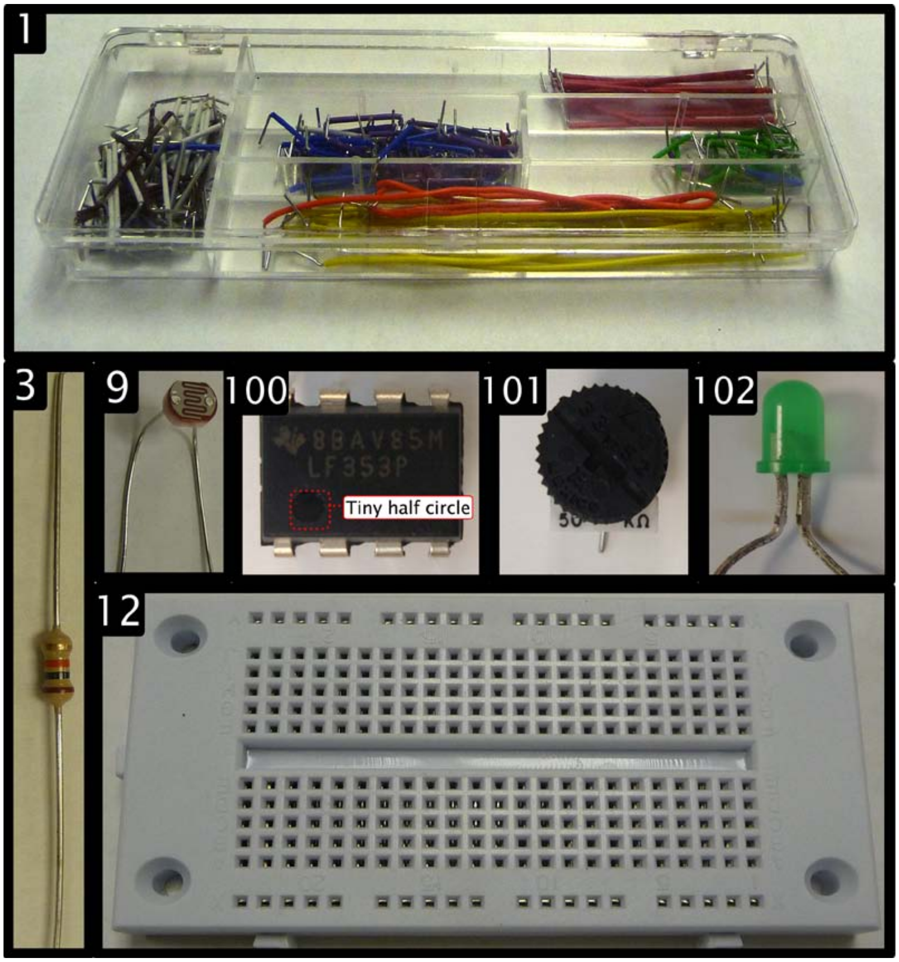
Part α: Building a simple 'Sensor Comparator':

Step 1: Locate the following circuit parts from your bag.

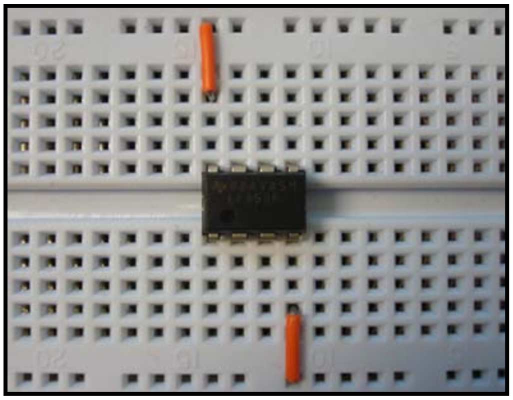


Fiendish objects

Part Number	Part name
1	Wire Kit: Contains wires.
3	10kΩ Resistor
9	Photodetector
12	Breadboard
100	LF353 Op-Amp
101	50kΩ Potentiometer
102	LED

Step 2: Hook up power to the LF353 Op-amp.

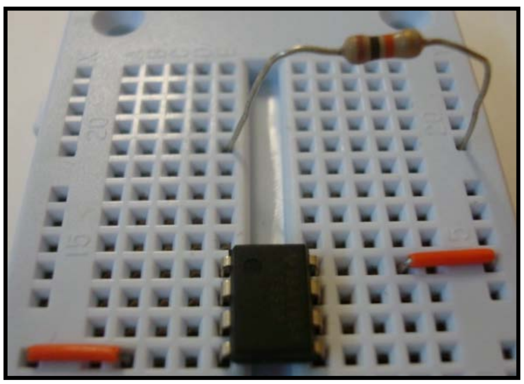
Hook up the LF353 Op-Amp (part #100) to the breadboard (part #12) in the following way. ***Note: The circle on the LF353 is facing***



LF353 Op-Amp hooked up to power and ground.

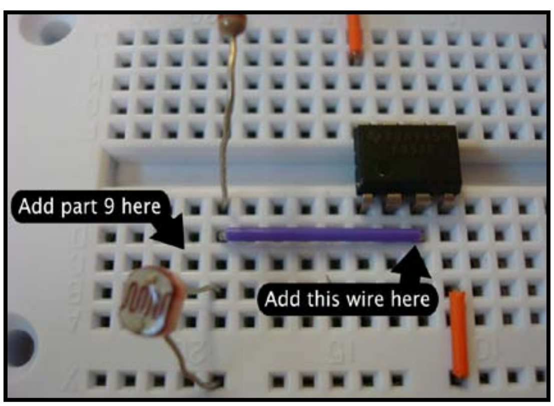
Step 3: Connect 10kΩ resistor

Connect the 10kΩ resistor (part 3) in the following way.



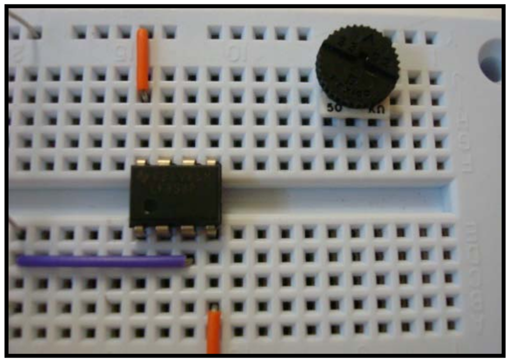
Step 4: Connect the Photodetector and resistor to the Op-Amp

Hook one end of the Photodetector (part 9) to ground (bottom of picture) and the other end to the 10kΩ resistor.



Step 5: Connect part 101 (the potentiometer)

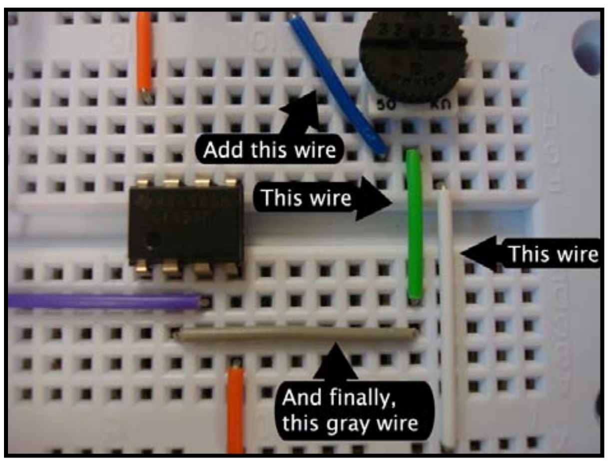
Connect the potentiometer to a seemingly random spot on the board.



Seemingly random

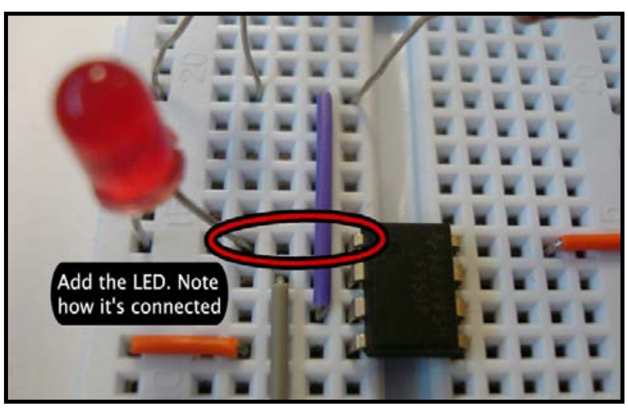
Step 6: Add a lot of wires to make it look nice

Add the four wires as shown to get the potentiometer to be connected from power to the Op-Amp to ground.

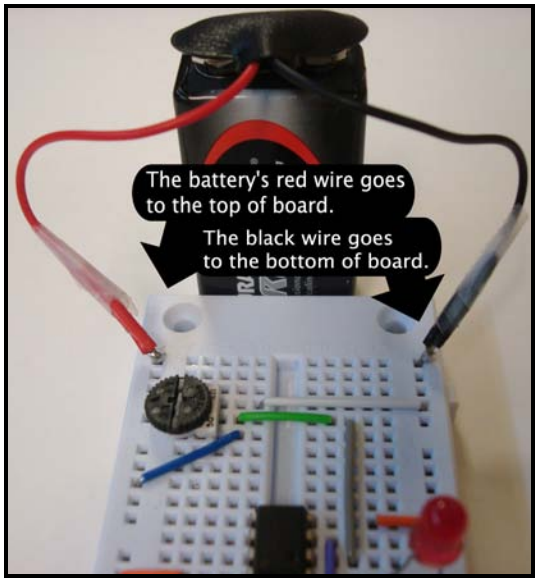


A lot of colorful wires are now connected

Step 6: Add the LED (part 102). It connects from pin 1 of the Op-Amp to Ground.



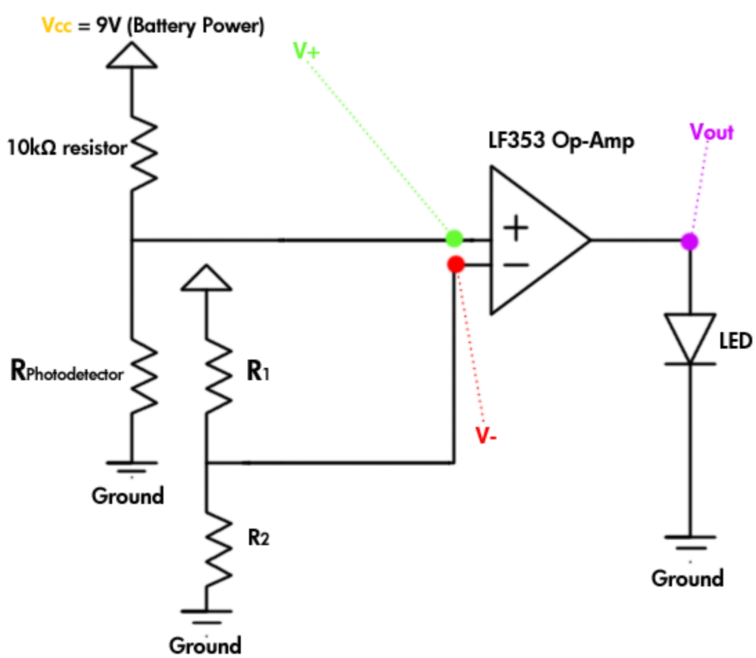
Final Step: Hook up the battery and watch…at least something happen.



Part β: Explaining the…the thing

Step 1: What's a schematic?

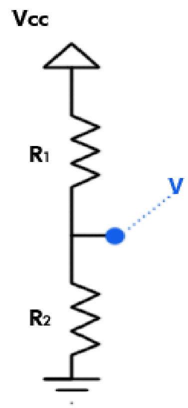
Whenever Electrical Engineers want to build a circuit, they always use something called a **schematic**. The useful part about creating a schematic is that it makes it easier to analyze the circuit you want to build. In a schematic, symbols are used to represent the different elements of a circuit. The schematic for the circuit that you've built looks like the following:



The freakish schematic for the ***Sensor Comparator*** *that you built. Note all the different symbols and how nice they look.*

All the colored V's are voltages that you will need to 'solve' this circuit.

Step 2: Voltage Divider…quick tutorial!
The schematic below shows a simple voltage divider. Does it look similar??? (Hint: Look above at the freakish schematic)



The basic equation for a voltage divider is the following:

$$V = Vcc * \frac{R_2}{R_2 + R_1}$$

Using that simple theorem, we can analyze the **Sensor Comparator** schematic above.

Step 3: Analyze!

Now, use the voltage divider equations to find equations for V+ and V-…….piece of cake, right? After going through all the analyzing, I've found out the following:

$$V_+ = 9 * \frac{R_{photodetector}}{R_{photodetector} + 10{,}000}$$

(Note: This is the equation for V+*, the voltage on your schematic)*

$$V_- = 9 * \frac{R_2}{R_2 + R_1}$$

(Note: This is the equation for V-, the voltage on the negative side of the op-amp.)

Ok, so now you have 2 algebraic equations…right?
What do these mean? Well I just remembered that I forgot to say something **very** important about the comparator:

If V+ > V-, then Vout = Vcc (Vcc is the battery voltage).
And when Vout = Vcc, the LED lights up.

Step 3: V+ and V-…
Let's take it up a step.
The 50kΩ potentiometer (part 101) is labeled as R_1 and R_2.
In the 50kΩ potentiometer (part 101), **$R_1 + R_2 = 50k\Omega$**. When the potentiometer is turned to the middle, the resistance is **halfway split**. With that, we can figure out *V-*.

$$V- = 9 * \frac{R_2}{R_2+R_1} = 9 * \frac{\mathbf{25{,}000}}{25{,}000+\mathbf{25{,}000}} = 4.5\ Volts$$

Now, what about V+?
When the Photodetector is given no light, then:

$$R_{dark\_photodetector} \approx 11k\Omega$$

When the Photodetector is given no light, then:

$$R_{light\_photodetector} \approx \mathbf{1k\Omega}$$

***Quick note: If you measured the values of the Photodetector from the digital multi-meter, then substitute your own values in for $R_{dark\_photodetector}$ and $R_{light\_photodetector}$. For example, if you found that the Photodetector gives off 20kΩ when you cover it with your hands, substitute 20kΩ in for 10kΩ. Do the same with the value you get when there's nothing covering the Photodetector.*

So, if we substitute 11,000 and 1,000 for $R_{photodetector}$, we finally get that:

$$V_{+}(in\ dark) = 9 * \frac{11{,}000}{11{,}000 + 10{,}000} = 4.71\ Volts$$

$$V_{+}(in\ light) = 9 * \frac{\mathbf{1{,}000}}{\mathbf{1{,}000}+10{,}000} = 0.82\ Volts$$

Therefore, when the Photodetector notices the dark,
V+ will be equal to 4.71 Volts.
V- will still be equal to 4.5 Volts (If you kept the potentiometer (part 101) arrow at the middle).
So… *V+ > V-*
then Vout = Vcc
And when THAT happens, The LED lights up!

Step 4: Things and things and things to try out

Ok, so you know what will happen when the potentiometer (part 101) is dialed to the middle.
Now, how about if you turn the potentiometer towards the '50' that's written on it?
Remember the equation: $R_1 + R_2 = 50k\Omega$?
As you turn the dial towards '50', R_1 gets smaller and smaller. If R_1 is getting smaller, what's happening to R_2? It's getting larger, right?

Now, use this equation:

$$\boldsymbol{V_-} = 9 * \frac{R_2}{R_2+R_1} = 9 * \frac{larger\ number}{larger\ number+smaller\ number} = Larger\ number$$

Well, now *V+* < *V-*....*thus* Vout = *0 Volts.* So, the LED is not lighting up…..hmmmm…..Ok now turn the dial the other way (towards the 'kΩ'). Now do you see what role the potentiometer (part 101) plays in this circuit?

Step 5: Concluding

That's the end of this demo. Now, here's a question to keep you thinking:

How would I get the LED to do the exact opposite of what it's doing right now? IE: If it's light, the LED turn ON. If it's dark, the LED turns OFF.