

Basic Electricity and Magnetism

ST- 05

SUBSTANCE

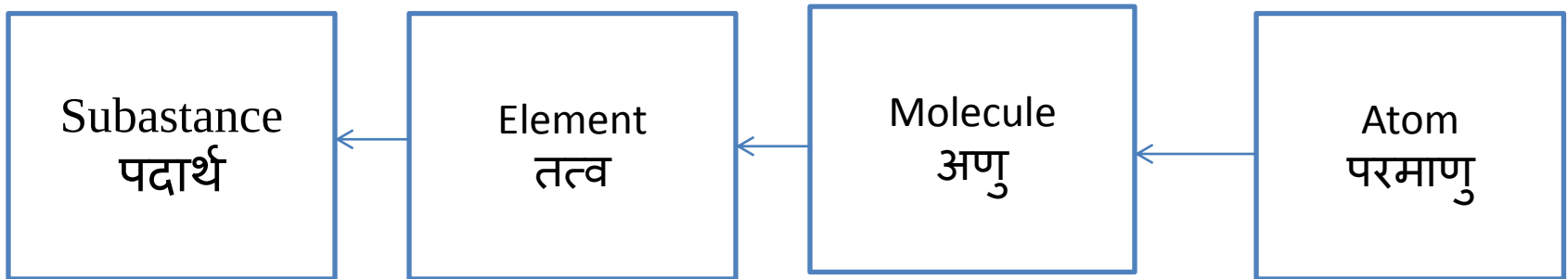
- Anything which occupies space and having mass is called matter.
- From electricity point of view, matters can be classified in to three part
 - I) Conductor
 - II) Semi- Conductor
 - III) Insulator

Classification of Substance

- I) The substance in which electric current flow and resistivity is of order of $10^{-8} \Omega\text{m}$.
- II) Semiconductor in which majority current flow in one direction and resistivity is from 10^{-4} to $0.5 \Omega\text{m}$.
- III) In which flow of current takes place at very high voltage or no flow and resistivity is of order of $10^7 \Omega\text{m}$

Formation of Substance

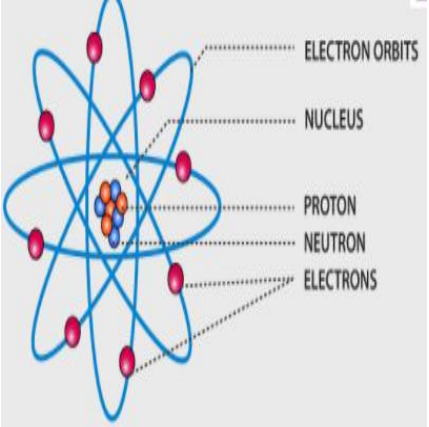
- Matters are formed due to combination of one or more than one Element.



Atomic structure

- Modern Atomic Model: An Atom consist of three sub-atomic particle i.e. neutron, proton, and electron.

Name of Particle	Mass	Charge	Symbol
Neutron	Mass of 1H atom	No	${}_0^1n$
Proton	Mass of 1H atom	Unit Positive	${}_{+1}^1p$
Electron	Mass of $\frac{1}{1837}$ times of 1H atom	Unit Negative	${}_{-1}^0$



The diagram illustrates the structure of an atom. At the center is the nucleus, composed of protons (red spheres) and neutrons (blue spheres). Surrounding the nucleus are electron orbits, represented by blue elliptical paths. Red spheres representing electrons are positioned along these orbits. Labels with dotted lines point to the 'ELECTRON ORBITS', 'NUCLEUS', 'PROTON', 'NEUTRON', and 'ELECTRONS'.

- Nucleus consists of Neutron and Proton.

Atomic structure

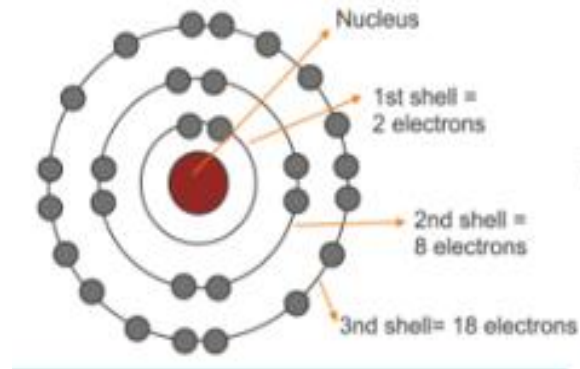
- Orbit: The path on which electron moves around the nucleus.
- Orbital: Probability of finding electron around the nucleus.
- Centrifugal force: Due to motion of electron they experience outward pull.
- Centrifugal force is counter balance by electrostatic force of attraction between electron and proton.

Atomic structure

- Valence electron: The electron in the outer most shell.
- Bound Electron: The electron in the shell nearest to the nucleus are held strongly by the electric pull of protons.
- Total number of electron is equal to the total number of proton in an atom.
- No. of Electron = No. of Proton

Electronic Configuration

- Distribution of electrons revolving around nucleus, in orbits (Energy level or shell) is called electronic configuration.
- Maximum number of electron that can be accommodated in in a shell is given by $2n^2$ (Where n = no. of shell).
- It is called Bohr-Bury scheme.



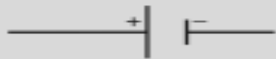
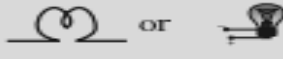
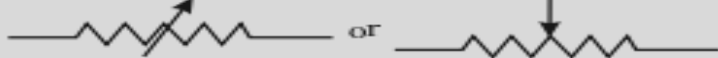
Electronic Configuration

- The outer most shell cannot have more than 8 electron and the shell next to it cannot have more than 18 electrons.

Electron Shell	Shell no.	Maximum Capacity
K	1	$2 \times 1^2 = 2$
L	2	$2 \times 2^2 = 8$
M	3	$2 \times 3^2 = 18$
N	4	$2 \times 4^2 = 32$

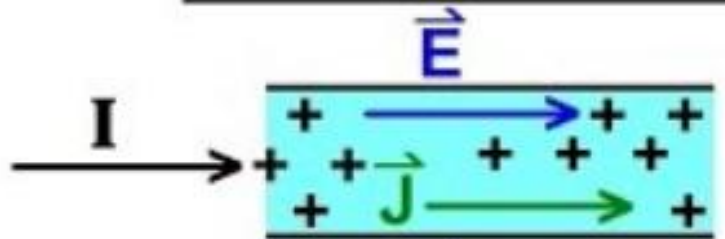
- New shell is formed as soon as the shell attain 8 electrons.
- An atom become stable when its outer most shell has 8 electrons or it has one shell containing 2 electron.

Component Symbol

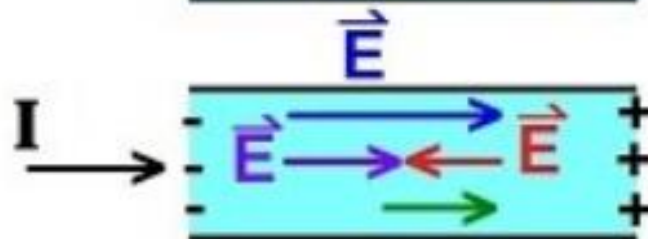
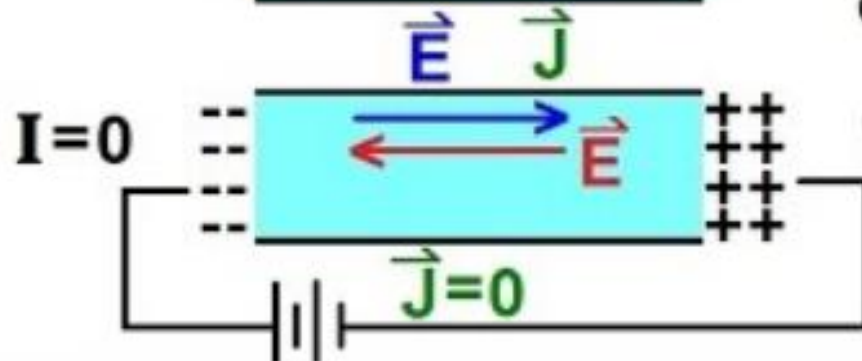
Sl. No.	Components	Symbols
1	An electric cell	
2	A battery or a combination of cells	
3	Plug key or switch (open)	
4	Plug key or switch (closed)	
5	A wire joint	
6	Wires crossing without joining	
7	Electric bulb	
8	A resistor of resistance R	
9	Variable resistance or rheostat	
10	Ammeter	
11	Voltmeter	

Electromotive Force

What is the Electromotive Force?

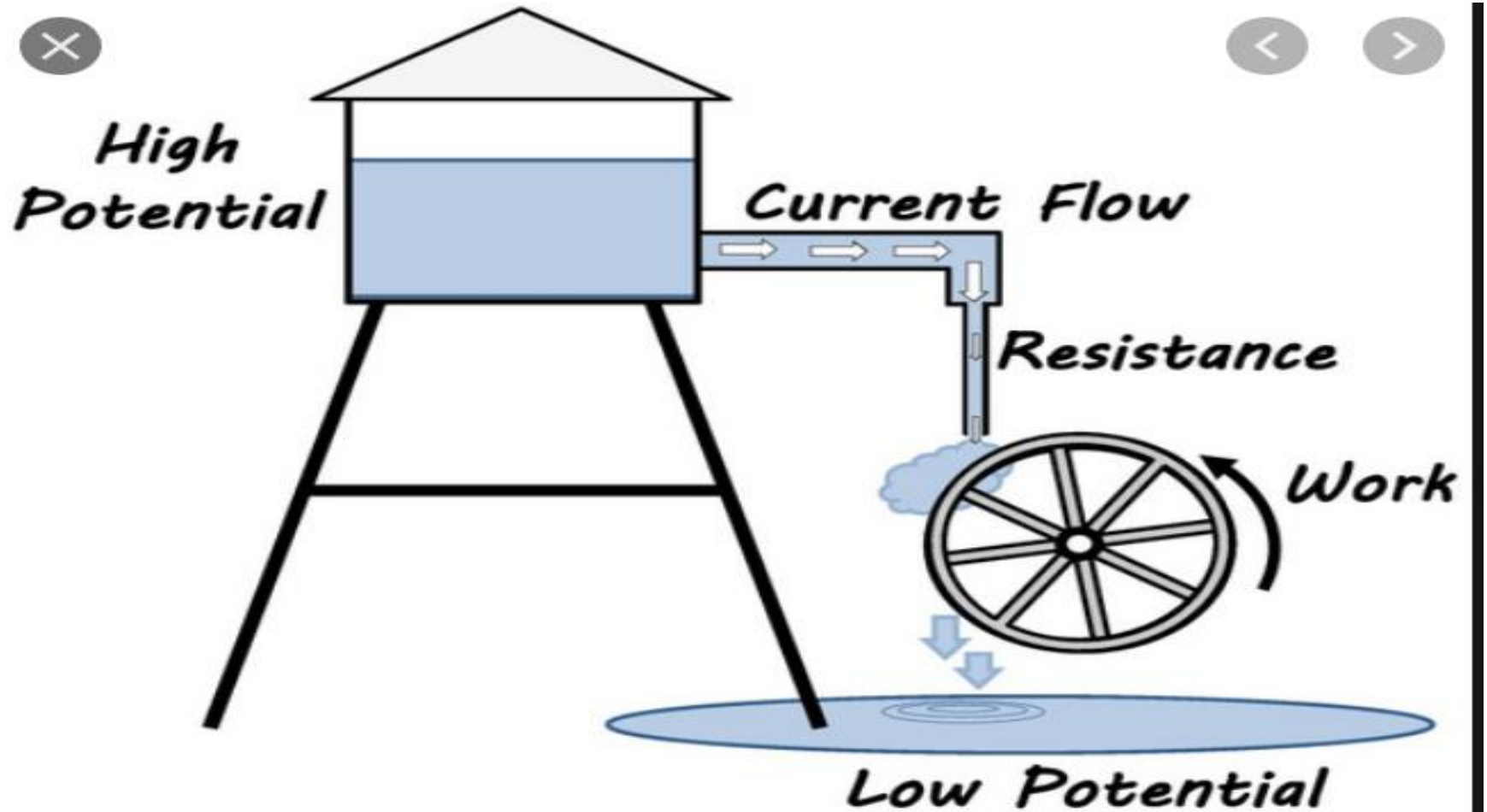


To keep the current flowing through the conductor there must be a force pushing the charges through the conductor.



The electromotive force (EMF)

EMF



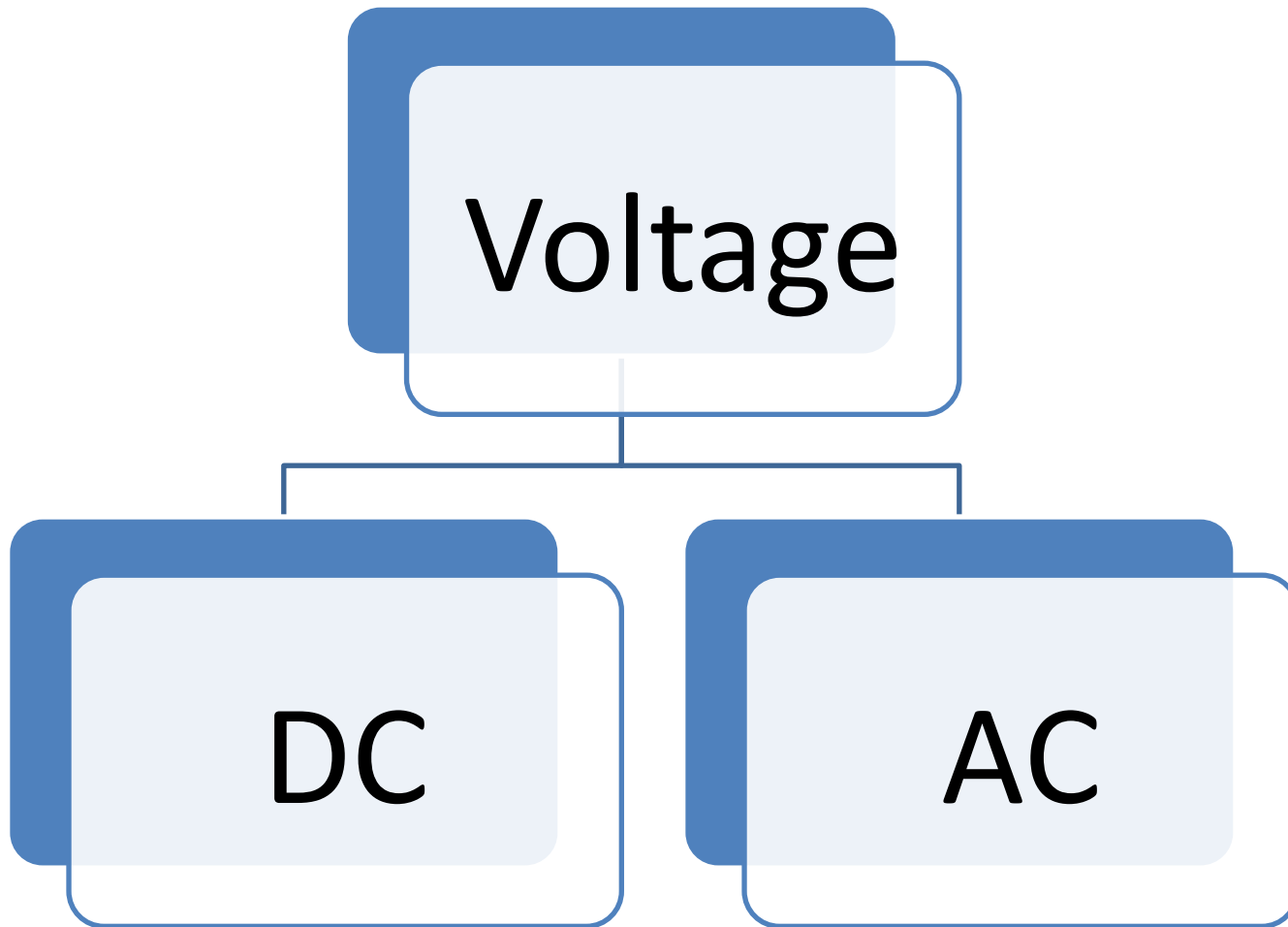
Voltage

- Voltage:- It is also known as EMF. It is a quantitative expression of the potential difference in charge between two points in an electric field. **SI unit:** volt
- **Other units:** Stat volt, **In SI units:** $V = \text{kg} \cdot \text{m}^2 \cdot \text{A}^{-1} \cdot \text{s}^{-3}$
- **Common symbols:** V, $\emptyset$
- **Dimension:** $\text{M L}^2 \text{T}^{-3} \text{I}^{-1}$
- Difference of potential in an electric field is called potential difference.

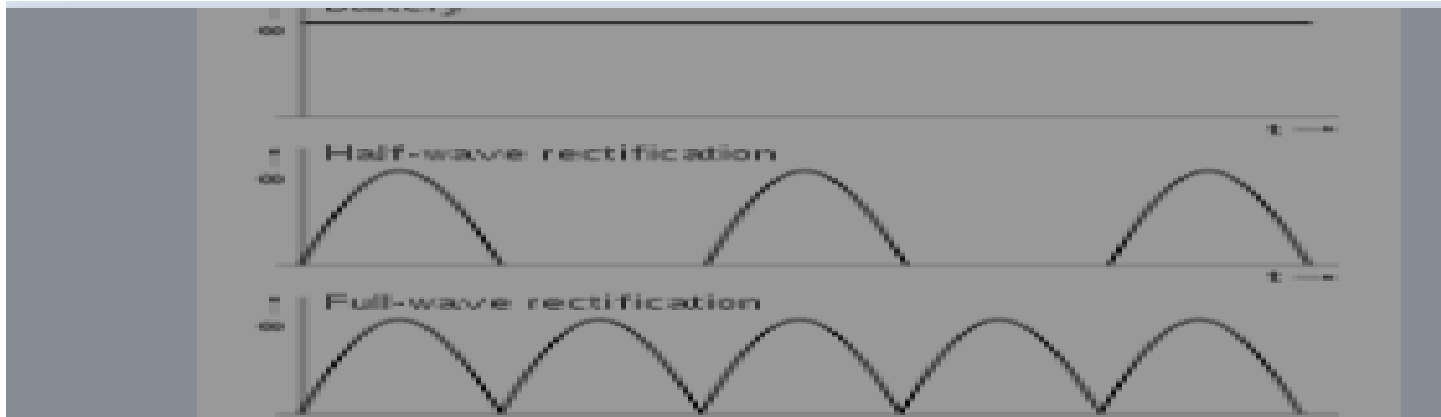
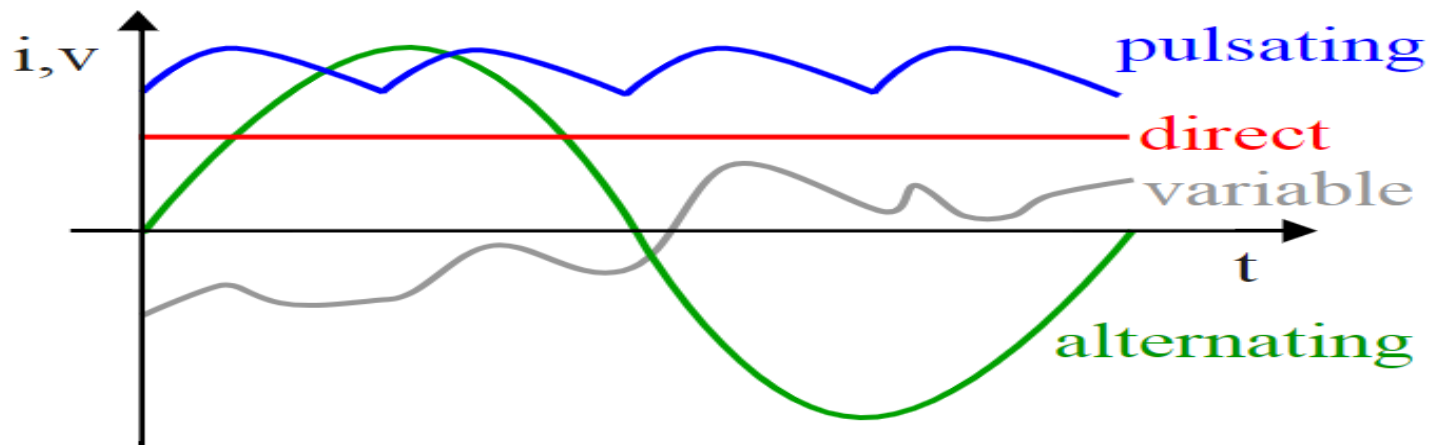
VOLTAGE

- Potential:- An electric potential is the amount of work needed to move a unit positive charge from infinity to a specific point inside the field without producing an acceleration. It is represented by ϕ ϕE or V .
- One volt is defined as energy consumption of one joule per electric charge of one coulomb
- $1V = 1J/C$. One volt is equal to current of 1 amp times resistance of 1 ohm.

Types of Voltage

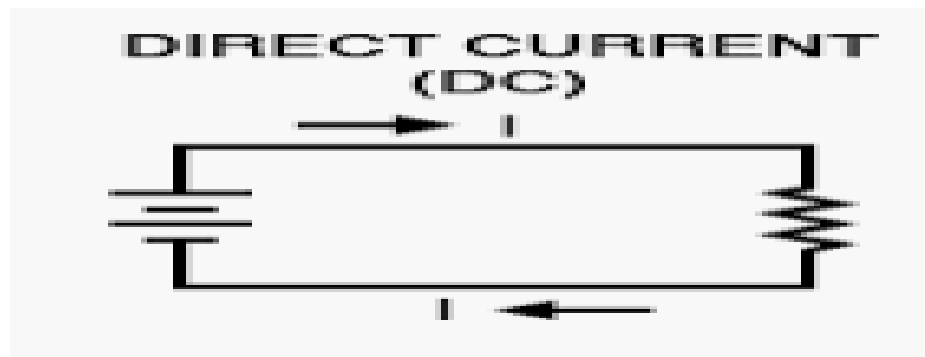


DC Voltage

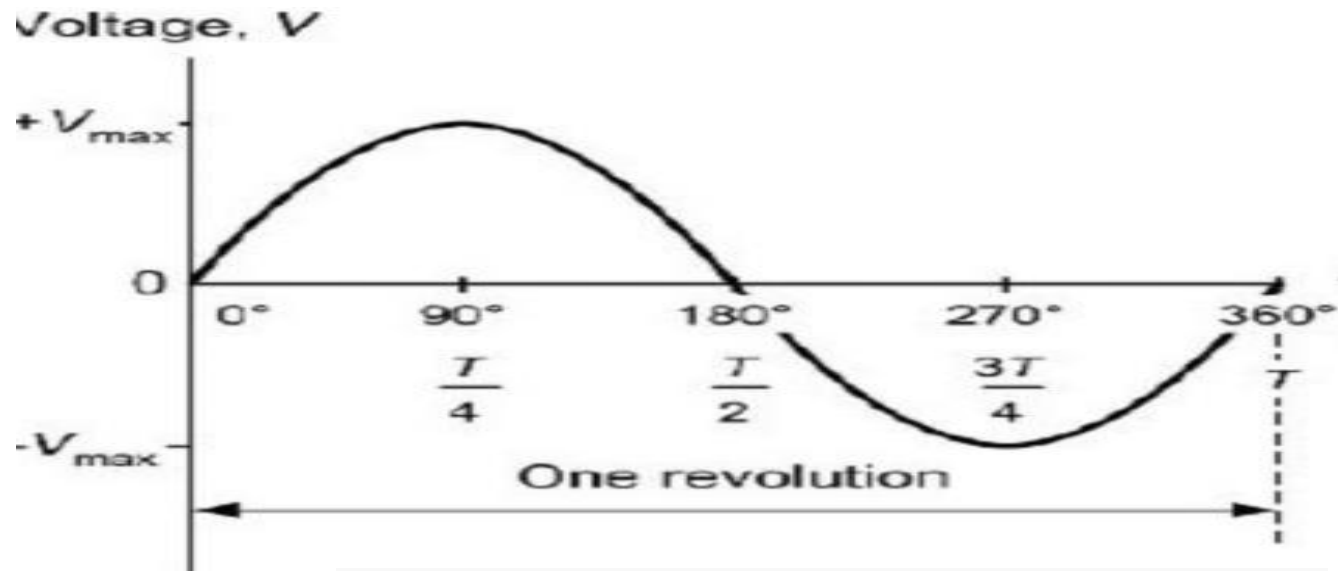
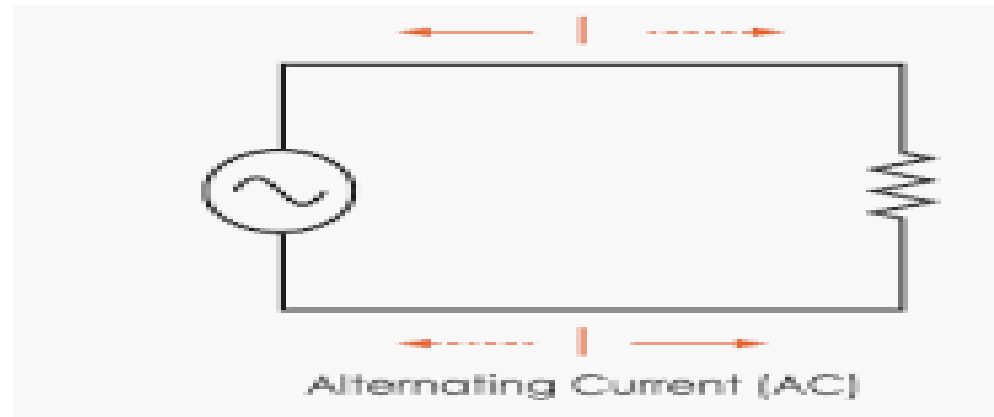


DC Voltage

- The DC Voltage induces the direct current between the two points.
- The polarity of the DC voltage is always same.
- Telecom equipment works on DC. Volt meter is used for measuring voltage in parallel.



AC Voltage



AC Voltage

- The AC voltage is the force that derive the alternating current between the two points.
- The polarity of the wave changes with the time.
- AC has frequency. In India 50Hz
- Frequency: No. of cycle completed in one second. Unit is Hertz (Hz).
- Rectifier is used for converting AC into DC.

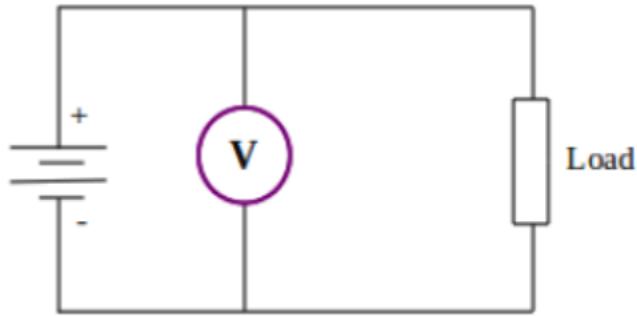
Current

- The amount of charge flowing through a particular area in unit time. OR, Rate of flow of electric charges.
- Current is denoted by “I” and unit is Ampere
- Current may be AC or DC
- Current is measured by ampere meter (Ammeter)

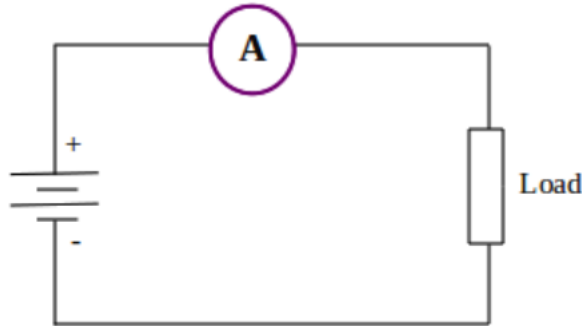
Current

- $Q = It$. This equation can now be used to define the Coulomb. ($Q = 6.25 \times 10^{18} e$)
- A current of I Amps means that I Coulombs of charge flow per second.
- 1 C is the quantity of charge which flows past any point in a circuit in which a current of 1A flows for 1 Sec.

Measurement of Voltage & Current



Voltage Measurement



Current Measurement

- Ideal Ammeter has zero resistance and Ideal volt meter has infinite resistance.

Electrical Power

- It is measures of the rate of electrical energy transferred by an electric circuit per unit time.
- Rate of doing work
- $P = \frac{W}{T}$, $P = V \times I$, $P = \frac{V^2}{R}$, $P = I^2 \times R$
- where, P= Power,
- V= voltage, I= Current
- R= Resistance, W= Work done,
- T= Time taken for the work to be done.

Electrical Energy

- It is derived from electrical potential energy. Its unit is Watt-hour.
- 1Unit= 1000Whr or 1KWhr
- 1HP= 746 Watt
- Electricity cost = No. of unit consumed X rate/unit

Power Factor

- Power factor is a special characteristics of AC.
- It is related to the phase angle between Voltage and current.
- If θ is the phase angle between voltage and current then $\cos \theta$ is power factor in AC circuit.
- Current is lagging when load is inductive and power factor is called as lagging power factor.
Ex.- Inductor, Induction Motor etc.
- Current is Leading when load is capacitive and power factor is called as leading power factor.
Ex.- Capacitive n/w, Synchronous motor.

Power Factor

- In resistive load no phase angle so, power factor $\cos \theta$ become one (1) ie. $\theta = 0$.
- Also power factor can be defined as the ratio of ratio of the real power absorbed by the load to the apparent power flowing in the circuit.
- Power Factor = (Real power)/(Apparent power)
- Real Power = $VA \cos \theta$
- Apparent Power = VA

Passive Components

- Power factor is measures of efficiency
- Components like *Resistor*, *Capacitor*, *Inductor* and *Transformer* are called passive components.
- The Devices using passive components are generally known as *passive devices*.

Resistor

- The property which “Resist” the flow of electrons is termed as *resistance*. The component, which possesses this property, is called a **Resistor**.
- The property of resistance changes from material to material and it is called as the *resistivity* of those materials. Resistivity is indicated by the symbol ρ (Rho).

Resistance

- $(R) = \rho \left(\frac{L}{A} \right)$ $L = (\text{length of conductor})$

$\text{Rho}(\rho) = \text{resistivity of material}$

$A = \text{Cross sectional Area}$

$$R_t = R_0 (1 + \alpha \times \Delta t)$$

$R_t = R$ at temperature 't'

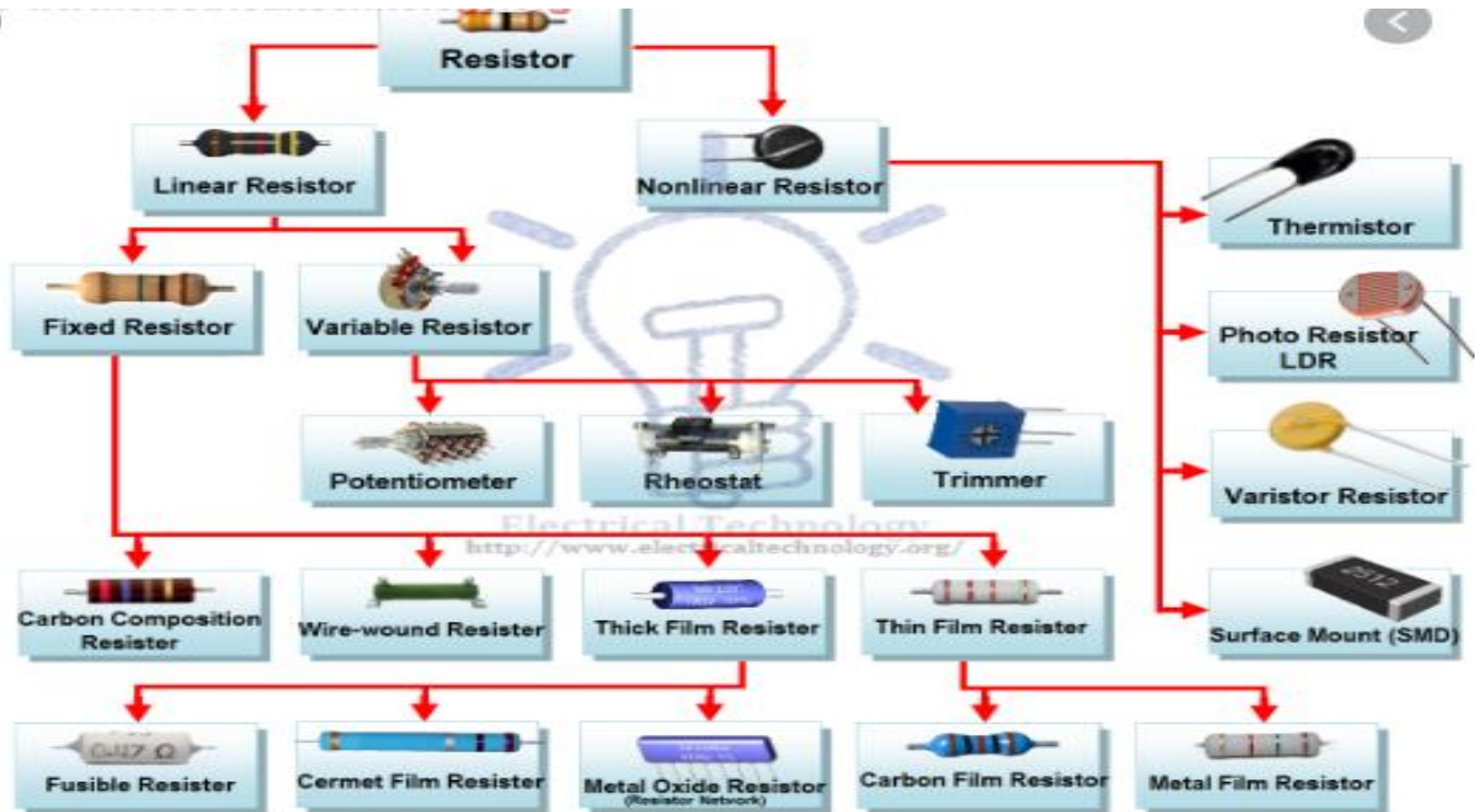
$R_0 = \text{Given value at temp.}$

$\alpha = \text{Temp. coefficient, } \Delta t = \text{Temp. Difference.}$

Unit of Resistance

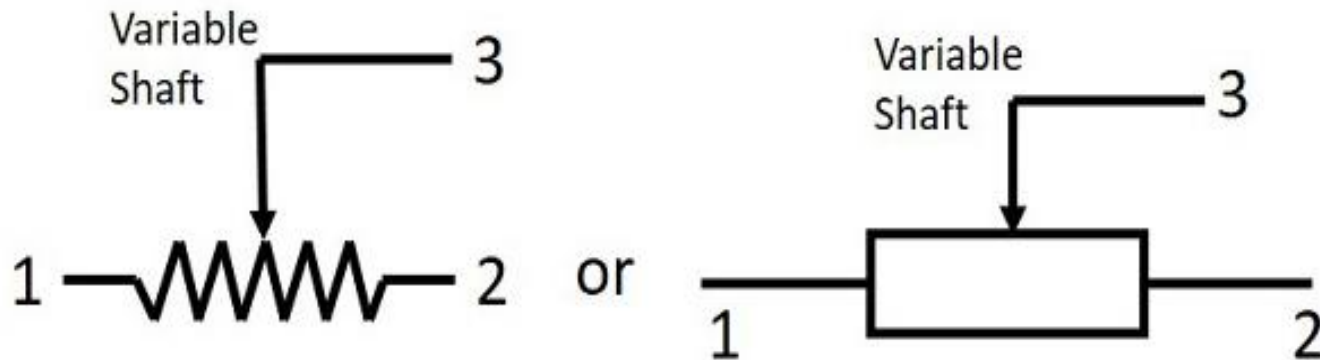
- The unit of resistance is the *OHM* (Ω). Higher resistance values are represented by k (kilo-ohms) and M (meg ohms). 120 000 is represented as 120k, while 1 200 000 is represented as 1M2. Another common practice is to use the letter E for resistance. For example, 120E (120R) stands for 120 Ω , 1E2 stands for 1R2 etc.
- The resistance of flat SMD resistors is marked with digits printed on their upper side
- For example, the printed number 754 stands for 750000 Ω , that is 750k.

Types of Resistance



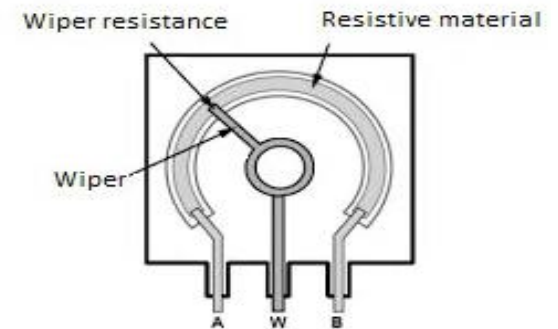
Linear Resistance

- Variable Resistors : Variable resistors are those whose values can be varied manually, according to the requirement



Variable Resistance

- A Potentiometer is simply called as a **Pot**. This is a three-terminal resistor having a shaft which slides or rotates. A potentiometer also measures the **potential difference** voltage in a circuit. Used as a volume controller in TV and Music systems.



Variable Resistance

- A Rheostat can be simply called as a Wire wound resistor. Rheostat is used to **control current**. It was replaced by switching electronic devices, as it have lower efficiency.



Single tube Rheostat



Double tube Rheostat

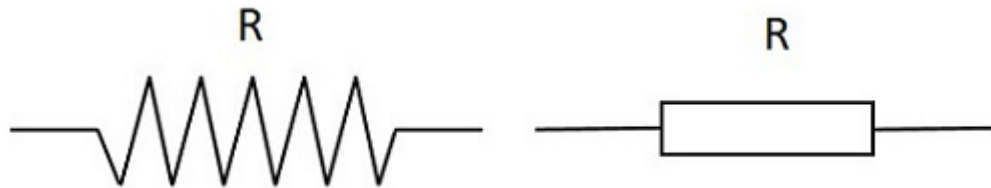
Variable Resistance

- Trimmer is both a variable resistor and a potentiometer measures potential difference . This Trimmer Potentiometer is, in short called as **Trim Pot**.



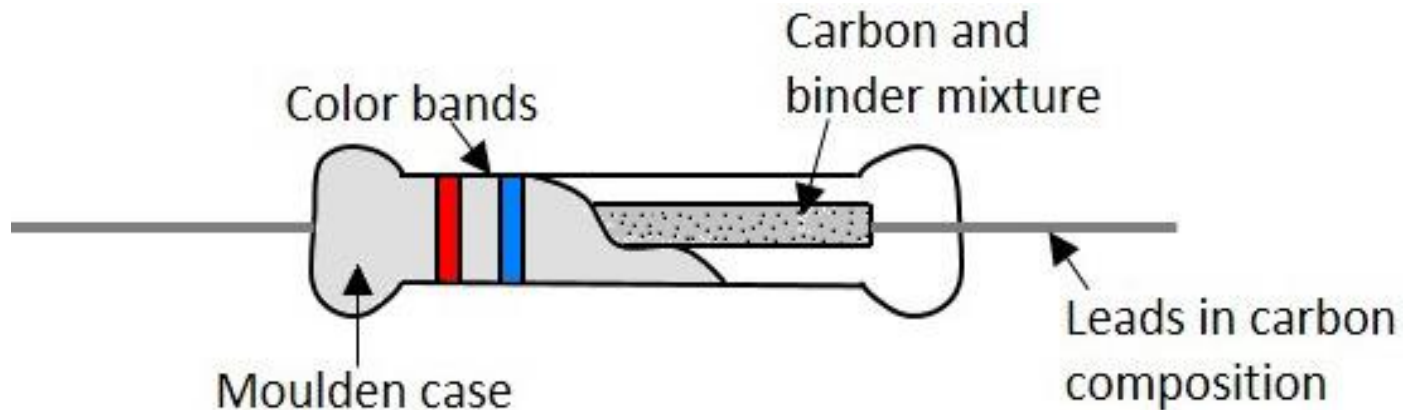
Fixed Resistors

- **Fixed resistors** are one type of linear resistors. A resistor is said to be a fixed resistor, if its value is fixed and its value is determined at the time of manufacturing itself.



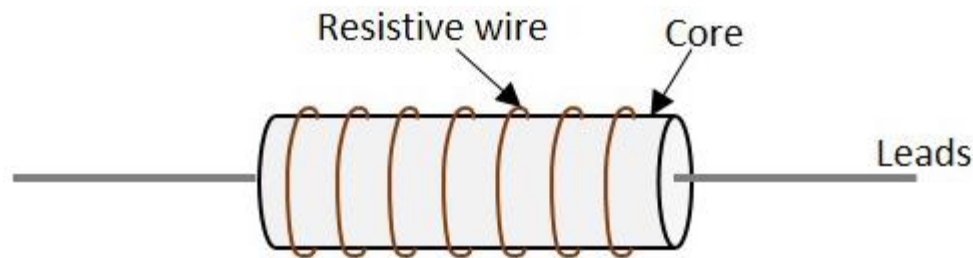
Fixed Resistors

- The **Carbon composition** resistors are a blend of carbon particles, graphite and ceramic dust mixed with a binder substance like clay. These resistors are used in Surge protection, Current limiting, and High voltage power supplies.



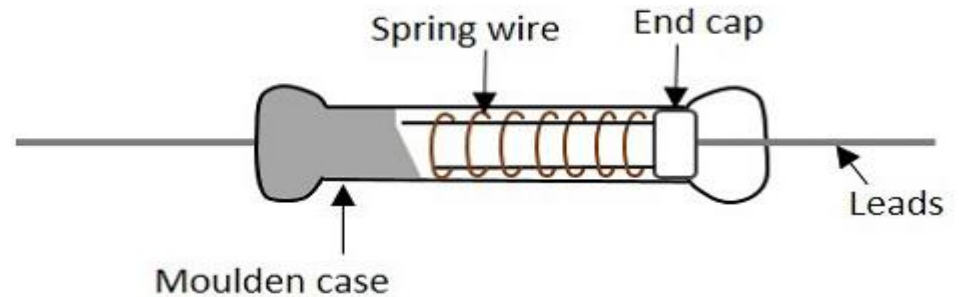
Fixed Resistors

- A Wire wound resistor is formed by winding a wire made up of a resistive material around a core. The metallic core acts as a non-conductive material while the resistive wire conducts, but with some resistance.



Fixed Resistors

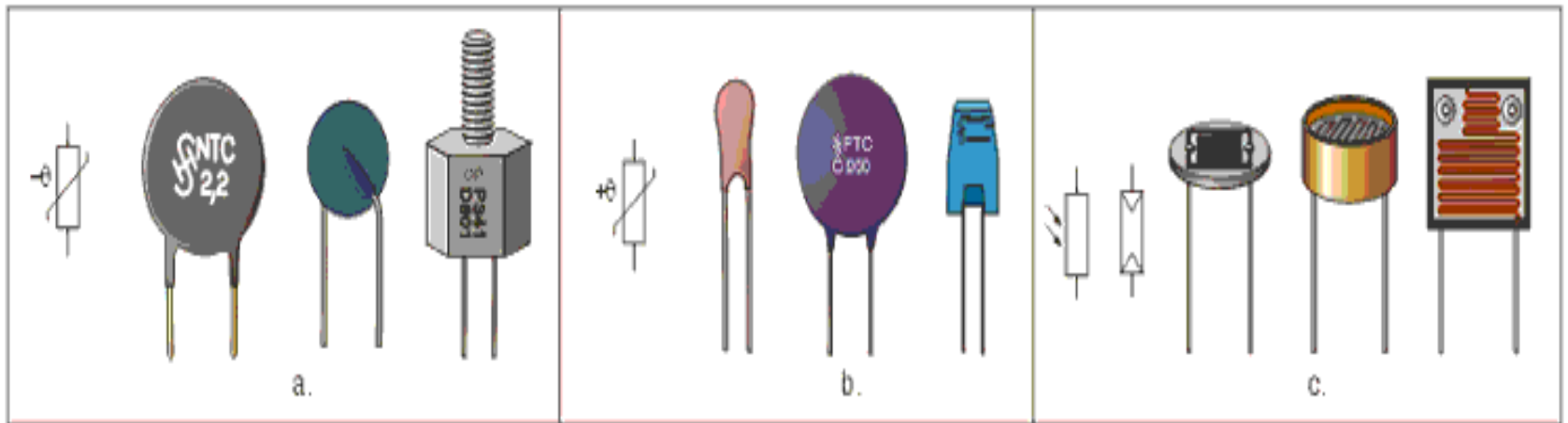
- The **Fusible resistors** are similar to wire wound resistors. But these resistors along with providing resistance, act as a fuse. The value of these resistors is usually of less than 10 Ohms. These resistors are generally used in TV sets, amplifiers and other expensive electronic circuits.



Fixed Resistors

- Thin film resistors have a resistive layer of width 0.1 micrometer or smaller on the ceramic base. Thin film resistors have a metallic film that is vacuum deposited on an insulating substrate.
- Thin film resistors are more accurate and have better temperature coefficient and is more stable. The thin film resistors are further divided into two types such as –
 - Carbon film resistors
 - Metal film resistors

Nonlinear resistors



- a. NTC, b. PTC, c. LDR
- Resistor Symbols



a) American symbol



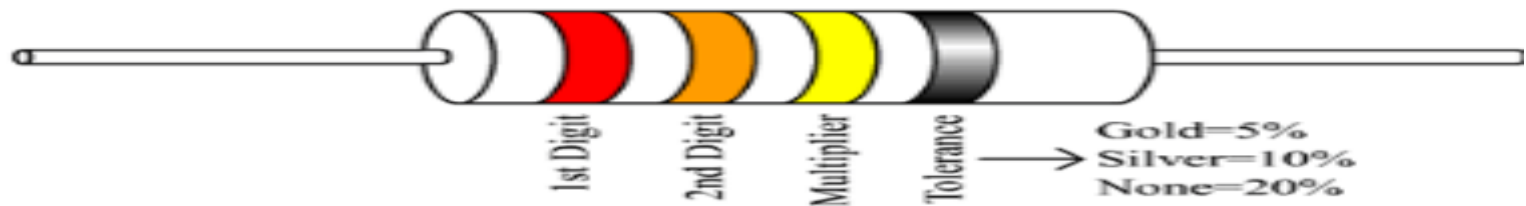
b) European symbol

Nonlinear resistors

- Nonlinear resistors: change value with a change in temperature or light, function may not be linear, hence the name Non linear resistor.
Ex. NTC (Negative Temperature Co-efficient)
PTC (Positive Temperature Co-efficient)
LDRs (Light Dependent Resistors)
VDRs (Voltage dependent Resistors)

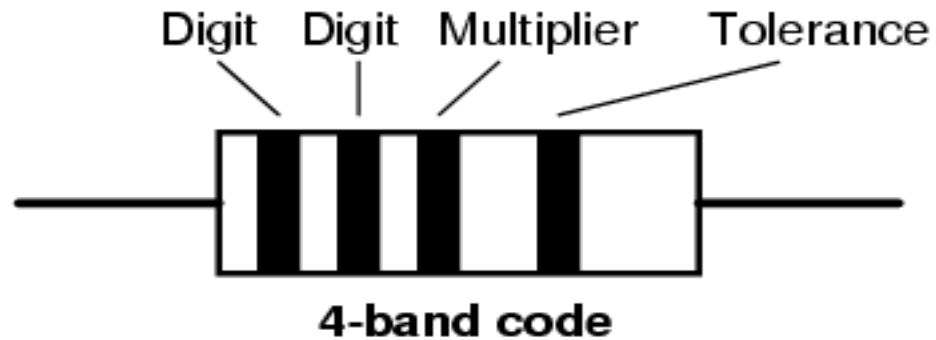
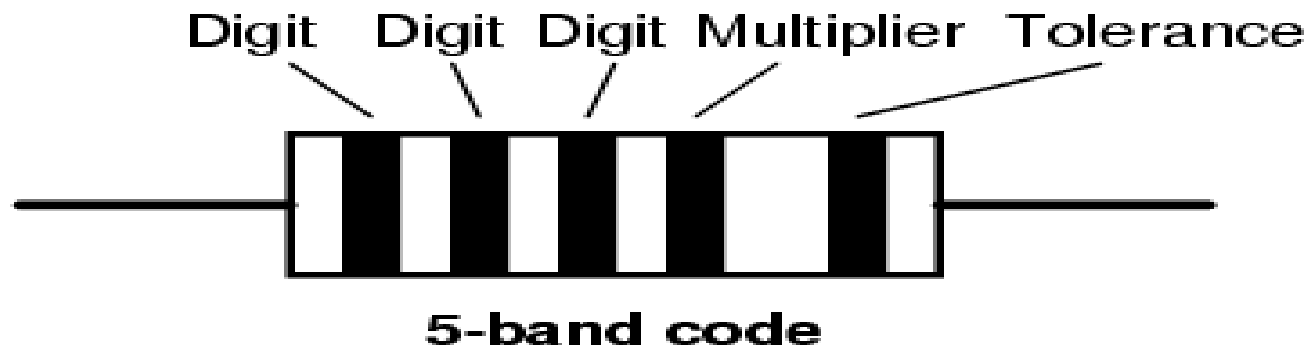
Resistance

- Colour coding of resistance:



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

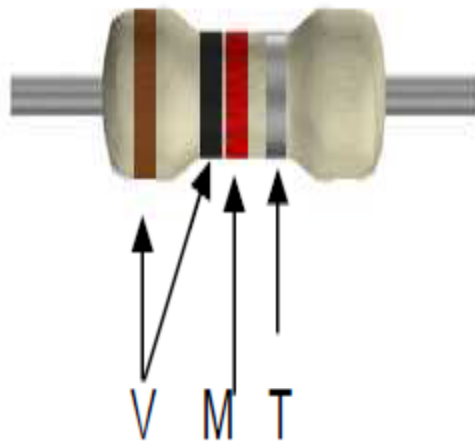
Resistance



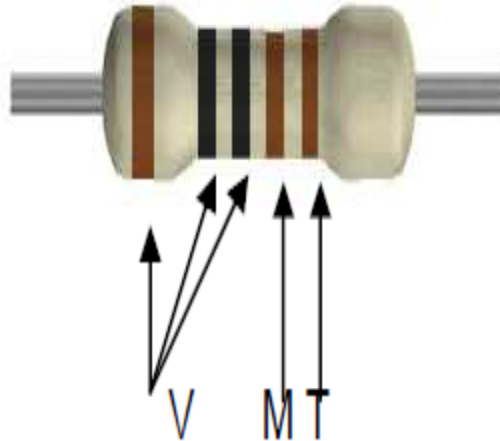
Resistance

Resistors with different bands of color code look like as shown below

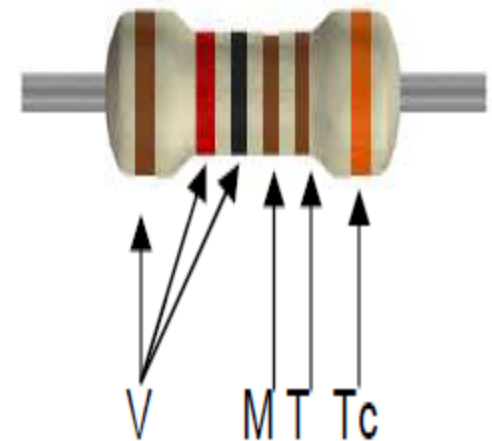
4 Band Resistor



5 Band Resistor



6 Band Resistor (for SMD)



V - Value digits

M - Multiplier

T - Tolerance

Tc - Temperature coefficient

Resistance Feature

- Wattage Rating: It shows how much maximum current will flow.
- Tolerance: Due to human, machine and manufacturing defect the measured value of resistance may be differ from rated value. It is written as $\pm 10\%$ or something like this.

Insulation Resistance

- Resistance insulating material between to conductor in a circuit is called Insulation Resistance.
- Generally PVC is used as Insulator between two conductor.
- In Overhead line Air act as insulator. Similarly in between overhead line and post, porcelain act as Insulator.

Insulation Resistance

- Insulation resistance must as high as possible to function the circuit efficiently i.e leakage current as low as possible.
- Leakage current $\propto 1/\text{Insulation resistance}$
- Insulation Resistance is measured by **Megar** and unit is in **M Ω** .

Testing of Insulation Resistance

- Insulation resistance is tested by two type.
 1. Core To Core: Measures the insulation resistance of different insulator material used between conductor of cable.
 2. Core To Earth: Measures the insulation resistance of insulator used between insulated conductors and armour.

Earthing

- Earth is a connection to the general mass of earth by means of an earth electrode (specn for earthing RDSO/SPN/197/2008)
 - It provides low impedance path to fault current
 - Reduces shock hazards to personnel
 - Provides protection from lightning
 - Controls electrical noise

Earthing

- reduces ambient noise levels
- Less system downtime
- fewer equipment failures
- Increased equipment life
- Earthing for signalling equipments to be adopted which are more susceptible due to surges, transients and over voltages
(EI, IPS, D/L, Dig A/C, STM & MUX, Exchange, Quad cable etc.)

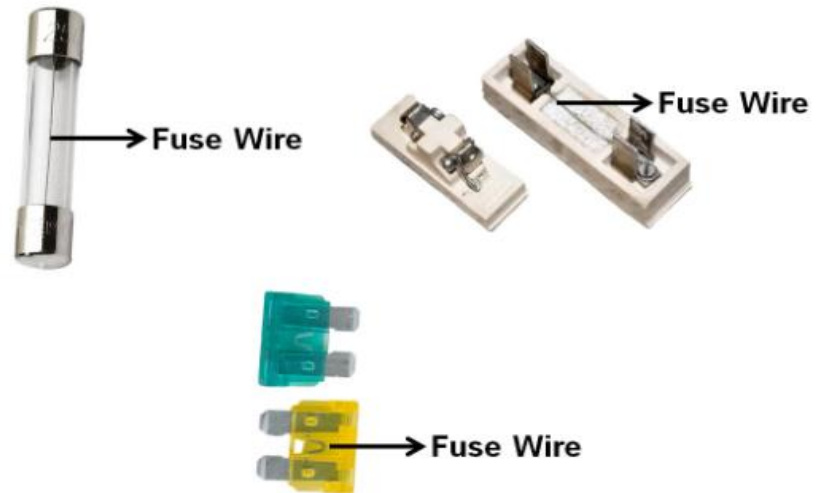
Surge Protection Device

- Classification of SPD
- Class-A: External lightning conductor on building connected to ground through conductor.
- Class-B: Before the equipment, at mains distribution panel. Operate on arc chopping principle
- Class-C: It is provided between phase and neutral
- Class-D: Provided between external data/ power supply (AC/DC) lines connected to electronic equipment. Comprise of MOVs and GDs and combinations.

Surge Protection Device

- Internal or Surge protection (Class-B, C & D renamed as Type I, II & III protection)
- Common SPD are
 1. Fuse
 2. MCB
 3. Relay

Fuse



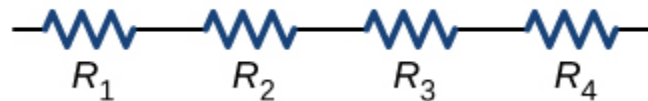
MCB

- **MCB** stands for **Miniature Circuit Breaker**. It automatically switches OFF electrical circuit during any abnormal condition in the electrical network such as overload & short circuit conditions.



Combination of Resistance

- **Resistance in series:** In a series circuit, the output current of the first resistor flows into the input of the second resistor and so on; therefore, the current is the same in each resistor.



Resistors connected in series

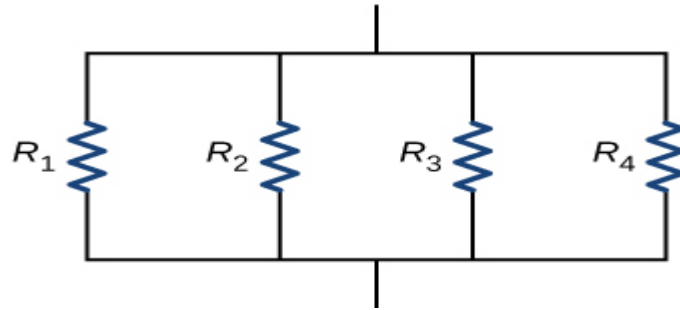
- Equivalent resistance for series combination is

$$R_S = R_1 + R_2 + R_3 + \dots + R_{N-1} + R_N = \sum_{i=1}^N R_i.$$

Resistor in Parallel

- In a **parallel circuit**, all of the resistor leads on one side of the resistors are connected together and all the leads on the other side are connected together. In the case of a parallel configuration, **each resistor has the same potential drop across it**, and the currents through each resistor may be different, depending on the resistor.

Resistor in Parallel



Resistors connected in parallel

- Equivalent resistance for series combination is

$$R_P = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots + \frac{1}{R_{N-1}} + \frac{1}{R_N} \right)^{-1} = \left(\sum_{i=1}^N \frac{1}{R_i} \right)^{-1}.$$

Proportional Voltage Formula

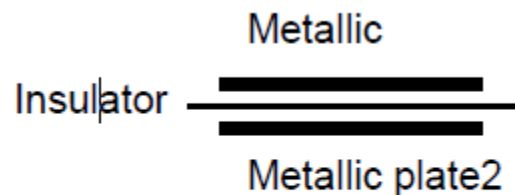
- $V_1 = V \times \frac{R_1}{R}$
- $V_2 = V \times \frac{R_2}{R}$
- $V_3 = V \times \frac{R_3}{R}$
- $V_4 = V \times \frac{R_4}{R}$

Proportional Current Formula

- $I_1 = I \times \frac{R_2}{R_1 + R_2}$
- $I_2 = I \times \frac{R_1}{R_1 + R_2}$

Capacitance

- A *capacitor* is a device that stores electrical energy in the form of charge and ability to store charge is called its capacity or *capacitance*.
- Two metallic parallel plates separated by a non-conducting substance (insulator) between them make a simple capacitor.



Construction



Symbol

Capacitor

- The charge stored by a capacitor is given by
- $Q = CV$, $C = \epsilon_r \frac{A}{D}$
- Where: Q = charge in coulombs,
 C = Capacitance in Farads, V = Volts.
 ϵ_r - Dielectric constant or relative permittivity
of the insulating material,
 A - Area of the plates,
 D - Distance between the plates

Capacitance

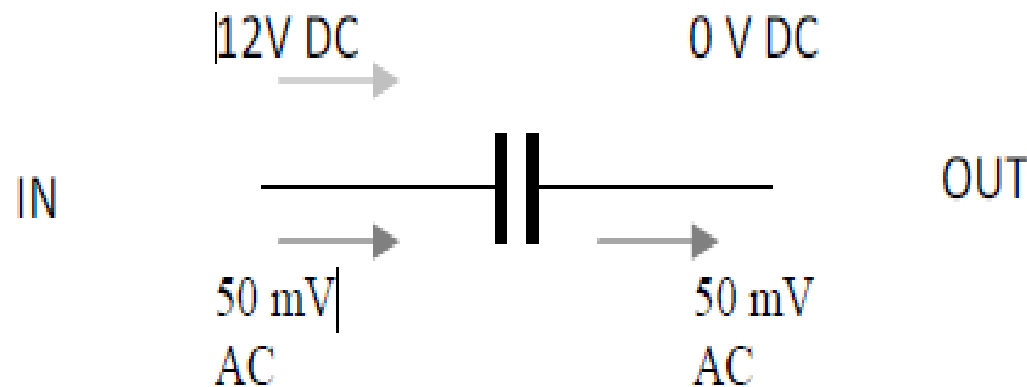
- **Capacitive Reactance:** The opposition to current flow in a capacitor is called **Reactance**. the reactance of a capacitor is called **Capacitive Reactance**, (X_C) which is measured in Ohms.

$$X_C = 1/2\pi fC$$

- **Unit of Capacitance :** The unit of charge is coulomb. If a capacitor is able to store one coulomb of charge at one volt it is said to have a capacitance of one Farad (F).

Capacitance

- The energy stored in a capacitor is given by
- $E = \frac{1}{2} C V^2$
- **Behaviour of Capacitors with AC and DC voltages:** Capacitors will pass AC currents but not DC.



Types of Capacitor

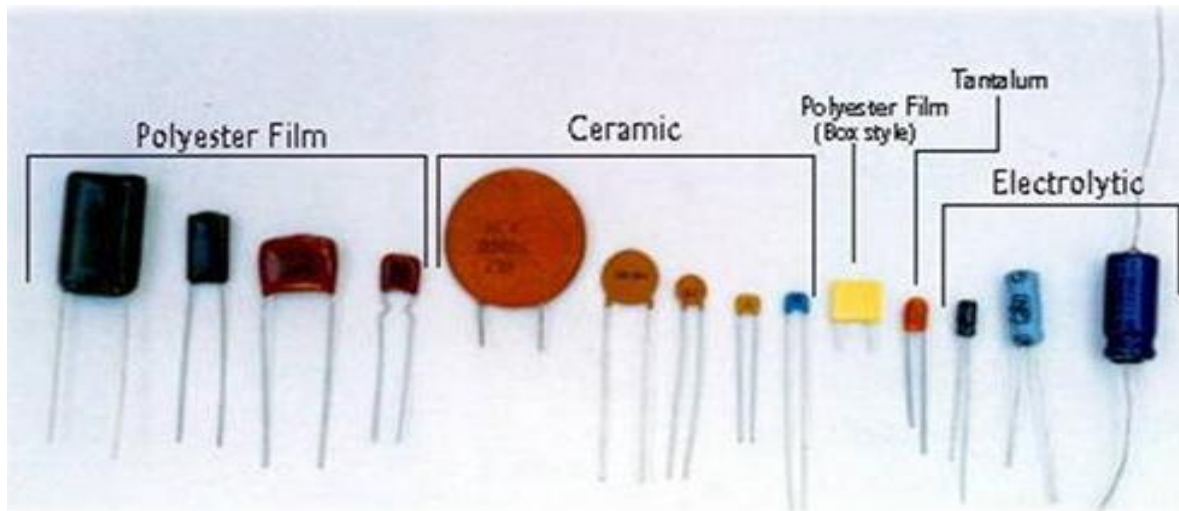
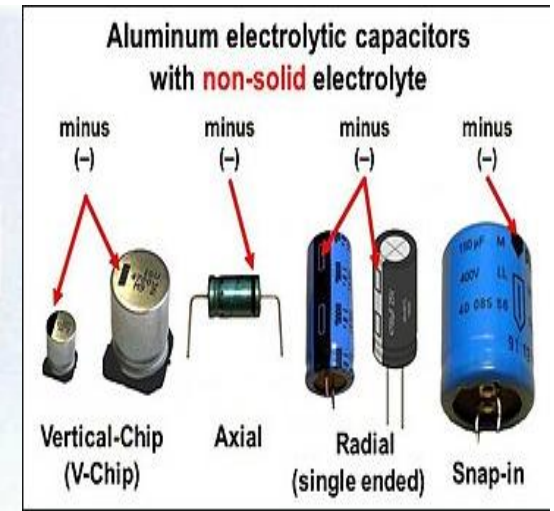
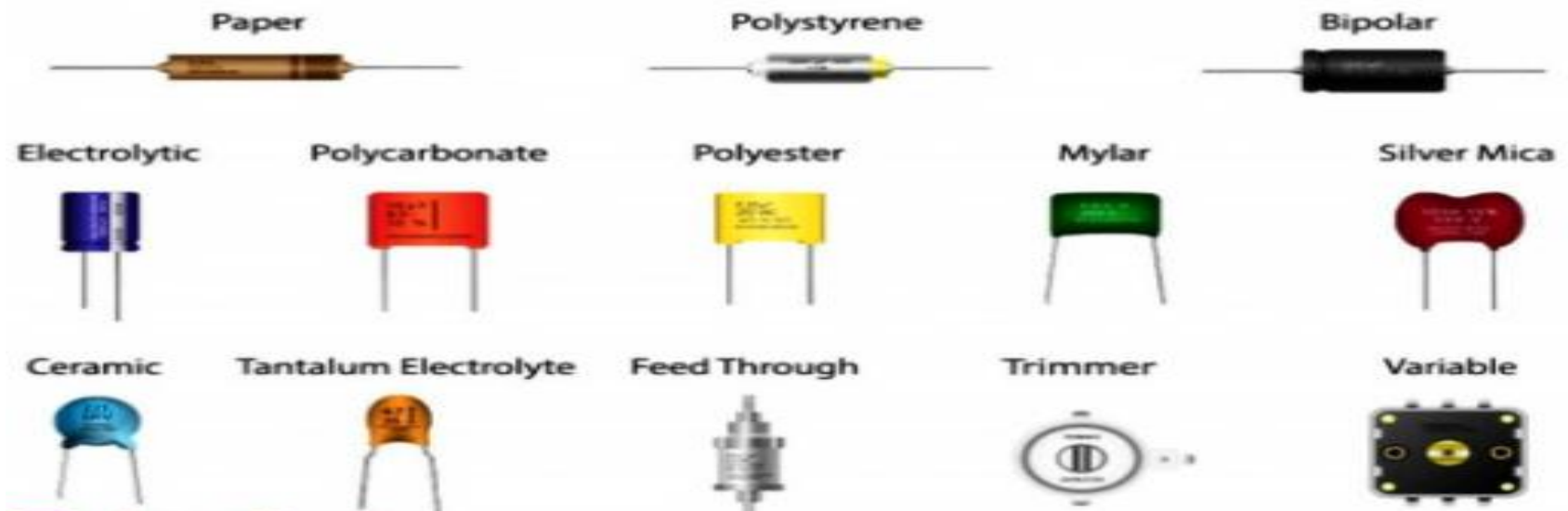
- It is of two type on the basis of current
 1. AC capacitor/Condenser: It can be used in both AC as well as DC. In AC capacitor no polarity
 2. DC Capacitor: It cannot be used in AC. Polarity is deciding factor. While connecting in circuit polarity must be maintained

Types of Capacitor

On the Basis of Dielectric used

1. Mica Condenser
2. Ceramic Condenser
3. Styroflex Condenser
4. Paper Condenser
5. Polyester Condenser
6. Electrolytic Condenser

Types of Capacitor



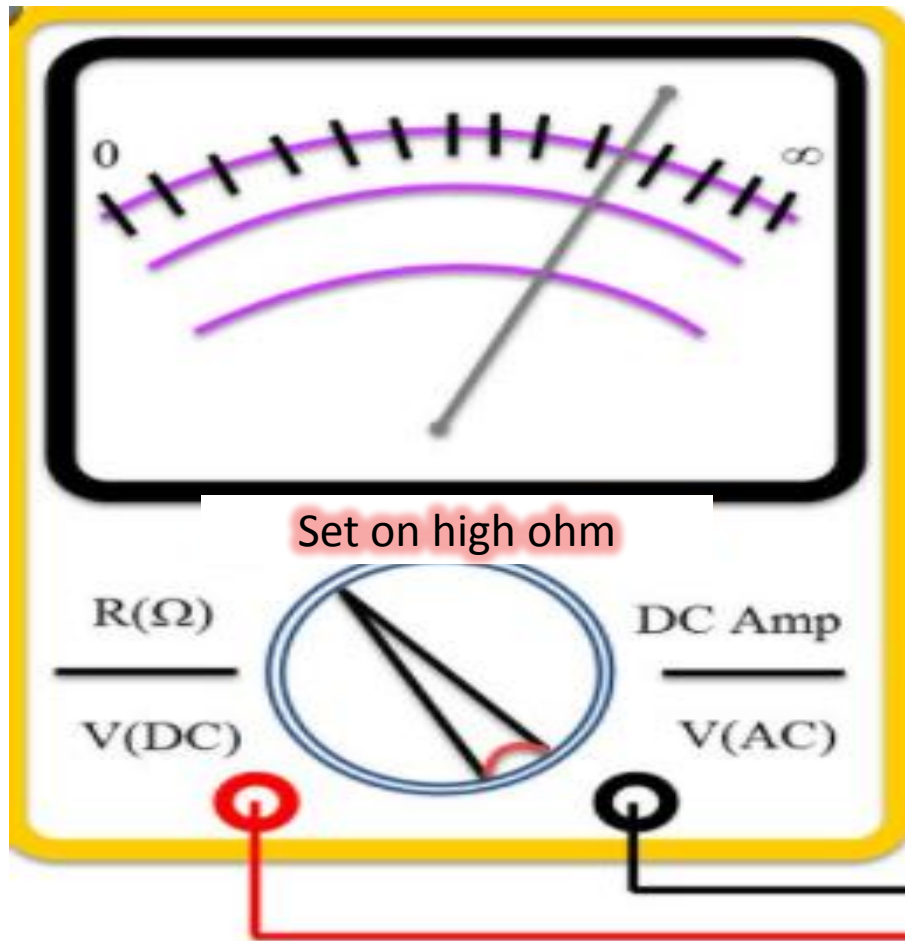
Uses of Capacitor

- It can be used in following circuit
 1. Filter circuit
 2. Stabilizer
 3. Slow to release
 4. Timer circuit
 5. Bypass Circuit
 6. Fan, Motor etc.

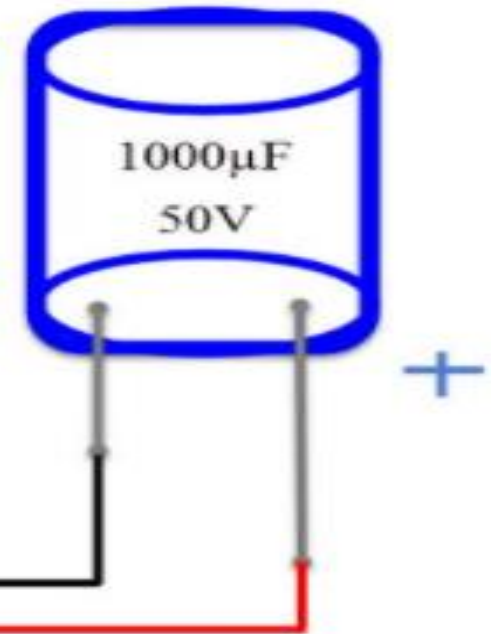
Capacitor Testing By AVO

1. Make sure the suspected capacitor is fully discharged.
2. Select meter on OHM (Select the higher range).
3. Connect the Meter leads to the Capacitor terminals.
4. Compare the reading with the following results.
5. **Short Capacitors:** It will show very low Resistance.
6. **Open Capacitors:** An Open Capacitor will not show any movement (Deflection) on OHM meter Screen.
7. **Good Capacitors:** Initially, it will show low resistance, and then gradually increases toward infinity.

Capacitor Testing



Good Capacitors: Initially, it will show low resistance, and then gradually increases toward infinity



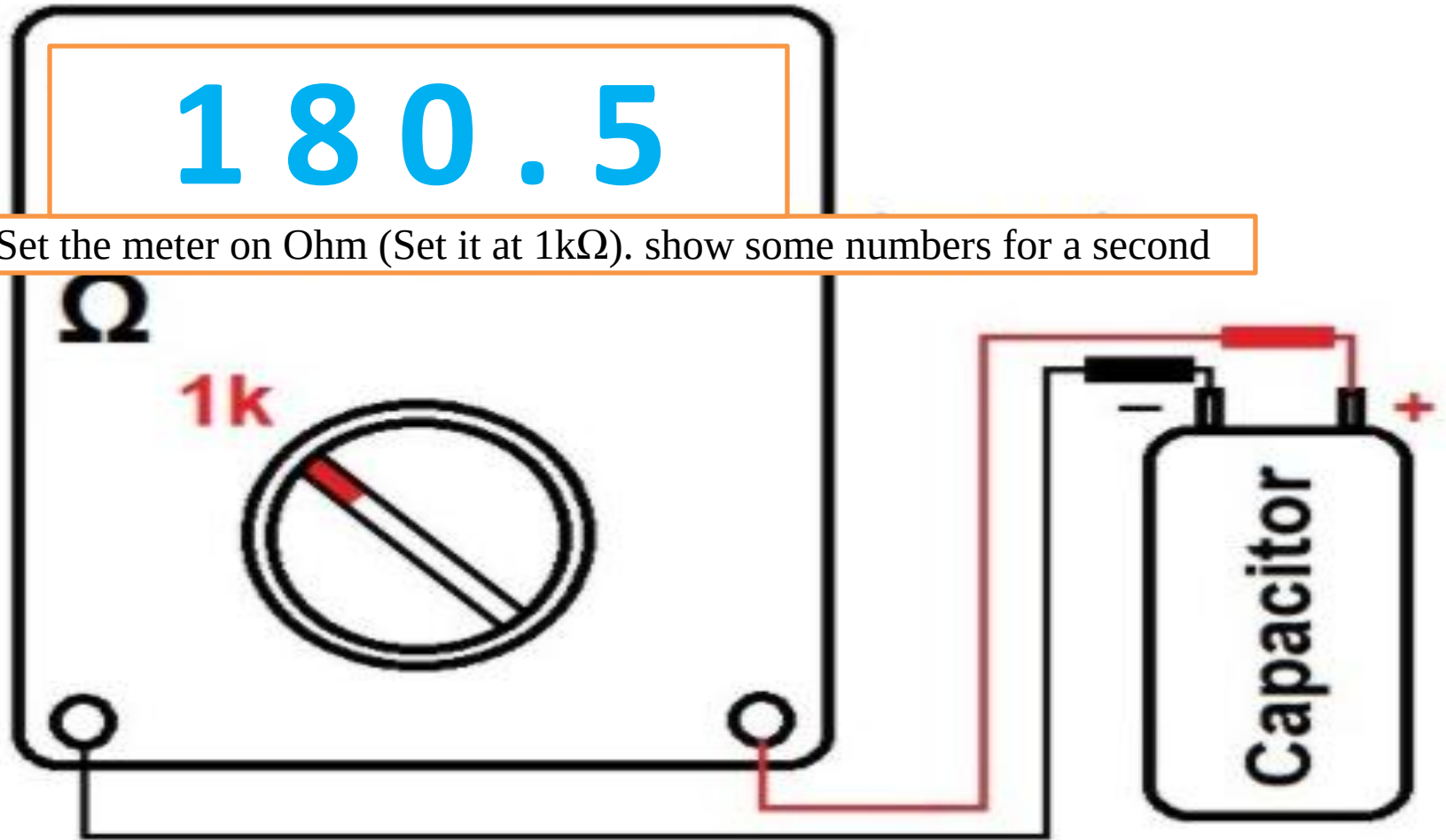
Capacitor Testing by DMM

1. Make sure the capacitor is discharged.
2. Set the meter on Ohm (Set it at $1000\text{Ohm} = 1\text{k}$).
3. Connect the meter leads to the capacitor terminals.
4. Digital meter will show some numbers for a second. Note the reading.
5. And then immediately it will return to the OL (Open Line). Every attempt of Step 2 will show the same result as was in step 4 and Step 5. It's mean that **Capacitor is in Good Condition**.
6. If there is no Change, then **Capacitor is dead**.

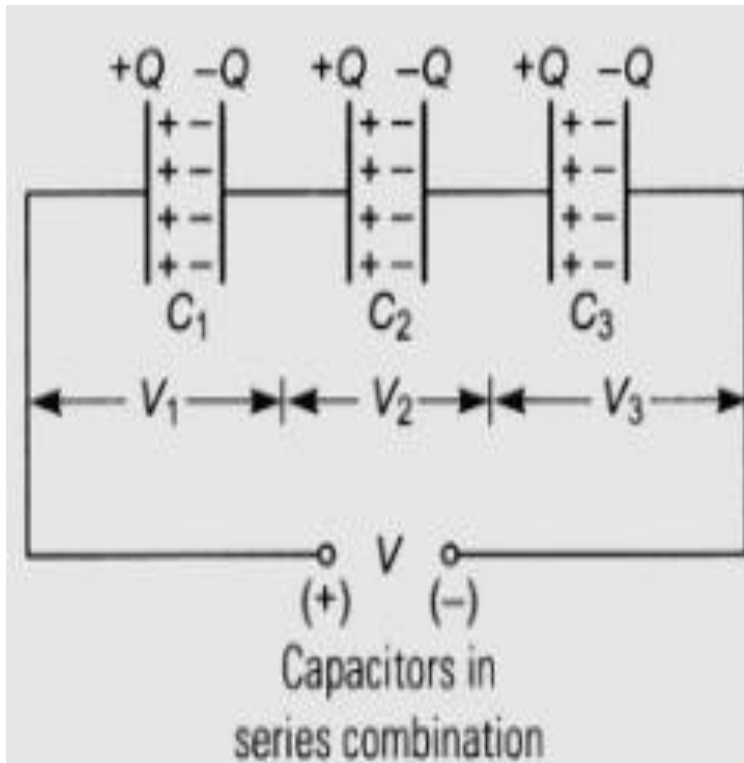
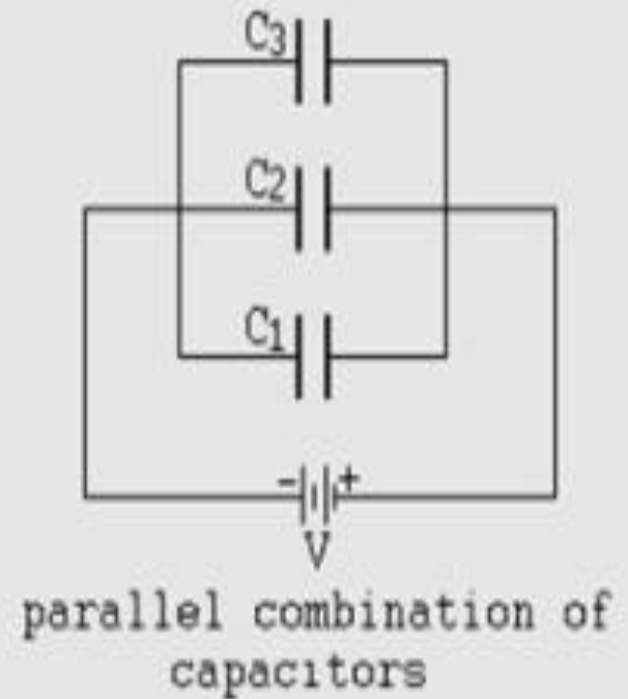
Capacitor Testing by DMM

180.5

Set the meter on Ohm (Set it at $1k\Omega$). show some numbers for a second



Combination of Capacitor



Combination of Capacitor

- Series Combination:

$$C_s = \frac{Q}{V}$$

$$\text{Or } V = \frac{Q}{C_s}$$

Substituting the values in the equation (i),

$$\frac{Q}{C_s} = \frac{Q}{C_1} + \frac{Q}{C_2} + \frac{Q}{C_3}$$

$$\therefore \frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

For n number capacitor

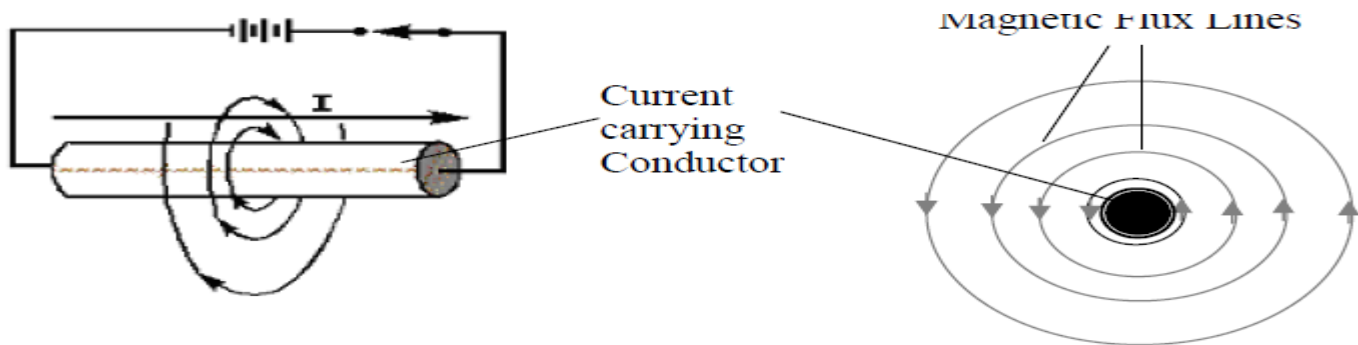
$$\frac{1}{C_s} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \dots + \frac{1}{C_n}$$

- Parallel Combination:

$$C = C_1 + C_2 + C_3 + \dots + C_n$$

Inductance

- When current flows through a wire or conductor a magnetic field is created around the conductor.



- An inductor is a piece wire wound in the form of a coil and current flowing through the coil produces a magnetic field

Inductance

- The current flowing through coil induces current in opposite to that of the original current flow, which caused the changing magnetic field around the coil and property is also called as **self-inductance**.
- A component, which possesses self-inductance is called inductor.
- Inductance is expressed by the symbol L and its unit of measurement is Henry, indicated by H.

Inductance

- One Henry is the inductance when current through the coil, changing at the rate of one ampere per second, induces one volt across the coil.

- Induced voltage is directly proportional to di/dt

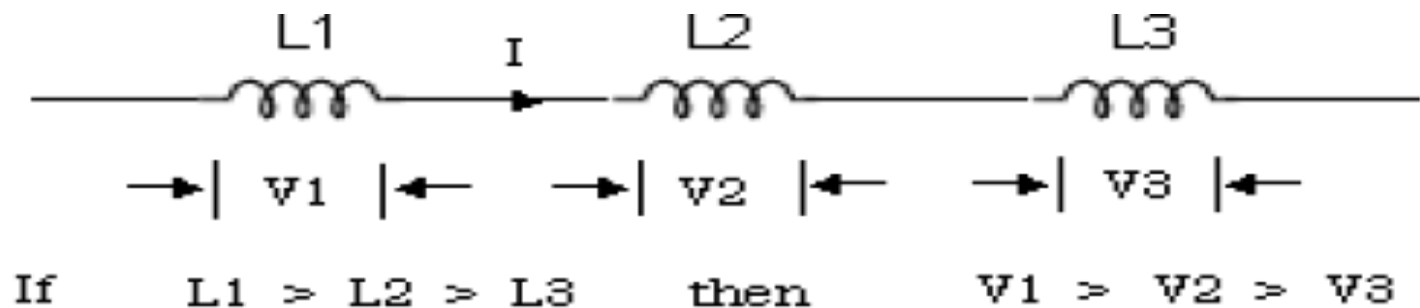
$$V_{\text{induced}} \propto di/dt \text{ or}$$

$$V_{\text{induced}} = L (di/dt).$$

Where, di/dt is the rate of change of current through the coil.

Inductance

- When constant current I is flowing through inductor, the induced voltage are proportional to their inductance values L . The higher is the L the more the induced voltage.



Inductance

- **Physical Factors that affect the value of inductance:**
- No. of turns in the coil and Core
- $$L = \frac{N^2 \mu A}{l}$$
- Where L inductance in Henries
- N no. of turns in the coil
- μ Permeability of the core material
- A cross sectional area in sq.mtrs, 'L' length of the coil

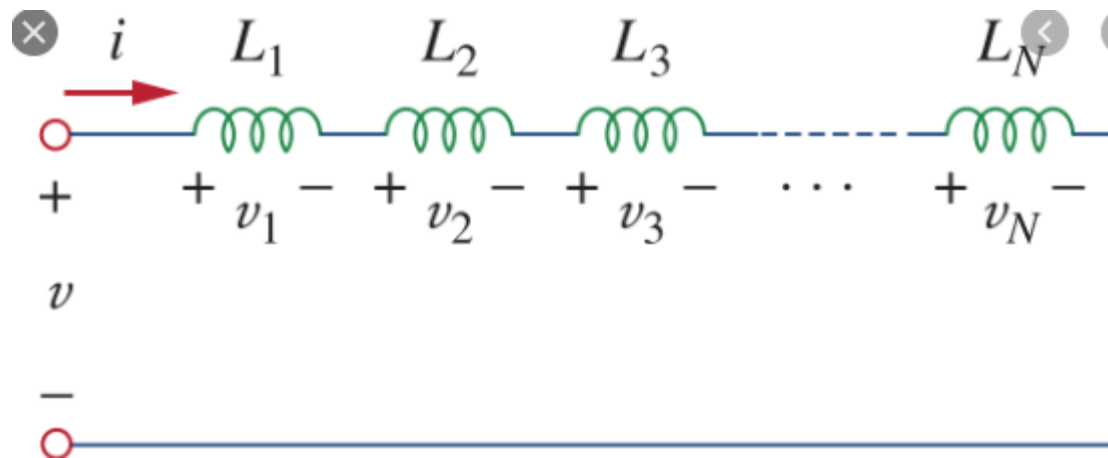
Inductance

- **Energy stored in inductor:** The energy stored in an inductor depends on the value of inductance, L , and the current, I , flowing through it.
- $E = \frac{1}{2} LI^2$
- **Inductive Reactance** :It is the opposition to sinusoidal current and expressed in ohms. Inductive reactance is given by the formula $X_L = 2\pi f L$

Where X_L is inductive reactance in ohms

Combination of Inductor

- Series Inductance:

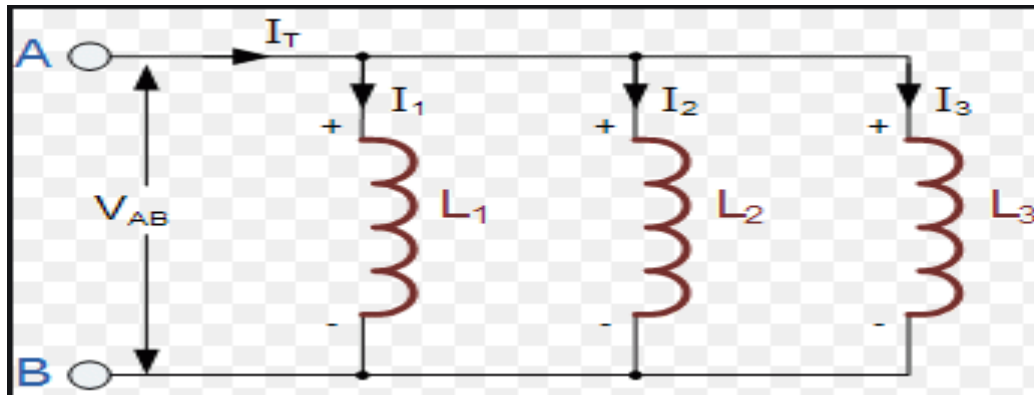


Series Inductances

$$\mathbf{L}_{\text{total}} = \mathbf{L}_1 + \mathbf{L}_2 + \dots \mathbf{L}_n$$

Combination of Inductor

- Parallel Combination:



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

Types of Inductor

Wire-Wound



NFC & Wireless Charging



Examples provided by Vishay website
www.vishay.com



Printed



Compilation by
www.RFCafe.com



Examples provided by Piconics website
www.piconics.com

Ceramic



Tunable



Examples provided by TDK / EPCOS website
www.tdk.com

Usage

1. Used in DC Track circuit as choke.
2. Filter Circuit
3. DC-DC converter.
4. Tuned Circuit
5. Relays
6. Sensor
7. Induction Motor, Tube light

LAWS AND THEOREMS

- Ohm's law
- **Kirchhoff's Laws:**
 - i) Kirchhoff's Current Law (KCL) and
 - ii) Kirchhoff's Voltage Law (KVL)
- **Theorems:**
 - i) Star-Delta Transformations
 - ii) Superposition Theorem
 - iii) Norton's Theorem
 - iv) Thevenin's Theorem
 - v) Maximum power transfer Theorem
 - vi) Reciprocity Theorem
 - vii) Compensation Theorem

Ohm's law

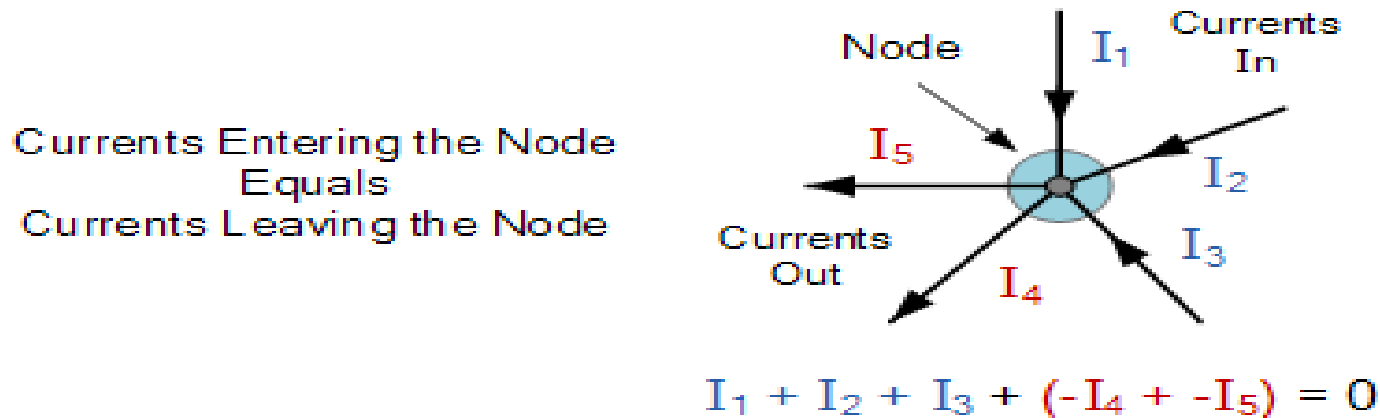
- Ohm's Law : The temperature and other physical conditions of the conductor being unchanged, the potential difference (V) between any two points on a passive, linear circuit element is directly proportional to the current (I) flowing between these points.
- i.e., $V \propto I$,

$$\frac{V}{I} = \text{constant} = R \text{ (Resistance)}$$

Kirchhoffs Current Law or KCL

- **Kirchhoffs Current Law** or KCL, states that the “*total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node*“. In other words the algebraic sum of ALL the currents entering and leaving a node must be equal to zero, $I_{(\text{exiting})} + I_{(\text{entering})} = 0$. This idea by Kirchhoff is commonly known as the **Conservation of Charge**.

Kirchhoff's Current Law or KCL



- Here, the three currents entering the node, I_1 , I_2 , I_3 are all positive in value and the two currents leaving the node, I_4 and I_5 are negative in value. Then this means we can also rewrite the equation as;

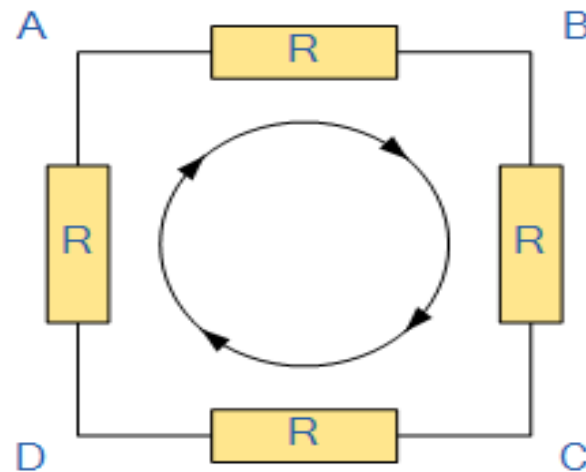
$$I_1 + I_2 + I_3 - I_4 - I_5 = 0$$

Kirchhoff's Voltage Law or KVL

- **Kirchhoff's Voltage Law** or KVL, states that “*in any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop*” which is also equal to zero. In other words the algebraic sum of all voltages within the loop must be equal to zero. This idea by Kirchhoff is known as the **Conservation of Energy**

Kirchhoff's Voltage Law or KVL

The sum of all the Voltage Drops around the loop is equal to Zero



$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$$

Impedance

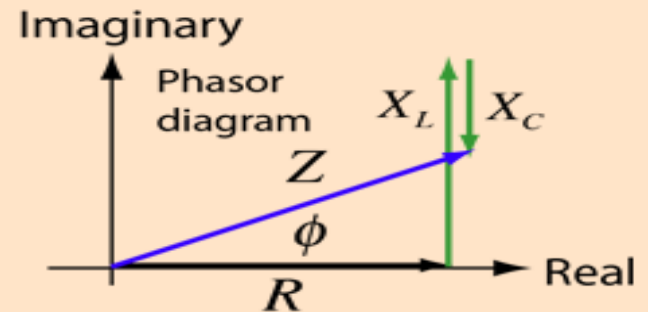
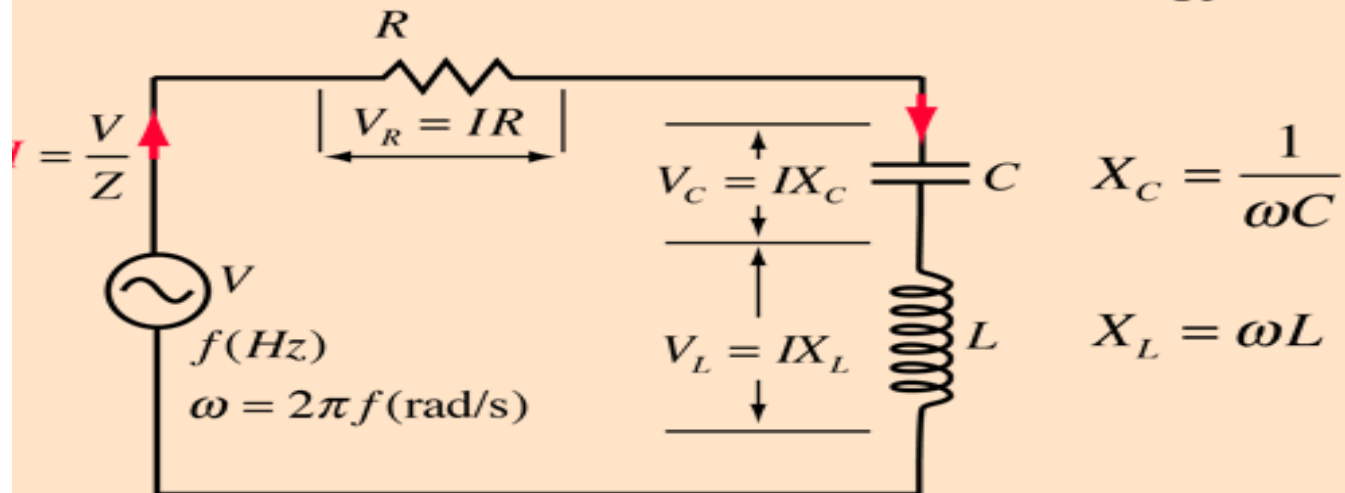
- Impedance is often mistakenly said to be the same as resistance, which is not correct. Impedance is a two-dimensional quantity comprising resistance (real component vector) and reactance (imaginary component vector). Impedance is also known as the frequency domain ratio of voltage and current. Frequency is involved because of alternating current (AC) whose sinusoidal wave is generated upon a certain frequency which directly or indirectly affects electrical components such as capacitors and inductors, whose resistance varies with frequency of the power source provided.

Impedance

Series resonant condition:

$$Z = R \quad \omega = \frac{1}{\sqrt{LC}}$$

$$X_C = X_L \quad \text{Phase} = \phi = 0$$

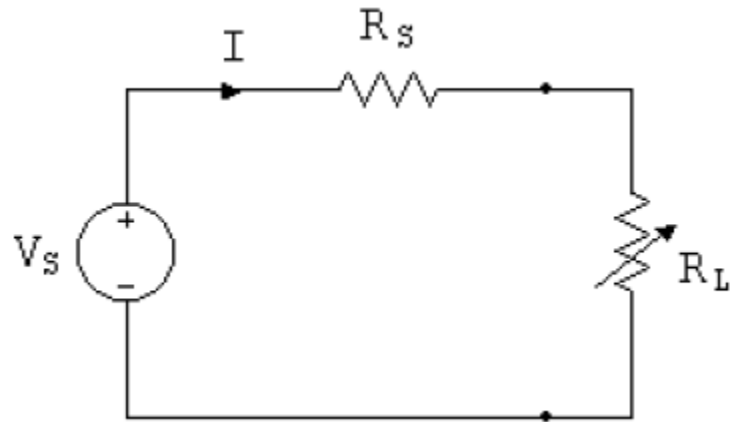


$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\text{Phase} = \phi = \tan^{-1} \left[\frac{X_L - X_C}{R} \right]$$

Maximum Power Transfer Theorem

- Maximum power transfer theorem states that ‘maximum power is delivered from source to a load when the load resistance is equal to the source resistance.
- $R_s = R_L$



Maximum Power Transfer Theorem

- On the basis of this theorem isolation transformer is used at following place.
- In cable hut with every pair.
- Cable joint of emergency post
- In PA System, loudspeaker and amplifier
- TMS Kit or dB meter.

TRANSFORMER & HYBRID

- A **transformer** is an electrical device that transfers energy from one electrical circuit to another by magnetic coupling without using any physical connection between them.
- Any device, which provides impedance matching between certain circuits and isolation between other circuits, may be referred as a '**Hybrid**'.
- Example: Transformer, a resistance bridge, or a wave-guide device for Microwave Frequencies.

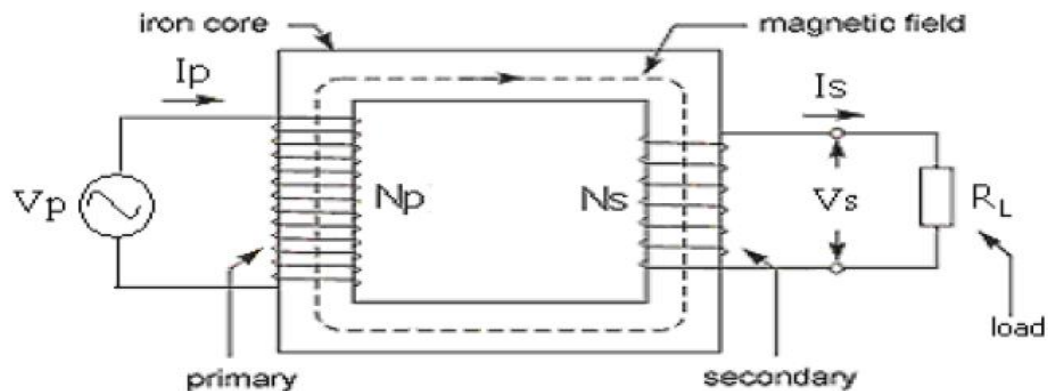
TRANSFORMER

- Transformer is used to convert between high and low voltages and for impedance transformation.
- It works on the principle of mutual inductance between two (or more) coils.
- It allows us to '**step up**' or '**step down**' the magnitude of an a.c. voltage by an amount, which depends upon the transformer's *turns ratio* between the coils.
- Turns ratio = N_p / N_s , also, $\frac{N_p}{N_s} = \frac{V_p}{V_s}$

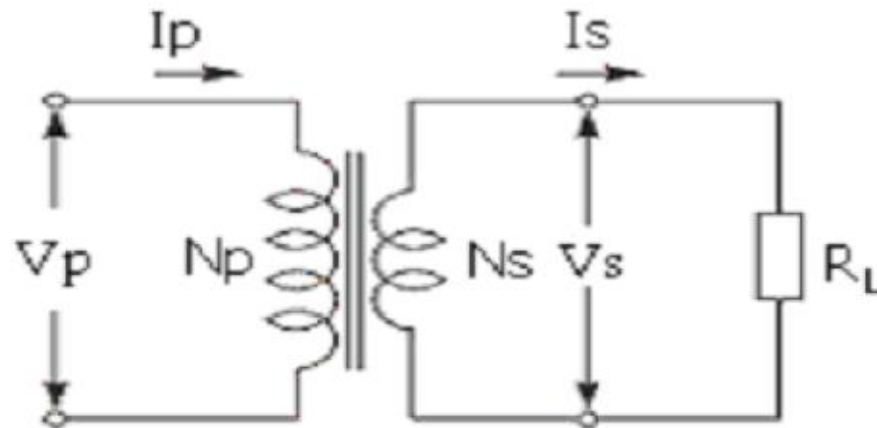
Where N_p is the no. of turns in primary winding and N_s is the no. of turns in secondary winding

TRANSFORMER

- Transformer construction:



- Transformer symbol:



TRANSFORMER

- Relation between the primary and the secondary current is described as ,

$$\frac{N_p}{N_s} = \frac{I_s}{I_p}$$

Transformer power can be calculated by one of the formulae

$$P = I_s V_s = I_p V_p$$

Efficiency of transformer is given as $\eta = \frac{P_s}{P_p}$

Impedance Matching with Transformer

- The relationship between the ratios of different transformer parameters is given as
- $\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$
- Effective Primary resistance = (Load resistance in secondary) $\times$ (Turns ratio)²

Q. 1: What turns ratio is required for a transformer to match a 640W audio power amplifier with an 8W speaker?

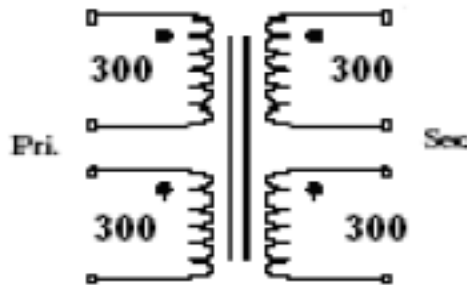
Q.2. The output voltage of an amplifier is 50V. This output voltage is to drive a loud speaker of 4W and 25W power, through a matching transformer. What should be the turns ratio for the transformer?

Hybrid

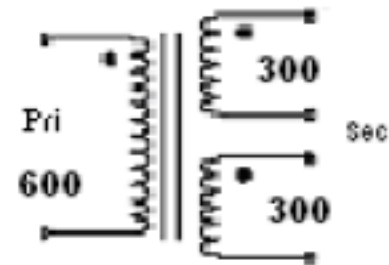
- The function of the Hybrid is to permit signals to pass freely between adjacent arms of the network, but to block signal passage between opposite arms.
- Ideally, a hybrid would have infinite loss between opposite sides and at the same time, there would be no loss between adjacent arms.
- The isolation between transmit and receive branches of the four wire line is called 'Trans Hybrid Loss'.
- The undesired loss between the two-wire line and the four-wire line is usually called 'Insertion Loss'. If the balance is not maintained, echoes may occur.
- There are mainly two types of hybrids namely
 - i) Transformer Hybrid and ii) Resistance Hybrid.

Transformer Hybrid

- It consists of basically two transformers and a balancing network. These transformers can be either 4-winding type or 3-winding type as shown below

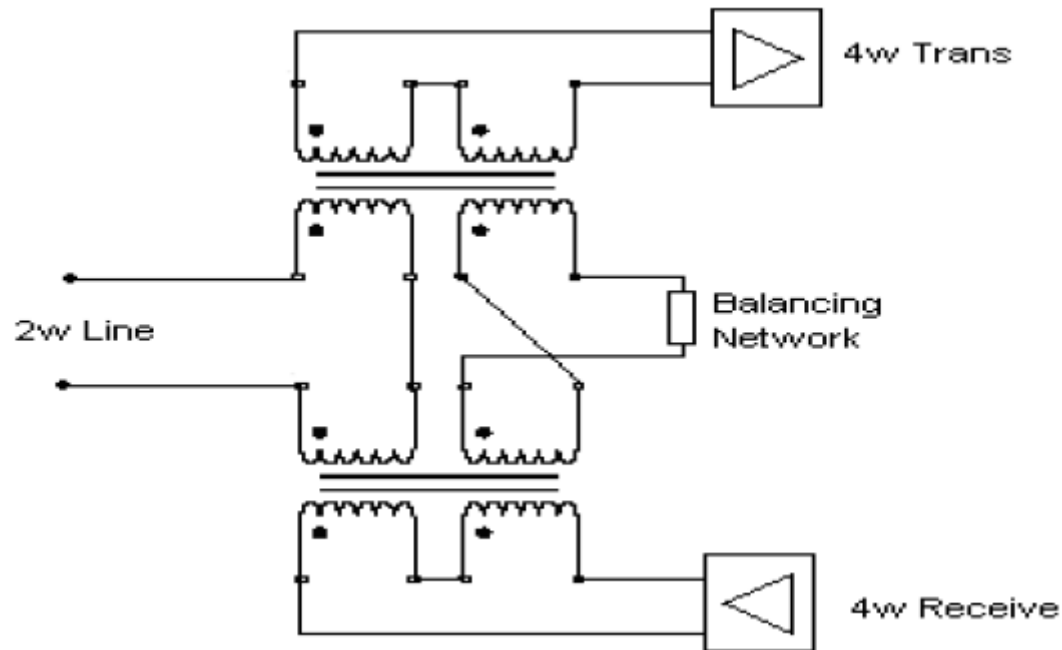


(a) Four winding type

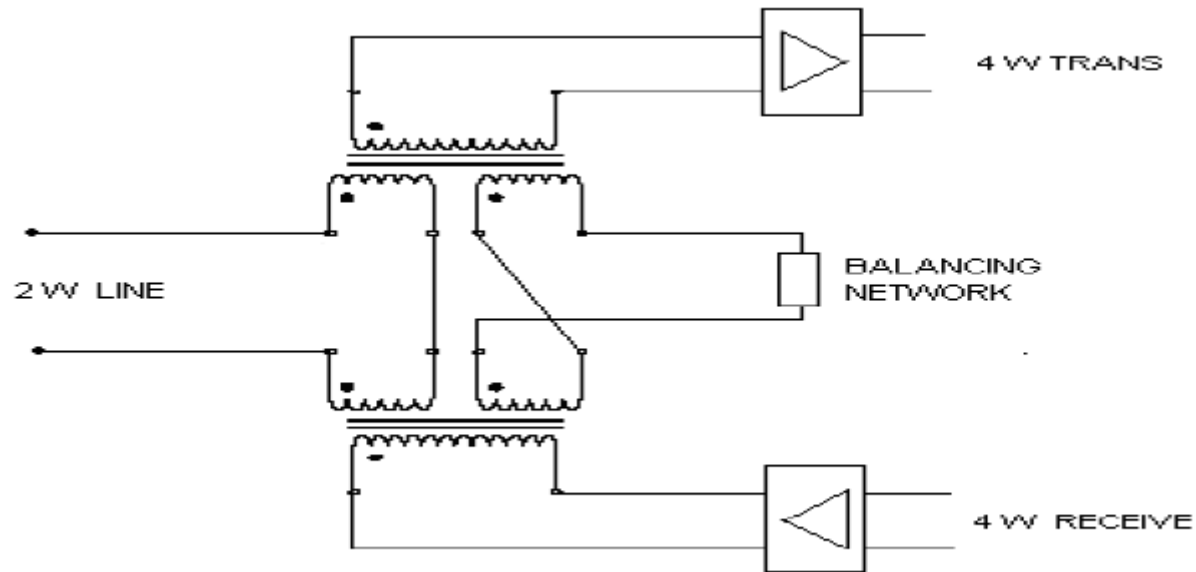


(b) Three winding type

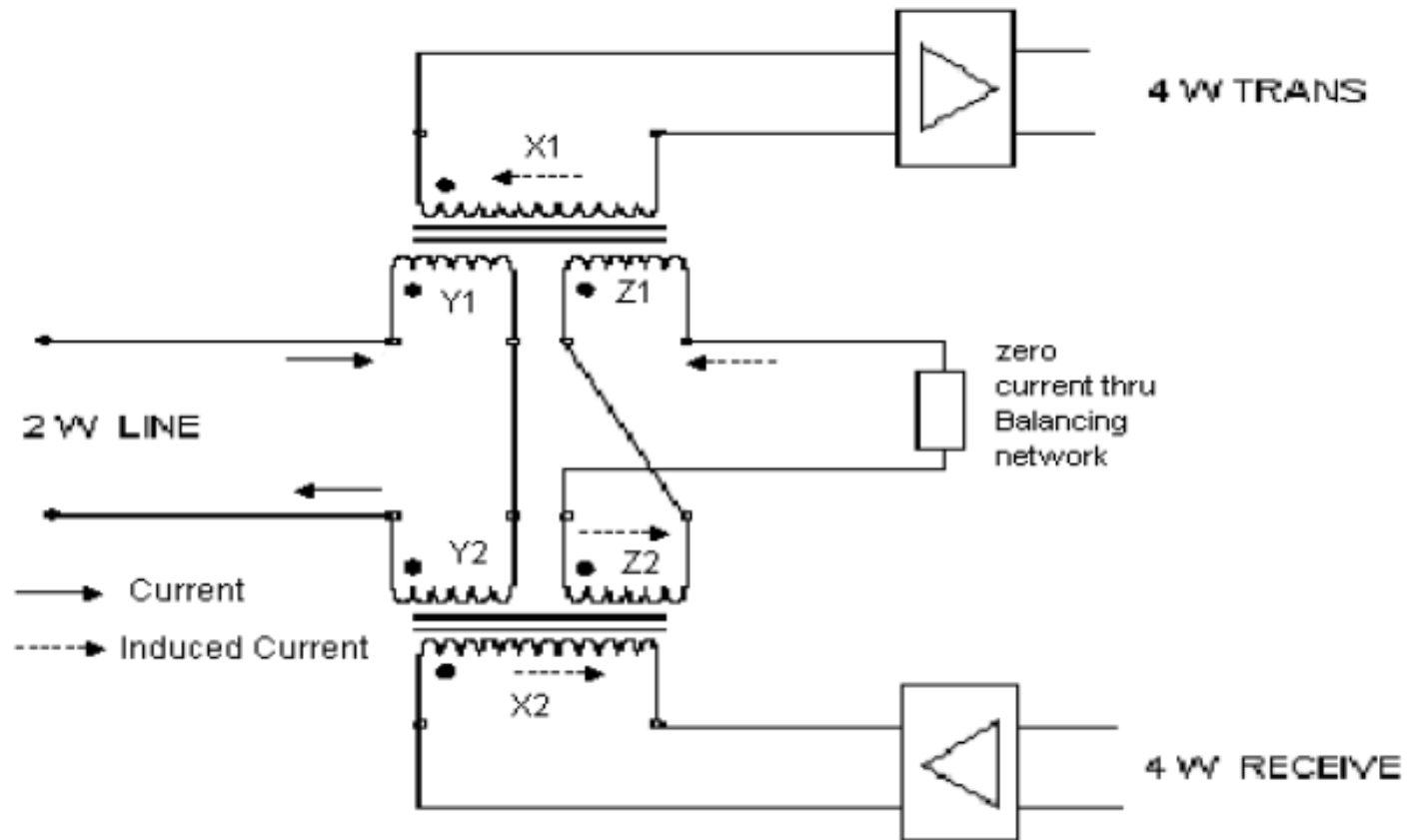
Transformer Hybrid(4 winding type)



Transformer Hybrid(3 winding type)



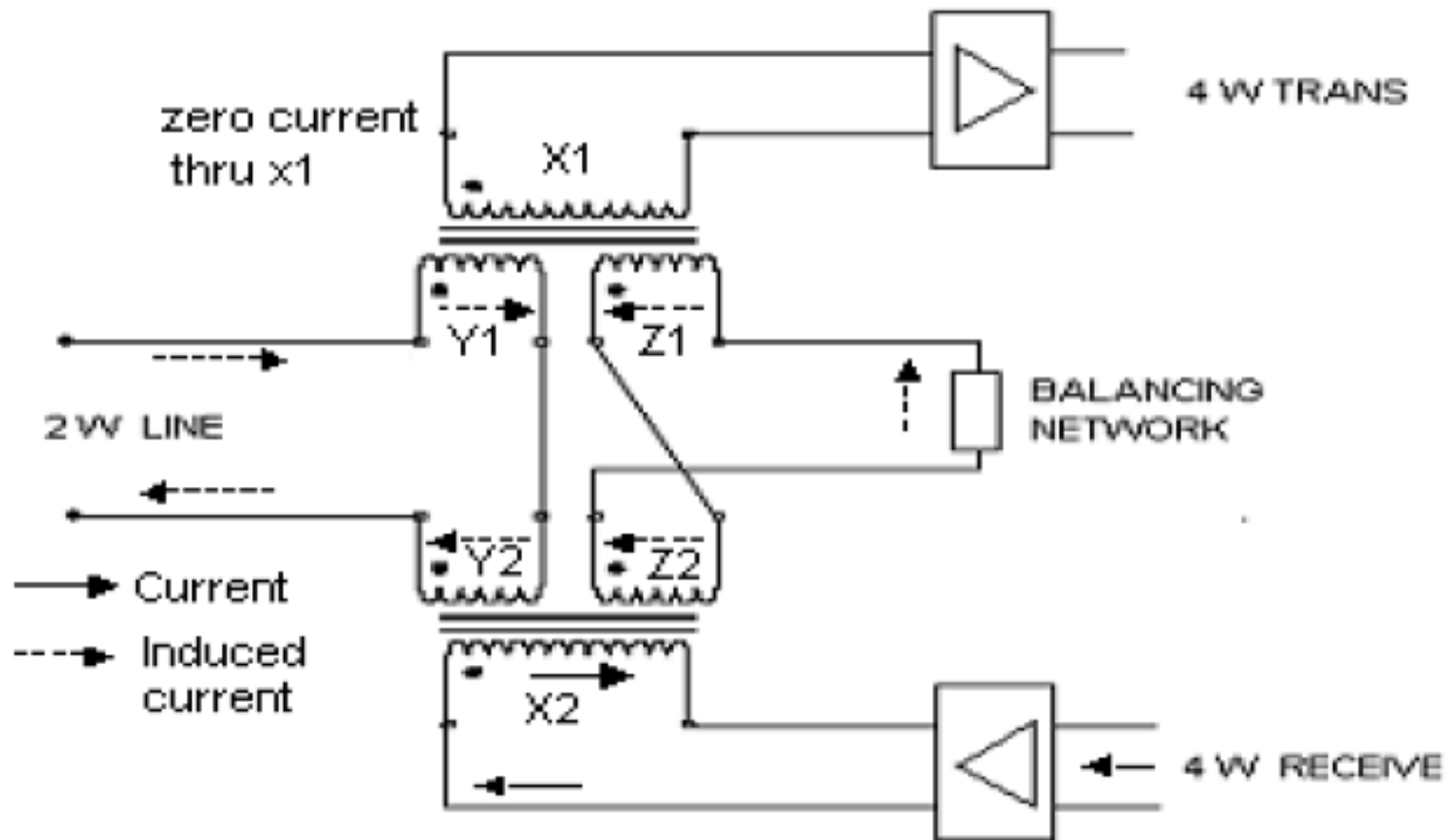
2 wire Trans to 4 wire Trans direction



2 wire Trans to 4 wire Trans direction

- 2w Trans current induces equal currents in both trans winding and receive winding.
- Hence half of the power is wasted in receive winding and net 4w Trans output is 3dB (min.) less to 2w trans power.
- No current flows through balancing network.

4W Receive to 2W Receive direction

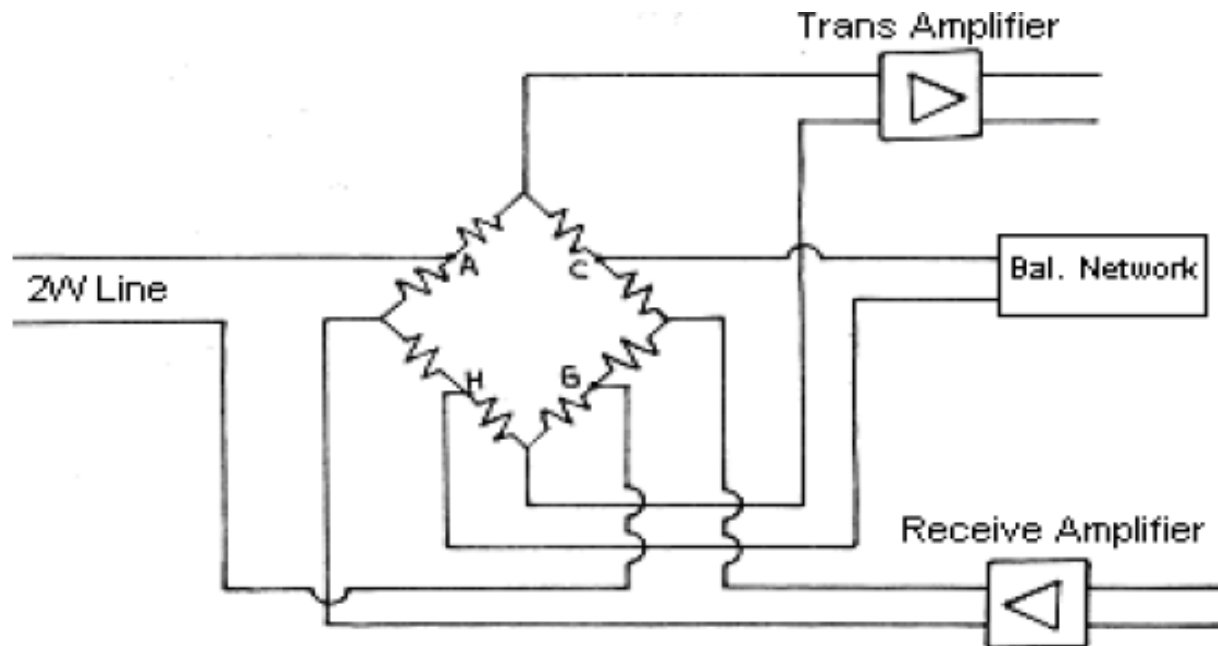


4W Receive to 2W Receive direction

- 4w receive signal induces equal currents in both 2w line and balancing network.
- No induced current in 4w trans winding due to equal and opposing currents in 2w line and balancing network.
- As a result, total isolation between 4w receive and 4w trans is achieved in this direction.

Resistance Hybrid

- It consists of 4 equal center tapped resistors.



Usage

- For voice frequency (300 - 3400 Hz) applications, the transmission loss of a resistance hybrid is 6db to 9.5 dB. In this frequency range the transformer hybrid is widely used because it introduces less loss (3.5 dB) as compared to resistance hybrid (6 dB minimum). But for frequencies above 1 MHz, the transformer losses increase and resistance hybrid is preferable. For this reason, in Microwave Radio equipment the resistance hybrids are widely used

Magnetism

- **Magnetism** is defined as the property of a magnetic material which able them to create an attraction or repulsion force.
- The earth behaves as a magnet with the magnetic field pointing approximately from the geographic south to the north.
- When a bar magnet is freely suspended, it points lie in the north-south direction.

Magnetism

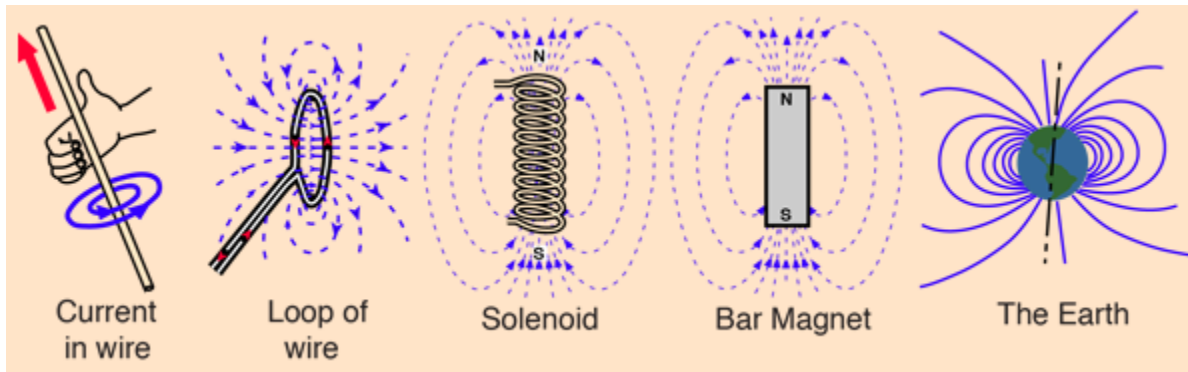
- There is a repulsive force when same poles of two magnets are brought close together.
- There is an attractive force between the opposite poles of the magnet.
- We cannot isolate the north or south pole of a magnet.
- It is possible to make magnets from iron, steel and its alloys.

Magnetism

- When bar magnets suspended freely, their north and south poles align themselves with geographical north and south poles.

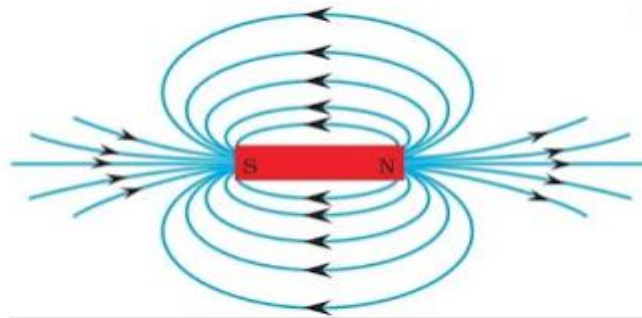


Magnetic Field



Magnetic field Lines

- The magnetic field lines of a magnet (or a solenoid) are continuous.
- The larger the number of field lines crossing per unit area, the stronger is the magnitude of the magnetic field B .
- The magnetic field lines do not intersect each other



Classification of Magnet

1. Permanent Magnet

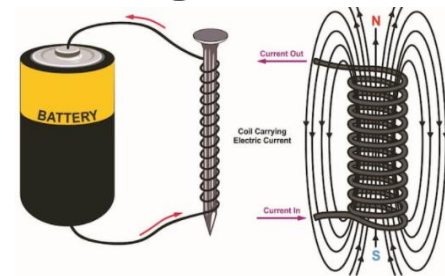
2. Temporary Magnet

Permanent Magnet that retain their magnetism once magnetized. Lodestone (also called *Magnetite* Fe_3O_4) is a naturally-occurring “permanent” magnet mineral.

- *Ferromagnetic* (Easily magnetized).
- *Paramagnetic* (Slightly magnetic).
- *Diamagnetic* (Tends to repel external magnetic fields by magnetizing in the opposite direction).

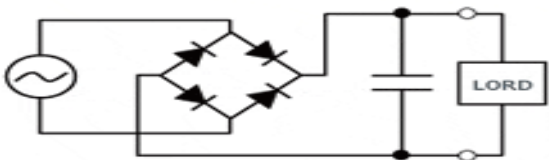
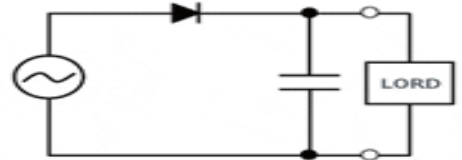
Temporary Magnet

- **Temporary Magnet:** Made from soft metals, and only retain their magnetism while near a permanent magnetic field or electronic current. i.e lose magnetism when not in magnetic field.
- Electromagnetism are wound coil of naked wire around core of soft ferromagnetic material(Steel) that function as magnets when an electric current is passed.

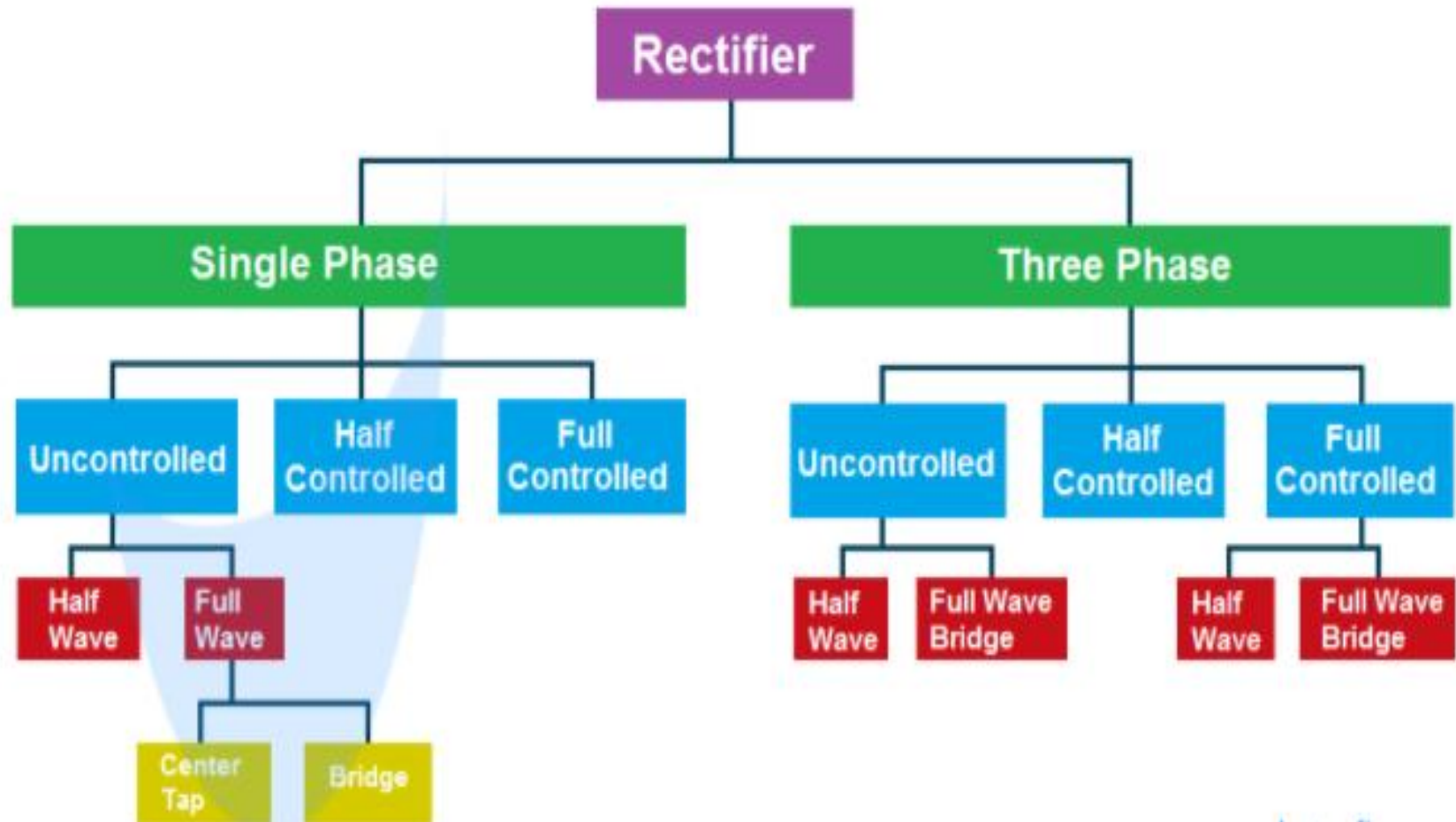


Rectifier

- A **rectifier** is an electrical device comprises of one or more diodes which allow the flow of current only in one direction. It basically converts alternating current into direct current.

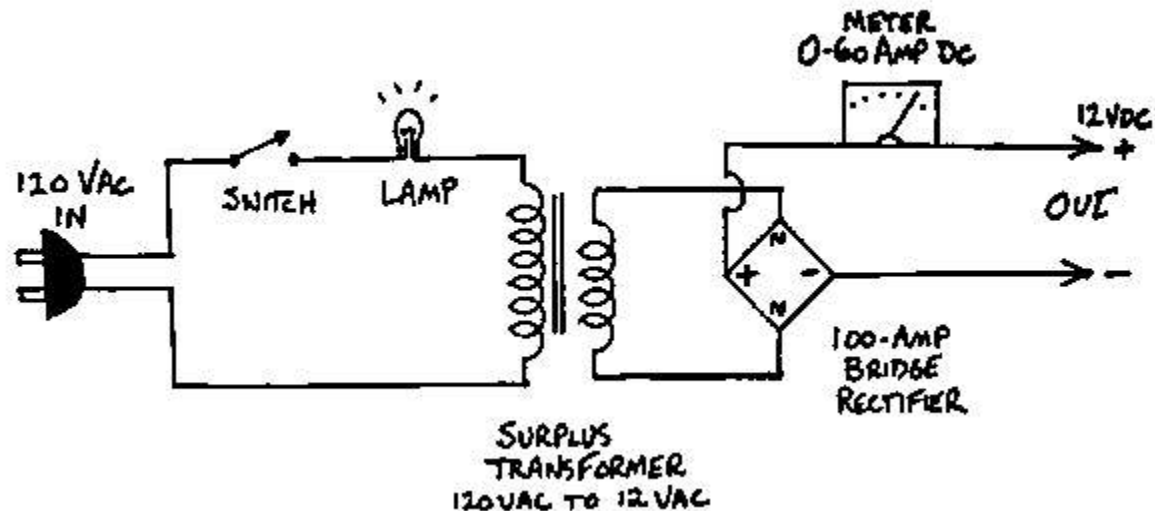
	Full-Wave Rectification	Half-Wave Rectification
Circuit Configuration		
Input Voltage Waveform		
Voltage Waveform After Rectification		
Voltage Waveform After Rectification Smoothing		

Rectifier



Battery Charger

- Charger is a device to charge the secondary cell by forcing electric current.
- Linear Regulated PSU is used in conventional chargers.

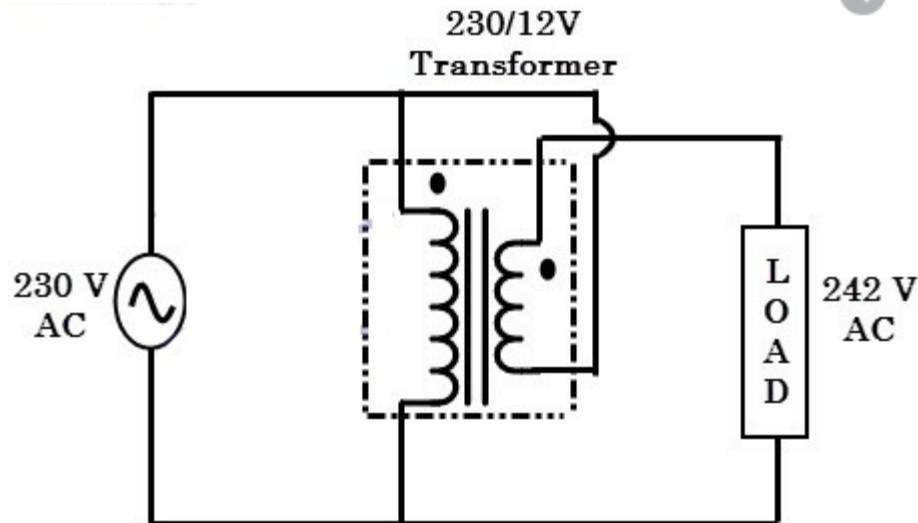


Linear Regulated PSU

- Simple in design, Efficiency $< 50\%$, bulky and less reliable.
- Shall work within 160V - 270V range and its of Self-regulating type
- In auto mode of working, If current across battery terminals increases by 8-12% of the rated current, the output voltage of the charger automatically change to 2.4V/cell (Boost mode)
- If batteries gets fully charged and the current drawn by batteries is less than 5% of rated current value the charger automatically changes to 2.15V/cell(Float mode) which is normal O/P V of charger

Stabilizer

- Stabilizer used for maintaining the voltage quantity stable in a power system is called as voltage stabilizer



Inverter

- It is an electronic device or circuitry that changes Direct Current (DC) to Alternating Current (AC)
- The inverter does not produce any power; the power is provided by the DC source.



DC-DC Converter

- A **DC-to-DC converter** is an electronic circuit device that converts a source of Direct Current (DC) from one voltage level to another.



THE END

Thank You