

Vertical Spinner Ant-weight Battlebot

ECE 445 Design Document - Spring 2026

Team #21

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1. Introduction

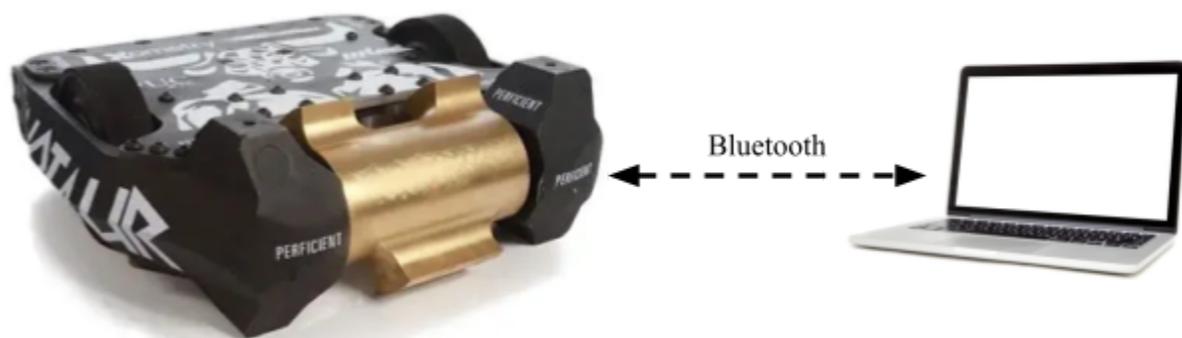
1.1 Problem

The Antweight 3D Printed Battlebots Competition entails up to eight battlebots competing in a bracket to determine which can outperform the rest. In order to compete in the competition, our robot must meet specific requirements including but not limited to: a maximum weight of 2 lbs; 3D-printed using PET, PETG, ABS, or PLA, PLA+; controlled using Bluetooth or Wifi; and the inclusion of a custom PCB. The custom PCB will house the microcontroller, Bluetooth or Wifi receiver, h-bridge, and additional sensors. The battlebot should be able to tolerate extreme mechanical stress from other bots while also being able to deliver damage using a weapon.

1.2 Solution

Our solution is a robot with a two-wheel drive and vertical drum spinner weapon. The robot will consist of four subsystems: power, drive, weapon, and control. Our custom PCB will contain an STM32WB series microcontroller which will control the weapon and drive subsystems while also monitoring electrical and mechanical stress to limit damage to the robot. The microcontroller will also connect to a PC using Bluetooth to remotely control the battlebot. We will use analog tank-style controls, allowing us to drive and steer the battlebot at variable speeds. The exterior of the battlebot will be 3D printed using PLA+, a flexible and durable filament. In case our robot is flipped during competition, it will be able to function right side up and upside down by being symmetrical over the horizontal axis.

1.3 Visual Aid



An example of a vertical spinner robot that would have a drum-like weapon.

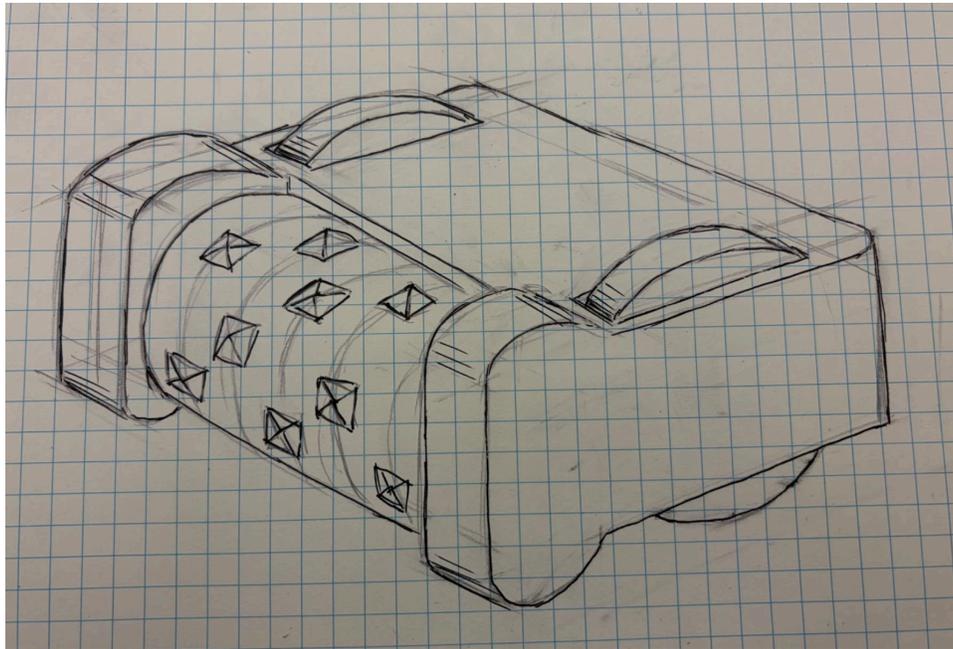
1.4 High Level Requirements

- **Mobility:** Given that the arena itself is only 10' by 10' top speed is not our main concern. Our area of control in the field will be our main focus rather than our speed, causing us to lean more towards a max speed near 1.5 meters per second.
- **Latency:** Our control in the field requires us to have as little latency as possible. In the ideal world, we are aiming towards a latency near 50ms, however, our minimum requirement is near 250ms.
- **Weapon Speed:** A large portion of our bot's weight will be in our weapon itself. This weight distribution will cause our bot to have harder control while our weapon spins. This issue will be worsened with faster spinning speeds from our weapon, however a higher weapon speed will allow for higher damage. Overall we are still leaning for a weapon speed near 11 meters per second for good damage and control in the field.

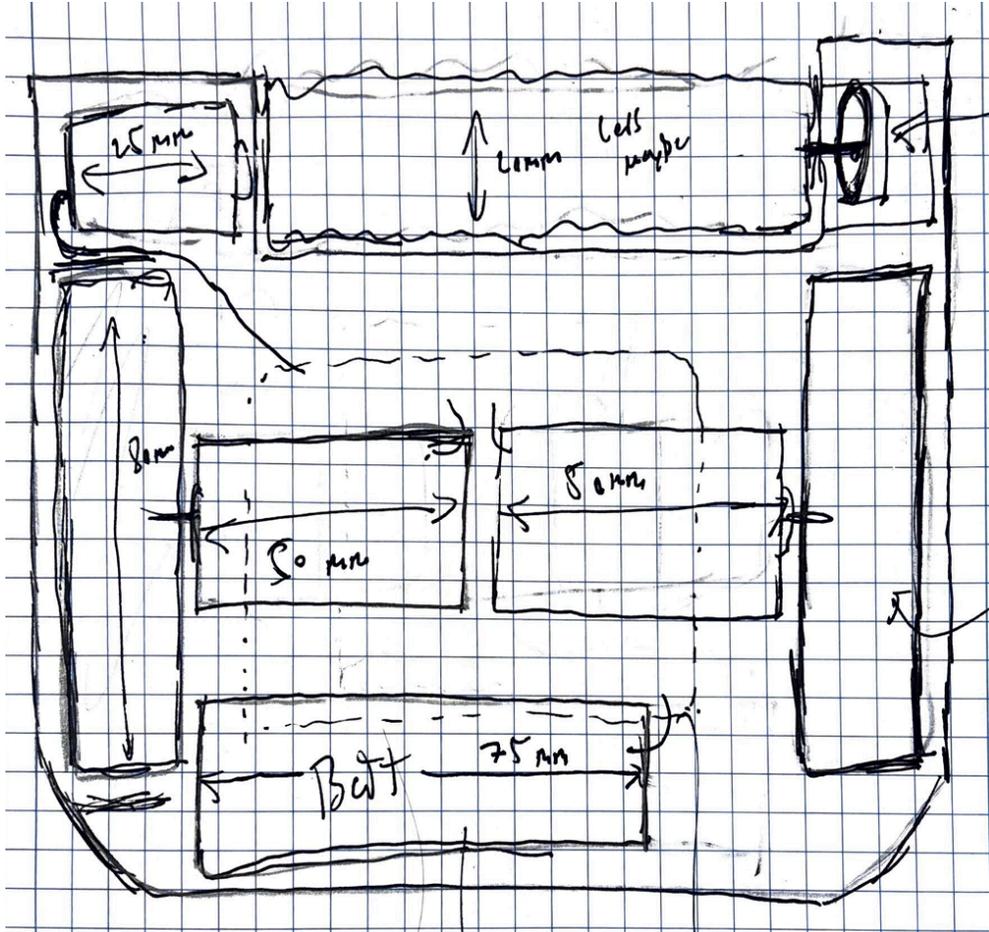
2. Design

2.1 Physical Design

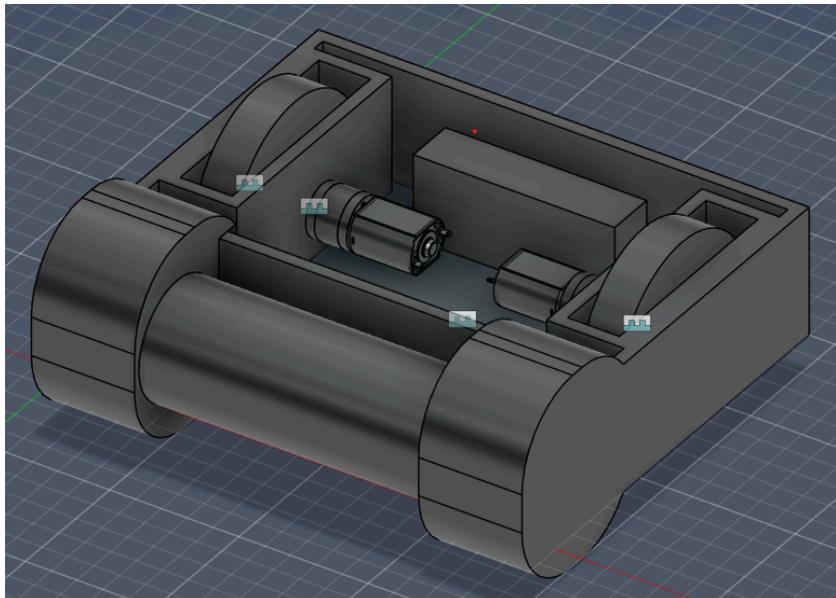
The physical design of our battlebot will be 3D printed out of PLA+ filament. PLA+ was chosen as opposed to other filaments due to its toughness, flexibility, and ease of printing. The physical design will include the body, weapon, and the wheels. These components will take up the bulk of the 2lb weight limit. The body must protect the internal electronics and motors of the battlebot while also being light in weight. In areas that we expect to receive the most damage, we will use a high infill percentage in the walls for shock absorption. We will use heat-set inserts and screws to attach the different parts of the body together to make replacing parts between matches easier. The spiked drum-like weapon will be the most dense physical portion of our robot in order to deliver powerful attacks to other bots. To achieve this, we will use a high infill to maximize mass and rotational inertia. For the wheels, we will coat them with a rubberized material such as Flex Seal to ensure the wheels have enough friction with the ground. This will improve speed, pushing power, and maneuverability.



A sketch of the exterior of the battlebot

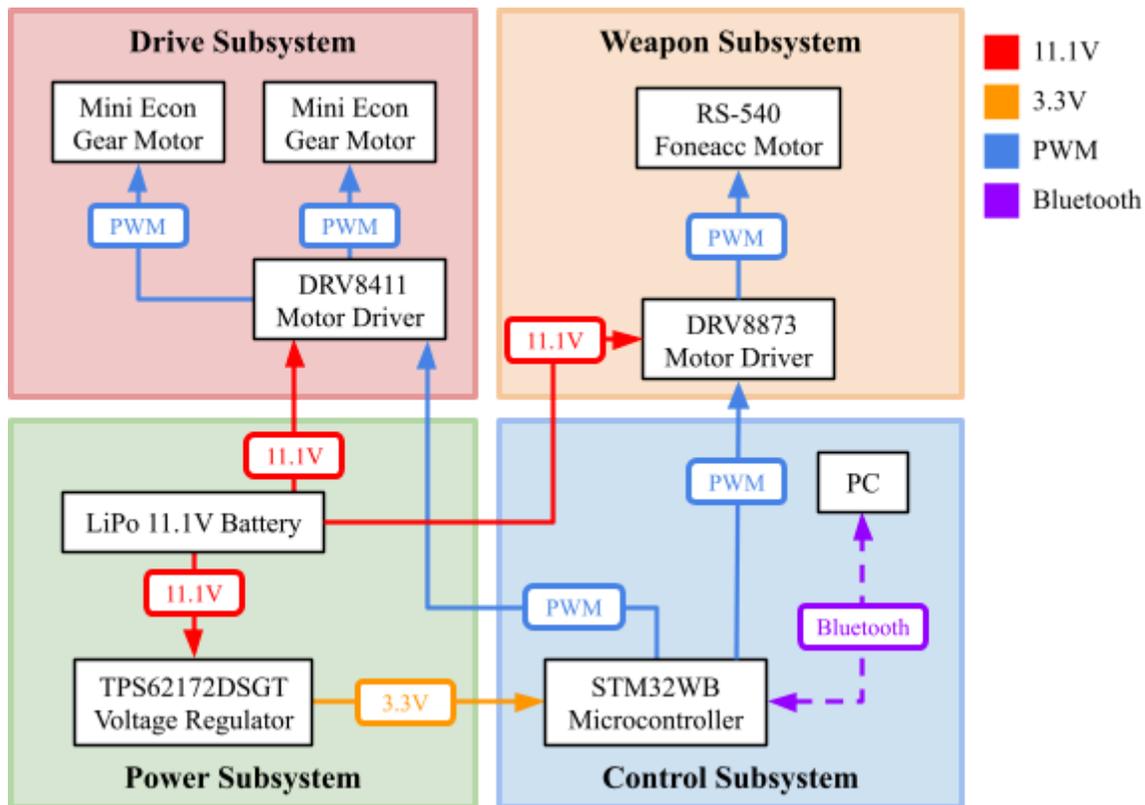


A top-down sketch of the interior of the battlebot



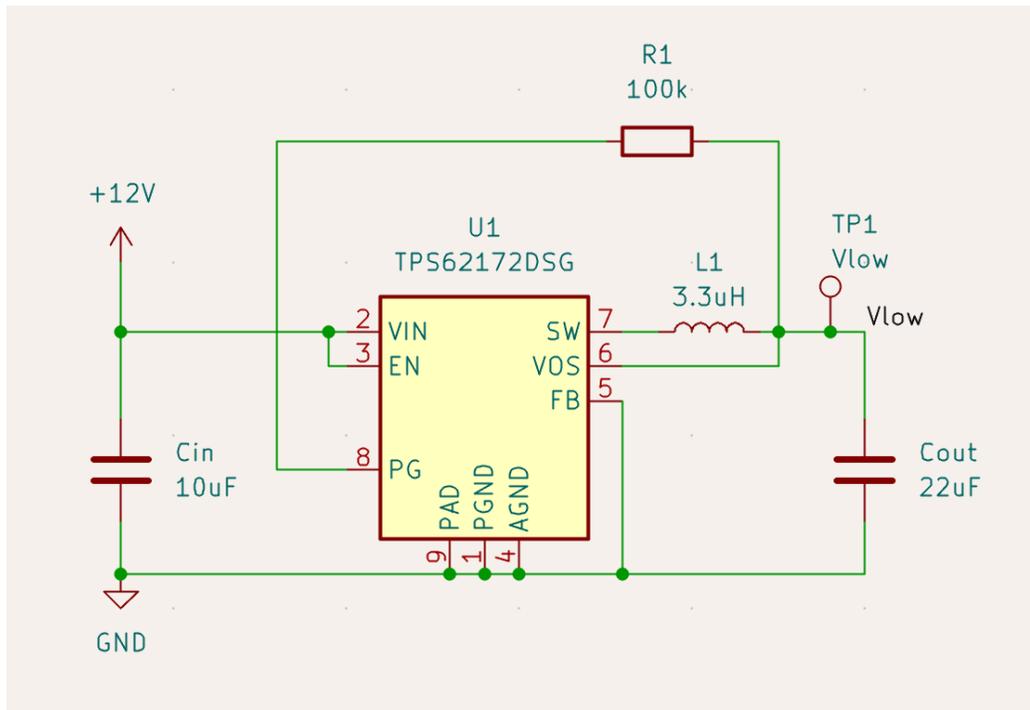
Initial CAD model to ensure major components fit

2.2 Block Diagram



The power subsystem includes our 11.1V LiPo battery and voltage regulator, which will step down the battery's voltage to 3.3V, a suitable level for our microcontroller. The drive subsystem contains the two DC brushless motors that are independently driven by a motor driver for left and right tank-steering. The driver inputs four PWM signals from the microcontroller and outputs two PWM signals to each of the wheels. The driver also utilizes current sensing to ensure the motors operate safely during high-current events such as pushing or collisions. The weapon subsystem consists of a single motor for the drum spinner and a driver. This driver operates in the same way as the driver from the weapon subsystem and uses current sensing to protect the motor if the weapon jams or stalls. Finally, the control subsystem includes the microcontroller and a PC, connected to each other over Bluetooth. Based on an analog input from the PC, the microcontroller will send the necessary signals to the rest of the bot.

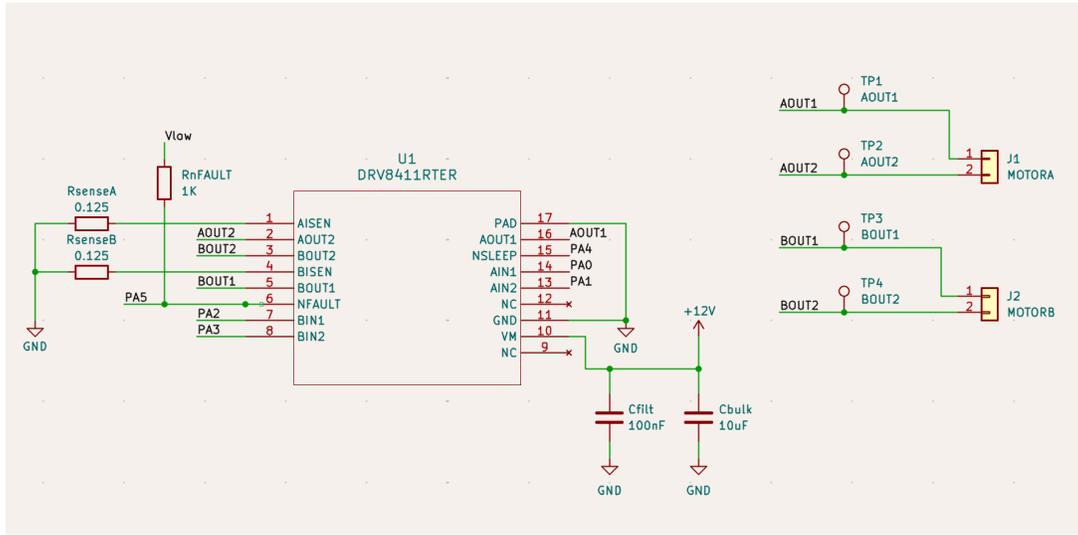
2.3 Power Subsystem



Power subsystem schematic

The main components of our power subsystem are the 1000mAh 11.1V LiPo battery and the TPS62172DSGT DC-DC voltage regulator. These two components are responsible for supplying power to the entire board at either 11.1V or 3.3V respectively. We chose a LiPo battery due to its lower weight, increased capacity, and power delivery. Additional safety precautions are required when using lithium-ion polymer batteries, which will be discussed later in this document. The TPS62172DSGT DC-DC step-down converter can take in a variable input voltage and produce a steady output voltage, supporting up to 0.5A. Since our microcontroller only requires 0.13A, this is more than enough current. The converter runs at a switching frequency of 2.25MHz, allowing us to use small capacitors and inductors for a faster transient response. The inductors, resistors, and capacitors external to this chip were sized based on the datasheet, which includes system examples pertaining to our project.

2.4 Drive Subsystem



Drive subsystem schematic

The drive subsystem consists of two 508 RPM Mini Econ Gear Motor and a DRV8411 Dual H-Bridge Motor Driver. The driver will input four signals (PA0, PA1, PA2, PA3) from the microcontroller and output two signals to each of the motors for variable motor speed. The control of either of the motors are described in the following tables from the datasheet:

Table 8-2. H-Bridge Control

nSLEEP	xIN1	xIN2	xOUT1	xOUT2	DESCRIPTION
0	X	X	High-Z	High-Z	Low-power sleep mode
1	0	0	High-Z	High-Z	Coast/ fast decay; H-bridge disabled to High-Z
1	0	1	L	H	Reverse (Current OUT2 → OUT1)
1	1	0	H	L	Forward (Current OUT1 → OUT2)
1	1	1	L	L	Brake; low-side slow decay

Table 8-3. PWM Control of Motor Speed

xIN1	xIN2	DESCRIPTION
PWM	0	Forward PWM, fast decay
1	PWM	Forward PWM, slow decay
0	PWM	Reverse PWM, fast decay
PWM	1	Reverse PWM, slow decay

We will opt to use PWM signals for variable speed control. It is recommended to switch between driving (forward or reverse) states and slow decay states (brake) for optimal performance.

With a peak motor current of 1.4A, we chose a trip current of 1.6A to size the sense resistors.

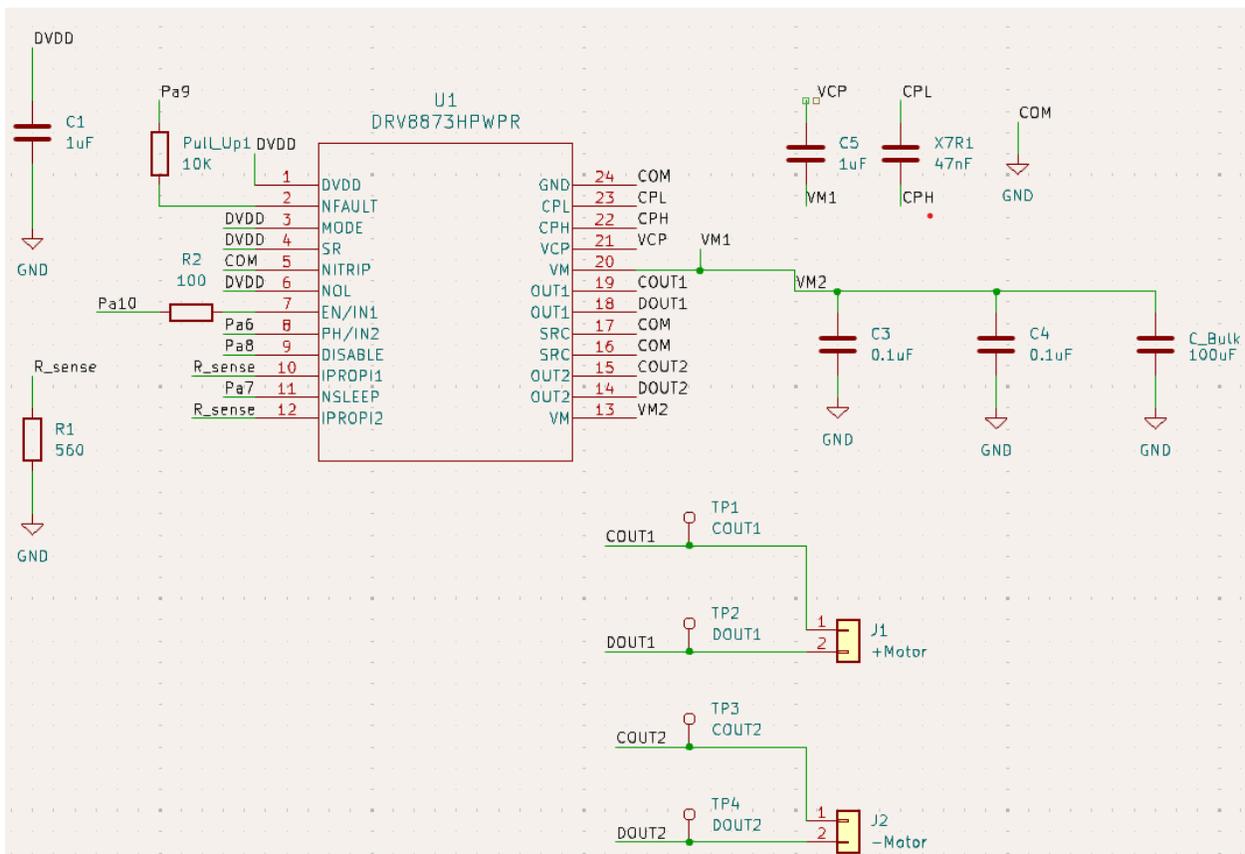
$$R_{sense,A} = R_{sense,B} = \frac{0.2V}{I_{trip}} = \frac{0.2V}{1.6A} = 0.125 m\Omega$$

The driver includes an nFAULT pin, which is pulled low during a fault, allowing the driver to notify the microcontroller if a fault occurs. For open drain operation, we connected an external pullup resistor R_{nFAULT} , which is between nFAULT and +3.3V. The voltage of nFAULT will fall within the [0.3, 5.75V] range, while the maximum current is 5mA. With this, we can size the pullup resistor.

$$R_{nFAULT} = \frac{V}{I} = \frac{3.3-0.3}{5e-3} = 600\Omega \Rightarrow \text{choose } 1k\Omega$$

The two capacitors at the input VM are a 100nF filter capacitor (C_{filt}) and a 10uF bulk capacitor (C_{bulk}). The filtering capacitor is used as an IC bypass capacitor, preventing input noise from reaching the driver. The bulk capacitor causes the motor voltage to remain stable despite parasitic wire inductance. Both of these capacitors should be placed physically as close as possible to the driver to minimize loop inductance.

2.5 Weapon Subsystem



Weapon subsystem schematic

The weapon subsystem consists of a vertically mounted solid drum spinner powered by a brushed DC motor. The subsystem converts electrical energy from the 11.1V LiPo battery into mechanical rotational energy using controlled PWM drive signals from the microcontroller. The weapon interfaces with the other subsystems, utilizing the Lipo battery from the power system and PWM control and current sensing from the control system.

In order for the weapon to qualify and succeed, the following requirements must be met:

- Weapon height ≤ 5 in
- Spin-down time ≤ 60 s
- Continuous operation ≥ 180 s
- Mounted operating speed: 4,000–5,700 RPM
- Tip speed ≥ 11 m/s

To ensure the weapon comes to a full stop within the required time, the DRV8873 will implement active braking by shorting the motor terminals.

The 3D design of the weapon will implement a cylindrical drum connected to the shaft of the motor. There will also be a bearing on the side without the motor to help rotate and support the drum. The dimensions of the drum will be as follows:

- Diameter: 45 mm
- Length: 80 mm
- Teeth Extrusions: 4 mm

Given the motors data sheet, the speed of the weapon will be as follows:

- $r = 22.5 \text{ mm} = 0.0225 \text{ m}$
- $\omega = 5000 \text{ RPM}$

$$v = \frac{2\pi r \omega}{60} = 11.78 \frac{m}{s}$$

The drum is powered by an RS-540 brushed motor driven by a DRV8873 H-bridge motor driver. The electrical characteristics of the motor and driver chip are as follows:

RS-540:

- Nominal voltage: 11.1 V
- Stall current: 8.7 A

- Normal operating current: 1.6 A

DRV8873:

- PWM-based speed control from STM32WB
- Current regulation for stalling
- Protection against overcurrent

A current limit of 6.5 A was selected to remain below the 8.7 A stall current of the RS-540 motor while allowing sufficient torque during impact events. To achieve this, the following parameters were applied:

- $I_0 = 6.5 \text{ A}$
- $k = 1100$
- $V_{ref} = 3.3 \text{ V}$ (From STM32WB)

$$R_{Sense} = \frac{k * V_{ref}}{I_0} = 560 \Omega$$

Once our microcontroller is correctly powered and connected we should be able to activate our blueconnection via the antenna and no longer be forced to wire our PC to our microcontroller. After this coding and uploading information should be very easy.

General requirements that we expect from this system are pretty straight forward. Connection between the microcontroller and any PC/controller should be minimal with a latency of near 250ms or less. All facets of design should be implemented to decrease this time to the lowest value achievable with this design. An additional requirement is total control over motors and accurate readings of stress and analog information given from the motors. This will allow us to protect our motors from any action our environment does to them or from our own inputs. We also just want motors to understand our inputs as clearly as possible and for no mix up information between the controller to motors data transfer.

2.7 Tolerance Analysis

The LiPo 11.1V battery must be able to supply enough current for the three motors during normal load conditions and worst case conditions. The battery supplies 2000 mAh of capacity at a voltage of 11.1V. With a capacity rating of 40C, the battery can supply up to 88A of current.

$$2.2 [Ah] * 40C = 88A$$

Under normal load conditions, the 508 RPM Mini Econ Gear Motors draw a 0.3A current each. During stall conditions, the motors can draw up to 1.4A each.

The weapon motor can draw up to 8.7 A for the single motor which is pretty significant compared to the other ones, but we are trying to give far more power to our hits than in our drive. However, the normal draw current 1.6 with a standard load given.

With our microcontroller we are at max going to pull near 500mA, but at the majority of the time we will see that our pull be closer to 300mA.

Considering these peaks we should have a margin of safety near 7.33 which keeps us pretty safe from killing our battery.

$$1.4[A] * 2 + .5[A] + 8.7[A] = 12[A]$$

$$88[A]/12[A] = 7.33$$

As it stands we currently need our robot to continuously run for at least 2 minutes, however we want the robot to comfortably handle 3 minutes. With current equipment we are able to easily do this as our battery is able to handle 2000 mAh mix and with the peak demand of 12A we are able to run continuously for 6 whole minutes.

$$(2[Ah] * 3600[s/h])/12[A] = 600[s]$$

Overall this just goes to show that our current equipment should be able to handle the demand of the design. We will still have to test these specs to make sure that everything comes out as clean as we predict. Also demands on the field may vary depending on the conditions we are facing, but on average our robot should be able to easily fulfil the wants and needs of this competition.

3. Cost & Schedule

3.1 Cost Analysis

Part	Vendor	Unit Cost	Quantity	Total Cost
508 RPM Mini Econ Gear Motor	Servo City	\$12.99	2	\$25.98
DRV8411 Dual H-Bridge Motor Driver	Digikey	\$2.30	1	\$2.30
RS-540 Carbon Brushed Micro DC motor	Foneacc	Inquiring	1	Inquiring
DRV8873HPWPR(Driver for the Carbon DC motor	Digikey	\$3.96	1	\$3.96
STM32WBA63CIU6	DigiKey	\$4.66	1	\$4.66
Lipo Battery 1000mAh	HobbyKing	\$8.79	3	\$26.37
TPS62172DSGT voltage regulator	Digikey	\$1.67	1	\$1.67
3.3uH inductor (BRC2012T3R3MD)	Digikey	\$0.21	1	\$0.21
22uF capacitor 25V	Digikey	\$0.47	1	\$0.47
10uF capacitor 25V	Digikey	\$0.08	2	\$0.16
100K OHM 1% 1/16W resistor	Digikey	\$0.10	1	\$0.10
125 mOhm sense resistor	Digikey	\$0.98	2	\$1.96
100 nF ceramic capacitor	Digikey	\$0.11	12	\$1.32
1uF	Digikey	\$0.08	2	\$0.16
100uF	Digikey	\$0.41	1	\$0.41
100 Ω	Digikey	\$0.10	1	\$0.10
560 Ω Sensor	Digikey	\$0.10	1	\$0.10
10k Ω pull_up	Digikey	\$0.11	1	\$0.11

32 Mhz Crystal	Digikey	\$0.88	1	\$0.88
100pF	Digikey	\$0.10	3	\$0.30
4.7uF	Digikey	\$0.21	6	\$1.26
Antenna	Digikey	\$0.63	1	\$0.63
low pass filter	Digikey	\$0.47	1	\$0.47
2.7nH	Digikey	\$0.10	1	\$0.10
0.8 pF	Digikey	\$0.22	1	\$0.22
0.3 pF	Digikey	\$0.36	1	\$0.36

3.2 Schedule

For scheduling, we will be focusing on a faster paced schedule than most projects to guarantee that we have time for testing and practicing for the competition. Attached to this project that more others wouldn't have to consider.

Week	Action/Deliverables
2/23	During this week, we will be focusing the majority of our energy in finishing our design document and hammering out any final ideas of design here. TA meetings and talking to colleagues will have us finalize our perspective of what we are able to achieve and what we can't in this project. As of now this seems to be on track to finishing. We will also finish up general schematics for our PCB and make sure we have a good set up to submit our PCB design for next week's audit.
3/2	After our presentation we should get good feedback from the TA's and professors that we would ideally implement during this week. After we finish up any fixes or additions that were given to us from the public we will start to organize ourselves to start an indepth design. One member of the group will start CADing our design for our robot while another will finish up the PCB and submit it for the audit this week. The last member will assist in either subproject to make sure we reach our goals.
3/9	If we haven't passed the audit then we will aggressively pursue the audit this week. However the main issue will be centered around finishing up our breadboard project due this week. This shouldn't be hard if we have our PCB mostly done at this point, but it will be a time crunch. CADing will also continue under two members while additional time will be spent on understanding the IDE for STM32 and potentially start coding for microcontroller logic.

3/16	SPRING BREAK, no expected work will be done here, but if we are behind on our schedule we are expected to gain ground here to make sure next week we are either ahead or will meet the expected requirements of the project.
3/23	FINAL PCB audit this week, but we should be done by now. Here we will start really hammering the project. Testing will be done on the PCB this week to make sure everything works as expected as we should have our PCB by now. Additional work will be done on the CAD and a lot more work will be done on the microcontroller's programming. Motors will also be given a test to see if they fulfil our required specs and in case we may have to reorder new brushed motors. We also need to start weighing things here like the PCB and any motors and such to get a very accurate reading on weight for our project.
3/30	Individual progress report is done this week and is expected to be done on individual time. Continuing working on the CAD and code is expected here and potentially printing anything finished for the CAD so we can start fitting and testing size, filament, and infill for the prints we do.
4/6	DEMO, we should have a decent demo by now either via motor testing and connecting to our PC or potentially having a full print job and seeing the equivalent of a moving RC car. The project could potentially be done by now if CADing and coding were easier than expected, but for the demo expect our PCB interacting with motors to have some movement be the minimum of the demo we should want. We should also be test driving this week to see which of us is the best driver for the future competition.
4/13	Finishing up and putting things together this week. Ideally we should have this mostly done this week or last week from the demo's we have already done. Here we need to finalize and touch up anything for next week's mock demo.
4/20	MOCK DEMO will be done this week and needs to be perfect.
4/27	FINAL DEMO will be done this week and will be perfect.
5/4	FINAL paper and competition will be done this week.

4. Ethics

In order to compete in the battle bot competition, we need to comply with the ethical standards set by IEEE and ACM. In ACM 1.2 and IEEE 1.1, it states that avoiding harm is necessary for professional projects. To maintain this, we will test our robot in approved areas that provide protection against danger from the active weapon. We are also making sure our robot can be turned off manually as well as a shutdown via bluetooth. We will also follow the guidelines laid out by IEEE 1.4 by not taking bribes or participating in unlawful activities. ACM 1.4, 1.6, and 1.7 mentions that we must respect privacy, confidentiality, and other people. Our project will reflect this by following the rules of the Robobrawl competition. This will be done by not using illegal weapons or material to strengthen our robots' durability.

5. Safety

5.1 Lab Safety

In order to maintain a safe lab environment, we will act in accordance with the lab rules including: maintaining a clean workspace, reporting broken equipment immediately, using appropriate PPE, and always working with a lab partner or partners.

5.2 Operational Safety

Battlebots are meant to destroy each other, meaning safe operation is necessary to avoid unintentional damage. In a competition setting, the battlebot will only be powered on in the battle arena. Following each match, we will inspect the robot for electrical and mechanical damage that may cause the bot to malfunction. In a testing environment, we will ensure the robot is in an enclosed area and that all operators and onlookers maintain a safe distance from the bot.

Since we are using a lithium-ion polymer battery, additional safety precautions must be followed. The LiPo 11.1V battery used in this project will be stored in a secure location with insulating material over the terminals to prevent a short circuit. Since cell damage in lithium-ion batteries may result in a chemical fire, we will complete additional fire safety and fire extinguisher training as required by ECE 445. We will include circuitry in our PCB to prevent the battery cell voltage from decaying below 3.0V/cell or exceeding 4.2V/cell. Charge and discharge tests will be conducted with the battery inside a lithium safety bag.

6. Citations

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