NFPA

Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

Final Presentation
NORTHERN ILLINOIS UNIVERSITY
DR. GHAZI MALKAWI
4/28/2023

NIU HUSKIES

Team Introduction

- Frame and Mechanical

Skot Lien

Eric Steiner

Thomas Brown

Jason Henry

Team Introduction

- Hydraulics

Romeo Aguilera

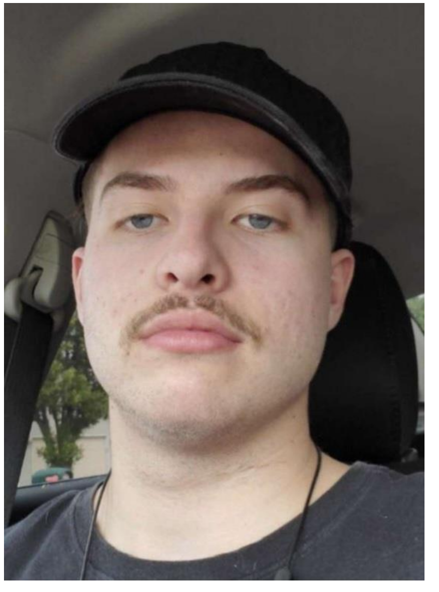
Marcus Paraggua

Michal Zima

Team Introduction

- Electrical and Controls






Milicia Samoukovic   Nikola Cuca   Radovan Magazin   Nerick Samayoa

Objectives

- Frame and Mechanical
  - Improve the rigidity of the frame
  - Increase the strength of the wheel mounts
  - Decrease the center of gravity
  - Balance the center of mass
  - Decrease the cross-sectional area of the vehicle
  - Build a simple, but solid foundation for future years

Objectives Cont'd

- Hydraulics
  - Simplify hydraulic circuit for greater efficiency
  - Create safe hydraulic system that achieves desired mph without overworking the operator
  - Gain greater knowledge of hydraulics

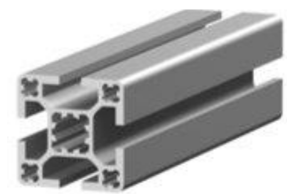
Objectives Cont'd

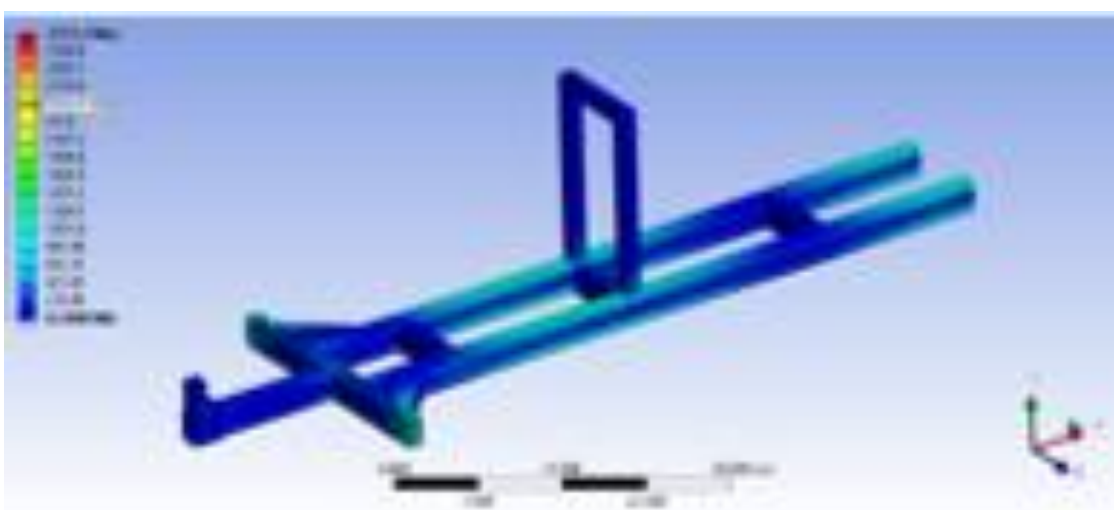
- Electrical and Controls
  - Create a system that maintains and monitors vehicle performance
  - Improve on circuitry from last year
  - Improve understanding of electronic/controls in application of hydraulics.

Midway Summary Review

- New Frame Material:
  - Maytec, 6061 Aluminum Extrusions
    - 40x40mm and 40x80mm
  - Lightweight, yet rigid
  - Easy assembly and mounting







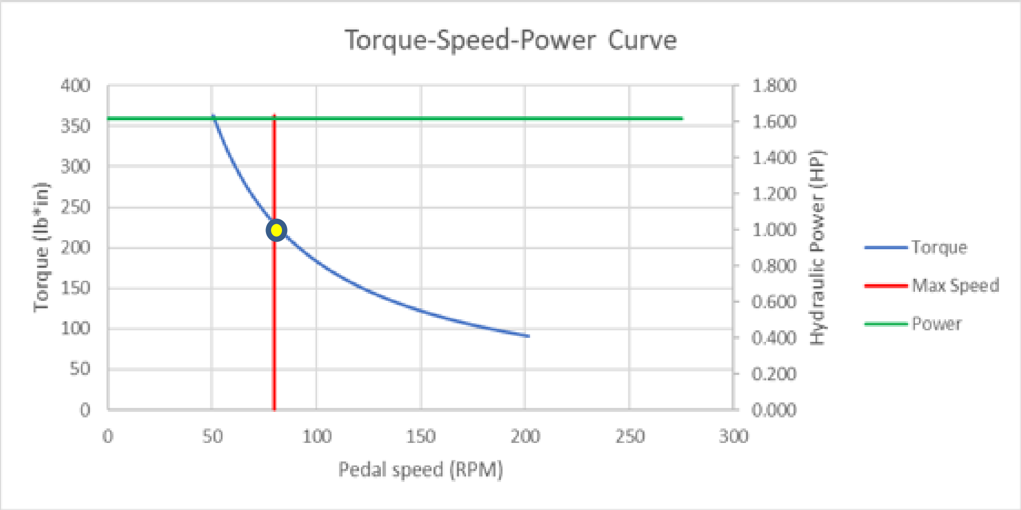
Max Deflection: 0.0003 in
Max Von Mises Stress: 3,400 psi

Shear Strength: 30,000 psi
FoS=8.9

Fatigue Strength: 13,000 psi
FoS=3.8

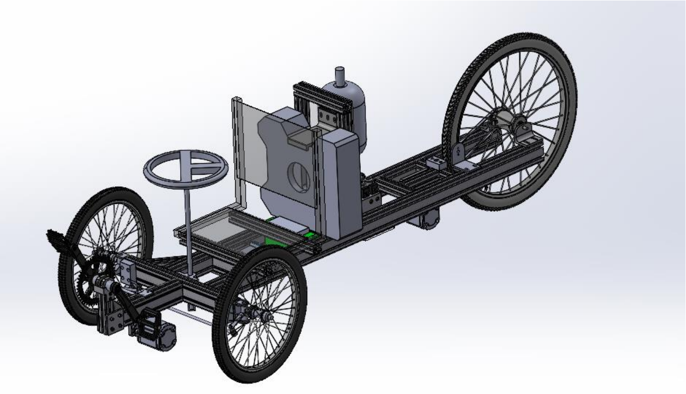
Midway Review Summary

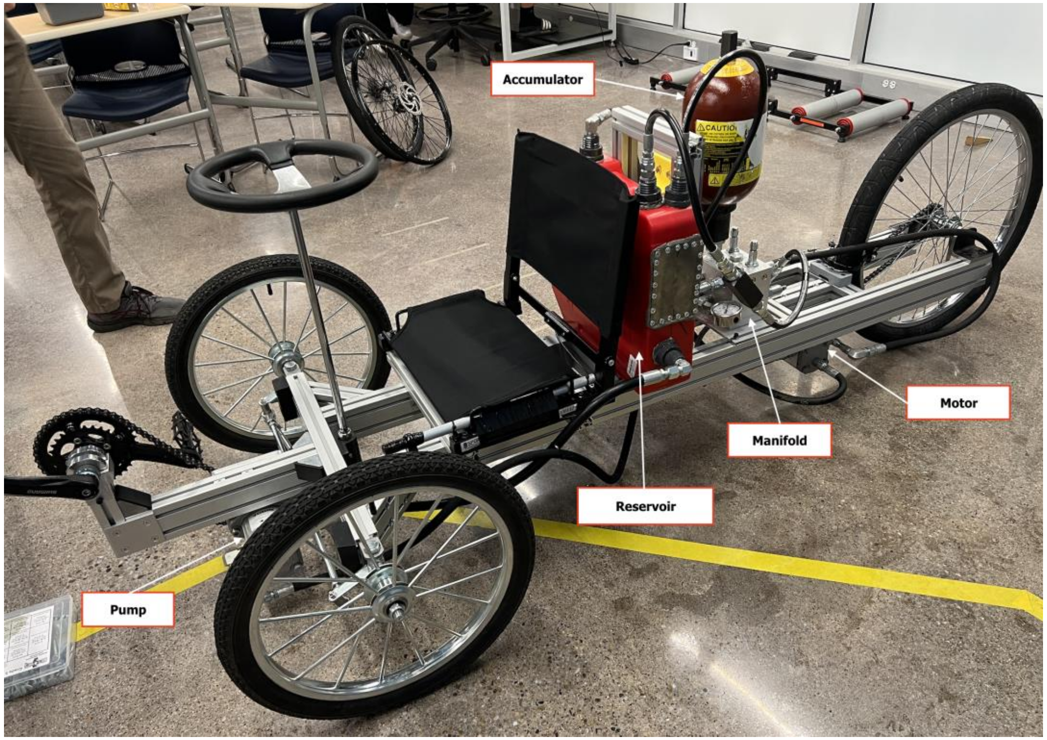
- Design goals:
  - Rider pedal input of 80 rpm
  - 2400 psi system pressure
  - 30 mph bike speed
  - 236 lb*in of torque
  - Gear Ratio: 5:1
    - Mechanical gear ratio: 2.5:1



Final Vehicle Layout

- Component Layout
  - Low Center of Gravity
  - Proper Fluid Flow
  - Minimal Tubing
  - Adjustability





Vehicle Construction

- Completed multiple 3D print prototypes and final designs for mounting
- CAD model and drawings created for all additional mounting components needing machining
- Cut and drilled several mounting plates and reservoir
- Wired multiple switches for controlling solenoids

Vehicle Construction

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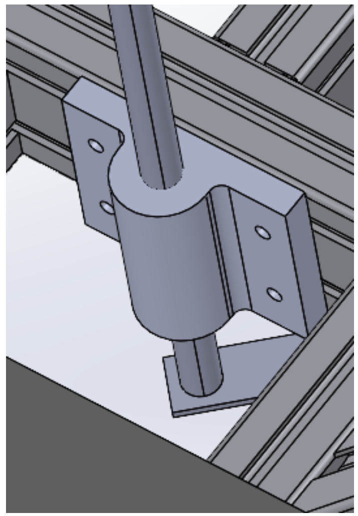
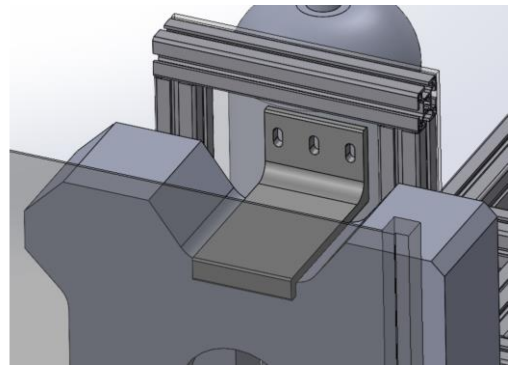
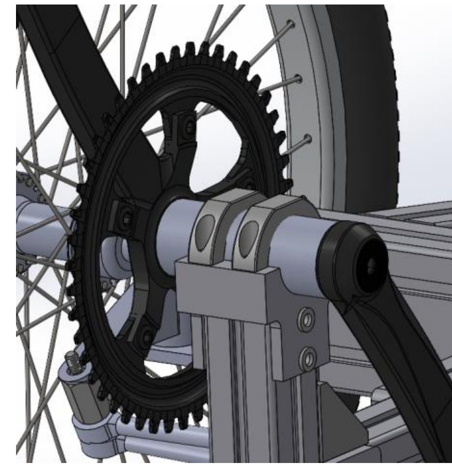
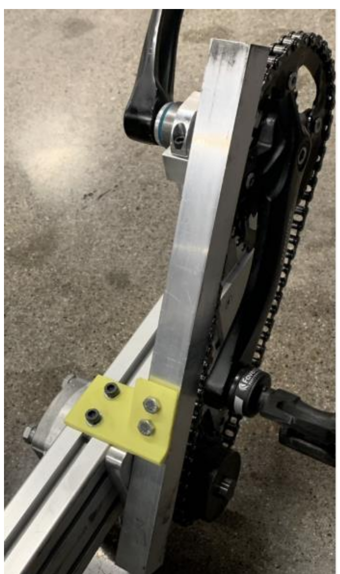
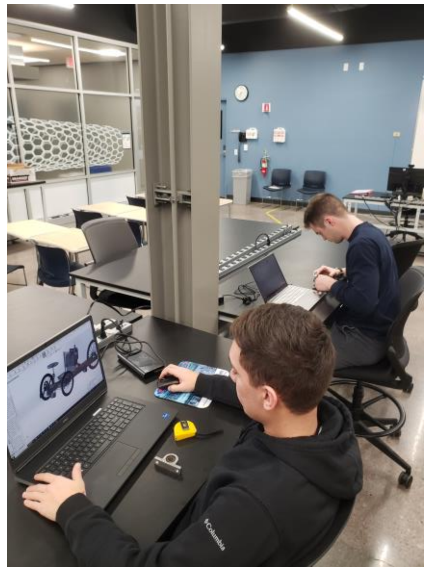
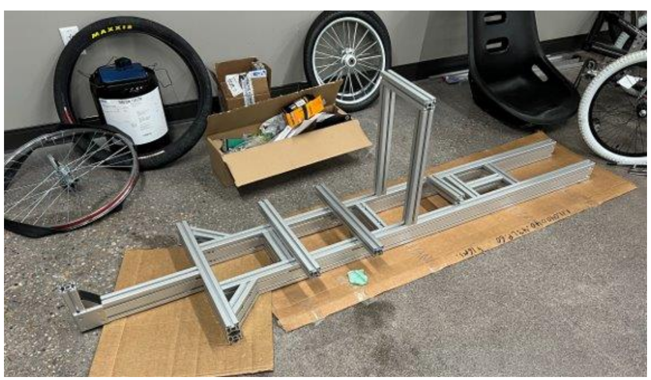






Vehicle Construction

NFPA Fluid Power Vehicle Challenge





Vehicle Construction

- Drivetrains
  - Front gear ratio: 2:1
  - Rear gear ratio: 1:2

Custom Reservoir Construction

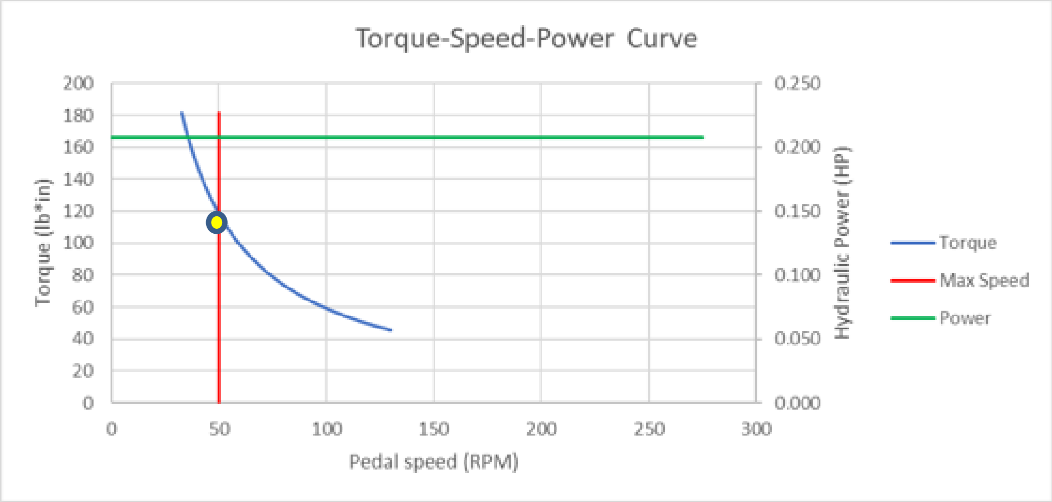
NFPA Fluid Power VEHICLE Challenge

Vehicle Testing

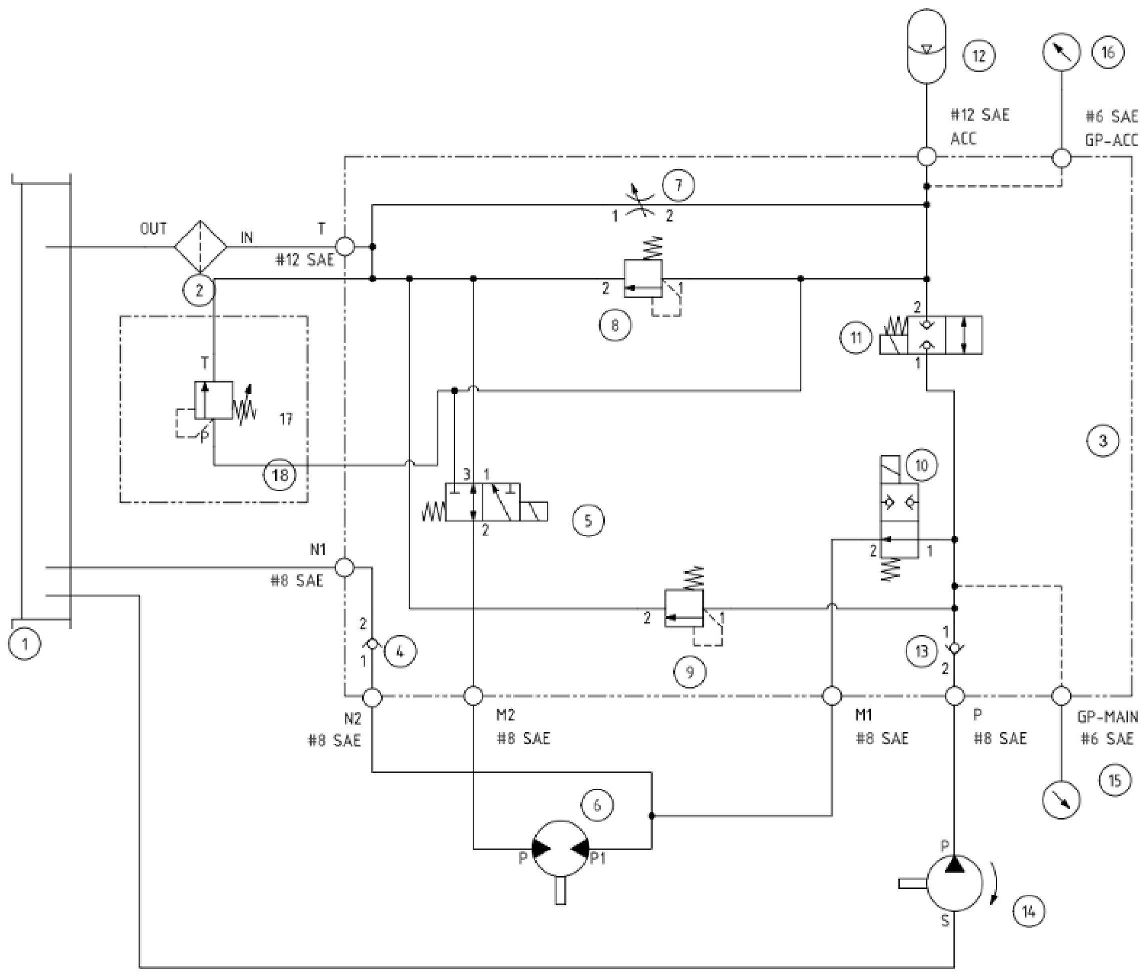
- Different gear ratios for optimal output
- Troubleshot issues with accumulator holding pressure
- Effect of different pre-charge pressures on performance
- Different accumulator stored pressures
- Optimal strategy for sprint race

Bike Performance - Actual

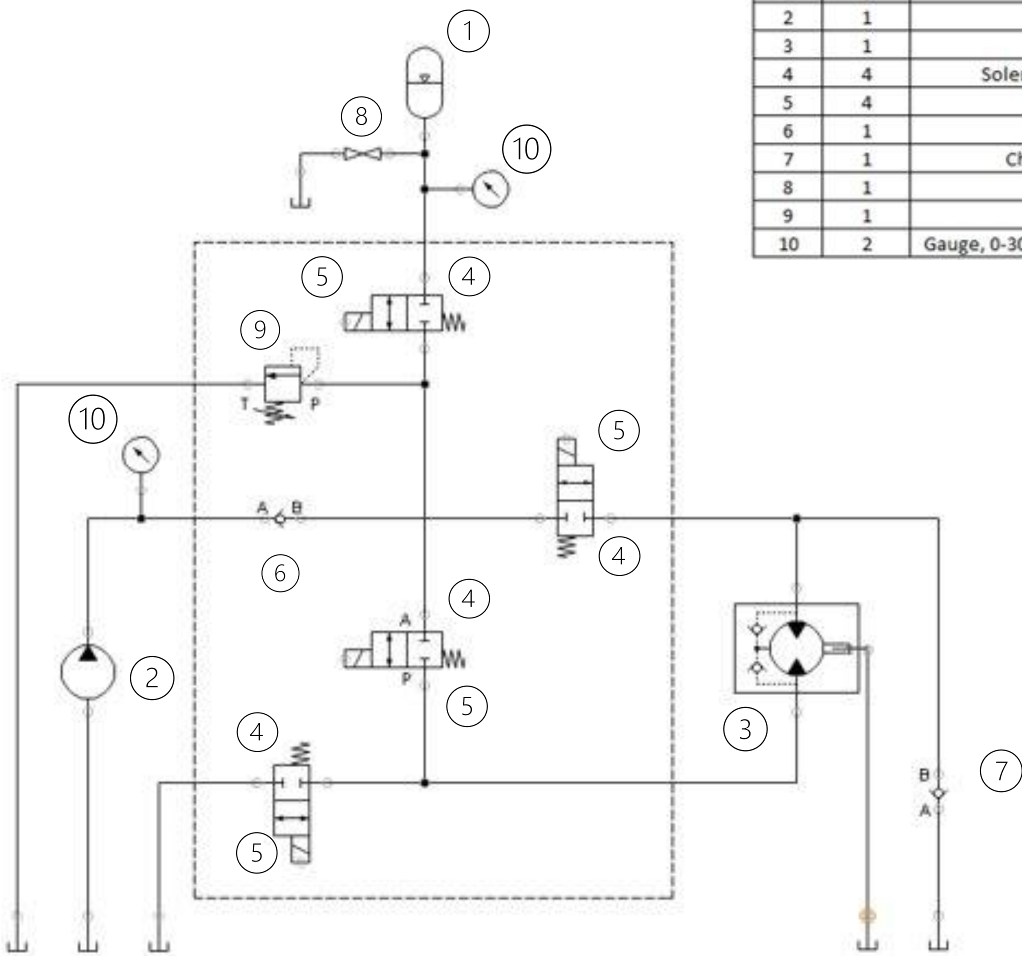
- Attained output:
  - Rider pedal input of 50 rpm
  - 1200 psi system pressure
  - 15 mph bike speed (20+ mph with accumulator)
  - 118 lb*in of torque
  - Gear Ratio: 2:1
    - Mechanical gear ratio: 1:1



Last Year Hydraulic Circuit



Current Hydraulic Circuit



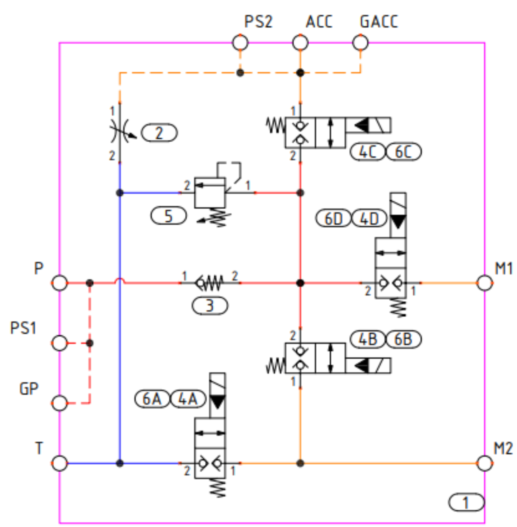
Bill of Materials			
BOM #	Quantity	Part Description	Part #
1	1	Accumulator	A13100
2	1	Casappa Pump CIR 1.446	PLP20.24,5D0-49S9-LOD/OC-N-EL
3	1	Casappa Motor CIR 0.687	PLM20.11,2R0-31S9-LOC/OC-N-EL
4	4	Solenoid, 2 pos. 2 way Bi- poppet, normally Closed	SBV1110C000
5	4	Coil, 12VDC DIN, J type	300AA00121A
6	1	Check, 1 to 2, size 10	CV10-NP-0.3-B-00
7	1	Check Valve, 15 gpm Max. Flow, 5,000 psi Max	C800S
8	1	Flow Control, Needle Valve	FC7-10-S-0-NV
9	1	Relief, Direct Acting	RV1-10-S-0-36
10	2	Gauge, 0-3000 PSI, SAE -4 male adjustable stem. 2-1/2" diameter	CF-1P-210-A-SAE

- System hose sizes:
  - Pump inlet: 1/2"
  - Pressure lines: 3/8"
  - Case drain: 1/4"

Custom Manifold

ITEM ID	PORT TYPE	PORT SIZE
ACC, M1, M2, P, T	SAE O-RING	#8 SAE
GACC, GP, PS1, PS2	SAE O-RING	#6 SAE

Item	Qty	Model Code	Description	Manufacturer
1	1	FV-14047-M1	Manifold body	Source Fluid Power
2	1	FCV7-10-S-0-NV	Flow Control Needle Valve	Eaton
3	1	CV10-NP-0.3-B-00	Check 1 to 2	Danfoss ICS
4	4	SBV11-10-C-0-00	Solenoid 2 pos. 2 way	Eaton
5	1	RV1-10-S-0-36	Relief Direct Acting	Eaton
6	4	300AA00121A	Coil 12VDC, DIN	Eaton



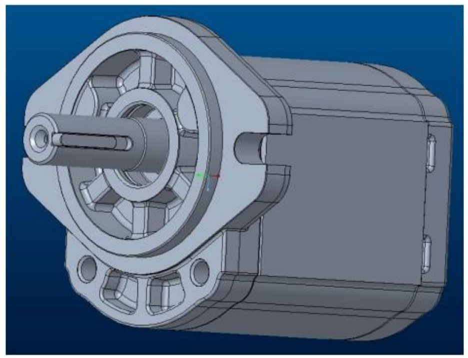
Notes:
-3000 PSI max
-Team to procure all parts listed on the BOM separately, and install at their location

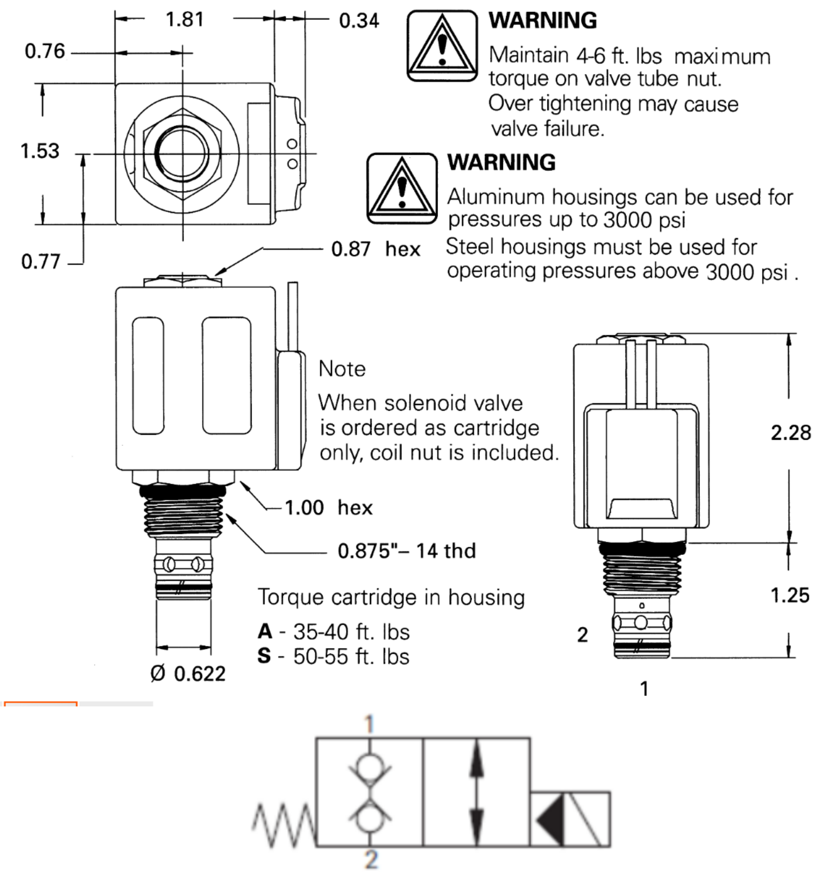
Creation Date 11/29/2022	Drawn By J. McCarthy	Customer Name Northern Illinois University
Material Aluminum	Print Checked By (Team)	Title NVPA-FPVC 22-23
Protective Finish None	Sheet Name Sheet 1 of 1	Part Number FV-14047-V1 schem
Size B — Dimensions are in inches. Do not scale drawing. Unless otherwise specified, apply standards per FV-1000-Spec1	Third Angle Projection	Rev B

Hydraulic Components

PUMP PLP20.24,5D0-49S9-LOD/OC-N-EL

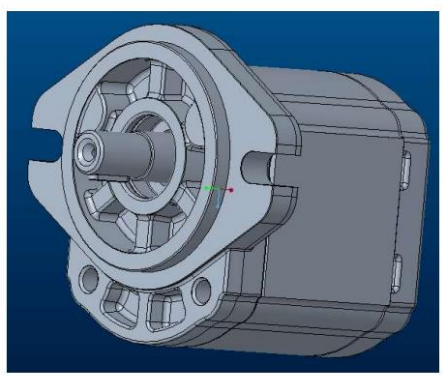
PUMP PLP20.24,5D0-49S9-LOD/OC-N-EL	
PL	Polaris
P	Pump
20	20 Series Frame Size
24,5	24.5cc (1.52cir) Displacement
D	Clockwise Rotation
0	No Outboard Bearing
49	SAE Ø3/4" Straight Key Shaft
S9	SAE A 2-bolt flange (Slotted)
L	Side Ports
OD/OC	1 1/16" ORB Inlet / 7/8" ORB Outlet
N	Buna Seals
EL	Aluminum Flange and Cover



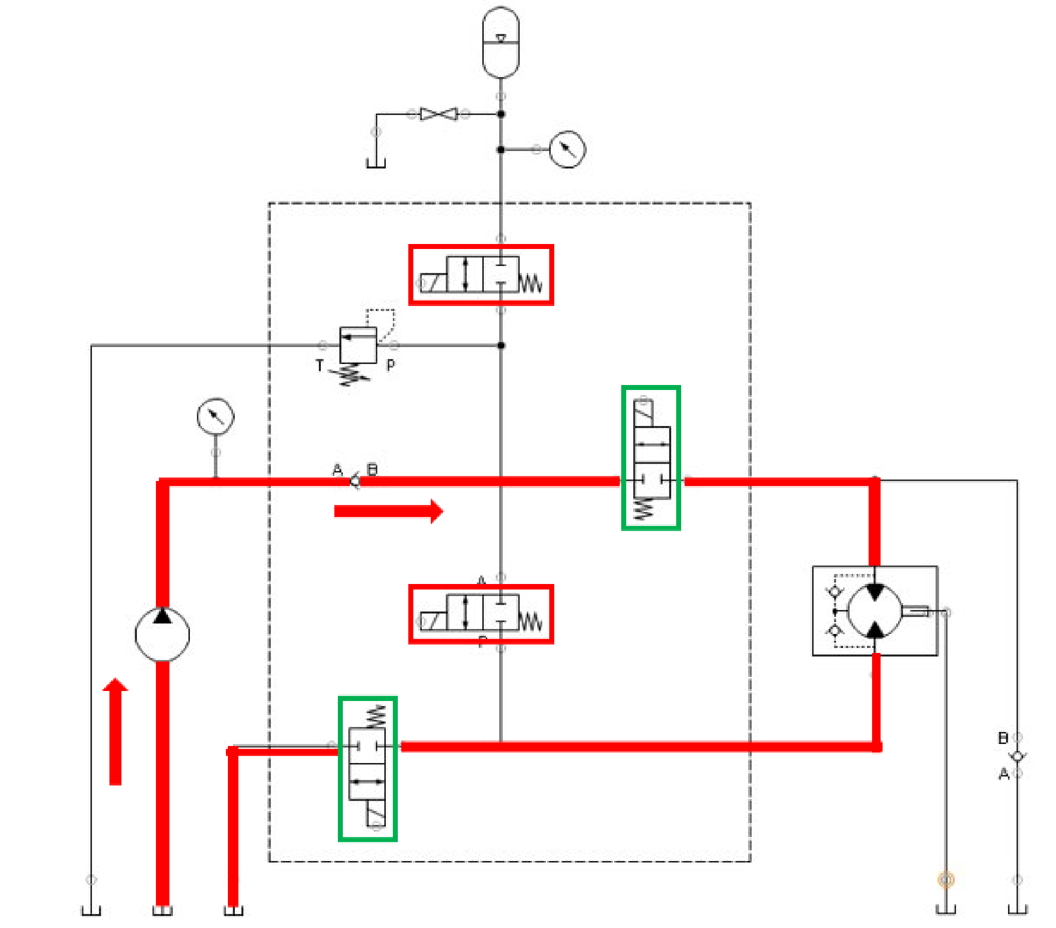


MOTOR PLM20.11,2R0-31S9-LOC/OC-N-EL

PLM20.11,2R0-31S9-LOC/OC-N-EL	
PL	Polaris
M	Motor
20	20 Series Frame Size
11,2	11.2cc (0.69cir) Displacement
R	Reversible, Rear External Drain
0	No Outboard Bearing
31	SAE Ø5/8" Straight Key Shaft
S9	SAE A 2-bolt flange (Slotted)
L	Side Ports
OC/OC	7/8" ORB Inlet / 7/8" ORB Outlet
N	Buna Seals
EL	Aluminum Flange and Cover



Hydraulic Subcircuit – Direct Drive

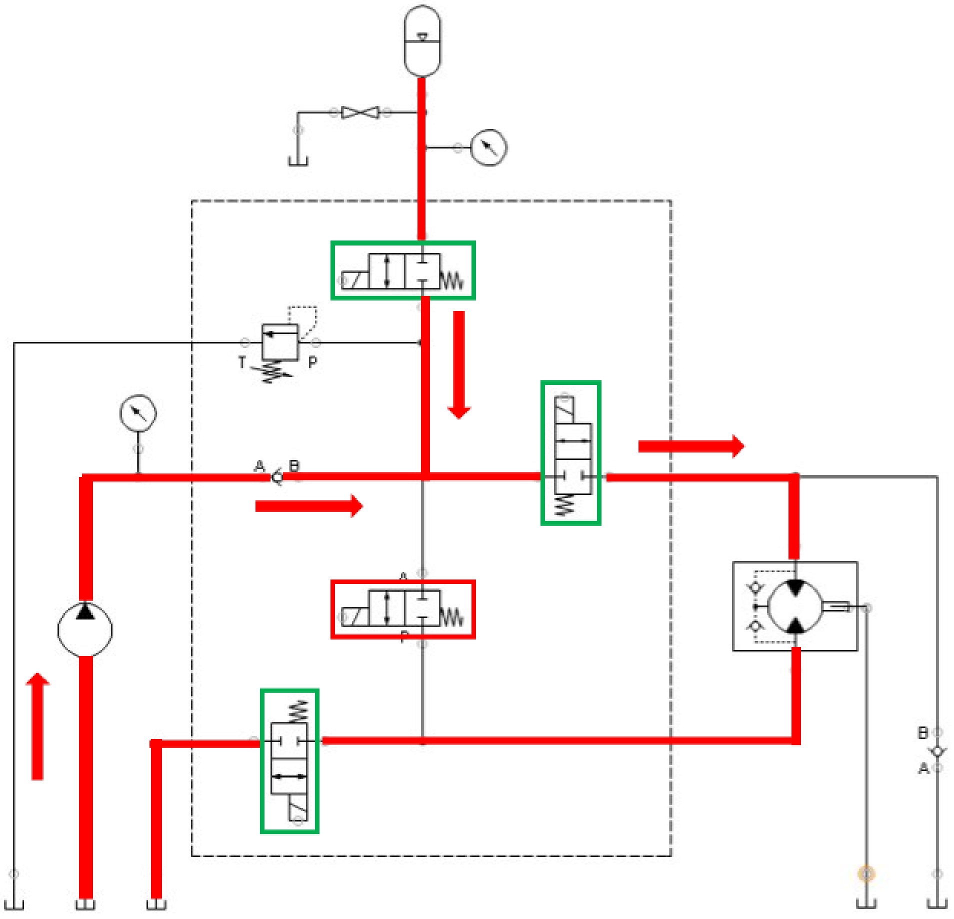


= Inactive Solenoid

= Active Solenoid

= Manifold Body

Hydraulic Subcircuit – Direct Drive + Accumulator Drive

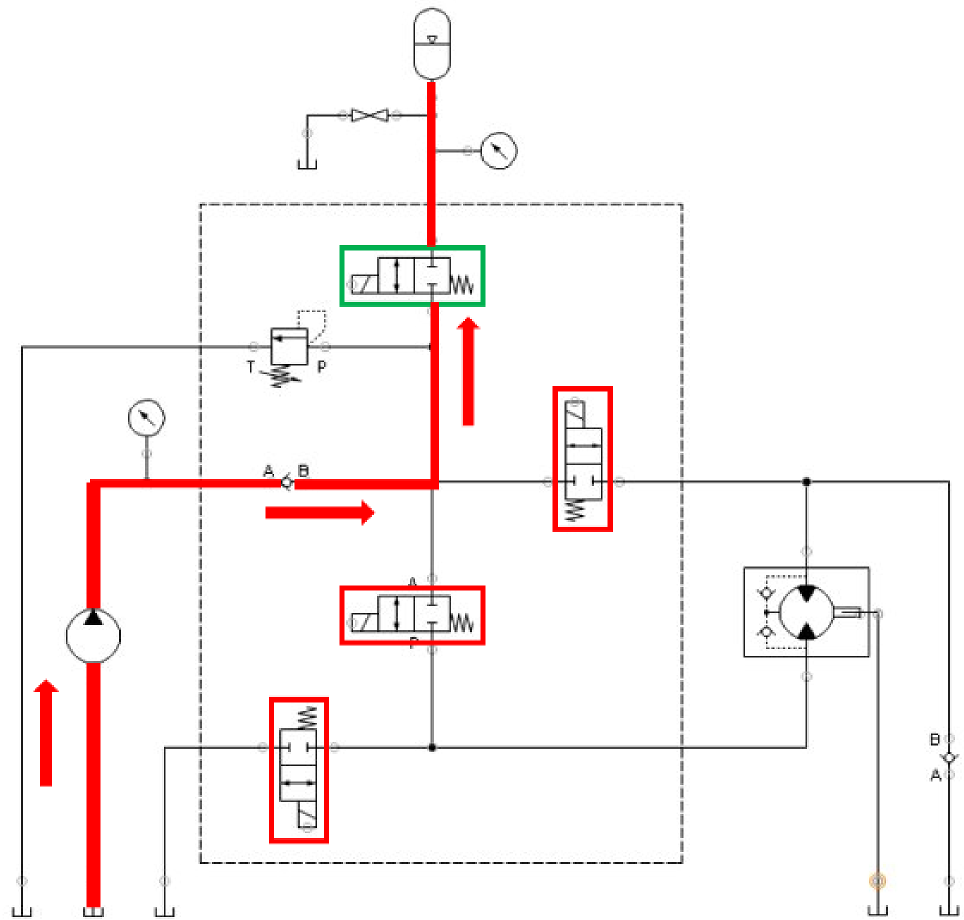


= Inactive Solenoid

= Active Solenoid

= Manifold Body

Hydraulic Subcircuit – Accumulator Charge

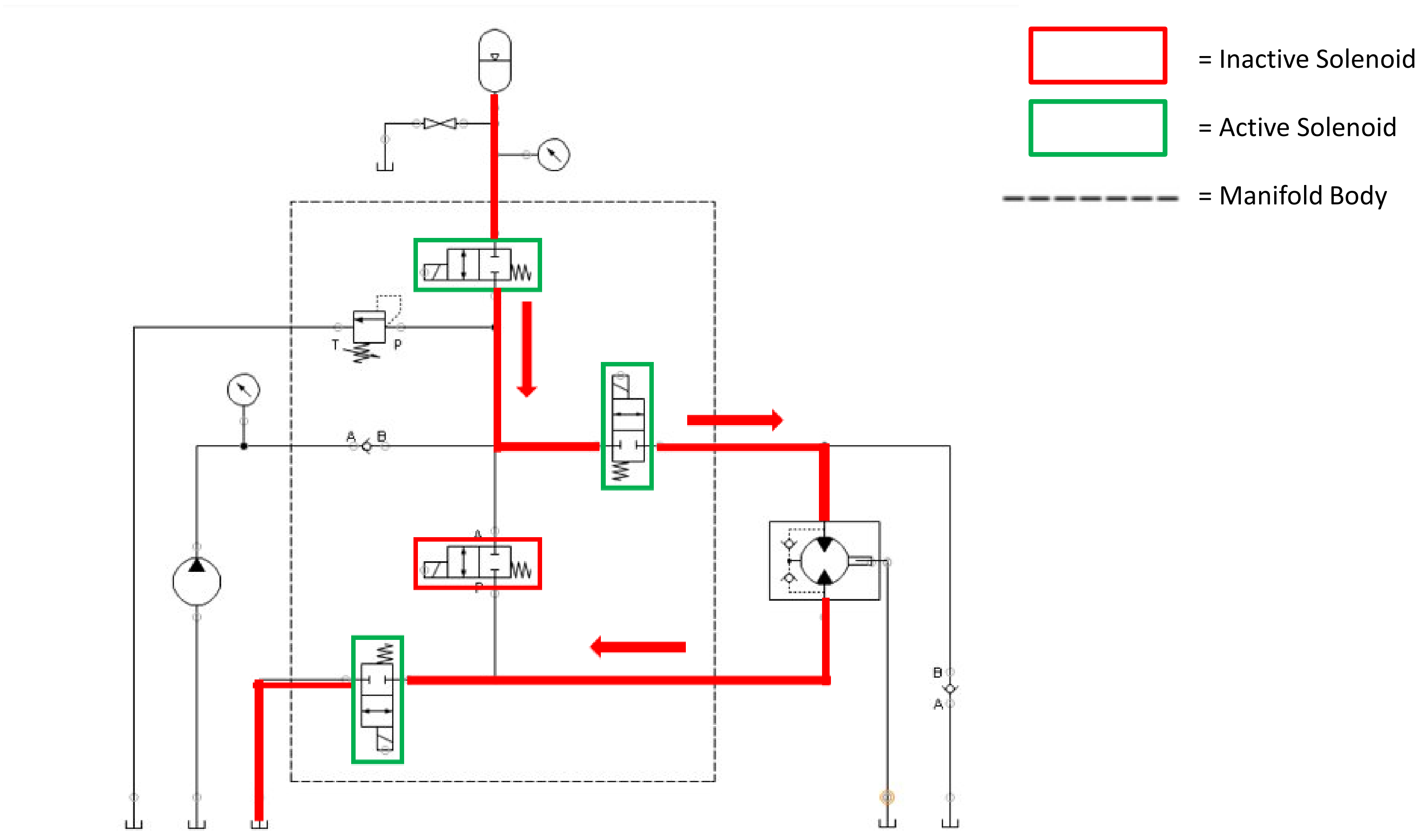


= Inactive Solenoid

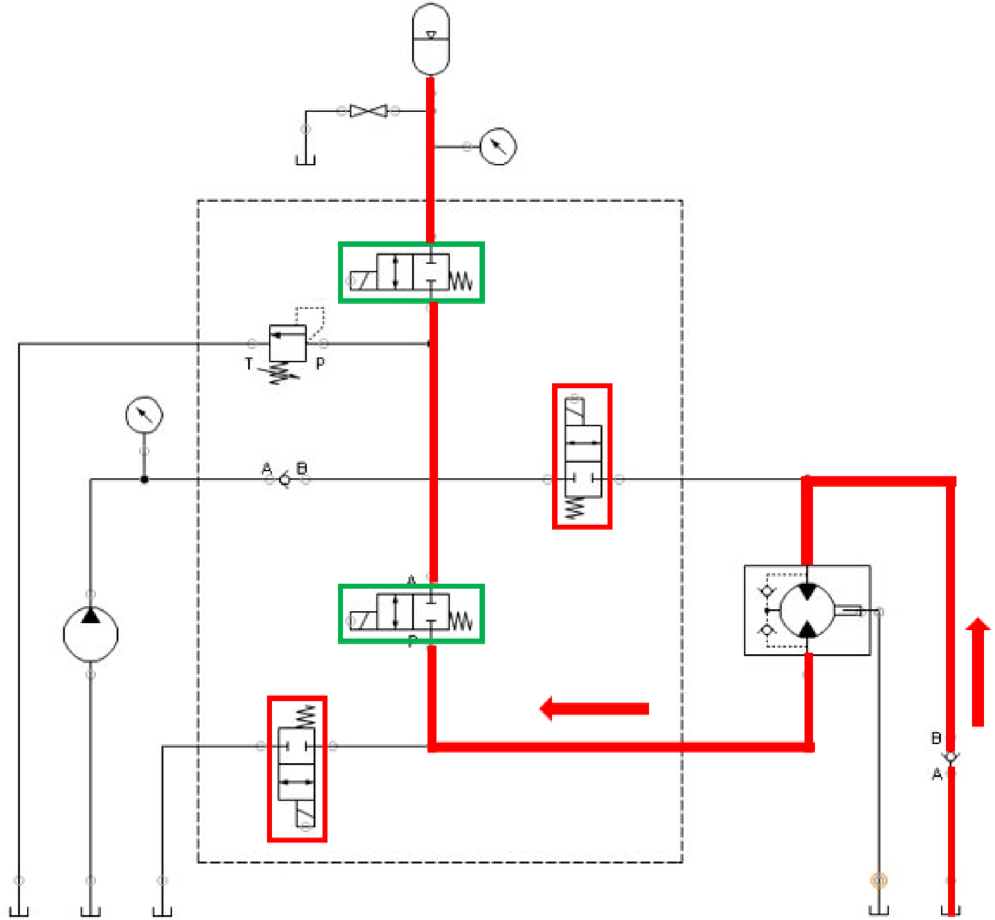
= Active Solenoid

= Manifold Body

Hydraulic Subcircuit – Accumulator Discharge



Hydraulic Subcircuit – Regenerative Mode

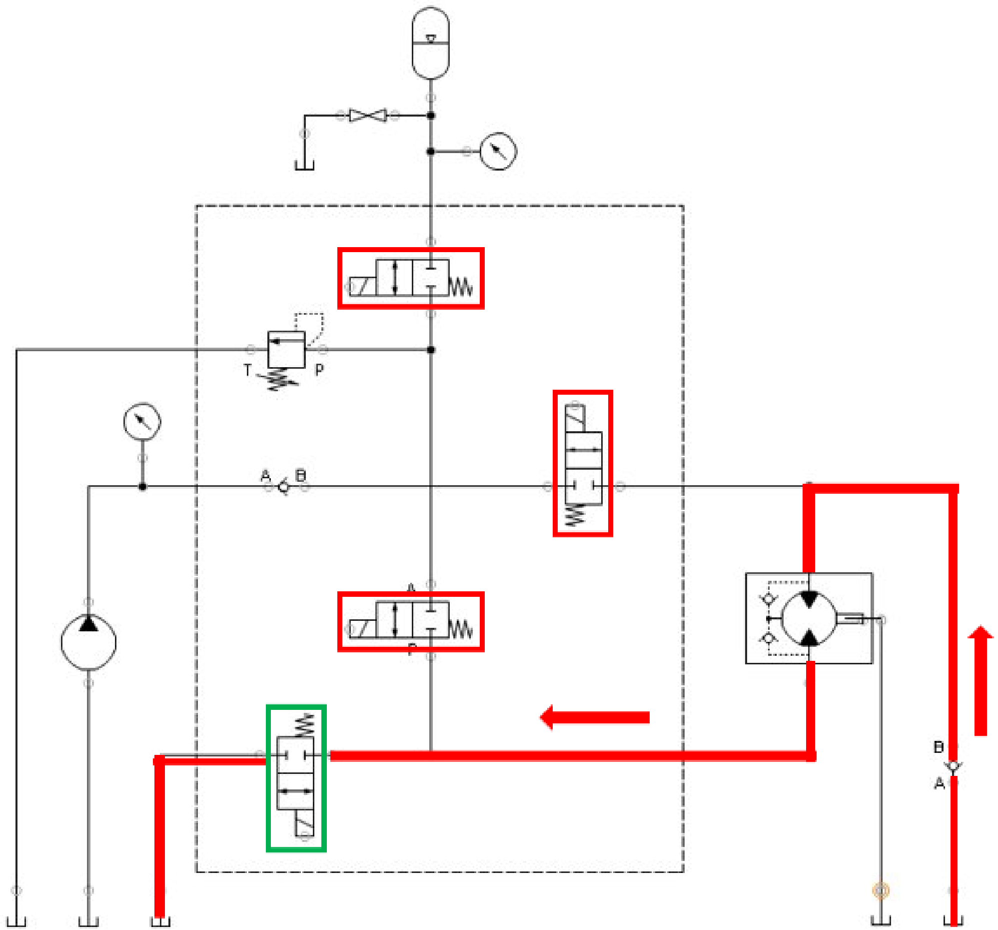


= Inactive Solenoid

= Active Solenoid

= Manifold Body

Hydraulic Subcircuit – Coast Mode

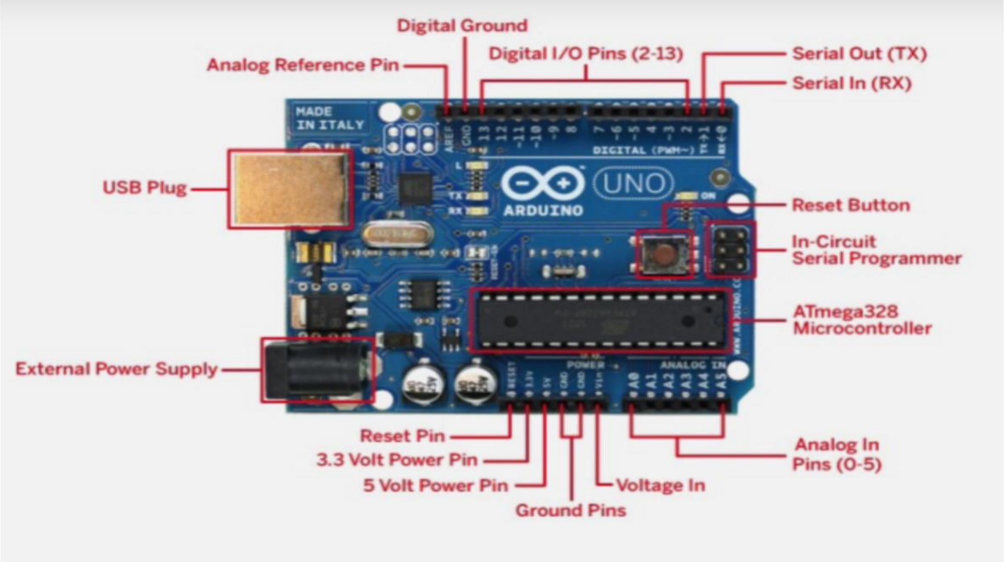


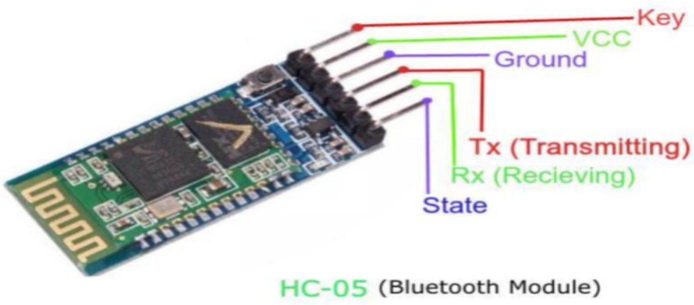
= Inactive Solenoid

= Active Solenoid

= Manifold Body

The Controller





The Arduino UNO will be used in combination with diodes, resistors and transistors to create a control unit that will send digital signals to our solenoids to actuate them. We will achieve this wirelessly using the HC-05 bluetooth module. The Arduino is easy to code and inexpensive.

The Switches

Switches are attached on the bike as a failsafe and can also be used to switch modes for the bike if the controller does not work. They are simply attached to the battery and the solenoids.

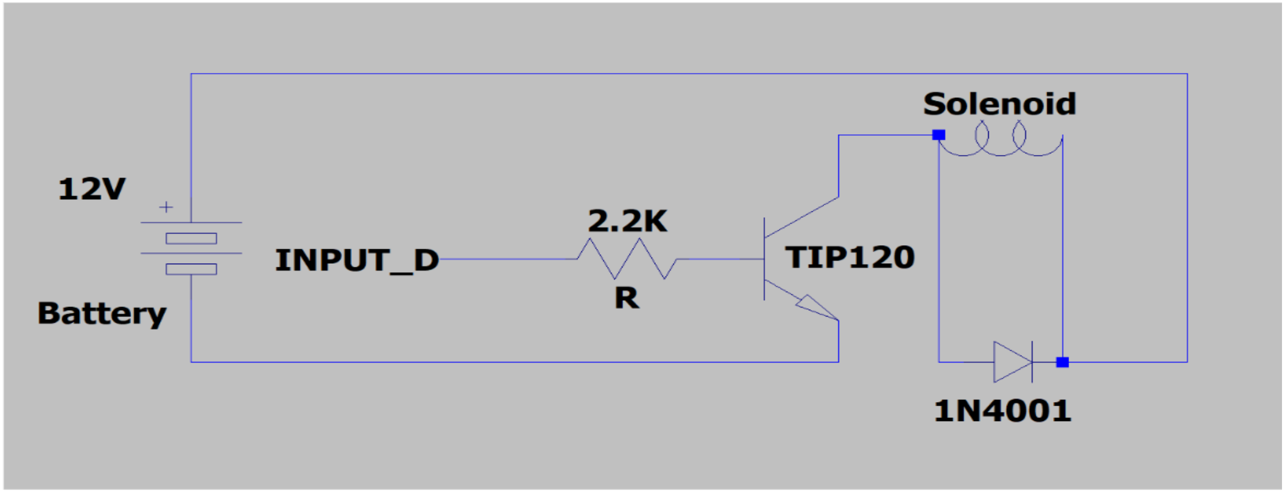
The Display

The display is a tablet but can also be a smartphone, as the app we used is called BlueControl and it allows us to connect to our bluetooth module and send it digital signals. The app allows us to select modes using buttons, terminal and voice control.

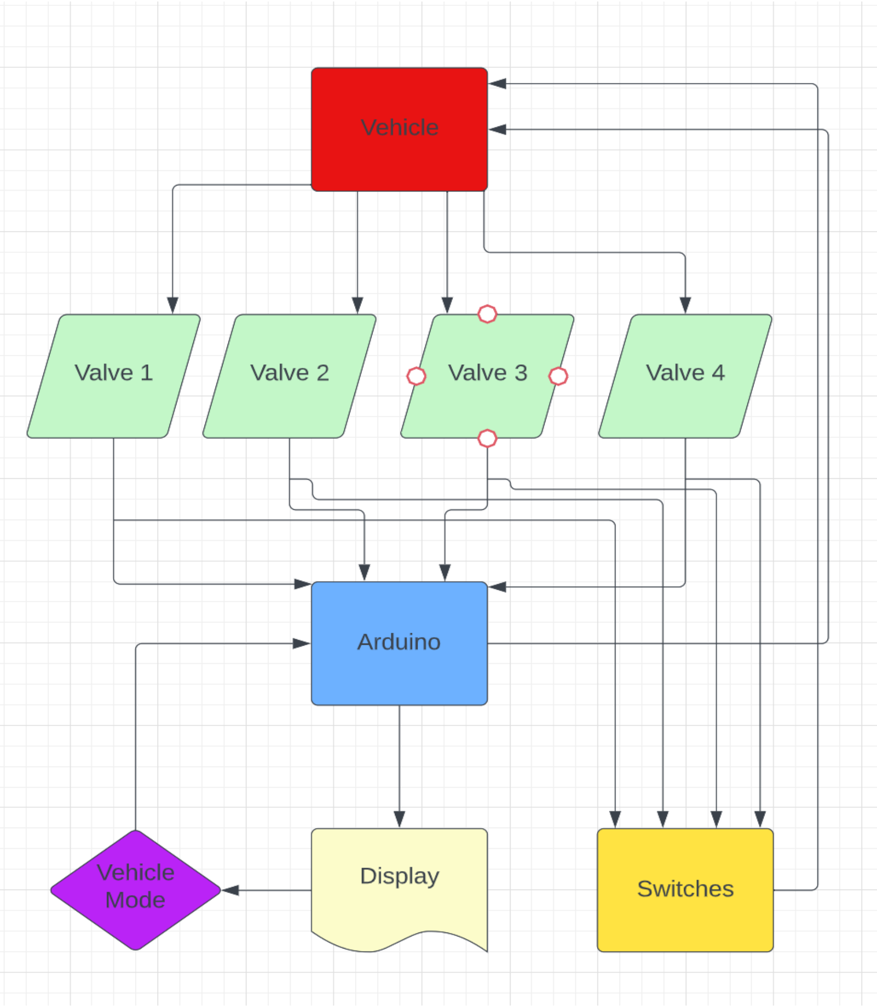
The Code and Schematic

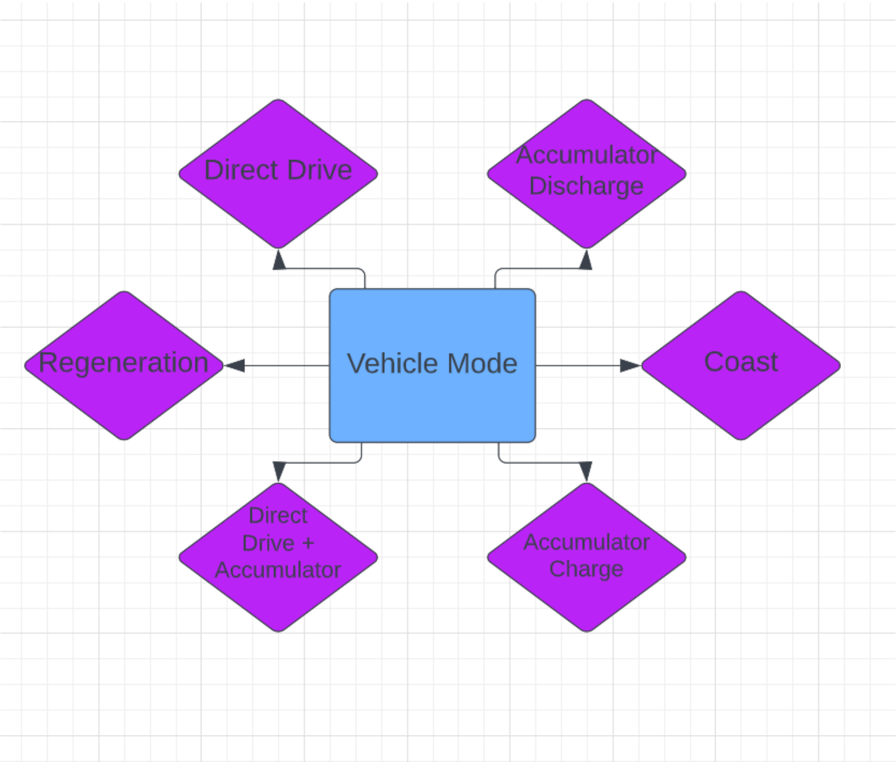
```
char Incoming_value; //variable to recieve data from serial port

void setup() {
Serial.begin(9600);


pinMode(4, OUTPUT); //A
pinMode(5, OUTPUT); //B
pinMode(6, OUTPUT); //C
pinMode(7, OUTPUT); //D

}

void loop() {

 if(Serial.available() > 0)
 {
   Incoming_value = Serial.read();
  Serial.print(Incoming_value);


// DIRECT DRIVE
if(Incoming_value == '1') //if direct drive selected
{
  digitalWrite(4, HIGH);  //4 high A
  digitalWrite(7, HIGH); //7 high D
}
if(Incoming_value == '0')
{
  digitalWrite(4, LOW); //4 low A
  digitalWrite(7, LOW); //7 low D
}
```

We used Arduino IDE, which uses C++, to code our controller.
Also we used LTspice to simulate our circuit.



The Method


Vehicle
Valve 1
Valve 2
Valve 3
Valve 4
Arduino
Display
Switches
Vehicle Mode


Direct Drive
Accumulator Discharge
Regeneration
Vehicle Mode
Coast
Direct Drive + Accumulator
Accumulator Charge

Accomplishments

- Solid mechanical foundation for integration of electrical and hydraulic components
- Decreased the center of mass
- Rigid wheel mounting
- Simplified hydraulic circuit design for greater efficiency
- Designed a hydraulic system capable of providing output to rear wheel
- Improved switch design from last year

Conclusion

- Lessons Learned
  - Real engineering project experience
    - Cross-functional teamwork experience
  - Understanding of planning and staying on schedule
  - Gained fundamental knowledge of hydraulics
  - Troubleshooting skills
  - Improved mechanical design skills for machinability and printability
  - Keep it simple and then improve

Acknowledgements

- Acknowledgements
  - David Lennon of Casappa
  - The National Fluid Power Association
  - Jeff McCarthy from Sunsource
  - Ryan Krajecki and Affiliated Control
  - Andrew, Arbrim, Gabe, Gordy, Jason, Jen, et al.