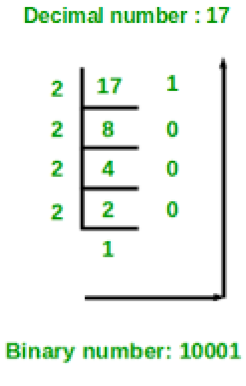
Prof. Surajit Dhara

Guest Lecturer,

Dept. Of Physics, Narajole Raj College

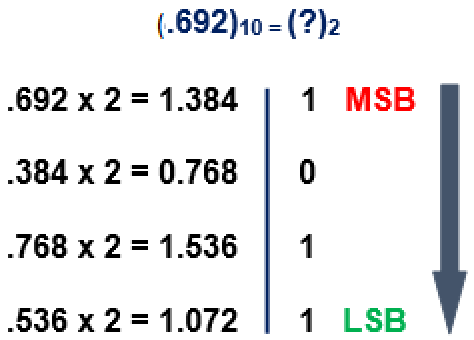
GE4T(Digital, Analog Circuits and Instrumentation) , Topic :- Digital Circuits

- **Analog signals and analog circuits :** The electrical signals that are continuous and can value any over a given range, are called " analog signals".
  The electronic circuits employed to process the analog signals are called "analog circuits".
- **Digital signals and digital circuits :** The electrical signals that have only discrete values, high and low, termed as " digital signals".
  The electronic circuits employed to process the digital signals are called " digital circuits".
- **Binary system :** A digital circuit functions only in two states i.e. two and high states or on and off states. To represent these two states we have two digit- "1"(one) and "0" (zero). Hence this system is called "Binary system".
- **Bit and bite :** A binary digit "0" or "1" is known as 'Bit". A group of bits with significance is called a "Bite".
  Example : In a binary number 10011, consists of 5 bits 1,0,0,1,1 and the total number is called "Bite".
- **Decimal to Binary conversion :**
  Example 1: Convert the digital number 17 into binary number.



$$(17)_{10} = (10001)_2$$

Example 2 : Convert the decimal number 0.692 nito binary number.



$(.692)_{10} = (?)_2$

.692 x 2 = 1.384 | 1 MSB

.384 x 2 = 0.768 | 0

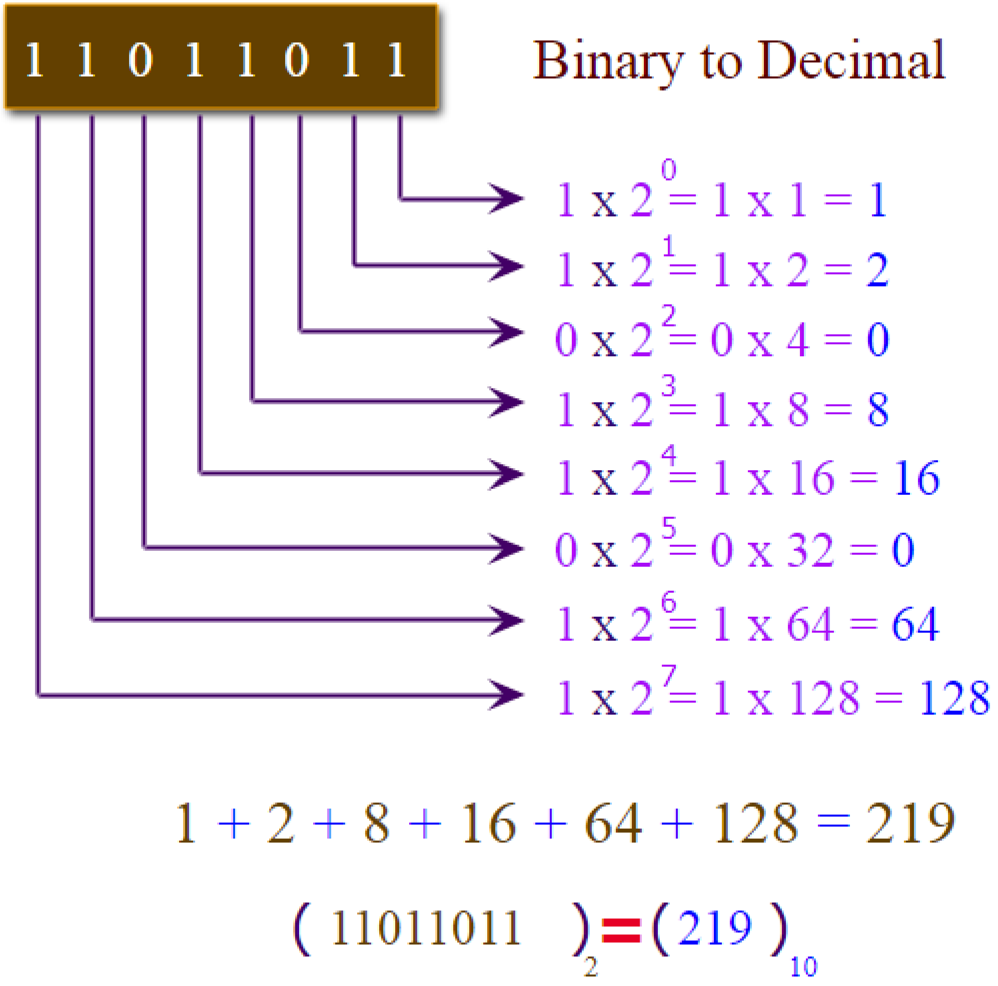
.768 x 2 = 1.536 | 1

.536 x 2 = 1.072 | 1 LSB

.: $(0.692)_{10} = (1011)_2$

- **Binary to Decimal conversion :**

  Example 1 : Convert the binary number 11011011 to its decimal equivalent.



$1 \times 2^0 = 1 \times 1 = 1$

$1 \times 2^1 = 1 \times 2 = 2$

$0 \times 2^2 = 0 \times 4 = 0$

$1 \times 2^3 = 1 \times 8 = 8$

$1 \times 2^4 = 1 \times 16 = 16$

$0 \times 2^5 = 0 \times 32 = 0$

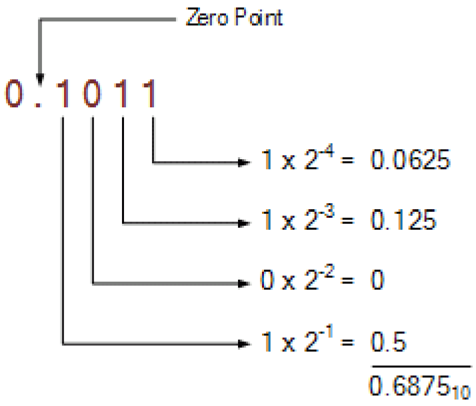
$1 \times 2^6 = 1 \times 64 = 64$

$1 \times 2^7 = 1 \times 128 = 128$

$1 + 2 + 8 + 16 + 64 + 128 = 219$

$(11011011)_2 = (219)_{10}$

Example 2 : Convert the binary number 0.1011 to its decimal equivalent.



$(0.1011)_2 = (0.6875)_{10}$

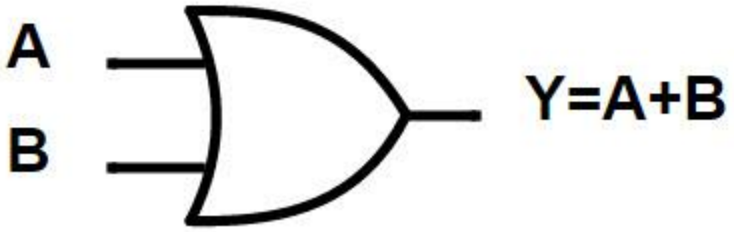
Logic Gates

- **Logic Gates :** A logic gate is a circuit with one or more inputs but only one output. The voltage level at the input and output of these gates can have only two states, either high and low. Thus the possible values of the inputs and output of these gates are 1 or 0.
  There are three fundamental gates – 1. AND gate 2. OR gate 3. NOT gate.
  The combinations of these gates produce other useful gates as –
  1. NAND gate
  2. NOR gate
  3. Ex- OR gate
  4. Ex-NOR gate
- Logic gates are the basic building blocks of all digital system like digital computers, digital control system etc.
- Truth table : The input – output combinations of any gate can be written in a tabular form, which is called truth table of that gate.

(1) OR GATE

- **Defination :** The logic gate whose output is “1” (high) if one or more than inputs are “1” (high) called OR- gate. It has two or more than two inputs ($N \geq 2$) but only one output.

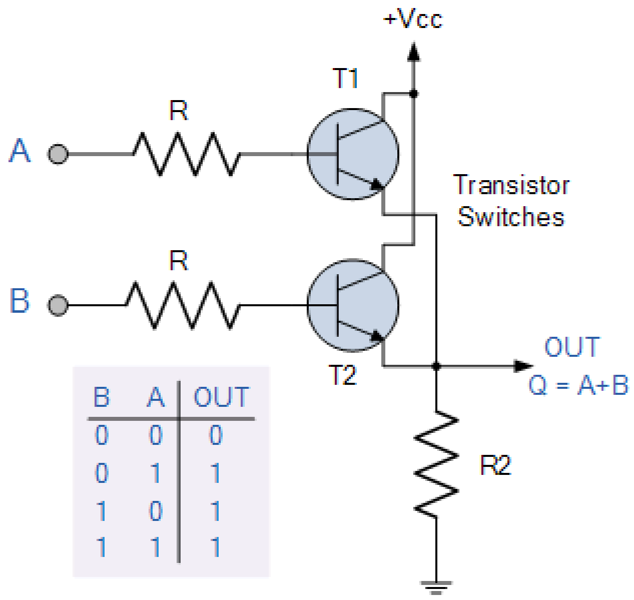
- **Circuit symbol :**



- **Truth Table : Y = A + B**

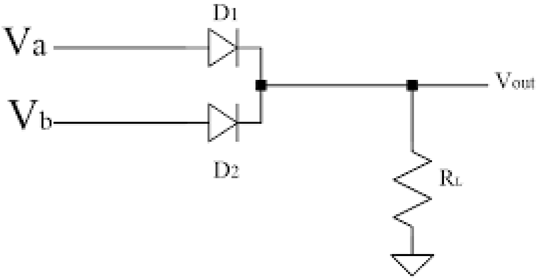
Inputs		Outputs
A	**B**	**Y**
0	**0**	**0**
0	**1**	**1**
1	**0**	**1**
1	**1**	**1**

- **Construction of 2-input OR gate (positive) using Transistors:**



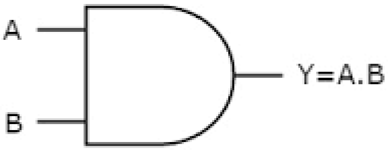
B	A	OUT
0	0	0
0	1	1
1	0	1
1	1	1

- **Construction of 2-input positive OR gate using Diodes:**



(2) AND GATE

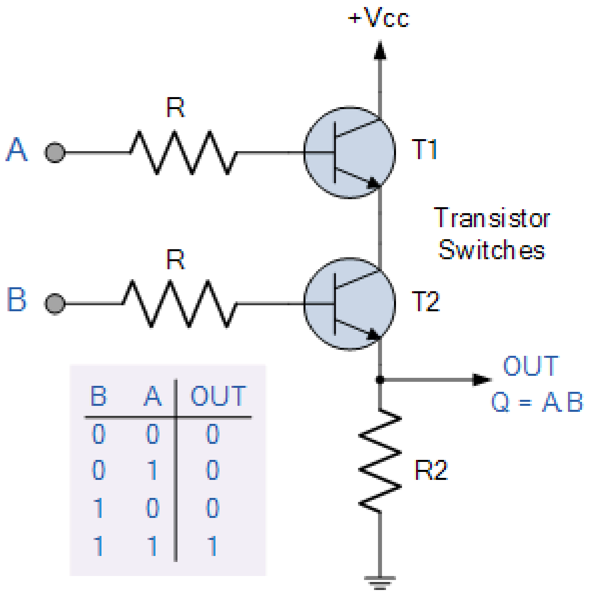
- **Defination :** The logic gate whose output is "1" (high) if and only if all the inputs are "1" (high). It has N inputs (N≥2) but only one output.
- **Circuit symbol:**



- **Truth Table : Y = A.B**

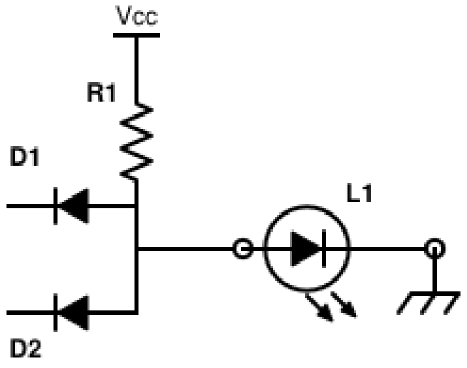
Inputs		Outputs
A	**B**	**Y**
0	**0**	**0**
0	**1**	**0**
1	**0**	**0**
1	**1**	**1**

- **Construction of 2-input AND gate using transistor:**



B	A	OUT
0	0	0
0	1	0
1	0	0
1	1	1

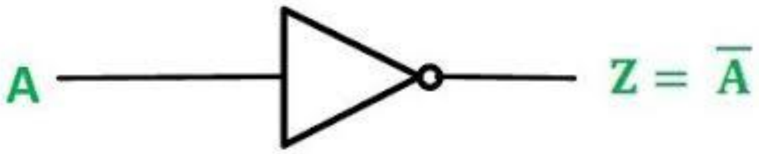
- **Construction of 2-input positive AND gate using Diodes :**



(3) NOT GATE

- **Defination :** A NOT gate is defined as the gate whose output is the complementary of the input. It is also called complementary gate. It has one input and one output.

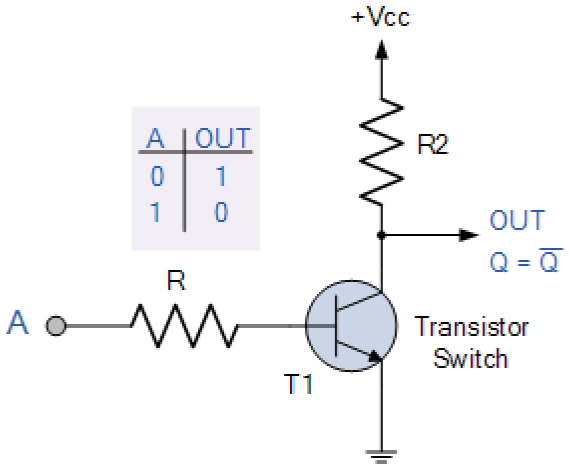
- **Circuit symbol:**



- **Truth Table :**

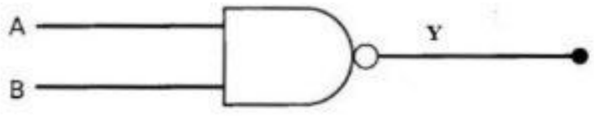
Input	Ouput
A	**Z**
0	**1**
1	**0**

- **Diagram of NOT gate using n-p-n transistor:**

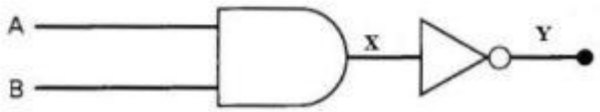


NAND GATE

- **Defination :** When an AND gate is followed by a NOT gate, then the gate combination is called NAND gate.
- **Circuit symbol :**



(a)

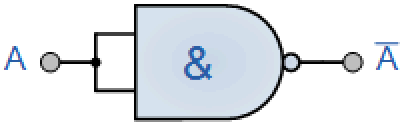


(b)

- **Truth Table :** $\boldsymbol{Y = \overline{A.B}}$

Inputs		**Outputs**
A	**B**	**Y**
0	**0**	**1**
0	**1**	**1**
1	**0**	**1**
1	**1**	**0**

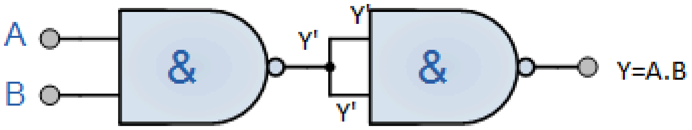
- **Why NAND gate is called universal gate?**
  Using NAND gate we can construct any type of basic gates i.e. AND, OR and NOT gate. Hence NAND gate is called universal gate.
  (i) Construction of NOT gate using NAND gate:



NOT Gate

$$.: Y = \overline{A.A} = \bar{A}$$

(ii) Construction of AND gate using NAND gates:

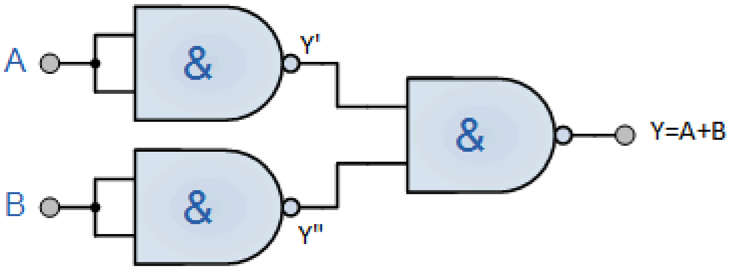


2-input AND Gate

$$.:\ Y' = \overline{A.B}$$

$$Y = \overline{Y'.Y'} = \overline{Y'} = \overline{\overline{A.B}} = A.B$$

(iii) Construction of OR gate using NAND gates :



2-input OR Gate

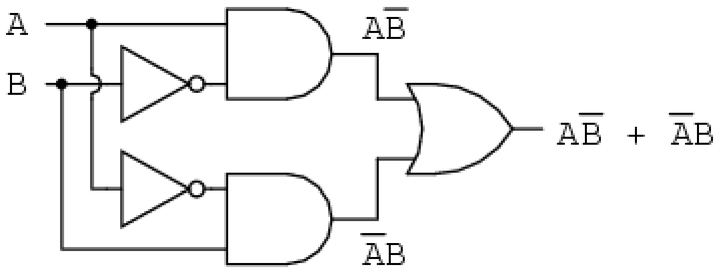
$$Y' = \overline{A.A} = \bar{A}$$

$$Y'' = \overline{B.B} = \bar{B}$$

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

Exclusive OR Gate

- **Defination :** An Ex-OR gate is defined as the output is zero when all the inputs are same. It has N inputs ($N \geq 2$) and one output.
- **Circuit :**



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

- **Truth Table :** $Y = A \oplus B = A\overline{B} + \overline{A}B$

Inputs		**Outputs**
A	**B**	**Y**
0	**0**	**0**
0	**1**	**1**
1	**0**	**1**
1	**1**	**0**

De-Morgan's Theorem

- **De- Morgan's Theorem I :** The complement of a sum of variables is equal to the product of the complements of the individual variables.

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

- **De- Morgan's Theorem II :** The complement of a variables is equal to the sum of the individual variables.

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

- **Applications of De-Morgan's Theorem:**

(i) Using De-Morgan's theorem on AND expression can be changed in OR expression or vice versa easily.

(ii) Using De-Morgan's theorem a NAND expression can be changed to OR expression or NOR to AND expression.

Boolean Relations

AND Relations	1	**A.0 = 0**
	2	**A.1 = AA**
	3	**A.A = A**
	4	**A.$\bar{A}$ = 0**
OR Relations	5	**A+0 = 0**
	6	**A+1 = 1**
	7	**A+A = A**
	8	$A + \bar{A} = 1$
Commutative Laws	9	**A+B=B+A**
	10	**A.B=B.A**
Associative Laws	11	**A+(B+C)=(A+B)+C**
	12	**A.(B.C)=(A.B).C**
Distributive Laws	13	**A.(B+C)=A.B+A.C**
De-Morgan's Laws	14	$\overline{A + B} = \bar{A}.\bar{B}$
	15	$\overline{A.B} = \bar{A} + \bar{B}$
Double Complement Laws	16	$\bar{\bar{A}} = A$

REVIEW QUESTIONS AND PROBLEMS

1. Implement a two input logic circuit whose output is 1only when the two inputs are unequal. Write the name of the logic gate.
2. Explain how an OR gate can be implemented using AND and NOT gate. Draw the circuit diagram.
3. Realize the following logic equations : (1) $Y = A + \bar{B} + \bar{A}B$ (2) $Y = (A + B).(B + C.(C+A)$.
4. Prove that $(A + C)(\bar{A} + B) = \bar{A}C + AB$.
5. Why NAND/ NOR gate is called universal gate?