OUC All-in-One Photovoltaic Sensor

Group 5

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Motivation

In order to be a convincing replacement for traditional fossil-fuel power sources, solar technology needs to be powerful and efficient.

As such, lots of research is done in the manufacturing of new solar panel technology. However, solar farm operators often have limited access to panel level data.

Our goal is to create a device which will give solar farm operators a simple and expandable way of collecting panel level data. It should work on a variety of solar arrays, whether they be small research arrays with a variety of different panels, or a production scale power generation array.

Project Goals and Objectives

Our **primary goal** is to create several prototypes of a photovoltaic sensor applicable in small-to medium-scale solar arrays that determine panel health by monitoring its voltage and amperage.

Our **secondary goal** is to incorporate two supplementary measuring instruments to our original design: a thermocouple capable of tracking panel temperature and a pyranometer that can detect incident light irradiance.

When installed in a solar array, the sensor will collect panel health data which the operator can then use to optimize the longevity and consistency of the array's power generation.

Specifications and Requirements

Engineering Requirements	Priority
32V Rating	High
10A Rating	High
10W Rating	Moderate
One-year + Lifespan	Moderate
Under $20 each	Low

Demonstrable Specifications	
Voltage Measurement Accuracy	±5%
Current Measurement Accuracy	±5%
Data Transmission	Received

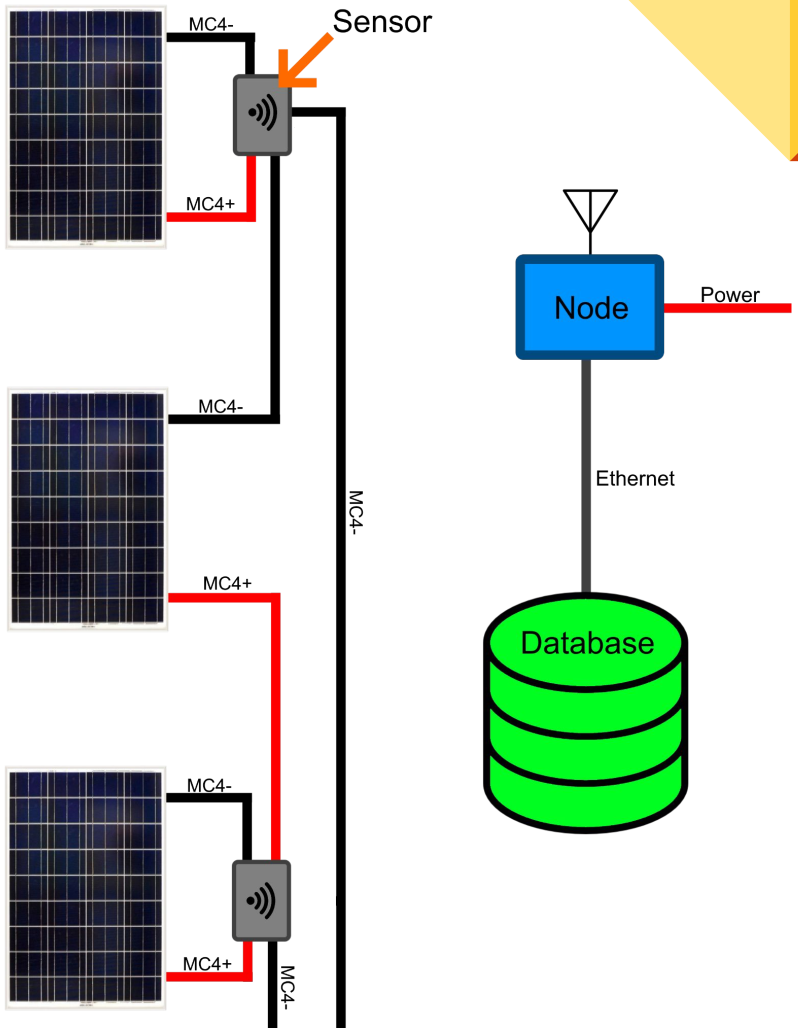
Marketing Specifications	Priority
Use MC4 connectors	High
Transfer data to database	High
NEMA 4X or 4R Enclosure	High
Comply with FCC standards	High
Filter out noise	Moderate
Portable	Moderate
Connect between solar panels	Moderate
Reproducible	Moderate
Connections for thermocouple and pyranometer	Low

Project Design Approach

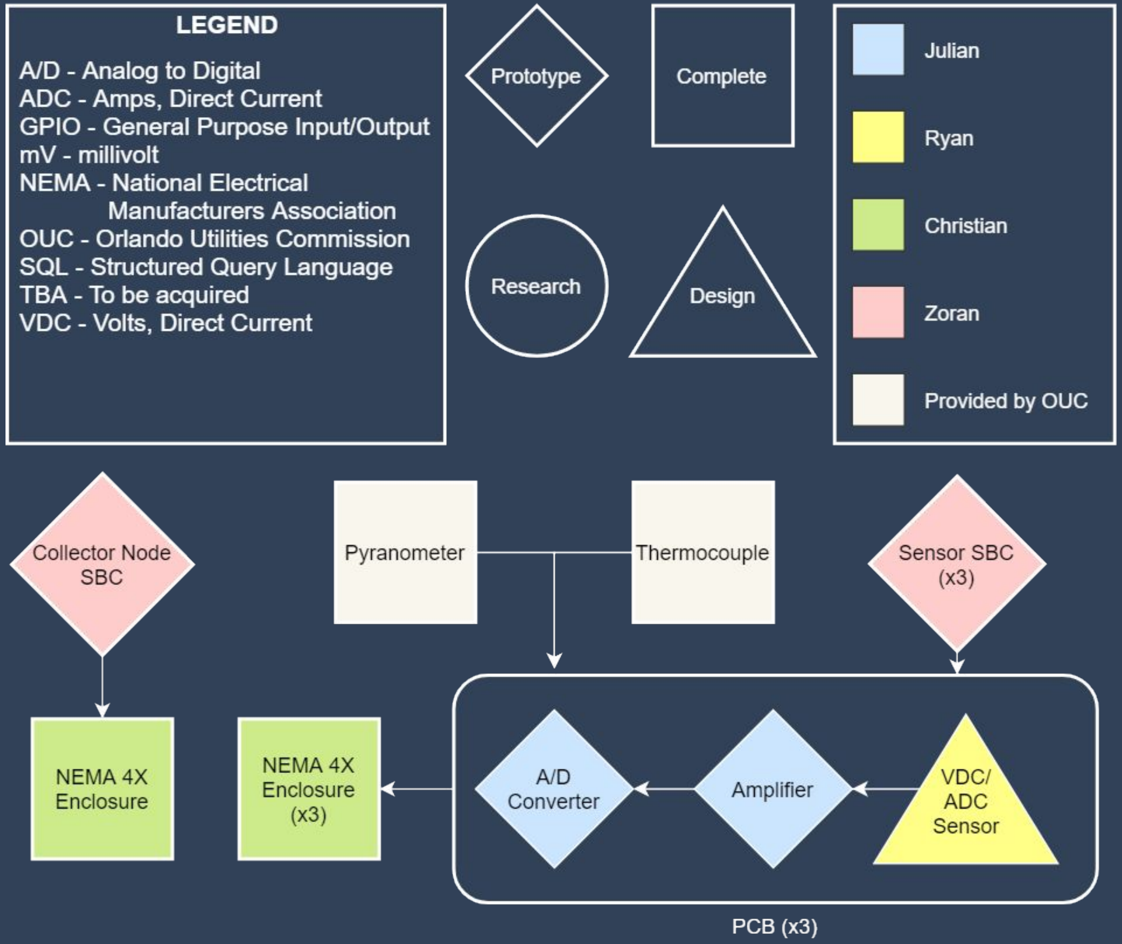
Project Design Implementation

- We want to create a simple sensor that provides convenience and ease to utility companies.
- Not only should it be able to read voltage and current levels, but the sensor should also monitor local irradiance and temperature.
- This will enable utility companies to better track the health of their solar installations.
- The sensor will take on a wireless approach to transmitting the data to the company's database.

Prototype Visualization



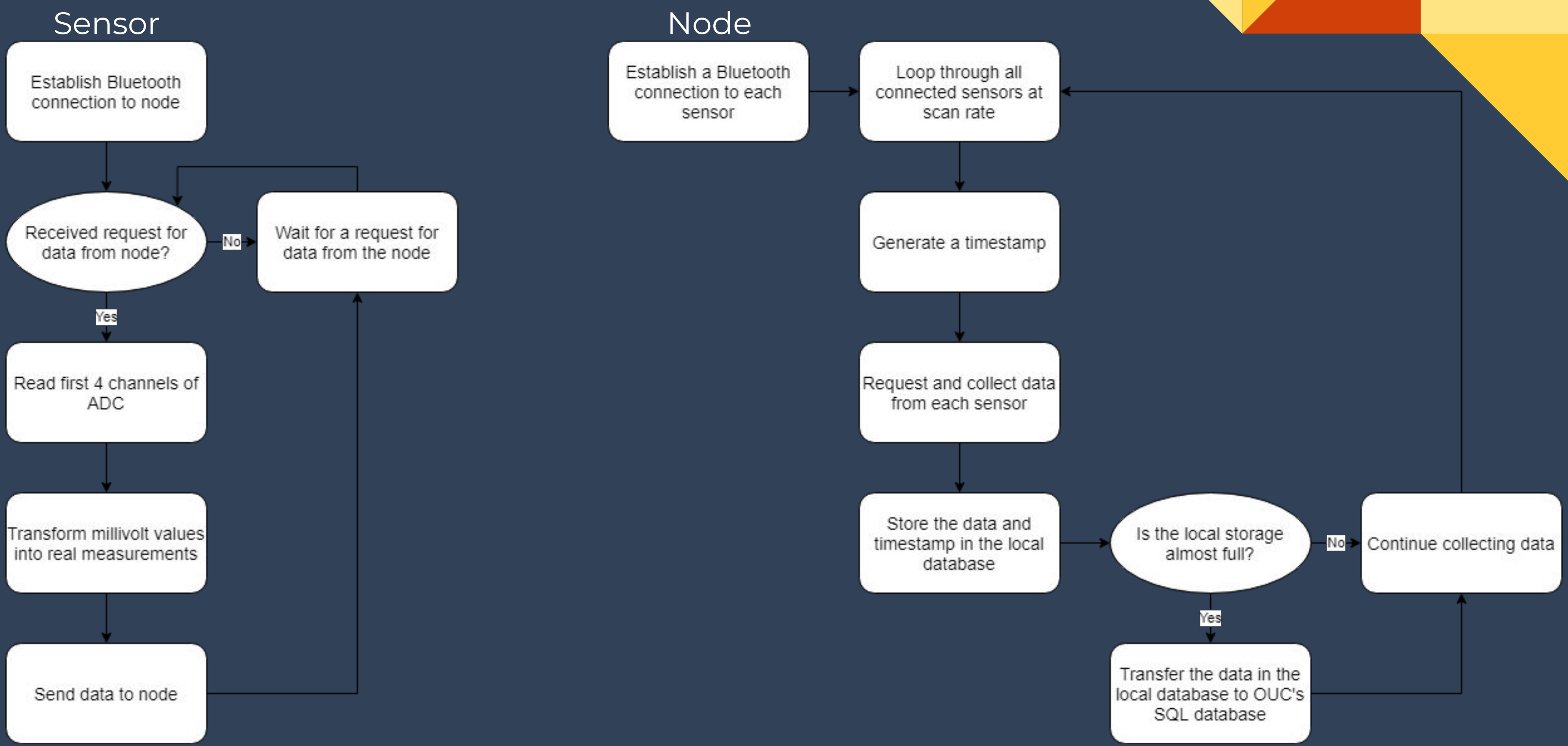
Block Diagram



Impact

- Economic impact
  - **We aim to maintain low costs while producing high-quality results**
- Manufacturability
  - **We will conduct thorough research into each component and explain why each decision was made**
  - **We aim to keep the sensor concept and design simple without reducing its potential**

Software Workflow



Project Standards

Project Standards: Enclosures

- NEMA 250
    - **NEMA 250 provides the standards of ingress protection tests for all of the enclosure types, from Type 1 to Type 13.**
    - **For our project, the OUC required a NEMA Type 4X enclosure, which establishes:**
        - Access to hazardous parts
        - Ingress of solid foreign objects (falling dirt)
        - Ingress of water (dripping and light splashing)
        - Ingress of water (rain, snow and sleet)
        - Ingress of solid foreign objects (windblown dust, lint, fibers and flyings)
        - Ingress of water (hose-down and splashing water)
        - Corrosive agents

Project Standards: Enclosures (ctd.)

- IEC 60529
  - A standard from the International Electrotechnical Commission that establishes a system for classifying levels of protection provided by enclosures. There are different degrees of protection laid out in the standard. The one with which we are concerned is IP 66.
  - This rating offers complete protection of the internal components from anything equal to or larger in size than dust particles.
  - This rating also offers complete protection against power water jets. This would include any type of power water hose, which could be encountered in the outdoors area on OUC's property.

Project Standards: Pyranometers

- IEC 61724-1:2017
    - IEC's assessment of solar irradiance measurement.
    - Created classifications for pyranometers and their appropriate application.
    - Defined new methods of upkeep for the devices.

Project Standards: Thermocouples

- IEC 60584-1:2013
  - IEC’s internationally-recognized classification system.
  - Distinguishes each device’s material properties.

Project Standards: MC4

- IEEE 802.15
    - Defined the protocol and compatible interconnection for data communication devices using low-data-rate, low-power, and low-complexity short-range radio frequency (RF) transmissions in a wireless personal area network (WPAN).

Project Standards: Software

- Python Enhancement Protocol (PEP) 8 -- Style Guide for Python Code
  - **Protocol establishing coding conventions for the Python code comprising the standard library in the main Python distribution**

Circuitry Hardware Selection

Core Requirements:

1. Syphon a small portion of panel voltage and current to the board
2. Have an onboard power supply
3. Properly amplify the voltage and current values
4. Convert the analog input to digital and transmit.

Other Considerations:

1. Power consumption
2. Price
3. Size
4. Ease of use

The Amplifier

Details:

Amplifies the voltage and current readings to a level able to be read by the ADC.
Voltage reading: Gain of 1
Current reading: Gain of 100

The TLV342A amplifier has a 0-4.4V input
Used for low-power applications - good for our purposes

Failure:
Our input range was too narrow - could not read both inputs.
Realized we had a model that would not fit our design criteria.
Switched from TL072 to TLV342A.

Success:
Fixed mistake by ordering correct part to begin the last phase of proto-testing.

The DC-DC Converter

Our priorities for the DC-DC converter:

1. High efficiency
2. Low BOM cost and count
3. Low ecological impact

Why the LMR50410X?

- 81.6% conversion efficiency
- BOM cost of $0.70
- Footprint of 142 mm^2

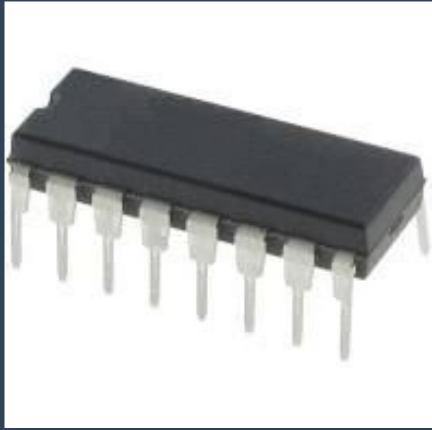
The Analog-to-Digital Converter

Our priorities for the analog-to-digital converter:

1. Accept voltage and current readings as input
2. Accept input from the pyranometer and thermocouple
3. Properly scale values to fit a desired range for the raspberry pi

Why the MCP3008?

- No need for higher resolution and the corresponding price
- Use of SPI rather than I2C protocol
- Ease of use



The Pyranometer

Our priorities for the pyranometer:

1. Read the irradiance surrounding the panel
2. Transmit the value to the ADC
3. Do it all at a low cost

Why the SP-110-SS: Self-Powered Pyranometer?

- Lightning fast response time
- Self-powered
- Inexpensive

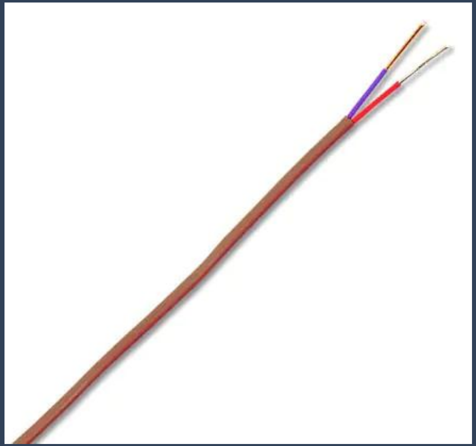
The Thermocouple

Our priorities for the thermocouple:

1. Read the temperature of the immediate panel area
2. Transmit the value to the ADC
3. Do it all at a low cost

Why the T-type thermocouple?

- -330 - 600 °F range
- Margin of error of 0.4-0.75%



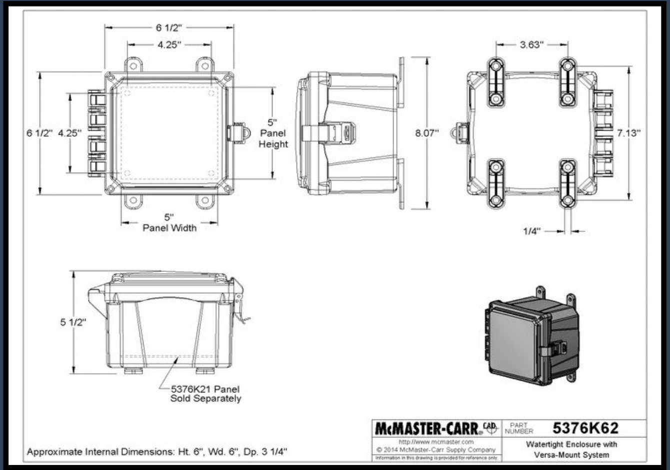
The Enclosure

Our priorities for the enclosure:

1. NEMA 4X rating
   a. **Protects from harsh weather, extreme temperatures, rain, and exposure to dust and dirt**
2. Provide more than enough room for our printed circuit board.
   a. **Enough room in the enclosure for installation, ventilation, & maintenance**

Why the Versa-Mount Polycarbonate Corrosion-Resistant Washdown Enclosure?

- IP66, NEMA 3S, NEMA 4X, and NEMA 13 ratings
- Sufficient operating room
- Inexpensive



Sensor Hardware Selection

Core Requirements:

1. Read an analog input signal
2. Wireless communication

Other Considerations:

1. Price
2. Ease of use
3. Size
4. Power consumption

Raspberry Pi Zero W

Why the Pi?

- Documented compatibility with MCP3008 ADC
- Bluetooth and Bluetooth Low Energy capable
- Only $10.00
- Lots of community support
- Very small (66.0mm x 30.5mm x 5.0mm)
- Less than 1.0W power consumption with Bluetooth on

Node Hardware Selection

Core Requirements:

1. Bluetooth communication
2. Expandable storage

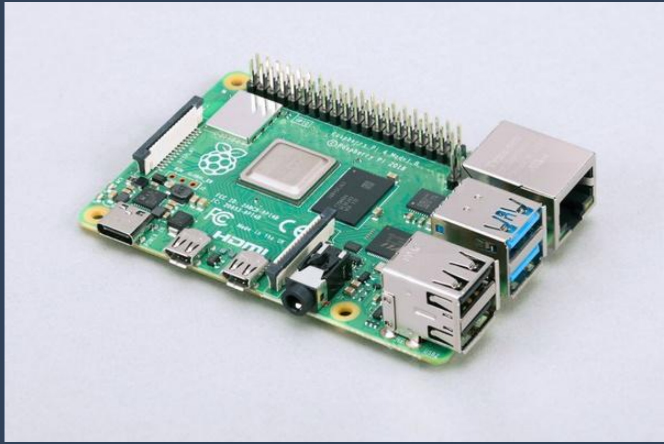
Other Considerations:

3. Price
4. Ease of use
5. Size
6. Power consumption

Raspberry Pi 4 Model B

Why the Pi?

- Bluetooth and Bluetooth Low Energy capable
- Only $30.00 for 1GB RAM model
- Lots of community support
- Fits easily within our enclosure
- Less than 6.5W power consumption under full load



Testing

ADC

Testing

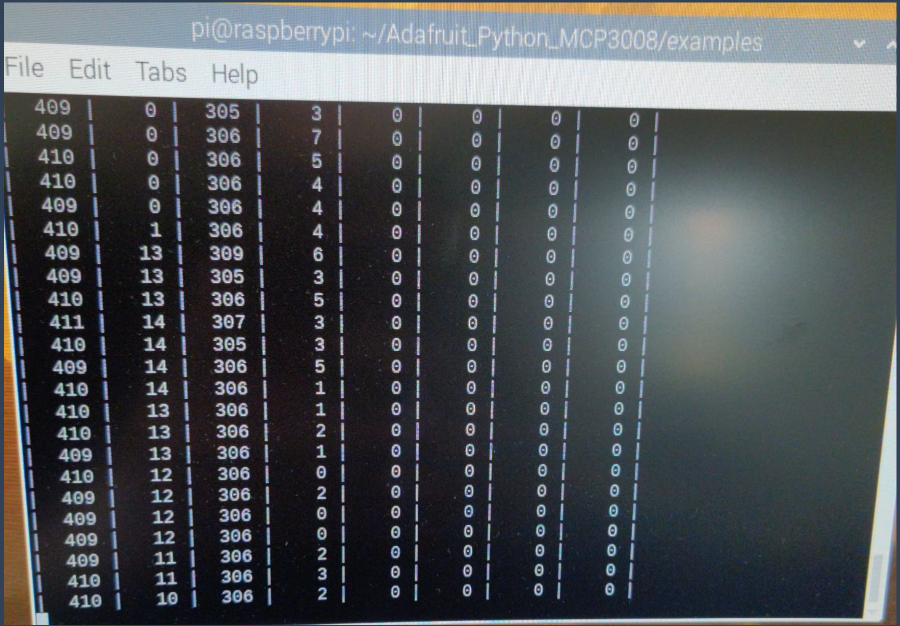
The testing setup was simple:

- Connect to the Raspberry Pi
- Use Power Supply as analog
- Convert to digital
- Transmit and read data

The columns represent the different inputs of the ADC.

VCC = 5V with 1024 steps → 0.005V/step

Column 1 = 2 V   Voltage Reading
Column 2 = 0.06 V   Pyranometer
Column 3 = 1.5 V   Current Reading



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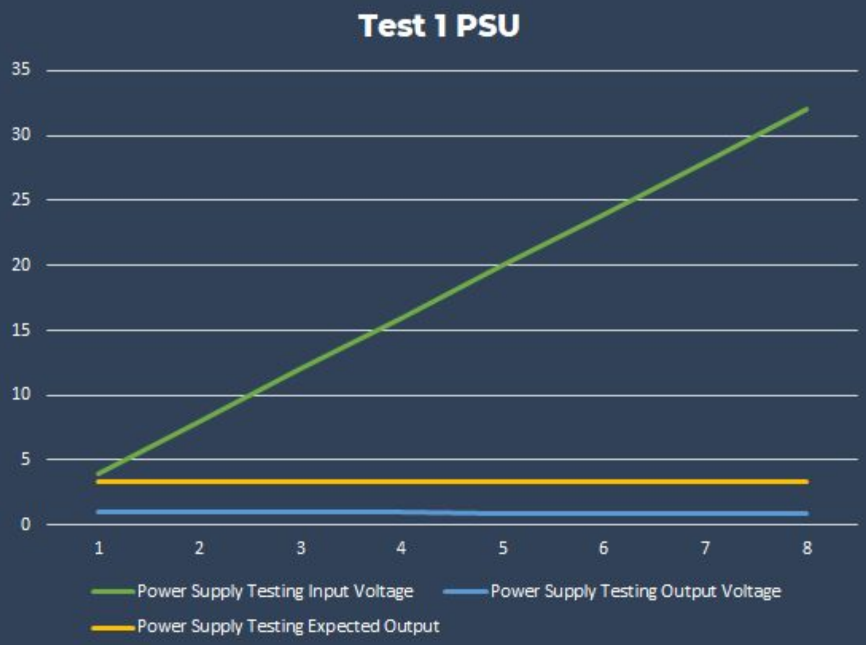
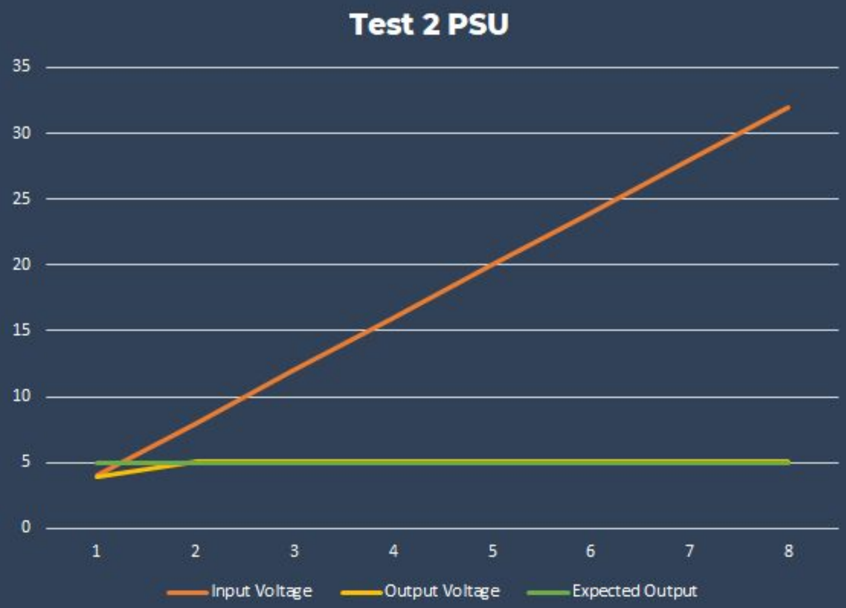
Power Supply

Testing Round 1: Power Supply gave a constant output, but wrong value.



***Testing Round 2:** Circuit restructuring gave us the output we need, consistently.*



Amplification

Data so far:

Input 1 (Range): 1-3 V
Input 2: 0.01 V

Need input range of 0-4 V

TL072 range - 4-5 V inputs
TLV342A range - 0-4.4 V

This is assuming a 5 V value for VCC.

Administrative Content

At This Moment In Time

Our design required tweaking, but we believe it is sound. Testing is nearing completion, and field testing and PCB ordering will soon follow.

Milestone	Status	
Part Selection	100%	- Initial Design/Schematic
Protoboard Design	100%	
Protoboard Testing	70%	- Breadboard Testing
Analog to Digital Signal Conversion	100%	
Bluetooth Transmission	70%	- Code Testing
Database	90%	
Construct First Prototypes	0%	- Field Testing
Field Testing	0%	
PCB Design	80%	- Ordering/Final Design
Enclosure Design	100%	

At This Moment In Time

Component	Quantity	Cost per Each	Estimated Total Cost
NEMA 4X Enclosure	4	$71.97	$287.88
Pyranometer	3	~~$223.00~~	Provided by OUC
T-Type Thermocouple	3	$~~10.00~~	Provided by OUC
Mounting Materials	Varies	Varies	$167.74
Raspi Zero W	3	$10.00	$30.00
Raspi 4B	1	$30.00	$30.00
Grand Total	Varies		515.62

Going Forward

Component	Quantity	Cost per Each	Estimated Total Cost
PCB	3	$4.00	$12.00
ICs	3 (5 copies ea.)	$0.75	$11.25
Raspi PoE Hat	1	$20.00	$20.00

Going Forward

- Continue testing
- Order remaining components
- Ensure all individual components work separately, then together
- Design a robust prototype for field testing
- Test enclosure mounting
- Submit a PCB design