AUTOMOBILE MECHATRONICS

Basics of Electrical and Electronics Engg.

UNIT-1

Electric current : It is the time rate of change of charge, measured in amperes (A).

$$I = dq / dt$$

Where q is charge in coulombs(C) .

A direct current (DC) is a current that remains constant with time. (I) An alternating current (AC) is a current that varies sinusoidally with time.

Voltage (or potential difference): It is the energy required to move a unit charge through an element, measured in volts(V).

$$V = dw / dq$$

Where w is energy in joules(J) And q is charge in coulombs(C) Reference direction or voltage polarity

$V>0$ means the real polarity is same to the reference polarity

$V<0$ means the real polarity is opposite to the reference polarity

POWER: Electrical power is the rate at which electrical energy is converted to another form, such as motion, heat, or an electromagnetic field. The common symbol for power is the uppercase letter P. The standard unit is the watt, symbolized by W. In utility circuits, the kilowatt (kW) is often specified instead;1 kW = 1000 W.

In a DC circuit, a source of *E* volts, delivering *I* amperes, produces *P* watts according to the formula:

$$P = EI$$

When a current of *I* amperes passes through a resistance of *R*ohms, then the power in watts dissipated or converted by that component is given by:

$$P = I^2R$$

When a potential difference of *E* volts appears across a component having a resistance of *R*ohms, then the power in watts dissipated or converted by that component is given by:

$$P = E^2/R$$

The algebraic sum of power in a circuit, at any instant of time, must be zero.

Power absorbed = - Power supplied

Active Components: Those devices or components which required external source to their operation is called Active Components.

For Example: Diode, Transistors, SCR etc.

Passive Components: Those devices or components which do not required external source to their operation is called Passive Components.

For Example: Resistor, Capacitor, Inductor etc.

Resistor:

A resistor is an electrical device which has a property to oppose the flow of electric current through it. Most of the time resistor is used in electrical and electronic circuits to limit the current. It is widely used element in electrical and electronic circuit.

resistor: 

Real resistors: 

The relationship between the current through a conductor with resistance and the voltage across the same conductor is described by **Ohm's law**:

$$V = IR$$

where *V* is the voltage across the conductor, *I* is the current through the conductor, and *R* is the resistance of the conductor. Its unit is Ohm.

The power dissipated by the resistor is equal to the voltage multiplied by the current:

$$P = IV$$

If *I* is measured in amps and *V* in volts, then the power *P* is in watts.

By plugging in different forms of *V=IR*, we can rewrite *P=IV* as:

$$P = I^2 R$$

or

$$P = \frac{V^2}{R}.$$

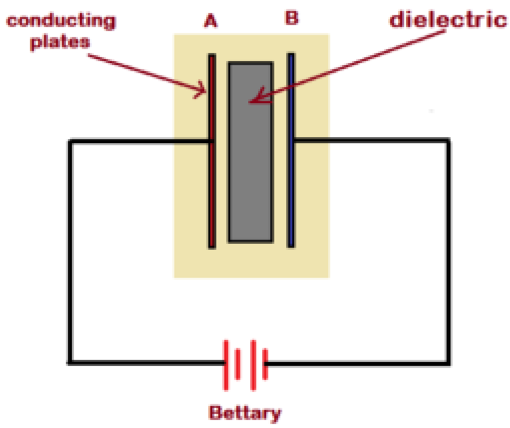
1. Linear resistors are those which obey the ohm law i.e. current through it is directly proportional to applied voltage.
– Fixed resistors the resistors whose value cannot be changed.
– Variable resistors are those whose value can be changed.

2. Non linear resistors are the resistors, in which current does not changes linearly with change in applied voltage i.e. these resistors do not obey the ohm law.

Capacitor:

A capacitor is a passive element that store electric charge. A capacitor is a device that store electric charge in the form of electric field.

we will learn exactly how does a capacitor store electric charge electric energy. Capacitor consists of two plates of conducting materials separated by an insulating material like paper, mica, air etc.
This insulating material is known as **"dielectric".**
Depending on the types and size of dielectric, the type of capacitor and application of capacitor is decided.



For example, high frequency capacitor and high voltage capacitor have difference in their dielectric material. When the capacitor is connected across a battery, one plate (plate A) of capacitor is connected with positive terminal of battery and other plate (plate B) of capacitor is connected with negative terminal of battery. This start charging of the capacitor.

Energy store in capacitor = $(1/2) \times C \times V^2$

C = capacitance of capacitor,v = applied voltage

The unit of measurement for the capacitance of a capacitor is the *farad*, which is equal to 1 coulomb per volt.

The two charges would like to routine with one another what cannot. Therefore, there is an electric potential energy associated with interacting charges and this is the stored energy in its electric field.

Inductor:

An inductor converts electrical energy flowing through it into magnetic energy and creates a magnetic field. Therefore, inductor can we define as
An inductor is a passive device which store energy in the form of magnetic field.

The unit for inductance is the *henry*, and is equal to a volt-second per ampere.

Before understanding the working of inductor you must have clear picture of how inductor is made or manufactured.

Inductors are simple in construction. **It is just a coil of conducting wires**. The conducting wire is generally made of copper.
This conducting wire is wound around a core at its centre.
This core might be iron, metal, glass non-metal and even air.

When the current start flowing through coil, the coil has tendency to build up a magnetic field. During this process of building magnetic field, the coils opposes the flow of electrons through it i.e. opposition to current. To overcome this opposition, the electrons have to release or utilised some of its extra energy which is stored in the form of magnetic field.Therefore, to build the magnetic field, an inductor takes the kinetic energy of moving electrons and store it in the form of magnetic field.

Suppose a current 'I' is flowing through an inductor of inductance 'L', then

Energy stored = (1/2) × L × I^2

Ohm's law:

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Kirchhoff's Law:

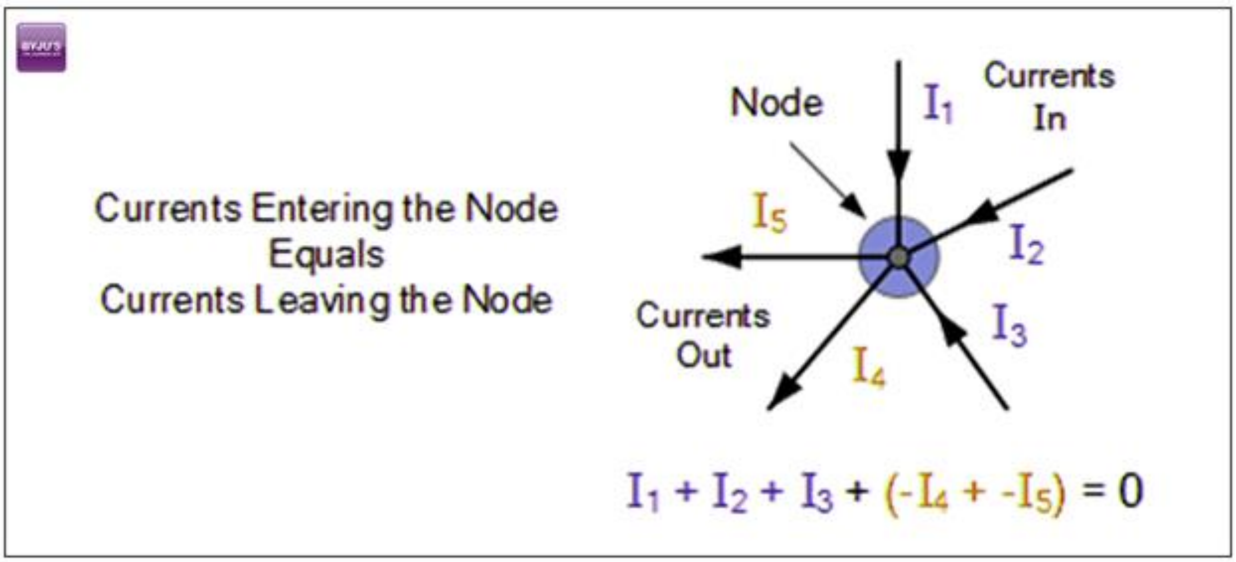
Some relationships do exist between voltages and currents under various branches of an electrical circuit. These relationships are identified by the laws of which are known as Kirchhoff's laws, derived by Guatov Robert Kirchhoff. These laws help in calculating the electrical resistance of a complex network or impedance in case of AC and the current flow in different streams of the network

- According to the Junction rule in a circuit, the total of the currents in a junction is equal to the sum of currents outside the junction.
- According to the loop rule, the sum of the voltages around the closed loop is equal to null.

Kirchhoff's First Law

According to Kirchhoff's Current law, the total current entering a junction or a node is equal to the charge leaving the node as no charge is lost. Put differently, the algebraic sum of every current entering and leaving the node has to be null. This property of Kirchhoff law is commonly called as Conservation of charge wherein, I(exit) + I(enter) = 0.

Kirchhoff's Current Law



In the above figure, the currents I1, I2 and I3 entering the node are positive and two currents I4 and I5 are negative in values. This can be expressed in the form of an equation:

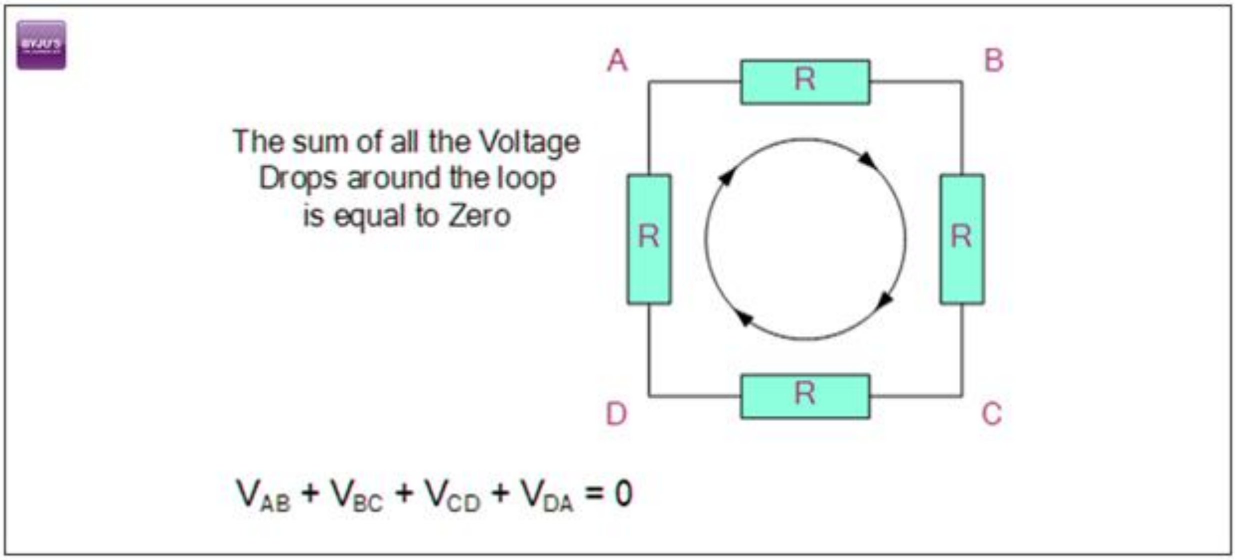
I1 + I2 + I3 – I4 – I5 = 0

The term Node refers to a junction or a connection of two or more current carrying routes like cables and other components. Kirchhoff's current law can also be applied to analyze parallel circuits.

Kirchhoff's Second Law

According to Kirchhoff's voltage law, the voltage around a loop equals to the sum of every voltage drop in the same loop for any closed network and also equals to zero. Put differently, the algebraic sum of every voltage in the loop has to be equal to zero and this property of Kirchhoff's law is called as conservation of energy.

Kirchhoff's Voltage Law

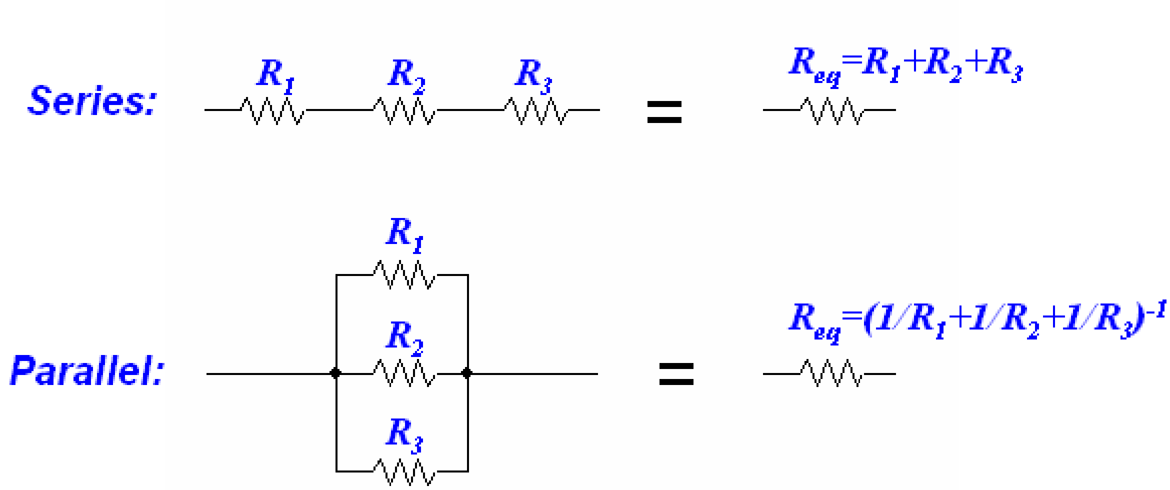


When you begin at any point of the loop and continue in the same direction, note the voltage drops in all the direction either negative or positive and return to the same point. It is essential to maintain the direction either counterclockwise or clockwise; else the final voltage value will not be equal to zero. The voltage law can also be applied in analyzing circuits in series.

When either AC circuits or DC circuits are analysed based on Kirchhoff's circuit laws, you need to be clear with all the terminologies and definitions that describe the circuit components like: paths, nodes, meshes, and loops.

Elements in Series and Parallel:

Resistors connected in **series** and **parallel**:



Two Elements in Series and Parallel

	Resistor	Capacitor	Inductor
Series	$R_{eq} = R_1 + R_2$	$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$	$L_{eq} = L_1 + L_2$
Parallel	$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$	$C_{eq} = C_1 + C_2$	$L_{eq} = \frac{L_1 L_2}{L_1 + L_2}$

More than 2 Elements in series or parallel

Here we provide the equations for calculating the equivalant resistance of three or more resistors in parallel; the same form can be applied to the corresponding equations for capacitors and inductors. Of course, you can always just simplify a network of elements by combining two at a time using the equations above.

To find the combined resistance of resistors connected in series, simply add the resistances:

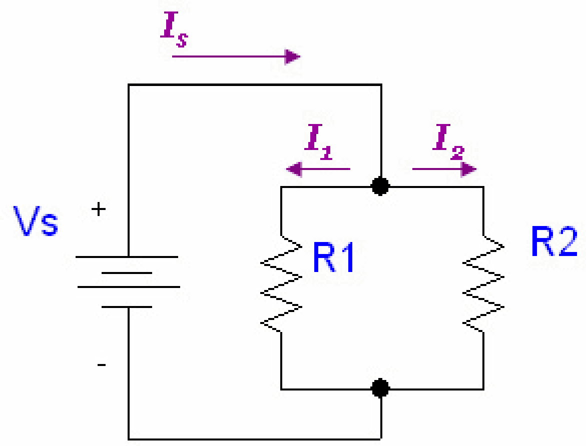
$$R_{eq} = R_1 + R_2 + \cdots + R_n$$

If the resistors are connected in parallel, the equation is:

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$

Proof for Resistors in Parallel equation

*Here we provide the derivation for the parallel resistors equation. The corresponding equations for capacitors and inductors can be derived with a similar me*thod.



We can prove the equation for parallel resistors by using Kirchhoff's voltage and current laws:

$V_s = V_{R1} = V_{R2}$ (KVL)

$I_s = I_1 + I_2$ (KCL)

Plugging in the constitutive law for resistors in the second equation yields:

$$I_s = \frac{V_s}{R_1} + \frac{V_s}{R_2} = V_s\left(\frac{1}{R_1} + \frac{1}{R_2}\right) = V_s\left(\frac{R_1 + R_2}{R_1 R_2}\right)$$

$$R_{eq} = \frac{V_s}{I_s} = \frac{R_1 R_2}{R_1 + R_2}$$

Voltage Source and Current Source:

Voltage Source: A device which can produce a continuous force to move the electrons (or, continuous voltage) through the wire connected into the two terminals of the device is called a Voltage Source. There are two types of the Voltage Source which are:

Ideal Voltage Source:

An Ideal Voltage source is a kind of Voltage source whose internal resistance is zero! Such that the supplied voltage does not changes even if the external load resistance is changes.

Ideal Current Source:

A current source is a device which provides the regular flow or electrons or current on a circuit.

A current source is a type of voltage source which have enough EMF and surplus electrons so as to produce the flow of electrons.

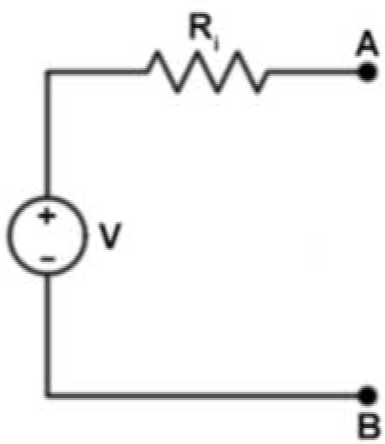
The current source made of a Direct Voltage Source is called Direct Current Source.

The current source made of a Alternating Voltage Source is called Alternating Current Source.

A current source which provides a constant current without any relation with the voltage supplied to the load **is called Ideal Current Source.**

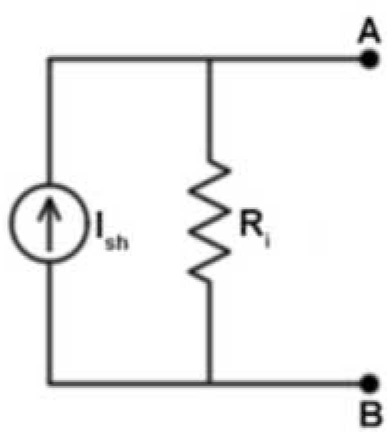
Conversion of Voltage Source to Current Source:

Let us draw a general form of a voltage source.



Here, the emf of the source is V volt. In addition, it has an internal resistance R_i. Without a doubt short circuit current from A to B is

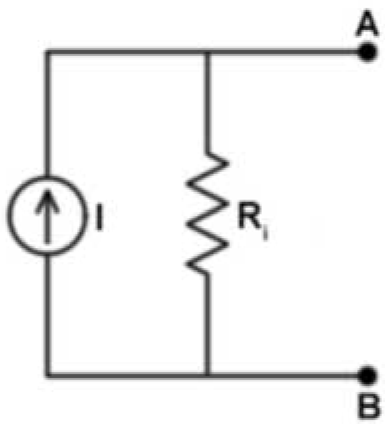
$$I_{sh} = \frac{V}{R_i}$$



The equivalent current source is

Conversion of Current Source to Voltage Source

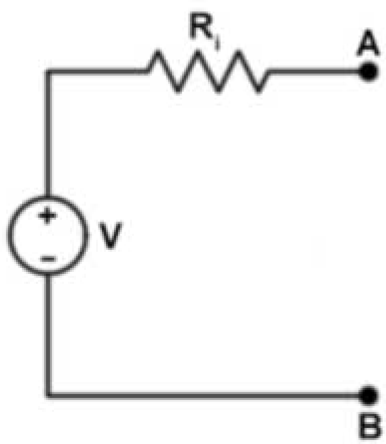
Let us draw a current source



The open circuit voltage across A and B is

$$V = IR_i$$

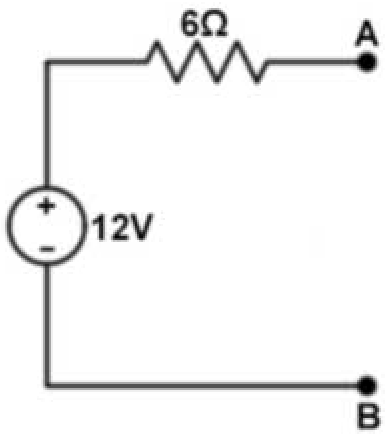
So, the equivalent voltage source has the emf of V volts. The internal resistance R_i now is in series in the source. Obviously, the equivalent voltage source is as



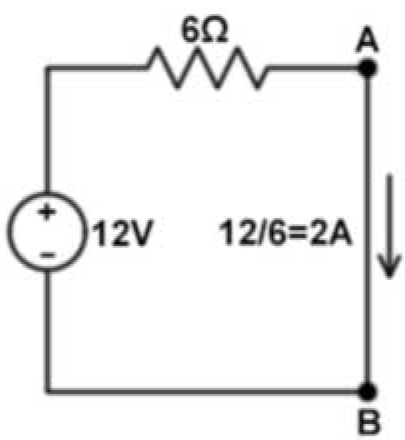
shown below.

We can convert a voltage source to an equivalent current source. For that, the current of the current source is the short circuit current between the voltage source terminals. Furthermore, the internal resistance of the current source will be the same internal resistance of the voltage. Differing from the voltage source, we connect that internal resistance in parallel for the current source. Conversely, we can convert a current source to an equivalent voltage source. At this time, the voltage of the voltage source will be the open circuit voltage of the current source. The internal resistance of the voltage source will be the same internal resistance of the current source. In contrast to the current source, we connect the internal resistance in series in the voltage source.

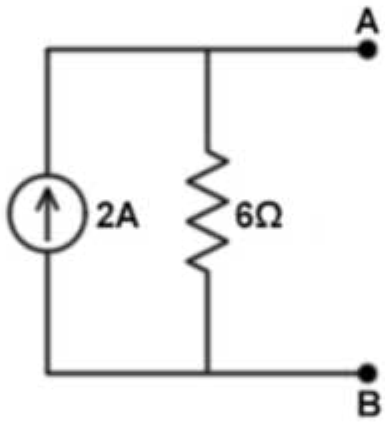
Let us draw an equivalent current source of the given voltage source.



First, we short circuit terminals A and B. Then the short circuit current is 12/6=2A.

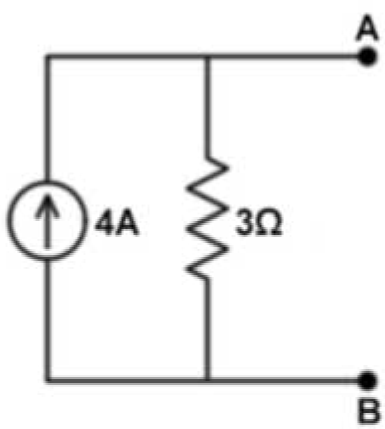


Finally, we draw the converted current source as,

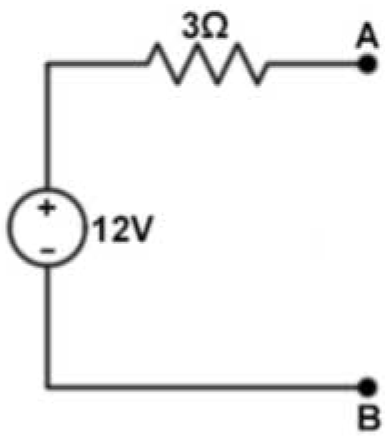


Current Source to Voltage Source Conversion

Alternatively, let us convert a current source to its equivalent voltage source.



The open circuit voltage of the current source is 4X3 or 12 Ω. Here, we have connected the internal resistance of 3Ω in series with the source voltage.



These were two very basic examples of electrical source conversion.