

## MODULE - 1

### Syllabus

Number Systems - 4

Decimal - 4

Binary - 5

Octal - 5

Hexadecimal - 5

Conversion from one system to another - 5

Representation of negative numbers - 15

Representation of BCD numbers - 17

Character representation - 20

Character coding schemes - 20

ASCII - 20

EBCDIC - 22

Addition of Binary Numbers - 22

Subtraction - 24

Multiplication - 33

Division - 35

Addition and Subtraction of BCD - 37

Addition and Subtraction of Octal and Hexadecimal numbers - 44

Representation of floating point numbers - 50

Precision - 51

Addition, subtraction, multiplication and division of floating point numbers - 54

Seen.

Next

6/7/17

## I Digital Computers and Digital Systems

- ↳ Digital computers have made possible many scientific, industrial and commercial advances.
- ↳ Computers are used in scientific calculations, commercial and business data processing, air traffic control, space guidance, the educational field and many other areas.
- ↳ Stacking property of a digital computer is its generality. It can follow a sequence of instructions called a program, that operates on given data.
- ↳ The user can specify and change programs and data according to the specific need.
- ↳ The general purpose digital computer is the best known <sup>example</sup> of a digital system.
- ↳ Characteristic of a digital system is its manipulation of discrete elements of information.

Discrete elements may be electric impulses the decimal digits, the letters of an alphabet arithmetic operations, punctuation marks etc

- ↳ Discrete elements of information are represented in a digital system by physical quantities called signals.

Electric signals such as voltages and currents are most common.

- ↳ The signals in all present-day electronic digital systems have only two discrete values and are said to be binary.

(3)

→ A block diagram of the digital computer is shown below.

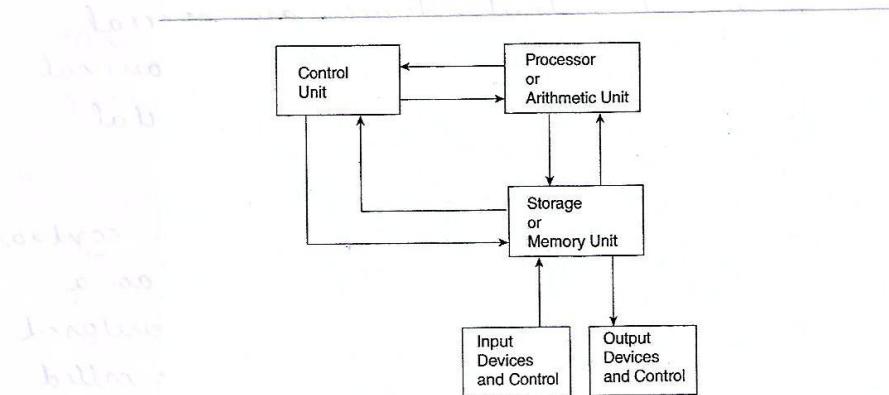


fig. Block diagram of a digital computer

- The memory unit stores programs as well as input output and intermediate data
- The processor unit performs arithmetic and other data-processing task as specified by a program.
- The control unit supervises the flow of information between the various units.

The control unit retrieves the instructions, one by one, from the program which is stored in memory. For each instruction the control unit informs the processor to execute the operation specified by the instruction. Both program and data are stored in memory. The control unit supervises the program instructions and the processor manipulates the data as specified by the program.

- The program and data prepared by the user are transferred into the memory unit by means of an input device such as punch-card reader or a teletypewriter.

(4)

- ↳ An output device such as a printer, receives the result of the computations and the printed results are presented to the user.
- ↳ The input and output devices are special digital systems driven by electromechanical parts and controlled by electronic digital circuits.
- ↳ A processor, when combined with the control units forms a component referred to as a central processor unit or CPU. A CPU enclosed in small integrated-circuit package is called a microprocessor.

A CPU combined with memory and interface control to form a small-size computer is called a microcomputer.

- ↳ A digital computer manipulates discrete elements of information and that these elements are represented in the binary form.
- ↳ Operands used for calculations are expressed in the binary number system.



## Number Systems

A number system of base, or radix  $r$  is a system that uses distinct symbols for  $r$  digits. Numbers are represented by a string of digit symbols.

- ↳ To determine the quantity that the number represents, it is necessary to multiply each digit by an integer power of  $r$  and the sum the sum of all weighted digits.

- i) Decimal Number System:- The decimal number system employs the radix 10 system. The 10 symbols are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9. The string of

(5)

digits 724.5 is interpreted to represent the quantity

$$7 \times 10^2 + 2 \times 10^1 + 4 \times 10^0 + 5 \times 10^{-1}$$

that is 7 hundreds, plus 2 tens, plus 4 units, plus 5 tenths.

ii) Binary Number System: The binary number system uses the radix 2. The two digit symbols used are 0 and 1. The string of digits 101101 is interpreted to represent the quantity

$$1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 = \underline{\underline{45}}$$

To distinguish between different radix numbers, the digits will be enclosed in parenthesis and the radix of the number inserted as a subscript.

For eg. to show the equality between decimal and binary forty-five will be written as

$$(101101)_2 = (45)_{10}$$

iii) Octal and Hexadecimal number system consists of radix 8 and 16 respectively. The eight symbols of the Octal system are 0, 1, 2, 3, 4, 5, 6 and 7. The 16 symbols of the hexadecimal system are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E and F. The symbols A, B, C, D, E, F correspond to the decimal numbers 10, 11, 12, 13, 14, 15 respectively.

### III Conversion from one system to another

The conversion of a decimal integer into a base  $n$  representation is done by successive divisions by  $n$  and accumulation of the remainders. The conversion of a decimal fraction to radix  $n$  representation is accomplished by successive

(6)

multiplications by 2 and accumulation of the integer digits so obtained.

### i) Decimal to Binary

Decimal to binary conversion can be done in 2 ways

#### 1. Sum of weights Method

Determine the set of binary weights whose sum is equal to the decimal number

$$\text{eg. } 9 = 8 + 1 = 2^3 + 2^0$$

Placing 1s in the appropriate weight positions,  $2^3$  and  $2^0$ , and 0s in the  $2^2$  and  $2^1$  positions determine the binary number for decimal 9

$$2^3 \quad 2^2 \quad 2^1 \quad 2^0$$

1 0 0 1      Binary number for decimal 9

examples

Convert the following decimal numbers to binary

- a) 12      b) 25      c) 58      d) 82

$$12_{10} = 8 + 4 = 2^3 + 2^2 \rightarrow 1100_2$$

$$25_{10} = 16 + 8 + 1 = 2^4 + 2^3 + 2^0 \rightarrow 11001_2$$

$$58_{10} = 32 + 16 + 8 + 2 = 2^5 + 2^4 + 2^3 + 2^1 \rightarrow 111010_2$$

$$82_{10} = 64 + 16 + 2 = 2^6 + 2^4 + 2^1 \rightarrow 1010010_2$$

#### 2. Repeated Devision by 2 Method

The number is divided by 2 and then dividing each resulting quotient by 2 until

(7)

there is a 0 quotient. The remainders generated by each division form the binary number. The first remainder to be produced is the LSB (least significant bit) in the binary number and the last remainder to be produced is the MSB (most significant bit):

$$\begin{array}{r} 2 \longdiv{12} \\ 2 \underline{6} - 0 \\ 2 \underline{3} - 0 \\ 1 - 1 \\ (\text{MSB}) \end{array} \xrightarrow{\quad} (1100)_2 \quad (\text{LSB})$$

$$\begin{array}{r} 2 \longdiv{19} \\ 2 \underline{9} - 1 \\ 2 \underline{4} - 1 \\ 2 \underline{2} - 0 \\ 1 - 0 \end{array} \xrightarrow{\quad} (10011)_2$$

$$\begin{array}{r} 2 \longdiv{45} \\ 2 \underline{22} - 1 \\ 2 \underline{11} - 0 \\ 2 \underline{5} - 1 \\ 2 \underline{2} - 1 \\ 1 - 0 \end{array} \xrightarrow{\quad} (101101)_2$$

$$\begin{array}{r} 2 \longdiv{39} \\ 2 \underline{19} - 1 \\ 2 \underline{9} - 1 \\ 2 \underline{4} - 1 \\ 2 \underline{2} - 0 \\ 1 - 0 \end{array} (100111)$$

## ii) Decimal fractions to Binary

### 1. Sum of Weights method

$$0.625 = 0.5 + 0.125 = 2^{-1} + 2^{-3} = 0.101$$

$2^{-1} = 0.5$
$2^{-2} = 0.25$
$2^{-3} = 0.125$
$2^{-4} = 0.0625$
$2^{-5} = 0.03125$

1 in the  $2^{-1}$  position, a 0 in the  $2^{-2}$  position and a 1 in the  $2^{-3}$  position.

### 2. Repeated Multiplication by 2

Decimal fractions can be converted to binary by repeated multiplication by 2. Multiply fractional number by 2 and then multiplying each

(8)

resulting fractional part of the product by 2 until the fractional product is zero. The carries generated by each multiplication form the binary number.

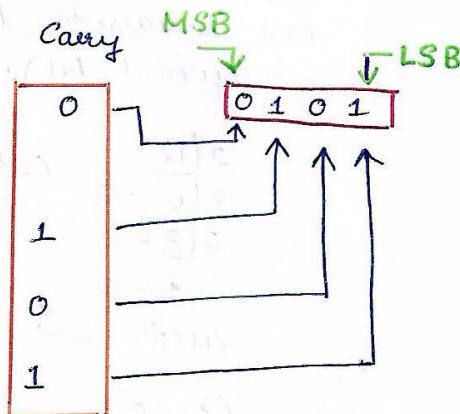
$$0.3125 \times 2 = 0.\underline{625}$$

$$0.625 \times 2 = 1.\underline{25}$$

$$0.25 \times 2 = 0.\underline{50}$$

$$0.50 \times 2 = 1.\underline{00}$$

stop when  
the fraction part  
is all zero



$$(0.0101)_2$$

### Questions

Convert each decimal number to binary by using the sum of weights method

- a) 23      b) 57      c) 45.5

$$23 = 16 + 4 + 2 + 1 = 2^4 + 2^2 + 2^1 + 2^0$$

$$\rightarrow (\underline{10111})_2$$

$$57 = 32 + 16 + 8 + 1 = 2^5 + 2^4 + 2^3 + 2^0$$

$$\rightarrow (\underline{111001})_2$$

$$45.5 = 32 + 8 + 4 + 1 + 0.5 = 2^5 + 2^3 + 2^2 + 2^0 + 2^{-1}$$

$$\rightarrow (101101.1)_2$$

(1)

Convert each decimal number to binary by using the repeated division by 2 method (repeated multiplication by 2 for fraction)

a) 14      b) 21      c) 0.375

$$\begin{array}{r} 14 \\ \times 2 \\ \hline 7 \\ \times 2 \\ \hline 3 \\ \times 2 \\ \hline 1 \\ \end{array}$$

$(1110)_2$

0.375

$$\begin{array}{r} 0.375 \\ \times 2 \\ \hline 0.75 \\ \times 2 \\ \hline 1.50 \\ \times 2 \\ \hline 1.00 \\ \end{array}$$

$0.375 \times 2 = 0.\underline{75} \quad 0$

$0.75 \times 2 = 1.\underline{50} \quad 1$

$0.5 \times 2 = 1.\underline{00} \quad 1$

$$\begin{array}{r} 21 \\ \times 2 \\ \hline 10 \\ \times 2 \\ \hline 5 \\ \times 2 \\ \hline 2 \\ \times 2 \\ \hline 1 \\ \end{array}$$

$(10101)_2$

$(011)_2$

### iii) Binary to decimal

- write down the binary number
- list the powers of two from right to left.
- write the digits of the binary number below their corresponding powers.
- write down the final value of each power of two
- connect the digits in the binary number with their corresponding powers.
- add the final values.
- write the answer along with base subscript.

$\rightarrow 10011011 \rightarrow \text{Decimal equivalent}$

$$\begin{array}{r}
 1 & 0 & . & 0 & 1 & 1 & 0 & 1 & 1 \\
 & 2^7 & & 2^6 & 2^5 & 2^4 & 2^3 & 2^2 & 2^1 & 2^0 \\
 128 & + & 0 & + & 16 & + & 8 & + & 2 & + & 1 \\
 \hline
 155
 \end{array}$$

$= \underline{\underline{155}}_{10}$

(10)

→ Convert binary to decimal

$$(101101.1)_2$$

$$\begin{array}{r} 1 \ 0 \ 1 \ 1 \ 0 \ 1 \cdot 1 \\ \underline{5} \quad \underline{3} \ \underline{2} \quad \underline{0} \quad \underline{-1} \\ 2 \quad 2 \quad 2 \quad 2 \end{array}$$

$$32 + 8 + 4 + 1 + .5$$

$$= (45.5)_{10}$$

#### iv) Octal to Decimal

$$\begin{aligned} (2374)_8 &= 2 \times 8^3 + 3 \times 8^2 + 7 \times 8^1 + 4 \times 8^0 \\ &= 2 \times 512 + 3 \times 64 + 7 \times 8 + 4 \times 1 \\ &= 1024 + 192 + 56 + 4 \\ &= (1276)_{10} \end{aligned}$$

Octal number system has a base of eight, each successive digit position is an increasing power of eight, beginning in the right-most column with  $8^0$ .

Octal to decimal conversion is accomplished by multiplying each digits by its weights and summing the products

$$\begin{aligned} (0.325)_8 &= 3 \times 0.125 + 2 \times 0.015625 \\ \text{Weight: } 8^3 \ 8^2 \ 8^1 \ 8^0 &= + 5 \times 0.001953 \\ \text{Octal Number: } 2 \ 3 \ 7 \ 4 &= 3 \times 8^{-1} + 2 \times 8^{-2} + 5 \times 8^{-3} \\ &= (0.\underline{\underline{4}}16015)_{10} \end{aligned}$$

#### v) Octal to Binary

Each octal digit can be represented by a 3-bit binary number. To convert an octal number to a binary number, replace each octal digit with the appropriate three bits.

(11)

Octal Digit	Binary
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

Convert octal to binary

a)  $(13)_8$    b)  $(25)_8$    c)  $140_8$    d)  $7526_8$

e)  $46_8$    f)  $723_8$    g)  $37.12_8$    h)  $5624 \cdot 37_8$

$$\begin{array}{c} 13_8 \\ \downarrow \\ (001 \ 011)_2 \end{array}$$

$$\begin{array}{c} 46_8 \\ \downarrow \\ (100 \ 110)_2 \end{array}$$

$$\begin{array}{c} 25_8 \\ \downarrow \\ (010 \ 101)_2 \end{array}$$

$$\begin{array}{c} 723_8 \\ \downarrow \\ (111010011)_2 \end{array}$$

$$\begin{array}{c} 140_8 \\ \downarrow \\ (001100000)_2 \end{array}$$

$$\begin{array}{c} 37.12_8 \\ \downarrow \\ (011111.001010)_2 \end{array}$$

$$\begin{array}{c} 7526_8 \\ \downarrow \\ (111101010110)_2 \end{array}$$

$$\begin{array}{c} 5624 \cdot 37_8 \\ \downarrow \\ (101110010100 \cdot 011111)_2 \end{array}$$

vi) Decimal to Octal

A method of converting a decimal number to an octal number is the repeated division by 8 method

$$\begin{array}{r}
 (359)_{10} \\
 \overline{8 \Big| 359} \\
 8 \overline{\Big| 44} - 4 \\
 5 - 4 \\
 \hline
 (547)_8
 \end{array}$$

### vii) Binary to Octal

Break the binary numbers into group of three bits and convert each group into the appropriate octal digit

a) 110101

$$\begin{array}{c} \underbrace{110} \\ \underbrace{101} \\ (6 \quad 5) \end{array}_8$$

$$6) \underbrace{001}_{(1)} \underbrace{001}_{(1)} \underbrace{1000}_{(4)} \underbrace{10}_{(2)}_8$$

$$c) \underline{0} \underbrace{1}_{2} \underbrace{0} \underbrace{1}_{7} \underbrace{1}_{7} \underbrace{1}_{1} \underbrace{0}_{1} \underbrace{0}_{1} \underbrace{1}_{1} \\ (2 \quad 7 \quad 7 \quad 1)_8$$

$$d) \quad \begin{array}{r} 101111001 \\ \hline (5 \quad 7 \quad 1)g \end{array}$$

(viii) Hexadecimal to binary

Replace each hexadecimal symbols with the appropriate four bit binary code.

10 4 4 16  
 ↓ ↓ ↓ ↓  
 0001 0000 0100 0100

$(0001\ 0000\ 0100\ 0100)_2$

CF83<sub>16</sub>  

 $(1100\ 1111)_{2} \rightarrow CF83_{16}$

(13)

Decimal	Binary	Hexadecimal
0	0000	0
1	0001	1
2	0010	2
3	0011	3
4	0100	4
5	0101	5
6	0110	6
7	0111	7
8	1000	8
9	1001	9
10	1010	A
11	1011	B
12	1100	C
13	1101	D
14	1110	E
15	1111	F

ix) Binary to hexadecimal

Break the binary number into 4-bit groups starting at the right-most bit and replace each 4-bit group with the equivalent hexadecimal symbol

a) 1100101001010111  
 (C A 5 F)16

b) 111111000101101001

0011|1111|0001|0110|1001  
 append zero to left to make a group of 4

(3 F 1 6 9)16

c) 01001111011110011100  
 append zero (4 F 7 9 C)16

(13) x) Hexadecimal to decimal

(14)

(1) Method

First convert the hexadecimal number to binary and then convert binary to decimal

$$a) 1C_{16}$$

$$\begin{array}{c} 1 \ C \\ \downarrow \quad \downarrow \\ (0001 \ 1100)_2 \\ \text{76543210} \\ 0001 \ 1100 \end{array}$$

$$\begin{aligned} &= 2^4 + 2^3 + 2^2 \\ &= 16 + 8 + 4 \\ &= (28)_{10} \\ &\underline{\underline{}} \end{aligned}$$

$$b) A85_{16}$$

$$\begin{array}{c} A \ 8 \ 5 \\ \downarrow \quad \downarrow \quad \downarrow \\ (1010 \ 1000 \ 0101)_2 \\ \text{1109876543210} \\ 1010 \ 1000 \ 0101 \end{array}$$

$$\begin{aligned} &= 2^{11} + 2^9 + 2^7 + 2^2 + 2^0 \\ &= 2048 + 512 + 128 + 4 + 1 \\ &= (2693)_{10} \\ &\underline{\underline{}} \end{aligned}$$

(2) Method

Multiply each hexadecimal digit by its weight and then taking the sum of these products

$$(E5)_{16}$$

$$\begin{array}{r} E \ 5 \\ 16^1 \ 16^0 \end{array}$$

$$E \times 16 + 5 \times 1$$

$$14 \times 16 + 5 \times 1$$

$$= 224 + 5$$

$$= (229)_{10} \\ \underline{\underline{}}$$

$$(1C)_{16}$$

$$\begin{array}{r} 1 \ C \\ 16^1 \ 16^0 \end{array}$$

$$1 \times 16 + C \times 1$$

$$1 \times 16 + 12 \times 1$$

$$= 16 + 12$$

$$= (28)_{10} \\ \underline{\underline{}}$$

$$(B2F8)_{16}$$

$$\begin{array}{r} B \ 2 \ F \ 8 \\ 16^3 \ 16^2 \ 16^1 \ 16^0 \\ 3 \ 2 \ 1 \ 0 \end{array}$$

$$B \times 16^3 + 2 \times 16^2 + F \times 16^1 + 8 \times 16^0$$

$$= 11 \times 16^3 + 2 \times 16^2 + 15 \times 16 + 8 \times 1$$

$$= 11 \times 4096 + 2 \times 256 + 15 \times 16 + 8 \times 1$$

$$= (45816)_{10} \\ \underline{\underline{}}$$

### xi) Decimal to Hexadecimal

(15)

Repeated division of a decimal number by 16 will produce the equivalent hexadecimal number, formed by the remainders of the divisions.

a)  $(650)_{10}$

$$\begin{array}{r} 16 \overline{)650} \\ 16 \overline{)40 - A} \quad (\text{LSD}) \\ \phantom{16 \overline{)4}} 2 - 8 \\ (\text{MSD}) \quad \xrightarrow{\hspace{1cm}} \\ \underline{(28A)}_{16} \end{array}$$

b)  $(2591)_{10}$

$$\begin{array}{r} 16 \overline{)2591} \\ 16 \overline{)161 - F} \\ \phantom{16 \overline{)16}} 10 - 1 \\ (\text{A 1 F})_{16} \end{array}$$

IV

### REPRESENTATION OF NEGATIVE NUMBERS

When an integer binary number is positive, the sign is represented by 0 and the magnitude by a positive binary number. When the number is negative, the sign is represented by 1, but the rest of the number may be represented in one of three possible ways

- 1) Signed-magnitude form
- 2) Signed-1's complement form
- 3) Signed-2's complement form

Signed magnitude representation of a negative number consists of the magnitude and a negative sign.

In other 2 representations the negative number is represented in either the 1's or 2's complement of its positive value.

### Example

Decimal number +25 is expressed as an 8-bit signed binary number using the sign-magnitude form

+25       $0001\ 1001$   
 Sign bit    ↑      Magnitude bits

$$\begin{array}{r} 2 \overline{) 25} \\ 2 \overline{) 12 - 1} \\ 2 \overline{) 6 - 0} \\ 2 \overline{) 3 - 0} \\ 1 - 1 \end{array}$$

-25       $1001\ 1001$   
 Sign bit    ↑      Magnitude bits

$$(11001)_2$$

As an example, consider the signed number 14 stored in an 8 bit register. +14 is represented by a sign bit of 0 in the left most position followed by the binary equivalent of 14:  $00001110$ . Each of the eight bits of the register must have a value and therefore 0's must be inserted in the most significant positions following the sign bit.

Although there is only one way to represent +14, there are 3 different ways to represent -14 with eight bits.

Signed magnitude form

$$(-14)$$

2's complement  
↓  
-ment

Signed 1's complement form

$$10001110$$

$$\begin{array}{r} 1110001 \\ + 1 \\ \hline 1110010 \end{array}$$

Signed 2's complement form

$$11110010$$

The signed-magnitude representation of -14 is obtained from +14 by complementing only the sign bit.

The signed-1's complement representation of

$-14$  is obtained by complementing all the bits of  $+14$ , including the sign bit

(17)

The signed 2's complement representation is obtained by taking the 2's complement of the positive number including its sign bit.

Express the decimal number  $-39$  as an 8-bit number in the sign-magnitude, 1's complement and 2's complement forms

$$+39 \rightarrow 00100111$$

$-39$

Sign-magnitude form  $\rightarrow 10100111$   
1's complement form  $\rightarrow 11011000$   
2's complement form  $\rightarrow 11011001$

$$\begin{array}{r} 2 | 39 \\ 2 | 19 - 1 \\ 2 | 9 - 1 \\ 2 | 4 - 1 \\ 2 | 2 - 0 \\ 1 - 0 \end{array}$$

$\downarrow$  1's complement  
 $11011000$   
 $+$   
 $\underline{\underline{11011001}}$

$\downarrow$   
 $\downarrow$  2's complement

IV

#### REPRESENTATION OF BCD NUMBERS

##### BCD - Binary Coded Decimal

Binary coded decimal (BCD) is a way to express each of the decimal digits with a binary code. There are only ten code groups in the BCD system.

The 8421 code is a type of BCD code. BCD means that each decimal digit 0 through 9 is represented by a binary code of four bits. The designation 8421 indicates the binary weight of the four bits ( $2^3, 2^2, 2^1, 2^0$ ).

(18)

Decimal Digit	BCD
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

Invalid Codes: With four bits, 16 numbers (0000 through 1111) can be represented. But in 8421 code, only ten of these are used. The six code combination that are not used - 1010, 1011, 1100, 1101, 1110 and 1111 - are invalid in the 8421 BCD code.

To express any decimal number in BCD simply replace each decimal digit with the appropriate 4-bit code.

To convert BCD to decimal, start at the right most bit and break the code into group of four bit. Then write the decimal digit represented by each 4-bit group.

3 ↓ 0011	9.2 ↓ → 1001.0010	34.8 ↓ → 0011 0100. 1000
----------------	-------------------------	--------------------------------

(19)

Convert each of the following decimal numbers to BCD

- a) 35    b) 98    c) 170    d) 2469    e) 321    f) 1472

a) 35

$$\begin{array}{r} 35 \\ \downarrow \\ 0011\ 0101 \end{array}$$

d) 2469

$$\begin{array}{r} \downarrow \quad \downarrow \quad \searrow \\ 00100100\ 01101001 \end{array}$$

b) 98

$$\begin{array}{r} 9\ 8 \\ \downarrow \quad \downarrow \\ 1001\ 1000 \end{array}$$

c) 321

$$\begin{array}{r} \downarrow \quad \searrow \\ 0011\ 0010\ 0001 \end{array}$$

c) 170

$$\begin{array}{r} \downarrow \quad \searrow \\ 000101110000 \end{array}$$

f) 1472

$$\begin{array}{r} \downarrow \quad \searrow \\ 00010100\ 0111\ 0010 \end{array}$$

Convert BCD to Decimal

a) 0011|0001

$$(31)_{10}$$

b) 0101|0011

$$(53)_{10}$$

c) 1001|0111|0100

$$(974)_{10}$$

d) 0001|0000|0110|0000.0111

$$(1860.7)_{10}$$

VI

CHARACTER REPRESENTATION

Many applications of digital computers require the handling of data that consist not only of numbers but also of the letters of the alphabet and certain special characters.

Such a set contains between 32 and 64 elements (if only uppercase letters are included) or between 64 and 128 (if both uppercase and lowercase letters are included). In the first case the binary code will require six bits and in the second case, 7 bits.

Need for character representation

In many applications symbols other than just numbers and letters are necessary to communicate completely. Spaces, periods, colons, semicolons, question marks are needed. So there is a requirement for alphanumeric code.

ASCII is the most common alphanumeric code.

Character Coding Schemas

- ASCII
- EBCDIC

ASCII

ASCII is the abbreviation for American Standard Code for Information Interchange. ASCII is a universally accepted alphanumeric code used in most computers and other electronic equipment. Most computer keyboards are standardized with the ASCII. On entering a letter, a number, or control command the corresponding ASCII code goes into the computer.

CONTROL CHARACTERS				GRAPHIC SYMBOLS											
NAME	DEC	BINARY	HEX	SYMBOL	DEC	BINARY	HEX	SYMBOL	DEC	BINARY	HEX				
NULL	0	0000000	00	space	32	0100000	20	@	64	1000000	40		96	1100000	60
SOH	1	0000001	01	!	33	0100001	21	A	65	1000001	41	a	97	1100001	61
STX	2	0000010	02	"	34	0100010	22	B	66	1000010	42	b	98	1100010	62
ETX	3	0000011	03	#	35	0100011	23	C	67	1000011	43	c	99	1100011	63
EOT	4	0000100	04	\$	36	0100100	24	D	68	1000100	44	d	100	1100100	64
ENQ	5	0000101	05	%	37	0100101	25	E	69	1000101	45	e	101	1100101	65
ACK	6	0000110	06	&	38	0100110	26	F	70	1000110	46	f	102	1100110	66
BEL	7	0000111	07	,	39	0100111	27	G	71	1000111	47	g	103	1100111	67
BS	8	0001000	08	(	40	0101000	28	H	72	1001000	48	h	104	1101000	68
HT	9	0001001	09	)	41	0101001	29	I	73	1001001	49	i	105	1101001	69
LF	10	0001010	0A	*	42	0101010	2A	J	74	1001010	4A	j	106	1101010	6A
VT	11	0001011	0B	+	43	0101011	2B	K	75	1001011	4B	k	107	1101011	6B
FF	12	0001100	0C	*	44	0101100	2C	L	76	1001100	4C	l	108	1101100	6C
CR	13	0001101	0D	-	45	0101101	2D	M	77	1001101	4D	m	109	1101101	6D
SO	14	0001110	0B	.	46	0101110	2E	N	78	1001110	4E	n	110	1101110	6E
SI	15	0001111	0F	/	47	0101111	2F	O	79	1001111	4F	o	111	1101111	6F
DLE	16	0010000	10	0	48	0110000	30	P	80	1010000	50	p	112	1110000	70
DCL	17	0010001	11	1	49	0110001	31	Q	81	1010001	51	q	113	1110001	71
DCC	18	0010010	12	2	50	0110010	32	R	82	1010010	52	r	114	1110010	72
DCS	19	0010011	13	3	51	0110011	33	S	83	1010011	53	s	115	1110011	73
DQ4	20	0010100	14	4	52	0110100	34	T	84	1010100	54	t	116	1110100	74
NAK	21	0010101	15	5	53	0110101	35	U	85	1010101	55	u	117	1110101	75
SYN	22	0010110	16	6	54	0110110	36	V	86	1010110	56	v	118	1110110	76
EIB	23	0010111	17	7	55	0110111	37	W	87	1010111	57	w	119	1110111	77
CAN	24	0011000	18	8	56	0111000	38	X	88	1011000	58	x	120	1111000	78
EM	25	0011001	19	9	57	0111001	39	Y	89	1011001	59	y	121	1111001	79
SUB	26	0011010	1A	:	58	0111010	3A	Z	90	1011010	5A	z	122	1111010	7A
ESC	27	0011011	1B	;	59	0111011	3B	[	91	1011011	5B	[	123	1111011	7B
FS	28	0011100	1C	<	60	0111100	3C	\	92	1011100	5C	\	124	1111100	7C
GS	29	0011101	1D	=	61	0111101	3D	]	93	1011101	5D	]	125	1111101	7D
RS	30	0011110	1E	>	62	0111110	3E	^	94	1011110	5E	~	126	1111110	7E
US	31	0011111	1F	?	63	0111111	3F	-	95	1011111	5F	Del	127	1111111	7F

ASCII has 128 characters and symbols represented by a 7-bit binary code. The first thirty two ASCII characters are non graphic commands that are never printed or displayed and are used only for control purposes. Examples of the control characters are "null", "line feed", "start of text" and "escape". The other characters are graphic symbols that can be printed or displayed and include the letters of the alphabet (lower case and uppercase), the ten decimal digits, punctuation signs and other commonly used symbols.

### EBCDIC

EBCDIC (Extended Binary Coded Decimal Interchange Code) is another widely used alphanumeric code, mainly popular with large systems. The code was created by IBM to extend the binary coded decimal existed at that time. All IBM mainframe computer peripherals and operating systems use EBCDIC code.

EBCDIC is an 8-bit code and therefore can accommodate 256 characters.

ASCII and EBCDIC codes are commonly used in data transfer and computer interface applications.

### BINARY ARITHMETIC

VII

Since digital systems do not process the decimal numbers and they only process binary numbers, it is necessary to learn the binary arithmetic.

i) Addition of Binary numbers

A (Augend)	B (Addend)	S (Sum)	C (Carry)
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

a)  $(1010)_2 + (0101)_2$

$$\begin{array}{r} 1010 \\ + 0101 \\ \hline \underline{\underline{1111}} \end{array} \quad \begin{array}{r} 10 \\ + 5 \\ \hline \underline{\underline{15}} \end{array}$$

b) Add.  $(10)_{10} + (11)_{10}$  in binary

$$\begin{array}{r} 1 \\ 1010 \\ 1011 \\ \hline \underline{\underline{10101}} \end{array} \quad \begin{array}{r} 10 \\ + 11 \\ \hline \underline{\underline{21}} \end{array}$$

c) Add 26 and 13 in binary

$$\begin{array}{r} 1 \\ 11010 \\ 01101 \\ \hline \underline{\underline{100111}} \end{array} \quad \begin{array}{r} 26 \\ + 13 \\ \hline \underline{\underline{39}} \end{array}$$

$$\begin{array}{r} 2 \Big| 26 \\ 2 \Big| 13 - 0 \\ 2 \Big| 6 - 1 \\ 2 \Big| 3 - 0 \\ 1 - 1 \end{array}$$

d) Add  $1011 \cdot 011$  and  $110 \cdot 1$

$$\begin{array}{r} 1011 \cdot 011 \\ 0110 \cdot 100 \\ \hline \underline{\underline{10001 \cdot 111}} \end{array}$$

$$\begin{array}{r} 100111 \\ 2^5 \quad 2^2 \quad 2^0 \\ 2^2 \quad 2^1 \quad 2^0 \end{array}$$

$$\begin{array}{r} 32 \\ + 4 \\ + 2 \\ + 1 \\ \hline \underline{\underline{39}} \end{array}$$

e) Add  $101 \cdot 11$ ,  $1101 \cdot 01$  and  $10000 \cdot 001$

$$\begin{array}{r}
 101 \cdot 11 \\
 1101 \cdot 01 \\
 \hline
 10000 \cdot 001 \\
 \hline
 \underline{100011 \cdot 001}
 \end{array}$$

## ii) Subtraction of Binary Numbers

Binary subtraction can be carried out in either one of two different ways

- a) Direct Subtraction
- b) Complement Subtraction

### a) Direct Subtraction

A (Minuend)	B (Subtrahend)	D (Difference)	B (Borrow)
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

a) Subtract  $10101$  from  $11011$

$$\begin{array}{r}
 11011 \\
 - 10101 \\
 \hline
 \underline{00110}
 \end{array} \Rightarrow \begin{array}{r}
 27 \\
 - 21 \\
 \hline
 6
 \end{array}$$

$$\begin{array}{r}
 1001 \cdot 10 \\
 - 0111 \cdot 01 \\
 \hline
 \underline{0010 \cdot 01}
 \end{array} \Rightarrow \begin{array}{r}
 9.50 \\
 - 7.25 \\
 \hline
 2.25
 \end{array}$$

$$\begin{array}{r}
 10000 \\
 - 1010 \\
 \hline
 \underline{00110}
 \end{array} \Rightarrow \begin{array}{r}
 16 \\
 - 10 \\
 \hline
 6
 \end{array}$$

$$\begin{array}{r}
 1010 \cdot 11 \\
 - 0110 \cdot 01 \\
 \hline
 \underline{0100 \cdot 10}
 \end{array} \Rightarrow \begin{array}{r}
 10.75 \\
 - 6.25 \\
 \hline
 4.50
 \end{array}$$

$$\begin{array}{r}
 10110 \\
 - 1010 \\
 \hline
 \underline{01100}
 \end{array} \Rightarrow \begin{array}{r}
 22 \\
 - 10 \\
 \hline
 12
 \end{array}$$

(25)

## b) Complement Subtraction Method

### 1. One's complement Subtraction method

Case(i) Subtraction of smaller number from larger number.

#### Procedure

- 1) Determine 1's complement of the smaller number (Subtrahend)
- 2) Add 1's complement to the larger number (minuend)
- 3) Carry generated after the addition is called "End-Around Carry" (EAC). Remove the EAC and add it to the result.

- 1) Subtract  $101011$  from  $111101$  using 1's complement method

$$\begin{array}{r}
 111101 \\
 + 010100 \quad \text{1's complement} \\
 \hline
 1010001
 \end{array}
 \quad \text{EAC} \rightarrow \boxed{1} \quad \text{Add EAC}$$

$$\begin{array}{r}
 101011 \\
 + 010100 \\
 \hline
 1010010 = (18)_{10}
 \end{array}$$

- 2)  $28 - 8$

$$28 = 11100$$

$$8 = 01000$$

$$\text{1's complement of } 8 = 10111$$

$$\begin{array}{r}
 11100 \\
 + 10111 \\
 \hline
 10100
 \end{array}
 \quad \text{EAC} \rightarrow \boxed{1} \quad \text{Add EAC}$$

$$\begin{array}{r}
 10100 = (20)_{10}
 \end{array}$$

$$\begin{array}{r}
 2 | 28 \\
 2 | 14 - 0 \\
 2 | 7 - 0 \\
 2 | 3 - 1 \\
 1 - 1
 \end{array}$$

$$\begin{array}{r}
 2 | 8 \\
 2 | 4 - 0 \\
 2 | 2 - 0 \\
 1 - 0
 \end{array}$$

(26)

3)  $30 - 25$

$30 \rightarrow 11110$

$25 \rightarrow 11001$

$$\begin{array}{r} 2 | 25 \\ 2 | 12 - 1 \\ 2 | 6 - 0 \\ 2 | 3 - 0 \\ \hline 1 - 1 \end{array}$$

$$\begin{array}{r} 2 | 30 \\ 2 | 15 - 0 \\ 2 | 7 - 1 \\ 2 | 3 - 1 \\ \hline 1 - 1 \end{array}$$

1's complement of 25 = 00110

$$\begin{array}{r}
 11110 \\
 + 00110 \\
 \hline
 \text{EAC} \rightarrow \boxed{1} 00100
 \end{array}$$

+ 1 Add EAC

$$\begin{array}{r}
 00101 \\
 \hline
 = (5)_{10}
 \end{array}$$

4)  $25.5 - 12.25$

$25.5 \rightarrow 11001.1$

$12.25 \rightarrow 01100.01$

$0.25 \times 2 \rightarrow 0.50$

$0.5 \times 2 \rightarrow 1.00$

01

1's complement of 12.25 = 10011.10

$$\begin{array}{r}
 11001.1 \\
 + 10011.10 \\
 \hline
 \text{EAC} \rightarrow \boxed{1} 01101.00
 \end{array}$$

+ 1 Add EAC

$$\begin{array}{r}
 01101.01 \\
 \hline
 = (13.25)_{10}
 \end{array}$$

5)  $10.625 - 8.75$

$10.625 \rightarrow 1010.101$

$8.75 \rightarrow 1000.110$

$0.625 \times 2 \rightarrow 1.25$

$0.25 \times 2 \rightarrow 0.50$

$0.5 \times 2 \rightarrow 1.00$

101

1's complement of 8.75 = 0111.001

$$\begin{array}{r}
 1010.101 \\
 + 0111.001 \\
 \hline
 \text{EAC} \rightarrow \boxed{1} 0001.110
 \end{array}$$

+ 1 Add EAC

$$\begin{array}{r}
 0001.111 \\
 \hline
 = (1.875)_{10}
 \end{array}$$

$0.75 \times 2 \rightarrow 1.50$

$0.50 \times 2 \rightarrow 1.00$

11

Case ii) Subtraction of larger number from smaller number

Procedure

- 1) Determine the 1's complement of the larger number (Subtrahend)
- 2) Add 1's complement to the smaller number (minuend)
- 3) After addition no carry will be generated by answer in 1's complement form (negative number)

To get the answer in true form, take the 1's complement of it and assign negative sign to the answer.

a)  $43 - 57$

$$57 \rightarrow 111001$$

$$\text{1's complement of } 57 \rightarrow 000110$$

$$43 \rightarrow 101011$$

$$\begin{array}{r}
 101011 \quad \text{Minuend} \\
 + 000110 \quad \text{Subtrahend 1's} \\
 \hline
 110001 \quad \text{complement}
 \end{array}$$

$$\begin{array}{r}
 2 \overline{) 57} \\
 2 \overline{) 28-1} \\
 2 \overline{) 14-0} \\
 2 \overline{) 7-0} \\
 2 \overline{) 3-1} \\
 \hline
 1-1
 \end{array}$$

The result has no carry, so the answer is in 1's complement form

$$\text{1's complement of } 110001 \rightarrow -001110$$

$$\text{answer in true form} = \underline{\underline{(-14)_{10}}}$$

b)  $8 - 10$

$$8 \rightarrow 1000$$

$$10 \rightarrow 1010$$

$$\text{1's complement of } 10 \rightarrow 0101$$

(28)

$$\begin{array}{r}
 1000 \quad \text{Minuend} \\
 + 0101 \quad \text{1's complement of} \\
 \hline
 1101 \quad \text{Subtrahend}
 \end{array}$$

$$\begin{aligned}
 & \text{1's complement of } 1101 \rightarrow -(0010) \\
 & \rightarrow -(2) \\
 & \quad \underline{\quad}^{10}
 \end{aligned}$$

c)  $8.75 - 10.625$

$$8.75 \rightarrow 1000.110$$

$$10.625 \rightarrow 1010.101$$

$$\text{1's complement of } 10.625 \rightarrow 0101.010$$

$$\begin{array}{r}
 1000.110 \quad \text{Minuend} \\
 + 0101.010 \quad \text{1's complement of} \\
 \hline
 1110.000 \quad \text{Subtrahend}
 \end{array}$$

$$\begin{aligned}
 & \text{1's complement of } 1110.000 \rightarrow -(0001.111) \\
 & \rightarrow -(1.875)_{10}
 \end{aligned}$$

d)  $\frac{5}{8} - \frac{7}{8}$

$$\frac{5}{8} \rightarrow 0.625 \rightarrow .101$$

$$\frac{7}{8} \rightarrow 0.875 \rightarrow .111$$

$$0.625 \times 2 \rightarrow 1.25$$

$$1.25 \times 2 \rightarrow 0.50$$

$$0.50 \times 2 \rightarrow 1.00$$

(101)

$$\text{1's complement of subtrahend}$$

$$\text{i.e. } .111 \rightarrow .000$$

$$0.875 \times 2 \rightarrow 1.75$$

$$1.75 \times 2 \rightarrow 1.50$$

$$1.50 \times 2 \rightarrow 1.00$$

(111)

$$\begin{array}{r}
 .101 \quad \text{Minuend} \\
 + .000 \quad \text{1's complement of} \\
 \hline
 .101 \quad \text{Subtrahend}
 \end{array}$$

$$\begin{aligned}
 & \text{1's complement of } .101 \rightarrow -(010)_2 \\
 & \rightarrow -(25)_{10}
 \end{aligned}$$

(29)

e)  $16 \cdot 875 - 11 \cdot 125$

$$16 \cdot 875 \rightarrow 10000 \cdot 111$$

$$11 \cdot 125 \rightarrow 01011 \cdot 001$$

1's complement of Subtrahend

$$01011 \cdot 001 \rightarrow 10100 \cdot 110$$

$$\begin{array}{r} 2 | 16 \\ 2 | 8 - 0 \\ 2 | 4 - 0 \\ 2 | 2 - 0 \\ 1 - 0 \end{array}$$

$$125 \times 2 = 0.25$$

$$25 \times 2 = 0.50$$

$$50 \times 2 = 1.00$$

(001)

$$\begin{array}{r} 10000 \cdot 111 \\ + 10100 \cdot 110 \\ \hline 100101 \cdot 101 \end{array} \rightarrow \underline{\underline{(5.75)}_{10}}$$

### Advantages

1. Since 1's complement subtraction can be accomplished with a binary adder, this method is useful in arithmetic logic circuits.
2. It is very easy to find the 1's complement of a number

### Disadvantages

1. Hardware implementation is difficult and it gives the concept of negative zero.

### 2's Complement method

The 2's complement of any binary number is determined by adding 1 to 1's complement of that number. 2's complement form is used to represent negative numbers. 2's complement of 1 is 1 and zero is 10

### Case i) Subtraction of a smaller number from larger number

#### Procedure

1. Determine the 2's complement of the small number (Subtrahend)

(30)

2. Add 2's complement to the minuend.
3. Discard the carry generated.

a)  $(111001)_2 - (101011)_2$

57

43

2's complement of Subtrahend  $43 \rightarrow 101011$

$$\begin{array}{r}
 & 010100 \\
 + & 1 \\
 \hline
 & 010101
 \end{array}$$

$111001$  Minuend  
 $+ 010101$  2's complement of  
 $\underline{\boxed{1}}001110 = (14)_{10}$  Subtrahend  
 Discard carry

b)  $(100.5)_{10} - (50.75)_{10}$

$100.5 \rightarrow 1100100 \cdot 10$

$50.75 \rightarrow 0110010 \cdot 11$

$$\begin{array}{r}
 2 \overline{)100} \\
 2 \overline{)50-0} \\
 2 \overline{)25-0} \\
 (11) \quad 2 \overline{)12-1} \\
 2 \overline{)6-0} \\
 2 \overline{)3-0} \\
 1-1
 \end{array}$$

2's complement of Subtrahend

$$\begin{array}{r}
 1001101 \cdot 00 \\
 + 1 \\
 \hline
 \underline{1001101 \cdot 01}
 \end{array}$$

$1100100 \cdot 10$  Minuend  
 $+ 1001101 \cdot 01$  2's complement of Subtrahend  
 $\underline{\boxed{1}}0110001 \cdot 11 = (49.75)_{10}$

Discard carry

c)  $(1111)_2 - (1010)_2$

15

10

2's complement of Subtrahend

$$\begin{array}{r}
 0101 \\
 + 1 \\
 \hline
 \underline{0110}
 \end{array}$$

(3.1)

$$\begin{array}{r}
 1111 \quad \text{Minuend} \\
 + 0110 \quad \text{2's complement of Subtrahend} \\
 \hline
 \boxed{1} \underline{0101} = (5)_{10}
 \end{array}$$

↑  
Discard carry

d)  $(112)_{10} - (65)_{10}$

$$112 \rightarrow 1110000$$

$$65 \rightarrow 1000001$$

2's complement of Subtrahend

$$\begin{array}{r}
 2 \overline{)112} \\
 2 \overline{)56-0} \\
 2 \overline{)28-0} \\
 2 \overline{)14-0} \\
 2 \overline{)7-0} \\
 2 \overline{)3-1} \\
 1-0
 \end{array}$$

$$\begin{array}{r}
 0111110 \\
 + \quad \quad \quad 1 \\
 \hline
 \underline{\underline{0111111}}
 \end{array}$$

$$\begin{array}{r}
 1110000 \quad \text{Minuend} \\
 + 0111111 \quad \text{2's complement of Subtrahend} \\
 \hline
 \boxed{1} \underline{0101111} = (47)_{10}
 \end{array}$$

↑  
Discard carry

e)  $22 - 7$

$$22 \rightarrow 10110$$

$$7 \rightarrow 00111$$

2's complement of Subtrahend

$$\begin{array}{r}
 00111 \\
 + 11000 \\
 \hline
 \underline{\underline{11001}}
 \end{array}$$

$$\begin{array}{r}
 2 \overline{)22} \\
 2 \overline{)11-0} \\
 2 \overline{)5-1} \\
 2 \overline{)2-1} \\
 1-0
 \end{array}$$

$$\begin{array}{r}
 10110 \quad \text{Minuend} \\
 + 11001 \quad \text{2's complement of Subtrahend} \\
 \hline
 \boxed{1} \underline{01111} = (15)_{10}
 \end{array}$$

↑  
Discard carry

(32)

Case ii) Subtraction of a larger number from smaller number

Procedure

1. Determine the 2's complement of the Subtrahend
2. Add the 2's complement to minuend
3. Answer is in 2's complement form. Take the 2's complement and assign negative sign to the answer.

No carry will be generated.

a)  $7 - 22$

$$7 \rightarrow 00111$$

$$22 \rightarrow 10110$$

2's complement of 22

$$\begin{array}{r} 01001 \\ + \quad 1 \\ \hline \underline{\underline{01010}} \end{array}$$

$$\begin{array}{r} 2 \longdiv{22} \\ 2 \longdiv{11-0} \\ 2 \longdiv{5-1} \\ 2 \longdiv{2-1} \\ 1-0 \end{array}$$

00111 Minuend

01010 2's complement of Subtrahend

Take 2's complement of  $10001 \rightarrow 01110$

$$\begin{array}{r} + \quad 1 \\ -( \underline{\underline{01111}} )_2 \end{array}$$

$$= -(15)_{10}$$

b)  $16.5 - 24.75$

$$16.5 \rightarrow 10000.1$$

$$24.75 \rightarrow 11000.11$$

$$\begin{array}{r} 2 \longdiv{24} \qquad 2 \longdiv{16} \\ 2 \longdiv{12-0} \qquad 2 \longdiv{8-0} \\ 2 \longdiv{6-0} \qquad 2 \longdiv{4-0} \\ 2 \longdiv{3-0} \qquad 2 \longdiv{2-0} \\ 1-1 \qquad 1-0 \end{array}$$

(33)

2's complement of Subtrahend

$$\begin{array}{r}
 11000 \cdot 11 \\
 00111 \cdot 00 \\
 + \quad \quad \quad 1 \\
 \hline
 \underline{\underline{00111 \cdot 01}}
 \end{array}$$

$$\begin{array}{r}
 10000 \cdot 10 \\
 + 00111 \cdot 01 \\
 \hline
 \underline{\underline{10111 \cdot 11}}
 \end{array}
 \text{ Minuend} \quad \text{2's complement of Subtrahend}$$

Take 2's complement of  $10111 \cdot 11$ 

$$\begin{array}{r}
 \rightarrow 01000 \cdot 00 \\
 + \quad \quad \quad 1 \\
 \hline
 \underline{\underline{01000 \cdot 01}} = (-8.25)_{10}
 \end{array}$$

iii) Multiplication of Binary Numbers

Multiplicand	Multiplicator	Product
A	B	P
0	0	0
0	1	0
1	0	0
1	1	1

a)  $7 \times 5$ 

$$\begin{array}{r}
 7 \rightarrow 0111 \\
 5 \rightarrow 0101
 \end{array}
 \begin{array}{r}
 \begin{array}{r}
 111 \\
 \times 101 \\
 \hline
 111 \\
 000 \\
 \hline
 111 \\
 \hline
 100011
 \end{array}
 = (35)_{10}
 \end{array}$$

b)  $4.75 \times 3.625$ 

$$4.75 \rightarrow 100 \cdot 110$$

$$3.625 \rightarrow 011 \cdot 101$$

(34)

$$1+1+1+1 = 100$$

↓      ↓      ↓      ↓  
 3rd column      2nd column      1st column

$$\begin{array}{r} 100 \cdot 110 \\ \times 011 \cdot 101 \\ \hline 100110 \\ 000000 \\ 100110 \\ 100110 \\ 100110 \\ \hline 10001001110 \end{array}$$

$$= (17 \cdot 21875)_{10}$$

$$\begin{array}{r} .001110 \\ -1-2-3-4-5 \\ \hline 2^3 + 2^4 + 2^5 \\ 0.125 + 0.0625 + \\ 0.03125 \\ = 0.21875 \end{array}$$

c)  $22 \times 6$ 

$$22 \rightarrow 10110$$

$$6 \rightarrow 00110$$

$$\begin{array}{r} 10110 \\ \times 110 \\ \hline 00000 \\ 10110 \\ \hline 10110 \\ \hline 10000100 = (132)_{10} \end{array}$$

$$\begin{array}{r} 2 \overline{)22} \\ 2 \overline{)11-0} \\ 2 \overline{)5-1} \\ 2 \overline{)2-1} \\ 1-0 \\ \hline 2 \overline{)6} \\ 2 \overline{)3-0} \\ 1-1 \end{array}$$

d)  $27 \times 21$ 

$$27 \rightarrow 11011$$

$$21 \rightarrow 10101$$

$$\begin{array}{r} 11011 \\ \times 10101 \\ \hline 11011 \\ 00000 \\ 11011 \\ 00000 \\ 11011 \\ \hline 1000110111 = (567)_{10} \end{array}$$

$$\begin{array}{r} 2 \overline{)27} \\ 2 \overline{)13-1} \\ 2 \overline{)10-1} \\ 2 \overline{)5-0} \\ 2 \overline{)2-1} \\ 1-0 \\ \hline 2 \overline{)6-1} \\ 2 \overline{)3-0} \\ 1-1 \end{array}$$

(35)

0.09375

e)  $\frac{3}{8} \times \frac{1}{4}$

$$\frac{3}{8} = 0.375 \rightarrow 0.011$$

$$\frac{1}{4} = 0.25 \rightarrow 0.01$$

$$\begin{array}{r}
 0.011 \\
 \times 0.01 \\
 \hline
 0011 \\
 0000 \\
 \hline
 00001 = (0.09375)_{10}
 \end{array}$$

$$0.375 \times 2 = 0.75$$

$$0.75 \times 2 = 1.50$$

$$1.50 \times 2 = 1.00$$

(011)

$$0.25 \times 2 \rightarrow 0.50$$

$$0.50 \times 2 \rightarrow 1.00$$

(01)

0.0625

+ 0.03125

#### v) Division of Binary Numbers

$$0 \div 1 = 0$$

$$1 \div 1 = 1$$

a)  $50 \div 5$

$$50 \rightarrow 110010$$

$$5 \rightarrow 101$$

$$110010 \div 101$$

$$\begin{array}{r}
 1010 \\
 \hline
 101 \Big| 110010 \\
 101 \\
 \hline
 00101 \\
 101 \\
 \hline
 00 \\
 0 \\
 \hline
 0
 \end{array}$$

$$\begin{array}{r}
 50 \\
 2 \overline{) 25.0} \\
 2 \overline{) 25 - 0} \\
 2 \overline{) 12 - 1} \\
 2 \overline{) 6 - 0} \\
 2 \overline{) 3 - 0} \\
 1 - 1
 \end{array}$$

$$110010 \div 101 = (1010)_2 = (10)_2$$

(36)

b)  $25 \div 4$

$$25 \rightarrow 11001$$

$$4 \rightarrow 100$$

$$11001 \div 100 =$$

$$\begin{array}{r} 2 \\ \overline{)25} \\ 2 \\ \overline{)12} \\ 2 \\ \overline{)6} \\ 2 \\ \overline{)3} \\ 1 \\ -1 \end{array}$$

$$\begin{array}{r} 110.01 \\ \hline 100 \quad | \quad 11001 \\ \quad 100 \\ \hline \quad 100 \\ \quad 100 \\ \hline \quad 010 \\ \quad 000 \\ \hline \quad 100 \\ \quad 100 \\ \hline \quad 0 \end{array}$$

$$11001 \div 100 = (110.01)_2 = (\underline{\underline{6.25}})_{10}$$

c)  $1010.10 \div 101.01$

$$1010.10 \rightarrow 10.50 \rightarrow 1050$$

$$101.01 \rightarrow 5.25 \rightarrow 525$$

Get rid of decimal

$$\begin{array}{r} 10 \\ \hline 1000001101 \quad | \quad 10000011010 \\ \quad 1000001101 \\ \hline \quad 00 \\ \quad 0 \\ \hline \quad 0 \end{array}$$

$$\begin{array}{r} 2 \\ \overline{)1050} \\ 2 \\ \overline{)525} \\ 2 \\ \overline{)262} \\ 2 \\ \overline{)131} \\ 2 \\ \overline{)65} \\ 2 \\ \overline{)32} \\ 2 \\ \overline{)16} \\ 2 \\ \overline{)8} \\ 2 \\ \overline{)4} \\ 2 \\ \overline{)2} \\ 1 \\ -0 \end{array}$$

$$=(2)$$

$$\underline{\underline{10}}$$

d)  $10 \overline{)1100.00}$

$$\begin{array}{r} 10 \\ 10 \\ \hline 00 \\ 0 \\ \hline 00 \\ 0 \\ \hline 00 \end{array}$$

$$1100.00 \div 10 = \underline{\underline{110.00}}$$

VIIIADDITION AND SUBTRACTION OF BCDi) BCD Addition

Addition is the most important operation because the other three operations (subtraction, multiplication, division) can be accomplished by the use of addition.

Procedure

1. Add the two BCD numbers, using the rules for binary addition.
2. If a 4 bit sum is equal to or less than 9 it is a valid BCD number.
3. If a 4 bit sum is greater than 9 or if a carry out of the 4-bit group is generated, it is an invalid result.

Add 6 (0110) to the 4-bit sum in order to skip the six invalid states and return the code to 8421

If a carry results when 6 is added, simply add the carry to the next 4-bit group.

a)  $(2)_{10} + (6)_{10}$

$$\begin{array}{r} 0010 \\ + 0110 \\ \hline \underline{\underline{1000}} \end{array} = (8)_{10}$$

(38)

b)  $(3)_{10} + (7)_{10}$

$$\begin{array}{r} 111 \\ 0011 \\ 0111 \\ \hline 1010 \end{array}$$

$10 > 9$  So add 6

$$\begin{array}{r} 1010 \\ + 0110 \\ \hline 0001 \quad 0000 \end{array} \rightarrow BCD$$

$\begin{matrix} 1 \\ 0 \end{matrix} \rightarrow \text{Decimal}$

c)  $(8)_{10} + (9)_{10}$

$$\begin{array}{r} 1000 \\ + 1001 \\ \hline 10001 \end{array}$$

Add 6

$$\begin{array}{r} 0110 \\ \hline 0001 \quad 0111 \end{array} \rightarrow BCD$$

$(1 \ 7)_{10}$

d)  $(57)_{10} + (26)_{10}$

$$\begin{array}{r} 01010111 \\ 00100110 \\ \hline 01111101 \end{array}$$

$13 > 9$  So add 6

$\begin{matrix} 7 \leftarrow \\ 13 \rightarrow \end{matrix}$

$$\begin{array}{r} 01111101 \\ + 0110 \\ \hline 10000011 \end{array}$$

Add 0110  $\rightarrow 6$

$(8 \ 3)_{10}$

e)  $(3)_{10} + (4)_{10}$

$$\begin{array}{r} 0011 \\ 0100 \\ \hline 0111 \end{array} \rightarrow (7)_{10}$$

f)  $(7)_{10} + (9)_{10}$

$$\begin{array}{r} 0111 \\ 1001 \\ \hline 1000 \\ + 0110 \\ \hline 10110 \end{array} \rightarrow (16)_{10}$$

(39)

**BCD Addition**Answer

Sum &lt; 9 Carry = 0 Correct

Sum &gt; 9 Carry = 0 Add 6

Sum &lt; 9 Carry = 1 Add 6

g)  $(7)_{10} + (8)_{10}$

$$\begin{array}{r}
 0111 \\
 1000 \\
 \hline
 1111 \\
 + 0110 \\
 \hline
 0001 \ 0101 \\
 \hline
 1 \quad 5
 \end{array} \rightarrow (15)_{10}$$

h)  $(83)_{10} + (34)_{10}$

$$\begin{array}{r}
 10000011 \\
 00110100 \\
 \hline
 10110111 \\
 + 0110 \\
 \hline
 0001 \ 0001 \ 0111 \\
 \hline
 1 \quad 1 \quad 7
 \end{array} \rightarrow (117)_{10}$$

Only add 6 to  
the group which is  
greater than 9

i)  $(16)_{10} + (15)_{10}$

$$\begin{array}{r}
 00010110 \\
 + 00010101 \\
 \hline
 00101011 \\
 + 0110 \\
 \hline
 00110001 \\
 \hline
 3 \quad 1
 \end{array} \rightarrow (31)_{10}$$

j)  $(67)_{10} + (53)_{10}$

$$\begin{array}{r}
 01100111 \\
 01010011 \\
 \hline
 10111010 \\
 + 01100110 \\
 \hline
 000100100000 \\
 \hline
 1 \quad 2 \quad 0
 \end{array} \rightarrow (120)_{10}$$

ii) BCD Subtraction

(Using 9's complement)

Procedure

1. Take 9's complement for Subtrahend
2. Add it to the Minuend using BCD addition
3. If the result is invalid BCD then correct by adding 6
4. Shift the carry to next bits
5. If end around carry generated then add it to the result.

9's Complement

9's complement of decimal number can be obtained by  $((10^n - 1))$  - number where  $n$  represents the number of digits in given number.

$$\text{eg } (1234)_{10}$$

9's complement of  $(1234)_{10}$  is

$$\begin{aligned} & (10^4 - 1) - 1234 \\ & 9999 - 1234 \\ & = \underline{\underline{8765}} \end{aligned}$$

$$\begin{array}{r} 9999 \\ 1234 \\ \hline \underline{\underline{8765}} \end{array}$$

10's Complement

10's complement of a decimal can be obtained by  $(10^n - \text{number})$  where  $n$  represents the number of digits in given number

$$\text{eg } (1234)_{10}$$

10's complement of  $(1234)_{10}$  is

$$\begin{aligned} & 10^4 - 1234 \\ & = \underline{\underline{8766}} \end{aligned}$$

(41)

a) Subtract 812 from 983

$$(983)_{10} - (812)_{10}$$

9's complement of Subtrahend

$$\begin{array}{r} 812 \\ \rightarrow 999 \\ 812 \\ \hline \underline{\underline{187}} \end{array}$$

$$\begin{array}{r} 1001 1000 0011 \\ + 0001 1000 0111 \\ \hline 1010 \boxed{1} 0000 1010 \\ + 0110 0110 0110 \\ \hline \boxed{1} 0001 10111 0000 \\ \text{EAC} \xrightarrow{\quad\quad\quad} \\ \hline \underbrace{0001}, \underbrace{0111}, \underbrace{0001} \rightarrow (171)_{10} \end{array}$$

b) Subtract 623.85 from 336.25 using 9's complement BCD subtraction

$$(336.25)_{10} - (623.85)_{10} = (287.60)_{10}$$

9's complement of Subtrahend

$$\begin{array}{r} 623.85 \\ \rightarrow 999.99 \\ - 623.85 \\ \hline \underline{\underline{376.14}} \end{array}$$

$$\begin{array}{r} 0011 0011 0110 . 0010 0101 \\ 0011 0111 0110 . 0001 0100 \\ \hline 0110 1010 1100 . 0011 1001 \\ 0110 0110 \\ \hline 0111 0001 0010 . 0011 1001 \\ \text{complement form} \xrightarrow{\quad\quad\quad} \\ \begin{matrix} 7 & 1 & 2 & . & 3 & 9 \end{matrix} \end{array}$$

So again 9's complement form

$$\begin{array}{r} 999.99 \\ 712.39 \\ \hline \underline{\underline{287.60}} \end{array} \rightarrow (287.60)_{10}$$

If the result has no EAC, the result is said to be negative & in complemented form

(42)

### (Using 10's complement)

#### Procedure

1. Take 10's complement of Subtrahend
2. Add it to the Minuend by using BCD addition
3. If error BCD digits are there correct by adding 6
4. Follow up the carry to next bits
5. If end around carry (EAC) is there discard the carry. If not, say result is -ve and is in 10's complement form. Take 10's complement again to get actual result.

a) Subtract  $02 \cdot 1$  from  $10 \cdot 2$

10's complement of Subtrahend

10's  
↓ complement

$$10^2 - 02 \cdot 1$$

$$= 100 - 02 \cdot 1$$

$$= \underline{\underline{97 \cdot 9}}$$

$10^n$ -number

$$\begin{array}{r}
 & 0001\ 0000 \cdot 0010 \\
 + & 1001\ 0111 \cdot 1001 \\
 \hline
 & 1010\ 0111 \cdot 1011 \\
 + & 0110 \qquad \qquad 0110 \\
 \hline
 & \boxed{1}0000\ 1000 \cdot 0001
 \end{array}$$

EAC → Discard carry

$= (08 \cdot 1)_{10}$

(43)

b)  $26 \cdot 25 - 38 \cdot 26$

10's complement of  $38 \cdot 26$

$10^n$ -number

$$10^2 - 38 \cdot 26$$

$$100 - 38 \cdot 26 = \underline{\underline{61 \cdot 74}}$$

10's complement  
of Subtrahend

$$\begin{array}{r} 0010 \quad 0110 \cdot 0010 \quad 0101 \\ + 0110 \quad 0001 \cdot 0111 \quad 0100 \\ \hline 1000 \quad 0111 \cdot 1001 \quad 1001 \\ \hline 8 \quad 7 \quad 9 \quad 9 \end{array}$$

So take 10's complement of result

No EAC means  
-ve & is in  
10's complement  
form

$$\begin{aligned} 10^2 - 87 \cdot 99 \\ = 100 - 87 \cdot 99 \\ = \underline{\underline{(12 \cdot 01)}}_{10} \Rightarrow \underline{\underline{(12 \cdot 01)}}_{10} \end{aligned}$$

c) Subtract 24 from 18 using 9's complement  
BCD Subtraction

$$18 - 24$$

9's complement of Subtrahend

$$\begin{array}{r} 99 \\ - 24 \\ \hline \underline{\underline{75}} \end{array}$$

9's  
↓ complement

$(10^n-1)$ -number

$$\begin{array}{r} 0001 \quad 1000 \\ + 0111 \quad 0101 \\ \hline 1000 \quad 1101 \\ + 0110 \\ \hline 1001 \quad 0011 \\ \hline 9 \quad 3 \end{array}$$

No EAC means  
-ve & is in  
9's complement  
form

9's complement of 93  $\rightarrow (10^2 - 1) - 93$

$$\begin{aligned} 99 - 93 \\ = \underline{\underline{-6}} \Rightarrow \underline{\underline{(-6)}}_{10} \end{aligned}$$

## TX ADDITION AND SUBTRACTION OF OCTAL AND

HEXADECIMAL NUMBERS

A-10

B-11

C-12

D-13

E-14

F-15

i) Hexadecimal AdditionProcedure

1. In any given column of an addition problem, think of the two hexadecimal digits in terms of their decimal values

$$5_{16} = 5_{10}$$

$$C_{16} = 12_{10}$$

2. If the sum of these two digits is  $15_{10}$  or less, bring down the corresponding hexadecimal digit.
3. If the sum of these two digits is greater than  $15_{10}$ , bring down the amount of the sum that exceeds  $16_{10}$  and carry a 1 to the next column

a) Add the following hexadecimal numbers

i)  $23_{16} + 16_{16}$

$$\begin{array}{r} 23 \\ + 16 \\ \hline 39 \\ \hline 16 \end{array}$$

ii)  $58_{16} + 22_{16}$

$$\begin{array}{r} 58 \\ + 22 \\ \hline 7A \\ \hline 16 \end{array}$$

$$\begin{array}{r} 8 \\ + 2 \\ \hline 10 \end{array} \rightarrow A$$

iii)  $2B_{16} + 84_{16}$

$$\begin{array}{r} 2B \\ + 84 \\ \hline AF \\ \hline 16 \end{array}$$

iv)  $DF_{16} + AC_{16}$

$$\begin{array}{r} DF \\ AC \\ \hline 18B \\ \hline 16 \end{array}$$

$$\begin{array}{r} B \xrightarrow{11} 4 \\ + 4 \\ \hline F \leftarrow 15 \end{array}$$

$16 \overline{(27)}$  27 is not  
1-11 hexadecimal number

$$\begin{array}{r} 1B \\ \hline CS \end{array}$$

(45)

$$\begin{array}{r} 1 \\ DF \\ AC \\ \hline 18B \\ \hline 16 \end{array}$$

$$\begin{array}{r} 1 \\ +D \\ +A \\ \hline +13 \\ +10 \\ \hline 24 \end{array}$$

$$16 \overline{(24)} \\ 1-8$$

v)  $3F8_{16} + 5B3_{16}$

$$\begin{array}{r} 1 \\ 3 F 8 \\ 5 B 3 \\ \hline 9 A B \\ \hline 16 \end{array}$$

$$\begin{array}{r} 18 \\ CS \\ +B \rightarrow 15 \\ +11 \\ \hline 26 \\ 16 \overline{(26)} \\ 1-10 \\ \hline 1A \\ CS \end{array}$$

vi)  $98F \cdot A2_{16} + B11 \cdot 94_{16}$

$$\begin{array}{r} 11 \\ 98F \cdot A2 \\ B11 \cdot 94 \\ \hline 14A1 \cdot 36 \\ \hline 16 \end{array}$$

$$\begin{array}{r} 916(19) \\ +A \\ \hline 19 \\ \hline 13 \\ CS \end{array}$$

$$\begin{array}{r} 16(17) \\ 1-1 +15 \leftarrow F \\ +1 \\ +1 \\ \hline 17 \end{array}$$

$$\begin{array}{r} 16(20) \\ 1-4 +9 \leftarrow B \\ +11 \\ \hline 20 \end{array}$$

vii)  $5689_{16} + 4574_{16}$

$$\begin{array}{r} 5689 \\ 4574 \\ \hline 9BFD \\ \hline 16 \end{array}$$

$$\begin{array}{r} 13 \\ 13 \\ \hline 26 \\ \leftarrow +D \end{array}$$

viii)  $ADD_{16} + DAD_{16}$

$$\begin{array}{r} 1 \\ A D D \\ D A D \\ \hline 188A \\ \hline 16 \end{array}$$

$$\begin{array}{r} 1 \\ +13 \\ +10 \\ \hline 24 \\ 16 \overline{(26)} \\ 1-10 \\ \hline 1A \\ CS \\ +10 \\ +13 \\ \hline 24 \\ \hline 18 \\ CS \end{array}$$

(46)

ii) Hexadecimal Subtraction

2's complement allows to subtract by adding binary number

$$a) 84_{16} - 2A_{16}$$

2's complement of Subtrahend

$$2A \rightarrow 00101010$$

$$\begin{array}{r} 11010101 \\ + 1 \\ \hline 11010110 \end{array}$$

$\underbrace{\hspace{1cm}}_D \quad \underbrace{\hspace{1cm}}_6$

$$\begin{array}{r} 84 \\ + D6 \\ \hline \boxed{1} \ 5A \end{array}$$

Discard carry

$$84_{16} - 2A_{16} = \boxed{5A}_{16}$$

$$\begin{array}{r} 8 \\ + D \\ \hline 16 \end{array} \quad \begin{array}{r} 8 \\ + 13 \\ \hline 21 \end{array}$$

$\overline{1-5}$

$$\begin{array}{r} 15 \\ \hline \boxed{C} \ 8 \end{array}$$

$$b) C3_{16} - 0B_{16}$$

2's complement of Subtrahend

$$0B \rightarrow 00001011$$

$$\begin{array}{r} 11110100 \\ + 1 \\ \hline 11110101 \end{array}$$

$\underbrace{\hspace{1cm}}_F \quad \underbrace{\hspace{1cm}}_5$

$$\begin{array}{r} C3 \\ + F5 \\ \hline \boxed{1} \ B8 \end{array}$$

Discard carry

$$C3_{16} - 0B_{16} = \boxed{B8}_{16}$$

$$\begin{array}{r} C \\ + F \\ \hline 16 \end{array} \quad \begin{array}{r} 12 \\ 15 \\ \hline 27 \end{array}$$

$\overline{1-11}$

$$\begin{array}{r} 1B \\ \hline \boxed{C} \ 8 \end{array}$$

(47)

iii) Octal Addition

a)  $147_8 + 261_8$

$$\begin{array}{r} 11 \\ 147 \\ 261 \\ \hline 430 \end{array}_8$$

8|8

1-0

10  
CS

$147_8 + 261_8 = \underline{\underline{430}}_8$

b)  $366 \cdot 23_8 + 243 \cdot 62_8 = (632.05)_8$

$$\begin{array}{r} 111 \\ 366 \cdot 23 \\ 243 \cdot 62 \\ \hline 632 \underline{05} \end{array}_8$$

c)  $243_8 + 212_8 = (455)_8$

$$\begin{array}{r} 243 \\ 212 \\ \hline 455 \end{array}_8$$

d)  $567_8 + 243_8 = (1032)_8$

$$\begin{array}{r} 11 \\ 567 \\ 243 \\ \hline 1032 \end{array}_8$$

$$\begin{array}{r} 1 \\ +1 \\ +2 \\ \hline \end{array}$$

Octal Number

(0 to 7)

$$\begin{array}{r} 7+1 = 8 \text{ not } \\ 11 \times \text{octal} \\ \hline 11 \end{array}$$

$$\begin{array}{r} 1 \\ +4 \\ +6 \\ \hline 11 \end{array}$$

$$\begin{array}{r} 8 | 11 \\ 1-3 \end{array}$$

$$\begin{array}{r} 13 \\ \hline CS \end{array}$$

$$\begin{array}{r} 1 \\ +6 \\ +3 \\ \hline 10 \end{array}$$

$$\begin{array}{r} 8 | 10 \\ 1-2 \end{array}$$

$$\begin{array}{r} 1 \\ +3 \\ +2 \\ \hline \end{array}$$

$$\begin{array}{r} 8 | 10 \\ 1-2 \end{array}$$

$$\begin{array}{r} 1 \\ +5 \\ +2 \\ \hline 8 \end{array}$$

$$\begin{array}{r} 1 \\ +7 \\ +7 \\ \hline 15 \end{array}$$

$$\begin{array}{r} 8 | 14 \\ 1-6 \end{array}$$

e)  $766_8 + 774_8 = (1762)_8$

$$\begin{array}{r} 11 \\ 766 \\ 774 \\ \hline 1762 \end{array}_8$$

iv) Octal Subtraction7's complement

To find the 7's complement, subtract each digit of the octal number from 7  
 7's complement of  $(76)_8$  is

$$\begin{array}{r} 77 \\ - 76 \\ \hline 18 \end{array}$$

7's complement of  $(144)_8$

$$\begin{array}{r} 777 \\ 144 \\ \hline 633 \end{array}_8$$

8's complement

8's complement of an octal number can be found by adding 1 to the 7's complement of that octal number

8's complement of  $(465)_8$

$$\begin{array}{r} 777 \\ 465 \\ \hline 312 \\ + 1 \\ \hline 313 \end{array}_8 \rightarrow \text{8's complement}$$

Procedure

- Find 8's complement of Subtrahend
- Add first number (minuend) and 8's complement of subtrahend.
- If carry is produced in the addition, discard the carry. If there is no carry take 8's complement of the sum and assign negative sign.

(49)

$$a) \quad 372_8 - 144_8$$

8's complement of Subtrahend

$$\begin{array}{r} 777 \\ - 144 \\ \hline 633 \\ + 1 \\ \hline 634_8 \end{array} \rightarrow 7's \text{ complement}$$

$$\rightarrow 8's \text{ complement}$$

$$\begin{array}{r} 1 \\ 372 \\ + 634 \\ \hline 1226 \end{array} \quad 8$$

*Discard  
the carry*

$$372_8 - 144_8 = 226$$

10 not  
octal  
so convert  
to octal  
 $8 \overline{)10}$   
1-2  
 $\frac{12}{C8}$

$$b) \quad 144_8 - 372_8$$

8's complement of Subtrahend

$$\begin{array}{r} 777 \\ - 372 \\ \hline 405 \\ + 1 \\ \hline 406_8 \end{array} \rightarrow 7's \text{ complement}$$

$$\rightarrow 8's \text{ complement}$$

$$\begin{array}{r} 1 \\ 144 \\ - 406 \\ \hline 552 \end{array} \quad 8$$

8's complement of  $652_8$

$$\begin{array}{r} 777 \\ 552 \\ \hline 225 \\ + 1 \\ \hline 226_8 \end{array}$$

$$144_8 - 372_8 = (-226)_8$$

## X REPRESENTATION OF FLOATING POINT NUMBERS

To represent very large integer (whole) numbers, many bits are required. Numbers with both integer and fractional parts such as 23.5618 also has to be represented.

The floating point number system, based on scientific notation is capable of representing very large and very small numbers without an increase in the number of bits and also for representing numbers that have both integer and fractional components.

A floating point number (also known as real number) consists of two parts plus a sign.

- i) Mantissa : is the part of a floating-point number that represents the magnitude of the number and is between 0 and 1.
- ii) Exponent : is the part of a floating-point number that represents the number of places that the decimal point (or binary point) is to be moved.

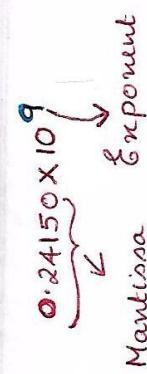
Example:

A decimal number in integer form is 241,506,800. The mantissa is .2415068 and the exponent is 9. When an integer is expressed as a floating point number, it is normalized by moving the decimal point to the left of all digits so that the mantissa is a fractional number and the exponent is the power of ten.

The floating point number is written as

$$0.2415068 \times 10^9$$

For binary floating number, the format is



defined by ANSI/IEEE standard 754-1985 in three forms

- Single-precision
- Double-precision
- Extended-precision

They all have the same basic formats except for the number of bits.

Single precision floating point numbers have 32 bits

Double precision numbers have 64 bits.

Extended-precision numbers have 80 bits.

### Example 2:

The decimal number +6132.789 is represented in floating-point with a fraction and an exponent as follows:

Fraction	Exponent
+0.6132789	+04

The value of the exponent indicates that the actual position of the decimal point is four positions to the right of the indicated decimal point in the fraction. This is equivalent to scientific notation  
 $+0.6132789 \times 10^4$

Floating-point is always interpreted to represent a number in the following form

$$m \times r^e$$

Only mantissa m and the exponent e are physically represented in the register (including signs)

Floating point binary number is represented in a similar manner, except that it uses base 2 for the exponent.

Sign bit  
1 for -ve  
0 for +ve