1. **Electrical circuit elements (R, L and C):** The interconnection of various electric elements in a prescribed manner comprises as an electric circuit in order to perform a desired function. The electric elements include controlled and uncontrolled source of energy, resistors, capacitors, inductors, etc. Analysis of electric circuits refers to computations required to determine the unknown quantities such as voltage, current and power associated with one or more elements in the circuit. To contribute to the solution of engineering problems one must acquire the basic knowledge of electric circuit analysis and laws. We shall discuss briefly some of the basic circuit elements and the laws that will help us to develop the background of subject.

a) **Resistor:** Resistor is a dissipative element, which converts electrical energy into heat when the current flows through it in any direction. The law governing the current into and voltage across a resistor is:

$$v = R.i \qquad \textbf{(i)}$$

The relationship is known as Ohm's law.

But resistor can be regarded as linear only within the specified limits, outside which the behavior becomes non-linear. The resistance of a resistor is temperature dependent and rises with temperature.

Mathematically it can be represented as:

$$R_t = R_0(1 + \alpha t) \qquad \text{(ii)}$$

Where R_0 = Resistance at 0°C and R_t = Resistance at t°C

α = Temperature coefficient and it may be positive and negative both

t = Temperature in °C

And power dissipated by resistor is $p = v.i$

$$p = i^2R = \frac{v^2}{R} \text{ Watts}$$

Resistor is represented by the symbol

Unit of Resistance is ohm (Ω)

b) **Capacitor (C):** It is a two terminal element that has the capability of energy storage in electric field. The law governing the $v - i$ relationship of capacitor is:

$$i = C\frac{dv}{dt} \qquad \textbf{(iii)}$$

After integrating equation (iii), we get

$$v = \frac{1}{C}\int_0^t i.dt + v_c(0) \qquad \text{(iv)}$$

Where $v_c(0) =$ Capacitor voltage at $t = 0$, for initially uncharged capacitor $v_c(0) = 0$

Hence, $$v = \frac{1}{C}\int_0^t i.dt \qquad \text{(v)}$$

The above expressions show that the voltage of a capacitor cannot change instantaneously.

Energy stored in capacitor can be represented by

$$W = \int p.dt = \int v.i.dt = C\int v.dv = \frac{1}{2}Cv^2\ Joule \qquad \text{(ix)}$$

Capacitor is represented by the symbol

Unit of Capacitance is Farad **(F)**

c) **Inductor (L):** It is a two-terminal storage element in which energy is stored in the magnetic field. The $v - i$ relation of an inductance is:

$$v = L\frac{di}{dt} \qquad \text{(vi)}$$

After integrating expression (vi), we get

$$i = \frac{1}{L}\int_0^t v.dt + i_L(0) \qquad \text{(vii)}$$

Where $i_L(0) =$ Inductor current at $t = 0$, for initially if current through inductor $i_L(0) = 0$

Hence, $$i = \frac{1}{L}\int_0^t v.dt \qquad \text{(viii)}$$

The above expressions show that the current through an inductor cannot change instantaneously.

Energy stored in inductor can be represented by

$$W = \int p.dt = \int v.i.dt = L\int i.di = \frac{1}{2}Li^2\ Joule \qquad \text{(ix)}$$

Inductor is represented by the symbol

Unit of Inductance is Henry **(H)**

2. Concept of active and passive elements:

Electrical Network: Any possible combination of various electric elements (Resistor, Inductor, Capacitor, Voltage source, Current source) connected in any manner what so ever is called an electrical network. We may classify circuit elements in two categories, passive and active elements.

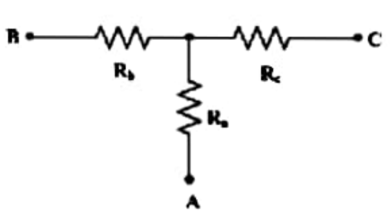


Fig: 1

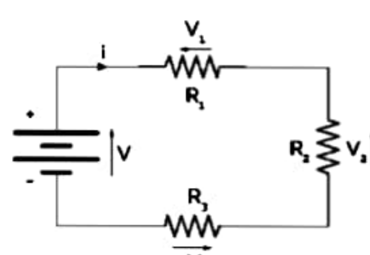


Fig: 2

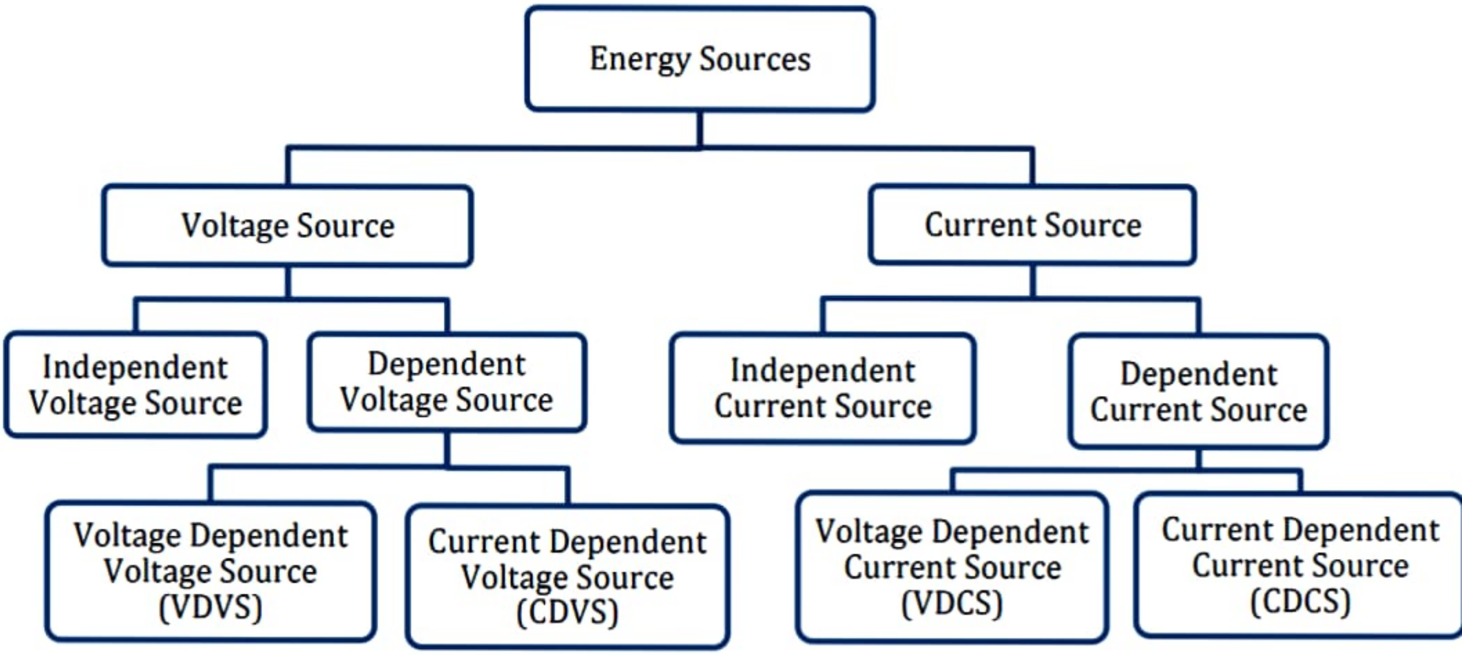
Electrical Circuit: An electric circuit is a closed energized electric network. It means circuit must have closed path with energy sources. From the above example, we can say that fig 1 and fig 2 are electric networks but only fig 2 is electric circuit.

It means, electric circuit is always an electric network but electric network may or may not be an electric circuit.

Passive Element: The element which receives energy (or absorbs energy) and then either converts it into heat (R) or stored it in an electric (C) or magnetic (L) field is called passive element, and the network containing these elements without energy sources are known as passive network. Examples are resistor, inductor, capacitor, transformer etc.

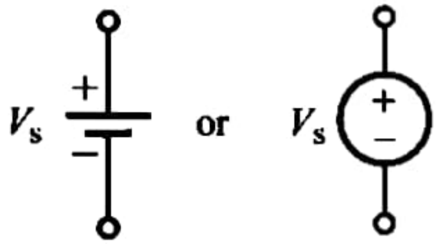
Active Element: The elements that supply energy to the circuit is called active element and the network containing these sources together with other circuit elements are known as active network. Examples of active elements include voltage and current sources, generators, and electronic devices that require power supplies. A transistor is an active circuit element, meaning that it can amplify power of a signal.

3. **Energy Sources (Voltage and Current Sources):** There are two types of energy sources namely Voltage Sources and Current Sources.



Here, we shall study only about independent voltage source and independent current source.

a) **Independent Voltage Source:** A hypothetical generator which maintains its value of voltage independent of the output current. It can be represented as:



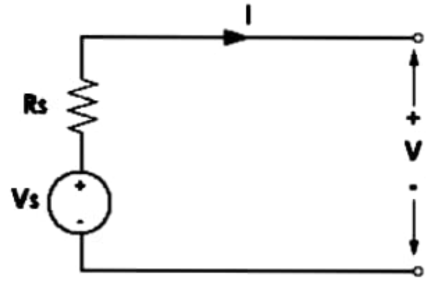


Fig: Ideal DC Voltage Source Fig: Practical DC Voltage Source

If the value of internal resistance will be zero, then the voltage source is called as ideal voltage source. The V-I characteristics for ideal and practical voltage source is given below:

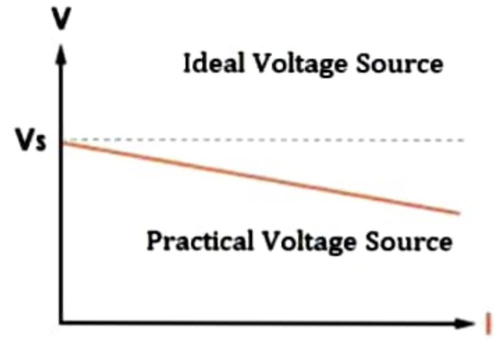
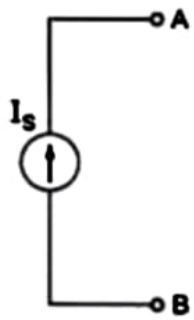


Fig: V-I Characteristic of Voltage Source

b) Independent Current Source: A generator which maintains its output current independent of the voltage across its terminals. It can be represented as:



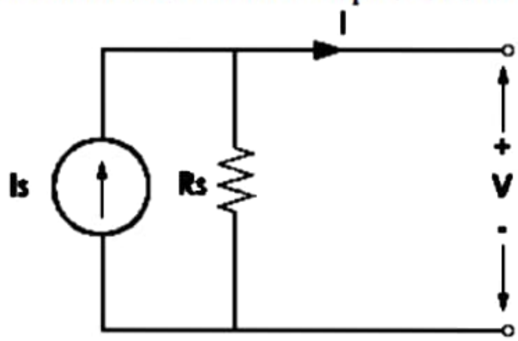


Fig: Ideal DC Current Source Fig: Practical DC Current Source

if the value of internal resistance will be infinity, then the current source is called as ideal current source. The V-I characteristics for ideal and practical current source is given below:

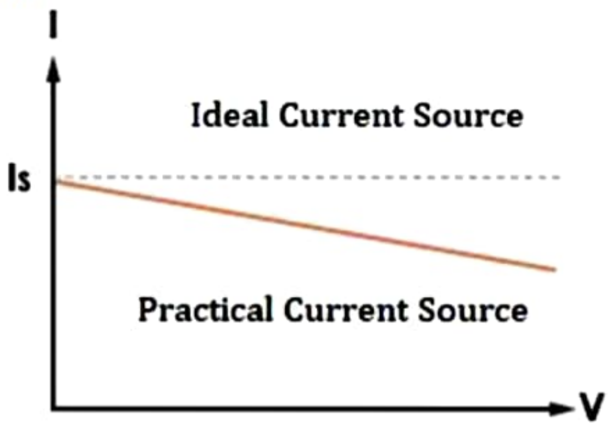


Fig: V-I Characteristic of Current Source

4. **Concept of Linearity and Linear Network:** For a network to be linear, it should have to follow the principle of superposition and homogeneity both.

Principle of Superposition: An element or circuit obeys the principle of superposition if the net effect of the sum of causes equals the sum of their individual effects.

Mathematically, let cause x and effect y be related as:

$$f(x) = y \qquad \text{(i)}$$

Let the cause be scaled by a factor α. Then the functional relationship obeys homogeneity, if

$$f(\alpha x) = \alpha f(x) = \alpha y \qquad \text{(ii)}$$

Consider two causes x_1 *and* x_2, then $f(x_1) = y_1$ *and* $f(x_2) = y_2$

Let the combined effect of these two causes be scaled by α_1 and α_2 respectively. The principle of superposition then yields if:

$$f(\alpha_1 x_1 + \alpha_2 x_2) = f(\alpha_1 x_1) + f(\alpha_2 x_2) \qquad \text{(iii)}$$

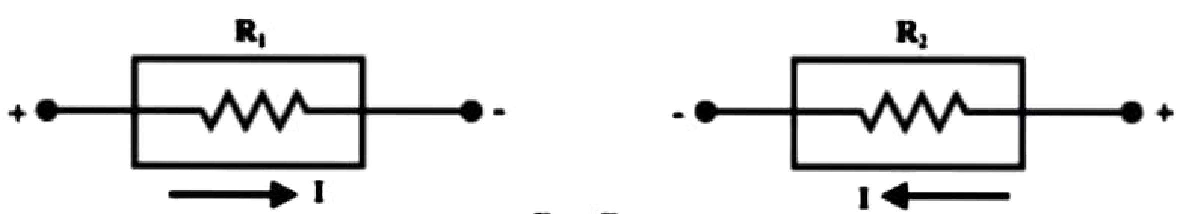
If homogeneity is also satisfied, then

$$f(\alpha_1 x_1 + \alpha_2 x_2) = \alpha_1 f(x_1) + \alpha_2 f(x_2) = \alpha_1 y_1 + \alpha_2 y_2 \qquad \text{(iv)}$$

A functional relationship is said to be linear if it obeys both superposition and homogeneity. Any element governed by such a functional relationship is linear. A circuit composed of such elements would also be linear.

5. **Unilateral and Bilateral Elements:**

Bilateral Elements: If by reversing the terminal connections of an element in a circuit, the circuit response remains same. Such elements are known as bilateral



$R_1 = R_2$

elements. Examples are Resistor, Inductor, Capacitor etc.

Unilateral Elements: If by reversing the terminal connections of an element in a circuit, the circuit response gets change. Such elements are called as unilateral elements. Examples are Voltage Source, Current Source, Diode etc.