ECE 445

SENIOR DESIGN LABORATORY

Final Report

Antweight Battlebot

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Abstract

This report highlights the design considerations that lead to the creation of a robot that grabs and lifts opposing robots and the steps taken to design a two-pound antweight combat robot. All information from the parts used, costs, mechanical design, software, hardware, printed circuit board design, and mechanical design are all detailed.

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1. Introduction

1.1 Problem

The world of combat robots is almost always in a setting where you and your opponent compete within a restricted time limit and where the winner is whoever's robot remains standing in the arena or whoever has scored higher in the judges' eyes. Like in wrestling, these robots are categorized by their weight bracket. From 75-gram flea-weights to the 250-pound heavy-weights seen on television, each bracket comes with their own considerations such as materials, costs, and electronics. Professor Gruev's robot competition lies within the 2-pound antweight bracket and our goal is to come up with a robot that is strong and reliable enough to defeat our opponents' robot within the professor's limitations. In this case, the robot must follow these restrictions:

1. Has to be less than 2 lb
2. Must be 3D printed using these materials: PET, PETG, ABS, or PLA, PLA+
3. Must be controlled from a PC via Bluetooth or Wi-Fi
4. Must have a fighting tool and be able to move
5. Easy manual shutdown (Power switch)

1.2 Solution

Our solution is to create a robot under 2 lbs that consists of four wheels (two on either side) for drive and motion, as well as a grabbing and lifting arm as our fighting tool. A 3D-printed chassis is used to house the electronics and safeguard against our opponents. It also provides easy access for maintenance and repairs. The robot will be driven wirelessly using Bluetooth Low Energy from a PC with a tethered Xbox controller for inputs. It will also have a power switch for manual shutdown, shown in Figures 1 and 2.

1.3 Visual-Aid

Figure 1: Design of 4-wheel drive system with a grabbing/lifting tool.

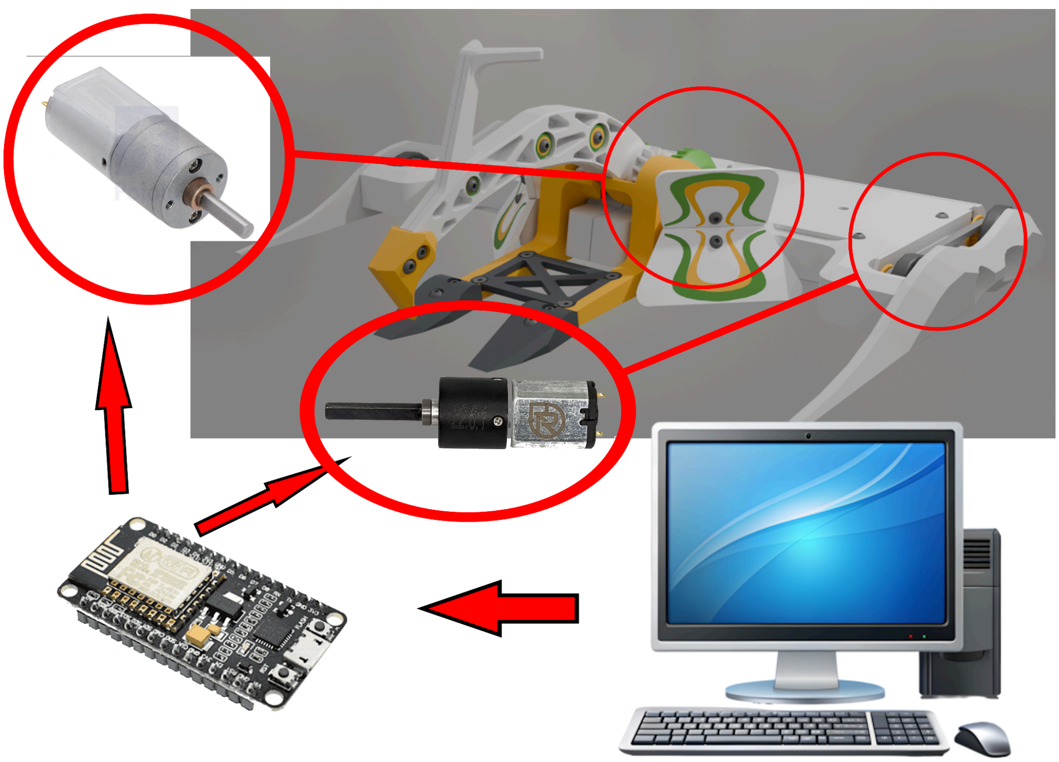

Figure 2: High-level overview: The computer sends controls (ex. go forward) to the ESP32 module via Bluetooth Low Energy, which then sends the corresponding PWM (pulse width modulation) signals required to tell the motor drivers to rotate.

1.4 High-Level Requirements

1. **Top Speed:** Given a 10-foot by 10-foot arena and the fact that the robot will weigh no more than 2 lb, we will focus on maximum speed since acceleration is typically not an issue. We will aim for a speed of 3 miles per hour (mph)
2. **Weapon Lift Strength:** The weapon must be able to lift at least 2 lb, the maximum weight of the opponent robots.
3. **Latency**: The robot in an ideal world should have as little latency as possible within our control. Trying to reduce latency between the PC and giving commands to the robot via Bluetooth Low Energy is crucial for an effective combat robot. We will aim for an input delay from the PC to the robot of no more than 1000 milliseconds.

2. Design

2.1 Block Diagram

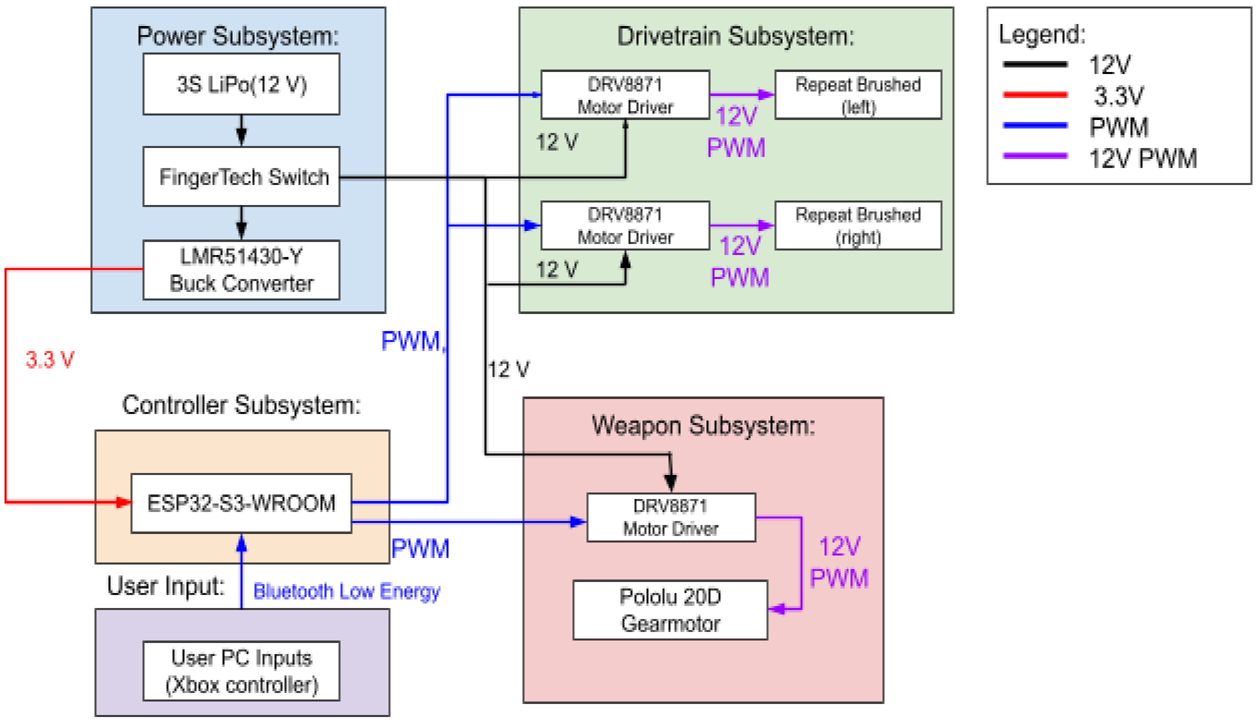

Figure 3: Block Diagram of Design.

The overall block diagram of our design can be seen in Figure 3. It shows four main subsystems, and there is an additional mechanical subsystem encasing all of them. The power subsystem provides power to all the other subsystems. The controller subsystem takes user input and sends out the corresponding PWM signals to the drivetrain and weapon subsystems. The drivetrain subsystem includes the two brushed drive motors and motor controllers for them. The weapon subsystem includes the brushed weapon motor and its motor controller. A more in-depth description of each subsystem and its interconnections will be given in Section 2.3.

2.2 Physical Design

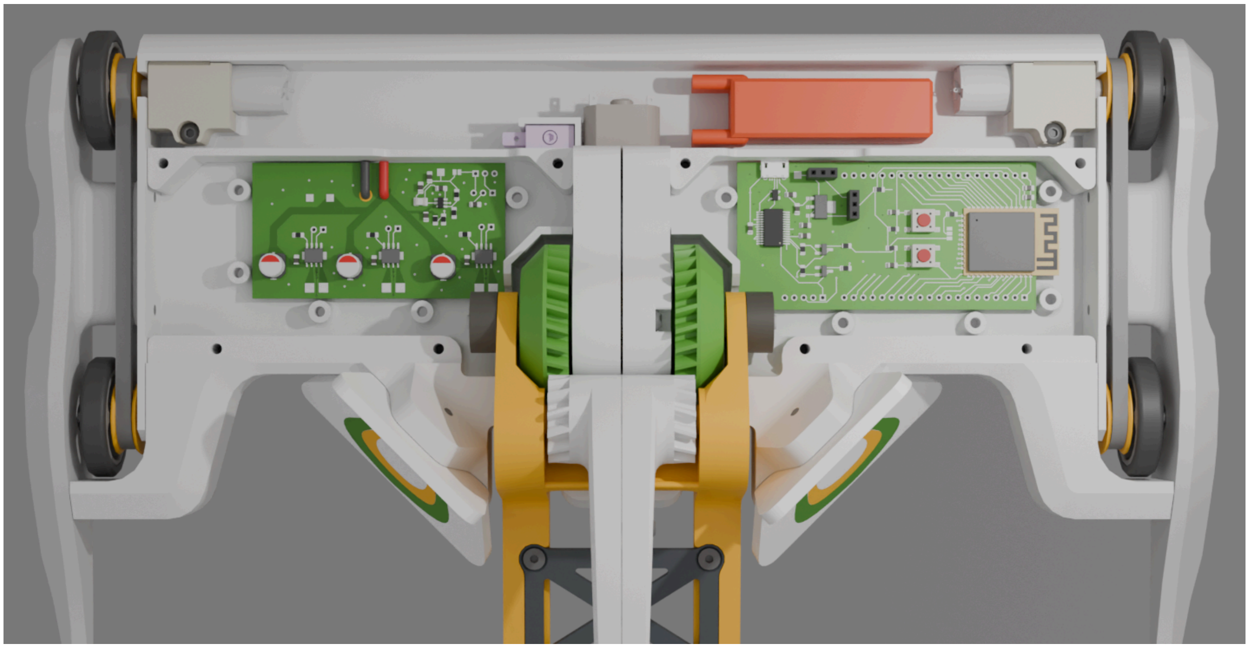

Figure 4: Physical layout of components.

The custom PCB (green) on the right houses the ESP32-S3 used for Bluetooth Low Energy communication with the computer for control and has another PCB on the left that holds the motor drivers as well as the weapon motor driver. The weapon motor (top middle grey) is embedded in a 3D printed gearbox to carry a substantial torque to lift an opponent as well as protection for the motor itself. All the electronics will be powered from the 3S LiPo battery (orange) that can be manually disconnected via the power switch (purple). The drive mechanism of each side has a motor that drives each rear wheel, which is then connected to the front wheels using a pulley and belt mechanism, providing traction to the front. In addition, all the white parts are 3D printed armor pieces meant to protect the electronics from opponent attacks.

The PCB is split into two separate rectangular PCBs. This is due to the 100 mm by 100 mm area limit of a single PCB for this course. Although the design can fit within these bounds, having a square-shaped PCB is not ideal for fitting inside a combat robot. The first PCB is the controller PCB, which includes the ESP32-S3-WROOM, its programming circuitry, and a backup linear voltage regulator. The second PCB includes the 3 motor controllers and the buck converter. The controller PCB designs can be seen in Appendix A.1 with Figures 6 and 7, and the motor PCB designs can be seen in Appendix A.2 with Figures 8 and 9.

2.3 Subsystem Overview

2.3.1 Power Subsystem

The power subsystem is responsible for supplying the necessary voltages for each of the other subsystems and is located on the motor PCB board. There are three key components for the power subsystem. First is the 300 mAh 3S LiPo battery that provides 11.1 V to the motors and motor controllers. The second component is the buck converter that steps down the 11.1 battery voltage to 3.3 V to power the ESP32-S3-WROOM microcontroller. Third is the Fingertech Switch that allows for easy manual disconnection of power to all subsystems by simply disconnecting the battery from everything.

The choice of battery mainly depends on its charge capacity to be able to power the entire robot for the duration of a match. The main current-drawing elements of the design are the motors. Based on the manufacturer's websites, the Repeat Robotics motors have a current draw of about 2 A peak, and the Pololu weapon motor would have a stall current of 1.6 A [1, 2]. On typical loads, the motors do not reach this current, but we use these transient values to calculate the worst-case scenario and maximum current needed. The total current from the motors is:

$$\text{(Eqn. 1)} \quad I_{totalmotor} = 2 * I_{drive} + I_{weapon} = 2 * 2A + 1.6A = 5.6A$$

The ESP32 will also draw a small amount of current of about 0.25 A. Thus, the total current draw is:

$$\text{(Eqn. 2)} \quad I_{total} = I_{totalmotor} + 0.25A = 5.6A + 0.25A = 5.85A$$

Thus, the total battery capacity needed for a 2-minute match is:

$$\text{(Eqn. 3)} \quad I_{total} * time = 5.85A * 2\,minutes * (1\,hour / 60\,minutes) = 195\,mAh$$

As such, using a 300 mAh 3S LiPo battery will be sufficient to power the robot for the duration of the match. It would also have the capacity to handle the occasional transient current spikes from the motors. The battery is chosen to be a 3S battery, as that is what the brushed motors we use are rated for. The Fingertech Switch is chosen as connecting and disconnecting the battery is simply from screwing in and unscrewing a screw. Using a screw rather than a normal switch means that random jostles during competition are less likely to shut down the robot.

The buck converter chosen is the LMR51430YFDDCR, as it is specified to allow for a 4.5 V to 36 V input and provide up to 3 A of output current. Since our battery is nominally 11.1 V, it is within the allowed range, and the 3 A current limit is suitable for the current draw of the

ESP32-S3-WROOM. The schematic used for the buck converter is shown in Figure 5, which follows the typical application schematic shown in its datasheet [3].

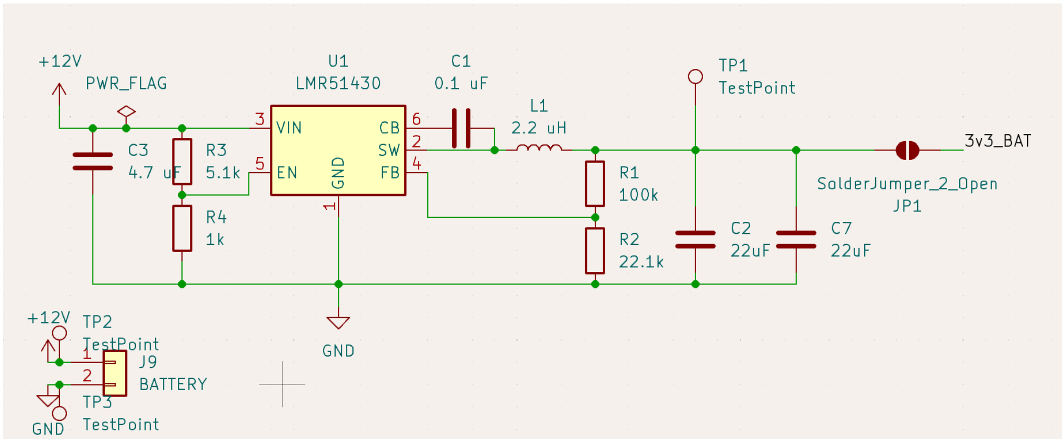

Figure 5: Buck converter schematic.

We had originally used the LMR51430XDDCR, which has a switching frequency of 500 kHz and uses PFM, as compared to the switching frequency of 1.1 MHz and FPWM of the eventual LMR51430YFDDCR. We originally chose the lower switching frequency and PFM operation as these decrease switching loss within the buck regulator [3]. However, we found that the output voltage ripple had a maximum peak-to-peak of 1.425 V, which is too great for our application, as can be seen in Appendix B.1 Figure 14. Switching to the higher frequency and FPWM results in lower output voltage ripple.

Table 1: Power Subsystem Requirements and Verification

Requirements	**Verification**
• 11.1 V 3S battery must provide a stable 3.3 V ± 0.3V to the ESP32 through the buck converter.	• Measure the output of the buck converter on an oscilloscope to ensure it stays within 3.0 - 3.6 V. RESULT: We measure an average voltage output of 3.25V with a peak to peak of 88 millivolts, well within the acceptable range. This can be seen in Appendix B.1 Figure 15.
• 3S battery must be capable of providing power for all systems over the 2-minute match duration and must not drop below 9.6 V after 2 minutes of operation.	• Measure the voltage of the battery and ensure that it is fully charged at around 12.6 V using a multimeter. • Connect the battery to the robot and power all systems. • Drive the robot around and use the

	weapon for 2 minutes. ● Measure the final voltage of the battery and ensure it has not dropped below 9.6 V using a multimeter. RESULT: After 2 minutes of continuous driving from a fully charged 12.523V battery, we find the measured voltage to be 12.116V. The measurements can be seen in Appendix B.1 Figure 16.

2.3.2 Controller Subsystem

The controller subsystem consists of an ESP32-S3-WROOM, a PC, and an Xbox controller. It is responsible for taking in user input and sending out the corresponding signals to the drivetrain and weapon subsystems. The controller is directly connected to the PC and takes in joystick and button inputs. The PC then transmits the data wirelessly to the ESP32-S3-WROOM, which sends PWM signals to the motor controllers of the drivetrain and weapon subsystems and is powered by 3.3 V from the power subsystem.

We chose the ESP32-S3-WROOM microcontroller due to its built-in Bluetooth and Wi-Fi modules and its many GPIO pins. The communication protocol we use is Bluetooth Low Energy (BLE). As shown in Appendix B.2 Figure 17, our ESP32-S3-WROOM begins by initializing itself as a server. Following the GATT(Generic Attribute Profile) communication, the server organizes data into services and characteristics, each with its own unique ID. It broadcasts advertising packets for our PC to scan and discover. On the PC side, it uses a Python script to detect the ESP32-S3-WROOM by connecting to its MAC address and then assigns the PC as the client. The PC deciphers the tethered Xbox controller inputs and writes the joystick values and button data to the server's characteristic. Finally, the ESP32-S3-WROOM is able to read these new values and change the PWM of the drivetrain and weapon accordingly.

To convert Xbox joystick values to PWM, we use an arcade drive where one axis controls throttle speed and the other controls rotation on a single joystick. The joystick inputs are divided into 4 quadrants. In each quadrant, a different function based on the amount of throttle and rotation sets the speed and direction of the left and right motors. There is also a deadband set for extremely low speed inputs to account for joystick drift when returning to the central position. Then there is a jump to almost 60% duty cycle PWM, which is the experimentally tested duty cycle required to start moving the entire load of the robot, before scaling linearly to a maximum speed input. The graph of this relationship for moving straight forward can be seen in Appendix B.2 Figure 18.

Table 2. Controller Subsystem Requirements and Verification

Requirements	Verification
• The ESP32 must be able to connect to the PC via BLE with delays of no more than 1000 milliseconds from a PC input to the resultant output of a motor.	• Connect the PWM output pin to an oscilloscope. • Set up the camera to have the controller and oscilloscope in frame. • Move the controller to send a non-zero speed input. • Measure the time it takes for the PWM signal to show when the controller stick is moved. RESULT: After three trials of timing the latency from the controller to changing the PWM, we find the average measured latency to be 135 milliseconds.
• The ESP32 must be able to receive instructions from the PC and send out the corresponding signals to the motor drivers to control motor speeds within ± 10% accuracy.	• Have the controller send an instruction for the motor to drive at a specific speed. • Measure the generated PWM signal using an oscilloscope and verify that the wave duty cycle is within ± 10% of the expected duty cycle. RESULT: We find an average error of 0.88% and a maximum error of 2.35%. The graph of expected vs. measured duty cycle can be seen in Appendix B.2 Figure 18.

2.3.3 Weapon Subsystem

The weapon subsystem consists of a DRV8871 motor driver and Polulu brushed motor with a 195 to 1 gear reduction. The motor driver will take PWM signals from the controller subsystem to set the rotational speed and direction of the fighting tool. The motor driver and the brushed motor are powered by 11.1 V directly from the battery.

The Polulu brushed motor is chosen due to its high torque rating of 1.7 kg*cm [1]. To determine the minimum torque required to lift a mass, we can use equation 4:

$$\text{(Eqn. 4)} \quad T_{min} = Mass * Length / Reduction$$

Since the maximum lifting mass is 0.907 kg or 2 lb with a maximum arm length of 15 cm and an additional gear reduction of 30:1 in the mechanical subsystem, we find a minimum torque requirement of 0.4535 kg*cm which means that the motor of choice is sufficient for the task of lifting an opposing robot of 2 lb.

The DRV8871 is chosen as it has a simple control interface consisting of 2 PWM inputs and has internal current regulation [4]. Depending on which input is set at ground and which one has a PWM input, the connected motor spins in different directions and at different speeds depending on the PWM duty cycle. The H-bridges are already integrated within the chip, so no external MOSFETS are needed, reducing the overall size needed for the PCB. It has a peak current of 3.6 A, making it suitable for the 1.6 A stall current of the motor.

We originally planned to use a brushless motor system with a Repeat Robotics hubmotor for a vertically spinning weapon. The motor controller that would've been used is the DRV8340, which can be programmed via SPI and can convert an input PWM speed signal to 3-phase AC to control the brushless motor [5]. As the chip is a gate driver, the external MOSFETs were chosen to be FDS6680A NMOS chips due to their high current rating of 12.5 A [6]. The PCB for this system can be seen in Appendix A.3. However, due to time constraints for tuning all the parameters, we decided to pivot to the simpler brushed motor system.

Table 3: Weapon subsystem requirements and verification

Requirements	**Verification**
• The weapon must be able to lift 2 lb	• Get a 2 lb object and verify its weight with a scale. • Put the object on the lifting mechanism and lift it until it is off the ground. RESULT: The weapon is able to lift a 2 lb water bottle as seen in Appendix B.3 Figures 19 and 20.
• The weapon must stop within 10 seconds of losing Bluetooth connection.	• Have the weapon in motion and then disconnect Bluetooth on the PC. • Use a timer to measure how long it takes for the weapon to stop to verify if it is within 10 seconds.

	RESULT: Weapon movement stops within a second of disconnecting Bluetooth. It averages about 0.1 s.

2.3.4 Drivetrain Subsystem

The drivetrain subsystem consists of two DRV8871 motor drivers and two Repeat Mini Brushed Mk2 motors. Similar to the weapon subsystem, the DRV8871 motor drivers take PWM signals from the controller subsystem, and the motor drivers and brushed motors are powered by 11.1 V from the battery.

The Repeat Mini Brushed Mk2 motors are chosen for our speed requirements. The free speed rotation of the motor is given to be 1220 RPM [2]. The wheels of our design have a diameter of 32 mm or 1.26 inches. Solving for the circumference will allow us to convert from angular velocity to linear velocity of miles per hour. We can use the following equation:

$$\text{(Eqn. 5)} \quad Velocity\ [mph] = \omega_{rpm} * \pi D\ [in] * \frac{60[min]}{1[hr]} * \frac{1\ [mile]}{63360[in]}$$

We find the velocity is around 4.57 miles per hour. Given our initial high-level requirement in section 1.4, this should be sufficient to reach 3 mph even with external factors such as load, friction, and air resistance.

The DRV8871 is chosen for the same reasons as it was chosen for the weapon subsystem. Additionally, using the same motor driver allows us to use similar code when programming and spend less time learning how to operate another motor driver. The drive motors have a peak current of 2 A, making the 3.6 A peak of the chip suitable as well.

Similar to the weapon subsystem, we originally planned to use a brushless system with DRV10983 motor drivers and Repeat Tangent Drive Motors. The DRV10983 has integrated MOSFETS, is tunable via I2C, and can convert an input PWM signal to 3-phase AC to control a brushless motor [7]. The PCB for this system is shown in Appendix A.3. However, after receiving the Repeat Tangent Drive Motors, we measure the phase-to-phase resistance of the motor to be around 0.41 Ω, which is outside of the 0.6 Ω to 38 Ω application range of the DRV10983 [8]. We then switched to the MCF8316A motor driver, which has similar functionality with the addition of FOC control during closed-loop operation and was recommended on Texas Instruments forums. The PCB designed for this system is shown in Appendix A.4. However, due to the chip being a QFN chip, we were unable to solder it ourselves and reordered it to be assembled by JLCPCB. This resulted in significant delays in tuning the motor controller to our motors, causing us to switch to the simpler brushed drive system.

Table 4: Drivetrain subsystem requirements and verification

Requirements	Verification
• The drivetrain must allow the robot to reach 3 mph.	• Send max speed PWM signals to the drive motors. • Use a slow-motion camera to capture the robot travelling 10 feet and measure the time taken. RESULT: The measured speed of the robot is 3.24 mph (4.74 feet per second).
• The drivetrain must stop all movement within 3 seconds if BLE connection is lost.	• Start with the robot moving forward at a constant speed, and then turn off the PC's Bluetooth functionality. • Measure the time it takes for the robot to come to a stop. RESULT: On average, the robot stops in 0.2 s.

2.3.5 Mechanical Subsystem

The chassis of the robot is made out of 3D printed PLA+ as the material is durable and more reliable when 3D printed. It holds all of the electronic components, including the PCB, motors, and battery. This is the main body of the robot and is used to protect the electrical components. The lifting/grabbing weapon is also 3D printed with the same material and attached to the weapon motor through gears and linkages.

Table 5: Mechanical subsystem requirements and verification

Requirements	Verification
• The chassis must have electronics protected and be capable of handling external impacts from opponents to a reasonable degree. There should be no cracks exceeding 1 in. on the chassis and no solder connections lost on the PCB.	• Battery and electronics should not be exposed. • There should be no wires hanging out from the robot. RESULT: Nothing is exposed by inspection.
• The weapon must be capable of handling internal stresses of its own	• The weapon motor, along with the weapon claw arm, will lift a 2-lb

mass, along with 2 lb of lifted mass. There should be no cracks exceeding a length of 1 in.	object for 10 seconds and be inspected for cracks afterward. RESULT: No cracks exceeding 1 in. long are found.
• The total weight of the entire robot must be under 2 lb.	• After final assembly, weigh everything on a scale and ensure that it is under 2 lb. RESULT: Weighs in at 1.73 lbs (785 grams) as seen in Appendix B.4 Figure 21.

3. Cost and Schedule

3.1 Cost Analysis

1. Labor:
    a. $30 per hour (Per person)
    b. Hours to Complete: 60 hours
    c. TOTAL = ($30/hour) x 3 x 60= $5400
2. Parts:

Table 6: Cost table

Description	Manufacturer	Quantity	Cost	Link
Repeat Mini Brushed Mk2	Repeat Robotics	2	$19	https://repeat-robotics.com/buy/brushed/?gQT=3
FingerTech Mini Power Switch	FingerTech Robotics	1	$8.43	https://www.fingertechrobotics.com/proddetail.php?prod=ft-mini-switch
Brushed 20D Metal Gearmotor	Pololu	1	$43.95	https://www.pololu.com/product/3481
3S 300mAH LiPo Battery	Amazon	1	$26.59	https://www.amazon.com
Duramic PLA+	Amazon	1	$16.99	https://www.amazon.com
Assorted M3 Screws	Amazon	1	$24.68	https://www.amazon.com
4.7 µF (0805)	ECE Shop	2	$0.77	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
1k Ω (0805)	ECE Shop	3	$0.18	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
5.1k Ω (0805)	ECE Shop	2	$0.10	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
.1 µF (0805)	ECE Shop	10	$0.671	http://courses.grainger.illinois.

				edu/ece445/lab/eshop_smd_request.pdf
100k Ω (0805)	ECE Shop	1	$0.24	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
10 µF (0805)	ECE Shop	7	$0.45	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
1 µF (0805)	ECE Shop	7	$0.671	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
2.2k Ω (0805)	ECE Shop	6	$0.11	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
ESP32-S3-WROOM	ECE Shop	1	$5.49	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
SS8050-G	ECE Shop	2	$0.24	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
SP0503BAHTG	ECE Shop	1	$0.70	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
Micro USB-B Connector	ECE Shop	1	$0.56	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
33 µF (0805)	ECE Shop	1	$0.91	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
10k Ω (0805)	ECE Shop	6	$0.25	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
Switch Tactile	ECE Shop	2	$1.96	http://courses.grainger.illinois.edu/ece445/lab/eshop_smd_request.pdf
LMR51430XDD	Texas	1	$1.29	https://www.digikey.com/en/pr

CR	Instruments			oducts/detail/texas-instruments/LMR51430XDDCR/17878357
DRV8871	Texas Instruments	3	$2.16	https://www.digikey.com/en/products/detail/texas-instruments/DRV8871DDAR/5722182?gQT=2
CB2012T470K	Taiyo Yuden	2	$0.15	https://www.digikey.com/en/products/detail/taiyo-yuden/CB2012T470K/2230241
CBC2012T470M	Taiyo Yuden	2	$0.15	https://www.digikey.com/en/products/detail/taiyo-yuden/CBC2012T470M/957985
BRL2012T470M	Taiyo Yuden	2	$0.15	https://www.digikey.com/en/products/detail/taiyo-yuden/BRL2012T470M/1788957
RMCF0805FT22K1	Stackpole Electronics	2	$0.10	https://www.digikey.com/en/products/detail/stackpole-electronics-inc/RMCF0805FT22K1/1760211
FT232RNL	FTDI	1	$4.80	https://www.digikey.com/en/products/detail/ftdi-future-technology-devices-international-ltd/FT232RNL-REEL/16836162
C0805C473K5RACTU	Kemet	2	$0.11	https://www.digikey.com/en/products/detail/kemet/C0805C473K5RACTU/411165
LM3940IMPX-3.3/NOPB	Texas Instruments	2	$1.63	https://www.digikey.com/en/products/detail/texas-instruments/LM3940IMPX-3-3-NOPB/367097
0805CS-562EJFS	Delta Electronics / Components	2	$0.28	https://www.digikey.com/en/products/detail/delta-electronics-components/0805CS-562EJFS/9764087
NR6045T470M	Taiyo Yuden	1	$0.29	https://www.digikey.com/en/products/detail/taiyo-yuden/NR6

				045T470M/1788972

3. Total Cost: ($5607.937)
   a. Labor: **$5400**
   b. Components: **$207.937**

3.2 Schedule

Table 7: Schedule

Week	Description
3/3	● Design and place orders for the first round of PCB parts (Evan) ● Order all electrical surface mount components (Evan) ● Order all motors (Allan) ● Prepare for the first breadboard demo ○ ESP32 Bluetooth should work (James) ○ ESP32 should be able to generate PWM waves (James)
3/10	● Breadboard demo (All) ● Start work and design of the chassis for the robot (Allan) ● Second wave of PCB orders (Evan) ● First wave of PCB parts arrives ○ Solder all components to the PCB and begin tests (All)
3/17	SPRING BREAK
3/24	● Test PCB (All) ● Program ESP32 for the drive motors controller (James) ● Program ESP32 for weapon motor controller (Evan)
3/31	● Complete individual progress reports (All) ● Finish programming (All)
4/7	● Final and fourth round of PCB order (Any last revisions must be made here to the PCB design) (Evan) ● Order any last components needed (All) ● The robot should be fully assembled (Allan) ○ Electronics soldered ○ Fully programmed and functions as intended ● Mechanical design changes, program bugs, or any final electrical changes must be completed by this week
4/14	● Complete team contract assessment (All) ● Robot completed and fully functional (All)

4/21	• Complete mock demo (All)
4/28	• Complete final demo (All) • Complete mock presentation (All)
5/5	• Complete final presentation (All) • Complete final papers (All)

4. Conclusion

This project successfully demonstrates the design and development of a fully functional two-pound antweight combat robot capable of grabbing and lifting opponents in a competitive environment. The robot meets all specified constraints, including weight, control via BLE, 3D printed components, and a reliable power shutdown mechanism. The system integrates custom PCB design, wireless communication, and mechanical functionality into a cohesive and robust platform. The lift mechanism was effectively optimized to handle at least two pounds of weight, and the drivetrain reached a top speed of 3.24 mph.

Though we had many successes, some issues arose during testing. For instance, the latency introduced by BLE communication, although minimized, may still affect responsiveness under certain conditions. Although the 135 ms delay meets our high-level requirement, we found this delay quite detrimental during the actual competition. To address this, future iterations could reduce delays by communicating through Wi-Fi or directly to another ESP32 module using ESPNow protocols. Another issue during testing in a combat environment was the general slow nature of the lifting arm due to its high torque requirements, resulting in speed as a tradeoff. A way to improve the speed of the lifting arm would be to utilize a more powerful motor that can naturally operate at a higher torque, resulting in fewer gear reductions, allowing increased speed and a more responsive control against opponents. An additional improvement that can be made in the future is to swap out our brushed systems with our original brushless designs after sufficient time to tune them.

In a broader context, this project highlights the evolution of the combat robot space, transitioning from conventional industrial processes needed to fabricate the parts and equipment used in these large-scale combat robots to a low-cost, rapidly manufacturable, and modular system that affordable household 3D printers, PCB manufacturing, and open-source software provide. The 3D printed design, modular electronics, and wireless control approach promote accessibility and sustainability in small-scale robotics.

4.1 Ethics

The IEEE Code of Ethics Section I [9] states that we disclose any factors that may endanger the public or the environment. One such factor is the use of an active weapon or fighting tool. If carelessly handled, the fighting tools of these robots could cause harm that could be lethal. Therefore, proper safety measures on our part will be taken with the utmost importance, guaranteeing the safety of the public and its members, such as designated work zones and safety procedures when handling combat robots.

4.2 Safety

In combat robotics, safety is the most important aspect. There are some variations in rules for safety from competition to competition but here are some of the most important based on NHRL rules [10]:

1. The robot should not be tested (with an active weapon) unless placed inside an enclosed test arena. This is to keep you and everyone else safe from coming into contact with the fighting tool.

2. Since the requirements of this project call for wireless Bluetooth or Wi-Fi connections to the robot, it should be expected that the robot automatically shuts down to a safe state if the connection between the PC and the robot is lost.

3. Batteries should never be left charging unattended.

References

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Appendix A: PCB Designs

A.1 Controller PCB Schematic and Layout

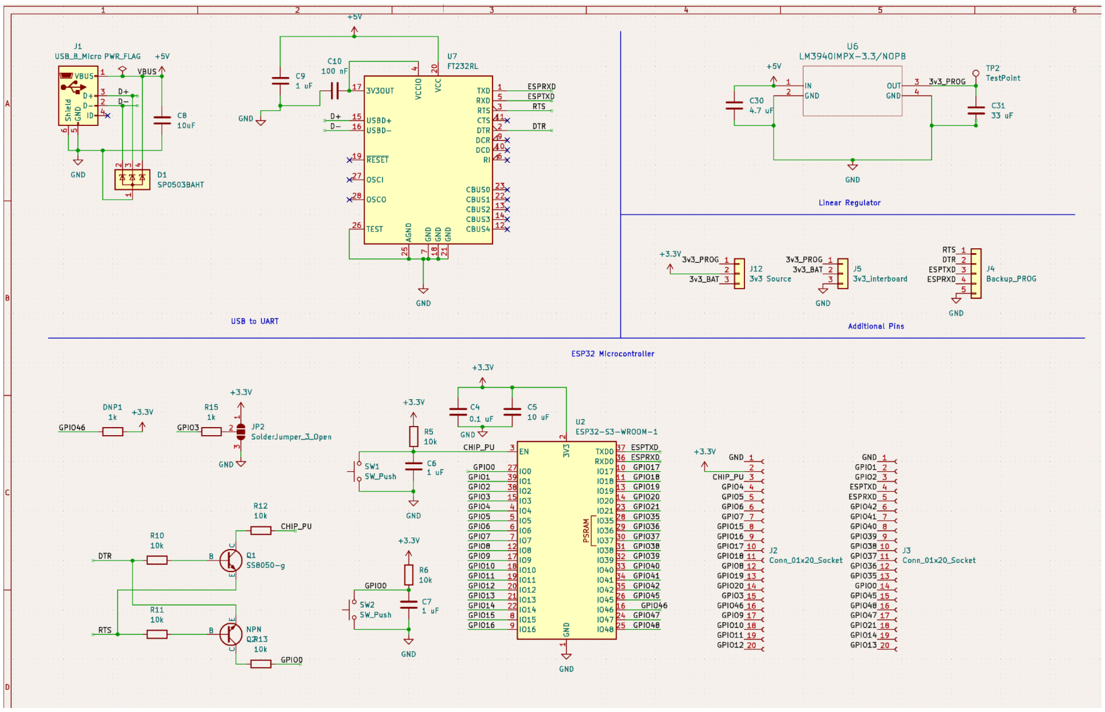

Figure 6: Controller PCB schematic

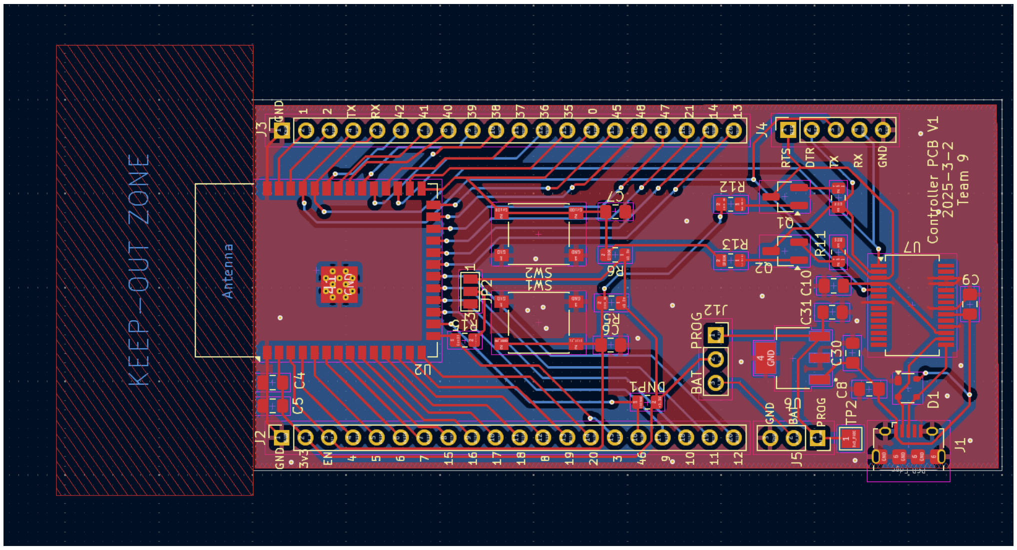

Figure 7: Controller PCB Layout

A.2 Motor PCB Schematic and Layout

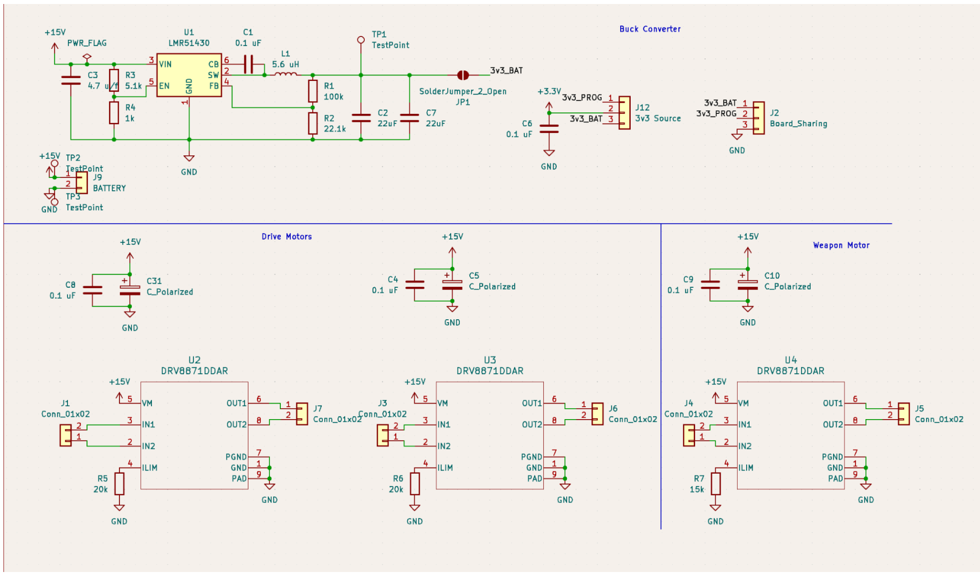

Figure 8: Motor PCB schematic

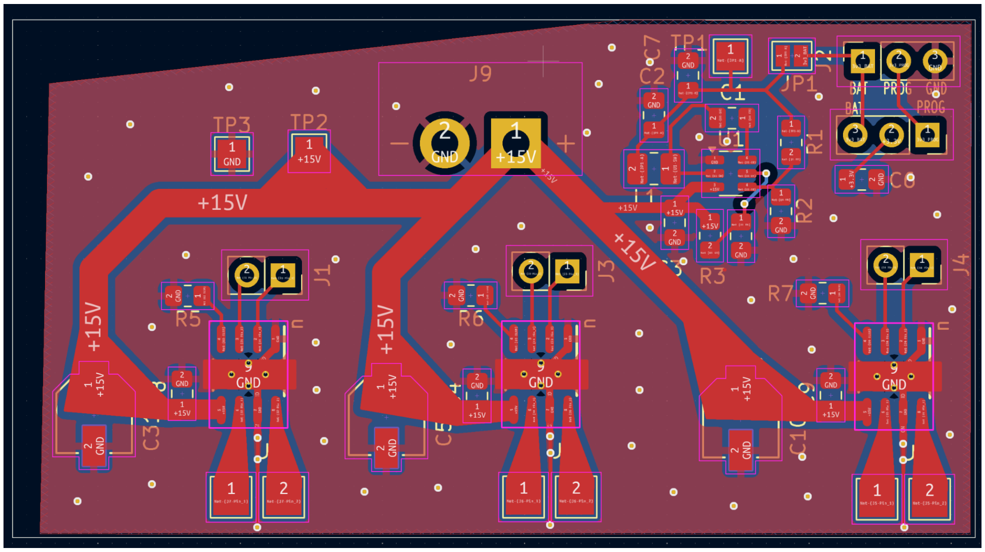

Figure 9: Motor PCB schematic

A.3 Old Motor PCB Schematics and Layouts

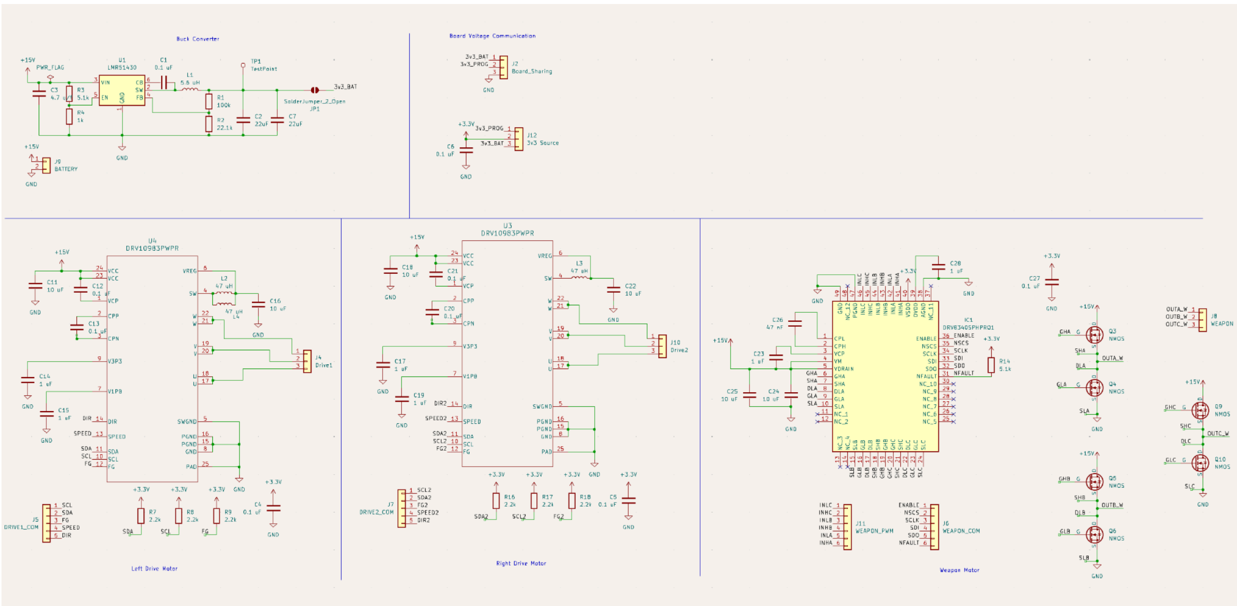

Figure 10: First round schematic of motor PCB.

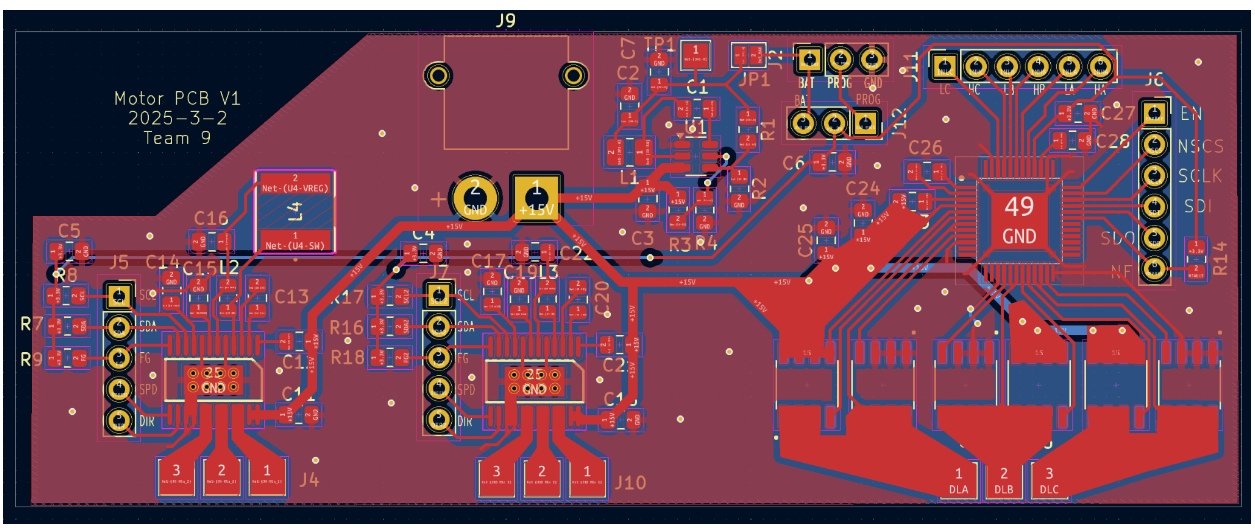

Figure 11: First round PCB layout of motor PCB.

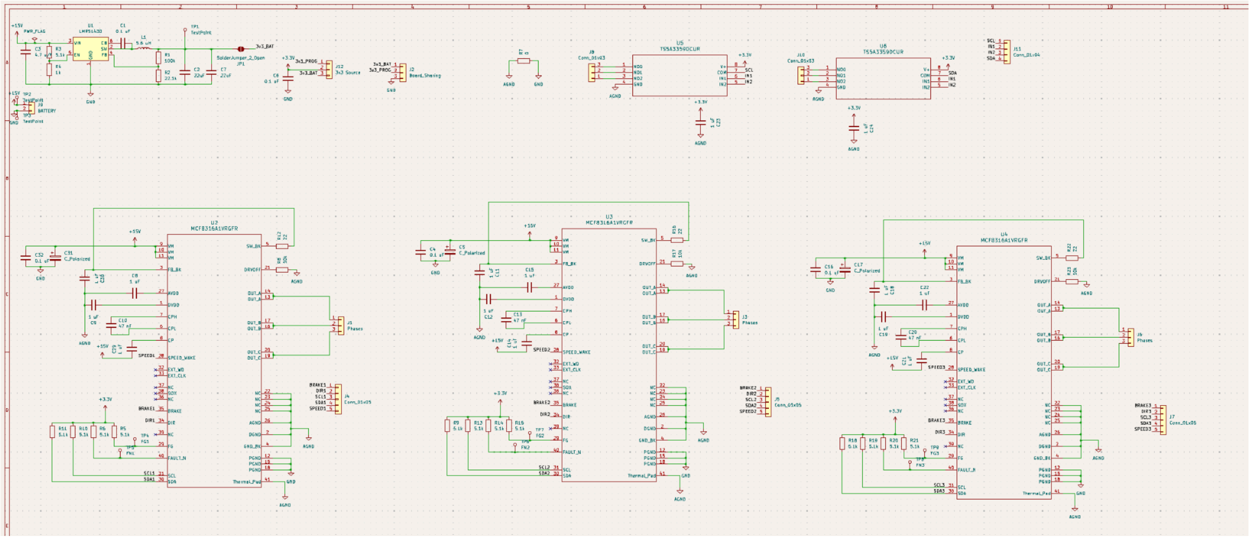

Figure 12: MCF8316A motor PCB schematic.

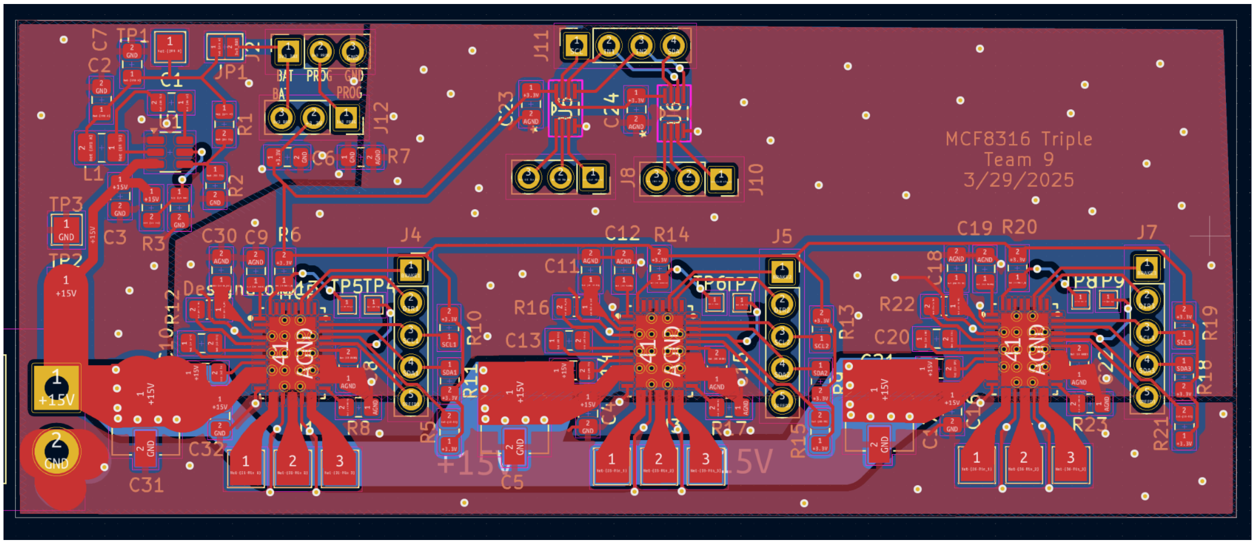

Figure 13: MCF8316A motor PCB layout.

Appendix B: Requirements and Verification

B.1 Power Subsystem

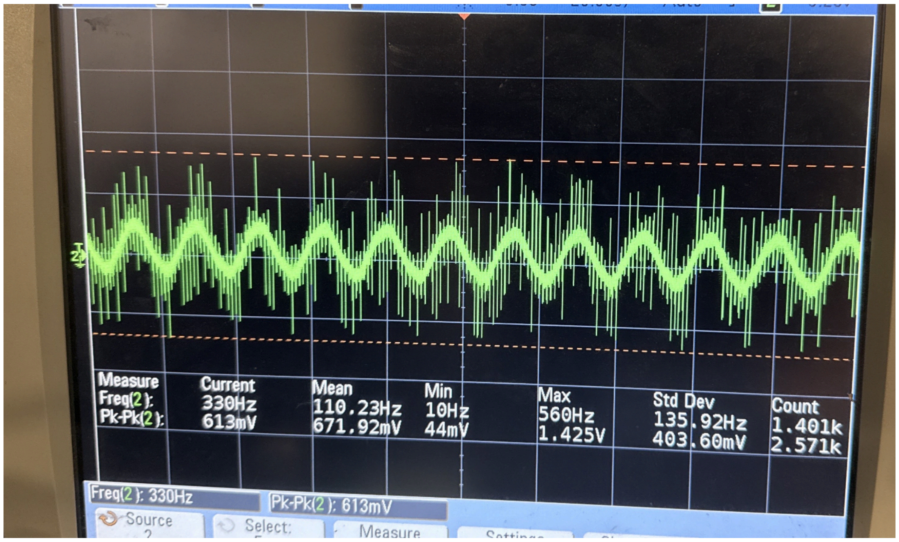

Figure 14: Buck regulator output with LMR51430XDDCR

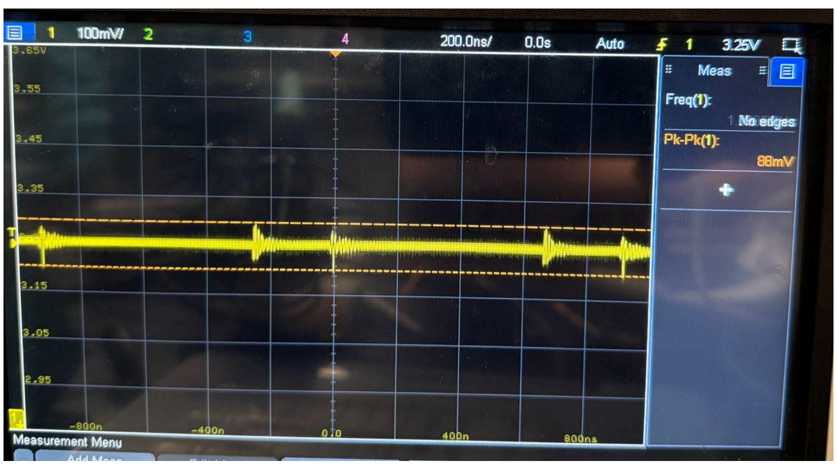

Figure 15: Buck regulator output with LMR51430YFDDCR

Figure 16: Battery voltage before (left) and after (right) of 2 minutes of robot operation

B.2 Controller Subsystem

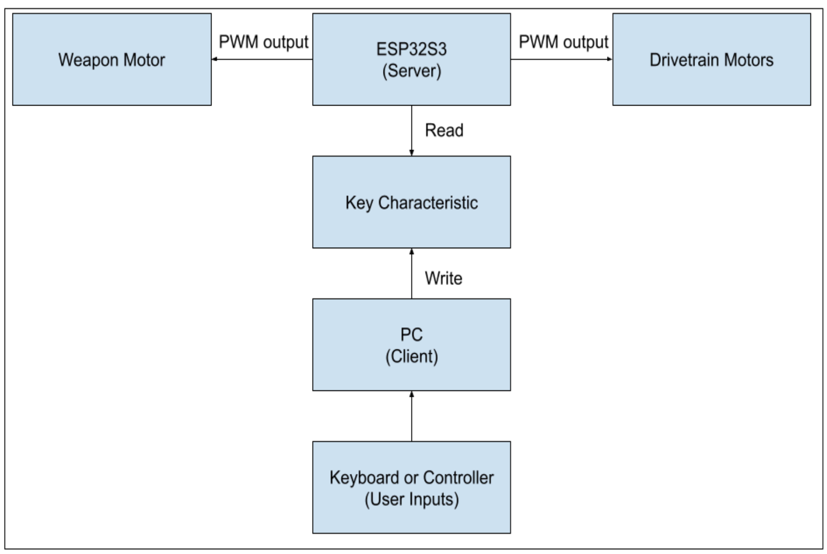

Figure 17: BLE operation block diagram

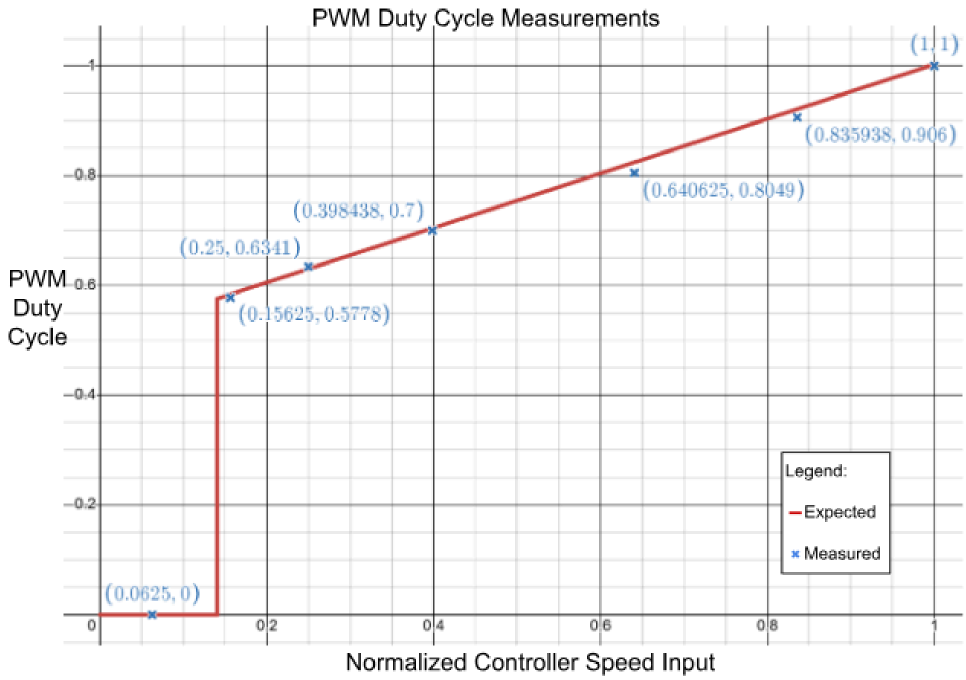

Figure 18: PWM duty cycle expected curve and measurements

B.3 Weapon Subsystem

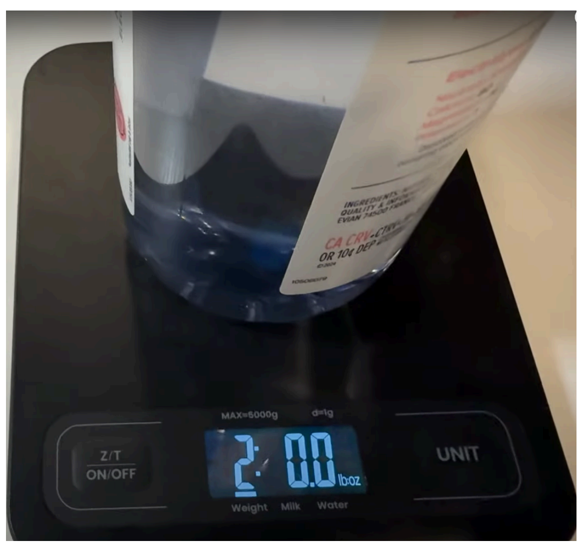

Figure 19: Bottle weight measurement of 2 lb

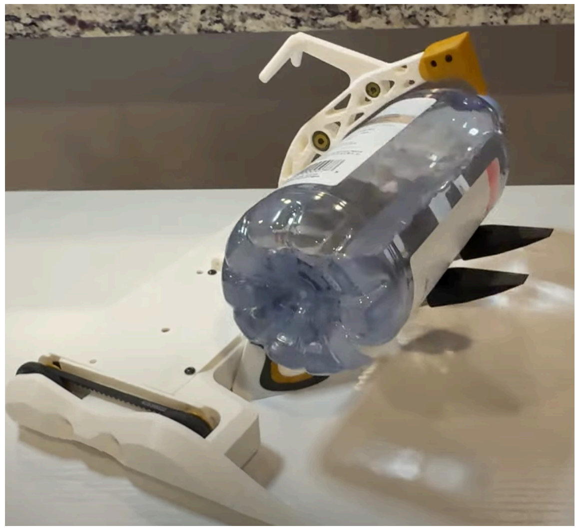

Figure 20: Robot picking up 2 lb bottle

B.4 Mechanical Subsystem

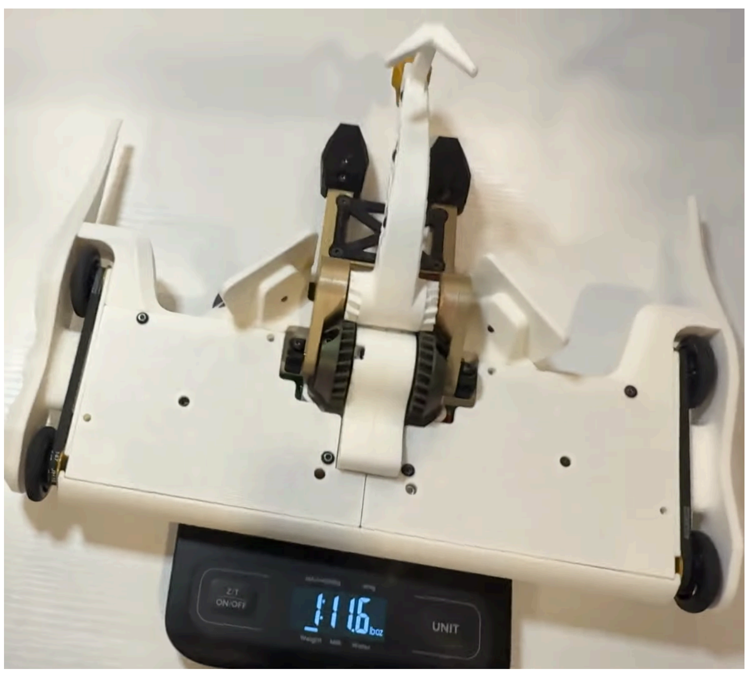

Figure 21: Weight measurement of the robot of 1 lb 11.6 oz.