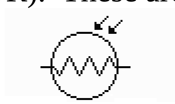
Written by Avery Louie:

TSK x REVO

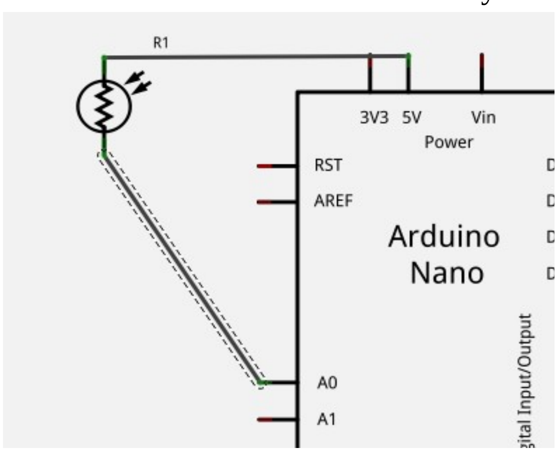
1.0:
Welcome back. This week we will be dealing with some of the most basic sensors that exist. Sensors are key parts of any system, be it a phone or an airplane, because it lets whatever you build respond to the environment or user input. They are used in everything from thermometers to flashlights to cars.

1.1:
The first sensor we will talk about is the resistive sensor, particularly the Cadmium Sulfide photoresistor, or light dependent resistor (LDR). These are denoted by the symbol:



It is pretty easy to remember, because it is a resistor, with light going into it. Sometimes it is drawn without the circle.

These particular resistors change resistance depending on how much light they are receiving; higher light means less resistance, lower light means more resistance. This is because light excites electrons in the valence band of the semiconductor and allows them to conduct. However, we would not just want to hook them up to power and a pin to measure the voltage; that would be silly, at least without using a special feature of the microcontroller. Lets see why:



We see here that some fool has hooked the photoresistor up to 5V and an input pin. We know that:

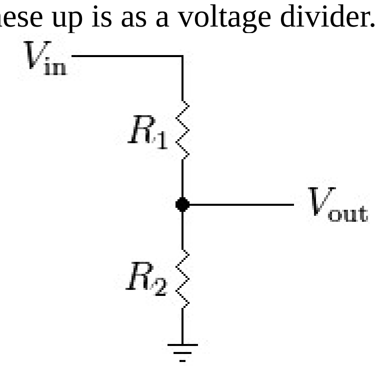
$$v=IR$$

so

$$I=V/R$$

So by changing R all we can do is change I! Current is not something a microcontroller can easily measure as raw input!

The way that makes sense to hook these up is as a voltage divider. Here is a diagram:



Analysis time! We know that:

$$Vin=(R1+R2)I$$

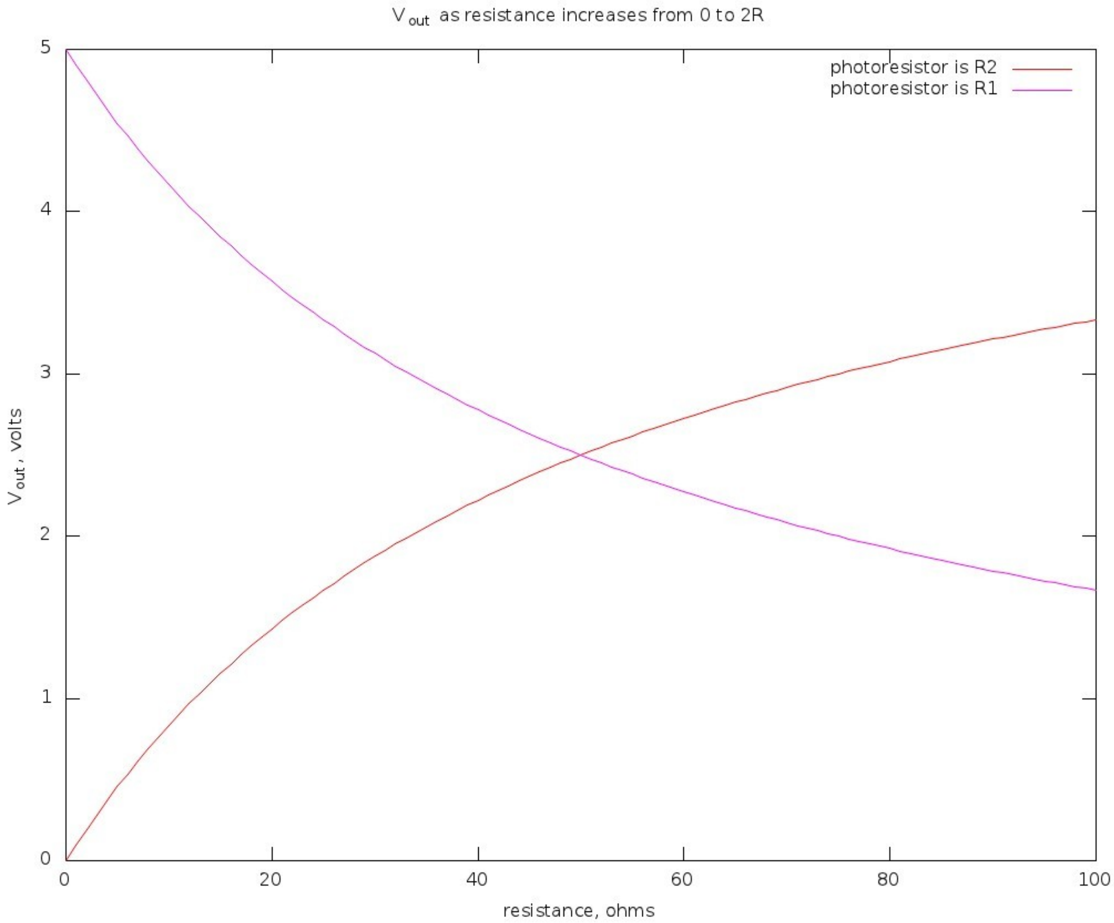
$$Vout=IR2$$

Since *I* is the same in both cases, we can say:

$$Vin/(R1+R2)=(Vout)/R1$$

$$Vout=(Vin*R1)/(R1+R2)$$

The key here is that *Vout* is dependent on R1 and R2. Below is an interesting graph that shows that this is not really linear, in either case where R1 or R2 are the photoresistor, so long as the photoresistor is nearly the same resistance as the other resistor. Bummer.



However, if we do something like make the other resistor much larger (1-2 orders of magnitude) we can make it much more linear. This is because as the other resistor gets bigger, the change that the photoresistor creates is much smaller. Of course, this means that the range that you can read in is smaller:

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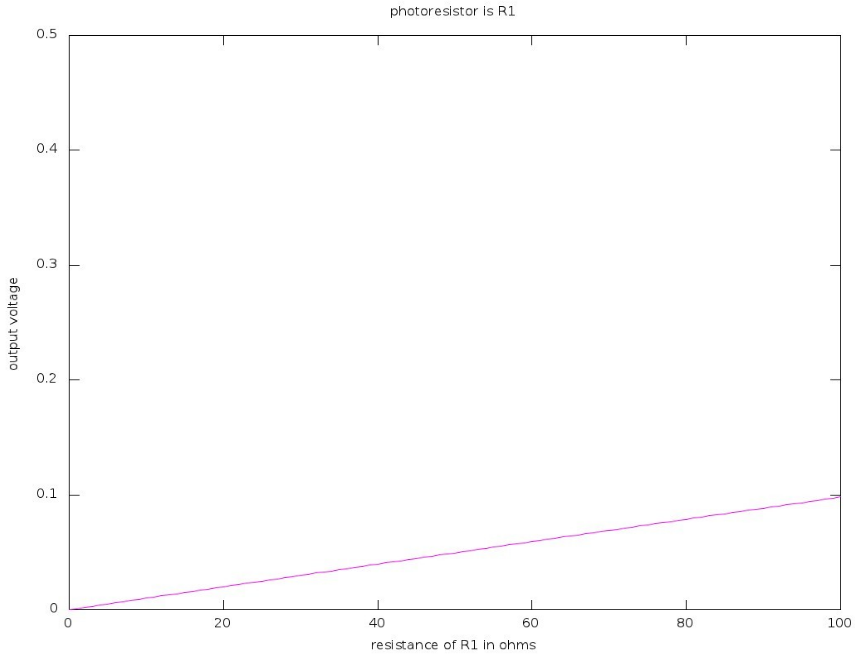

As you can see here, the difference in voltage is .1 v, but it is very linear. This is the case where R2=5000 ohms. You can imagine this can be frustrating, because on one hand you want a linear system, but on the other, you want a wide delta V.

1.2:
Now is a good time to look at the ADC in more detail. The way this ADC works is by comparing two voltages internally. It starts (probably) at the middle, and then adjusts if the guess is too low or too high Eventually it is close enough to your input voltage and it stops guessing. Based on when the two are equal, it knows what voltage you are at. The test voltages are produced by an internal DAC (digital to analog converter). This repeated testing takes time, and has limited resolution. The ATMega328p has several (8) 10 bit ADCs. This means that there are 1024 steps of .0048 volts between 0 and 5. This is pretty sensitive, but it is not super accurate, as the signals tend to be noisy. As you can see, there are about 20 “ticks” in between 0 and .1 in the graph above. However this may or may not be useful, because the noise may be in in the range of 10-20 ticks.

1.5:
Now a long time ago someone realized it would be a huge pain in the butt to have to build tons of resistive networks for sensors on the breadboard. Also, they realized that inputs (like switches) are really noisy, so they invented the internal pull-up resistor. The value of the pull up actually changes with Vcc, but it should be around 1K5 ohms. This resistor connects to an internal 5V supply, which connects to the input pin. Then you put your sensor or switch from the input pin to ground. This makes breadboarding a lot neater, and is really convenient for things like playing with sensors.

1.4:
Another kind of very sensitive sensor is a diode that varies how much current can flow through it based on temperature or light. We will be dealing with photodiodes in the form of LEDs. Diodes are tricky devices, and we won't get into them too much. However, we can use some simple facts to figure out

why LEDs might behave as photodiodes. The first is that diodes (generally) conduct current in only one direction. They can conduct current the other way as well, but only at very high “breakdown” voltages. We wont be subjecting any diodes to that any time soon. The second fact is that when current flows through an LED in the forward direction, light is produced. This happens when a hole (a lack of an electron) and an electron “meet”. The electron “falls” into the hole, releasing energy in the form of light. The wavelength of this light is dependent on the the energy gap (band gap) between the electron and the hole.

When this is done backwards, certain wavelengths of light stimulate current to flow in the diode. This creates a buildup of voltage across the leads. LEDs make very interesting sensors because they respond differently to different light colors, come with a variety of different lens shapes, and because they are amazingly cheap.

1.5:
The last class of sensors we will talk about are digital sensors. These are “smart” in that they have on-board logic, and sometimes calibration. You can plug them into microcontrollers and they will talk over one of many protocols