NFPA Fluid Power Vehicle Challenge

NFPA
Education and
Technology
Foundation

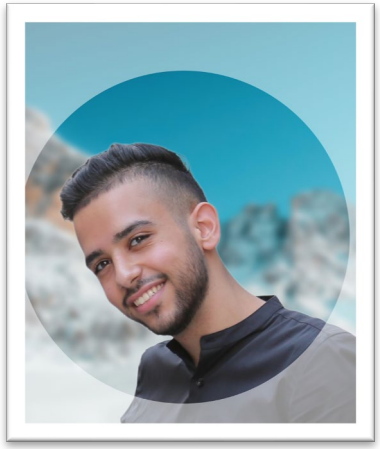
FINAL PRESENTATION
NORTHERN ILLINOIS UNIVERSITY
TEAM ADVISOR: GHAZI MALKAWI
DATE:04/21/2025

Northern Illinois University

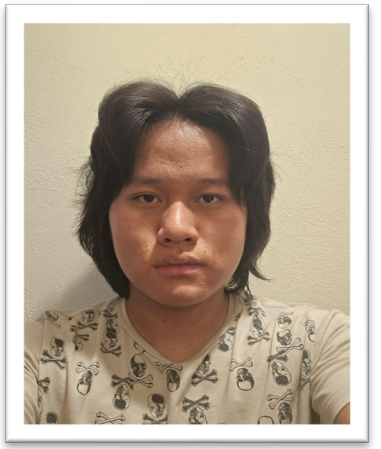
Team Introductions

Frame and Mechanical

Max Kahler



Rakan Abu Al Rub



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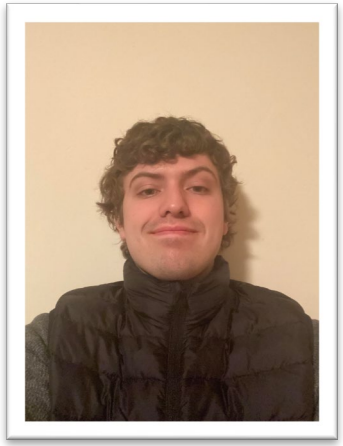
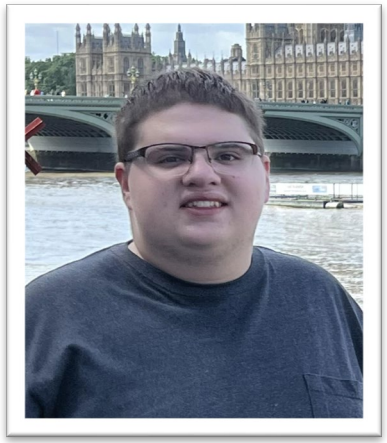
Team Introductions

Hydraulics and Controls

Arthur Kozlowski



James Simmons



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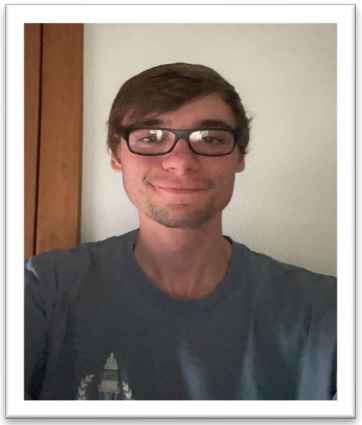
Jaron Benson



Jacob Connors

Old vs New Vehicle Design

2024

2025

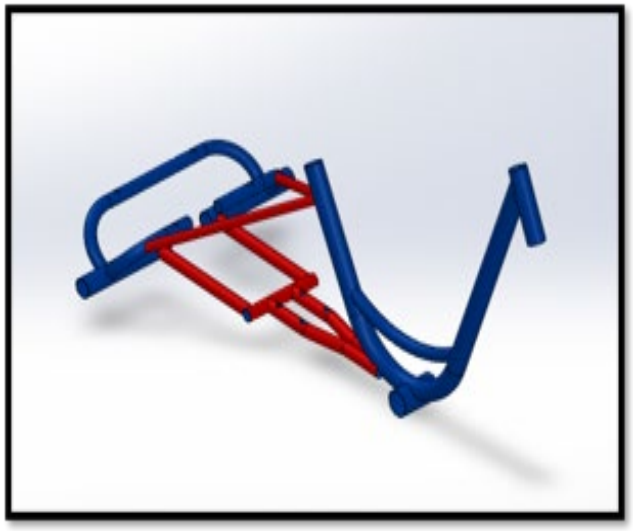
Weak Points

- **Chain Interference:** Chain contacted the frame, causing friction and wear.
- **Accumulator Pre-Charge:** Time-consuming and difficult.
- **Poor Layout:** Inefficient component placement made maintenance harder and increased weight.
- **Bulky Brackets:** Oversized and heavy, taking up excess space.
- **Weight:** 2024 vehicle weighed 190lbs

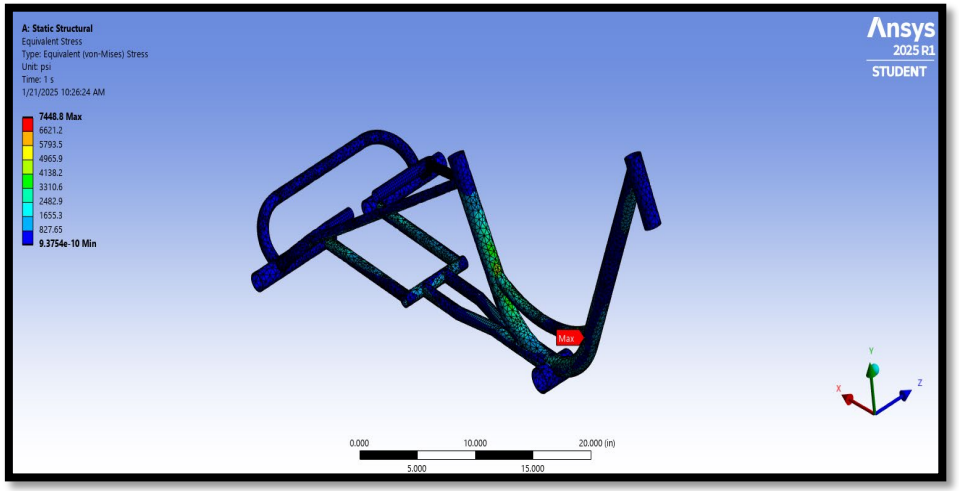
Improvements

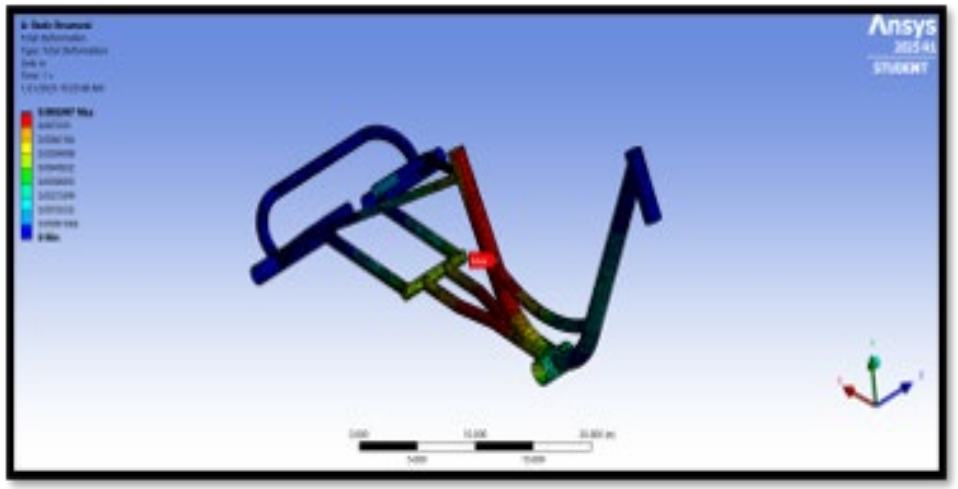
- **Redesigned Rear Frame:** Removed chain interference and improved component layout.
- **Better Chain Clearance:** Fixed friction with improved alignment.
- **Refined Brackets:** Lighter, compact, and easier to remove.
- **Easier Pre-Charge:** New gear ratio adds torque for faster charging.
- **Less Weight:** 2025 vehicle weighs 162lbs

Frame Modifications & FEA Analysis



Modified frame sections are shown in RED





The analysis was conducted using ANSYS Workbench 2025, with a 200lbf load applied to the seat post to simulate the weight of a 200lb rider under flat, level ground conditions with a constant force.

Results:

- Maximum deformation: 0.0082”
- Maximum equivalent stress: 7,448 psi
- Safety Rating: 4.43

Improved Gear Ratios

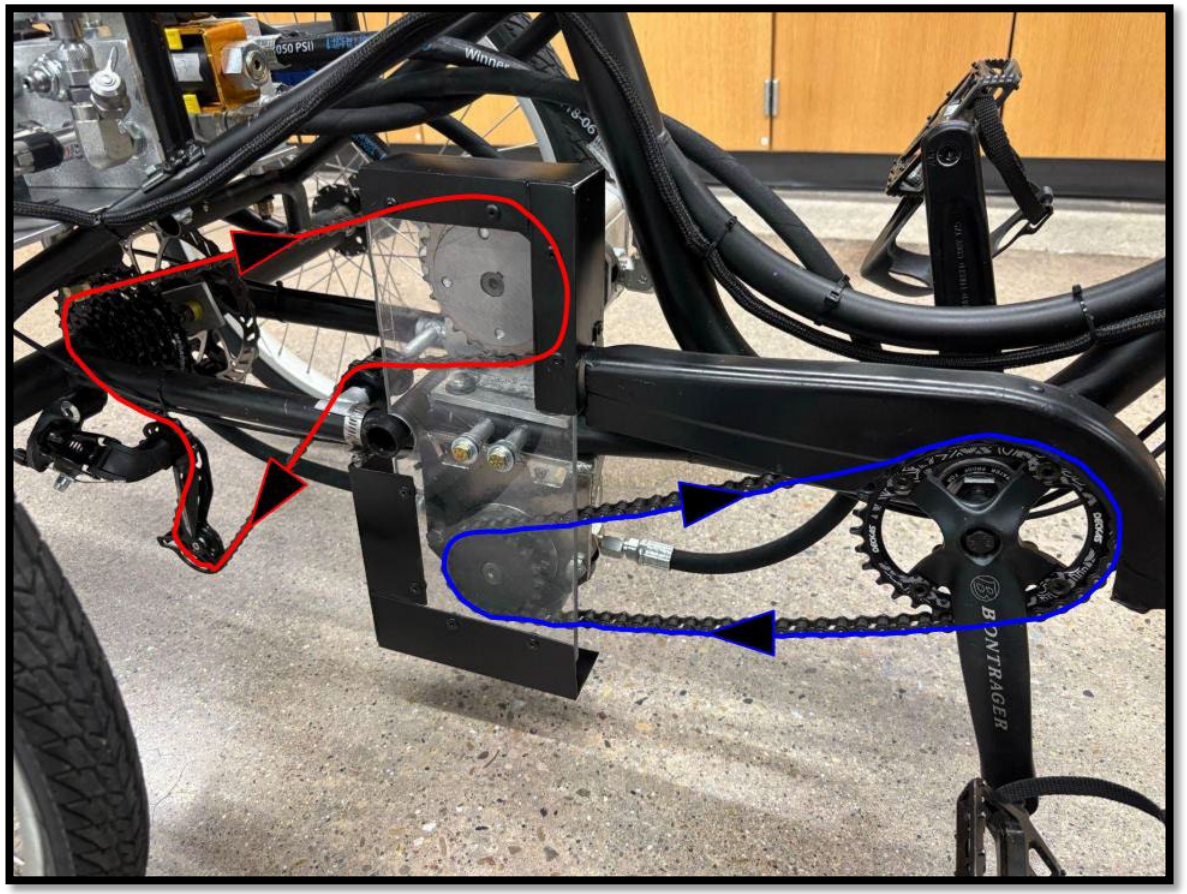
Pedal to Pump

Last Year		
Pedal Sprocket	Pump Sprocket	Ratio
36	36	1

This Year		
Pedal Sprocket	Pump Sprocket	Ratio
32	18	1.78

Motor to Axle

Gear Selection	Motor Sprocket	Rear Sprocket	Ratio
1	28	34	0.82
2	28	28	1.00
3	28	24	1.17
4	28	21	1.33
5	28	18	1.56
6	28	15	1.87
7	28	13	2.15



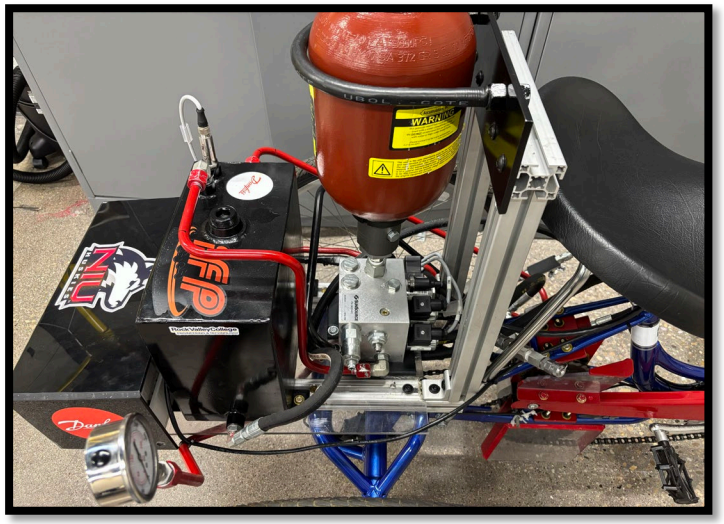
The revised pedal-to-pump gear ratio makes accumulator pre-charging easier and enables full use of the motor-to-axle gear range, resulting in a more efficient and improved riding experience

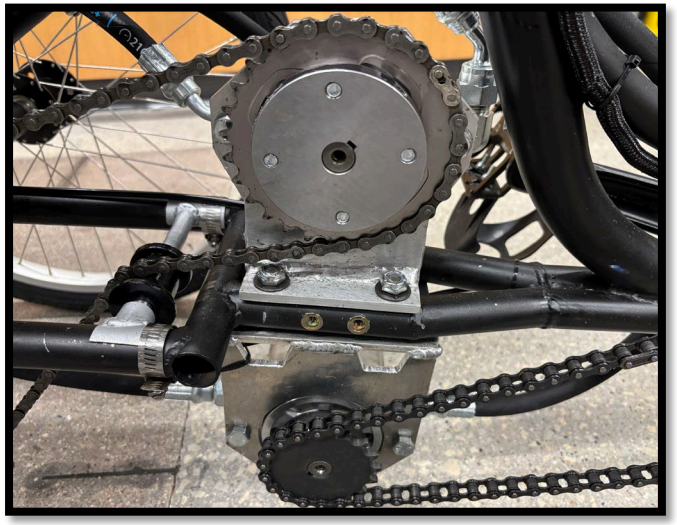
Custom Hydraulic Mounting Brackets

Pump & Motor Brackets

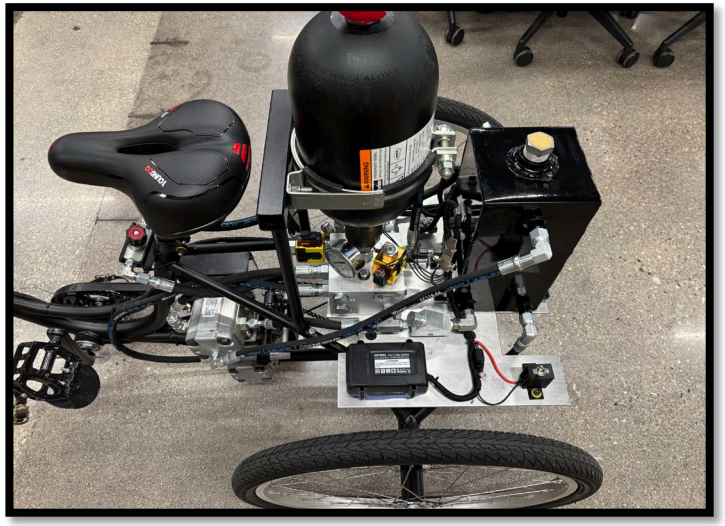
Hydraulic Component Mounting

2024





2025



Pump & Motor Brackets:
The new pump & motor mounts are more compact, lighter, and easier to remove, allowing for better maintenance and assembly.

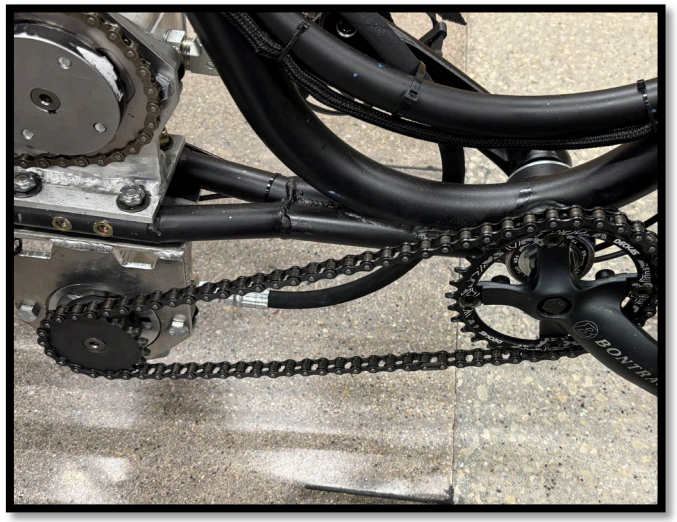
Component Mounting:
The new design is lighter, more compact, and provides secure mounting for key components while allowing easier access for maintenance and adjustments.

Chain Clearance & Safety

Chain Interference

Safety Guarding

2024



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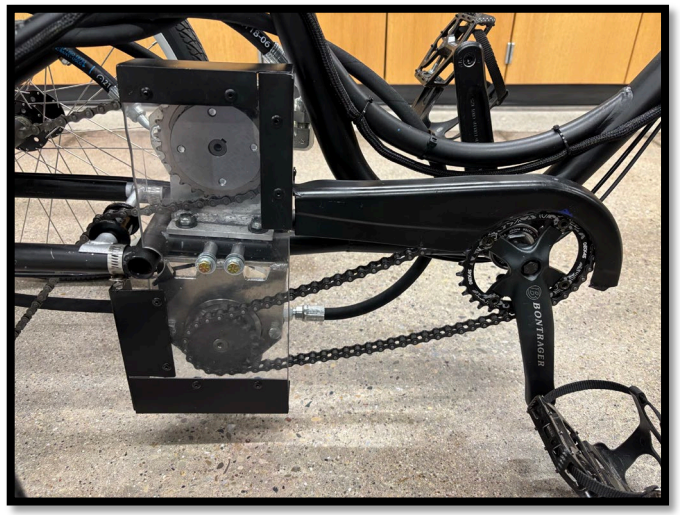
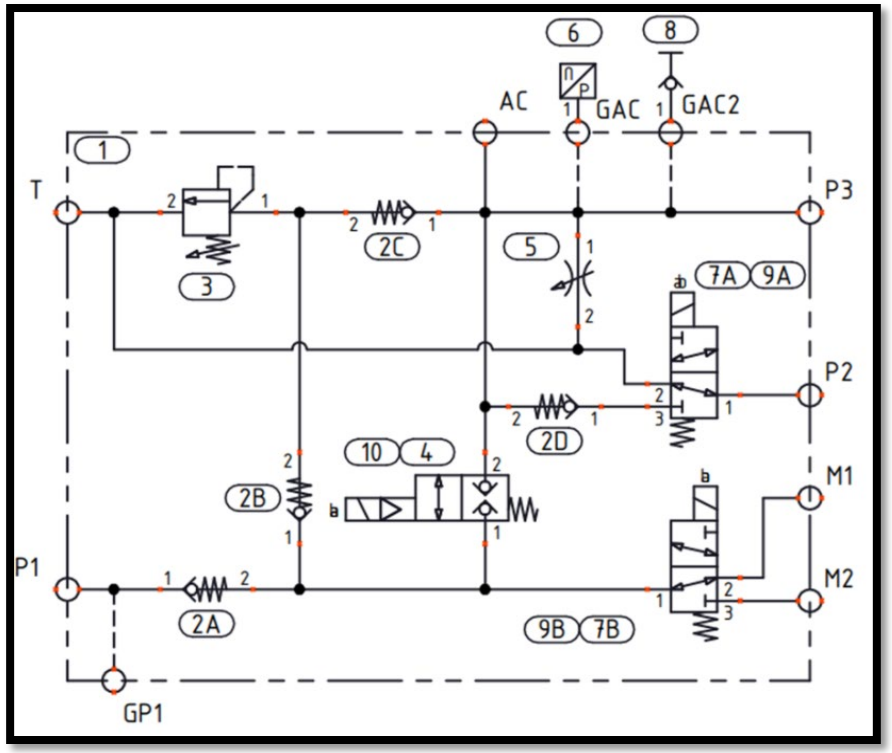
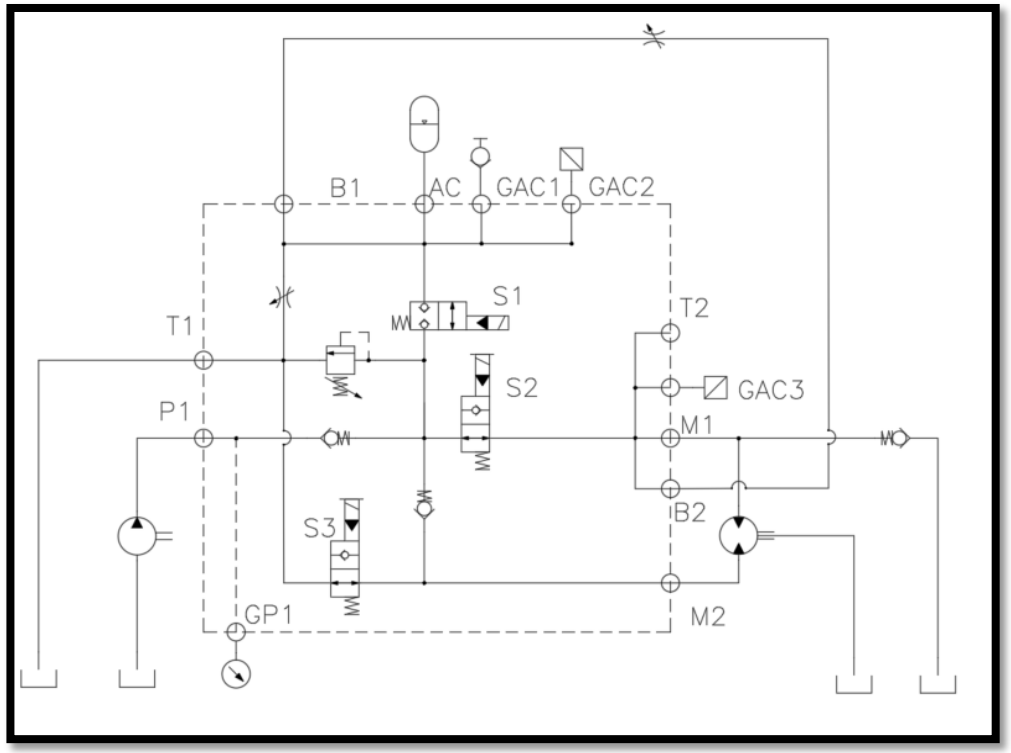


Chain Interference:
The chain interference was eliminated by the frame redesign, eliminating unwanted friction and chain derailment.

Safety Guarding:
The chain guard allows quick removal for easy access to the pump and motor during gear changes or maintenance.

Old vs New Hydraulic Schematic





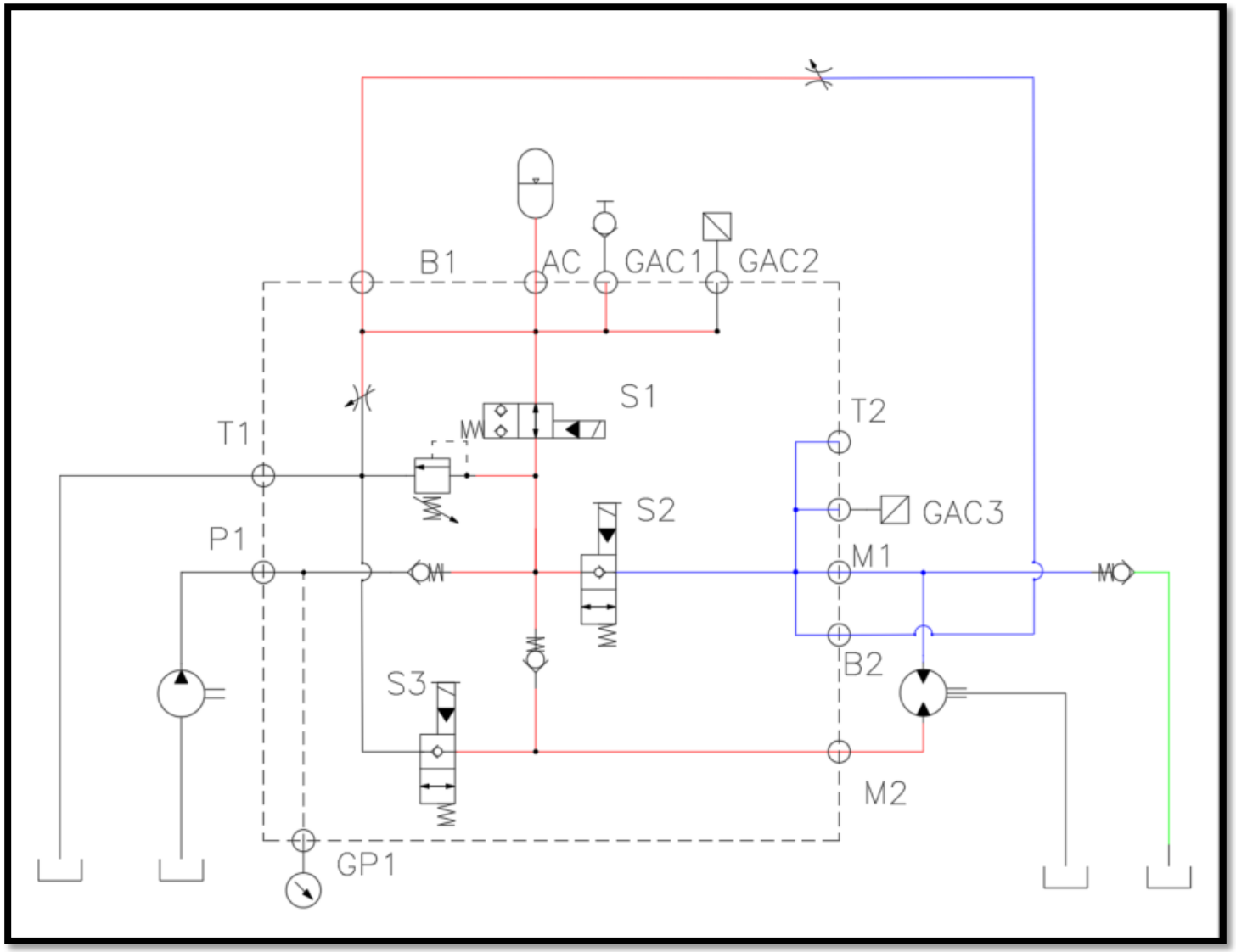
Old Schematic Weak Points

- Higher pressure loss from 3-way 2-positions solenoids
- Spool type solenoids to hold pressure
- Can't tell the pressure at the motor

New Schematic Improvements

- Three 2-way 2-positions solenoid design
- Poppet style solenoids to reduce pressure losses
- Additional pressure transducers at motor inlet
- External needle valve for discharging

New Hydraulic System
Regenerative Braking

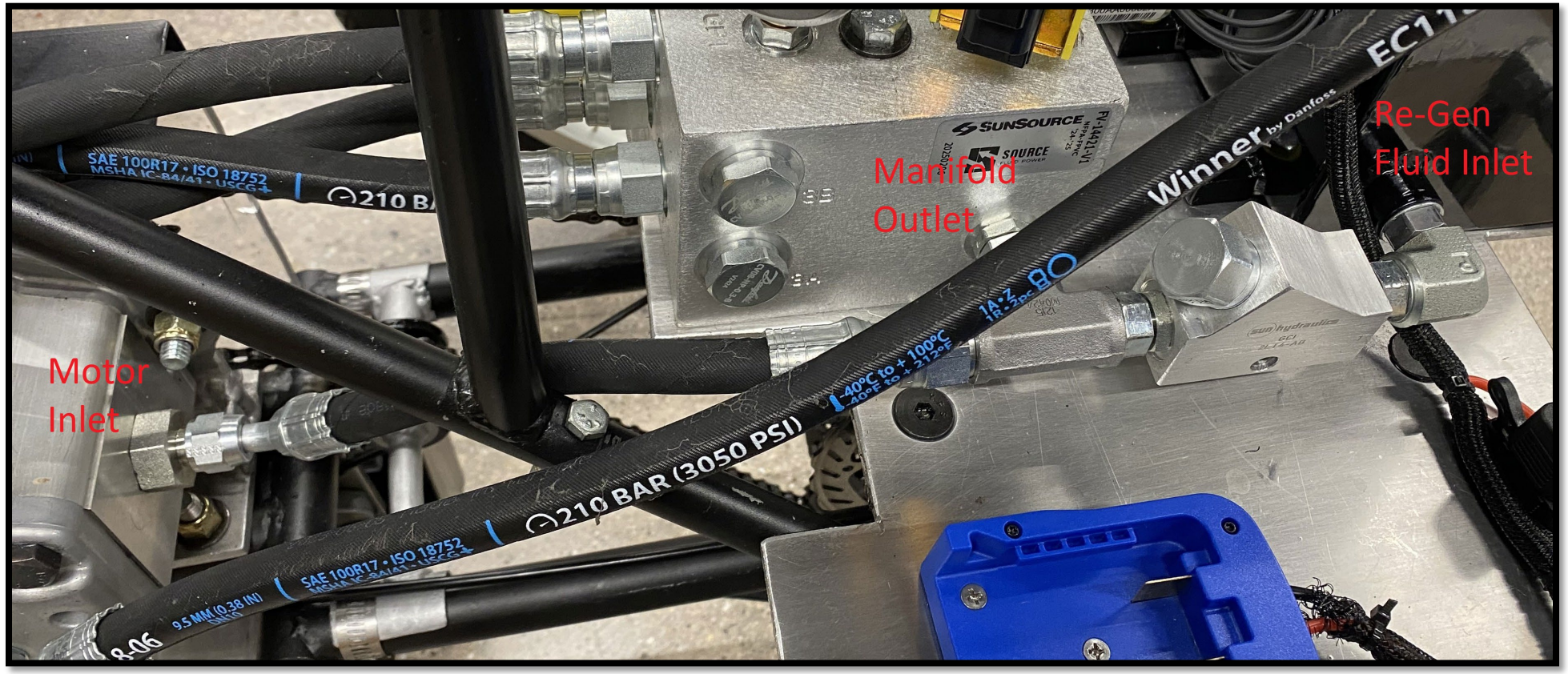


Old Hydraulic System

Weak Points

- Motor cavitation
- Many fittings at inlet of motor causing restriction
- 90-degree elbow into motor
- Upside down motor

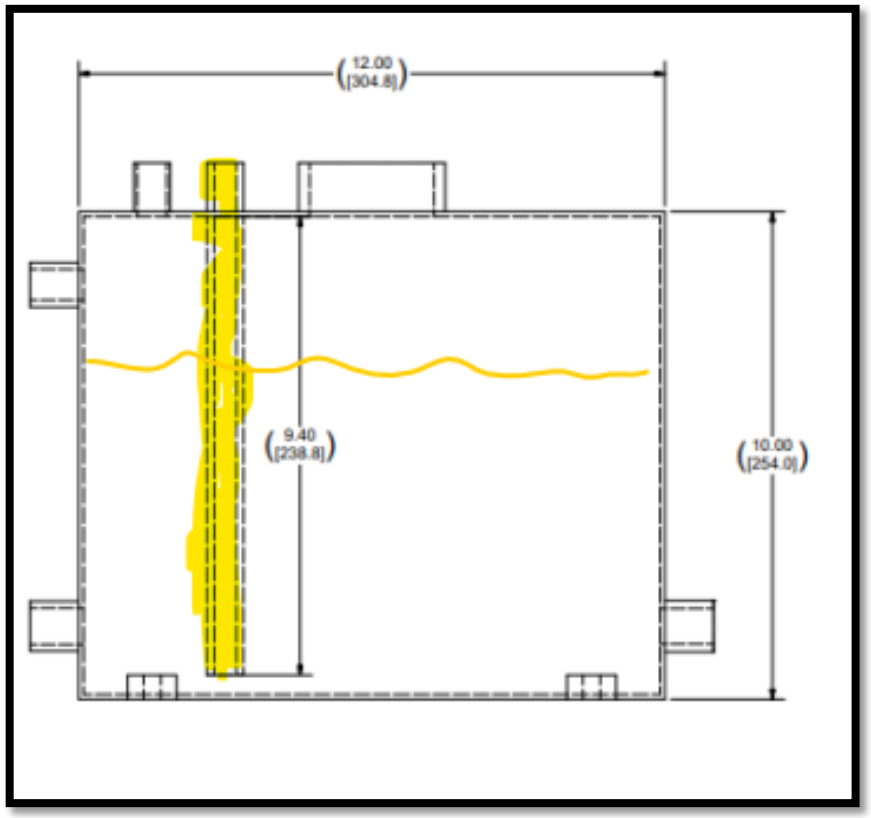
New Hydraulic System



Improvements

- Horizontal motor
- Reduced fittings and 90 elbow at inlet

Old Vs. New Tank



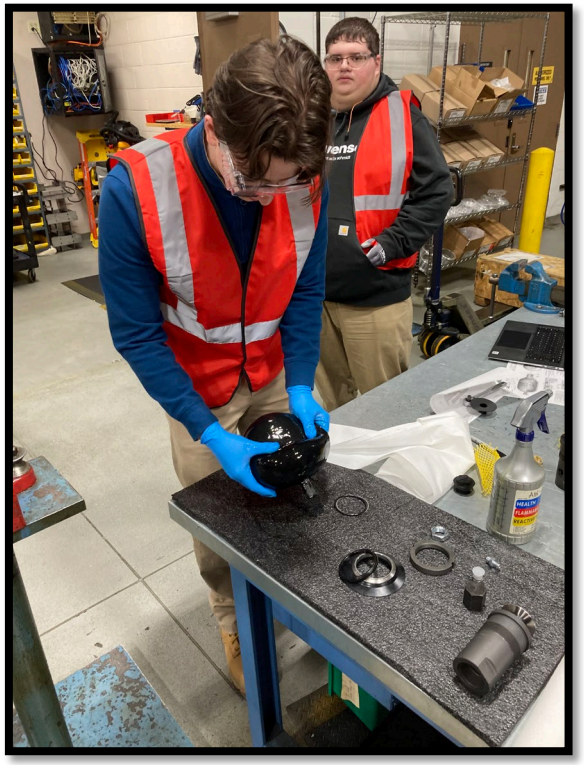
Old Tank Weak Points

- Oversized
- Shared connection for return line and regenerative braking inlet

New Tank Improvements

- Taller design for increased static pressure
- Smaller volume for weight reduction
- Additional connection for regenerative braking inlet
- Breather cap

Hydraulic Components



Parker BA01B3T01P2
SAE Bladder Accumulator
1 Gallon

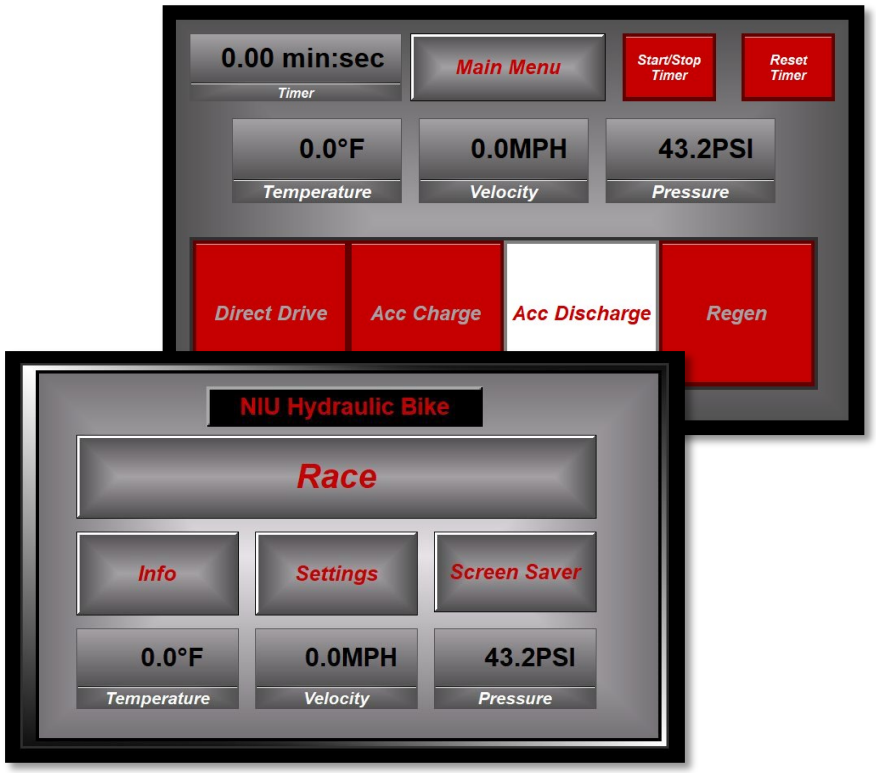
Danfoss 111.20.243.00
Gear Pump
0.659 CIR

Danfoss 121.20.045.00
Gear motor
1.025 CIR

Old vs New Controls System

Standard Features

- Displays PSI and MPH
- Can store max velocity, pressure and distance values
- Only requires one input to control drive modes



2025 Improvements

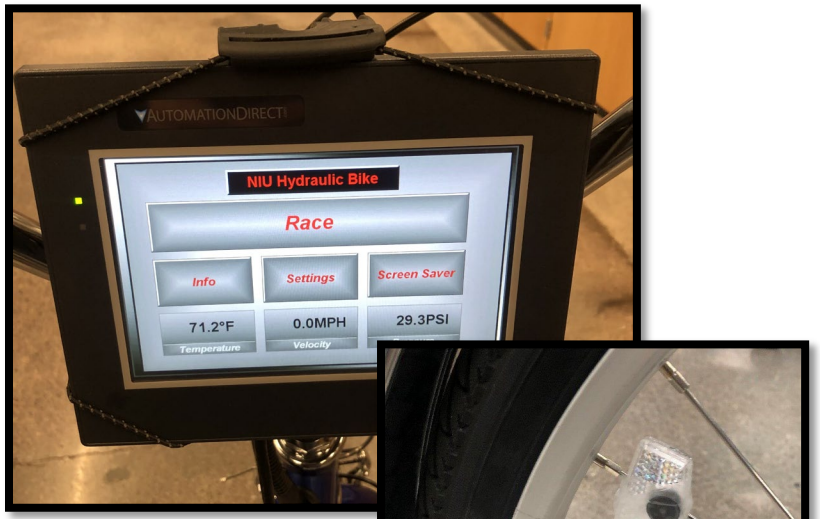
- More responsive buttons
- Additional pressure sensor for system PSI
- Dial gauges for reading velocity and pressure
- No switching between screens
- Components secured to bike

Display and Speed Sensor

2025 Improvements

- Physical buttons on display panel for controlling modes
- Speed sensor with custom 6 tooth speed ring for more responsive readings

2024



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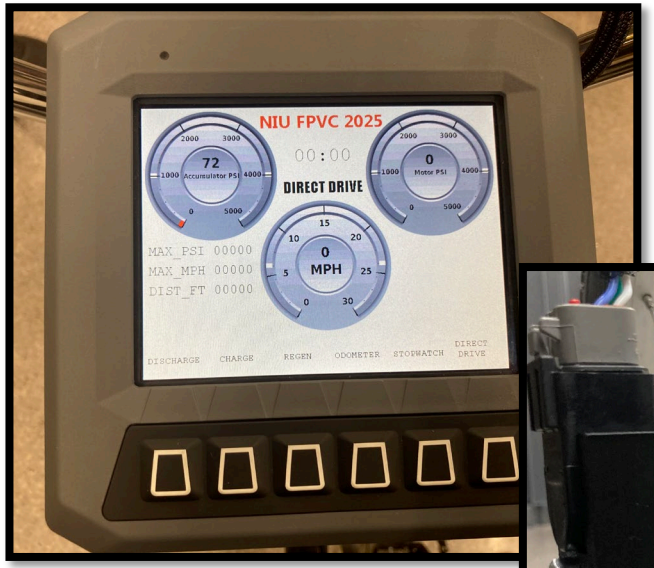
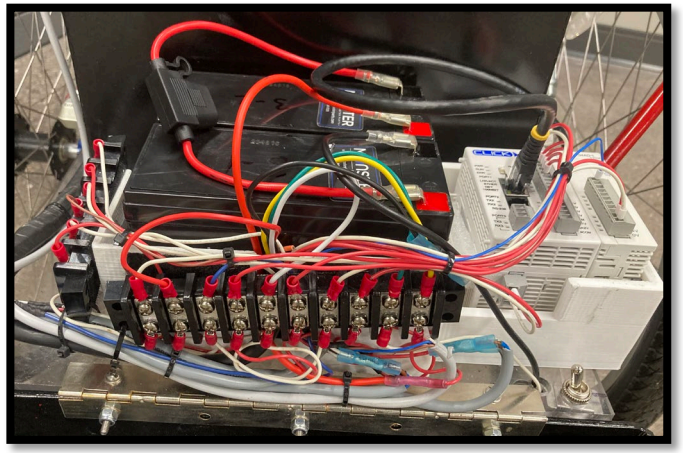


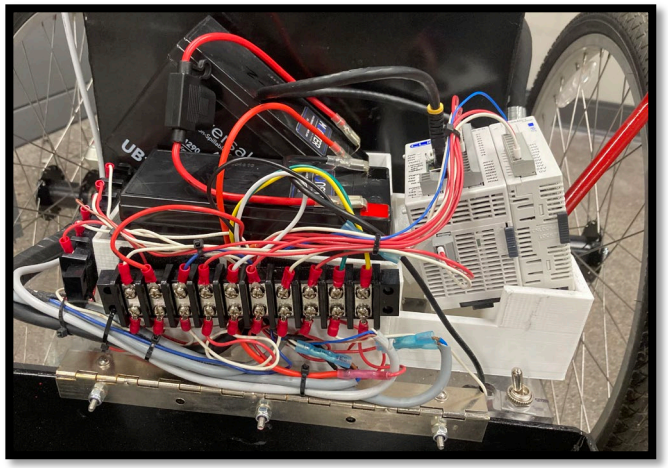
Controls & Battery

2025 Improvements

- Lighter Battery
- Battery and Controller Secured to mounting plate

2024





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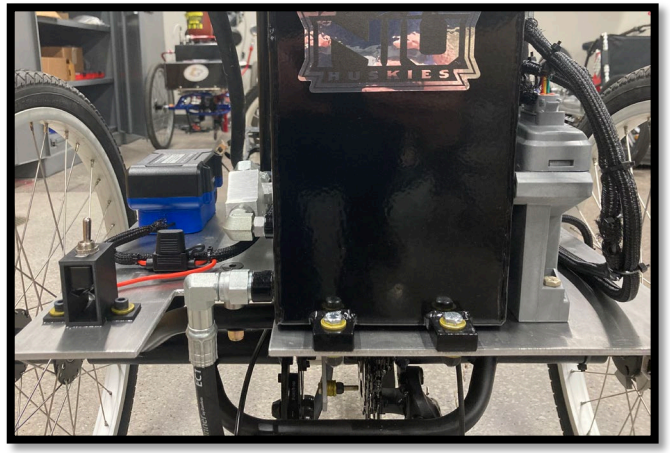
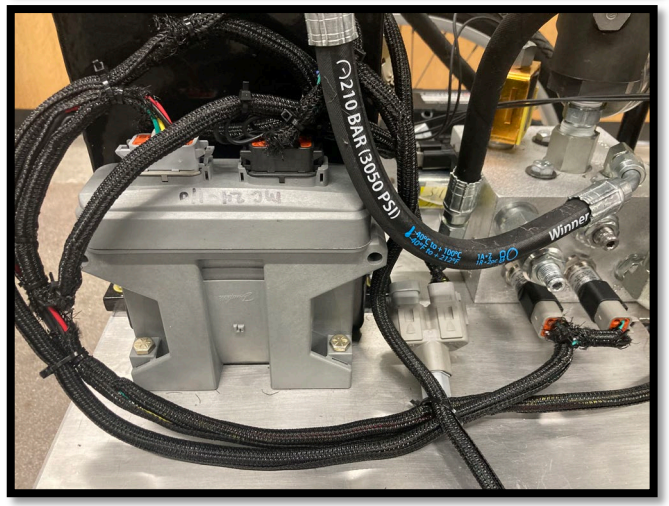
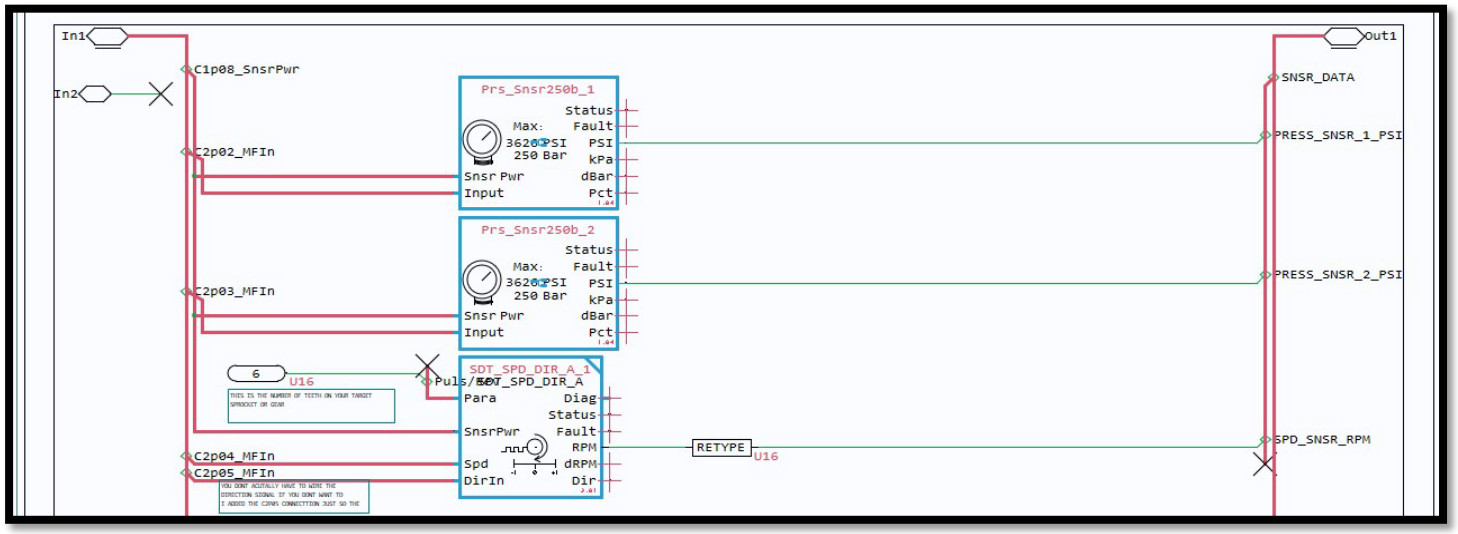


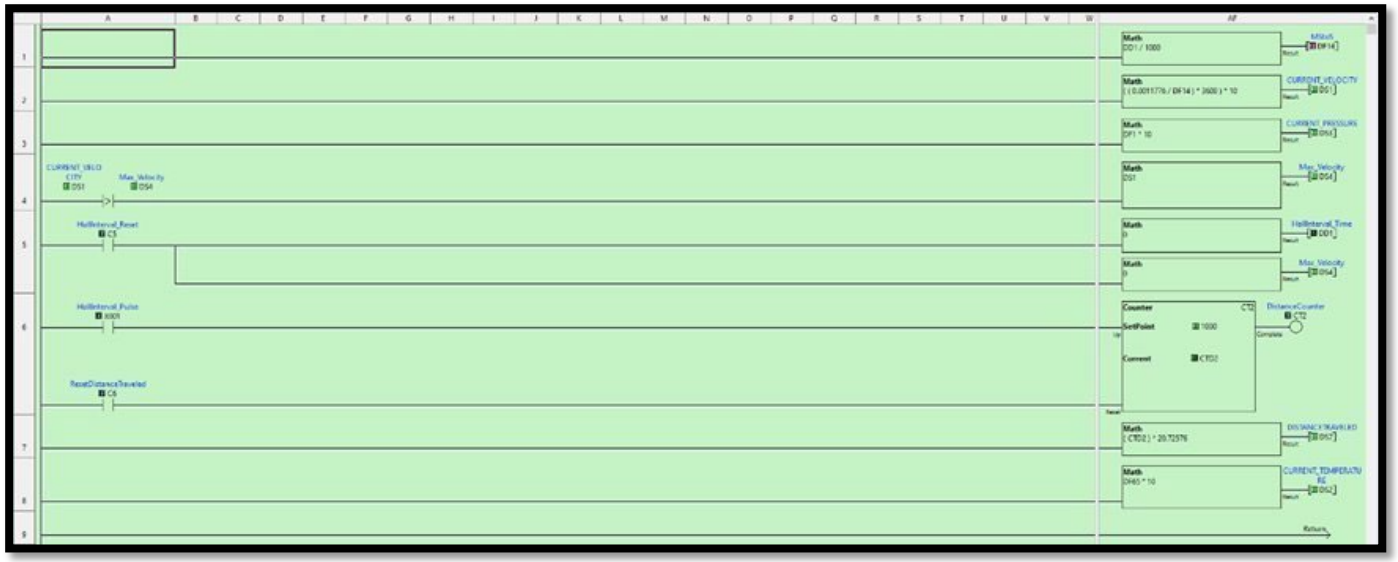


Controls Programing For Sensors



2025

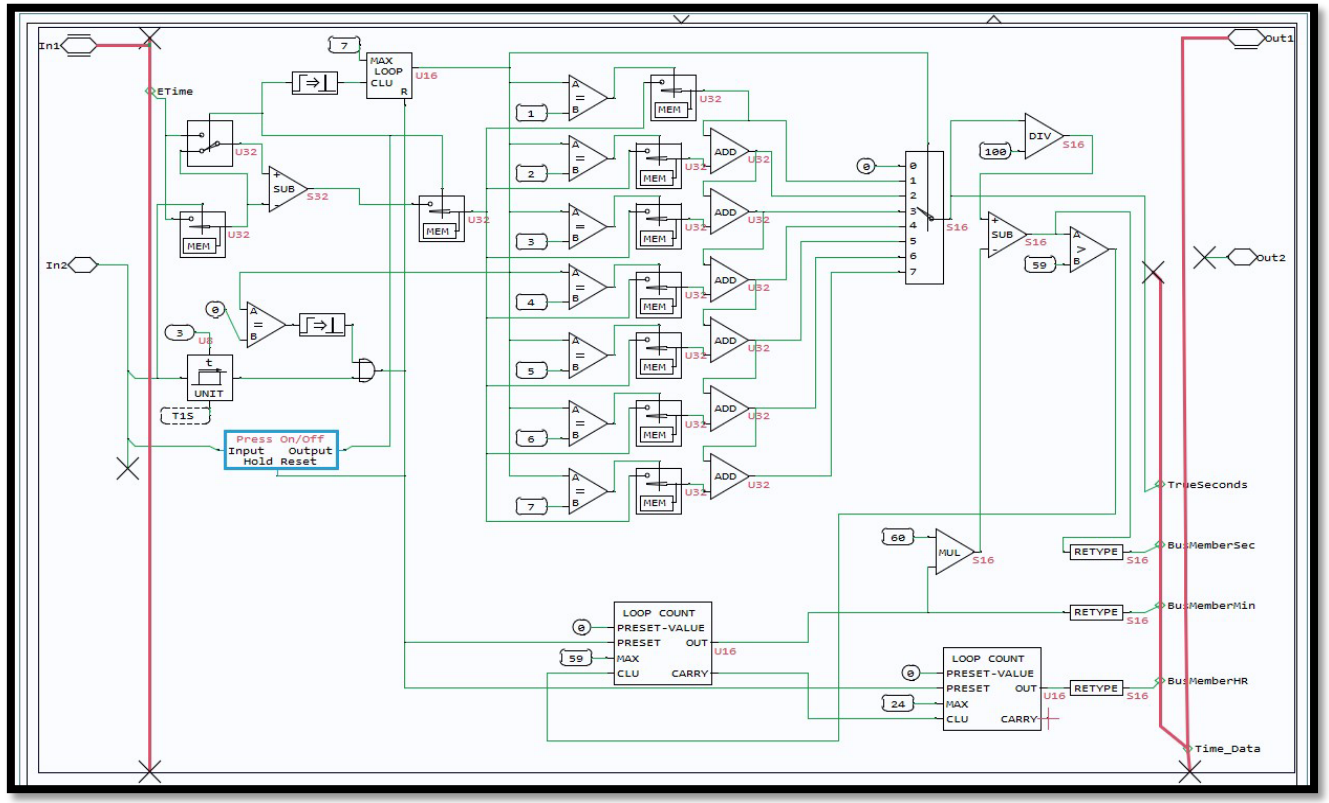
Graphical Drag and Drop



2024

Ladder Logic

Controls Programing for Stopwatch



2025
Graphical Drag and Drop

2024
Ladder Logic

Calculations

Motor CIR	Pedal RPM	N Pre Charge	Max Charge
1.025	60	1200	3000

Gear Selection	Speed Ration	Calculated Pull	Max Lbs Pull	Avg Lbs Pull	Distance Traveled	MPH_1	MPH_2
1	1.21	16	51	29	655	4.0	2.2
2	1.00	20	42	24	796	4.8	2.7
3	0.86	23	36	21	928	5.6	3.1
4	0.75	27	31	18	1061	6.4	3.6
5	0.64	31	27	15	1238	7.5	4.2
6	0.54	37	22	13	1485	9.0	5.0
7	0.46	43	19	11	1714	10.3	5.8

Pump CIR	Pedal RPM
0.659	60

Gear Selection	Gear Ratio	Max Lbs Pedal	Avg Lbs. Pedal	Pump RPM
1	1.78	80	46	107
2	1.00	45	26	60

Calculation used to determine vehicle configuration

- 1.78 gear ratio nearly doubles speed compared to last years hydraulic bike with a 1.00 gear ratio.
- Any pre-charge over 1200 psi would result in loss of pressure before the end of sprint race at motor gear selection 1.
- Bike can not begin to be propelled forward starting at a motor gear selection of 5 and up.

Vehicle Testing

- Sprint Test
  - First test – 1600 psi pre-charge at 3000 psi – used gears 1-7 - speed of 13.2 mph at a time of 30.96 seconds
  - Best average speed of 17.51 mph over 600 ft (1200 psi pre-charge at 3000 psi hydraulic pressure – Used gear 1 for entire race).
  - Time of 23.36 seconds
- Endurance Test
  - 2024 bike test – 5122 ft in 11:06 (average speed of 5.2 mph, max speed of 14.2 mph)
  - 2025 bike test - 5069 ft in 7:26 (average speed of 7.8 mph, 1.78 pedal to pump ratio, max speed of 15.5 mph).

Vehicle Testing Cont.

- Regen Test
  - Accumulator pre-charge of 1200 psi
  - From a hill of 14 ft elevation and 185 ft long
    - Distanced travelled of 220 ft from discharging
- Efficiency Test
  - Optimal efficiency 19%
  - Accumulator pre-charge of 1200 psi
  - Hydraulic pressure of 2500 psi
  - Distance travelled of 1856 ft

Lessons Learned

- Frame:
  - A good CAD model is key to designing an accurate and functional real-world model
  - Gear ratio changes significantly affect system behavior
  - Testing is extremely important to improve performance

- Controls:
  - Programming using Danfoss Plus+1 drag and drop programing method.
  - Went through several iterations of stopwatch programing and getting accurate seconds.
  - Collecting and storing data in controls.
  - Wiring components using Deutsch connections.

- Hydraulics:
  - Schematic Design
  - Importance of laminar flow
  - Importance of reduced restriction
  - Effect of gear ratios and accumulator pre-charge on hydraulic system

Thanks Sponsors

Thanks for Listening

- Any questions or comments?

NFPA Fluid Power Vehicle Challenge

National Fluid Power Association NFPA

NIU Huskies

Northern Illinois University + Rock Valley College

NIU & RVC

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(be)tter together