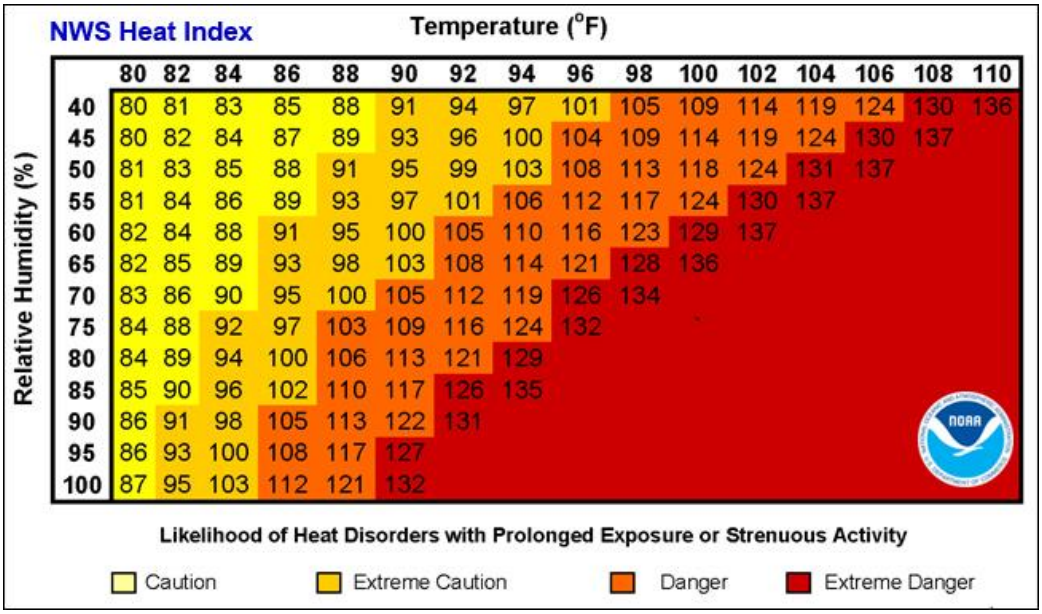
Heat Index Hat

Introduction and Use Case

In this tutorial, we will build a wearable hat that tells you when the heat index is too high.

Heat stroke can be deadly, and can be surprisingly easy to get, especially if someone is working or exercising in the heat. To combat this, you can use the heat index to tell how hot it is; even double-digit temperatures can be deadly if the humidity is too high. You can see from the chart below how humidity and temperature are combined to get the heat index.



Using a lightweight hat, this project ensures that you know when the heat index has gotten too high, using both LEDs and a buzzer to alert you once you reach different heat index thresholds. If you do a lot of work outdoors, especially in either high humidity or high temperatures, this project could be very useful and can easily be incorporated into your favorite baseball cap or sun hat.

Required Materials

You will need the following materials. Some materials can be swapped for alternatives but be conscious of what you are replacing.

- A baseball cap or sun hat
- One Adafruit Flora v3

- One Adafruit HTU31 Temperature and Humidity Sensor Breakout Board
- One HiLetgo through-hole phototransistor
- Two Adafruit Flora NeoPixel v3s
- Any 2-terminal buzzer (I used one from the LilyPad ProtoSnap Plus)
- One Adafruit 3.7v Lithium-Ion Polymer Battery
- One 1K ohm through-hole resistor
- Conductive thread
- 22AWG wire
- Any non-conductive thread
- Scissors
- Needle
- You will also need a soldering iron, solder and flux

Code

It is easiest to flash the code before constructing the hat. The code can be found on the GitHub repository.

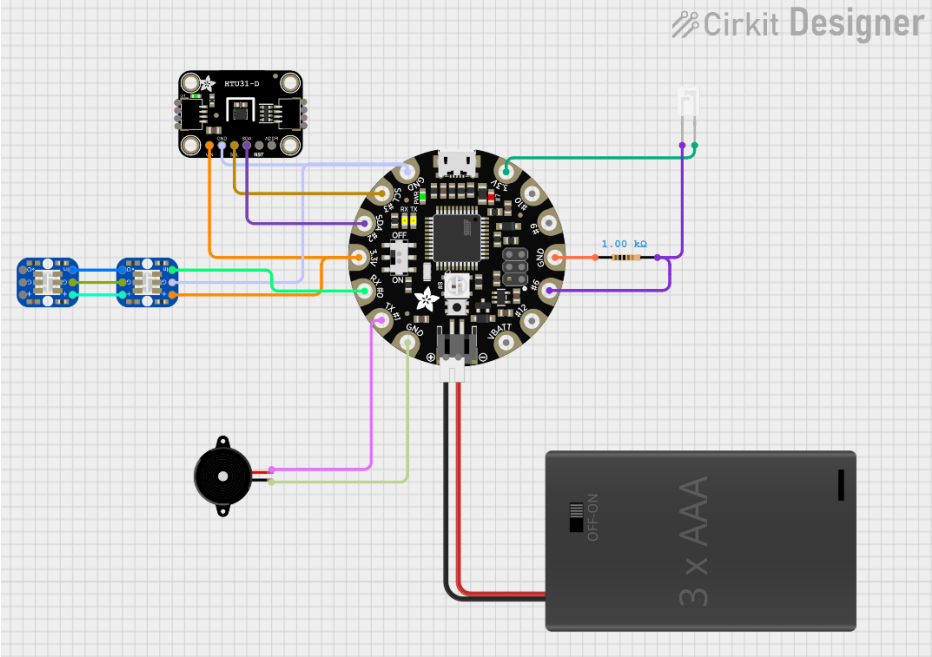
The primary function in the codebase is getHeatIndex, which uses the formulas provided by the National Weather Service to determine the heat index given the temperature and humidity. It also adds an offset to account for the heat of the sun, if the user is in direct sunlight.

At any point in this tutorial, you are welcome to change the pins you use. If you do change them, be sure to adjust their pin definition at the top of the sketch. Along with that, if at any point you want to debug your circuit, you can set DEBUG to 1. This will enable the serial monitor, and the program will log crucial values.

Constructing the Hat

Overview

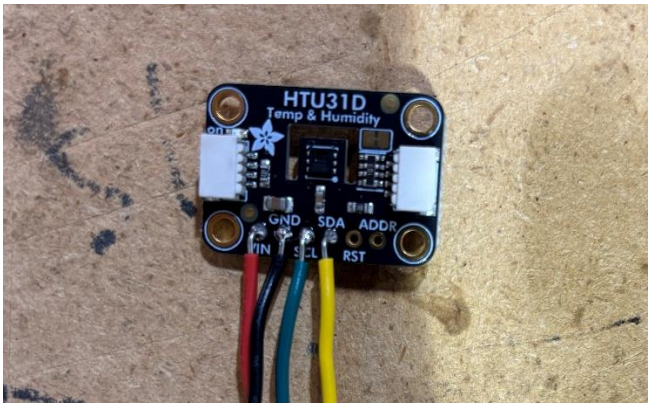
We will need to construct the hat according to this schematic. Most of the connections can be done using conductive thread, except for the HTU31D, which will be explained next.



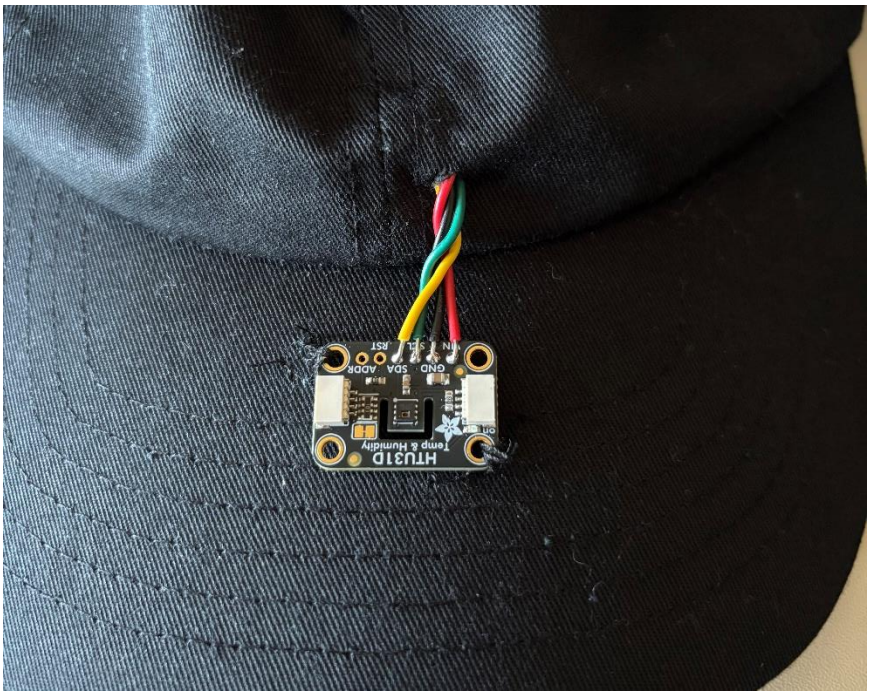
Temperature and Humidity Sensor

We first want to create a connection to the HTU31D sensor board. Since the board has Stemma QT connectors on it, you could buy a Qwiic to male headers cable, and skip to step 3 directly. However, I instead used solid-core wire and soldered it directly to the board's pins. We can't use conductive thread because the pins are too close together and the risk of shorting two threads would be very high.

1. Grab 4 solid-core wires and cut them to about the length of the edge of the bill of the cap to the top center. For my cap, this was about 6 inches. Be sure to leave a couple of extra inches just in case.
2. Solder each wire to the VIN, GND, SCL, and SDA pins of the HTU31D board, as shown below. I used red for VIN, black for GND, green for SCL, and yellow for SDA.



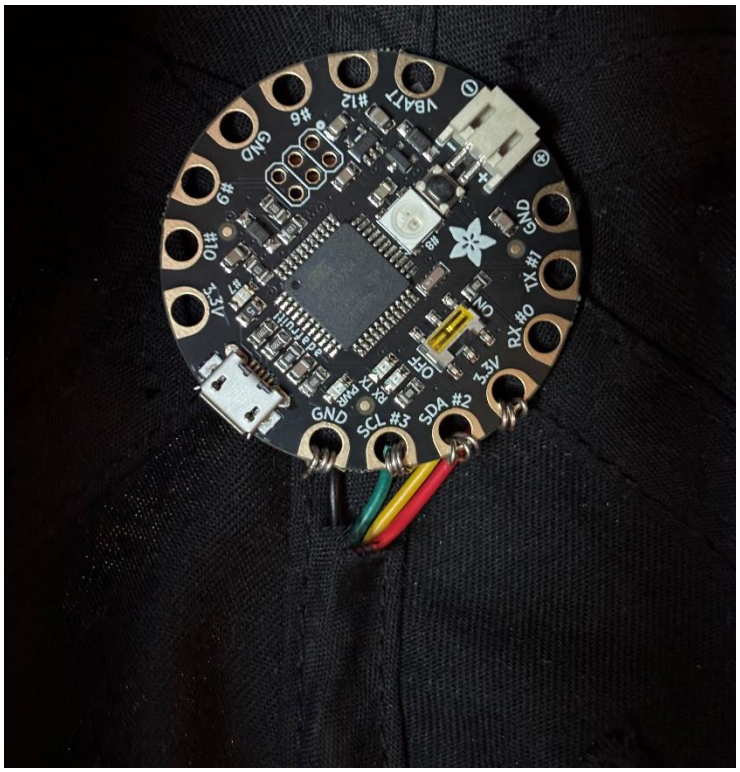
3. Cut a small hole in the front of the hat, just above the bill, big enough to fit the four wires.
4. Braid the wires together and push them through the hole.
5. Tie down the sensor board to the bill of the hat with non-conductive thread. In the end it should look like this:



Placing the Flora

Now that we have the HTU31D sensor down, we can wire it to the Flora. It is easier to do this when the Flora is not yet tied down, so do the following before tying the Flora to the hat.

1. For each wire, strip them so there is ½ to 1 inch of bare wire at the ends.
2. Wrap each bare wire around its respective pin on the Flora. Be sure to make it tight.
3. Wrap conductive thread around the wire and the pin to ensure a good connection. It should end up looking somewhat like this:

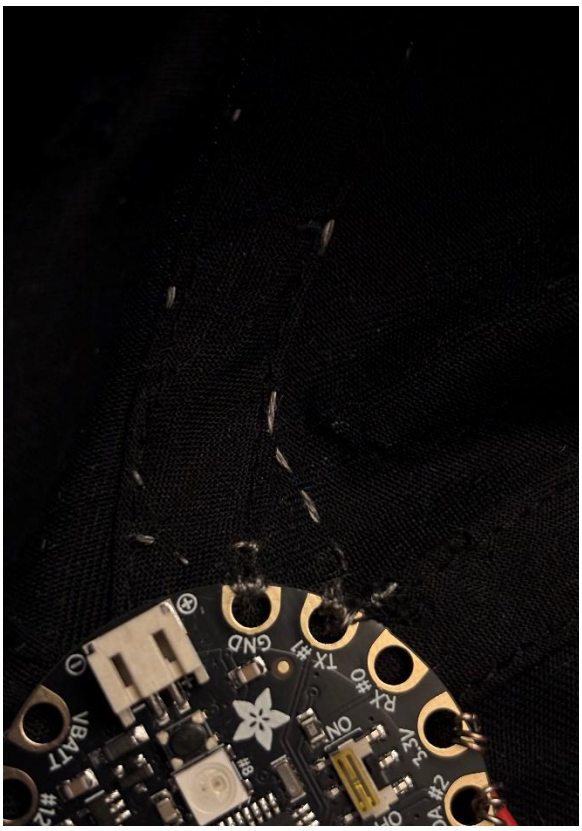


Now that the wires are in place, you can tie down the Flora using non-conductive thread to make it more secure as we do the other components. It will be easiest to use the #1 and #9 pins to do this. We can now move on to the other components. You can do these in any order.

The Buzzer

The buzzer will make a noise when the heat index is in the extreme danger zone. To do this we will need to wire it to the #1 and GND pins of the Flora.

1. Place the buzzer on the right side of the hat.
2. Using conductive thread, connect the #1 (TX) pin of the Flora to the positive pin of the buzzer. To ensure a good connection, you should wrap the thread around the pin 4-5 times and make sure it is completely taught before tying it off. If you don't do this the buzzer may intermittently turn off due to connection instability.
3. Do the same to connect the GND pin of the Flora to the negative pin of the buzzer. Make sure not to let the thread get too close to the positive thread and try not to cross them at any point (using these pins you shouldn't need to cross them).



Inside connections


Outside buzzer

We now have the buzzer fully constructed, so we can move on to the NeoPixels.

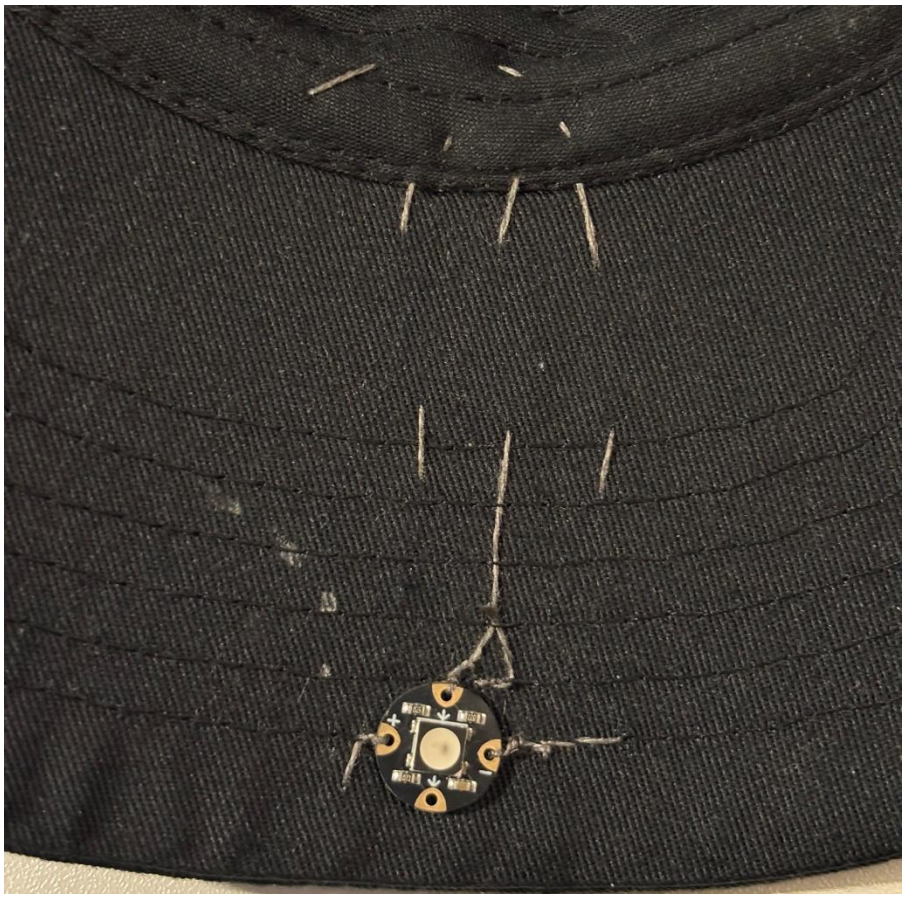
The NeoPixels

The NeoPixels are what tell the user the heat index threshold. Placing the NeoPixels is tricky, due to the abundance of different traces, so make sure to be especially careful to avoid shorting traces together. We need to route conductive wire through the 3.3V and GND pins of the NeoPixels, as well as routing a data line from pin #0 to the first NeoPixel, and another data line from that NeoPixel to the other NeoPixel.

1. Place one NeoPixel along the front center of the hat, an inch or so above the bill.
2. Using conductive thread, connect the GND pin of the Flora to the negative pin of the NeoPixel. Like the buzzer, make sure to wrap the pin a couple of times and to make the thread completely taught before tying it off.
3. Connect the 3.3V pin of the Flora to the positive pin of the NeoPixel using conductive thread. Be sure to give as wide of a clearance as possible from the GND trace.

4. Now connect pin #0 of the Flora to the data in pin of the NeoPixel. You will have to cross the 3.3V trace so be careful to keep as much fabric between the two when you do. The finished NeoPixel is shown below.

5. Now we can place the second NeoPixel, on the bottom of the bill near the edge. Routing the conductive threads on the bill is difficult, because of how stiff it is. If you have a pair of tweezers, those can be helpful in guiding the needle and pushing thread through the holes of the NeoPixel.
6. Use the positive trace that we routed through the first NeoPixel and extend it to connect to the second NeoPixel's positive pin using conductive thread.
7. Connect the negative pins of the NeoPixels together. You will have to cross this trace over the positive trace, so once again be careful not to short them together.
8. Finally, use conductive thread to create a trace between the first NeoPixel's data out pin to the second NeoPixel's data in pin. Be mindful of the positive and negative traces and try to keep as large of a clearance as possible. The final construction should be similar to what's shown below.



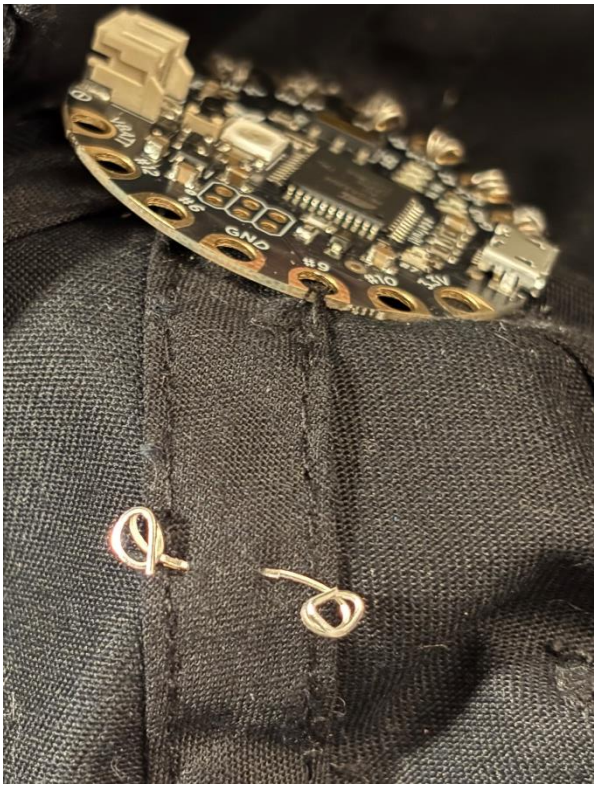
Now the NeoPixels should be fully connected. This is optional, but at this point, you can use a multimeter to check for any shorts. You can do this by probing two different traces while in continuity mode, making sure the multimeter does not detect a connection. Do this for each combination of traces.

Constructing the Phototransistor

The final components we need to add are the phototransistor and its resistor. The phototransistor is used to determine whether the hat is in bright sunlight or not, which we can use to add an offset to the heat index to account for the heat of the sun. This tutorial won't go into depth on how phototransistors work and why we have set the circuit up the way we have but just know that the 1k resistor is used to provide a voltage reference so we can measure how much current is passing through the phototransistor, and thus the light level.

1. Use a pin to poke two holes a couple of millimeters apart near the center of the hat, then stick the phototransistor's legs through the holes. Make sure the longer leg (collector pin) is closest to the Flora's 3.3V pin.

2. Curl both legs of the phototransistor away from each other as shown below. Be careful not to bend the tops of the legs too much, as that may damage the phototransistor's internal components.



Inside the hat

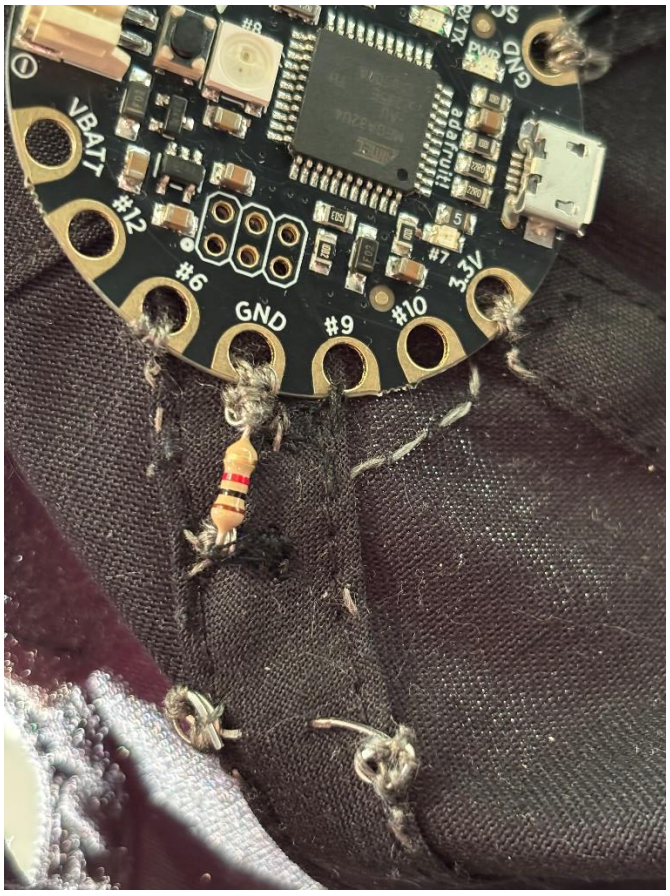

Outside the hat

3. Using conductive thread, create a trace between the Flora's 3.3V pin and the collector pin of the phototransistor (the longer leg).
4. Curl the legs of the 1k resistor as shown below, leaving them just large enough to stick a needle through.

5. Place the resistor somewhere between the phototransistor's emitter pin and the Flora's GND pin, then use conductive thread to first connect the phototransistor's emitter pin to one leg of the resistor and then connect the GND pin of the Flora to

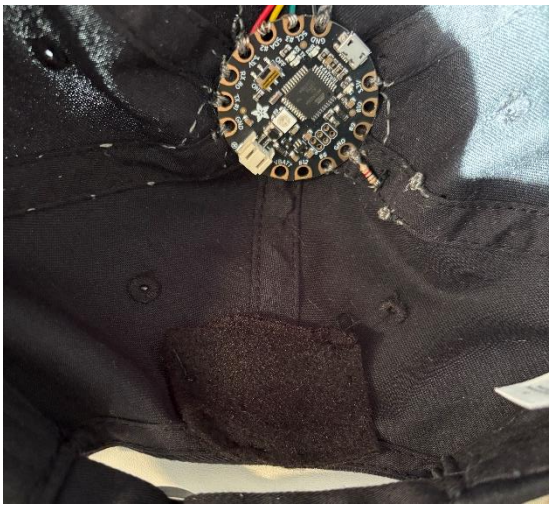
the other leg of the resistor. Make sure to leave sufficient clearance from the Flora's pin #6.

6. Using conductive thread, connect the leg of the resistor that is connected to the phototransistor to the Flora's #6 pin. The finished construction should look like the following:



The Battery Holder

Now that we have all the components, we can create a quick battery holder and connect the battery to the Flora.



1. Cut an approximately 2 by 1 ½ inch rectangle of fabric.
2. Place the fabric inside the hat in the back, and using non-conductive thread, sew the top, bottom, and one side of the fabric to the hat. Leave one side open.

Assembled Hat

The fully assembled hat should look like the images below.

Top of the hat

Bottom of the hat

Similar Projects and Attribution

This project was not directly inspired by anything, however, here are a couple of projects which use similar components:

- Adafruit Sunscreen Reminder Hat
- Adafruit LED Ampli-tie

Everything in the project is original – although the code utilizes some of the libraries provided by Adafruit for the HTU31D sensor board as well as the NeoPixels.