15CS21T - DIGITAL AND COMPUTER FUNDAMENTALS

Note: This is only Basic Information for students. Please refer “Reference Books” prescribed as per syllabus

UNIT- 1: DIGITAL PRINCIPLES

Number System

Numbers are extremely important in our personal life. The Abacus is one of the earliest known calculators. It is used presently also. In 1962 Gottfried Wilhelm von Leibniz developed a machine which performed all basic arithmetic operations (addition, subtraction, multiplication and division). New invention was digital system. There are various systems of arithmetic which are widely used in digital electronics.

1. Binary Number System :- The binary number system is base 2 system using 0 and 1.
2. Octal Number System :- The octal number system is base 8 system using 0 to 7.
3. Decimal Number System :- The decimal number system is base 10 system using 0 - 9
4. Hexadecimal number system:- The hexadecimal number system is base 16 system using 0 to 9 and A, B, C, D, E & F.

Binary Number System

The binary number system is base 2 system where only digits 0 & 1 are used. In this numbering system all numbers are represented by 0's and 1's.
Ex:- 01, 11, 10,110 etc.

Binary to Decimal conversion.

The decimal equivalent of a number is written in binary is found by adding the products of the absolute & positional values.
Ex (i) Decimal equivalent of binary number is $1011_{(2)}$

Binary no.	1	0	1	1
Binary weight	2^3	2^2	2^1	2^0
Decimal value	8	4	2	1

$1011_{(2)} = 1\times2^3 + 0\times2^2 + 1\times2^1 + 1 \times 2^0$
$= 8 + 0 + 2 + 1$
$1011_{(2)} = 11_{(10)}$

Ex (ii) Decimal equivalent of binary number is $11001.011_{(2)}$

Binary No.	1	1	0	0	1	0	1	1
Binary weight	2^4	2^3	2^2	2^1	2^0	2^{-1}	2^{-2}	2^{-3}
Decimal value	16	8	4	2	1	1/2	1/4	1/8

$11001.011_{(2)} = 1\times16 + 1\times8 + 0\times4 + 0\times2 + 1\times1 + 0\times1/2 + 1\times1/4 + 1\times1/8$
$= 16 + 8 + 0 + 0 + 1 + 0 + 1/4 + 1/8$
$= 25 + 3/8$
$11001.011_{(2)} = 25.375_{(10)}$

Octal Number System

The Octal number system is formed by grouping 3 bits. This system has base 8 & using absolute numbers from 0 to 7.Hence there are eight digits.

Ex :- 567, 603,741 .....

Octal to Decimal conversion.

Octal to Decimal conversion is done by multiplying the value in each position by its octal weight & add each value.

Ex (i) $576_{(8)} = (?)_{(10)}$

Octal Number	5	7	6
Octal Weight	8^2	8^1	8^0
Decimal Value	64	8	1

$576_{(8)} = 5\times64 + 7\times8 + 6\times1$

$576_{(8)} = 320 + 56 + 6$

$576_{(8)} = 382_{(10)}$

Ex (ii) $34.125_{(8)} = (?)_{(10)}$

Octal Number	3	4	1	2	5
Octal Weight	8^1	8^0	8^{-1}	8^{-2}	8^{-3}
Decimal Value	8	1	1/8	1/64	1/512

$34.125_{(8)} = 3\times8 + 4\times1 + 1\times1/8 + 2\times1/64 + 5\times1/512$

$34.125_{(8)} = 24 + 4 + 1/8 + 2/64 + 5/512 = 28\frac{85}{512}$

$34.125_{(8)} = 28.166_{(10)}$

Decimal to Octal conversion.

The decimal equivalent of an octal number is obtained by successive division with base 8 and the remainder values. The division is continued until the quotient is zero. The decimal equivalent of a octal number is a reverse order of the remainders.

Ex (i) $754_{(10)} = (?)_{(8)}$

8	754	-
8	94	- 2
8	11	- 6
	1	- 3

$754_{(10)} = 1362_{(8)}$

Ex (ii) Convert 0.12 in decimal to octal

0.12 x 8 = 0.96 -- 0

0.96 x 8 = 7.68 -- 7

0.68 x 8 = 5.44 -- 5

0.44 x 8 = 3.52 -- 3

0.52 x 8 = 4.16 -- 4

$0.12_{(10)} = 0.07534_{(8)}$

Octal to Binary conversion

To convert any octal number to any corresponding binary number use 2 steps.

i) Convert the number to its 3 bit binary equivalent.

ii) Next combine the 3 bit sections by removing the spaces.

Ex: i)Convert octal $2314_{(8)}$ to binary

Octal number	2	3	1	4
Binary Number	010	011	001	100

$2314_{(8)} = 010011001100_{(2)}$

Ex: ii) Convert octal $246.72_{(8)}$ = ?

Octal number	2	4	6	7	2
Binary Number	010	100	110	111	010

$246.72_{(8)} = 010100110.111010_{(2)}$

Binary to Octal conversion

To convert any octal number to its corresponding binary number use 2 steps.

i) Convert the number to its 3 bit binary equivalent

ii) Combine all the three bit sections by removing spaces.

Ex (i) Convert into octal

$1100011010001_{(2)} = (?)_{(8)}$

Binary Number	001	100	011	010	001
Octal number	1	4	3	2	1

$1100011010001_{(2)} = (14321)_{(8)}$

Ex (ii) Convert into octal

$11001.101011_{(2)} = (?)_{(8)}$

Binary Number	011	001	101	011
Octal number	3	1	5	3

$11001.101011_{(2)} = 31.53_{(8)}$

Decimal Number System

In decimal number system numbers are expressed in units, tens, hundreds, thousands and so on. Decimal numbers are expressed as powers of 10

Ex. 67854.78 is expressed as

60000 + 7000 + 800 + 50 + 4 + 0.70 + 0.08

Hexadecimal Number System.

Hexadecimal numbers are extensively used in association with microprocessors. This system use base 16 and absolute values from 0 to 9 and the letters A, B, C, D, E & F. Finally 16 combinations of 4-bit binary numbers are possible.

Decimal to Hexadecimal Conversion

Integer Part Conversion:- The decimal equivalent of hexadecimal number is obtained by successive division with base 16 and writing down the remainder values. The division is continued until quotient is zero. The decimal equivalent of a given hexadecimal number is reverse order of the remainders.

Ex (i) $964_{(10)} = (?)_{(16)}$

$$\begin{array}{r|l} 16 & 964 \quad - \\ \hline 16 & 60 \quad - \ 4 \\ \hline 16 & 3 \quad - \ 12 \\ \hline \end{array}$$

$964_{(10)} = (3C4)_{(16)}$

Fraction Part Conversion :- The decimal fraction part number is multiplied by 16 and carry is noted down. This process is cumulative till the desired accuracy is obtained. The carry reading represents down direction.

Ex (i) $0.0664_{(10)} = (?)_{(16)}$

0.0664 x 16 = 1.0624 – 1

0.0624 x 16 = 0.9984 – 0

0.9984 x 16 = 15.9744 – 15 (F)

0.9744 x 16 = 15.5904 – 15 (F)

$0.0664_{(10)} = 0.10FF_{(16)}$

Hexadecimal to Binary Conversion

Hexadecimal Numbers are represented using group of 4 digits.

Decimal No.	Octal No.	Binary No.	Hexadecimal No.
0	0	0000	0
1	1	0001	1
2	2	0010	2
3	3	0011	3
4	4	0100	4
5	5	0101	5
6	6	0110	6
7	7	0111	7
8	10	1000	8
9	11	1001	9
10	12	1010	A
11	13	1011	B
12	14	1100	C
13	15	1101	D
14	16	1110	E
15	17	1111	F

To convert integer hexadecimal number to its corresponding binary number use 2 steps.
i) Convert the given number to its 4 bit binary equivalent.
ii) Combine the 4 bit section by removing the spaces.

Ex i) perform $FCFD_{(16)}=(\ ?\ )_{(2)}$

Hexadecimal No	F	C	F	D
Binary No	1111	1100	1111	1101

$FCFD_{(16)}=1111110011111101_{(2)}$

Ex ii)Perform $155.D1_{(16)}=(\ ?\ )_{(2)}$

Hexadecimal No	1	5	5	D	1
Binary No	0001	0101	0101	1101	0001

$155.D1_{(16)}=(1010101010.11010001)_{(2)}$

Binary to hexadecimal conversion

Convert from binary numbers to hexadecimal number and follow the 2 steps
I) Break the binary number into 4 bit sections from LSB to MSB
II) Convert the 4 bit binary number to its hexadecimal equivalent.

Ex(i) : perform $11001011010001_{(2)} = (?\ )_{(16)}$

Binary No	0011	0010	1101	0001
Hexadecimal No	5	2	D	1

$11001011010001_{(2)} = 52D1_{(16)}$

Ex (ii) : Perform $1011110101.0111_{(2)} = (\ ?)_{(16)}$

Binary No	0010	1111	0101	0111
Hexadecimal No	2	F	5	7

$1011110101.0111_{(2)} = 2F5.7_{(16)}$

Hexadecimal to octal conversion

Convert from Hexadecimal numbers to Octal number and follow the steps.
i) Convert Hexadecimal to binary.
ii) Convert resultant of convert binary number in to octal by grouping 3 digits from right to left.

Ex (i): Perform $2AB9_{(16)} = (\ ?\ )_{(8)}$

Step 1: Convert given Hexadecimal number to binary.

Hexadecimal No	2	A	B	9
Binary No	0010	1010	1011	1001

Step 2: Convert resultant of converted binary equivalent in to octal by grouping 3-bits from right to left.

Binary No	010	101	010	111	001
Octal No.	2	5	2	7	1

2AB9 $_{(16)}$ =(25271) $_{(8)}$

Octal to Hexadecimal conversion

To convert Octal to hexadecimal number follow the 2 steps.

i) Convert Octal to binary.

ii) Convert resultant of converted binary equivalent number into hexadecimal number by grouping 4-digits from right to left.

Ex (i) 615$_{(8)}$ = (?) $_{(16)}$

Step 1: Convert given octal number to binary.

Octal number	6	1	5
Binary Number	110	001	101

Step 2: Convert resultant of converted binary equivalent in to hexadecimal by grouping 4-digits from right to left.

Binary Number	0001	1000	1101
Hexadecimal No	1	8	D

615$_{(8)}$ = (18D) $_{(16)}$

1's and 2's complement

1's complement of any binary number is obtained by replacing each '0' by '1' and '1' by '0' as shown below.

Binary number	1's complement
1010	0101
111001	000110
110010	001101

Addition using 1's complement

Subtraction using 1's complement

1's complement is useful in performing subtractions using addition operations. The standard format of subtraction is

Minuend – subtrahend = Difference

Following steps should be followed to subtract smaller number from larger number.

1) Get the 1's complement of subtrahend.

2) Add 1's complement of subtrahend to the minuend.

3) Perform addition if carry is generated, add this carry to the result to get the final answer, i.e positive.

Ex (i) Evaluate 110010 – 101101 using 1's complement.

110010 - Minuend 101101 - subtrahend

Step 1) 1's complement of subtrahend is 010010

Step 2) Add 1's complement of subtrahend to the minuend

```
  110010
  010010
------------
1000100
            1
-------------
 000101
-------------
```

Step 3) If carry is generated at this carry to the result to get final answer.

Cross Check :- $50_{(10)} - 45_{(10)} = 05_{(10)}$

Following steps should be followed to subtract larger number from smaller number.

1) Get the 1's complement of subtrahend.
2) Add 1's complement of subtrahend to the minuend.
3) If no carry is generated, take 1's complement of the result and place –ve sign to the result i.e negative.

Ex (ii) Evaluate 1101011 – 1110101 using 1's complement

1101011 – Minuend 1110101 – Subtrahend

Step 1) Get the 1's complement of subtrahend is 0001010

Step 2) Add 1's complement of subtrahend to the minuend

1101011 + 0001010

```
 1101011
 0001010
-----------
1110101
-----------
```

Step 3) No carry is generated.1's complement of the result 1110101 is 0001010.By placing –ve sign to the answer.The final answer is -0001010.

2's complement

2's complement of a binary number is obtained by adding 1 to the 1's complement. 2's complement of a number = 1's complement + 1 .

Binary No.	1's Complement	2's Complement
1101	0010	0011
11011	00100	00101
110001	001110	001111

Subtraction using 2's Complement

2's complement is useful in performing subtraction using addition operations.2's complement subtraction carry is neglected.

The standard format of subtraction is Minuend – Subtrahend = Difference

Following steps should be followed to subtract smaller number from larger number.

1) Get the 2's complement of subtrahend.
2) Add 2's complement of subtrahend to the minuend.
3) Perform addition if carry is generated, neglect this carry and the result is positive.

Ex (i) Evaluate $53_{(10)} - 49_{(10)}$ using 2's complement

Minuend is $110101_{(2)}$ & Subtrahend is $110001_{(2)}$

Step 1:- 1,s complement of 110001 is 001110

2,s complement of 110001 is 001111

Step 2:- Add 001111 to the minuend 110101

```
  110101
  001111
 -----------
 1000100
 ------------
```

Step 3:- Carry is generated, neglect it & the answer is 000100

Checkpoint :- $53_{(10)} - 49_{(10)} = 4_{(10)}$

Following steps should be followed to subtract larger number from smaller number.

1) Get the 2's complement of subtrahend.
2) Add 2's complement of subtrahend to the minuend.
3) Perform addition if no carry is generated, take 2's complement of the result and place negative sign to the result.

Ex (ii) Evaluate $11001_{(2)} - 110101_{(2)}$ using 2's complements

Step 1:- 2,s complement of 110101 = 1's complement of 110101 + 1 = 001010+1 =001011

Step 2:- Add 001011 to the minuend

```
  110001
  001011
 -----------
  111100
 ------------
```

Step 3:-No Carry is generated, 2's complement of 111100 is 000011 + 1 = 000100

Place negative sign to resultant to get final answer is -000100

Checkpoint :- $49_{(10)} - 53_{(10)} = -4_{(10)}$

Binary Coded Decimal (BCD)

In digital electronic system is an encoding for decimal numbers in which each digit is represented by its own binary numbers. In BCD digits are represented by 4 bits. A group of 4 binary bits are called nibble & a group of 8 bits are called byte.

BCD uses binary number system to specify 0 to 9 decimal numbers.

Decimal	Binary	Octal	Hexadecimal	BCD
0	0000	0	0	0000
1	0001	1	1	0001
2	0010	2	2	0010
3	0011	3	3	0011
4	0100	4	4	0100
5	0101	5	5	0101
6	0110	6	6	0110
7	0111	7	7	0111
8	1000	10	8	1000
9	1001	11	9	1001
10	1010	12	A	0001 0000
11	1011	13	B	0001 0001
12	1100	14	C	0001 0010
13	1101	15	D	0001 0011
14	1110	16	E	0001 0100
15	1111	17	F	0001 0101

BCD Addition

BCD addition is used to add to 2 BCD numbers.

1) Add two binary numbers using ordinary binary addition.
2) If four bit sum is equal to 0 or less than 9 ,no correction is needed.
3) If four bit sum is greater than 9 or if carry is generated from 4 bit sum, the sum is invalid.
4) Correct the invalid sum by adding 6 (0110) to the four bit sum.

Ex (i) Perform BCD addition 00110010 + 00011000

```
00110010
00011000
--------------
010001010     1010 (10>9) is invalid BCD sum
--------------  Add 6 (0110) to the four bit sum
01001010
        0110
------------
0101000
-----------
```

Cross Check 00110010 (BCD) + 00011000 (BCD) = 01010000 (BCD)

32 (10) + 18(10) = 50 (10)

Decimal to BCD Conversion

The BCD of a decimal number is obtained by replacing each decimal digit by the appropriate 4-bit code.

Ex (i) Convert into BCD 95.85

Decimal no.	9	5	8	5
BCD no.	1001	0101	1000	0101

95.85(Decimal) = 1001010110000101 (BCD)

BCD to Decimal Conversion

The decimal equivalent of BCD number is obtained by grouping 4-bits & representing decimal digit to each 4-bit group.

Ex (i) Convert BCD to decimal 0011001100101

BCD no.	0011	0110	0101
Decimal no.	3	6	5

0011001100101 (BCD) = 365(Decimal)

Extended Binary Coded Decimal Information Code (EBCDIC)

EBCDIC is a 8-bit alpha numeric code. The EBCDIC was developed by IBM. Each code word of EBCDIC code consist of 8-bits i.e 28 = 256 possible combinations are available to represent characters, symbols & numbers.

American Standard Code for Information Interchange (ASCII)

The standard binary code for alphanumeric characters is ASCII.It use 7-bits to code 128 characters. The advantages of ASCII code are,

Each code word of ASCII code consist of 8 bits, 28 = 256 possible combinations are available to represent different characters, symbols & numbers.Each code word of ASCII has total 8-bits & it can be divided into two 4 bit groups.

Dec	Hex	Name	Char	Ctrl-char	Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char
0	0	Null	NUL	CTRL-@	32	20	Space	64	40	@	96	60	`
1	1	Start of heading	SOH	CTRL-A	33	21	!	65	41	A	97	61	a
2	2	Start of text	STX	CTRL-B	34	22	"	66	42	B	98	62	b
3	3	End of text	ETX	CTRL-C	35	23	#	67	43	C	99	63	c
4	4	End of xmit	EOT	CTRL-D	36	24	$	68	44	D	100	64	d
5	5	Enquiry	ENQ	CTRL-E	37	25	%	69	45	E	101	65	e
6	6	Acknowledge	ACK	CTRL-F	38	26	&	70	46	F	102	66	f
7	7	Bell	BEL	CTRL-G	39	27	'	71	47	G	103	67	g
8	8	Backspace	BS	CTRL-H	40	28	(	72	48	H	104	68	h
9	9	Horizontal tab	HT	CTRL-I	41	29	)	73	49	I	105	69	i
10	0A	Line feed	LF	CTRL-J	42	2A	*	74	4A	J	106	6A	j
11	0B	Vertical tab	VT	CTRL-K	43	2B	+	75	4B	K	107	6B	k
12	0C	Form feed	FF	CTRL-L	44	2C	,	76	4C	L	108	6C	l
13	0D	Carriage feed	CR	CTRL-M	45	2D	-	77	4D	M	109	6D	m
14	0E	Shift out	SO	CTRL-N	46	2E	.	78	4E	N	110	6E	n
15	0F	Shift in	SI	CTRL-O	47	2F	/	79	4F	O	111	6F	o
16	10	Data line escape	DLE	CTRL-P	48	30	0	80	50	P	112	70	p
17	11	Device control 1	DC1	CTRL-Q	49	31	1	81	51	Q	113	71	q
18	12	Device control 2	DC2	CTRL-R	50	32	2	82	52	R	114	72	r
19	13	Device control 3	DC3	CTRL-S	51	33	3	83	53	S	115	73	s
20	14	Device control 4	DC4	CTRL-T	52	34	4	84	54	T	116	74	t
21	15	Neg acknowledge	NAK	CTRL-U	53	35	5	85	55	U	117	75	u
22	16	Synchronous idle	SYN	CTRL-V	54	36	6	86	56	V	118	76	v
23	17	End of xmit block	ETB	CTRL-W	55	37	7	87	57	W	119	77	w
24	18	Cancel	CAN	CTRL-X	56	38	8	88	58	X	120	78	x
25	19	End of medium	EM	CTRL-Y	57	39	9	89	59	Y	121	79	y
26	1A	Substitute	SUB	CTRL-Z	58	3A	:	90	5A	Z	122	7A	z
27	1B	Escape	ESC	CTRL-[	59	3B	;	91	5B	[	123	7B	{
28	1C	File separator	FS	CTRL-\	60	3C	<	92	5C	\	124	7C	|
29	1D	Group separator	GS	CTRL-]	61	3D	=	93	5D	]	125	7D	}
30	1E	Record separator	RS	CTRL-^	62	3E	>	94	5E	^	126	7E	~
31	1F	Unit separator	US	CTRL-_	63	3F	?	95	5F	_	127	7F	DEL

Gray Code

The gray code is a variable weighted & unweight code. There are no specific weights assign to the bit position. It is arranged and every transition from one value to the next value involves only 1 bit change. Gray code is also referred as reflected binary, because the first eight values compare with those of last eight values but it is in reverse order.

The gray code along with corresponding decimal & binary numbers as shown below.

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

Excess-3 Code (XS-3)

This code is also called Stibitiz code .It is an unweighted code where each coded combination is obtained from the corresponding binary values plus 3.It uses only 10 combinations out of 16 possible combinations that can be arranged with 4-bits.6 are unused combinations & have no meaning.

Decimal digit	Excess-3
0	0001
1	0100
2	0101
3	0110
4	0111
5	1000
6	1001
7	1010
8	1011
9	1100
10	0000 unused
11	0001 unused
12	0010 unused
13	1101 unused
14	1110 unused
15	1111 unused

Decimal to Excess-3 code conversion

The following steps are used to convert a decimal number to XS-3 code.

1) Add 3 to the each digit in the given decimal number.
2) Convert each sum to its equivalent binary code.

Ex (i) Convert decimal 129 to excess-3 code.

```
   1   2   9
 +3  +3  +3
 -----------
   4   5   12
 ------------
```

Resultant	4	5	12
XS-3 code	0100	0101	1100

Excess-3 code for 129 (10) is 010001011100

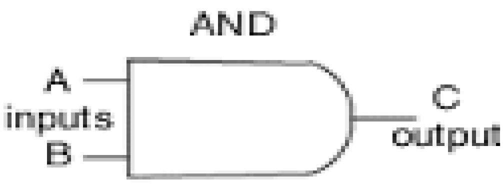
UNIT:2 LOGIC GATES AND BOOLEAN ALGEBRA

Logic Gates

AND Gate:

AND gate performs logical multiplication known as AND function. AND gate has two or more inputs and a single output. The AND operation produces a HIGH output only if all the inputs arc HIGH, When one input is HIGH and the other input is HIGH, the output is HIGH. When any or all inputs are LOW. the output is LOW. The AND operation is implemented by a logic circuit known as an AND gate.

Truth table for AND Gate with two inputs is as shown below



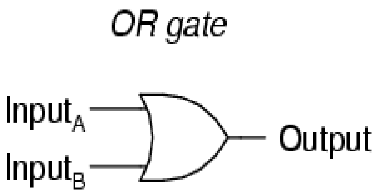
A	B	C (OUTPOUT)
0	0	0
1	0	0
0	1	0
1	1	1

SYMBOL FOR AND GATE Truth table for AND Gate with two inputs

Boolean Expression $C = A . B$ OR $C = AB$

OR Gate:

OR gate performs logical addition known as OR function.OR gate has two or more inputs and a single output. The OR operation produces a HIGH output when any of the inputs is HIGH, When one input is HIGH or the other input is HIGH or both inputs are HIGH, the output is HIGH. When both inputs are LOW. the output is LOW. The OR operation is implemented by a logic circuit known as an OR gate.



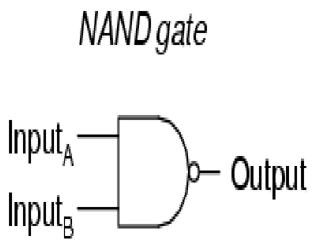
A	B	C (OUTPOUT)
0	0	0
1	0	1
0	1	1
1	1	1

SYMBOL FOR AND GATE Truth table for OR Gate with two inputs

Boolean Expression $C = A + B$

NAND Gate:

It is a combination of NOT and AND and implies an AND Function with a complimented output. It is a universal gateused to construct AND gate OR gate,Inverter or any combination of these. A low output occurs only when all the inputs are high.When any of the input is low the output will be high.



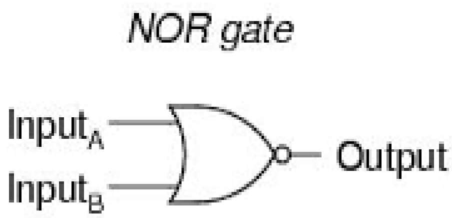
A	B	C (OUTPOUT)
0	0	1
1	0	1
0	1	1
1	1	0

SYMBOL FOR NAND GATE Truth table for NAND Gate with two inputs

Boolean Expression C = $\overline{\mathrm{A}}\,.\,\mathrm{B}$ OR C = $\overline{\mathrm{AB}}$

NOR Gate :

It is a combination of NOT and OR and implies an OR Function with a complimented output. It is a universal gate used to construct AND gate, OR gate, Inverter or any combination of these. A low output occurs only when any of its inputs are high. When any of the input is low the output will be high.



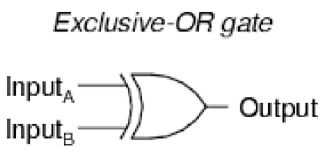
A	B	C (OUTPOUT)
0	0	1
1	0	0
0	1	0
1	1	0

SYMBOL FOR NOR GATE Truth table for NOR Gate with two inputs

Boolean Expression C = $\overline{\mathrm{A}+\mathrm{B}}$

The Exclusive OR Gate :

The abbreviation for Exclusive OR gate is Ex-OR .It has two or more inputs and one input . A low output occurs only when both inputs are high low. A high output occurs only when both the input is high or low . Similarly regardless of the number of inputs the output is high evn when number of inputs are high or when all the inputs are zeroes.



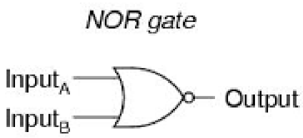
A	B	C (OUTPUT)
0	0	0
1	0	1
0	1	1
1	1	0

SYMBOL FOR EX-OR GATE Truth table for EX-OR Gate with two inputs

Boolean Expression $C = A \oplus B$

The Exclusive NOR GATE :

The abbreviation for Exclusive NOR gate is Ex-NOR .It has two or more inputs and one input . It is logically equivalent to EX-OR gate followed by Inverter.For even number of ones at input,or the inputs all having zeroes, the output is HIGH.



A	B	C (OUTPOUT)
0	0	1
1	0	0
0	1	0
1	1	0

SYMBOL FOR EX-NOR GATE Truth table for EX-NOR Gate with two inputs

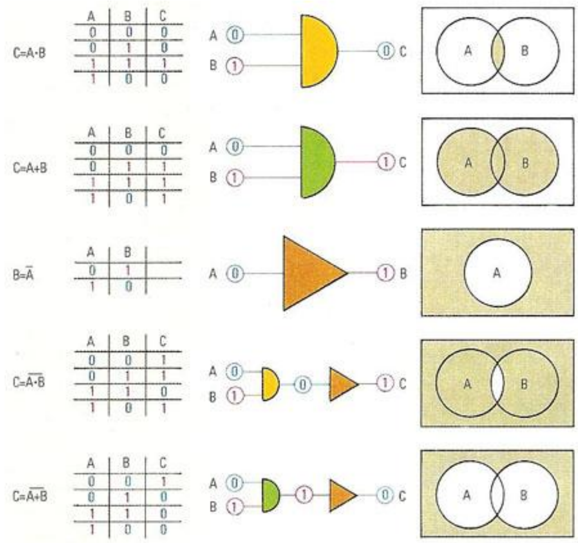
Boolean Expression $C = \overline{A \oplus B}$

SUMMARY

- ✓ Gates are used to control the flow of data from input to output.
- ✓ In digital system, two voltage levels represents the two binary digits,1 and 0.If the higher of two voltages represents 1 and the lower voltage represents 0.
- ✓ The Logic gates are the basic elements that make up a digital system.
- ✓ The logic gate is a digital circuit with one or more inputs but only one output.
- ✓ The inverter output is the complement of the Input.
- ✓ The AND gate output is HIGH only if all the inputs are HIGH.
- ✓ The OR gate output is HIGH if any of the Inputs is HIGH
- ✓ The NAND gate output is LOW only if all the inputs arc HIGH
- ✓ The NOR gate output is LOW if any of the inputs is HIGH
- ✓ The NOR can be viewed as a negative-AND whose output is HIGH only If all the inputs are LOW.
- ✓ The exclusive-OR gate output is HIGH when the inputs are not the same.
- ✓ The exclusive-NOR gate output is LOW when the inputs are not the same.

Boolean Algebra

It is mathematics of digital system. It is used to simplify Boolean equation to make simple logic circuit.



Laws of Boolean Algebra

The basic laws of Boolean algebra—the commutative, the associative laws, and the distributive law.

Commutative law:

Law 1: A + B = B + A : This states that the order in which the variables are ORed makes no differenc in the output. The truth tables are identical. Therefore A OR B is same as B OR A

A	B	A+B
0	0	0
1	0	1
0	1	1
1	1	1

A	B	A+B
0	0	0
1	0	1
0	1	1
1	1	1

LAW2 : AB =BA : This states that the order in which the variables are ANDed makes no differenc in the output. The truth tables are identical. Therefore A AND B is same as B AND A

A	B	AB
0	0	0
1	0	0
0	1	0
1	1	1

A	B	BA
0	0	0
1	0	0
0	1	0
1	1	1

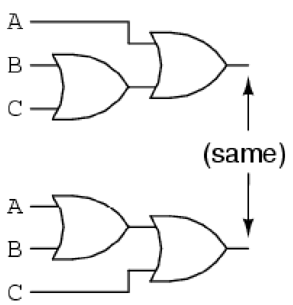
It is important to note that commutative law can be extended to any number of variables.

For example A+B+C = C+B+A and similarly ABC =CBA=ACB and so on.

Associative Law:

Law 1: A+(B+C) = (A+B)+C : This law states that in ORing of several variables ,the result is the same regardless of the grouping of the variables .For three variables A OR B ORed with C is same as A ORed with B OR C.

Associative law states A +(B+C) = (A+B)+C



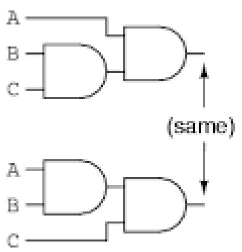
A	B	C	A+B	(A+B)+C
0	0	0	0	0
0	0	1	0	1
0	1	0	1	1
0	1	1	1	1
1	0	0	1	1
1	0	1	1	1
1	1	0	1	1
1	1	1	1	1

A	B	C	B+C	A+(B+C)
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	1	1
1	0	0	0	1
1	0	1	1	1
1	1	0	1	1
1	1	1	1	1

Associative law applied to OR Gate Truth Tables

Law 1: A+(B+C) = (A+B)+C : This law states that in ANDing of several variables ,the result is the same regardless of the grouping of the variables .For three variables A AND B ANDed with C is same as A ANDed with B AND C.

Associative law states A .(B.C) = (A.B).C



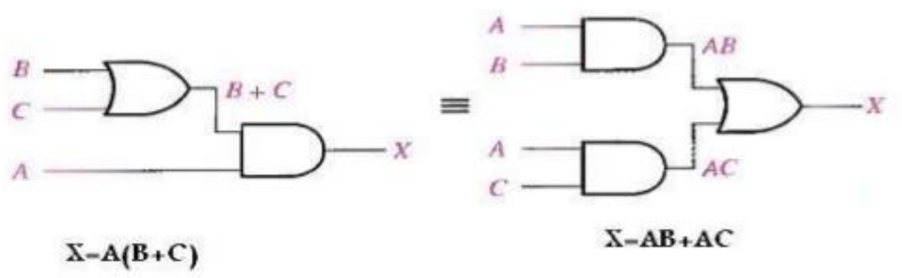
	B	C	AB	(AB)C
0	0	0	0	0
0	0	1	0	0
0	1	0	0	0
0	1	1	0	0
1	0	0	0	0
1	0	1	0	0
1	1	0	1	0
1	1	1	1	1

A	B	C	BC	A(BC)
0	0	0	0	0
0	0	1	0	0
0	1	0	0	0
0	1	1	1	0
1	0	0	0	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

Associative law applied to AND Gate Truth Tables

Distributive Law:

Law 1:Distribution of AND over OR : A(B+C) = AB+AC : This law states that ORing of several variables and ANDig the result with a single variable is equivalent to ANDing the lone variable with each of the variables and then ORing products.



Distributive law applied to AND Gate

A	B	C	B+C	A(B+C)
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	1	0
1	0	0	0	0
1	0	1	1	1
1	1	0	1	1
1	1	1	1	1

A	B	C	AB	AC	AB+AC
0	0	0	0	0	0
0	0	1	0	0	0
0	1	0	0	0	0
0	1	1	0	0	0
1	0	0	0	0	0
1	0	1	0	1	1
1	1	0	1	0	1
1	1	1	1	1	1

Truth Tables

Law 2:Distribution of OR over AND : A+(B.C) = AB.AC
This law states that ANDing of several variables and ORig the result with a single variable is equivalent to ORing the lone variable with each of the variables and then ANDing products.

Rules of Boolean Algebra:

Rule 1: Annulment Law – A term AND´ed with a "0" equals 0 or OR´ed with a "1" will equal 1.

- A . 0 = 0 A variable AND'ed with 0 is always equal to 0.
- A + 1 = 1 A variable OR'ed with 1 is always equal to 1.

Rule 2: Identity Law – A term OR´ed with a "0" or AND´ed with a "1" will always equal that term.

- A + 0 = A A variable OR'ed with 0 is always equal to the variable.

- A . 1 = A A variable AND'ed with 1 is always equal to the variable.

Rule 3: Idempotent Law – An input that is AND´ed or OR´ed with itself is equal to that input.

- A + A = A A variable OR'ed with itself is always equal to the variable.
- A . A = A A variable AND'ed with itself is always equal to the variable.

Rule 4: Complement Law – A term AND´ed with its complement equals "0" and a term OR´ed with its complement equals "1".

- A . A = 0 A variable AND'ed with its complement is always equal to 0.
- A + A = 1 A variable OR'ed with its complement is always equal to 1.

Rule 5: Commutative Law – The order of application of two separate terms is not important.

- A . B = B . A The order in which two variables are AND'ed makes no difference.
- A + B = B + A The order in which two variables are OR'ed makes no difference.

Rule 6: Double Negation Law – A term that is inverted twice is equal to the original term.

- A = A A double complement of a variable is always equal to the variable.

Rule 7: de Morgan´s Theorem – There are two "de Morgan´s" rules or theorems,

(1) Two separate terms NOR´ed together is the same as the two terms inverted (Complement) and AND´ed for example, A+B = A. B.

(2) Two separate terms NAND´ed together is the same as the two terms inverted (Complement) and OR´ed for example, A.B = A +B.

Demorgan's theorem

DeMorgan's first theorem is stated as follows:

The complement of a product of variables is equal to the sum of the complements of the variables.

Stated another way,

The complement of two or more variables ANDed is equivalent to the OR of the complements of the Individual variables.

The formula for expressing this theorem for two variables

$$\overline{AB} = \overline{A} + \overline{B}$$

$$\overline{A.B} = \overline{A} + \overline{B}$$

$\overline{A.B} = \overline{A}+\overline{B}$

Proof

A	B	$\overline{A}$	$\overline{B}$	$\overline{A.B}$	$\overline{A}+\overline{B}$
0	0	1	1	1	1
0	1	1	0	1	1
1	0	0	1	1	1
1	1	0	0	0	0

DeMorgan's second theorem is stated as follows:
The complement of a sum of variables is equal to the product of the complements of the variables.
Stated another way.
The complement of two or more variables ORed Ls equivalent to the AND or the complements of the individual variables.
Tlie formula for expressing this theorem for two variables is

$\overline{A + B} = \overline{A} . \overline{B}$

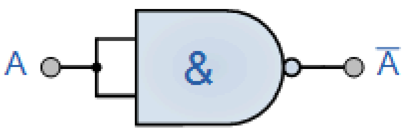
$\overline{A}.\overline{B}=\overline{A+B}$

Universal Gates:

The NAND and NOR gates are known as universal gates.

NAND Gate as a universal Building Block :

1) INVERTER(NOT) :(Realization of NOT using NAND):
   A NOT gate can be made out of a NAND gate by connecting all its inputs together as shown below.



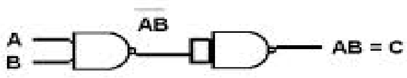
NOT Gate

NOT function using NAND gate

If A is 0, the output of the NAND gate is
$(\overline{A.A}) = (\overline{0.0}) = \overline{0}=1 = \overline{A}$
And if A is 1 the output is
$(\overline{A.A}) = (\overline{1.1}) = \overline{1}=0 = \overline{A}$

2) AND gate :(realization of AND using NAND gate):

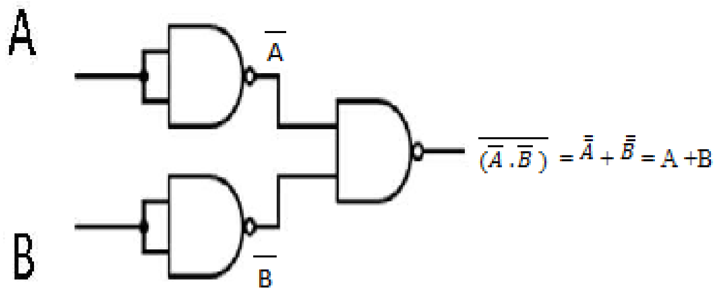
We can use NAND gates to make an AND gate.



The output of the NAND gates is (A.B). The second NAND gate then complements previous A.B .

Double compliment of a quantity is the quantity itself. That is $\overline{(A.B)}$ = A B.Thus NAND gates can be comnnected to perform the AND function.

3) OR Gate : (realization of OR using NAND gate) :

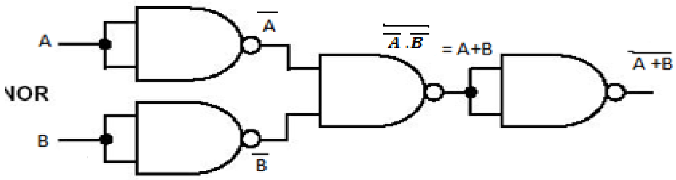


The first two NAND gates invert A and B produce $\overline{A}$ and $\overline{B}$ .The two –input NAND gate then produces n output of $\overline{(\overline{A}.\overline{B})} = \overline{\overline{A}} + \overline{\overline{B}} = A + B$

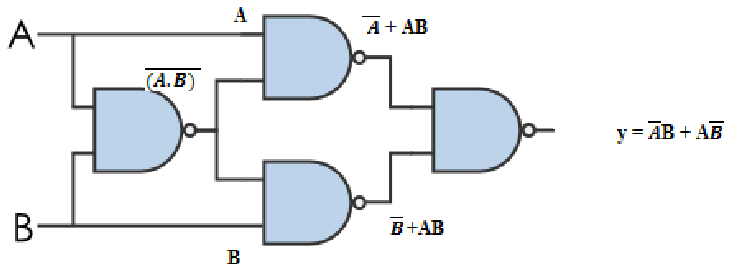
4) NOR gate:

The NOR function using NAND gate is realized as shown below.

$$\overline{\overline{A}.\overline{B}} = \overline{\overline{A}} + \overline{\overline{B}} = A + B$$



5) XOR gate : (realization of XOR function using NAND gates)



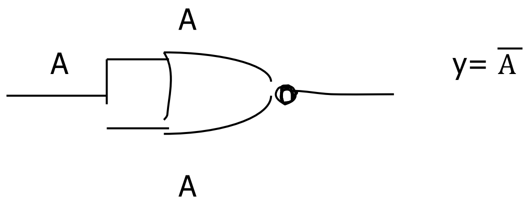
The XOR function using NAND gates is realized as shown above.

$(\overline{A} + AB) . (\overline{B} + AB) = \overline{A}B + A\overline{B}$

NOR GATE AS A UNIVERSAL BUILDING BLOCK :

Just like the NAND gate ,th NOR gate is also a universal building block.The NOT function as realized as shown in the figure.

$$Y = \overline{A + A} = \overline{A} . \overline{A} = \overline{A}$$

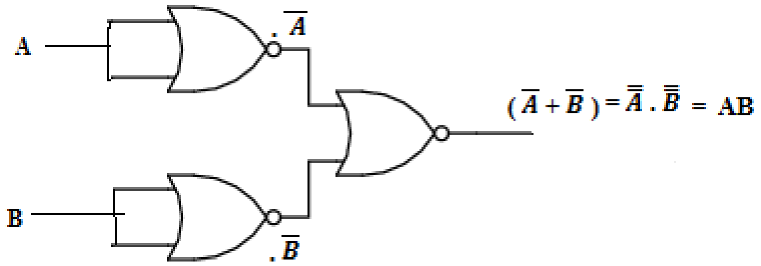


1) AND gate (realization of And function using NOR gate):

$$Y = A . B$$

$$= \overline{(\overline{A} + \overline{B})}$$

$$= \overline{\overline{A}} . \overline{\overline{B}} = A . B$$



2) OR gate : (realization of OR gate using NOR gate):

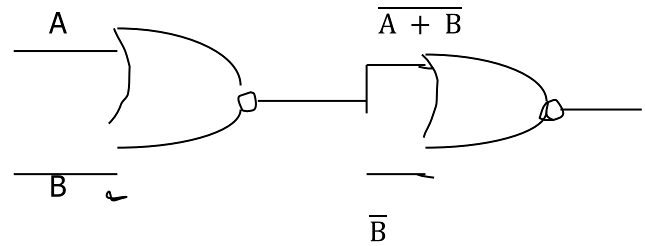
The OR function is realized using NOR gates as shown in the figure below.

Here y = A + B

$= \overline{\overline{A} + \overline{B}}$

= A + B

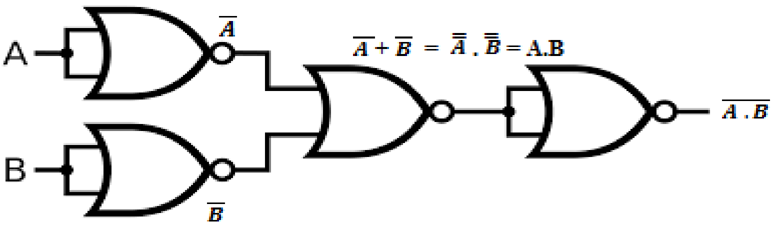
A + B



3) NAND Gate : realization of NAND gate using NOR gate

$\overline{(\overline{A} + \overline{B})} = \overline{\overline{A}} . \overline{\overline{B}}$ = A.B

When A .B applied to NOR the output would be $\overline{A.B}$.



Boolean Expressions Simplification

Simplify the following Boolean expressions.

1. $\mathbf{Q = A.B + B}$

$$Q = A.B + B$$
$$Q = B.(A+1)$$
$$Q = B.1$$
$$Q = B$$

2. $\mathbf{Q = C.(A + \overline{C})}$

$$Q = C.(A + \overline{C})$$
$$Q = A.C + C.\overline{C}$$
$$Q = A.C + 0$$
$$Q = A.C$$

3. $\mathbf{Q = A.B.\overline{C} + A.\overline{C} + \overline{A}.\overline{C}.D + \overline{A}.\overline{C}.\overline{D}}$

$$Q = A.B.\overline{C} + A.\overline{C} + \overline{A}.\overline{C}.D + \overline{A}.\overline{C}.\overline{D}$$
$$Q = A.\overline{C}.(B+1) + \overline{A}.\overline{C}.(D + \overline{D})$$
$$Q = A.\overline{C}.1 + \overline{A}.\overline{C}.1$$
$$Q = A.\overline{C} + \overline{A}.\overline{C}$$
$$Q = \overline{C}.(A + \overline{A})$$
$$Q = \overline{C}.1$$
$$Q = \overline{C}$$

4. $\mathbf{Q = A.B.(\overline{B} + C) + B.C + B}$

$$Q = A.B.(\overline{B} + C) + B.C + B$$
$$Q = A.B.\overline{B} + A.B.C + B.C + B$$
$$Q = A.0 + A.B.C + B.(C+1)$$
$$Q = A.B.C + B.1$$
$$Q = A.B.C + B$$
$$Q = B.(A.C + 1)$$
$$Q = B.1$$
$$Q = B$$

5. $\mathbf{Q = B.(A + \overline{C}) + A + A.(\overline{A} + B)}$

$Q = B.(A+\overline{C}) + A + A.(\overline{A}+B)$

$Q = A.B + B.\overline{C} + A + A.\overline{A} + A.B$

$Q = A.B + B.\overline{C} + A$

$Q = A.(B+1) + B.\overline{C}$

$Q = A + B.\overline{C}$

6. $\mathbf{Q = A.B.\overline{C} + B.C + \overline{A}.B.\overline{C} + A.B.\overline{B}}$

$Q = A.B.\overline{C} + B.C + \overline{A}.B.\overline{C} + A.B.\overline{B}$

$Q = B.\overline{C}.(A+\overline{A}) + B.C + A.0$

$Q = B.\overline{C}.1 + B.C$

$Q = B.\overline{C} + B.C$

$Q = B.(\overline{C} + C)$

$Q = B.1$

$Q = B$

7. $\mathbf{Q = A.B.C + B.C.D + B.C.\overline{D} + B.\overline{C}.D + A.B.\overline{C} + \overline{A}.B.\overline{C}}$

$Q = A.B.C + B.C.D + B.C.\overline{D} + B.\overline{C}.D + A.B.\overline{C} + \overline{A}.B.\overline{C}$

$Q = A.B.C + B.C.(D+\overline{D}) + B.\overline{C}.D + B.\overline{C}.(A+\overline{A})$

$Q = A.B.C + B.C.1 + B.\overline{C}.D + B.\overline{C}.1$

$Q = A.B.C + B.C + B.\overline{C}.D + B.\overline{C}$

$Q = B.C.(A+1) + B.\overline{C}.(D+1)$

$Q = B.C.1 + B.\overline{C}.1$

$Q = B.C + B.\overline{C}$

$Q = B.(C+\overline{C})$

$Q = B.1$

$Q = B$

8. $\mathbf{Q = A.B.C.D + A.B.D + A.\overline{B}.D + A.\overline{B}.C.D + A.C.D + \overline{A}.C.D}$

$$Q = A.B.C.D + A.B.D + A.\overline{B}.D + A.\overline{B}.C.D + A.C.D + \overline{A}.C.D$$
$$Q = A.B.D.(C+1) + A.\overline{B}.D + A.C.D.(\overline{B}+1) + \overline{A}.C.D$$
$$Q = A.B.D.1 + A.\overline{B}.D + A.C.D.1 + \overline{A}.C.D$$
$$Q = A.B.D + A.\overline{B}.D + A.C.D + \overline{A}.C.D$$
$$Q = A.D.(B+\overline{B}) + C.D.(A+\overline{A})$$
$$Q = A.D.1 + C.D.1$$
$$Q = A.D + C.D$$
$$Q = D.(A+C)$$

1. Simplify the following expression by applying Rules of Boolean Algebra

$$\mathbf{Q = A.B.\overline{C} + A.B.C + A.\overline{B}}$$

Simplification can begin by combining the first two terms only as follows:

$$\mathbf{Q = A.B.(\overline{C} + C) + A.\overline{B}}$$

Using our sixth identity the term $\mathbf{C + \overline{C} = 1}$ so the expression now becomes:

$$\mathbf{Q = A.B.1 + A.\overline{B}}$$

Using the first identity A.B.1 = A.B so the expression becomes

$$\mathbf{Q = A.B + A.\overline{B}}$$

Now we can remove the common term again to leave:

$$\mathbf{Q = A.(B + \overline{B})}$$

Using our sixth identity the term $\mathbf{B + \overline{B} = 1}$ so the expression now becomes:

$$\mathbf{Q = A.1}$$

Using the first identity A.1 = A so the expression finally becomes

$$\mathbf{Q = A}$$

2. Simplify the following expression:

$$\mathbf{Q = \overline{A}.B + A.B.\overline{C} + A.B + C}$$

Start by looking for possible common factors which will leave behind one of our two key identities inside the bracket, in this case A.B in terms 2 and 3. This gives the following simplification.

$$\mathbf{Q = \overline{A}.B + A.B.(\overline{C} + 1) + C}$$

Using our fourth identity the term $\mathbf{\overline{C} + 1 = 1}$ so the expression now becomes:

$$\mathbf{Q = \overline{A}.B + A.B.1 + C}$$

Using the first identity A.B.1 = A.B so the expression becomes

$$\mathbf{Q = \overline{A}.B + A.B + C}$$

Again we look for common terms, this time between the first two terms to give the following:

$$\mathbf{Q = B.(\overline{A} + A) + C}$$

Using our sixth identity the term $\mathbf{A + \overline{A} = 1}$ so the expression now becomes:

$$\mathbf{Q = B.1 + C}$$

Using the first identity B.1 = B so the expression becomes

$$\mathbf{Q = B + C}$$

3. Simplify the following expression.

$$Q = \overline{A}.B + \overline{A}.B.C + \overline{A}.\overline{B}.\overline{C} + A.\overline{B}.\overline{C}$$

Solution:

$$Q = \overline{A}.B + \overline{A}.B.C + \overline{A}.\overline{B}.\overline{C} + A.\overline{B}.\overline{C}$$

$$Q = \overline{A}.B + \overline{A}.B.C + \overline{B}.\overline{C}.(\overline{A} + A)$$

$$Q = \overline{A}.B + \overline{A}.B.C + \overline{B}.\overline{C}.1$$

$$Q = \overline{A}.B.(1 + C) + \overline{B}.\overline{C}$$

$$Q = \overline{A}.B.1 + \overline{B}.\overline{C}$$

$$Q = \overline{A}.B + \overline{B}.\overline{C}$$

4. Simplify the following expression.

$$Q = B.C.(\overline{C} + D) + C.D + C + \overline{A}$$

$Q = B.C.(\overline{C} + D) + C.D + C + \overline{A}$

$Q = B.C.\overline{C} + B.C.D + C.D + C + \overline{A}$

$Q = B.0 + B.C.D + C.(D+1) + \overline{A}$

$Q = B.C.D + C + \overline{A}$

$Q = C.(B.D+1) + \overline{A}$

$Q = C.1 + \overline{A}$

$Q = C + \overline{A}$

Simplify the expression : $Q = A.B.C + A.\overline{C} + C.(D + \overline{C}) + A$

Solution.

$Q = A.B.C + A.\overline{C} + C.(D + \overline{C}) + A$

$Q = A.(B.C + \overline{C}) + C.D + C.\overline{C} + A$

$Q = A.(B + \overline{C}) + C.D + 0 + A$

$Q = A.B + A.\overline{C} + C.D + A$

$Q = A.(B+1) + A.\overline{C} + C.D$

$Q = A + A.\overline{C} + C.D$

$Q = A.(1 + \overline{C}) + C.D$

$Q = A + C.D$

Simplify the expression : $Q = A.B.\overline{C} + A.\overline{C} + \overline{A}.\overline{C}.D + \overline{A}.\overline{C}.\overline{D}$

$Q = A.B.\overline{C} + A.\overline{C} + \overline{A}.\overline{C}.D + \overline{A}.\overline{C}.\overline{D}$

$Q = A.\overline{C}.(B+1) + \overline{A}.\overline{C}.(D + \overline{D})$

$Q = A.\overline{C}.1 + \overline{A}.\overline{C}.1$

$Q = A.\overline{C} + \overline{A}.\overline{C}$

$Q = \overline{C}.(A + \overline{A})$

$Q = \overline{C}.1$

$Q = \overline{C}$

Simplify the expression: $Q = A.B.(\overline{B} + C) + B.C + B$

$$Q = A.B.(\overline{B} + C) + B.C + B$$
$$Q = A.B.\overline{B} + A.B.C + B.C + B$$
$$Q = A.0 + A.B.C + B.(C + 1)$$
$$Q = A.B.C + B.1$$
$$Q = A.B.C + B$$
$$Q = B.(A.C + 1)$$
$$Q = B.1$$
$$Q = B$$

Simplify the expression: $Q = B.(A + \overline{C}) + A + A.(\overline{A} + B)$

$$Q = B.(A + \overline{C}) + A + A.(\overline{A} + B)$$
$$Q = A.B + B.\overline{C} + A + A.\overline{A} + A.B$$
$$Q = A.B + B.\overline{C} + A$$
$$Q = A.(B + 1) + B.\overline{C}$$
$$Q = A + B.\overline{C}$$

Simplify the expression: $Q = A.B.\overline{C} + B.C + \overline{A}.B.\overline{C} + A.B.\overline{B}$

$$Q = A.B.\overline{C} + B.C + \overline{A}.B.\overline{C} + A.B.\overline{B}$$
$$Q = B.\overline{C}.(A + \overline{A}) + B.C + A.0$$
$$Q = B.\overline{C}.1 + B.C$$
$$Q = B.\overline{C} + B.C$$
$$Q = B.(\overline{C} + C)$$
$$Q = B.1$$
$$Q = B$$

Simplify the expression: $Q = A.B.C + B.C.D + B.C.\overline{D} + B.\overline{C}.D + A.B.\overline{C} + \overline{A}.B.\overline{C}$

$$Q = A.B.C + B.C.D + B.C.\overline{D} + B.\overline{C}.D + A.B.\overline{C} + \overline{A}.B.\overline{C}$$
$$Q = A.B.C + B.C.(D + \overline{D}) + B.\overline{C}.D + B.\overline{C}.(A + \overline{A})$$
$$Q = A.B.C + B.C.1 + B.\overline{C}.D + B.\overline{C}.1$$
$$Q = A.B.C + B.C + B.\overline{C}.D + B.\overline{C}$$
$$Q = B.C.(A + 1) + B.\overline{C}.(D + 1)$$
$$Q = B.C.1 + B.\overline{C}.1$$
$$Q = B.C + B.\overline{C}$$
$$Q = B.(C + \overline{C})$$
$$Q = B.1$$
$$Q = B$$

Simplify the expression: $Q = A.B.C.D + A.B.D + A.\overline{B}.D + A.\overline{B}.C.D + A.C.D + \overline{A}.C.D$

$$Q = A.B.C.D + A.B.D + A.\overline{B}.D + A.\overline{B}.C.D + A.C.D + \overline{A}.C.D$$
$$Q = A.B.D.(C+1) + A.\overline{B}.D + A.C.D.(\overline{B}+1) + \overline{A}.C.D$$
$$Q = A.B.D.1 + A.\overline{B}.D + A.C.D.1 + \overline{A}.C.D$$
$$Q = A.B.D + A.\overline{B}.D + A.C.D + \overline{A}.C.D$$
$$Q = A.D.(B+\overline{B}) + C.D.(A+\overline{A})$$
$$Q = A.D.1 + C.D.1$$
$$Q = A.D + C.D$$
$$Q = D.(A+C)$$

Simplify the expression using De Morgans Theorem $Q = \overline{\overline{(A+\overline{B})}.\overline{(A.\overline{B})}} + \overline{A}.B$

$$Q = \overline{\overline{(A+\overline{B})}.\overline{(A.\overline{B})}} + \overline{A}.B$$
$$Q = \overline{\overline{(A+\overline{B})}} + \overline{\overline{(A.\overline{B})}} + \overline{A}.B$$
$$Q = (A+\overline{B}) + (A.\overline{B}) + \overline{A}.B$$
$$Q = A + \overline{B} + A.\overline{B} + \overline{A}.B$$
$$Q = A.(1+\overline{B}) + (\overline{B} + \overline{A}.B)$$
$$Q = A.1 + (\overline{B} + \overline{A})$$
$$Q = A + \overline{B} + \overline{A}$$
$$Q = \overline{B} + (A + \overline{A})$$
$$Q = \overline{B} + 1$$
$$Q = 1$$

Simplify the expression using De Morgans Theorem: $Q = \overline{\overline{\overline{A.\overline{C}}.\overline{B}}.D} + \overline{\overline{C}.D}$

$$Q = \overline{\overline{\overline{A.\overline{C}}.\overline{B}}.D} + \overline{\overline{C}.D}$$
$$Q = \overline{\overline{\overline{A.\overline{C}}.\overline{B}}} + \overline{D} + \overline{\overline{C}} + \overline{D}$$
$$Q = \overline{A.\overline{C}}.\overline{B} + \overline{D} + C$$
$$Q = (\overline{A} + \overline{\overline{C}}).\overline{B} + \overline{D} + C$$
$$Q = \overline{A}.\overline{B} + \overline{B}.C + \overline{D} + C$$
$$Q = \overline{A}.\overline{B} + C.(\overline{B}+1) + \overline{D}$$
$$Q = \overline{A}.\overline{B} + C.1 + \overline{D}$$
$$Q = \overline{A}.\overline{B} + C + \overline{D}$$

Standard form of Boolean expressions

In the previous section we saw how Boolean expressions can be simplified using Boolean algebra and Boolean theorems. In this section we use basic laws and theorems of Boolean algebra for simplifying Boolean expressions by two basic forms:

1. Sum of Products form(SOP)
2. Product of Sums form(POS)

Sum of Products form(SOP)

It is a group of product term ORed together. That is two or more product terms are sumed by Boolean addition and resulting expression is SOP. An SOP expression has a single variable term also

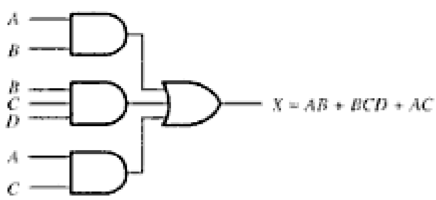
Ex: $A+\overline{A}BC+B\overline{C}D$

Some examples of SOP:

Ex:$A+ABC+\overline{BC}D$, $\overline{AB}C+CDE+BCD$, $\overline{AB}+ABC+AC$

Implementation of SOP:

Implemetating an SOP expression requires ORing the outputs of two or more AND gates. A product term is produced by AND Operation and sum of two or more product items is produced by OR operation. Thus an SOP expression is implemented by AND-OR logic.



Conversion of a General Expression to SOP Form

Any logic expression can be changed into SOP form by applying Boolean algebra techniques. For example, the expression $A(B + CD)$ can be converted to SOP form by applying the distributive law:

$$A(B + CD) = AB + ACD$$

Convert each of the following Boolean Expression to SOP Form:

1. AB+B(CD+EF)

$$AB + B(CD + EF) = AB + BCD + BEF$$

2. (A+B)(B+C+D)

$$(A+B)(B+C+D)=AB+AC+AD+BB+BC+BD$$

Standard SOP Expression: In which all the variables in the domain appear in each product indicates a Standard SOP Expression. An SOP Expression is equal to 1 only if one or more of the product terms in the expression is equal to 1.

The Product-of-Sums(POS) Form

When two or more sum terms are multiplied the resulting expression is POS.

Some Examples:

$$(\overline{A} + B)(A + \overline{B} + C)$$

$$(\overline{A} + \overline{B} + \overline{C})(C + \overline{D} + E)(\overline{B} + C + D)$$

$$(A + B)(A + \overline{B} + C)(\overline{A} + C)$$

In a Pos expression a single overbar cannot extend ovcr more than one variable..However morethan one variable can have an overbar

Ex:POS expression can have the term

$\overline{A}+\overline{B}+\overline{C}$ but not $\overline{A+B+C}$

Implementation an POS expression requires ANDing the outputs of two or more OR gates.A sum term is produced by OR Operation and product of two or more sum items is produced by AND operation.Thus an POS expression is implemented by OR gates connect to the inputs of an AND gate

Standard POS Expression: In which all the variables in the domain appear in each sum indicates a Standard POS Expression.An SOP Expression is equal to 0 only if one or more of the sum terms in the expression is equal to 0.

Karnaugh MAP:

Karnaugh Map is similar to a truth table because it presents all possible values of input variables and the resulting output for each value. K Map is an array of cells in which each cell represents a binary value of the input variables.K Maps can be used with two,three,four and five variables

UNIT-3 : COMBINATIONAL CIRCUITS

Digital circuits can be broadly classified into two categories.They are

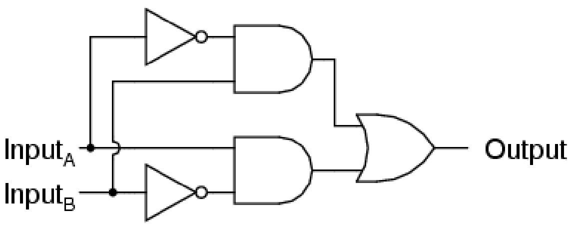
1) Combinational circuits
2) Sequential circuits

Combinational circuits are the circuits in which the output(s) at any instant of time depend upon the inputs present at that instant of time only and does not depent upon past conditions. Combinational circuits have no storage area /memory elements. Some examples are Adders, Subtractors, comparators,encoders, decoders, multiplexers ,demultiplexers etc.

The combinational circuits consists of input variables ,logic gates and output variables. The logic gates accept signals from input variables and generate output signals.

An example for a simple combinational circuit is given below

Exclusive-OR equivalent circuit



A	B	Output
0	0	0
0	1	1
1	0	1
1	1	0

Sequential circuits: are the circuits in which the output at any instant of time depends upon the present values as well as the output values. That is the sequential circuits have memory elements. Some examples of sequential circuits are fliup-flop, shift registers counters etc.

Design procedure for Combinational circuit:

Any combinational circuit can be designed by following the design procedure given below.

1) From the problem description, identify the inputs, outputs and draw a block diagram.
2) Draw the Truth Table such that it describes the operation of the circuit for different combination of inputs.
3) Note down the switching expressions for the outputs.
4) Simplify the switching expression.
5) Implement the simplified expression using logic gates.

Adders:

Digital computers perform a variety of information processing tasks. The basic functions are various arithmetic operations. The most basic arithmetic operation is addition of two binary digits

Simple addition consists of four possible elementary operations namely

0 + 0 = 0 → sum

0 + 1 = 1 → sum

1 + 0 = 1 → sum

1 + 1 = 10 → sum

↓

Carry

Arithmetic Circiuts:

Half – Adder : A combinational circuit that performs the arithmetic addition of two binary bits is called a half-Adder. The half adder needs two binary inputs Augend and addend and produces two binary outputs Sum and Carry.

The Block diagram and truth Table for half adder is as shown below.

Inputs		Output	
A	B	S	C
0	0	0	0
0	1	1	0
0	1	1	0
1	1	0	1

The simplified Boolean functions for two outputs can be obtained directly from the above truth table.

The simplified sum-of-product(SOP) expressions are:

$$S = \bar{A}B + A\bar{B}$$

$$C = AB$$

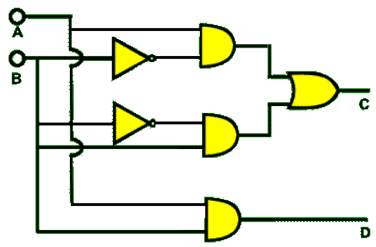
The half-adder circuit can be implemented using

i) Basic gates AND ,OR,and NOT

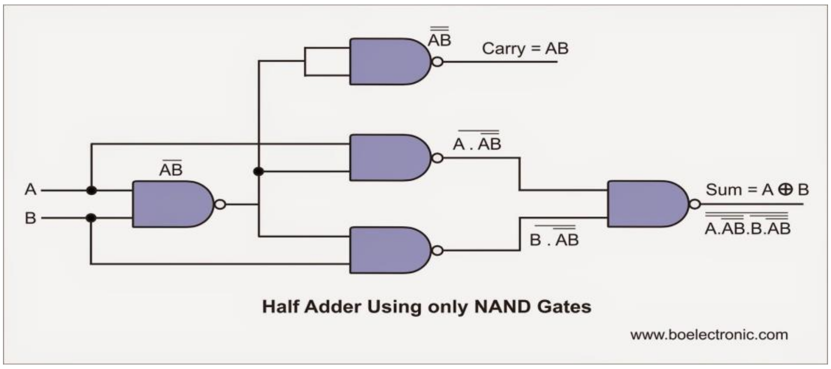
ii) NAND gate

iii) Ex-OR and AND

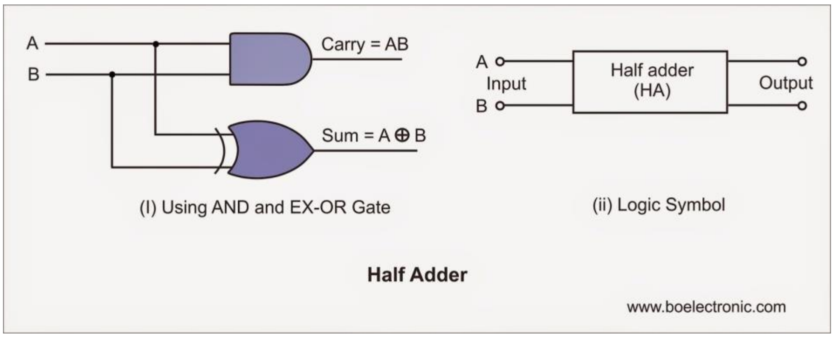
The Half –adder circuit using Basic gates AND ,OR,and NOT is as shown below:



The Half –adder circuit using NAND gate is as shown below:



The Half –adder circuit using Ex-OR and AND :

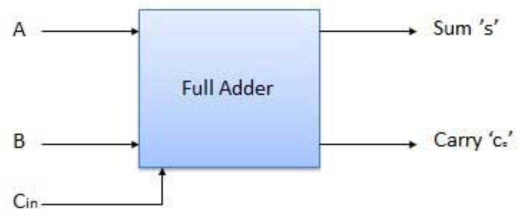


Full Adder :

A Half-adder has only two inputs and there is no provision to add a carry coming from the lower order bits when multibit addition is performed. To overcome this a full adder is designed.

A full- adder is a combinational circuit that performs the arithmetic sum of three input bits and produce two outputs(SUM and Carry). Two inputs are denoted by A and B ,which represents two significant bits to be added. The third input C_{in} represents the carry from the previous lower order bits.

The logic Diagram and truth Table for full-adder is as shown below.



Inputs			Output	
A	B	Cin	S	Co
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

The eight rows iunder the input variables designate all possible combinations of 1's and 0's.when all input bits are 0's,the output is zero.Ths sum S ,output is equal to 1 when only one input is equal to 1 or when all inputs are equal to 1.The carry C output has a carry of 1 if two or three inputs are equal to 1.
From th truth table the logic equation for S can be writtern by summing up the inputs combination for which the sum output is 1.

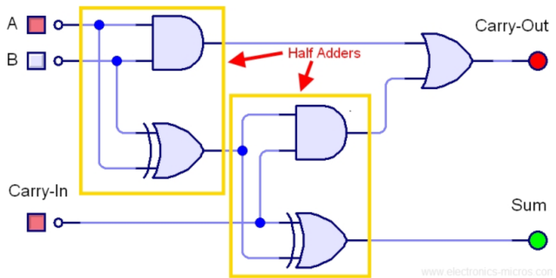
$$S = \overline{A}\overline{B}C_{in} + \overline{A}B\overline{C}_{in} + A\overline{B}\overline{C}_{in} + ABC_{in}$$

$$C_{out} = \overline{A}BC_{in} + A\overline{B}C_{in} + AB\overline{C}_{in} + ABC_{in}$$

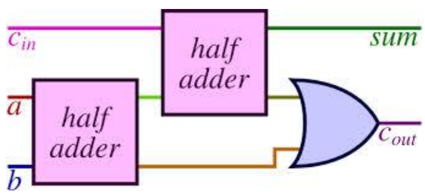
$$= C_{in}(\overline{A}B+A\overline{B})+AB(\overline{C}_{in} + C_{in})$$

$$C_{out} = (A \oplus B) C_{in} + AB$$

Implementation of full adder circuit using EX-OR gates ,AND gates and OR gate is shown below.



Block diagram representation of full adder using two half adder blocks is shown below



Note: This is only Basic Information for students. Please refer "Reference Books" prescribed as per syllabus

Difference Between Half Adder and a Full Adder:

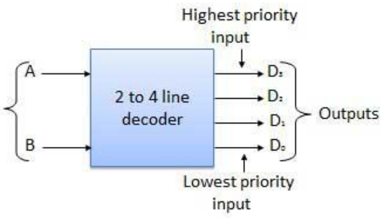
1. The main difference between a half-adder and a full-adder is that the full-adder has three inputs and two outputs,where as half adder has only two inputs and two outputs.
2. For complex addition, there may be cases when you have to add two 8-bit bytes together. This can be done only with the help of full-adder logic.
3. When a full adder logic is designed we will be able to string eight of them together to create a byte-wide adder and cascade the carry bit from one adder to the next.
4. Full adder is difficult to implement than half adder. Full adder make use of half adders cascaded together.

Decoder:

A decoder is a combinational circuit that converts binary information from n input lines to a maximum of 2n unique output lines.

The simplest is 1 to 2 line decoder , 2 to 4 line decoder , 3 to 8 line decoder etc.

Decoder circuits can be connected together to form a larger decoder circuit. A 4 x 16 decoder can be implemented using two 3 x 8 decoders.Thus there exist decoders for converting from BCD to Decimal , Binary decoder, BCD to 7 segment decoder.



A 2 to 4 decoder has two inputs A and B and four outputs (D0 to C3).Based on 2 inputs one of the four output is selected ,i.e., 2 inputs are decoded into 4 outputs.

Inputs		Output			
A	B	D_0	D_1	D_2	D_3
0	0	1	0	0	0
0	1	0	1	0	0
0	1	0	0	1	0
1	1	0	0	0	1

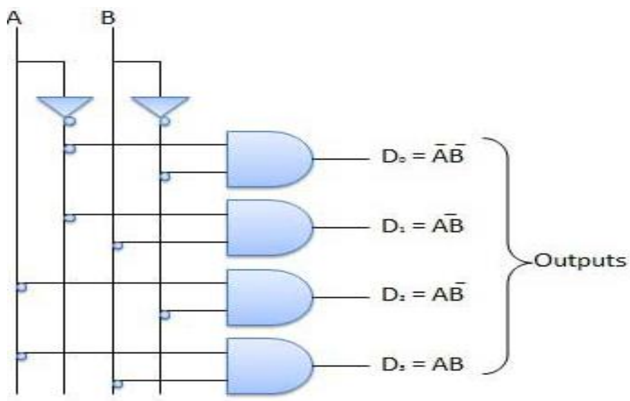
From the truth table the logic expressions for the outputs can be written as follows:

D0 = $\overline{AB}$ D1 = $\overline{A}B$

D2 = $A\overline{B}$ D3 = AB

Here 2 inputs are decoded into four outputs, each output representing one of the minterms of the 2 input variables.

Using the above expressions, the logic circuit for 2 to 4 decoder can be implemented as shown in the figure below.



3 to 8 decoder:

A 3 to 8 decoder has three inputs A,B,C and eight outputs D0 to d7.Based on 3 inputs one of the eight output is selected. That is, the 3 inputs are decoded into 8 outputs, where each output representing one of the minterms of the 3 input variables.

The truth table for 3 to 8 decoder is as shown in the figure below.

Inputs			Outputs							
X	Y	Z	D_0	D_1	D_2	D_3	D_4	D_5	D_6	D_7
0	0	0	1	0	0	0	0	0	0	0
0	0	1	0	1	0	0	0	0	0	0
0	1	0	0	0	1	0	0	0	0	0
0	1	1	0	0	0	1	0	0	0	0
1	0	0	0	0	0	0	1	0	0	0
1	0	1	0	0	0	0	0	1	0	0
1	1	0	0	0	0	0	0	0	1	0
1	1	1	0	0	0	0	0	0	0	1

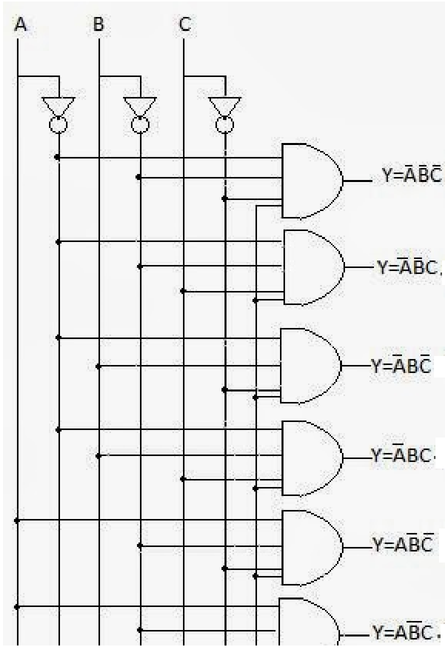
From the truth table the logic expressions for the outputs can be written as follows

$D0=\overline{ABC}$ $D1=\overline{AB}C$ $D2= \bar{A}B\bar{C}$ $D3= \bar{A}BC$

$D4=A\overline{BC}$ $D5=A\bar{B}C$ $D6 = AB\bar{C}$ $D7= ABC$

Using the above expressions ,the logic circuit for a 3 to 8 decoder can be implemented using 3 NOT gates and eight 3 –input AND gates as shown in the figure. This application implements Binary to Octal conversion.The input variables represents a binary number,and the output will represents the eight digits in the actual numbers system.This decoder is called as 1-of-8 decoder, since only one of eight output lines is HIGH for a particular input combination

A 3 to 8 line decoder is as shown below.

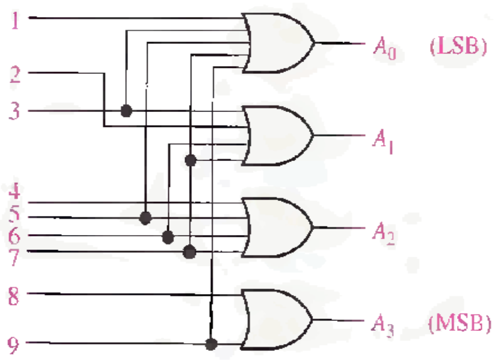


Applications of Decoders:
1. Decoders are used in counter systems.
2. Decoders are used in Analog-to-Digital Converters
3. Decoders outputs can be used to drive a display system.

Encoders:

An encoder is a combinational logic circuit which performs reverse of decoder function. An encoder has
2^n (or less)input lines and n output lines. The output lines generate binary code for the 2^n input variables.
That is, an encoder accepts decimal or octal digit and converts it to a coded output such as BCD or binary.
An encoder can encode various symbols and alphanumeric characters.
We can define Encoder as Ä process of converting from familiar symbols or numbers to a coded format .

Decimal to BCD encoder is as shown in figure.



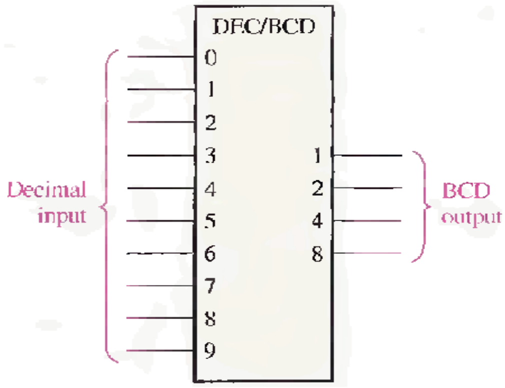


Fig. Logic circuit for Decimal to BCD encoder

Fig. Logic Symbol for Decimal to BCD

A decimal to BCD encoder converts each of the decimal digits (0 through 9) to a binary code .This encoder has ten inputs(i_0 to i_9) one for each decimal digit and four outputs corresponding to the BCD code.

The truth table for Decimal to BCD encoder is as shown below.

Decimal Inputs										BCD Outputs			
I_0	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	A	B	C	D
1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	0	0	0	1
0	0	1	0	0	0	0	0	0	0	0	0	1	0
0	0	0	1	0	0	0	0	0	0	0	0	1	1
0	0	0	0	1	0	0	0	0	0	0	1	0	0
0	0	0	0	0	1	0	0	0	0	0	1	0	1
0	0	0	0	0	0	1	0	0	0	0	1	0	0
0	0	0	0	0	0	0	1	0	0	0	1	0	1
0	0	0	0	0	0	0	0	1	0	1	0	0	0
0	0	0	0	0	0	0	0	0	1	1	0	0	1

From the Truth Table the output A is HIGH whenever the input 8 or 9 is HIGH.

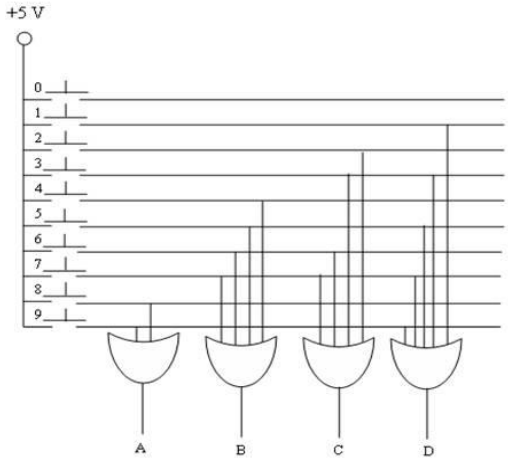
Therefore $A = I_8 + I_9$

$B = I_4 + I_5 + I_6 + I_7$

$C = I_2 + I_3 + I_6 + I_7$

$D = I_1 + I_3 + I_5 + I_7 + I_9$

Using above expressions,the Decimal inputs BCD encoder can be implemented as shown in figure



Seven Segment display :

A seven segment Display is normally used for displaying any one of the decimal digits,0 through 9 Figure shows a 7 segment display composed of 7 elements or segments.

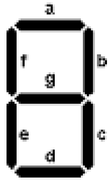


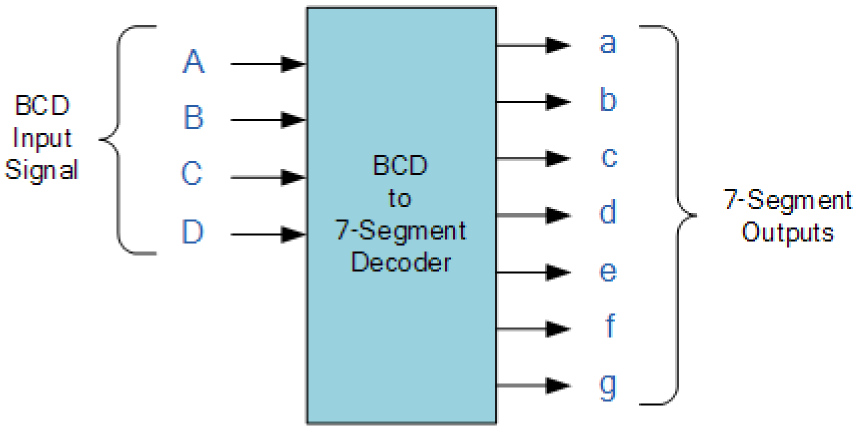
Fig: Seven Segment Display

Each segment LED emits light when current flows through it.

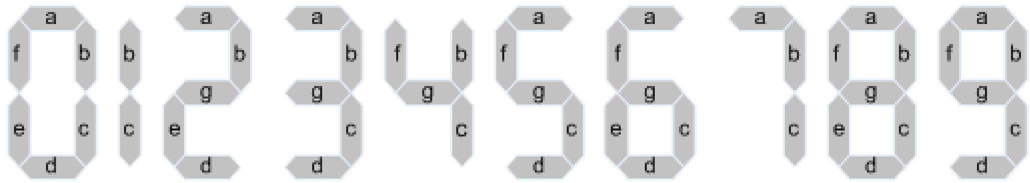
Design of BCD-to-Seven Segment Decoder:

A BCD to 7 Segment decoder can be designed using logic gates.A block diagram of BCD to Seven Segment Decoder with 4 BCD inputs(A , B , C and D) and 7 outputs(a,b,c d,e,f and g) corresponding to 7 segment of a display.

General block diagram for BCD to 7 Segment decoder is as shown below.



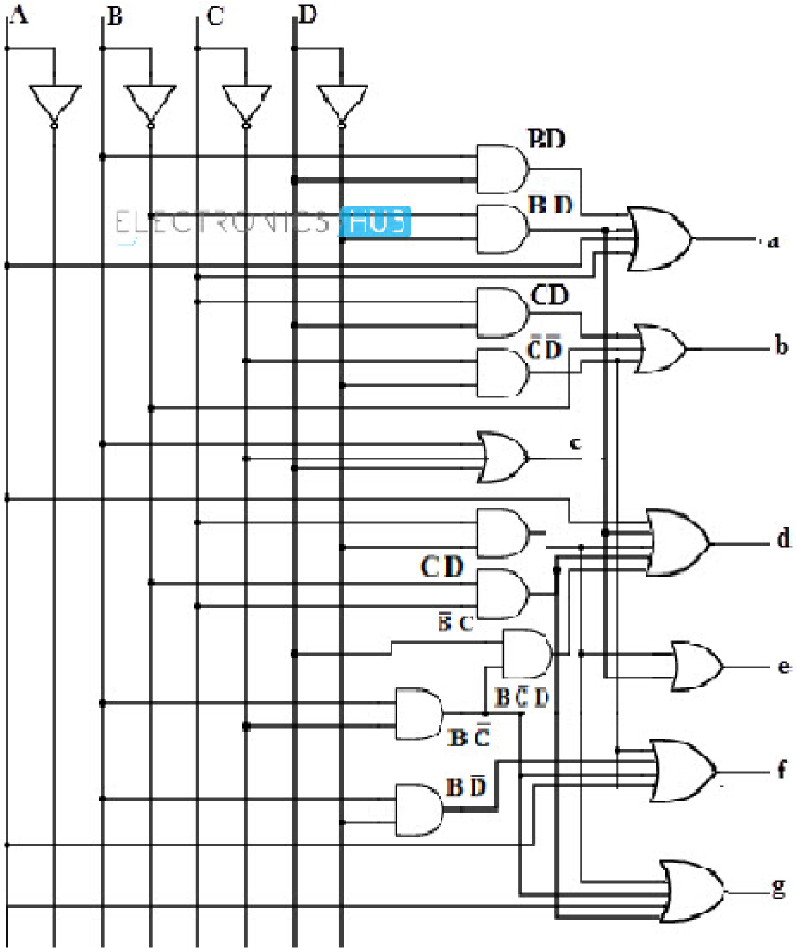
Digits 0 through 9 with the the possible LE D display elements are as below.



Binary Inputs				Decoder Outputs							7-Segment Display Outputs
D	C	B	A	a	b	c	d	e	f	g	
0	0	0	0	1	1	1	1	1	1	0	0
0	0	0	1	0	1	1	0	0	0	0	1
0	0	1	0	1	1	0	1	1	0	1	2
0	0	1	1	1	1	1	1	0	0	1	3
0	1	0	0	0	1	1	0	0	1	1	4
0	1	0	1	1	0	1	1	0	1	1	5
0	1	1	0	1	0	1	1	1	1	1	6
0	1	1	1	1	1	1	0	0	0	0	7
1	0	0	0	1	1	1	1	1	1	1	8
1	0	0	1	1	1	1	1	0	1	1	9

Fig. The truth table for a seven segment display

The outputs from truth table can be solved using Karnaugh Map .Hence generated Logic diagram is as shown below.



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Multiplexers:

Multiplex Means ''many into one ''. A digital multiplexer is a combinational circuit that selects binary information from one of many input lines and directs it to a single output line. The selection of a particular input line is controlled by a set of selection lines. There are 2^n input lines and 'n 'selection lines determine input selected. A multiplexer is also called a DATA SELECTOR since it selects one of many inputs and steers the information to the output.

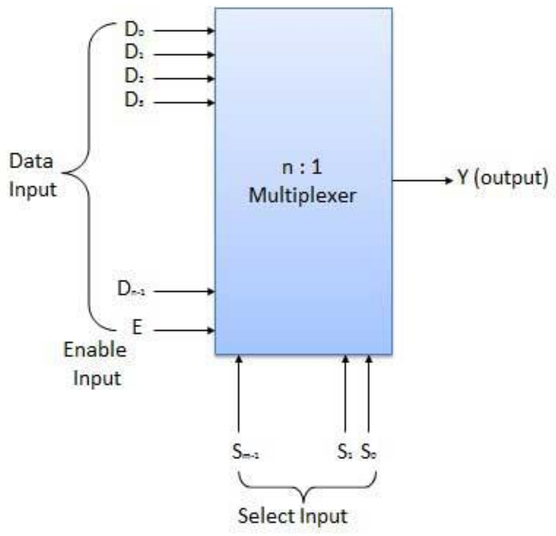
Multiplexer are used in basic electronic components. They are used in mechanical switches. When high speed of operation is needed multiplexers are used.

Multiplexer can handle two types of data that is analog and digital. The multiplexer used for digital transmission are called digital multiplexer.

Multiplexer come in multiple variations.

- 2:1 multiplexer
- 4:1 multiplexer
- 16:1 multiplexer
- 32:1 multiplexer

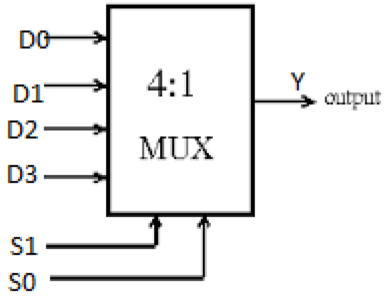
General block diagram for multiplexer is a shown below



Four –to-One multiplexer :

The logic symbol of a 4 to 1 multiplexer is as shown below.It has four data input lines (D_0,D_1,D_2,D_3), a single output line (y) and two select lines(S_0 an S_1) to select one of the four input lines.

The logic symbol of 4 to 1 multiplexer is shown below



The truth table for a 4 to 1 multiplexer is shown below.

Data Select inputs		Output
S1	S0	y
0	0	D_0
0	1	D_1
1	0	D_2
1	1	D_3

A logical expression for the output in terms of the data input and the selsect inputs can be derived as follows:

The data output y = data input D_0 if and only if $S_1 = 0$ and $S_0 = 0$

Therefore $y = D_0\overline{S1S0} = D_0.\overline{0}.\overline{0} = D_0.1.1 = D_0$

The data output y = data input D_1 if and only if $S_1 = 0$ and $S_0 = 1$

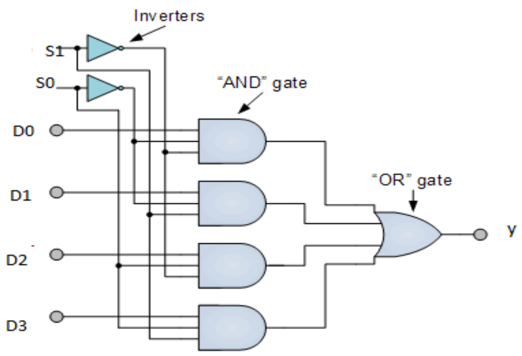
Therefore $y = D_0\overline{S}_1S_0 = D_1.\overline{0}.1 = D_1$

Similarly $y = D_2S_1\overline{S}_0 = D_2$ when $S_1 = 1$ $S_0 = 0$

And $y = D_3S_1S_0 = D_3$ when $S_1 = S_0 = 1$

The final expression for the data output is given by

$$Y = D_0\overline{S}_1\overline{S}_0 + D_1\overline{S}_1S_0 + D_2S_1\overline{S}_0 + D_3S_1S_0$$



Applications of multiplexer :

A Multiplexer is used in numerous applications like, where multiple data can be transmitted using a single line.

Communication System – A Multiplexer is used in communication systems, which has a transmission system and also a communication network. A Multiplexer is used to increase the efficiency of the communication system by allowing the transmission of data such as audio & video data from different channels via cables and single lines.

Computer Memory – A Multiplexer is used in computer memory to keep a vast amount of memory in the system, and also to decrease the number of copper lines necessary to connect the memory to other parts of the computer.

Telephone Network – A multiplexer is used in telephone networks to integrate the multiple audio signals on a single line of transmission.

Transmission from the Computer System of a Satellite:

A Multiplexer is used to transmit the data signals from the computer system of a satellite to the ground system by using a GSM communication

An everyday example of an analog multiplexer is the source selection control on a home stereo unit.

Multiplexers are used in building digital semiconductors such as CPUs and graphics controllers.

Applications of Demultiplexers :

Demultiplxer is used to connect a single source to multiple destinations. The main application area of de –multiplexer is communication system where multiplexers are used.

They are used in Communication system to break into many forms of signals from common source of input signal

They are used in data and address lines transmission in ALU(arithmetic and logic Unit) of a computer system.

They are used in Converters. That is Serial-to-Parallel converter and Parallel-to-serial converters.

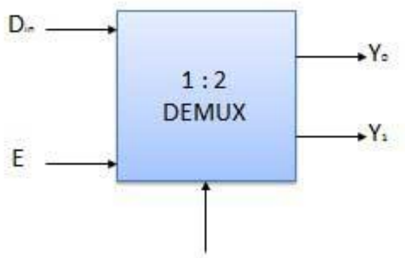
Demultiplexer

Demultiplexer(DEMUX) means one into many. Demultiplexer is a combinational circuit taking information from single input line and transmits this information on one of 2n possible output lines. It takes digital information from one input line and distributes across many output lines. Hence it is also called as a DISTRIBUTOR.

The DEMUX types are

1: 2 Demultiplexer (1 Select Line)
1:4 Demultiplexer (2 Select Line)
1:8 Demultiplexer (3 Select Line)
1:16 Demultiplexer (4 Select Line)

The general block diagram for 1:2 DEMUX is as shown below.



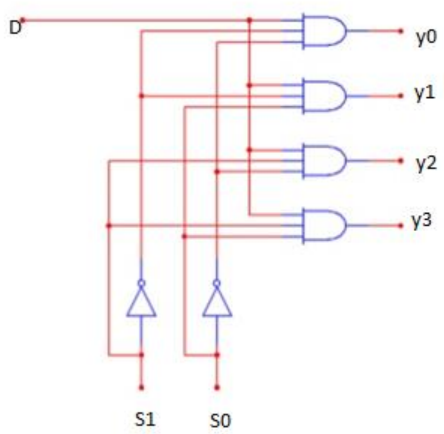
Enable	Select	Output	
E	S	Y0	Y1
0	x	0	0
1	0	0	Din
1	1	Din	0

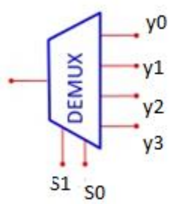
x = Don't care

One to Four Demultiplexer:

One to Four demultiplexer ha s single input (D),four outputs(y0 to y3) and two select inputs(S0 and S1). The logic symbol and truth table is given as below.

1-to-4 De-Multiplexer (DEMUX)





S1	S2	Y3	Y2	Y1	Y0
0	0	0	0	0	D
0	1	0	0	D	0
1	0	0	D	0	0
1	1	D	0	0	0

From the truth table the data input is connected to output y0 when S1=0 and S1=0

Similarly y0 = D when S1 = 0 and S0 = 0

y1 = D when S1 = 0 and S0 = 1

y2 = D when S1 = 1 and S0 = 0

y3 = D when S1 = 1 and S0 = 1

The expression for the outputs can be written as

$Y0 = \overline{S1S0}D \quad y1=\overline{S1}S0D$

$Y2 = S1\overline{S0}D \quad y3 = S1S0D$

Using the above expression a 1 to 4 demux can be implemented as shown above .

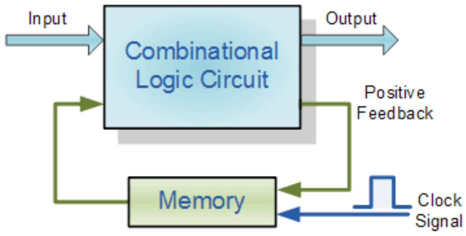
UNIT-4 :SEQUENTIAL CIRCUITS

Sequential circuits:

The logic circuits whose outputs at any instant of time depend not only on the present inputs but also on the past outputs are called sequential circuits.

It consists of memory elements capable of storing binary information. The sequential circuit receives binary information from external inputs.

The block diagram of a sequential circuit is as shown below



The sequential circuits are broadly classified into 2 types.

1. Synchronous sequential circuit
2. A Synchronous sequential circuit

Synchronous sequential circuit is a system whose behavior can be defined from the knowledge of its signals at discrete instant of time. The synchronization is achieved by a master clock generator which generates periodic clock pulses.

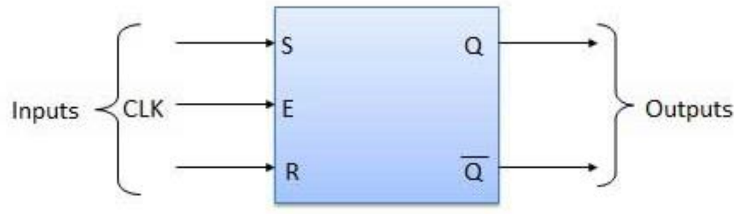
Asynchronous sequential circuit depends upon the order in which input signals change and can be affected at any instant of time . In asynchronous sequential circuits, events can occur after one event is completed and there is no need to wait for a clock pulse.

In general , Asynchronous sequential circuits are considerably faster than Synchronous sequential circuits. but in Asynchronous sequential circuit as events are allowed to occur without any synchronization the system may become unstable.

Sl.No	COMBINATIONAL CIRCUITS	SEQUENTIAL CIRCUITS
1	In a combinational circuits, the output at any time depends only on	In a sequential circuits, the output at any time depends on
	input values at that moment.	present input values as well as the past output values.
2	Memory units are not required	Memory units are required to store the past output values.
3	Output signals are not fed back to input of the circuit.	Output signals are fed back to input of the circuit.
4	Faster in circuits operation.	Slower in circuits operation.
5	Easy to design	Harder to design
6	Ex: Parallel Adder, Multiplexer, Decoders etc	Ex: Serial adder, Flip-Flops, Counters, Registers etc

Flip flops:

It is a simplest type of sequential circuit. It is the basic memory element or memory cell which can store 1bit (A binary either 0 OR 1).It can store binary state(0 OR 1) as long as power is available to the circuit.It is also known as a latch.



Logic Symbol of flip flop:

Clock:

In synchronous sequential circuits, the term synchronous means the changes in the output occur at a specified point is called the clock .The clock is a square wave or rectangular pulse train.

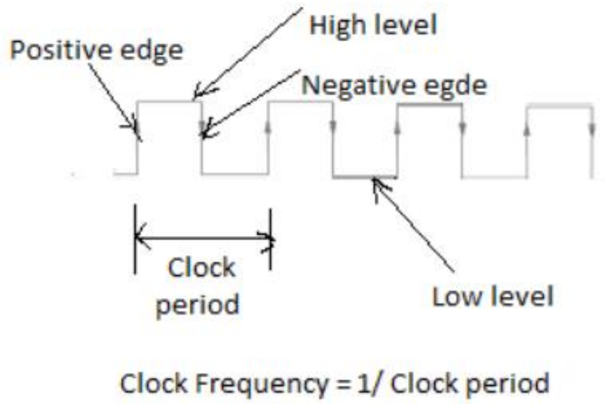


fig: clock pulse train.

Types of Triggering:

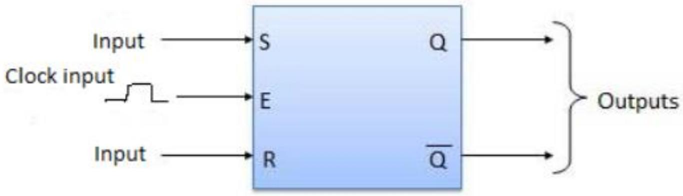
Based on the specific interval or point in the clock during or at which triggering of flip flops takes place, it can be classified into two different types.

1) Level triggering ----> 1) Positive (High) level triggering
2) Negative(low) level triggering
2) Edge triggering ----> 1)Positive (Rising) edge triggering
2) Negative(Falling) edge triggering

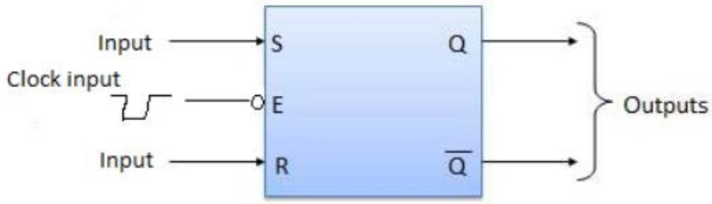
Level triggering

The Flip –Flop that responds to a clock signal during the time at which clock is in the logic HIGH state, are called High level triggering flip flops.

It is indicated by a straight lead at the clock output as shown below.



The flip flops that responds to a clock signal during the time at which clock is in logic low state are called low level triggered flip flops. This type is identified by a straight lead with a low state indicator bubble at the clock output .



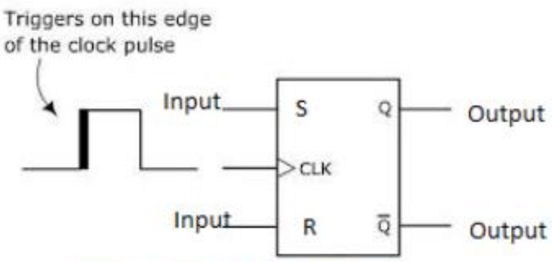
The draw back of level triggering is that as long as the clock is positive or negative, the Flip Flop changes its state more than once or many times for the change in inputs. If the inputs are made stable for the entire clock duration, then the output changes only once. On the other hand , if the frequency of input change is higher than the input clock frequency, the output of the flip flop undergoes multiple changes when the clock is positive or negative.

Edge triggering in flip flops:

A clock pulse goes through two signal transitions from 0 to 1 and returns 1 to 0. A +ve transition (0 to 1) is defined as the +ve edge or rising edge or leading edge and –ve transition (1 to 0) is defined as the –ve edge or falling edge or trailing edge. The term edge-triggered means that flip flop changes its state either at the +ve edge or at the –ve edge of the clock pulse .

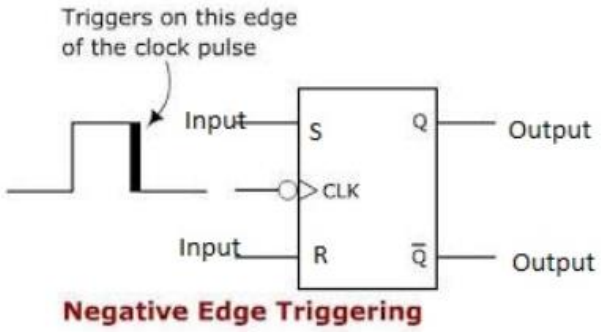
The Flip Flops that responds to a clock signal during the low-to-high (+ve edge) transition are called +ve edge triggering Flip Flops.

This type is identified by a clock input lead with a triangle as shown below .



Positive Edge Triggering

The flip flops that respond to a clock signal during the high-to-low (-ve edge) transition are called –ve edge triggering Flip Flops. This type is identified by a clock input with a bubble as shown below



Flip Flops and its types

Flip flops:

It is a simplest type of sequential circuit. It is the basic memory element or memory cell which can store 1bit (A binary either 0 OR 1).It can store binary state(0 OR 1) as long as power is available to the circuit. It is also known as a latch.

Types of Flip Flops:

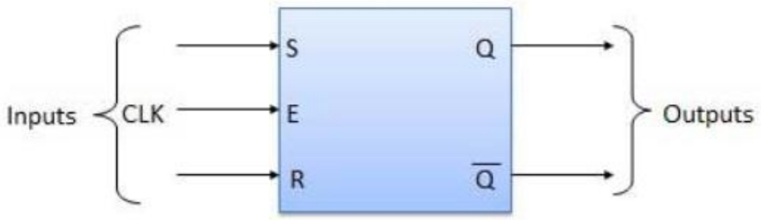
There are different types depends upon their inputs and clock pulse causing transitions between two states. Basic 4 types of flip flops are

1.RS(OR SR)- Flip Flop
2.D Flip Flop
3.T Flip Flop
4.JK Flip Flop

SR Latch(Non Clocked SR FF):

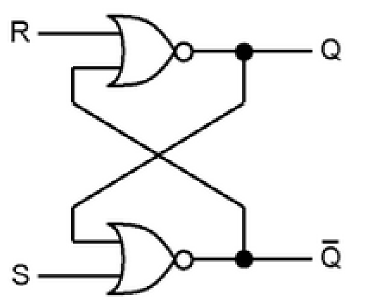
It has two inputs SET(S) AND RESET(R) and 2 outputs Q and Q. The 2 outputs are complement to each other.

The block diagram of SR Latch is shown below:



The SR FF can be implemented using NOR OR NAND gates.

(a)NOR-Gate based SR Latch:

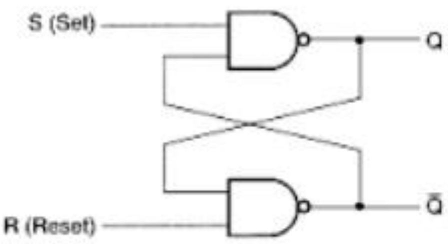


Note: This is only Basic Information for students. Please refer "Reference Books" prescribed as per syllabus

The cross-coupled connections from the output of one gate to input of other gate constitute feedback path.
The truth table is as shown below:

S	R	Q	Q'	
0	0	NC	NC	No change. Latch remained in present state.
1	0	1	0	Latch SET.
0	1	0	1	Latch RESET.
1	1	0	0	Invalid condition.

(a) (b) NAND-Gate based SR Latch:The NAND-Gate based SR Latch is constructed using cross coupled NAND gates and its truth table is as shown below.



(a) Logic diagram

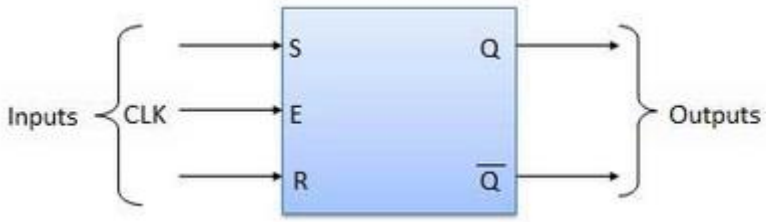
S	R	Q	$\bar{Q}$	
0	1	1	0	Set state
1	1	1	0	
1	0	0	1	Reset state
1	1	0	1	
0	0	1	1	Undefined

(b) Function table

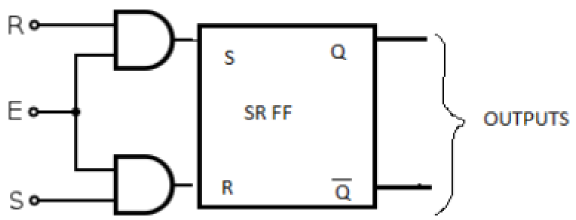
Clocked RS Flip Flop (Synchronous Sequential circuits):

The basic RS Flip Flop is a asynchronous sequential circuit. This FF can also be converted to synchronous sequential circuit by providing an additional control input(clock) that determines when the state of the flip flop to be changed . This FF is called as Clocked RS FF.

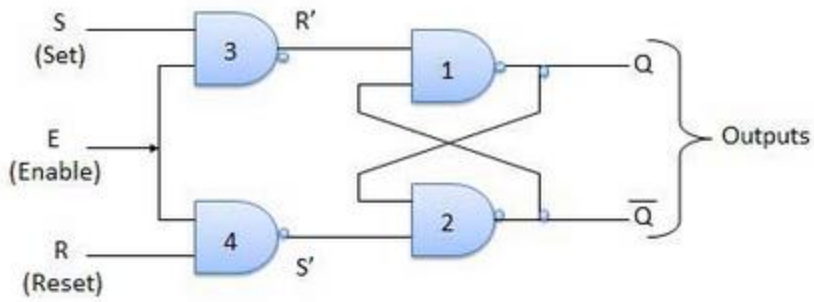
The logic symbol is as shown below:



The block diagram of clocked SR Flip Flop is as shown below:



The clocked SR Flip-Flop circuit diagram using NAND based latch is as shown below.



The Truth table of clocked SR Flip Flop is as shown below:

Inputs			Outputs		Comments
E	S	R	Q_{n+1}	$\overline{Q}_{n+1}$	
1	0	0	Q_n	$\overline{Q}_n$	No change
1	0	1	0	1	Rset
1	1	0	1	0	Set
1	1	1	x	x	Indeterminate

Operation

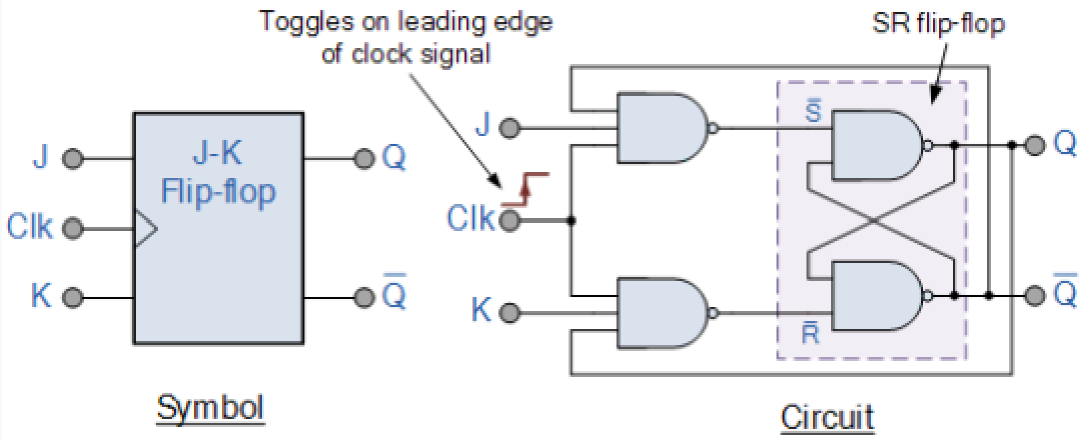
S.N.	Condition	Operation
1	**S = R = 0 : No change**	If S = R = 0 then output of NAND gates 3 and 4 are forced to become 1. Hence R' and S' both will be equal to 1. Since S' and R' are the input of the basic S-R latch using NAND gates, there will be no change in the state of outputs.
2	**S = 0, R = 1, E = 1**	Since S = 0, output of NAND-3 i.e. R' = 1 and E = 1 the output of NAND-4 i.e. S' = 0.Hence Q_{n+1} = 0 and Q_{n+1} bar = 1. This is reset condition.
3	**S = 1, R = 0, E = 1**	Output of NAND-3 i.e. R' = 0 and output of NAND-4 i.e. S' = 1.Hence output of S-R NAND latch is Q_{n+1} = 1 and Q_{n+1} bar = 0. This is the reset condition.
4	**S = 1, R = 1, E = 1**	As S = 1, R = 1 and E = 1, the output of NAND gates 3 and 4 both are 0 i.e. S' = R' =0.Hence the **Race** condition will occur in the basic NAND latch.

Jk flip flops:

The basic gated SR NAND flip flop suffers from two basic problems: number one, the S = 0 and R = 0 condition (S = R = 0) must always be avoided, and number two, if S or R change state while the enable input is high the correct latching action may not occur. Then to overcome these two fundamental design problems with the SR flip-flop design, the JK flip Flop was developed.

The JK flip-flop is the most versatile flip-flop, and the most commonly used flip flop. The functioning of the JK Flip-Flop is similar to that of the RS flip-flop. Like the RS flip-flop, it has two data inputs, J and K, and a clock input. It has no undefined states or race condition.

The logic symbol and block diagram of JK Flip-Flop is as shown below.



The truth table of JK FF is shown below.

Clock	Inputs		Outputs	Action
	J	K	Q_{n+1}	
x	0	0	Q_n	No Change
1	0	1	0	RESET
1	1	0	1	SET
1	1	1	Q_n	TOGGLE
0	X	X	Q_n	NO CHANGE

Operation of the JK FF using SR FF can be explained as below

Case 1: J=0 and K=0,Clock=x -->The outputs of both the gates are low and the FF remains in the previous state.

Case 2:J=0 nd K-=1 and Clock=1 and let $Q_{n=1}$ and $\overline{Q_n}$ =0

S=J. $\overline{Q_n}$ R=K. Q_n

S=0.0=0 =1.1=1

S=0 and R=1, the FF RESETs on application of clock pulse.But if the FF is already in the RESET state ($Q_{n=0}$ and =1) ,then this condition of inputs(J=0 and K=1 and clock=1) will not alter the state of the FF and it remains in the RESET state.

Case 3: J=1 and K-=0 and Clock=1 and let $Q_{n=}$0 and $\overline{Q_n}$ =1

S=J. $\overline{Q_n}$ R=K. Q_n

S=1.1=1 =0.0=0

S=0 and R=1, the FF will SETs on application of clock pulse.But if the FF is already in the SET state ($Q_{n=}$1 and $\overline{Q_n}$ =0) ,then this condition of inputs(J=1 and K=0 and clock=1) will not alter the state of the FF and it remains in the RESET state.

Case 4: J=1 and K-=1 and Clock=1 and let $Q_{n=}$1 and $\overline{Q_n}$ =0

S=J. $\overline{Q_n}$ R=K. Q_n

S=1.0=1 =1.1=1

Since S=0 and R=1 the FF resets on application of clock pulse.ie the FF toggles from SET to RESET STATE.

J=1 and K-=1 and Clock=1 and let $Q_{n=}$0 and $\overline{Q_n}$ =1

S=J. $\overline{Q_n}$ R=K. Q_n

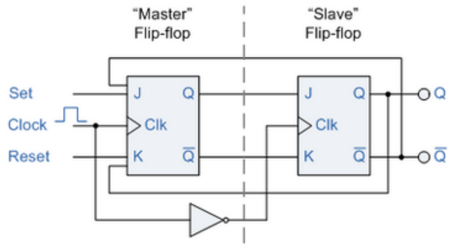
S=1.1=1 =1.0=0

Since S=1 and R=0 the FF toggles from RESET to SET state on application of clock pulse.The FF will continously change its state when J=K=1 and clock=1 resulting in an unstable output.

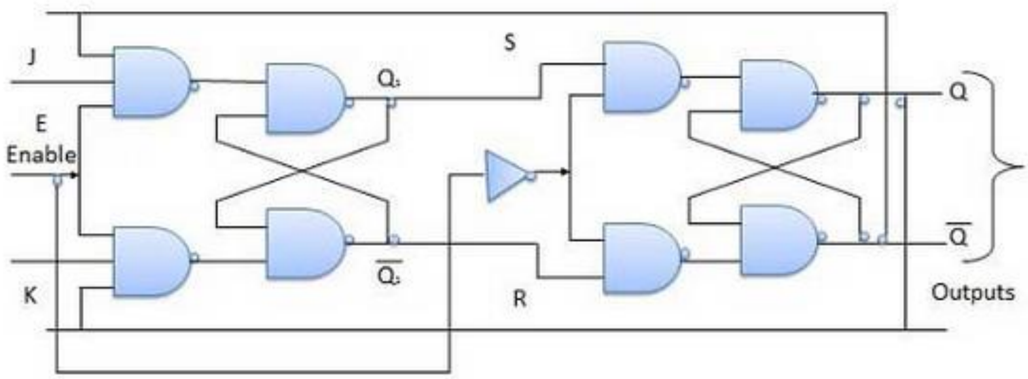
JK Master slave Flip Flop:

Master slave JK FF is constructed using two separate FFs connected serially. The first FF is called the Master and it is driven by positive edge of the clock pulse. The second FF called the slave is driven by positive edge of the clock pulse It is also known as Pulse-triggered FF.

Block diagram of Master-Slave Flip Flop is shown below:



The circuit diagram of MS JK FF is shown below



The truth table of MS JK FF is shown below.

Inputs			Outputs		Comments
E	J	K	Q_{n+1}	$\overline{Q}_{n+1}$	
1	0	0	Q_n	$\overline{Q}_n$	No change
1	0	1	0	1	Rset
1	1	0	1	0	Set
1	1	1	$\overline{Q}_n$	Q_n	Toggle

Operation:

S.N.	Condition	Operation
1	**J = K = 0 (No change)**	When clock = 0, the slave becomes active and master is inactive. But since the S and R inputs have not changed, the slave outputs will also remain unchanged. Therefore outputs will not change if J = K =0.
2	**J = 0 and K = 1 (Reset)**	Clock = 1 − Master active, slave inactive. Therefore outputs of the master become Q_1 = 0 and Q_1 bar = 1. That means S = 0 and R =1.Clock = 0 − Slave active, master inactive. Therefore outputs of the slave become Q = 0 and Q bar = 1.
3	**J = 1 and K = 0 (Set)**	Clock = 1 − Master active, slave inactive. Therefore outputs of the master become Q_1 = 1 and Q_1 bar = 0. That means S = 1 and R =0.Clock = 0 − Slave active, master inactive. Therefore outputs of the slave become Q = 1 and Q bar = 0. Again clock = 1 − then it can be shown that the outputs of the slave are stabilized to Q = 1 and Q bar = 0.
4	**J = K = 1 (Toggle)**	Clock = 1 − Master active, slave inactive. Outputs of master will toggle. So S and R also will be inverted.Clock = 0 − Slave active, master inactive. Outputs of slave will toggle. These changed output are returned back to the master inputs. But since clock = 0, the master is still inactive. So it does not respond to these changed outputs. This avoids the multiple toggling which leads to the race around condition. **The master slave flip flop will avoid the race around condition.**

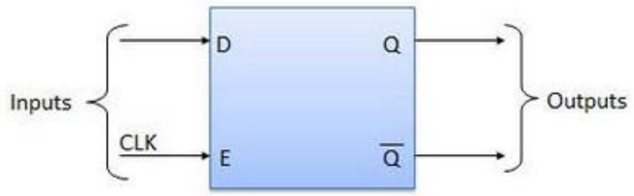
Race around condition:

Before the development of edge-triggered flip-flops, the timing problem in level-triggered Flip-flops was handled by Master-slave Flip-flops. The codition S= 1 And R= 1 is not allowed in SR flip-flop. This is eliminated in the JK flip-flop by using feedback connection. Because of the feedback connection Q at the input to k ,the input will change during the clock pulse(clock = 1) . Hence the output will oscillate back and forth between 0 and 1 in the duration of the clock pulse width..Thus at the end of the clock pulse, the value of Q is ambiguous. This situation is known as a RACE AROUND CONDITION and it is avoided in Master-Slave Flip-Flops

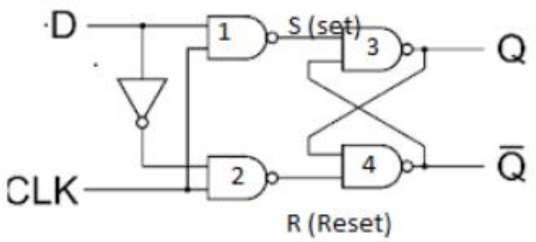
D-Flip-flop (Delay Flip Flop)

D-Flip Flop has one input called Delay(D) input and 2 Outputs Q and qbarr . It can be constructed from SR FF by inserting an inverter between S and R and assigning symbol D to the S input.

Block diagram of D Flip Flop is shown below:



The circuit diagram of D Flip Flop is shown below



Truth Table of Delay Flip Flop is shown below

Clock	Input D	Output Q_{n+1}
0	X	Q_n (No Change)
1	0	0
1	1	1

Operation:

When clock input is low , D input has no effect, since S and R inputs of NAND gates 1 and 2 are kept HIGH.

When Clock=1 and D=1 NAND gate1 output goes 0 which is the S input and NAND gate 2 output goes HIGH which is the R input i.e., S=0 and R=1. The NAND based Flip Flop output will be 1 i.e., it follows D input.

When Clock=1 and D=0 ,,the Flip Flop output will be 0.

When clock=1 the Q output will take the value of D input. As the transfer of data from the input D to the output Q is delayed, it is known as Delay(D) Flip Flop. The Delay depends on the clock

Applications of flip flop

Flip flops are widely used in
1.Counters
2.Frequency dividers
3.Shift registers
4.Storage registers
5.Transfer of data
6.Parallel data stirage
7.Serial-to-parallel and Parallel-to-serial data conversion etc.

Shift Registers:

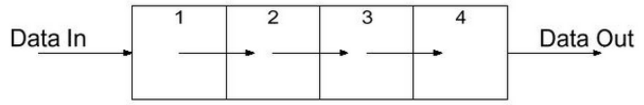
A register is a group of flip flops suitable for storing binary information. Each Flip flop is a binary cell capable of storing 1-bit of information. An n-bit register has a group of n flip flops and is capable of storing n-bits of information.
The register is mainly used for storing and shifting the binary data entered into it from an external source.

Types of shift registers:

They are classified into 4 types based on how binary information is entered or shifted out:
1.Serial -in-Serial-Out (SISO)
2.Serial -in-Parallel-Out (SIPO)
3.Parallel -in-Serial-Out (PISO)
4.Parallel-in-Parallel-Out (PIPO)

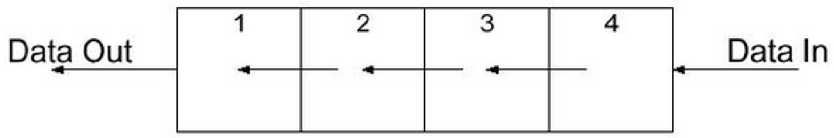
Shift Right Operation

Data is shifted in the right
And direction one bit at time with each transition of the clock signal. The data enters the s hift register serially from the left hand side and after four clock transitions the 4-
Bit register has 4-bits of data. The data is shifted out serially one bit at
a time from the right hand side of the register if clock signals are continuously
applied. Thus after 8 clock signals the 4-
Bit data is completely shifted out of the shift register.



Shift Left Operation

Data is shifted in the left-hand direction one bit at a time with each transition of the clock signal. The data enters the shift register serially from the right hand side and after four clock transitions the 4-bit register has 4-bits of data. The data is shifted out serially one bit at time from the left hand side of the register if clock signals are continuously applie d.Thus after 8 clock signals the 4-bit data is completely shifted out of the shift register

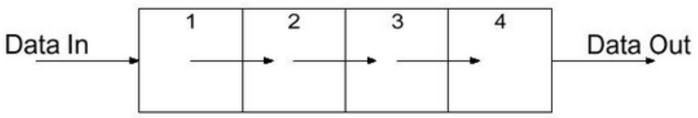


Serial in serial out (siso) shift registers:

Serial-in-serial-out (SISO) shift register accepts data serially,i,e.,one bit at a time on a single input line.It produces the stored information on its sinlge output line in serial form. Data may be shifted left using shift-left register or shifted right by using shift- right register

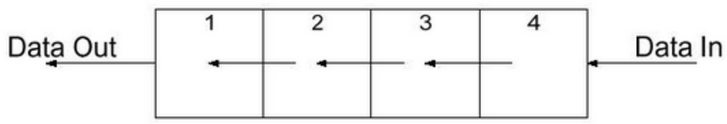
Shift Right Operation

Data is shifted in the right-hand direction one bit at a time with each transition of the clock signal. The data enters the shift register serially from the left hand side and after four clock transitions the 4-bit register has 4-bits of data. The data is shifted out serially one bit at a time from the right hand side of the register if clock signals are continuously applied. Thus after 8 clock signals the 4-bit data is completely shifted out of the shift register.

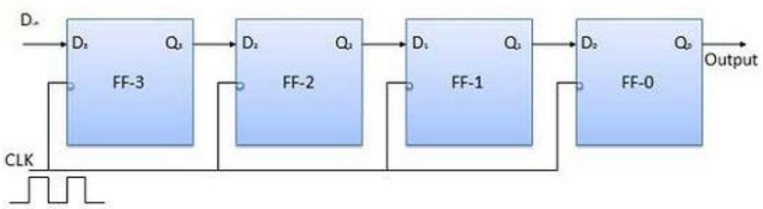


Shift Left Operation

Data is shifted in the left-hand direction one bit at a time with each transition of the clock signal. The data enters the shift register serially from the right hand side and after four clock transitions the 4-bit register has 4-bits of data. The data is shifted out serially one bit at a time from the left hand side of the register if clock signals are continuously applied. Thus after 8 clock signals the 4-bit data is completely shifted out of the shift register.

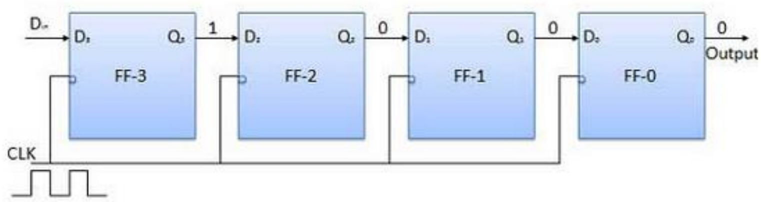


The block diagram of SISO is shown below

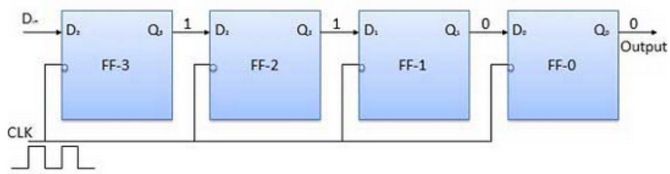


Operation

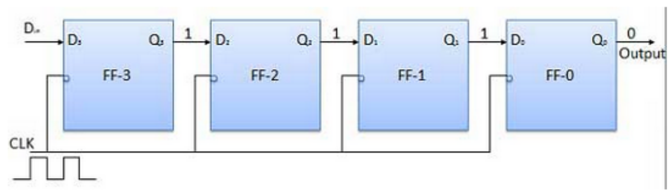
Before application of clock signal, let $Q_3\ Q_2\ Q_1\ Q_0$ = 0000 and apply LSB bit of the number to be entered to D_{in}. So $D_{in} = D_3 = 1$. Apply the clock. On the first falling edge of clock, the FF-3 is set, and stored word in the register is $Q_3\ Q_2\ Q_1 Q_0$ = 1000.



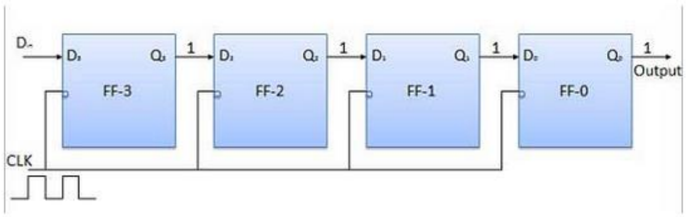
Apply the next bit to D_{in}. So D_{in} = 1. As soon as the next negative edge of the clock hits, FF-2 will set and the stored word change to $Q_3\ Q_2\ Q_1\ Q_0$ = 1100.



Apply the next bit to be stored i.e. 1 to D_{in}. Apply the clock pulse. As soon as the third negative clock edge hits, FF-1 will be set and output will be modified to $Q_3\ Q_2\ Q_1\ Q_0$ = 1110.



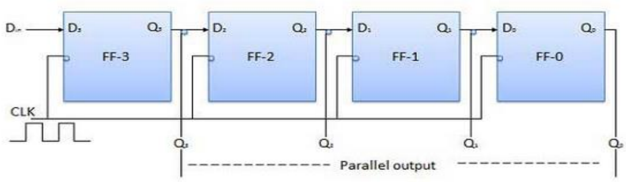
Similarly with D_{in} = 1 and with the fourth negative clock edge arriving, the stored word in the register is $Q_3\ Q_2\ Q_1\ Q_0$ = 1111.



Serial in parallel out (sipo):

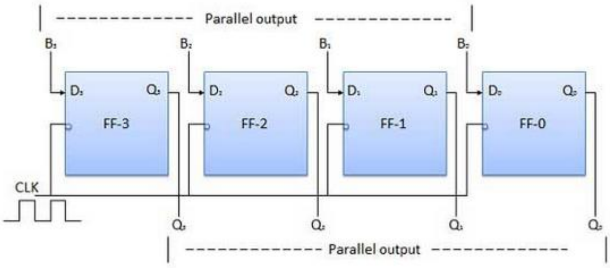
A 4-bit serial-in-parallel-out consists of one serial port input and outputs are taken from all the flip flops in parallel. The data is shifted in serially but shifted out in parallel.As soon as the data loading gets completed, all the flip-flops contain their required data, the outputs are enabled so that all the loaded data is made available over all the output lines at the same time.4 clock cycles are required to load a four bit word. Hence the speed of operation of SIPO mode is same as that of SISO mode.

The block diagram of 4 bit SIPO shift register is shown below



Parallel in parallel out(pipo) shift register

In PIPO shift register the data is entered into the register in parallel form and also the data is taken out of the register in parallel form.



In this mode, the 4 bit binary input B_0, B_1, B_2, B_3 is applied to the data inputs D_0, D_1, D_2, D_3 respectively of the four flip-flops.Data is applied to the input terminals when the clock pulse is applied.Accordingly input data(D_0, D_1, D_2, $D_{3)}$ are shifted into the outputs(Q_3,Q_2,Q_1,Q_0)of the Flip Flops.

Clock Pulse	Parallel data input				Parallel data output			
	A	B	C	D	Q_A	Q_B	Q_C	Q_D
0	1	0	1	1	X	X	X	X
1	X	X	X	X	1	0	1	1

Parallel in serial out(piso) shift register

A 4 bit parallel in-serial-out shift register is as shown below. Let A,B,C nd D be the 4 parallel data input lines and shift/Load is control input that allows:

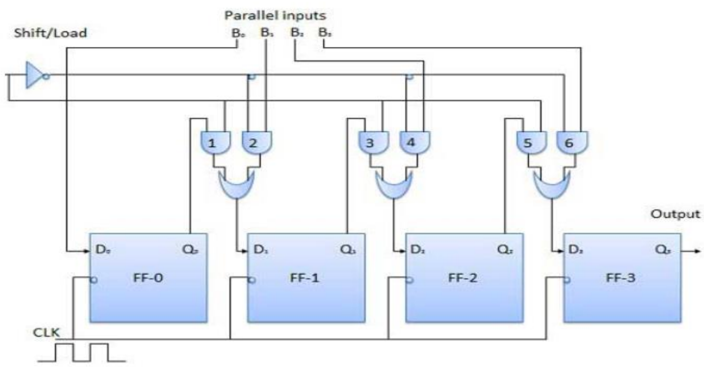
(a) The data to enter into the register in parallel form(shift/Load=0)

(b) (b) To shift the data in serial(shift/Load=1)

When shift/Load is low, AND gates 2,4 and 6 are enabled. Allowing the data at parallel inputs,i.e, B1,B2,B3 to the inputs respective of Flip Flops. The input B0 is directly connected to the first FF input.

When shift/Load is high, AND gates 2,4 and 6 are disabled and the remaining AND gates 1,3 and 5 are enabled allowing the data bits to shift right from one stage to the next.

The OR gates allow either normal shifting operation or the parallel data entry operation depending on which AND gates are enabled.



Applications of shift registers:

The major application of a shift register is

1. Shift registers can be used as serial data to parallel data converters and vice versa.

2. Shift registers are also used as keyboard encoders.

3. SISO shift register can be used as a time delay device.The amount of delay can be controlled by

   a)Number of stages in register(N)

   b)The clock frequency(f)

   Time delay $\Delta T = N.1 \div f$

4. They are used for arithmetic operations. ex:serial addition

5. They are used in UART (Universal Asynchronous Receiver Transmitter)

Counters

A counter is a sequential circuit consisting of set of Flip Flops,used to count the sequence of input pulses presented to it in digital form

They can be classified under 3 categories:

1.Asynchronous and synchronous counters.

2.Single(up or down) and multi(both up and down) mode counters.

3.Modulus counters.

An **Asynchronous or ripple counter** can be constructed using minimum hardware. Each flip flop is triggered by the output from the previous flip flop,which limits the speed of operation.The settling time in Asynchronous counters is the cumulative sum of the individual settling times of the flip flop. It is also called as the **serial counter**.

In **synchronous counter** the speed limitation of ripple counters is overcome by applying clock pulse to all the flip flops which leads to the settling time of the counter being equal to the propagation delay of the single flip flop.It is also called as the **Parallel counter**.

Single mode counter operates in sinlge mode i.e., it counts either in UP or DOWN mode, where as Multi mode counter operates in both UP and DOWN modes.

Modulus counters are defined based on the number of states they are capable of counting .Ex. mod 5 counter has 5 states .

Comparison between Asynchronous and Synchronous Counters

SI.NO	ASYNCHRONOUS COUNTERS	SYNCHRONOUS COUNTERS
1	The term asynchronous refers to the events that do not occur at the same time i.e., the events will occur at different time.	The term synchronous refers to the events that occur at the same time.
2	All the Flip Flops do not change their states simultaneously.	All the Flip Flops change their states simultaneously
3	The clock is connected to only first Flip Flop and other Flip Flops are triggered by the output of previous Flip Flops.	The clock is connected directly to all Flip Flops.
4	It requires minimum hardware.	It requires more hardware
5	Easy to design(It is simplest in term of logical operation)	Difficult to design.(complex in terms of logical operations)
6	They suffer from Spikes	They will not suffer from Spikes
7	Slower operation speed	Faster operation speed
8	Also known as serial or Ripple counter	Also known as parallel counter
9.	The sequence can be either upward(UP-counter) or downward(down-counter).And it can't have any specified random sequence.	It is possible to design for any specified random sequence.

ASYNCHRONOUS COUNTERS:

The term Asynchronous refers to events that do not have a fixed time relationship with each other . It is the one in which the flip flops within the counter do not change the states at exactly the same time because they dont have common clock pulse.

Ripple or serial counters can be constructed as 2 bit binary counters,3 bit binary counters,4 bit binary counters upto modulus N (< 2^n) .

Mod-Number or MODULUS:

The Mod-number of a counter is the total number of states it sequences through in each complete cycle.In other words, the number of states through which the counter passes before returning to the starting state.

Mod-number = 2^n where n= Number of flip flops

The maximum binary number counted by the counter is $2^n - 1$.

Ex. n= 4, 4-flip flop counter

Mod number = $2_{4\ =\ 16}$

Maximum binary number counted by the counter is $2^4 - 1 = 16 - 1 = 15$.

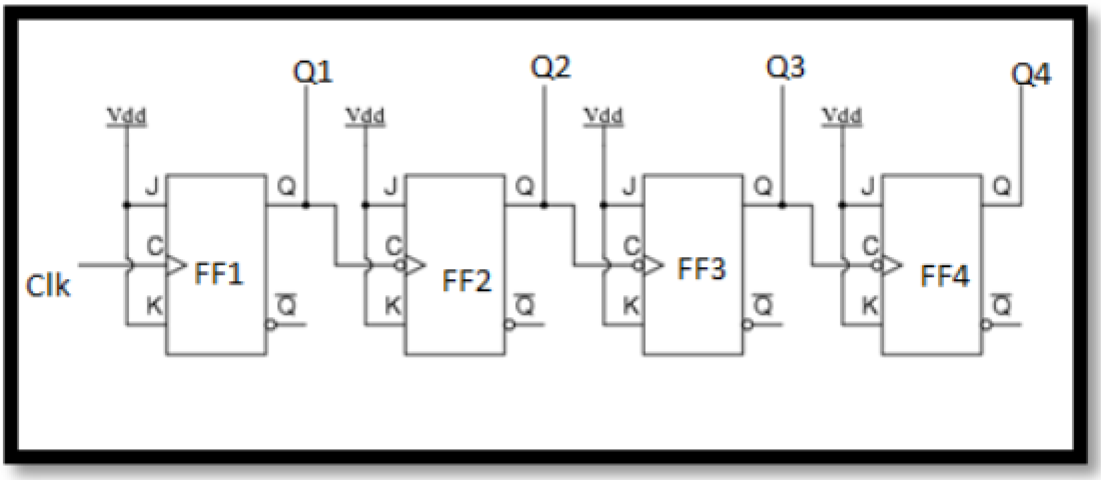
4 BIT ASYNCHRONOUS (RIPPLE OR SERIAL) COUNTERS:

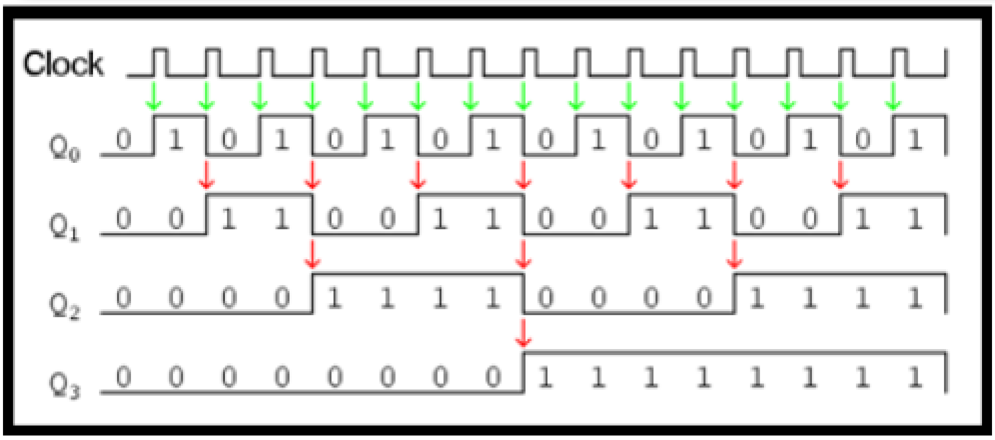
The term Asynchronous refers to events that do not have a fixed time relationship with each other . It is the one in which the flip flops within the counter do not change the states at exactly the same time because they don't have common clock pulse.

The below figure shows a 4-bit binary ripple counter constructed using JK flip flops.The output of FF1 drives FF2, the output of

FF2 drives FF3 and the output of FF3 drives FF4. All the J&K inputs are connected to Vdd,where each ff toggles on the negative edge of its clock input.

Consider initially all Flip flops to be in logical 0 state(Q1=Q2=Q3=Q4=0) . A negative transition in clock input drives FF1 and causes Q1 to change from 0 to 1. FF2 does not change its state since it also requires negative transition at its clock input.with the arrival of the second clock pulse to FF1 Q1 goes from 1 to 0. This change of state creates the negative going edge needed to trigger FF2, and thus Q2 goes from 0 to 1. Thus before the arrival of the 16th clock pulse all the ff are in the logical 1 state. Clock pulse 16 causes Q1 Q2 Q3 Q4 to go logic 0 state.





Truth table of 4 bit binary Ripple counter

State	Q_4	Q_3	Q_2	Q_1
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0
13	1	1	0	1
14	1	1	1	0
15	1	1	1	1
0	0	0	0	0

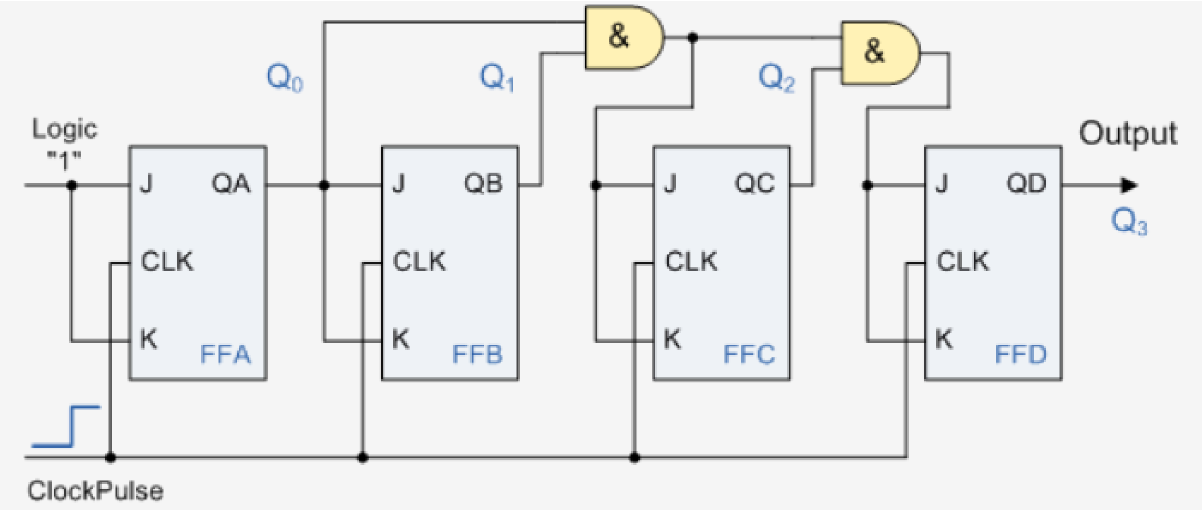
SYNCHRONOUS COUNTERS

The speed of operation of asynchronous counter is low because the propagation delay time of all Flip Flops is cumulative and the total settling time is the product of the total number of Flip Flops and the propagation delay of a single flip flop.

In synchronous counters the clock pulse is applied to all the flip flops simultaneously. The speed of operation in synchronous counters is limited by the propagation delay of control gating and flip flop.

4 BIT SYNCHRONOUS COUNTERS:

A 4-bit (MOD 16) synchronous counter with parallel carry is shown below:



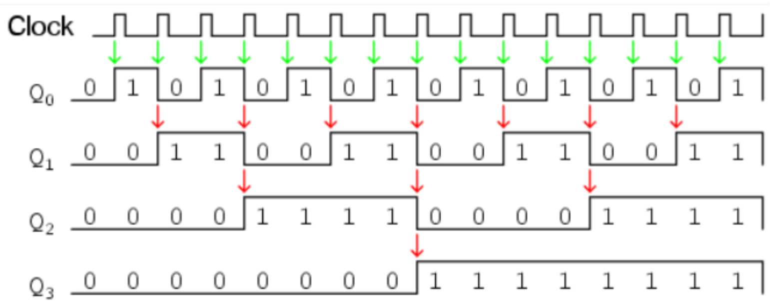
It can be seen that the external clock pulses (pulses to be counted) are fed directly to each J-K flip-flop in the counter chain and that both the J and K inputs are all tied together, but only in the first flip-flop, flip-flop A (LSB) are they connected HIGH, logic "1" allowing the flip-flop to toggle on every clock pulse.

The J and K inputs of flip-flop B are connected to the output "Q" of flip-flop A, but the J and K inputs of flip-flops C and D are driven from AND gates which are also supplied with signals from the input and output of the previous stage. If we enable each J-K flip-flop to toggle based on whether or not all preceding flip-flop outputs (Q) are "HIGH" we can obtain the same counting sequence as with the asynchronous circuit but without the ripple effect, since each flip-flop in this circuit will be clocked at exactly the same time. As there is no propagation delay in synchronous counters because all the counter stages are triggered in parallel the maximum operating frequency of this type of counter is much higher than that of a similar asynchronous counter.

Truth table of 4-bit Binary Synchronous Counter is shown below

State	Q_4	Q_3	Q_2	Q_1
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
11	1	0	1	1
12	1	1	0	0
13	1	1	0	1
14	1	1	1	0
15	1	1	1	1
0	0	0	0	0

Timing diagram of 4-bit Binary Synchronous Counter is shown below



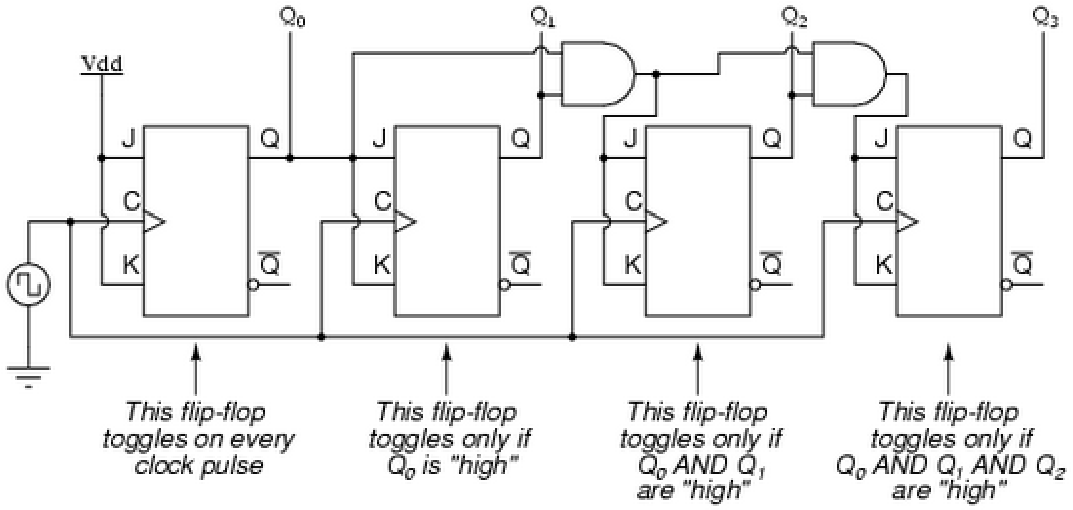
4 BIT SYNCHRONOUS UP/DOWN COUNTERS

Examining the four-bit binary count sequence, another predictive pattern can be seen. Notice that just before a bit toggles, all preceding bits are "high:"

0 0 0 0
0 0 0 1
0 0 1 0
0 0 1 1
0 1 0 0
0 1 0 1
0 1 1 0
0 1 1 1
1 0 0 0
1 0 0 1
1 0 1 0
1 0 1 1
1 1 0 0
1 1 0 1
1 1 1 0
1 1 1 1

This pattern is also something we can exploit in designing a counter circuit. If we enable each J-K flip-flop to toggle based on whether or not all preceding flip-flop outputs (Q) are "high," we can obtain the same counting sequence as the asynchronous circuit without the ripple effect, since each flip-flop in this circuit will be clocked at exactly the same time:

A four-bit synchronous "up" counter



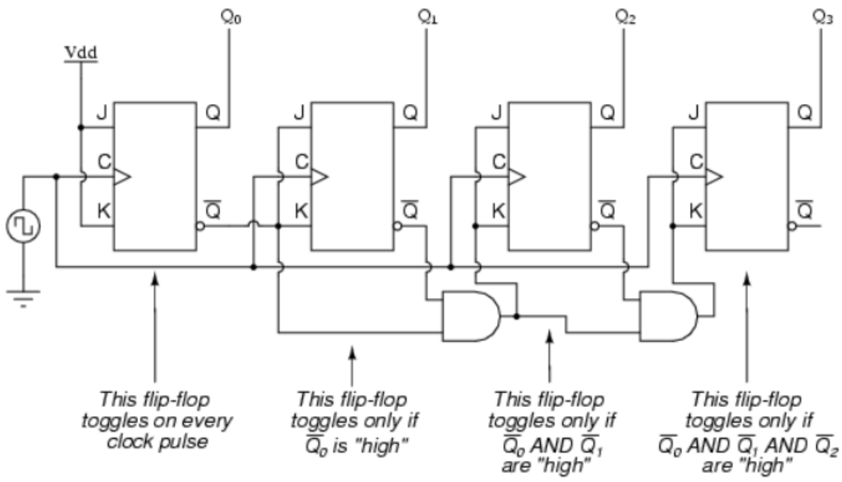
The result is a four-bit synchronous "up" counter. Each of the higher-order flip-flops are made ready to toggle (both J and K inputs "high") if the Q outputs of all previous flip-flops are "high." Otherwise, the J and K inputs for that flip-flop will both be "low," placing it into the "latch" mode where it will maintain its present output state at the next clock pulse. Since the first (LSB) flip-flop needs to toggle at every clock pulse, its J and K inputs are connected to Vcc or Vdd, where they will be "high" all the time. The next flip-flop need only "recognize" that the first flip-flop's Q output is high to be made ready to toggle, so no AND gate is needed. However, the remaining flip-flops should be made ready to toggle only when all lower-order output bits are "high," thus the need for AND gates.

To make a synchronous "down" counter, we need to build the circuit to recognize the appropriate bit patterns predicting each toggle state while counting down. Not surprisingly, when we examine the four-bit binary count sequence, we see that all preceding bits are "low" prior to a toggle (following the sequence from bottom to top):

```
0 0 0 0
0 0 0 1
0 0 1 0
0 0 1 1
0 1 0 0
0 1 0 1
0 1 1 0
0 1 1 1
1 0 0 0
1 0 0 1
1 0 1 0
1 0 1 1
1 1 0 0
1 1 0 1
1 1 1 0
1 1 1 1
```

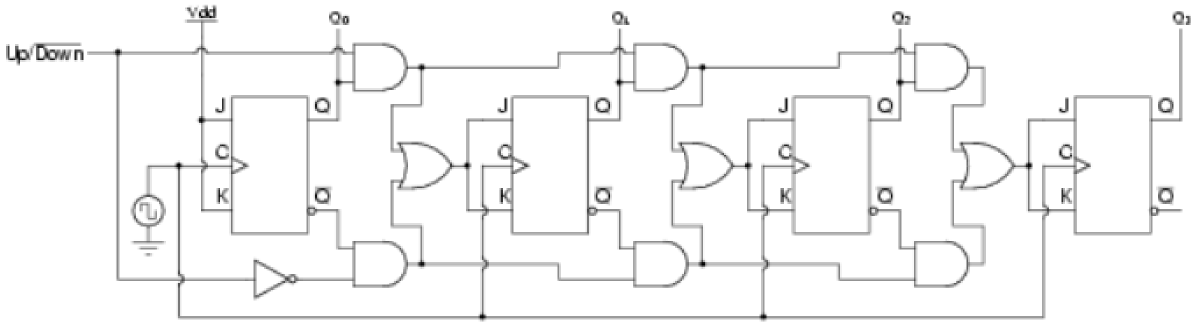
Since each J-K flip-flop comes equipped with a Q' output as well as a Q output, we can use the Q' outputs to enable the toggle mode on each succeeding flip-flop, being that each Q' will be "high" every time that the respective Q is "low:"

A four-bit synchronous "down" counter



Taking this idea one step further, we can build a counter circuit with selectable between "up" and "down" count modes by having dual lines of AND gates detecting the appropriate bit conditions for an "up" and a "down" counting sequence, respectively, then use OR gates to combine the AND gate outputs to the J and K inputs of each succeeding flip-flop

A four-bit synchronous "up/down" counter



Applications of counters

1.The counters in general can be used to measure frequency. For eg, we can use it to count line frequency.
2. As object counters.
3. In various Analog to Digital converters
4. Used in Timers.
5. can be used as a frequency counter.
6. Counters can also be used as a digital clock- a time clock which displays the time of the day in hours,minutes and seconds.

UNIT-5 :INTRODUCTION TO COMPUTERS.

Introduction

The term computer is derived from the word compute or calculate. Computer is an electronic device which is capable of doing computations or calculations with high speed & accuracy. Charles Babbage was the father of computer. The applications of computers depends totally on the human creativity & imagination using the artificial intelligence. Applications of computers include education, government, industries, social science, law, entertainment, different scientific & research fields.

Characteristics of Computers

The major characteristics of computer are :-

1. Speed
2. Accuracy
3. Reliability
4. Storage Capability
5. Versatility
6. Diligence

Speed :- The processing speed is extremely fast i.e. it can execute million instructions per seconds. The speed of computer is calculated in megahertz. i.e One million instructions per second. Presently powerful computers can perform billions of instructions operation in 1 second.

Accuracy :- . Accuracy of a computer is consistently high and the degree of accuracy of a particular computer depends on the instructions and the type of processor. Computer is capable of doing only what is instructed to do, faulty instructions for processing the data automatically lead to faulty results.

Reliabilty :- Reliability is an attribute of any computer that consistently performs according to its specifications. It is the measurement of the performance of the computer.

Storage Capability :- Computers can store large amount of data & it will provide the information immediately. Storage capacity refers to how much disk space one or more storage devices provides. It measures how much data a computer system may contain. For an example, a computer with a 500GB hard drive has a storage capacity of 500 gigabytes. A network server with four 1TB drives, has a storage capacity of 4 terabytes.

Versatility:- It performs multiple tasks simultaneously. The group of jobs are called tasks. More than one process work simultaneously are called multiprocessing.

Diligence:-A computer does not suffer from limitations associated with living beings like tiredness and lack of concentration and hence can work for hours at a stretch without error arising. This characteristic is especially useful for those jobs where same tasks are done again and again. It can perform long and complex calculations with same speed and accuracy from the start till the end.

Evolution of Computers

Pebbles' are used to represent numbers, they are known to be the earliest device for computation. Afterwards sand tables were modified extensively & these modifications device are called as Abacaus. This device allows users to do computations using a system of sliding beads arranged on a rack. Manipulating beads on the wires carry out arithmetic operations.

In 1614 John Napier made a more sophisticated computing machine called Napier bones. It is a small instrument made of ten rods, on which multiplication table was engraved. Napier also played a key role in the development of logarithms.

In 1620 the inventions of logarithms & development of another invention slide rule. The two scales enabled the slide rule to perform multiplication & division by a method of addition & subtraction.

In 1642 Blaise Pascal invented the first functional automatic calculator. It had a complex arrangement of wheels, gears & windows for the display of numbers.This device was limited to the addition & subtraction.

In 1694 Von Leibriz extended the Pascal's design to perform multiplication,division & to find square root. This machine was called stepped reckoner.

In 1801 Jacquard invented a powerloom with an automatic card reader are called Punch Card machine.

In 1822 Charles Babbage devised a calculating machine are called difference engine. The difference engine can be viewed as a complex Abacus. It was intended to solve differential equations.

Analytical engine is considered to be the first general purpose programmable computer. Babbage also designed this device to advance or reverse the flow of punched cards to permit branching to any desired instruction within a program. This was the fundamental difference between analytical engine & difference engine. Lady Ada Lovelace helped him in the development of analytical engine. Babbage never completed the analytical engine, but his proposal for this device reviewed the basic elements of modern computers.

In 1896 Hollerith founded the tabulating machine company which was named IBM.

In 1904 Sir John Ambrose Fleming worked to developed the first thermionic valve are called vacuum tubes. Two element vacuum tubes are called diodes. This is the first generation of computers.

In 1906 Lee de Forest introduced vacuum tube.

In 1931 Vannevar Bush introduced the differential analyser to solve the differential equations.

In 1938 Claude Shannon designed the connection between electronic circuits & Boolean algebra.

Early Computers.

MARK-I Computer from the year 1937 to 1944.It was essentially a serial collection of electromechanical calculators & had many similarities to Babbage Analytical Machine. It was capable of performing additions, subtraction, division, multiplication & table reference. It was extremely slow, noisy & bulky. The length was 50 feet long, 8 feet high & weighted 5 tons.

ABC Computer In 1939 John Vincent Atansoft & Clifford Berry formulated the idea of using the binary number system to simplify the construction of an electronic calculator. They built a first electronic computer named as ABC (Atansoft Berry Cliffored).It is considered the first computing machine which introduced the idea of binary arithmetic, regenerative memory & logic circuits.

COLOSSUS In 1944 British mathematician Alan mathison created a computer called COLOSSUS which comprised 1800 vacuum tubes. This was the one of the world's earliest working programmable electronic digital computer.

ENIAC In 1946 John Eckert & John Mauchly developed Electronic Numerical Integrator & Calculator (ENIAC). It embodied all the components & concepts of high speed,electronic digital computers. This machine discriminate the sign of numbers, compare quantities & add, sub, multiply, divide & extract square root. ENIAC consist of 108000 vacuum tubes, required around 160 KW of electricity & weighted 30 tons.It had a limited amount of space to store & manipulate information.

EDVAC John Eckert & John Mauchly proposed the development of Electronic Discrete variable Automatic Computer (EDVAC). It came into existence in 1949.It was the first electronic computer to use the stored program concept introduced by John Von Neuman. It could stop any time & resume again. It contained 4000 vacuum tubes & 1000 crystal diodes.

EDSAC Electronic Delay Storage Automatic Calculator (EDSAC) was BASED ON John Von Neuman's stored program concept. The first successful program was run in 1949 .It used mercury delay lines for memory & vacuum tubes for logic. It had 3000 vacuum valves arranged on 12 racks & used tubes filled with mercury for memory. It executed 650 instructions per second & occupied a room measured 5 metres by 4 metres.

UNIVAC Universal Automatic Computer was the first commercially available electronic computer. It was the first general purpose computer which was designed to handle numerical & textual information. UNIVAC computed at the speed of around 120-3600 microseconds. Magnetic tapes were used as input & output mediums. At a speed of 13000 caharacters per seconds. The machine was 25 feet by 50 feet in length,contained 5600 tubes,18000 crystals & 300 relays.

Generations of Computers

The word generation is described as a stage of technological development or innovation. A major technological development resulted in smaller, cheaper, powerful, efficient & reliable devices. According to the type of processor installed in a machine there are five generations of computers.

First Generation (1940 -56) – Vacuum Tubes
Second Generation (1956-63)- Transistors
Third Generation (1964- Early 1970) – Integrated Circuits
Fourth Generation (Early 1970s –Till Date) – Microprocessor
Fifth Generation (Present & Beyond) – Artificial Intelligence

First Generation (1940 -56) – Vacuum Tubes

These computers were based on vacuum tube technology. It is a fastest computing device & the computation time was in milliseconds. These computers in large & required a lot of space for installation. These computers relied on binary coded languages to perform operations & solved only one problem at a time.

These were non-portable & very slow in execution. They lacked in versatility & speed. It is very expensive & used large amount of electricity. It is unreliable & prone to frequent hardware failures. Constant maintenance was required. It used machine languages & difficult for programming.

Ex :- ENIAC, ADVAC, UNIVAC

Second Generation (1956-63) - Transistors

These computers were based on transistor technology**.** They were smaller as compared to first generation computers. The computational time was reduced to microseconds. It is more reliable & less prone to hardware failures & required less frequent maintenance. These computers are better portability & generated less amount of heat. It supports assembly language was used to program computers. Transistor is made up of semiconductor materials & it performed electrical functions such as voltage, current with power requirement. This component reduced the size of the computers & faster, cheaper & more reliable. These computers supports primary memory & number of secondary storage devices. It is possible to execute high level programming languages like FORTARN, COBOL.

Ex:- PDP-8, IBM-1401, IBM-7090

Third Generation (1964- Early 1970) – Integrated Circuits

These computers were based on integrated circuits technology (IC). IC consists of single chip with many components of transistors, resistors fabricated on it. This made smaller in size, reliable & efficient .These computers reduced the computational time from microseconds to nanoseconds. These computers are easily portable & more reliable than second generation computers. It uses less power & generates less heat. The size of computers was smaller & maintenance cost was very low. It is possible to execute high level programming languages like FORTARN, COBOL, C.

Fourth Generation (Early 1970s –Till Date) – Microprocessor

These computers are microprocessor based systems. It is very small in size, cheapest among all the generations. It is portable, more reliable & require minimum maintenance. A microprocessor is built on to a single piece of silicon called chip. Large Scale Integration (LSI) technology allow thousands of transistors to be constructed on one small slice of silicon material. Very large Scale Integration (VLSI) squeezed thousands of components on to a single chip. Ultra Large Scale Integration (ULSI) increased that number into the millions. These computers could be linked to **networks**. This generation supports development of internet & Graphical User Interface **(GUI**). It is possible to execute all high level programming languages like FORTARN, COBOL, C,C++, Java.

Ex :- Apple-II, Altaire-8800, CRAY-I, PARAM

Fifth Generation (Present & Beyond) – Artificial Intelligence

These computers are in the development stage. It is used in Super large Scale Integrated (SLSI) chips. It consist of millions of electronic components on a single chip. These computers used intelligent programming like artificial intelligence (LISP, Prolog) & knowledge based problem solving techniques. This generation is based on parallel processing hardware and AI (Artificial Intelligence) software. AI is an emerging branch in computer science, which interprets means and method of making computers think like human beings. All the high-level languages like C and C++, Java, .Net etc., are used in this generation.

AI includes:

- Robotics
- Neural Networks
- Game Playing
- Development of expert systems to make decisions in real life situations.
- Natural language understanding and generation.

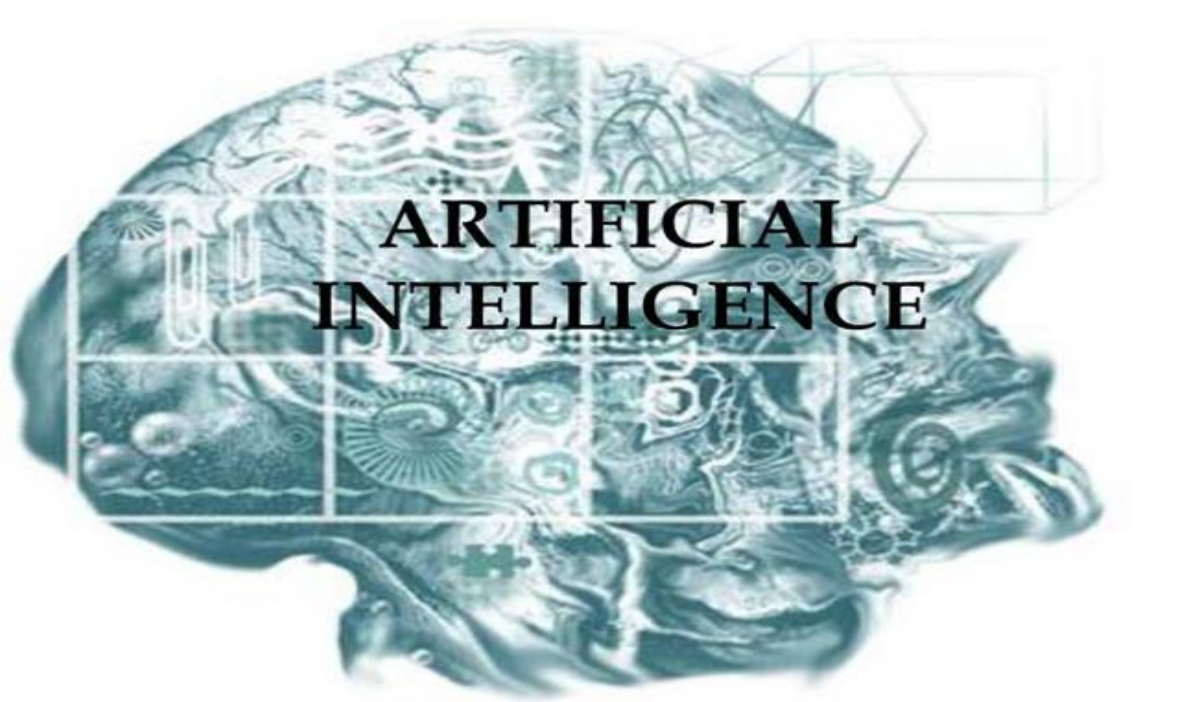
The main features of fifth generation are:

- ULSI technology
- Development of true artificial intelligence
- Development of Natural language processing
- Advancement in Parallel Processing
- Advancement in Superconductor technology
- More user friendly interfaces with multimedia features
- Availability of very powerful and compact computers at cheaper rates

Some computer types of this generation are:

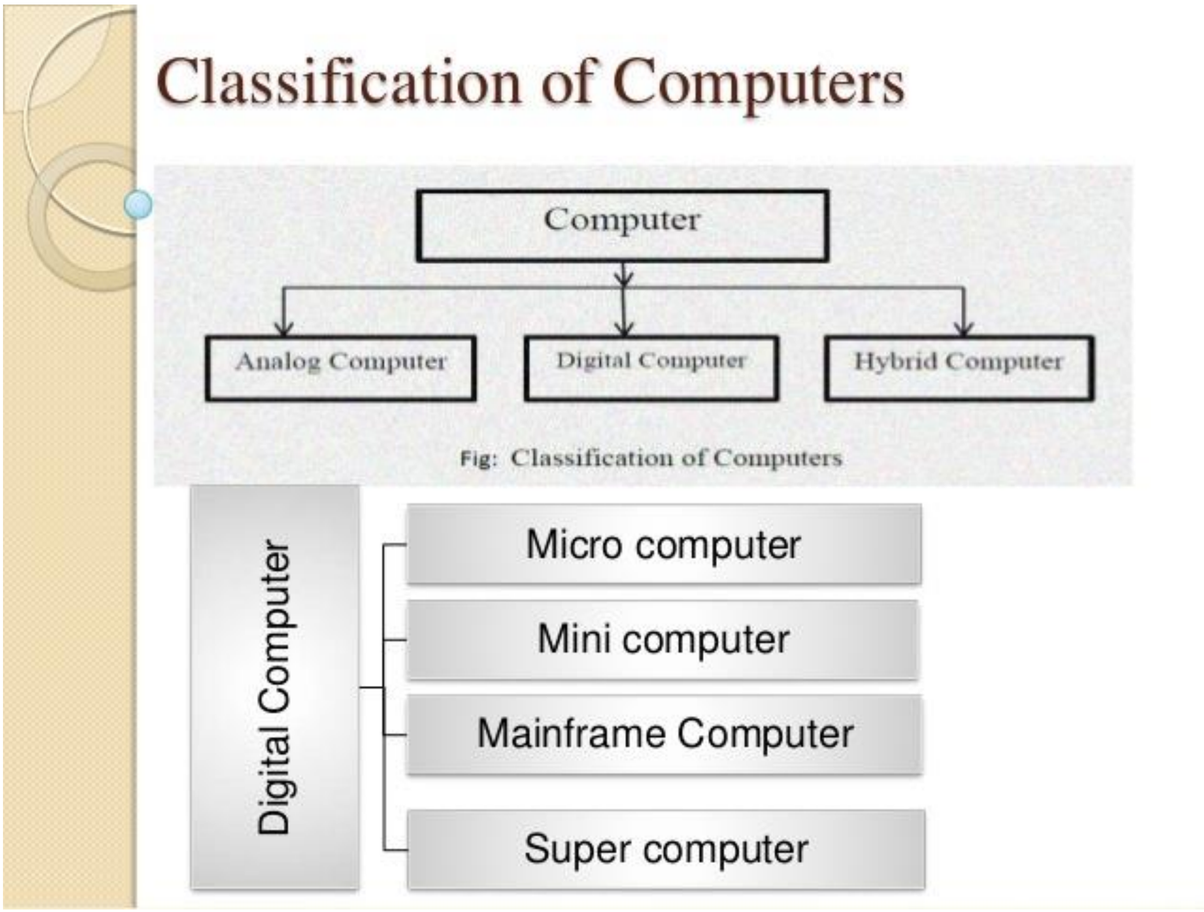
- Desktop
- Laptop
- NoteBook

- UltraBook
- ChromeBook



Classification

Computers can be classified into three categories



Analog Computer

An analog computer is a form of computer that uses *continuous* physical phenomena such as electrical, mechanical, or hydraulic quantities to model the problem being solved.

Digital Computer

A computer that performs calculations and logical operations with quantities represented as digits, usually in the binary number system.

Hybrid Computer (Analog + Digital)

A combination of computers those are capable of inputting and outputting in both digital and analog signals. A hybrid computer system setup offers a cost effective method of performing complex simulations.

Digital Computers

Super Computer

The fastest and most powerful type of computer Supercomputers are very expensive and are employed for specialized applications that require immense amounts of mathematical calculations. For example, weather forecasting requires a supercomputer. Other uses of supercomputers include animated graphics, fluid dynamic calculations, nuclear energy research, and petroleum exploration.

The chief difference between a supercomputer and a mainframe is that a supercomputer channels all its power into executing a few programs as fast as possible, whereas a mainframe uses its power to execute many programs concurrently.

Mainframe Computer

A very large and expensive computer capable of supporting hundreds, or even thousands, of users simultaneously. In the hierarchy that starts with a simple microprocessor (in watches, for example) at the bottom and moves to supercomputers at the top, mainframes are just below supercomputers. In some ways, mainframes are more powerful than supercomputers because they support more simultaneous programs. But supercomputers can execute a single program faster than a mainframe.

Mini Computer

A midsized computer. In size and power, minicomputers lie between *workstations* and *mainframes*. In the past decade, the distinction between large minicomputers and small mainframes has blurred, however, as has the distinction between small minicomputers and workstations. But in general, a minicomputer is a multiprocessing system capable of supporting from 4 to about 200 users simultaneously.

Micro Computer or Personal Computer

• **Desktop Computer**: a personal or micro-mini computer sufficient to fit on a desk.

• **Laptop Computer**: a portable computer complete with an integrated screen and keyboard. It is generally smaller in size than a desktop computer and larger than a notebook computer.

• **Palmtop Computer/Digital Diary /Notebook /PDAs**: a hand-sized computer. Palmtops have no keyboard but the screen serves both as an input and output device.

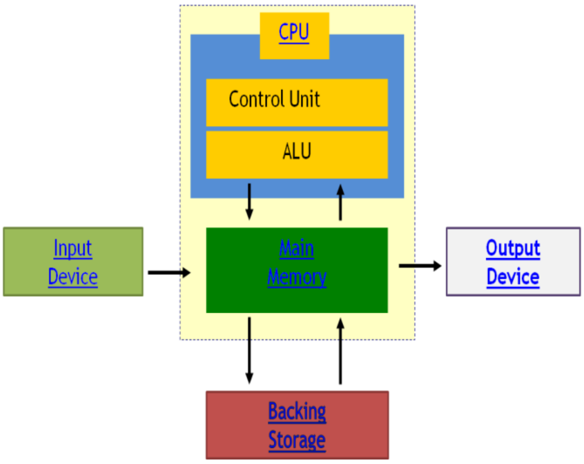
Workstations

A terminal or desktop computer in a network. In this context, workstation is just a generic term for a user's machine (client machine) in contrast to a "server" or "mainframe."

Computer System

Computer is an electronic device which is capable of doing computations or calculations with high speed & accuracy.

A system of interconnected computers that share a central storage system and various peripheral devices such as a printers, scanners, or routers. Each computer connected to the system can operate independently, but has the ability to communicate with other external devices and computers.



Input unit

The role of an input in a computer system is to provide data for further processing. An input consists of data or commands that are entered into the computer system usually via an input device such as a keyboard, mouse, OMR, barcode reader, scanner etc. The input data is converted into digital data that can be dealt with by the computer.The input is already in

digtial format, for example when it has been transmitted from another computer but most of the time it needs to be converted into a digital format before processing can take place.
Examples : Keyboard, Mouse, Touch screen, scanner, joystick etc

Output unit
Output is the stage where the information obtained via processing is presented to the user in a suitable format. Outputs involve converting digital data into some physical effect that the person senses with eyes or ears. This means that we might be able to ***see*** the output, a print out or displayed on the computer screen or we can ***hear*** the output via music, voice instructions or a computer generated alarm.
Examples : Monitor, Printer, Speaker.

Central processing unit (cpu)
Processing is the stage where the input data is manipulated in order to produce meaningful information.Processing can include a number of stages such as sorting, searching, calculations, graphing.The results obtained from processing the data can then be used in the next stage, called "output".
Central processing unit is the heart & brain of the system.CPU mainly consists of Arithmetic Logic Unit (ALU), Control Unit (CU) & Memory Unit (MU).
Arithmetic Logic Unit performs arithmetic & logical operations. All calculations are carried out in this unit.
Control Unit controls all the activities of the computer. It coordinates all the different units.

Memory unit
Memory is a storage unit. It is a unit where all the information & data are stored. The memory that directly communicates to CPU is called primary memory. There are two types of memory.
I Primary Memory
Ex :- Random Access Memory (RAM) ,Read Only Memory (ROM)

II Secondary Memory
Backing storage memory are called secondary memory.
Ex : Magnetic hard Disk, Magnetic Tape, Compact Disk/ Digital versatile Disk, Pen Drive etc

Applications
Business
A computer has high speed of calculation, diligence, accuracy, reliability, or versatility which made it an integrated part in all business organisations.
Computer is used in business organisations for:

- Payroll calculations
- Budgeting
- Sales analysis
- Financial forecasting

- Managing employees database
- Maintenance of stocks etc.

Banking

Today banking is almost totally dependent on computer.
Banks provide following facilities:

- Banks provide online accounting facility, which includes current balances, deposits, overdrafts, interest charges, shares, and trustee records.

- ATM machines are making it even easier for customers to deal with banks.

Education

The computer has provided a lot of facilities in the education system.

- The computer provides a tool in the education system known as CBE (Computer Based Education).
- CBE involves control, delivery, and evaluation of learning.
- The computer education is rapidly increasing the graph of number of computer students.
- There are number of methods in which educational institutions can use computer to educate the students.

Marketing

In marketing, uses of computer are following:

- **Advertising -** With computers, advertising professionals create art and graphics, write and revise copy, and print and disseminate ads with the goal of selling more products.
- **At Home Shopping -** Home shopping has been made possible through use of computerised catalogues that provide access to product information and permit direct entry of orders to be filled by the customers.

Health Care

Computers have become important part in hospitals, labs, and dispensaries. The computers are being used in hospitals to keep the record of patients and medicines. It is also used in scanning and diagnosing different diseases. ECG, EEG, Ultrasounds and CT Scans etc., are also done by computerised machines.
Some major fields of health care in which computers are used are:

- **Diagnostic System -** Computers are used to collect data and identify cause of illness.
- **Lab-diagnostic System -** All tests can be done and reports are prepared by computer.
- **Patient Monitoring System -** These are used to check patient's signs for abnormality such as in Cardiac Arrest, ECG etc.
- **Pharma Information System -** Computer checks Drug-Labels, Expiry dates, harmful drug's side effects etc.
- **Surgery :** Nowadays, computers are also used in performing surgery

Engineering Design

Computers are widely used in Engineering purpose.
One of major areas is CAD (Computer aided design). That provides creation and modification of images. Some fields are:

- **Structural Engineering -** Requires stress and strain analysis for design of Ships, Buildings, Budgets, Airplanes etc.
- **Industrial Engineering -** Computers deal with design, implementation and improvement of integrated systems of people, materials and equipments.
- **Architectural Engineering -** Computers help in planning towns, designing buildings, determining a range of buildings on a site using both 2D and 3D drawings.

Military

Computers are largely used in defence. Modern tanks, missiles, weapons etc. Military also employs computerised control systems. Some military areas where a computer has been used are:

- Missile Control
- Military Communication
- Military Operation and Planning
- Smart Weapons

Communication

Communication means to convey a message, an idea, a picture or speech that is received and understood clearly and correctly by the person for whom it is meant for. Some main areas in this category are:

- E-mail
- Chatting
- Usenet
- FTP
- Telnet
- Video-conferencing

Government

Computers play an important role in government. Some major fields in this category are:

- Budgets
- Sales tax department
- Income tax department
- Male/Female ratio
- Computerization of voters lists
- Computerization of driving licensing system
- Computerization of PAN card
- Weather forecasting

Computer Software –

Software :- It is a collection of programs that enable the user to interact with a computer and its hardware to perform tasks.

Software categories:-

Software is divided into two main categories:
(1) System software: controls the basic functions of a computer and comes preinstalled with the machine.

Ex : Operating System, Compiler, Loader, Linker, Translator

(2) Application software: It handles multitudes of common and specialized tasks a user wants to perform like accounting, communicating, data processing, word processing.

Ex : Ms-Office, CAD, CAM, ORACLE etc

Machine language,

Programming language that can be directly understood and obeyed by a machine (computer) without conversion (translation). Different for each type of CPU, it is the native binary language (comprised of only two characters: 0 and 1) of the computer and is difficult to be read and understood by humans.

Programmers commonly use more English-like languages (called high level languages) such as Basic, C, Java, etc., to write programs which are then translated into machine language (called a low level language) by an assembler, compiler, or interpreter

Assembly Language: - Intermediate-level programming language which is higher than machine language and lower than a high-level language such as Basic, FORTRAN, or Java. Programs written in assembly language are converted into machine language by specialized programs called assemblers or compilers for their execution.

High level language :- It is a user readable form**,** machine-independent, sophisticated programming language that uses familiar English like syntax. In a HLL,each statement can represent several instructions that perform complex computing operations.

Software terminologies :-

Liveware :- Human beings who write programs, operate & maintain the computers are known as liveware, humanware or peopleware.

Ex: System Analyst, Programmers, Hardware Engineers

Public Domain Software :- It refers to any program that is not copy righted .This software is free & can be used without restrictions.

Freeware :- It is commonly used for copy righted software given away for free by its author. The freeware software permits redistribution but not modification.

Ex: Linux

Shareware :- It is the software which comes with permission for people to redistribute copies for limited period. To use this software we need to pay a license fee.

Ex: Winzip Software

Commercial Software :- It is developed by a business organization & it is a proprietary software.

Ex: MS Windows

Proprietary Software :- It is not a free software & used for a specific purpose.

Ex: Oracle

Semi-free Software :- It is not absolutely free & comes with permission for individuals to use, copy, distribute & modify for non-profit purposes.

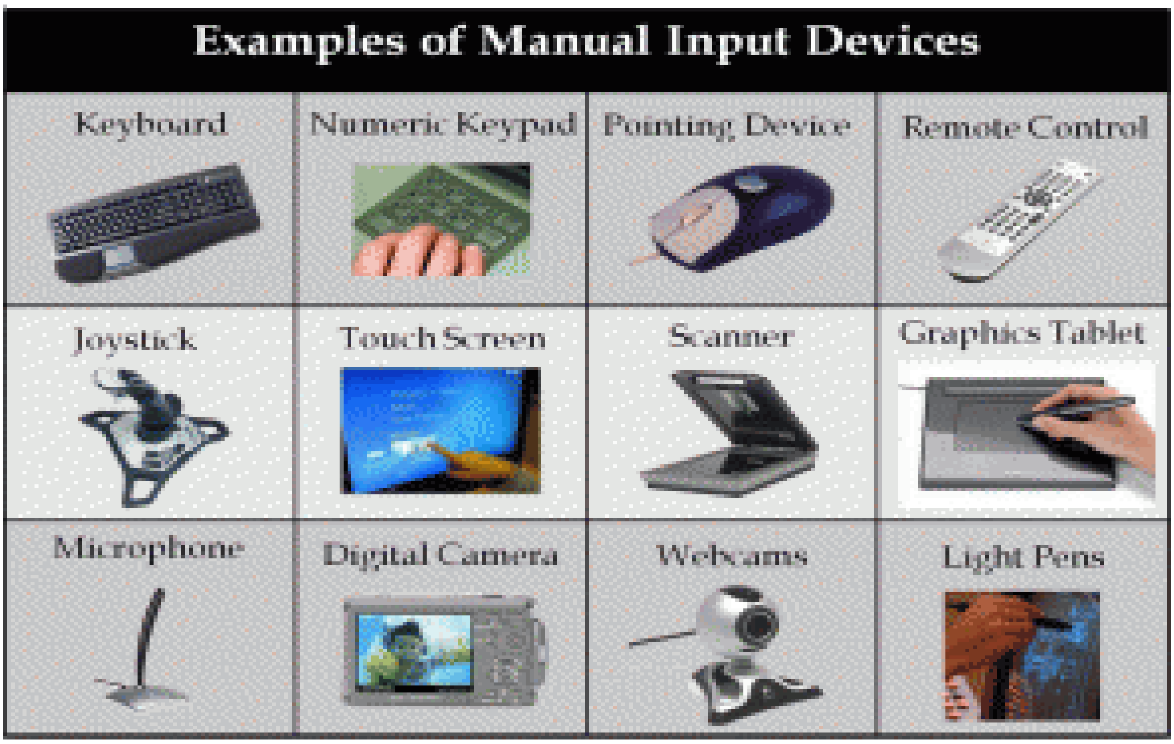
Ex : Pretty Good Privacy (**PGP**)

UNIT – 6 : PERIPHERALS

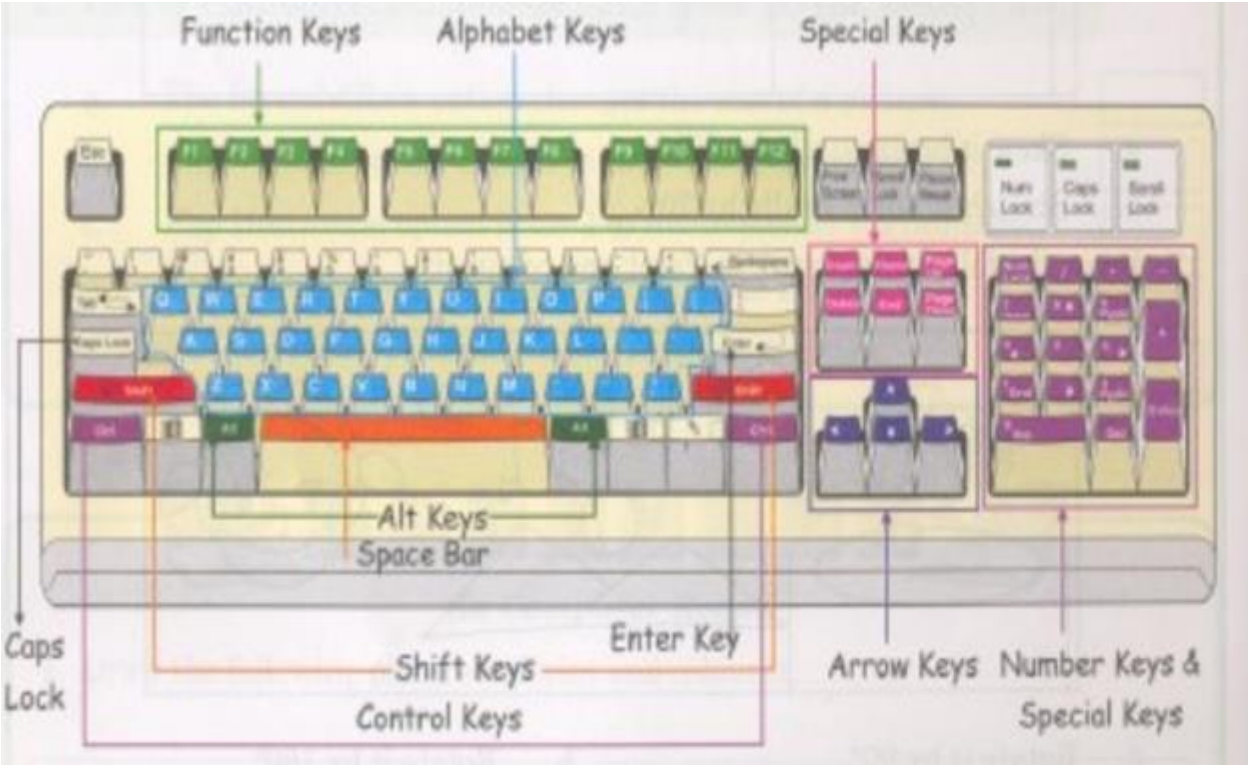
Input devices:
The devices which are responsible for getting in all kinds of original information into the computer are called input devices. All input devices are designed to get different types of data like video, audio, text, Graphics and images into the computer system.

Input devices process and referred by 3 stages of process:
1.Data input at keyboard and mouse
2.Data processing at Central Processing Unit (CPU)
3.Data Output at Cathode Ray Tube(CRT) or Liquid Crystal Display(LCD)

Various types of input devices are
Keyboard, Mouse, Touch Screen, Light pen, Joystick, Scanner, Web Camera etc.



Key Board and its working principle



The most common input deviceis a keyboard used for manual data entry process. The keys are arranged on a standard keyboard can be identified in terms of 5 key groups.

1.Alpha Numeric key
2.Modifier key
3.Functional key
4.cursor movement key
5.Special purpose key

Keyboard consists of electronic circuit to decide which key has been pressed.The keyboard control electronic circuits it performs major 3 functions

1.Sensing a key pressed.
2.Encode the sensed key.
3.Send the encoded data to computer.

Working of a Keyboard: Inside the keyboard, there are metallic plate, circuit board and processor, which are responsible for transferring information from the keyboard to the computer. Depending upon the working principle, there are two main types of keys, namely, capacitive and hard-contact.

When a key is pressed, the corresponding key switch is activated. The keyboard electronic circuit make use of matrix scanning technique in order to determine which key has been pressed. Then a standard 8 bit binary code called as scan code is generated to correspond to the depressed key value activate key switch .Now this 8 bit scan code is sent into the computer as an input data.

The keyboard control electronics circuitry not only just senses the pressed key but it also keep track that when the operator or user releases that key. Each separate key action is recorded by the keyboard control electronic circuit and sent to the computer as a distinct scan code. The scan codes are communicated to the processing unit via interrupt mechanism.

Advantages of using Keyboard:

1. Keyboards have special key that perform specific functions.
2. Instead of using the mouse to move the cursor you can use the arrow key situated on the keyboard to move the cursor on the monitor.
3. Keyboard is less expensive because it comes with every computer.

Disadvantages of keyboard are:

1. The person using the keyboard have to learn how to type.
2. The frequent movement from keyboard to move and back could cause carpal tunnel syndrome.

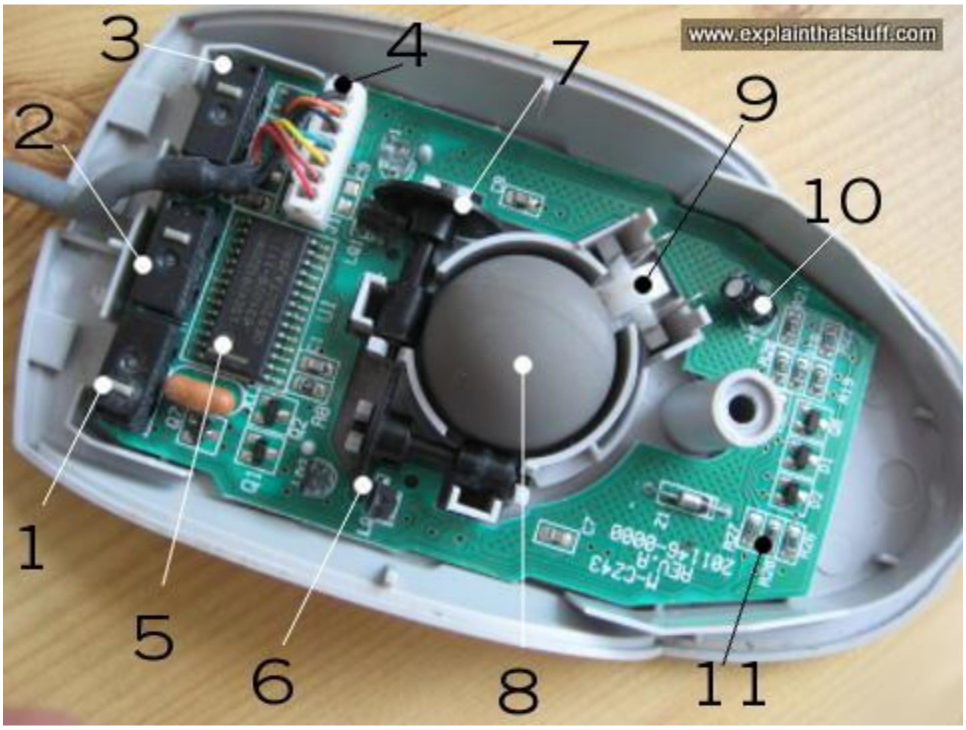
Mouse:

The modern digital system consists of a display screen(VDU),a keyboard for entering numbers and text matter and a hand held pointing device called as a Mouse. Mouse is a tiny box resting on a small tracker ball with 2 or 3 buttons on top and a thin flexible cable connects it to the CPU of computer. Mouse is a graphical input device.

The common mouse involves 5 different actions such as
Pointing – Slide the mouse pointer anywhere on the screen
Clicking- Single click to select , i.e. press once the mouse left button.

Double clicking – Press twice the mouse left button to launch
Dragging – Drag and drop selected object, text etc from one location to another
Right clicking – Clicking the right button of the Mouse once.

Working Principle of Mouse:



Switch detects clicks of left mouse button.
Switch for middle button.
Switch for right button.
Old-style connection to PS/2 socket on computer.
Chip turns back-and-forth mouse movements into numeric signals computer can understand.
X-axis wheel turns when you move mouse left and right.
Y-axis wheel turns when you move mouse up and down.
Heavy rubber wheel.
Spring presses rubber ball firmly against X- and Y-axis wheels so they register movements properly.
Electrolytic capacitor
Resistors

The mouse works by measuring how much it moves in a given direction. A mechanical mouse has a rubber ball in the bottom. Inside the bottom of the mouse are three rollers. It is there to hold the ball against the other two rollers. The other two rollers are usually larger, and of different color. These rollers are mounted at a 90° angle to the one other, one roller measures how fast the ball is turning horizontally and the other measures how fast it is turning vertically. When the ball rolls, it turns these two rollers. The rollers are connected

to axles, and the axles are connected to a small sensor that measures how fast the axle is turning. Both sets of information are passed to the electronics inside the mouse.
Optical mouse:

It uses an infrared light or a light emitting diode(LED) to illuminate the flat surface on which it is placed and a light sensitive device senses the light reflected from the surface. The reflected light changes as the mouse rotates.A light sensor senses and allow for generating pulse outputs. It is a non mechanical device.Clicking,double clicking and dragging graphical objects are carried out with the left mouse button. Right Clicking can be carrid out with the right mouse button that opens a short cut menu of properties.

Advantages of using Mouse:
No need to operate cursor movement keys on a keyboard.
It helps to position the cursor anywhere on the screen quickly.
Rather typing, issue commands by click-start.

Touch screen:
Touch Screen computer system consists of sensors on the screen outer surface to Locate or point touch of a finger movement on the screen.The touch screen is touch Panel is a glass coated with conductor. Electronic sensor circuit are used to detect touch position on the conductive coating. The touch screen systems like bank AUTOMATIC TELLER MACHINE accept user choice of account types, transaction type and money withdrawal details etc
It consists of 3 main parts, they are touch sensors, controller and driver software.

Advantages of touch screen

1. Touchscreen devices usually have more simple user interfaces Ex. Ipod Apps
2. Having less or not buttons means that you can put more effort into having a big screen
3. For the people worried about hygiene, most devices are easy to clean, some are even dirt, dust and grease resistant
4. For people new or uncomfortable with normal desktops, touch screens, ATM screens are easy to use helping more people get used to using computers.

Light Pen :-

It is a hand held electro-optical pointing graphical input device that make use of photo electric detector to select objects or images & drawings on the screen. It is also called mouse pen.

The light sensitive photodiodes or sensors will capture the light reflection of the screen objects at the point at which light pen is pointed on the screen.
The movement of the light pen is directed towards the screen will draw the lines or images at the selected places on the display screen.
They are used where drag-n-drop, point and menu driven selections.

Joystick

It is a thick stick mounted on spherical ball that rotates in a socket to provide right left & forward & backward movements. It allows to move freely in two directions. The movement is sensed & conveyed to the system & finally on to the game being played.

It is a gaming device that provides three types of game controls –digital, glide & direct.
The digital control restrict the motion of joystick handle in of two directions. The x-axis movement
is forward-backward or up-down and y-axis movement is left-right or sliding.
Applications of Joystick
It is used for playing games.
It is used in Flight Simulators.
It is use in Electrical Rail Engines ,Earth Movers & Excavators
Used in Industrial Robot Control.
Used in CAD/CAM Systems.

Scanner
A scanner is a device that captures images from photographic prints, posters, magazine pages, and similar sources for computer editing and display. Scanners come in hand-held, feed-in, and flatbed types and for scanning black-and-white only, or color. Very high resolution scanners are used for scanning for high-resolution printing, but lower resolution scanners are adequate for capturing images for computer display. Scanners usually come with software, such as Adobe's Photoshop product, resize and modify a captured image.
There are four different types of optical scanners.

Optical Character Reader (OCR) :- It is a recognition process of scanning printed text document or pages as optical images on a flat bed scanner & then employing OCR software to identify the individual character of the text page as Ascci text characters.

Optical Mark Reader (OMR) :- It detects optically the presence of intended darkened marls as required responses. It senses a little less light at the darkend. It scans the OMR sheet quickly and detects the specific darker area.

Magnetic Ink Character Reader (MICR)
Bank cheques number are designed and written with magnetic ink. Special magnetic ink is used to carve manufacture these cheque to maintain originality of the corresponding bank authorisation as a valid cheque .Forging or duplicating of cheques can be avoided.

Bar Code Reader (BCR) :- It is a special type of image scanner. It will convert the printed images, typed documents, numbers etc into digitized formats that can be recorded. It scans the bar code image on any of the items. It emits a high intensity beam of red laser beam on to a printed bar code image.
Flat bed bar code reader & hand held bar code reader are used in food worlds, shops etc.

Hand held Bar code reader

Flat bed bar code reader

Web Camera:- A web camera is a video camera that feeds its image in real time to or through a computer to computer network. When "captured" by the computer, the video may be saved, viewed or sent on to other networks via systems such as the internet, and email as an attachment. When sent to a remote location, the video stream may be saved, viewed or on sent there. Unlike an IP camera a webcam is generally connected by a USB cable, or similar cable, or built into computer hardware, such as laptops.

The term 'webcam' (a clipped compound) may also be used in its original sense of a video camera connected to the Web continuously for an indefinite time, rather than for a particular session, generally supplying a view for anyone who visits its web page over the Internet. Some of them, for example, those used as online traffic cameras, are expensive, rugged professional video cameras

Output Devices
An output device is any device used to send data from a computer to another device.
Computer data output that is meant for humans is in the form of audio or video. Most output devices used by humans are monitors, projectors, speakers, headphones and printers.

Printers
Printer is an output device, which is used to print information on paper.
There are two types of printers:

- Impact Printers
- Non-Impact Printers

Impact Printers
The impact printers print the characters by striking them on the tape/ribbon which is then pressed on the paper.
Characteristics of Impact Printers are the following:
Very low consumable costs
Very noisy
Useful for bulk printing due to low cost
There is physical contact with the paper to produce an image
These printers are of two types

- Character printers
- Line printers

Character Printers

Character printers are the printers which print one character at a time.

These are further divided into two types:

- Dot Matrix Printer(DMP)
- Daisy Wheel

Dot matrix printer

In the market one of the most popular printers is Dot Matrix Printer. These printers are popular because of their ease of printing and economical price. Each character printed is in form of pattern of dots and head consists of a Matrix of Pins of size (5*7, 7*9, 9*7 or 9*9) which come out to form a character that is why it is called Dot Matrix Printer.

Advantages

Inexpensive

Widely Used

Other language characters can be printed

Disadvantages

Slow Speed

Poor Quality

Daisy wheel

Head is lying on a wheel and pins corresponding to characters are like petals of Daisy (flower name) that is why it is called Daisy Wheel Printer. These printers are generally used for word-processing in offices which require a few letters to be sent here and there with very nice quality.

Advantages
More reliable than DMP
Better quality
The fonts of character can be easily changed

Disadvantages
Slower than DMP
Noisy
More expensive than DMP

Line Printers
Line printers are the printers which print one line at a time.

These are of further two types
- Drum Printer
- Chain Printer

Drum printer
This printer is like a drum in shape so it is called drum printer. The surface of drum is divided into number of tracks. Total tracks are equal to size of paper i.e. for a paper width of 132 characters, drum will have 132 tracks. A character set is embossed on track. The different character sets available in the market are 48 character set, 64 and 96 characters set. One rotation of drum prints one line. Drum printers are fast in speed and can print 300 to 2000 lines per minute.

Advantages
Very high speed
Disadvantages
Very expensive
Characters fonts cannot be changed

Chain printer
In this printer, chain of character sets are used so it is called Chain Printer. A standard character set may have 48, 64, or 96 characters.
Advantages
Character fonts can easily be changed.
Different languages can be used with the same printer.
Disadvantages
Noisy

Non-impact Printers
Non-impact printers print the characters without using ribbon. These printers print a complete page at a time so they are also called as Page Printers.
These printers are of two types
- Laser Printers
- Inkjet Printers

Characteristics of Non-impact Printers
Faster than impact printers.
They are not noisy.
High quality.
Support many fonts and different character size.
Laser Printers
These are non-impact page printers. They use laser lights to produce the dots needed to form the characters to be printed on a page.
Advantages
Very high speed
Very high quality output
Give good graphics quality
Support many fonts and different character size
Disadvantages
Expensive.
Cannot be used to produce multiple copies of a document in a single printing.

Inkjet Printers

Inkjet printers are non-impact character printers based on a relatively new technology. They print characters by spraying small drops of ink onto paper. Inkjet printers produce high quality output with presentable features.

They make less noise because no hammering is done and these have many styles of printing modes available. Colour printing is also possible. Some models of Inkjet printers can produce multiple copies of printing also.

Advantages

High quality printing

More reliable

Disadvantages

Expensive as cost per page is high

Slow as compared to laser printer

The differences between impact printer and non-impact printer

Si.No.	Characteristics	Impact	Non Impact
1	Descriptions	Produces text and images when tiny wire pins on print head strike the ink ribbon by physically contacting the paper	Pr produces text and graphics on paper without actually striking the paper
2	Types	Dot-matrix printer	Inkjet printer, laser printer and thermal printer
3	Speed	Low printing speed	Reasonably fast
4	Quality	Print quality lower in some types	High quality of output, capable of printing fine and smooth details
5	Letter quality	Pr produce near letter quality (NLQ) print only, which is just suitable for printing mailing labels, envelopes, or invoices	L letter-quality printouts
6	Consumption	Not commonly used today	Most commonly used printer today
7	Tools	Uses ink ribbon	Uses ink spray or toner powder
8	Cost	Less expensive	More expensive
9	Durability	Reliable, durable (long time)	- P print head is less durable, inclined towards to clogging and damage
10	Sound effects	N Noisy because of the striking activity	G generally much quieter than impact printers because there is no striking mechanism
11	Image clarity	Poor graphics	Can handle graphics and often a wider variety of fonts than impact printers
12	Multipart forms	I Ideal for printing multipart forms because they can easily print through many layers of paper	Cannot print multipart forms
13	Color output	Limited color printing	C capable of printing in strong clear color, good for printing pictures

Monitors

Monitors, commonly called as Visual Display Unit (VDU), are the main output device of a computer. It forms images from tiny dots, called pixels that are arranged in a rectangular form. The sharpness of the image depends upon the number of pixels.

There are two kinds of viewing screen used for monitors.

Cathode-Ray Tube (CRT)

Flat- Panel Display

Cathode-Ray Tube (CRT) Monitor

CRT is an evacuated conical glass tube with phosphorus coated on the inner surface called screen .A source of electrons called electron gun at one end of the tube emits electron beam. An oxide coated metal called a cathode is heated by a heating filament.

When the cathode gets heated then it emits electrons continuously. The electrons emitted by cathode are accelerated by applying a positive voltage to control grid. The control grid voltage determines the number electrons finally succeed to strike on the phosphor coated screen. If a negative grid voltage is applied to the control grid then no electrons are allowed to pass the grid.

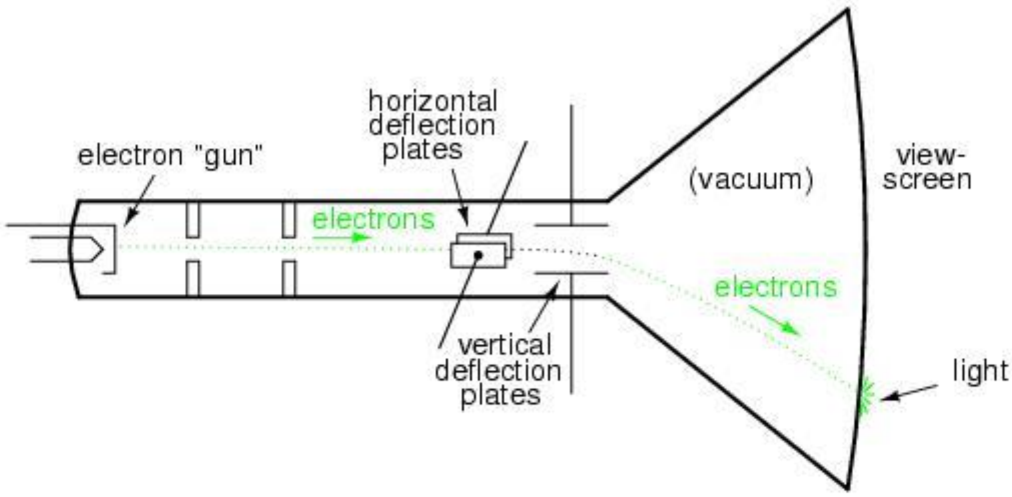
The electrons come out of the control grid are further accelerated by an accelerating anode

To which a positive voltage is applied. Hence accelerated electrons are focussed to produce a sharp & highly concentrated beam by a focusing structure.

The electron beam intended for striking on a screen finally come out of the hole of cylindrical metal enclosure of focusing structure.

The total arrangement of electron beam source the cathode, accelerating anode and focusing assembly is called electron gun.

Finally electron beam passes through a set of horizontal deflection plates & then vertical deflection plates. The electron beam movement can be controlled along x-axis & y-axis over the screen surface. The electron beam when it comes out of deflection plates, further accelerated along the path towards the screen, by applying a high positive voltage to a inner metallic coating of the conical surface of the CRT screen.



CRT Advantages

1. Resolution and Aspect Ratio. They operate at any resolution, geometry and aspect ratio without the need for rescaling the image.
2. Highest Resolutions CRTs run at the highest pixel resolutions generally available.
3. Black-Level and Contrast Produce a very dark black and the highest contrast levels normally available. Suitable for use even in dimly lit or dark environments.
4. Color and Gray-Scale Accuracy CRTs produce the very best color and gray-scale and are the reference standard for all professional calibrations. They have a perfectly smooth gray-scale with an infinite number of intensity levels. Other display technologies are expected to reproduce the natural power-law Gamma curve of a CRT, but can only do so approximately.
5. Motion Artifacts CRTs have fast response times and no motion artifacts. Best for rapidly moving or changing images.
6. Cost CRTs are less expensive than comparable displays using other display technologies.

CRT Disadvantages

1. Sharpness The CRT's Gaussian beam profile produces images with softer edges that are not as sharp as an LCD at its native resolution. Imperfect focus and color registration also reduce sharpness. Generally sharper than LCDs at other than native resolutions.
2. Interference All color CRTs produce annoying Moiré patterns. Many monitors include Moiré reduction, which normally doesn't eliminate the Moiré interference patterns entirely.
3. Geometric Distortion Subject to geometric distortion and screen regulation problems. Also affected by magnetic fields from other equipment including other CRTs.
4. Brightness Relatively bright but not as bright as LCDs. Not suitable for very brightly lit environments.
5. Screen Shape Some CRTs have a rounded spherical or cylindrical shape screen. Newer CRTs are flat.
6. Emissions CRTs give off electric, magnetic and electromagnetic fields. There is considerable controversy as to whether any of these pose a health hazard, particularly magnetic fields. The most authoritative scientific studies conclude that they are not harmful but some people remain unconvinced.
7. Physical They are large, heavy, and bulky. They consume a lot of electricity and produce a lot of heat.

MEMORY

Introduction

Memory refers to the devices used to store information for use in a computer. The required storage facilities are provided with separate & dedicated unit are called memory unit. There are two types of memory i.e primary memory & secondary memory.

Units of measuring computer memory:

Memory representation refers to units of measure for computer memory & storage units. It operates between two states ON (1) and OFF(0).

Units of Computer Memory Measurements

1 Bit = Binary Digit

8 Bits = 1 Byte

1024 Bytes = 1 KB (Kilo Byte)

1024 KB = 1 MB (Mega Byte)

1024 MB = 1 GB(Giga Byte)

1024 GB = 1 TB(Terra Byte)

1024 TB = 1 PB(Peta Byte)

1024 PB = 1 EB(Exa Byte)

1024 EB = 1 ZB(Zetta Byte)

1024 ZB = 1 YB (Yotta Byte)

1024 YB = 1 (Bronto Byte)

1024 Brontobyte = 1 (Geop Byte)

Geop Byte is The Highest Memory

Primary Memory :- The primary memory is also called main memory which is required for execution of the programs. It is a semiconductor memory. It is volatile in nature. Volatile means contents are lost when the computer is switched off. This memory communicates directly to the CPU. It is in the form of Integrated Circuits(IC).

Ex. Random Access Memory (RAM)

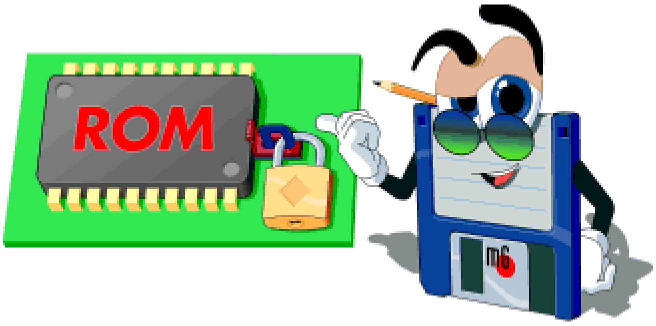
There are two types of primary memory

Read Only Memory (ROM)

Random Access Memory (RAM)

Note: This is only Basic Information for students. Please refer "Reference Books" prescribed as per syllabus

Read Only Memory (ROM) :- ROM permits read operation only. CPU access the contents of ROM chips for system routines like BIOS, monitor programs, driver routines, POST diagnostic routines etc. It is Non-Volatile in nature. It retains stored information even if there is power failure or switched off or shut down. The stored information can be read only. The stored contents are not altered.



Types of ROM

There are different types of ROM's.

Masked ROM

Programmable ROM (PROM)

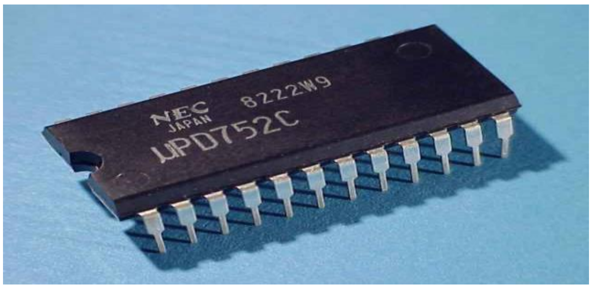
Erasable Programmable ROM (EPROM)

Electrically Erasable Programmable ROM (EEPROM)

Flash ROM (Flash BIOS)

Masked ROM :-

ROM memory can be permanent memory i.e. stored contents cannot be altered like Masked ROM. The contents of ROM are sealed by masking & metallization process used during ROM chip fabrication, so the contents cannot be erased. It holds pre-programmed set of instructions. It is the first hard-wired memory device.



Programmable ROM (PROM) :-

PROM consists of nichrome or poly silicon wires arranged in a matrix. PROM chips can be created from scratch is time consuming & expensive process. Developers created a type ROM which is called PROM. It can be programmed once & information stored in permanent. PROM is a "Write Once, Read Many Times".

Erasable Programmable ROM (EPROM):-

It consists of MOSFET(Metal Oxide Semiconductor Field Effect Transistor) gates array. Bit patterns are stored in EPROMS by using an programmer that applies a high voltage to charge the floating gates of FET's. This charge is stored permanently for a longer period as it has no leakage path. Stored bit patterns or charges can only be erased by exposing the chip to ultra violet light. The blank EPROM IC can be reprogrammed for new data bit pattern storage & can be reused again. Selective erasing is not possible.

Electrically Erasable Programmable ROM (EE-PROM):-

It is functionally similar to EPROM but erased by an electrical charge & then written by using higher than normal voltage. In this contents can be selectively erased .EE-PROM IC's are used in microprocessor based systems & computers wherever hardware configuration alteration is required.

Flash ROM :-

The sections of the memory cell called memory blocks can be erased instantaneously therefore the name flash .It is constantly powered non-volatile memory that can be erased & reprogrammed in blocks. It is used in digital camera, cell phones& digital setup boxes.

Random Access Memory (RAM):-

It is a read write memory .Any data, information, command, programs & instructions are first stored in RAM. It is considered as a scratch pad inside the computer system. RAM cells are made out of small capacitors i.e holds electronic charge & small transistors (on/off switch) are all fabricated on a chip of a silicon in millions.

They are termed as SIMM's (Single Inline Memory Module) and DIMM's (Dual Inline Memory Module).

RAM Memory Module Strips (SIMM's & DIMM's) of the storage sizes are 256MB, 512MB IGB , 2GB ,4GB....Higher is the capacity of RAM, Higher is the speed of system. RAM is original place to remember John Von Neumann's stored program concept. Modern computers uses stored program computers. It holds the operating system, compiler, assembler like system programs.RAM provides faster access to read/write data compared to all the secondary memory.

Types of RAM :-

RAM can be classified two types.

1) Static RAM (SRAM)

2) Dynamic RAM (DRAM)

1) Static RAM (SRAM) :-
SRAM uses multiple transistors like 4-to-6, each memory cell represent a bit of 0/1.
Data bit is stored as voltage. It holds data as long as power is on otherwise data is lost.
It does not require memory refreshing. It is a volatile memory.

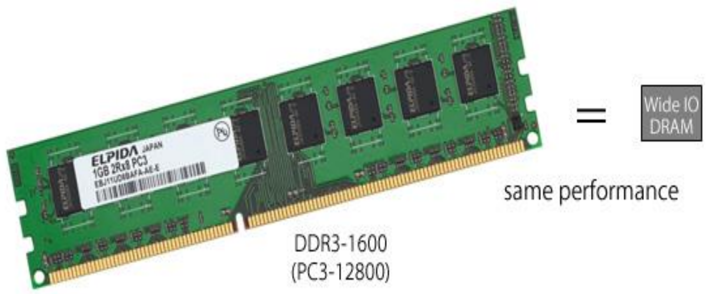
There are different types of SRAM. They are Asynchronous SRAM (ASRAM), Burst SRAM (BSRAM) and Pipeline Burst SRAM (PB SRAM).

Advantages
SRAM is faster access.
It is faster than DRAM.
No memory refreshing required.

Disadvantage
Expensive to use for larger system.
Packing density is low.
High power consumption.

Applications of SRAM
It is used primarily as Cache Memory and in dot matrix printer as printer buffer.

2) Dynamic RAM (DRAM) :- It consist of memory cells with a paired transistor & a capacitor, requiring constant memory refreshing. It is an array of capacitors that stores data bit as charge. The presence of charge on the capacitor represents '1 ' and the absence of a charge represents '0'.



Advantages :
Low power consumption.
They are cheaper than SRAM.
Higher packing density.

Disadvantages :

DRAM is slower than SRAM.

It requires memory refreshing.

There are several types of DRAM. They are

Synchronous Dynamic Random Access Memory (S DRAM)

Fast Page Mode Dynamic Random Access Memory (FPM DRAM)

Extended Data Out Dynamic Random Access Memory (EDO DRAM)

Rambus Dynamic Random Access Memory (R DRAM)

Video Dynamic Random Access Memory (V DRAM)

Windows RAM (VRAM)

Double Data Rate Synchronous Dynamic Random Access Memory (DDR SDRAM)

Flash RAM

Intersystems 64K Dynamic RAM Board

Comparison of RAM & ROM

	RAM	ROM
Definition	Random Access Memory or RAM is a form of data storage that can be accessed randomly at any time, in any order and from any physical location allowing quick access and manipulation.	Read-only memory or ROM is also a form of data storage that cannot be easily altered or reprogrammed. Stores instructions that are not necessary for re-booting up to make the computer operate when it is switched off. They are hardwired.
Stands for	Random Access Memory	Read-only memory
Use	RAM allows the computer to	ROM stores the program required

	RAM	ROM
	read data quickly to run applications. It allows reading and writing.	to initially boot the computer. It only allows reading.
Volatility	RAM is volatile i.e. its contents are lost when the device is powered off.	It is non-volatile i.e. its contents are retained even when the device is powered off.
Types	The two main types of RAM are static RAM and dynamic RAM.	The types of ROM include PROM, EPROM and EEPROM.

Secondary Memory:-

Few cheaper storage devices used to serve as a backup for storing the information that is not currently used by the CPU but is required for future are called secondary memory or auxiliary memory. This memory can store large amount of data. It is non-volatile in nature. Manufacturing of these memory storage devices involve very precise & micron-level tolerances.

Ex. Floppy Disk, Zip Disk, Magnetic Hard Disk, Magnetic Tape ,Optical Disk, Compact Disk Rom, DVD.

Benefits / Advantages of Secondary Storage:-

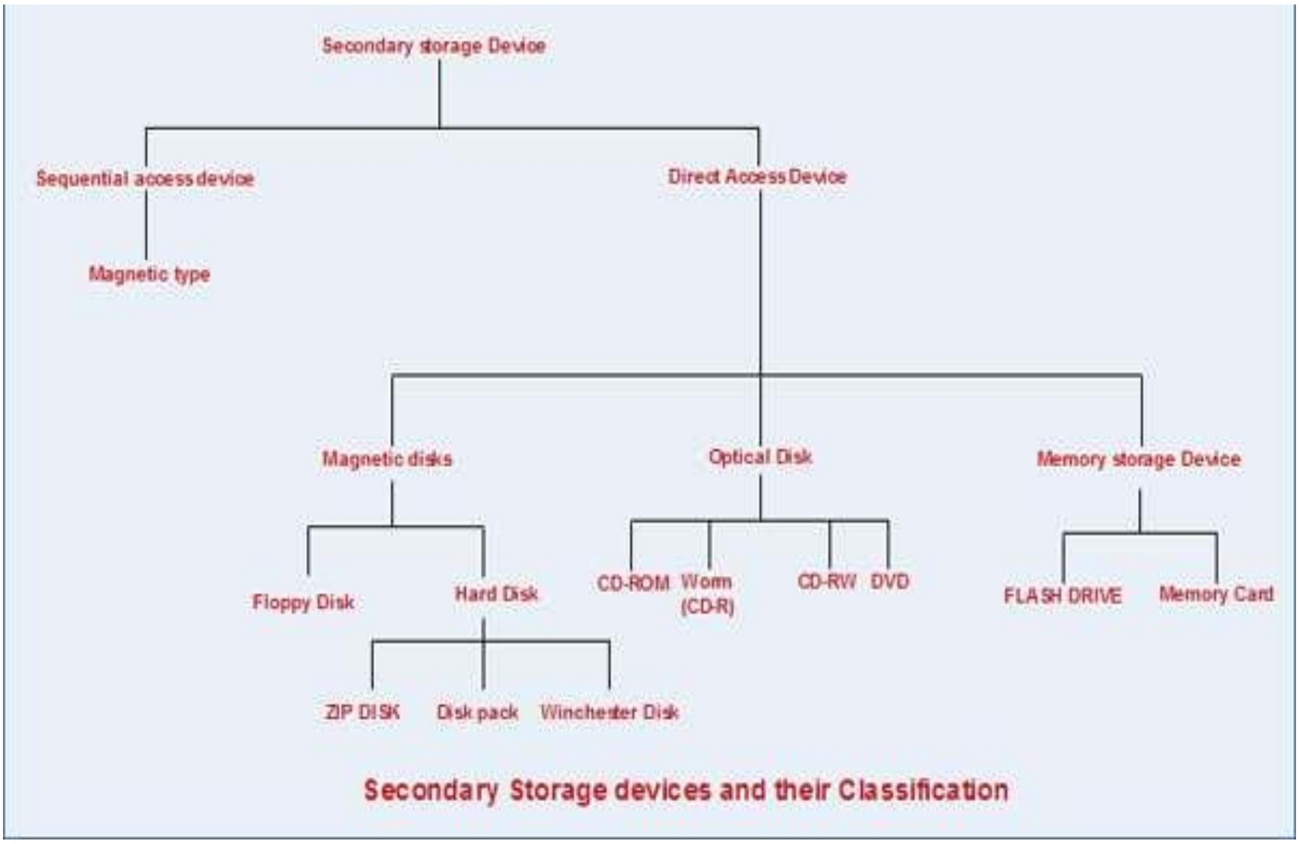
1) Non-Volatility nature of secondary storage.
2) Low Cost
3) Portability
4) Ease of use
5) Large storage capacity
6) Reusable
7) Reliability
8) Provides Backup
9) Various Shape & Size
10) Different Types of Access Method

Differences between Primary Memory & Secondary Memory

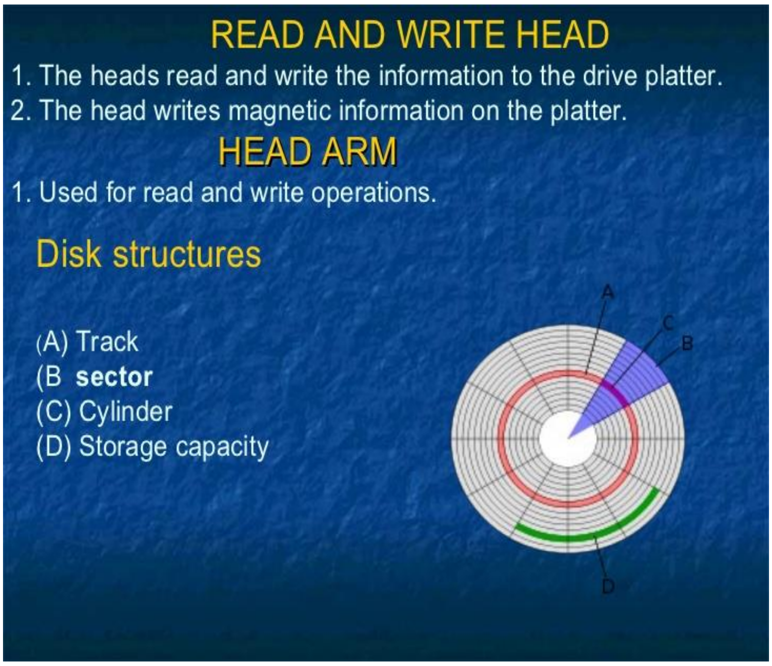
Sl.No.	Primary memory	Secondary memory
1	The memory devices used for primary memory are semiconductor memories	The secondary memory devices are magnetic and optical memories.
2	The primary memory is categorized as volatile and non volatile memories, RAM is the volatile memory and ROM is the non volatile memory	The secondary memory is always non volatile
3	The primary memory is composed of programs and data that are presently being used by the micro processor	The secondary memory is capable to store huge amount of information
4	The primary memories are more effective and	The secondary memories are somewhat slow in

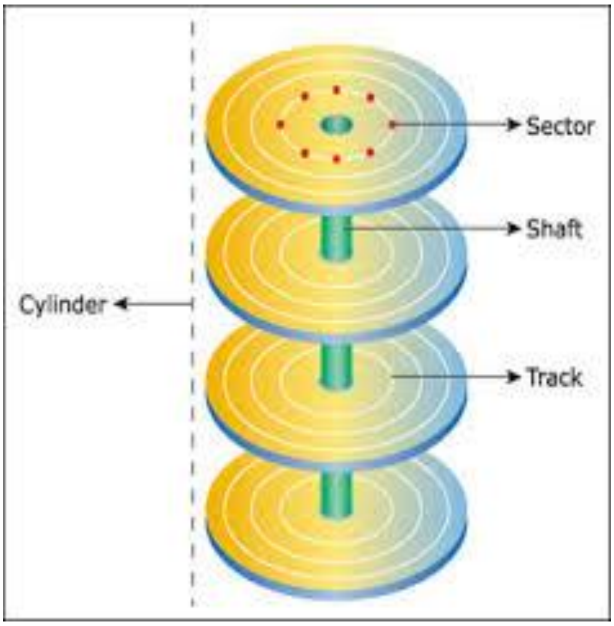
	fast to interact with the micro processor	interacting with the micro processor, when compared with the primary memory.
5	Primary memory is known as main memory	Secondary memory is known as additional memory or backup memory or auxiliary memory
6	These memories are also called as internal memory	These memories are also called as external memory
7	Primary memory is temporary	The secondary memory is permanent
8	Commonly used primary memory (main memory) available in the range of 512 MB to 8 GB RAMs.	Generally secondary memories range between 80 GB to 4 TB Hard Disc Drives.
9	The primary memory devices are connected to the computer through "slots"	The secondary memory devices are connected to the computer through Cables
10	Memory unit that communicates directly with the processor.Ex RAM & ROM	Memory unit that provides additional backup storage Ex. Hard Disk, DVD, Pen Drive, Thumb Drive etc

Classification of secondary storage devices



There are two types of access method in secondary storage.
Sequential Access – It is step by step access method for data in sequential order.
Direct Access –It is also called Random access. In this access method for locating data we use direct or random access method on to secondary storage devices.
Hard Disk and its working Principle :





A magnetic disk is an electromechanical assembly of rigid aluminium platters, containing flat, thin circular metal plates or disks coated with magnetic material on both sides. Many disks are mounted on one spindle with read write heads available for both surfaces of all the disk. The disk assembly is mounted on a disk drive. The disk drive consist of a motor to rotate the disk assembly at high speed of 3600 revolutions per minute (rpm), 7200 rpm,10000 rpm & 15000 rpm.
The read/write heads mounted on arm can move in & out radially on the disk surfaces for reading & writing operations. Data is stored or read on the magnetic recording surfaces of the disk when the disk rotates at high speed about its axis.

Data bits 0's & 1's are stored in the magnetized recording surface of the disks along concentric circles called tracks. A track is further divided into sectors. Each disk platter has equal number of circular tracks & track location that cuts all platters is called as cylinder. A sector can store 128 to 1024 bytes of data depending upon its storage organization. Tracks sectors can be grouped into a segment are called cluster.

Read/Writing head pairs are used for each disk. Read/write head assembly move radially in & out uniformly over the disk surface. Its positioning mechanism make the read/write head arms assembly to move horizontal towards center and away from the disk pack.

The data transfer operations of storage & retrieval or read & write on magnetic disk involve 3 different ways of accessing data on the magnetic disk.

Disk Seek

Rotate the Disk

Perform disk data transfer

The various memory sizes of hard disk are 160GB, 500GB, 1TB etc.

Optical Disk :

Information is written to or read from an optical disk using laser beam. Optical disks are not suitable memory storage units because their access time is more than that of hard disks. Their advantage is that they have very high storage capacity.

Types of optical memory are: CD –ROM, CD-R, CD-RW, DVD-ROM, DVD-R and DVD-RW. Information on a CD-ROM is written at the time of manufacture. CD-R/W of 700 MB are available.

A DVD-ROM is similar to CD-ROM. It uses shorter wave length of laser beam and hence, stores more data than CD-ROM.

With every new application and software there is greater demand for memory capacity. It is the necessity to store large volume of data that has led to the development of optical disk storage medium. Optical disks can be divided into the following categories:

1. Compact Disk/ Read Only Memory (CD-ROM): CD-ROM disks are made of reflective metals. CD-ROM is written during the process of manufacturing by high power laser beam. Here the storage density is very high, storage cost is very low and access time is relatively fast. Each disk is approximately 4 1/2 inches in diameter and can hold over 600 MB of data. As the CD-ROM can be read only we cannot write or make changes into the data contained in it.

2. Write Once Read Many (WORM): The inconvenience that we cannot write anything in to a CD-ROM is avoided in WORM. A WORM allows the user to write data permanently on to the disk. Once the data is written it can never be erased without physically damaging the disk. Here data can be recorded from keyboard, video scanner, OCR equipment and other devices. The advantage of WORM is that it can store vast amount of data amounting to gigabytes (109 bytes). Any document in a WORM can be accessed very fast, say less than 30 seconds.

3. Erasable Optical Disk: These are optical disks where data can be written, erased and re-written. This also applies a laser beam to write and re-write the data. These disks may be used as alternatives to traditional disks. Erasable optical disks are based on a technology known as magnetic optical (MO). To write a data bit on to the erasable optical disk the MO drive's laser beam heats a tiny, precisely defined point on the disk's surface and magnetizes it.

4. Digital Versatile Disk : The term versatile in DVD comes from the fact that it can store large amount of data & high quality of sound & videos. Double sided double density dual layer DVD can store upto 17GB of data. A DVD can hold 4.7GB of data which is 7 times of a normal CD.

Blu-ray or Blu-ray Disc (BD, BRD) is a digital optical data storage format. It was designed to supersede the DVD format, in that it is capable of storing high-definition video resolution. The plastic disc is 120 mm in diameter and 1.2 mm thick. Blu-ray Discs contain 25 GB per layer, with dual layer discs (50 GB) being the industry standard for feature-length video discs. Triple layer discs (100 GB) and quadruple layers (128 GB) are available re-writer drives. The name "Blu-ray" refers to the blue laser (a violet laser) used to read the disc, which allows information to be stored at a greater density than is possible with the longer-wavelength red laser used for DVDs. The main application of Blu-ray is as a medium for video material such as feature films and physical distribution of video games.

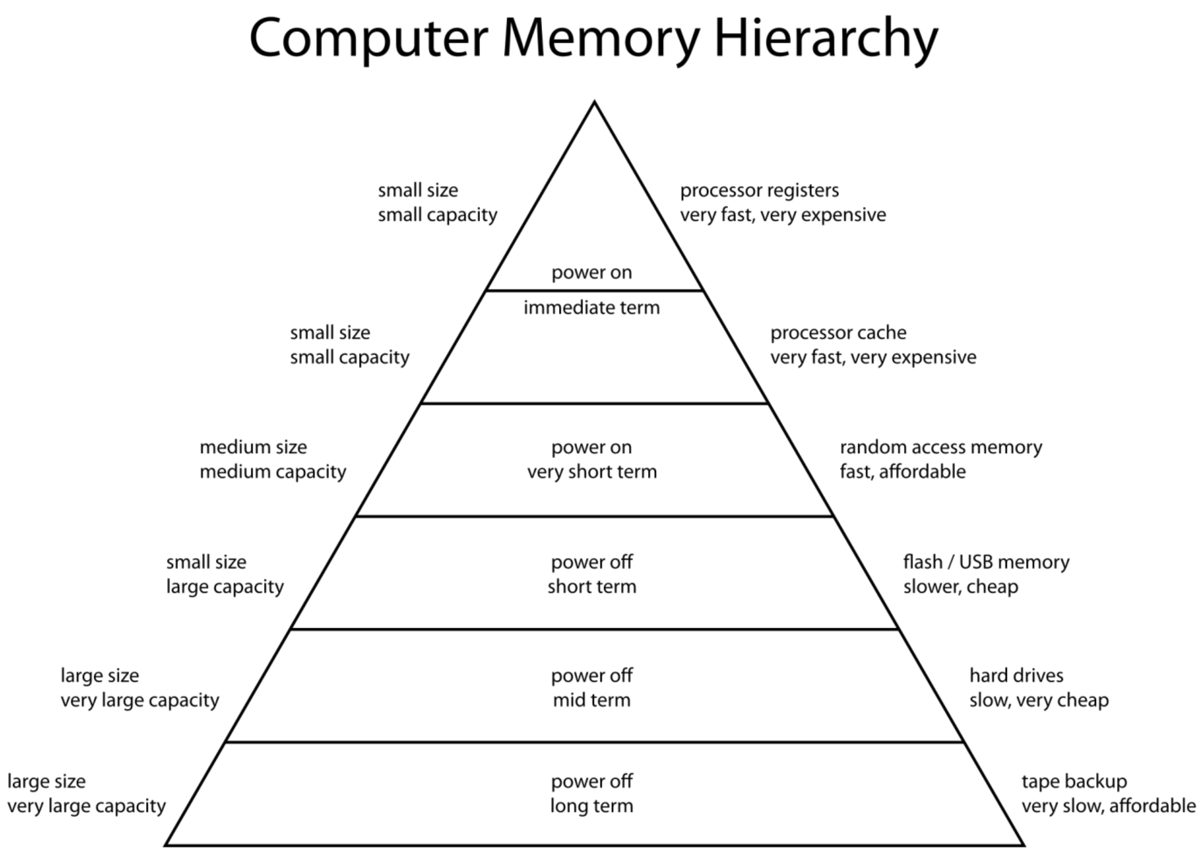
Advantages of Optical Disk

Easily portable
Smaller in size & light weight
Not susceptible to magnetic field damages
Used as video, audio & multimedia CD's.
Storing multiple forms of data.
Higher storage capacity with less cost
Reliable data storage (upto 10 + years)
High data recording density

Disadvantages of Optical Disk

Prone to physical damages as scratches on the recording media.
Data access speed is lesser than magnetic disk.
Additional software is required for copying/writing optical disk.
Optical Disk read/write drive mechanism uses laser beam exploration which sometimes may lead to health hazards.

Memory Hierarchy



Type of memory	Features/functions	size
Processor register	Very fast, very expensive	Small capacity
Cache memory	Very fast, very expensive	Small capacity
Random Access Memory	Fast & affordable	Medium capacity
Flash Rom	Slower & cheap	Small capacity
Hard Disk	Slow & very cheap	Large size & very large capacity
Magnetic tape	Very slow & affordable	Large size & very large capacity