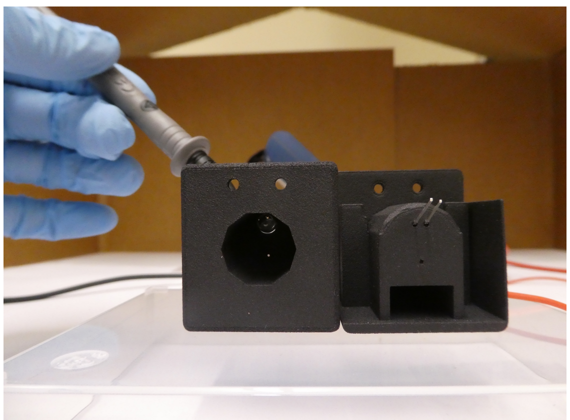
LED (Light Emitting Diodes)

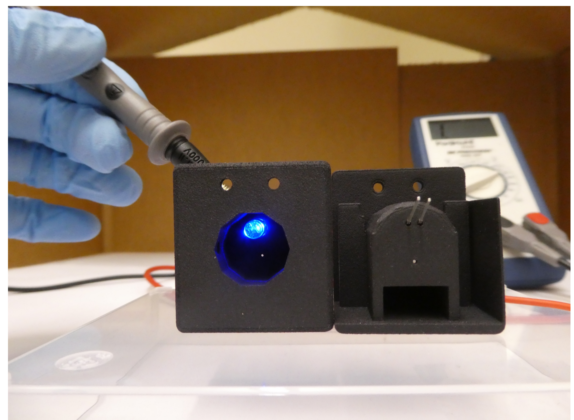
<u>**What you will learn:** Basics of LEDs and how to solder them on to the customized nose ports</u>

LEDs (light emitting diodes) are very cheap and abundant in our everyday lives. That's why traditional Med Associates operant boxes use them for stimuli and why we are going to use them as well.

For our operant boxes, we will be incorporating the LEDs into our customized nose ports.



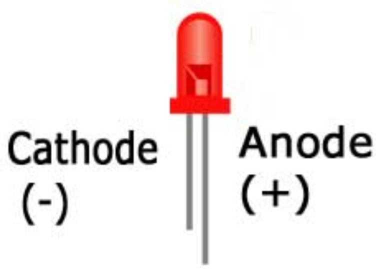
Picture 1: It is a little hard to see, but the LED has been threaded through the holes in the noseports



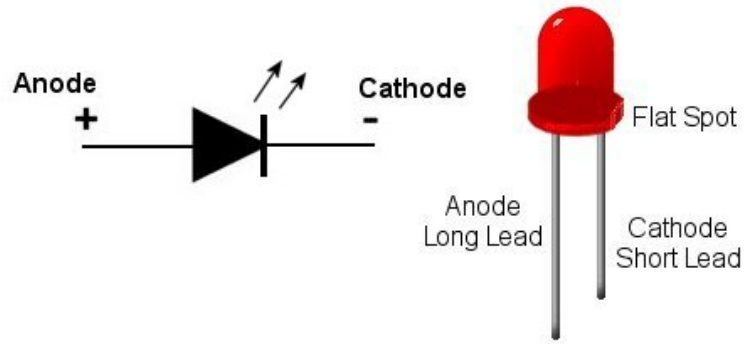
Picture 2: Now you can clearly see the LED in place! Using the multimeter to test the LEDs can be one way to weed out the faulty LEDs before soldering it in place.

Introduction

A little primer on the LEDs before we actually venture too far in. LEDs, or diodes in general, have two polarized legs. One is cathode (-) and the other is anode (+). What I mean by polarized is that there is a directionality in current flow. LEDs won't light up unless you connect the cathode to GND and anode to PWR. You might have already guessed it from Picture 2, but current can only flow from anode to cathode. And just a quick refresher if you are an engineering student. The little diagonal arrows going in the 1 o'clock direction in the circuit symbol signifies that it is a light-emitting diode. Without the small arrows, the circuit symbol would signify a diode.



Picture 3: LED with a cathode and an anode. Source: http://sciencewithkids.com/science-facts/facts-about-LEDs.html



Picture 4: Diagram of how electricity flows in an LED. Source: http://www.mainbyte.com/ti99/electronics/led.html

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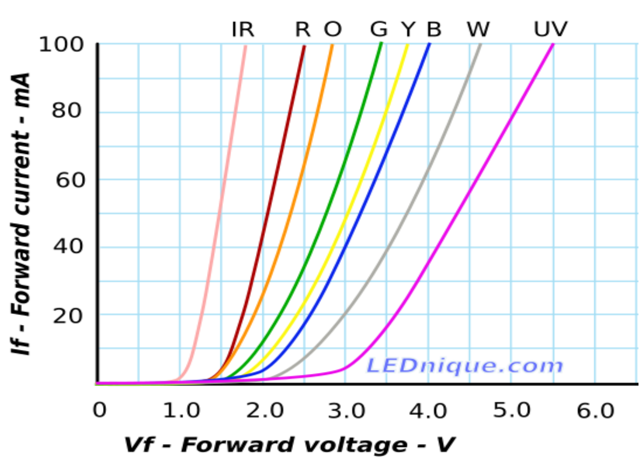
There's one more thing we need to discuss before we actually solder the LEDs in place. The brightness of an LED depends directly on how much current it draws. So the more current it draws, the brighter it is going to be. Sounds good right? Well… there is one catch. The problem with LEDs is that they are self-destructive. If possible, LEDs will try to draw as much power as it is allowed to draw. You can see this from picture 5. The forward current increases exponentially as a function of forward voltage. ***(If the terms forward current (I_f), forward voltage (V_f) are unfamiliar to you, it simply means how much current and voltage is being run across that component.)*** Too much current equals too much power and too much heat, which will eventually kill the LED and potentially damage your whole circuit (your precious Arduino). The whole process is kind of like the life cycle of a star, where the star burns bright and meets a violent end, creating that black hole of a mess where you find that LEDs have damaged your IC chip and rendered it useless…



Picture 5: IV curve for different types of LEDs. You can notice that the current increase is exponential as a function of forward voltage. Source: http://lednique.com/current-voltage-relationships/iv-curves/

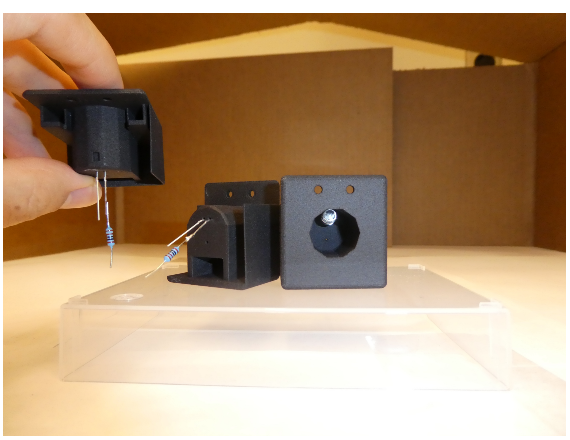
Essentially this is why we need current-limiting resistors for LEDs. The name is self-explanatory. Resistors prevent excessive current flow to LEDs so that they may operate under maximum forward current (I_f) and not burn themselves out. Typically, the maximum forward current is 20mA for most LEDs.

To calculate current-limiting resistor values for different types of LEDs [see here], but if you just want the short answer, we use 1k Ω for our blue LEDs. Considering that blue LEDs typically have a forward voltage of 3.0V, this will effectively give us 2mA of operating current for the LED.

Soldering LEDs

Note of Warning:
Do a simple continuity test with a multimeter on the LEDs so that you know that the LEDs are not faulty. Remember to connect the anode to ***PWR (red)*** *and cathode to* ***GND (black)****. This is just to save you time in the long run so that you don't spend 10 hours debugging a circuit board for a faulty LED. Additionally, if you have a breadboard and an Arduino in hand, you can just hook up a simple circuit with a resistor to test out the LEDs.*

Since everything will be connected in series, the current limiting resistor can go on either anode or cathode. The LEDs will receive a dialed-down current no matter where you connect the resistor. To standardize things however, we will solder the resistor to the cathode (-) so that it will be easier to distinguish the cathode terminal. As I've mentioned before, the cathodes have shorter leads than anodes. If you've already cut the terminals however, and can't distinguish the length, there are other ways to tell. If you look at picture 2, you will see that cathodes have a flat surface on the LED. On the other hand, anodes will have a rounder surface. Since cathodes connect to GND, I like to remember this scheme as ***"blunt is black"*** (Electrical engineers typically color code **PWR with red** and **GND with black**).



Picture 6: LEDs and nose-ports after the resistors have been soldered on. Note that all the resistors have been soldered to the cathode (shorter lead)