PHYSICS

NEET and JEE Main 2020 : 45 Days Crash Course

Semiconductor Electronics

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Transistor

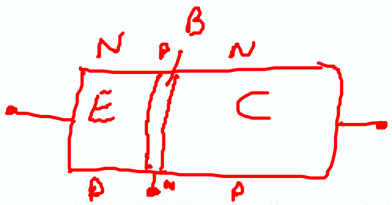
Inventor William Bradford Shockley, John Bardeen and Walter Houser Brattain.

Transistor is a three terminal device which transfers a singal from low resistance circuit to high resistance circuit.

It is formed when a thin layer of one type of extrinsic semiconductor (P or N type is sandwitched between two thick layers of other two type extrinsic semiconductor.

Each transistor have three terminals which are :-

(i) Emitter
(ii) Base
(iii) Collector



Emitter

It is the left most part of the transistor. It emit the majority carrier towards base. It is highly doped and medium in size.

Base

It is the middle part of transistor which is sandwitched by emitter (E) and collector (C). It is lightly doped and very thin in size.

Collector

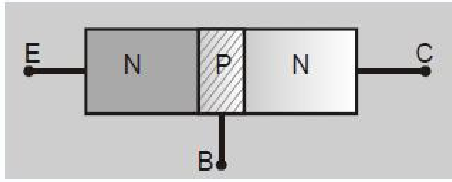
It is right part of the transistor which collect the majority carrier which is emitted by emitter. It have large size and moderately doped.

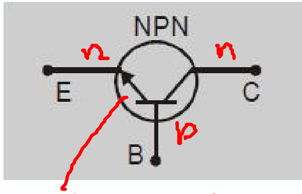
There are two semiconductor junction in transister

(i) The junction between emitter and base is known as emitter-base junction **(J_{EB})**.
(ii) The junction between base and collecter is known as base-collector junction **(J_{CB})**.

Types of Transistor

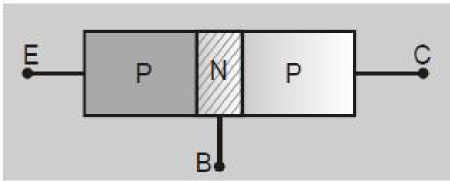
- **N-P-N Transistor**
  If a thin layer of P-type semiconductor is sandwitched between two thick layers of N-type semiconductor is known as NPN transistor.

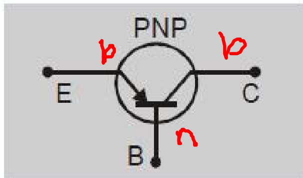


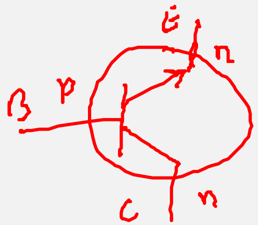


Arror ⇒ emitter

- **P-N-P Transistor**
  If a thin layer of N-type of semiconductor is sandwitched between two thick layer of P-type semiconductor is known as PNP transistor.

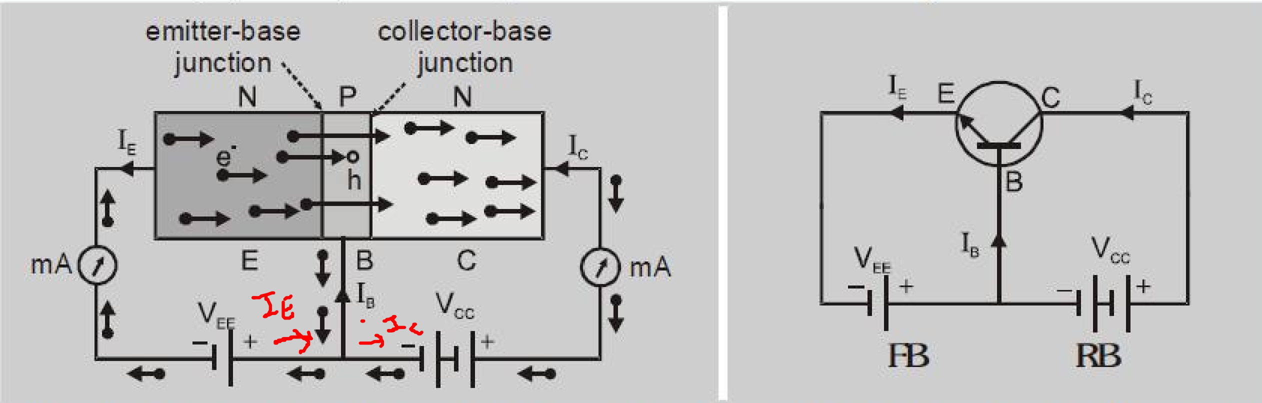






Working of NPN Transistor

The emitter Base junction is forward bias and collector base junction is reversed biased of N-P-N transistor in circuit (A) and symbolic representation is shown in Figure.



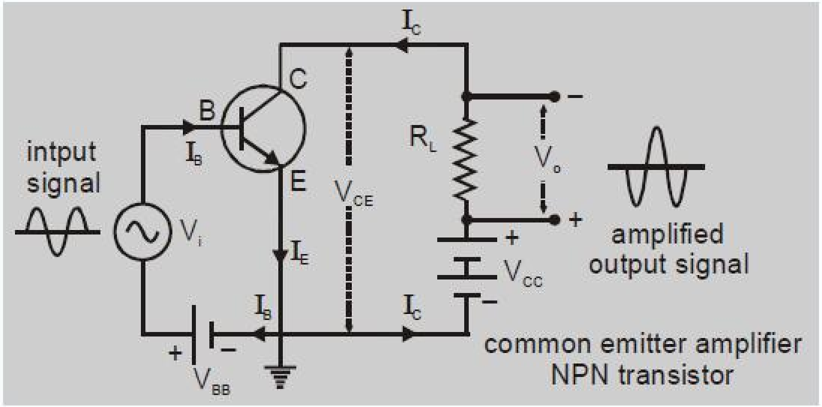
When emitter base junction is forward bias, electrons (majority carriers) in emitter are repelled toward base. The barrier of emitter base junction is reduced and the electron enter the base, about 5% of these electron recombine with hole in base region result in small current (I_B). The remaining electron ($\approx$95%) enter the collector region because they are attracted towards the positive terminal of battery results collecter current (I_C)

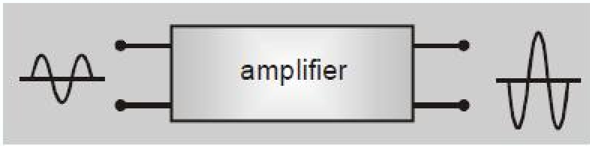
For each electron entering the positive terminal of the battery is connected with collector base junction an electron from negative terminal of the battery connected with emitter base junction enters the region. The emitter current (I_E) is more than the collector (I_C). The base current is the difference between I_E and I_C and proportional to the number of electron hole recombination in the base.

$$I_E = I_B + I_C$$

Transistor as an Amplifier

The process of increasing the amplitude of input signal without distorting its wave shape and without changing its frequency is known as amplification.
A device which increases the amplitude of the input signal is called amplifier.



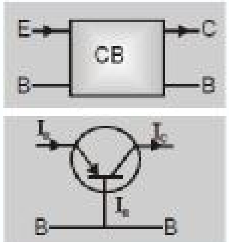
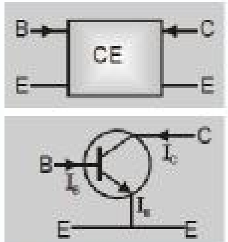


Phase change π

Comparative Study of Transistor Configuration

$I_E = I_C + I_B$

$I_E > I_C$

	1. Common Base **(CB)**	2. Common Emitter **(CE)**
	C B	**C E**
		
Current Gain	$(A_I \text{ or } \alpha)$	$(A_I \text{ or } \beta)$
	$\alpha = \frac{I_C}{I_E} < 1$	$\beta = \frac{I_C}{I_B} > 1$
Voltage Gain	$A_V = \frac{V_o}{V_i} = \frac{I_C R_L}{I_E R_i}$	$A_V = \frac{V_o}{V_i} = \frac{I_C R_L}{I_B R_i}$
	$A_v = \alpha \frac{R_L}{R_i}$	$A_v = \beta \frac{R_L}{R_i}$
Power Gain	$A_p = \frac{P_o}{P_i}$	$A_p = \frac{P_o}{P_i}$
	$A_p = \alpha^2 \frac{R_L}{R_i}$	$A_p = \beta^2 \frac{R_L}{R_i}$
Phase difference (between output and input)	same phase	opposite phase
Application	For High Fequency	For Audioable fequency

Relation between α and β

$$I_E = I_B + I_C$$

divide by I_C

$$\frac{I_E}{I_C} = \frac{I_B}{I_C} + 1$$

$$\frac{1}{\alpha} = \frac{1}{\beta} + 1$$

$$\beta = \frac{\alpha}{1-\alpha}$$

$$\alpha = \frac{I_C}{I_E}$$

$$\beta = \frac{I_C}{I_B}$$

$$\alpha = \frac{\beta}{1+\beta}$$

Logic Gates

Introduction :

- A logic gate is a digital circuit which is based on certain logical relationship between the input and the output voltages of the circuit.
- The logic gates are built using the semiconductor P-N junction diodes and transistors.
- Each logic gate is represented by its characteristic symbol.
- The operation of a logic gate is indicated in a table, known as truth table. This table contains all possible combinations of inputs and the corresponding outputs.
- A logic gate is also represented by a Boolean algebraic expression. Boolean algebra is a method of writing logical equations showing how an output depends upon the combination of inputs. Boolean algebra was invented by George Boole.

Basic Logic Gates

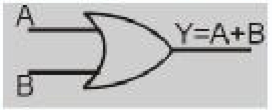
There are three basic logic gates. They are (1) OR gate (2) AND gate, and (3) NOT gate

$0+0=0$
$0+1=1$
$1+0=1$
$1+1=1$

$0 \rightarrow$ Low
$1 \rightarrow$ High

- **The OR gate :-** The output of an OR gate attains the state 1 if one or more inputs attain the state 1.

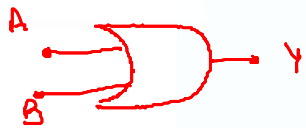
  Logic symbol of OR gate



  The **Boolean expression** of OR gate is Y = A + B read as Y equals A ORing B.

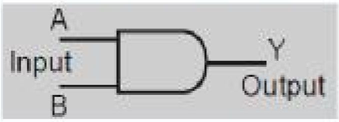
  Truth table of a two-input OR gate

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



- **The AND gate :-** The output of an AND gate attains the state 1 if and only if all the inputs are in state 1.

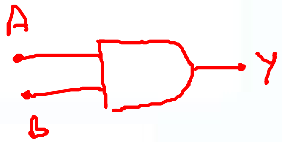
  Logic symbol of AND gate



  The **Boolean expression** of AND gate is Y = A.B It is read as Y equals ANDing B

  Truth table of a two-input AND gate

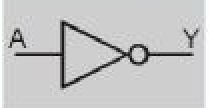
A	B	Y
0	0	0
0	1	0
1	0	0
1	1	1



Basic Logic Gates

- **The NOT gate :** The output of a NOT gate attains the state 1 if and only if the input does not attain the state 1.

  Logic symbol of NOT gate

  The **Boolean expression** is

  $Y = \overline{A}$, read as Y equals NOT A.

  Truth table of NOT gate

A	Y
0	1
1	0

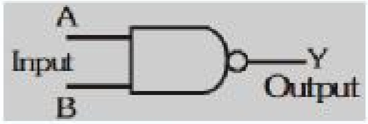
  'NOT gate have only one input'

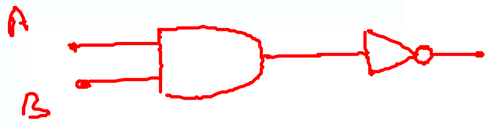
Combination of Gates

The three basis gates (OR, AND and NOT) when connected in various combinations give us logic gates such as NAND, NOR gates, which are the universal building blocks of digital circuits.

- **The NAND gate :**

  Logic symbol of NAND gate





The **Boolean expression** of NAND gate is

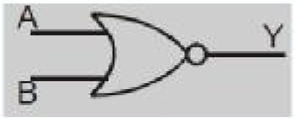
$$Y = \overline{A.B}$$

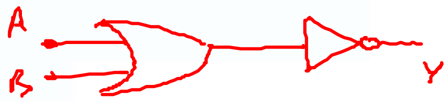
Truth table of a NAND gate

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

- **The NOR gate :**

  Logic symbol of NOR gate





The **Boolean expression** of NOR gate is

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

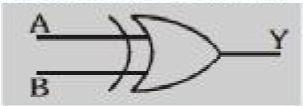
Truth table of a NOR gate

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

XOR and XNOR Gates

- **The Exclusive - OR gate (XOR gate):-** The output of a two-input XOR gate attains the state 1 if one and only one input attains the state 1.

  Logic symbol of XOR gate

  The **Boolean expression** of XOR gate is

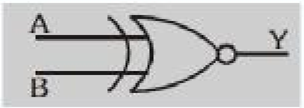
  $$Y = A.\bar{B} + \bar{A}.B \text{ or } Y = A \oplus B$$

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

  Truth table of a XOR gate

- **Exclusive - NOR gate (XNOR gate):-** The output is in state 1 when its both inputs are the same that is, both 0 or both 1.

  Logic symbol of XNOR gate

  The **Boolean expression** of XNOR gate is

  $$Y = A.B + \bar{A}.\bar{B} \text{ or } Y = \overline{A \oplus B} \text{ or } A \odot B$$

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

  Truth table of a XNOR gate

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Laws of Boolean Algebra

Basic OR, AND, and NOT operations are given below :

OR	AND	NOT
$A + 0 = A$	$A . 0 = 0$	$A + \bar{A} = 1$
$A + 1 = 1$	$A . 1 = A$	$A . \bar{A} = 0$
$A + A = A$	$A . A = A$	$\bar{\bar{A}} . A = A$

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

Boolean algebra obeys commutative, associative and distributive laws as given below :

- **Commutative laws :**

  $A + B = B + A$;

  $A.B = B.A$

- **Associative laws :**

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

  $A. (B . C) = (A. B) . C$

- **Distributive laws :**

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

- **De Morgan's theorem :**

  First theorem : $\overline{A + B} = \bar{A}.\bar{B}$

  Second theorem : $\overline{A.B} = \bar{A} + \bar{B}$

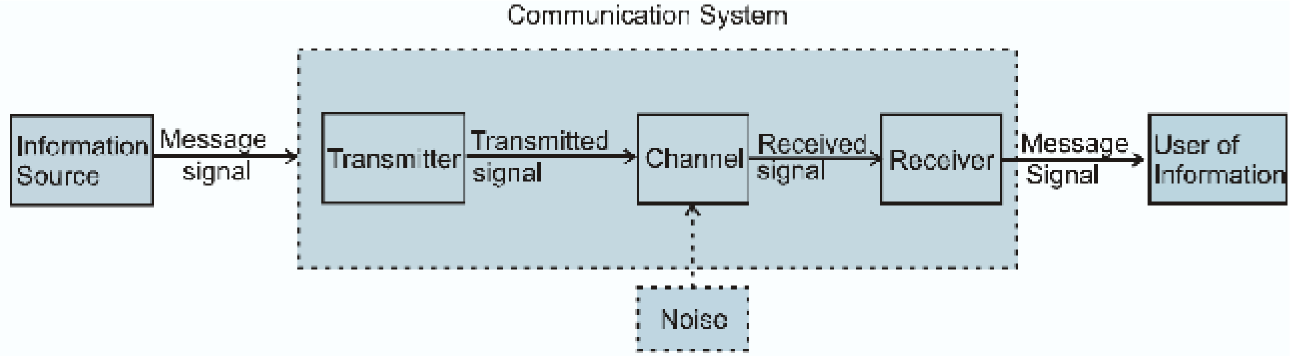
Communication System

The transmission of information is known as communication. For transmission of information from one place to other, there are three essential elements.

Transmitter- Transmitter is used to transmit the input signal from the information source.

Channel- Channel is defined as the medium through which the signal is sent from transmitter to receiver.

Receiver- Receiver is used to extract the desired message signal from the received signal at the channel output.



Bandwidth of signal – The difference between the maximum and minimum frequency of a signal is known as the bandwidth of that signal.

Propagation of Electromagnetic Waves

Ground wave Propagation

The radio waves which travel through atmosphere following the surface of the earth are known as ground waves or surface waves and their propagation is called ground wave propagation or surface wave propagation.

Points to remember

(1) The ground wave transmission becomes weaker with the increase in frequency because more absorption of ground waves takes place at a higher frequency during propagation through the atmosphere.

(2) The ground wave propagation is suitable for low and medium frequency i.e. upto 2 or 3 MHz only.

(3) The ground wave propagation is generally used for local band broadcasting.

Sky wave Propagation

The sky waves are the radio waves of frequency between 2 MHz to 30 MHz.

Points to remember

(1) The ionospheric layer acts as a reflector for a certain range of frequencies (3 to 30 MHz). Electromagnetic waves of frequencies higher than 30 MHz penetrate the ionosphere and escape.

(2) The highest frequency of radio waves which when sent straight (normally) towards the layer of ionosphere gets reflected from the ionosphere and returns to the earth is called critical frequency.

$f_c = 9 (N_{max})^{1/2}$, where N is the number density of electron/m^3.

Propagation of Electromagnetic Waves

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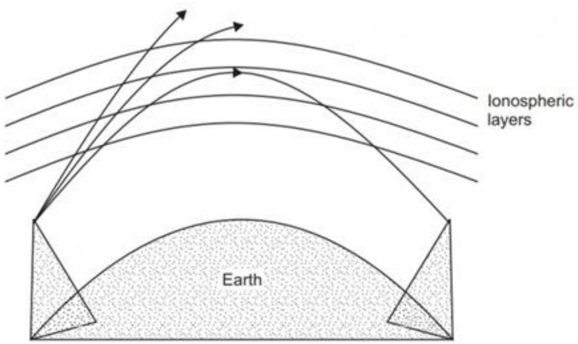


Propagation of Electromagnetic Waves

<u>Space wave propagation</u>

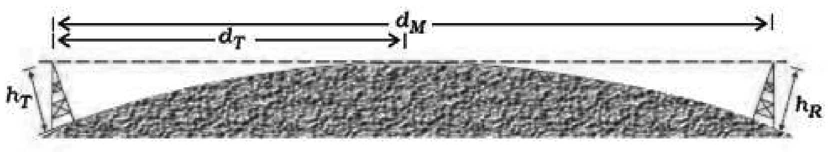
The space waves are the high-frequency radio waves. These waves can travel through the atmosphere from the transmitter antenna to receiver antenna either directly or after reflection from the ground in the earth's troposphere region. Therefore the space wave propagation is also called as tropospheric propagation or line of sight propagation.

Points to remember

(1) The range of communication of space wave propagation can be increased by increasing the heights of transmitting and receiving antenna.

(2) If the transmitting antenna is at a height h_T, the distance to the horizontal d_T is given as; $d_T = \sqrt{2RhT}$ $\sqrt{2Rh_T}$
where R is the radius of the earth (approximately 6400 km).

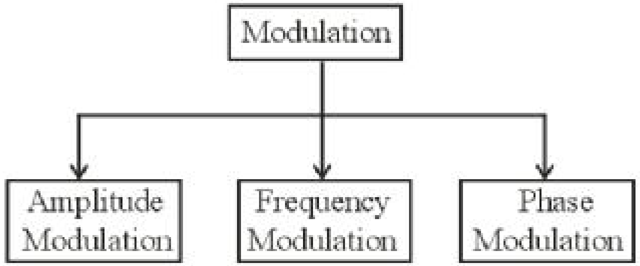
Area $= \pi(d_T)^2$



d_T is also called the radio maximum line-of-sight distance d_m between the two antennas having heights h_T and h_R above the earth is given by: $d_M = \sqrt{2RhT} + \sqrt{2RhR}$ $\sqrt{2Rh_T} + \sqrt{2Rh_R}$
where h_R is the height of receiving antenna.

Modulation

Modulation is a process by which the input signal or modulating the signal, is mounted onto another signal of a high frequency which is known as the carrier signal. The signal which results from this process is known as the modulated signal.



height of antenna $\simeq \frac{\lambda}{4}$ $f \downarrow$ $\lambda \uparrow$

Amplitude Modulation

In amplitude modulation, the amplitude of the carrier is varied in accordance with the information signals.

Let $c(t) = A_C \sin\omega_C t$ represent carrier wave and $m(t) = A_m \sin\omega_m t$ represent the message or the modulating signal where $\omega_m = 2\pi f_m$ is the angular frequency of the message signal.

The modulated signal $c_m(t)$ can be written as

$$c_m(t) = (A_c + A_m \sin\omega_m t)\sin\omega_c t$$

$$c_m(t) = A_c\left(1 + \frac{A_m}{A_c}\sin\omega_m t\right)\sin\omega_c t \qquad \text{........(1)}$$

$$c_m(t) = A_c \sin\omega_c t + \mu A_c \sin\omega_m t \sin\omega_c t \qquad \text{......(2)}$$

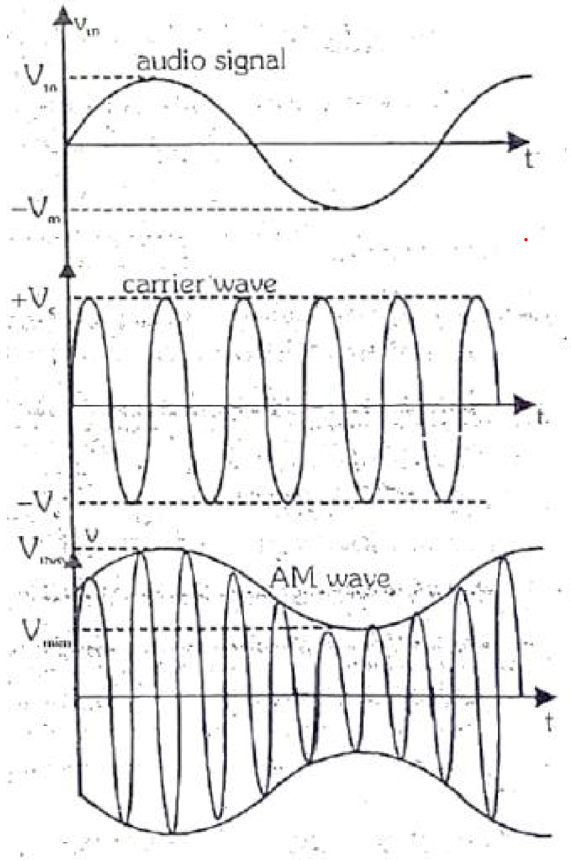
Here, $\mu = A_m/A_c$ is the modulation index.

$\mu < 1$

Maximum amplitude, $V_{max} = V_c + V_m$

Minimum amplitude, $V_{min} = V_c - V_m$

Modulation index, $\mu = \frac{V_{max} - V_{min}}{V_{max} + V_{min}}$



Side Band Frequencies and Band Width in AM Wave

(i) Side band frequencies : The AM wave contains three frequency f_c, $(f_c + f_m)$ and $(f_c - f_m)$, f_c is called carrier frequency,

$(f_c + f_m)$: Upper side band (USB) frequency

$(f_c - f_m)$: Lower side band (LBS) frequency

Side band frequency are generally close to the carrier frequency.

(ii) Band width : The two side bands lie on either side of the carrier frequency at equal frequency interval f_m.

So, band width = $(f_c + f_m) - (f_c - f_m) = 2f_m$