RC Lawn Mower

Senior Design Project

Group 17

Design Goal

Our goal was to enhance the design of modern lawn mowers by focusing on convenience and safety, using smart autonomous features to make mowing easier and more reliable.

Our team

Brayden Anderson
Electrical Engineering

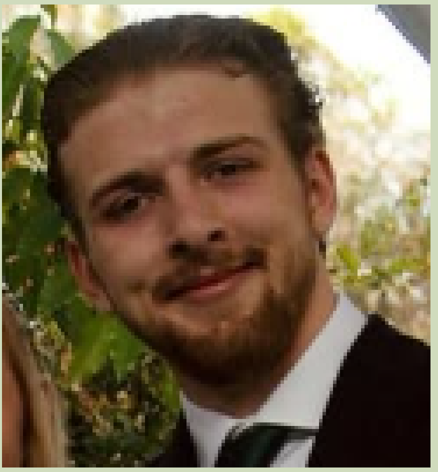
Steven Huynh
Computer Engineering

Project Motivation

- **Lawn mowing is a repetitive and time-consuming chore**
  - For many homeowners, mowing the lawn is a routine task that takes up valuable time and energy, especially during peak growing seasons. It often requires frequent attention and physical effort, making it a less-than-enjoyable part of home maintenance.

- **Remote-controlled automation reduces physical effort**
  - Introducing remote-controlled or automated functionality allows users to manage lawn mowing with minimal manual involvement.
  - This not only saves time but also makes the task more accessible to individuals with physical limitations or busy schedules.

- **Adding obstacle avoidance enhances safety and autonomy**
  - Integrating obstacle detection and avoidance systems helps the mower navigate safely around people, pets, and objects. This technology not only reduces the risk of accidents but also supports more intelligent, hands-free operation, bringing the mower closer to full autonomy.



Goals

Basic Goals

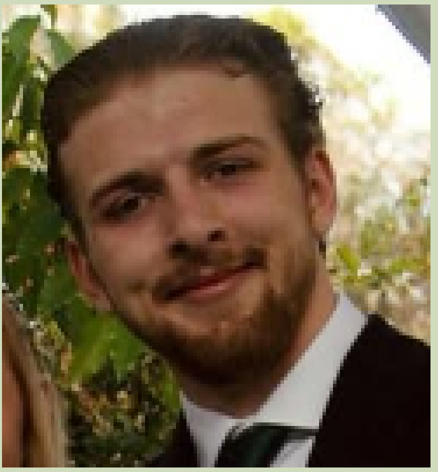
- Design and build a fully remote-controlled, rideable electric lawnmower with a strong emphasis on efficiency, safety, and user convenience.
- Ensure the lawnmower can navigate and operate reliably across various types of terrain without interruption or failure.
- Achieve continuous operation for a minimum duration of 10 minutes under normal conditions.
- Demonstrate a total travel distance of over 500 feet during a single operational cycle.

Advanced Goals

- Implement obstacle detection using ultrasonic sensors.
- Lawn mower must be able to detect obstacles within a 1-foot radius.
- Program the mower to autonomously navigate around detected obstacles.
- Integrate audio and/or visual indicators for object detection alerts.

Stretch Goals:

- Achieve at least 80% path coverage in autonomous mowing mode.
- Maintain an FPV video feed with <1 second latency over Wi-Fi/Bluetooth.
- GPS accuracy within ±1 meter for navigation boundaries.
- Solar panel must provide at least 10% of operating power under direct sunlight.
- App interface must support Bluetooth or Wi-Fi connection, and control all major functions.



Objectives

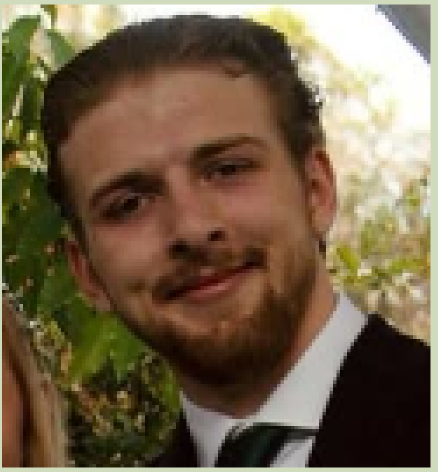
Basic Objectives

- The lawnmower must run continuously for at least 10 minutes.
- It must successfully travel at least 500 feet without failure.
- Must operate on multiple terrain types (grass, gravel, dirt) without stalling or having to be repositioned..
- The frame must support a rider of at least 200 lbs safely.
- A remote-control system must respond within 200 milliseconds of input.

Advanced Objectives

- Use at least 3 ultrasonic sensors (e.g., HC-SR04) for full front coverage.
- System must identify obstacles within 12 inches with at least 90% accuracy.
- On detection, mower must perform a predefined evasion maneuver (e.g., stop, turn, move forward).
- Include LED indicators or buzzer that activates object detection.

Stretch Objectives



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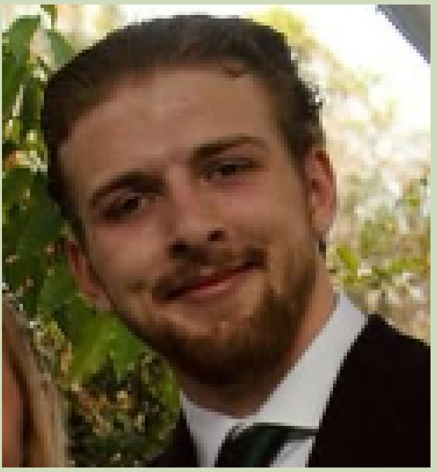
Engineering Specifications

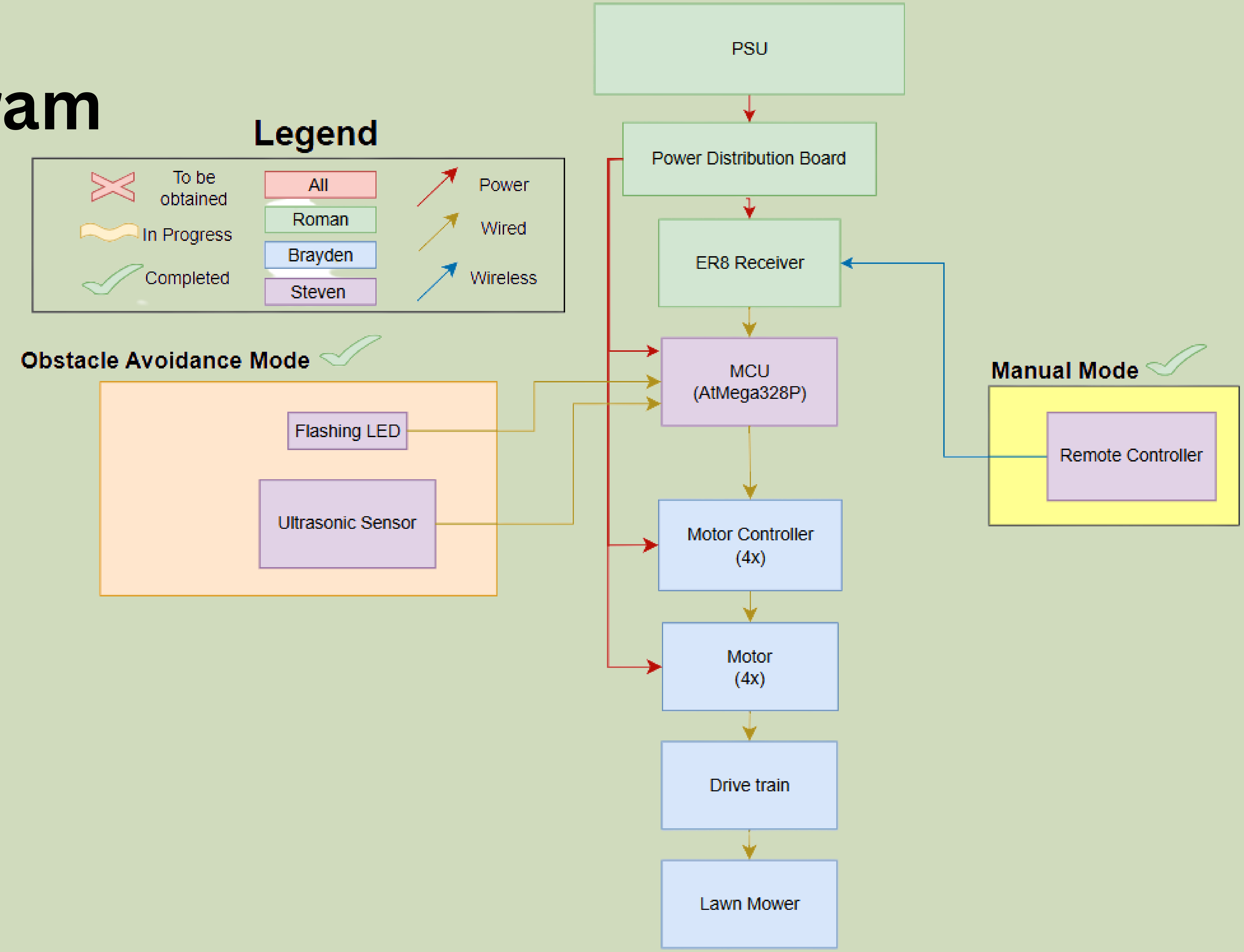
Remote Controlled Lawn Mower	
Weight	≤ 200 lbs.
Distance Travelled (Without failure)	< 500 ft
Obstacle Detection Range	1ft to 2ft
Continuous Run Time	≥ 10 minutes
Obstacle Detection Accuracy	≥ 90%
Remote Control Range	≥ 50 ft
Remote Control Response Time	< 0.2 Seconds
Obstacle Avoidance Latency	≤ 0.3 Seconds
Degree of Rotation	≥ 90 Degrees
Power Consumption	250 Watts

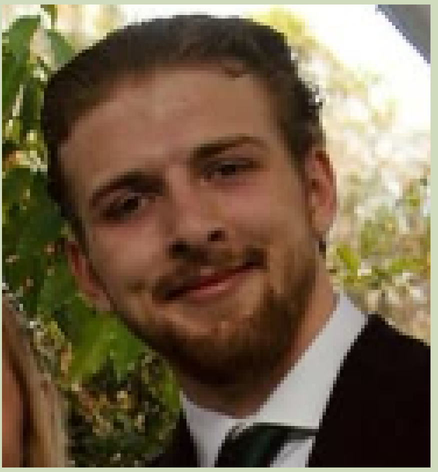


Hardware Block Diagram

Here is the hardware block diagram, as you can see

- Manual Mode
  - PWM goes from the remote to the ER8 then to the drive train
- Obstacle Avoidance Mode
  - The sensor sends a signal to the MCU then the MCU send preprogrammed instructions to the drive train





Motor Comparison

With our research we chose the Vex 393 because

Seamless VEX Integration

- Compatible with VEX gears, shafts, and structural parts, enabling quick assembly without custom mounts or complex engineering.

Tailored Performance

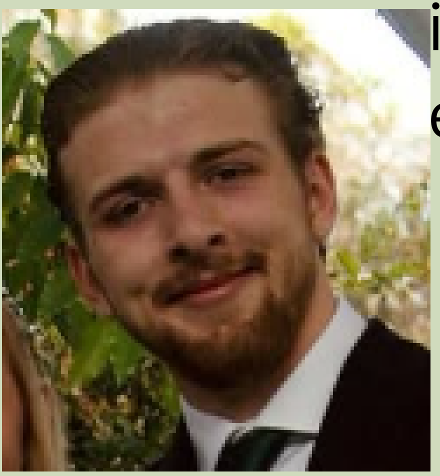
- Offers adaptable torque and speed through gearing, suitable for mower movement and blade rotation without requiring high-voltage power.

Simple Control System

- Brushed motor design requires only basic motor controllers or H-bridges, reducing electronics complexity.

Compact and Lightweight

- Smaller and lighter than industrial alternatives, improving the mower's maneuverability and energy efficiency.



Motor Component	Pros	Cons
RS-775	High torque & Speed	High current draw, runs hot and needs cooling
CIM	FRC-Proven, High torque	Large current spikes, super heavy
BAG	Good power to size balance	Lower peak torque, gets hot
Brushless Outrunner	Super efficient, good power-to weight ratio	Needs Specials ESCs, integration & cooling is complex
NEO	High efficeny & torque	Complex and expensive, requires Spark MAX controller
Vex 393	Power aligns with motor needs, light & compact	Lower peak torque than contenders

Receiver Comparison

The Radiolink ER8 provides:

A reliable 2.4Ghz frequency-hopping protocol

- Extremely reliable extended range signal that is stable which suits the needs for our lawn mower

Long Range Capability

- Strong and stable signal even in extended distances, ideal for our Lawn Mower

Supports 8 Channels

- Sufficient for complex setups involving throttle, steering etc.

Failsafe capability

- If signal is lost then the mower will safely stop/go idle

Receiver Component	Pros	Cons
Spektrum AR620	lightweight & compact, DSMX protocol	High current draw, runs hot and needs cooling
Fly Sky FS-iA6B	Cost-effective, decent range for price, PWM support	Large current spikes, super heavy
FrSky X8R	Full telemetry support, long range and robust link	Lower peak torque, gets hot
Futaba R2106GF	Compact form factor, reputable brand quality	Needs Specials ESCs, integration & cooling is complex
TBS Crossfire Nano RX	Compact and lightweight, fast telemtry feedback	Complex and expensive, requires Spark MAX controller
Radiolink ER8	Reliable 2.4GHz protocol, sufficient channel count, good range	Lower peak torque than contenders

Sensor Comparison

The HC-SR04 was a solid choice for our project due to:

High affordability

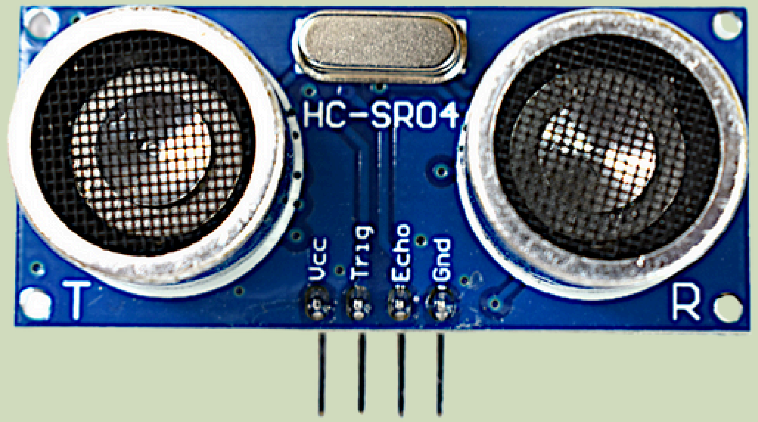
- allowing us to easily replace the sensor if any damages were to occur.

Effective detection range

- 2cm to 400cm
- Allows for plenty of time for the robot to detect outdoor objects (fences, trees, bushes)

Straightforward interface

- Allows for easy integration for microcontrollers such as Arduino



Sensor Component	Pros	Cons
Parallax Ping Ultrasonic	Reliable, single pin interface, consistent readings	High cost, limited range optons
MaxBotix LV-MaxSonar	Long detection range, high quality,multiple output options	Higher cost, interference in multi sensor arrays
Sharp GP2Y0A21YKOF IR	Less interference, compact size, continuous analog output	Reduced maximum range, potential light inteference
LIDAR-Lite v3	High precison + Long range, fast update rate	Significant cost, complex setup, outdoor interference
Photoelectric Retroreflective	Long ranges, simple on and off signals	Requires reflectors, less versatile, high cost
HC-SR04 Ultrasonic	Affordable, accessible, simple interface with wide documentation	Not as precise compared to other contenders

Power Supply Comparison

The 24V 15A Switching PSU provides:

Voltage and Current Balance

- Supplies 24V at 15A, ideal for small to medium-sized DC motors.

Handles Startup Surges

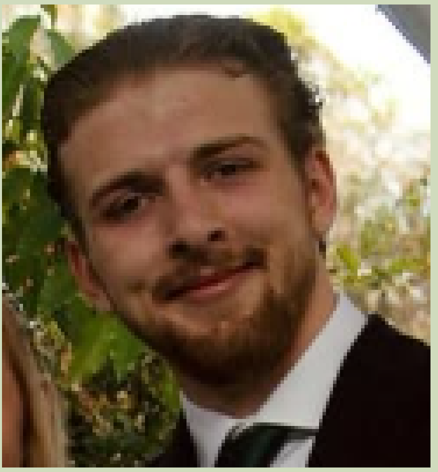
- Provides sufficient current headroom to manage motor startup and normal lawn mowing operations without oversizing.

High Efficiency

- Switching power supply technology minimizes energy waste and heat buildup.

Cost-Effective Choice

- Offers more capacity than a 10A unit (which may struggle with peaks) without the higher cost and bulk of a 20A supply.

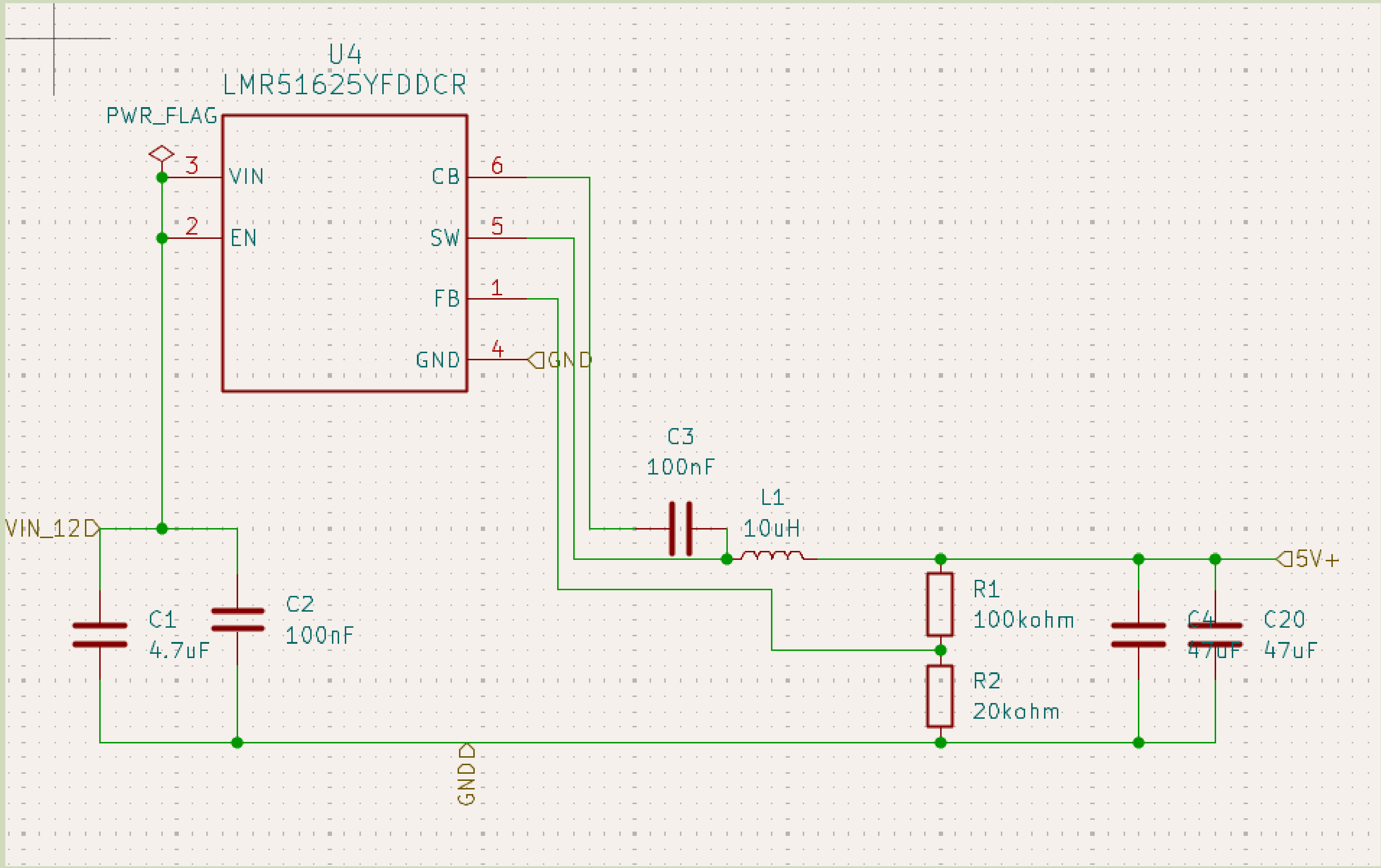


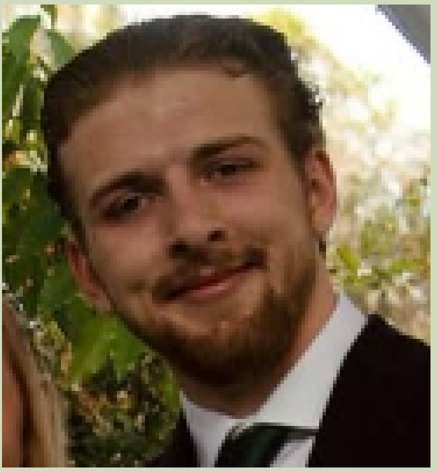
Power Supply	Pros	Cons
12V 30A Switching PSU	High amperage capacity, simple for 12V Components	Reduced voltage for motors, potential increased current draw
24V 10A Linear PSU	Clean stable output, less interference	Lower current rating, heavy , bulky, low effiency
24V 20A Switching PSU	Increased current, lightweight & compact	Higher size, expensive, unnecessary power capacity
48V 7.5A Switching PSU	Reduced current at higher voltage, suitable for industrial motors	Not compatible for 24V components, motor over spec risks
Battery-Only System	Complete mobility, clean DC output, scalable capacity	Weight and maintenance issues, limited continous operation
24V 15A Switching PSU	Optimal voltage for motors, efficient design and cost effective	Lower peak torque than contenders

Regulator Schematic

LMR51625YDDCR - Highly-integrated wide-input synchronous buck converter

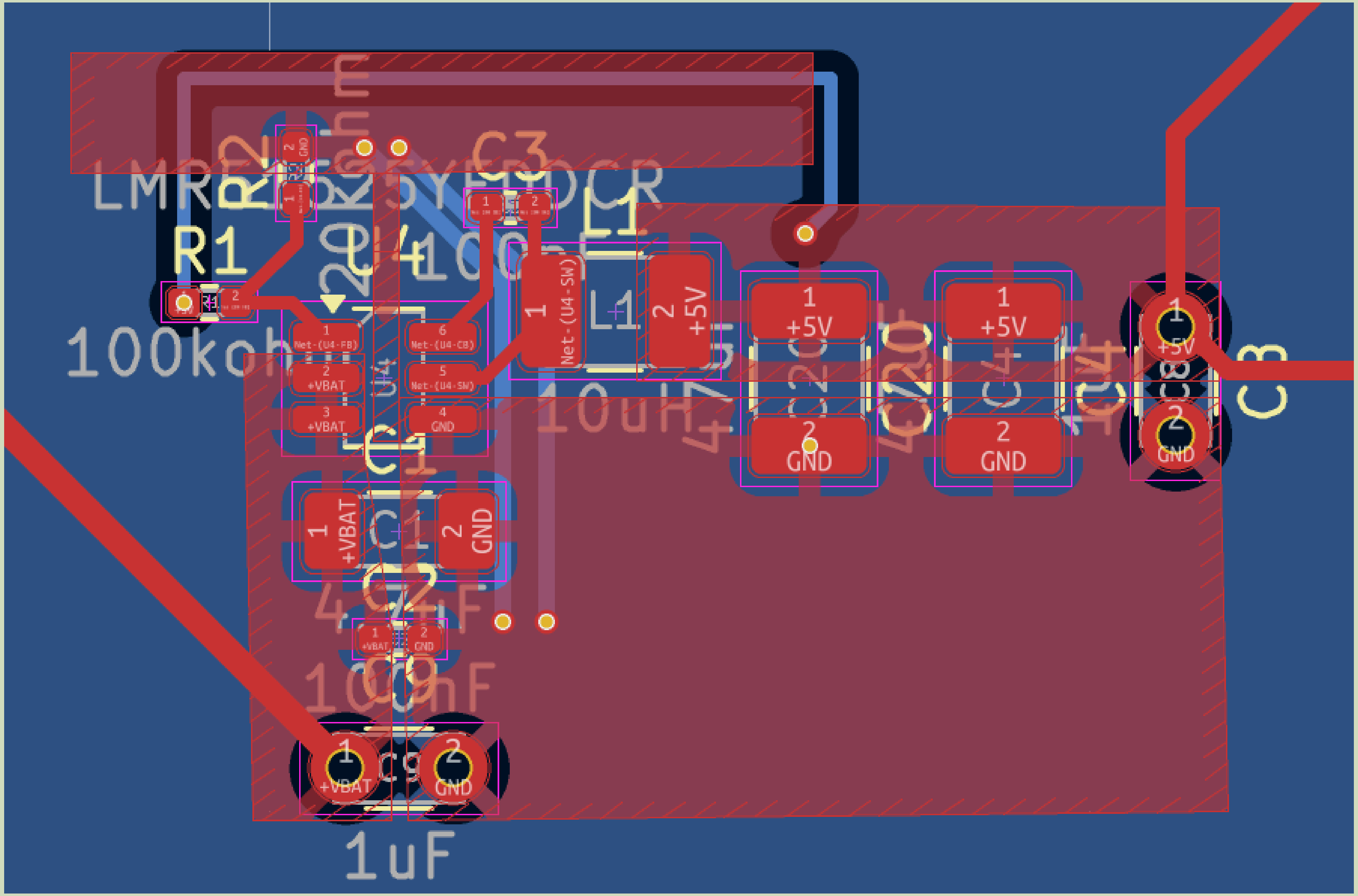
- Converts up to 18V input into a stable 5 volts and 5 amps
- Protection features include overcurrent fuses and thermal shutdown paths

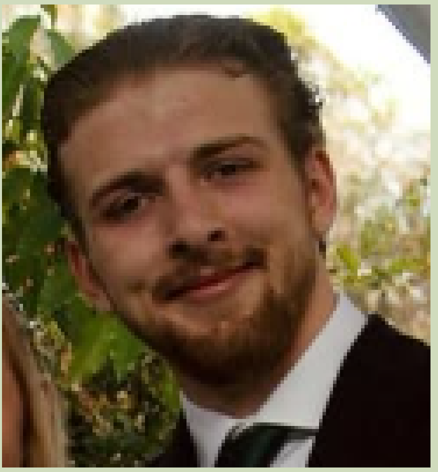




Regulator PCB

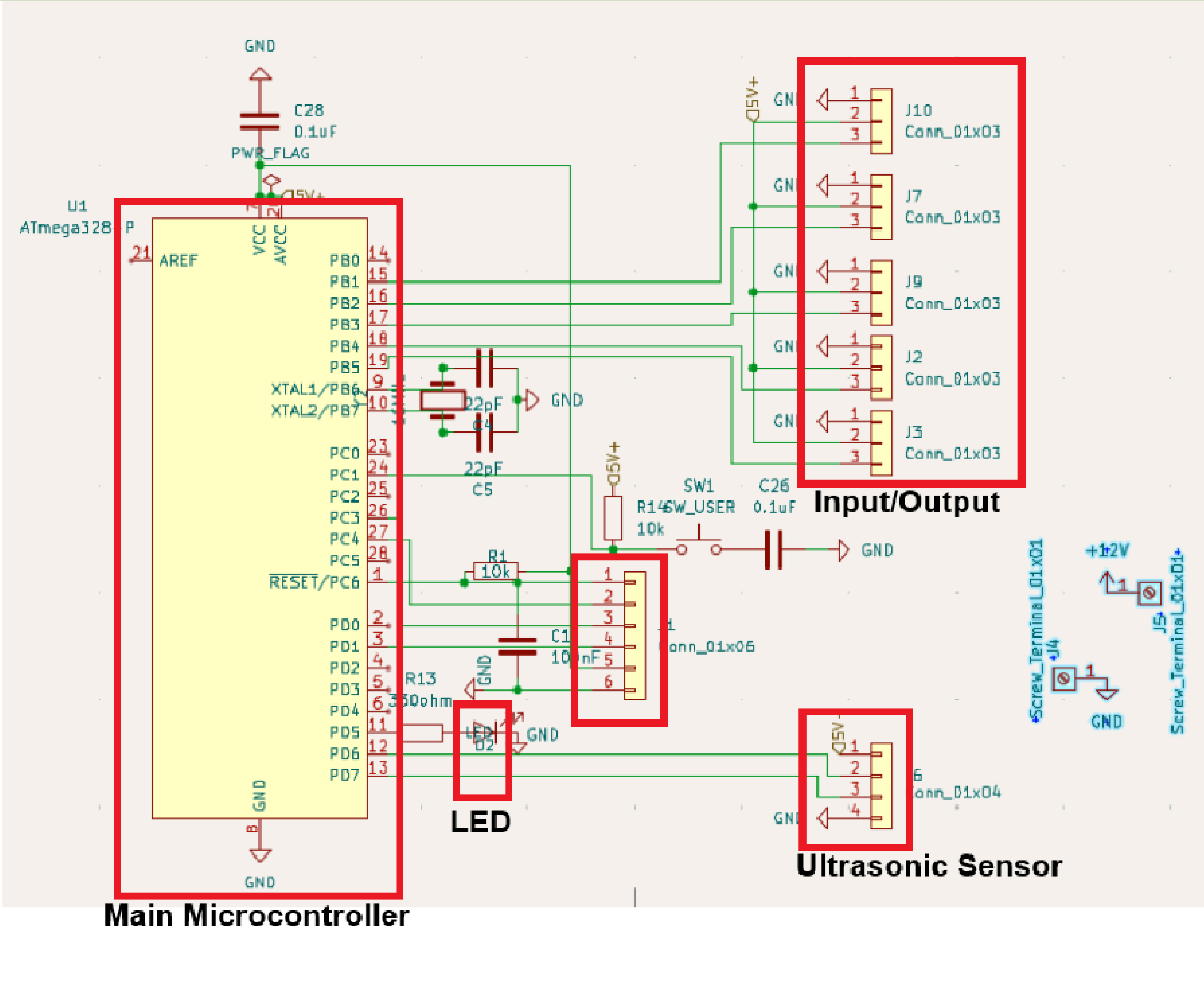
- Uses large copper pours and thermally isolated pads to dissipate heat

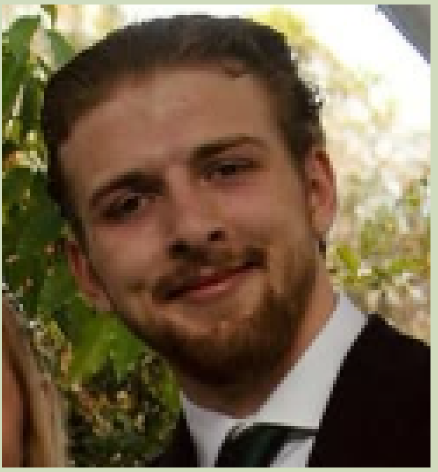




MCU Schematic

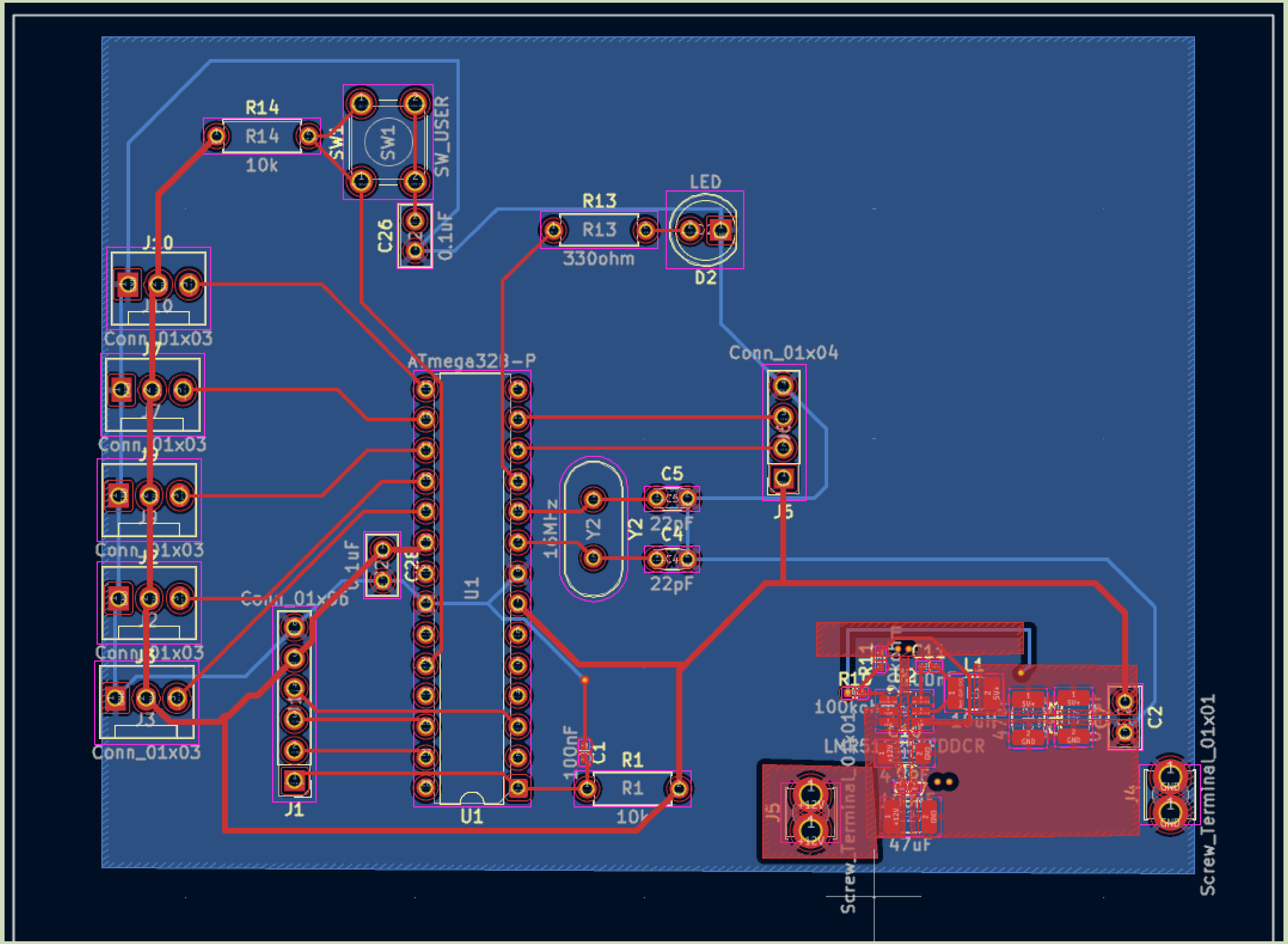
- Connects an AtMega328-p to PWM outputs, ultrasonic sensor, and ER8 radio receiver

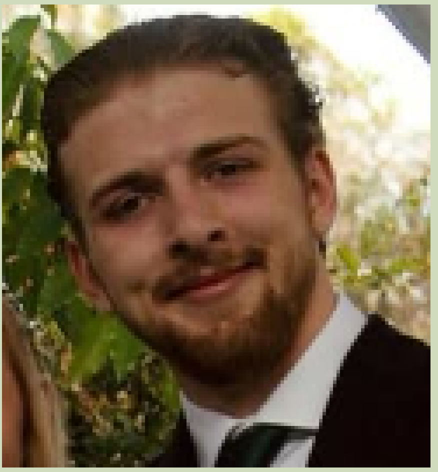




MCU PCB

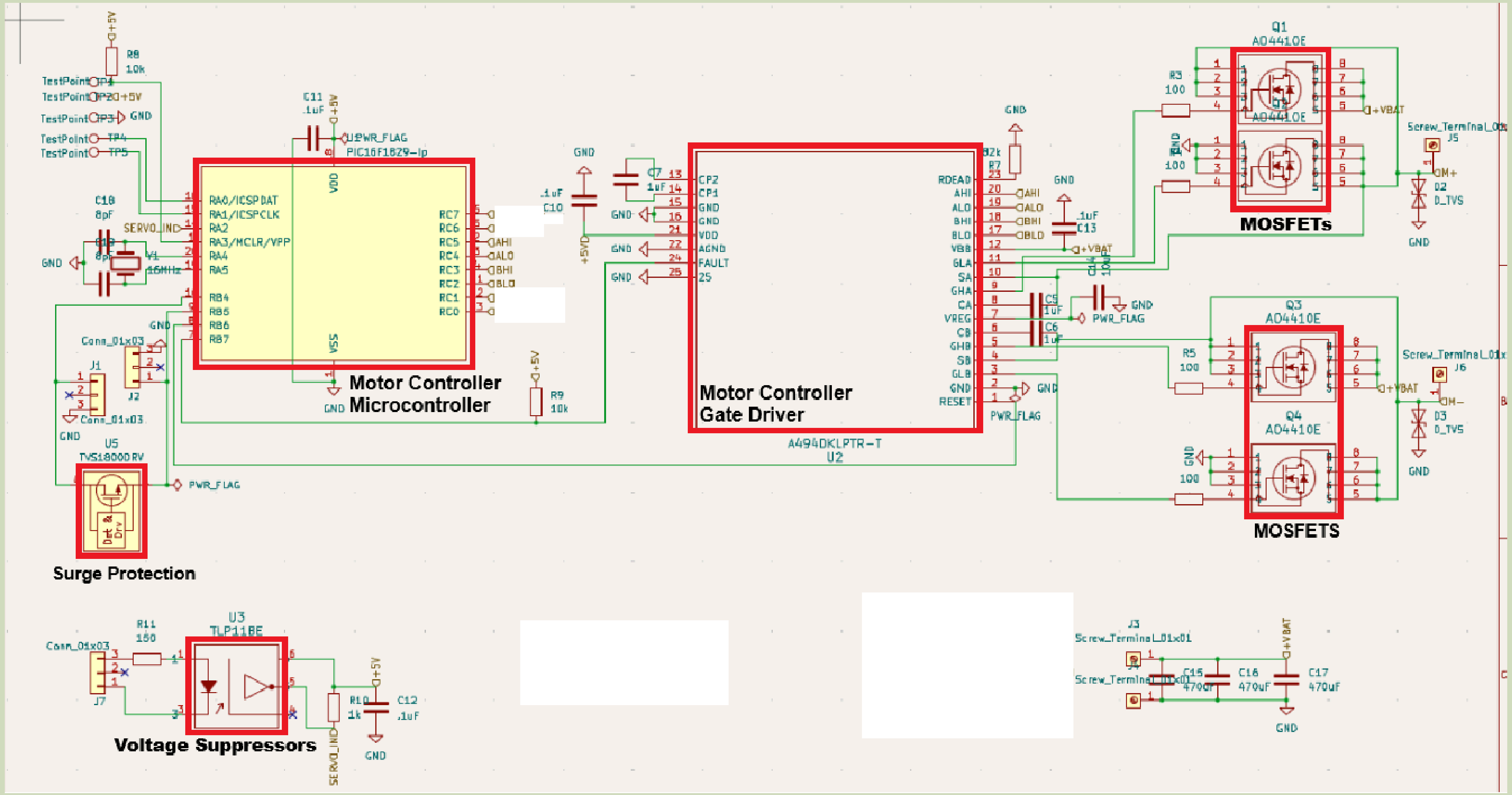
- Trace routing keeps signals separate and connector placement is optimized for chassis integration/debugging access

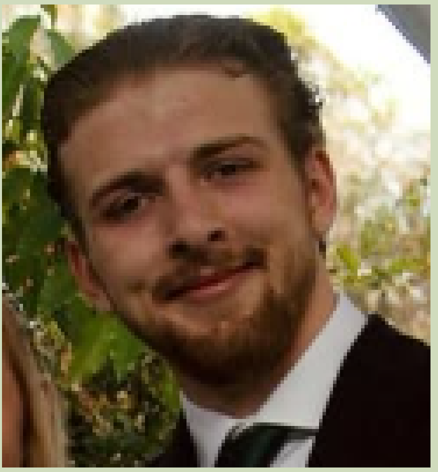




Motor Controller Schematic

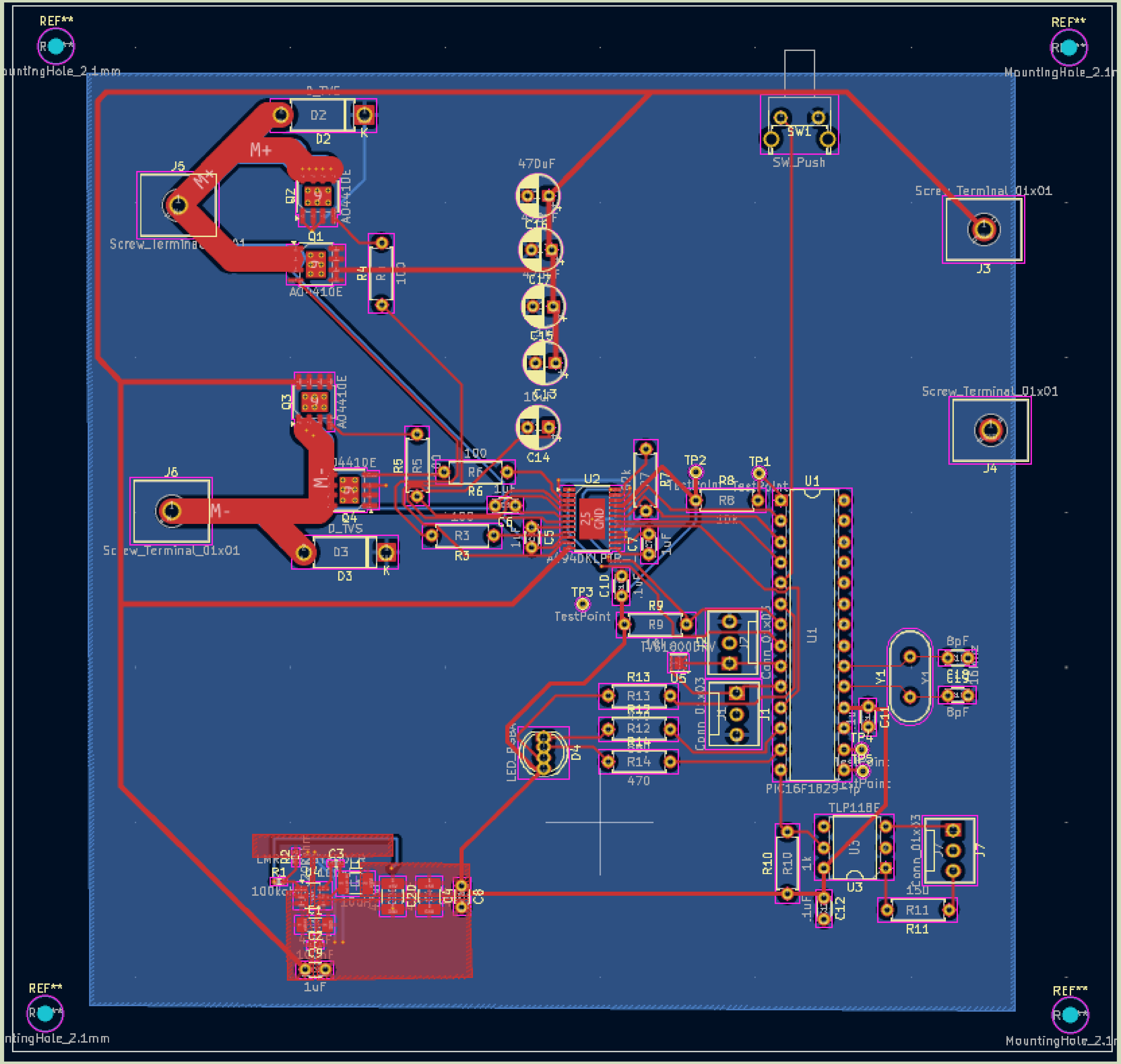
- Uses a dual H-bridge config for bidirectional control

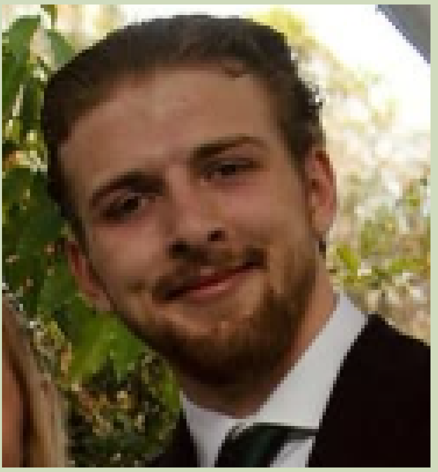




Motor Controller PCB

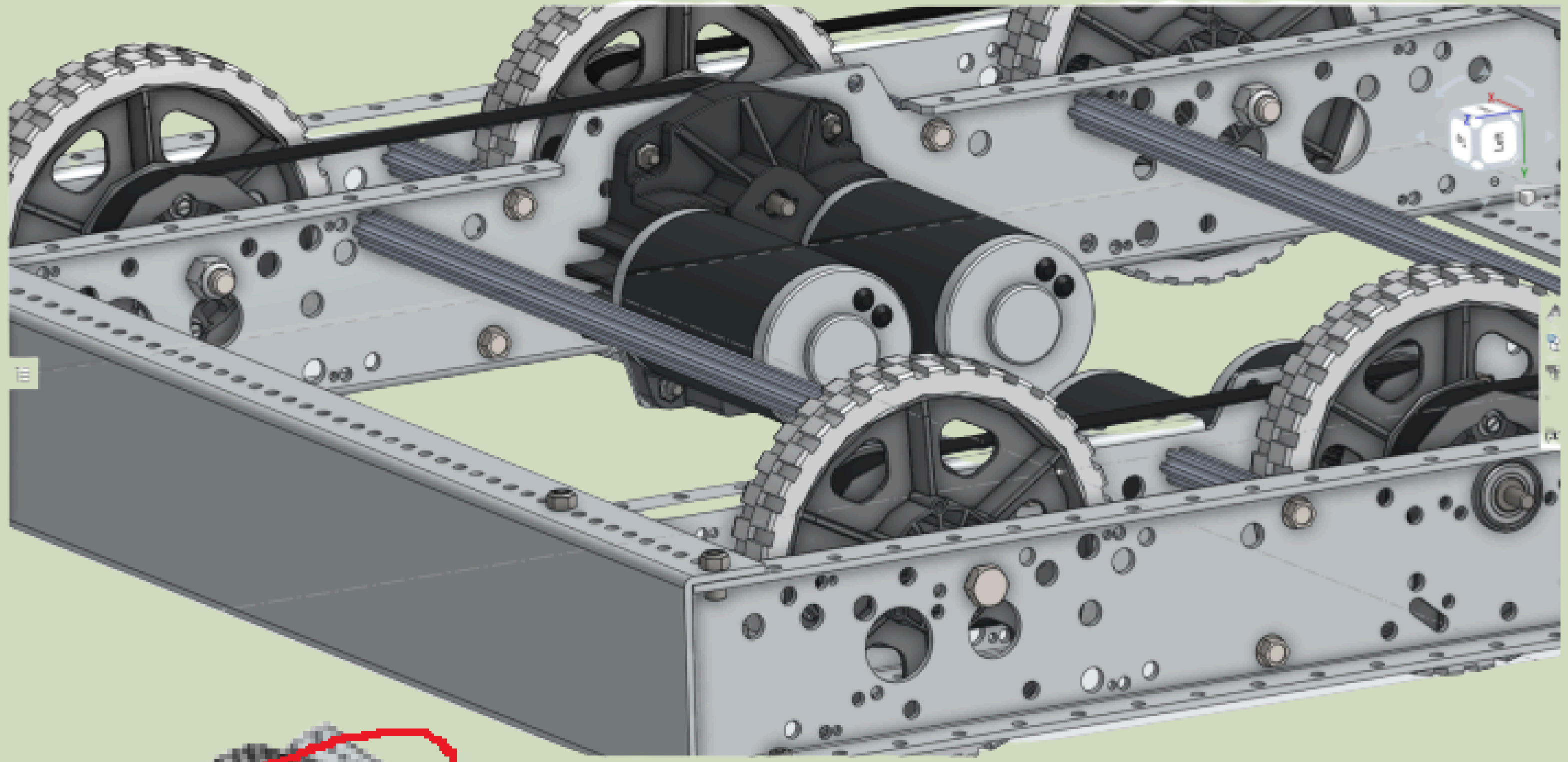
- Cleanly laid out with wide copper traces for high-current paths, screw terminals for field wiring, and tight trace grouping for minimal EMI

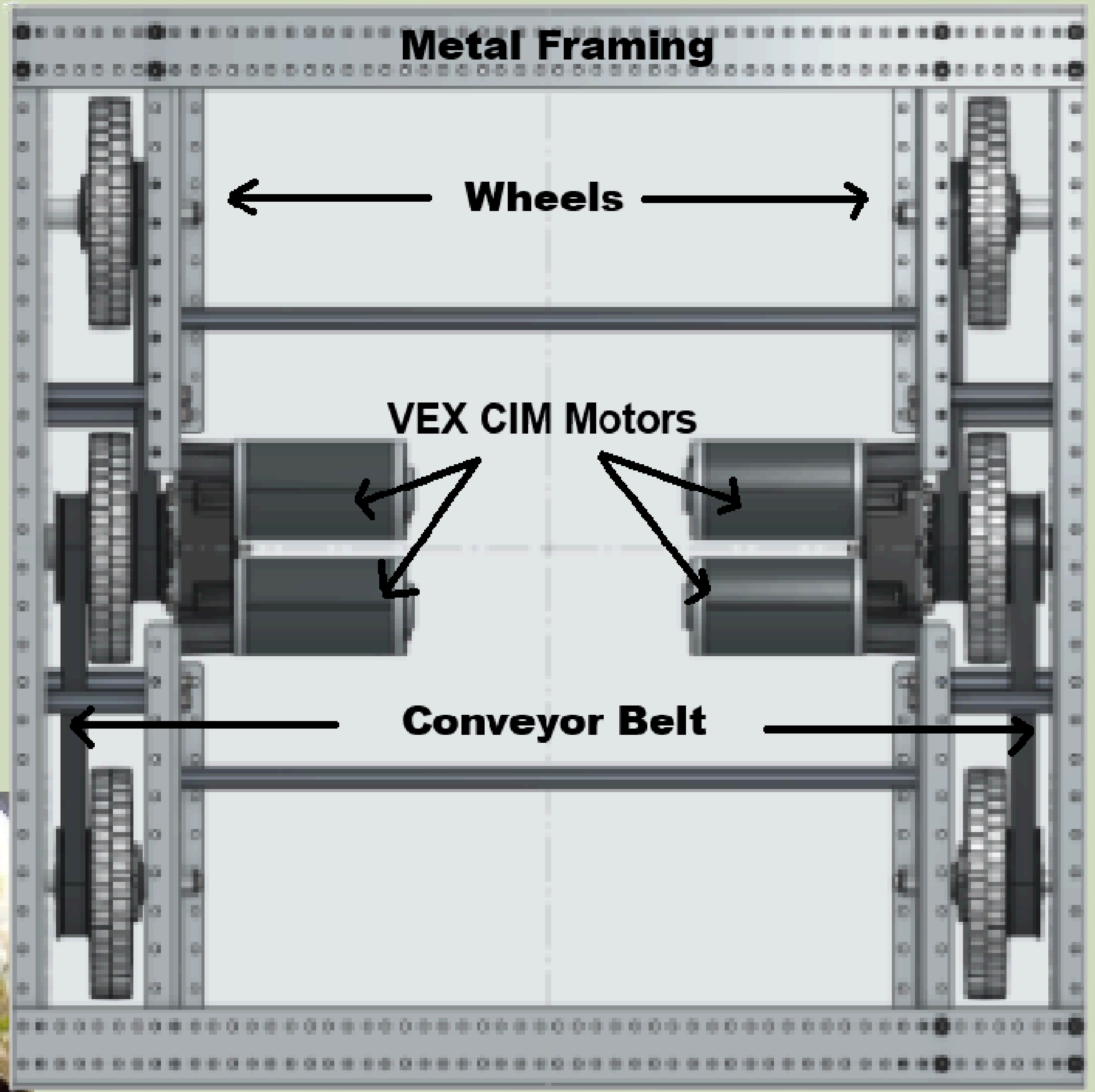


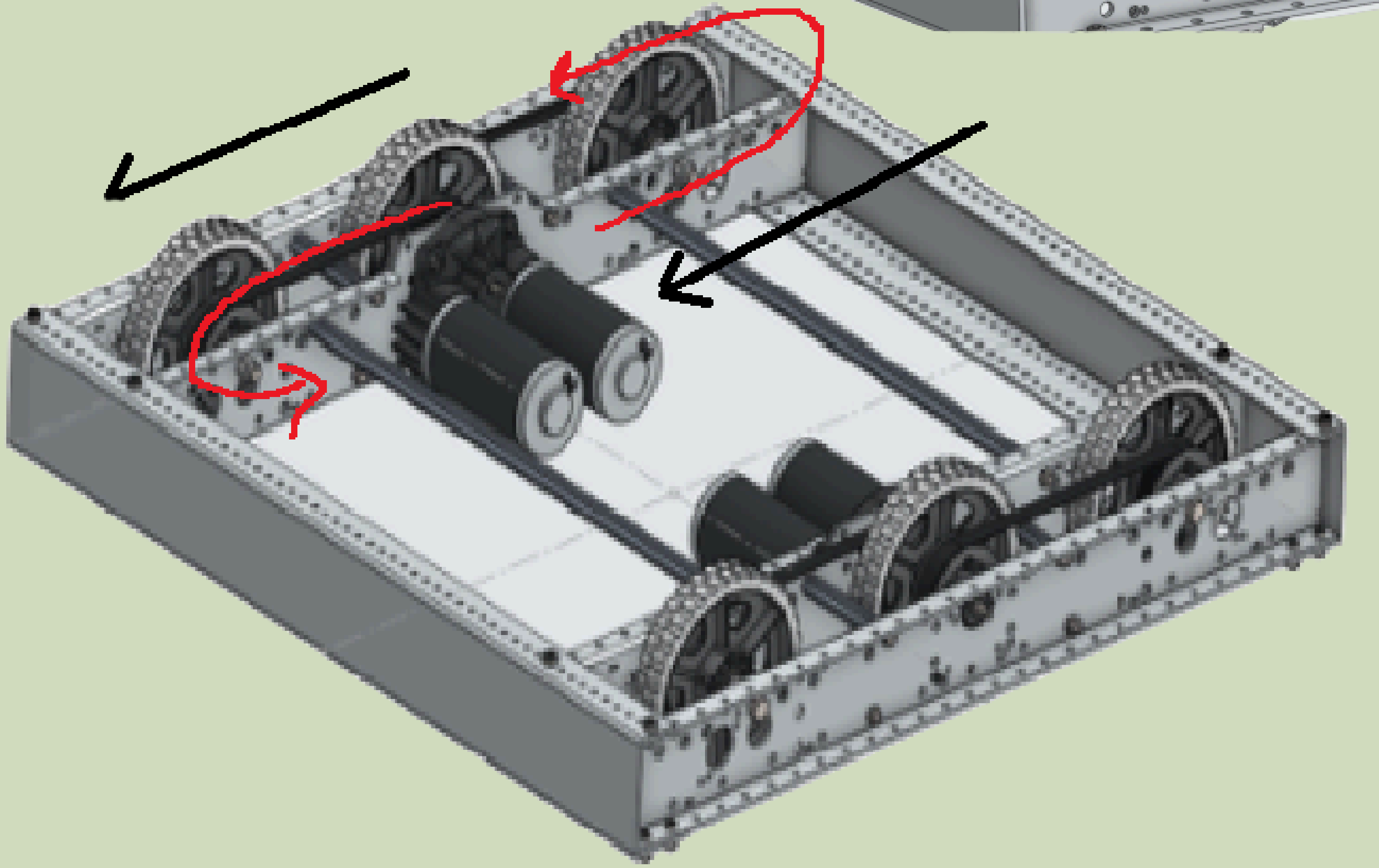


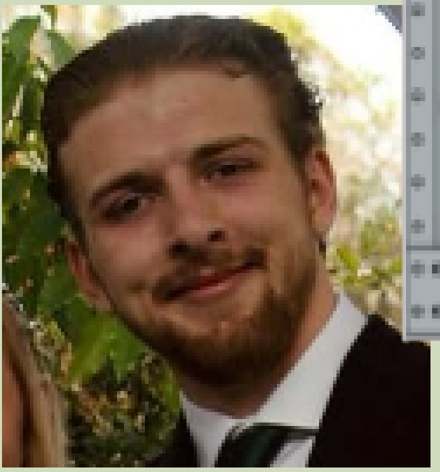
Drive Train

- The drive train was designed in CAD initially, then built
- A seat was added
- Front panel was adapted to account for lawn mower









Software used

Arduino IDE

BETAFPV

MPLAB X IDE & PicKIT5

Allowed for building and flashing code directly to the PIC16F1829

Arduino IDE

Direct coding and flashing to ATMega328P microcontroller.
Serial Monitor Output allowed us to see visually if our code and hardware was working in real time

BETAFPV Configurator

Allowed to link ER8 Receiver and FPV Remote Controller with link phrase
Allowed us to assign what PWM was being outputted in which button/trigger

Communication Protocols

ExpressLRS

- open source,
- high refresh radio control link protocol
- ultra low latency, high range connection
- Binds our transmitter and receiver through a "binding phase"

Allows us to send wireless PWM signals straight to the ATMega328P

Software Block Diagram

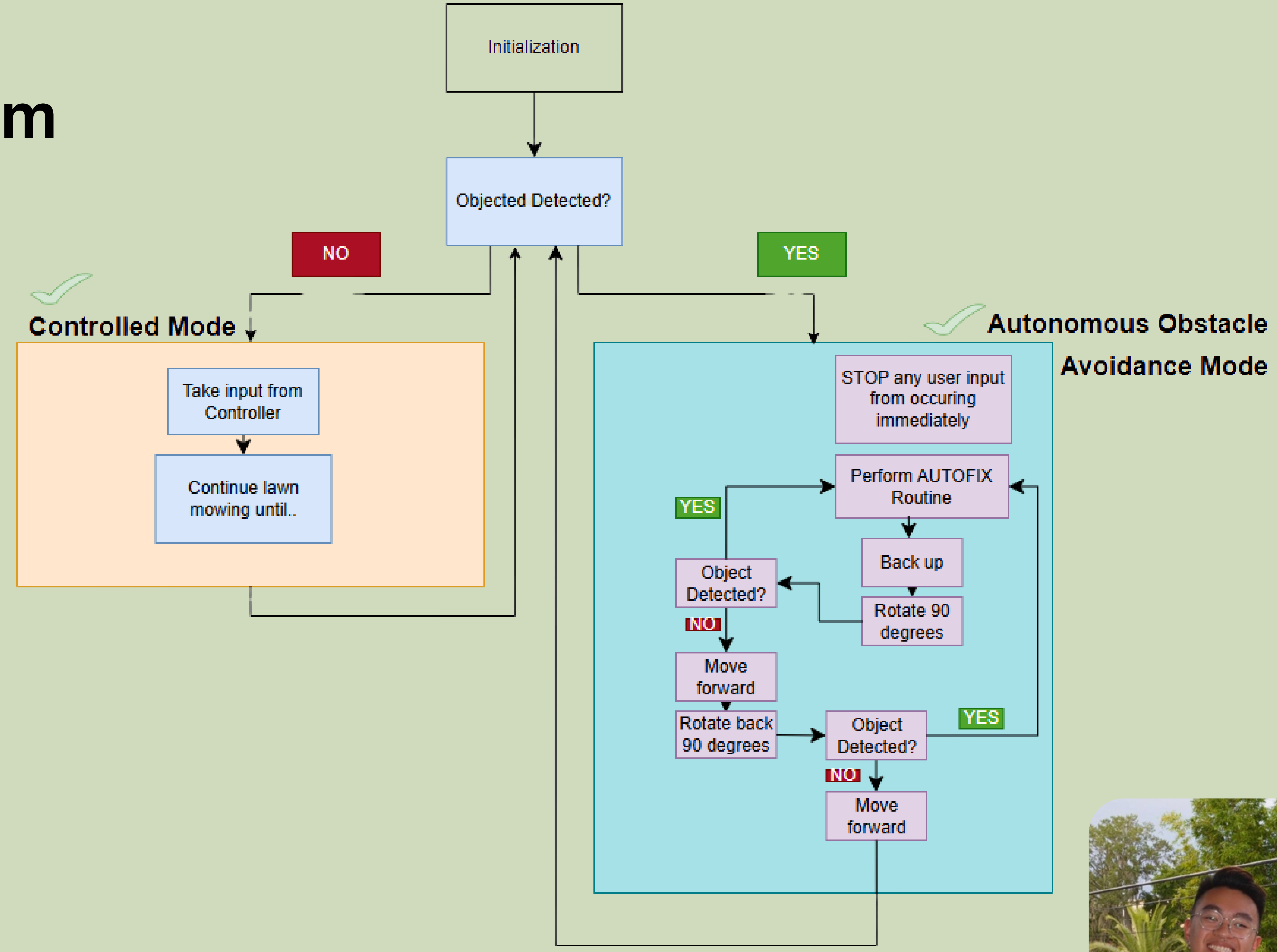
Here is the software block diagram, as you can see the workload is divided into two sections based on whether the ultrasonic sensor detects an object or not

- **No object is detected**

Continue scanning for objects and keep on taking input from the remote controller

- **Object is detected**

Immediately stop taking any input from the remote controller and perform the autofix routine



Software

Servo.h: Arduino library that allows control for servo motors using Pulse Width Modulation (PWM) signals.

- Allowed development of code for our autonomous procedure
- Used for steering and driven control logic

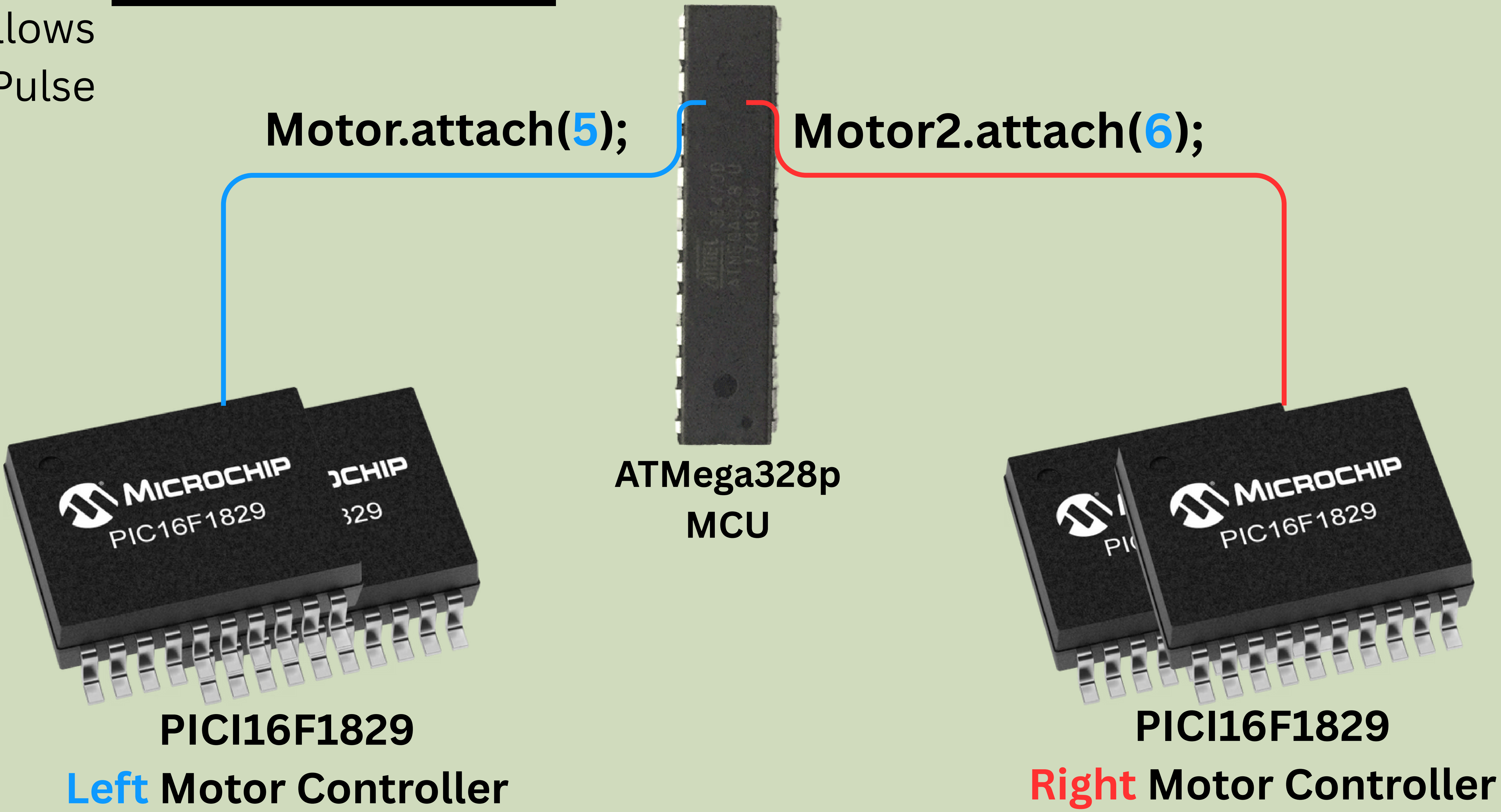
Here we were directly able to connect our motor controllers by assigning them to Pins 5 & 6 of our arduino

motor declaration

```
Servo motor;
```

```
Servo motor2;
```

motor pin assignment



Control Basics

This command directly sends PWM signals to motor controllers

motor1.writeMicroseconds(pwm_signal)

Direction Control based on PWM Signals sent to Motor

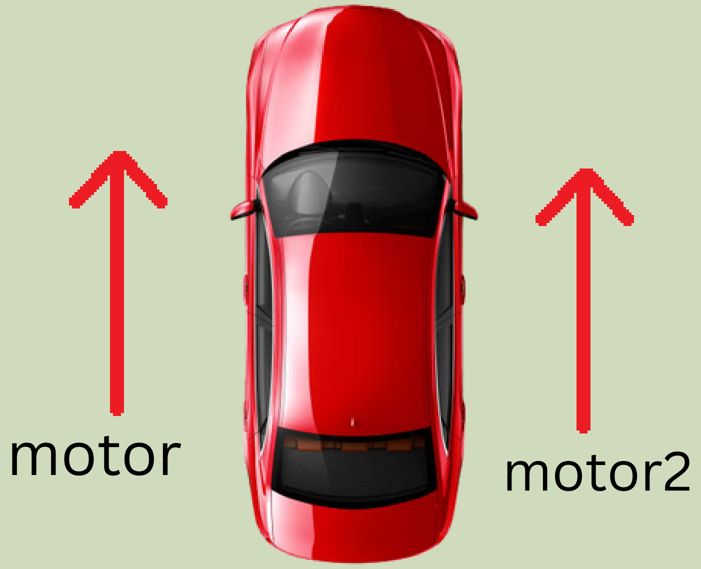
Forward >= 1600

Backward <= 1400

*we can increase the acceleration of the motor controllers by increasing/decreasing the PWM signal

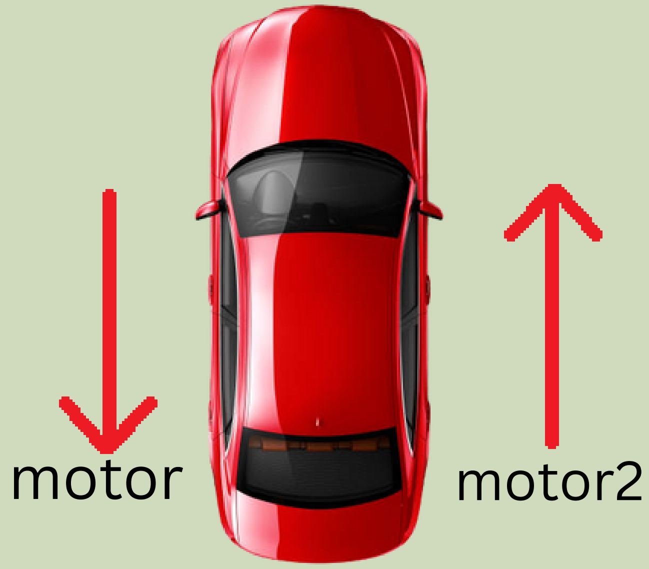
motor.writeMicroseconds(1700)
motor2.writeMicroseconds(1700)

Forward



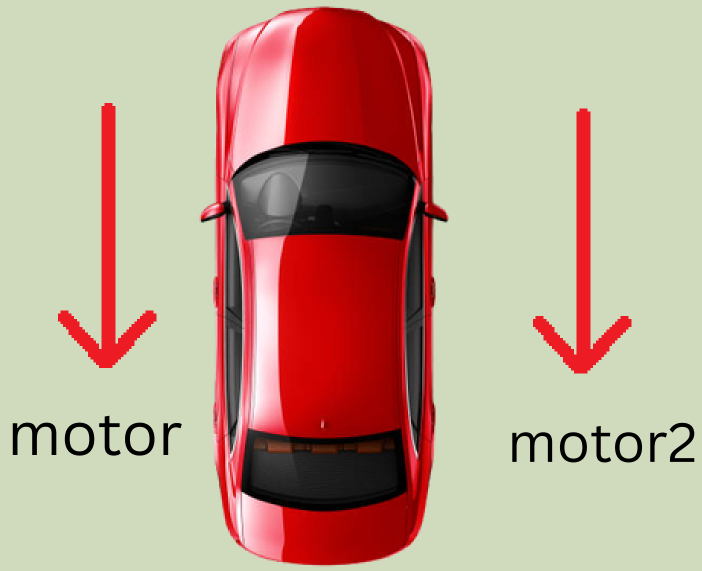
motor.writeMicroseconds(1200)
motor2.writeMicroseconds(1700)

Left



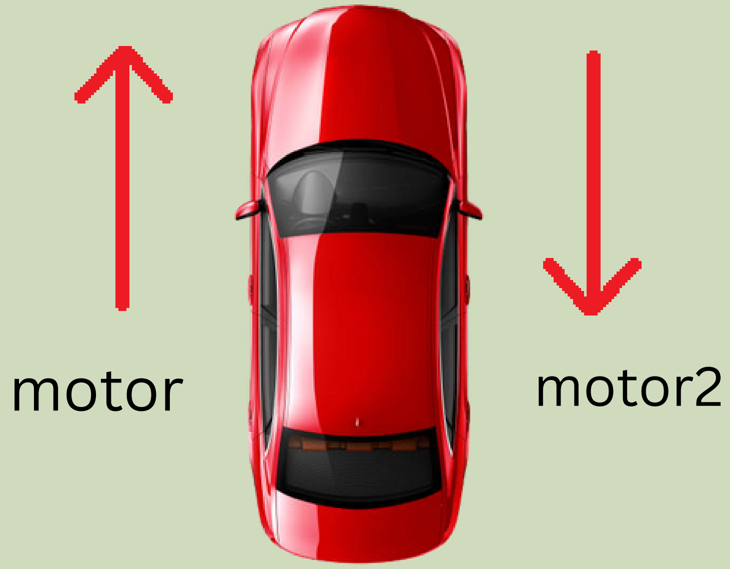
motor.writeMicroseconds(1200)
motor2.writeMicroseconds(1200)

Backward



motor.writeMicroseconds(1700)
motor2.writeMicroseconds(1200)

Right



Obstacle Avoidance procedure

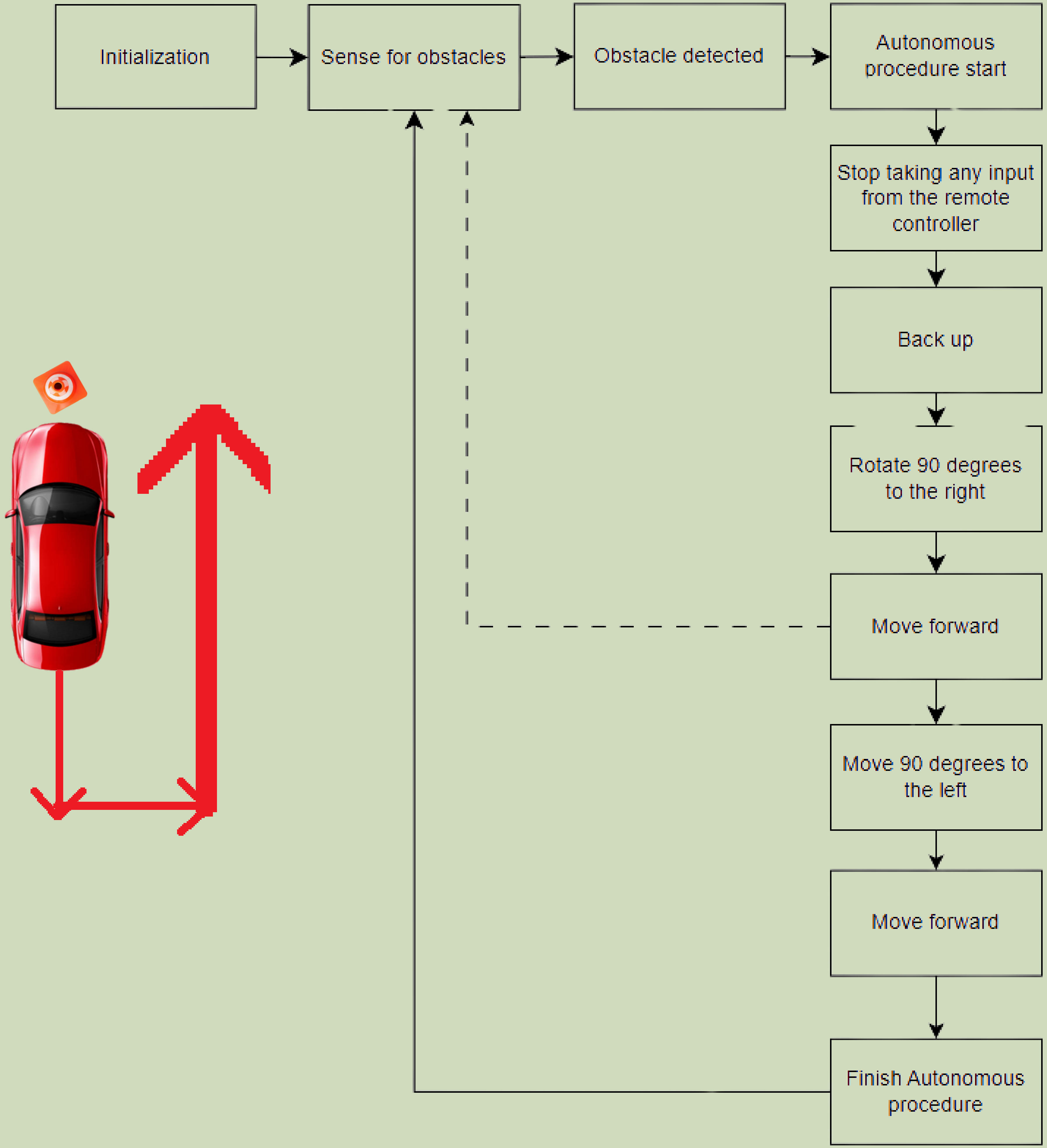
Procedure starts once sensor reads something within 60cm

Once procedure begins, no signals from remote controller will be read

Redetection is set up after every forward movement to ensure obstacle avoidance

If redetected, reset procedure

Once procedure is done, resumes back to take signals from remote controller



Software Development Cycle

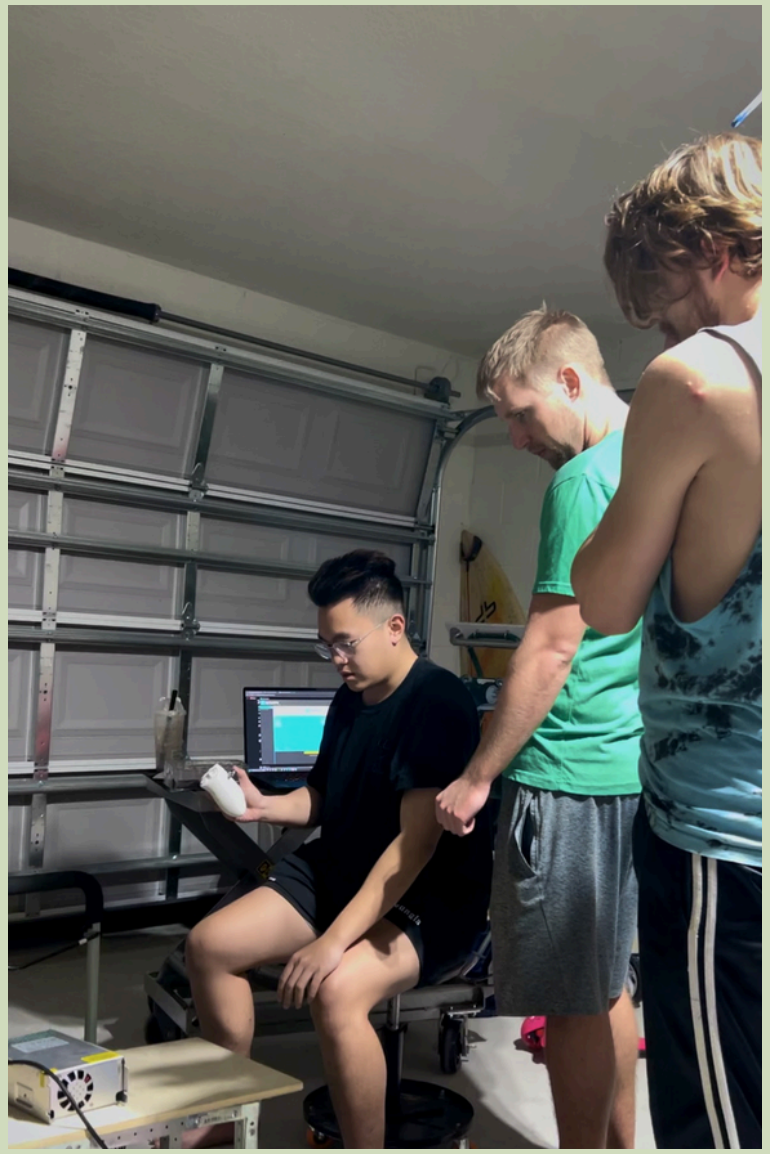
1. Ensure Lawnmower moves in all four directions from procedured code

2. Link with ER8 Receiver with Remote Controller and ensure remote signals coordinate with lawnmower movements

3. Code Ultrasonic functionality and ensure that it detects objects within a 2ft radius

4. Program autonomous mode and controlled mode capability and ensure that one mode doesn’t conflict with the other

5. Code Emergency Stop Functionality and make sure it works



Software Difficulties & Solutions

- Difficulties figuring out how to use MPLab X IDE and develop and flash code with a new software
- Errors regarding code for the Obstacle Avoidance Procedure led to potential damage to physical parts
- Confusion in coding/reading pin outs for digital vs hardware pins
- Trial and Error regarding PWM adjustments for Obstacle avoidance procedure

```
Servo motor;    // Motor 1 (Steering)
Servo motor2;   // Motor 2 (Throttle)

const int trigPin = 6;    // PD6 → physical pin 12
const int echoPin = 7;    // PD7 → physical pin 13
const int ledPin  = 5;    // PD5 → physical pin 11

const int ch1Pin = 9;     // Steering channel
const int ch4Pin = 10;    // Throttle channel
const int ch5Pin = 11;    // Manual override
```

```
Sketch uses 5976 bytes (18%) of program storage space. Maximum is 32256 by
Global variables use 657 bytes (32%) of dynamic memory, leaving 1391 bytes
avrdude: ser_open(): can't open device "\\.\COM10": The system cannot find


Failed uploading: uploading error: exit status 1
```

Tests and Solutions

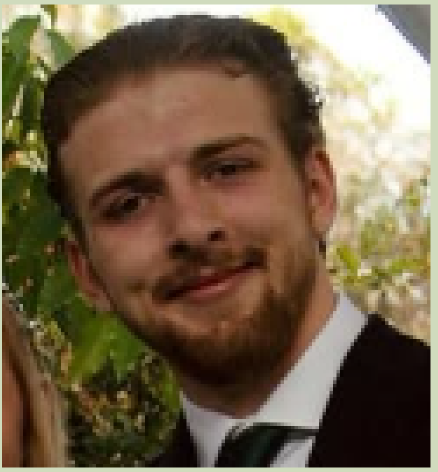
Goal: Get a functional robot working with everything included

Issues During Testing:

- Burned through all electronics once
- Drive train is custom built so adjustments took a lot of time
- The motor controller PCB was designed with 2 obsolete parts
- Code Issues (discussed in previous slide)

Solution:

- Rebuilt the electronics and remembered to turn the robot off when moving wires
- **E**xtra “perf boards” had to be used to get the correct pins on the replacement parts



Test Results - Obstacle Detection Range

Trial #	Pass / Fail?	Speed	Notes
1	PASS	Slow	Detected within 60cm
2	PASS	Slow	Detected within 60cm
3	PASS	Slow	Detected within 60cm
4	PASS	Moderate	Detected within 60cm
5	PASS	Moderate	Detected within 60cm
6	FAIL	Moderate	Potential ultrasonic short?
7	PASS	Moderate	Detected within 60cm
8	PASS	Full Throttle	Detected within 60cm
9	PASS	Full Throttle	Detected within 60cm
10	PASS	Full Throttle	Detected within 60cm

9/10 Passed with a 1 to 2 ft detection range

Obstacle Detection Accuracy Results

Trial	Detected / Procedure Start?	Object
1	Y / Y	Yellow Pole
2	Y / Y	Yellow Pole
3	Y / Y	Yellow Pole
4	Y/Y	Dumpster
5	Y/Y	Dumpster
6	Y/Y	Dumpster
7	Y/N	Cemex Bag
8	Y/Y	Cemex Bag
9	Y/Y	Cemex Bag
10	Y/Y	Green Traffic Cone

100 % Detection Rate with a 90% trials beginning with a procedure

Remote Controller Response Time

Trial #	Time
1	0.11
2	0.11
3	0.9
4	0.13
5	0.10
6	0.8
7	0.8
8	0.11
9	0.9
10	0.10

Average response time of .10 seconds, completes the specification of <20 seconds

Bill Of Materials

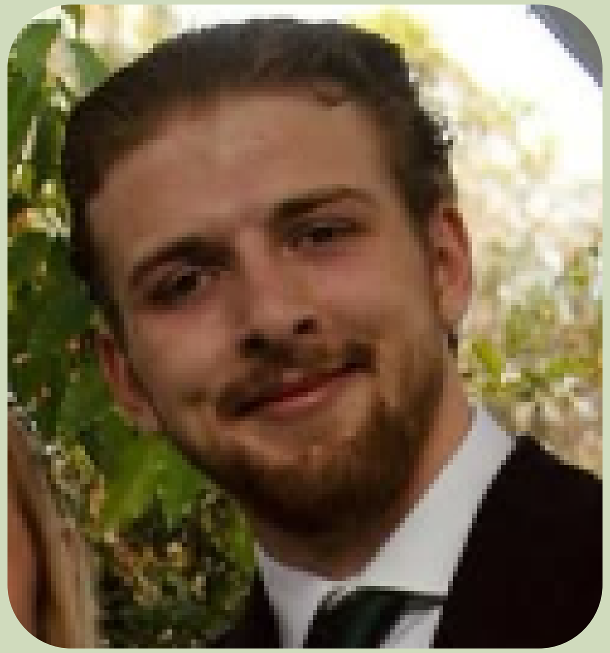
Here is the Bill of Materials that was estimated if we were to build everything from scratch

Thankfully we were able to receive a handful of spare components from our workplaces which cut the costs by a good majority

Item	Qty	Cost (Each)	Total Cost	Notes
Greenworks 25322 Mower Base	1	$250	$250	Repurposed electric mower
VEX 393 Motors	4	$80	$320	High-torque motors
Motor Controllers	4	$45	$180	One per motor
ER8 Receiver + Transmitter	1	$60	$60	2.4GHz wireless controller
Power Supply (24V 15A)	1	$90	$90	Primary system power
Distribution Board + Fuses	1	$120	$120	FRC-style layout w/ protection
Sensors (Ultrasonic)	2	$10	$20	Obstacle detection
Wiring, Connectors, Hardware	N/A	-	$150	Includes tools and cables
Acrylic, Aluminum Mounts	N/A	-	$100	Frame mounting and housing

Estimated Total: $1,290

Work Distribution



Brayden Anderson

PCB Design

Mechanical Framework Design

Electrical Wiring and Design

Steven Huynh

Software Development

Remote Controller & Receiver Handling

Autonomous Functionality & Design


Thank you!