

Build tutorial on open-source hardware alternatives for SNR-based GPS/GNSS Reflectometry (GNSS-R)



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Step 0: List of materials

You can use this link to a bill of materials with all the necessary items:

<https://www.adafruit.com/wishlists/469752>

For convenience, we list below the items in the Adafruit shopping cart; other shops can be used for some of the items:

1x - 2.1mm female/male barrel jack extension cable - 1.5m / 5 ft

<https://www.adafruit.com/product/327>



1x - GPS Antenna - External Active Antenna - 3-5V 28dB 5 Meter SMA

<https://www.adafruit.com/product/960>



1x - CR1220 12mm Diameter - 3V Lithium Coin Cell Battery - CR1220

<https://www.adafruit.com/product/380>



1x - SMA to uFL/u.FL/IPX/IPEX RF Adapter Cable

<https://www.adafruit.com/product/851>



1x - Header Kit for Feather - 12-pin and 16-pin Female Header Set

<https://www.adafruit.com/product/2886>



1x - Adafruit Ultimate GPS FeatherWing

<https://www.adafruit.com/product/3133>



1x - Adafruit Feather 32u4 Adalogger
<https://www.adafruit.com/product/2795>



1x - Lithium Ion Battery Pack - 3.7V 4400mAh
<https://www.adafruit.com/product/354>



1x - 3.5 / 1.3mm or 3.8 / 1.1mm to 5.5 / 2.1mm DC Jack Adapter Cable
<https://www.adafruit.com/product/2788>



1x - Waterproof DC Power Cable Set - 5.5/2.1mm
<https://www.adafruit.com/product/743>



1x - 10K Precision Epoxy Thermistor - 3950 NTC
<https://www.adafruit.com/product/372>



1x - Cable Gland PG-9 size - 0.158" to 0.252" Cable Diameter - PG-9
<https://www.adafruit.com/product/761>



1x - USB / DC / Solar Lithium Ion/Polymer charger - v2

<https://www.adafruit.com/product/390>



1x - Huge 6V 6W Solar panel - 6.0 Watt

<https://www.adafruit.com/product/1525>



1x - Through-Hole Resistors - 2.2K ohm 5% 1/4W - Pack of 25

<https://www.adafruit.com/product/2782>



1x - Cable Gland PG-7 size - 0.118" to 0.169" Cable Diameter - PG-7

<https://www.adafruit.com/product/762>



1x - 2.1mm to 2.5mm DC Barrel Plug Adapter

<https://www.adafruit.com/product/2897>



1x - Large Plastic Project Enclosure - Weatherproof with Clear Top

<https://www.adafruit.com/product/905>



JST 2-pin Extension Cable with On/Off Switch - JST PH2

<https://www.adafruit.com/product/3064>



Step 1: Installing the firmware

You'll need:

- 1x - Adafruit Feather 32u4 Adalogger
- SD card with file system fat32

1.1 - Download and install the Arduino IDE

Available at: <https://www.arduino.cc/en/Main/Software>

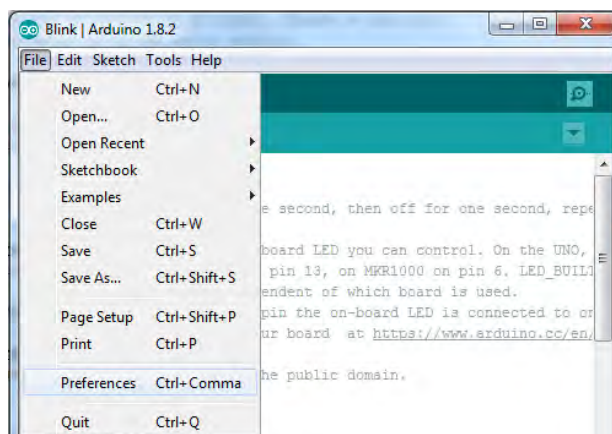
1.2 - Install Adafruit drivers for the IDE

The steps are detailed in this link, but we'll shown a summary below.

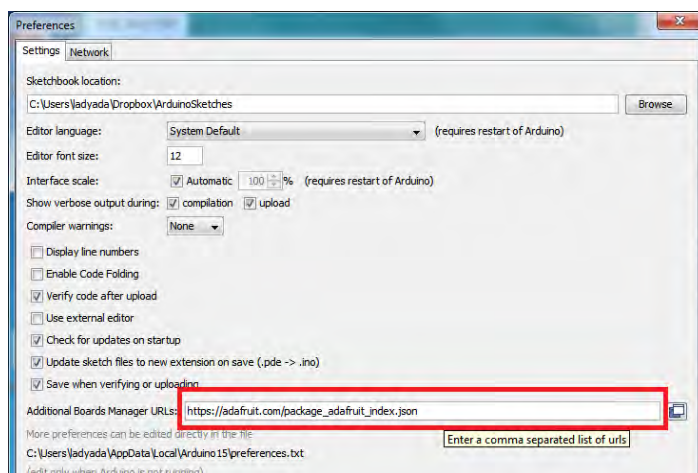
<https://learn.adafruit.com/adafruit-feather-32u4-basic-proto/arduino-ide-setup>

Portion reused from Adafruit tutorial:

“After you have downloaded and installed **the latest version of Arduino IDE**, you will need to start the IDE and navigate to the **Preferences** menu. You can access it from the **File** menu in *Windows* or *Linux*, or the **Arduino** menu on OS X.



A dialog will pop up just like the one shown beside.



We will be adding a URL to the new **Additional Boards Manager URLs** option. The list of URLs is comma separated, and *you will only have to add each URL once*. New Adafruit boards and updates to existing boards will automatically be picked up by the Board Manager each time it is opened. The URLs point to index files that the Board Manager

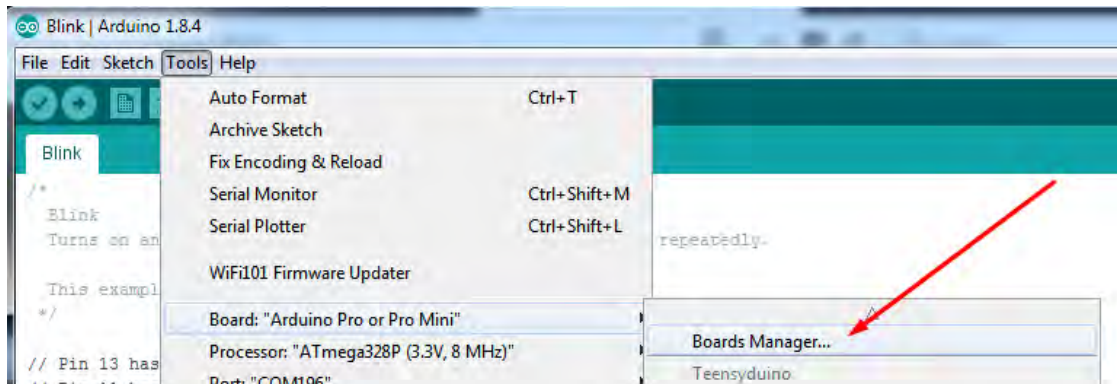
uses to build the list of available & installed boards.

Insert this link in the Arduino IDE preferences:

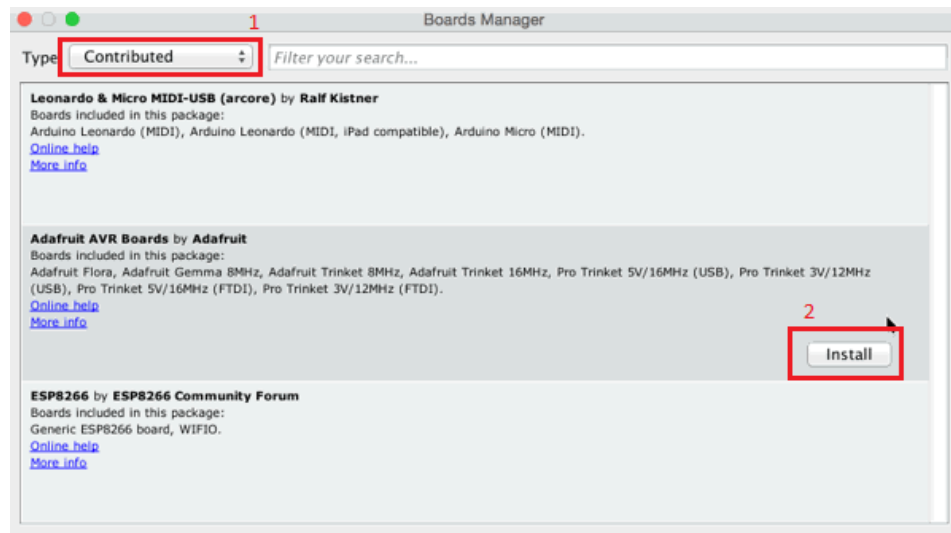
https://adafruit.github.io/arduino-board-index/package_adafruit_index.json

Click “Ok” button to save.

Now that you have added the appropriate URLs to the Arduino IDE preferences, you can open the **Boards Manager** by navigating to the **Tools->Board** menu.



Once the Board Manager opens, click on the category drop down menu on the top left hand side of the window and select **Contributed**. You will then be able to select and install the boards supplied by the URLs added to the preferences. In the example below, we are installing support for **Adafruit AVR Boards**, but the same applies to all boards installed with the Board Manager.



Next, **quit and reopen the Arduino IDE** to ensure that all of the boards are properly installed. You should now be able to select and upload to the new boards listed in the **Tools->Board** menu.”

1.3 - Install Adafruit drivers for Windows

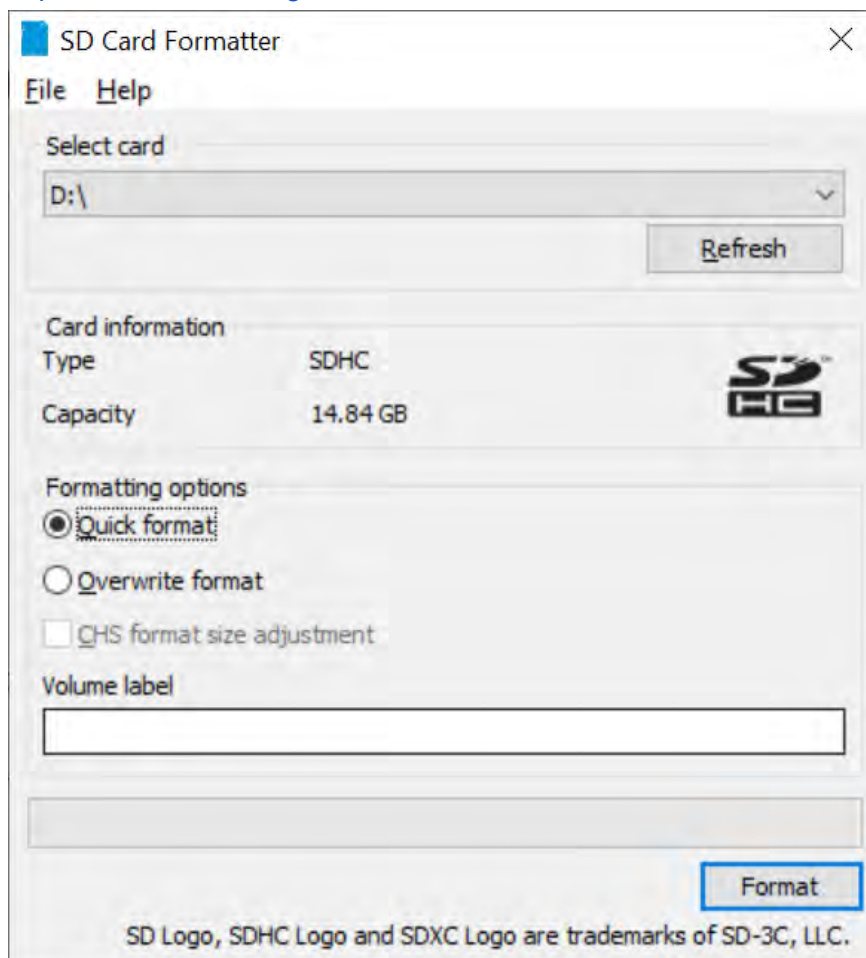
Download and run the installer:

https://github.com/adafruit/Adafruit_Windows_Drivers/releases/tag/2.3.4

1.4 Format the SD card to file system FAT32

We recommend to use this software to format the SD card:

<https://www.sdcard.org/downloads/formatter/>

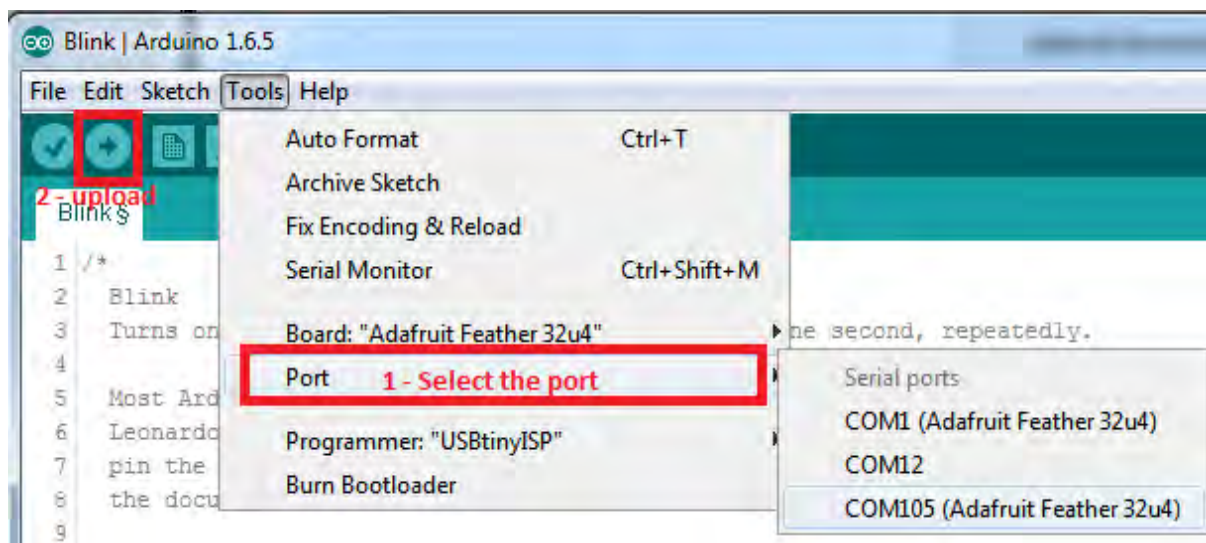


1.5 - Upload the Arduino sketch

0) Download the source code on this link and open it on the Arduino IDE:

<http://cdn.jsdelivr.net/gh/fgnievinski/mphw/code/ardu/ardu.ino>

1) Plug in the Feather 32u4 to the computer using a USB cable. Wait for it to be recognized by the operating system (it just takes a few seconds). It will create a serial COM port, which you can select from the dropdown menu -- it'll even be 'indicated' as Feather 32u4!



2) Finally, we need to upload the firmware, that makes the Arduino system run. Simply click on the Upload button (arrow icon) and wait (it may take a while to finish).

1.6 - Update the GPS firmware (optional)

The GPS module has its own firmware, independent from the Arduino firmware as installed above. The GPS factory default firmware outputs SNR values as integer numbers, i.e., with 1-dB numerical resolution. Other GPS firmware versions may offer greater resolution, outputting SNR as decimal values. This section serves just a reminder in case you have access to such a GPS firmware.

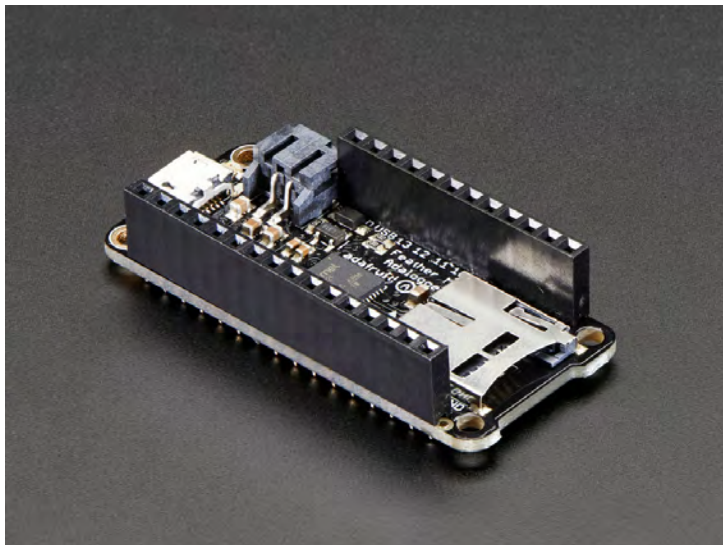
Step 2: Connecting the electronics

2.1 - Connecting the Arduino and GPS shield

You'll need:

- 1x - Adafruit Feather 32u4 Adalogger
- 1x - Header Kit for Feather - 12-pin and 16-pin Female Header Set
- 1x - Adafruit Ultimate GPS FeatherWing

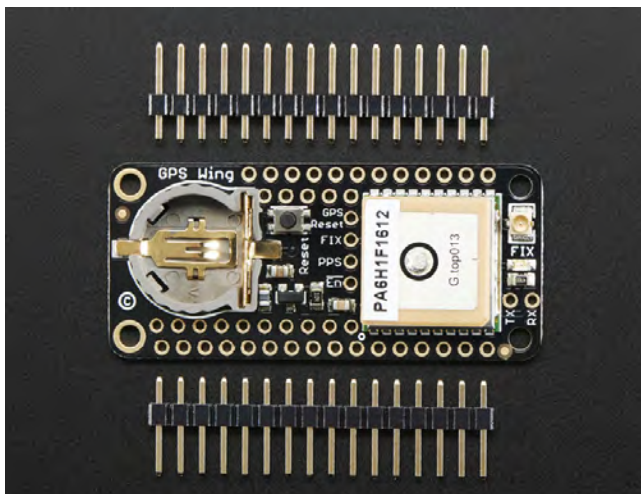
Solder the "Header Kit for Feather - 12-pin and 16-pin Female Header Set" on the Feather as below.



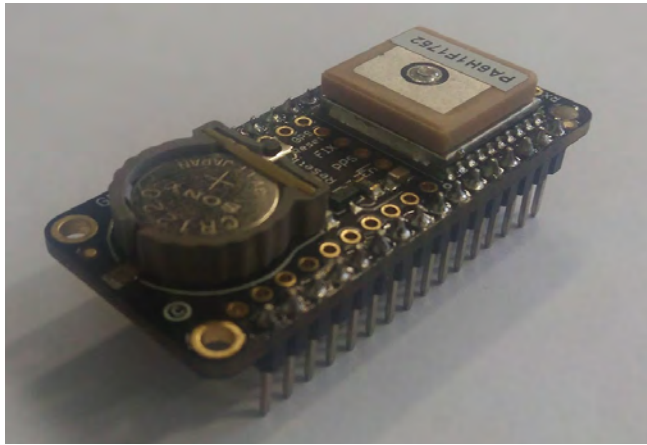
Check "Soldering on Female Header" at this link for detailed instructions:

https://cdn-learn.adafruit.com/downloads/pdf/adafruit-feather-32u4-adalogger.pdf?timestamp=1557404503#_WKANCHOR_q

Prepare the GPS module to attach on the Adafruit Feather soldering the male headers:



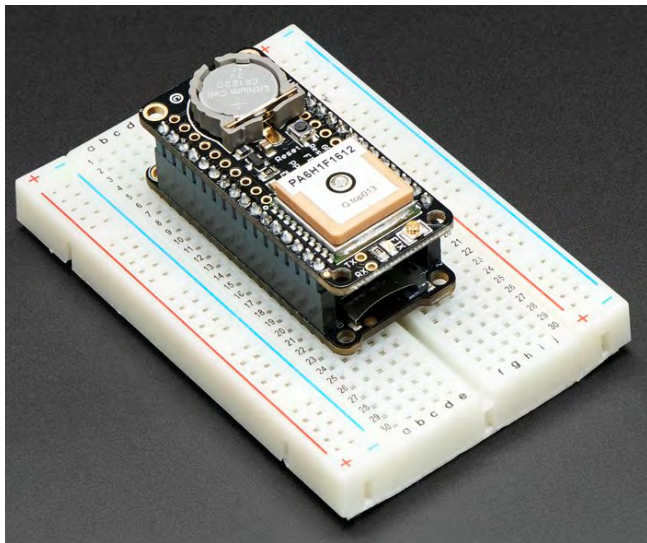
Make sure to solder the pins with the longer part facing down



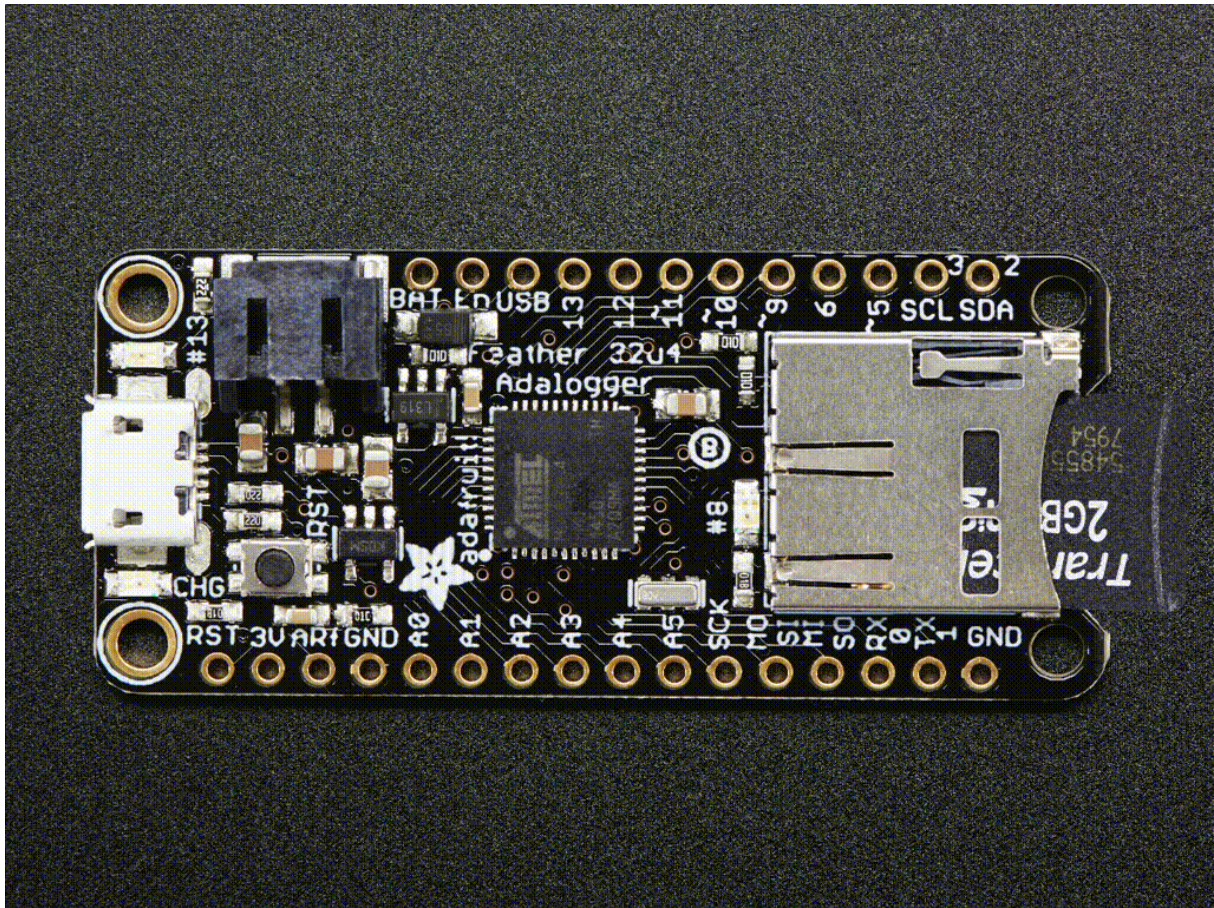
Check “Adafruit Ultimate GPS featherwing” for details:

<https://learn.adafruit.com/adafruit-ultimate-gps-featherwing?view=all>

Finally, we can connect the boards pressing down
(note: the protoboard in white is not necessary):



Insert the SD card into the slot on the Adafruit Feather Adalogger:



2.2 - Building the solar power supply system

You'll need:

- USB / DC / Solar Lithium Ion/Polymer charger - v2
- Huge 6V 6W Solar panel - 6.0 Watt
- Lithium Ion Battery Pack - 3.7V 4400mAh
- 10K Precision Epoxy Thermistor - 3950 NTC

2.2.1 - Capacitor installation

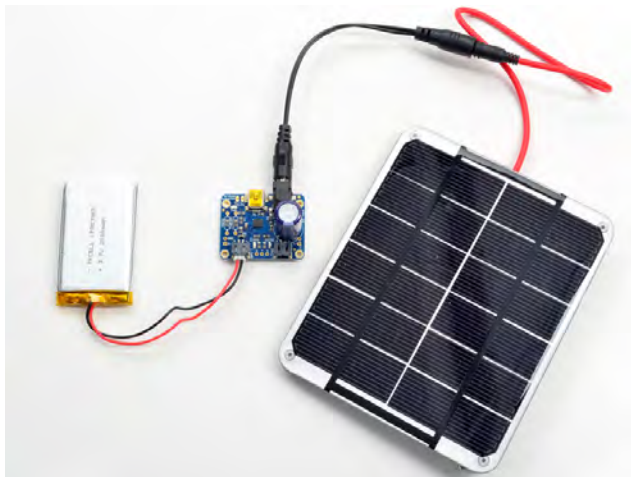
The first thing to do before starting to charge with a solar panel, is to install the large capacitor on the USB / DC / Solar Lithium Ion/Polymer charger. Watch out to check the polarity of the capacitor, make sure the positive lead of the capacitor goes into the pad marked with a plus sign, + !

Follow these steps to prepare the capacitor of the solar charger

<https://learn.adafruit.com/usb-dc-and-solar-lipoly-charger/solar-charger-preparation>



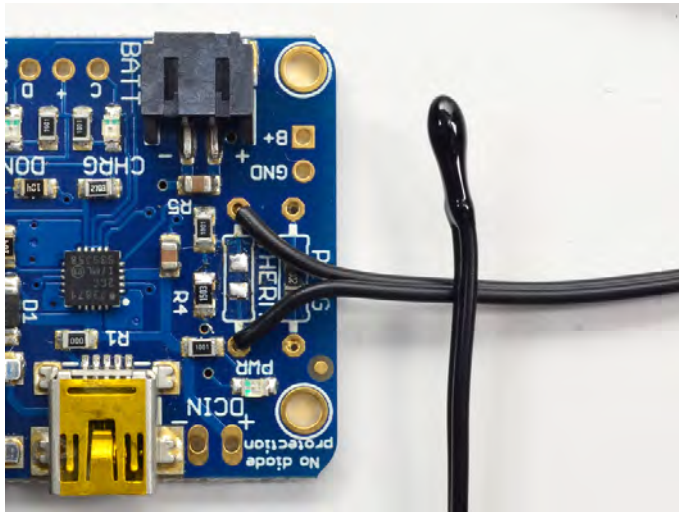
Then connect the cables; once you've done that, you have something like this:



2.2.2 - Adding temperature sensing

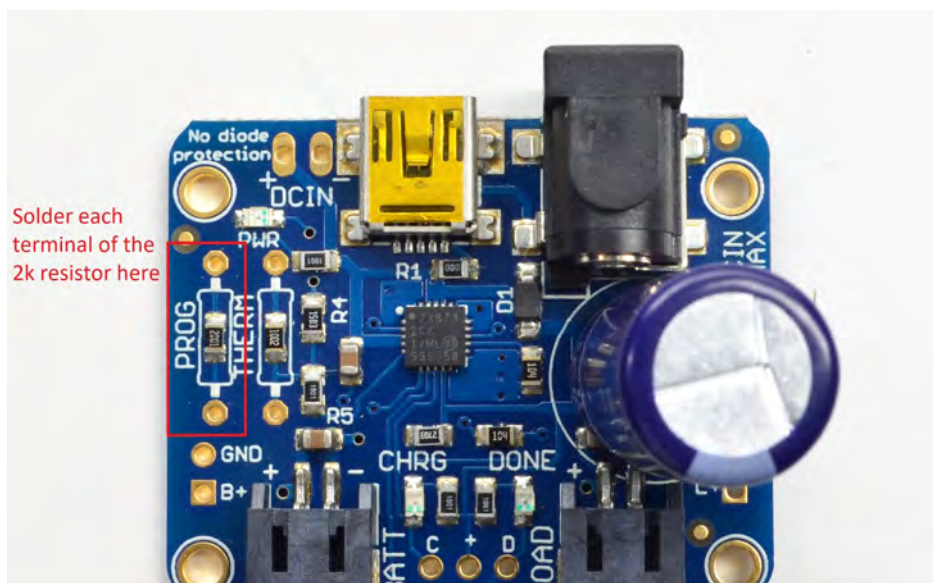
Portion reused from Adafruit tutorial:

“Remove the 10K surface mount resistor from the **THERM** pads (or cut the trace going to it) and solder in a 10K NTC thermistor. Test out the system by trying to charge while you place the thermistor in a freezer or against some ice, as well as in a cup of $> 50^{\circ}\text{C}$ hot water. The charger should stop charging the battery. Once you are sure it is working, attach the sensing element (the epoxy bulb in this case) so it is resting against the battery.”

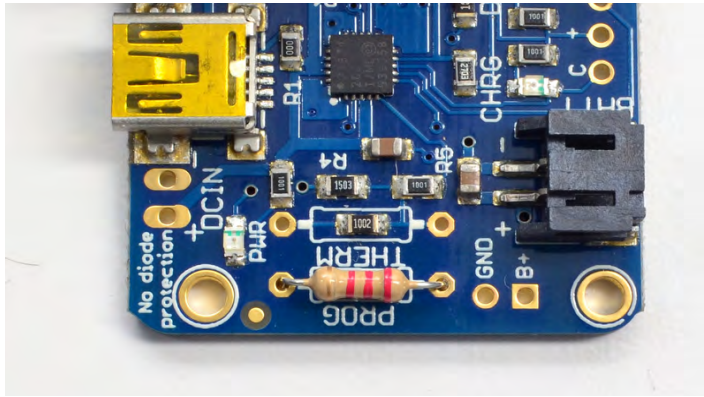


2.2.3 - Adjusting the maximum charging current

For the recommended battery (4400mAh capacity), solder a 2k-ohm resistor over the existing one in the PROG pads (or remove the existing one and solder a 1k-ohm resistor):



After doing that, you'll have a thing like this:



For details, please refer to:

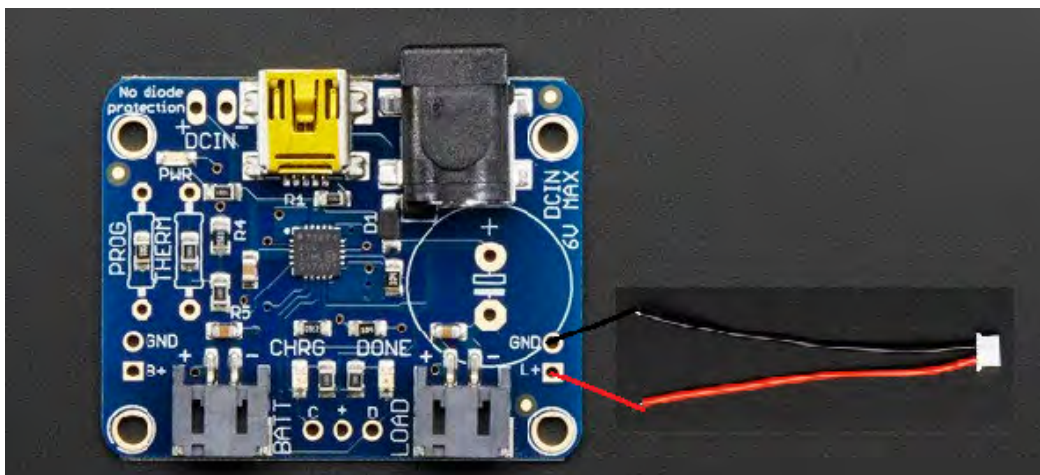
<https://learn.adafruit.com/usb-dc-and-solar-lipoly-charger?view=all#adjusting-the-max-charge-current-5-20>

Portion reused from Adafruit tutorial:

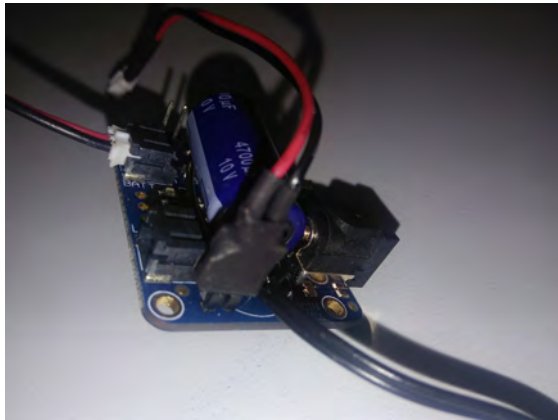
“CAUTION: This modification is indicated only for batteries bigger than 2000mAh! The USB/Solar charger comes with a preset rate of 500mA which will work for USB ports, USB wall adapters and solar panels up to 3 Watts. If you have a project that uses a larger panel, or perhaps some other sort of setup, you can easily adjust the current by soldering a resistor into the **PROG** pads.”

2.2.4 - Connecting the Arduino to power supply

You can solder the black and the red wires here to connect the Feather: we recommend applying some silicone glue to avoid breaking the wires



As an alternative, we've soldered a pair of male pins to the board and soldered a pair of female plugs to the wires, using heat-shrink tubing for protection:



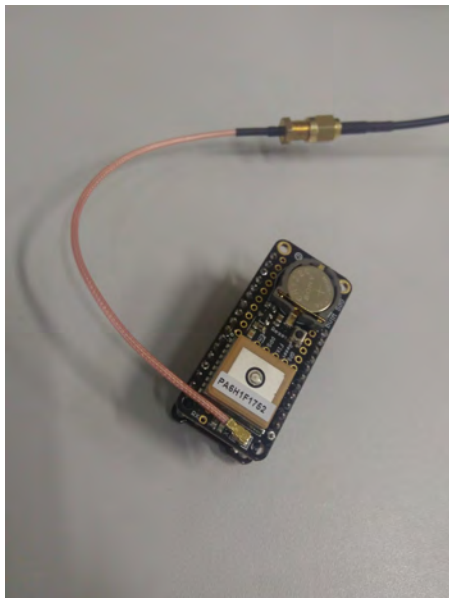
2.3 - Putting it all together

You'll need:

- 1x - SMA to uFL/u.FL/IPX/IPEX RF Adapter Cable
- 1x - 2.1mm female/male barrel jack extension cable - 1.5m / 5 ft
- 1x - 3.5 / 1.3mm or 3.8 / 1.1mm to 5.5 / 2.1mm DC Jack Adapter Cable
- all items made before

2.3.1 - Connecting the antenna

Use the adapter cable SMA to uFI to connect the GPS shield to the antenna.

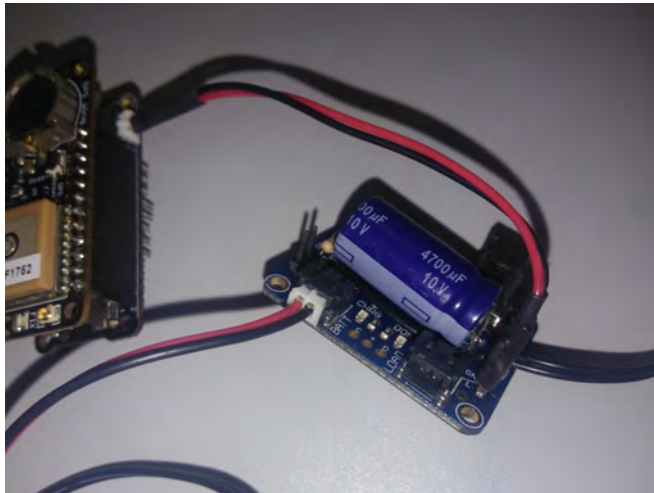


We recommend to put some silicone on the connection to avoid disconnecting by mechanical stresses:



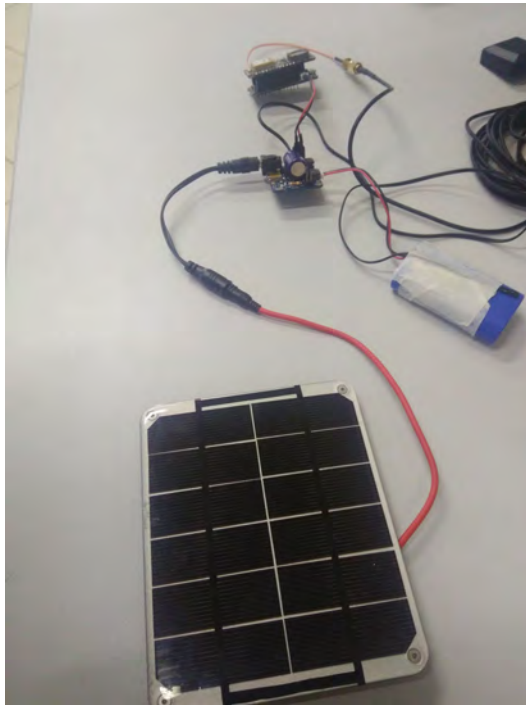
2.3.2 - Connect the power supply:

Connect the black and red wire on the Adafruit



2.3.4 - Connect the solar panel to the power supply

Use the Jack Adapter Cable to connect the solar panel to the power supply. It will recharge the battery when is sunny.



You may also use the extension cable with On/Off switch:



2.3.5 First look

This is a look of our system outside the box:



Step 3: Preparing the enclosure

You'll need:

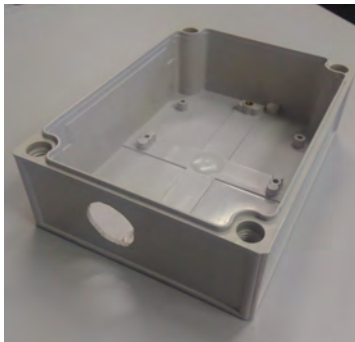
- 1x - Cable Gland PG-7 size - 0.118" to 0.169" Cable Diameter - PG-7

- 1x - Small Plastic Project Enclosure - Weatherproof with Clear Top

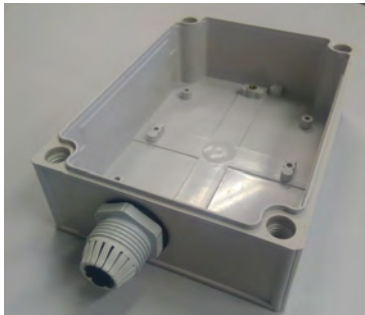
- 1x - White Nylon Screw and Stand-off Set – M2.5 Thread (optional)

<https://www.adafruit.com/product/3658>

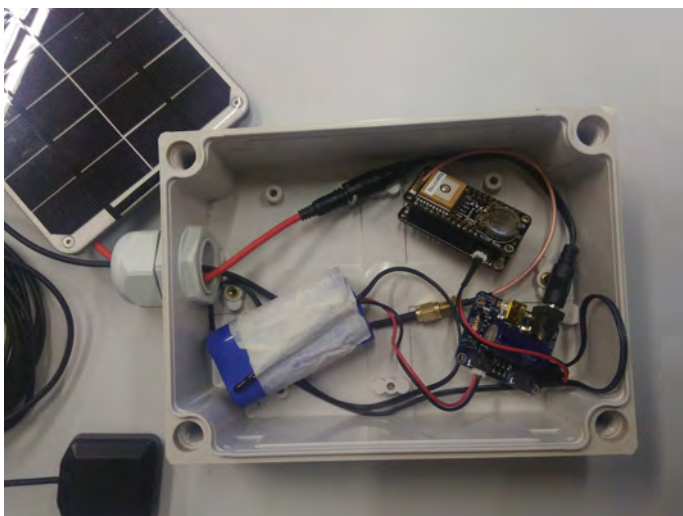
First of all you need to make a hole on the bottom side of the weatherproof box to pass the wiring through. You can use a drill or something alike to do this.



Then you install the cable gland:



Now you have to put all this inside the box, using the cable gland to pass the cables:



Step 6: Mounting it outdoors

You'll need:

- 1x - <https://www.voltaicsystems.com/small-bracket>
- 1x - stick or mast
- 1x - silver tape
- 1x - U support
- 1x - base (bi-pod, quadri-pod)

6.1 Basic precautions

Outdoors there is the risk of rain and humidity. So you need to suspend the elements as shown below. Add some little packets of silica gel to absorb moisture.



As you can see, even if water enters the enclosure it does not affect the electronics. (This picture is of another enclosure version of our system.)

For a more professional setup, our suggestion is to use stand-off pins:

<https://www.adafruit.com/product/3658>



6.2 Preparing the mast and base

Fix the antenna on the top of a mast. Make sure to have some slack on the antenna cable -- coaxial cables should not be bent!



Setup the base:

Use anchor bolts to the ground for stability.





The base anchor bolts are reinforced by inserting sealant into the hole, such as this:



Use washers and nuts to level the base.



6.3 Solar panel support

You have two options of a solar panel support: you can buy one or make your own.

This is a model that you can buy at <https://www.voltaicsystems.com/small-bracket>



Alternatively you can simply bend a metal sheet and drill holes as shown below:



6.4 Fixing the enclosure on the mast

To fix the enclosure on the mast you can use a support for TV antenna, which you can find in a hardware store. The support has holes in which you can insert bolts and nuts to hold the components.



6.5 Adjusting the solar panel orientation

The sun incidence varies according to your position on Earth. You need to check the best orientation of the solar panel.

Adjusting tilt (vertical angle):

Check this link to ensure the correct angle <https://www.solarpaneltilt.com/>

Adjusting azimuth (horizontal angle):

Face the equator, opposite from the nearest geographical pole (for example, face north in the southern hemisphere).

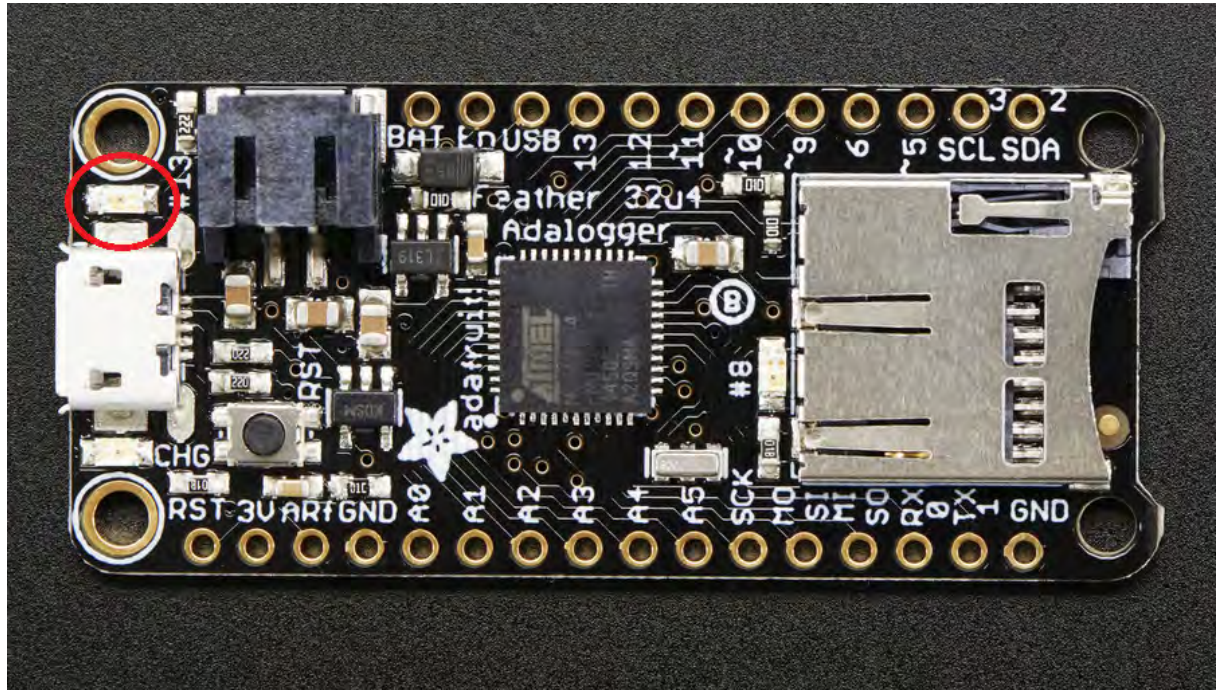


You're all done -- congratulations! :-)

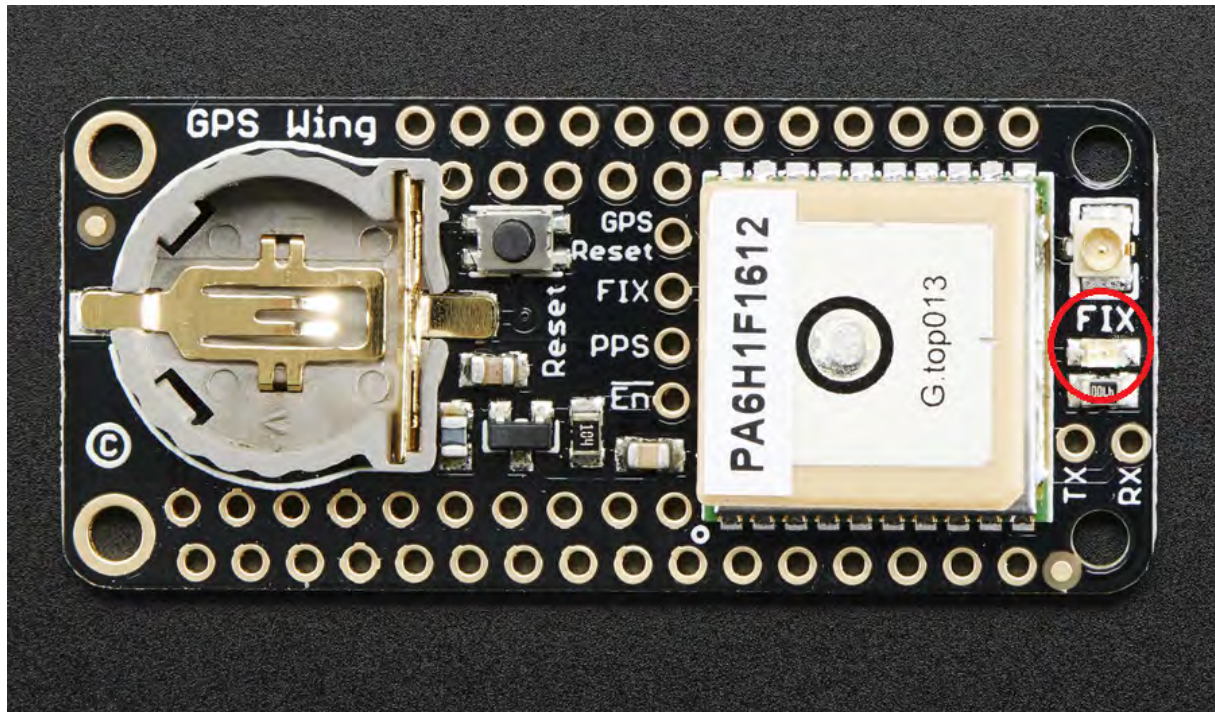
Step 7: Checks

7.1 Activity LEDs

There is a red LED on the Arduino feather, close to the USB port, which will blink every time data is written to the SD card (normally once per second):



There is another red LED in the GPS shield, near the antenna plug. It will blink once per second while searching for the satellite signals. When it has found at least four satellites, it stops blinking. Put the antenna outdoors (near a window, for example). Make sure the antenna cables are connected correctly. If that LED doesn't stop blinking you will need to put your antenna in another place because it means that the satellites are not visible.



7.2 Files in the SD card

TURN OFF the system to remove the SD card!

Plug the SD card to a PC reader open the SD card.

There will be two types of files: the .BAT and the .LOG

7.2.1 Files extensions

.LOG files

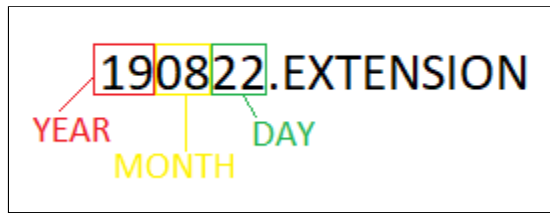
Has the raw NMEA sentences. This is the aim of the Arduino system that we've built.

.BAT files

Has information about the voltage measurement from the battery.
It can be used to monitor the battery autonomy.

7.2.2 File Names

In both extensions the file names will follow this template:



The system will automatically create a new file for each day while system is running.