Elements of Electronics-(EEX)

(17215)

Semester: Second (ET/EJ/IE/IS)

Teaching Scheme			Examination Scheme					
TH	TU	PR	PAPER HRS	TH	PR	OR	TW	TOTAL
04	--	04	03	100	50 #	--	25@	175

Notes by-

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Chapter 1:

Passive Components

Contents:

1.1- Resistors:

- *Classifications of resistors, material used for resistor.*
  General specification of resistor- maximum voltage rating, power rating, temp. coefficient, ohmic ranges, operating temperature
- *Classification and application of resistor*
- *Colour coding: with three, four & five bands*
- *LDR – Working, Characteristics & application*
- *TDR- listing of its type.*
- *Potentiometer : linear and logarithmic, constructional diagram, specifications, applications of carbon and wire wound resistor*

Marks : 20

Learning Resources:

1. Books:

Sr. No.	Title	Author	Publisher
01	Electronics Device & Circuit Theory	Robert L. Boylestead Louis Neshelsky	Pearson
02	Basic Electronics & Linear Circuit	N.N.Bhargava S.C. Gupta	Tata McGraw Hill
03	Electrical Technology	B.L. Thereja	S.Chand
04	Electronics Device & Circuit	David J. Bell	Oxford

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Electronic Components:

The components used in designing or assembling of an electronic circuit are called as electronic components.

Classification of Electronic Components:

- Electronic Components
  - Active Components
    - Electronic tubes
    - Semiconductor Devices
      - Diodes
      - Transistors
      - FET
  - Passive Components
    - Resistors
    - Capacitors
    - Inductors

Active Components:

- The electronic components which by themselves are capable of amplifying and processing an electrical signal are called active components.
- In short an active device is one which introduces gain.
- Eg. Electronic tubes and Semiconductor devices such as Diodes, Transistors FET's and UJT's.

Passive Components:

- The Electronic Components which by themselves are not capable of amplifying or processing and electrical signal are called passive components.

- In other words, the passive component is the one which does not introduces any gain.
- Eg. Resistors, Capacitors and Inductors.

RESISTANCE:

- The opposition to the flow of electric current through any material is called resistance. This property of a device is called Resistor. It is measured in Ohms (Ω).
- The mathematical expression for Resistance is shown as below.
- R is directly proportional to Length (L)
  $R \propto L$
- R is inversely proportional to Area (A)
  $R \propto \frac{1}{A}$
  Therefore, $\boxed{R \propto \frac{L}{A}}$
- To, remove proportionality sign, proportionality constant is defined which is called as specific resistance of a material used and denoted as "rho (ρ)"
  Therefore, $\boxed{R = \rho \frac{L}{A}}$
  Where,
  ρ = Specific resistance of a material used
  L = Length of a material.
  A = Cross- Sectional Area.
- According to Ohms law;
  $V = I R$
  Therefore, Resistance $R = \frac{V}{I}$

RESISTOR:

Defination:

- The Passive component, which opposes the flow of electric current and has positive temperature coefficient of resistance is called a resistor.
- It can conduct current in both the directions and therefore known as bilateral device.
- OR, A Resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element.

Unit:

- The value of a resistor is called resistance. It is denoted by R and the unit of resistance is Ohms (Ω).
  1 milli ohms (m Ω) = 1 x 10^{-3} Ω
  1 kilo ohms (K Ω)= 1 x 10^{3} Ω
  1 Mega ohms (M Ω)= 1 x 10^{6} Ω

Symbol:

Fixed resistor symbol

Variable Resistor Symbol

Materials used in Resistors:

- Various materials are used for manufacturing different types of resistors. These materials have different properties.
    1. For the carbon composition resistors, the resistive element is made from a mixture of finely ground (powdered) carbon and an insulating material (usually ceramic).
    2. The materials used for thin film resistors can be tantalum nitride, ruthenium oxide, lead oxide, nickel chromium etc.
    3. The thick film resistors may use some conducting ceramics but they are mixed with powdered glass and a carrier liquid.
    4. The metal film resistors use one of the materials used for the thin film resistor.
    5. The metal oxide film resistors are made of metal oxide such as tin oxide.
    6. The wire wound resistors are commonly made by winding a metal wire usually nicrome (nickel + chromium).

Sr. No.	Type of Resistor	Material Used
1.	Carbon composition	Mixture of carbon powder and ceramic
2.	Thin film	Tantalum nitride, ruthenium oxide, lead oxide, nickel chromium etc.
3.	Thick film	Mixture of conducting ceramics, powdered glass.
4.	Metal film	Same as thin film resistors
5.	Metal oxide film	Tin oxide
6.	Wire Wound	Nicrome wire.

General Specifications of Resistors:

1. Maximum voltage rating:
   The maximum voltage at which the resistor can operate without failure is called maximum voltage rating.
   OR
   The maximum voltage that can be applied to a resistor without any damage to it is called the voltage rating and it is given by.

Vmax = $(Power\ rating\ x\ Resistance\ value)^{1/2}$
Therefore,
Vmax = $(P\ x\ R)^{1/2}$.

2. Power Rating:
The maximum amount of heat dissipated by a resistor at maximum specified temperature without damage to resistor is called power rating of a resistor.
It is expressed in watt(W) at specified temperature.

3. Temperature coefficient of resistance:
It is defined as the percentage change in resistance per unit change in temperature. It is denoted by letter "alpha (α)".
The temperature coefficient can be positive or negative depending upon whether resistance increases or decreases with temperature.
Temperature coefficient (α) = $\frac{Rt1-Rt2}{Rt1(t1-t2)}\ x\ 10^6\ (\frac{ppm}{degree}C)$.
Where;
Rt1 = value of resistance at temperature T1 degree C.
Rt2 = value of resistance at temperature T2 degree C.

4. Tolerance:
The tolerance means that the actual value of the resistor may be either larger or smaller than that of the indicated value by a factor given by specified tolerance.

5. Operating Temperature:
The maximum temperature at which the resistor can be operated without failure is called maximum operating temperature. It is also called temperature rating.

6. Wattage:
   The wattage of a resistor is the power handling capacity of a resistor. It can dissipate without excessive heating. The power rating of a resistor is given in wattage.
   The normal available resistors have power ratings of 1/8 W, ¼ W, ½ W, 1W, 2W.
   The size of a resistor depends on its power handling capacity.

7. Resistivity (or specific resistance):
   It is defined as the resistance of the piece of that material which is 1 meter long and of unit cross sectional area.

8. Frequency Range:
   The range of frequency upto which the resistor offers pure resistance is called frequency range.
   The resistor may be pure resistor at low frequency as it offers only resistance, but it may have a capacitive or inductive impedance at high frequencies.

9. Shelf life:
   It is defined as the change in value of resistance during storage usually quoted for 1 year.

10. Load Life:
    It is defined as the change in value of resistance after specified time at specified temperature.
    Resistors are tested for change in resistance after 1000 hours at $70^0\ C$.

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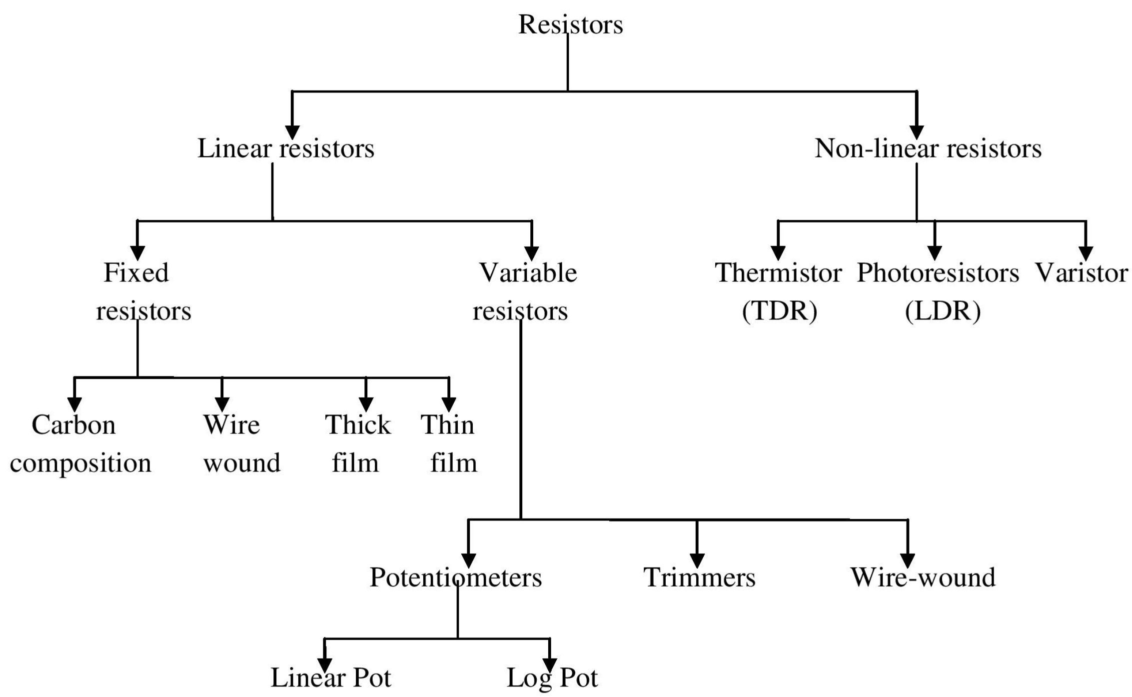
Classification of Resistors:



Linear Resistors:

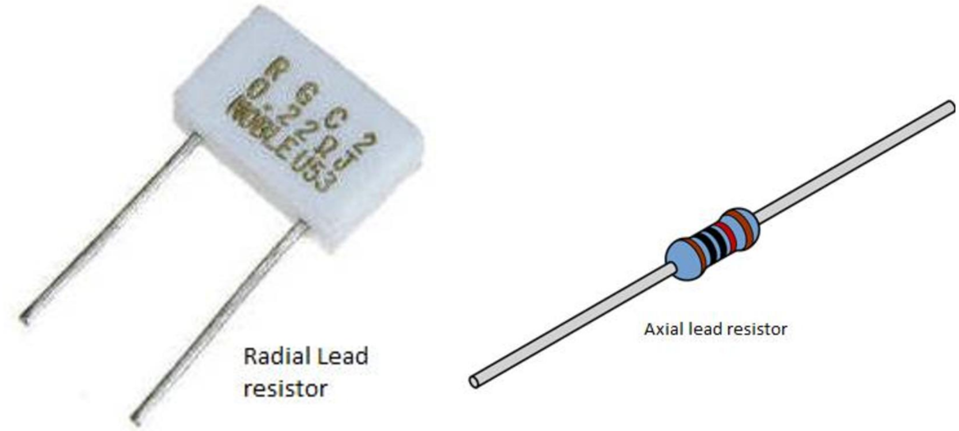
- The resistors, through which the current is directly proportional to the applied voltage, are called linear resistors. Such resistors have a property that their resistance value does not change with the variation in applied voltage, temperature or light intensity.
- The linear resistors are of two types namely fixed resistors and variable resistors.

Non- Linear Resistors:

- The resistors, through which the current is not directly proportional to the applied voltage, are called non-linear resistors. Such resistors have a property that their resistance values change with the variation in applied voltage, temperature or light intensity.
- The non-linear resistors are of three types namely thermistor, photo-resistor and varister.

Fixed Resistors:

- The fixed resistors are those, whose value does not change with the variation in applied voltage, temperature or light intensity. Such resistors are available in various shapes and sizes, with both axial and radial leads as shown below.



- The fixed resistors are of following types:

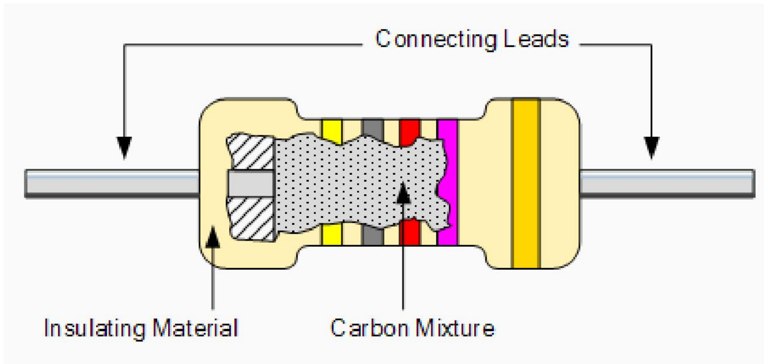
1. Carbon Composition Resistor.
2. Thin film Resistor.
3. Thick film Resistor.
4. Wire-wound Resistor.

Carbon Composition Resistor

Concept:

- The type of resistor is manufactured in both, insulated and the uninsulated form. The uninsulated type allows better heat dissipation and the insulated one avoids any possibility of shock circuit to the adjacent components and metal chassis.
- It is made of carbon dust or graphite paste, low wattage values
- The construction of a moulded (insulated) carbon composition resistor is shown below.

Construction:



- These resistors are made by mixing carbon powder and insulating binders to produce the desire value of resistors.
- The resulting resistance values are within $\pm 10\%$ of the desired value. However, the resistors with $\pm 5\%$ tolerance are also obtained through special techniques.
- Usually, the resistance element is a simple rod of carbon powder, which is enclosed in a plastic case for insulation and mechanical strength.
- The two ends of the carbon resistance element are joined to metal caps with leads of tinned wire. The leads are provided for soldering the resistor into the circuit.
- The carbon composition resistors are available in resistance values ranging 1Ω to $22\ M\Omega$ and power ratings of $\frac{1}{8}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, \frac{2}{3}, 1\ and\ 2\ Watts$. The size of these resistors varies with the power ratings.

Applications:

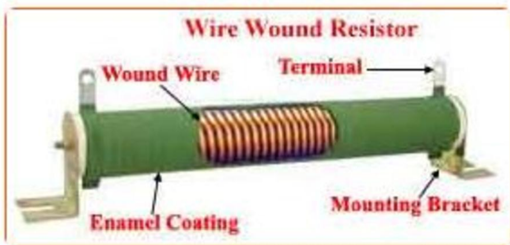
- Carbon composition resistors are suitable to withstand high energy pulses, while having a relatively small size. For this reason the carbon composition resistor is still used in many applications today.
- Applications include the protection of circuits (surge or discharge protection), current limiting, high voltage power supplies, high power or strobe lighting, and welding.

Wire- Wound Resistors:

Concept:

The power handling capacity of carbon composition resistors is very low. Power handling capacity of wire-wound resistors is much higher than the carbon composition resistors.

Construction:



- The construction of this type of resistor is also very simple. In wire wound resistor a wire of manganin or constantan is wound around a cylinder of insulated material. The resistance of these two materials is almost zero. So there would no resistance variation with temperature.
- The wounded wire is covered with an insulating material such as baked enamel. This cover of insulating heat resistive material is provided to resist the effect of ambient temperature variation.
- Different sizes and ratings of wire wound resistor can easily be achieved by using different lengths and diameters of the wire.
- These resistors are easily available for wide range of ratings. The range of resistance values varies from 1 Ω to 1 MΩ. Typical tolerance limit of these resistors varies from 0.01 % to 1 %.
- They can be used for high power applications of 5 to 200 W dissipation ratings.
- The cost of these resistors is much higher than carbon resistor. Normally wire wound resistor is used where carbon composition resistor cannot meet the purpose because of its limitations.

Applications:

- Zener Voltage Regulator.
- Power Amplifiers.
- High power resistors in DC power supplies.
- High power circuits in radio and TV receivers.
- Low frequency, high power applications.

Film type Resistors:

The flim type resistors are as follows

- Carbon film resistor
- Metal film resistor
- Cermet resistor (Thick film resistors)

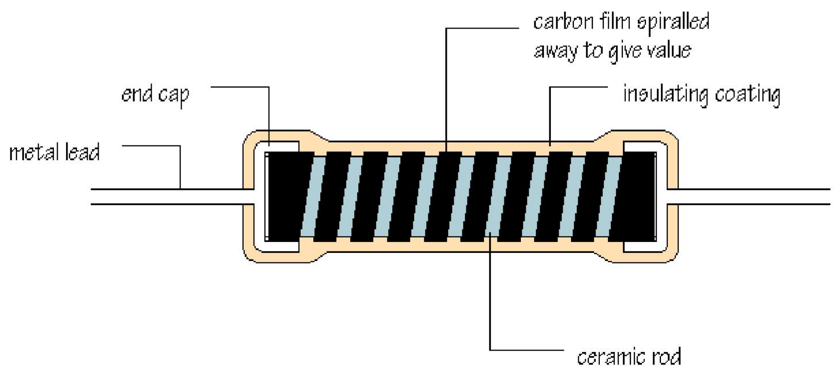
Carbon film Resistors:

Concept:

- The resistive film deposited on the glass or ceramic rod is of pure carbon that is why they are called as carbon film resistors.
- The thickness of the film will decide the value of the resistor.
- Spirally is done in order to adjust the value of resistor.

Construction:

- During manufacture, a thin film of carbon is deposited onto a small ceramic rod. The resistive coating is spiralled away in an automatic machine until the resistance between the two ends of the rod is as close as possible to the correct value.
- Metal leads and end caps are added; the resistor is covered with an insulating coating and finally painted with coloured bands to indicate the resistor value.
- Carbon film resistors are cheap and easily available, with values within ±10% or ±5% of their marked, or 'nominal' value.



- Metal film and metal oxide resistors are made in a similar way, but can be made more accurately to within ±2% or ±1% of their nominal value. There are some differences in performance between these resistor types, but none which affect their use in simple circuits.

<u>Applications:</u>

Applications of carbon film resistors are same as those of the carbon composition resistors. But they are preferred for applications that need operation over wide range such as military applications.

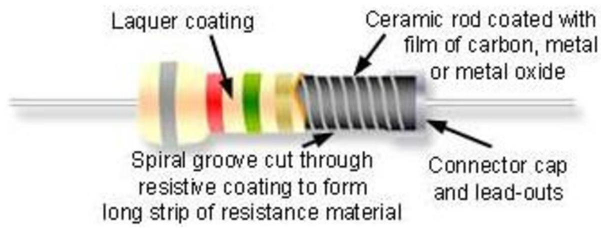
<u>Metal Film Resistors:</u>

<u>Concept:</u>

These resistors are made by depositing a very thin layer of metal on ceramic or glass rod. The metal film is spiral cut to the desired resistance. These resistors have tolerances ranging from ± 0.025% to 2%, of the desired value.

Types of metal film resistors:

1. Nickel chromium resistors
2. Metallic oxide film resistors
3. Cermets



Applications:

- These resistors are used for the applications that need better stability, better reliability and long life. The applications are transmitter, modulators and demodulators, oscillators, feedback amplifiers etc.
- These are also used in applications that demand high endurance.

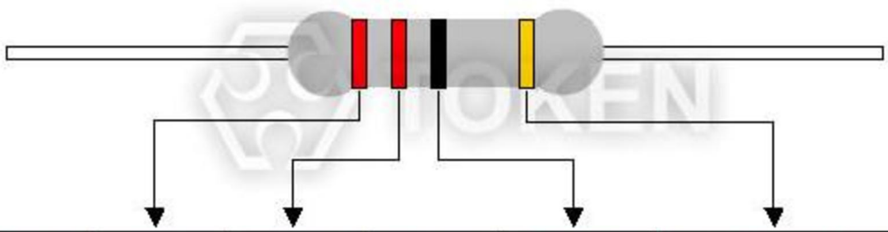
Colour Coding:

- The resistance and tolerance specifications for fixed resistors are, usually printed on the body of a resistor.
- Most wire wound resistor specifications(including power rating) are also printed on the resistor.
- However, carbon-composition, carbon film and some metal film resistors are designated by a colour code system.
- In this system, the bands of different colour are used to identify the resistance value and tolerance ratings of the resistor.
- The power rating is determined from the physical size of the resistor.

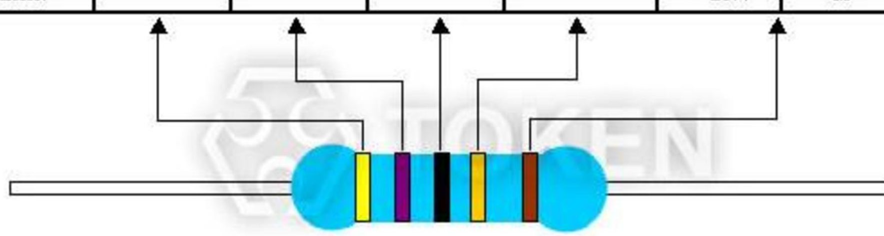
Types of Colour Codes:

- Depending upon the number of colour band used, the resistor colour codes can be classified into following types:
    1. Three band colour code.
    2. Four band colour code.
    3. Five band colour code.
    4. Six band colour code.

4 Band Colour Code



COLOR	1ST BAND	2ND BAND	3TH BAND	MULTIPLIER	TOLERANCE	
BLACK	0	0	0	1		
BROWN	1	1	1	10	± 1%	F
RED	2	2	2	100	± 2%	G
ORANGE	3	3	3	1K		
YELLOW	4	4	4	10K		
GREEN	5	5	5	100K	± 0.5%	D
BLUE	6	6	6	1M	± 0.25%	C
VIOLET	7	7	7	10M	± 0.10%	B
GREY	8	8	8		± 0.05%	A
WHITE	9	9	9			
GOLD				0.1	± 5%	J
SILVER				0.01	± 10%	K
PLAIN					± 20%	M



Five Band colour code

Examples:

1. Write down a four band colour code for the following resistors:
   (i) $150\Omega \pm 5\%$
   (ii) $2.7\ k\Omega \pm 10\%$
   (iii) $56\ k\Omega \pm 20\%$
   (iv) $10\ M\Omega \pm 10\%$

Solution:

(i) 150Ω ± 5%

We know that in this case, the first significant figure is 1, second is 5 and the multiplying factor is 10. Therefore,

1	5	×10	± 5%
↓	↓	↓	↓
Brown	Green	Brown	Gold
(1^{st} band)	(2^{nd} band)	(Multiplier)	(Tolerance)

Thus, the four band colour code for 150Ω ± 5% resistor is <u>brown, green, brown and gold.</u>

(ii) 2.7 kΩ ± 10%

We know that 2.7kΩ = 2700Ω. In this case, the first significant figure is 2, second is 7 and the multiplier is 100. Therefore,

2	7	×100	±10%
↓	↓	↓	↓
Red	Violet	Red	Silver
(1^{st} band)	(2^{nd} band)	(Multiplier)	(Tolerance)

Thus, the four band colour code for 2.7 kΩ ± 10% resistor is <u>Red, Violet, Red and Silver.</u>

(iii) 56 kΩ ± 20%

We know that 56kΩ = 56000Ω. In this case, the first significant figure is 5, second is 6 and the multiplier is 1000. Therefore,

5	6	$\times 1000$	$\pm$ 20
↓	↓	↓	↓
Green	Blue	Orange	Plain
(1st band)	(2nd band)	(Multiplier)	(Tolerance)

Thus, the four band colour code for56 kΩ $\pm$ 20% resistor is <u>Green Blue and Orange.</u> There is no colour band for the tolerance value (because it is plain).

(iv) 10 MΩ $\pm$ 10%

We know that 10MΩ = 10 000 000Ω. In this case, the first significant figure is 1, second is 0 and the multiplier is 1 000 000. Therefore,

1	0	$\times$1 000 000	$\pm$ 10%
↓	↓	↓	↓
Brown	Black	Blue	Sliver
(1st band)	(2nd band)	(Multiplier)	(Tolerance)

Thus, the four band colour code for 10 MΩ $\pm$ 10% resistor is <u>Brown, Black, Blue and Silver.</u>

2. Determine the resistance and tolerance ratings for the following four band colour codes:
   (i) Brown, Black, Yellow, --
   (ii) Yellow, Violet, Black and Gold.
   (iii) Green, Blue, Brown and Silver.

Solution:

(i) Brown, Black, Yellow, --

We, know that in this case,

(1st band)	(2nd band)	(Multiplier)	(Tolerance)
Brown	Black	Yellow	--
↓	↓	↓	↓
1	0	× 10 000	± 20%

Therefore, Resistance value is <u>10 × 10 000 = 100KΩ ± 20%.</u>

(ii) Yellow, Violet, Black and Gold.

We, know that in this case,

(1st band)	(2nd band)	(Multiplier)	(Tolerance)
Yellow	Violet	Black	Gold
↓	↓	↓	↓
4	7	×1	± 5%

Therefore, Resistance value is <u>47 × 1 = 47Ω ± 5%.</u>

(iii) Green, Blue, Brown and Silver.

We, know that in this case,

(1st band)	(2nd band)	(Multiplier)	(Tolerance)
Green	Blue	Brown	Silver
↓	↓	↓	↓
5	6	×10	± 10%

Therefore, Resistance value is 56 × 10 = 560Ω ±10%

3. For the five band colour cold find the resistance and tolerance value.
   (Blue, Gray, Black, Red, Gold)

Solution:

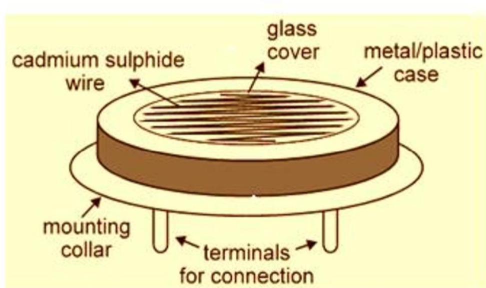
(1st band)	(2nd band)	(3rd band)	(Multiplier)	(Tolerance)
Blue	Gray	Black	Red	Gold
↓	↓	↓	↓	↓
6	8	0	×100	± 5%

Light Dependent Resistor (LDR):

Concept:

- When the light is incident on the semiconductor materials, the covalent bonds are broken and the charge carriers i.e. electron hole pairs are produced.
- The amount of intensity light on the surface of the semiconductor material determines the no. of electron-hole pair generated.
- As the light intensity increases, conductivity of semiconductor material increases and thus the resistance decreases.
- Thus, the resistance of the material varies inversely with the amount of light intensity.

Construction:



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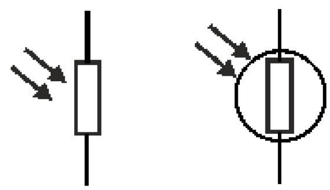
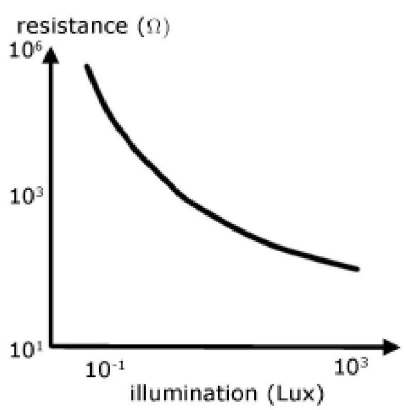
- These are made in disc shapes with wire lead end on one side.
- They have ceramic substrate over which layer of cadmium sulphide (cds) or lead sulphide (pbs) is deposited in zigzag form to increase the length hence resistance value increases.
- Depending upon the layer the resistance changes.
- Electrodes are formed by evaporating metal in vaccum .Leads are connected and put in plastic case as shown in fig above.

Symbol:



Characteristics:



From the characteristics the resistance of an LDR decreases as the light intensity falling on it increases.

Specifications:

Resistance Range, Power Rating,

Dark Resistance, Response time.

Applications:

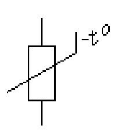
- It is used in burglar alarm to give alarming sound when a burglar invades sensitive premises.
- It is used in street light control to switch on the lights during dusk ***(evening)*** and switch off during dawn ***(morning)*** automatically.
- It is used in Lux meter to measure intensity of light in Lux.
- It is used in photo sensitive relay circuit.

Temperature Dependent Resistor (TDR):

Concept:

- Temperature dependent resistors are also called as Thermistors.
- The word thermistor is an acronym for thermal resistor i.e. a temperature – sensitive-resistor. It is used to detect very small changes in temperature.
- The variation in temperature is reflected through an appreciable variation of the resistance of the device.
- Thermistors with both Negative temperature coefficient (NTC) and Positive temperature coefficient (PTC) are available.
- NTC means that the resistance decreases with the increase in temperature.
- PTC means that the resistance increases with the increase in the temperature.

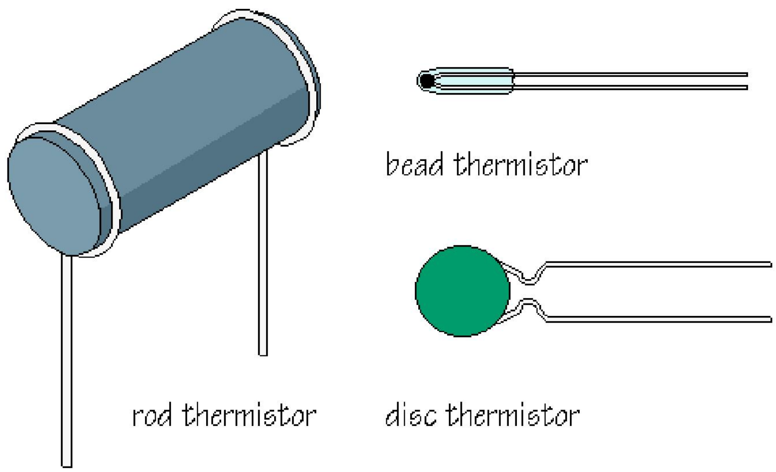
Symbol:



thermistor
circuit symbol

Construction:

- Thermistors are manufactured in the form of beads, probes, discs, washers and rods.
- They are useful where temperature sensing must be done in a limited spaces



NTC Thermistors:

- NTC means that the resistance decreases with the increase in temperature.
- NTC thermistors are manufactured by sintering (it is a process in which powered materials are fused together by the application of heat) semiconductor ceramic materials prepared from mixtures of metallic oxides of cobalt, nickel, manganese etc.
- These materials have high negative temperature coefficient.
- NTC thermistors offer mechanical, thermal and electrical stability together with high degree of sensitivity.
- NTC have inversely proportional relationship between resistance and temperature and characteristic curve .

$$R \propto \frac{1}{T}$$

- NTC thermistor can operate over +200°C to +1000°C.

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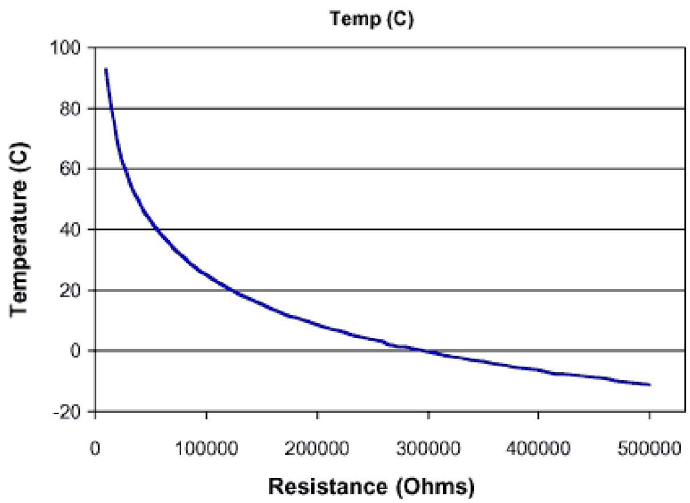
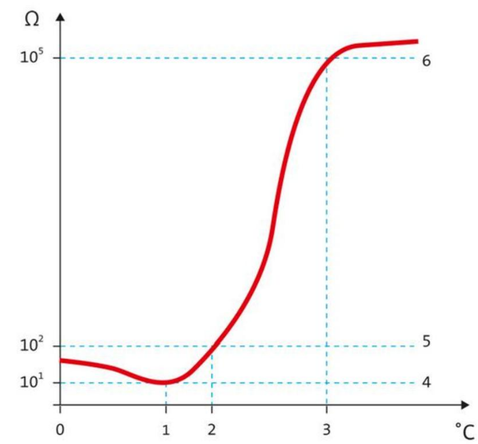


Applications:

- For temperature measurement and control.
- Temperature compensation.
- Fluid flow measurement.

PTC Thermistors:

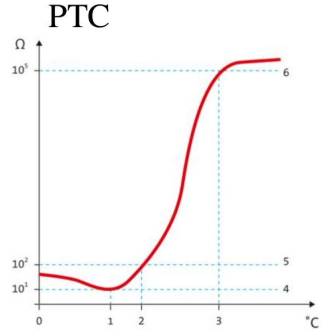
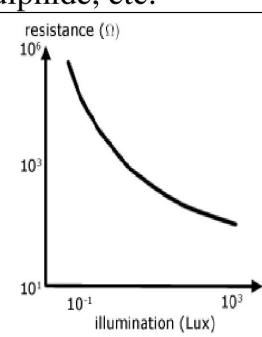
- PTC means that the resistance increases with the increase in the temperature.
- PTC semiconductors are made from doped barium titanate semiconducting material.
- This material have very large change is resistance for a small change in temperature.
- PTC thermistors are used when a drastic change in resistance is required at specific temperature.
- PTC thermistors operate over 60°C to 180°C.
- PTC have directly proportional relation between temperature and resistance and the characteristic curve.
  T α R.

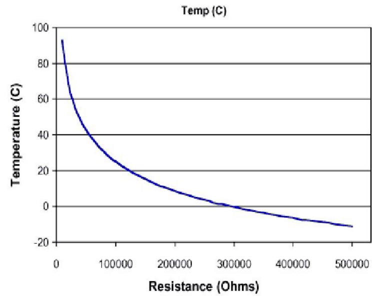


Applications:

- Temperature sensing in electrical motors and transformers protection.
- Liquid level sensor.
- To protect solid state fuse against excess current.

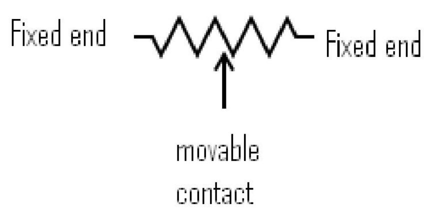
Compare TDR and LDR:

Sr. No.	Characteristics	TDR	LDR
1.	Working Principle	Resistance value of TDR changes in temperature.	Resistance value of LDR changes with change in light intensity.
2.	Material Used	Oxides of metals such as manganese, cobalt, titanium, copper and nickel.	Cadmium sulphide, tallium sulphide, lead sulphide, etc.
3.	Characteristics	PTC 	

		NTC 	
4.	Applications	• Automatic Temperature Control • Used in fluid flow measurement. • Liquid level sensor. • Temperature sensing in electrical motors and transformers protection.	• Automatic Contrast and brightness control in TV • Used in camera light meters, street lights. Etc.

Potentiometers:

- A potentiometer is a manually adjustable electrical resistor that uses three terminals. In many electrical devices, potentiometers are what establish the levels of output.
- For example, in a loudspeaker, a potentiometer is used to adjust the volume. In a television set, computer monitor or light dimmer, it can be used to control the brightness of the screen or light bulb.



- The symbol of potentiometer is shown above. The arrow represents is a movable contact which can be moved on a continuous resistive element.

- The position of the movable contact will decide the value of resistance.
- Some has wired wound resistance as their primary element while others have carbon element.

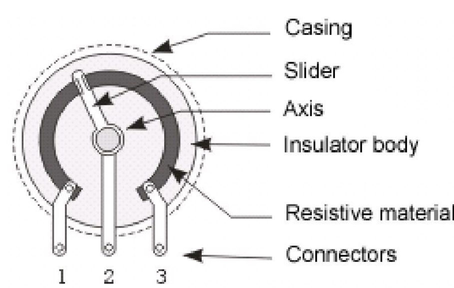
Types of Potentiometers:

Depending upon the material used, following are the some of important potentiometers.

1. Carbon Potentiometers.
2. Wire-wound Potentiometers.
3. Conductive plastic Potentiometer.
4. Cermet Potentiometers.
5. Trimmers (presets).

Wire- Wound Potentiometer:

- Wire-wound potentiometers are made of conductor wire coiled around insulator body. There is a slider moving across the wire, increasing the resistance between slider and one end of pot, while decreasing the resistance between slider and the other end of pot.
- Coated pots are much more common. With these, resistance can be linear, logarithmic, inverse-logarithmic or other, depending upon the angle or position of the slider.



- Most common are linear and logarithmic potentiometers, and the most common applications are radio-receivers, audio amplifiers, and similar devices where pots are used for adjusting the volume, tone, balance, etc.

- Wire-wound potentiometers are used in devices which require more accuracy in control. They feature higher dissipation than coated pots, and are therefore in high current circuits.

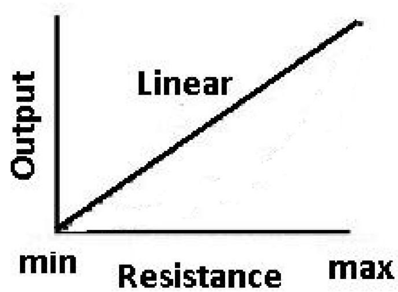
<u>Types of Wire- Wound Potentiometer:</u>

The potentiometers are of two types:

1. Linear Potentiometer
2. Log Potentiometer

1. <u>Linear Potentiometer:</u>

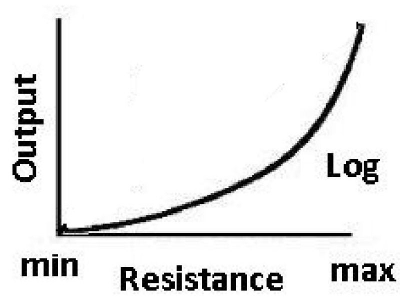
- In linear potentiometers the relationship between resistance and rotation of shaft characteristic is straight line as shown in fig below.



- Linear potentiometers are used where approximately proportional relation is desired between rotation of shaft and resistance value.
- For, eg. Controls used for adjusting the centering of cathode-ray-oscilloscope use linear potentiometers.
- In consumer electronics, user controls uses linear potentiometers.
- The figure below shows the construction of the linear wire wound potentiometer. Here a former (that is the part over which the wire is wound) is of uniform height
- The former or flat strip is made of insulating material usually a synthetic resin bonded sheet.
- The wire is uniformly wound on this format. Due to the uniform height of the format , the resistance varies linearly with the rotation of the contact.

2. Nonlinear (Logarithimic Potentiometer):

- The relation between the rotational position and the resistance value of this type of potentiometers is nonlinear (generally logarithimic) as shown in the fig below.



- For logarithimic potentiometer resistance verses rotation of shaft characteristics is logarithmic curve.
- These potentiometers are used for volume control in radio receivers which is not possible with linear potentiometers.
- Logarithimic Potentiometer is often used in connection with audio amplifiers.
- Logarithimic Potentiometers are more expensive as compared to linear potentiometers.
- Fig below shows the construction of a non linear wirewound potentiometer. As shown, the height of the former is not uniform.
- A tapered strip is taken and the resistance wire is wound on it. After completing the winding , the strip is bend into a round shape as shown below.
- The desired nonlinear relationship between the position of movable contact and the resistance value is obtained due to the tapered strip used.

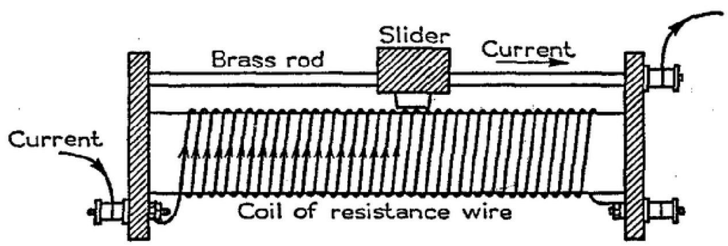
- The logarithmic potentiometers are generally used as volume control potentiometers in radio receivers and music systems.
- Different resistance values can be obtained by changing the diameter of the wire or spacing between wire turns or core length or type of wire.
- Due to coiled wire construction the inductance offered by these potentiometers is high. The maximum operating frequency of these potentiometers is upto 50 KHz only.

Rheostats:

Concept:

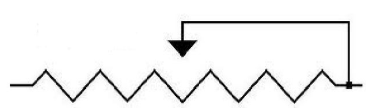
The variable wire wound resistor which is used for varying the high current , designed mainly for laboratory and industrial use where considerable amounts of power have to be dissipated is called rheostat.

Construction:



Wire-wound rheostat

Symbol:



- The former (core) is made up of ceramic or steel and is of round shape.
- Resistance winding of nickel copper in oxidized form is wound over it.
- The wire is covered with insulating coating.
- The adjustable top rider along the exposed wire makes the electrical contact with the wire

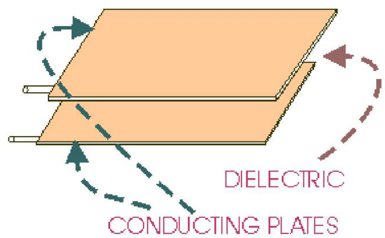
- A sliding contact selects desired resistance value.
- Brushes are made up of copper or graphite.

Cermet Potentiometers:

Cermet is nothing but a mixture of ceramic and metal or metal oxide. A layer of cermet is given on the ceramic or glass substrate. Then temperature is raised to melt the glass.

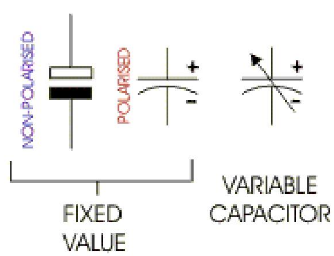
Capactitors:

- Capacitors are components that are used to store an electrical charge and are used in timer circuits.
- A capacitor may be used with a resistor to produce a timer. Sometimes capacitors are used to smooth a current in a circuit as they can prevent false triggering of other components such as relays.
- When power is supplied to a circuit that includes a capacitor - the capacitor charges up. When power is turned off the capacitor discharges its electrical charge slowly.



Construction of basic capacitor

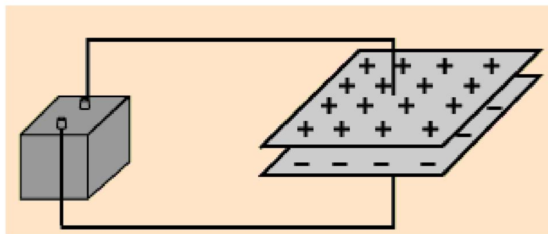
- A capacitor is composed of two conductors separated by an insulating material called a DIELECTRIC.
- The dielectric can be paper, plastic film, ceramic, air or a vacuum. The plates can be aluminium discs, aluminium foil or a thin film of metal applied to opposite sides of a solid dielectric.
- The CONDUCTOR - DIELECTRIC - CONDUCTOR sandwich can be rolled into a cylinder or left flat



Symbols

Capacitance:

- Capacitance is the ability (or property) of a capacitor, which opposes the changes in voltage by means of energy storage in the form of electrostatic energy.



- Capacitance is typified by a parallel plate arrangement and is defined in terms of charge storage.
- As the applied voltage across plate is constant the electric charge "Q" across the metal plate is also constant.
- $Q \propto V$

  $Q = CV$

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

  C= Proportionality constant and called as capacitance.

  Q = magnitude of charge stored on each plate (Coulomb).

  V= voltage applied to the plates (Volts).
- Unit = $\frac{\text{Coulomb (Q)}}{\text{Volt (V)}}$ = Farad (F)
- For a parallel plate capacitor,

  $C \propto \frac{\varepsilon A}{d}$ or $C = \frac{\varepsilon 0\ \varepsilon r\ A}{d}$

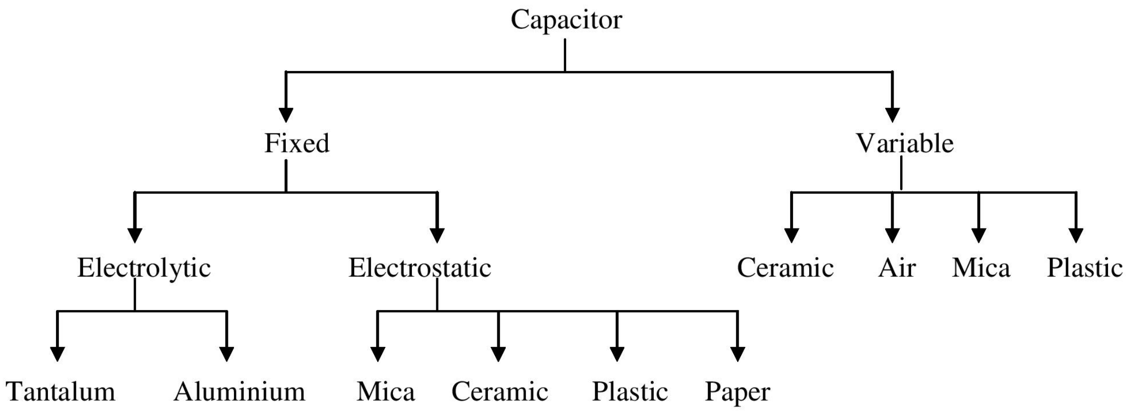
  ε0 = Absolute permiticity (8.854×10^{-12} farads/meter)

  εr = Relative permittivity (εr = 1 for air)

  A = Area of the plate.

  d = Distance between the plates.
- Capacitor has the property to bypass (AC) and block (DC).

Classification of Capacitors:



Dielectric materials used in Capacitor:

Materials	Permittivity
Vaccum	1.0
Air	1.00006
Teflon	2.1
Polyethylene	2.0 to 3.0
Impregnated paper	4.0 to 6.0
Glass and Mica	4.0 to 7.0
Ceramic ()	

Capacitor Specifications:

1. Capacitor Working Voltage:

- It is defined as the maximum voltage at which a capacitor can operate without failure. The working voltage is usually rated as DC value.
- Working voltage is dependent on the dielectric strength of the material used.

2. Insulation Resistance:

- The certain amount of current flowing through the dielectric material of a capacitor is known as leakage current. The insulation resistance is measured across the terminals of a capacitor at specified voltage and temperature.

- Insulation resistance is expressed in Mega Ohms (MΩ).

3. <u>Equivalent Series resistance (ESR):</u>

- The effective resistance, which is used to describe the resistive parts of the impedance of electronic component is called equivalent series resistance (ESR).
- The capacitors have an ESR of 0.01Ω.
- It reflects the losses inside the capacitor.

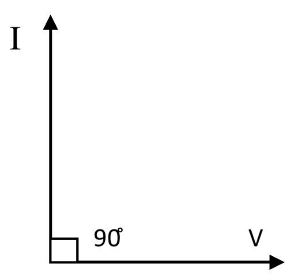
$$\text{ESR} = \frac{\text{Losses inside a capacitor}}{I^2}$$

4. <u>Dissipation factor:</u>

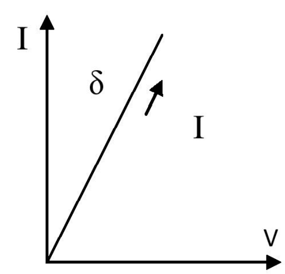
- When AC voltage is applied to the dielectric, capacitor current does not lead by 90° , but a little less as shown in figure (b).
- Thus dissipation factor = tan δ

  δ= The dielectric loss angle and depends upon the;

  Nature of dielectric material, Frequency, Temperature and Voltage



(a) Ideal



(b) Actual

5. <u>Power Factor:</u>

   It is a sine or cosine of the dissipation factor (δ).

   Power Factor P.F. = cos δ or sin δ

6. <u>Capacitance:</u>

- It is the property of a capacitor, which opposes the changes in voltage by means of energy storage in the form of electrostatic energy.
- The value of capacitance depends upon the area of conducting plates, thickness of dielectric material and its permittivity.

7. Effect of frequency on **Capacitive reactance**:

- Capacitive reactance (Xc) is given by

$$Xc = \frac{1}{2 \Pi f C}$$

- The capacitive reactance decreases with the increase in frequency of a voltage applied across the capacitor.
- The operation of capacitor with various frequency may change the value of capacitance.

Fixed Value Capacitors:

The capacitors in which the capacitance value cannot be varied by any means (i.e. either by changing plate separation or area) are called fixed capacitors. These capacitors are broadly of two types namely electrostatic (or non-electrolytic) and electrolytic capacitors.

Electrostatic Capacitors:

These capacitors are made up of two metal conductors (called plates) separated by dielectric. They are characterized by very low leakage current and high leakage resistance. Following are the types of electrostatic capacitors.

1. <u>Ceramic Capacitors:</u>

These capacitors are made by using various ceramic materials as dielectrics.

<u>Specifications:</u>

- Capacitance Value: 10ρF to 1μF
- Working Voltage: >500 V DC
- Max. Operating temperature: 150□ C
- Max. frequency: 200 MHz

<u>Applications:</u>

Amplifiers as coupling, decoupling, bypass, fettering, sample and hold and in timing circuits.

2. <u>Mica Capacitors:</u>

These capacitors are formed by placing the alternate layers of metal foils and mica sheet. This structure is then clamped on both ends to form a capacitor

<u>Specifications:</u>

- Capacitance Value : 1ρF to 10,000 ρF
- Working Voltage: ~ 500 V DC
- Max. frequency: 200 MHz

<u>Applications:</u>

The mica capacitors are widely used in radio and telecommunication applications R.F. tuned circuits and pulse circuits

3. **<u>Plastic film capacitors:</u>**

These capacitors are made by using plastic materials as a dielectric. The plastics used for this purpose are polester, (mylar), polypropylene, polystyrene, Teflon etc.

Specifications:

Capacitance Value: 0.001μF to 10 μF (polyester) and 5ρF to 0.05 ρF (polystyrene)

Working Voltage: 1000 Vdc.

Max. Operating temperature: 250□ C.

Tolerance: ± 20%.

4. **Paper Capacitors:**

These capacitors are made by using strips of aluminum foil with treated paper as dielectric.

Specifications:

Capacitance Value: 0.001μF to 1 μF

Working Voltage: 2000 Vdc.

Applications:

Paper capacitors are used as filter capacitors in the power supplies and as coupling capacitors in amplifiers.

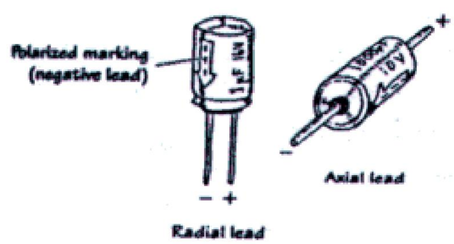
Polarity in DC circuits:

- Paper capacitor, mica and ceramic capacitor are non-polarized capacitors.
- There is no necessity to take care for connecting in DC circuits.
- Electrolytic capacitor is a polarized capacitor.
- This capacitor may get damaged due to application of the DC voltage of incorrect polarity and this may damage the capacitor.

Electrolytic Capacitor:

Concept:

- An ELECTROLYTIC CAPACITOR is used where a large amount of capacitance is required. As the name implies, an electrolytic capacitor contains an electrolyte.
- This electrolyte can be in the form of a liquid (wet electrolytic capacitor). The wet electrolytic capacitor is no longer in popular use due to the care needed to prevent spilling of the electrolyte.
- A dry electrolytic capacitor consists essentially of two metal plates separated by the electrolyte. In most cases the capacitor is housed in a cylindrical aluminum container which acts as the negative terminal of the capacitor.
- The positive terminal (or terminals if the capacitor is of the multisection type) is a lug (or lugs) on the bottom end of the container. The capacitance value(s) and the voltage rating of the capacitor are generally printed on the side of the aluminum case.



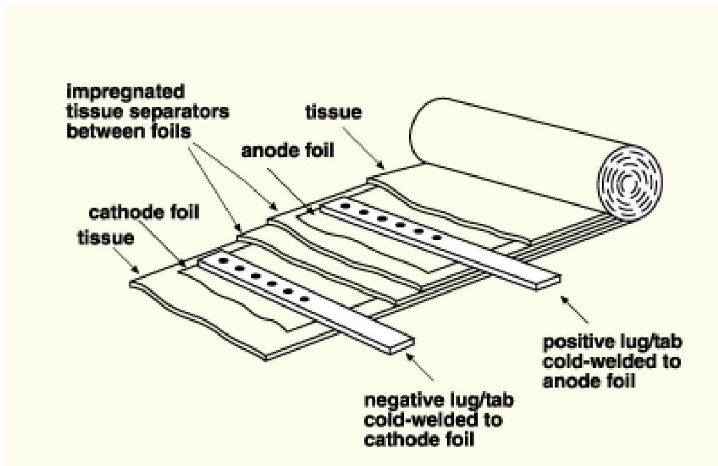
- When a voltage of correct polarity is applied to a capacitor, a very thin layer of oxygen atoms forms between the anode and the oxide layer. A reversal of polarity removes the insulating layer, here by allowing high currents. Thus electrolytic capacitors are known as polarized capacitors.
- The metal electrodes of an electrolytic capacitor, can be either of an aluminum or tantalum metal. Accordingly, the electrolytic capacitors are divided into two types.

1. Aluminum electrolytic capacitor.
2. Tantalum electrolytic capacitor.

Aluminum Electrolytic Capacitor:

Concept: These capacitors have a higher working voltage and low cost as compared to other capacitors of similar capacity. But they are susceptible to certain compounds like Freon, trichloroethylene and carbon tetrachloride etc.

Construction:



It consists of following parts,

1. First aluminium foil
2. Oxide film
3. Electrolyte
4. Metal (Al)

- A thin film of aluminum oxide is deposited on the surface of aluminum plate.
- Aluminum Electrode is placed in a solution of ammonium borate.
- Two strips of aluminum foil are used.
- These aluminum foils are separated by two layers of paper soaked with electrolyte.
- It is rolled, ends closed with wax and sealed in a container.
- The aluminum foil is used as positive electrode called an 'anode' and the film of aluminum oxide is used as 'dielectric film'.

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- The metallic container of aluminum is in contact with the electrode paste and it is used as a negative electrode called a cathode.

Variable Capacitors:

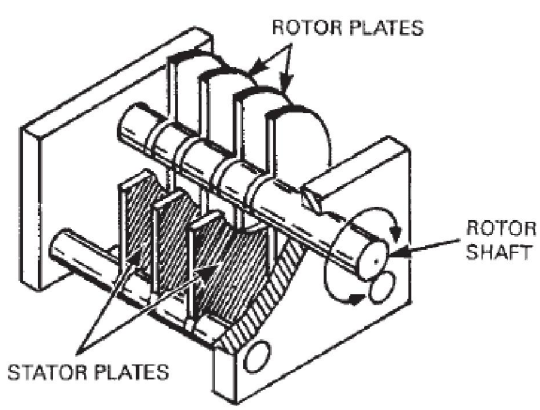
- The capacitors, in which the capacitance value may be changed by some means, are called variable capacitors.
- The capacitance value is, usually changed either by varying the area between the plates or by adjusting the spacing between them.
- The variable capacitors are made by using air, mica, ceramic or plastic as dielectric.
- The variable capacitors, using air as a dielectric, are used as gang capacitors in radio receivers. The variable capacitors, using other dielectrics, are called trimmers or padders.

Air Gang Capacitors (Variable capacitor with Air as Dielectric):

Concept:

A tuning capacitor is a variable air-dielectric capacitor with plates that move within other plates to change the overall capacitance value.

Construction:



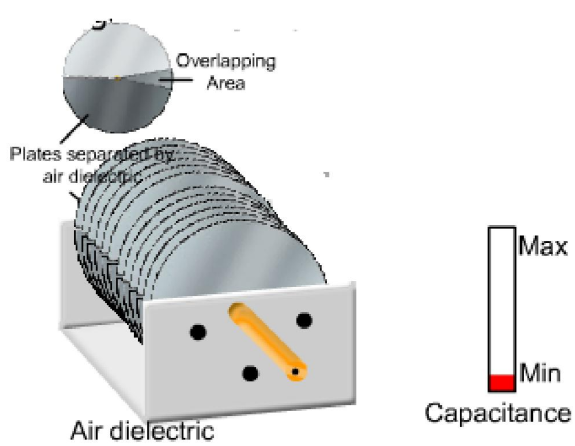
The air gang capacitor consists of following parts.

1. <u>Rotar :</u>
    - The rotar is a rotating part and is usually constructed of several semi-conductor disk or plates, affixed to the shaft.
    - The rotar plates are moved in and out of the fixed plates, the capacitance value varies.
2. <u>Stator:</u>
    - The stator is the fixed portion and consists of similar shaped plates as shown in the figure.
    - These are mounted such that the rotor plates can be intermeshed with stator plates by rotating the rotor shaft.
    - Made up of brass, copper or aluminium.
3. <u>Dielectric:</u>
    - The air is used as dielectric medium between Stator and Rotor.

<u>Case 1. :</u>

When the rotor plates are completely out of the stator plates, minimum area is covered by rortor plates and hence the capacitance is also minimum by .

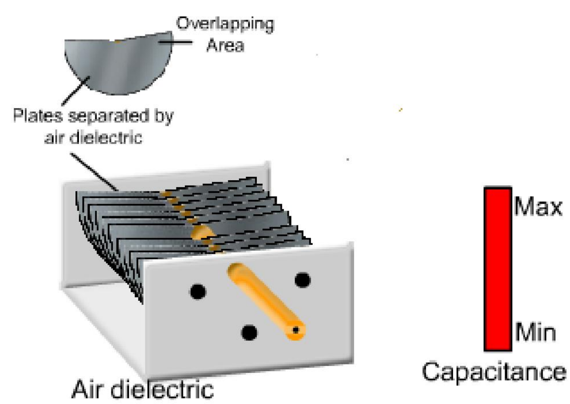
$$\boxed{C = \frac{\varepsilon A}{d} \text{ (min)}}$$



Case 2.:

When the rotor plates are completely inside the stator plates, area covered id maximum and capacitance is also maximum.

$$\boxed{C = \frac{\varepsilon A}{d}\ (\text{max})}$$



Applications

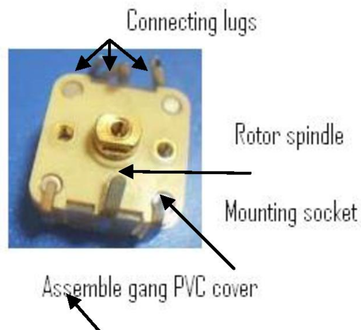
Used in radio receivers for tuning to different radio stations.

PVC Gang capacitor:

Concept:

The gang capacitor which used the PVC (poly-vinyl chloride) as the dielectric medium is called PVC gang capacitor.

Construction:



- The variable plate (Rotor) is made up of cadmium-plated aluminum.
- Dielectric spacer is used between the plates.
- The dielectric spacer is made up of polyethylene.
- The total assembly is tied together by four screws, whose heads are fixed to a plastic base.
- The alternate layer of stator plates, PVC dielectric and rotor plates are arranged.
- All the rotor plates are connected to common screw and adjustable head is provided at the top for adjustment.

Specification:

Capacitance Range: 7ρF to 350ρF or 5ρF to 250ρF

Applications:

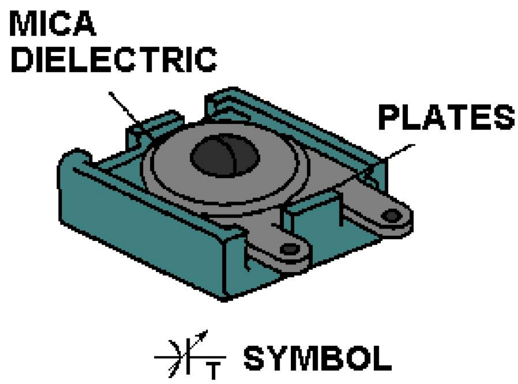
Used in radio receivers and super heterodyne receivers for tuning purpose because of its smaller size.

Trimmer Capacitor:

Concept:

These capacitors are variable capacitors and are used exclusively for making fine adjustments on the total capacitance of a device.

Construction:



1. Rotor:
    - The rotor carries a semiconductor pattern. This pattern consists of metallization of rotor to provide an electrode.
    - The rotor pattern is usually semicircular to utilize maximum resolution capability during tuning.
2. Stator:
    - The stator consist of metalized pattern deposited on disk.
3. Dielectric:
    - The dielectric is usually titanate ceramic or mica, is placed between rotor and stator electrode.
    - The botton surface of rotor plate and top surface of stator plate are made flat to provide contact between plates and to exclude air between the two plates.
    - The spacing between the plates can be changed by means of a screw adjustment.

Case1. :

As the screw is rotated inwards the plates are compressed and distance between plates is reduced, and hence capacitance increases

Since $\boxed{C = \frac{\varepsilon A}{d} \text{ (max)}}$

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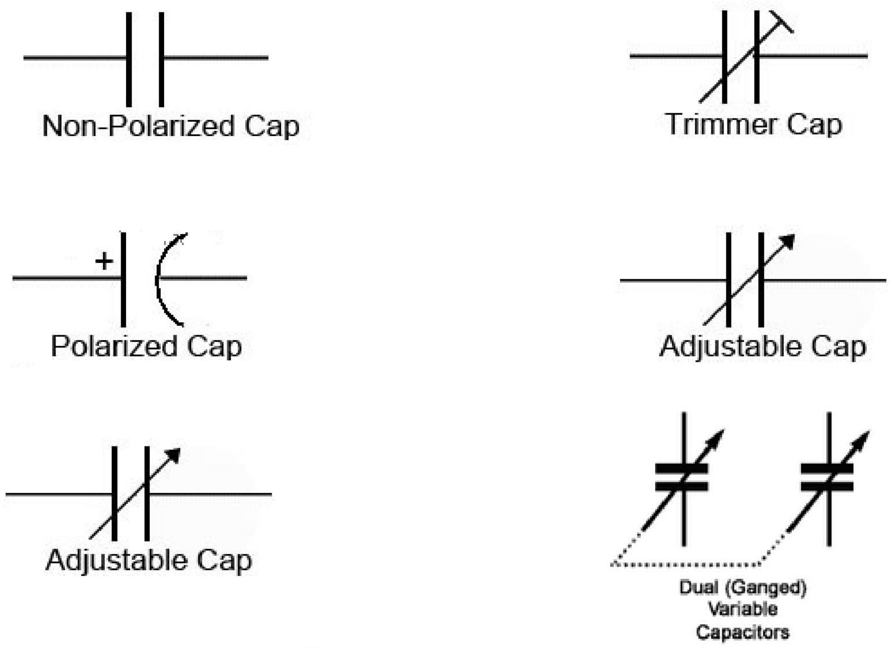
Case 2. :

As the screw is rotated outwards, the distance between plates is increased, and hence capacitance decreases,

Since, $\boxed{C = \frac{\varepsilon A}{d} \text{ (min)}}$

Symbols of capacitor:



Coding of capacitors:

1. Based on Numeral codes.
2. Based on Alpha-Numeral codes.
3. Based on Direct value printed on body.
4. Based on color code marking.
5. Based on values printed on body of capacitor.

1. <u>Based on Numeral codes.</u>

a) Two digit Numeral code:
   Step 1. Write both digits and then multiply this value by Pico (i.e. 10^{-12}).
   Step 2. This gives value of capacitor in farads.

Ex. 1. 32

i.e. C = 32 × 10^{-12} F = 32 PF

Ex. 2. 85

i.e. C = 85 × 10^{-12} F = 85 PF.

b) Three digit Numeral Code.
   Step 1. Write first two digit as it is.
   Step 2. Use third digit as a power of '10'
   Step 3 . Multiply value by pice (10^{-12}).

Ex .1. 532

i.e. (53 × 10^{2}) × 10^{-12}

= 53 × 10^{-10} F = 5.3 × 10^{-9} F = 53 nF.

2. <u>Based on Alpha- Numeric code:</u>

a)

Step 1. When letter 'K' comes after digit, multiply digit by 10^{3} (i.e. 1000).

Step 2. Again multiply it by 10^{-12}

Ex.1. 3K

C = (3 × 10^{3}) × 10^{-12} = 3 × 10^{-9} = 3pF.

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Ex.2. 12K

$$C = (12 \times 10^{3}) \times 10^{-12} = 12 \times 10^{-9} = 12pF.$$

b)

Step 1. When 'K' comes between two digits, remove 'K' from there and insert decimal point.

Step 2. For 'K' multiply it by 10^{3} (i.e. 1000) and again multiply it by 10^{-12}.

Ex. 1. 3 K 3

$$C = (3.3 \times 10^{3}) \times 10^{-12} = 3.3 \times 10^{-9} = 3.3nF.$$

Ex.2. 1 K 2

$$C = (1.2 \times 10^{3}) \times 10^{-12} = 1.2 \times 10^{-9} = 1.2nF.$$

3. Based on direct value printed on body.

Step 1. If decimal point is there before digit then value is directly in microfarads (μF).

Ex.1. C = 0.2 = 0.2 μF

C = 0.44 = 0.44 μF.

4. Based on color code printed.

a)

Step 1. For three band for first band write 1st digit and for second band write 2nd digit from table.

Step 2. Third band is multiplier write from table again.

Step 3. Again multiply it by 10^{-12}

Ex .1. Orange Orange Blue

$C = (3 \quad 3 \quad \times 10^6) \times 10^{-12}$

$C = 33 \times 10^{-6} = 33\mu F$

b) Four band

Step 1. For four band last band is vale of tolerance

c) For five band.

Step 1. The fourth band indicates value of tolerance and 5th band indicates working voltage.

Ex. 1. Yellow violet Orange Silver

$C = (4 \quad 7 \quad \times 10^3) \times 10^{-12}$, ± 10%

$C = 47 \times 10^{-9}$, ± 10%

C = 47nF, ± 10%.

Ex. 2. Orange yellow white silver blue

$C = (3 \quad 4 \quad \times 10^9) \times 10^{-12}$, ± 10% , 600 V

$C = 34 \times 10^{-3}$F, ± 10% , 600 V

C =0.034 μF, ± 10% , 600 V.

5. Based on direct value printed.

Step 1. X / Y / Z

X = Value of capacitor (from method 1 to 4).

Y = Tolerance

X = Working voltage

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Ex. 1. 0.15 / 10 / 250

C = 0.15μF, ± 10% , 250 V.

Ex. 2. 1 K 2 / 10 / 500

C = $(1.2 \times 10^{3}) \times 10^{-12}$ / 10 / 500

C = (1.2×10^{-9}) F, ± 10%, 500 V

C = 1.2nF, ± 10%, 500 V

6. Color code based in value of capacitor

Step 1. The valur of capacitor will be in terms of microfarad shift the decimal digit and write the multiplier accordingly.

Step 2. Convert the multiply always in terms of 10^{-12} by multiplying and dividing by that factor.

Step 3. Write down the value of first digit second digit and multiplier from table and leave 10^{-12} as it is.

Ex. 1. C = 0.68μF

$$C = 68 \times 10^{-2} \times 10^{-6}$$

$$C = 68 \times 10^{-8} \times \frac{10^{-4}}{10^{-4}}$$

$$C = 6\ 8 \times 10^{4} \times 10^{-12}$$

C = Blue gray Yellow

Color code for 0.68μF is Blue, gray ,Yellow

1. 3. - Inductors:

Magnetic Field:

The magnetic field is defined as the region near a magnet within the effect or influence of the magnet is felt. The influence of a magnet can be tested by using a simple compass niddle or by using an another magnet.

Magnetic Flux ϕ:

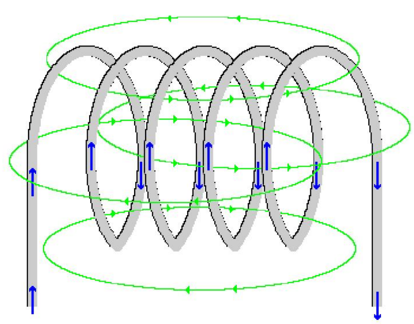
The magnetic flux is defined as the total no. of lines of force in a magnetic field. It is denoted by ϕ and measured in Weber.

Inductance:

- It is the property of a coil, which opposes changes in current by means of energy storage in the form of magnetic field.
- It has been observed that a current carrying conductor or a coil has a magnetic field (or flux) associated with it.
- The strength of this magnetic field is directly proportional to the amount of current in the coil.
- *The inductance is a measure of the energy stored in the coil in the form of magnetic field. The unit of inductance is Henry(H).*

Inductors (or coils):

An inductor (or a coil) is an electrical component, which is manufactured with a specified amount of inductance.



Introduction to magnetic materials:

Magnetic materials:

- All the molecules of a material contain electrons orbiting around nucleus.
- These revolving electrons are equivalent to circulating current and so develop the magneto-motive force (mmf)
- The dipole is created by circulating current.

Classification of magnetic materials:

Magnetic materials can be classified into five groups according to the type of magnetic behavior such as.

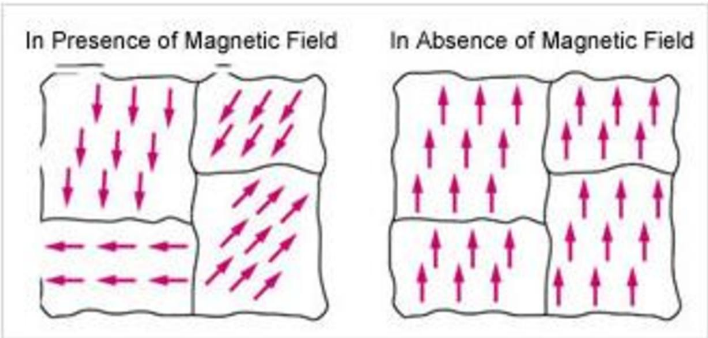
1. Diamagnetic 2. Paramagnetic

3. Ferromagnetic 4. Anti-ferromagnetic

5. Ferrimagnetic.

1. **Ferromagnetic Materials:**

- Ferromagnetic materials are those magnets that shows spontaneous magnetization. If these materials are brought closer to a magnet they will be strongly attracted towards it regardless of orientation.



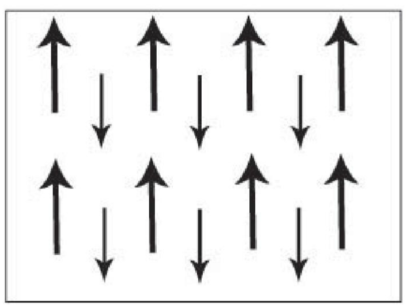
Ferromagnetism

- These are materials in which magnetic dipoles interact in such a manner that they tend to line up in parallel are called Ferromagnetic Material.

- The direction of the magnetization varies from domain to domain as shown in the fig above.
- If an external field 'H' is applied, the domains with proper direction of spontaneous magnetization grow at the expense of that are magnetized in other direction by virtue of a motion of domain walls.
- Ultimately the whole specimen may become one single domain on increasing field. Hence saturation is achieved.
- Eg. Iron, cobalt, Nickel, Cadmium etc.

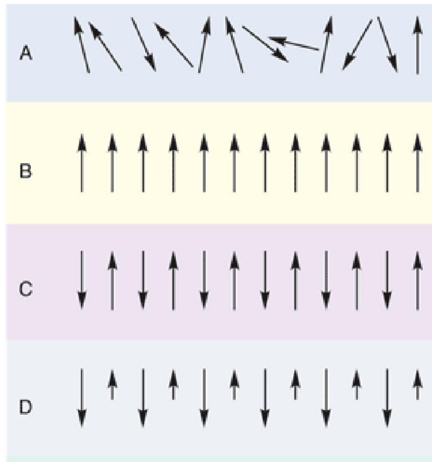
<u>Ferrimagnetic materials:</u>

- The aligned magnetic moments are not of the same size; that is to say there is more than one type of magnetic ion. An overall magnetisation is produced but not all the magnetic moments may give a positive contribution to the overall magnetisation.



- Under normal conditions the magnetic characteristics of ferromagnetic materials are similar to those of ferromagnetic material below a certain temperature they show spontaneous magnetization.
- Ex. Magnetite, nickel ferrite etc.

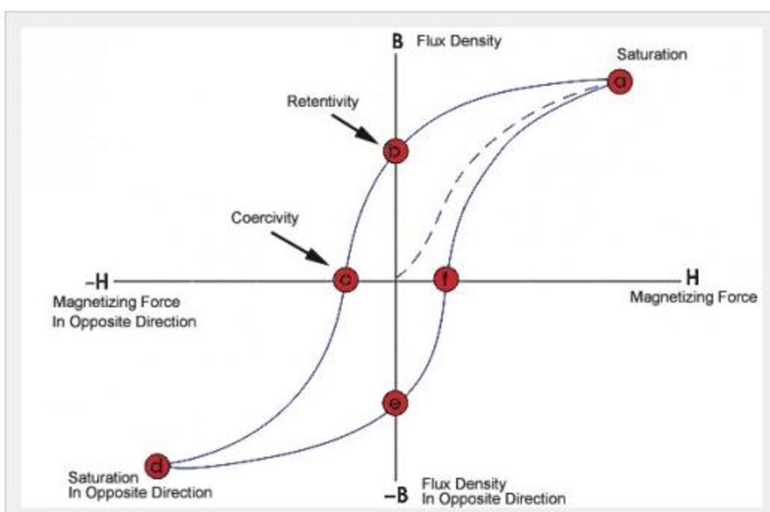
Overall classification:



A. Paramagnetism
B. Ferromagnetism
C. Anti- Ferromagnetism
D. Ferrimagnetism

B-H curve or Magnetization Curve:

- The magnetization curve of magnetic material specimen between the flux density ‘B’ and the fiel intensity



The B-H curve can be plotted by increasing and then decreasing field intensity.

1. Curve oa:
   The flux density B increases when external filed intensity H applied to it is increased.
   When the saturation of flux density arises the increase in flux density ceases even though the field strength is increased.
2. Curve ab:
   If the external field is gradually reduced then the original curve ‘oa’ is not retraced but follows the curve ‘ab’.
   When external field is reduced to zero the magnetic flux does not reduce to zero, i.e. material remains magnetized.
3. Flux density ob:
   The value of flux density ‘ob ‘is called remanant flux density or Br(residual magnetism)
4. Curve bc:
   In order to demagnetize the material completely, the external magnetic field must be reversed and when it reaches the value OR in reverse direction, it is seen that the flux density is zero.

Coercive force:

The applied reverse magnetizing force which causes the magnetic flux to zero is called the coercive force.

5. Curve cd:
   Further increase of field intensity in the reverse direction will now increase the flux density in reverse direction and again at the point S the saturation occurs.
6. Curve oe:
   The residual magnetism in reverse direction is represented by ‘oe’ and to neutralize it the magnetic field intensity must be increases in positive direction to the value ‘of’.

Hysteresis loop:

When the magnetic material is taken through one complete cycle of magnetization it traces the loop that is called hysteresis loop.

Terms related to magnetic materials:

1. Permeability:

- The capability if the magnetic materials to conduct the magnetic flux is called permeability.
- It is defined as the ratio of magnetic flux density 'B' in a medium to the magnetic flux intensity 'H' at the same location in the medium.
- It is denoted by a letter 'μ' and is expressed as

$\boxed{M = B/H}$

2. Retentivity:

- The residual magnetic flux density i.e. residual; magnetism is called retentivity.
- After magnetization, the magnetic material specimen retains certain amount of magnetization.

3. Coercivity:

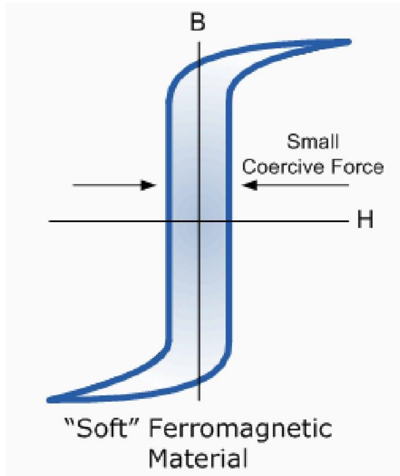
The reverse magnetizing i.e. coercive force applied to reduce the magnetic flux density to zero is called coercivity.

SOFT magnetic materials:

Definition:

The ferromagnetic material having steeply rising magnetization (B-H) i.e. hysteresis curve are called soft magnetic materials.

- These materials can be easily magnetized and they may easily lose their magnetism.
- Its B-H curve is very narrow with low coercive force.
- They are used for transformers, motors, generators, relays.



Properties:

- It has high permeability.
- It has very narrow B-H curve.
- It has a low coercive force.
- It can be easily magnetized.
- It has low residual magnetism.

Examples:

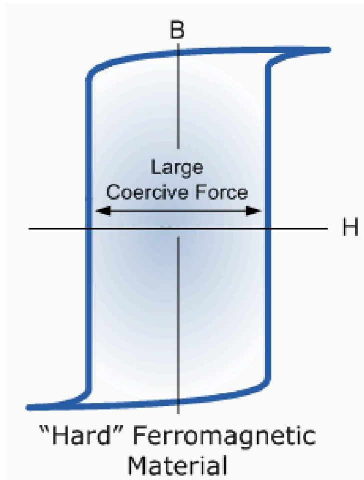
Pure iron, iron-silicon alloy, Nickel-iron alloy, Soft ferrites.

HARD Magnetic materials:

Definition:

The ferromagnetic materials having a gradually rising magnetization curve and maximum energy product $(B\times H)_{max}$ are called hard magnetic materials.

- These materials are very hard to be magnetized and it is difficult to orient domains of hard magnetic materials as compared to soft magnetic materials.
- They are used for fabrication of permanent magnet.



Properties:

- It has high coercivity.
- It has high retentivity.
- It has low permeability.
- It has rectangular hysteresis loop.
- It has high residual magnetism.
- It is hard to be magnetized.

Examples:

Rare earth cobalt, tungsten steel, hard ferrites, alnico, cobalt steel.

Comparison of soft and hard magnetic materials

Write the properties, b-h curve and examples as comparison from above.

MR. NIKHIL S.

Losses in Magnetic Materials:

Magnetic materials have different losses like.

1. Hysteresis loss.
2. Eddy current loss
3. Core loss or iron loss.

1. Hysteresis loss:

- Certain amount of energy need to be supplied to generate a magnetic field in free space.
- If magnetic field applied to a magnetic material is increased and then decreased back to its original value, the magnetic field inside the material does not return to its original value.
- The internal field lags behind the external field.
- This behavior results in loss of energy called the hysteresis loss, when sample is repeatedly magnetized and demagnetized.
- During the return, part of energy to the circuit, the same energy is lost in the form of heat, if the field is wholly or partially stored in ferromagnetic material.

Factors effecting Hysteresis loss:

- Frequency of magnetization: Directly proportional.
- Volume of the material: Proportional.
- Area enclosed by the hysteresis: Directly proportional.

Hysteresis loss is directly proportional to the frequency and volume. So by reducing them we can reduce the loss.

2. **Eddy current loss:**

- A coil is wound on the iron core and an alternating current is forced through the coil.
- When the current starts flowing through the coil, it produces an alternating magnetic flux.
- This flux will induce emf in the coil.
- This emf gives rise to circulating currents in the iron core, which are called as Eddy current.
- The eddy current flows in close loop as shown in the fig below.

Effects of eddy current:

The eddy current flows through iron core and produces power loss equal to I^2R in the form of heat.

Faraday's law of Electromagnetic Induction:

First law of Electromagnetic Induction:

Statement:

This law states that whenever the magnetic lines of force (flux lines) linking with a coil or conductor changes, an emf gets induced in the coil or conductor. Such an emf lasts as long as this change is taking place.

OR

Whenever a conductor cuts a magnetic field or vice versa an emf is induced in it and it sets up in such a direction so as to oppose the cause of it.

Second law of Electromagnetic Induction:

Statement:

This law states that magnitude of induced emf is directly proportional to the change of magnetic flux linkage.

OR

The magnitude of induced emf is directly proportional to the product of number of turns and rate of change of magnetic flux linking with the coil.

Electromagnetic Induction:

The electromagnetic induction is phenomenon by which emf is induced in a conductor when it is cutting the magnetic flux.

Expression for Induced E.M.F.:

Induced emf ‘e’

$\frac{d\phi}{dt}$ = Rate of change of flux linkage

e = No. of turns × Rate of change of flux.

$$\boxed{\begin{array}{l} e = N\frac{d\phi}{dt} \\[2ex] e = -N\frac{d\phi}{dt} \end{array}}$$

(Acc to lenz’s law)

-ve sign indicates that induced emf opposes the cause producing it.

Lenz’s law:

The direction of induced emf produced due to process of electromagnetic induction is always such that it will set up a current to oppose the basic cause responsible for inducing the emf.

OR

The induced emf will always oppose the cause behind its production

Types of induced EMF

- Dynamically Induced EMF
- Statically Induced EMF
  - Self Induced EMF
  - Mutually Induced EMF

INDUCED EMF

Whenever a conductor is placed in a varying magnetic field, EMF is induced in the conductor and this EMF is called induced EMF.

Dynamically Induced EMF:

When the conductor is in motion and the field is in stationary so the EMF is induced in the conductor, this type of EMF is called dynamically induced EMF.

Statically Induced EMF:

When the conductor is in stationary and the field is changing (varying) then in this case EMF is also induced in the conductor, which is called statically induced EMF.

1. Self Induced EMF

- Self-induced EMF is that EMF which is induced in the conductor by changing in its own. When current is changing the magnetic field is also changing around the coil and hence Faraday law is applied here and EMF are induced in the coil to itself which called self induced EMF.
- The set up consist of a coil (with N turns) wound on a magnetic material core. A battery along with a variable resistance ‘R’ is used to adjust the current I flowing through the coil.

Self Inductance:

- The property of a coil due to which it opposes any change of current through it is called as self inductance.
- It is measured in terms of inductance 'L'.
- Its unit is Henry i.e. 'H'

Mutually Induced EMF:

- When an alternating voltage or current is applied to the coil 'a' alternating current will flow in the coil' a' and is a result of which a varying magnetic field will produced around the coil 'a'.
- If we placed another coil 'b' in the field of coil 'a' then Faraday law is also applied here and EMF are induced in coil `b' this EMF is called mutually induced EMF.

Mutual Inductance:

- The property of a coil to induce emf in another coil, when the current in the first coil is changed and the flux produced by the first coil is linking with the second, is called mutual inductance.
- Its unit is Henry.

Coefficient of coupling:

- When two coils 'A' and 'B' having turns 'N1' and 'N2' respectively are placed together all the flux produced by the coil 'A' does not link with the other coil 'B'.
- Only a certain proportion, say 'K' , of the flux produced by the coil 'A' links with the other coil 'B'.
- 'K' being less than unity.
- 'K' is called coefficient of coupling

$$K = \frac{M}{\sqrt{Li\ L2}}$$

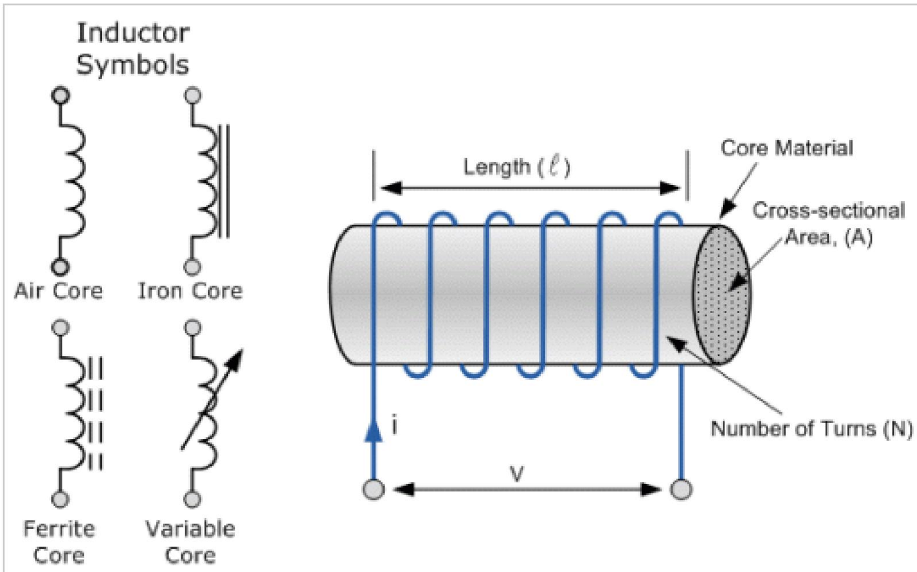
Inductors:

- An inductor is a coil of electromagnetic device that oppose any change is current.
- Inductors or coils, probably vary more in design than any other component. Superficially they consist merely of wire wound on an insulator.
- Inductor is the name of a component.
- Its value is inductance.

Unit:

- Inductance is measured in Henry (H).
- It is denoted by L.

Construction and Symbol:



Specifications of Inductors:

1. Inductance of a coil:

- Inductance is that property of an electric circuit where by changes in the current flowing through it produces changes in the magnetic field.
- Its unit is Henry (H).

  Refer above diagram

Where $\boxed{L = \frac{\mu N^2 A}{l}}$

Where, L = Inductance of a coil,

N = No. of turns

A = Area of the coil

l = length of the core in meter.

μ = permeability of medium.

2. **<u>Inductive Reactance:</u>**

- When an AC sinusoidal current is applied to an inductor a voltage is induced in a direction to always oppose the change in the AC current.
- The resistance to the change in the AC inductor current is called Inductive reactance (X_L) and is measured in ohms (Ω).

  $X_L = \omega L = 2\Pi F\ L$

  ω = frequency in radians per second

  F = frequency in Hertz (Hz)

  L = Inductance in Henry (H).
- Inductive Reactance (X_L) of the inductor is directly proportional with frequency.

3. **Self Inductance**
4. **Mutual Inductance**
5. **Coefficient of coupling.**

6. **<u>Quality factor:</u>**

The ability of an inductor to store energy as compared to the dissipation of energy within the inductor is called Q-factor.

$$Q = \frac{\text{Energy stored}}{\text{Energy dissipated}} = \frac{I^2.X_L}{I^2.R_O} = \frac{X_L}{R_O}$$

Classification of Inductors:

- Inductors
  - Fixed
    - Air core
    - Cored
      - Iron core
      - Ferrite core
  - Variable
    - Slug tunned
    - Tapped

Fixed Inductors:

The inductors whose inductance is fixed and cannot be varied by any means are called fixed value inductors.

Air- core Inductor:

Concept:

- Air core inductor consists of number of turns of a wire on a ordinary card-board called as former.
- Since there is air inside the former, hence this type of coil is called as air-core inductor.

Construction:

- In the construction of air core inductors, a core is made up of ceramics, plastic or cardboard type insulating material.
- The conductive wire is wound on this core hence there is air inside the coil.
- Due to this all magnetic lines produced by the changing current, do not link with every turn of the coil.
- These magnetic lines last in the surrounding space therefore the inductance value is reduced.

Applications:

- They are used for intermediate or Radio frequency (I.F or R.F.) applications in tuning coils.
- Used for interstage coupling.
- It is used in filter circuits.

Iron core inductor:

Concept:

- The air core inductors have a very low values of inductance.
- The inductance value of an inductor can be increased by using iron core.
- The fixed value inductor having an iron core placed inside the coil is called an iron core inductor.

Construction:

- The iron core is laminated to avoid eddy current losses.
- When iron core is placed inside a coil, the lines of flux produced by AC flowing in the coil finds a much easier path through the iron core and do not tend to leak to the outside of the core.
- Instead the lines of flux produced by the AC complete their path through the iron core.
- When a current flows in a coil, the iron gets magnetized and adds its own flux to those produced directly by the current.

- Hence the total flux linked with the coil increases i.e. the inductance of the coil is much greater in an iron cored inductor.

Applications:

- It is used in filter circuits to smooth out the ripple voltage.
- It is used in fluorescent tube lights as AF choke .
- Used in Audio frequency applications.

Ferrite core inductors:

Concept:

The fixed value inductor having a ferrite core placed inside the coil is called a ferrite core inductor.

Construction:

- Ferrite is a ferrous magnetic material. In this type of inductor, wire is wound on a ferrite core.
- These inductors usually employ pot cores i.e. cores consisting of an outer cylinder with closed ends.
- The winding is placed in annular space.
- The air gap is induced in the central core and by choosing a suitable length for this air gap, the properties of pot may be changes to suit a wide range of design requirements.

Applications:

- It can be used at high and medium frequencies.
- Ferrite rod antenna is used for medium wave receivers.

Variable Inductors:

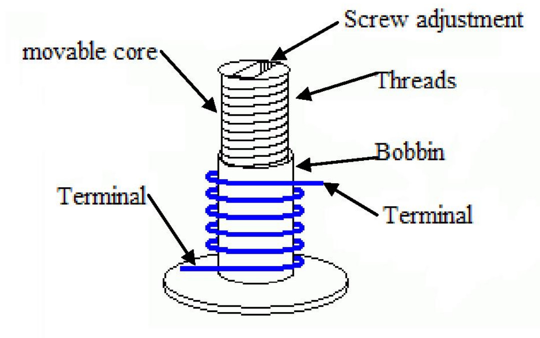
The inductors whose inductance values can be varies manually to it's maximum specified limit is called variable inductors.

Slug – tuned Inductor:

Concept:

- Tuning inductors can be either air core, ferrite or powdered iron core coils. The air core coils are not adjustable unless either an expensive roller contact mechanism or clumsy taps on the windings are provided.
- However, the ferrite and powdered iron slug-tuned core coils are adjustable.

Constructional diagram



Variation in the value of inductor:

Case 1.:

- When the slug (i.e. moving) coil is moved in to the coil, more no of turns are covered by the core.
- Due to this there will be maximum flux linkage and hence inductance value increases.

Case 2.:

- When the slug (i.e. moving coil) is moved out of the bobbin less no. of turns are covered by the core and hence flux linkage will be less and due to that inductance value decreases.

Parts in Slug tuned Inductor:

1. Bobbin:
- This is one on which the coil is wound.
- Bobbin has a slot at it's top through which the ferrite core is inserted and is moved in and out.
2. Coil:
- This is used for passing the electric current and for the flux linkage.
3. Movable Ferrite core:
- This core is moved in and out of the bobbin and due to this value of inductance increases and decreases respectively.

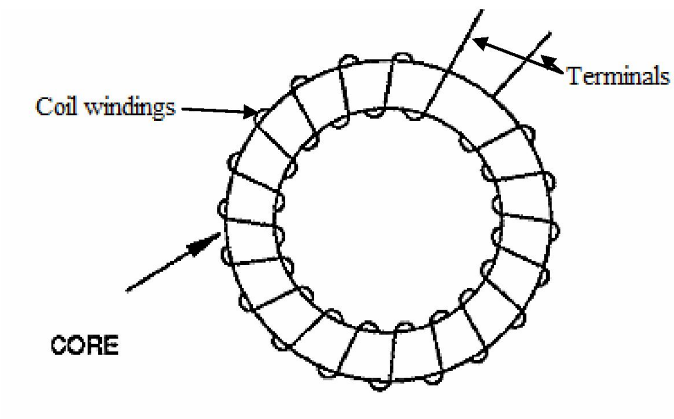
4. Screw Slot:

- This slot is provided for screw driver to change the value of inductance.

Applications :

- It is used in tuning and filter circuits.
- Used for width and linearity controls on (TV) receiver set.

Toroidal Inductor:



- In this type of inductor, the core is toroid or doughnut shape.
- The advantage of this shape is that it provides a continuous magnetic flux path and is confined to the volume enclosed by winding.
- The result is large inductance value for it's size.

Frequency Range Inductors:

1. Audio Frequency inductors (AF).
2. Intermediate Frequency inductors (IF).
3. Radio Frequency inductors (RF).
4. Toroidal inductors.

Audio Frequency inductors (AF) or Low Frequency (LF) or AF chokes:

- The inductor which is operated at low frequencies is called a AF inductor.
- It is large in size and inductance value.
- But compared to filter choked, they are small in size and have lower inductance value.
- AF chokes are used to provide high impedance to audio frequencies (60Hz to 5KHz).

Intermediate Frequency inductors (IF):

- If coil ir inductor are designed for use in FM superheterodyne receivers.
- Coils are precision wound and tuning is accomplished by movable iron core.

Applications:

- Double conversion receivers
- Filters.
- Mixers.

Radio Frequency inductors (RF) or High Frequency inductors (HF) or RF chokes:

- The inductor which is operated at high frequencies is called a high frequency (HF) inductor.
- These chokes are smaller in size and inductance value.
- The laminated cores are not used for these chokes since the core losses are proportional to the square of the frequency.
- Some of these chokes have solid or powdered iron cores. For very high and ultra high frequencies plastic cores are used.
- The windings are commonly build up in a no. of sections, each section being several layers deep, but not very wide as a means of reducing capacitance that exists between wire turns.
- These inductors are air core, iron core, iron slugs and ferrite core.

Applications:

- It is used in oscillator circuits.