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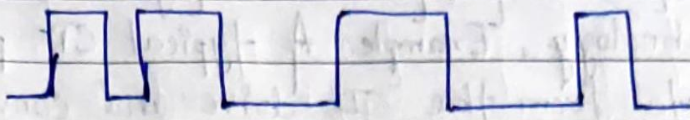
Digital Signal Representation

Digital data 0 1 0 1 1 0 0 1 1 0 0 1 0

Digital signal



What is Digital Electronics

- Digital electronics deals with the electronic manipulation of numbers, or with the manipulation of varying quantities by means of numbers. Because it is convenient to do so, today's digital systems deal only with the numbers 'zero' and 'one', because they can be represented easily by 'off' and 'on' within a circuit.
- Digital stand for digit, digital electronics basically has two conditions which are possible, 0(low logic) and 1 (high logic).
- Digital electronic systems use a digital signal that are composed of mathematical features to work.
- "1" as true and "0" as false are called bit and the group of bits are named byte.
- Digital electronic circuits are usually made from large assemblies of logic gates.
- Digital ~~dese~~ describes electronic technology that generates, stores, and processes data in terms of two states: 1 and ~~not~~ number 0.

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Analog Vs Digital

Many systems use a maximum of analog and digital electronics to take advantages of each technolgy technology. Example: A typical CD player accepts digital data from the CD drive and converts it on an analog signal for amplification. Digital data CD drive 1011001101 Analog reproduction of music audio signal Speaker Sound waves Digital-to-analog converter Linear amplifier.

Analog Signal Vs Digital Signal Representation

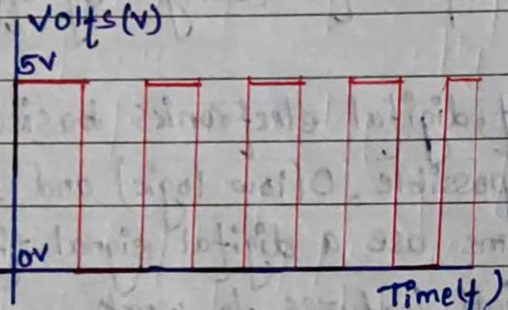

Fig:- Digital signal comprises of only two values High by 1 bit (5V) & Low by 0 bit (0V)

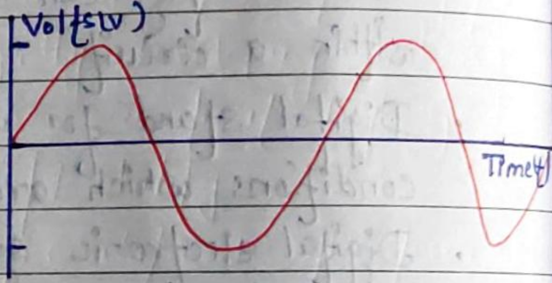

Fig:- Analog signal comprises of infinite values between given limits

How the conversion of Analog to Digital Occur?

Analog IN ⟶ Analog to Digital converter (ADC) ⟶ Digital system

Analog OUT ⟵ Digital to Analog converter (DAC) ⟵ Digital system

Benefits of Digital over Analog

- Reproducibility
- Not effected by noise means quality
- Ease of design
- Data protection Programmable Speed
- Economy

Advantages of Digital Electronics

- Computer-controlled digital systems can be controlled by software, allowing new functions to be added without changing hardware.
- Information storage can be easier in digital systems than in analog ones.
- The noise-immunity of digital systems permits data to be stored and retrieved without noise.
- In a digital system are easier to design and more precise representation of a signal can be obtained by using more binary digits to represent it.
- More digital circuity can be fabricated on IC chips.
- Error management method can be inserted into the signal path. To detect errors, and then either correct the errors, or at least ask for a new copy of the data.

Disadvantages of Digital Electronics

- Digital circuits are sometimes more expensive, especially in small quantities.

- Conversion to digital format and re-conversion to analog format is needed, which always include the lost of information.
- In some cases, digital circuits uses more energy than analog circuits and produce more heat and need heat sinks.

Applications of Digital Electronics

It's applications are infinite, ranging for high end computing to miniature circuits that can be very versatile, signal processing, communication etc. Digital Electronics is currently rapidly developing and removing conventional analogue machines due to its high speed, more accuracy and greater flexibility.

- The digital systems send the data in the form of packets of digital codes, thus we can encode and decode them in various formats and codes.
- Data encryption is also possible in the digital systems hence the data transmission is more secure, and can be manipulated in many formats.
- Digital systems are much advantageous in communications Data Transmission using Digital Systems.

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Number System

Decimal Numbers	Binary Numbers	Octal Numbers	Hexadecimal Numbers
Base 10(0-9)	Base 2(0,1)	Octal 8(0-7)	Hexadecimal 16 (0-9, A-F)

Number System

Weighted Codes

Non-Weighted Codes

Number System

A number system is the set of certain set of values used to represent any physical quantity. For example: UID of student, number plate of car. $(2A)_{16}$ and $(52)_8$ and $(42)_{10}$

Radix or Base :- Each number set is defined with particular digits or bits

Types of Number Systems

- Decimal
- Binary
- Octal
- Hexadecimal
- BCD
- Excess - 3
- Gray Code

~~Other Base System to Decimal~~
~~Binary to Decimal~~

Weighted Number System

- Decimal is the basis number which is used in our day to day life. Decimal means base 10
  0, 1, 2, 3, 4, 5, 6, 7, 8, 9
- Binary means base 2 and used ~~to reduce the number bits.~~ by computer.
  0, 1
- Octal means radix is 8 and used to reduce the number bits.
  0, 1, 2, 3, 4, 5, 6, 7
- Hexadecimal means base is 16 used in assembly language
  0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
- Base 5 means 5 digits are used.
  0, 1, 2, 3, 4
- BCD based on which code is used
  i.e., 8421, 2421, 5311

Decimal to Other Base System

Following rules are used

- Divide and multiply by the decimal number to be converted by the base of the desired number system.
- The number before decimal point is to be divided by base

of desired number system and the number after decimal point is to be multiplied by base of the desired number system.

- While ~~driving~~ dividing the remainder is to be written from Bottom to Top and while multiplying the answer is to be written from Top to Bottom.

Decimal to Binary

2	29	
2	14	1
2	7	0
2	3	1
2	1	1
	0	1

29 decimal = 11101 binary

Decimal to Octal

Convert $(73.04375)_{10}$ into octal

8	73	1
8	9	1
	1	

$(73)_{10} = 111_8$

$0.4375 \times 8 = 3.5$

$0.5 \times 8 = 4.0$

$0.4375_{10} = 0.34_8$

$(73.04375)_{10} = (111.34)_8$

Decimal to Hexadecimal

Convert $(250.4375)_{10}$ to hexadecimal

16	250	
16	15	A
	0	

$(250)_{10} = (FA)_{16}$

$0.4375 \times 16 = 7.0$

$(250.4375)_{10} = (FA.7)_{16}$

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Summary of Various Number Systems

Number system	Radix or base	symbols used	example	application
Decimal	10	0, 1, 2, ...9	$(234.9)_{10}$	used by humans
Binary	2	0, 1	$(1001.01)_2$	used in computers
Octal	8	0,1,2,3...7	$(23.45)_8$	used in computers
Hexadecimal	16	0,1,2,....9, A, B....F	$(A57.9F)_{16}$	used in computers

Comparison of Number Systems (2^n)

Decimal	Binary	Octal	Hexadecimal
0	0	0	0
1	1	1	1
2	10	2	2
3	11	3	3
4	100	4	4
5	101	5	5
6	110	6	6
7	111	7	7
8	1000	10	8
9	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1110	17	F

2^n :- $n = 1$

$2^1 = 2$

$0 \rightarrow 0$

$1 \rightarrow 1$

$n = 2$

$2^2 = 4$

A	B	
0	0	= 0
0	1	= 1
1	0	= 2
1	1	= 3

$n = 3$

$2^3 = 8$

A	B	C	
0	0	0	= 0
0	0	1	= 1
0	1	0	= 2
0	1	1	= 3
1	0	0	= 4
1	0	1	= 5
1	1	0	= 6
1	1	1	= 7

$n = 4$

$2^4 = 16$

~~A~~	~~B~~	~~C~~	~~D~~
	~~0~~	~~0~~	
	~~0~~	~~0~~	
	~~0~~	~~1~~	
	~~0~~	~~1~~	
	~~1~~	~~0~~	
	~~1~~	~~0~~	
	~~1~~	~~1~~	
	~~1~~	~~1~~	
	~~0~~	~~0~~	
	~~0~~	~~0~~	
	~~0~~	~~1~~	
	~~0~~	~~1~~	
	~~1~~	~~0~~	
	~~1~~	~~0~~	
	~~1~~	~~1~~	
	~~1~~	~~1~~	

=

A	B	C	D	
0	0	0	0	= 0
0	0	0	1	= 1
0	0	1	0	= 2
0	0	1	1	= 3
0	1	0	0	= 4
0	1	0	1	= 5
0	1	1	0	= 6
0	1	1	1	= 7
1	0	0	0	= 8
1	0	0	1	= 9
1	0	1	0	= A
1	0	1	1	= B

A	B	C	D	
1	1	0	0	= C
1	1	0	1	= D
1	1	1	0	= E
1	1	1	1	= F

Binary - Hexadecimal

In binary to hexadecimal conversion, 4 binary bits are combined to make one hexa digit based on 8421 code

$$\overset{D}{1101}\ \overset{F}{1111}\ \overset{7}{0111}\ .\ \underset{0}{0000}\ \underset{A}{1010}$$

~~DF.7~~ DF7.0A

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Binary to Decimal

- $(10101.101)_2 \rightarrow (\ )_{10}$

$2^4 \times 1 + 2^3 \times 0 + 2^2 \times 1 + 2^1 \times 0 + 2^0 \times 1 = 16+0+4+0+1$
$= 21$

$2^{-1} \times 1 + 2^{-2} \times 0 + 2^{-3} \times 1 = \frac{1}{2} + 0 + \frac{1}{8} = \frac{4+1}{8} = \frac{5}{8} = 0.625$

$(10101.101)_2 \rightarrow (21.625)_{10}$

Octal to Decimal

- $(37.6)_8 \rightarrow (\ )_{10}$

$8^1 \times 3 + 8^0 \times 7 = 24 + 7$
$= 31$

$8^{-1} \times 6 = \frac{1}{\cancel{8}_4} \times \cancel{6}^3 = \frac{3}{4}$
$= 0.75$

$(37.6)_8 \rightarrow (31.75)_{10}$

Hexadecimal to Decimal

$(AC9.B1)_{16} \rightarrow (\ )_{10}$

$16^2 \times 10 + 16^1 \times 12 + 16^0 \times 9 = 2560 + 192 + 9$
$= 2761$

$16^{-1} \times 11 + 16^{-2} \times 1 = 0.6875 + 0.00390625$
$= 0.69140625$

$(AC9.B1)_{16} \rightarrow (2761.69140625)_{10}$

Binary to Octal

$(10101100.10110)_2 \rightarrow (\ )_8 \quad 2^3 = 8$

$\frac{001}{1}\ \frac{010}{2}\ \frac{110}{6} \cdot \frac{101}{5}\ \frac{100}{4} \Rightarrow (126.54)_8$

$(10101101 \cdot 101011)_2 \rightarrow (\ )_8$

$\underline{010}\ \underline{101}\ \underline{101} \cdot \underline{101}\ \underline{011} \Rightarrow (355 \cdot 54)_8$

$2\ \ 5\ \ 5\ \cdot 5\ \ 3$

Binary - hexadecimal

$(101101 \cdot 101110)_2 \rightarrow (\ )_{16}$

$\underline{0010}\ \underline{1101}\ \underline{1011} \cdot \underline{1000} \Rightarrow (2D \cdot B8)_{16}$

$2\ \ D\ \ B\ \ 8$

$(10101101 \cdot 1011010)_2 \rightarrow (\ )_{16}$

$\underline{1010}\ \underline{1101} \cdot \underline{1011}\ \underline{0100} \Rightarrow (AD \cdot B4)_{16}$

$A\ \ D\ \ B\ \ 4$

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Octal to Binary

- $(743.26)_8 \rightarrow (\ )_2$

$(111100011.010110)_2$

Hexadecimal to Binary

- $(AC6.F89)_{16} \rightarrow (\ )_2$

$(101011000110.111110111001)_2$

Binary Arithmatics

Binary Multiplication | Binary Addition | Binary Subtraction

Binary Multiplication

-
```
     1111
     1111
   ------
     1111
    1111×
   1111××
  1111×××
 --------
 11100001
```

-
```
 (1101)₂ → (13)
 (1001)₂ → (9)
 --------------
     1101     117
    0000×
   0000××
  1101×××
 --------
  1110101
```

Binary Addition

```
  101110.101011
  110111.011110
 --------------
 1100110.001001
```

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Octal addition

$$
\begin{array}{r}
(742.63)_8 \\
(623.54)_8 \\
\hline
1566.37
\end{array}
$$

$8 \,|\, 11$
$8 \,|\, 1 \;\; 3$
$\;\; 0 \;\; 1$

$8 \,|\, 13$
$8 \,|\, 1 \;\; 5$
$\;\; 0 \;\; 1$

Binary Subtraction

$$
\begin{array}{r}
11011 \\
10101 \\
\hline
00110
\end{array}
$$

$$
\begin{array}{r}
01000010 \\
10101101 \\
\hline
0100101
\end{array}
$$

$$
\begin{array}{r}
01000010 \\
10101101 \\
\hline
110010101
\end{array}
$$

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Binary Subtraction

```
  1000          128 64 32 16 8 4 2 1
- 0011            0  1  0  0 0 0 1 0
------            1  0  1  0 1 1 0 1
  0101          ----------------------
                - 0  1  1  0 1 0 1 1
```

1's and 2's complement / Sign Magnitude Representation

+5 101

-5 101

0 represent +ve sign

1 represent -ve sign

	Unsigned	Signed	1's complement	2's complement
+5	101	0101	0101	0101
-5	—	1101	1010	1011

1's Complement Procedure

0110 → 1001 (0 → 1, 1 → 0)

2's Complement Procedure

```
0110 →  1001
           1
        ----
        1010
```

• +123

	64	32	16	8	4	2	1	
	0 1	1	1	1	0	1	1	
-123	1 0	0	0	0	1	0	0	→ 1's complement
	1 0	0	0	0	1	0	1	→ 2's complement

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1's Complement Arithmatics

Range :- $-(2^{n-1}-1)$ to $+(2^{n-1}-1)$

Case I

- +5 -4

  +5+(-4)   +5 = 0101   +4 = 0100

  -4 = 1011

  ~~=5~~

$$
\begin{array}{r}
0101 \\
1011 \\
\hline
10000
\end{array}
\rightarrow
\begin{array}{r}
0000 \\
1 \\
\hline
0001
\end{array}
\rightarrow +(001) = +1 \text{ Ans}
$$

- +125-63

  +125 → ~~+(63)~~ → 64 32 16 8 4 2 1

  0 1 1 1 1 1 0 1

$$
\begin{array}{rr}
+63 = & 0\,0\,1\,1\,1\,1\,1\,1 \\
-63 = & 1\,1\,0\,0\,0\,0\,0\,0 \\
+125 = & 0\,1\,1\,1\,1\,1\,0\,1 \\
\hline
 & 10\,0\,1\,1\,1\,1\,0\,1 \\
 & 1 \\
\hline
 & 0\,0\,1\,1\,1\,1\,1\,0
\end{array}
= +(0111110) \text{ Ans}
$$

Case II

- +2 -6

  +2 +(-6)

+2 = 0010 +6 = 0110

~~+6~~ -6 = 1001

$$\begin{array}{r} 0010 \\ 1001 \\ \hline 1011 \end{array} = \underset{-4}{-(100)} \text{ Ans}$$

Case III

- -5 - 2 -5 + (-2)

+5 = 0101 +2 = 0010

-5 = 1010 -2 = 1101

$$\begin{array}{r} 1010 \\ 1101 \\ \hline 0111 \\ 1 \\ \hline 1000 \end{array} = -(111) = -7 \text{ Ans}$$

Case IV

- -5 - 4 = -9 -5 + (-4)

+5 = 00101 +4 = 00100

-5 = 11010 -4 = 11011

$$\begin{array}{r} 11010 \\ 11011 \\ \hline 10101 \\ 1 \\ \hline 10110 \end{array} = -(1001) = -9 \text{ Ans}$$

~~-(1001) = -9~~

2's Compliment Arithmatic

Range:- $-(2^{n-1})$ to $+(2^{n-1}-1)$

Case I

- $+5-2$ $\quad\quad$ $+5+(-2)$

$+5 = 0101$ $\quad\quad$ $+2 = 0010$

$-2 = 1101$

$$\begin{array}{r} 1101 \\ 1 \\ \hline 1110 \end{array}$$

$$\begin{array}{r} 0101 \\ 1110 \\ \hline \cancel{1}0011 \end{array} = +(011) = +3 \text{ Ans}$$

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Case II

- +2 - 6 ⇒ +2 + (-6)

+2 = 0010

-6 = 1010

1100 = -(011)

1

-(100) ~~Ans~~

+6 = 0110

-6 = 1001

1

1010

Case III

- -5 - 2 = -5 + (-2)

+5 = 0101

-5 = 1010

1

1011

+2 = 0010

-2 = 1101

1

1110

-5 = 1011

-2 = 1110

1 1001 = -(110)

1

-(111)

Case IV :-

- -5 - 4

-5 + (-4)

+5 = 00101

-5 = 11010

1

11011

+4 = 00100

-4 = 11011

1

11100

5 bits = $-(2^4)$ to $+(2^4 - 1)$

-16 to +15

11011

11100

1 10111 = -(1000)

1

-(1001)

Boolean Algebra

We need boolean algebra in order to minimize boolean expression

↓

No. of gates required is reduced

↓

More gates can be placed in IC.

↓

Area is increased on IC

↓

Cost is reduced

① NOT GATE

0	1
1	0

$0 \rightarrow \bar{A} / A'$

$1 \rightarrow A$

(i) $\bar{\bar{A}} \rightarrow A$

$A = 0 \Rightarrow \bar{\bar{0}} = \bar{1} = 0$

② AND GATE

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

$A \cdot 0 = 0$

$\bar{A} \cdot 0 = 0$

$A \cdot 1 = A$

$\bar{A} \cdot 1 = \bar{A}$

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(ii) $A \cdot A = A$

$A=0 \Rightarrow 0 \cdot 0 = 0$

$A=1 \Rightarrow 1 \cdot 1 = 1$

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

(iii) $A \cdot \bar{A} = 0$

$A=0 \Rightarrow 0 \cdot 1 = 0$

$A=1 \Rightarrow 1 \cdot 0 = 0$

③ OR GATE

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

$A+0 = A$

$A=0 \Rightarrow 0+0 = 0$

$A=1 \Rightarrow 1+0 = 1$

(iv) $A+A=A$

$A=0 \Rightarrow 0+0=0$

$A=1 \Rightarrow 1+1=1$

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

$A=0 \Rightarrow 0+1=1$

$A=1 \Rightarrow 1+0=1$

(vi) $A+1$

$A=0 \Rightarrow 0+1=1$

$A=1 \Rightarrow 1+1=1$

Q. $AB+A\bar{B}$ (Minimize this boolean expression using boolean algebra)

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

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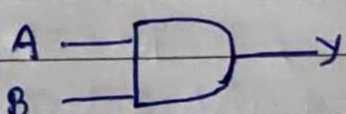
Logic Gates

- Basic Logic Gates
  - AND Gate
  - NOT Gate
  - OR Gate
- Universal Logic Gates
  - NAND Gate
  - NOR Gate
- Other Logic Gates
  - EX-OR Gate
  - EX-NOR Gate

AND LOGIC GATE

AND gate has n no. of inputs and one output whereas in the symbol there are only two inputs. IC used for two input AND gate is 7408.



A(input)	B(input)	Y(output)
0	0	0
0	1	0
1	0	0
1	1	1

Boolean Expression:- $Y = A.B$

OR LOGIC GATE

OR gate has n no. of inputs and one outputs whereas in the symbol there are only two inputs. IC used for two input OR gate is 7432.

A (input)	B(input)	Y (output)
0	0	0
0	1	1
1	0	1
1	1	1

Boolean Expression:- $Y = A+B$

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NOT LOGIC GATE

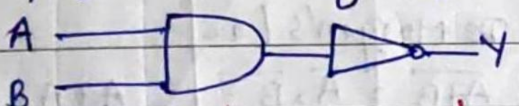
NOT gate has only one input and one output. IC used for two input NOT gate is 7404.

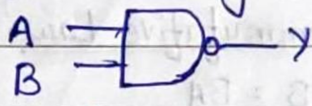
Boolean Expression: $Y = \bar{A}$

A (input)	Y (output)
0	1
1	0

NAND LOGIC GATE

NAND gate has n no. of ~~outputs~~ inputs and one output whereas in the symbol there are only two inputs. IC used for two input NAND gate is 7400.



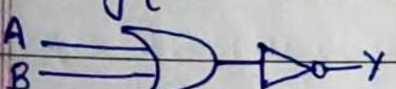


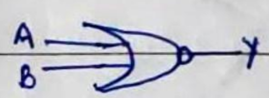
A (input)	B (input)	C (output)
0	0	1
0	1	1
1	0	1
1	1	0

Boolean expression
$Y = \overline{A \cdot B} / \bar{A} + \bar{B}$

NOR LOGIC GATE

NOR gate has n no. of inputs and one output whereas in the ~~sysm~~ symbol there are only two inputs. IC used for two input NOR gate is 7402.



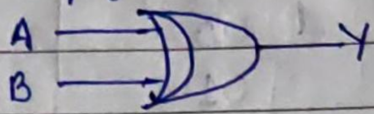


Boolean expression: $Y = \overline{A + B} / \bar{A} \cdot \bar{B}$

A(input)	B(input)	Y(output)
0	0	1
0	1	0
1	0	0
1	1	0

EX-OR LOGIC GATE

XOR gate has n no. of inputs and one outputs whereas in the symbol there are only two inputs. IC used for two input XOR is 7486



A(input)	B(input)	Y(output)
0	0	0
0	1	1
1	0	1
1	1	0

Boolean Expression: $Y = A \oplus B$

Boolean Laws

Commutative Law

$AB = BA$

$A+B = B+A$

Distributive Law

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

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

Associative Law

$A(BC) = (AB)C$

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

De-Morgan's Law

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

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

$A+A = A$

$A+0 = A$

$\bar{A}+A = 1$

$A+1 = 1$

$A.A = A$

$A.0 = 0$

$\bar{A}.A = 0$

$A.1 = 1$

$0' = 1$

$A'' = A$

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Boolean Expression

(vii) $(A+B)(A+C) = AA+BC = A+BC$ (Distribution Theorem)

(viii) $AB+\bar{A}C+BC = AB+\bar{A}C$ (Consensus Theorem)

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(ix) Demorgan Law

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

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

Weighted / Non-weighted Codes

1. Grey Code (non-weighted codes) → EXOR GATE

Binary ↓ Process ↓ Grey

1011010 → 1110111

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- Grey ↓ Process ↓ Binary

1011010 → 1101100

2. Binary Coded Decimal (BCD code) / 8421 code (weighted code)

BCD (limited weighted) — 8 4 2 1

Binary (weight not limited) — 128 64 32 16 8 4 2 1

0-9 (same as binary)

	8	4	2	1
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

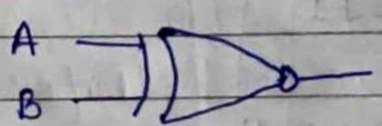
10 → 00010000

226 → 001000100110

19672 → 00011001011001
110010

Boolean Algebra + Gates

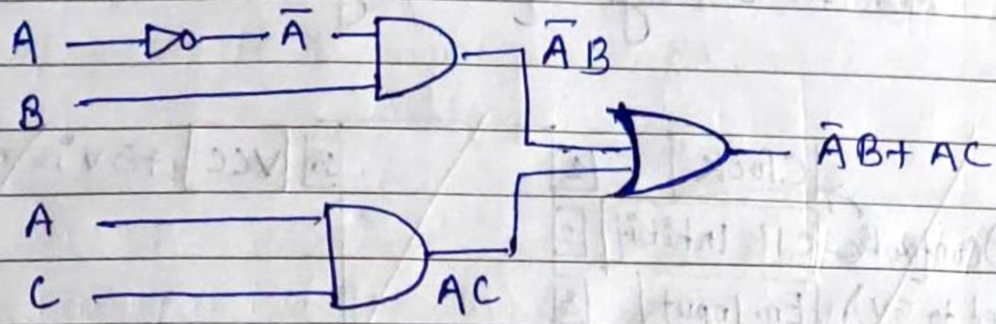
EXNOR LOGIC Gate



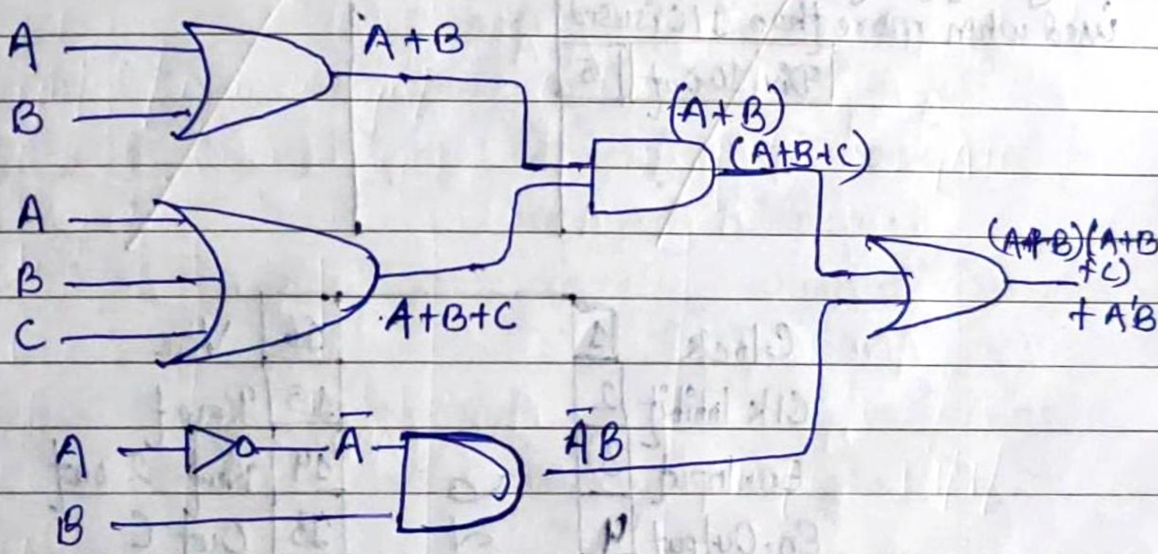
$\overline{A \oplus B}$

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

eg:- $\bar{A}B + AC$ Implement it using Gates



$y = (A+B)(A+B+C) + A'B$ Using Gate



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CD4026G- An IC that performs a function of both a counter as well as seven segment driver.

Dark → R↑, C↓, V↑ $(V = IR)$

Light → R↓, C↑, V↓

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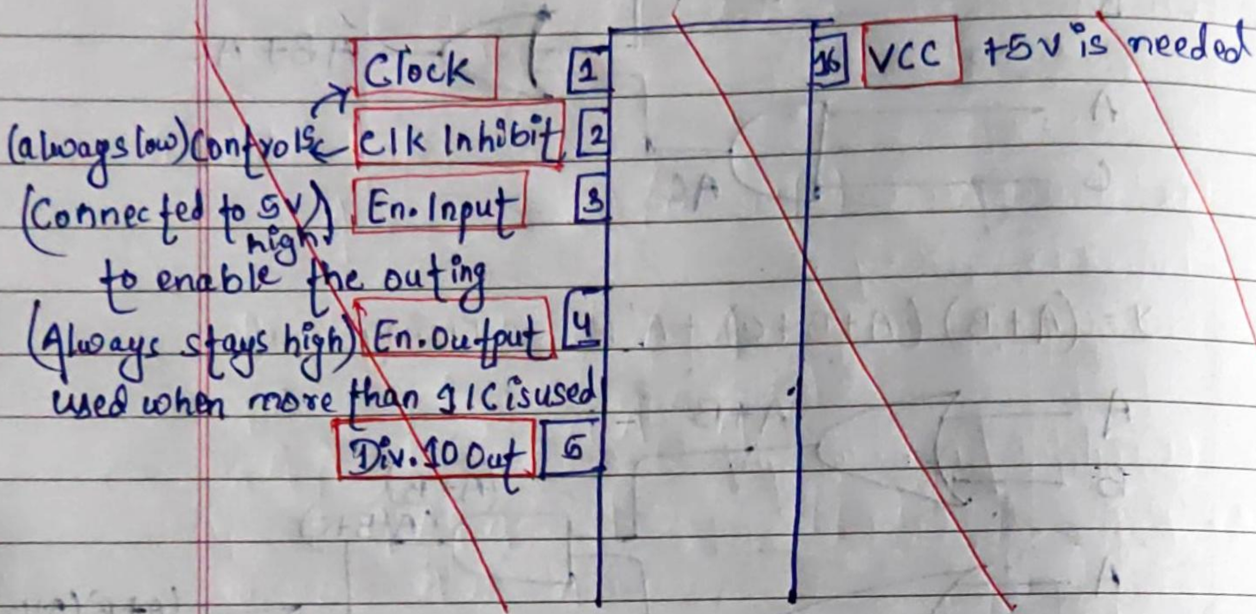
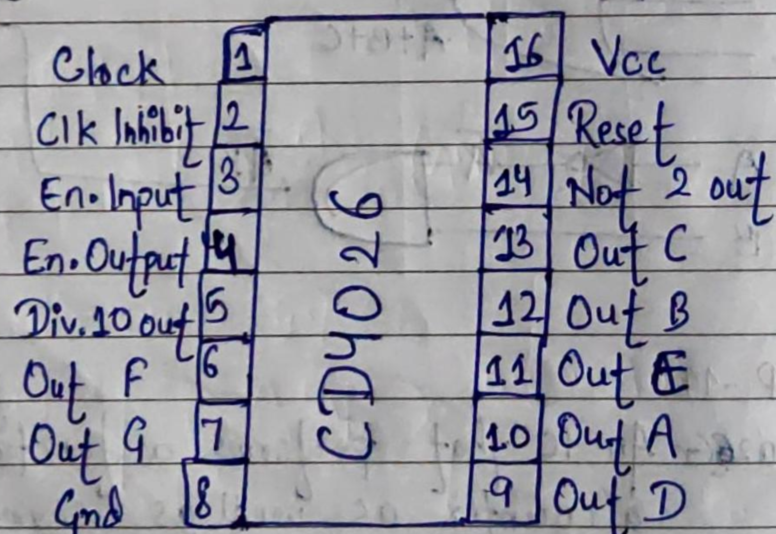
- when the clock goes low to high, 0-9 ~~displ~~ count will on 7 segment display.





- Clock - when it changes from ~~high~~ low to high, 0-9 count occurs on 7 segment display.

- Clk inhibit - It is always low due to which clock works. It controls clock.
- En. Input - It is connected to 5v (high) to enable the outing/output.
- En. Output - Always high. It is needed ~~when~~ to cascade when more than 1 IC is used.
- VCC - +5v (high) is needed for the circuit to work.
- Gnd - Ground pin
- Div. 10 out - It gives a pulse when the count 0 to 9 is completed. It is also helpful in cascadeing other IC with this IC.
- Out F, G, C, B, E, A, D - Output pins connected to 7 segment display.
- Not 2 out - used very rarely when division is needed.
- Reset - Resets the count to 0. (After giving 1 0 is compulsory for this pin).

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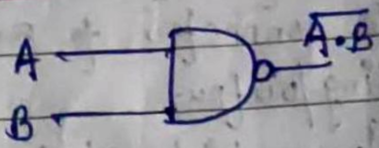
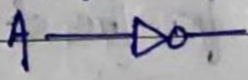
Universal Gates

NAND GATE

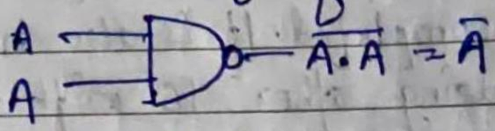


① NOT Gate :-



(NOT Gate)

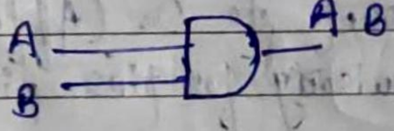
In NAND Gate if B = A



$A \cdot A = A$

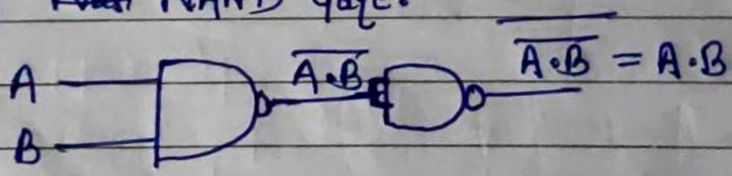
Therefore $\overline{A \cdot A} = \bar{A}$

② AND Gate:-

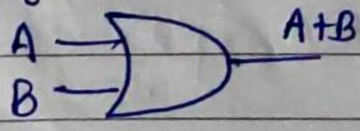


(AND Gate)

In ~~AND~~ NAND Gate.

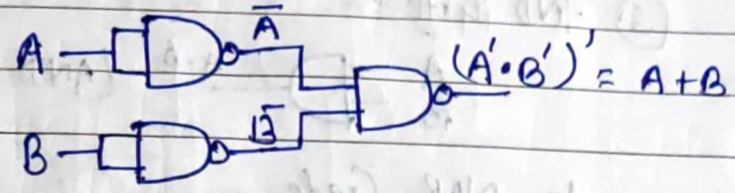


③ OR Gate:-



(OR Gate)

In NAND Gate

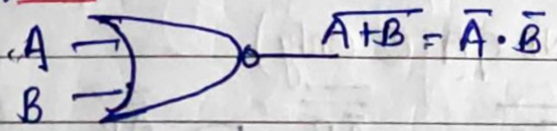


$(A' \cdot B')'$ By applying Demorgan's theorem

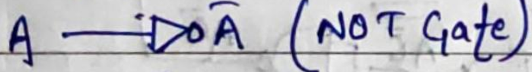
$(A')' + (B')'$

$A+B$

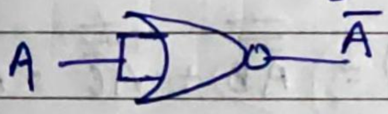
NOR GATE



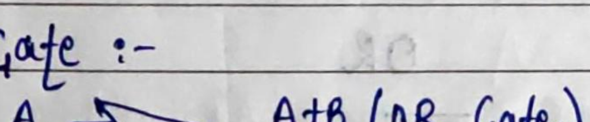
① NOT Gate:-



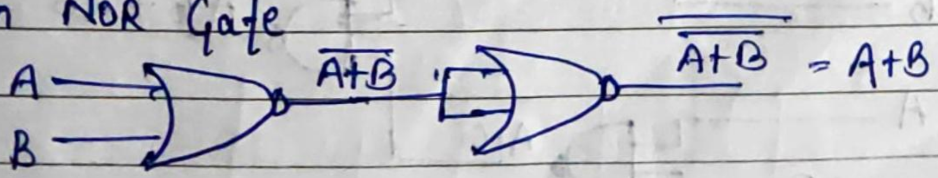
In NOR Gate, if B = A



② OR Gate :-



In NOR Gate



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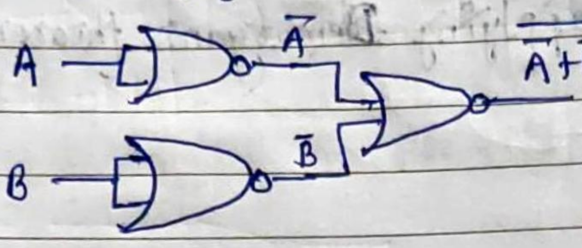
(3) AND Gate :-

(AND Gate)

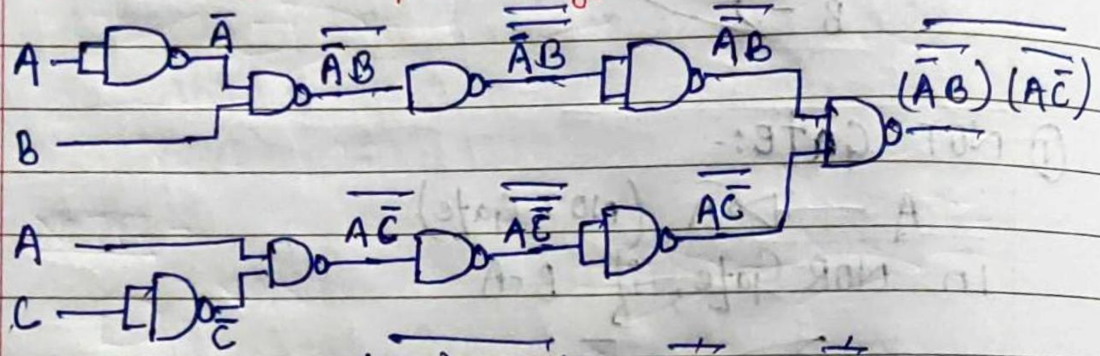
In NOR Gate



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

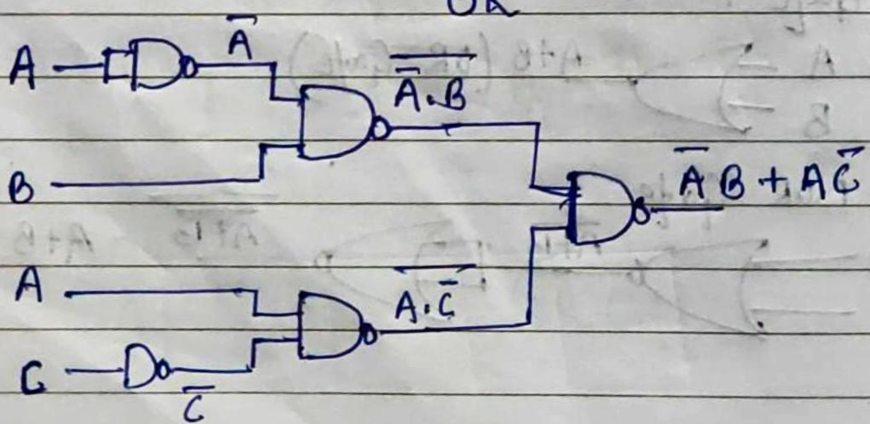
$= A\cdot B$

Q $\bar{A}B + A\bar{C}$ (NAND GATE Only)



Now, $\overline{(\overline{\bar{A}B})(\overline{A\bar{C}})} = \overline{\overline{\bar{A}B}} + \overline{\overline{A\bar{C}}} = A'B + AC'$

OR



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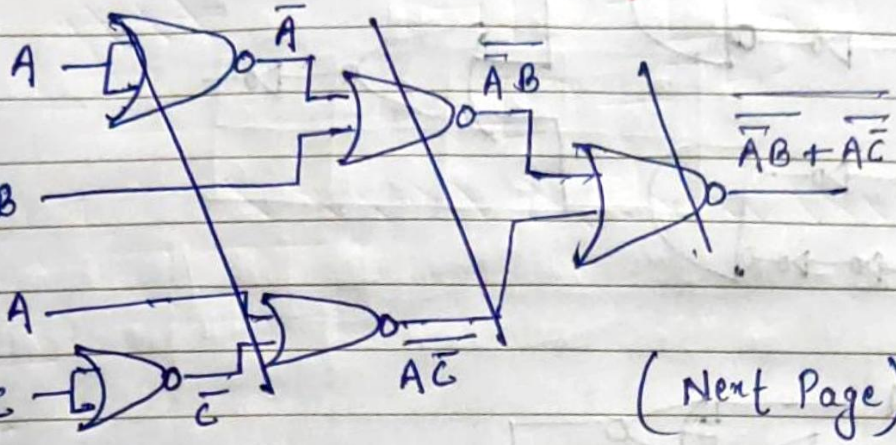
Q $\bar{A}B + A\bar{C}$ (NOR GAGTE Only)

9.



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K-Map (Karnough Map)

It is the graphical representation of reducing the boolean expression

$2^n, n=2, 2^n=4$

A \ B	0	1
0	0	1
1	2	3

A, B

$n=3, 2^n=8$

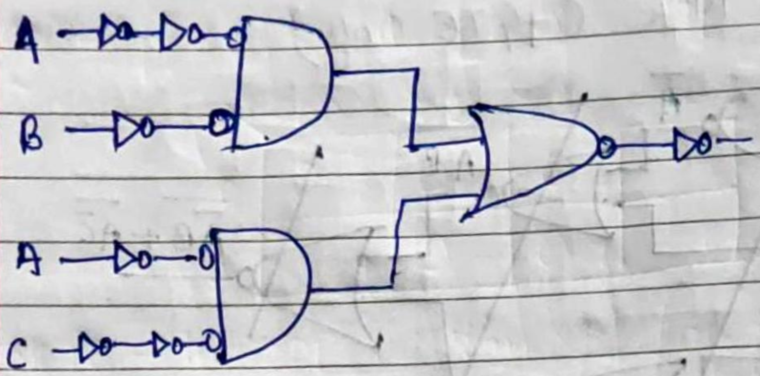
A \ BC	00	01	11	10
0	0	1	3	2
1	4	5	7	6

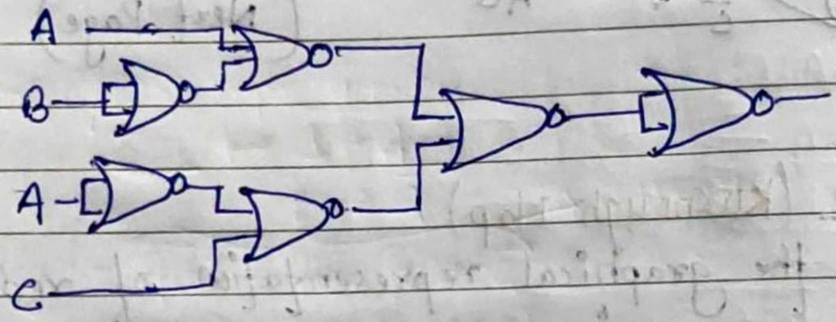
A, B, C

$n=4, 2^n=16$

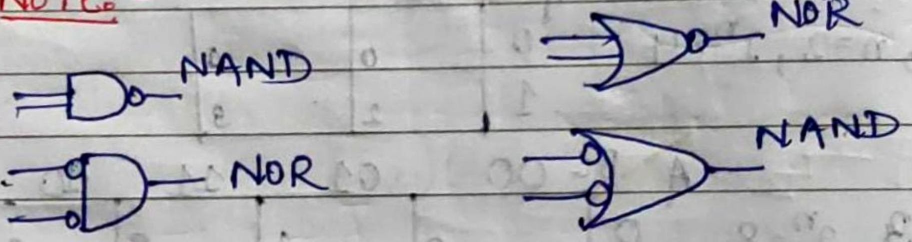
AB \ CD	00	01	11	10
00	0	1	3	2
01	4	5	7	6
11	12	13	15	14
10	8	9	11	10

A, B, C, D





NOTE:-



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A, B

A \ B	0	1
0	0	1
1	2	3

A, B, C

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

A, B, C, D

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

SOP/POS (Sum of products / Product of sums)

- $\Sigma m \rightarrow$ SOP
  ↳ min term
- $\pi_m \rightarrow$ POS
  ↳ max term

eg 1:- $f(A,B) = \Sigma m(0,1,3)$ Reduce minimized boolean exp. using K-map

A \ B	0	1
0	1 (0)	1 (1)
1	(2)	1 (3)

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eg2:- $f(A,B,C) = \pi_m [0,1,3,5,7]$

A \ BC	00	01	11	10
0	0 $_0$	0 $_1$	0 $_3$	$_2$
1	$_4$	0 $_5$	0 $_7$	$_6$

NOTE:- In SOP we have to fill the boxes with 1 &
In POS we have to fill the boxes with 0

SOP/POS expressions:-

SOP → 1 → A
0 → $\bar{A}$

eg3:- $\underbrace{\bar{A}\bar{B}C + A\bar{B}C + AB\bar{C}}_{\text{Canonical form}}$

(001) (101) (110)

1 5 6 ⇒ $\underbrace{f(A,B,C) = \Sigma m (1,5,6)}_{\text{standard form}}$

POS → 1 → $\bar{A}$
0 → A

eg 4: $(A+\bar{B}+C)\ (\bar{A}+\bar{B}+\bar{C})\ (A+\bar{B}+\bar{C})$

(0 1 0) (1 1 1) (0 1 1)

2 7 3

A \ BC	00	01	11	10
0	$_0$	$_1$	0 $_3$	0 $_2$
1	$_4$	$_5$	0 $_7$	$_6$

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Grouping

2, 4, 8, 16 → Priority :- 16
8
4
2

eg-1,

1	
	1

~~Diagno~~ Diagonals never make a group

eg-2

1	1

& eg3

1	1

& eg4

	1
	1

eg-5

1	1
1	1

eg-6

1	1	I
	1	II

In order to make a group I need one 1 empty, means that particular 1 should not be the part of any other group.

eg-7

	1	1		I
		1	1	II

eg-8

1		1	1	I
		1	1	

II

eg 9

		1	1
1		1	1

→ I

→ II

eg 10

1		1	1
1		1	1

→ I

→ II

eg 11

1	1		1
	1	1	1

→ I

→ II

→ III

eg 12

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

AB \ CD	$\bar{C}\bar{D}$ 00	$\bar{C}D$ 01	CD 11	$C\bar{D}$ 10
$\bar{A}\bar{B}$ 00	1_0	1_1	1_3	$_2$
$\bar{A}B$ 01	$_4$	1_5	1_7	$_6$
AB 11	$_{12}$	1_{13}	1_{15}	$_{14}$
$A\bar{B}$ 10	1_8	1_9	1_{11}	$_{10}$

→ I

→ II

eg 13 -

1			1
1			1

→ quad

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eg 1 :- $f(A,B) = \Sigma m(2,3)$

A \ B	$\bar{B}$ 0	B 1
$\bar{A}$ 0	0	1
A 1	1 (2)	1 (3)

A	B
1	~~0~~
1	~~1~~
A	

$f(A,B) = A$

eg 2 :- $f(A,B,C) = \Sigma m(0,2,3,6,7)$

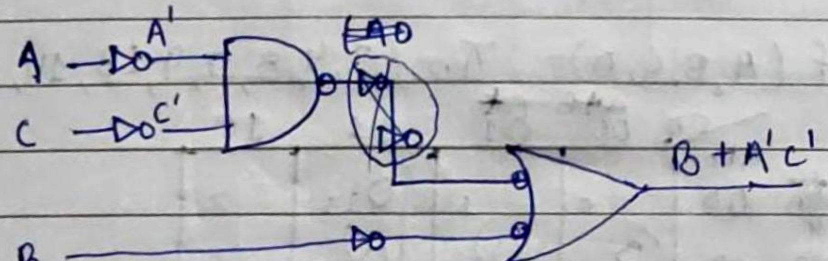
A \ BC	$\bar{B}\bar{C}$ 00	$\bar{B}C$ 01	BC 11	$B\bar{C}$ 10
$\bar{A}$ 0	1 (0)	1	1 (3)	1 (2)
A 1	4	5	1 (7)	1 (6)

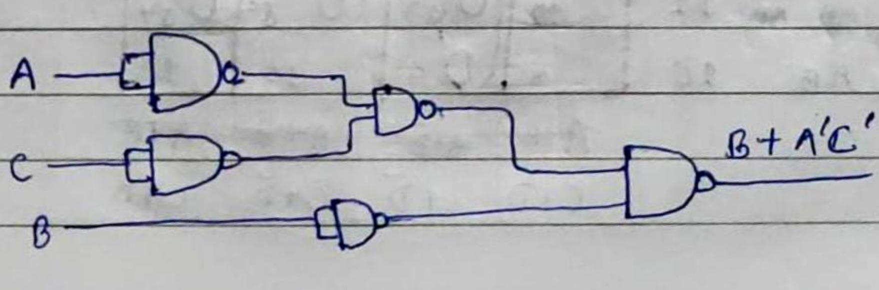
A	B	C
0	0	0
0	1	0
$\bar{A}$	x	$\bar{C}$

A	B	C
0	1	1
0	1	0
1	1	1
1	1	0
x	B	x

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

$B + A'C' \rightarrow$ NAND GATE





eg 3 :- $f(A,B,C,D) = \Sigma m(0,1,3,5,7,8,9,11,13,15)$

AB \ CD	00 ($\bar{C}\bar{D}$)	01 ($\bar{C}D$)	11 (CD)	10 ($C\bar{D}$)
$\bar{A}\bar{B}$ 00	1 ₀	1 ₁	1 ₃	₂
$\bar{A}B$ 01	₄	1 ₅	1 ₇	₆
AB 11	₁₂	1 ₁₃	1 ₁₅	₁₄
$A\bar{B}$ 10	1 ₈	1 ₉	1 ₁₁	₁₀

A	B	C	D
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	1
1	1	0	1
1	1	1	1
1	0	0	1
1	0	1	1
x	x	x	D

A	B	C	D
0	0	0	0
0	0	0	1
1	0	0	0
1	0	0	1
x	$\bar{B}$	$\bar{C}$	x

$f(A,B,C,D) = D + B'C'$

eg 4:- $f(A,B,C,D) = \pi m(3,4,5,7,9,13,14,15)$

	AB \ CD	00	01	11	10
$A+B$	00	₀	₁	0 ₃	₂
$A+\bar{B}$	01	0 ₄	0 ₅	0 ₇	₆
$\bar{A}+\bar{B}$	11	₁₂	0 ₁₃	0 ₁₅	0 ₁₄
$\bar{A}+B$	10	₈	0 ₉	₁₁	₁₀
		~~A+B~~	~~$A+\bar{B}$~~	~~$\bar{A}+\bar{B}$~~	~~$\bar{A}+B$~~
		$C+D$	$C+\bar{D}$	$\bar{C}+\bar{D}$	$\bar{C}+D$

A	B	C	D
0	0	1	1
0	1	1	1
A	$\times$	$\bar{C}$	$\bar{D}$

$\hookrightarrow A + \bar{C} + \bar{D}$

A	B	C	D
0	1	0	0
0	1	0	1
A	B	C	$\times$

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

A	B	C	D
1	1	0	1
1	0	0	1
$\bar{A}$	$\times$	C	$\bar{D}$

$\hookrightarrow \bar{A} + C + \bar{D}$

A	B	C	D
1	1	1	1
1	1	1	0
$\bar{A}$	$\bar{B}$	$\bar{C}$	$\times$

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

$$f(A,B,C,D) = (A+\bar{C}+\bar{D})\cdot(A+\bar{B}+C)\cdot(\bar{A}+C+\bar{D})\cdot(\bar{A}+\bar{B}+\bar{C})$$

Q7 $f(A,B,C,D) = \pi m(0,1,3,8,9,10,14,15)$

		C+D	C+D̄	C̄+D̄	C̄+D
	AB \ CD	00	01	11	10
A+B	00	0 (0)	0 (1)	0 (3)	2
A+B̄	01	4	5	7	6
Ā+B̄	11	12	13	0 (15)	0 (14)
Ā+B	10	0 (8)	0 (9)	11	0 (10)

A	B	C	D
0	0	0	0
0	0	0	1
1	0	0	0
1	0	0	1
$\times$	B	$+C$	$\times$

A	B	C	D
0	0	0	1
0	0	1	1
$A+B$		$\times$	$+\bar{D}'$

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

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

$$f(A,B,C,D) = (B+C)\cdot(A+B+\bar{D})\cdot(\bar{A}+\bar{B}+\bar{C})\cdot(\bar{A}+\bar{C}+D)$$

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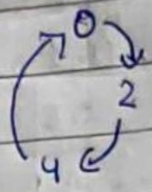
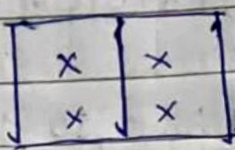
Don't Care -

Represented by x



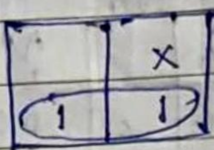
* In Σm(SOP) : $x \rightarrow 1$
* In Πm (POS) : $x \rightarrow 0$

eg 1 :-

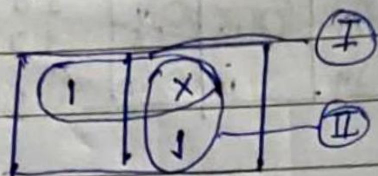


Don't care doesn't group with each other

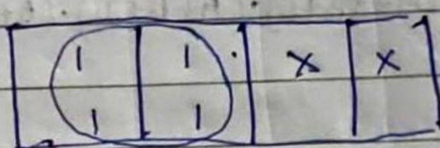
eg 2 :-



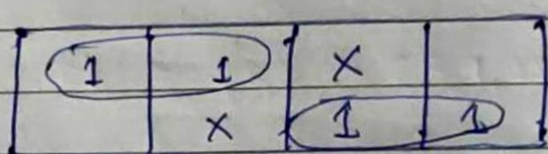
eg 3 :-



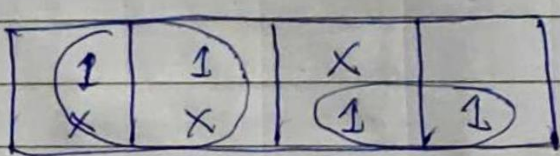
eg 4 :-



eg 5 :-



eg 6 :-



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eg 7:- $f(A,B,C,D) = \Sigma m(0,1,3,5,7,8,9,11,13,15)$ ~~+Σd(~~
$+ \Sigma d(2,10)$

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

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eg 6

X

1	1	x	
x	x	1	1

A	B	C	D
0	0	0	
0	0	1	
1	0	0	
1	0	1	
x	$\bar{B}$	x	

A	B	C	D
1	1	1	
1	1	0	
A	B	x	

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

A \ BC	$\bar{B}\bar{C}$ 00	$\bar{B}C$ 01	BC 11	$B\bar{C}$ 10
$\bar{A}$ 0	1 ₀	1 ₁	x ₃	₂
A 1	x ₄	x ₅	1 ₇	1 ₆

eg 1:-

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

eg 2:- $f(A,B,C,D) : \sum m(2,4,6,8,9,13) + \sum d(0,7,14,12)$

AB \ CD	$\bar{C}\bar{D}$ 00	$\bar{C}D$ 01	CD 11	$C\bar{D}$ 10
$\bar{A}\bar{B}$ 00	X ₀	₁	₃	1 ₂
$\bar{A}B$ 01	1 ₄	₅	X ₇	1 ₆
AB 11	X ₁₂	1 ₁₃	₁₅	X ₁₄
$A\bar{B}$ 10	1 ₈	1 ₉	₁₁	₁₀

eg 3:- $f(A,B,C,D) = \sum m(0,1,3,5,7,8,9,11,13,15) + \sum d(2,10)$

1 ₀	1 ₁	1 ₃	X ₂
₄	1 ₅	1 ₇	₆
₁₂	1 ₁₃	1 ₁₅	₁₄
1 ₈	1 ₉	1 ₁₁	X ₁₀

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eg 4:- $\pi m(1,2,4,6,8,10,14) + \pi d(0,3,8,12)$

X 0	0 1	X 3	0 2
0 4	5	7	0 6
X 12	13	15	0 14
X 8	0 9	11	0 10

Standard and Canonical form:-

eg:- $AB + BC + AC$

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

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

$ABC + AB\bar{C} + \bar{A}BC + A\bar{B}C$ — Canonical form

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

$f(A,B,C) = \Sigma m(3, 5, 6, 7)$ — standard form

eg:- $\bar{A}+B$ (min forms)

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

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

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

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$f(A,B) = \Sigma m(0, 1, 3)$

eg:- $\bar{A}\bar{B}D + AB\bar{C}\bar{D} + ABC\bar{D} + \bar{A}\bar{B}\bar{C}D$ (using universal gate)

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

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

0011 0001 1100 1110

$f(A,B,C,D) = \Sigma m(3, 1, 12, 14)$