NUMBER SYSTEM

- Decimal,
- binary,
- octal and
- hexadecimal,
- Conversion from one system to another,
- 1's,2's and 9's,10's complements
- signed numbers
- Codes:
  - BCD,
  - Excess-3,
  - Gray codes
  - weighted and non-weighted codes,
- binary arithmetic,

Digital Number System

- A digital system can understand positional number system only. There are a few symbols called digits and these symbols represent different values depending on the position they occupy in the number.

A value of each digit in a number can be determined using

- The digit
- The position of the digit in the number
- The base of the number system

Base : It is defined as the total number of digits available in the number system.

Conversion of Number System

Binary to Decimal Conversion :

$(10101)_2 = (\ldots\ldots)_{10}$

Conversion :

$(10101)_2 = (1 \times 2^4) + (0 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$

$= (16 + 0 + 4 + 0 + 1)_{10}$

$= (21)_{10}$

Therefore, $(10101)_2 = (21)_{10}$

Decimal to Binary conversion

$(29)_{10} = (\ldots\ldots\ldots\ldots)_2$

Step	Operation	Result	Remainder
Step 1	29 / 2	14	1
Step 2	14 / 2	7	0
Step 3	7 / 2	3	1
Step 4	3 / 2	1	1
Step 5	1 / 2	0	1

Octal to Decimal Conversion :

$(12570)_8 = (........)_{10}$

Conversion :

$(1257)_8 = (1 \times 8^4) + (2 \times 8^3) + (5 \times 8^2) + (7 \times 8^1) + (0 \times 8^0)$

$= (4096 + 1024 + 320 + 56 + 0)_{10}$

$= (5496)_{10}$

Therefore, $(12570)_8 = (5496)_{10}$

Decimal to octal Conversion :

Step	Operation	Result	Remainder
Step 1	5496 / 8	687	0
Step 2	687 / 8	85	7
Step 3	85 / 8	10	5
Step 4	10 / 8	1	2
Step 5	1 / 8	0	1

Hexadecimal to Decimal conversion :

$(19FDE)_{16} = (........)_{10}$

Conversion :

$(19FDE)_{16} = (1 \times 16^4) + (9 \times 16^3) + (F \times 16^2) + (D \times 16^1) + (E \times 16^0)$

$= (1 \times 16^4) + (9 \times 16^3) + (15 \times 16^2) + (13 \times 16^1) + (14 \times 16^0)$

$= (65536 + 36864 + 3840 + 208 + 14)_{10}$

$= (106462)_{10}$

Decimal to Hexadecimal conversion :

Step	Operation	Result	Remainder
Step 1	5496 / 16	343	8
Step 2	343 / 16	21	7
Step 3	21 / 16	1	5

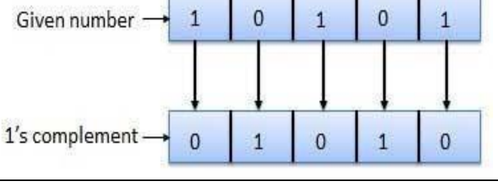
$(5496)_{10} = (578)_{16}$

Binary system complements

- As the binary system has base r = 2.
- So the two types of complements for the binary system are 2's complement and 1'scomplement.

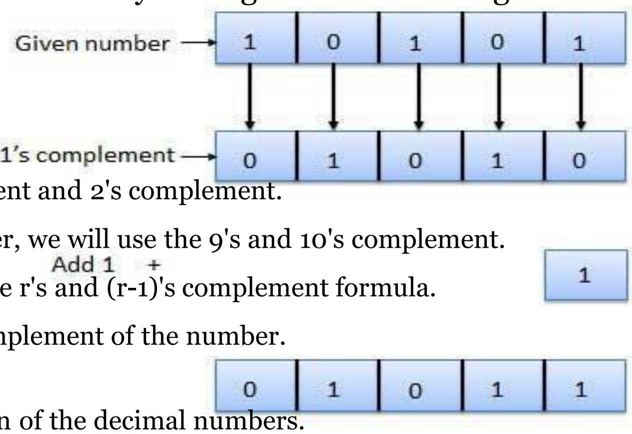
1's complement

- The 1's complement of a number is found by changing all 1's to 0's and all 0's to 1's.
- This is called as taking complement or 1's complement.



2's complement

- The 2's complement of binary number is obtained by adding 1 to the Least Significant Bit(LSB) of 1's complement of the number.
- 2's complement = 1's complement + 1



Decimal system complements

- If the number is binary, then we use 1's complement and 2's complement.
- But in case, when the number is a decimal number, we will use the 9's and 10's complement.
- We can find the 9's and 10's complement using the r's and (r-1)'s complement formula.
- The 10's complement is obtained from the 9's complement of the number.

9's Complement

- The 9's complement is used to find the subtraction of the decimal numbers.
- The 9's complement is calculated by subtracting each digit of the number by 9.

Example : Find the 9's complement of the number 1423.

```
 9999
-1423
-----
 8576 <------ 9's complement
```

So, the 9's complement of the number 1423 is = 8576.

10's Complement

- The 10's complement is also used to find the subtraction of the decimal numbers.
- The 10's complement is calculated by subtracting each digit by 9 and then adding 1 to the result.
- Simply, by adding 1 to its 9's complement we can get its 10's complement value.

Example : Find the 10's complement of the number 1423.

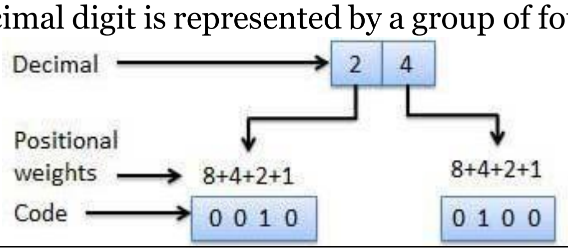
```
 9999
-1423
-----
 8576 <------ 9's complement
+   1
-----
 8577 <------ 10's complement
```

Binary Codes

- The digital data is represented, stored and transmitted as group of binary bits.
- This group is also called as binary code.
- The binary code is represented by the number as well as alphanumeric letter.

Weighted Codes

- Weighted binary codes are those binary codes which obey the positional weight principle.
- Each position of the number represents a specific weight.
- Several systems of the codes are used to express the decimal digits 0 to 9.
- In these codes each decimal digit is represented by a group of four bits.



Binary Coded Decimal (BCD) code

- In this code each decimal digit is represented by a 4-bit binary number.
- BCD is a way to express each of the decimal digits with a binary code.
- In binary, four bits is used to represent sixteen numbers (0000 to 1111).
- But in BCD code only first ten of these are used (0000 to 1001).
- The remaining six code combinations i.e. 1010 to 1111 are invalid in BCD.

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

Non-Weighted Codes

- In this type of binary codes, the positional weights are not assigned.
- The examples of non-weighted codes are Excess-3 code and Gray code.

Excess-3 code

- The Excess-3 code is also called as XS-3 code.
- It is non-weighted code used to express decimal numbers.
- The Excess-3 code are derived from the 8421 BCD code to adding (0011)2 to each code word in 8421.

Decimal Number $\longrightarrow$ 8421 BCD $\xrightarrow[\text{0011}]{\text{Add}}$ Excess-3

Decimal	BCD 8 4 2 1	Excess-3 BCD + 0011
0	0 0 0 0	0 0 1 1
1	0 0 0 1	0 1 0 0
2	0 0 1 0	0 1 0 1
3	0 0 1 1	0 1 1 0
4	0 1 0 0	0 1 1 1
5	0 1 0 1	1 0 0 0
6	0 1 1 0	1 0 0 1
7	0 1 1 1	1 0 1 0
8	1 0 0 0	1 0 1 1
9	1 0 0 1	1 1 0 0

Gray Code

- It is the non-weighted code and it is notarithmetic codes.
- That means there are no specific weightsassigned to the bit position.
- It changes only one bit at a time, it is called unit distance code.
- The gray code is a cyclic code.
- Gray code is used in K-Map.

Decimal	BCD	Gray
0	0 0 0 0	0 0 0 0
1	0 0 0 1	0 0 0 1
2	0 0 1 0	0 0 1 1
3	0 0 1 1	0 0 1 0
4	0 1 0 0	0 1 1 0
5	0 1 0 1	0 1 1 1
6	0 1 1 0	0 1 0 1
7	0 1 1 1	0 1 0 0
8	1 0 0 0	1 1 0 0
9	1 0 0 1	1 1 0 1

Binary Arithmetic

- It is a key for binary subtraction, multiplication, division. There are four rules ofbinary addition.

Binary Addition

Case	A + B	Sum	Carry
1	0 + 0	0	0
2	0 + 1	1	0
3	1 + 0	1	0
4	1 + 1	0	1

Binary Subtraction

Case	A - B	Subtract	Borrow
1	0 - 0	0	0
2	1 - 0	1	0
3	1 - 1	0	0
4	0 - 1	0	1

Binary Multiplication

Case	A x B	Multiplication
1	0 x 0	0
2	0 x 1	0
3	1 x 0	0
4	1 x 1	1

Binary Division

101010 / 000110 = 000111

- ❖ 1÷1 = 1
- ❖ 1÷0 = Meaningless
- ❖ 0÷1 = 0
- ❖ 0÷0 = Meaningless

```
             1 1 1        = 7₁₀
000110 ) 1 0 1 0 1 0      = 42₁₀
        -1 1 0            = 6₁₀
        ------
         1 0 0 1
        -1 1 0
        --------
           1 1 0
          -1 1 0
          ------
               0
```

Signed-Magnitude representation :

- The representation of decimal numbers in everyday is commonly called the signed-magnitude representation.
- In this system, a number consists of a magnitude and a symbol which indicates whether themagnitude is

  positive or negative.

  Example : + 79, - 82, - 25.2 etc. are interpreted in the usual manner.
- This mode of representation can be quite easy by using an extra bit position to represent thesign.
- This extra bit is called the SIGN BIT and is placed before the magnitude of the number to berepresented.
- When the sign bit is 0, the number represented is positive and when the sign bit is 1, thenumber is negative.

$(00000000)_2 = +(0)_{10}$

$(10000000)_2 = -(0)_{10}$

$(01101101)_2 = +(109)_{10}$

$(11101101)_2 = -(109)_{10}$

$(00101011)_2 = +(43)_{10}$

$(10101011)_2 = -(43)_{10}$

Unit – 02 : LOGIC GATES AND FLIP FLOPS :

- Definitions, symbols and truth table of
  - Basic gates NOT, OR, AND.
  - Universal gates NAND, NOR.
  - Special gates XOR, XNOR.
- De Morgan's Theorems.
- Sum of Product, Product of Sum, Min term , Max term,
- Karnaugh-Map ,
- Logical diagram, truth table, Flip -Flops-
  - RS, T, D, JK, Master/ Slave JK and timing diagram.

Standard form of Boolean Expressions

- All Boolean expressions can be converted into either of two standard forms :
  1. Sum-of Product(SOP)
  2. Product-of-Sum(POS)

What is SOP ?

- SOP stands for Sum of Products($\sum$).
- The product terms are also known as min-terms(m).
- When two or more product term are ORed, then the resulting expression is called SOP.

Example : $AB + BCD$

$ABC + CDE + \bar{B}C\bar{D}$

- A product term is equal to 1 if and only if each of the literals in the term is 1.
- A product term is equal to 0 when one or more literals are 0.

Conversion of a general expression to SOP :

a) $(A + B)(C + \bar{B})$

b) $(A + \bar{B}C)C$

c) $(A + C)(B + AC)$

The standard SOP :

Q1. Convert it into standard SOP function $F = AB + AC + BC$

Q2. Convert the Boolean expression $F = A\bar{B}C + \bar{B}C\bar{D} + A\bar{C}D$

Q3. Convert the Boolean expression $F = A\bar{B}C + \bar{A}B + AB\bar{C}D$

What is POS ?

- POS stands for Product of Sums($\prod$).
- The sum terms are also known as max-terms(M).
- When two or more sum terms are multiplied, then the resulting expression is called POS.

Example : $(A + B) + (B + C + D)$

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

- A sum term is equal to 0 if and only if each of the literals is 0.
- A sum term is equal to 1 when one or more of the literals in the term are 1.

SOP	POS
SOP stands for Som-of-Product.	POS stands for Product-of-Sum.
A way of representing boolean expressions as sum of product terms.	A way of representing boolean expressions as product of sum terms.
SOP is product of boolean variables either in normal form or complemented form.	POS is sum of boolean variables either in normal form or complemented form.
It is sum of minterms. Minterms are represented as 'm'	It is product of maxterms. Maxterms are represented as 'M'
SOP is formed by considering all the minterms, whose output is HIGH(1)	POS is formed by considering all the maxterms, whose output is LOW(0)

Canonical Form (Standard SOP and POS Form)

- Any Boolean function that is expressed as a sum of minterms or as a product of max terms is said to be in its "canonical form".
- It mainly involves in two Boolean terms, "minterms" and "maxterms".

Conversions of Canonical Forms

There are 2 steps to follow to convert the canonical form of the equations.
Step 1: Interchanging the operational symbols, Σ and Π in the equation.
Step 2: Writing the indexes of the terms that are not presented in the given form of equation.

Conversion of SOP to POS form

Example:

The SOP function

$$F = \sum A, B, C\,(0, 2, 3, 5, 7)$$

$$= A'B'C' + A'BC' + A'BC + AB'C + ABC$$

Step 1: changing the operational sign to Π

Step 2: writing the missing indexes of the terms 1, 4 and 6.

$$1 = 001 = (A + B + C')$$

$$4 = 100 = (A' + B + C)$$

$$6 = 110 = (A' + B' + C)$$

Writing down the new equation in the form of POS form, F

$$= \Pi A, B, C\,(1, 4, 6)$$

$$= (A + B + C')(A' + B + C)(A' + B' + C)$$

Conversion of POS to SOP form

Example :

The POS function

$F = \Pi\, x, y, z\, (2, 3, 5)$

$= (x+y'+z)(x+y'+z')(x'+y+z')$

- For getting the SOP form the POS form, we have to change the symbol $\prod$ to $\sum$.
- After that, we write the numeric indexes of missing variables of the given Boolean function.

So the SOP form is:

$F = \Sigma\, x, y, z\, (0, 1, 4, 6, 7) = (x'y'z') + (x'y'z) + (xy'z') + (xyz') + (xyz)$

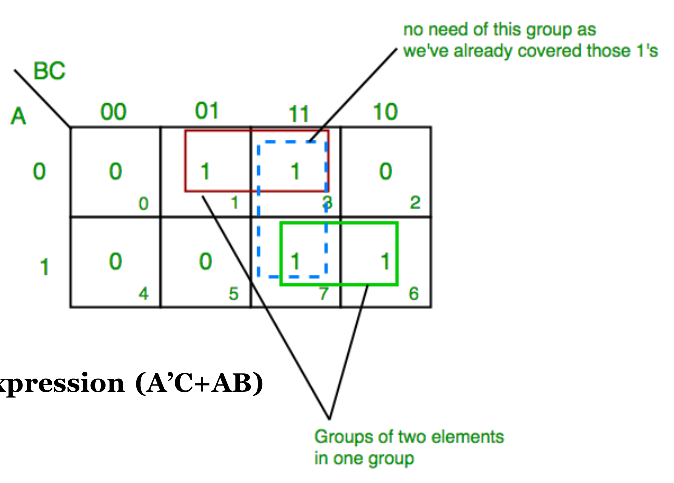
Introduction of K-Map (Karnaugh Map)

- In digital circuits and practical problems we need to find expression with minimumvariables.
- We can minimize Boolean expressions of 3, 4 variables very easily using K-map without using any Boolean algebra theorems.
- So it is known as minimization technique.
- It can take two forms SOP and POS according to the need of problem.
- K-Map is aa array of squares(cell) in which each squares represents a binary value of theinput variable.

Steps to solve expression using K-map

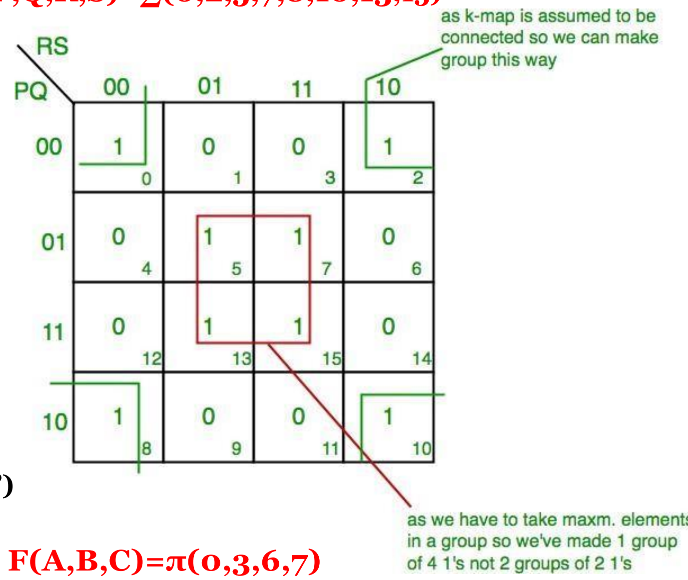
1. Select K-map according to the number of variables.
2. Identify minterms or maxterms as given in problem.
3. For SOP put 1's and for POS put 0's in blocks of K-map.
4. Make rectangular groups containing total terms in power of two like 2,4,8 and try tocover as many elements in one group.
5. From the groups made in step 5 find the product terms and sum them up for SOP form.

1. K-map of 3 variables   Z= ∑A,B,C(1,3,6,7)



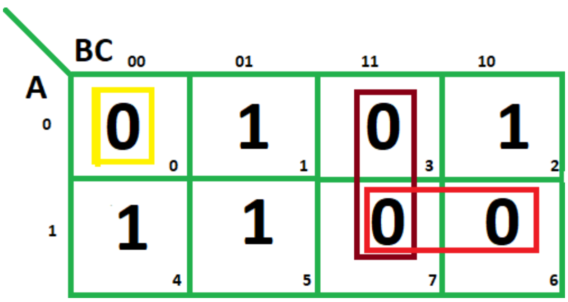
Final expression (A'C+AB)

K-map for 4 variables F(P,Q,R,S)=∑(0,2,5,7,8,10,13,15)



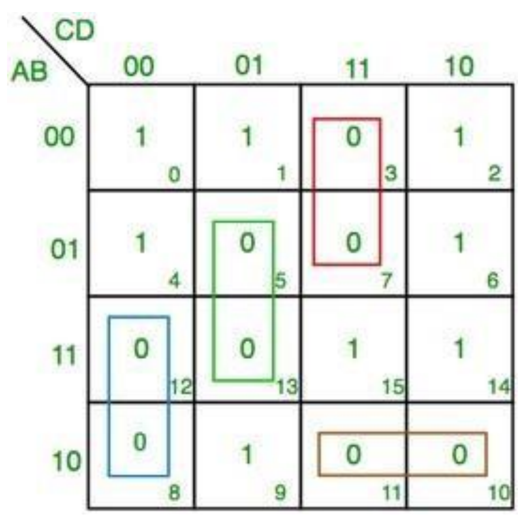
Final expression (QS+Q'S')

K-map of 3 variables – F(A,B,C)=π(0,3,6,7)



Final expression – (A' + B') (B' + C') (A + B + C)

K-map of 4 variables – F(A,B,C,D)=π(3,5,7,8,10,11,12,13)



Finally we express these as product – **(C+D'+B').(C'+D'+A).(A'+C+D).(A'+B+C')**

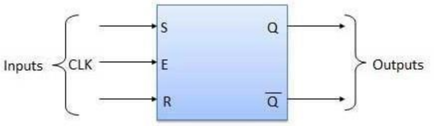
What is Flip Flop ?

- A circuit that has two stable states is known as a flip flop. A flip-flop is a memory element which is capable of storing one bit of information.
- It has two outputs, one for normal value and other for complement value.
- A flip flop is also known as bistable multivibrator.
- It is a sequential circuit which generally samples its inputs and changes its outputs only at particular instants of time and not continuously.
- There are 4 types of Flip-Flop :
  1) S-R FF
  2) J-K FF
  3) D - FF
  4) T - FF

S-R Flip Flop

- It is basically S-R latch using NAND gates with an additional **enable** input.
- It is also called as level triggered SR-FF.
- In short this circuit will operate as an S-R latch if E = 1 but there is no change in the output if E = 0.

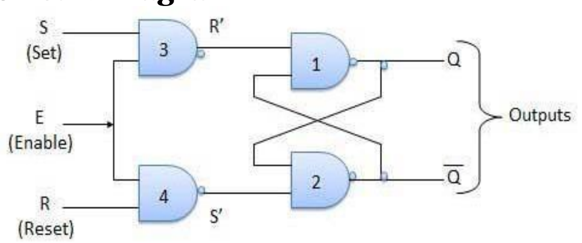
Block Diagram



Truth Table

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

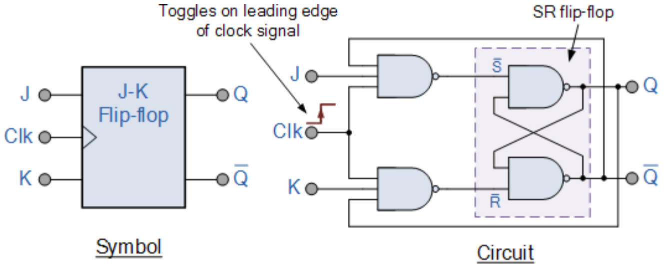
Circuit Diagram



J-K Flip-Flop

- The basic S-R NAND flip-flop circuit suffers from two basic switching problems.
  1. the Set = 0 and Reset = 0 condition (S = R = 0) must always be avoided
  2. if Set or Reset change state while the enable input is high the correct latching action may not occur.
- Then to overcome these two fundamental problems, **JK flip Flop** was developed.
- The inputs are labeled J and K in honor of the inventor of the device, Jack Kilby.

Circuit Diagram

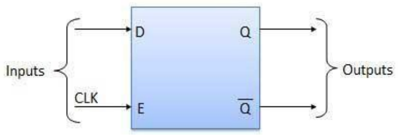


Truth Table

Clk	J	K	Q	Q'	State
1	0	0	Q	Q'	No change in state
1	0	1	0	1	Resets Q to 0
1	1	0	1	0	Sets Q to 1
1	1	1	-	-	Toggles

D Flip Flop

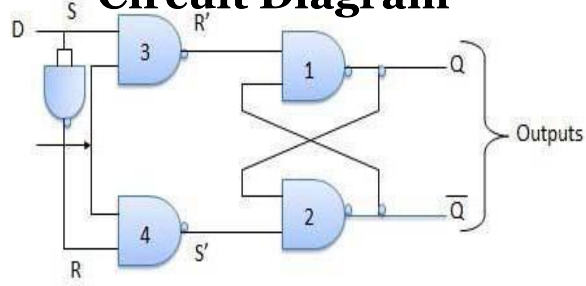
- D Flip Flop is known as Delay Flip Flop.
- D-FF is simple S-R latch with a NAND inverter connected between S and R inputs.
- It has only one input.
- The input data is appearing at the output after some time, due to this data delay between i/p and o/p, it is called delay flip flop.



Truth Table

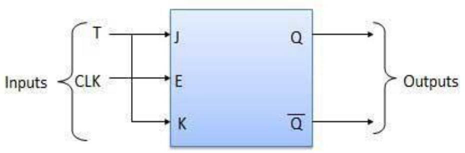
Inputs		Outputs		Comments
E	D	Q_{n+1}	$\overline{Q}_{n+1}$	
1	0	0	1	Rset
1	1	1	0	Set

Circuit Diagram



T Flip Flop

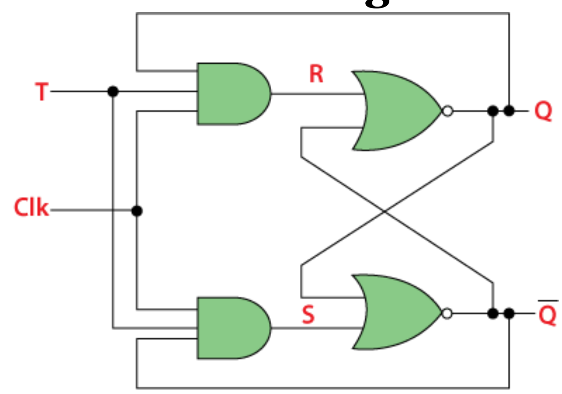
- Toggle flip flop is basically a JK flip flop with J and K terminals permanently connected together.
- It has only input denoted by **T** as shown in the Symbol Diagram.



Truth Table

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

Circuit Diagram

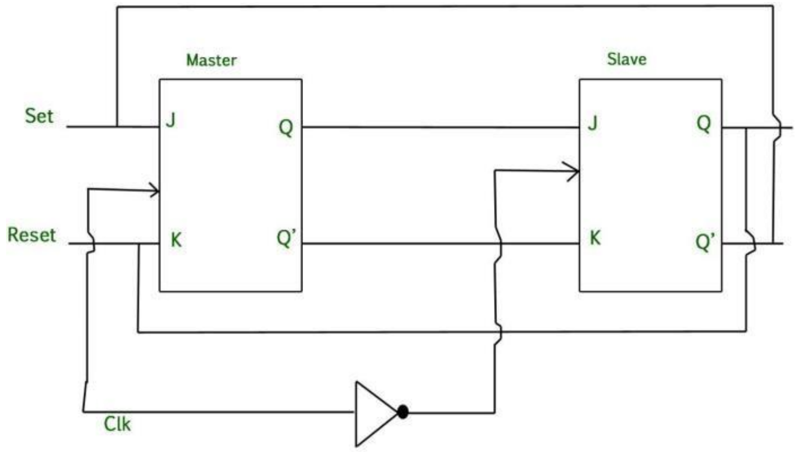


Race Around Condition In JK Flip-flop

- For J-K flip-flop, if J=K=1, and if clk=1 for a long period of time, then Q output will toggle as long as CLK is high, which makes the output of the flip-flop unstable or uncertain.
- This problem is called race around condition in J-K flip-flop.
- This problem (Race Around Condition) can be avoided by ensuring that the clock input is at logic "1" only for a very short time.
- This introduced the concept of **Master Slave JK** flip flop.

Master-Slave JK Flip Flop

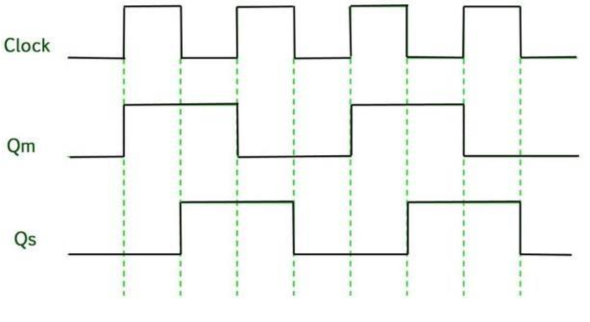
- The Master-Slave Flip-Flop is basically a combination oftwo JK flip-flops connected together in a series configuration.
- Out of these, one acts as the **"master"** and the other as a **"slave"**.
- The output from the master flip flop is connected to the two inputs of the slave flip flop whose output is fed back to inputs of the master flip flop.



Master-slave JK Flip-Flop

Timing Diagram of a Master flip flop

1. When the Clock pulse is high the output of master is high and remains high till the clock is low because the state is stored.
2. Now the output of master becomes low when the clock pulse becomes high again and remains low until the clock becomes high again.
3. Thus toggling takes place for a clock cycle.
4. When the clock pulse is high, the master is operational but not the slave thus the output of the slave remains low till the clock remains high.
5. When the clock is low, the slave becomes operational and remains high until the clock again becomes low.
6. Toggling takes place during the whole process since the output is changing once in a cycle.



REGISTER

- Shift Registers
  - Serial in Serial out
  - Serial in Parallel out
  - Parallel in Parallel out
  - Parallel in Serial out
- Bidirectional Shift Register

Digital Registers

- A set of several flip-flops which are used to store data is called register.
- A Register is a device which is used to store data or information.
- N flip flops are stores n-bits of data.
- It is a group of flip flops connected used to store multiple bits of data.

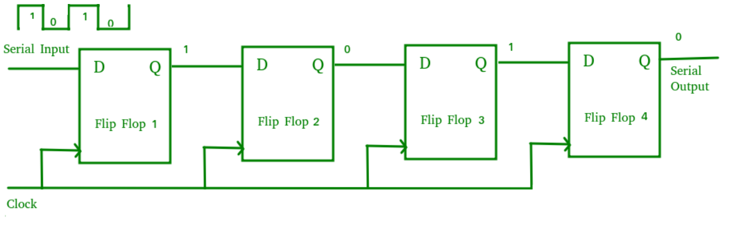
Shift registers

- Shift Register is a group of flip flops used to store multiple bits of data.
- The bits stored in such registers can be move within the registers.
- The registers which will shift the bits to left are called “Left Shift registers”.
- The registers which will shift the bits to right are called “Right Shift registers”.
- Shift registers are basically of 4 types.
  1. Serial In Serial Out shift register(SISO)
  2. Serial In parallel Out shift register(SIPO)
  3. Parallel In Serial Out shift register(PISO)
  4. Parallel In parallel Out shift register(PIPO)

Serial-In Serial-Out Shift Register (SISO)

- The shift register, which allows serial input and produces a serial output is known as SISO shift register.
- Since there is only one output, the data leaves only one bit at a time in a serial pattern,thus it is known as Serial-In Serial-Out Shift Register.

Logic circuit :

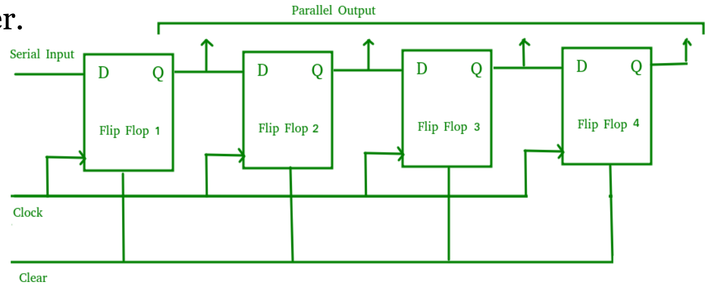


- The circuit consists of four D flip-flops which are connected in a serial manner.
- All flip-flops are synchronous with each other since the same clock signal is applied.

Serial-In Parallel-Out shift Register (SIPO)

- The shift register, which allows serial input and produces a parallel output is known asSIPO shift register.

Logic circuit :

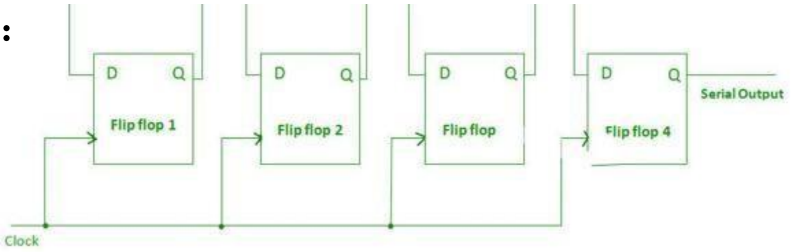


- The circuit consists of four D flip-flops which are connected.
- The clear (CLR) signal is connected in addition to the clock signal to all the 4 flip flopsin order to RESET them.
- The output of the first flip flop is connected to the input of the next flip flop and so on.

Parallel-In Serial-Out Shift Register (PISO)

- The shift register, which allows parallel input and produces a serial output is known asPISO shift register.

Logic circui:

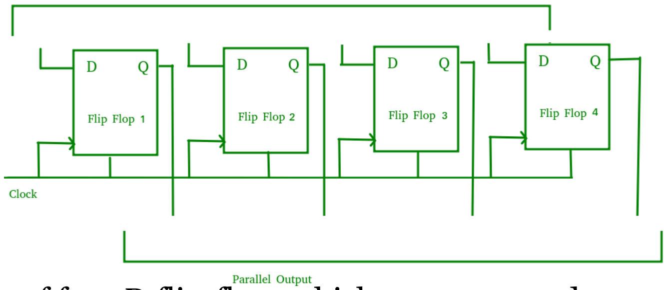


- The circuit consists of four D flip-flops which are connected.
- The clock input is directly connected to all the flip flops but the input data is connected
  individually to each flip flop through a multiplexer at the input of every flip flop.

Parallel-In Parallel-Out Shift Register (PIPO)

- The shift register, which allows parallel input and also produces a parallel output is known as Parallel-In parallel-Out shift register.

Logic circuit :

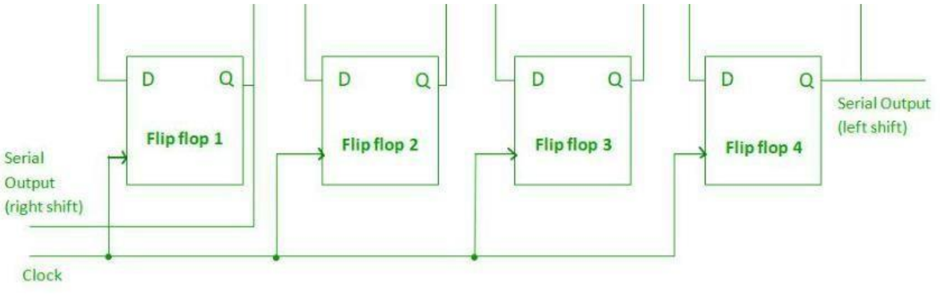


- The circuit consists of four D flip-flops which are connected.
- In this type of register, there are no interconnections between the individual flip-flopssince no serial shifting of the data is required.
- Data is given as input separately for each flip flop and in the same way, output alsocollected individually from each flip flop.

Bidirectional Shift Register

- Bidirectional shift registers are the registers which are capable of shifting the data either right or
  left shift depending on the mode selected.
- If the mode selected is 1(high), the data will be shifted towards the right direction and if themode selected is 0(low), the data will be shifted towards the left direction.

Logic circuit :



Unit – 04 : COUNTERS:

- Asynchronous counters
- Synchronous Counter
- Decade counter and its application
- Cascade Counter,
- Encoder & Decoder

Digital Counters

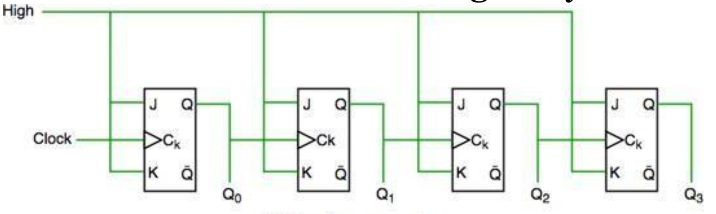
- Counter is a sequential circuit.
- A digital circuit which is used for a counting pulses is known counter.
- Counter is the widest application of flip-flops.
- It is a group of flip-flops with a clock signal applied.
- Counters are used in digital electronics for counting purpose, they can count specific eventhappening in the circuit.

Counters are of two types.

1. Asynchronous or ripple counters.
2. Synchronous counters.

Asynchronous or ripple counters

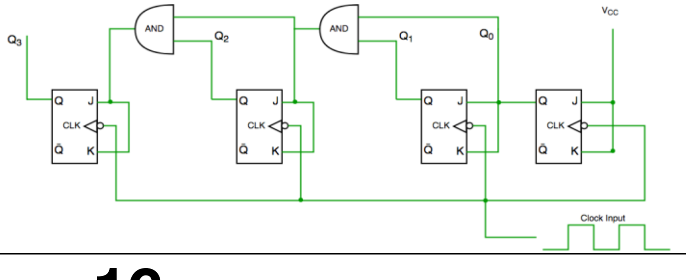
- It is a sequential circuit.
- It don't use universal clock, only first flip flop is driven by main clock and the clock input of rest of the following flip flop is driven by output of previous flip flops.
- It is also known as ripple counter.
- In the Asynchronous counter, the present counter's output passes to the input of the next counter.
- So, the counters are connected like a chain.
- The drawback of this system is that it creates the counting delay.



(a) Asynchronous counter

Synchronous counters

- It is also a sequential circuit.
- The synchronous counter is designed to remove this drawback asynchronous counter.
- The same clock pulse is passed to the clock input of all the flip flops.
- If the "clock" pulses are applied to all the flip-flops in a counter simultaneously, then such acounter is called synchronous counter.



Decade Counter

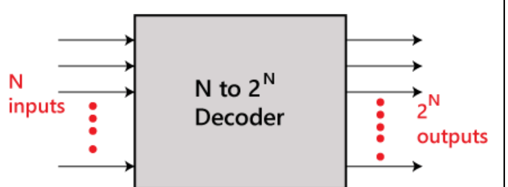
- It is an electronic circuit with a 4-bit binary output and an input clock signal.
- With each clock pulse the outputs to the next higher value, resetting to 0000 when the output is 1001 and a subsequent clock pulse is received.
- A decade counter counts ten different states and then reset toits initial states.
- A simple decade counter will count from 0 to 9.
- Decade counters are used in clock circuits, frequency dividers, state machines, and sequencers.

Input Pulses	D	C	B	A
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
0	0	0	0	0 (resets)

Cascade Counters

- The grouping of two or more counters together is called cascading.
- The counters which are made up of cascading of small counters together to the larger ones is called cascade counter.
- The cascade is the larger counters that can be built by combining of smaller counters together.
- With the help of cascading, increasing of both the modulus of the count sequence and also in the frequency division.
- Cascaded Counter can be either synchronous or asynchronous counters.

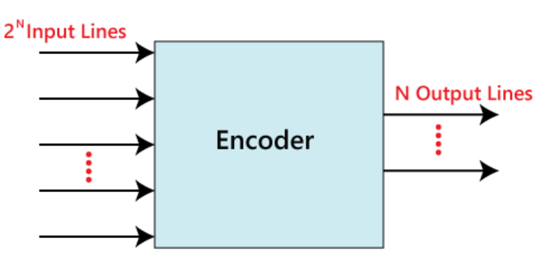
Decoder



- A decoder is a combinational circuit.
- It has n input and maximum $m=2^n$ outputs.
- It is also known as some to many circuit.
- Decoder is identical to a demultiplexer without any data input.
- It performs operations which are exactly opposite to those of an encoder.

Encoder

- A encoder is also a combinational circuit.
- Encoder is designed to perform the inverse operation of the decoder.
- An encoder has 2^n number of input lines and n number of output lines.
- It is also known as many to some circuit.



Unit-05

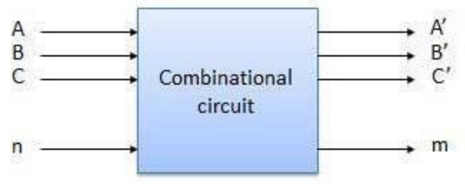
Combinational Circuits

- Combinational circuit is a circuit in which we combine the different logic gates in the circuit.
- Example adder, Subtractor, encoder, decoder, multiplexer and demultiplexer etc.

Some of the characteristics of combinational circuits are following :

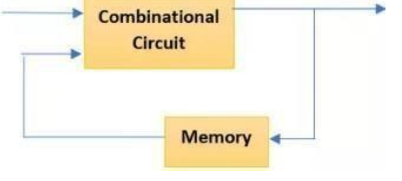
- The combinational circuit do not use any memory.
- The output of combinational circuit at any instant of time, depends only on the present at input.
- The previous state of input does not have any effect on the present state of the circuit.
- A combinational circuit can have an n number of inputs and m number of outputs.

Block diagram



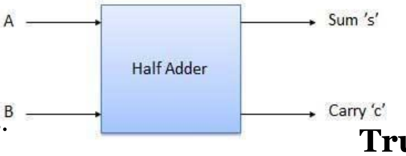
Combinational Circuits	Sequential Circuits
It is the combination of different gates.	It is the combination of different Flip-Flop.
It has no memeory element.	It has memeory element.
Its Output depends on only current input.	Its Output depends on current input as well as past output.
It is used for arithmetic circuits and boolean circuits.	It is mostly used to build memory devices.
It is easy to design and also easy to use.	Its design and use are complex.
It is fast in speed.	It is slow in speed.
Example: Multiplexer, demultiplexer, encoder, decoder, half-adder, full-adder etc.	**Example:** Flip-flops like SR flip-flop, JK flip-flop, T flip-flop, registers, counters, etc.

Block diagram



Half Adder

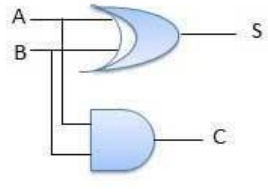
- Half adder is a combinational circuit with two inputs and two outputs.
- This circuit has two outputs **sum** and **carry**.
- It does not take any carry.
- It is designed to add two single bit binary numbers.



Truth Table

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

Circuit Diagram



Logical Expression :

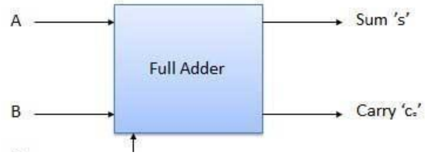
Sum = A XOR B = $A \oplus B$

Carry = A AND B = AB

Full Adder

- Full adder is developed to overcome the drawback of Half Adder.
- It can add two one-bit numbers, and carry.
- The full adder is a three input and two output combinational circuit.

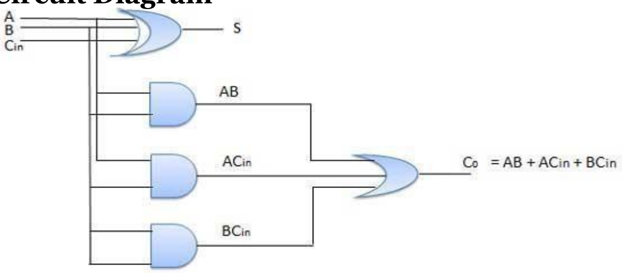
Block diagram



Truth Table

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

Circuit Diagram



Logical Expression :

SUM = (A XOR B) XOR Cin = $(A \oplus B) \oplus Cin$

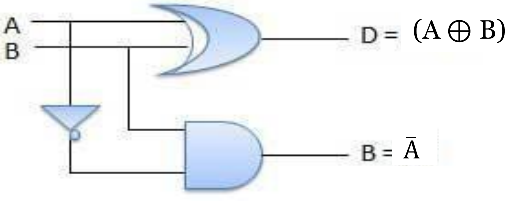
CARRY-OUT = $A.B + Cin(A \oplus B)$

= $AB + BC + AC$

Half Subtractors

- Half subtractor is a combination circuit with two inputs and two outputs (difference and borrow).
- It produces the difference between the two binary bits and an output (Borrow).
- In the subtraction (A-B), A is called as Minuend bit and B is called as Subtrahend bit.

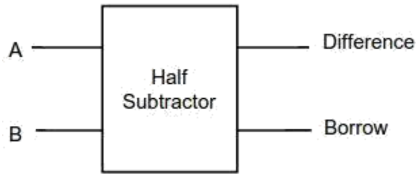
Circuit Diagram



Logical Expression

Difference = A XOR B

Borrow = $\bar{A}B$

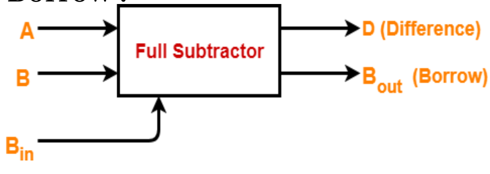


Truth Table

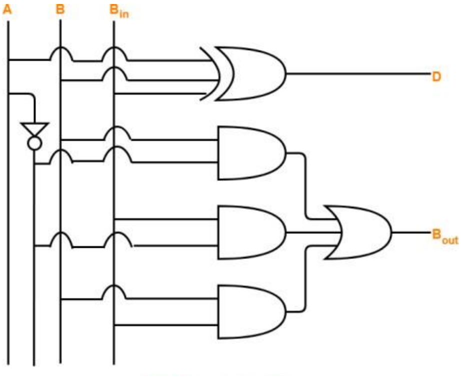
Inputs		Output	
A	B	(A – B)	Borrow
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0

Full Subtractors

- The disadvantage of a half subtractor is overcome by full subtractor.
- The full subtractor is a combinational circuit with three inputs and two output Diff. and Borrow'.



Circuit Diagram



Truth Table

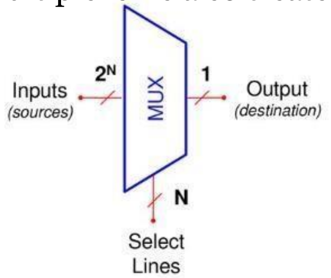
Inputs			Outputs	
A	B	$Borrow_{in}$	Diff	Borrow
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

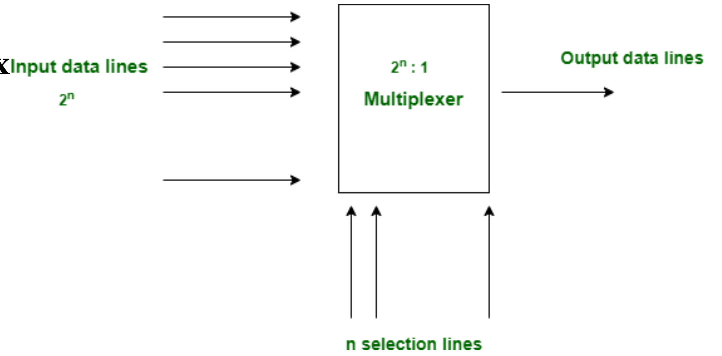
DIFFERENCE = $(A \oplus B) \oplus Cin$

BORROW = $\bar{A}B + \bar{A}Bin + BB\ in$

Multiplexer

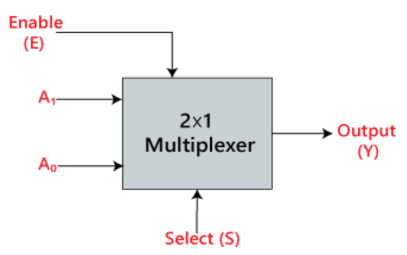
- A multiplexer is a combinational circuit.
- it has 2^n input lines and a single output line.
- Simply, the multiplexer is a multi-input and single-output combinational circuit.
- It is also known as data selector.
- A multiplexer is also treated as **Mux**





2×1 Multiplexer:

- In 2×1 multiplexer, there are only two inputs, i.e., A_0 and A_1, 1 selection line, i.e., S_0 and single outputs, i.e., Y.
- On the basis of the combination of inputs which are present at the selection line S^0, one of these 2 inputs will be connected to the output.
- The block diagram and the truth table of the 2×1 multiplexer are given below.

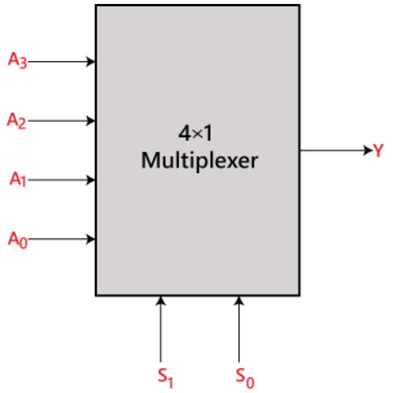


INPUTS	Output
S_0	Y
0	A_0
1	A_1

$$\boxed{Y=S_0'.A_0+S_0.A_1}$$

4×1 Multiplexer:

- In the 4×1 multiplexer, there is a total of four inputs, i.e., A_0, A_1, A_2, and A_3, 2 selection lines, i.e., S_0 and S_1 and single output, i.e., Y.
- On the basis of the combination of inputs that are present at the selection lines S^0 and S_1, one of these 4 inputs are connected to the output.
- The block diagram and the truth table of the 4×1 multiplexer are given below.

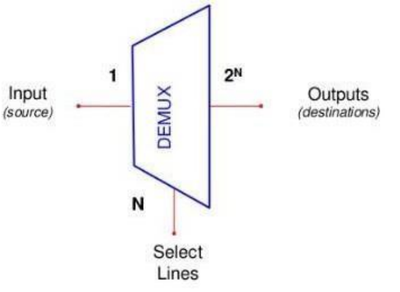


INPUTS		Output
S_1	S_0	Y
0	0	A_0
0	1	A_1
1	0	A_2
1	1	A_3

$$\boxed{Y=S_1'\,S_0'\,A_0 + S_1'\,S_0\,A_1 + S_1\,S_0'\,A_2 + S_1\,S_0\,A_3}$$

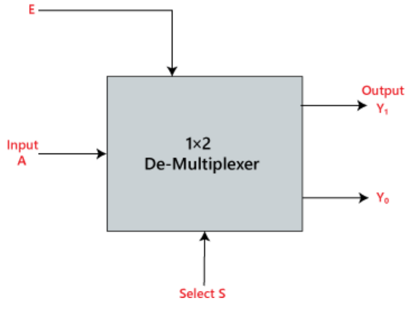
De-multiplexer

- A De-multiplexer is a combinational circuit.
- It has only 1 input line and 2^N output lines.
- Simply, the multiplexer is a single-input and multi-output combinational circuit.
- De-multiplexer is opposite to the multiplexer.
- It is also known as data distributor.
- De-multiplexer is also treated as **De-mux**.



1×2 De-multiplexer:

- In the 1 to 2 De-multiplexer, there are only two outputs, i.e., Y_0, and Y_1, 1 selection lines, i.e.,S_0, and single input, i.e., A.
- On the basis of the selection value, the input will be connected to one of the outputs.
- The block diagram and the truth table of the 1×2 multiplexer are given below.



INPUTS	Output	
S_0	Y_1	Y_0
0	0	A
1	A	0

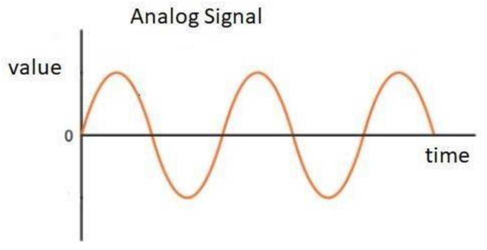
$Y_0 = S_0'.A$

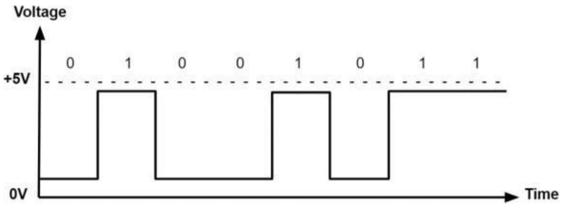
$Y_1 = S_0.A$

Unit – 6 : A/D AND D/A CONVERTERS

- Analog to digital convertor,
- Digital to Analog Convertor,
- ADC comparator,
- Dual Slope ADC,
- Successive ADC.

Signals :





What is converter ?

- A converter is a circuit that converts data into one form to another form.
- Those circuit which are used to convert analog to digital or vice-versa is called converter.
- There are two types of converter in digital electronics :

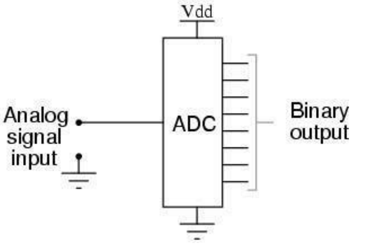
1. Analog to digital converter (ADC)
2. Digital to analog converter (DAC)

Analog to digital convertor(ADC) :

- ADC is a type of converter which converts the analog input signal to digital output signal.
- It is an electronic circuit which directly converts the continuous form of signal to discrete form.
- An ADC is used to convert an analogue signal such as voltage to a digital form so that it canbe read and processed by a microcontroller.
- It can be expressed as A/D or A-to-D or A-D or ADC.
- The analog to digital converter (ADC) carry out the inverse function of the DAC.

Types of Analog to Digital Converter(ADC) :

- Counter type(simplest)
- Successive Approximation
- Flash ADC
- Sigma Delta

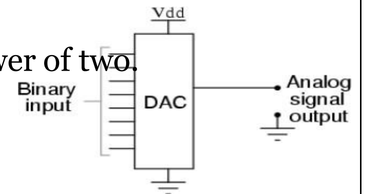


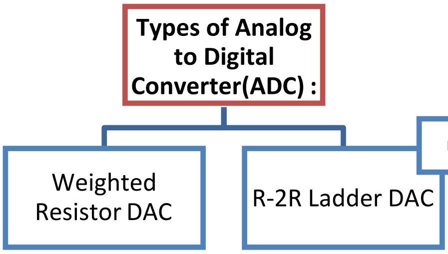
Application of ADC :

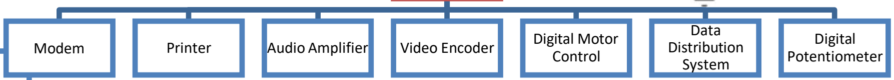
- Used in computer to convert the analog signal to digital signal.
- Used in cell phones.
- Used in scanner
- Used in microcontrollers.
- Used in digital voltmeter.
- Used in voice recorder.
- Used in music reproduction technology etc.

Digital to Analog Converter (DAC) :

- DAC is a type of converter which converts the digital input signal to analog output signal.
- It is an electronic circuit which directly converts the discrete form of signal to continuousform.
- It can be expressed as D/A or D-to-A or D-A or DAC.
- The digital to converter (DAC) carry out the inverse function of the ADC.
- The digital signal is represented with a binary code, which is a combination of bits 0 and 1.
- In general, the number of binary inputs of a DAC will be a power of two.







ADC comparator :

- An ADC comparator is a 1-bit analog to digital converter.
- If the non-inverting input is greater than that to the inverting input, the output is a logical 1.
- If the non-inverting input is less than that to the inverting input, the output is a logical 0.
- We have the key element for asking "is the signal above or below a threshold level ?

Successive ADC

- It is a type of analog to digital converter.
- It is used to convert analog signal into digital signal.
- It is designed to reduce the conversion and to increase speed of operation.

Advantages :

- Conversion time is very small.
- Conversion time is constant and independent of the amplitude.

Disadvantages:

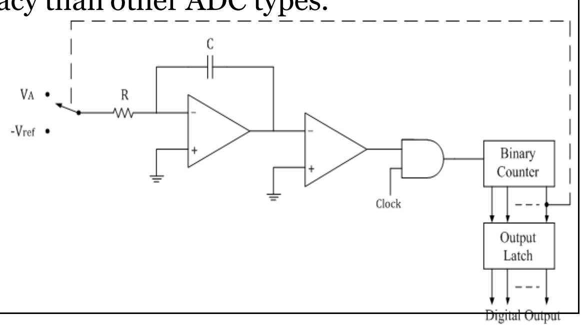
- Circuit is complex.
- The conversion time is more compared to flash type ADC.

Dual Slope ADC

- It is a type of analog to digital converter.
- A dual slope ADC produces an equivalent digital output for a corresponding analog input by usingtwo (dual) slope technique.
- The integrator of a dual-slope has a switch at its input side which can either connect to a reference voltage or an input voltage.
- Hence it is called dual slope A to D converter.
- It provides better noise immunity and good accuracy than other ADC types.

Applications

- Temperature Transducers
- Digital multimeters



Unit – 7 : MEMORIES AND DISPLAY DEVICES

- Memory Unit
- Concept of memories using registers
- Primary Memory
- Secondary Memory
- Static and Dynamic Memory
- LCD, LED,
- Seven Segment Display, Basic operation and Applications,
- Dot Matrix display.

Difference between LED and LCD.

LED	LCD
LED stands for Light Emitting Diode.	LCD stands for Liquid Crystal Display.
It has better response time.	It has slower response time.
LED consumes more power.	It consumes less power.
LED delivers good picture quality.	LCD also delivers the good picture quality but less than LED.
LED is costlier than LCD.	While it is less costlier than LED.
LED have wider viewing angle than the LCD.	While in LCD, the wide angle decreases with 30 degrees from the center in the image then the contrast ratio.

Seven Segment Displays :

- Seven segment displays are the output display device.
- We can display number from 0 to 9 using seven segment display.
- It is used in digital clocks, basic calculators, electronic meters, and other electronicdevices.
- It consists of seven segments of light emitting diodes which is assembled like numerical 8.

Working of Seven Segment Displays :

- The number 8 is displayed when the power is given to all the segments and if youdisconnect the power for 'g', then it displays number 0.
- If the power at different pins can be applied at the same time, so we can display numericalfrom 0 to 9.
- Since seven segment displays can not form alphabet like X and Z, so it can not be used foralphabet.
- It can form alphabets A, B, C, D, E, and F, so they can also used for representing hexadecimal digits.

Applications of Seven Segment Displays :

Common applications of seven segment displays are in:

- Digital clocks
- Clock radios
- Calculators
- Wristwatchers
- Speedometers
- Motor-vehicle odometers
- Radio frequency indicators

Dot-matrix display :

- A dot-matrix display is a output display device.
- It is a low cost electronic digital display device that displays information on machines suchas clocks, watches, calculators, and many other display devices of limited resolution.
- The display consists of a dot matrix of lights arranged in a rectangular configuration suchthat by switching on or off selected lights.
- These displays are normally created with LCD or LED.
- It is created in Germany by Rudolf Hell in 1925.

Application of Dot Matrix Display :

- Showing advertisement information in shops,
- clocks,
- railway departure indicators,
- bus routes, etc

Unit – 8 : MICROPROCESSORS

- Evaluation of microprocessors,
- 8085 architecture,
- 8085 pin diagram
- 8085 flag register & timing diagram,
- instruction sets,
- addressing modes,
- 8086 architectures,
- 8086 pin diagram,
- addressing modes

What is Microprocessor ?

- A microprocessor is an electronic component that is used by a computer to do its work.
- It is a single integrated circuit chip containing millions of very small components including transistors, resistors, and diodes that work together.

Technology Used :

- Transistor-Transistor Logic (TTL)
- Emitter Coupled Logic (ECL)
- Complementary Metal-Oxide Semiconductor (CMOS)
- N-channel metal-oxide semiconductor (NMOS)
- High-speed Metal Oxide Semiconductor(HMOS)

Classification of Microprocessors :

Based on size of data bus

- 4-bit microprocessor
- 8-bit microprocessor
- 16-bit microprocessor
- 32-bit microprocessor
- 64-bit microprocessor

Based on architecture :

- Reduced Instruction Set Computer (RISC) processors
- Complex Instruction Set Computer (CISC) processors

RISC	CISC
Focus on software	Focus on hardware
Fixed sized instructions	Variable sized instructions
Can perform only Register to Register Arithmetic operations	Can perform REG to REG or REG to MEM or MEM to MEM
Code size is large	Code size is small
An instruction executed in a single clock cycle	Instruction takes more than one clock cycle

Evaluation/Generations of microprocessors :

- Generation in computer terminology is a change in technology a computer is being used.
- There are five generations of microprocessor till date :

First-generation :

- The period of first generation of 4-bit microprocessor from 1971 to 1972
- Processors like INTEL 4004/4040 etc.

Second generation

- The period of second generation of 8-bit microprocessors from 1973 to 1978.
- INTEL 8085 Motorola 6800 and 6801 etc came into existence.

Third generation

- The period of third generation of 16-bit processors from 1979 to 1980.
- INTEL 8086/80186/80286 Motorola 68000 68010 etc.

Fourth generation

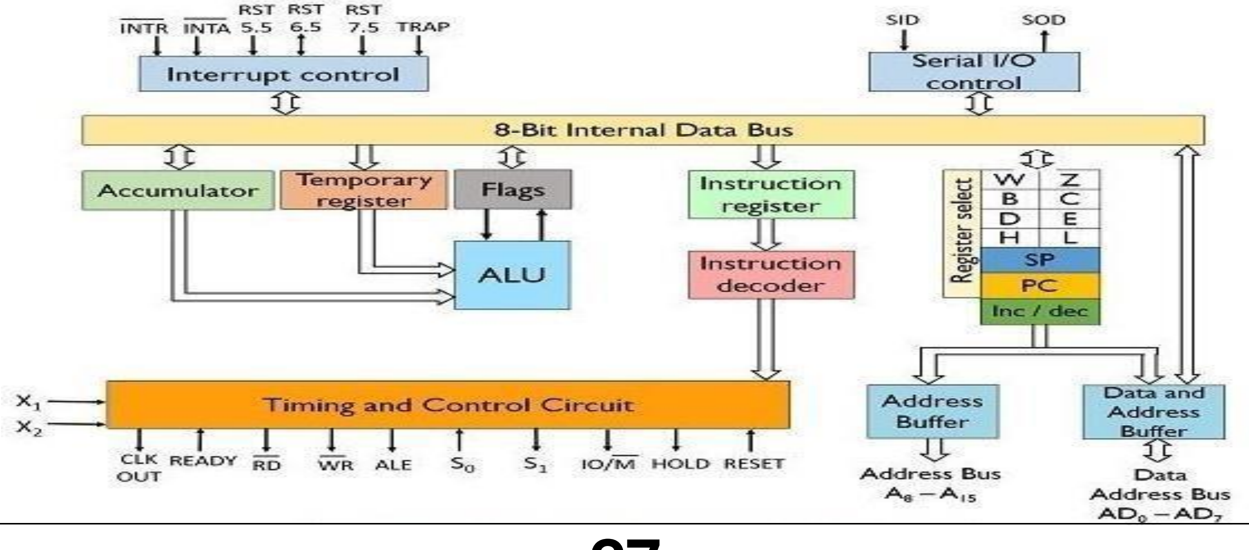
- The period of fourth-generation of 32-bit processors from 1981 to 1995.
- INTEL 80386 and Motorola 68020 are some of the popular processors of this generation.

Fifth-generation

- From 1995 till now we are in the fifth generation.
- 64-bit processors like PENTIUM, Celeron, dual, quad, and octa-core processors came into existence.

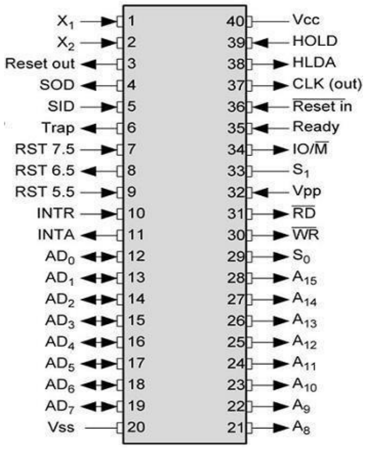
Microprocessor - 8085 Architecture

- It is an 8-bit microprocessor designed by Intel in 1977 using NMOS technology.
- It has the following configuration
  - 8-bit data bus
  - 16-bit address bus, which can address upto 64KB
  - Six 8-bit registers arranged in pairs: BC, DE, HL
  - Requires +5V supply to operate at 3.2 MHz single phase clock
  - It is a 40-pin IC package.
  - It is used in washing machines, microwave ovens, mobile phones, etc.



Pin diagram of 8085 microprocessor :

- 8085 is a 8-bit microprocessor having 40 pin.
- It has 16-bit address bus and 8-bit data bus.



The pins of a 8085 microprocessor can be classified into seven groups :

- A15 - A8, it carries the most significant 8-bits of memory/IO address.
- AD7-AD0, it carries the least significant 8-bit address and data bus.
- Three control signals are RD, WR & ALE.
- Three status signals are IO/M, S0 & S1.
- There are 2 power supply signals – VCC & VSS.VCC indicates +5v power supply and VSS indicates ground signal.
- There are 3 clock signals, i.e. X1, X2, CLK OUT.
- There are 5 interrupt signals, i.e. TRAP, RST 7.5, RST 6.5, RST 5.5, and INTR.

Flag Register :

- The flag register is a status register and it is used to check the status of the currentoperation which is

  being carried out by ALU.
- It is a 8-bit register, out of which 5-bits are important and the rest of 3-bits are Don't Care.
- The flag register is a dynamic register because after each operation to check whether theresult is zero,

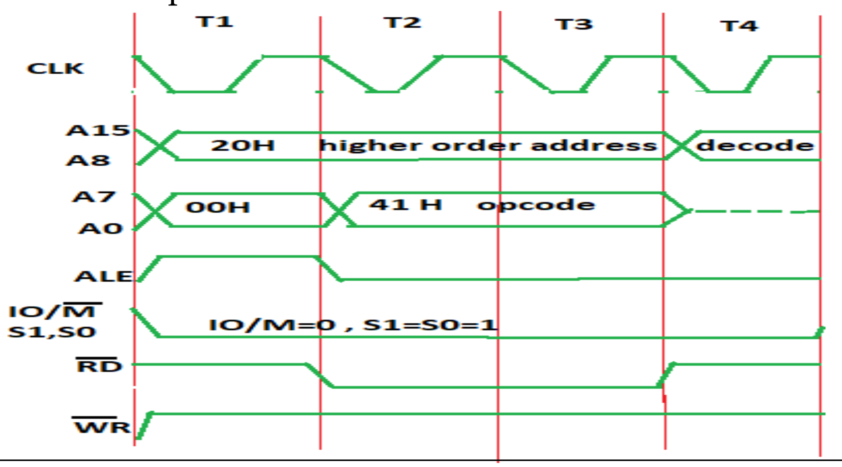
  positive or negative whether there is any overflow occurred or not.

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
S	Z		AC		P		CY

1. **S = Sign Flag,** S=1, if MSB of ALU result is 1.
2. **Z = Zero Flag,** Z=0, if ALU result is zero.
3. **AC = Auxiliary Carry Flag** AC=1, if carry is occurs from lower toupper nibble
4. **P = Parity Flag** P=1, if ALU result is even parity.
5. **CY = Carry Flag** CY=1, if carry is occurs.

Timing Diagram of 8085 microprocessor :

- Timing Diagram of 8085 microprocessor is a graphical representation of T- states.
- It represents the execution time taken by each instruction in a graphical format.
- The execution time is represented in T-states.



Instruction Set of 8085

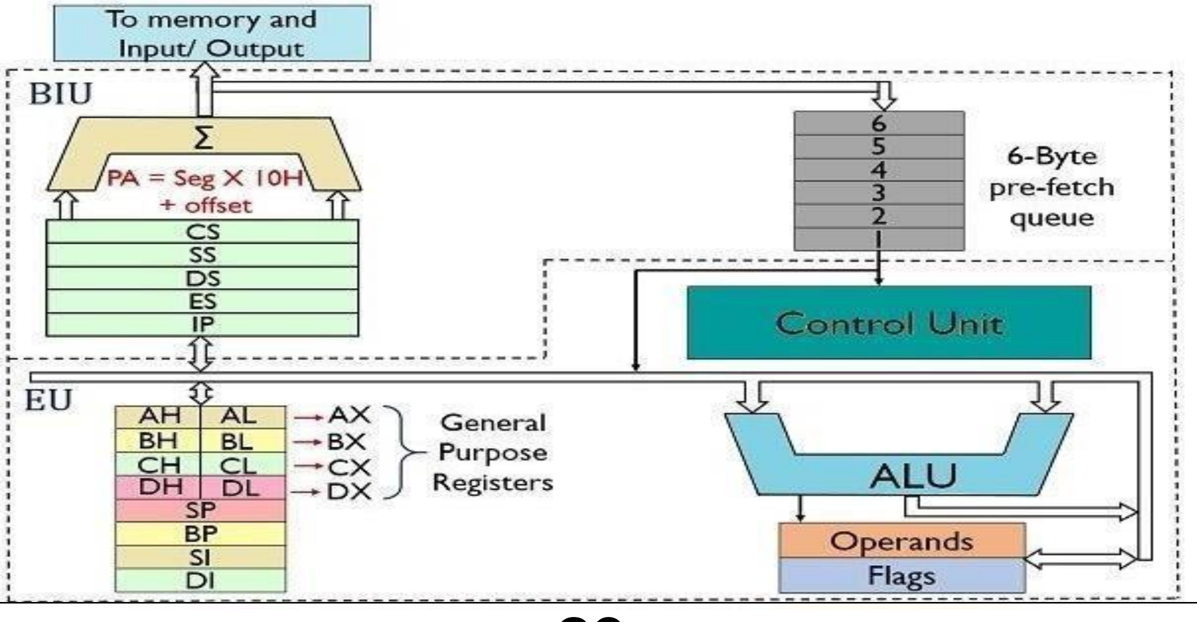
- An instruction is a binary pattern designed inside a microprocessor to perform a specificfunction.
- The entire group of instructions that a microprocessor supports is called Instruction Set.
- 8085 microprocessor has 246 instructions.
- Each instruction is represented by an 8-bit binary value.
- These 8-bits of binary value is called Op-Code or Instruction Byte.

Addressing modes in 8085 microprocessor :

- The way of specifying data to be operated by an instruction is called addressing mode.
- In 8085 microprocessor there are 5 types of addressing modes :
  1. **Immediate Addressing :** In immediate addressing mode the source operand is always data.
  2. **Register Addressing :** Data is copied from one register to another register.
  3. **Direct Addressing Mode :** Data is directly copied from the given address to the register.
  4. **Indirect Addressing Mode :** The data is transferred from the address pointed by the data in a register to other register.
  5. **Implied Addressing Mode :** This mode doesn't require any operand. The data isspecified by opcode itself.

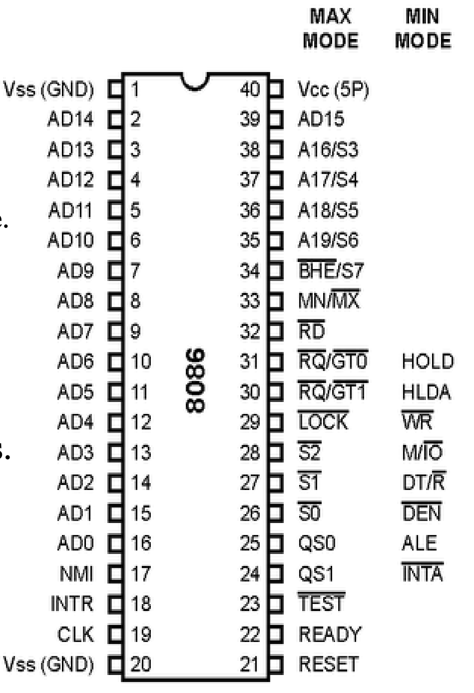
8086 microprocessor :

- Intel 8086 microprocessor is the enhanced version of Intel 8085 microprocessor.
- It was designed by Intel in 1976.
- The 8086 microprocessor is a 16-bit, N-channel, HMOS microprocessor.
- HMOS is used for "High-speed Metal Oxide Semiconductor".
- It is a 40-pin IC package. The type of package is DIP (Dual Inline Package).
- Intel 8086 uses 20 address lines and 16 data- lines.
- It can directly address up to 2^{20} = 1 Mbyte of memory.
- 8086 is designed to operate in two modes, i.e., Minimum and Maximum mode.



8086 Pin diagram :

- It is available in 40 pin DIP chip.
- It uses a 5V DC supply for its operation.
- The 8086 uses 20-address bus.
- It has a 16-line data bus.
- The 20 lines of the address bus operate in multiplexed mode.



Addressing modes of 8086 :

- The way for which an operand is specified for an instruction in the accumulator is called **addressingmode**.
- The 8086 microprocessors have 8 addressing modes.
- Two addressing modes have been provided for instructions which operate on register or immediatedata.
- **These two addressing modes are :**
  1) Register Addressing &
  2) Immediate Addressing.
- The remaining 6 addressing modes specify the location of an operand which is placed in a memory.
- **These 6 addressing modes are :**
  3) Register Indirect Addressing mode
  4) Direct Addressing mode
  5) Indexed Addressing mode
  6) Base Relative Addressing mode
  7) Base Indexed Addressing mode

8085 Microprocessor	8086 Microprocessor
It is an 8-bit microprocessor.	It is a 16-bit microprocessor.
It has a 16-bit address line.	It has a 20-bit address line.
It has a 8-bit data bus.	It has a 16-bit data bus.
The memory capacity is 64 KB.	The memory capacity is 1 MB.
It has five flags.	It has nine flags.
8085 microprocessor does not support memory segmentation.	8086 microprocessor supports memory segmentation.
It has no minimum or maximum mode.	It has minimum and maximum modes.
It contains about 6500 transistor.	It contains about 29000 in size.
The cost of 8085 is low.	The cost of 8086 is high.