Iridium 9603N Solar Beacon Prototype

Background:

Following on from the work I did on the Iridium_9603_Beacon:

https://github.com/PaulZC/Iridium_9603_Beacon

which got some nice coverage on Hackaday:

http://hackaday.com/2016/12/19/a-beacon-suitable-for-tracking-santas-sleigh/

and which flew on UBSEDS22 and sent updates all the way from the UK to China before the batteries gave up:

https://github.com/PaulZC/Iridium_9603_Beacon/blob/master/Iridium_9603_Beacon.pdf

https://github.com/PaulZC/Iridium_9603_Beacon/blob/master/UBSEDS22I_KML/iridium_linestring.kml

I decided to set myself the challenge of modifying the design of the beacon to make it solar-powered, removing the need for the lithium batteries and allowing the beacon to send updates during daylight hours for as long as the balloon continues to float.

The design I've ended up with is based largely on the prototype for the Iridium 9603 beacon https://github.com/PaulZC/Iridium_9603_Beacon_Prototype but is powered by a single PowerFilm Solar MPT3.6-150 solar panel:

http://www.powerfilmsolar.com/products/?mpt36150&show=product&productID=271537&productCategoryIDs=6573

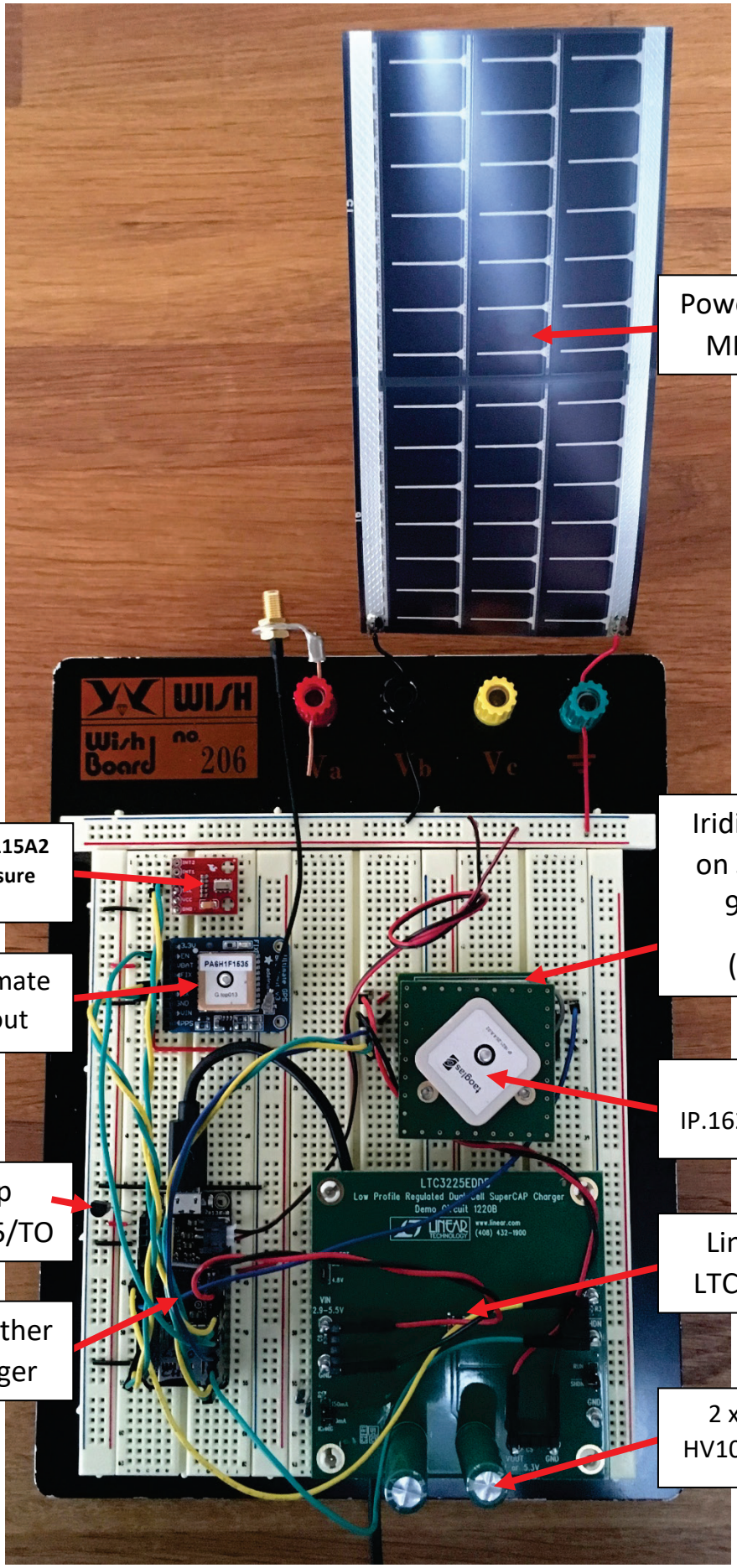
This amazing little panel weighs only 3.1g but can deliver a really useful amount of power: 100mA at 3.6V at Air Mass 1.5. This is enough to power the beacon's SAMD21G18 processor and the GPS receiver or the LTC3225EDDB super capacitor charger which delivers power to the Iridium 9603N.

The current status is that the prototype has worked successfully under full sun at sea level in the UK (during April). The next step will be to condense the design onto a single PCB and ask those nice students at Bristol University UBSEDS if they might be able to fly it on another of their small super-pressure balloons.

Tell me about the design

The key components of the Iridium 9603N Solar Beacon Prototype are:

- Iridium 9603N Module
    - Available (in the UK) from e.g.:
    - http://www.ast-systems.co.uk/Product-Pages/Iridium-9603-SBD—Satellite-Tracking-Transceiver.aspx
    - http://www.rock7mobile.com/products-iridium-sbd
    - Other UK and International distributors can be found at:
    - https://iridium.com/products/details/Iridium-9603?section=wtb
    - For breadboard prototyping, you can mount the module on a Satelligent 9603-DIP: http://satelligent.ca/products/accessories/9603-dip/
    - **Make sure you purchase the 9603N and not the older 9603** (the 9603N will run from 5V ± 0.5V which is important as the super capacitor charger will be set to produce 5.3V; the older 9603 is only rated to 5V ± 0.2V)
- Taoglas IP.1621.25.4.A.021 Iridium Patch Antenna
    - Available from e.g. Mouser (Part# 960-IP1621254A02)
    - You can mount this on a small PCB above the 9603N:
    - https://github.com/PaulZC/Iridium_9603_Beacon/blob/master/Eagle/V2/Iridium_9603_Antenna.brd
    - And connect it to the 9603N with a short Molex uFL cable (part number 73412-0508, available from Farnell / Element14 (1340201))
- Linear Technology LTC3225EDDB SuperCapacitor Charger
    - http://www.linear.com/product/LTC3225
    - For breadboard prototyping, you can use Linear's demo circuit (1220B):
        - http://www.linear.com/solutions/2187
    - Charges two e.g. Bussmann HV1030-2R7106-R 10F 2.7V capacitors (Farnell / Element14 2148486)
- Adafruit Feather M0 Adalogger
    - https://www.adafruit.com/product/2796
- Adafruit Ultimate GPS Breakout
    - https://www.adafruit.com/product/746
- SparkFun MPL3115A2 Altitude/Pressure Sensor Breakout
    - https://www.sparkfun.com/products/11084
- PowerFilm Solar MPT3.6-150 solar panel
    - http://www.powerfilmsolar.com/products/?mpt36150&show=product&productID=271537&productCategoryIDs=6573
    - Available (in the UK) from e.g.:
    - http://www.selectsolar.co.uk/prod/264/powerfilm-mpt36150-100ma-36v-mini-solar-panel



PowerFilm Solar
MPT3.6-150

SparkFun MPL3115A2 Altitude / Pressure Sensor

Iridium 9603N on Satelligent 9603-DIP

(Hidden)

Adafruit Ultimate GPS Breakout

Taoglas
IP.1621.25.4.A.021

Microchip
MCP111-195/TO

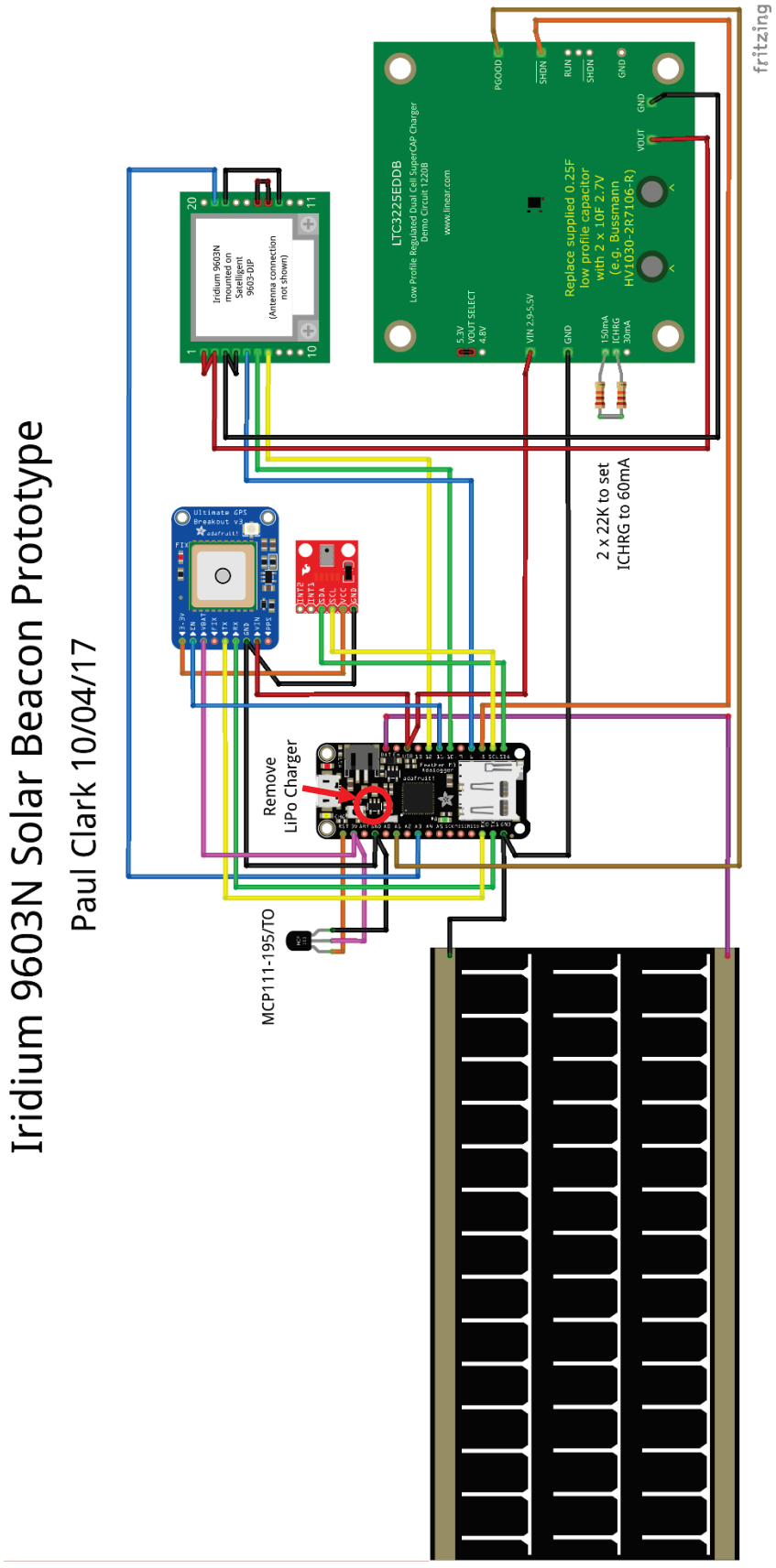
Linear Tech.
LTC3225EDDB

Adafruit Feather M0 Adalogger

2 x Bussmann
HV1030-2R7106-R

How do I connect everything?

Here's a Fritzing diagram to help:



Connect:

MPT3.6-150 Solar Panel V+	to	Adalogger BAT / VBAT (or JST LiPo V+)
MPT3.6-150 Solar Panel V-	to	Adalogger GND (or JST LiPo V-)
MCP111-195/TO VDD	to	Adalogger 3V / 3V3 (Out)
MCP111-195/TO VSS	to	Adalogger GND
MCP111-195/TO VOUT	to	Adalogger RST
Ultimate GPS 3.3V (Out)	to	Sparkfun MPL3115A2 VCC
Ultimate GPS EN	to	Adalogger D11
Ultimate GPS VBAT (In)	to	Adalogger 3V / 3V3 (Out)
Ultimate GPS Tx (Out)	to	Adalogger RxD / D0 (In)
Ultimate GPS Rx (In)	to	Adalogger TxD / D1 (Out)
Ultimate GPS GND	to	Adalogger GND
Ultimate GPS VIN (In)	to	Adalogger USB / VBUS (Out)
Sparkfun MPL3115A2 SDA	to	Adalogger SDA / D20
Sparkfun MPL3115A2 SCL	to	Adalogger SCL / D21
Sparkfun MPL3115A2 GND	to	Adalogger GND
Iridium 9603N Pin 1 (EXT_PWR) (In)	to	LTC3225EDDB VOUT
Iridium 9603N Pin 2 (EXT_PWR) (In)	to	LTC3225EDDB VOUT
Iridium 9603N Pin 3 (EXT_GND) (In)	to	LTC3225EDDB GND
Iridium 9603N Pin 4 (EXT_GND) (In)	to	LTC3225EDDB GND
Iridium 9603N Pin 5 (ON/OFF) (In)	to	Adalogger D6
Iridium 9603N Pin 6 (DF_S_TX) (**In**)	to	Adalogger D10
Iridium 9603N Pin 7 (DF_S_RX) (**Out**)	to	Adalogger D12
Iridium 9603N Pin 13 (DF_RTS) (In)	to	Iridium 9603N Pin 18 (SIG_GND)
Iridium 9603N Pin 14 (DF_DTR) (In)	to	Iridium 9603N Pin 15 (SIG_GND)
Iridium 9603N Pin 19 (Net Avail) (Out)	to	Adalogger A3 / D17
LTC3225EDDB VIN	to	Adalogger USB / VBUS (Out)
LTC3225EDDB GND	to	Adalogger GND
LTC3225EDDB PGOOD	to	Adalogger A1 / D15
LTC3225EDDB SHDN	to	Adalogger D5

Tell me about the Arduino code

You can find the Arduino code for the Adalogger in:

https://github.com/PaulZC/Iridium_9603N_Solar_Beacon/tree/master/Iridium9603NSolarBeaconPrototype

The code is based extensively on Mikal Hart's IridiumSBD Beacon example:

https://github.com/mikalhart/IridiumSBD/tree/master/examples/Beacon

The main loop is structured around a large switch / case statement which:

- Initialises the serial ports; checks the solar panel voltage
- Powers up the GPS and MPL3115A2; checks the solar panel voltage
- Waits until the GPS establishes a fix; checks the solar panel voltage
- Reads the temperature and pressure from the MPL3115A2
- Powers down the GPS and powers up the LTC3225EDDB supercapacitor charger; checks the solar panel voltage
- Waits for the supercapacitors to charge; checks the solar panel voltage
- Queues the Iridium message transmission; checks the solar panel voltage
- Powers everything down and puts the processor to sleep until the next alarm interrupt

If the solar panel voltage falls below a useful level at any time, the code jumps to the sleep case and waits for the next alarm interrupt.

Do I need the reset supervisor?

The SAMD21G18 has a built-in power-on reset and brown-out detector circuit, but the solar panel will ramp up its output voltage very slowly at sunrise so I would recommend including a separate reset supervisor. The Microchip MCP111-195 has an open drain output which can be used to reset the processor whenever the 3.3V supply falls below 1.95V.

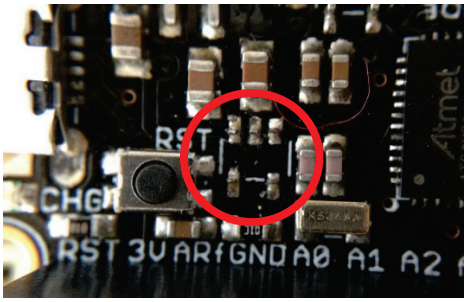
The SAMD21G18 datasheet isn't much help here. Section 8.2.4.1 specifies:

> ***Minimum Rise Rate***
>
> *The integrated power-on reset (POR) circuitry monitoring the VDDANA power supply requires a minimum rise rate.*

But then the supply characteristics section (37.4) specifies a ***maximum*** supply rise rate of 0.1V/µs. The solar panel rise rate will be much slower than that.

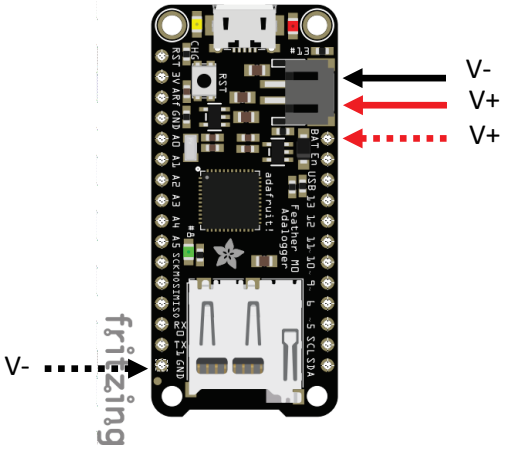
Do I need to modify the Adalogger?

Yes. You'll need to remove the LiPo charger chip, otherwise when you connect to the Adalogger via USB the LiPo charger will attempt to charge the solar panel which will almost certainly damage it. The easiest way to remove the LiPo charger is to carefully cut through the chip legs with a scalpel blade.

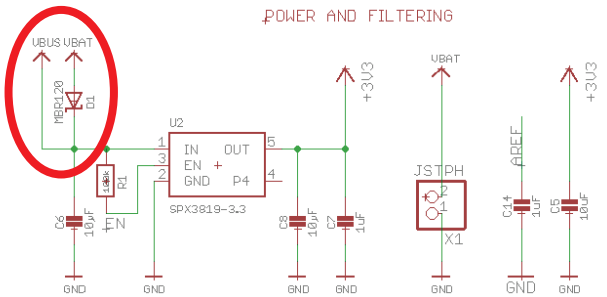


Where do I connect the solar panel?

If you have a convenient cable with a JST connector on the end, maybe a cable taken from an old LiPo cell, you can connect the solar panel directly to the Adalogger LiPo battery connector. If you don't have a suitable cable, connect the panel V+ strip to the BAT pin and the V- strip to GND:



We use the BAT connection as it includes an MBR120 diode which will protect the solar panel when the Adalogger is powered via USB:



Do I need to modify the LTC3225EDDB Demo Circuit?

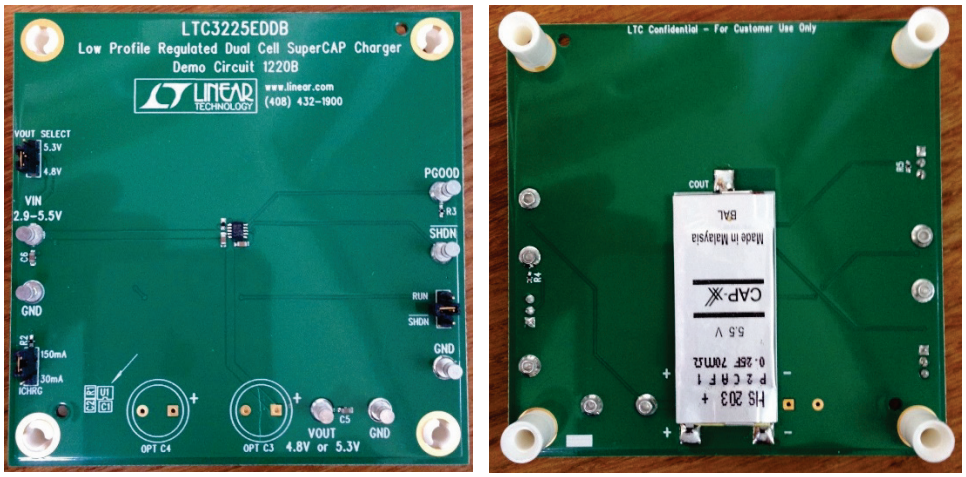
Yes. You'll need to remove the slim 0.25F capacitor from the back of the PCB and add two e.g. Bussmann HV1030-2R7106-R 10F 2.7V capacitors instead. You can also solder pin headers onto the terminals to make it easy to use hook-up wires and glue single pin headers into the legs so it will sit securely in breadboard.

Bizarrely, Linear decided to use a four layer board and provided no thermal relief on the C4 –ve pin. This makes it almost impossible to solder. I had to leave the capacitor leg long, bend it over and solder it to the –ve pad for the original slim capacitor.

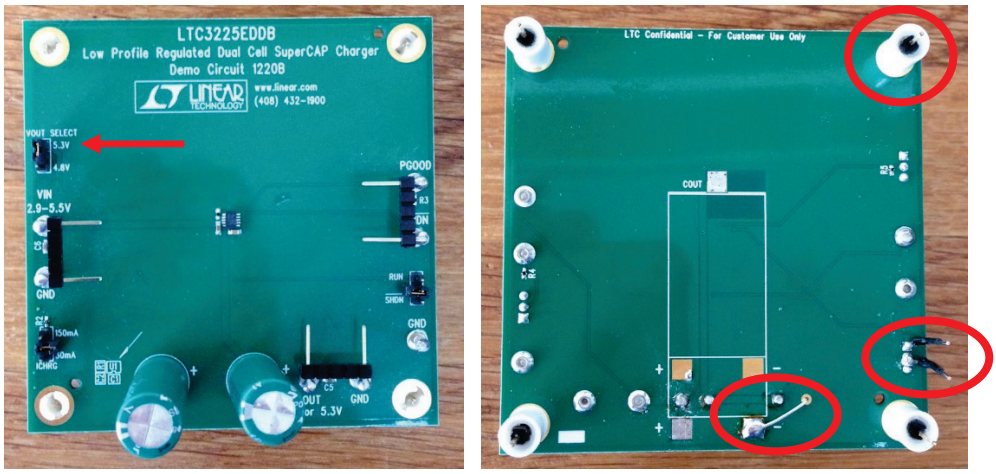
Make sure that:

- The VOUT_SELECT jumper link is set to 5.3V
- The RUN/SHDN and ICHRG jumper links are removed

From this:

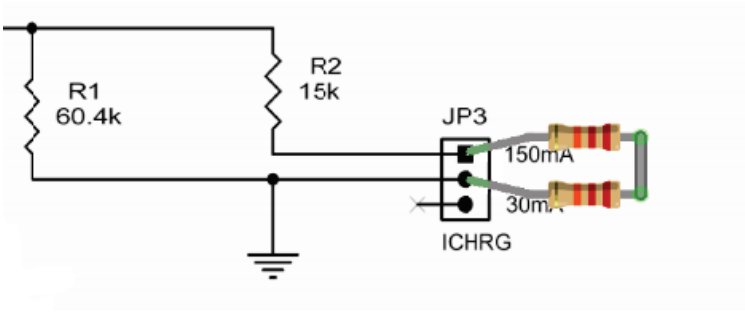


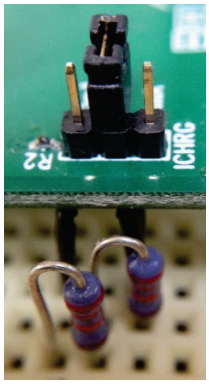
To this:



To set the charge current to 60mA:

- Solder two short lengths of solid core wire to two pins on the ICHG header
- Bend these wires down, cut and strip them to the correct length so they can poke into breadboard
- Add two 22K resistors in series to change the combined PROG resistance to 30K (60.4K in parallel with 15K + 22K + 22K)
- http://cds.linear.com/docs/en/demo-board-manual/dc1220B.pdf





Why 60mA?

The datasheet for the 9603N quotes: an average idle current of 34mA; and an average receive current of 39mA. We need to charge the capacitors at a higher current than this, but keep the total current draw within what the solar panel can deliver.

Why do you need the Super Capacitors?

The Iridium 9603 module draws an average current of 145mA and a peak current of 1.3A when transmitting its short data bursts. That's too much for the solar panel to provide. The LTC3225 super capacitor charger draws 60mA from the panel to charge two 10F 2.7V capacitors, connected in series, to 5.3V. The capacitors then deliver the 1.3A to the module when it sends the data burst.

Will you modify the design for the PCB version?

Yes. The main changes will be:

- Replace the GlobalTop FGPMMOPA6H GPS receiver (used on the Adafruit Ultimate GPS Breakout) with the u-blox SAM-M8Q:
  - https://www.u-blox.com/en/product/sam-m8q-module
- Add a second MPT3.6-150 solar panel with its own MBR120 diode

Can I leave the Adalogger USB connected during testing?

Yes. Leaving the USB connected is useful as you can monitor the Serial messages produced by the code in the Arduino IDE Serial Monitor. If you use a standard USB cable then the Adalogger will draw its power from USB. To test the prototype running on solar power, you will need to break the USB 5V power connection. You can do this with a home-made power-break cable. Take a short male to female USB extension cable; carefully strip the outer sheath from cable somewhere near the middle; prise apart the screen connection to reveal the four USB wires (red (5V); black (GND); green and white (data)); cut and insulate the ends of the red 5V wire leaving the black, green and white wires and the screen connection intact:

Thanks!

I'm very grateful to Richard Meadows and his fellow students at UBSEDS (University of Bristol Students for the Exploration and Development of Space).

http://www.bristol-seds.co.uk/

I'm also very grateful to the UKHAS (UK High Altitude Society) team who provide the habhub flight tracker:

https://ukhas.org.uk/

http://tracker.habhub.org/

This project wouldn't have been possible without the open source designs and code kindly provided by:

- **Adafruit**:
  - the Adafruit SAMD Board library

    - the design for the Feather M0 Adalogger
        - For more details, check out the product page at
            - https://www.adafruit.com/product/2772
        - Adafruit invests time and resources providing this open source design, please support Adafruit and open-source hardware by purchasing products from Adafruit!
        - Designed by Adafruit Industries.
        - Creative Commons Attribution, Share-Alike license
    - the MPL3115A2 library
    - sercom examples
        - https://learn.adafruit.com/using-atsamd21-sercom-to-add-more-spi-i2c-serial-ports/creating-a-new-serial
- **Mikal Hart**:
    - the Iridium SBD library (distributed under the terms of the GNU LGPL license)
    - TinyGPS
    - PString
- **Sparkfun:**
    - the MPL3115A2 Breakout
        - https://www.sparkfun.com/products/11084
- **Arduino**:
    - the Arduino IDE
    - Arduino SAMD Board library
    - RTCZero library
- **Cave Moa**:
    - the SimpleSleepUSB example
        - https://github.com/cavemoa/Feather-M0-Adalogger/tree/master/SimpleSleepUSB
- **MartinL**:
    - sercom examples
        - https://forum.arduino.cc/index.php?topic=341054.msg2443086#msg2443086

The small print