SEMESTER – V

Applications of Electricity & Magnetism

UNIT - I : Introduction to Passive Elements

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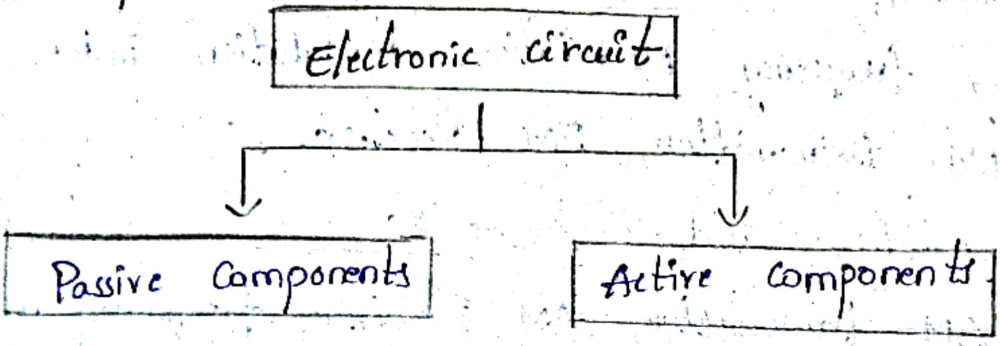
UNIT-I Introduction to Passive Elements.

Part - A . Passive elements.

An electronic circuit is comprised of two different types of components.



Eg : R, L & C

* **Passive Components :**

The components which are not capable of amplifying (or) Processing an electric Signal are passive components.

* **Active Components :**

Components which Provide amplification (or) Switching are called active components.

(i) Resistors :

An electrical component that limits (or) regulates the flow of electric current in a circuit

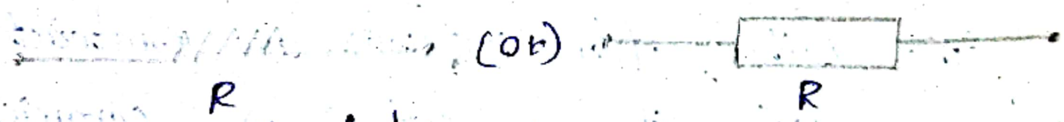
units ohms.

Resistors are used to Control current levels, divide voltage, & ensure circuits function Properly.

Resistors

- linear
  - Fixed
    - carbon composition
    - Carbon film
    - Metal film
    - wire wound
  - variable
    - potentiometer (control voltage). used in
      1. Audio volume control
      2. voltage regulation.
    - Rheostat (control current)
      1. light i.e; control brightness of light.
- non-linear
  - thermistors, (temperature)
  - photo resistors (light).

Fixed Resistors : Have a constant resistance value & cannot be changed.

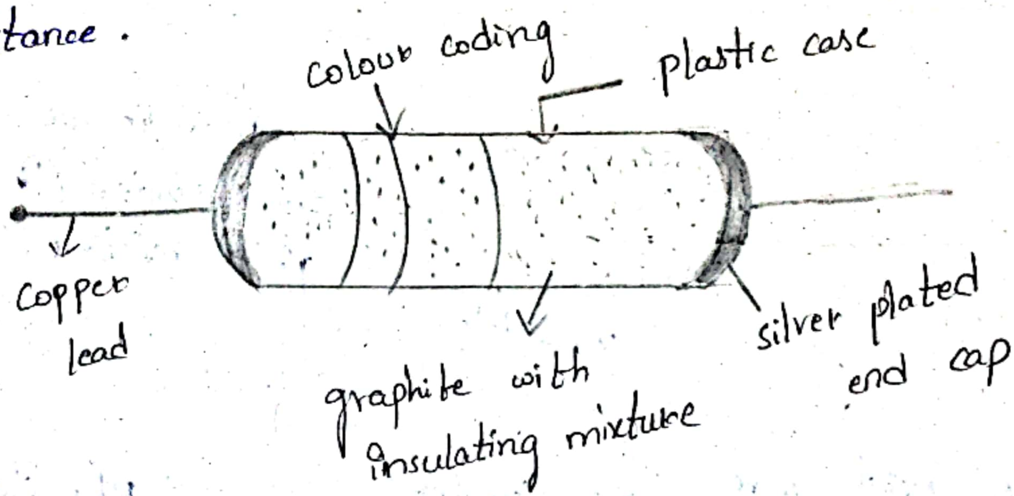


They are classified as,

* Carbon Composition Resistors :

They are made of graphite (or) finely ground carbon mixed with a powdered insulating material in suitable proportional. Graphite is a moderately good conductor. The ratio of graphite to insulating material determines the final value of resistance.

The mixture is compressed in the form of a cylindrical rod. The ends of this rod are joined to silver plated end caps with leads of Copper wires. Finally, the whole resistor is moduled in plastic case with coloured bands for specifying its resistance.



* Advantages :
  * cheap & reliable.
  * stability is very high.

* Drawback :
  * Develop electric noise.

* Carbon Film resistors :

The Carbon film resistors are constructed by depositing a thin film of carbon on ceramic rod (or) Core.

→ Smaller values of resistance &

→ lower tolerance.

→ midly negative temperature coefficient which is useful in certain electrons circuits.

* Metal film Resistors : (thin film resistors)

These are constructed by deposing a thin metal coating (using deposition ~~temper~~ techniques) on an insulating (glass, ceramic) substance. The resistance is determined by the thickness of the film Small size then wire-wound resistors.

⇒ range in values upto 10,000 MΩ.

* Advantage :

→ High accuracy.

→ low temperature coefficient.

→ low noise.

→ Excellent tolerance.

* Wire wound Resistors :

The wire wound Resistors are manufactured by winding a resistance wire around insulating hallow cylindrical core. Usually wires of materials such as constantan (60% Copper, 40% nickel) and manganin are used.

These materials have high resistivities & low temperature coefficients.

The range of resistance values of wire wound resistors varies from resistance values of wire wound 1Ω to 1MΩ by varying length.

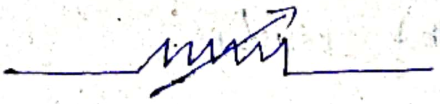
Advantage :

→ More accurate than Carbon Composition resistors.

Drawback :

→ Inductance arises due to winding at high frequencies, these resistors are not suitable.

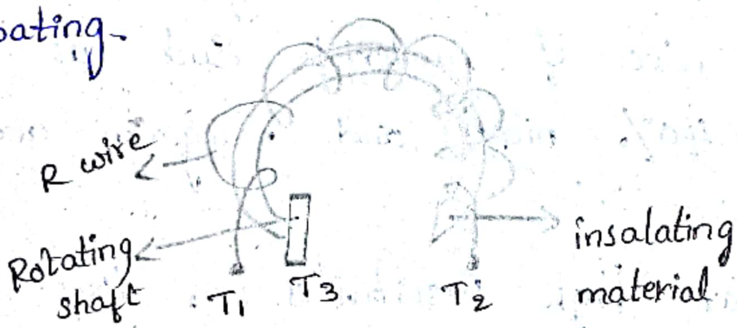
⇒ Variable Resistors :

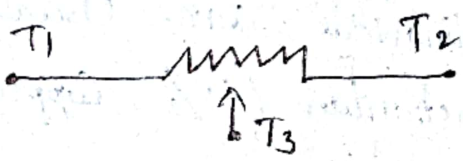


These are the resistors whose resistance can be changed between zero & a certain maximum value used to adjust the values of voltage & currents.

Ex : Volume Control in radio & brightness Control in T.V.

They are made of resistance wire (usually copper alloy wire for low R & nickel-chromium for high R) wound on a ceramic core caused with insulating coating.

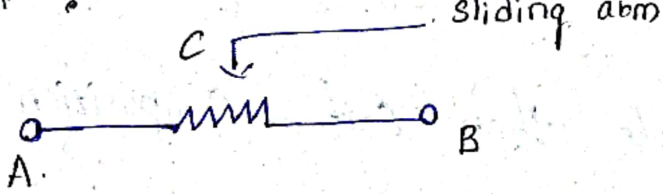




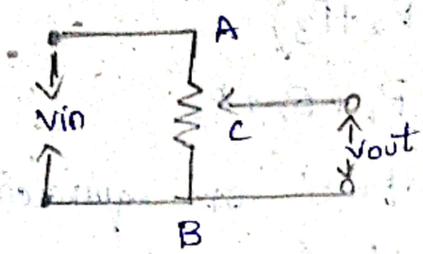
→ T_3 moves towards T_2 then resistance b/w T_1 & T_3 increases.

→ T_3 moves toward T_1 then R b/w T_1 & T_3 decreases.

* Potentiometer :

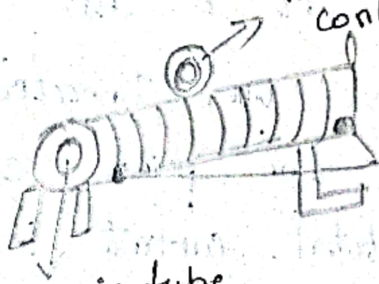


This is a three terminal variable resistor. It is often used as voltage dividers to Control (or) vary voltage across a circuit - branch.



* Rheostat :

A wire wound potentiometer that can dissipate more then 5W is reffored as rheostat.



→ Commonly used to control relatively high currents such as those found in motor & lamp loads.

(9) * Resistors in series combination (voltage division) :

It is also known as voltage division circuit. Resistors are connected end-to-end, forming a single path for current flow. The circuit consists of three resistors R_1, R_2 & R_3 connected in series with a voltage source V. In this circuit combination, the amount of current flow through all the resistors is the same. The voltage across each resistor is different.

According to the KVL, $V - V_1 - V_2 - V_3 = 0$.

$$V = V_1 + V_2 + V_3$$

$$IR = IR_1 + IR_2 + IR_3$$

$$IR = I(R_1 + R_2 + R_3)$$

$$R \text{ (or) } R_{eq} = R_1 + R_2 + R_3$$

Hence, the total resistance or equivalent resistance is the sum of the individual resistances.

(3) * Resistors in parallel Combination [Current division]:

It is also known as Current division Circuit. Resistors are Connected with both ends connected to the same two points, creating multiple paths for current flow the total current is divided among all the parallel resistors. The voltage across each resistor is the Same and equal to the source voltage.

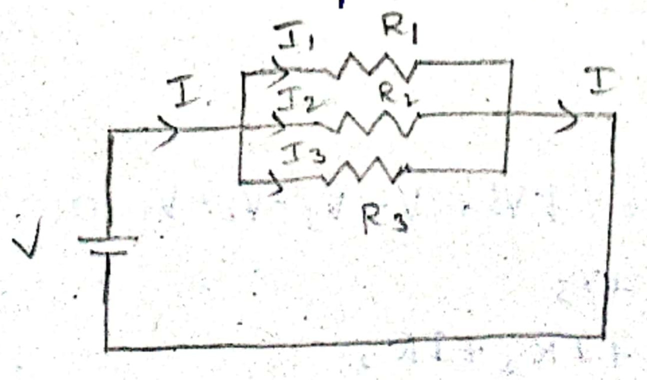
The circuit consists of three resistors R_1, R_2 & R_3 Connected in parallel with a voltage source V. Current through each resistor can be found using Ohm's law $I = \frac{V}{R}$, where the voltage is constant across each resistor.

According to the KCL, $I = I_1 + I_2 + I_3$

$$\frac{V}{R} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$V \cdot \frac{1}{R} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

$$\frac{1}{R_{eq}} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$



Hence, the inverse of the total resistance is the sum of the inverse of the individual resistance.

(4) * Inductors.

When a current is passed through a conductor, the lines of magnetic flux are generated around it. The magnetic flux opposes any change in ~~change~~ current due to induced e.m.f. The opposition to change in current is known as inductance. Therefore, the component which produces inductance is known as inductor.

The induced e.m.f. (e) in an inductor is given by

$$e = -L \left[\frac{dI}{dt}\right]$$

where, L = inductance in henry.

and $\left[\frac{dI}{dt}\right]$ = rate of change of current.

(5) * E.M.F. Induced in an Inductor.

When a current flows in a coil, magnetic field is developed in it as shown in Fig. (12 a).

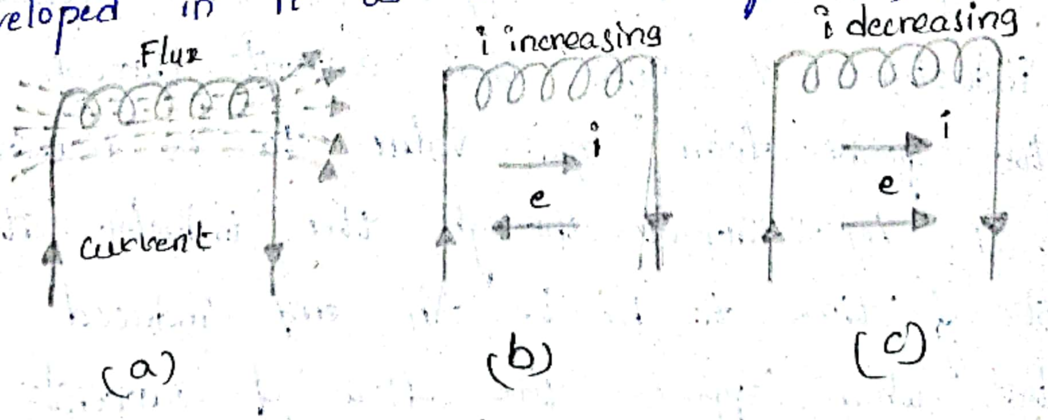


Fig.[12]

If the current passing through the coil changes with time, an induced E.M.F. is set up in the

Coil. By Lenz's law, the direction of induced e.m.f. is such as to oppose the change in current. when the current is increasing, the induced E.M.F. is against the current [Fig. (12 b)] and when the current is decreasing it is in the direction of current [Fig.(12C)]. So the induced e.m.f. opposes any change of the original current. This phenomenon is called self induction. This resembles with inertia in mechanics.

when the current in a coil is switched on, self induction opposes the growth of the current, and when current is swiched off, the self induction is opposes the decay of current as shown in Fig. (13).

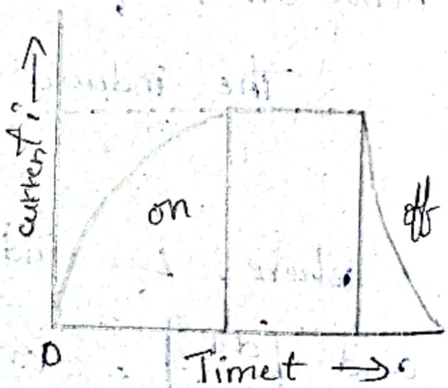


Fig.(13)

⑥ Energy Stored in an Inductor :

A current I is applied to an inductor coil of inductance L such that current through the inductor grows from zero value to a maximum value I. Let current through the inductor at any instant of time t be i. An emf induced in the inductor which opposes the flow of current and is given by the formula, $E = -L \frac{di}{dt}$ ------ (1).

The work done is given by, $\frac{dw}{dt} = -Ei$

$dW = -Ei\,dt$ ------ (2).

Substitute eq (1) in eq (2)

$$dW = -\left(-L\frac{di}{dt}\right) i\,dt$$

$$= iL\,di.$$

Integrating on both sides,

$$\int_0^W dW = \int_0^I iL\,di$$

$$W = L\int_0^I i\,di$$

$$W = L\left[\frac{i^2}{2}\right]_0^I$$

$$W = L\left[\frac{I^2}{2}\right]$$

$$\therefore W = \frac{1}{2}LI^2$$

⑦ * Relation between voltage and Current :

when an AC voltage is applied to a pure inductor, the current lags behind the voltage by 90° ($\frac{\pi}{2}$ radians). This is because the inductor opposes changes in current, storing energy in its magnetic field as the current increases and releasing it as the current decreases. This opposition to current change is called inductive reactance.

$$E = L\frac{di}{dt} \quad (or) \quad E_0 \sin\omega t = L\frac{di}{dt} \quad \text{------} (1)$$

$$di = (E_0/L)\sin\omega t\,dt.$$

Integrating the above equation, we get

$$i = (E_0/L)\int \sin\omega t\,dt$$

$$= (E_0/\omega L)\,(-\cos\omega t)$$

$$= -\frac{E_0}{\omega L}\cos \omega t$$

$$= \frac{E_0}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$$

$$= i_0 \sin\left(\omega t - \frac{\pi}{2}\right)\left(\because i_0 = \frac{E_0}{\omega L}\right) \quad \text{---(2)}$$

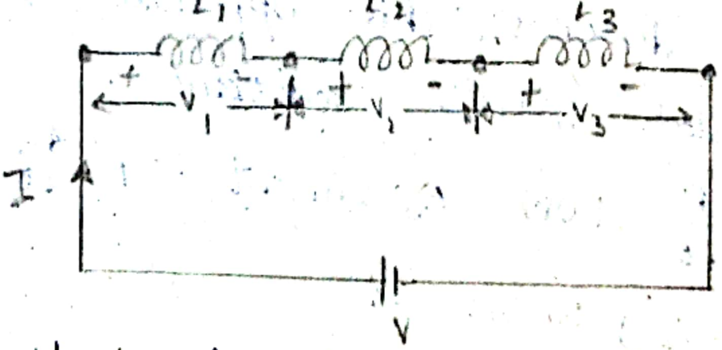
From eqs (1) & (2) it is observed that current lags behind the voltage by $\frac{\pi}{2}$.

*(8) Combination of Inductance :

Inductors can be connected in two ways; Series and parallel.

Series Combination of Inductors :

In Series Combination the inductors are connected end-to-end, forming a single path for current flow. The circuit consists of three inductors L_1, L_2 & L_3 Connected in Series with a voltage source V. In this circuit Combination, the amount of current flows through all the inductors in the Same. The voltage across each inductor is different.



According to the KVL, $V - V_1 - V_2 - V_3 = 0$

$$V = V_1 + V_2 + V_3$$

$$L\frac{di}{dt} = L_1\frac{di}{dt} + L_2\frac{di}{dt} + L_3\frac{di}{dt}$$

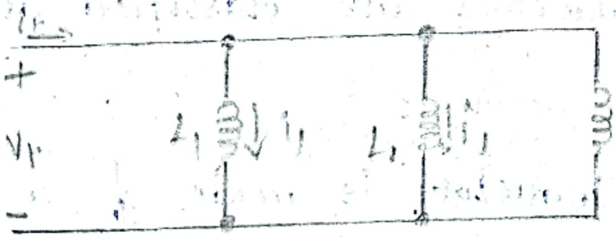
$$L\frac{di}{dt} = (L_1 + L_2 + L_3)\frac{di}{dt}$$

$$L \text{ (or) } L_{eq} = (L_1 + L_2 + L_3)$$

Hence, the total inductance or equivalent inductance is the sum of the individual inductances.

~~Resistances~~ Inductors in parallel (Current division):

Inductors are connected with both ends connected to the same two points, creating multiple paths for current flow. The total current I is divided among all the parallel inductors. The ~~equal~~ voltage across each inductor is the same and equal to the source voltage.



The circuit consists of three inductors L_1, L_2 & L_3 connected in parallel with a voltage source V. Current through each inductor can be found using ohm's law $I = \frac{V}{R}$, where the voltage is constant across each resistor.

According to the KCL, $I = I_1 + I_2 + I_3$.

$$\frac{V}{L} = \frac{V}{L_1} + \frac{V}{L_2} + \frac{V}{L_3}$$

$$\frac{V}{L} = V\left(\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}\right)$$

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

(9) * Types of Inductors.

The inductors are classified as follow:
The inductors are of two types namely fixed inductors and variable inductors.

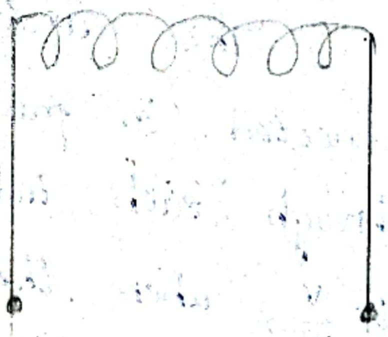
- Inductor
  - Fixed inductors
    - Air Core Inductor
    - Iron core Inductor
    - Ferrite core inductor.
  - Variable Inductors.

1. Fixed Inductors.

The fixed inductors are classified as follows:

a. Air Core inductor:

This inductor is made of a number of turns wound on a non-ferrous material such as ordinary cardboard as shown in Fig. (15).

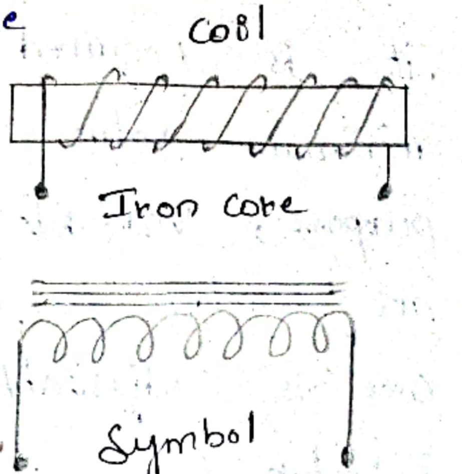


Air core inductor
Fig (15)

As there is air inside the coil and hence this is called as air core inductor. This inductor has low inductance (from a fraction of μH to a few μH). Due to their low inductance, they are suitable for high frequency (R.F.) applications.

b. Iron core inductors :

The inductors is made of a coil of wire wound over a solid iron core. The inductor is shown in Fig. 18 with its symbol. By putting iron inside the inductor, the inductance is increased. In order to avoid eddy current loss, iron core is laminated i.e., consists of Sometimes, Such an inductor is also called as a choke. The iron core inductors are very suitable for audio frequenc (A.F.) applications.

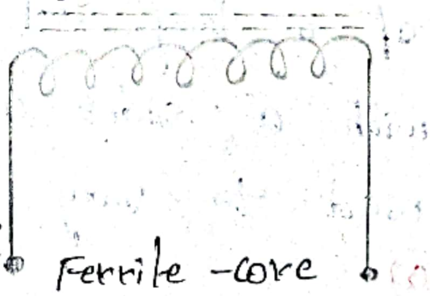


Iron core Inductor
Fig. (16)

c. Ferrite-core inductors :

The iron core inductors are not suitable for high frequency applications. The difficulty is overcome by the use of ferrite materials as core. A ferrite is basically an insultor having very high permeability.

This inductor consists of a coil of wire wound on a ferrite core (non-metallic compounds consisting of mainly of ferric oxide embedded in an insulating binder). The ferrite core has minimum eddy current loss even at high frequencies. The ferrite core inductor is shown in Fig. (17).



Ferrite -core inductor
Fig. (17)

2. Variable Inductors.

In certain applications such as turned circuits it is required to vary the inductance from a minimum value to a maximum value. For this purpose, variable inductors are used. These inductors are similar to fixed ferrite-core inductors but the core is adjustable. Fig. (18) shows variable core inductor.

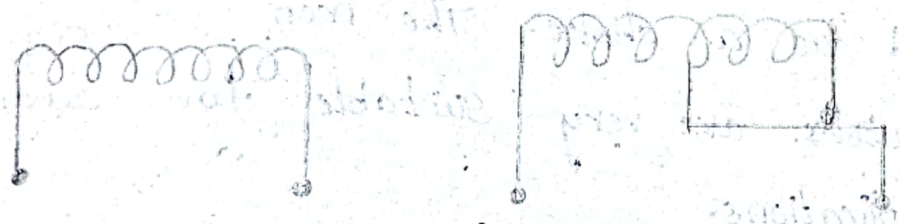


Fig. (18)

Large inductance variable coil

As shown in figure, a variable inductor is made of a long coil wound on a ferrite core provided with a slider contact. The slider contact can be used to vary the inductance of the coil.

(10)

* Types of capacitors :

All commonly used capacitors are divided into two general categories, i.e., fixed capacitors & variable capacitors. They are futher divided as shown below :

Capacitors

- Capacitors
  - Fixed
    - Non-electrolytic capacitors
      - Paper capacitor
      - Mica capacitor
      - Ceramic capacitor
      - plastic film Capacitor
    - Electrolytic Capacitors
      - Aluminium
      - Tantalum
  - Variable

Fixed Capacitors.

a. Non-electrolytic Type.

Such capacitors have no polarity requirement, i.e. they can be connected in either direction circuit. they include paper, mica, ceramic and plastic film capacitors. We shall discuss these capacitor one by one.

i, Paper capacitors :

These capacitors are most widely used. It consists of two tinfoil sheets are separated by thin sheets of tissue paper as a dielectric.

paper Capacitors have a capacitance range from 0.001 μF to 2.0 μF. withstand very high voltage (2000 V) the leakage currents are high tolerances are relatively poor.

ii, Mica capacitors :

Mica capacitor is a Sandwhich of several thin metal plates separated by sheets of mica.

placed in contact with dielectric.

(iv) another aluminium foil plate is placed in contact with spacer. This plate serves as cathode foil. It forms the negative terminal.

The electrolyte capacitors have largest capacitance values per volume of element of any capacitor type. The main drawback is that they possess very large leakage current. These capacitors are available in values ranging from 1 μF to 5,00,000 μF.

Variable Capacitors.

In some electronic circuit [receivers, oscillators, etc.], it is required to change capacitance for for tuning pupose.

a. Air gang capacitor.

This is most commonly used type of variable capacitors. Figure (28) the schematic of air-gang capacitor. It consists of two sets of plates [usually mad of aluminum separated from each other by air. These plates are in the shape of half discs.

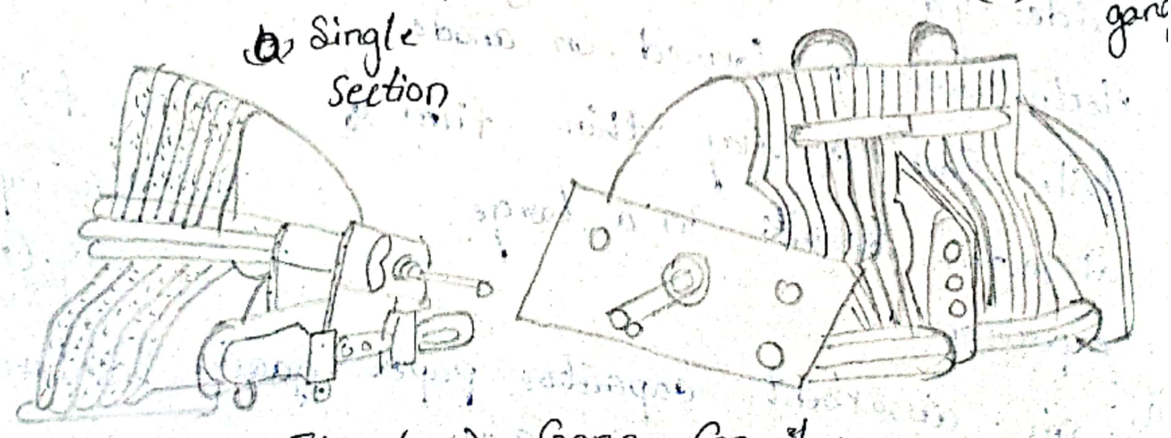


Fig. (28): Gang Capacitor.

when the rotor is moved in or out the stator, the capacitance value varies. The capacitance maximum when the moving plates are completely in and minimum when the moving plate completely out.

b. Trimmer (Padder) :

These capacitors are variable capacitors which are exclusively uses making fine adjustments on the total capacitance of a device. A trimmer consists of two small flex metal plates separated by a dielectric such as air, mica, plastic or ceramic, The spacing between the can be changed by means of screw adjustment.

when the screw is rotated in wards, the plates are compressed and its capacitance is increased.

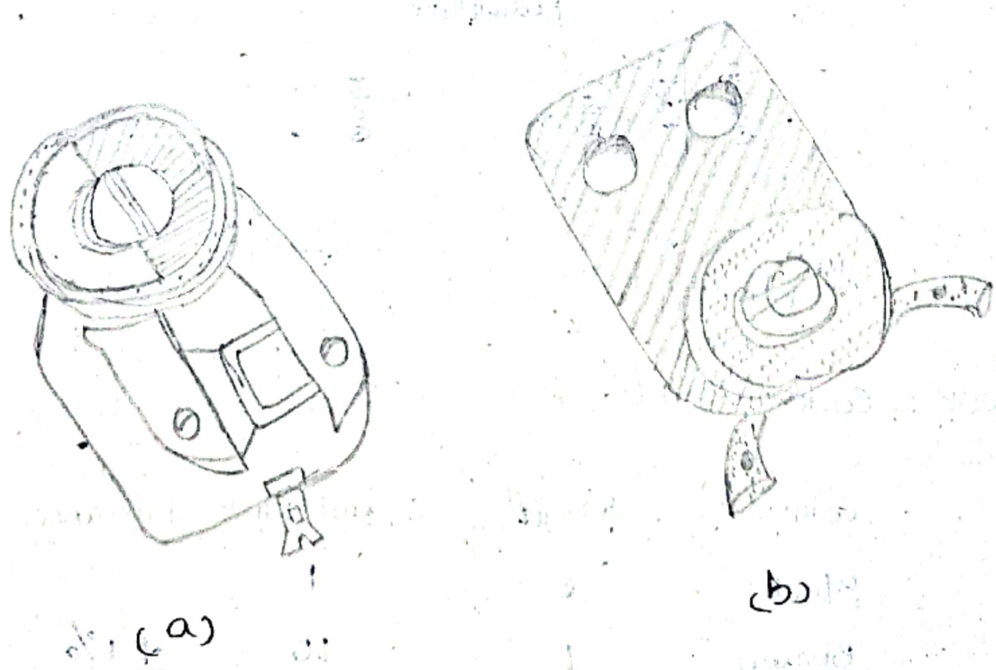


Fig. (29) Ceramic type trimmer.

* Colour coding of Resistors.

Resistor colour coding is a method in which coloured bands are printed on the resistor to show its resistance value. Each colour represents a number, and by reading the colours in order, we can calculate the resistance in ohms (Ω).

Purpose of Colour Coding :

→ Used to identify resistance value and tolerance of small resistors.

→ Colour bands represent numbers, a multiplier, and toleranc

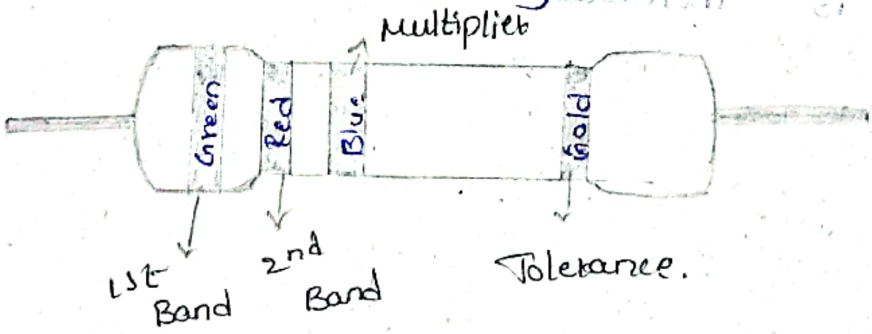
4-Band Colour Code System :

⇒ Band 1 → First digital

⇒ Band 2 → Second digital.

⇒ Band 3 → Multiplier (zeros to add).

⇒ Band 4 → Tolerance (accuracy of resistor).



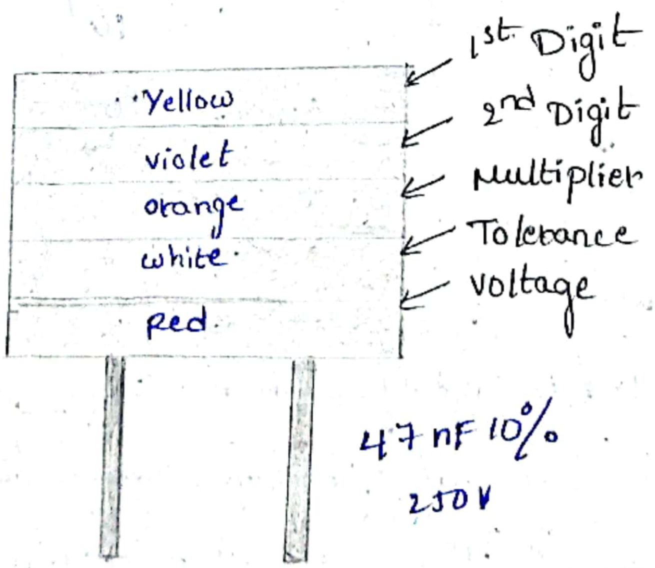
Colour Code Table :

Colour	Digit	Multiplier	Tolerance
Black	0	1	
Brown	1	10	± 1%
Red	2	10^2	± %
Orange	3	10^3	
Yellow	4	10^4	

Green	5	10^5	±
Blue	6	10^6	
violet	7	10^7	
Gray	8	10^8	
white	9	10^9	
Gold		10^{-1}	± 5%
silver		10^{-2}	± 10%
No colour			± 20%

(12) * Colour Coding of Capacitors:

Capacitors are electronic components that are store electrical energy. Like resistors, many Capacitors are Small in Size and do not have space to write values directly. Colour coding is used to indicate the capacitance value on them. This Colour Coding is mostly used in older or ceramic disc capacitors.



Colour Bands on Capacitors.

Most colour-coded Capacitors have three or four colour bands. These bands represent :

→ First digit
→ Second digit
→ Multiplier (in Pico farads, PF)
→ Tolerance (optional)

Colour Code Table :

Colour	1st Digit	2nd Digit	Multiplier	Tolerance
Black		0	1	± 20%
Brown	1	1	10^{-1}	± 1%
Red	2	2	10^{-2}	± 2%
orange	3	3	10^{-3}	
Yellow	4	4	10^{-4}	
Green	5	5	10^{-5}	± 5%
Blue	6	6	10^{-6}	
violet	7	7	10^{-7}	
Gray	8	8	10^{-8}	± 20%
white	9	9	10^{-9}	± 10%
Gold			10^{-1}	± 5%
Silver			10^{-2}	± 10%

(13)

* Ohm's law

In 1827, George Simon ohm discovered that if you have metal at Constant temperature, for constant length & area, then if you increase the increase the voltage the Current increasesing the Same proportion.

$$V \propto I$$

$$V = IR$$

This describes the ration between V, I & R.

Limitations of ohm's Law

1. Does not apply to non linear elements like diodes, transistors, thyristors, and electric arcs. In this R varies with V & I.

2. Does not apply to unilateral networks, which have elements that only allow current to flow in one direction.

3. ohm's law only applies to metallic conductors but not to non-metallic conductor. temperature dependance.

4. Ohm's law does not apply when the R varies with temperature. filament light blubs have resistance that increases with temperature, So the current flowing through them is not proportional to the applied voltage.

5. Ohm's law is simplified model that assumes a basic circuit, so it may not be accurate for complex circuits multiple components.

(14) * Charging and Discharging in capacitor.

Charging of a capacitor:- Consider a circuit consisting of capacitor c in series with a Resistor R and a battery e.m.f. 'E' through a Morse key k as shown in the figure. when the key is pressed, the capacitor c begins to store charge until the potential difference across the plates of the Condenser becomes E. Let q be the charge across condenser plates at any instant of time t.

The potential differente across resistor = IR

The potential difference between the plates of the capacito

$= \frac{q}{c}$

$\therefore E = IR + \frac{q}{c}$

By definition $I = \frac{dq}{dt}$. Let q_0 be the maximum possible charge on the plates of the Condenser when the maximum possible potential difference at the plates is E. Thus $q_0 = CE$ or $E = \frac{q_0}{c}$.

Substituting these values, we get $\frac{q_0}{c} = IR + \frac{q}{c}$

$$\frac{q_0}{c} - \frac{q}{c} = R\frac{dq}{dt}$$

$$\frac{q_0 - q}{c} = R\frac{dq}{dt}$$

$$\frac{dt}{CR} = \frac{dq}{q_0 - q}$$

Integrate the above equation and after simplification we get, $\boxed{q = q_0\left(1 - e^{-t/CR}\right)}$ (or) $q = q_0\left(1 - e^{-t/\tau}\right)$.

where τ (Time Constant) = CR, which gives the value of charge on the Capacitor at any time t during charging.

Discharing of a capacitor. After the condenser is fully charged the key k is released, the circuit is broken without introducing any additional resistance. The

The battery is now out of the circuit, and the capacitor will discharge itself through R at a definite rate. If I is the current at any instant of time t during discharge, then putting E = 0 in $E = IR + \frac{q}{c}$.

$$0 = IR + \frac{q}{c}$$

$$0 = R\frac{dq}{dt} + \frac{q}{c}$$

$$-\frac{q}{c} = R\frac{dq}{dt}$$

$$\int_{q_0}^{q} \frac{dq}{q} = -\int \frac{1}{CR}\, dt$$

Integrate the above equation and after simplification

we get, ~~$q = q_0(1 - e^{-t/CR})$~~

$$\log q - \log q_0 = -\frac{t}{RC} \Rightarrow \log \frac{q}{q_0} = -\frac{t}{RC}$$

$$\frac{q}{q_0} = e^{-t/RC}$$

$$\boxed{q = q_0 e^{-t/RC}}$$

Time constant :- (τ)

It is the product of Resistance & capacitance of circuit

$$\tau = RC$$

→ Time required to charge the capacitor from initial charge voltage zero to 63% of the value of applied DC voltage,

→ Time required to discharge the capacitor to 37% of its initial charge voltage,

Part - B : Applications of Passive elements

* Applications of a Resistor as a heating element in
(15) 1. heaters & in 2. in a fuse.

Resistors can indeed be used as heating elements due to their ability to convert electrical energy into heat through a Process called joule heating.

joule's law of heating states that, heat generated in Conductor directly proportional to square of current, Resistance of the conductor & time of current flow.

Heat generated $H = i^2 R t$

$i \rightarrow$ Current flowing through conductor.

$R \rightarrow$ Resistance of Conductor.

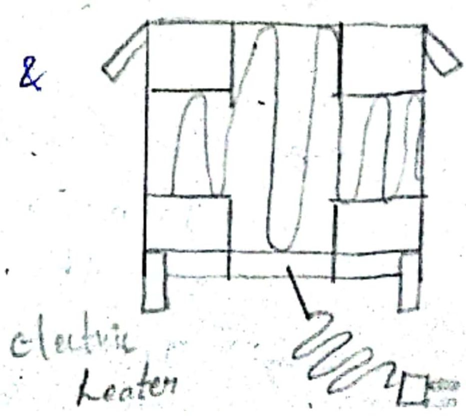
$t \rightarrow$ time for which Current flows.

Electric heater :

In Electric heaters, a high resistance wire (often nichrome) is used as the heating element.

when Current flows through it, the resistance causes the wire to heat up, producing desired thermal energy.

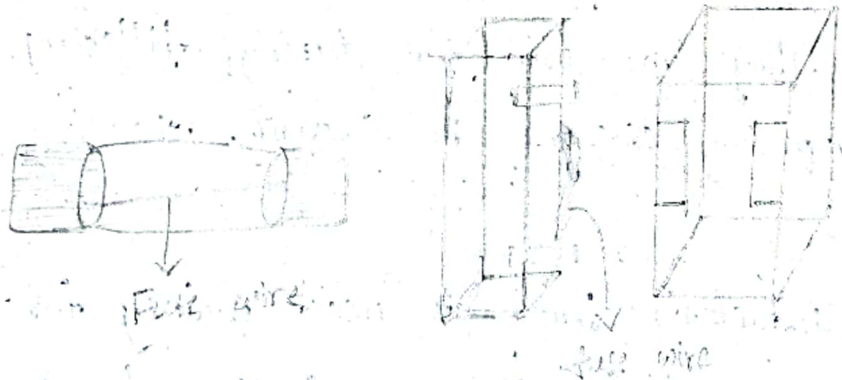
Ex : water heaters, electric irons & oven filaments in incandescent light bulbs.



Electric Fuse :

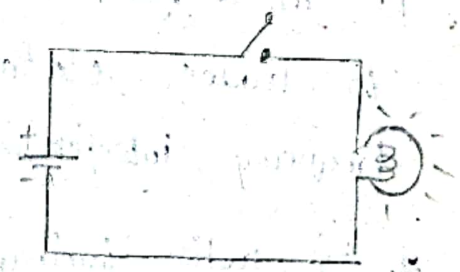
In fuses, a low-melting point wire acts as a resistor. (such as lead (or) an alloy).

If the current Exceeds a safe limit, the fuse wire heats up, melts, and breaks the circuit, Preventing damage to other components.



(16) * Open circuit :

An open circuit is a break in the path of an electrical circuit.



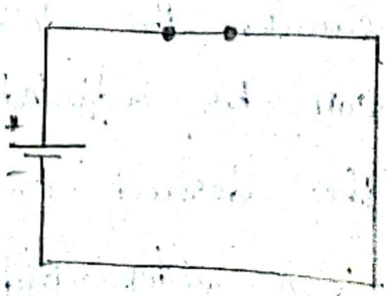
→ No current flows in an open circuit.

→ Resistance in an open circuit Considered infinite (or) very high.

Ex : Broken wire, disconnected switch (or) a blown fuse.

* Short circuit :

A Short circuit is an unintended low-resistance Path that allows current to flow.



→ It Allows a large amount of current to flow, Potentially Causing damage.

→ Resistance in a short circuit is,

considered very low, ideally zero.

Ex : A wire touching another wire, faculty appliance can create a short circuit.

(17) * Applications of Inductors : (in choke a fan & in a radio tuning circuit.)

Inductors, based on the principle of electromagnetic induction. They have diverse applications in electrical & electronic circuits. They are used for, tuning, filtering signals, storing energy opposing changes in current, enabling transformers & motors.

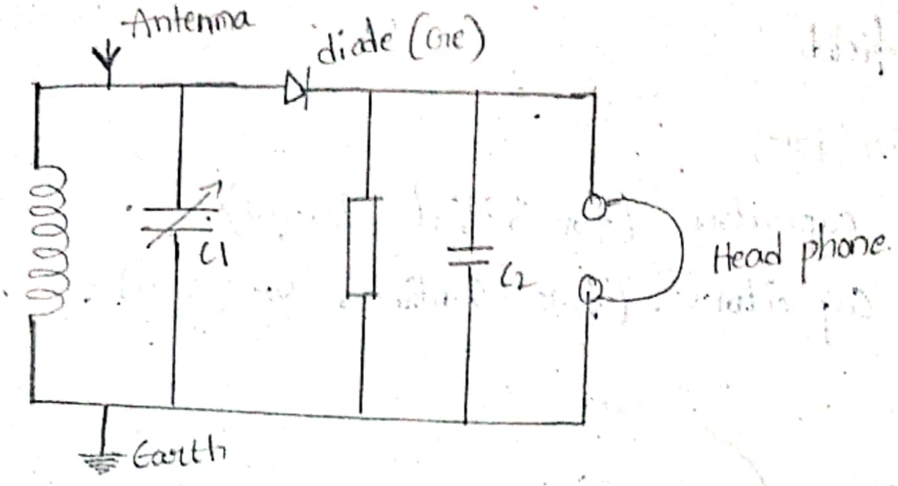
A choke (Inductor) that is used mainly for blocking high frequency AC while passing DC & low frequency ACs in circuit.

1. In a fan, a choke acts as a noise filter, specifically to reduce Electromagnetic interference (EMI) & radio frequency interference (RFI) generated by fan's motor.

2. In radio tuning, inductors are crucial components in tuned circuits (also known as LC circuit) that select specific ~~ra~~ radio frequencies.

By varying the inductance (or) capacitance in the circuit, the resonance frequency of the tank circuit can be adjusted. This allows the receiver to select the desired radio frequency signal & reject others.

Ex : older radios.



→ Diode passes +ve half cycle of ~~q~~ R.F & removing -ve cycle.

→ C_2 filter of the Radio frequencies & Passes audio from to headset.

(18)
* Applications of Capacitor in power Supplies & motors (Fans):

They have wide range of application in electrical & electronic systems, due to their ability to store electrical energy & influence signal behavior. voltage stabilization, filtering.

In power supplies, they smooth out voltage fluctuations, filter out noise, and provide (~~high~~ bursts of) high power during high demand.

Capacitors acts as temporary energy storage, absorbing voltage spikes & releasing energy during voltage dips, thus maintaining a stable output voltage.

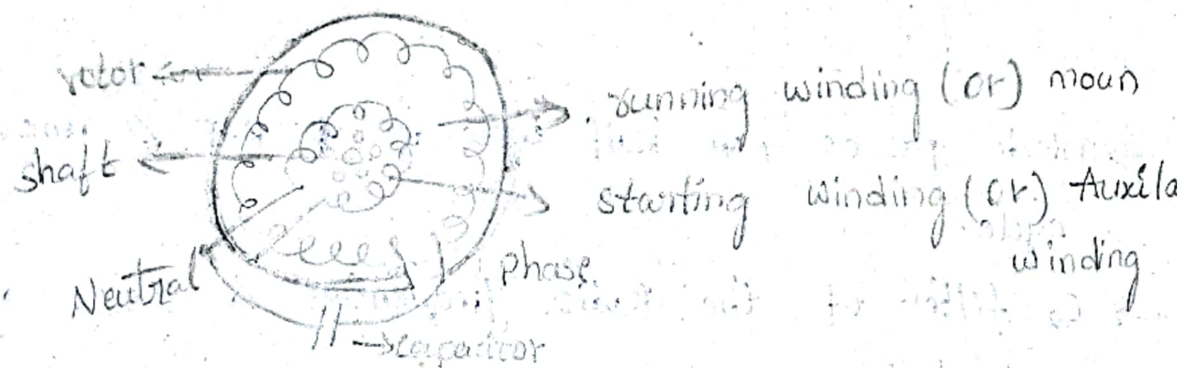
Ex : Computers, Smartphones.

In motors, capacitors are crucial for starting & running single-phase motors by creating a rotating magnetic field.

Example in fan,

→ starting capacitors (for initial torque).

→ running capacitors (for continous operation).



Start capacitor :

It provides a temporary boost of power to help the motor to overcome inertia & start rotating.

Run Capacitor :

This helps maintain the rotating magnetic field in the motor, ensuring it continues to run efficiently.

Dual - Run Capacitor :

In a fan, the dual-run capacitor combines these functions, Providing both the starting surge & the sustained support for continuous operation.