Grounded Rope-Management System for Belaying

Team 24 | ECE 445

Dec 5th, 2022

Agenda

Introduction and Objective

Introduction

Problem

- Roped-climbing currently requires at least 2 people for proper belaying
- Current solutions are fixed (indoor) and immediately lower climbers during a fall

Objective

Solution

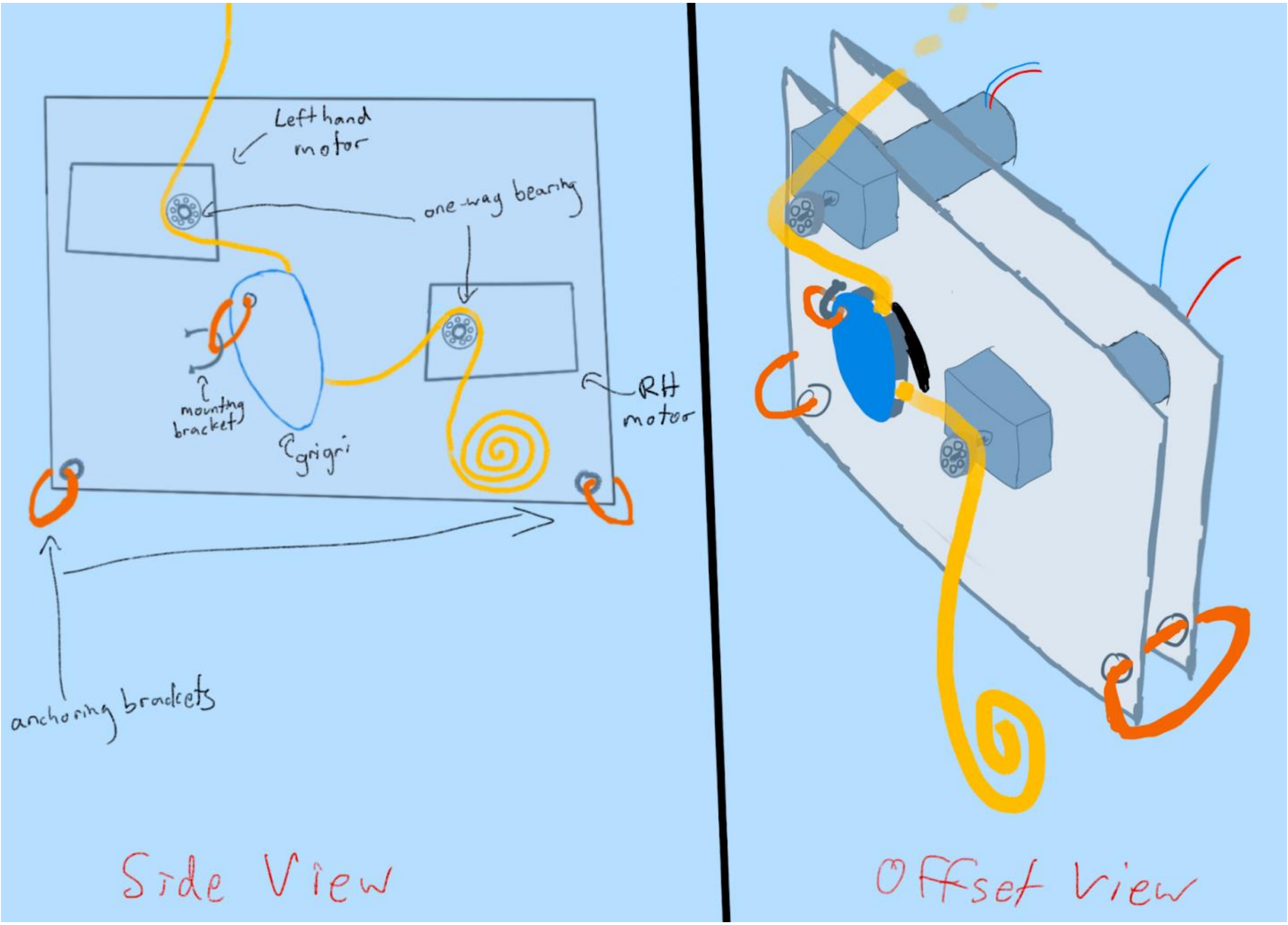
- A portable rope-management system that can replace a belayer
- Emulate belaying motion with motors and servo
- Communication via Phone

Design and Requirements

Brief High-Level Requirements

- Rope system maintains acceptable slack
- Climber must be able to communicate with system
- System should catch a fall

Original Design



Rope-management system

- 2 motors and a servo surrounding a Petzl Grigri
- Pinned grigri, one-way bearing, and mounting brackets to handle climber fall

Changes and Final Design

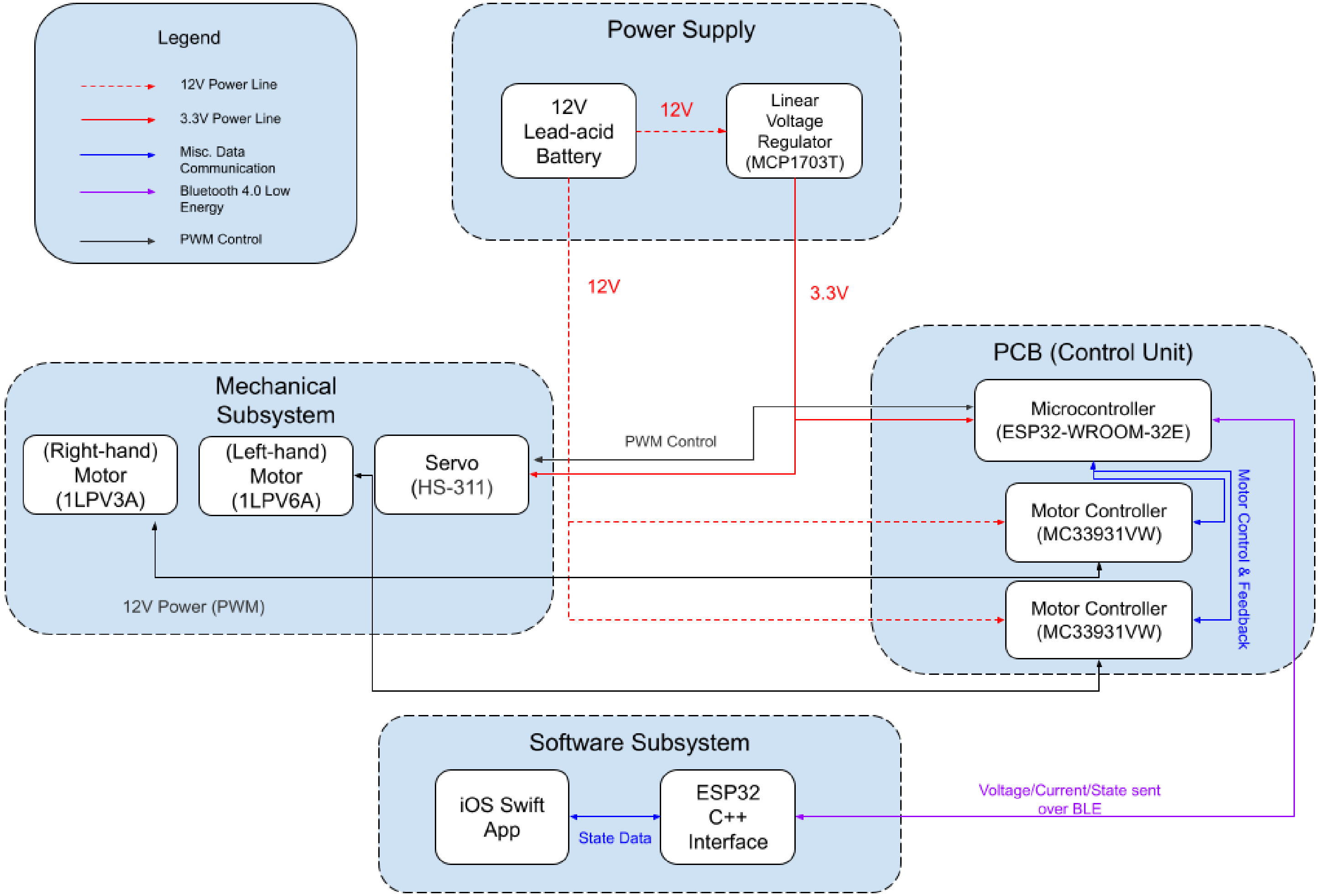
Changes

- Decided against using one-way bearing
- Back-EMF addressed by Battery Usage
- Several iterative improvements for 6^{th} PCB

Final Build Design

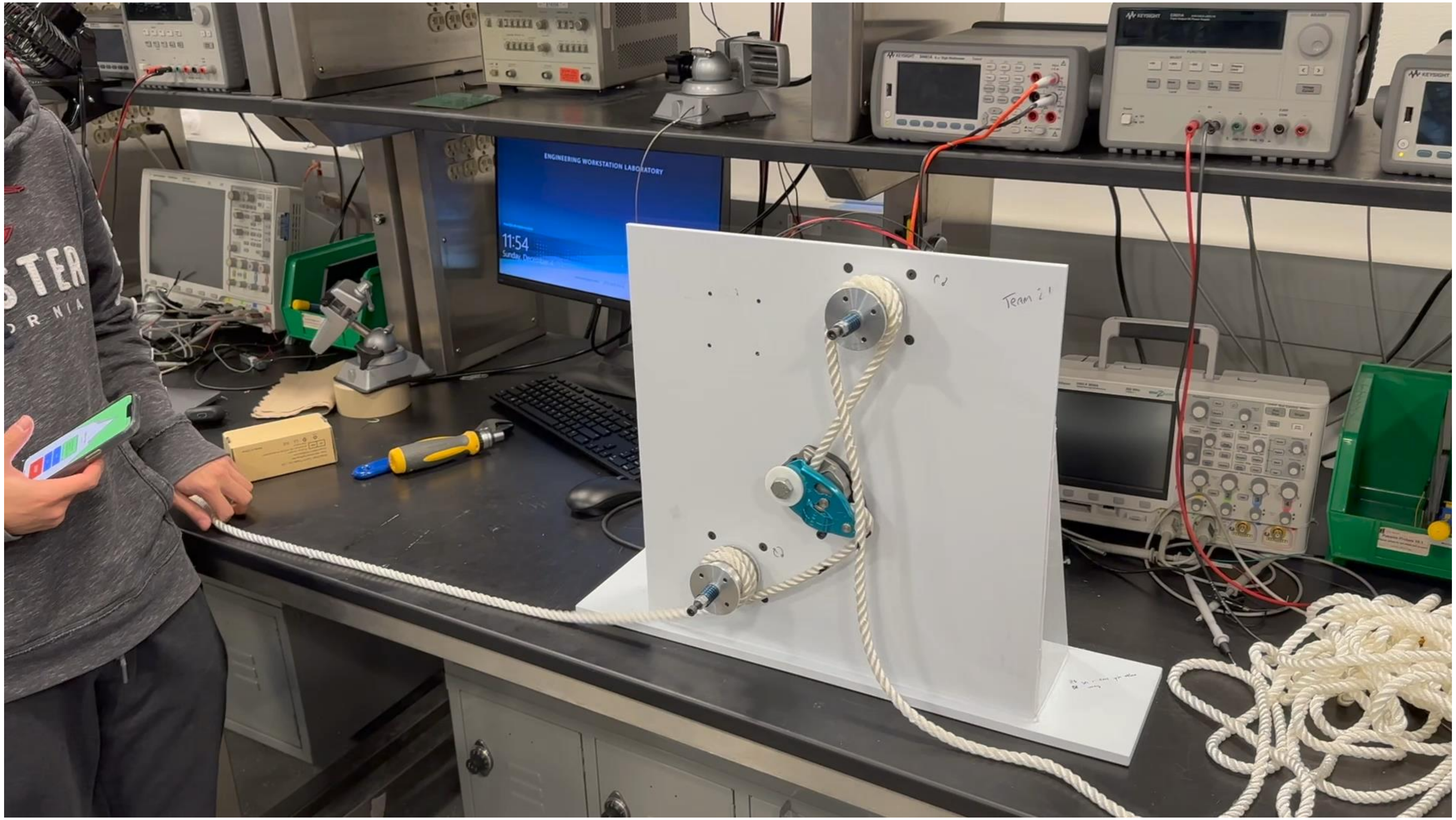
- Functioning clutch system
- Mounted battery and boards vertically

Block Diagram



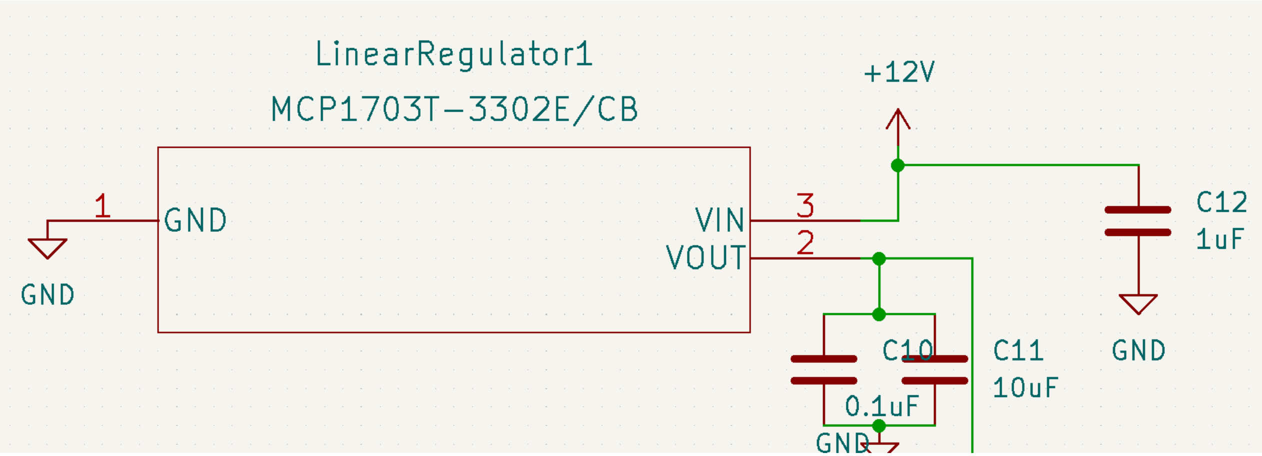
Project Build and Test Results

Demo Video



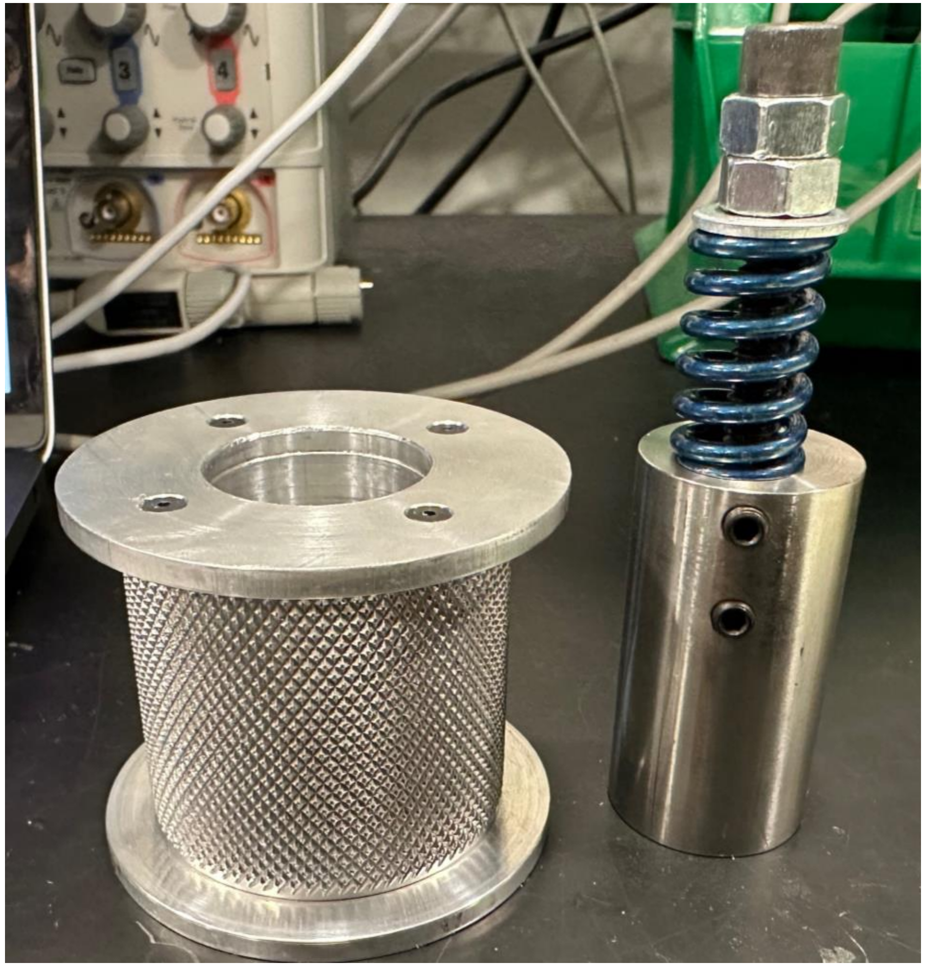
Power Supply Subsystem Overview

- Adjustable Linear Regulator
- 12V lines for Motors and controllers
- 3.3V lines for all other components
- Changed to LM317T



Mechanical Subsystem Overview

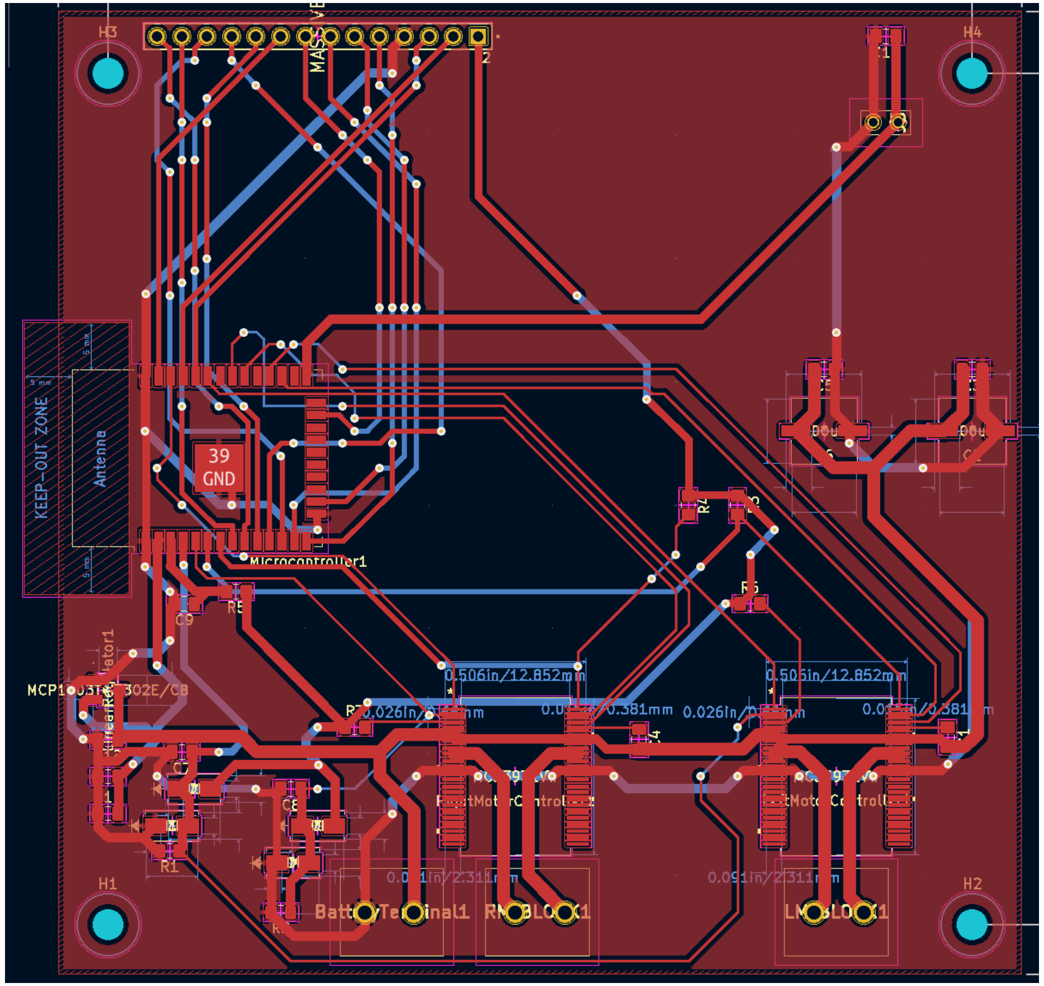
- Clutch system with Teflon
- Multiple shafts allows for slipping
- Spring-adjustable for tightness
- Threated shaft for rope grip



Shaft system with spring (right fits into left)

Control Subsystem Overview

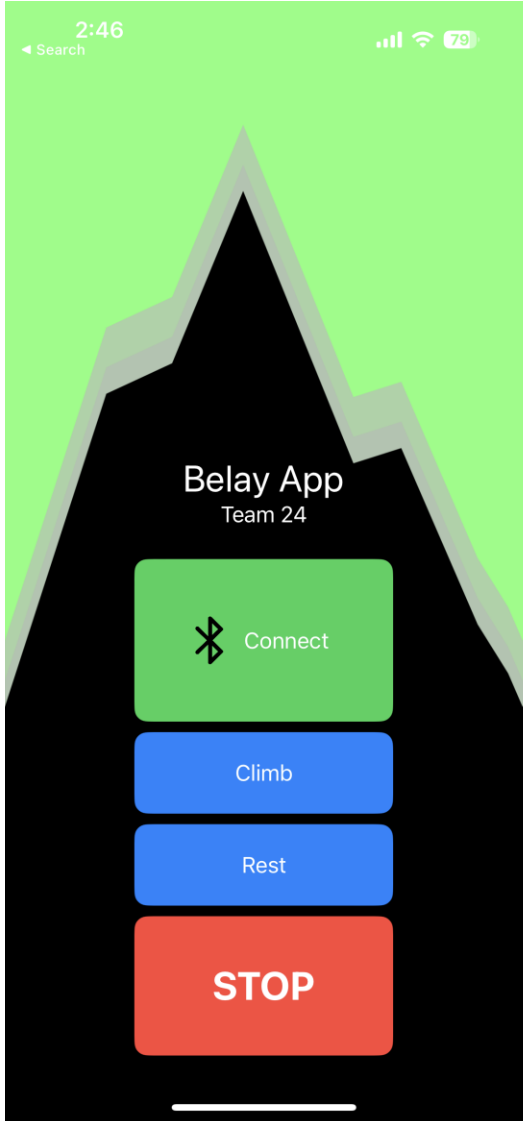
- ESP32-WROOM-32D Microcontroller
- 2x MC3931VW Motor controllers
- Current sensing circuit



Final PCB Design (V6 with issues) with 2 motor controllers

Software Subsystem Overview

- BLE (Bluetooth Low-Energy) iOS app
- Interact with system, get feedback
- Demonstrative – not ideal for actual use



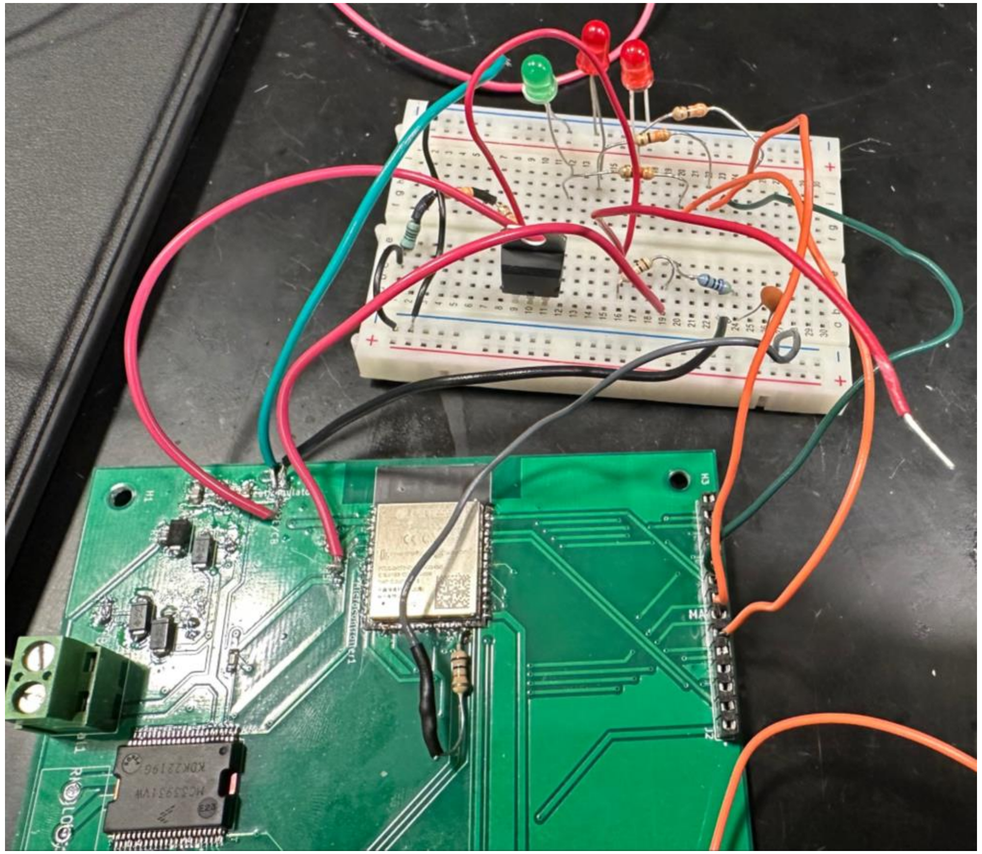
Challenges & Successes

Challenges

- Ordering/Parts mishaps
- PCB shorted the night before the demo
- First few iterations of PCB were non-functional
- Mechanical challenges with threading, motors, and clutch system

Successes

- System was able to perfectly catch falls
- App and Bluetooth communication were fully functional
- System was able to belay
- PCB was fully-functioning until a certain point



Failed Verifications

Requirement

- System needs to detect falls and signal the app

Verification

- Obtains current change to provide reference voltage

Failures

- 0.24% of load/normal current is not received

- Does not detect current change for signaling

Reasons

- Motor controller chips busted
- Doesn't detect current feedback

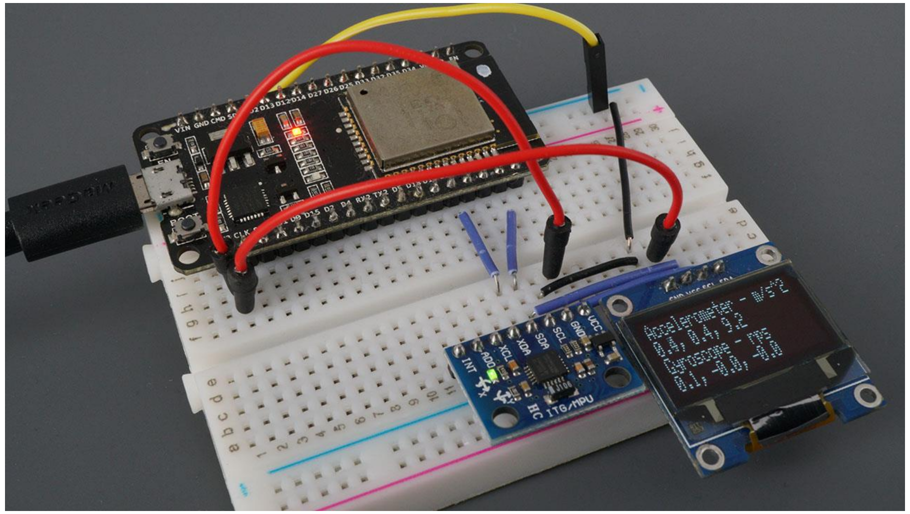
PCB

- Feedback resistors module
- No reference voltage on the sensor pins

Dev Board

Possible Solutions

- Use amplifiers to boost reference voltage
- Use better sensor modules on the dev board
- Use a motor controller with a different sensing layout



Conclusion & Further Work

What we Learned

- How to design and construct a PCB, read datasheets, and select parts
- iOS App Development
- Mechanical Design
- Problem solving under budget and time constraints
- Iterative design through feedback and testing

Things we would do differently

- Perform module testing earlier
- More robust planning for servo position
- Add feedback protection and diodes to 12V power lines
- Add switches and buttons to PCB
- Use climbing-grade rope and identical motors

Recommendations for the future

- Rope-threading to prevent cross-over
- Mounting brackets
- Automatic Descent after timeout or connection failure
- Testing in proper climbing setting

Thank You

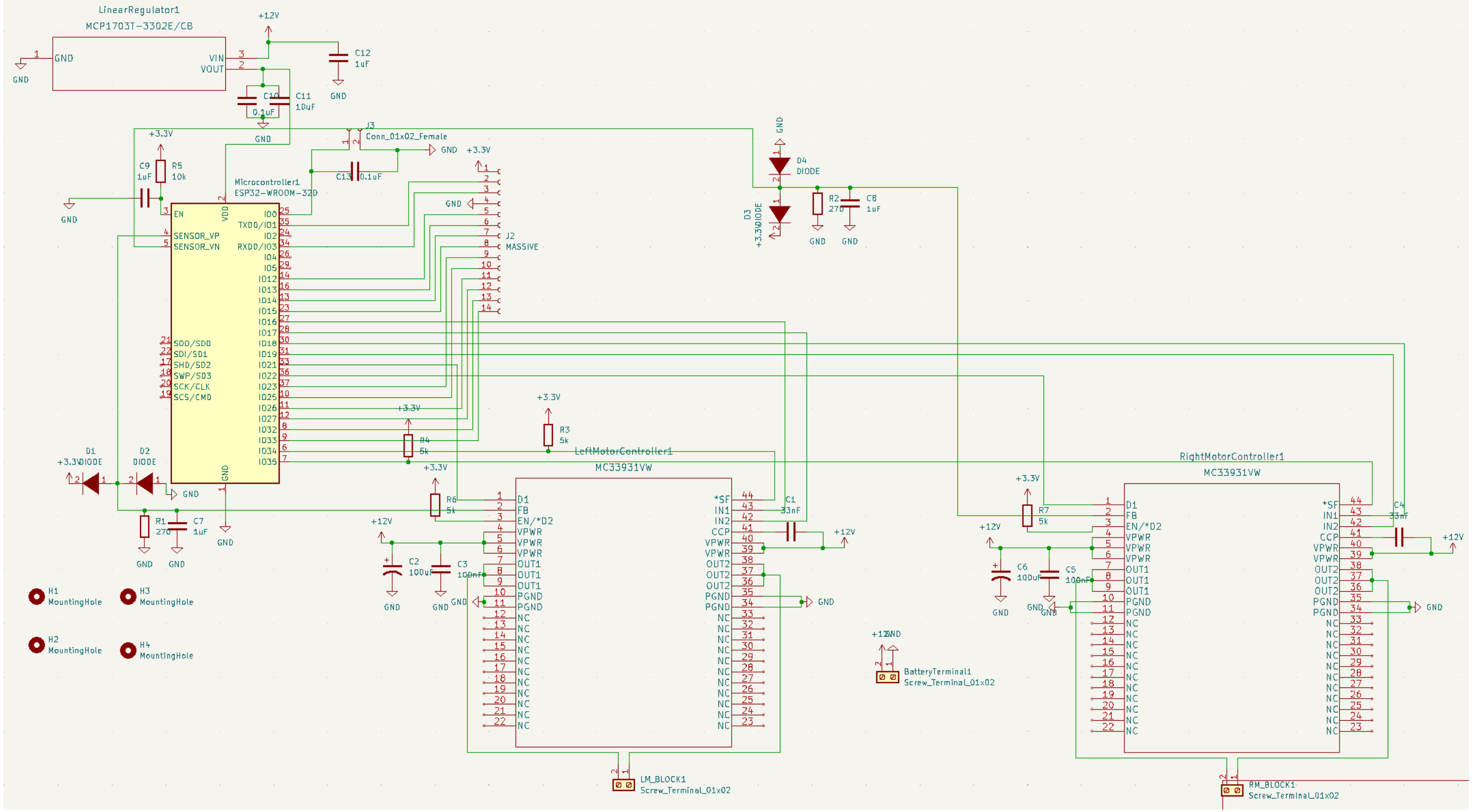
A special thanks to Jason, Gregg, and Skee for their help

Questions?

abhyanj2@Illinois.edu
czzhang3@Illinois.edu
sehsu2@Illinois.edu

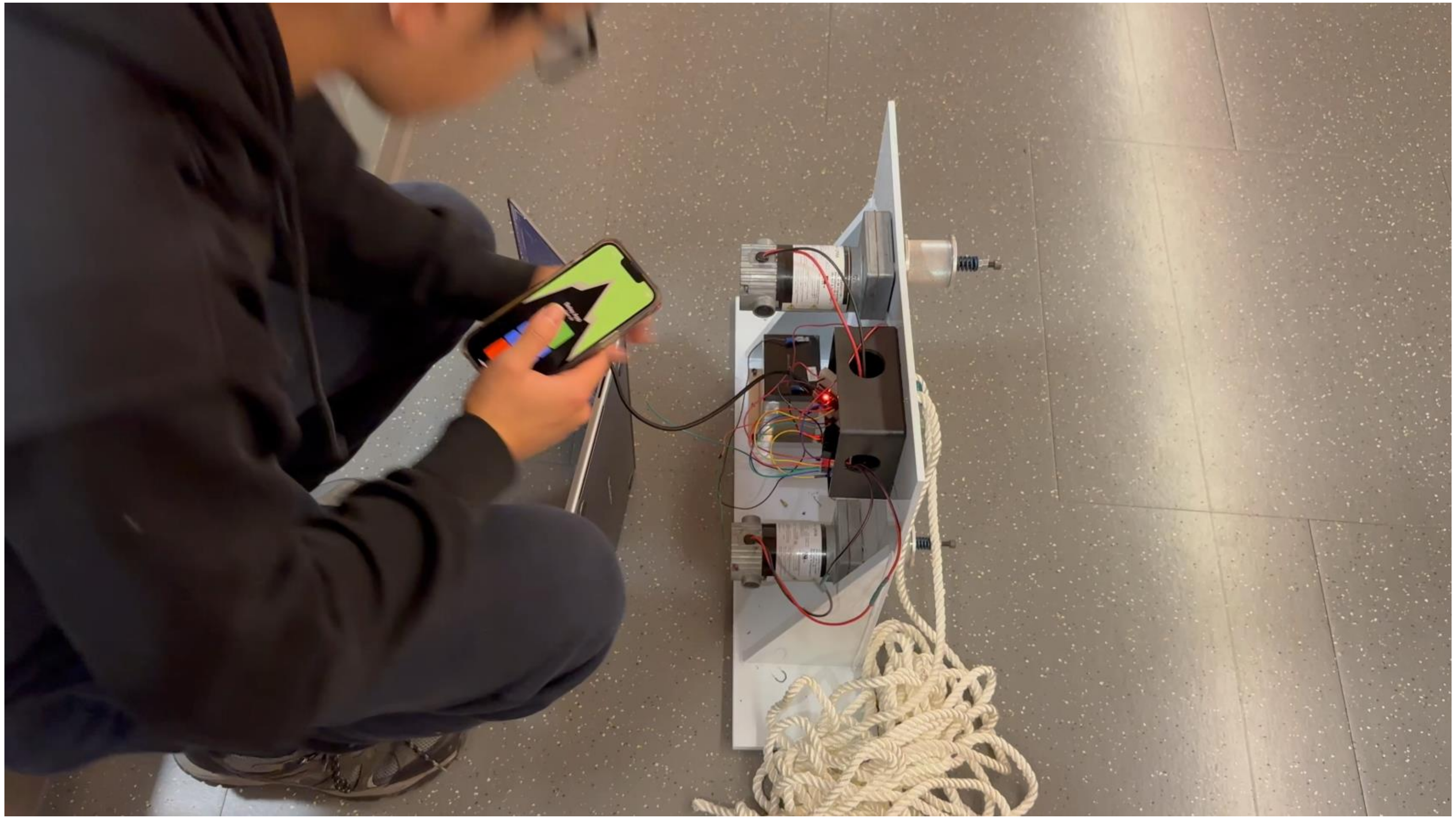
Appendix

Circuit Schematic

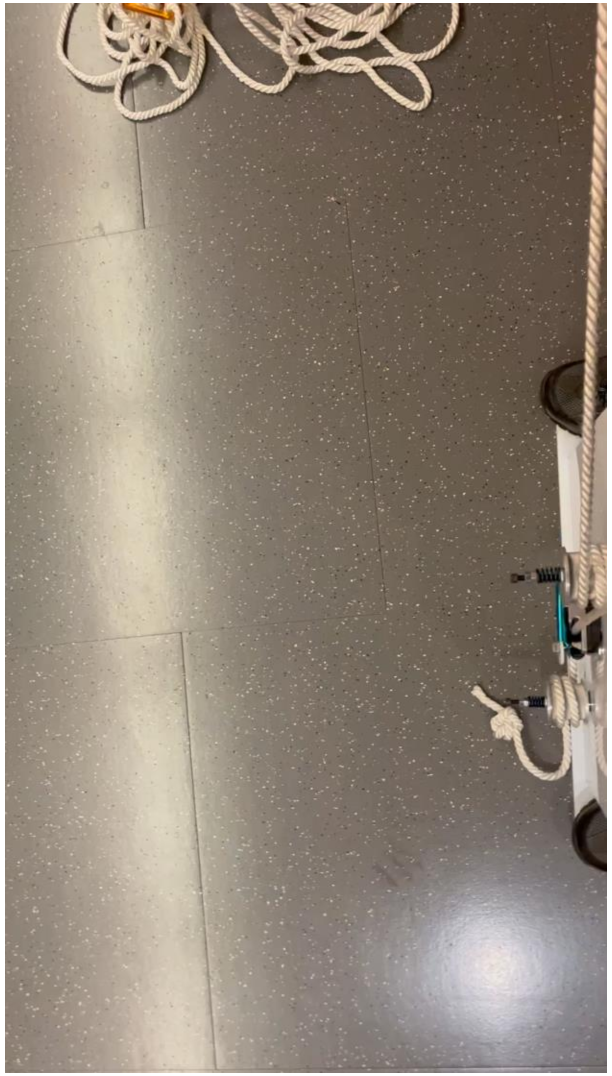


Power Dissipation Verification Video

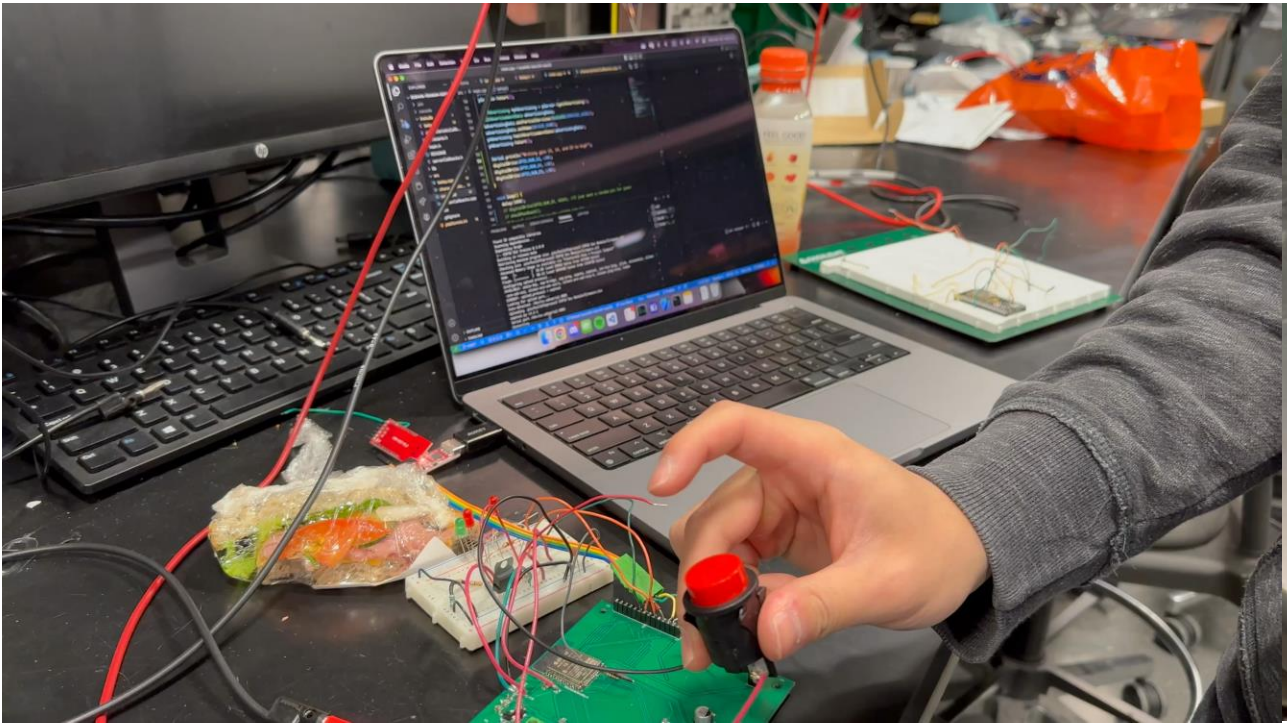
Bluetooth Range Verification

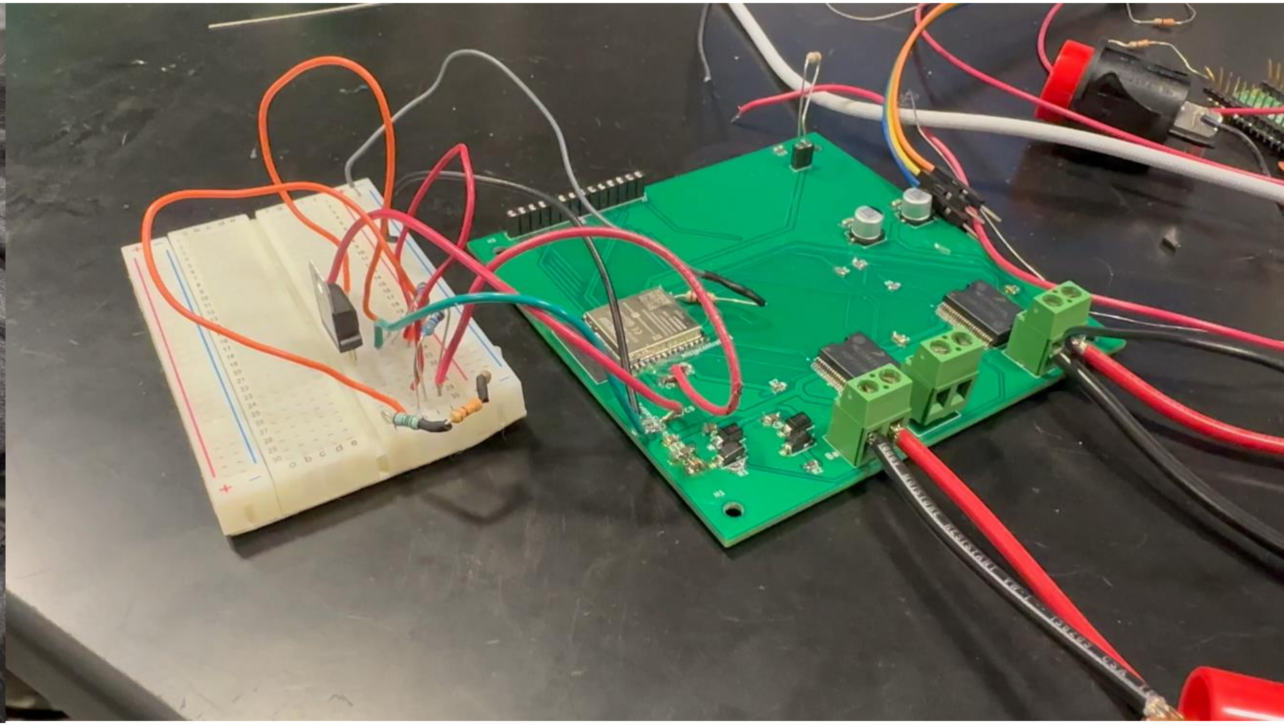


Fall Test



PCB (Before and After)





Ethics and Safety Concerns

- Supervision with belay certified individuals
- Adhered to procedures in lab & machine shop
- Followed IEEE and climbing standards


UNIVERSITY OF
ILLINOIS
URBANA-CHAMPAIGN