UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Durian Antweight BattleBot

Electrical & Computer Engineering

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4/30/2026

Agenda

Project Background
Design and Verification
Conclusion and Future Work

Project Background

BattleBot Competition (National Robotics Challenge)

- 2lb weight limit
- 3D Printed
- Custom PCB
- Killswitch
- Use of a sensor
- No metal in the weapons and/or armor system

Project Objective

To defeat other competing robots in 1 on 1 combat

- A drill weapon was chosen as the specific weapon in our design.

Deliverables for Team:

- Mechanical components, Physical Design (Mechanical Subsystem)
- Custom PCB (Electrical Subsystem)
- Firmware (Microcontroller Subsystem)
- Safety fallbacks (Safety/Reliability Subsystem)

High Level Objectives:

- Proper drivetrain operation
- High degree of electrical component reliability
- WiFi-led wireless control of the Battlebot within 10 feet
- Remains under 2lb weight limit
- Absolute voltage limit for the system should range at around 15-16V for any component and DC bus
- Chassis must be 2mm thick at 60% infill
- Ground clearance for the wheels must be 3-4 mm’

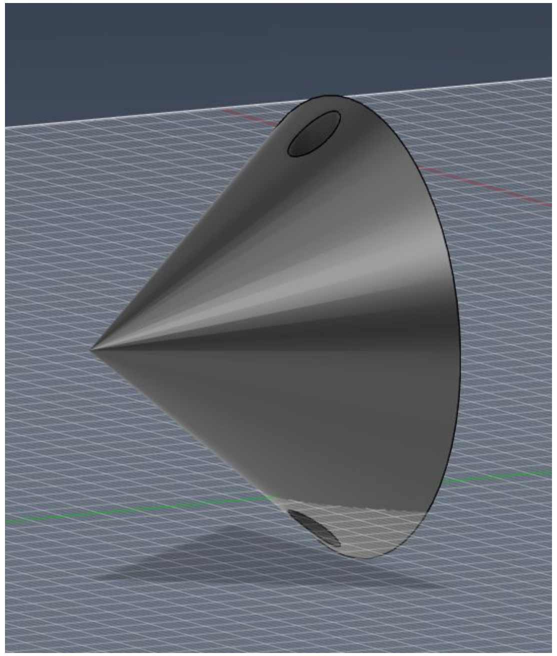
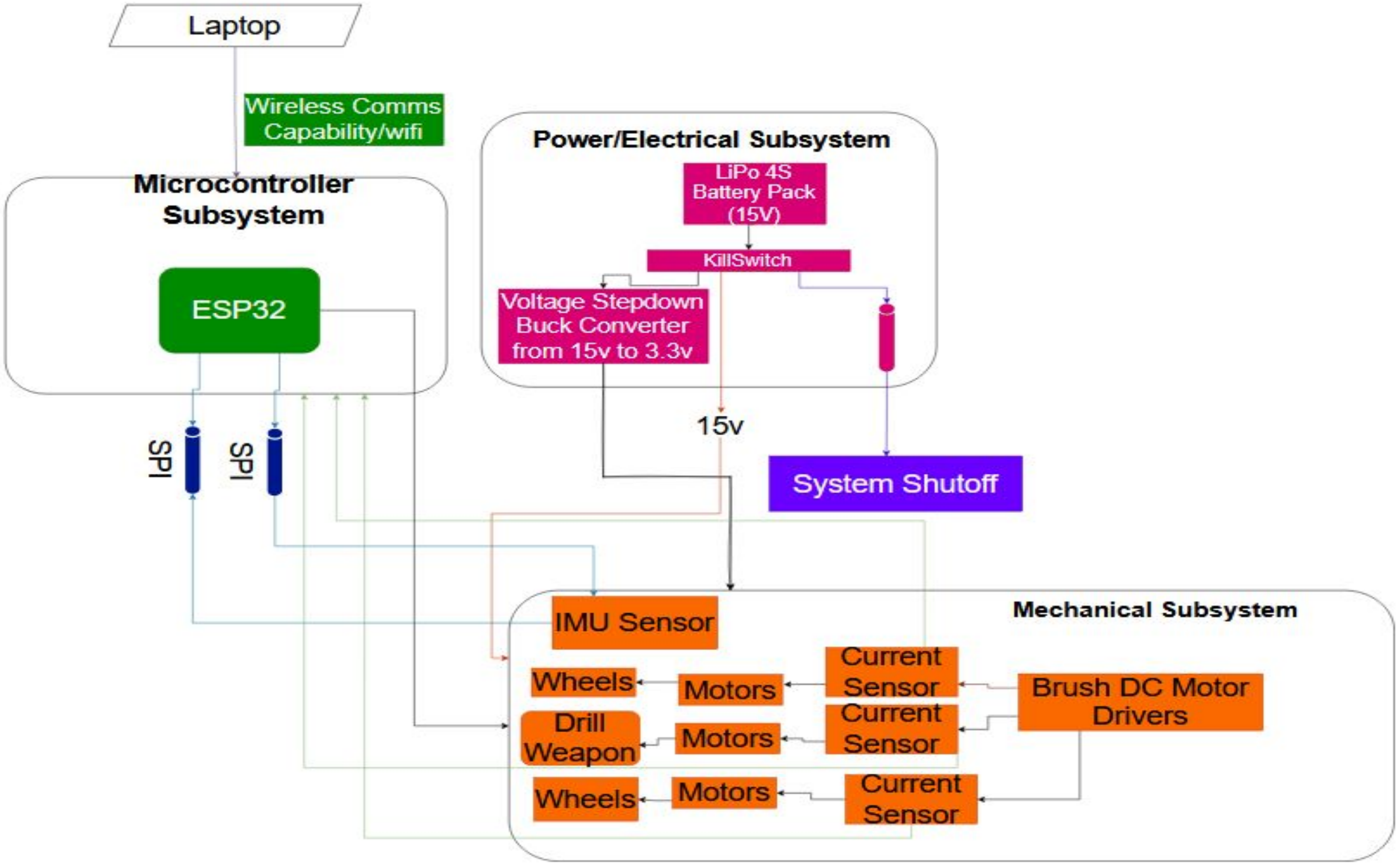


Figure 1: The drill (with retention screwholes to pin down the driveshaft)

Overarching System Overview

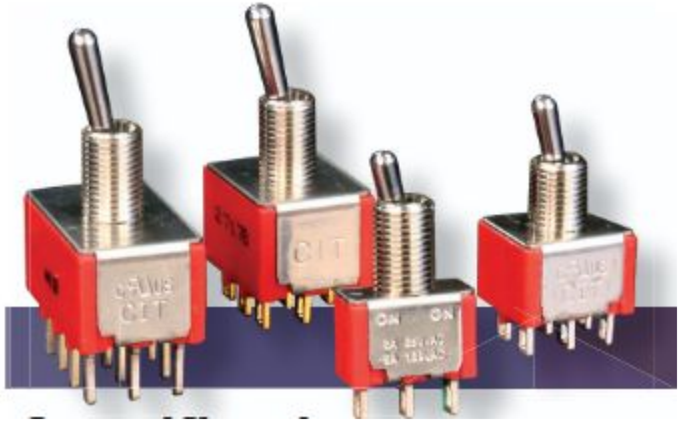


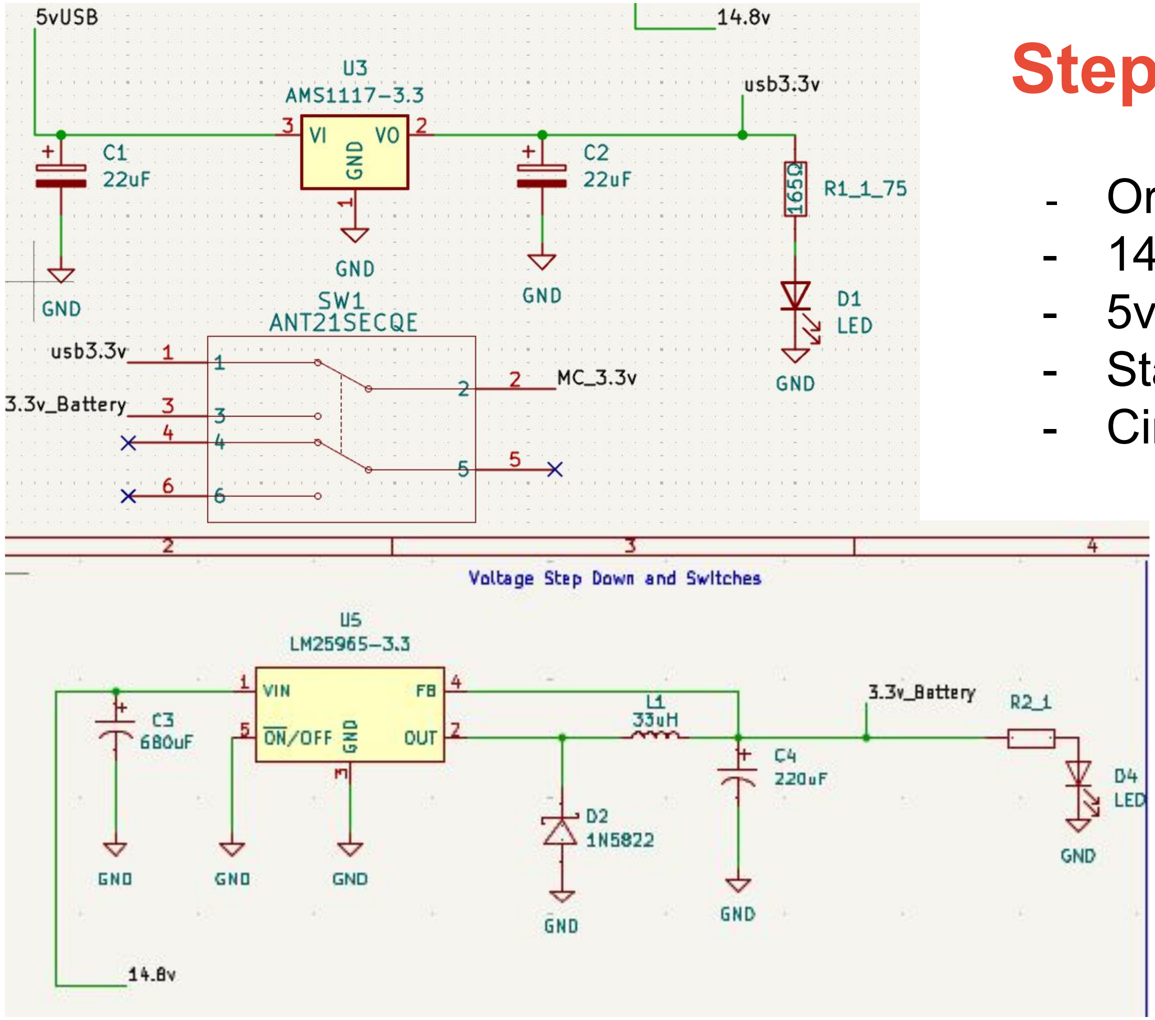
Block diagram of all subsystems

Electrical Subsystem

Subsystem Overview

- Killswitch
- It takes up to 60 seconds to turn off robot safely
- Power Circuitry steps down voltage to 3.3v
- Power lasts for at least 2 minute duration

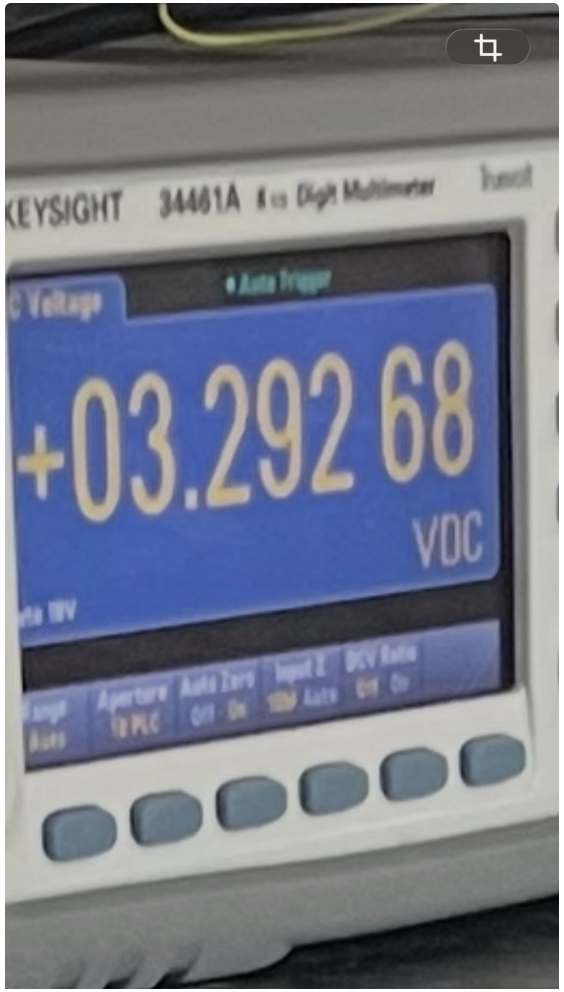




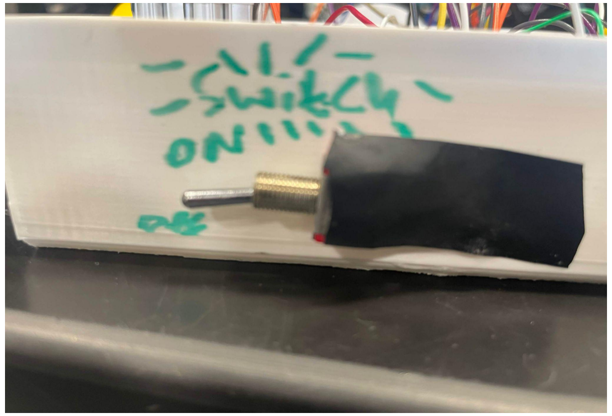
Stepping Down Voltage

- Orginally used regulators for both
- 14v to 3.3v buck converter
- 5v to 3.3v Voltage Regulator
- Stable 3.3v
- Circuit Protection

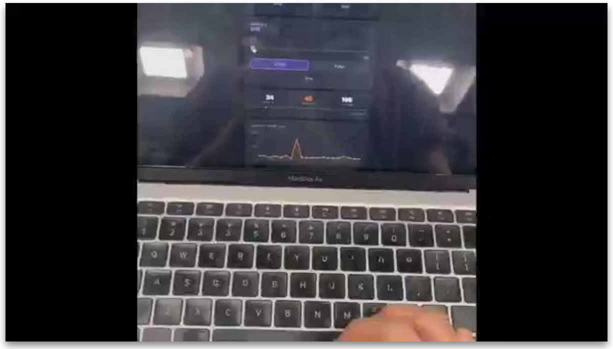
Electrical Subsystem Verification



The voltage regulator stays at 3.3V within an acceptable tolerance range.



KillSwitch



Video of motors running for 2 minutes without failling

Requirements	Verification
A stop switch that can be activated to stop the robot from operating and the robot must be shut off in 60 seconds or less.	Perform trial runs with the robot and during it perform a safe shutdown of the robot by pressing the button on the robot and record with a timer how long it takes for the weapon and motors to stop rapidly spinning for safe handling.
Voltage Regulator can supply a stable input voltage of 3.3v with a ±2% tolerance for microcontroller, IMU, and current sensor voltage input.	Measure test points at voltage inputs and observe under an oscilloscope that the voltages will be stable while components are running.
Voltage Regulator can supply a stable input voltage of 5v with a ±2% tolerance for the motor drivers.	Measure test points at the motor driver's voltage input pin with an oscilloscope and see if the supplied voltage will be stable while motors are running.
The battery should be able to supply enough voltage for the 2 minute duration of the competition.	Run the robot with motors running constantly while the robot is placed on a box or an object that can put the robot on a height to prevent the robot from moving. Measure for 2 minutes on a timer and check to see if the robot can continuously run during that time period.

Mechanical Subsystem

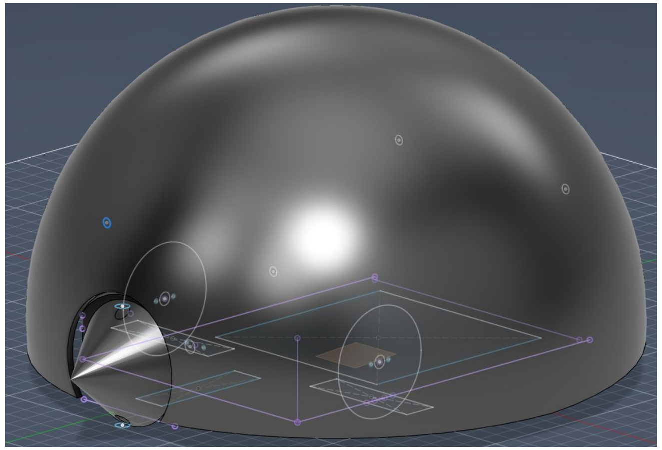


Figure 2: The Fusion360 perspective of the shell + chassis + drill.

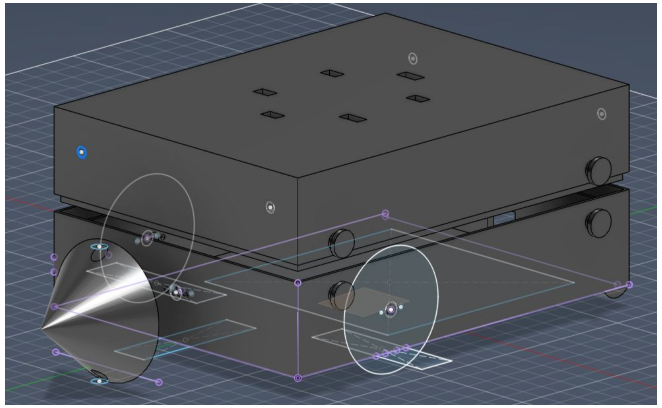


Figure 3: The Fusion360 perspective with the shell hidden.

Subsystem Overview

Comprised of 4 component types:

- Chassis (protecting and centralizing components)
- Shell (shock absorption and provides 2-castle defense)
- Drill (blunt force propagation + inertia assistance with rotary capabilities)
- Drivetrain components (gearmotors, wheel hubs, wheel)

Fusion360 Design

Weight estimations using PETG density and Fusion360's volume calculator suggest that ~0.9lb was left for the remaining components based on:

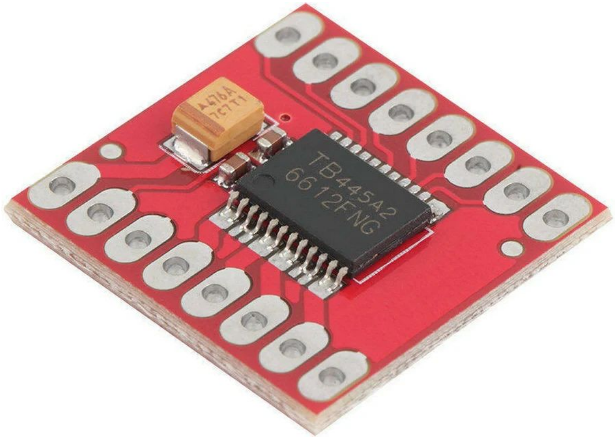
- Shell -> 80% infill
- Drill -> 100% infill
- Chassis halves -> 60% infill

Configuration

- Front-wheel drive with rear skid setup
- Gearmotors fasten to a metal hub with M.2 screws
- Gearmotors connect to gearmotor drivers that communicate with the IMU sensor and ESP32
- BONUS: A third gearmotor is used to spin the drill, and will rely on retention screws that pinch the driveshaft from both ends

Video Demonstration of drivetrain and weapon

Gearmotor + hub + wheel assembly.



TB6612FNG (gearmotor drivers)

Mechanical Subsystem RV Table

Requirements	Verification
The gearmotors should be able to withstand 2 minutes of nonstop, maximum output conditions.	A dyno test was run with a two-minute timer to validate this requirement.
The drill and wheels need to be easily replaceable.	M.2 and M.3 screws can be removed/installed using hex keys to secure the drill and wheels to the gearmotor driveshaft.
The inner components must be easily accessible for repair/configuration purposes.	The chassis halves, joined together using zip ties and a lip conjoinment design, can be removed with ease.
The gearmotors must be able to withstand inertial turbulence for the match duration.	This was passively tested with the two-minute dyno test.
All components are designed to operate in a room-temperature environment with a plus-minus tolerance of 5 Celsius.	This was passively tested with the two-minute dyno test within ECEB2072, which was an operating setting slightly above room temperature.

Mechanical Subsystem - RV Table

Microcontroller Subsystem

Figure 6: ESP32-S3-WROOM-1 chip.

Subsystem Overview

Our microcontroller is the brains of the project. For the battlebot, it is a functional requirement that the hardware is controlled through a wireless signal such as WiFi. Furthermore, the board has some simple but non-trivial algorithms to detect overload to any of the components and potentially cause damage to our design.

Espressif ESP32-S3-WROOM-1

We have chosen the ESP32-S3-WROOM-1 microcontroller. The biggest reason for thai is because it offers WiFi and bluetooth signal and connectivity out of the box, native to the chip itself.

The microcontroller will be set as a webserver. The client (or controlling device) will connect to the new router that’s opened through the microcontroller, and communicate with the devices on board

Microcontroller Subsystem RV Table

Requirements	Verification
Latency from input to output via the websocket should be under 1 second. With a tolerance of 20ms	This can be measured by tracking the elapsed time between sending the payload through the websocket and receiving the acknowledge bit from the microcontroller
Memory and CPU power should consistently be well under threshold for microcontrollers. Specifically, RAM usage should be < 2MB with tolerance of 30kb	Can track critical system benchmarks like the stack/heap and report back to the host device. Upon exceeding these numbers potentially can reset the system as a whole to reset all cache.
Code must have >80% test coverage for system critical functions.	Tests can be written using a framework natively supported in C such as µnit. Running the test suite summary yields the percentage of main function code that's covered.

Microcontroller Subsystem - RV Table

Safety & Reliability Subsystem

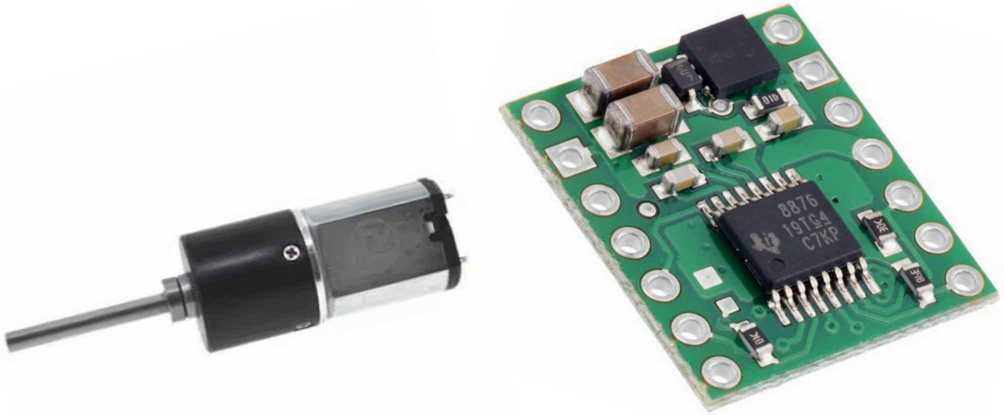


Figure 7: The driver keeps the gearmotor current in-check.

Figure 8: The LM2596 (buck converter) with built-in safety functions.

Subsystem Overview

The safety/reliability subsystem is largely a passive one that was formed through deliberate and careful selection of components. Some examples of deliberate choices made:

- Gearmotor drivers have a current limit of 2 Amps
- Buck converter has built-in thermal shutdown and OCP.
- The voltage tolerance for capacitors, resistors, drivers, and IC’s all have wiggle room to account for transients

Safety & Reliability Subsystem RV Table

Requirements	Verification
Components must be properly torqued/conjoined to avoid risky operating conditions	Stress tests on the drill and wheels, pull tests on soldered wires, and other validation techniques were used to ensure a fairly high degree of reliability.
Inrush current must be controlled to prevent the ESP32, drivers, and other sensitive components from overloading.	Capacitors and resistors have been placed to behave as precautions against inrush current by reducing and redirecting it.
Software functionality should prioritize gearmotor health.	Variable speed control on the gearmotors ramps up with PWM to prevent inrush current by commanding 0→1.0 per-unit load.

Safety & Reliability Subsystem - RV Table

Challenges

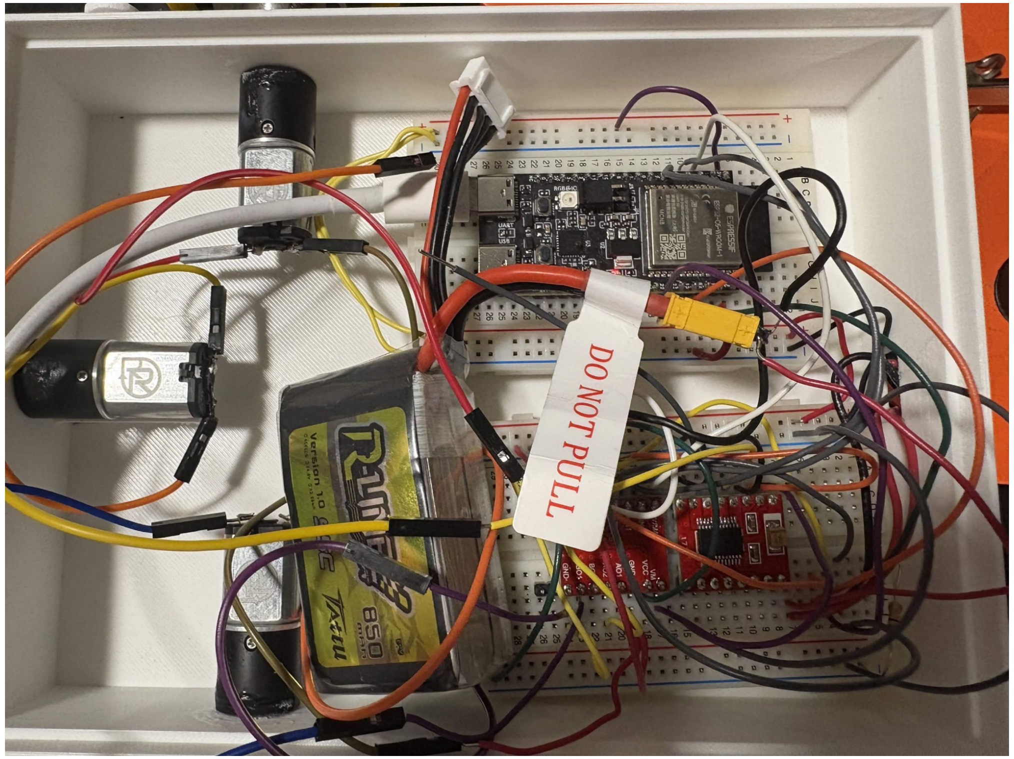


Figure 9: Breadboard demo configuration.

Experience Overview

There were several issues that prevented this Battlebot from reaching its functional and design ceiling:

- Electrical faults that fried the ESP32, gearmotor drivers
- Incorrect trace widths, floating and/or incorrectly pathed bus lines (e.g inductor)
- Bridging due to improper soldering
- PCB ordering timeline
- Shell print times were too long (30hrs)

Takeaways

- Hardware is extremely finicky to debug, and requires extra time to sort out/iterate versions
- Redundant safety features are essential for reliability
- Ordering spare parts in anticipation of errors is proper

Summary

The end-result of this project was a great deal of learning and retrospection. From a design and field perspective, there were certain decisions and experiences that led us to becoming more experienced engineers.

- Evolution of soldering skill set, knowledge, and tool utilization
- Ground-up learning of Fusion360 3D modeling capabilities
- Improved subject knowledge expertise regarding PCB design
- Debugging process exposure
- Bolstered ESP32 Microcontroller operation knowledge

Retrospective and Future Work

In general, this project gave us the exposure to developing a system from the ground-up. In our experience, the biggest bottleneck was the time it took for parts to arrive and assemble. As such, if we were to redo this project from the ground up another time, we would order and assemble the PCB at the earliest convenience to prepare for any delays.

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