BEE
(Basics of Electrical Engineering)

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Electric current

Definition:

An electric current is a flow of electric charge in a circuit. More specifically, the electric current is the rate of charge flow past a given point in an electric circuit.

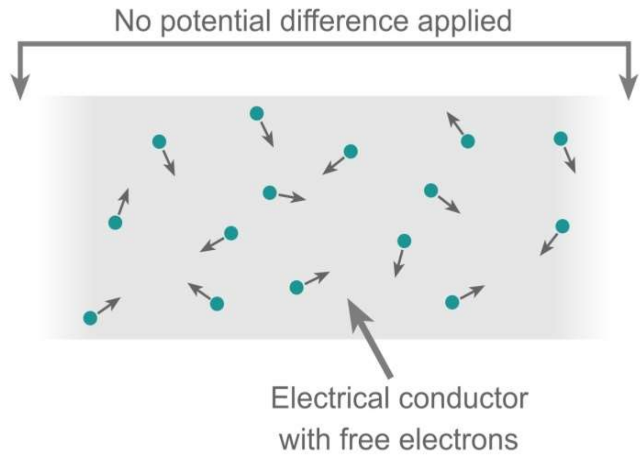
- The magnitude of the electric current is measured in coulombs per second, the common unit for this being the Ampere or amp which is designated by the letter ‘A’.
- Basic concept of current is that it is the movement of electrons within a substance.
- One very important point to note about the electrons is that they are charged particles - they carry a negative charge. If they move then an amount of charge moves and this is called current.

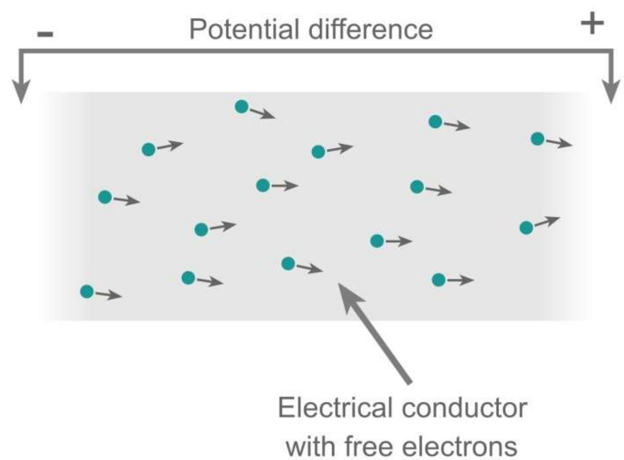
Lightning strike is an impressive show of electrical current flow

Photo taken from top of Petronas Towers in Kuala Lumpur Malaysia

Electric current

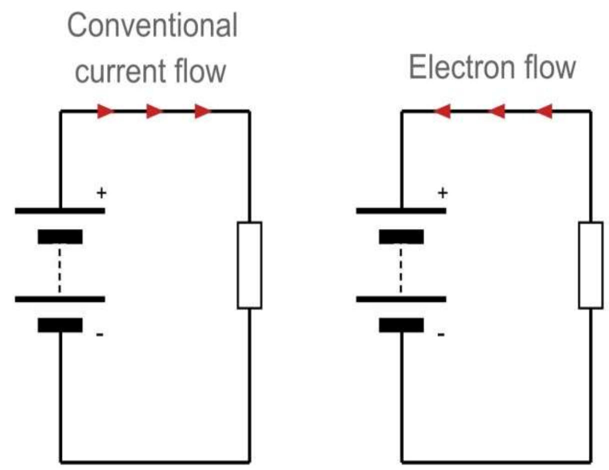
- To gain a little more understanding about what current is and how it acts in a conductor, it can be compared to water flow in a pipe.
- The current can be considered to be like water flowing through a pipe. When pressure is placed on one end it forces the water to move in one direction and flow through the pipe.
- The amount of water flow is proportional to the pressure placed on the end.
- The pressure or force placed on the end can be likened to the electro-motive force.
- When the pressure is applied to the pipe, or the water is allowed to flow as a result of a tap being opened, then the water flows virtually instantaneously.
- The same is true for the electrical current.





Conventional Current and Electron flow

- There is often a lot of misunderstanding about conventional current flow and electron flow
- The particles that carry charge along conductors are free electrons.
- The electric field direction within a circuit is by definition the direction that positive test charges are pushed.
- Thus, these negatively charged electrons move in the direction opposite the electric field.



Representing Electron and conventional current flow

Effects of current

- When an electric current flows through a conductor there are a number of signs which tell that a current is flowing

i. *Heat is dissipated*

ii. *Magnetic effect:*

Contents

- Electric current
- Flow of electric charges in a metallic conductor
- Drift velocity
- Ohm's law
- Electrical resistance
- V–I characteristics
- Law of resistance
- Electrical Energy and Power
- Electrical Resistivity and conductivity

Mechanism of current flow in a metallic conductor

- Flow of current in metals is due to preferential flow of free electrons.

- In the absence of any externally applied emf (by means of a battery), the free electrons move randomly through the metal from one point to another giving zero net current.

- When connected to a battery, the free electrons get accelerated due to the electric field (set up by the battery) and they gain velocity and energy.

- However, the passage is not smooth and the electrons collide with the lattice ion in which the ultimate gainer (of energy) is the ion

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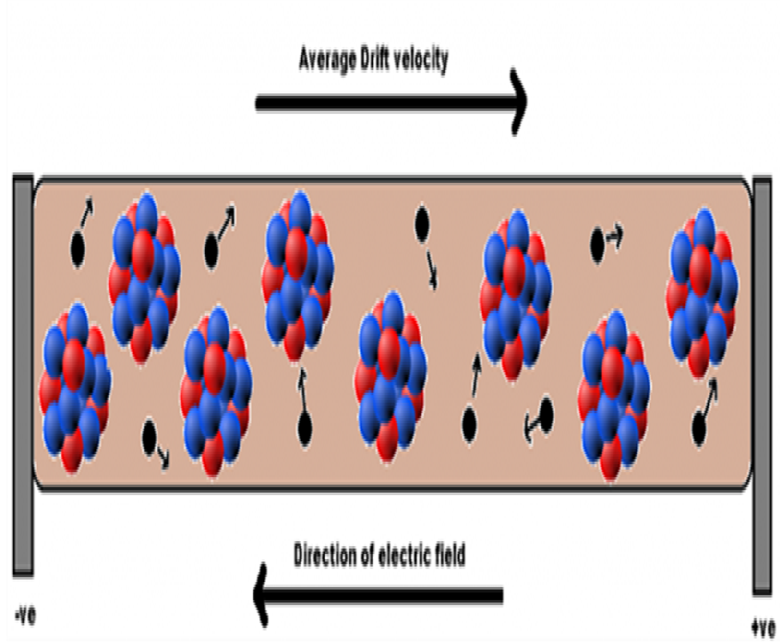
Drift Velocity

- **Definition:** The average velocity attained by charged particles, (eg. electrons) in a material due to an electric field is known as drift velocity. The SI unit of drift velocity is m/s.
- $V_d = \frac{e.E}{m}.\tau$



- **Relation between current and Drift Velocity**
- $I = nAev_d$
- n=No. of electrons per unit volume
- A= Area of Cross section
- V_d = Drift Velocity
- e= total charge inside the conductor

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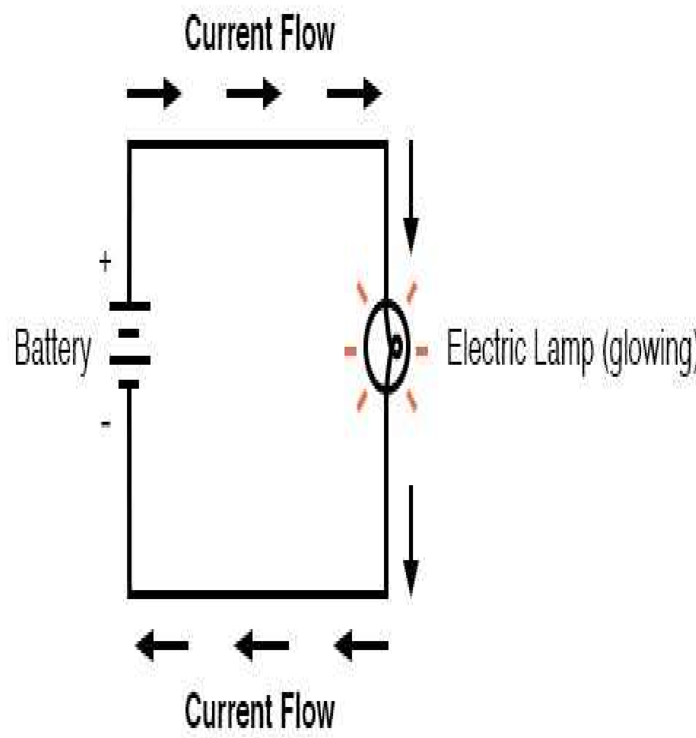
Ohm’s Law

- The first, and perhaps most important, the relationship between current, voltage, and resistance is called Ohm’s Law, discovered by Georg Simon Ohm
- **Definition:** According to Ohm’s law, the potential difference across any two points of the conductor will be directly proportional to the current flowing through it , for any given temperature.

$$E = I R$$

- In this algebraic expression, voltage (E) is equal to current (I) multiplied by resistance (R). Using algebra techniques, we can manipulate this equation into two variations, solving for I and for R, respectively:

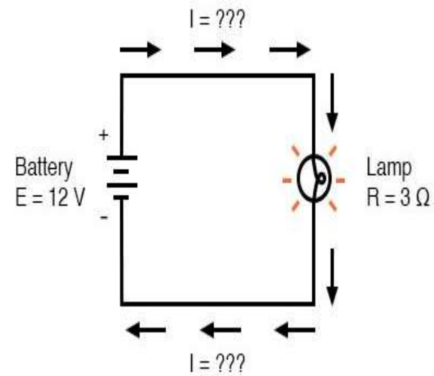
$$I = \frac{E}{R} \qquad R = \frac{E}{I}$$

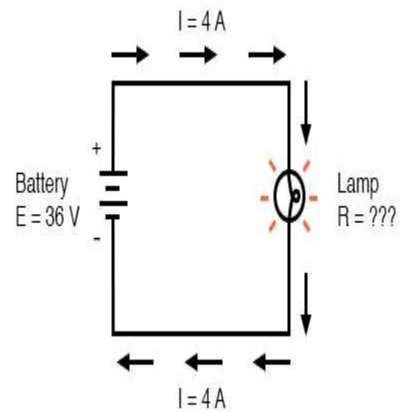


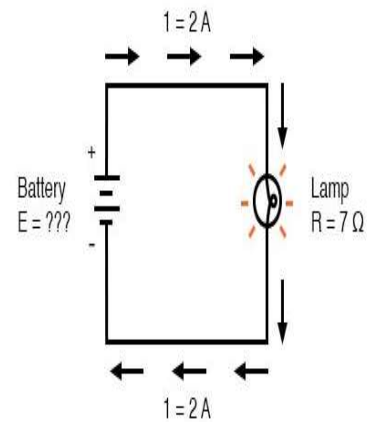
Ohm's Law (contd.)

- In the above circuit, there is only one source of voltage (the battery, on the left) and only one source of resistance to current (the lamp, on the right).

- This makes it very easy to apply Ohm's Law. If we know the values of any two of the three quantities (voltage, current, and resistance) in this circuit, we can use Ohm's Law to determine the third.







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Electrical Resistance

- **Resistance** (also known as ohmic resistance or electrical resistance) is a measure of the opposition to current flow in an electrical circuit.
- Resistance is measured in ohms, symbolized by the Greek letter omega (Ω).
- When a voltage is applied across a substance there will be an electric current through it.
- The applied voltage across the substance is directly proportional to the current through it. The constant of proportionality is resistance.

$$\frac{1\,volt}{1\,ampere} = 1\,ohm(\Omega)$$

$$V \propto I \Rightarrow V = RI \Rightarrow R = \frac{V}{I}$$

- To understand the concept let us take examples of metallic substances. There are numbers of free electrons moving randomly in the crystal structure of a metallic substance.
- When a voltage is applied across the resistance due to the electric field the free electrons drift from lower potential point to higher potential point in the substance.

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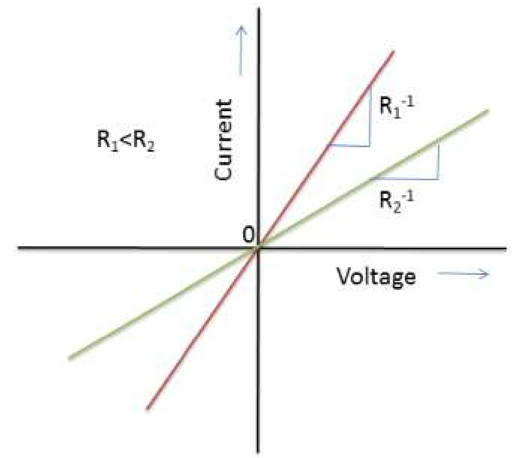
V-I characteristics

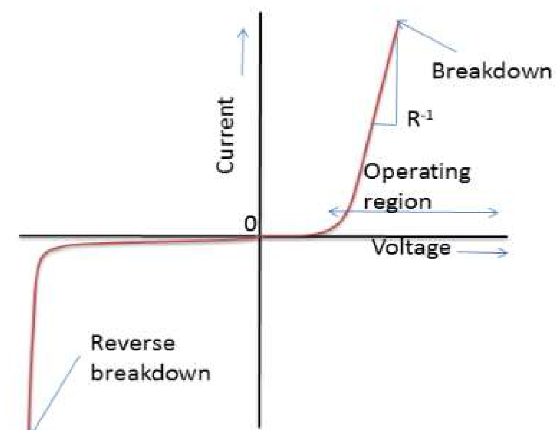
- V-I characteristics stand for voltage-current characteristics of an electrical component or device.
- The V-I graph yields valuable information about the resistance and breaks down an electronic component.
- It also provides the operating region of a component.
- By studying these characteristics we can understand where and how to use a component in an electric circuit.

Types of V-I Characteristics

- Linear VI Characteristics
- Non-linear VI Characteristics



Linear VI Characteristics



Non-Linear VI Characteristics

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Laws of Resistance

- The resistance of any substance depends on the following factors,

I. Length of the substance.
II. Cross sectional area of the substance.
III. The nature of material of the substance.
IV. Temperature of the substance

- *First Law of Resistivity*

The resistance of a substance is directly proportional to the length of the substance. electrical resistance R of a substance is:

$$R \propto L$$

- *Second Law of Resistivity*

The resistance of a substance is inversely proportional to the cross-sectional area of the substance. Electrical resistance R of a substance is:

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

- *Third Law of Resistivity*

The resistance of a substance is directly proportional to the resistivity of the materials by which the substance is made. This can be shown as:

$$R \propto \rho$$

- *Fourth Law of Resistivity*

The temperature of the substance also affects the resistance offered by the substance. This is because, the heat energy causes more inter-atomic vibration in the metal, and hence electrons get more obstruction during drifting from lower potential end to higher potential end

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Electrical Energy and Power

Electrical Energy: Electrical energy is the energy derived from electric potential energy or kinetic energy of the charged particles. We can define electrical energy as the energy generated by the movement of electrons from one point to another. The movement of charged particles along/through a medium (say wire) constitute current or electricity.

A few examples of electrical energy are:

- In a car battery, a chemical reaction results in the formation of an electron which possesses the energy to move in an electric current. These moving charges provide electrical energy to the circuits in the car.
- Lightning, during a thunderstorm, is an example of electrical energy – what we see as lightning is nothing but electricity discharging in the atmosphere.

Power: Power is defined as the rate at which a specific work is done, or which the energy is transmitted. The unit used to measure this is watt or joules per secondl

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Electrical Resistivity and conductivity

Electrical Resistivity:

- The electrical resistivity of a particular conductor material is a measure of how strongly the material opposes the flow of electric current through it.
  - This resistivity factor, sometimes called its "specific electrical resistance", enables the resistance of different types of conductors to be compared to one another at a specified temperature according to their physical properties without regards to their lengths or cross-sectional areas.

The factors which affect the resistance (R) of a conductor can be listed as:

i. The resistivity (ρ) of the material from which the conductor is made.
ii. The total length (L) of the conductor.
iii. The cross-sectional area (A) of the conductor.
iv. The temperature of the conductor

$$\rho = \frac{R \times A}{L} = \frac{\text{ohms} \times \text{meters}^2}{\text{meters}} = \Omega.\text{m}$$

Electrical Resistivity and conductivity

Electrical Conductivity

- Conductivity, or specific conductance relates to the ease at which electric current can flow through a material. Conductance (G) is the reciprocal of resistance (1/R) with the unit of conductance being the siemens (S) and is given the upside down ohms symbol mho, ℧.
- Conductivity, σ (Greek letter sigma), is the reciprocal of the resistivity. That is 1/ρ and is measured in siemens per metre (S/m).
- Since electrical conductivity σ = 1/ρ, the previous expression for electrical resistance, R can be rewritten as:

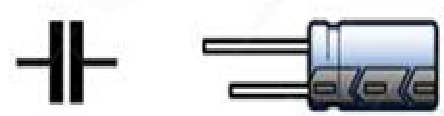
$$R = \rho \frac{L}{A} \quad \text{and} \quad \sigma = \frac{1}{\rho}$$

$$\therefore R = \frac{L}{\sigma A}\ \Omega$$

RLC Circuit

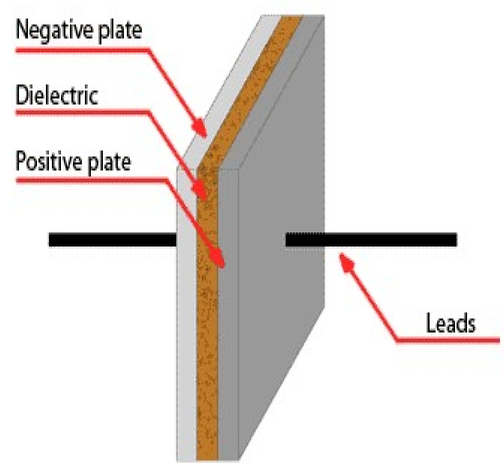
WHAT IS A CAPACITOR? (C)

- Used to store an electrical charge
- Sometimes used to smooth a current in a circuit
- 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



PARTS OF A CAPACITOR

Insulating material called a dielectric
- Dielectrics usually made of ceramics such as mica and glass, or paper soaked in oil



HOW A CAPACITOR WORKS

- When you turn on the power, an electric charge gradually builds up on the plates.

- One plate gains a positive charge and the other plate gains an equal and negative charge

- If you disconnect the power, the capacitor will slowly leak away over time

USES OF CAPACITOR

- Can be found in almost every electronic and electrical products
- In car audio systems, large capacitors store energy for the amplifier to use on demand
- Also can be used as rechargeable batteries in many appliances

CAPACITANCE (C)

•The amount of electrical energy a capacitor can store is called its capacitance
•Is measured in units called farads (F)

$$C = \frac{\varepsilon A}{d}$$

Where,

$C =$ Capacitance in Farads

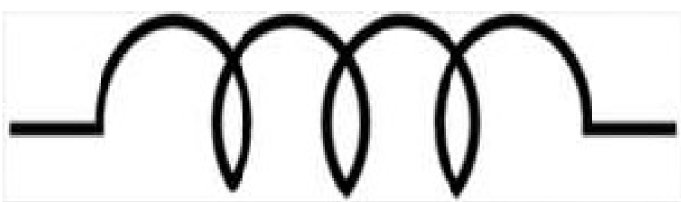
$\varepsilon =$ Permittivity of dielectric (absolute, not relative)

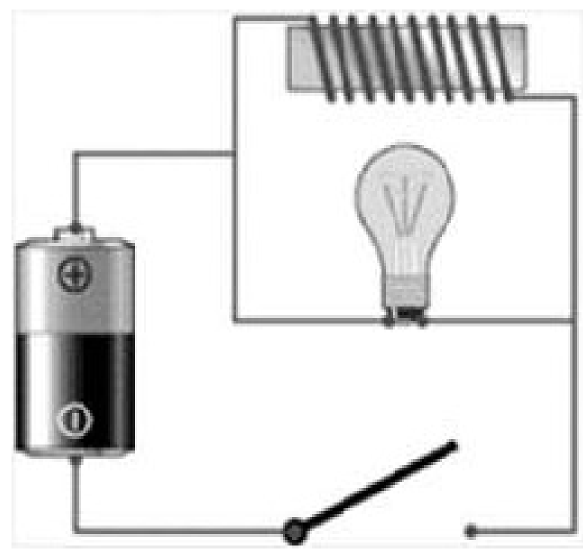
$A =$ Area of plate overlap in square meters

$d =$ Distance between plates in meters

WHAT IS AN INDUCTOR? (I)

•A passive electronic component that stores energy in the form of a magnetic field
•Simplest inductor consists of a wire loop or coil





HOW DOES AN INDUCTOR WORKS?

•When current first starts flowing in the coil, the coil wants to build up a magnetic field

•While the field is building, the coil inhibits the flow of current

•Once the field is built, current can flow normally through the wire

•When the switch gets opened, the magnetic field around the coil keeps current flowing in the coil until the field collapses

USES OF INDUCTOR

- Used extensively with capacitors and resistors to create filters for analogue circuits and in signal processing
- Can be used to sense magnetic fields or the presence of magnetically permeable material from a distance
- Are used in traffic light to detect the amount of traffic and adjust the signal accordingly

INDUCTANCE

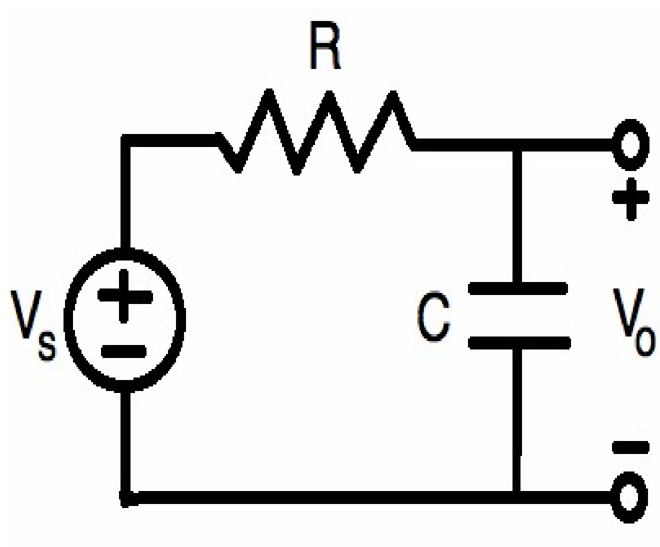
•A change in current flowing through it that induces an electromotive force in both the conductor itself and in any nearby conductors

$$L = \frac{n^2 \times \mu_0 \times a}{l}$$

where: L = inductance in henrys
n = number of turns
μ_0 = permeability of free space ($4\pi \times 10^{-7}$ henrys/metre)
a = cross-sectional area of winding in square metres
l = length of winding in metres

WHAT IS A RC CIRCUIT?

•Is an electric circuit composed of resistors and capacitors driven by a voltage or current source



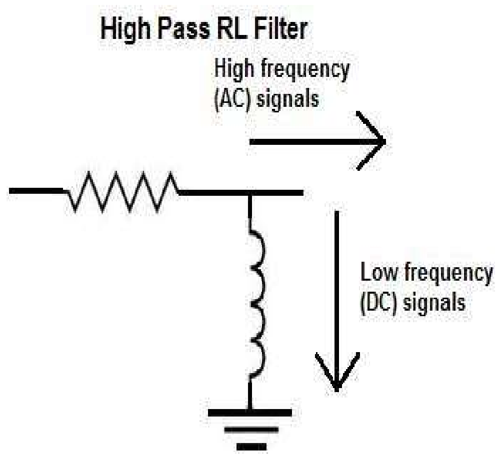
WHAT DOES A RC CIRCUIT DO?

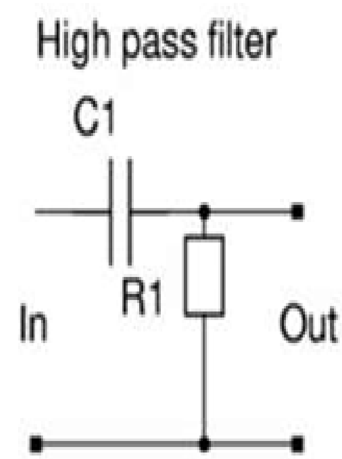
- Plays an important role in the transmission of electrical signals
- Capacitor will discharge its stored energy through the resistor

APPLICATION OF RC CIRCUIT

High-pass filter

•Is an electronic filter that offer easy passage of a high-frequency signal from source to load and difficult passage to a low-frequency signal



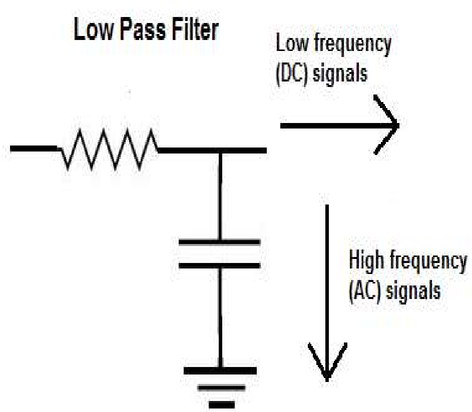


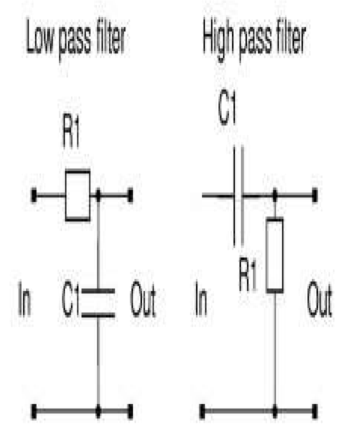
APPLICATION OF RC CIRCUIT

Low-pass filter

•Is the opposite of a high-pass filter

•Offers easy passage to low-frequency signals and difficult passage to high-frequency signals





APPLICATION OF RC CIRCUIT

Band-pass filter

- Combines the properties of low-pass and high-pass into a single filter

- Widely used in wireless transmitters and receivers

- Limit the bandwidth of the output signal from transmitters to the band allocated for the transmission

- Allows signals within a selected range of frequencies to be heard, while eliminating other unwanted frequencies from getting through

APPLICATION OF RC CIRCUIT