Antweight BattleBot

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Project #41

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1. Introduction

1.1. Problem

Figure (1): Battlebot Stadium

Eight teams will compete with their own battlebots in a tournament with the goal of dominating the opposing robot. Two battlebots will be placed in a ten-by-ten foot walled-off arena shown in figure (1) for two minutes. A winner is deemed when a battlebot is disabled or through a judge's decision at the end of the time limit. In this version of battlebot, the robot must be less than 2 lbs, 3D printed from plastics, contain a custom PCB that connects the microcontroller to a remote-control system, use a motor or pneumatic fighting tool, and have easy manual/automatic shutdown. Other rules and constraints are detailed in the National Robotics Challenge 2025 Contest Manual [1].

1.2. Solution

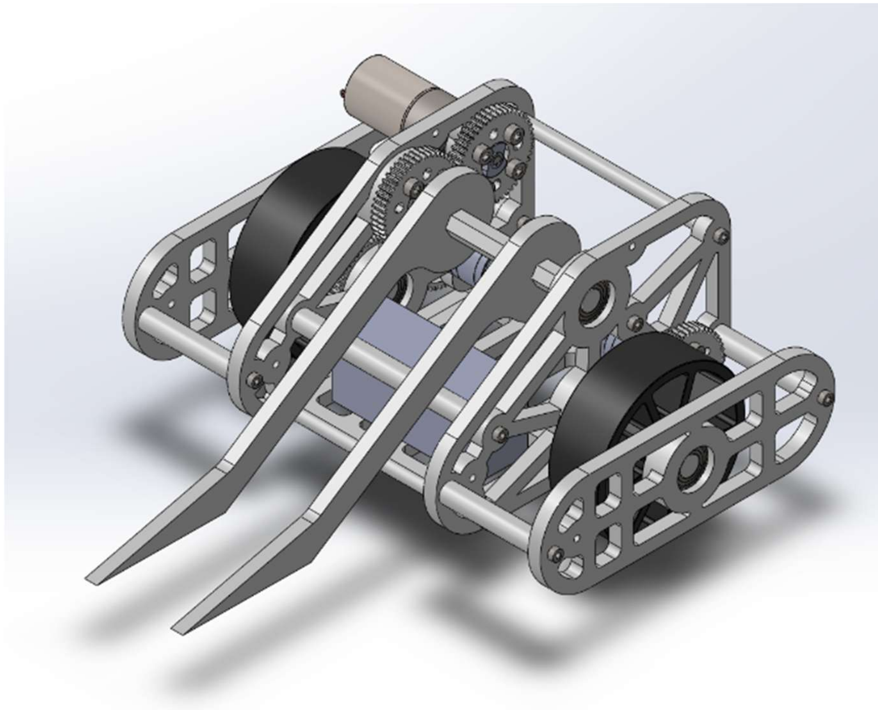

Figure (2): 3D CAD Model of Battlebot

We will create a battlebot with the objective of controlling the opposing battlebot. Our goal is to win by a judge's decision at the end of the two-minute time limit. Our battlebot will be equipped with a lifting mechanism to lift the opposing battlebot into the air. When suspended in the air, the opposing battlebot will be unable to move or to attack our battlebot. To successfully achieve this mechanism, our lifting arm will be required to be strong enough to lift the other robots. Additionally, we will employ defense measures to keep our battlebot safe when approaching and after lifting the opposing battlebot. Our battlebot will have a strong frame that encompasses our drivetrain motors, lifting motor, wheels, PCB, and battery. The controlling weapon system paired with a strong and durable design should prove to be a tough challenge for any battlebots we come up against.

1.3. Visual Aid

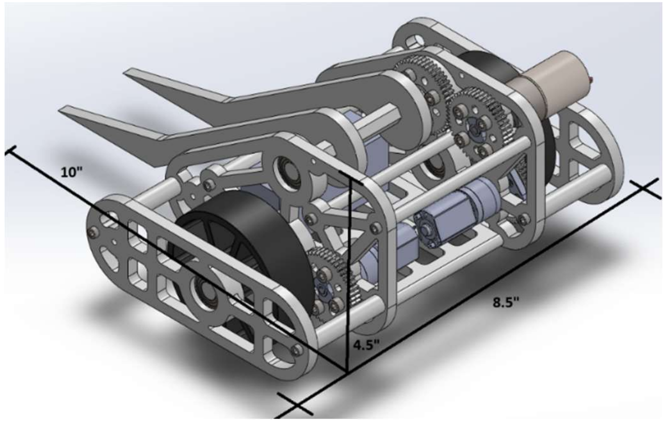

Figure (3): 3D CAD Model of Battlebot with Dimensions

The physical model of our battlebot can be seen in figure (1). While the design of the robot will go through more iterations, the overall design will be similar to that seen above. Currently under the assumption that the components are 3D printed at 100% infill it weighs 1.95 lbs and is 8.5” x 10” x 4.5” and is within the given requirements shown in figure (3). We will go into more detail about physical design in the latter part of this report.

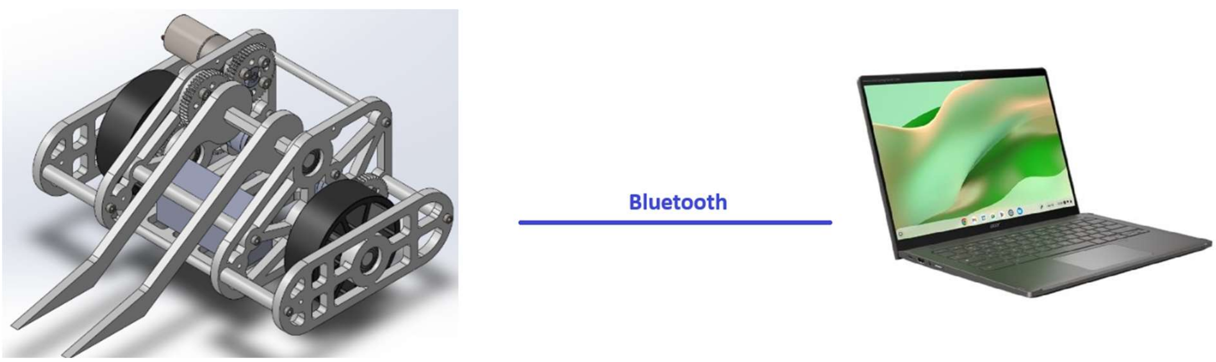

Figure (4): Visual Aid of Battlebot User Interface

The robot will be able to be controlled by the user remotely from their computer. This is done through a Bluetooth connection between the computer and the Bluetooth chip on the robot.

1.4. High-Level Requirements List

Our high-level requirements are quantitative goals that we plan on achieving at the end of the project.

1. Bluetooth remote control of the robot within at least a 15ft range.
2. The robot should automatically disable within 500ms of the connection being lost
3. The robot should drive at a speed of at least 5 ft/s and operate a lifter weapon capable of lifting at least 2 lbs.

All these requirements are easy to test utilizing simple measuring and timing tools. After the completion of our project, our battlebot should be able to successfully perform all these requirements.

2. Design

2.1. Physical Design

2.1.1. General Design Overview

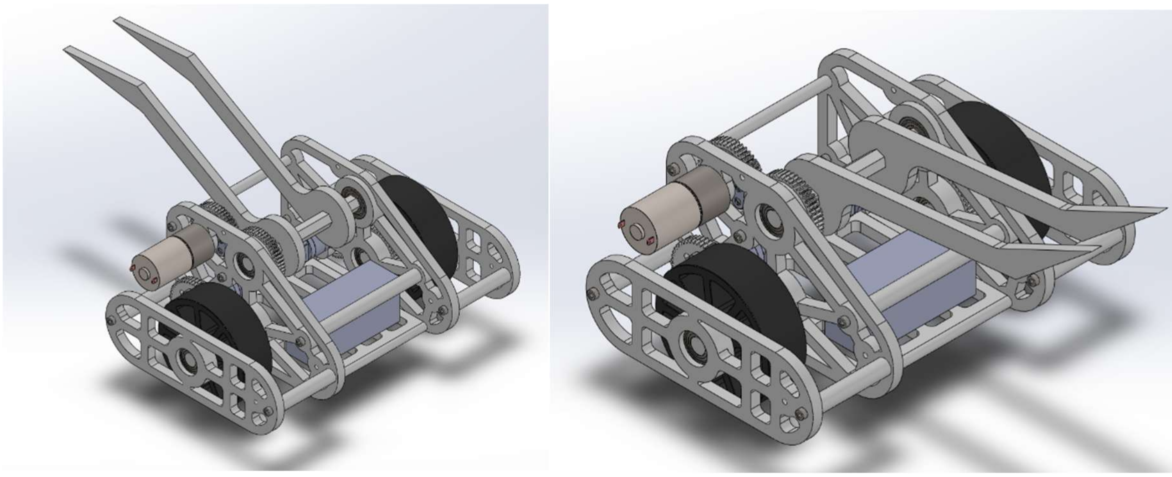

Figure (5): Isotropic Views of Physical Model

The physical design of our battlebot is crucial to its success. By maximizing our weapon system and preventing damage to vital components, we have a design we believe can win this battlebot competition. The durability and defensive ability of our battlebot will be crucial to its survival. We will need to approach and lift the opposing battlebot without taking damage. Our battlebot will employ protective safety measures to protect the vital components of our battlebot. It is important to keep the battery and PCB protected because our battlebot will not operate without them. Our battery and PCB will be placed inside of the frame. The frame will also entirely surround the wheels to keep the driving system safe.

Figure (6): Battlebot Whiplash

Within battlebots there are 2 types of weapons (Lifters, Kinetic Spinners) generally used. We chose a weapon system inspired by the lifting mechanism on the battlebot Whiplash shown in figure (6) for a few reasons. First, because of the weight class and restrictions on the use of metal for offensive and defensive purposes, we believe that kinetic spinners will be less effective. Second, we decided to use a lift motor rather than pneumatics because of the weight constraint. Weight constraints impact our ability to place an onboard compressor meaning that our robot would need to pre-pressurized and have a limited number of lifts. Pneumatics also require an air tank and solenoid on top of a pneumatic cylinder. These component weights quickly add up and would require severe compromises in other systems. Our approach to the lifter system consists of two lifter prongs that will get under the enemy robot and lift them up. These prongs will also serve as a way to self-right our robot in the event it is flipped over.

Figure (7): Battlebot Copperhead

Drive Train	Mobility	Pushing Power
H Drive		
Mecanum		
Tank Drive		

Figure (8): Drivetrain Decision Matrix

Our drivetrain configuration is a 2-wheel Tank Drive inspired by the battlebot Copperhead shown in figure (7). We initially considered a few different drive trains like H-Drive (3 Motors Required), Mecanum (4 Motors Required), and Tank Drive (2 Motors Required). We quickly settled on Tank Drive because of its simplicity (weight and design) and resistance to being pushed around when compared to the other options at the cost of the mobility the other 2 options provide. We settled on a 2-wheel rather than

4-wheel Tank Drive because it allows the front of the robot to rest on the ground and to get underneath the enemy robot.

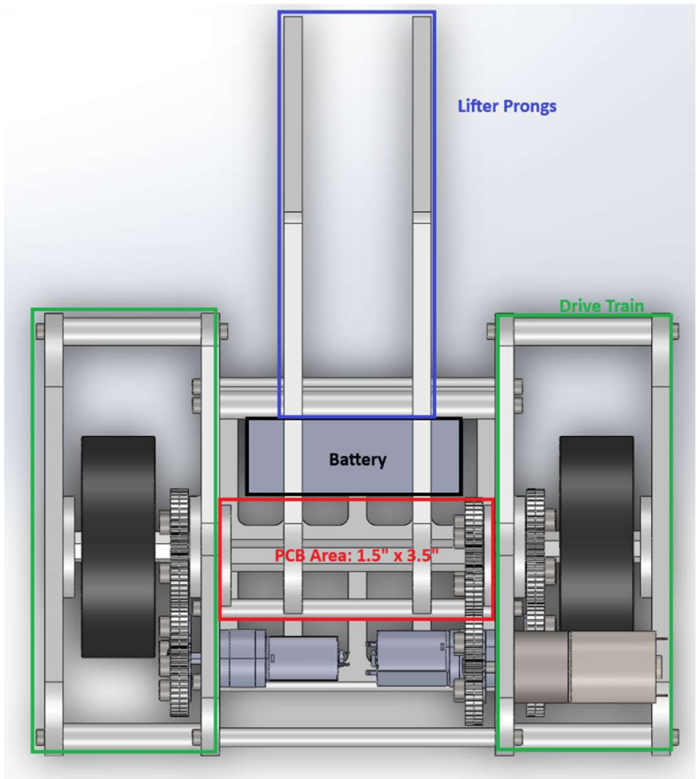

Figure (9): Birds Eye View of Physical Model

After performing an initial 3D model of the robot, we are able to design the PCB around the battery and motor placement, as well as determine a PCB size constraint. This allows us to place the battery connectors at the front of the PCB while the motor connectors in the back to reduce wire management problems.

2.1.2. Weight Consideration

The weight and size constraint of the event significantly influenced the design of the robot on top of the considerations previously discussed. First, we opted to utilize spur gear gearboxes that were built into the motors in order to save weight and area that would come with building an in-house solution. Second, the robot has pockets of material strategically removed around areas of low stress in order to save weight while still providing protection to fragile components. Third, the entire robot including gears will be built using ABS plastic because of its strength but also lighter weight. Finally, we chose lighter motors (also weaker) for the drivetrain when compared to the lifter arm because robot is designed to get underneath the opponent and lift them up rather than push them around.

2.1.3. 3D Printing Considerations

Material	Strength	Weight	Ease of Printing
PLA			
ABS			
PETG			

Figure (10): Material Decision Matrix

One of the key rules of this competition is that both the offensive and defensive capabilities of the robot must be 3D printed. As a result, the choice of material is very important to the robot's success. We considered the 3 main options (ABS, PLA, PETG) available to us and chose to use ABS as previously mentioned. The first consideration was the impact resistance and strength of the material. In this area ABS and PETG are generally regarded as having better characteristics in this area when compared to PLA [14]. The next consideration, weight, as previously mentioned, favored ABS over PLA and PETG [15]. Finally ease of printing is also very important and PLA is widely used because of its forgiving nature [14]. While ease of printing is an important property of the material, we have access to a high-quality printer (Bambu Labs X1 Carbon) that has great print quality for all the materials. Ultimately because of our access to high quality printer and physical consideration of our robot, we chose to utilize ABS.

Another consideration is that we are using FDM printers which deposit material layer by layer. As a result, this results in a strong direction when the force is applied perpendicular to the layer, but weak when parallel. For this reason, we will orient our 3D printed components accordingly with the expected direction of force applied to it.

2.1.4. Motor Considerations

Motor Considerations

Motor	Power	Size	Instant Torque	Implementation Difficulty
Brushless				
Brushed				

Figure (11): Motor Decision Matrix

For our battlebot, we considered 2 types of motors (Brushed and Brushless), and ultimately chose Brushed motor for an easier control scheme. We initially wanted to use Brushless motor because it is superior in weight, power, and size. However, further investigation led us to discover some drawbacks that ultimately pushed us to use Brushed motors. First is that the weight savings associated with a brushless motor is quickly negated by the need of bigger gearboxes to lower the RPM of the motor. Second, brushed motors have a higher starting torque that is desirable for our lifter weapon system [16]. Finally, the complexity of the control scheme which requires additional hardware to convert PWM to the 3 phases used by the brushless motors would add additional points of failure and potential blocks to our project [16].

2.2. Block Diagram

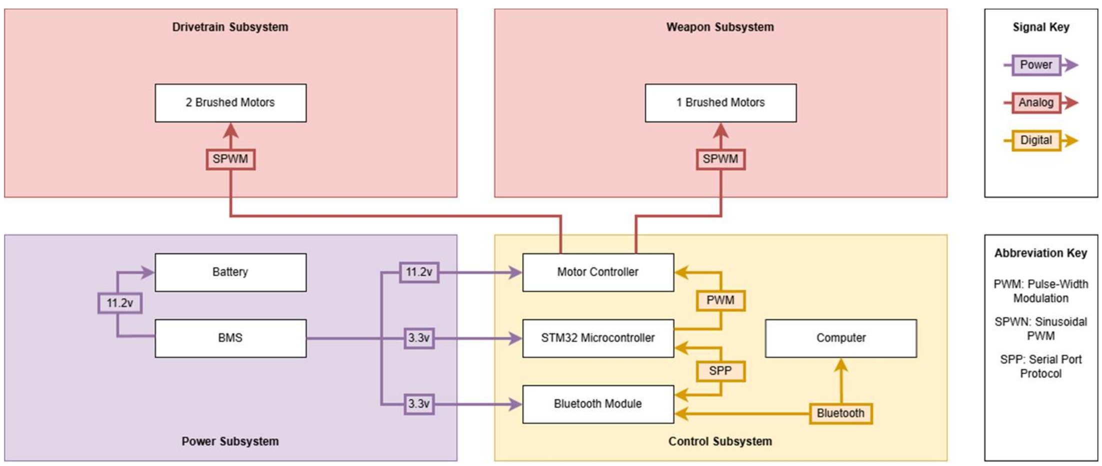

Figure (12): Block Diagram

Our battlebot design is organized into four main subsystems shown in figure (12). These subsystems are the power subsystem, control subsystem, drivetrain subsystem, and the weapon subsystem. The power system is to manage power delivery to all the different components of our battlebot. The motors demand a different voltage than the STM32 Microcontroller and HC-05 Bluetooth module to operate properly. Additionally, the microcontroller and the Bluetooth module demand a very stable power source. The control system will encompass the microcontroller, Bluetooth module, and motor control. With these components, we will be able to remotely control our battlebot and operate the motors through an H-Bridge. The drivetrain subsystem utilizes two high rpm brushed motors to be able to drive the battlebot. The weapon subsystem consists of one high torque brushed motor to be able to lift opposing battlebots.

2.3. Subsystem Overview and Requirements

2.3.1. Drivetrain Subsystem

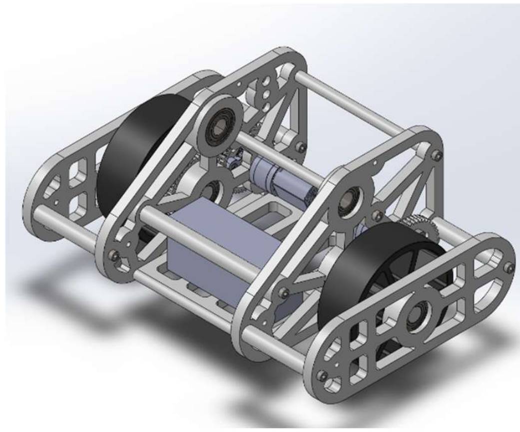

Figure (13): Drivetrain Physical Model

The drivetrain shown in figure (13) has a speed set at 5 ft/s for increased user drivability. Our initial idea was to set a drivetrain speed of 12 ft/s based on initial research of other combat robots in the similar class, however in the context of the arena size, it becomes apparent why that is too fast. An arena for this class is around 10 ft x 10 ft which means at 12 ft/s the robot will travel from end to end of the arena in 0.833 seconds. In our configuration our robot can travel across the arena in 2 seconds. Instead of prioritizing straight-line speed, we believe that prioritizing the turning speed of our robot to angle the front towards the enemy is more important. Calculations are detailed in figure (14).

Time to Travel from End to End of Arena 1 (s) = Arena Length (ft) / Robot Speed (ft/s) = 8 / 12 = 0.667

Time to Travel from End to End of Arena 2 (s) = Arena Length (ft) / Robot Speed (ft/s) = 8 / 5 = 1.6

Turning Speed (Radians/Second) = (Left Wheel Velocity (ft/s) – Right Wheel Velocity (ft/s)) / Wheel Base Length (ft)

= (5 - (-5)) / 0.458 = 21.834

Turning Speed (Revolutions/Second) = Turning Speed (Radians/Second) / Radians per Revolution = 21.834 / 2 * Pi = 3.474

Figure (14): Turning Speed Calculations

The drivetrain consists of 2 brushed motors that will be appropriately geared in conjunction with the wheels to give a top speed of at least 5 ft/s. The 508 RPM Mini Econ Gear Motor that we plan on using has 508 rpm and torque of 0.173 ft-lbs. [2]. With three-inch diameter wheels, 508 rpm corresponds to 6.649 ft/sec which satisfies part of the third task in our high-level requirements. Calculations are detailed in figure (15).

Motor Revolutions Per Second = Revolutions Per Minute / Seconds Per Minute = 508 / 60 = 8.466

Wheel Circumference (Inches) = Pi * Diameter of Wheel (Inches) = Pi * 3 = 9.425

Speed (Inches Per Second) = Motor Revolutions Per Second * Wheel Circumference = 8.466 * 9.425 = 79.796

Speed (Feet Per Second) = Speed (Inches Per Second) / Inches Per Foot = 79.796 / 12 = 6.650

Figure (15): Speed Calculations

The .173 ft-lbs of torque at each wheel should be enough to push around the opposing robots as well. The motors weigh about 0.09 lbs each [2]. The weight of some additional gears, wheels, and axles will be negligible compared to the motor weight. The total weight of the drivetrain subsystem is going to be around 0.2 lbs. This is a reasonable weight for the subsystem. The motors draw 11 volts and are controlled by the motor control subsystem [2]. The power supply and motor control subsystem will be detailed further in the power subsystem and control subsystem sections. We will deem our drivetrain subsystem successful if it satisfies the requirements in figure (16).

Requirements	Verification
Minimum top speed of 5 ft/s	This requirement can easily be verified with a tape measure and a timer. We can measure out a distance of 10 feet. Then with a timer, we can measure the amount of time it takes the battlebot to traverse the distance. If this time is less than or equal to 2 second, we have successfully fulfilled this requirement.
Minimum 0.1 ft-lbs torque per wheel	This requirement can be verified with a force gauge. The force gauge measures the force that is being pushed onto it. By fixing the force in a solid position, we will drive the battlebot into the gauge. Using the force gauge reading, we can calculate the torque at each wheel when considering that there are two wheels with a diameter of 3 inches. If the torque at each wheel is 0.1 ft-lbs, we have successfully fulfilled this requirement.

Figure (16): Drivetrain Subsystem Requirements and Verification

2.3.2. Weapon Subsystem

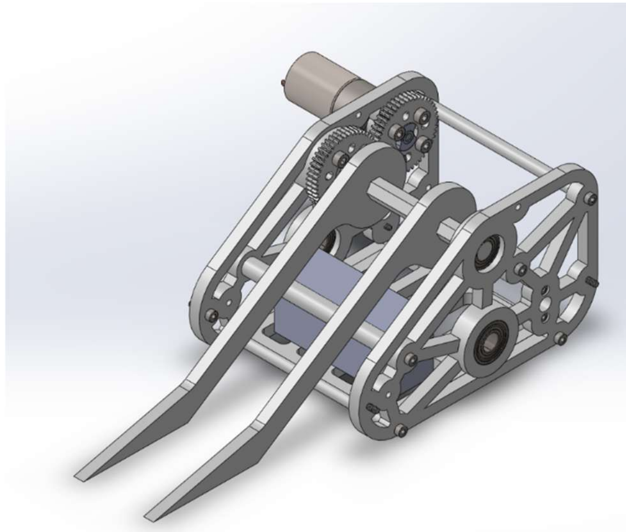

Figure (17): Weapon Physical Model

The Lifter Prongs consists of 1 brushed motor that will be appropriately geared to provide at least 1.333 ft-lbs of torque. The 56 RPM Econ Gear Motor that we plan on using has 56 rpm and torque of 4.760 ft-lbs [3]. With a max theoretical torque of 1.33 ft-lbs and the motor supplying 4.760 ft-lbs this satisfies part of the third task in our high-level requirements. Calculations are detailed in figure (18).

Max Torque at Prong(ft-lbs) = Force (lbs) * Arm Length (ft) = 2 * 0.667 = 1.333

Motor Revolutions Per Second = Motor Revolutions Per Minute / Seconds Per Minute = 56 / 60 = 0.933

Total Time to Travel Full Prong Range (Seconds) = Arm Range (Revolutions) / Revolutions Per Second = 0.5 / 0.933 = 0.536

Figure (18): Weapon Subsystem Calculations

The weapons system contains a lifting arm with the objective of lifting the opposing robot into the air. The lifting arms are made of two prongs. These prongs will need be able to lift the opposing battlebot. Additionally, they will be used to flip our robot over in the event that we are flipped over. The maximum weight of the battlebots is two pounds so it would need to be able to lift at least two pounds. We can approximately calculate the torque necessary by using the maximum weight of the opposing battlebot as well as our prong length, 8 inches. The lifting arms need to provide approximately 1.333 ft-lbs of torque. This higher demand for torque is the reason we will go with the 56 RPM Econ Gear Motor. This high torque brushed motor can provide up to 4.760 ft-lbs of torque [3]. Additionally, the prongs will be vulnerable to getting damage from lifting heavy weight and from the opposing battlebots weapon systems. For this reason, we will 3D print them using ABS with high infill. The motor weighs about

0.205 lbs each [3]. The weight of some additional gears and axles will be negligible compared to the motor weight; However, the lifting arms themselves might have a significant contribution. We predict that the total weight of the drivetrain subsystem is going to be around 0.3 lbs. If needed, we can reduce the weight of the system with lower lifting arm infill. The motors draw 11 volts and are controlled by the motor control subsystem [3]. The power supply and motor control subsystem will be detailed further in the power subsystem and control subsystem sections. We will deem our weapon subsystem successful if it satisfies the requirements in figure (19).

Requirements	Verification
Minimum 1.333 ft-lbs torque at the lifting points	This requirement can be verified with a force gauge. The force gauge measures the force that is being pushed onto it. By fixing the force gauge below the lifting arm, we will lower the lifting arm into the force gauge. Using the force gauge reading and the length of the lifting arm, we can calculate the torque. If the torque is 1.333 ft-lbs, we have successfully fulfilled this requirement.
Fully extended arm length and chassis length must be within 13” size limit	This can be verified using a ruler and measuring the dimensions of the battlebot with the arms fully extended.
Lifting mechanism must raise opponents a minimum 2 inches from ground	This requirement can be verified with a 2-pound load and a ruler. If the battlebot can lift the two pound two inches off of the ground, we have successfully fulfilled this requirement.
Must complete full deployment motion within 1 second	This requirement can be verified with a 2-pound load and a timer. If the battlebot can flip over the 2-pound load within a second, we have successfully fulfilled this requirement.
Self-righting capability must function when robot is flipped over	We will place the battlebot upside down. If we can get the battlebot to flip over using the lifting arms, we have successfully fulfilled this requirement.
Arms must withstand impact force of 20 N without structural failure	We can verify this requirement with a force gauge. We can press the force gauge against the lifting arm until the gauge reads 20 N. If the lifting arms can withstand the force without permanent deformation, we have successfully fulfilled this requirement.

Figure (19): Weapon Subsystem Requirements and Verification

2.3.3. Power Subsystem

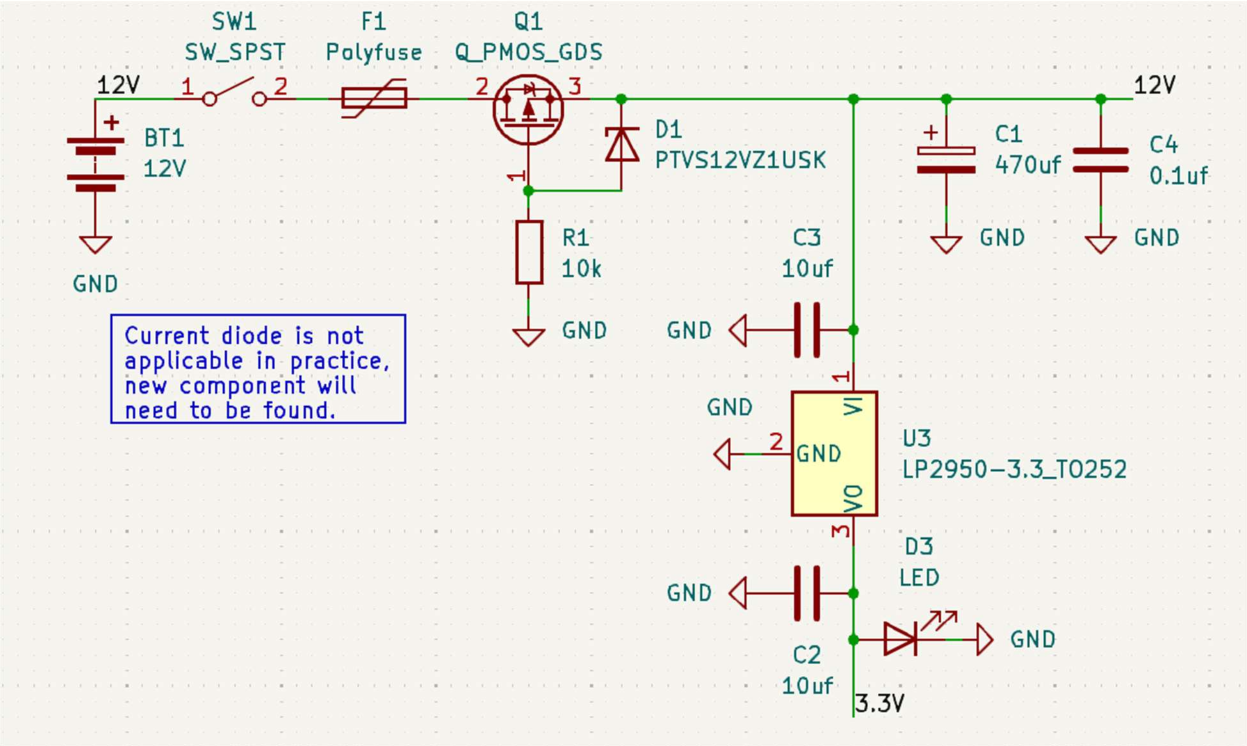

Figure (20): Power Subsystem PCB Schematic

The power subsystem will distribute the 11V from the 3S LiPo battery to the motor controller and microcontroller. It will step down the voltage from 11V to 3.3V to be used in our STM32 microcontroller and HC-05 Bluetooth module [5, 6]. The voltage will be stepped down using a with a LP2950CZ-3.3 voltage regulator [7]. The power subsystem will also contain a MOSFET and diodes to provide reverse polarity and over-current protection. A switch is utilized to turn on and manually shut off the system, which is one of the competition requirements. It is important that the microcontroller receives a steady power source, so it does not turn off randomly during the battlebot competition. Capacitors are used to provide smoother and more stable power to the microcontroller. A fuse is utilized to provide over-current protection. The power subsystem PCB schematic is shown in figure (20). Majority of the weight of the power subsystem will come from the battery, which has a weight of about 0.3 lbs [8].

Battery Type	Power Density	Discharge Rate	Weight
LiIon			
LiPo			

Figure (21): Drivetrain Decision Matrix

For the battery there were 2 choices (LiPo and LiIon) that were considered, and we ultimately chose to go with the LiPo because of its higher discharge rate at the cost of lower power density. Under our expected power draw, Li-ion batteries that were capable of the discharge rate were also significantly heavier than a LiPo

While this subsystem is not directly responsible for completing any high-level requirement, it is critical for all the other subsystems to complete their tasks. We will deem our power subsystem successful if it satisfies the requirements in figure (22).

Requirements	**Verification**
Voltage regulation must maintain 3.3V ±5% for microcontroller under all load conditions	This requirement can be verified utilizing a multimeter. If the voltage at the voltage regulator output when operating the motors at different speeds is within 3.3V ±5%, we have successfully fulfilled this requirement.
Battery management system (BMS) must supply sufficient current to the robot for 2 mins.	This requirement can be verified by running the robot and utilizing all subsystems. If the robot runs for the complete duration, we have successfully fulfilled this requirement.

Figure (22): Power Subsystem Requirements and Verification

2.3.4. Control Subsystem

The control subsystem consists of the STM32 microcontroller, HC-05 Bluetooth Module, and two DRV8952 H-Bridges [5, 6, 10]. The microcontroller onboard the robot will interface with the computer through the Bluetooth module to allow for wireless control. It will also provide the appropriate signals to the H-bridge for the drivetrain motors and lifting motors. In the event that the microcontroller disconnects with the computer or when a manual shut down button is pressed, the battlebot will turn off within 500ms. This subsystem is critical to completing tasks 1 and 2 in the high-level requirements. Additionally, the STM32 microcontroller needs to be connected to a 8 MHz crystal oscillator for proper operation [5]. The Bluetooth module has a range of up to 10-20 meters [9] which is more than enough for the 10 feet by 10 feet arena. The interfacing of the microcontroller, H-bridges, and Bluetooth module can be seen in figure (23).

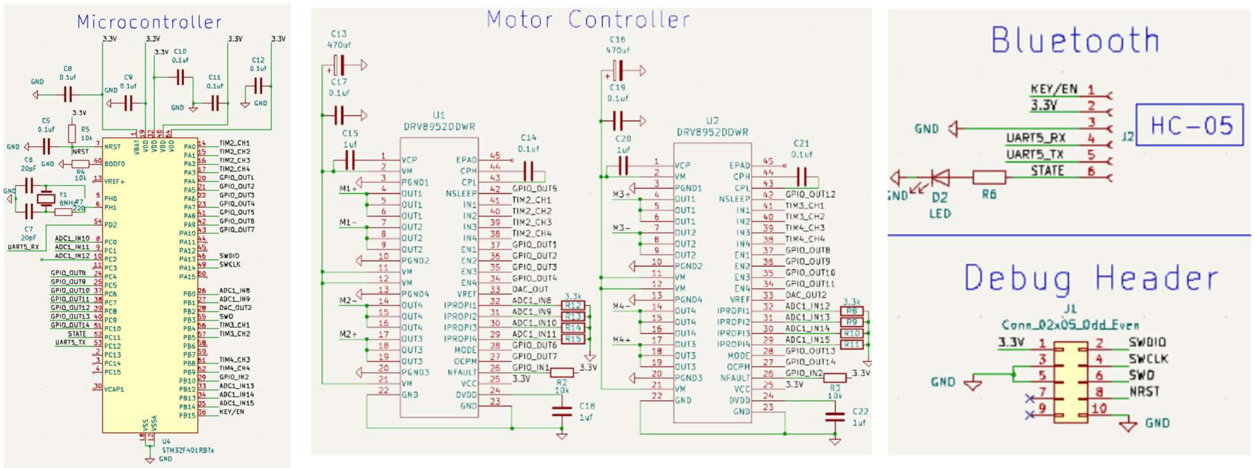

Figure (23): Microcontroller, Motor Controller, Bluetooth Module, and Debug Header PCB Schematic

We will deem our control subsystem successful if it satisfies the requirements in figure (24).

Requirements	Verification
Bluetooth communication must maintain stable connection at 15-foot range	This can be verified with a measuring tape. When positioned 15 feet away from the motor, if the battlebot still operates properly, we have successfully fulfilled this requirement.
Emergency stop must trigger within 500ms of signal loss	This can be verified with a timer. After disconnecting the signal to the battlebot, if the battlebot shuts off within 500 ms, we have successfully fulfilled this requirement.
Motor controller can temporarily supply max stall current to the motors	This can be verified by stalling the motor on the robot for 2 seconds. Afterwards if the motor controller continues to power the motor after releasing the motor from the stall, we have successfully fulfilled this requirement.

Figure (24): Control Subsystem Requirements and Verification

2.4. Tolerance Analysis

A critical aspect of our design is ensuring the power system can handle peak loads while maintaining stable voltage for the control system. This analysis focuses on the worst-case scenario when all motors are under maximum load.

System Parameters:

- Battery: 11.1V 3S LiPo (nominal voltage) [8]
- Drive Motors: 2× 11.1V, 1.4A peak each [2]
- Weapon Motors: 1 × 11.1V, 3.85A peak each [3]
- Control System: 3.3V, 200mA
- Internal resistance of battery: 20mΩ (typical for quality 3S LiPo)
- Voltage regulator efficiency: 76.9% [7]

Peak Current Analysis:

1. Maximum total current draw:
   - Drive motors: 2.8A
   - Weapon motors: 3.4A
   - Total peak current: 6.2A

2. Voltage drop calculation:
   - V_drop = I_total × R_internal
   - V_drop = 7A × 0.02Ω = 0.140V
   - Minimum battery voltage under load = 11.1V - 0.12V = 10.960V

3. Voltage Regulator Analysis:
   - Input voltage range: 11.6V - 12.6V [7]
   - Required output: 3.3V ±5% (3.135V - 3.465V)
   - Maximum Current output: 100 mA [7]
   - Power dissipation = (Vin - Vout) × I_control
   - Maximum dissipation = (12.6V - 3.3V) × 0.1A = 0.93W

Results:

- The voltage drop under peak load (0.306V) is within acceptable limits
- The voltage regulator maintains 3.3V regulation with input variation of 11.6V-12.6V
- Power dissipation in regulator (0.93W max) requires minimal heatsinking
- System maintains required voltage levels with 20% safety margin

This analysis demonstrates that our power system design can handle worst-case loads while maintaining stable operation, with sufficient margins for unexpected peak demands.

3. Cost and Schedule

3.1. Costs

The total cost of all the parts before shipping is $219.31 which can be seen in figure (25). Assuming 15% shipping costs, the total parts cost becomes $252.21. Parts offered by the ECEB self-service shop are free. An average electrical engineer salary pays $52.41 per hour [4]. Estimating that each person puts in 8 hours a week for 16 weeks, the total cost of labor for the entire team amounts to $20,125.44. 3D printing is offered for free. We will not have any shop service costs. The total cost for the project is $20,377.64.

Part	**Provider**	**Quantity**	**Extended Price**
MOSFET P-CH 60V 28A TO220F-3SG	Self-Service Shop	1	$0
3.3V Voltage Regulator LP2950CZ-3.3	Self-Service Shop	1	$0
Resettable Fuse 16R400GU	Self-Service Shop	1	$0
Ceramic Capacitors (2 pF, 0.1 uF, 1uF)	Self-Service Shop	17	$0
Tantalum Capacitors (10 uF)	Self-Service Shop	2	$0
Electrolytic Capacitor (470 uF)	Self-Service Shop	3	$0
Resistors (220 Ohms, 10k Ohms)	Self Service Shop	7	$0
Diode	Self Service Shop	3	$0
STM32F401RBT6 Microcontroller	ECEB Services Shop	1	$0
HC-05 Bluetooth Module	Amazon	1	$10.39
DRV8952 (H-Bridge)	Texas Instrument	2	$9.57
8 MHz Crystal Oscillators	Self-Service Shop	1	$0
3S Lipo Battery 2200mAh 11.1V 50C	Zeee Battery	1	$38.99
Lipo Charger	Amazon	1	$36.99
508 RPM Mini Econ Gear Motor (638402)	ServoCity	2	$24.98
56 RPM Econ Gear Motor (638348)	ServoCity	1	$14.99
1314 Series Steel Set-Screw Hub (1314-0016-0004)	ServoCity	3	$17.97
WD Bearing (WCP-0776)	West Coast Productions	6	$17.94
M2 M3 M4 M5 Nuts and Bolts set	Amazon	1	$24.99
Wheels (am-3946_blue)	AndyMark	2	$22.50

Figure (25): Parts Cost Table

3.2. Schedule

Week	Task	Person
3/3	Order Parts	All
	Mechanical Design Prototype Done	Anthony
	PCB Design Prototype Done	Praman
	Start Testing Electrical Parts	Batu
3/10	Mechanical Prototype Assembled	Anthony
	Breadboard Prototype Assembled	Praman and Batu
	Breadboard Demo (3/11)	All
	PCB Order (3/13)	All
3/17	Final Mechanical Design Done	Anthony
	Debug PCB	All
	Revise PCB Design (If needed)	Praman
	Confirm Tolerance Analysis	Batu
3/24	Mechanical Systems Assembled	Anthony
	Test Drivetrain and Weapon Subsystem Requirements	Anthony and Batu
	Test Power and Control Subsystems Requirements	Praman and Batu
	Design Revisions	All
3/31	PCB Order (3/31)	All
	Test Drivetrain and Weapon Subsystem requirements	Anthony and Batu
	Test Power and Control Subsystems Requirements	Praman and Batu
4/7	PCB Order (4/7)	All
	Design Revisions	All
4/14	Final Assembly and Testing	All
4/21	Demo and Presentation	All

Figure (26): Schedule

4. Ethics and Safety

4.1. Lab Safety

To make our battlebot, we will need to 3D print and solder. To stay safe while soldering, we will use proper soldering lab procedures. These safety precautions include PPE, safety glasses, maintaining a clean/organized environment, checking equipment before use, and working with a lab partner. We will also follow proper procedures when 3D printing. Although 3D printers aren't necessarily dangerous, they can be fragile. By following standard operating procedure, we can ensure safety for ourselves and the 3D printer. Our goals to maintain lab safety reflect the ACM Code of Ethics [11]. (ACM Code of Ethics 1.2)

4.2. Operational Safety

Safety is essential and a serious concern when it comes to battlebots. These battlebots are designed to damage each other. In most cases, these battlebots can just as easily hurt people. We will equip our battlebot with manual and automatic disable. This will allow us to shut off the battlebot if we lose control of it or if we lose connection to it. We will also ensure safe operation of the 11V 3s LiPo battery. If shorted or damaged, these batteries can catch on fire [13]. Detailed safety precautions for LiPo batteries can be found in reference 13 [13]. We will undergo examination of our circuit to ensure that we abide by the tolerance analysis detailed earlier in this report. We will also undergo thorough testing of our battlebot in a controlled environment before the competition to make sure everything is operating properly. Our goals to maintain a safe environment reflect the IEEE Code of Ethics [12]. (IEEE Code of Ethics I.1)

4.3. Ethics and Integrity

In other battlebot competitions, there have been lots of cheating scandals. We will follow all the rules for the competition. If we are unsure of a rule, we will contact a TA or a professor for clarification. After finishing our battlebot, we will go back to the rulebook and make sure that we are abiding by all of the rules. Our goals to honor integrity reflect the ACM Code of Ethics [11]. (ACM Code of Ethics 1.3, 2.2, and 2.3)

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