(1) Study of Intel 8086 Microprocessor

Aim: To study the given Microprocessor Trainer Kit and to familiarize with the various Hardware and Software specifications

Hardware specifications:

(1) FREQUENCY: CPU gets Clock signal from Clock generator 8284 which uses a quartz Crystal of frequency, 14.318 MHz. Processor Clock frequency = (Crystal frequency)/3 = 14.318/3 = 4.77 MHz. PCLK signal frequency of VXT Bus connector = (4.77 MHz)/2 = 2.385 MHz.

(2) MEMORY:

(a) EPROM:
Intel 2764 (8 KB Chip) – 2 Nos.
Memory Map: F0000 H to F3FFF H (Total 16KB)

(b) SRAM (Static RAM):
6264 (8 KB Chip) – 2 Nos.
Memory Map: 00000 H to 03FFF H (Total 16KB)
User area of RAM - 01000 H to 03FFF H

Memory Usage	Memory storage (capacity)	Memory Map (Linear form)	Memory Map (Segment:Offset form)	Memory Chip used
⋮		FFFFF -- -- F4000	F000:FFFF -- -- F000:4000	(this area is Not Used)
Monitor EPROM	16 KB	F3FFF -- -- F0000	F000:3FFF -- -- F000:0000	EPROM Intel 2764 × 2 Nos. 8K + 8K = 16 KB
		EFFFF -- -- 04000	0000:4000	(this area is Not Used)
User area of RAM	12 KB	**03FFF** -- -- **01000**	**0000:3FFF** -- -- **0000:1000**	SRAM 6264 × 2 Nos. 8K + 8K = 16 KB
System Stack (System Scratch Pad area)	3 KB	00FFF -- -- 00400	0000:0FFF -- -- 0000:0400	
Interrupt Vector Table (IVT)	1 KB	003FF -- -- 00000	0000:03FF -- -- 0000:0000	

16 KB

400H = 1K; 800H = 2K; 1000H = 4K; 2000H = 8K; 4000H = 16K and so on.

(3) INPUT/OUTPUT PERIPHERALS:

Parallel: 48 I/O lines using two numbers of 8255 PPI
Serial: One number of RS232C Serial Interface using 8251 USART *(RS stands for Recommended Standard)*
Timer: 3 Channel 16-bit programmable Timer 8253. Channel 0 is used as baud rate generator for the serial port
Interrupts: 8 Interrupt lines using 8259 Programmable Interrupt Controller

(4) DISPLAY:
20 × 4 Alphanumeric LCD Display

(5) Keyboard: IBM PC-AT Keyboard

(6) On-board Battery Back-up for SRAM: 3.6 V, Ni-Cd cell

(7) Internal Power Supply of the Kit: +5V DC, 3A (regulated)

(8) Mains AC Input: 230 V, 50 Hz AC

(9) BUS Expansion: An expansion Slot called VXT BUS is used in the Kit which facilitates addition of extra hardware on to the Kit. Fully buffered Address bus, Data bus and Control bus are brought out to this expansion bus for interfacing with external devices.

Important Commands and description:

- is the Command Prompt
<cr> - Carriage Return (Enter Key)

1) **Assemble Command:** – will generate op-code from the mnemonic entered
#A <cr>
After entering the 'A' command, the Kit displays: 'Line Assembler'
Then it asks the starting address. Here enter the starting address. It can be any number in the range 1000 to 3FFF (i.e., user area of RAM)

2) **Unassemble (Disassemble) Command:** - will generate mnemonic from the op-code
#U <cr>
After entering the 'U' command, the Kit displays: 'Disassembler'
Then it asks the starting address. Here enter the starting address. It can be any number in the range 1000 to 3FFF (ie, user area of RAM)

3) **Substitute memory Command:** (to modify or view memory content – byte or word)
#SB <addr> <cr> ; view or modify byte
#SW <addr> <cr> ; view or modify word
The address (addr) can be entered in either 'Segment:Offset' form or only 'Offset form'.
Use Enter Key for incrementing memory address
Use – (minus) Key for decrementing memory address
Dot (.) command can be used for terminating a Command and to return to the Command Prompt.

4) **Register view /modify Command:–** to view/modify register contents
#R <cr>

Initial values of Register Contents:
AX = 0000H; BX = 0000H; CX = 0000H; DX = 0000H

SP = 0800H; BP = 0000H; SI = 0000H;; DI = 0000H

CS = 0000H; DS = 0000H; SS = 0000H; ES = 0000H

IP = 1000H; FL = 0000H;

5) **Trace Command (Single step Execution): -** This helps the user to execute programs in steps (i.e., Single step mode)
That is, executing Instruction by Instruction. This is helpful in debugging the programs.
#TR <addr> <cr>
Procedure:

i) Enter the Trace command as above.
ii) Now the first instruction is executed and the registers are automatically updated.
iii) The next instruction to be executed and the memory locations are displayed.
iv) To view the register contents after execution of each instruction, Press the dot (.) key for command termination and to return control to the monitor program. Here type the # R command to view the Register contents, or #SB or #SW command to view the memory contents. Again Press the dot key for command termination and to return control to the monitor program. To continue single step execution, from where it has stopped, enter the Command '#TR' alone, without any argument.

6) **Normal Execution Command: - GO command**
GO command is used to RUN a program. This command transfers control of the CPU from the Monitor program to User Program.
Syntax: **GO <start addr> <cr>**
Procedure:

i) Type GO command and the address from where execution should start.
ii) Now the control is transferred to the User program at the entered address location and the display shows 'Executing …', since the Last Instruction used in the program is **HLT**. Or, equivalently a JMP instruction can be used instead of HLT, which will put the execution in an infinite Loop. For example: HERE: JMP HERE
iii)To Exit from execution and to return control to the monitor program, press **RES** (Reset key) or **INT** (Interrupt key). But in this case the contents of registers will be cleared and hence cannot be observed.

'Dot' command will not work for terminating the execution, in this situation.

<u>Note1</u>: RES Key can also be used for breaking an infinite loop execution. INT key can also be used for Single Step execution
<u>Note2:</u> In the Keyboard, in the case of Keys having two characters written on a Key (for example the #Key), the upper Character is obtained by depressing the Shift Key first, then releasing the finger and then depressing the Character Key. Simultaneous depressing of the Shift Key and the Character Key will not work.

7) **Execution with Break Point: - (ie, GO command with break point)**

Syntax: **GB <start addr> <end addr> <cr>**
When the execution reaches the end address, execution automatically stops and the control is returned to the Command Prompt. Now the register contents can be observed using #R command or the memory contents by the #SB or #SW commands. This command is useful in observing register contents as they are not cleared since we are not using the RES or INT keys for terminating execution in this case.

Aim: To add two 16-bit unsigned integer numbers stored in memory locations and to store the 16-bit sum into memory locations.

Algorithm:

Assumption: It is assumed that the numbers to be added are stored in consecutive memory locations.

Step 1: Start.
Step 2: Initialise a register to hold carry, to zero.
Step 3: Bring the first number from memory into another register
Step 4: Add the second number from memory to the contents of the above register.
Step 5: If a carry is not generated, go to Step 7.
Step 6: Increment the Carry holding register.
Step 7: Store the result of addition into the next consecutive memory location.
Step 8: Store the contents of the Carry holding register into the next memory location.
Step 9: Stop

Assembly language Program:

OFFSET ADDRESS	MACHINE CODE	LABEL	MNEMONICS	COMMENT
1000	C7, C1, 00, 00		MOV CX, 0000H	CX holds the Carry and is initialised to 0.
1004	8B, 06, 00, 12		MOV AX, [1200]	
1008	03, 06, 02,12		ADD AX, [1202]	
100C	73, FE		JNC L1	
100E	41		INC CX	
100F	89, 06, 00, 13	L1:	MOV [1300], AX	
1013	89, 0E, 02, 13		MOV [1302], CX	
1017	F4		HLT	

Sample Input:

First set of data:
NUM1: [1200, 1201] = 1234H
NUM2: [1202, 1203] = 5613H
SUM: [1300, 1301, 1302, 1303] = 0000 6847H

1234 +
5613

00006847

Second set of data:
NUM1: [1200, 1201] = FFFFH
NUM2: [1202, 1203] = FFFFH
SUM: [1300, 1301, 1302, 1303] = 0001 FFFE H

FFFF +
FFFF

0001FFFE

Note 1: **Forward JMP and Forward CALL instructions:** In this case the 'Target Address'. JMP and CALL instructions are not known before hand until we reach the Target address lo To resolve such problem, use the 'Self Address' of the instruction temporarily as the 'target To resolve such problem, use the 'Self Address' by the actual 'Target Address' b and proceed till the end. Later on replace the 'Self Address' by the actual 'Target Address' b the JMP or CALL instructions using the Assemble Command '#A', making use of the act address.

But there is no such problem in the case of Backward JMP and Backward CALL ir

Note 2: The destination Label (ie, the target address) of all Jump instructions must be in the range of -128 bytes (ie,80H) to +127 (ie,7F H) bytes relative to the address of the instruction immediately after the Jump instruction. That is, from the current IP location. The relative address of the current IP location is taken as 00H.

Note 3: While entering mnemonics of instructions, the operands should be separated by comma, without a space. For example, MOV AX,BX (no space permitted between AX and BX). The Hexadecimal numbers can be entered with or with out suffixing of 'H'. For example, MOV AX,1234H or MOV AX,1234 (both are valid Hexadecimal numbers).

2 (b) Subtraction of Two 16-bit numbers

Aim: To subtract two 16-bit unsigned integer numbers stored in memory locations and to store the 16-bit difference into memory locations. Borrow is to be used as a word, indicating the sign (+ or -).

Algorithm:

Assumption: It is assumed that the numbers to be subtracted are stored in consecutive memory locations.

Step 1: Start.
Step 2: Initialise a register to hold borrow, to zero.
Step 3: Bring the first number from memory into another register
Step 4: Subtract the second number from memory from the contents of the above register.
Step 5: If a borrow is not generated, go to Step 8.
Step 6: Increment the Borrow holding register.
Step 7: Take two's complement of the result.
Step 8: Store the result of subtraction into the next consecutive memory location.
Step 9: Store the contents of the Borrow holding register into the next memory location.
Step 10: Stop

Assembly language Program:

OFFSET ADDRESS	MACHINE CODE	LABEL	MNEMONICS	COMMENT
1000			MOV CX, 0000H	CX holds the Borrow and is initialised to 0.
			MOV AX, [1200]	
			SUB AX, [1202]	
			JNB L1	
			INC CX	
			NEG AX	Taking 2's complement
		L1:	MOV [1300], AX	
			MOV [1302], CX	
			HLT	

Sample Input:

First set of data:
NUM1: [1200, 1201] = 5678H
NUM2: [1202, 1203] = 1101H
DIFFERENCE: [1300, 1301, 1302, 1303] = 0000 4577H
(0000 indicates +ve result)

5678 -
1101

00004577

Second set of data:
NUM1: [1200, 1201] = 1101H
NUM2: [1202, 1203] = 5678H
DIFFERENCE: [1300, 1301, 1302, 1303] = 0001 4577H

1101 -
5678

00014577

(0001 indicates -ve result)

3 (a) Addition of Two 64-bit numbers (Multi-byte addition)

Aim: To add two 64-bit unsigned integer numbers stored in memory locations and to store the 80-bit sum into memory locations.

Theory: Here the addition can be done 'byte by byte' or 'word by word' starting from the least significant byte or word. The instruction for addition is ADC, operating on Byte register or Word register. While using ADC the initial Carry should be cleared.

Algorithm:

Assumption: It is assumed that the numbers to be added are stored in consecutive memory locations. Also it is assumed that a Word by Word addition is done.

Step 1: Start.
Step 2: Initialise a register to hold the word count value, to 4. (The preferred register is CX)
Step 3: Clear the Carry flag.
Step 4: Initialise three memory pointer registers to point to the least significant word locations of the First number, the second number and the result location, in memory.
Step 5: Bring the word pointed by the first pointer into a register.
Step 6: Add the word pointed by the second pointer in memory to the contents of the above register using **add with carry** (ADC) instruction. Store the partial result in memory, making use of the corresponding memory pointer.
Step 7: Increment the three memory pointes to point to the next word locations. Decrement the word counter. If the counter value is not zero, go to step 5.
Step 8: Store the Carry generated by the addition of the most significant words, into the result memory locations.
Step 9: Stop

Assembly language Program:

OFFSET ADDRESS	MACHINE CODE	LABEL	MNEMONICS	COMMENT
1000			MOV CX, 0004	CX holds the word count value
			CLC	Initial carry is cleared
			MOV S!, 2000	SI is used as a Memory pointer and is initialized to point to location 2000
			MOV DI, 3000	DI is used as a Memory pointer and is initialized to point to location 3000
			MOV BX, 3500	BX is used as a Memory pointer and is initialized to point to location 3500 (Instead of BX, BP can also be used as a pointer)
		L1:	MOV AX, [SI]	
			ADC AX, [DI]	Do not use ADD instruction (think why?)
			MOV [BX], AX	
			INC SI	
			INC SI	
			INC DI	
			INC DI	
			INC BX	
			INC BX	
			LOOP L1	
			MOV AX,0000	
			ADC AX,0000	
			MOV [BX],AX	Store the carry generated from the addition of the most significant words into memory
			HLT	

(Alternatively, the Last 4 lines of the above can be replaced by):

	MOV AX,0000
	JNC L2
	MOV AX,0001
L2:	MOV [BX],AX
	HLT

Sample Data:

2000

NUM1: [2000-2007] → [SI] 4444 3333 2222 1111 +
NUM2: [3000-3007] → [DI] F987 F678 F345 F123

SUM: [3500-3509] → [BX] 0001 3DCC 29AC 1568 0234

3 (b) Subtraction of Two 64-bit numbers

Aim: To subtract two 64-bit unsigned integer numbers stored in memory locations and to store the 64-bit difference into memory locations.

Algorithm:

Assumption: It is assumed that the numbers to be subtracted are stored in consecutive memory locations. Also it is assumed that a 'Word by Word' subtraction is done and that the Subtrahend is smaller than the Minuend.

Step 1: Start.
Step 2: Initialize a register to hold the word count value, to 4. (The preferred register is CX)
Step 3: Clear the Borrow flag (ie, same as Carry flag)
Step 4: Initialize three memory pointer registers to point to the least significant word locations of the First number, the second number and the result location, in memory.
Step 5: Bring the word pointed by the first pointer into a register.
Step 6: Subtract the word pointed by the second pointer in memory from the contents of the above register using Subtract with borrow instruction. Store the partial result in memory, making use of the corresponding memory pointer.
Step 7: Increment the three memory pointers to point to the next word locations. Decrement the word counter. If the counter value is not zero, go to step 5.
Step 8: Stop

OFFSET ADDRESS	MACHINE CODE	LABEL	MNEMONICS	COMMENT
1000			MOV CX, 0004	CX holds the word count value
			CLC	
			MOV SI, 2000	SI is used as a Memory pointer and is initialized to point to location 2000
			MOV DI, 3000	DI is used as a Memory pointer and is initialized to point to location 3000
			MOV BX, 3500	BX is used as a Memory pointer and is initialized to point to location 3500 (Instead of BX, BP can also be used as a pointer)
		L1:	MOV AX, [SI]	
			SBB AX, [DI]	

			MOV [BX], AX	
			INC SI	
			INC SI	
			INC DI	
			INC DI	
			INC BX	
			INC BX	
			LOOP L1	
			HLT	

Sample Data:

NUM1: [2000-2007] → [SI]   F987 F678 F345 F123 -
NUM2: [3000-3007] → [DI]   4444 3333 2222 1111

Difference: [3500-3507] → [BX]   B543 C345 D123 E012

CODE CONVERSIONS

[Note: Read Chapter 10 (Code conversion) of Microprocessor Architecture, Programming and Applications with 8085 by Ramesh Gaonkar, for understanding the need for Code conversions and the algorithms]

The need for Code conversion

In microcomputer applications, various number systems and codes are used to input data or to display results. The ASCII (American Standard Code for Information Interchange) keyboard is a commonly used input device for microcomputers. Similarly, alphanumeric characters (letters and numbers) are displayed on a display device using the ASCII code. However, inside the microprocessor, data processing is usually performed in binary. In some instances, arithmetic operations are performed in BCD numbers. Therefore data must be converted from one code to another code.

The programming techniques used for code conversion fall into four general categories:

(i) Conversion based on the position of a digit in a number (eg. BCD to binary and Binary to BCD conversions).
(ii) Conversion based on sequential order of digits (eg, Binary to ASCII and ASCII to binary).
(iii) Conversion based on hardware consideration (eg, Binary to 7-segment code using table look-up procedure).

4 (a) BCD to Binary Conversion

Aim: To convert the given two digit packed BCD number to its equivalent binary number.

Theory: BCD represents each of the digits of an unsigned decimal as the 4-bit binary equivalents. Unpacked BCD representation contains only one decimal digit per byte. The digit is stored in the lower nibble; the upper nibble in not relevant to the value of the represented number (usually the upper nibble is zero). Packed BCD representation packs two decimal digits into a single byte.

Decimal	Binary	BCD	
		Unpacked	Packed
0	0000 0000	0000 0000	0000 0000
1	0000 0001	0000 0001	0000 0001
2	0000 0010	0000 0010	0000 0010
8	0000 1000	0000 1000	0000 1000
9	0000 1001	0000 1001	0000 1001
10	0000 1010	0000 0001 0000 0000	0001 0000
11	0000 1011	0000 0001 0000 0001	0001 0001
12	0000 1100	0000 0001 0000 0010	0001 0010
19	0001 0011	0000 0001 0000 1001	0001 1001
20	0001 0100	0000 0010 0000 0000	0010 0000

Invalid BCD Numbers

These binary numbers are not allowed in the BCD code: `1010, 1011, 1100, 1101, 1110, 1111`

The conversion uses the principle of positional weighting in a number. To convert a 2-digit packed BCD number into its equivalent binary, first the digits are to be separated into MSD and LSD and then each digit is multiplied by its position value (place value) and added together.

ie, Binary equivalent = MSD × 0AH + LSD

Algorithm:

1) Start
2) Get the BCD number from memory and store it in a register.
3) Separate the LSD of the two-digit packed BCD number (ie, unpack the packed BCD) by ANDing (masking) the packed BCD number with 0FH.and storing it in a register.
4) Separate the MSD of the packed BCD number by ANDing (masking) the packed BCD number with F0H.and shifting the bits 4 times to the right to get the MSD. Multiply the MSD by the place value 10 (0AH).
5) Add the Product obtained by multiplication in step 3, with the LSD obtained in step 2
6) Stop

✓

ALP

OFFSET ADDRESS	MACHINE CODE	LABEL	MNEMONICS	COMMENT
1000			MOV BX,1100	BX is used as a memory pointer and is initialized to point to location 1100
			MOV AL,[BX]	
			MOV DL,AL	Value in AL is copied to DL
			AND DL,0F	Now DL contains LSD
			AND AL,0F0	
			MOV CL,04	
			ROR AL,CL	Now AL contains MSD
			MOV DH,0A	
			MUL DH	(AX) ← (AL) × (DH) Now AX contains MSD×0A AH will be zero always, because the maximum value possible is 09×0A which is 5A
			ADD AL,DL	Since AH is zero
			MOV [BX+1],AL	
			HLT	

Input and Output:

First Set of Data:

Input: [1100] = 72 (BCD)
Output: [1101] = 48 (Binary in HEX)

Second set of Data:

Input: [1100] = 99 (BCD)
Output: [1101] = 63 (Binary in HEX)

✓

4 (b) Binary to BCD Conversion

Aim: To convert an 8-bit Binary number to its BCD equivalent.

Theory: An 8-bit unsigned binary number has the range from 00H to FF H. Its BCD equivalent number has the range from 00 to 255 (packed BCD). BCD equivalent number is obtained from the 8-bit binary number by finding the number of 100s (ie, 64Hs), 10s (ie, 0AHs) and 1s (01Hs). Let the most significant digit be BCD_3, the middle digit be BCD_2 and the least significant digit be BCD_1

Algorithm:

1) Start
2) If the binary number is less than 64H (ie, 100dec), go to Step 3; otherwise, divide the binary number by 64H or equivalently, subtract 64H repeatedly until the remainder is less than 64H. The quotient of division is the most significant BCD digit, BCD_3. (It is the same as the number of times the repeated subtraction is done).
3) If the binary number is less than 0AH (ie, 10dec), go to Step 4; otherwise, divide the binary number by 0AH or equivalently, subtract 0AH repeatedly until the remainder is less than 0AH. The quotient of division is the middle BCD digit, BCD_2. (It is the same as the number of times the repeated subtraction is done).
4) The remainder from Step 3 is the least significant BCD digit, BCD_1.
5) Store the three BCD digits obtained in steps 2, 3 and 4 in consecutive memory locations as either (i) unpacked BCD digit for the MSD and two-digit packed BCD digits for the LSD and Middle digit or (ii) three unpacked BCD digits, BCD_3, BCD_2, BCD_1 (This is better).
6) Stop

OFFSET ADDRESS	MACHINE CODE	LABEL	MNEMONICS	COMMENT
1000			MOV BX,2000	BX is used as a memory pointer and is initialized to point to location 2000
			MOV AL,[BX]	
			MOV DX,0000	DX holds the BCD digits
		HUND:	CMP AL,64	Comparison is done by subtraction
			JC TEN	
			SUB AL,64	
			INC DL	DL holds the number of times subtraction is done (ie, 100s)
			JMP HUND	
		TEN:	CMP AL,0A	
			JC UNIT	
			SUB AL,0A	The last subtraction gives BCD1 in AL.
			INC DH	DH holds the number of times subtraction is done (ie, 10s)
			JMP TEN	
		UNIT:	MOV CL,04	
			ROR DH,CL	ROR 4 times, will swap nibbles in a byte or swap bytes in a word. 10s in DH is moved to High Nibble and added to Units.
			ADD AL,DH	
			MOV [BX+1],AL	
			MOV [BX+2], DL	
			HLT	

Input Data:	Output Result
(2000) = FE	(2001) = 54 (Packed BCD)
	(2002) = 02 (Most significant digit as unpacked BCD)

(But display of 05, 04, 02 is better)

✓

4 (c) HEX digit to ASCII code Conversion

Aim: To convert a given Hexadecimal digit (ie, 0, 1,…9, A, B, C, D, E, F) into its equivalent ASCII code in Hex.

Theory:
Each HEX digit can be converted to an 8-bit ASCII code as shown below. For HEX digit in the range 0 to 9, add 30 to get the ASCII code. For HEX digit in the range A to F, add 37 (ie 30+7) to get the ASCII code.

HEX digit	ASCII Code in HEX	
0	30	Here the difference between the two is **30** (For example, 32-2 = 30)
1	31	
2	32	
3	33	
4	34	
5	35	
6	36	
7	37	
8	38	
9	39	
..	..	
..	..	
A	41	Here the difference between the two is **37 (ie, = 30 + 7)** (For example, 41 - A = 37)
B	42	
C	43	
D	44	
E	45	
F	46	

Algorithm:
1) Start
2) Compare the given HEX digit with '0A'. If it is less than 0A, add 30 to it and Go to step 4.
3) Else, add 30 and 7 to it.
4) Stop

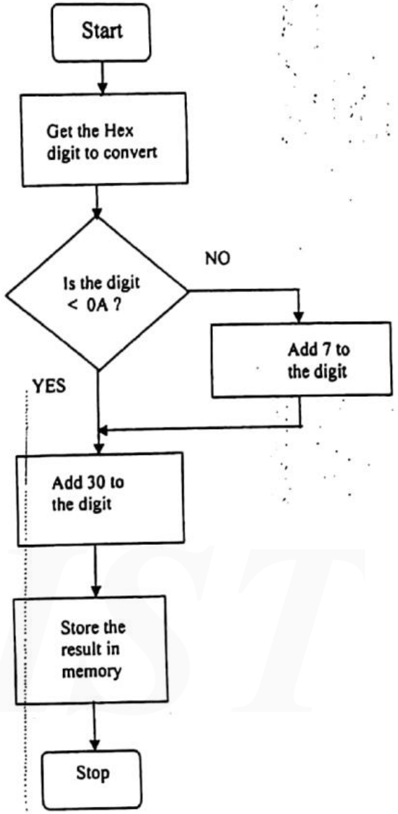
<u>Input Data (HEX digit):</u> <u>Output Result (ASCII code in HEX):</u>

First sample of data:
(2000) = 07 (2001) = 37H

Second sample of data:
(2000) = 0B (2001) = 42H

✓

FLOW CHART:



OFFSET ADDRESS	MACHINE CODE	LABEL	MNEMONICS	COMMENT
1000			MOV SI, 3000H	SI pointer initialized to point to the data location.
			MOV AL,[SI]	
			SUB AL,30H	
			CMP AL,0AH	
			JC L1	
			SUB AL,07H	
		L1:	MOV [SI+1],AL	
			HLT	

Input Data:	Output Result (HEX value)
First sample data: (3000) = 33H	(3001) = 03H
Second sample data: (3000) = 42H	(3001) = 0BH

5 (a) BCD addition

Aim: To add two 4-digit (16-bit) BCD numbers stored in memory

Theory: The 8086 processor will perform only binary addition. Hence for BCD addition, the binary addition of BCD data is performed first and then the Sum is corrected to get the result in BCD. The following is the correction to be done:

(iv) If the binary sum of lower nibbles of the BCD numbers stored in AL, exceeds 9 or if there is an Auxiliary carry generated from the lower nibble to the upper nibble of the Sum in AL, then 06 is added to the lower nibble of the Sum in AL.

(v) If the binary sum of upper nibbles of the BCD numbers stored in AL, exceeds 9 or if there is a Carry generated from the upper nibble of the Sum in AL, then 60 is added to the Upper nibble of the Sum in AL.

The correction is automatically done using the DAA instruction.

DAA instruction: Decimal Adjust AL after BCD addition. DAA works on 8-bit only. The result of the addition must be in AL for DAA to work correctly.

Algorithm:

1. Start
2. Get the BCD numbers from the memory locations.
3. Add the lower two digits of the 4-digit BCD numbers and adjust for correction using DAA instruction.
4. Add the upper two digits of the 4-digit BCD numbers along with Carry, if any, generated from Step 3 and adjust for correction using DAA instruction.
5. Store the BCD sum and the final Carry in memory locations
6. Stop

OFFSET ADDRESS	MACHINE CODE	LABEL	MNEMONICS	COMMENT
1000			MOV SI,2000H	SI pointer initialized to point to the data location.
			MOV CL,00H	To hold the final carry (initialised to 0)
			MOV AX,[SI]	
			MOV BX,[SI+2]	
			ADD AL,BL	
			DAA	
			MOV DL,AL	
			MOV AL,AH	
			ADC AL,BH	
			DAA	
			MOV DH,AL	
			JNC L1	
			INC CL	
		L1:	MOV [SI+4],DX	
			MOV [SI+6],CL	
			HLT	

Input Data:

BCD NUM1: [2000-2001]: 1245

BCD NUM2: [2002-2003]: 9566

```
 1245 +
 9566
------------
010811
-----------
```

Output Result:

BCD SUM: [2004-2005]: 0811
[2006]: 01

5 (b) BCD subtraction

Aim: To subtract two 4-digit (16-bit) BCD numbers stored in memory

Theory: The 8086 processor will perform only binary subtraction. Hence for BCD subtraction, the binary subtraction of BCD data is performed first and then the Difference is corrected to get the result in BCD. The following is the correction to be done:

(i) If the binary difference of lower nibbles of the BCD numbers stored in AL, exceeds 9 or if there is an Auxiliary carry generated from the lower nibble to the upper nibble of the difference in AL, then 06 is subtracted from the lower nibble of the Difference in AL.

(ii) If the binary difference of upper nibbles of the BCD numbers stored in AL, exceeds 9 or if there is a Carry generated from the upper nibble of the Difference in AL, then 60 is subtracted from the Upper nibble of the Difference in AL.

The correction is automatically done using the DAS instruction.

DAS instruction: Decimal Adjust AL after BCD subtraction. DAS works on 8-bit only. The result of the subtraction must be in AL for DAS to work correctly.

Algorithm:

1. Start
2. Get the BCD numbers from the memory locations.
3. Subtract the lower two digits of the 4-digit BCD numbers and adjust for correction using DAS instruction.
4. Subtract the upper two digits of the 4-digit BCD numbers along with Borrow, if any, generated from Step 3 and adjust for correction using DAS instruction.
5. Store the BCD difference and the final Carry (borrow) in memory locations
6. Stop

OFFSET ADDRESS	MACHINE CODE	LABEL	MNEMONICS	COMMENT
1000			MOV SI,2000H	SI pointer initialized to point to the data location.
			MOV CL,00H	To hold the final carry (initialised to 0)
			MOV AX,[SI]	
			MOV BX,[SI+2]	
			SUB AL,BL	
			DAS	
			MOV DL,AL	
			MOV AL,AH	
			SBB AL,BH	
			DAS	
			MOV DH,AL	
			JNC L1	
			INC CL	
		L1:	MOV [SI+4],DX	
			MOV [SI+6],CL	
			HLT	

Input Data:

BCD NUM1: [2000-2001]: 9123H

BCD NUM2: [2002-2003]: 7368H

9123 -
7368

001755

Output Result:

BCD Difference: [2004-2005]: 1755
[2006]: 00

Study of MASM and Debug commands and usage of CodeView debugger

Microsoft Macro Assembler **masm.exe** is used for assembling an 8086 assembly language program. The other files associated with it are **link.exe** (linker program), **ml.exe** and **ml.err**. For debugging and execution, a DOS debugger, **debug.exe** or Microsoft debugger **cv.exe** (CodeView) is used. The assembler version used is ver 6.11 and CodeView version used is ver 3.14. DOS debugger gives a command line interface whereas CodeView debugger gives an IDE interface (Integrated Development Environment).

Configuration of Path setting:

Store the files **masm.exe, link.exe, ml.exe, ml.err, debug.exe, cv.exe** and **cv.hlp** in a folder (named say, masm) and the folder is placed in a drive (for example under c:\.) The absolute path of this folder is included in the path statement as follows for gaining universal access to the above files from any location (in any drive).

My Computer → Properties →Advanced → Environment Variables → System variables → Path → Edit → Edit System variables → Variable value →
Here add, after semi colon, the absolute path of the 'masm' folder, after the last entry in the path statement.
For example **;c:\masm** Click **ok, ok, ok.** (take care not to delete the existing path-do only append).

Alternatively, the above 7 files may be copied in to the 'Current folder' where user programs are stored. But in this case, universal access of 'masm' files are not obtained.

Creating Source file and Assembling:

Create an 8086 ALP source file with extension **.asm** using any text editor such as notepad, edit.com, Norton editor, wordpad etc. The file name should not exceed 8 characters in length and file extension is 3 characters.
Go to the DOS command prompt. In Windows XP: start → run → cmd
Now a default folder is displayed. (For example: c:\Documents and settings\Prog>). Under this folder create a user folder to store the user files namely: **.asm, .lst, .obj and .exe files.**
For assembling the source file, use the following command:
If the source file is **add.asm,** type the command as:

```
c:\ ...\user> masm.exe  /la  add.asm
```

(here **.exe** extension and .asm extension are optional) (/la means list all)
(That is, you can even type: c:\...\user>masm /la add)
This will assemble the source file and generate two files: **add.lst** and **add.obj**
(Note: For exiting from DOS Command Window, use 'exit' command)
The **command summary** of masm can be obtained by the command: **masm /?**
Usage: masm /options source(.asm),[out(.obj)],[list(.lst)],[cref(.crf)][;]

```
/c                Generate cross-reference
/D<sym>[=<val>] Define symbol
/e                Emulate floating point instructions and IEEE format
/I<path>          Search directory for include files
/l[a]             Generate listing, a-list all
/M{lxu}                   Preserve case of labels: l-All, x-Globals, u-Uppercase Globals
/n                Suppress symbol tables in listing
/t                Suppress messages for successful assembly
/w{012}                   Set warning level: 0-None, 1-Serious, 2-Advisory
/X                List false conditionals
/Zi               Generate symbolic information for CodeView
/Zd               Generate line-number information
```

Linking the .obj file, debugging and running the .exe file:

Type the command as:

```
c:\ ...... \user> link.exe  add.obj
```

(here **.exe** extension and .obj extension are optional)

✓

(That is, you can even type: c:\...\user>link add)
If a semicolon is typed after .obj the prompt options will not be asked.
ie., type c:\ ... \user> **link add;**
Here, **add.exe** file is created.

Since .exe files are self executing files, the file name can be given as a dos command in the dos command prompt for running the program and for observing the result. (note:- if a display routine is written in the main program a display can be seen in the screen – other wise nothing can be seen).

Alternatively, the **.exe** file can be loaded into memory, debugged and executed using DOS debugger (debug.exe) or Microsoft debugger cv.exe (CodeView).

CodeView Debugger:

Microsoft debugger **CodeView** (cv.exe) (version 3.14) can be used for loading the .exe file to memory, debugging and executing. CodeView gives an IDE interface (Integrated Development Environment) and is a better debugger than DOS debugger **debug.exe.**

Usage: c:\ ...\user> **cv.exe add.exe** (.exe extension of cv and add are optional)
(That is, you can even type: c:\...\user>cv add). In the CV Window, go to the 'Run' menu, click 'Restart' and then click 'Animate' for running the Program.
The **Result** of execution can be observed in Memory by typing the following command in the CV command prompt: For example: **> d ds: 0 8** (where 8 is the no. of bytes 'n' to be displayed).

DOS Debugger:

Alternatively, DOS Debugger can also be used.
Type the command as:

```
c:\ ... \user> debug.exe    add.exe
```

(here .exe extension of debug is optional)

(That is, you can even type: c:\...\user>debug add.exe)

Now the debug command prompt, hyphen, is displayed.
The debug command summary is obtained by: **-?**
To execute the user program **add.exe,** give the debug command as:
- g = 0000 xxxx where 0000 is the starting offset address and xxxx denotes the ending offset address. The ending offset address (which is a break point) can be obtained from the offset address of the MOV AH, 4CH instruction displayed in the .lst file. The result of execution can be observed in **memory** by the debug command: **-d ds:0000** (if no ending offset address is given, 128 bytes will be displayed by default). The result of execution can also be observed in **registers** using the debug command **–r.**
(Note: For exiting from DOS Debugger Window, use 'q' command (quit))

Example:

(1) To add two 16-bit unsigned numbers stored in memory and to get the 32-bit sum in memory:
add.asm

```
.MODEL SMALL
.STACK 1000H
```

These dot directives define the stack segment. This will avoid the warning indication namely, "Warning: no stack segment" during the Linking process.
These are not absolutely necessary.

```
          ;Logical Data  Segment DATA1 begins
DATA1          SEGMENT
  NUM1         DW 1234H   ;DW is a directive to tell the assembler to reserve two successive memory
                          ; locations for a word type variable, to store the values in those memory
                           ; locations and to assign the name NUM1 to the first memory location.ie The
                   ; First byte. NUM1 can be considered as an array of one word.
  NUM2         DW 0F562H  ; Pre-fix 0 for hexadecimal numbers starting with A to F.
```

✓

```
SUM        DW 2 DUP(0) ; Sets aside storage for two words in memory and assigns the name SUM to the
DATA1      ENDS        ;first memory location. The DUP(0) part initializes the two words to all zeros.

;Logical Code Segment CODE1 begins

CODE1      SEGMENT
           ASSUME  CS:CODE1, DS:DATA1 ;It is a directive to tell the assembler to use a logical
;segment named CODE1 as the Physical Code Segment and to use a logical segment named DATA1
      as the Physical Data Segment for the user's program
    START: MOV AX, DATA1  ;To initialize the Data Segment register DS. Segment Registers cannot be
           MOV DS, AX     ;directly loaded with an immediate number. The number is to  be loaded
                          ; first to a general purpose register and then from that register
                          ;to the Segment register. DS holds the upper 16-bit of the Base Address
                          ;(ie, the upper 16-bit of the Starting address of the physical Data Segment).
           MOV CX, 0000H ; Initializes the Carry holding register
           MOV AX, NUM1
           ADD AX, NUM2
           JNC L1
           INC CX
    L1:    MOV SUM, AX
           MOV SUM+2,CX

           MOV AH, 4CH    ;DOS function Call to terminate the execution of the user program and to exit
           INT 21H        ;to DOS command prompt

CODE1      ENDS
           END START     ; END directive indicates end of assembly.
```

```
     1234 H +
     F562 H
---------------------
0001 0796 H (32-bit sum)
```

```
         eg.  ADD AX, NUM2
(AX) ← (AX) + NUM2  (symbolic illustration)
```

Syntax of ADD instruction: **ADD <destination>, <source>**
where destination is a register or a memory location specified in one of 24 different ways and source is an immediate number or a register or a memory location specified in one of 24 different ways. Destination and Source cannot be both memory locations in the same instruction.

Syntax of MOV instruction: **MOV <destination>, <source>**
where destination is a register or a memory location specified in one of 24 different ways and source is an immediate number or a register or a memory location specified in one of 24 different ways. Destination and Source cannot be both memory locations in the same instruction.

8086 FLAGS			
FLAGS	**Name**	**SET symbol (flag value= 1)**	**CLEAR (RESET) symbol (flag value= 0)**
OF	Overflow Flag	OV (overflow)	NV (not overflow)
DF	Direction Flag	DN (down)	UP
IF	Interrupt Flag	EI (enable interrupt)	DI (disable interrupt)
TF	Trap Flag	-	-
SF	Sign Flag	NG (negative)	PL (positive)
ZF	Zero Flag	ZR (zero)	NZ (not zero)
AF	Auxiliary Carry Flag	AC	NA
PF	Parity Flag	PE	PO
CF	Carry Flag	CY (carry)	NC (no carry)

<u>NOTE:</u>

```
Augend +        Minuend -
Addend          Subtrahend
----------      ----------
Sum             Difference
```

✓

24 Different ways of specifying Memory Locations

Only, index registers **SI** and **DI** and base registers **BX** and **BP** can be used as memory pointers.

Column 1	Column 2	Column 3
[BX]+[SI]	Column 1 + d8	Column 1 + d16
[BX]+[DI]	Column 1 + d8	Column 1 + d16
[BP]+[SI]	Column 1 + d8	Column 1 + d16
[BP]+[DI]	Column 1 + d8	Column 1 + d16
[SI]	Column 1 + d8	Column 1 + d16
[DI]	Column 1 + d8	Column 1 + d16
[d16]	[BP] + d8	[BP] + d16
[BX]	Column 1 + d8	Column 1 + d16

<u>Note1:</u> No stack segment is defined in the above program and is left out because DOS automatically allocates a 128-byte stack for all programs. The Linker program indicates a warning message saying that <u>no stack is present.</u> The instruction that uses stack in the program is INT 21H which Calls a procedure in DOS. This warning can be ignored because the Stack memory used here is fewer than 128 bytes.

<u>Note2:</u> **<u>Signed 8-bit numbers and Overflow Flag:</u>**
D7 is the sign bit. D7 is zero for positive numbers and D7 is 1 for negative numbers. The magnitude of negative number is represented in 2's complement form (ie for D6 to D0 bits). Consider 3 Cases:

Case1:

```
  +96 (dec)      +60(hex)      0 110 0000 (binary)
  +70 (dec)      +46 (hex)     0 100 0110 (binary)
 -----------    -----------   ---------------------
 +166 (dec)      +A6 (hex)     1 010 0110 (binary)
                               D7         D0
```

Here, since D7 is 1, the magnitude of the result (ie, D6 to D0 bits) is in 2's complement form. ie, D6 to D0 namely, 010 0110 is in 2's complement form. To get the answer, take 2's complement of the magnitude. We get 101 1010 . ie 5A or 90 dec. That is, the answer is -90 dec which is Incorrect. Therefore the overflow flag OV is Set to 1.

Case2:

```
 -128 (dec)      -80(hex)      1 000 0000 (binary)
   -2 (dec)      - 2 (hex)     0 000 0010 (binary)
 -----------    -----------   ---------------------
 -130 (dec)      -82 (hex)     1 000 0010 (binary)
                               D7         D0
```

Here, since D7 is 1, the magnitude of the result (ie, D6 to D0 bits) is in 2's complement form. ie, D6 to D0 namely, 000 0010 is in 2's complement form. To get the answer, take 2's complement of the magnitude. We get 000 0011 . ie 03 or 3 dec. That is, the answer is -3 dec which is Incorrect. Therefore the overflow flag OV is Set to 1.

Case3:

```
  -2 (dec)       -2(hex)       1 000 0000 (binary)
  -5 (dec)       -5(hex)       0 000 0010 (binary)
 -----------    -----------   ---------------------
  -7 (dec)       -7 (hex)      1 000 0010 (binary)
                               D7         D0
```

Here, since D7 is 1, the magnitude of the result (ie, D6 to D0 bits) is in 2's complement form. ie, D6 to D0 namely, 000 0010 is in 2's complement form. To get the answer, take 2's complement of the magnitude. We get 000 0011 . ie 03 or 3 dec. That is, the answer is -3 dec which is Incorrect. Therefore the overflow flag OV is Set to 1.

<u>Question:</u> When is the Oveflow Flag Set to 1? It will be Set to 1, if there is a Carry from D6 to D7 or from D7, but not from both.

✓

Contents of the List file **add.lst**

```
Microsoft (R) Macro Assembler Version 6.11                01/14/10 15:51:40
add.asm                                                   Page 1 - 1

0000                           DATA1        SEGMENT
0000 1234                            NUM1   DW 1234H
0002 F562                            NUM2   DW 0F562H
0004  0002 [                         SUM    DW 2 DUP(0)
       0000
     ]
0008                           DATA1        ENDS

0000                           CODE1        SEGMENT
                                            ASSUME CS:CODE1, DS:DATA1

0000  B8 ---- R                START: MOV AX, DATA1
0003  8E D8                                 MOV DS, AX

0005  B9 0000                               MOV CX, 0000H
0008  A1 0000 R                      MOV AX, NUM1
000B  03 06 0002 R                          ADD AX, NUM2
000F  73 01                                 JNC L1
0011  41                                    INC CX
0012  A3 0004 R                 L1:  MOV SUM, AX
0015  89 0E 0006 R                          MOV SUM+2, CX

0019  B4 4C                                 MOV AH, 4CH
001B  CD 21                                 INT 21H

001D                           CODE1        ENDS
                                            END START

Microsoft (R) Macro Assembler Version 6.11                01/14/10 15:51:40
add.asm                                                   Symbols 2 - 1
```

'R' stands for Re-locatable address which Linker program must resolve.

```
Segments and Groups:

          N a m e          Size    Length  Align  Combine Class

CODE1 . . . . . . . . .   16 Bit   001D    Para    Private
DATA1 . . . . . . . . .   16 Bit   0008    Para    Private


Symbols:

          N a m e          Type    Value   Attr

L1 . . . . . . . . . . .  L Near   0012    CODE1
NUM1 . . . . . . . . . .  Word     0000    DATA1
NUM2 . . . . . . . . . .  Word     0002    DATA1
START . . . . . . . . . . L Near   0000    CODE1
SUM . . . . . . . . . . . Word     0004    DATA1

           0 Warnings
           0 Errors
```

✓

---

(2) To subtract two 16 bit unsigned numbers stored in memory and to get the 32 bit difference in memory, the high order word being a sign indicator

```
;sub.asm

DATA1 SEGMENT
        NUM1    DW    1243H
        NUM2    DW    0F231H
        DIFF    DW    2 DUP(0)
DATA1 ENDS


CODE1 SEGMENT
        ASSUME        CS:CODE1, DS:DATA1
START: MOV AX, DATA1
        MOV DS, AX
        MOV CX, 0000H; CX holds borrow
        MOV AX, NUM1
        SUB AX, NUM2
        JNC L1
        INC CX
        NEG AX   ; it takes the 2's complement of the difference, if the result if negative.
   L1:  MOV DIFF, AX
        MOV DIFF+2, CX

        MOV AH, 4CH
        INT 21H

CODE1 ENDS
        END START
```

Syntax: SUB <destination>, <source>

(a reg)
or
(a mem. loc.)

(an immediate number)
or
(a reg)
or
(a mem. loc.)

Destination and Source cannot be both memory locations in the same instruction.

SUB AX, NUM2
(AX) ← (AX) - NUM2

```
   1243 H -
   F231 H
---------
   2012 H
```

(the result is a negative number in 2's complement form - taking 2's complement of the result gives the actual answer – 2's complement of 2012 gives DFEE – the borrow flag (ie, carry flag) = 1, is a sign indicator. The actual answer can also be obtained by doing the subtraction 'Larger number' minus 'Smaller number' and prefixing a minus sign. ie, F231 – 1243 → – DFEE

;(3) To multiply two 16 bit unsigned numbers stored in memory and to get the 32 bit product in memory

```
;mul.asm

DATA1 SEGMENT
        MULTIPLICAND DW   204AH
        MULTIPLIER   DW   3B2AH
        PRODUCT      DW   2 DUP(0)
DATA1 ENDS


CODE1 SEGMENT
        ASSUME  CS:CODE1, DS:DATA1
START: MOV AX, DATA1
        MOV DS, AX
        MOV AX, MULTIPLICAND
        MUL MULTIPLIER
        MOV PRODUCT, AX
        MOV PRODUCT+2, DX

        MOV AH, 4CH
        INT 21H

CODE1 ENDS
        END START
```

Syntax: MUL <source> {byte×byte or word×word multiplication}

(Source is the multiplier which is a byte or a word in a reg)
or
(is the multiplier which is a byte or a word in a mem. Loc.)

Product ← Multiplicand × Multiplier
For Byte × Byte multiplication, the Multiplicand is in AL and the product is in AX by dafult. For Word × Word multiplication, the Multiplicand is in AX and the product is in DX AX by default.
Eg,

```
      204A H ×
      3B2A H
-------------
 0776 5A24 H
```

✓

;(4)word by byte division

```
DATA            SEGMENT
     DIVIDEND   DW 75A5H
      DIVISOR   DB 7FH
     QUOTIENT   DB 1 DUP(0)
   REMAINDER    DB 1 DUP(0)
DATA            ENDS


CODE            SEGMENT
                ASSUME CS:CODE, DS:DATA
        START:  MOV AX, DATA
                MOV DS, AX

                MOV AX, DIVIDEND
                DIV DIVISOR

                MOV QUOTIENT, AL
                MOV REMAINDER, AH


                MOV AH, 4CH
                INT 21H

CODE            ENDS
                END START
```

Syntax: DIV <source> {word+byte or doubleword+word division is performed}

(source is the divisor which is a byte or a word in a reg)
or
(a byte or a word in a mem. Loc.)

```
 Word in AX (dividend)
---------------------------     → Quotient in AL
Byte in Source (divisor)      and Remainder in AH

DoubleWord in DX AX (dividend)
-------------------------------    → Quotient in AX
Word in Source (divisor)          and Remainder in DX
```

```
Example (word by byte division):
75A5 H
--------
  7F H

Q=ED H =(AL)
R=12 H = (AH)
```

;(5) double word by word division

```
DATA            SEGMENT
     DIVIDEND   DD 0CF7564CH
       DIVISOR  DW 3567H
     QUOTIENT   DW 1 DUP(0)
   REMAINDER    DW 1 DUP(0)
DATA            ENDS


CODE            SEGMENT
                ASSUME CS:CODE, DS:DATA
       START:   MOV AX, DATA
                MOV DS, AX

                MOV AX, WORD PTR DIVIDEND ;PTR will override the type declaration specified earlier
                MOV DX, WORD PTR DIVIDEND+2
                DIV DIVISOR

                MOV QUOTIENT, AX
                MOV REMAINDER, DX


                MOV AH, 4CH
                INT 21H

CODE            ENDS
                END START
```

```
Example (Doubleword  by  Word division):
0CF7564C H
------------         Q = 3E28 H  = (AX)
 3567 H              R = 0C34 H  = (DX)
```

✓

;(6) To display the message 'Welcome to MBCET, Thiruvananthapuram' on the display monitor
;disp.asm

```
DATA1 SEGMENT
        MSG  DB  'Welcome to MBCET, Thiruvananthapuram$'      ; here $ functions as a string terminator
DATA1 ENDS


CODE1 SEGMENT
        ASSUME   CS:CODE1, DS:DATA1
START: MOV AX, DATA1
        MOV DS, AX

        MOV AH, 09H           ; DOS function call for displaying a string on the screen. AH reg. is to be preloaded
        MOV DX, OFFSET MSG    ;with 09H and DX reg is to be preloaded with the offset address of the First Byte of
        INT 21H               ;the string

        MOV AH, 4CH            ; DOS function Call to terminate the execution of the user program and to exit
        INT  21H               ;to DOS command prompt

CODE1  ENDS
        END START      ;Note: Here, to display the string, run the .exe file as a command in the DOS command prompt.
```

;(7) To move a string from a source location to a destination location, skipping over 100 bytes of memory locations
;movestr.asm

```
DATA1                 SEGMENT
          SRC_STR     DB  'Mar Baselios Engineering College'
          STR_LENGTH  EQU  ($ - SRC_STR)
                       DB    100 DUP(?) ;here a name can be
                                         ;given such as SKIP_LOC

          DST_STR      DB   STR_LENGTH DUP(0)
DATA1                  ENDS


CODE1 SEGMENT
          ASSUME   CS:CODE1,  DS:DATA1, ES:DATA1
START: MOV AX, DATA1
          MOV DS, AX
          MOV ES, AX
          LEA SI, SRC_STR
          LEA DI, DST_STR
          MOV CX, STR_LENGTH
          CLD
  REP  MOVSB  ; or  (REP  MOVS  DST_STR,   SRC_STR)

          MOV AH, 4CH
          INT 21H

CODE1 ENDS
          END START
```

Location Counter:
Here, $ is acting as a location counter. When assembler reads through the source code for a program, it uses a 'location counter' to keep track of the offset of each data item in a segment. The character $ is used to symbolically represent the current value of the location counter at any point. The initial value of the location counter is zero. When the first character (byte) is read, the location counter value becomes 1; when the second character (byte) is read, the value becomes 2 and so on.
Location counter can be used to find the length of a string.

Syntax of MOV instruction related to string:
There are three forms:
(1) MOVS <dest_string>, <src_string>
(2) MOVSB ⎤ here, no additional arguments
(3) MOVSW ⎦ are to be given
For string instructions, the default association of **'segment:offset'** is as follows:
DS:SI (for source string)
ES:DI (for destination string)
(refer page-17 for more about the syntax)

Note: Redo the above program with 'MOVS' instruction instead of 'MOVSB' ie, substitute 'REP MOVSB' by 'REP MOVS DST_STR, SRC_STR'

Also instead of 'LEA SI, SRC_STR', we can write 'MOV SI, OFFSET SRC_STR' and similarly instead of 'LEA DI, DST_STR', we can write 'MOV DI, OFFSET DST_STR'

✓

; (8) Program for adding a series of 8-bit numbers – addser.asm

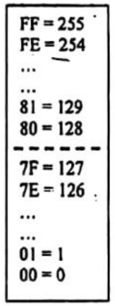
```
DATA        SEGMENT
     LIST   DB     25H, 23H, 12H, 0FFH, 0FFH, 86H
    COUNT   EQU    06H ; or write COUNT EQU ($ - LIST) for automatic computation of count
     SUM    DB     02H DUP(?)
DATA        ENDS

CODE        SEGMENT
            ASSUME CS:CODE, DS:DATA
   START:   MOV    AX, DATA
            MOV    DS, AX
            MOV    CX, COUNT
            MOV    AX, 0000H
            MOV    SI, OFFSET LIST
     L2:    ADD    AL, [SI]
            JNC    L1
            INC    AH
     L1:    INC    SI
            DEC    CX }  LOOP L2
            JNZ    L2 }
            MOV    SUM, AL
            MOV    SUM+1, AH
            MOV    AH, 4CH
            INT    21H
CODE        ENDS
            END    START
```

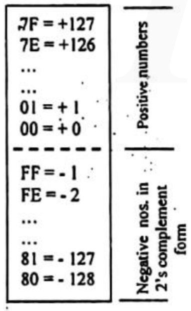
<u>Registers used as Memory Pointers:</u>
1)Base Registers: BX, BP
2) Index Registers: SI, DI
No other registers can be used for Memory Pointers (refer p-5 for the 24 different ways of specifying memory locations)

Rewrite the program making use of Loop instruction instead of JNZ

Unsigned and Signed Numbers

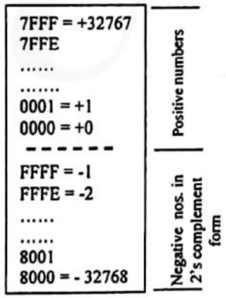


Unsigned 8-bit Numbers



Signed 8-bit Numbers

Unsigned 16-bit Numbers



Signed 16-bit Numbers

;(9) to find the largest Signed number - largests.asm

```
DATA          SEGMENT
      LIST    DB     7FH, 0F3H, 80H, 8FH
     COUNT    EQU    04H   ;number of elements
   LARGEST    DB     01H  DUP(?)
DATA          ENDS

CODE          SEGMENT
              ASSUME CS:CODE,  DS:DATA
     START:   MOV AX, DATA
              MOV DS, AX                ;Data Segment register initialised
              MOV SI, OFFSET LIST ;SI memory pointer initialised to point to the first data location
              MOV CX, COUNT-1           ;counter register initialised to n-1
              MOV AL, [SI]
        L2:   CMP AL, [SI+1]            ;compares ith element with (i+1)th element
              JGE  L1                   ;Jump if ith element is Greater than or Equal to (i+1)th element
              MOV AL, [SI+1]            ;AL holds always the Greater element
        L1:   INC SI
              DEC CX
              JNZ L2
              MOV LARGEST, AL    ;result stored in memory location named LARGEST
              MOV AH, 4CH               ;DOS function call invoked for exiting to DOS
              INT 21H
CODE          ENDS
              END START
```

While comparing Signed numbers using 'CMP' instructions, use the following 'Jump' instructions for making decision for branching:
JGE – Jump if First no. is **Greater than or Equal** to Second no.
JLE – Jump if First no. is **Less than or Equal** to Second no.
Here, 'Greater Than' means more positive and 'Less Than' means less positive

Rewrite the program making use of Loop instruction instead of JNZ

Syntax: CMP <destination>, <source>

(a reg) or (a mem. loc.)

(an immediate number) or (a reg) or (a mem. loc.)

Destination and Source cannot be both memory locations in the same instruction.

;(10) to find the smallest Signed number - smallets.asm

```
DATA          SEGMENT
      LIST    DB     0FFH, 0F2H, 85H, 62H
     COUNT    EQU    04H
  SMALLEST    DB     01H  DUP(?)
DATA          ENDS

CODE          SEGMENT
              ASSUME CS:CODE,  DS:DATA
     START:   MOV AX, DATA
              MOV DS, AX
              MOV SI, OFFSET LIST
              MOV CX, COUNT-1
              MOV AL, [SI]
        L2:   CMP AL, [SI+1]
              JLE  L1          ;Jump if ith element is Less than or Equal to (i+1)th element
              MOV AL, [SI+1]   ;AL holds always the Smaller element
        L1:   INC SI
              DEC CX
              JNZ L2
              MOV SMALLEST, AL   ;result stored in memory location named SMALLEST
              MOV AH, 4CH
              INT 21H
CODE          ENDS
              END START
```

; (11) to find the largest Unsigned number - largestu.asm

```
DATA        SEGMENT
      LIST  DB     00H, 7FH, 80H, 0F3H
     COUNT  EQU    04H
   LARGEST  DB     01H  DUP(?)
DATA        ENDS

CODE        SEGMENT
            ASSUME CS:CODE, DS:DATA
    START:  MOV AX, DATA
            MOV DS, AX
            MOV SI, OFFSET LIST
            MOV CX, COUNT-1
            MOV AL, [SI]
       L2:  CMP AL, [SI+1]
            JAE  L1          ;Jump if  the  ith element is Above or Equal to the (i+1)th element
                             ;It  is the same as JNC
            MOV AL, [SI+1]  ; AL holds always the Greater element
       L1:  INC SI
            DEC CX
            JNZ L2
            MOV LARGEST, AL
            MOV AH, 4CH
            INT 21H
CODE        ENDS
            END START
```

While comparing Unsigned numbers using 'CMP' instructions, use the following 'Jump' instructions for making decision for branching:
JAE – Jump if First no. is Above or Equal to Second no.
JBE – Jump if First no. is Below or Equal to Second no.
Here, 'Above' means larger in magnitude and 'Below' means smaller in magnitude.

Rewrite the program making use of Loop instruction instead of JNZ

;(12) to find the smallest Unsigned number - smalletu.asm

```
DATA        SEGMENT
      LIST  DB     0FFH, 0F2H, 80H, 90H
     COUNT  EQU    04H
  SMALLEST  DB     01H  DUP(?)
DATA        ENDS

CODE        SEGMENT
            ASSUME CS:CODE,  DS:DATA
    START:  MOV AX, DATA
            MOV DS, AX
            MOV SI, OFFSET LIST
            MOV CX, COUNT-1
            MOV AL, [SI]
       L2:  CMP AL, [SI+1]
            JBE  L1       ;JBE is almost same as JC- both will give same result but JBE is better
                          ; Jump if  the  ith element is Below or Equal to the (i+1)th element
            MOV AL, [SI+1]  ; AL holds always the Smaller element
       L1:  INC SI
            DEC CX
            JNZ L2
            MOV SMALLEST, AL
            MOV AH, 4CH
            INT 21H
CODE        ENDS
            END START
```

✓

```
            MOV SI, OFFSET LIST
     L2:    MOV AL, [SI]        ; because CMP [SI],  [SI+1] is invalid (two mem. Locations)
            CMP AL, [SI+1]
            JAE L1            ;Jump if the ith no. is Above or Equal to the (i+1)th no.
            XCHG  AL, [SI+1]     ; because  XCHG  [SI],  [SI+1] is invalid (two mem. Locations)
            MOV   [SI], AL
     L1:    ADD SI, 01   ;or use INC SI
            DEC CX
            JNZ   L2
            DEC BX
            JNZ  L3

            MOV AH, 4CH
            INT 21H
CODE        ENDS
            END START
```

```
Syntax; XCHG <destination>,     <source>
                   ↑               ↑
                (a reg)         (a reg)         Destination and
                   or              or           Source cannot be
              (a mem. loc.)   (a mem. loc.)     both memory
                                                locations in the
                                                same instruction.
```

;(15) to sort 8-bit unsigned nos in ascending order - ascendu.asm

```
DATA        SEGMENT
     LIST   DB     7FH, 00H, 0FFH, 80H
     COUNT  EQU    04H
DATA        ENDS


CODE        SEGMENT
            ASSUME CS:CODE, DS:DATA
   START:   MOV AX, DATA
            MOV DS, AX

            MOV BX, COUNT-1    ;BX is the Pass counter
     L3:    MOV CX, BX         ;CX is the Comparison counter which is initialised to the Pass counter
                               ; value at the beginning of each Pass
            MOV SI, OFFSET LIST
     L2:    MOV AL, [SI]
            CMP AL, [SI+1]
            JBE L1            ;Jump if the ith no.is Below or Equal to the (i+1)th no.
            XCHG  AL, [SI+1]
            MOV   [SI], AL
     L1:    ADD SI, 01     ;or use INC SI
            DEC CX
            JNZ  L2
            DEC BX
            JNZ  L3

            MOV AH, 4CH
            INT 21H

CODE        ENDS
            END START
```

;(16) to sort 8-bit signed nos in descending order - descends.asm

```
DATA        SEGMENT
     LIST   DB     80H, 0FFH, 00H, 7FH
     COUNT  EQU    04H
DATA        ENDS
```

✓

(13) to find out the number of even and odd numbers from a given set of 16-bit hex nos.- evenodd.asm

```
DATA        SEGMENT
      LIST   DW       1234H, 0FCD7H, 8526H, 6278H
     COUNT EQU      04H
   EVENNOS DB       01H  DUP (?)
    ODDNOS DB       01H  DUP (?)
DATA        ENDS

CODE        SEGMENT
            ASSUME CS:CODE,  DS:DATA
     START: MOV AX, DATA
            MOV DS, AX
            MOV BL, 00H    ; (or Write XOR BL,BL)   -BL stores no. of even nos.
            MOV DL, 00H    ; (or Write XOR DL,DL)   -DL stores no. of odd nos.
            MOV SI, OFFSET LIST  ; or  LEA  SI, LIST
            MOV CX, COUNT

     AGAIN:  MOV AX, [SI]
            ROR AX, 01
            JC  ODD
            INC BL
            JMP NEXT
     ODD:   INC DL
     NEXT:  ADD SI, 02H ;  (SI) ← (SI)  + 02   {is equivalent to INC SI;  INC SI}
            DEC CX
            JNZ AGAIN

            MOV EVENNOS, BL ;result stored in memory location named EVENNOS
            MOV ODDNOS,  DL ;result stored in memory location named ODDNOS
            MOV AH, 4CH
            INT 21H

CODE        ENDS
            END START
```

The simplest logic to decide whether a binary number is even or odd, is to check the LSB of the number. If the LSB is zero, the number is even; if it is one, the number is odd. Check the LSB by rotating the number through Carry flag and increment the 'Even' or 'Odd' counter accordingly.

```
Syntax: XOR  <destination>,     <source>
                  ↑                 ↑                      Destination and
               (a reg)      (an immediate number)          Source cannot be
                 or                  or                    both memory
            (a mem. loc.)         (a reg)                  locations in the
                                     or                    same instruction.
                                (a mem. loc.)
```

```
Syntax: ROR  <destination>,     <count>
                  ↑                ↑
               (a reg)          1 or CL reg content.
                 or             For count >1, load CL
            (a mem. loc.)       reg.    eg.
                                MOV CL, 05H
```

This gives 8-bit rotation for byte or 16 bit rotation for word. To rotate more than one bit position, load the desired number in the CL register.

---

(14) to sort 8-bit unsigned nos in descending order - descendu.asm

```
DATA        SEGMENT
     LIST   DB       80H, 0FFH, 00H, 7FH
     COUNT EQU      04H   ; or  COUNT EQU  ($ - LIST)
DATA        ENDS

CODE        SEGMENT
            ASSUME CS:CODE, DS:DATA
     START: MOV AX, DATA
            MOV DS, AX
            MOV BX, COUNT-1     ;BX is the Pass counter
     L3:    MOV CX, BX          ;CX is the Comparison counter which is initialised to the Pass counter
                                 ;value at the beginning of each Pass
```

```
CODE        SEGMENT
            ASSUME CS:CODE, DS:DATA
     START: MOV AX, DATA
            MOV DS, AX

            MOV BX, COUNT-1     ;BX is the Pass counter
     L3:    MOV CX, BX          ;CX is the Comparison counter which is initialised to the Pass counter
                                 ; value at the beginning of each Pass
            MOV SI, OFFSET LIST
     L2:    MOV AL, [SI]
            CMP AL, [SI+1]
            JGE L1              ;Jump if the ith no.is Greater than or Equal to the (i+1)th no.
            XCHG  AL, [SI+1]
            MOV   [SI], AL
     L1:    ADD SI, 01          ;or use INC SI
            DEC CX
            JNZ  L2
            DEC BX
            JNZ  L3

            MOV AH, 4CH
            INT 21H

CODE        ENDS
            END START
```

;(17) to sort 8-bit signed nos in ascending order - ascends.asm

```
DATA        SEGMENT
     LIST   DB      7FH, 00H, 0FFH, 80H
     COUNT EQU     04H
DATA        ENDS

CODE        SEGMENT
            ASSUME CS:CODE, DS:DATA
     START: MOV AX, DATA
            MOV DS, AX
            MOV BX, COUNT-1     ;BX is the Pass counter
     L3:    MOV CX, BX          ;CX is the Comparison counter which is initialised to the Pass counter
                                 ;value at the beginning of each Pass
            MOV SI, OFFSET LIST
     L2:    MOV AL, [SI]
            CMP AL, [SI+1]
            JLE L1              ;Jump if the ith no.is Less than or Equal to the (i+1)th no.
            XCHG  AL, [SI+1]
            MOV   [SI], AL
     L1:    ADD SI, 01          ;or use INC SI
            DEC CX
            JNZ  L2
            DEC BX
            JNZ  L3

            MOV AH, 4CH
            INT 21H

CODE        ENDS
            END START
```

```
;(18) addition of two 64-bit nos – 64bitadd.asm  (for multibyte addition use ADC instead of ADD – think why?)

DATA        SEGMENT
   NUM1     DB  0EFH, 0CDH, 0ABH, 89H, 67H, 45H, 23H, 0F1H
   NUM2     DB   01H, 23H, 45H, 67H, 89H, 0ABH, 0CDH, 0EFH
   NUM3     DB  09H  DUP(00)  ;to store the result
  COUNT     EQU 08H
DATA        ENDS

CODE        SEGMENT
            ASSUME CS:CODE, DS:DATA
    START:  MOV  AX, DATA
            MOV DS, AX

            MOV  CX, COUNT
            MOV  SI, OFFSET NUM1
            MOV  DI, OFFSET NUM2
            MOV  BX, OFFSET NUM3
            XOR  AX, AX  ;AX is initialized to Zero and Carry flag is Reset – MOV AX, 0000H will not
                          ;reset Carry Flag – if  MOV AX, 0000H is used, CLC instruction can be used for
    NEXT:   MOV AL, [SI]    ; resetting  carry flag
            ADC  AL, [DI]
            MOV [BX], AL
            INC SI
            INC DI
            INC  BX
            DEC  CX
            JNZ  NEXT
            JNC  NOCARRY
            MOV  [BX], 01
NOCARRY:    MOV AH, 4CH
            INT 21H
CODE        ENDS
            END  START
```

```
;(19) addition of two  3×3 matrices  - matadd.asm

DATA        SEGMENT
    MAT1    DB  0FFH, 02H, 03H, 04H, 05H, 06H, 07H,08H, 09H
    MAT2    DB  0FFH, 02H, 03H, 04H, 05H, 06H, 07H, 08H, 09H
    MAT3    DW  09H  DUP(00)  ; to store the result matrix – byte addition may give word type value
                              ; and hence DW is used
    COUNT   EQU  09H
DATA        ENDS


CODE        SEGMENT
            ASSUME CS:CODE, DS:DATA
   START:   MOV AX, DATA
            MOV  DS, AX

            MOV CX, COUNT
            MOV SI, OFFSET MAT1
            MOV  DI, OFFSET MAT2
            MOV BX, OFFSET MAT3
    NEXT:   XOR  AX, AX  ; AX is initialized to zero and Carry flag is reset – MOV AX, 0000H can also
                         ;be used here since we need not have to consider Carry as we are using ADD
```

✓

```
                    ; instead of ADC
        MOV AL, [SI]
        ADD AL, [DI]   ;since it is not a multibyte addition, ADD can be used instead of ADC
        JNC  L1
        INC AH
L1:     MOV [BX], AX
        INC SI
        INC DI
        ADD BX, 02     ; add 02 since the result matrix elements are of type word – or use INC BX
                       ;twice – CY is automatically taken care of here since the result
                       ;elements are of word type
        DEC CX
        JNZ  NEXT

        MOV AH, 4CH
        INT 21H

CODE    ENDS
        END  START
```

String Instructions

A string is a series of bytes or words stored in successive memory locations. Often a string consists of a series of ASCII character codes.

1) **Move String Instructions**

MOVS/MOVSB/MOVSW

These are used for moving (copying) a **byte** or a **word** from a location in the data segment to a location in the extra segment.

There are three forms for the syntax:

a) MOVS <dst_str>, <src_str> ; dst_str can be a reg or a mem.loc and src_str can be a reg or mem.loc or an immediate number (Can both be memory locations? Can both be registers? – verify)

b) MOVSB
c) MOVSW } - No operands specified here

The offset address of the source byte or word in the **data-segment** must be in the **SI** Register.
(ie, SI should point to a byte or word in the Data Segment)
The offset address of the destination location in the **extra-segment** must be contained in the **DI** Register.
(ie, DI should point to a byte or word in the Extra Segment)
For multiple-byte or multiple-word moves, the number of elements to be moved is put in the **CX** register and **CX** acts as a down counter.

After a byte or a word is moved, SI and DI are automatically adjusted to point to the next source and next destination locations (ie, it can be either **auto-increment** or **auto-decrement**, depending on the value of the Direction Flag, DF)

If the Direction Flag is reset (= 0) using CLD instruction, then SI and DI will be auto-incremented by 1 for byte movement and by 2 for word movement.
If the Direction Flag is set (= 1) using STD instruction, then SI and DI will be auto-decremented by 1 for byte movement and by 2 for word movement.

✓

```
DATA              SEGMENT
    PWDSTR         DB 'ABCD'                ;source string (stored password)
   PWDSTR_LEN  EQU ($-PWDSTR)        ;length of stored password string
    INPUTSTR       DB 'ABCD'               ;destination string (user input password)
  INPUTSTR_LEN EQU ($-INPUTSTR)      ; length of user input  password string
     CORRECT        DB  'Password is CORRECT$'
    INCORRECT     DB  'Password is INCORRECT$'
DATA              ENDS

CODE              SEGMENT
                  ASSUME CS:CODE,  DS:DATA,   ES:DATA
       START:     MOV AX, DATA
                  MOV DS, AX
                  MOV ES, AX
                  MOV AX, PWDSTR_LEN
                  CMP AX, INPUTSTR_LEN
                  JNZ L1            ; same as JNE
                  LEA SI, PWDSTR
                  LEA DI, INPUTSTR
                  MOV CX, PWDSTR_LEN
                  CLD
                  REPE CMPSB    ; or (REPE  CMPS  INPUTSTR,   PWDSTR)
                  JNZ L1        ;this checks the zero flag – same as JNE

                  DISP    CORRECT
                  JMP  L2
           L1:    DISP    INCORRECT

           L2:    MOV AH, 4CH
                  INT 21H

CODE              ENDS
                  END START
```

3) **Scan String Instructions (Scan or search a string for a Byte or a word)**

SCAS / SCASB / SCASW

There are three forms for the syntax:

a) SCAS <dst_str>

b) SCASB
c) SCASW } - No operands specified here

When a match is found (ie, when the two elements are the same) Zero flag is SET

These are used for searching (scanning) through a string to find if it contains a specified string byte or string word. This **compares** a byte in **'AL'** or a word in **'AX'** with a byte or word pointed to by DI in Extra Segment. The string to be scanned must be in Extra Segment, and DI must contain the offset of the byte or word to be compared. The length of the string must be stored in **CX**.
If the Direction Flag is reset (= 0) using CLD instruction, then DI will be auto-incremented by 1 for byte comparison and by 2 for word comparison.

If the Direction Flag is set (= 1) using STD instruction, then DI will be auto-decremented by 1 for byte comparison and by 2 for word comparison.
This instruction is often used with a repeat prefix REPNE (Repeat If Not Equal to – meaning, repeat if the First element is not equal to the Second element) to find the occurrence of a specified byte (in AL) or a specified word (in AX) in a given string of characters. REPNE is same as REPNZ.
This prefix will cause the string instruction to be repeated if 'REPNE' is True and if 'CX' has not counted down to zero. (After each repeated execution, CX is automatically decremented).
In other words, the repeated execution stops when 'REPNE' is False or CX = 0

Usage Example

```
MOV AX, DATA    ; DATA is the name of the Data Segment
MOV DS, AX
MOV  ES, AX ;here Data Segment and Extra Segment are initialized with the same address -
   ;if an Extra Segment is defined, ES can be initialized with Extra Segment base address.
MOV  DI, OFFSET  DST_STR   (or LEA  DI,  DST_STR)
MOV AL, 0DH; Byte to the scanned for in AL
CLD
MOV CX, 80  ;length of the string is stored in CX
REPNE  SCASB    ; or   REPNE   SCAS  DST_STR
```

(22) Programming Example:

```
 ; occur1.asm--to find the number of occurrences of a given character in a given string of
 ; characters and to display the result in memory or register

DATA            SEGMENT
   CHAR         DB   'e'
   STRG         DB   'Mar Baselios College of Engineering'
   STRGLEN      EQU   ($-STRG)
DATA            ENDS

CODE            SEGMENT
                ASSUME   CS:CODE,  DS:DATA, ES:DATA
     START:     MOV AX, DATA
                MOV DS, AX
                MOV ES, AX ;Data segment and Extra segment are initialized to the same base address
                MOV CX, STRGLEN      ;counter CX initialised with the string length
                INC CX          ;this is required to take account of a matching character at the end of the
                                ;string   ie, (n+1)
                MOV DI, OFFSET STRG     ;DI pointer points to the first character in the string
                CLD
                XOR BX, BX        ;or(MOV BX, 0) -- BX stores the no. of occurrences-it is initialized
                                  ; to 0
                MOV AL, CHAR
     AGAIN:     REPNE SCASB ; or (REPNE  SCAS  STRG) - DI is auto-incremented and CX is
                                  ;auto-decremented after each repetition
                JCXZ  L1        ;jump if CX register is zero - this instruction does not check zero flag –
                         ; exits when end of String has reached (see note below)

                INC BX          ;BX holds the number of occurrences of the given character
                JMP AGAIN
        L1:     MOV AH, 4CH
                INT 21H
CODE            ENDS
                END START
```

Note: We cannot use JZ L1, because when REPNE SCASB is false (ie, the first operand in AL becomes equal to second operand) the Zero flag will be Set and the program will exit to DOS.

(23) to find the number of occurrence of a given character in a string of characters (without using Scan string instruction but only Compare instruction)

```
 ; occur2.asm
DATA          SEGMENT
   CHAR       DB  'e'
  STRNG       DB  'Mar Baselios'
  STRLN       EQU  ($-STRNG)   (here Extra segment is not required)
DATA          ENDS

CODE          SEGMENT
              ASSUME    CS:CODE,  DS:DATA
   START:     MOV AX, DATA
              MOV DS, AX
              MOV CX, STRLN ;counter CX initialised to the count value
              MOV AL, CHAR
              XOR BX, BX      ; or  MOV BX, 0
              MOV SI,  OFFSET STRNG     ;SI pointer points to the first character in the string
   AGAIN:     CMP AL,  [SI]
              JNZ  SKIP
              INC  BX
   SKIP :     INC  SI
              LOOP  AGAIN
              MOV AH, 4CH
              INT 21H
CODE          ENDS
              END START
```

(24) To find the number of occurrences of a given single byte integer in a given series of integers

```
 ; occurint.asm
DATA          SEGMENT
      BYTE1 DB      24H
      LIST  DB      43H, 02H, 24H, 03H, 24H, 06H
      LEN   EQU  $-LIST
DATA          ENDS

CODE          SEGMENT
              ASSUME CS:CODE, DS:DATA
      START: MOV AX, DATA
              MOV DS, AX       ;Data Segment register initialised
              MOV CX, LEN
              MOV AL, BYTE1
              XOR  BX, BX      ;or MOV BX, 0000H
              MOV SI, OFFSET LIST
      AGAIN: CMP AL, [SI]
              JNZ SKIP
              INC BX
      SKIP:   INC SI
              LOOP  AGAIN

              MOV AH, 4CH      ;DOS function call invoked for exiting to DOS
              INT 21H
CODE          ENDS
              END START
```

DOS and BIOS interrupts

Software interrupts are the primary means to access the services of an operating system. The DOS (Disk Operating System) and BIOS (Basic Input Output system) provide a large number of functions to access devices, files, memory and process control services that are available to any program which is capable of setting registers and invoking software interrupts.

DOS and BIOS services for device access such as reading from Keyboard, writing to screen, disk read, disk write etc, communicates in ASCII format. For example, the numeric Key '1' on keyboard is read as the ASCII code 31H. The numeric value '1' can be displayed on the screen by writing the ASCII code 31H on to the screen. Therefore the ASCII codes read from the keyboard have to be converted to 'numeric data' for processing and back to ASCII form for displaying on the screen. This process is required for numeric data processing.

The operating system service access interface is called 'System Call'. The services provided by INT 21H (Software Interrupts) are called DOS services or DOS function (system) call. DOS interrupts and the corresponding services are listed below.

DOS INTERRUPTS:

DOS INTERRUPTS (SERVICES)	
Interrupt Type	**Service Name**
INT 20H	Program Terminate
INT 21H	DOS System Call (or DOS Services) (or DOS Function Call)
INT 22H	Terminate Handler Pointer (address)
INT 23H	Control Break Handler Pointer
INT 24H	Critical Error Handler Pointer
INT 25H	Absolute Disk Read
INT 26H	Absolute Disk Write
INT 27H	Terminate and Stay Resident (TSR)
INT 28H	DOS Time Slice
INT 2EH	Perform DOS Command
INT 2FH	Multiplex Interrupts

For example, consider DOS System Call (Function Call) INT 21H:

The DOS services INT 21H are categorized into various 'Functions'. The function numbers vary from Function 00H to Function 63H. Some of the functions are:

INT 21H, Function 00H : Program Terminate
INT 21H, Function 01H : Read Character from Standard Input Devices (ie, Keyboard)
INT 21H, Function 02H : Write Character to Standard Output Devices (ie, Display Monitor)
INT 21H, Function 03H : Read Character from Standard Auxiliary Input Devices (ie, Serial Port COM1)

INT 21H, Function 09H : Display String to Standard Output Devices (ie, Display Monitor)

INT 21H, Function 4CH : Terminate execution with Return Code
etc,

The steps involved in accessing DOS Interrupts are:

(i) Load a Function Number in the AH register. If there is a sub-function, its value is stored in AL register. That is, use instructions such as MOV AH, function_num and MOV AL, sub-function_num
(ii) Load other registers, if required, as specified in the DOS service format.
(iii) Prepare Buffers, ASCIIZ (zero terminated string), and control blocks, if necessary.
(iv) Invoke DOS service INT n
(v) Process Response: Look for the error indicators by examining the carry flag and error code register (generally AX) as set by the DOS service Call. The system call communicates results through register parameters.

BIOS INTERRUPTS:

BIOS is the lowest level software in the PC. Even DOS uses BIOS functions to control the hardware. BIOS service functions are supplied by the manufacturer of the hardware device.

BIOS INTERRUPTS (SERVICES)

Interrupt Type	Service Name
INT 10H	Video Services
INT 11H	Machine Configuration
INT 12H	Usable RAM Memory Size
INT 13H	Disk I/O
INT 14H	Serial Port I/O (RS 232 C)
INT 15H	AT Services
INT 16H	Keyboard I/O
INT 17H	Printer I/O

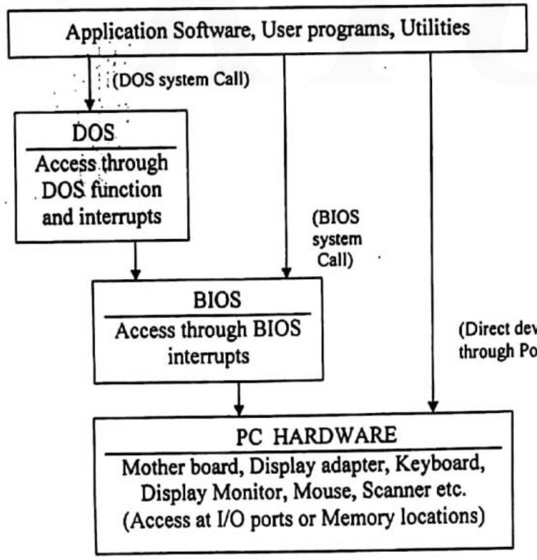
For example, consider BIOS Function Call INT 10H:

The BIOS function call INT 10H are categorized into various 'Functions'. The function numbers vary from Function 00H to Function FFH. Some of the functions are:

INT 10H, Function 00H : Set Video Mode
INT 10H, Function 01H : Set Cursor Shape
INT 10H, Function 02H : Set Cursor Position
INT 10H, Function 03H : Read Cursor Position , etc

The steps involved in accessing BIOS Interrupts are:

(i) Load a Function Number in the AH register. If there is a sub-function, its value is stored in AL register. That is, use instructions such as MOV AH, function_num and MOV AL, sub-function_num
(ii) Load other registers, if required, as specified in the BIOS service format.
(iii) Prepare Buffers, ASCIIZ (zero terminated string), and control blocks, if necessary.
(iv) Invoke BIOS service INT n
(v) Process Response: Look for the error indicators by examining the carry flag and error code register (generally AX) as set by the BIOS service Call. The system call communicates results through register parameters.



SOFTWARE MODEL FOR DEVICE ACCESS

Syntax of Some functions of DOS function Call INT 21H

DOS function Call	Required Preloading of Registers	Action of the Function Call	Usage example
INT 21H, Function 01H	**AH** register is to be preloaded with the Function number **01H.**	This function call Reads an ASCII Character from Standard Input Device (ie, Key Board) with simultaneous echoing of the character on the Screen. The ASCII code of the input Key is returned to **AL** register.	MOV AH, 01H INT 21H

INT 21H, Function 02H	**AH** register is to be preloaded with the Function number **02H.**	This function call Writes an ASCII Character whose ASCII code is stored in **DL** register on to the standard output device-ie., Display monitor (screen)	MOV DL, 'A'
			MOV AH, 02H
			INT 21H

INT 21H, Function 09H	**AH** register is to be preloaded with the Function number **09H** and **DX** register is to be preloaded with the offset address of the starting byte of the string to be displayed. The string should be terminated with a $ sign.	This function call Displays a string terminated with $ sign on to the standard Output device (ie Display monitor)	MOV DX, OFFSET string MOV AH, 09H INT 21H
INT 21H, Function 4CH	**AH** register is to be preloaded with the Function number **4CH.**	This function call terminates execution of the current program and exit to DOS. (It also stores the return code in AL register which can be used to set error level using batch commands).	MOV AH, 4CH INT 21H

(25) DOS function call to Read a character from the keyboard and to echo the character on to the screen, with suitable message string

INT 21H-function 01H (here ASCII code of the input key is returned to AL register)

```
;int21_01.asm

;Macro is defined
DISP_STR      MACRO   MSG        ; 'MSG' is the dummy argument
              MOV  AH, 09H
              MOV DX, OFFSET MSG
              INT 21H
              ENDM
```

Any number of dummy arguments can be used. For example, MACRO_NAME MACRO <arg1>, <arg2>, ... ,<argn>
MACRO can also be defined without any dummy arguments.

```
DATA        SEGMENT
    MSG1    DB 'Type any key:$'  ;MSG1 is the actual argument
DATA        ENDS

CODE        SEGMENT
            ASSUME CS:CODE, DS:DATA
     START: MOV AX, DATA
            MOV DS, AX
            DISP_STR  MSG1     ;here macro is 'Called' - MSG1 is the Actual argument. Actual parameter is
                               ;passed  from Calling program to the Dummy argument in the Macro definition

            MOV AH, 01H  ;This function Reads a Character from Key Board with simultaneous echoing of the character on
            INT 21H      ;the Screen.  The ASCII code of the input Key is returned to the  AL register.

            MOV AH, 4CH
            INT 21H

CODE        ENDS
            END START
```

ASCII character	ASCII code (in HEX)
A	41H
a	61H
CR (carriage return)	0DH
LF (Line feed)	0AH
0	30H
9	39H
$	24H
Space /Blank	20H or 2CH

(26) DOS function call to display the ASCII character whose ASCII code is stored in DL register

INT 21H-function 02H

```
;int21_02.asm
DATA        SEGMENT
    MSG     DB 'Hello world - DOS function Call INT 21H, function 02H'
    LEN     EQU  ($-MSG)
DATA        ENDS

CODE        SEGMENT
            ASSUME CS:CODE, DS:DATA
     START: MOV AX, DATA
            MOV DS, AX
            MOV CX, LEN
            MOV SI, OFFSET MSG

            MOV AH, 02H   ;this function call displays the ASCII character whose ASCII code is stored in DL register
 NEXT_CHAR: MOV DL, [SI]  ;The ASCII code pointed by the SI pointer is stored in DL register
            INT 21H

            INC  SI
            LOOP  NEXT_CHAR

            MOV AH, 4CH
            INT 21H
CODE        ENDS
            END START
```