Strand Products Automated Cable Cutter

C.G. Automation
Cutting Cables, Cutting Costs

STRAND PRODUCTS Incorporated

Design Competition 2020

C. G.

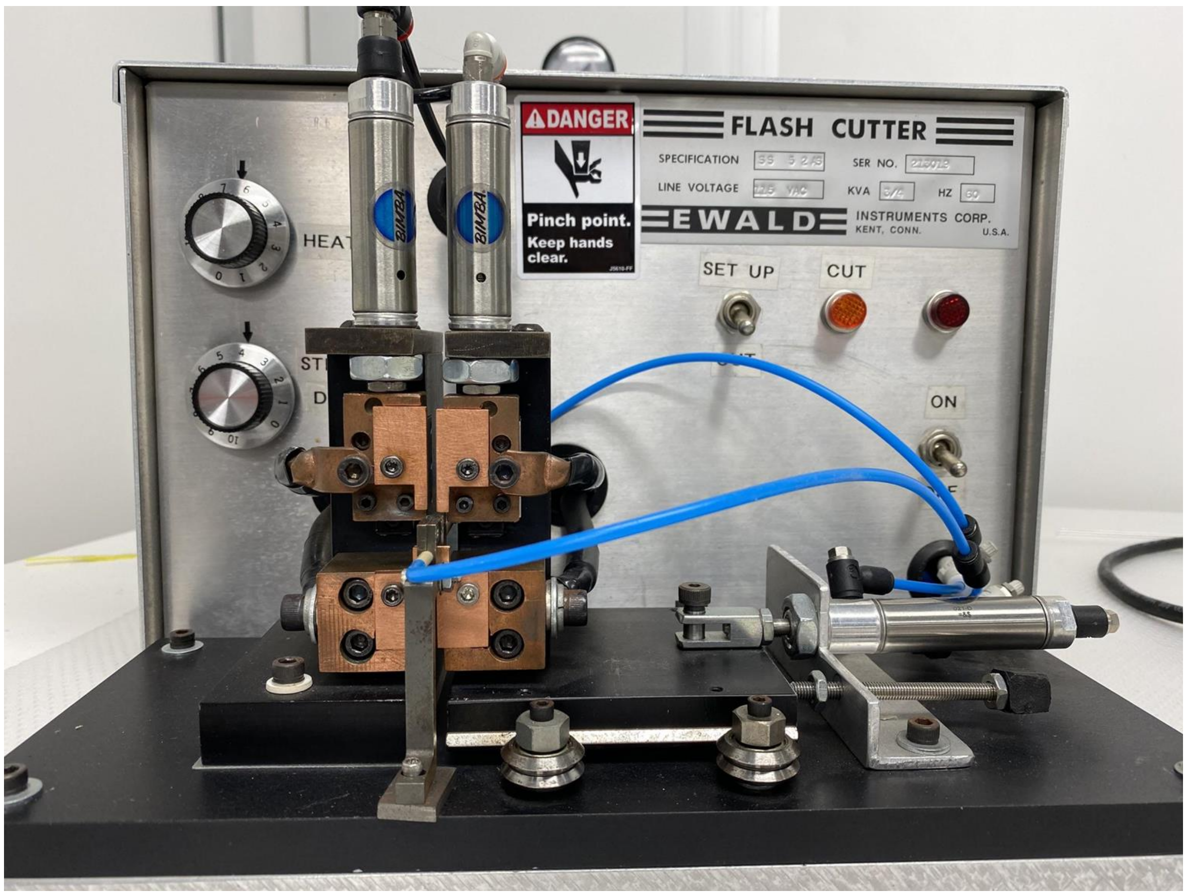
Automation

Cutting Cables, Cutting Costs

Chris

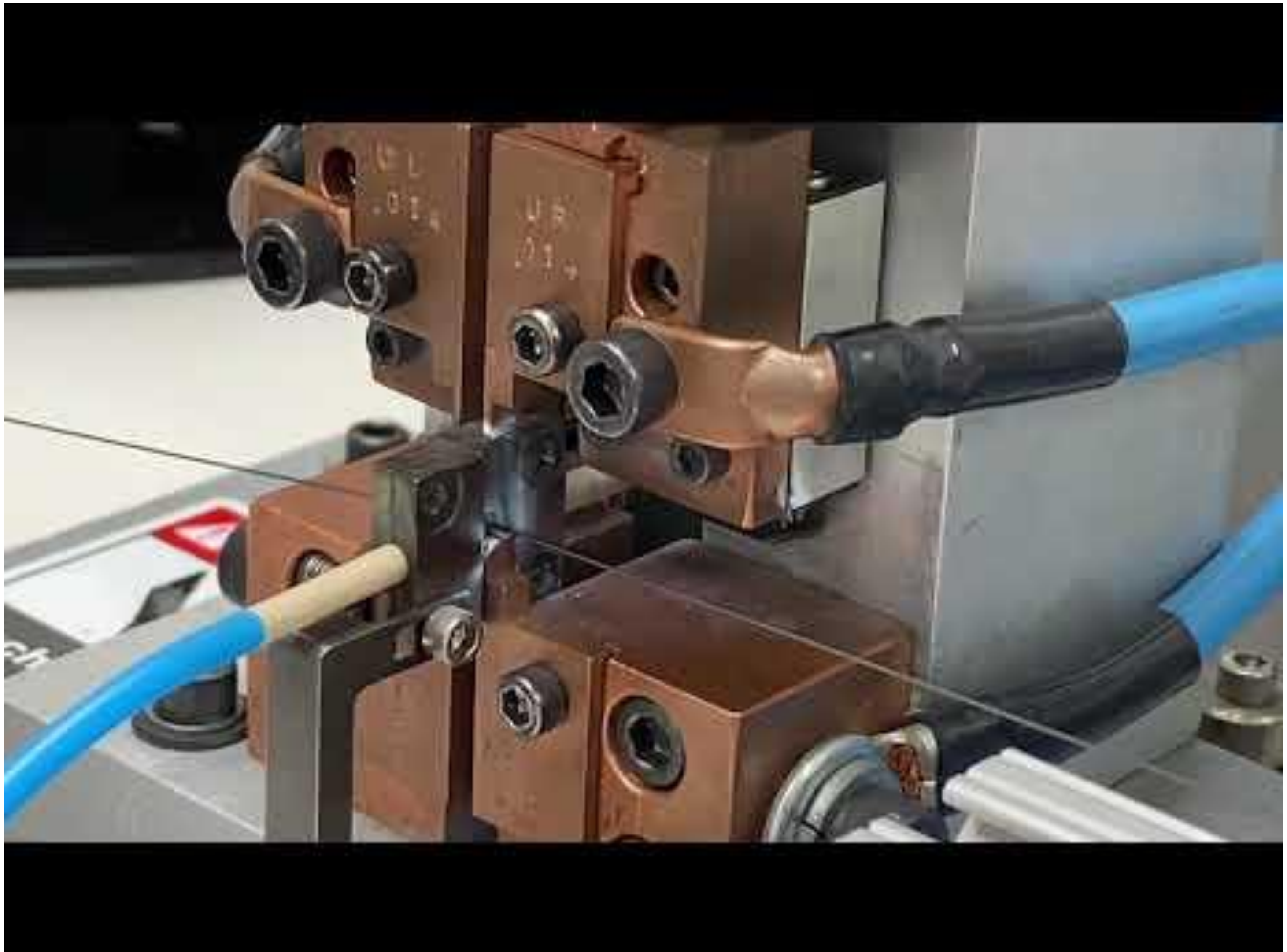
The Task

- ➢ Automate cutting process of *Ewald* Flash Cutter
  - ○ Be able to operate either automated or manually



Chris

Manual Flash Cutter Process



Chris

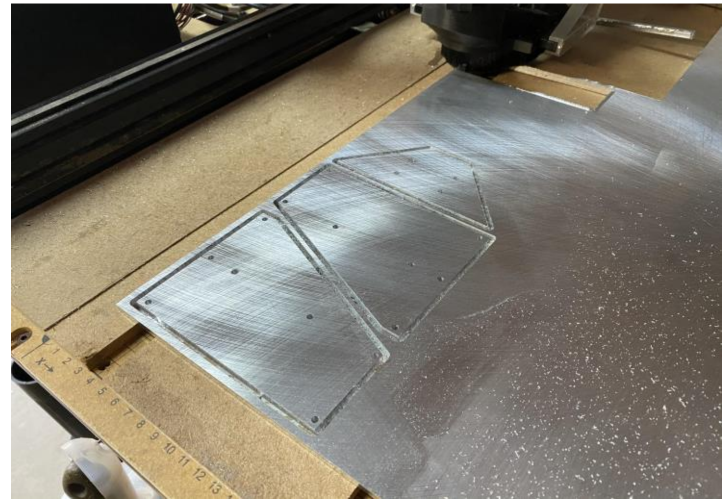
Automated Flash Cutter Process

Kaya

Covid-19 Manufacturing Response

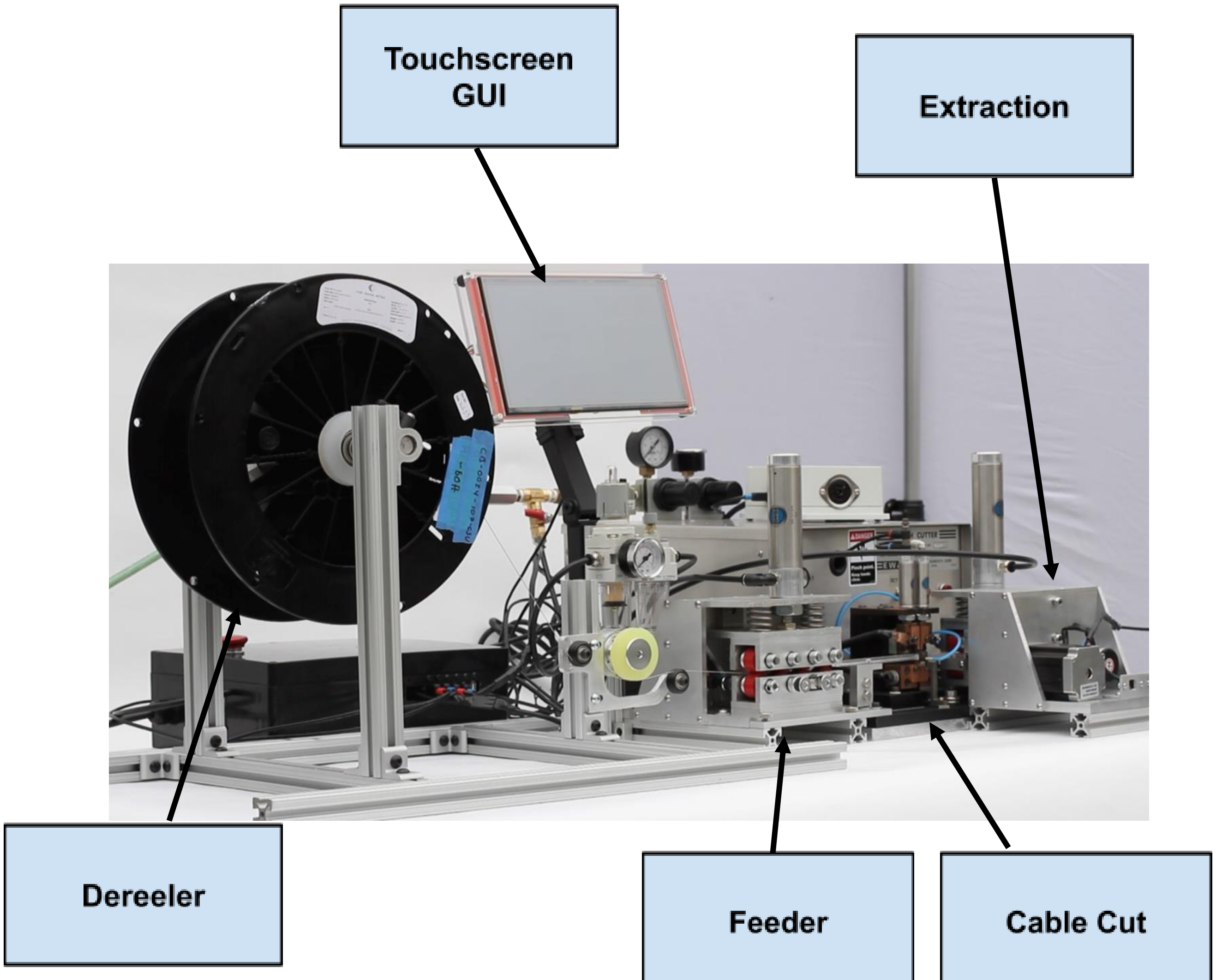
Kaya

Manufactured Parts



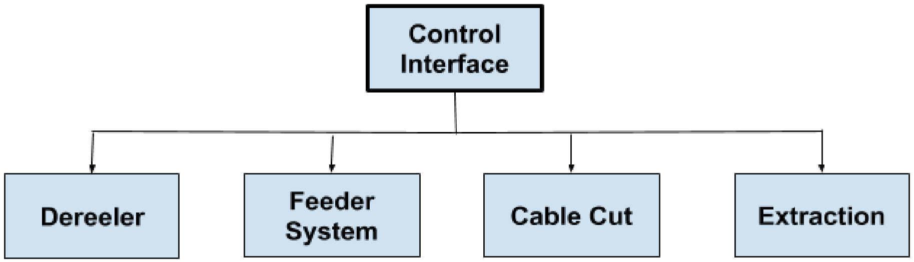
Jake

System Overview



Start
↓
Open Extraction
↓
Feed Stepper 1
↓
Close Extraction
↓
Open Feeder
↓
Feed Stepper 2
↓
Close Feeder
↓
Cut Cable
↓
Feed Stepper 2
↓
Finish

Vance

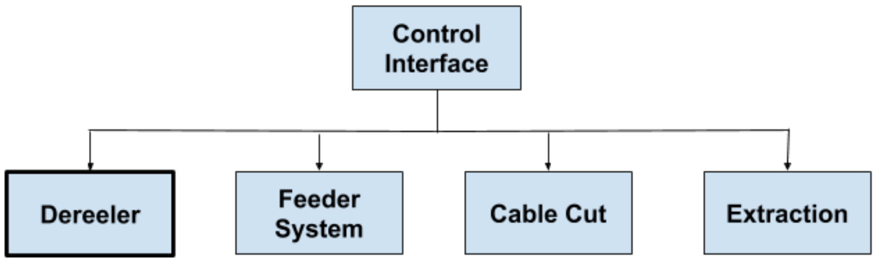


Touchscreen GUI

- Nextion Enhanced 7” Touch Screen
  - Integrated processor

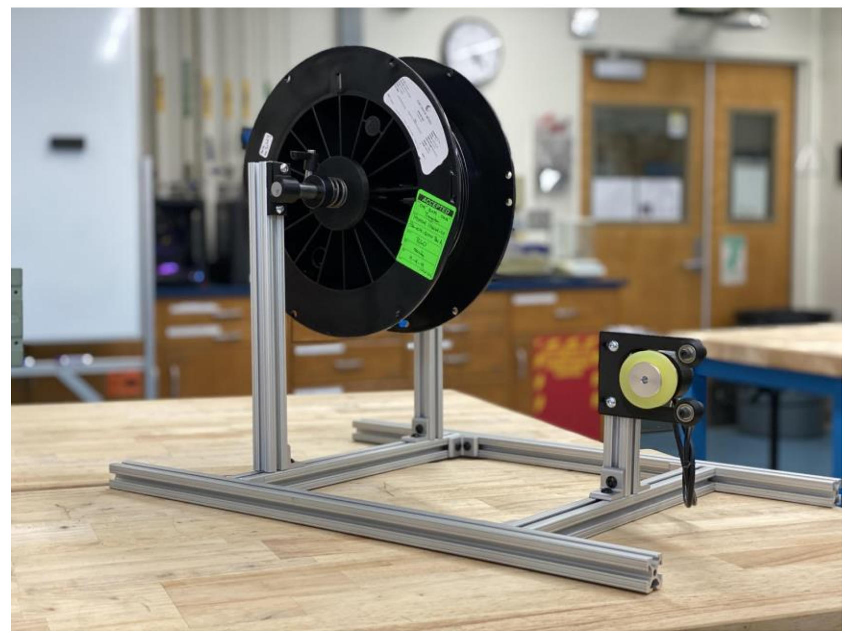
- Features
  - Setup
  - Manual Feed
  - Job Submission / Progress Page

Vance

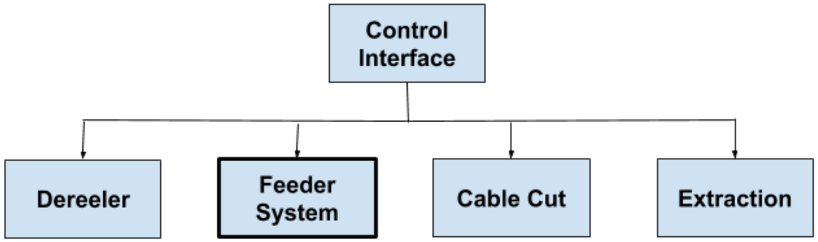


Dereeler

- ➢ Tensioned spool holder and cable dereeler system
- ➢ Spring-loaded plates provide friction & tension

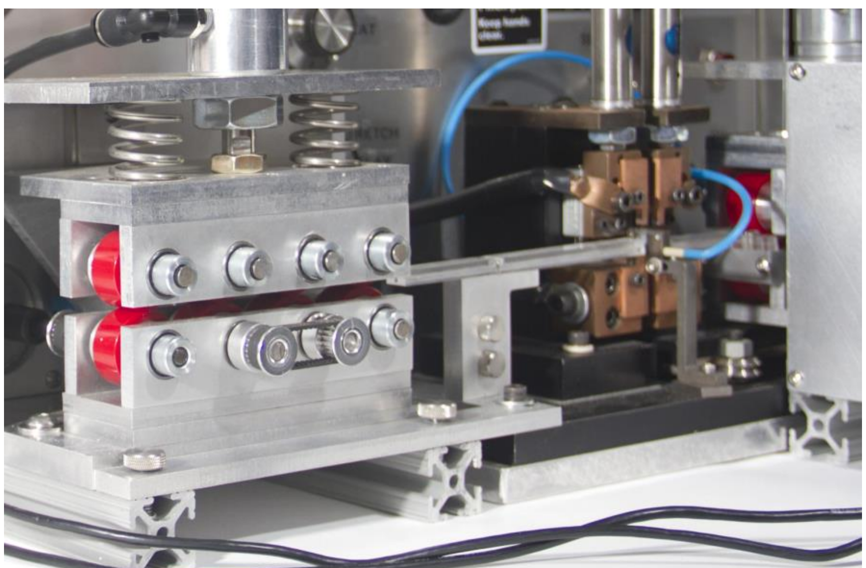


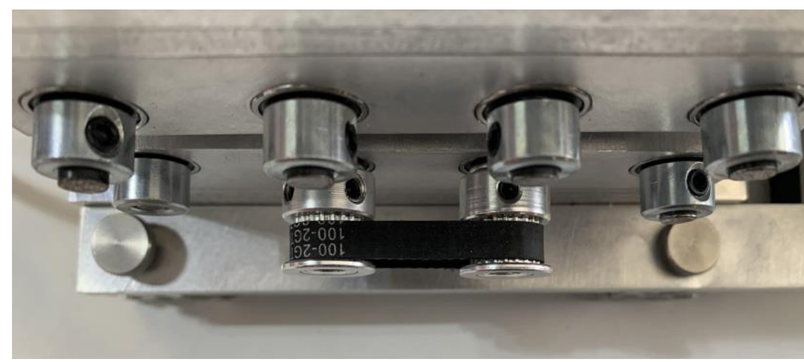
Vance



Feeder System

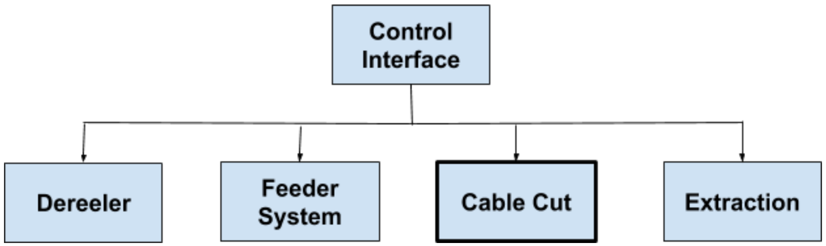
- ➢ Roller wheels in series driven by a stepper motor
  - Quick Disconnect system



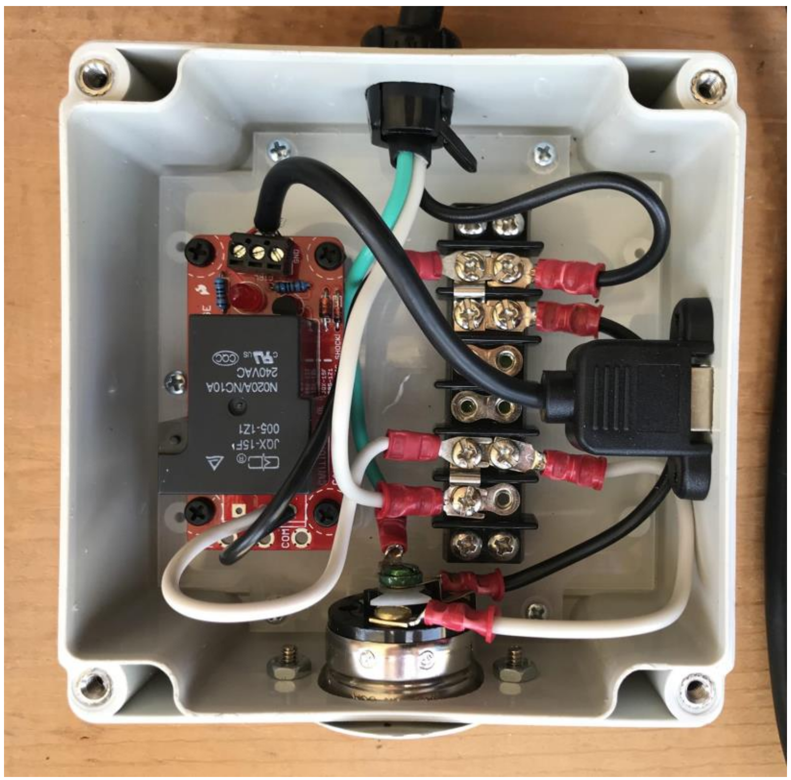


Jake

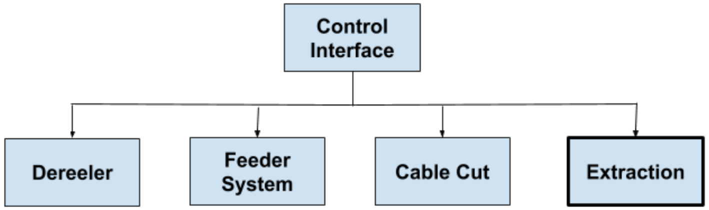
Foot Pedal Automation



- ➢ Allows for both automated and manual operation

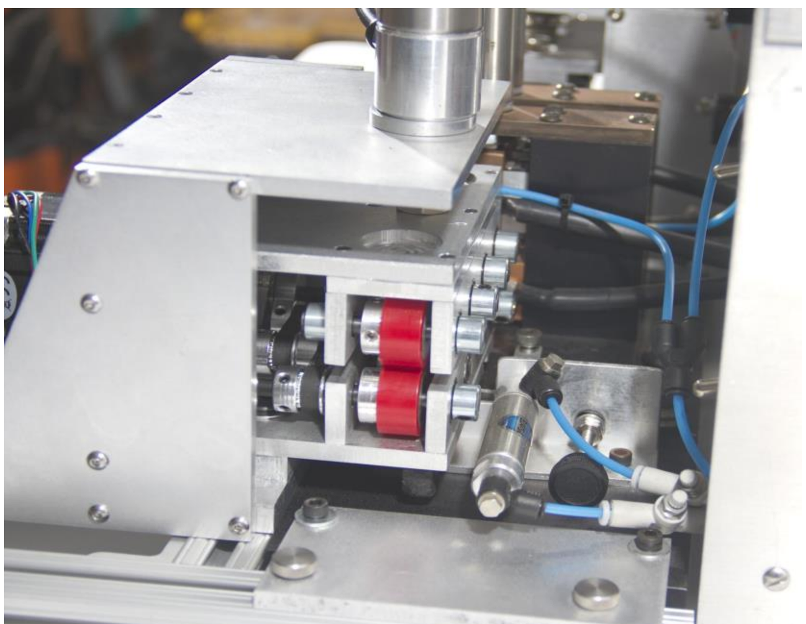


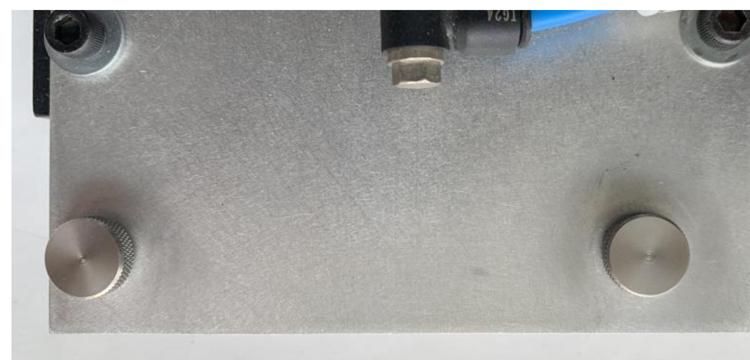
Jake



Extraction System

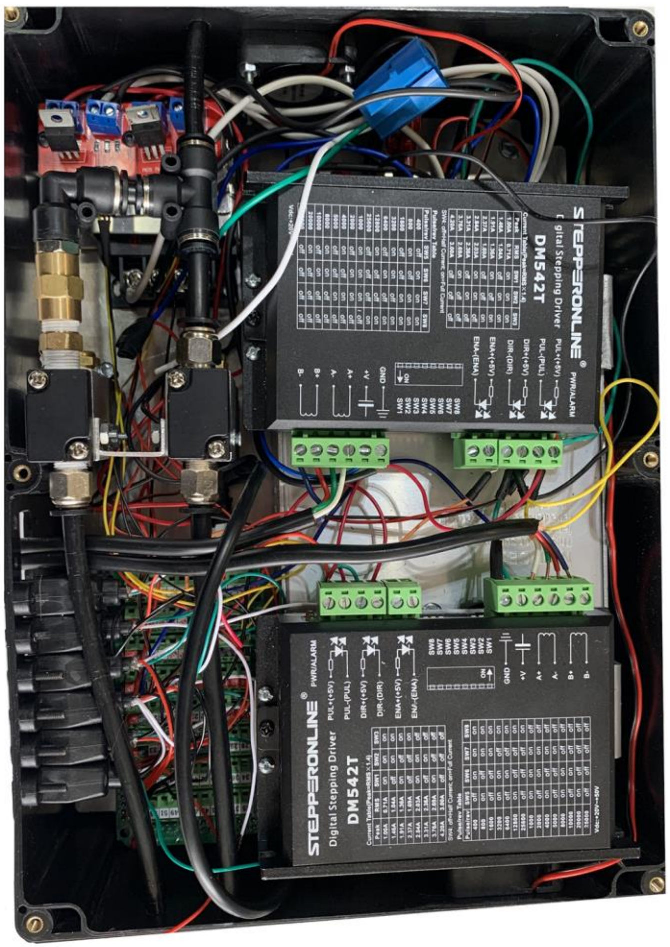
- ➢ Spring-loaded wheels keep the cable in tension
- ➢ Extraction system mimics the feeder system





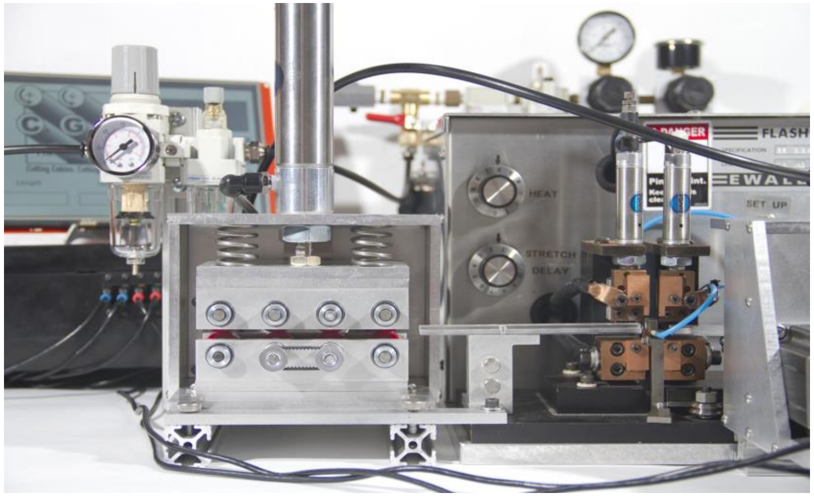
Jake

Electronics Box



Alex

Calculated Safety Factors

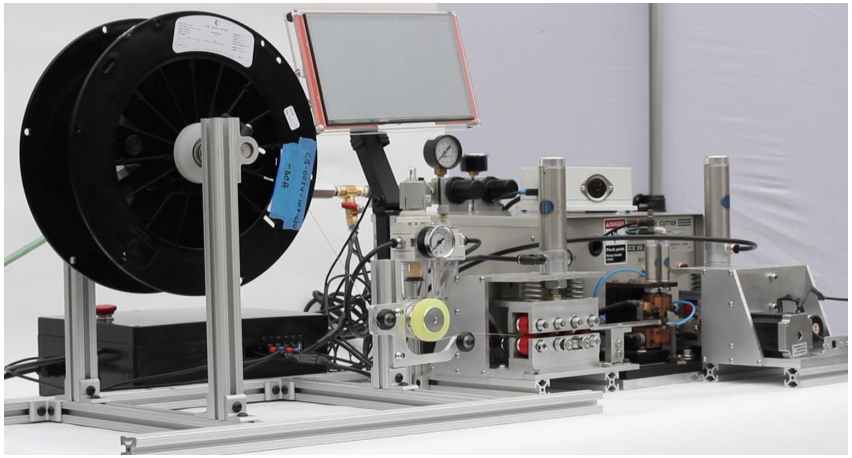


$SF_{cable\ slip}$	2.9
$SF_{tension\ cut}$	4.5
$SF_{spring\ force}$	2.5
$N_{spring\ life}$	$>10^7$ cycles

Chris

CG Automation Summary

- Increased work efficiency
- Simple touchscreen user-interface
- Versatile manual or automated cutting job



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Appendix Slides

Spring Quarter Recap

- Plan of action developed for spring quarter
- Manufactured & constructed the final prototype
  - The feeder & extraction subsystems
  - Foot pedal integration box
  - Electrical housing
  - Mounting
- Performed analysis & testing on final prototype
- Finalized and tweaked written Arduino IDE code

Whos Did What?

1. Chris led the manufacturing of mechanical components for the various subsystems with other members adhering to social distancing protocols

1. Kaya, Jake, and Vance led CAD model revisions, GD&T, and various tests

1. Kaya managed the team's finance while members ordered parts for their different delegated tasks

1. Jake worked on electro-mechanical integration by scripting code for the Arduino MEGA to communicate with the various sensors and actuators

1. Alex handled electrical hardware management by creating an electrical spreadsheet and schematic to aid construction of a PCB
   a. Also, handled meeting scheduling and other logistical tasks

Chris

Project Deliverables

Chris

Engineering Requirements

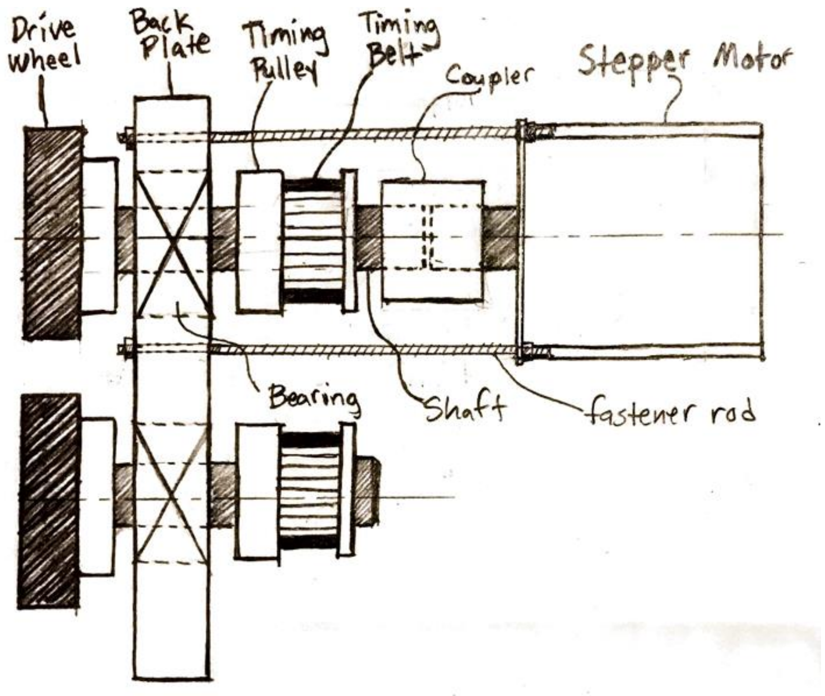
	Deliverables	Final Product
Tolerance	❖ 3" to 30": ±1/64" ❖ 30" to 60": ±1/32" ❖ 60" to 100": ±1/16"	❖ 3" to 30": ~ ❖ 30" to 60": ~ ❖ 60" to 100": ~
Cut Lengths	3" - 100"	3" - 100"
Cycle Time	< 30 s	< 5 s
Cable Diameters	0.006" - 0.050"	0.006" - 0.050"
User Inputs	- # Cable Cuts - Length (in/mm) - Emergency Stop - Pause & Resume	- # Cable Cuts - Length (in/mm) - Emergency Stop - Pause & Resume - Progress Bar - Exit Job

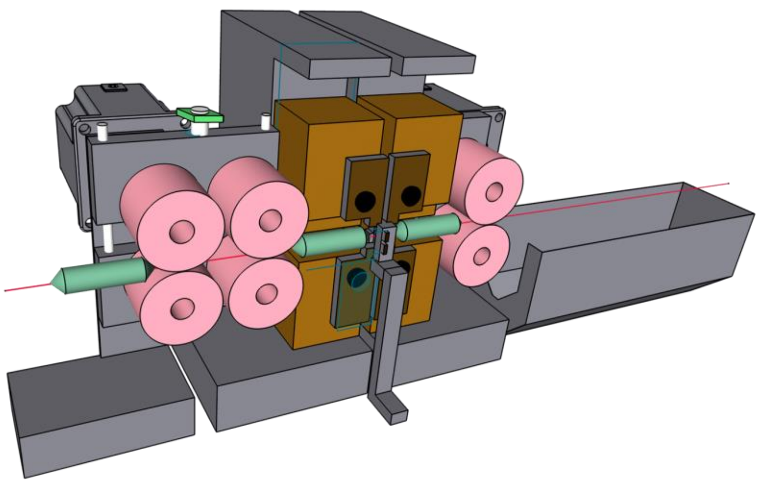
Chris

Feeder System Evolution

Chris

Feeder Prototype Engineering Drawing

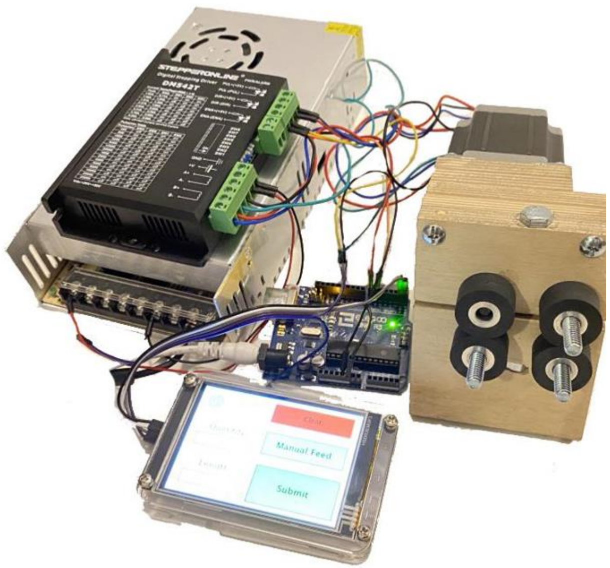


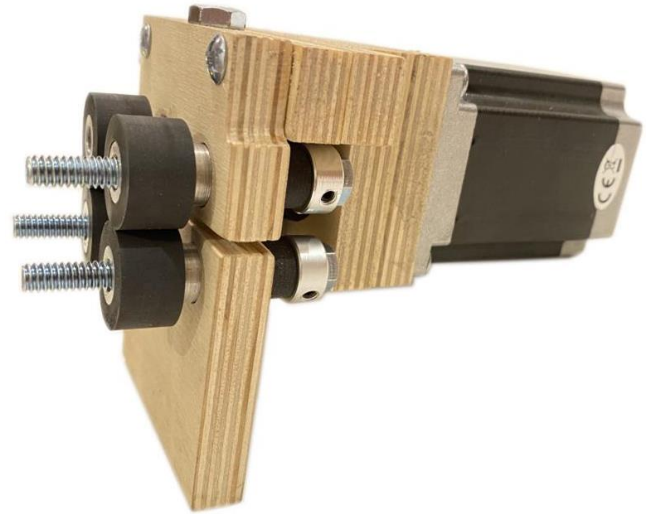


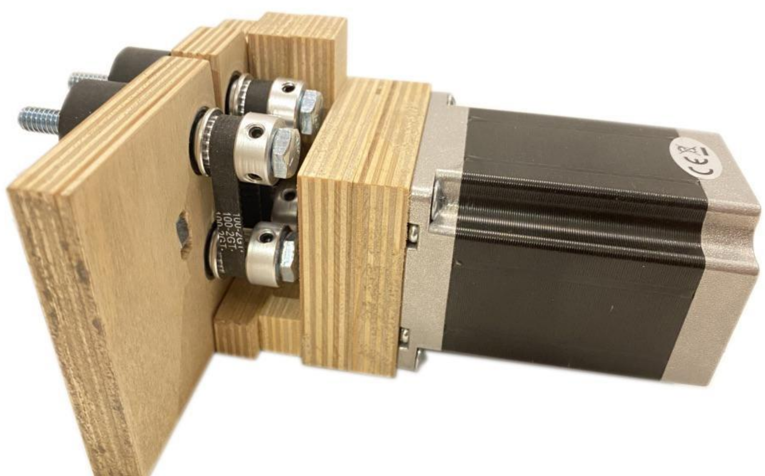
Fall Quarter 2019

Chris

Feeder Prototype V1

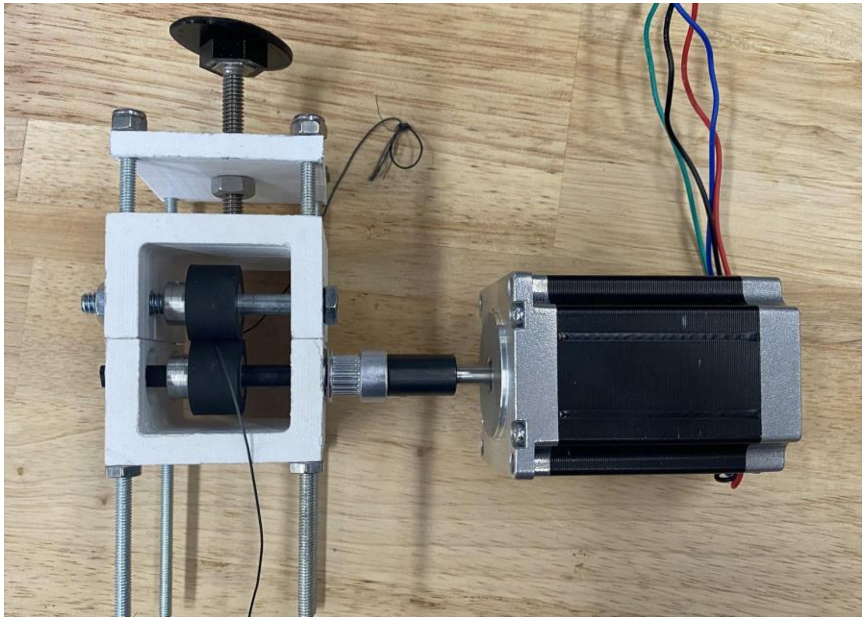






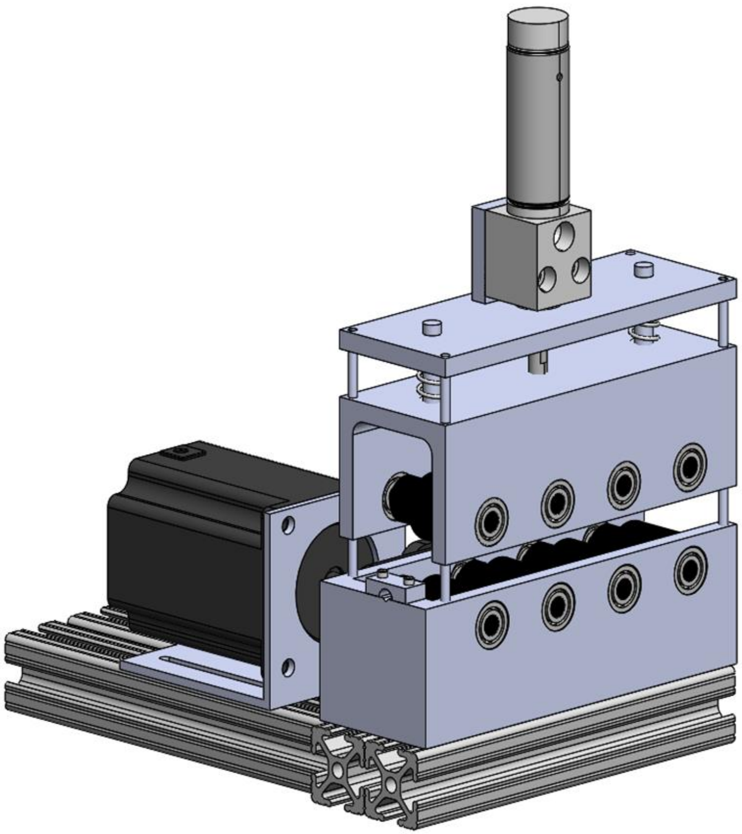
Chris

Feeder System Prototype V2



Chris

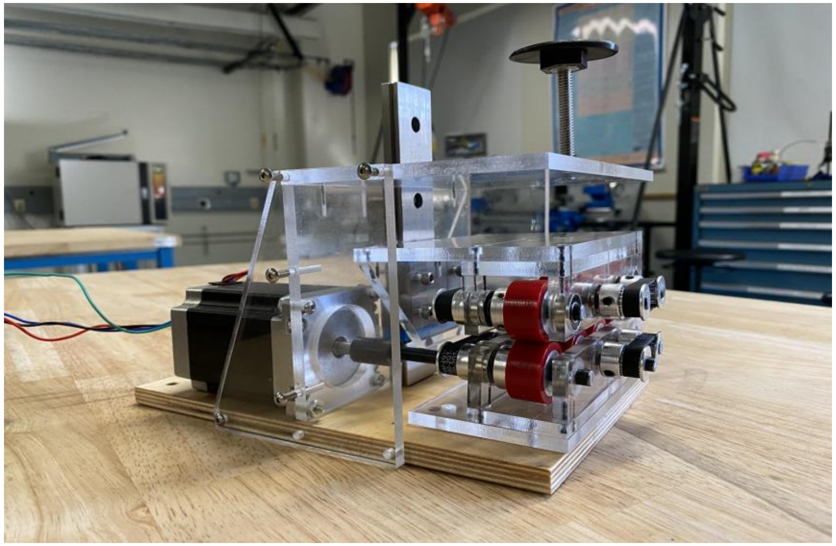
Feeder Prototype Initial CAD

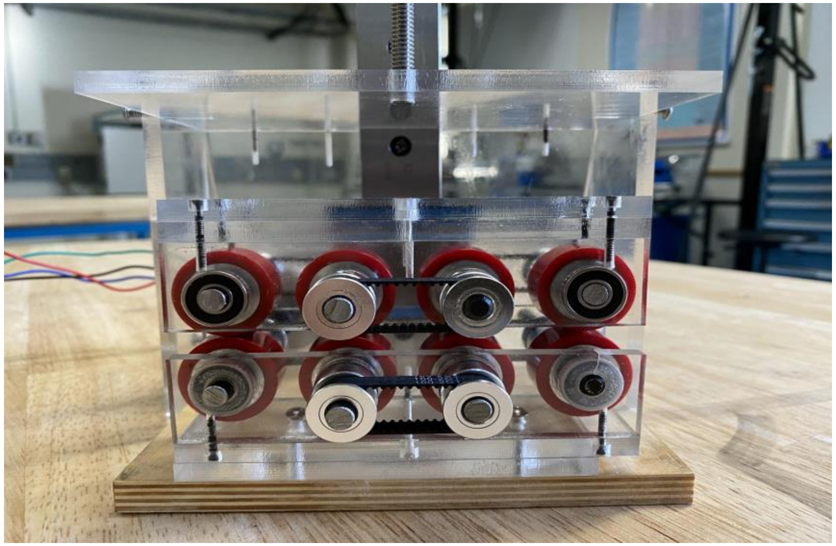


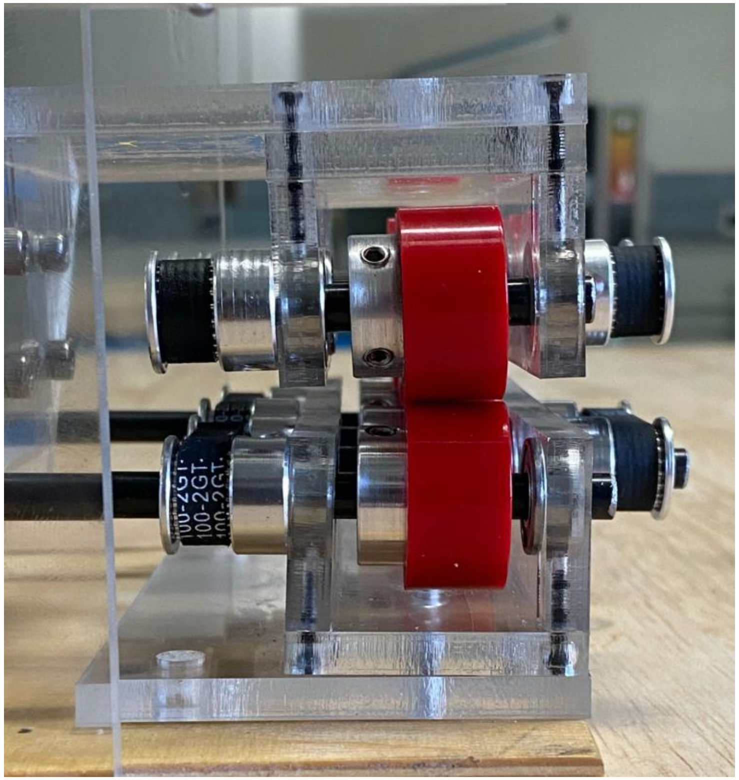
Winter Quarter 2020

Chris

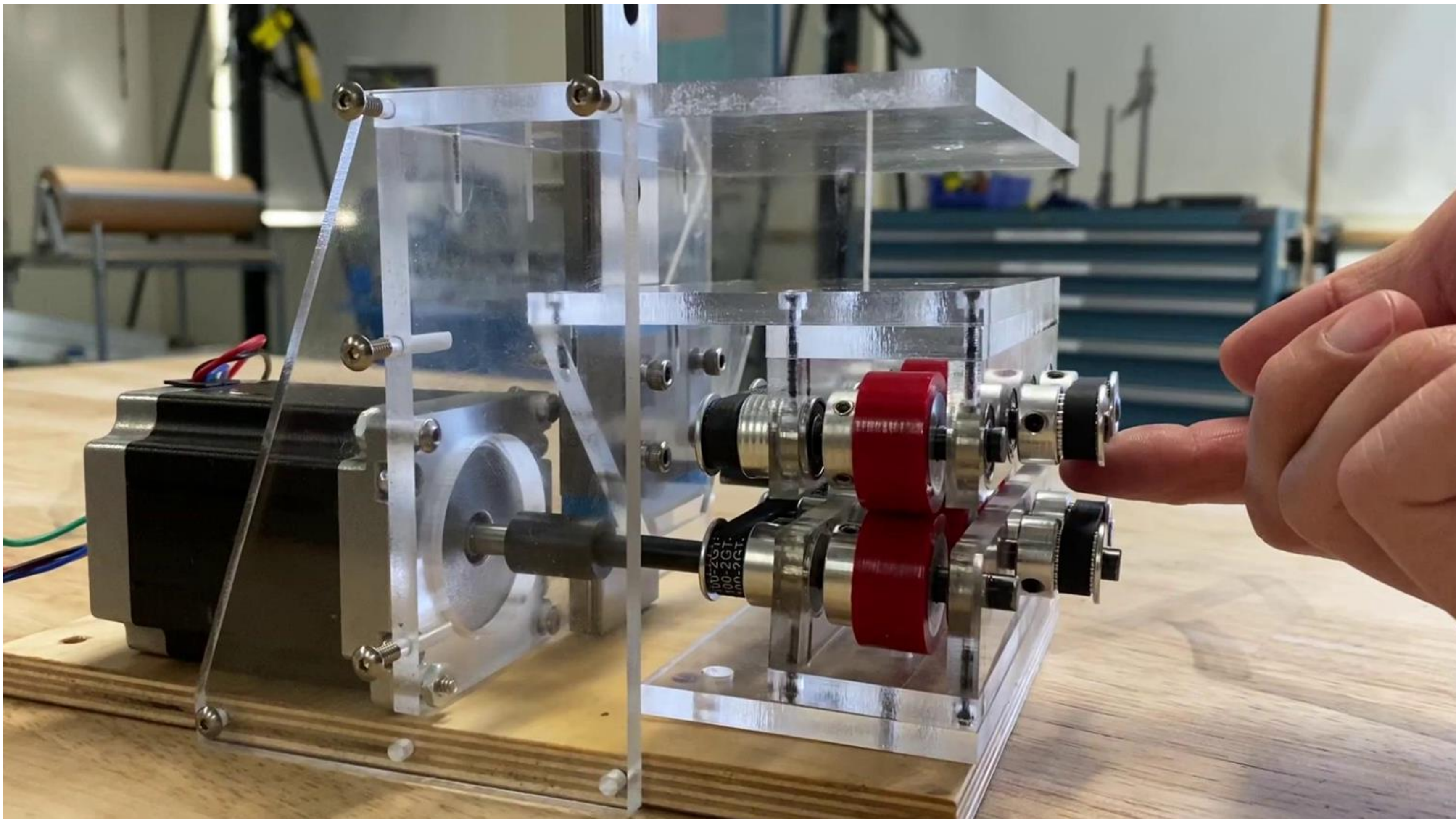
Feeder System Prototype V3





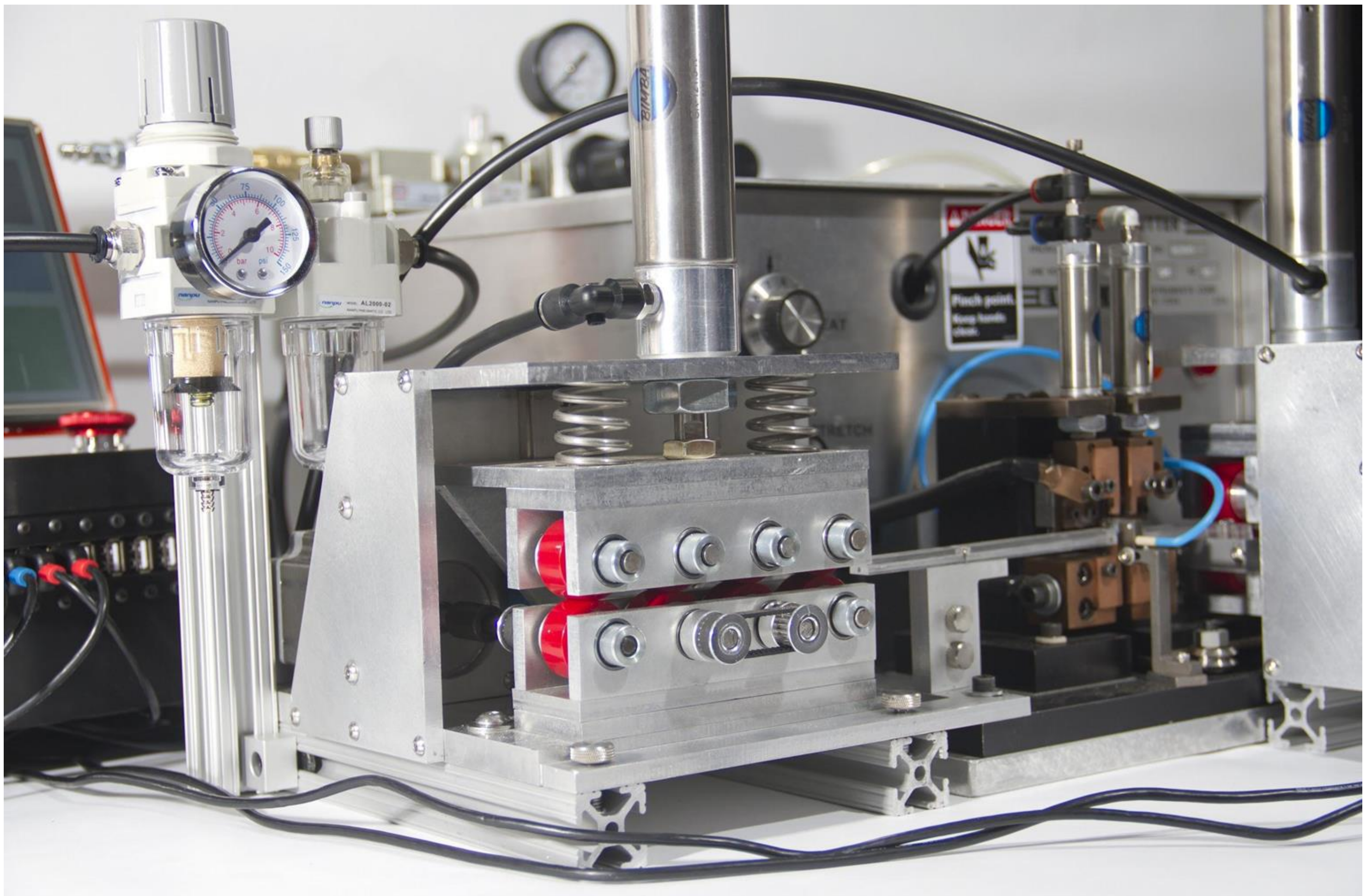


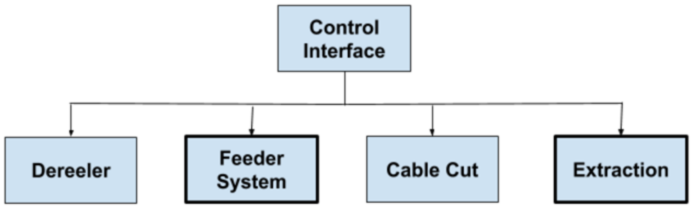
Feeder System Prototype V3



Chris

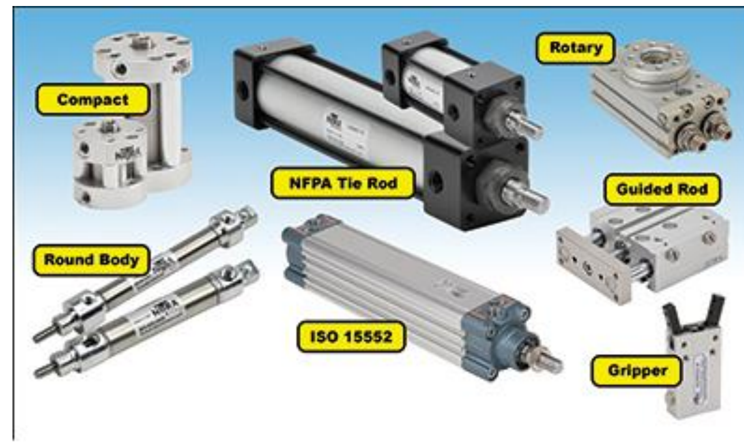
Feeder System Final Product





Feeder & Extraction System Actuation

- Spring-loaded feeder & extraction system
  - Appies constant pressure to wheels
- Pneumatic Cylinder
  - Compressed air acts on a piston inside a cylinder to move a load along a linear path
    - Feeder & Extraction System
  - The actuator controls tension and slack in cable
    - Compress springs to separate wheels
    - Release springs to bring wheels back together



Lpd3806-600bm-G5-24c Incremental Optical Rotary Encoder

- Mechanical Specifications:
  - Starting Torque: $1.5*10^3$ Nm
  - Moment of Inertia: $3.5*6$ kgm^2
  - Shaft loading/Radial: 10 N
  - Thrust loading/Radial: 20 N
  - Max Allowable Revolution: 2000 rpm
  - Net Weight: 100 g
- Electrical Specifications:
  - Resolution: 600 pulses/revolution
  - Operating voltage: DC5-24V
  - Max Current Consumption: 40 mA
  - Max Response Frequency: 30 kHz
  - Maximum Mechanical Speed: 5000 rev/min
  - Integrated Speed: 2000 rev/min
- Environment:
  - Ambient Temperature: -20 to 80 ^oC
  - Storage: -25 to 85 ^oC
  - Ambient Humidity: 35 - 85 %
  - Degree of Protection: IP50
  - Vibration: 50 m/s^2, 10-200 HZ
  - Shock: 980 m/s^2, 6ms

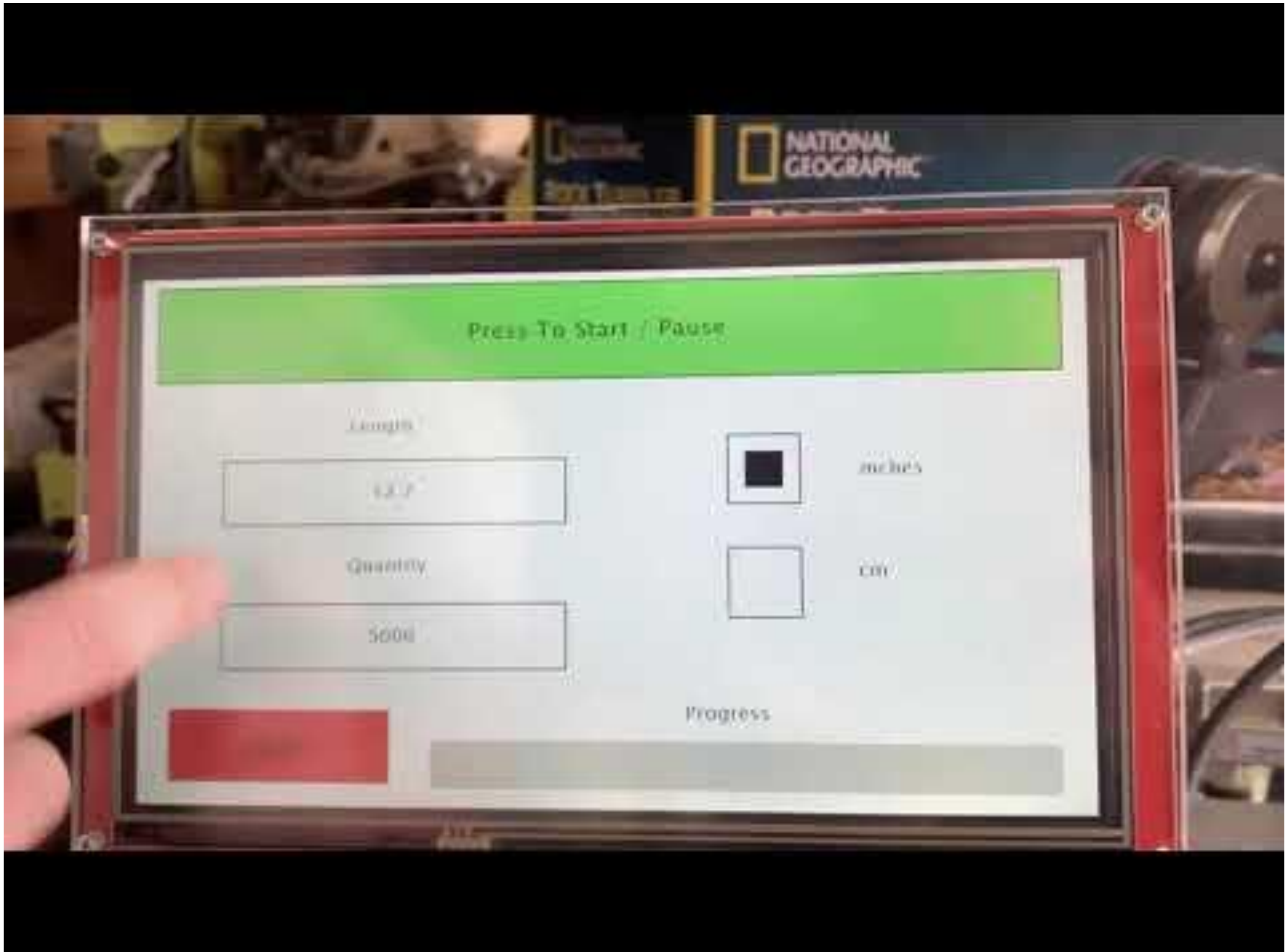
Kaya

Manufactured Feeder & Extraction Parts

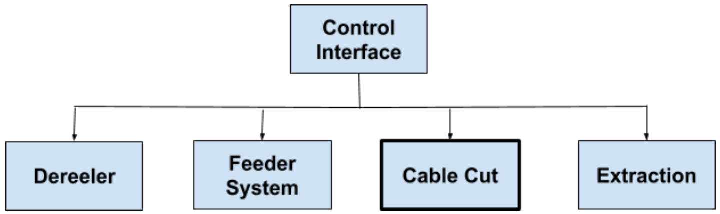
Chris

Detailed Subsystem Descriptions

Touchscreen User-Interface Demo

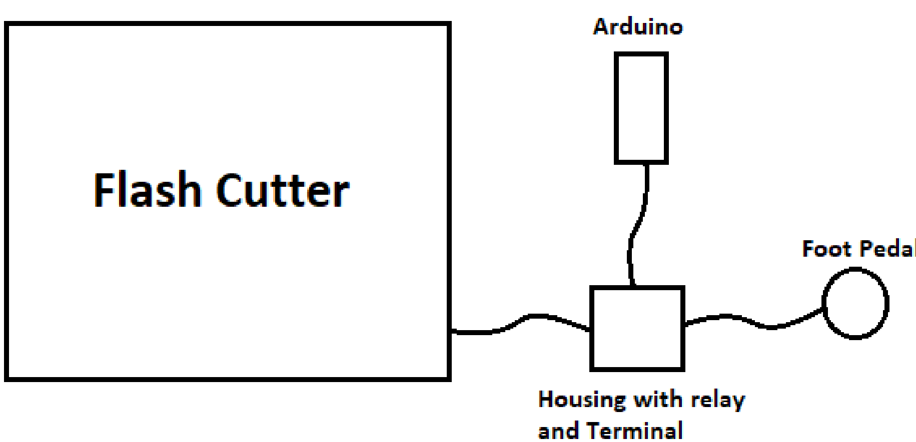


Jake



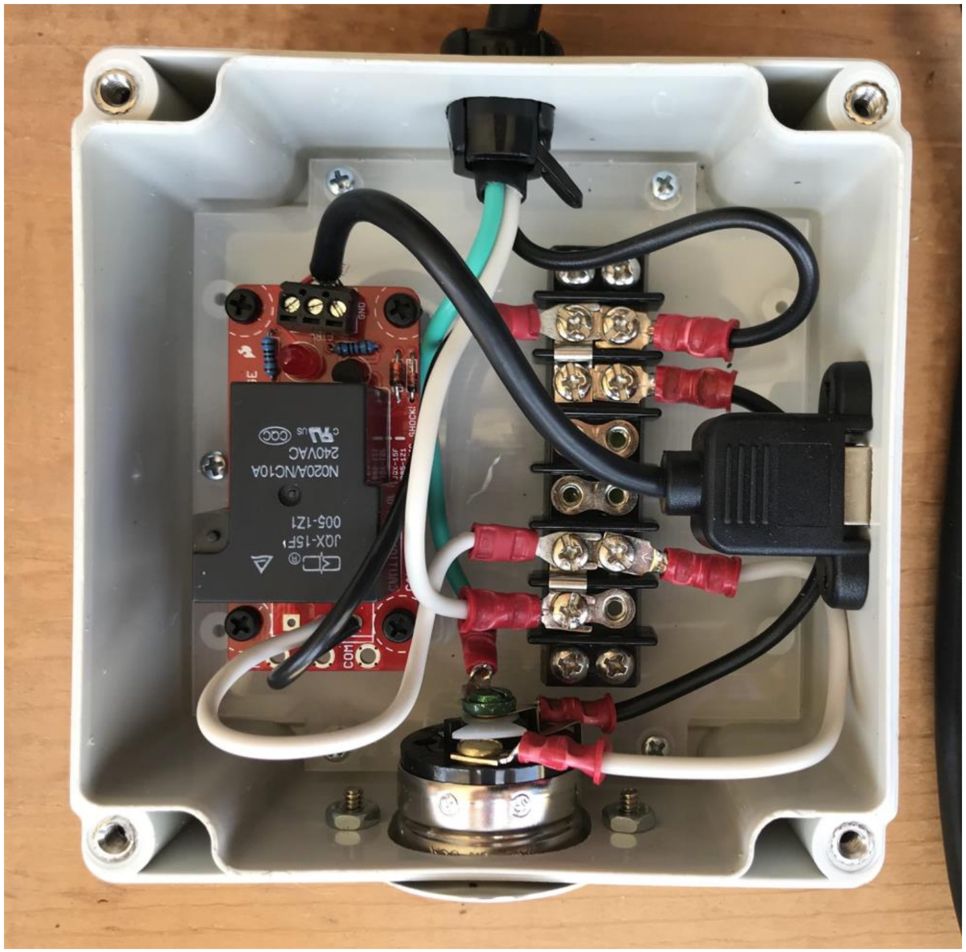
Foot Pedal Automation

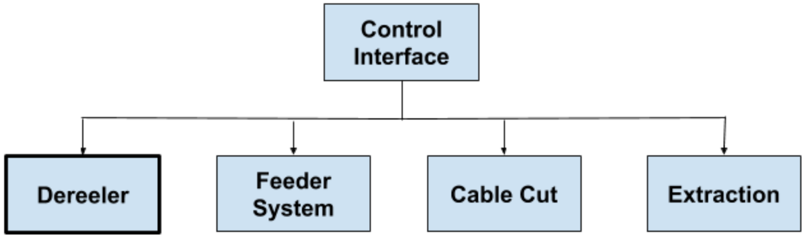
- Foot pedal is a switch that closes an AC circuit
  - Midget locking plug
- Relay in parallel with the foot pedal
  - Allows for automated and manual operation



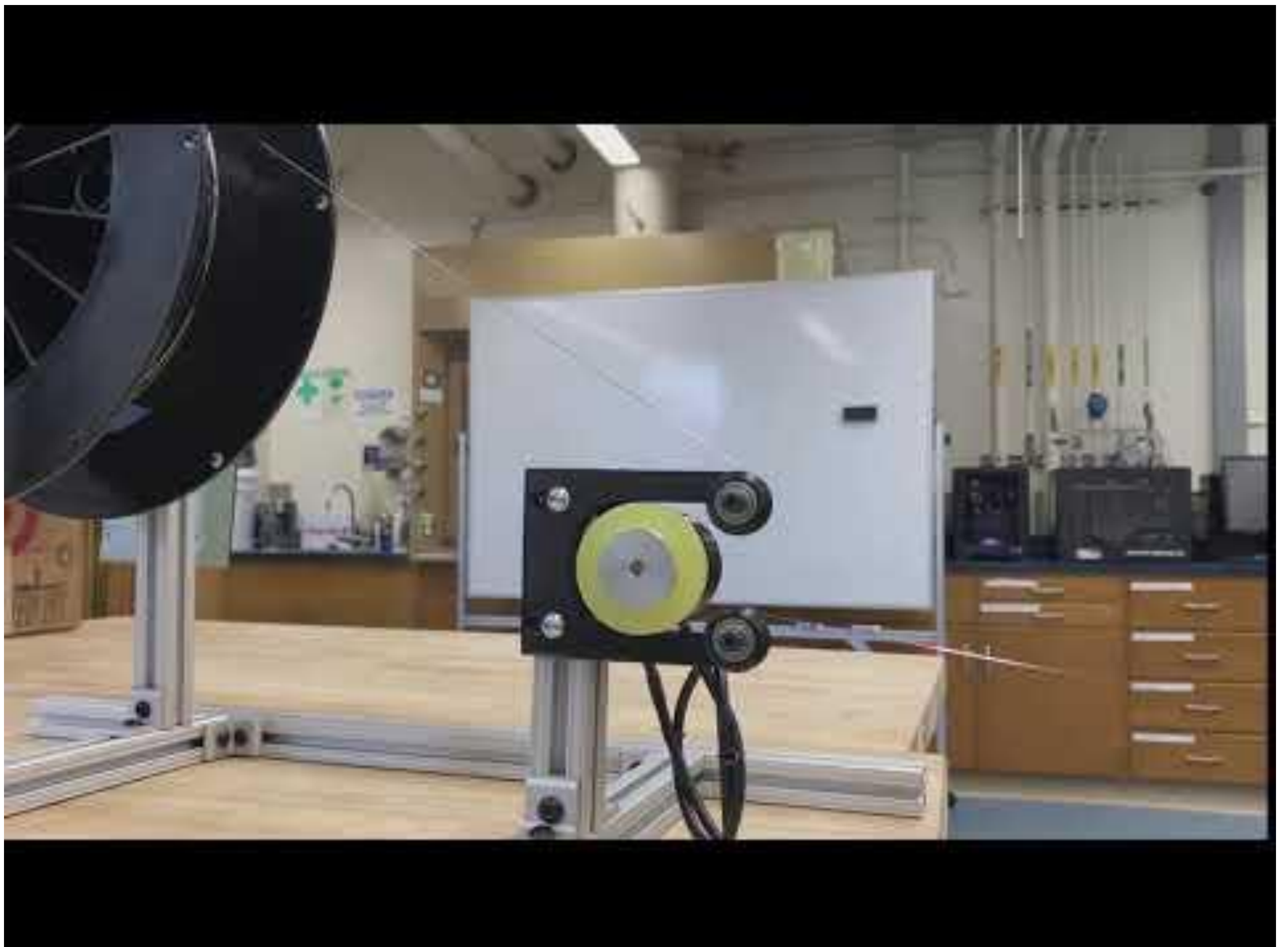
Jake

Foot Pedal Integration



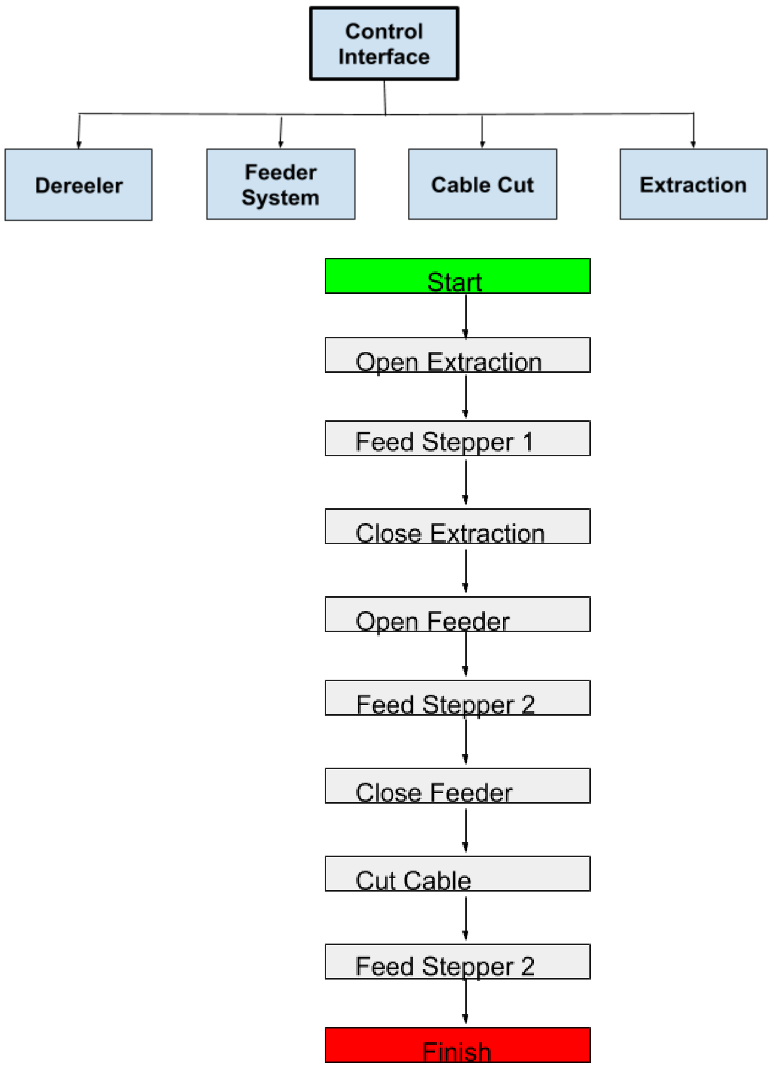


Spool Mount and Tension System V1



Jake

Arduino Code Flowchart



Block Diagram Explanation

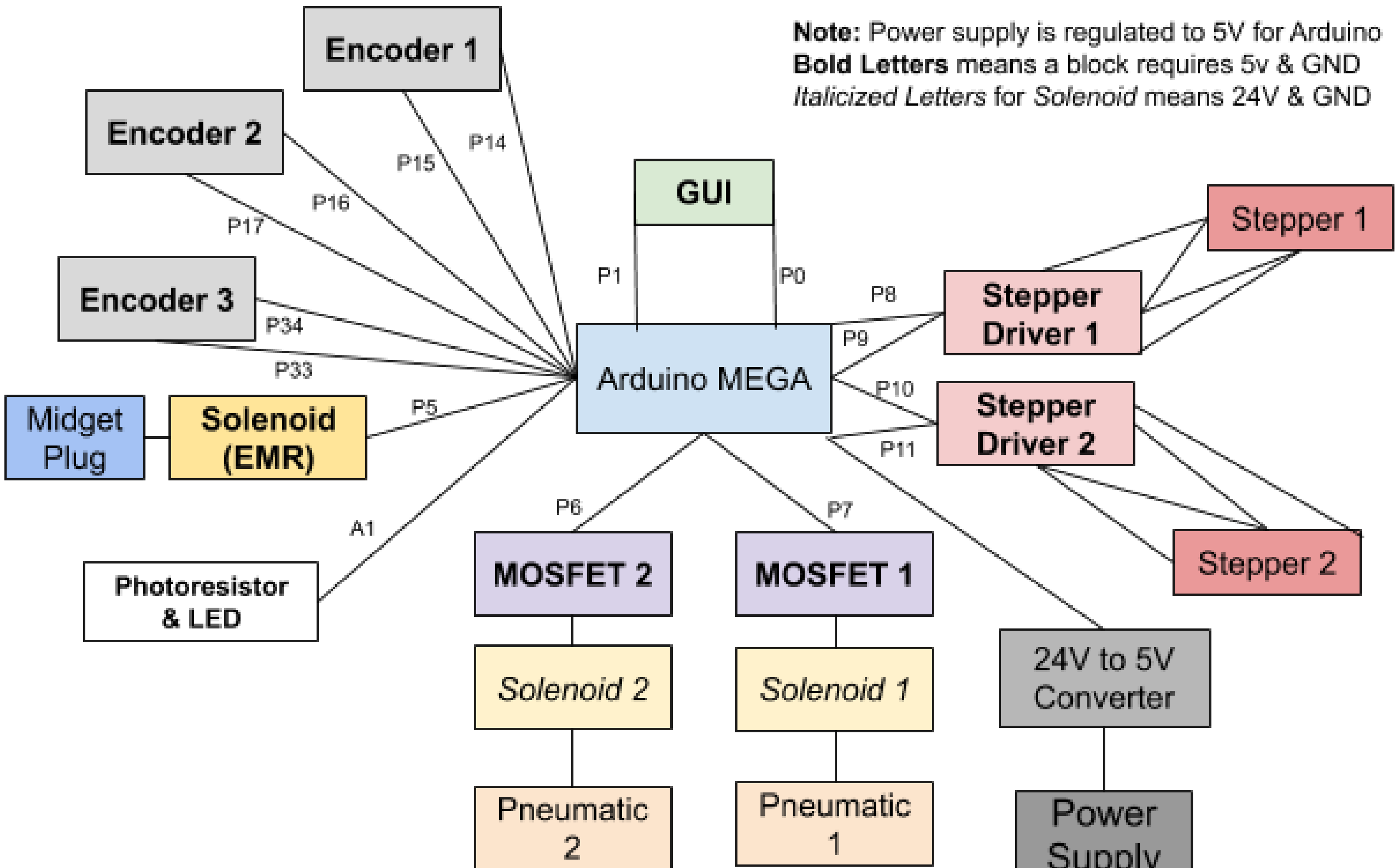
```
digitalWrite(air2, HIGH);
stepper1.step(1910);
digitalWrite(air2, LOW);
delay(250);
digitalWrite(air1, HIGH);
stepper2.step(-(steps - 1910));
digitalWrite(air1, LOW);
digitalWrite(cut, HIGH);
delay(2000);
digitalWrite(cut, LOW);
stepper2.setSpeed(150);
stepper2.step(-3400);
stepper2.setSpeed(40);
```

Arduino IDE code

Alex

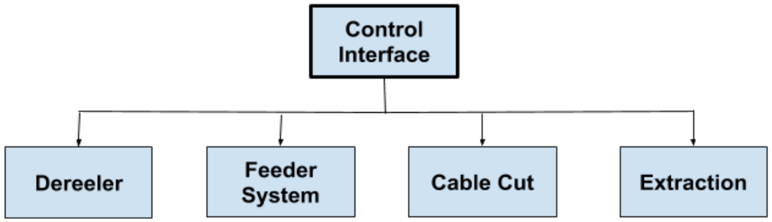
Electrical Wiring Schematic

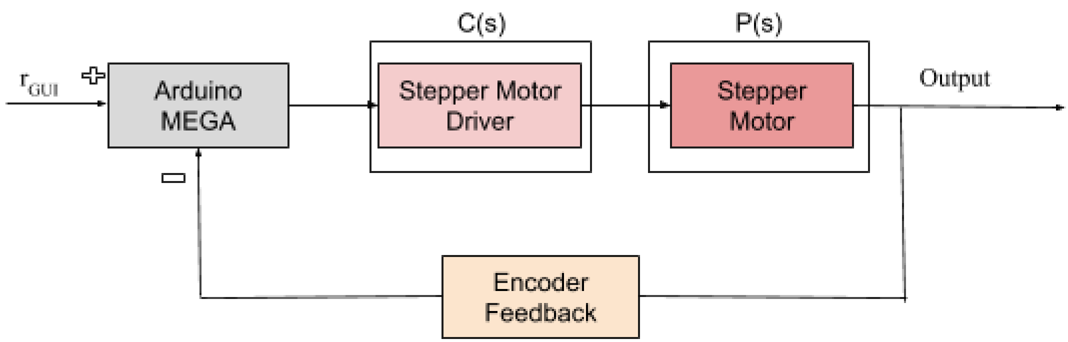
Note: Power supply is regulated to 5V for Arduino
Bold Letters means a block requires 5v & GND
Italicized Letters for *Solenoid* means 24V & GND



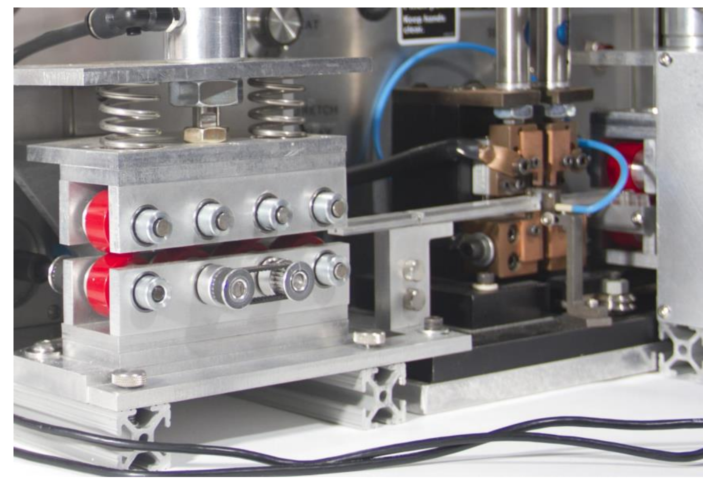
Alex

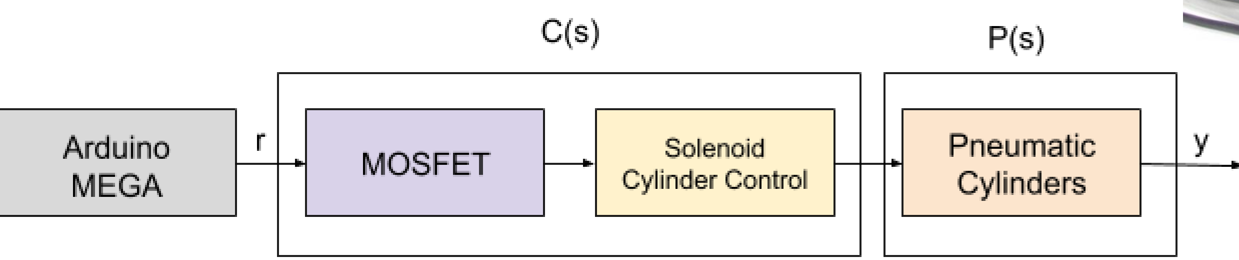
Feeder & Extraction System Control





Stepper Motor Control

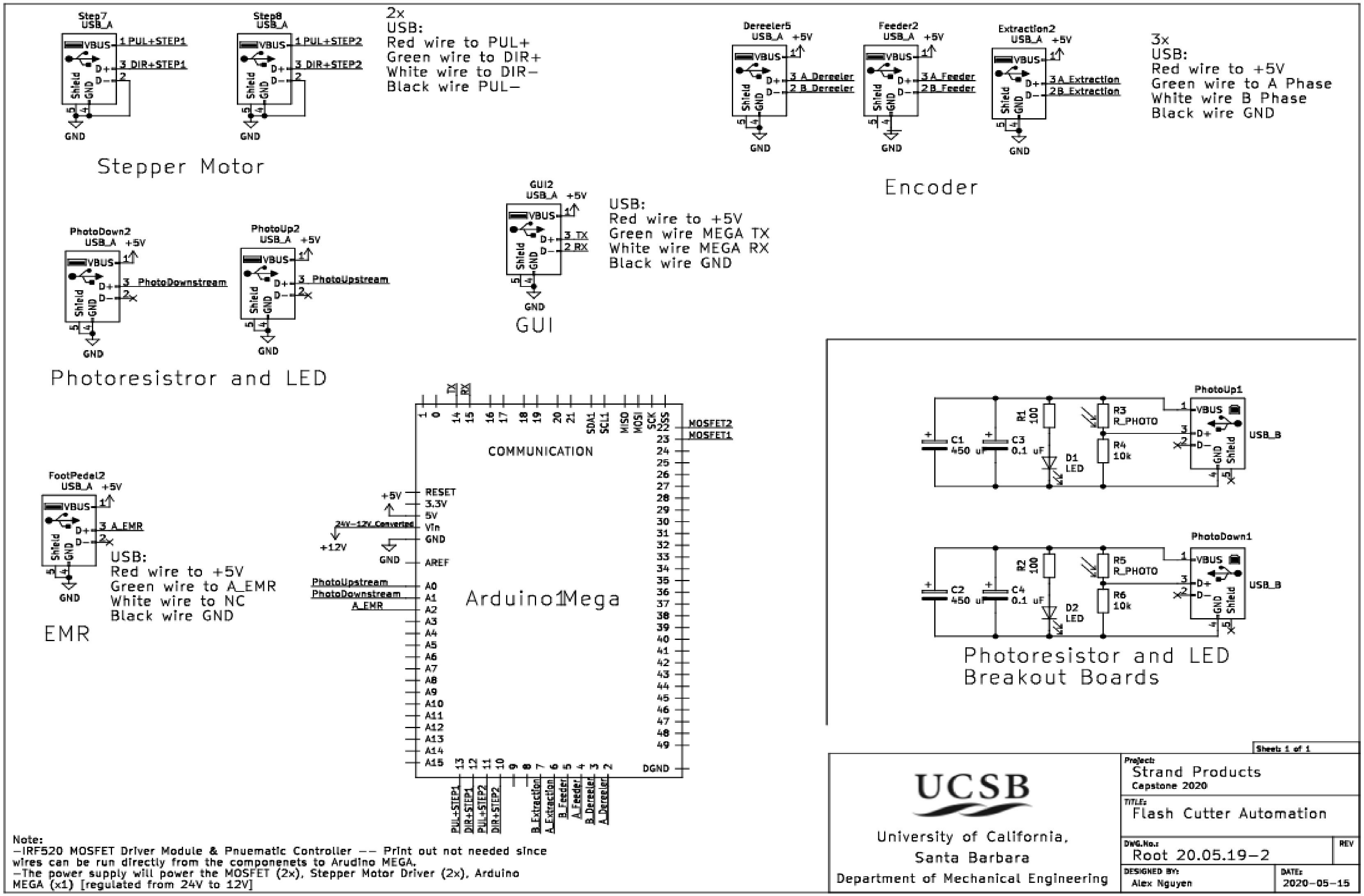




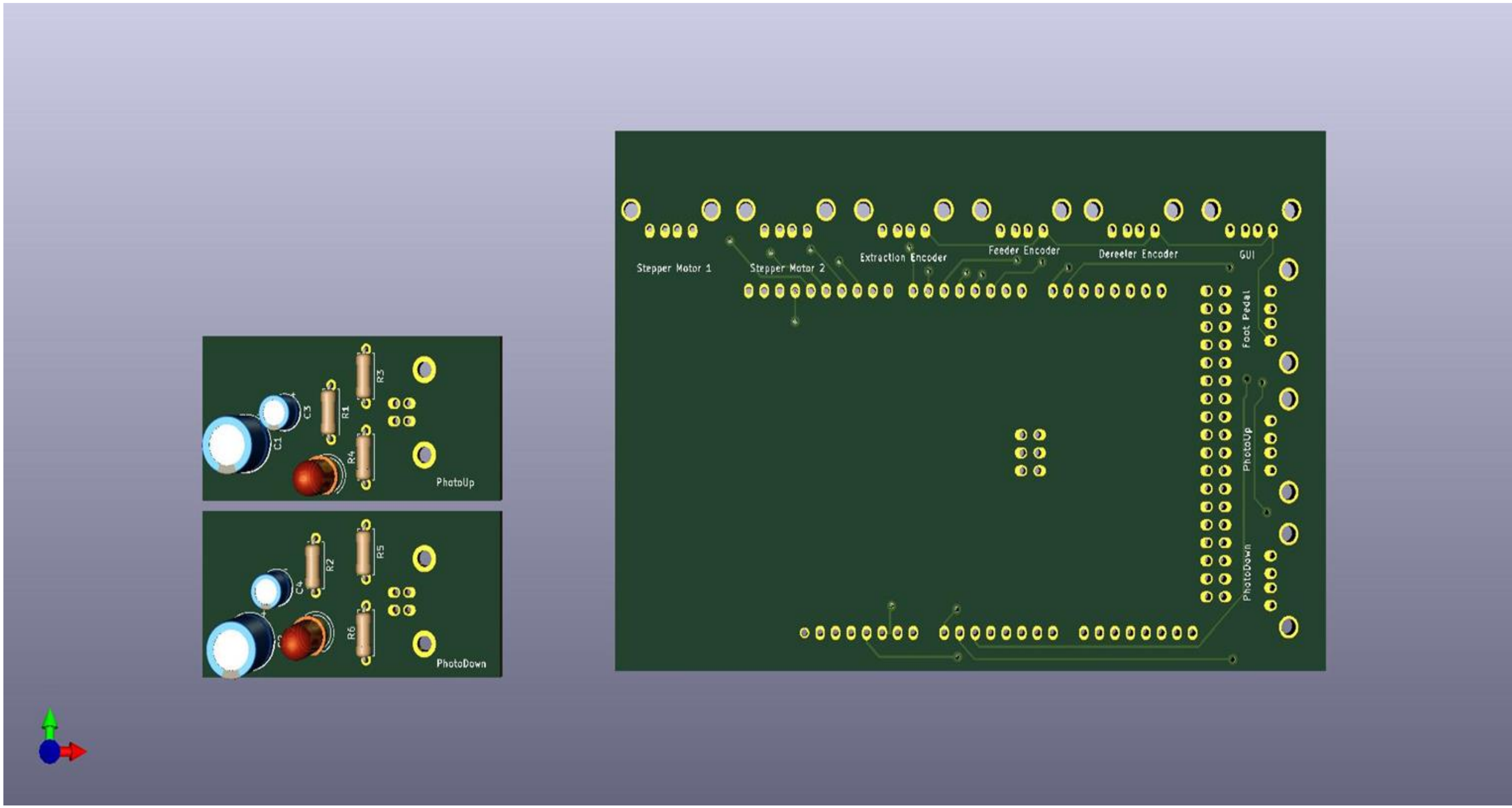
Pneumatic Cylinder Control

Printed Circuit Board (PCB)

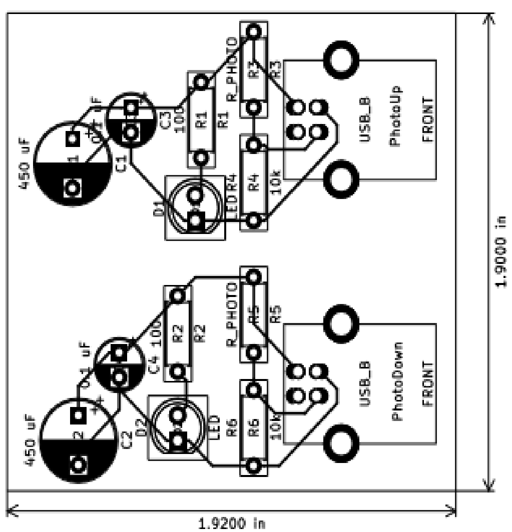
Electrical Schematic

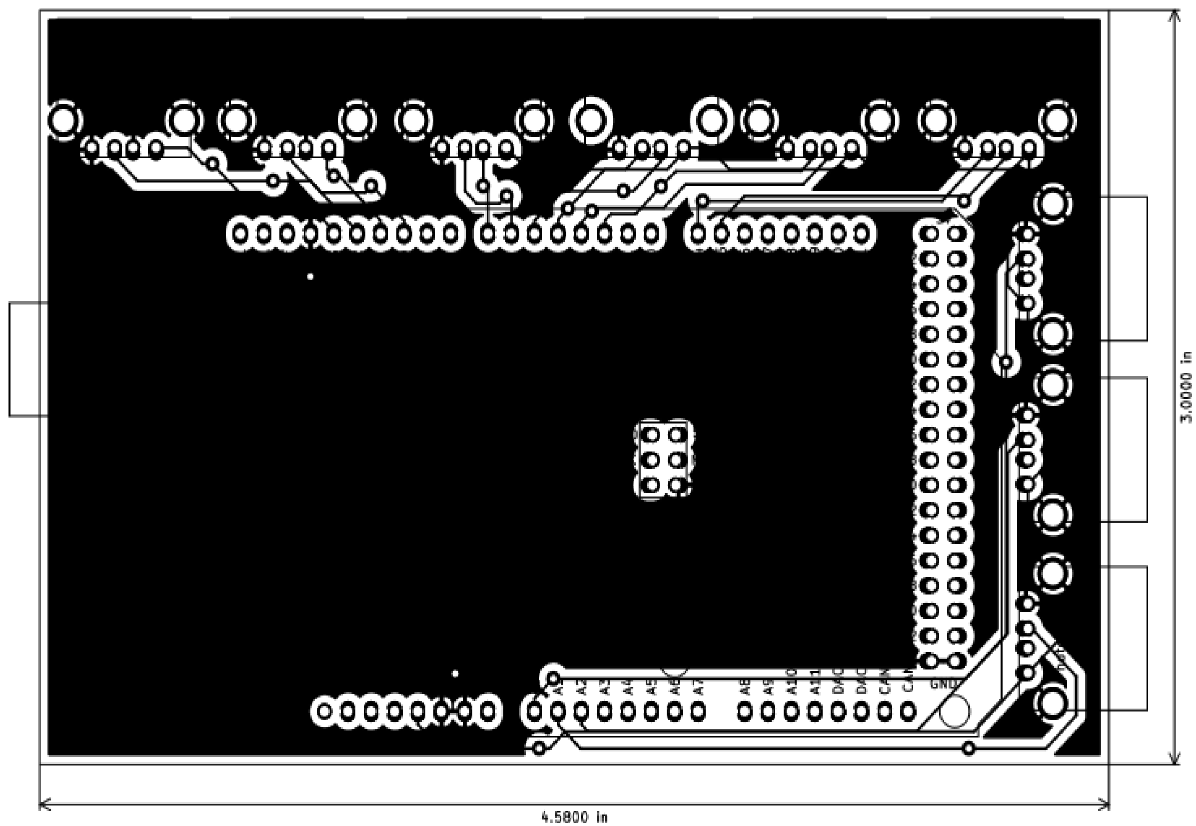


PCB 3D-View

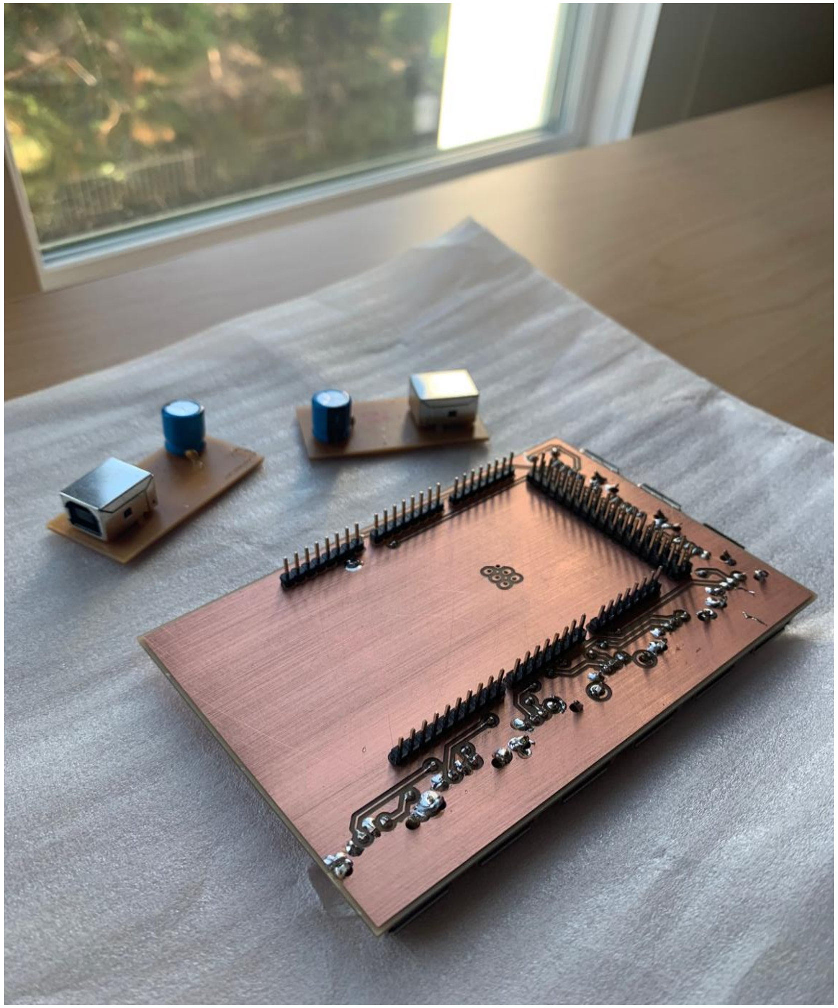

R3
R1
C3
C1
R4
PhotoUp
R5
R2
C4
C2
R6
PhotoDown
Stepper Motor 1
Stepper Motor 2
Extraction Encoder
Feeder Encoder
Dereeler Encoder
GUI
Foot Pedal
PhotoUp
PhotoDown

PCB Dimensions





Printed Circuit Board (PCB)



Alex

Prototype Analysis

FBD Analysis of Single Wheel Feeder System

T: tension

R: radius of wheel

N: normal force/clamping force

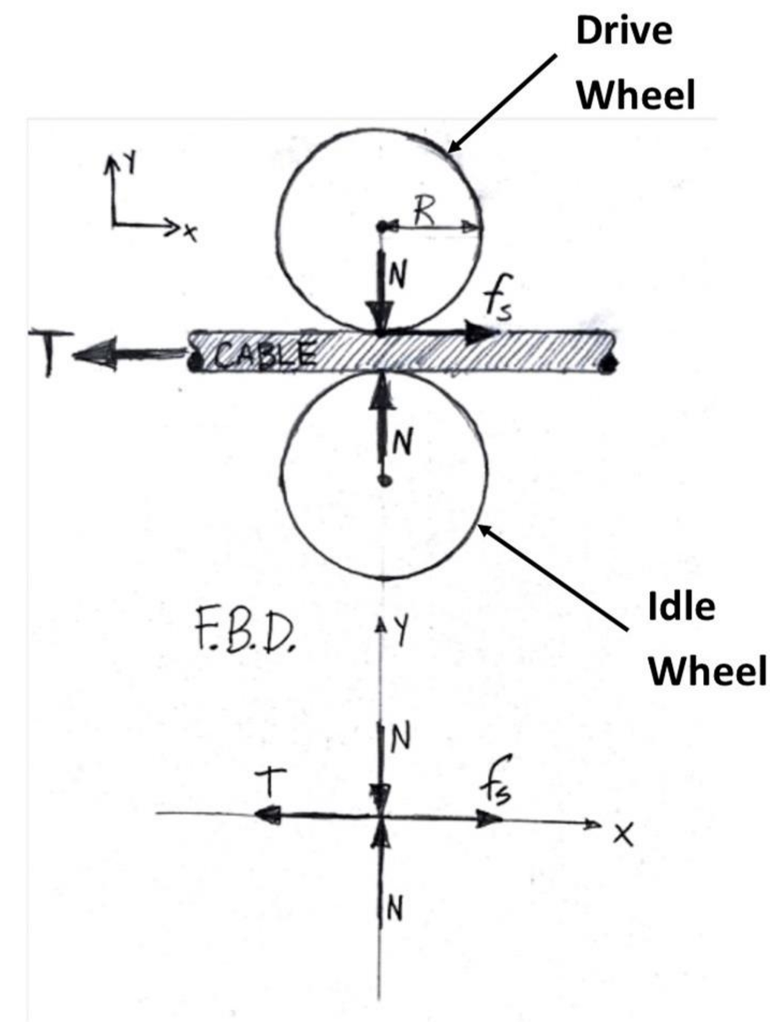
f_s : friction force, $f_s = \mu_s N$

<u>Assumptions</u>: Idle wheel acts as frictionless roller

$$\Sigma F_y = 0 = f_s - T$$

$$\mu_s N - T = 0$$

$$\boxed{N = \frac{T}{\mu_s}}$$



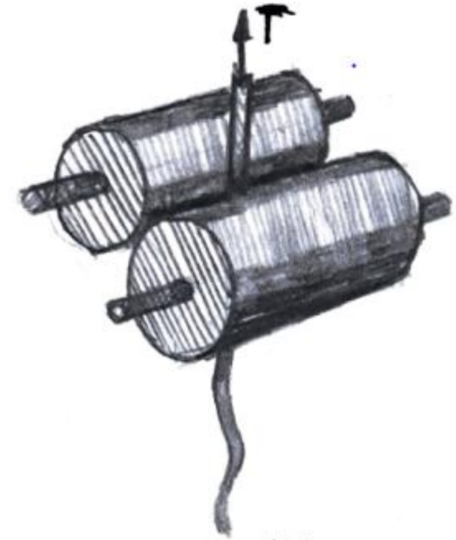
Determining Static Friction Coefficient

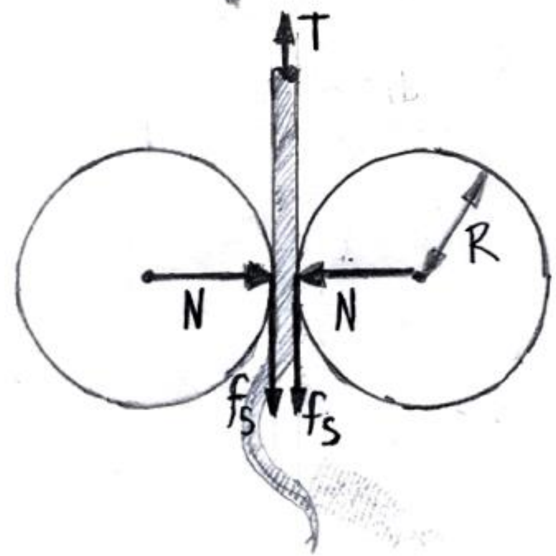
T: tension

R: radius of wheel

N: normal force/clamping force

f_s : friction force, $f_s = \mu_s N$





$$\Sigma F_y = 0 = T + 2f_s$$

$$\mu_s = \frac{T}{2N}$$

Feeder & Extraction System Wheel Number

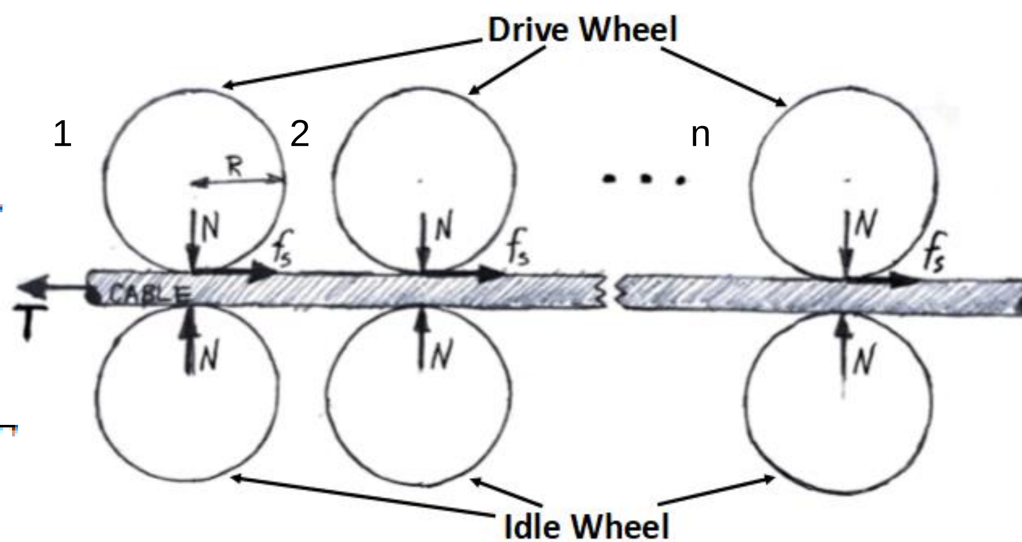
$T = tension$

$T = 10\ lbs$

$f_s = friction\ force = \mu * N$

$f_{s,experimental} = 3\ lbs$

$n = number\ of\ pairs\ of\ wheels$



$\Sigma F_{horizontal} = 0 = n * f_s - T$

$n * \mu * N = T$

$n = \frac{T}{\mu * N} = \frac{T}{fs}$

$n = \frac{10}{3} \approx 4\ wheel\ pairs$

Alex

Dereeler Tension Analysis

Assumptions:

1. $\Delta x = 0.5$" (Spring Compress 0.5")
2. $\mu = 0.1$ Polyethylene (HDPE)
3. Normal Force = Spring Force

Spring Constant:

$$\begin{aligned} k &= 53\,\frac{\text{lb}}{\text{in}} \\ \rightarrow k_{eff} &= 2k = 106\,\frac{\text{lb}}{\text{in}} \end{aligned}$$

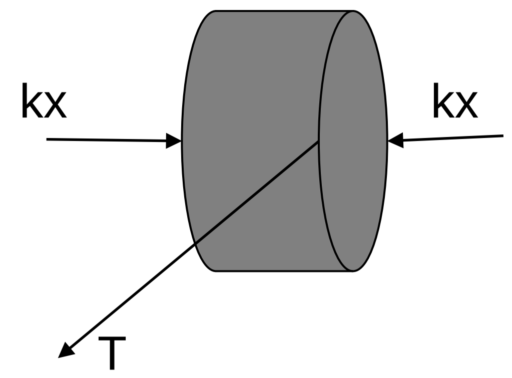
Spring Force:

$$\begin{aligned} F_{spring} &= k_{eff}\Delta x \\ &= (106)(0.5) = 53\text{ lb} \end{aligned}$$

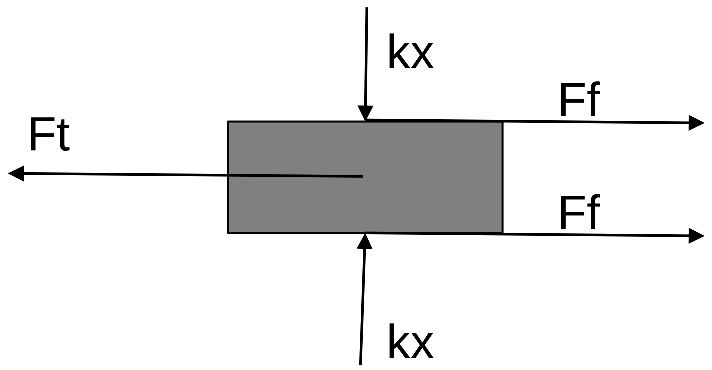
Friction Force:

$$\begin{aligned} F_f &= \mu F_{spring} = (0.1)(53) \\ &= 5.3\text{ lb} \end{aligned}$$

$\Longrightarrow$ Dereeler cable tension needs to be $\geq$ **5.3 lbs**



Front View

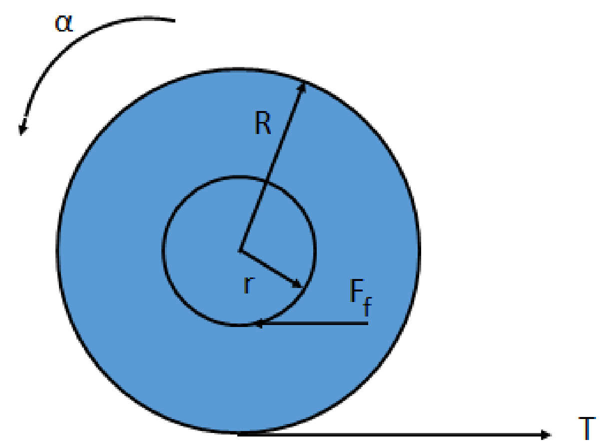


Top View

1. https://www.engineersedge.com/coeffients_of_friction.htm

Alex

Dereeler Dynamic Analysis



Assumptions:

1. Frictional Force Acts as a Vector
2. Only Considering Carbon Steel Rod, Cable Spool, and Spool Adapter Inertia
3. Forces: T (tension at feeder), F_f (Spool Adapter Friction Force), and F_r (Carbon Steel Rod Friction Force)

Torque:

$$\sum \tau = TR - F_f r - F_r r$$

Inertia:

$$\begin{aligned} I &= \frac{1}{2}MR^2 + 2\frac{1}{2}m_{sa}r^2 + \frac{1}{2}m_r r^2 \\ &= \frac{1}{2}MR^2 + (m_{sa} + \frac{1}{2}m_r)r^2 \end{aligned}$$

Angular Acceleration:

$$\begin{aligned} \alpha &= \frac{\sum \tau}{I} \\ &= \boxed{\frac{TR - (F_f + F_r)r}{\frac{1}{2}MR^2 + (\frac{1}{2}m_r + m_{sa})r^2}} \end{aligned}$$

I: Moment of Inertia
α: Angular Acceleration
T: Cable Tension
R: Spool Radius
r: Frictional Force Radius
μ: Kinetic Friction Coefficient
k: Spring Constant
x: Spring Displacement

Alex

Cable Capstan Tension

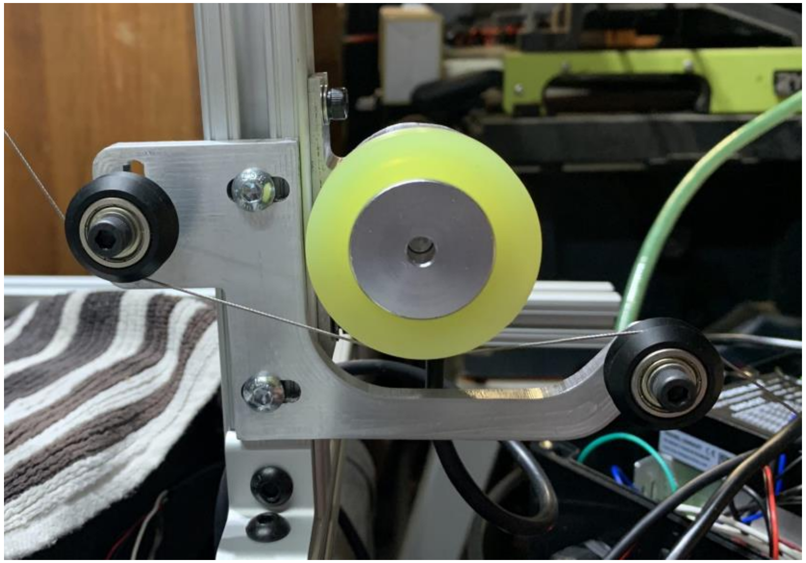
Assumptions:

1. $\mu_{cap} = 0.2$ V-Groove Wheel Coefficient
2. Wrap Angles: $\phi_1 = \frac{\pi}{4}$ (Pulley 1), $\phi_2 = \frac{\pi}{3}$ (Encoder), and $\phi_3 = \frac{\pi}{4}$
3. P_{hold} = Friction Force

Capstan Force:

$$
\begin{aligned}
T &= F_f e^{[\mu_{cap}(\phi_1+\phi_2+\phi_3)]} \\
&= (5.3)e^{[(0.2)(\frac{\pi}{4}+\frac{\pi}{3}+\frac{\pi}{4})]} \\
&= 8.95 \text{ lb}
\end{aligned}
$$

$\Longrightarrow$ Tension in cable at the feeder system is **8.95 lbs**



Derееler Cable Angle

1. https://www.engineersedge.com/coeffients_of_friction.htm

Alex

Feeder System Spring Analysis

Assumptions:

- Equilibrium Spring Length, $x_0 = 1.5$ in
- Current Spring Length, x = 1.1565 in
- Spring Constant, k = 60 $\frac{lb}{in}$
- Wire Diameter, d = 0.105 in
- Outer Diameter, OD = 0.97

Effective Spring Constant:

$$K_{eff} = 2k = 120\frac{lb}{in}$$

Spring Index:

$$C = \frac{D}{d} = 9.238$$

Effective Max Spring:

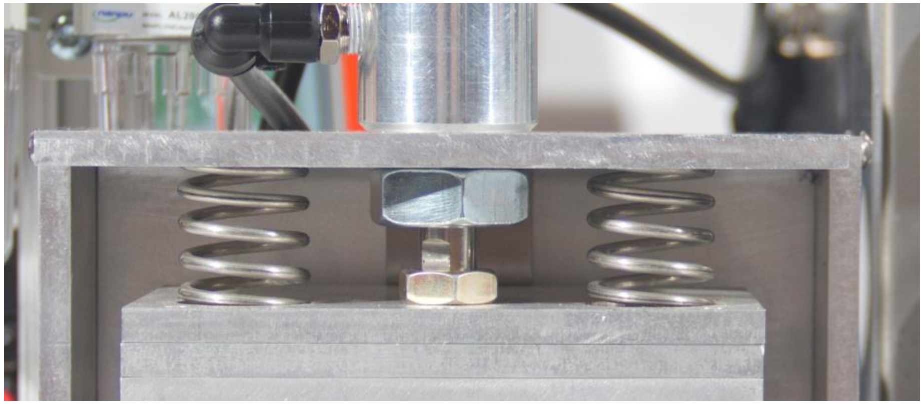
$$F_{eff\ max} = (2)(50.4\ lb) = 100.8\ lb$$

Spring Force (Both):

$$\begin{aligned} F_{Spring} &= k_{eff}(x_0 - x) \\ &= (120\ \frac{lb}{in})(1.5\ in - 1.1565\ in) \\ &= \boxed{41.22\ \text{lb}} \end{aligned}$$

Spring Safety Factor:

$$\begin{aligned} SF_{spring} &= \frac{F_{effmax}}{F_{Spring}} \\ &= \frac{100.8\ lb}{41.22\ lb} \\ &= \boxed{2.4454} \end{aligned}$$



Feeder/Extraction System Springs

Alex

Feeder System Pneumatic Force

Known:

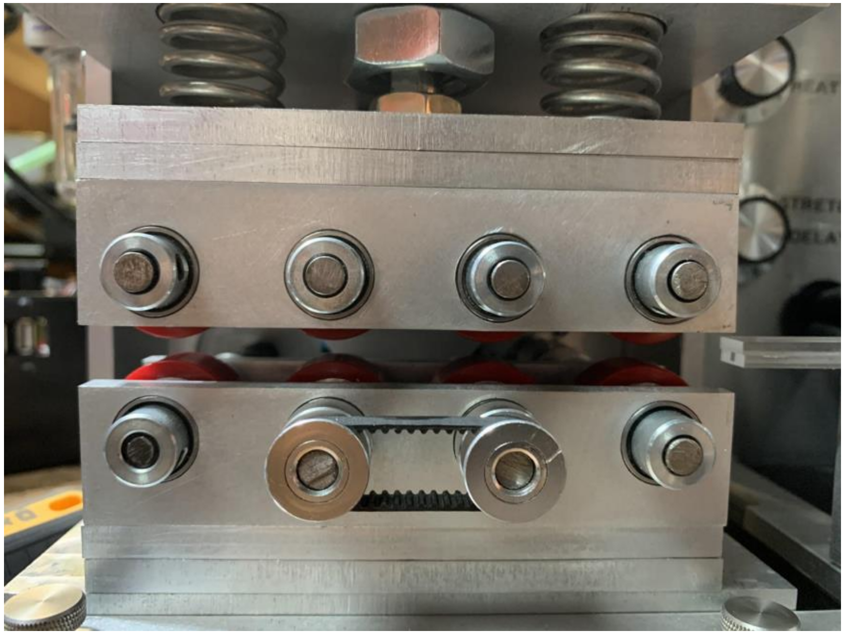
- Bore Diameter, $d_{bore} = 1.25$ in
- Stroke, S = 1.5 in
- Available Pressure, $P_{avail} = 80$ psi
- Piston Area, $A_{piston} = \frac{\pi d_{bore}^2}{4} = 1.2272\ in^2$

Pneumatic Force:

$$\begin{aligned} F_{avail} &= P_{avail} A_{piston} \\ &= (80)(1.2272) \\ &= \boxed{98.2 \text{ lb}} \end{aligned}$$

Displacement Check:

$$\begin{aligned} \Delta x &= \frac{(F_{avail} - 4F)}{k_{eff}} \\ &= \frac{(98.2 - 41.2)}{120} \\ &= \boxed{0.475 \text{ in}} \end{aligned}$$



Pneumatic Actuator Distance

Alex

Safety Factor Calculations

Known:

- Neoprene Friction Coefficient on Tungsten $\mu = 0.62$
- Feeder System Normal Force, $F_N = 41.22$ lb
- Feeder System Force, $F_{pull} = 8.95$ lb
- Tension Required to Cut, T = 2 lb
- Max Spring Force, $F_{s,max} = 100.8$ lb

Wheel Clamp:

$$\begin{aligned} SF &= \frac{\mu F_N}{F_{pull}} \\ &= \frac{25.5565 \text{ lb}}{8.95 \text{ lb}} \\ &= \boxed{2.86} \end{aligned}$$

Cable Cut:

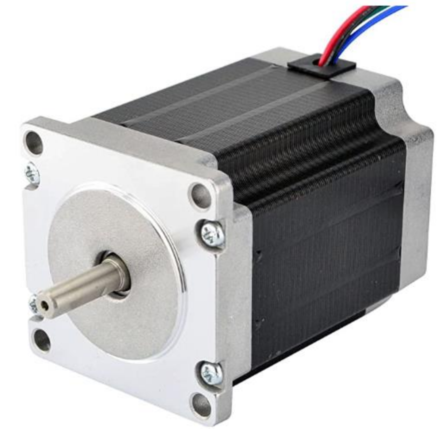
$$\begin{aligned} SF &= \frac{F_{pull}}{T} \\ &= \frac{8.95 \text{ lb}}{2 \text{ lb}} \\ &= \boxed{4.47} \end{aligned}$$

Feeder and Extraction Springs:

$$\begin{aligned} SF &= \frac{F_{s,max}}{F_N} \\ &= \frac{100.8 \text{ lb}}{41.22 \text{ lb}} \\ &= \boxed{2.45} \end{aligned}$$

Alex

Step Size Calculations



Known:

- Wheel Diameter, D = 1.0”
- Stepper = 1.8 $\frac{\text{degree}}{\text{step}}$
- Microstep Resolution = 0.45 $\frac{\text{degree}}{\text{pulse}}$ (Stepper Driver can vary from 400 to 25000 $\frac{\text{pulse}}{\text{rev}}$)

Cable Length, S = rθ where S: arc length, r: radius, and θ: angle

Stepper Motor:
Step Resolution: 200 $\frac{\text{steps}}{\text{rev}} \rightarrow 1.8 \frac{\text{degree}}{\text{step}}$

Minimum Step Size:

$$\begin{aligned} S &= \frac{D}{2}\theta \\ &= \frac{1.0}{2}\frac{1.8\pi}{180} \\ &= 0.0157 \text{ in} \end{aligned}$$

Stepper Driver Micro-Step:
Step Resolution: 800 $\frac{\text{pulse}}{\text{rev}} \rightarrow 0.45 \frac{\text{degree}}{\text{pulse}}$

Minimum Step Size:

$$\begin{aligned} S &= \frac{D}{2}\theta \\ &= \frac{1.0}{2}\frac{0.45\pi}{180} \\ &= 0.0039 \text{ in} \end{aligned}$$

Alex

Encoder Resolution

Known:

- Encoder Resolution $= 600 \frac{\text{pulse}}{\text{rev}}$
- Encoder Wheel Diameter: $D_d = 1.9685$” (Dereeler), $D_f = 1.0$” (Feeder), and $D_e = 1.0$” (Extraction)

Dereeler: Wheel Diameter: $D_d = 1.9685$”

$$\begin{aligned} \frac{\text{pulse}}{\text{length}} &= \left(\frac{600 \text{ pulse}}{\text{rev}}\right)\left(\frac{1 \text{ rev}}{\pi D_d} \text{ in}\right) \\ &= \frac{600 \text{ pulse}}{6.1842 \text{ in}} \end{aligned}$$

$\therefore$ Length per Pulse $= 0.0103 \frac{\text{in}}{\text{pulse}}$

Feeder Extraction: Wheel Diameter: $D_d = 1$”

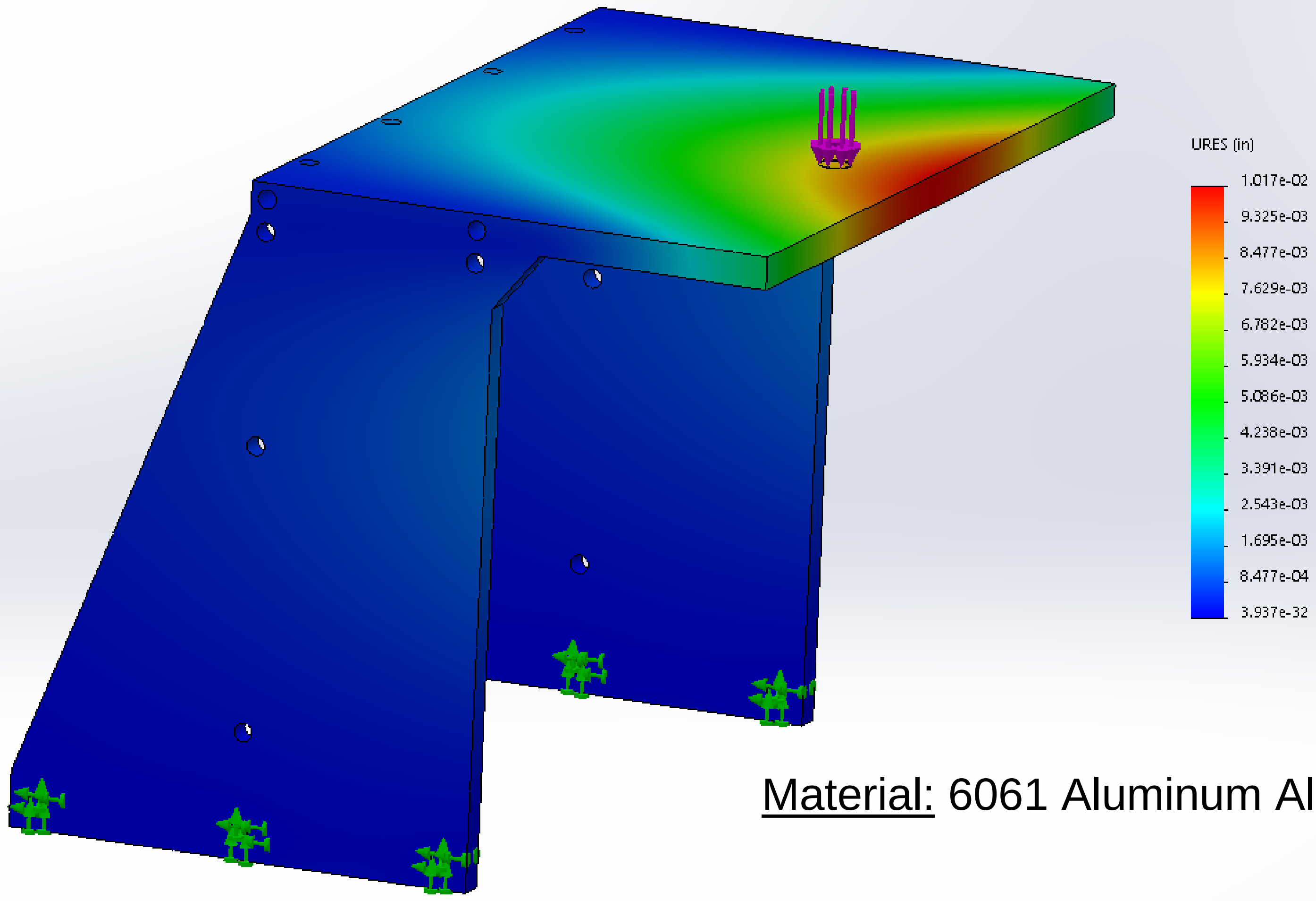
$$\begin{aligned} \frac{\text{pulse}}{\text{length}} &= \left(\frac{600 \text{ pulse}}{\text{rev}}\right)\left(\frac{1 \text{ rev}}{\pi D_f} \text{ in}\right) \\ &= \frac{600 \text{ pulse}}{1.5708 \text{ in}} \end{aligned}$$

$\therefore$ Length per Pulse $= 0.0026 \frac{\text{in}}{\text{pulse}}$

$\rightarrow$ The encoders on each subsystem will be able to reach all tolerance values. Although, the feeder and extraction subsystem encoders will be the most accurate.

Alex

Max Displacement Simulation



Material: 6061 Aluminum Alloy

Max Displacement at force is **0.01”**

Prototype Testing

Vance

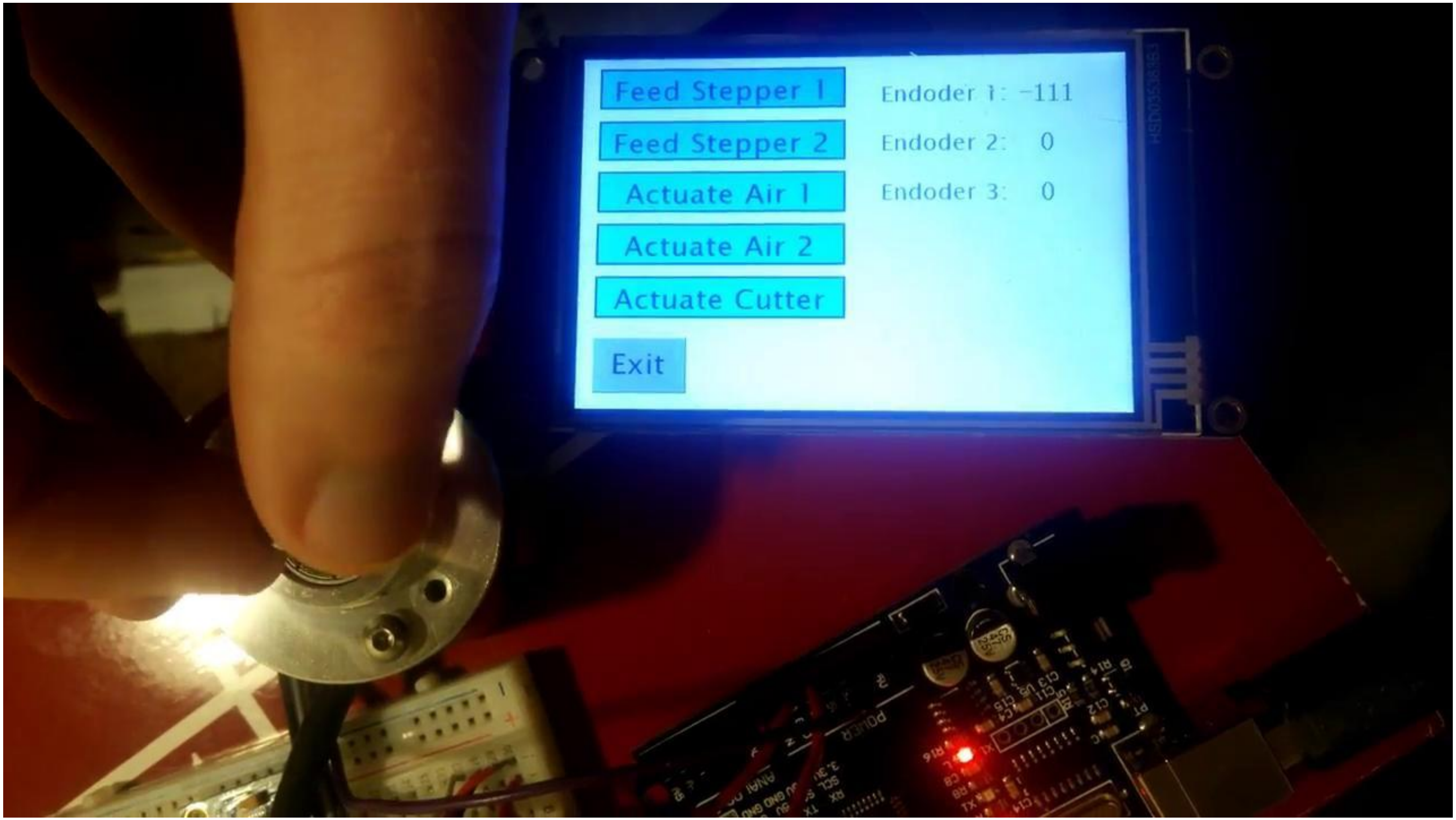
Wheel Slip Test Results

Wheel(s)	Force (lbs)
Upstream	3
Downstream	3
Both	6.6

- The force was measured with an electronic fish-scale
- When tested independently, upstream and downstream wheel sets gave identical results
- Results may differ with new materials & build

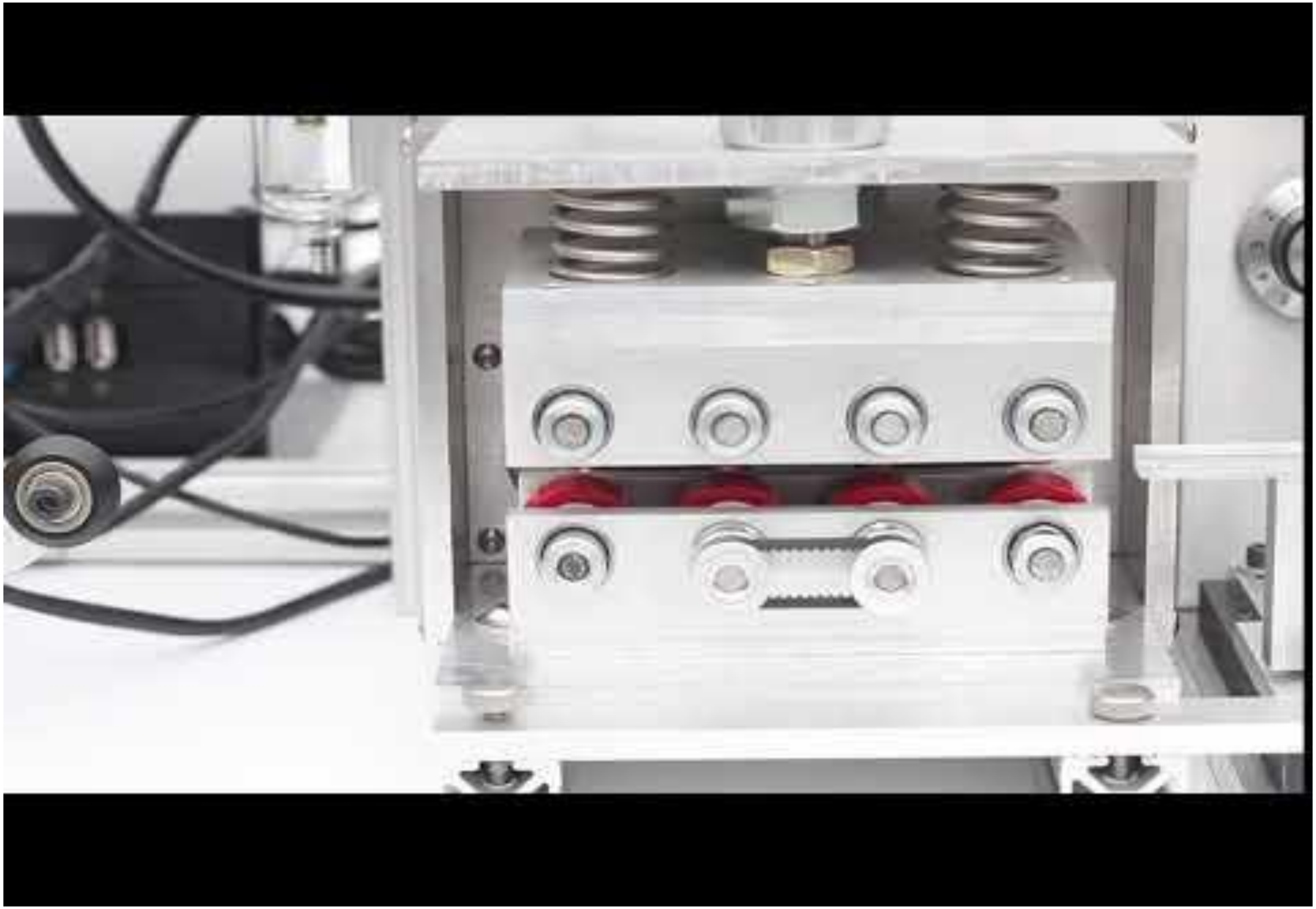
Alex

Encoder Counting Revolutions



Alex

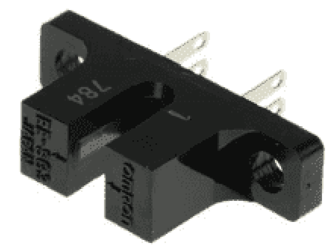
Pneumatic Cylinder Test



Sensors

Sensor Testing

➢ Break-Beam Sensor

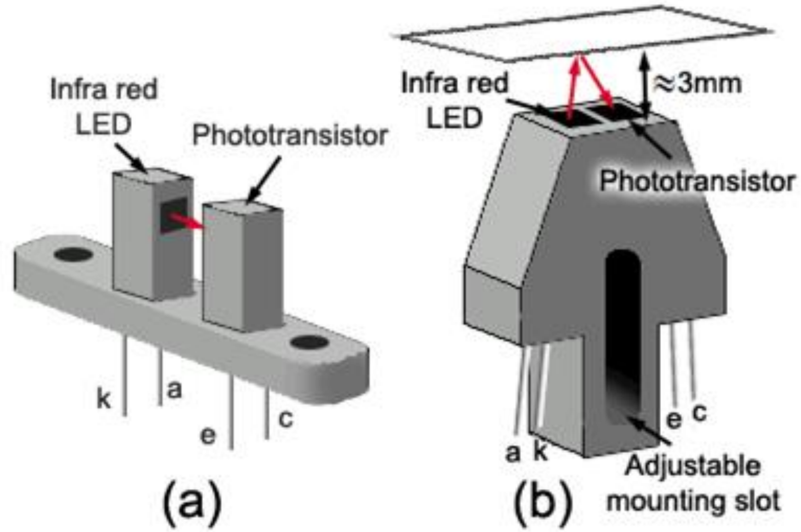


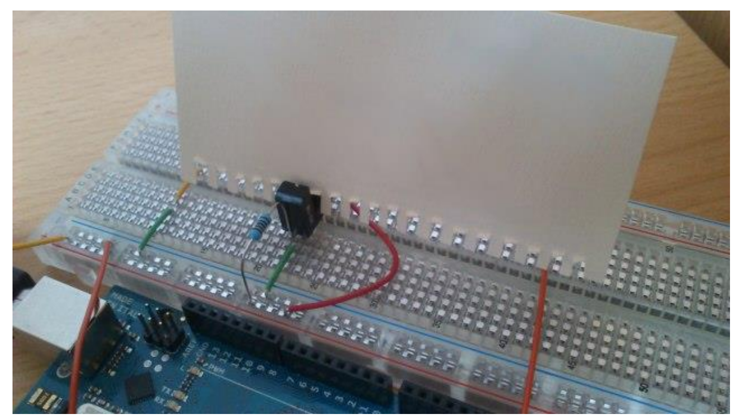
➢ Photoresistor with LED

Alex

Break Beam Sensor Test

- **Goal:** Find the hole size which breaks the laser's path
- Machine Aluminum sheet
  - Drill various hole sizes
- Align sheet holes with the photoresistor aperture
  - Detect passing cable





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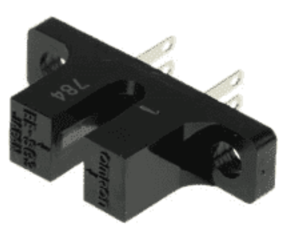
Break-Beam Test

- Machined aluminum test plate
- 0.1875” to 0.041”
- “Does sensor detect obstruction?”



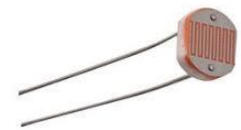
RESULTS

Hole Size (inch)	Obstruction Detection (Y/N)
3/16	No
5/32	No
9/64	No
1/8	No
7/64	No
3/32	No
5/64	No
1/16	No
0.052	No
0.041	No

Vance

Sensor Fault Detection Result

- Photoresistor with LED
  - Guide tube ambient light detection
    - Extraction tube only
  - Sequence integration



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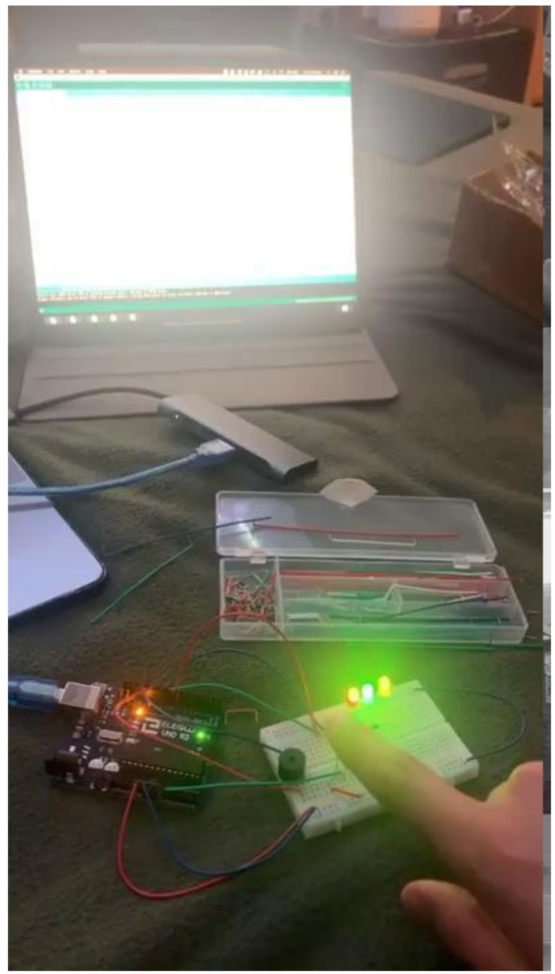
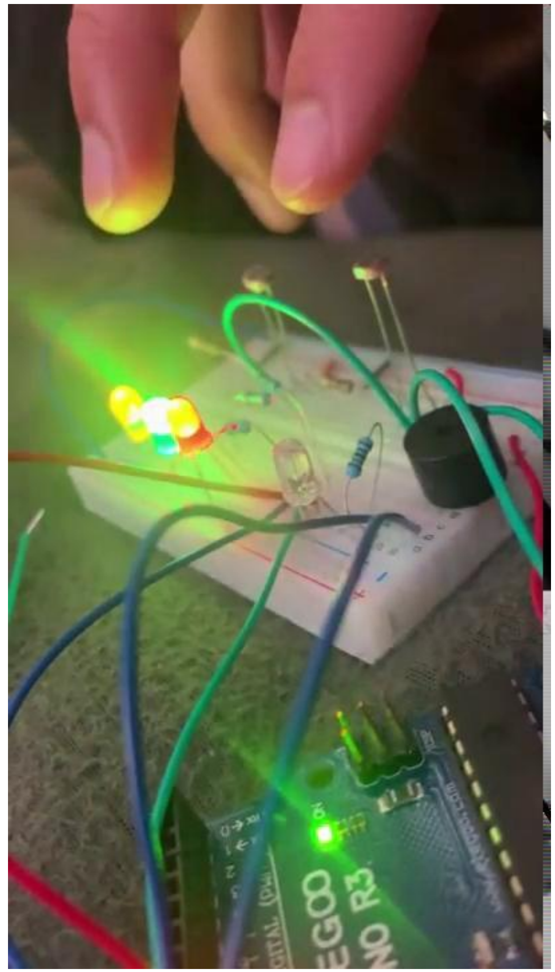
Sensor Demo

Single Configuration

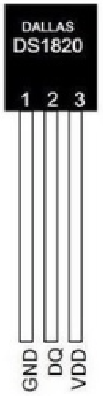


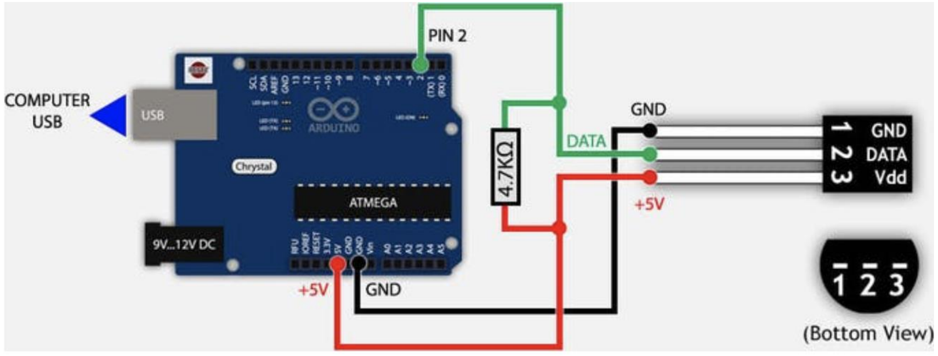
Photoresistor Dual Configuration



I.R. Temperature Sensing

- IR Temperature Sensor
  - Electronics box thermals





Vance

Temperature Sensor Test Results

F5XAS9CIFMTNEBR

```
#include <OneWire.h>
#include <DallasTemperature.h>

// Data wire is plugged into pin 2 on the Arduino
#define ONE_WIRE_BUS 2

// Setup a oneWire instance to communicate with any OneWire devices
// (not just Maxim/Dallas temperature ICs)
OneWire oneWire(ONE_WIRE_BUS);

// Pass our oneWire reference to Dallas Temperature.
DallasTemperature sensors(&oneWire);

void setup(void)
{
  // start serial port
  Serial.begin(9600);
  Serial.println("Dallas Temperature IC Control Library Demo");

  // Start up the library
  sensors.begin();
}


void loop(void)
{
  // call sensors.requestTemperatures() to issue a global temperature
  // request to all devices on the bus
  Serial.print(" Requesting temperatures...");
  sensors.requestTemperatures(); // Send the command to get temperatures
  Serial.println("DONE");

  Serial.print("Temperature is: ");
  Serial.print(sensors.getTempFByIndex(0)); // Why "byIndex"?
    // You can have more than one IC on the same bus.
    // 0 refers to the first IC on the wire
    delay(1000);
}
```

```
15:14:40.668 -> Temperature is: 73.96 Requesting temperatures...DONE
15:14:42.395 -> Temperature is: 73.74 Requesting temperatures...DONE
15:14:44.094 -> Temperature is: 73.40 Requesting temperatures...DONE
15:14:45.819 -> Temperature is: 73.51 Requesting temperatures...DONE
15:14:47.515 -> Temperature is: 73.51 Requesting temperatures...DONE
15:14:49.249 -> Temperature is: 73.62 Requesting temperatures...DONE
15:14:50.956 -> Temperature is: 73.74 Requesting temperatures...DONE
15:14:52.663 -> Temperature is: 73.74 Requesting temperatures...DONE
15:14:54.386 -> Temperature is: 73.74 Requesting temperatures...DONE
15:14:56.080 -> Temperature is: 73.62 Requesting temperatures...DONE
15:14:57.798 -> Temperature is: 73.51 Requesting temperatures...DONE
15:14:59.534 -> Temperature is: 73.51 Requesting temperatures...DONE
15:15:01.216 -> Temperature is: 73.51 Requesting temperatures...DONE
15:15:02.943 -> Temperature is: 73.51 Requesting temperatures...DONE
15:15:04.662 -> Temperature is: 73.40 Requesting temperatures...DONE
15:15:06.353 -> Temperature is: 73.40 Requesting temperatures...DONE
15:15:08.061 -> Temperature is: 73.29 Requesting temperatures...DONE
15:15:09.797 -> Temperature is: 73.18 Requesting temperatures...DONE
15:15:11.505 -> Temperature is: 73.18 Requesting temperatures...DONE
15:15:13.227 -> Temperature is: 73.29 Requesting temperatures...DONE
15:15:14.915 -> Temperature is: 73.29 Requesting temperatures...DONE
15:15:16.641 -> Temperature is: 73.40 Requesting temperatures...DONE
15:15:18.365 -> Temperature is: 73.40 Requesting temperatures...DONE
15:15:20.070 -> Temperature is: 73.51 Requesting temperatures...DONE
15:15:21.777 -> Temperature is: 73.51 Requesting temperatures...DONE
15:15:23.485 -> Temperature is: 73.51 Requesting temperatures...DONE
15:15:25.202 -> Temperature is: 73.29 Requesting temperatures...DONE
15:15:26.934 -> Temperature is: 73.29 Requesting temperatures...DONE
15:15:28.634 -> Temperature is: 73.40 Requesting temperatures...DONE
15:15:30.342 -> Temperature is: 73.40 Requesting temperatures...DONE
15:15:32.065 -> Temperature is: 73.29 Requesting temperatures...DONE
15:15:33.780 -> Temperature is: 73.29 Requesting temperatures...DONE
15:15:35.469 -> Temperature is: 73.18 Requesting temperatures...DONE
15:15:37.188 -> Temperature is: 73.06 Requesting temperatures...DONE
15:15:38.890 -> Temperature is: 72.95 Requesting temperatures...DONE
15:15:40.628 -> Temperature is: 72.72 Requesting temperatures...DONE
15:15:42.322 -> Temperature is: 72.61 Requesting temperatures...DONE
```

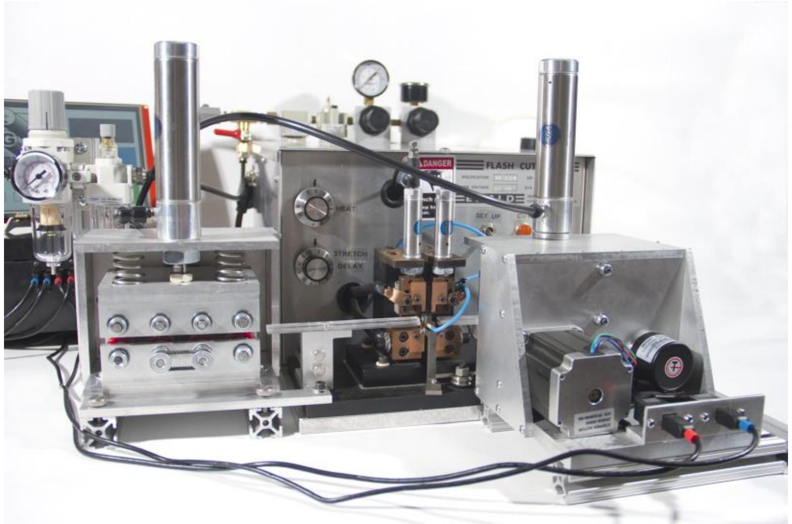
Final Design Cost

Prototyping	**Final Product**				
Fall and Winter Quarter	Dereeler	Touchscreen	Feeder/Extractor (Mounting to Flashcutter)	Electronics	Tooling
$1350.00	$200.00	$155.00	$1318.00	$725.00	$1050.00
Total = $4800.00					

Acknowledgements

Special Thanks To The Following Individuals:

- ➔ John Hottinger
- ➔ Dasun Hemachandra
- ➔ Syaza Mustafah
- ➔ Chandler Bartz
- ➔ Dr. Tyler Susko
- ➔ Dr. Trevor Marks



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