SwitchDoc Labs

SolarMax Lead Acid Assembly and Testing Guide

March 2020
Version 1.5

For powering solar systems such as systems based on the Raspberry Pi, Arduino and ESP32/ESP8266 and the SwitchDoc Labs System

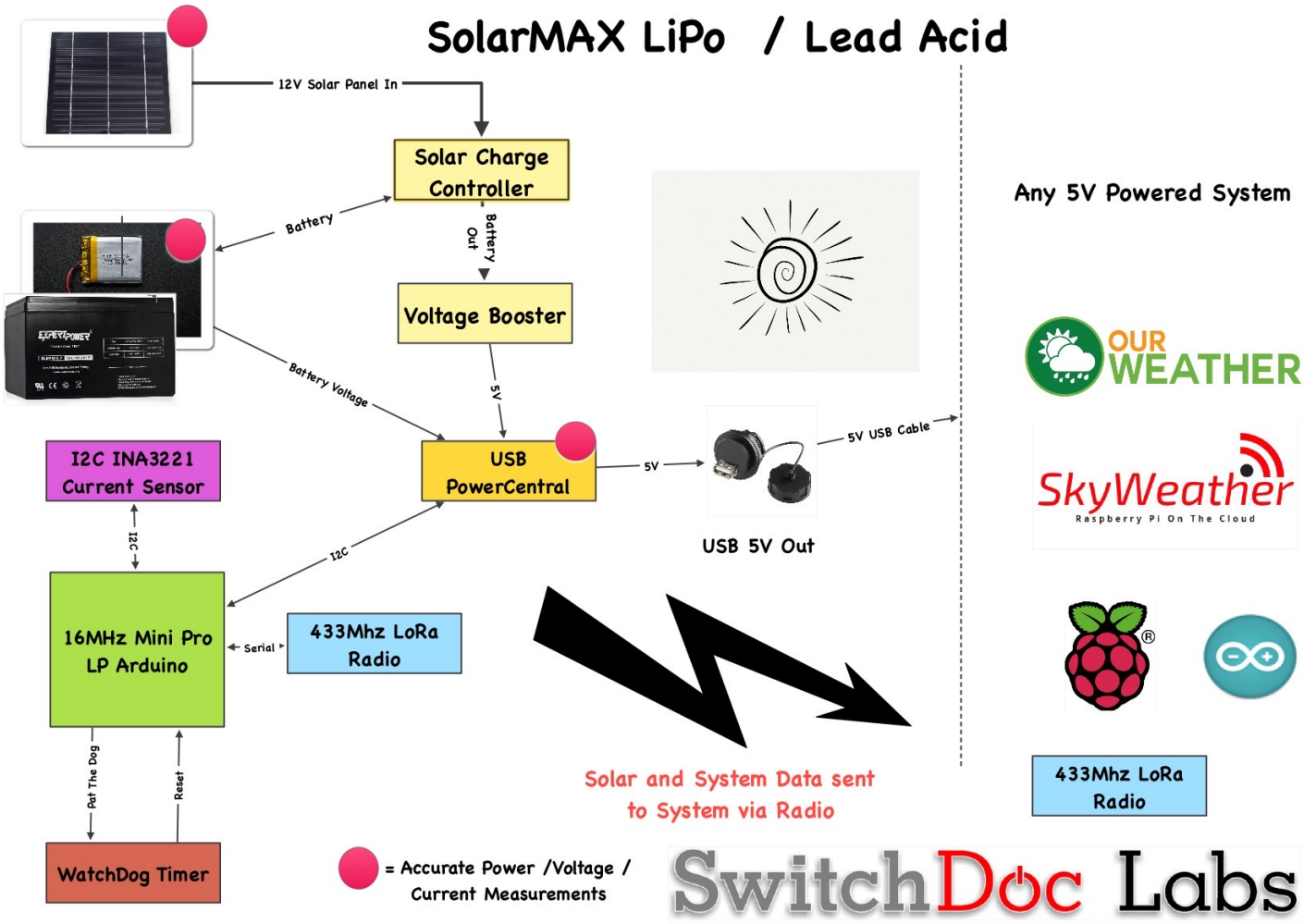
Table of Contents

Errata

Version 1.3 - Removed single jumper pin from LIPOBATIN to 5V. Added Grove cable from Arduino Mini Pro LP to USB PowerCentral Enable/Control port to implement hysteresis during low power conditions. See article on www.switchdoc.com

Version 1.4 - Removed step W8 - Not needed

Version 1.5 - Added Raspberry Pi Serial Port Configuration



What is SolarMAX Lead Acid?

SolarMAX Lead Acid is a SwitchDoc Labs designed system to charge Lead Acid batteries from 18V Solar panels in order to provide more power to small computer systems. SolarMAX is designed to collect and return data about the solar panel system to the powered (or other) computer via a LoRa link. SolarMAX collects and transmits the following data every 30 seconds:

- Battery Voltage
- Battery Current
- Solar Panel Voltage
- Solar Panel Current
- Load Voltage
- Load Current

It also supplies the following about inside the SolarMAX box:

- Inbox Temperature
- Inbox Humidity

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SolarMAX uses a 433MHz LoRa module which can transmit up to 2 kilometers or further with larger antennas and uses very little power.

This is a perfect system for powering SkyWeather and other small computer systems.

SolarMAX Specifications

Table 1-1

Solar Max LeadAcid				Solar Max LeadAcid
	Minimum	Nominal	Maximum	
Solar Panel Voltage	15V	18V	18V	Solar Panel Voltage
Solar Panel VOC			25V	Solar Panel VOC
5V Load Current			5A	5V Load Current
Solar Charging Current			4A	Solar Charging Current
Battery Type		12V Lead Acid		Battery Type
Size of Battery		Large		Size of Battery
Cost of Battery		Low		Cost of Battery
Available Output Voltages		5V, 12V		Available Output Voltages

What is in the SolarMax Lead Acid Kit?

- High Current INA3221 with Terminals
- Solar Charger for 12V Lead Acid Batteries
- USB PowerCentral
- Dual WatchDog Timer
- 16MHz Mini Pro LP
- 6 Port I2C Hub
- HDC1080 Temp Hum
- LoRa 433MHz Radio
- LoRa 433MHz Radio
- MC4 Plus Female (and Pin)
- MC4 Minus Male (and Pin)
- USB Weatherproof Plug
- Short USB Cable Type A - Type A
- 20cm Grove Cables - 7 Cables
- Grove Connector to Female Pin Headers - 1 Cable
- Single Wire Female to Female Jumper - 2 Wires

What Else is Required for the SolarMax Lead Acid Kit?

12 V Lead Acid battery - We recommend >= 20000mAh - https://amzn.to/2qGCVd8 (This battery fits PERFECTLY in the Bud Enclosure below)

M2 Nylon Hex Thread Assortment - https://shop.switchdoc.com/products/140pcs-box-m2-nylon-hex-thread-assortment-kit

Solid Core Hookup Wire 22 Gauge - https://amzn.to/3202Ppa

Bud Enclosure NBB-22241 Style B - 6-25/32" x 10-23/32" x 6-25/32" - https://amzn.to/2zk8B8R

Spade Quick Connect Crimp Cold-Pressed Terminals (for 12V Battery) - https://amzn.to/2OgxqLm

You can buy all the above from SwitchDoc Labs as the SolarMAX Weather Proofing Kit.

100W 12V Solar Panel with MC4 Connectors - https://amzn.to/2rjjmYi (VOC 21.6V Max Power 17.4V)

Optional

Solar Panel Crimping tools for MC4 (optional) - https://amzn.to/2U6IN9J

Tools

Soldering Iron
Straight blade Small Screwdriver
Crosspoint Small Screwdriver
Super Glue
Silicon Caulking
Wire cutter
Wire stripper
Pliers

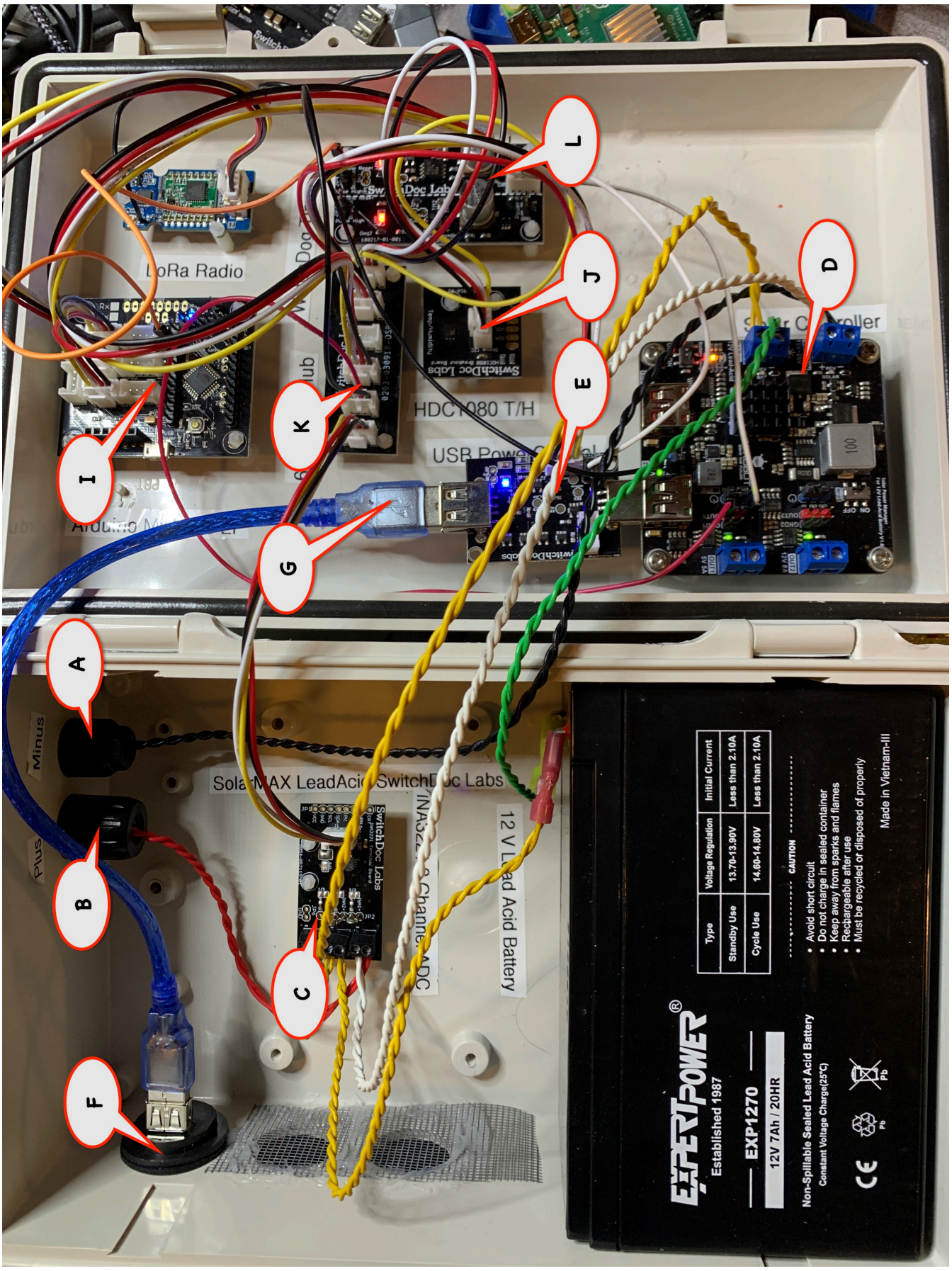
Drill
Drill Bits for:
1” holes
2/3” holes

SolarMax Lead Part Identification

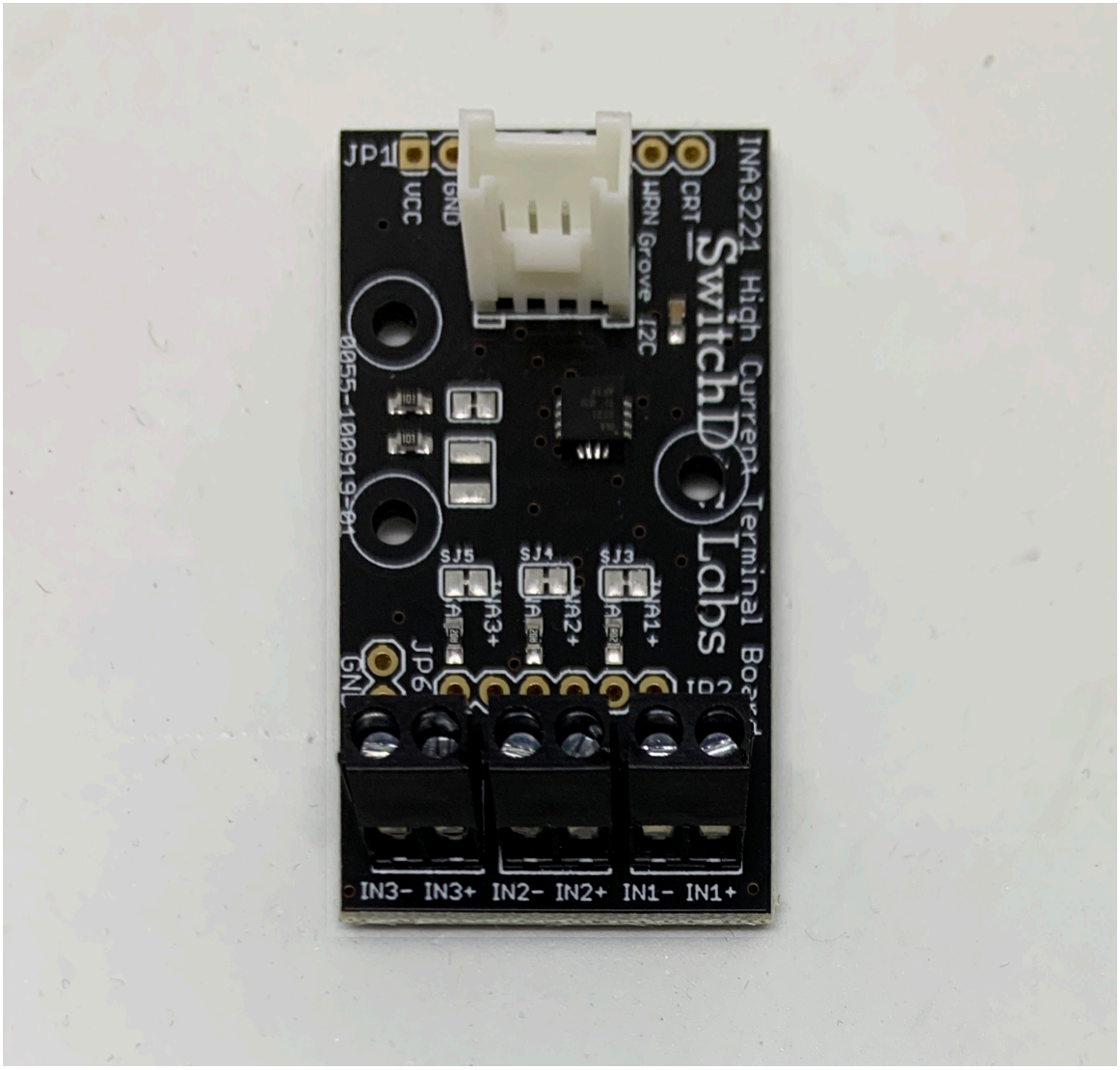
- **Part A - MC4 Minus Male (and Pin)**
- **Part B -MC4 Plus Female (and Pin)**
- **Part C -High Current INA3221 with Terminals**
- **Part D -Solar Charger for 12V Lead Acid Batteries**
- **Part E - USB PowerCentral**
- **Part F - USB Weatherproof Plug**
- **Part G - Short USB Cable Type A - Type A**
- **Part H - Identical LoRa 433MHz Radio (one for SolarMax)**
- **Part H - Identical LoRa 433MHz Radio (one for receiving Computer)**
- **Part I - 16MHz Mini Pro LP**
- **Part J - HDC1080 Temp Hum**
- **Part K - 6 Port I2C Hub**
- **Part L - Dual WatchDog Timer**

Cables

- **20cm Grove Cables - 6 Cables**
- **Grove Connector to Female Pin Headers - 1 Cable**
- **Single Wire Female to Female Jumper - 2 Wires**


A
B
C
D
E
F
G
I
J
K
L
LoRa Radio
HDC1080 T/H
Minus
Plus
12 V Lead Acid Battery
EXPERT POWER
Established 1987
EXP1270
12V 7Ah / 20HR
Non-Spillable Sealed Lead Acid Battery
Constant Voltage Charge(25°C)
Type
Standby Use
Cycle Use
Voltage Regulation
13.70-13.90V
14.60-14.80V
Initial Current
Less than 2.10A
Less than 2.10A
CAUTION
Avoid short circuit
Do not charge in sealed container
Keep away from sparks and flames
Rechargeable after use
Must be recycled or disposed of properly
Made in Vietnam-III

Note: Part C (High Current INA3221) will look like the picture below:



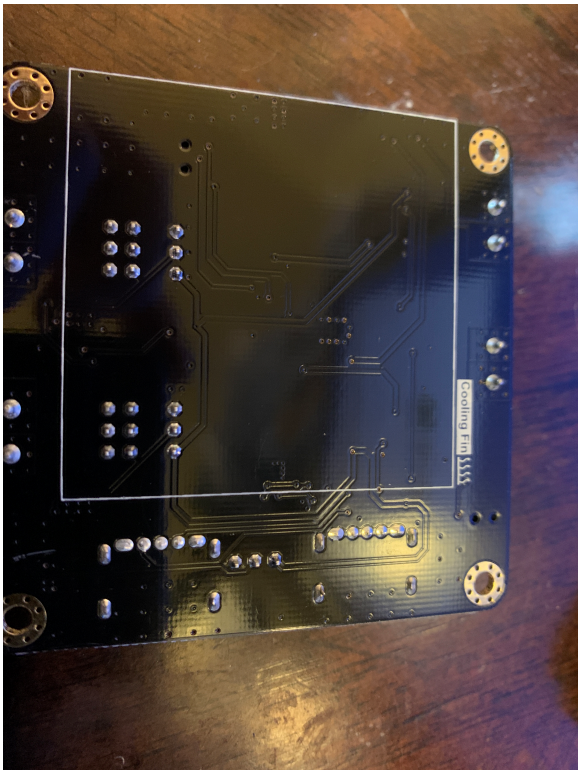
Step by Step Assembly

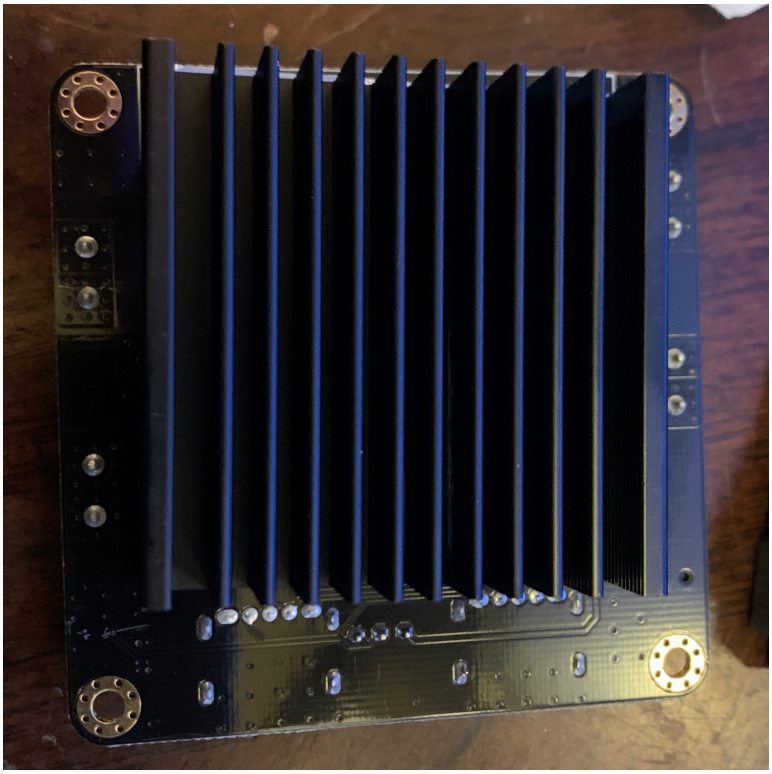
Step 1) Drill two 2/3” holes in the upper left side of the lower part of the Bud Box. (See Part A and Part B location on pictures above)

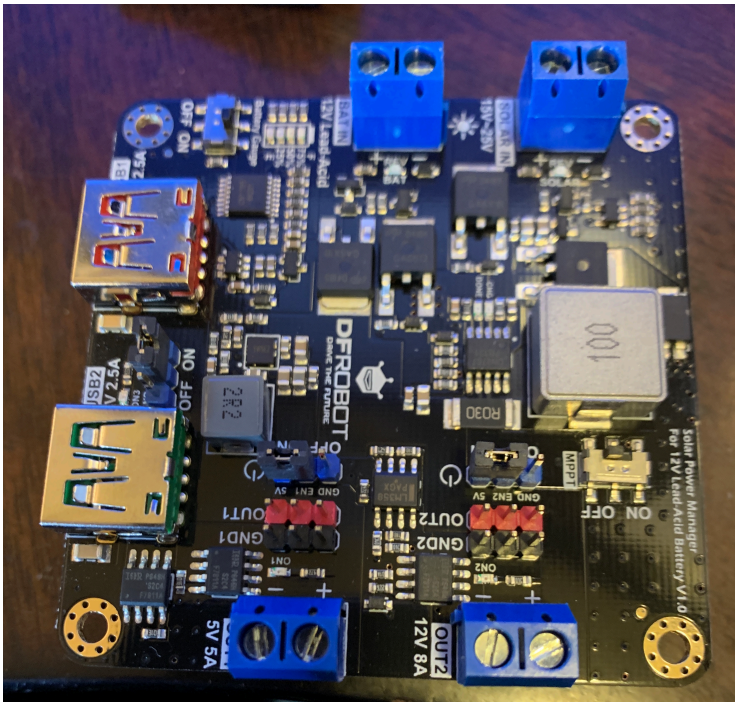
Step 2) Drill 3 1” holes in the front of the lower part of the box. Separate the holes by at least 2 inches, center to center. (Two vent holes and one hole for the Part F- USB Weatherproof Plug.

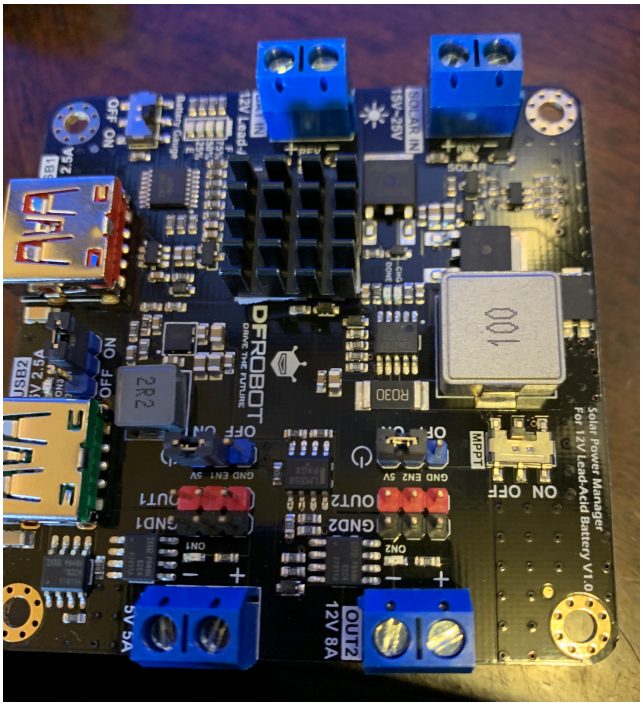
Step 3) Insert Part F - USB Weatherproof Plug into the BUD Box, with the cap on the outside in the rightmost 1” hole. Screw down.

Step 4) Place the large heat sink on the back of Part D, the Solar Controller. Place the smaller heat sink on the top of Part D, the Solar Controller. If the heat sinks don't want to stay on, us a small amount of superglue under the heat sinks.

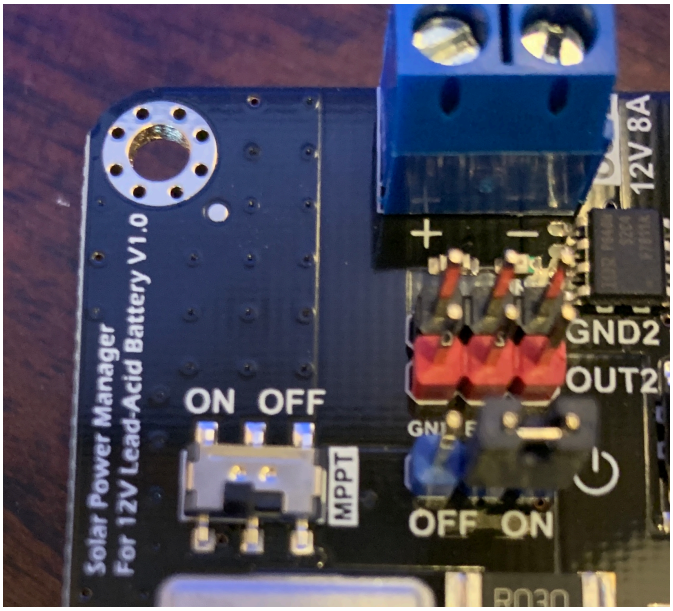


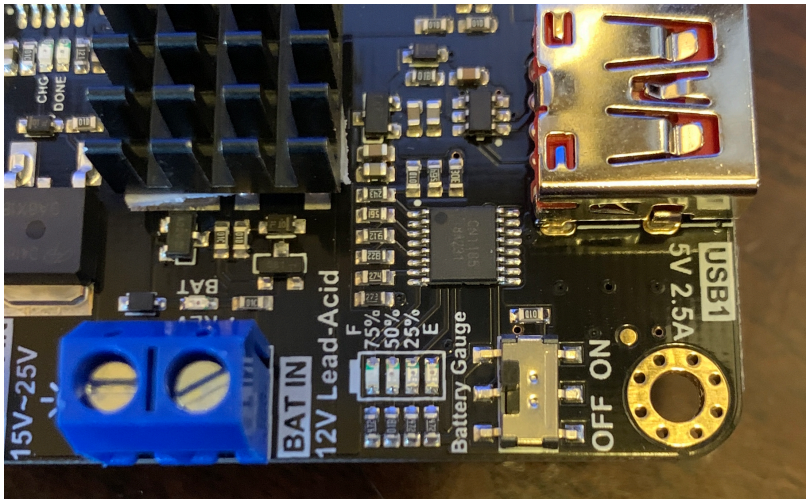






Step 5) Set the slide switch on the Solar Charger (Part D) to MPPT for the most efficient charging. Then set the Battery Gauge slide switch to Off also on the Solar Charger (Part D).





Step 6) Attach Nylon Headers (with screws or nuts) to all the boards (Parts C, D, H, I, J, K and L). Note: Part E (USB PowerCentral) will hang off the Solar Control by itself without supports. Feel free to add them if you wish! Note that the Solar Charger has screws and headers included in the package with the heatsink.

Step 7) Glue an additional nylon spacer on Part J (HDC1080 Temp/Humidity Sensor) and two on Part C (INA3221) the same height of the spacers from Step 5) to provide a stable base.

Step 8) Removed

Step 9) Removed

Step 10) Using the super glue, attach all the boards to the locations shown in the two two part identification pictures above. Let dry. The plug in the USB PowerCentral board (Part E) into the Solar Charger Board (Part D). Note you won't have the battery in the box yet. But it's OK if you do.

Step 11) Label all parts - optional - but you will be happy you did.

Step 12) Using some Silicon Caulking, attach some door screen over the center and left 1" hole to keep the bugs out of the box.

Now we move on to the wiring of the SolarMAX Lead Acid.

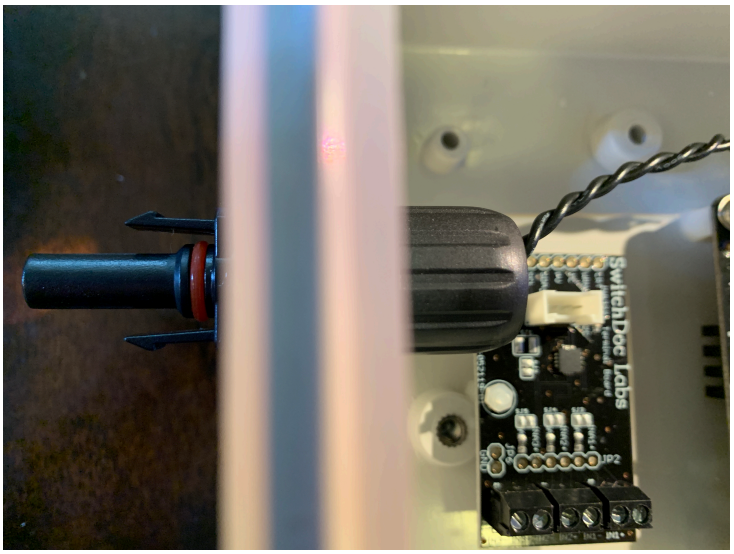
Wiring the SolarMax Lead Acid

As you wire this unit, remember you are dealing with lots of current and voltages. Triple check your wiring! Wiring things backwards or incorrectly can result in destruction of the electronics and possible over heating. BE CAREFUL!

Solar Panel Wiring

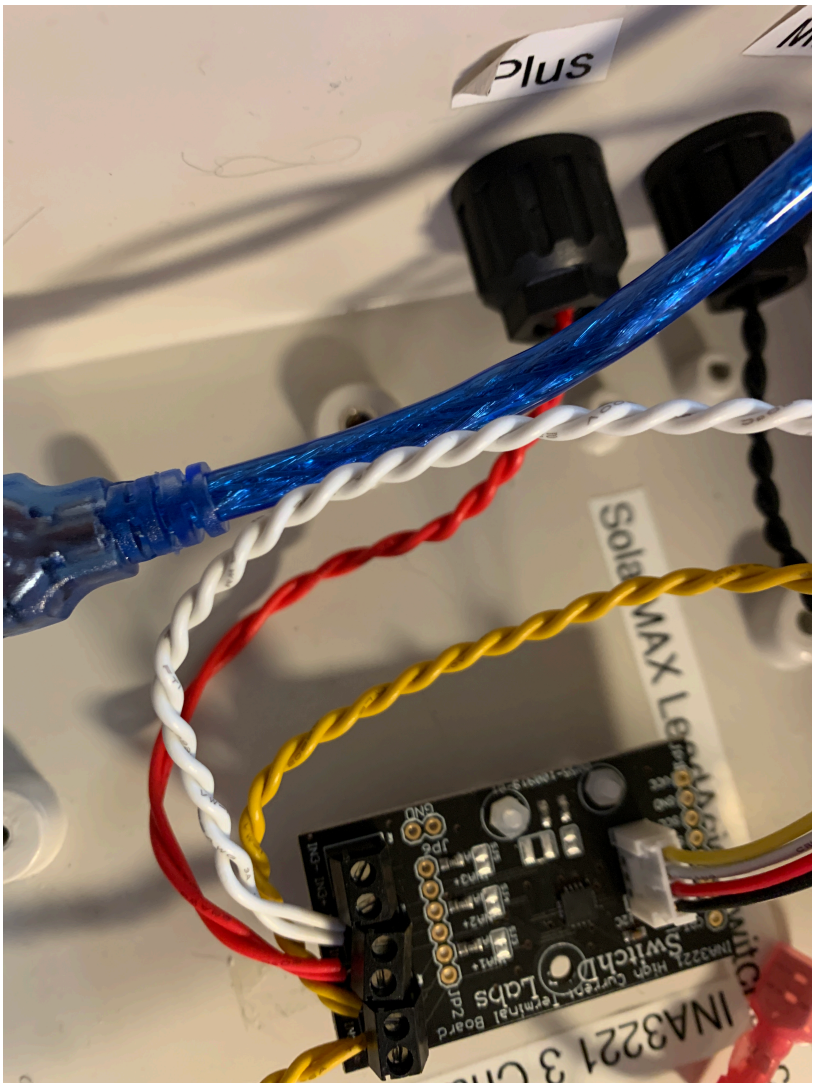
Step 1) Take the male Part A - MC4 Minus Male (and Pin) and two 33cm lengths of black wire. Strip the ends, twist them together (here's a fast way of doing that - https://www.switchdoc.com/2015/07/handy-tip-building-braided-cables-for-projects/). **NOTE: We have now determined that if you are using 22 AWG wire you do not need to to double the wires. One wire is sufficient for all the currents used inside the box.**

Now insert one end of the braided wire (with then ends stripped of the insulation) into the pin (the male pin has the larger hole in the end) and crimp it down. We recommend you buy the crimper tool for MC4 plugs as mentioned above. Slide the Male MC5 Plug into the Minus Hole in the box and put on the other parts and screw it down.

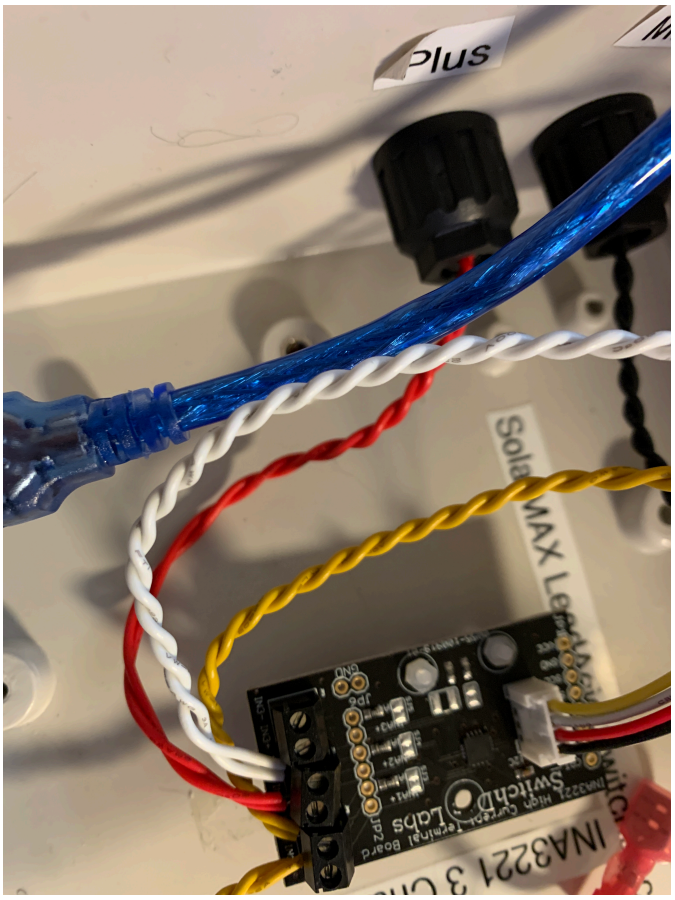


Step 2) Place the other end of the black wire into the "-" terminal of the Solar Charger SOLAR IN terminal.

Step 3) Using red 10cm long wires, braid them together, strip, crimp then and assemble the female MC4 and install it in the Plus Hole in the box. Run the end of this wire to the 3 Channel INA3221 ADC (Part C) and secure them in the IN2+ screw terminal.



Step 4) Using Red 38cm long wires (We used White in the pictures above), braid them together and strip the ends. Run this wire from the 3 Channel INA3221 ADC (Part C) IN2- screw terminal to the "+ terminal on the Solar Charger (Part D) in the SOLAR IN block.



This completes the Solar Panel Wiring. CHECK YOUR WORK! You will destroy the electronics if you mess up with this wiring.

Now we move on the Grove Wiring table.

Grove Wiring Table

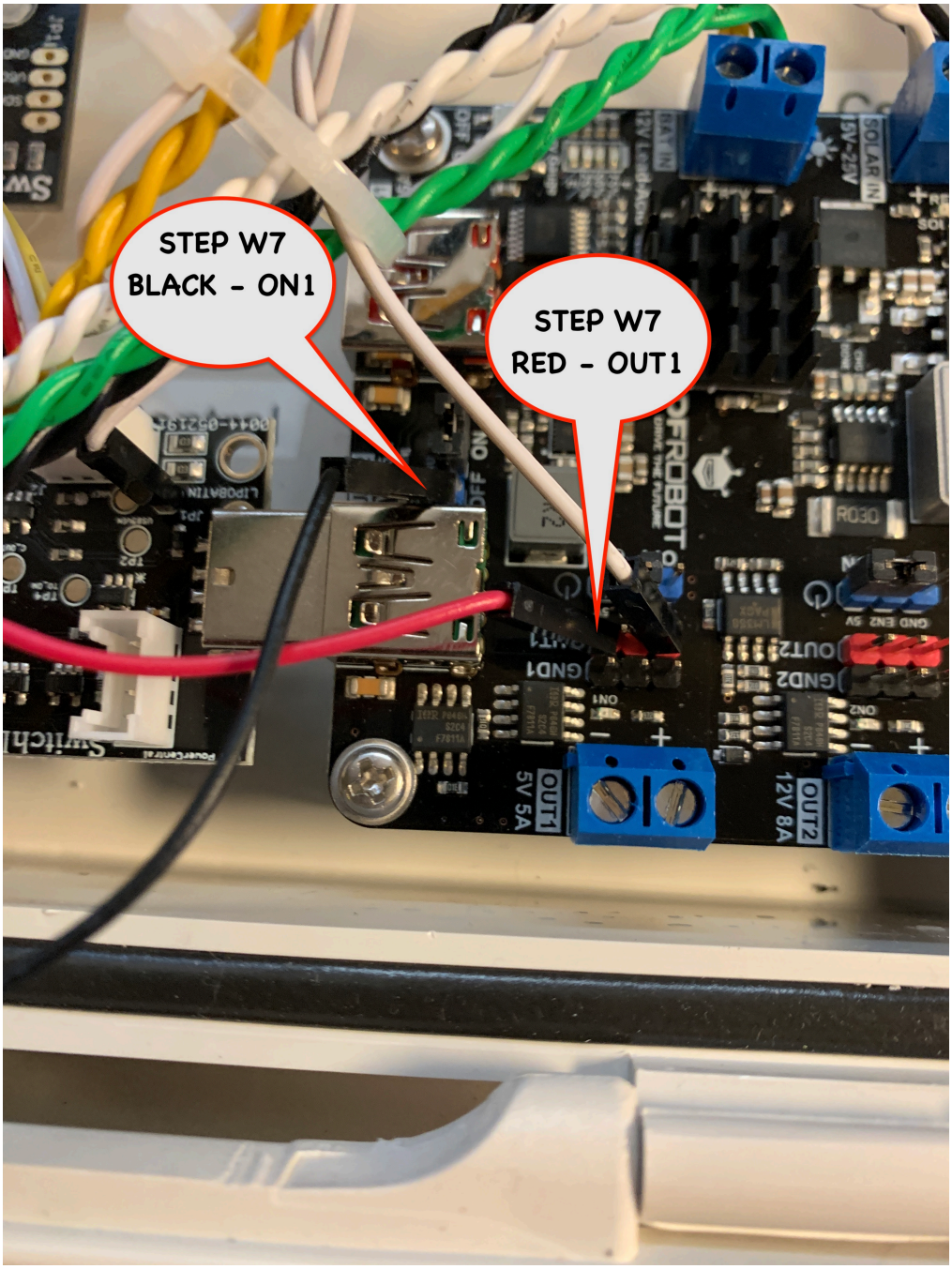
Note - again, make sure you are connecting things to the right places. It all matters. Optional: We find the plastic clips on the Grove cable plugs annoying and often cut them off with wire clippers.

Select the proper grove cables and connect them as shown in the table.

SolarMAX Lead Acid Grove Wiring Table				
Step #	Cable Type	From	To	Notes
Step W1	20cm Grove	Grove Connector on INA3221 Part C	Any Port on the 6 Port I2C Hub (Part K)	
Step W2	20cm Grove	Grove Connector Marked I2C on USB PowerCentral (Part E)	Any Port on the 6 Port I2C Hub (Part K)	
Step W3	20cm Grove	Grove Connector on HDC1080 Temp/ Humidity (Part J)	Any Port on the 6 Port I2C Hub (Part K)	
Step W4	20cm Grove	Grove Connector Marked Grove I2C on Mini Pro LP (Part I)	Any Port on the 6 Port I2C Hub (Part K)	
Step W5	20cm Grove	Grove Connector Marked D6/D7 on Mini Pro LP (Part I)	Grove Connector on LoRa TX (Part H)	

SolarMAX Lead Acid Grove Wiring Table				
Step #	Cable Type	From	To	Notes
Step W6	20cm Grove	Grove Connector Marked D8/D9 on Mini Pro LP (Part I)	Grove Connector on WatchDog Timer (Part L)	
Step W7	20cm Grove With Female Headers	Any Port on the 6 Port I2C Hub (Part K)	Red Wire to OUT1 Pin (red header) - Black Wire to GND1 (black header LABLED ON1 - See picture below) on Solar Charger (Part D)	Clip the Yellow and White wires near the Grove Plug
Step W8	Removed			
Step W9	20cm Grove	Grove Connector Marked D3/D4 on Mini Pro LP (Part I)	USB PowerCentral Control/ Enable Grove Connector	

The below picture shows the results of Step W7 from above. **Don't get this wrong! Check it again!**



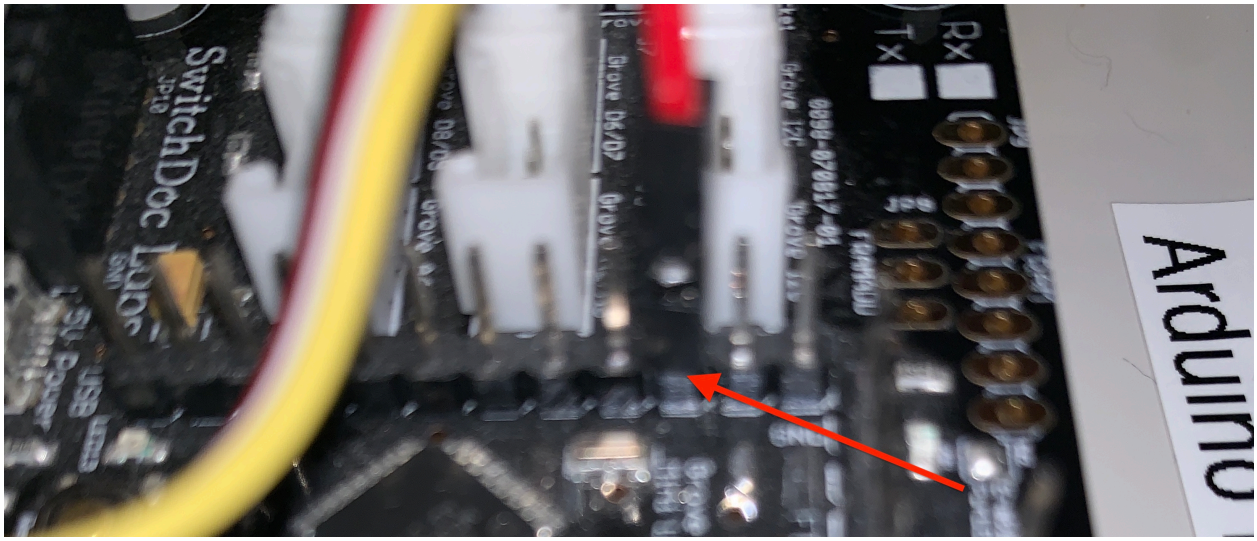
This completes the Grove Wiring for SolarMAX Lead Acid. Next is the jumper wiring.

Jumper Wiring

Step 1) REMOVED

Step 2) Take a Female to Female single wire jumper and connect it to the Arduino Reset on plug JP4 on the WatchDog Timer board (see picture).

Step 3) Then connect the other end of the wire in Step 2) it to the 3rd to the left most pin on the second row of the male pins on the Mini Pro LP Arduino board (Part I). See the picture below to get it right! This is the wire that is connected to the WatchDog timer board. If the WatchDog timer is not patted by the Arduino periodically, then the WatchDog reboots the Arduino Mini Pro LP. This makes sure the computer doesn't get lost and powers up correctly regardless of the funky way the power comes on from the solar panels. :)



If your jumper wires are loose, then put a drop of super glue at the place where the jumper meets the header. This will secure them.

CHECK YOUR WORK! Things will not work if you don't get the jumper wires correct!

This finishes the Jumper Wiring. Now on to the USB wiring.

USB Cable Wiring

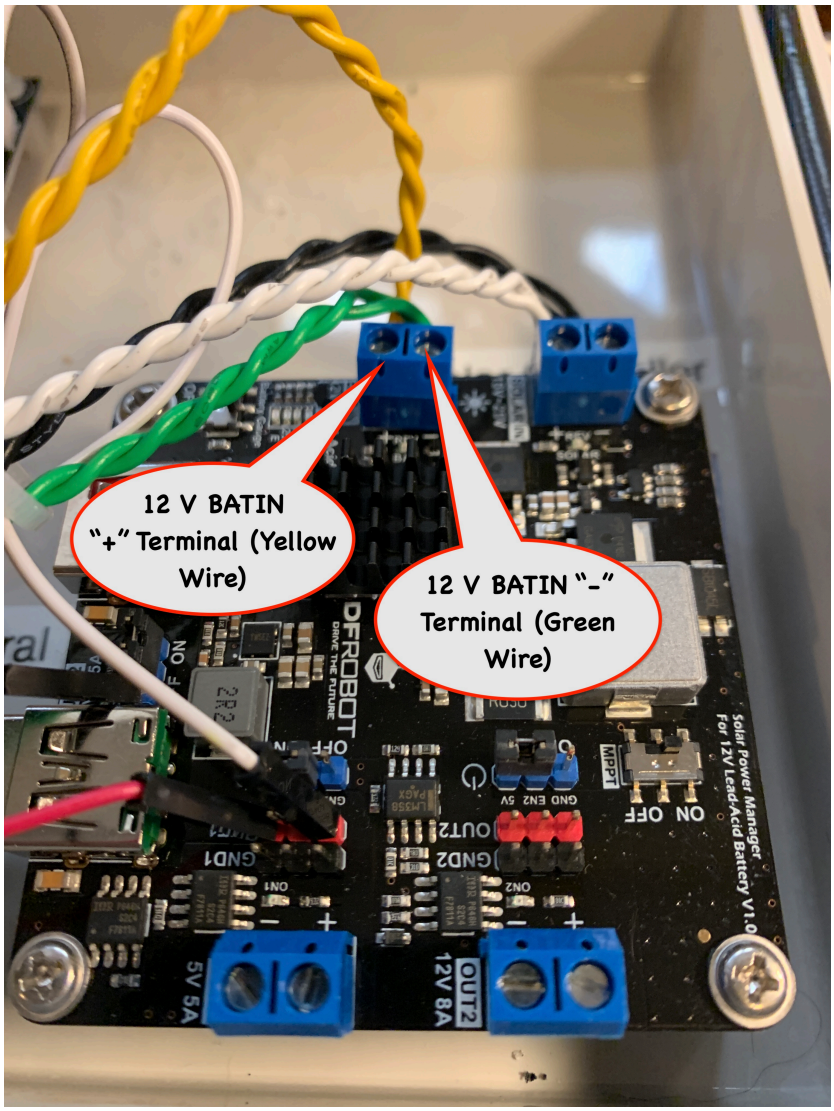
Step 1) Take your short Type A to Type A USB Cable (Part G) and plug one end into the USB connector on USB PowerCentral (Part E) to the USB Connection on the USB Weatherproof Plug (Part F).

This finishes the USB Wiring. Now on to the Battery wiring.

Lead Acid Battery Wiring

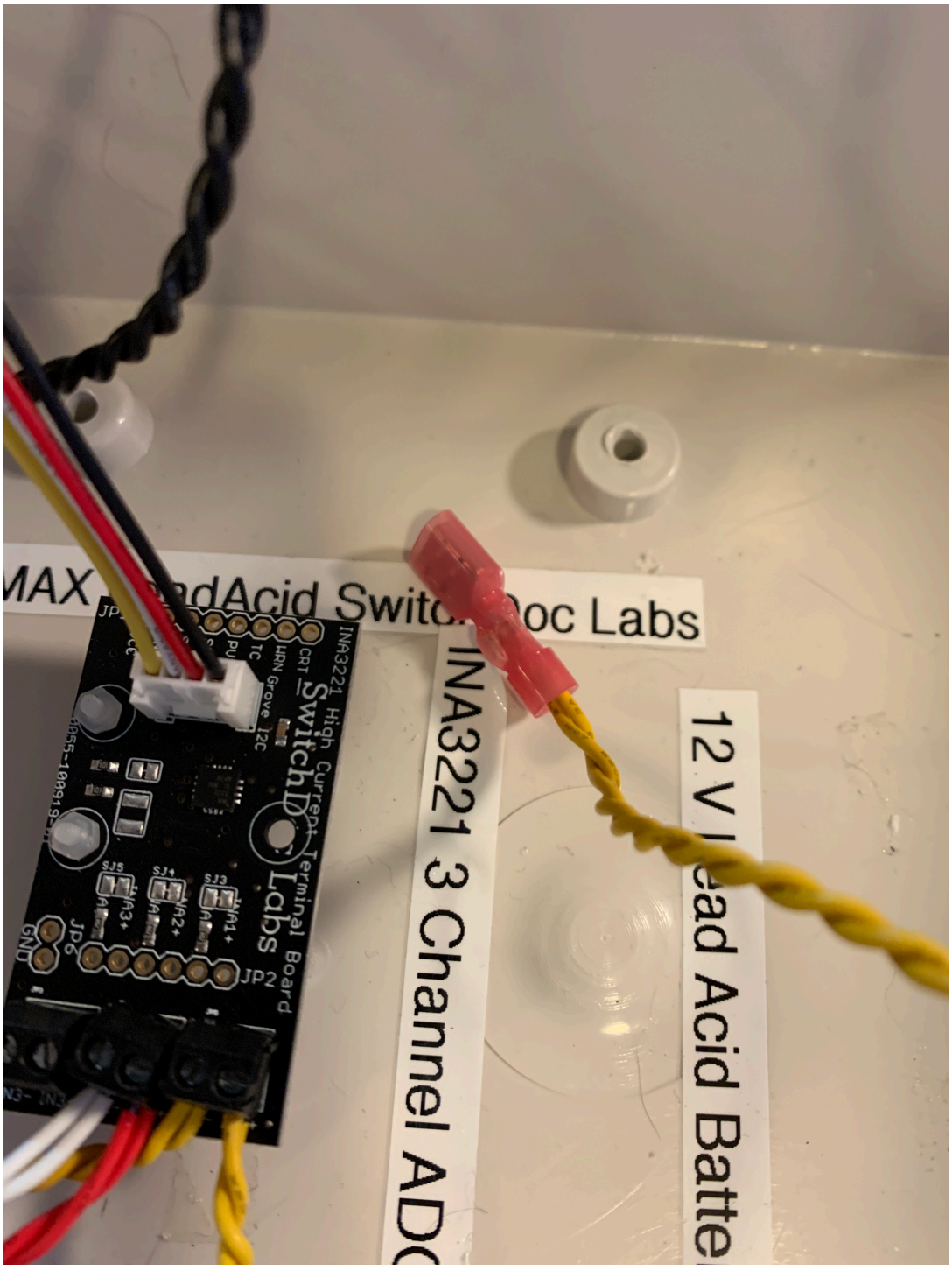
This is the last of our wiring for SolarMax Lead Acid.

Step 1) Cut two 38cm Yellow wires, braid them and strip both ends. Connect one end to IN1- screw terminal and the other end to the "+ Plus terminal on the 12 V BAT IN plug on the Solar Charger (Part D). **BE CAREFUL TO DO THIS CORRECTLY. CHECK IT AGAIN.**



Step 2) Cut two 26cm Green wires, braid them and strip both ends. Connect on end of the Green wires to the 12V BATIN "-" screw terminal as shown in the picture above.

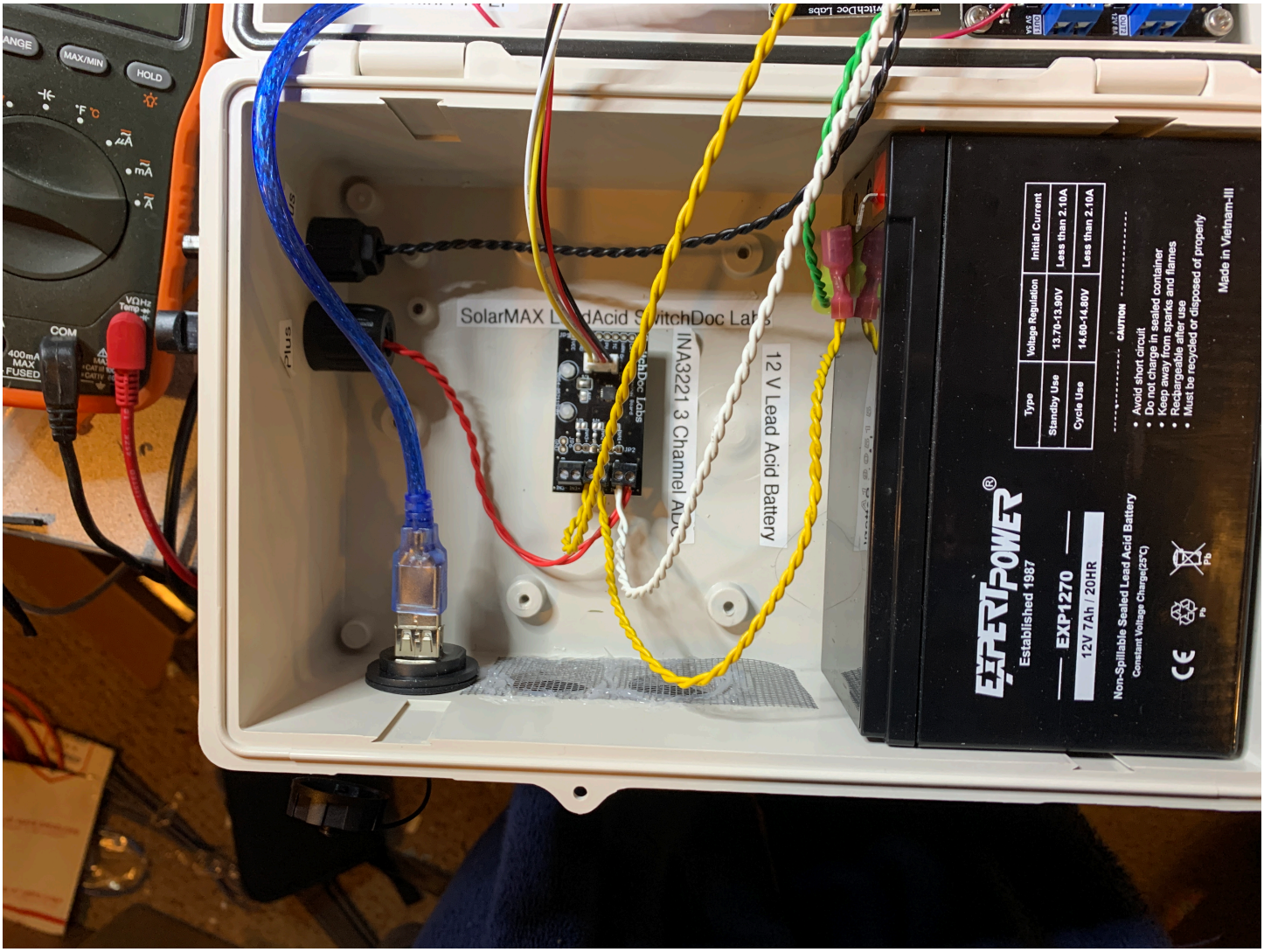
Step 3) Take the Red Cold Press Crimp spade connector and place the stripped Yellow Wires (from the INA1+ Screw down connector on the INA3221 ADC (Part C) into the spade connector and crimp the connector to hold them in place (and make connection with the spade).



Step 4) Take the Yellow Cold Press Crimp spade connector and place the Green Wires (From the 12V BATIN "-" Screw Connector on the Solar Controller Board (Part D) into the spade connector and crimp the connector to hold the wires in place (and make connection with the spade).

Connect your 12 V Lead Acid Battery

Step 1) If you have selected the recommended 12 V Lead Acid battery (https://amzn.to/2qGCVd8), then place it into the Bud Box as shown. Positive terminal up. Use Velcro to hold the heavy battery in place. It fits snug into place.

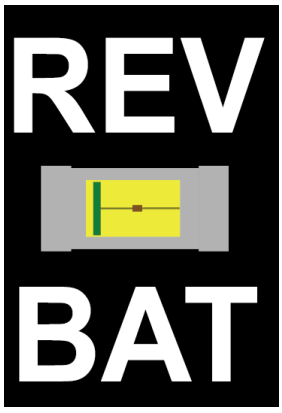


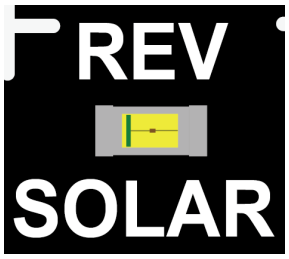
Step 2) Slide the Yellow Spade connector (connected to the Green wire which is connected to the "-" terminal on the Solar Control (Part D) 12V BATIN "-" screw down terminal) on the **Negative** Spade on the 12 V Battery (CHECK YOUR WORK!!!!)

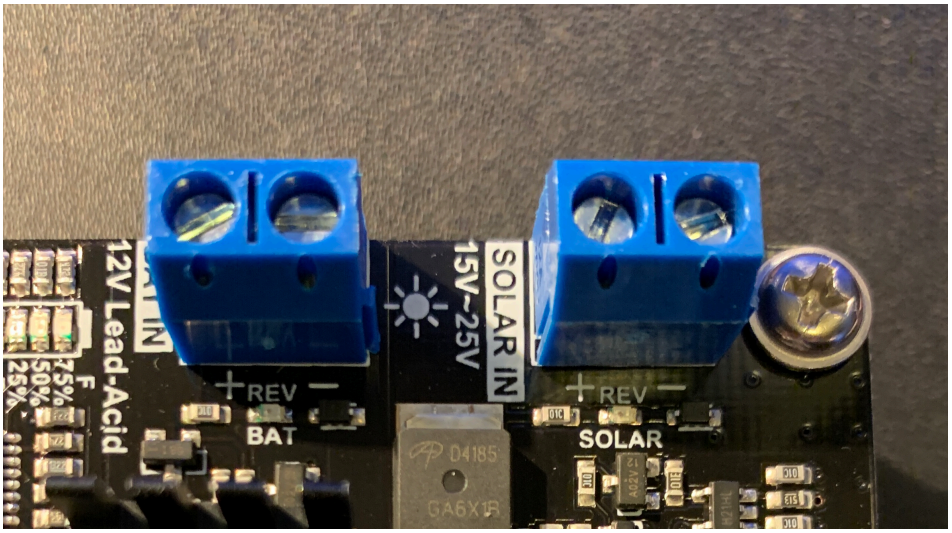
Step 3) Slide the Red Spade connector (connected to the Yellow Wire which is connected to the IN1+ screw terminal on the IN3221A (Part C) board onto the **Positive** spade on the 12 V Battery (Make sure you do this right!).

NOTE: The Solar Charger Board (Part D) has protection for reversing the 12V battery and the solar panels. If you reverse them, the appropriate LED will light up an there will be no damage. But, nothing will work either. :)

Reverse connection LED indicator: when the battery is reverse connected at the BAT IN or SOLAR IN, the corresponding orange LED **REV BAT** or **REV SOLAR** turns ON, informing the user a reverse connection error.



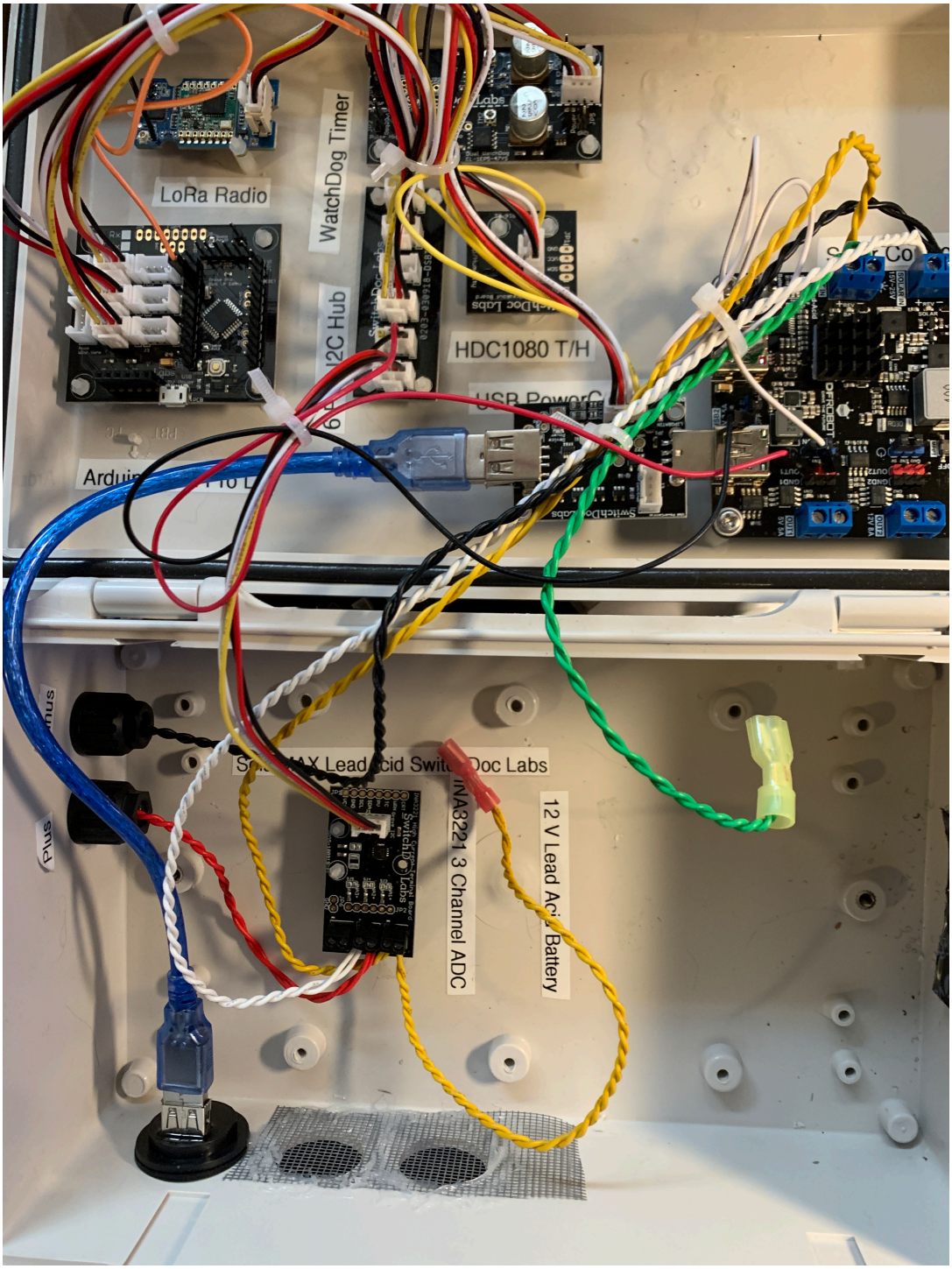




If you have hooked up everything correctly you will see a number of LED lights on the WatchDog timer (Part L), the Mini Pro LP board (Part I) and the USB PowerCentral board (Part E).

Finally

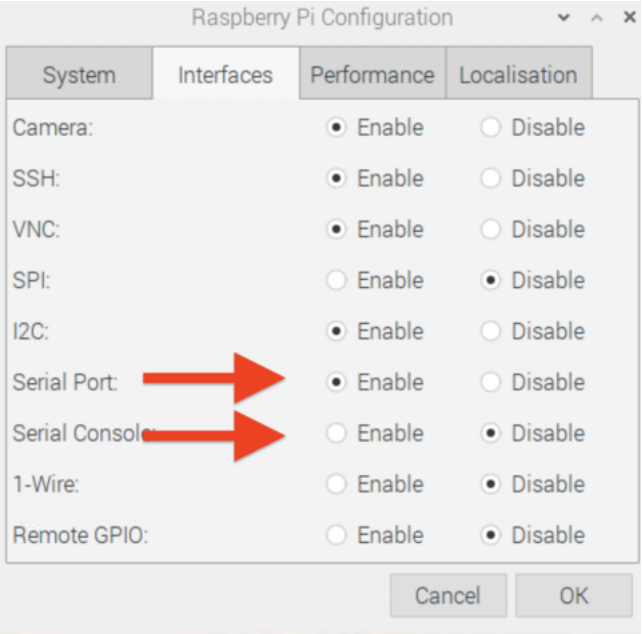
Clean up your wiring by using some wire ties to make it neat!



Testing Your SolarMAX Lead Acid System

Check your Raspberry Pi Configuration

If operating on GUI, open up Preferences->Raspberry Pi Configuration and the Interfaces tab on the screen. Make sure the Serial Port and Serial Console are marked Enable and Disable as shown below. If you are using a headless unit, invoke "sudo raspi-config" from a command line and change the same values.



Continuing Testing

If you are using a SkyWeather system, SkyWeather comes with support for SolarMAX. If you don't have a SkyWeather system, jump down to "Testing your SolarMAX with a Raspberry Pi". If you see the yellow light on the Mini Pro LP board (Part D) flicker about every 30 seconds then you are transmitting data. If you want to see what you are transmitting, hook up an FTDI cable (https://shop.switchdoc.com/products/ftdi-cable-5v-3-3v-with-usb-cable or https://www.adafruit.com/product/70) and look at the serial panel (baud = 115200) in the Arduino IDE and you will see lots of data about what the SolarMAX system is doing and reporting.

In either of these two testing methods, the first thing to do is to power down your Raspberry Pi and plug the second LoRa Radio (Part H) into the Serial port on your Pi2Grover board (https://shop.switchdoc.com/products/pi2grover-raspberry-pi-to-grove-connector-interface-board).

Testing With SkyWeather

Power down your system. Then plug in the LoRa Radio (Part H) into the Serial Grove connector on the Raspberry Pi Pi2Grover board.

Next, login into your Raspberry Pi in the SkyWeather kit and “cd SDL_Pi_SkyWeather”

Note: You can’t be running SkyWeather in the background when you are running this test. You must kill the process by doing something similar to this (your process number will be different):

```
pi@switchdoclabs:~/SDL_Pi_SkyWeather $ ps xaf | grep python
  236 ?        Ss    24:52 /usr/bin/python -O /usr/share/wicd/daemon/wicd-daemon.py --no-daemon --
keep-connection
  502 ?        S     13:29  \_ /usr/bin/python -O /usr/share/wicd/daemon/monitor.py
22940 pts/0    S+     0:00  |           \_ grep --color=auto python
22889 pts/1    S+     0:00              \_ sudo python SkyWeather.py
22894 pts/1    Sl+    0:18                  \_ python SkyWeather.py
pi@switchdoclabs:~/SDL_Pi_SkyWeather $
```

Then you have to kill the process:

```
sudo kill -9 22894
```

Then you can check to see the process has been killed.

```
pi@switchdoclabs:~/SDL_Pi_SkyWeather $ ps xaf | grep python
  236 ?        Ss    24:53 /usr/bin/python -O /usr/share/wicd/daemon/wicd-daemon.py --no-daemon --
keep-connection
  502 ?        S     13:30  \_ /usr/bin/python -O /usr/share/wicd/daemon/monitor.py
23014 pts/0    S+     0:00  |           \_ grep --color=auto python
pi@switchdoclabs:~/SDL_Pi_SkyWeather $
```

Now type the following command on your command line:

```
sudo python testWXLink.py
```

After a while you will see something like this and then your SolarMax is working! You will see protocol 10, as this is a SolarMAX Lead Acid system. Otherwise you will see Protocol 8 (SolarMAX LiPo) or protocol 3, if you have a WXLink system.

```
Good CRC Recived
('protocol_ID = ', 10)
('protocol_software_version = ', 3)
protocol 10 SolarMAX received
SMOTFloat=02d2a41
ITemperature from SolarMAX temperature: 10.6C
IHumidity from SolarMAX humidity: 77.3%
SolarMax batteryVoltage =  13.53
SolarMax batteryCurrent = -444.00
SolarMax loadVoltage =   5.16
SolarMax loadCurrent = 170.90
SolarMax solarPanelVoltage =  18.70
SolarMax solarPanelCurrent = 412.00
SolarMax auxA =   0.00
SolarMax Message ID 14675
```

Testing with a Raspberry Pi (without SkyWeather)

To test on a Raspberry Pi (without SkyWeather) you need to hook up the LoRa Radio to the serial port on the Raspberry Pi. This can be done most easily by using a Pi2Grover and plugging the Grove cable into the Grove Serial connector on the device. Otherwise, you will need to wire up the device to 3V, Ground and then connect Rx (GPIO 14) and Tx (GPIO 15). Easier to use use a Pi2Grover (https://shop.switchdoc.com/products/pi2grover-raspberry-pi-to-grove-connector-interface-board) IMHO.

Step 1) Download the SolarMAX python library:

git clone https://github.com/switchdoclabs/SDL_Pi_SolarMAX

Step 2) run the program testWXLink.py

After a bit (30 seconds or so) you will see something like the following:

```
pi@switchdoclabs:~/SDL_Pi_SolarMAX $ sudo python testWXLink.py
block1= [171, 102, 103, 173, 84, 39, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 204, 40, 165, 64,
0, 45, 42, 65, 64, 132, 154]
block2= [66, 177, 114, 88, 65, 1, 0, 222, 67, 102, 230, 42, 67, 105, 145, 149, 65, 0, 0, 206, 195,
0, 0, 0, 0, 83, 57, 0, 0, 128, 175]
-----------
block 1
ab6667ad5427000000000000000000000000000cc28a540002d2a4140849a
block 2
42b17258410100de4366e62a43699195410000cec300000005339000080af
-----------
('>>>>>>>>>>>>protocolblock=', 103)
Starting readWXLink
('block1 length=', 32)
('block2 length=', 31)
ReversedreceivedCRC= 80af
length of stb1+sb2= 59
ab6667ad5427000000000000000000000000000cc28a540002d2a4140849a
42b17258410100de4366e62a43699195410000cec3000000005339
calculatedCRC = 80af
Good CRC Recived
('protocol_ID = ', 10)
('protocol_software_version = ', 3)
protocol 10 SolarMAX received
SMOTFloat=02d2a41
ITemperature from SolarMAX temperature: 10.6C
IHumidity from SolarMAX humidity: 77.3%
SolarMax batteryVoltage =  13.53
SolarMax batteryCurrent = -444.00
SolarMax loadVoltage =   5.16
SolarMax loadCurrent = 170.90
SolarMax solarPanelVoltage =  18.70
SolarMax solarPanelCurrent = 412.00
SolarMax auxA =   0.00
SolarMax Message ID 14675
```

It’s working!

Installing Your SolarMAX Lead Acid System

Plug your solar panel into the appropriate MC4 plugs on the outside of your box and your SolarMAX system is complete.

Take a TypeA USB to TypeA USB Cable and plug in your computer system. SolarMAX provides 5V through the USB cable. If you need a USB Micro, or USB C cable you will need to get the appropriate converters to go from USB Type A to your device.

SkyWeather comes with a Type A USB input so you just need a Male to Male Type A USB extender cord.

Enjoy getting all this data about your solar system!

The Science and Education Goals Behind SolarMax

Everything we build for the Maker market is designed for education and learning. Making is education. Making is learning. Building your own projects allows you to innovate around a framework and do wonderful things that of which we have never thought.

The educational goals for SOlarMAX are:

- Building a solar panel controller and charger system
- Using an Arduino and LoRa radio to gather and transmit data to a Raspberry Pi or Arduino
- Connecting up a radio to the Raspberry Pi
- Understand how your Solar Panel system is behaving by looking at the4 data.
- Understand your solar environment and what affects it
- Learn about the new technology called the Internet of Things

Support

As with all SwitchDoc Labs products, technical support is given through the forums on Forum.switchdoc.com If you have issues that can be solved by our fabulous customer service department, please go to www.switchdoc.com and send your issues through our Contact page on the top menu.

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