

Variable Resistors

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In the previous lessons you worked with resistors of fixed values. A fixed resistor has a specific resistance value that can't be changed. In this lesson you will learn about **variable resistors**. As the name suggests, the resistance of a variable resistor can change. A **potentiometer** is a mechanical type of variable resistor. By turning a knob or screw, the resistance of a potentiometer is changed. The volume of radios is commonly controlled by potentiometers. When you turn the knob to make the radio louder, the potentiometer is reduced in resistance, which increases the volume.

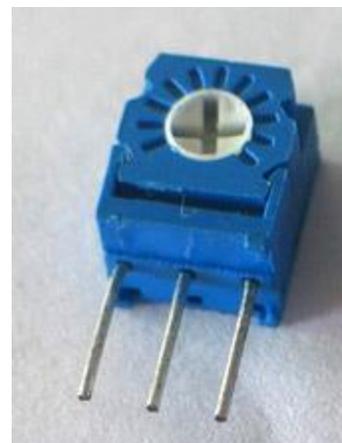


Figure 1. Potentiometer

Figure 1 is a photo of a potentiometer (or pot). This kind of pot is adjusted by inserting a screwdriver into the white slot in the center. Rotating the screwdriver changes the resistance. Pots are rated by resistance at the maximum setting. For example, if the pot is 10 k Ω , it can be adjusted from 0 to 10,000 ohms. Notice that the pot has three pins. Suppose that the pot in Figure 1 is 10,000 ohms. If you touched your meter probes to the left and right pins, the meter would display 10,000 ohms. It would not matter how you adjusted the pot, the right and left pins would always have 10,000 ohms of resistance between them. The variable resistance is obtained by using the middle pin with either of the other pins. When the pot is turned all the way counterclockwise, there will be 0 ohms resistance between the middle pin and one of the outer pins and 10,000 ohms resistance between the middle pin and the other outer pin. When turned all the way clockwise, the resistances between the middle pin and outer pins will be reversed. When the pot is adjusted to the middle of its range, then there will be 5,000 ohms resistance between the middle pin and both right and left pins. It is possible to adjust the pot to get any resistance you desire between 0 and 10,000 ohms. You will be using potentiometers in this lesson.

Another kind of variable resistor is the photoresistor (also known as a photocell). The photoresistor does not have a knob or screw because it is not a mechanical type of variable resistor. Instead, the resistance of a photoresistor is controlled by the amount of light that shines on it. When placed in the dark, the photoresistor will have its maximum value of resistance. When placed under a very bright light, the photoresistor will have its minimum value of resistance. At other levels of light, the photoresistor will have values between minimum and maximum. The more light, the less resistance it will have.

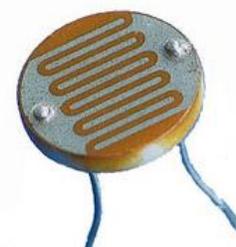


Figure 2. Photoresistor.

The photoresistor contains a semiconductor material in the space between the metal fingers (you can see the fingers in Figure 2). When light shines on the semiconductor material, some of the electrons of the semiconductor atoms are raised to a higher energy level and are able to escape. As more light shines on the semiconductor material, more electrons escape the atoms. The

liberated electrons allow more current to flow between the metal fingers of the photoresistor. That is how it works.

The line following robot has four photoresistors in groups of two to detect a line on the floor. Suppose you place a dark line on a light-colored floor. The photoresistors of the robot are pointing at the floor. A photoresistor directly above the dark line will have more resistance than a photoresistor above the light-colored floor. By placing four photoresistors across the front of the robot, the robot can detect where the line is under the robot by comparing the resistances of the two groups of photoresistors. The robot can make steering adjustments if the line is not centered under the robot. We can say that the photoresistors are the eyes of the robot. You will be using photoresistors in this lesson to build the circuit that detects the line.

Adjusting the brightness of a LED with a trimmer potentiometer

Now you will build a temporary circuit on your breadboard to help you learn how to use a potentiometer. You will be using a **trimmer** potentiometer like the one in Figure 1. A trimmer pot does not have a knob, only a slot for a screwdriver. Trimmer pots are used to make an adjustment in a circuit. After the initial adjustment, the trimmer is usually not changed again unless something else happens in the circuit. For example, with age, some of the other components of a circuit may change a little, which may require the trimmer to be adjusted again. You would not use a trimmer pot to adjust the volume of a radio because you would want to change the volume many times as you use the radio. Trimmer pots are designed to make infrequent adjustments. They cannot withstand constant adjustments.

Parts list

One fixed resistor of 560 ohms

One potentiometer of 100,000 ohms (it is labeled with the number 104, which means 100,000, just like the color code: first two digits are 10 followed by 4 zeroes = 100,000)

One red LED

Assemble the circuit on the breadboard as follows.

1. Disconnect the battery from the breadboard as a safety measure.
2. Connect a red wire from the positive power bus to an available row (row 13 in photo).
3. Connect one end of the 560 ohm resistor to the same row containing the red wire and connect the other end of the resistor to an available row.
4. Insert the 100,000 ohm pot, with the middle pin in the same row as the 560 ohm resistor (look at Figure 3 for

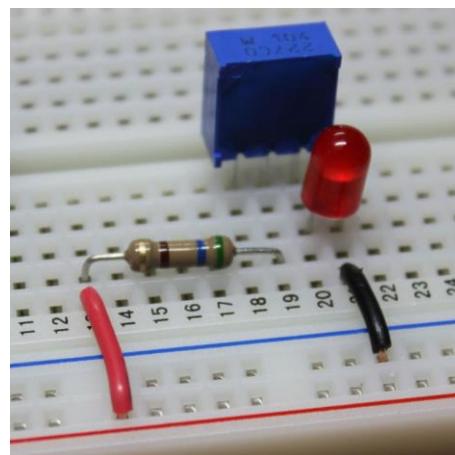


Figure 3. Circuit for adjusting brightness of a LED

help). The slot to adjust the pot is on the back so that you can get to it easily with the screwdriver.

5. Insert the red LED with the anode wire in the same row that contains the right pin of the pot (the cathode wire is inserted at the same time into the next row to the right).
6. Connect one end of a black wire to the same row that contains the cathode wire of the LED. Connect the other end of the black wire to the negative power bus.
7. Your circuit is now complete. Have an adult check your circuit before you reconnect the battery to the breadboard.

Let's take a look at the schematic for the circuit you just completed (Figure 4). There is a new symbol for you to learn. The symbol for R2 is a potentiometer. It is similar to a fixed resistor symbol, but has an arrow pointing to the zig-zag line. The arrow represents the middle pin of the pot. Imagine the arrow moving along the zig-zag line to adjust the resistance. The symbol is really similar to the way some pots actually work. You can see why the right and left pins have a fixed resistance between them. The only thing that changes when the pot is adjusted is the position of the arrow, which represents the connection to the middle pin.

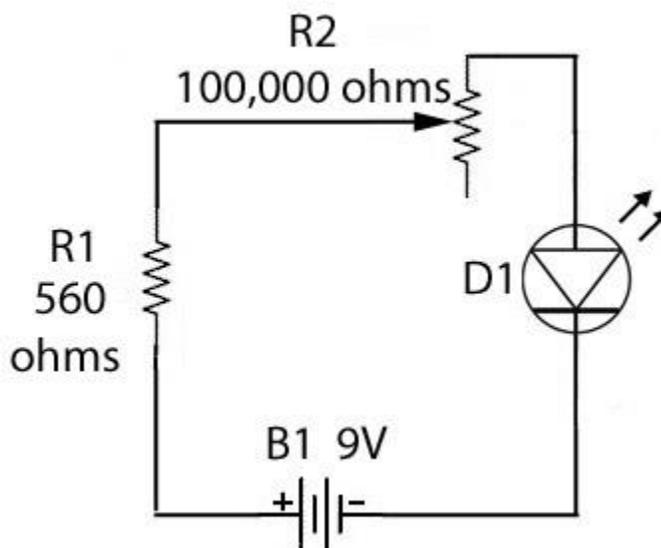


Figure 4. Variable brightness circuit

What is the purpose of R1? Can't we just get rid of R1 and only use R2? Well, that would be a good way to destroy the LED (D1). If you adjusted the pot to 0 ohms resistance, then the full power of the battery would be applied to the LED. By adding R1 to the circuit, the minimum resistance of the combined resistor and pot will be 560 ohms, even when R2 is adjusted to 0 ohms. Resistor R1 prevents damage to the LED.

Now you will see an advantage of using a pot. If you have not connected the battery to the breadboard, go ahead and do that now. Set the power switch to on. The power circuit LED should be glowing. The LED in the variable brightness circuit should also be glowing. Insert a small screwdriver into the pot and rotate it clockwise and counterclockwise. The LED will change brightness dramatically. You can set the brightness of the LED to the

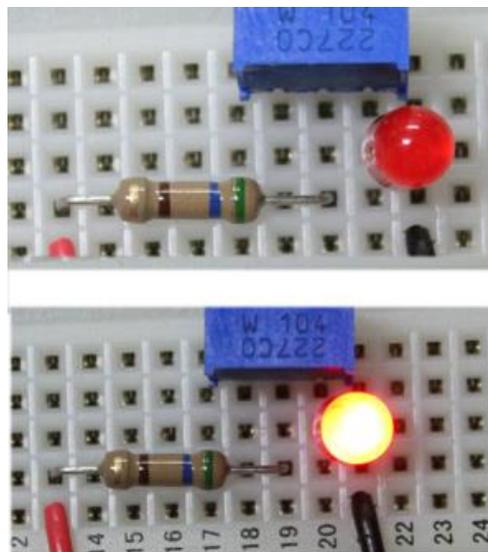


Figure 5. Variable brightness circuit - top is highest resistance of pot, bottom is lowest resistance of pot

level you want by adjusting the pot. To do this with fixed resistors you might need to test many resistors before finding one that provides the brightness you want. The pot is a better solution when you want to adjust the brightness. After finding the brightness you like, you could measure the resistance of the pot and substitute a fixed resistor. Or you could just keep the pot in the circuit (they are inexpensive).

You will now build the circuit shown in Figure 6.

1. Insert R3, a 20,000 ohm pot, into the breadboard as shown in Figure 6 (the middle pin of the pot is inserted into row 21 in the photo).
2. Insert R2, a 560 ohm fixed resistor, with one wire in the same row as the middle pin of R3 and the other end of R2 into an unused row (row 15 in photo).
3. Connect a red wire from the positive power bus to the row with R2, as shown in Figure 6.
4. Connect green wires to the left and right pins of R3 as shown in Figure 6.
5. You will need to measure voltage drops in this circuit at the left and right pins of R3. But your meter probes can't reach the pins when the pot is inserted into the breadboard. You will add two bent copper wires to the rows that have the green wires coming from R3. These are test points TP1 and TP2. You will touch the meter probe to test points one and two.
6. The circuit has four photoresistors, R4, R5, R6 and R7. Insert R4 with one wire in the same row as test point one and the other wire in a free row. Insert one wire of R5 into the same row as the right wire of R4 and the other wire in a free row. Use a short black wire to connect the row containing the right wire of R5 to the negative power bus.
7. Insert one wire of R6 into the same row as test point two and the other wire into a free row. Insert one wire of R7 into the same row as the left wire of R6 and the other wire in a free row. Use a short black wire to connect the row containing the left wire of R7 to the negative power bus.

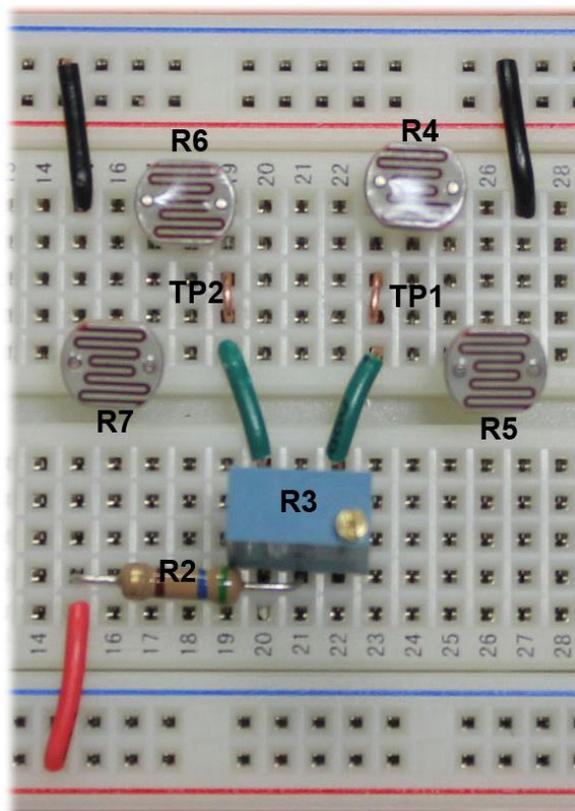


Figure 6. The photoresistor circuit.

Figure 7 shows the paths of current flow in the circuit marked by light blue arrows. The current flows through the fixed resistor to the potentiometer, where it is divided into two paths. In each path the current flows through one photoresistor and then another photoresistor. The two photoresistors of each path are connected in series. Remember that when resistors are in series, their resistances are added together to get the total resistance. After the current flows through both photoresistors of a group, it returns to the negative terminal of the battery by way of the negative power bus.

It is likely that the two groups of photoresistors (the left and right groups) will not have exactly the same resistance when the same amount of light shines on both groups. By adding the potentiometer to the circuit, it is possible to adjust the amount of resistance in both paths so that both groups of photoresistors have the same amount of resistance when combined with the potentiometer. The potentiometer acts to balance the two groups of photoresistors. When the complete robot is assembled, the pot is used to balance the photoresistors so that the robot follows a line properly.

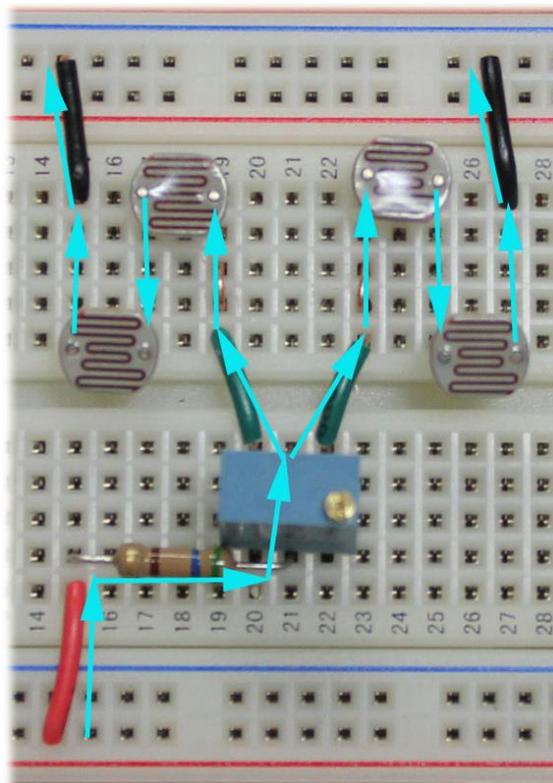


Figure 7. Current flow in the photoresistor circuit.

The potentiometer used in this circuit is not the same type that was used in the other exercise. Notice in Figure 7 that the potentiometer has a screw on the top edge. Unlike the other potentiometer, the one in Figure 7 is a multi-turn type. You can turn the screw many turns while the previous one could be turned just one turn. The multi-turn potentiometer allows a finer adjustment of its variable resistance, which is needed for the photoresistor circuit.

Figure 8 is the schematic for the photoresistor circuit. Notice the symbol for a photoresistor (the arrow through the zig-zag line indicates a variable resistor, the two arrows pointing to the circle represent light shining on the photoresistor).

Remember that the power circuit contains the resistor R1. Therefore, this circuit begins with resistor R2, the fixed resistor of 560 ohms. R3 is the multi-turn potentiometer of maximum

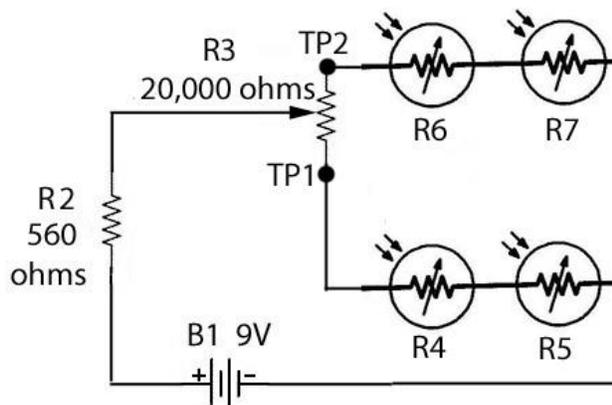


Figure 8. Photoresistor circuit.

20,000 ohms resistance. R4, R5, R6 and R7 are the photoresistors. TP1 and TP2 are the test points.

You will now measure the voltage drop of the circuit at test point one (TP1) and test point two (TP2).

1. Turn the power on. The red LED in the power circuit should be glowing.
2. Set your meter to measure DC volts (VDC or 20 volts DC)
3. Touch the red meter probe to test point 1 and the black meter probe to the black wire of the battery. Make sure you don't cast a shadow on the photoresistors while making the measurements.
4. Record the voltage drop _____ volts at TP1
5. Touch the red meter probe to test point 2 and the black meter probe to the black wire of the battery.
6. Record the voltage drop _____ volts at TP2
7. Now cover R4 and R5 with a dark strip of construction paper. This will increase the resistance of these two photoresistors.
8. Repeat the voltage measurement for TP1. _____ volts TP1

Compare the voltage measurements of TP1 and TP2 (steps 4 and 6). It is likely that the voltages will be different. The voltages of the test points can be adjusted to be the same by adjusting R3. I will not ask you to adjust the R3 potentiometer in this exercise. In the next lesson you will add two LEDs to the voltage comparator circuit. When the voltage comparator receives higher voltage from one test point than the other, then one of the LEDs lights up. When the other test point is higher, then the other LED lights up. It is then easy to balance the photoresistors by adjusting R3 while watching the LEDs.

Compare the voltage drops at TP1 in steps 4 and 8. The voltage drop should be more in step 8, when R4 and R5 were covered with paper. As less light shines on the photoresistors, the resistance increases. As the resistance increases, the voltage drop also increases.

In the next lesson you will connect wires to both test points and connect the other ends of the wires to different pins of the voltage comparator. The voltage comparator will compare the voltages from the test points to determine where the line is underneath the robot. The voltage comparator also controls the two motors of the robot to keep the line centered underneath the robot.

You have now completed the lesson on variable resistors. The next lesson will cover the voltage comparator circuit.