

WATER SENSOR Experiment UCSD NanoLab

**Professor Michael J. Sailor
University of California, San Diego
La Jolla, CA 92093-0358**

Parts List*

9 V Battery
Battery clip
100 k Ω resistor (2)
330 Ω resistor (1)
npn transistor (2)
red LED
30 pF capacitor (water vapor sensor-see text)
100 k Ω variable resistor
plug-in board
Auto range digital multimeter
Assorted wires

*Parts can be obtained from commercial vendor such as Radio Shack

Equipment

The Multi-Meter

Electricity terms: Current, Voltage, and Resistance.

Fundamental concepts of electricity are current, voltage, and resistance. If electricity were water, current would be the amount of water flowing. For instance, your garden hose can deliver perhaps 3 gallons of water per minute when the spigot is wide open, and only a few drops per hour when it is almost closed. A multimeter set to measure current can measure these flow rates. The units on current are *amperes* (amps for short). Sometimes it is more convenient to operate in terms of thousandths of amps, or milliamps (abbreviated mA). Voltage is like water pressure: the higher the voltage the greater the pressure. The units on voltage are *volts* (V for short). It is also more convenient to operate in terms of thousandths of volts, or millivolts (abbreviated mV on your multimeter). The last concept is resistance. Resistance is like the spigot on your faucet. You can place a resistor in line with a circuit and it will limit amount of electricity, or current, that can flow. You will see in the LED experiment below how a resistor is used to keep too much current from flowing through the light, which protects it from burning out. The units on resistance are *Ohms* (Ω for short). There are many different values of resistance, but the common ones are Ohms, kiloOhms (k Ω), and megaOhms (M Ω). The *kilo* stands for a thousand and the *mega* stands for a million. So 1.5 kiloOhms is 1500 Ohms. Your multimeter has an autoranging feature, so it will automatically tell you whether it is reading in Ohms, kiloOhms, or megaOhms in the bottom right hand corner of the display.

Measuring Resistance with the Multimeter.



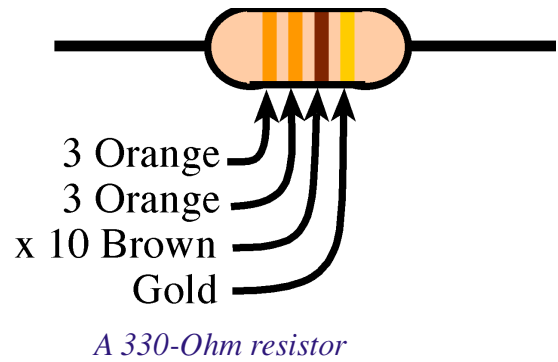
Measuring skin resistance with the multimeter

Test the resistance of your skin with the multimeter set to “k Ω ” (this stands for the resistance measurement setting). Now hold the the metal tip of the black probe between the thumb and forefinger of one hand and the metal tip of the red probe in the other. Your skin resistance should read around 0.5 M Ω . Again, the “M” stands for “mega”, which is one million. Your skin resistance is therefore 500,000 ohms. If your skin is dry it will register higher; if it is moist you will get a lower reading. This is the principle on which police “lie detector” tests operate. The lie detector assumes that if you are lying you will sweat, causing the reading to change to a smaller value. Now test the resistance of the resistors supplied in your kit. Theresistors have a color code painted on them in a series of stripes so that you can easily identify their values without

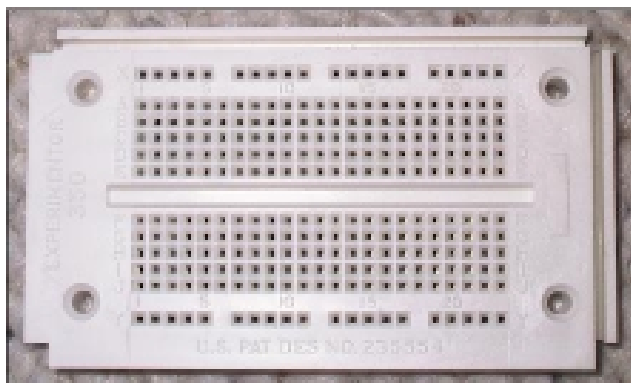
having to measure them. The first color band is the tens place, the second color band is the ones, and the third band is called the multiplier. The fourth color band is called the tolerance (it’s like the quality of the device), which you can ignore. So the resistor pictured on the next page is orange-orange-brown and should be 3-3 times 10, or 330 Ohms. When you measure this resistor with your multimeter set to “k Ω ,” it should read pretty close to 330 Ohms. The other two resistors in your kit have resistance

values much larger than the resistor you just measured. The color code Brown is 1, Black is 0, and yellow is 10,000. What resistance value should it have? Does it match your measurement?

Test the resistance of several items around the house: metal items such as aluminum foil, coins, etc. (NOTE: DO NOT INSERT THE PROBES OF YOUR MULTIMETER INTO A WALL OUTLET; SPARKS CAN FLY AND YOU STAND A GOOD CHANCE OF ELECTROCUTING YOURSELF). Place the probe tips in a cup of water. You will notice that the reading will be several k Ω depending on the purity of the water; more salt content makes the water more conductive (less resistive), so the resistance readings will be smaller in salty water. You will also notice that the measurement will not be stable in water. This is because the probe tips corrode in water, so don't leave it in for too long or you will ruin the probes.



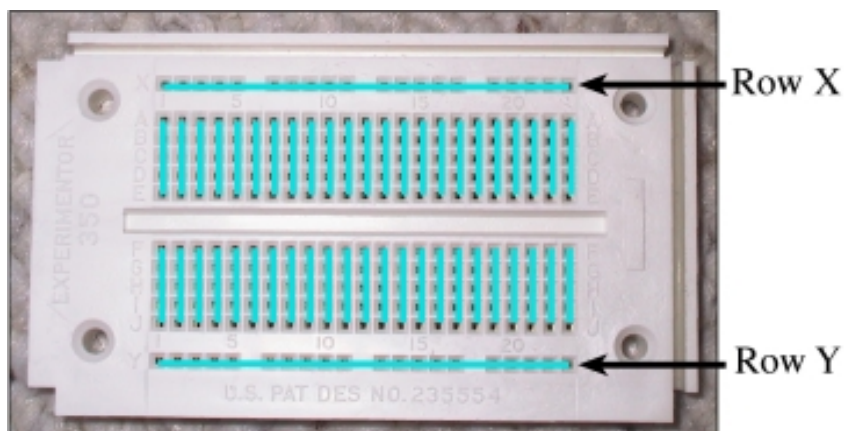
The plug-in board



The plug-in board

The plug-in board allows you to connect all the components together. It is wired as follows: All holes in row X are connected together and all holes in row Y are connected together. Each individual column of five holes are connected together. The blue lines in the picture below indicate the connections:

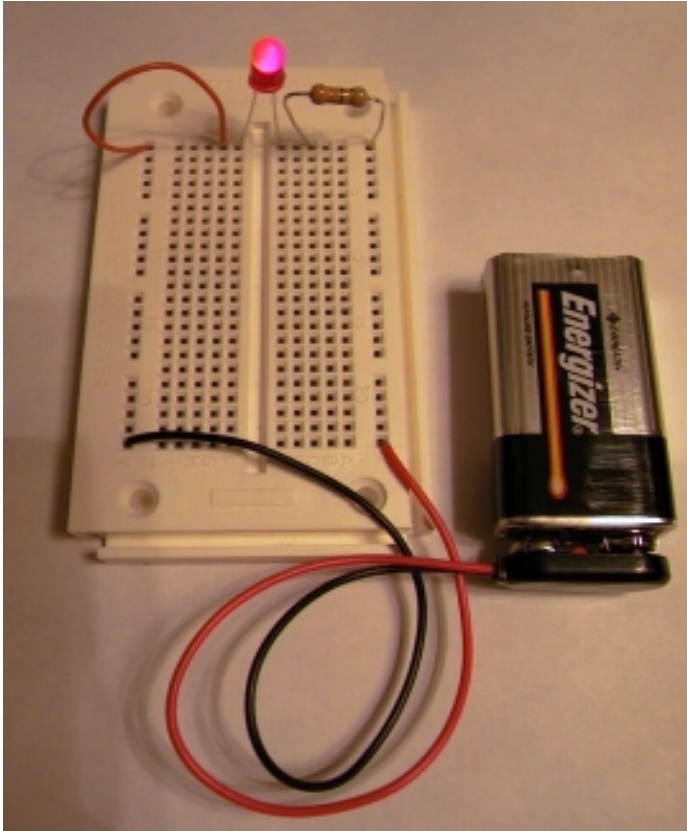
Rows X and Y will be used to supply power from the battery. Each column consists of 5 holes, which are all connected to each other. If you plug something into column #1-D, you can connect it to something else by putting a wire into column #1-A, 1-B, 1-C, or 1-E.



Pattern of connections in the plug-in board

Experiments

Experiment #1 Wiring up a Light-Emitting Diode (LED)



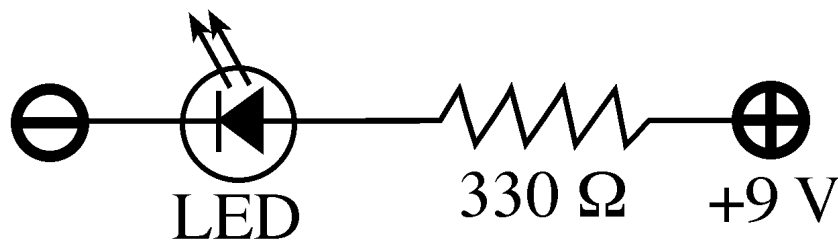
In this experiment you will test how the plug-in board works by lighting up the red lamp provided. It is referred to as a "light-emitting-diode" or LED.

- 1) Plug in 9V battery, red wire into row X and black wire into row Y
- 2) Plug in 330Ω resistor to pinholes 1-X and 1-C.
- 3) Plug in the LED to holes 1-E and 1-F (longer of the 2 wires should be in 1-F)
- 4) Plug in jumper wire from 1-G to 1-Y

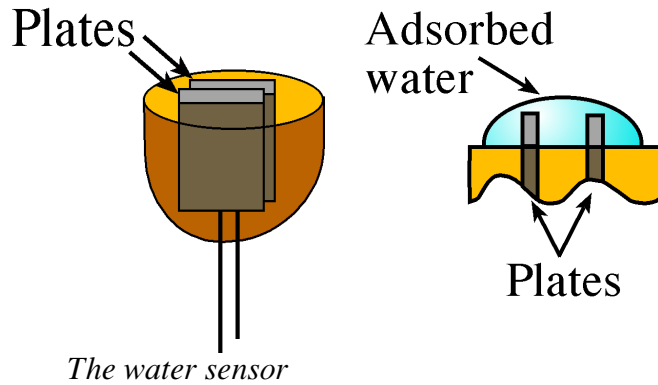
Does the red light come on? If not, you plugged in the LED backwards. The long wire from the LED should be in hole 1-F, not 1-E, which is because a Diode only lets electricity flow in one direction. We say it has a "polarity" because you have to pay attention to which side goes to (+) and which to (-) on the battery.

In this last experiment, the resistor was needed to resist the flow of electricity. If you don't use it, too much electricity flows through the LED, causing it to burn out. The

resistor is called a "current limiter" because it limits the flow of current, or electricity, in the circuit. The diagram for the circuit you just built is as follows:

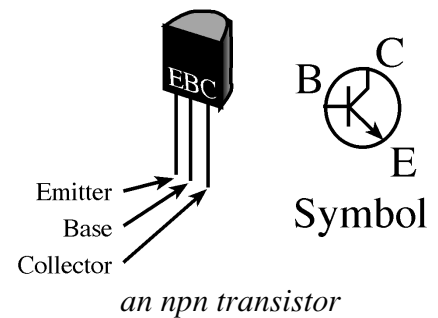


Experiment #2 A Water Vapor Sensor



The water sensor. In this project you use a transistor to amplify the signal from the humidity (water) sensor. The humidity sensor works by electrical conductivity; when water vapor condenses on the plates it forms a thin film that conducts electricity between the two plates. In that sense the water sensor is like a resistor except that its resistance value changes depending on the amount of water in the air. It was made by clipping the top off of a 30 pF capacitor using a pair of wire clippers.

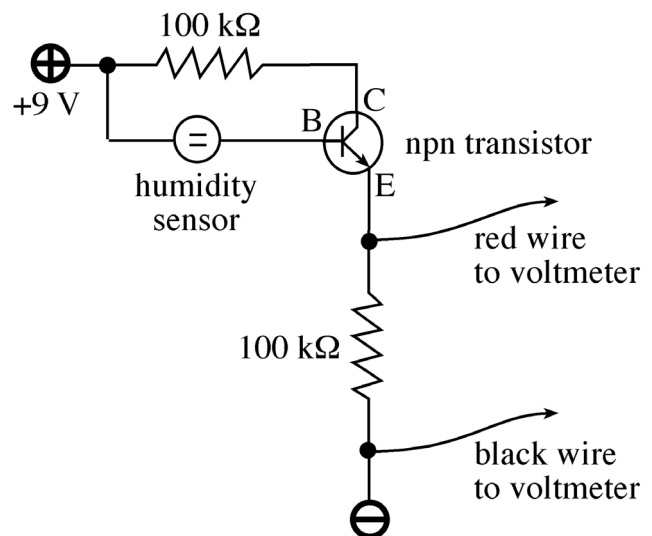
Transistor. A transistor is an amplifier that will convert the very small change in resistance from the humidity sensor into a larger resistance change that you will measure with your voltmeter. It has three connections; the collector, the base (also called the gate), and the emitter. The collector and the emitter are like the connections to a pipe that carries water, and the base is like the faucet. Ordinarily the base is closed and the resistance between the collector and the emitter is very large. When a small voltage is applied to the base, it reduces the resistance between the collector and the emitter, allowing current to flow. Your kit contains a transistor which is marked with the letters E, B, and C, which stand for emitter, base, and collector, respectively.

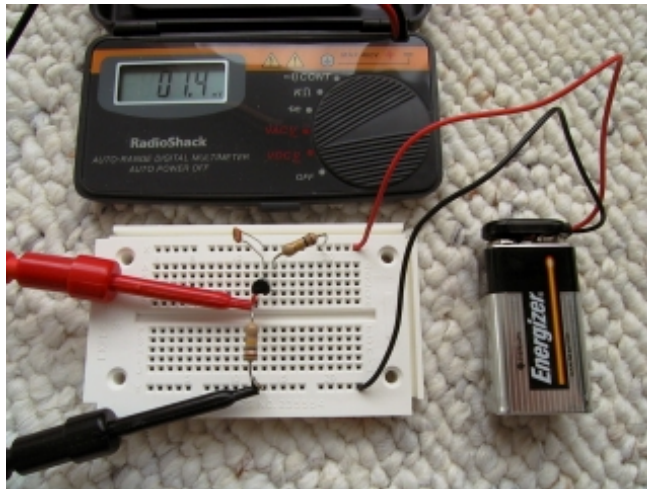


Wiring up the water sensor

The circuit diagram is shown at right and a photograph of the complete circuit is shown below.

Test the circuit. With the multimeter on the “VDC” (Volts-Direct Current) setting, touch the sensor with your fingertip. The voltage reading should change. Blow on the sensor. A change in the voltage reading indicates a change in the humidity of the air around the sensor. This circuit is sensitive enough to detect the water vapor on your breath, and can even detect the water evaporating from your skin. If you place your finger close to the sensor without touching it you should notice a small change in the voltage reading.

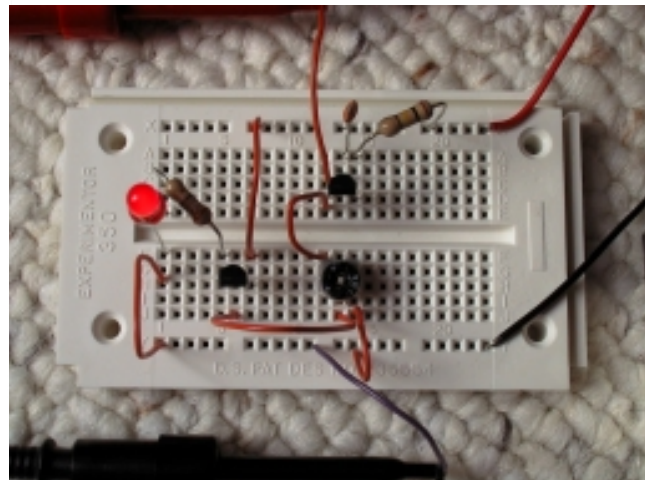
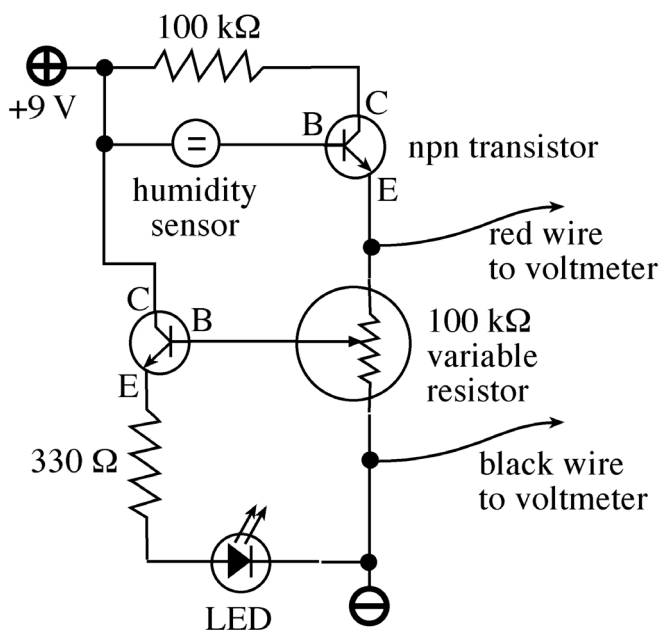




The water sensor circuit

Adding an over limit alarm to the water sensor

In this part of the experiment, you will add a red LED to the circuit as an over-limit alarm. The LED will light up when the sensor detects a high amount of water vapor. The circuit diagram is shown below, along with a photograph of the circuit. You will add a second transistor to the circuit which will drive the LED. The voltage signal output from the first transistor is sent to the gate of the second transistor. The circuit also incorporates a 100 kΩ variable resistor in place of one of the 100 kΩ resistors. The variable resistor allows you to set the threshold level for the over-limit alarm. The red light should come on when you touch the sensor with your finger or get it wet with a drop of water. You will be able to adjust the threshold level where the red light comes on by adjusting the dial on the variable resistor using a small screwdriver.



The water sensor circuit with over-limit indicator (red LED)