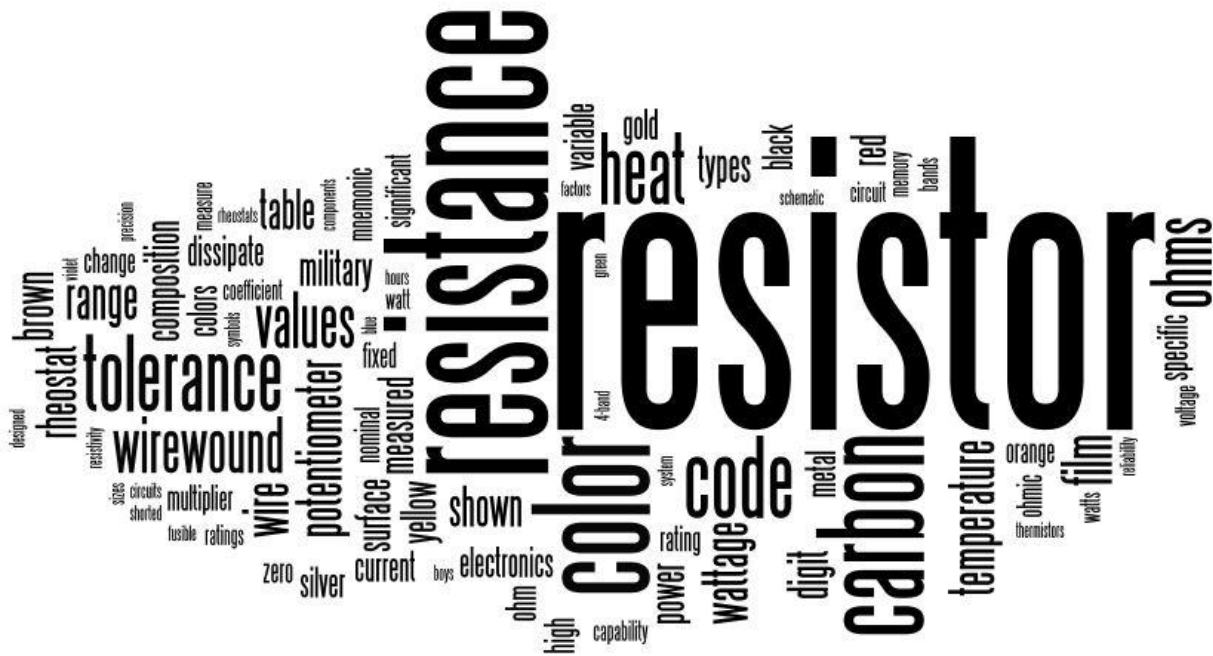


## 2 Resistors



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## Resistors

**Resistance** is a property of every electrical component. At times, its effects will be undesirable. However, resistance is used in many varied ways. **Resistors** are components manufactured to possess specific values of resistance. They are manufactured in many types and sizes. A table of common resistor types and their schematic symbols is shown in Figure 1.





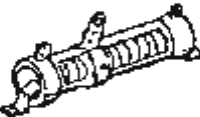

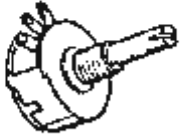



| TYPICAL RESISTOR                                                                         | TYPE                     | SYMBOL                                                                               |
|------------------------------------------------------------------------------------------|--------------------------|--------------------------------------------------------------------------------------|
| A<br>   | FIXED CARBON             |    |
| B<br>   | FIXED WIREWOUND (TAPPED) |    |
| C<br>  | ADJUSTABLE WIREWOUND     |   |
| D<br> | POTENTIOMETER            |  |
| E<br> | RHEOSTAT                 |  |

Figure 1: Table of Common Resistor Types



Video 1: Introduction to Resistors

## *Types of Resistors*

### **Carbon Composition**

One of the most common types of resistors is the molded composition, usually referred to as the **carbon resistor** (Figure 2). These resistors are manufactured in a variety of sizes and shapes. The chemical composition of the resistor determines its **ohmic value** and is accurately controlled by the manufacturer in the development process. They are made in ohmic values that range from one ohm to millions of ohms. The physical size of the resistor is related to its **wattage rating**, which is the ability of resistor to dissipate heat caused by the resistance.

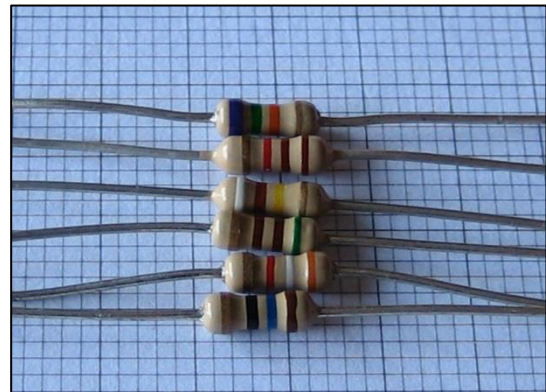


Figure 2: Carbon Composition

A **carbon composition** resistor consists of compressed carbon and a binder with insulating properties such as ceramic. Carbon is a semiconductor and ceramic is an insulator. It is the

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ratio of these which determines the resistor's value. In the manufacture of carbon resistors, fillers or binders are added to the carbon to obtain various resistor values. Examples of these fillers are clay, Bakelite, rubber, and talc. These fillers are **doping agents** and cause the overall conduction characteristics to change.

Carbon resistors are the most common resistors because they are easy to manufacture, inexpensive, and have a tolerance that is adequate for most electrical and electronic applications. A disadvantage, albeit slight, is that they may change value as they age. One other disadvantage of carbon resistors is their limited power handling capacity.

### Try This!

- With a #2 pencil, draw several lines of varying thickness and lengths on a piece of paper.
- Use an ohmmeter to measure the resistance of each line by placing one lead of the ohmmeter at each end of the line.
- Measure the resistance along a line at the  $\frac{1}{4}$ ,  $\frac{1}{2}$ , and  $\frac{3}{4}$  points.
- Consider the following questions:
  - For lines of similar length, but differing weights, was there a difference in resistance?
  - Was the resistance change constant as you moved the measurement point? Was it twice what was at the halfway point as it was at the one-quarter point?
  - What conclusions can you make about resistance after performing this experiment?

## Carbon Film Resistors

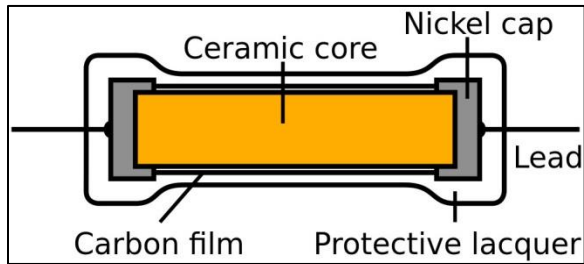


Figure 3: Carbon File Resistor

A **carbon film resistor** (Figure 3) uses a film of carbon attached to an insulator, then cut into a spiral to determine the resistance. Carbon film resistors are more accurate than carbon composition resistors and are less susceptible to noise, heat, and other external factors.

## Metal Film Resistors

In a **metal film resistor**, a metal spiral of a specific width and length allows for a more accurate resistance value. These are used in electronics which have a higher requirement for accuracy, such as military components, satellites, and cell phones. There are applications where environmental conditions, such as in outer space, or the need for accuracy, such as for missile guidance systems, require the use of precision resistors such as metal film. In Figure 4, one of the resistors has had the coating removed to better show the metal film construction.

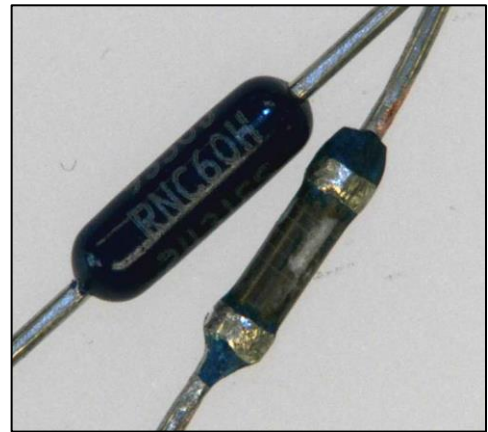


Figure 4: Metal File Resistor

## Surface Mount Resistors



Figure 5: Surface Mount

A **surface mount resistor** (Figure 5) is very small and is used for printed circuits board. Resistance is printed on them with code – the first 2 or 3 numbers are the digits and the final number is the multiplier. For the resistor shown, the value would be as follows:

205: Digit 1 = 2; Digit 2 = 0; Multiplier of 5 =  $\times 100,000$  =  $20 \times 100,000$  =  $2,000,000$  ohms =  $2 \text{ M}\Omega$

## Thermistors

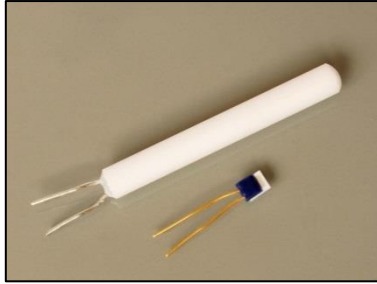


Figure 6: Thermistors

**Thermistors** (Figure 6) are resistors that react to heat and are used in situations where extreme temperature changes can affect electronics or create dangerous situations. As an example, high wattage electronics may use a thermistor near power transistors. As the power transistors heat up, the surrounding area will also heat up. A thermistor will react to the heat and can

be configured to activate a fan or kill-switch. Thermistors can have either a negative temperature coefficient or a positive temperature coefficient. To review, a **negative temperature coefficient** indicates that as the temperature increases, resistance decreases. A **positive temperature coefficient** indicates that as the temperature increases, the resistance increases.

## Fusible Resistors

**Fusible resistors** (Figure 7) can be carbon, carbon film, metal film, or wirewound. A fusible resistor is designed to operate as a resistor during normal operating conditions, but to respond as a fuse in case of overloading. They are usually flame retardant and are used in many consumer electronics such as

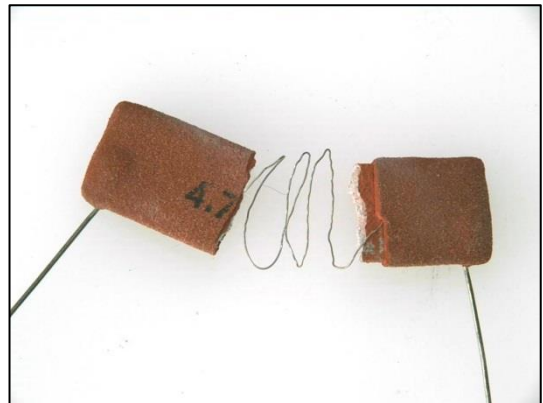


Figure 7: Fusible Resistor

phones, televisions, and battery chargers.

## Zero Ohm Resistors



Figure 8: Zero Ohm Resistor

**Zero ohm resistors** are used in situations where a jumper is desired, but when a wire may not be feasible. Surface mounted zero ohm resistors look like other surface mount resistors but will have a “0” printed on the surface. As shown in Figure 8, the color code scheme is a single black line.



## Wirewound

The disadvantage of carbon resistors can be overcome by the use of wirewound resistors. **Wirewound resistors** (Figure 9) have very accurate values and possess a higher current handling capability than carbon resistors. The material that is frequently used to manufacture wirewound resistors is **German silver**, or nickel silver, which is composed of copper, nickel, and zinc. The qualities and quantities of these elements present in the wire determine the **resistivity** of the wire. (The resistivity of the wire is the measure or ability of the wire to resist current. Usually the percent of nickel in the wire determines the resistivity.) One disadvantage of the wirewound resistor is that it takes a large amount of wire to manufacture a resistor of high ohmic value, thereby increasing the cost. A variation of the wirewound resistor provides an exposed surface to the resistance wire on one side. An adjustable tap is attached to this side. Such resistors, sometimes with two or more adjustable taps, are used as voltage dividers in power supplies and other applications where a specific voltage is desired to be "tapped" off.



Figure 9: Wirewound Resistor

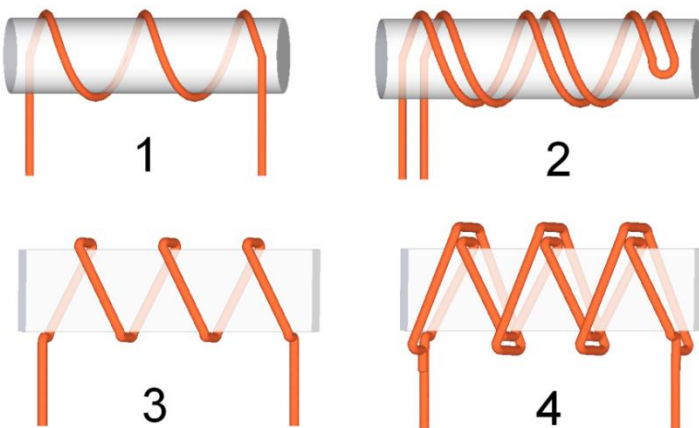
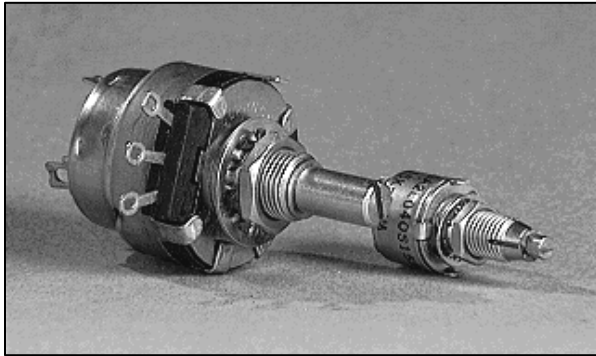


Figure 10: Wire Winding Styles

As shown in Figure 10, there are several different ways the wire may be wound. **Windings** are created in such a manner as to create and cancel electromagnetic fields, thus allowing for a very precise resistance. In future modules, you will learn more about electromagnetic fields.

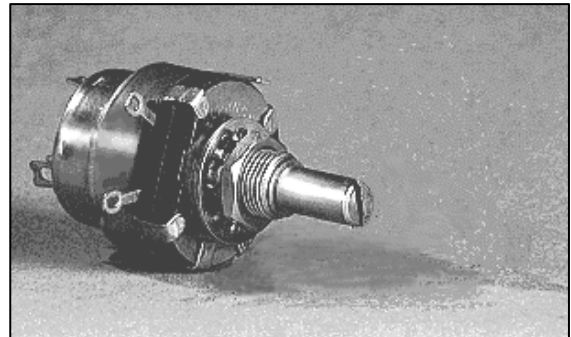
**Variable Resistors**



**Figure 11: Potentiometer**

There are two kinds of resistors, fixed and variable. The **fixed resistor** will have one value and will never change (other than through temperature, age, etc.). The resistors that we have discussed in the first part of this module are classed as fixed resistors. The **variable resistor** is constructed such that the value of resistance can be easily adjusted.

There are two types of variable resistors, one called a **potentiometer** and the other a **rheostat** (see Figures 11 and 12 respectively). An example of the potentiometer is the volume control on your radio, and an example of the rheostat is the dimmer control for the dash lights in an automobile. There is a slight difference between them. Rheostats usually have two connections, one fixed and the other moveable. Any variable resistor can properly be called a rheostat. The potentiometer always has three connections, two fixed and one moveable. Refer to Figure 1 for the schematic symbols for potentiometers and rheostats. Generally, the rheostat has a limited range of values and a high current-handling capability. The potentiometer has a wide range of values, but it usually has a limited current-handling capability. Potentiometers are always connected as voltage dividers. Refer to Video 2 for further information on this configuration.



**Figure 12: Rheostat**

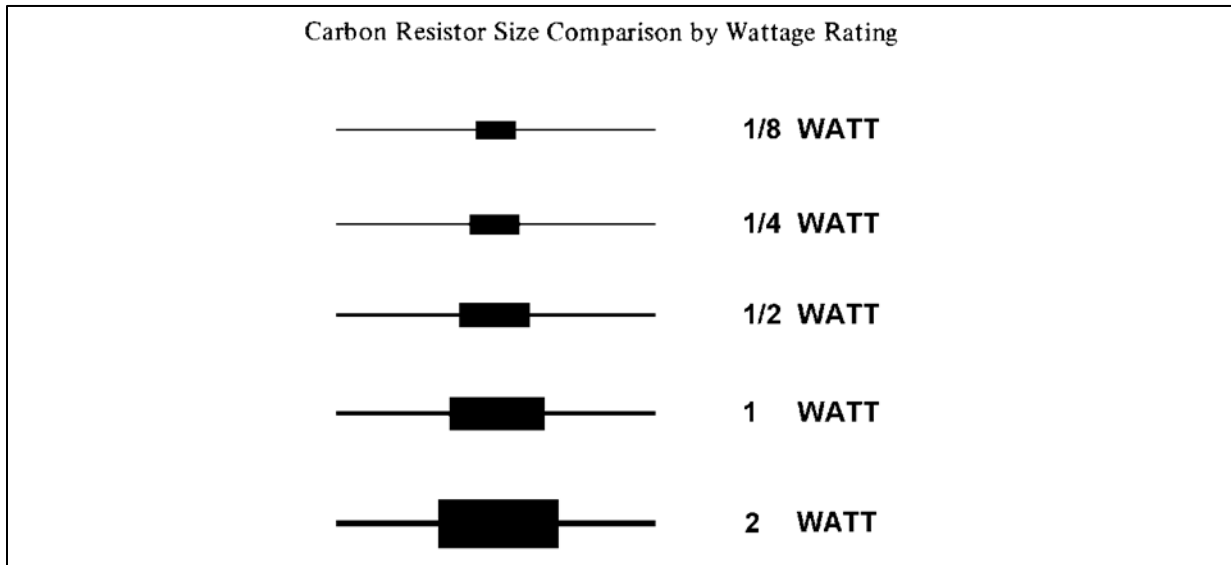
|                      |             |                          |                                |
|----------------------|-------------|--------------------------|--------------------------------|
| <b>Potentiometer</b> | 3 Terminals | Wider Resistance Range   | Limited Current Capabilities   |
| <b>Rheostat</b>      | 2 Terminals | Limited Resistance Range | Increased Current Capabilities |

**Table 1: Comparison of Potentiometers and Rheostats**

## ***Power Ratings***

When current passes through a resistor, heat is developed within the resistor. The resistor must be capable of dissipating this heat into the surrounding air; otherwise, the temperature of the resistor rises, causing a change in resistance, or possibly causing the resistor to burn out.

The ability of the resistor to dissipate heat depends upon the design of the resistor itself. This ability to dissipate heat depends on the amount of surface area which is exposed to the air. A resistor designed to dissipate a large amount of heat must therefore have a large physical size. The heat dissipating capability of a resistor is measured in **watts**. Some of the more common wattage ratings of carbon resistors are: one-eighth watt, one-quarter (or one-fourth) watt, one-half watt, one watt, and two watts. In some of the newer state-of-the-art circuits of today, much smaller wattage resistors are used. The higher the wattage rating of the resistor the larger is the physical size. Resistors that dissipate very large amounts of power (watts) are usually wirewound resistors. Wirewound resistors with wattage ratings up to 50 watts are not uncommon. Figure 13 shows some resistors which have different wattage ratings. Notice the relative sizes of the resistors.



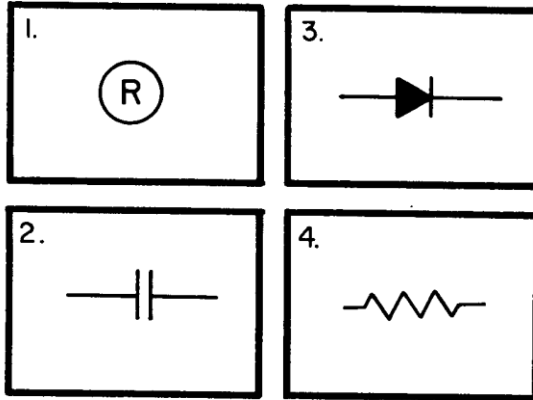
**Figure 13: Size comparison by wattage**



**Video 2: Types of Resistors**

## Knowledge Check

1. Which of the following schematic symbols is used to represent a resistor?

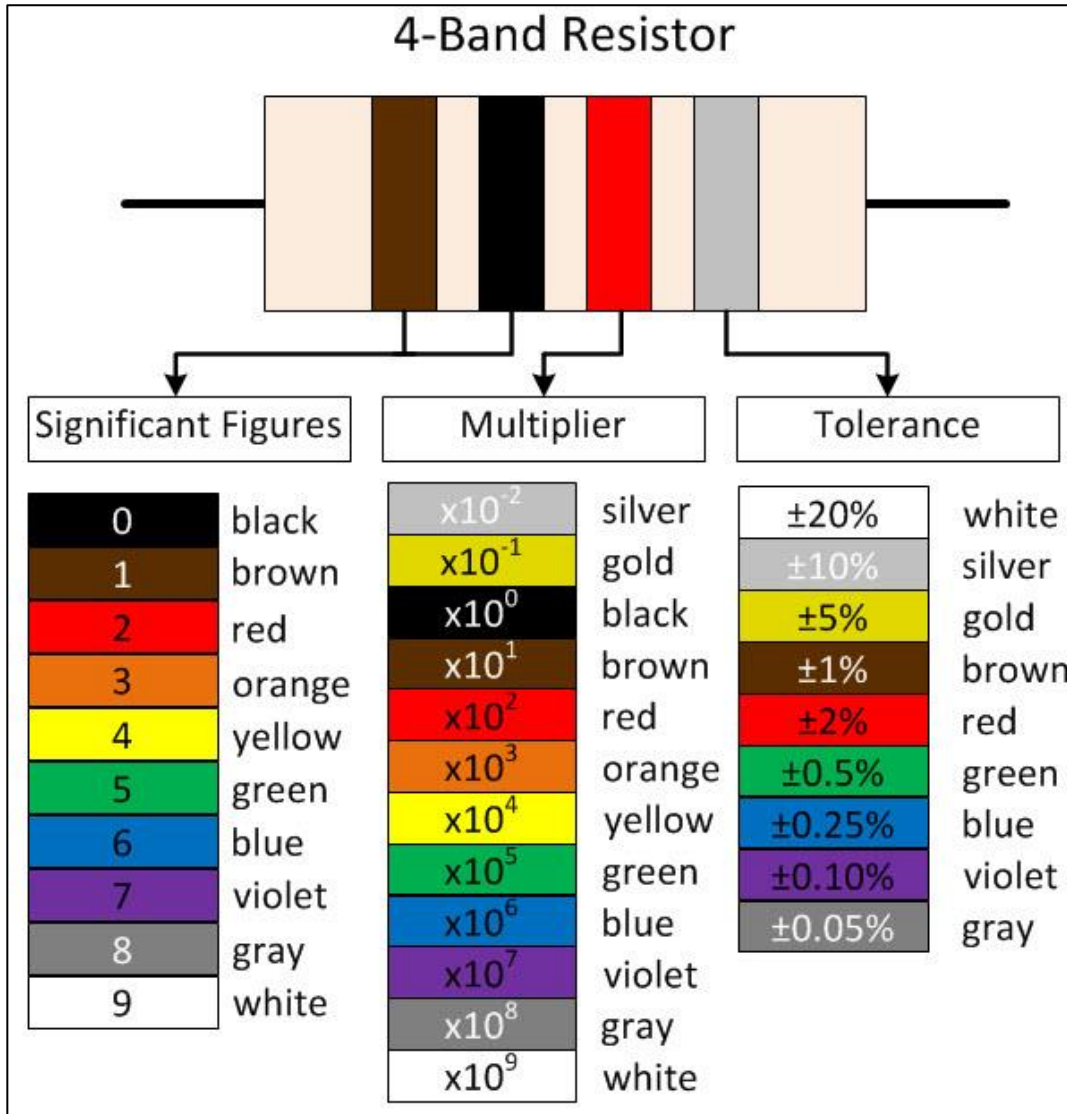


2. How is the ability of a resistor to dissipate heat indicated?
- By the wattage rating
  - By the voltage rating
  - By the resistance rating
  - By the tolerance
3. Carbon resistors have which of the following disadvantages?
- A high cost factor
  - An extremely large physical size
  - The resistance value changes with age
  - A limited range of resistance values
4. Which of the following types of resistors will overcome the disadvantages of a carbon resistor?
- Rheostat
  - Potentiometer
  - Molded composition
  - Wirewound resistor

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5. What is the total number of connections on (a) a rheostat and (b) a potentiometer?
- a. (a) Two      (b) two
  - b. (a) Two      (b) three
  - c. (a) Three     (b) two
  - d. (a) Three     (b) three
6. Which, if any, of the following types of variable resistors is used to control a large amount of current?
- a. Rheostat
  - b. Potentiometer
  - c. Wirewound potentiometer
  - d. None of the above

## Resistor Color Coding



### ***Standard Color Code System***

Resistors tend to be too small to write their value directly on them; therefore, a color-coding system has been devised and standardized. The different colors correspond to specific numbers while the band number corresponds to different factors depending on the number of bands and their placement. Shown graphically in Figure 14 and as a table below is the color

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code scale for 4-band resistors. Gaining an understanding of the color code takes time, but, with regular use and practice, it becomes second nature.

The color of the first band indicates the value of the first significant digit. The color of the second band indicates the value of the second significant digit. The third color band represents a decimal multiplier by which the first two digits must be multiplied to obtain the resistance value of the resistor. The colors for the bands and their corresponding values are shown in Table 2.

| Color  | 1 <sup>st</sup> Band<br>First Digit | 2 <sup>nd</sup> Band<br>Second Digit | 3 <sup>rd</sup> Band<br>Multiplier | 4 <sup>th</sup> Band<br>Tolerance |
|--------|-------------------------------------|--------------------------------------|------------------------------------|-----------------------------------|
| Black  | 0                                   | 0                                    | 1                                  | ± 20%                             |
| Brown  | 1                                   | 1                                    | 10                                 | Military ± 1%                     |
| Red    | 2                                   | 2                                    | 100                                | Military ± 2%                     |
| Orange | 3                                   | 3                                    | 1,000                              | Military ± 3%                     |
| Yellow | 4                                   | 4                                    | 10,000                             | Military ± 4%                     |
| Green  | 5                                   | 5                                    | 100,000                            |                                   |
| Blue   | 6                                   | 6                                    | 1,000,000                          |                                   |
| Violet | 7                                   | 7                                    |                                    |                                   |
| Grey   | 8                                   | 8                                    |                                    |                                   |
| White  | 9                                   | 9                                    |                                    |                                   |
| None   |                                     |                                      |                                    | Military ± 20%                    |
| Gold   |                                     |                                      | 0.1                                | ± 5%                              |
| Silver |                                     |                                      | 0.01                               | ± 10%                             |

**Table 2: Color code for 4-band resistors.**

As evidenced by the tolerance column, acceptable resistor values can vary significantly. When a device is designed using specific resistances, it needs to be taken into account that there will be an acceptable range of variance, or **tolerance**. For example, a resistor with a **nominal** (or labeled) value of 100 Ω and a tolerance level of ± 5% is considered within tolerance if its measured value is between 95 Ω and 105 Ω. Precision resistors are available, but with greater precision come greater cost.



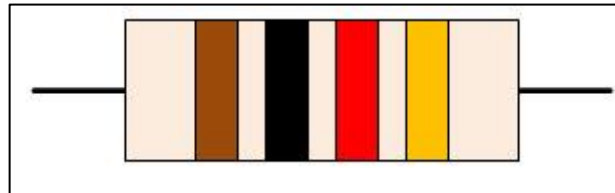
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How would you know if a resistor is within tolerance? The **percent difference formula** allows you to input nominal values and measured values and calculates the difference in percent. The formula subtracts the nominal (named, calculated, or expected) value from the measured (or actual) value. The result is then divided by the nominal value. The end result is multiplied by 100 to provide the result as a percentage.

$$\% \text{ difference} = \left( \frac{\text{measured value} - \text{nominal value}}{\text{nominal value}} \right) 100$$

**Equation 1: Percent difference formula**

### Decoding the Color Code



**Figure 15: Decoding the color code, part 1.**

Figure 15 shows a 4-band resistor with the colors: Brown, Black, Red, and Gold. To decode this resistor's color code start at first band (far left). Brown indicates that the first significant digit is 1. The second band is black; therefore the second significant digit is 0. The third band is red, which indicates that the number from the first two bands (10) is multiplied by 100. In this case  $10 \times 100 = 1000 \text{ ohms} = 1 \text{ k-ohm} = 1 \text{ k}\Omega$ . The last band on the resistor indicates the tolerance; that is, the manufacturer's allowable ohmic deviation above and below the numerical value indicated by the resistor's color code. In this example, gold indicates a tolerance of 5-percent, indicated as  $\pm 5\%$ . The actual value of the resistor may fall somewhere within 5% above and 5% below the value indicated by the color code, as shown in Figure 16.

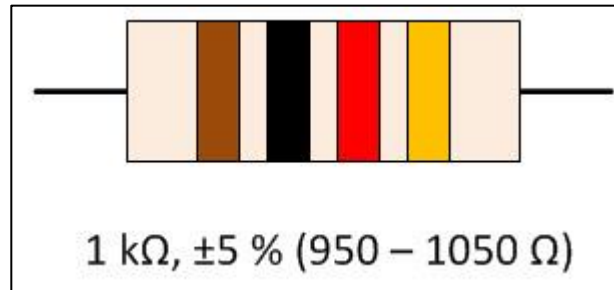


Figure 16: Decoding the color code, part 2.

## Engineering Notation Review

When measuring resistors, you will find situations where the quantities measured are extremely large, and the resulting number using the basic unit, the ohm, may prove cumbersome. Therefore, a metric system prefix is usually attached to the basic unit of measurement to provide a more manageable unit.

Two of the most commonly used prefixes are **kilo** and **mega**. Kilo is the prefix used to represent thousand and is abbreviated **k**. Mega is the prefix used to represent million and is abbreviated **M**.

0.000000001 = nano = 1 nΩ  
0.000001 = micro = 1 μΩ  
0.001 = milli = 1 mΩ  
1,000 = kilo = 1 kΩ  
1,000,000 = Mega = 1 MΩ  
1,000,000,000 = Giga = 1 GΩ

Figure 17: Metric prefixes

In the example given above, the 1,000 ohm resistor could have been written as 1 k-ohm or as 1 kΩ. Other examples are: 10,000 ohms = 10 kΩ; 100,000 ohms = 100 kΩ. Likewise, 1,000,000 ohms is written as 1 megohm or 1 M and 10,000,000 ohms = 10 MΩ.

## Simplifying the Color Code

Resistors are the most common components used in electronics. The technician must identify, select, check, remove, and replace resistors. Resistors and resistive circuits are usually the easiest branches of electronics to understand. The resistor color code sometimes presents problems to a technician. However, there is a strategy that can help with recall.

There is a memory aid, or **mnemonic**, that will help you remember the code in its proper order. In a mnemonic, each word starts with the first letter of the colors. If you match it up with the color code, you will not forget the code.

### What's a Mnemonic?

A mnemonic is a memory aid where the first letter of each term to be remembered is used in an easily remembered phrase. A very common one is H.O.M.E.S. This uses the first letter of the names of the Great Lakes in order: Huron, Ontario, Michigan, Erie, Superior. Memory aids can be very useful and it is helpful to create ones that are meaningful to you.

A common mnemonic for resistor color codes is: **Bad Boys Run Over Yellow Gardenias Behind Victory Garden Walls**, or:

|               |   |           |
|---------------|---|-----------|
| <b>Black</b>  | — | Bad       |
| <b>Brown</b>  | — | Boys      |
| <b>Red</b>    | — | Run       |
| <b>Orange</b> | — | Over      |
| <b>Yellow</b> | — | Yellow    |
| <b>Green</b>  | — | Gardenias |
| <b>Blue</b>   | — | Behind    |
| <b>Violet</b> | — | Victory   |
| <b>Gray</b>   | — | Garden    |
| <b>White</b>  | — | Walls     |

There are many other memory aid sentences that you might want to ask about from experienced technicians. You might find one of the other sentences easier to remember.

Other mnemonics include:

- **Big Boys Race Our Young Girls But Violet Generally Wins**
- **Better Be Right Or Your Great Big Venture Goes West**
- **Big Brown Rabbits Often Yield Great Big Vocal Groans When Gingerly Slapped** (the last two words are added for clarity)

There is still a good chance that you will make a mistake on a resistor's color band. Most technicians do at one time or another. If you make a mistake on the first two significant colors, it usually is not too serious. If you make a mistake on the third band, you are in trouble, because the value is going to be at least 10 times too high or too low. Some important points to remember about the third band are:

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| Color  | Resistance Range |
|--------|------------------|
| Black  | < 100 ohms       |
| Brown  | 100's            |
| Red    | 1,000's          |
| Orange | 10,000's         |
| Yellow | 100,000's        |
| Green  | 1,000,000's      |
| Blue   | 10,000,000's +   |

**Table 3: 3<sup>rd</sup> Band - Multiplier**

Although you may find any of the above colors in the third band, red, orange, and yellow are the most common. In some cases, the third band will be silver or gold. You multiply the first two bands by 0.01 if it is silver and 0.1 if it is gold.

The fourth band, which is the tolerance band, usually does not present too much of a problem. If there is no fourth band, the resistor has a 20-percent tolerance; a silver fourth band indicates a 10-percent tolerance; and a gold fourth band indicates a 5-percent tolerance. Resistors that conform to

military specifications have a fifth band. The fifth band indicates the reliability level per 1,000 hours of operation as shown in

| 5 <sup>th</sup> Band Color | Reliability Level per 1,000 hours |
|----------------------------|-----------------------------------|
| Brown                      | 1.0%                              |
| Red                        | 0.1%                              |
| Orange                     | 0.01%                             |
| Yellow                     | 0.001%                            |

For a resistor with the fifth band color coded brown, the resistor's chance of failure will not exceed 1- percent for every 1,000 hours of operation.

**Table 4: Reliability Levels for 5-Band Resistors**

Some resistors, both wirewound and composition, will not use the resistor color code. These resistors will have the ohmic value and tolerance imprinted on the resistor itself.

| 5 <sup>th</sup> Band Color | Reliability Level per 1,000 hours |
|----------------------------|-----------------------------------|
| Brown                      | 1.0%                              |
| Red                        | 0.1%                              |
| Orange                     | 0.01%                             |
| Yellow                     | 0.001%                            |

### Measuring Resistance

Refer back to the module on Electricity for specific instructions on how to measure resistance using a digital multimeter (DMM) or analog meter (VOM). Remember that when measuring

## Air Washington Electronics – Direct Current

resistors, the circuit must be disconnected from the power source, or deenergized. In addition, it is important to ensure that the proper range setting is selected.

When measuring a resistor in circuit, the type of circuit configuration needs to be considered. As you will learn in later modules, resistors in parallel will have a lower measured resistance compared to their nominal resistance. Therefore, ensure that parallel resistances are taken into account, or eliminated when taking measurements.

It is not uncommon for resistors to fail due to surges, heat, or other factors. In this case, the resistor will become opened. When measured, the resistance will be infinite ohms. Do not confuse this with zero ohms, however. Infinite ohms means that the resistance is very, very high. Zero ohms means that there is no resistance and would indicate that the resistor is shorted. However, it is virtually impossible for a resistor to become shorted within itself, though it can be shorted by another part of the circuit.

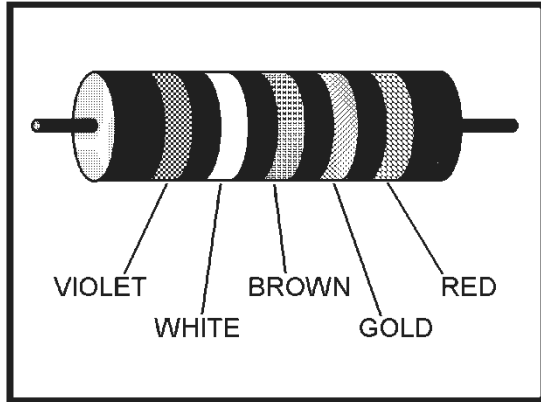


**Video 3: Resistor Color Codes**



***Knowledge Check***

7. A carbon resistor is color-coded orange, orange, orange. What is the resistance value of this resistor?
  - a. 2.2 k $\Omega$
  - b. 3.3 k $\Omega$
  - c. 33.0 k $\Omega$
  - d. 440.0 k $\Omega$
  
8. What are the allowable limits of ohmic value in a resistor color coded blue, green, yellow, gold?
  - a. 682.5 k $\Omega$  to 617.5 k $\Omega$
  - b. 715.0 k $\Omega$  to 585.0 k $\Omega$
  - c. 7.98 M $\Omega$  to 7.22 M $\Omega$
  - d. 8.36 M $\Omega$  to 6.84 M $\Omega$
  
9. Of the following, which color of the fifth band on a resistor indicates the LEAST chance of failure?
  - a. Red
  - b. Brown
  - c. Yellow
  - d. Orange



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Figure 18: Resistor with color coding

10. Referring to Figure 18, what is the ohmic value of the resistor?

- a.  $8\Omega$
- b.  $79\Omega$
- c.  $790\Omega$
- d.  $800\Omega$

11. Referring to Figure 18, what is the specified tolerance of the resistor?

- a. 1%
- b. 5%
- c. 10%
- d. 20%

12. Referring to Figure 18, what is the specified reliability of the resistor?

- a. 1.0%
- b. 0.1%
- c. 0.01%
- d. 0.001%



## Resistor Lab 1: Measuring Resistance

### *Components & Equipment Needed*

- Digital Multimeter (DMM)
- Resistors with values corresponding to the following color codes:
  - Brown-Black-Red-Gold
  - Orange-Orange-Brown-Gold
  - Brown-Red-Green-Gold
  - Yellow-Orange-Gold-Gold

### *Procedure*

#### **Step 1: Determining the Resistances and Calculating Difference**

- Using the standard color code determine and record the resistor’s value in the “Nominal Value” column of Table 5.
- Using the DMM, measure the value of each resistor and record in Table 5.
- Calculate the percentage of difference between the nominal value and the measured value and record in Table 5.

### *Tables for Resistor Lab 1: Measuring Resistance*

| Resistor                 | Nominal Value | Measured Value | Percent Difference | Within Tolerance? |
|--------------------------|---------------|----------------|--------------------|-------------------|
| Brown-Black-Red-Gold     |               |                |                    |                   |
| Orange-Orange-Brown-Gold |               |                |                    |                   |
| Brown-Red-Green-Gold     |               |                |                    |                   |
| Yellow-Orange-Gold-Gold  |               |                |                    |                   |

**Table 5: Resistor Lab 1: Measuring Resistance**

### ***Observations and Conclusions***

In your lab report, include your results from Table 5 as well as any observations or conclusions you may have made during this exercise.

Some questions to consider:

- Was the difference between the nominal resistance and the measured resistance within tolerance?
- Did the meter react differently when measuring the very largest and very smallest of the resistors compared to the other resistors?

## Resistor Lab 2: A Simple Resistive Circuit

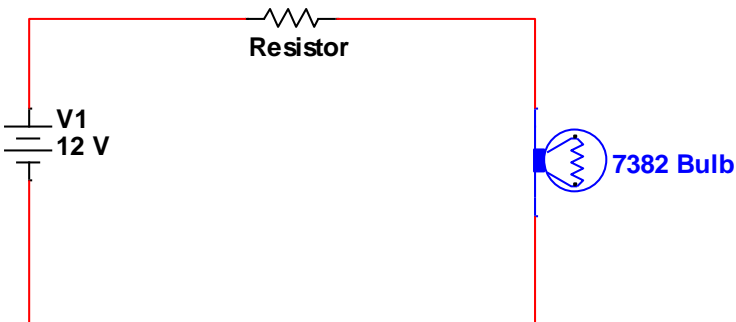
A resistive circuit is a circuit comprised of a power source and a resistor. The relationship that exists between voltage, current, and resistance is a major foundation of electronics.

Experimentation with a resistive circuit allows you to observe that relationship.

### *Components & Equipment Needed*

- Bread Board
- Wire (22 AWG)
- DC Power Supply
- DMM
- Resistors: 10  $\Omega$ , 100  $\Omega$ , 1k  $\Omega$ , 3 M $\Omega$
- 7382 Bulb, or similar

### Circuit Diagram



Circuit 1: Resistor Lab 2 Circuit Diagram

### *Procedure*

For this exercise, you will be swapping out resistors to determine the effect that they have on a simple circuit. Be sure to follow the steps as described below.

#### **Step 1: Build the circuit and make observations.**

- Starting with the 10 $\Omega$  resistor, build the circuit as shown in Circuit 1.
- Observe the bulb and record whether it is brightly lit or dim.
- Measure and record the voltages across the resistor and across the lamp.

## Air Washington Electronics – Direct Current

- Add the voltage drops across the resistor and lamp and record.
- Measure and record the current. Review the previous module on how to measure current.
- Repeat for each each resistor.

### *Tables for Resistor Lab 2: A Simple Resistive Circuit*

| Resistor     | Observation | $V_{\text{Resistor}}$ | $V_{\text{Lamp}}$ | $V_{\text{Resistor}} + V_{\text{Lamp}}$ | Current |
|--------------|-------------|-----------------------|-------------------|-----------------------------------------|---------|
| 10 $\Omega$  |             |                       |                   |                                         |         |
| 100 $\Omega$ |             |                       |                   |                                         |         |
| 1 k $\Omega$ |             |                       |                   |                                         |         |
| 3 M $\Omega$ |             |                       |                   |                                         |         |

Table 6: Resistor Lab 2: A Simple Resistive Circuit

### *Observations and Conclusions*

In your lab report, include your results from Table 6 as well as any observations or conclusions you may have made during this exercise.

Some questions to consider:

- Did the bulb react as you expected?
- Is there a relationship between the applied voltage and the voltage drops at the resistor and the lamp?

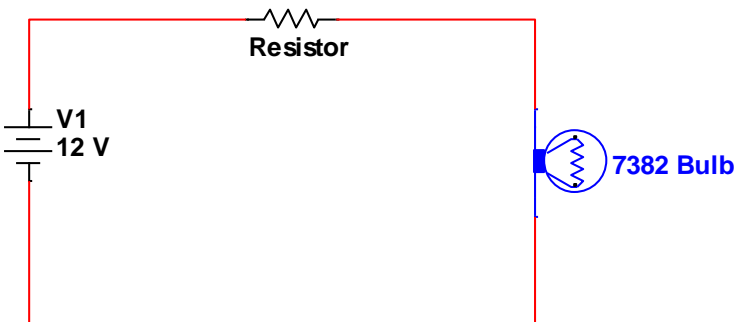
## Resistor Lab 3: Variable Resistance

There are applications where a variable resistance is desired and in these cases, a potentiometer is used. A pot, as it is known for short, allows the user to adjust the amount of resistance in a circuit. Some pots are used for fine tuning precision resistance on circuit boards; others are more general purpose, such as a dimmer dial for lights.

### *Components & Equipment Needed*

- Bread Board
  - Wire (22 AWG)
  - DC Power Supply
  - DMM
  - Potentiometer (random value)
  - 7382 Bulb
- 2.

### Schematic



Circuit 2: Resistor Lab 3 Circuit Diagram

### ***Procedure***

For this exercise, you will be inserting a potentiometer into a simple resistive circuit and analyzing the effects.

A potentiometer provides two different resistances: the full resistance for which it is rated and a variable resistance between 0 and its full rated value. Most potentiometers are linear, meaning that they increase or decrease on an even slope. However, there are potentiometers which are logarithmic in scale.

#### **Step 1: Measuring the Potentiometer**

Following the directions below, take three measurements – one with the dial turned all the way to the left, another with the dial midway, and finally another with the dial turned all the way to the right. Read the directions below carefully to ensure that the measurements are taken at the correct locations. Record your measurements in Table 7.

- Measure and record the resistance between the left side terminal and the center terminal of the potentiometer.
- Measure and record the resistance between the right side terminal and the center terminal of the potentiometer.
- Measure and record the resistance between the left and right terminals of the potentiometer.

#### **Step 2: Build the Circuit**

- Following Circuit 2, connect the circuit using the variable resistor (potentiometer) in place of the static resistor shown. To allow for varying resistances, use only the outer terminals.

#### **Step 3: Varying the Resistance**

- Vary the setting on the dial and observe the effect this has on the lamp.

***Tables for Resistor Lab 2: A Simple Resistive Circuit***

| <b>Measured Between:</b>  | <b>Dial to the Right</b> | <b>Dial Midway</b> | <b>Dial to the Left</b> |
|---------------------------|--------------------------|--------------------|-------------------------|
| Left Terminal and Center  |                          |                    |                         |
| Right Terminal and Center |                          |                    |                         |
| Left and Right Terminals  |                          |                    |                         |

**Table 7: Resistor Lab 3: Variable Resistance**

***Observations and Conclusions***

In your lab report, include your results from Table 6 as well as any observations or conclusions you may have made during this exercise.

Some questions to consider:

- What are your conclusions regarding the potentiometer after analyzing these measurements?
- What are some potential applications for variable resistances in a circuit?
- How did the potentiometer affect the bulb?

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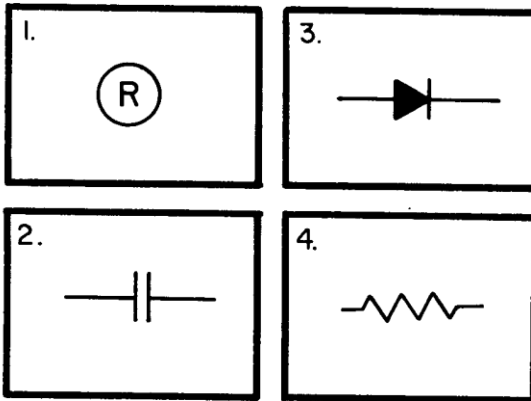
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## Answers to Knowledge Checks

### *Introduction and Resistor Types*

1. Which of the following schematic symbols is used to represent a resistor? (4)



2. How is the ability of a resistor to dissipate heat indicated?
- By the wattage rating (CORRECT)
  - By the voltage rating
  - By the resistance rating
  - By the tolerance
3. Carbon resistors have which of the following disadvantages?
- A high cost factor
  - An extremely large physical size
  - The resistance value changes with age (CORRECT)
  - A limited range of resistance values

## Air Washington Electronics – Direct Current

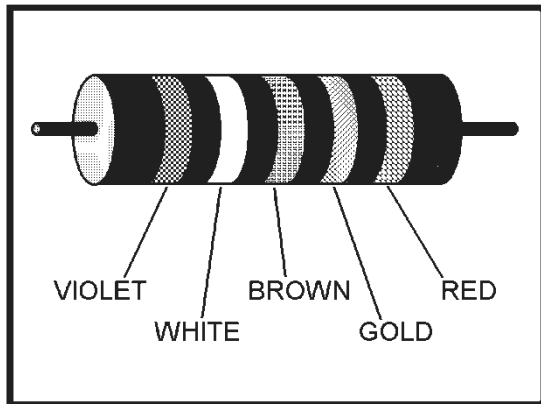
4. Which of the following types of resistors will overcome the disadvantages of a carbon resistor?
  - a. Rheostat
  - b. Potentiometer
  - c. Molded composition
  - d. Wirewound resistor (CORRECT)
  
5. What is the total number of connections on (a) a rheostat and (b) a potentiometer?
  - a. (a) Two      (b) two
  - b. (a) Two      (b) three (CORRECT)
  - c. (a) Three     (b) two
  - d. (a) Three     (b) three
  
6. Which, if any, of the following types of variable resistors is used to control a large amount of current?
  - a. Rheostat (CORRECT)
  - b. Potentiometer
  - c. Wirewound potentiometer
  - d. None of the above

### ***Resistor Color Codes***

7. A carbon resistor is color-coded orange, orange, orange. What is the resistance value of this resistor?
  - a. 2.2 k $\Omega$
  - b. 3.3 k $\Omega$
  - c. 33.0 k $\Omega$  (CORRECT)
  - d. 440.0 k $\Omega$

## Air Washington Electronics – Direct Current

8. What are the allowable limits of ohmic value in a resistor color coded blue, green, yellow, gold?
- a. 682.5 k $\Omega$  to 617.5 k $\Omega$  (CORRECT)
  - b. 715.0 k $\Omega$  to 585.0 k $\Omega$
  - c. 7.98 M $\Omega$  to 7.22 M $\Omega$
  - d. 8.36 M $\Omega$  to 6.84 M $\Omega$
9. Of the following, which color of the fifth band on a resistor indicates the LEAST chance of failure?
- a. Red
  - b. Brown
  - c. Yellow (CORRECT)
  - d. Orange



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Figure 19: Resistor with color coding

10. Referring to Figure 18, what is the ohmic value of the resistor?
- a. 8 $\Omega$
  - b. 79 $\Omega$
  - c. 790 $\Omega$  (CORRECT)
  - d. 800 $\Omega$

## Air Washington Electronics – Direct Current

11. Referring to Figure 18, what is the specified tolerance of the resistor?

- a. 1%
- b. 5% (CORRECT)
- c. 10%
- d. 20%

12. Referring to Figure 18, what is the specified reliability of the resistor?

- a. 1.0%
- b. 0.1% (CORRECT)
- c. 0.01%
- d. 0.001%

## Additional Resources

### *Video References*

- Sukubasukuba: Resistors (NEETS Module 1 Chapter 1)  
<http://www.youtube.com/watch?v=a1nGFQqNLpM>
- MAKE Presents: The Resistor  
<http://www.youtube.com/watch?v=VPVoY1QR0Mg>

### *Color Code Guides*

- Sam's Tech Library
  - 4 Band Resistor Color Codes  
<http://samstechlib.com/24614782/en/read/?history=610938>
  - 5 Band Resistor Color Codes  
<http://samstechlib.com/15924820/en/read/?history=610938>
  - 6 Band Resistor Color Codes  
<http://samstechlib.com/46436194/en/read/?history=610938>

### *Resources from All About Circuits*

- A Lecture on Resistors by Tim Fiengenbaum of North Seattle Community College  
<http://www.allaboutcircuits.com/videos/14.html>

## References

Szymkewicz, M. (2010, September). Professor of Electronics, Olympic College. Bremerton, Washington.

United States Navy. (1998). Module 19 - The Technican's Handbook. In *Navy Electricity and Electronics Training Series (NEETS)*. Pensacola, FL: Naval Education and Training Professional Development and Technology Center.

United States Navy. (2003). Module 1 - Introduction to Matter, Energy, and Direct Current. In *Navy Electricity and Electronics Training Series (NEETS)*. Pensacola, FL: Naval Education and Training Professional Development and Technology Center.

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