Revolutionizing Vertical Farming:
Tower Garden Commander

TOWER POWER

Sweetwater Urban Farms

Georgia Tech

The Team

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Deliverable Lead

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Design Lead

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Technical Lead

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Agenda

1. Project Overview & Progress Recap
2. Electrical Update
3. Mechanical Update
4. Software Update
5. Final Steps

Project Overview

Goal:

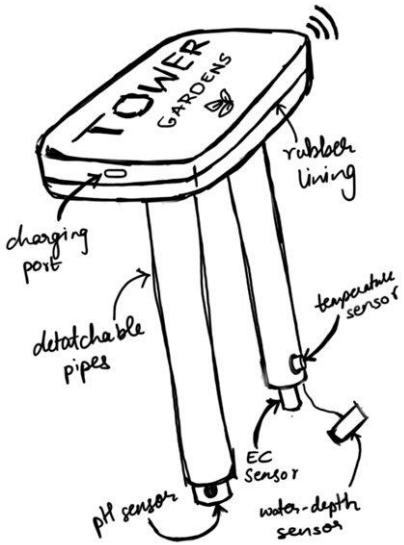
To develop a smart sensing device that measures water health in Tower Gardens

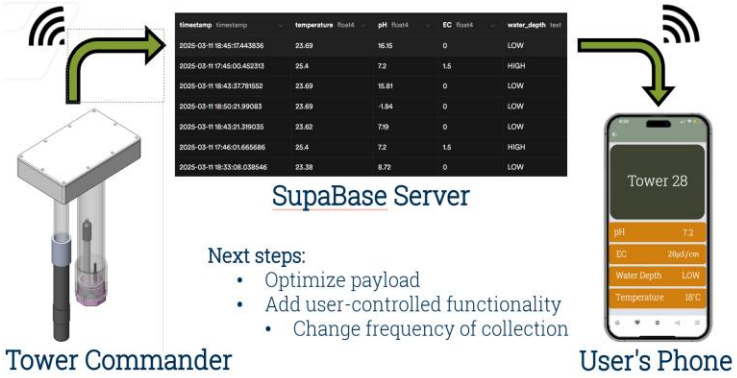
How we measure water health:

pH, EC, Temperature, and Depth

Where We Left Off in Week 10

- Design Concept Selection
- Sensor Selection
- Proof-of-Concept PCB Design
- Preliminary Communication Software
- Battery Life Optimization & Charging
- Initial Packaging Design

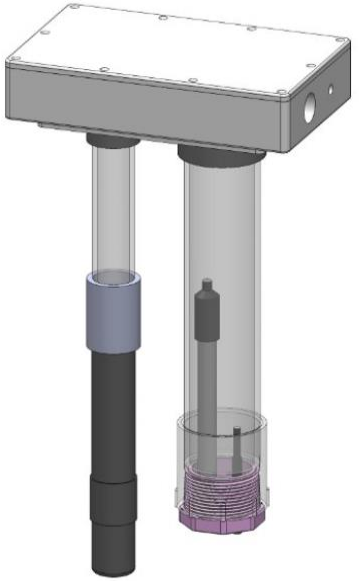


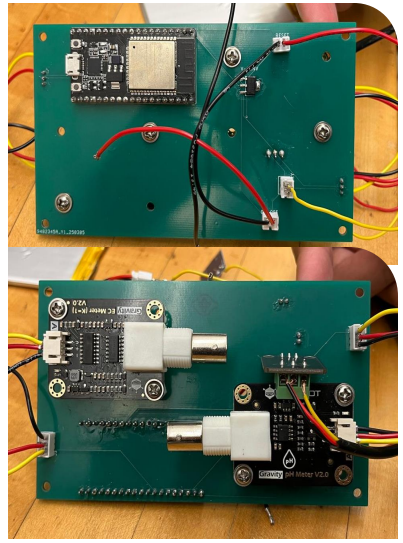


Next steps:
- Optimize payload
- Add user-controlled functionality
  - Change frequency of collection

Battery Life

Planned Optimizations:
- Using deep sleep (0.1 mA) & turning off sensors in downtime (in hardware)
  - (150mA * 0.2hr) + (0.1mA * 23.8hr) = 32 mAh
  - 93 days battery life
  - Downside: no real-time capture
- Replacing the ESP32
  - Low-power WiFi module
  - Downside: low-level programming
- Software
  - Reducing dependency on libraries -> lower memory





Electrical Development

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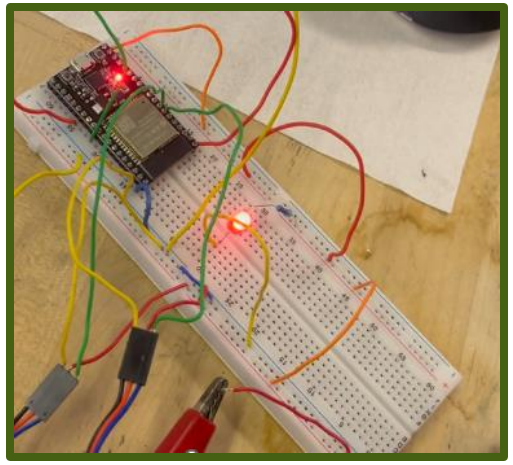
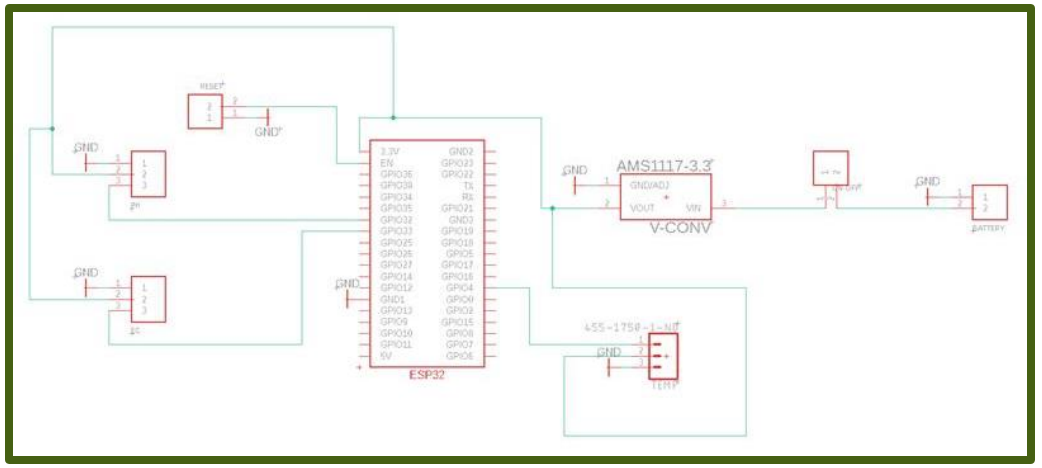
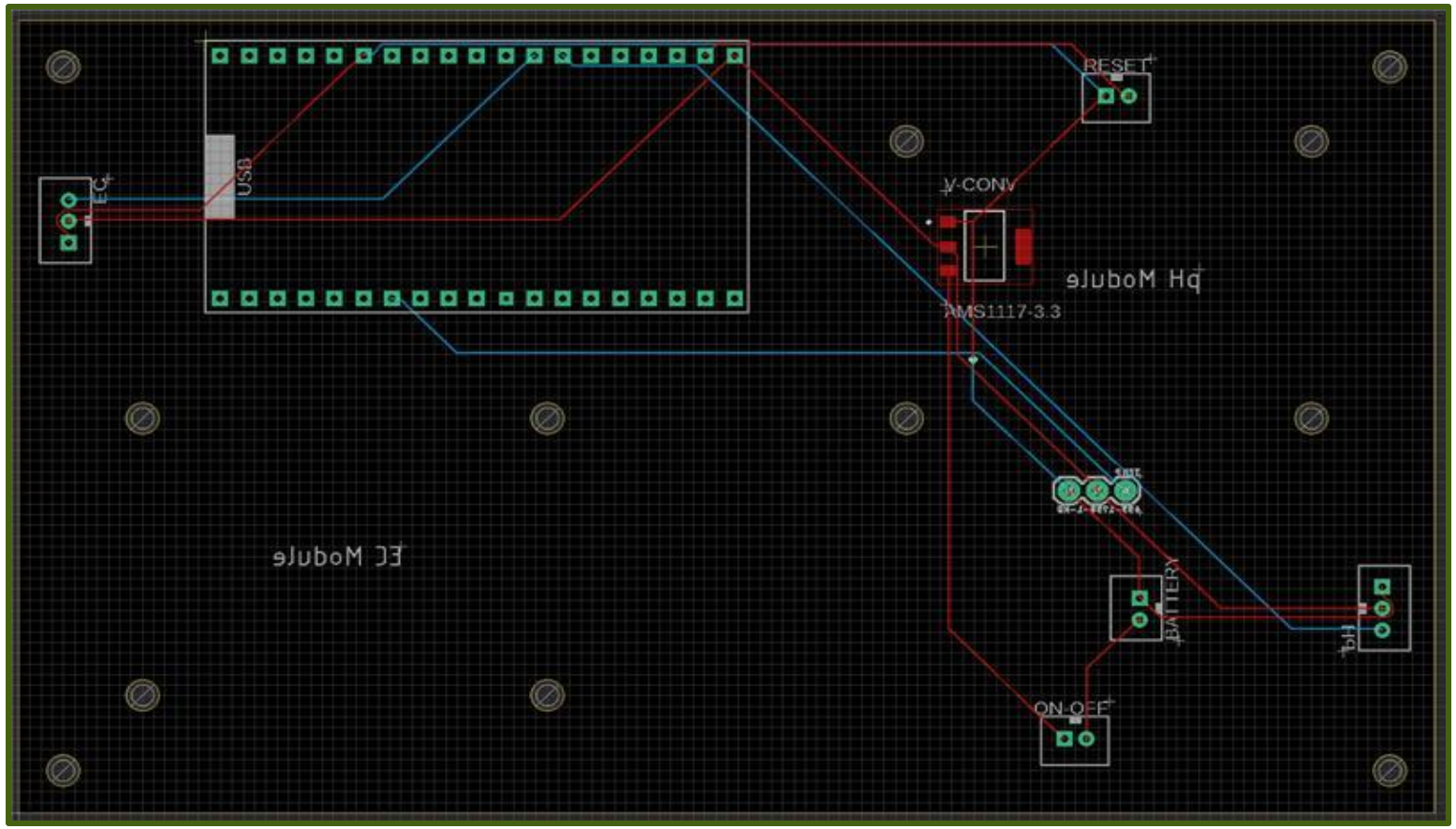
Where We Left Off

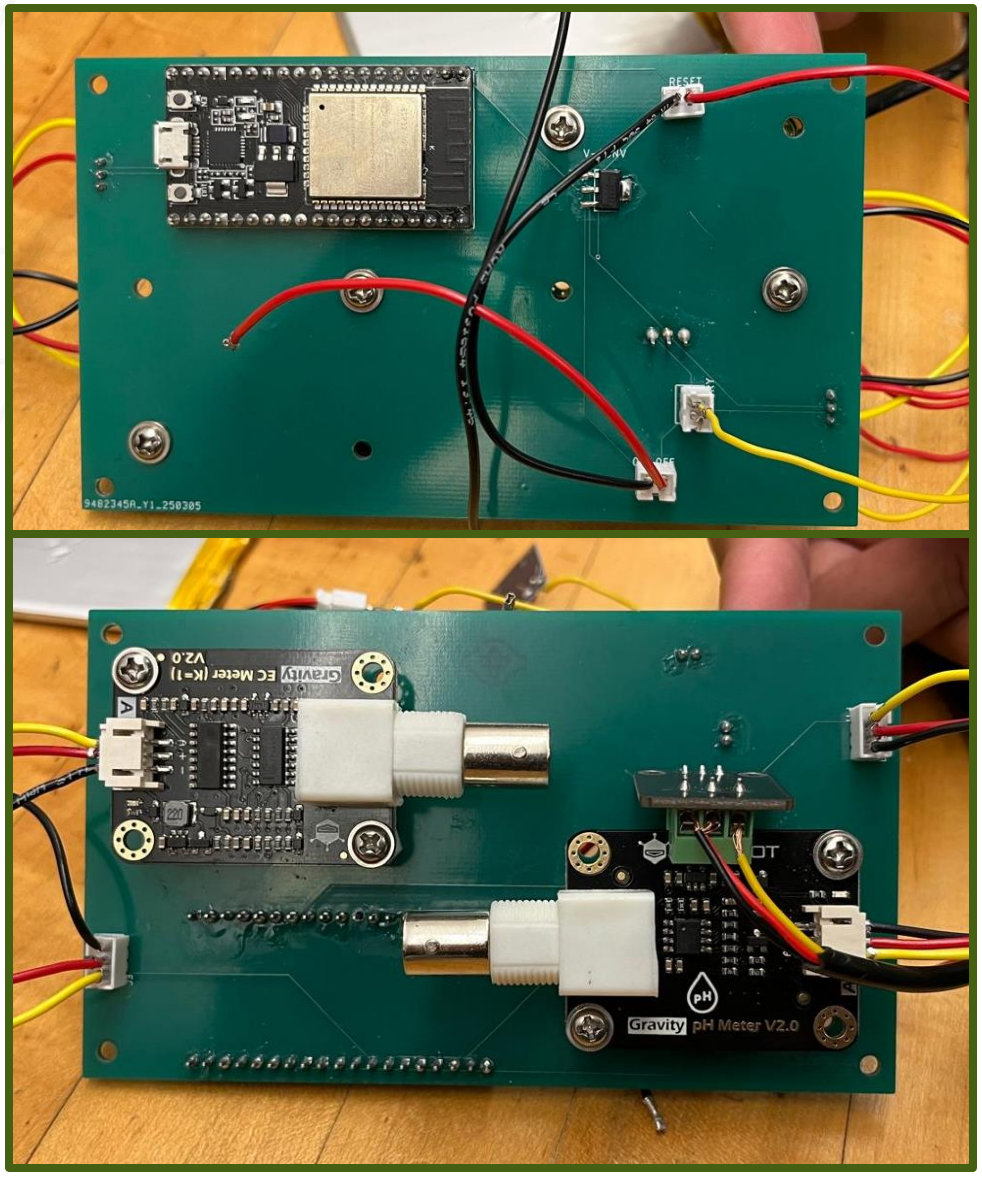
- Proof-of-Concept PCB design
- Utilized sensor modules
- Battery Life
- Error Found: Not properly soldering component connecting power

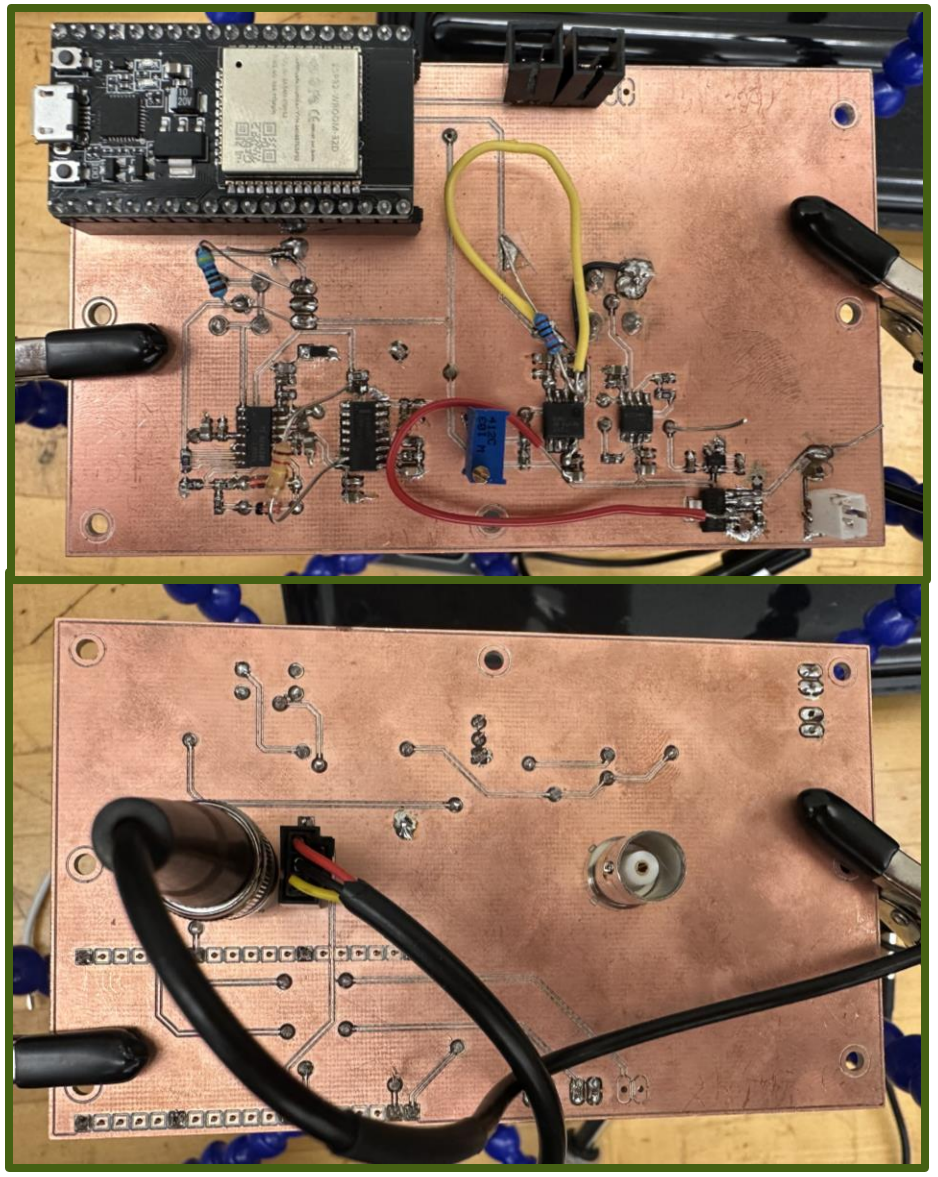






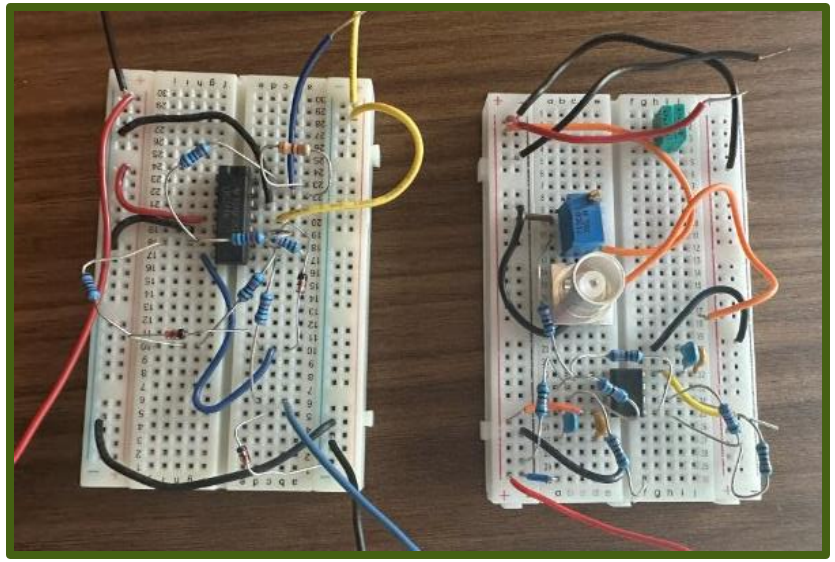
What Did We Change

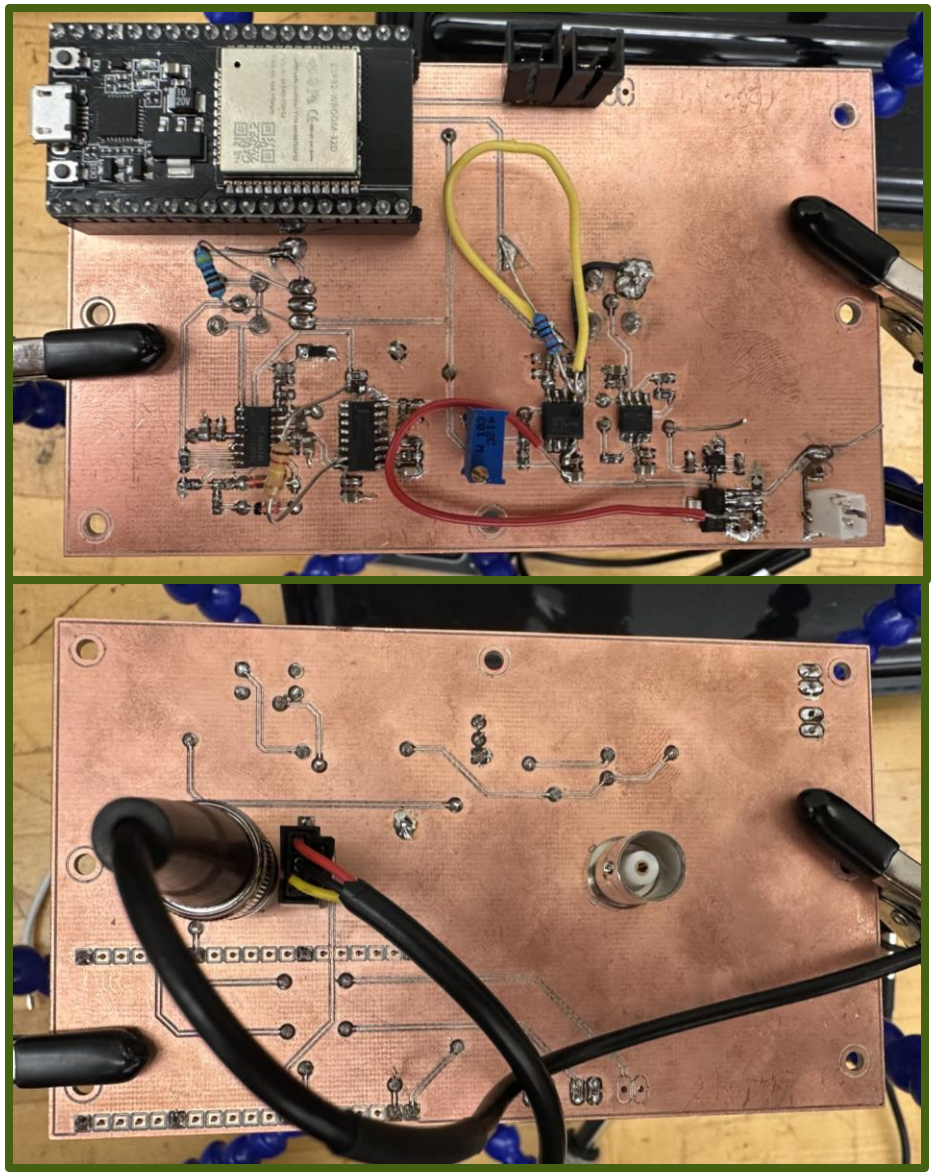




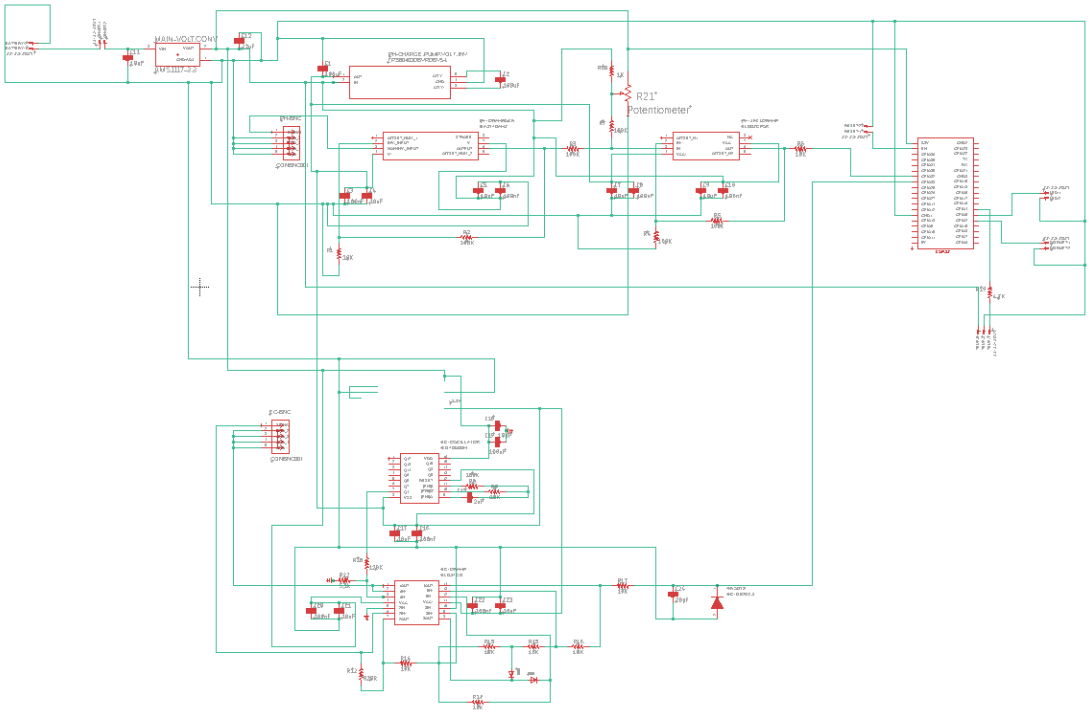
What Did We Change

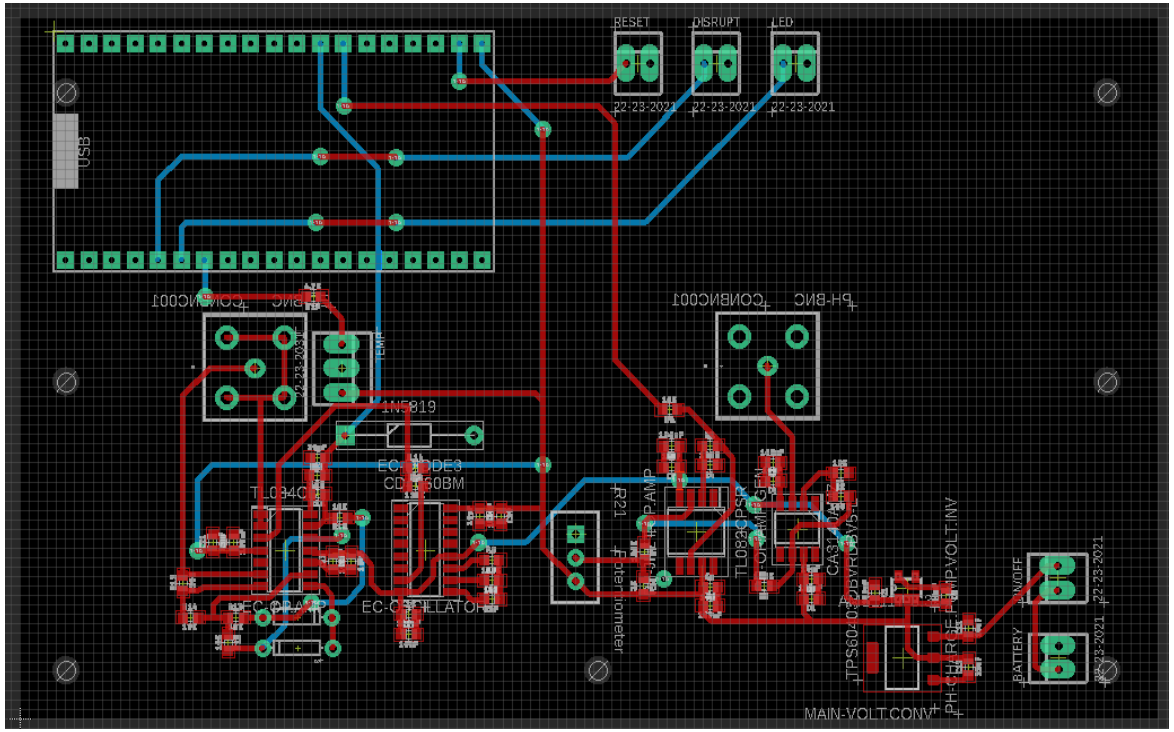
- Reverse engineer each sensor modules ➡Embed all components onto a single, central PCB
- Design an integrated charging circuit for enclosed, external battery charging



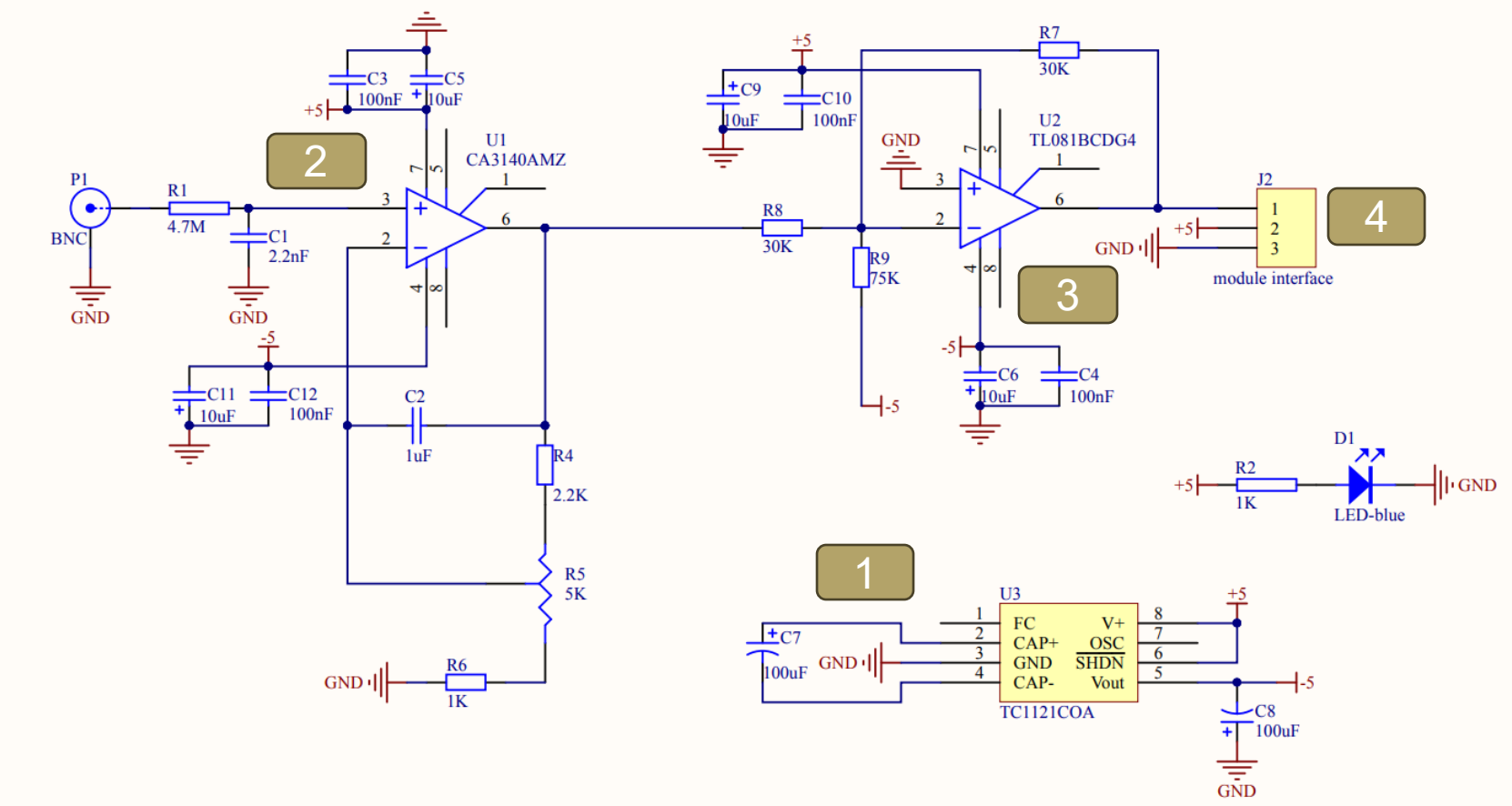


v2 PCB Design





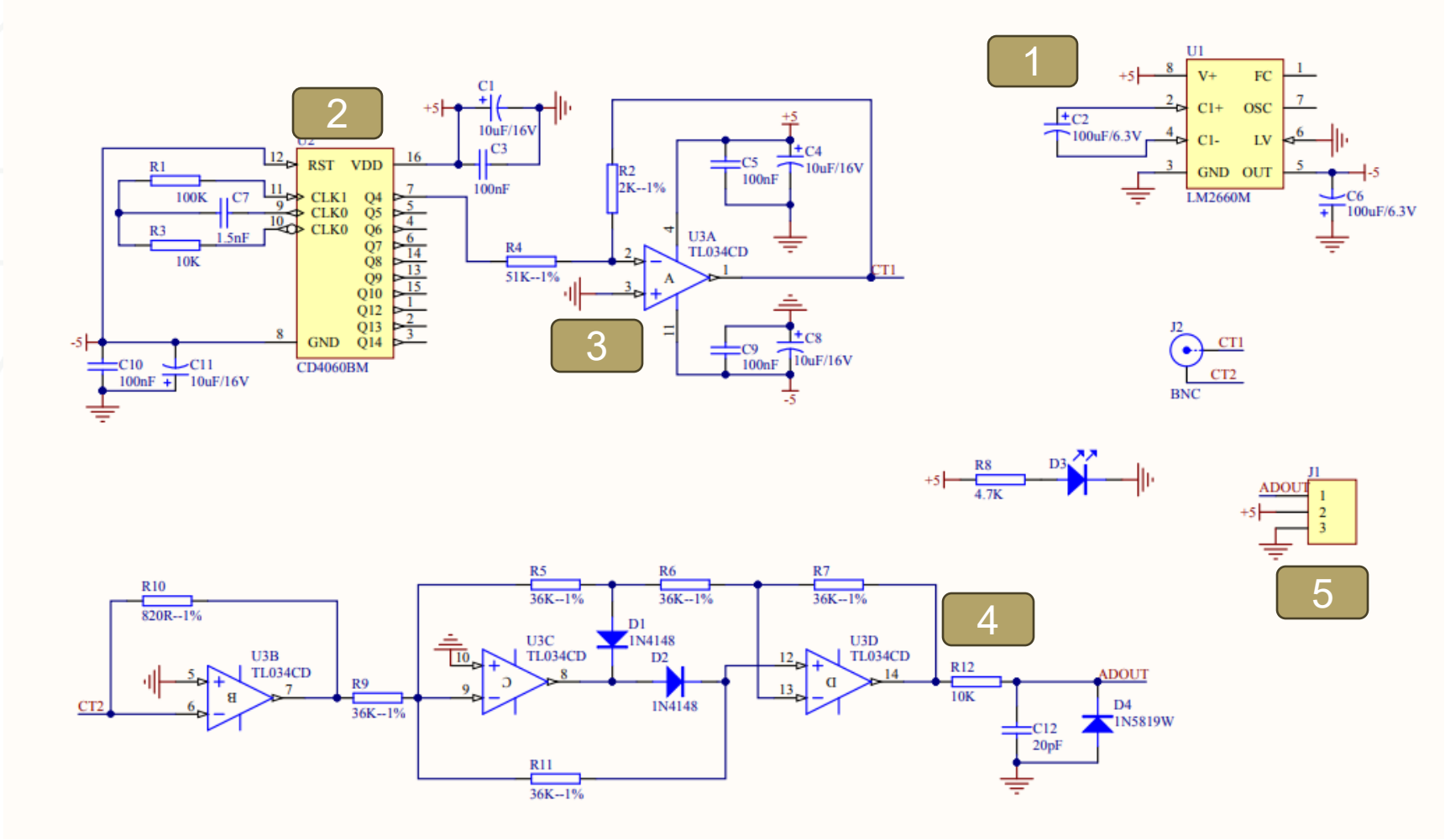
pH Sensor



Key Points:

1) Negative Supply
2) Op Amp
3) JFET Amplifier
4) Output Voltage

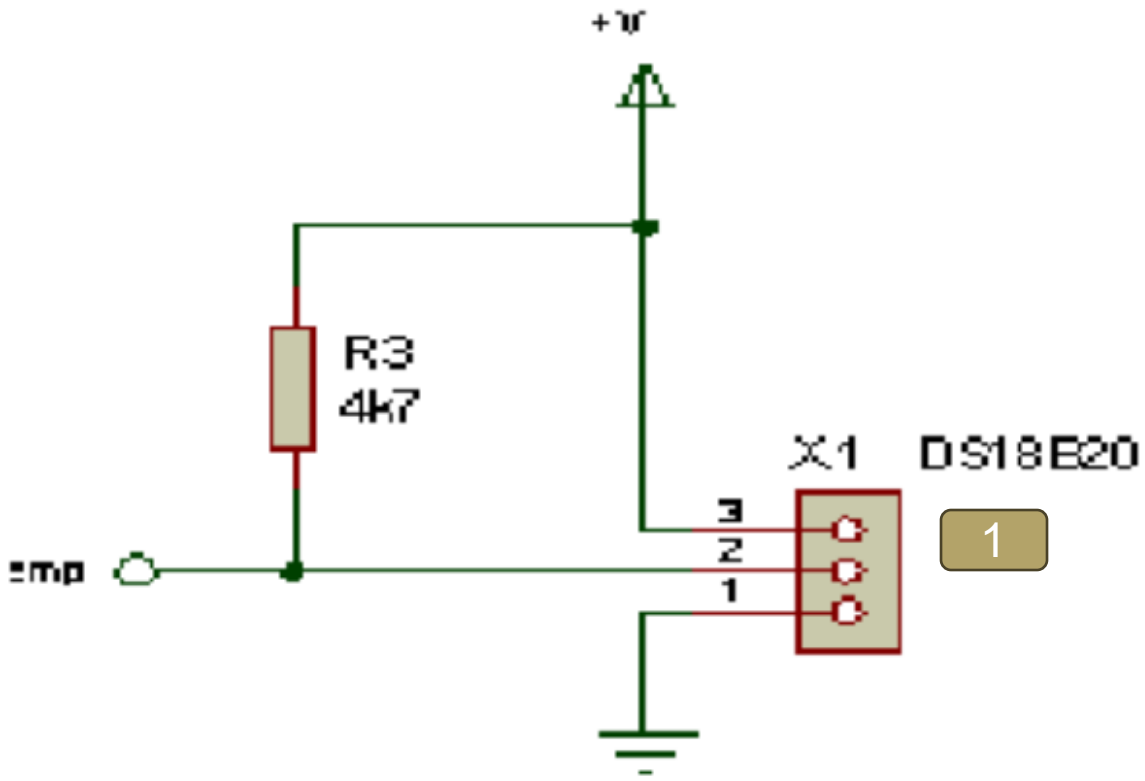
EC Sensor



Key Points:

1) Negative Supply
2) Oscillator
3) JFET Amplifier (Signal)
4) JFET Amplifier (GND)
5) Output Voltage

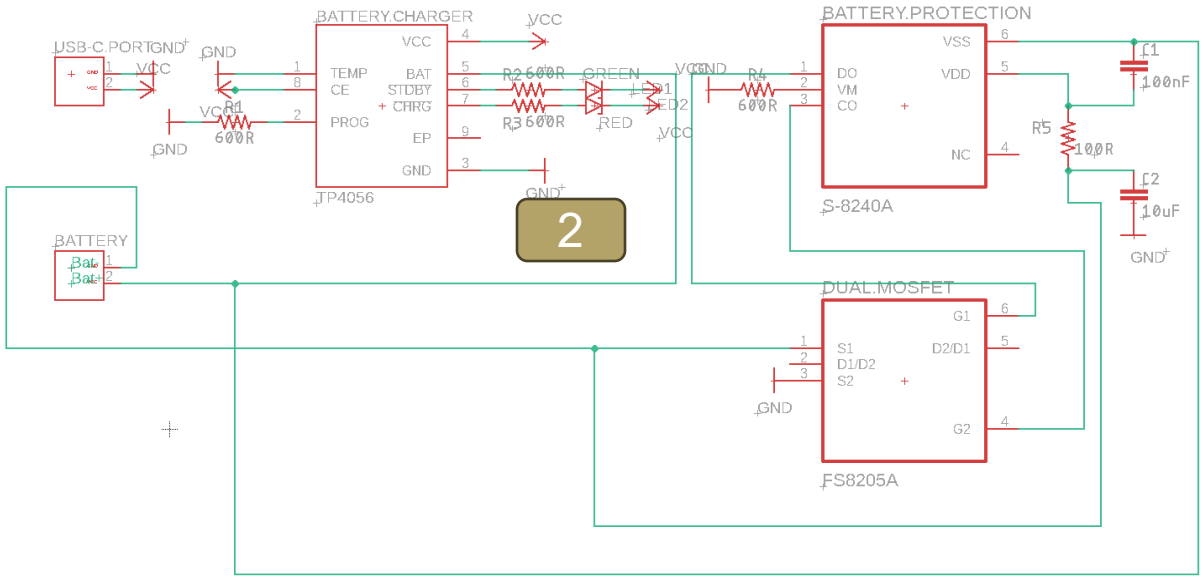
Temperature Sensor

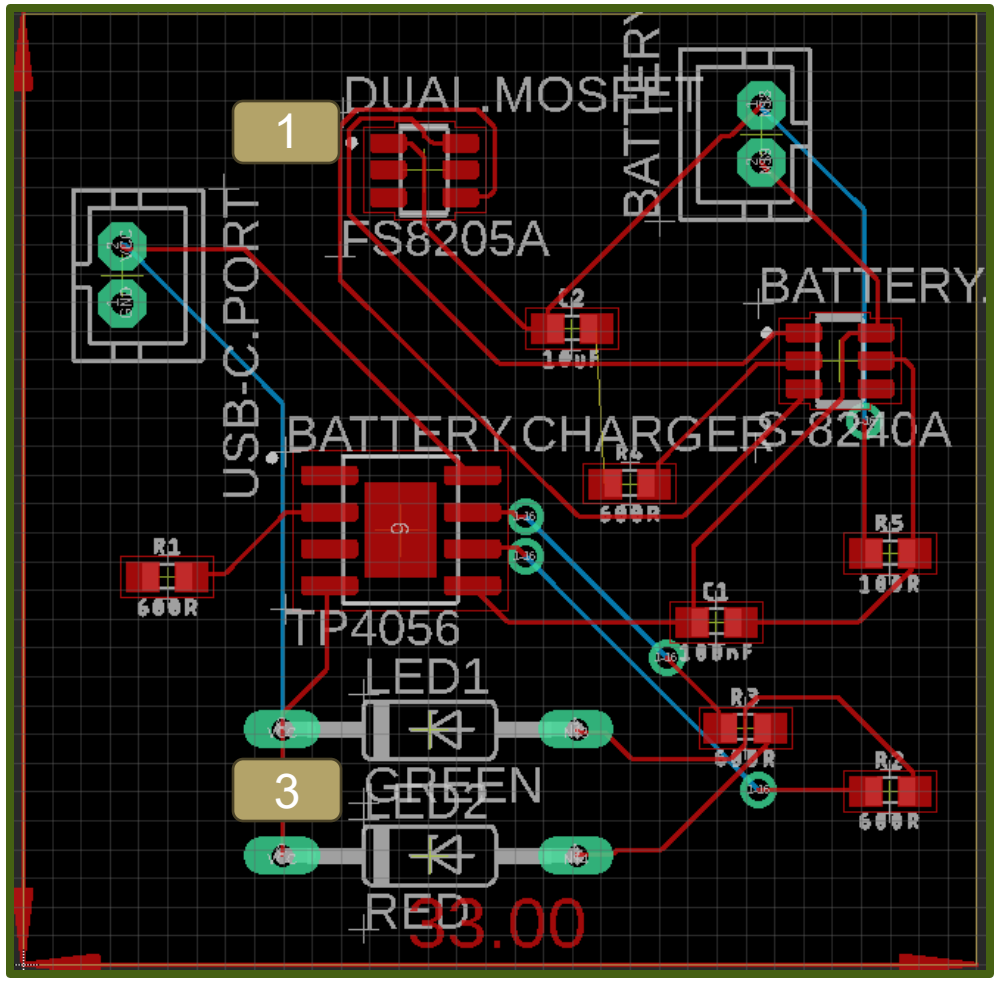


Key Points:

1) Output Temperature

Battery Charging





Key Points:

1) USB-C
2) Battery Charging and Protection
3) Charging LEDs

Additional Components

- **On/Off Switch:** Toggle power
- **Reset Button:** Reset device
- **Disrupt/Calibration Button:**
  - 1 push: Disrupt – Takes readings at un-predetermined times
  - 2 push: Calibration – Lower Value
  - 3 push: Calibration – Higher Value
- **LED:** Status Indication
  - Flash 3x Green: Turning on
  - Flash 3x Red: Turning off
  - Flash Continuous Yellow: Currently reading sensors
  - Permanent Red: Something wrong with sensors
  - Permanent Yellow: Need to charge battery
  - Permanent Blue: Need to recalibrate sensor

PCB Demo Video

Example Readings (PCB)

```
Temperature: 25.12 °C | pH Voltage: Error | EC Voltage: 0.15 V
Temperature: 25.12 °C | pH Voltage: Error | EC Voltage: 1.23 V
Temperature: 25.12 °C | pH Voltage: Error | EC Voltage: 1.22 V
Temperature: 25.12 °C | pH Voltage: Error | EC Voltage: 1.21 V
Temperature: 25.12 °C | pH Voltage: Error | EC Voltage: 1.23 V
Temperature: 25.12 °C | pH Voltage: Error | EC Voltage: 1.22 V
Temperature: 25.12 °C | pH Voltage: Error | EC Voltage: 1.20 V
Temperature: 25.12 °C | pH Voltage: Error | EC Voltage: 1.24 V
Temperature: 25.12 °C | pH Voltage: Error | EC Voltage: 1.22 V
Temperature: 25.19 °C | pH Voltage: Error | EC Voltage: 1.20 V
Temperature: 25.12 °C | pH Voltage: Error | EC Voltage: 1.22 V
Temperature: 25.12 °C | pH Voltage: Error | EC Voltage: 1.22 V
```

- Lower Temp
- 12.88 mS/cm

```
Temperature: 28.56 °C | pH Voltage: Error | EC Voltage: 0.03 V
Temperature: 28.62 °C | pH Voltage: Error | EC Voltage: 0.03 V
Temperature: 28.75 °C | pH Voltage: Error | EC Voltage: 0.04 V
Temperature: 28.81 °C | pH Voltage: Error | EC Voltage: 0.03 V
Temperature: 28.87 °C | pH Voltage: Error | EC Voltage: 0.02 V
Temperature: 28.94 °C | pH Voltage: Error | EC Voltage: 0.03 V
Temperature: 29.00 °C | pH Voltage: Error | EC Voltage: 0.00 V
Temperature: 29.06 °C | pH Voltage: Error | EC Voltage: 0.03 V
Temperature: 29.19 °C | pH Voltage: Error | EC Voltage: 0.03 V
Temperature: 29.19 °C | pH Voltage: Error | EC Voltage: 0.03 V
Temperature: 29.25 °C | pH Voltage: Error | EC Voltage: 0.03 V
Temperature: 29.31 °C | pH Voltage: Error | EC Voltage: 0.03 V
```

- Higher Temp
- 1430 uS/cm

Next Steps - Electrical

- Continue troubleshooting and debugging PCB pertaining to pH sensor
- V&V testing

- Manufacturing:
  - Embed charging circuit onto main PCB
  - Edge testing with power supply
  - Alter schematic to embed ESP32 chip

Packaging Development

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Where We Left Off

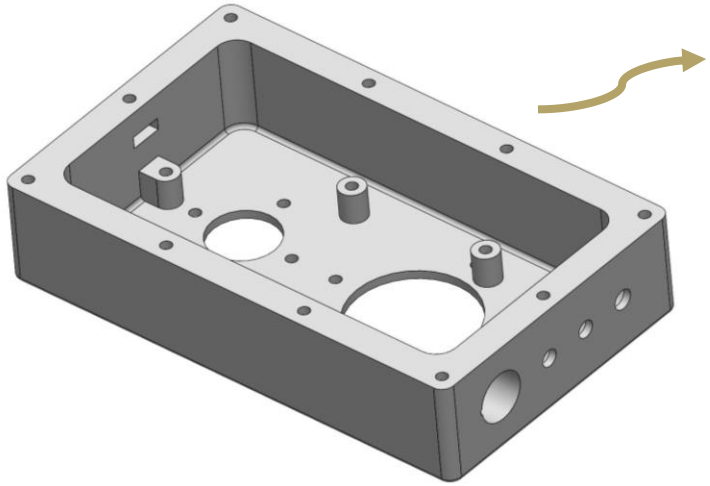
Prototype Design

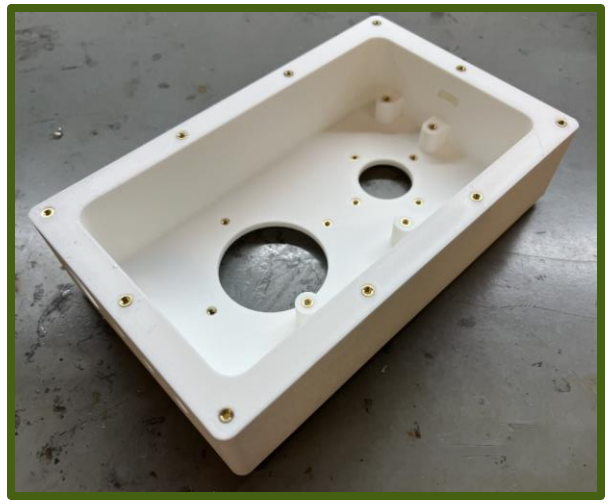
- PLA 3D printed enclosure and lid
- PVC pipes to hold sensors
- ABS 3D-printed pipe attachments
- Tolerancing issues with threaded inserts and pipe attachments
- Missing details for parts interfacing

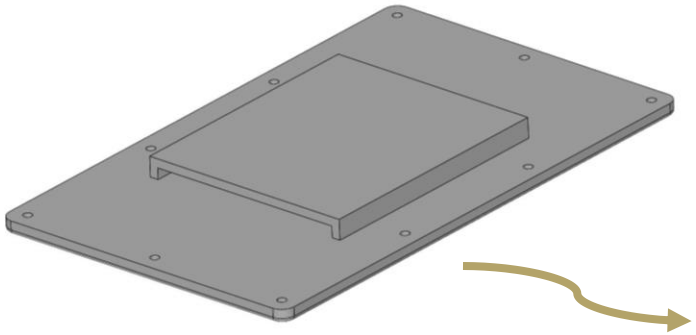
Packaging – Enclosure

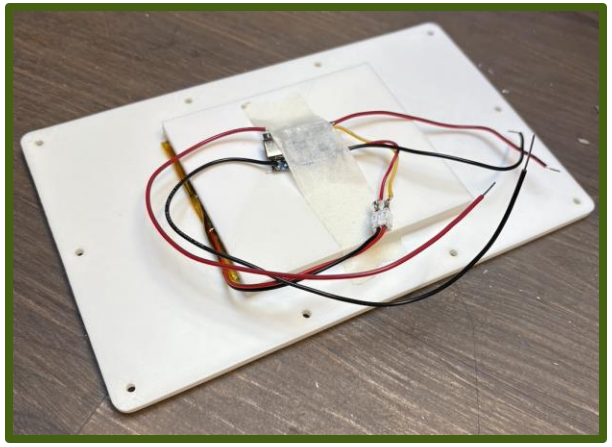
Improvements

- Standoffs for PCB added, placing BNC connectors above respective tubes
- Sleeve for battery added on lid
- USB-C charging port and LED added
- Heat-set insert tolerancing issue fixed









Sealing

Improvements

- ABS pipe attachment tolerancing issue fixed, ABS-PVC pipe cement implemented
- Gaskets implemented

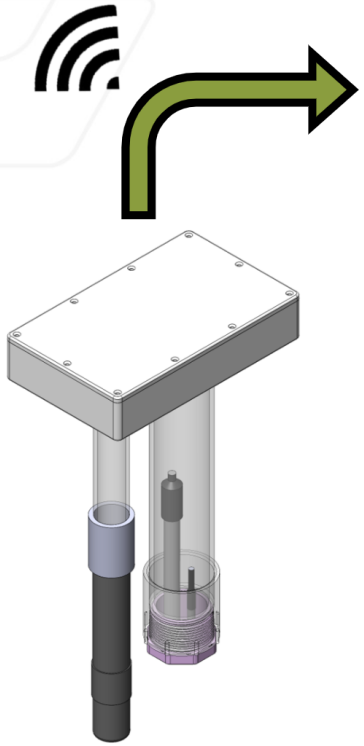
Testing for IPX8 Standards

- Joints on pipes – Waterproof
- pH sensor connection – Waterproof
- Temp sensor connection – Waterproof
- ***EC sensor connection – Not Waterproof***
  - *New grommet for EC sensor to be implemented*

Software Development

Where We Left Off

- Backend data setup
- Problems:
  - Constant running of ESP drains power
  - Requires manual updating of software
  - No structure in database



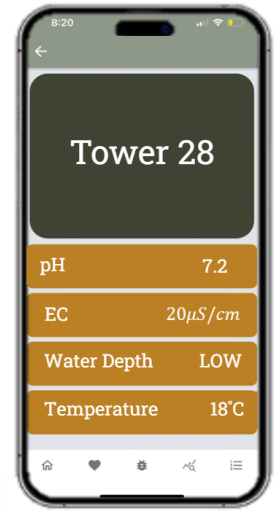
Tower Commander

timestamp timestamp	temperature float4	pH float4	EC float4	water_depth text
2025-03-11 18:45:17.443836	23.69	16.15	0	LOW
2025-03-11 17:45:00.452313	25.4	7.2	1.5	HIGH
2025-03-11 18:43:37.781552	23.69	15.81	0	LOW
2025-03-11 18:50:21.99083	23.69	-1.84	0	LOW
2025-03-11 18:43:21.319035	23.62	7.19	0	LOW
2025-03-11 17:46:01.665686	25.4	7.2	1.5	HIGH
2025-03-11 18:33:08.038546	23.38	8.72	0	LOW

SupaBase Server

Next steps:

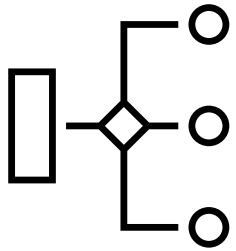
- Optimize payload
- Add user-controlled functionality
  - Change frequency of collection



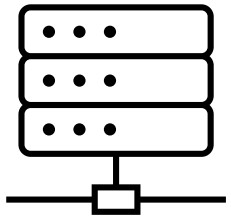
User's Phone

n8n

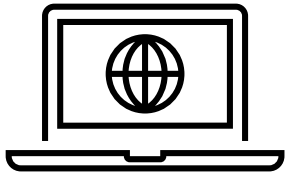
"free, open-source workflow automation tool that uses a node-based approach"



Systematic Data-flow



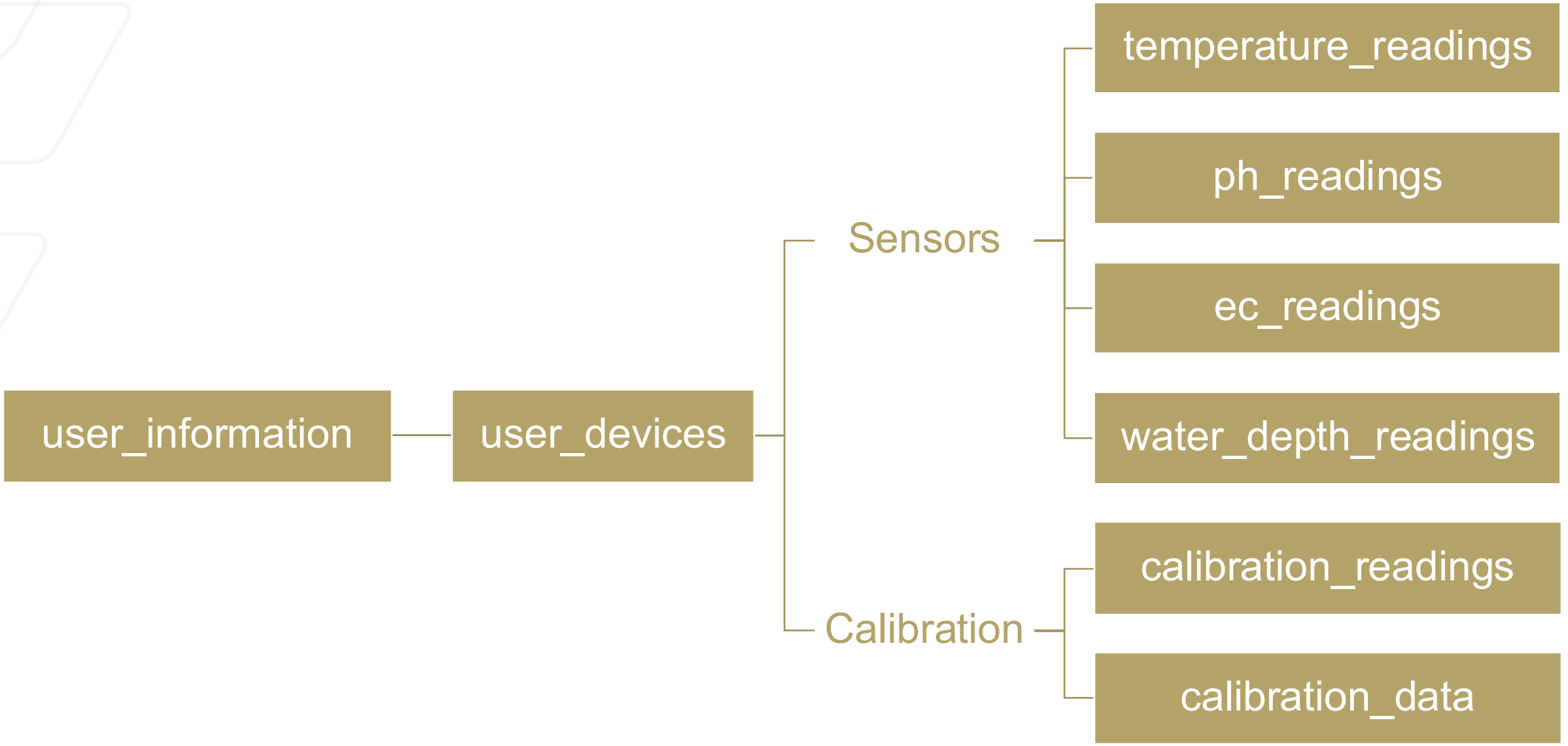
Remote Data Processing



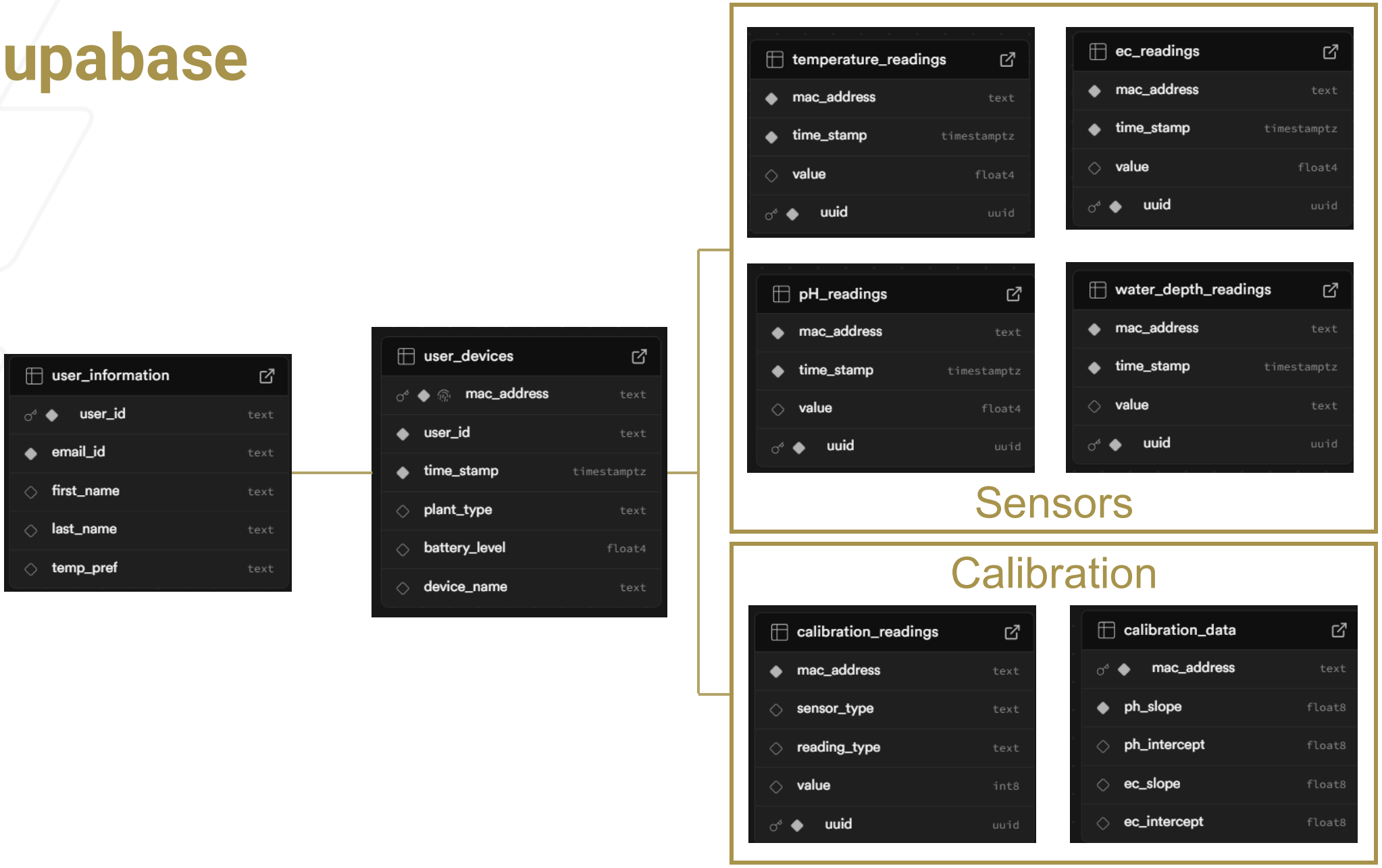
Software Update Capability

ESP → n8n → Supabase → Flutterflow

Supabase Structure



Supabase


user_information
user_id text
email_id text
first_name text
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user_id text
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plant_type text
battery_level float4
device_name text
temperature_readings
mac_address text
time_stamp timestamptz
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time_stamp timestamptz
value text
uuid uuid
Sensors
Calibration
calibration_readings
mac_address text
sensor_type text
reading_type text
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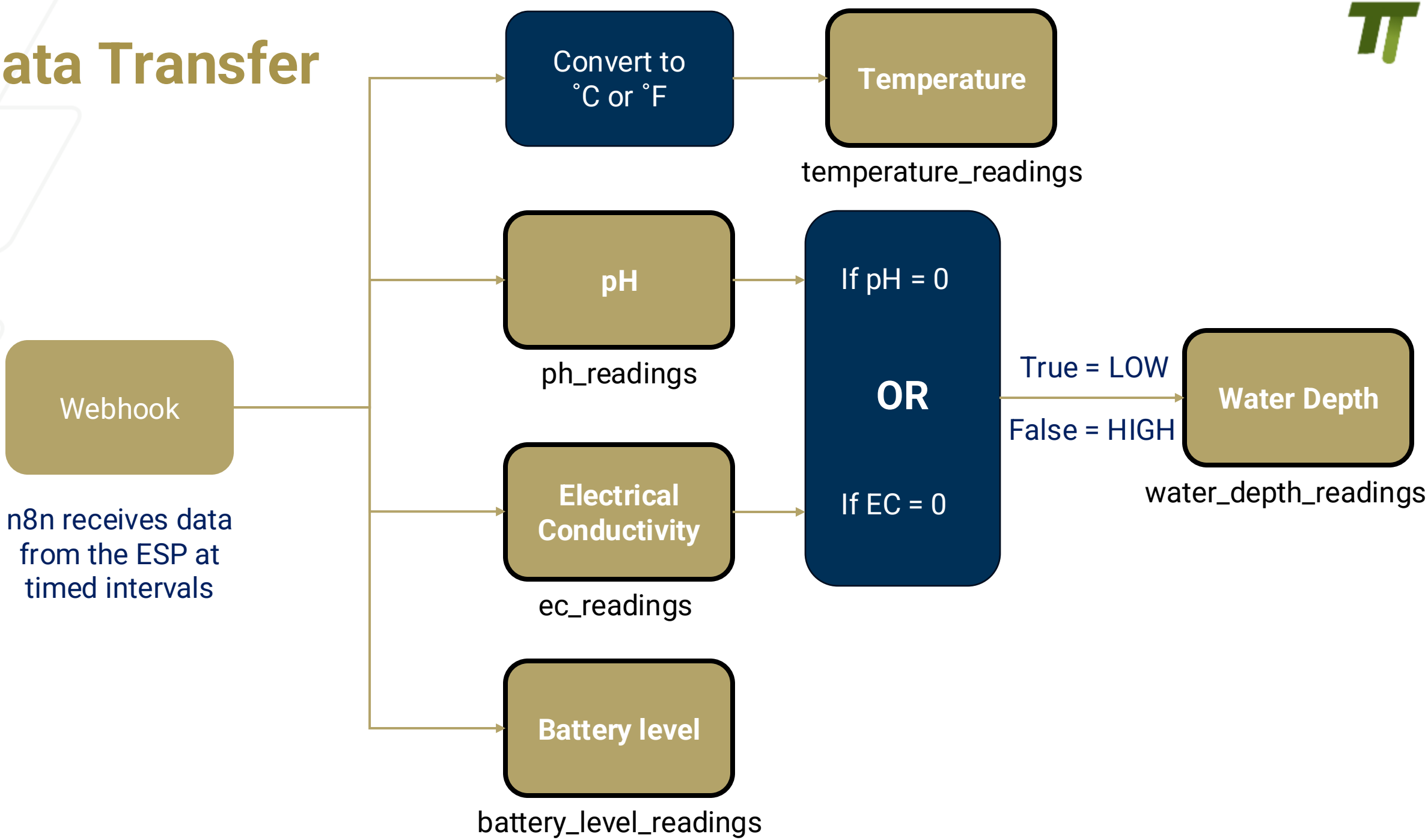
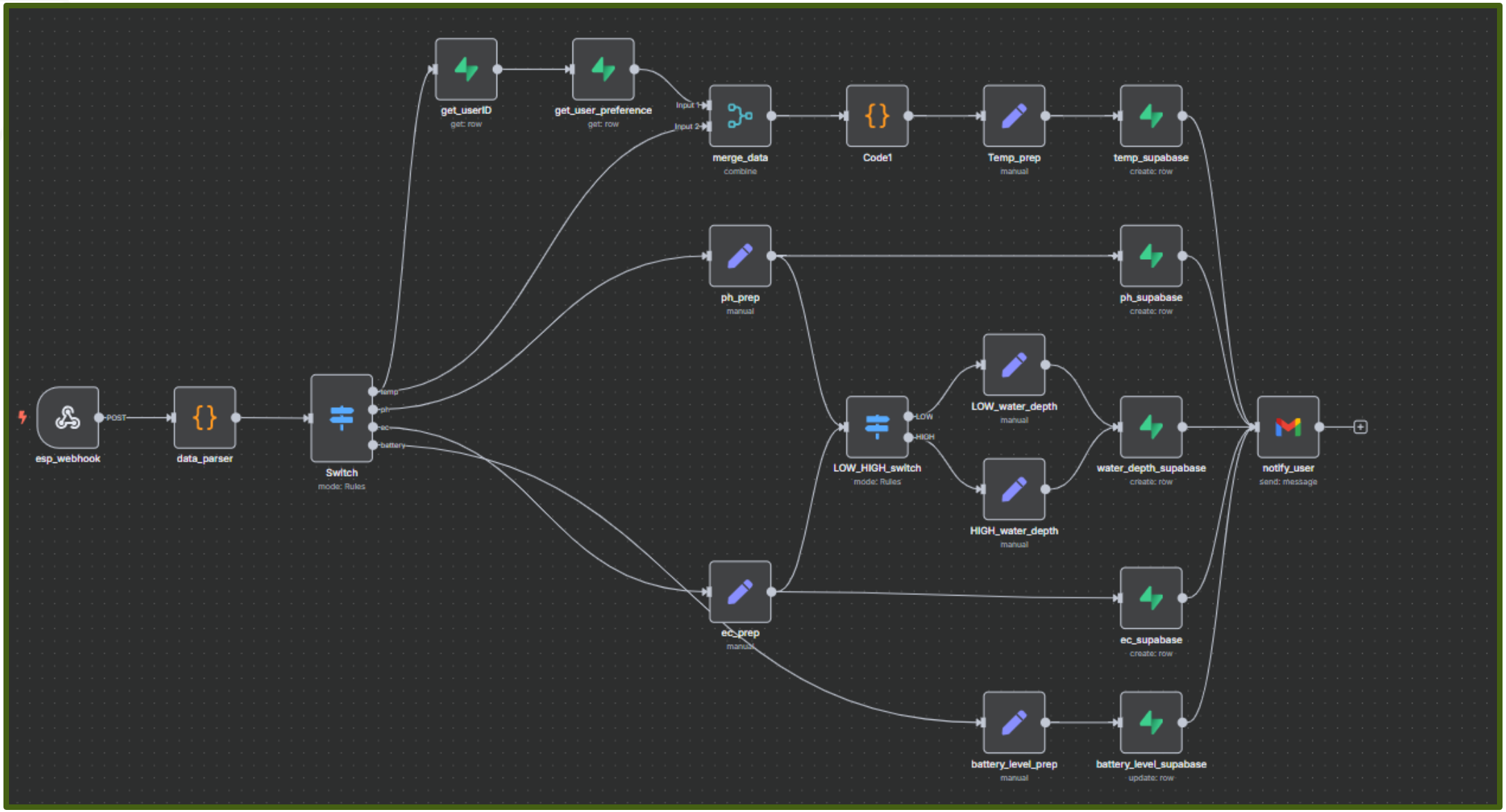
ec_slope float8
ec_intercept float8

Data Transfer



Data Transfer

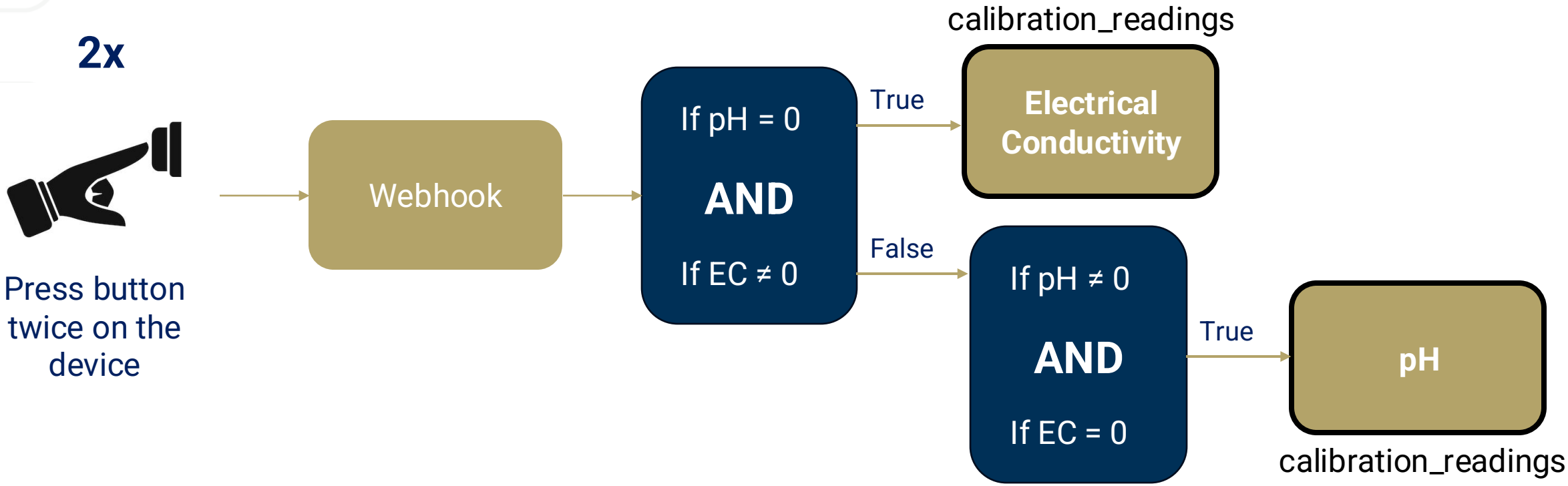


Calibration

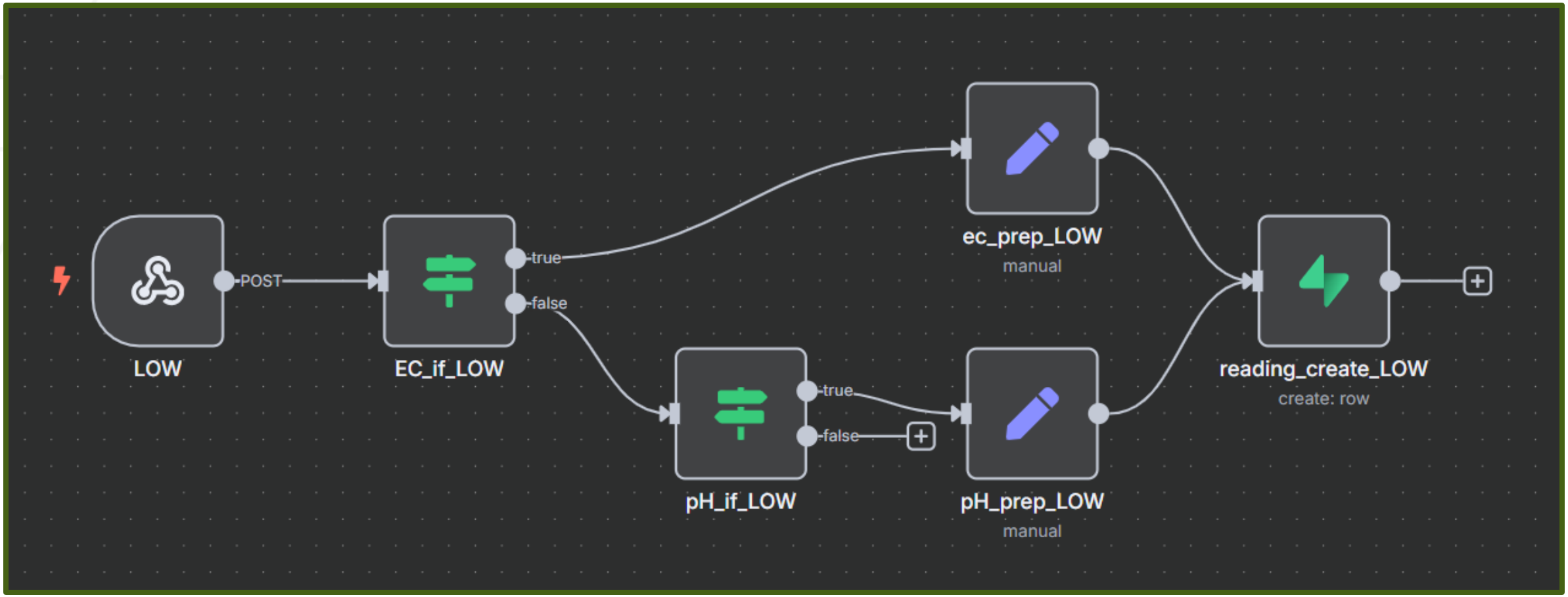
- Why do we need to calibrate?
  - Sensors inevitably drift and deviate from their intended performance due to various factors, leading to inaccurate readings
    - Length of Operation (Natural Degradation)
    - Temperature Fluctuations
    - Humidity-induced Corrosion
    - Debris Contamination

- How to calibrate:
  - Read output voltage from a known "low pH/EC" solution
  - Read output voltage from a known "high pH/EC" solution
  - Create a linear relationship that transforms the sensor reading to the expected measurement
    - y = mx + b:
      - m: slope of the voltage & pH/EC relationship
      - b: intercept of the voltage & pH/EC relationship
  - Now, every voltage reading is correlated to its proper value reading

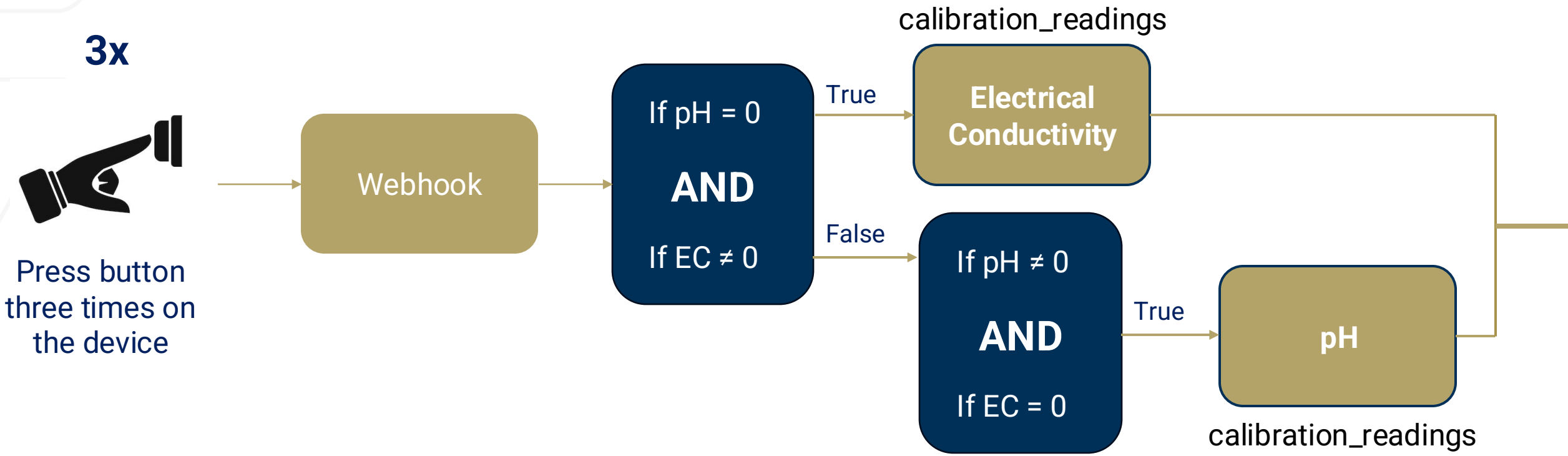
Calibration - Lower Value



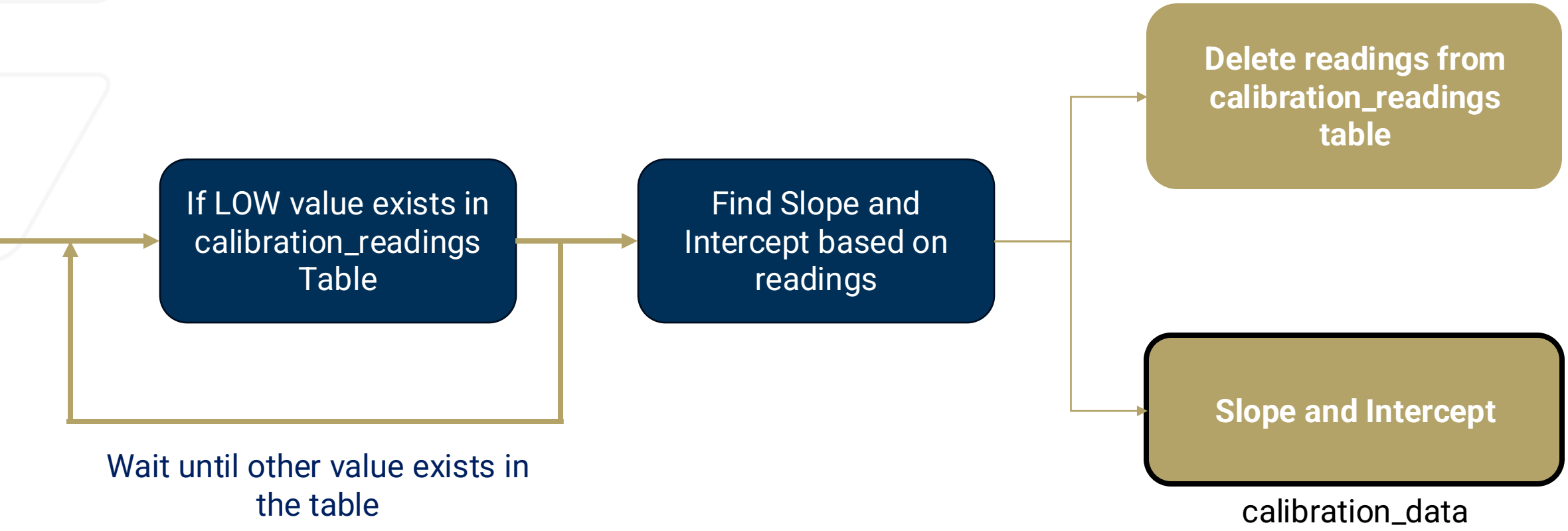
Calibration - Lower Value



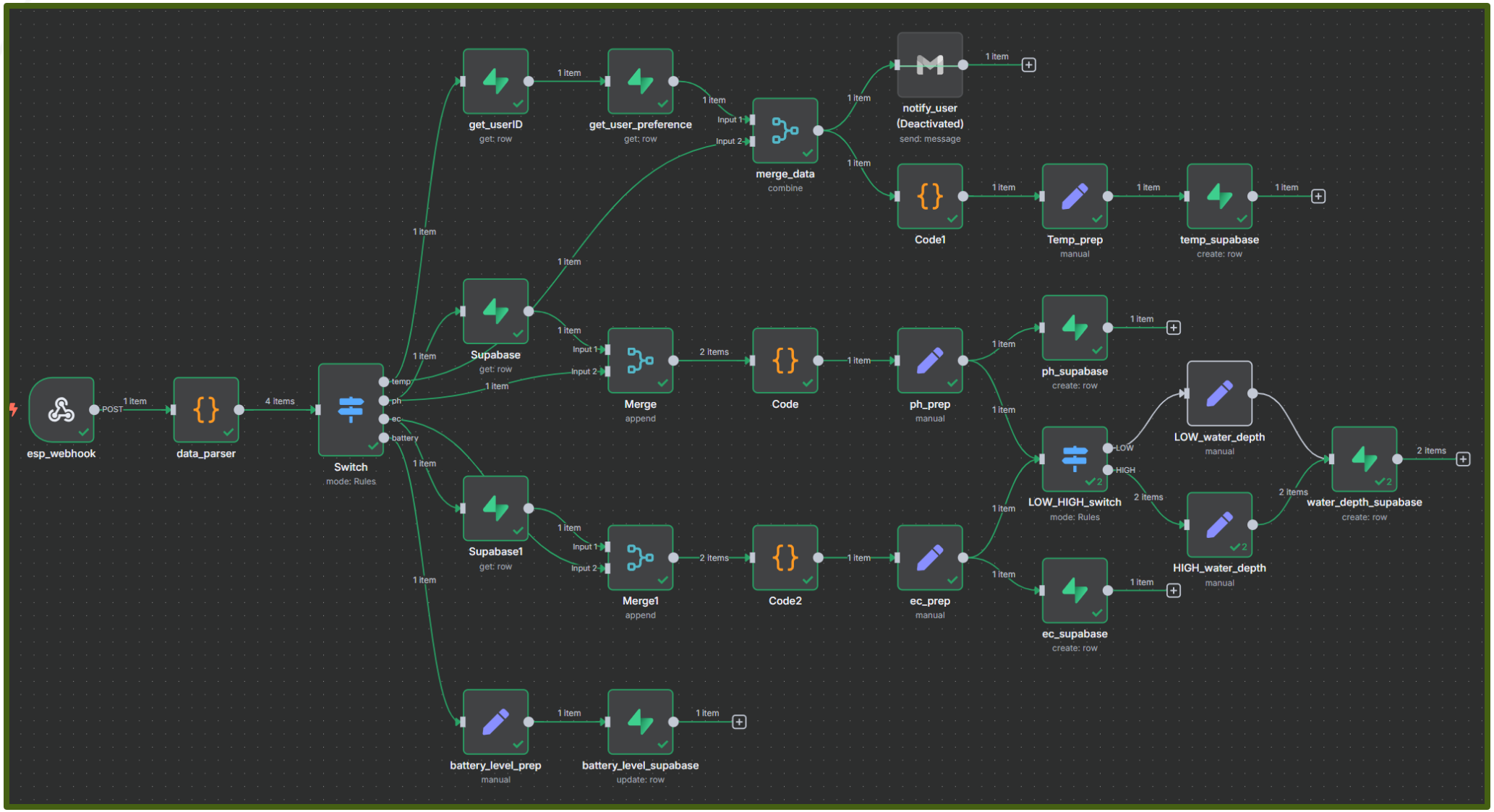
Calibration - Higher Value



Calibration



Calibration - Higher Value

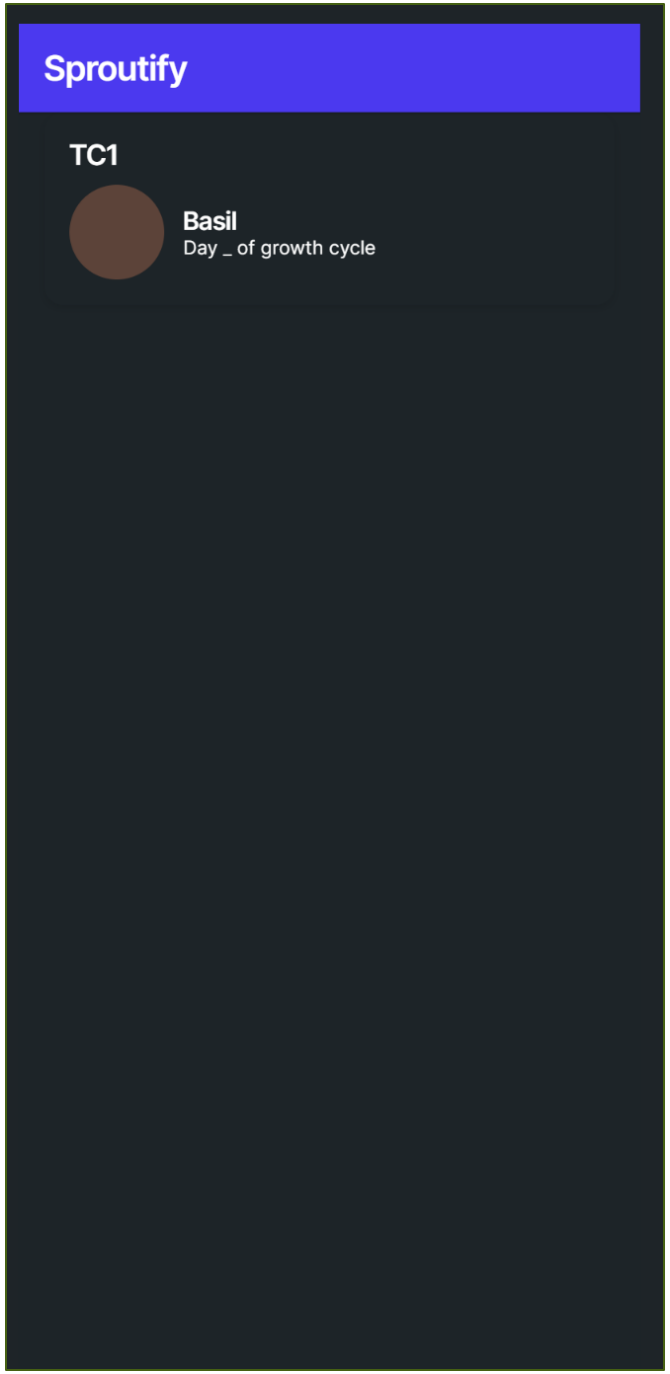


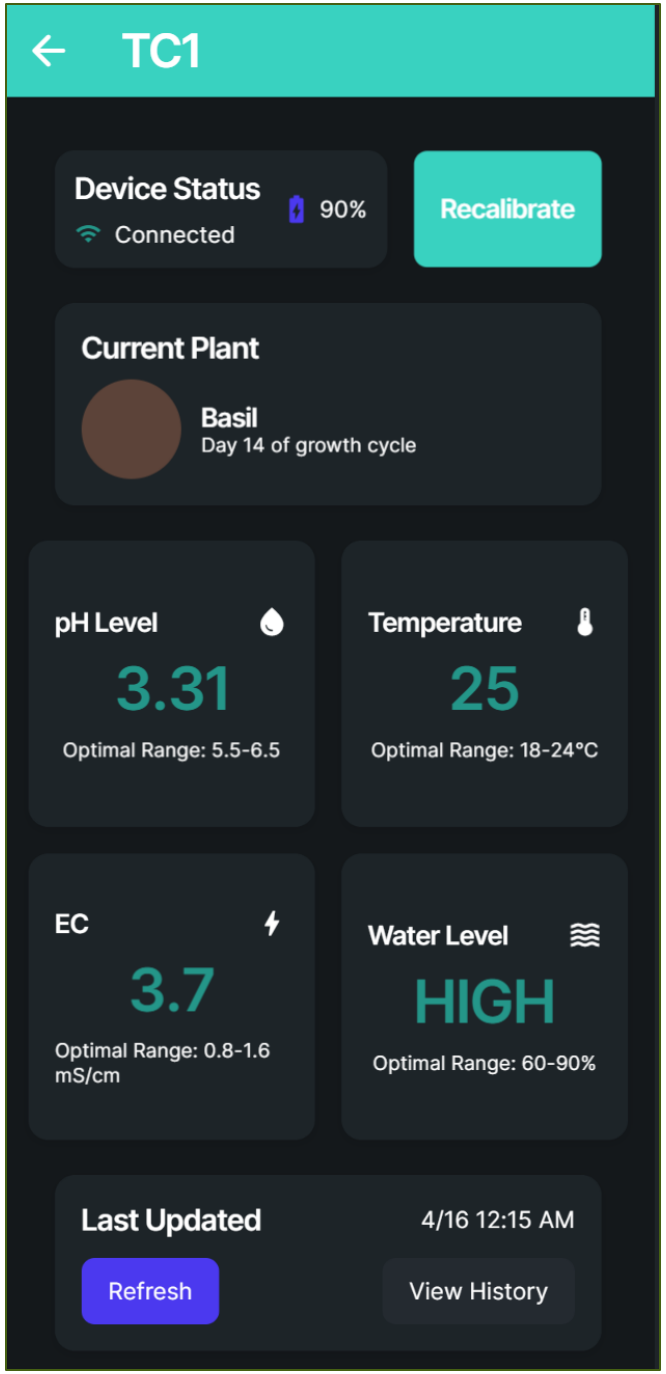
Front End - FlutterFlow

Homepage:
List of user’s devices

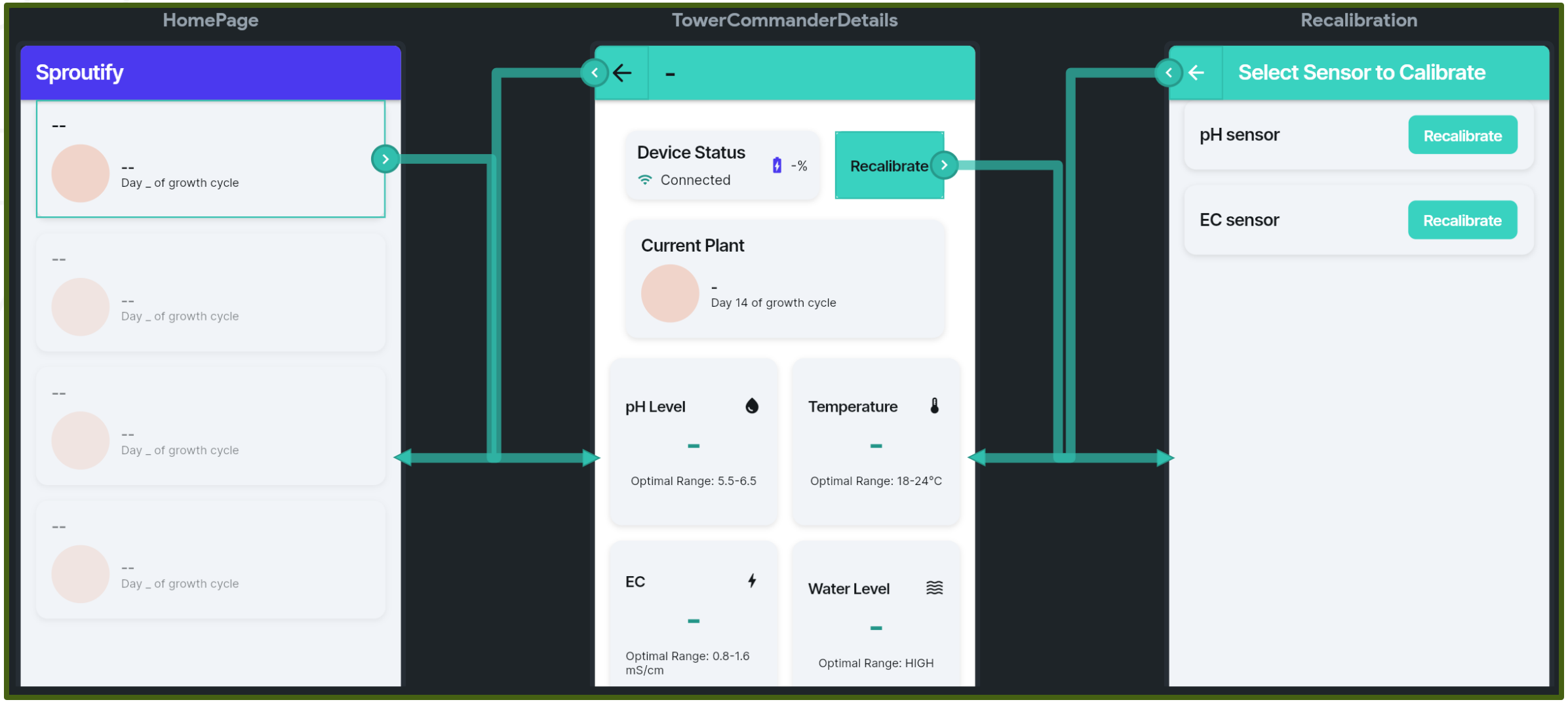
TowerCommander Details Page:
Device and Sensor Data displayed in user-friendly UI

Recalibration button:
Walks user through calibration

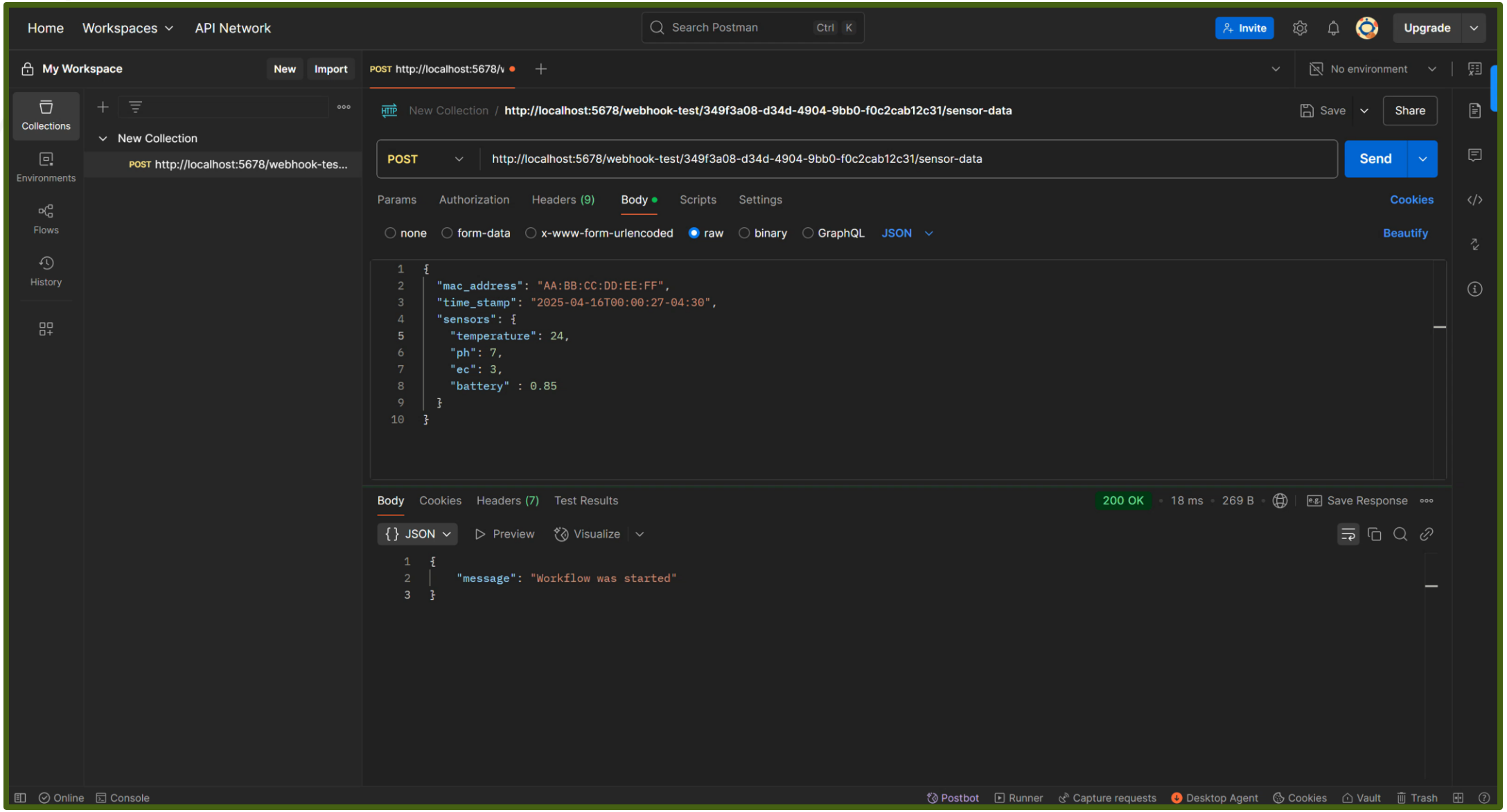




Front End - FlutterFlow

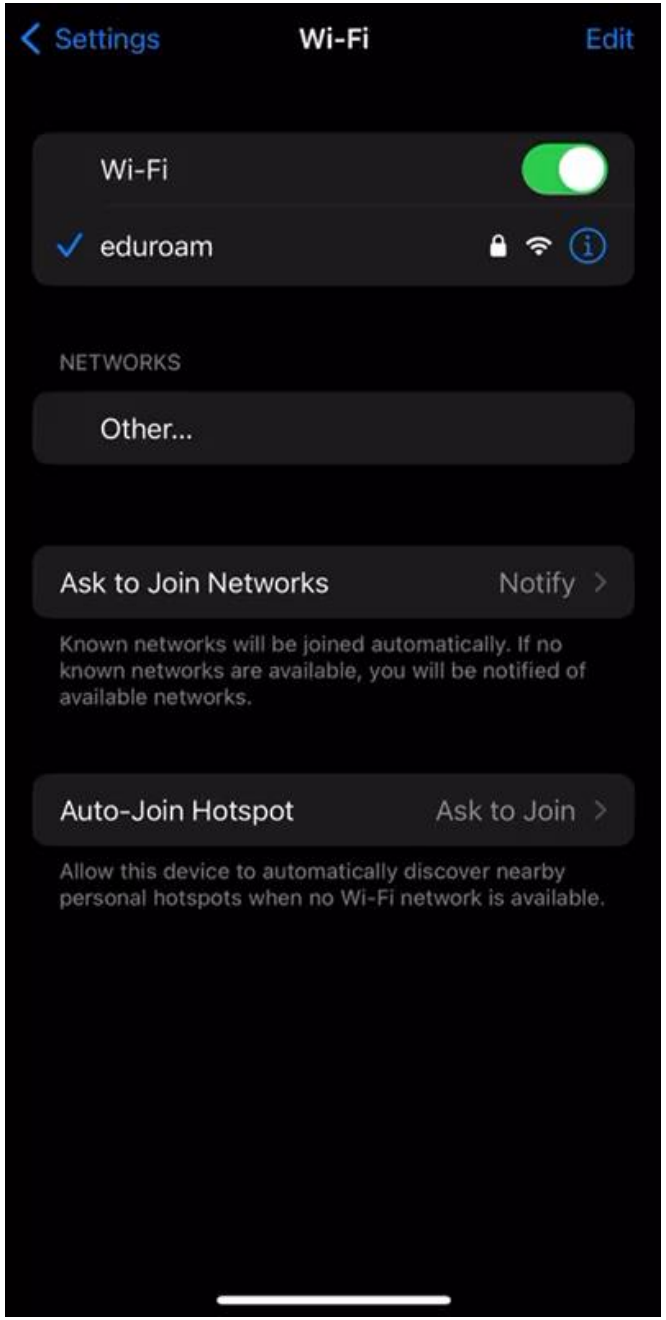


N8N Webhook ➡ Supabase ➡ Frontend



Device Wi-fi Setup

1. The ESP generates a local Access Point (AP)
2. The user connects to the AP which prompts a wifi-portal
3. The user connects to their home wifi through this portal



Driving Code & Data Send

1. Wakes up from deep sleep
2. Connects to configured WiFi
3. Takes sensor readings
4. Compiles data into JSON Payload
5. Sends to N8N
6. Goes to deep sleep*

*Would go to sleep for much longer

Next Steps - Software

- Use Supabase filtering techniques to reduce number of tables for sensor readings
- Finalize recalibration method and display information in the application
- Rigorous testing to handle edge cases in n8n

Next Steps

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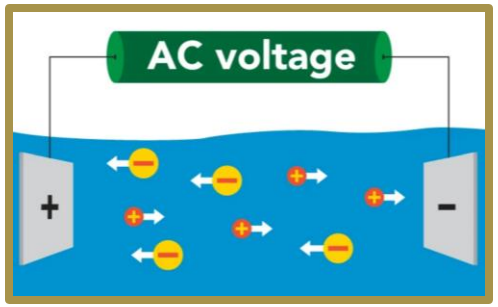
Prototype ➡ Product

- Cost
  - Total Prototype Cost: ~$180
  - Sponsor's Desired Market Cost: $99
    - ~$70 with a minimum 40% retail markup

How can this be achieved?

1. Mass production
2. Injection-molded Packaging
3. Sensor R&D



- Manufacturing
  - Plastic-injection molded packaging
  - PCB with integrated modules
  - Gasket Lining & Custom Grommets

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Product Value

Scissortail Farms in Tulsa, OK utilizes 1200 Tower Gardens

1200 Tower Gardens
× 5 minutes/tower/day

100 labor-hours each day

36,500+ hours → $700,000 in labor each year (approx.)

At $99/unit → $120,000 Tower Commander Investment

−$50,000 Annual Overhead

Year 1 → **$530K SAVINGS**

Year 2+ → **$650K ANNUAL SAVINGS**

Represents $500+ of value *per Tower Garden* each year

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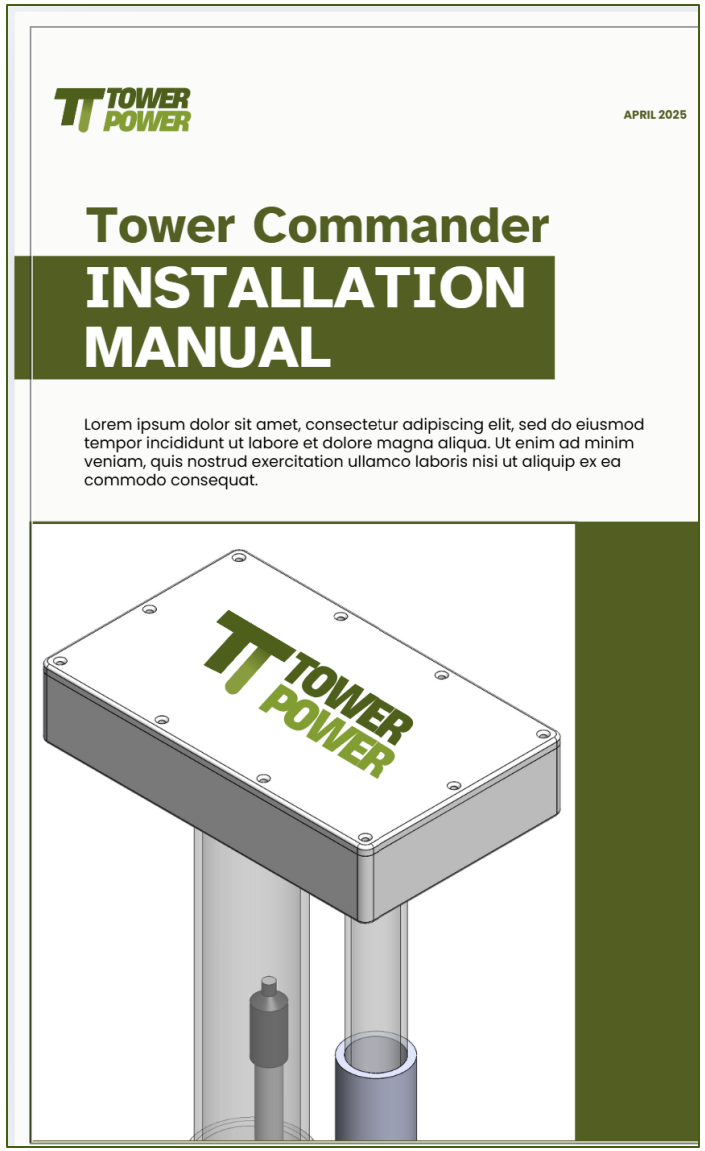
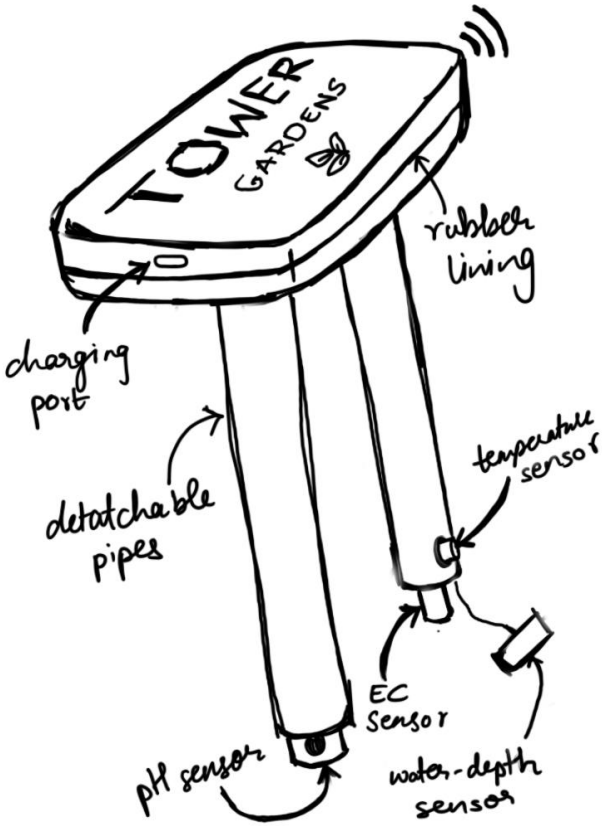
Overall Next Steps

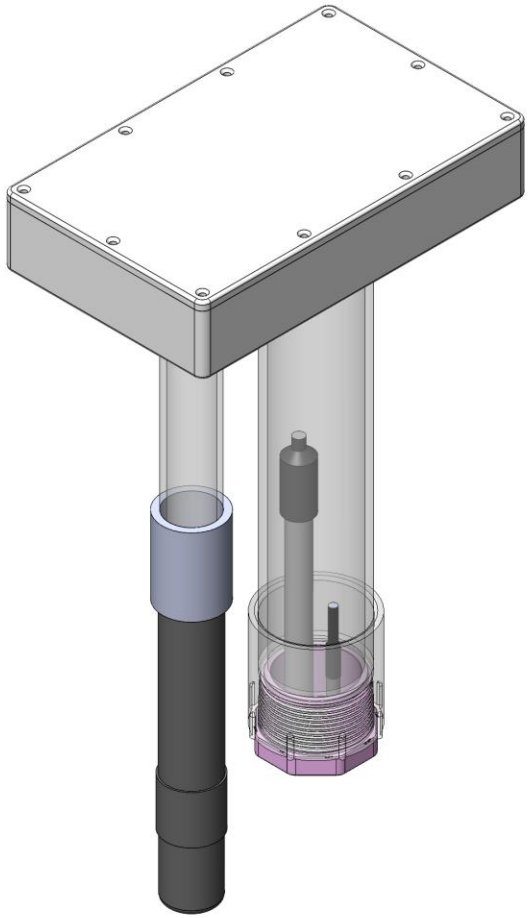
- Goal by Expo:
  - Completed and functioning sensor manipulation
  - Successfully printed and assembled packaging
  - Further comprehensive software (back-end)
  - Development of Device Usage Instruction Manual

- Current Issues:
  - pH sensor unsuccessful in reading
  - Integration of PCB into enclosure
  - Temp sensor connection – Not Waterproof



Thank You! Questions?





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Approximate Battery Life

- **Active**: 3 sensors activate 4x per day (60s each)
  - Sensing & transmitting on WiFi ➡150 mA
- **Sleep**: ESP32 WiFi-on modem sleep ➡20 mA
- **Deep Sleep**: Disconnects from WiFi ➡0.1 mA

For 1 Day:

(150mA * 0.2hr) + (20mA * 3.0hr) + (0.1 mA * 20.8hr)

= (30 + 60 + 2.08) mAh = 92.08 mAh

3000 mAh battery life is **~32.5 days**

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