Parker Chainless Challenge 2015-2016

University of Cincinnati

Mechanical Engineering / Mechanical Engineering Technology

Team Members

- Jacob Wiegand - Frame, Suspension, and Steering
- Jacob Wethington - Electronics
- Chris Hinkle - Regenerative Braking
- Chris Ferguson - Hydraulic Circuit
- Kelly Merrick - Hydraulic Circuit
- Muthar Al-Ubaidi - Team Advisor

Agenda

- Design Approach
  - Project Plan
  - Objectives
- Design Specifics
  - Frame
  - Fluid Circuit
  - Hydraulic Drive System
  - Steering, Suspension, and Mechanical Brakes
- Electronics/Solenoid Valve Programming
- Testing
- Manufacturability
- Cost analysis
- Results
- Lessons Learned

Design Approach – Project Plan

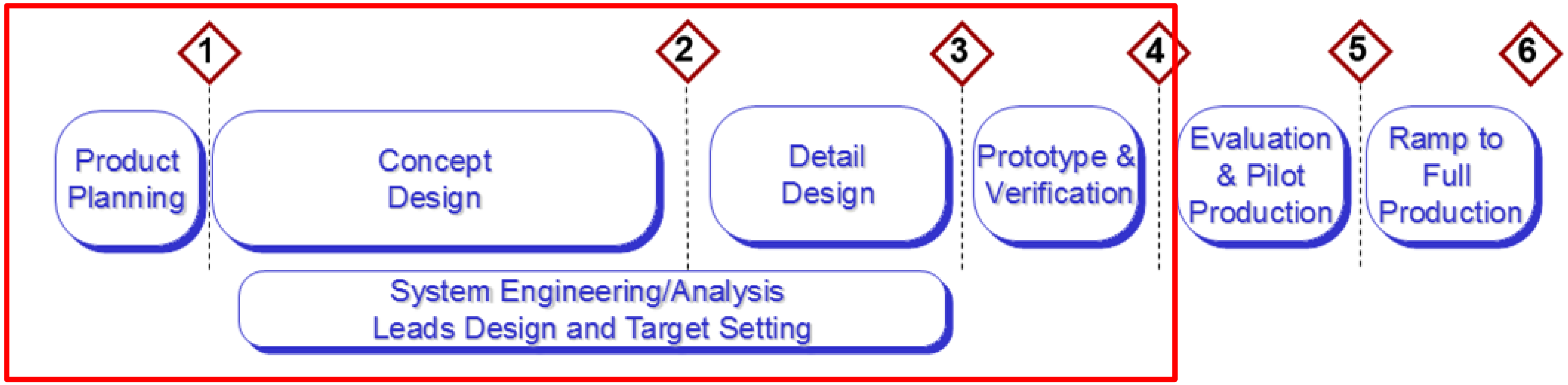
Concurrent Product and Manufacturing Process Development (CPPD®)

Step 1: Product Planning

Step 2: Concept Design

Step 3: Detail Design

Step 4: Prototype & Verification



Design Approach – Project Plan

Concurrent Product and Manufacturing Process Development (CPPD®)

Step 1: Product Planning

- Product evaluations
- Setting product targets
- Writing specifications
- Creating concept Ideas

Step 2: Concept Design

- Product level simulation/analysis
- Design
- Creating concept Ideas

Step 3: Detail Design

- Model/Drawing
- Assembly Planning
- Cost Estimating
- Detailed Analysis

Step 4: Prototype & Verification

- Building Prototypes
- Conducting tests
- Problem Solving

Design Approach – Project Plan

Timeline

	University of Cincinnati Parker Chainless Challenge Schedule Overview															
	September		October		November		December		January		February		March		April	
Description	**1,2**	**3,4**	**1,2**	**3,4**	**1,2**	**3,4**	**1,2**	**3,4**	**1,2**	**3,4**	**1,2**	**3,4**	**1,2**	**3,4**	**1,2**	**3,4**
Brainstorming	🟦	🟦														
Kickoff Meeting			🟦													
Hydraulic Design			🟦	🟦												
Frame Design				🟦	🟦											
Order Components					🟦	🟦	🟦									
Initial Testing							🟦	🟦								
Midway Review							🟦									
Fabrication								🟦	🟦	🟦	🟦					
Testing/Adjusting											🟦	🟦	🟦	🟦	🟦	

Design Approach – Objectives

The team had five primary design requirements:

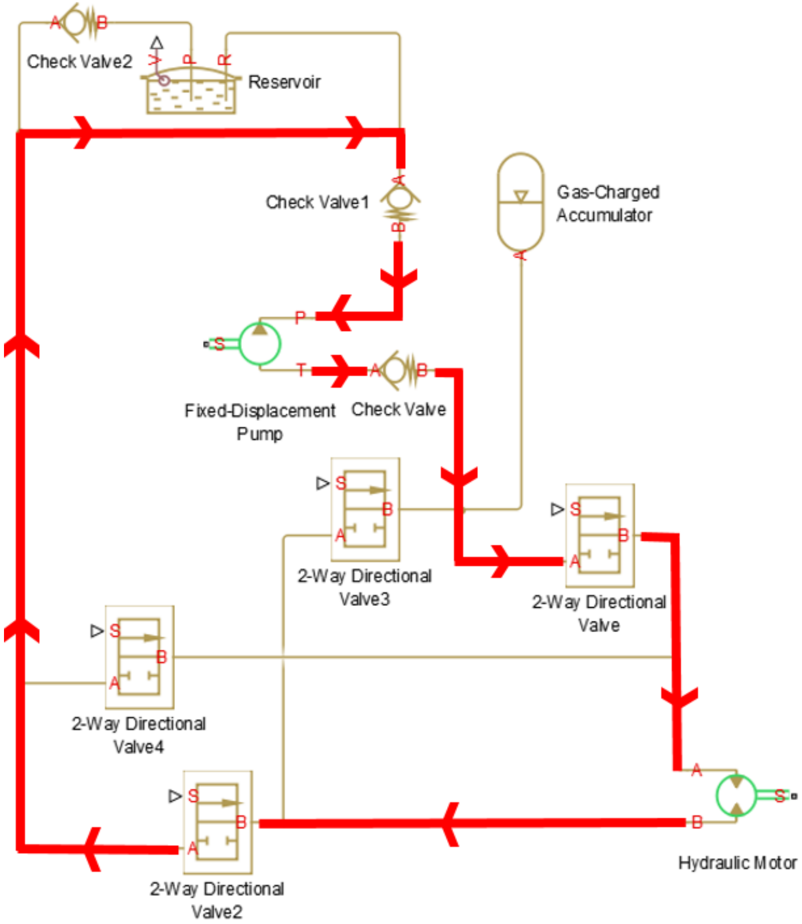
1. A driveline that does not utilize a chain or sprocket.
2. A hydraulic bicycle that achieves speeds up to 10-15 mph.
3. An overall weight of less than 210 pounds without rider or fluid
4. A frame that can easily maneuver and is stable.
5. A braking system that utilizes regenerative braking.

FLUID CIRCUIT

Fluid Circuit Design

- The first step of the process was to determine the fluid circuit.
- These schematics show the hydraulic flow in various situations
  - Direct drive, pre-charge, discharge, regenerative braking and coasting

Hydraulic System - Direct Drive



To power the bicycle a direct drive system was created. This system replaces the need for a chain and sprocket when pedaling. In this configuration a rider would pedal the bicycle, which would turn the hydraulic pump. This would pull fluid from the reservoir through the intake port and cycle through to the motor. This causes the motor to rotate and propels the bike forward.

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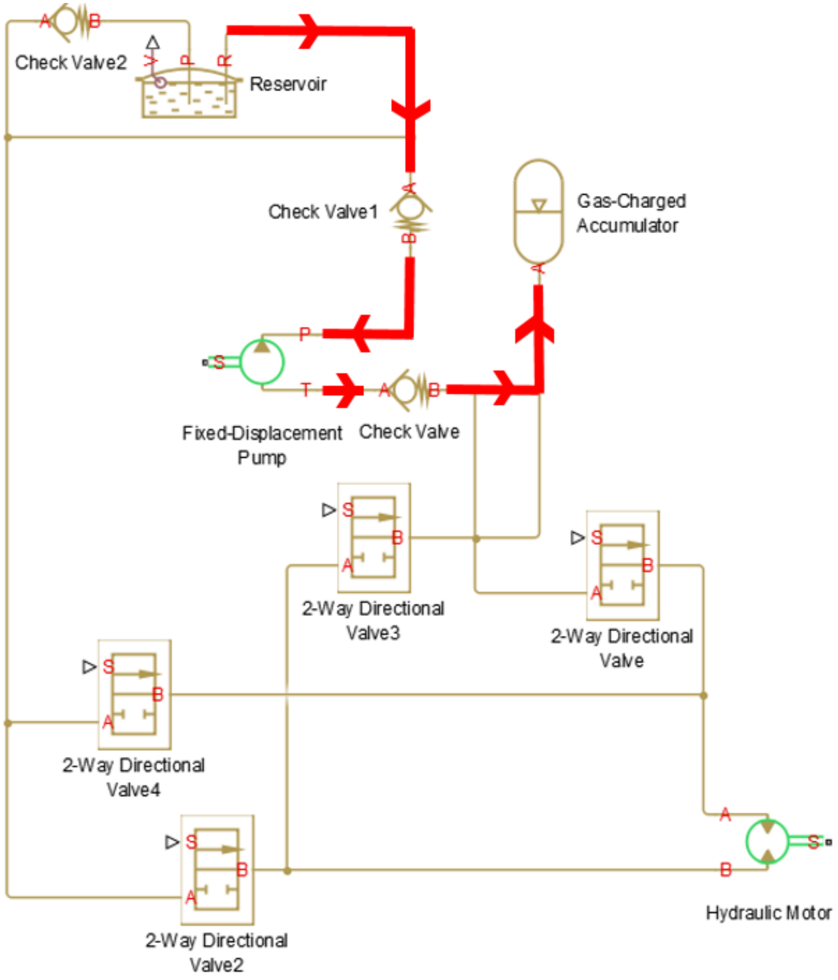
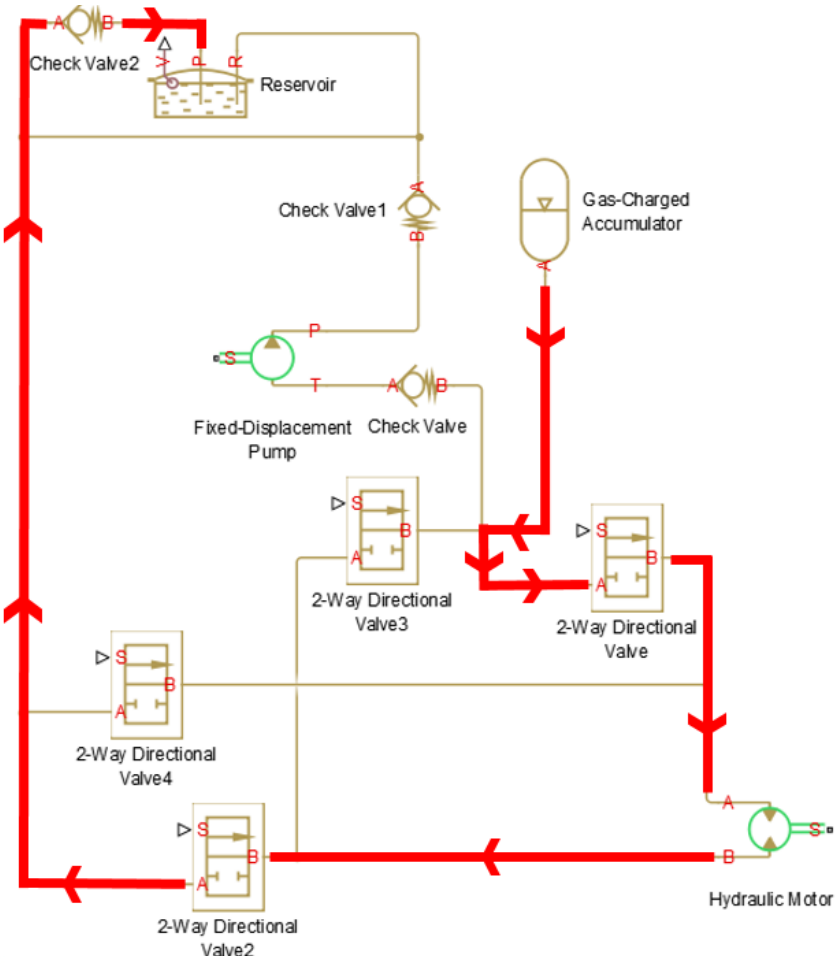
Hydraulic System - Accumulator Charging



Before the race teams are allowed to manually pressurize a storage device. This storage device is known as an accumulator. When pedaling, fluid will be pulled from the reservoir to the accumulator and build up pressure in the accumulator.

Hydraulic System - Accumulator Discharging



Discharging the accumulator is what propels the bike forward without the need to pedal. Once the pressure gauge reads 1500 PSI the operator can press a button on the bicycle. This will allow the solenoid valve to open, allowing flow through the system. The fluid turns the motor and flows back to the reservoir to recharge the accumulator.

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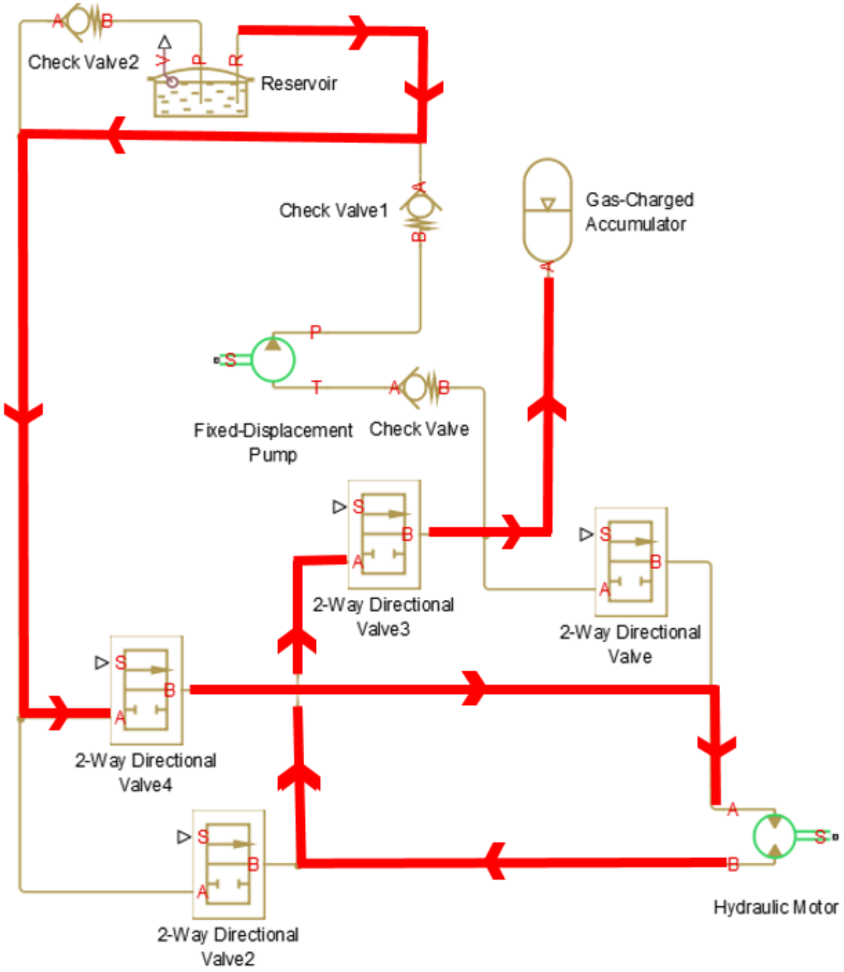
Hydraulic System - Regenerative Braking



Whenever the bike needs to slow down the regenerative braking system is useful to store that kinetic energy used to stop. When stopping the first check valve will close, isolating the accumulator. The pump will pull fluid from the reservoir and pump it into the accumulator using the inertia from the bike.

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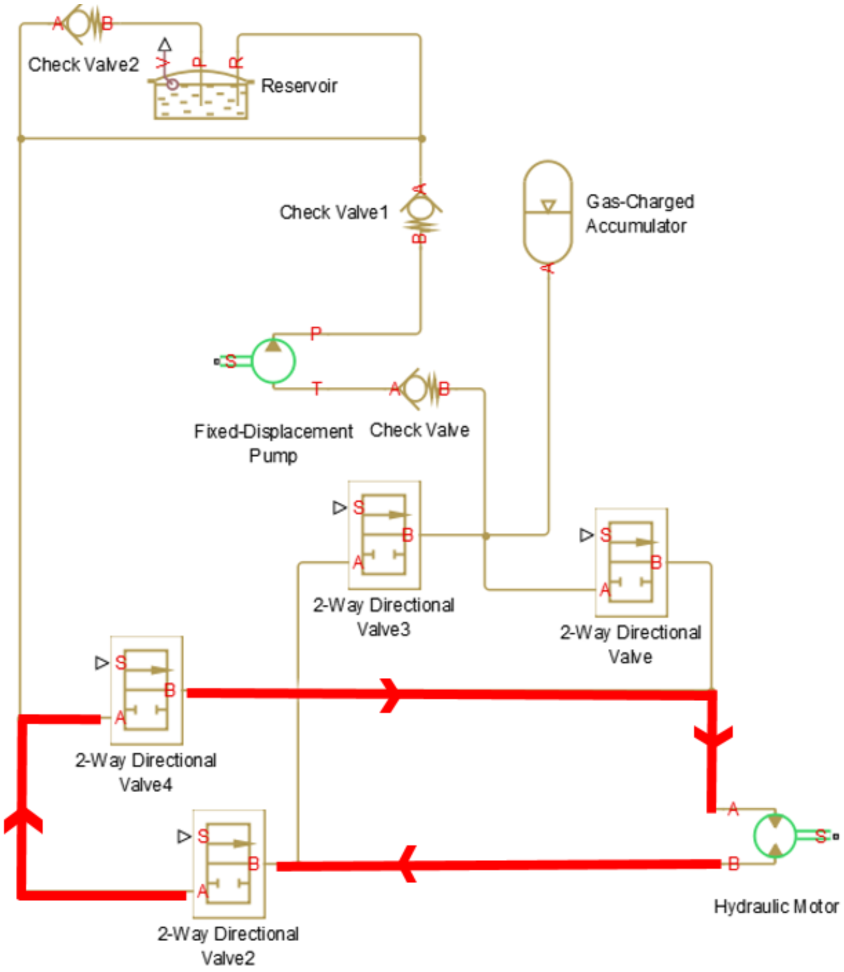
Hydraulic System - Coasting



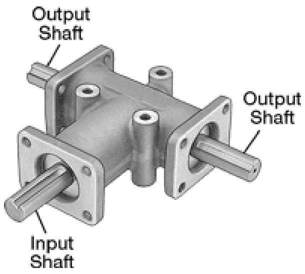
A system needed to be developed to ensure fluid was circulating with the least amount of resistance. This circuit ensures that by creating a more direct route for the fluid to circulate around the motor, which acts as a pump.

HYDRAULIC DRIVE SYSTEM

Component Selection

The next step was to determine which components to utilize to maximize the performance of the hydraulic bicycle. The different components that were selected were the following:

- Motor and Pump
- Valves
- Hose
- Accumulator
- Gear Boxes
- Reservoir



Motor and Pump

The first step was determining the pump and motor. The following inputs were used to determine these components:

- Operating Input Power: 0.5 HP
- Motor Gear Ratio: 5:1
- Wheel Radius: 12”
- Desired Speed: 10-15 mph
- Tire Type: Cruiser

Motor and Pump

The following equations are what the motor and pump were based off of:

Drawbar Pull: $F = G \times sin \propto + r$
Wheel Torque: $T_w = F \times R$
Motor Torque: $T_m = \frac{T_w}{i}$
Motor Speed: $n_m = \frac{168 \times v \times i}{R}$
Motor Flow Rate: $Q = \frac{D \times n}{1000}$
Power Output: $P = \frac{P\ x\ (V_p\ x\ n_p)}{395934\ x\ n_{t.p.}}$
Force to be placed on pedals: Type equation here.

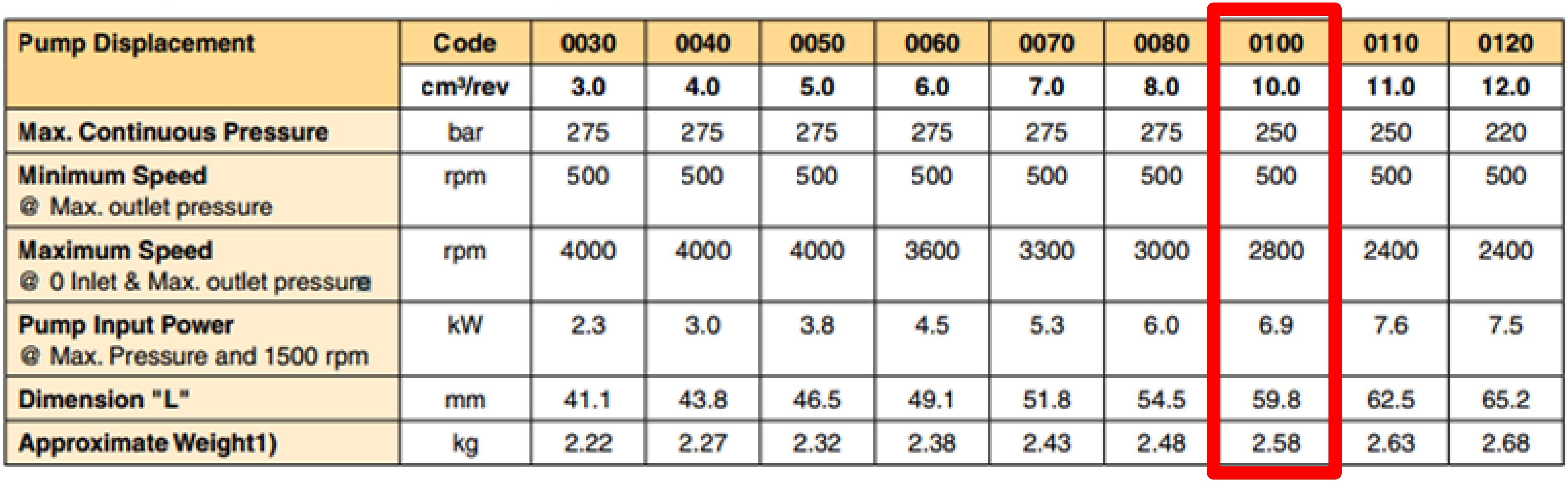
Where:
F = drawbar pull, force in pounds
G = maximum vehicle weight in pounds
∝ = maximum incline angle
r = rolling resistance
Tw = wheel torque in inch-pounds
R = wheel radius in inches
Tm = motor shaft torque in inch pounds
i = gear ratio of axle or reduction hub
nm = motor shaft speed in rpm
v = velocity in miles per hour
D = displacement in cm^3 per revolution
n = revolutions (RPM)

Motor Gear Ratio	Wheel radius (in)	Desired Speed (mph)	Rolling Resistance	Drawbar Pull (lbs)	Wheel Torque (lbin)	Motor Torque (lbin)	Motor Torque (ftlbs)	Motor Speed (rpm)	Motor Flow Rate (gpm)	Pump Dis-placement (cuin)	Calculated Pressure Drop (psi)	Power output by motor (HP)	Motor out Torque (ftlbs)	Operating Pressure (psi)	Power Required to Drive Pump at Ideal Pressure (HP)	Torque Required to Crank (ftlb)	Volume of Reservoir (gallon)
1	12	20	0.005	4.5	54	54.0	4.5	280	0.89	0.37	686.70	0.77	14.43	1445	0.52	45.44	2.94

Selection of Hardware

Motor

- Part: PGM-505-0100

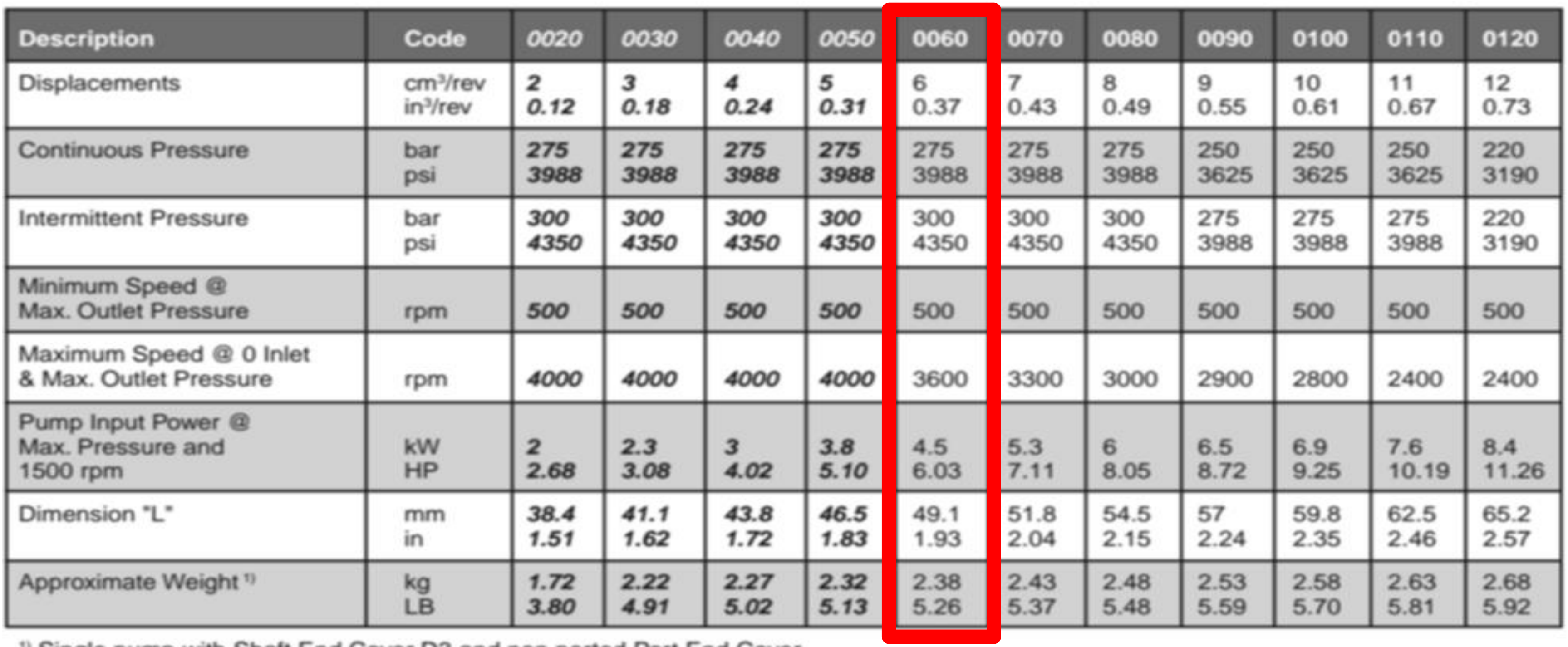


Pump Displacement	**Code**	**0030**	**0040**	**0050**	**0060**	**0070**	**0080**	**0100**	**0110**	**0120**
	cm^3/rev	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**10.0**	**11.0**	**12.0**
Max. Continuous Pressure	bar	275	275	275	275	275	275	250	250	220
Minimum Speed @ Max. outlet pressure	rpm	500	500	500	500	500	500	500	500	500
Maximum Speed @ 0 Inlet & Max. outlet pressure	rpm	4000	4000	4000	3600	3300	3000	2800	2400	2400
Pump Input Power @ Max. Pressure and 1500 rpm	kW	2.3	3.0	3.8	4.5	5.3	6.0	6.9	7.6	7.5
Dimension "L"	mm	41.1	43.8	46.5	49.1	51.8	54.5	59.8	62.5	65.2
Approximate Weight1)	kg	2.22	2.27	2.32	2.38	2.43	2.48	2.58	2.63	2.68

Selection of Hardware

Pump

- Part: PGP-505-0600



Description	Code	0020	0030	0040	0050	0060	0070	0080	0090	0100	0110	0120
Displacements	cm³/rev in³/rev	2 0.12	3 0.18	4 0.24	5 0.31	6 0.37	7 0.43	8 0.49	9 0.55	10 0.61	11 0.67	12 0.73
Continuous Pressure	bar psi	275 3988	275 3988	275 3988	275 3988	275 3988	275 3988	275 3988	250 3625	250 3625	250 3625	220 3190
Intermittent Pressure	bar psi	300 4350	300 4350	300 4350	300 4350	300 4350	300 4350	300 4350	275 3988	275 3988	275 3988	220 3190
Minimum Speed @ Max. Outlet Pressure	rpm	500	500	500	500	500	500	500	500	500	500	500
Maximum Speed @ 0 Inlet & Max. Outlet Pressure	rpm	4000	4000	4000	4000	3600	3300	3000	2900	2800	2400	2400
Pump Input Power @ Max. Pressure and 1500 rpm	kW HP	2 2.68	2.3 3.08	3 4.02	3.8 5.10	4.5 6.03	5.3 7.11	6 8.05	6.5 8.72	6.9 9.25	7.6 10.19	8.4 11.26
Dimension "L"	mm in	38.4 1.51	41.1 1.62	43.8 1.72	46.5 1.83	49.1 1.93	51.8 2.04	54.5 2.15	57 2.24	59.8 2.35	62.5 2.46	65.2 2.57
Approximate Weight [1]	kg LB	1.72 3.80	2.22 4.91	2.27 5.02	2.32 5.13	2.38 5.26	2.43 5.37	2.48 5.48	2.53 5.59	2.58 5.70	2.63 5.81	2.68 5.92

[1] Single pump with Shaft End Cover D3 and non ported Port End Cover.

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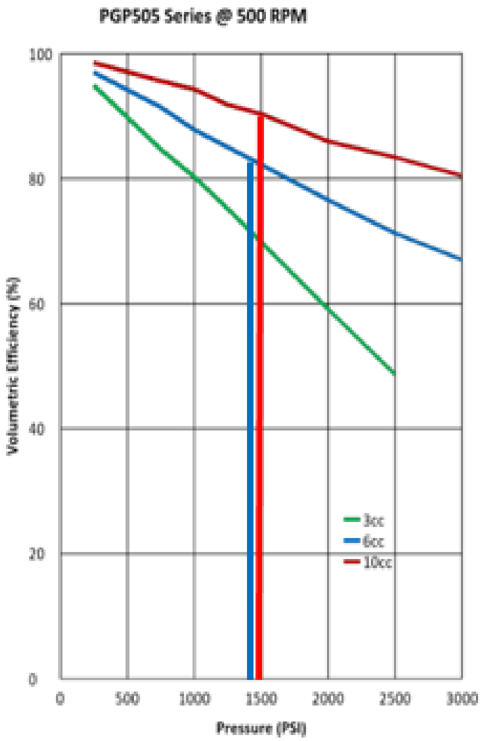
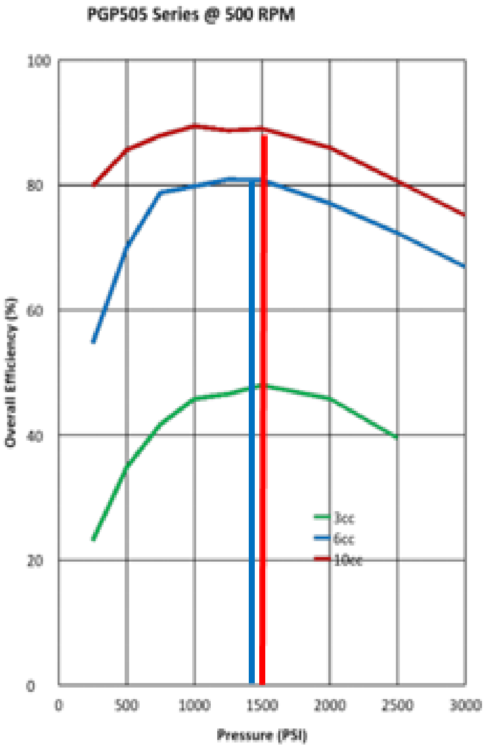
Pump and Motor Selection

Efficiencies

- PGP 505 series
- 10cc & 6cc Displacement

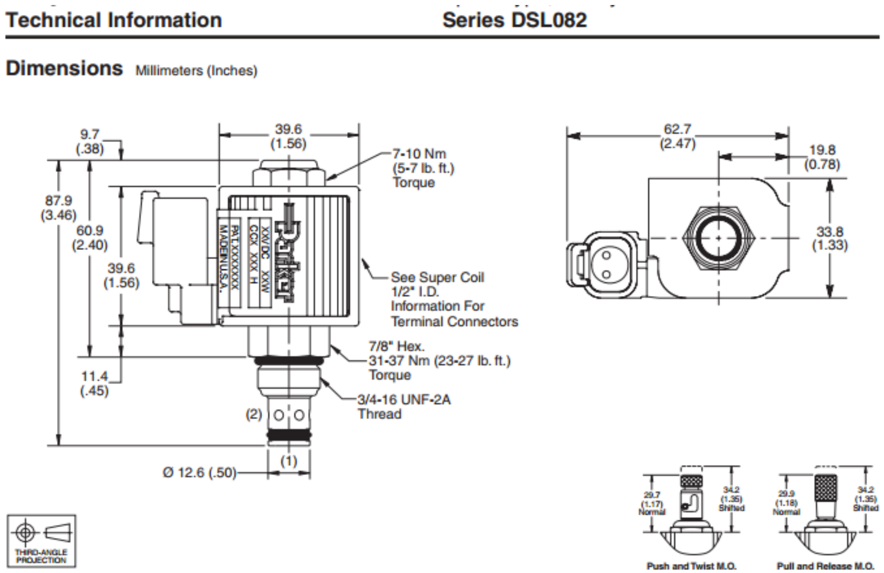




All units run as pumps

Valve Selection: 2-Way

Solenoid Valves



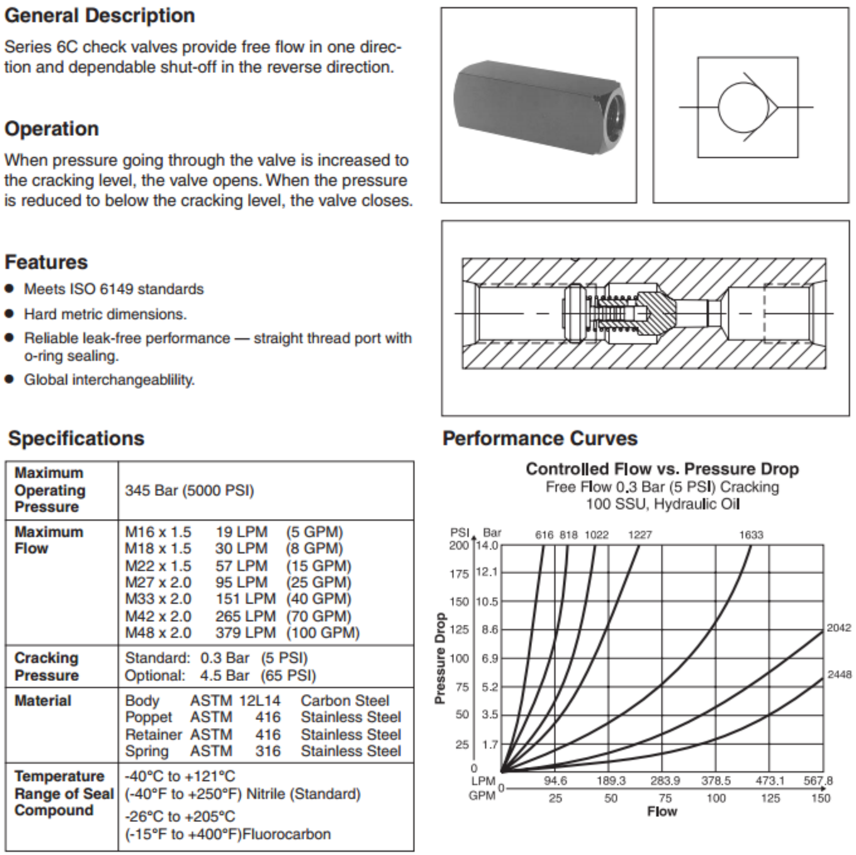
Technical Information **Series DSL082**

Dimensions Millimeters (Inches)

- •DSL082 Series 2 way valve
- •4 GPM max flow
- •Spool Valve
- •12V drive
- •Selected for small form factor and ease of operation

Valve Selection: Check Valve

In-line Check Valve



General Description

Series 6C check valves provide free flow in one direction and dependable shut-off in the reverse direction.

Operation

When pressure going through the valve is increased to the cracking level, the valve opens. When the pressure is reduced to below the cracking level, the valve closes.

Features

- Meets ISO 6149 standards
- Hard metric dimensions.
- Reliable leak-free performance — straight thread port with o-ring sealing.
- Global interchangeablility.

Specifications

Maximum Operating Pressure	345 Bar (5000 PSI)
Maximum Flow	M16 x 1.5 19 LPM (5 GPM) M18 x 1.5 30 LPM (8 GPM) M22 x 1.5 57 LPM (15 GPM) M27 x 2.0 95 LPM (25 GPM) M33 x 2.0 151 LPM (40 GPM) M42 x 2.0 265 LPM (70 GPM) M48 x 2.0 379 LPM (100 GPM)
Cracking Pressure	Standard: 0.3 Bar (5 PSI) Optional: 4.5 Bar (65 PSI)
Material	Body ASTM 12L14 Carbon Steel Poppet ASTM 416 Stainless Steel Retainer ASTM 416 Stainless Steel Spring ASTM 316 Stainless Steel
Temperature Range of Seal Compound	-40°C to +121°C (-40°F to +250°F) Nitrile (Standard) -26°C to +205°C (-15°F to +400°F)Fluorocarbon

Performance Curves

Controlled Flow vs. Pressure Drop
Free Flow 0.3 Bar (5 PSI) Cracking
100 SSU, Hydraulic Oil

- Series 6C
- 5 GPM flow rate
- 5000 psi max pressure

Hydraulic Hosing

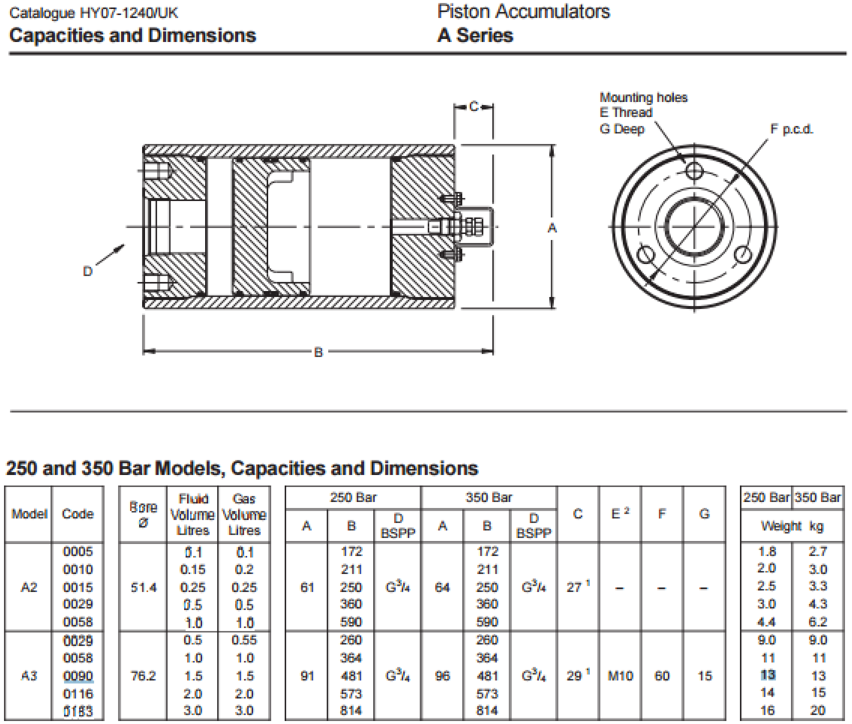
Hose Design

- ½" ID
- 3000 PSI rating
- Larger diameter reduces friction, but increases weight

Accumulator

Piston Accumulator

- A3 piston accumulator
- 1.5L fluid volume
- 250 Bar
- 13 kg



Catalogue HY07-1240/UK
Capacities and Dimensions

Piston Accumulators
A Series

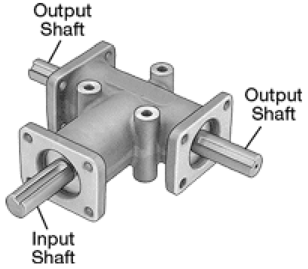
250 and 350 Bar Models, Capacities and Dimensions

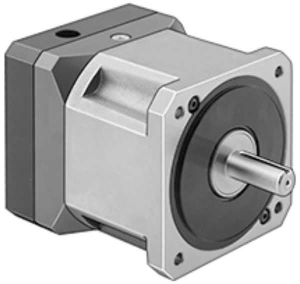
Model	Code	Bore Ø	Fluid Volume Litres	Gas Volume Litres	250 Bar			350 Bar			C	E ^{2}	F	G	250 Bar	350 Bar
					A	B	D BSPP	A	B	D BSPP					Weight kg	
A2	0005	51.4	0.1	0.1	61	172	$G^3/_4$	64	172	$G^3/_4$	27 ^{1}	–	–	–	1.8	2.7
	0010		0.15	0.2		211			211						2.0	3.0
	0015		0.25	0.25		250			250						2.5	3.3
	0029		0.5	0.5		360			360						3.0	4.3
	0058		1.0	1.0		590			590						4.4	6.2
A3	0029	76.2	0.5	0.55	91	260	$G^3/_4$	96	260	$G^3/_4$	29 ^{1}	M10	60	15	9.0	9.0
	0058		1.0	1.0		364			364						11	11
	0090		1.5	1.5		481			481						13	13
	0116		2.0	2.0		573			573						14	15
	0183		3.0	3.0		814			814						16	20

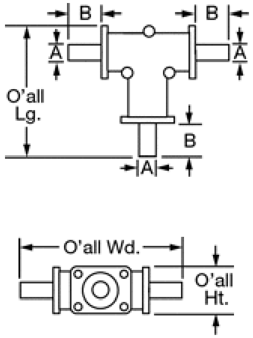
Gear Boxes

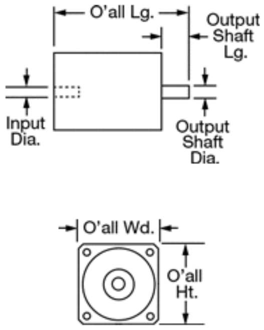
Bevel Gear & Planetary

- Bevel Gear box
  - Used for pedal motion
  - 60 RPM Human Input
  - 1:1 ratio
- Planetary Gear Box
  - 5:1 ratio
  - Output of 300 RPM









STEERING, SUSPENSION, & BRAKES

Brakes

We used a rim brake on the front tire and disc brakes on the rear.

Rim Brakes:

- Higher braking force
- Heat from brakes can warp tire
- More likely to be affected by debris or water

Disc Brakes:

- Lower braking force
- Less dependency on rim to be straight
- Less likely to be affected by water and debris

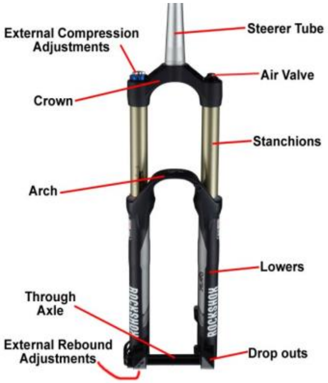
Rim Brake

Disc Brake

Suspension

Purpose

To provide a more comfortable ride over rough terrain and to protect the bike components, such as the wheel, from damage.



Due to the bicycle only being utilized on a flat terrain the team decided that extra suspension was not necessary.

Steering Final Design

- The Traditional style steering was selected for the front end of the bike due to its simplicity and the sharper cornering at lower speeds.
- Stability is a major issue for two wheeled bikes therefore we decided to make the bike stable by adding a 3rd wheel, creating a trike.
    - This will not be implemented in the steering but, on the rear end instead.

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FRAME

Frame

Types of frames

- Upright Bicycle
- Recumbent Bicycle
- Tricycle

Frame

The team decided to go with an adult tricycle as our frame style.

Adult Trike

- Center of gravity/stability not a concern
- Downward force on pedals greater
- More “real estate”
- Less aerodynamic
- Heavier
- Rear wheel base requires wider turns around obstacles

Frame

Modified 2013 Parker Chainless Team’s Frame

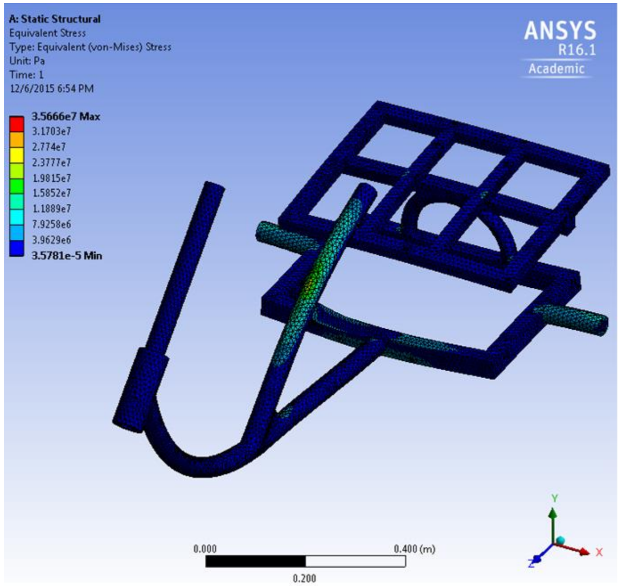
- Directly correlates with the needs of our system
- Stable
- Sufficient component storage space
- More force provided to pedals than recumbent

Frame

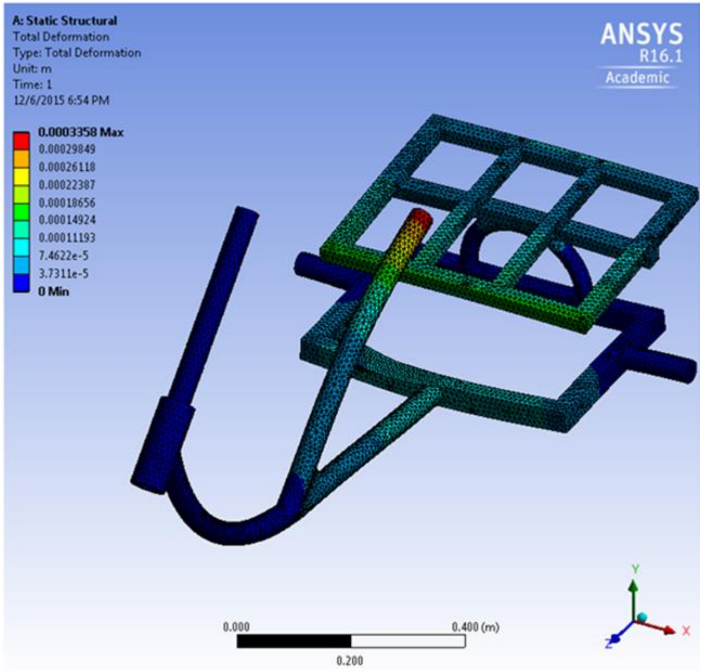
Design Validation

•Used high tensile steel – 710 MPa

• 300 lb load – 35.6 MPa max stress



- Max Deflection – 0.0003358m



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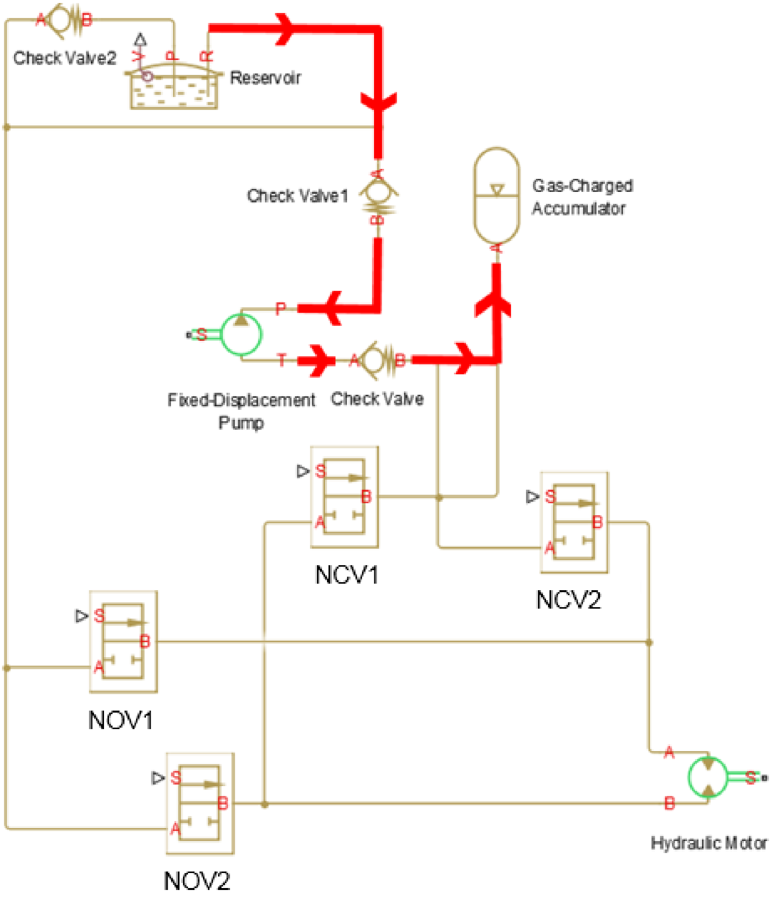
Electronics/Solenoid Valve Programming

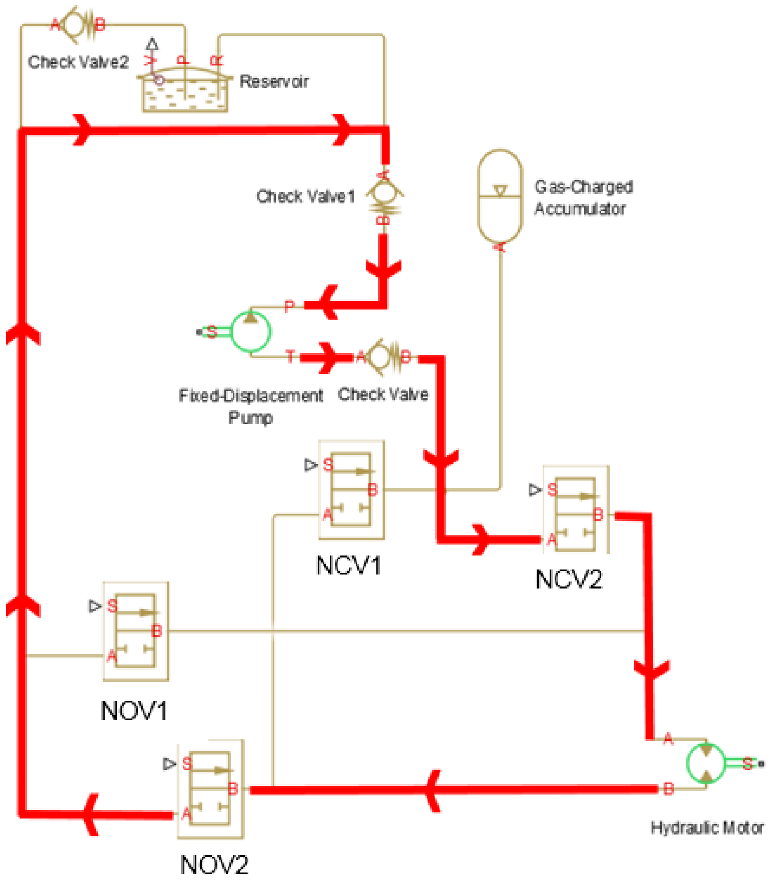
Solenoid Valves

Coasting/Accumulator Charging Mode



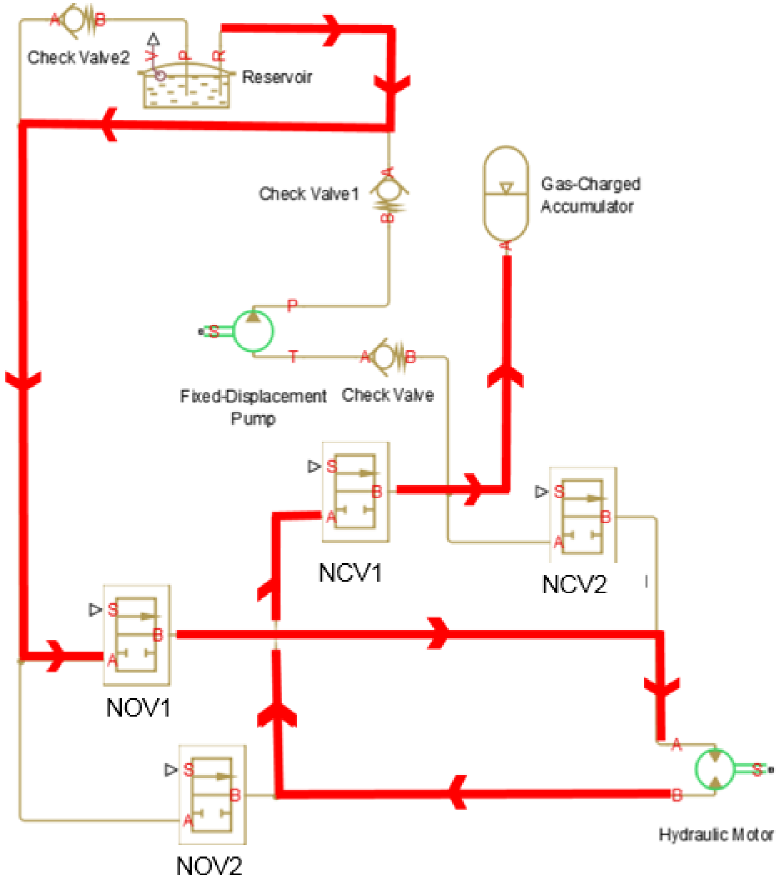
Solenoid Valves

Direct Drive/Accumulator Discharging Mode



Solenoid Valves

Regenerative Braking Mode



Solenoid Valves

PLC, Fuses, and Relays

10 amp circuit breaker

Ground Terminals

Power Terminals

6 amp fuse

6 amp fuse

PLC

4x 6 amp fuse

4x relays

Solenoid Valves

Battery and Button Selection

- A 12V 35 amp hour battery was selected because it fit our design needs with the selected solenoids, and the length of time they would be powered.
    - This battery was also selected over a comparable, yet larger 55 amp hour battery because it was 20 pounds less.
- Momentary switches were used in this application over DPST switches because we wanted it to go back to the default mode, coasting, in case anything happened to the wires connected to the switches.

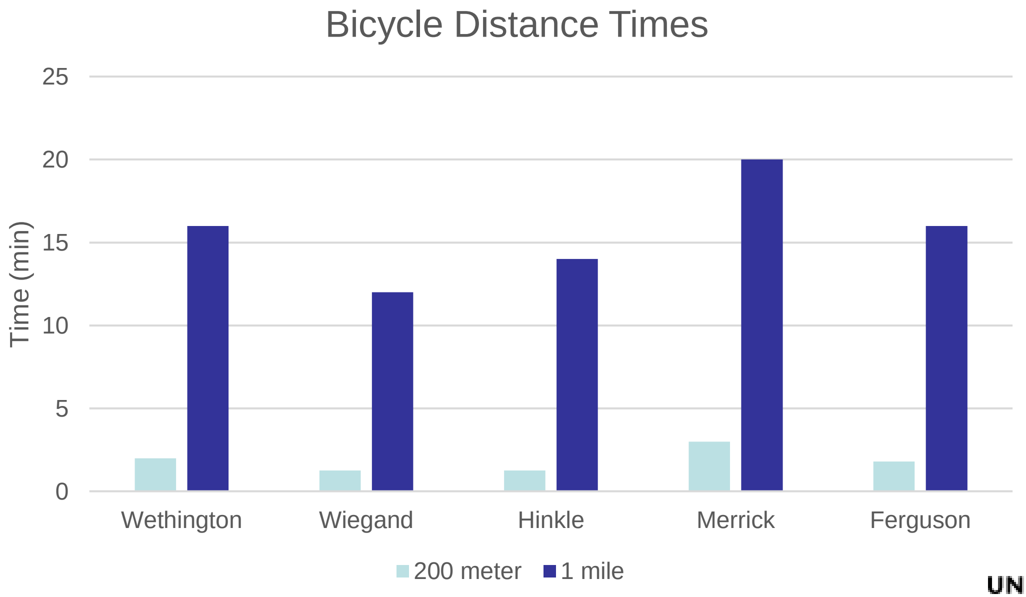
Testing

Testing

Timed Distance - Pedaling

The chart below outlines how much time it took each team member to complete 200 meters as well as a mile.

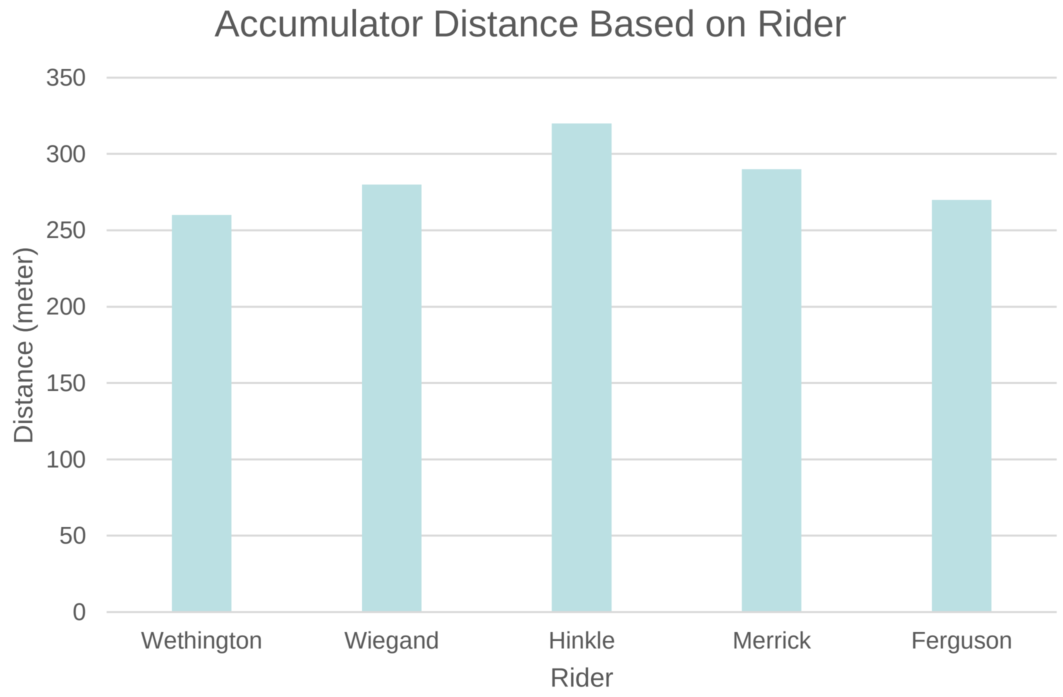
- The average pace for a mile is 4 mph
- The fastest 200m is 6 mph



Testing

Accumulator Distance

This test showed how far the bicycle traveled without any traveling when pre-charged to 3,000 PSI. The bicycle traveled a maximum of 320 meters with Chris Hinkle as the rider.



Manufacturability

- Suppliers
  - Hydraulic components from Parker Hannifin
  - Gearboxes: Parker and Crown
  - Couplings: Lovejoy
- Materials
  - Rolled Steel Tubing/angle
  - Grade 8 Hardware
- Processes
  - Butt and 90 degree angle fillet welds
  - Slotted holes and rubber filler grommets for drive train

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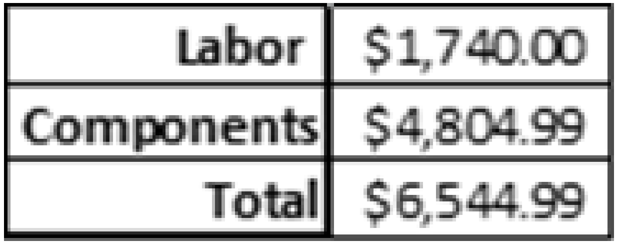
Cost Analysis

Prototype: All components and parts at normal prices

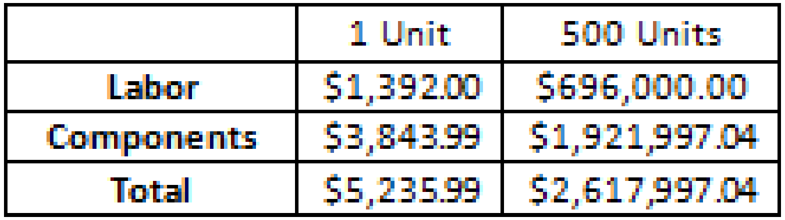


Labor	$1,740.00
Components	$4,804.99
Total	$6,544.99

Mass Production :

20% for wholesale

20% for skilled laborer and automation



	1 Unit	500 Units
Labor	$1,392.00	$696,000.00
Components	$3,843.99	$1,921,997.04
Total	$5,235.99	$2,617,997.04

Results

- Sprint: Approximately 6 mins
- Efficiency: Approximately 6.5’
- Time Trial: Did not finish

Lessons Learned

1. Gearing
2. Weight
3. Account for incline

Questions?