Ohm's Law

Objectives : At the end of this lesson you shall be able to
- **state Ohm's law**
- **calculate the total resistance of series resistance circuits**
- **calculate the total resistance of parallel resistance circuits**
- **power dissipation in parallel reistive circuits.**

OHM'S LAW

The quantity of current flowing through a resistor depends on two factors:

1 The ohmic value of the resistor.

2 The voltage applied across the resistor.

If the voltage applied across a resistor is kept constant, higher the resistance of the resistor, lower will be the current flowing through it. In other words current (I) through a resistor is inversely proportional to resistance(R) value of the resistor.

On the otherhand, if the applied voltage (V) across a fixed value resistor is increased, the current flowing through the resistor also increases. In other words current (I) through a resistor is directly proportional to the applied voltage(V) across the resistor.

Combining the above two relationships between resistance(R), current (I) and applied voltage(V), it can be written as,

$$I = \frac{V}{R}$$

This relationship of I = V/R was found by the scientist *George Simon Ohm* and hence this is referred to as *ohm's law.*

The relationship of I = V/R can be expressed mathematically in different forms as

$$I = \frac{V}{R} \text{ or } V = I \times R \text{ or } R = \frac{V}{I}$$

These formulas are used invariably while designing or testing electrical/electronic circuits.

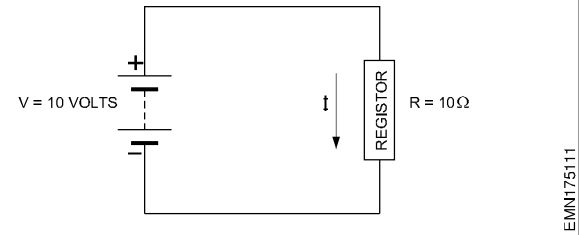
Generalising, ohm's law can be stated as follows:

Under a given constant temperature, the current flowing through a resistor is directly proportional to the voltage across the resistor and inversely proportional to the value of resistance.

This statement holds good not only for a resistor, but in common to all resistive circuits.

Example 1 : Using ohms law, find the current flowing through the resistor in Fig 1.

Fig 1



Solution :

Applied voltage across the resistor is : 10 volts

Resistance value of the resistor is given as 10 ohms.

Therefore current(I) through the resistor by Ohm's law is;

$$I = \frac{V}{R} \text{ Amps.} = \frac{10 \text{ volts}}{10 \text{ ohms}} = 1 \text{ amp.}$$

Current through the resistor is 1 ampere.

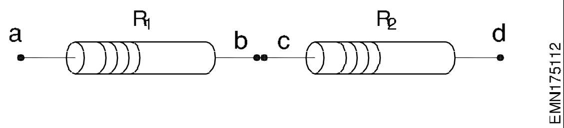
Resistors in series

When resistors are connected end to end as shown in Fig 3, the resistors are said to be in series with each other.

Total resistance of resistors in series

When resistors are connected in series, the total resistance of the series connection will be equal to, the sum of individual resistance values. In Fig 2, total resistance across points a-d will be equal to $R_1 + R_2$.

Fig 2



Example : In Fig 2, if R_1 is 1 K ohms and R_2 is 2.2K ohms. The total or effective resistance between the terminals a and d will be,

(R_1 and R_2 are connected in series).

$= R_1 + R_2$

$= 1.0\ k\Omega + 2.2\ k\Omega = 3.2$ kW.

Current through a series circuit

When resistors are connected in series as shown in Fig 2, the current that flows through R_1 can only flow through R_2. This is because

– there is no other path for any other extra current to flow through R_2

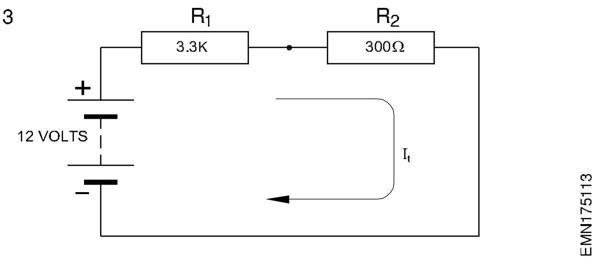
– there is no other path for the current through R_1 to escape from flowing through R_2.

Therefore *in a series circuit, the quantity of current will be the same at all the points (a,b,c,d) of the circuit*.

The quantity of current flowing through the series path is decided by both the resistors put together or the effective resistance of the circuit.

Example : Find the total circuit current(I_t) in the circuit at Fig 3.

Fig 3



Solution :

Resistors R_1 & R_2 are in series. Therefore, the effective resistance of the circuit = $R_1 + R_2$

= 3.3kΩ + 330Ω.

= 3300 + 330 = 3630 ohms.

$$\text{Circuit current } I_t = \frac{V}{R} = \frac{12\text{ V}}{3630\ \Omega} = 0.0033 \text{ amps} = 3.3 \text{ mA.}$$

Example : Calculate the voltage drops across R_1 and R_2 for the circuit at Fig 3.

Solution :

In the circuit (Fig 3), R_1 and R_2 are in series. Hence the current through both the resistors is the same. This current is 3.3 mA as calculated in the previous example.

From Ohm's Law

Therefore the voltage drop across R_1

= I x R_1 volts

= 3.3 mA x 3.3 kΩ

= $(3.3 \times 10^{-3}) \times (3.3 \times 10^{3})$

= 3.3 x 3.3 = 10.89 volts.

Similarly the voltage drop across R_2

= (3.3×10^{-3}) x 330 ohms

= 1089 milli-volts

= 1.089 volts.

Verification of solution

Since R_1 and R_2 are in series, the sum of the voltage drops across R_1 and R_2 must be equal to the applied battery voltage of 12V. i.e, 10.89 + 1.089 = 11.979 » 12 volts = applied battery voltage.

Power dissipation in resistors

When current flows through a resistor heat is generated. This is because, the voltage driving the current through the resistor is doing some amount of work in overcoming the opposition to the flow of electrons. It is found through experiments and analysis that, the amount of work done by the voltage is directly proportional to the ohmic value(R) of the resistor and square of the current(I^2) flowing through the resistor. This work done is dissipated in the form of heat generated by the resistor. This heat dissipating capacity is known as the power or wattage of a resistor. The unit of power is *Watt*.

Power dissipated by a resistor = I^2 x R Watts.

Where,

I is the current through the resistor

and R is the resistance of the resistor.

Example : If 10 mA flow through a resistor of 10 K ohms, what is the power dissipated by the resistor ?

Power dissipated by the resistor = I^2 x R = (Ix I) x R

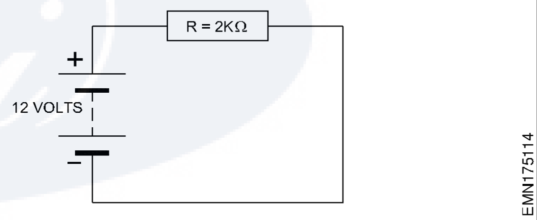
= $(10 \times 10^{-3}) \times (10 \times 10^{-3}) \times (10 \times 10^{3})$

= 1000×10^{-3} = 1000 milli-watts = 1 watt.

The power dissipated by the resistor is 1 watt.

Example : What is the total power dissipated by the circuit given at Fig 4.

Fig 4



Solution :

Current through the circuit is I_t = V/R

= 12V/ 2 kΩ = 6 mA

Power dissipated by the circuit is

= (circuit current)^2 x circuit resistance

= $(36 \times 10^{-6}) \times (2 \times 10^{3})$

= 72×10^{-3} watts

= 72 milli-watts = 0.072 watts.