NFPA Fluid Power VEHICLE Challenge

NFPA
Education and
Technology
Foundation

FINAL PRESENTATION & DESIGN REVIEW

Clear Creek Cruisers- Colorado School of Mines

Team Advisor: Gabriel Flechas

April 23, 2025

Introductions

From left to right

- Nathan Gonnet, Kyle Coleman, Andres Saa, Weston Wall, Troy Lancaster, Tim Hoffman, Nate Foster, Mathew Crabtree, Colton Wall, Isaac Snyder

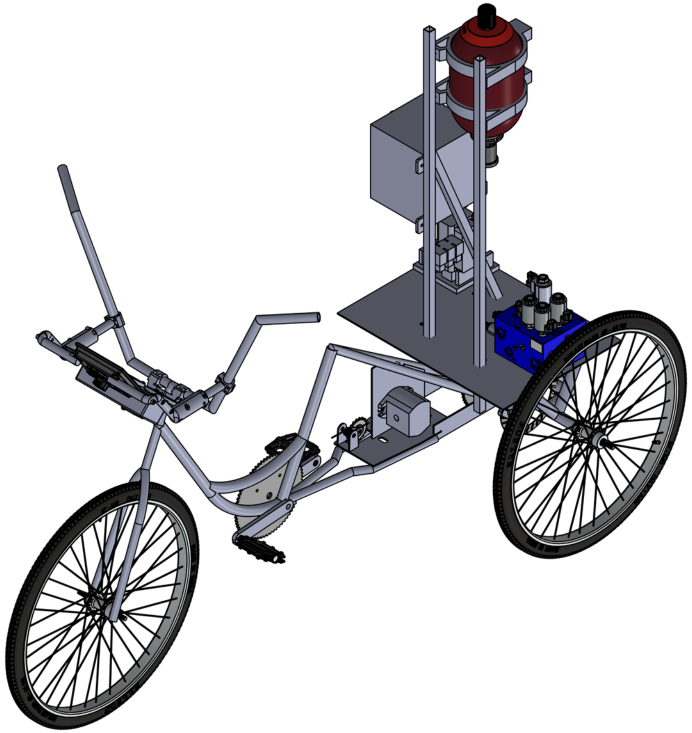
All Seniors in Mechanical Engineering

Mines' first year competing in FPVC

Acknowledgments

- Thank you to Joe Jackan and Randy Nobles for their technical support throughout the project.
- Thank you to Josh Caldwell and Jackson Minick from Hydraquip for their support with hose fabrication.
- Additional thanks to the competition sponsors for components and engineering support.

Vehicle Design - Frame



- An off-the-shelf tricycle frame was used for simplicity
- Hydraulics mounted to steel plates welded and bolted onto the frame
- Uses stock friction brakes
  - Tested for adequate braking force
- Upgraded ANSI 35 roller chain (Calculations shown in slide 13.)

Hydraulic Component sizing

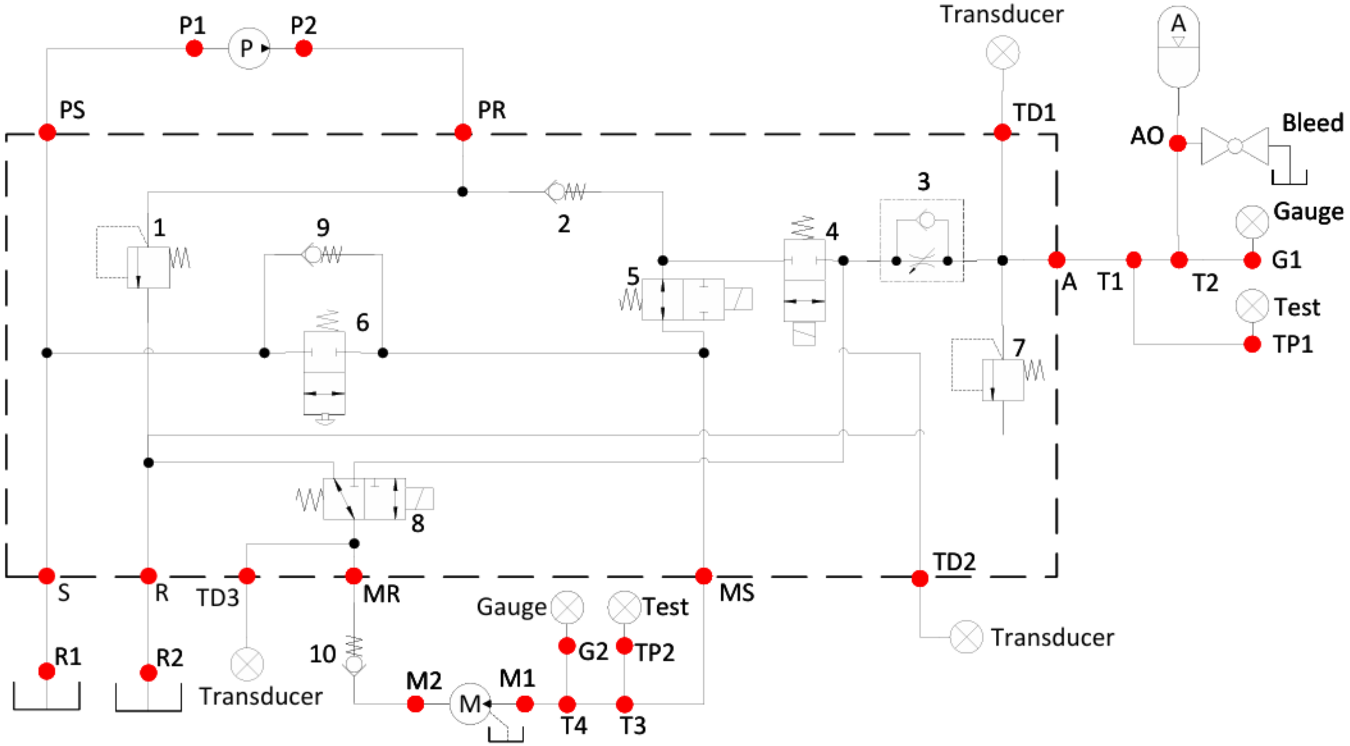
Pump			
RPM Pedaling	125.0	RPM	Input
GPM	0.330	GPM	CIR*RPM/231
Power required	0.225	hp	GPM*PSI/1714
RPM multiplier to pump	8.4		Input
RPM Pump	1050.0	RPM	Pedal RPM*Ratio
CIR	0.085	in^3	Input
Volumetric Eff.	0.850		Input
Pressure	1170.0	PSI	Input

Motor			
Input Gpm	1.030	GPM	From Pump
MPH	22.29	MPH	Flow*rpm/336
Volumetric Efficiency	0.85		Input
Actual GPM	0.875	GPM	Flow*efficiency
Input Pressure	1170	PSI	From Pump
CIR	0.120	in^3	Input
RPM Motor	1685.3	RPM	Flow*231/CIR
Gear ratio	5.4		Input
RPM driveshaft	312.1	RPM	RPM/Ratio
Motor Torque	22.3		Flow*Pressure*36.77/RPM
Actual Torque	120.7		
Power Output	0.598	hp	Motor Torque*Ratio

- Pump and motor displacement was minimized to maximize RPM
- Pump gear ratio of 8.4:1 was chosen to maximize pump RPM while ensuring bike remains easy to pedal,
- Motor gear ratio of 5.4:1 was chosen to maximize motor RPM and top speed while maintaining adequate torque for acceleration.
- Expected continuous speed of 7.4 MPH for endurance race.
- Theoretical top speed of 22.3 with accumulator fully charged

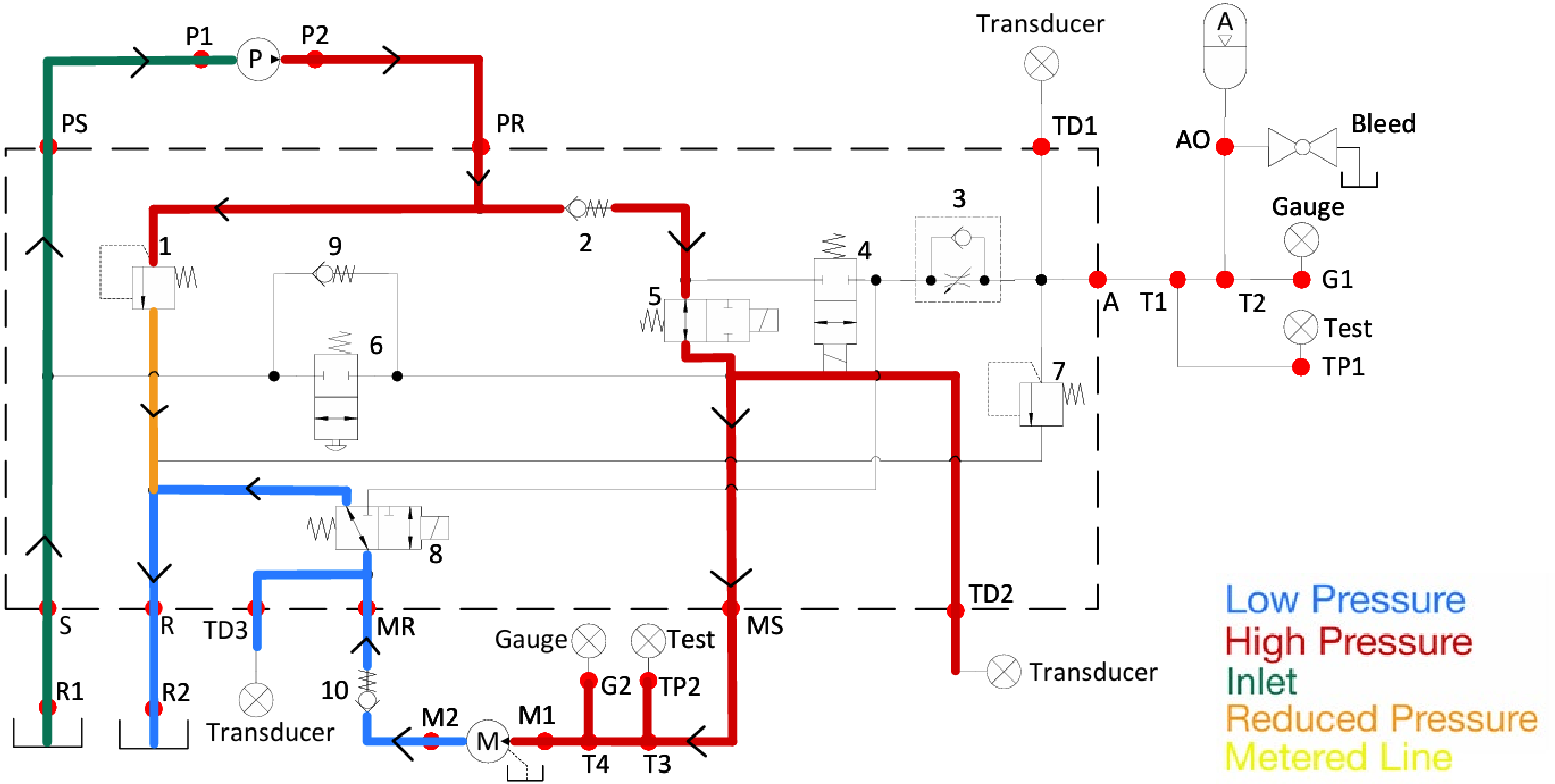
Schematic

- 5 drive modes
  - Direct Drive
  - Direct Charge
  - Direct Discharge
  - Coast
  - Regen



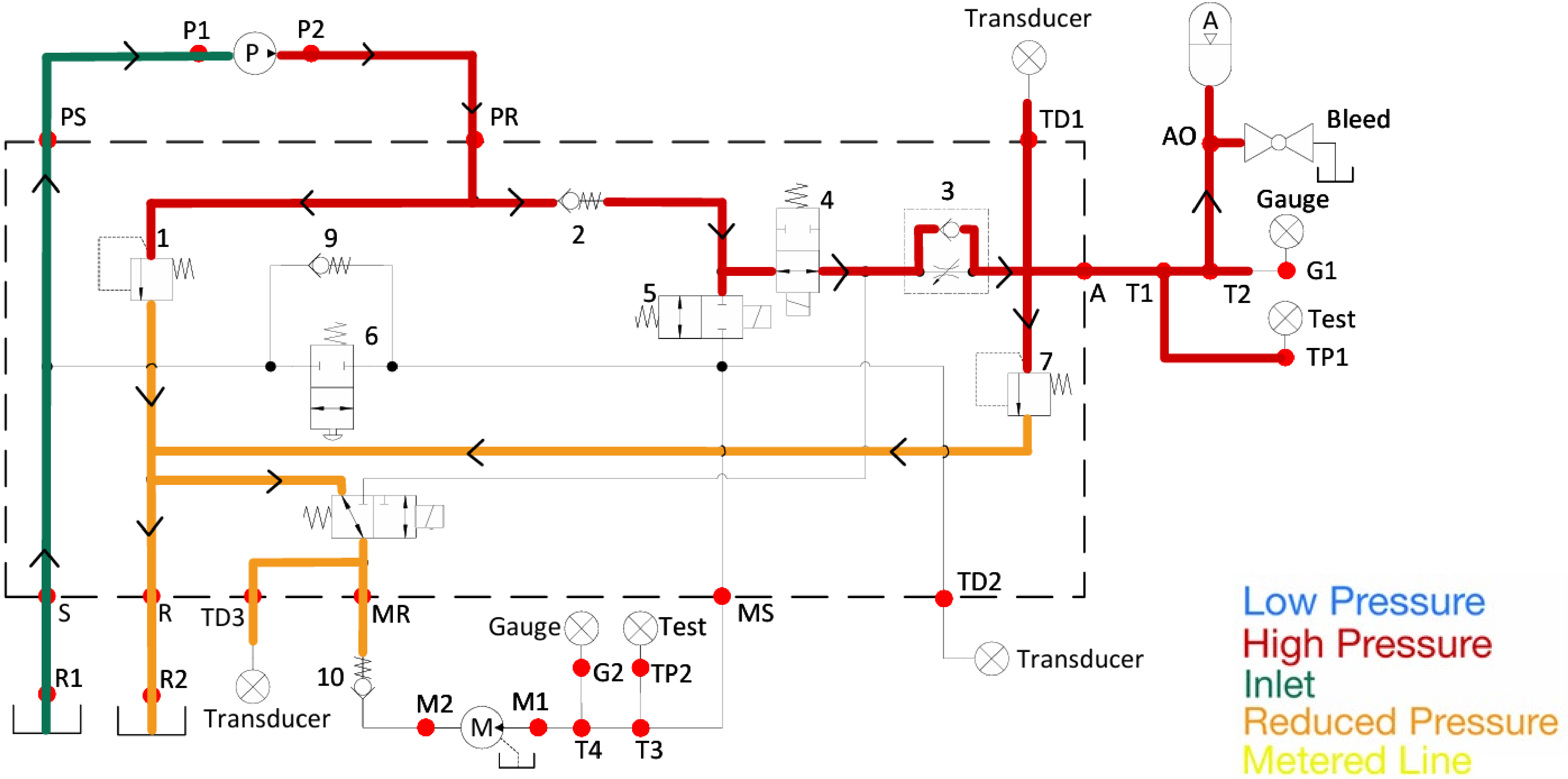
Schematic

Direct Drive:
No Valves Energized



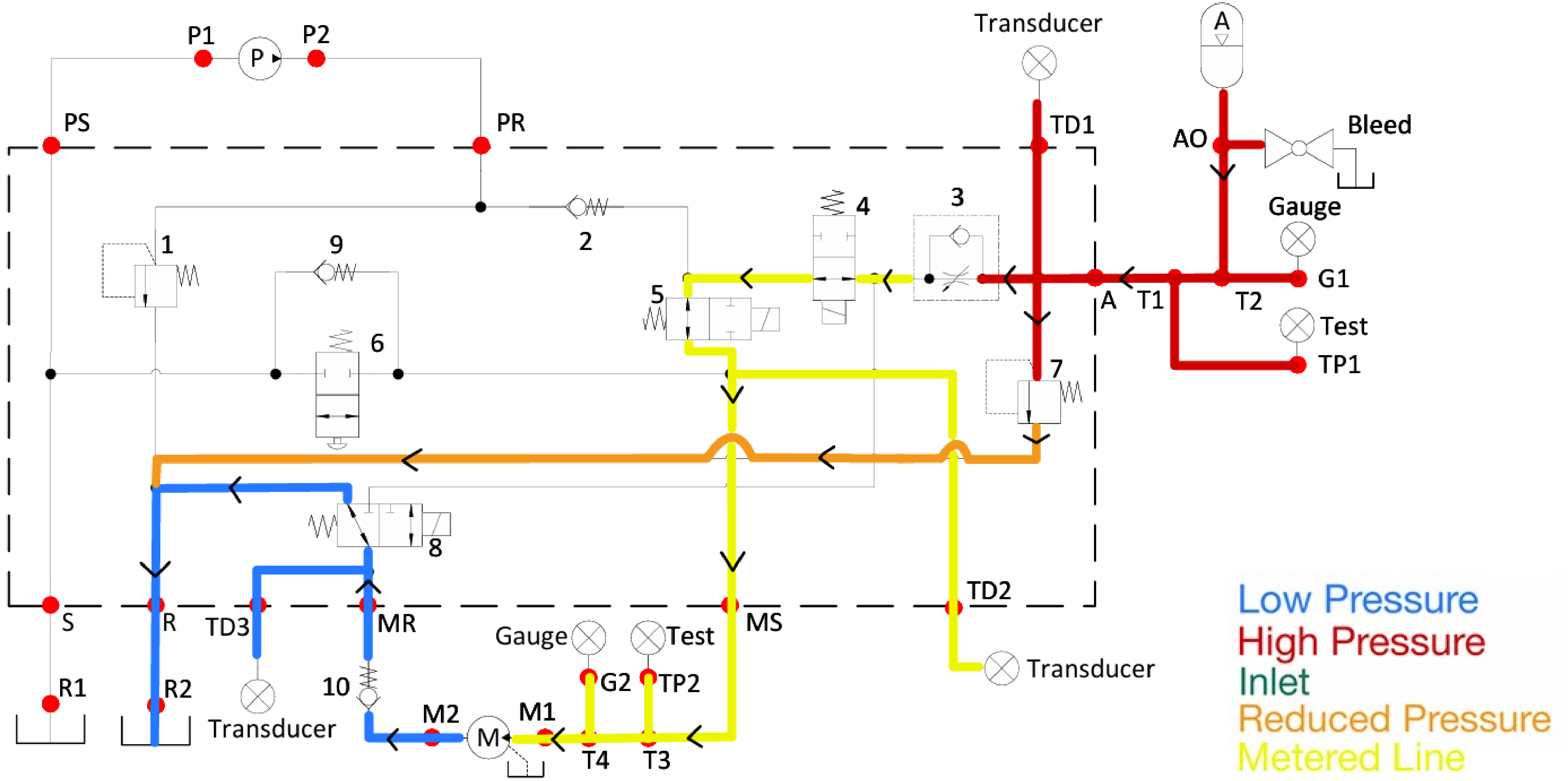
Schematic

Direct Charge:
Valves 4 and 5 Energized



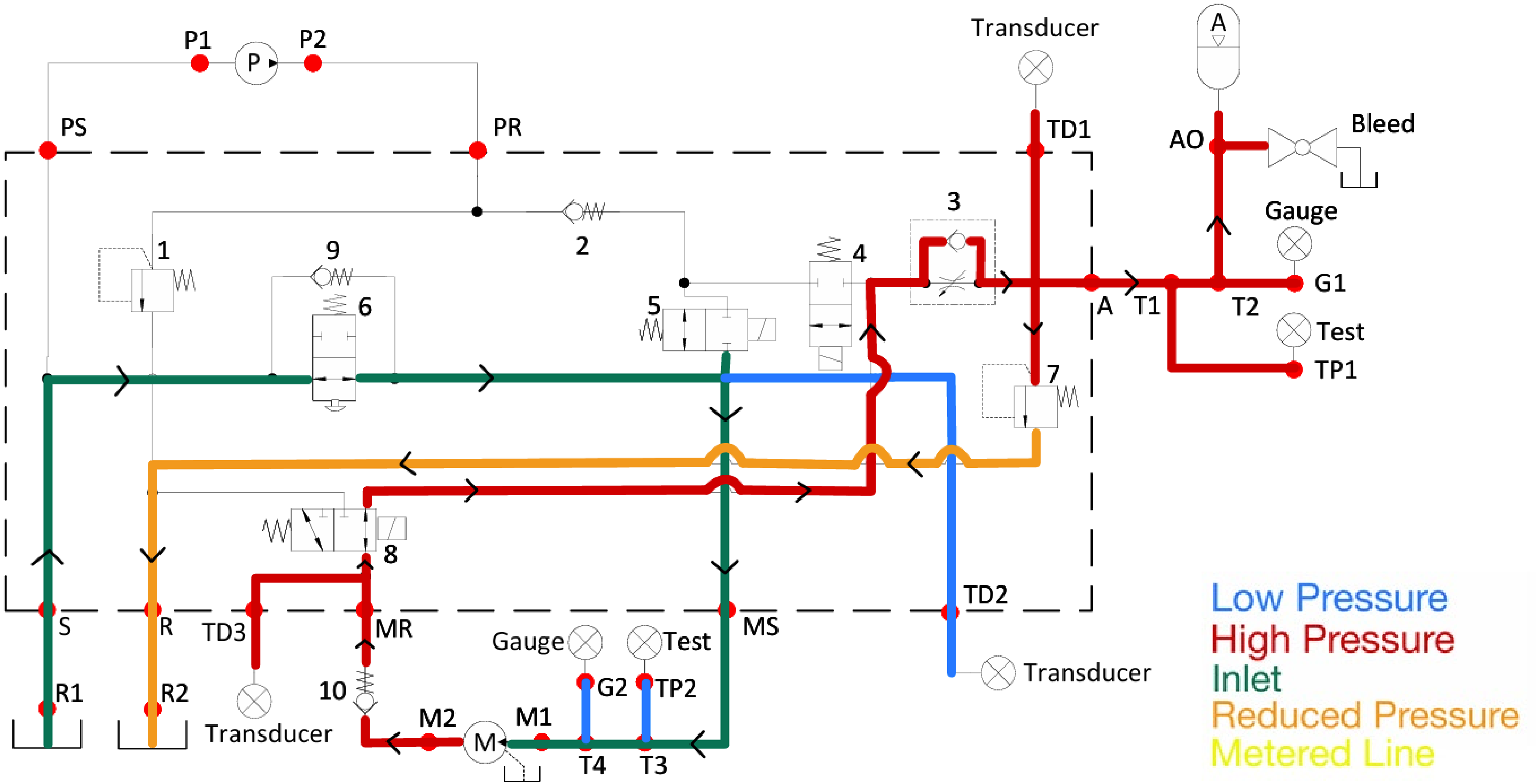
Schematic

Direct Discharge:
Valve 4 Energized



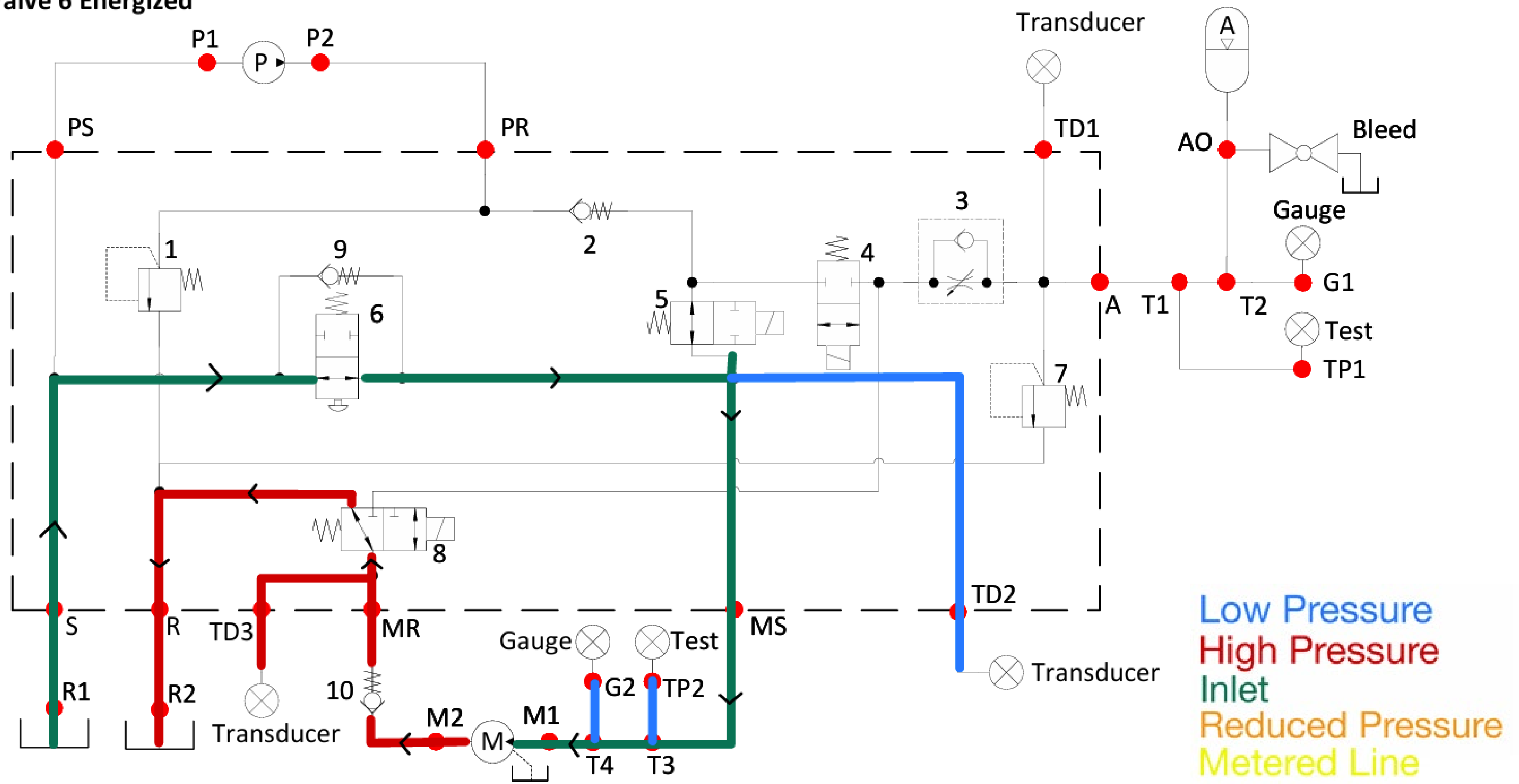
Schematic

Regenerative Braking:
Valves 5, 6 and 8 Energized



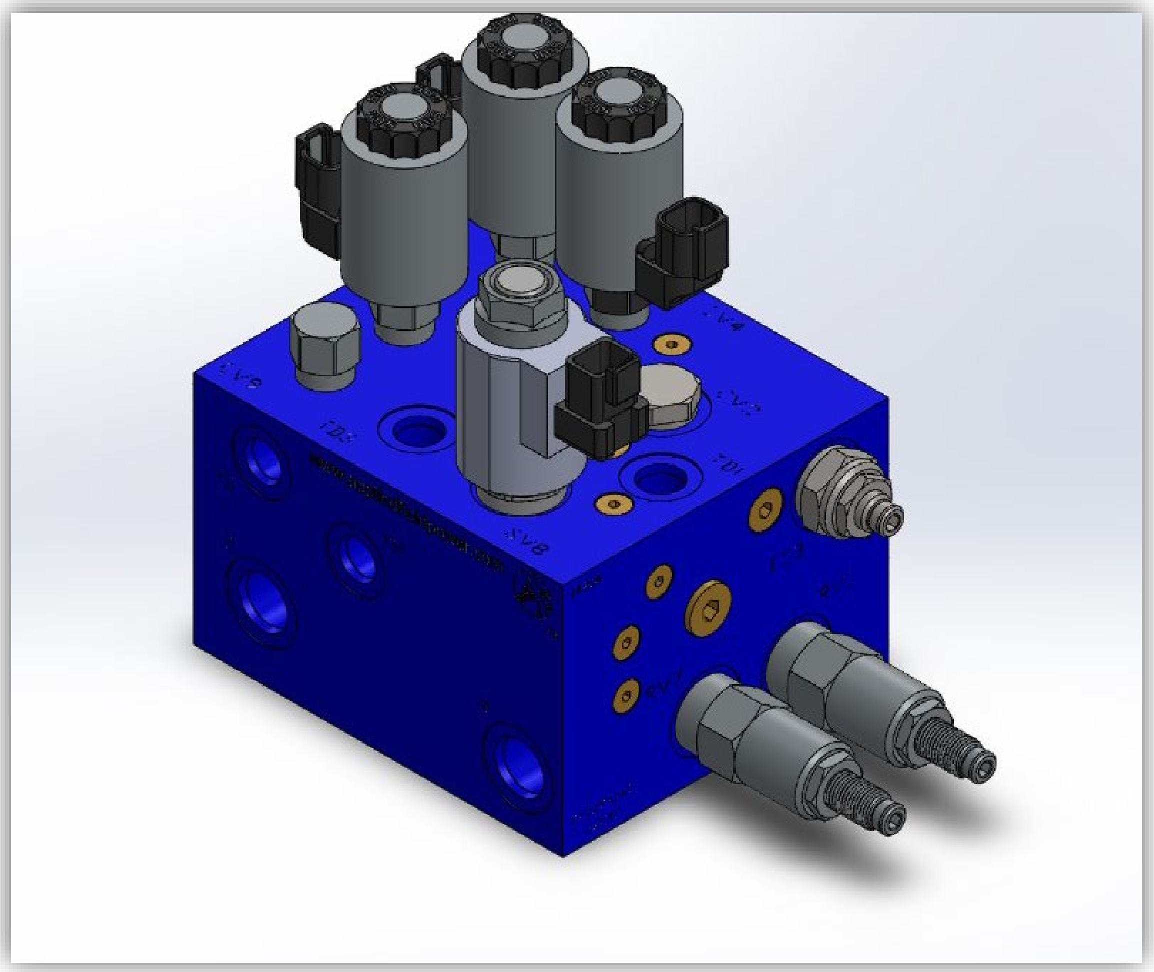
Schematic

Coast:
Valve 6 Energized



Manifold

- Manufacturer:
  - Applied Fluid Power
- Direct acting solenoid valves:
  - Oversized to minimize pressure drop
- Hoses:
  - Supplier/Installer: Hydraquip,
  - SAE-8 and SAE-6 hoses



Drivetrain Selection

Crank Length (m)	Crank Length (in)
0.17	6.69

70T gear OD (in)	10T gear OD (in)
8.58	1.38
54T gear OD (in)	
6.66	

Req. Power (W)	Req. RPM
155.11	70
Req. Force (lbf)	
27.98	

Actual Torque (lb*in)	206.29
Max Force from Acccum. (lbf)	299.41

** at max accum. press. of 3000 psi

Human Power	
Max Torque (lb*in)	187.28
CL Tensile Force (lbf)	271.81
Accumulator Power	
Max Torque (lb*in)	997.04
CL Tensile Force (lbf)	1,447.08

- Assumptions:
  - Linear driving force
  - Static loading at a snapshot of time
- Listed from left to right:
  - ANSI 35 Roller Chain with 2,400 lbf tensile load capacity
  - Steel ANSI 35 Hubbed Roller Chain Sprocket for motor (10T), pump (10T), and wheel axle connection (54T)
  - Steel ANSI 35 Flat Roller Chain Sprocket (84T) for connection to OEM one-piece crank attached to bike

Control Systems - Hardware

- Controls system managed by a PLC from Enovation
- Hybrid UI with a touchscreen from Enovation with physical switches for switching between drive modes
- Electronics hardware connected with an industry standard style wiring harness
- E-Stop Circuit to protect hydraulics from electrical malfunction

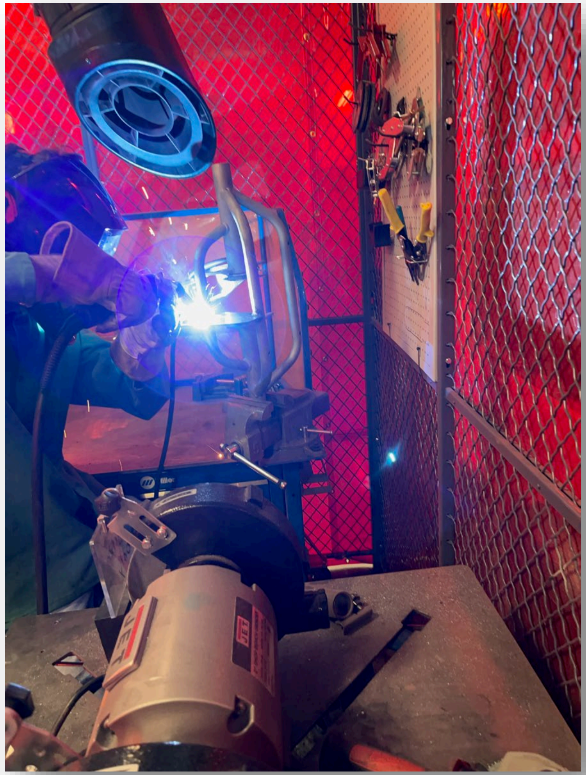
Control Systems - Software

- Programmed valve sequences allow driver to change between drive modes quickly
- Pressure readings for accumulator, motor inlet, and motor outlet
- Speedometer and pump/motor RPM measured using Hall effect sensors
- Odometer, timer, and integrated efficiency calculation included to improve testing
- Audio cues to alert driver of vehicle state changes
- Anomaly detection to ensure safety of driver and system

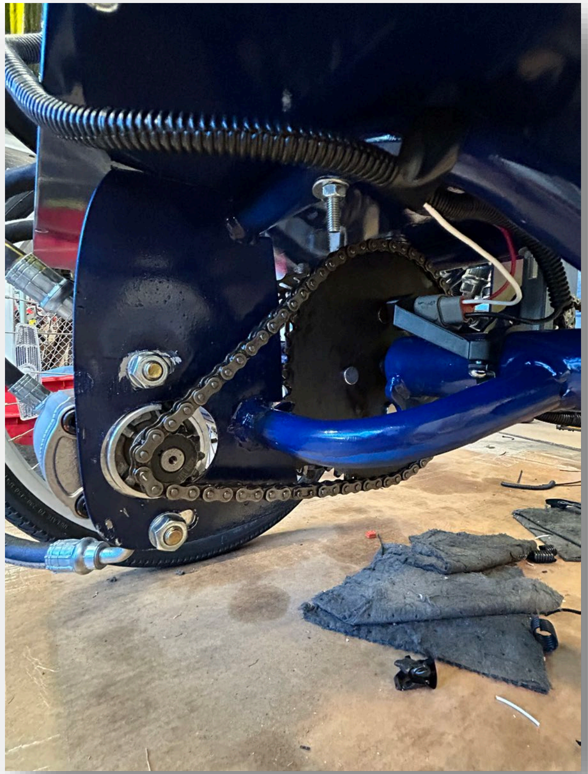
Touch screen rider UI

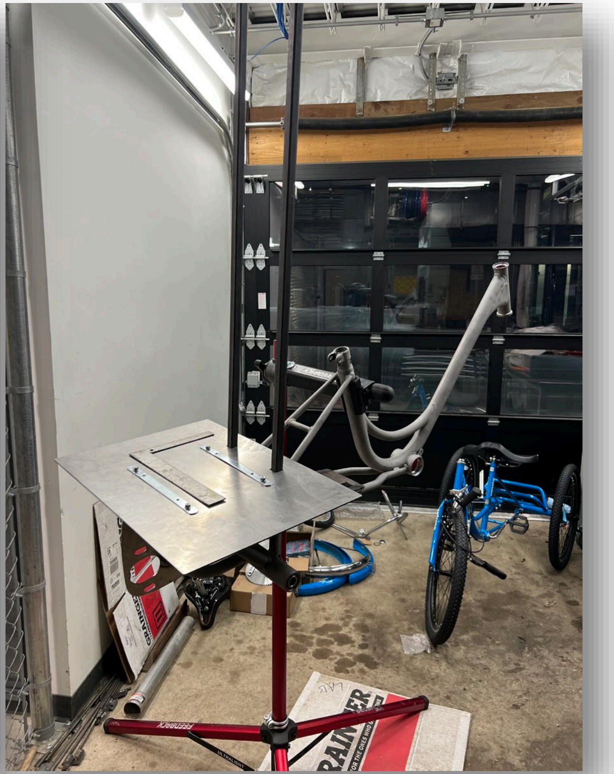
Frame Construction

- Mounting Plates are bolted and welded to the frame
- Mounting systems were designed to be modular to allow for easy modification
- Mounts manufactured using 3D printing and laser cutting.

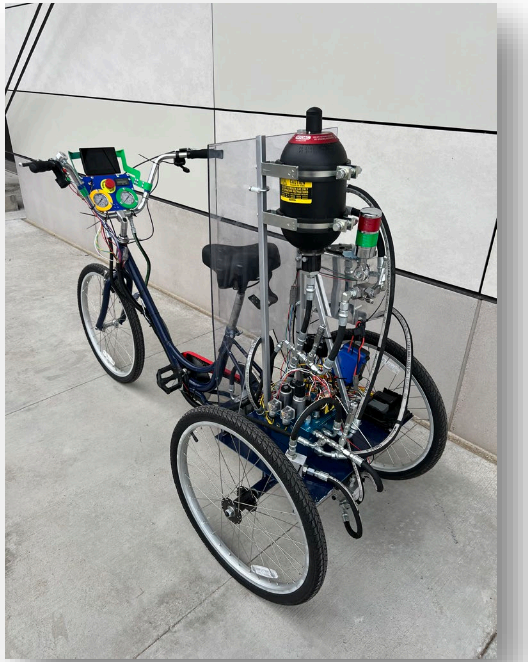


Frame Construction





Construction



Hydraulics Construction

- All hoses were assembled by Hydraquip
- Hoses manufactured with vehicle fully assembled

Construction - Setbacks

- Setback: Over torqued valve in manifold, valve did not function and was unable to be removed
- Solution: Repaired by JARP Industries, care was taken to ensure other valves were installed properly

Testing

- First system tests were conducted in direct drive.
- Electronics and controls were shaken down and tested for reliability.
- Accumulator precharge and outlet needle valve optimized for different races.
- Pump Gear ratio increased from 7 to 8.4 for higher top speed

Lessons learned

- Begin frame construction earlier to prevent hold ups
- Proper sizing of components and hydraulic system design saves time and problems during construction
- Ensure proper torque is used to prevent leaks
- Cycle fluid through the motor at low pressure in coast mode before pressurizing
- Use NFPA technical resources
- You can’t un-destroy threads

Conclusion

- As first-year team, creating a functional vehicle is a huge success
- Thank you to Joe Jackan and Randy Nobles for their support as technical advisors
- Thank you to Josh Caldwell and Jackson Minick from Hydraquip for their support assembling hoses.

Center: Blaster the Burro
From left to right: Matthew C., Colton W., Nathan G., Weston W.