

# Resistors

There is always some resistance in every circuit.

- A circuit is always made up of some wire, so there will be some resistance there.
- Even the battery has parts that offer resistance to the flow of electrons.
- The only circuits that come near to zero resistance are superconductors.
- This resistance that is from the parts of the circuit itself (especially the battery) is called **internal resistance**.
  - This internal resistance is usually drawn into a circuit diagram (*schematic*) as shown in Figure 1.
  - Notice the squiggly line just before the positive terminal of the battery? That's to show the internal resistance of the circuit.
- That symbol, drawn any other place in the circuit, represents an actual **resistor** placed in the circuit.
  - A resistor is a device found in circuits that has a certain amount of resistance.

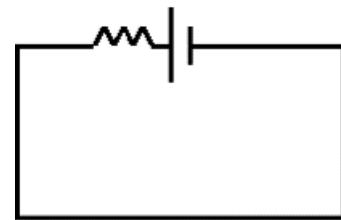


Figure 1: A schematic diagram showing internal resistance and a battery.

Why would you ever want to add resistance to a circuit by using a resistor?

- The most common reason is that we need to be able to adjust the current flowing through a particular part of the circuit.
  - If voltage is constant, then we can change the resistor to change the current.

$$I = \frac{V}{R}$$
 If "V" is constant and we change "R", "I" will be different.

## Actual Resistors

The resistors that you would most likely see if you opened up a CD player, VCR, or other electronic device would look like the ones in Figure 2.

- They basically look like little cylinders with colored lines painted on them.
- The colored lines tell you the resistance and error range (tolerance) for a resistor according to the following rules and table of numbers. You do NOT have to memorize this table... it will be given to you if you need it.
- To use the table you need to remember the following rules:
  1. The first line is the first digit
  2. The second line is the second digit
  3. The third line is the multiplier
  4. The last line (if any) is the tolerance
- Some resistors may have additional colored bands, but we will ignore them here.
  - They usually have something to do with measuring things like failure rates or temperature coefficients.

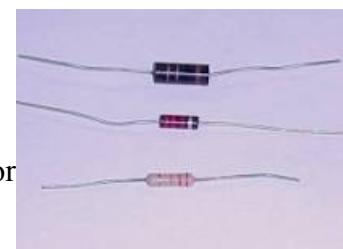
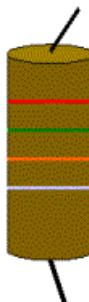


Figure 2: Three resistors used in electronic devices.

Color	Number	Multiplier	Tolerance
Black	0	$10^0$	
Brown	1	$10^1$	$\pm 1\%$
Red	2	$10^2$	$\pm 2\%$
Orange	3	$10^3$	
Yellow	4	$10^4$	
Green	5	$10^5$	
Blue	6	$10^6$	
Violet	7	$10^7$	
Grey	8	$10^8$	
White	9	$10^9$	
Gold		$10^{-1}$	$\pm 5\%$
Silver		$10^{-2}$	$\pm 10\%$
No Color			$\pm 20\%$

**Example 1:** What is the resistance of this resistor?



Notice that the colors on this resistor are (in order) Red, Green, Orange, and Silver.

1. The first line is the first digit → **Red** = 2
2. The second line is the second digit → **Green** = 5
3. The third line is the multiplier → **Orange** =  $10^3$
4. The last line (if any) is the tolerance → **Silver** =  $\pm 10\%$

So the final answer would be  $25 \times 10^3 \Omega \pm 10\%$

- Yes, I know it's not proper scientific notation this way. You can also write it as  $25000 \Omega$  (notice there are three zeros), or even  $2.5 \times 10^2 \Omega$ .

## Methods of Making Resistors

There are two main methods that are used to make resistors.

- The most common is to just have a bunch of wire wound up inside that little cylinder.
  - Known as **wire-wound** resistors, they depend on the fact that a certain length of a certain piece of wire will have a certain resistance.

- These resistors tend to be very reliable (with low tolerances), but cost more because of the price of metals used in them and the machinery needed to carefully cut and wind the wire.
- The other type of resistor is made of a piece of carbon.
  - Known as a **composition** resistor, they depend on the size of the piece of carbon, and the fact that carbon is a metalloid (has some metal-like properties) that does conduct electricity.
  - Because they are made from cheap carbon, **composition** resistors can cost much less than similar **wire-wound** resistors. The drawback is that the carbon can be cracked while making them, or become cracked in use. They have higher tolerances because of the uncertainty in cutting the carbon.

**Did you know?**

When buying electronics, the price partly depends on the brand name that is on it. A Sony DVD player will cost a lot more than an Apex DVD player with similar features. Another reason one may cost much less than another is the quality of the components used. For example, a high end DVD player will likely use wire-wound resistors, while the cheaper one will have composition resistors.

In some cases it is necessary to have a circuit with resistors that you can adjust.

- These resistors are known as **potentiometers** or **variable resistors**.
  - Often they are just a modified version of a **wire-wound** resistor, although newer versions use advanced electronics instead.
- You've used one if you've ever used a dimmer switch for lights in a room, or played with an electric race car set.
- Most variable resistors are designed so that by turning a dial or sliding a switch, you change the amount of conducting material the current has to go through.
  - The more conducting material the current has to go through, the higher the resistance... less material and the resistance is less.

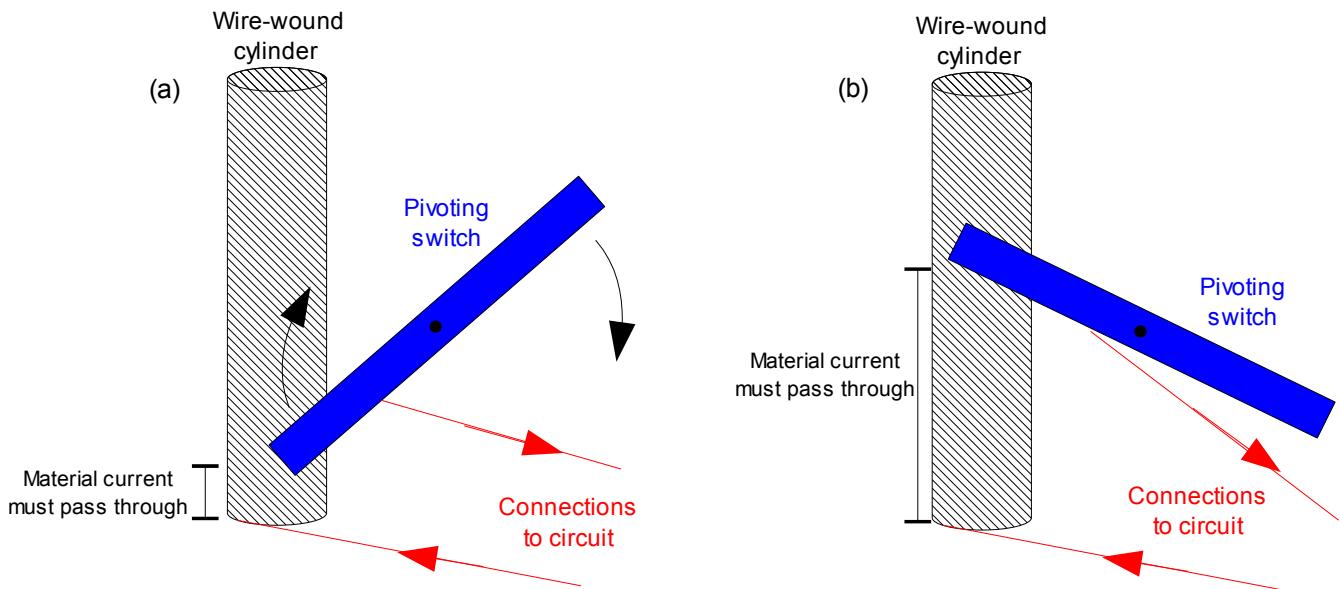


Figure 3: By pivoting the switch from one position (a) to another (b), the amount of material (and resistance) increases.