Electrical Components - What They Are, How They Work and What They Look Like on Drawings

An Online Continuing Education Course for Engineers

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1. Introduction

There are three basic electrical devices from which most of the rest are made. No course whose stated purpose is to bring a basic understanding of electrical devices to the students would be complete without a review of these devices. These are **resistors, capacitors, and inductors** and have the properties of **resistance, capacitance, and inductance.** Without further ado, let's review these three devices.

2. Resistors

Resistance is a property of materials. All materials have resistance as it is the opposition to current flow. Conductors have a low resistance while insulators have a high resistance. Metals (copper, aluminum, silver, iron, and so on) which have a low resistance can be covered by an insulator (plastic, nylon, rubber, and so on) which has a high resistance. Electrical current can then flow in the conductor, and be held in by the insulator.

If a piece of material has a length and a cross sectional area, it's resistance can be determined by:

$$\mathbf{R = (\rho * l) / A}$$

Where R is resistance in ohms, ρ is a constant called resistivity whose units are ohm – circular mills per foot, l is length in feet, and A is area in circular mills (CM). A circular mill is the area of a circle 0.001 inches in diameter. For copper, ρ is 10.37 ohm –CM per foot at 20 degrees Centigrade. If metric units are used ρ is $1.724 * 10^{-8}$ ohm – meter^2 / meter.

Let's take an example of # 10 copper wire. The diameter of # 10 wire is 0.1019 inches, in circular mills the diameter is 10,384 CM. 1000 feet of # 10 copper wire then has a resistance of 1.001 ohms.

$$\mathbf{R = (\rho * l) / A = \{10.37\ (\Omega - CM / ft) *1000\ ft\} / 10384\ CM}$$

$$\mathbf{R = 1.001\ \Omega}$$

If that 1000 feet of copper wire were an insulator, such as rubber, with a resistivity of 10^{23} ohm circular mills per foot, its resistance would be about 10^{20} ohms. Resistivity of materials has one of the greatest ranges of any property of materials in all of nature.

The symbol for a resistor is:

Figure 2.1 Symbol for a Resistor

Physically, they have many shapes and functions. Inside of integrated circuits they can be too small to see without a microscope. Discrete resistors in electronic circuits range from 1/8 inch long and 1/16 inch in diameter, to 2 or 3 inches long and up to ½ inch in diameter. Power resistors can be several feet long and up to 2 or 3 inches in diameter. They are used as heaters in both industrial and consumer products. Your home electric water heater, stove and oven all use resistors to turn electrical energy into heat.

If a voltage is put across a resistor, current flows. If current flows, heat is generated. The following circuit shows an AC voltage across a resistor:

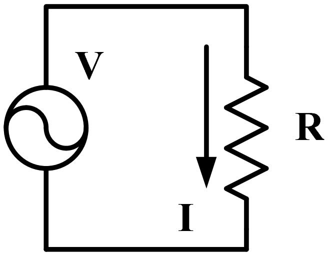


Figure 2.2 Resistor Circuit

The basic equation relating V, I, and R is called Ohm's Law, and is:

V = I * R

If the voltage is a sine wave, the current will follow exactly. The basic power equation is:

P = V * I

Figure 2.3 shows how voltage, current, and power look versus time for a one resistor circuit. Notice that the power curve is double the frequency of the voltage and current.

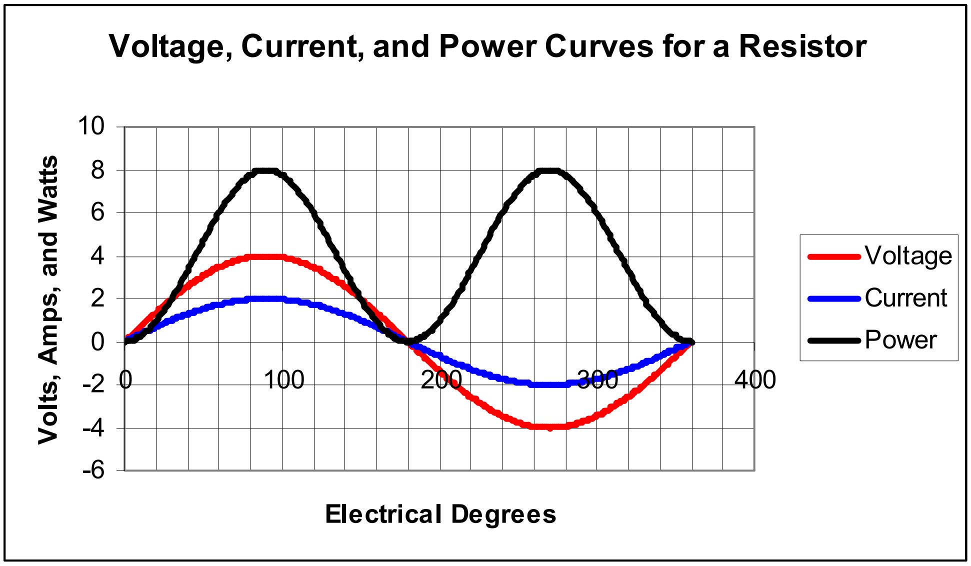


Figure 2.3 Voltage, Current, and Power Curves for a Resistor

Values were chosen for voltage and current so that their product, Power, could be displayed on the same scale. The resistor value in this case would be the peak voltage divided by the peak current or 2 ohms.

3. Capacitors

A capacitor is an electrical device which consists of two conductors separated by an insulator. This capacitor has a property called capacitance which is determined by the size of the metal plates, the distance between them, and the dielectric constant of the material between the metal plates. The equation for capacitance is:

$$\mathbf{C = (\varepsilon * A) / d}$$

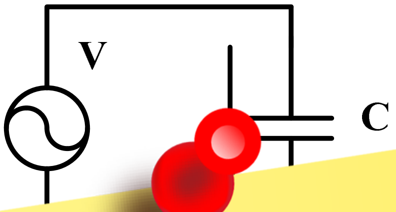
Where ε is the permittivity of the insulator (for a vacuum ε_o is approximately $8.854 * 10^{-12}$ F/meter), A is the area of the metal plates in meters^2, d is the distance between the metal plates in meters, and C is the capacitance in farads. The unit of capacitance (farad) is so large that capacitance is usually given in micro farads (10^{-6}) or micro micro-farads (10^{-12}). The permeability of the insulating material is equal to $\varepsilon_r * \varepsilon_o$, where ε_r is the relative permeability of the insulating material. The range of ε_r is not nearly as great as the range of resistivity for resistors. It can range from 1 for a vacuum to 10,000 for special electrolytics.

Capacitors do not dissipate power, but they can store energy if a voltage is put across them. The energy stored by a capacitor that is holding a charge is:

$$\mathbf{W = (C * V^2) / 2}$$

Where W is energy in Joules, C is the capacitance, and V is the voltage on the capacitor caused by the charge that is stored.

If an AC voltage is put across a capacitor, a current will flow. That current is no longer in phase with the voltage, as with a resistor. The current leads the voltage. In other words, the current comes before the voltage in time. I know that that sounds strange, but that is what really happens. Figure 3.1 shows a capacitor with an AC voltage across it.



Since the curre e, current and
power for a capa ship. Note that
the average pow f the capacitor.
That means that t er supply. At
any time, the ener energy stored
by the capacitor ar f the voltage.
The energy content

Because the current l voltage across it, some way must be found to handle th vectors and imaginary numbers. The current is said to lead by 90º or by the vector +j. So, the voltage can be denoted by V /_0º_, which would make the current be I /_+90º. If it is desired to know the AC resistance of the capacitor it would be –j / (2πfC). The –j is the same as -90º. C is the capacitance and f is the frequency. That means that the AC resistance or reactance of a capacitor depends upon the frequency of the AC voltage. If vectors were drawn showing the voltage across and current through a capacitor, the diagram would look like Figure 3.3.