Electrical Conductors

An Online Continuing Education Course for Engineers

Course Number: E-3011

Credit: 3 Hours / 3 PDH / 3 CPD

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Circuit components provide the majority of the operating characteristics of any electrical circuit. They are useless, however, if they are not connected together. Conductors are the means used to tie these components together.

Many factors determine the type of electrical conductor used to connect components. Some of these factors are the physical size of the conductor, its composition, and its electrical characteristics. Other factors that can determine the choice of a conductor are the weight, the cost, and the environment where the conductor will be used.

CONDUCTOR SIZES

To compare the resistance and size of one conductor with that of another, we need to establish a standard or unit size. A convenient unit of measurement of the diameter of a conductor is the mil (0.001, or one-thousandth of an inch). A convenient unit of conductor length is the foot. The standard unit of size in most cases is the MIL-FOOT. A wire will have a unit size if it has a diameter of 1 mil and a length of 1 foot.

SQUARE MIL

The square mil is a unit of measurement used to determine the cross-sectional area of a square or rectangular conductor (views A and B of figure 1). A square mil is defined as the area of a square, the sides of which are each 1 mil. To obtain the cross-sectional area of a square conductor, multiply the dimension of any side of the square by itself. For example, assume that you have a square conductor with a side dimension of 3 mils. Multiply 3 mils by itself (3 mils × 3 mils). This gives you a cross-sectional area of 9 square mils.

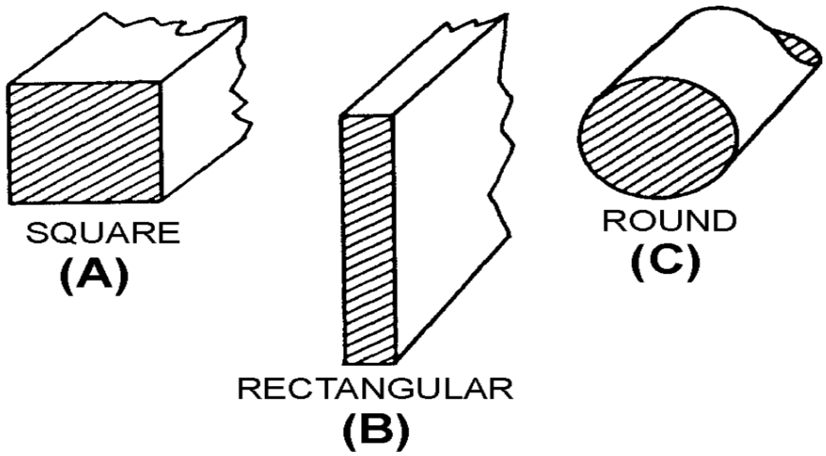


Figure 1.—Cross-sectional areas of conductors.

To determine the cross-sectional area of a rectangular conductor, multiply the length times the width of the end face of the conductor (side is expressed in mils). For example, assume that one side of the rectangular cross-sectional area is 6 mils and the other side is 3 mils. Multiply 6 mils × 3 mils, which equals 18 square mils. Here is another example. Assume that a conductor is 3/8 inch thick and 4 inches wide. The 3/8 inch can be expressed in decimal form as 0.375 inch. Since 1 mil equals 0.001 inch, the thickness of the conductor will be 0.001 × 0.375, or 375 mils. Since the width is 4 inches and there are 1,000 mils per inch, the width will be 4 × 1,000, or 4,000 mils. To determine the cross-sectional area, multiply the length by the width; or 375 mils × 4,000 mils. The area will be 1,500,000 square mils.

CIRCULAR MIL

The circular mil is the standard unit of measurement of a round wire cross-sectional area (view C of figure 1). This unit of measurement is found in American and English wire tables. The diameter of a round conductor (wire) used to conduct electricity may be only a fraction of an inch. Therefore, it is convenient to express this diameter in mils to avoid using decimals. For example, the diameter of a wire is expressed as 25 mils instead of 0.025 inch. A circular mil is the area of a circle having a diameter of 1 mil, as shown in view B of figure 2. The area in circular mils of a round conductor is obtained by squaring the diameter, measured in mils. Thus, a wire having a diameter of 25 mils has an area of 25^2, or 625 circular mils. To determine the number of square mils in the same conductor, apply the conventional formula for determining the area of a circle ($A = nr^2$). In this formula, A (area) is the unknown and is equal to the cross-sectional area in square mils, n is the constant 3.14, and r is the radius of the circle, or half the diameter (D). Through substitution, A = 3.14, and $(12.5)^2$; therefore, 3.14 × 156.25 = 490.625 square mils. The cross-sectional area of the wire has 625 circular mils but only 490.625 square mils. Therefore, a circular mil represents a smaller unit of area than the square mil.

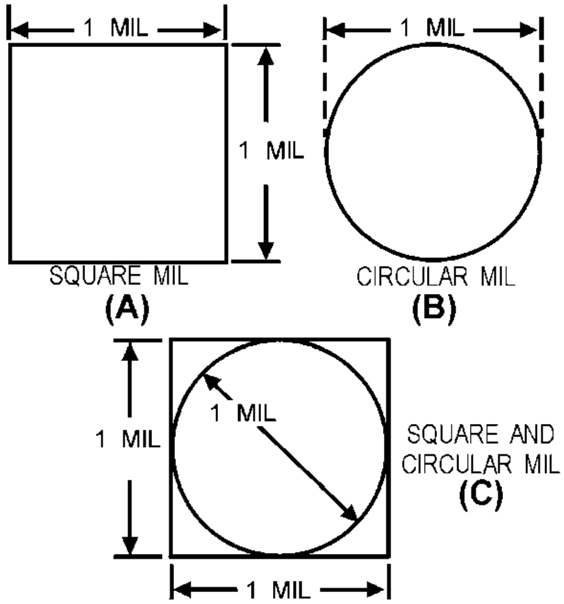


Figure 2.—A comparison of circular and square mils.

If a wire has a cross-sectional diameter of 1 mil, by definition, the circular mil area (CMA) is $A = D^2$, or $A = 1^2$, or $A = 1$ circular mil. To determine the square mil area of the same wire, apply the formula $A = nr^2$; therefore, $A = 3.14 \times (.5)^2$ (.5 representing half the diameter). When $A = 3.14 \times .25$, $A = .7854$ square mil. From this, it can be concluded that 1 circular mil is equal to. 7854 square mil. This becomes important when square (view A of figure 2) and round (view B) conductors are compared as in view C of figure 2.

When the square mil area is given, divide the area by 0.7854 to determine the circular mil area, or CMA. When the CMA is given, multiply the area by 0.7854 to determine the square mil area. For example,

Problem: A 12-gauge wire has a diameter of 80.81 mils. What is (1) its area in circular mils and (2) its area in square mils?

Solution:

(1) $A = D^2 = 80.81^2 = 6{,}530$ circular mils
(2) $A = 0.7854 \times 6{,}530 = 5{,}128.7$ square mils

Problem: A rectangular conductor is 1.5 inches wide and 0.25 inch thick. What is (1) its area in square mils and (2) in circular mils? What size of round conductor is necessary to carry the same current as the rectangular bar?

Solution:

(1) 1.5 inches = 1.5 inches × 1,000 mils per inch = 1,500 mils

0.25 inch = 0.25 inch × 1,000 mils per inch = 250 mils

A = 1,500 × 250 = 375,000 square mils

(2) To carry the same current, the cross-sectional area of the round conductor must be equal. There are more circular mils than square mils in this area. Therefore:

$$A = \frac{375{,}000}{0.7854} = 477{,}000 \text{ circular mils}$$

A wire in its usual form is a single slender rod or filament of drawn metal. In large sizes, wire becomes difficult to handle. To increase its flexibility, it is stranded. Strands are usually single wires twisted together in sufficient numbers to make up the necessary cross-sectional area of the cable. The total area of stranded wire in circular mils is determined by multiplying the area in circular mils of one strand by the number of strands in the cable.

CIRCULAR-MIL-FOOT

A circular-mil-foot (figure 3) is a unit of volume. It is a unit conductor 1foot in length and has a cross-sectional area of 1 circular mil. Because it is a unit conductor, the circular-mil-foot is useful in making comparisons between wires consisting of different metals. For example, a basis of comparison of the RESISTIVITY (to be discussed shortly) of various substances may be made by determining the resistance of a circular-mil-foot of each of the substances.

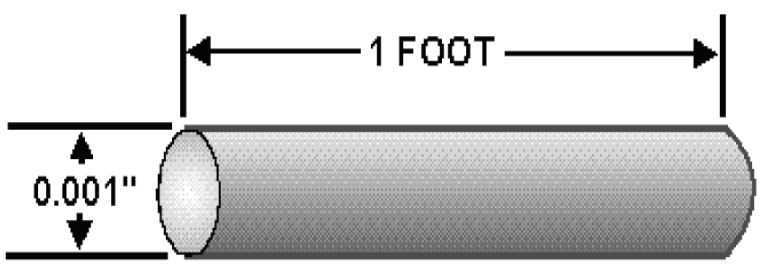


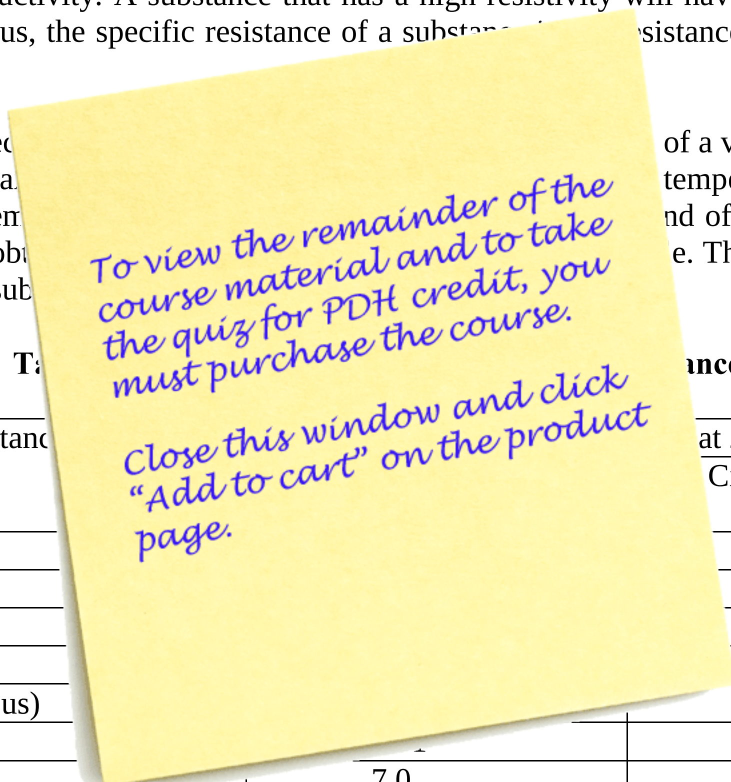
Figure 3.—Circular-mil-foot.

In working with square or rectangular conductors, such as ammeter shunts and bus bars, you may sometimes find it more convenient to use a different unit volume. A bus bar is a heavy copper strap or bar used to connect several circuits together. Bus bars are used when a large current capacity is required. Unit volume may be measured as the centimeter cube. Specific resistance, therefore, becomes the resistance offered by a cube-shaped conductor 1 centimeter in length and 1 square centimeter in cross-sectional area. The unit of volume to be used is given in tables of specific resistances.

SPECIFIC RESISTANCE OR RESISTIVITY

Specific resistance, or resistivity, is the resistance in ohms offered by a unit volume (the circular-mil-foot or the centimeter cube) of a substance to the flow of electric current. Resistivity is the reciprocal of conductivity. A substance that has a high resistivity will have a low conductivity, and vice versa. Thus, the specific resistance of a subst sistance of a unit volume of that substance.

Many tables of spec of a volume of a substance 1 foot in length a temperature at which the resistance measurem nd of metal a conductor is made of, you can ob e. The specific resistances of some common sub



Ta ances

Substanc		at 20°C.
		Circular-mil-foot (ohms)
Silver		9.8
Copper (drawn)		10.37
Gold		14.7
Aluminum		17.02
Carbon (amorphous)		
Tungsten		33.2
Brass	7.0	42.1
Steel (soft)	15.9	95.8
Nichrome	109.0	660.0

The resistance of a conductor of a uniform cross section varies directly as the product of the length and the specific resistance of the conductor, and inversely as the cross-sectional area of the conductor. Therefore, you can calculate the resistance of a conductor if you know the length, cross-sectional area, and specific resistance of the substance. Expressed as an equation, the "R" (resistance in ohms) of a conductor is

$$R = \rho \frac{L}{A}$$