Fluid Powered Vehicle Team

NFPA Education and Technology Foundation

GROUP MEMBERS: MATT ANDRUS, ISAIAH PARFAIT AND DYLAN BABINEAUX

GROUP ADVISORS: YASMEEN QUDSI AND JOHN CARROLL

INDUSTRY MENTORS: BOB MOSEY AND EDGAR TORRES

UNIVERSITY of LOUISIANA LAFAYETTE

NFPA Fluid Power VEHICLE Challenge

Team Introductions

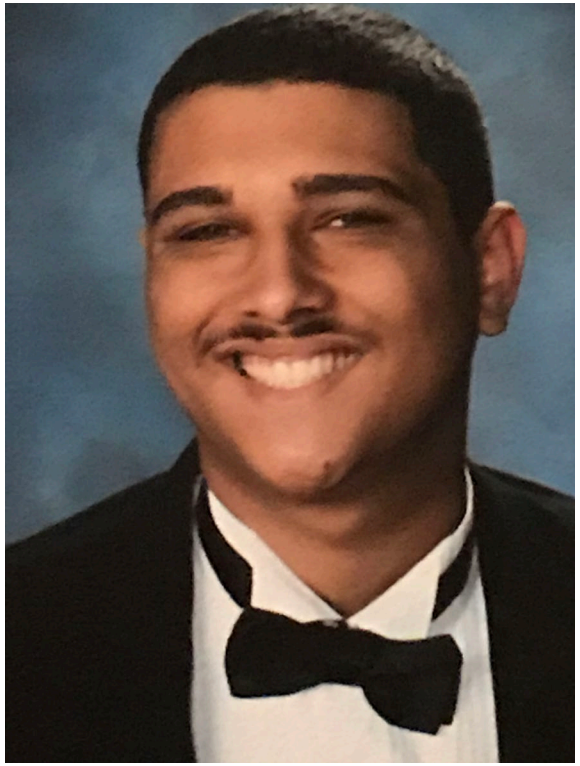
Isaiah Parfait

- Team Leader
- Documentation
- Structural Design

Team Introductions

Dylan Babineaux

- Hydraulics
- Programming
- Electronics

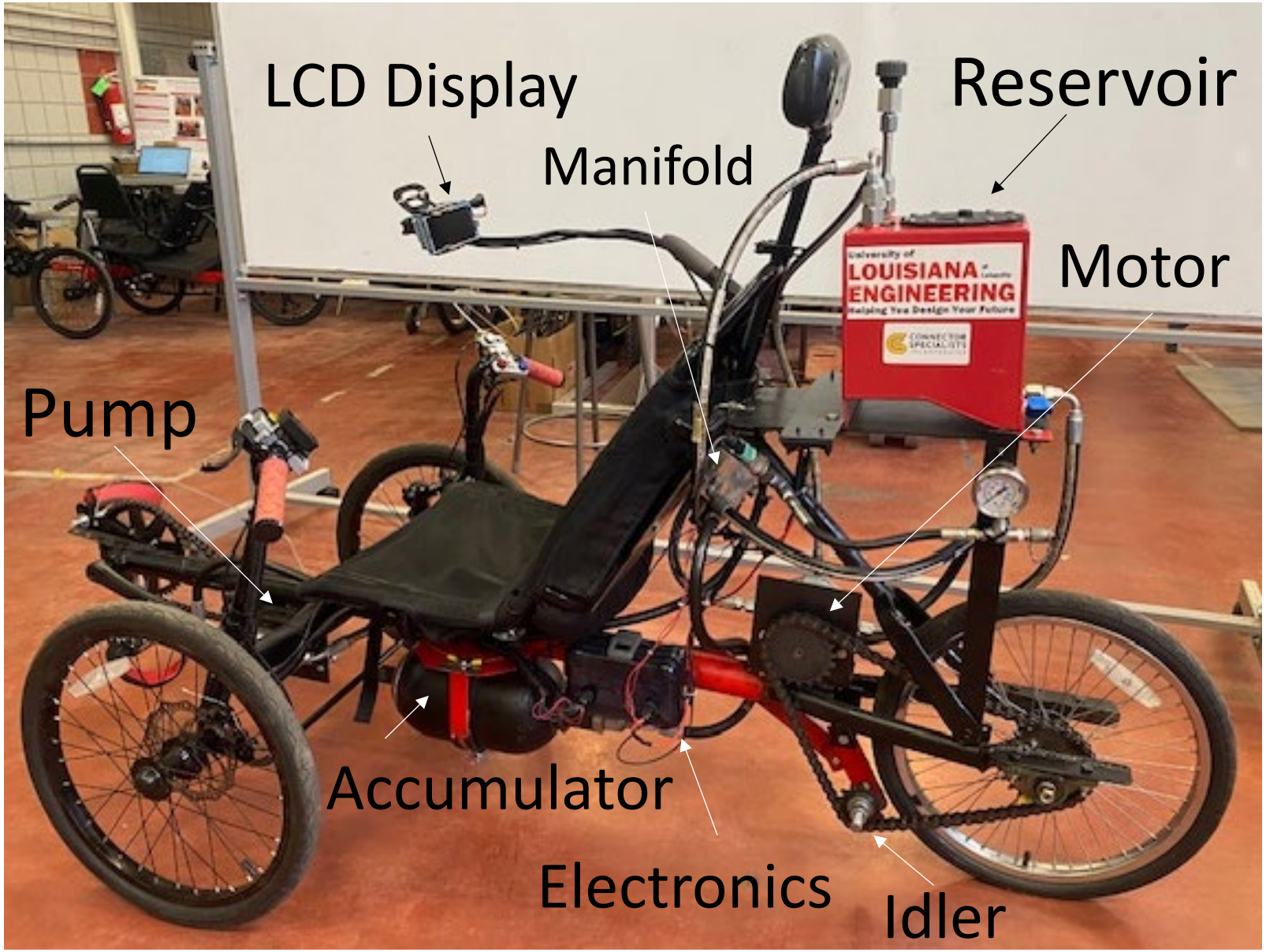


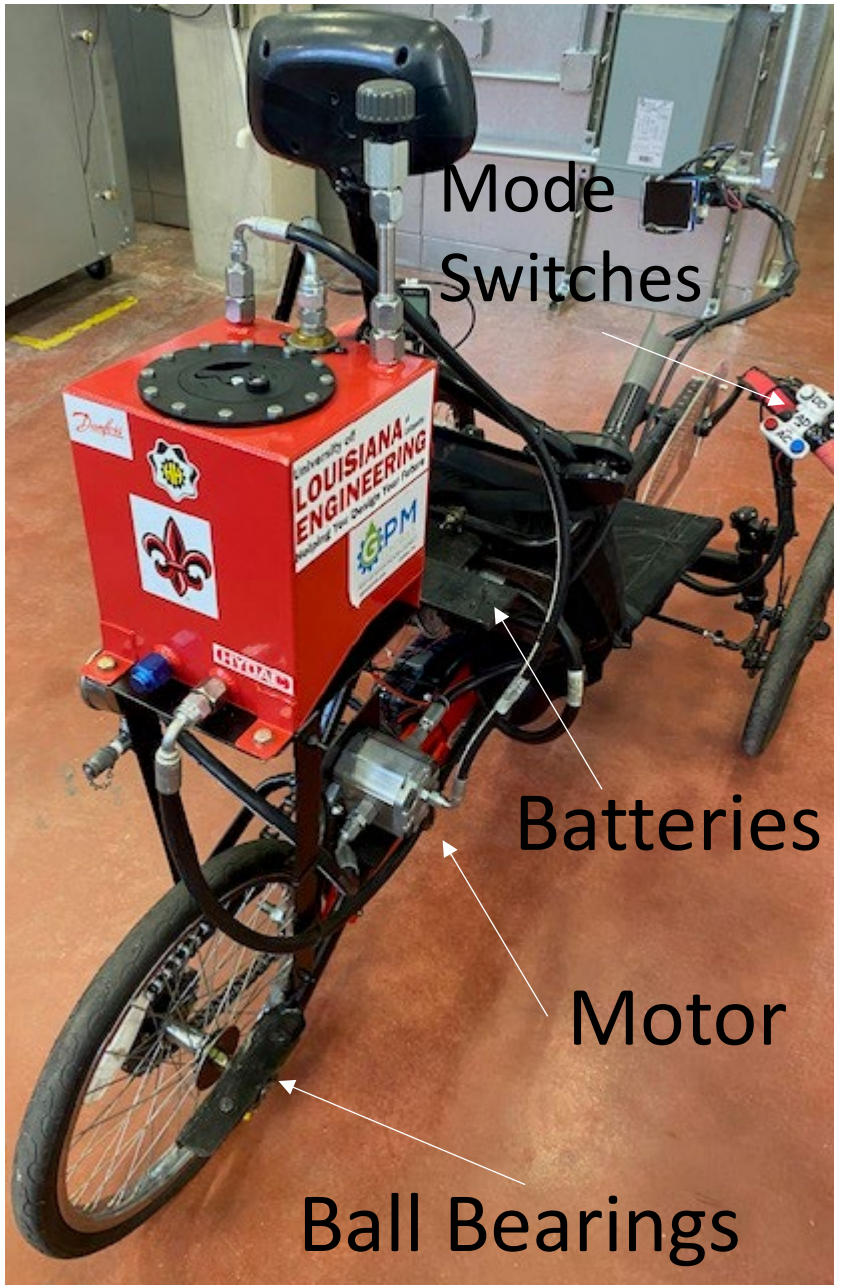
Team Introductions

Matthew Andrus

- Vehicle Construction
- Presentations
- Safety

2022-2023 Vehicle





Background

- The ‘22-’23 UL FPVC Team managed to place 1st overall at the competition
  - 1st in Sprint
  - 3rd in Regenerative Braking
  - 1st in Endurance
  - Below 3rd in Efficiency

Team	Top Speed(mph)	Efficient(%)	Weight(lb)	Sprint(s)
2022-2023	28	35	178	18.04

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Vehicle Design

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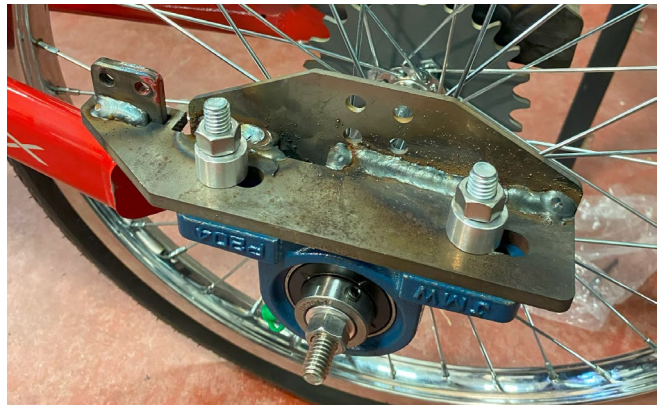
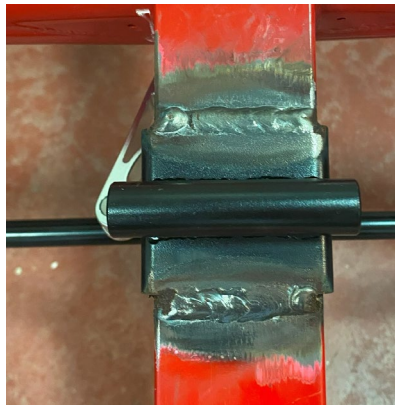
Bike Construction

- Stage 1: Frame Modifications
  - Extended arms that hold up the seat
  - Welded seat in place
  - Added rear extension for the bearings, rear rack





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Bike Construction

- Stage 2: Mounting Components
  - Welded together mounting plates for pump and motor
  - Constructed rear rack
  - Mounted pump, motor and manifold
  - Mounted bearings, rear drive wheel/axle

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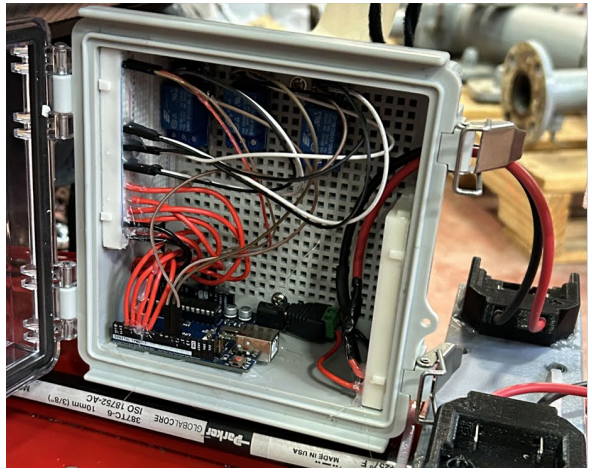
Bike Construction

- Stage 3: Hydraulic Installation
  - Finalized all hose positionings
  - Sized and installed hydraulic lines
  - Tested for leaks within the system

Bike Construction

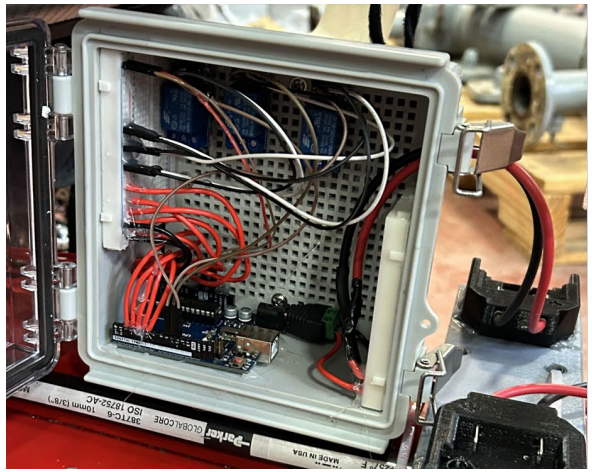
- Stage 4: Electronics Implementation
  - Tested electronic subsystem before installation
  - Mounted electrical box, battery mount, and button housings
  - Finished wiring



Electronic Subsystem

Consists of:

- 5 LED Push Buttons
- 2 Arduino Microcontrollers
- 3 Solenoid Valves
- 3 5V Relays
- 2 12V Batteries
- 1 LCD Screen
- 1 Pressure Transducer



First Arduino:

- Reads button presses and sends impulses to matching relays to match solenoid positions with drive mode

Second Arduino:

- Reads transducer voltage, converts voltage to pressure, displays pressure on LCD screen

Drive Mode	Solenoid Valve 8	Solenoid Valve 9	Solenoid Valve 10
Accumulator Charge	1	0	0
Accumulator Drive	1	1	0
Direct Drive	0	1	0
Regenerative Braking	0	0	1
Coasting	0	0	0

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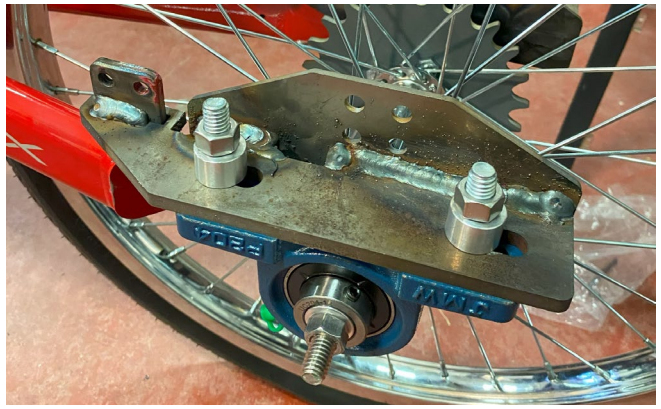
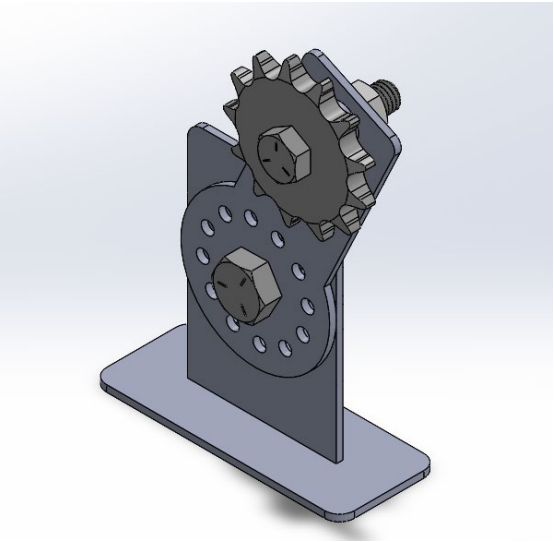
Rear Wheel Assembly

Consists of:

- Fully Threaded 3/8” Steel Axle
- 22” Rear Wheel
- 2 – ¾” Bore Pillow Block Bearings
- 2 – 3/8” Round Standoffs
- 23 teeth, 5/8” pitch flat sprocket
- Dial tensioner
- 20 teeth, 5/8” pitch sprocket
- Motor mount
- ANSI 50 Chain





Specs:

- Motor, Gear, 1.025 CID, Keyed Shaft .625", Bi-rotation, external drain
- Gear ratio: 1.15 Rear Wheel to Motor

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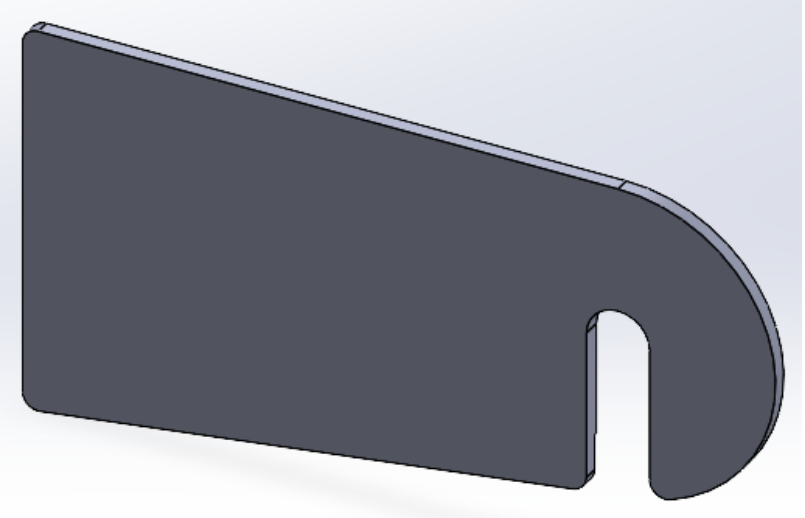
Pedal Assembly

Consists of:

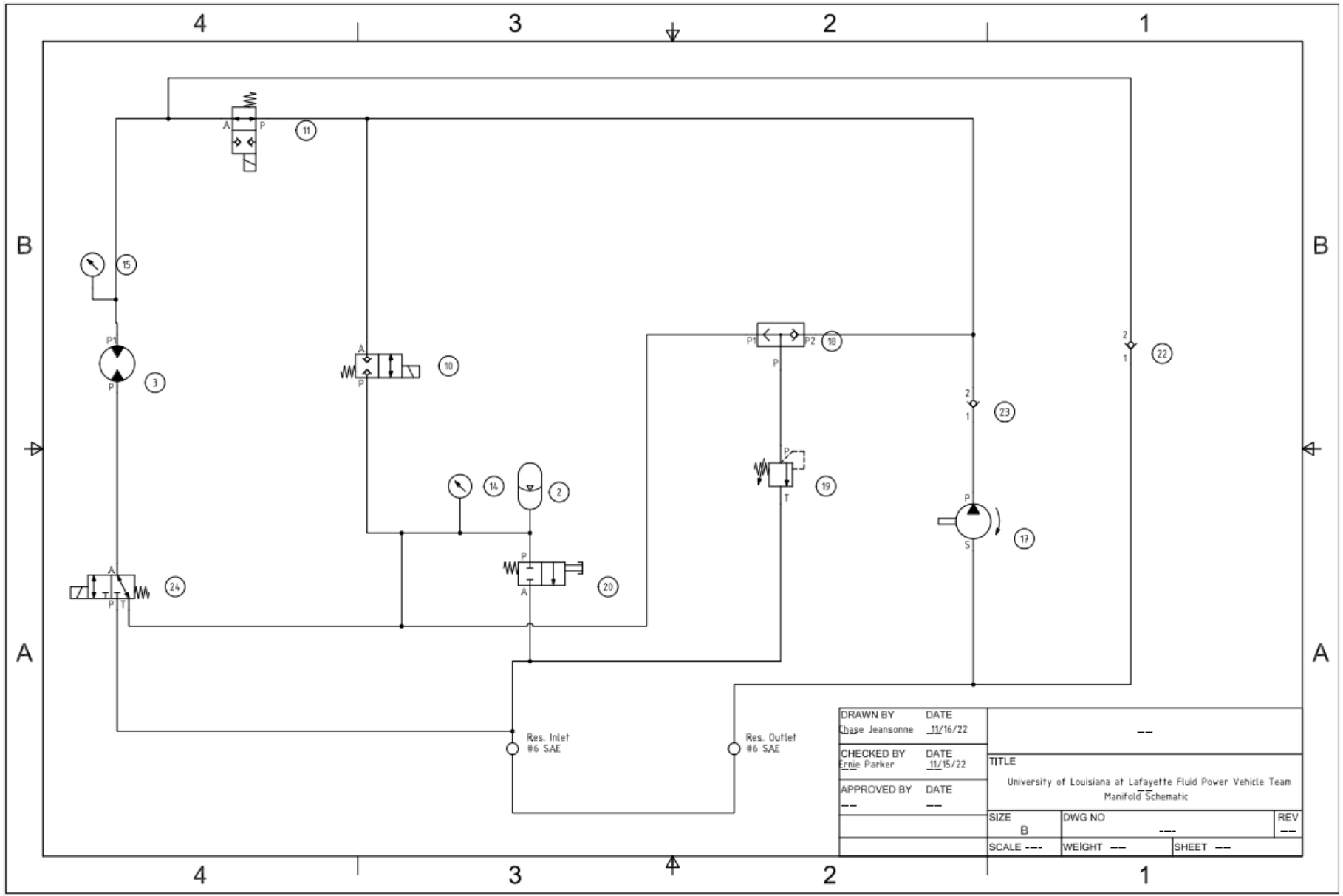
- Pump mount
- Pedal sprocket – 45 teeth, ½” pitch
- Pump sprocket – 18 teeth, ½” pitch
- ANSI 40 Chain
- Plexiglass Mount*ADD SOLIDMODEL*

Specs:

- Pump, Gear, 0.659 CID, Keyed Shaft .625", CW rotation
- Gear Ratio: 2.5 Pedal:Pump(Changed during testing)



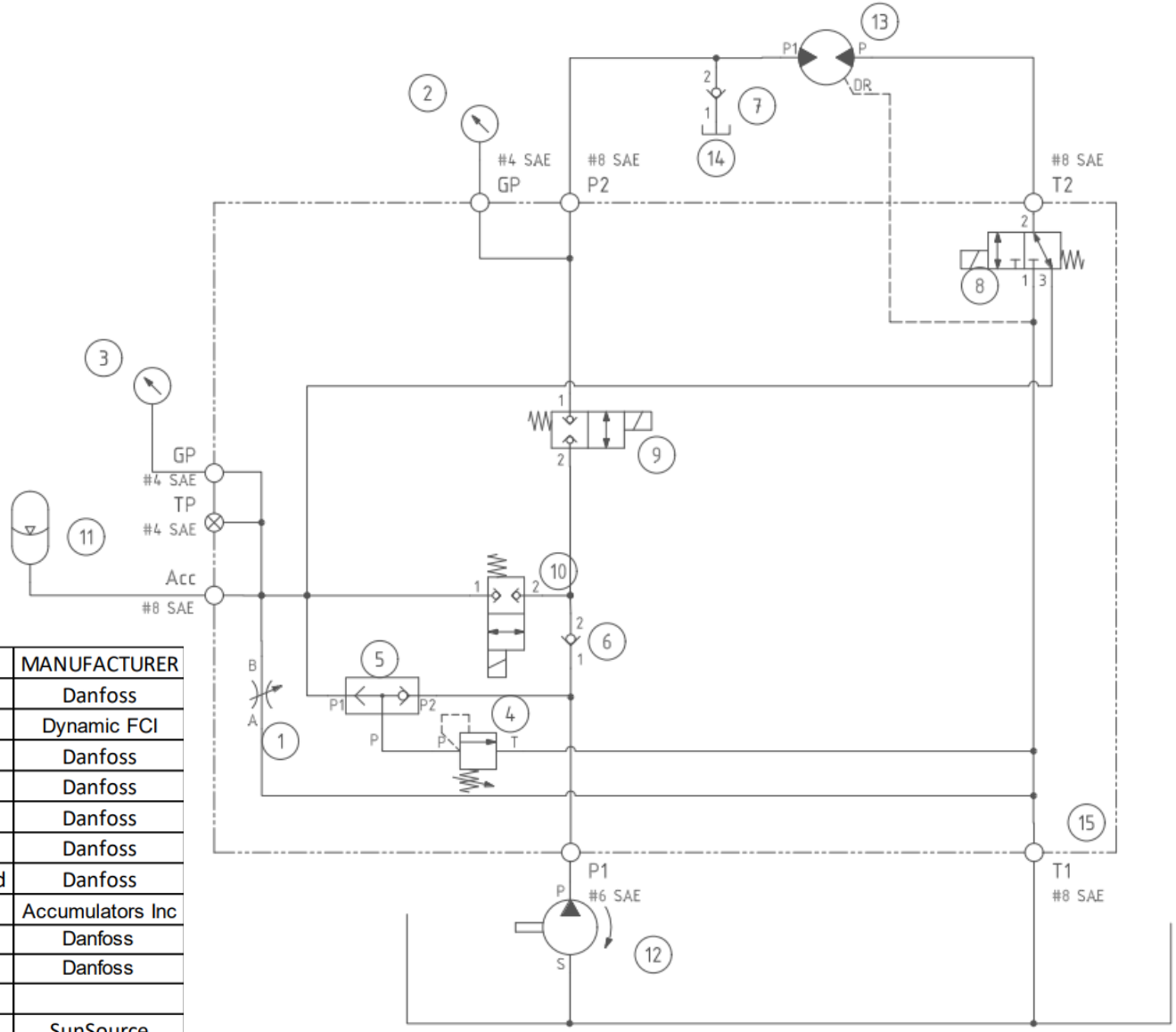
22’-23’ Hydraulic Circuit



Hydraulic Circuit

Drive Mode	Solenoid Valve 8	Solenoid Valve 9	Solenoid Valve 10
Accumulator Charge	1	0	0
Accumulator Drive	1	1	0
Direct Drive	0	1	0
Regenerative Braking	0	0	1
Coasting	0	0	0

Legend	
0	Non-energized
1	Energized



ITEM	QTY	MODEL CODE	DESCRIPTION	MANUFACTURER
1	1	NV1-8-S-0	Cartridge Valve, Flow Control, Needle Valve	Danfoss
2,3	2	CF-1P-210-A-SAE	Gauge, 0-3000 PSI, SAE -4 male adjustable stem. 2-1/2" diameter.	Dynamic FCI
4	1	RV1-10-S-0-36	Cartridge Valve, Relief, Direct Acting	Danfoss
5	1	DSV2-8-B-0	Cartridge Valve, Shuttle, High side, Ball type	Danfoss
6,7	2	CV08-NP-0.3-B-00	Cartridge Valve, Check, 1 to 2, size 8	Danfoss
8	1	SV1-10-3-0-00	Cartridge Valve, Solenoid, 2 pos. 3 way Spool 1-2/1-3	Danfoss
9,10	1	SBV1110C000	Cartridge Valve, Solenoid, 2 pos. 2 way Bi-poppet, normally Closed	Danfoss
11	1	A13100-3	Accumulator, 1 gallon, SAE -20 port	Accumulators Inc
12	1	111.20.243.00	Pump, Gear, 0.659 CID, Keyed Shaft .625", CW rotation	Danfoss
13	1	121.20.045.00	Motor, Gear, 1.025 CID, Keyed Shaft .625", Bi-rotation, external drain	Danfoss
14	1		Hydraulic Reservoir	
15	1		Manifold Body	SunSource

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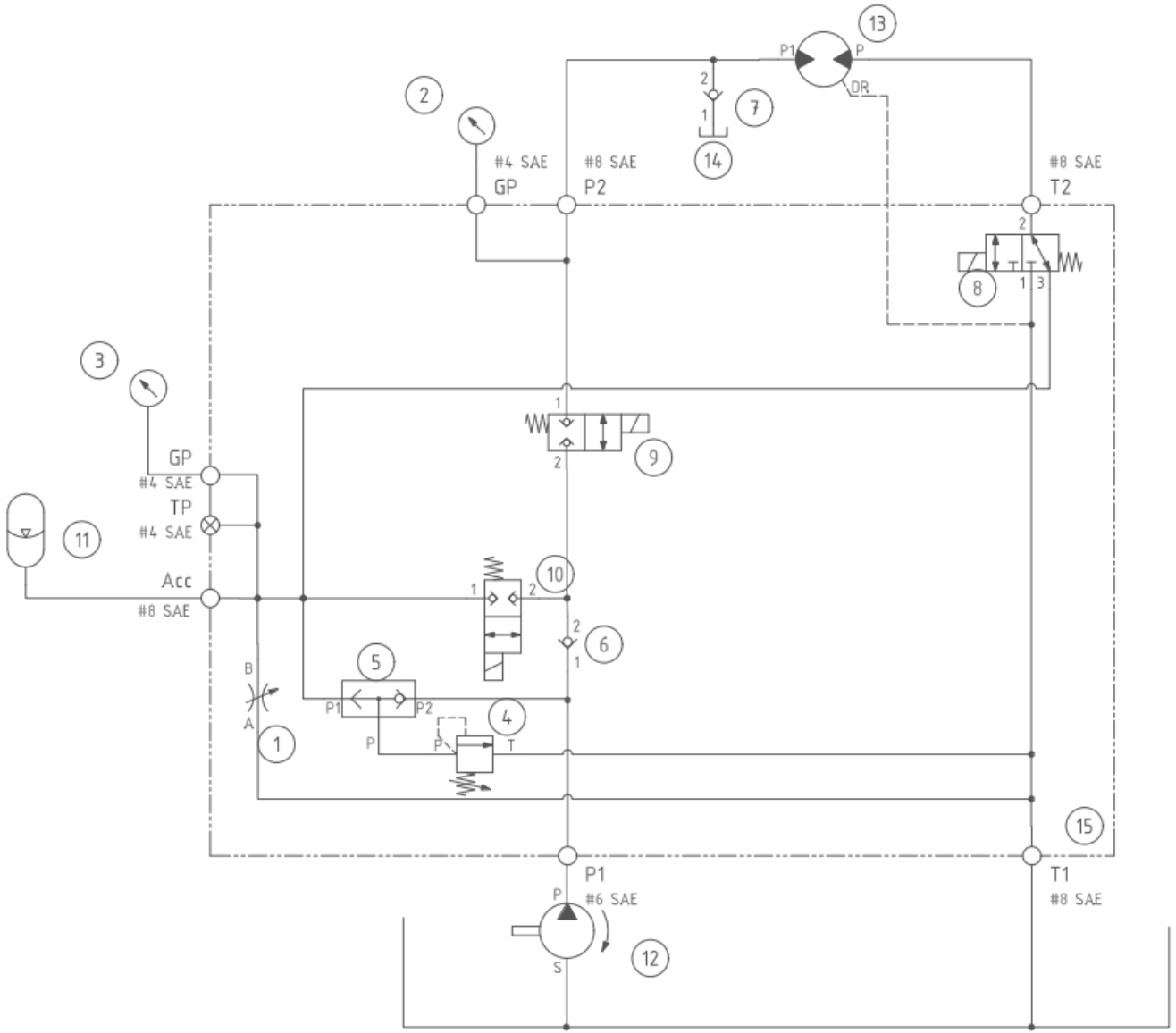
Hydraulic Circuit

Shown to the right is the current year's hydraulic manifold circuit.

The circuit has 5 drive modes:

- Accumulator Charge
- Accumulator Drive
- Direct Drive
- Regenerate Braking
- Coasting



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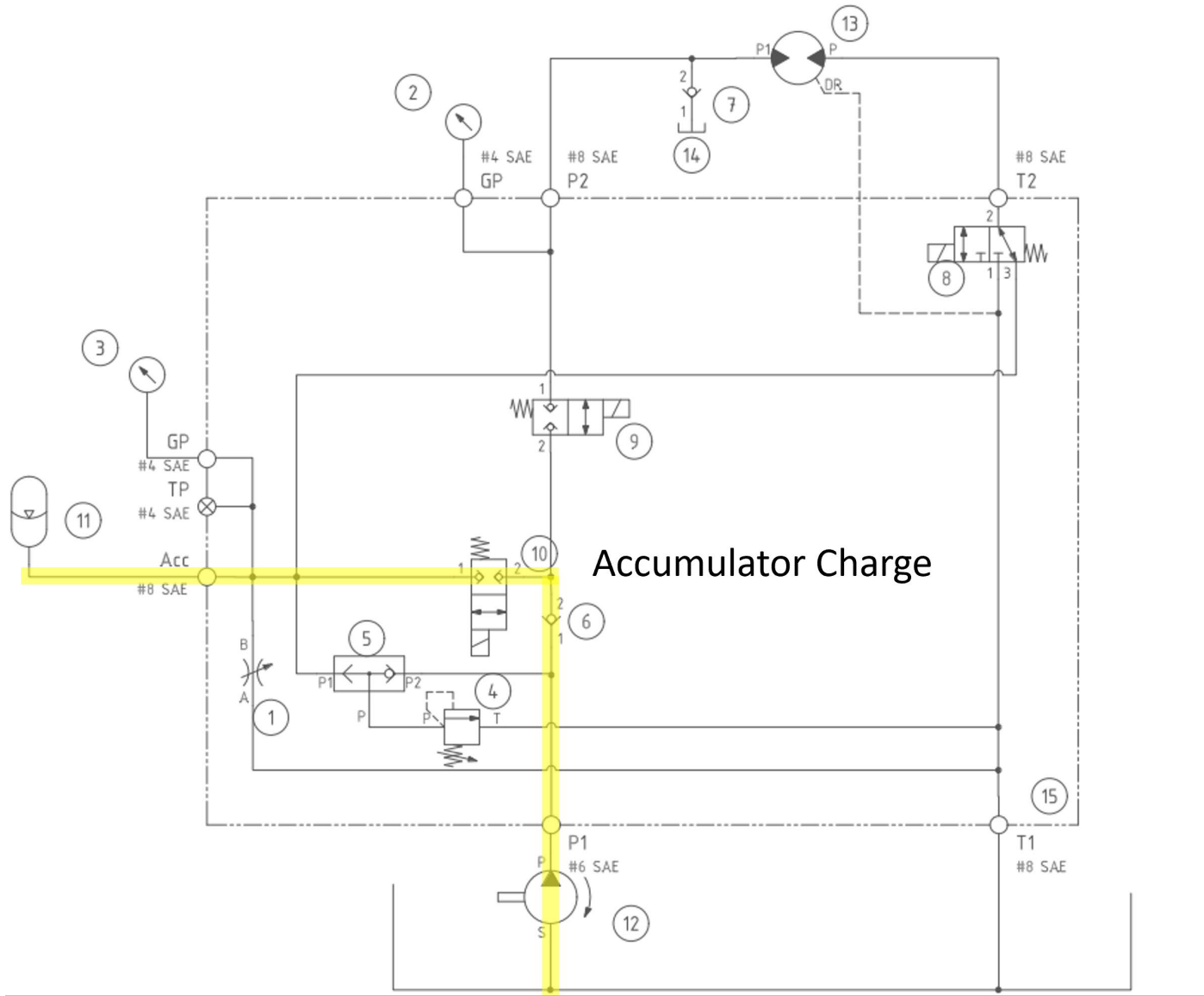
Hydraulic Circuit

Accumulator Charge Drive Mode

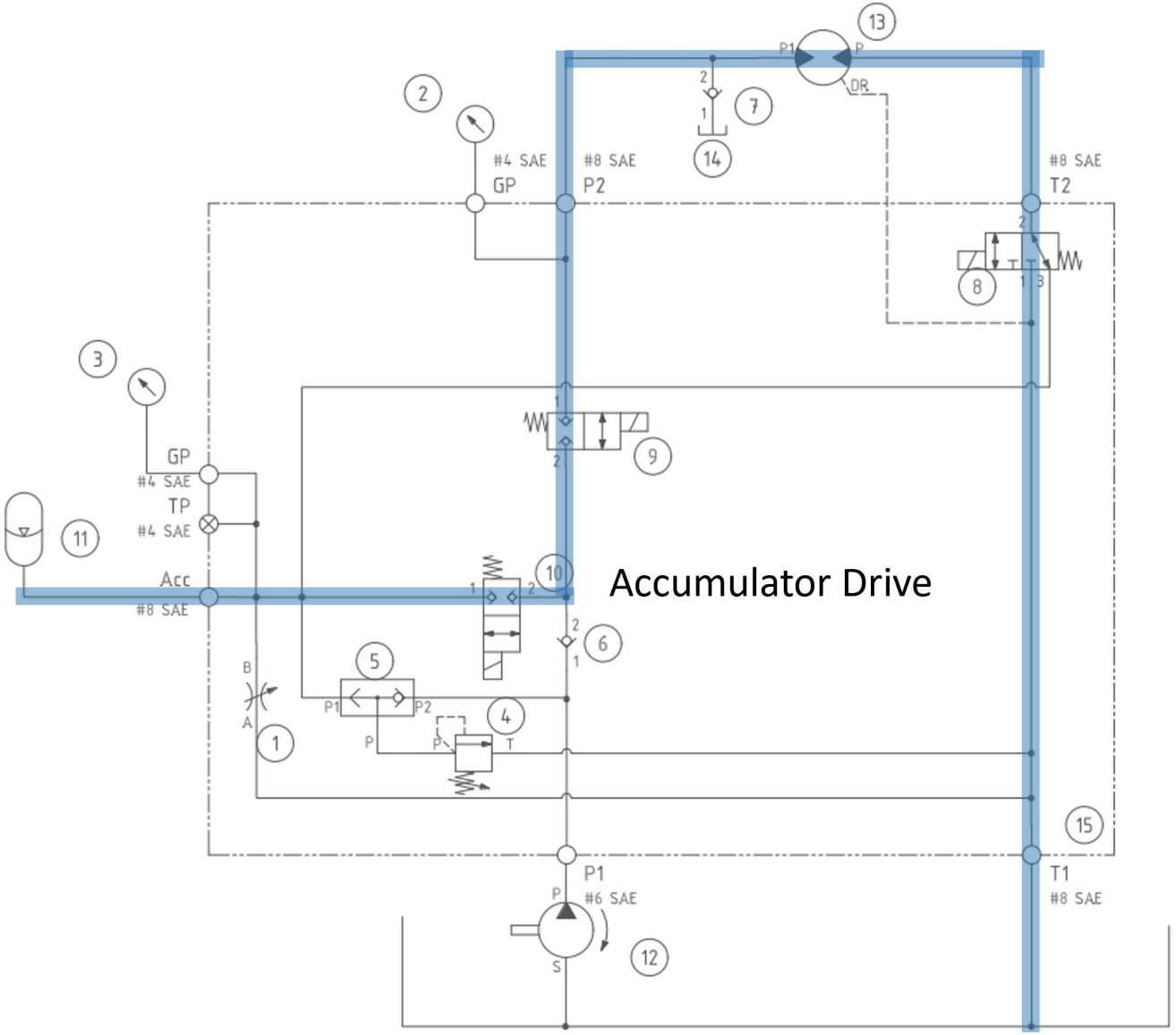
- Bike remains stationary while pedaling to charge the accumulator.
- This mode will be used to get the accumulator up to pressure for the sprint and efficiency race



Hydraulic Circuit

Accumulator Drive Mode

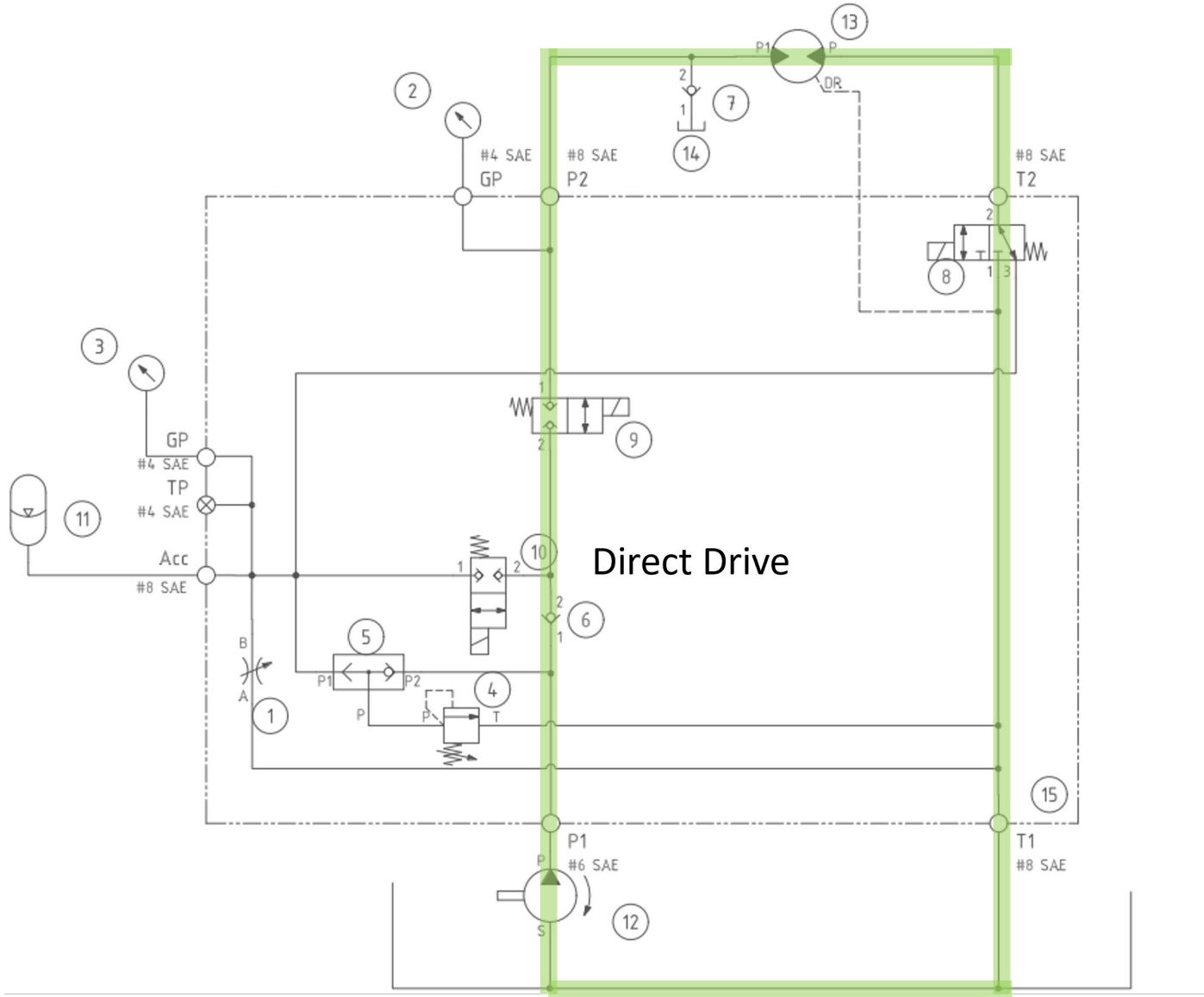
- Bike releases stored pressure in the accumulator, propelling the bike forwards.
- This mode will be used to start the sprint and efficiency race.



Hydraulic Circuit

Direct Drive Mode

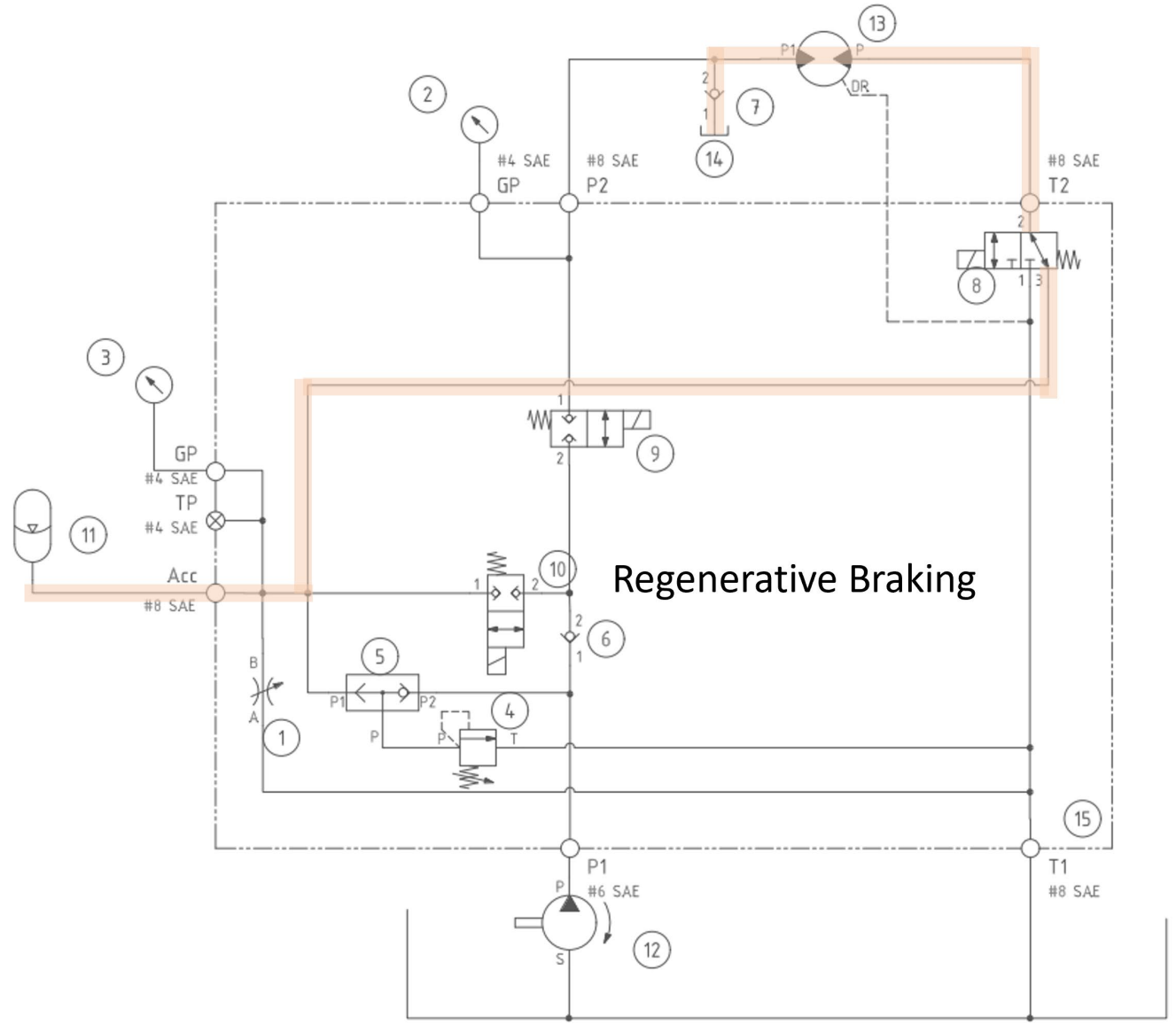
- The pressure sent to the accumulator by pedaling is immediately sent to the motor, so no pressure is stored in this mode.
- This mode will be used for the endurance race.



Hydraulic Circuit

Regenerative Breaking Drive Mode

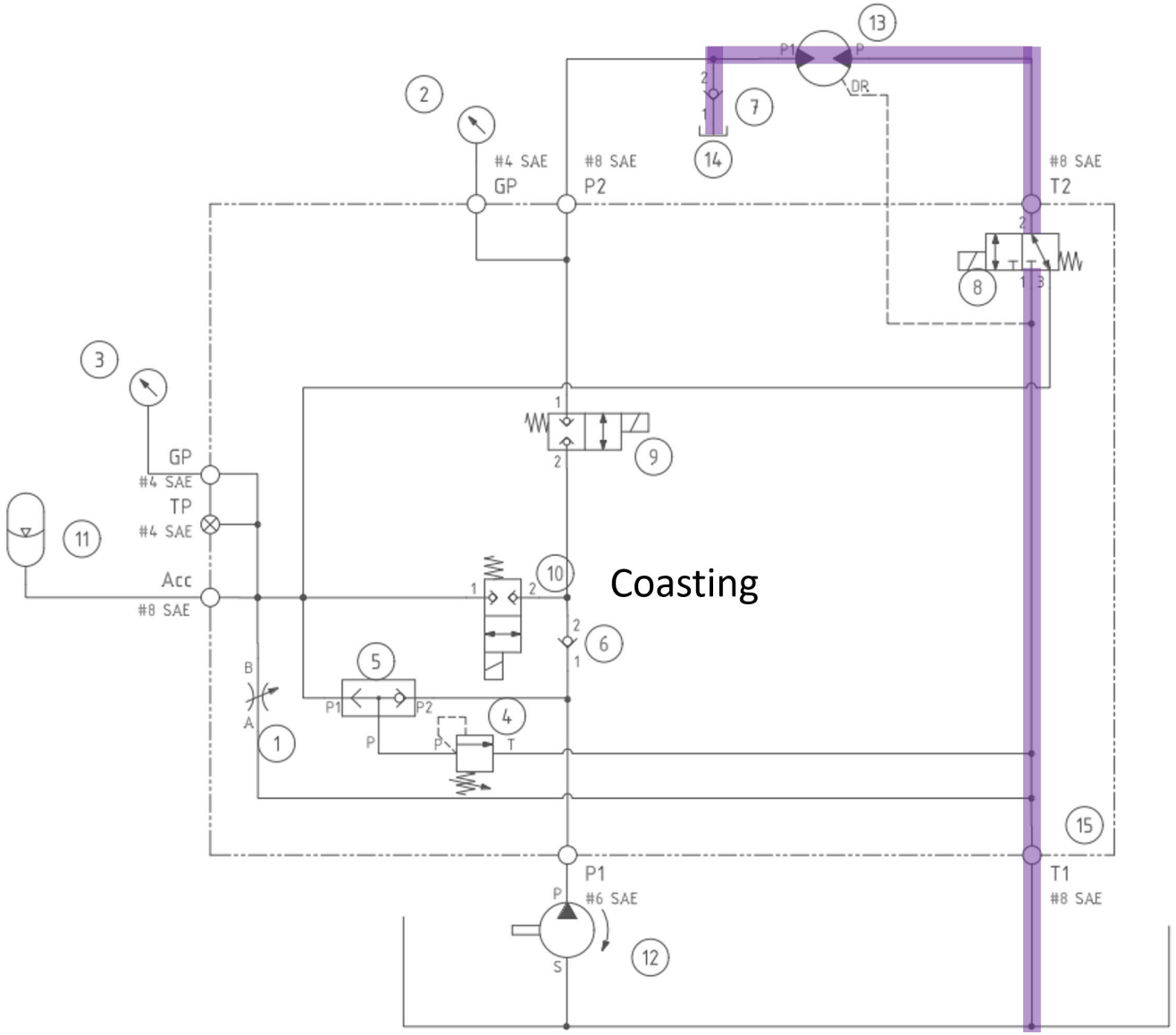
- This mode will be used in the regenerative braking race.
- This drive mode allows the motor to charge the accumulator, converting the kinetic energy from going downhill into pressure in the accumulator.



Hydraulic Circuit

Coasting Drive Mode

- The coasting drive mode works similarly to the regenerative braking drive mode, except that pressure is not stored in the accumulator.
- Hydraulic fluid is routed from the reservoir through the motor and back into the reservoir, allowing the vehicle to coast.



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Calculations

Assumptions used in calculations:

- 5% Grade
- Average combined weight of each rider and bike are approximately 370lbs(using weight of last year's design, 178lbs)
- 22in wheels
- Rolling resistance coefficient on concrete = 0.002

Calculations

- Pulling force, rolling resistance, and torque

$$F_{Pull} = \sin(tan^{-1}(0.05)) * 370lbs = 18.48\ lbs\ of\ pull$$

$$F_{RR} = \cos(\arctan(0.05)) * 370lbs * 0.002 = 0.739lbs$$

$$T = 11in * (18.48lbs + 0.739lbs) = 211.38\ lb * in$$

CIR of the motor and the pump (assumed gear ratio from the pedals - pump is 5:1 & the rear wheel - motor gear ratio is 1.7). The previous team found these ratios to be optimal for the sprint
A 1.025 CIR motor and a 0.659 CIR Pump will be used due to wait time concerns

$$CIR(Motor) = \frac{(211.38\ lb * in) * (2\pi)}{1000} = 1.328\ in^3/rev$$

$$RPM(Motor) = \frac{336\ *\ 30mph}{22\ in\ *\ 1.8} = 254.54\ RPM$$

$$GPM = \frac{254.54\ RPM\ *\ 1.476\ CIR}{231} = 1.63\ GPM$$

$$CIR(Pump) = \frac{2.93\ GPM * 231}{90\ RPM\ *\ 5} = 0.835\ in^3/rev$$

Calculations

Line sizing. The ISO standard for high pressure lines states that flow should not exceed 20 ft/s, and 5 ft/s at the inlets. Using the formula below, we determined we will need 1/4” hosing throughout and 3/8” hosing at the inlets.

$$A_{Net} = \frac{0.32 * 1.63}{20} = 0.026\ in^2, D = \sqrt{\frac{4 * 0.026}{\pi}} = 0.182\ in$$

Component Selection

Ordered from online source

Frame selection criteria:

- Can support the combined weight of the rider and components ~300 lbs.
- Large enough to house all components.
- Steel(for welding purposes)

Component Selection

Accumulator, 1 gallon, SAE -20 port

- From Accumulators, Inc on SunSource catalog - $935.00
- Model number: A13100-3

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Component Selection

Motor, Gear, 1.025 CID, Keyed Shaft .625", Bi-rotation, external drain

- From Danfoss\Eaton on SunSource catalog - $405.00
- Model Number: SNM2NN-/-017-B-N-06-GA-M6-E5-E5-NN-N-N-/-NNN-N-N
- Originally desired a 1.3 CIR Hydraulic motor, but due to wait time, we opted to go with the 1.025 CIR Motor from the catalog for convenience.

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Component Selection

Pump, Gear, 0.659 CID, Keyed Shaft .625", CW rotation

- From Danfoss\Eaton on SunSource catalog - $293.00
- Model Number: SNP2NN-/-011-R-N-06-GA-P1-E6-E5-NN-N-N-/-NNN-N-N
- Like the motor, we sized down the pump due to wait time concerns.

Component Selection

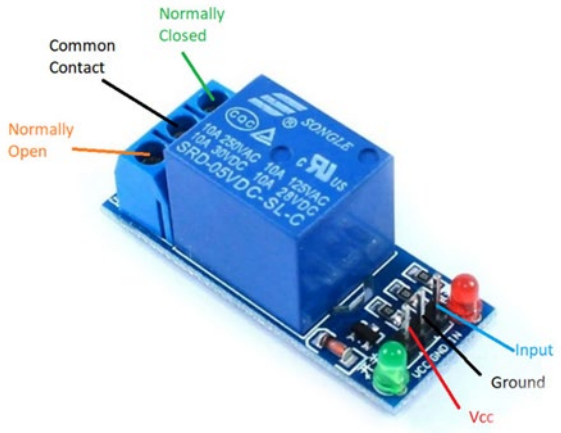
Hosing

- Connector Specialists Inc. Lafayette
- Provided us with hosing, adapters, and fittings

Component Selection

Electronic drive mode controls and screen

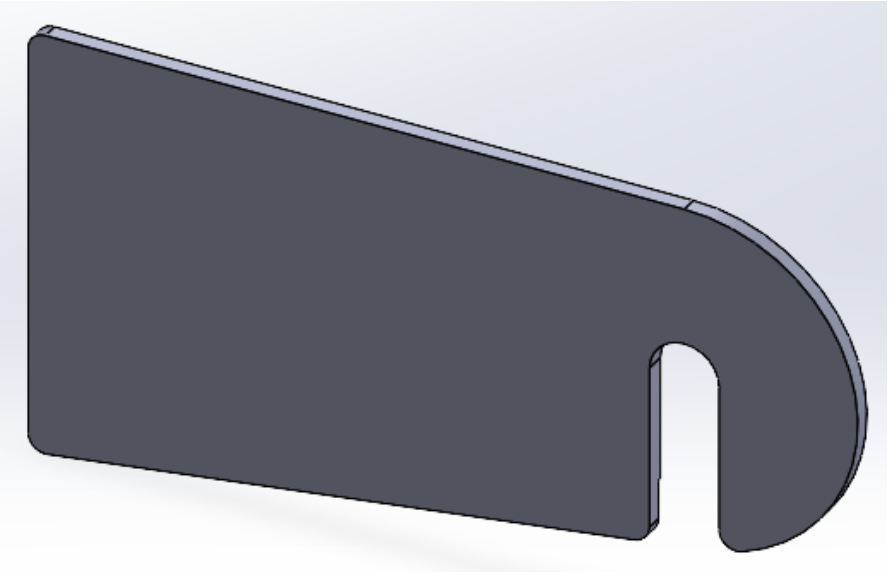
- Buttons will open and close the solenoid valves
- Allows quick switching between different drive modes



Safety

Proposed safety features:

- Added delays in code for switching between drive modes
- Ensured no sharp edges on any manufactured parts
- Added front chain cover
- Added algorithm that disallows buttons to be pressed simultaneously
- Ensured chain alignment for front and back chains



Team Budget

Component	Cost	Quantity	Total
SunSeeker ECO-TAD SX	$1,484.00	1	$1,484.00
SUPERFASTRACING 2.5 Gallon 9.5L Aluminum Level Racing Sender Drift Fuel Cell Gas Tank Polished	$69.40	1	$69.40
ARDUINO MEGA 2560 REV3 [A000067]		2	$0.00
Wheel + Tire	$95.85	1	$95.85
Chains + Sprockets	$179.83	1	$179.83
Sheet Metal	$340.22	1	$340.22
Electronics	$157.59	1	$157.59
Easy-to-Weld 4130 Alloy Steel Round Tube, 0.035" Wall Thickness, 5/8" OD, 6 ft	$37.16	1	$37.16
Component Mounting	$287.30	1	$287.30
Check Valve Line Body	$75.93	1	$75.93
Rear Wheel Components	$130.96	1	$130.96
Bike Accessories	$45.95	1	$45.95
Shipping Costs	$159.59	1	$159.59
		Total	$3,063.78
		Budget	$4,000.00
		Remaining	$936.22

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Catalog Budget

Component	Manufacturer	Model number	Cost	Quantity	Total
Accumulator, 1 gallon, SAE -20 port	Accumulators Inc	A13100-3	$935.00	1	$935.00
Fitting, Test Point- Accumulator Side. SAE -6 Male. M16-2 test thread.	Dynamic FCI	D1620-01-06SAE	$18.00	1	$18.00
Gauge, 0-3000 PSI, SAE -4 male adjustable stem. 2-1/2" diameter.	Dynamic FCI	CF-1P-210-A-SAE	$23.00	2	$46.00
Motor, Gear, 1.025 CID, Keyed Shaft .625", Bi-rotation, external drain	Danfoss	121.20.045.00	$405.00	1	$405.00
Pump, Gear, 0.659 CID, Keyed Shaft .625", CW rotation	Danfoss	111.20.243.00	$293.00	1	$293.00
Cartridge Valve, Relief, Direct Acting	Danfoss	RV1-10-S-0-36	$40.00	1	$40.00
Cartridge Valve, Shuttle, High side, Ball type	Danfoss	DSV2-8-B-0	$22.00	1	$22.00
Cartridge Valve, Solenoid, 2 pos. 2 way Bi-poppet, normally Closed	Danfoss	SBV1110C000	$128.00	2	$256.00
Cartridge Valve, Solenoid, 2 pos. 3 way Spool 1-2/1-3	Danfoss	SV1-10-3-0-00	$43.00	1	$43.00
Cartridge Valve, Solenoid Coil, 12VDC Deutsch, H Type	Danfoss	300AA00141A	$25.00	2	$50.00
Cartridge Valve, Solenoid Coil, 12VDC Deutsch, J Type	Danfoss	300AA00101A	$19.00	1	$19.00
Cartridge Valve, Solenoid Coil, 12VDC DIN, J type	Danfoss	300AA00081A	$27.00	1	$27.00
Cartridge Valve, Check, 1 to 2, size 16	Danfoss	CP102-1-B-0-005	$40.00	1	$40.00
Cartridge Valve, Check, 1 to 2, size 8	Danfoss	CV08-NP-0.3-B-00	$12.00	1	$12.00
Cartridge Valve, Flow Control, Needle Valve	Danfoss	NV1-8-S-0	$26.00	1	$26.00
Fitting, plug, -4 ORB male, external hex	Brennan	6408-04-O	$1.00	1	$1.00
				Total	$2,233.00
				Budget	$5,000.00
				Remaining	$2,767.00

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Bike Testing

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Thank you to our mentors and sponsors for their time and efforts!

Thank you to the NFPA and all companies who offered their services!

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Questions?

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