Antweight Battlebot - BladeBlade

ECE 445 Design Document - Fall 2025

Project: #16

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Content

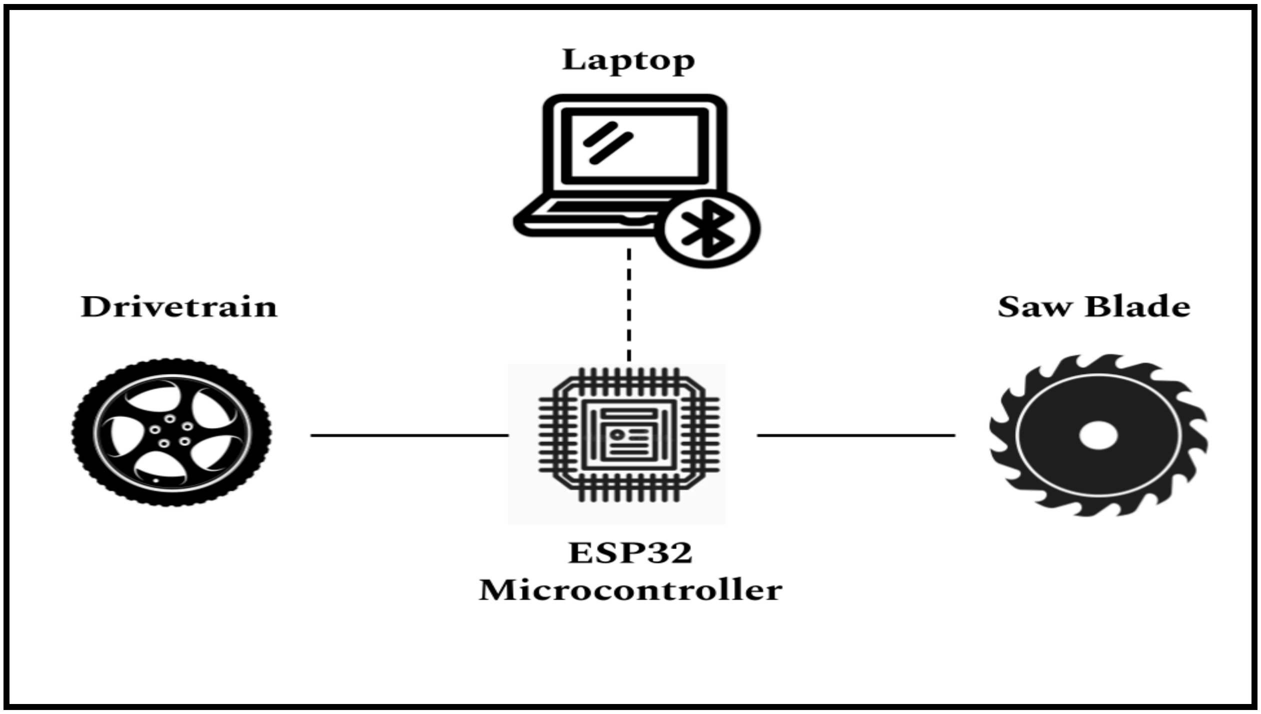
1. Introduction

1.1 Problem and Solution

Battlebots are an American competition in which remote controlled armed and armored robots battle in a ring to disable each other. Our problem and goal here is to design a battlebot to compete against other teams at the end of the semester. However, being an antweight battlebot, we have a couple restrictions on our design. The bot must weigh up to 2 pounds, its parts must be 3D printed, it must house a custom PCB, be controlled via bluetooth or Wifi, and the attacking mechanisms must be controlled with motors or pneumatically. The battlebot must have a balance of being long-lasting, indestructible, offensive, but lightweight to survive the 2-minute battle and disable the opponent.

Our solution is to create a bot with a sturdy body that attacks with a horizontal circular saw blade that can also lift up to flip the opponent. This way we can either target a specific part of the enemy with a blunt force or try to throw them off balance. The bot will consist of the mechanical parts such as the 3D printed chassis, the saw blade, the arm that lifts the saw, and the holder for the PCB. It will also contain electrical components such as the microcontroller, the motors and drive train for the wheels, the motors and servo for the saw blade spin and lift, the battery, and power distribution system. The bot will lastly require some programming to allow for remote control of individual systems via Bluetooth.

1.2 Visual Aid



As you can see, the bot simply consists of user input from the laptop to control driving and attacking.

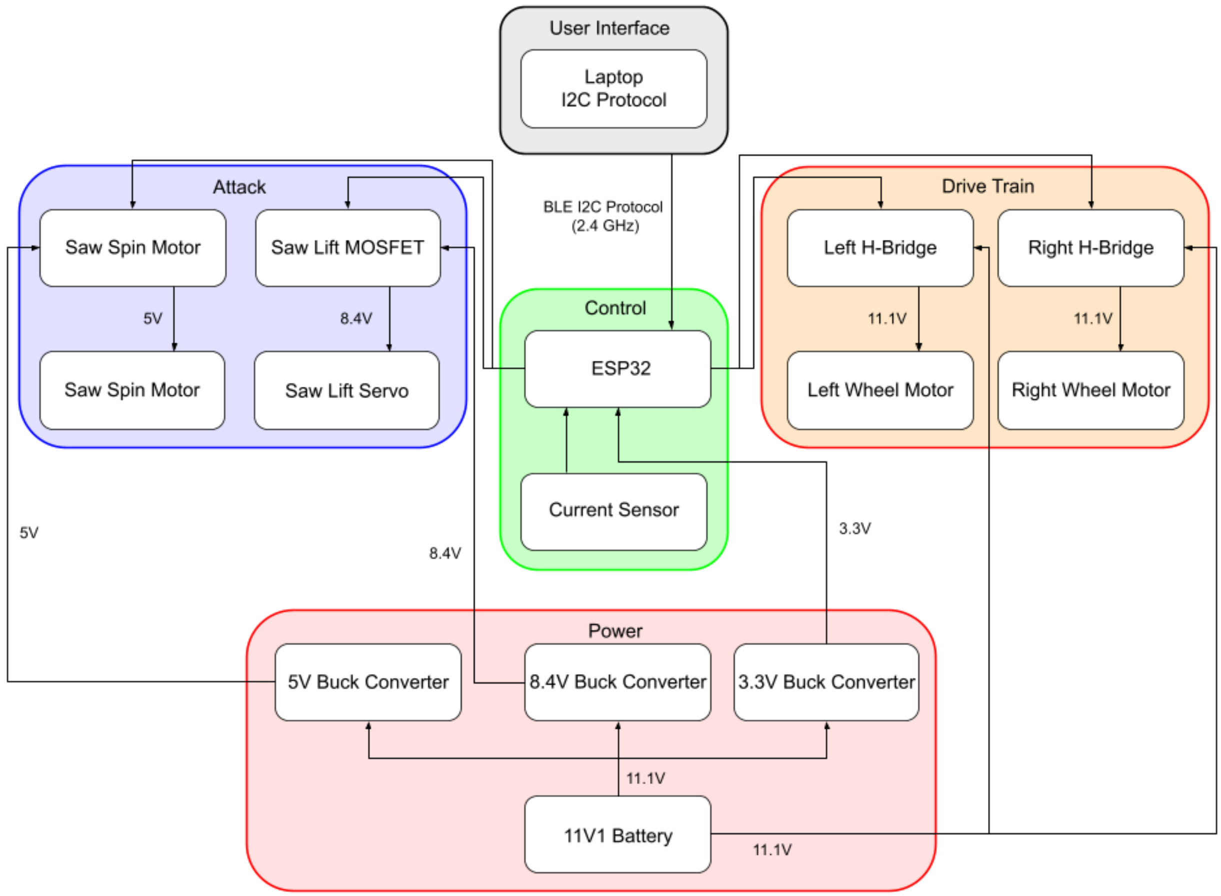
1.3 High-Level Requirements List

To consider our bot successful, we want to meet the following requirements:

1. The battlebot will be controlled by a laptop via Bluetooth. The user will be able to control the microcontroller to output PWM signals to adjust the saw blade spin speed and lift angle, as well as the DC signals to wheel motors for acceleration and steering.
2. The battlebot will have 2 attack mechanisms, one to spin the saw blade and one to lift it. We require that the saw can handle the torque of lifting the opponent, which would be about 2 pounds of force at approximately 10 inches from the servo.
3. We lastly require that the bot can handle a blunt force of about 40N centered at the top of the chassis. This would be a preventative measure to protect the PCB in the case the opponent plans on using a hammer-like attack mechanism. The center would be the weakest spot and hold the 'brain' of the bot.

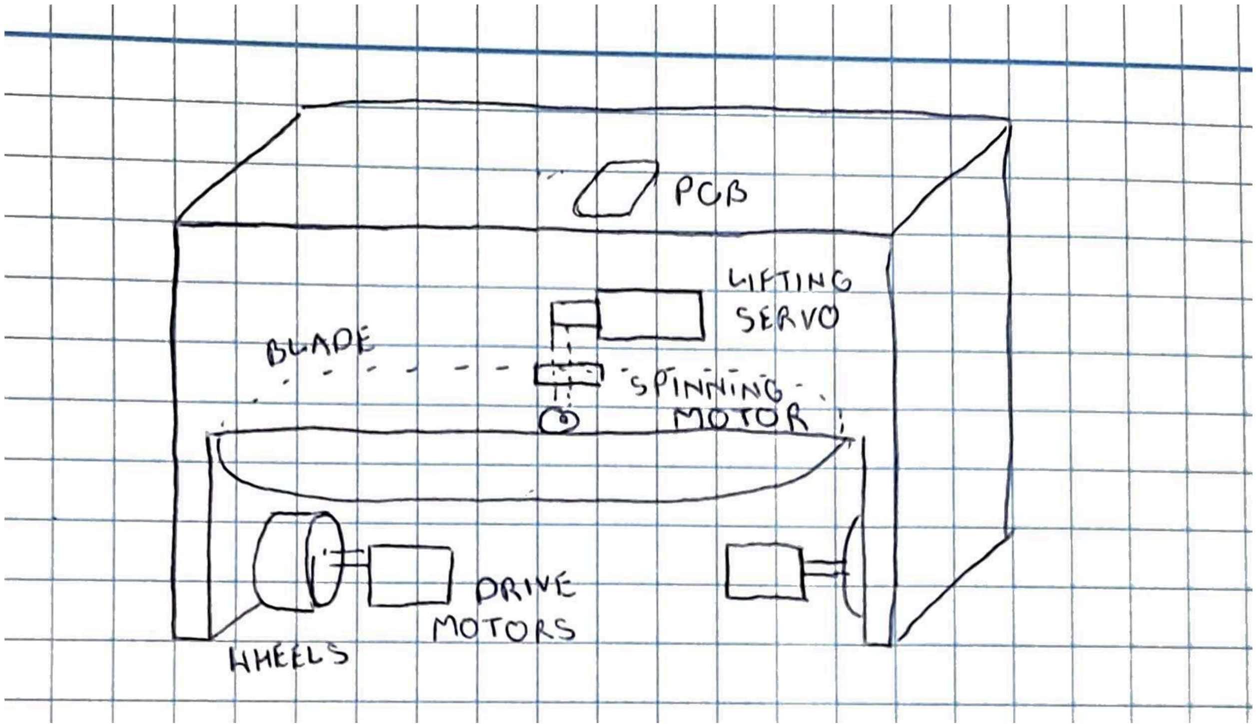
2. Design

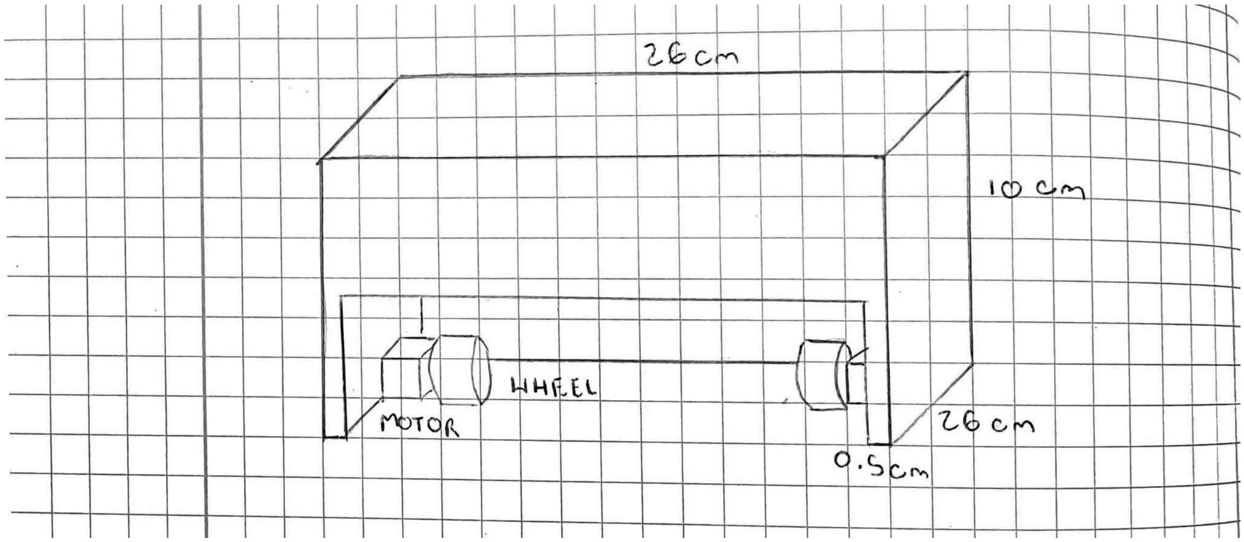
2.1 Block Diagram

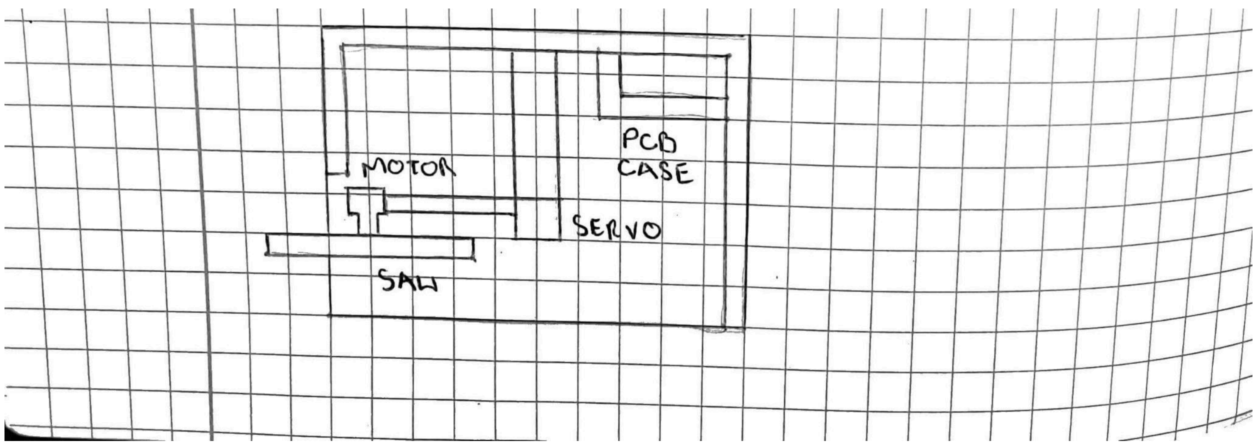


2.2 Physical Design

The bot from the outside will look like a simple box. Our goal here is just to ensure that the goods on the inside (pcb and attack motors) are well protected, speed is not a goal so aerodynamics are not taken into consideration. Wheel motors will be sticking out of the sides at the bottom, held in place by another 3D printed casing. The PCB will be held in a casing at the roof of the bot, near the back where it should feel the least impact. The blade servo will be held in place near the center of the bot, hanging from the top. Attached to it, positioned towards the front is a bar with the blade motor at the tip of it, facing down. The blade will be attached in a somewhat complex way. Imagine an empty cylinder (like an empty cup) and at the top of the cylinder are two holes. The holes allow for the servo bar to through and connect to the empty cylinder. Inside of the empty cylinder will be the motor, which also has a cylinder shape. The idea is the motor goes through the cylinder held up by the servo bar going through the two holes in the cylinder and then the saw attaches at the bottom through a small hole in the cylinder where the motor piece peaks through. Initial 3d Prototype plus images provided.







2.3 Power Subsystem and Current Sensor Subsystem

Battery -> LiperiAir 850mAh 3S 80C 11.1V Lipo Battery With XT30 Plug for RC Plane / Heli / Car / Boat

The basics of our power system from the outside consist of a battery, buck converters, programmable PWM pins, and an H-bridge. The buck converter generates from an 11.1V input three different stepped-down voltages: 3.3V, 5V, and 8.4V. These voltages are generated due to the constraints of our powered systems. This is the ESP32 microcontroller which runs at 3.3 volts, 5 volts goes to the motor for the saw, 8.4 volts for the servo and the H bridge is powered directly by the battery.

Cutting power regardless of the Bluetooth connection is going to be done using the current sensor. The current sensor converts the analog signal to a 16-bit digital output. Once the current sensor is functional, we are going to sample what amperage corresponds to what bit value. The idea is to do a reduction (tree of ors) on the upper bits which indicate over threshold current to detect if a one exists up there. If it does, our current must be too high, and then cut the voltage. The voltage will be cut by a simple CMOS inverter circuit, where, based on the reduction output, we either tie to ground (nmos on) or tie to a GPIO pin (pmos on). A simple diagram is shown below.

2.4 Controller Subsystem

We will use an ESP32 microcontroller. The primary benefit is that it has integrated WIFI and Bluetooth. This will allow us to add custom telemetry to our laptop to control our bot, such as controlling the motor speed, raising our blade to flip the opponent's bot, or cutting out power as a fail-safe. The ESP32 has plenty of peripheral support. There are many PWM outputs, so we can directly drive multiple items at different pulses. There are also ADC inputs that would allow us to detect battery life or sensor information. It provides everything needed, is very compact, and doesn’t use much power.

2.5 Drive Subsystem

Mentioned in the power system is a lot of the related information, but essentially, we have 2 wheels total, requiring an H-bridge per wheel to allow for forward and backwards motions. Additionally, with MOSFET signals having each GPIO pin, we can allow for turning left and right by turning a wheel off. Additionally, to allow for smooth turning, we are putting a roller on the front (essentially a spherical ball that can rotate in any direction), which is non-powered. This will assist in steering and keeping the battle bot up.

2.6 Attack Subsystem

The attack subsystem consists of a servo motor, saw motor, and 3d parts. First, the servo motor hangs from the top of the chassis upside down. There will be a 3d printed contraption which allows for this, the design isn't finalized as waiting on the servo motor part. Once hung upside down, the servo motor is going to lift a 3d printed bar. This bar is going to go into an empty cylinder, which has two holes at the top. Imagine a cylinder being a bucket of water, and the bar being a 2x4, which is connected to the bucket and lifts it using the force of the servo. Inside the cylinder, in this case, is not water, but a motor that sticks through the bottom and has a saw attached. When the servo lifts the cylinder, in this case, it in part lifts the motor. This allows for lifting the opponent, and also having different attack angles with the saw. Reference pyhsical design description above. The attack subsystem is powered as mentioned in power systems, and with time allowed will have PWM enabled.

2.8 Tolerance Analysis

Below is the Power analysis of our system.

Power Source: 11.1v LiPo Battery, 850mAh.

Microcontroller: ESP32(3.3v, 0.5A) = 1.65Li

Current Sensor: INA237(3.3v, 2mA) = 6.6*10e-3

2 Wheel Motors: 11.1v, 2A Rated, 3.8A stall = 44.4W

H Bridge: 8 MOSFETS Total, 4 on at a time

200mOhms Ros, 2A -> 20w *4 = 80w

Saw Motor:

130mOhms, 11.1v -> 16w

Saw Servo: 8.4v, 2A -> 16.8w

Buck Converters: 3A, 3.3v, 8.4v = 9w, 25.2w

Total: 193w

E = 11.1V *.85Ah = 9.435Wh

$T = 9.433Wh/1934 = .0489\ h = 2.93\ m$

To Do :

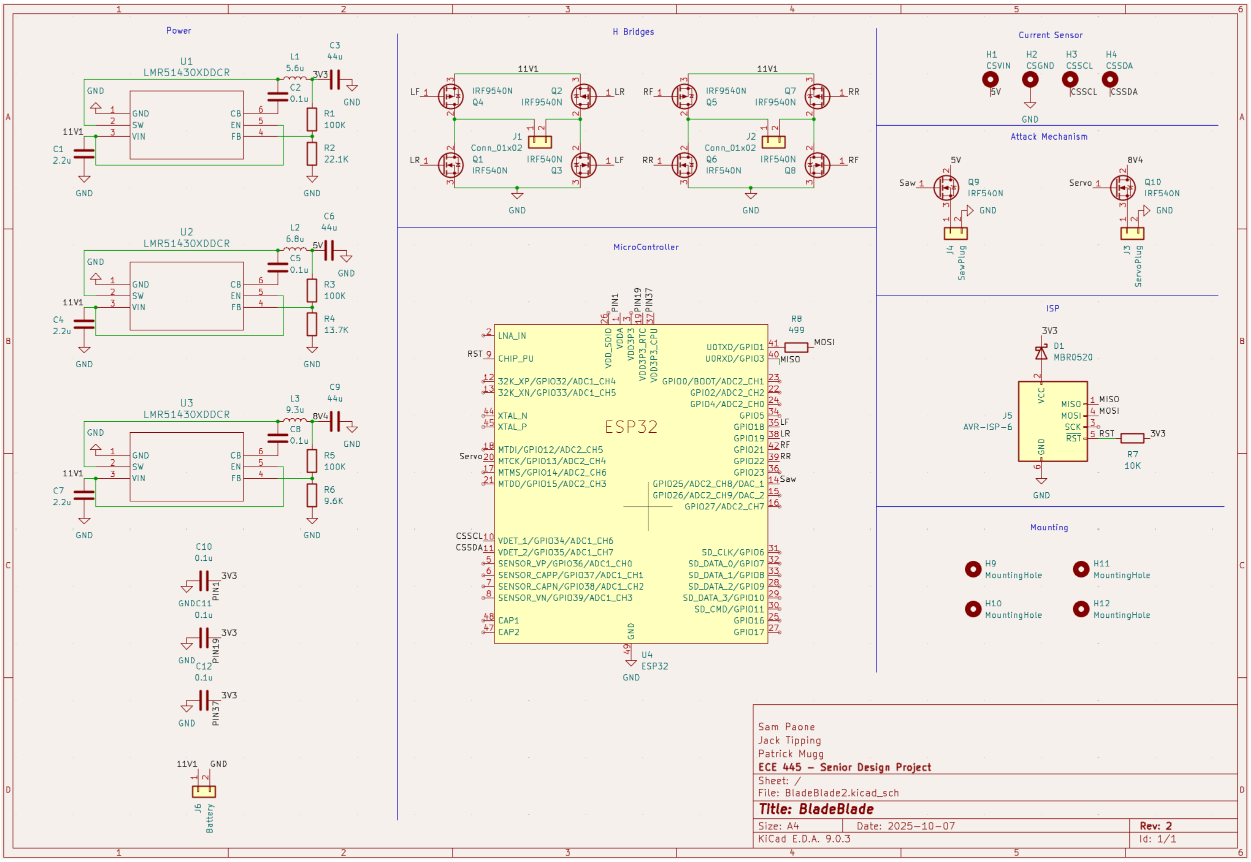
Find Datasheets for components for sizes, and make a custom footprint. Need ESP32, H-B transistors, spin and motor transistor, Servo Transistor, and ESP Programmer.

The largest concern in our project is the weight restriction. Having two functionalities to our weapon means more weight space has to be allocated to adding these objects. In addition, it also means our system will have a larger current draw, which means to sustain for 2 minutes of operation we need an increasingly larger battery. With some initial estimates:

Wheel Motors (Kohree's 12V 60 RPM 37 mm) x 2 = 276g
Saw Motors (EMAX MT2204) = 25g
Metal Gear Servo Motor = 55g
Current Sensor = 5g
500mah battery (Ovonic 3S 500 mAh) = 44g

These components add up to 410g, which constrains our chassis and PCB to weigh about 500g. Given this and the density of the plastic, about 1.2g/cm^3, we can determine what dimensions the chassis of the bot could be. We determined that the blade will have a 5cm radius and .5cm thickness, while the box will have dimensions of 18cm in both length and width, 6cm height, and .5cm thickness of the walls. This will be about 470g total. The extra weight will go into the PCB holder.

Full PCB Layout:


Power
U1
LMR51430XDDCR
GND
SW
VIN
CB
EN
FB
L1
5.6u
C2
0.1u
C3
44u
3V3
R1
100K
R2
22.1K
C1
2.2u
11V1
U2
LMR51430XDDCR
L2
6.8u
C5
0.1u
C6
44u
5V
R3
100K
R4
13.7K
C4
2.2u
U3
LMR51430XDDCR
L3
9.3u
C8
0.1u
C9
44u
8V4
R5
100K
R6
9.6K
C7
2.2u
C10
0.1u
PIN1
C11
0.1u
PIN19
C12
0.1u
PIN37
J6
Battery
H Bridges
11V1
IRF9540N
Q4
Q2
Q1
Q3
IRF540N
J1
Conn_01x02
LF
LR
Q5
Q7
Q6
Q8
J2
RF
RR
GND
Current Sensor
H1
CSVIN
H2
CSGND
H3
CSSCL
H4
CSSDA
Attack Mechanism
Saw
Q9
IRF540N
J4
SawPlug
Servo
Q10
IRF540N
J3
ServoPlug
MicroController
ESP32
U4
R8
499
MOSI
MISO
RST
Servo
CSSCL
CSSDA
ISP
D1
MBR0520
J5
AVR-ISP-6
R7
10K
Mounting
H9
MountingHole
H10
MountingHole
H11
MountingHole
H12
MountingHole
Sam Paone
Jack Tipping
Patrick Mugg
ECE 445 - Senior Design Project
Sheet: /
File: BladeBlade2.kicad_sch
Title: BladeBlade
Size: A4
Date: 2025-10-07
Rev: 2
KiCad E.D.A. 9.0.3
Id: 1/1

3 Cost and Schedule

3.1 Cost Analysis

We each spend roughly 12 hours a week for this class. Looking at a recent Illini success report, the average ECE major earns roughly $100,000 salary per year. This correlates to roughly $50 an hour.

Labor = $50 * 2.5 * 12 * 16 = $24,000

For our 3 person group this value reaches $72,000

Parts

Name	Description	Manufacturer	Part #	Qua-ntity	Cost
ESP32-WROOM Microcontroller	The ESP32-WROOM-32 is a dual-core Wi-Fi and Bluetooth microcontroller module that provides high processing power, multiple I/O interfaces, and efficient wireless communication for embedded and IoT applications.	Espressif		1	$4.84
Adafruit INA237 85V 10A 16-bit DC Current Monitor	A precision breakout board that can measure high-side or low-side DC current (up to 10 A) and bus voltage (up to 85 V), using a 16-bit ADC, and presents	Adafruit	INA237	1	$9.95
Mini 3-12VDC Gear Motor	Lightweight gearmotor with metal gears, specified as Model GA12-N20; rated at ≈ 100 RPM at 6 V with no load, ~80 RPM under load, reduction ratio ~10:1, shaft 3 × 10 mm, torque 2 kg·cm nominal, stall torque 16 kg·cm, stall current ~1 A, net weight ~10 g, dimensions ~24 × 12 × 10 mm	Aretronics	GA12-N20	2	$6.75
EMAX ECO II	A lightweight,	EMAX	ECO II	1	$26.99

3115 Brushless Motor	high-efficiency brushless motor suited for macro and cinematic drones, offering smooth throttle response and durable construction.		3115		
LiPeriAir 850 mAh 3S 80C LiPo Battery with XT30 Plug	A compact 3-cell (11.1 V nominal) lithium-polymer battery rated for high discharge (80C), commonly used for RC and robotics applications needing bursts of current.	LiPeriAir	3S, 80C, XT30 plug	1	$14.99
LMR51430	A high-efficiency synchronous buck (step-down) DC-DC regulator designed for portable and battery-powered systems; it supports relatively high current with good efficiency.	Texas Instruments	LMR51430 YFDDCR	3	$1.58
Dave Brown Lite Flite Wheels (1-1/2″)	Lightweight foam-core wheels designed for model aircraft and robotics, offering minimal weight while providing traction on surfaces.	Dave Brown Products	“Lite Flite Wheels” 1-1/2″ version	1	$4.75
Hiwonder HPS-2018 Full Metal Gear Digital Servo	A high-torque digital PWM servo with full-metal gears, dual ball bearings, and an aluminum case, capable of delivering ~20 kg·cm torque at 7.4 V.	Hiwonder	HPS-2018 (SKU: 21100012)	1	$14.99
VN10LM	An N-channel enhancement-mode MOSFET intended for switching / amplification tasks, typically in low-to-moderate power circuits.	Siliconix		4	$0.70
IRF9510	A P-channel power MOSFET designed for switching/regulation applications, especially	Siliconix		4	$0.70

	where a high-side switch is needed.				

Parts summed up: $100.35

Combined group salary: $72,000

Group cost for the 16 week semester: $28,800

Total cost: $29,900.35

3.2 Schedule

Week	Task	Description and team assignments
10/20	Complete breadboard prototype for second demo	The team will finish wiring and testing all subsystems on the breadboard, including motor drivers, servo control, Bluetooth communication, and current sensor functionality. Power regulation and kill-switch safety logic will be verified. Sam Paone will handle microcontroller programming and Bluetooth communication, Jack Tipping will focus on motor and servo circuit integration, and Patrick Mugg will manage wiring, power regulation, and documentation.
10/27	Begin 3D printing and physical assembly; prepare PCB iteration 3	Work will shift to 3D printing the chassis and component mounts while continuing circuit integration. The team will also evaluate the breadboard prototype and make any PCB updates needed before submitting a third fabrication round. Jack will oversee mechanical design and printing, Sam will manage PCB edits and testing, and Patrick will focus on assembly and wiring layout.
11/3	Continue to 3D print and construct our bot and prepare for fourth round PCB order if we need	Assembly of printed parts will continue, including mounting motors, servos, and power distribution boards. If required, a fourth PCB order will be submitted to address design improvements. Jack will handle chassis assembly, Sam will refine the firmware and debug circuits, and Patrick will verify the power system and connections.
11/10	Prepare for mock demo	The team will complete full subsystem integration and begin combined testing of driving and weapon systems. Wireless reliability, mechanical strength, and safety systems (guards, kill-switch, etc.) will be verified. Sam

		will refine Bluetooth control software and data logging, Jack will tune the mechanical systems, and Patrick will inspect electrical integrity and confirm safety compliance.
11/17	Mock Demo	The fully integrated prototype will be demonstrated, showing both driving and attack mechanisms. The team will collect TA and peer feedback to identify improvements for the final demo. All members will participate equally in presenting and testing.
12/1	Prepare and complete Final Demo	The team will refine the bot based on feedback, improve control responsiveness, and perform endurance and safety tests under competition conditions. Sam will finalize firmware tuning, Jack will reinforce mechanical structure, and Patrick will manage battery safety and testing.
12/8	Prepare and complete Final Presentation	The team will summarize the design process, testing results, and ethical/safety considerations in the final presentation. They will collaboratively prepare the slides, poster, and live demo materials to showcase the finished system.

4 Discussion of Ethics and Safety

IEEE Code of Ethics – Safety and Well-Being

Following the IEE Code of ethics, our team will ensure that we place an emphasis on the health and safety of all our team members, competition officials, and spectators throughout the entire process. The assembly and testing of our bot will take place in extremely controlled environments, such as an enclosed lab or an official competition arena. Since our project contains moving mechanical parts as well as a spinning weapon, we want to have strict safety measures so there are no accidental injuries. Our robot will not be energized unless it is secured on a safe surface and under proper supervision. We will utilize a physical guard attached to the blade during testing if we determine it is sharp enough to cause harm, as well as a kill-switch will be installed to disconnect the battery in case of emergency. Another priority will be our battery. We want to only use LiPo batteries that are properly rated for our current draw. As well as storing them in fire-resistant containers when we are not using them. The charging will be done using lab-approved power supplies under our supervision. These practices will help ensure the well-being of our team, and the surrounding ones too.

IEEE Code of Ethics – Security and Responsible Use

Our robot is controlled using Bluetooth between our laptop interface and the ESP32 microcontroller. Wireless communication allows for the risk of unauthorized control or interference. In order to comply with the standards of responsible technology use from IEEE, we will securely pair devices using unique identifiers and authentication protocols. We will avoid unencrypted and open pairing mode. The software that we write will have security in mind. The ESP32 will ignore commands from unrecognized addresses, and the connection status will be monitored on our laptop interface. During the competition, connections will be tested to prevent unintended cross-communication with other robots. Prioritizing data integrity and responsible use will mitigate the chance of interference that could cause harm to people or equipment.

IEEE Code of Ethics – Fairness and Compliance

The ACM code puts an emphasis on adherence to rules and fairness. We will build our bot to fully comply with the regulations of the competition. We will ensure there are no hidden features or modifications that give us an unfair advantage in the competition. The materials we choose to use will be properly documented and transparent to the organizers. We are big fans of supporting integrity and fair competition.

Anticipated Safety Concerns and Mitigation Procedures

Our project has several safety concerns that we will carefully address to ensure we operate our bot safely during development, testing, and in competition. The first area involves battery hazards. Overcharging, short-circuiting, or potentially puncturing a LiPo battery can lead to harm through a fire or overheating. In order to prevent this, we will use an overcharge protector and store batteries in fireproof safe bags when not in use. There will be a voltage monitor that will automatically cut off the power if we are operating below safe operating limits. In addition, we will inspect batteries before and after use to check for swelling or damage which are a sign of potentially unsafe conditions.

Another concern we have are mechanical hazards. Given the rotating saw blade and lifting mechanism there is always the potential for error. During assembly, transportation, or testing, we want to mitigate all risks. In order to achieve this, we will have a removable guard over the blade when it is not in competition. During operation, we will maintain a safe distance around the bot and always have a hardware and software kill switch for any emergency stops. The blade will only be activated inside any approved test or competition areas. Finally, the batteries will be disconnected with the blade removed when we are transporting the bot.

Another hazard we must properly deal with are electrical issues. All exposed wires we have will be insulated to prevent accidental contact or disconnection. We will test all solder joints for continuity before powering-up. In order to prevent overvoltage damages, we will ensure we properly supply our components with the correct voltage amounts.

We also recognize the potential for wireless interference. Our bot relies on Bluetooth communication, so this will be a major concern for the safety and simply the function of our bot. Another nearby device could attempt to pair or interfere with our connection. To avoid this, we will use fixed pairing modes along with unique device identifiers. We will conduct all testing on dedicated communication channels.

5 Citations

Institute of Electrical and Electronics Engineers. "P7.8: IEEE Code of Ethics." *IEEE*, https://www.ieee.org/about/corporate/governance/p7-8.html. Accessed 13 Oct. 2025.

Association for Computing Machinery. *ACM Code of Ethics and Professional Conduct*. Association for Computing Machinery, 2018, https://www.acm.org/code-of-ethics