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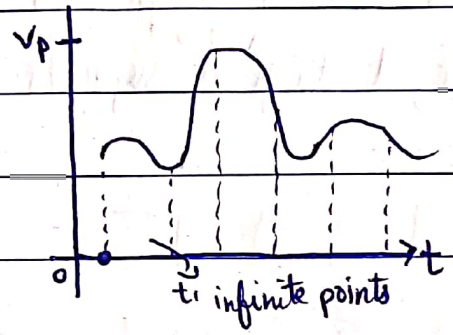
Hardware consists of electronic components / circuit.

Types of electronic signal → 2

analog digital

→ any signal which is continuous in time.
→ Doesn't have any discrete value.
→ all natural waves are analog signals.



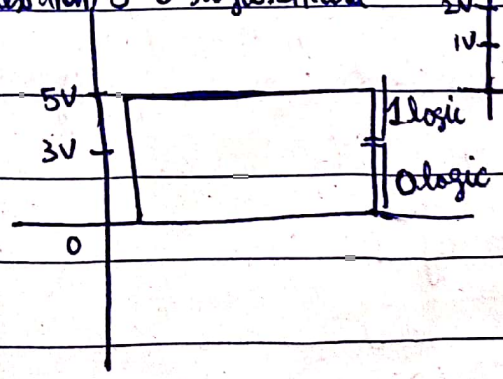
Sampling Choose specific value on specific time.

Every wave requires medium.

Quantization

digital signals less error.

less than 3 0 logic. Like wise



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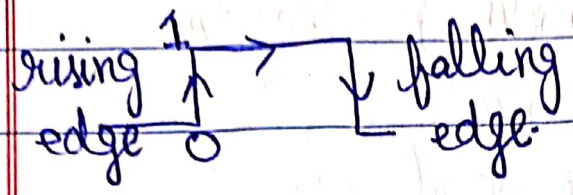
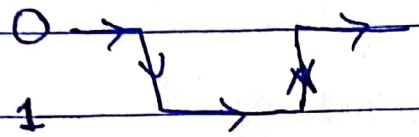
Pulse

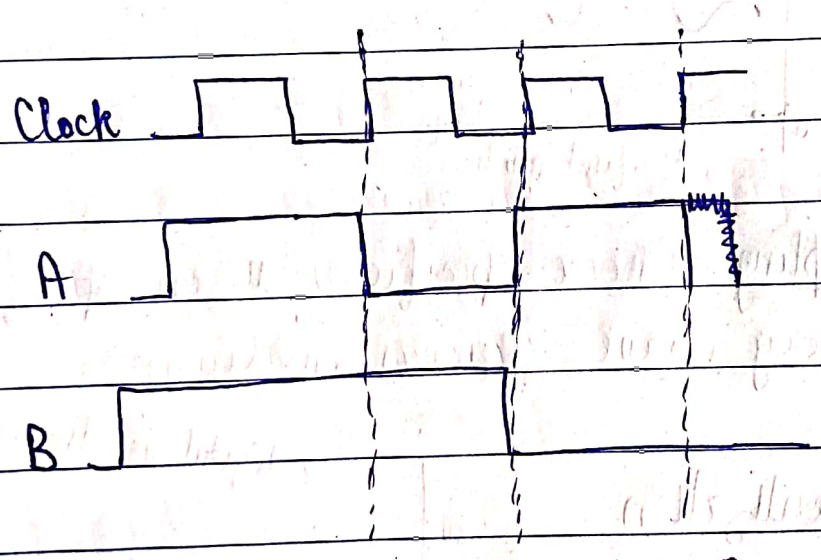


[high → logic 1
low → logic 0
+ve logic



[high → logic 0
low → logic 1
-ve logic

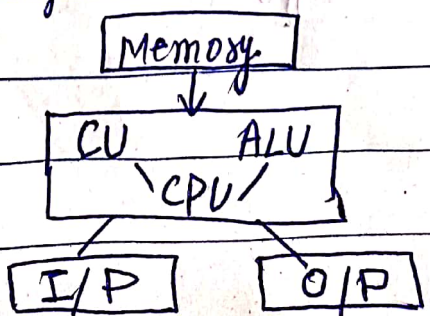
Clock . continuous train of pulses.
• synchronized digital signals.



∴ 0101 or anything → bits = voltage level.

Data signals → Data → in form of signals.

∴ Types of digital devices :-



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Decimal No: Base 10 → 0-9.
Octal No : Base 8 → 0-7
Hexa No : Base 16 → 0-F
Binary No : Base 2 → 0-1

Conversion

$(17.683)_{10} \rightarrow (?)_2$

17 = 10001

.683 x 2 → 1.366 → .336 x 2 → 0.732 → .732 x 2 → 1.464 →

.464 x 2 → 1.00 → 1011

$(10001.1011)_2$

$(1C)_{16} \rightarrow (?)_{10}$

$112 \rightarrow 1 \times 16^1 + 12 \times 16^0 = 16 + 12 = (28)_{10}$

$(650.342)_{10}$

16 | 650
16 | 40 - 10
2 - 8

.342 x 16 = 5.472
.472 x 16 = 7.542
.542 x 16 = 8.672

$(28A.578)_{16}$

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$(240)_{10} \rightarrow (?)_8$

$$\begin{array}{r|l} 8 & 240 \\ \hline 8 & 30-0 \\ & 3-6 \end{array}$$

$= (360)_8$

$(360)_8 \rightarrow (?)_2 \Rightarrow 8 \Rightarrow 2^3$

011 110 000

$(011110000)_2$

BCD system

seperate every numeral. then apply binary code

1, 3, 4

$(0001\ 0011\ 0100)_2$

ASCII

7 bits coding schem $\Rightarrow$ 0-127 $\Rightarrow$ 128 characters.

$\downarrow$

2^7

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Graycode (no weights, 8421)
(one bit change).

0	0000
1	0001
2	0011
3	0010
4	0110
5	0111
6	0101
7	0100

Little Endian / Big Endian

term that describes the order in which a sequence of bytes is stored in memory.

Little Endian is an order which "little end" (least significant term) is stored first.

Big Endian is an order which "the big end" (most significant term) is stored first.

e.g.

In hexadecimal · 4E69 would be storage.

In big endian 4E and 69 be stored in 1000 and 1001 address respectively.

In little endian 69 & 4E be stored in 1000 & 1001 address respectively.

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$(28A)_{16} \rightarrow (\quad)_8$

$2 \times 16^2 + 8 \times 16^1 + 10 \times 16^0$

$= (650)_{10} \rightarrow (\quad)_8$

$$\begin{array}{r|l} 8 & 650 \\ \hline 8 & 81 - 2 \\ \hline 8 & 10 - 1 \\ \hline & 1 - 2 \end{array} \Rightarrow (1212)_8$$

Parity Bit → no of bits in a sequence.

→ even or odd according to number of 1's.

→ error detection.

i.e even parity

0 0010001

i.e odd parity

1 0010001

Addition

(Hexa)

$$\begin{array}{r} 59F \\ +\ E46 \\ \hline 13E5 \end{array}$$

$F \rightarrow 15$

$$\begin{array}{r|l} 16 & 21 \\ & 16 \\ \hline & 5 \end{array}$$

$$\begin{array}{r|l} 16 & 19 \\ \hline & 1 - 3 \end{array}$$

(Octal)

$$\begin{array}{r} 375 \\ +\ 246 \\ \hline 643 \end{array}$$

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

$$\begin{array}{r|l} 8 & 12 \\ \hline & 1 - 4 \end{array}$$

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```
        1 1 1 1
        01101011
(binary) 10011010
        100000101
```

Subtraction

```
        1 1 1 1
        1 1 0 0 0
(binary) -  1 1 1
        10001
```

```
(Hexa)  C D 8 8
       -7 F 4 5
        5 E 4 3
```

13+16=29-15
=14

12
-7

```
(Octal)  4 7 1 5
        -1 2 3 7
         3 4 5 6
```

8+5=13-7

Multiplication

```
      2 D E
      x 5 F
    2 B 0 2
    E 5 6 x
  1 1 0 6 2
```

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(binary)

```
      11000
    x   101
    -------
      11000
     00000x
    11000xx
    -------
    11111000
```

(Octal)

```
      745
    x  27
    -----
     5215
    1490x
    -----
    20115
```

(all numbers multiplied must be from (0-7)).

```
      745
    x  27
    -----
     6503
    1490x
    -----
    25623
```

8|35
4-3

8|37
4-5

8|60
7-4

8|10
1-2

8|9
1-1

8|15
1-7

8|53
6-5

8|32
4-0

8|3
1-5

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M T W T F S

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signed.	Unsigned.
• magnitude	• magnitude.
• sign (+ or −)	

To represent

- Signed magnitude.
- 1's compliment.
- 2's compliment.

Signed Magnitude

MSBit Magnitude bits

0, 1101001

+, 105 if 1 then (−).

1, 0011010

− 26

1's compliment

changing 0 into 1 & 1 into 0.

128 64 32 16 8 4 2 1

⇒ [(00100110)₂ ⇒ (38)₁₀

64 32 16 8 4 2 1

→ 1s compliment (1101001)

− 0100110 ⇒ (−38)₁₀

64
16
8
+1

M☐T☐W☐T☐F☐S☐ Date: ...../...../20.....

2's compliment

add 1 in 1s compliment is 2's compliment

$$\begin{array}{r} 11011001 \\ + \quad 1 \\ \hline 11011010 \end{array}$$

	signed	1's	2's
+0	0000	0000	0000
+1	0001	0001	0001
+2	0010	0010	0010
+3	0011	0011	0011
+4	0100	0100	0100
+5	0101	0101	0101
+6	0110	0110	0110
+7	0111	0111	0111
-0	1000	1111	$\boxed{1}$0000
-1	1001	1110	1111
-2	1010	1101	1110
-3	1011	1100	1101
-4	1100	1011	1100
-5	1101	1010	1011
-6	1110	1001	1010
-7	1111	1000	1001

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M T W T F S Date: ...../...../20.....

6 - 13

	16	8	4	2	1
6	0	0	1	1	0
13	0	1	1	0	1

00110

$-$ ~~01101~~

0011

00010

+1

00011

$-16+2+1$

$=-13$

00110

+ 10011

11001

16 8 4 2 1

$\boxed{11001}$

$-16+8+1$

$-16+9$

$=-7$

⇒ dealing with same signs will have overflow flag.

⇒ dealing with opposite signs will have carry flag.

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M. Abdullah Atif

~~Prob 1~~

$F(x,y,z) = \bar{x}yz + \bar{x}y\bar{z} + xz$

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

$\Rightarrow \bar{x}y + xz$

L.H.S

$xy + \bar{x}z + yz = xy + \bar{x}z$ Prove

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

$xy + \bar{x}z + yzx + yz\bar{x}$

$xy(1+z) + \bar{x}z(1+y)$ $\therefore 1+z=1$ $\therefore 1+y=1$

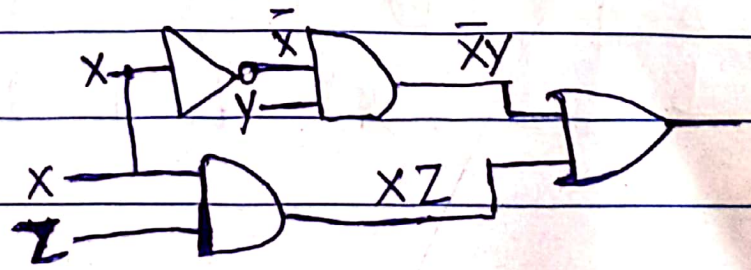
$xy + \bar{x}z$

$xy + \bar{x}z + yz = xy + \bar{x}z$ → dual

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

$F = \bar{x}yz + \bar{x}y\bar{z} + xz$

reduced in circuit $\Rightarrow \bar{x}y + xz$



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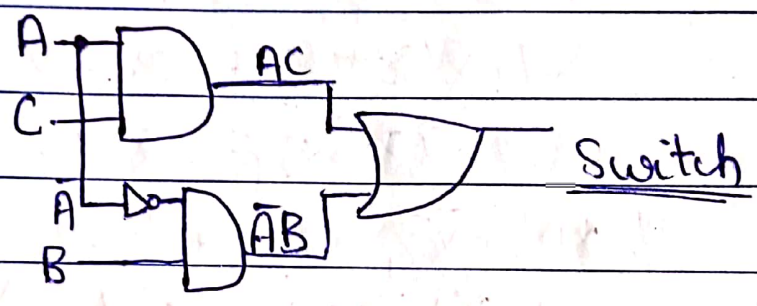
$(A+B)(\bar{A}+C)$

$\bar{A}A + AC + B\bar{A} + BC$ $\quad (A \cdot \bar{A} = 0)$

$0 + \underline{AC + \bar{A}B + BC}$ consesis theorem

$XY + \bar{X}Z + YZ = XY + \bar{X}Z$

$\Rightarrow AC + \bar{A}B$ $\quad \therefore$ consensis theorem



A	B	C	$\bar{A}$	AC	$\bar{A}B$	$AC+\bar{A}B$
0	0	0	1	0	0	0
0	0	1	1	0	0	0
0	1	0	1	0	1	1
0	1	1	1	0	1	1
1	0	0	0	0	0	0
1	0	1	0	1	0	1
1	1	0	0	0	0	0
1	1	1	0	1	0	1

Truth Table

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$X + XY = X$

$X(1+Y) = X$ $\quad \therefore 1+Y=1$

$X = X$ proved

$X(X+Y) = ?$

$\Rightarrow XX + XY$ $\quad \therefore (X \cdot X = X)$

$X + XY$

$X(1+Y)$ $\quad \therefore (1+Y=1)$

$X \cdot 1 = X$ proved

$XY + \bar{X}Y$

$Y(X+\bar{X})$ $\quad \therefore (X+\bar{X}=1)$

$Y \cdot 1 = Y$ proved.

$(X+Y)(X+\bar{Y})$

$XX + X\bar{Y} + YX + Y\bar{Y}$ $\quad \therefore (Y \cdot \bar{Y} = 0)$

$X + X\bar{Y} + XY + 0$ $\quad \therefore (X \cdot X = X)$

$X(1+\bar{Y}) + XY$ $\quad \therefore (1+\bar{Y} = 1)$

$X + XY$ $\quad \therefore (1+Y=1)$

$X(1+Y)$ proved

$X \cdot 1 = X$

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$X(\bar{X}+Y)$

$X\bar{X}+XY$ $\quad \therefore X\cdot\bar{X}=0$

$0+XY$ proved

$X+\bar{X}Y =$ $\quad$ ∵ 2nd distributive law ∴

$(X+\bar{X})(X+Y)$ $\quad 1\cdot(X+Y)$

$\cancel{XX+XY+\bar{X}X+\bar{X}Y}$ $\quad = X+Y$

$\cancel{X+XY+0+\bar{X}Y}$

$\cancel{X(1+Y)+\bar{X}Y}$

$\cancel{\Rightarrow X+\bar{X}Y}$ $\quad$ proved

$F=XY+X(Y+Z)+Y(Y+Z)$

$=XY+XY+XZ+YY+YZ$ $\quad \therefore (Y\cdot Y=Y)$

$=\cancel{XY+XZ+YY+YZ}$

$=XY+XY+XZ+Y(1+Z)$

$=XY+XY+XZ+Y$ $\quad \therefore (1+Z=1)$

$=XY+Y(1+X)+XZ$ $\quad \therefore (1+X=1)$

$=Y(1+X)+XZ$ $\quad \therefore (1+X=1)$

$=Y+XZ$

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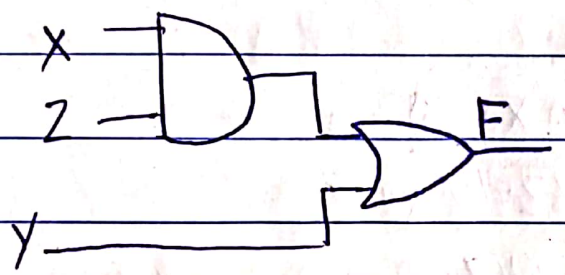
$F = Y + XZ$

Truth Table

x	Y	Z	XZ	Y + XZ
0	0	0	0	0
0	0	1	0	0
0	1	0	0	1
0	1	1	0	1
1	0	0	0	0
1	0	1	1	1
1	1	0	0	1
1	1	1	1	1

Circuit $F = Y + XZ$



$\overline{\overline{AB} + \overline{AC} + \overline{ABC}}$

$(\overline{AB}) \cdot (\overline{AC}) + \overline{ABC}$

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

$\overline{A}\,\overline{A} + \overline{AC} + \overline{AB} + \overline{BC} + \overline{ABC}$

$\overline{A} + \overline{AC} + \overline{AB}(1 + C) + \overline{BC}$ $\quad 1 + C = 1$

$\overline{A}(1 + \overline{C}) + \overline{AB} + \overline{BC}$

$\overline{A}(1 + \overline{B}) + \overline{BC}$

$\overline{A} + \overline{BC}$

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Q $\overline{AB}+\overline{AC}+\overline{ABC}$

$\Rightarrow \overline{AB}\cdot\overline{AC}+\overline{ABC}$

$\Rightarrow \overline{AB}(\overline{A}+\overline{C}+C)$ $\quad \therefore \overline{C}+C=1$

$\Rightarrow \overline{AB}(\overline{A}+1)$ $\quad \therefore \overline{A}+1=1$

$\Rightarrow \overline{A}+\overline{B}$ $\quad \Rightarrow$ De Morgan's law

Standard Representation of Boolean Expressions:

SOP → Sum of Product

POS → Product of Sum.

SOP ⇒ $\boxed{XY+YZ+\overline{X}YZ}$

POS

$XY\cdot 1+YZ\cdot 1+\overline{X}YZ$

$XY(Z+\overline{Z})+YZ(X+\overline{X})+\overline{X}YZ$

$XYZ+XY\overline{Z}+XYZ+\overline{X}YZ+\overline{X}YZ$

$\Rightarrow \boxed{XYZ+XY\overline{Z}+\overline{X}YZ}$

<u>Minterm</u>: Each term in SSOP is called a minterm.

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$\bar{Z} = \bar{Y} = \bar{X} \rightarrow 0$

$Z = Y \; X \rightarrow X$

$m_j \rightarrow j$ is decimal equivalent.

X	Y	Z	Terms	m_0	m_1	m_2	m_3	m_4	m_5	m_6	m_7
0	0	0	$\bar{X}\bar{Y}\bar{Z}$	1							
0	0	1	$\bar{X}\bar{Y}Z$		1						
0	1	0	$\bar{X}Y\bar{Z}$			1					
0	1	1	$\bar{X}YZ$				1				
1	0	0	$X\bar{Y}\bar{Z}$					1			
1	0	1	$X\bar{Y}Z$						1		
1	1	0	$XY\bar{Z}$							1	
1	1	1	XYZ								1

$\boxed{\text{Sum of Minterm } \sum m_j = 1}$

X	Y	Z	F			
0	0	0	1	m_0	$\bar{X}\bar{Y}\bar{Z}$	$F = m_0 + m_2 + m_5 + m_7$
0	0	1	0	M_1	$X+Y+\bar{Z}$	$= \bar{X}\bar{Y}\bar{Z} + \bar{X}Y\bar{Z} + X\bar{Y}Z +$
0	1	0	1	m_2	$\bar{X}Y\bar{Z}$	XYZ min
0	1	1	0	M_3	$X+\bar{Y}+\bar{Z}$	
1	0	0	0	M_4	$\bar{X}+Y+Z$	$F = M_1 \cdot M_3 \cdot M_4 \cdot M_6$
1	0	1	1	m_5	$X\bar{Y}Z$	$= (X+Y+\bar{Z}) \cdot (X+\bar{Y}+\bar{Z}) \cdot$
1	1	0	0	M_6	$\bar{X}+\bar{Y}+Z$	$(\bar{X}+Y+Z) \cdot (\bar{X}+\bar{Y}+Z)$
1	1	1	1	m_7	XYZ	Max

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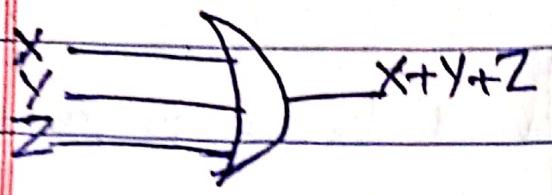
POS

Product of Sum Terms



$X \cdot \bar{X} = 0$
$Z \cdot \bar{Z} = 0$

$$F = (X+Y)\cdot(Y+Z)\cdot(X+Y+Z)$$

$$\Rightarrow (X+Y)+(0)\cdot(Y+Z)+(0)\cdot(X+Y+Z)$$

$$\Rightarrow (X+Y)+(Z\cdot\bar{Z})\cdot(Y+Z)+(X\cdot\bar{X})\cdot(X+Y+Z)$$

$$\Rightarrow \underbrace{(X+Y+Z)}(X+Y+\bar{Z})\cdot\underbrace{(X+Y+Z)}(\bar{X}+Y+Z)\cdot\underbrace{(X+Y+Z)}$$

$$\Rightarrow (X+Y+Z)(X+Y+\bar{Z})(\bar{X}+Y+Z).$$

Maxterm

Each term in SPOS is maxterm.

$$X=Y=Z=0, \quad \bar{X}=\bar{Y}=\bar{Z}=1$$

$\Rightarrow$ $M_j \rightarrow j$ is a decimal equivalent

$\Rightarrow$ $M_j = \overline{m_j}$ (or vice versa).

Sum of Maxterm $\Sigma M_j = 0$.

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Q :) $F = A\bar{B}C + \bar{A}\bar{C} + AB$

$\therefore \; F = \bar{\bar{F}}$

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

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

$\therefore \; \bar{x} = 0$
$x = 1$

$\boxed{\bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C} + \bar{A}BC + A\bar{B}\bar{C} + ABC}$ SSOP.

$= 000 + 010 + 011 + 101 + 111$

$= (m_0) + (m_2) + (m_3) + (m_5) + (m_7)$

$\bar{x} = 1$
$x = 0$

$\Leftrightarrow M_1 \cdot M_4 \cdot M_6$

$(001) \cdot (100) \cdot (110)$

$\Rightarrow \boxed{(A+B+\bar{C}) \cdot (\bar{A}+B+C) \cdot (\bar{A}+\bar{B}+C)}$ SPOS.

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

In Truth table Minterm

A	B	C	F	Terms
0	0	0	0	M_0
0	0	1	1	m_1
0	1	0	0	M_2
0	1	1	0	M_3
1	0	0	1	m_4
1	0	1	0	M_5
1	1	0	0	M_6
1	1	1	1	m_8

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

$\bar{x}=1$
$x=0$

$(0+0+0)(0+1+0)(0+1+1)(1+0+1)(1+1+0)$

A	B	C	F	
0	0	0	0	M_0
0	0	1	1	
0	1	0	0	M_2
0	1	1	0	M_3
1	0	0	1	
1	0	1	0	M_5
1	1	0	0	M_6
1	1	1	1	

-: K-Maps :-

$2^2=4$

$\bar{x}=0$
$x=1$

$F = xy + \bar{x}y$
(x,y)

Minterm $xy \Rightarrow 11$, $\bar{x}y \Rightarrow 01$

x \ y	0	1
0	00	01 [1]
1	10	11 [1]

$\Rightarrow$ x is changing

x \ y	0	1

$\Rightarrow$ y

3-Variable K-map :-

A B C → $2^3 = 8$

X Y Z

A \ BC	00	01	11	10
0	m_0	m_1	m_3	m_2
1	m_4	m_5	m_7	m_6

Q (A,B,C) $Y = \bar{A}\bar{B}C + \bar{A}B\bar{C} + AB\bar{C} + ABC$

$\Rightarrow 001 + 010 + 110 + 111$

$\Sigma m(1,2,6,7)$

A \ BC	00	01	11	10
0	0	1	0	1
1	0	0	1	1

ABC
111
110
AB

ABC
110
010
$B\bar{C}$

ABC
001
$\bar{A}\bar{B}C$

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

Two missing — one missing

$\bar{A} + \bar{A}\bar{B} + AB\bar{C}$ SOP but not SSOP.

~~(0)+(10)+~~

000 100 110

001 101

010

011

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

A \ BC	00	01	11	10
	1	1	1	1
	1	1	0	1

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

$$F(A,B,C) = \Sigma m(1,3,4,5,6)$$

$$m_1 + m_3 + m_4 + m_5 + m_6$$

$$(001) + (011) + (100) + (101) + (110)$$

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

ABC	ABC	ABC	ABC
1 0 1	0 0 1	1 0 0	1 0 0
0 0 1	0 1 1	1 0 1	1 1 0
$\bar{B}\bar{C}$	$\bar{A}C$	$A\bar{B}$	$A\bar{C}$

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

*Don't use already covered ones.

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4- Variable K-MAP

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

AB \ CD	00	01	11	10
00		1	1	
01	1			
11	1	1	1	
10				1

ABCD	ABCD	ABCD	ABCD
1100	1101	0001	1010
0100	1111	0011	
$B\bar{C}D$	ABD	$\bar{A}\bar{B}D$	$A\bar{B}C\bar{D}$

$B\bar{C}D + ABD + \bar{A}\bar{B}D + A\bar{B}C\bar{D}$.

$F(A,B,C,D) = \sum m(0,2,3,5,7,8,10,11,14,15)$

$(0000)+(0010)+(0011)+(0101)+(0111)+(1000)+(1010)+(1011)+(1110)+(1111)$

AB \ CD	00	01	11	10
00	1		1	1
01		1	1	
11			1	1
10	1		1	1

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$F(A,B,C,D) = \sum M(1, 4, 6, 9, 12, 13)$

$(0+0+0+1) \cdot (0+1+0+0) \cdot (0+1+1+0) \cdot (1+1+0+0) \cdot (1+1+0+1)$

AB \ CD	00	01	11	10
00		0		
01	0			0
11	0	0		
10		0		

ABCD	ABCD	ABCD
0100	0001	1100
0110	1001	1101
$A\bar{B}D$	$BC\bar{D}$	$\bar{A}\bar{B}C$

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

$F(A,B,C) = \sum m(2,3,4,5) + \sum d(6,7)$

A \ BC	00	01	11	10
0			1	1
1	1	1	X	X

$F = B + A$.

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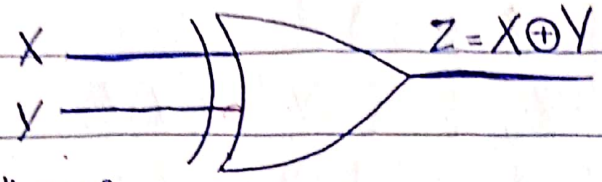
XOR GATE :-

Circuit



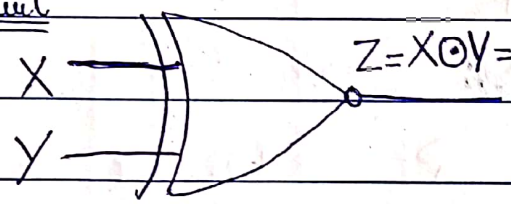
$Z = X \oplus Y = XY' + X'Y$

Truth Table

X	Y	$Z = XY' + X'Y$	$Z = X'Y' + XY$
0	0	0	1
0	1	1	0
1	0	1	0
1	1	0	1

XNOR GATE :-

Circuit



$Z = X \odot Y = X'Y' + XY$

3-bit data : Even Parity generator.

X	Y	Z	P
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

all even numbers.

X \ YZ	00	01	11	10
0		1		1
1	1		1	

$\bar{X}\bar{Y}Z + \bar{X}Y\bar{Z} + X\bar{Y}\bar{Z} + XYZ$

circuit of 3bit data, even parity generator.

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$\cancel{Q}$ $(X \oplus Y) \oplus Z$

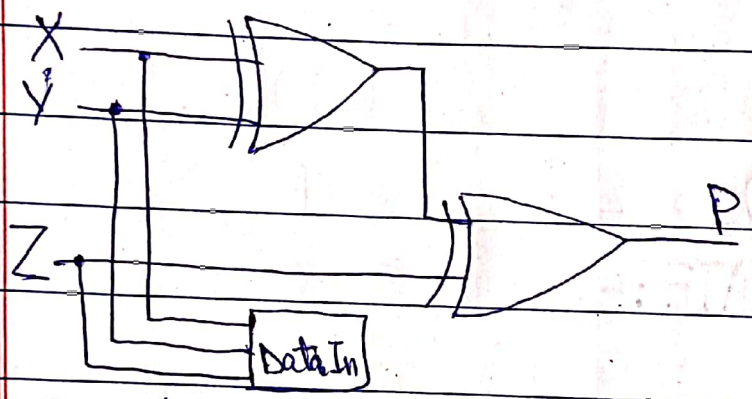
$\Rightarrow (XY' + X'Y) \oplus Z$

$\Rightarrow (XY' + X'Y)Z' + (XY' + X'Y)Z$

$\Rightarrow XY'Z' + XYZ' + [(X'+Y)(X+Y')]Z$

$\Rightarrow XY'Z' + XYZ' + X'Y'Z + XYZ$

$\Rightarrow F \Rightarrow (X \oplus Y) \oplus Z.$



Even Parity checker:

	X	Y	Z	P	Checker
error free	0	0	0	0	0
error	0	0	0	1	1
error free	0	0	1	1	0
error	0	0	1	0	1
"	0	1	0	1	0
"	0	1	0	0	1
"	0	1	1	0	0
"	0	1	1	1	1

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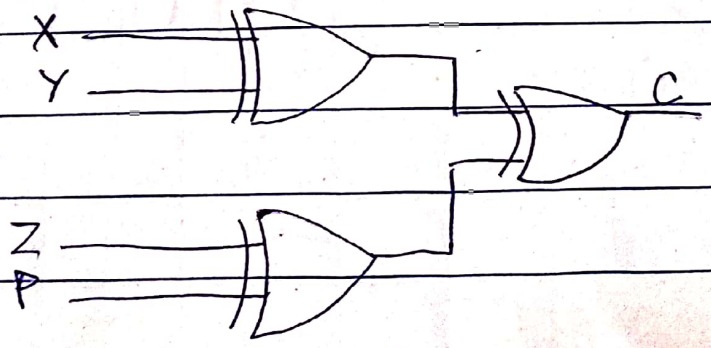
			P	Check
1	0	0	1	0
1	0	0	0	1
1	0	1	0	0
1	0	1	1	1
1	1	0	0	0
1	1	0	1	1
1	1	1	1	0
1	1	1	0	1

XY = AB \ CD = ZP	00	01	11	10
00		1		1
01	1		1	
11		1		1
10	1		1	

$\bar{X}\bar{Y}\bar{Z}P + \bar{X}\bar{Y}Z\bar{P} + \bar{X}YZ\bar{P} + \bar{X}YZP + XY\bar{Z}P +$

$XYZ\bar{P} + X\bar{Y}\bar{Z}\bar{P} + X\bar{Y}ZP$

$\Rightarrow X \oplus Y \oplus Z \oplus P$



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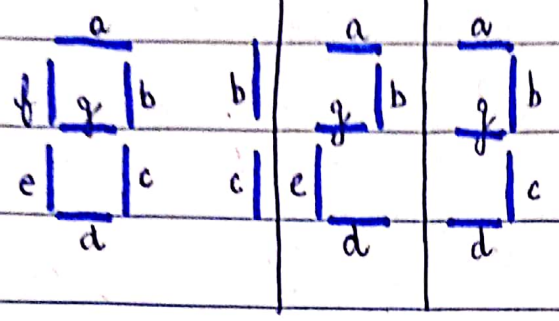
Q BCD on 7 segment display:-



Hexadecimal Solinputs $2^4=16$

⇒	H_3	H_2	H_1	H_0	a	b	c	d	e	f	g
0	0	0	0	0	1	1	1	1	1	1	0
1	0	0	0	1	0	1	1	0	0	0	0
2	0	0	1	0	1	1	0	1	1	0	1
3	0	0	1	1	1	1	1	1	0	0	1
4	0	1	0	0	0	1	1	0	0	1	1
5	0	1	0	1	1	0	1	1	0	1	1
6	0	1	1	0	1	0	1	1	1	1	1
7	0	1	1	1	1	1	1	0	0	0	0
8	1	0	0	0	1	1	1	1	1	1	1
9	1	0	0	1	1	1	1	1	0	1	1
10	1	0	1	0							
11	1	0	1	1							
12	1	1	0	0							
13	1	1	0	1							
14	1	1	1	0							
15	1	1	1	1							

dont care terms

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(a)

$H_3H_2 \backslash H_1H_0$	00	01	11	10
00	1	0	1	1
01	0	1	1	1
11	X	X	X	X
10	1	1	X	X

$$a = H_3 + H_1 + H_2H_0 + \overline{H_2}\,\overline{H_0}$$

$$a = H_1 + H_3 + H_0 \odot H_2.$$

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