpaulcarter.com/pcasm/

(b) The Art of Assembly Language, 2nd Edition - Randall Hyde

(c) Assembly Language Step-by-Step: Programming with Linux - Jeff Duntemann

(d) The Intel Microprocessors (8th Edition) by Barry B. Brey