UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

CO2ffee

Coffee Bean Freshness Tracker

Team 4

Abrar Murtaza
Nathan Colunga
Joshua Meier

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Problem

Coffee is best when your beans are fresh!
But we don't know how fresh our beans actually are.

Solution

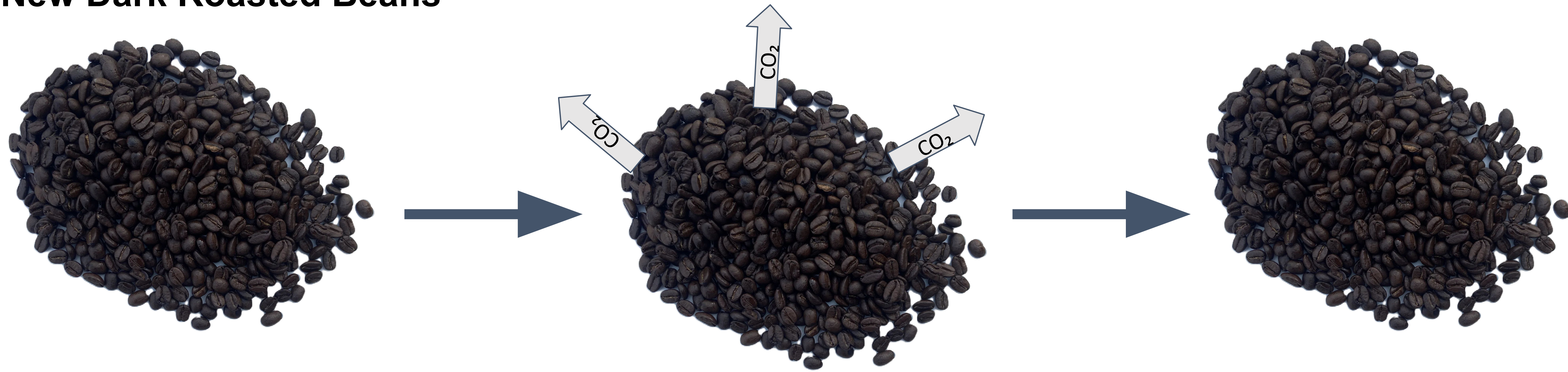
We created a device that tells you exactly how fresh your coffee beans are!

Coffee Bean Freshness

CO_2 Content = The Key Indicator of Freshness!

Releases CO_2 Over Time

New Dark Roasted Beans

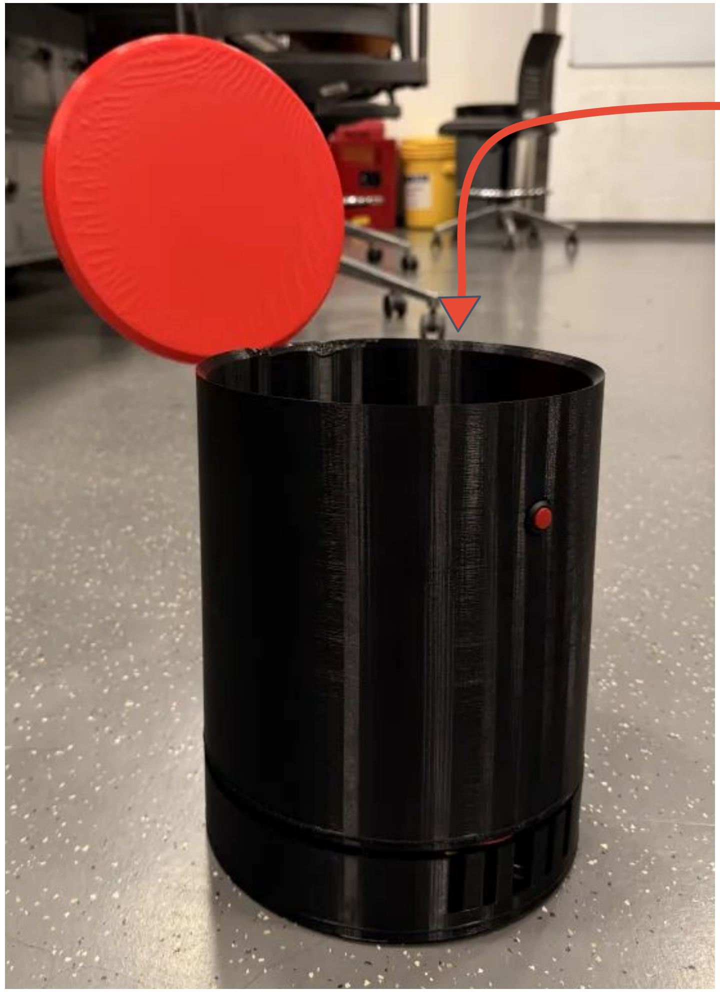


CO_2 Content: 10 mg / g of beans
Freshness: 100%

Releases 2 mg of CO_2 / g of beans

CO_2 Content: 8 mg / g of beans
Freshness: 80%

Freshness Tracking



One-Way Valve Coffee Bean Bag

After Lid Closes

- Record **baseline CO_2** (500 ppm)
- Beans **release CO_2**

Every Minute

- Sample **current CO_2** (700 ppm)
- **ΔCO_2** = current – baseline (200 ppm)
- ΔCO_2 x container volume = **mg of CO_2 released**
- Divide by bean weight → **mg of CO_2 released per gram**
- Update **freshness score**

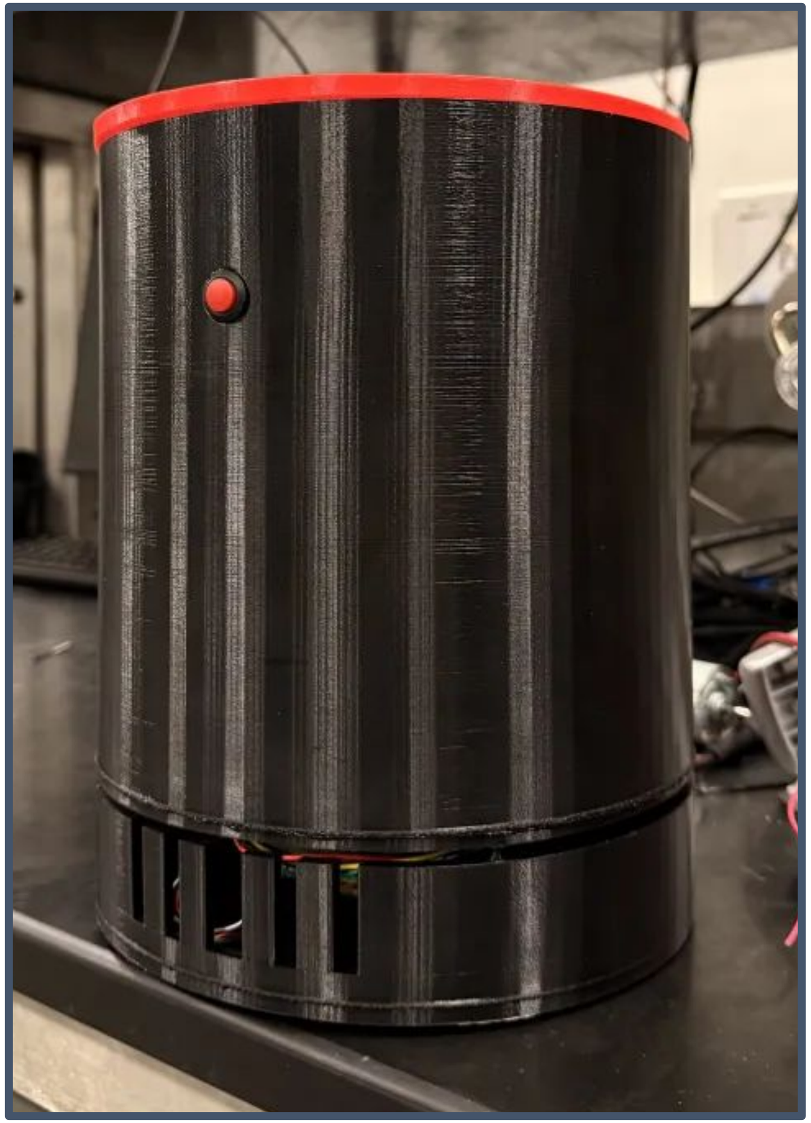
How To Use

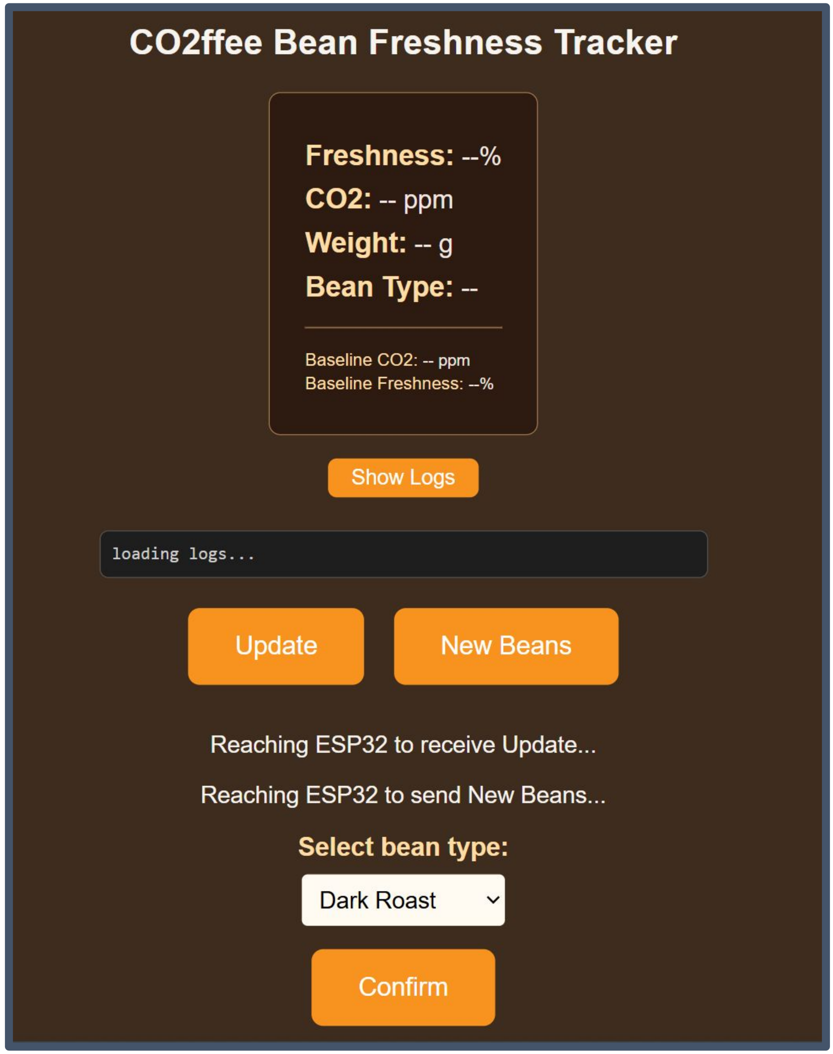
Adding New Beans

1) Open lid
2) Insert <u>new</u> beans
3) Select bean type
4) Close lid
5) Freshness tracking begins

Withdrawing Beans

1) Open lid, tracking pauses
2) Take beans out, return bag
3) Close lid
4) Resume freshness tracking





CO2ffee Bean Freshness Tracker

Freshness: --%
CO2: -- ppm
Weight: -- g
Bean Type: --

Baseline CO2: -- ppm
Baseline Freshness: --%

```
loading logs...
```

Reaching ESP32 to receive Update...

Reaching ESP32 to send New Beans...

Select bean type: Dark Roast

High Level Requirements

- The freshness rating must be reported as a percentage, representing the CO2 remaining in the beans relative to its original state (100%).

- The weight sensor readings must accurately reflect bean withdrawal by ±2 %, and combined with CO2 sensor data, they must determine the CO2 loss per gram of beans.

- The user can select from three bean types, and press a button to open/close the outer lid for bean withdrawal.

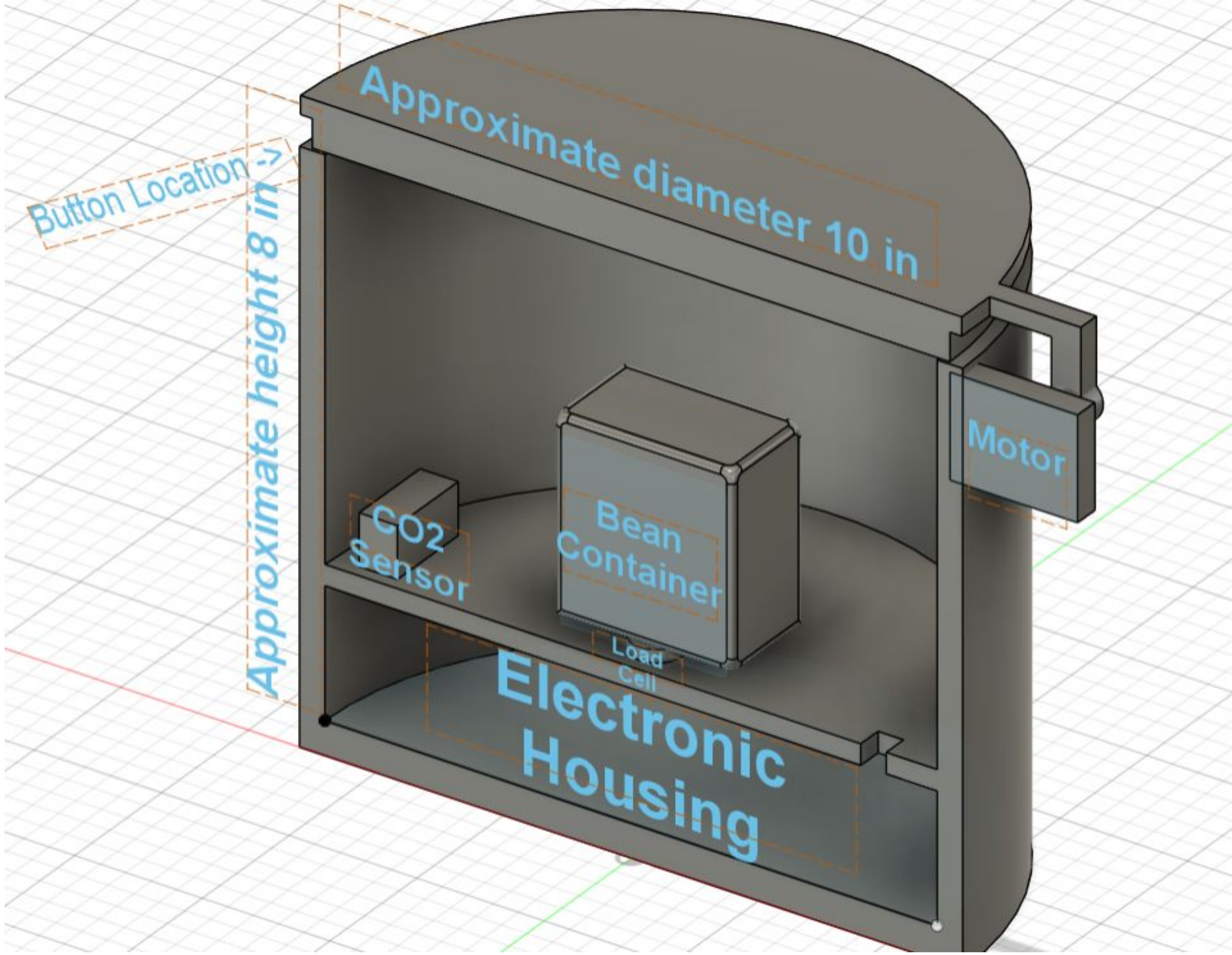
Preliminary Design

<u>Compare our CO2 Release to Study:</u>

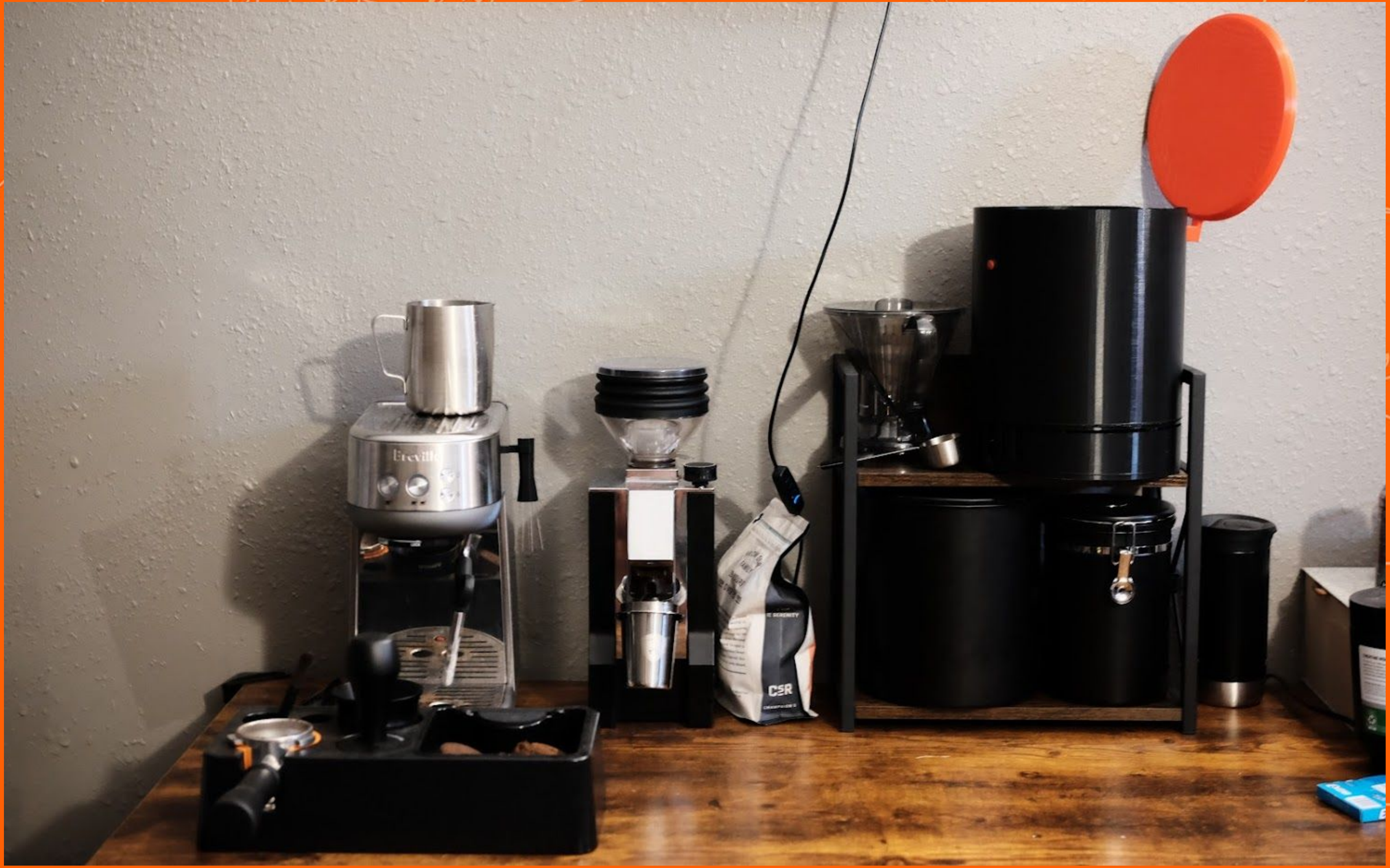
- Monitor the rate of the release
- Track exact amount of CO2 released

<u>UI for information submission and display:</u>

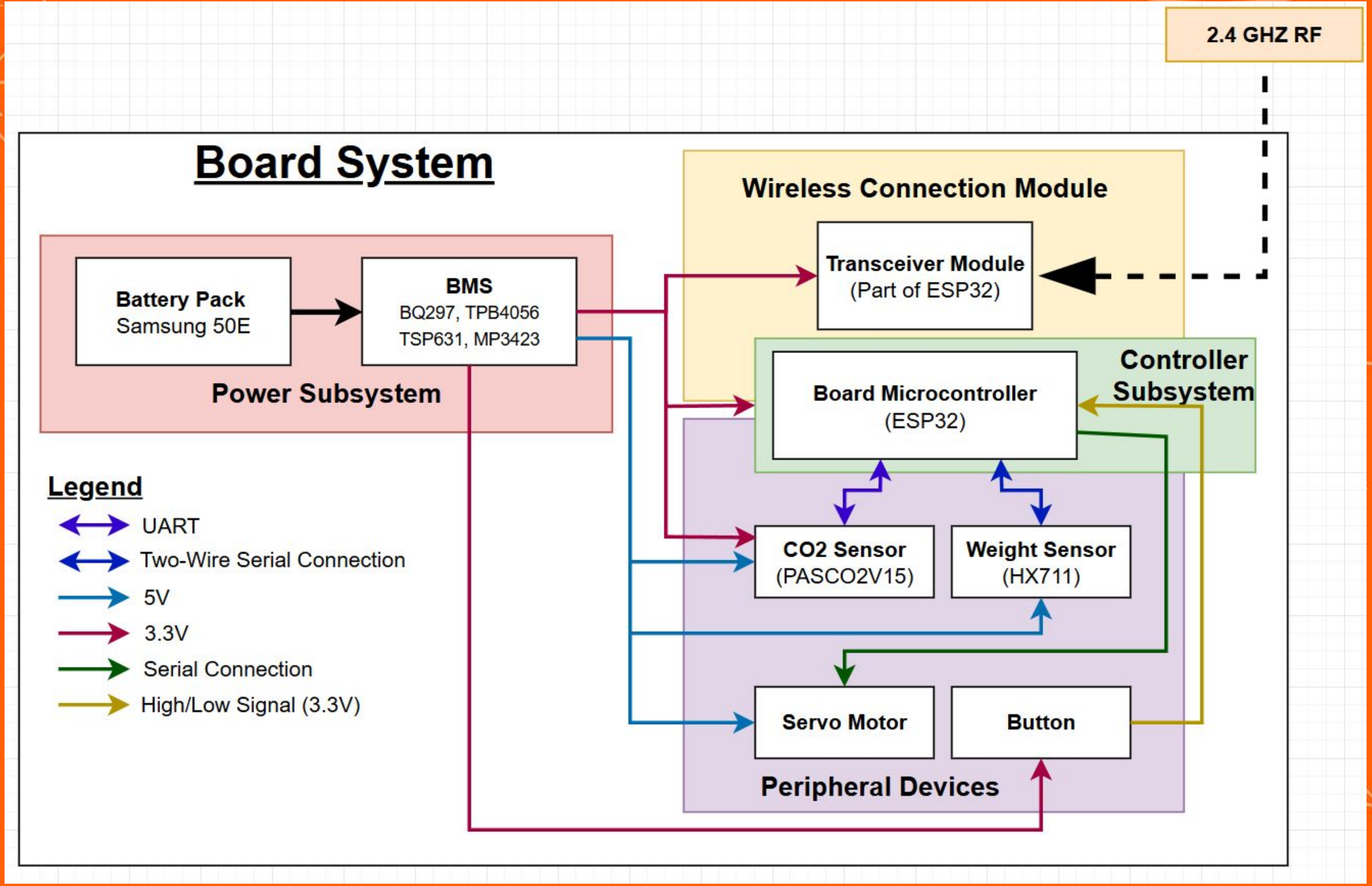
- Small screen to display information independently of network
- Bluetooth or Wi-Fi to interface with mobile app



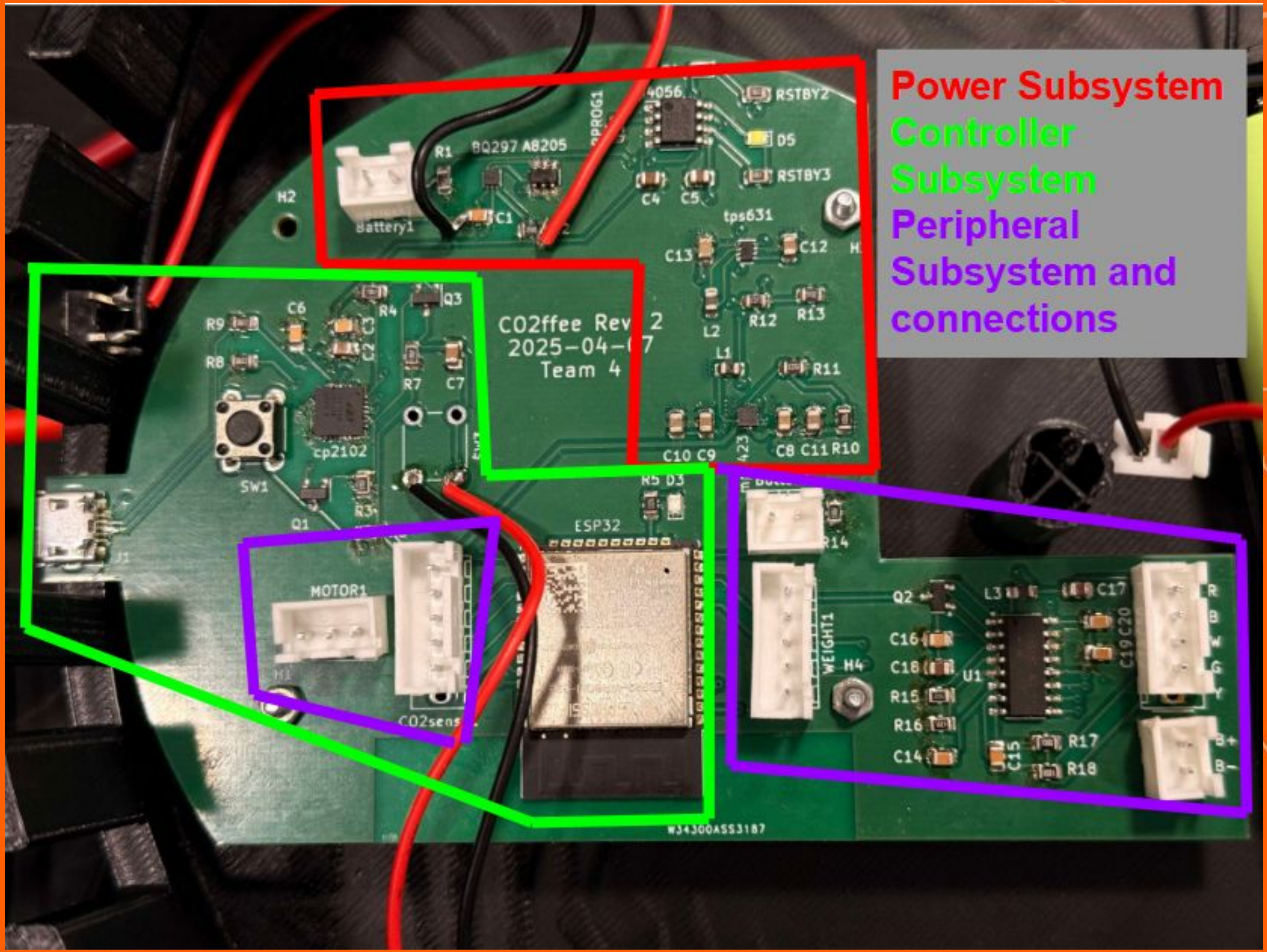
Final Design



Subsystems Functionality



Subsystems Functionality

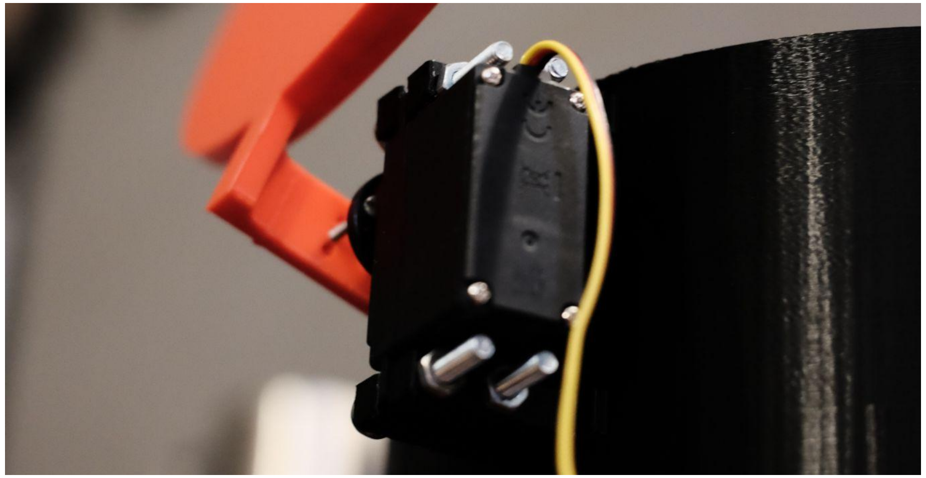


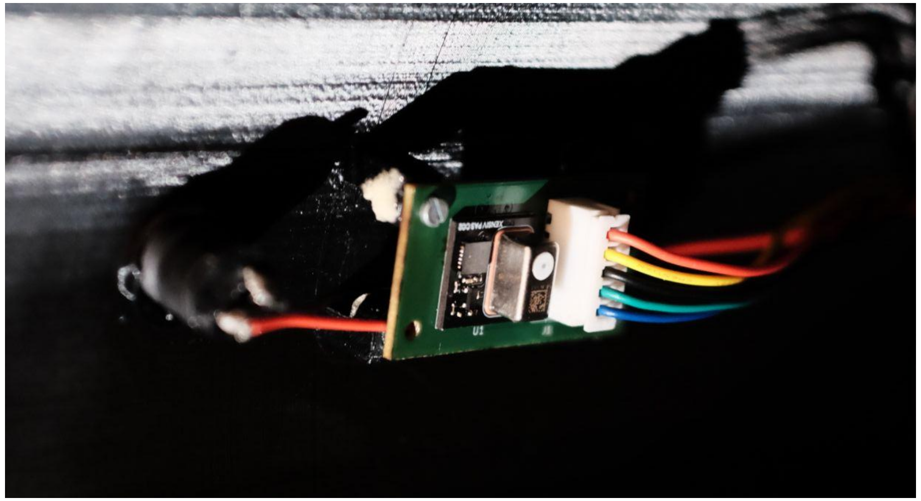
Power Subsystem

Controller Subsystem

Peripheral Subsystem and connections

Peripheral Subsystem Functionality





Motor(above) and CO2 sensor next to backside of button (below)

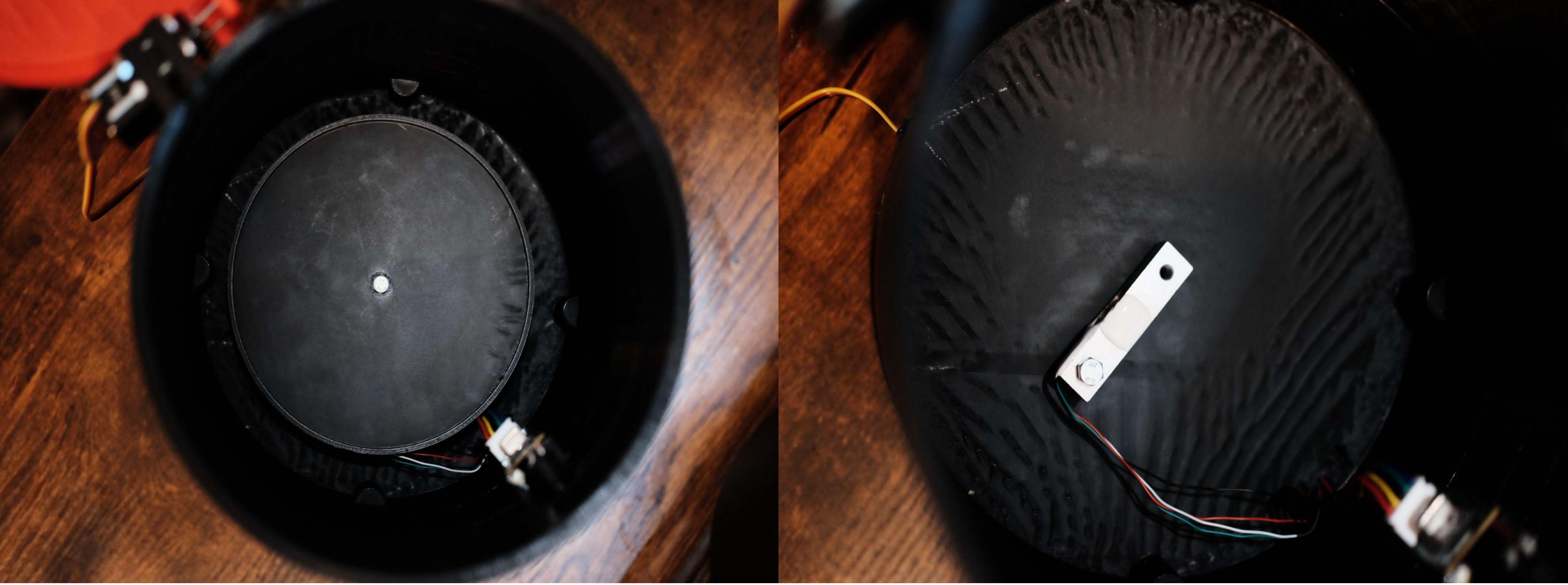
Components of this subsystem

1. **CO2 sensor**
   a. UART
   b. Independent PCB

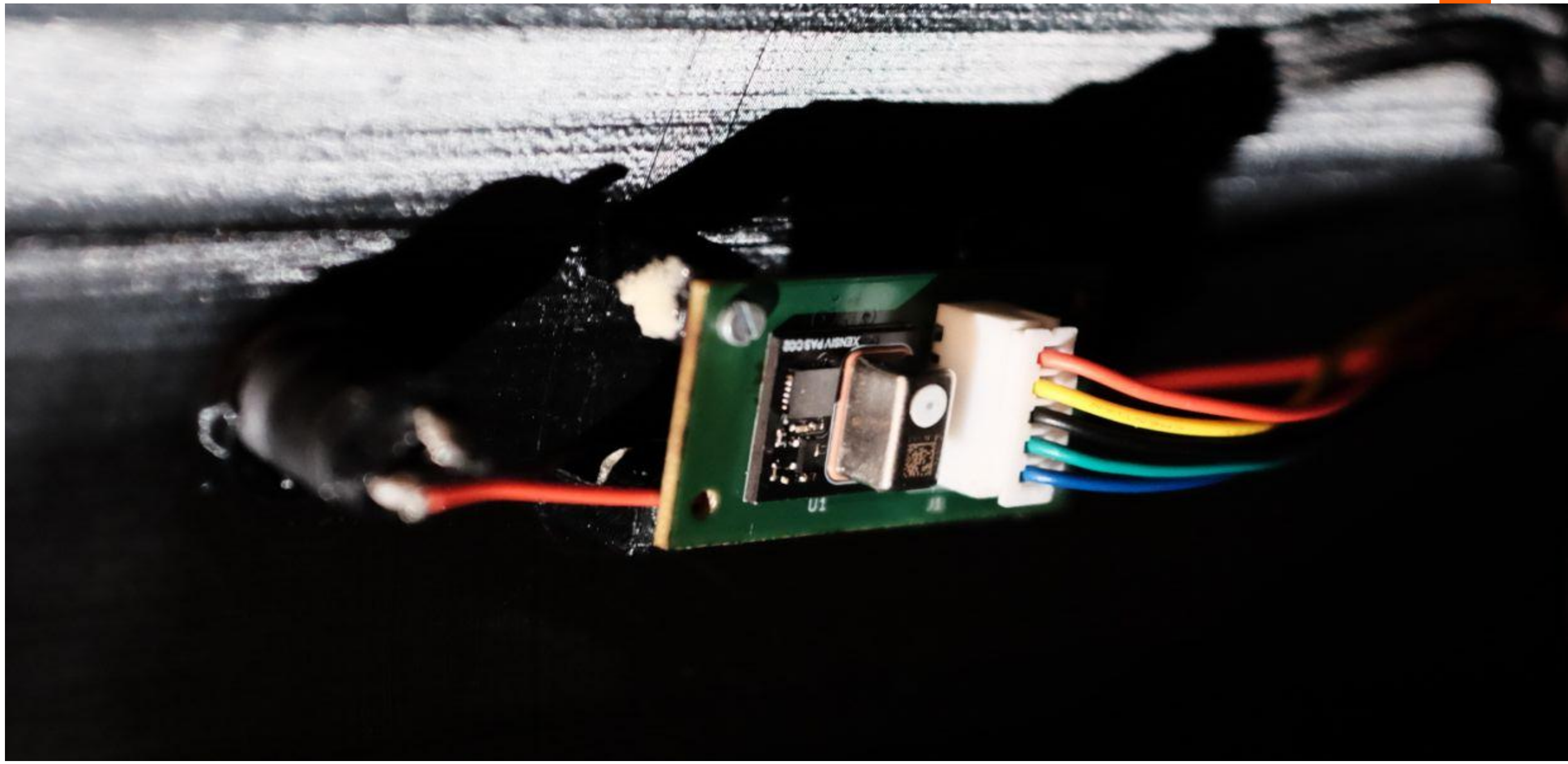
2. **Weight sensor**
   a. Proprietary communication method
   b. Implement HX711 on main PCB

3. **Servo Motor**
   a. PWM controlling
   b. Firmly mounted

4. **Switch Button**
   a. Binary I/O device

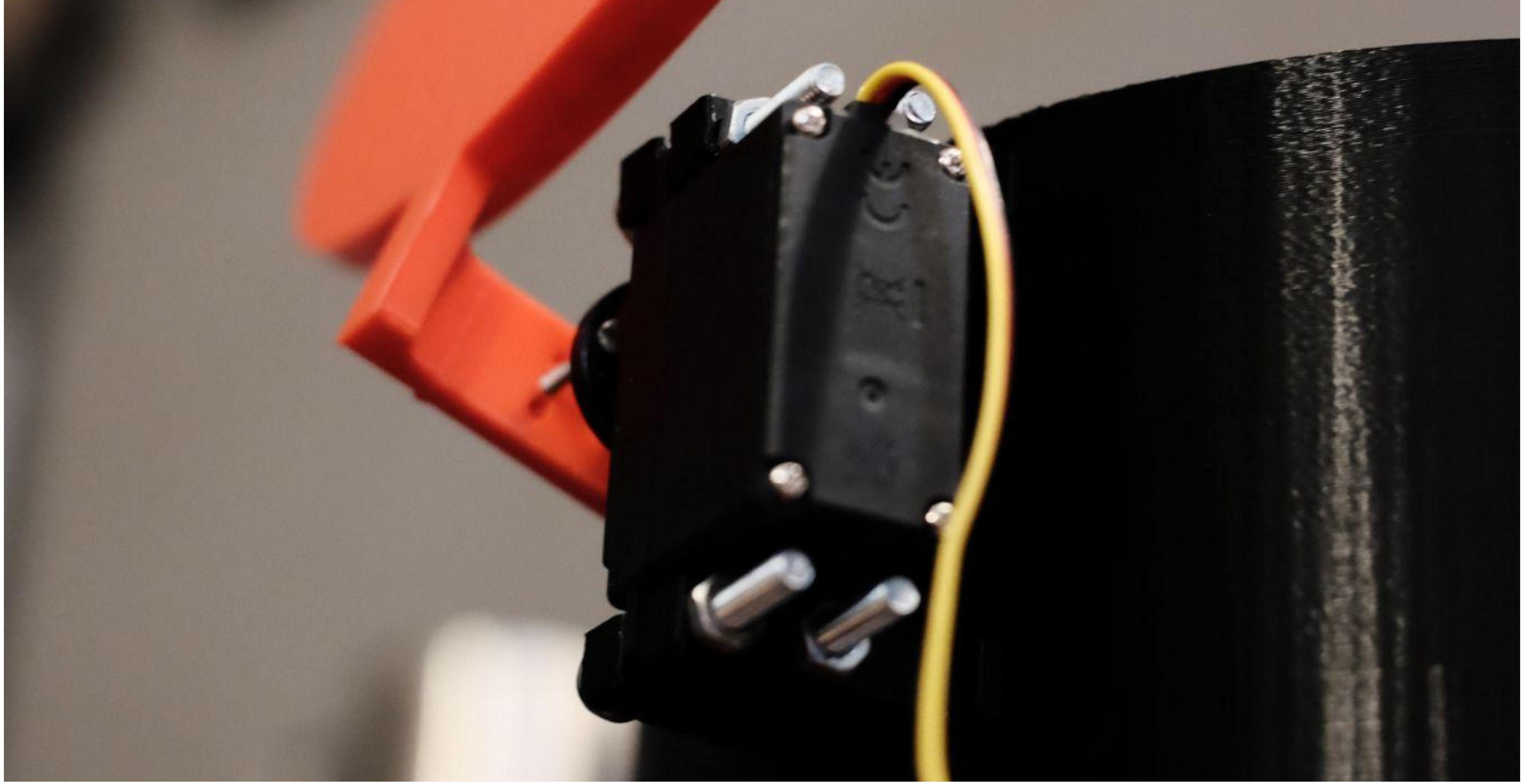


Weight Sensor
With weight plate (left) and without plate (right)



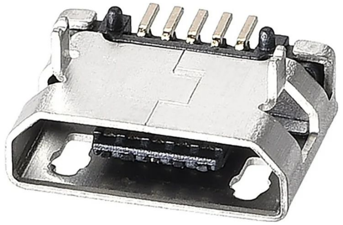
CO2 Sensor

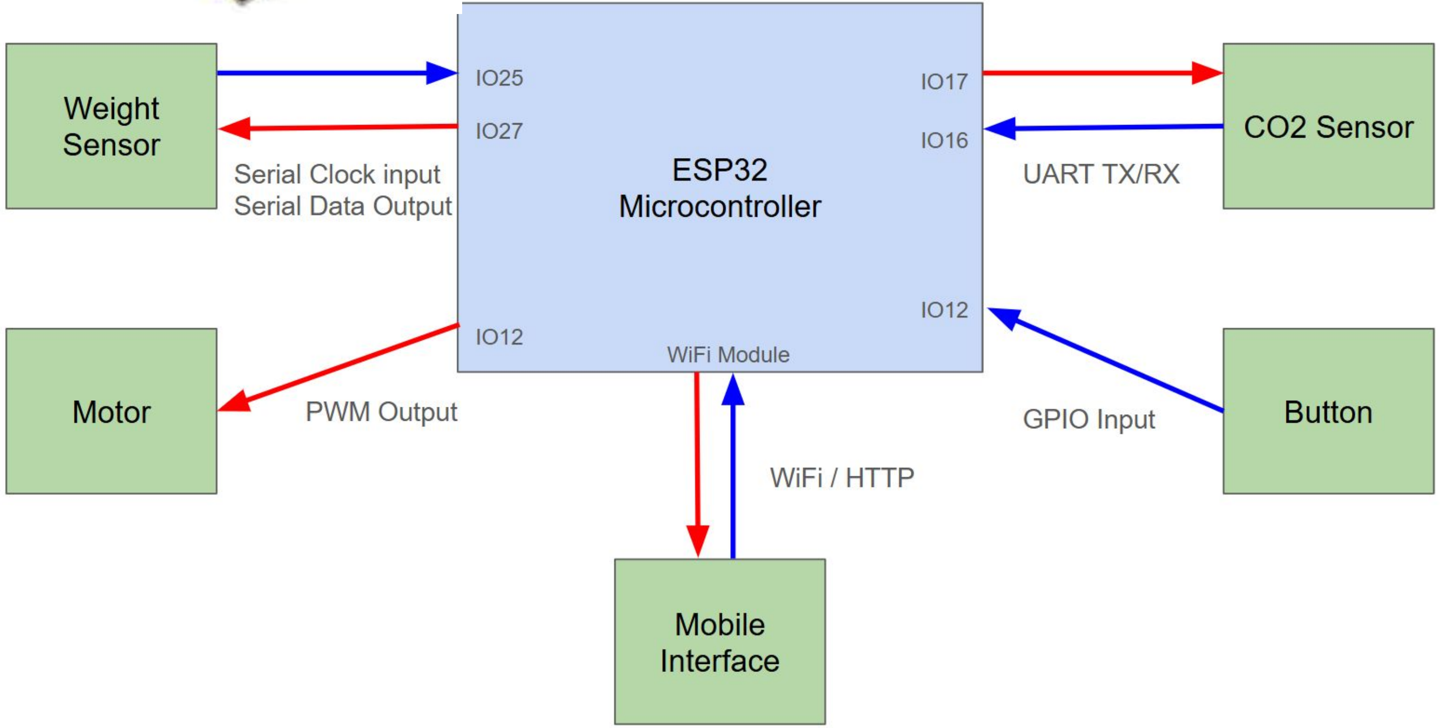
Actual component (left) and mounted in container (right)



Servo Motor
Mounted using 3D printed bracket and M4 screws

Controller Subsystem Functionality





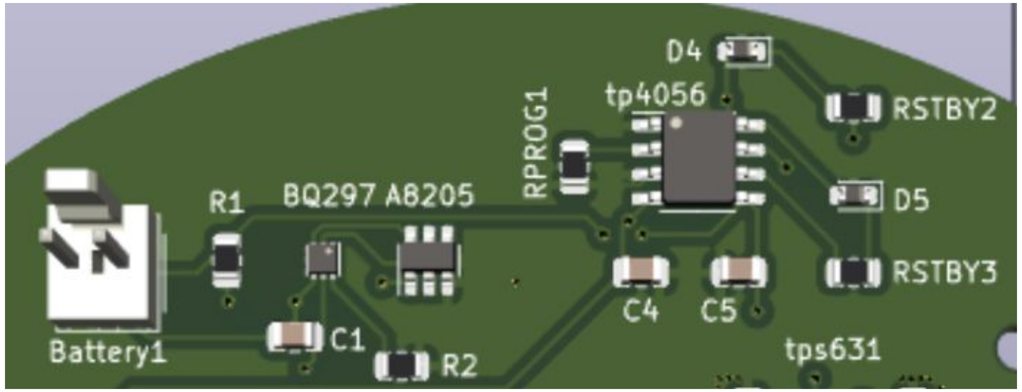
Components of this Subsystem

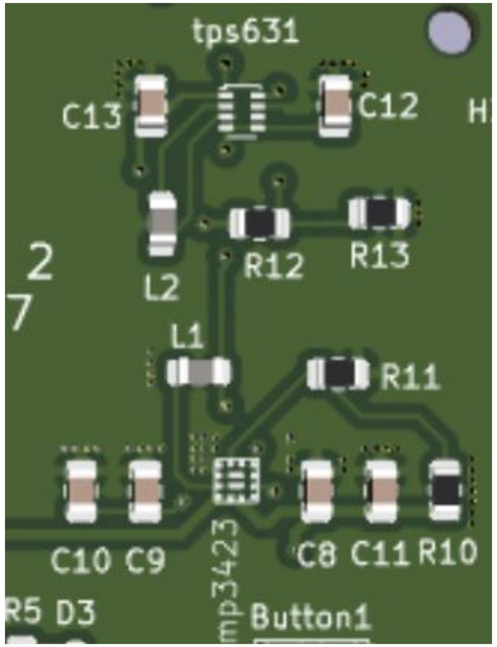
1. **ESP32 Microcontroller**
   a. WiFi capabilities
   b. Manages peripherals
2. **USB to UART**
   a. Enables programming

Control Tasks

1. **Lid & Button Task**
   a. Polls every 500ms
   b. Press → open lid
   c. Release → close lid, record baseline
2. **CO_2 Sampling Task**
   a. 1 meas / min
   b. Update freshness
   c. Skip if lid open
   d. CO_2 > 3000 ppm → trigger aeration

Power Subsystem Functionality





Power Subsystem Build

Battery:

- 3.7V, 2.6Ah Li-ion Battery

BMS:

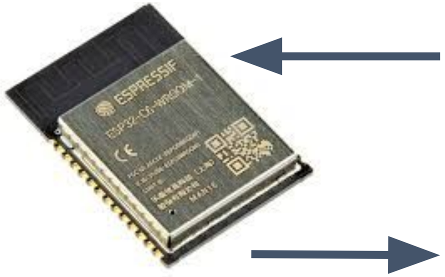
- BQ297: Single Cell Battery Protection
- TP4056: Linear Charging Circuit

DC-DC Converters:

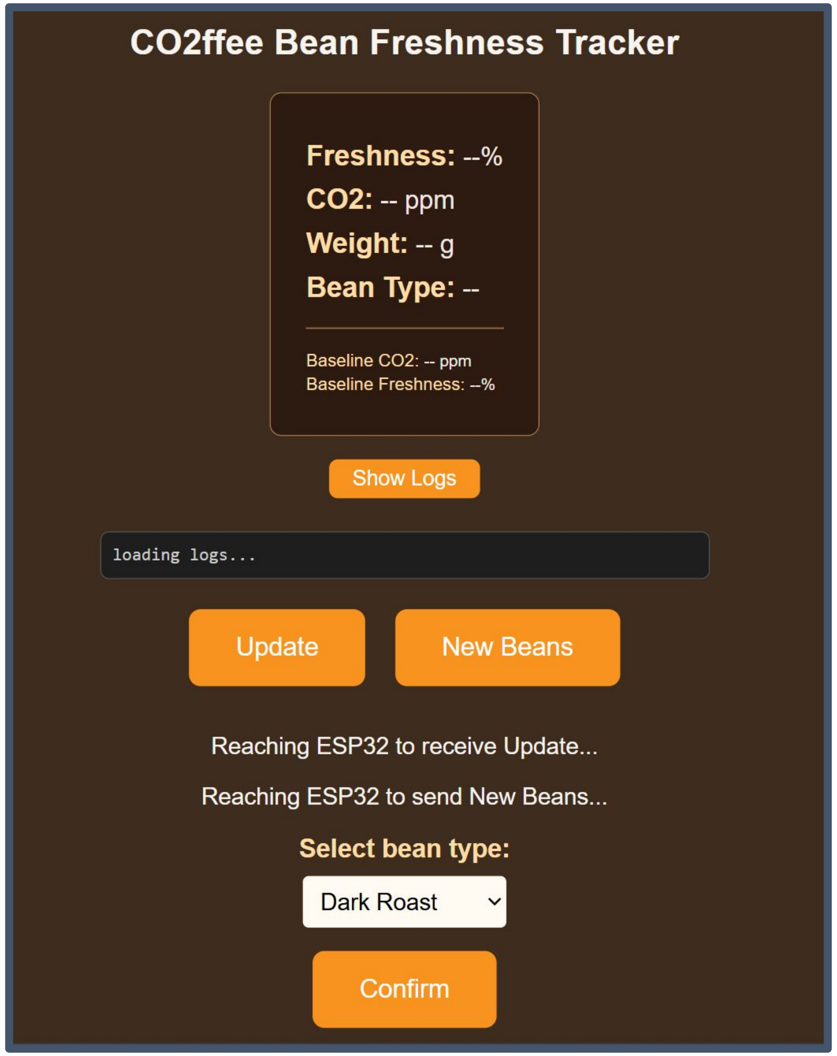
- TPS631: Battery (3.7V) → 3.3V, 1.5A
- MP3423: Battery (3.7V) → 5V, 3.1A

Wireless Interface Subsystem Functionality

HTTP Request



HTTP Response



CO2ffee Bean Freshness Tracker

Freshness: --%
CO2: -- ppm
Weight: -- g
Bean Type: --

Baseline CO2: -- ppm
Baseline Freshness: --%

```
loading logs...
```

Reaching ESP32 to receive Update...

Reaching ESP32 to send New Beans...

Select bean type:

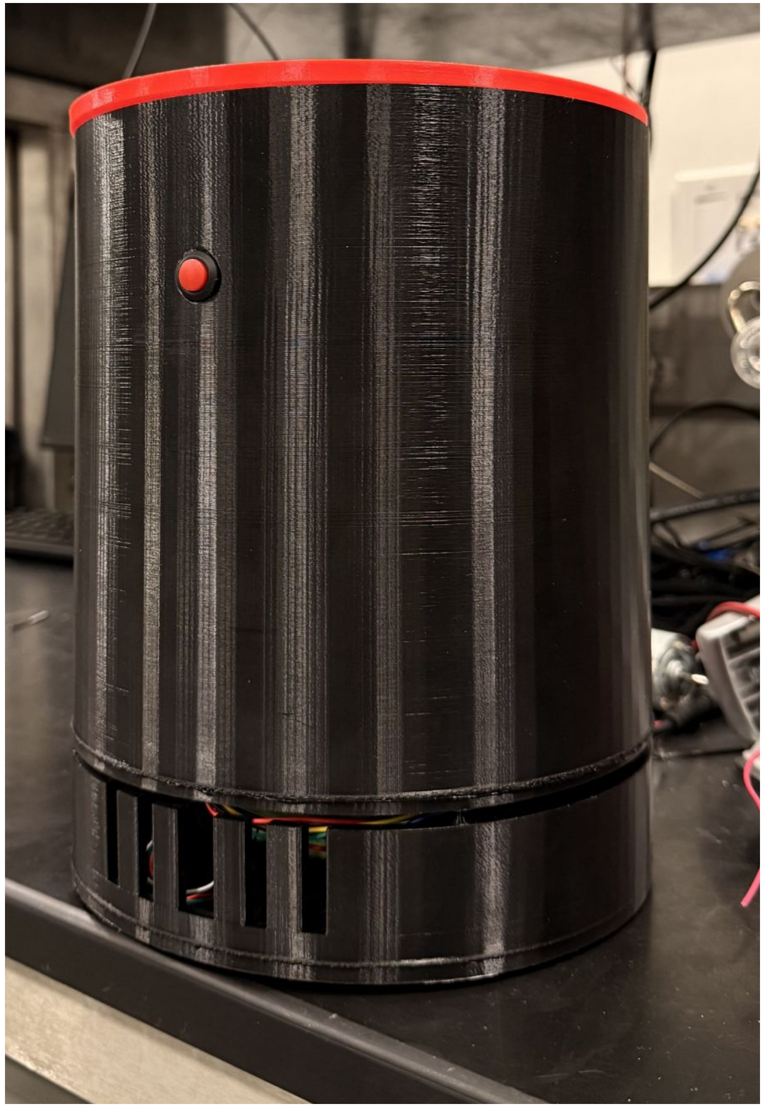
Dark Roast

Components of this Subsystem

1. **ESP32 Microcontroller (Server)**
   a. Built-in Wi-Fi module
   b. Hosts Wi-Fi
   c. HTTP server
      i. Update (GET)
      ii. New Beans (POST)
      iii. Show Logs (GET)

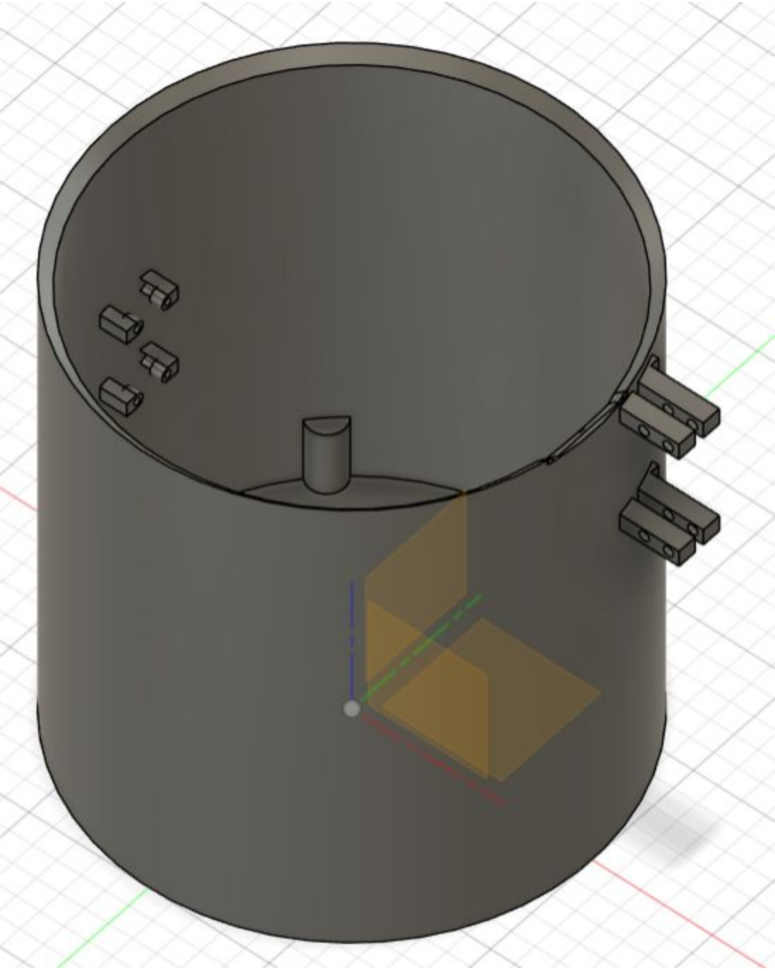
2. **User Interface (Client)**
   a. Phone, laptop, etc.
   b. Connects to Wi-Fi
   c. Sends HTTP requests
   d. Auto-request updates

Physical Design

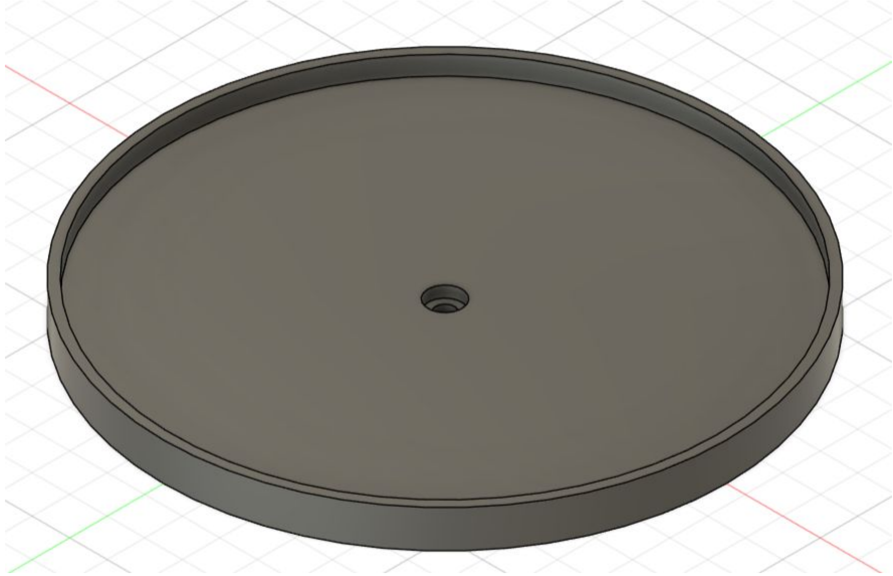


Design Requirements

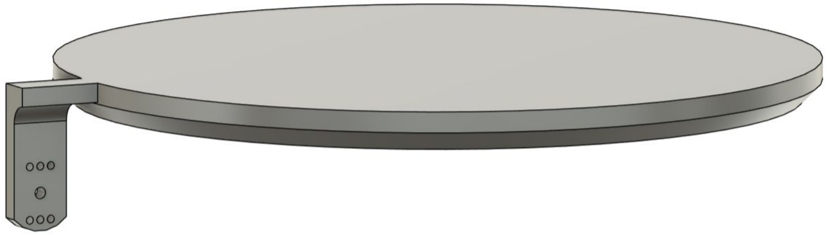
- Contain coffee bag
- Airtight
- Mounting apparatuses
  - Main PCB and Battery in electronic housing
  - Load cell
  - CO2 sensor
  - Button mounting
  - Motor and lid
- Room for wires
- Lower and upper container fit together



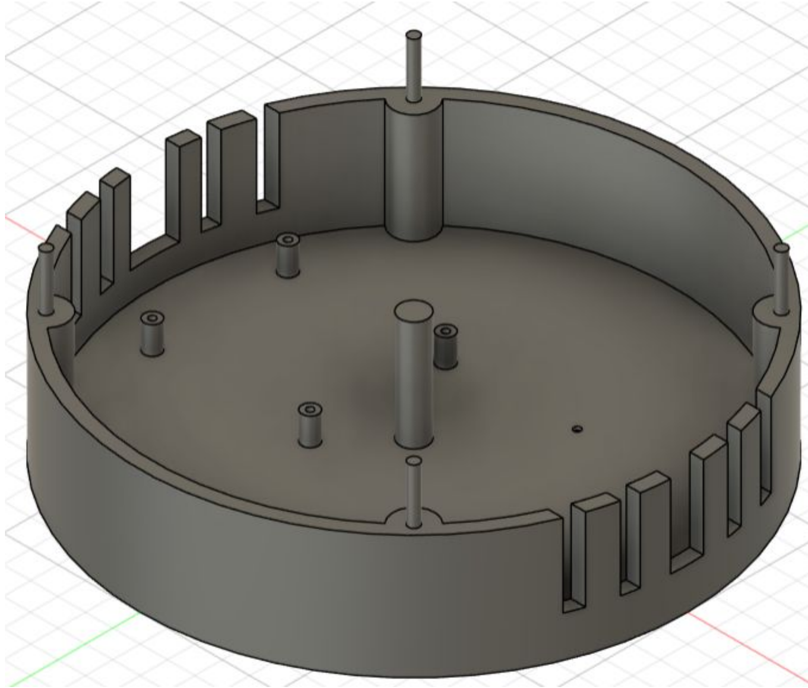
Main Container



Weight Plate



Container Lid



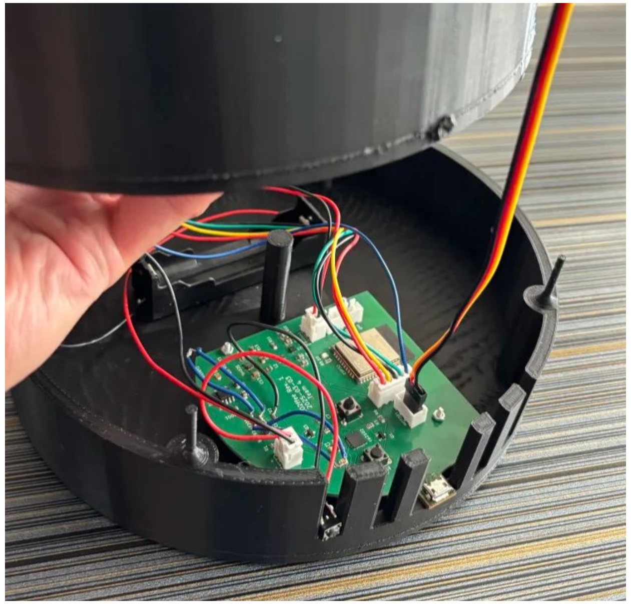
Electronic Housing

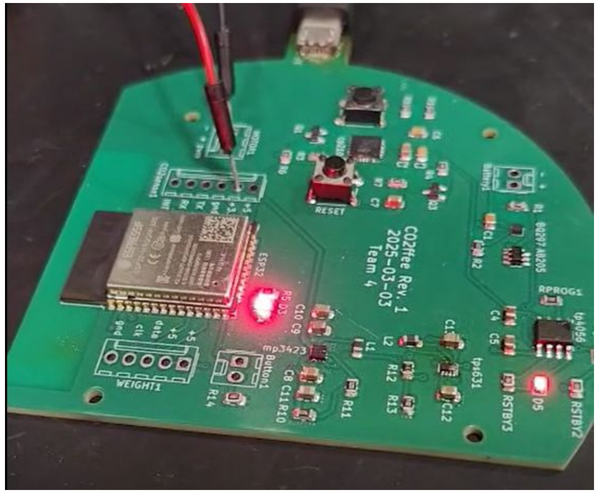
Testing & Results

Success and Challenges

Challenges

1. **Hardware**
    a. Soldering small components
    b. Load Cell Wires Delicate
    c. CO2 Sensor Datasheet Not Clear
2. **Software**
    a. Concurrency & Thread Safety

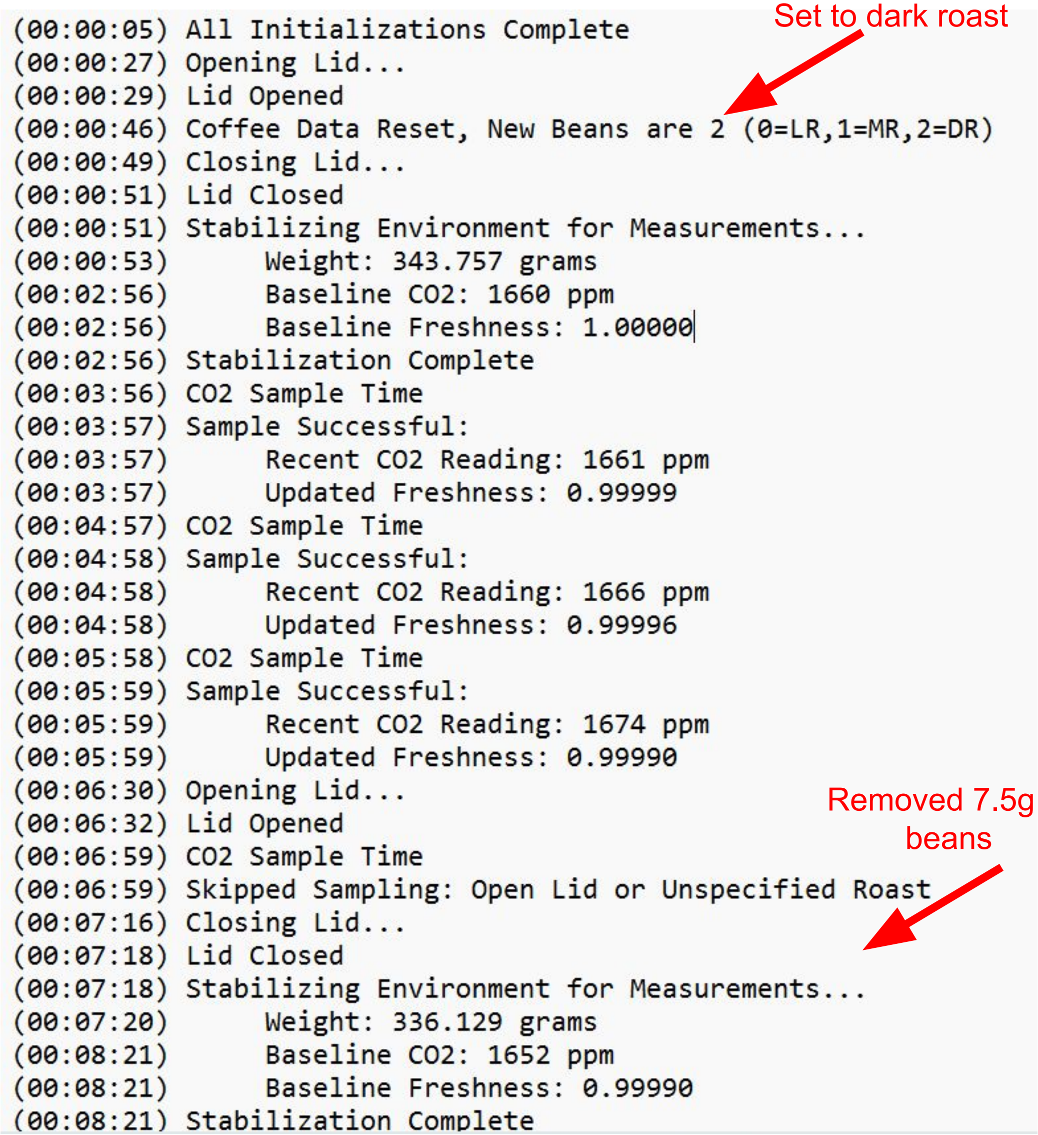




Overall Success!

- **2 Simulations to Highlight Results**

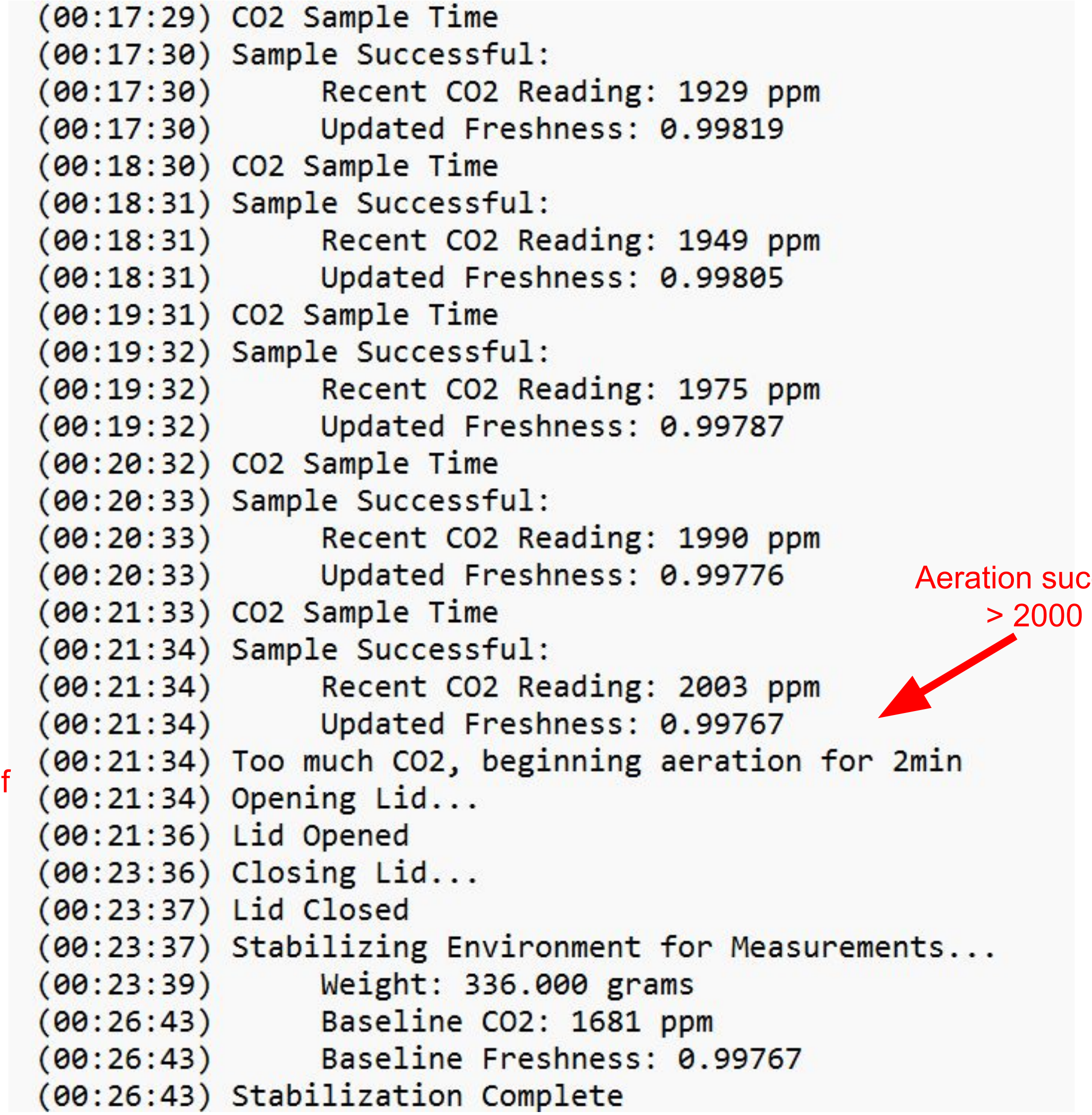
Simulation 1 Results (Logs)



```
(00:00:05) All Initializations Complete
(00:00:27) Opening Lid...
(00:00:29) Lid Opened
(00:00:46) Coffee Data Reset, New Beans are 2 (0=LR,1=MR,2=DR)
(00:00:49) Closing Lid...
(00:00:51) Lid Closed
(00:00:51) Stabilizing Environment for Measurements...
(00:00:53)      Weight: 343.757 grams
(00:02:56)      Baseline CO2: 1660 ppm
(00:02:56)      Baseline Freshness: 1.00000
(00:02:56) Stabilization Complete
(00:03:56) CO2 Sample Time
(00:03:57) Sample Successful:
(00:03:57)      Recent CO2 Reading: 1661 ppm
(00:03:57)      Updated Freshness: 0.99999
(00:04:57) CO2 Sample Time
(00:04:58) Sample Successful:
(00:04:58)      Recent CO2 Reading: 1666 ppm
(00:04:58)      Updated Freshness: 0.99996
(00:05:58) CO2 Sample Time
(00:05:59) Sample Successful:
(00:05:59)      Recent CO2 Reading: 1674 ppm
(00:05:59)      Updated Freshness: 0.99990
(00:06:30) Opening Lid...
(00:06:32) Lid Opened
(00:06:59) CO2 Sample Time
(00:06:59) Skipped Sampling: Open Lid or Unspecified Roast
(00:07:16) Closing Lid...
(00:07:18) Lid Closed
(00:07:18) Stabilizing Environment for Measurements...
(00:07:20)      Weight: 336.129 grams
(00:08:21)      Baseline CO2: 1652 ppm
(00:08:21)      Baseline Freshness: 0.99990
(00:08:21) Stabilization Complete
```

Set to dark roast

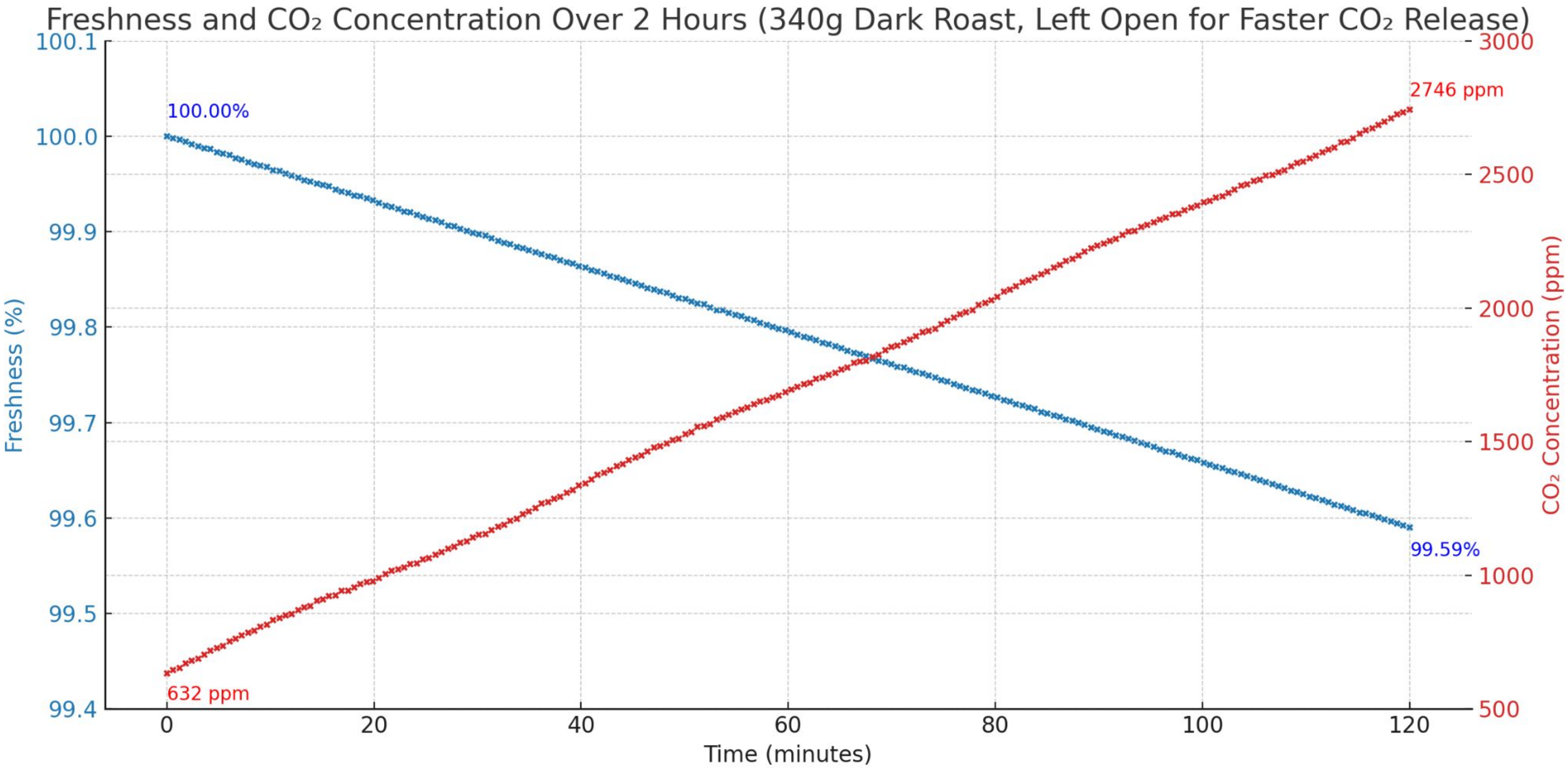
Removed 7.5g of beans



```
(00:17:29) CO2 Sample Time
(00:17:30) Sample Successful:
(00:17:30)      Recent CO2 Reading: 1929 ppm
(00:17:30)      Updated Freshness: 0.99819
(00:18:30) CO2 Sample Time
(00:18:31) Sample Successful:
(00:18:31)      Recent CO2 Reading: 1949 ppm
(00:18:31)      Updated Freshness: 0.99805
(00:19:31) CO2 Sample Time
(00:19:32) Sample Successful:
(00:19:32)      Recent CO2 Reading: 1975 ppm
(00:19:32)      Updated Freshness: 0.99787
(00:20:32) CO2 Sample Time
(00:20:33) Sample Successful:
(00:20:33)      Recent CO2 Reading: 1990 ppm
(00:20:33)      Updated Freshness: 0.99776
(00:21:33) CO2 Sample Time
(00:21:34) Sample Successful:
(00:21:34)      Recent CO2 Reading: 2003 ppm
(00:21:34)      Updated Freshness: 0.99767
(00:21:34) Too much CO2, beginning aeration for 2min
(00:21:34) Opening Lid...
(00:21:36) Lid Opened
(00:23:36) Closing Lid...
(00:23:37) Lid Closed
(00:23:37) Stabilizing Environment for Measurements...
(00:23:39)      Weight: 336.000 grams
(00:26:43)      Baseline CO2: 1681 ppm
(00:26:43)      Baseline Freshness: 0.99767
(00:26:43) Stabilization Complete
```

Aeration successful at > 2000 ppm

Simulation 2 Results (Graph)



Total CO2 Loss:

- 2114 ppm
- 17.617 ppm/min
- 13.84 mg
- 0.115 mg/min

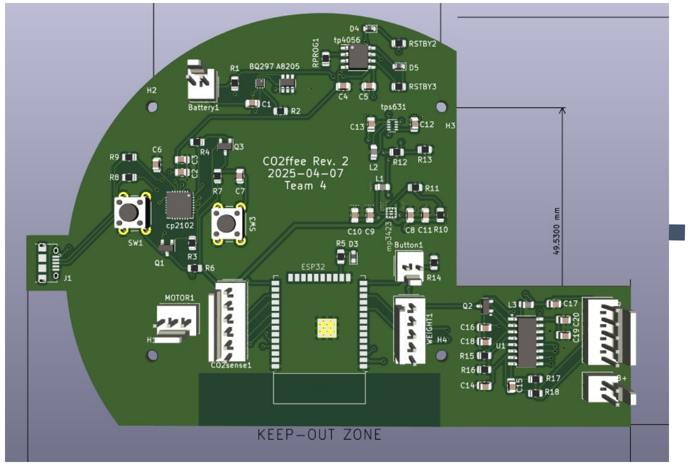
Freshness Value:

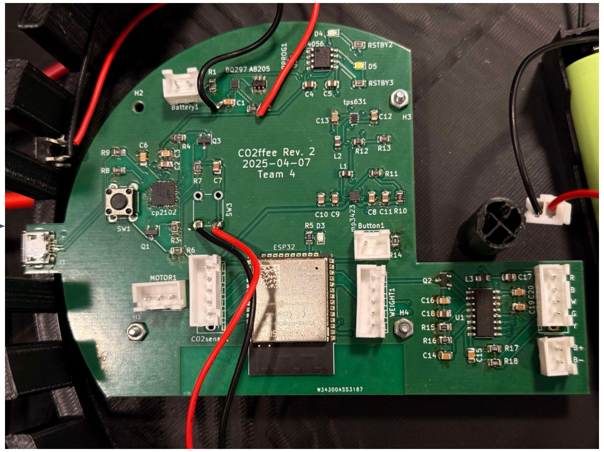
- 13.84 mg CO2 loss
- 0.0407 mg/g lost
- (10 - 0.0407)/10 = 99.59%

- CO2 release appears linear due to the short 2-hour observation.
- Over longer periods, degassing is rapid at first and slows down over time.

PCB Module Testing

Component	Test Description	Results
BMS	Make sure there is negative current in our system under charging conditions and ensure charging works overnight	Battery is able to charge even under full load and for a long time
Voltage Conversions	Components receive proper voltage and current under full load	All components were able to function at full load at same time with necessary power
USB to UART for controller	Confirming the ESP32 is programmable from the USB port	The ESP32 was successfully programmed and could run basic code
CO_2 Sensor	CO2 reading close to expected values in multiple environments	CO2 levels as expected in ECEB, outside, different classrooms, and Abrar’s bedroom



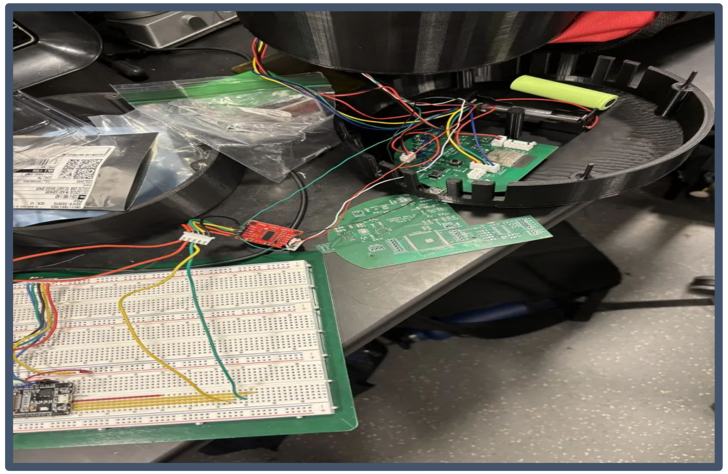


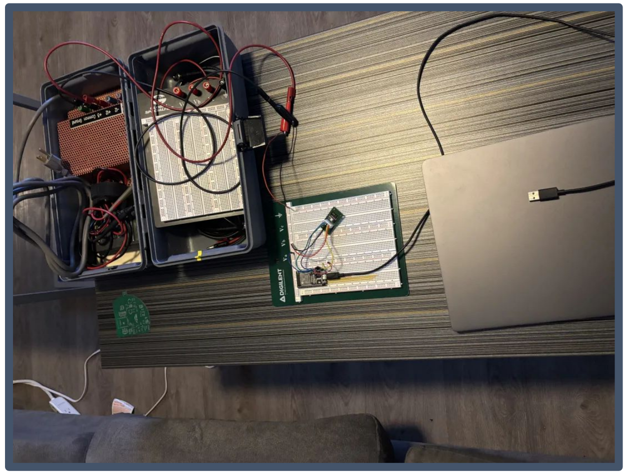
Modular Software Testing

***** Helps isolate points of failures *****

***** Tested on breadboard and ESP32 dev board before PCB *****

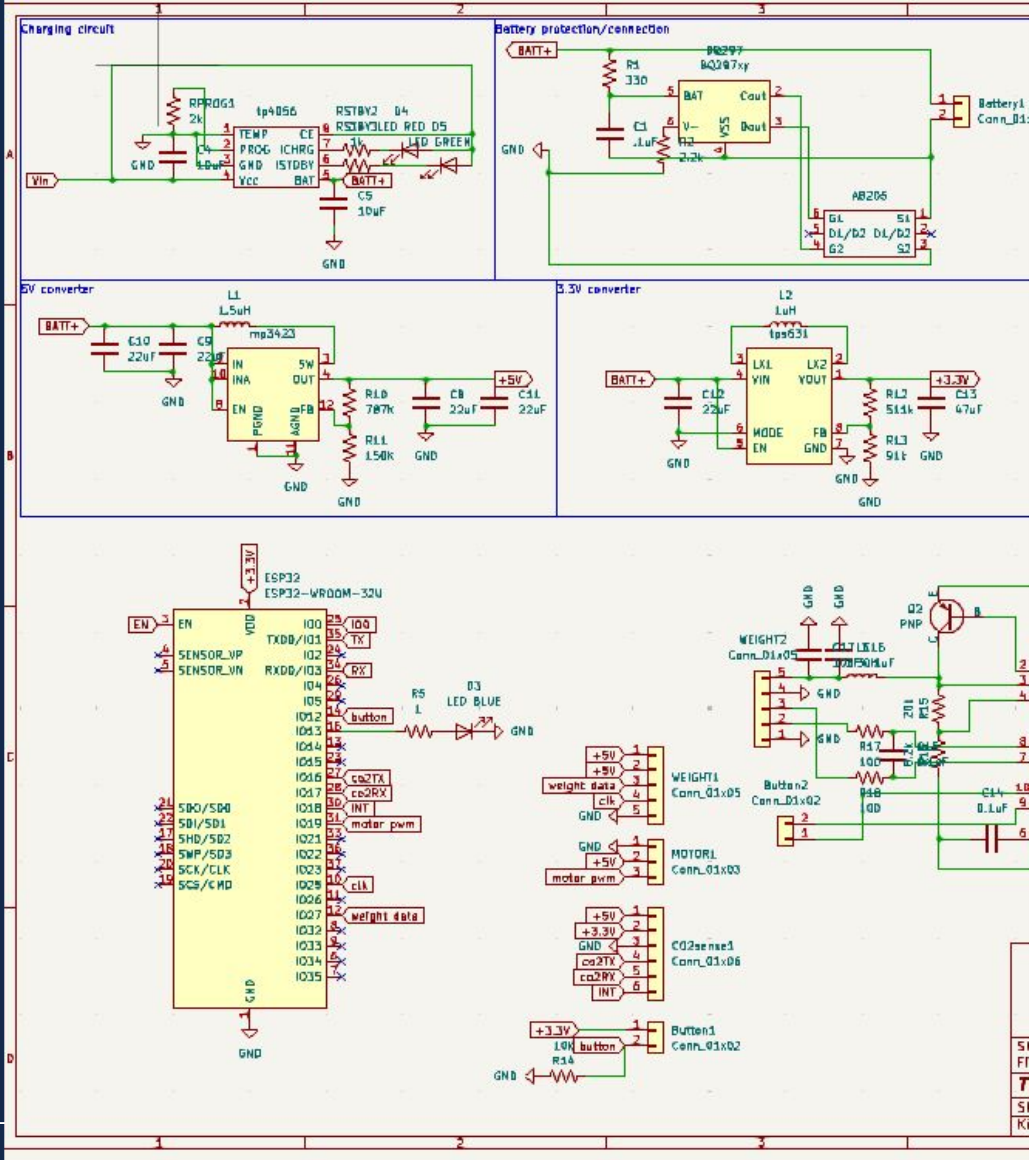
Component	Test Description	Results
LED	Blinking light	Confirmed GPIO control and flashing
Button	State polling (500ms)	Detected button press consistently
Motor	Angle sweep	Smooth movement between 60-120 degrees
Weight Sensor	Periodic reading (2s)	Confirmed accurate readings; set calibration
CO_2 Sensor	Periodic CO_2 reading (1min)	Consistent readings; reliable UART
Wireless	Host WiFi and HTTP server	Reliable data communication established





Conclusion

- Learning outcomes
- What to do differently
- Recommendations for future work



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