NFPA Fluid Power VEHICLE Challenge

NFPA Education and Technology Foundation

Purdue Northwest University
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Grant Noll
Date: 4/26/2024

PURDUE UNIVERSITY NORTHWEST

The 2024 PNW Fluid Power Vehicle Team

<u>The President</u>

- Samuel Torres

<u>Vice President/Treasurer</u>

- Diego Jimenez

<u>Secretary</u>

- Sajedul Robin

<u>Designers/Members</u>

- Enoc Gutierrez
- Adam Hayman
- Mitchell McKendry
- Jordan Lefchak
- Elizabeth Cortes

NPFA Competition

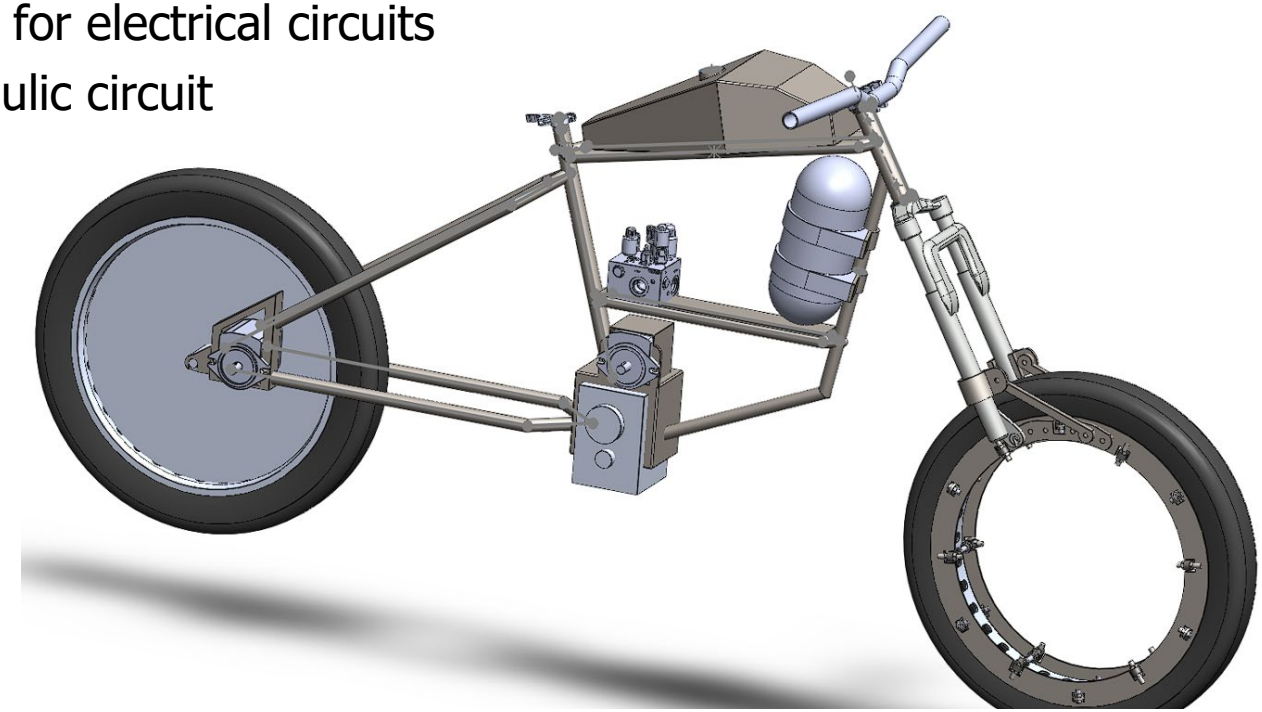
- Danfoss Headquarters in Ames, Iowa
- The Challenges
  - Regenerative breaking
  - Sprint race
  - Endurance
  - Efficiency

Deliverables

- Hydraulic circuit
- Pneumatically actuated automatic transmission
- Custom two wheeled bicycle frame
- Custom reservoir
- Spokeless gear driven wheels
- PLC and HMI
- 3D printed airless tires

Design Specifications

- 300 RPM in the Pump
- Achieves a speed of 10mph
- Max Bike weight <210lbs
- Use of 24V battery for electrical circuits
- Max 3000psi hydraulic circuit



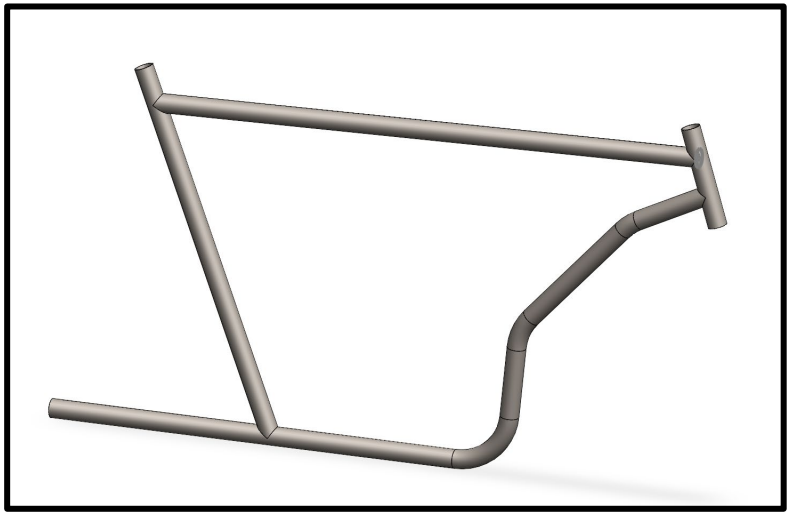
The Chassis

The old bike design and what we learned.

- The size
- Manual Transmission
- Positions
- Wheel design
- Chassis
- Hydraulics

The New Vehicle design

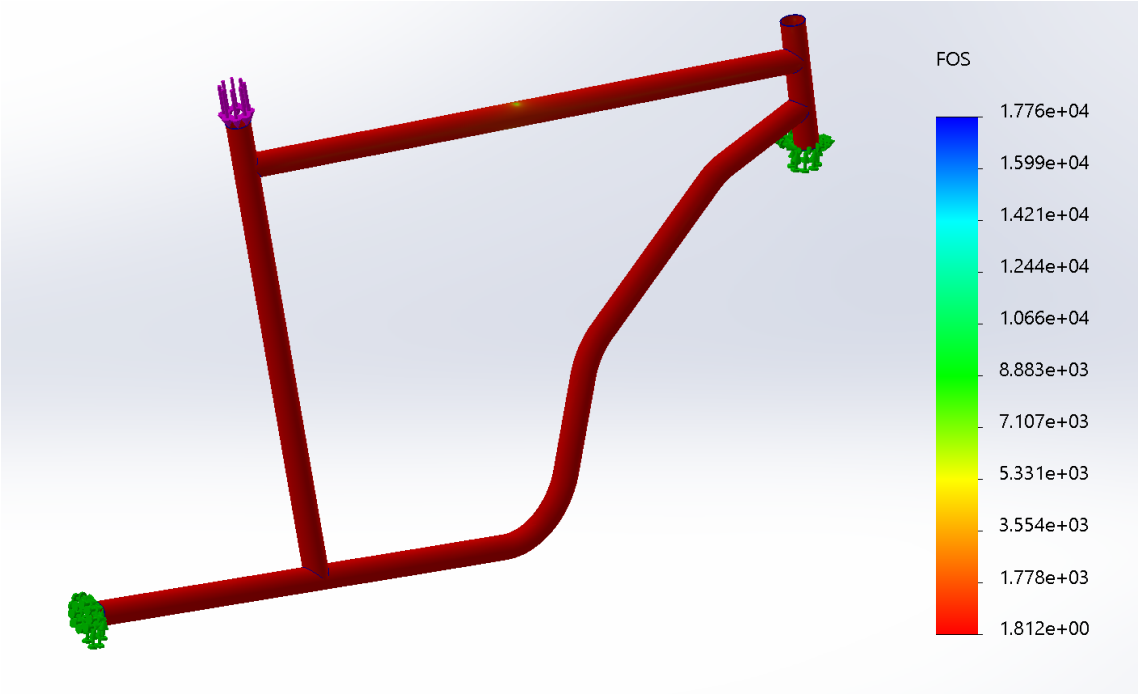
- The Hydraulic Spokeless wheel Automatic Transmission Vehicle (Hydro S.W.A.T).
- More Classic Design



The Chassis

Factor of Safety

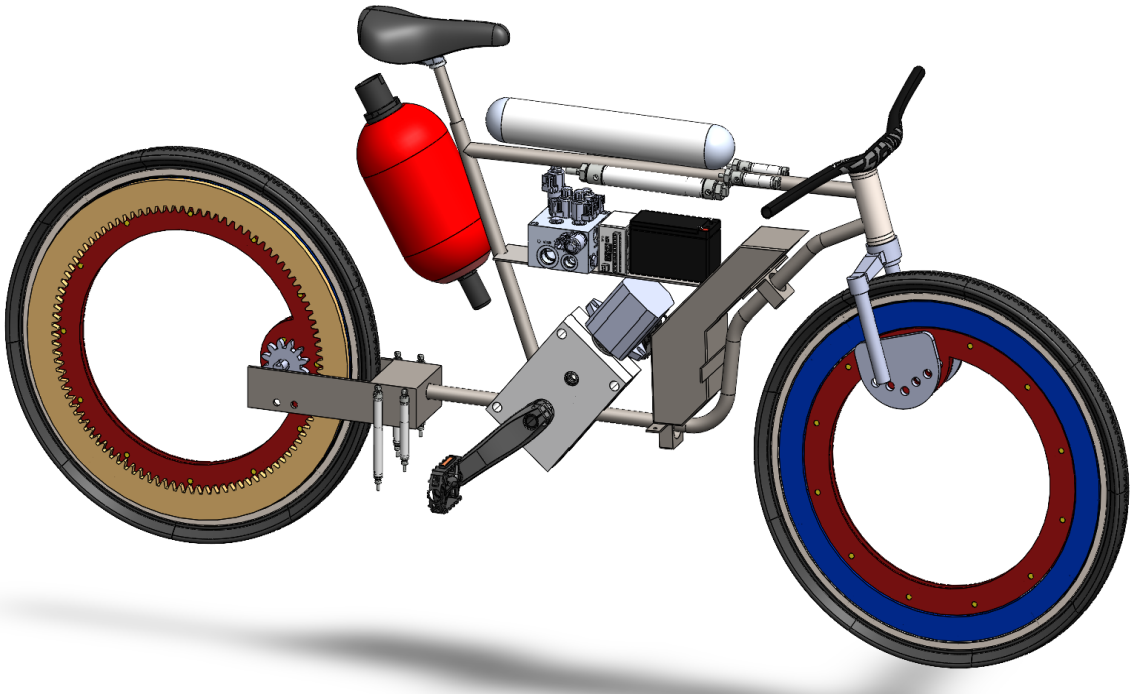
- At 250lbs: FOS = 1.9
- At 500lbs: FOS = 1
- Previous frame had issues in steerer tube.



The Chassis

New Look!

- Reduced length
- Custom Made
- Unique Wheels
- Compact Design
- Lower Center of Gravity
- Improved Steering



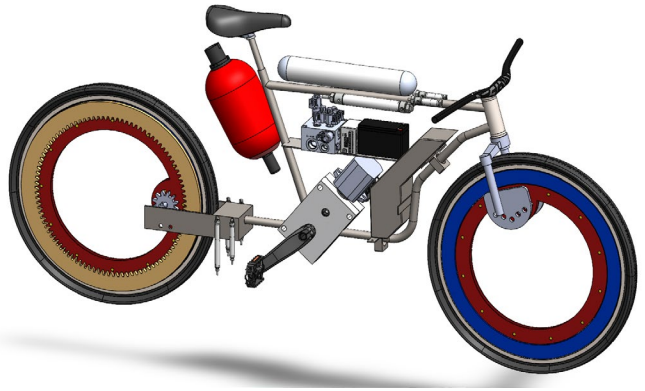
The Chassis Calculations

Weight	Acceleration (ft^2/min) @20sec	Velocity needed (ft/s)	Rolling Resistance (Ff)	Moment (lb)	Torque needed to Accelerate (lb*ft)	Estimated Vehicle (MPH)
500	.88	17.6	47.59	61.24	66.7	15.0

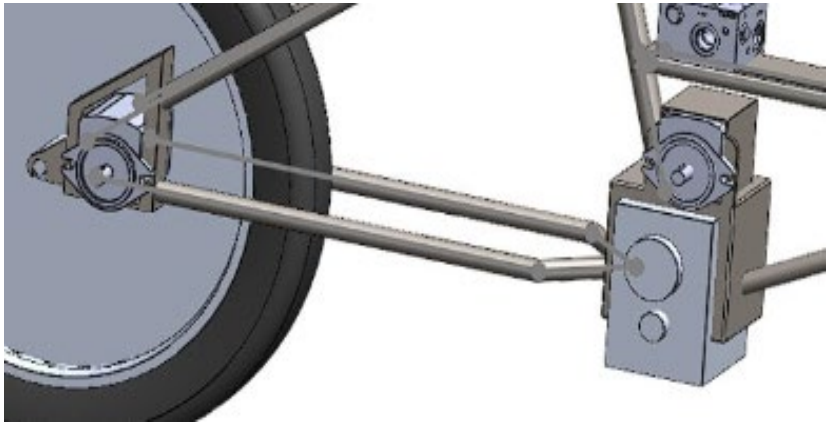
Estimated Velocity of the Wheel (RPM)	Estimated Rotational Mechanical Power (HP)
194	1.09

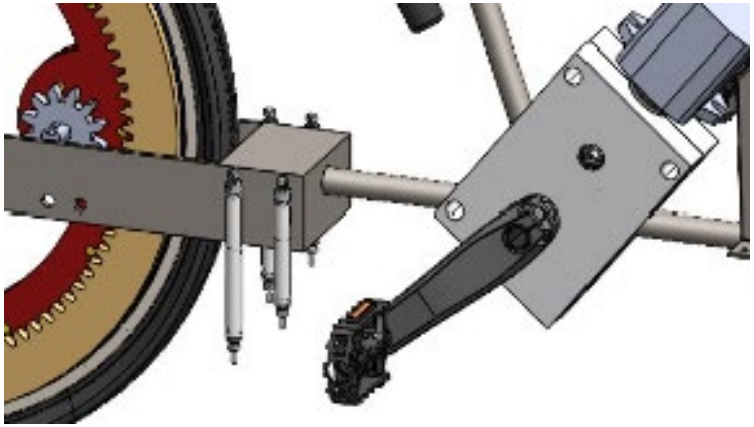
Given:

- 500 lbs
- Distance 600 ft of track
- Desired Speed: 15 mph
- Time we want to achieve the speed: 20 sec
- Diameter of wheel: 27 in



Safety





<u>The old bike design and what we learned.</u>

- Exposed gears
- Loose parts
- Dead Space

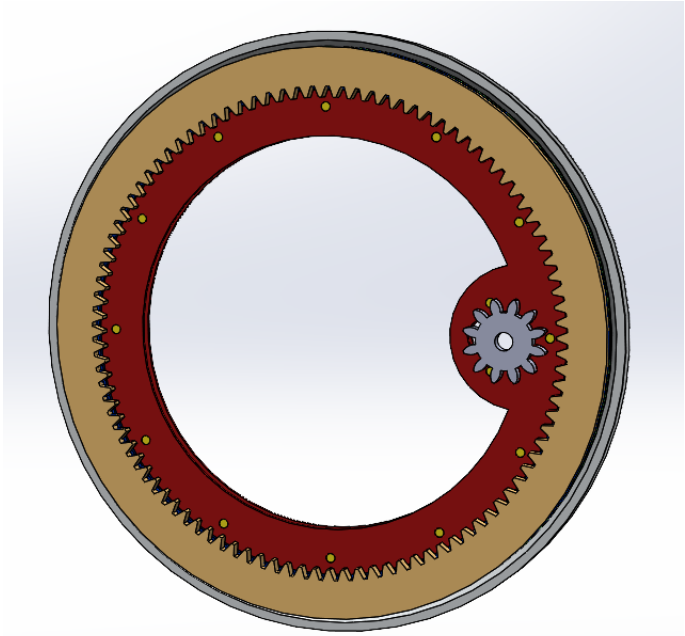
<u>The New Bike Design</u>

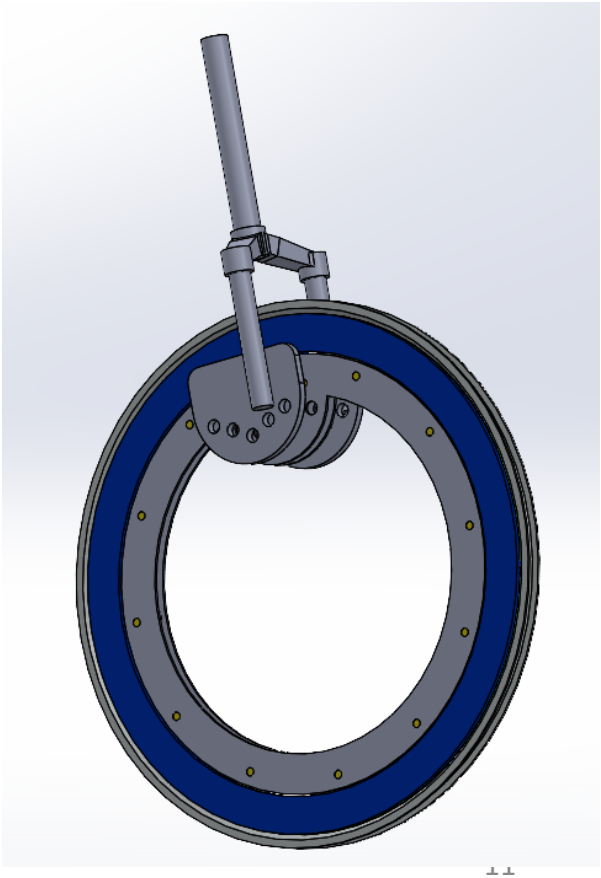
- Less Exposure
- More Screws and Welds
- Cleaner Look

The Spokeless Wheel and Rear Drive Design

- The previous spokeless wheel
- Double the friction

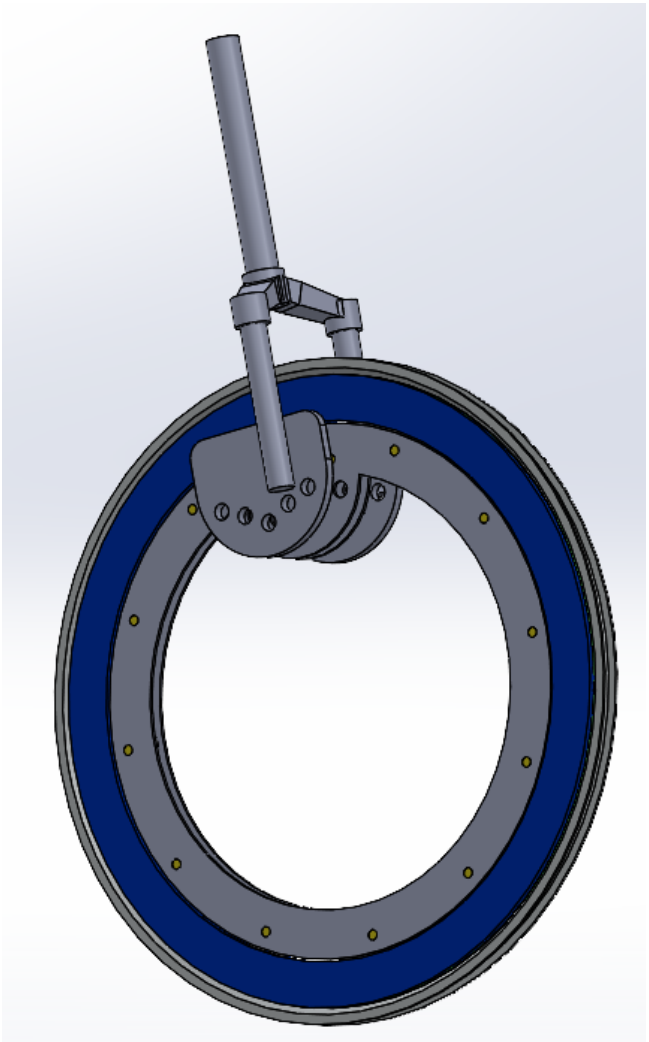
- The New spokeless wheels
- Now adding back wheel spokeless drive

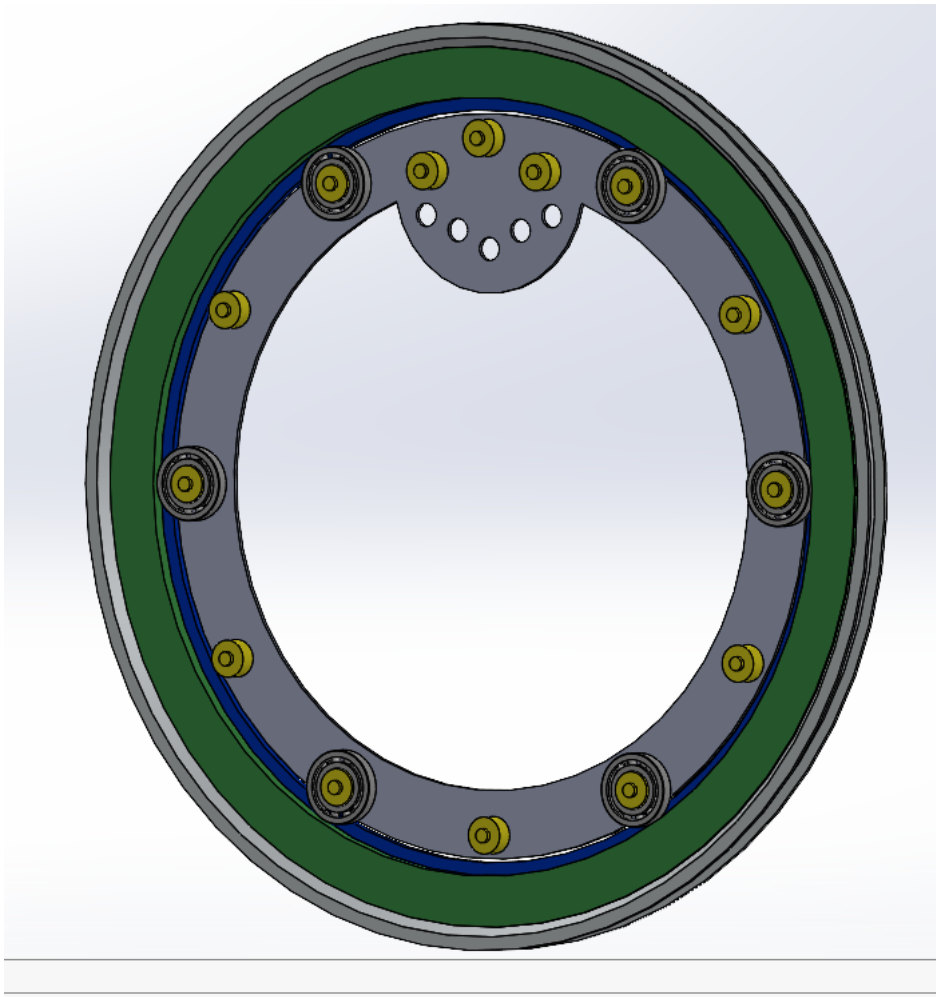




Front Wheel

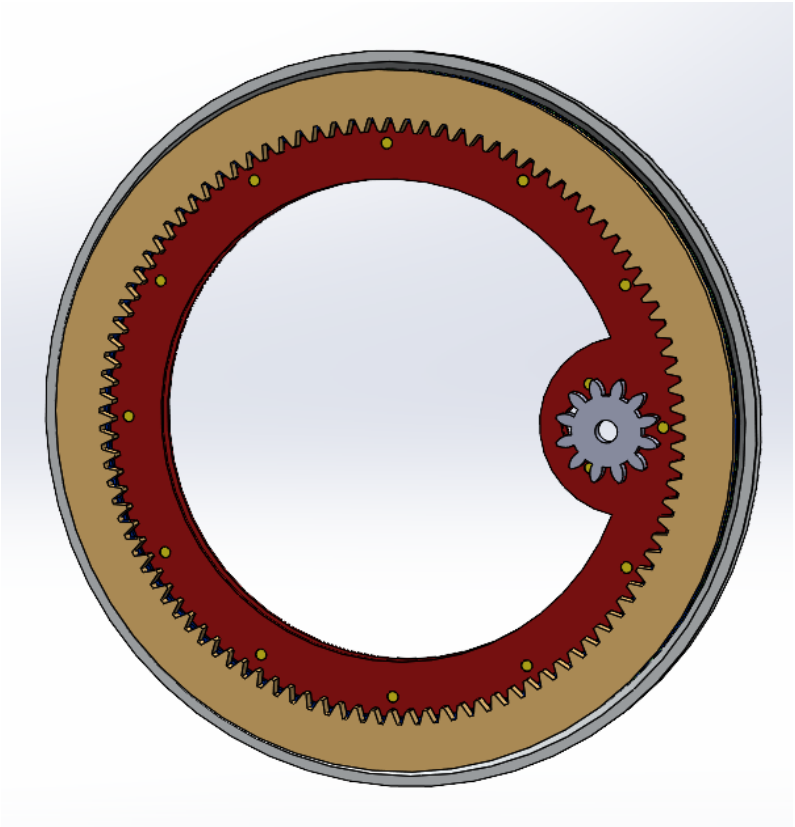
- Custom build frames
- New design with improvements



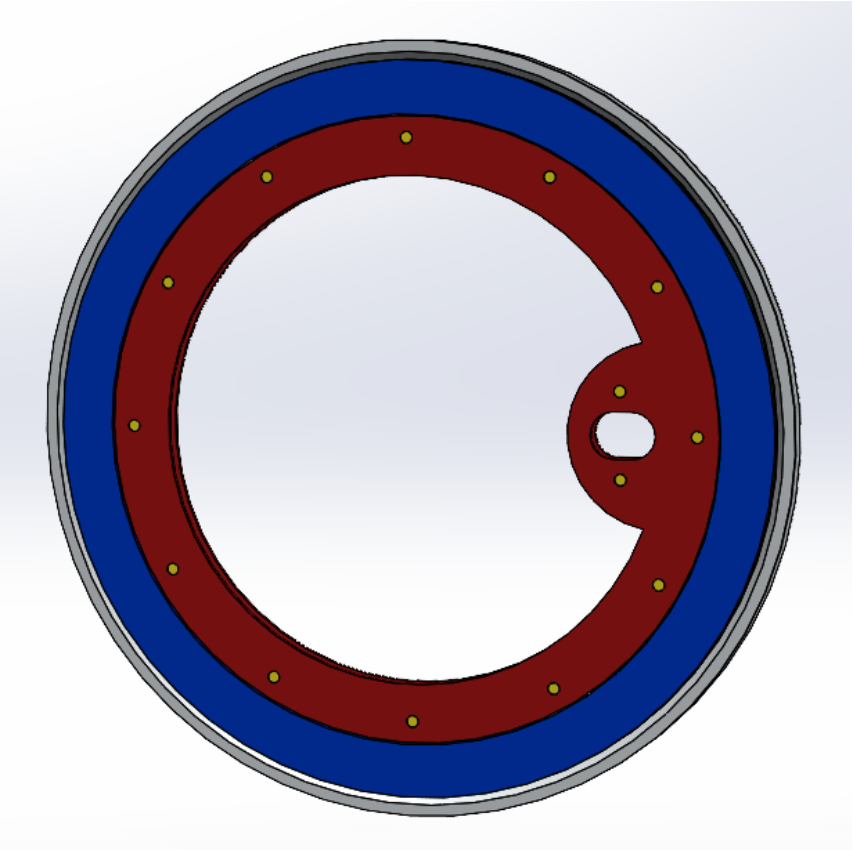


Back Wheel Drive

- With gears
- Gears connected with the rim.

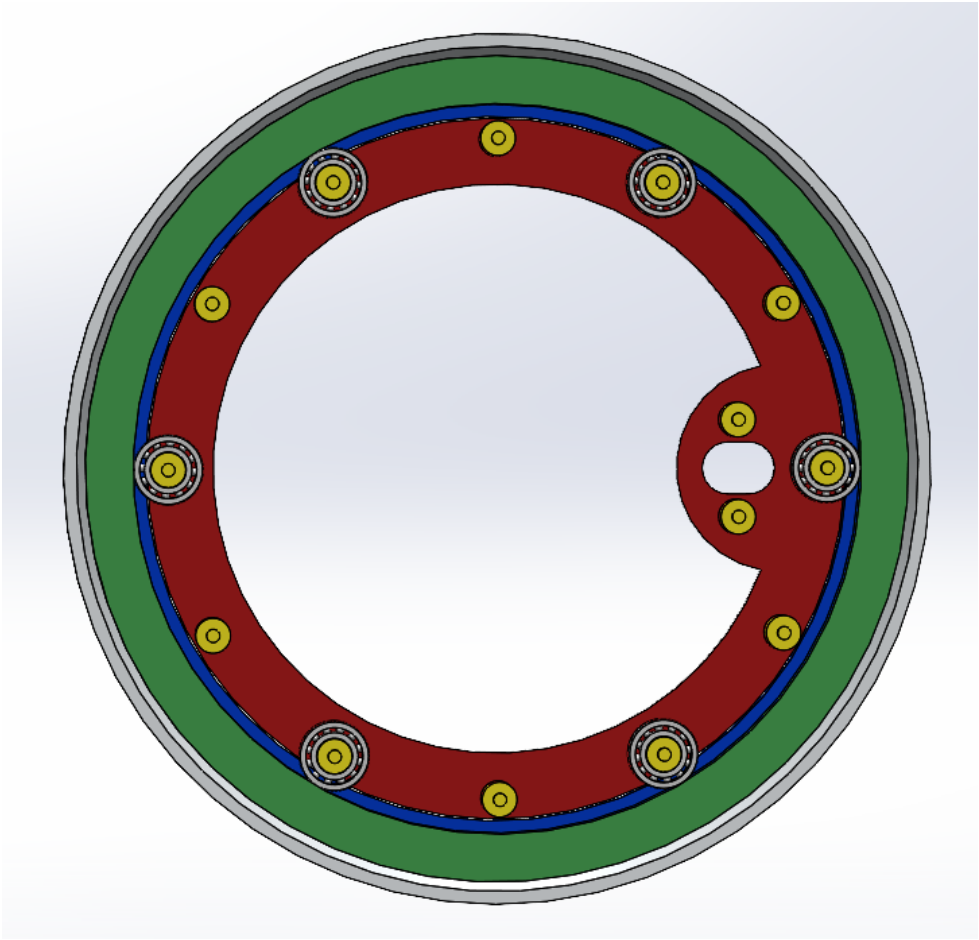


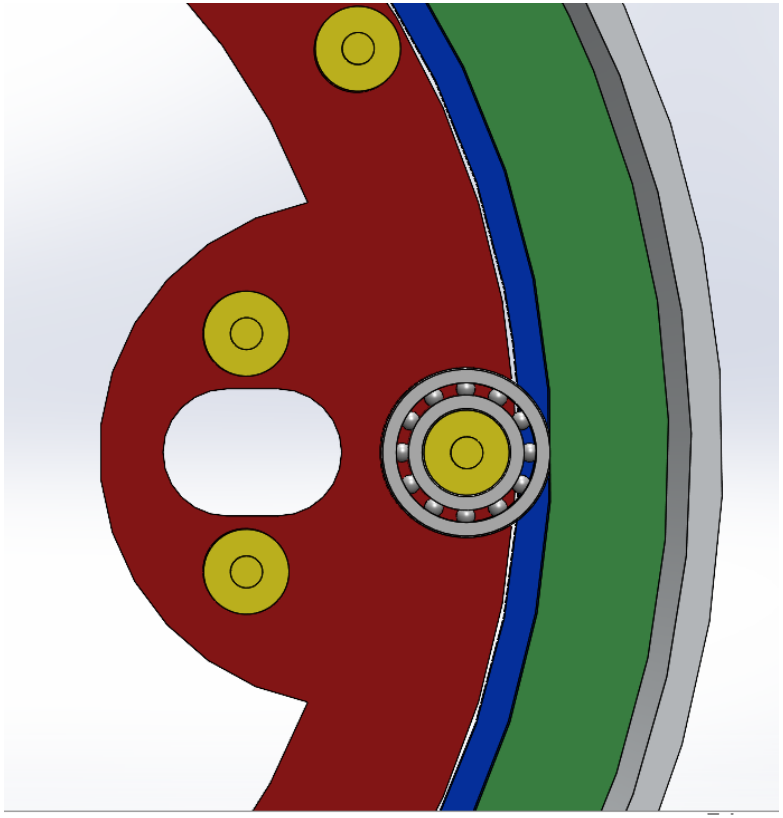
- Without gears
- The inner red frame is fixed.



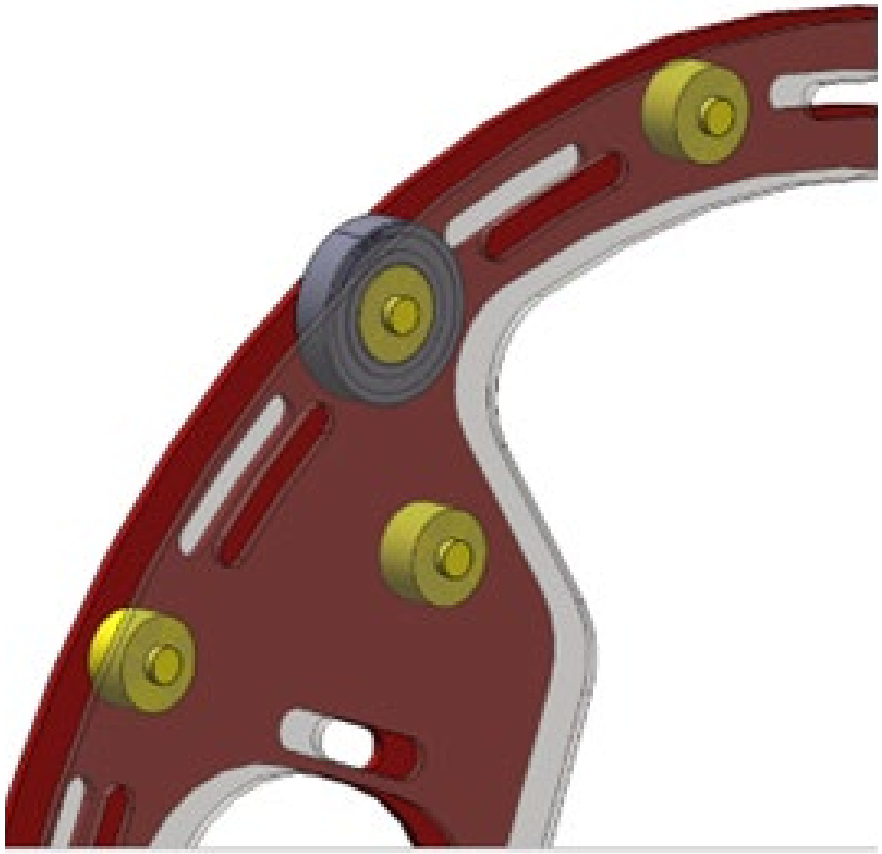
Back Wheel Bearing

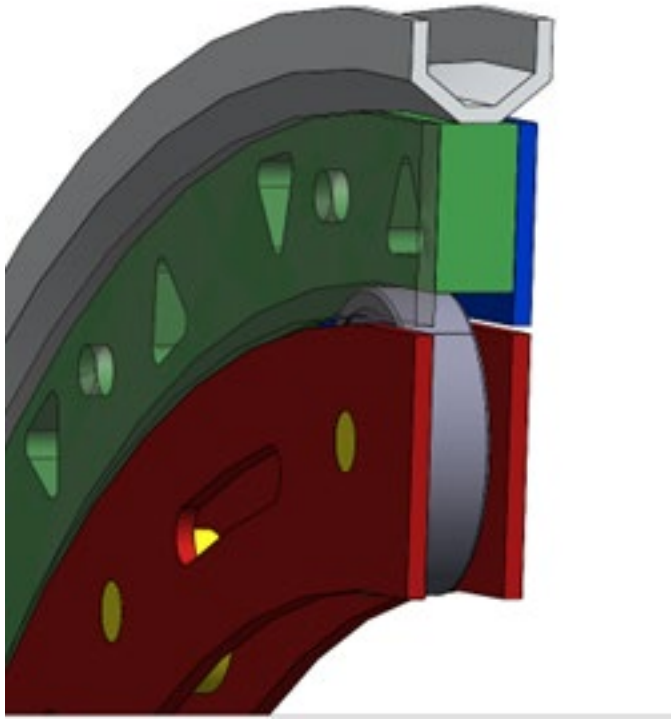
- Bearing are rotating the outer wheel frame and rim





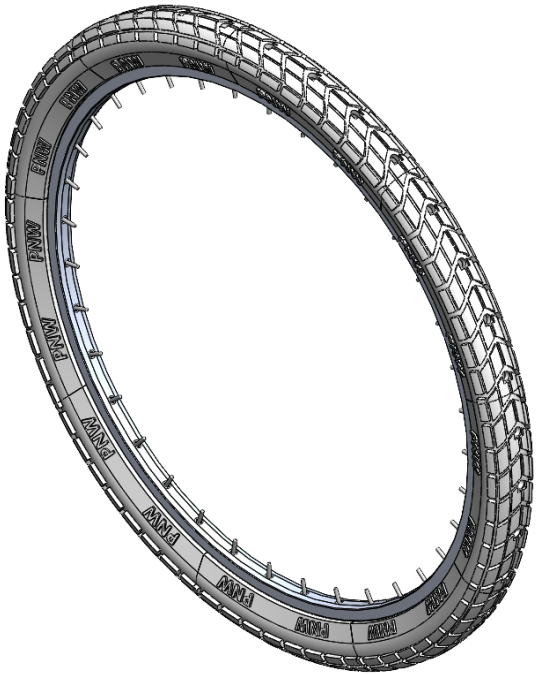
Back Wheel Bearing



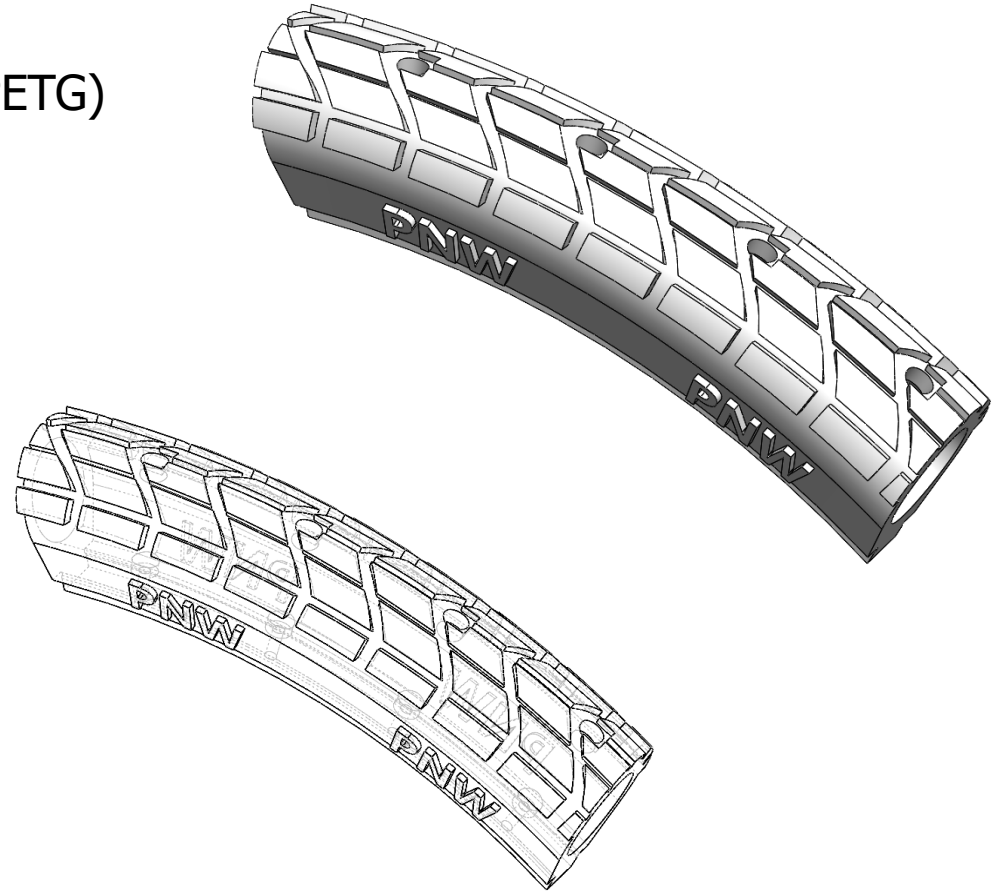


Airless Tires

- Thermoplastic Polyurethane (TPU)
- Polyethylene Terephthalate glycol (PETG)
- Sealed with liquid rubber

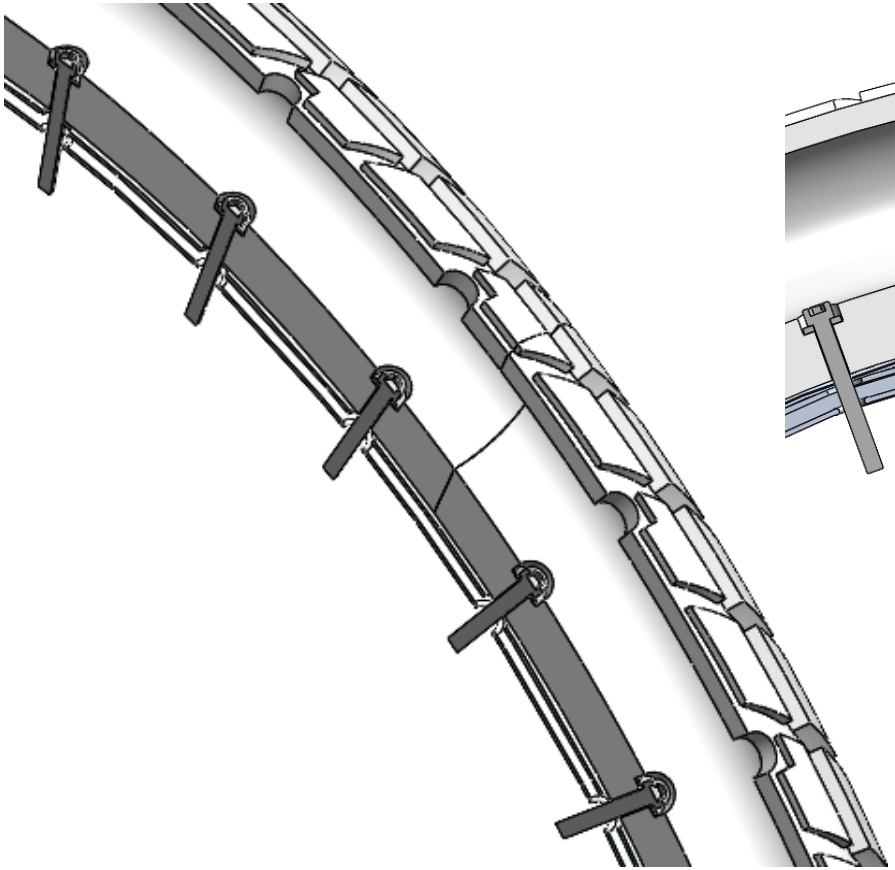


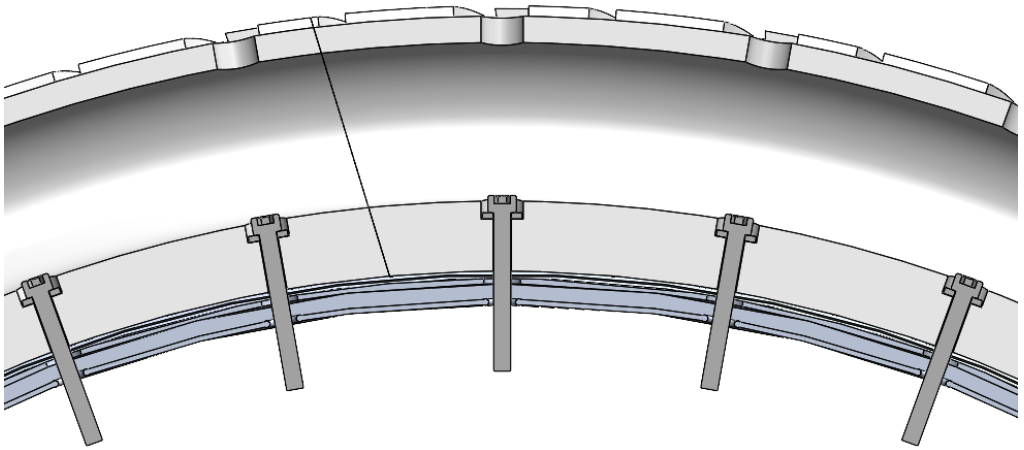
Assembled



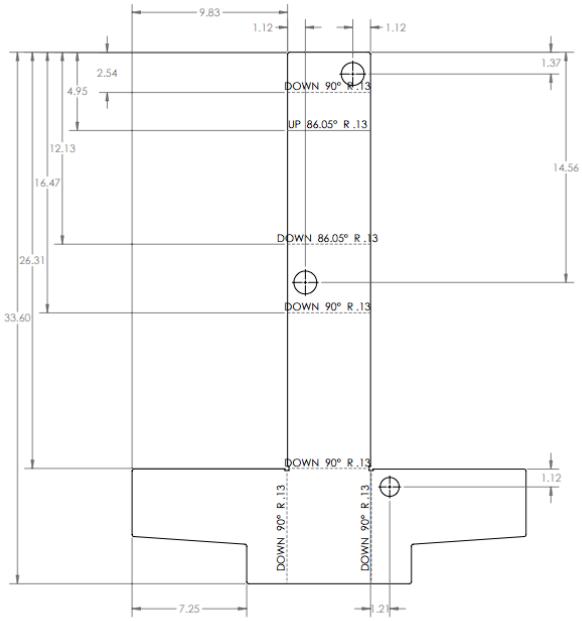
Single Section

Cross Section/ Hardware

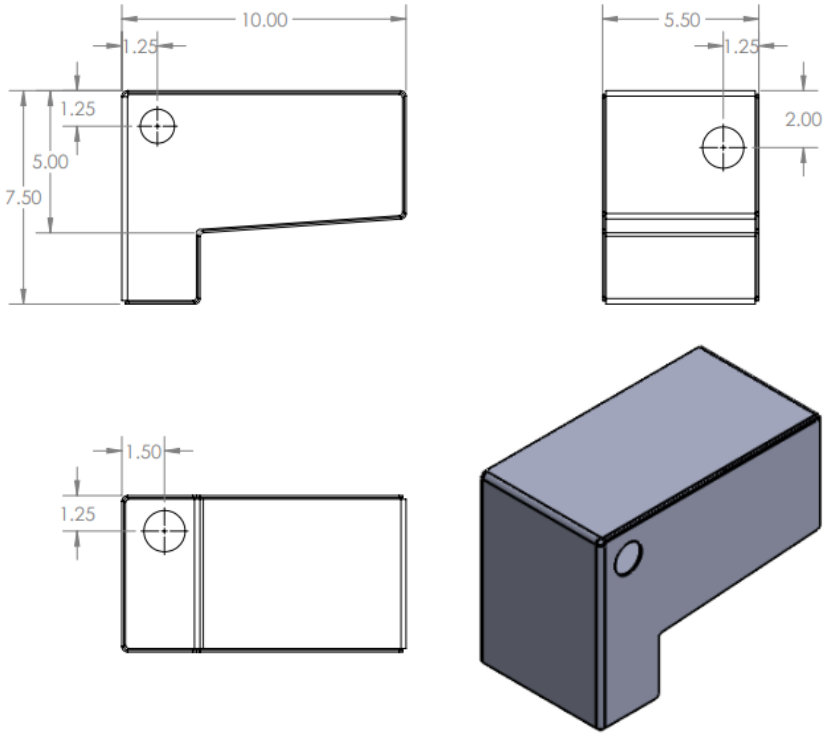




Reservoir



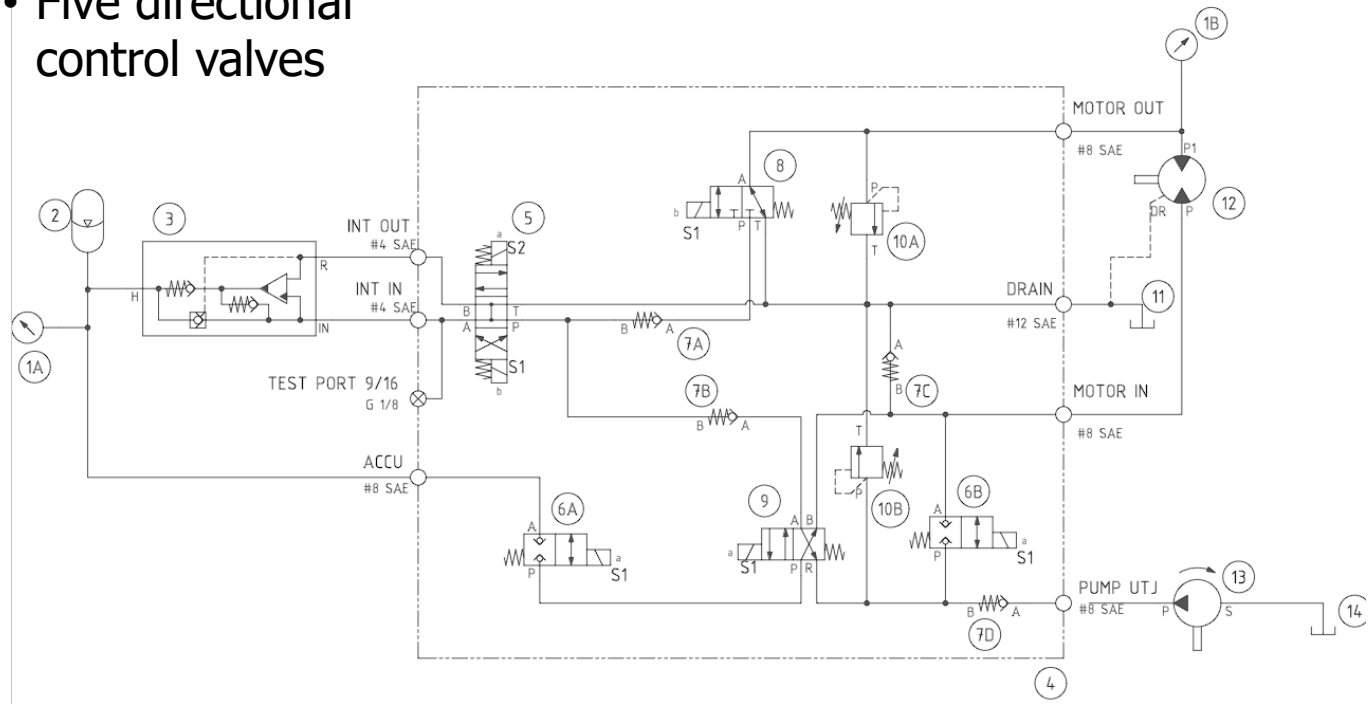
Open Sheet Metal Model



- Closed Sheet Metal Model
- 16-gauge A36

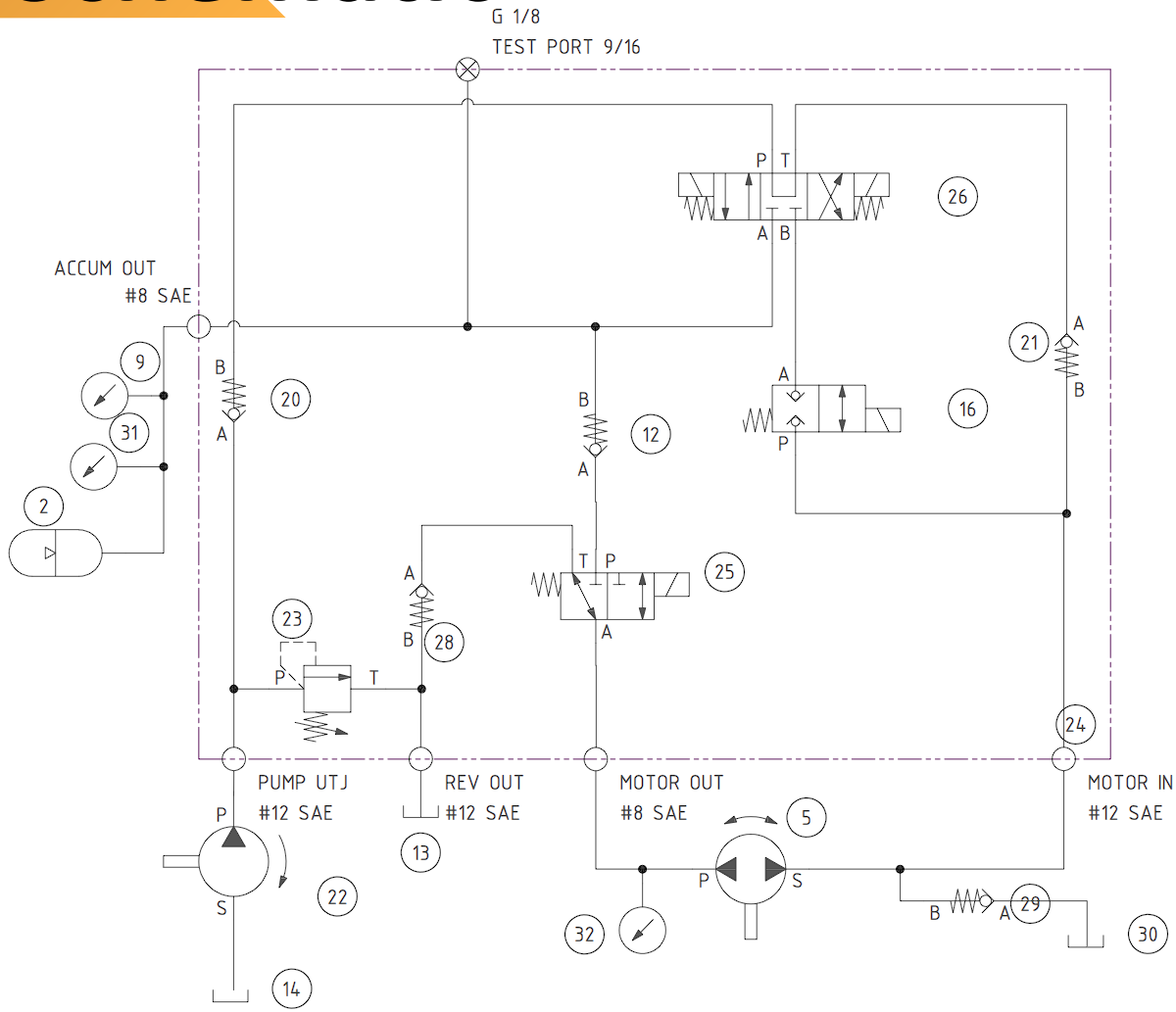
Hydraulic Schematic

- Hydraulic Intensifier is now added
- 3000 PSI
- Five directional control valves

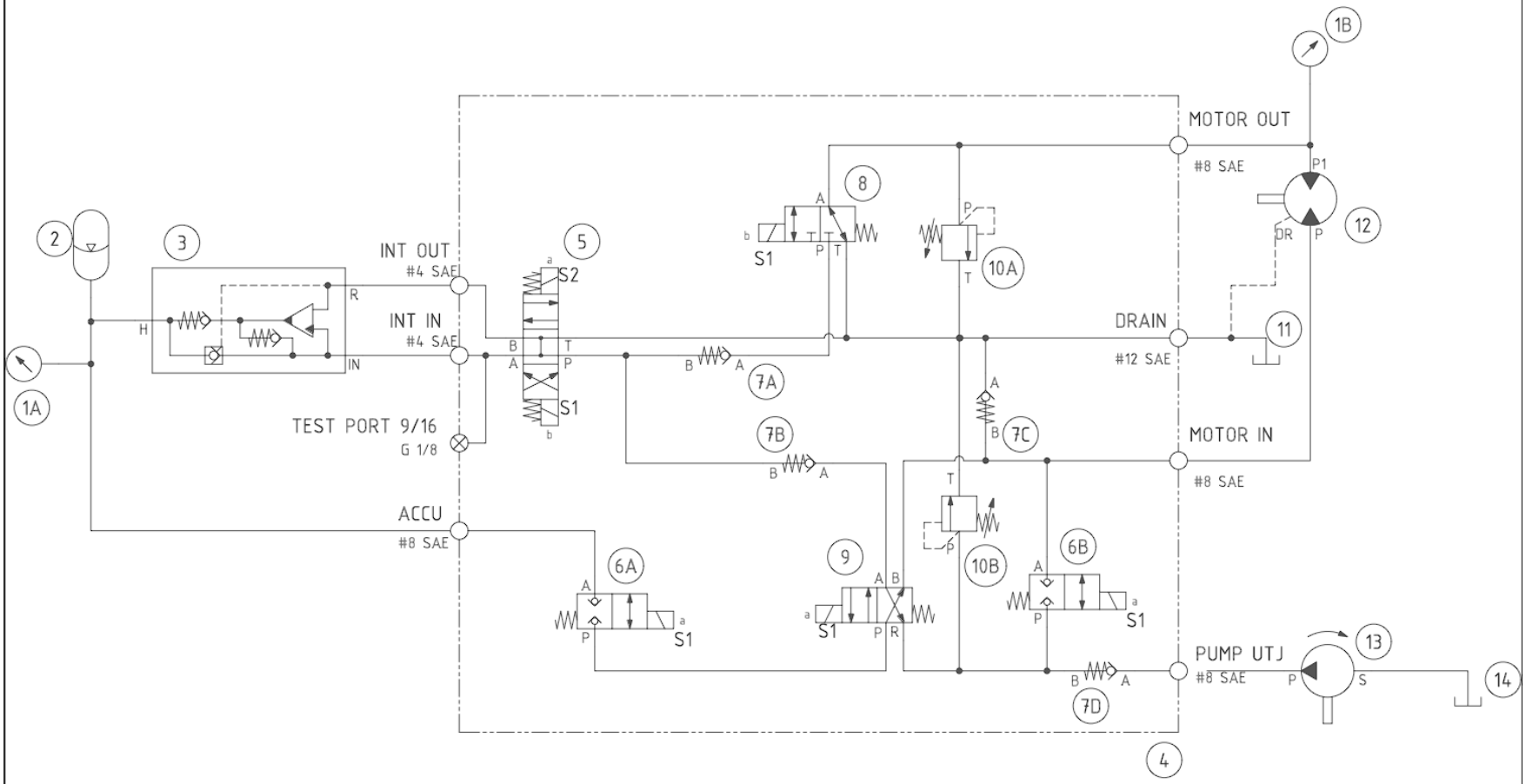


Previous Year Hydraulic Schematic

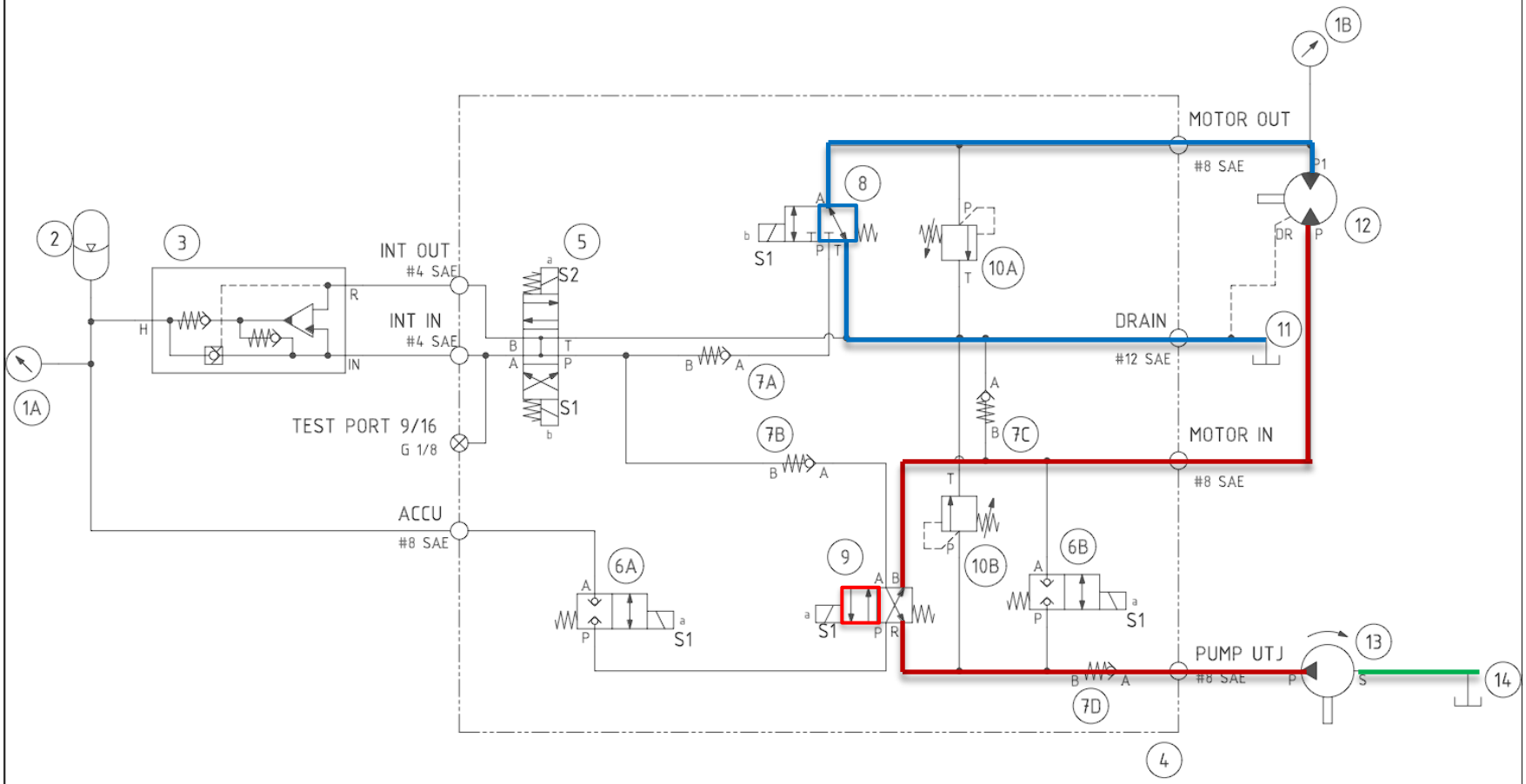
- Bleed from accumulator.
- Difficult to build pressure



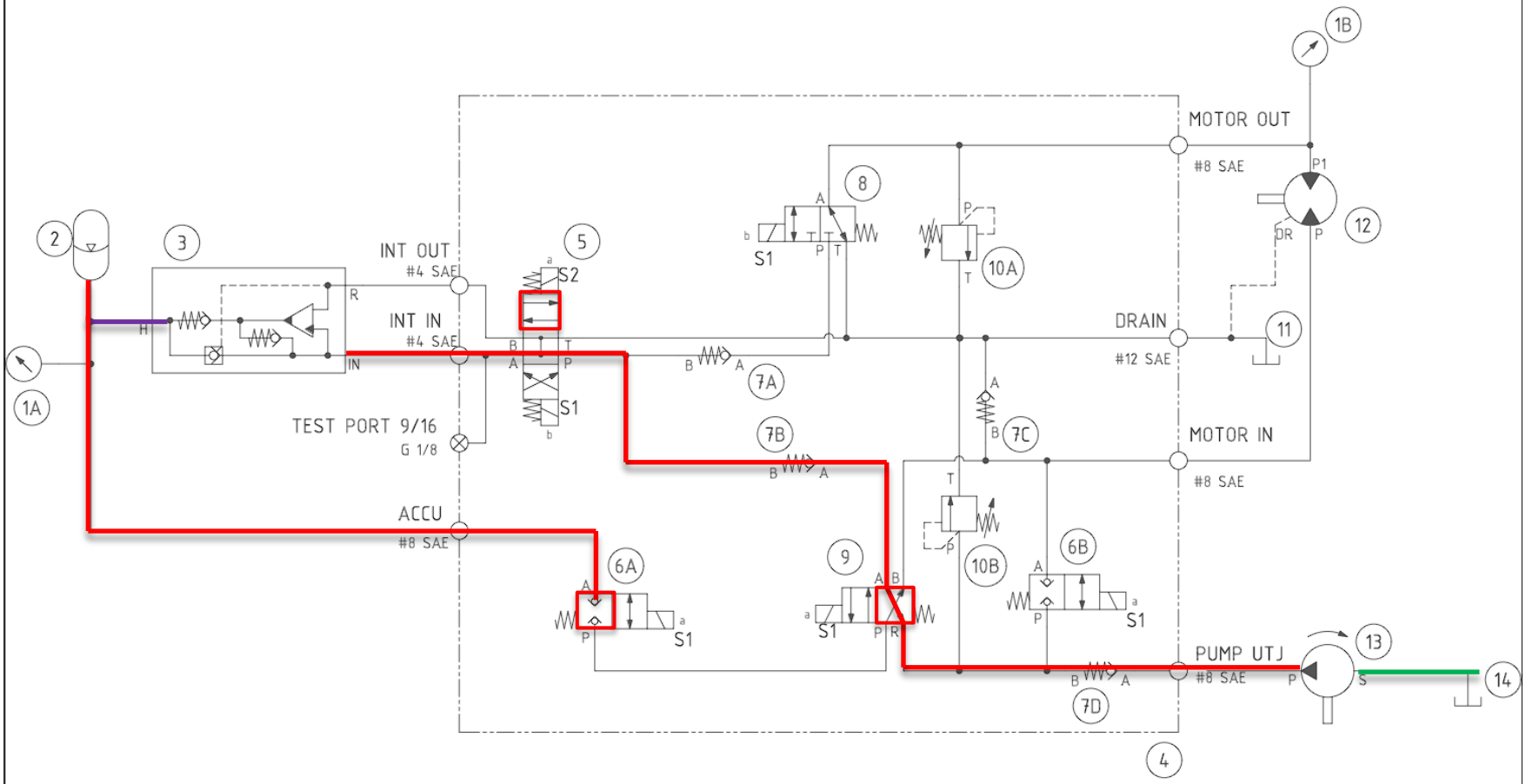
Hydraulic Schematic



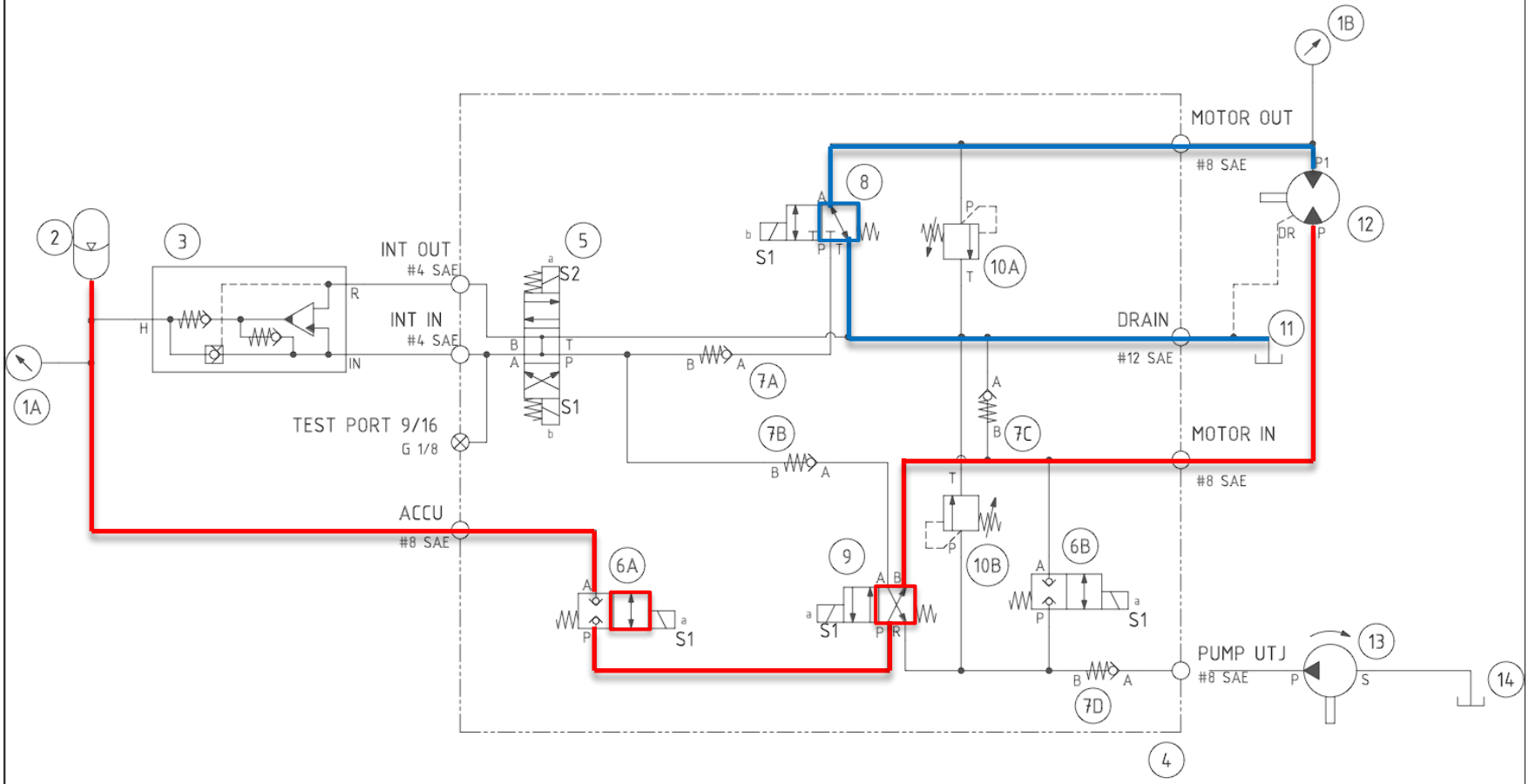
Neutral


1B
MOTOR OUT
#8 SAE
P1
12
DR
P
8
A
P
T
S1
10A
T
DRAIN
#12 SAE
11
2
3
INT OUT
#4 SAE
5
S2
R
H
INT IN
#4 SAE
IN
B
A
T
P
S1
7A
1A
TEST PORT 9/16
G 1/8
7B
7C
MOTOR IN
#8 SAE
ACCU
#8 SAE
6A
9
10B
6B
S1
S1
S1
PUMP UTJ
#8 SAE
13
14
7D
4

Charge


1A
1B
2
3
4
5
6A
6B
7A
7B
7C
7D
8
9
10A
10B
11
12
13
14
INT OUT
#4 SAE
INT IN
#4 SAE
TEST PORT 9/16
G 1/8
ACCU
#8 SAE
MOTOR OUT
#8 SAE
DRAIN
#12 SAE
MOTOR IN
#8 SAE
PUMP UTJ
#8 SAE
S1
S2
P1
DR
IN
R
H

Discharge


1B
MOTOR OUT
#8 SAE
P1
12
DR
P
8
A
P
T
S1
10A
T
DRAIN
#12 SAE
11
2
3
INT OUT
#4 SAE
5
S2
INT IN
#4 SAE
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1A
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7A
B
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TEST PORT 9/16
G 1/8
7B
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7C
MOTOR IN
#8 SAE
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10B
ACCU
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6A
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S1
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S1
PUMP UTJ
#8 SAE
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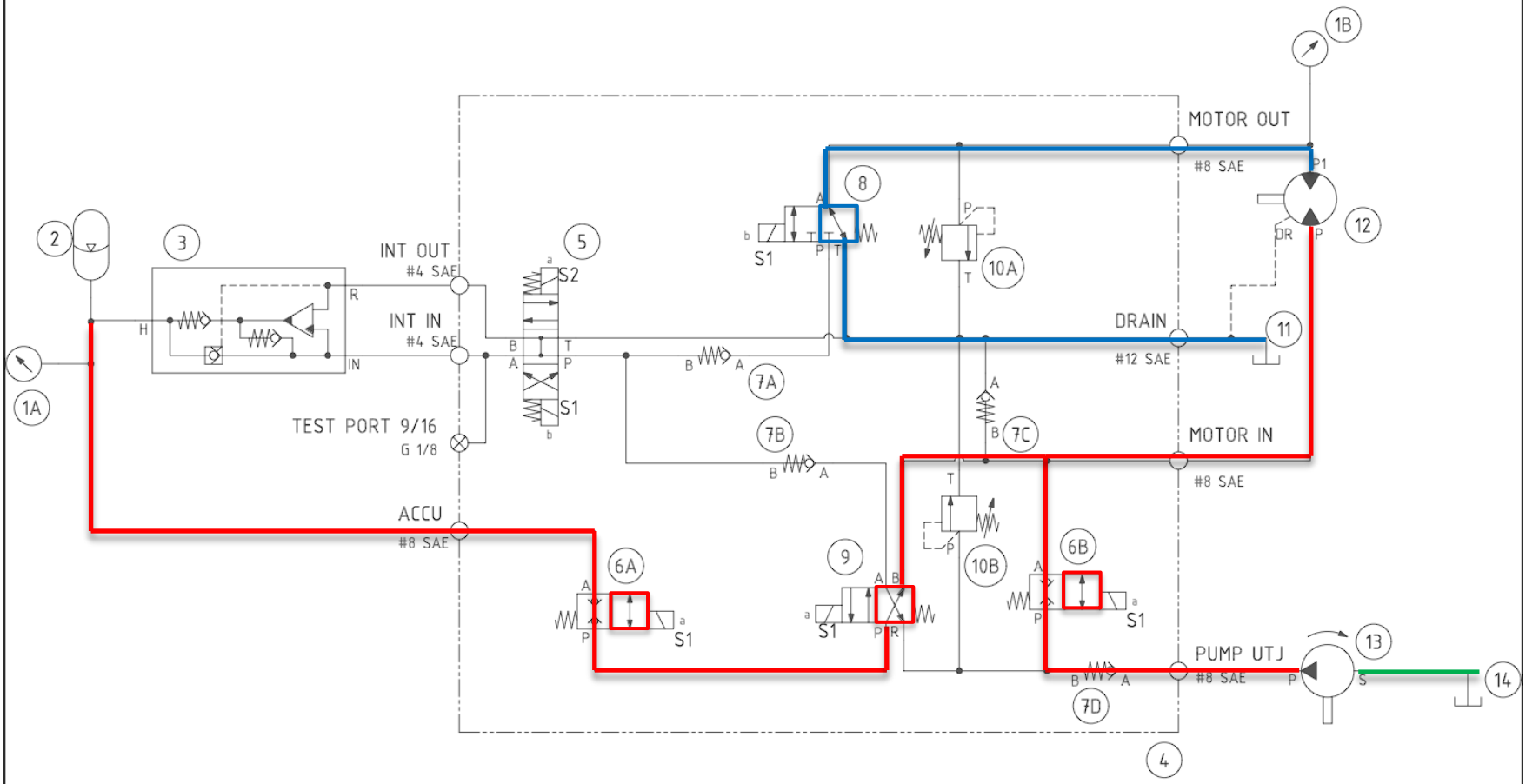
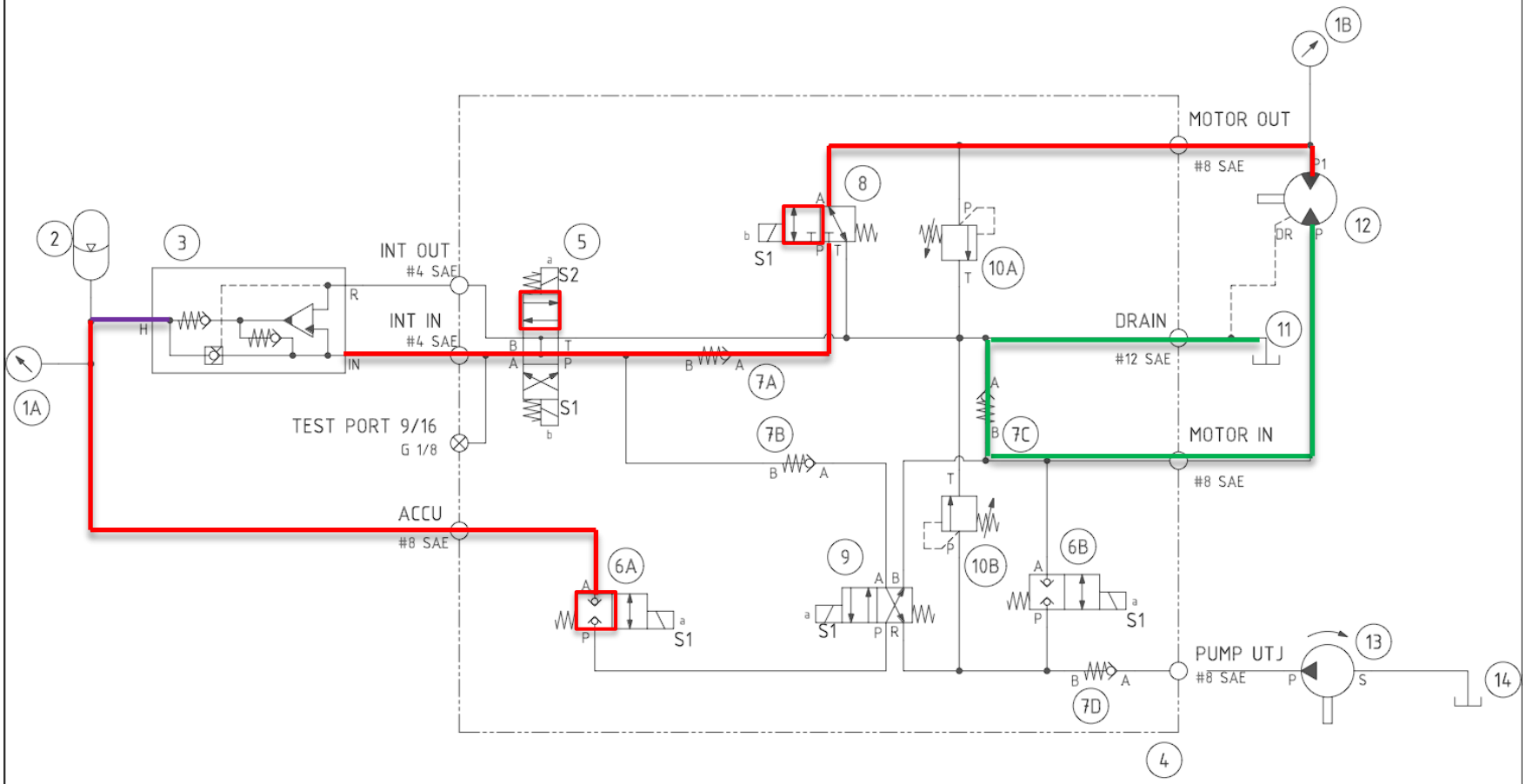
7D
4

Overdrive Neutral



Regenerative Braking



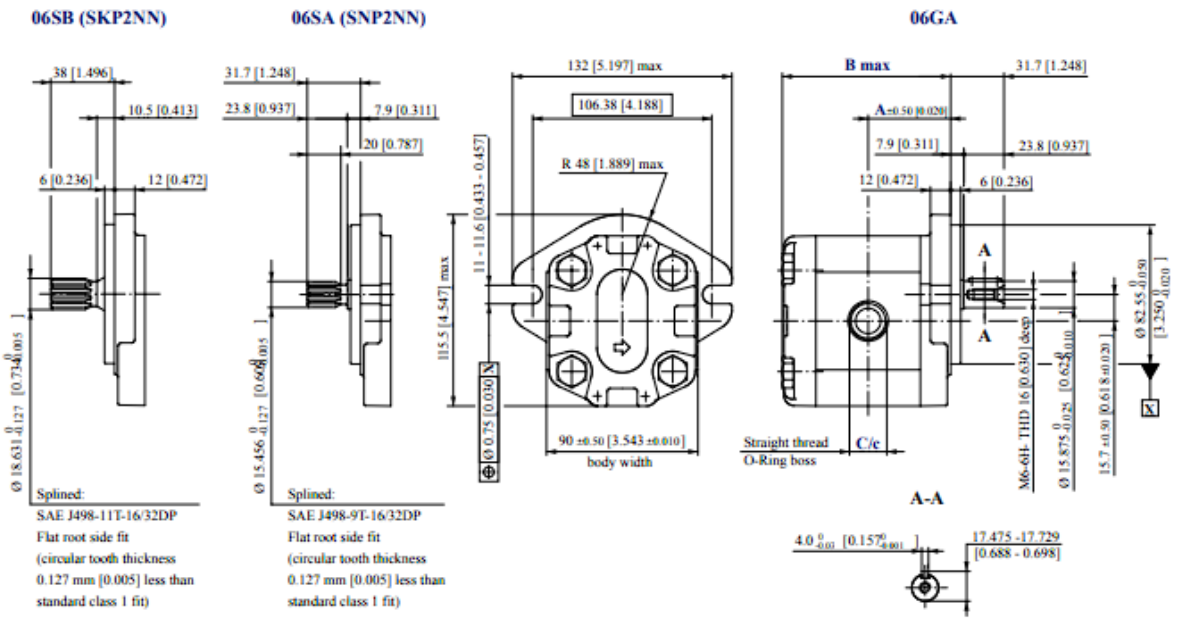
Hydraulic Pump

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

Dimensions

SKP2NN - 06SB and SNP2NN - 06SA, 06GA

Standard porting for 06SB (SKP2NN), and 06SA, 06GA (SNP2NN)



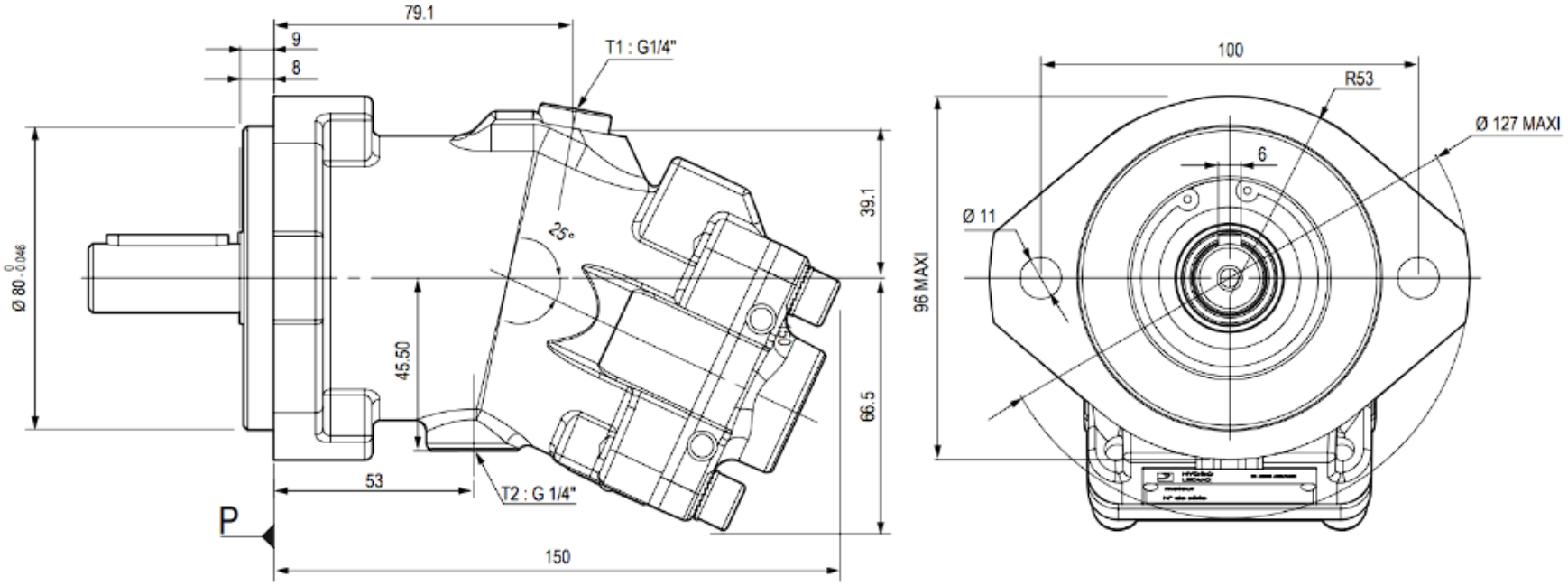
Frame size		4,0	6,0	8,0	011	014	017	019	022	025
Dimension	A	43.25 [1.703]	45 [1.772]	47 [1.850]	49 [1.920]	52 [2.047]	54 [2.205]	56 [2.205]	59 [2.323]	61 [2.402]
	B	90 [3.543]	93.5 [3.681]	97.5 [3.839]	101.5 [3.996]	107.5 [4.232]	111.5 [4.390]	115.5 [4.547]	121.5 [4.783]	125.5 [4.941]
Inlet	C	11/16–12UNF–2B, 18.0 [0.709] deep								
Outlet	c	7/8–14UNF–2B, 16.7 [0.658] deep								

Hydraulic Motor

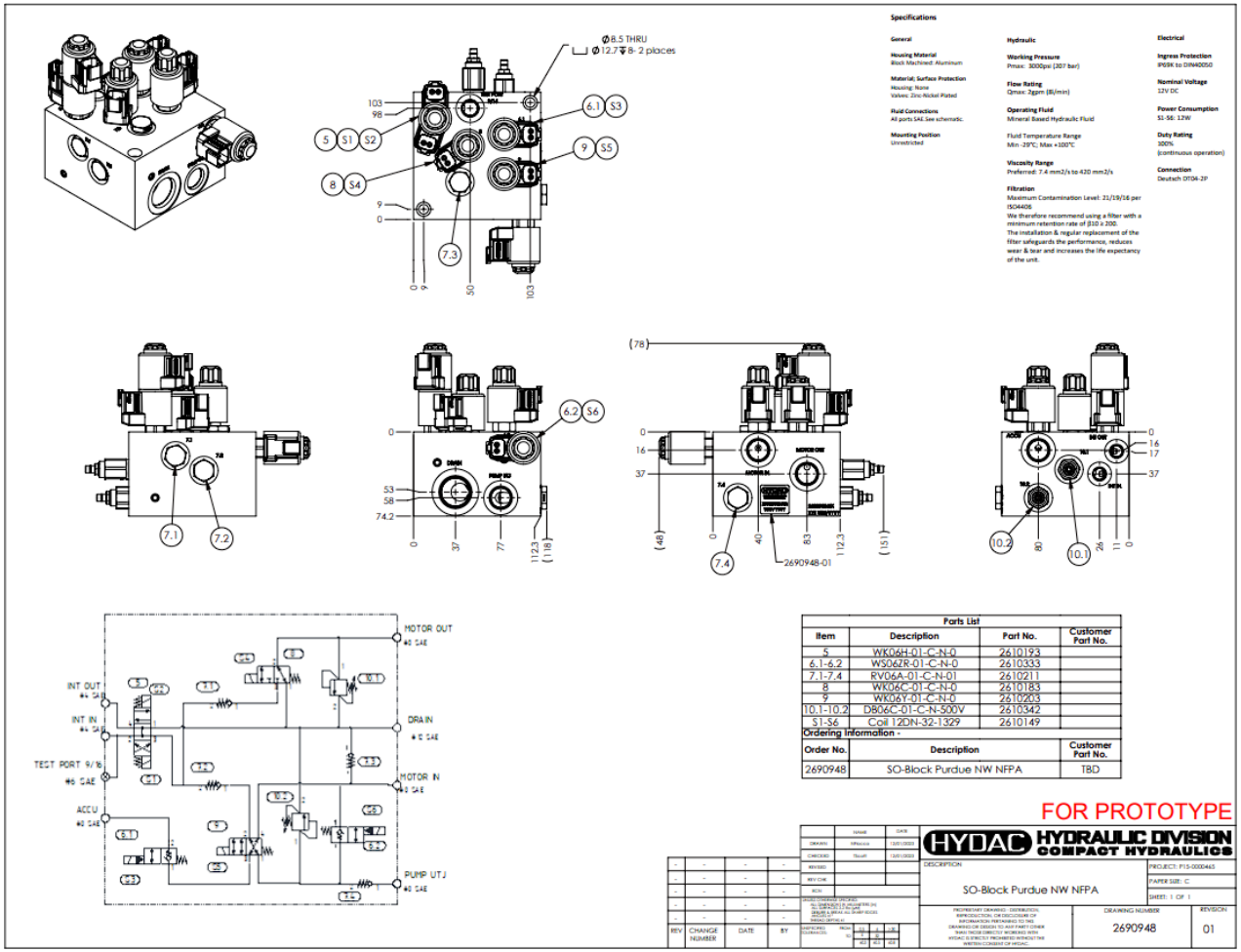
M series motors M 5_093840

- Bent Axis Piston Motor CETOP Flange (2 bolt) .305 CID with Keyed Shaft

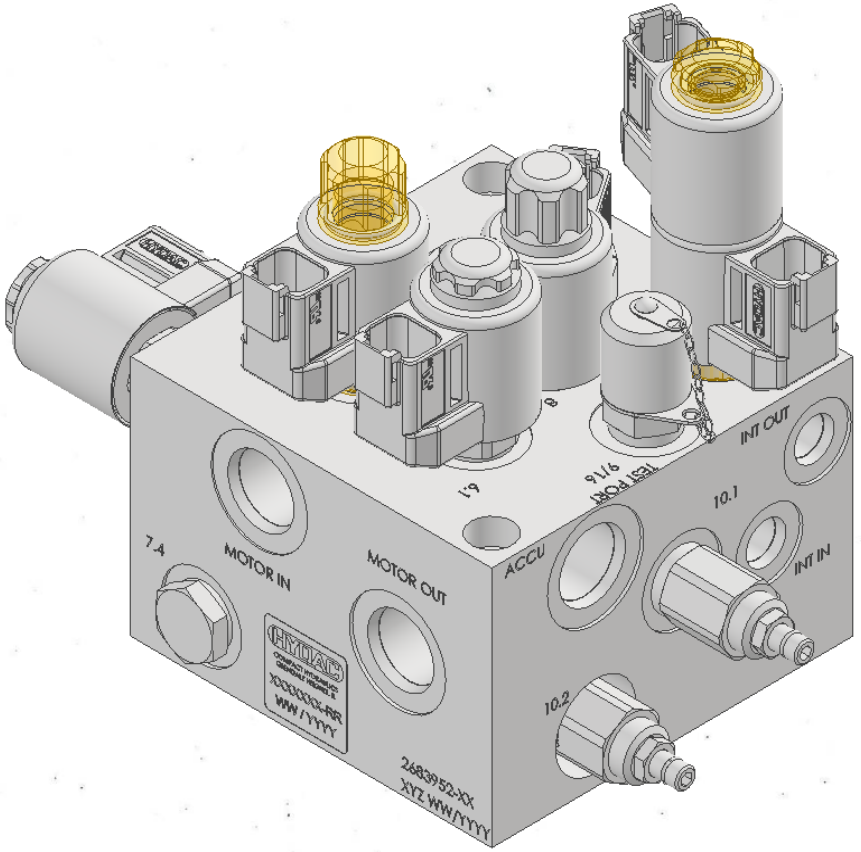
CETOP flange, 2 bolts

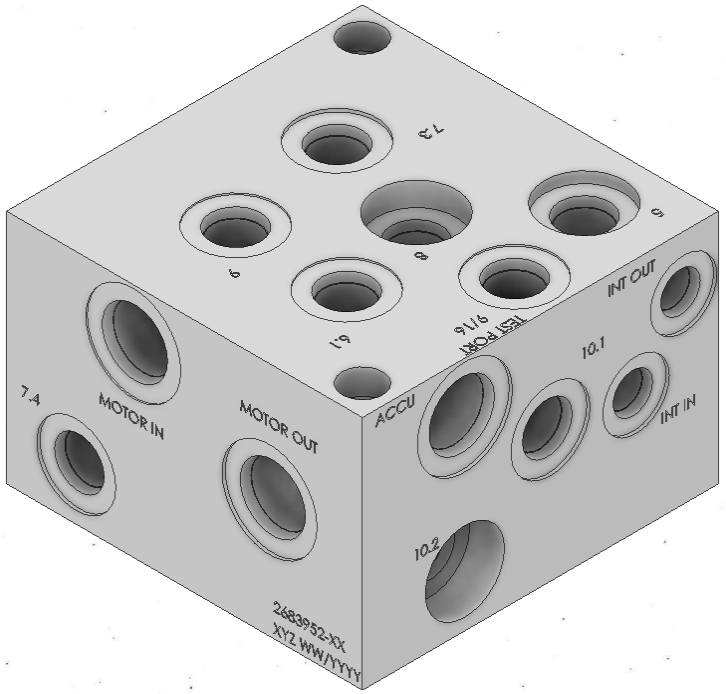


Manifold


Specifications
General
Housing Material
Block Machined: Aluminum
Material; Surface Protection
Housing: None
Valves: Zinc-Nickel Plated
Fluid Connections
All ports SAE See schematic.
Mounting Position
Unrestricted
Hydraulic
Working Pressure
Pmax: 3000psi (207 bar)
Flow Rating
Qmax: 2gpm (8l/min)
Operating Fluid
Mineral Based Hydraulic Fluid
Fluid Temperature Range
Min -25°C; Max +100°C
Viscosity Range
Preferred: 7.4 mm2/s to 420 mm2/s
Filtration
Maximum Contamination Level: 21/19/16 per ISO4406
We therefore recommend using a filter with a minimum retention rate of β10 ≥ 200.
The installation & regular replacement of the filter safeguards the performance, reduces wear & tear and increases the life expectancy of the unit.
Electrical
Ingress Protection
IP69K to DIN40050
Nominal Voltage
12V DC
Power Consumption
S1-S6: 12W
Duty Rating
100%
(continuous operation)
Connection
Deutsch DT04-2P
Ø8.5 THRU
Ø12.7 8- 2 places
MOTOR OUT
#8 SAE
INT OUT
#4 SAE
INT IN
#4 SAE
DRAIN
#8 SAE
TEST PORT 9/16
#6 SAE
MOTOR IN
#8 SAE
ACCU
#8 SAE
PUMP UTJ
#8 SAE
2690948-01
Parts List
Item | Description | Part No. | Customer Part No.
5 | WK06H-01-C-N-0 | 2610193
6.1-6.2 | WS06ZR-01-C-N-0 | 2610333
7.1-7.4 | RV06A-01-C-N-01 | 2610211
8 | WK06C-01-C-N-0 | 2610183
9 | WK06Y-01-C-N-0 | 2610203
10.1-10.2 | DB06C-01-C-N-500V | 2610342
S1-S6 | Coil 12DN-32-1329 | 2610149
Ordering Information -
Order No. | Description | Customer Part No.
2690948 | SO-Block Purdue NW NFPA | TBD
FOR PROTOTYPE
HYDAC HYDRAULIC DIVISION COMPACT HYDRAULICS
SO-Block Purdue NW NFPA
2690948
01

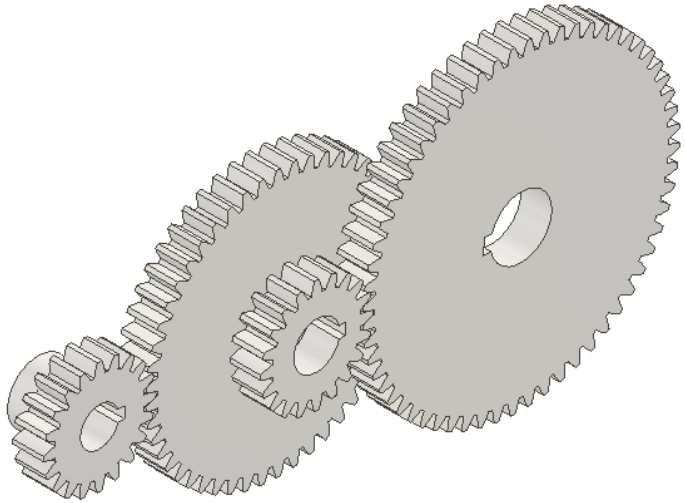
Manifold Model

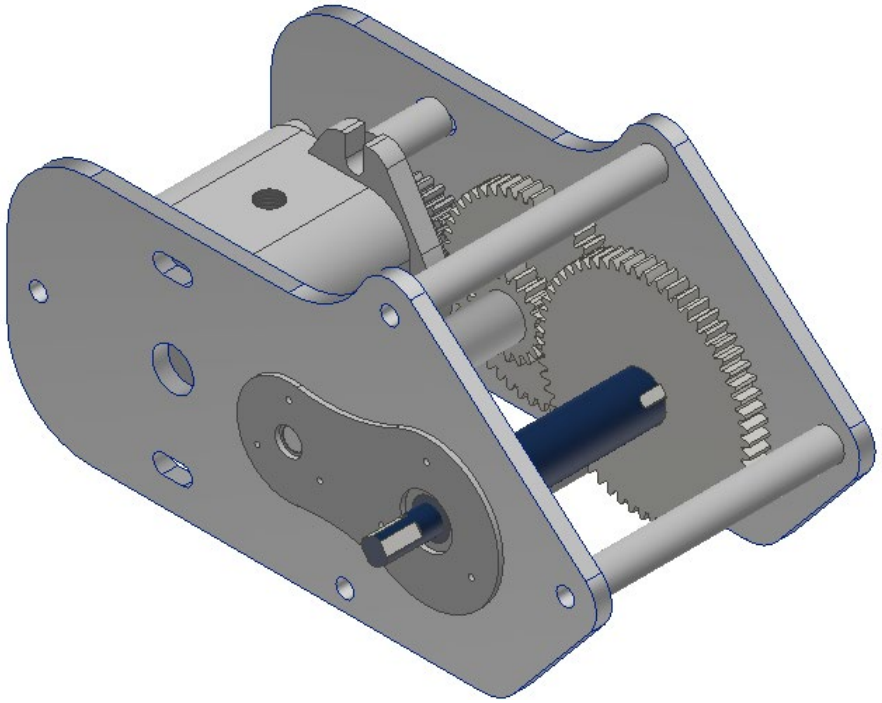




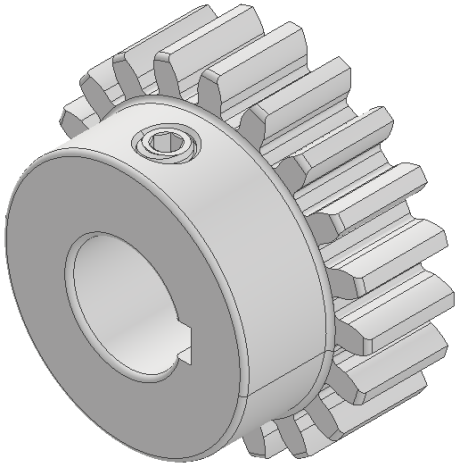
Compound Gear

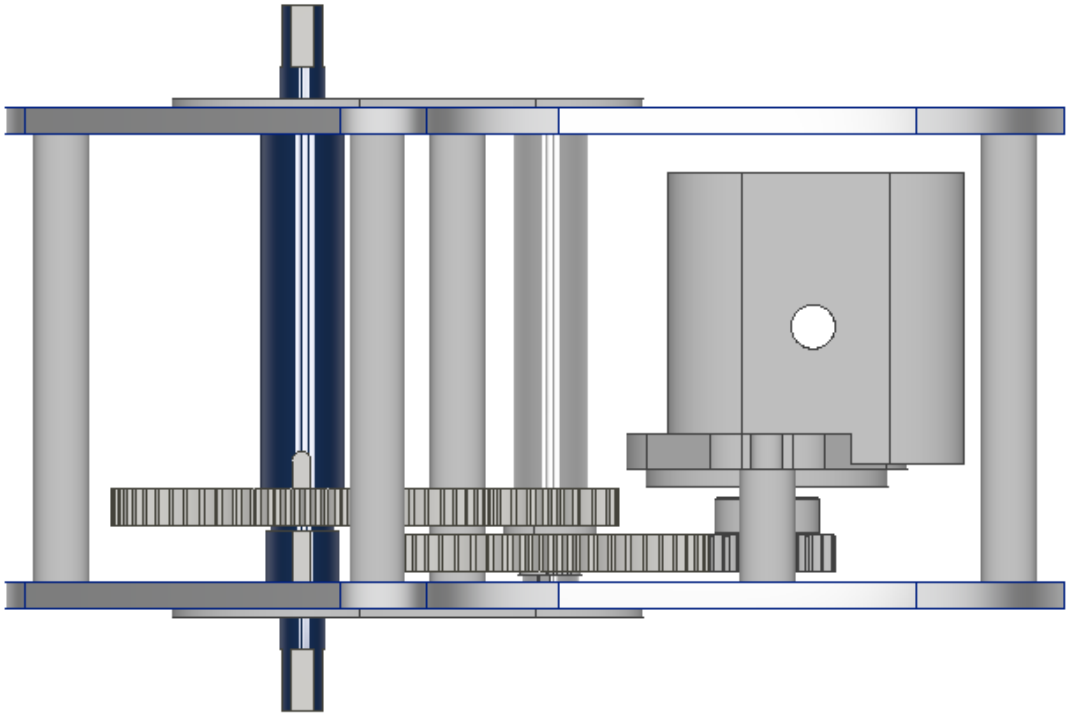
- 5 Speed increaser
- Spur to compound Gears
- Pedals to pump





Compound Gear





Transmission Calculations

INPUT RPM	COMPOUND RATIO	PUMP RPM	GPM	MOTOR RPM	REAR WHEEL RPM	VEHICLE MPH
60	5	300	.86	366	73	5.7

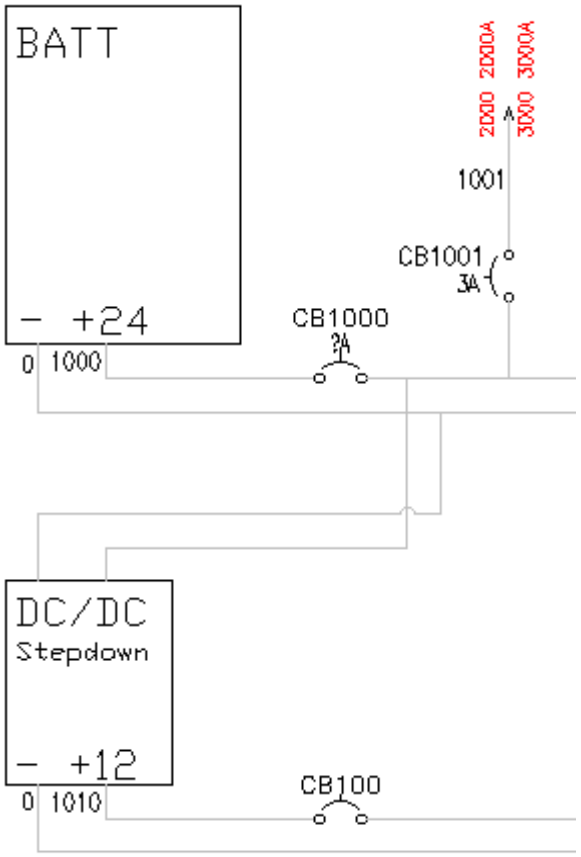
- Input RPM= Baseline of our body's pedaling speed.
- Compound Gear Ratio= Pedal speed to motor increaser.
- Motor RPM= From the output of the compound gears.
- GPM= Gallons Per Minute of oil out of motor.
- Pump RPM= Double the motor RPM
- Rear Wheel RPM= 5 to 1 step down ratio to rear wheel.
- Vehicle MPH= Output speed of rear wheel

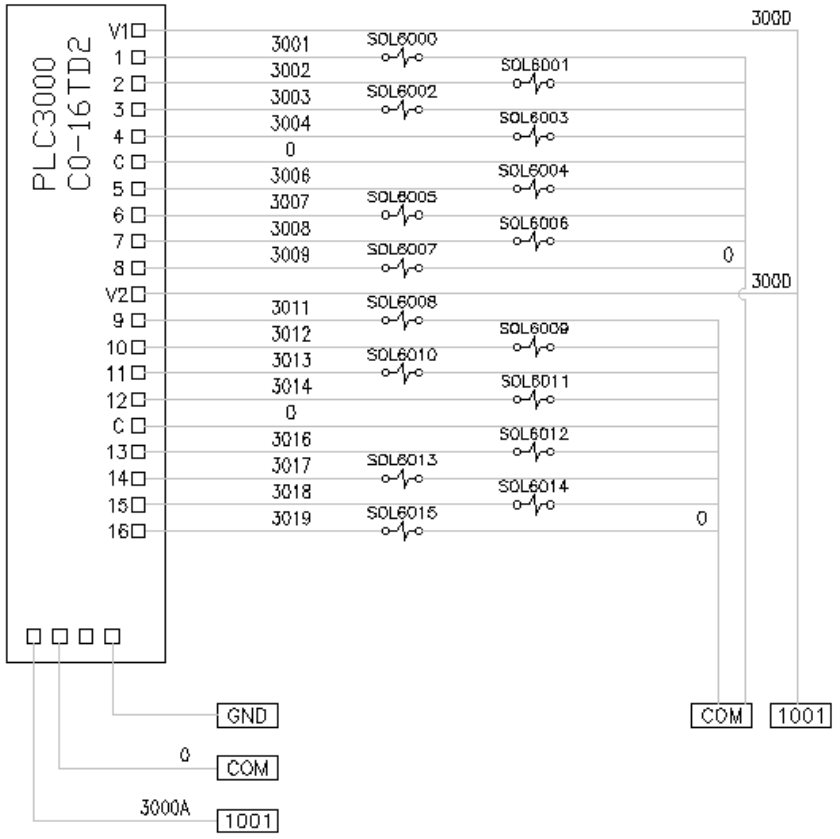
PLC

- Using CLICK PLC
- Industry standard device
- Simple to use
- Using input buttons to control the bike

PLC

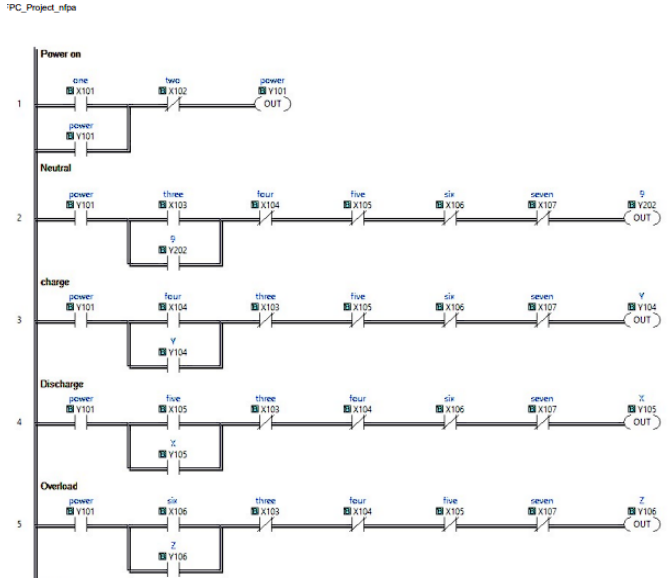
- Electrical power distribution and I/O mapping example.

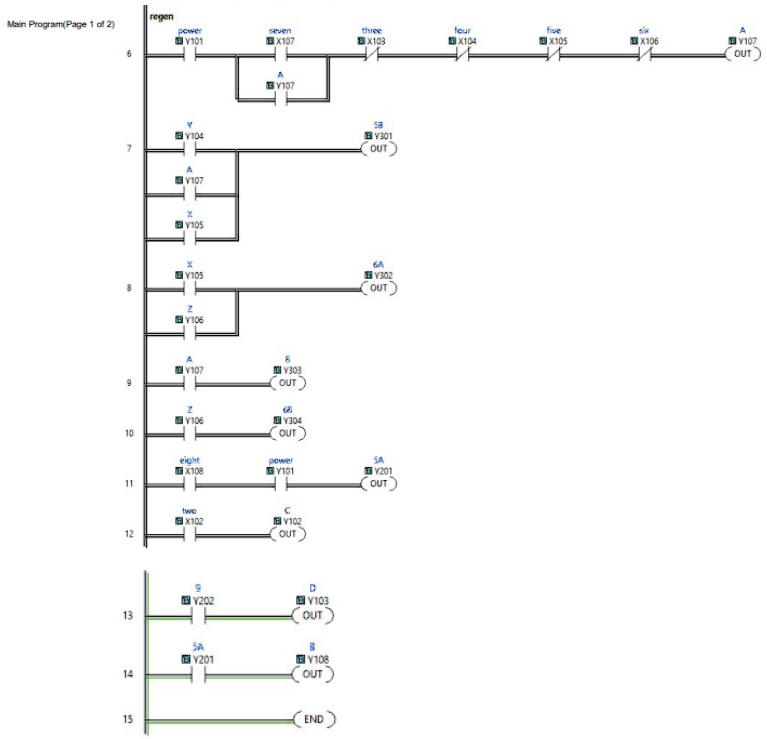




PLC

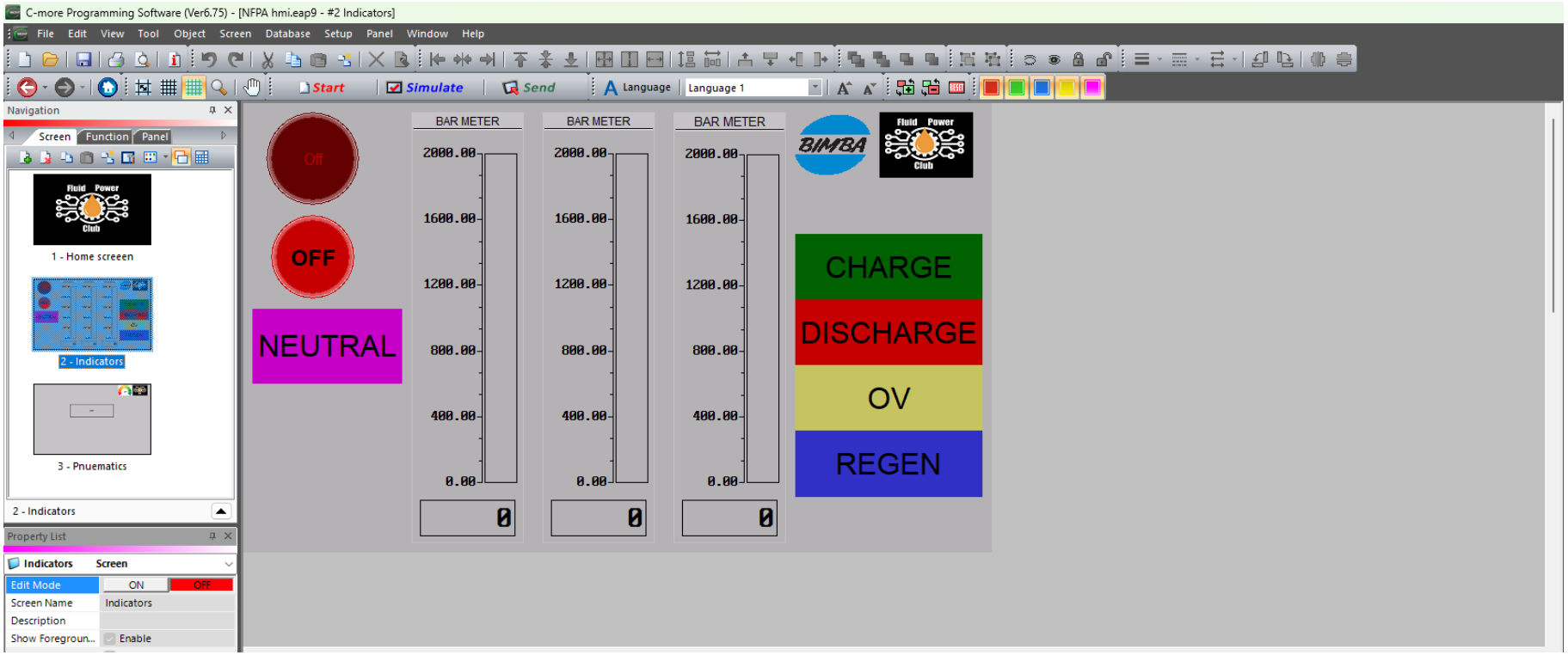
- Ladder logic using the PLC CLICK Program
- Ladder logic for the Hydraulic controls.



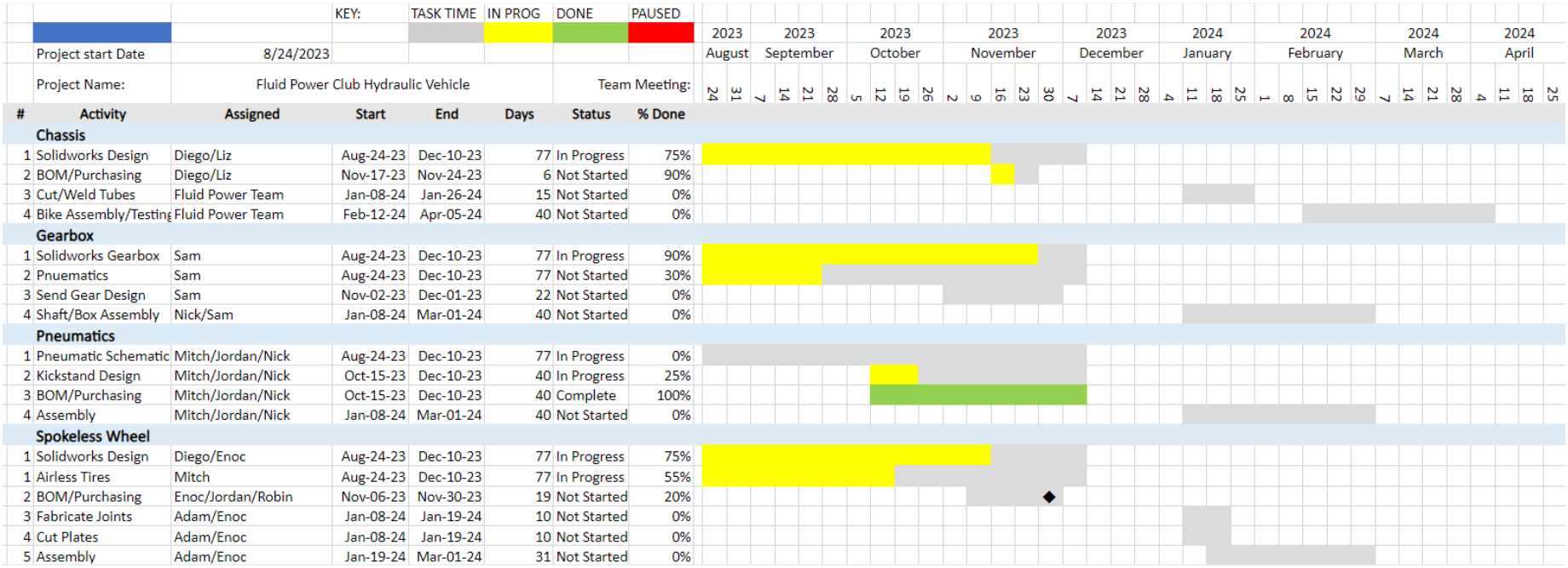


HMI

- HMI, Human Machine Interface
- Mode visualizer.
- Three hydraulic sensor readings.



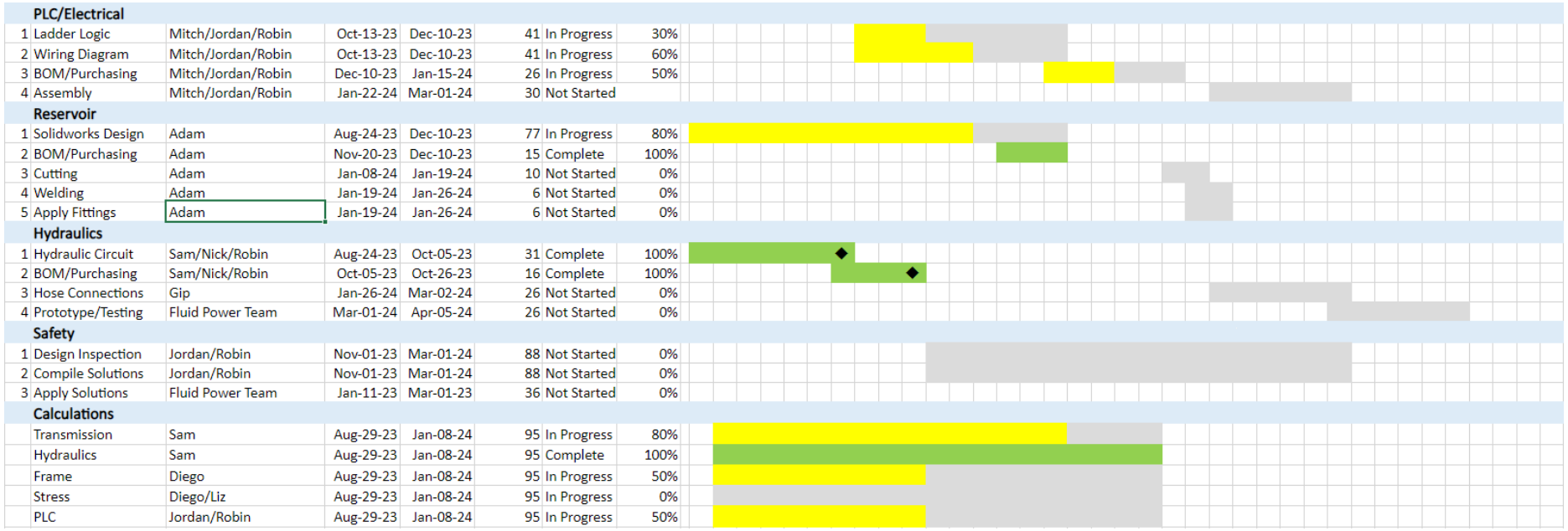
Gantt Chart



			KEY:	TASK TIME	IN PROG	DONE	PAUSED
	Project start Date	8/24/2023					
	Project Name:	Fluid Power Club Hydraulic Vehicle				Team Meeting:	

#	Activity	Assigned	Start	End	Days	Status	% Done
	Chassis						
1	Solidworks Design	Diego/Liz	Aug-24-23	Dec-10-23	77	In Progress	75%
2	BOM/Purchasing	Diego/Liz	Nov-17-23	Nov-24-23	6	Not Started	90%
3	Cut/Weld Tubes	Fluid Power Team	Jan-08-24	Jan-26-24	15	Not Started	0%
4	Bike Assembly/Testing	Fluid Power Team	Feb-12-24	Apr-05-24	40	Not Started	0%
	Gearbox						
1	Solidworks Gearbox	Sam	Aug-24-23	Dec-10-23	77	In Progress	90%
2	Pnuematics	Sam	Aug-24-23	Dec-10-23	77	Not Started	30%
3	Send Gear Design	Sam	Nov-02-23	Dec-01-23	22	Not Started	0%
4	Shaft/Box Assembly	Nick/Sam	Jan-08-24	Mar-01-24	40	Not Started	0%
	Pneumatics						
1	Pneumatic Schematic	Mitch/Jordan/Nick	Aug-24-23	Dec-10-23	77	In Progress	0%
2	Kickstand Design	Mitch/Jordan/Nick	Oct-15-23	Dec-10-23	40	In Progress	25%
3	BOM/Purchasing	Mitch/Jordan/Nick	Oct-15-23	Dec-10-23	40	Complete	100%
4	Assembly	Mitch/Jordan/Nick	Jan-08-24	Mar-01-24	40	Not Started	0%
	Spokeless Wheel						
1	Solidworks Design	Diego/Enoc	Aug-24-23	Dec-10-23	77	In Progress	75%
1	Airless Tires	Mitch	Aug-24-23	Dec-10-23	77	In Progress	55%
2	BOM/Purchasing	Enoc/Jordan/Robin	Nov-06-23	Nov-30-23	19	Not Started	20%
3	Fabricate Joints	Adam/Enoc	Jan-08-24	Jan-19-24	10	Not Started	0%
4	Cut Plates	Adam/Enoc	Jan-08-24	Jan-19-24	10	Not Started	0%
5	Assembly	Adam/Enoc	Jan-19-24	Mar-01-24	31	Not Started	0%

Gantt Chart Cont'd



	PLC/Electrical						
1	Ladder Logic	Mitch/Jordan/Robin	Oct-13-23	Dec-10-23	41	In Progress	30%
2	Wiring Diagram	Mitch/Jordan/Robin	Oct-13-23	Dec-10-23	41	In Progress	60%
3	BOM/Purchasing	Mitch/Jordan/Robin	Dec-10-23	Jan-15-24	26	In Progress	50%
4	Assembly	Mitch/Jordan/Robin	Jan-22-24	Mar-01-24	30	Not Started	
	Reservoir						
1	Solidworks Design	Adam	Aug-24-23	Dec-10-23	77	In Progress	80%
2	BOM/Purchasing	Adam	Nov-20-23	Dec-10-23	15	Complete	100%
3	Cutting	Adam	Jan-08-24	Jan-19-24	10	Not Started	0%
4	Welding	Adam	Jan-19-24	Jan-26-24	6	Not Started	0%
5	Apply Fittings	Adam	Jan-19-24	Jan-26-24	6	Not Started	0%
	Hydraulics						
1	Hydraulic Circuit	Sam/Nick/Robin	Aug-24-23	Oct-05-23	31	Complete	100%
2	BOM/Purchasing	Sam/Nick/Robin	Oct-05-23	Oct-26-23	16	Complete	100%
3	Hose Connections	Gip	Jan-26-24	Mar-02-24	26	Not Started	0%
4	Prototype/Testing	Fluid Power Team	Mar-01-24	Apr-05-24	26	Not Started	0%
	Safety						
1	Design Inspection	Jordan/Robin	Nov-01-23	Mar-01-24	88	Not Started	0%
2	Compile Solutions	Jordan/Robin	Nov-01-23	Mar-01-24	88	Not Started	0%
3	Apply Solutions	Fluid Power Team	Jan-11-23	Mar-01-23	36	Not Started	0%
	Calculations						
	Transmission	Sam	Aug-29-23	Jan-08-24	95	In Progress	80%
	Hydraulics	Sam	Aug-29-23	Jan-08-24	95	Complete	100%
	Frame	Diego	Aug-29-23	Jan-08-24	95	In Progress	50%
	Stress	Diego/Liz	Aug-29-23	Jan-08-24	95	In Progress	0%
	PLC	Jordan/Robin	Aug-29-23	Jan-08-24	95	In Progress	50%

Budget

	Vendor	Model Code (Links to Datasheets)	Description	Net Price (each)	Quantity	Extended Price
1	HYDAC	Coil 12DN-32-1329 QS	Size -6 Solenoid Coil, 32mm, 12V Deutsch	$19.26	8	$154.08
2	HYDAC	DB06C-01-C-N-500V QS	Pressure Relief, Direct Acting, Poppet Type	$42.38	2	$84.76
3	HYDAC	RV06A-01-C-N-01 QS	Check Valve, Ball type	$15.18	3	$45.54
4	HYDAC	WK06C-01-C-N-0 QS	Directional 3W/2P Direct Acting, Spool Type	$47.65	1	$47.65
5	HYDAC	WK06H-01-C-N-0 QS	Directional 4W/3P Direct Acting, Spool Type	$77.45	1	$77.45
6	HYDAC	WK06Y-01-C-N-0 QS	Directional 4W/2P Direct Acting, Spool Type	$55.83	1	$55.83
7	HYDAC	WS06ZR-01-C-N-0	Bi-Directional 4W/2P, NC, Pilot Op. Poppet Type	$42.37	2	$84.74
8	HYDAC	1620 (9/16-18 UNF) MC/NBR	Hydraulic Test point	$21.99	1	$21.99
9	Dynamic FCI	CF-1P-210-A-SAE	Gauge, 0-3000 PSI, SAE -4 male. 2-1/2" diameter.	$23.00	4	$92.00
10	Danfoss	SNP2NN-/-011-R-N-06-GA-P1-E6-E5-NN-N-N-/-NNN-N-N	Pump, Gear, 0.659 CID, Keyed Shaft .625", CW rotation	$293.00	1	$293.00
11	Balluff	BSP B250-FV004-A04A1A-S4	Pressure Sensor, 250Bar, 0-10, 3W	$146.93	3	$440.79
12	Murr	7000-12221-6140500	Cable -M12 Connector -4 Wire - 5 Meters Long	$15.16	3	$45.48
13	Hydro Leduc	M5 093840	Bent Axis Piston Motor CETOP Flange (2 bolt) .305 CID with Keyed Shaft	$643.75	1	$643.75
14	Minibooster	HC1-2.8-A-1	Oil Intensifier, 2.8 Ratio,	$963.75	1	$963.75
15	Automation Direct	C0-01AC	Power Supply 1.3A	$63.00	1	$63.00
16	Automation Direct	C0-12DD1E-1-D	Ethernet Analog CPU	$253.00	1	$253.00
17	Automation Direct	C008TR-3	8-point Relay Output Module	$61.00	1	$61.00
18	Automation Direct	C0-16ND3	16-Point Sink/Source DC Input Module	$63.00	1	$63.00
19	Automation Direct	C0-04AD-2	4-Channel Analog Voltage Input	$129.00	1	$129.00
					TOTAL=	$3,619.81

Budget Cont'd

ONLINE ORDERS												
ORDER DATE	No.	ITEM NAME	VENDOR	WEB LINK	COST	QUANTITY	TOTAL	ORDERED BY	PURCHASED ?	FINAL TOTAL	TOTAL RECIEVED	REMAINING
11/6/2023	1	Wheel Master 700c Road Front Wheel - 700 x 25, Weinmann AS23X Rim, Alloy Hub, 36H, QR, Silver	TREK	https://a.co/d/0r4C0xs	$68.87	2	$137.74	Enoc	YES	$382.46	$3,200.00	$1,022.60
11/6/2023	2	130MM LENGTH -50/48MM OD HEAD TUBE- INTERNAL RELIEF - 44MM HEADSET COMPATIBLE	BIKE FABRICATION	130MM LENGTH - 50/48MM OD HEAD TUBE- INTERNAL RELIEF - 44MM HEADSET COMPATIBLE — BICYCLE FABRICATION SUPPLY (bikefabsupply.com)	$24.23	1	$24.23	DIEGO	YES			
11/30/2023	3	TPU Filament	Hatch Box	https://a.co/d/5QR3aYF	$30.99	5	$154.95	Mitchell	YES			
11/30/2023	4	TPU Filament	Creality	https://a.co/d/0dJXuAB	$26.99	5	$134.95	Mitchell	YES			
11/30/2023	5	PETG Filament	Sunlu	https://a.co/d/67Qu7Y2	$17.99	5	$89.95	Mitchell	YES			
1/9/2023	6	E stop	mxuteuk	https://a.co/d/6KJ4bd0	$13.99	1	$13.99	Sam	YES			
1/10/2024	7	Deutch Connectors	JReady	https://a.co/d/1Rmdt72	$39.99	2	$79.98	Sam	YES			
1/10/2024	8	14 gauge silicon wire red and black	BNTECHGO	https://a.co/d/i3OBEIo	$32.88	1	$32.88	Sam	YES			
1/10/2024	9	14 Guage silicon wire Blue	BNTECHGO	https://a.co/d/0Kmzaup	$18.88	1	$18.88	Sam	YES			
1/10/2024	10	14 guage silicon wire White	BNTECHGO	https://a.co/d/16FcbtY	$18.88	1	$18.88	Sam	YES			
1/10/2024	11	200 pcs Solder Seal Wire Connectors	TICONN	https://a.co/d/djE2Ok9	$14.95	1	$14.95	Sam	YES			
2/6/2024	12	1-1/8" threadless bike headset	cydzaw	https://a.co/d/fiy5M3k	$14.99	1	$14.99	Sam	YES			
1/16/2024	13	PHSB3 rod end bearing 3/16 bore, #10-32	HiPicco	https://a.co/d/1SdTeoG	$8.99	4	$35.96	Sam	YES			
2/6/2024	14	110MM LENGTH - 39MM OD HEAD TUBE BMX SHORT TAPER IS42/42 -4130	BIKE FABRICATION	https://www.bikefabsupply.com/head-tubes-machined-bmx-is4242/110mm-length-39mm-od-head-tube-bmx-is4242-gyro-tab-drilled-4130	$15.50	1	$15.50	Sam	YES			
2/6/2024	15	Dropper Post w/External routing 27.2mm	TranzX Kitsuma	https://a.co/d/iRFGW9i	$148.00	1	$148.00	Sam	YES			
2/6/2024	16	29.6/28.6MM Ø ZERO UNO EXT BUTTED SEAT TUBE 1.1/.6/.8 X 635MM 27.2 SEAT POST MTV286B310	BIKE FABRICATION	https://www.bikefabsupply.com/seat-tubes/296286mm-zero-uno-ext-butted-seat-tube-1168-x-635mm	$44.78	1	$44.78	Sam	yes			
2/14/2024	17	1/2" x 24" x 24" A36 plate	AAA Steel		$67.53	1	$67.53	enoc	yes			

PNW College of Technology

Fluid Power Club

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Questions?