

**10 YEARS**

N F P A

**Fluid Power**  
**=VEHICLE**  
**Challenge**



NFPA  
Education and  
Technology  
Foundation

Final Presentation  
PURDUE UNIVERSITY NORTHWEST  
TEAM ADVISOR: Ali Alavizadeh & Edward Vavrek ,  
INDUSTRY ADVISOR :Matthew Bagely & Ernest Parker  
DATE: 04/23//2026



# THE TEAM!

Ciara Black

- Mechatronics Engineering Technology
- Hydraulics/Pneumatics Lead

Malina Harris

- Mechanical Engineering Technology
- Mechanics Lead

Edwin Ogeda

- Mechanical Engineering Technology
- Additive manufacturing & mechanical

Nevin DeLong

- Mechatronics Engineering Technology
- Electronics, testing, and assembly

Christopher Guillame

- Mechatronics Engineering Technology
- Electronics, Mechanics, & Miscellaneous



# Previous Team



2021-2022



2022-2023

Creativity over functionality. Innovation appreciated, however 2025-2026 strived for a bike to achieve more competition goals.

# DESIGN OBJECTIVES



- Engineer a closed-loop hydraulic drivetrain for a light-weight 3-wheel vehicle that optimizes power transmission efficiency, controllability, and structural integrity
- Chassis and drivetrain capable of smooth acceleration and reliable braking
- Maintain operator safety and meeting NFPA competition constraints
- Stimulate education in fluid power components, circuits, and systems, incorporating them into a systems engineering experience.

# GOALS



- Develop a three-wheeled vehicle design with effective weight distribution, while increasing rider maneuverability
- Hydraulic Circuit must functionally store and move fluid energy for direct drive, boost, and regenerative braking circuits
- Creative initiatives (not limited) including pneumatic sprung objects and plc automated features
- The vehicle must abide by all safety regulations for enclosed fluid and hazardous material.

# SPECIFICATIONS



- Complete Vehicle (without rider) must not exceed 210lbs
- Hydraulic Circuit must have maximum pressure limit of 3000 psi throughout the system
- Hydraulic System must have a fluid capacity of 1 gallon
- Factoring 60-80% efficiency to achieve speeds of 0-2 mph min and a max speed from 5-10 mph
- Finite Element Analysis conducted with 210 lb maximum limits with rider weight

# SAFETY



Risk Matrix		Insignificant	Minor	Moderate	Major Injury	Severe Injury
Likelihood	Almost Certain	Medium	High	Very High	Very High	Very High
	Likely	Medium	High Faulty/Damaged Hose line	High	Very High	Very high
	Possible	Low	Medium Excessive Wheel Radius	High Hydraulic Fluid Spill	High Gear Misalignment	Very high Ineffective Braking
	Unlikely	Low	Low	Medium	Medium	High Frame cracking/ weld
	Rare	Low	Low	Low	Low	Medium

Risk	Severity	Effect	Damage Cost
Hydraulic Fluid Spill	R1	System and rider hazard	\$150
Ineffective Braking	R2	system	\$200
Gear Misalignment	R3	Material wear and chain lock	\$350
Faulty/Damaged Hose line	R4	maintenance effect	\$40
Excessive Wheel Radius	R5	limit turns	\$150
Frame cracking/ weld	R6	Weaken tensile strength; breaks	\$120

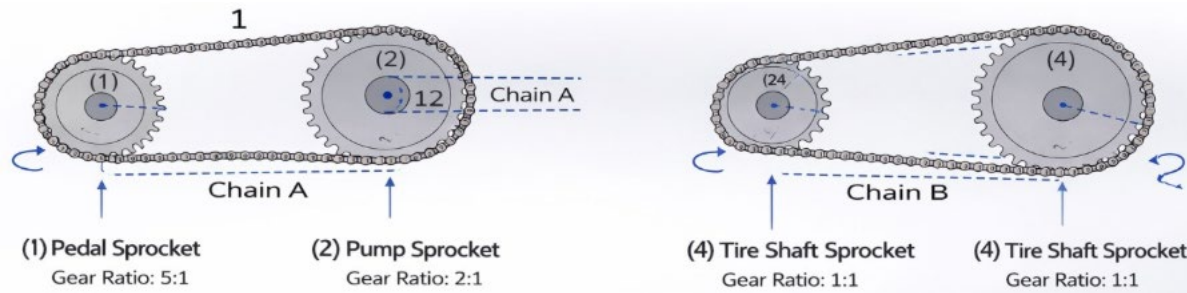
- The vehicle will be stored in a trailer and transported by the team
- Accumulator is Nitrogen charged by professional sponsor or in-house shop up to 900psi

# DELIVERABLES

- Tricycle Design & FEA Analysis
- Efficient Hydraulic circuit
- Risk Assessment
- Budget Report
- Final Project Report



# CHAIN DRIVE



$$V.R = \frac{n_1}{n_2} = \frac{T_2}{T_1} = \frac{P.D_2}{P.D_1} = \frac{N_2}{N_1}$$

Parameter	Sprocket (1) Pedal	Sprocket (2) Pump	Parameter	Sprocket (3) Motor	Sprocket (4) Tire Shaft
Gear Ratio	5:1	5:1	Gear Ratio	1:1	1:1
Teeth	60	12	Teeth	24	24
Pitch Diameter (in)	9.554	2.652	Pitch Diameter (in)	4.1	4.1
Speed Input (rpm)	75	75	Speed Input (rpm)	174.77	174.77
Speed Output (rpm)	75	375	Speed Output (rpm)	174.77	174.77
Torque (max) (in·lb)	375	75	Torque (max) (in·lb)	150	150
Torque (min) (in·lb)	187.5	37.5	Torque (min) (in·lb)	75	75
Pitch Radius (in)	4.777	1.326	Pitch Radius (in)	2.05	2.05
Chain Tension (lb)	78.5 → 39.3	56.6 → 28.3	Chain Tension (lb)	73.2 → 36.6	same
Chain Velocity (ft/min)	187.5	187.5	Chain Velocity (ft/min)	187.5	187.5
Chain Length	~25.9 in	~25.9 in	Chain Length	~25.9 in	~25.9 in

$$T = F \times d$$

**Pedal to Pump Sprocket Ratio=  $N_2/N_1$**

$$12/60 = 1:5$$

**Target ratio: 1:5**

**Pedal speed: 75 rpm → Pump speed: 375 rpm**

✓ Innovative use of **2-stage pump** for optimizing speed and torque

✓ Matches **.70 / .17 in<sup>3</sup>/rev two-stage pump calculations**

✓ Keeps chain wrap acceptable on small sprocket

✓ No intermediate shaft require

**Motor to Rear Axle Sprocket Ratio=  $N_2/N_1$**

$$20/20 = 1:1$$

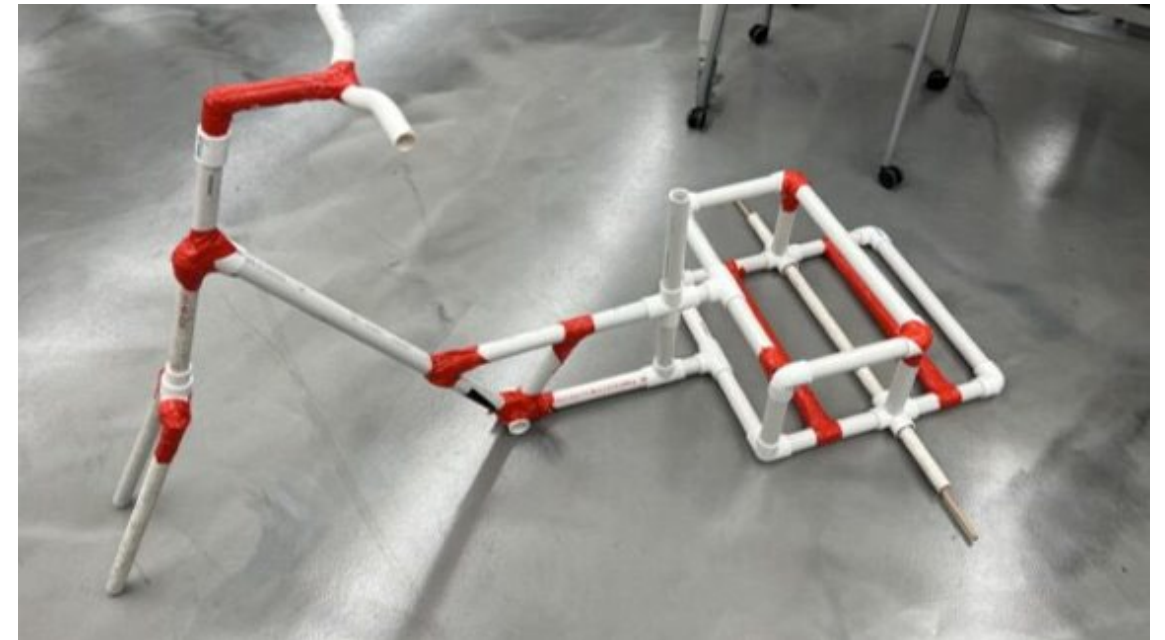
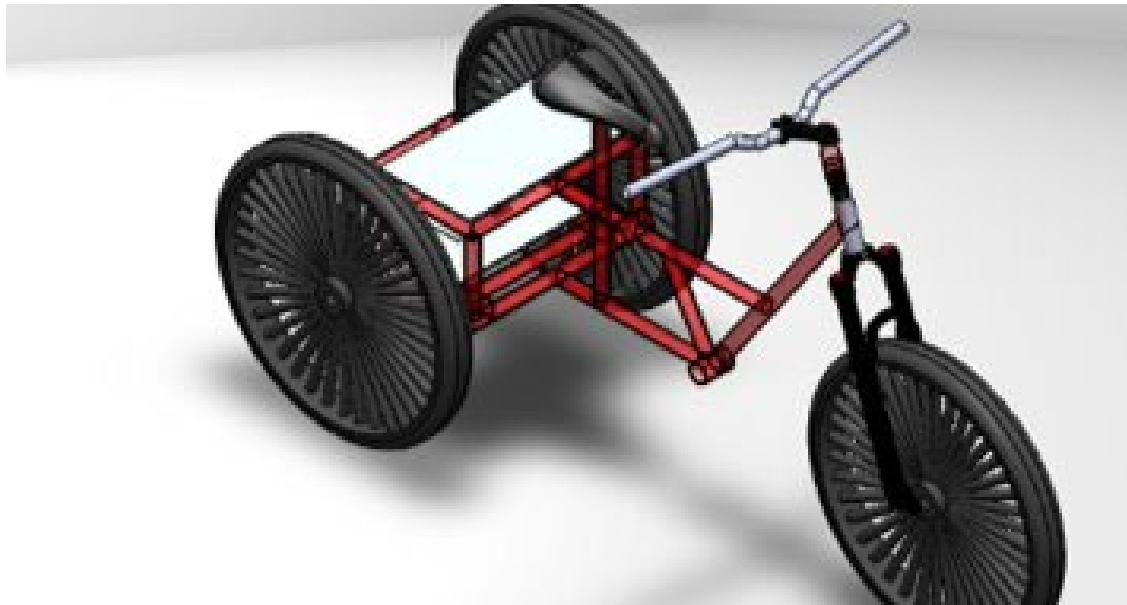
**Target ratio: 1:1**

**Motor speed: 65.8 rpm → Axle speed: 65.8rpm**

**Purpose:** Direct torque transfer with minimal losses

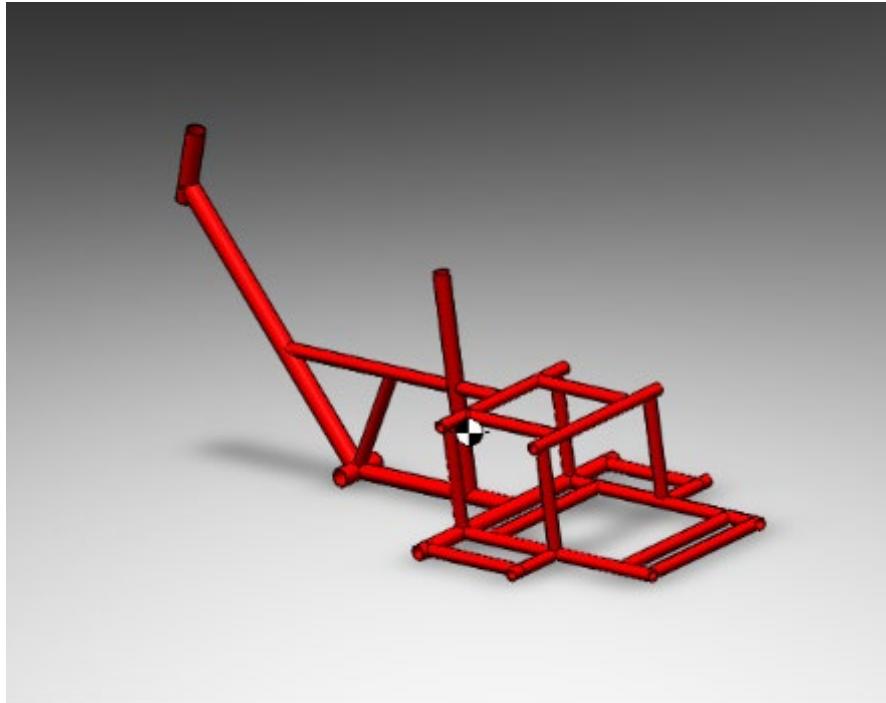
**Motor displacement: 4 in<sup>3</sup>/rev**

# Initial Frame Conceptual Design

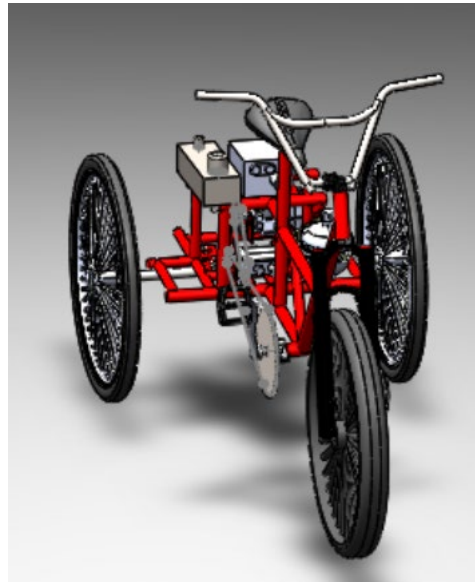


- 4130 Chromoly Steel tubing in reference to previous teams and for tensile strength
- Schedule 40 PVC Model Design

# Final Frame Design



# Final Assembly



*Figure 8: Final Bike Assembly minus hose connections represented in SolidWorks -- Right Side View*



*Figure 7: Final Bike Assembly minus hose connections represented in SolidWorks -- Front View*

# CALCULATIONS



Pump CiR	Pedal RPM	Gear Ratio (Pedal/Pump size)	Pedal Lever Length	Max Pump Torque	Pedal Torque	Lbs. of Push on Pedal	Pump RPM	Pump GPM	Input Horsepower	Max Pedaling Wheel RPM	Max. Pedaling MPH
0.7	75	5	7.5	1988	9942	1326	375	1.14	1.97	12.5	2.60
0.18	75	1	7.5	1988	1988	265	75	0.06	0.10	3.214285714	0.77

Motor CIR	Max PSI	Pre-Charge	Wheel Dia.	Speed Ratio (Wheel/Motor Size)	Average Motor PSI	Max Motor Torque	Average Motor Torque	Max Wheel Torque	Ave. Wheel Torque	Wheel Radius	Max lbs. of pull	Average lbs. of pull	Accum. Useable Vol.	Distance Traveled under power in ft.
4.2	2973	1000	26	1	1578	1988	1055	1988	1055	13	153	81	153	247
4.2	2973	1000	26	1	1578	1988	1055	1988	1055	13	153	81	153	247

# HARDWARE SELECTION



Location	Teeth/Description	Bore
Pedal (driver)	60T	1" shaft to Sqr taper
Pump (driven)	12T	1/2" keyed
Motor (driver)	20T	1 1/4" keyed
Rear axle (driven)	20T	1" shaft
Standard 40 chain	10 FT	1" Flanged Bearings
Master Links	4 Links	1" pillow block bearings
2-Stage Pump	0.7/.17 CIR	
Motor	4 CIR	

# BOM

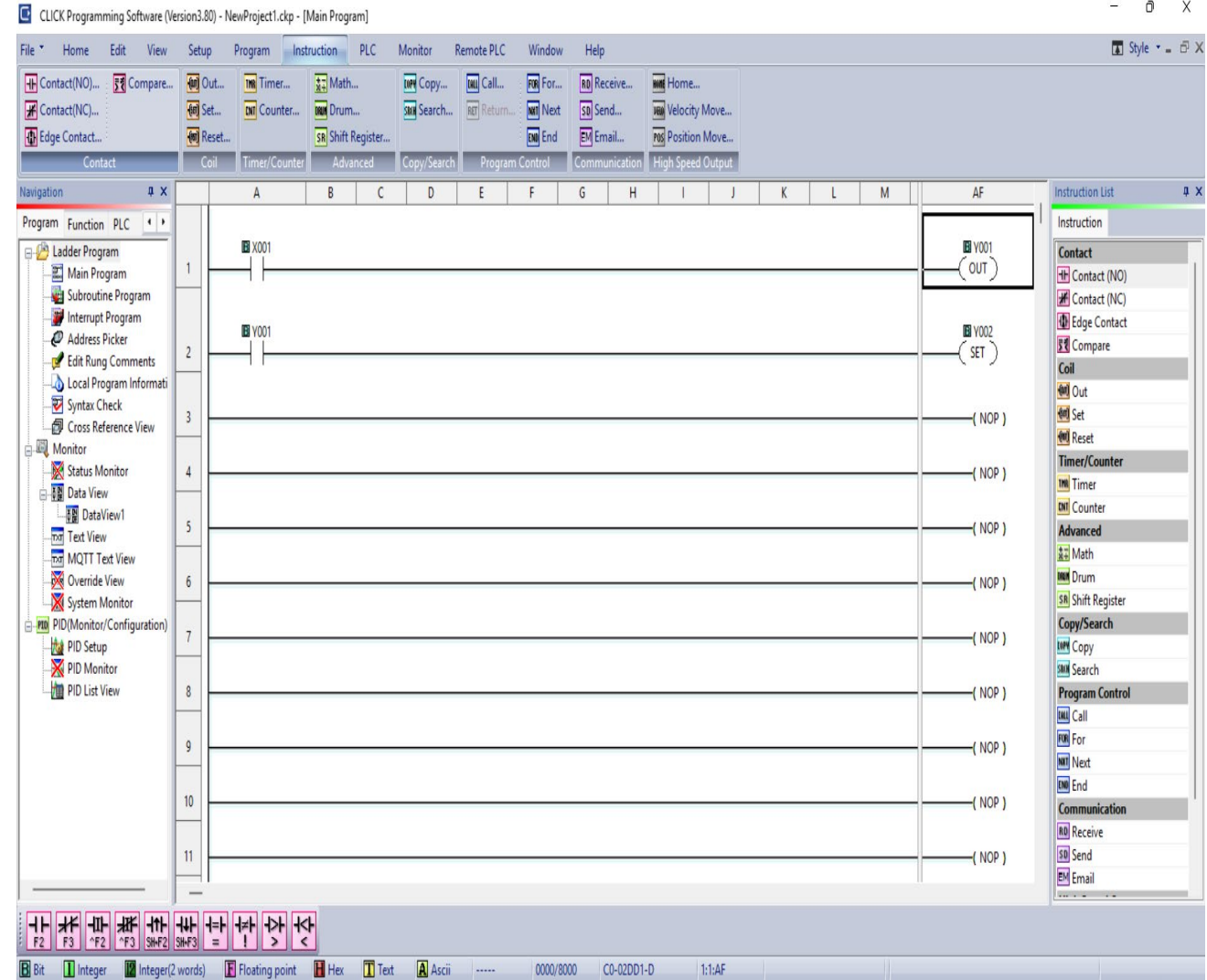


Category	Part	Description	Vendor/Supplier	Unit Cost	Qty	Total Cost	Approved By
Classes	PVC Schedule 40 Pipe	3 in. x 10 ft, PVC Schedule 40 Tubing (20ft) Pipe	Home Depot	\$1.65	3	\$33.54	
Classes	4130 Chromium Steel	2in OD x 0.200 wall thickness 4130 Steel	402 Metals	\$4.76	6	\$28.56	
Classes	4130 Chromium Steel	1.54 in (20 x 0.200) wall thickness 4130 Steel	402 Metals	\$11.40	6	\$68.40	
Classes	4130 Chromium Steel	Heavy Steel Round Tube 4130, 0.200 in Wall Thick, 1.57 in Outside Dia, Seamless	402 Metals	\$6.46	4	\$27.60	
Classes	1" Shaft	1" x 48in 1040 Cold Rolled Steel	Delmar Metals	\$66.37	1	\$66.37	
Classes	1/2" Bore Pin	in House		\$1.00	1	\$1.00	
Classes	Left & Right Cross Arm Set	2x1000 Square Upper Arms (each) Brand: 800 - Rear (on Axle Material) 1040 Steel	Walmart	\$36.00	1	\$36.00	
Classes	400 1" Shaft	400 Shaft Size - 100 1"	800 Parts	\$35.00	1	\$35.00	
Classes	Roller Chain Sprocket - 12 teeth	12 Tooth Sprocket: 48, For 1/2 in Chain Pitch, 1/4 in Bore Dia, 1.812 in Pitch Dia, Steel	Orange	\$17.00	1	\$17.00	
Classes	Roller Chain Sprocket - 20 teeth	Chain Part #: 2000 in 20 Tooth Sprocket: 48, For 1/2 in Chain Pitch, 1/4 in Bore Dia, 2.475 in Pitch Dia, Steel	Hydra-Sprockets	\$52.00	1	\$52.00	
Classes	Roller Chain Sprocket - 24 teeth	24 Tooth Sprocket: 48, For 1/2 in Chain Pitch, 1.14 in Bore Dia, 2.475 in Pitch Dia, Steel	Bobby Hydrolics	\$22.25	2	\$44.50	
Classes	Roller Chain Sprocket - 24 teeth	24 Tooth Sprocket: 48, For 1/2 in Chain Pitch, 1.14 in Bore Dia, 2.475 in Pitch Dia, Steel	Orange	\$84.20	1	\$84.20	
Classes	Standard 40 Chain	40B Chain: 48, For 1/2 in Chain Pitch, 1.14 in Bore Dia, 2.475 in Pitch Dia, Steel	Orange	\$12.00	1	\$12.00	
Classes	1040 Roller Chain (Master Link)	1040 Roller Chain: 48, Single Strand, 1/2 in Pitch, 1.14 in Bore Dia	Orange	\$1.40	4	\$5.60	
Classes	1" Flange Bearings	1" Flange Bearing: 1.57 in Bore, 1.57 in ID, 1.57 in OD, 0.5 in Width	Orange	\$22.25	2	\$44.50	
Classes	1" Pillow Block	1" Pillow Block: 1.57 in Bore, 1.57 in ID, 1.57 in OD, 0.5 in Width	Orange	\$42.20	2	\$84.40	
Classes	Weld Tube	3/4" x 10' 1040 Cold Rolled Steel	Summit Supply	\$1.00	4	\$4.00	
Classes	Throttle Headset (Park Assym)	Throttle Headset: 1.57 in Bore, 1.57 in ID, 1.57 in OD, 0.5 in Width	MidlandTech	\$28.00	1	\$28.00	
Classes	Max Stem	Max Stem: 1.57 in Bore, 1.57 in ID, 1.57 in OD, 0.5 in Width	MidlandTech	\$12.00	1	\$12.00	
Classes	Head Tube Headset Top Cap/Star Nut	Head Tube Headset Top Cap/Star Nut: 1.57 in Bore, 1.57 in ID, 1.57 in OD, 0.5 in Width	MidlandTech	\$1.00	2	\$2.00	
Classes	20AWG Wire (Solid Copper/Cable)	20 AWG (Pack)		\$15.45	1	\$15.45	
Classes	Emergency Stop Button Module	1 module		\$12.00	1	\$12.00	

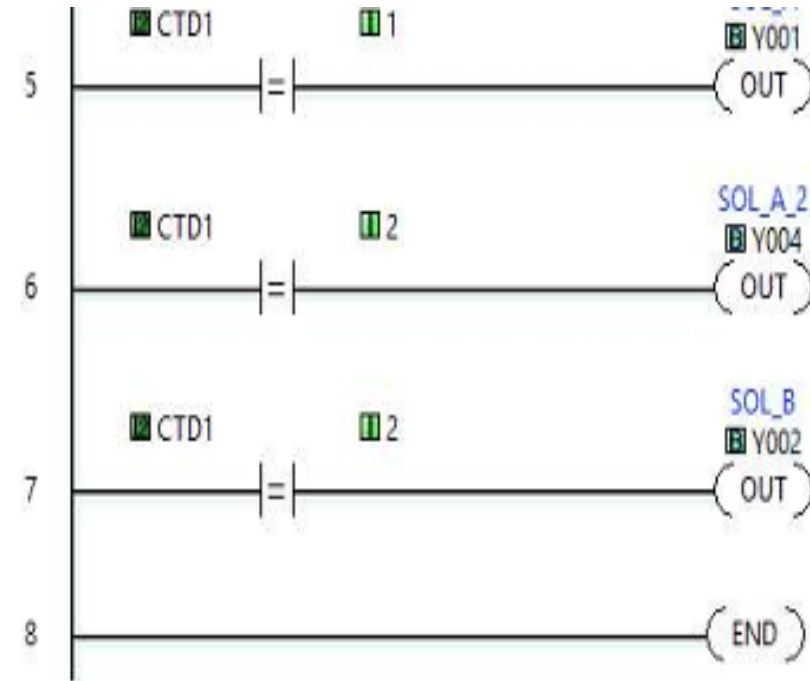
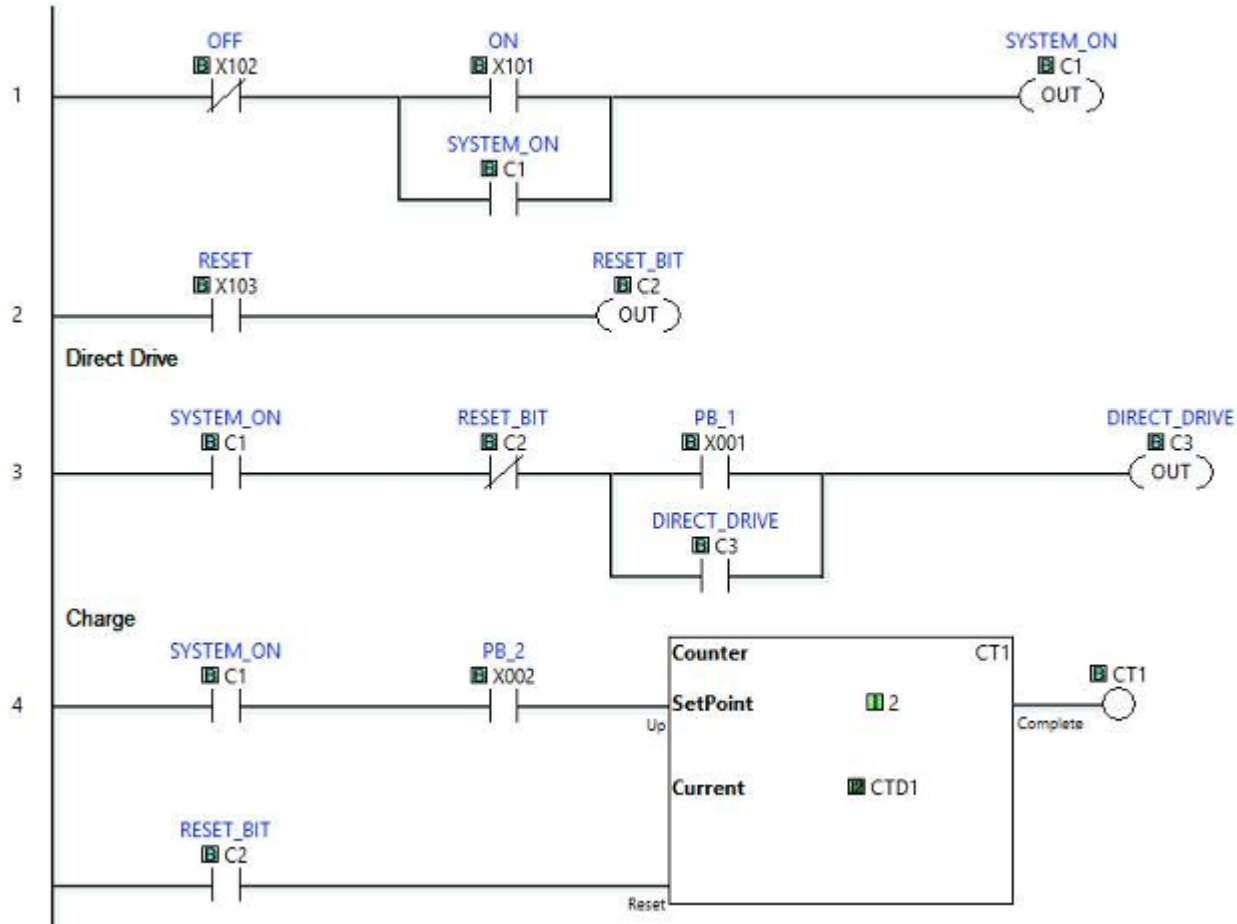
Electronics	Pushbutton Module	Pushbutton Module		\$1.00	4	\$4.00	
Electronics	Wire Stripping Tool	Wire Stripping Tool		\$12.00	2	\$24.00	
Electronics	Utility Terminal Block	Utility Terminal Block		\$6.00	1	\$6.00	
Electronics	Hydraulic Cables	100' Positive/Negative Lead		\$17.00	1	\$17.00	
Electronics	Reset Power Supply	Adjustable Bench Power Supply		\$24.00	1	\$24.00	
Electronics	Programming Cable	USB P.C. Programming Cable		\$6.00	1	\$6.00	
Electronics	12 volt Battery	Rechargeable Battery		\$25.00	2	\$50.00	
Electronics	Terminal Plug	100' Utility Terminal Plug for USB P.C. Terminal		\$12.00	1	\$12.00	
Chain Drive	24T Sprocket	24 Tooth Sprocket: 48, For 1/2 in Chain Pitch, 1/4 in Bore Dia, 1.812 in Pitch Dia, Steel	Bobby Hydrolics	\$22.25	2	\$44.50	\$44.50
Chain Drive	48T Sprocket	48 Tooth Sprocket: 48, For 1/2 in Chain Pitch, 1/4 in Bore Dia, 2.475 in Pitch Dia, Steel	Hydra-Sprockets	\$52.00	1	\$52.00	
Chain Drive	12T Sprocket	12 Tooth Sprocket: 48, For 1/2 in Chain Pitch, 1/4 in Bore Dia, 1.812 in Pitch Dia, Steel	Orange	\$17.00	1	\$17.00	
Chain Drive	Standard 40 Chain	40B Chain: 48, For 1/2 in Chain Pitch, 1.14 in Bore Dia, 2.475 in Pitch Dia, Steel	Orange	\$12.00	1	\$12.00	
Chain Drive	1040 Roller Chain (Master Link)	1040 Roller Chain: 48, Single Strand, 1/2 in Pitch, 1.14 in Bore Dia	Orange	\$1.40	4	\$5.60	
Chain Drive	1" Flange Bearings	1" Flange Bearing: 1.57 in Bore, 1.57 in ID, 1.57 in OD, 0.5 in Width	Orange	\$22.25	2	\$44.50	
Chain Drive	1" Pillow Block	1" Pillow Block: 1.57 in Bore, 1.57 in ID, 1.57 in OD, 0.5 in Width	Orange	\$42.20	2	\$84.40	
Hydraulics	Hydraulic Manifold	Hydraulic Manifold		\$1.00	1	\$1.00	\$1.00
Hydraulics	4000 Hydraulic Log Splitter Pump	4000 Hydraulic Log Splitter Pump: 1.5 GPM (1000 PSI)		\$71.20	1	\$71.20	
Hydraulics	4000 Hydraulic Log Splitter Pump	4000 Hydraulic Log Splitter Pump: 1.5 GPM (1000 PSI)		\$71.20	1	\$71.20	
Hydraulics	Hydraulic Motor	Hydraulic Motor: 1/2 HP, 1.5 GPM (1000 PSI)	Bobby Hydrolics	\$48.75	1	\$48.75	\$48.75

\$1,101.00 Total
\$1,101.00 Budget

# PLC Program Design Concept



# PLC LADDER LOGIC

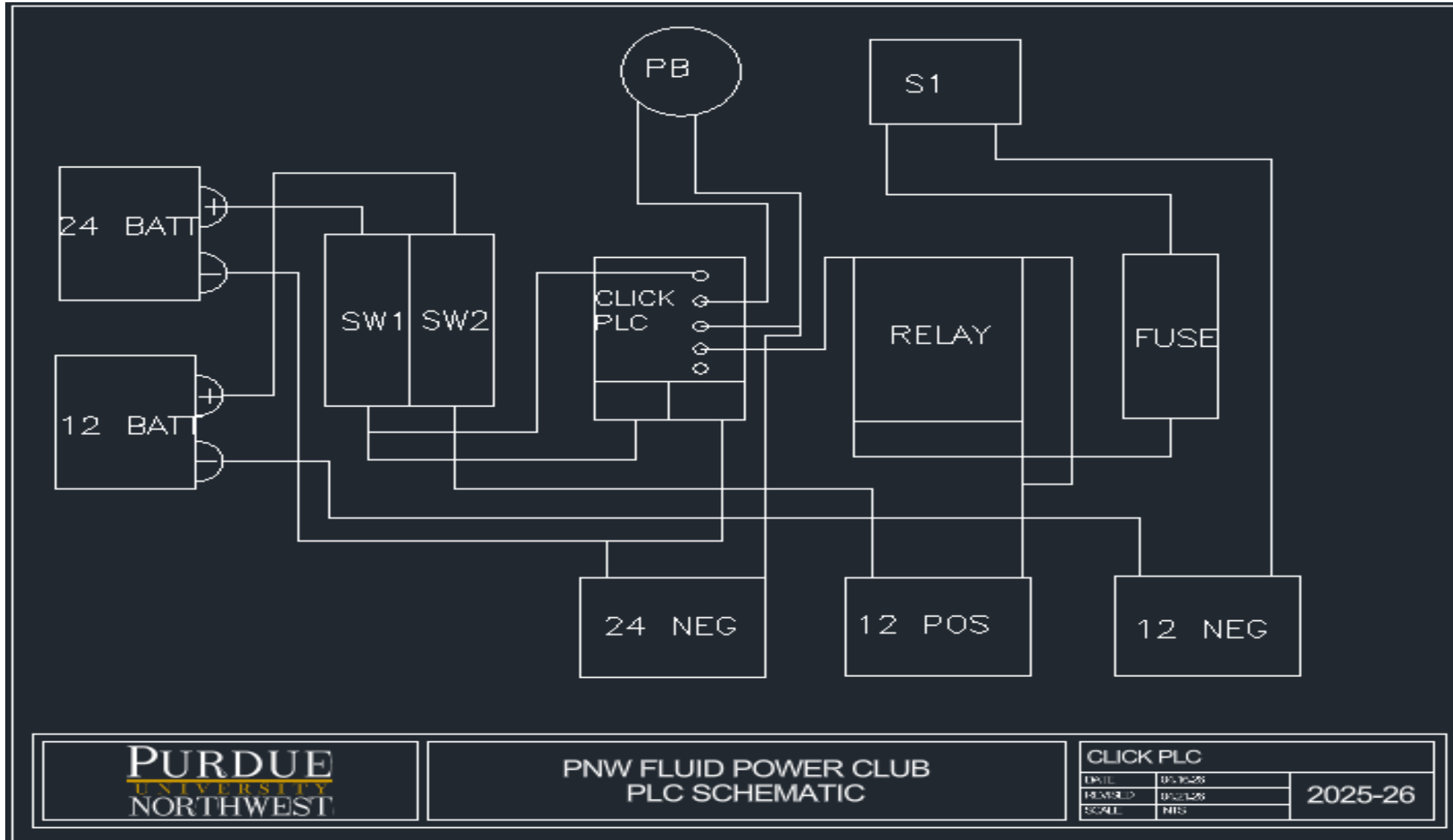


# PLC COMPONENT LIST

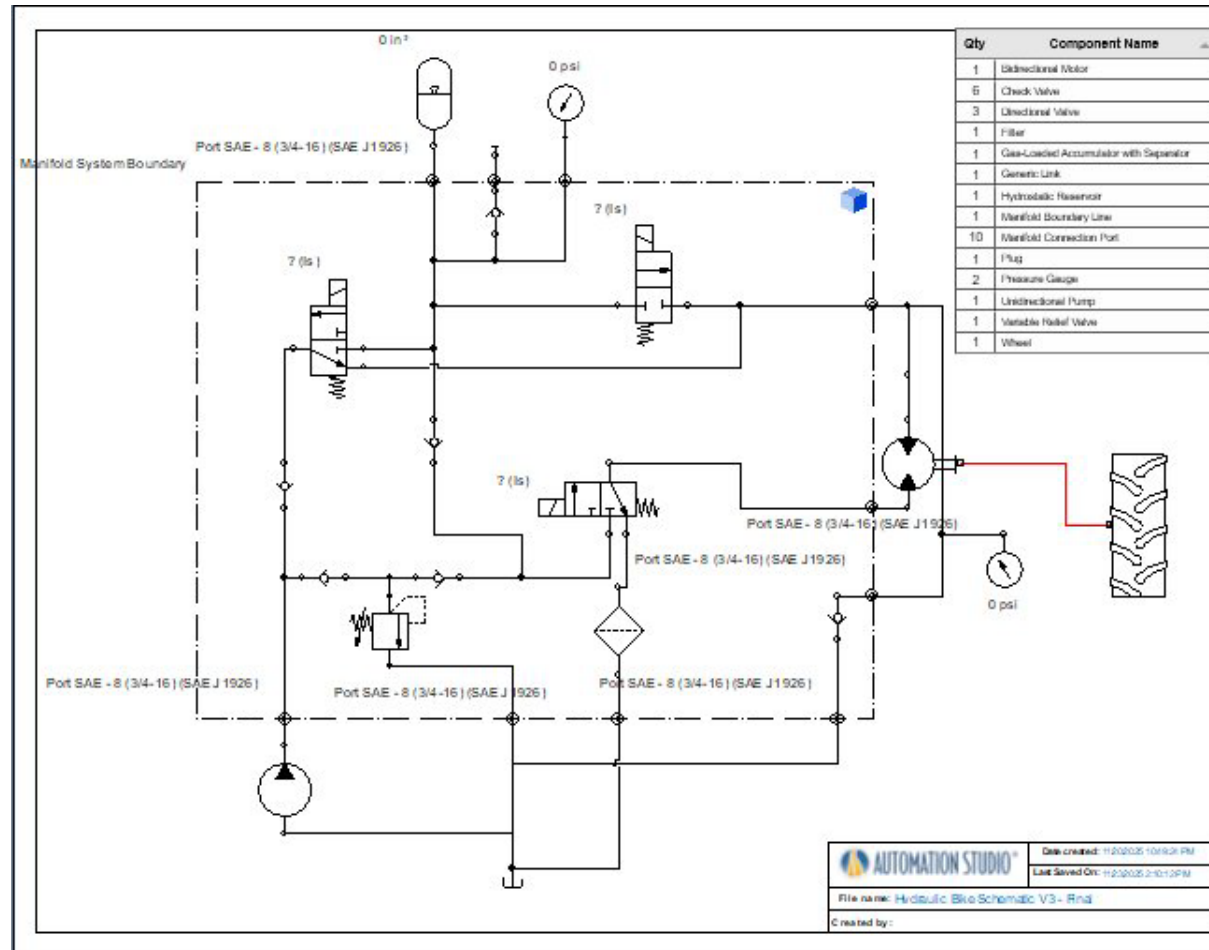


Component Name	Quantity	Vendor	PriceUnit	Website Link	Total
22 AWG Wire (Solid Core)	6-30ft wires	Amazon	\$15.49	<a href="#">Here</a>	15.49
Emergency Stop Button	1	Automation Direct	\$12	<a href="#">Here</a>	12
Pushbutton (Assorted)	8	Automation Direct	\$3	<a href="#">Here</a>	24
Switch Module??		Automation Direct	\$4.25	<a href="#">Here</a>	
Pneumatic PushButton?	2	Automation Direct	\$3	<a href="#">Here</a>	\$6
Wire Strippers	2	Automation Direct	\$12.50	<a href="#">Here</a>	\$25
Terminal Blocks (20ct)		Automation Direct	\$8.50	<a href="#">Here</a>	8.5
Terminal Plug (10pk) 3 Pole	1	Automation Direct	\$13	<a href="#">Here</a>	13
Multimeter Leads	1	Amazon	\$17	<a href="#">Here</a>	17
Bench Power Supply	1	Amazon	\$54	<a href="#">Here</a>	54
Programming Cable	1	Automation Direct	56	<a href="#">Here</a>	56
12 Volt Recharge Battery		Cabela's	\$19.99	<a href="#">Here</a>	\$40
					270.99

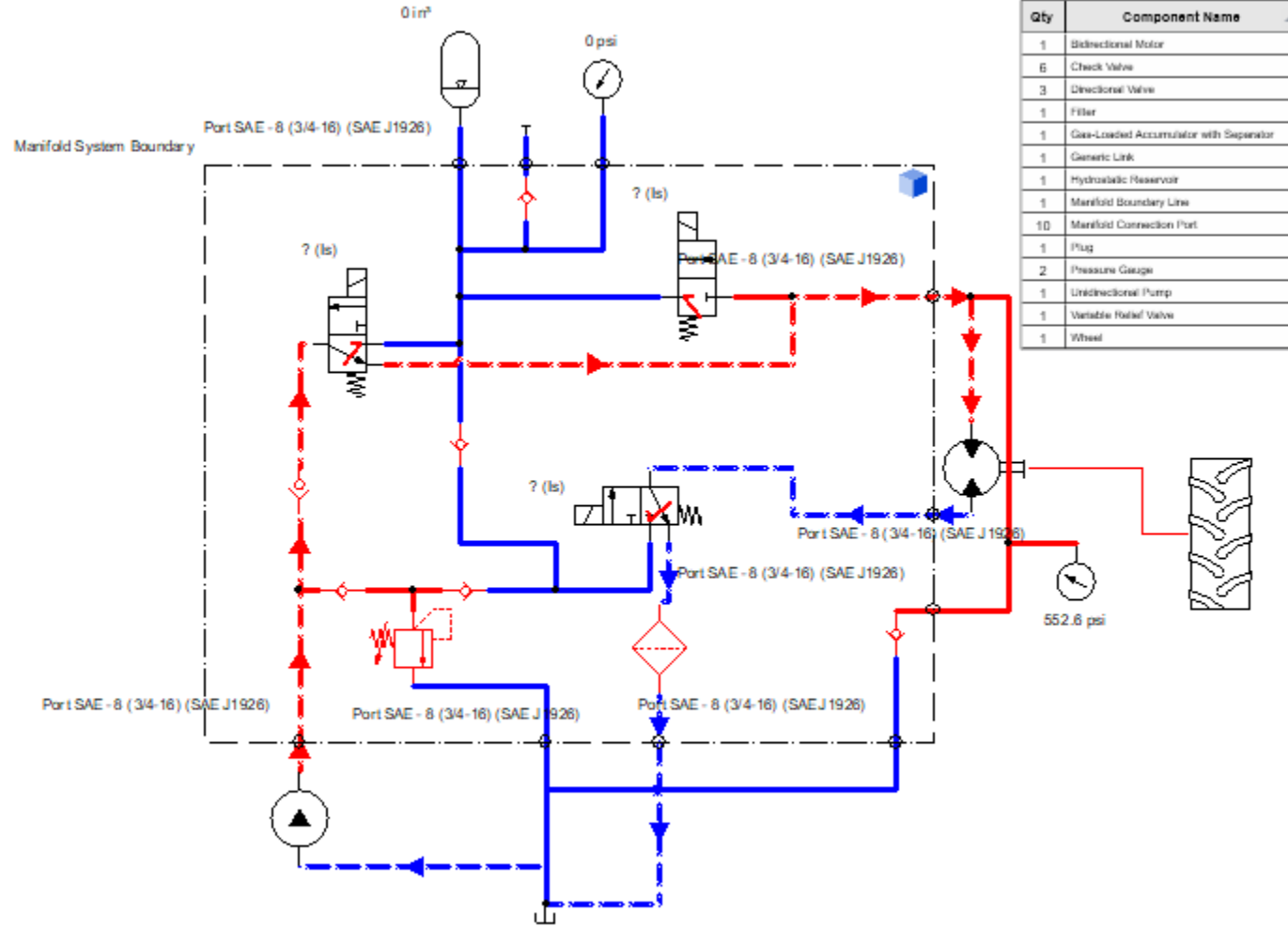
# PLC/ELECTRIC SCHEMATIC



# HYDRAULIC CIRCUIT DESIGN

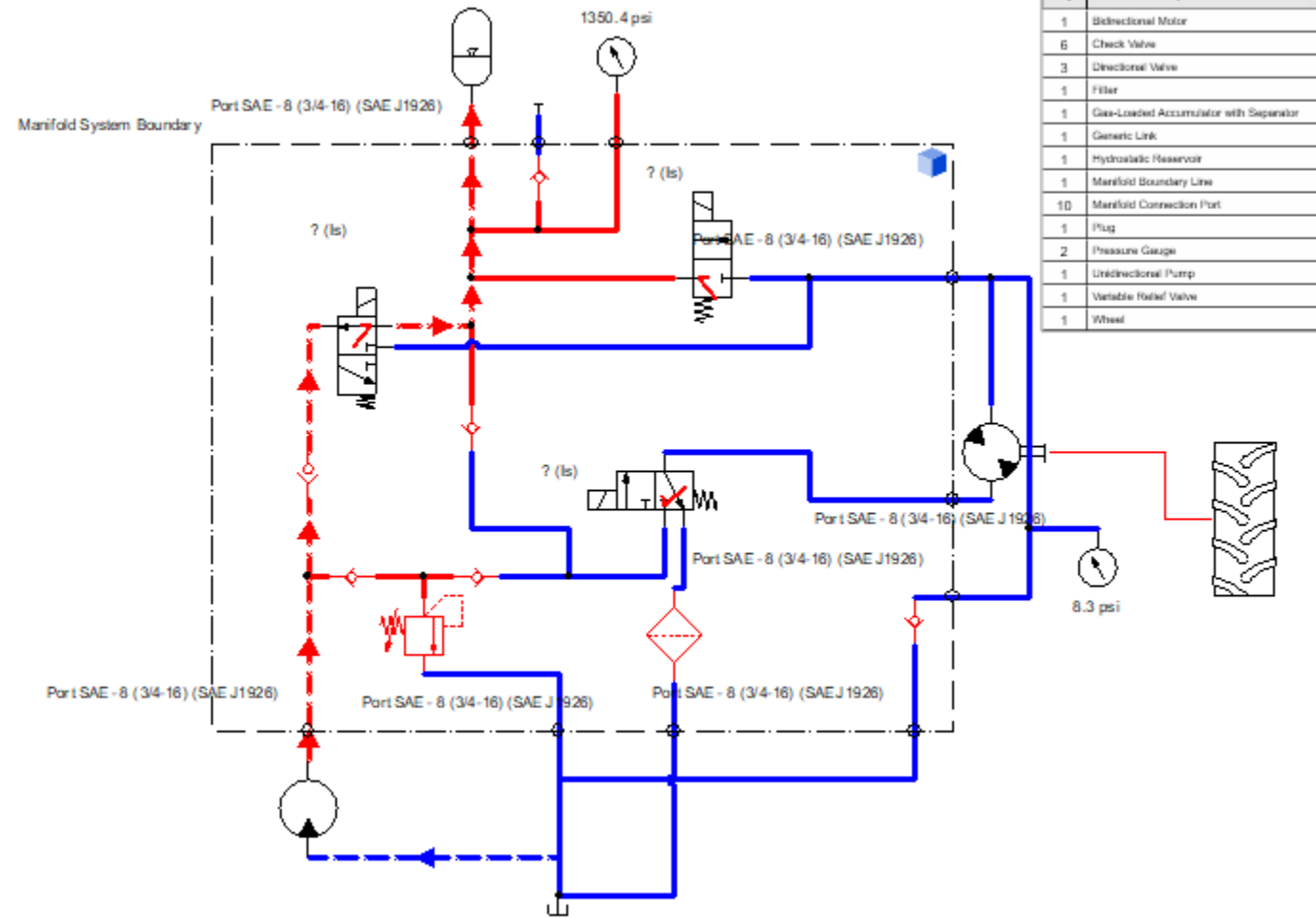


# DIRECT DRIVE CIRCUIT

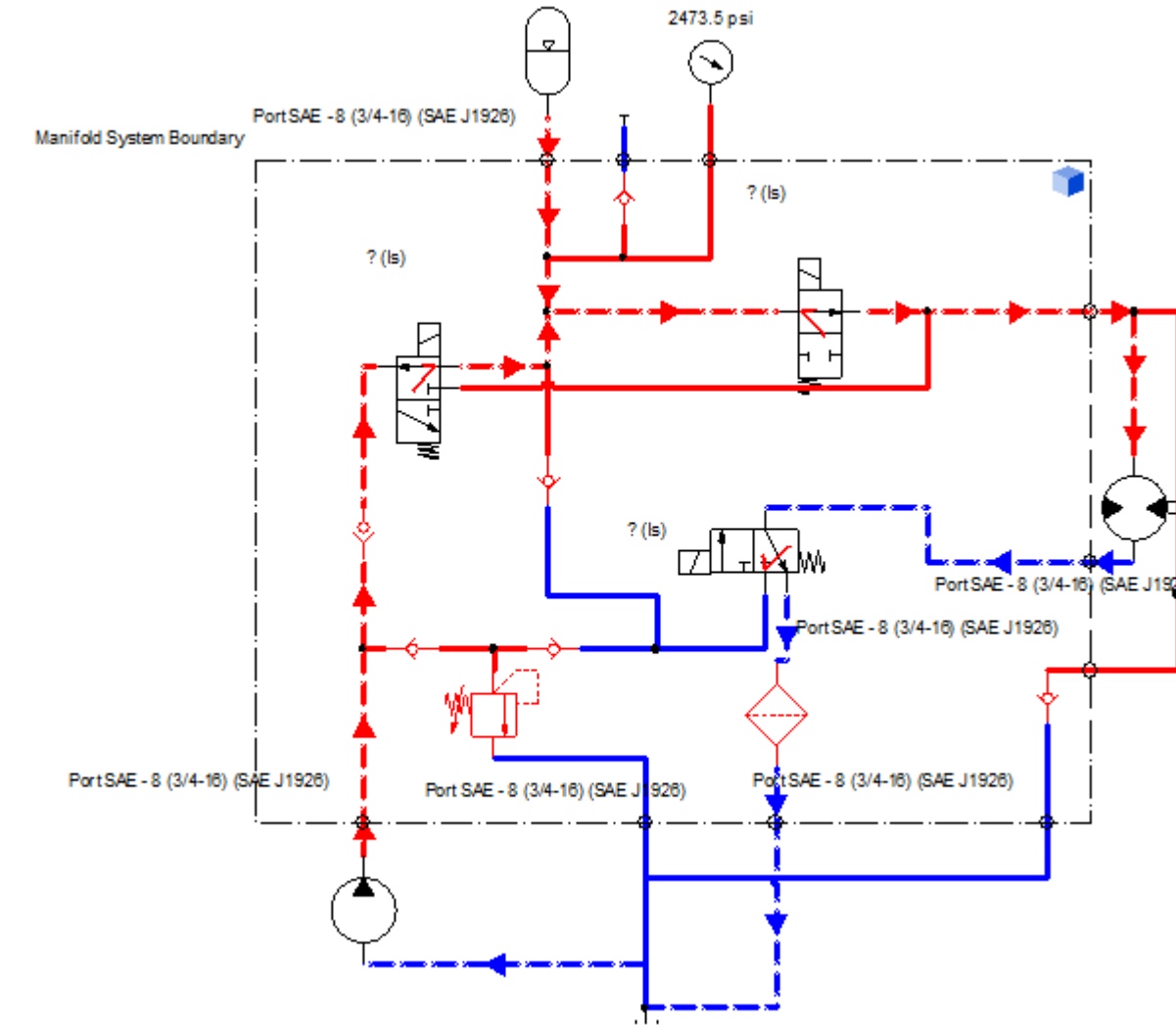


Qty	Component Name
1	Bidirectional Motor
6	Check Valve
3	Directional Valve
1	Filter
1	Gas-Loaded Accumulator with Separator
1	Generic Link
1	Hydraulic Reservoir
1	Manifold Boundary Line
10	Manifold Connection Port
1	Plug
2	Pressure Gauge
1	Unidirectional Pump
1	Variable Relief Valve
1	Wheel

# CHARGING CIRCUIT



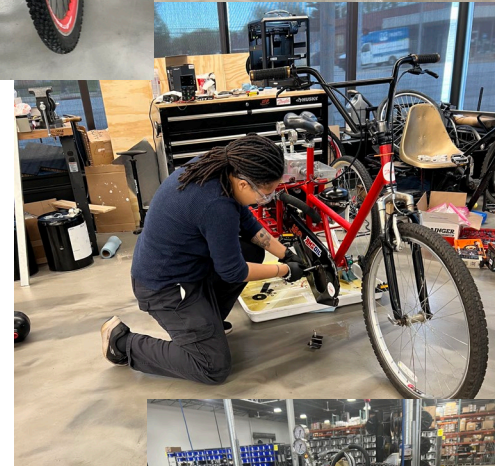
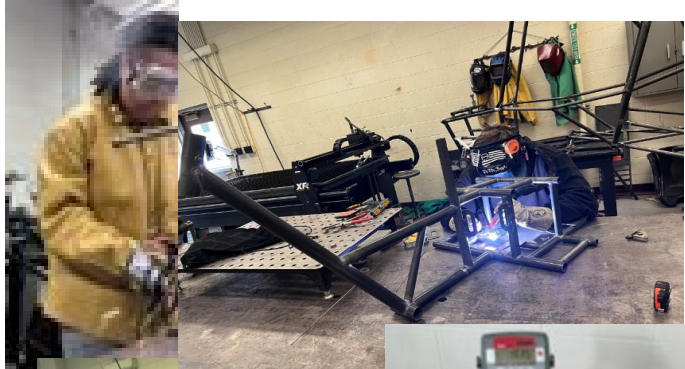
# BOOST CIRCUIT





# Fabrication & Assembly

10 YEARS  
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**Fluid Power**  
=VEHICLE  
**Challenge**



# Testing



- Chain Drive alignment & tolerance trials and tribulations
- Solenoid & schematic troubleshooting
- Leak detection

# Lessons Learned



- Future vehicle design should optimize for aluminum or structured polymer outside of steel for less weight
- Testing hydraulic system for most efficient fluid flow in manifold, accumulator charge, pressure gauges, etc.
- Improve stable communication and project management with future designs when accessing inventory



THANK YOU!!