UNIT I
ELECTRONIC COMPONENTS

Electronic Components

- **Active Components** – **Active components** are devices that can amplify an electric signal and produce power.(It requires external power, Dynamic operation)
  - Ex: Semiconductor devices, Transistors, Tunnel diodes

- **Passive Components -** It doesn’t generates power but instead dissipates, stores, and/or releases it.(Static operation)
  - Ex: Resistors, capacitors, Inductors

ELECTRONIC COMPONENTS CLASSIFICATION

- Electronic components
  - Active components
    - Electronic Tubes
    - Semiconductor devices
  - Passive components
    - Resistors
    - Capacitors
    - Inductors

By G SUDHA KIRAN, ASTPRO, ECE, AITSR

ELECTRONIC COMPONENTS

- **Passive components**
  - Resistors
    - Fixed value resistor
      - Carbon composition resistor
      - Wire wound resistor
      - Carbon film resistor
      - Metal film resistor
    - Variable value resistor
      - Carbon composition type
      - Wire wound rotary
      - Wire wound solenoid
      - Helical wound
  - Capacitors
    - Fixed Paper capacitor
      - Mica capacitor
      - Ceramic capacitor
      - Polystyrene capacitor
      - Electrolyte capacitor
    - Variable General purpose
      - Precision
      - Trimmer
  - Inductors
    - Filter choke
    - Audio frequency choke
    - Radio frequency choke
- **Active components**
  - Tube devices
    - Diode
    - Triode
    - Tetrode
    - Pentode
    - Thyratron
  - Semiconductor devices
    - Diode
    - BJT
    - UJT
    - FET
    - Zener diode
    - SLR

Resistors:

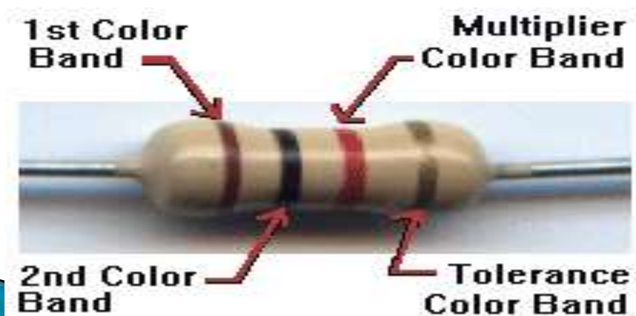
- Resistors are passive elements that **oppose/restrict the flow of current.**

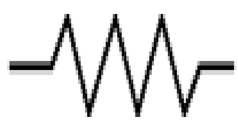
—Each material has got some resistance.It depends upon its shape, size and temperature

Unit of Resistance: Measured in ohms.

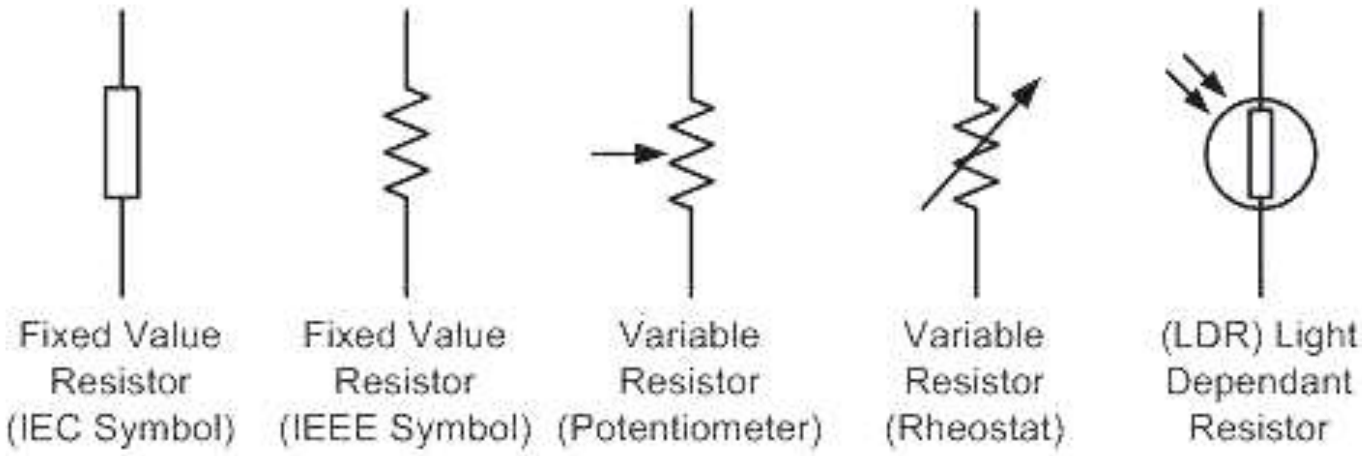
It is denoted by Greek word Ω (omega)

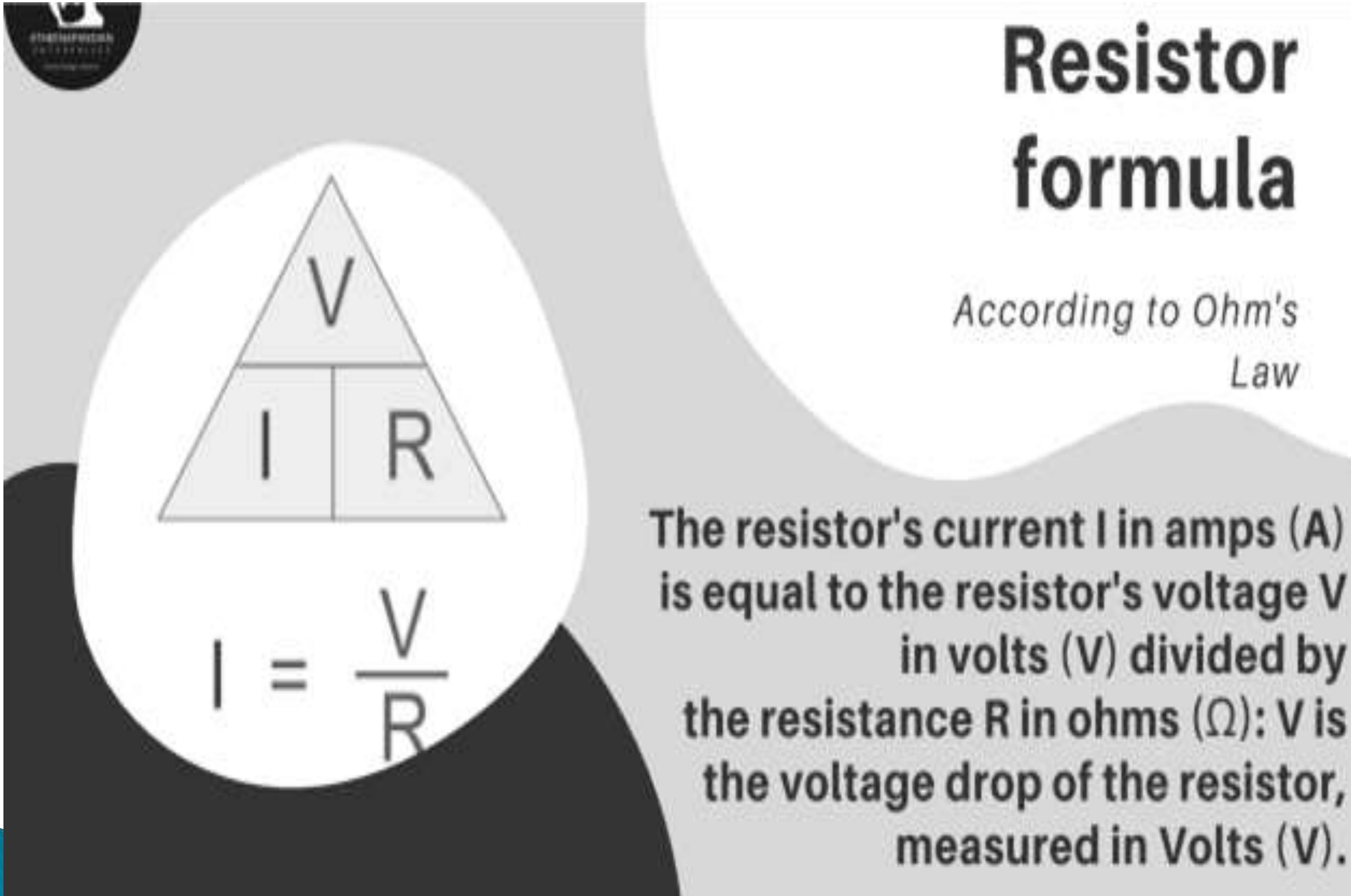
Units: Ohms (Ω)





Symbols of Resistor:




Resistor formula
V
I R
I = V/R
According to Ohm's Law
The resistor's current I in amps (A) is equal to the resistor's voltage V in volts (V) divided by the resistance R in ohms (Ω): V is the voltage drop of the resistor, measured in Volts (V).

<u>Ohms Law:</u> At constant temperature, the current flowing through a conductor is directly proportional to voltage across the conductor.

$$V \alpha\ I$$

$$V = IR$$

$$R = V/I$$

$$P = VI = IR \times I = I2R$$

$$P = VI = V \times V/R = V2/R$$

Resistance

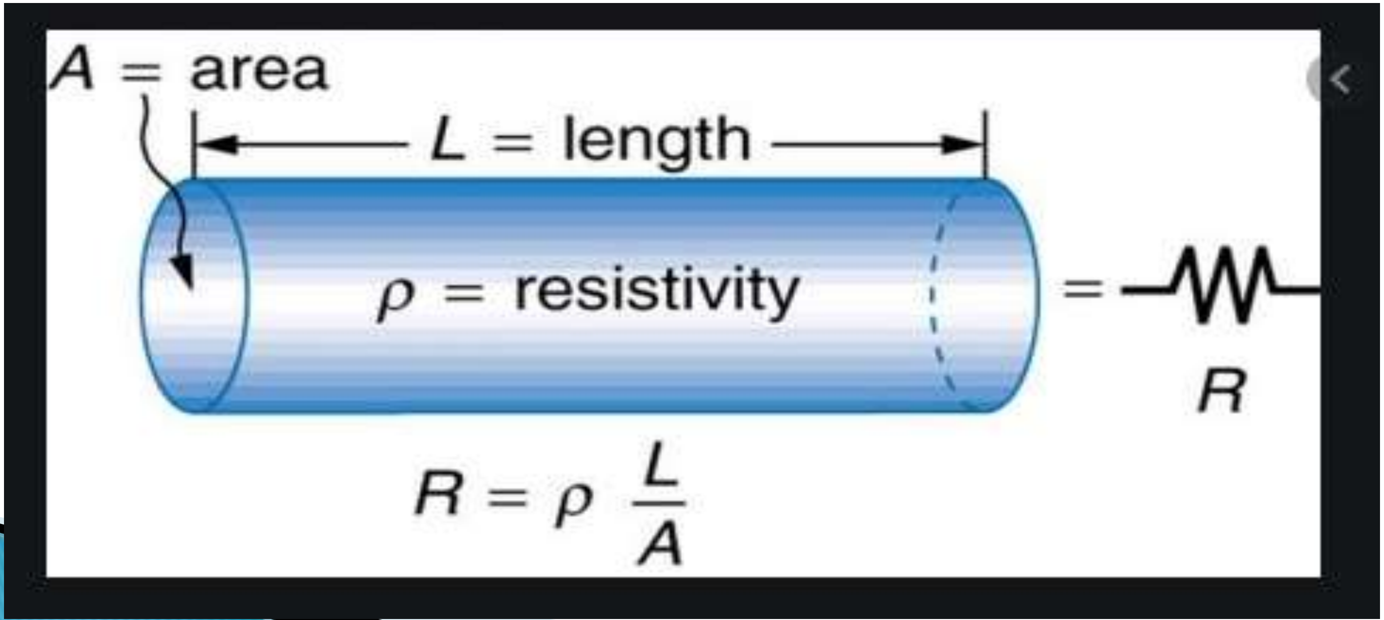
The resistance of a conductor depends on the following factors:

- It varies directly with the length of the conductor
- It is inversely proportional to the cross section
- It also depends on the material
- It is affected by temperature

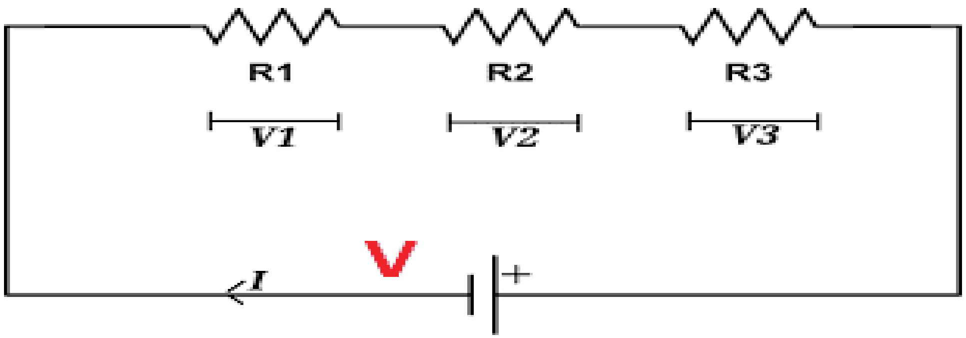
$$R \alpha L$$

$$R \alpha L/A$$

$$R = \rho L/A \text{ ohm/meter}$$



Resistors connected in Series:



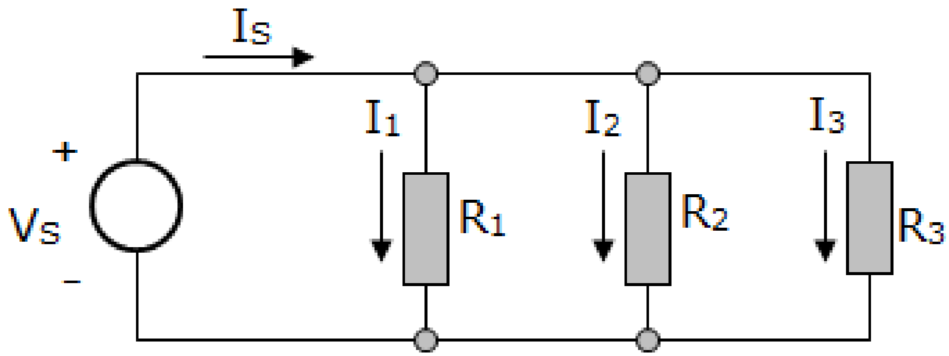
$$V = V1 + V2 + V3$$

$$I * Requ = IR1 + IR2 + IR3$$

$$\boxed{Requ = R1 + R2 + R3}$$

I = V/R

<u>Resistors in Parallel:</u> Resistors are said to be connected together in parallel when both of their terminals are respectively connected to each terminal of the other resistor



$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$$

$$I_T = I_1 + I_2 + \cdots$$

$$V_S = I_1 R_1 = I_2 R_2 = \cdots .$$

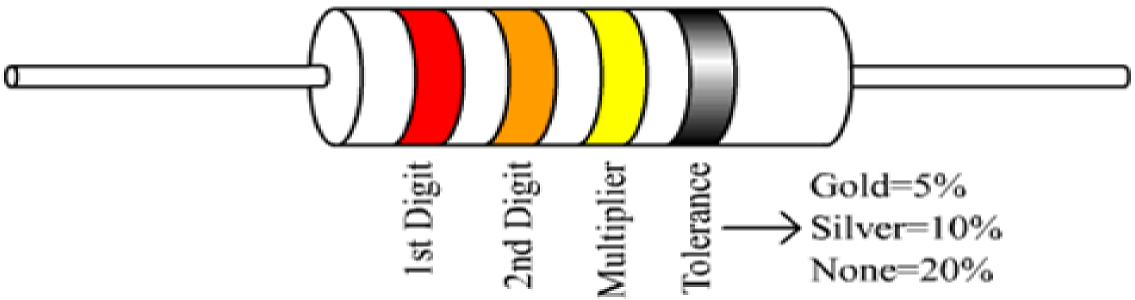
Resistor Colour Code

RED

GREEN

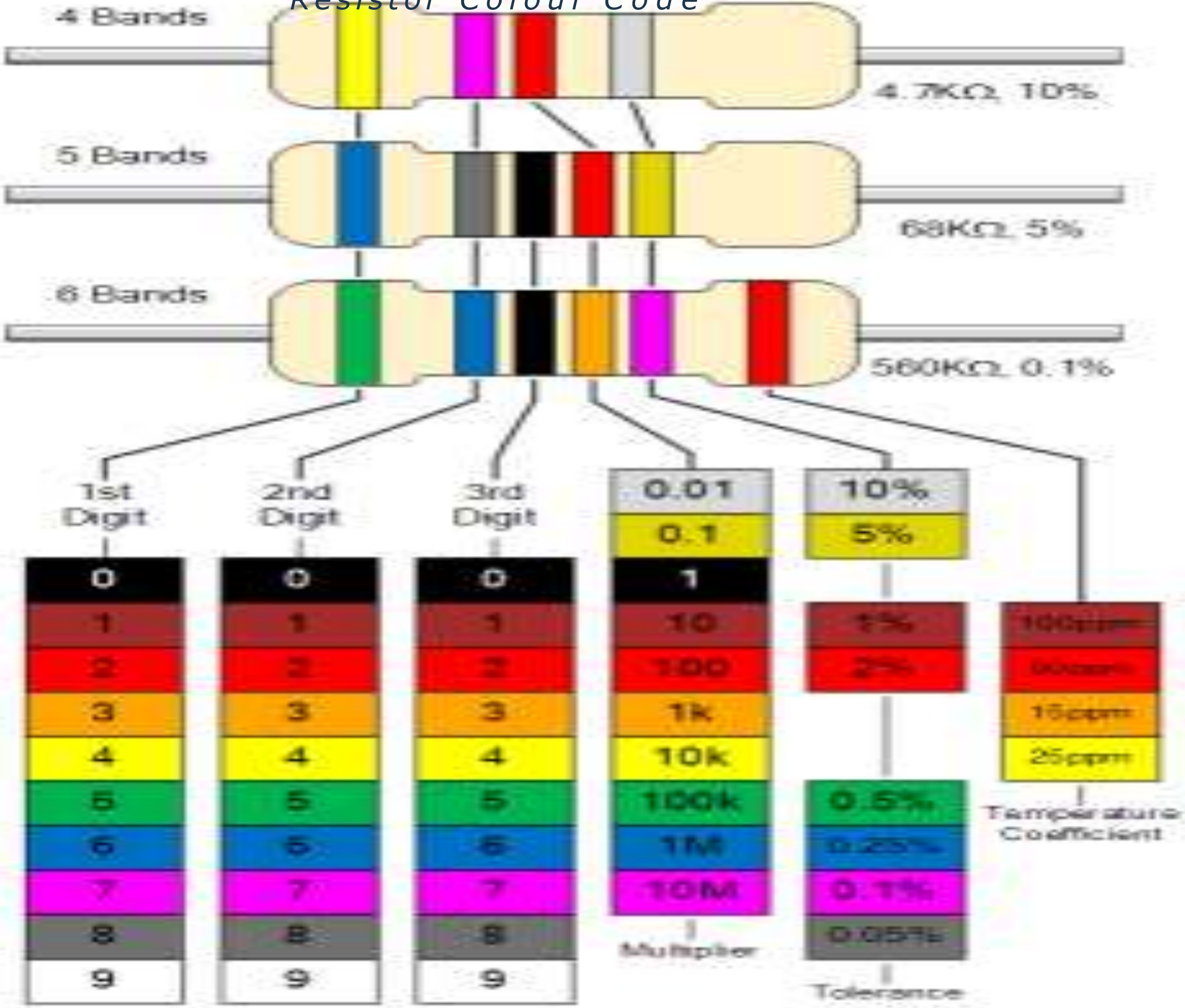
BLUE

VIOLET



Color	Digit	Multiplier	Tolerance (%)
Black	0	10^0 (1)	
Brown	1	10^1	1
Red	2	10^2	2
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	0.5
Blue	6	10^6	0.25
Violet	7	10^7	0.1
Grey	8	10^8	
White	9	10^9	
Gold		10^{-1}	5
Silver		10^{-2}	10
(none)			20

Resistor Colour Code



Fixed Resistors Types

1. Carbon composition Resistor
2. Wire wound Resistor
3. Carbon film Resistors
4. Metal film Resistors
5. Metal oxide film Resistor
6. Foil Resistor

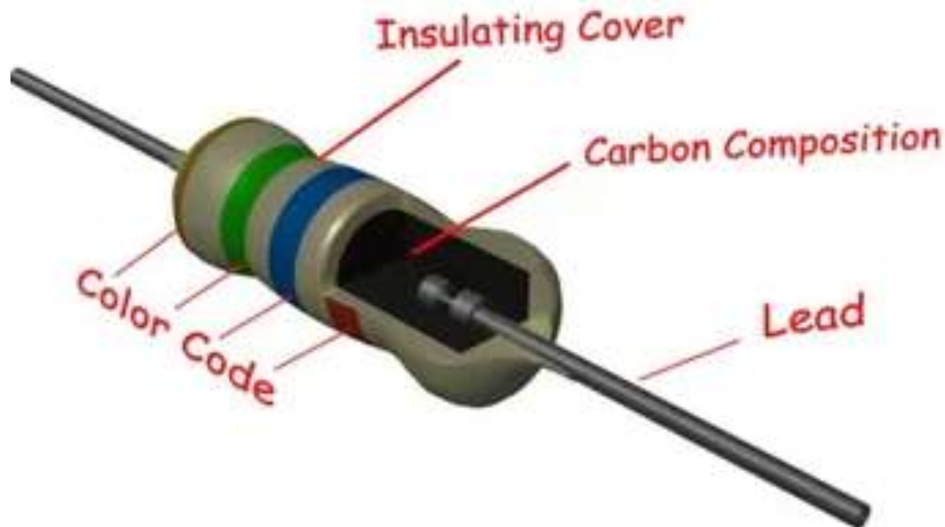
Resistor Manufacturing process steps

1. Substrate preparation
2. Preparation of resistive elements
3. Cap and terminal fitting
4. Protective coating
5. Color coding

Selection of resistors is made based on the following factors

- Ohmic values
- Size, Shape, Leads
- Power rating, Tolerance,
- Maximum operating voltage

1. <u>Carbon Composition resistors</u>: These are used in general purpose electronic equipment

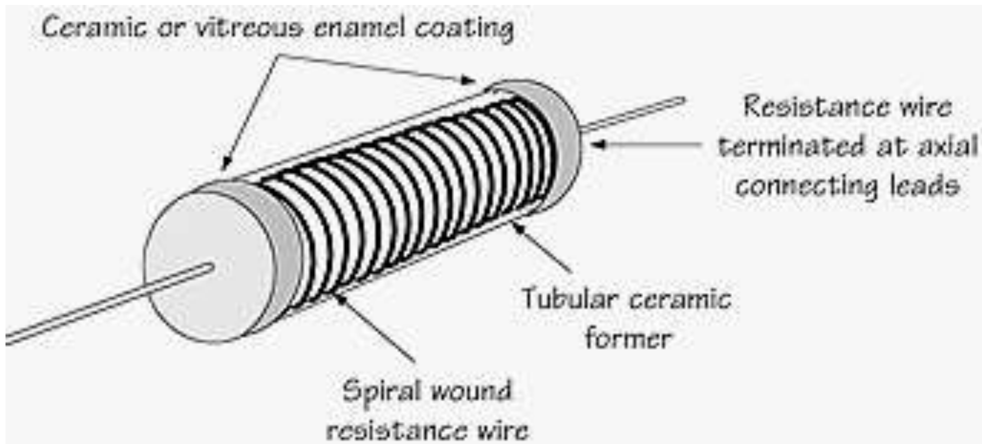


Specifications:

Resistance range : 2 Ω to 2M Ω
Tolerance : $\pm 5\%\ to\ \pm 10\%$
Power rating :1/8 to 2W
working voltage :125V to 800V
operating Temperature: $-55°C\ to\ 150°C$

2. <u>Wire Wound Resistors:</u> These are constructed by winding a length of wire made from special alloys on an insulating cylindrical ceramic core.

This resistors are suitable for low resistance and low noise applications



Specifications:

Resistance range : 0.1 Ω to 1M Ω

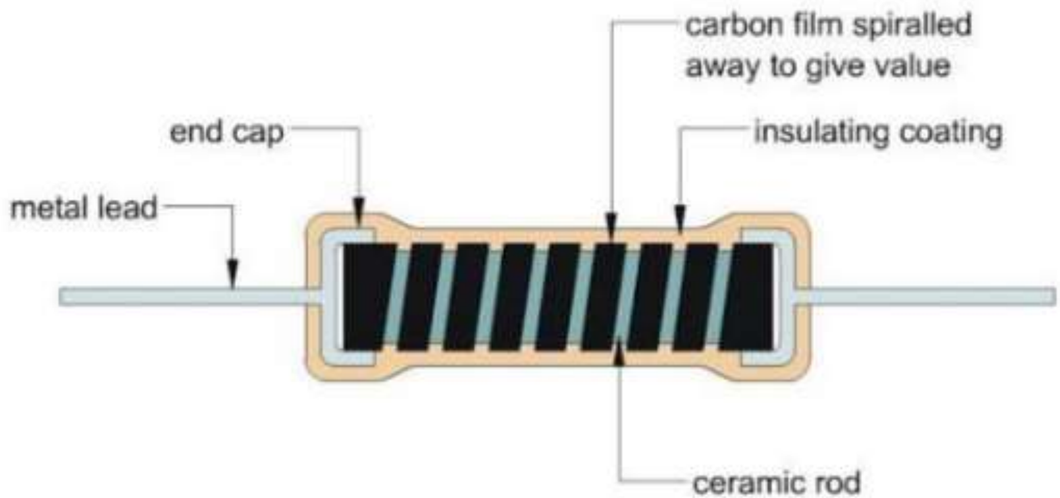
Tolerance : $\pm 0.1\%\ to\ \pm 5\%$

Power rating :10 to 75W

working voltage :<150V

operating Temperature: $55°C\ to\ 375°C$

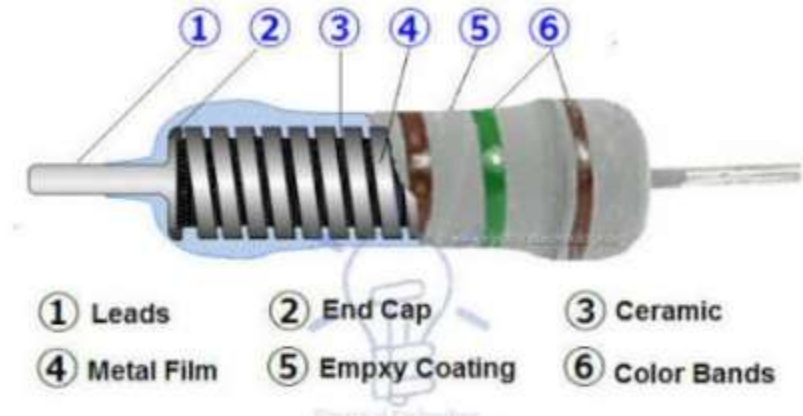
3. <u>Carbon Film Resistors:</u> Pure carbon is deposited on ceramic substrate by thermal decomposition of hydrocarbons at $1000°C$
They are used in measuring instruments where close tolerances are required



Specifications:

Resistance range : 1 Ω to 10M Ω
Tolerance : $\pm 1\% \ to \ \pm 5\%$
Power rating :5W
working voltage : 500V

4. Metal Film Resistors: Nickel film is deposited on ceramic substrate by electrolytic decomposition of nickel in a chemical bath containing Hypophosphate



Specifications:

Resistance range : 0.5 Ω to 10K Ω
Tolerance : $\pm 2\%$ to $\pm 3\%$
Power rating : 5W
working voltage : 300V
operating Temperature: -$40°C$ to $150°C$

Metal oxide film resistor

- It is a type of passive component in which metal oxide film is used as the resistive element to restrict the flow of electric current to certain level.

- In metal oxide film resistors, the film is constructed by using the metal oxide such as tin oxide.

- The cost of metal oxide film resistor is low compared to the carbon composition resistor. These resistors operate at high temperatures.

Foil resistor

•These are the most accurate and stable components used to restrict the flow of electric current to certain level.

•Foil resistors produce low noise compared to the other types of resistors. These resistors are also called high precision resistors.

•Foil resistors have low TCR (Temperature Co-efficient of Resistance.

Variable Type Resistors

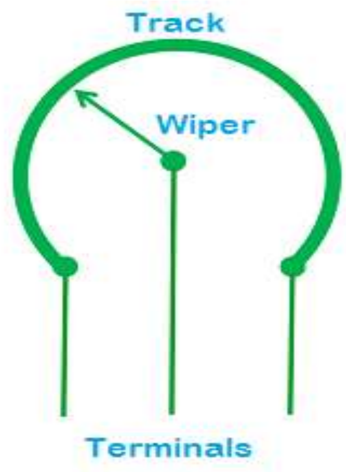
1. Carbon Composition Potentiometer
2. Wire Wound Variable Resistor
3. Wire Wound solenoid
4. Helical Wound Variable Resistor

The characteristics of variable resistors include

- Resistance law (Relation between change in resistance and movement of wiper)
- Tolerance
- Insulation resistance must be high
- Minimum effective resistance
- Effective angle of rotation
- Operating torque
- Speed of operation
- Life and performance under given conditions

Variable Resistors

Potentiometers



- When we increase the resistance of the potentiometer, the electric current flowing through the potentiometer will decrease.

- In the similar way, when we decrease the resistance of the potentiometer, the electric current flowing through the potentiometer will increase.

1.Carbon Composition Potentiometer: It can be manufactured in 2 ways

Coated film: A mixture of carbon, filler(silica) and binder is coated on a ring of insulating material

- They are used as preset potentiometers in T.V(brightness and contrast control, radio and in measuring instruments

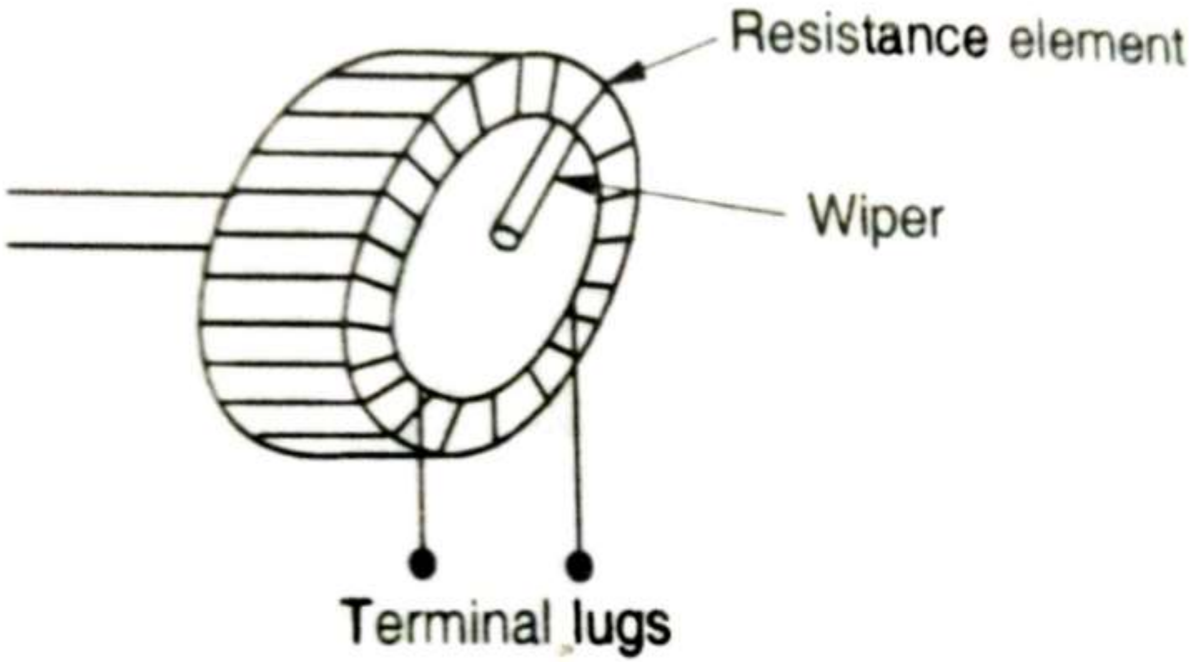
- Resistance range :100 to 107 ohms
- Power : ½ w to 2 1/4 w
- Tolerance : ± 20 percent for 1 to 106 ohm

Moulded Tract: A mixture of carbon is moulded into a cavity in a plastic base. Moving contact is a carbon brush

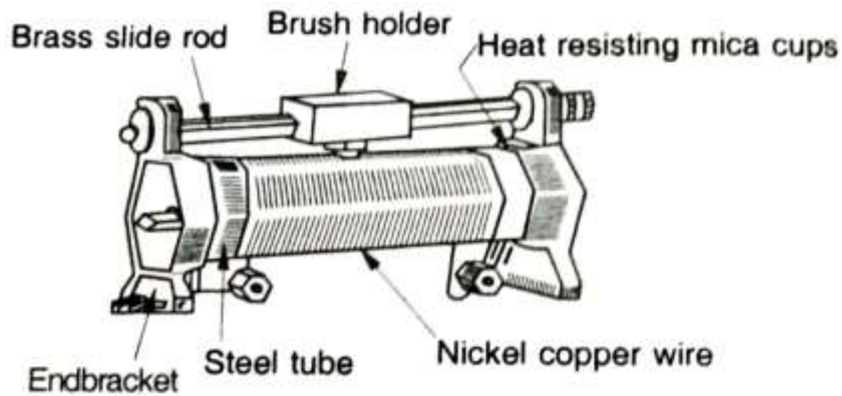
- They are used in servo systems, computers, industrial and defence applications

2. Wire Wound Variable Resistor

A flat strip of bakelite or paper is taken and nichrome wire is wound by maintaining proper gap between the turn.



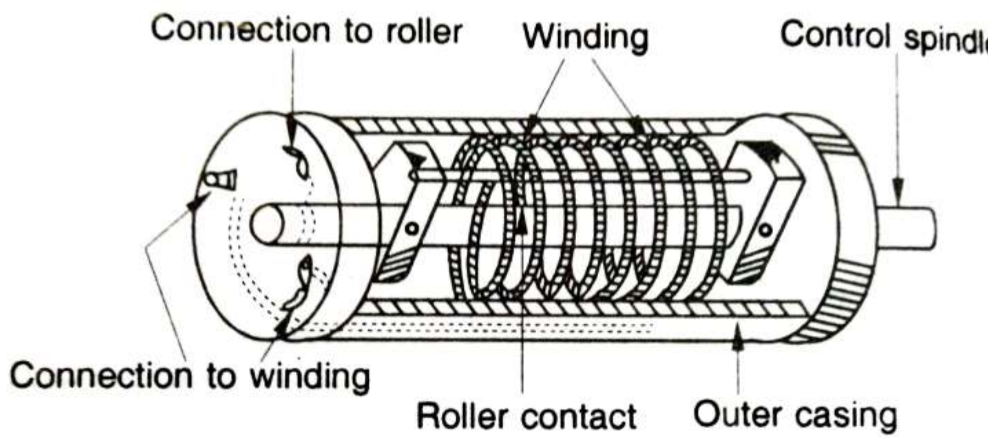
3. <u>Wire Wound solenoid</u>: They are used in laboratories and industries where large power has to be dissipated. Copper or graphite is used as brushes
Resistance: 500 to 1000ohms,
Current: 0.1 to 20 Amperes



4. <u>Helical Wound Variable Resistor</u>: This resistor is wounded on circular or rectangular cross section

Specifications:

Resistance	1 to 125000 ohm
Power rating	100 W to 200 W
Tolerance	± 2%
Linearity	± 0.5% to ± 2%



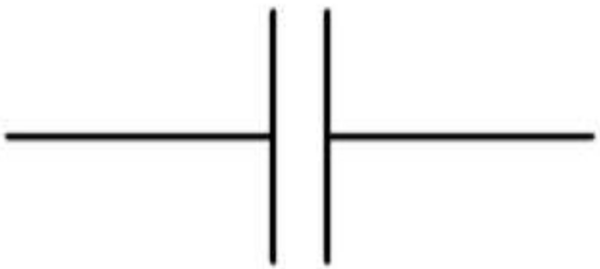
Capacitors

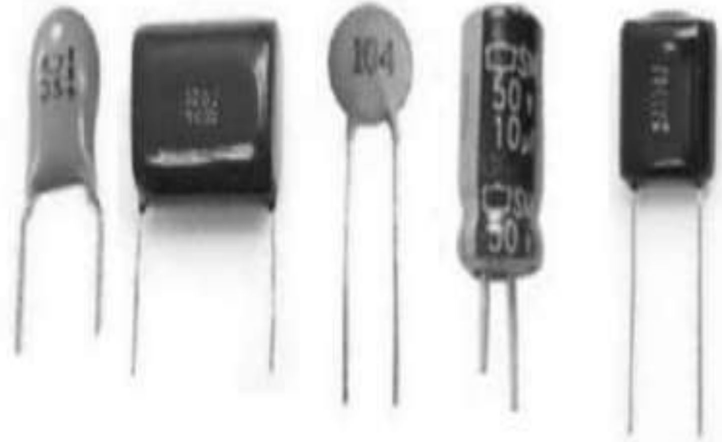
- A **capacitor** is a device that stores electric charge.

- A capacitor consists of two conductors separated by an insulator.

- Capacitors have many applications:
  - Computer RAM memory and keyboards.
  - Electronic flashes for cameras.
  - Electric power surge protectors.
  - Radios and electronic circuits.

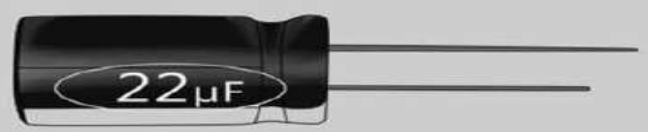
The Symbol of Capacitor





The Unity of Measurement The Capacitor

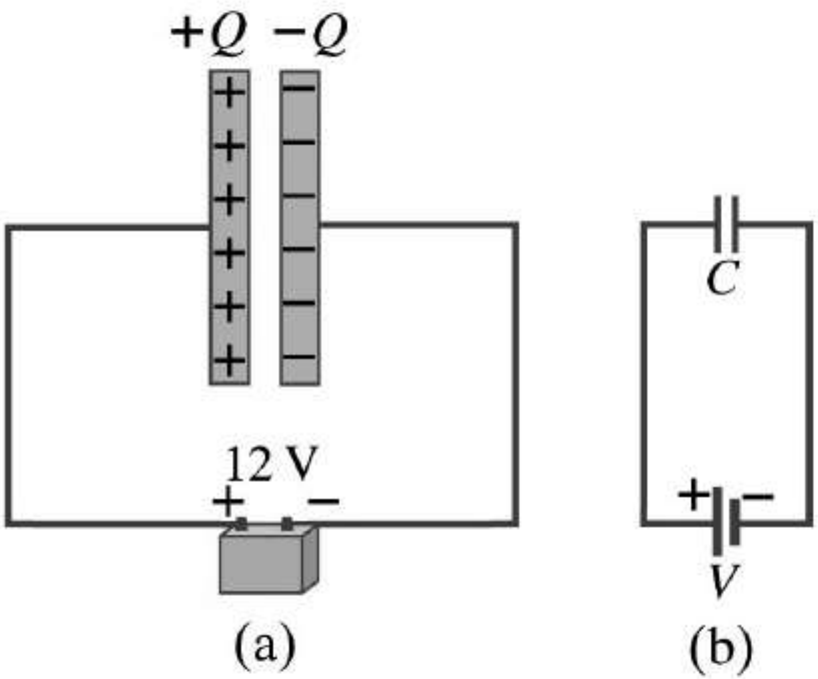
farad (F)



µF uF mF	MICROFARAD	10^{-6}F
nF	NANOFARAD	10^{-9}F
pF mmf uuf	PICOFARAD	10^{-12}F

wiki How to Read a Capacitor

Capacitors and Capacitance



A capacitor in a simple electric circuit.

Charge Q stored:

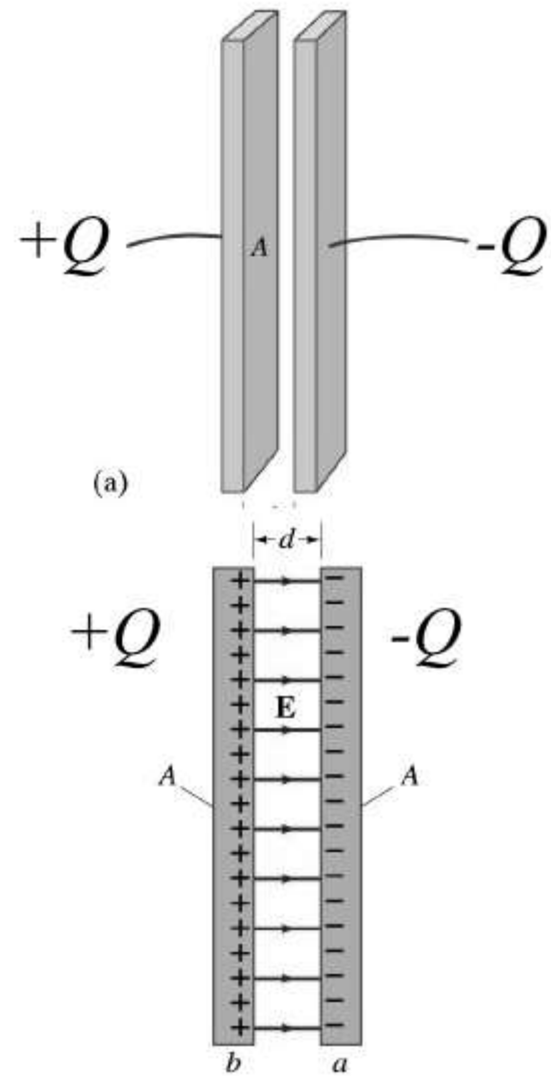
$$Q = CV$$

The stored charge Q is proportional to the potential difference V between the plates. The capacitance C is the constant of proportionality, measured in Farads.

Farad = Coulomb / Volt

Parallel-Plate Capacitor

- A simple parallel-plate capacitor consists of two conducting plates of area A separated by a distance d.
- Charge $+Q$ is placed on one plate and $-Q$ on the other plate.
- An electric field $\boldsymbol{E}$ is created between the plates.



- When a voltage source is connected to a capacitor, current flows until the capacitor is charged.
- Once it is charged the current stops flowing and the capacitor voltage is equal to the source voltage

Factors affecting the capacitor:

1 Area of the plates: larger the area, the more charge can store in the capacitor

2 Distance between the plates: The smaller is this distance, the higher is the ability of the plates to store charge

3 Dielectric material:

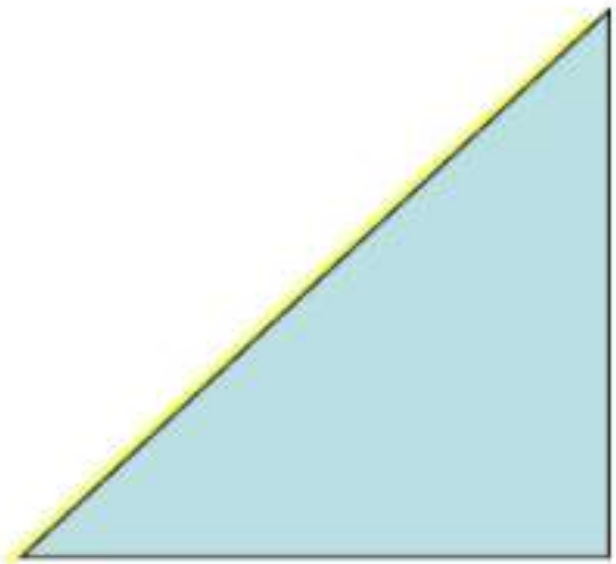
$$C = \varepsilon\, A/d$$

The capacitance 'C' value of a capacitor is the charge that is developed across the capacitor per unit voltage

$$C = \frac{Q}{V}, Q = VC$$

Energy stored by a capacitor

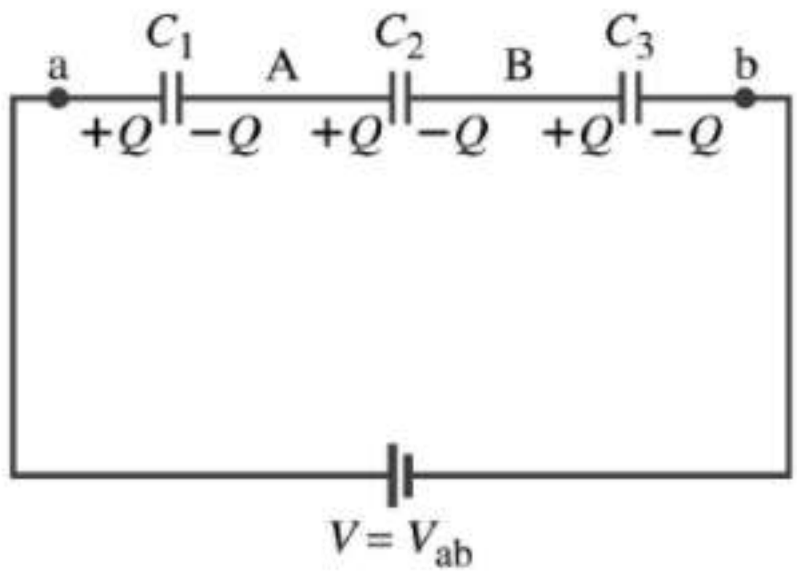
- By general definition E=QV
  - product of charge and voltage
- By graphical consideration...



$$E = \frac{1}{2}QV$$

Capacitors in Series

$$V = V_1 + V_2 + V_3$$
$$= \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$
$$= Q\left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}\right)$$
$$= \frac{Q}{C_{eq}}$$



For n capacitors in series:

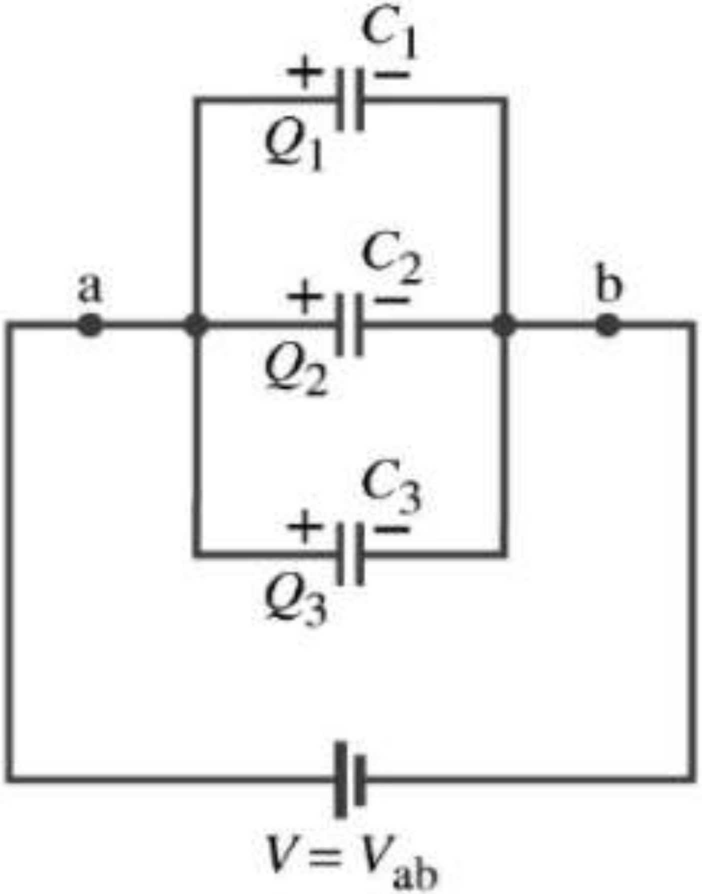
$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots$$

Capacitors in Parallel

$$Q = Q_1 + Q_2 + Q_3$$
$$= C_1V + C_2V + C_3V$$
$$= (C_1 + C_2 + C_3)V$$
$$= C_{eq}V$$

Capacitors in Parallel:

$$C_{eq} = C_1 + C_2 + C_3 + \ldots$$



Important characteristics of capacitor to be considered are

- Capacitance Value
- Working Voltage
- Power Loss
- Power Factor
- Loss Factor
- Dielectric Strength
- Leakage Current
- Permittivity
- The Effect Of Frequency

Types of Capacitors

Fixed capacitor: Whose value remains constant

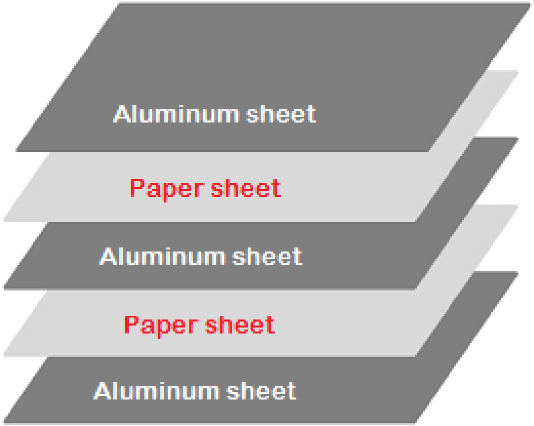
Variable capacitor: Whose values can be varied by the user

Different types of fixed capacitors

- Paper capacitor
- Mica capacitor
- Ceramic capacitor
- Polystyrene capacitor
- Electrolytic capacitor

Paper Capacitor:

These are constructed by rolling paper(7.5 to 20 microns) between metal electrodes (22microns).



Capacitance: 1000pF to 1 micro F

Voltage: 400 to 2000V

Uses are blocking, coupling, filtering,

Timing circuits..

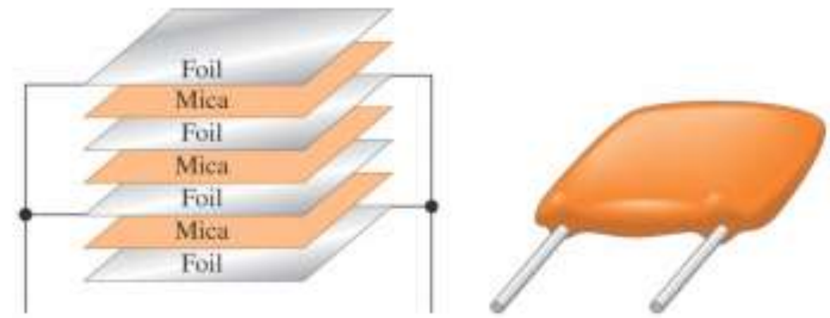
Mica Capacitor: It consists of a stack of thin metal plates alternating with thin layer of mica

Capacitance: 5pF to 1000pF

Voltage: 500V

Uses are coupling, by passing, resor

and measuring circuits



(a) Stacked layer arrangement

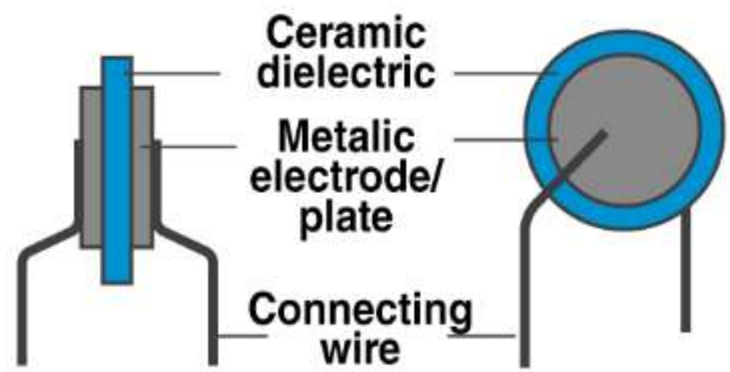
(b) Layers are pressed together and encapsulated.

Ceramic Capacitor: It consists of a ceramic dielectric on which a thin metallic film is fixed at a high temperature

Capacitance: 3pF to 2 micro F

Voltage: 3 to 6000V

Uses are blocking, coupling, filtering, Amplifiers and resonant circuits

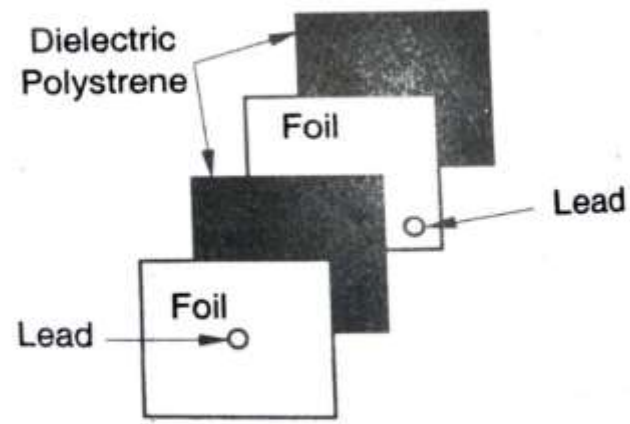


Polystyrene capacitor: These are the plastic dielectric capacitors. Polystyrene film is made from polystyrene granules by heating process

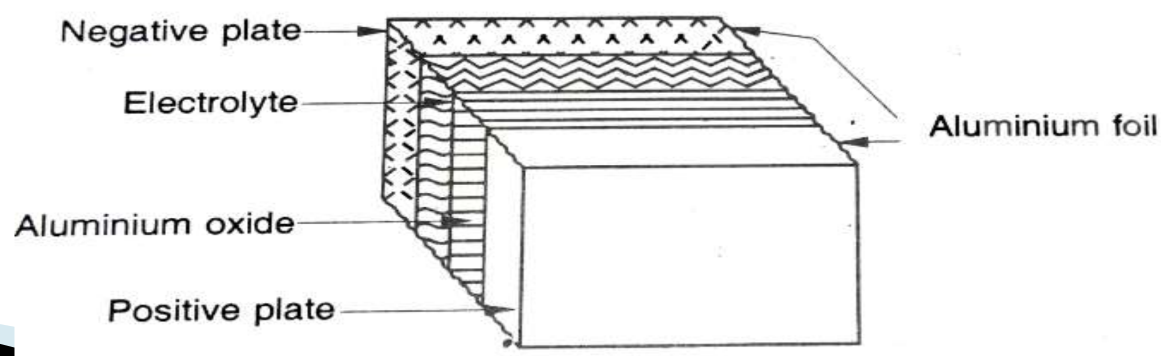
Capacitance: 10 micro F

Voltage: 500V

Uses are radio frequency tuned circuits, digital equipment, X-ray therapy…

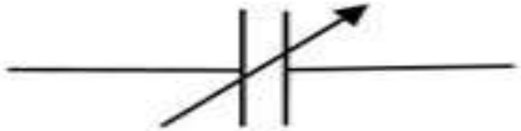


Electrolytic capacitor: Two strips of aluminium foils are separated by two layers of porous papers soaked with electrolyte. Then aluminium oxide is formed on the surface of foil and it becomes dielectric medium



Variable Capacitors

- A Variable Capacitor is one whose capacitance may be intentionally and repeatedly changed mechanically.
- This type of capacitors utilized to set frequency of resonance in LC circuits.
- To adjust the radio for impedance matching in antenna tuner devices.



Symbol of a variable capacitor

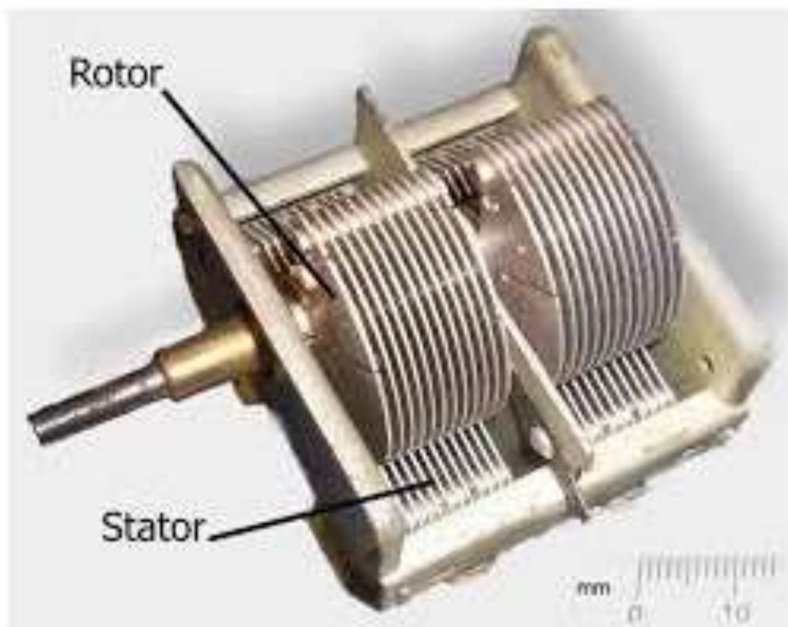
Variable capacitor types

1. General purpose variable capacitors
2. Precision variable capacitors
3. Trimmer capacitors

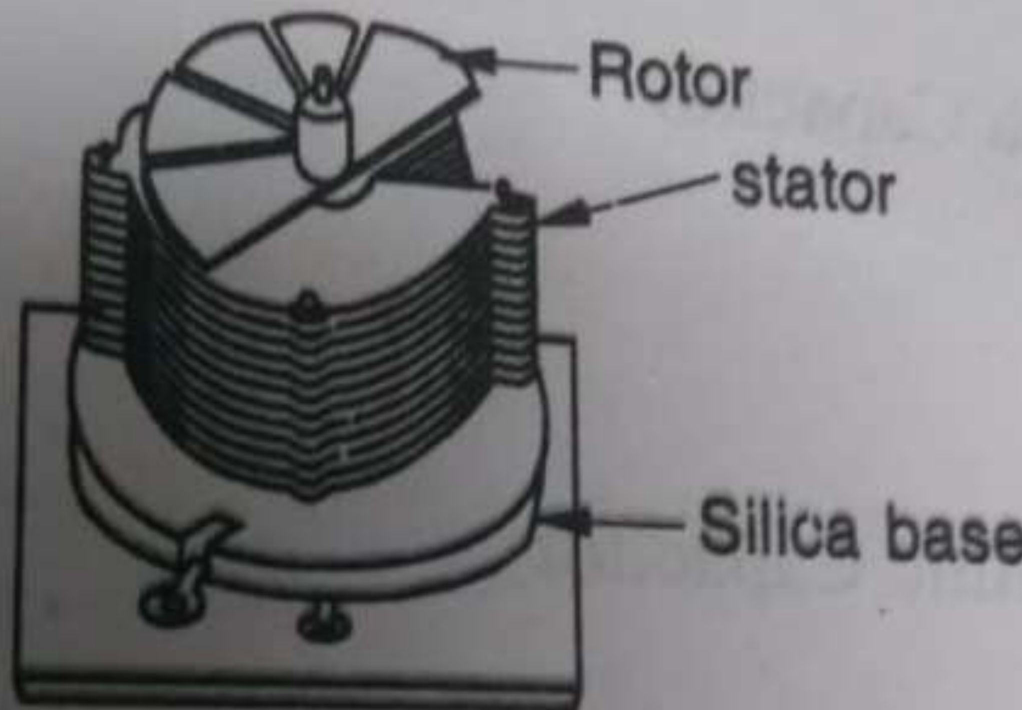
1. General purpose variable capacitors

Different parts

- Frame : Built up type or bent or Die cast type
- Rotor, Stator
- Spindle and Bearing



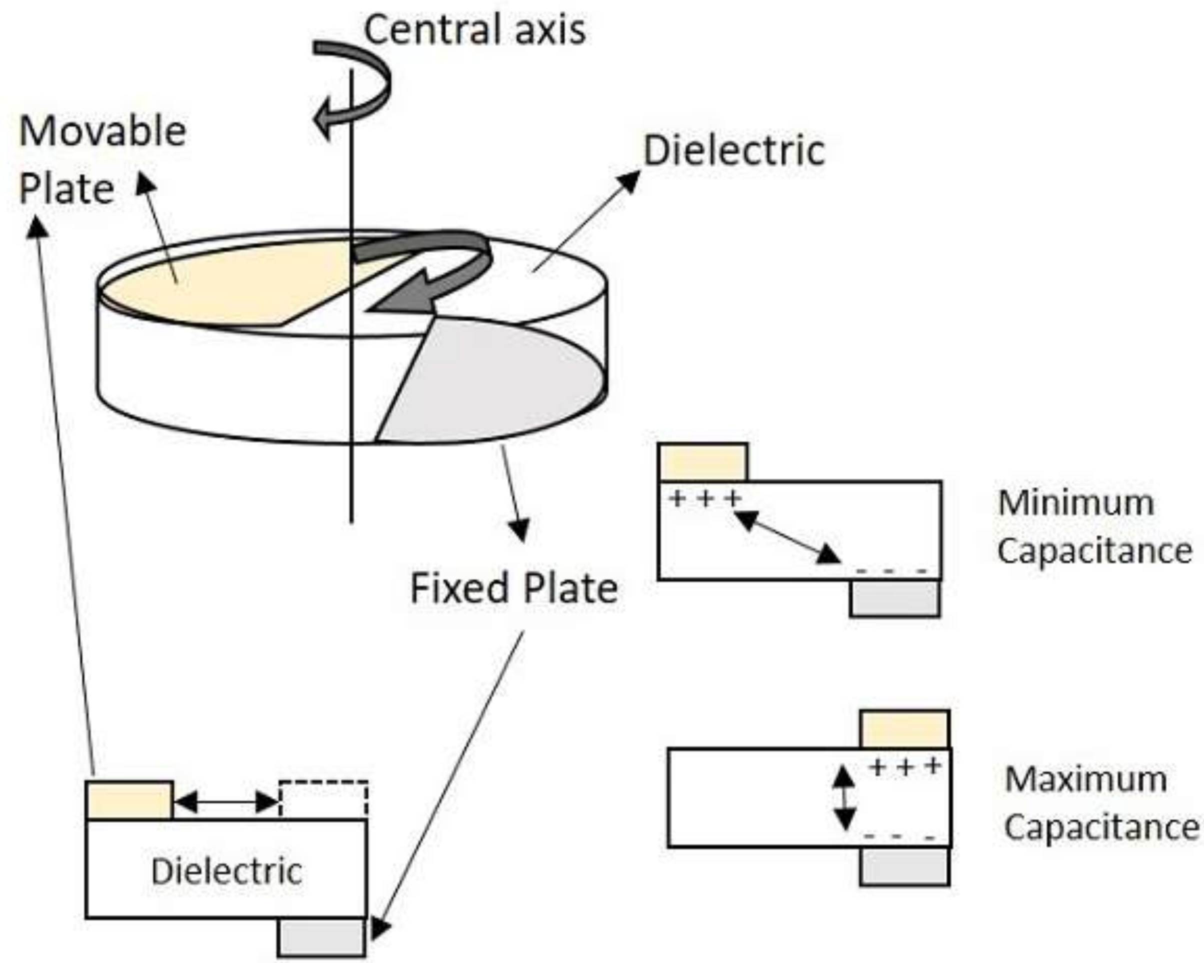
2. Precision variable capacitor



Precision Variable Capacitor

3. Trimmer capacitors

Image of a Trimmer Capacitor



Dissipation factor

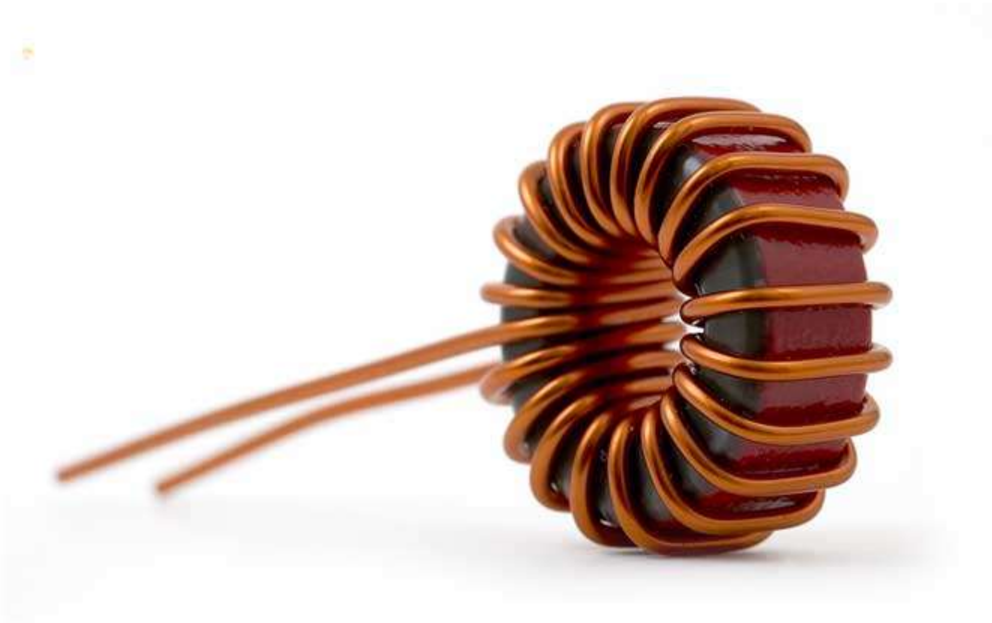
- D F = Power wasted per cycle/power stored per cycle

Uses of capacitors

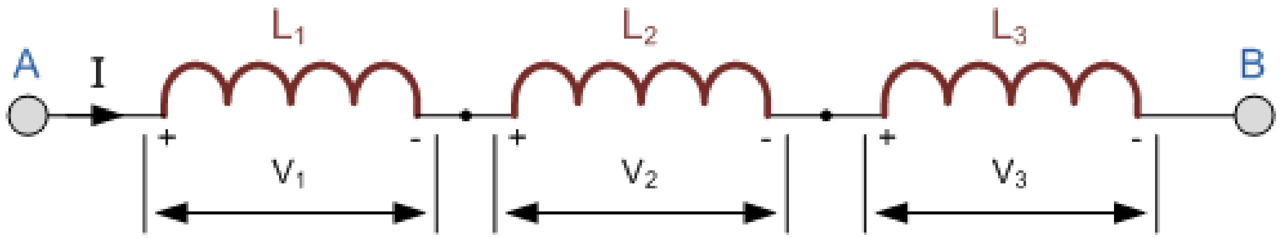
- **Paper**: Blocking, Coupling, By passing, Filtering,Timing circuits, Motor starting
- **Mica**: Filtering AF TX circuits, High voltage circuits, Resonant and measuring circuits
- **Ceramic**: Temperature compensation, amplifiers
- **Polystyrene**: RF tuned circuits
- **Electrolytic** : Radio circuits, decoupling
- **General purpose variable capacitor** : Tuning capacitors in broadcast receivers, test equipment
- **Precision**: Laboratory **Trimmer** : TV tuners

Inductors

An inductor is a coil of wire which opposes the flow of current through itself In the form of magnetic field.



Inductors in series

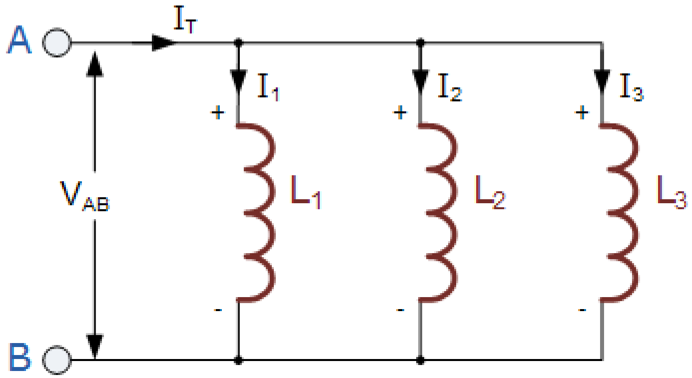


$I_{L1} = I_{L2} = I_{L3} = I_{AB}$ ...etc.

$L_{total} = L_1 + L_2 + L_3 + \ldots.. + L_n$ etc.

$V_S = V_{L1} + V_{L2} + V_{L3}$

Inductors in parallel



$$V_{L1} = V_{L2} = V_{L3} = V_{AB} \text{ ...etc}$$

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} \text{ ......} + \frac{1}{L_N}$$

$$I_T = I_{L1} + I_{L2} + I_{L3}$$

Types of Inductors

1. Filter chokes
2. Audio Frequency chokes
3. Radio Frequency chokes

Semiconductors

- *Semiconductors are materials whose electronic properties are intermediate between those of Metals and Insulators.*
- *They have conductivities in the range of 10^{-4} to 10^{+4} S/m.*
- *The interesting feature about semiconductors is that they are bipolar and current is transported by two charge carriers of opposite sign.*

Classification of Materials:

- Conductors: valence electrons<4
- Insulators: valence electrons>4
- Semiconductors: valence electrons=4

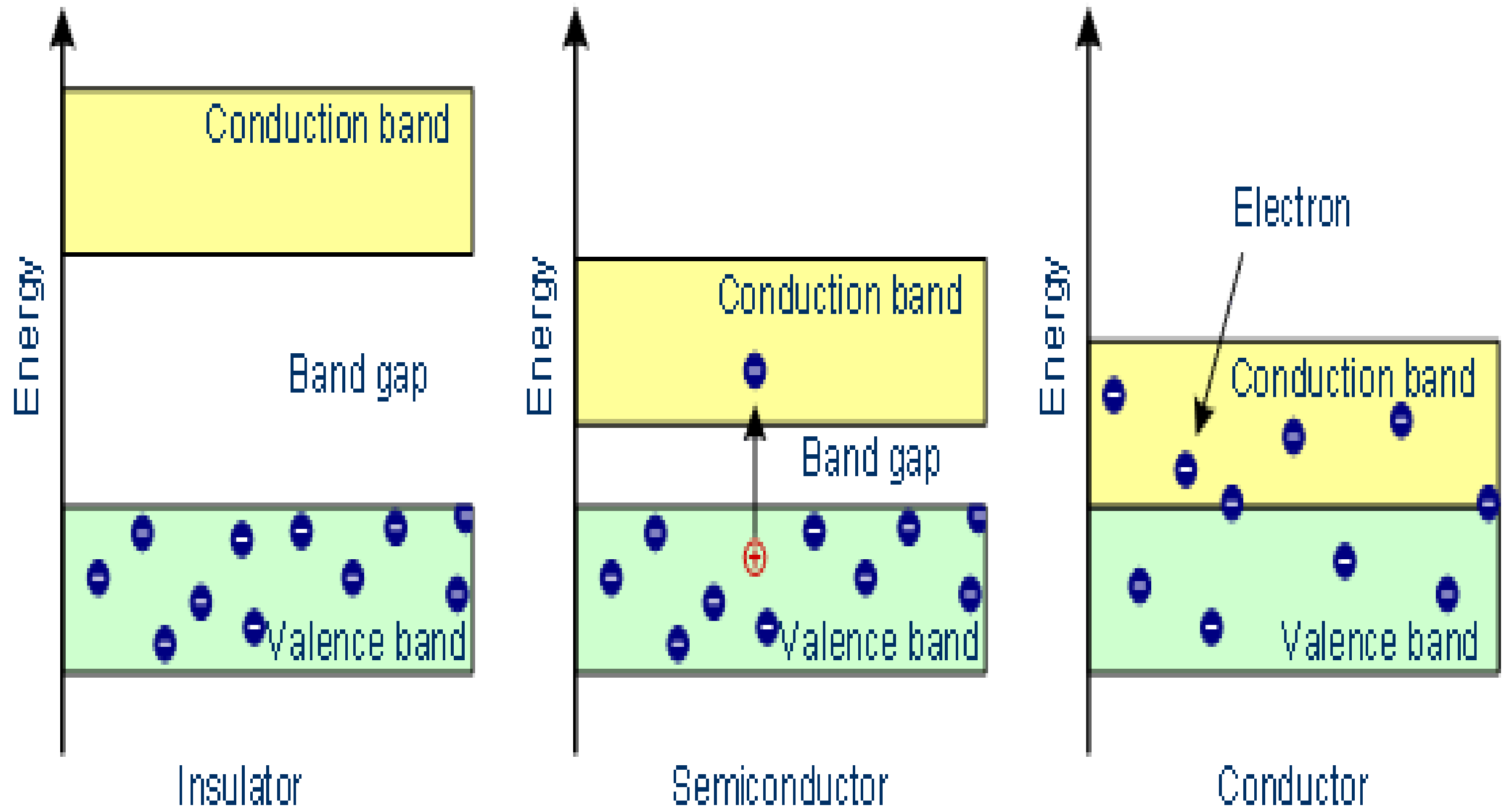


Fig: Energy band diagrams of insulator, semiconductor, conductor

Classification of Semiconductors:

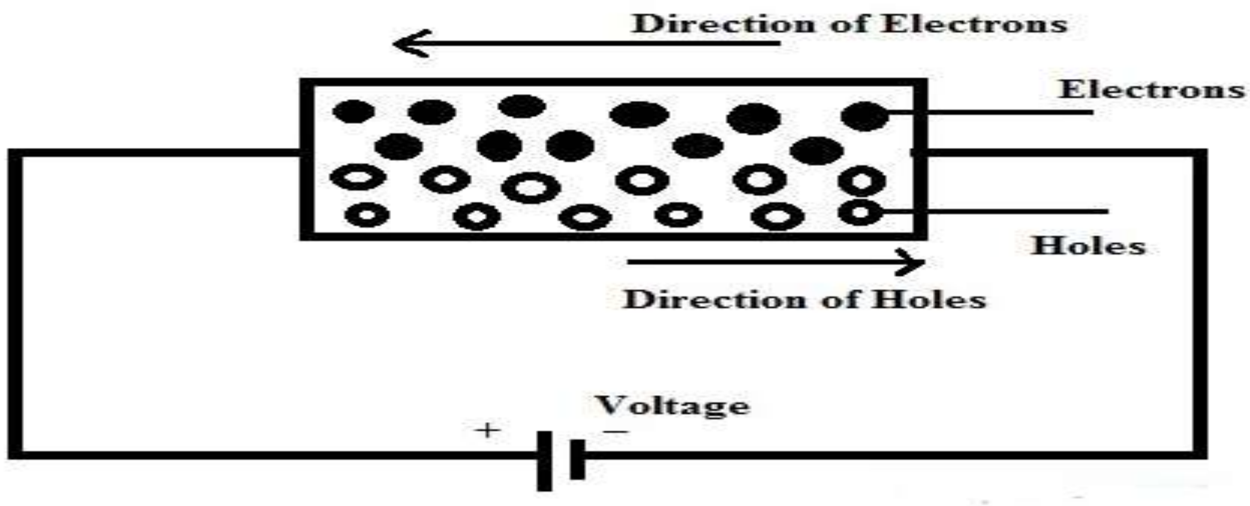
1. Intrinsic Semiconductors (Pure)
2. Extrinsic Semiconductors (Impure)

Properties of Intrinsic Semiconductor:

1. They have four Valence Electrons
2. Properties lies between conductor and insulator
3. Conduction property can be varied by varying the temperature
4. They have negative temperature coefficient of resistance
5. Properties can be varied by adding impurities to semiconductor
6. Resistivity is greater than conductor and less than an insulator
7. Current in a semiconductor consists of movement of electrons and holes

Hole formation in Intrinsic Semiconductor:

- At room temperature some electrons move from valence band to conduction band
- As the electron leaves in the valence band it creates a vacant space known as hole
- When electric field is applied both electrons and holes constitute current
- Total current is sum of electron and hole current



Extrinsic Semiconductor: Conduction in semiconductors can improved by adding impurities to it.

Doping: Process of adding impurities to a semiconductor is called doping.

Doping Agent or Dopant: Impurity added is called dopant or doping agent.

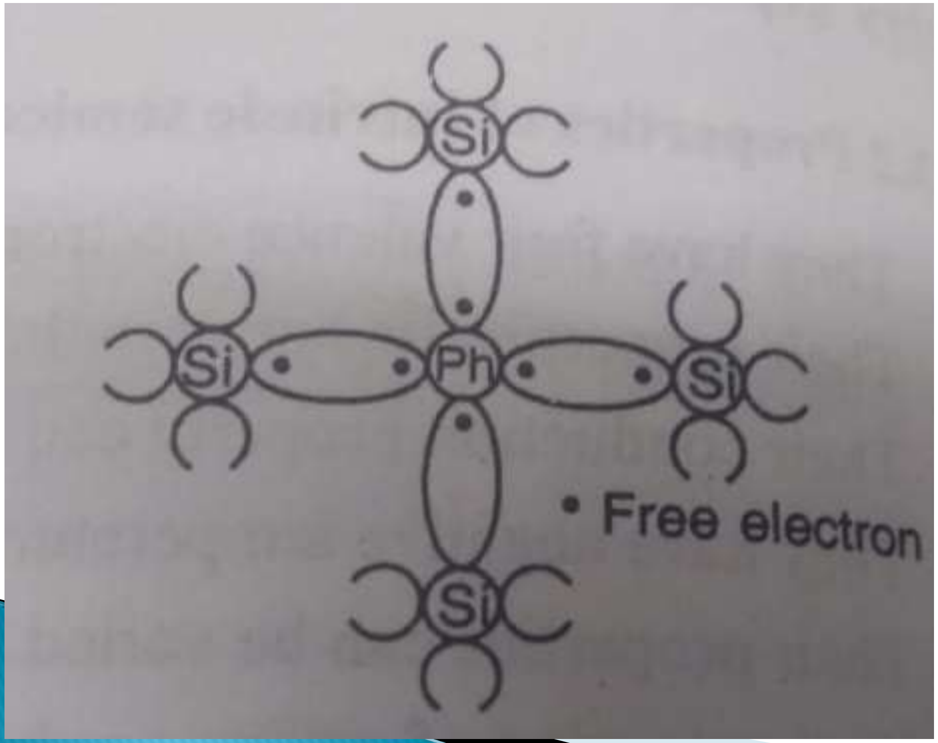
Based on the impurities present in the Extrinsic Semiconductors, they are classified into two categories.

1. N - type Semiconductors
2. P - type Semiconductors

N-type semiconductor: It is obtained by adding a pentavalent impurity to a semiconductor

Elements are such as arsenic, bismuth, phosphorous and antimony

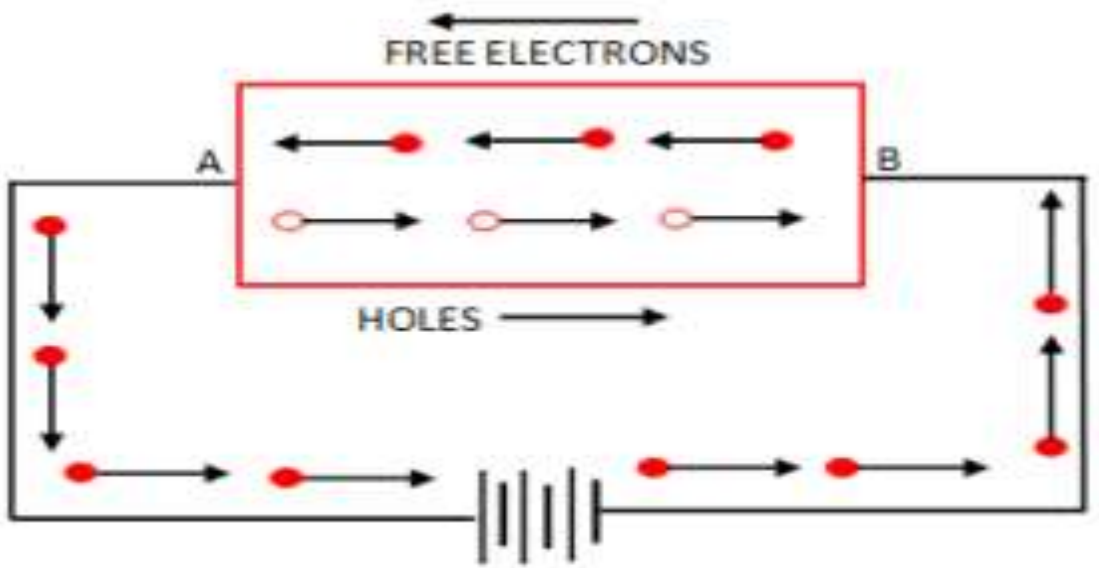
Donor: A pentavalent impurity when doped with a semiconductor donates one electron to the conduction band. Such doping agent is called donor



Si = 4 valence electrons
Ph = 5 valence electrons

Conduction in N-type semiconductor

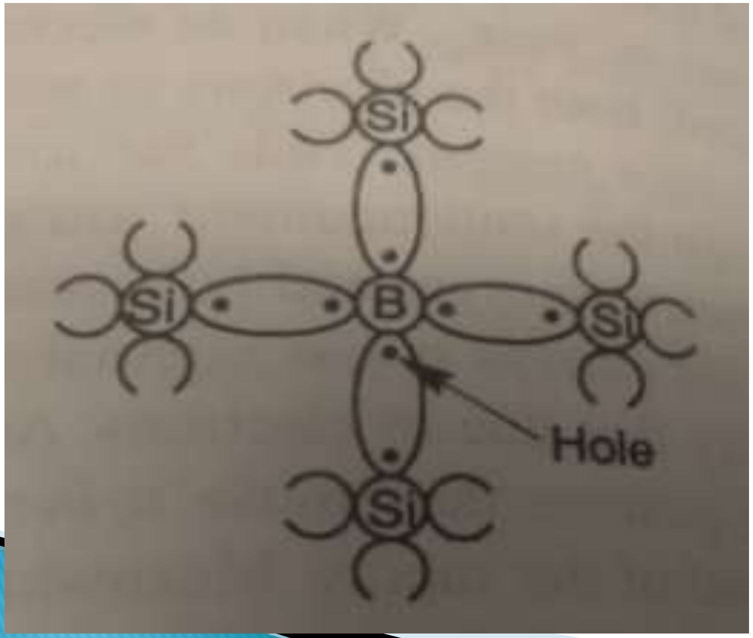
- Due to more free electrons electron current is dominant over the hole current.
- Majority carriers are electrons and minority carriers are holes



P-type semiconductor: It is obtained by adding a trivalent impurity to a semiconductor

Elements are such as Gallium, boron and Indium

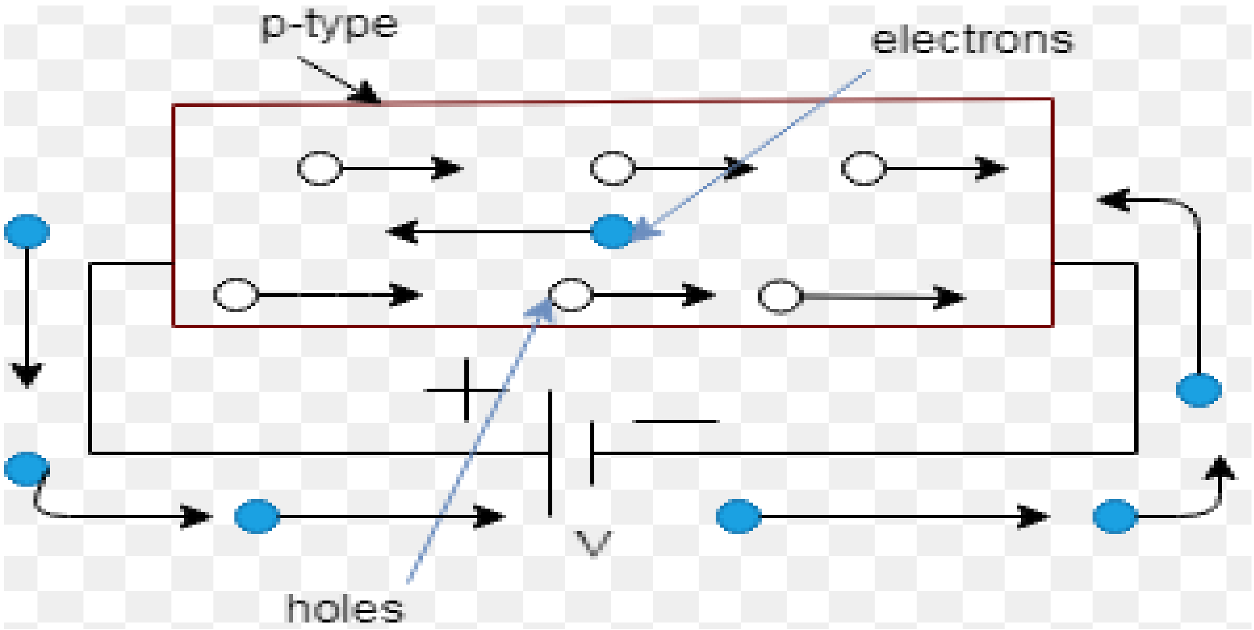
Acceptor: A trivalent impurity when doped with a semiconductor accepts one electron to achieve stable state. Such doping agent is called acceptor



Si = 4 valence electrons
B = 3 valence electrons

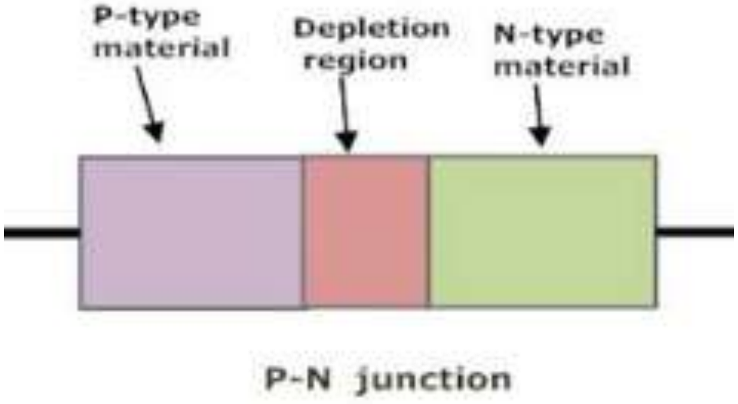
Conduction in P-type semiconductor

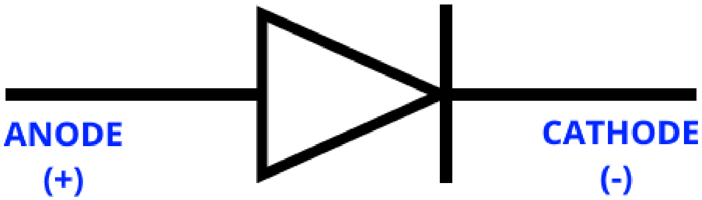
- Due to more holes, hole current is dominant over the electron current.
- Majority carriers are holes and minority carriers are electrons



P-N Diode

The materials p-type and n-type are chemically combined with a fabrication technique to form a p-n junction. The p-n junction forms a popular semiconductor device called diode.





Symbol of PN junction diode

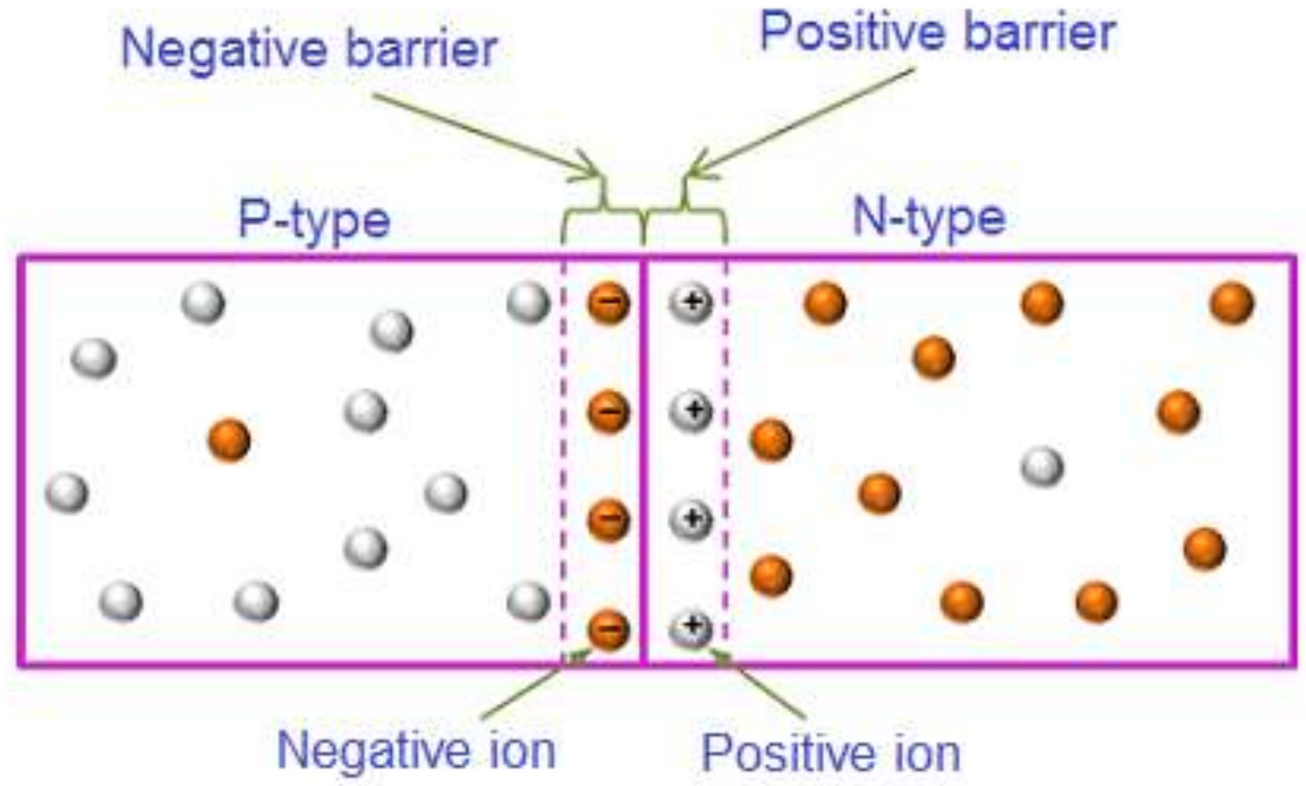
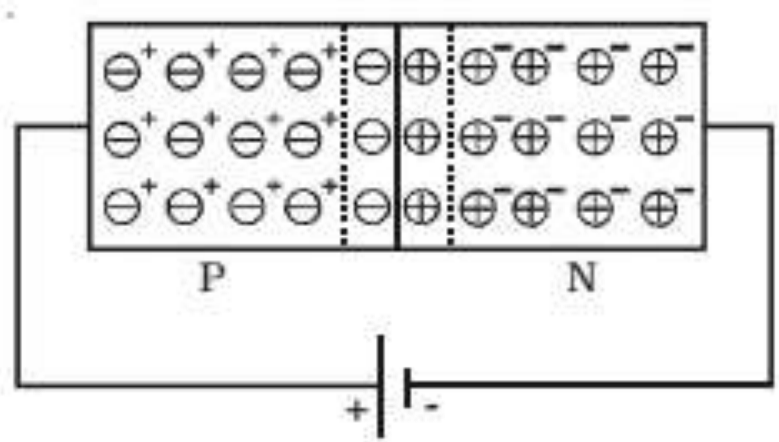
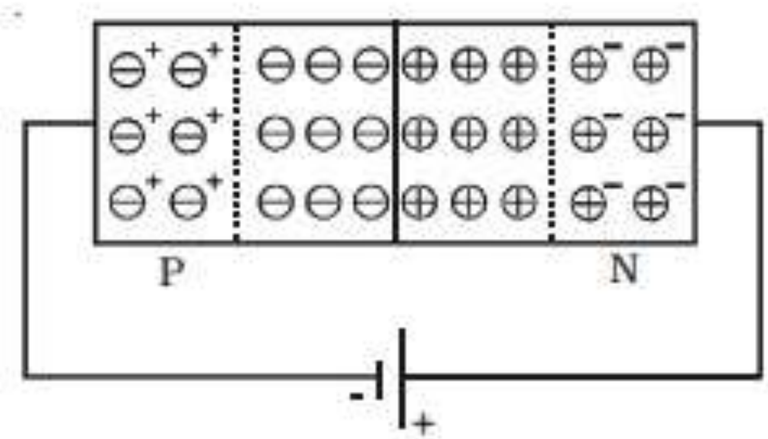


Fig : P N Junction diode

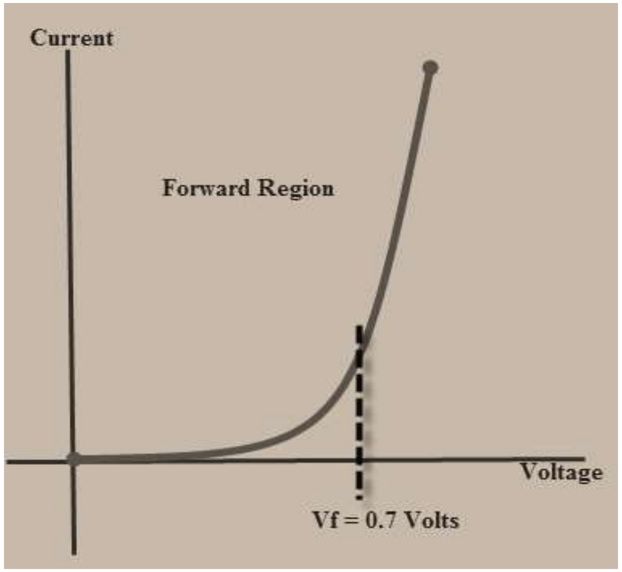
Forward bias



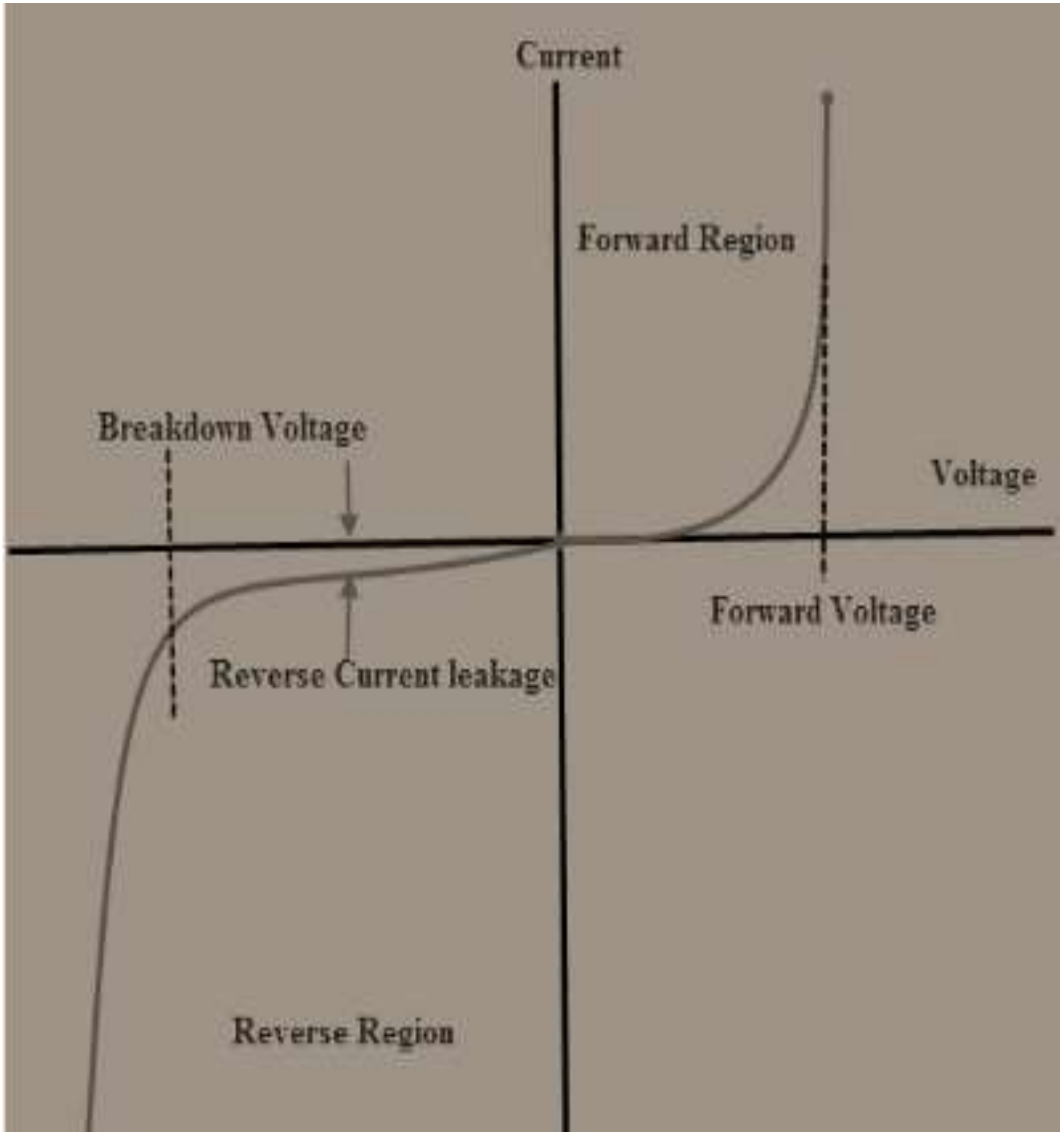
Reverse bias

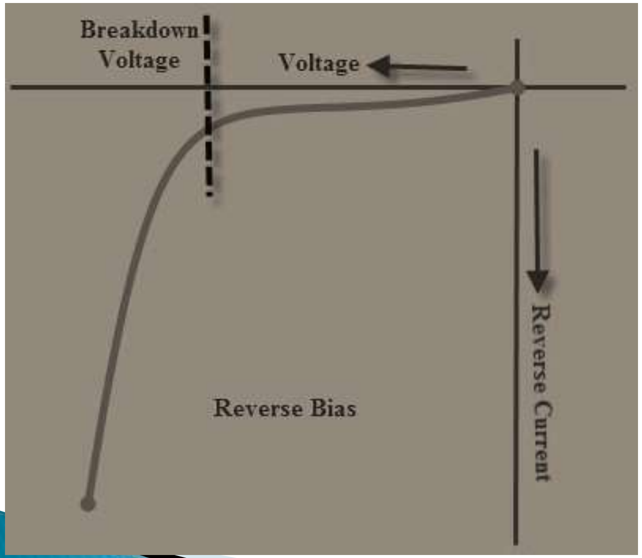


Forward bias characteristics



V-I characteristics





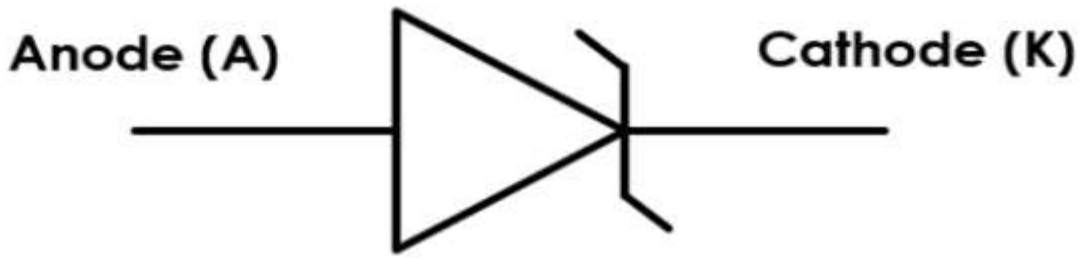
Reverse bias characteristics

Limiting values of P N junction diode

1. Maximum forward current
2. Peak inverse voltage (PIV)
3. Maximum power rating
4. Maximum average forward current

Zener diode

A property doped with adequate power dissipation capabilities to operate in breakdown region is known as zener diode.



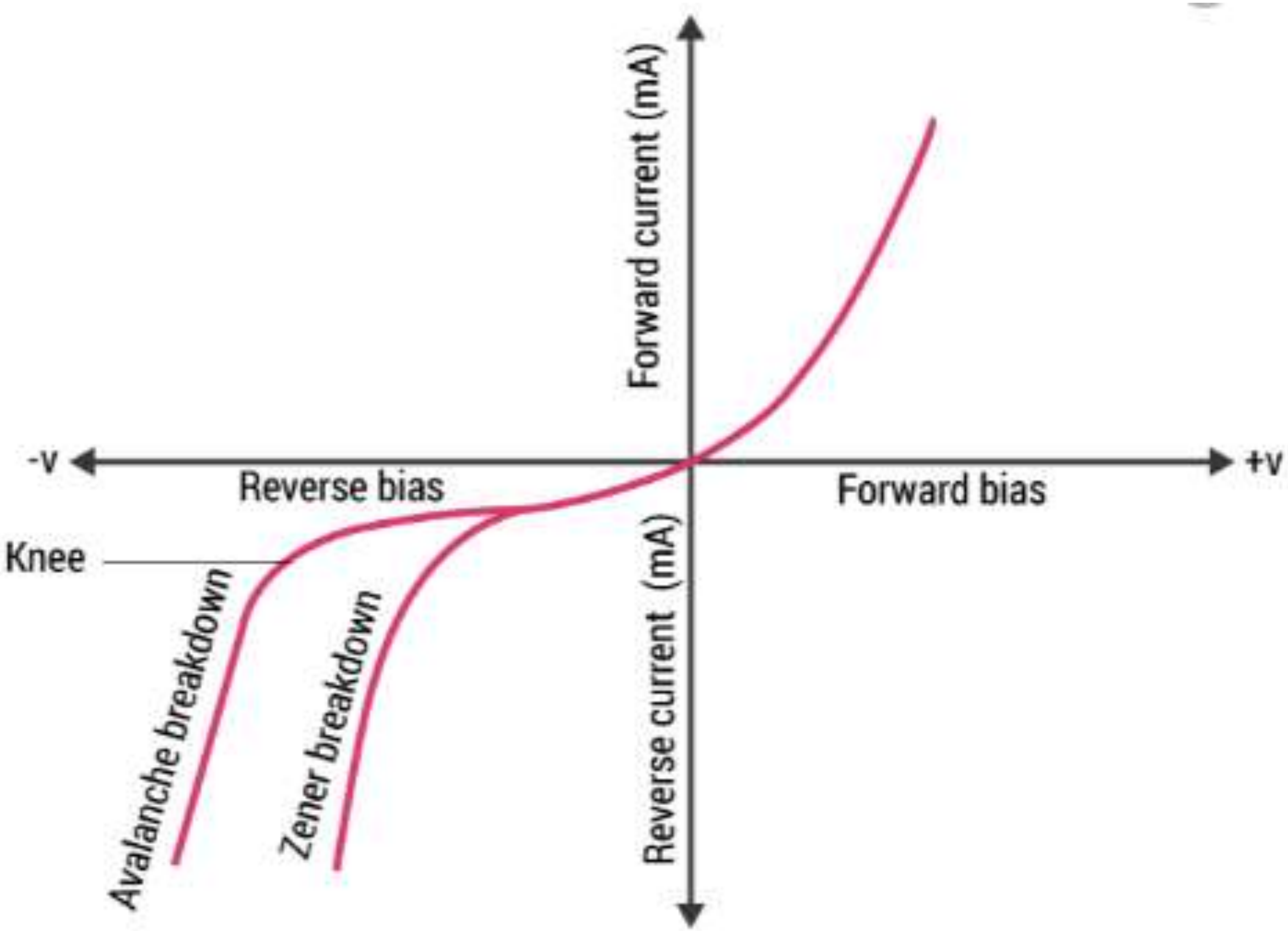
Two types of breakdown conditions

1. Avalanche breakdown
2. Zener breakdown

DIFFERENCE BETWEEN ZENER AND AVALANCHE BREAKDOWN

Zener Breakdown	Avalanche breakdown
1.This occurs at junctions which being heavily doped have narrow depletion layers	1. This occurs at junctions which being lightly doped have wide depletion layers.
2. This breakdown voltage sets a very strong electric field across this narrow layer.	2. Here electric field is not strong enough to produce Zener breakdown.
3. Here electric field is very strong to rupture the covalent bonds thereby generating electron-hole pairs. So even a small increase in reverse voltage is capable of producing Large number of current carriers.	3. Her minority carriers collide with semi conductor atoms in the depletion region, which breaks the covalent bonds and electron-hole pairs are generated. Newly generated charge carriers are accelerated by the electric field which results in more collision and generates avalanche of charge carriers. This results in avalanche breakdown.
4. Zener diode exhibits negative temp:	4. Avalanche diodes exhibits positive temp:

V-I characteristics of zener diode

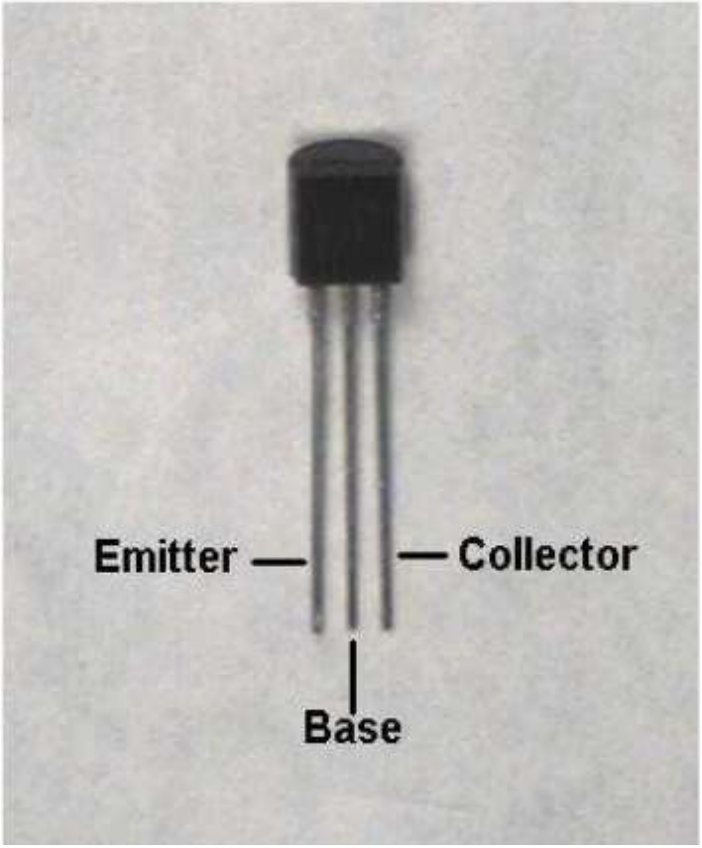


Transistors

*A **transistor** is a semiconductor device used to amplify and switch electronic signals and electrical power. It is composed of semiconductor material with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals changes the current flowing through another pair of terminals., a transistor can amplify a signal. found embedded in integrated circuits.*

Transistor

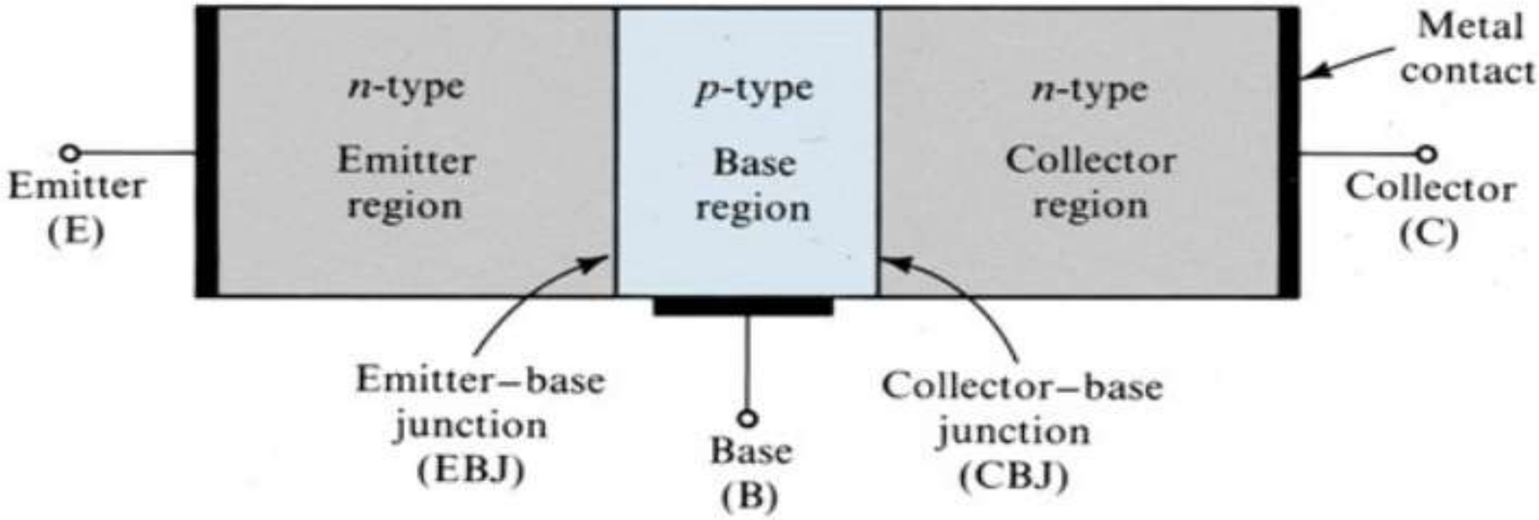
- It has got 3 parts :
- emitter
- Base
- Collector.



Types of transistor

- BJT - Bipolar Junction Transistor
- UJT- Unipolar Junction Transistor
- FET - Field Effect Transistor
- MOS - Metal Oxide Semiconductor

The Bipolar Junction Transistor (BJT)



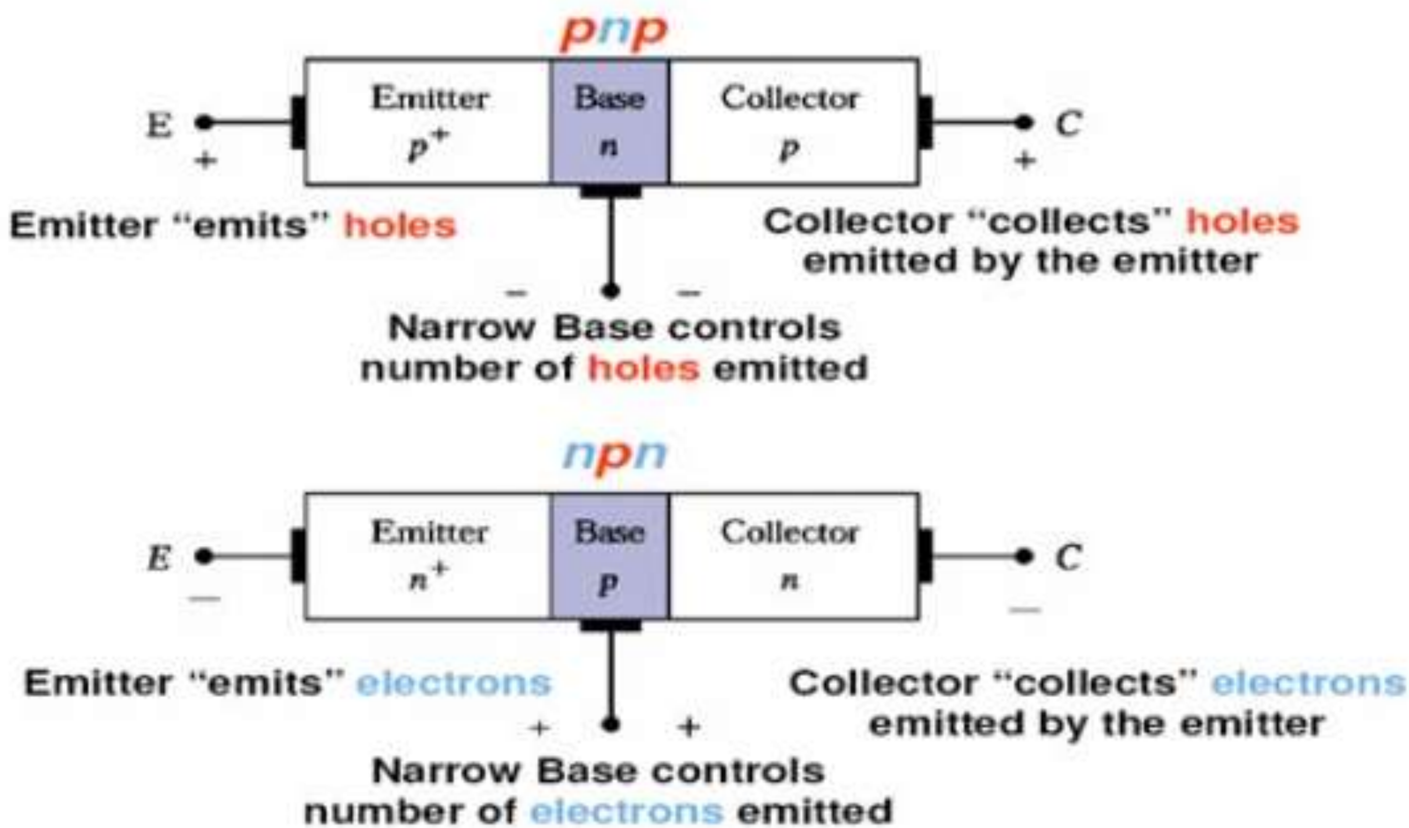
- **Bipolar** : both electrons and holes are involved in current flow.
- **Junction** : has two *p-n* junctions.
- **Transistor** : Transfer + Resistor.
- It can be either ***n-p-n*** type or ***p-n-p*** type.
- Has three regions with three terminals labeled as

  i. Emitter (E)

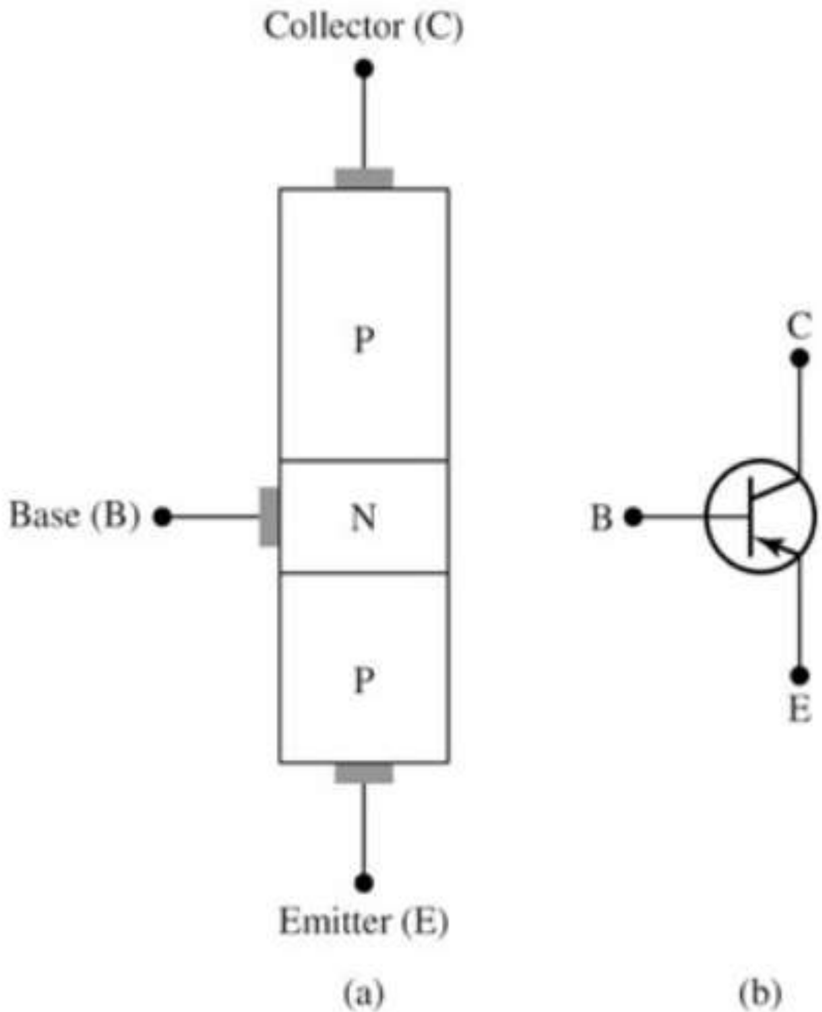
  ii. Base (B) and

  iii. Collector (C)

- Base is made much narrow.
- Emitter is heavily doped (p^+, n^+).
- Base is lightly doped (p^-, n^-).
- Collector is lightly doped (p, n).



Layout and Circuit Symbol: p-n-p Transistor

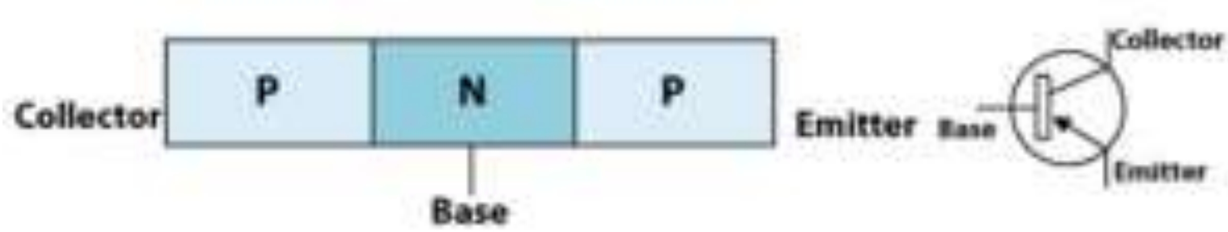


- The arrow indicates the direction of current flow.
- The current flows from emitter to collector in an p-n-p transistor.
- The arrow points towards the n-type.
- So the base is n-type and transistor is p-n-p type.

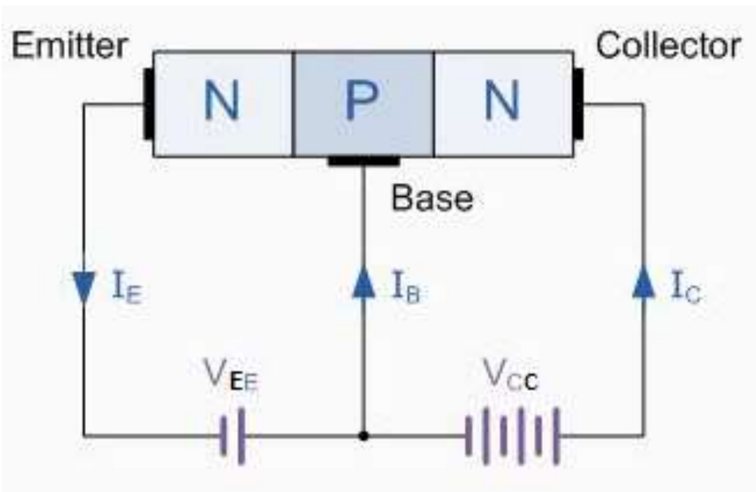
Modes of Operation

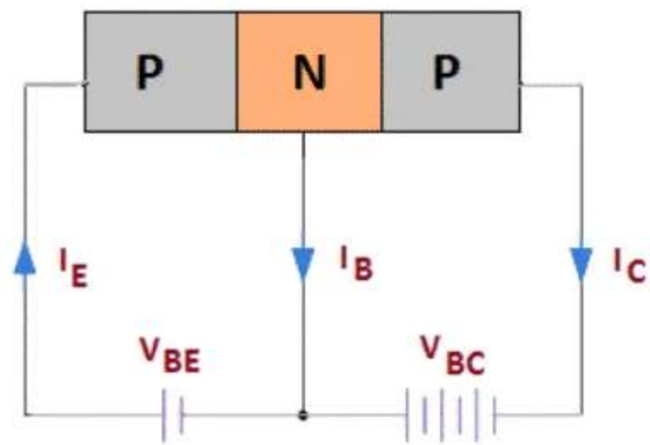
- Based on the bias voltages applied at the two p-n junctions, transistors can operate in three modes:
    1. **Cut-off** (both EB and CB junctions are reversed biased)
    2. **Saturation** (both EB and CB junctions are forward biased)
    3. **Active mode** (EBJ is forward biased and CBJ is reversed biased)
- Cut-off and Saturation modes are used in switching operation.
- Active mode is used in amplification purposes.

Bipolar Junction transistor

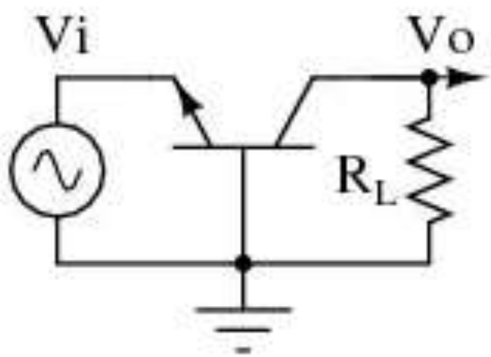


Operation of transistor

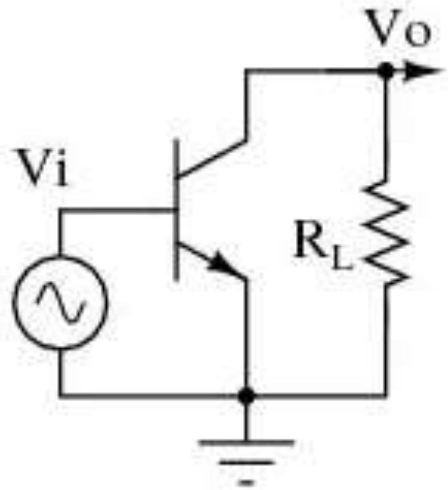




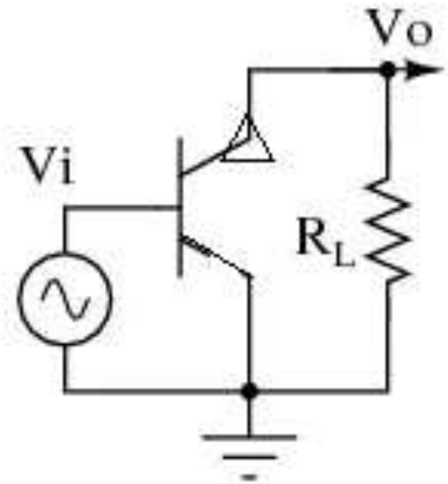
Transistor Configurations



Common-base

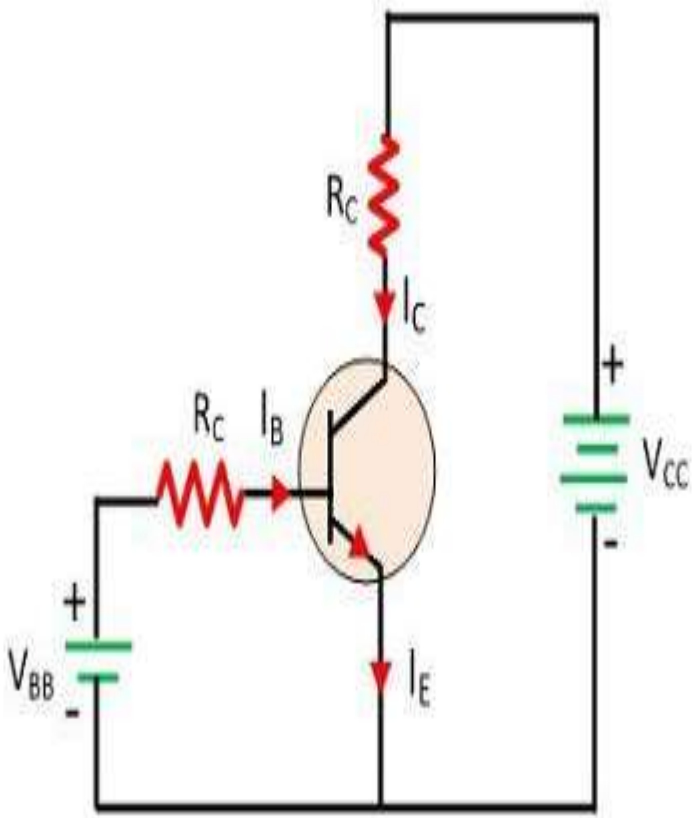


Common-emitter

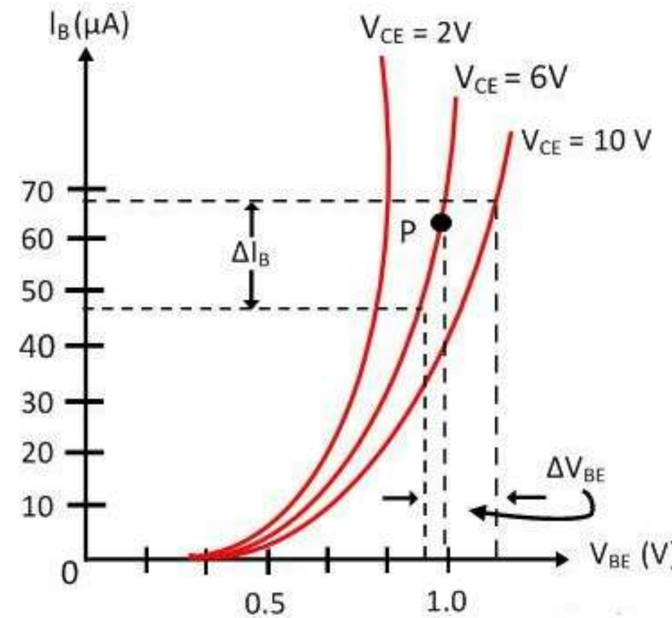


Common- collector

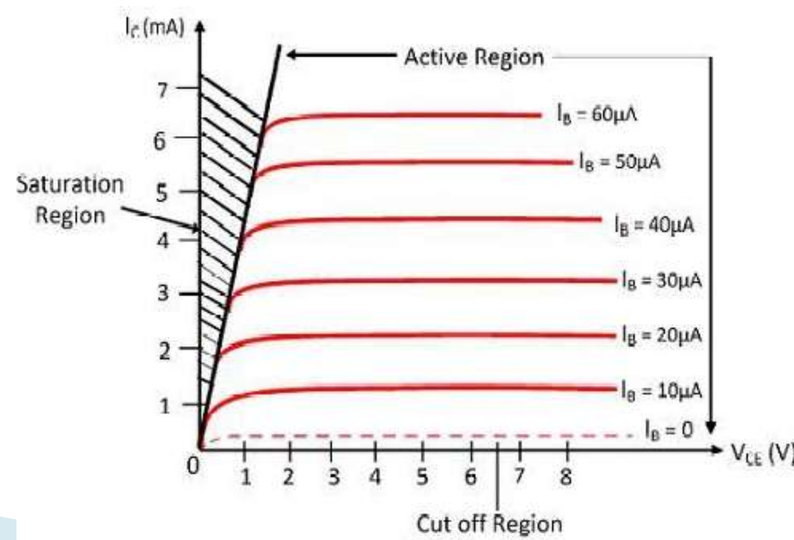
Transistor Characteristics



Input Characteristics



Output Characteristics



Parameters of Transistor

1. Input resistance (r_i)

It is the ratio of change in base emitter voltage to the resulting change in base current at constant collector emitter voltage .

$$r_i = \Delta V_{BE} \,/\, \Delta I_B, \quad V_{CE} \text{ constant}$$

2. Output resistance (ro)

In CE configuration, from the output characteristics we can see that change in collector – emitter voltage causes the little change in collector current for constant base current.

$$r_o = \Delta V_{CE} \,/\, \Delta I_C \qquad I_B \text{ constant}$$

3. Current amplification factor (α)

$$I_C = \alpha I_E + I_{CBO}$$

$$I_C = \alpha I_E$$

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

Current amplification factor (β)

$$I_C = \alpha I_E + I_{CBO}$$

$$I_E = I_C + I_B$$

$$I_C = \alpha(I_C + I_B) + I_{CBO}$$

$$I_C(1-\alpha) = \alpha I_B + I_{CBO}$$

$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{I_{CBO}}{1-\alpha}$$

$$I_C = \left(\frac{\alpha}{1-\alpha}\right) I_B + \left(\frac{1}{1-\alpha}\right) I_{CBO}$$

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

$$I_C=\beta\, I_B+(1+\beta)\, I_{CBO}$$

The term $(1+\beta)\, I_{CBO}$ is the reverse leakage current in CE configuration. It is designated as I_{CEO}

$$I_B \ll I_C$$

$$I_{CEO} = (1+\beta)\, I_{CBO}$$

$$I_C = \beta I_B + I_{CEO}$$

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

Relation between ‘α’ and ‘β’

$$\alpha = \frac{I_C}{I_E} \qquad \beta = \frac{I_C}{I_B}$$

$$I_E = I_C + I_B$$

$$I_B = I_E - I_C$$

$$\beta = \frac{I_C}{I_E - I_C}$$

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

Divide RHS and LHS by 1+β

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

Substitute β in RHS we get

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

Advantages of transistor

1. Longer life
2. Low power consumption
3. Higher efficiency
4. Smaller in size
5. Light in weight
6. Does not require filaments

Applications

1. Transistors are used as switches
2. They are used in amplifiers to enhance weak signals
3. They are used in oscillator circuits