Design Overview

Remote Area Monitoring

Group 10

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RAM

Motivation

- Over 10 million acres of land consumed in 2020 alone
- Forest fires have a lasting impact on both the environment and those living within it
- We as perspective engineers have an opportunity to make an impact

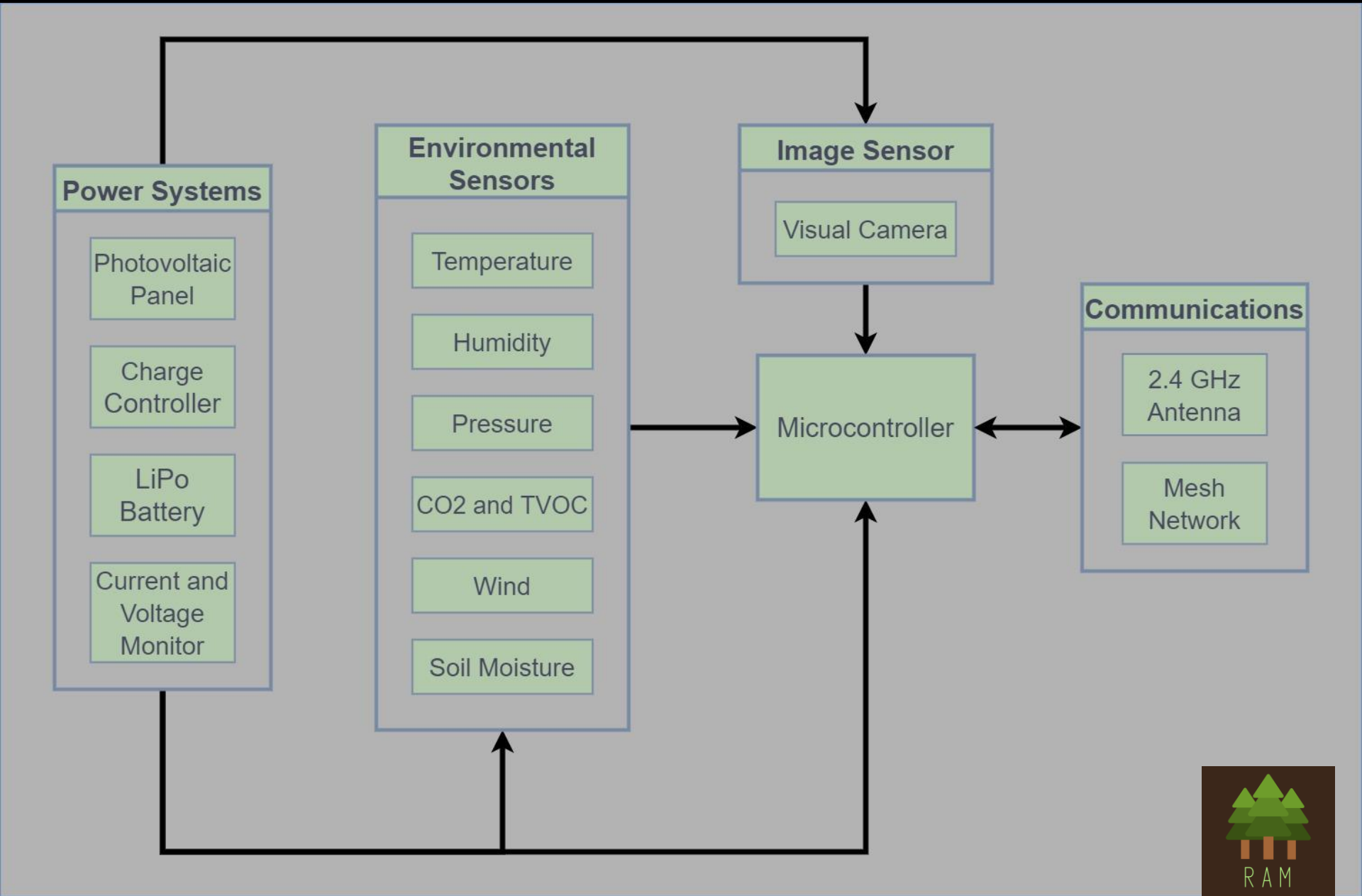
Goals and Objectives

- Gather Data for the Prevention of Forest Fires
- Create a network of sensing nodes capable of off-grid communications and operation
- Collect the data gathered by each node and aggregate the data in a database. This data may be exported or viewed for a historical representation of the area
- Each sensing node shall adopt a modular design
- All design files will be open source

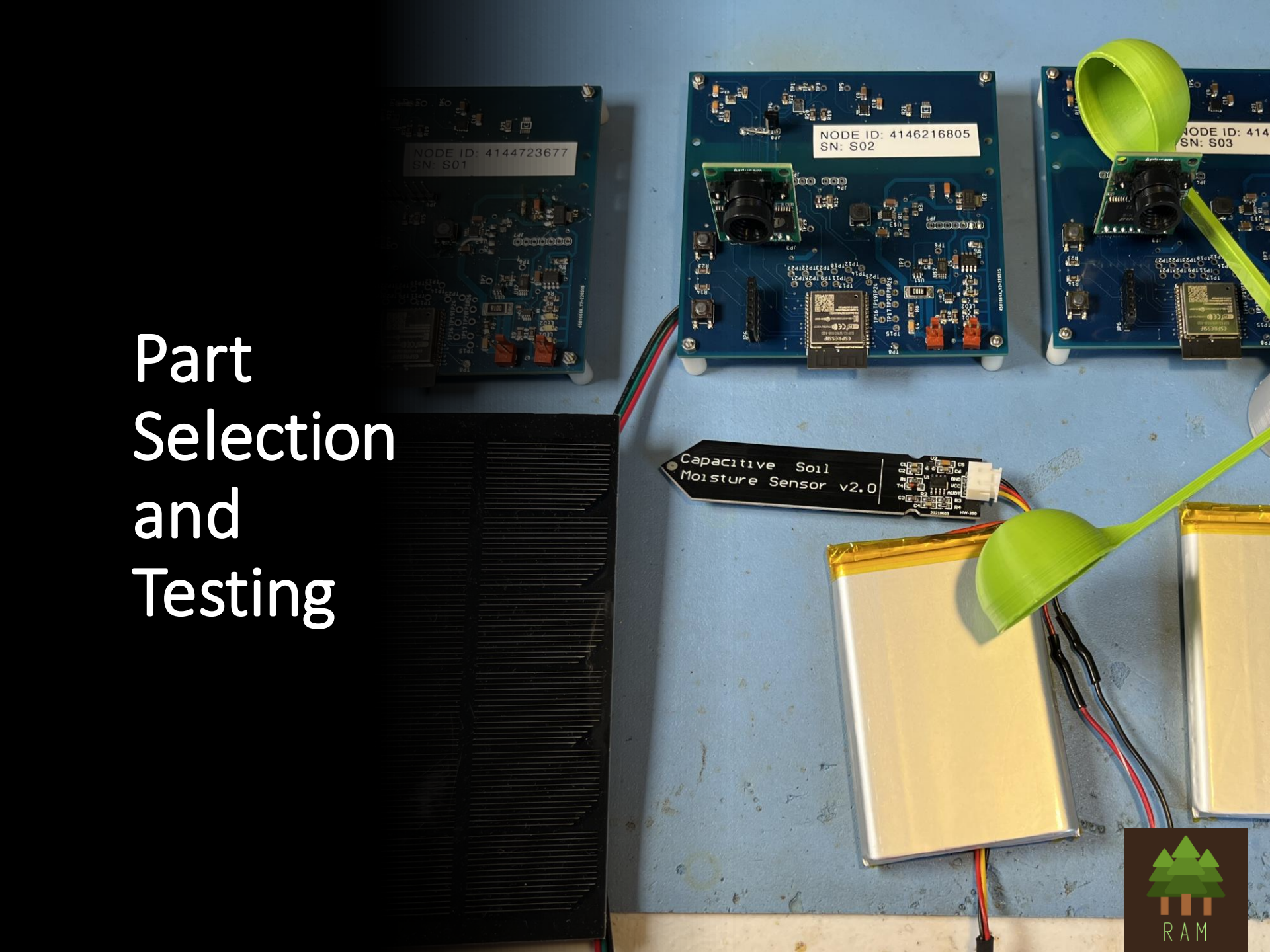
Hardware Engineering Specifications

Requirement ID	Specification	Value
H01	Range	100 Meters
H02	Visual Camera	350x288 Resolution
H03	Charging	3-Watt Charging Rate
H04	Node Body Max Size	6in x 6in
H05	Wind Speed	+- 10% Accuracy
H06	Wind Direction	+- 10% Accuracy
H07	Relative Humidity Sensor	Accuracy +- 10%
H08	Temperature Sensor	Accuracy +- 0.5C
H09	Barometer	Accuracy: +- 1.5mbar
H10	Soil Moisture Sensor	Minimum 850 ADC Count Change Over Sensing Range

Node Hardware Block Diagram

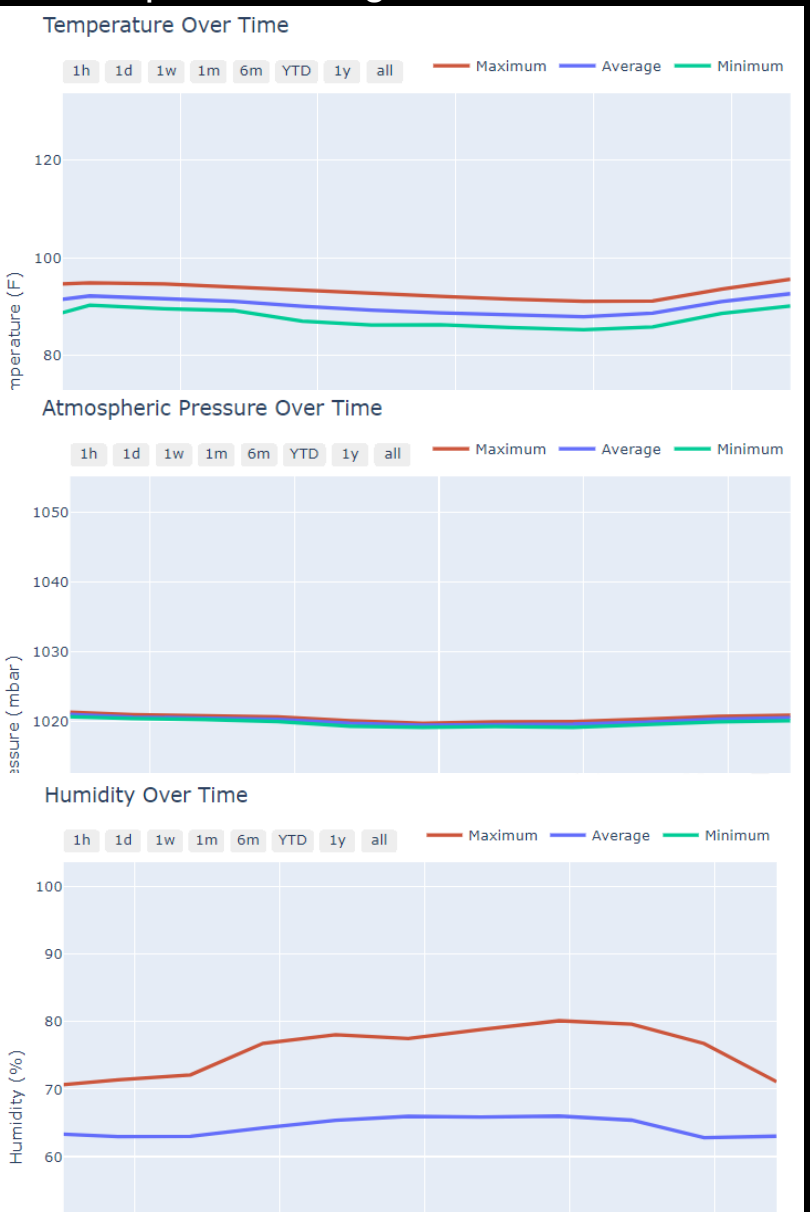


Part Selection and Testing



Temperature, Pressure, and Humidity

All Graphs Showing 8 Hours of Data



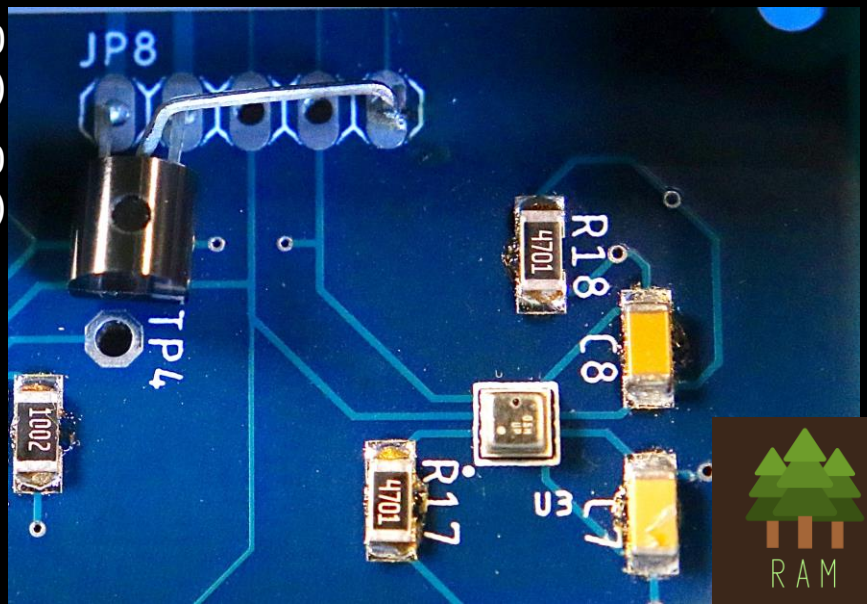
- Bosch BME280
  - Temperature
  - Relative Humidity
  - Pressure
- DS18B20
  - Temperature

- DS18B20 not available in SMD package

- Long Term Testing:
  - Filtering modes enabled on BME280
  - Pressure very consistent
  - DS18B20 may not be required

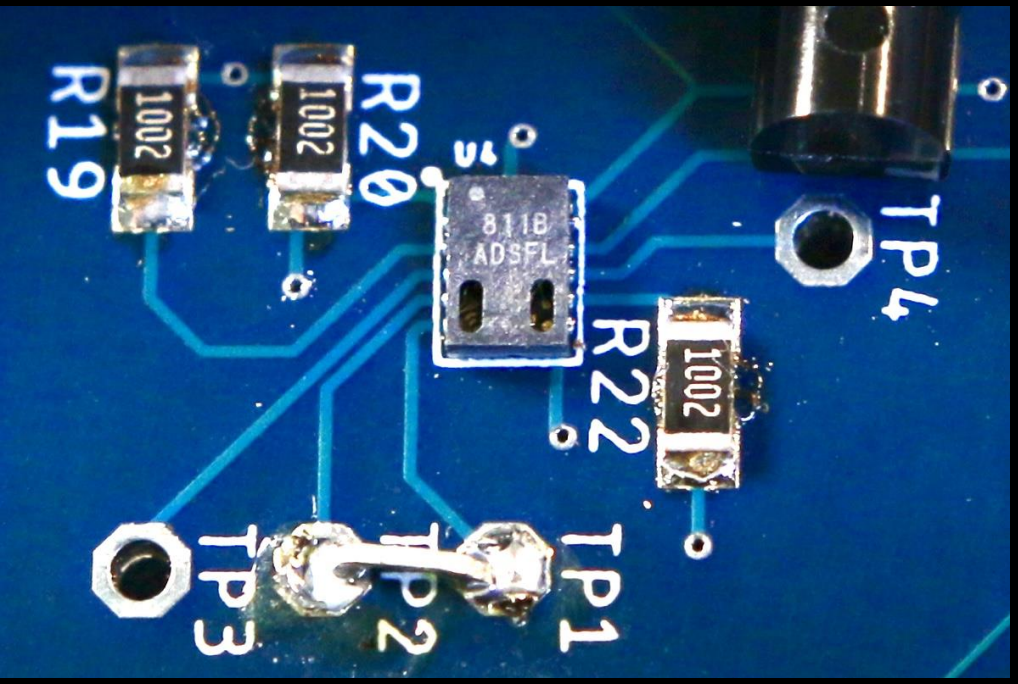
BME280 (Right)

DS18B20 (Left)



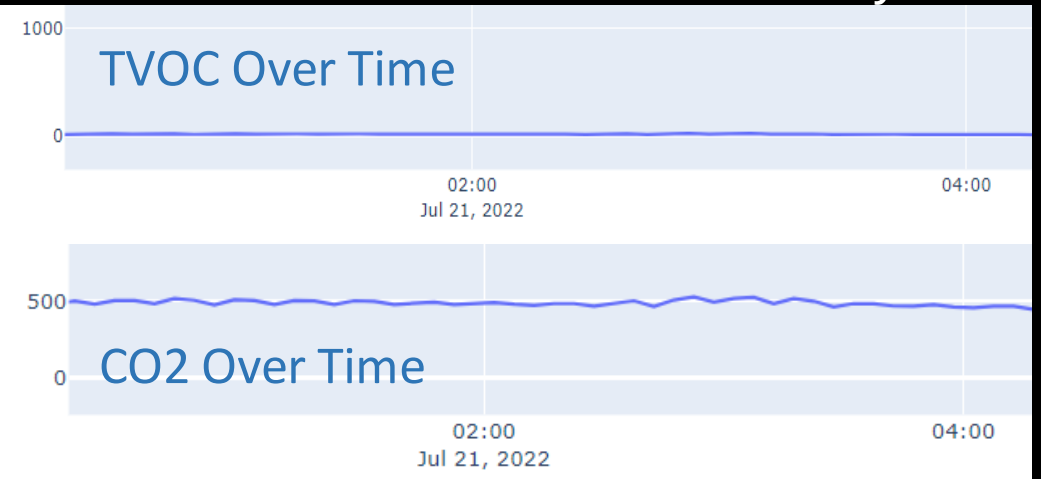
Air Quality – CO2 and TVOCs

CCS811 Inside a Node



- ScioSense CCS811
- Electrical Design Rework
  - Feedback loop required for startup
  - Pin 4 (TP2) connected to Pin 5 (TP1)
- Long Term Testing:
  - Added environmental offsets
  - Reduced polling rate
  - Stability reached with lower than expected power consumption

Data Gathered from a Node in Our System



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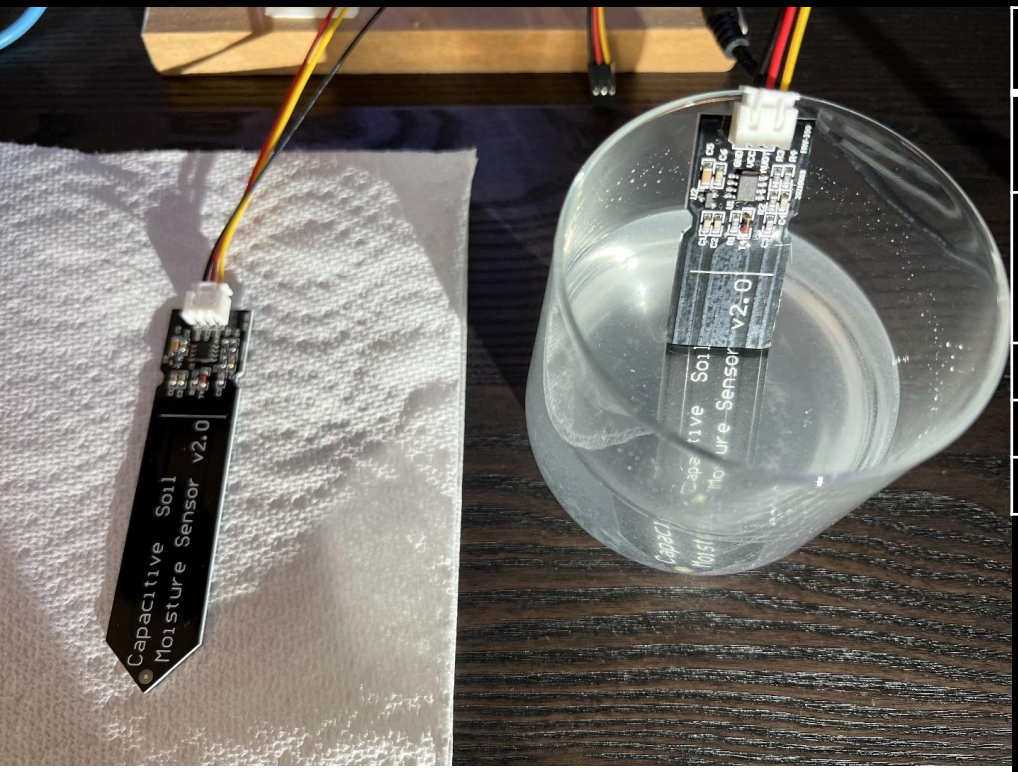
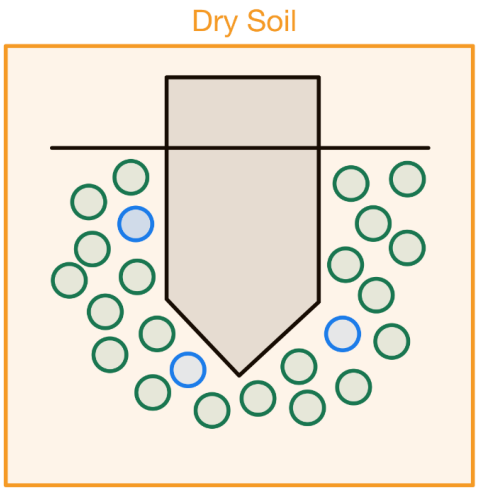
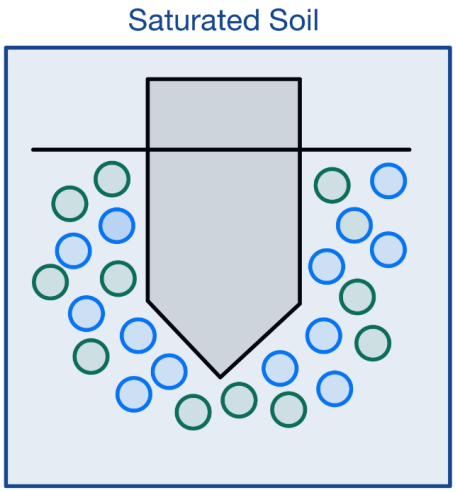
Soil Moisture Sensor



Soil Sensor 1 Test Results			
Continuous Current Draw (mA)		5.64	
Cycle Number	Dry Output (Counts)	Submerged Output (Counts)	Delta (Counts)
1	2870	953	1917
2	2909	961	1948
3	2903	946	1957

- Capacitive Soil Moisture Sensor V2.0
- Used as an Indirect Measure of Rainfall
- Uses Soil as a Dielectric
- Testing Conducted to Expose Minimums and Maximums
- Testing Shows Two Conclusions:
  - Results are consistent
  - The delta in counts is approximately half the range of the microcontroller





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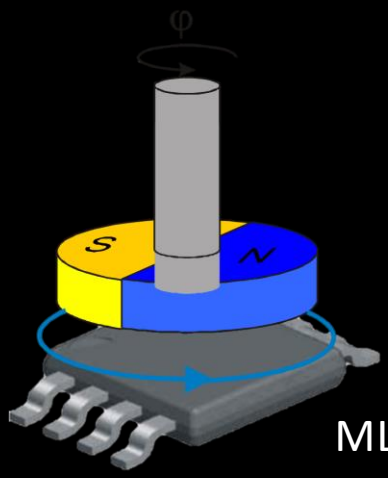
Anemometer – Overview

- Wind speed sensor
  - A3144 hall effect magnetic sensor
  - Produces pulses as the magnet passes by the sensor

- Wind direction sensor
  - Melexis MLX90316
  - Absolute position rotary encoder
  - Measures magnetic flux passing through the part



MLX90316 with magnet attached to an axle

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Anemometer – Wind Speed

Wind Speed Test Results		
Vehicle Speed (MPH)	**Measured Speed (MPH)**	**Percent Error**
10	10.1	1%
10	10.6	6%
20	21.3	6.5%
20	19.4	-3%
40	40.9	2%
40	38.4	-4%

- Low-Cost Design – less than $2

- Calibrated using speedometer on vehicle
- Potential Calibration Errors:
  - Wind gusts
  - Wind direction with or against the vehicle's direction of travel
  - Variations in vehicle speed

- Results show we are under our 10% accuracy requirement

Calibration Setup

Mechanical Design

Pulses While Spinning

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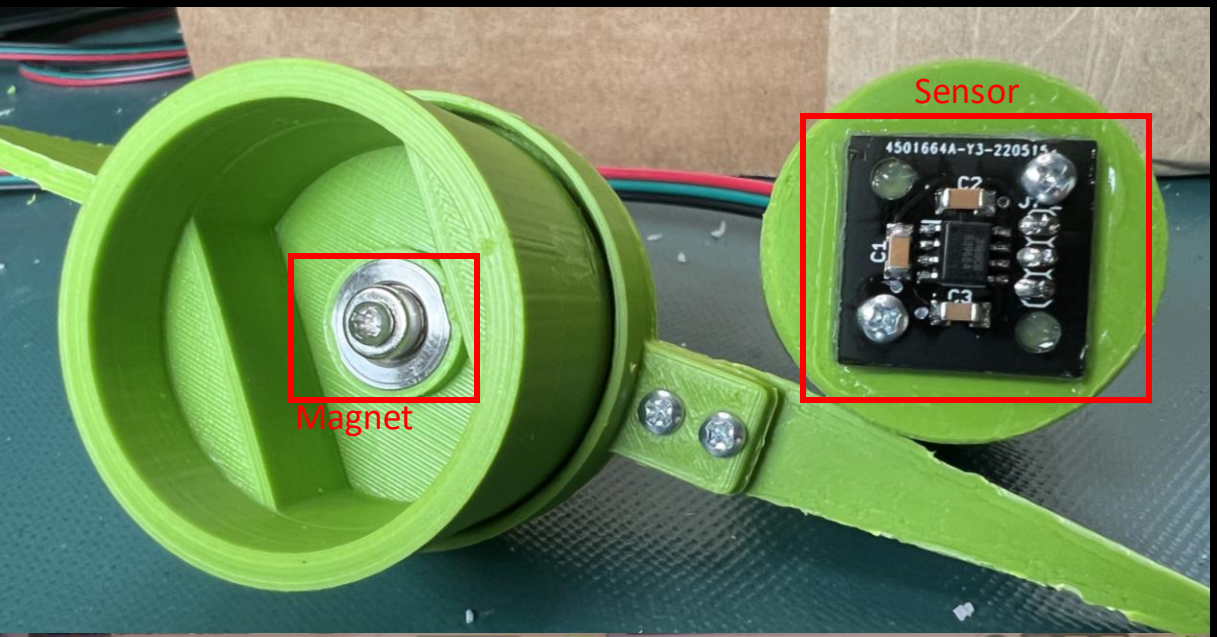
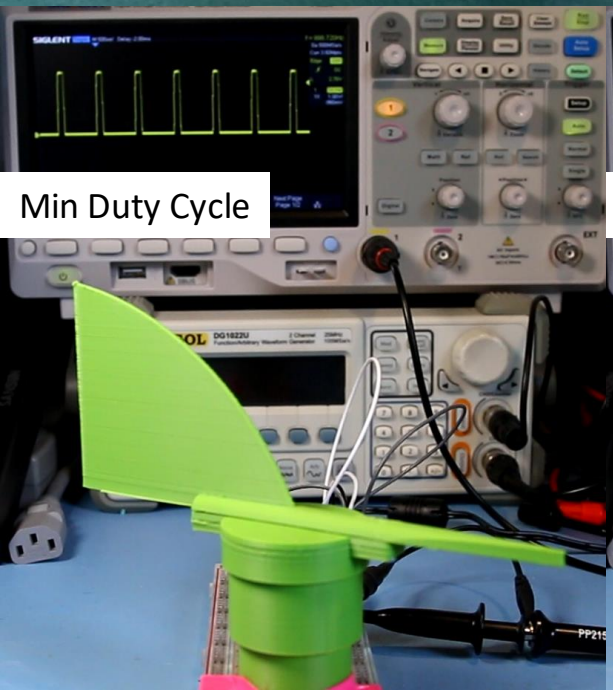
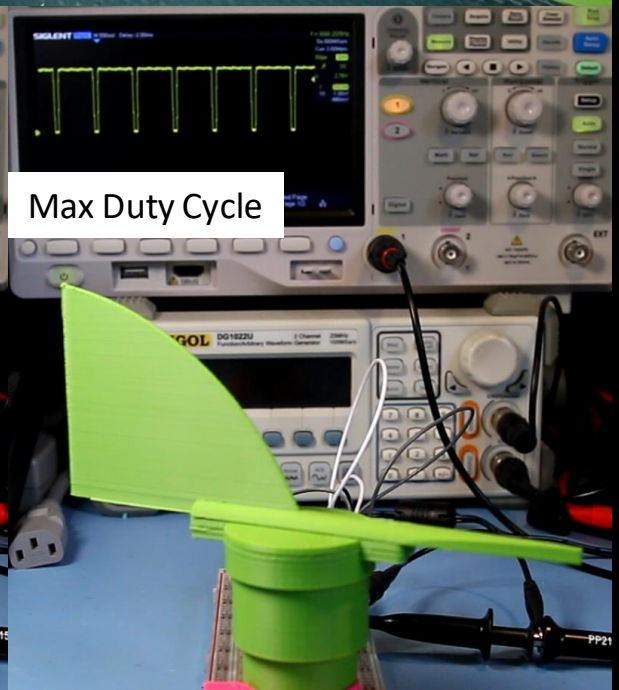
Anemometer – Wind Direction







- Sensor comes pre-programmed to output a PWM signal
- The microcontroller measures the duty cycle of the sensor signal

- We tested the sensor by attaching an oscilloscope to the output and observing the consistency of the transition from min to max duty cycle

- We correlate duty cycle to degrees with the following equation:

$$Degrees = 360 - \frac{DutyCycleTime - MinDutyCycleTime}{CalibrationFactor}$$

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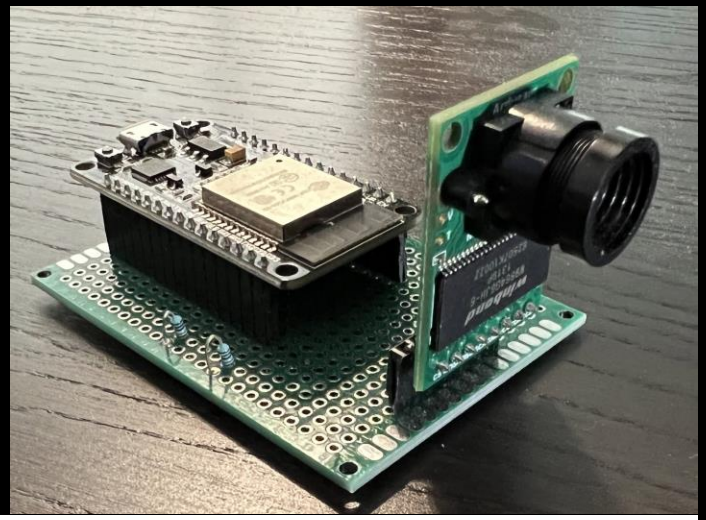
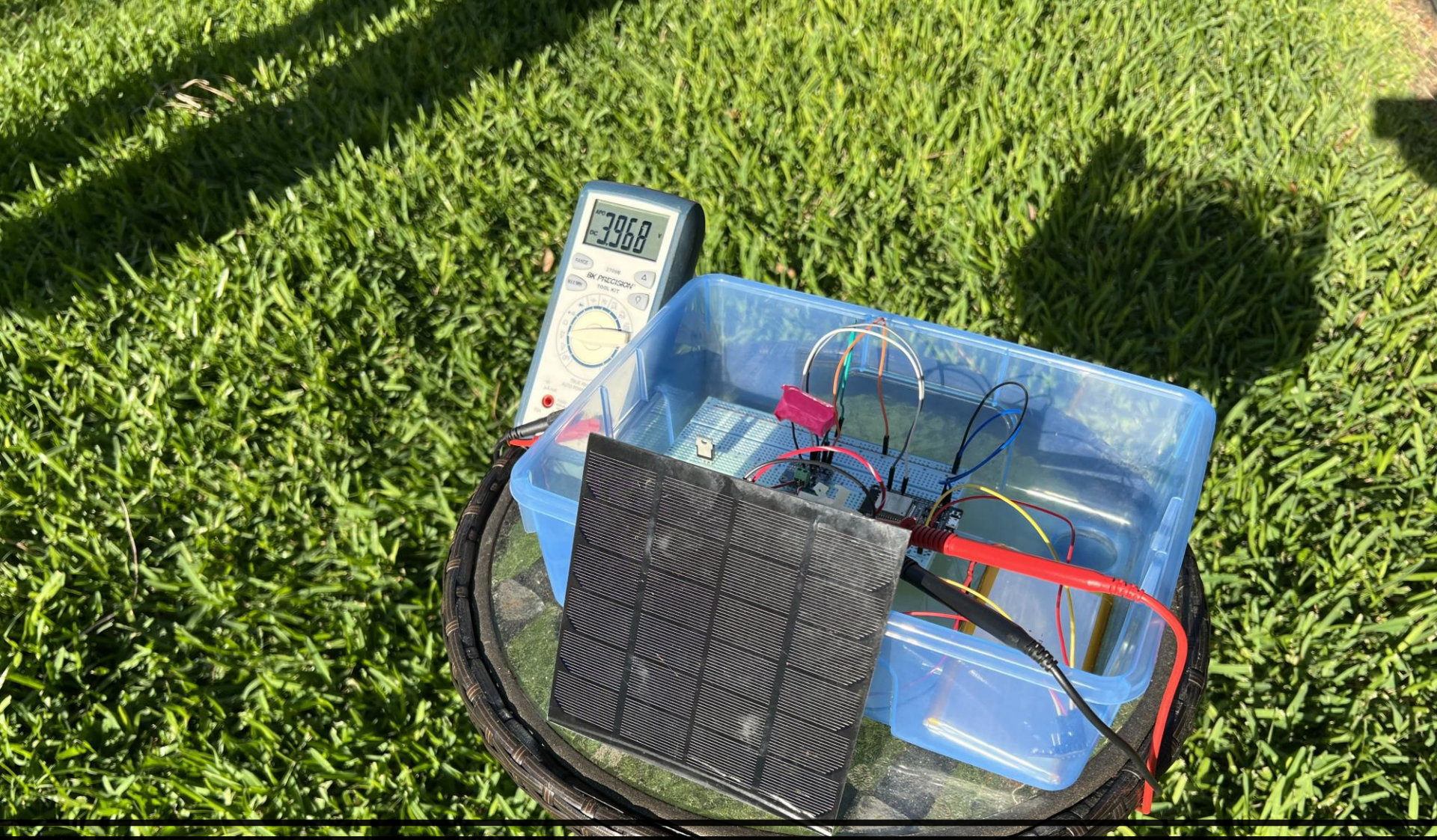
Camera Selection and Testing

Camera Testing Prototype



- ArduCam Mini 2mp
  - Built-in Image Buffer
  - 2mp Max Resolution
  - Auto-Lighting Modes
- Images Give an Indication of the Fuel Loading of an Area
- Lower Resolution is Sufficient
- Mesh Network Limits the Data Size of the Images



Part Selection – Power Delivery

RAM

Microcontroller ESP 32

Widely Available and Supported

Part of the Arduino Family of Boards

Built-in Wi-Fi Antenna for Mesh Networking

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Software Engineering Specifications

Requirement ID	Specification	Description
S01	Application	Web application to display current and historical data
S02	Map View	Show each node on a map with the status of the node
S03	Map Overlay	Display a gradient on the map representing the environmental conditions such as temperature
S04	Off-Grid Network	Network for communicating to and from the nodes without relying on established networks such as cellular
S05	Notifications	Notify the user of issues in the mesh network
S06	Maximum Number of Nodes per Aggregator	150

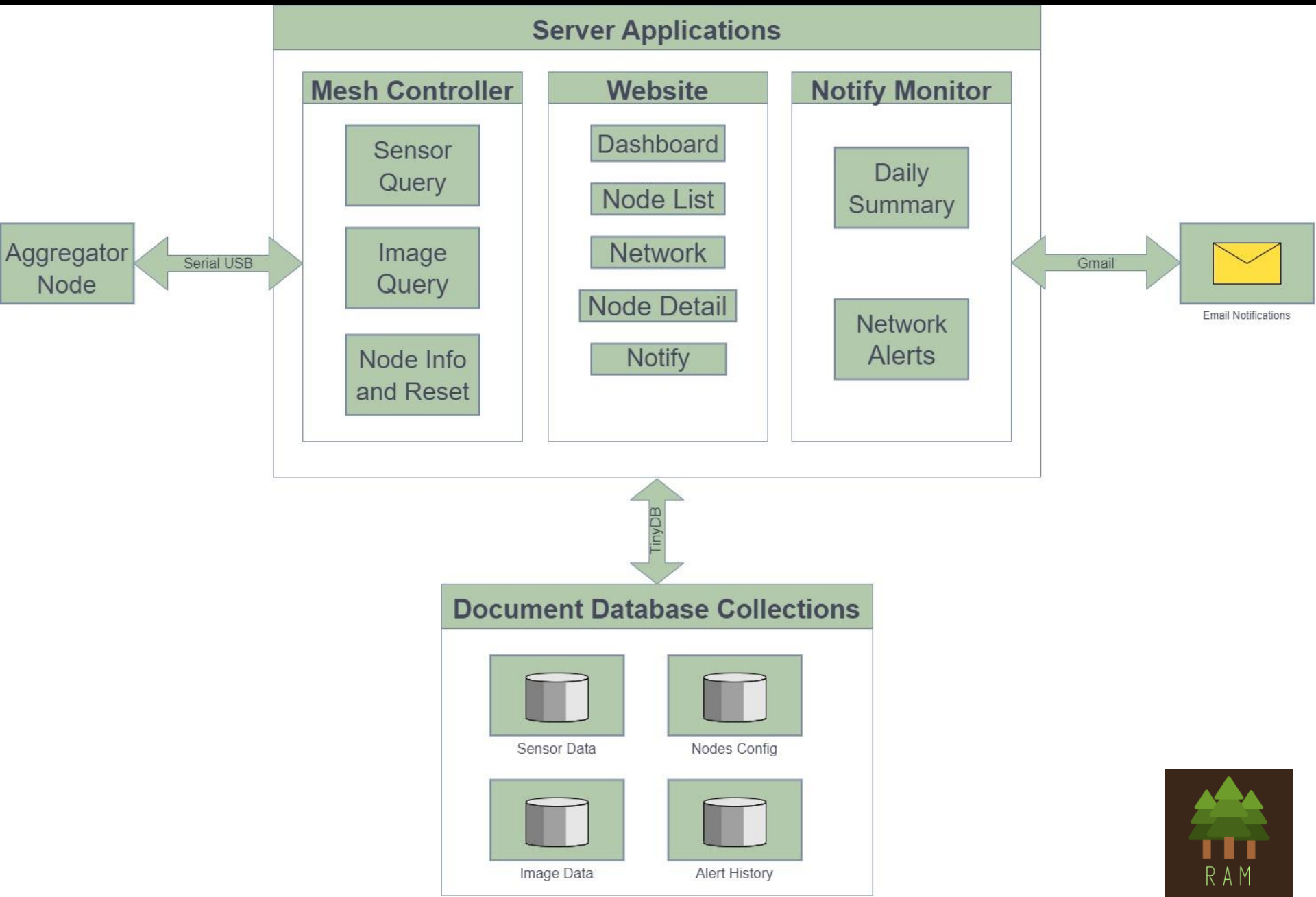
Software Components

- Quickly adaptive in a prototype environment
- Strong data manipulation

- Dash is a web interface built using Python
- Plotly is a data visualization framework
- Plotly and Dash are tightly integrated

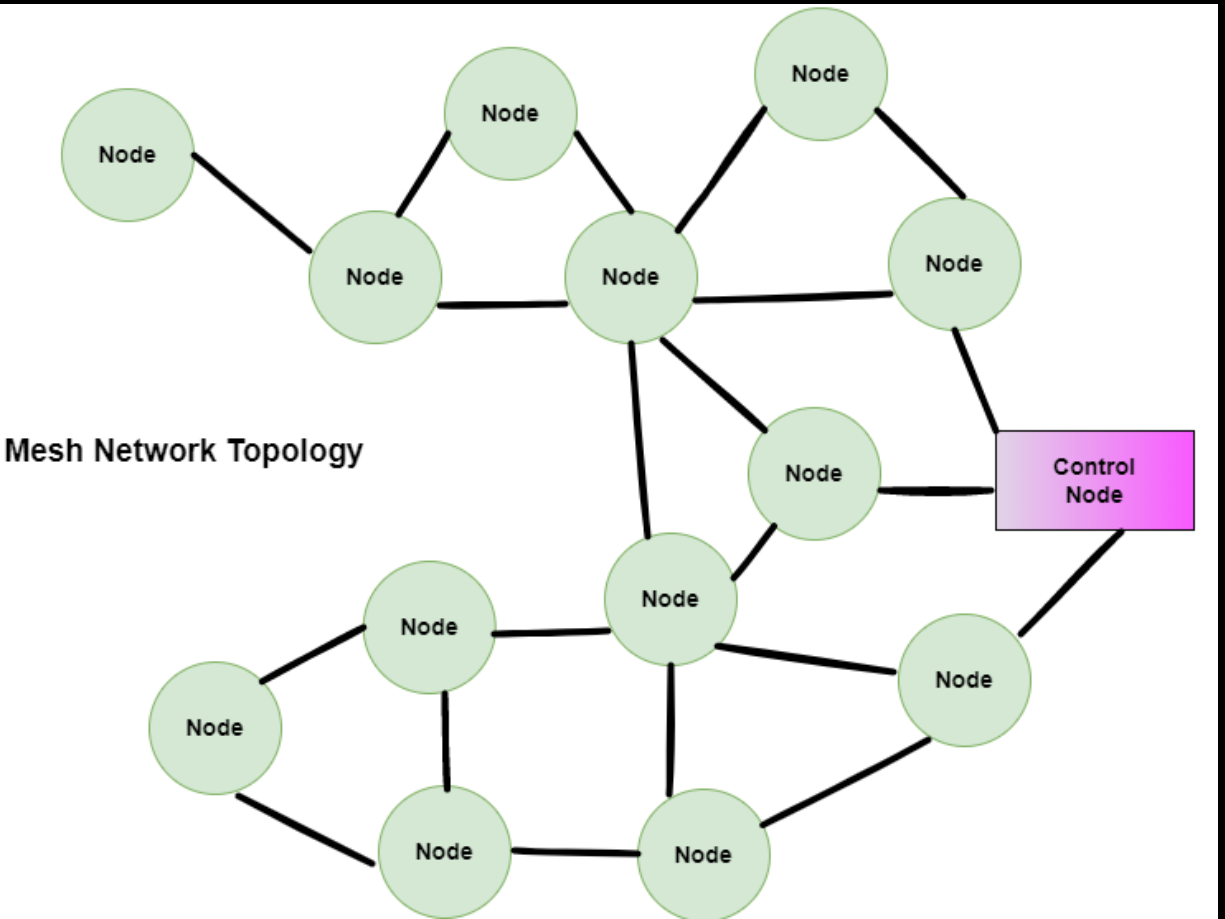
- Flexible Data Model
- Scalability
- Ease of Use for Developers

Server Software Design



Mesh Network

- Benefits Advantages:
  - Cover a wide area
  - Resilient to failures of individual nodes
  - Expandability
- Disadvantages:
  - Slow data rate



Painless Mesh

- Out of the box support for ESP32 microcontroller
- Arduino Library Available
- Built-in handling for mesh functionality:
  - Self-Healing
  - Optimized Paths
  - Automatic Detection of New Nodes

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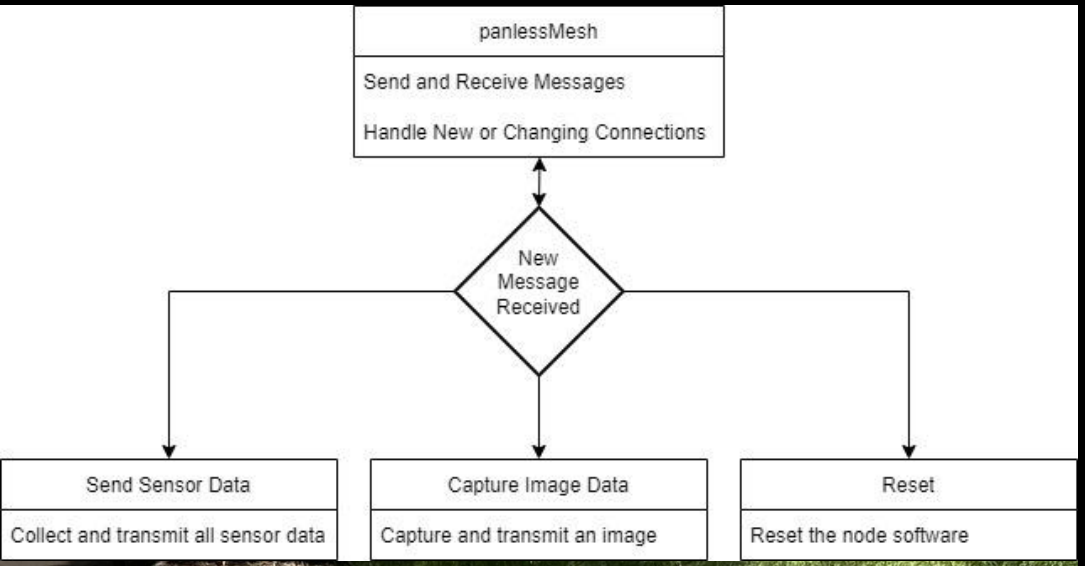
Node Software Design



- Arduino Platform
- Painless Mesh Networking
- Three Discrete Commands:
  - Get a snapshot of sensor data
  - Get an image capture
  - Reset the node

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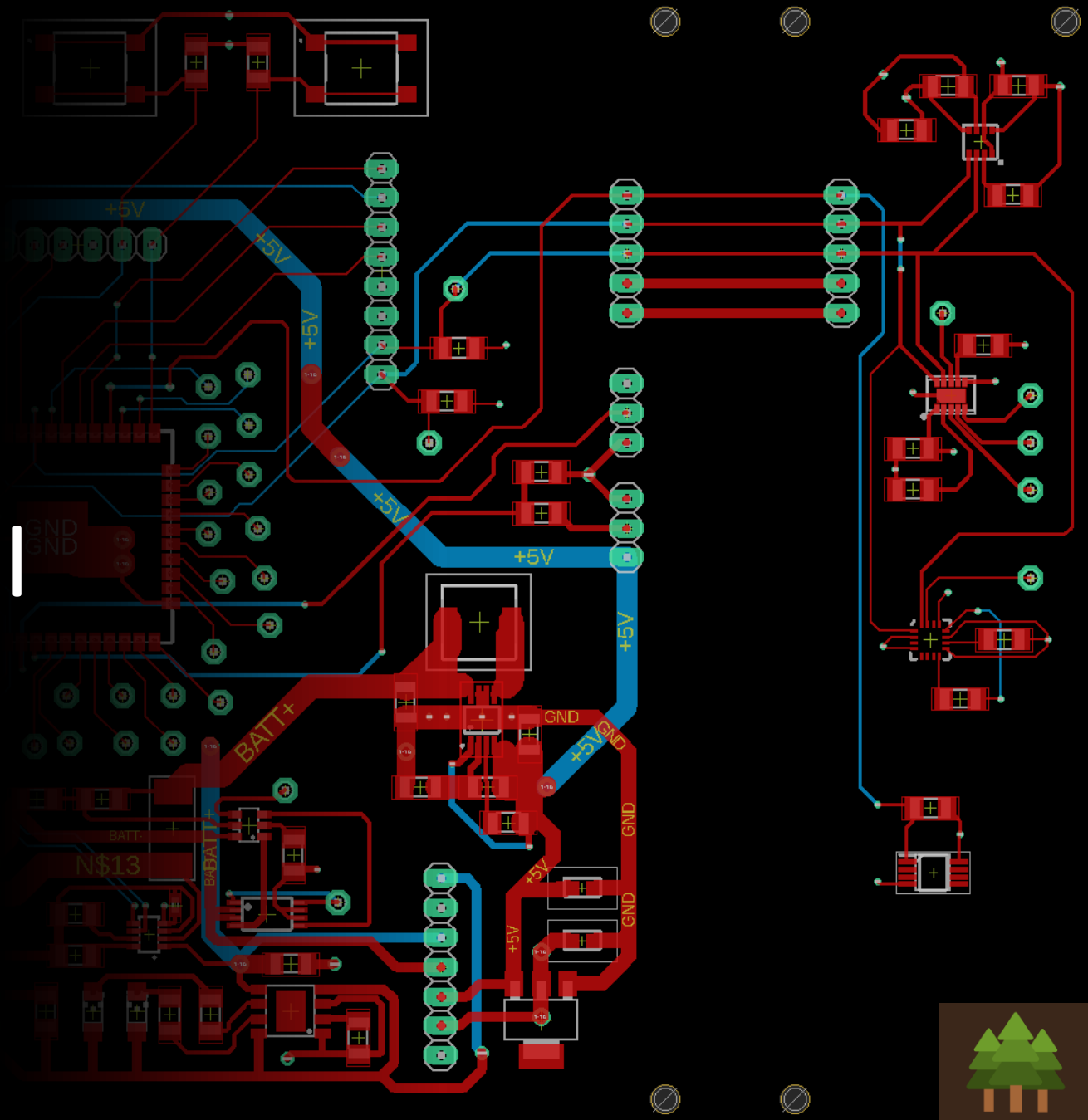
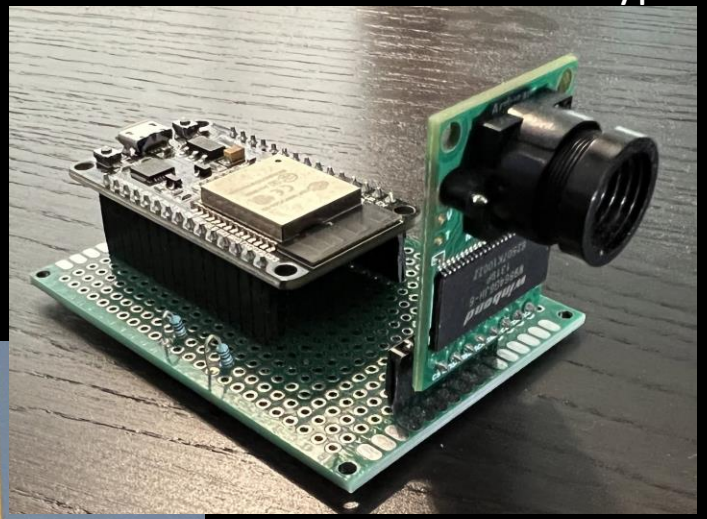
Electrical Design

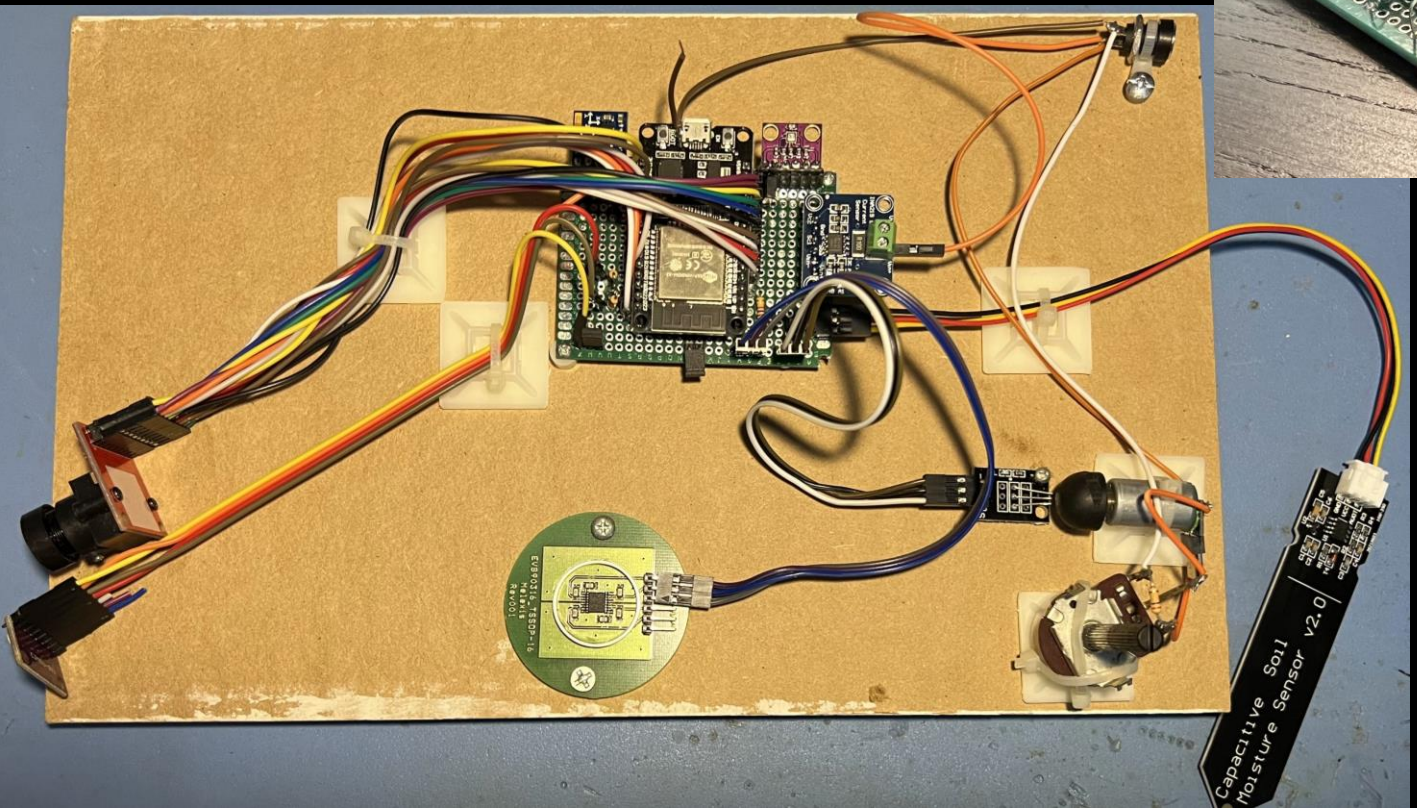


Development Prototypes

- Developmental Prototypes used to:
  - Test individual components
  - Test software and hardware integration
  - Validate electrical designs

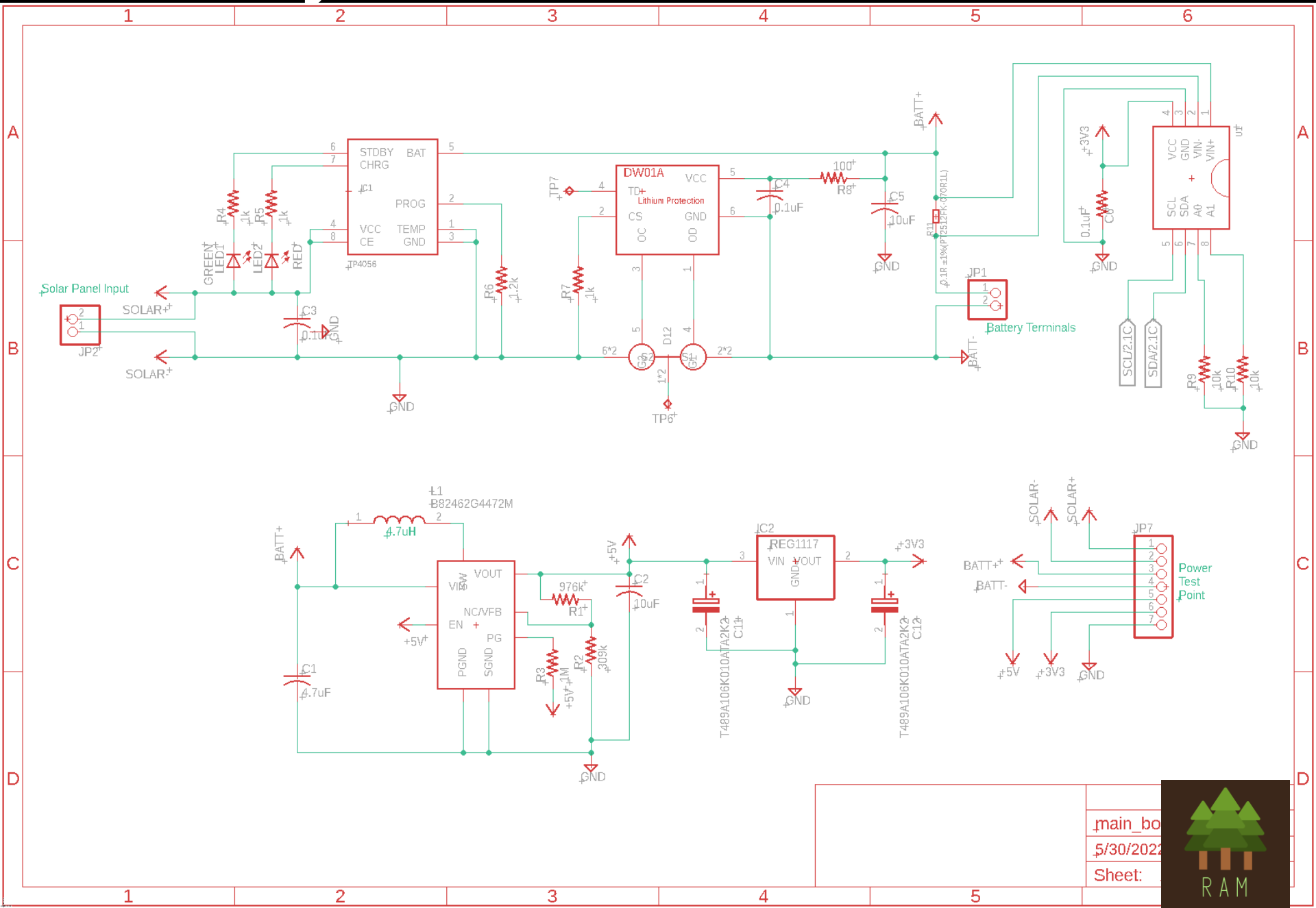
Camera Testing Node Prototype



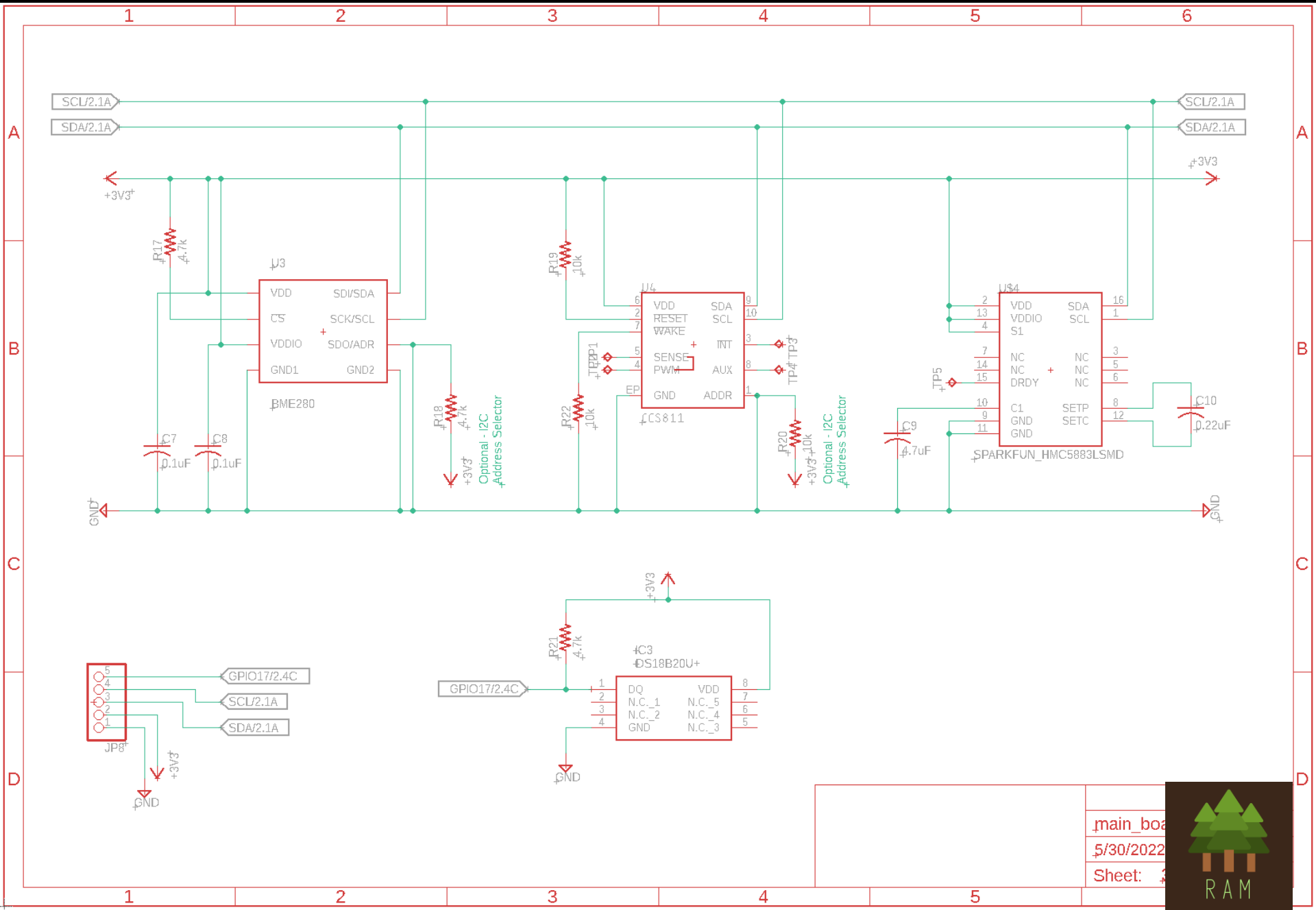


Sensor Testing Node Prototype

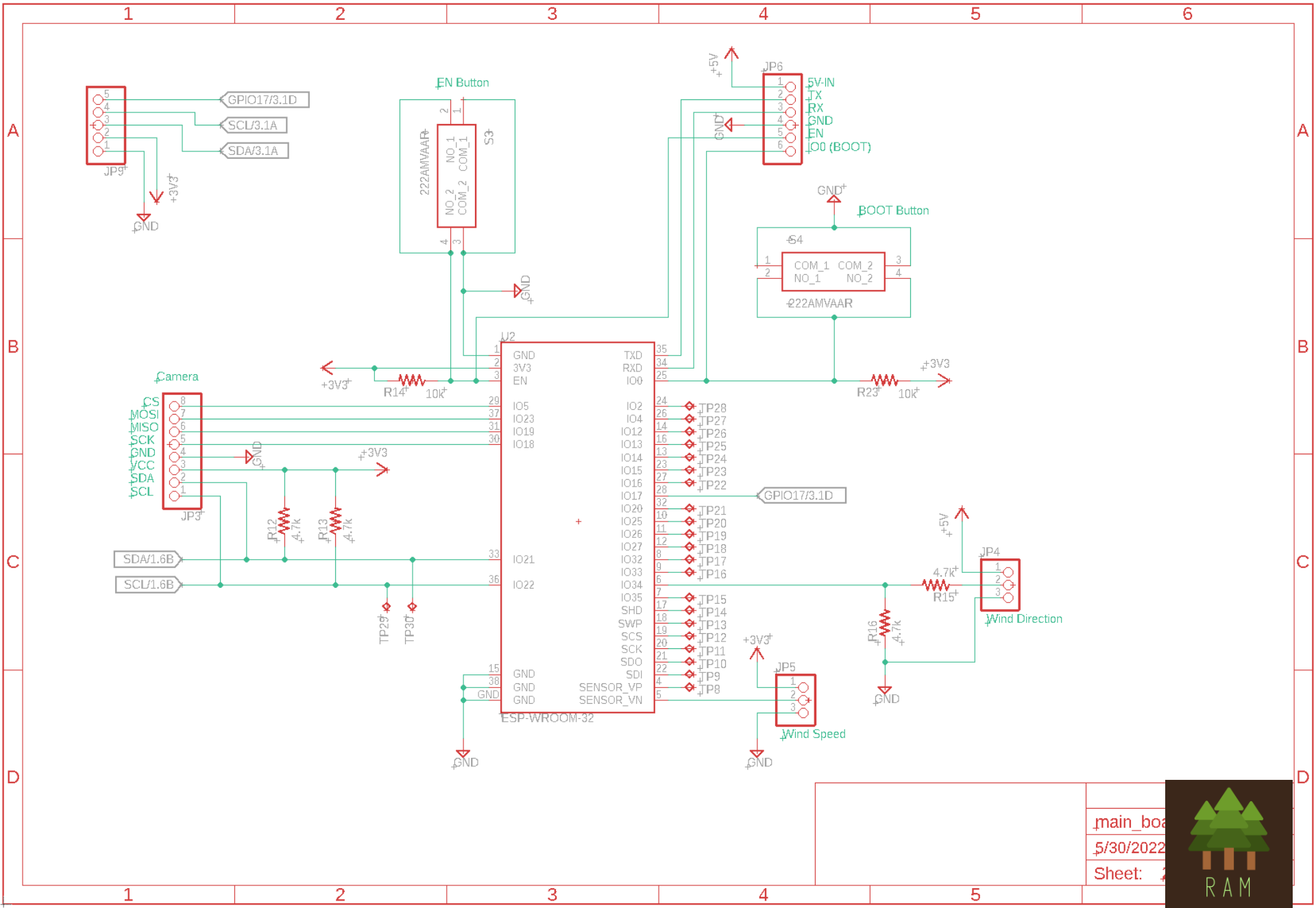
Power Systems



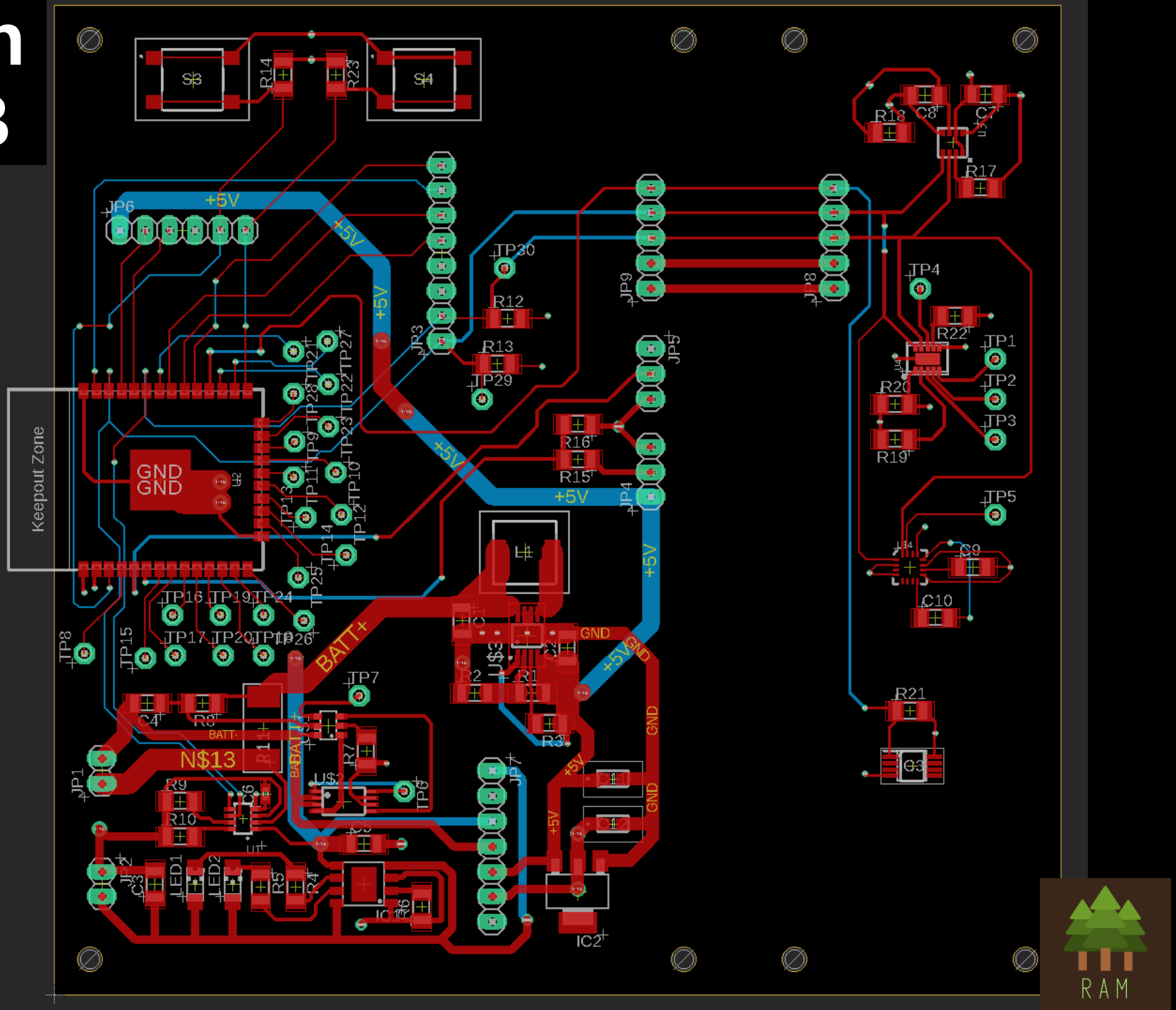
Sensors


SCL/2.1A
SDA/2.1A
+3V3
U3
BME280
VDD
SDI/SDA
CS
SCK/SCL
VDDIO
SDO/ADR
GND1
GND2
R17
4.7k
C7
0.1uF
C8
0.1uF
R18
4.7k
Optional - I2C Address Selector
U4
CCS811
VDD
RESET
WAKE
SENSE
PWM
GND
EP
SDA
SCL
INT
AUX
ADDR
R19
10k
R22
10k
TP1
TP2
TP3
TP4
R20
10k
U$4
SPARKFUN_HMC5883LSMD
VDD
VDDIO
S1
NC
DRDY
C1
GND
SDA
SCL
SETP
SETC
TP5
C9
4.7uF
C10
0.22uF
GND
JP8
GPIO17/2.4C
SCL/2.1A
SDA/2.1A
R21
4.7k
IC3
DS18B20U+
DQ
N.C._1
N.C._2
GND
VDD
N.C._5
N.C._4
N.C._3
main_boa
5/30/2022
Sheet:
RAM

Microcontroller



Main PCB



Keepout Zone
GND
GND
+5V
BATT+
N$13
S3
S4
R14
R23
JP6
JP3
JP9
JP8
JP5
JP4
JP7
JP1
TP30
R12
R13
TP29
R16
R15
TP4
R22
TP1
TP2
TP3
R20
R19
TP5
C9
C10
R21
G3
R18
C8
C7
R17
L1
U$3
R2
R1
R3
TP7
C4
R8
R11
R7
U$2
TP6
R9
R10
C6
U1
LED1
LED2
R5
R4
C3
IC1
R6
IC2
TP8
TP15
TP16
TP19
TP24
TP17
TP20
TP26
TP25
TP14
TP13
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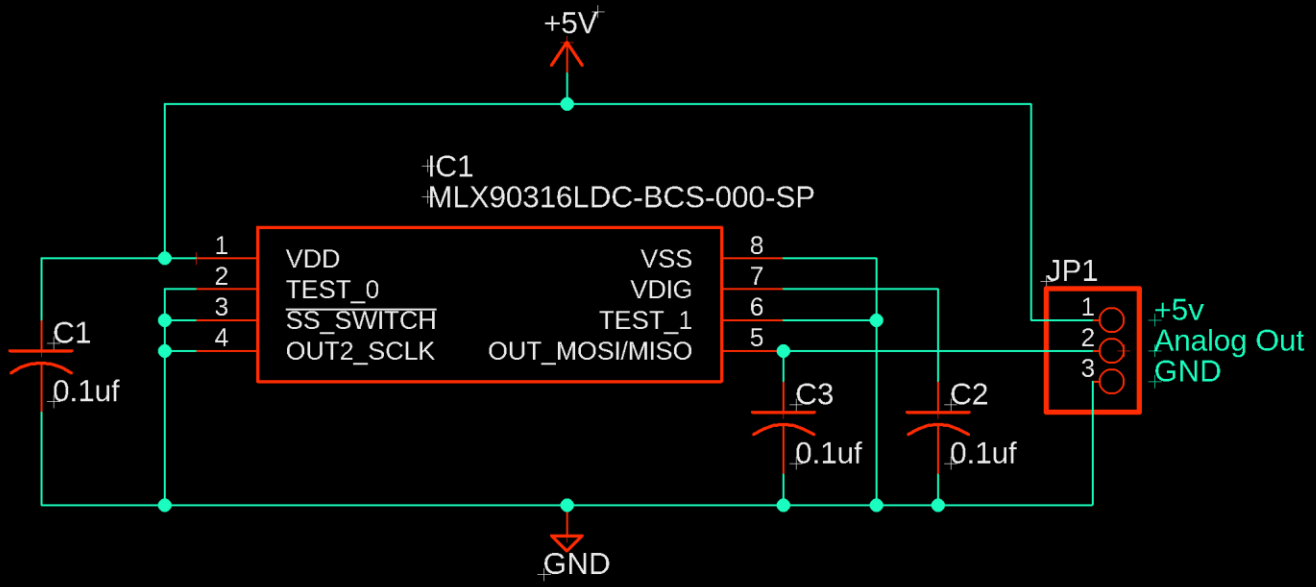
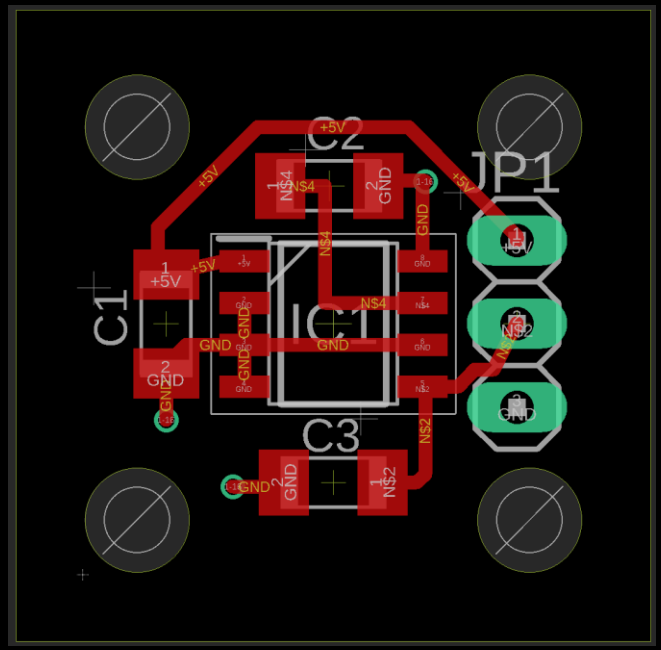
TP12
TP10
TP9
TP23
TP22
TP27
TP28
TP21

Wind Direction Sensor



- External module to minimize magnet interference on compass sensor
- Small footprint for easier mechanical design
- Allows for iteration and changes without the need to modify the main PCB



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Top 5 Future Improvements

Enhanced Notifications

Balanced Power Budget

Addition of Environment Trends

Higher Resolution Images

Allow User Devices to Connect and Communicate Over the Network in an Emergency

Questions?

Remote Area Monitoring

Group 10 : Wyatt Vining, Johan Castillo, Abhijeet Malviya, Nicholas Gonzalez