Two Wheel Drive Electronic Differential

Senior Design 2014

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NC State Engineering Programs at UNC-Asheville

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Introduction

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The Project

An electronically controlled differential.

The Purpose

- To create a device that demonstrates a mechatronic system
- Possible future collaboration with other schools in EV projects

Goals

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1. Design and build a vehicle employing an electronic differential
2. Success defined as the demonstration of improved performance in comparison with the solid axle and an uncontrolled split axle

Initial Approach

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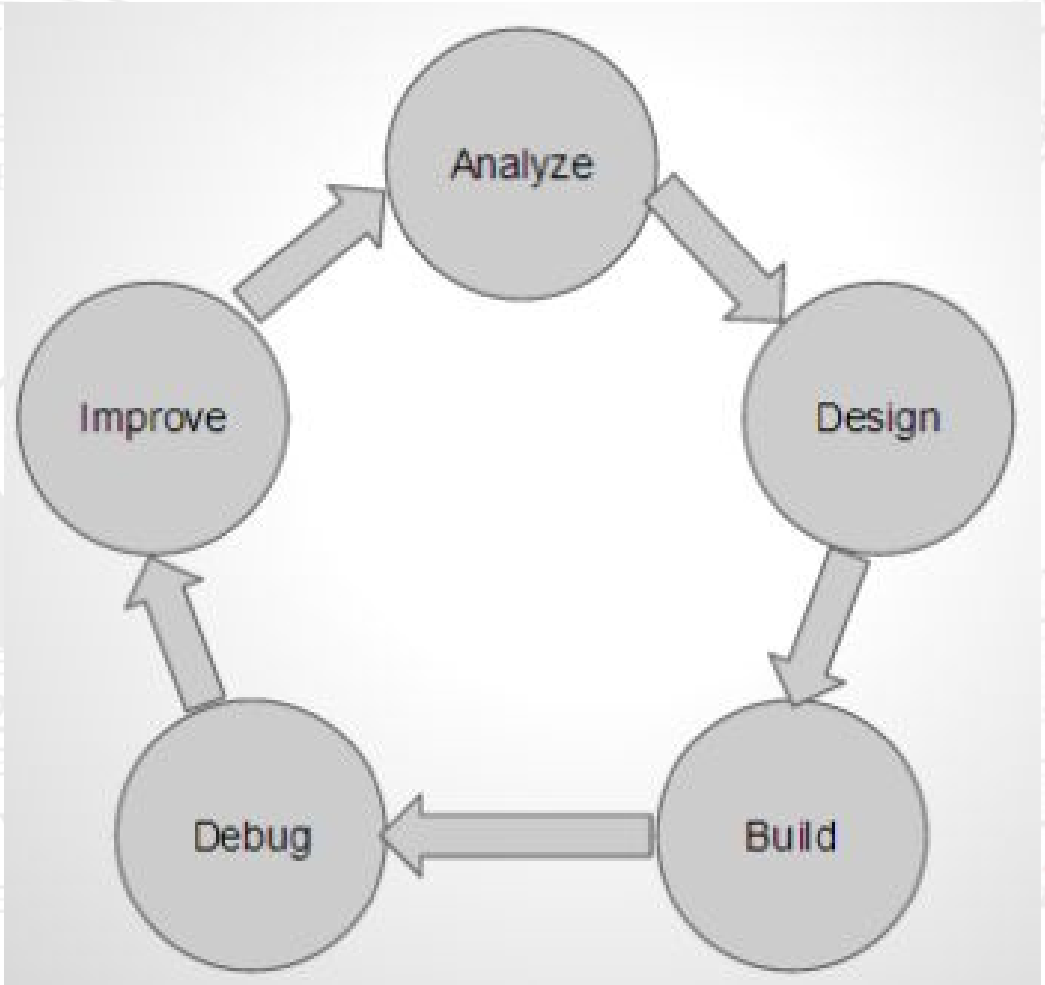

Figure: Approach Diagram

Design

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2D Drawing

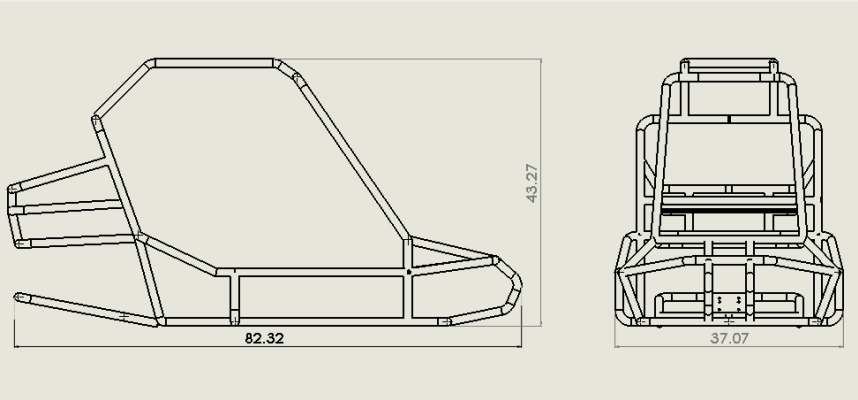

Figure: Initial 2D Chassis Drawing

3D Model

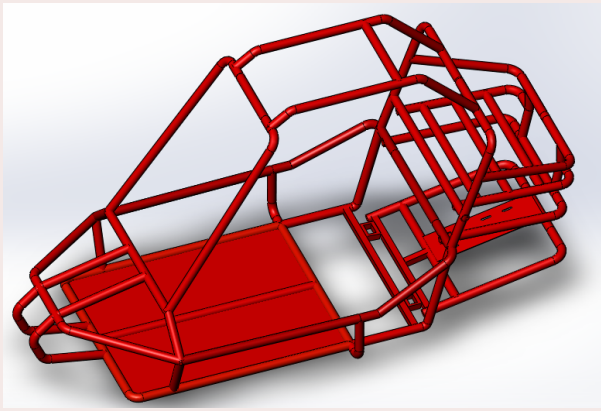

Figure: Initial 3D Chassis Design

Build

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- Acquire parts within budget
- Construct a drivetrain
- Implement a control system
- Retain a sufficient level of safety for the driver

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Team Management

Fabrication & Mechanical

- Responsible for carrying out all mechanical operations necessary to create a working vehicle
- Chassis modification to satisfy the requirements

Electrical

- Responsible for research, procurement, and implementation of sensors, a microcontroller, motors, and programmable motor controllers

Programming & Controls

- Responsible for implementing the algorithms necessary to achieve differential control
- Programming code to take sensor input and produce a controlled output

Mechanical

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Chassis

- Repair
- Retrofitting
- Brakes

Battery Box

- Seat
- Safety
- Control Panel

Motors

- Motor Mounts
- Chain Drive

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Chassis Repair and Fabrication

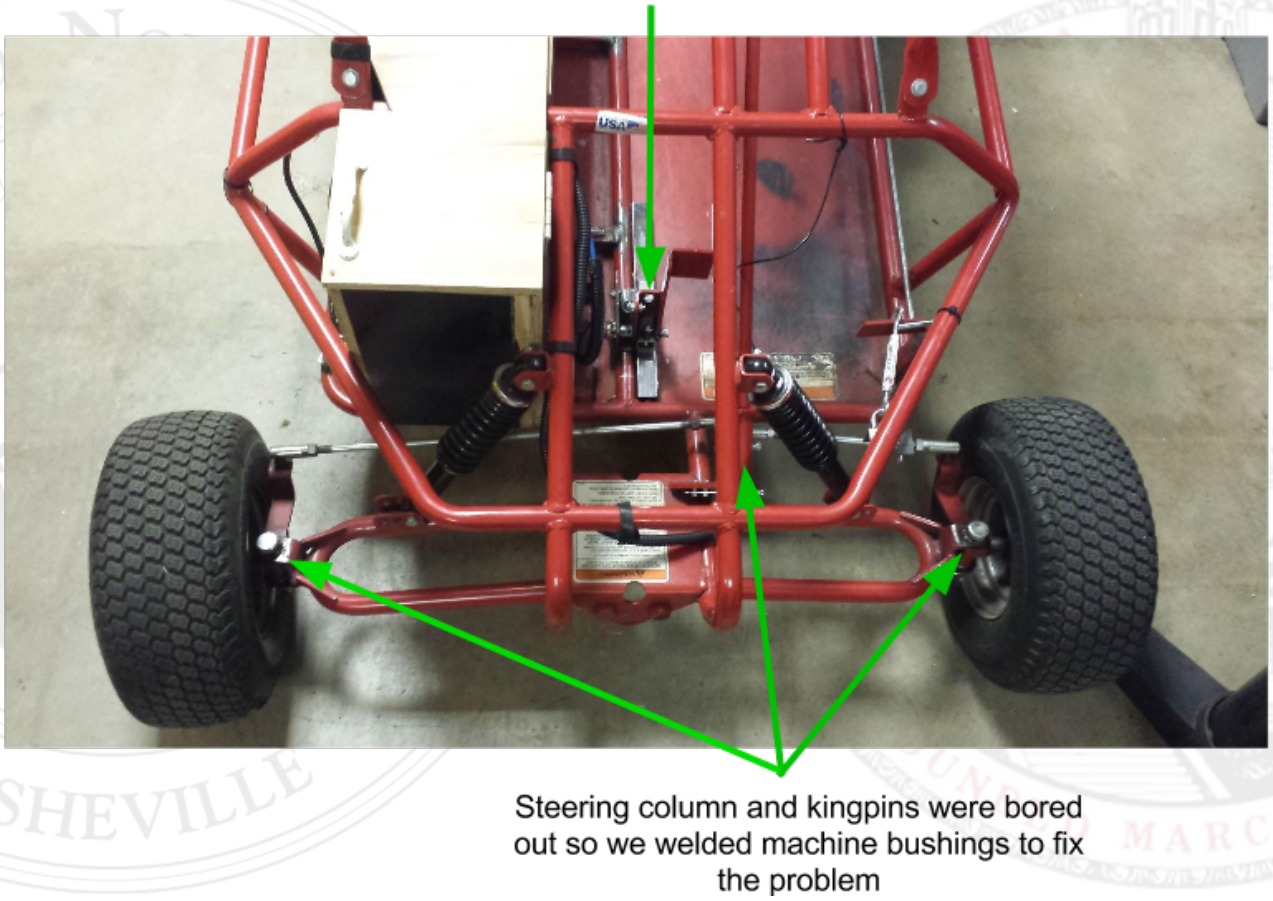

Figure: Front End Repairs

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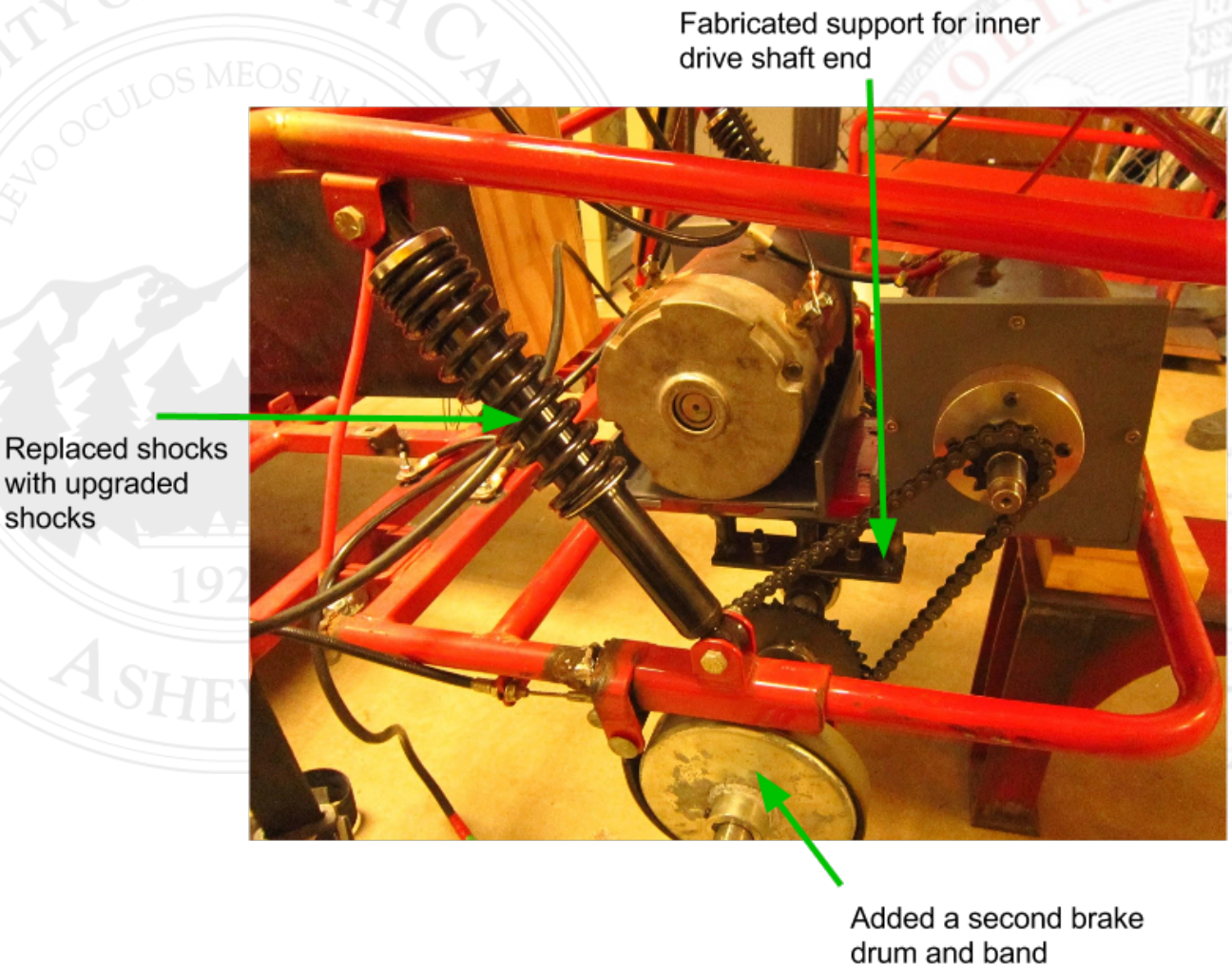
Chassis Repair and Fabrication



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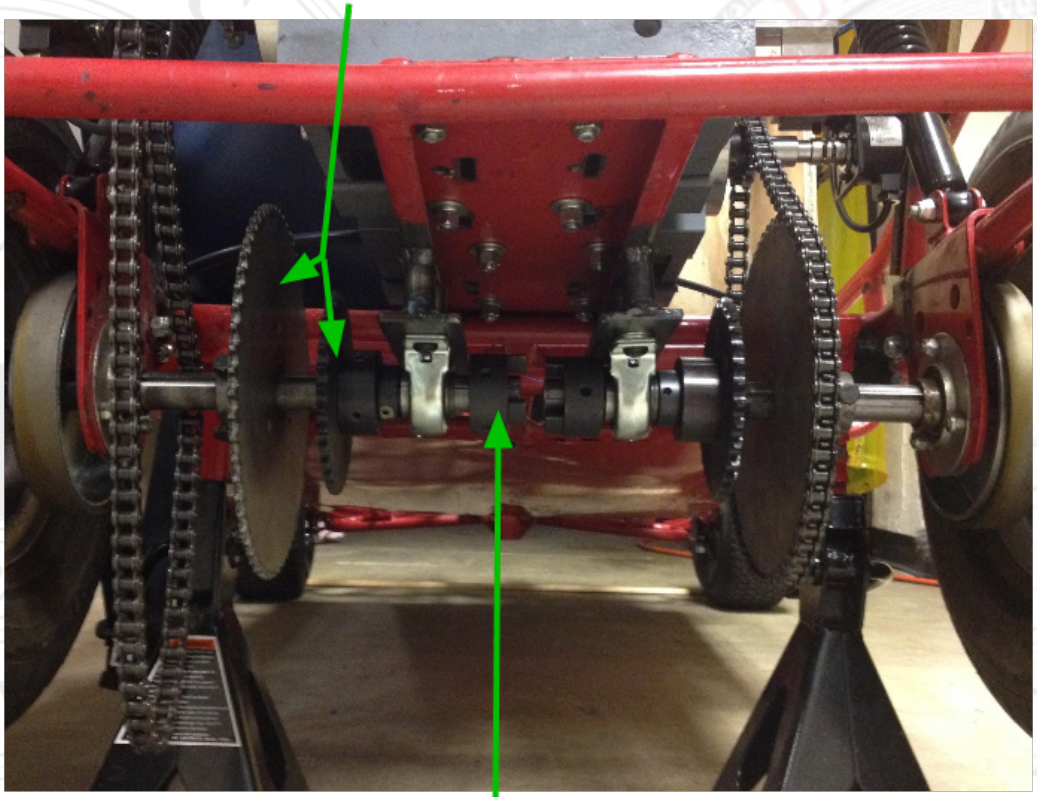
Chassis Repair and Fabrication

Added 2 sized gears to change the top speed/torque of the motors to suit what we needed



Split the axle and added a 3 jaw coupler so we can choose between solid axle and split axle.

Motors

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Motor

Figure: Advanced D.C. Motors

Motor Information

- Motor manufactured by Advanced D.C. Motors
- Sepex (shunt wound) motor design
- 36 volt maximum input

Motors

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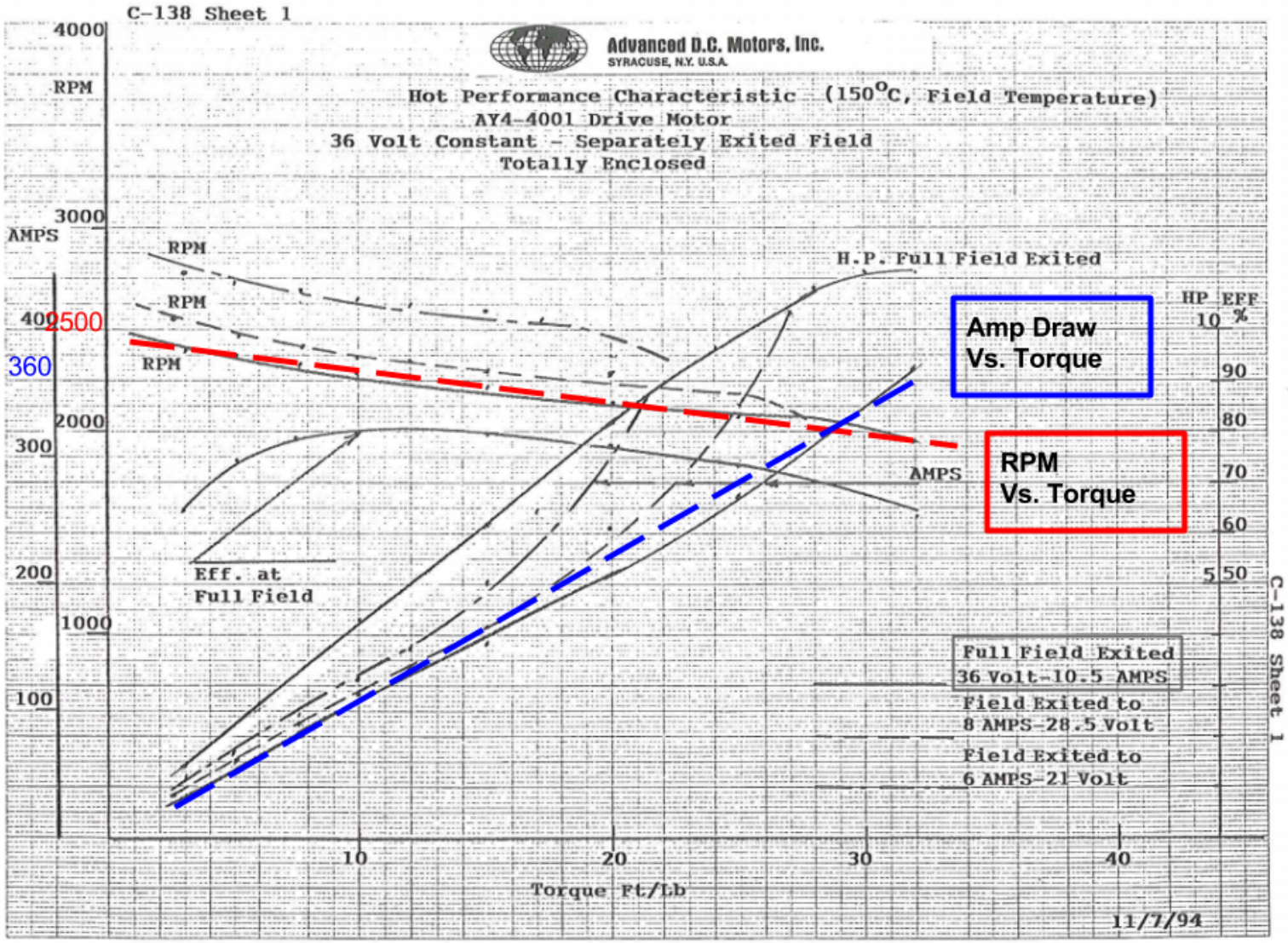

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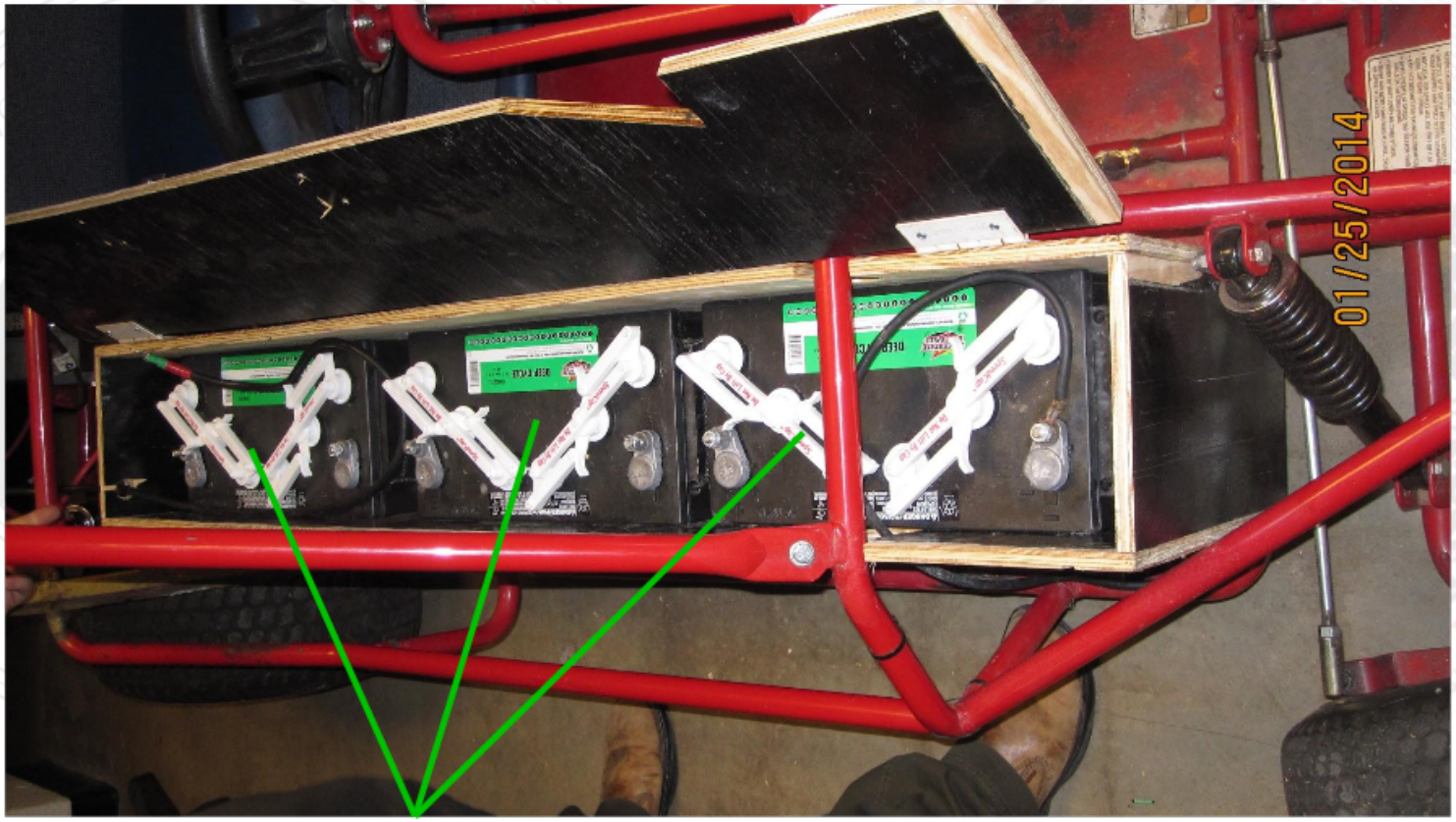
Battery Box



Deep Cycle 12V batteries
5.5 kWh capacity

Cockpit

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Electrical

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Arduino Due

- Advantages
- Implementation

Op-Amp Circuitry

- Reasons needed and design
- Resistance calculations

Control Panel

- Solenoids

Control Panel

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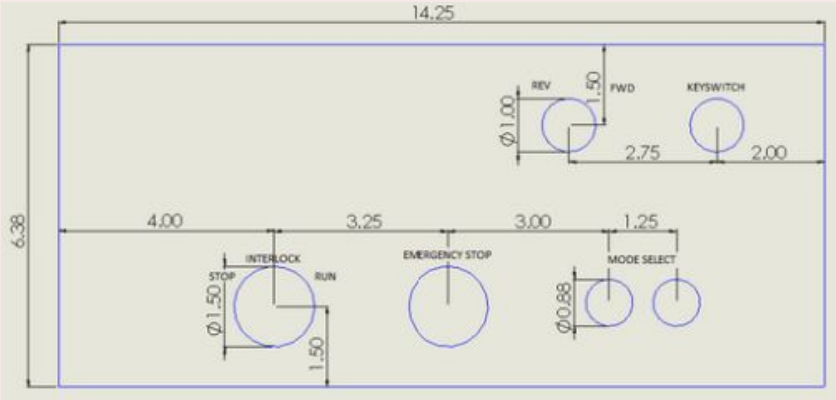
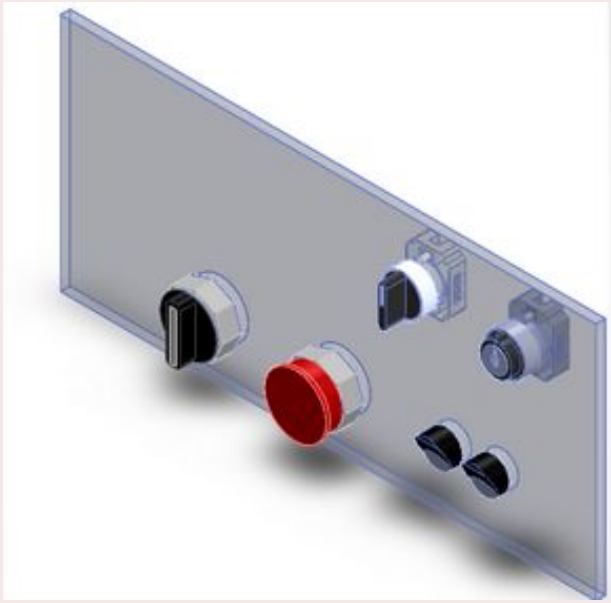
Panel Drawing



Panel Rendering



Control Panel

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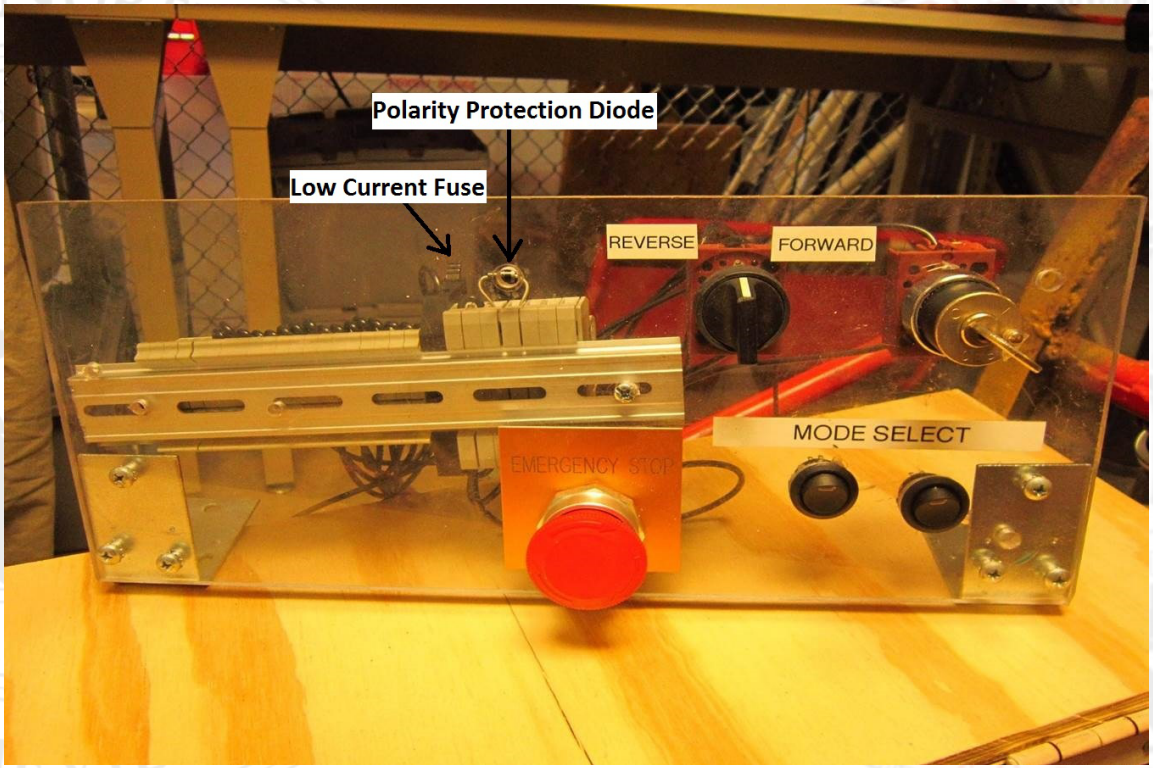

Figure: Finished Control Panel

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Main Contactors & Solenoids

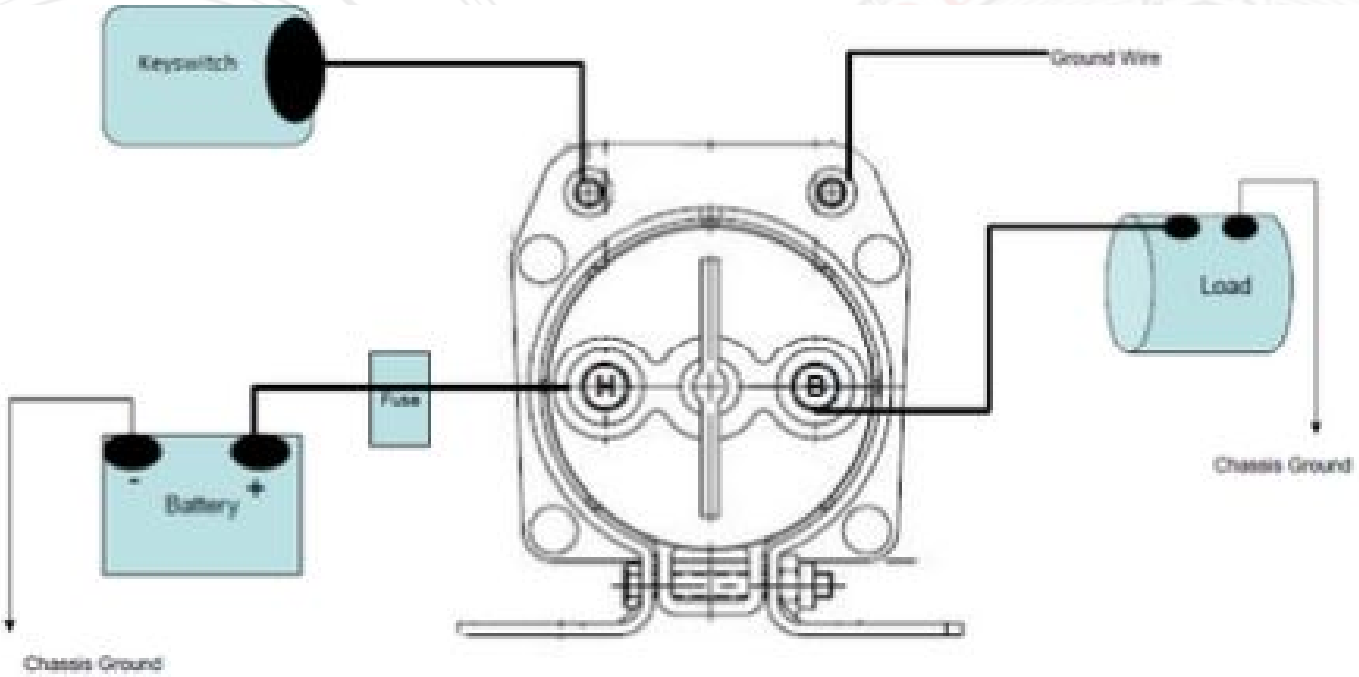

Figure: Solenoid Schematic

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Curtis Motor Controllers

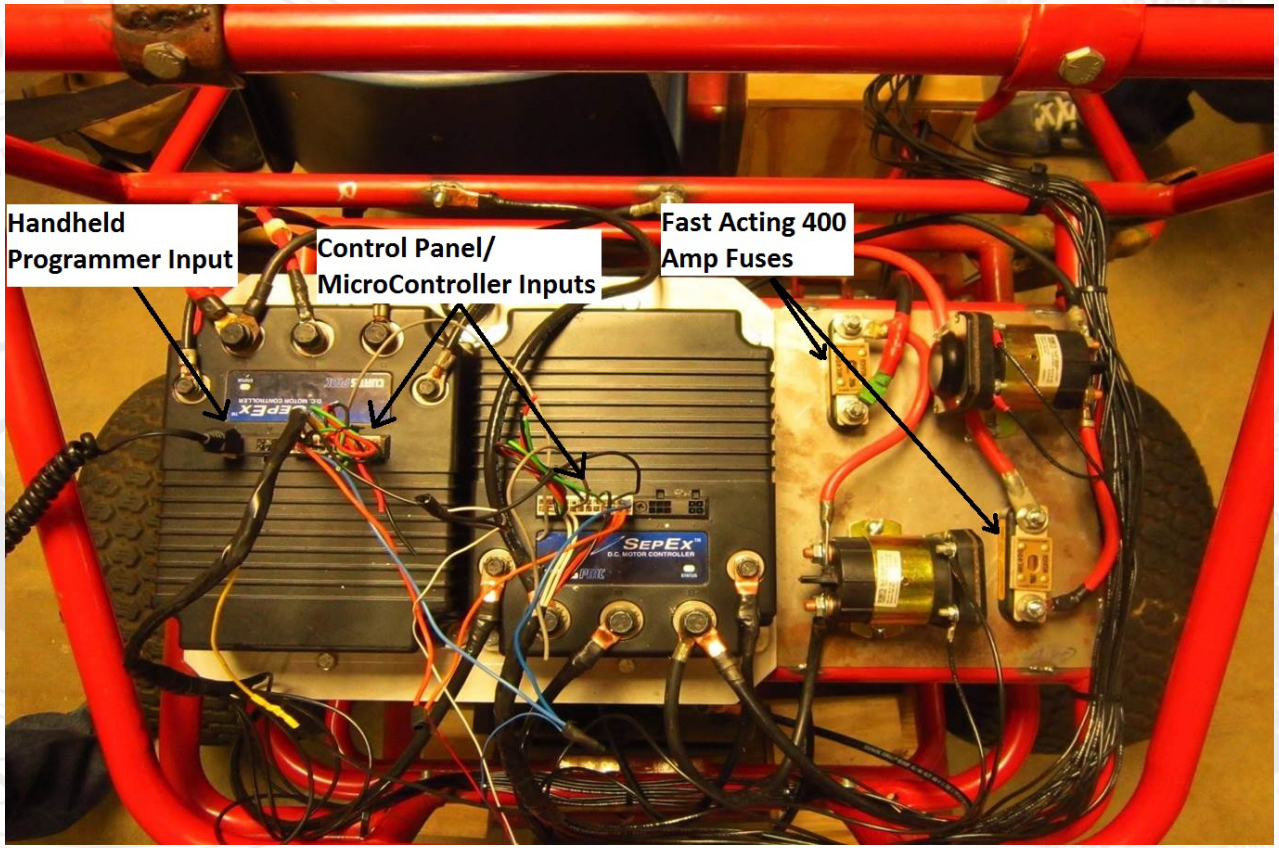

Figure: Curtis Controllers

Arduino Due

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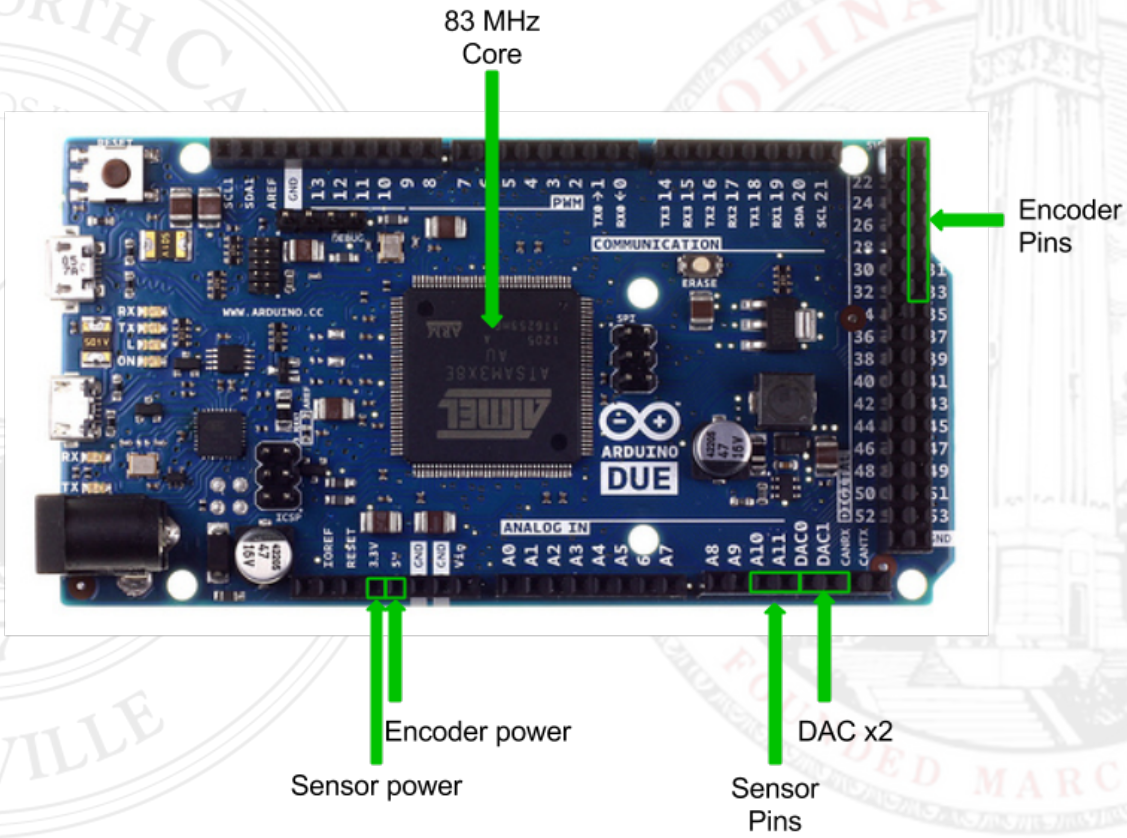

Arduino Due

Arduino Due

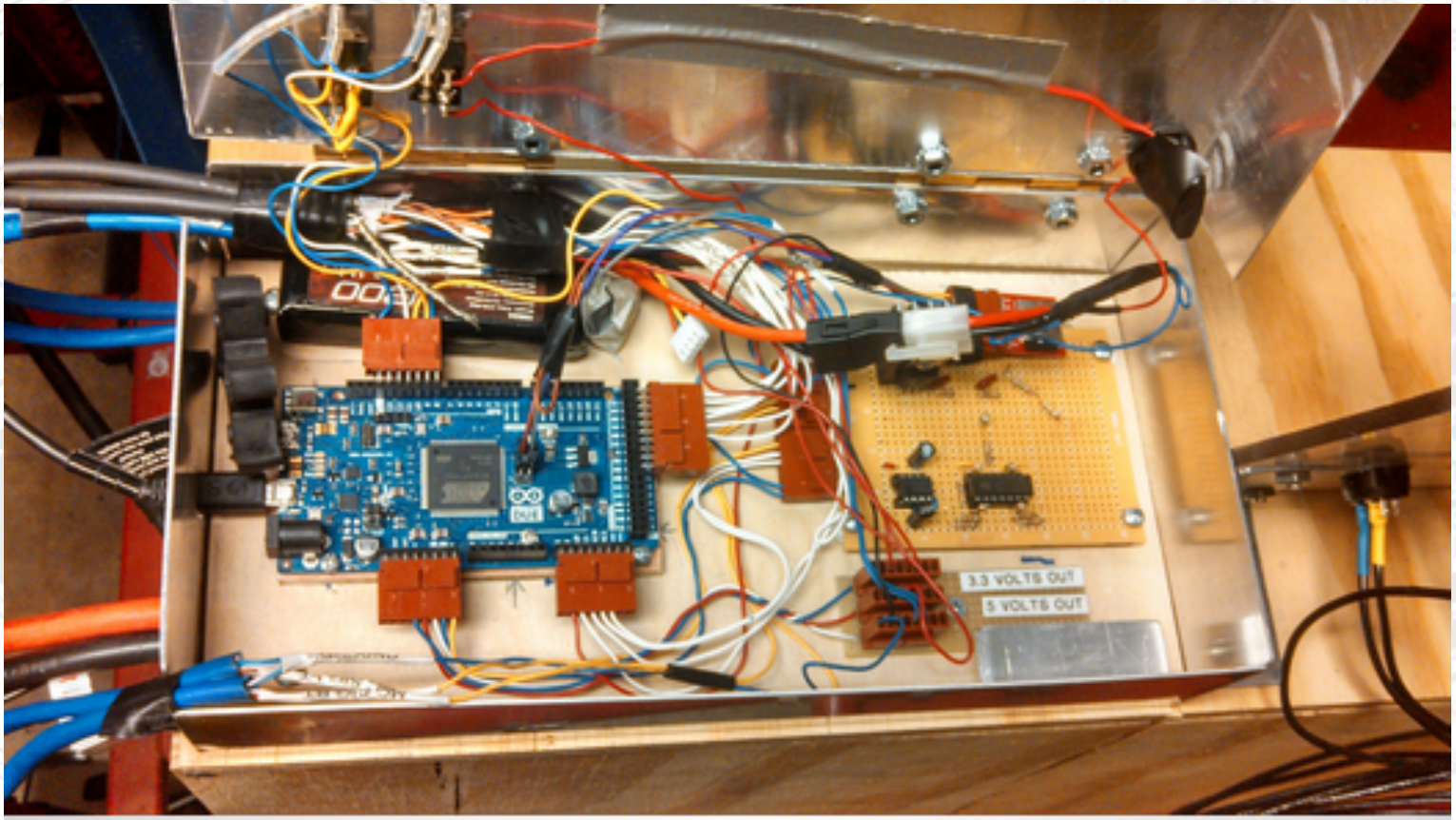

Figure: Arduino Due

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Op Amp Circuit

Intended Purpose

- Fix voltage range problem

Design Implementation

- Inverting amplifier
- Summing amplifier

Problems Encountered

- Arduino pin needed converting to negative voltage
- Back current

Op Amp Circuit

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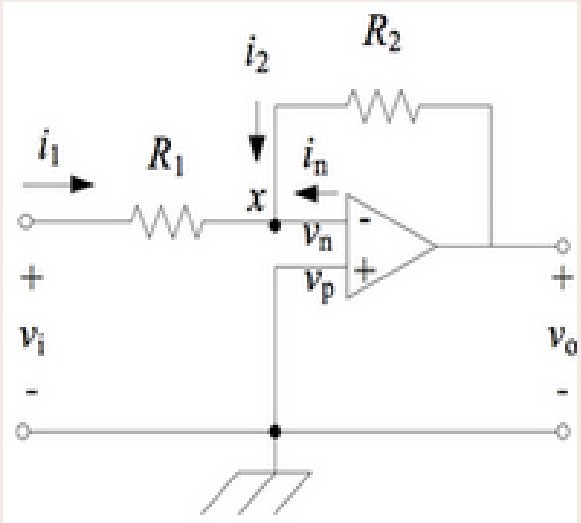
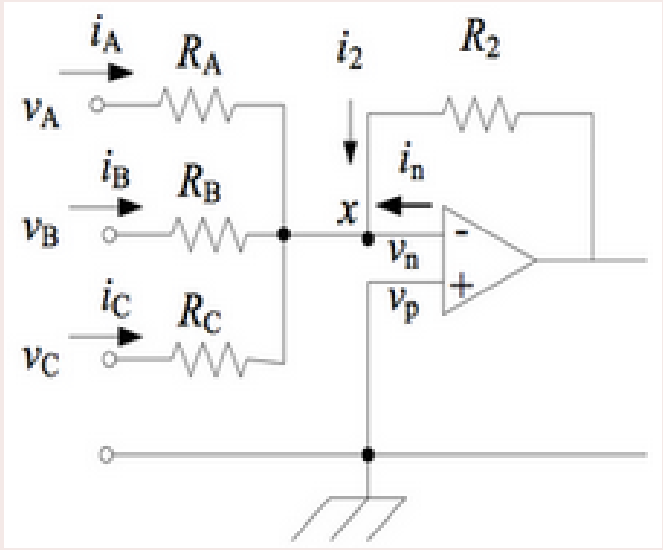
Inverting Amplifier



Summing Amplifier



Related Equations

$$\frac{v_o}{v_i} = -\frac{R_2}{R_1}$$

Equation 1

$$V_o = -\left(\frac{R_2}{R_A}V_A + \frac{R_2}{R_B}V_B + \frac{R_2}{R_C}V_C\right)$$

Equation 2

Op Amp Circuit

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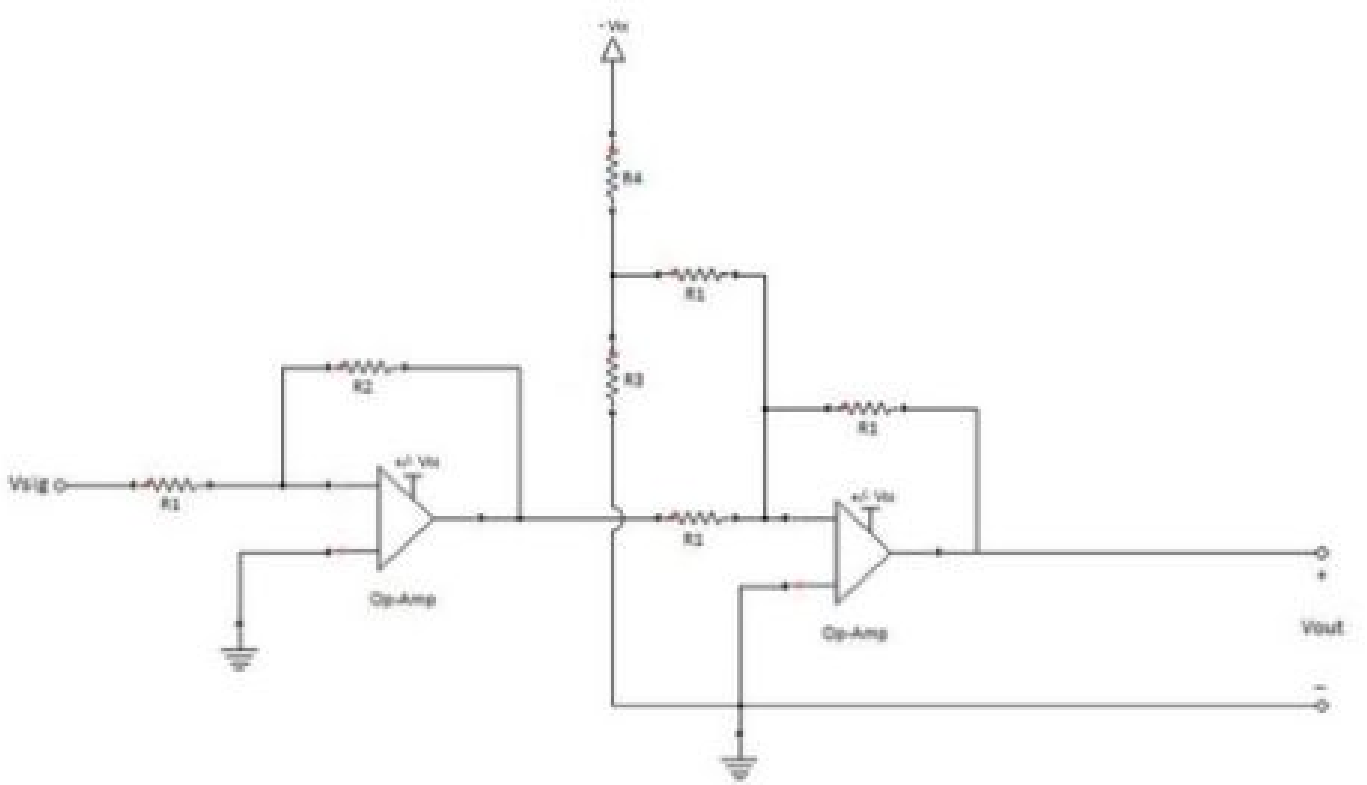

Figure: Final Op Amp Design

Op Amp Circuit

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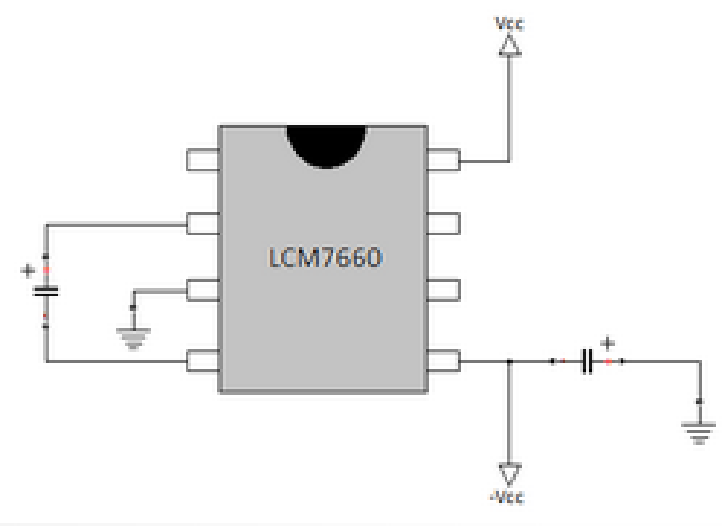
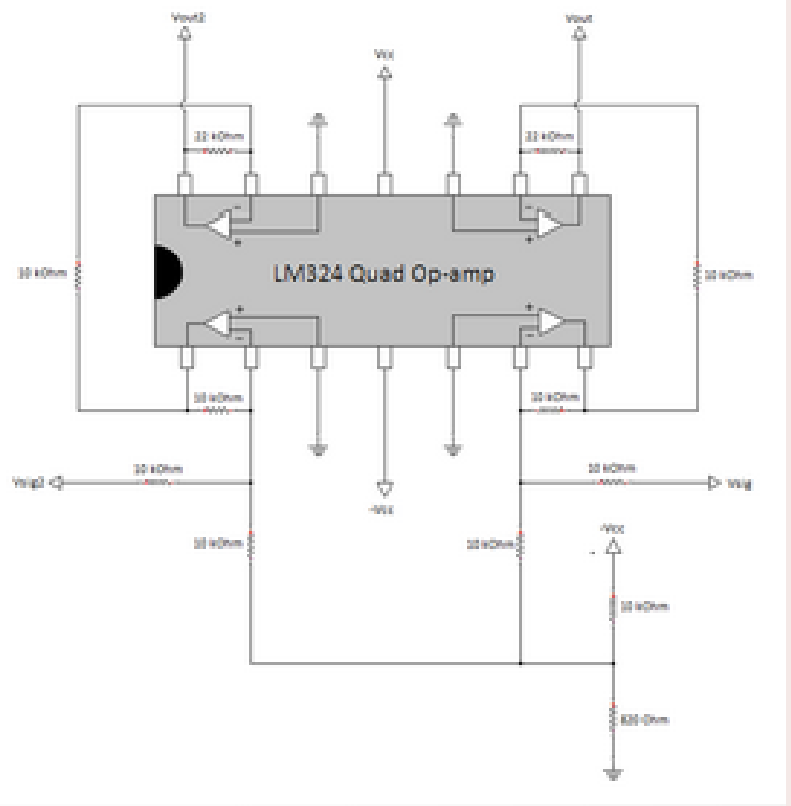
Negative Voltage Implementation



Op-Amp Circuit Implementation



Op Amp Circuit

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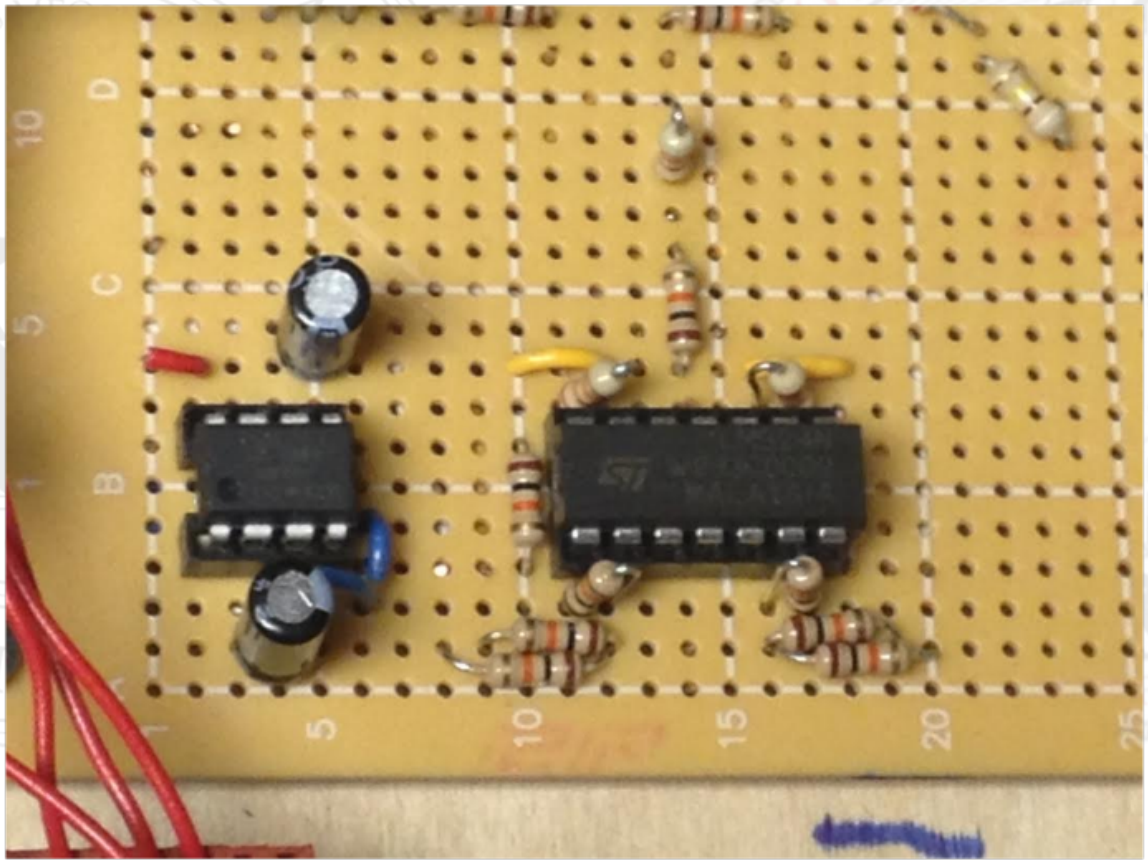

Final Circuit

Control

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Equations of Motion

- Ackermann steering
- Hierarchy of control

Sensors

- Throttle
- Steering angle
- Wheel speed

Programming & Data Collection

- Throttle
- Steering
- Encoders
- Differential

Equations of Motion

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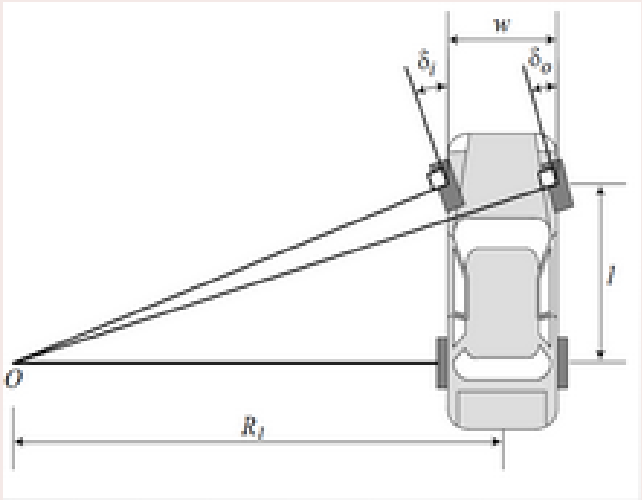
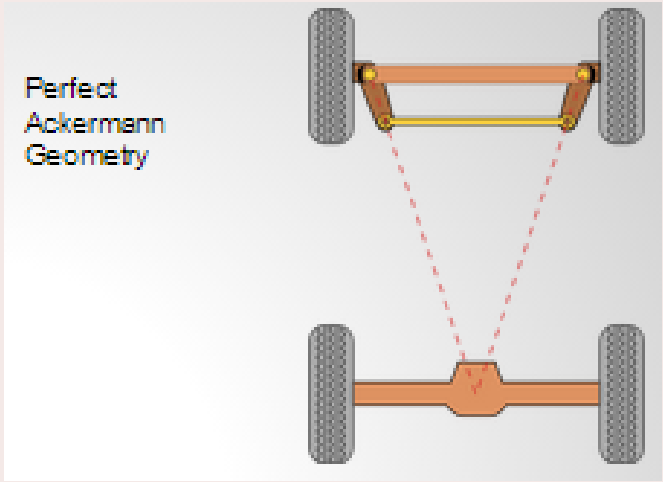
Ackermann Steering



Ackermann Geometry



Related Equations

$$\frac{\omega_o}{\omega_i} = \frac{R_1 + \frac{w}{2}}{R_1 - \frac{w}{2}}$$

$$\omega_i = \omega_o \left(R_1 - \frac{w}{2}\right) / \left(R_1 + \frac{w}{2}\right)$$

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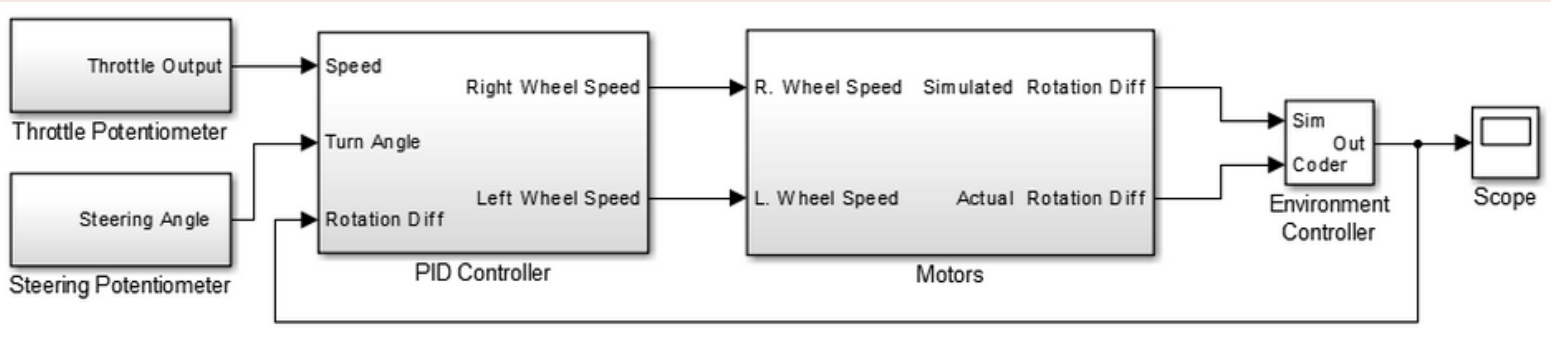
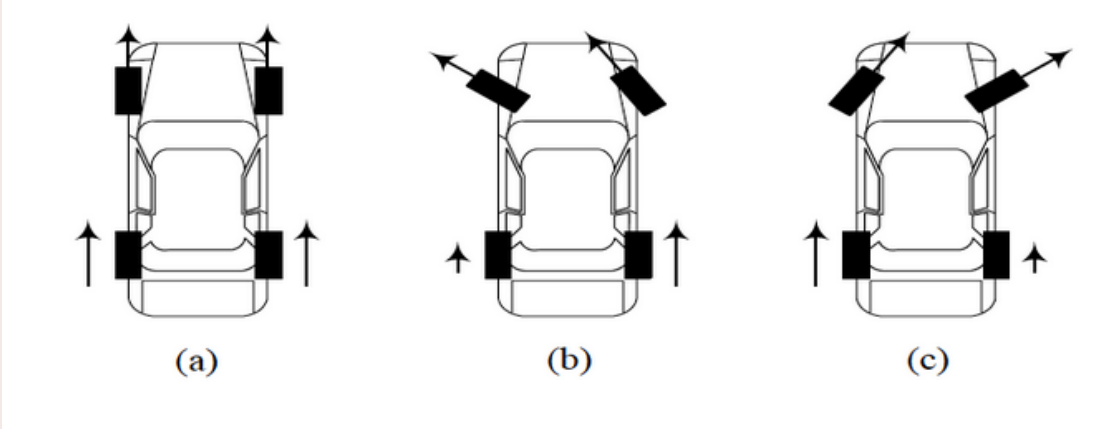
Control System Description

Control Block Diagram



Control Goal



Sensors

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Steering and Throttle

- Potentiometers
  - 5K Ohm each
  - Analog values
  - Used to measure rotation

Wheel Speed

- Encoders
  - A-B Quadrature (400x / revolution)
  - Z Pulse Absolute (1x / revolution)
  - Max 3000 RPM (continuous)

Sensors

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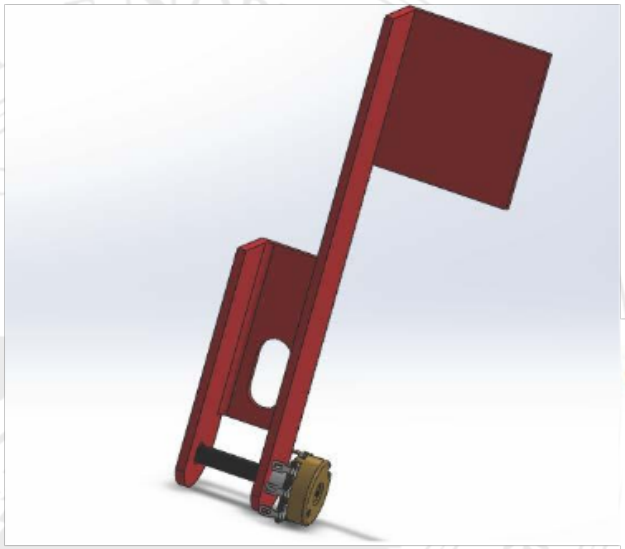
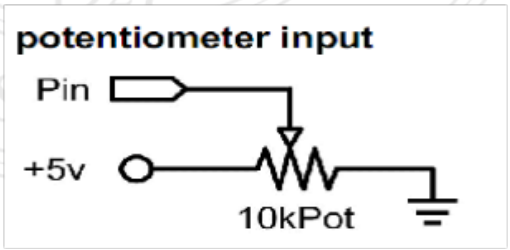
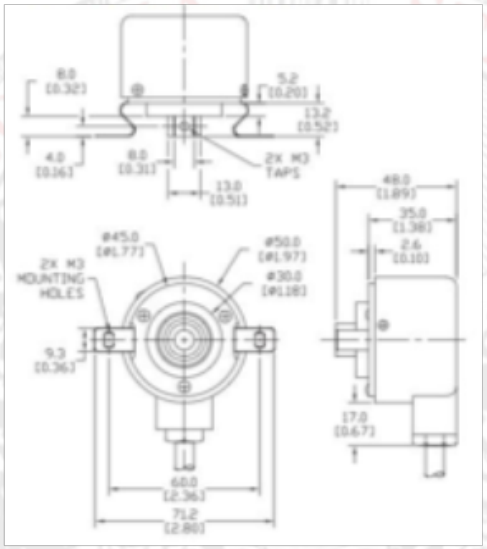


Throttle Pedal





Encoders

The Array of Sensors

Software

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Control Algorithms & Sensor Integration

- Throttle
- Steering
- Feedback
- Control Algorithms

Data Logging Programs

- Individual Sensors
- Turn Radius
- Feedback Collection

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Software Control

Github

- Versioning
- Collaboration
- Issues

Future Students

- Documentation
- Setting next year up for success

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Throttle & Steering Code

Implementation

- Reads output based on position
- Uses analogRead function (Arduino)
- Measures rotation in range of 0-1023 (integer value) based on voltage 0-3.3V

Problems

- Limited rotation
- Analog input
  - Resistance vs. Capacitor Charge Time
  - Noise

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Encoder Code

Implementation

- Loop to measure pulses for given time (1/8 of second) & Calculate time for x pulses
- Measured speed of both encoders separately
- Values normalized to wheel speed

Problems

- A-B Quadrature vs. Z Absolute Pulse
- Speed of rotation vs. Arduino Clock Cycle
- Consideration of Interrupts

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Integration & Control

Process

1. Initialize values and constants
2. Collect sensor readings
3. Compute control (Digital PI control scheme)
4. Add control to running sum
5. Apply voltage to motors based on computed control values
6. Loop back to collect readings and repeat

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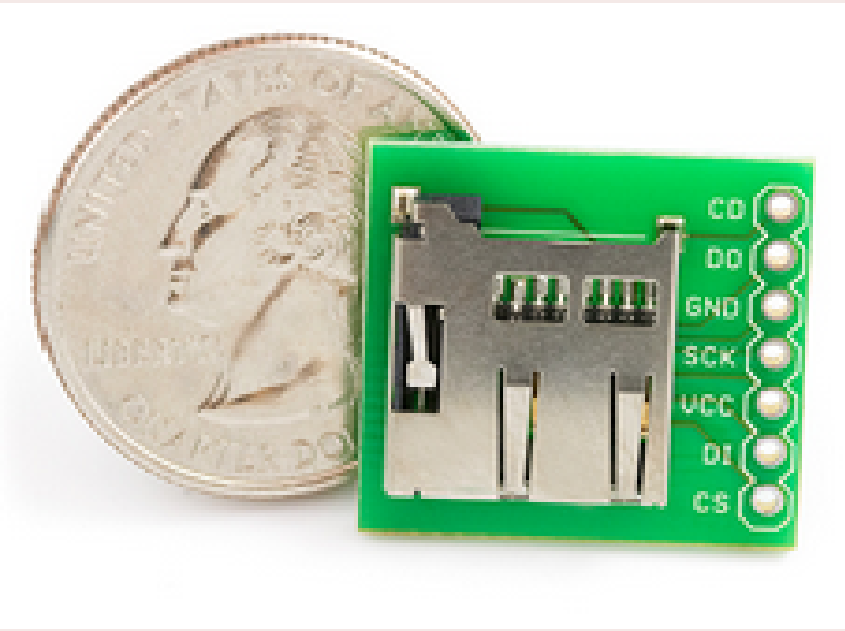
Data Collection

Process

- Employed an SD Card for data logging
- Code for Testing
  - Throttle
  - Steering
  - Encoder Response
  - Turn Radius
- Could not integrate into main code due to negative effects
- Saved to CSV file

Breakout Board



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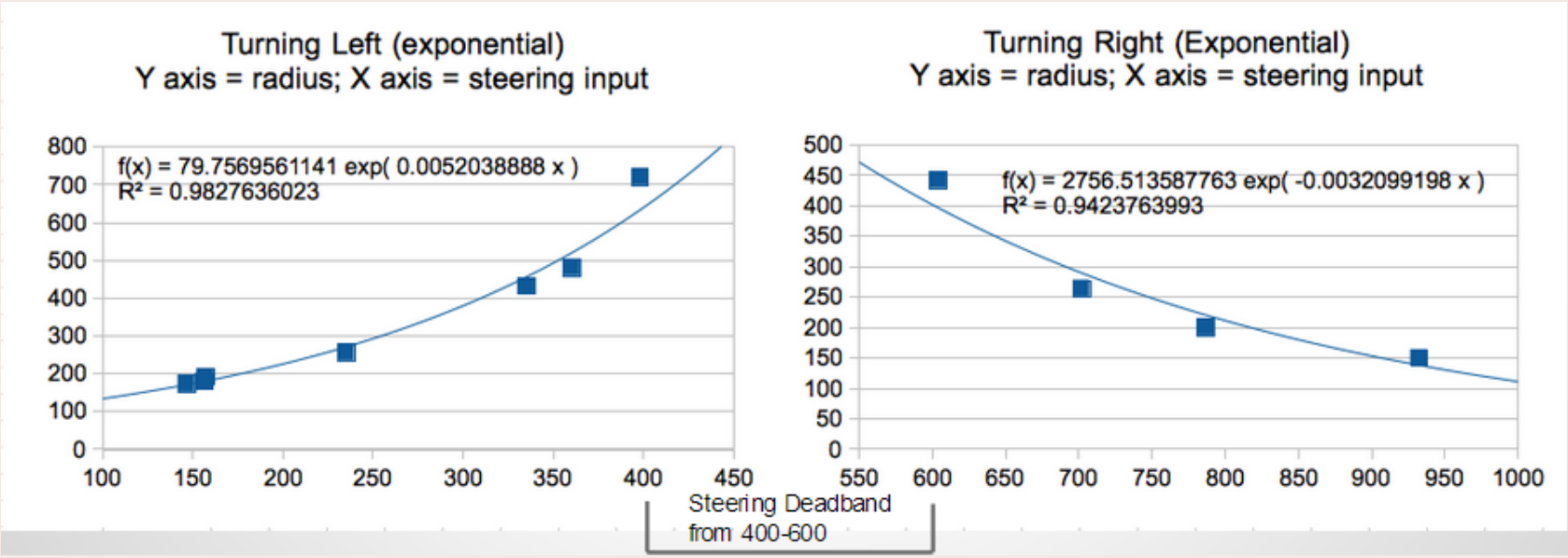
Data Logging Results

Measured turn radius with respect to steering analog input



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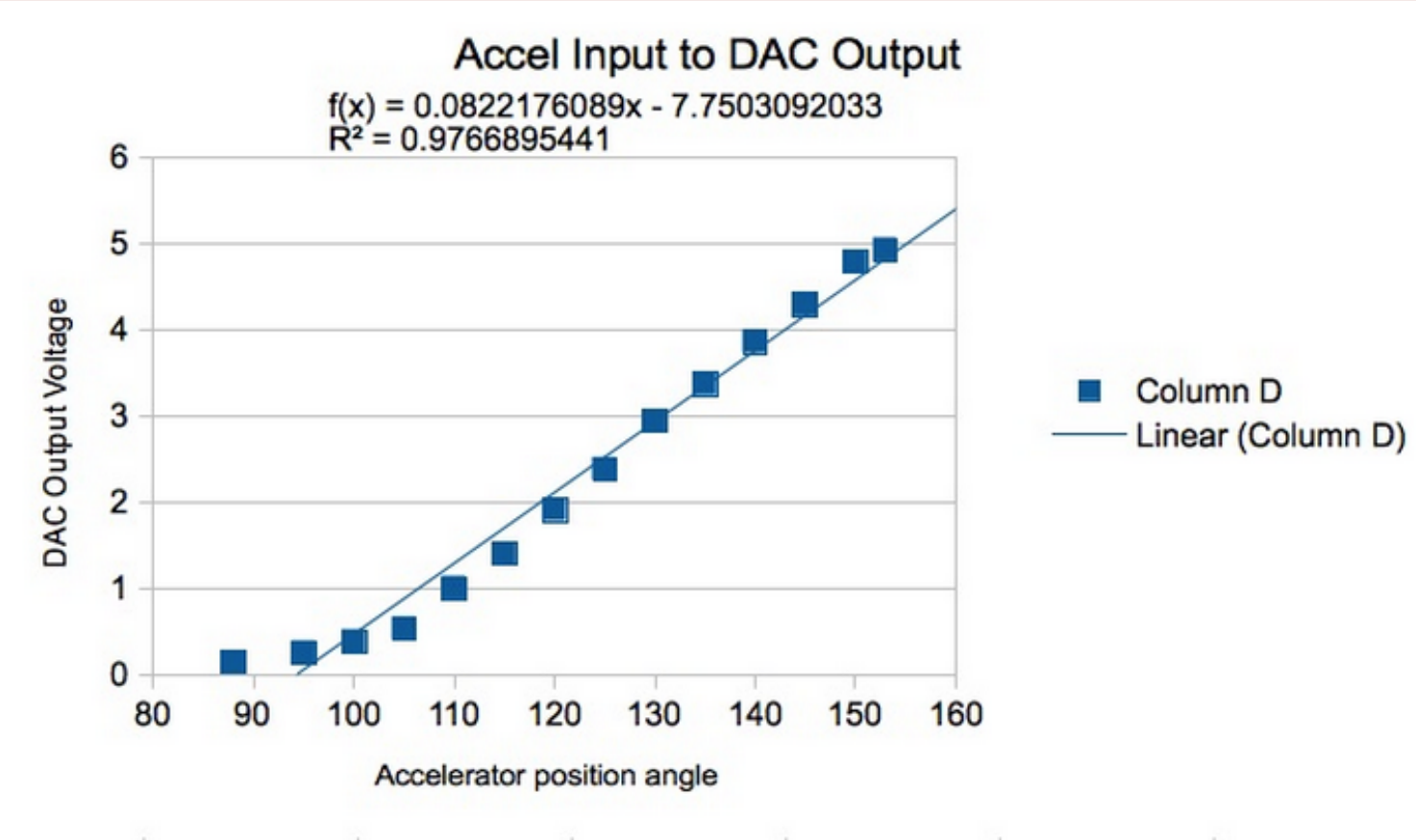
Data Logging Results

Accel Input to DAC Output



Debugging

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Troubleshooting

- Encoder
- Dissimilar motor behavior
- Brake behavior
- Multiple analog inputs

Testing

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Process

- The electronic differential system must show measurable improvement over a solid axle system and a forced couple system in a turning radius test.
- Wheel "hopping" during solid-axle testing

Results

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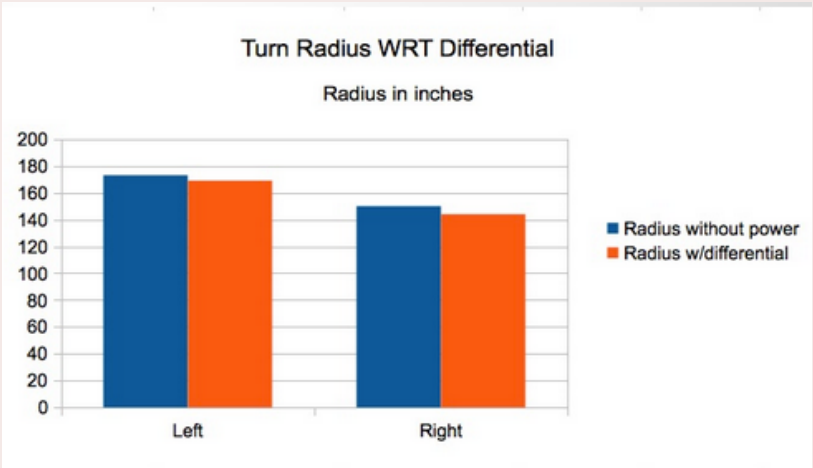
Outcome

- Solid-Axle Testing
  - Video of differential testing (YouTube Link)
  - Video of solid axle testing (YouTube Link)
- Unmet Goals
  - Traction Control
  - Regenerative Braking

Data



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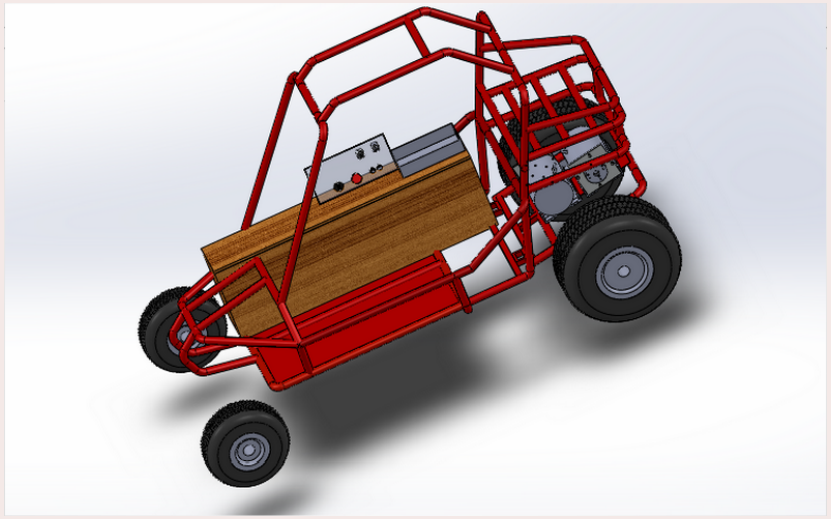
The Final Product

Final Rendering



Finished Kart

Conclusion

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- Successfully created a two wheel electronic differential
- Maintained documentation for next year
- The beginning of new things at UNC Asheville

Thank you for your interest and support!

Acknowledgments

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Special thanks to.....

IEEE
Advancing Technology for Humanity
WNC Section

Reece Engineered Bovine

EZGO
A Textron Company

Mountaintop Golf Cars Inc.
of Banner Elk

ProMATIC Automation
Asheville

Existential Motorcycles
a small joke that got out of hand

Skyland Auto Group

Questions

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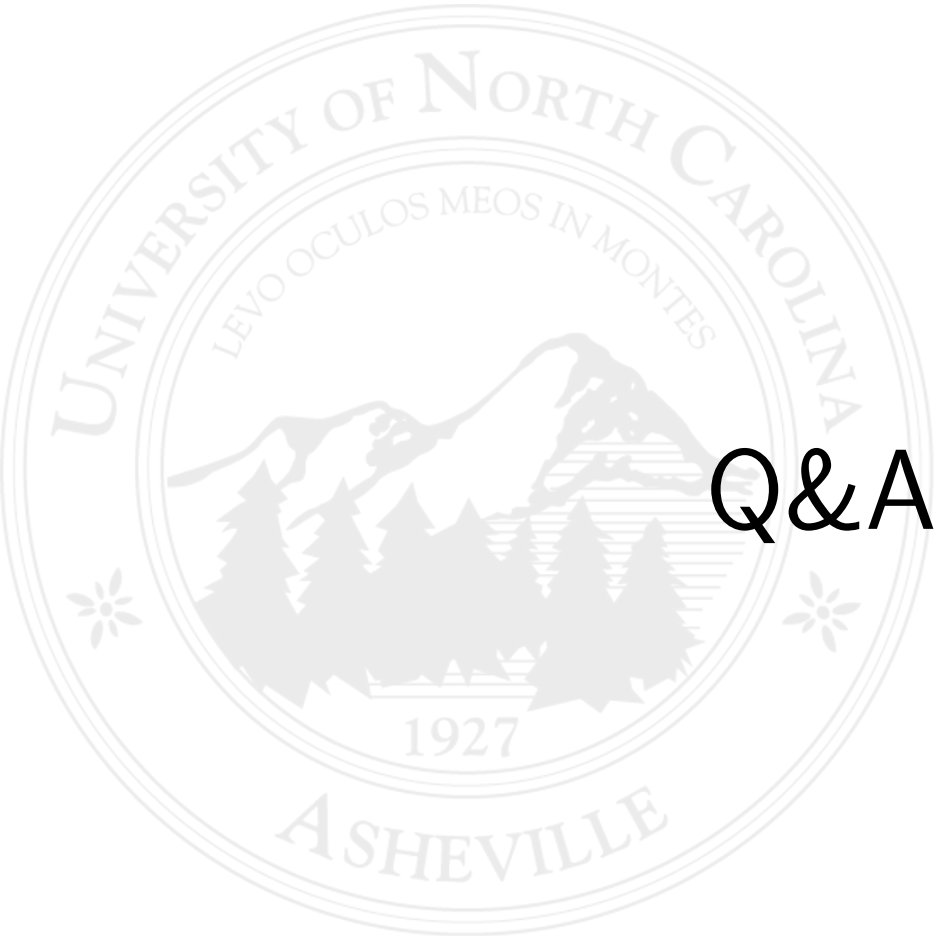

Q&A Session