Resistance

A. Resistance

1. Introduction to Resistance

   a. Friction between walls of the pipe and water molecules creates some resistance to water flow. Just as an electrical conductor offers resistance (R) to current flow. A good conductor offers low resistance because its outer electrons are held loosely and can readily move from atom to atom. A poor conductor provides the opposite effect.

   b. The fact that a wire conducting current can become hot is evidence that work done by the applied voltage must be accomplished against some form of opposition or resistance. The size and substance of wires in an electrical circuit are chosen to keep electrical resistance as low as possible. The table below lists the resistance of several materials relative to copper.

   c. Electrical resistance is measured in units of ohms (Ω), with an ohm defined as the quantity of resistance producing a potential drop of one volt when current through the conductor is one amp.

Relative Resistances and Conductances of a Few Common Materials

Material	Relative Resistance	Relative Conductance
Silver	0.92	1.08
Copper	1.00	1.00
Gold	1.38	0.725
Aluminum	1.59	0.629
Tungsten	3.20	0.312
Zinc	3.62	0.275

Brass	4.40	0.277
Platinum	5.80	0.172
Iron	6.67	0.149
Nickel	7.73	0.129
Tin	8.20	0.121
Steel	8.62	0.116
Lead	12.76	0.081
Manganin	26.00	0.0385
Mercury	54.60	0.018
Nichrome	60.00	0.0166
Carbon	2030.00	0.0004

d. The table above also gives the conductance of the various materials, relative to copper. The ability of a material to conduct an electrical current is commonly termed the conductivity of the material.

2. Conductance

a. Conductance is the measure of conductivity and is defined as the reciprocal of resistance. The unit of conductance is mho, ohm spelled backward.

3. Conductor Resistance

a. All materials in nature offer some resistance to electrical current, however small. In addition to resistance imposed on a circuit by the electrical load, there is also resistance of circuit wiring. A logical question at this point is how to compute wire resistance. Referring to the mechanical analogy, consider one foot of water pipe offering friction to a current of water flowing through it. 10 feet of pipe offers 10 times as much resistance as one foot of pipe (assuming all other parameters are constant). This is also true for electrical resistance.

b. For electrical circuits this is referred to as the Law of Lengths; that is, the resistance of a conductor is directly proportional to its length. In other words, doubling the length of a conductor doubles the resistance.

c. There is also a Law of Areas. A six-inch pipe carries a larger flow of water than a one-inch pipe, assuming the same pressure. Much more friction is encountered when water is forced through a pinhole opening than through a larger opening. In the same manner, a small wire offers more resistance to electrons than a larger wire. A wire with an area of 1 mm2 (square mm) has two times as much resistance as the same length of wire with an area of 2 mm2 The law of areas states that the resistance of a conductor is inversely proportional to the area. In other words, halving the area of a conductor doubles its resistance.

d. The relationship between resistance (R), resisitivity (ρ), length (L), and area (A) algebraically is:

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

e. Electron flow is usually enhanced by lowering the temperature of the conductor. More current will flow through a cold conductor than a hot one. Therefore, resistance of most pure metallic conductors increases with temperature.

f. And finally, as pointed out previously in the section under conductors and insulators, resistance depends on the material.

g. For comparison, an ordinary 100-watt electric lamp used on a 120 volt circuit has a resistance of about 144 ohms when hot. The length of 24 gauge copper wire (which has a cross-sectional area of 3.17 x 10-14 in2) equivalent to a resistance of 144 ohms would be about 5500 feet.

h. In summary, resistance of a conductor depends upon: length, cross sectional area, temperature and material

i. Some materials are used throughout an electrical circuit to control the total current flow through a circuit or branch. Materials such as carbon provide a moderate resistance to current flow. They can be concentrated to form resistors ranging from a few ohms to several meg-ohms. The effect of these resistors on current flow and voltage will be discussed in the next chapter on electrical circuits.

B. Types of Resistors

1. Carbon Composition resistors

   a. The most widely used resistor in industry is the standard carbon composition resistor. These components range in value from just a few ohms to several million ohms. Accuracy of these components is usually limited to approximately 5%. Resistors of this type are cylindrical inform and have several colored bands depicting the value and tolerance of the individual component. The following table provides information on the interpretation of these colored bands.

Standard Resistor Color Code

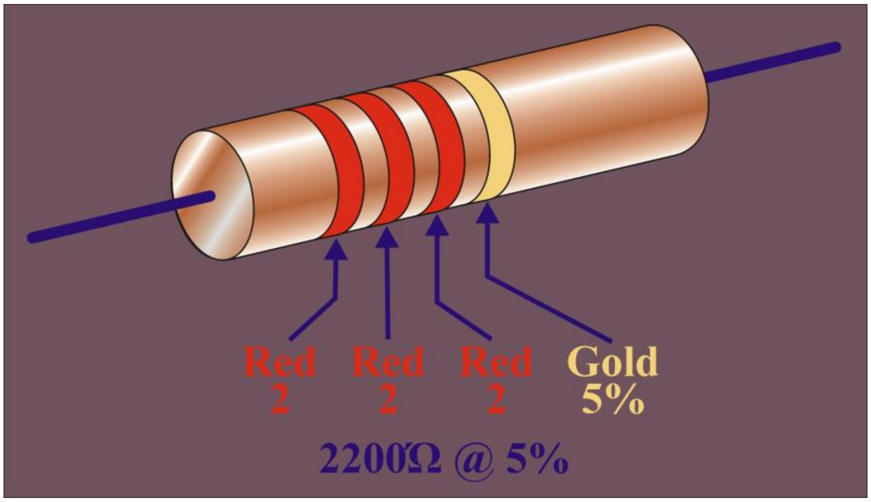
COLOR	1ST DIGIT	2ND DIGIT	MULTIPLIER	TOLERANCE (percent)
Black	0	0	1	
Brown	1	1	10	
Red	2	2	100	

Orange	3	3	1,000	
Yellow	4	4	10,000	
Green	5	5	100,000	
Blue	6	6	1,000,000	
Violet	7	7	10,000,000	
Gray	8	8	100,000,000	
White	9	9	1,000,000,000	
Gold			.1	5
Silver			.01	10
No Color				20

2. Using the information from the above able, you can determine the value of a color-coded resistor by:
   a. Starting with the color band closest to the end of the resistor
   b. The color of the first band provides the 1st digit in the component value
   c. The color of the second bank provides the 2nd digit in the component value
   d. The color of the third band provides the number of zeros to follow the first two digits
   e. The fourth band (if supplied) is the tolerance value for the component.

3. Note that only Gold and Silver provide tolerance values, the absence of a fourth band means that the resistor's tolerance value is 20%.

4. Example: Find the value of the resistor shown below.



Picture 1, Color Coded Resistor Example

5. High Accuracy Resistors

   a. Where a tolerance of ± 5% is unacceptable as it is in today's modern electronics, carbon composition resistors are replaced with the high accuracy wire wound resistors. These components are constructed by winding several thousand turns of very fine wire around a ceramic form to produce a very accurate value of resistance. Tolerances of 0.001% are not uncommon using this technique. Values for these components are determined by deciphering an alpha-numeric code imprinted on the component.

6. Variable Resistors

   a. In applications where fixed values of resistance do not provide sufficient circuit control, variable resistors are used. Frequently called "potentiometers" or "rheostats", these components are generally similar to a wire wound resistor with a variable “tap” or “wiper” incorporated into their construction to allow for providing a variable resistance value.

PRACTICE:

1 What is the unit of measure for resistance?

2. What is the unit of measure for conductance?