NFPA Fluid Power Vehicle Challenge

NFPA
Education and
Technology
Foundation

FINAL PRESENTATION
UC IRVINE
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Team Introductions

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Electronics Design and Testing

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Mechanical Design and Documentation

Team Introductions

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Mechanical Design and Manufacturing

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Mechanical Design and Hydraulic Design

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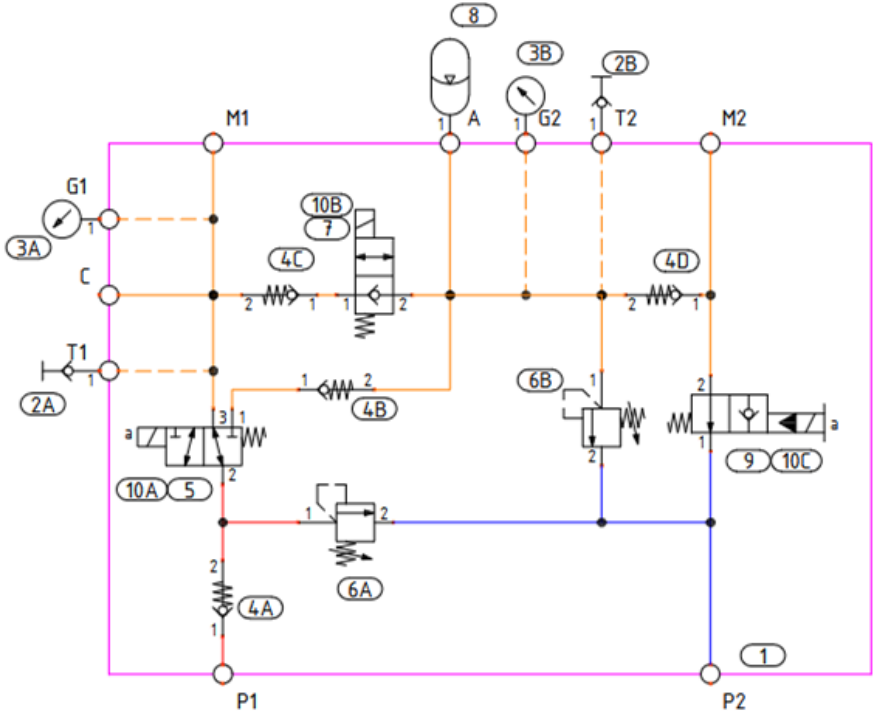
Mechanical Design and Hydraulic Design

Completed Vehicle

- Vehicle weight: ~140 lbs
- Prefabricated trike frame
- Hydraulic manifold
- LCD electronic display
- Pedal-to-pump gear ratio:
  - 38/16 = 2.375
- Wheel-to-motor gear ratio:
  - 18/20 = 0.9
- Drum and V-brakes

Hydraulic Circuit

- 4 Drive States
  - Direct drive (Default)
  - Direct charging
  - Regenerative braking
  - Accumulator venting
- 3 Solenoid Cartridge Valves
- 2 Pressure Relief Valves
  - Main line pressure
  - Accumulator pressure

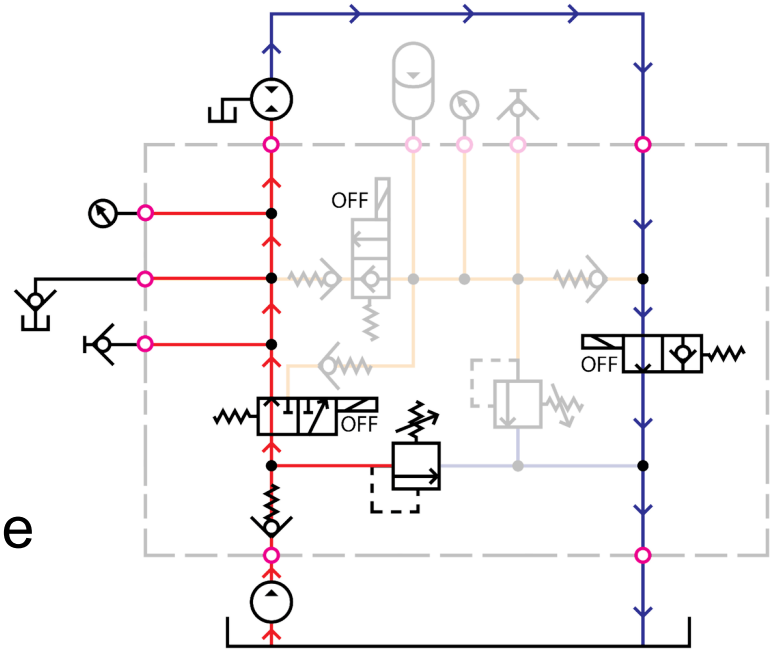


Hydraulic Circuit - Direct Drive

- Default State, all three solenoids deactivated
- Reservoir → Pump → Motor → Reservoir

Red - Pressure lines

Blue - Low pressure return line

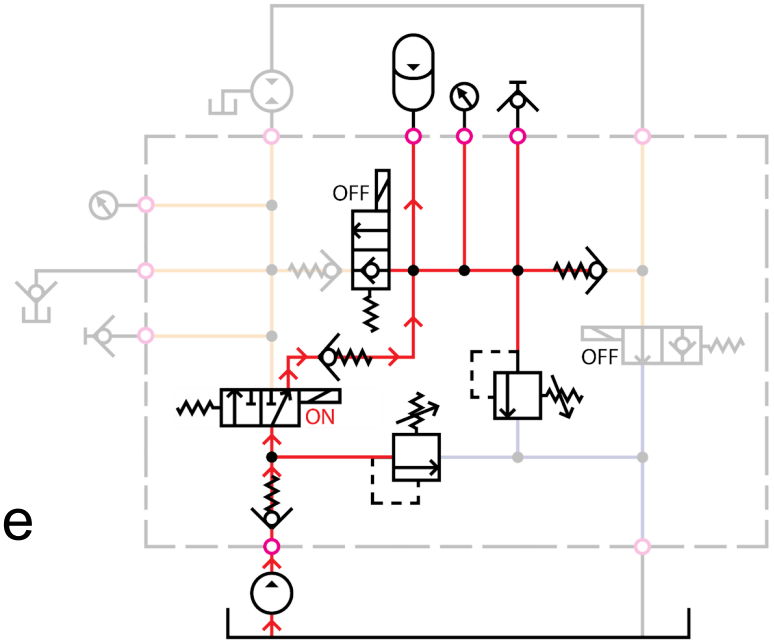


Hydraulic Circuit - Direct Charging

- Solenoid A energized
- Reservoir → Pump
  → Accumulator

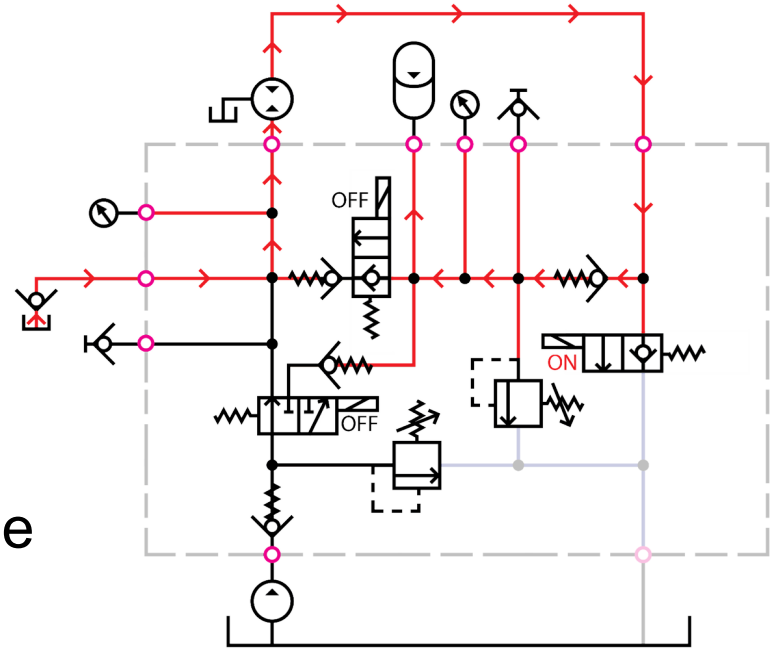
Red - Pressure lines

Blue - Low pressure return line



Hydraulic Circuit - Regen. Braking

- Solenoid C energized
- Reservoir → Motor → Accumulator

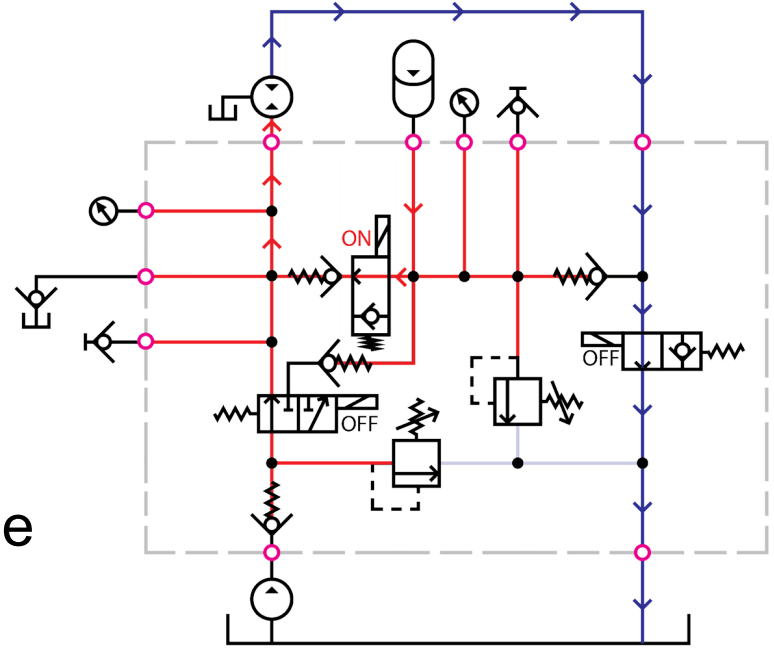


Red - Pressure lines

Blue - Low pressure return line

Hydraulic Circuit - Accumulator Venting

- Solenoids B energized
- Accumulator → Motor → Reservoir

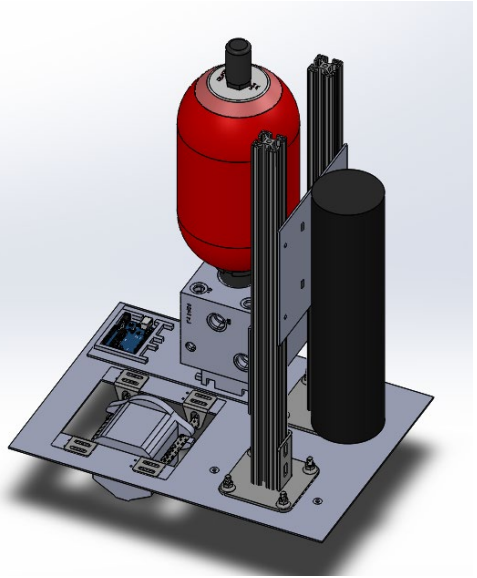


Red - Pressure lines

Blue - Low pressure return line

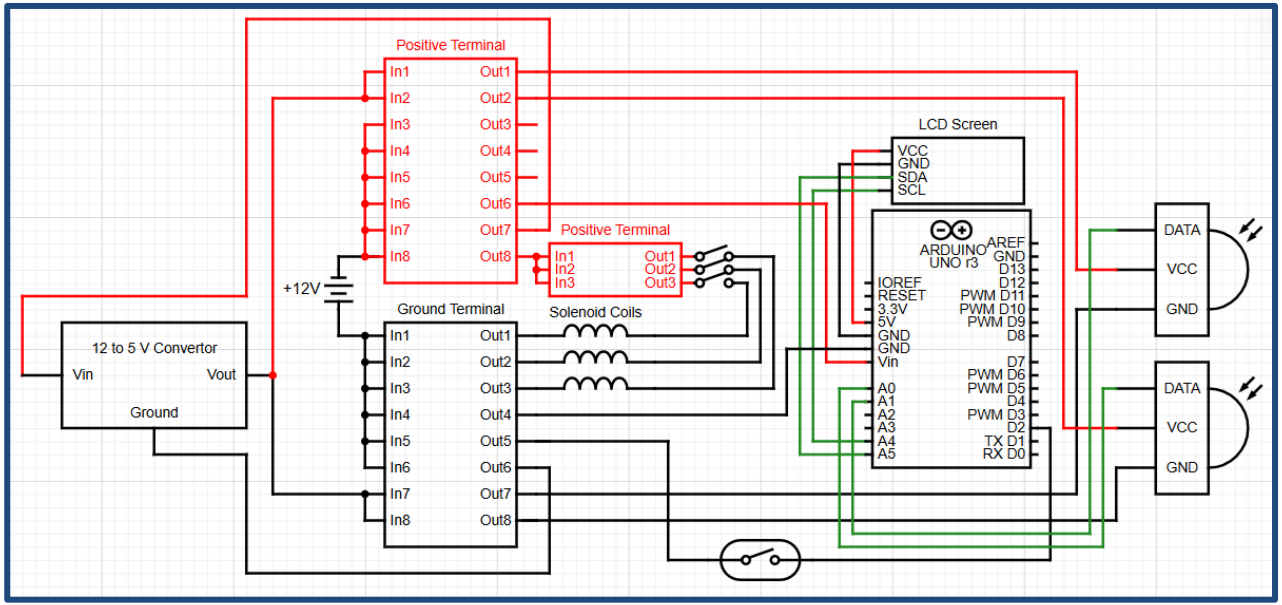
Frame Structure

- Modified single-speed Schwinn Meridian tricycle



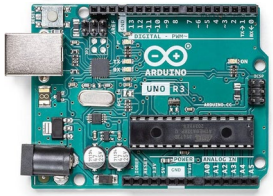
Controls and Electronic System

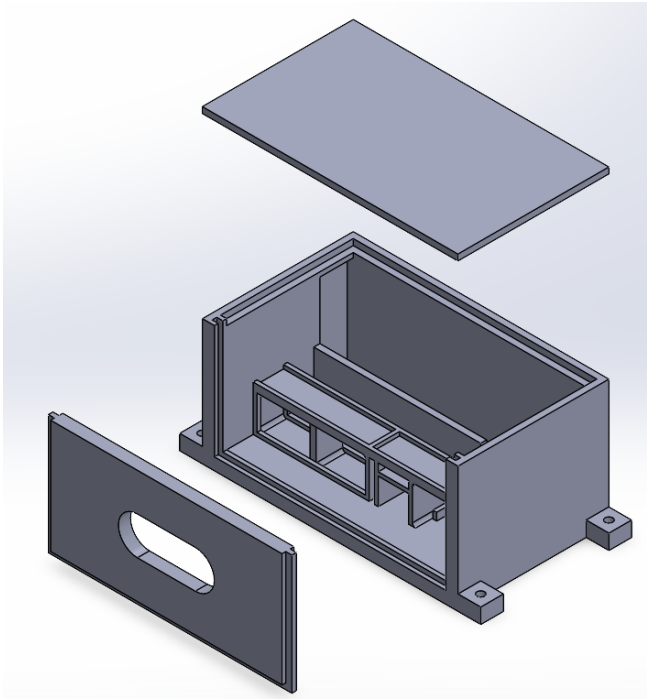
- Vehicle hydraulic state controlled by 3 toggle switches
- Heads-up LCD displays displays pressure transducers reading, RPM, and speed
    - Uses Arduino UNO R3 for data processing



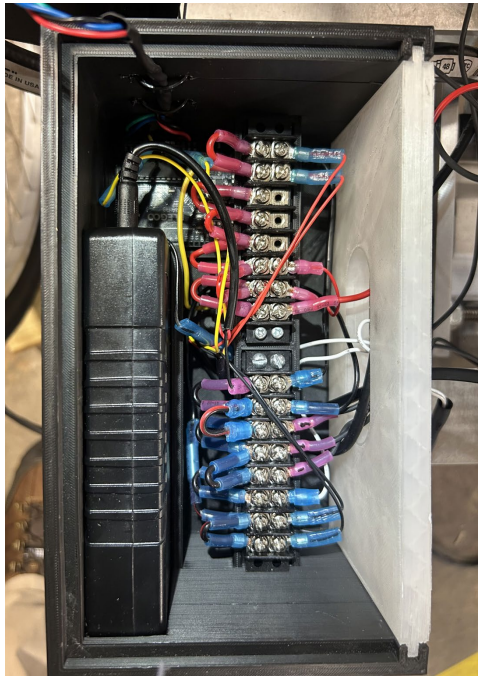
Rear Electronics Box(3 pieces)

- 12V rechargeable battery
  - 6000mAh
- Arduino UNO R3
  - Powers LCD screen and displays data
- Three Solenoid Switches
- Two 5V Pressure Transducers
- 12 to 5 V Convertor
  - Necessary to power the transducers
- Two 8 circuit terminal power blocks

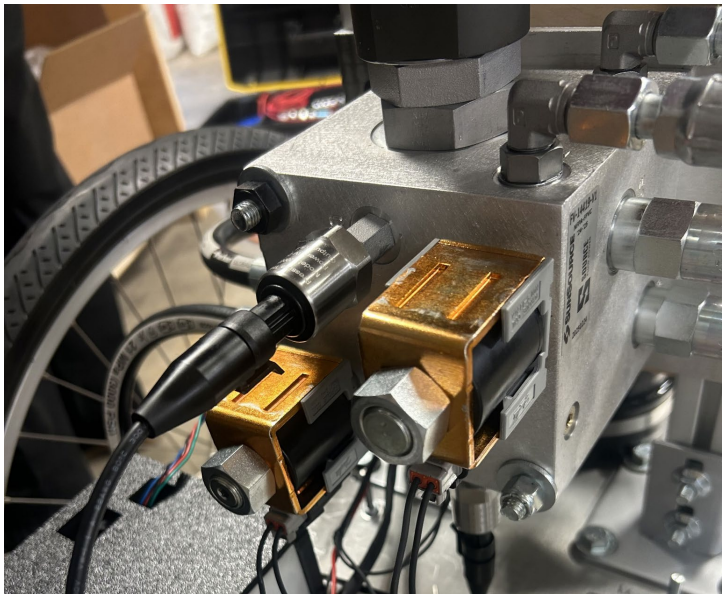




Rear Electronics Box



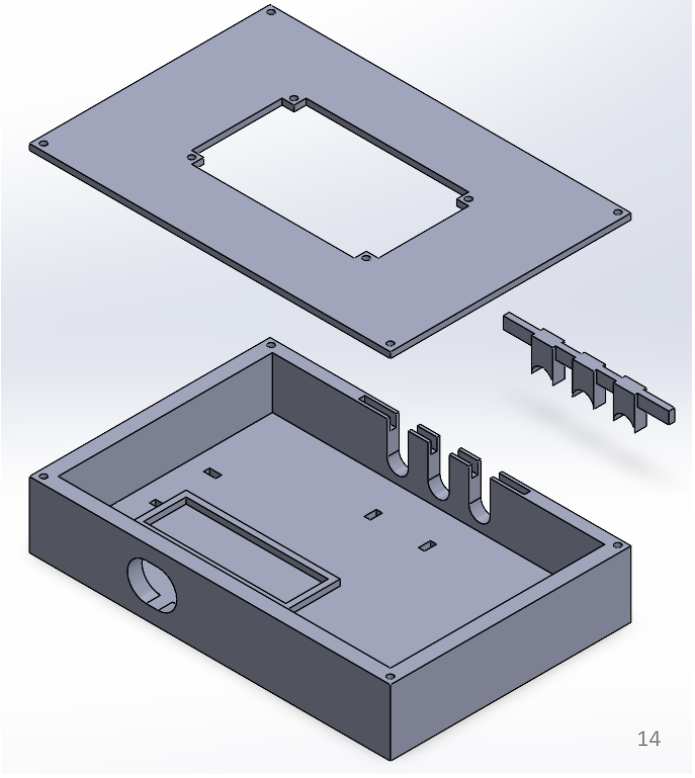
Rear Wiring



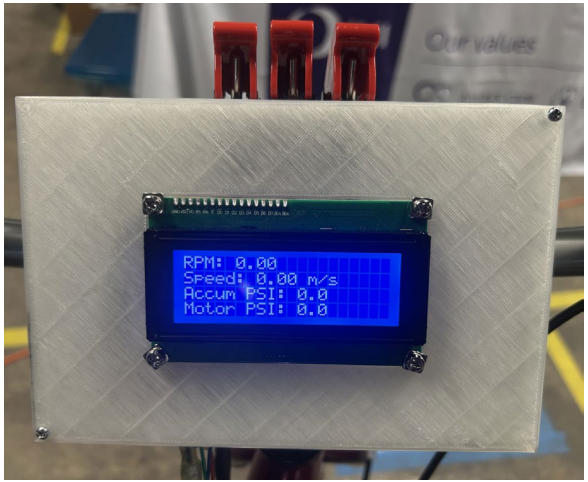
Solenoid Magnets and
Pressure Transducers

Front Electronics Box(3 pieces)

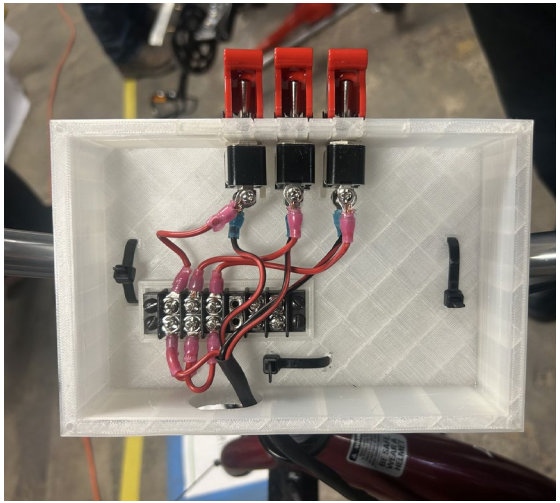
- LCD Screen
  - Displays readings for pressure, RPM, and speed
- Three Toggle Switches
  - Powered by 3 circuit power block
- Reed Switch
  - Reads RPM
- One 6 circuit terminal power block



Front Electronics Box



LCD Screen and Toggle Switches



Front Wiring

Reed Switch and Magnet

Arduino Code

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

#define REED_SWITCH_PIN 2           // Reed switch connected to digital pin 2
#define PRESSURE_SENSOR_ACCUM A0    // Accumulator pressure sensor
#define PRESSURE_SENSOR_MOTOR A1    // Motor pressure sensor

const float wheel_diameter = 0.6604;  // Wheel diameter in meters
const float wheel_circumference = 3.14 * wheel_diameter; // Circumference in meters
volatile int reed_count = 0;
unsigned long last_time = 0;
unsigned long last_reed_time = 0;
float rpm = 0.0, speed = 0.0;
LiquidCrystal_I2C lcd(0x27, 20, 4);  // LCD I2C Address (0x27 is common)

// Pressure Sensor Calibration (Based on your actual baseline readings)
float accum_min_voltage = 0.137;
float motor_min_voltage = 0.826;
float sensor_max_voltage = 4.5;
float sensor_max_psi = 3000;

void countRevolutions() {
    reed_count++; // Increment on each magnet pass
    last_reed_time = millis();
}

void setup() {
    Serial.begin(9600);
    pinMode(REED_SWITCH_PIN, INPUT_PULLUP);
    attachInterrupt(digitalPinToInterrupt(REED_SWITCH_PIN), countRevolutions, FALLING);

    lcd.begin(20, 4);
    lcd.backlight();
    lcd.setCursor(0, 0);
    lcd.print("Fluid Power Trike");
}

void loop() {
    unsigned long current_time = millis();
    float time_elapsed = (current_time - last_time) / 1000.0;

    // RPM & Speed Calculation
    if (time_elapsed >= 1.0) {
        if (reed_count > 0) {
            rpm = (reed_count / time_elapsed) * 60.0;
            speed = (rpm * wheel_circumference) / 60.0;
            reed_count = 0;
            last_time = current_time;
        }

        // Timeout condition to reset speed if no pulses
        if (current_time - last_reed_time > 3000) {
            speed = 0.0;
        }
    }

    // Read raw voltages
    float voltage_accum = analogRead(PRESSURE_SENSOR_ACCUM) * (5.0 / 1023.0);
    float voltage_motor = analogRead(PRESSURE_SENSOR_MOTOR) * (5.0 / 1023.0);

    // Convert to PSI using your calibrated offsets
    float psi_accum = ((voltage_accum - accum_min_voltage) / (sensor_max_voltage - accum_min_voltage)) * sensor_max_psi;
    float psi_motor = ((voltage_motor - motor_min_voltage) / (sensor_max_voltage - motor_min_voltage)) * sensor_max_psi;

    // Clamp negative and very low readings to zero
    if (psi_accum < 5) psi_accum = 0;
    if (psi_motor < 5) psi_motor = 0;

    // Update LCD Display
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("RPM: ");
    lcd.print(rpm);

    lcd.setCursor(0, 1);
    lcd.print("Speed: ");
    lcd.print(speed, 2);
    lcd.print(" m/s");

    lcd.setCursor(0, 2);
    lcd.print("Accum PSI: ");
    lcd.print(psi_accum, 1);

    lcd.setCursor(0, 3);
    lcd.print("Motor PSI: ");
    lcd.print(psi_motor, 1);

    // Debug in Serial Monitor
    Serial.print("RPM: "); Serial.print(rpm);
    Serial.print(" | Speed: "); Serial.print(speed, 2);
    Serial.print(" m/s | Accum PSI: "); Serial.print(psi_accum, 1);
    Serial.print(" | Motor PSI: "); Serial.println(psi_motor, 1);

    delay(500); // Update every 500ms
}
```

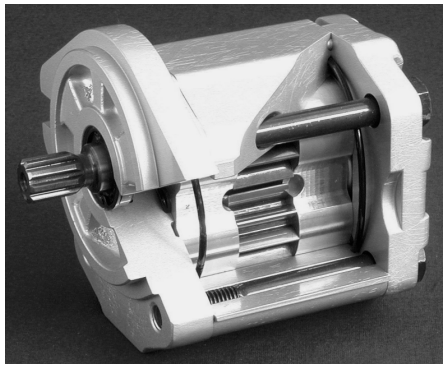
Component Selections

Hydraulic Gear Motor

- Product # 121.20.045.00
- 1.025 CID
- Inlet/Outlet Size: ⅞-14UNF
- Bi-rotational

Hydraulic Gear Pump

- Product #: 111.20.348.00
- 0.513 CID
- Inlet size: ⅞-14UNF
- 9 tooth spline
- CW rotation



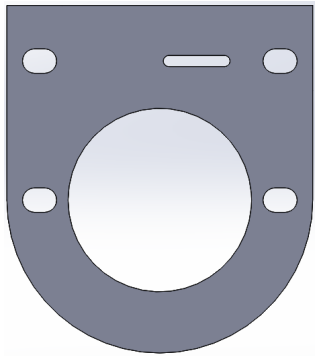
Component Selections

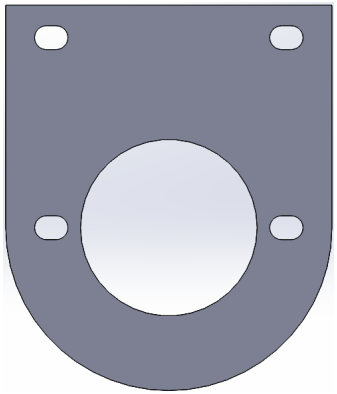
- **Accumulator**
  - Volume: 1 gallon
  - Port type: SAE-20
  - Pressure rating: 3000 PSI
  - Pre-charge: 1000 PSI
- **Solenoid:** Danfoss, Eaton, Comatol
  - Product: Cartridge solenoid valves
    - **x1** 2 pos, 3 way spool 1-2/1-3
    - **x2** 2 pos, 2 way uni-poppet

2 position, 2 way spool

2 position, 2 way uni-poppet

Custom Manufactured Parts



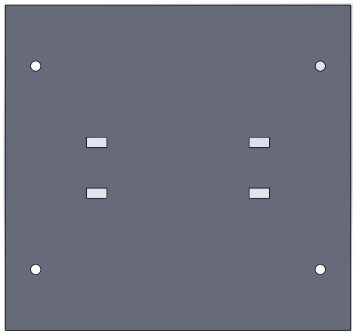


- **Modified spline hub**
  - Fastens to 16T bike sprocket
  - Fits gear pump
- **Custom aluminum drum**
  - For drum brake
- **Aluminum pump mount**
- **Aluminum motor mount**
- *Courtesy of Moseys Production Machinists*

Custom Manufactured Parts

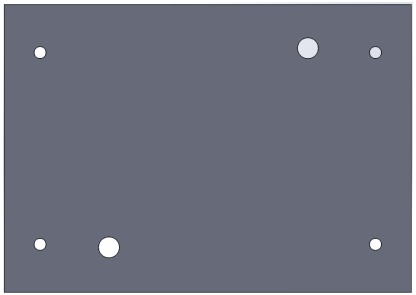
Reservoir / Accumulator Plate

- 8” x 8.5”
- ¼” tapped holes
- ½” x ¼” slots



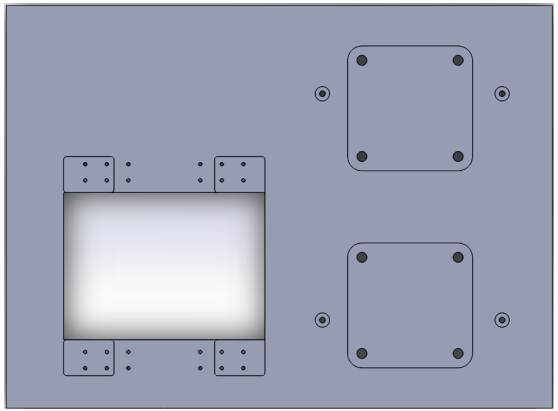
Manifold Plate

- 6” x 8.5”
- ¼” and ⅜” tapped holes



Base Plate

- 14” x 19”
- ⅛”, ¼”, and ⅜” tapped holes
- 5.125” x 7” slot
- All done by SendCutSend



Lessons Learned

- Working with bike sprockets is restrictive
  - Industrial roller sprockets offer more freedom
- A more popular tricycle frame is more likely to use standard sizes
  - Avoid the need for custom-machined parts
- A hand pump mechanism for testing hydraulic circuit
  - Does not rely on working drivetrain
- Anticipate lead times!

Questions?

Special thanks to:

- **David Copp**, *University of California, Irvine*
- **Bob Mosey**, *Mosey's Production Machinists*
- **Edgar Torres**, *Bucher Hydraulics*
- **John Zmuda**, *Mosey's Production Machinists*
- **Eric Flores**, *Motion and Flow Control Products Inc.*
- **Gordon Baker**, *Motion and Flow Control Products Inc.*
- **Ernie Parker**, *International Fluid Power Society*
- **Mary Pluta**, *National Fluid Power Association*