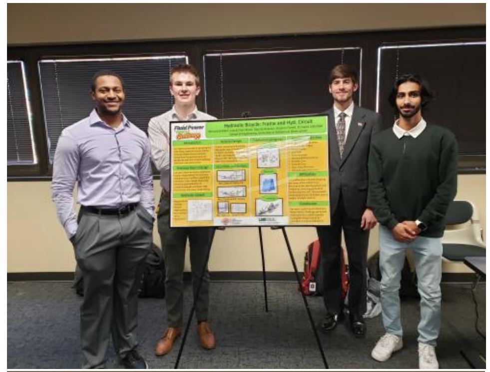
NFPA Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

Final Presentation
University of Alabama at Birmingham
Dr. David Littlefield
April 12, 2023

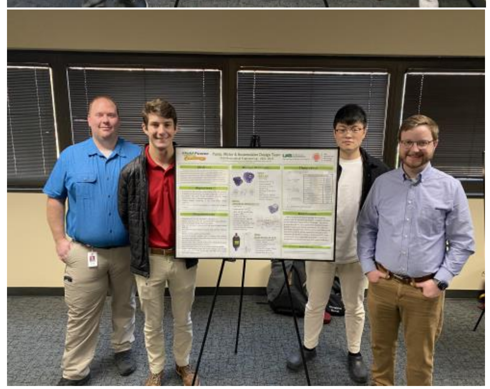
Introduction

Frame & Hydr. Circuit
Team 1 (Left to right):
Daunte Deloach,
Jacob Churchman,
Stephen Ferrell,
Almuaiyad Al-Abri



All Senior Mechanical Engineering students at the University of Alabama at Birmingham.

Hydr. Pump & Motor
Team 2 (Left to right):
Joshua Rodman,
Caelan March,
Kyunghoon Cho,
Drew Maharrey



UAB is returning to the FPVC for the second time
Building a trike from scratch to improve on several aspects of the first bicycle design

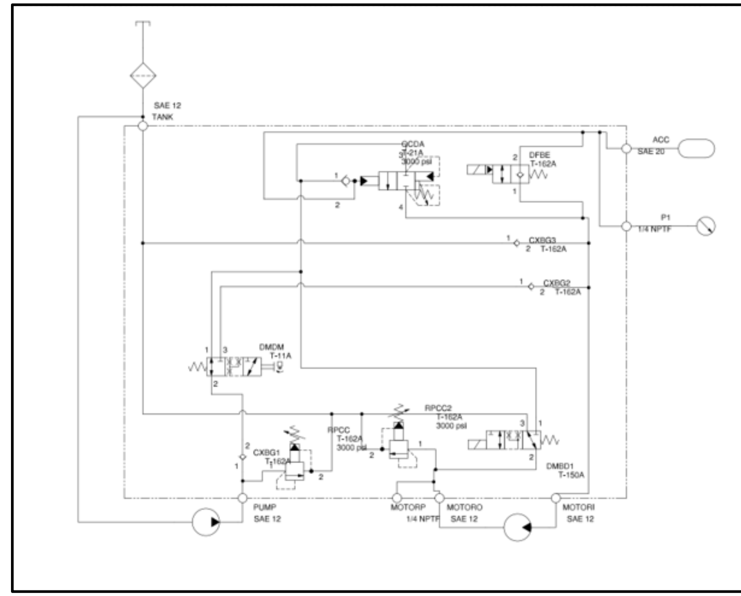
Academic Advisor:
Dr. David Littlefield, UAB

Industry Mentor:
Jay Dalal, Ross Controls

Fabrication Mentor:
Steve Thompson, UAB

Previous Design

2021-2022 Finalized Hydraulic Bicycle



2021-2022 Hydraulic Circuit Schematic

- Last year’s design used a standard bicycle frame, and simply mounting hydraulic components to a platform welded to the frame.
- Some components seemed to be mounted haphazardly, such as the reservoir not being welded in place.
- The hydraulic circuit had an issue that caused the outlet side motor seals to be blown out repeatedly.
- The ¾” hydraulic hoses were oversized, reducing the velocity and efficiency.
- An undersized 1-quart accumulator limited the regeneration capabilities and the volumetric flow rate.
- A high center of gravity rendered the bicycle harder to handle in taking off.

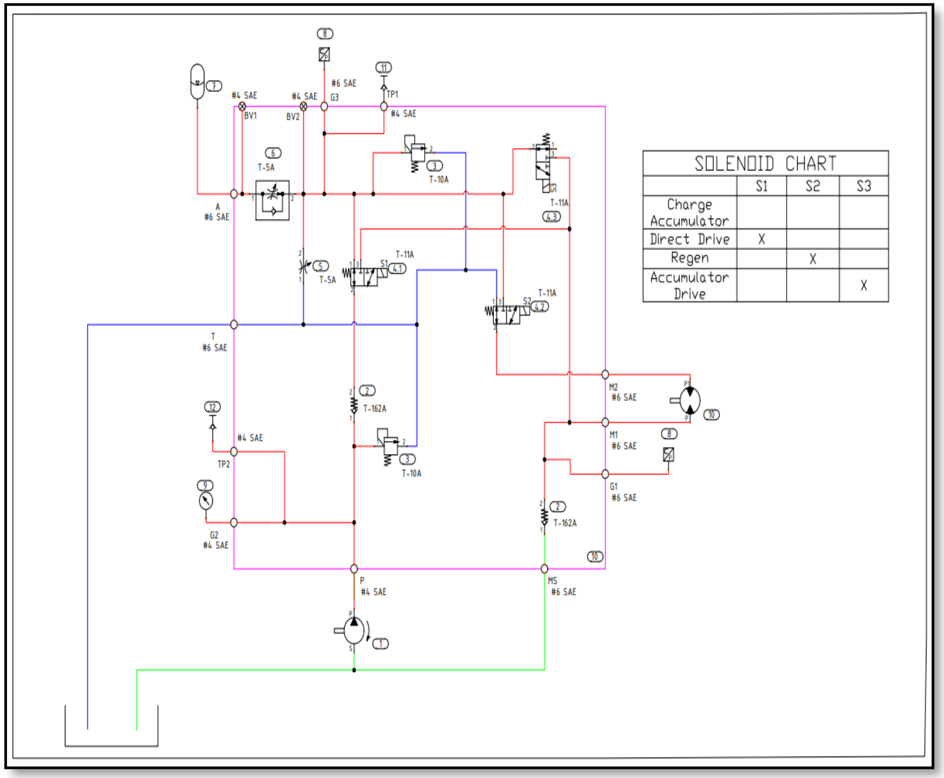
Hydraulic Circuit

Components of Circuit

- The circuit includes a manifold sourced through SunSource
- 24V Solenoid controlled 3-way 2-position directional valves
- Relief valves (3000 psi), check valves (5 psi)
- Pressure compensated flow control valve controls accumulator output rate
- If pressure loss had been too great through the flow control, a ball valve was the backup plan. Alternating on and off the solenoid valves was an additional option.

4 Modes of the Hydraulic Circuit

- Pump Accumulator Charge
- Direct Drive
- Regenerative Braking
- Accumulator Drive



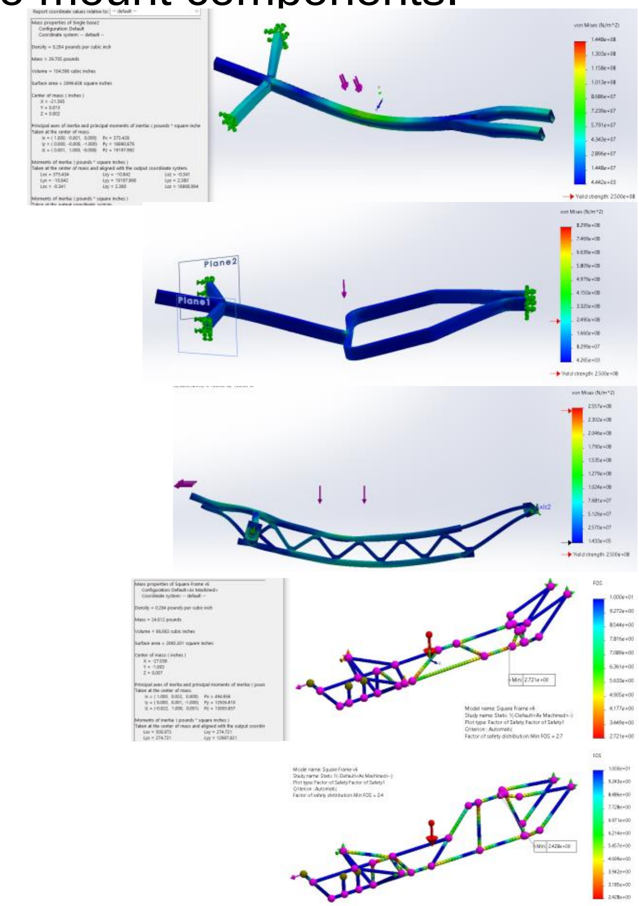
Hydraulic Circuit Schematic

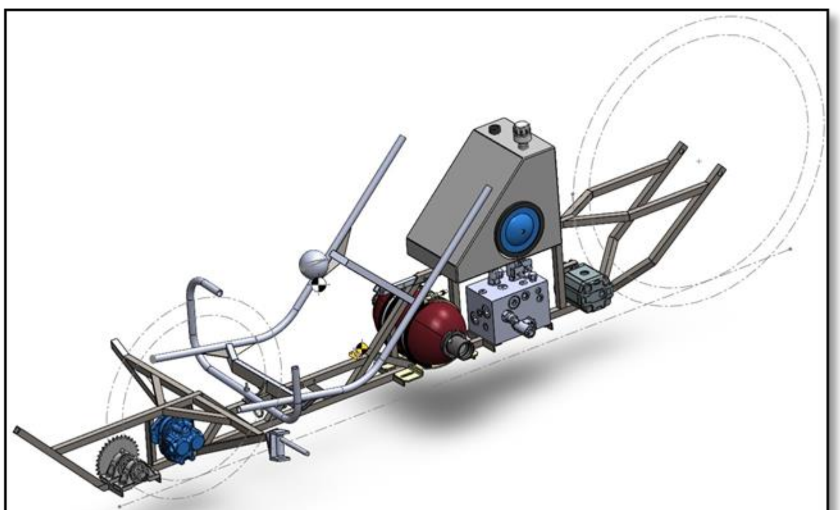
Vehicle Design

Rather than improve the bicycle from the previous year, we decided to fabricate a vehicle from scratch, keeping the lessons learned in mind. Though a single tube "t"-style frame was initially considered, the truss design was elected to provide a more robust solution with more options to mount components.

Design Objectives:

- Manufacture a vehicle with improved safety and durability
- Improve the efficiency of power delivery throughout the system
- Demonstrate improved technical knowledge of fluid power systems





CAD Assembly of Frame and Major Components

Midway Review Summary

- Components
  - ✓ Hydraulic circuit finalized and all hydraulic components ordered
  - ✓ Controls and bike components selected and ordered
- Fabrication
  - ✓ Final frame design chosen
  - ✓ Stress analysis conducted
  - ✓ Main frame tack-welding completed
- Feedback
  - ✓ Re-design accumulator mount from horizontal to vertical for improved accumulator output
  - ✓ Allow time for testing and optimization of gear ratios

Progress since Midway Review

- Designed and implemented under-seat dual drag link steering
- Re-designed accumulator mount from horizontal to vertical
- Completed vehicle fabrication
- Tested and optimized input gear ratio
- Adjusted default HMI and PLC programs to accommodate vehicle needs

Hardware Selection
Pump

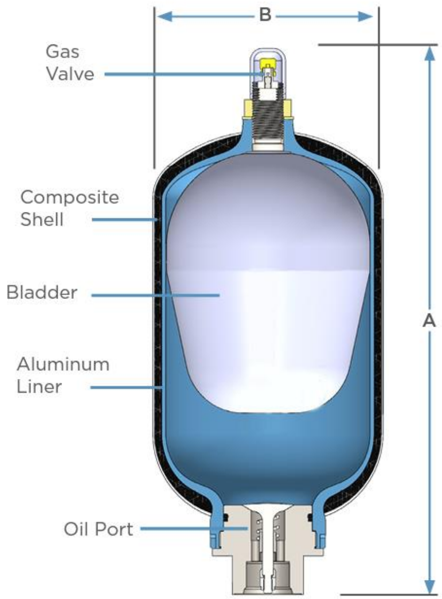
- **Danfoss** – SNP2NN/8.0LN06SAP1E6E5NNNN/NNNNN
- **Gear Pump**
- **Displacement** – 0.513 CID
- **Speed** – 600 RPM
- **Flow Rate** – 1.33 GPM
- **Weight** – 6lbs
- **Mount** – 2-Bolt SAE A Flange
- **Max Pressure** – 3000 PSI
- **Housing Material** – Aluminum
- **Rotation** - Clockwise

Hardware Selection
Motor

- **Danfoss** - SNM2NN/017BN06GAM6E5E5
- **Gear Motor**
- **Displacement** – 1.025 CID
- **Torque** – 377 in-lbs
- **Weight** – 6.5 lbs
- **Rotation** – Bidirectional
- **Mounting** – 2-Bolt SAE A Flange
- **Max Pressure** – 3000 PSI
- **Housing Material** – Aluminum

Hardware Selection Accumulator

- **Steelhead Composites** - AB30CN010G0N
- **Volume** – 1 Gal
- **Style** – Bladder
- **Max Pressure** – 3000 PSI
- **Weight** – 10lbs
- **Pre-Charge** – 700 PSI



Hardware Selection
Brakes and Rotor

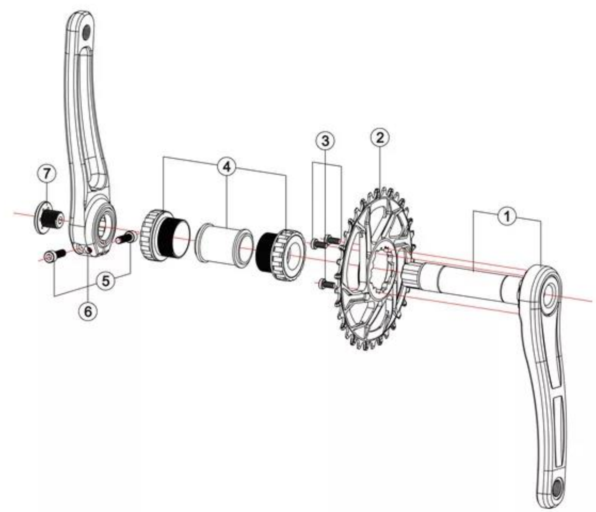
- **Brake Caliper:** Shimano SLX M7100: 2 – Piston hydraulic brakes with metal brake pads
- **Brake Lever:** Shimano SLX M7100: Standard bike brake lever with reach adjustment
- **Rotors:** 140mm 6-bolt metal disc rotors removed from previous years' bicycle
- **Fluid:** Shimano Hydraulic Brake Fluid
  - Mineral Oil
  - Boiling Point: 200º C

Hardware Selection
Wheels and Tires

- **Front Wheels: Custom:**
  - Industry 9 & Box One:
    - 6-Bolt Disc
    - 28-Spoke Hole
    - 110x15mm Axle Size
    - 20” Rims
- **Rear Wheel:**
  - Industry 9 1/1 Hub and Rim:
    - 6-Bolt Disc
    - 28-Spoke Hole
    - 12x148 Axle Size
    - 29” Rim
    - HG Cassette Interface
- **Tires:**
  - Front: Vee Tire Co. Speed Booster
  - Rear: Maxis Hookworm
    - Low Rolling Resistance

Hardware Selection
Crankset Assembly

- **Crankset:** Standard 175mm Crankset
- **Pedals:** Standard flat pedals
- **Chainring:** 32-tooth oval profile
  - Oval profile is being used here to smooth out pedal strokes
- **Bottom Bracket:**
  - Built a bottom bracket using steel tubing to have a press-fit for standard bike bottom bracket components

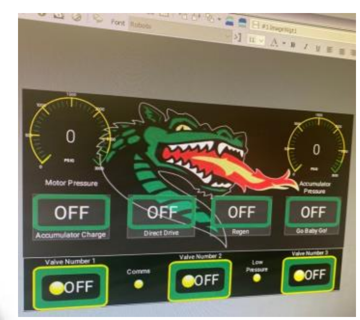


Hardware Selection
Electronic Components

- Control kit sourced through IFP
- Programmable eX705 HMI is being used to monitor system pressures and control modes of operation
- HY TTC 32 CD micro-controller required for valve driving capabilities
- Controls powered by 24VDC battery

HY-TTC-32-CD-00-000

eX705 HMI



Customized

Vehicle Construction

Tack welded the main frame

Welded seat parts together

Assembled tires and wheels

Installed under-seat steering

Mounted reservoir

Mounting Manifold and controller to the frame

Vehicle Construction 2

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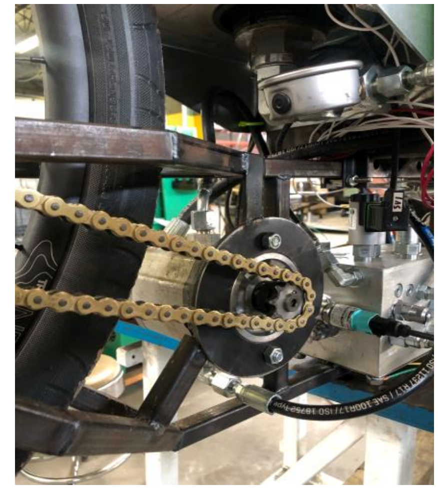
Mounted accumulator behind reservoir


Attached pump on the front


Attached motor on the rear


Fixed dual drag link to the front wheels


Installing hoses to the hydraulic components


Bolted HMI bracket

Final Vehicle

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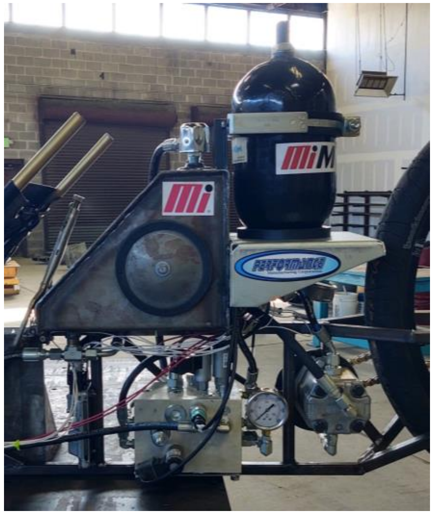

Vehicle Testing and Improvements

- Delays in the fabrication process left little time for testing and gathering of quantifiable data for performance improvements
- Reduced input gear ratios from 10.24 to 2.56 and then back to 5.12 to lessen the input force required and increase the achievable top speed of the vehicle by increasing flow through the motor
- Confirmed that the initial accumulator pre-charge approximation of 700 psi was ideal for the system
- Altered chain lengths to prevent the chain from skipping teeth on the sprockets
- Corrected an oversight with the free-hub rear wheel that rendered useless the regenerative braking capabilities
- Eliminated excessive play within the steering system
- Simplified electrical wiring and improved cable management within the vehicle

Lessons Learned

- Fundamentals of fluid power systems and hydraulic circuit design
- HMI and controller programming utilizing JMobile and CoDeSys
- CAD is useful but can become a time sink if you are not careful
- During the fabrication process, there are likely to be unforeseen obstacles that need to be accounted for in the project timeline
- The more time allotted for testing the better

Thanks!

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Questions?