NFPA

Fluid Power Vehicle Challenge

Final Presentation

Kennesaw State University

Students: Michael Bakareke (PM)
Kendarius Chatman
Nyiem Dailey
Hunter Whitworth

NATIONAL FLUID POWER ASSOCIATION · NFPA ·

NFPA Education and Technology Foundation

Advisors: Drs. Laura & Richard Ruhala

April 14, 2022

KENNESAW STATE UNIVERSITY

Introduction

- Kennesaw State is located in Georgia, specifically in the metro Atlanta area.
- We are the 10th largest undergraduate mechanical engineering program in the United State of America.
- This is Kennesaw State's third appearance in the Fluid Power Vehicle Challenge (2019, 2021, 2023).

Team Introduction

Hunter Whitworth	**Michael Bakareke**	**Kendarius Chatman**	**Nyiem Dailey**

Design Objectives

- Vehicle must adhere to the constraints of the FPVC
- Vehicle can compete in all 4 events
  - Sprint, Endurance, Regenerative, and Efficiency challenges
- Design a vehicle that is unique to Kennesaw State
  - Vehicle design is substantially different in comparison to previous KSU FPVC teams

Team Advisors & Mentors

Laura Ruhala Ph.D.
Associate Professor
Kennesaw State University

& Instructor for Senior Design I

<u>FPVC Mentor #1</u>
Matthew Kruse,
Systems Engineer,
Danfoss Power Solutions

Nov 2022 – March 2023

Richard Ruhala Ph.D.
Professor
Kennesaw State University

& Instructor for Senior Design II

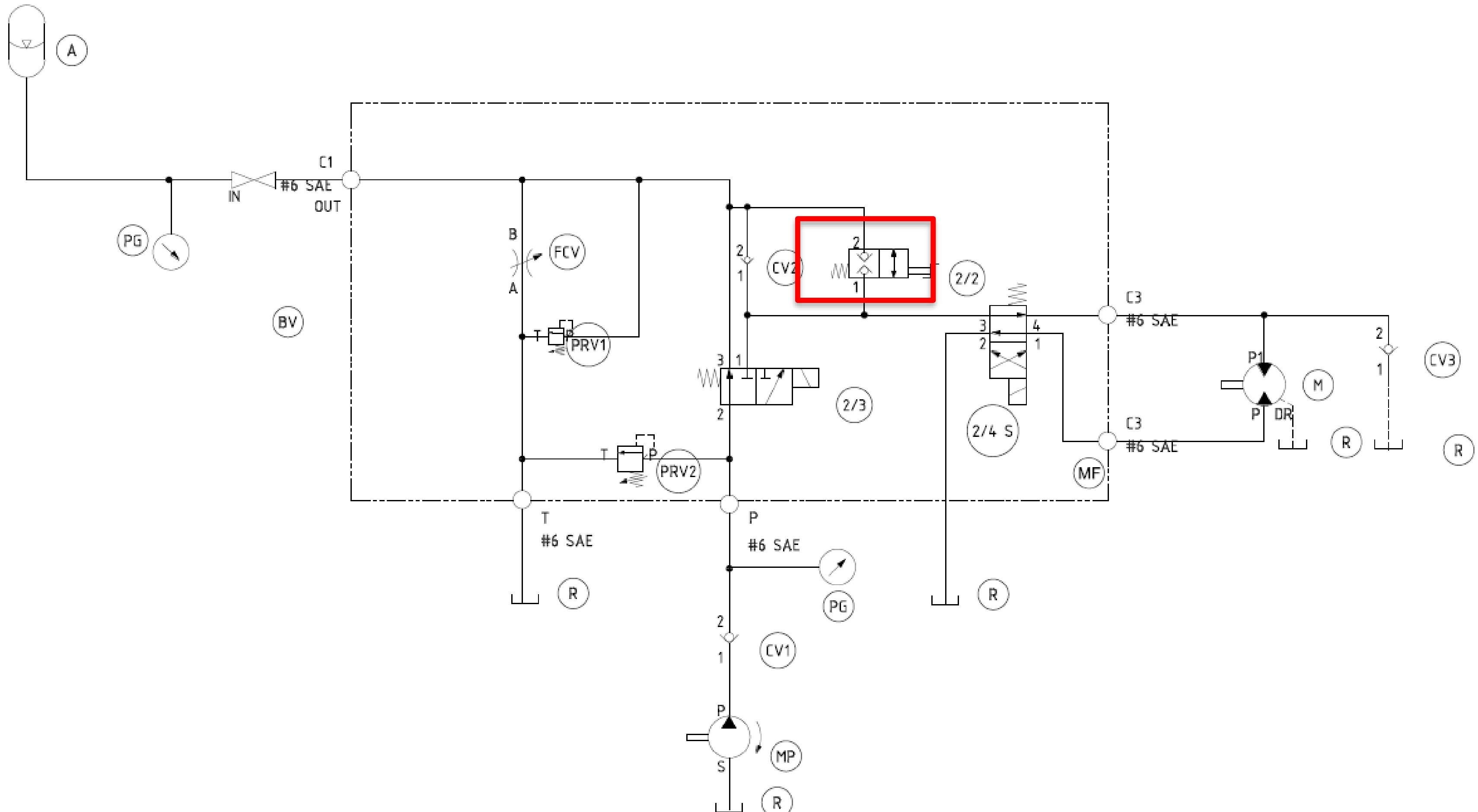
<u>FPVC Mentor #2</u>
Richard Lyman,
Chief Engineer,
Danfoss Power Solutions

April 2023

Summary of Midway Review

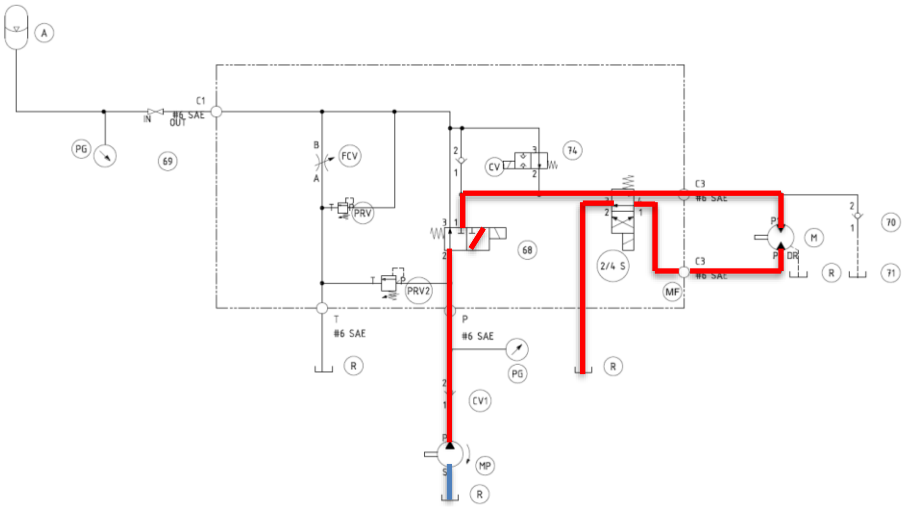
- Hardware selection
  - Hydraulics
    - Pump: 0.659 CID CW rotational gear pump
    - Motor: 0.659 CID Bi-rotational gear motor
    - Accumulator: 1 gallon bladder
  - Pneumatics
    - 9/16 Single acting, spring return cylinder
    - #10-32 Port – 1/4” Tube Flow Control Valve
- Bicycle Frame

Midway Review Changes

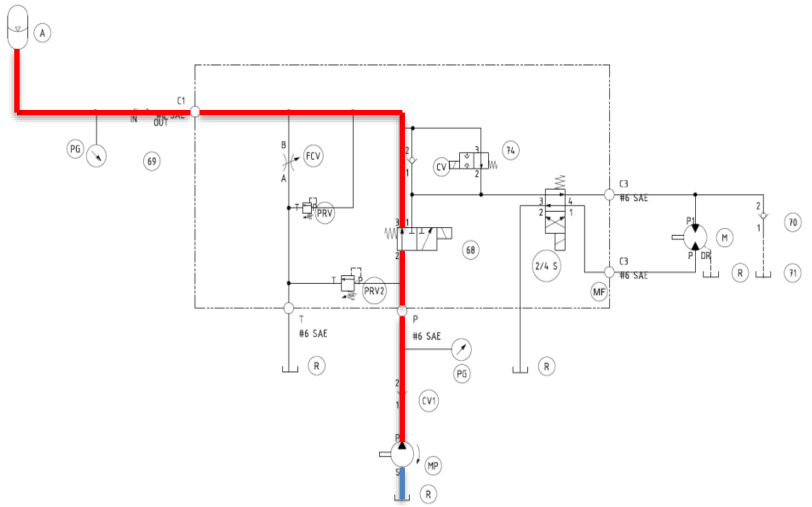


- Replaced solenoid powered 2/2 DCV with manual 2/2 DCV to create fail safe options in Accumulator charging mode

Hydraulic Schematics – Modes 1 & 2

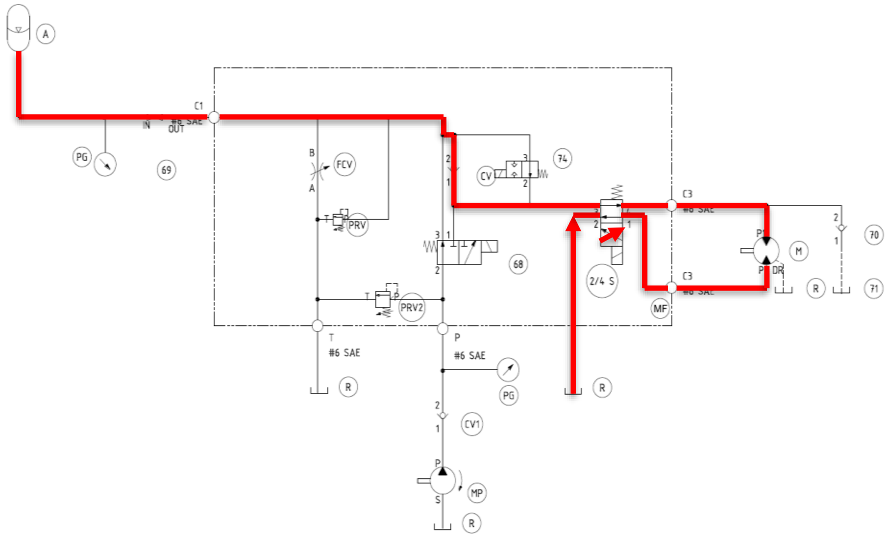


Direct Drive

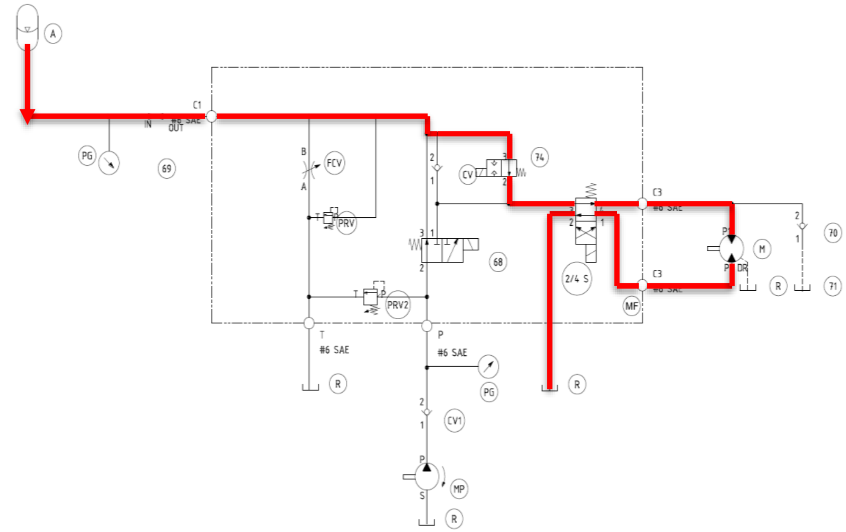


Direct Charge

Hydraulic Schematics – cont. – Modes 3 & 4



Regenerative Braking



Accumulator Charging

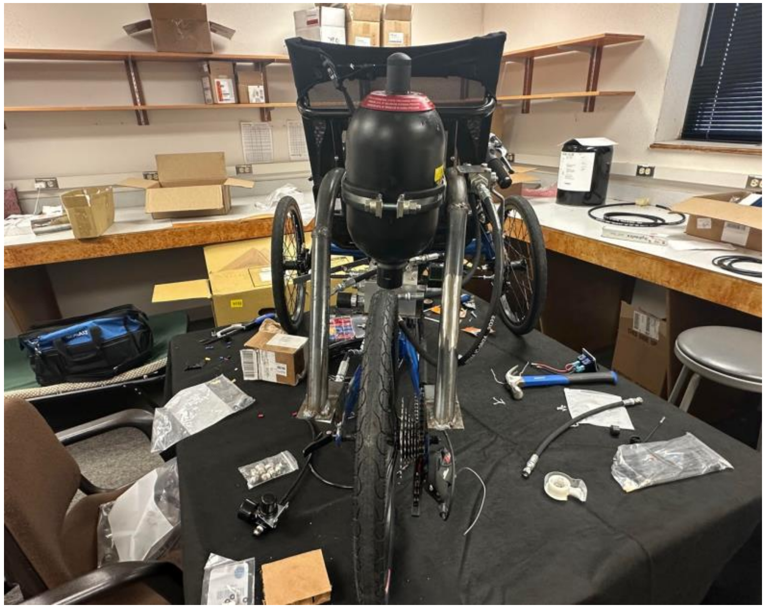
Bike Selection

- Purchased Eco-Tad SX Recumbent Trike
- Trike allowed us to center our hydraulic system in the rear and low center of gravity.

- Ground clearance allowed for us to safely store the reservoir.
- Significant modifications made by KSU Team.

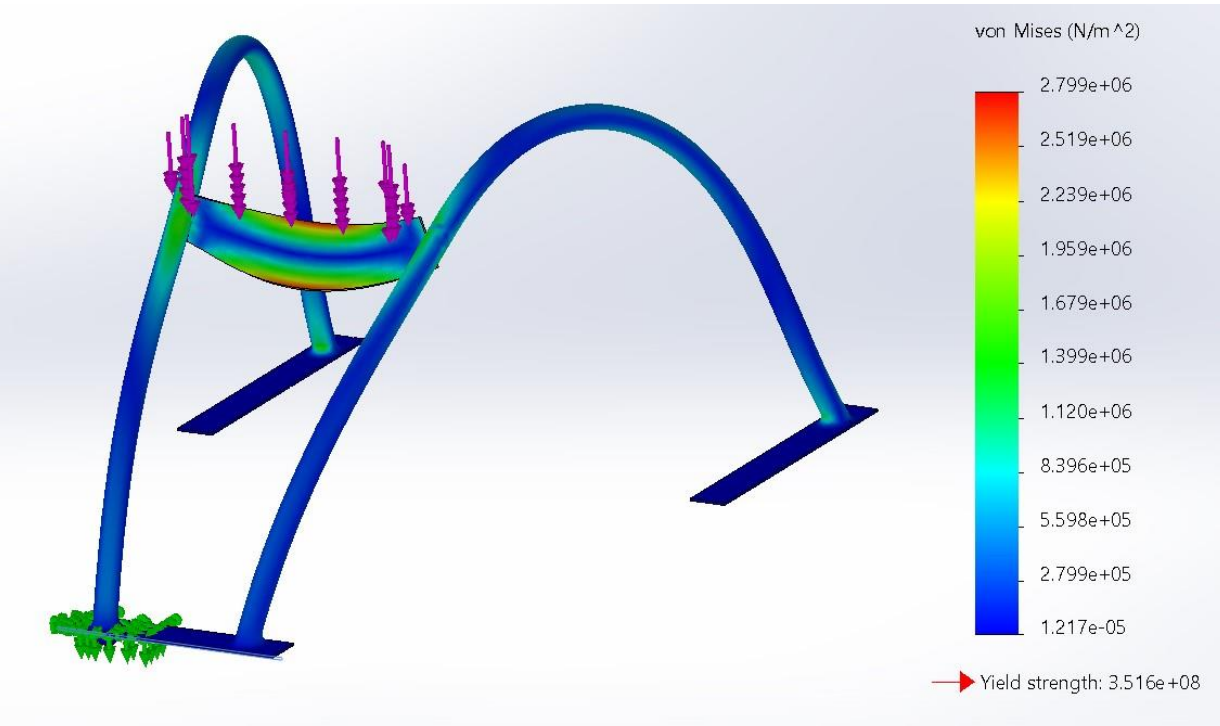
Vehicle Construction & Modifications

- Implementation of 1 ¼ metal tubing.
- Rods mount
  - Accumulator
  - Toggle switch
  - Regulator
  - Ball Valve



Frame Modification and Strength Analysis

- Emphasis on stress and displacement of rear hydraulic components on new frame.
  - Simulation conducted on 1-1/4 tubing.



- Load of Hydraulic Equipment on upper frame Evaluated
- Maximum stress experiences on rods: <u>2.8 MPa</u>
- Yield Strength is <u>352 MPa</u>
- Maximum Displacement of <u>0.00118 in</u>

→ *Meets Design Goals*

Vehicle Construction – cont.

- Female 9/16-18 and 3/4-16 bungs welded to reservoir

KENNESAW STATE UNIVERSITY

Vehicle Construction – Issues and Solutions

- There was issues finding a shaft that was a match to our 9-tooth spline and trike chain

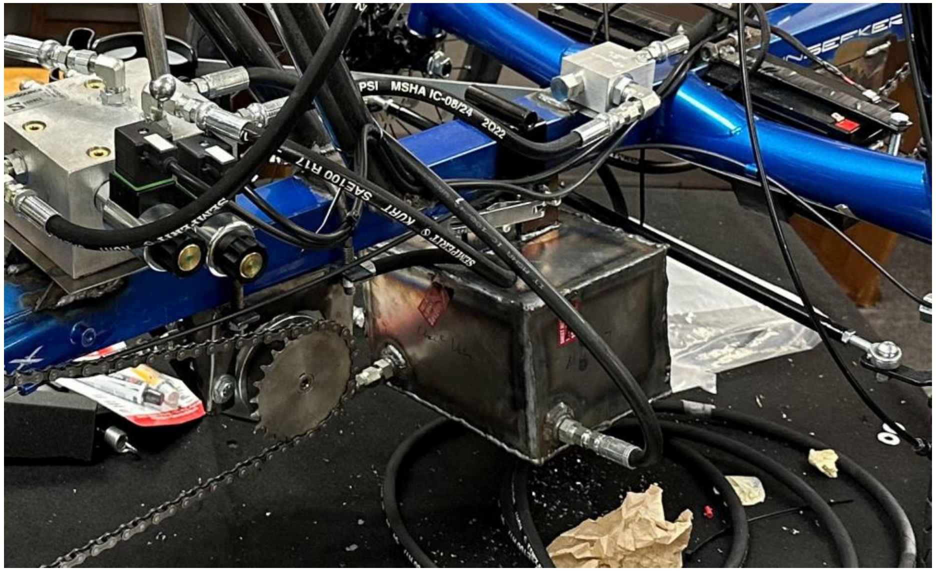
- Our mentor was able to source a 9-tooth coupling that was than welded into a corresponding sprocket.

Vehicle Construction – cont.

- Welded Sprocket

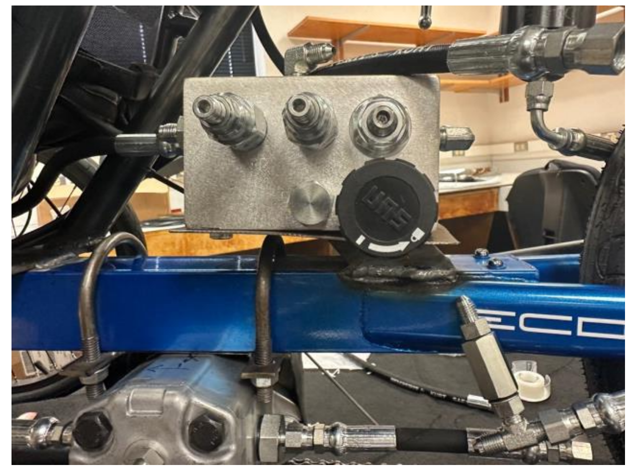
Vehicle Construction – cont.

- Tabs welded to frame of trike to hold reservoir.



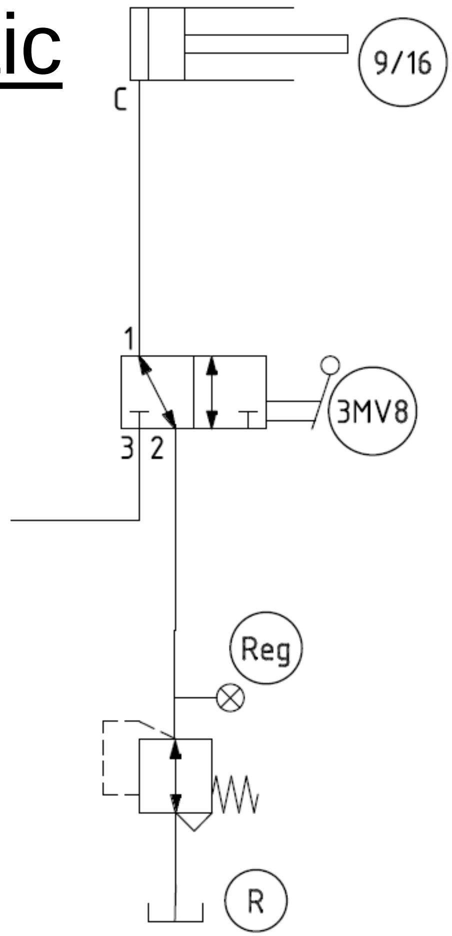
Vehicle Construction – cont.

- Manifold mounting plate welded to rear of trike



Final Pneumatics Configuration

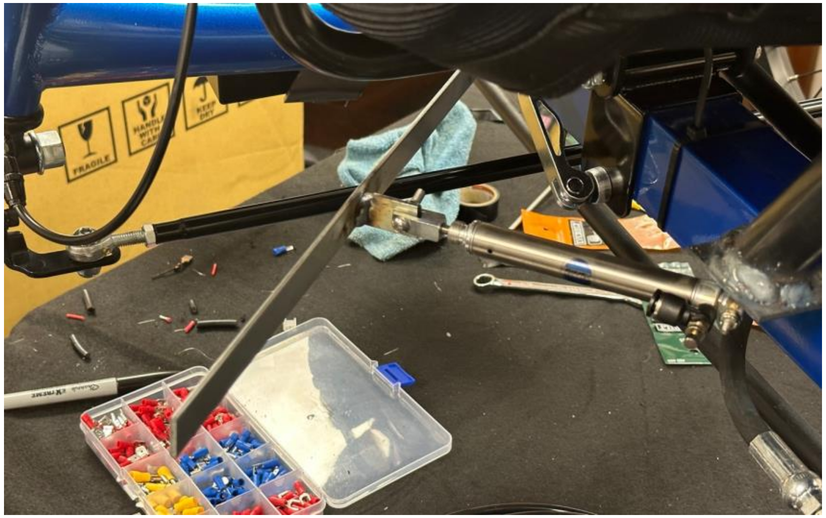
Schematic



Purpose – to move holder for phone and water bottle into position when needed.

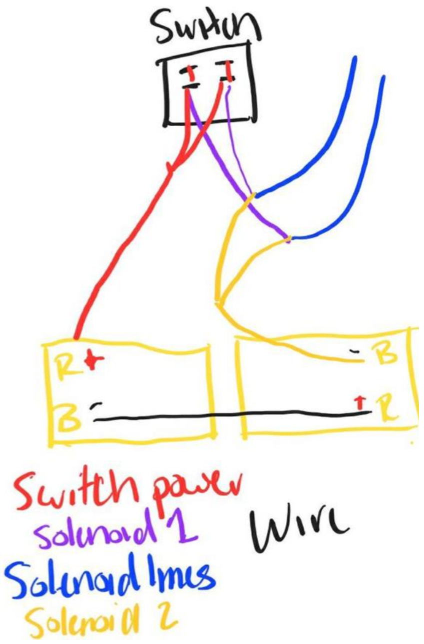
Final Pneumatics Configuration

- 1/8 in. piece of sheet metal welded to frame to directly behind the rider.
- Half gallon air tank, regulator, and toggle switch mounted onto reader rod.
- Cylinder full extended at 50 psi.



Electronic Configuration

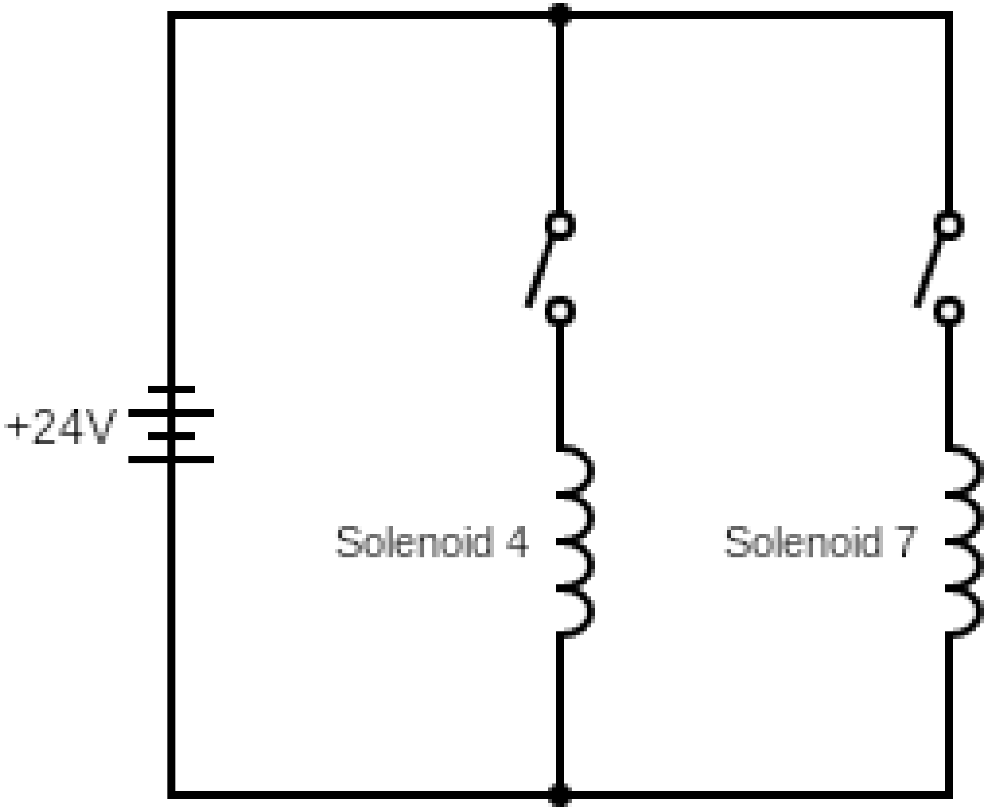
- Two 24 V solenoids connected to two 12 V paired in series.
- Solenoids are toggled through aluminum rocker switch panel, mounted directly in front of rider.



KENNESAW STATE UNIVERSITY

Electronic Configuration

Schematic



Final Vehicle

Hydraulic Power Analyses

Power required to reach a constant velocity of 20 mph.

Weight (kg)	136	Force (N)	46.5
Inline grade	5%	Desired Speed (m/s)	8.9
Surface resistance (N)	2.9	Power required (W)	416

Vehicle Testing Modes - Truth Table

Inputs							Results				
Ball	**Accumulator**	**Pump**	**#2 Bleed**	**#4 Mode**	**#6 Accum**	**#7 Direction**	**Motor**	**C1 (Accum)**	**T**	**Ext CV**	**Major/**Minor **Modes**
Closed	N/A	No Flow	Open	N/A	Closed	Off (Fwd)	No speed (free fwd/rev)	None	No flow (Flow out/No flow)	No flow (Flow in/No flow)	**Towing Mode**
Closed	N/A	Flow in	Closed	On	Closed	Off (Fwd)	Fwd speed	None	Flow out	No flow	Direct Drive Fwd
Closed	N/A	Flow in	Closed	On	Closed	On (Rev)	Rev speed	None	Flow out	No flow	Direct Drive Rev
Open	N/A	Flow in	Closed	Off	Closed	Off (Fwd)	No speed (free fwd)	Flow out (No flow)	No flow (Flow out)	No flow (Flow in)	**Pedal Pressurize**
Open	Acc > Sys	Flow in	Closed	On	Closed	Off (Fwd)	Fwd speed	None	Flow out	No flow	**Direct Drive FWD**
Open	Acc > Sys	Flow in	Closed	On	Closed	On (Rev)	Rev speed	None	Flow out	No flow	**Direct Drive REV**
Open	Acc < Sys	Flow in	Closed	On	Closed	Off (Fwd)	Fwd torque	Flow out	Flow out	No flow	Direct Drive FWD, Acc steals flow
Open	Acc < Sys	Flow in	Closed	On	Closed	On (Rev)	Rev torque	Flow out	Flow out	No flow	Direct Drive REV, Acc steals flow
Open	Acc > Sys	No Flow	Closed	On	Open	Off (Fwd)	Fwd torque	Flow in	Flow out	No flow	**Hyd Accel Fwd**
Open	N/A	No Flow	Closed	On	Open	On (Rev)	Rev torque	Flow out	Flow in	Flow in	**Hyd Braking Fwd (1)**
Open	N/A	No Flow	Closed	On	Closed	On (Rev)	Rev torque	Flow out	Flow in	Flow in	**Hyd Braking Fwd (2)**
Open	Acc > Sys	No Flow	Closed	On	Open	On (Rev)	Rev torque	Flow in	Flow out	No flow	**Hyd Accel Rev**
Open	N/A	No Flow	Closed	On	Open	Off (Fwd)	Fwd torque	Flow out	Flow in	No flow	**Hyd Braking Rev (1)**
Open	N/A	No Flow	Closed	On	Closed	Off (Fwd)	Fwd torque	Flow out	Flow in	No flow	**Hyd Braking Rev (2)**

- Truth table developed by our mentor Richard Lyman.

Vehicle Testing

Hydraulics

- Direct Drive
  - Two pressure regulators are set to 2500 and 2750 psi respectively.
  - Flow control valve fully closed, allowing motor rotation
- Direct Charging and Accumulator Charging
  - The position of the manual valve decides the route of fluid
  - Closing valve results in direct charging
  - Opening valve results in accumulator drive

Vehicle Testing – cont.

Hydraulics

- Accumulator charging
  - Our motor turns CCW when the 3/2 DCV is actuated
- Turn shaft stiffness
  - Trike pedaling was initially stiff. Removing the air in the system allowed for a smoother rotation and easier shifting.

Pneumatics

- The relief valve of the cylinder broke, but by incorporating a rotary valve it allowed us to use a regular fitting on the cylinder.

Lessons learned

- Start the fabrication process as soon as possible
- Exhaust your resources: Mentors, Alumni, Past Vehicles
- Selectively optimize
- Flexibility

Future Improvements

- Improved ball bearings on trike
- Incorporate hard lining
- Emphasizes the ergonomics of the design with the use of manual and ball valves

Acknowledgements

- Ernie Parker
- Romeo Locke
- Dan Turner
- Jeff McCarthy
- Mary Pluta

- In addition to our Mentors and Advisors

NFPA

Fluid Power VEHICLE Challenge

Final Presentation

Kennesaw State University

Students: Michael Bakareke (PM)
Kendarius Chatman
Nyiem Dailey
Hunter Whitworth

Advisors: Drs. Laura & Richard Ruhala

April 14, 2022

NATIONAL FLUID POWER ASSOCIATION · NFPA ·

NFPA Education and Technology Foundation

KENNESAW STATE UNIVERSITY