Resistors, Diodes, Transistors, and the Semiconductor

Value of a Resistor

Most resistors look like the following:

A Four-Band Resistor

As you can see, there are four color-coded bands on the resistor. The value of the resistor is encoded into them. We will follow the procedure below to decode this value.

- When determining the value of a resistor, orient it so the gold or silver band is on the right, as shown above.
- You can now decode what resistance value the above resistor has by using the table on the following page.
- We start on the left with the first band, which is BLUE in this case. So the first digit of the resistor value is 6 as indicated in the table.
- Then we move to the next band to the right, which is GREEN in this case. So the second digit of the resistor value is 5 as indicated in the table.
- The next band to the right, the third one, is RED. This is the multiplier of the resistor value, which is 100 as indicated in the table.
- Finally, the last band on the right is the GOLD band. This is the tolerance of the resistor value, which is 5%. The fourth band always indicates the tolerance of the resistor.
- We now put the first digit and the second digit next to each other to create a value. In this case, it's 65. 6 next to 5 is 65.
- Then we multiply that by the multiplier, which is 100. 65 x 100 = 6,500.
- And the last band tells us that there is a 5% tolerance on the total of 6500. Therefore, we have a resistor value of 6,500 ohms plus or minus 5% (i.e., plus or minus 325 ohms).

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Value of a Resistor

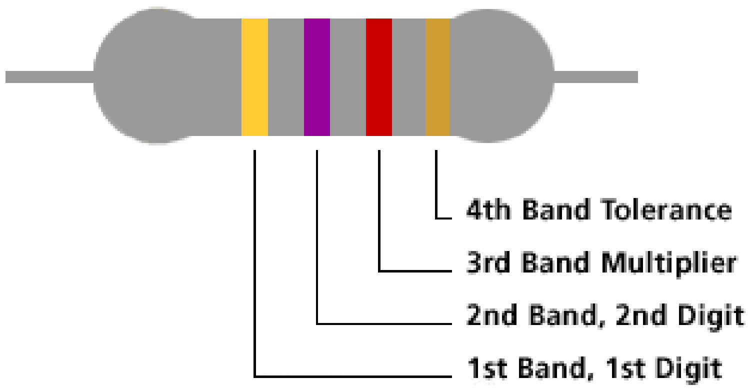
Band Code Reference Table

Band Color	First Band	Second Band	Third Band (Multiplier)	Fourth Band (Tolerance)
Black	0	0	1	N/A
Brown	1	1	10	1%
Red	2	2	100	2%
Orange	3	3	1000	N/A
Yellow	4	4	10000	N/A
Green	5	5	100000	N/A
Blue	6	6	1000000	N/A
Violet	7	7	10000000	N/A
Gray	8	8	100000000	N/A
White	9	9	1000000000	N/A
Gold	N/A	N/A	0.1	5%
Silver	N/A	N/A	0.01	10%

Value of a Resistor

Example

Here is another example of color bands on a resistor. The color bands are hiding the value of the resistor. Can you figure out the value of the resistor?



Measure the value of the resistor using an ohmmeter or a multimeter. To measure the value on an ohmmeter, turn on the ohmmeter, touch the two sides of the resistor with the two probes attached to the ohmmeter, and read the value on the scale. To measure the value on a multimeter, turn on the multimeter, set the multimeter to measure ohms, touch the two sides of the resistor with the two probes attached to the multimeter, and read the value on the scale. The value you calculated by decoding the bands on the resistor should be close to the value displayed on the ohmmeter or the multimeter.

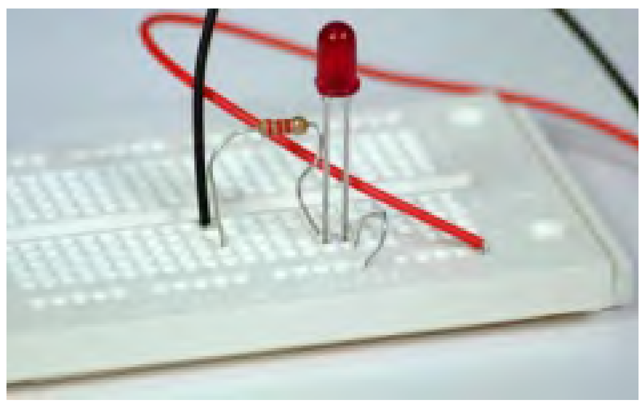
Diodes

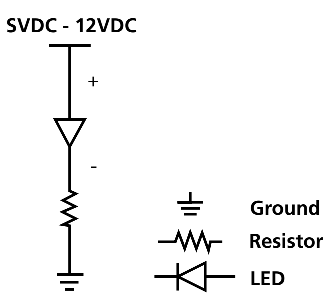
Procedures

The following two experiments demonstrate that the diode conducts only in one direction. Engineers use this property to design complex circuits in which diodes control the flow of electrons.

Forward-biased diode

- Connect one terminal of the resistor to the negative terminal of the battery.
- Connect the other terminal of the resistor to the negative terminal of the diode (the shorter leg of the diode).
- Connect the positive terminal of the diode (the longer leg of the diode) to the positive terminal of the battery.
- The LED should light up if the connections were made correctly. This circuit is shown in the schematic diagram and in the picture of the breadboard below.





Procedures *(cont.)*

Backward-biased diode

- Connect one terminal of the resistor to the negative terminal of the battery.
- Connect the other terminal of the resistor to the positive terminal of the diode (the longer leg of the diode).
- Connect the negative terminal of the diode (the shorter leg of the diode) to the positive terminal of the battery.
- The LED should NOT light up if the connections were made correctly, because we changed the direction of the diode.

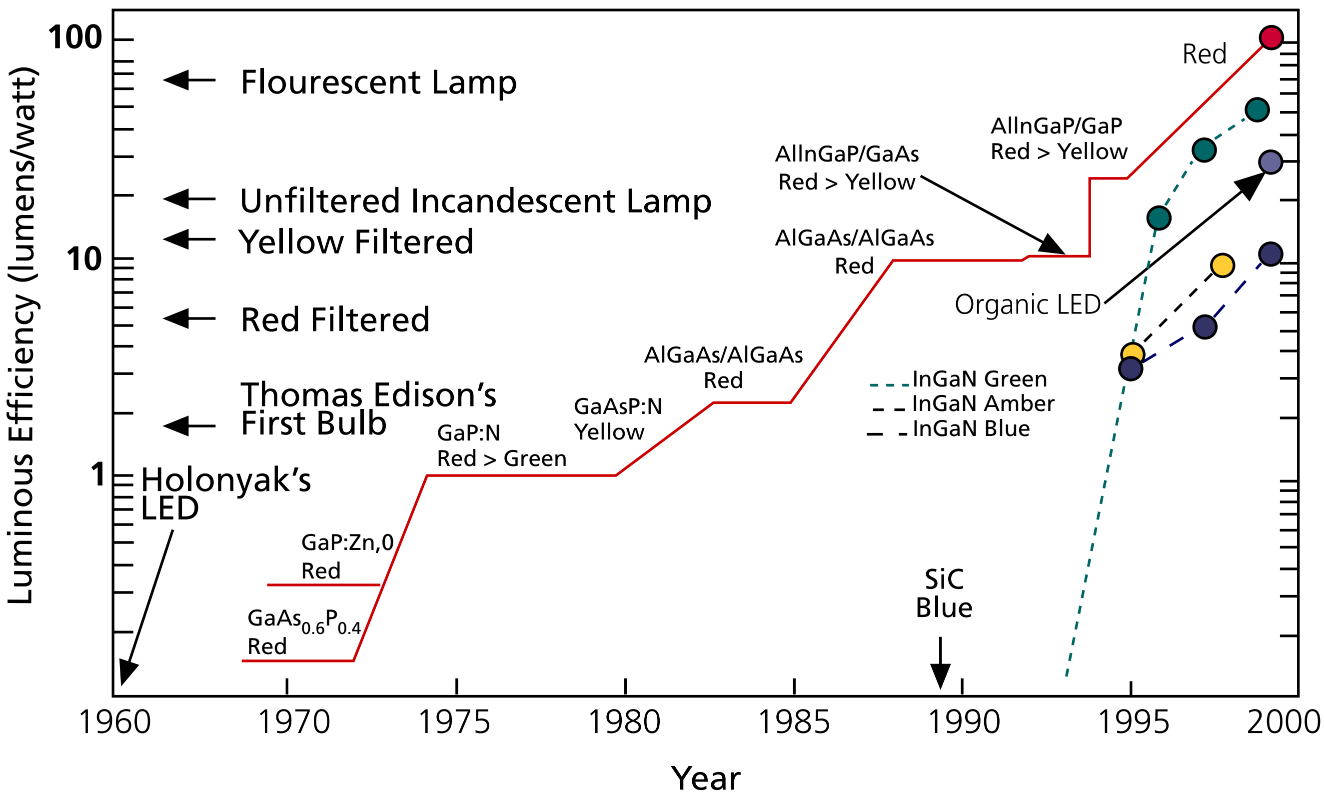
Changing the Brightness of the Diode

In this experiment, we will see how a change in the flow of electrons affects the brightness of the LED. A change in the value of the resistor in our circuit will change the amount of current or electrons flowing through the LED.

- Change the resistor in the forward-biased diode circuit with a resistor of higher value.
- Does this increase the amount of current or decrease the amount of current?
  Hint: R=V/I, so I=V/R. Remember, we are not changing the battery, which means V stays the same. So when we increase R, I should decrease. A decrease in I should make the LED dimmer.
- Now replace the resistor with one with a value smaller than the original. The current should increase due to the lower resistance making the LED brighter.

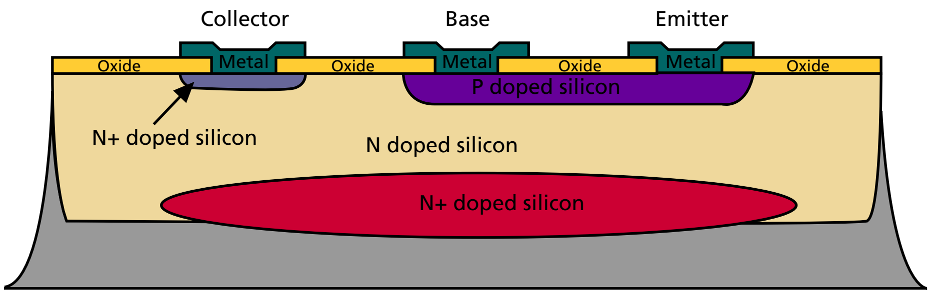
LED Development Timeline

Many kinds of light emitting diodes (LEDs) have been developed over the years. LEDs are junctions of appropriate materials that produce a color of light specific to those materials when contacted by the flow of electrons. The following timeline shows when the materials were discovered and the color of light they emit. Use a periodic table to find the names of the materials listed on the chart.

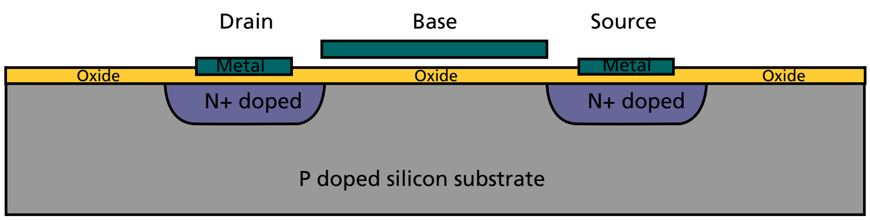


Transistors and the Semiconductor

NPN BJT Transistor



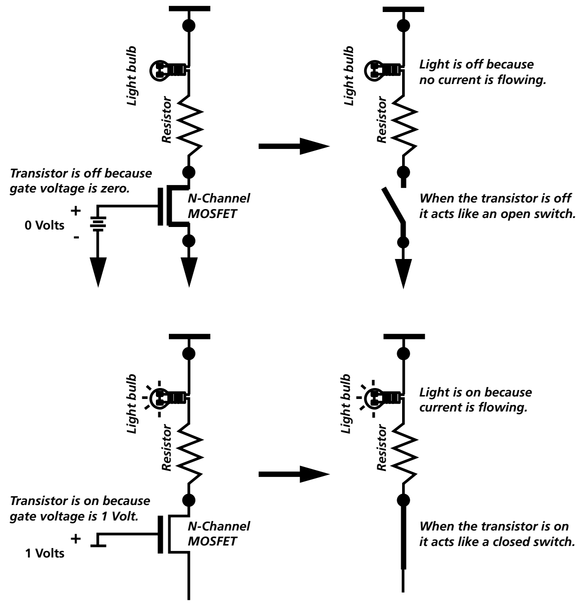
N-Channel MOSFET



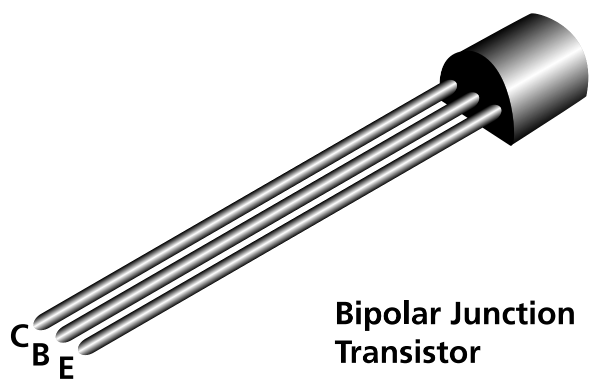
There are two main semiconductor processes used to make transistors. The first and oldest process is called the "Bipolar" process. It's used to make Bipolar Junction Transistors (BJT) commonly known as NPNs and PNPs. NPN and PNP refer to the layering of "N" (negative) doped silicon or "P" (positive) doped silicon. "N" doped silicon is silicon that is doped with a substance containing a donor electron such as arsenic or phosphorus. "P" doped silicon is silicon that is doped with a substance containing an acceptor hole such as boron.

The second semiconductor process used to make transistors is known as Complimentary Metal Oxide Semiconductor or CMOS. The CMOS process is much simpler and thus is more commonly used. There are two types of CMOS transistors, the N-Channel and the P-Channel. The N-Channel transistor is similar to the NPN BJT in its layering of "N" doped silicon and "P" doped silicon. The P-Channel transistor is similar to the PNP BJT in its layering of "P" doped silicon and "N" doped silicon.

Transistor as a Switch



Identify the Terminals of a Transistor



A typical Bipolar Junction Transistor (BJT) has three terminals attached to a plastic body. The body has a flat side. The terminals can be recognized by their position on the body. With the terminals pointing towards you and the flat side pointing away from you, the right terminal is the emitter (labeled E in the diagram), the middle terminal is always the base (labeled B in the diagram), and the left terminal is the collector (labeled C in the diagram).

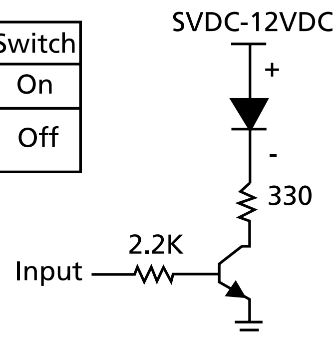
Resistors, Diodes, Transistors, and the Semiconductor

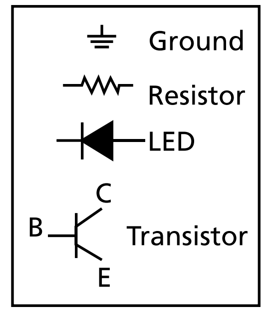
Transistors and the Semiconductor

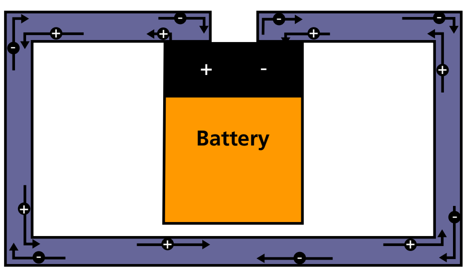
Procedure

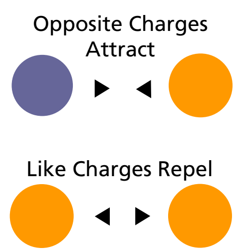
Connect two resistors, one transistor, one battery, and a diode as shown in the schematic below.

Input	Switch
5V	On
0V	Off

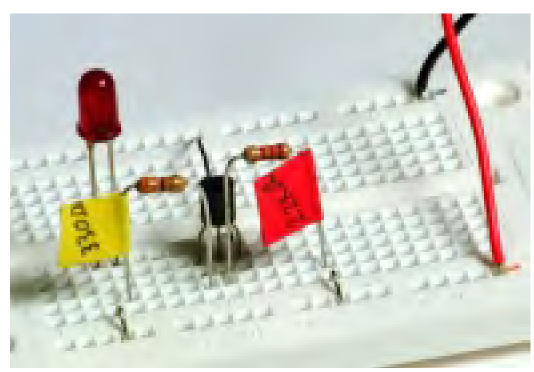






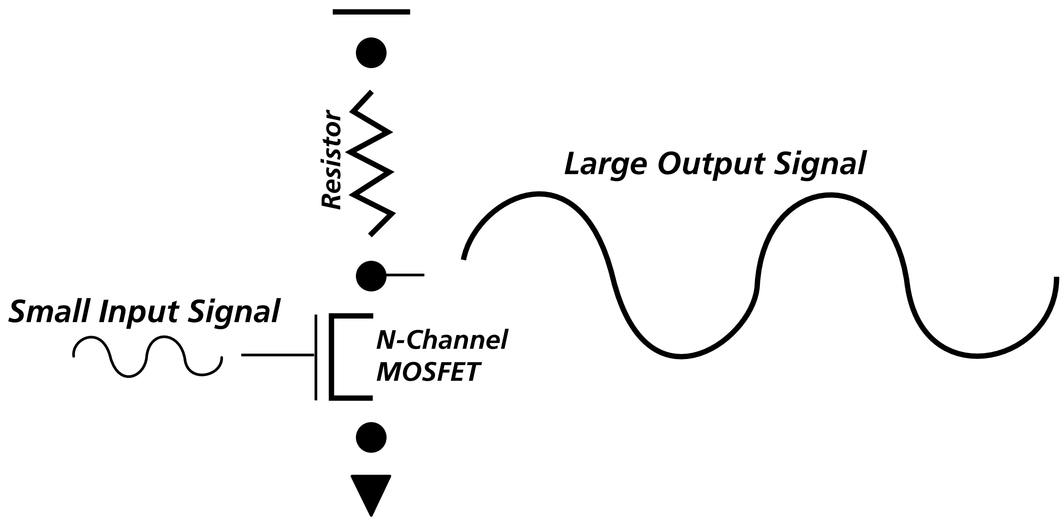


Your connections should look like the photo on the left.



Transistors and the Semiconductor

Transistor as an amplifier



Resistors, Diodes, Transistors, and the Semiconductor
Glossary

Alternating current - Electricity fluctuating between specific high and low voltage limits at a specific rate.

Ampere - Rate of flow of electrons through a circuit.

Battery - Source of electrons/electricity.

Conductor - Any material that allows the flow of electrons. Some examples of conductors are metals and water.

Coulomb - A measure of electrical charge. The number of electrons flowing past a particular point in one second.

Current - The flow of electrons between two points in response to a voltage difference between those two points. It is measured in amps.

Diode - A specialized electronic component that has a conductor in one direction and an insulator in the other. The longer leg should be the positive terminal.

Direct current - Current that stays at a specified positive or negative voltage level.

Electricity - The physical phenomenon rising from the behavior of electrons and protons that is caused by the attraction of particles with opposite charges and the repulsion of particles with the same charge.

Insulator - Any material that does not allow the flow of electrons. Some examples are rubber, wood, and air. However, some insulators WILL conduct electricity if there is a high enough voltage. Air, for example, will begin to conduct at approximately 1 million volts per inch (static shock!).

LED (Light Emitting Diode) - Emits light in the conducting direction. More current equals more light used.

Multimeter - Device used to measure electrical parameters, such as resistance, voltage, etc.

Ohmmeter - Device used to measure resistance.

Open circuit - Any circuit that has an insulator preventing the flow of electrons.

Potential - Electrical pressure (difference) between two points.

Rectifier - Converts electricity from alternating current to direct current.

Resistance - Any material that restricts the flow of electrons. Electrons can still flow, but they do not flow freely. Measured in ohms.

Resistors, Diodes, Transistors, and the Semiconductor
Glossary

Resistor - Component in an electric circuit regulating the flow of electrons.

Semiconductor - A material that is neither a good conductor nor a good insulator.

Short circuit - A connection between two points without any resistance.

Tolerance - Expected variation from the target value.

Transistor - A small electronic device containing a semiconductor and having at least three electrical contacts. A transistor is used in a circuit as an amplifier, a detector, or a switch.

Volt - Unit of measure of the pressure of electrons (electrical potential difference) between two points.

Voltage - Electrical pressure (difference) between two points.