UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Board Buddy - Team 34

Electrical & Computer Engineering

ECE 445 Senior Design Laboratory

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Problem Statement

1. Main issue is a disruption of class due to an erasing hiatus. This inhibits the flow of thought of both students and professors.

2. Supporting problem is the cost the University of Illinois Urbana Champaign pays to have the board being erased throughout the year.
    a. Through team interviews of custodians, 7.5 hours a week are spent on erasing, costing the university over four thousand dollars a year for erasing board in the ECEB alone.

Objective

High Level Objectives

1. The first quantitative characteristic is that this device must erase the majority of the residue in a single pass.

2. The next quantitative characteristic is that it must pass through a typical ECEB educational board (4’ x 8’) in under two minutes.

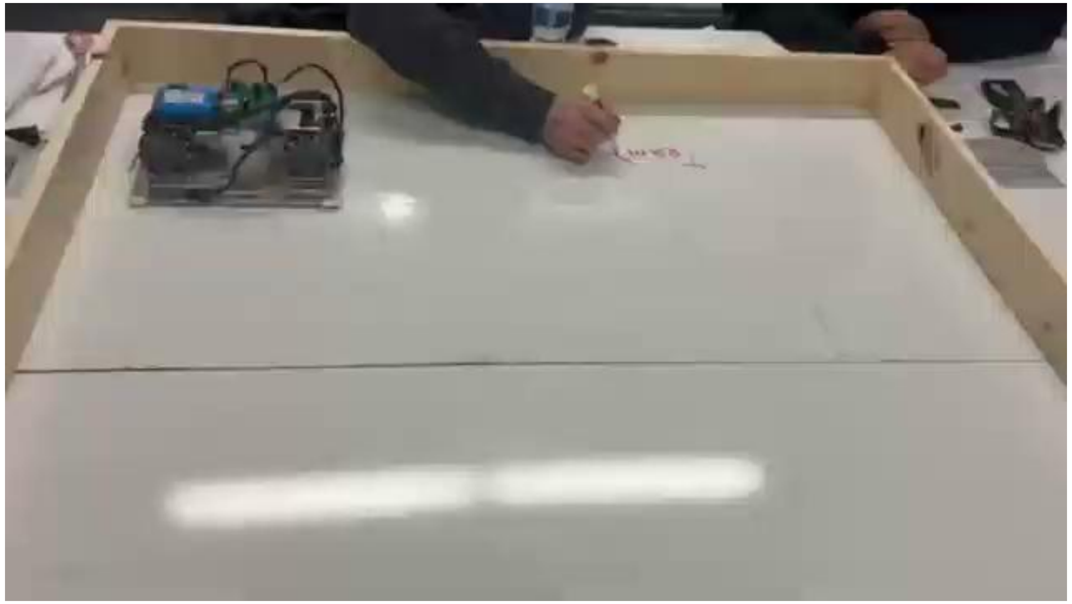
3. The final quantitative characteristic is that it must have app integration that will allow for remote and timed activation.

Problems Solved

1. Team 34 has proposed and implemented a solution for the automatic and remotely activated erasing of these educational boards, deemed the Board Buddy.

2. Given the price point of the Board Buddy, its use will pay itself off in 23 weeks, saving the university money from that point on.

Demo Video

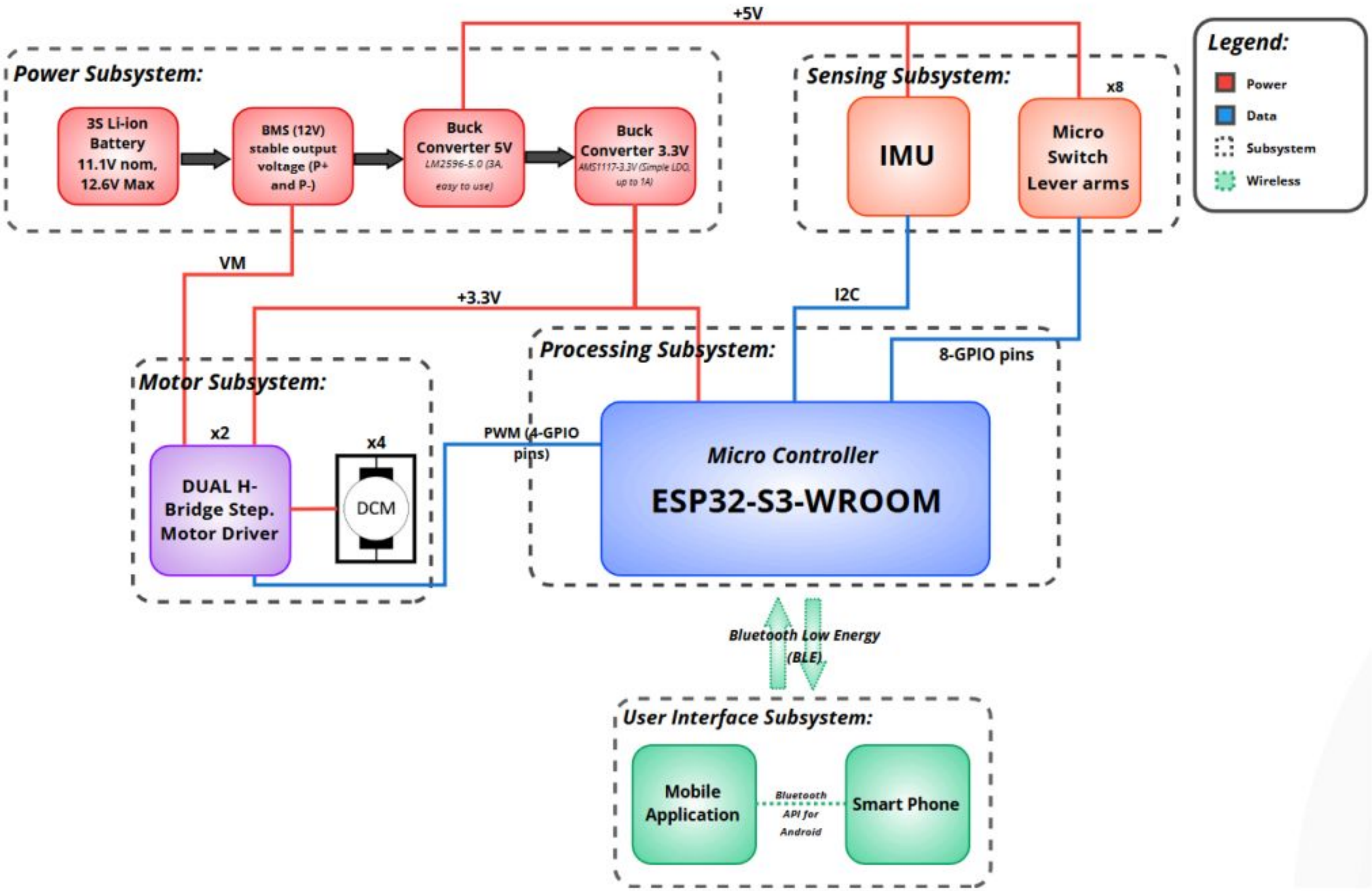



2:29 Fri, May 2
28%
Connect to Device
Room4070 BoardBuddy
F4:12:FA:EE:3F:B9
Connect

Design Overview

(Hardware)

Block Diagram



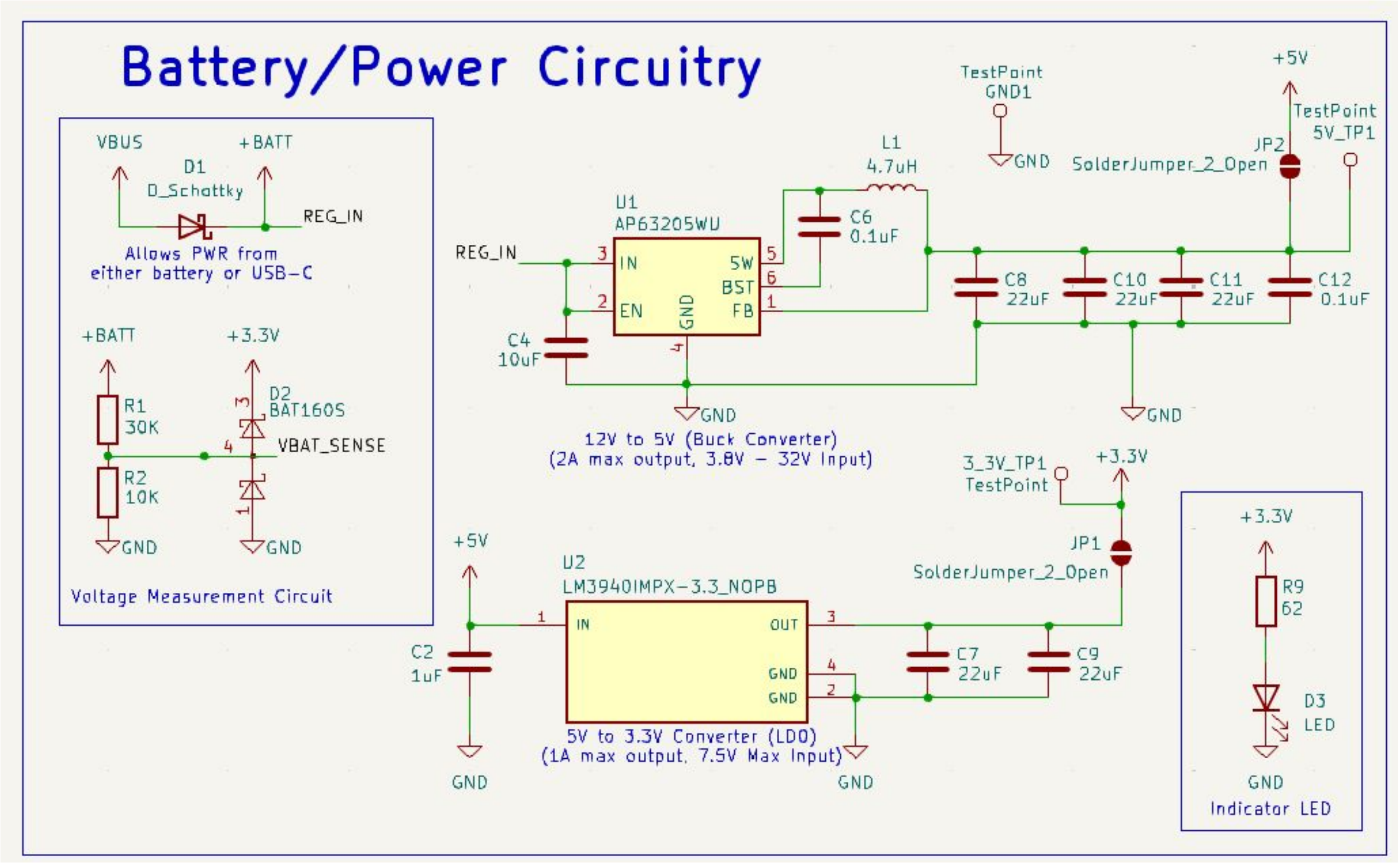
Power Subsystem and Verifications

- BMS module on battery (Output Voltage 12.6 - 11.1V) **12.623 V** ✅
  - Protects short Circuit, Overcharge/Discharge
  - Load sharing between Cells

- Buck Converter (AP63205WU) 12V to 5V (Verification was 5V +/- 10%) **4.962 V** ✅

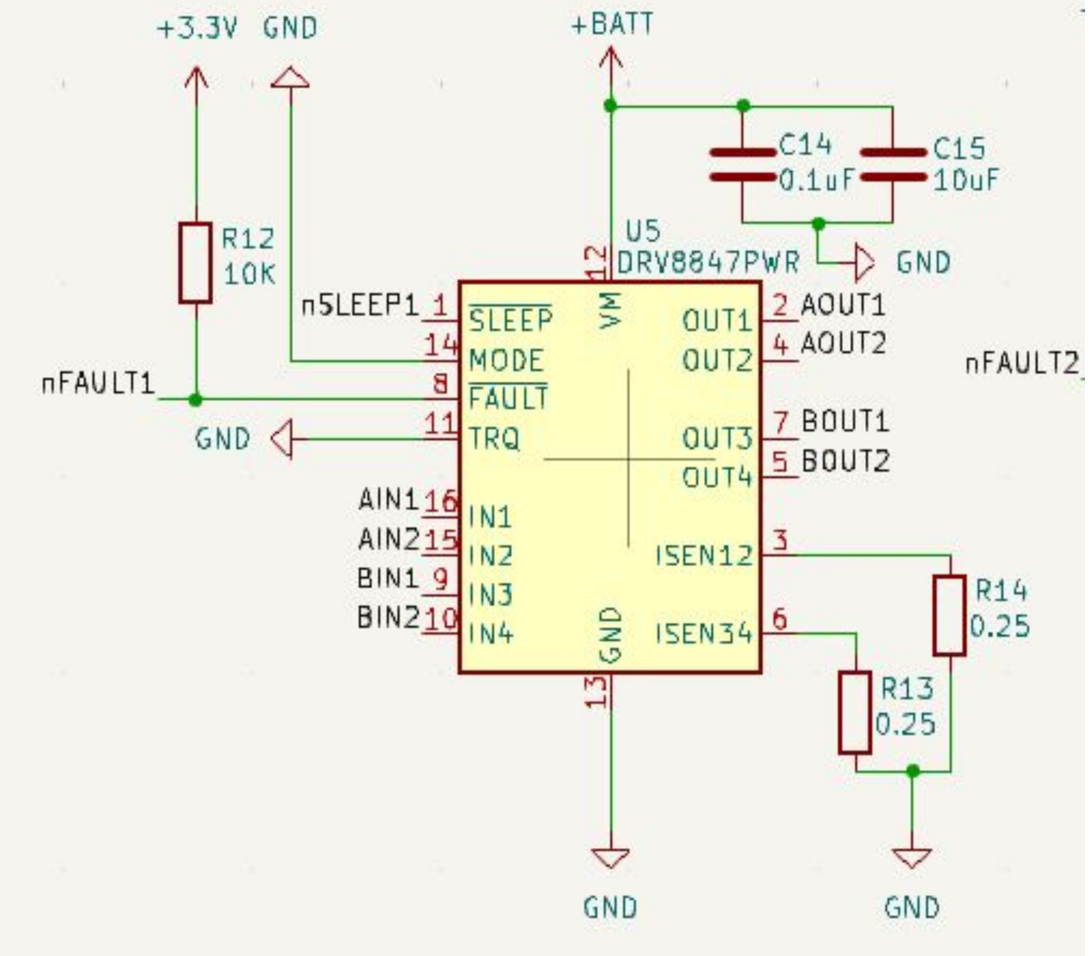
- Linear Regulator (LM3940IMPX-3.3) 5V to 3.3V (Verification was 3.3V +/- 10%) **3.291 V** ✅

  - Switching regulator and Linear regulator used in tandem for cleaner 3.3V signal and higher efficiency on LDO

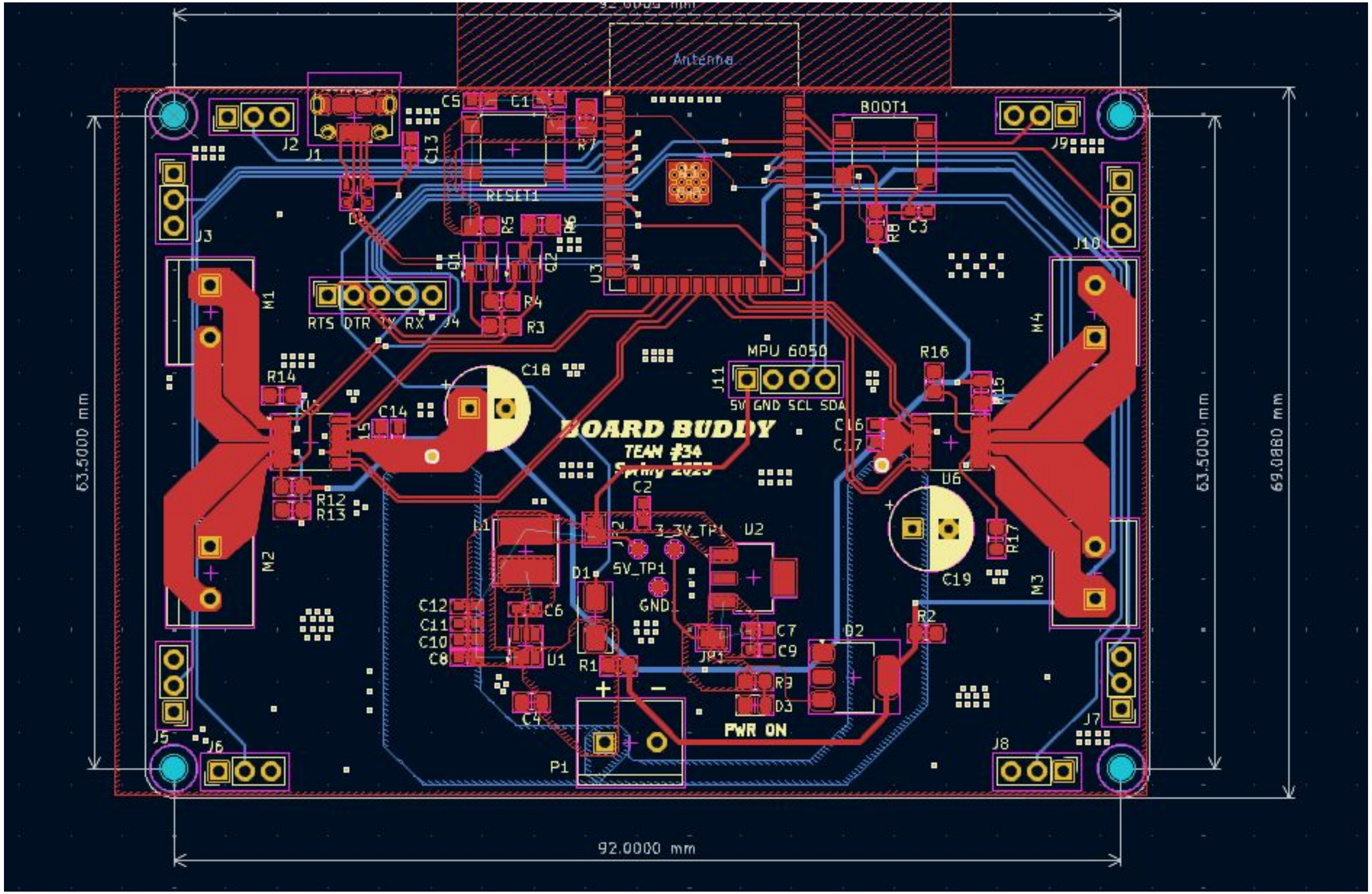


Motor Driver Subsystem

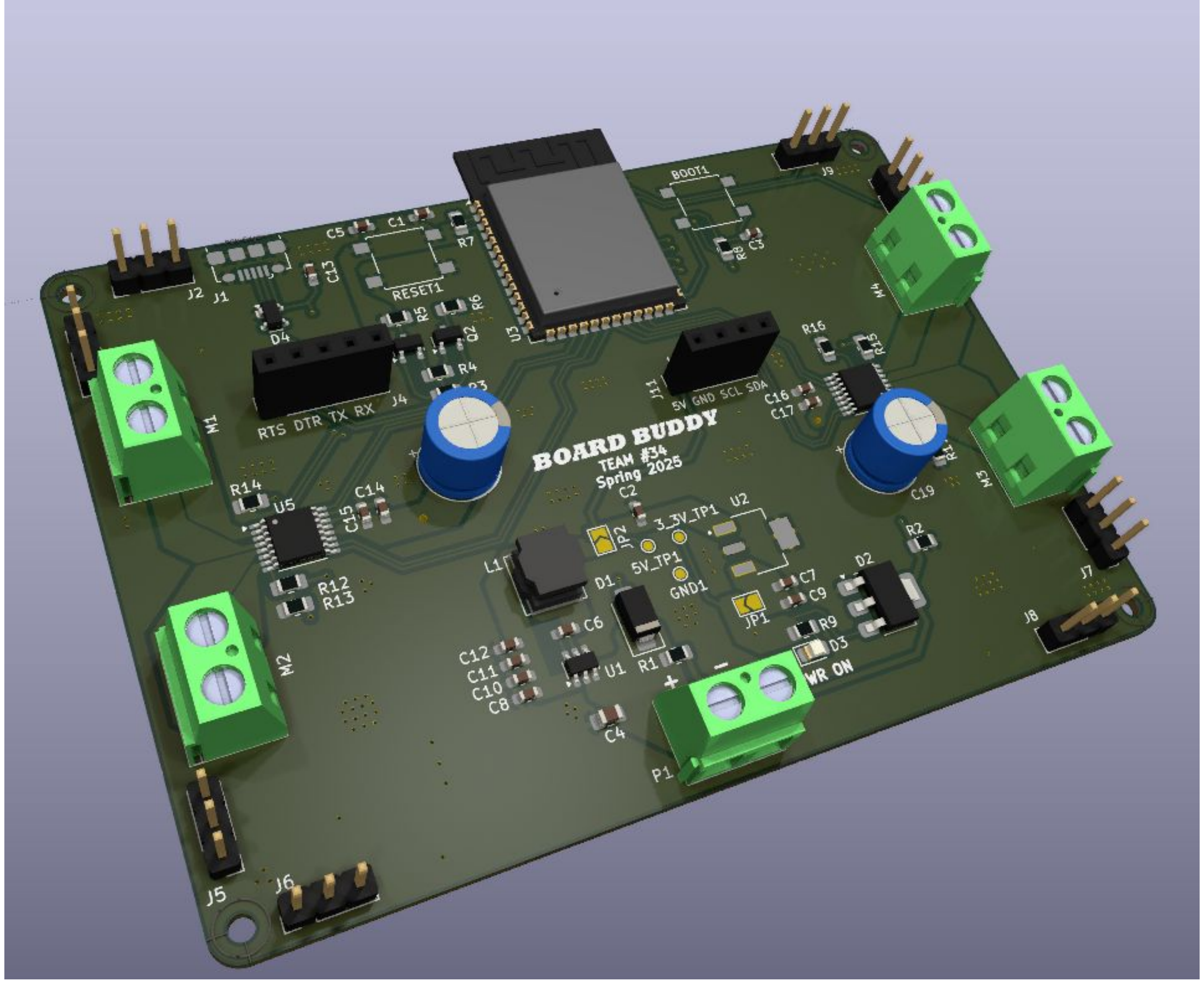
- **Motor driver** we used was a DRV8847 from TI
  - Vm of 20 V (Max)
  - Peak Output Current: 2A
  - Supports PWM interface and bidirectional movement ✅
- **Motor: QCDENG 200 RPM Motor** (need 30 RPM for high level requirement)
  - 0.2 lbs, 10kg-cm for torque, Max 2A rating
  - 200 RPM with 3” wheels: 5.78 lbf
  - Current limited each motor to 1A, so 2.89 lbf * 4 ✅
- **Bulk Capacitance:** 470 uF * 2 = 940 uF
  - 2 large electrolytic capacitors



Project Build - PCB Layout



Project Build - PCB 3D View



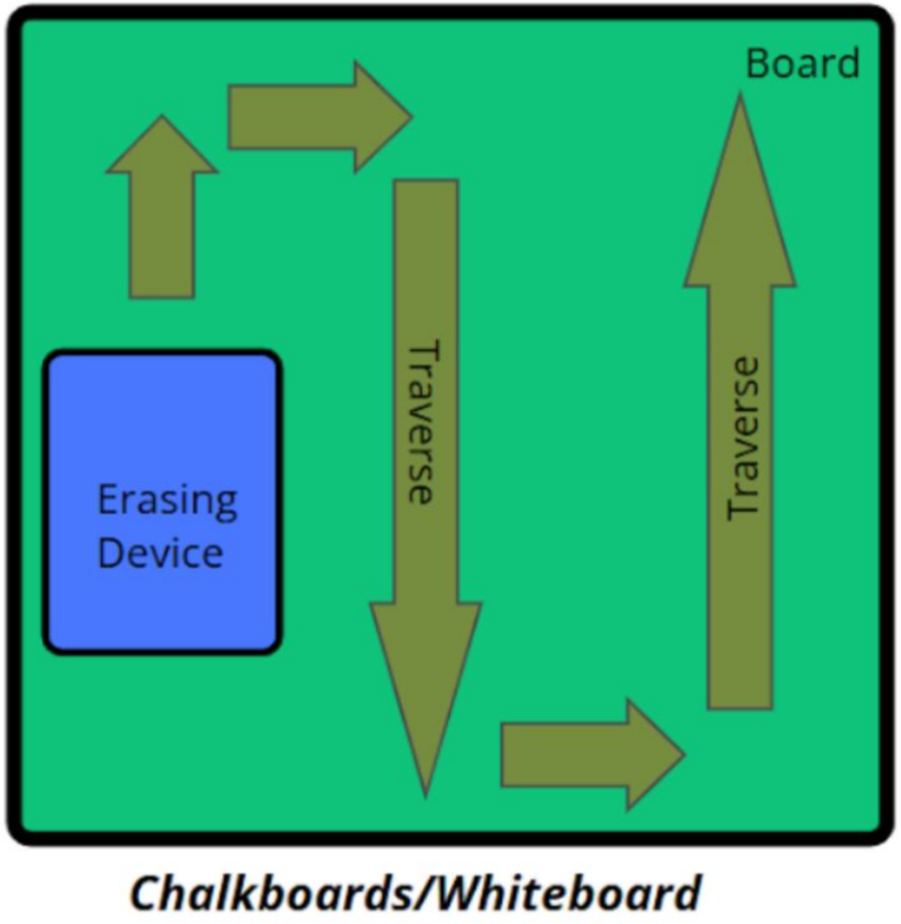
Design Overview
(Software & Firmware)

Purpose of Firmware

The firmware serves as the core control system of the Board Buddy, that enables for real-time interactions with all hardware components through the ESP32 microcontroller. It connects all portions of the project allowing for autonomous operations by being able to read sensor inputs, and control motor speeds.

Purpose of Software

The software provides a user interfacing application for all Android devices. This application allows for the instant and timed remote activation of the Board Buddy. This application interacts with the device via BLE to the ESP32 microcontroller.



Micro Switch Lever Arm Actuator

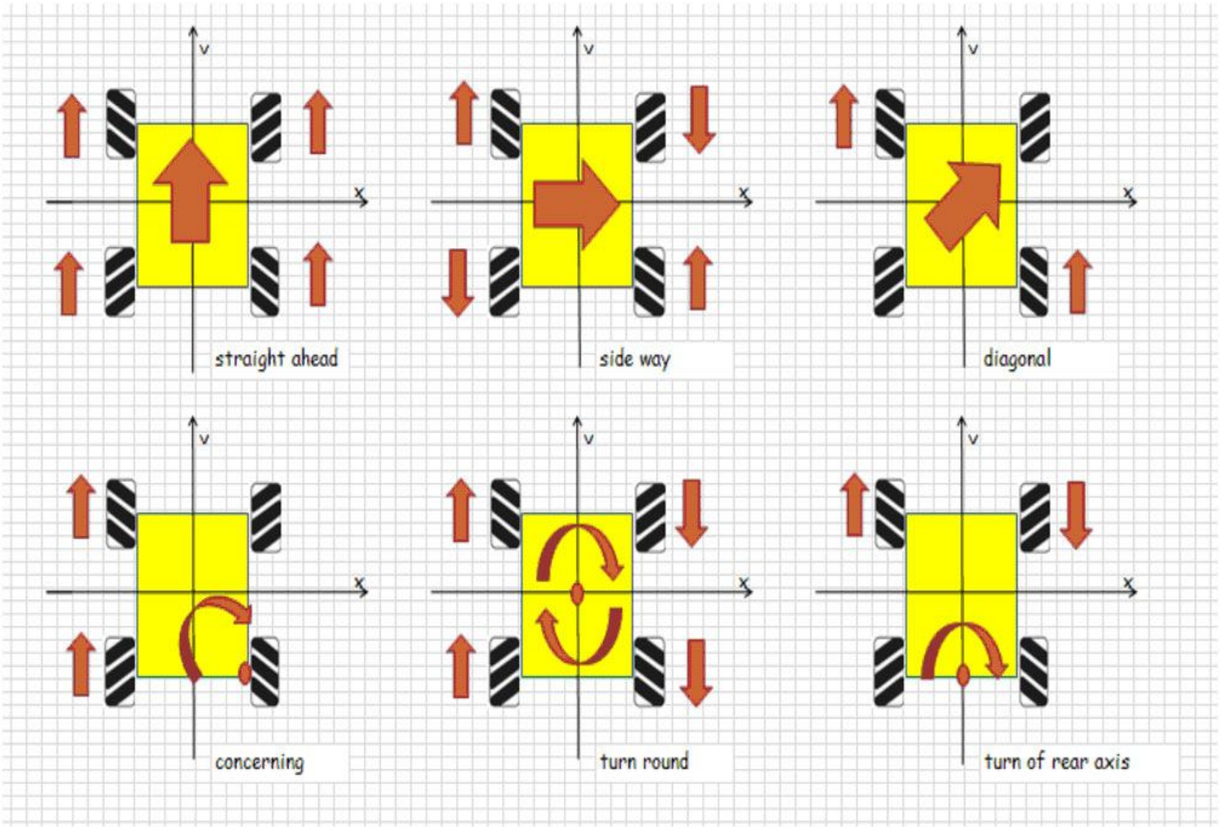
- **S-Shaped Traversal using 5 limit switches**
  - Starting position bottom left corner of whiteboard.
  - Homes back to bottom left corner when done cleaning board.

- **Limit Switches**
  - Simple I/O interfacing

Core Functionalities

Motor Control with PWM

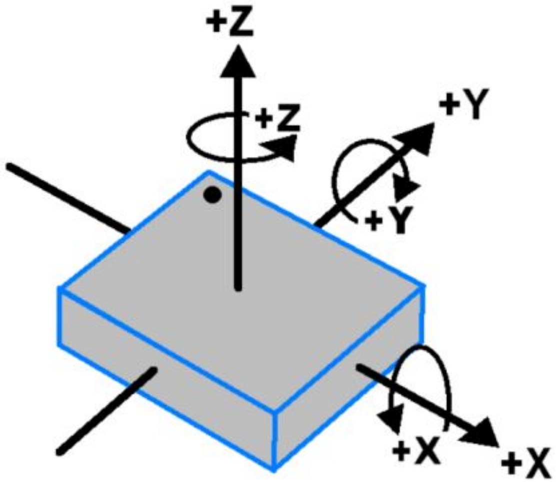
- **PWM**
  - Duty Cycles
    - Varied based on I2C signals from IMU to correct drift
  - 1 kHz operating frequency
    - Ideal for RC applications
- **Omni-Directional Wheel Integration**
  - Omni-directional wheels
    - Allowed for horizontal movement rather than typical turning
      - Crucial for erasing along side-to-side movement



Sensing Subsystem

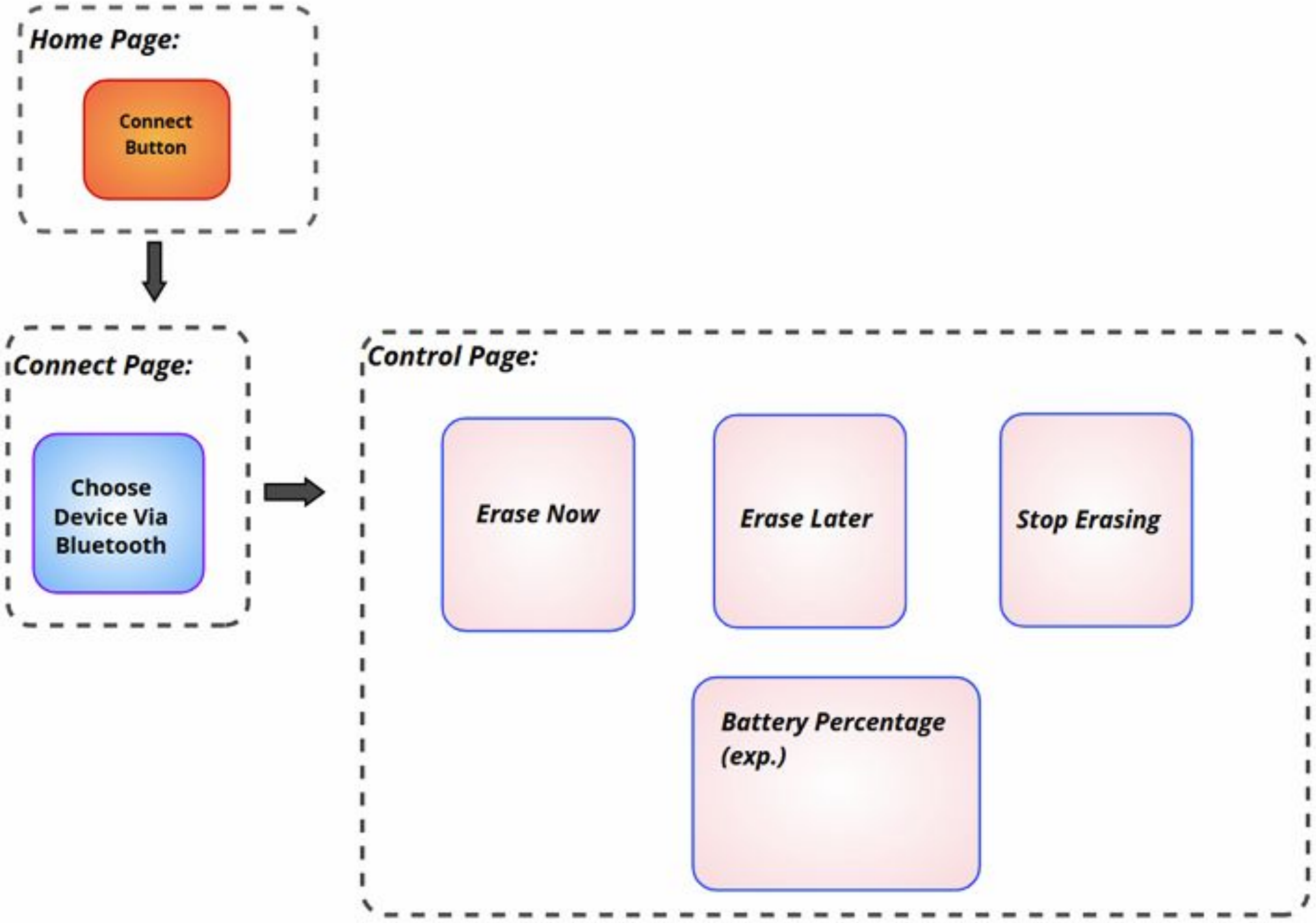
MPU6050 IMU Integration

- **MPU6050 (IMU) Sensor Integration**
  - Combines a 3-axis gyroscope and 3-axis accelerometer in one module
- **Re-zeroing**
  - Upon Start
  - Upon limit switch actuation
- **Off Axis Correction**
  - Read angles in the Z-Axis and when an angle |Z|≥1.5°




```
->  Forward mode | angleZ = 1.49  no correction
-> angleZ=1.50
->  Forward mode | angleZ = 1.50  no correction
-> angleZ=1.52
->  Forward mode | angleZ = 1.52boosting left motors by 35
-> angleZ=1.55
->  Forward mode | angleZ = 1.55boosting left motors by 35
```

User Interface Subsystem

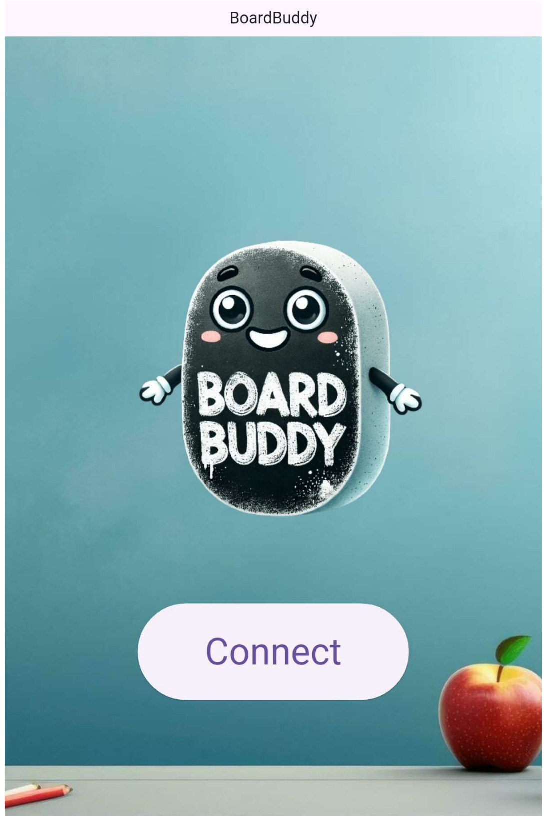


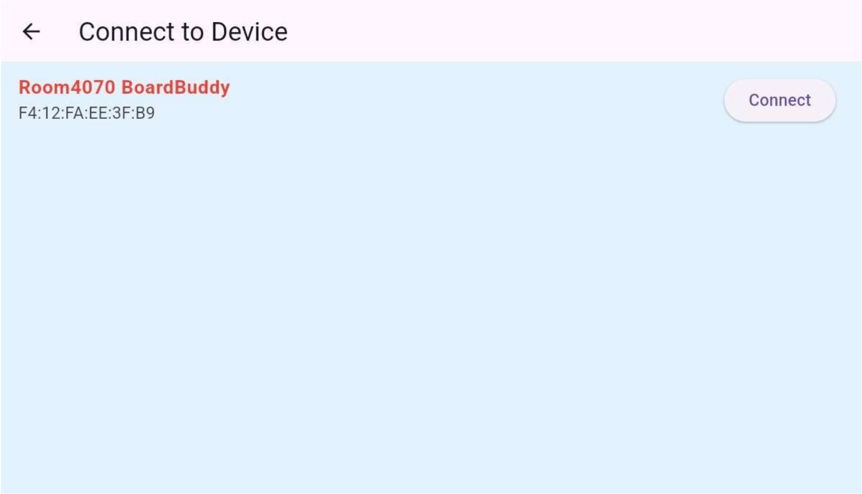
Android Flutter Application

Android Application made in Flutter app building framework through DART programming. Application device connection via BLE.

- **Home Page**

- **Connect Page**
    - Specifically searching for any Board Buddy device via device name and UUID.
    - Allows connection and operation up to a tested 20 feet.



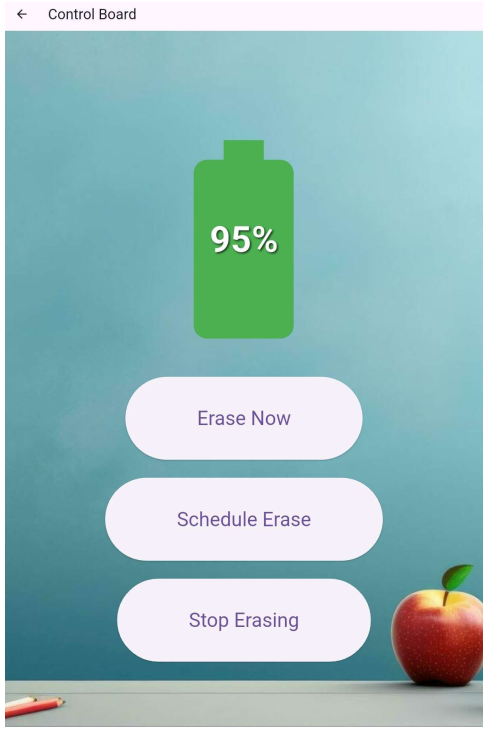


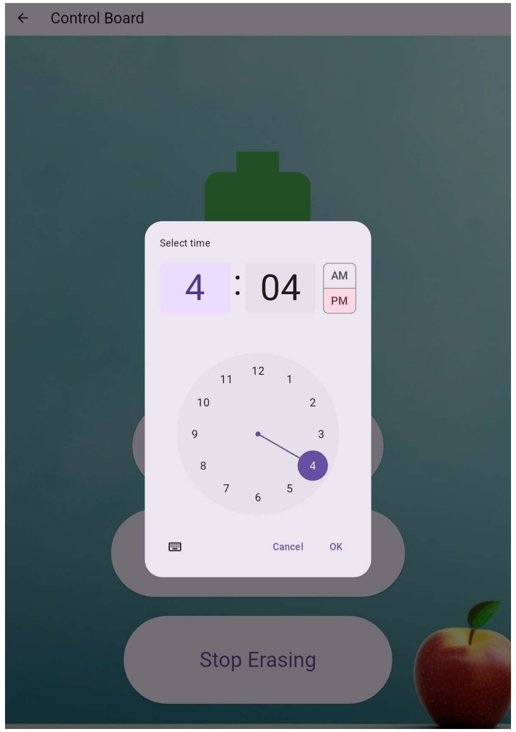
Android Flutter Application

- **Control Page**
  - Allows for instant and remotely scheduled activation.
  - Allows for a hard stop erasing for safety reasons.
- **Battery Percentage**

$$Battery\ Percentage = \frac{Reading - 11.1}{1.5} \times 100\%$$

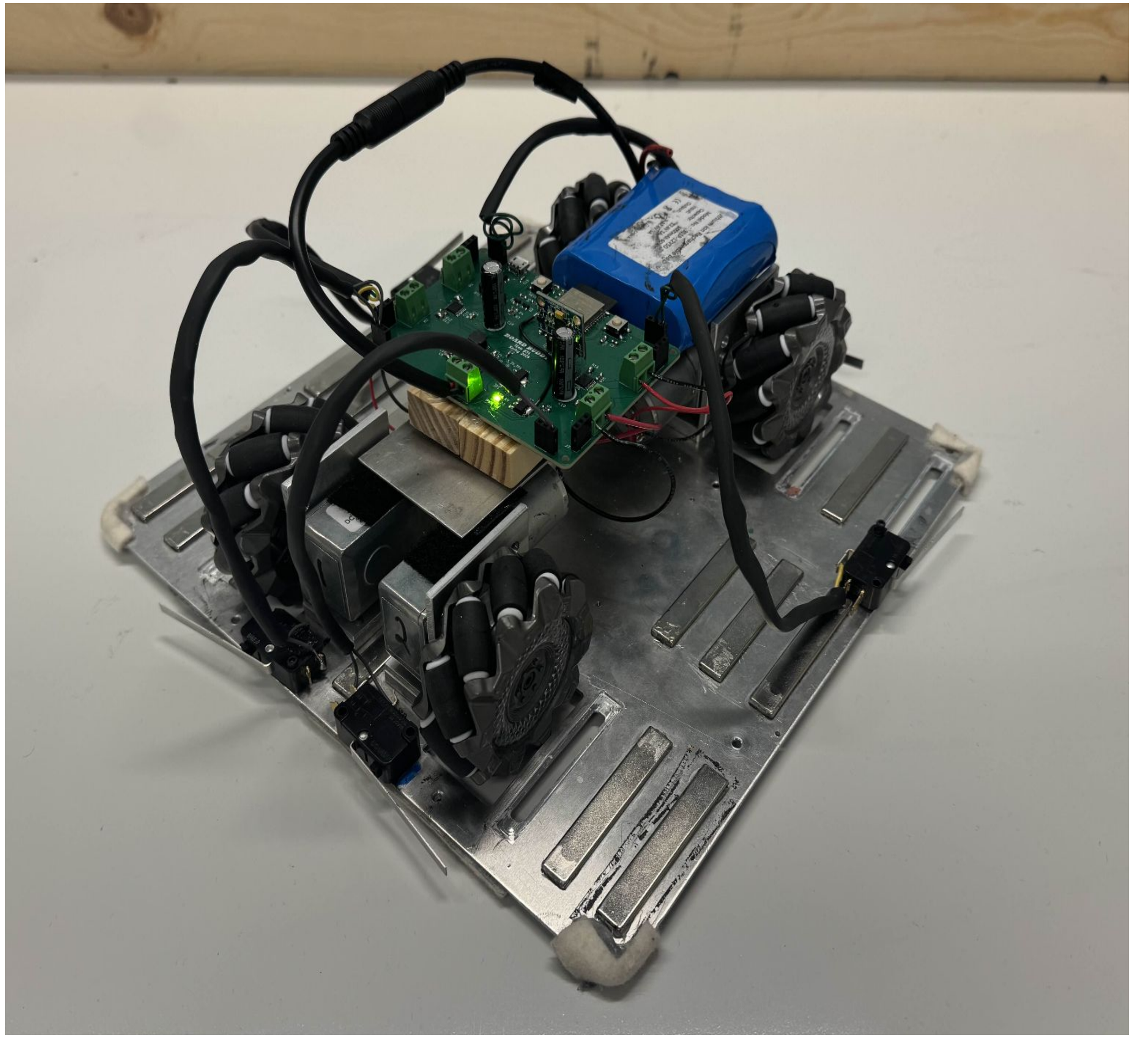
- **Scheduled Erasing**
  - Uses time input to delay sending the starting signal to ESP32.
  - Allows for scheduling up to 24 hours.





Reflections

Physical Implementation



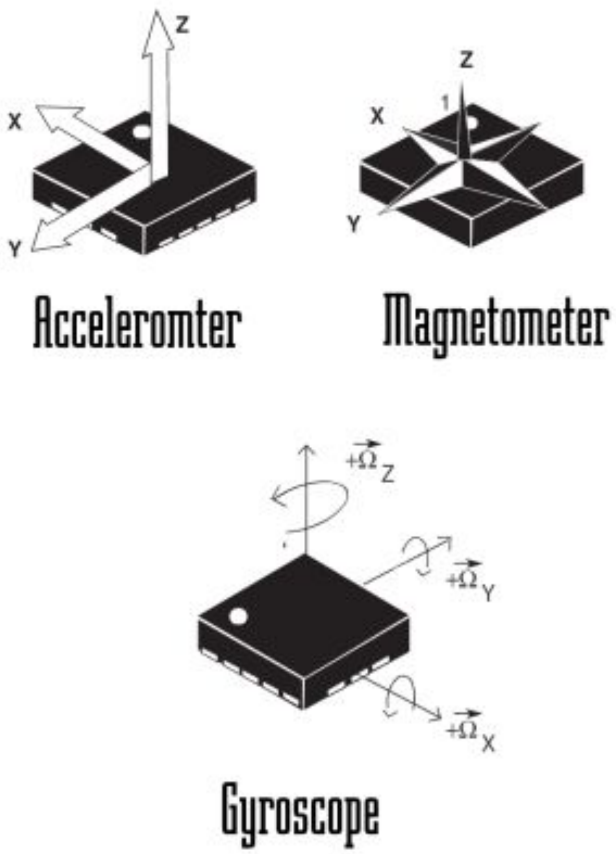
What Went Right?

Results

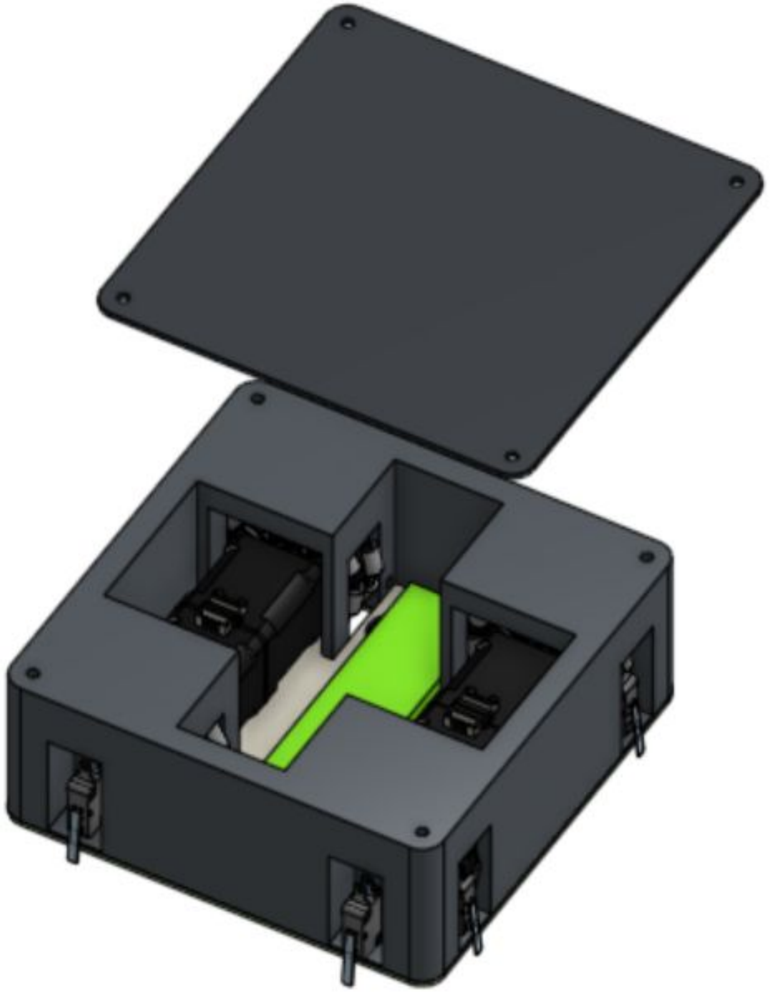
- **User Interface Subsystem**
  - Fully implement bluetooth connections between an android device and the ESP32.
  - Schedule cleanings as we wanted, and were able to create a user friendly application over all.
- **Partial Sensing Subsystem**
  - Correct S traversal
  - Correct signal interfacing between limit switches, IMU, and motors.
- **Processing Subsystem**
  - Properly interfaced signals through ESP32 to make IMU and limit switches interact with Motor Subsystem.
  - Power Subsystem properly send battery signals to be referenced in the application.

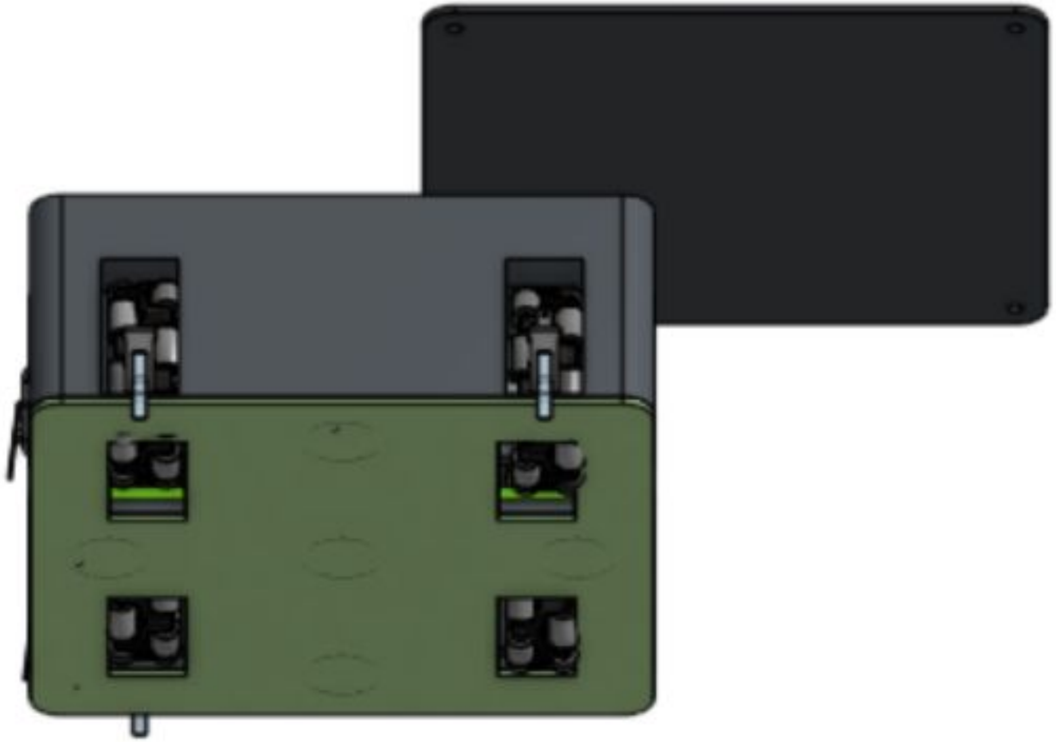
Challenges Faced

- **Partial Sensing Subsystem - IMU Implementation**
  - IMU Drift
    - Re-zeroing IMU at multiple points.
    - Tried implementing multiple filters.
    - New professional grade IMU (9-axis/magnetometer).
- **Body**
  - Unlevel Chassis
    - 3D Printing
    - Consider uneven load distributions.
    - Mounting



Improved Physical Implementation

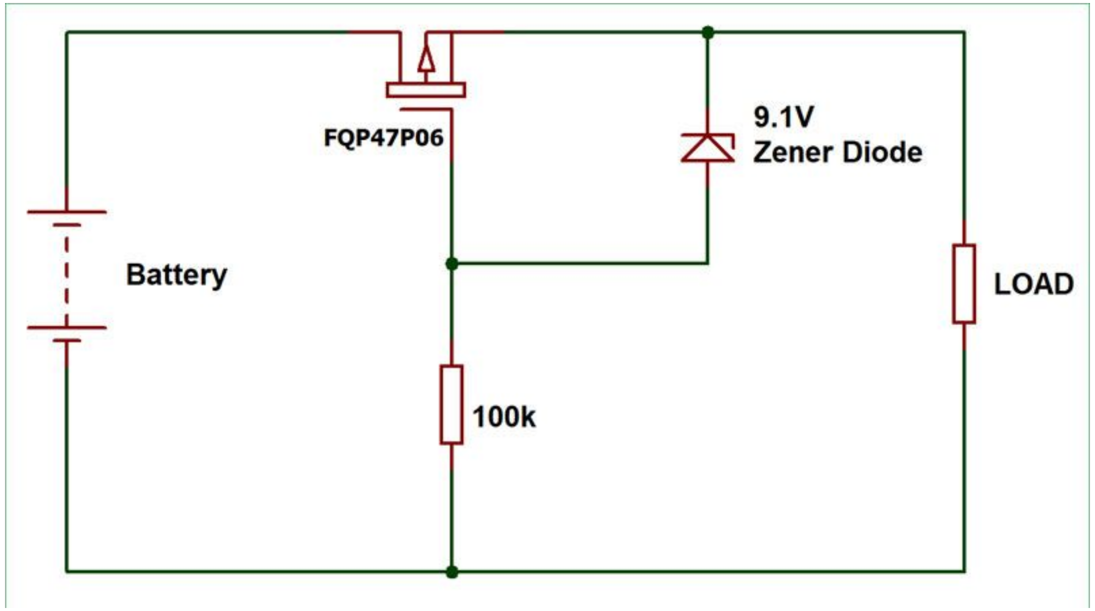




Failures in Design & Possible Improvements

Motor

- Early testing revealed uneven torque across motors
- PWM adjustments
- Custom PWM signals were created for specific motions (e.g., turning, straight movement).
- Higher torque motors



Power

- An accidental reverse polarity connection
- Going forward, we'll integrate polarity protection

Lessons Learned

- Making an Application
  - Flutter framework
  - Dart programming
- PCB Work-Flow
  - Schematic Capture
  - PCB Layout
  - Hand Soldering SMD Components
- Microcontroller Interfacing
  - BLE Connections to Application
    - Service and Characteristic UUIDs

Citations:

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Thank You!

Questions?

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