Building an Electronic Data Acquisition System for a Cosmic Ray Detector

Armando Mora, 2022

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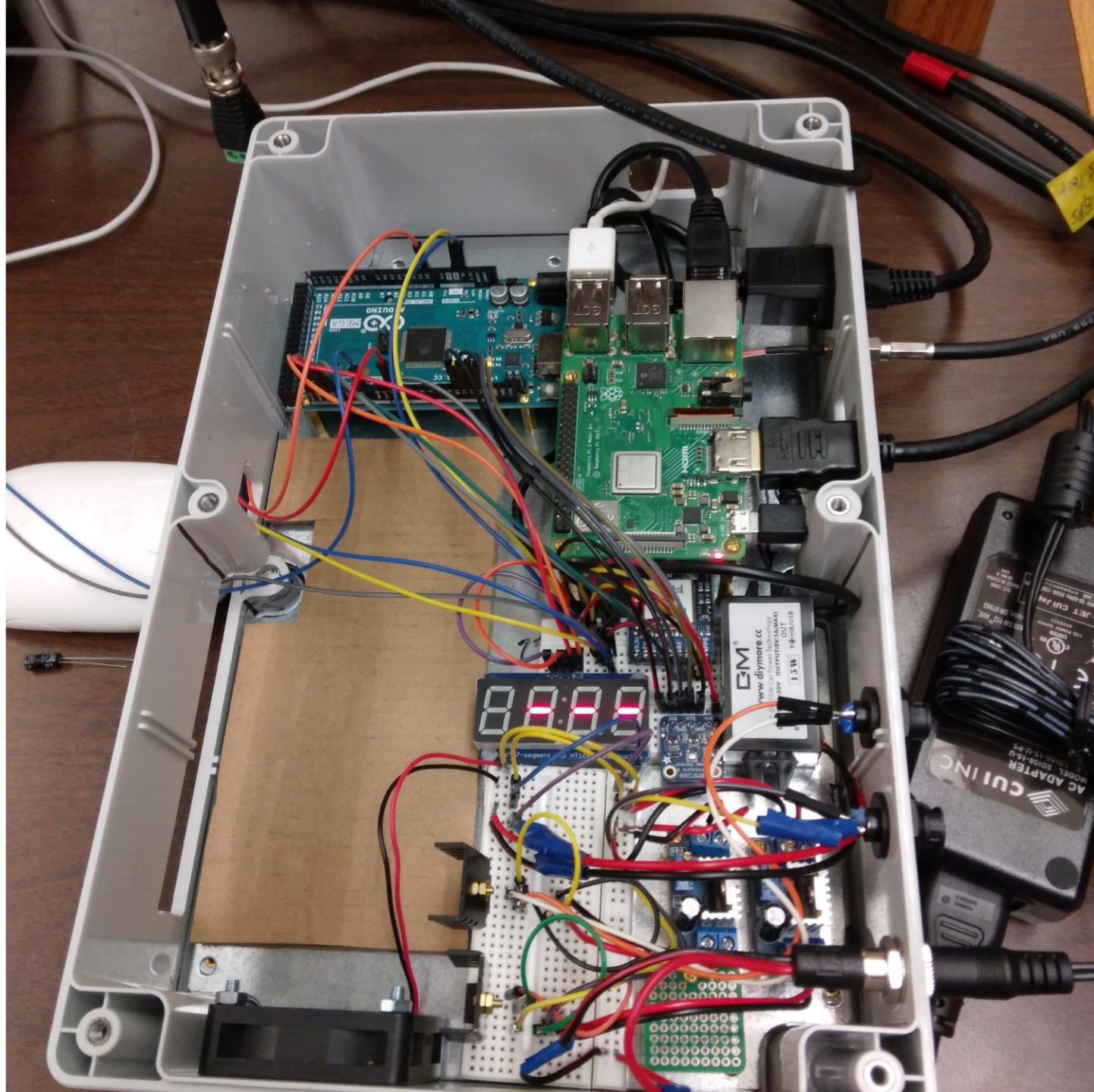
Research Experience for Undergraduates (REU)

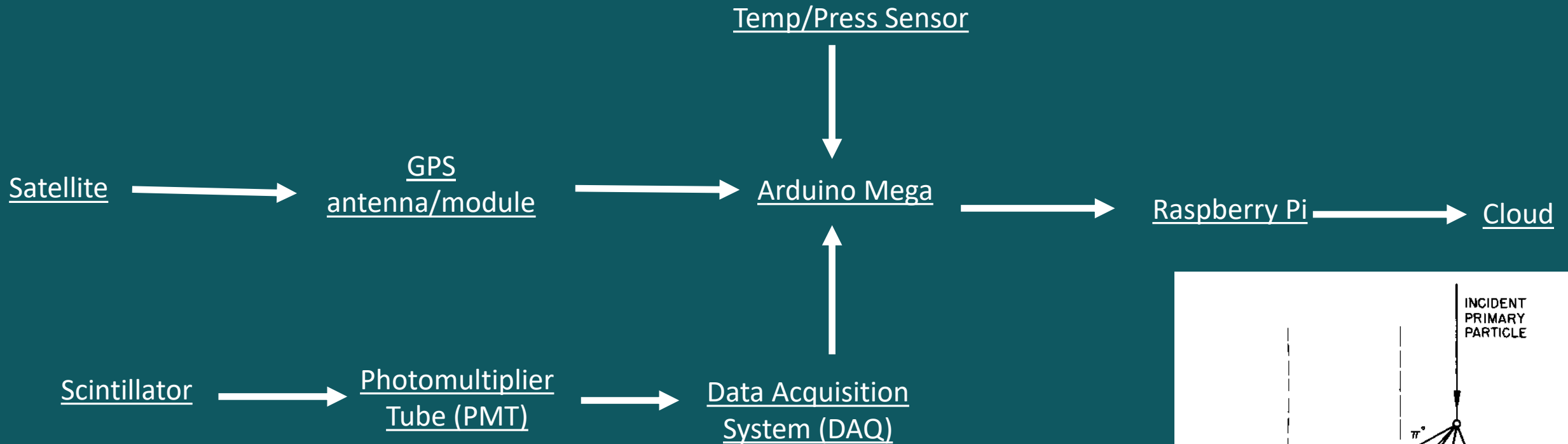Astrophysics and Electrical Engineering

Outline

- Schematic of the Muon Data Acquisition System.

- Arduino arrangement.

- Arduino breadboard connections and schematics.

- Raspberry pi connections.

- Amperage measurement in each branch and total current draw.

- 3D arrangement of components

DAQ electronics –

LM317s for PMT LV power, GPS, atmospheric temp/pressure sensors, Arduino Mega microcontroller, Raspberry Pi computer, and LCD event counter (missing the DAQ front-end circuit)

Schematic of the Muon Data Acquisition System

Temp/Press Sensor

Satellite → GPS antenna/module → Arduino Mega → Raspberry Pi → Cloud

Scintillator → Photomultiplier Tube (PMT) → Data Acquisition System (DAQ)

- The temperature and pressure sensor sends data directly to the Arduino.
- The satellite sends longitude, latitude, altitude, and UTC time.
- The scintillator receives our secondary particle and produces light (photons) that then are transformed into electrons.
- The PMT sends a pulse that then gets stretched by the DAQFE.
- The Arduino sends this information to the Raspberry pi and the latter prints it.
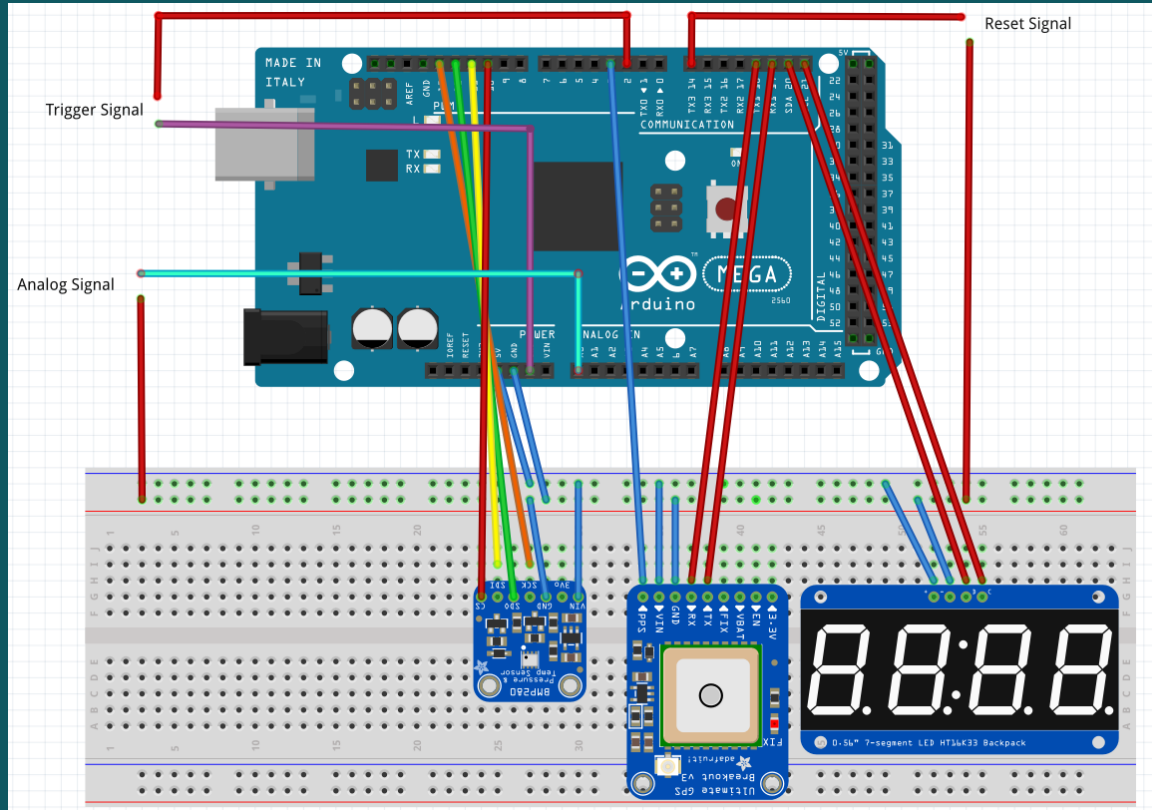

Muon
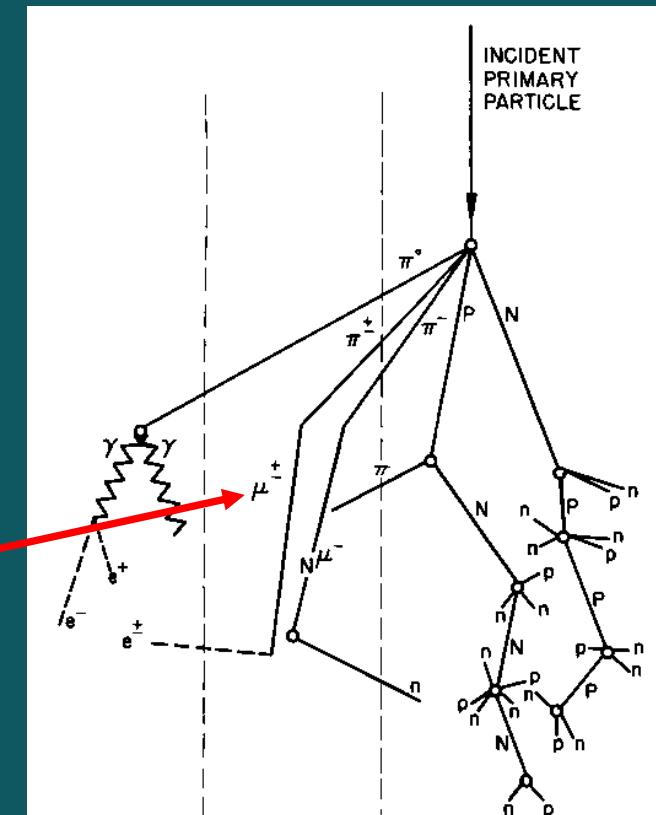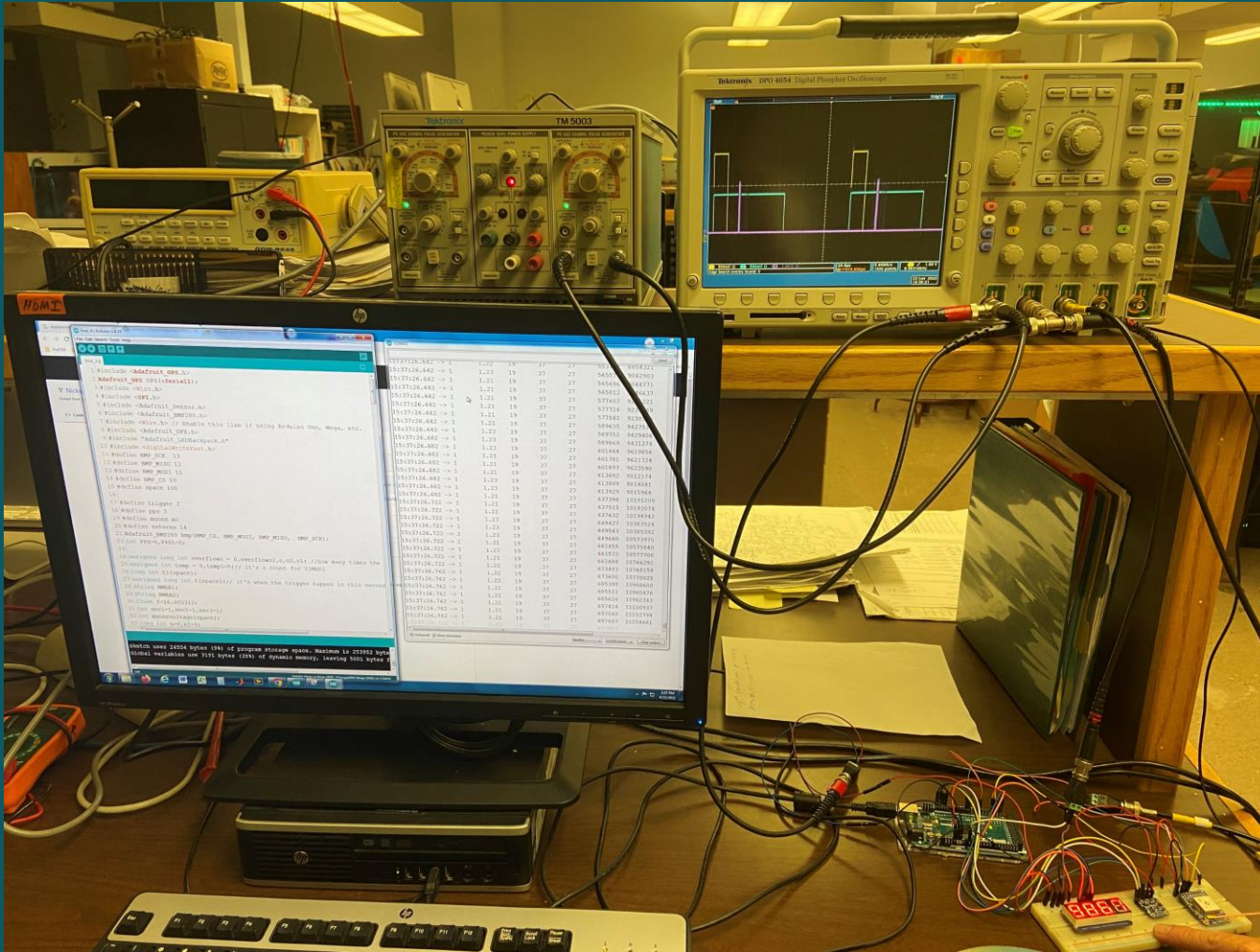
Arduino Setup

- The basic setup to simulate the pulse a muon generates.
- The pulse is generated by a pulse generator and displayed on the oscilloscope and the serial monitor/plotter.

Breadboard Connections

List of connections:

BMP280 Temperature and Pressure Sensor:
-Pin13 (Arduino) to sck (Temp/Press sensor)
-Pin12 (Arduino) to sdo (Temp/Press sensor)
-Pin11 (Arduino) to sdi (Temp/Press sensor)
-Pin10 (Arduino) to cs (Temp/Press sensor)
-GND2 (Arduino) to GND (Temp/press sensor)

Ultimate GPS Breakout v3:
-Pin3 (Arduino) to PPS (GPS receiver)
-TX1 (Arduino) to RX (GPS Receiver)
-RX1 (Arduino) to TX (GPS Receiver)
-GND2 (Arduino) to GND (GPS Receiver)
-5v (Arduino) to VIN/+ (GPS Receiver)

7-Segment LED Backpack:
-SDA20 (Arduino) to D (7-segment)
-SCL21 (Arduino) to C (7-segment)
-GND2 (Arduino) to GND (7-segment)
-5v (Arduino) to VIN/+ (7-segment)

DAQ:
-GND2 (Arduino) to GND (Analog signal, reset signal)
-Pin2 (Arduino) to Trigger signal
-TX3 (Arduino) to Reset Signal
-GND (Arduino) to Trigger Signal
-PinA0 (Arduino) to Analog signal

- The breadboard schematic of the basic Arduino setup.
- Labeled list of connections.
- This can help future students involved in the same project.

Arduino Basic Schematics

- The schematic works for better identification of the connections.
  - Each component is connected in parallel to the 5v and GND output of the Arduino.
- Connection labels are easily visible.
- They can be easily tracked down also.
- The connections are better identifiable with the breadboard schematic.
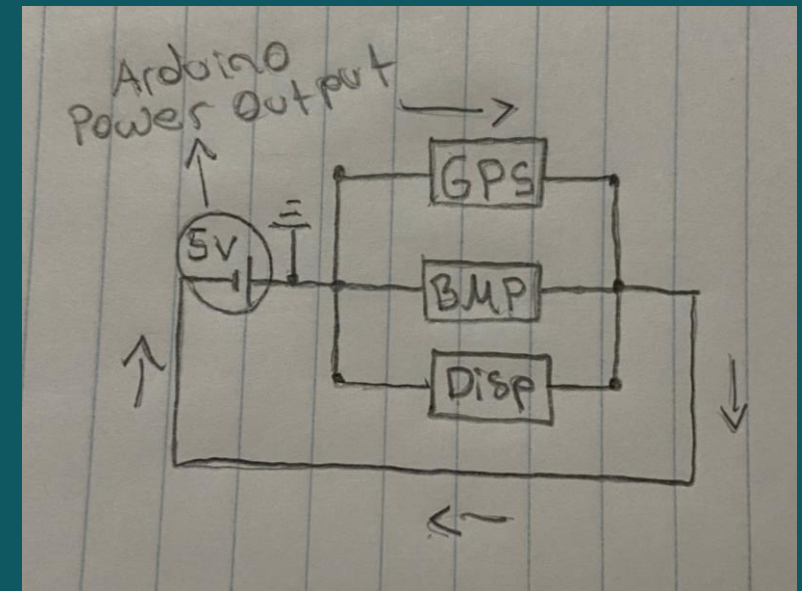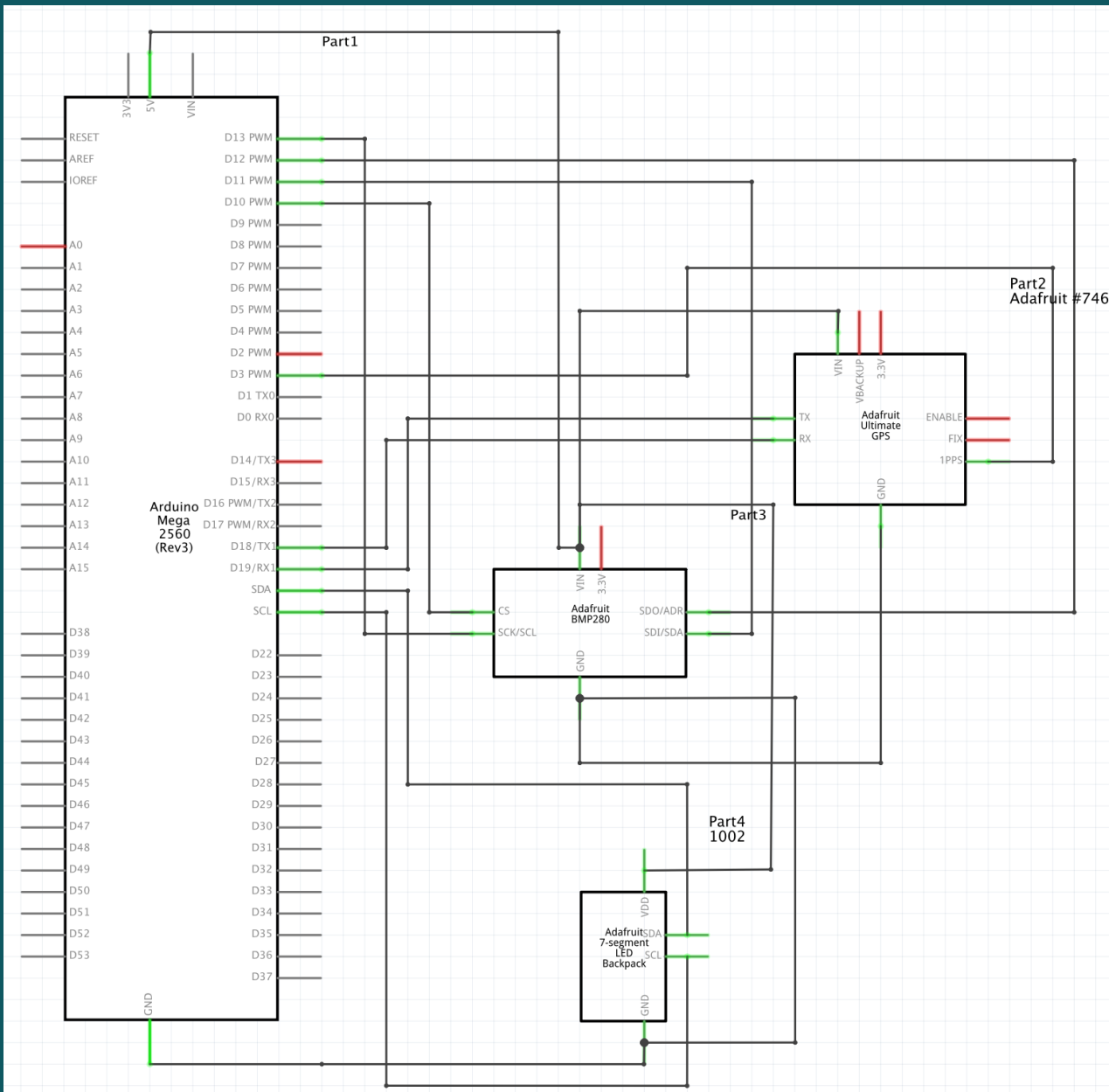
Arduino/Raspberry Pi System
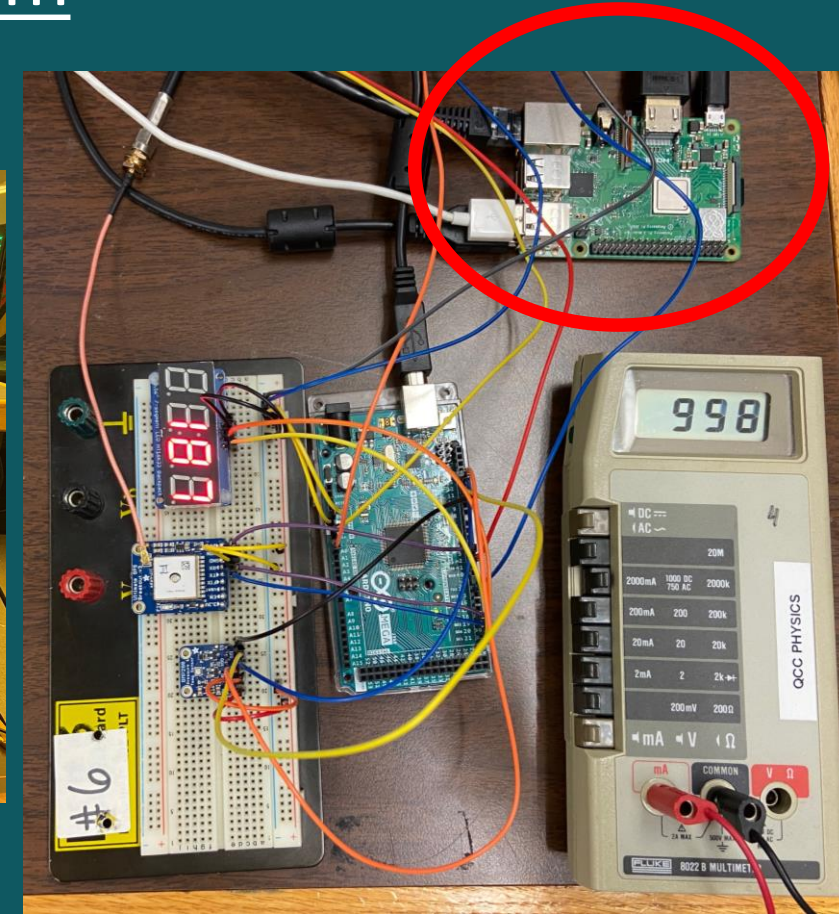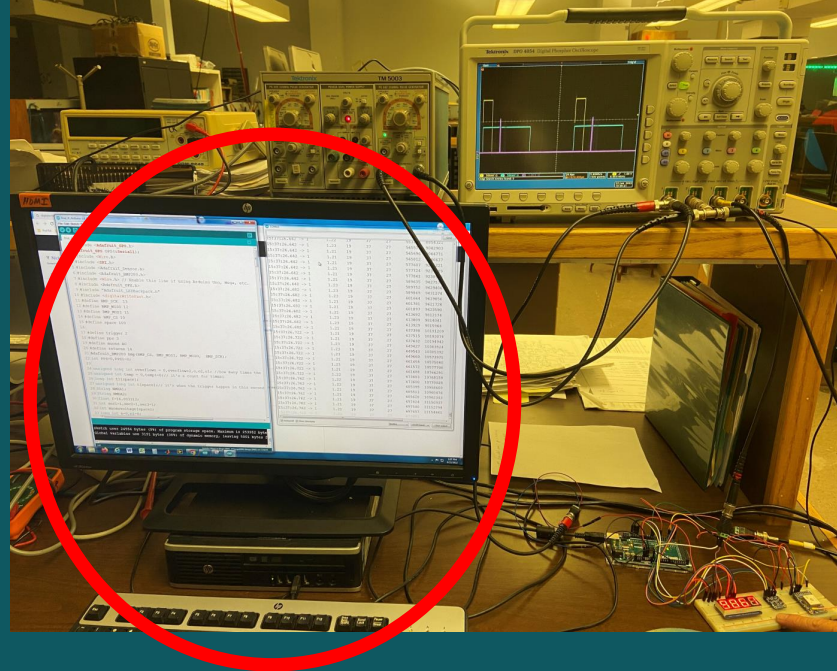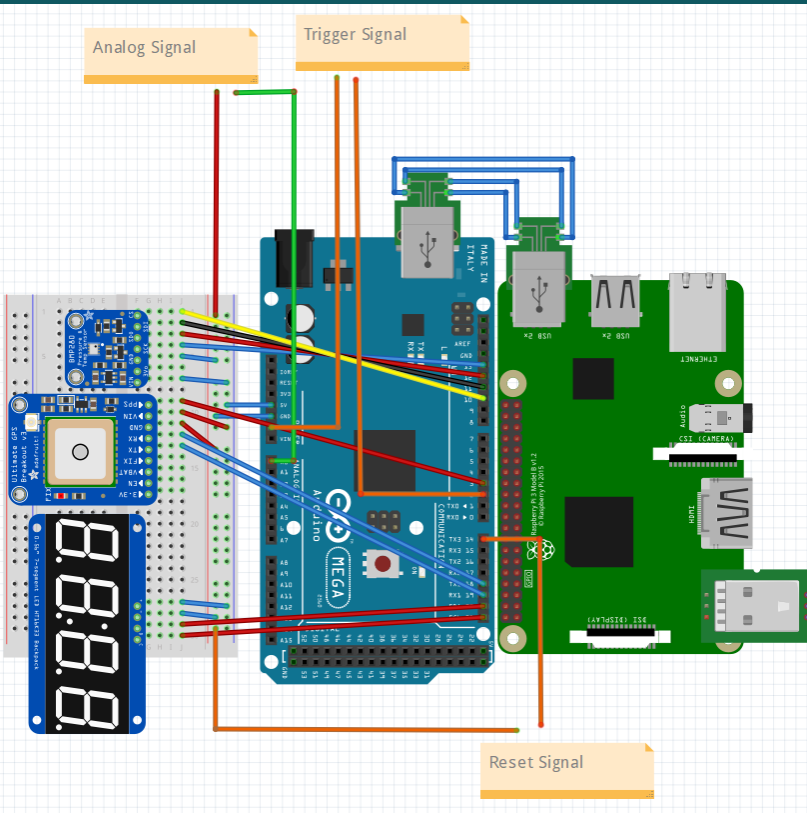
- This configuration reduces the size of our Arduino system.
- The connections are straightforward, with the only twist that we use a Raspberry Pi 3 B+ this time.
    - The same Arduino system connects directly to the raspberry pi.
- Besides utilizing less power, the raspberry pi will continuously receive data and send it to the cloud without needing to connect it to a monitor or mouse and keyboard.

Amperage Measurement

Without any device connected

Under heavy load (USB ports and HDMI in use)
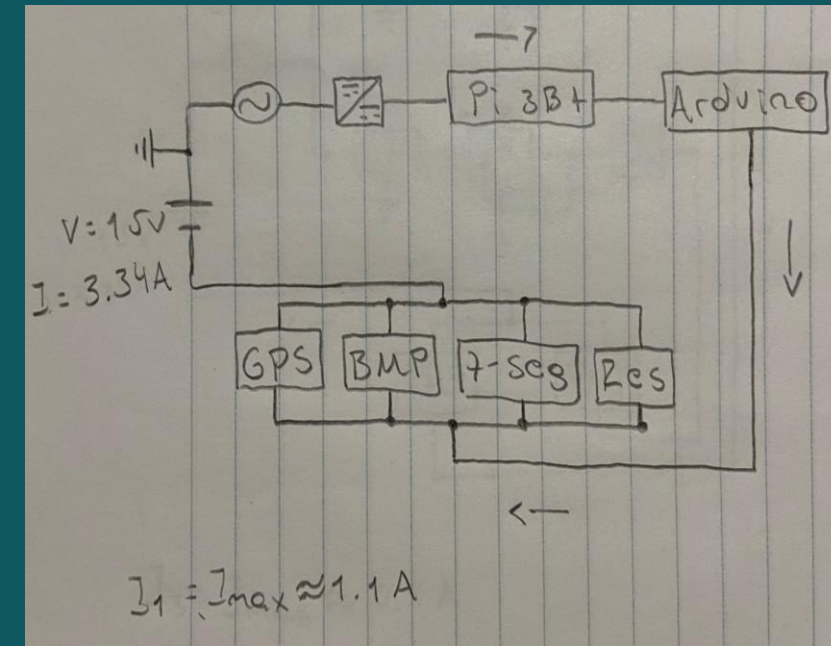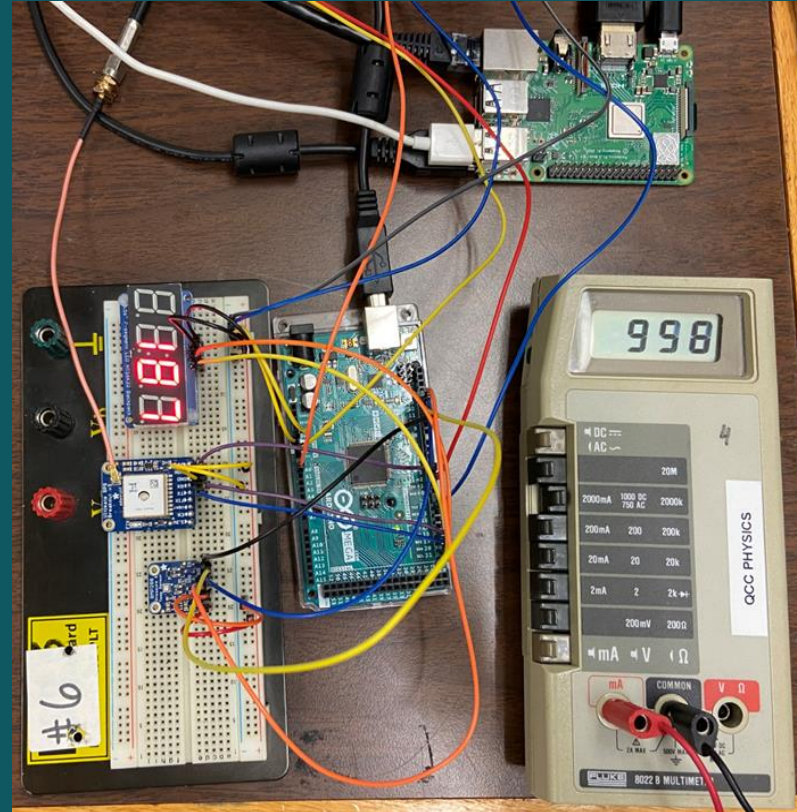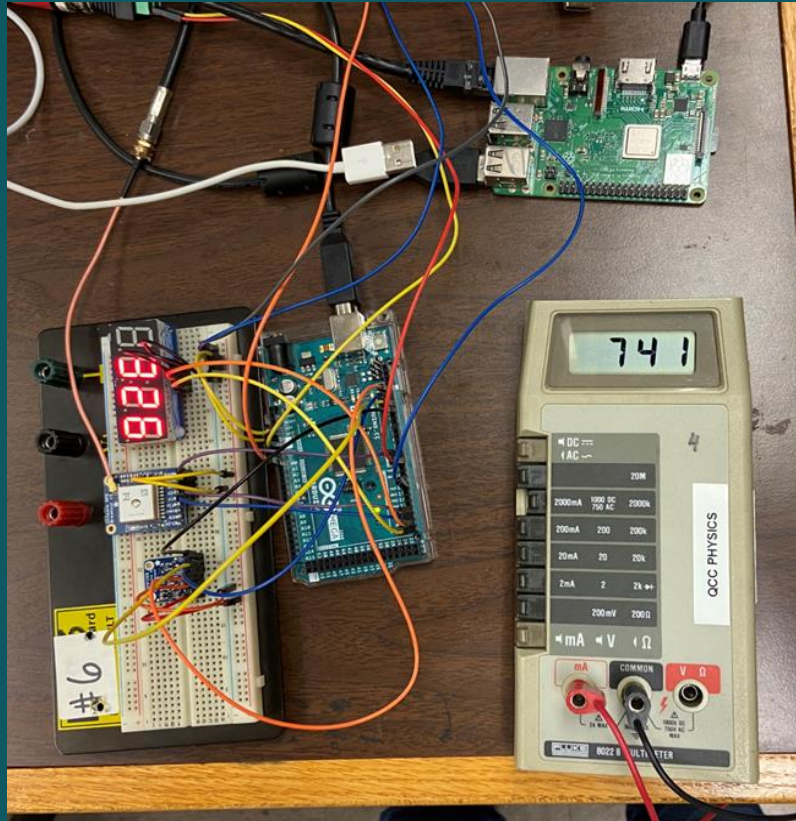
- Without any device being connected to the raspberry pi (keyboard, mouse, monitor, etc), it draws less current.
- Under heavy load and with all the USB ports in use, it reaches the 1Amp range.
- The maximum amperage it reaches is 1.03Amps.
- To make sure, we set the maximum amperage for this branch to be 1.1Amps
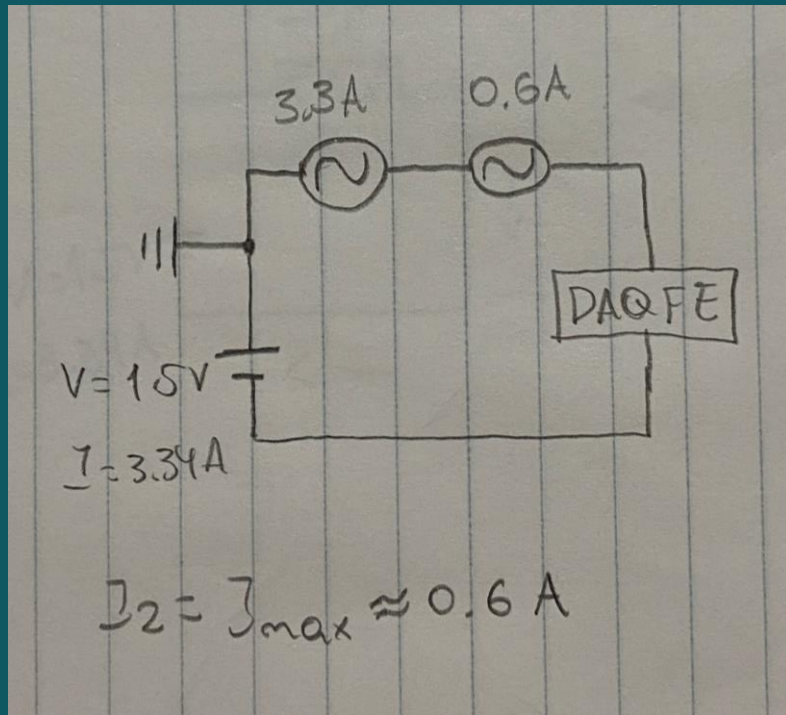
DAQFE Branch

- The first fuse is to protect the entire system, outputting just 3.3A of current.
- We implemented a 0.6A fuse for this branch for extra protection.
- The DAQFE is the component that makes the reading of the pulse possible for the Arduino.
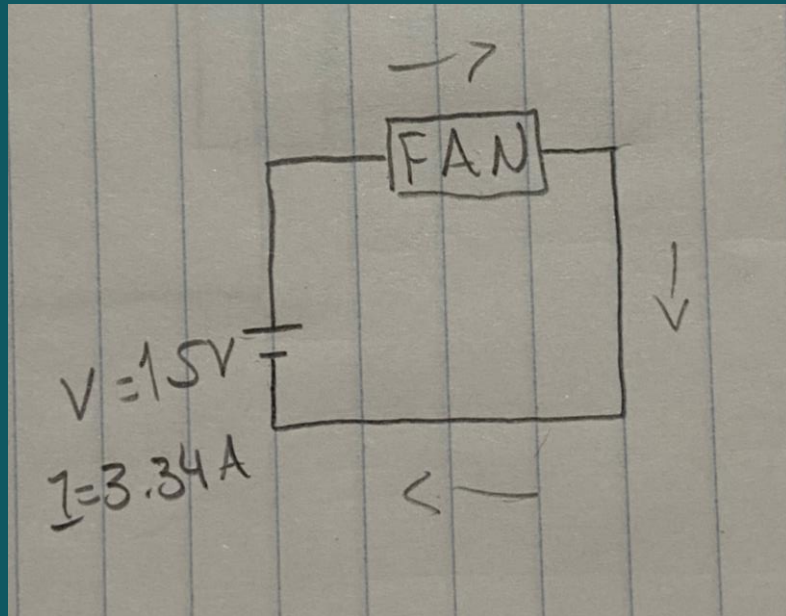

Fan Branch

- The fan was stress tested for a week.
- The advertised power input is 12v-0.024A.
  - It receives energy directly from the power source without the need for voltage regulators.
- The maximum current through the fan is 16mA.

PMT Branch

- In this branch 15v-3.34A goes in the LM317 and 13.75v-1A comes out.
  - After some testing 13.9V were output.
- Same concept with our voltage regulators. They have a voltage dropout of 1.1v giving us 12.65v, but this does not matter since we will only need a maximum of 12v for out PMTs.
- The maximum current draw for this branch is 0.8A (0.4A out of each DC-DC converter).
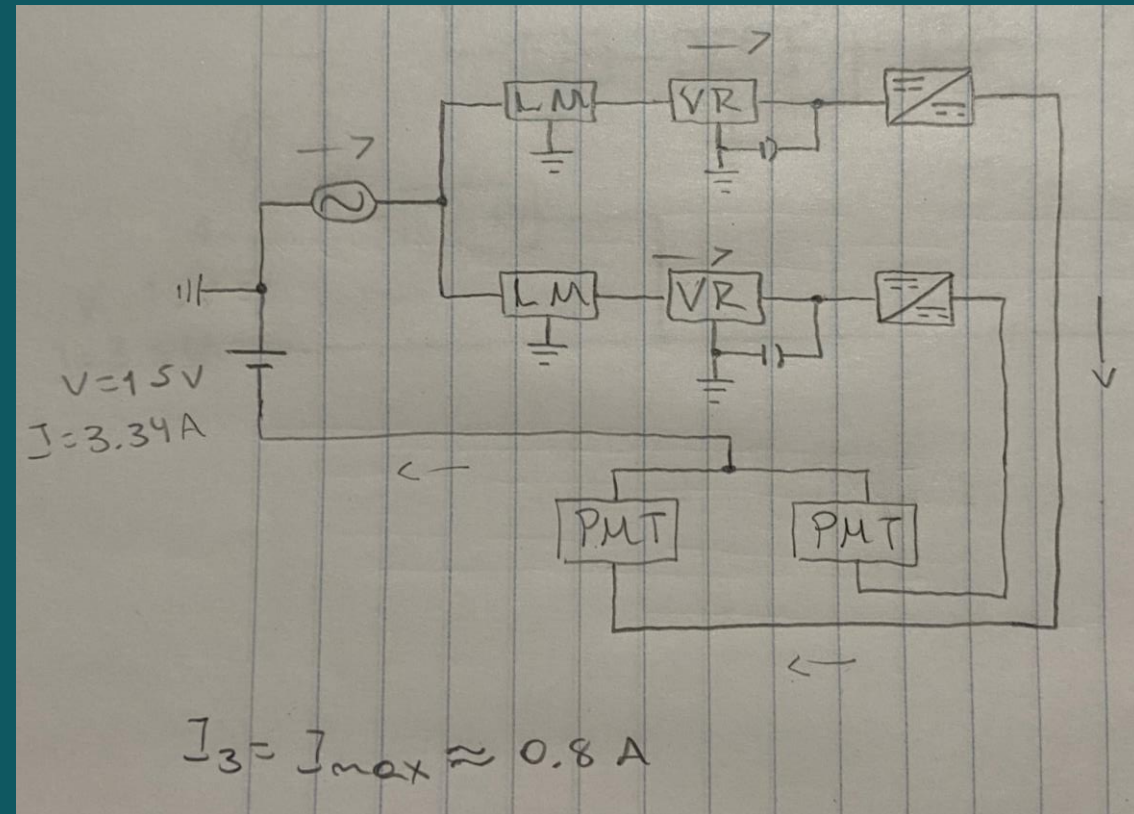
Voltage regulator issue

- Since the lm317 outputs 13.75 volts (1.25v dropout from 15v)
- Previous voltage regulator theoretical 2v dropout-max at 1amp.
- We found a voltage regulator that meets our needs.
- 12v output(fixed) at 800mAmps with a voltage dropout of 1.35 volts-max.
- Voltage dropout never surpasses the 1.1Vdrop range.
- This gives us 12.45 volts out.
- We will only get 12 volts from it.
- This voltage regulator needs a 10uF output capacitor to improve stability.
- It also needs a heatsink to dissipate the heat produced by the excess voltage.
- Which can be calculated by the power formula $p = (V_{in} - V_{out})(I_{out})$ "Watts"
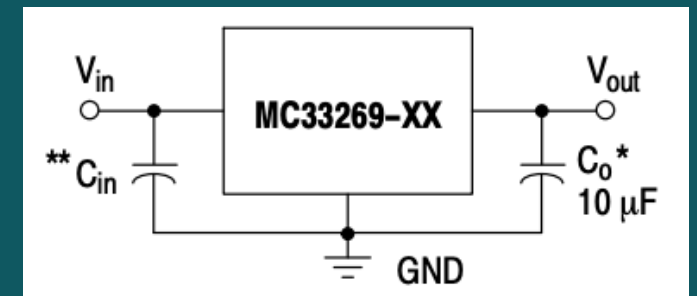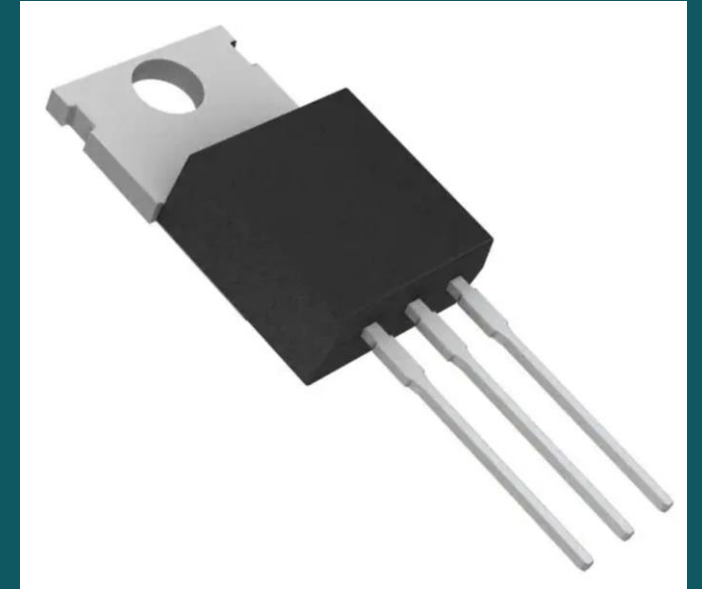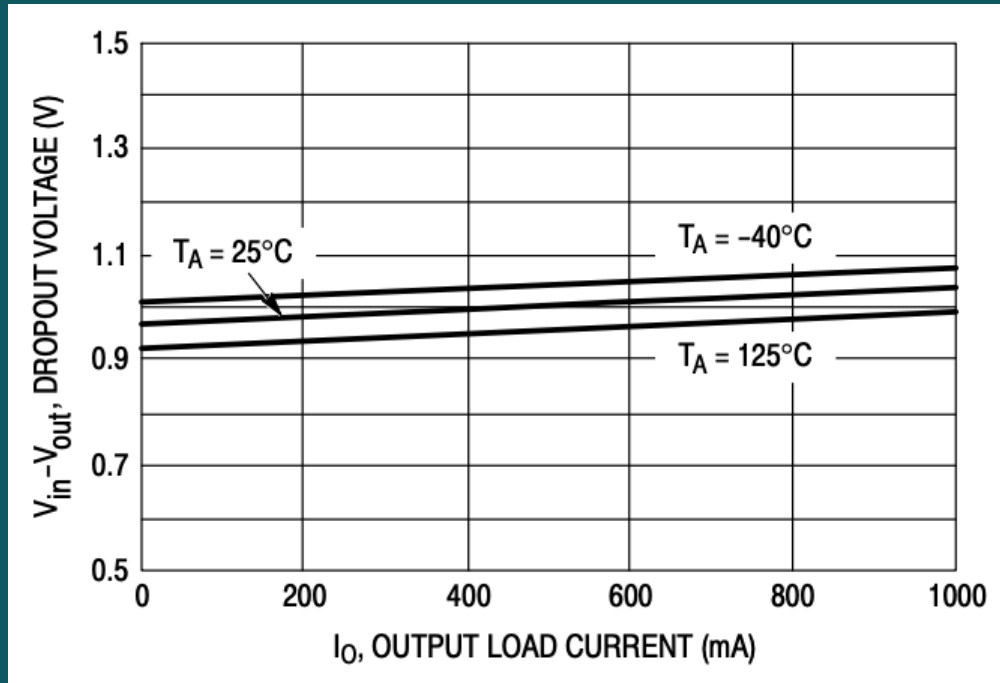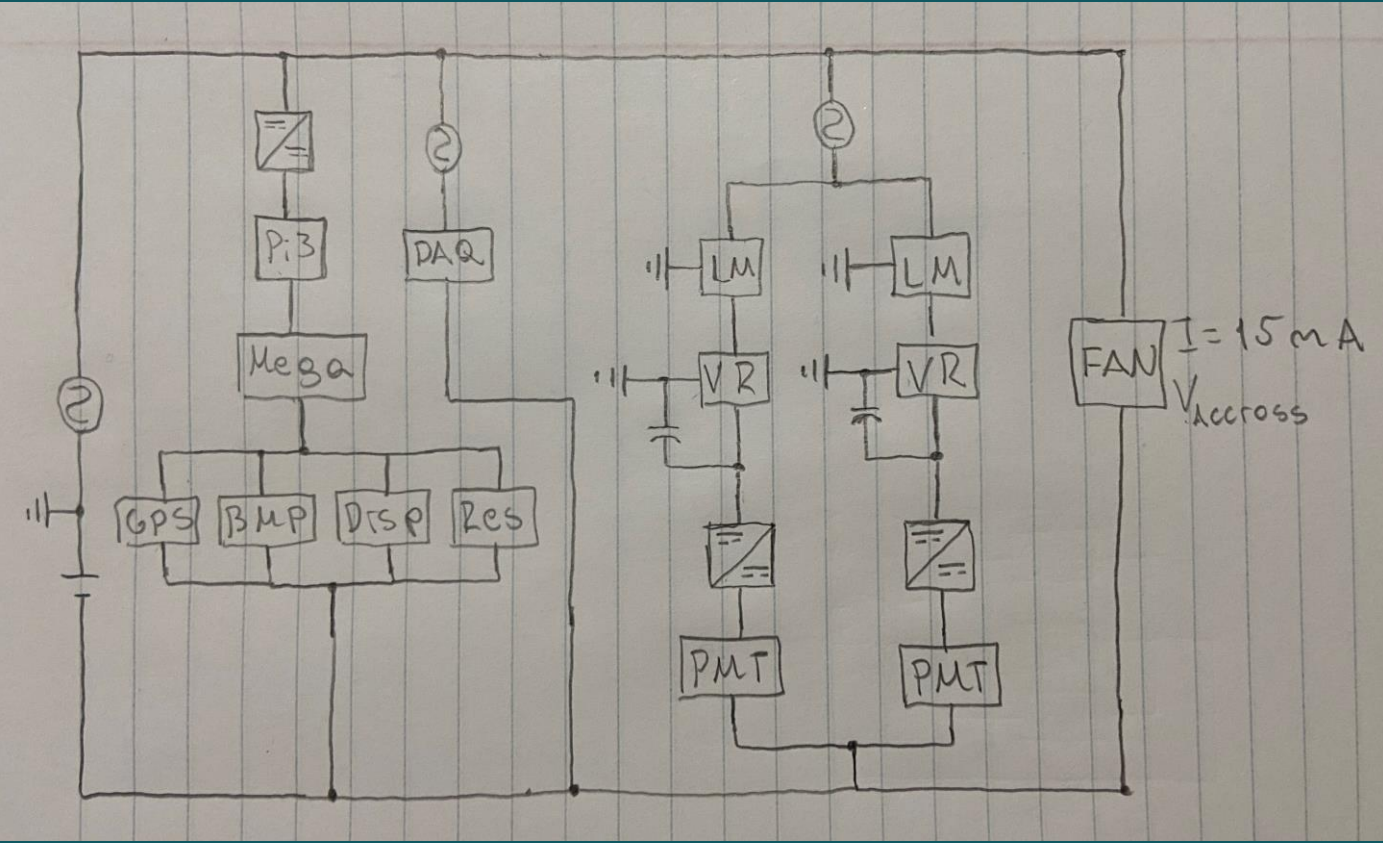
Full Circuit

- These are all the branches combined.
- It uses the same power source as the other branches.
- Logically, because all the branches are combined. Hence, they draw more current from the power source.

Total Current Draw

$$\sum I_{in} = \sum I_{out}$$

$$I_{source} \geq I_{system}$$

$$I_{system} = I_1 + I_2 + I_3 + I_4 = \sum_{n=1}^{branches} (I_n)$$

$$\approx 0.6A + 0.8A + 1.1A + 0.015A$$

$$I_{system} \approx \boxed{2.515A}$$

- Kirchhoff's Current Law says that any current entering a node leaves the node.
- The current used must be less than the rated amperage of the power source.
- Summing all currents from all the branches we obtain 2.5Amps of current.
- This satisfies our demand for current leaving some wiggle room for the internal current draw of all the components.
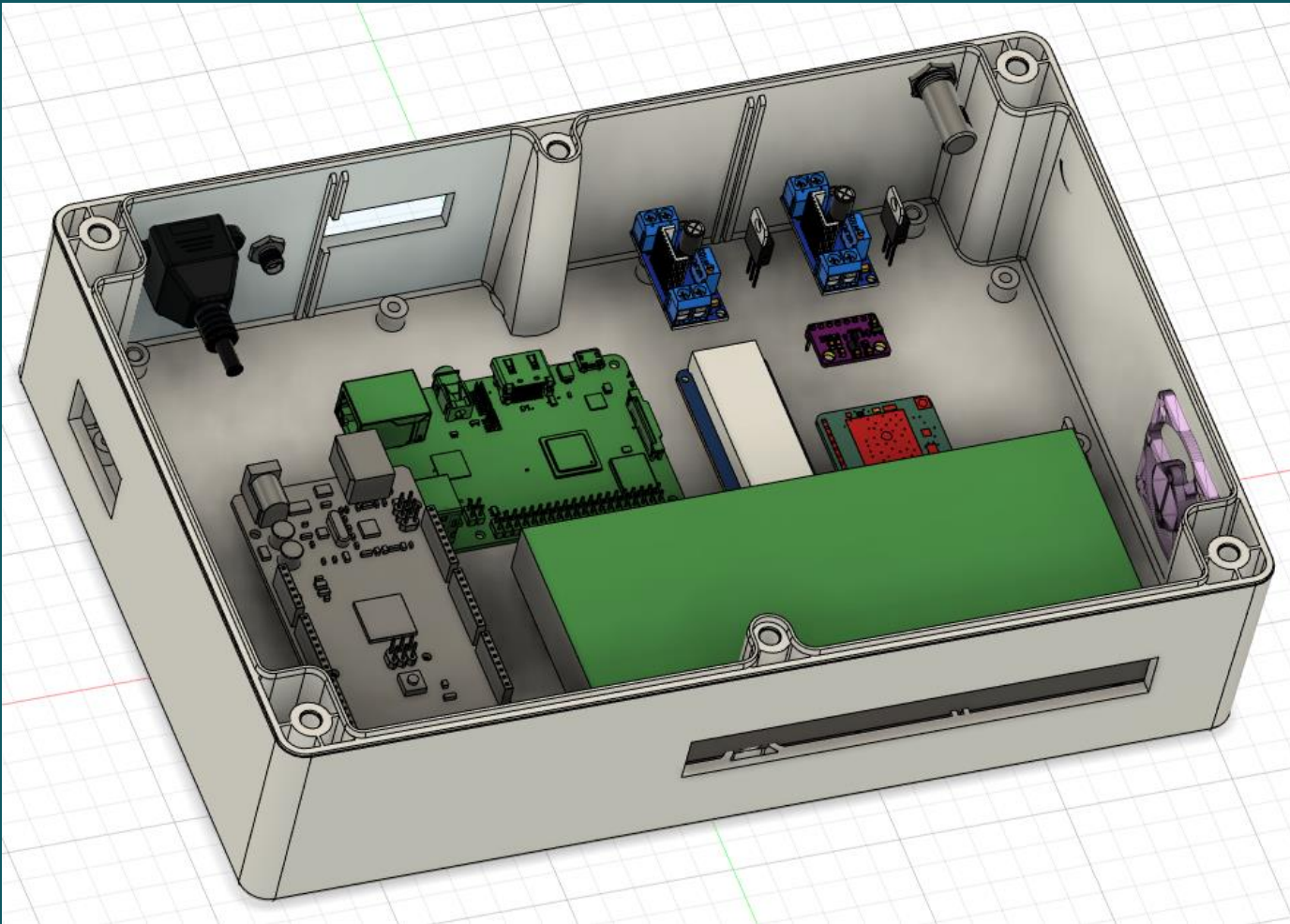
3D model arrangement

- This version includes the voltage regulator, GPS SMA wall mount, wall mount ethernet, and slits for the USBs, BNCs, and HDMI.
- We decided to go for slits because this will speed up the process of finishing the final arrangement.
- They will be adjusted to the outputs/inputs as new versions are built.

Purpose of the Project

- Muon counts are relatively constant.
- The system can detect sudden changes.
- Our Data Acquisition System can help us study what caused these variations.

Acknowledgements

Questions?