UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Mobile Hive Checker

Electrical & Computer Engineering

Team 1 : Fiona Cashin, Olivia Guido, Rawda Abdeltawab

TA : Hossein Ataee

Professor : Arne Fliflet

May 2026

Problem

Problem

Current Methods of Hive Inspection

Disrupts Colony's Controlled Environment,

Stresses Bees,

and

Lowers Productivity

Figure 1 :
Fiona's Mom Checking Hive in Wadsworth, Illinois

Solution

Solution

No Need To Open The Hive!

Commercially Viable

Only Device

That Can Be

Easily Removed

To Use On

Multiple Hives!

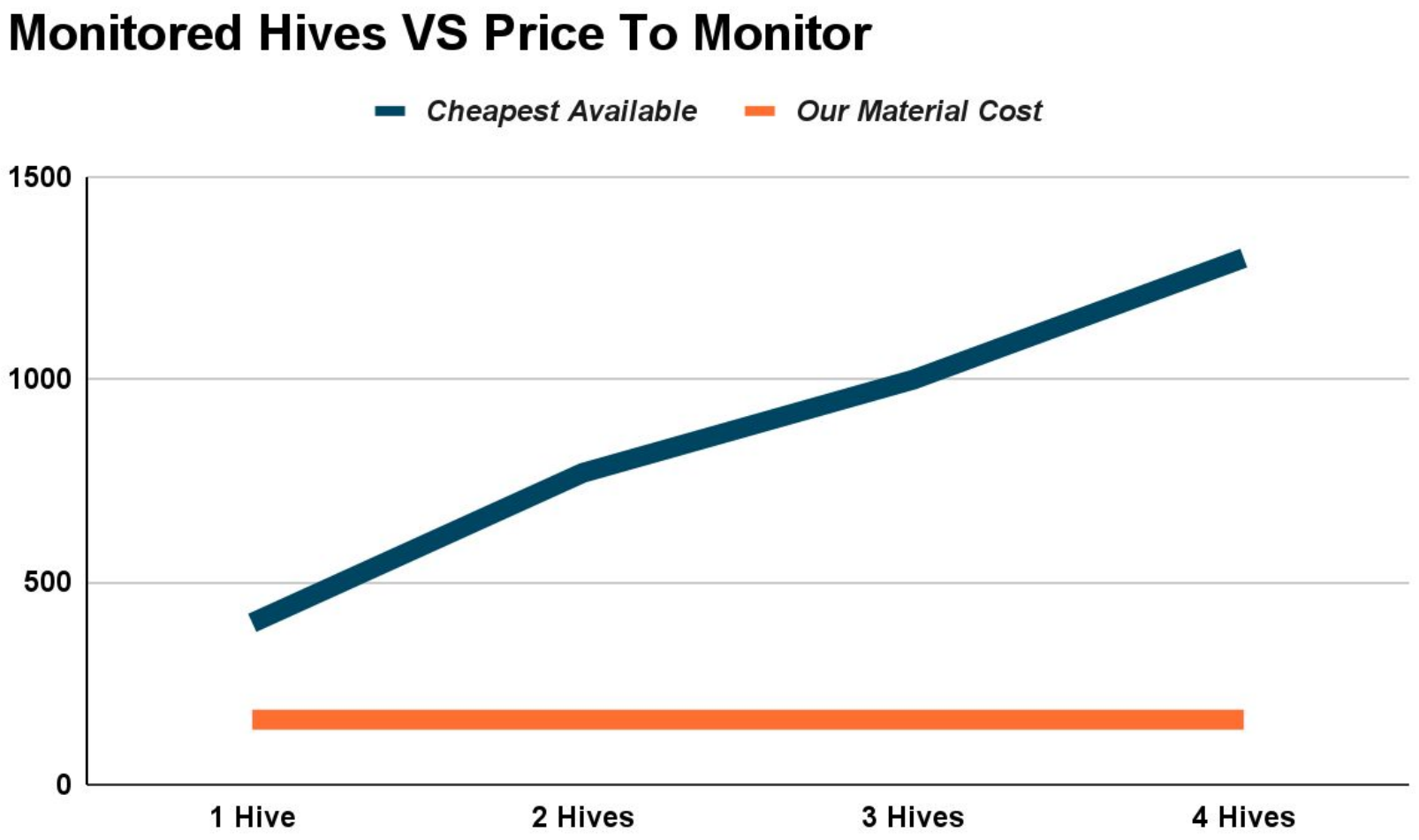
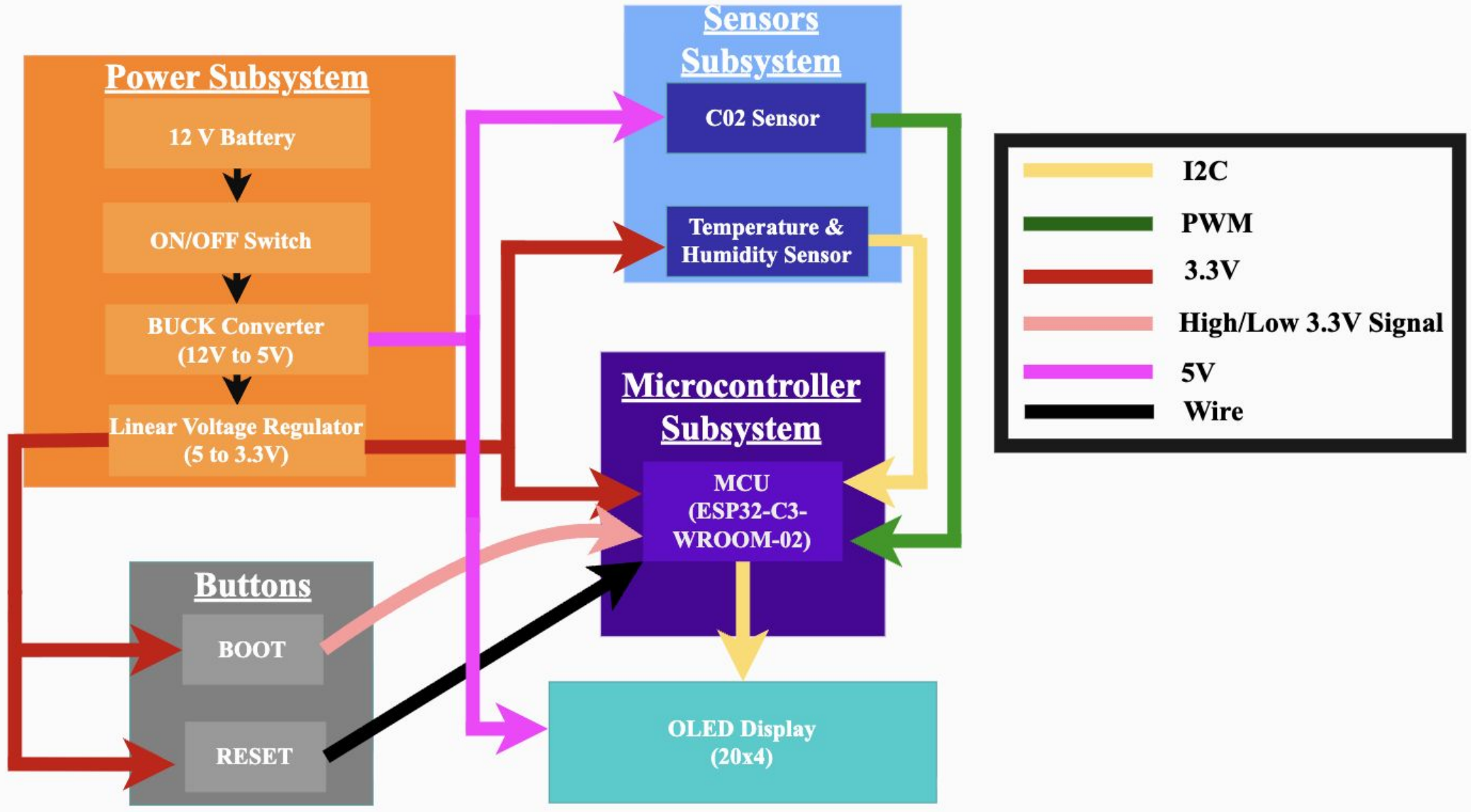


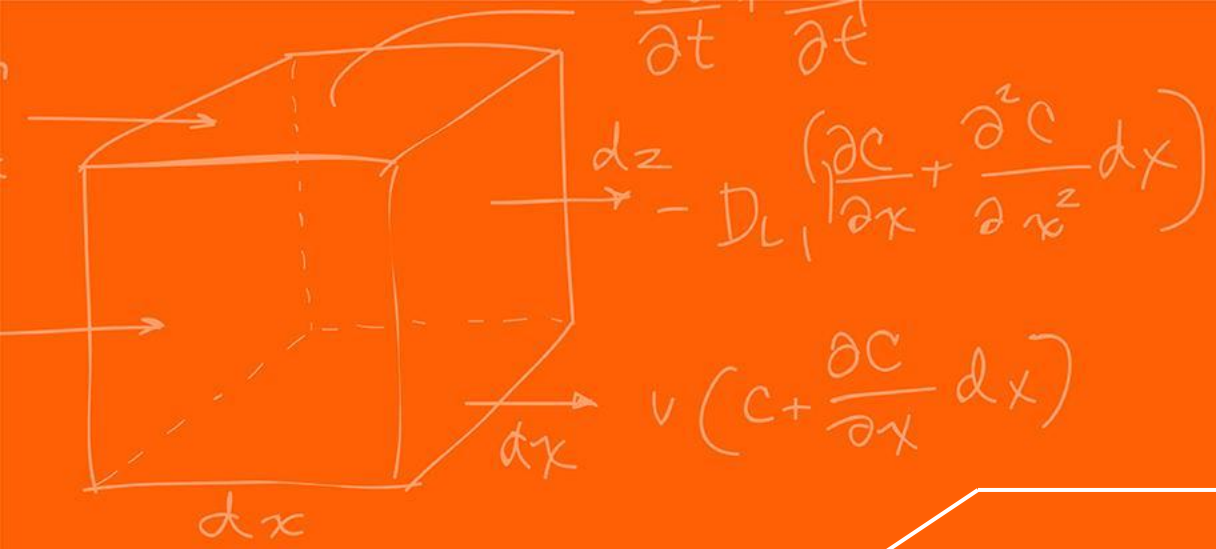
Figure 2 : Cost Comparison to HiveGenie
(https://shop.hivegenie.com/products/hivegenie-monitor/?variant=32317471686742)

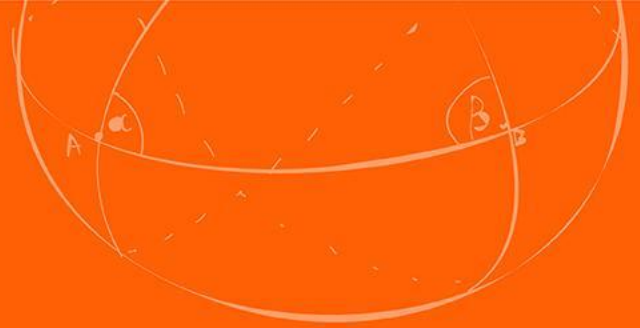
Design

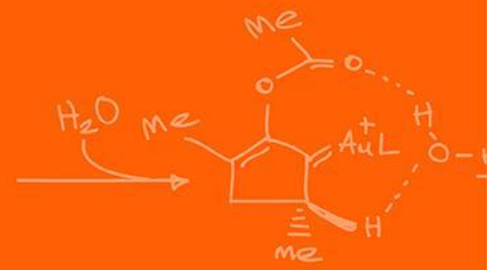
Block Diagram

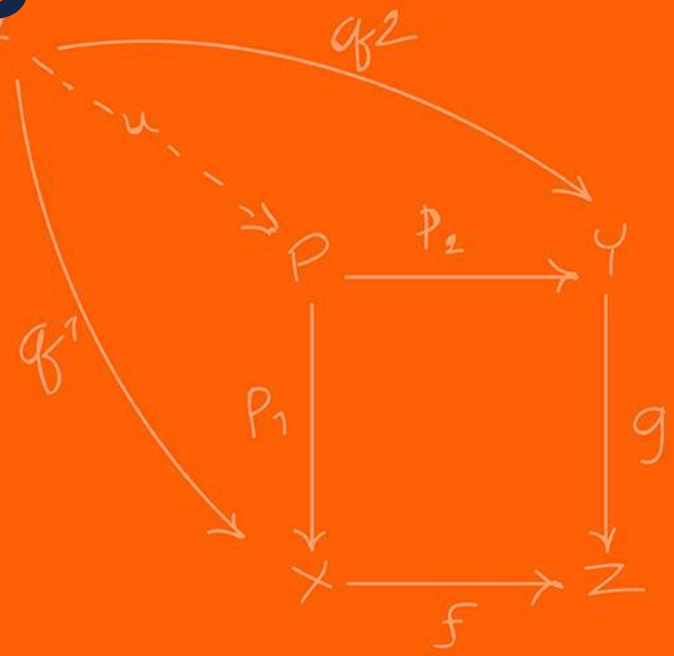


Subsystems





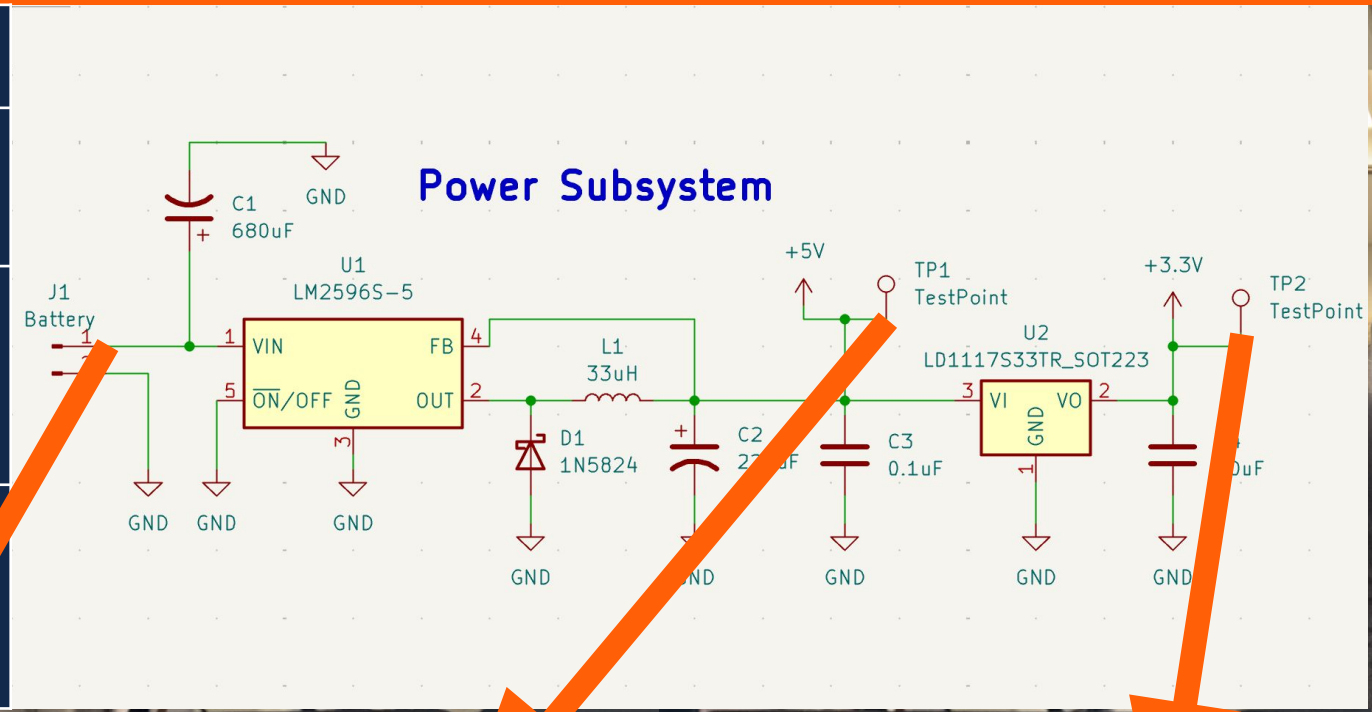




Power Subsystem

Requirements

- Battery supplies 12V DC and 1 A
- Buck Converter converts 12V to 5V ±5%
- Linear Voltage Regulator regulates 5V to 3.3V ±3%



Power Subsystem

Battery Analysis

- 12 V . 1200 mAh
- PCB Requires 510.00098 mA

$$Time = \frac{1200\ (mAh)}{510.00098\ (mA)}$$

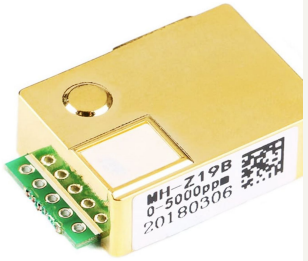
$$= 2.353(hours)$$

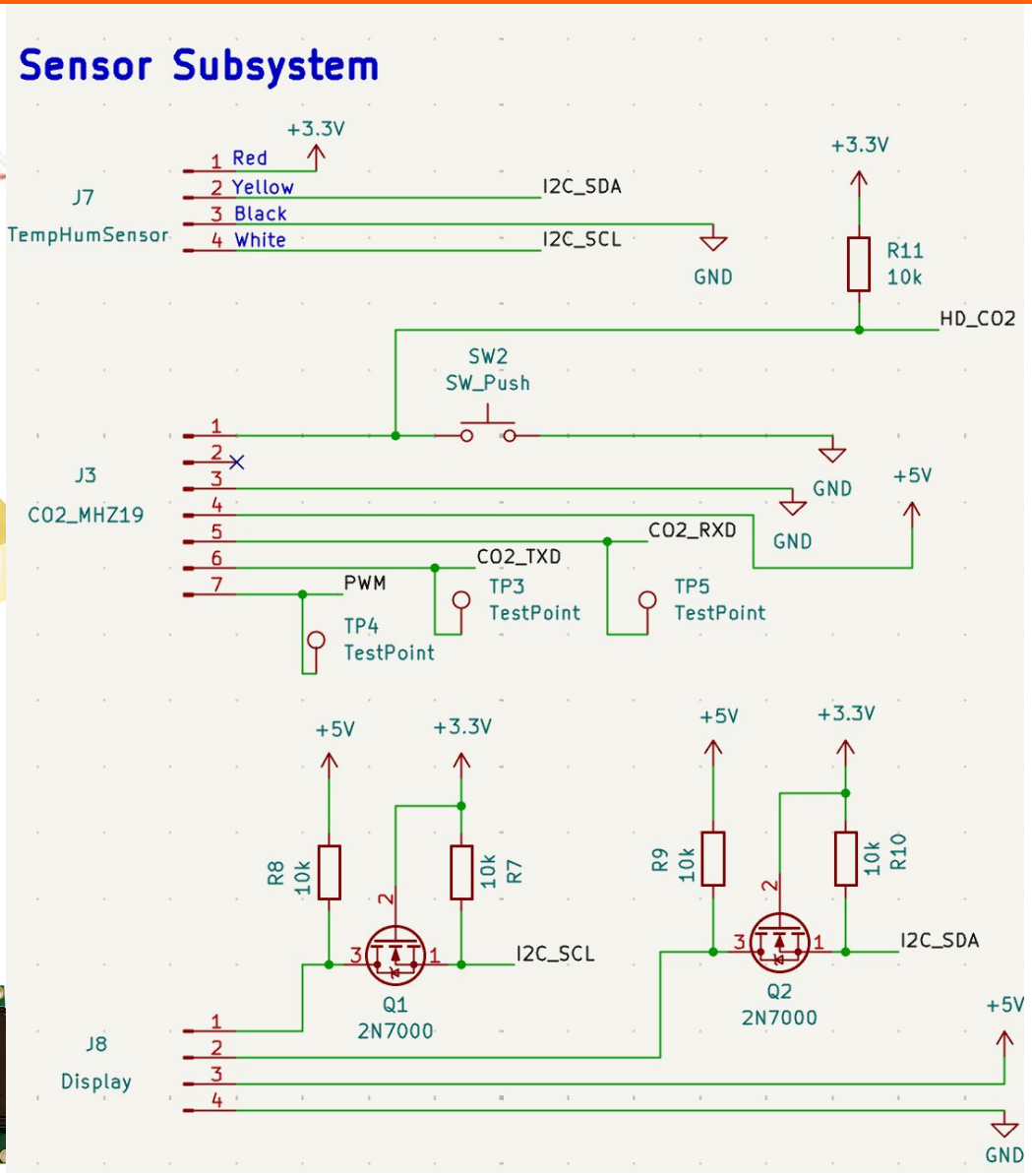
Component	Max Current Draw (mA)
CO_2 Sensor	125
Display	40
Microcontroller	345
Temperature & Humidity Sensor	0.00098

Battery takes about 2 hours and 21 minutes to drain at full load.

*About 4 hours to Fully Charge

Sensor Subsystem





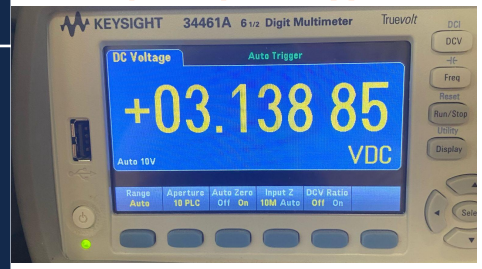
Measurement	Healthy Hive Range	Sensor Range	Sensor Accuracy
Temperature	*70°F - 97 °F*	*−40 - 176°F*	*±0.54°F (±0.3°C)*
Relative Humidity	*50% RH - 60% RH*	*0% RH - 80% RH*	*±2% RH*
CO_2 Concentration	*< 5,000 ppm*	*400 ppm - 5,000 ppm*	*± (50ppm + 5%value)*

Sensor Subsystem

Requirements

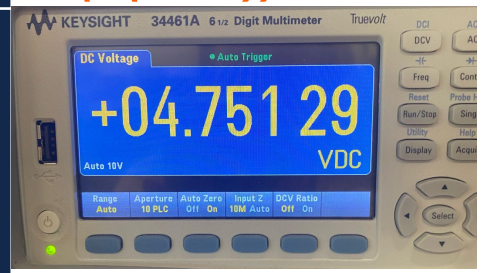
- Temperature and Humidity Sensor operates within ±5% of its rated +3.3V supply voltage and provides accuracy of ±0.54 °F and ±2% RH.
- CO2 Sensor operates within ±5% of its rated +5V supply voltage provides accuracy of ±(50 ppm + 5% reading)

3.3-(3.3(0.05)) = 3.135V

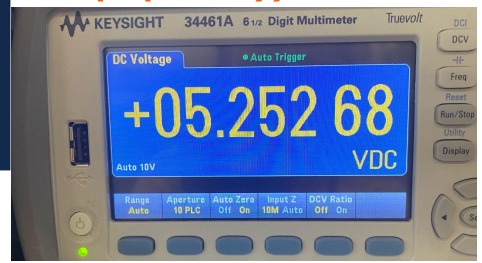


3.3+(3.3(0.05)) = 3.465V

5-(5(0.05)) = 4.75V



5+(5(0.05)) = 5.25V



Temp is off by only 0.5°F

National Oceanic & Atmospheric Administration Data : April 16, 2026.

Average: 427.58 ppm

Sensor Subsystem

Single Conversion - Software

- CO2 Sensor
  - Pulse Width Modulation (PWM)
  - Based on Duty Cycle

$$\textbf{CO2}\ [ppm] = \frac{TH - 2(ms)}{T - 4(ms)}(5{,}000)$$

TH: High level output time during cycles
T: output during cycle (1004ms±5%)

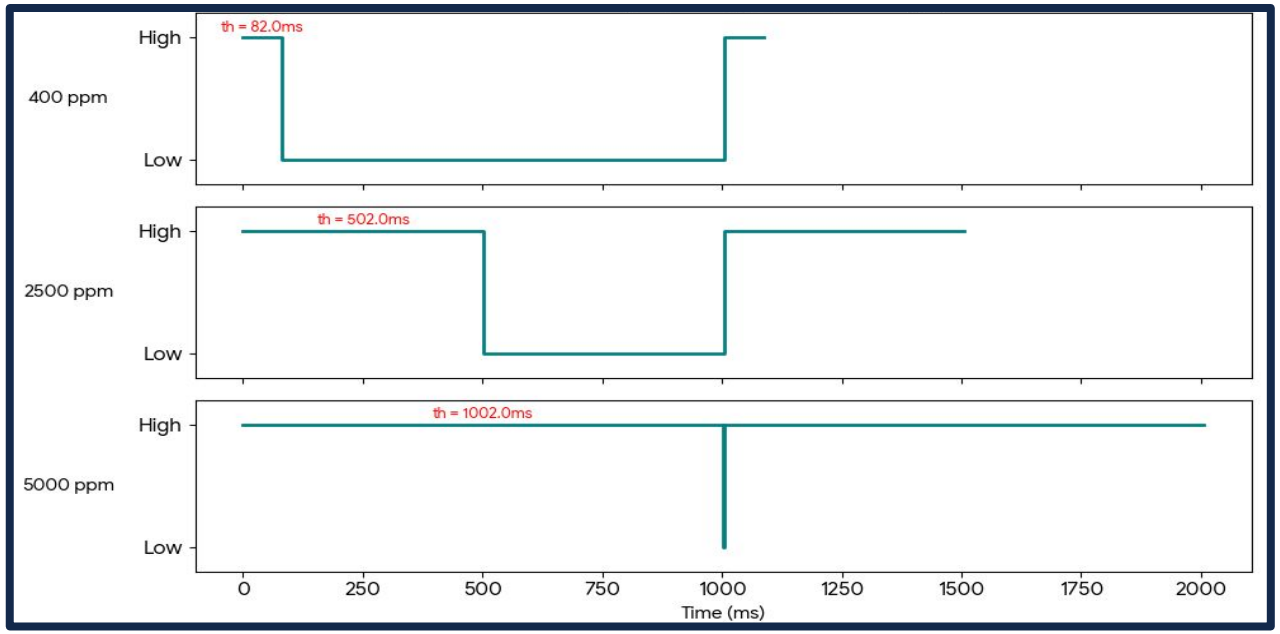


Figure 3 : *PWM Output Timing for 5,000 ppm Sensor*

- Temperature and Humidity computed from raw 20-bit values using formulas defined in datasheet

$$\textbf{Temperature}\ [^{\circ}C] = \frac{Raw\ Data}{2\text{^}20}(150) \qquad \textbf{Humidity}\ [\%] = \frac{Raw\ Data}{2\text{^}20}(100)$$

  - Celsius to Fahrenheit Conversion : $(^{\circ}C \times \frac{9}{5}) + 32 = {}^{\circ}F$

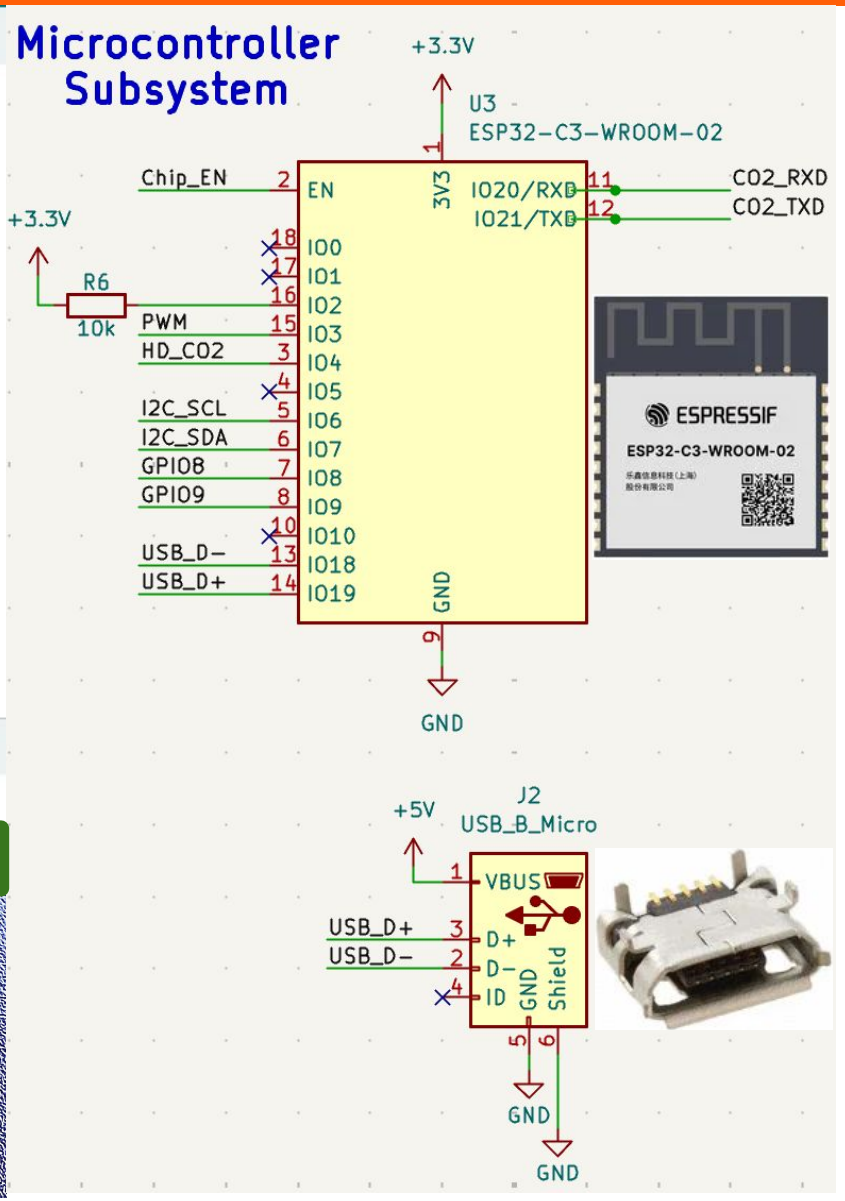
Microcontroller Subsystem

Requirements

- MCU boots system with the USB-B Micro mode
- MCU receives data from sensors when data is available. Data will be received from:
  1. Temperature and Humidity Sensor
  2. CO_2 Sensor
- MCU delivers correct data to Display

```
final_beehive_w_wifi_manger.ino   config_m.h
101
102   byte char_cross[8] = {
103       0b00000,
104       0b10001,
105       0b01010,
106       0b00100,
107       0b01010,
108       0b10001,
109       0b00000,
110       0b00000
111   };
112
113   void lcd_init_chars() {
114       lcd.createChar(0, char_check);  // slot 0 = checkmark
115       lcd.createChar(1, char_cross);  // slot 1 = X
116   }
117   void lcd_print_labels() {
118       lcd.setCursor(0, 0); lcd.print("CO2:      ppm");
119       lcd.setCursor(0, 1); lcd.print("Temp:       F");

Output   Serial Monitor ×
Message (Enter to send message to 'ESP32C3 Dev Module' on 'COM8')
[DATA] CO2: 402 ppm (n=3) | Temp: 57.5F | Hum: 29.8% | Pass/Fail/Fail
```



Microcontroller Subsystem

CO2 Warming Up for 1 min

START/IDLE

ON/OFF Button Pressed

TESTING

All three measurements within range

Measurement Display Update Every 4 sec Interval

One measurement exceed threshold

Clear State
Display Start Screen

RESET

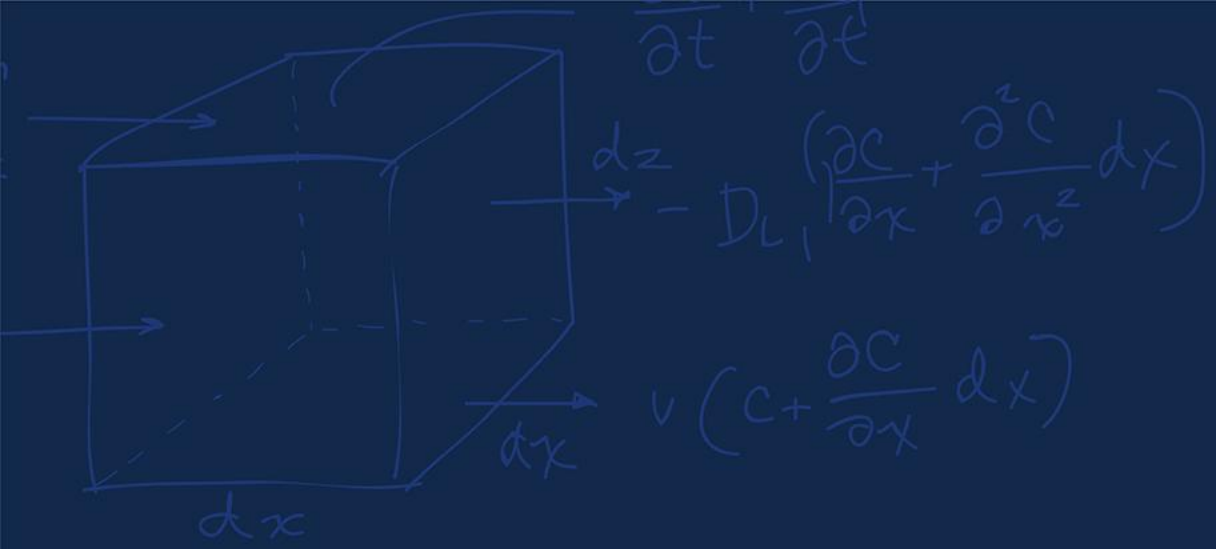
RESULT
Overall Status: Passed

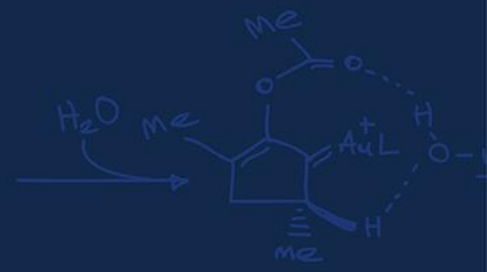
RESULT
Overall Status: Failed

RESET Button Pressed

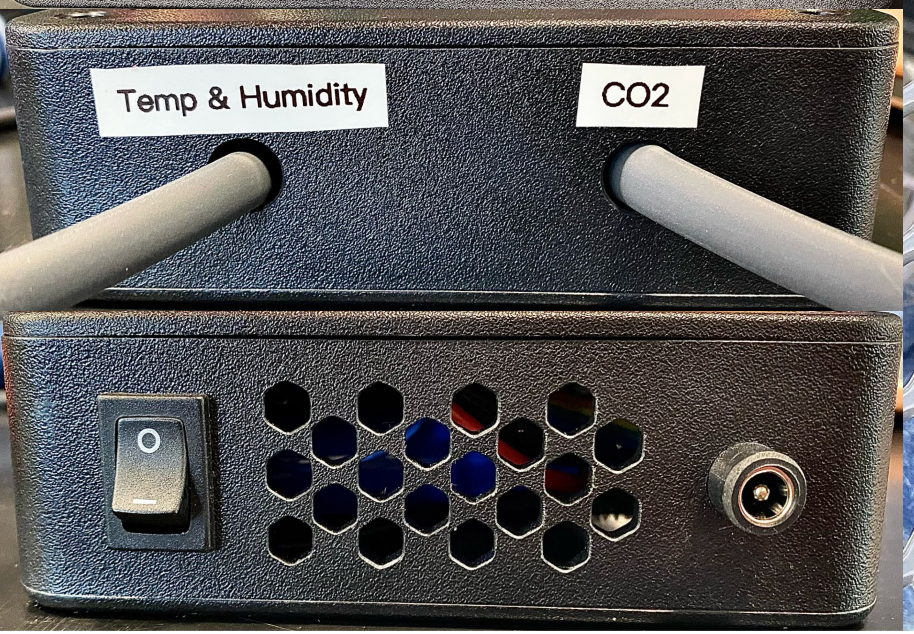
RESET Button Pressed

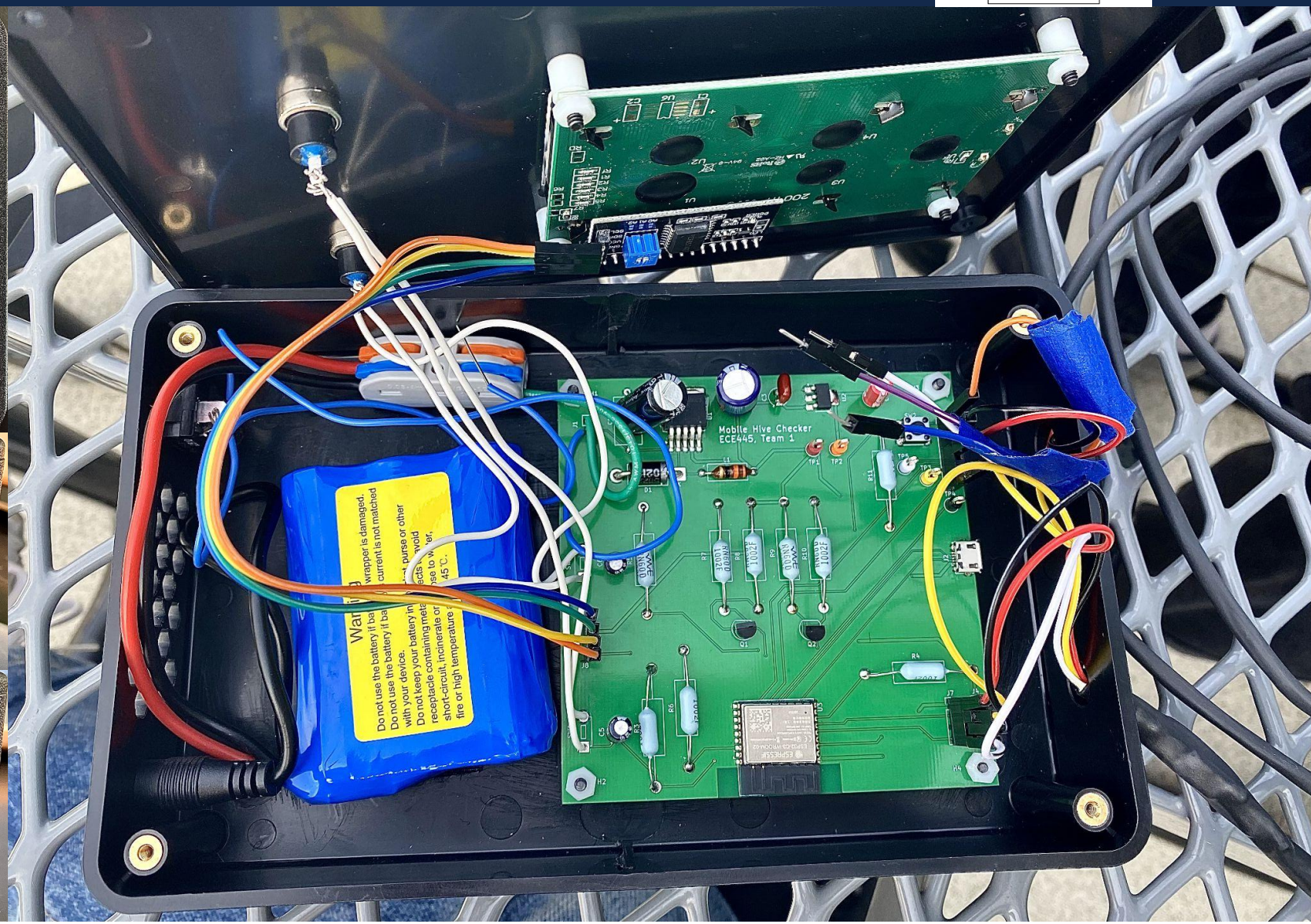
Conclusion





Final Product



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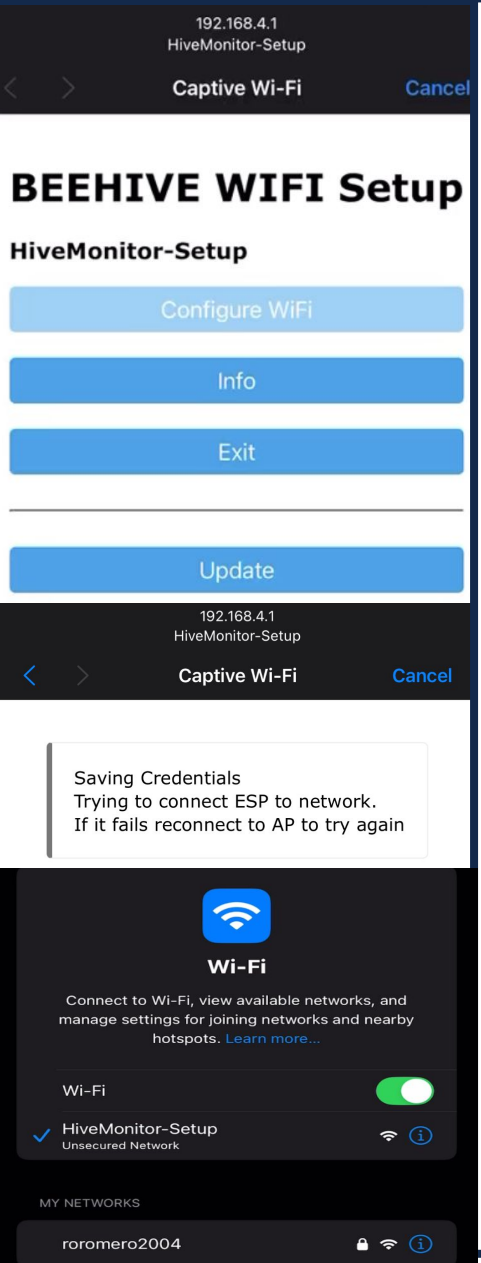
MANNLAKE

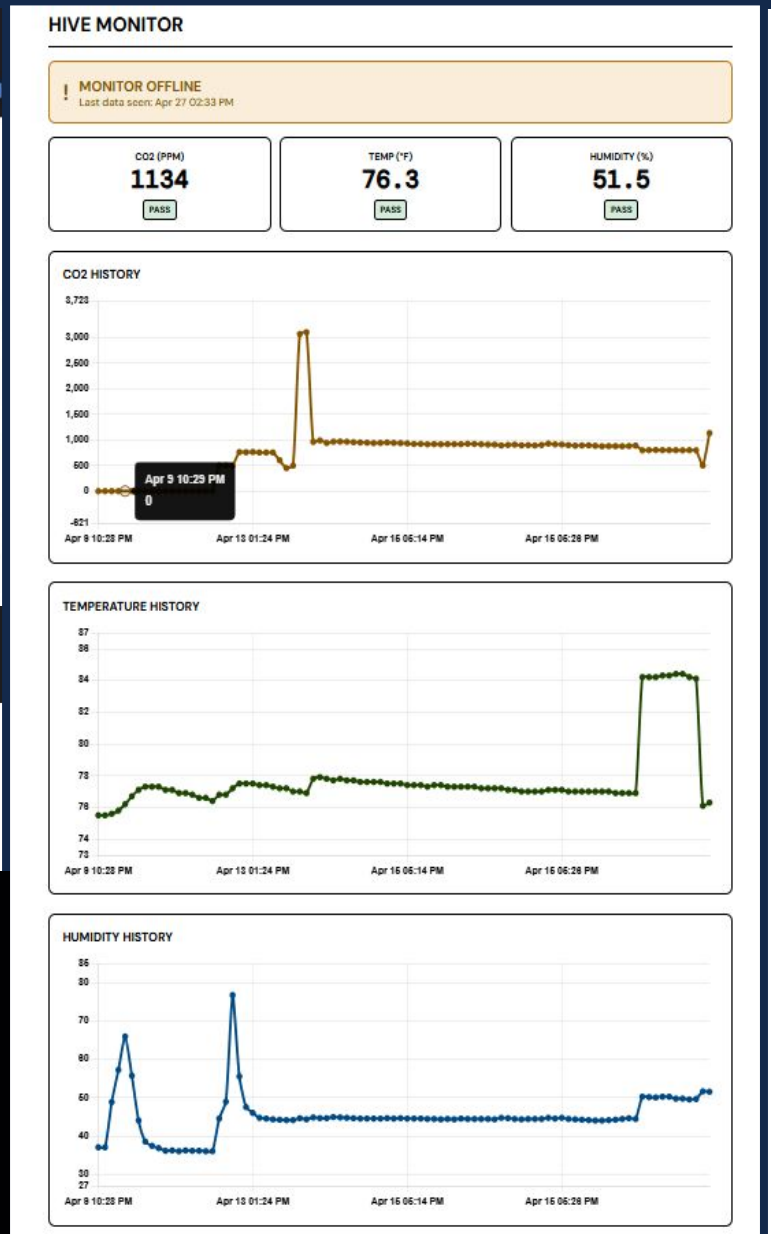

Boot
Reset
CO2: 554 PPM
Temp: 80.9 F
Hum: 42.6 %
RESULT:FAIL


CO2: 561 PPM
Temp: 81.2 F
Hum: 45.0 %
RESULT:FAIL


Boot
Reset
CO2: 564 PPM
Temp: 81.2 F
Hum: 45.7 %
RESULT:FAIL

Successes

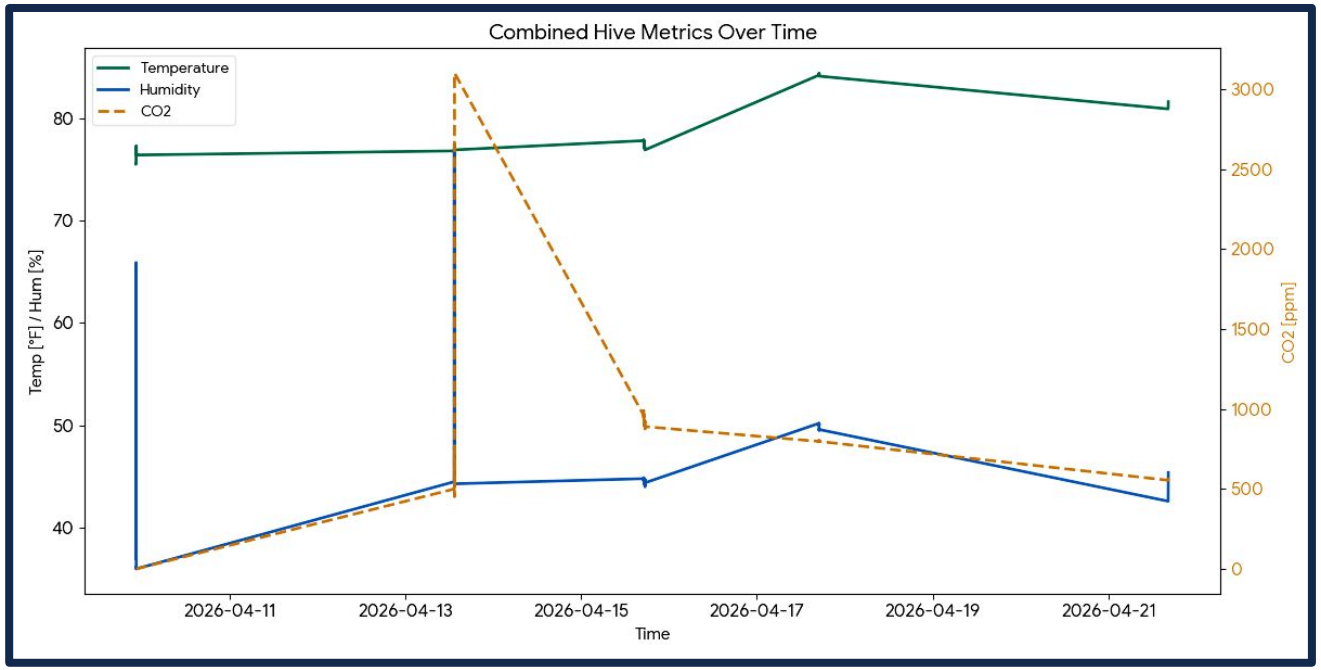




← ***Figure 4 :*** *GitHub HTML Hive Monitor Dashboard*

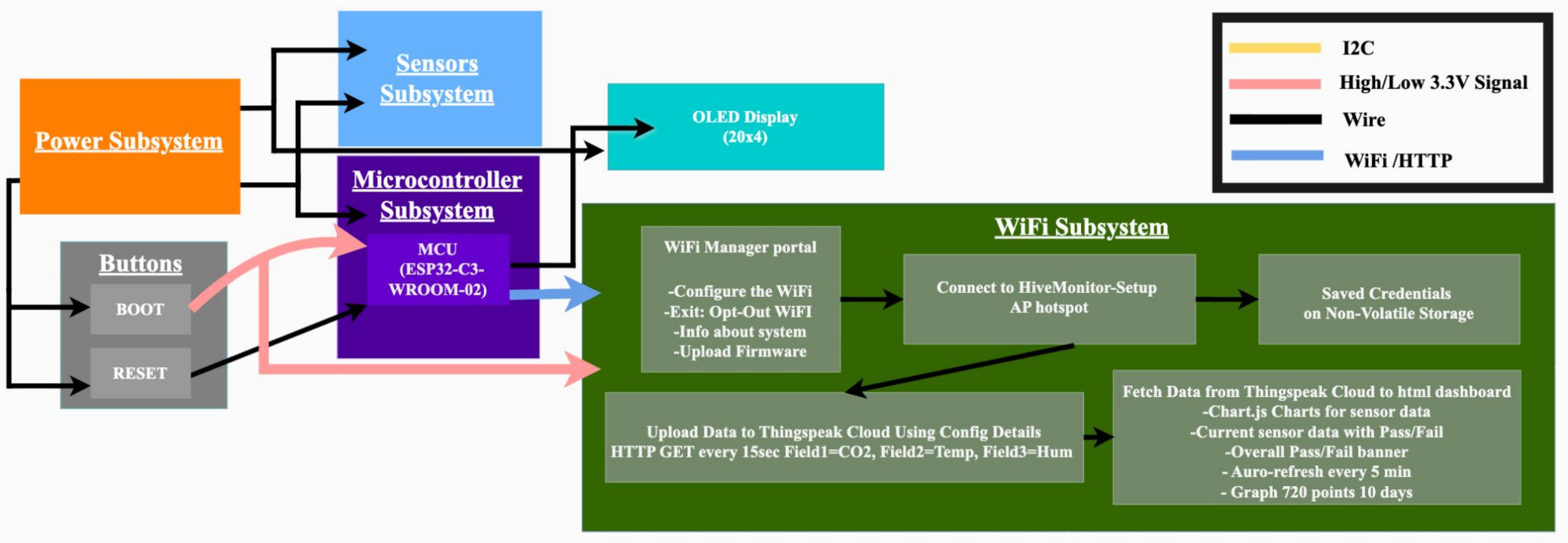
WIFI !

↓ **Figure 5 :** Beehive Monitor - ThingSpeak IoT



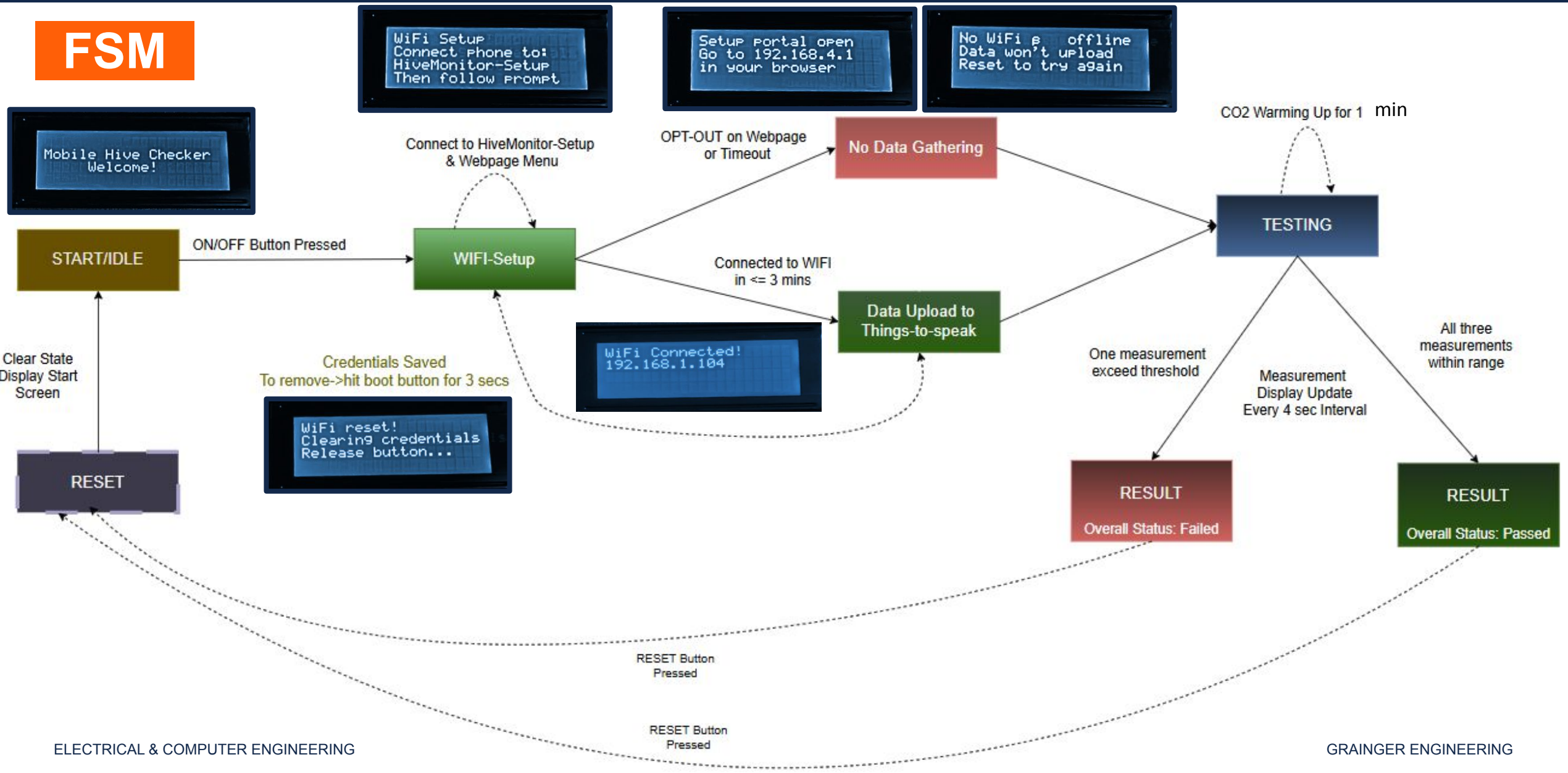
Successes WIFI

Block Diagram

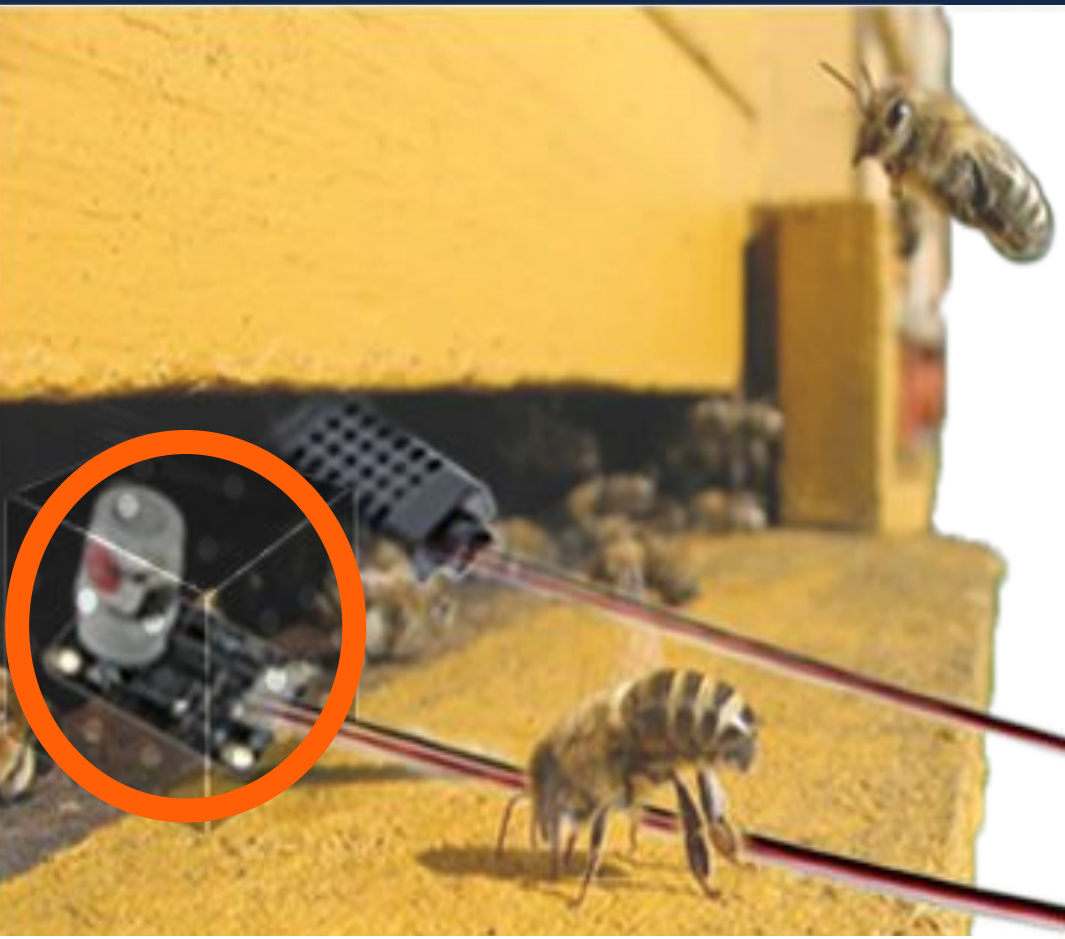


Successes

FSM



Challenges



What We Would Do Differently

- Spent More Time Picking the CO2 Sensor
- No Access to Controlled Environment Testing

*This is our old sensor.

We are using a new CO2 sensor because of calibration challenges

Takeaways

What We Learned

- Surface Mount Soldering
- 3D Printing
- Importance of Personal Protective Equipment
- Advantage of Testing Each Subsystem
- Different Communication Protocols

Societal Impact

Easier to Keep Bees.

More Beekeepers

More Honeybees

More Pollination

More Crops! More Honey!

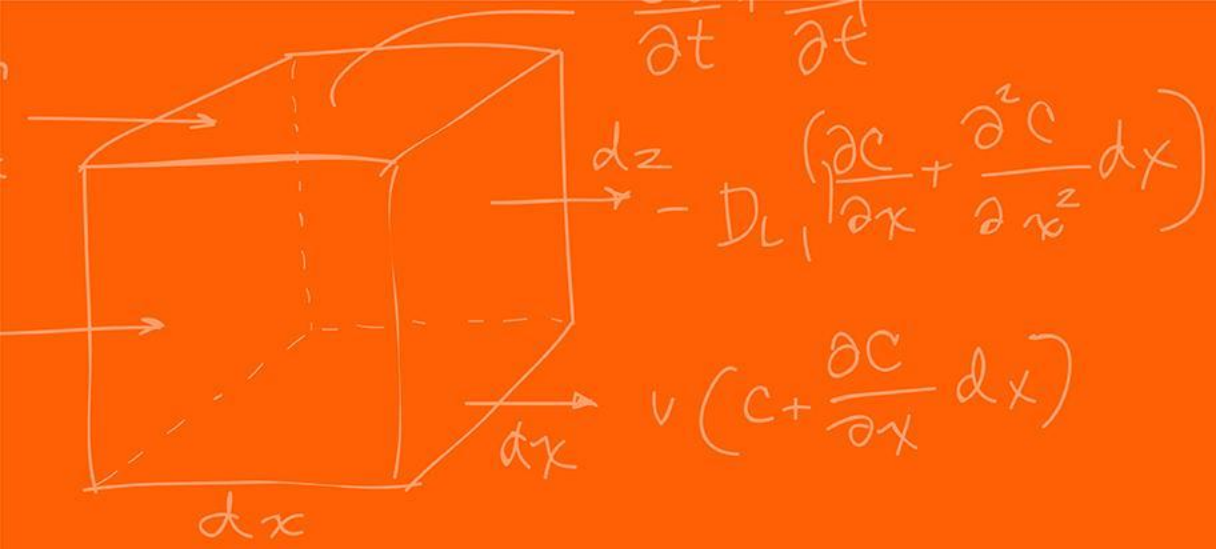
More Money!

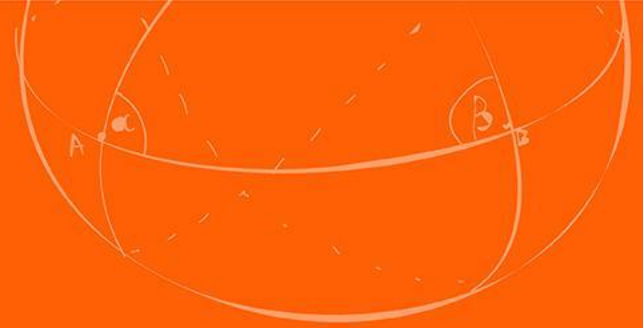
Thank You !

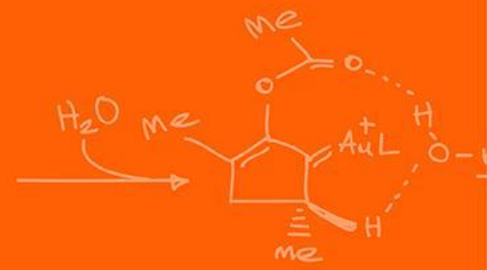
Questions ?

Special Thanks To …

- Arne Fliflet
- Hossein Ataee
- Paul Hood
- Beekeeping Club at UIUC
- Jack Blevins
- Jonathan Ashbrook







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