LOGIC GATES AND FLIP FLOPS

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* **Logic Gate :—**

Logic gate is a digital device or circuit which take some input and give suitable output using suitable logic rule.

Input ⟶ $\boxed{\text{Logic Rule}}$ ⟶ Output

* In logic gate world we use two digit they are 0 and 1.

0 means → off, False, No, Low, disable
1 means → on, True, Yes, High, enable

* **Truth Table (TT) :—**

The tabular representation of possible input and output.

Classification of logic gate :—

Logic Gate
- Basic gate
  - OR gate
  - AND gate
  - NOT gate
- Universal gate
  - NAND gate
  - NOR gate
- Derived gate
  - X-OR gate
  - X-NOR gate

* Logic gate operator :-

→ OR operator → (+)
→ AND operator → (·)
→ NOT operator → ($\bar{A}$)

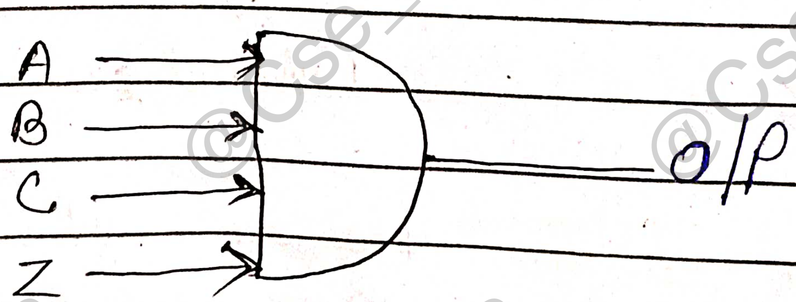
1) AND GATE :-

→ It is a type of basic gate.
→ It has many input and one output.
→ If we give A, B, C.... in the input then we get A·B·C....... in the O/P.
→ Here, dot (·) means ANDing.
→ If we assume input as a switch then ANDing means all switch connected in series.

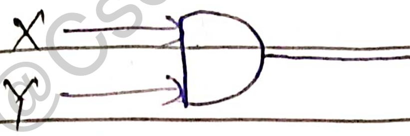
(Input) A, B, C, D → AND GATE → Output

Symbol :-

I/P :-



Two input AND gate :—

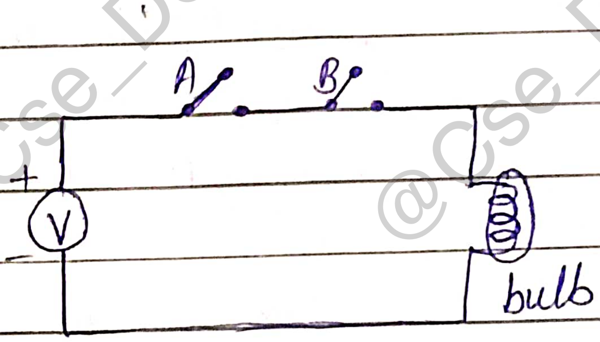


O/P = X · Y.

Truth Table

Input		Output
X	Y	X·Y
0	0	0
0	1	0
1	0	0
1	1	1

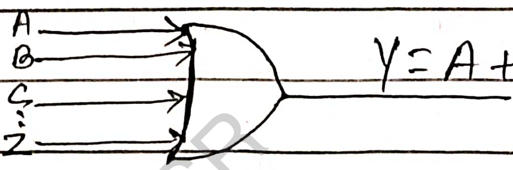
Circuit Diagram



OR GATE :—

It is a type of basic gate.
It has many input and one output.
If we give A, B, C, ... in the input then we get A+B+C+ ... in the output.
Here plus (+) sign indicate all input act as a switch and they are connected in parallel.

Symbols :—



$Y = A + B + C + \dots + Z$

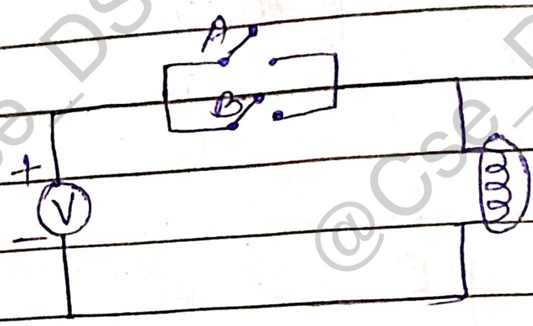
Two input OR gate :-

O/P = A+B

Truth Table

Input		Output
A	B	A+B
0	0	0
0	1	1
1	0	1
1	1	1

Circuit Diagram

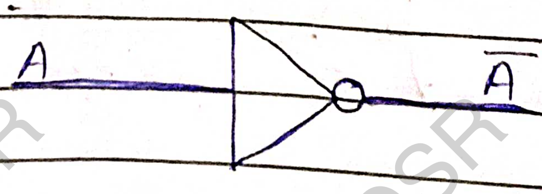


3) **NOT GATE :-**

- It is the type of basic gate.
- It has one input and one output.
- If we give A in the input then we get $\bar{A}$ in the output.
- The main work of this logic gate to invert the input.
- So, NOT gate is also called INVERTER.

Symbol :-

I/P

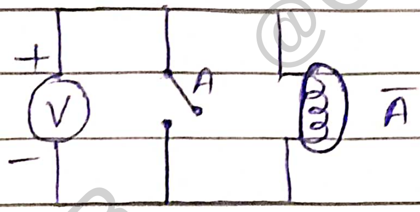


O/P

Truth Table

Input	Output
A	$\bar{A}$
0	1
1	0

Circuit Diagram



* Basic Gate :-

→ AND, OR and NOT gates are called basic gate.

→ These gates are called basic gate because all logic circuit made by help of these logic gate.

* Universal Gate :-

→ By the help of NAND gate and NOR gate, we can made every type of logic gate and logic circuit.

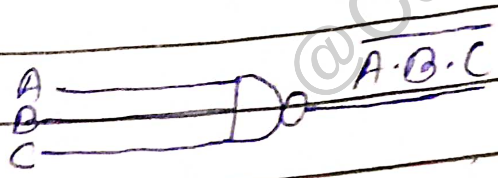
4) NAND Gate :-

→ It is the type of universal gate.

→ It is the combination of two basic logic gate. They are NOT gate and AND gate.

→ It has many Input and one output.

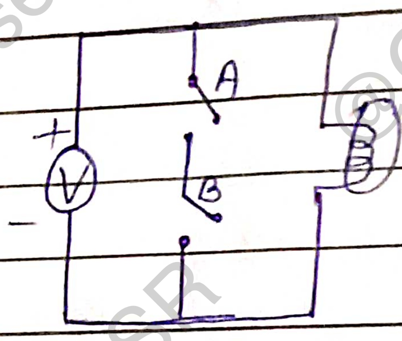
→ If we give A, B, C .... in the input then we get $\overline{A \cdot B \cdot C \ldots}$ in the output.



Truth Table

Input		Output
A	B	$\overline{A \cdot B}$
0	0	1
0	1	1
1	0	1
1	1	0

Circuit Diagram



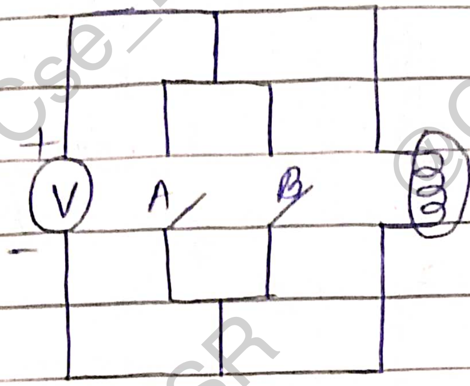
5) NOR Gate :-

→ It is the type of universal gate.
It is the combination of two basic logic gate.
They are NOT gate and OR gate.
It has many input and one output.
If we give A, B, C .... in the input, then we get $\overline{A+B+C \ldots}$ in the output.

Truth Table

Input		Output
A	B	$A+B$
0	0	1
0	1	0
1	0	0
1	1	0

Circuit Diagram



X-OR, Exclusive OR, Ex-OR :—

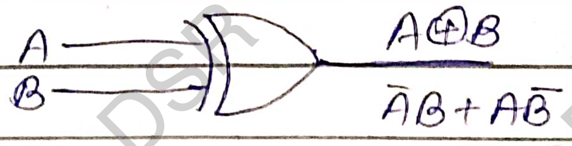
It is the type of special gate.
It is the combination of AND, OR and NOT.
If we give A, B in the input then we get $\bar{A}B + A\bar{B}$.

Exclusive OR

$\bar{A}B + A\bar{B}$ is written as $A \oplus B$

i.e. $\bar{A}B + A\bar{B} = A \oplus B$

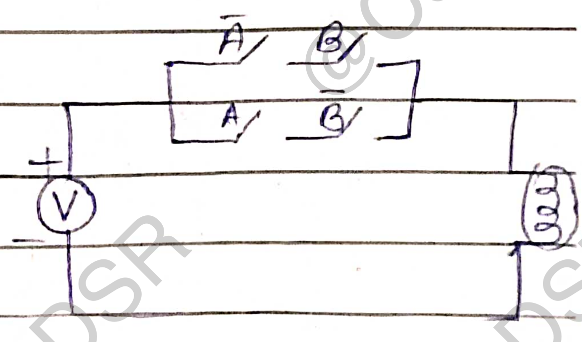
Symbol :—



Truth Table

A	B	$A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

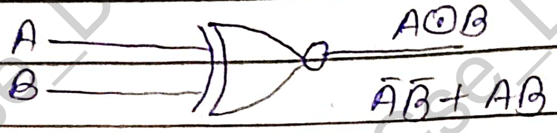
Circuit Diagram



7) X-NOR, Exclusive NOR, Ex-NOR :-

→ It is the type of special gate.
→ It is the combination of AND, OR and NOT.
→ If we give A, B in the input then we get $\bar{A}\bar{B} + AB$.
→ $\bar{A}\bar{B} + AB$ is written as $A \odot B$. ← Exclusive NOR

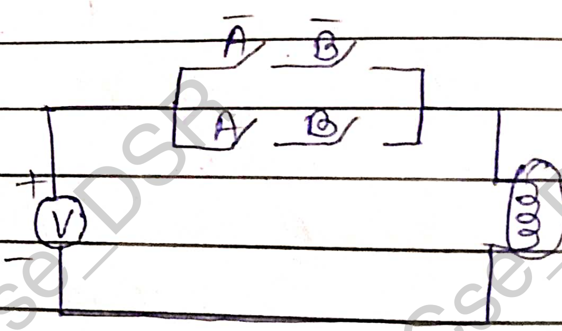
i.e, $\bar{A}\bar{B} + AB = A \odot B$



Truth Table

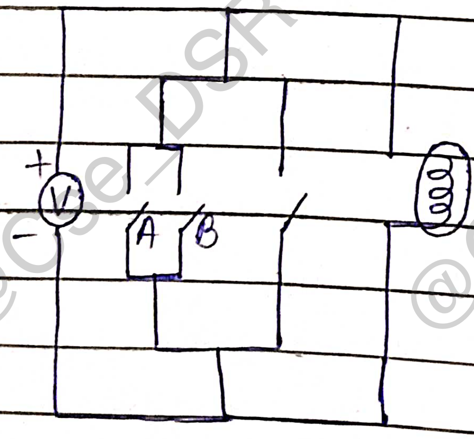
A	B	A⊙B
0	0	1
0	1	0
1	0	0
1	1	1

Circuit Diagram



H.W

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



(2) $Y = \overline{AB + \bar{A}C}$

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Note:—

i) To make any equivalent electrical circuit, we should mind the followings:—

a) If given expression is $A \cdot B$, then both are connected in a series and it connect with bulb in series also.

b) If expression is $\overline{A \cdot B}$, then both will be connected in series with each other and whole will be connected in parallel with bulb.

ii)

a) If expression is $A + B$, then it will be connected to each other in parallel and whole will be connected with the bulb in series.

If expression is $\overline{A + B}$, then it will be connected to each other in parallel and whole will be connected with bulb in parallel also.

* De-Morgan's Theorem :-

It states that :-

i) The complement of sum is equal to product of complements.

i.e,

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

ii) The complement of product is equal to sum of complements.

i.e,

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

Proof (Using truth table) :-

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

Now, from above that table, it is clear that

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

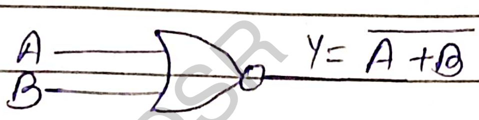
and $\overline{A \cdot B} = \overline{A} + \overline{B}$

Proved

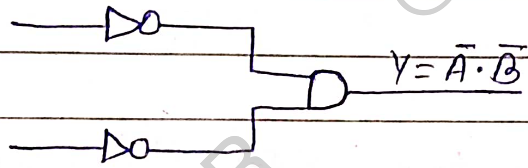
Proof - II (Using gate)

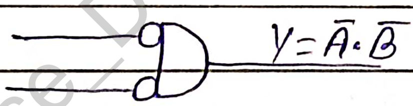
1. $\overline{A+B} = \bar{A}\cdot\bar{B}$

$LHS = \overline{A+B}$



$RHS = \bar{A}\cdot\bar{B}$

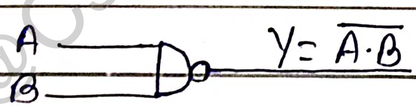




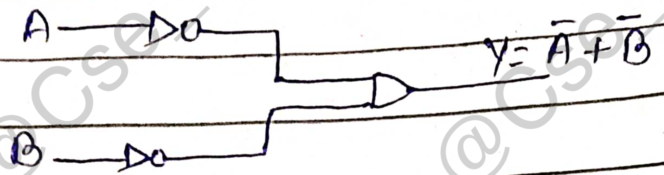
From the above decision, it is clear that NOR gate is replaced by inverted AND gate, that is negative AND gate.

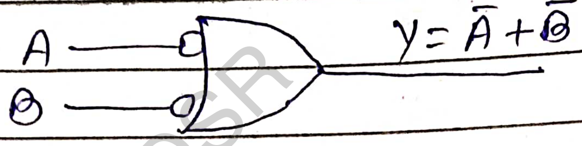
2. $\overline{A\cdot B} = \bar{A}+\bar{B}$

$LHS = \overline{A\cdot B}$



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





NAND gate can be replaced by negative OR gate or inverted OR gate.

Q. Prove that $AB + \bar{A}C = AB + \bar{A}C + BC$
{this is known as concensus theorem)

$RHS = AB + \bar{A}C + BC$
multiplying by $(A+\bar{A})$ into BC

$= AB + \bar{A}C + BC(A+\bar{A})$
$= AB + \bar{A}C + ABC + \bar{A}BC$
$= AB + ABC + \bar{A}C + \bar{A}BC$

we know that
$1 + C = 1$
and $1 + B = 1$
$\Rightarrow AB(1) + \bar{A}C(1)$
$= AB + \bar{A}C = LHS$

Proved

2^{nd} proof :-

$$LHS = AB + \bar{A}C$$

Now, multiplying the AB with $(1+C)$ and $\bar{A}C$ with $(1+B)$

$$= AB(1+C) + \bar{A}C(1+B)$$
$$= AB + ABC + \bar{A}C + \bar{A}BC$$
$$= AB + \bar{A}C + ABC + \bar{A}BC$$
$$= AB + \bar{A}C + BC(A+\bar{A})$$
$$= AB + \bar{A}C + BC(1) \quad \{\because A + \bar{A} = 1\}$$
$$= AB + \bar{A}C + BC = RHS$$

Proved

Q. Prove that $AB + AB\bar{C} + ABD = AB$ (Redundency theorem)

$$LHS = AB + AB\bar{C} + ABD$$
$$= AB(1 + \bar{C} + D)$$
$$= AB(1+D)$$
$$= AB = RHS$$

Proved

H.W

Q. Prove that :-

(i) $A \oplus B = \overline{A \odot B}$

(ii) $A\bar{B} + B = A + B$

(iii) $A \oplus B = \bar{A} \oplus \bar{B}$

(iv) $\overline{A \oplus B} = \bar{A} \oplus B = A \oplus \bar{B}$

(v) $B \oplus (B \oplus AC) = AC$

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Some formulae :-

For XOR gate :-

(I) $A \oplus A = 0$

(II) $A \oplus \bar{A} = 1$

(III) $A \oplus 1 = \bar{A}$

(IV) $A \oplus 0 = A$

For XNOR gate :-

(I) $A \odot A = 1$

(II) $A \odot \bar{A} = 0$

(III) $A \odot 1 = A$

(IV) $A \odot 0 = \bar{A}$

(I) $1 + A = 1$

(II) $1 + \bar{A} = 1$

(III) $A + \bar{A} = 1$

Q. Prove that :-

(a) $A \oplus B = \overline{A \odot B}$

$LHS = A \oplus B$

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

$RHS = \overline{A \odot B}$

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

$= \overline{\bar{A}\bar{B}} \cdot \overline{AB}$ (using Demorgon's theorem)

$= (\bar{\bar{A}} + \bar{\bar{B}}) \cdot (\bar{A} + \bar{B})$

$= (A + B) \cdot (\bar{A} + \bar{B})$

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

$= 0 + A\bar{B} + \bar{A}B + 0$

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

$= LHS$

Proved

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

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

$= A\bar{B} + B(1 + A)$

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

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

$= A + B$

$= RHS$

Proved

(c) $A \oplus B = \bar{A} \oplus \bar{B}$

LHS $= A \oplus B$

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

RHS $= \bar{A} \oplus \bar{B}$

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

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

$=$ LHS *Proved*

(d) $\overline{A \oplus B} = \bar{A} \oplus B = A \oplus \bar{B}$

LHS $= \overline{A \oplus B}$

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

$= (\bar{\bar{A}} + \bar{B}) \cdot (\bar{A} + \bar{\bar{B}})$

$= (A + \bar{B}) \cdot (\bar{A} + B)$

$= A \cdot \bar{A} + AB + \bar{A}\bar{B} + B \cdot \bar{B}$

$= 0 + AB + \bar{A}\bar{B} + 0$

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

$RHS_1 = \bar{A} \oplus B$

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

$= AB + \bar{A}\bar{B} =$ LHS

$RHS_2 = A \oplus \bar{B}$

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

$= AB + \bar{A}\bar{B} = LHS = RHS_1$

Hence, $LHS = RHS_1 = RHS_2$ *Proved*

(e) $B \oplus (B \oplus AC) = AC$

1^{st} proof :—

$LHS = B \oplus B \oplus AC$

$= 0 \oplus AC$

$= AC$

$= RHS$

Proved

2^{nd} proof :—

$LHS = B \oplus (B \oplus AC)$

$= \bar{B}(B \oplus AC) + B(\overline{B \oplus AC})$

$= \bar{B}(\bar{B}AC + B\overline{AC}) + B(\overline{\bar{B}AC + B\overline{AC}})$

$= A\bar{B}C + \bar{B}B\overline{AC} + B(\overline{\bar{B}AC} \cdot \overline{B\overline{AC}})$

$= A\bar{B}C + 0 + B((\bar{\bar{B}} + \overline{AC}) \cdot (\bar{B} + \overline{\overline{AC}}))$

$= A\bar{B}C + B((B + \overline{AC}) \cdot (\bar{B} + AC))$

$= A\bar{B}C + B(B\bar{B} + ABC + \bar{B}\overline{AC} + 0)$

$= A\bar{B}C + B(0 + ABC + \bar{B}\,\overline{AC} + 0)$

$= A\bar{B}C + ABC + 0$

$= AC(\bar{B} + B)$

$= AC$

$= RHS$

Proved

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* Minimize the given function :-

i) $Y = \overline{ABC + \bar{A}BC} + AB + \overline{AC}$

$= \overline{ABC} \cdot \overline{\bar{A}BC} + AB + \overline{AC}$

$= \overline{ABC} \cdot A\overline{BC} + AB + (\bar{A} + \bar{C})$

$= (\bar{A} + \bar{B} + \bar{C}) \cdot \{\bar{\bar{A}} + \bar{B} + \bar{C}\} + AB + (\bar{A} + \bar{C})$

$= (\bar{A} + \bar{B} + \bar{C}) \cdot (A + \bar{B} + \bar{C}) + AB + \bar{A} + \bar{C}$

$= 0 + \bar{A}\bar{B} + \bar{A}\bar{C} + A\bar{B} + \bar{B} + \bar{B}\bar{C} + A\bar{C} + \bar{B}\bar{C} + \bar{C}$
$\quad + AB + \bar{A} + \bar{C}$

$= \bar{A}\bar{B} + \bar{A}\bar{C} + A\bar{B} + \bar{B} + A\bar{C} + \bar{B}\bar{C} + \bar{C} + AB + \bar{A}$

$= \bar{A}\bar{B} + \bar{A}\bar{C} + \bar{A} + A\bar{B} + \bar{B} + \bar{B}\bar{C} + A\bar{C} + \bar{C} + AB$

$= \bar{A} + \bar{B} + \bar{C} + AB$

$= \bar{A}(1 + B) + \bar{B} + \bar{C} + AB$

$= \bar{A} + \bar{A}B + AB + \bar{B} + \bar{C}$

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

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

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

$= \bar{A} + \bar{C} + 1$

$= \bar{A} + 1$

$= 1$

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* **SOP formed expression (Sum of Product):—**

Any boolean function is ORed of indivisual ANDed terms then that function is said to be in SOP form.

Ex:—

$$Y = AB + BC + AC + B\bar{C}$$

* **POS formed expression (Product of sum):—**

Any boolean function is ANDed of indivisual ORed terms then that function is said to be in POS form.

Ex:—

$$Y = (A+B)(B+C)(A+C)(B+\bar{C})$$

* **Standard form:—** If any function containing all variables in each term then that function is said to be in standard form.

Q. Convert the given expression into standard SOP form:—

1. $Y = AB + BC + AC$

$= AB(C+\bar{C}) + BC(A+\bar{A}) + AC(B+\bar{B})$

$= ABC + AB\bar{C} + ABC + \bar{A}BC + ABC + A\bar{B}C$

$= ABC + AB\bar{C} + A\bar{B}C + \bar{A}BC$

This is the standard SOP form.

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Q. Convert the given expression into standard POS form:—

1. $Y = (A+B)(B+C)(A+C)$

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

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

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

This is the standard POS form.

Formula:— $A+B+C\bar{C} = (A+B+C)(A+B+\bar{C})$

* Min term, Max term & Don't care term

* Min term:—

Each term present in standard SOP form expression is known as min term. That means output for each min term is 1. It is represented by

$\sum_m (\quad)$ or, $\sum m(\quad)$.

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* Max term :-

Each term present in standard POS form expression is known as max term. That means output for each max term is 0. It is represented by $\prod_M(\quad)$

* Don't care term :-

For any contradictory statement or any missing condition output may be represented as don't care term or it may be term as 0 or 1 for any truth table. It is denoted by d, x, $\sum_d x$

Q. Represent the given function in term of min term, max term and dont care term.

$$Y = \bar{A}\bar{B}C + A\bar{B}C + A\bar{B}\bar{C} + ABC$$

$$\quad 001 \qquad 101 \qquad 100 \qquad 111$$

	ABC	Y
0	000	0
1	001	1
2	010	0
3	011	0
4	100	1
5	101	1
6	110	0
7	111	1

Min term :-

$\sum_m (1, 4, 5, 7)$

Max term :-

$\prod_M (0, 2, 3, 6)$

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Q. Find the expression for given logic term:

4 person Ali, Bil, Charli, Donald may fight with certain conditions:—

i) Ali can fight with anyone, if someone is watching.
ii) Bil can fight with Charli, if noone is watching.
iii) Charli can fight with anyone, if no one is watching.
iv) Donald never start fighting.

ABCD	Y
0000	0
0001	0
0010	0
0011	1
0100	X
0101	1
0110	0
0111	X
1000	0
1001	X
1010	1
1011	1
1100	0
1101	1
1110	1
1111	1

Min term :—

$\sum_m (3, 6, 10, 11, 13, 14, 15) + \sum_d (5, 7, 9)$

Max term :—

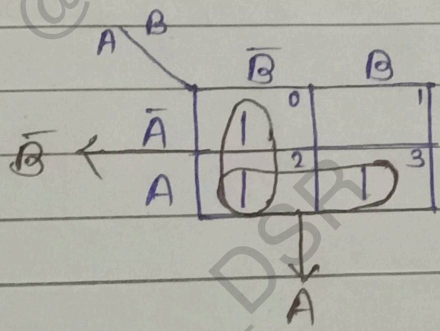
$\prod_M (0, 1, 2, 4, 8, 12) + \sum_d (5, 7, 9)$

* Karnaugh Map (K-Map) :-

K-map is the graphical representation of boolean function by which we can minimize any boolean function.

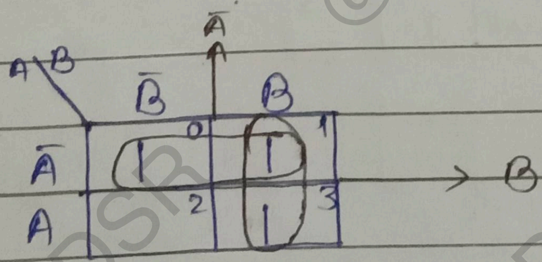
* Two variable K-map :-

Q.1. $Y = \sum_m (0, 2, 3)$



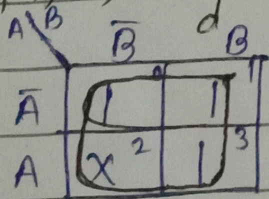
$Y = A + \bar{B}$

Q.2. $Y = \sum_m (0, 1, 3)$



$Y = \bar{A} + B$

Q.3. $Y = \sum_m (0, 1, 3) + \sum_d (2)$



$Y = (\bar{A} + A)(\bar{B} + B)$

$= 1 \cdot 1 = 1$

Q.4. $Y = \sum_m (1,2) + \sum_d (0)$

$A \backslash B$	$\bar{B}$	B
$\bar{A}$	X [0]	1 [1]
A	1 [2]	[3]

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

Q5. $Y = \sum_m (0,3)$

$A \backslash B$	$\bar{B}$	B
$\bar{A}$	1 [0]	[1]
A	[2]	1 [3]

$Y = \bar{A}\bar{B} + AB$

Q.6. $Y = \sum_m (1,2)$

$A \backslash B$	$\bar{B}$	B
$\bar{A}$	[0]	1 [1]
A	1 [2]	[3]

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

* Steps :—

i) Divide the big sequence box into 4 equal parts.

ii) Let AB are two variables where A is MSB and B is LSB.
Separate these two variables into two parts. Write MSB (i.e A) vertically and LSB (i.e. B) horizontally.

MSB — A \ B — LSB

$A \backslash B$	$\bar{B}$	B
$\bar{A}$	0	1
A	2	3

iii) Place 1 for each ~~mean~~ min term, X for don't care terms and for max term keep blank the respective box.

iv) For grouping purpose, try to make a group of four once. If not then two once, if not then indivisual and write its expression.

$A \backslash BC$	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	0	1	3	2
A	4	5	7	6

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Q. $Y = f(A,B,C) = \sum_m (0,1,3,5,6,7) + \sum_d 2$

$A \backslash BC$	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1 (0)	1 (1)	1 (3)	X (2)
A	(4)	1 (5)	1 (7)	1 (6)

$Y = \bar{A} + B + C$

Q. $Y = f(A,B,C) = \sum_m$ all odd no. $+ \sum_d 0, 2$

$A \backslash BC$	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	X (0)	1 (1)	1 (3)	X (2)
A	(4)	1 (5)	1 (7)	(6)

$Y = C$

Q. $Y = \sum_m$ all even no. $+ \sum_d 0, 3$

$A \backslash BC$	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	X (0)	(1)	X (3)	1 (2)
A	1 (4)	(5)	(7)	1 (6)

$Y = \bar{C}$

Q. $Y = \sum_m (2,4) + \sum_d 0, 3$

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	X [0]	[1]	X [3]	1 [2]
A	1 [4]	[5]	[7]	[6]

$Y = B + \bar{B}\bar{C}$

Q. $Y = \sum_m (0,1,2,3,4,5,6)$

A \ BC	$\bar{B}\bar{C}$	$\bar{B}C$	BC	$B\bar{C}$
$\bar{A}$	1 [0]	1 [1]	1 [3]	1 [2]
A	1 [4]	1 [5]	[7]	1 [6]

$Y = \bar{A} + \bar{B} + \bar{C}$

Q. $Y = \sum (0,1,6,7,8,9,10,13,14) + \sum_d (2,12)$

AB \ CD	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	1 [0]	1 [1]	[3]	X [2]
$\bar{A}B$	[4]	[5]	1 [7]	1 [6]
AB	X [12]	1 [13]	[15]	1 [14]
$A\bar{B}$	1 [8]	1 [9]	[11]	1 [10]

$Y = \bar{B}\bar{C} + A\bar{C} + C\bar{D} + \bar{A}BC$

Q $Y = \sum_m (\text{all odd no's}) + \sum_d 0, 2, 4, 6, 8, 10$

$AB \backslash CD$	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	X (0)	1 (1)	1 (3)	X (2)
$\bar{A}B$	X (4)	1 (5)	1 (7)	X (6)
AB	(12)	1 (13)	1 (15)	(14)
$A\bar{B}$	X (8)	1 (9)	1 (11)	X (10)

Q. Minimize the given function by using K-map.

$Y = ABC + \bar{A}CD + A\bar{D}$

$Y = ABC(D+\bar{D}) + \bar{A}CD(B+\bar{B}) + A\bar{D}\{(B+\bar{B})(C+\bar{C})\}$

$= ABCD + ABC\bar{D} + \bar{A}BCD + \bar{A}\bar{B}CD + ABC\bar{D} + AB\bar{C}\bar{D}$
$+ A\bar{B}C\bar{D} + A\bar{B}\bar{C}\bar{D}$

$= \overset{1}{A}\overset{1}{B}\overset{1}{C}\overset{1}{D} + \overset{1}{A}\overset{1}{B}\overset{1}{C}\overset{0}{\bar{D}} + \overset{0}{\bar{A}}\overset{1}{B}\overset{1}{C}\overset{1}{D} + \overset{0}{\bar{A}}\overset{0}{\bar{B}}\overset{1}{C}\overset{1}{D} + \overset{1}{A}\overset{1}{B}\overset{0}{\bar{C}}\overset{0}{\bar{D}} + \overset{1}{A}\overset{0}{\bar{B}}\overset{1}{C}\overset{0}{\bar{D}}$
$+ \overset{1}{A}\overset{0}{\bar{B}}\overset{0}{\bar{C}}\overset{1}{\bar{D}}$

$= 15, 14, 7, 3, 12, 10, 8$

So, $Y = \sum_m (3, 7, 8, 10, 12, 14, 15)$

$AB \backslash CD$	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$	(0)	(1)	1 (3)	(2)
$\bar{A}B$	(4)	(5)	1 (7)	(6)
AB	1 (12)	(13)	1 (15)	1 (14)
$A\bar{B}$	1 (8)	(9)	(11)	1 (10)

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Q. To run motor there are certain conditions:-

i) If switches A & C are closed but switches D is open, then motor will run.

ii) If switches C & D are closed, other switches are open then motor will run.

iii) If switches A & B are closed but switch D is open then motor will run.

iv) If switch D is closed then we can't say motor will run or not.

* Flip-Flop :-

Flip-flop is a sequential circuit which store the smallest unit of memory (i.e, data). It stores one bit data at a time. It is also known as bistable circuit.

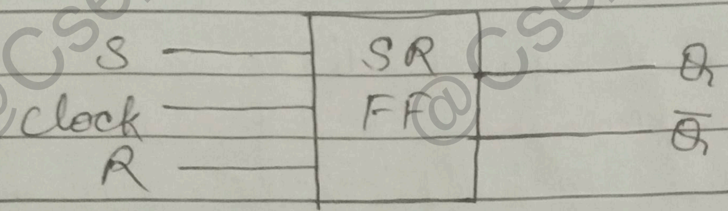
There are 5 types of FF:-

i) SR FF ii) JK FF iii) D FF
iv) T FF v) Master Slave FF

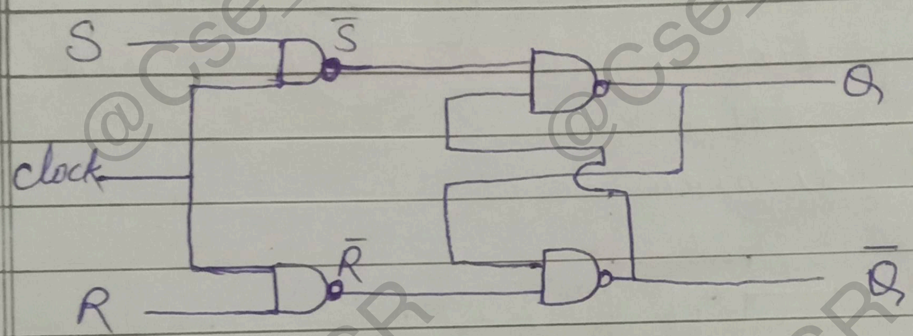
i) SR Flip-Flop :-

SR is the common flip-flop. It has two input signals (i.e S(set) and R(rest). A flip-flop must have a special input signal is called clock signal. The clock signal enable or disable the state change of the flip-flop.

→ Block diagram :-



→ Main diagram :-



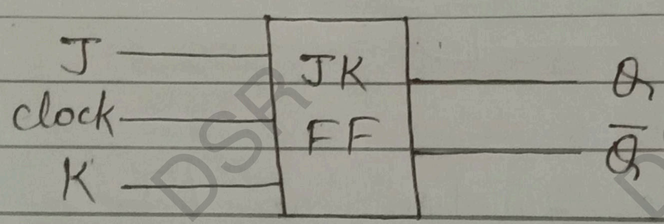
* Characteristics function table / ~~Table~~ Truth Table

Clock	S	R	Q	$\bar{Q}$	comment
0	X	X	Q	$\bar{Q}$	NC
1	0	0	Q	$\bar{Q}$	NC
1	0	1	0	1	Reset
1	1	0	1	0	Set
1	1	1	?	?	Invalid

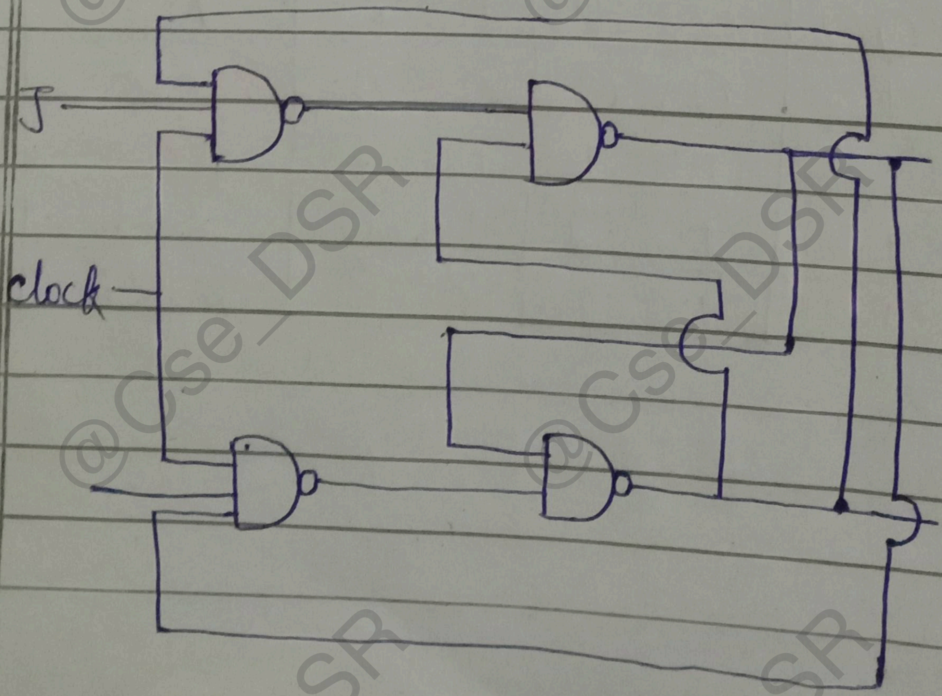
ii) JK Flip-Flop :-

JK flip-flop is the advance version of SR flip-flop. In SR FF, at S=1, and R=1 and clock = 1, the system will give invalid condition. To overcome this problem JK FF has developed. In JK FF indeterminaned condition of SR FF is defined in the JK FF. The input J and K behaves like input S and R respectively.

Block diagram :-



Main diagram :-



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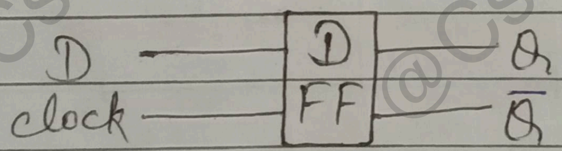
Truth Table :-

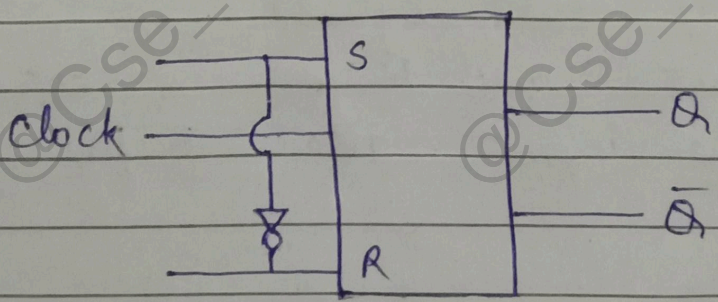
Clock	S	R	Q	$\bar{Q}$	comment
0	X	X	Q	$\bar{Q}$	NC
1	0	0	Q	$\bar{Q}$	NC
1	0	1	0	1	Reset
1	1	0	1	0	Set
1	1	1	$\bar{Q}$	Q	Toggle

iii) **D Flip-Flop :-** D flip-flop is also known as data transfer flip-flop. It is slidely modification of SR flip-flop. And SR FF is converted to D FF by connecting R with NOT gate through S.

Block diagram :-



DFF by using SR FF :-



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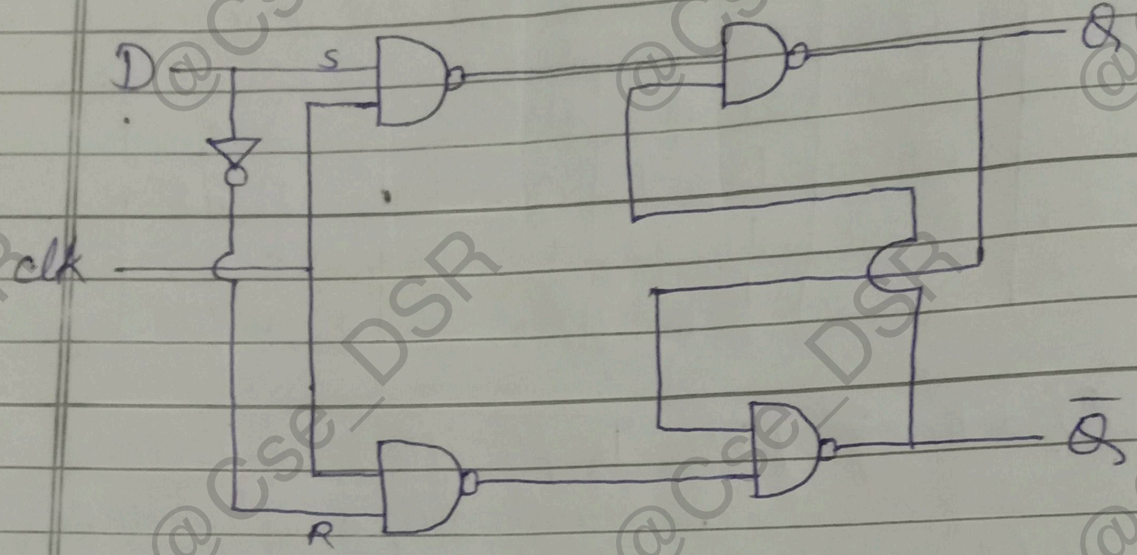
Main diagram of D FF using SR FF :-



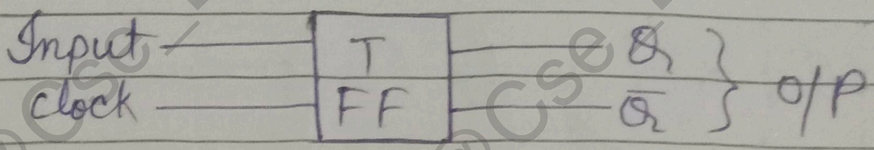
Truth Table

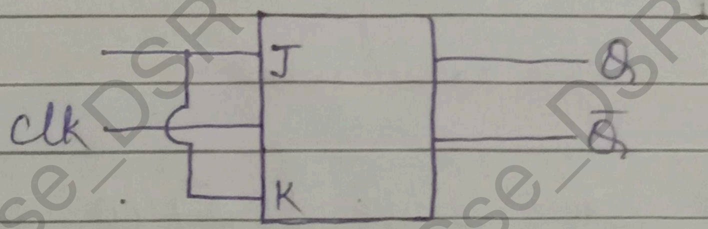
clock	D	Q	$\overline{Q}$	comment
0	X	Q	$\overline{Q}$	NC
1	0	0	1	reset
1	1	1	0	set

iv) T Flip-Flop :-

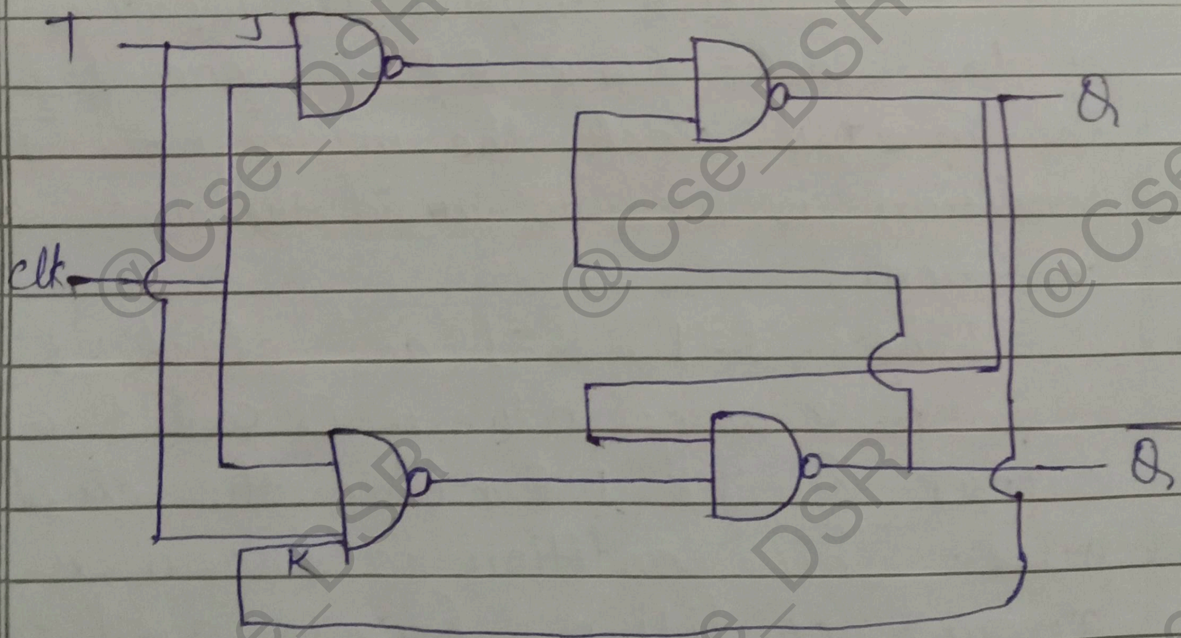
T flip-flop is known as toggle FF. This FF is made by JK flip-flop, when input J and K are connected with single input called T flip-flop.

Block diagram :-





Main diagram :-



Truth Table

Clock	T	Q $\bar{Q}$	comment
0	x	Q $\bar{Q}$	NC
1	0	Q $\bar{Q}$	NC
1	1	$\bar{Q}$ Q	toggle

v) Master Slave ~~statement~~ FF :-

Master slave flip-flop is an another type of FF. In this FF, two FF are used, first is master FF, which response to positive level of the clock. Second is slave FF, which respond the negative level of the clock. Slave FF is connected to the inverted clock the master FF. This condition is used to avoid the race arround condition.

Where J=1, K=1 and clock =1, then there is a race between 0 and 1 at the output of JK FF within the clock pulse. This condition is known as race arround condition. Race arround condition can be overcome by using master slave flip-flop.