Binary language

(0, 1) 2 values

1 - on , 0 - off

← Inc. value

MSB ——— LSB

First Method of Decimal to Binary

① 2

16	8	4	2	1
2^4	2^3	2^2	2^1	2^0
0	0	0	1	0

② 6 = 4 + 2

32	16	8	4	2	1
2^5	2^4	2^3	2^2	2^1	2^0
0	0	0	1	1	0

③ 25 = 16 + 8 + 1

16	8	4	2	1
2^4	2^3	2^2	2^1	2^0
1	1	0	0	1

④ 128

128	64	32	16	8	4	2	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	0	0	0	0	0	0	0

⑤ 228
128+64+32+4

512	256	128	64	32	16	8	4	2	1
2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
0	0	1	1	1	0	0	1	0	0

⑥ 1221
1024 + 128 + 64
+ 4 + 1

1024	512	256	128	64	32	16	8	4	2	1
2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	0	0	1	1	0	0	0	1	0	1

⑦ 1024

1024	512	256	128	64	32	16	8	4	2	1
2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	0	0	0	0	0	0	0	0	0	0

Binary language

(0, 1) 2 values

1 - on , 0 - off

← Inc. value

MSB ———— LSB

First Method of Decimal to Binary

① 2

16	8	4	2	1
2^4	2^3	2^2	2^1	2^0
0	0	0	1	0

② 6 = 4 + 2

32	16	8	4	2	1
2^5	2^4	2^3	2^2	2^1	2^0
0	0	0	1	1	0

③ 25 = 16 + 8 + 1

16	8	4	2	1
2^4	2^3	2^2	2^1	2^0
1	1	0	0	1

④ 128

128	64	32	16	8	4	2	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	0	0	0	0	0	0	0

⑤ 228

128 + 64 + 32 + 4

512	256	128	64	32	16	8	4	2	1
2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
0	0	1	1	1	0	0	1	0	0

⑥ 1221

1024 + 128 + 64 + 4 + 1

1024	512	256	128	64	32	16	8	4	2	1
2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	0	0	1	1	0	0	0	1	0	1

⑦ 1024

1024	512	256	128	64	32	16	8	4	2	1
2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	0	0	0	0	0	0	0	0	0	0

Second Method of Decimal to Binary

① 25

2 | 25
2 | 12 - 1
2 | 6 - 0
2 | 3 - 0
  | 1 - 1

11001

② 256

2 | 256
2 | 128 - 0
2 | 64 - 0
2 | 32 - 0
2 | 16 - 0
2 | 8 - 0
2 | 4 - 0
2 | 2 - 0
  | 1 - 0

100000000

③ 1023

2 | 1023
2 | 511 - 1
2 | 255 - 1
2 | 127 - 1
2 | 63 - 1
2 | 31 - 1
2 | 15 - 1
2 | 7 - 1
2 | 3 - 1
  | 1 - 1

1111111111

Binary to Decimal

① 011010

32	16	8	4	2	1
2^5	2^4	2^3	2^2	2^1	2^0
0	1	1	0	1	0

16 + 8 + 2 = 26

② 11111101

128	64	32	16	8	4	2	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	1	1	1	1	1	0	1

128 + 64 + 32 + 16 + 8
+ 4 + 1 = 253

Base 2 = Binary
Base 8 = Octal (0 to 7) We take only 3 value, 4, 2, 1.
Base 10 = Decimal
Base 16 = Hexa (0 to 15)
0–9, A B C D E F
10 11 12 13 14 15

Octal to Binary

① $(6566120)_8 = (\quad)_2$

421	421	421	421	421	421	421
110	101	110	110	001	010	000
6	5	6	6	1	2	0

② $(06200560)_8 = (\quad)_2$

421	421	421	421	421	421	421	421
000	110	010	000	000	101	110	000
0	6	2	0	0	5	6	0

Hexadecimal with Base 16.

(We take 4 values 8, 4, 2, 1 . $2^3, 2^2, 2^1, 2^0$.)

0-9, 10 - A, 11 - B, 12 - C, 13 - D,
14 - E, 15 - F

① $(ABCDF19243ED)_{16}$ to binary

8421	8421	8421	8421	8421	8421	8421	8421	8421	8421	8421	8421
1010	1011	1100	1101	1111	0001	1001	0010	0100	0011	1110	1101
A	B	C	D	F	1	9	2	4	3	E	D

② $(50009E8FF5)_{16} = (\quad)_2$

8421	8421	8421	8421	8421	8421	8421	8421	8421	8421
0101	0000	0000	0000	1001	1110	1000	1111	1111	0101
5	0	0	0	9	E	8	F	F	5

③ $(36556)_8 = (\quad)_{16}$

$(\underbrace{011}_{3}\,\underbrace{110}_{6}\,\underbrace{101}_{5}\,\underbrace{101}_{5}\,\underbrace{110}_{6})_8$

$(\underbrace{0011}_{3}\,\underbrace{1101}_{13}\,\underbrace{0110}_{6}\,\underbrace{1110}_{14})_{16}$

3D6E

★ ④ $(1256)_{10} = (\quad)_2$

1024 + 128 + 64
+ 32 + 8

2048	1024	512	256	128	64	32	16	8	4	2	1
2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
0	1	0	0	1	1	1	0	1	0	0	0

⑤ $(856)_{10} = (\quad)_2$

$512+256+64$
$+16+8$

512	256	128	64	32	16	8	4	2	1
2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
1	1	0	1	0	1	1	0	0	0

⑥ $(100001001010)_2 = (\quad)_{16}$

$\underbrace{\overset{8421}{1000}}_{8}\ \underbrace{\overset{8421}{0100}}_{4}\ \underbrace{\overset{8421}{1010}}_{10} = 84A$

⑦ $(AFD655)_{16} = (\cancel{10})_{10}$

8388608 2097152 524288 131072 32768 8192 2048 512 256 64

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

4194304 1048576 262144 65536 16384 4096 1024 128 32 16 8 4 2 1

$= (11,523,669)_{10}$

⑧ $(1776542)_8 = (\quad)_{10}$

262,144 65536 16384 4096

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

131072 32768 8192 2048 1024 512 256 128 64 32 16 8 4 2 1

$= (523,617)_{10}$

⑨ $(8594)_{16} = (\quad)_8$

$\underbrace{1000}\ \underbrace{0101}\ \underbrace{1001}\ \underbrace{0100}$

$(\underbrace{001}_{1}\ \underbrace{000}_{0}\ \underbrace{010}_{2}\ \underbrace{110}_{6}\ \underbrace{010}_{2}\ \underbrace{100}_{4})_8$

(10) $(AF896)_{16} = (\quad)_2$

$(101011111000100101 10)_2$

(11) $(1221)_8 = (\quad)_2$

$(001010010001)_2$

(12) $(1AF)_{16} = (\quad)_2$

$(000110101111)_2$

(13) $(18918)_{16} = (\quad)_2$

$(00011000100100011000)_2$

(14) $(8F9625)_{16} = (\quad)_8$

Step 1 $(\underbrace{1000}_{8}\ \underbrace{1111}_{F}\ \underbrace{1001}_{9}\ \underbrace{0110}_{6}\ \underbrace{0010}_{2}\ \underbrace{0101}_{5})_2 =$

Step 2 $\underbrace{100}_{4}\ \underbrace{011}_{3}\ \underbrace{111}_{7}\ \underbrace{001}_{1}\ \underbrace{011}_{3}\ \underbrace{000}_{0}\ \underbrace{100}_{4}\ \underbrace{101}_{5}$

$(43713045)_8$

Hexadecimal conversion to octal.

Octal :- $8 \,|\, 59$
$\quad | \, 7 - 3$ $\qquad (73)_8$

Hexadecimal :- $16 \,|\, 59$
$\quad | \, 3 - 11$ $\qquad (3B)_{16}$

⇒ 5.8 into binary

$(101.110011)_2$

0.8
× 2
0.6
× 2
0.2
× 2
0.4
× 2
0.8
× 2
0.6
× 2
0.2

⇒ 5.7 into binary
$(101.10110)_2$

⇒ 0.8
$(0.1100)_2$

⑮ $(78)_{10} = (\ )_{16}$

128	64	32	16	8	4	2	1
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
0	1	0	0	1	1	1	0

$\underbrace{0100}_{4}\ \underbrace{1110}_{14}$ $\qquad (4E)_{16}$

One's Compliment

00110
11001 1's

10101
01010

Second Compliment +1

① 0000 0000

1st 1111 1111

2nd +1

100000000

② 1111 1111

1st 0000 0000

2nd +1

0000 0001

③ 1111011111

1st 0000100000

2nd +1

0000100001

④ 0001100010

1st 1110011101

2nd +1

1110011110

⑤ 10011111111

1st 01100000000

2nd +1

01100000001

2nd Compliment

① 11100 11100

2nd:- 00011 00100

② 000 111 00000
2nd :- 111 001 00 000

③ 1001010001
2nd 0110101111

④ 111111 0
2nd 000001 0

$(28)_{16}$ into Decimal

1st Method

8421 8421
0010 1000

00101000
32168421 = $(40)_{10}$

2nd Method = $2 \times 16^1 + 8 \times 16^0$
32 + 8
= 40

Addition

0+0 = 0 , 0+1 = 1,
1+0 = 1 , 1+1 = 0 ① Carry
1+1+1 = 1 ① Carry

① 1110011 00
+1101100 11
1101111 1111

② 1010010
+ 0101110
10000000

③ 11110000
+10100000
110010000

④ 110011001
+ 111111111
1110011000

$$\begin{array}{r} \cancel{2}\cancel{2}\cancel{2}2 \\ \cancel{1}0000 \\ -11 \\ \hline 01101 \end{array}$$

(5)
$$\begin{array}{r} 10111101010 \\ +01000010101 \\ \hline \cancel{01000010110} \\ 11111111111 \end{array}$$

(6)
$$\begin{array}{r} 1000011111 \\ +1001111111 \\ \hline \cancel{1100011}11110 \\ 10010 \end{array}$$

$\boxed{0-0=0,\ 1-0=1,\ 1-1=0}$

$\boxed{0-1=1 \text{ with barrow } 1}$

Subtraction

(1)
$$\begin{array}{r} 1010100 \\ -0000001 \\ \hline 1010011 \end{array}$$

(2)
$$\begin{array}{r} \cancel{1}0111010 1 \\ -010001100 \\ \hline 011101001 \end{array}$$

(3)
$$\begin{array}{r} 111001001 \\ -001100010 \\ \hline \cancel{1}\cancel{1}01100\cancel{1}11 \end{array}$$

(4)
$$\begin{array}{r} 1110011100 \\ -0001101111 \\ \hline 1100101101 \end{array}$$

⇒ Subtraction with help of 1's compliment.

Carry

$$\begin{array}{r} 10 \\ 10 \\ \hline 00 \\ +1 \\ \hline 01 \end{array}$$

No Carry

$$\begin{array}{r} 10 \\ +00 \\ \hline 10 \\ -(01) \end{array}$$

01 - x

10 - x'

(1) 110010101 from 111110100

001101010

$$\begin{array}{r} 111110100 \\ +001101010 \\ \hline 001011110 \\ +1 \\ \hline 001011111 \end{array}$$ - Ans.

②
X: 11011011 from Y: 11110101
001001000

①
11110101
+ 001001000
000111101
+1
000111110 - Ans

③
X: 11011011 from Y: 11100100
00100100

①
11100100
+ 00100100
00001000
+1
00001001

Without Carry

① 11011011 from 101110101
001001000

101110101
+ 001001000
110111101 - 1's Compliment
-(001000010)

② 11011011 from 10100100
00100100

10100100
+ 00100100
11001000 1's compliment
-(00110111)

(3) 11001000 from 00011011
00110111

  00011011
+ 00110111
  01010010
-(10101101) One's Compliment

(4) 11010101 from 00010101
00101010

  00010101
+ 00101010
  00111111
-(11000000) One's Compliment

(5) 11110011 from 11100110
00001100

  11100110
+ 00001100
  11110010
-(00001101) One's Compliment

1 Byte = 8 bits
1 Nibble = 4 bits

8 Byte = 64 bits
64 bits = 16 Nibble

Subtraction with help of 2's compliment

① 00101001 from 10001010

2's C 11010110
+1
11010111

①
10001010
+11010111
+(01100001)

② 101000101
100100010 → 2's Com. 011011101
+1
011011110

①
101000101
+011011110
+(000100011)

③ 01011010
10110101 → 2's Com. 01001010
+1
01001011

01011010
+01001011
10100101 } 2's Compl.
Ans (-01011011)

Without carry

① 01001011
11000101 2's C → 00111010
+1
00111011

$$
\begin{array}{r}
01001011 \\
+\ 00111011 \\
\hline
10000110 \\
-\ 01111010 \\
\hline
\end{array}
$$

2's

②
$$
\begin{array}{r}
00100101 \\
-\ 10001010 \\
\hline
\end{array}
\xrightarrow{} 2's \quad
\begin{array}{r}
01110101 \\
+1 \\
\hline
01110110
\end{array}
$$

$$
\begin{array}{r}
00100101 \\
+\ 01110110 \\
\hline
10011011 \\
01100101 \\
\hline
\end{array}
$$

2's

③
$$
\begin{array}{r}
1110001 \\
-\ 0001110 \\
\hline
\end{array}
\xrightarrow{} 2's \quad
\begin{array}{r}
1110001 \\
+1 \\
\hline
1110010
\end{array}
$$

$$
\begin{array}{r}
①\ 1110001 \\
+\ 1110010 \\
\hline
-(1100011)
\end{array}
$$

④
$$
\begin{array}{r}
11111100 \\
-\ 00011111 \\
\hline
\end{array}
\xrightarrow{} 2's \quad
\begin{array}{r}
11100000 \\
+1 \\
\hline
11100001
\end{array}
$$

$$
\begin{array}{r}
①\ 11111100 \\
+\ 11100001 \\
\hline
-(11011101)
\end{array}
$$

(5) 00010001
- 11100000 → 2's

$$\begin{array}{r} 00011111 \\ +1 \\ \hline 00100000 \end{array}$$

$$\begin{array}{r} 00010001 \\ +00100000 \\ \hline 00110001 \\ \hline 11001111 \end{array}$$

2's

LOGIC GATE

A Device which take decision. A logic Gate is a device which ~~takes~~ acts as a building block for digital circuits. They perform basic logical functions that are fundamental to digital circuits.

Types of logic gates :-

All the gates are 2 Inp Gates except Not Gate. Not is one Input Gate

1. AND
2. OR — Basic Gates
3. NOT — inverter, complimenter
4. NOR
5. NAND — Universal Gates
6. XOR
7. XNOR — Arithmetic Gates

Input is either 0 or 1.

OR GATE

withrespect to c.

$2^3 = 8$

X	Y	Z	Output
0	0	0	0
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	1

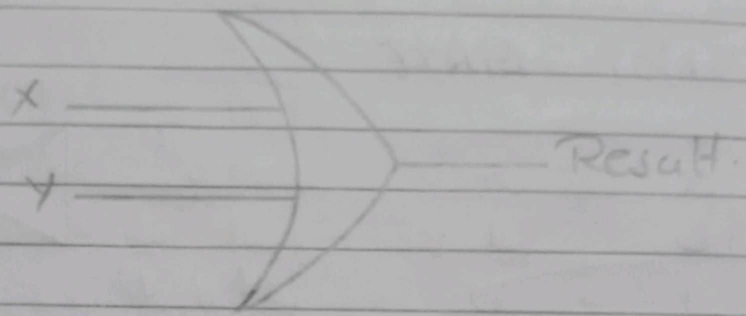
e.g. (a == b) OR (b == c), OR (c == d)

$2^4 = 16$

A	B	C	D	Output
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	0	1	1	1
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	1
1	0	0	1	1
1	0	1	0	1
1	0	1	1	1

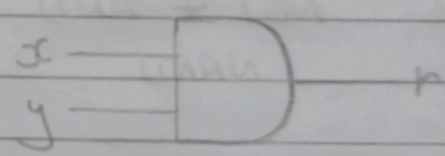
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

Symbol of OR GATE (Hardware)



⇒ AND GATE

x	y	r
0	0	0
0	1	0
1	0	0
1	1	1



$2^3 = 8$

(+) = OR

(·) = AND

x	y	z	r
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

★ $x + 1 = 1$

$x + 0 = x$

$x \cdot 1 = x$

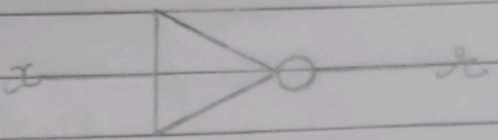
$x \cdot 0 = 0$

$x + x = x$

$x \cdot x = x$

=> NOT GATE

x	r
0	1
1	0

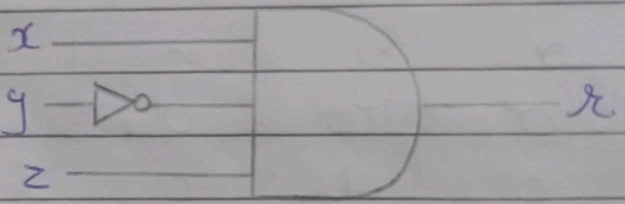


At a time, there is only 1 Input.

NOT GATE - $\bar{x}$

Q1.

$2^3 = 8$ NOT + AND
NAND



x	y	$\bar{y}$	z	r
0	0	1	0	0
0	0	1	1	0
0	1	0	0	0
0	1	0	1	0
1	0	1	0	0
1	0	1 ~~0~~	1	1
1	~~0~~ 1	0	0	0
1	1	0	1	0

$2^2 = 4$

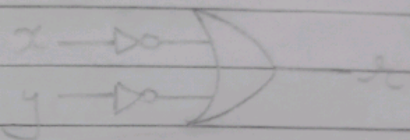
Q2.

x	$\bar{x}$	y	$\bar{y}$	r
0	1	0	1	1
0	1	1	0	0
1	0	0	1	0
1	0	1	0	0

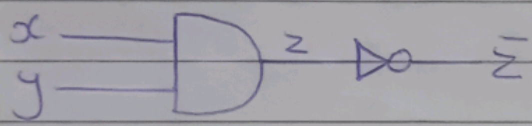
Q3.

x	$\bar{x}$	y	$\bar{y}$	r
0	1	0	1	1
0	1	1	0	1
1	0	0	1	1
1	0	1	0	0

NOT+OR ~~+~~/AND = NOR
1



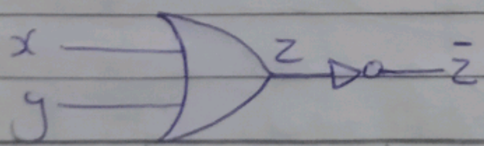
Q4



NOT + AND = NAND
0

x	y	z	$\bar{z}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

Q5.



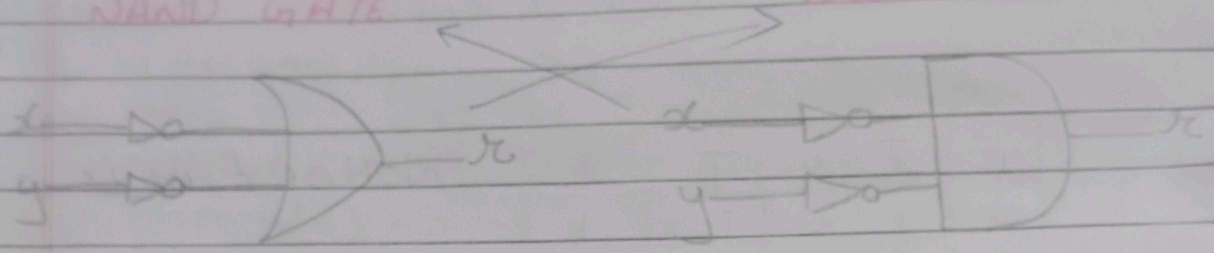
x	y	z	$\bar{z}$
0	0	0	1
0	1	Φ	0
1	0	1	0
1	1	1	0

★ $x + x + x = x$

$x + 1 + x = 1$

$x + 0 + x = \cancel{0}\, x$

NAND GATE NOR GATE



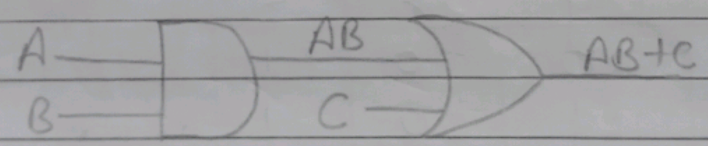
Their symbol as well as result are also different

(I) $AB + C$

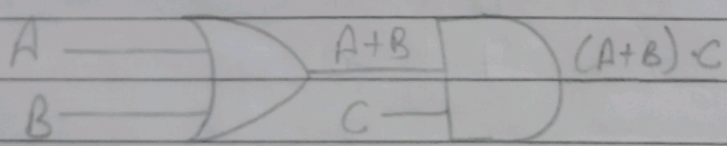
(II) $(A+B) \cdot C$

(III) $AB + CD$

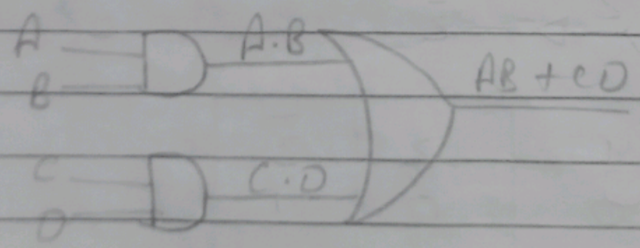
(i)



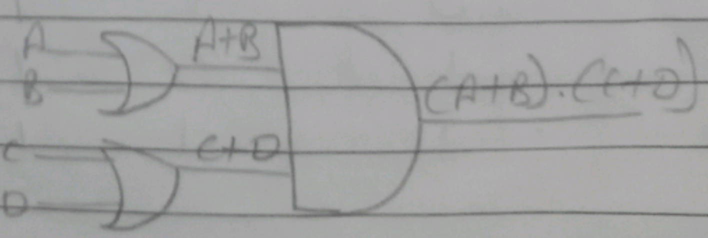
(ii)



(iii)



(IV) $(A+B) \cdot (C+D)$



OR = 1 (+)
AND = 0 (·)

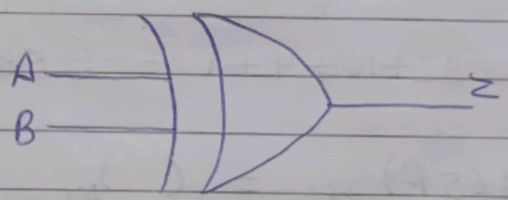
EX-OR ⊕
X-OR $A \oplus B = \bar{A}B + A\bar{B}$
Exclusisive OR

① $\bar{A}B + A\bar{B}$

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

If Input is same than result is 0, if Input is diff. than result is 1.

Symbol



EX-NOR Exclusive NOR
X-NOR $(A \odot B)$

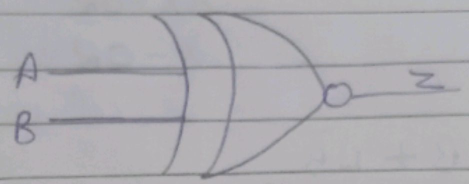
② $AB + \bar{A}\bar{B}$

A	B	AB	$\bar{A}$	$\bar{B}$	$\bar{A}\bar{B}$	$AB + \bar{A}\bar{B}$
0	0	0	1	1	1	1
0	1	0	1	0	0	0
1	0	0	0	1	0	0
1	1	1	0	0	0	1

Input output

If Input is same than result is 1. If input is diff. than result is 0.

Symbol



★ Number System

① $(110101)_2 = (\ )_{10}$

$$\begin{array}{ccccccc} 64 & 32 & 16 & 8 & 4 & 2 & 1 \\ 2^6 & 2^5 & 2^4 & 2^3 & 2^2 & 2^1 & 2^0 \\ & 1 & 1 & 0 & 1 & 0 & 1 \end{array}$$

$32+16+4+1 = (53)_{10}$

② $(B65F)_{16} = (\ )_{10}$

$$\begin{array}{cccccccccccccccc} & 16384 & & 4096 & & 1024 & 256 & 128 & & 32 & & & & & & \\ 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 0 & 1 & 0 & 1 & 1 & 1 & 1 & 1 \\ & 32768 & & 8192 & & 2048 & & 512 & & 64 & & 16 & 8 & 4 & 2 & 1 \end{array}$$

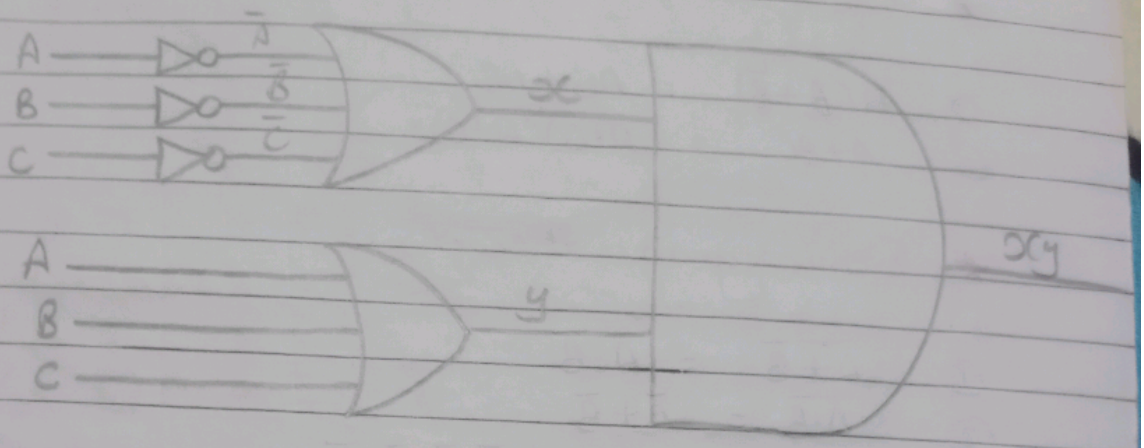
$(46687)_{10}$

③ $(153)_{10} = (\ )_8$

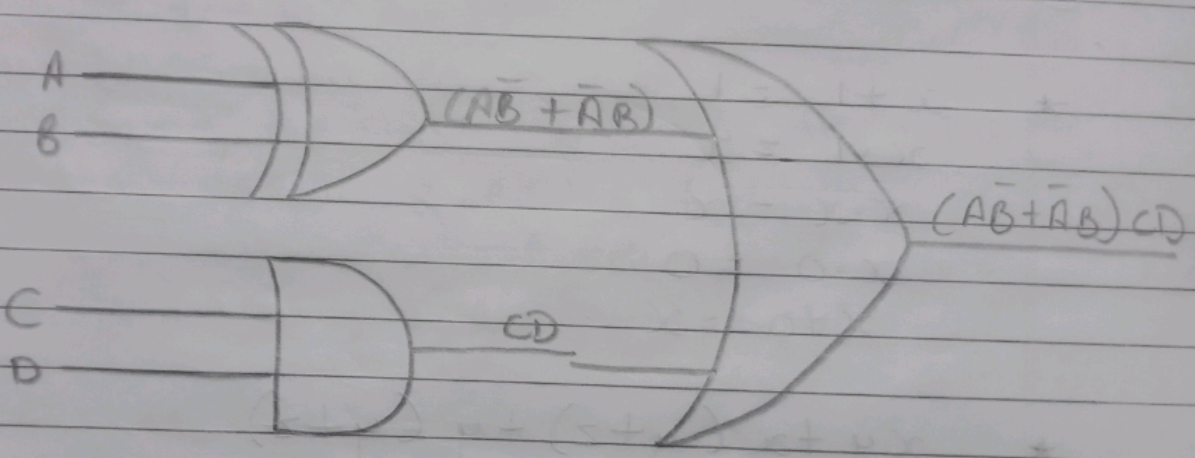
$$\begin{array}{ccc} 4\,2\,1 & 4\,2\,1 & 4\,2\,1 \\ \underbrace{010}_{2} & \underbrace{011}_{3} & \underbrace{001}_{1} \end{array}$$

$(231)_8$

③ $(\bar{A}+\bar{B}+\bar{C})(A+B+C)$



④ $(A\bar{B}+\bar{A}B)+C\cdot D$



★ Commutative law

① $A+B = B+A$
② $A\cdot B = B\cdot A$

★ Associative law

① $A+(B+C) = (A+B)+C$
② $A\cancel{+}(BC) = \cancel{(A+B)(A+C)}\ (AB)C$

★ Distributive law

① $A(B+C) = AB+AC$

② $A+BC = (A+B)(A+C)$

★ Demorgan's theorem

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

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

③ $\overline{A+B+C+D\ldots} = \bar{A}\cdot\bar{B}\cdot\bar{C}\cdot\bar{D}\ldots$

④ $\overline{A\cdot B\cdot C\cdot D\ldots} = \bar{A}+\bar{B}+\bar{C}+\bar{D}\ldots$

★ $x+1 = 1$

$x\cdot 1 = x$

$x\cdot x = x$

$x\cdot 0 = 0$

$x+0 = x$

★ $xy + x(y+z) + y(y+z)$

$xy + xy + xz + y\cdot y + yz$

$xy + xz + y + yz$

$xy + xz + y(1+z)$

$xy + xz + y$

$xz + y(x+1)$

$xz + y$

★ $x(\bar{x}+z)(\bar{x}y+\bar{z})$

$(x\bar{x}+xz)(\bar{x}y+\bar{z})$

$$\boxed{\cancel{x\bar{x}}\ \bar{x}y + \cancel{x\bar{x}\cdot\bar{z}} + \cancel{xz\cdot\bar{x}y} + xz\bar{z}}$$
$$\bar{x}(x\cdot y) +$$

$$(0 + xz)(\bar{x}y + \bar{z})$$
$$xz(\bar{x}y + \bar{z})$$
$$xz\bar{x}y + xz\bar{z}$$
$$0 + 0 = 0$$

★ $(A+B)(A+C)$

$$AA + AC + BA + BC$$
$$\cancel{(A(A+C) + B(A+C))}$$
$$1 + AC + BA + BC$$
$$A(1+C) + BA + BC$$
$$A + BA + BC = A(1+B) + BC$$
$$A + BC$$

★ $A(A+B) = A$ (Absorption Law)

$$AA + AB$$
$$1 + AB$$
$$A(1+B)$$
$$A = A$$

★ $\overline{x+y+z+\bar{\bar{z}}} = \bar{x}\cdot\bar{y}\cdot\bar{z}\cdot\bar{\bar{\bar{z}}}$

$$\bar{x}\cdot\bar{y}\cdot\bar{z}\cdot z = 0 \text{ Ans}$$

★ $\overline{x\cdot y\cdot\bar{z}\cdot\bar{w}} = \bar{x} + \bar{y} + \bar{\bar{z}} + \bar{\bar{w}}$

$$= \bar{x} + \bar{y} + z + w$$

$a+0 = a$ $a+a' = 1$
$a \cdot 1 = a$ $a \cdot a' = 0$
Identity law Complement law

★ $A \cdot A = A$
$A+A = A$
$A = A$

Questions

① $A+(B+C) \overset{?}{=} (A+B)+C$

Take $A = 1$, $B = 2$, $C = 3$

$1+(2+3) = (1+2)+3$

$1+(5) = (3)+3$

$6 = 6$

Hence Proved

② As per Associative law :- If a logical operation of any two variables is performed first and then the same operation is performed with the remaining variable gives the same result.

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

$A(BC) = (AB)C$

③ Write down about Distributive law :-

Distributive law states that the multiplication of two variables and adding the result with a variable will result in the same value as multiplication of addition of the variable with individual variables.

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

$A(B+C) = AB + AC$

(4) $\overline{x \cdot y \cdot \bar{z} \cdot z} = \bar{x} + \bar{y} + z + \bar{z}$

$\overline{x + y + \bar{z} \cdot \bar{w}} = \bar{x} \cdot \bar{y} \cdot z + w$

(5) $(A+B)(A+C) = ?$ $A+BC$

$(A+B)(A+C) = AA + AC + BA + BC$

$= A + AC + AB + BC$

$= A(1 + C + B) + BC$

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

(6) $(25 \cdot 20)_{10}$ to $(\ )_2$

$11001 \cdot 0011$

$$\begin{array}{r} .20 \\ \times 2 \\ \hline .40 \\ \times 2 \\ \hline .80 \\ \times 2 \\ \hline 1.60 \\ \times 2 \\ \hline 1.20 \end{array}$$

(7) Shortcut for 2's Compliment :- A shortcut to manually convert a binary number into its two's complement is to start at the least significant bit (LSB), and copy all the zeros, working from LSB toward the most significant bit until the first 1 is reached; then copy that 1 and flip all the remaining bits.

for e.g. $\left.\begin{array}{l} 00110101 \\ 11001011 \end{array}\right\}$ 2's

SOP (Sum of Product) = AB+CD Minterm
POS (Product of sum) = (A+B)(C+D) Max term

x	y	z	minterm (SOP)	maxterm (POS)
0	0	0	$\bar{x}\cdot\bar{y}\cdot\bar{z}$	$x+y+z$
0	0	1	$\bar{x}\bar{y}z$	$x+y+\bar{z}$
0	1	0	$\bar{x}y\bar{z}$	$x+\bar{y}+z$
0	1	1	$\bar{x}yz$	$x+\bar{y}+\bar{z}$
1	0	0	$x\bar{y}\bar{z}$	$\bar{x}+y+z$
1	0	1	$x\bar{y}z$	$\bar{x}+y+\bar{z}$
1	1	0	$xy\bar{z}$	$\bar{x}+\bar{y}+z$
1	1	1	xyz	$\bar{x}+\bar{y}+\bar{z}$

$2^4 = 16$

x	y	w	z	minterm	maxterm
0	0	0	0	$\bar{x}\bar{y}\bar{w}\bar{z}$	$x+y+w+z$
0	0	0	1	$\bar{x}\bar{y}\bar{w}z$	$x+y+w+\bar{z}$
0	0	1	0	$\bar{x}\bar{y}w\bar{z}$	$x+y+\bar{w}+z$
0	0	1	1	$\bar{x}\bar{y}wz$	$x+y+\bar{w}+\bar{z}$
0	1	0	0	$\bar{x}ywz$	$x+\bar{y}+\bar{w}+\bar{z}$
0	1	0	1	$\bar{x}y\bar{w}z$	$x+\bar{y}+w+\bar{z}$
0	1	1	0	$\bar{x}yw\bar{z}$	$x+\bar{y}+\bar{w}+z$
0	1	1	1	$\bar{x}ywz$	$x+y+\bar{w}+\bar{z}$
1	0	0	0	$x\bar{y}\bar{w}\bar{z}$	$\bar{x}+y+w+z$
1	0	0	1	$x\bar{y}\bar{w}z$	$\bar{x}+y+w+\bar{z}$
1	0	1	0	$xyw\bar{z}$	$\bar{x}+y+\bar{w}+z$
1	0	1	1	$x\bar{y}wz$	$\bar{x}+y+\bar{w}+\bar{z}$
1	1	0	0	$xy\bar{w}\bar{z}$	$\bar{x}+\bar{y}+w+z$
1	1	0	1	$xy\bar{w}z$	$\bar{x}+\bar{y}+w+\bar{z}$
1	1	1	0	$xyw\bar{z}$	$\bar{x}+\bar{y}+\bar{w}+z$
1	1	1	1	$xywz$	$\bar{x}+\bar{y}+\bar{w}+\bar{z}$

min term $= \Sigma m$
max term $= \Pi M$

min y $= ABC + \bar{A}BC + A\bar{B}\bar{C}$ (SOP)

min y m_7, m_3, m_4

max y M_0, M_4, M_3

ABC
1 1 1
4 2 1

max y $= A\bar{B}C + ABC + \bar{A}\bar{B}C$

M_2, M_0, M_6

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

$\boxed{SOP} = m_6, m_4, m_2, m_7$

$\boxed{POS} = M_1, M_3, M_5, M_0$

#

A	B	C	R	
0	0	0	1	– min
0	0	1	1	
0	1	0	0	– max
0	1	1	0	
1	0	0	1	
1	0	1	0	
1	1	0	0	
1	1	1	1	

min term $(\Sigma m) = \left((\bar{A}\bar{B}\bar{C}) + (\bar{A}\bar{B}C) + (A\bar{B}\bar{C}) + (ABC)\right)$

max term $(\Pi M) = \left((A\bar{B}C) + (A\bar{B}\bar{C}) + (\bar{A}B\bar{C}) + (\bar{A}\bar{B}C)\right)$

min-1 - otebor

$\Sigma m = \underset{m_1}{\bar{A}\bar{B}C} + \underset{m_5}{A\bar{B}C} + \underset{m_2}{\bar{A}B\bar{C}}$

$\Pi m = M_6, M_2, M_5$

A	B	C	result	Σm	ΠM
0	0	0	0	[illegible]	$A+B+C$
0	0	1	1	$\bar{A}\bar{B}C$	
0	1	0	1	$\bar{A}B\bar{C}$	
0	1	1	0		$A\bar{B}\bar{C}$
1	0	0	0		$\bar{A}+B+C$
1	0	1	1	$A\bar{B}C$	
1	1	0	0		$\bar{A}\bar{B}C$
1	1	1	0		$\bar{A}\bar{B}\bar{C}$

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

$\Sigma m = m_5, m_0, m_4$

A	B	C	result	Σm	ΠM
0	0	0	1	$\bar{A}\bar{B}\bar{C}$	
0	0	1	1	$\bar{A}\bar{B}C$	
0	1	0	0	[illegible]	$A\bar{B}C$
0	1	1	0	[illegible]	$A\bar{B}\bar{C}$
1	0	0	1	$A\bar{B}\bar{C}$	
1	0	1	1	$A\bar{B}C$	
1	1	0	1	$AB\bar{C}$	
1	1	1	0	[illegible]	$\bar{A}\bar{B}\bar{C}$

$\bar{x}\bar{z} + \bar{y}$

SOP $(\bar{x}y\bar{z}) + (\bar{x}\bar{y}\bar{z})$

$\bar{x}$	$\bar{y}$	$\bar{z}$
0	0	0
0	1	0

$(\bar{x}\bar{y}\bar{z}) + (x\bar{y}\bar{z}) +$
$(\bar{x}\bar{y}z) + (x\bar{y}z)$

$\bar{x}$	$\bar{y}$	$\bar{z}$
0	0	0
1	0	0
0	0	1
1	0	1

$\bar{x}y + y$

SOP $(\bar{x}y) + (xy) + \cancel{(x\bar{y})}$
$\cancel{+ (\bar{x}\bar{y}) + (y) + (\bar{y})}$

$\bar{x}$	y
0	1
~~0~~	1
x 1	~~0~~ y
0	~~0~~

$\Sigma(x, y, w, z)$

$(\bar{x}yz) + (xz) + (xw)$

$\bar{x}$	y	z	w
0	1	1	0
0	1	1	1

x	y	z	w
1	0	1	0
1	0	1	1
1	1	1	0
1	1	1	1

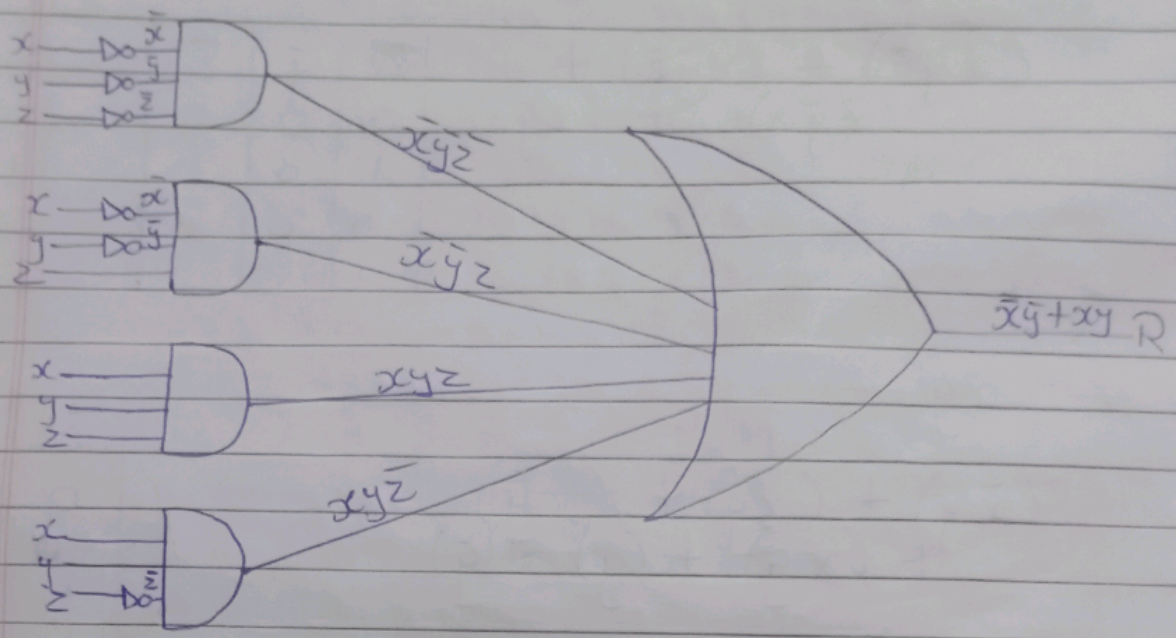
x	y	z	w
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

$(\bar{x}yz\bar{w}) + (\bar{x}yzw) + (x\bar{y}z\bar{w}) + \cancel{(x\bar{y}zw)}$
$+ (xyz\bar{w}) + \cancel{(xyzw)} + (x\bar{y}\bar{z}w) +$
$\cancel{(x\bar{y}zw)} + (xy\bar{z}w) + (xyzw)$

* $\bar{x}\bar{y}\bar{z} + \bar{x}\bar{y}z + xyz + xy\bar{z}$

$\bar{x}\bar{y}(\bar{z}+z) + xy(z+\bar{z})$

$\bar{x}\bar{y} + xy$



K - MAP

x	y
0	0
0	1
1	1
1	0

A \ B	0	1
0	00_0	01_1 → Cell
1	10_2	11_3

A \ BC	00	01	11	10
0	000	001	011	010
1	100	101	111	110

AB \ CD	00	01	11	10
00	0000_0	0001_1	0011_3	0010_2
01	0100_4	0101_5	0111_7	0110_6
11	1100_{12}	1101_{13}	1111_{15}	1110_{14}
10	1000_8	1001_9	1011_{11}	1010_{10}

① $\Sigma m(1,3)$

A \ B	0	1
0	00_0	01_1
1	10_2	11_3

$\bar{A}B + AB$

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

$= B$ Ans.

② $\Sigma m(A,B) = (0,2)$

A \ B	0	1
0	00_0	01_1
1	10_2	11_3

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

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

$= \bar{B}$ Ans

③ $\Sigma m(A,B) = (0,3)$

A \ B	0	1
0	00_0	01_1
1	10_2	11_3

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

④ $\Sigma m(A,B,C) = (0,1,4,5)$

A \ BC	00	01	11	10
0	000 0	001 1	011 3	010 2
1	100 4	101 5	111 7	110 6

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

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

$\bar{A}\bar{B}$ Ans

② $A\bar{B}\bar{C} + A\bar{B}C$

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

$A\bar{B}$ Ans.

③ $(0,4)$

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

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

④ $(1,5)$

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

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

$\bar{B}C$ - Ans.

⑤ $\Sigma m(A,B,C) = (0,2,5,6,7)$

A \ BC	00	01	11	10
0	000 0	001 1	011 3	010 2
1	100 4	101 5	111 7	110 6

① $(0,2)$

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

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

$\bar{A}\bar{C}$ - Ans.

② $(5,7)$

$A\bar{B}C + ABC$

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

AC - Ans.

③ $(7,6)$

$ABC + AB\bar{C}$

$AB(C+\bar{C})$

AB - Ans.

④ $(2,6)$

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

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

$\bar{C}B$ - Ans

⑥ $\Sigma m(A,B,C) = (0,1,2,4)$

A \ BC	00	01	11	10
0	000 [0]	001 [1]	011 [3]	010 [2]
1	100 [4]	101 [5]	111 [7]	110 [6]

① (0, 1)
$\bar A\bar B\bar C + \bar A\bar B C$
$\bar A\bar B(\bar C + C)$
$\bar A\bar B$ - Ans

② (0, 2)
$\bar A\bar B\bar C + \bar A B\bar C$
$\bar A\bar C(\bar B + B)$
$\bar A\bar C$ - Ans

③ (0, 4)
$\bar A\bar B\bar C + A\bar B\bar C$
$\bar B\bar C(\bar A + A)$
$\bar B\bar C$ - Ans

⑦ $\Sigma m(0,1,3,5,7,8,9,11,13,15)$

$2^4(16)$

Pairing of 4. $\bar B\bar C$ - Ans

Pairing of 8 D - Ans

$\boxed{D + \bar B\bar C}$ Ans.

AB \ CD	00	01	11	10
00	0000 [0]	0001 [1]	0011 [3]	0010 [2]
01	0100 [4]	0101 [5]	0111 [7]	0110 [6]
11	1100 [12]	1101 [13]	1111 [15]	1110 [14]
10	1000 [8]	1001 [9]	1011 [11]	1010 [10]

Pairing of 2

① (0,1)
$\bar A\bar B\bar C$

② (3,7)
$\bar A CD$

③ (8, 9)
$A\bar B\bar C$

④ (13,15)
ABD

⑤ (11,15)
ACD

⑥ (9, 11)
$A\bar B D$

⑦ (9,13)
$A\bar C D$

⑧ $\Sigma m(0,1,3,5,7,8)$

AB \ CD	00	01	11	10
00	0 1	1 1	3 1	2
01	4	5 1	7 1	6
11	12	13	15	14
10	8 1	9	11	10

$\bar A D + \bar B\bar C\bar D$

⑨ $f(w,x,y,z) = \Sigma m(1,3,4,6,9,11,12,14)$

wx \ yz	00	01	11	10
00	0	1 ₁	3 ₁	2
01	4 ₁	5	7	6 ₁
11	12 ₁	13	15	14 ₁
10	8	9 ₁	11 ₁	10

$$\underbrace{\bar{w}\bar{x}z + w\bar{x}z}_{\bar{x}z + x\bar{z}} + \underbrace{\bar{w}x\bar{z} + wx\bar{z}}$$

⑩ $f(A,B,G,H) = \Sigma m(3,4,5,7,9,13,14,15)$

AB \ GH	00	01	11	10
00	0	1	3 ₁	2
01	4 ₁	5 ₁	7 ₁	6
11	12	13 ₁	15 ₁	14 ₁
10	8	9 ₁	11	10

$(\cancel{3}, \cancel{7}, 5, 7, 13, 15), (4,5), (13,9), (14,15), (3,7)$

$$BH + \bar{A}B\bar{G} + A\bar{G}H + ABG + \bar{A}GH$$

⑪ $f(x,u,v) = (1,6,4)$

x \ uv	00	01	11	10
0	0	1	3	2
1	4 ₁	5	7	6 ₁

$(4,6), (1)$

$x\bar{v} + \bar{x}\bar{u}v$

⑫ $f(x,u,v) = (1,3,4)$

$(1,3), (4)$

$\bar{x}\cancel{u}\bar{v} + x\bar{u}\bar{v}$

(13) $f(x, u, v) = (1, 2, 4)$

$x \backslash w$	00	01	11	10
0	0	1 1	3	2 1
1	4 1	5	7	6

$(1), (2), (4)$

$\bar{x}\bar{u}v + \bar{x}u\bar{v} + x\bar{u}\bar{v}$

(14) $f(A,B,C) = (0, 1, 4, 5, 7, 6)$

$A \backslash BC$	00	01	11	10
0	0 1	1 1	3	2
1	4 1	5 1	7 1	6 1

$\Rightarrow (0, 1), (4, 5, 7, 6)$

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

$\Rightarrow (0, 1, 4, 5), (7, 6)$

$\bar{B} + AB$

$\Rightarrow (4, 5, 7, 6), (0, 1, 4, 5)$

$A + \bar{B}$

(15) $\Sigma(A, B, C, D) = (0, 1, 2, 3, 4, 8, 9, 10, 11, 12)$

$AB \backslash CD$	00	01	11	10
00	0 1	1 1	3 1	2 1
01	4 1	5	7	6
11	12 1	13	15	14
10	8 1	9 1	11 1	10 1

$= (0, 1, 3, 2, 8, 9, 11, 10)$

$\bar{B}$

$(0, 4, 12, 8)$

$\bar{C}\bar{D}$

⑯ (A, B, C, D) = (2, 5, 8, 10, 15)

AB \ CD	00	01	11	10
00	0	1	3	2_1
01	4	5_1	7	6
11	12	13	15_1	14
10	8_1	9	11	10_1

(8, 10), (2, 10), (5), (15)

$A\bar{B}\bar{D} + \bar{B}C\bar{D} + \bar{A}B\bar{C}D + ABCD$

⑰ (A, B, C, D) = (0, 2, 8, 10)

AB \ CD	00	01	11	10
00	0_1	1	3	2_1
01	4	5	7	6
11	12	13	15	14
10	8_1	9	11	10_1

(0, 2), (8, 10)

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

⑱ (A, B, C, D) = (1, 2, 4, 8, 10, 15)

AB \ CD	00	01	11	10
00	0	1_1	3	2_1
01	4_1	5	7	6
11	12	13	15_1	14
10	8_1	9	11	10_1

(1), (4), (15), (10, 2)

$\bar{A}\bar{B}\bar{C}D + \bar{A}B\bar{C}\bar{D} + ABCD + \bar{B}C\bar{D} +$

(10, 8)

$A\bar{B}\bar{D}$

⑲ (A, B, C, D) = (0, 1, 2, 4, 5, 6, 8, 9, 12, 13, 14

AB \ CD	00	01	11	10
00	0_1	1_1	3	2_1
01	4_1	5_1	7	6_1
11	12_1	13_1	15	14_1
10	8_1	9_1	11	10

(0, 1, 4, 5, 12, 13, 8, 9), ~~(0, 4, 12, 2, 6, 14~~ ~~(2, 14)~~ (6, (6, 14)

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

(0, 2)

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

m, Σ = SOP
m, Π = POS

20. $xy'z + x'y'z + w'xy + wx'y + wxy$

Sol.

w	x	y'	z		
0	1	0	1	→	5
1	1	0	1	→	13

w	x'	y'	z		
0	0	0	1	→	1
1	0	0	1	→	9

w'	x	y	z		
0	1	1	0	→	6
0	1	1	1	→	7

w	x'	y	z		
1	0	1	0	→	10
1	0	1	1	→	11

w	x	y	z		
1	1	1	0	→	14
1	1	1	1	→	15

21. $F(A,B,C,D) = m(1,2,6,7,8,13,14,15) + d(0,3,5,12)$

Sol.

AB \ CD	00	01	11	10
00	0 x	1 1	3 x	2 1
01	4	5 x	7 1	6 1
11	12 x	13 1	15 1	14 1
10	8 1	9	11	10

(8, 0), (12, 13, 15, 14), (1, 5, 3, 7), (3, 7, 2, 6)
$\bar{B}\bar{C}\bar{D} + AB + \bar{A}D + \bar{A}C$

22. K-MAP (5, 13, 1, 9, 6, 7, 10, 11, 14, 15)

wx \ yz	00	01	11	10
00	0	1 1	3	2
01	4	5 1	7 1	6 1
11	12	13 1	15 1	14 1
10	8	9 1	11 1	10 1

6, 14
(1, 5, 13, 9), (7, 15, 6, 14), (11, 10)
$\bar{y}z + xy + wy$

POS

21. $\Pi(0,5,4,6) = f(A,B,C)$

A \ BC	00	01	11	10
0	0 0	1	3	2
1	4 0	5 0	7	6 0

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

22. $f(A,B,C,D) = \Pi M(3,4,5,7,9,13,14,15)$

AB \ CD	00	01	11	10
00	0	1	3 0	2
01	4 0	5 0	7 0	6
11	12	13 0	15 0	14 0
10	8	9 0	11	10

3,7 + 4,5 + 13,9 + 15,14

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

23. $f(A,B,C,D) = M(1,2,6,7,8,13,14,15) + d(0,3,5,12)$

AB \ CD	00	01	11	10
00	0 x	1 0	3 x	2 0
01	4	5 x	7 0	6 0
11	12 x	13 0	15 0	14 0
10	8 0	9	11	10

(12,8), (3,2,7,6)

(0,1,3,2), (12,13,15,14)+

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

24. $f(W,X,Y,Z) = \Pi M(5,13,1,9,6,7,10,11,14,15)$

WX \ YZ	00	01	11	10
00	0	1 0	3	2
01	4	5 0	7 0	6 0
11	12	13 0	15 0	14 0
10	8	9 0	11 0	10 0

$(Y+\bar{Z}) * (\bar{X}+\bar{Y}) * (\bar{W}+\bar{Y})$

25 $(A,B,C,D) = \Pi(0,1,2,4,5,6,8,9,12,13,14)$

AB \ CD	00	01	11	10
00	0 0	1 0	3	2 0
01	4 0	5 0	7	6 0
11	12 0	13 0	15	14 0
10	8 0	9 0	11	10

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

26 $(A,B,C,D) = \Pi(1,2,4,8,10,15)$

AB \ CD	00	01	11	10
00	0	1 0	3	2 0
01	4 0	5	7	6
11	12	13	15 0	14
10	8 0	9	11	10 0

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

27 $(A,B,C,D) = \Pi(0,1,2,3,4,8,9,10,11,12)$

AB \ CD	00	01	11	10
00	0 0	1 0	3 0	2 0
01	4 0	5	7	6
11	12 0	13	15	14
10	8 0	9 0	11 0	10 0

$(B) * (C+D)$

28 $f(w,x,y,z) = \Pi(1,3,4,6,9,11,12,14)$

wx \ yz	00	01	11	10
00	0	1 0	3 0	2
01	4 0	5	7	6 0
11	12 0	13	15	14 0
10	8	9 0	11 0	10

$(x+\bar{z}) * (\bar{x}+z)$

29 $f(A,B,C,D) = \Pi(0,1,3,5,7,8,9,11,13,15)$

AB \ CD	00	01	11	10
00	0 0	1 0	3 0	2
01	4	5 0	7 0	6
11	12	13 0	15 0	14
10	8 0	9 0	11 0	10

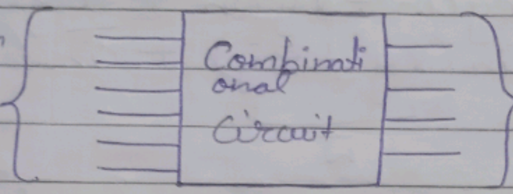
$(\bar{D}) * (B+C+D)$

Combinational Circuits :

- The output of Combinational circuit depends on the present state input.

- Input comes from external source and output goes to external destination. • It has no memory

- Block Diagram



✪ Types of Combinational circuit :-

2-Input , 2 outp

1.) Half - adder

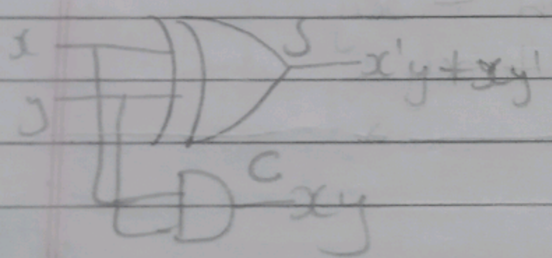
$\underbrace{xy + \bar{y}z}_{\text{logic function}}$

Sum ↓

$x \backslash y$	0	1
0	0	1 , 1
1	2 , 1	3

$\underbrace{\bar{x}y + x\bar{y}}_{\text{EX-OR GATE}}$

	Input		Output	
	x	y	Carry	Sum
0	0	0	0	0
1	0	1	0	1
2	1	0	0	1
3	1	1	1	0



Carry →

$x \backslash y$	0	1
0	0	1
1	2	3 , 1

xy

2.) full - adders 3-In , 2-Out

$x \backslash yC_{in}$	00	01	11	10
0	0	1 , 1	3★	2 , 1
1	4 , 1	5★	7★ , 1	6★ , 1

$$Sum - \overset{(4)}{x\bar{y}\bar{C}_{in}} + \overset{(1)}{\bar{x}\bar{y}C_{in}} + \overset{(7)}{xyC_{in}} + \overset{(2)}{\bar{x}y\bar{C}_{in}}$$

$$Carry - \underset{(5,7)}{xC_{in}} + \underset{(3,7)}{yC_{in}} + xy\,(7,6) \Rightarrow (x \oplus y)z + xy$$

	Input			Output	
	x	y	C_{in}	Sum	C_{out}
0	0	0	0	0	0
1	0	0	1	1	0
2	0	1	0	1	0
3	0	1	1	0	1
4	1	0	0	1	0
5	1	0	1	0	1
6	1	1	0	0	1
7	1	1	1	1	1

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

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

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

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

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

$=$ EX-NOR

$= A \odot B$.

★ Sum: $xy\,cin + \bar{x}\bar{y}\,cin + \bar{x}y\,\overline{cin} + x\bar{y}\,\overline{cin}$

$= cin\,(\underbrace{xy + \bar{x}\bar{y}}_{\bar{w}}) + \overline{cin}\,(\underbrace{\bar{x}y + x\bar{y}}_{w})$

$\bar{w} = \bar{x}\bar{y} + xy$

$=$ X-NOR

$w = \bar{x}y + x\bar{y}$

$= x \oplus y$

$=$ X-OR

$= cin\,(\bar{w}) + \overline{cin}\,(w)$

$= cin \oplus w$

$= cin \oplus x \oplus y$

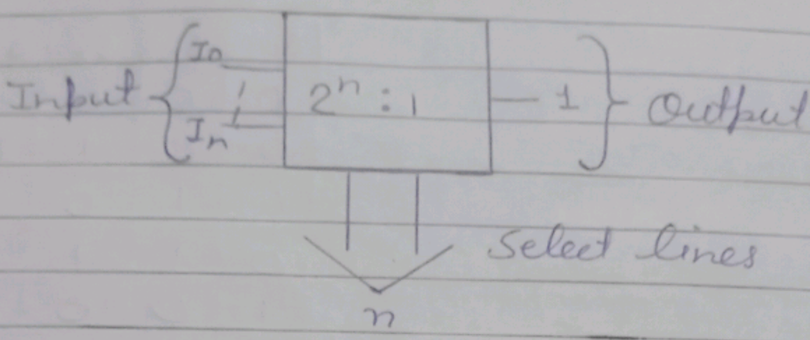
[Sum Carry] Diagram :- 1st AND Gate then All AND GATE in OR GATE.

★ Carry : $x\,cin + y\,cin + xy$

$= cin\,(x+y) + xy$

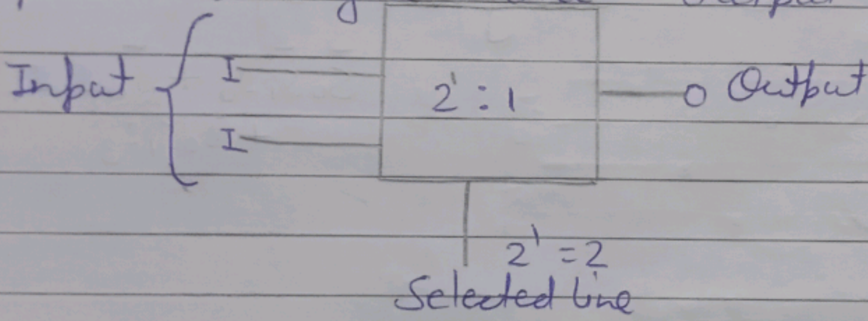
— ★ — ★ — ★ —

★ MULTIPLEXER is an electronic switch

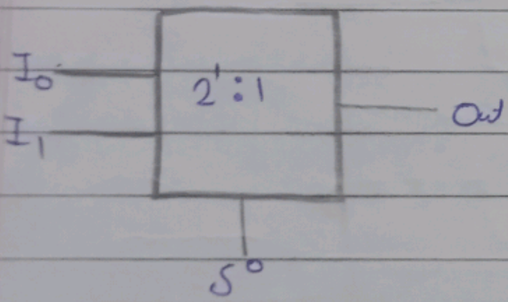


2^n	
$2^1=2$	$2^3=8$
$2^2=4$	$2^4=16$

→ It is a combinational circuit which except 2^n inputs and give 1 output. n is the select line or control line. Accept Multiple Input and give one output.



① →

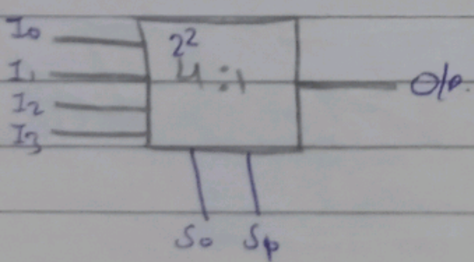


S_0	O/P
0	I_0
1	I_1

$\bar{S}_0 I_0 + S_0 I_1$

$x + 0 = x$

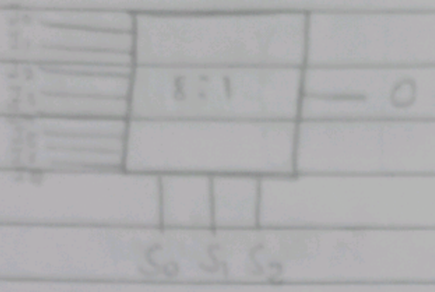
② →



S_0	S_1	O/P
0	0	I_0
0	1	I_1
1	0	I_2
1	1	I_3

$\bar{S}_0\bar{S}_1 I_0 + \bar{S}_0 S_1 I_1$
$+ S_0 \bar{S}_1 I_2 + S_0 S_1 I_3$

③ → $2^3 = 8:1$

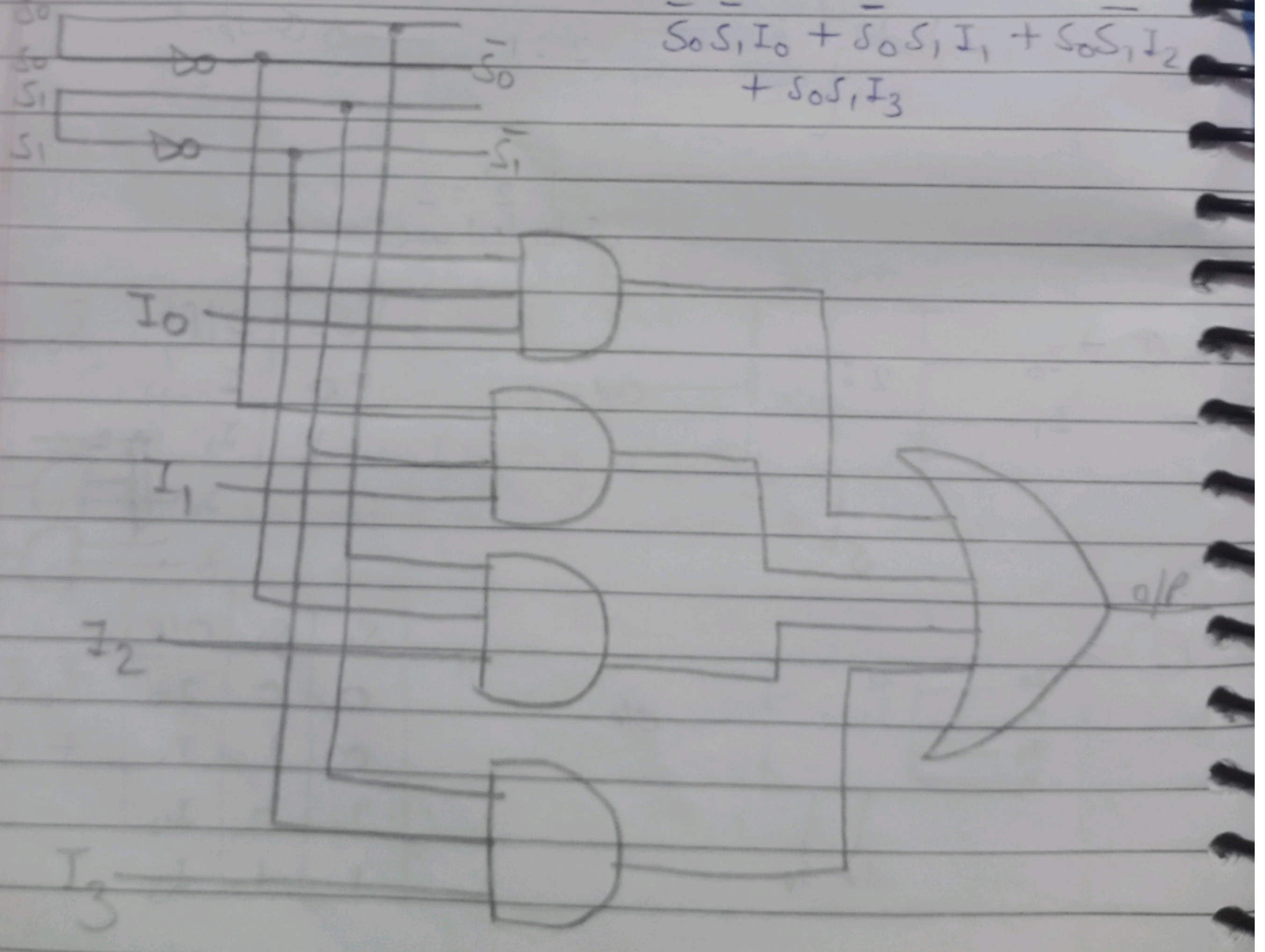


S_0	S_1	S_2	o/p
0	0	0	I_0
0	0	1	I_1
0	1	0	I_2
0	1	1	I_3
1	0	0	I_4
1	0	1	I_5
1	1	0	I_6
1	1	1	I_7

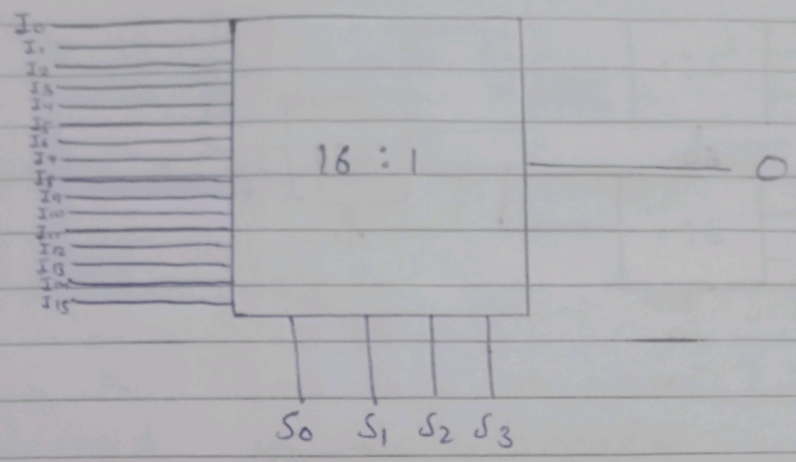
$\bar{S}_0\bar{S}_1\bar{S}_2 I_0 + \bar{S}_0\bar{S}_1 S_2 I_1 + \bar{S}_0 S_1 \bar{S}_2 I_2$
$+ \bar{S}_0 S_1 S_2 I_3 + S_0\bar{S}_1\bar{S}_2 I_4 +$
$S_0\bar{S}_1 S_2 I_5 + S_0 S_1 \bar{S}_2 I_6 + S_0 S_1 S_2 I_7$

→ Circuit diagram of 4:1.

$\bar{S}_0\bar{S}_1 I_0 + \bar{S}_0 S_1 I_1 + S_0 \bar{S}_1 I_2$
$+ S_0 S_1 I_3$



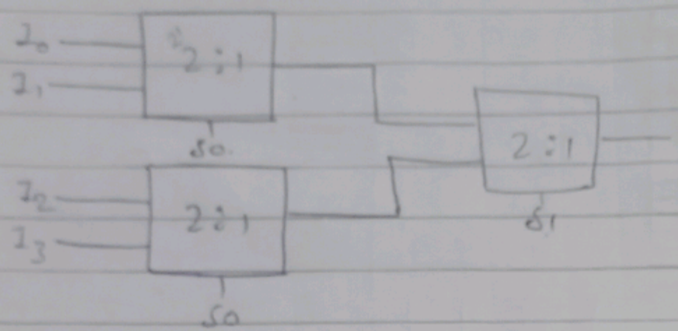
$\Rightarrow$ 16 : 1



S_0	S_1	S_2	S_3	O/P
0	0	0	0	I_0
0	0	0	1	I_1
0	0	1	0	I_2
0	0	1	1	I_3
0	1	0	0	I_4
0	1	0	1	I_5
0	1	1	0	I_6
0	1	1	1	I_7
1	0	0	0	I_8
1	0	0	1	I_9
1	0	1	0	I_{10}
1	0	1	1	I_{11}
1	1	0	0	I_{12}
1	1	0	1	I_{13}
1	1	1	0	I_{14}
1	1	1	1	I_{15}

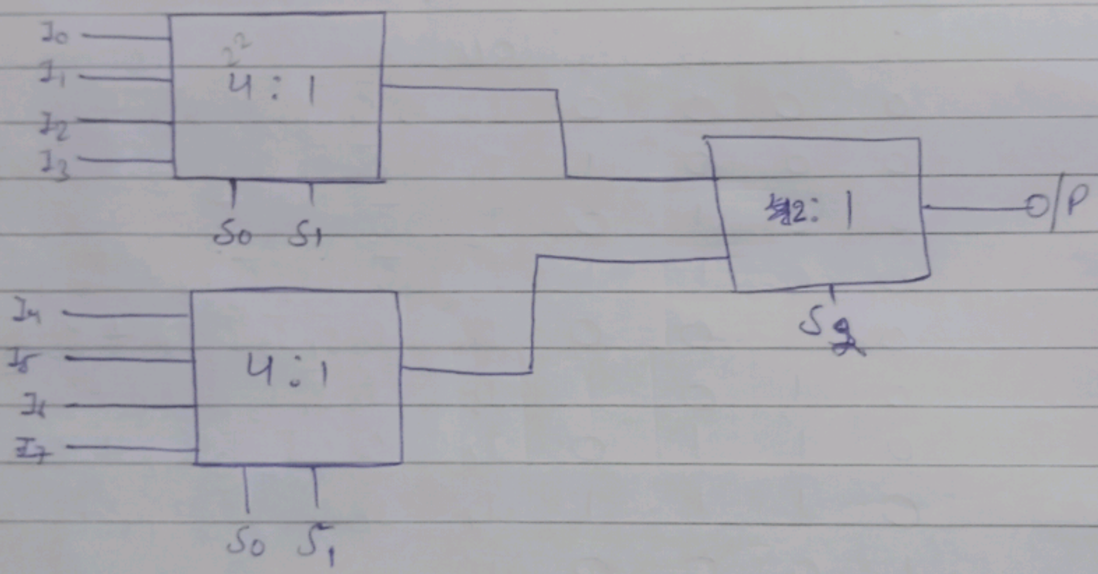
$\Rightarrow \bar{S}_0 \bar{S}_1 \bar{S}_2 \bar{S}_3 I_0 + \bar{S}_0 \bar{S}_1 \bar{S}_2 S_3 I_1 +$
$\bar{S}_0 \bar{S}_1 S_2 \bar{S}_3 I_2 + \bar{S}_0 \bar{S}_1 S_2 S_3 + I_3 +$
$\bar{S}_0 S_1 \bar{S}_2 \bar{S}_3 I_4 + \bar{S}_0 S_1 \bar{S}_2 S_3 I_5 +$
$\bar{S}_0 S_1 S_2 \bar{S}_3 I_6 + \bar{S}_0 S_1 S_2 S_3 I_7 +$
$S_0 \bar{S}_1 \bar{S}_2 \bar{S}_3 I_8 + S_0 \bar{S}_1 \bar{S}_2 S_3 I_9 +$
$S_0 \bar{S}_1 S_2 \bar{S}_3 I_{10} + S_0 \bar{S}_1 S_2 S_3 I_{11} +$
$S_0 S_1 \bar{S}_2 \bar{S}_3 I_{12} + S_0 S_1 \bar{S}_2 S_3 I_{13} +$
$S_0 S_1 S_2 \bar{S}_3 I_{14} + S_0 S_1 S_2 S_3 I_{15}$

5. 4:1



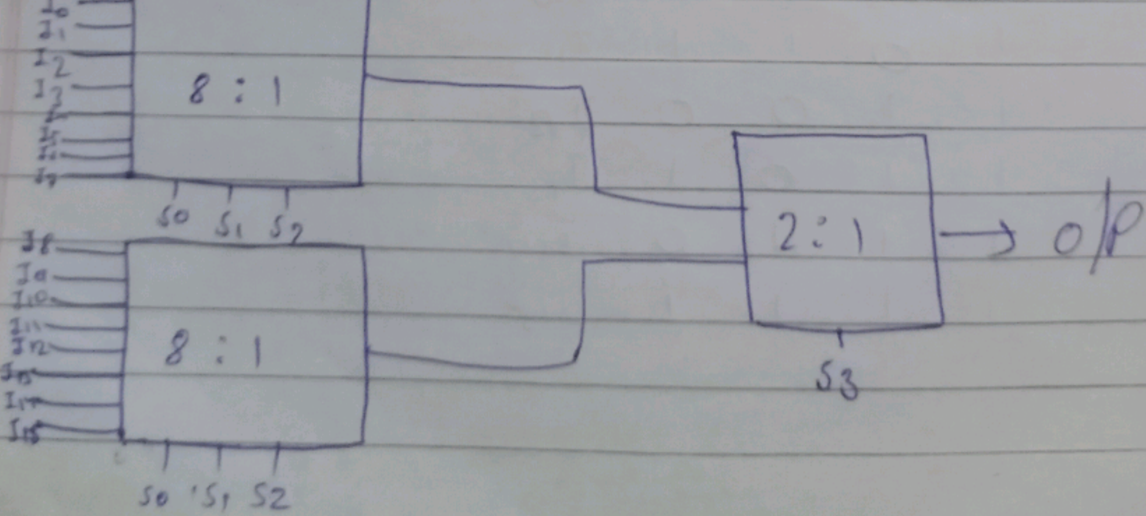
I_0
I_1
I_2
I_3
2:1
2:1
2:1
S_0
S_0
S_1

6. 8:1

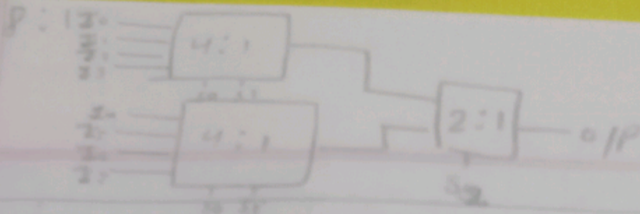


I_0
I_1
I_2
I_3
I_4
I_5
I_6
I_7
4:1
4:1
2:1
S_0 S_1
S_0 S_1
S_2
O/P

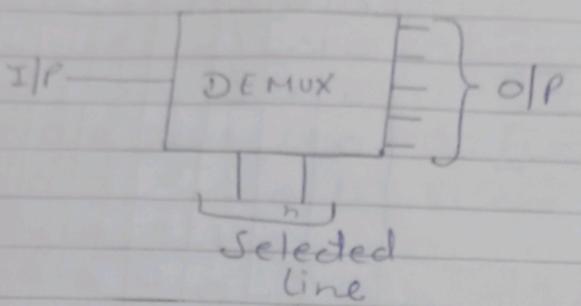
7. 16:1



8:1
8:1
2:1
S_0 S_1 S_2
S_0 S_1 S_2
S_3
O/P

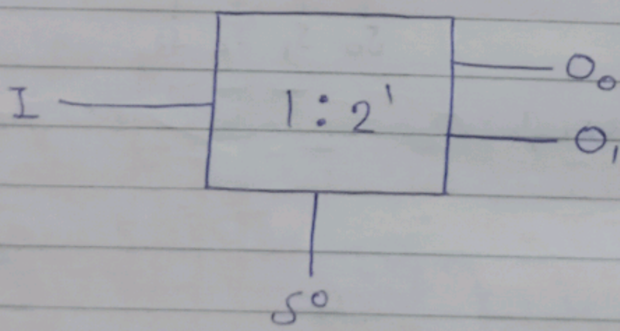


★ Demux :-



Demultiplexer is a combinational circuit which accepts an single input and gives multiple output or it can forward a single input to multiple output. for e.g.:- 1 person has a file in a soft form. It can be the input for a printer or a fax machine that depends on the purpose of a file.

⇒

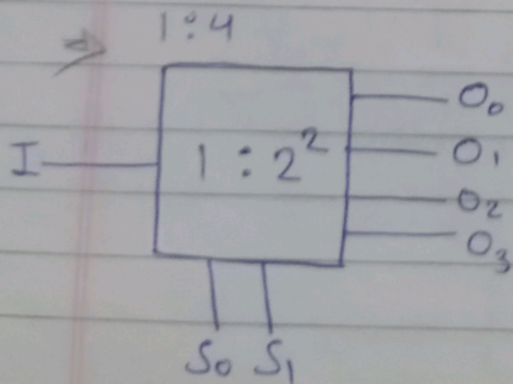


S_0	O_0	O_1
0	I	0
1	0	I

$O^0 = \bar{S_0} I$

$O_1 = S_0 I$

⇒ 1:4

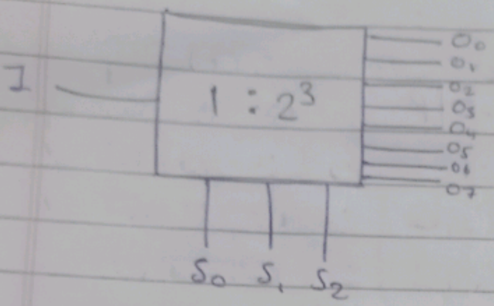


S_0	S_1	O_0	O_1	O_2	O_3
0	0	I	0	0	0
0	1	0	I	0	0
1	0	0	0	I	0
1	1	0	0	0	I

$O_0 = \bar{S_0} S_1 I$, $O_1 = \bar{S_0} S_1 I$, $O_2 = \bar{S_0} \bar{S_1} I$

$O_3 = S_0 S_1 I$

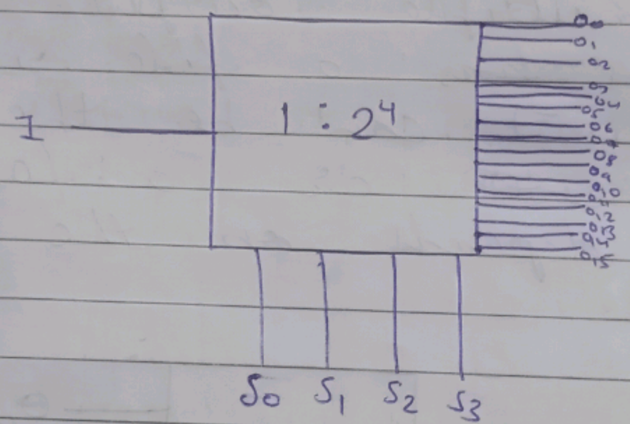
⇒ 1 : 8



S_0	S_1	S_2	O_0	O_1	O_2	O_3	O_4	O_5	O_6	O_7
0	0	0	I	0	0	0	0	0	0	0
0	0	1	0	I	0	0	0	0	0	0
0	1	0	0	0	I	0	0	0	0	0
0	1	1	0	0	0	I	0	0	0	0
1	0	0	0	0	0	0	I	0	0	0
1	0	1	0	0	0	0	0	I	0	0
1	1	0	0	0	0	0	0	0	I	0
1	1	1	0	0	0	0	0	0	0	I

$O_0 = \bar{S}_0\bar{S}_1\bar{S}_2 I$, $O_1 = \bar{S}_0\bar{S}_1 S_2 I$, $O_2 = \bar{S}_0 S_1 \bar{S}_2 I$,
$O_3 = \bar{S}_0 S_1 S_2 I$, $O_4 = S_0\bar{S}_1\bar{S}_2 I$, $O_5 = S_0\bar{S}_1 S_2 I$,
$O_6 = S_0 S_1 \bar{S}_2 I$, $O_7 = S_0 S_1 S_2 I$

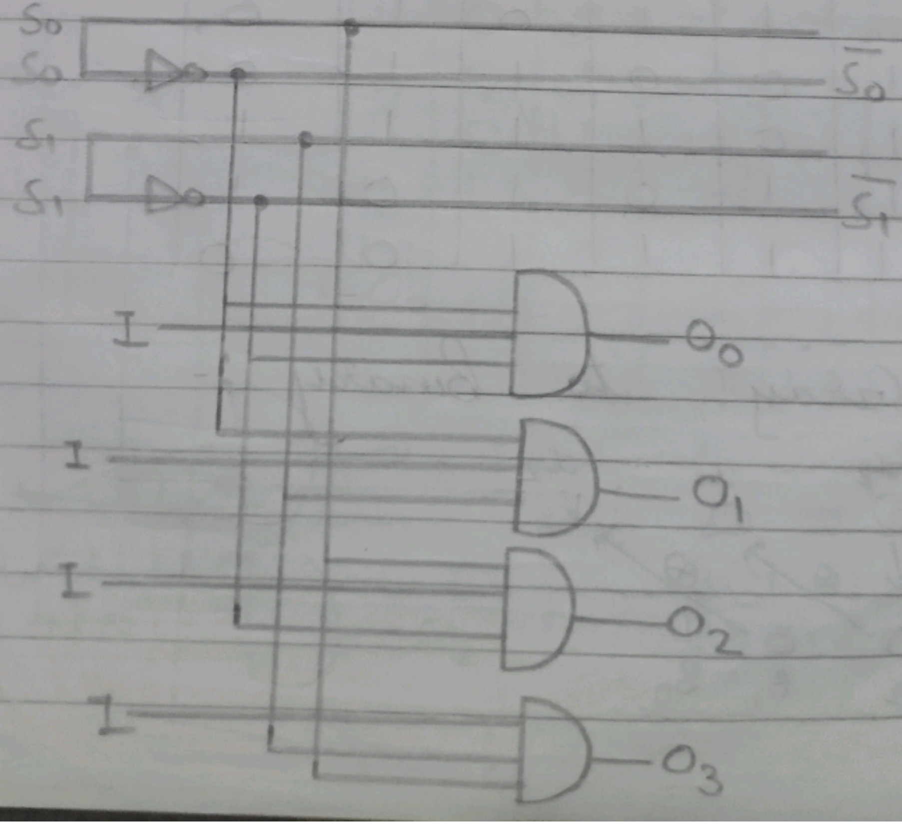
⇒ 1 : 16



expression :- $O_0 := \bar{S}_0\bar{S}_1\bar{S}_2\bar{S}_3 I$, $O_1 := \bar{S}_0\bar{S}_1\bar{S}_2 S_3 I$, $O_2 := \bar{S}_0\bar{S}_1 S_2\bar{S}_3 I$, $O_3 := \bar{S}_0\bar{S}_1 S_2 S_3 I$,
$O_4 := \bar{S}_0 S_1\bar{S}_2\bar{S}_3 I$, $O_5 := \bar{S}_0 S_1\bar{S}_2 S_3 I$, $O_6 := \bar{S}_0 S_1 S_2\bar{S}_3 I$,
$O_7 := \bar{S}_0 S_1 S_2 S_3 I$, $O_8 := S_0\bar{S}_1\bar{S}_2\bar{S}_3 I$
$O_9 := S_0\bar{S}_1\bar{S}_2 S_3 I$, $O_{10} := S_0\bar{S}_1 S_2\bar{S}_3 I$
$O_{11} := S_0\bar{S}_1 S_2 S_3 I$, $O_{12} := S_0 S_1\bar{S}_2\bar{S}_3 I$
$O_{13} := S_0 S_1\bar{S}_2 S_3 I$, $O_{14} := S_0 S_1 S_2\bar{S}_3 I$
$O_{15} := S_0 S_1 S_2 S_3 I$

S_0	S_1	S_2	S_3	O_0	O_1	O_2	O_3	O_4	O_5	O_6	O_7	O_8	O_9	O_{10}	O_{11}	O_{12}	O_{13}	O_{14}	O_{15}
0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	1	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	0	0
1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

⇒ Diagram 1 : 4



A	B	A⊕B
0	0	0
0	1	1
1	0	1
1	1	0

★ Binary to Gray code converter :

0100 (Most Significant bit ... Least sig bit) $\rightarrow$ $\overset{x_3}{0} \oplus \overset{x_2}{1} \oplus \overset{x_1}{0} \oplus \overset{x_0}{0}$

0110

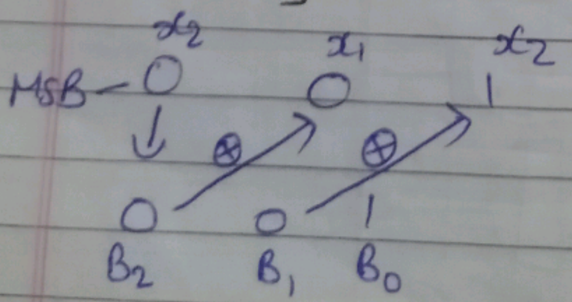
→ Copy the MSB bit as it.
→ To find out the next bit in the gray code you have to perform $x_3 \oplus x_2$. for the e.g given above

⇒ $1 \oplus 0 \oplus 1 \oplus 0 \oplus 0 \oplus 1 \oplus 0 \oplus 1 \rightarrow 11110111$

⇒ $01000010001 \rightarrow 01100011001$

B_2	B_1	B_0	G_2	G_1	G_0
0	0	0	0	0	0
0	0	1	0	0	1
0	1	0	0	1	1
0	1	1	0	1	0
1	0	0	1	1	0
1	0	1	1	1	1
1	1	0	1	0	1
1	1	1	1	0	0

★ Gray to Binary :-



→ In gray to binary conversion, copy the MSB as given in the above e.g.

⇒ 100100 → 111000

⇒ 16 Bits.

B_3	B_2	B_1	B_0	G_3	G_2	G_1	G_0
0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	1
0	0	1	0	0	0	1	1
0	0	1	1	0	0	1	0
0	1	0	0	0	1	1	0
0	1	0	1	0	1	1	1
0	1	1	0	0	1	0	1
0	1	1	1	0	1	0	0
1	0	0	0	1	$\cancel{0}$ 1	0	0
1	0	0	1	1	$\cancel{0}$ 1	0	1
1	0	1	0	1	$\cancel{0}$ 1	1	1
1	0	1	1	1	$\cancel{0}$ 1	1	0
1	1	0	0	1	0	1	0
1	1	0	1	1	0	1	1
1	1	1	0	1	0	0	1
1	1	1	1	1	0	0	0

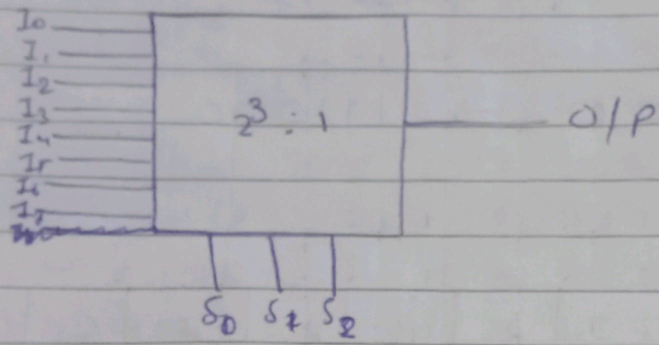
① G to B

100111101
111010110

② B to G

101101001111
1001$\cancel{0}$101000

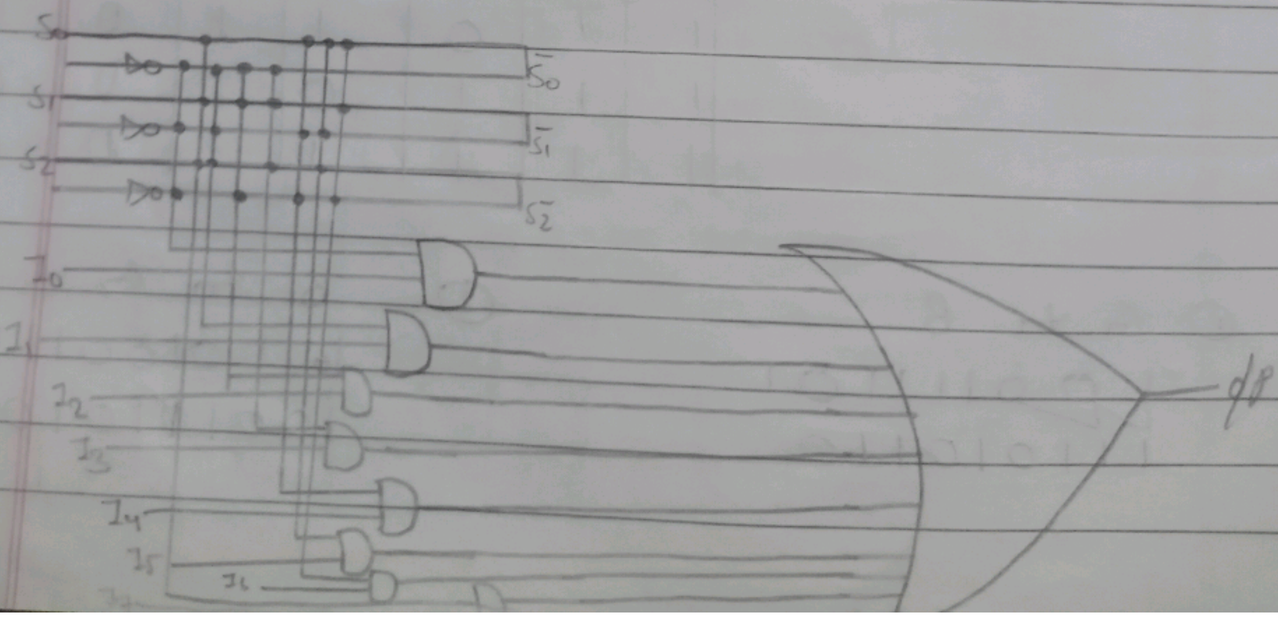
③ 8 : 1 ~~De~~mux



Truth Table

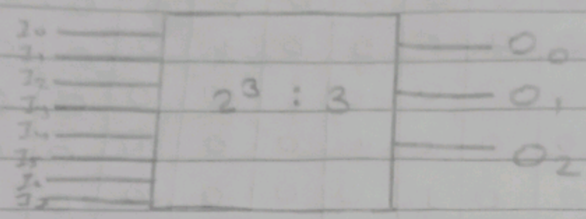
S_0	S_1	S_2	O/P
0	0	0	I_0
0	0	1	I_1
0	1	0	I_2
0	1	1	I_3
1	0	0	I_4
1	0	1	I_5
1	1	0	I_6
1	1	1	I_7

$$\bar S_0 \bar S_1 \bar S_2 I_0 + \bar S_0 \bar S_1 S_2 I_1$$
$$+ \bar S_0 S_1 \bar S_2 I_2 + \bar S_0 S_1 S_2 I_3$$
$$+ S_0 \bar S_1 \bar S_2 I_4 + S_0 \bar S_1 S_2 I_5$$
$$+ S_0 S_1 S_2 I_6 + S_0 S_1 S_2 I_7$$



encoder ⟹ 2^n I/P n O/P
decoder ⟹ n I/P 2^n O/P

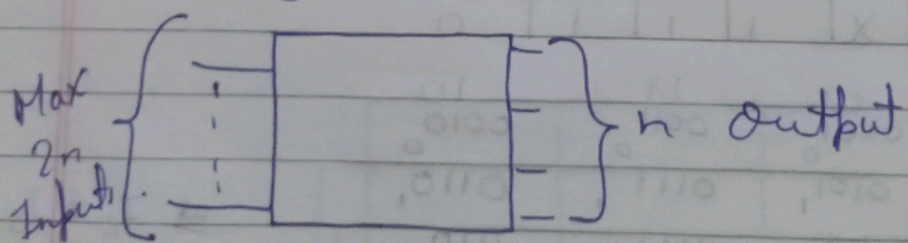
encoder :-



I_7	I_6	I_5	I_4	I_3	I_2	I_1	I_0	O_2	O_1	O_0
0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	1	0	0	0	1
0	0	0	0	0	1	0	0	0	1	0
0	0	0	0	1	0	0	0	0	1	1
0	0	0	1	0	0	0	0	1	0	0
0	0	1	0	0	0	0	0	1	0	1
0	1	0	0	0	0	0	0	1	1	0
1	0	0	0	0	0	0	0	1	1	1

$O_0 = I_1 + I_3 + I_5 + I_7$
$O_1 = I_2 + I_3 + I_6 + I_7$
$O_2 = I_4 + I_5 + I_6 + I_7$

Encoder is a combinational circuit which accepts max. 2^n input & give n outputs. encoder converts the code into binary format. for e.g BCD to Binary encoder.



BCD (Binary Coder Decimal (0-9))

$\cancel{2^3 = 8}$

I_9	I_8	I_7	I_6	I_5	I_4	I_3	I_2	I_1	I_0	O_3	O_2	O_1	O_0
0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0	0	1
0	0	0	0	0	0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	0	0	0	0	1	1
0	0	0	0	0	1	0	0	0	0	0	1	0	0
0	0	0	0	1	0	0	0	0	0	0	1	0	1
0	0	0	1	0	0	0	0	0	0	0	1	1	0
0	0	1	0	0	0	0	0	0	0	0	1	1	1
0	1	0	0	0	0	0	0	0	0	1	0	0	0
1	0	0	0	0	0	0	0	0	0	1	0	0	1

$O_0 \rightarrow I_1 + I_3 + I_5 + I_7 + I_9$
$O_1 \rightarrow I_2 + I_3 + I_6 + I_7$
$O_2 \rightarrow I_4 + I_5 + I_6 + I_7$
$O_3 \rightarrow I_8 + I_9$

Parity :- It is concept to detect errors. A single bit error is detected by it

★ Priority encoder

I_3	I_2	I_1	I_0	O_1	O_0	V	Invalid
0	0	0	0	X	X	0	1
0	0	0	1	0	0	1	0
0	0	1	X	0	1	1	0
0	1	X	X	1	0	1	0
1	X	X	X	1	1	1	0

O_1

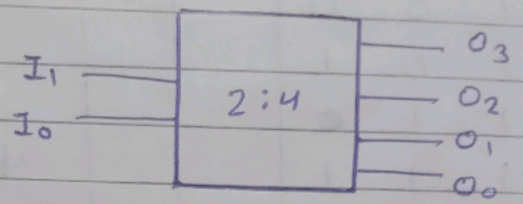
$I_3I_2 \backslash I_1I_0$	00	01	11	10
00	0000 X	0001 0	0011 0	0010 0
01	0100 1	0101 1	0111 1	0110 1
11	1100 1	1101 1	1111 1	1110 1
10	1000 1	1001 1	1011 1	1010 1

$\Rightarrow I_2 + I_3$

I_3I_2 \ I_1I_0	00	01	11	10
00	0000 x	0001 0	0011 1	0010 1
01	0100 0	0101 0	0111 0	0110 0
11	1100 1	1101 1	1111 1	1110 1
10	1000 1	1001 1	1011 1	1010 1

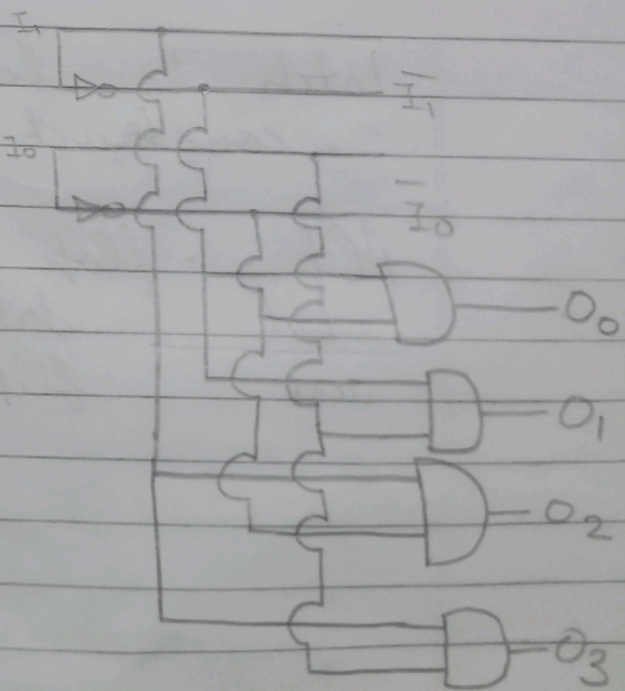
$\Rightarrow I_3 + \bar{I}_2 I_1$

⇒ Decoder



I_1	I_0	O_3	O_2	O_1	O_0
0	0	0	0	0	1
0	1	0	0	1	0
1	0	0	1	0	0
1	1	1	0	0	0

$O_0 \Rightarrow \bar{I}_1 \bar{I}_0$
$O_1 \Rightarrow \bar{I}_1 I_0$
$O_2 \Rightarrow I_1 \bar{I}_0$
$O_3 \Rightarrow I_1 I_0$



Binary to BCD

I_3	I_2	I_1	I_0	O_9	O_8	O_7	O_6	O_5	O_4	O_3	O_2	O_1	O_0
0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	1									1	0
0	0	1	0								1	0	0
0	0	1	1							1	0	0	0
0	1	0	0						1				
0	1	0	1					1					
0	1	1	0				1						
0	1	1	1			1							
1	0	0	0		1								
1	0	0	1	1									

★ ~~Latch~~ :- In the sequential circuit output depend on current input and past output for e.g. latch , flip flop

Latch :- Latch is used to construct the flip flop.

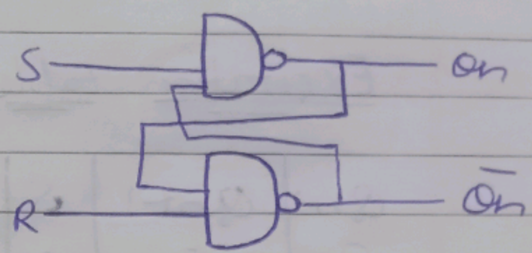
Flip -flop :- To store one bit data we have to use flip flop.

NAND GATE

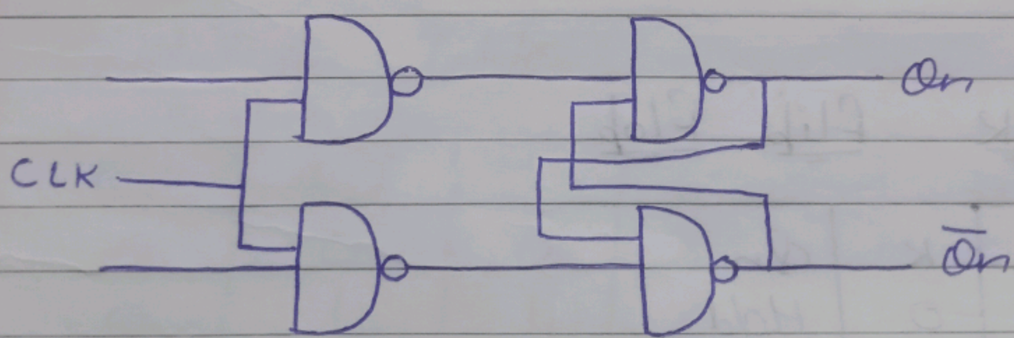
X	Y	R	$\bar{R}$
0	0	0	1
0	1	0	1
1	0	0	1
1	1	1	0

SR Latch

S	R	Q_{n+1}
0	0	invalid
0	1	1
1	0	0
1	1	HOLD



SR flip-flop



S	R	Q_n
0	0	HOLD
0	1	0
1	0	1
1	1	INVALID ~~HOLD~~

Characterstic table

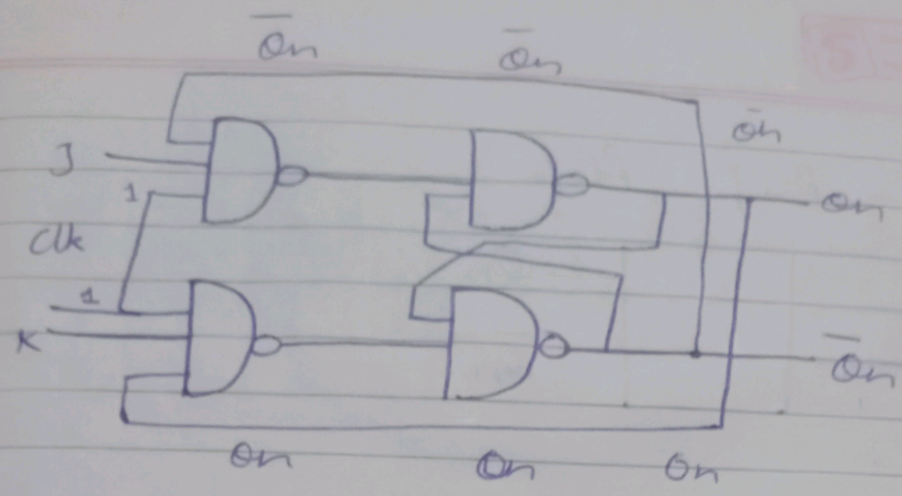
S	R	Qn	Qn+1
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	Invalid
1	1	1	Invalid

Excitation table

Qn	Qn+1	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

JK flip flop

J	K	Qn
0	0	Hold
0	1	0
1	0	1
1	1	Toggle



Characteristic table

	J	K	Q_n	Q_{n+1}
0	0	0	0	0
1	0	0	1	1
2	0	1	0	0
3	0	1	1	0
4	1	0	0	1
5	1	0	1	1
6	1	1	0	1
7	1	1	1	0

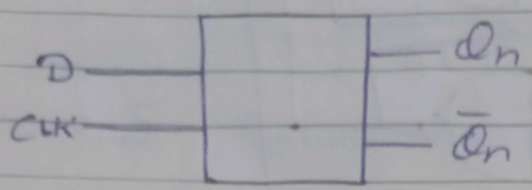
Excitation Table

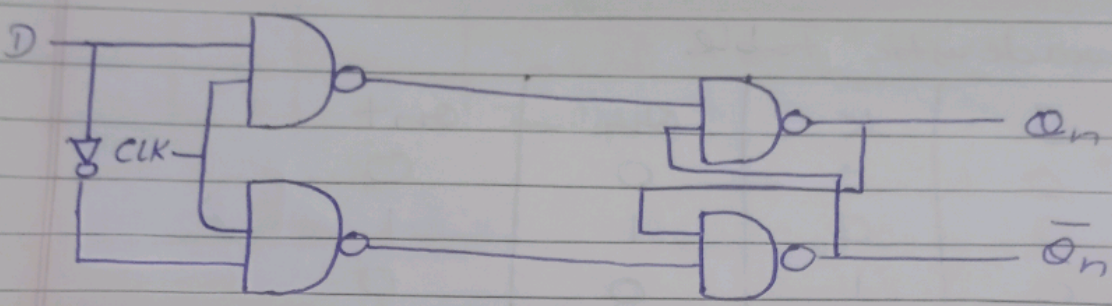
Q_n	Q_{n+1}	J	K
0	0	0	X
0	1	1	X
1	0	X	1
1	1	X	0

J \ KQ_n	00	01	11	10
0	0	1 1	3	2
1	4 1	5 1	7	6 1

$\Rightarrow \bar{K}Q_n + J\bar{Q}_n$

D - flip flop





D	Q_n
0	0
1	1

→ Truth table

Characteristic table

D	Q_n	Q_{n+1}
0	0	0
0	1	0
1	0	1
1	1	1

D \ Q_{n+1}	0	1
0	0	1
1	2 1	3 1

D

Excitation table

Q_{n+1}	Q_n	D
0	0	0
0	1	~~0~~ 1
1	0	D
1	1	1

T- flip flop

T	Q_{n+1}
0	Q_n
1	$\overline{Q_n}$

Characteristics Table

	T	Q_n	Q_{n+1}
0	0	0	0
1	0	1	1
2	1	0	1
3	1	1	0

X-OR

T \ Q_n	0	1
0	0	1 1
1	2 1	3

$\bar{T}Q_n + T\bar{Q_n}$

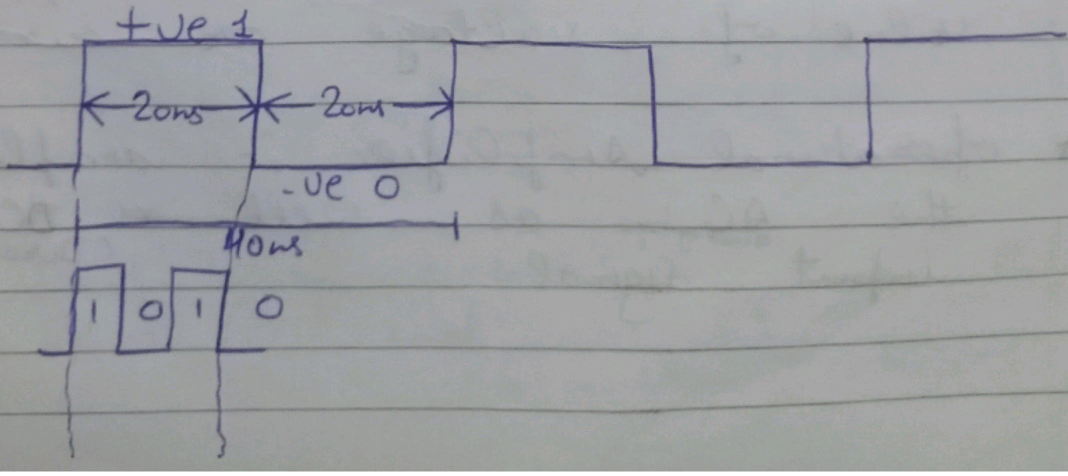
Excitation Table

Q_{n+1}	Q_n	T
0	0	0
0	1	1
1	0	1
1	1	0

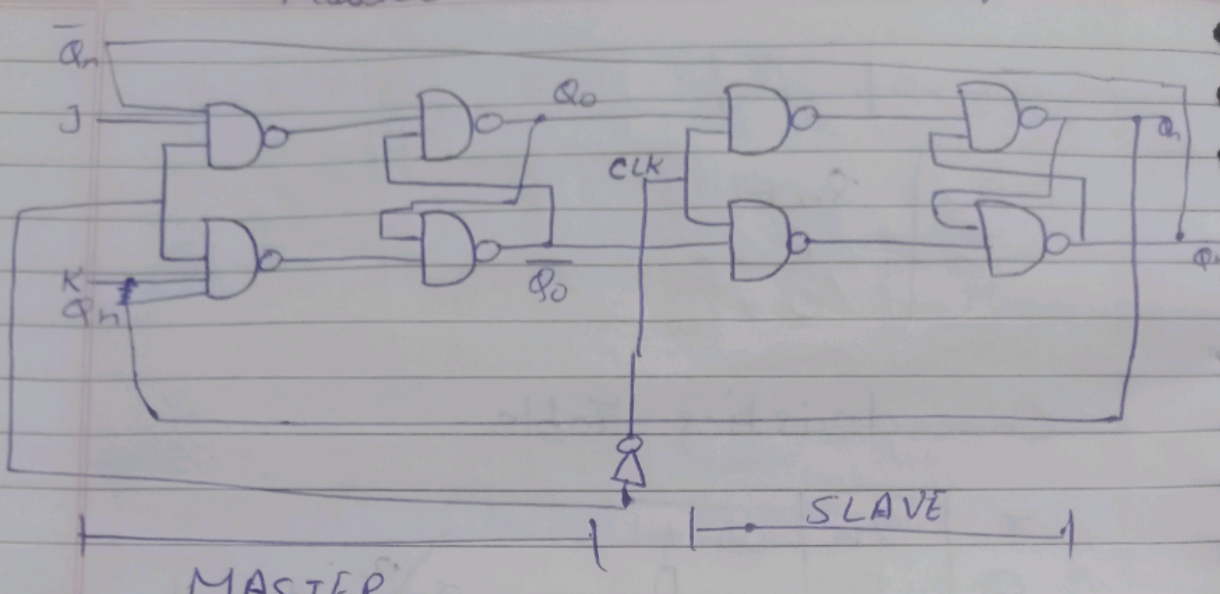
Q_{n+1} \ Q_n	0	1
0	0	1 1
1	2 1	3

$\overline{Q_{n+1}}\, Q_n + Q_{n+1}\,\overline{Q_n}$

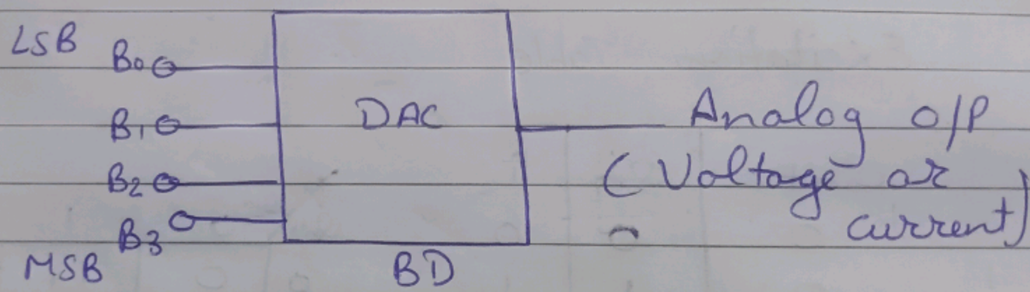
★ Race Round Condition



Master Slave JK flip flop



★ Digital to Analog converter (DAC)



DAC :- It receives the I/P in the form of binary digits and convert it into corresponding value of voltage or current.

★ operational Amplifier :- amplifies the AC (analog!) as well as DC (Direct current) input signal.

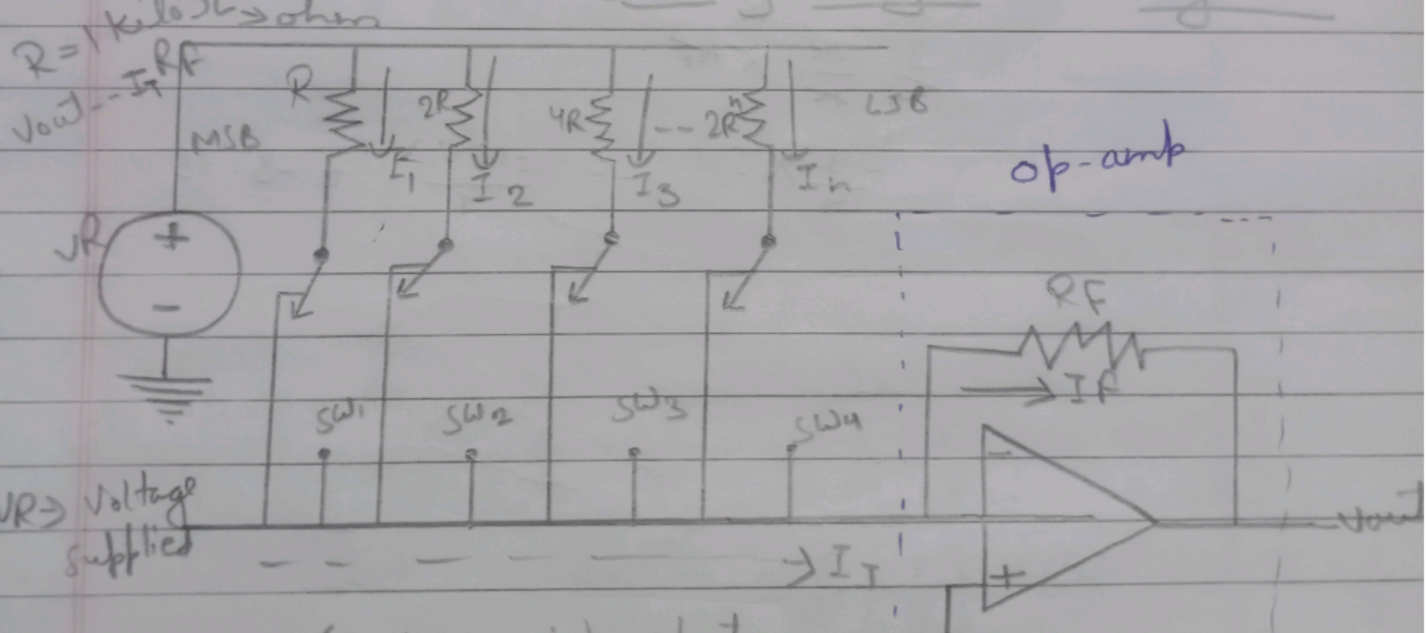
☆ Resolution :- It is the smallest change occur due to change in input.

☆ Accuracy :- How much the actual o/p is matching with the expected o/p.

☆ Full scale Range (FSR) :- Maximum o/p signal for the DAC.

☆ Settling time :- every digital signal take some time to produce the o/p

Binary weighted register



A_v (Voltage gain) = $\frac{V_{out}}{V_{in}}$

I_T → Total current

R_f → feed back resistor (to control the voltage gain)

R & R_f = 1 Kilo ohm Ω

$V_{out} = I_T R_f$

$\frac{V_{out}}{R_T}$

MSB

$I_T = I_1 + I_2 + I_3 + I_4$

$I_T = \cancel{\frac{VR}{R}}^{\text{-Voltage}} + \frac{VR}{2R} + \frac{VR}{4R} + \cancel{\frac{VR}{8R}}$

$\frac{VR}{R}\left[\frac{1}{2} + \frac{1}{4}\right]$

$\frac{VR}{R}\left[\frac{2+1}{4}\right] \frac{3}{4}$

$\frac{VR}{R} \times \frac{3}{4}$

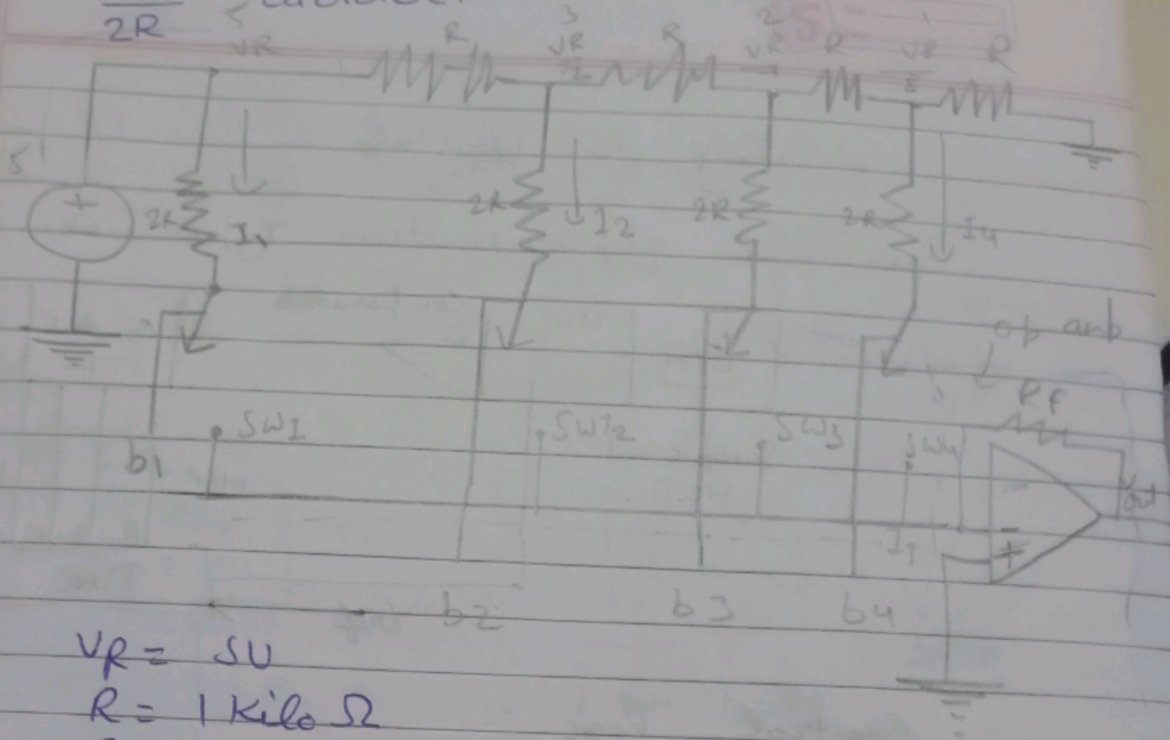
$\therefore V = \underline{IR}$ Total current

$I = \frac{V}{R}$

$\frac{3}{4} \frac{VR}{\cancel{R}} \times R_f$

$-\frac{3}{4} \times 5V = \frac{-15V}{4} = -3.75V$

$\frac{R}{2R}$ Ladder



$V_R = 5V$

$R = 1$ Kilo Ω

$R_f = 1$ Kilo Ω

$I_T = I_1 + I_2 + I_3 + I_4$

$= VR + \frac{VR/2R}{2R} + \frac{VR/2R}{4R} + \frac{VR/2R}{8R}$

0 1 1 0

$= \frac{VR}{4\cancel{2}R} + \frac{VR}{8\cancel{4}R}$

$= \frac{VR}{R}\left[\frac{1}{4} + \frac{1}{8}\right] = VR\left[\frac{2+1}{8}\right] = \frac{VR}{R}\left[\frac{3}{8}\right]$

$V_{out} = -I_f R_f = \frac{-VR}{\cancel{R}}\left[\frac{3}{8}\right] \times R_f = -VR \times \frac{3}{8}$

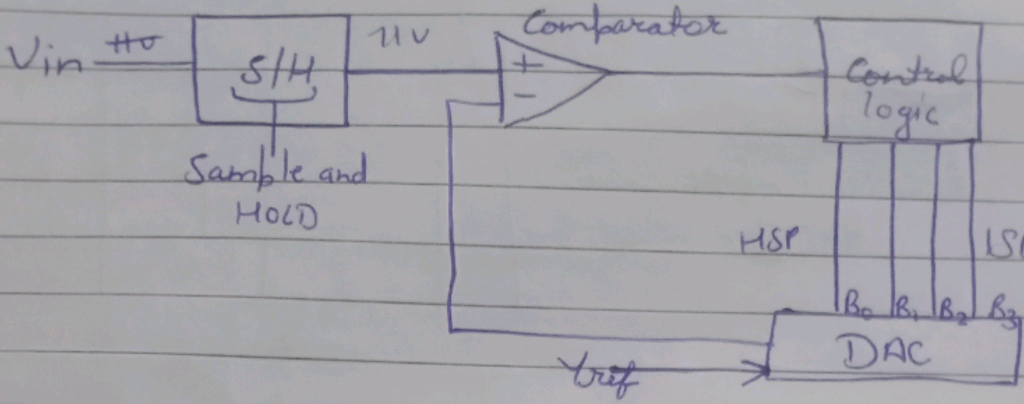
$VR = 5V$

$= -5V \times \frac{3}{8} = \frac{-15V}{8}$

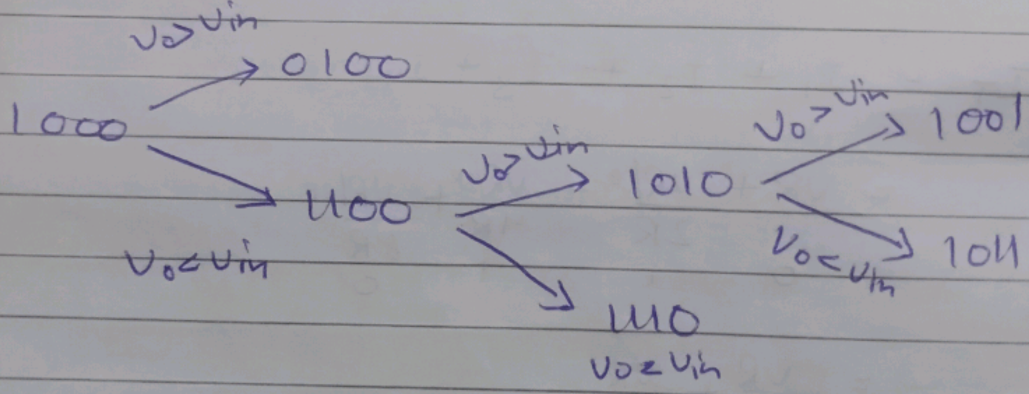
8, 7, $\boxed{4,5}$, 2, 3, Race Round,

Analog to Digital

Successive approximation Type DAC

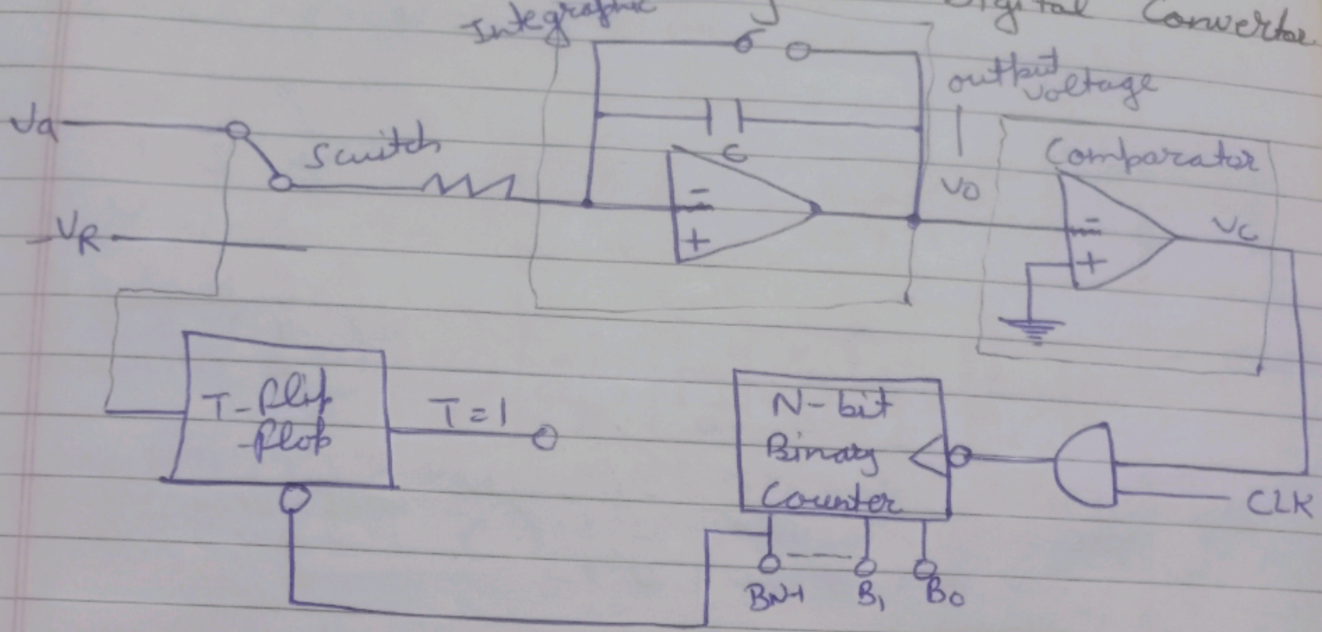


Control logic :-



Initial O/P for successive approxi register is 1000.

Dual slop Analog to Digital Converter



Va = Analog voltage that we want to convert in Digital form.

VR = Reference voltage

$$V_o = \frac{-1}{RC}\int_0^t V_a\,dt = \frac{-1}{RC} V_a t$$