SHREE H. N. SHUKLA GROUP OF COLLEGES

S.Y.B.Sc. SEM – IV

Subject: Physics

Paper- 401

Unit -4

DIGITAL ELECTRONICS

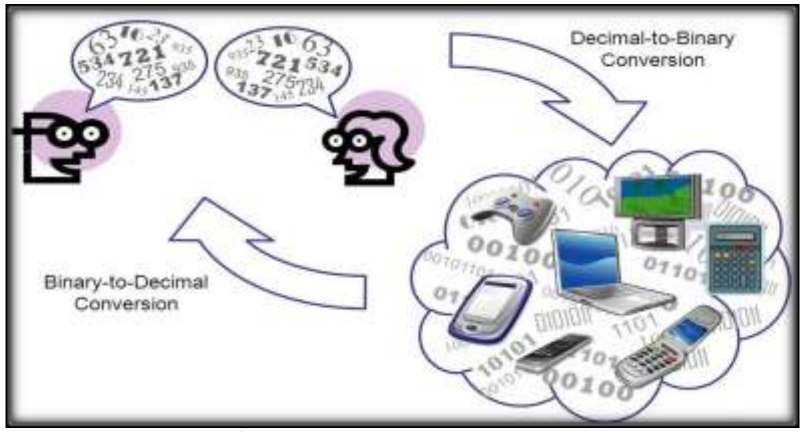
- INTRODUCTION
- ANALOG SIGNAL
- DIGITAL SIGNAL
- DIGITAL CIRCUIT
- NUMBER SYSTEM
- BINARY TO DECIMAL CONVERTER
- DECIMAL TO BINARY CONVERTER
- LOGIC GATE
- ENCODER &
- NUMERICALS

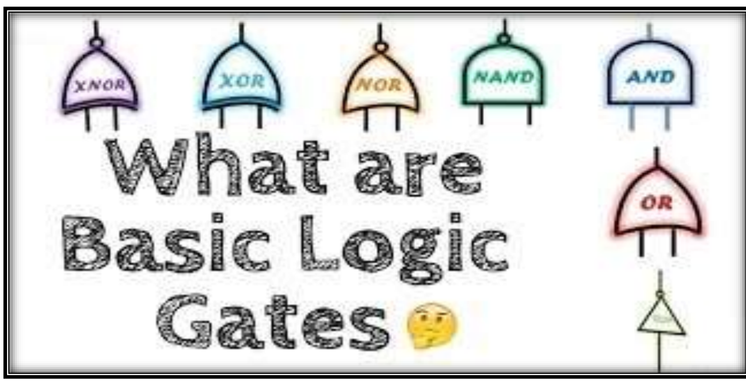
✪ TITLE ELUCIDATION :

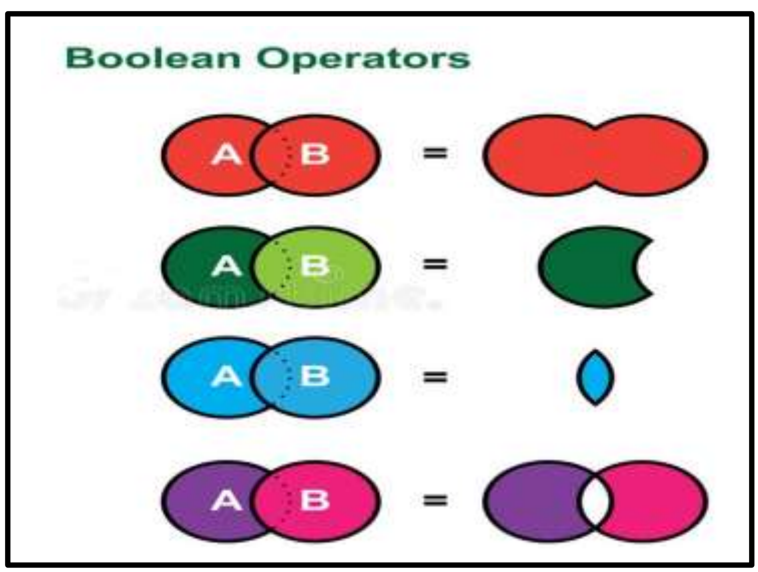
- We often hear that we are living in the information age. Large amount of information can be obtained via the internet, for example - and can also be obtained quickly over long distance via satellite communication system.
- This all happens because of semiconductor material. The development in semiconductor physics has lead to these remarkable capabilities. One of the most dramatic examples of IC technology is the **Digital Electronics** - relatively small laptop computer today has more computing capability than the equipment used to send a man to the moon a few years ago.
- **Digital electronics** is a field of electronics involving the study of digital signals and the engineering of devices that use or produce them. This is in contrast to analog electronics and analog signals.

✪ PREVIEW OF SEGMENT :

NUMBER SYSTEM







✪ LEARNING OUTCOME :

- ✓ In this chapter the text begins with introductory physics, moves on to the **DIGITAL CIRCUIT** and then the covers the physics of electronics device like **LOGIC GATE** and its application.
- ✓ The main purpose of the chapter is to provide a basic understanding of **Logic gate operation** and **Truth table of gates**.
- ✓ Since Logic gates itself is sold in stores as electrical appliances, it may to be hard to understand, but in fact it is used in many **electric appliances**.
- ✓ Many digital consumer products in everyday life such as **mobile phones** / smartphones, **digital cameras**, televisions, washing machines, refrigerators and **LED bulbs** also use logic gates.

✪ INTRODUCTION :

- Digital electronics is the branch of electronics which deals with the digital signals to perform vvarious tasks and meet various requirements.
- It uses only binary digits, i.e. either ’0’ or ’1’. In digital circuits diodes and transistors are used as a switch to change from one voltage level to another voltage level. A switch may be open or close.
- Therefore, output states of digital circuit can be designated accordingly as OFF or ON states, LOW or HIGH states and FALSE or TRUE states. These two states correspond to the 0 and 1 states.
- For many years, the application of digital electronics was only in the computer system. But now-a-days, digital electronics is used in many other applications like industriall process control, military system, television, communication system, medical equipment, radar, navigation etc.

✪ ANALOG & DIGITAL SIGNAL :

- “A continuously varying signal (voltage or cur-rent) is called an *analog signal*.”

  For example, a sinusoidal voltage is an analog signal. (FIG 1)

- “A signal (voltage or current) which can have only two discrete values is called a *digital signal*.”

  For example, a square wave is a digital signal. (FIG 2)

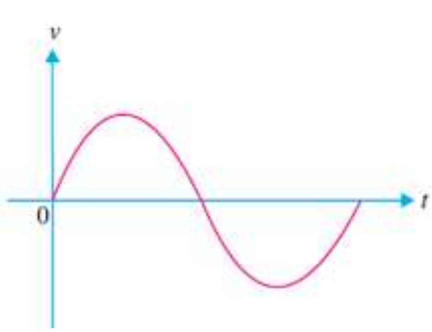


FIG - 1

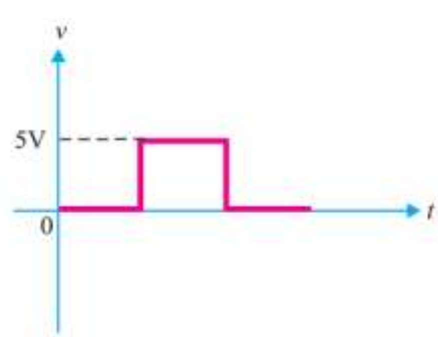


FIG - 2

✪ DIGITAL CIRCUIT :

"An electronic circuit that handles only a digital signal is called a **digital circuit."**

✪ DIGITAL ELECTRONICS :

"The branch of electronics which deals with digital circuits is called **digital electronics**."

✪ Number System:

"A number system is a code that uses symbols to count the number of items." The most common and familiar number system is the decimal number system. The decimal number system uses the symbols 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9. Thus, the decimal system uses 10 digits for counting the items. A binary system uses only two digits (0 and 1) for counting the items.

1. DECIMAL NUMBER :

"A number system which has ten digits (0,1,2,3,....9) is known as a decimal number system."

This system has a base of 10. decimal can de expressed as a $(6)_{10}$, $(12)_{10}$ ...... etc.

Consider the decimal number 642.

$$642 = 600 + 40 + 2$$

$$= (6\times10^2) + (4\times10^1) + (2\times10^0)$$

In decimal system the digit to the extreme right is referred to as the **least significant digit (LSD)** as its value is lowest.

In decimal system the digit to the extreme left is referred to as the **most significant digit (MSD)** as its value is highest.

2. BINARY NUMBER :

"A number system which has only two discrete value (0 and 1) is known as Binary number system".

This system has a base of 2. Binary number expressed as a $(10011)_2$, $(1011)_2$ etc.

Extreme right is referred as a **LSB** (least significant binary)

Extreme left is referred as a **MSB** (most significant binary).

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

View now

✪ DECIMAL TO BINARY CONVERTER:

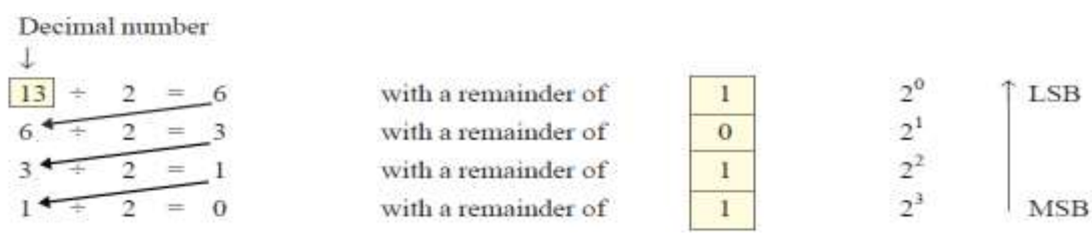
STEP 1: Divide the given decimal number repeatedly by 2.

STEP 2: Write down the reminder after each division.

STEP 3: continue this process till you get a quotient 0 and reminder 1.

STEP 4: write down reminders in reverse order (bottom to top), which gives the binary number.

let us consider the decimal number 13 into binary number :



$(13)_{10} = (1101)_2$

✪ FRACTIONAL DECIMAL TO BINARY CONVERTER:

STEP 1: Multiply the fractional part repeatedly by 2.

STEP 2 : if there is a 1 in the unit place, then transfer this 1 to the binary record and repeat the process for the fractional number and if there is a 0 in the unit place then transfer this 0 to the binary record and repeat the process for the fractional number.

STEP 3: continue this process till the fractional part is zero or desired accuracy is achieved.

STEP 4: write the carries in forward order (top to bottom) which gives the binary number.

let us consider the decimal number 0.3125 into binary number :

$0.3125\times2 = 0.6250$ carry = 0

$0.6250\times2 = 1.2500$ carry = 1

$0.2500\times2 = 0.5000$ carry = 0

$0.5000\times2 = 1.0000$ carry = 1

$$(0.3125)_{10} = (0.0101)_2$$

✪ BINARY TO DECIMAL CONVERTER:

https://youtu.be/F7RZPT_CjcE

STEP 1: Write the given binary number.

STEP 2: Write the position value under each bit in terms of power of 2.

STEP 3: write down the decimal value of each bit.

STEP 4: add all the possible values to get the decimal number of a given binary number.

let us consider the decimal number $(110001)_2$ into binary number :

$$\begin{aligned}(110001)_2 &= 1\times2^5+1\times2^4+1\times2^0\\ &= 32+16+1=49\\ (110001)_2 &= (49)_{10}\end{aligned}$$

$$(110001)_2 = (49)_{10}$$

✪ FRACTIONAL BINARY TO DECIMAL CONVERTER:

$$\begin{aligned}10.101 &= 1\times2^1+0\times2^0+1\times2^{-1}+0\times2^{-2}+1\times2^{-3}\\ &= 2+0+1/2+0+1/8\\ &= 2+0.5+0.125\\ &= 2.625\end{aligned}$$

$$(10.101)_2 = (2.625)10$$

This is called a double dabble method.

- Each binary digit (0,1) is reffered As bit.
- 4 – bit = nibble
- 8 –bit = byte.

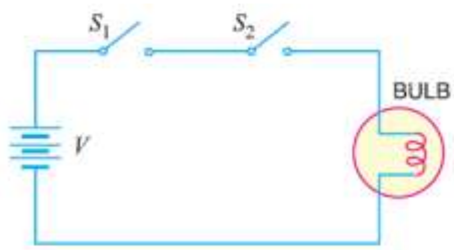
SRNO	QUESTION	ANSWER
1	Which signal is having continues time varying signal of current or voltage?	**Analog signal**
2	Which signal having two discrete value of current or voltage ?	**Digital signal**
3	How many types of number systems are there? Which?	**1. Binary number** **2. Decimal number**
4	Give the full form of MSD and LSD.	Least significant digit Most significant digit
5	Give the full form of MSB and LSB.	Least significant binary Most significant binary
6	What is the base of decimal number system.	**10**
7	What is the base of Binary number system.	**2**
8	Give the binary number of digit 5.	0101
9	Give the binary number of digit 8.	1000
10	Give the decimal value of binary number 0011.	**3**
11	___________ is referred as bit.	**0,1**
12	4 bit is referred as a ___________ .	**Nibble**
13	8 bit is referred as a ___________ .	**Byte**

✪ LOGIC GATE :

"A digital circuit with one or more input signals but only one output signal is called a **logic gate**."

"A **truth table** lists all input possibilities and the corresponding output for each input.."

Fig. shows the basic idea of a *logic gate using switches.



(i)

S_1	S_2	Bulb
open	open	OFF
open	closed	OFF
closed	open	OFF
closed	closed	ON

(ii)

Truth Table

S_1	S_2	Output
0	0	0
0	1	0
1	0	0
1	1	1

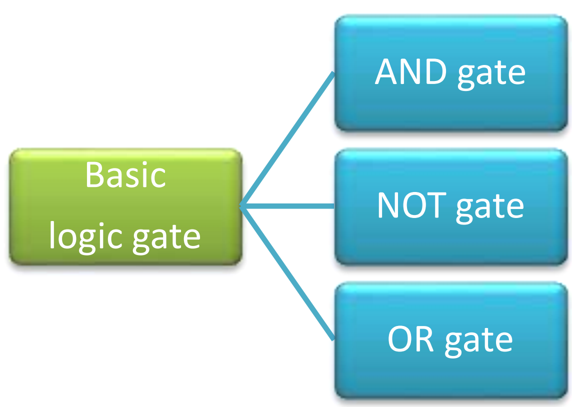
(iii)

FIG : 3

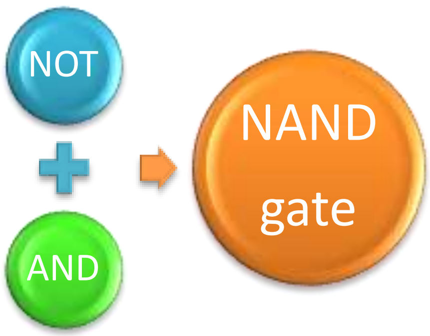
1. When $S1$ and $S2$ are open, the bulb is *OFF*.
2. When $S1$ is open and $S2$ closed, the bulb is *OFF*.
3. When $S2$ is open and $S1$ closed, the bulb is *OFF*.
4. When both $S1$ and $S2$ are closed, the bulb is *ON*.

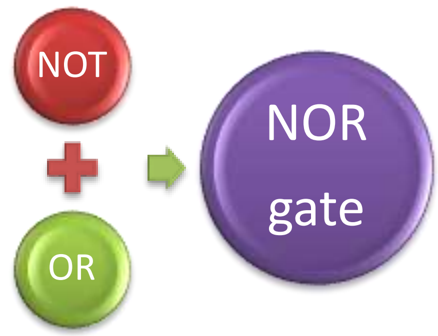
The term "logic" is usually used to refer to a decision-making process. A logic gate makes logical decisions regarding the existence of output depending upon the nature of the input. Hence, such circuits are called logic circuits.

There are THREE basic logic gate listed as below:

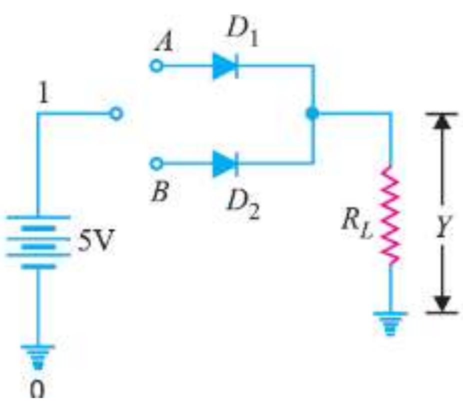


There are TWO Combinational logic gate listed as below:





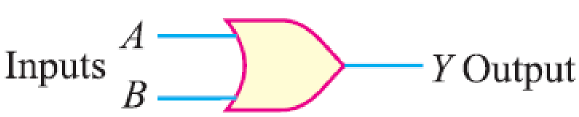
✪ <u>OR gate:</u>



Circuit diagram

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

Truth table



Symbol

$$A + B = Y$$

Boolean equation

FIG : 4

"The output is high if any or all of the inputs are high. The only way to get a low output is by having all inputs low."

1. When both A and B are connected to ground, both diodes are non-conducting. Hence, the output voltage is ideally zero (low voltage). In terms of binary, when $A = 0$ and $B = 0$, then $Y = 0$ as shown in the truth table.
2. When A is connected to ground and B connected to the positive terminal of the battery, diode $D2$ is forward biased and diode $D1$ is non-conducting. Therefore, diode $D2$ conducts and the output voltage is ideally +5 V. In terms of binary, when $A = 0$ and $B = 1$, then $Y = 1$.
3. When A is connected to the positive terminal of the battery and B to the ground, diode $D1$ is on and diode $D2$ is off. Again the output voltage is +5 V. In binary terms, when $A = 1$ and $B = 0$, then $Y = 1$.
4. When both A and B are connected to the positive terminal of the battery, both diodes are on. Since the diodes are in parallel, the output voltage is +5 V. In binary terms, when $A = 1$ and $B = 1$, then $Y = 1$.

✪ AND Gate:

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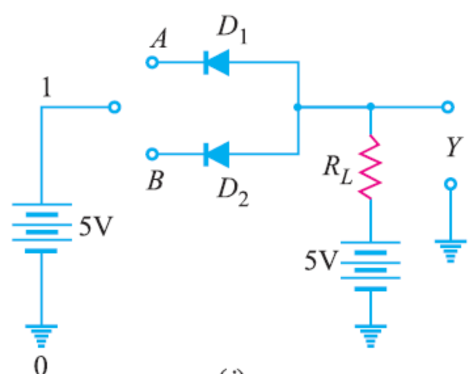
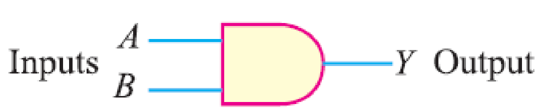


Circuit diagram

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

Truth table



Symbol

$$A \, . \, B = Y$$

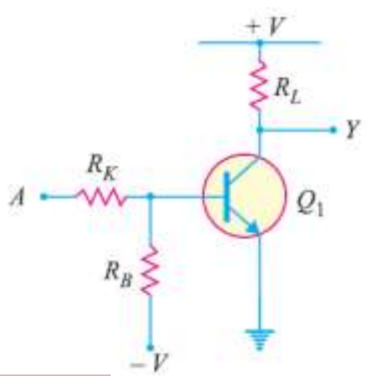
Boolean equation

FIG:5

For AND gate, "the output is high if all the inputs are high. However, the output is low if any or all inputs are low."

1. When both A and B are connected to ground, both the diodes ($D1$ and $D2$) are forward biased and hence they conduct current. Consequently, the two diodes are grounded and output voltage is zero. In terms of binary, when $A = 0$ and $B = 0$, then $Y = 0$.
2. When A is connected to the ground and B connected to the positive terminal of the battery, diode $D1$ is forward biased while diode $D2$ will not conduct. Therefore, diode $D1$ conducts and is grounded. Again output voltage will be zero. In binary terms, when $A = 0$ and $B = 1$, then $Y = 0$.
3. When B is connected to the ground and A connected to the positive terminal of the battery, the roles of diodes are interchanged. Now diode $D2$ will conduct while diode $D1$ does not conduct. As a result, diode $D2$ is grounded and again output voltage is zero. In binary terms, when $A = 1$ and $B = 0$, then $Y = 0$.
4. When both A and B are connected to the positive terminal of the battery, both the diodes do not conduct. Now, the output voltage is +5 V because there is no current through RL.

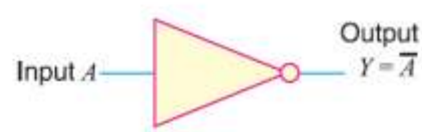
✪ NOT Gate :



Circuit diagram

A	Y
0	1
1	0

Truth table



Symbol

$$Y = \overline{A}$$

Boolean equation

Figure: 6

- The NOT gate or inverter is the simplest of all logic gates. It has only one input and one output, where the output is opposite of the input. The NOT gate is often called inverter because it inverts the input.
- When A is connected to ground, the base of transistor $Q1$ will become negative. This negative potential causes the transistor to cut off and collector current is zero and output is + V volts. In binary terms, when $A = 0$, $Y = 1$.
- If sufficiently large positive voltage is applied at A, the base of the transistor will become positive, causing the transistor to conduct heavily. Therefore, the output voltage is zero. In binary terms, when $A = 1$, $Y = 0$. Fig. shows truth table for an inverter.
- It is clear from the truth table that whatever the input to the inverter, the output assumes opposite polarity. If the input is 0, the output will be 1 ; if the input is 1, the output will be 0.

✪ NAND Gate:

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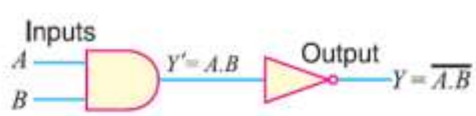
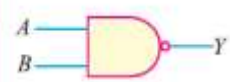


Inputs		Output	
A	B	AND (Y')	NAND (Y)
0	0	0	1
1	0	0	1
0	1	0	1
1	1	1	0



Circuit diagram **Truth table** **Symbol**

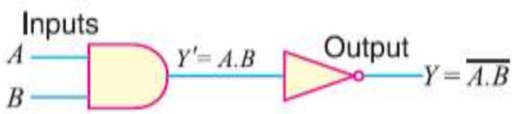
Boolean equation $Y = \overline{A \cdot B}$

Figure: 7

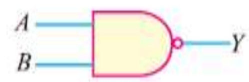
- It is a combination of AND gate and NOT gate. In other words, output of AND gate is connected to the input of a NOT gate as shown in Fig. Clearly, the output of a NAND gate is opposite to the AND gate. This is illustrated in the truth table for the NAND gate. Note that truth table for NAND gate is developed by *inverting the outputs* of the AND gate.

- To perform the Boolean algebra operation, first the inputs must be ANDed and then the inversion is performed. Note that output from a NAND gate is always 1 except when all of the inputs are 1. Fig. shows the logic symbols for a NAND gate. The little bubble (small circle) on the right end of the symbol means to invert the AND.

✪ NOR Gate :



Inputs		Output	
A	B	AND (Y')	NAND (Y)
0	0	0	1
1	0	0	1
0	1	0	1
1	1	1	0



Circuit diagram **Truth table** **Symbol**

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

Boolean equation

Figure: 8

- It is a combination of OR gate and NOT gate. In other words, output of OR gate is connected to the input of a NOT gate as shown in Fig. Note that output of OR gate is inverted to form NOR gate. This is illustrated in the truth table for NOR gate. It is clear that truth table for NOR gate is developed by *inverting the outputs* of the OR gate.
- This Boolean expression can be read as Y = not A or B. To perform the Boolean algebra operation, first the inputs must be ORed and then the inversion is performed. *Note that output from a NOR gate is high (1) only when all the inputs are low (0). If any of the inputs is high (1), the output is low (0).* Fig. shows the logic symbol for a NOR gate. The bubble (small circle) at the Y output indicates inversion.

✪ NAND Gate as a Universal Gate:

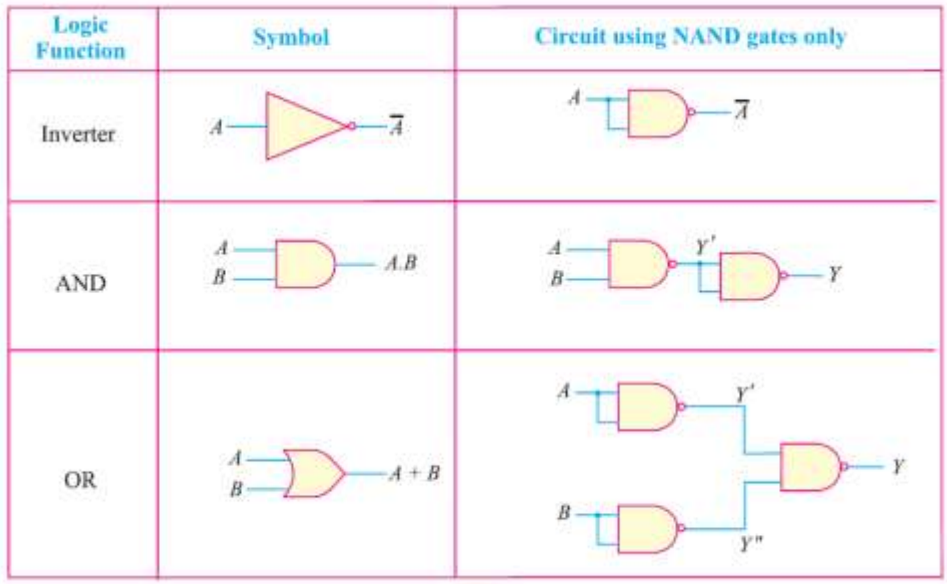


Figure: 9

1. **NOT gate from NAND gate:** When two inputs of NAND gate are joined together so that it has one input, the resulting circuit is NOT gate.

A	$B\,(= A)$	Y
0	0	1
1	1	0

2. **AND gate from NAND gates:**

For this purpose, we use two NAND gates in a manner as shown above. The output of first NAND gate is given to the second NAND gate acting as inverter (*i.e.*, inputs of NAND gate joined). The resulting circuit is the AND gate. The output Y of first NAND gate (AND gate followed by NOT gate) is inverted output of AND gate. The second NAND gate acting as inverter further inverts it so that the final output Y is that of AND gate.

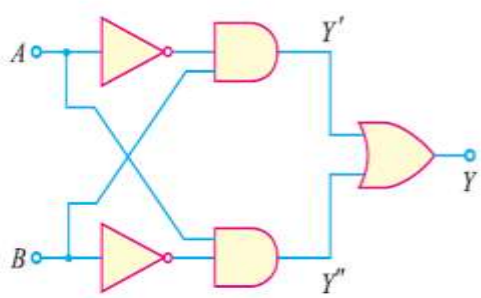
A	B	Y'	Y
0	0	1	0
1	0	1	0
0	1	1	0
1	1	0	1

3. **OR gate from NAND gates:**

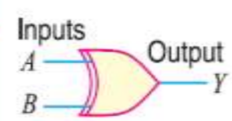
For this purpose, we use three NAND gates in a manner as shown above. The first two NAND gates are operated as NOT gates and their outputs are fed to the third. The resulting circuit is OR gate. This fact is also indicated by the truth table.

A	B	$Y' = \overline{A}$	$Y'' = \overline{B}$	Y
0	0	1	1	0
1	0	0	1	1
0	1	1	0	1
1	1	0	0	1

- **X- OR Gate:**



Inputs		Output	
A	B	OR	XOR
0	0	0	0
1	0	1	1
0	1	1	1
1	1	1	0



Circuit diagram **Truth table** **Symbol**

Figure: 9

- The name exclusive OR gate is usually shortened to XOR gate. The XOR gate can be obtained by using OR, AND and NOT gates as shown in Fig. Fig. shows the truth table for XOR gate. The table shows that the output is HIGH (1) if any but not all of the inputs are HIGH (1).
- This *exclusive* feature eliminates the similarity to the OR gate. The OR gate truth table is also given so that you can compare the OR gate truth table with XOR gate truth table. The logic symbol for XOR gate is shown in Fig. Note that the symbol is similar to that of OR gate except for the additional curved line at the input side.

SRNO	QUESTION	ANSWER
1	How many basic logic gates are there? Which?	Three AND, OR , NOT
2	How many combination logic gates are there? Which?	TWO NAND, NOR
3	NOT gate is known an _____________.	Inverter
4	The output is high if all the inputs are high. However, the output is low if any or all inputs are low is known as____.	AND Gate
5	The output is high if any or all of the inputs are high. The only way to get a low output is by having all inputs low is known as ________.	OR Gate.
6	NAND gate is combination of ______ + ________ logic gate.	NOT + AND
7	NOR gate is combination of _________+ ________ logic gate.	NOT + OR
8	NOT + AND gate is created __________.	NAND
9	NOT + OR gate is created __________.	NOR
10	Write Boolean equation of AND gate.	$Y= A.B$
11	Write Boolean equation of OR gate.	$Y= A + B$
12	Write Boolean equation of NAND gate.	$Y= \overline{A.B}$
13	Write Boolean equation of NOR gate.	$Y= \overline{A + B}$

- **Encoders & Decoders :**

The circuit that converts decimal form to digital (binary) form is called **encoder** and the circuit that converts digital form to decimal form is called **decoder.**

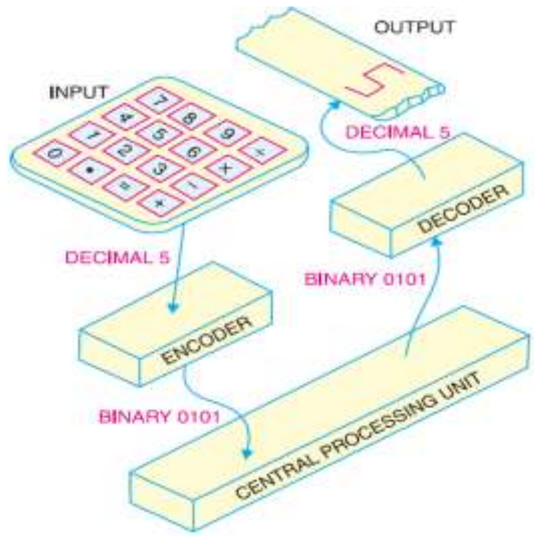


Figure: 10

- **Advantage of Disadvantage of digital electronics:**

Advantages:

1. Digital systems are generally easier to design. It is because the circuits that are used are switching circuits where exact values of voltages or currents are not important, only the range (HIGH or LOW) in which they fall is important.
2. Digital circuits provide greater accuracy and precision. It is because digital circuits can handle as many digits of precision as you need simply by adding more switching circuits. In analog systems, precision is usually limited to three or four digits because the values of voltage and current are directly dependent on the circuit components.
3. Digital circuits are less affected by noise. Suprious fluctuations in voltage (noise) are not as critical in digital systems as in analog systems. It is because in a digital circuit, the exact value of a voltage is not important as long as the noise is not large enough to prevent us from distinguishing a HIGH from a LOW.

4. More digital circuitry can be fabricated on IC chips. Analog system uses such devices (high-value capacitors, inductors, transformers) that cannot be economically integrated. For this reason, analog systems cannot achieve the same degree of integration as digital circuits.
5. Information storage is easy with digital circuits.

Disadvantages:

1. The real world is mainly analog. However, the digital circuits can handle only digital signals. This necessitates encoders and decoders which increase the cost of the equipment.
2. There are situations where using only analog techniques is simpler and more economical. For example, the process of signal amplification is most easily accomplished using analog circuitry.

However, advantages of digital techniques outweigh the disadvantages.

• Boolean Algebra:

https://youtu.be/tN80FzdvB_A

Digital circuits perform the binary arithmetic operations with binary digits 1 and 0. These operations are called logic functions or logical operations.

The algebra used to symbolically describe logic functions is called **Boolean algebra.** Boolean algebra is a set of rules and theorems by which logical operations can be expressed symbolically in equation form and be manipulated mathematically.

(*i*) equals sign (=) (*ii*) plus sign (+)

(*iii*) multiply sign (·) (*iv*) bar (–).

• Boolean Theorem:

We now discuss the basic Boolean theorems that are useful in manipulating and simplifying Boolean expressions. For convenience, we divide the theorems into two groups:

(*i*) Single variable theorems

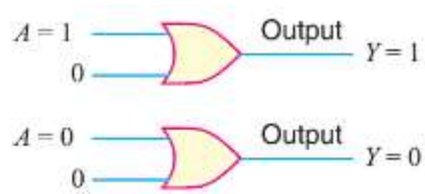
(*ii*) Multivariable theorems.

- **<u>Single variable theorem:</u>**

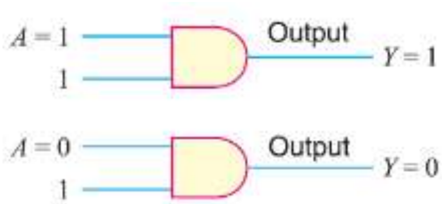
These theorems refer to the condition when only one input to the logic gate is variable.

Theorem 1 :	$A + 0 = A$
Theorem 2 :	$A \cdot 1 = A$
Theorem 3 :	$A + \overline{A} = 1$
Theorem 4 :	$A \cdot \overline{A} = 0$
Theorem 5 :	$A + A = A$
Theorem 6 :	$A \cdot A = A$
Theorem 7 :	$A + 1 = 1$
Theorem 8 :	$A \cdot 0 = 0$
Theorem 9 :	$\overline{\overline{A}} = A$

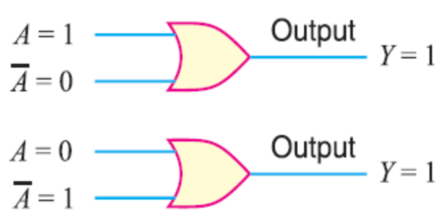
Theorem 1. $(A + 0 = A)$.



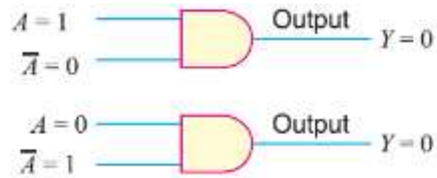
Theorem 2. $(A \,.\, 1 = A)$.



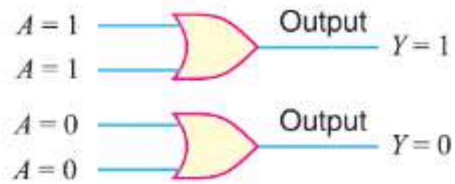
Theorem 3. $\left(A + \overline{A} = 1\right)$



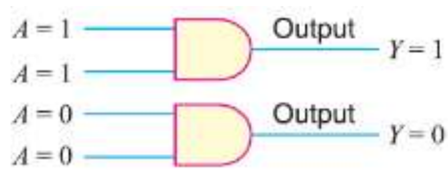
Theorem 4. $\left(A \cdot \overline{A} = 0\right)$.



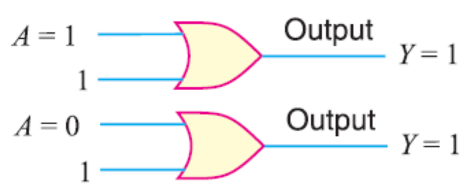
Theorem 5. $\left(A + A = A\right)$.



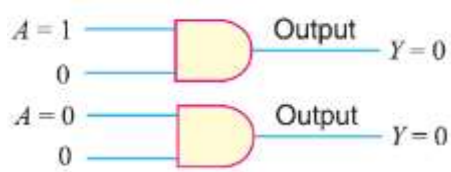
Theorem 6. $(A \cdot A = A)$.



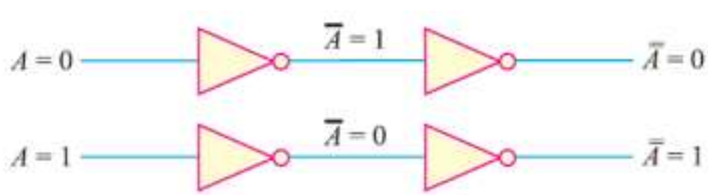
Theorem 7. $(A + 1 = 1)$.



Theorem 8. $(A \cdot 0 = 0)$.



Theorem 9. $\left(\overline{\overline{A}} = A\right)$.



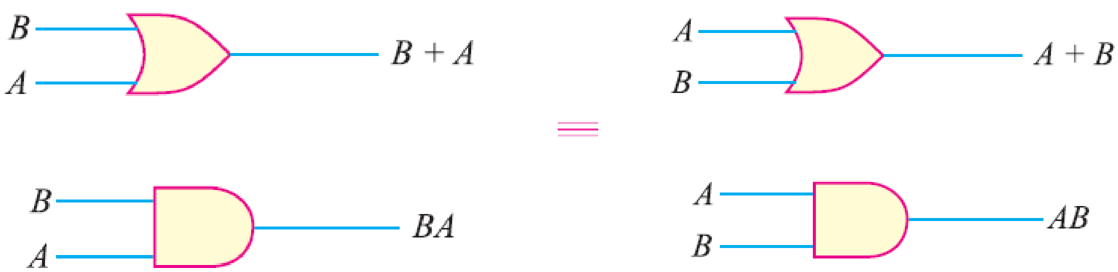
- **<u>Multi variable theorem :</u>**

These theorems refer to the condition when more than one inputto the logic gate are variable.

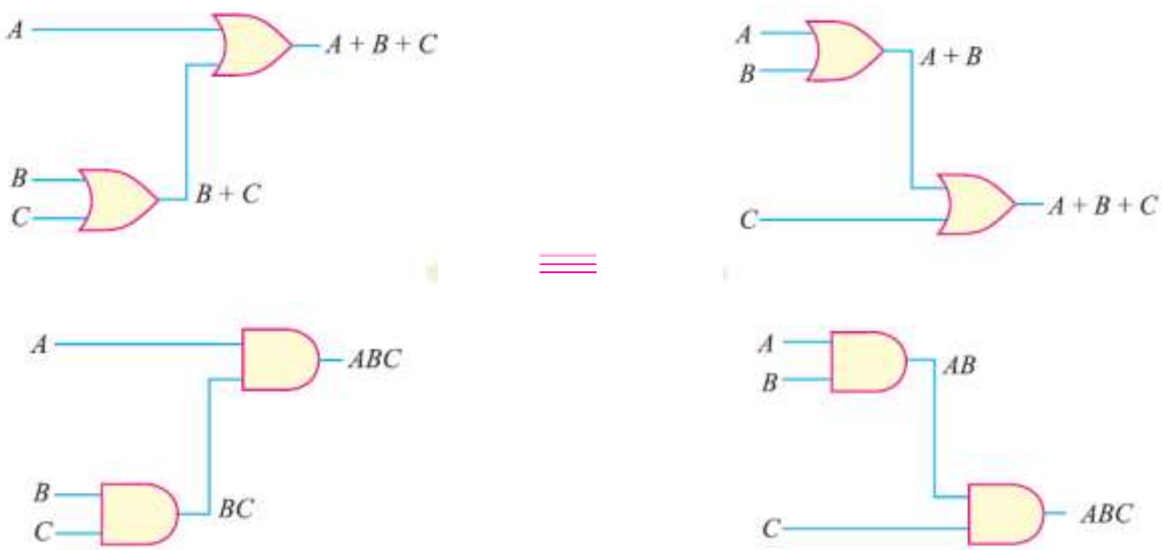
Theorem 10	:	$A+B=B+A$	*Commutative Law*
Theorem 11	:	$A \cdot B=B \cdot A$	
Theorem 12	:	$A+(B+C)=(A+B)+C$	*Associative Law*
Theorem 13	:	$A \cdot (B \cdot C)=(A \cdot B) \cdot C$	
Theorem 14	:	$A \cdot (B+C)=A \cdot B+A \cdot C$	*Distributive Law*
Theorem 15	:	$(A+B) \cdot (C+D)=A \cdot C+B \cdot C+A \cdot D+B \cdot D$	
Theorem 16	:	$A+A \cdot B=A$	*De Morgan's Theorems*
Theorem 17	:	$(\overline{A+B})=\overline{A} \cdot \overline{B}$	
Theorem 18	:	$(\overline{A \cdot B})=\overline{A}+\overline{B}$	

The following points may be noted about these theorems :

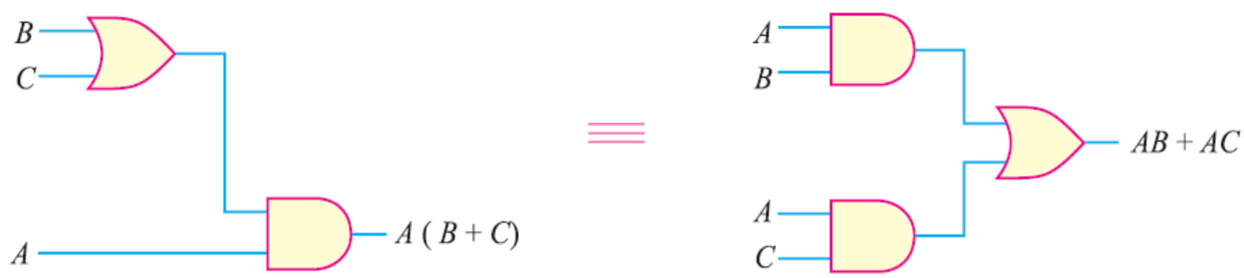
(a) Theorems 10 and 11 obey **commutative law**. This law states that the order in which the variables are ORed or ANDed makes no difference.



(b) Theorems 12 and 13 obey **associative law.** *This law states that in the ORing or ANDing of several variables, the result is the same regardless of the grouping of the variables.*



(c) *Theorems 14 and 15 obey* ***distributive law****. This law states that a Boolean expression can be expanded by multiplying term-by-term just the same as in ordinary algebra.*



(d) We will prove Theorem 16 by factoring and using Theorems 2, 7, 10 and 14.

$A + A \cdot B = A \cdot 1 + A \cdot B$ ...Theorem 2

$= A \cdot (1 + B)$ ...Theorem 14

$= A \cdot (B + 1)$ ...Theorem 10

$= A \cdot 1$ ...Theorem 7

$= A$ ...Theorem 2.

(d) Theorems 17 and 18 are the two most important theorems of Boolean algebra and were contributed by the great mathematician named *De Morgan*. Therefore, these theorems are called De Morgan's theorems.

✪ De- Morgan's theorem:

De Morgan's theorems are extremely useful in simplifying expressions in which a product or sum of variables is inverted. The two theorems are :

(i) $\left(\overline{A+B}\right) = \overline{A} \cdot \overline{B}$

(ii) $\left(\overline{A.B}\right) = \overline{A} + \overline{B}$

(i) The first De Morgan's theorem may be stated as under :

"When the OR sum of two variables is inverted, this is equal to inverting each variable individually and then ANDing these inverted variables".

i.e. $\left(\overline{A+B}\right) = \overline{A} \cdot \overline{B}$

In this expression, *A* and *B* are the two variables. The L.H.S. is the complement of the OR sum of the two variables. The R.H.S. is the AND product of individual inverted variables.

(*ii*) The second De Morgan's theorem may be stated as under :

"When the AND product of two variables is inverted, this is equal to inverting each variable individually and then ORing them."

i.e., $(\overline{A \cdot B}) = \overline{A} + \overline{B}$

In this expression, *A* and *B* are the two variables. The L.H.S. is the complement of the AND product of the two variables. The R.H.S. is the OR sum of the individual inverted variables.

SRNO	QUESTION	ANSWER
1	The circuit that converts decimal form to digital (binary) form is called ___________.	**Encoder**
2	The circuit that converts digital form to decimal form is called ___________.	**Decoder**
3	The algebra used to symbolically describe logic functions is called _____________.	**Boolean algebra**
4	Write D'morgan's theorem.	$(\overline{A+B}) = \overline{A} \cdot \overline{B}$ $(\overline{A \cdot B}) = \overline{A} + \overline{B}$
5	How many types of Boolean theorem? Which?	**2** **Single variable ,** **Multi variable**
6	Write any two single variable theorem.	**Theorem 1.** $(A + 0 = A)$. **Theorem 2.** $(A \, . \, 1 = A)$.
7	Write commutative law.	**A+B= B+A** **A.B = B.A**
8	Write associative law.	**A+(B+C) = (A+B)+C** **(A.B). C = A.(B.C)**
9	Write distributive law.	**A.(B+C) = (A.B)+ (A+C)**

Example 1: Simplify the following Boolean expressions to a minimum number of literals:

$(i)\quad Y = A + \bar{A}B \qquad (ii)\quad Y = AB + \bar{A}C + BC$

Solution. *(i)*

$$Y = A + \bar{A}B$$
$$= A + AB + \bar{A}B \qquad [\because A = A + AB \text{ from Theorem 16}]$$
$$= A + B(A + \bar{A})$$
$$= A + B \qquad [\because A + \bar{A} = 1 \text{ from Theorem 3}]$$
$$\therefore \quad Y = A + B$$

(ii)

$$Y = AB + \bar{A}C + BC$$
$$= AB + \bar{A}C + BC \cdot (A + \bar{A})$$
$$= AB + \bar{A}C + ABC + \bar{A}BC$$
$$= AB(1 + C) + \bar{A}C(1 + B)$$
$$= AB + \bar{A}C$$
$$\therefore \quad Y = AB + \bar{A}C$$

Example 2 : Simplify the following Boolean expressions to a minimum number of literals:

$(i) \quad Y = AB\bar{C} + A\overline{BC}$

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

Solution. *(i)*

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

Applying De Morgan's theorem :

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

Again applying De Morgan's theorem to the each expression inside the brackets :

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

(ii)

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

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

Applying De Morgan's theorem :

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

Again applying De Morgan's theorem to the expression inside the bracket :

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

Applying De Morgan's theorem for the third time we get :

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

or

$$\bar{Y} = A + \overline{BC} + BC$$

Example 3 : Simplify the following Boolean expressions to a minimum number of literals:

(*i*) $Y = (A + B + C) \cdot (A + B)$

(*ii*) $Y = AB + ABC + AB\overline{C}$

(*iii*) $Y = 1 + A(B \cdot \overline{C} + BC + \overline{B}\,\overline{C}) + A\overline{B}C + AC$

(*iv*) $Y = \overline{(A + \overline{B} + C) + (B + \overline{C})}$

Solution. (*i*)

$$Y = (A + B + C) \cdot (A + B)$$
$$= A \cdot A + A \cdot B + B \cdot A + B \cdot B + C \cdot A + C \cdot B$$

Using $A \cdot A = A$, we get,

$$Y = A + AB + AB + B + AC + BC$$
$$= A + AB + B + AC + BC \qquad [\because AB + AB = AB]$$
$$= A + B + AC + BC \qquad [\because A + AB = A]$$
$$= A(1 + C) + B(1 + C)$$
$$= A \cdot 1 + B \cdot 1 \qquad [\because 1 + C = 1]$$

$$\therefore \quad Y = A + B$$

(*ii*)

$$Y = AB + ABC + AB\overline{C}$$
$$= AB + AB\,(C + \overline{C})$$
$$= AB + AB \qquad [\because C + \overline{C} = 1]$$

$$\therefore \quad Y = AB$$

(*iii*)

$$Y = 1 + A(B \cdot \overline{C} + BC + \overline{B}\,\overline{C}) + A\overline{B}C + AC$$

Using $1 + A = 1$, we get,

$$Y = 1 + A\overline{B}C + AC \qquad [\because 1 + A(B\overline{C} + BC + \overline{BC}) = 1]$$
$$= 1 + AC$$

$$\therefore \quad Y = 1$$

Thus, because of the first term Y reduces to 1. Therefore, any Boolean expression ORed with 1, results in 1.

(*iv*)

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

Applying De Morgan's theorem :

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

Again applying De Morgan's theorem :

$$Y = (\overline{A} \cdot B \cdot \overline{C}) \cdot (\overline{B} \cdot C) = 0 \qquad [\because B \cdot \overline{B} = 0,\ C \cdot \overline{C} = 0]$$

• SUMMARY:

- A signal is an electric current or voltage used to convey data from one place to another. A continuous time varying signal of current or voltage is called an analog signal. The circuit that uses such type of signal is called analog circuit.

- Transistor amplifier circuit is an analog circuit that gives amplified output voltage which also varies sinusoidal.

- A signal having two discrete values of current or voltage is called digital signal. The circuit that uses such type of signal is called digital circuit. The operation performed by digital circuit is called digital operation.

- Digital operation is in binary form (means, it has only two values) therefore it is more reliable than multi valued analog operation and signals can be easily recognized as either low or high.

- A number system which has only two digits (0 and 1) is known as binary number system.

- A number system which has ten digits (0, 1, 2, 3, 4, 5, 6, 7, 8, 9) is known as decimal number system.

- A number system which has sixteen distinct counting digits 0 through 9 and A through F (0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F) is known as Hexadecimal number system.

- A number system has eight distinct counting digits (0,1,2,3,4,5,6,7) is known as Octadecimal number system.

- Binary Addition: (0 + 0 = 0, 1 + 0 = 1, 1+1+1 = 11) Binary Subtraction: (0 - 0) = 0,1 - 0) = 1, 0 - 1 = 1) Binary Multiplication: (1 x 0 = 0, 1 x 1 = 1)

- Logic gates are digital circuit which works according to some logical relationship between input and output.

- An OR gate is a logic gate whose output is 1 (HIGH) if at least one of its input is 1 (HIGH). (Y=A+B)

- An AND gate is a logic gate whose output is 1 (HIGH) if all the inputs are 1 (HIGH). (Y=A.B)

- A NOT gate is a logic gate whose output is opposite of inpu ($Y=\bar{A}$) NAND and NOR gates are also known as universal logic gates.

- NAND = AND + NOT (Y=AB), NOR = OR + NOT (Y=A + B) The XOR gate can be obtained by using AND, OR and NOT gates. (Y=AB)

- Boolean algebra is a set of different rules, laws and theorems by which the logical operations can be expressed symbolically in the form of equations.

- De' Morgan's theorem: When a sum of variables is inverted, it can be simplified by ANDing all the individually inverted variable.

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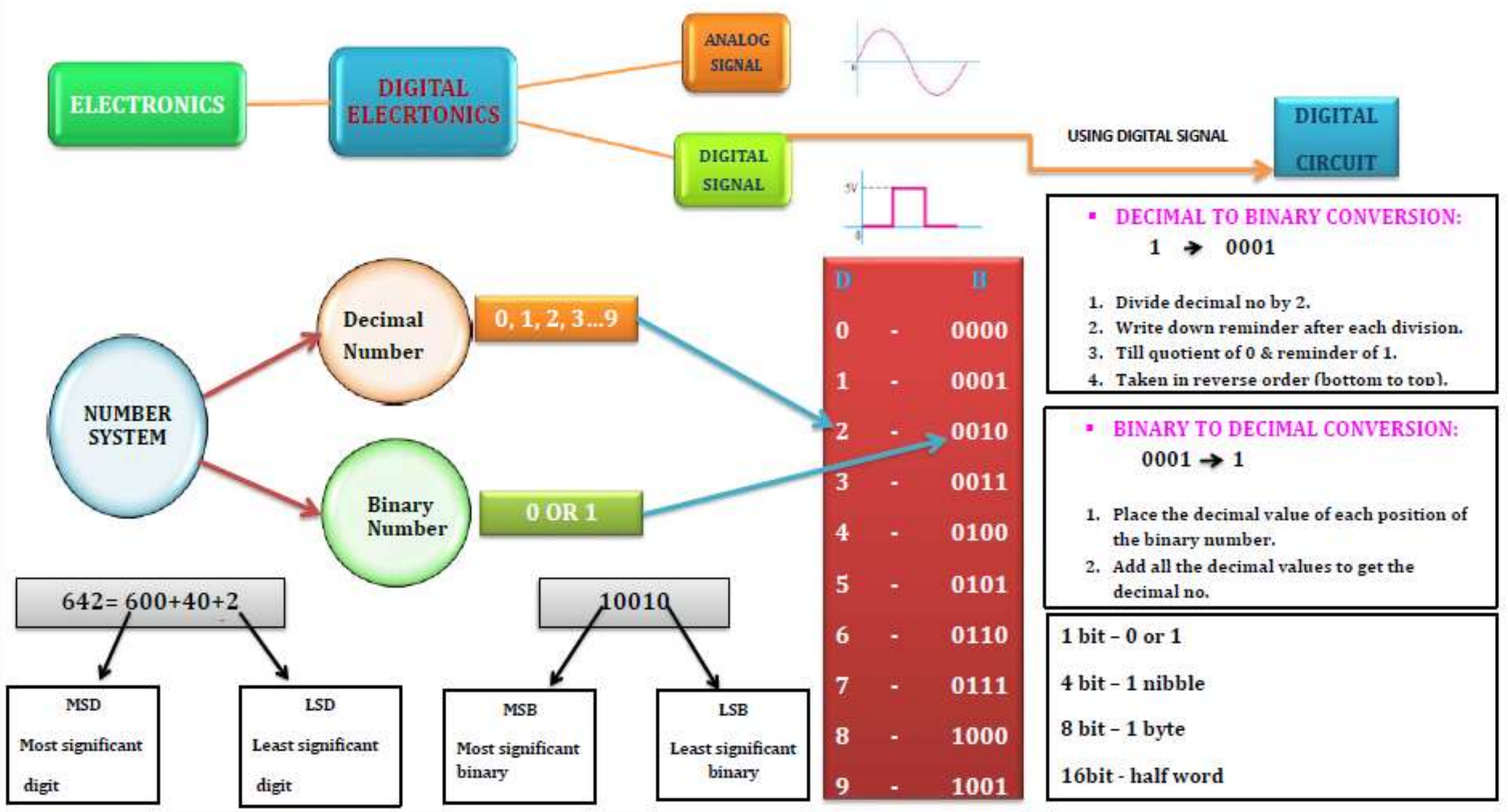
MIND MAP

UNIT- 4 - DIGITAL ELECTRONICS



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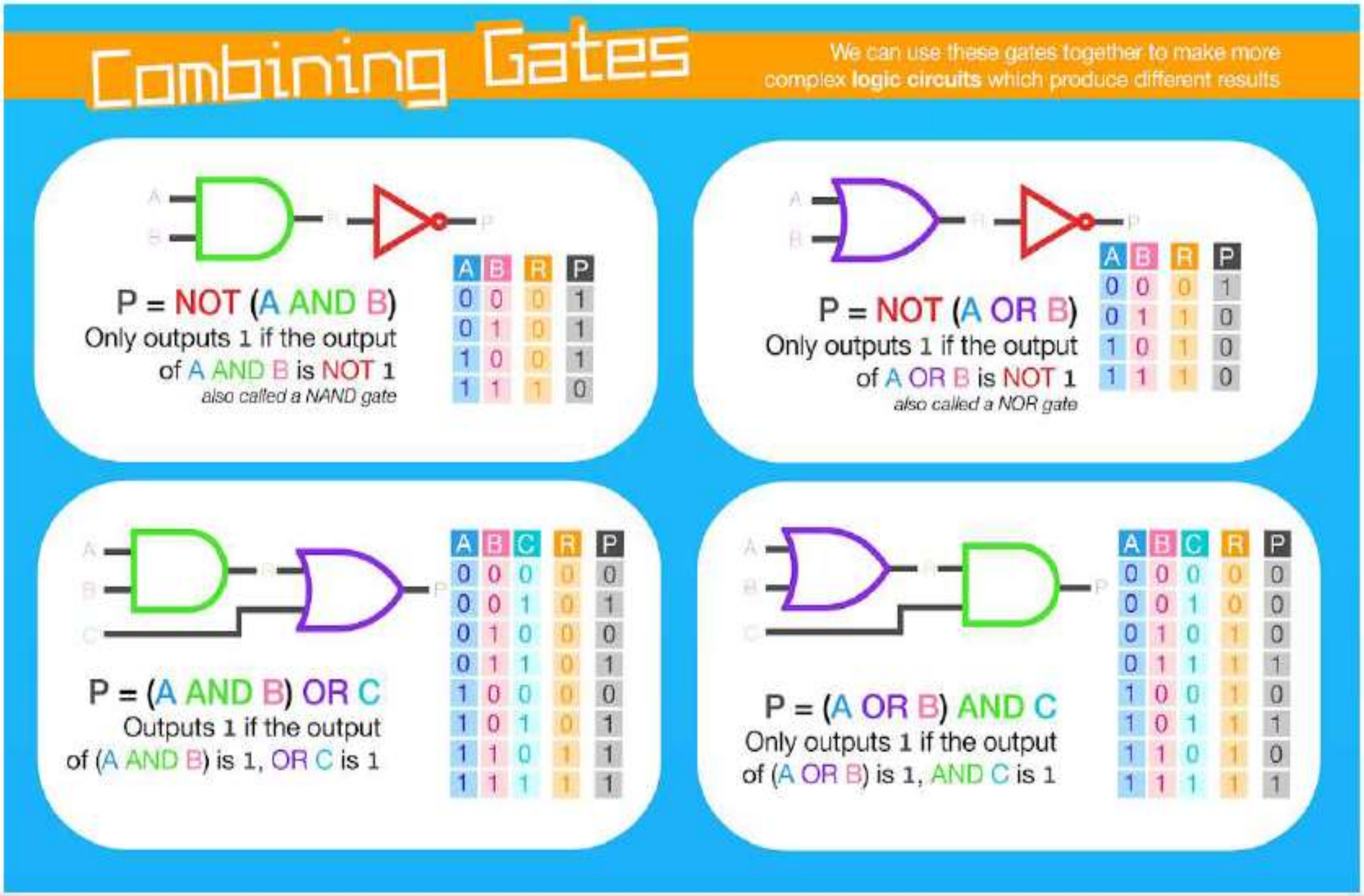
UNIT- 4 - DIGITAL ELECTRONICS



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MIND MAP

UNIT- 4 - DIGITAL ELECTRONICS

BOOLEAN ALGEBRA

- **The Rules of Boolean Algebra :**

AND Operations ($\cdot$)

$0 \cdot 0 = 0 \quad A \cdot 0 = 0$

$1 \cdot 0 = 0 \quad A \cdot 1 = A$

$0 \cdot 1 = 0 \quad A \cdot A = A$

$1 \cdot 1 = 1 \quad A \cdot A' = 0$

OR Operations (+)

$0+0 = 0 \quad A+0 = A$

$1+0 = 1 \quad A+1 = 1$

$0+1 = 1 \quad A+A = A$

$1+1 = 1 \quad A+A' = 1$

NOT Operations (')

$0' = 1 \quad A'' = A$

$1' = 0$

Associative Law

$(A \cdot B) \cdot C = A \cdot (B \cdot C) = A \cdot B \cdot C$

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

Distributive Law

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

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

Commutative Law

$A \cdot B = B \cdot A$

$A+B = B+A$

Precedence

$AB = A \cdot B$

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

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

DeMorgan's Theorem

$(A \cdot B)' = A' + B'$ (NAND)

$(A+B)' = A' \cdot B'$ (NOR)