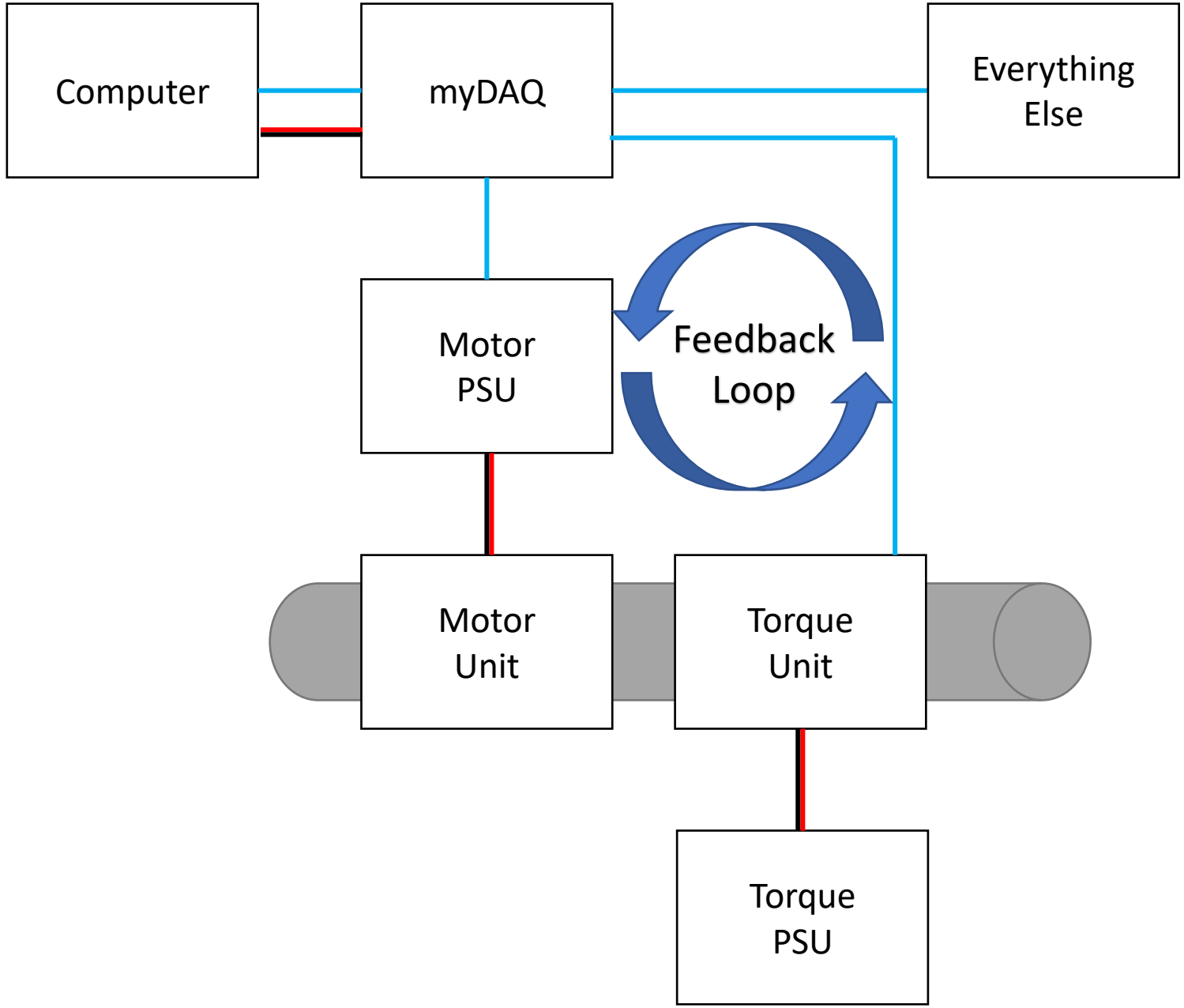
Bearing Testing Rig

What Aleks has done

Week 1

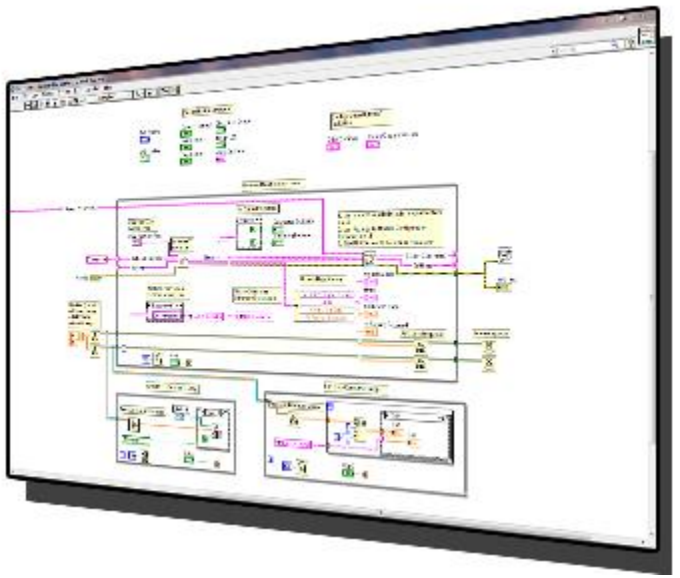
Electrical Plan

- myDAQ acts as central control unit for the circuit
- Motor PSU is controlled via myDAQ to make the Motor variable
- Torque PSU is just on or off
- Everything else will include accelrometers



Software Plan

- Use LabVIEW



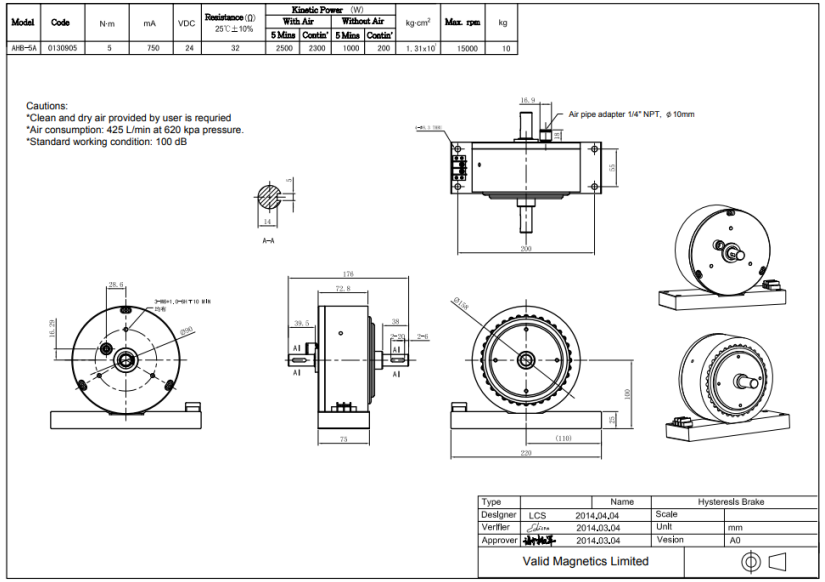
What’s Been Done

- Can variably control the motor myDAQ
- Need the cable for the torque sensor to do the rest of it
- Need to know what “Everything Else” entails
- How do we want the data out?

Week 2

EM Brake: AHB-5 Air-Cooled Hysteresis Brake

- Using the one recommended by the capstone report: ABH-5
  - USD $800
  - 10mm diameter air supply needed
  - 24VDC power supply
- Controller: ICS2000
  - USD $160
  - Variable Current Controller
  - 24VDC power supply needed
  - RS485 communication
- Other
  - $50 USD per coupling
  - Shipping is $200 USD, 2 weeks to arrive



Model	Code	N·m	mA	VDC	Resistance (Ω) 25℃±10%	Kinetic Power (W) With Air 5 Mins	With Air Contin'	Without Air 5 Mins	Without Air Contin'	kg·cm²	Max. rpm	kg
AHB-5A	0130905	5	750	24	32	2500	2300	1000	200	1.31×10	15000	10

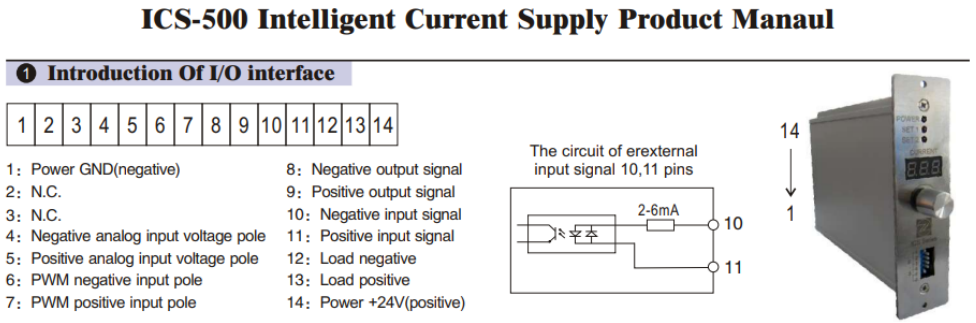
Cautions:
*Clean and dry air provided by user is requried
*Air consumption: 425 L/min at 620 kpa pressure.
*Standard working condition: 100 dB

Air pipe adapter 1/4" NPT, ϕ 10mm

Type		Name	Hysteresis Brake
Designer	LCS	2014.04.04	Scale
Verifier		2014.03.04	Unit mm
Approver		2014.03.04	Vesion A0

Valid Magnetics Limited

AHB-5 Data Sheet



ICS-500 Intelligent Current Supply Product Manaul

❶ Introduction Of I/O interface

1	2	3	4	5	6	7	8	9	10	11	12	13	14

1：Power GND(negative)
2：N.C.
3：N.C.
4：Negative analog input voltage pole
5：Positive analog input voltage pole
6：PWM negative input pole
7：PWM positive input pole
8：Negative output signal
9：Positive output signal
10：Negative input signal
11：Positive input signal
12：Load negative
13：Load positive
14：Power +24V(positive)

The circuit of erexternal input signal 10,11 pins

ICS 200 Interface

Accelerometers

- Using similar model to what capstone group recommended, exact one is not produced anymore
- Two styles from CTC: Industrial and Scientific
- Capstone recommended an industrial one with 100 mV/g sensitivity
- Probably go with similar one, but need further input into the frequency range we're expecting to measure (kilohertz , usually 1-5kHz, 1 accelerometer for low frequency and 1 for high)

Industrial Options

CTC Types

TEA110

TEST AND MEASUREMENT ACCELEROMETER, SIDE EXIT 10-32 COAXIAL CONNECTOR, 10-32 MOUNTING, 100 MV/G, ±10%

- 30-1,800,000 CPM Frequency Response (±3dB)
- -58 to 250°F (-50 to 121°C) Temperature Range
- Welded, Hermetic Sealing

Scientific Option

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PRODUCTS RESOURCES ABOUT MY ACCOUNT RMA DISTRIBUTORS

Home ▸ Products ▸ CTC Line ▸ Industrial Accelerometers ▸ 100 mV/g Triaxial

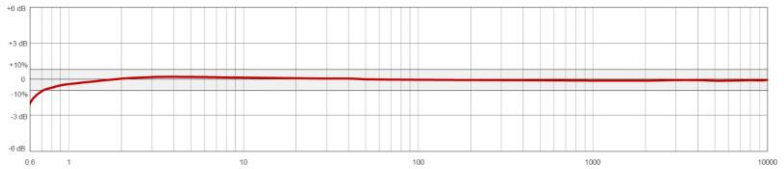
AC230

PREMIUM TRIAXIAL ACCELEROMETER, SIDE EXIT 4 PIN MINI-MIL CONNECTOR, 100 MV/G, ±5%

- 36-600,000 CPM Frequency Response (±3dB)
- -65 to 250°F (-54 to 121°C) Temperature Range
- Welded, Hermetic Sealing
- Premium Triaxial Sensor
- Collect 3 Axis of Data Simultaneously

DATASHEET
3D MODELS
STEP FILES
CTC TRIAXIAL SENSOR RESOURCES
WIRING DIAGRAM
CERTIFICATES

AC230 TYPICAL FREQUENCY RESPONSE



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PRODUCTS RESOURCES ABOUT MY ACCOUNT RMA DISTRIBUTORS

Home ▸ Products ▸ CTC Line ▸ Industrial Accelerometers ▸ 100 mV/g Standard Size

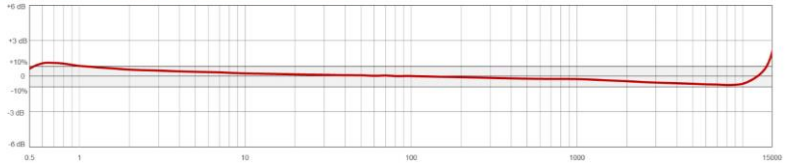
AC102

MULTIPURPOSE ACCELEROMETER, TOP EXIT 2 PIN CONNECTOR, 100 MV/G, ±10%

- 30-900,000 CPM Frequency Response (±3dB)
- -58 to 250°F (-50 to 121°C) Temperature Range
- Welded, Hermetic Sealing
- Affordably Priced, Hermetically Sealed Sensors
- Perfect for Thousands of Applications

DATASHEET
3D MODELS
STEP FILES
WIRING DIAGRAM
CERTIFICATES

AC102 TYPICAL FREQUENCY RESPONSE



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PRODUCTS RESOURCES ABOUT MY ACCOUNT RMA DISTRIBUTORS

Home ▸ Products ▸ TMP Line ▸ Test & Measurement Products ▸ General Purpose

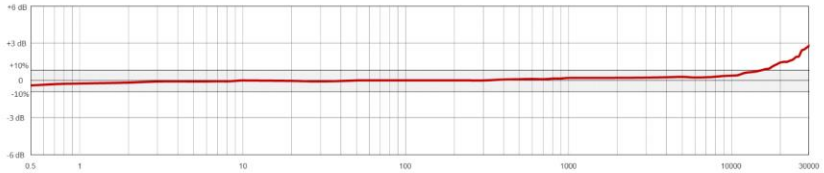
TEB110

TEST AND MEASUREMENT ACCELEROMETER, TOP EXIT 10-32 COAXIAL CONNECTOR, 10-32 MOUNTING, 100 MV/G, ±10%

- 30-1,800,000 CPM Frequency Response (±3dB)
- -58 to 250°F (-50 to 121°C) Temperature Range
- Welded, Hermetic Sealing

DATASHEET
3D MODEL
PRODUCT MANUAL

TEB110 TYPICAL FREQUENCY RESPONSE



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PRODUCTS RESOURCES ABOUT MY ACCOUNT RMA DISTRIBUTORS

Home ▸ Products ▸ CTC Line ▸ Industrial Accelerometers ▸ 100 mV/g Standard Size

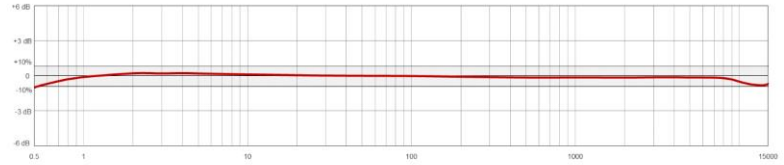
AC210

PREMIUM ACCELEROMETER, TOP EXIT 2 PIN CONNECTOR, 100 MV/G, ±5%

- 30-900,000 CPM Frequency Response (±3dB)
- -58 to 250°F (-50 to 121°C) Temperature Range
- Welded, Hermetic Sealing
- High Performance Sensor for Demanding Applications
- High Dynamic Range with Excellent Frequency Response

DATASHEET
3D MODELS
STEP FILES
WIRING DIAGRAM
CERTIFICATES

AC210 TYPICAL FREQUENCY RESPONSE



Pricing

	AC230	AC102	TEB110	AC210
Frequency Low (Hz)	0.8	2	0.5	0.6
Frequency High (Hz)	10000	11200	10000	15000
Axis	3	1	1	1
Sensitivity (mV/g)	100	100	100	100
Error	5%	10%	10%	5%
Price (Low)	$ 1,276.22	$ 113.10	$ 262.35	$ 229.70
Price (High)	$ 1,496.22	$ 288.00	$ 262.35	$ 257.96
Total Price (Low)	$ 1,276.22	$ 339.30	$ 787.05	$ 689.10
Total Price (High)	$ 1,496.22	$ 864.00	$ 787.05	$ 773.88

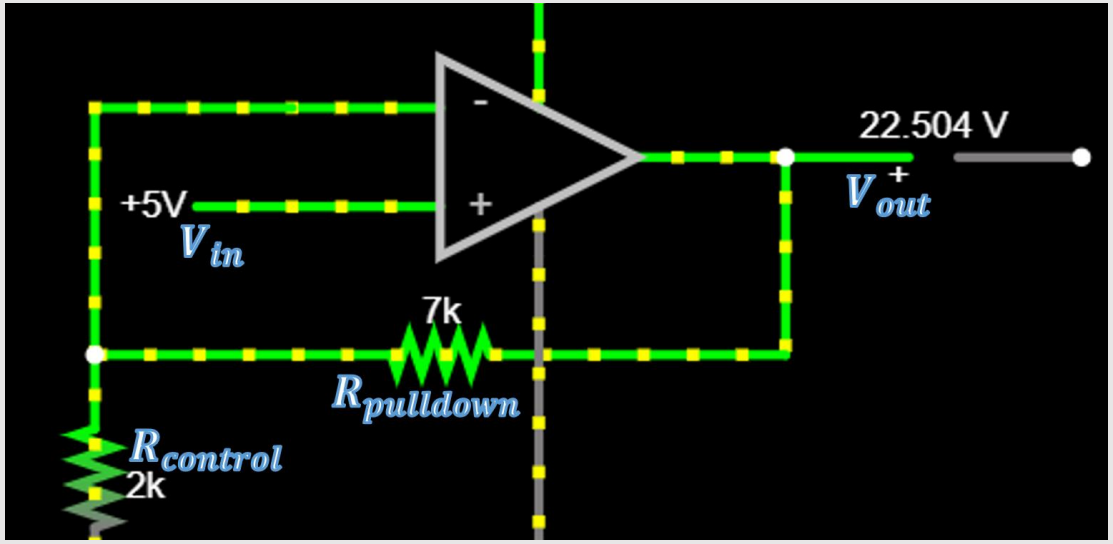
- Recommend AC210
  - Very high frequency range
  - Good sensitivity
  - Low error margin
  - Good price

Week 3

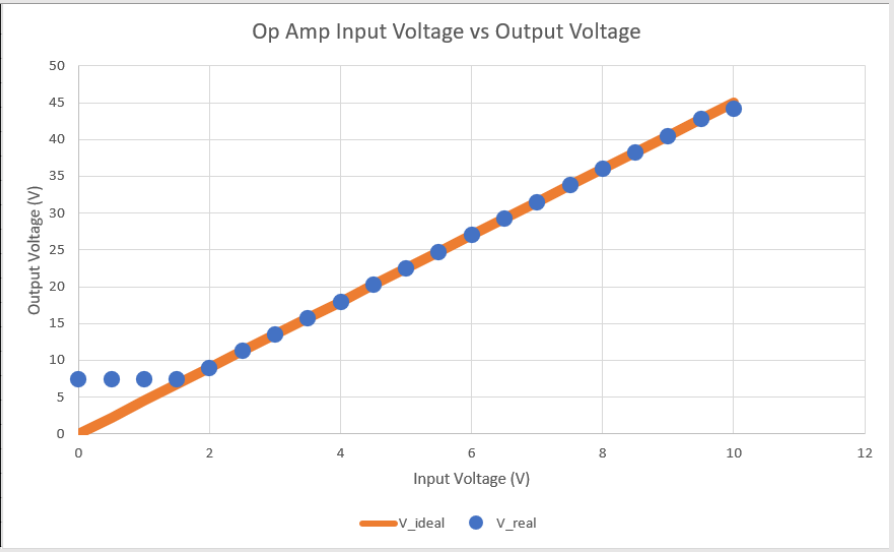
DAQ Amp

- Goal is to linearly increase the DAQ to give it a full voltage range
- Non ideal voltage is not a problem because it's a feedback loop
- Highest price part of the system is getting a 45v output from the wall, could use a spare power supply if we have one
  - $183.34 total with new power supply
  - $39.84 without

$$V_{out} = V_{in} * \left(\frac{R_{control}}{R_{pulldown}} \right)$$



V_in	V_ideal	V_real
0	0	7.406
0.5	2.25	7.406
1	4.5	7.406
1.5	6.75	7.41
2	9	9.004
2.5	11.25	11.254
3	13.5	13.504
3.5	15.75	15.754
4	18	18.004
4.5	20.25	20.254
5	22.5	22.504
5.5	24.75	24.754
6	27	27.004
6.5	29.25	29.254
7	31.5	31.504
7.5	33.75	33.754
8	36	36.004
8.5	38.25	38.254
9	40.5	40.504
9.5	42.75	42.754
10	45	44.221



Item	Price	Amount	Total
LCE80PS42	$71.75	2	$143.50
SOLDERBREAD02	$ 6.22	2	$ 12.44
PA0006-ND	$ 5.66	2	$ 11.32
RSF100JB-73-2K	$ 0.44	2	$ 0.88
ALSR1j-7.0k-ND	$ 3.11	2	$ 6.22
MAX4080FASA+T	$4.49	2	$ 8.98
		Total	$183.34

The Load

From Iurii Storozhenko:

Two types of loads: Electromagnetic particle break and Generator.

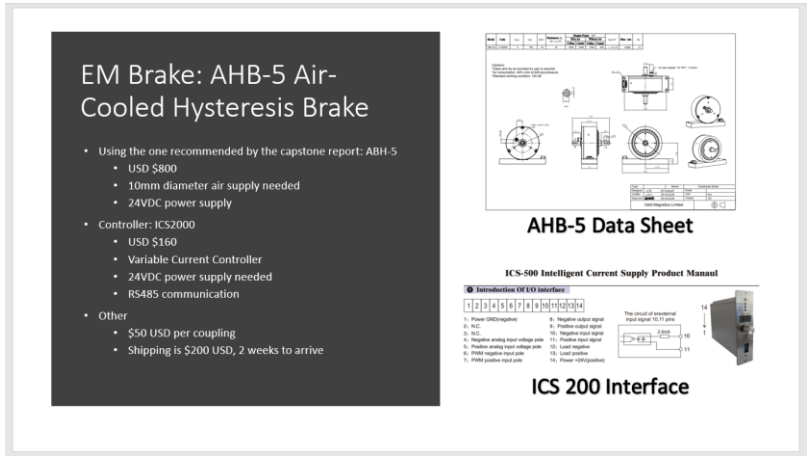
EMP break
- Simplest : Easy to use, and easy to control
- Usually used in test rigs
- Torque can be controlled very accurately
- Ideal for tension control, load simulation, cycling/indexing, and soft starts and stops
- If goal is to use vibration from the drivetrain and not current signals from the generator, this is ideal

Generator
- Main limitation is the control system
- Not sure of range where we can control the load with permanent magnet generator
- Control system of a doubly-fed induction generator is one of the most complicated
- Speed range in a wind turbine in which the generator can be operated is about +-30% of the generator's nominal speed.
- Also need to make the gearbox gear ratio appropriate to the generator

TL;DR: EMP Break is easy to use and is used in a lot of test rigs. Generator is confusing and I don't see any pros to it*

*this is very outside of my area of expertise, so I may be missing the reason we're thinking of a generator at all

Refer back to week 2 slide



Finding A Generator

Generator Specs:

- p = Rated Power in Watts
- z = Generator Efficiency in Percent

Variables:

- T = Torque in (hopefully) Newton Meters
- p’ = Rater Power in Kg-m/s
- y = Shaft rotations per second

Need help finding y, T, and z.

$$T = \frac{p' \frac{Kg\ m}{sec}}{2\pi * y \frac{rotations}{sec}} * z\%$$

$$p' \frac{Kg\ m}{sec} = \frac{T * 2\pi * y \frac{rotations}{sec}}{z\%}$$

p’ in Kg-m/sec → p in Watts

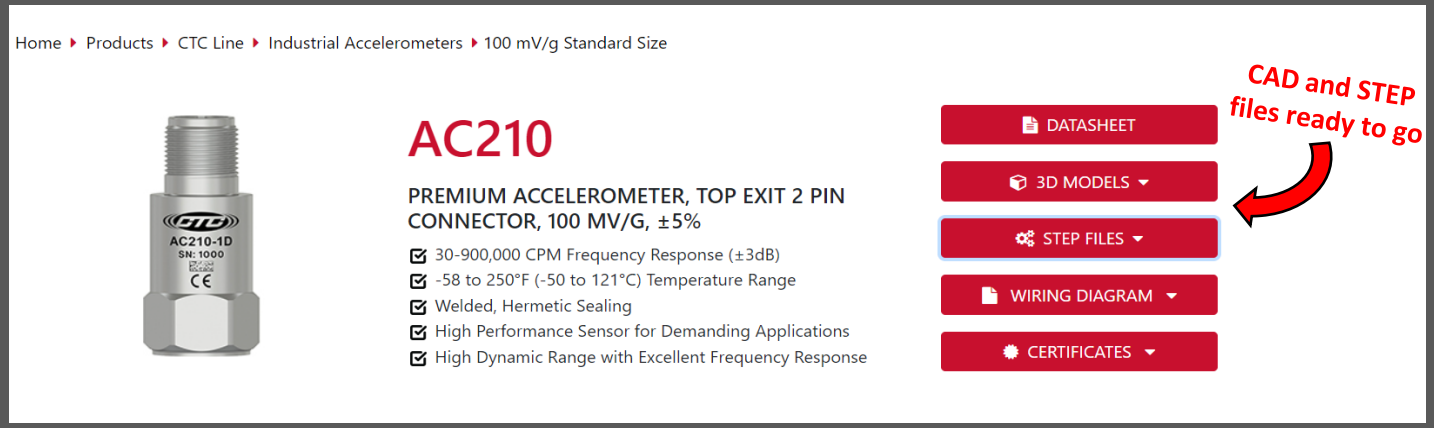
Use power in watts to find generator

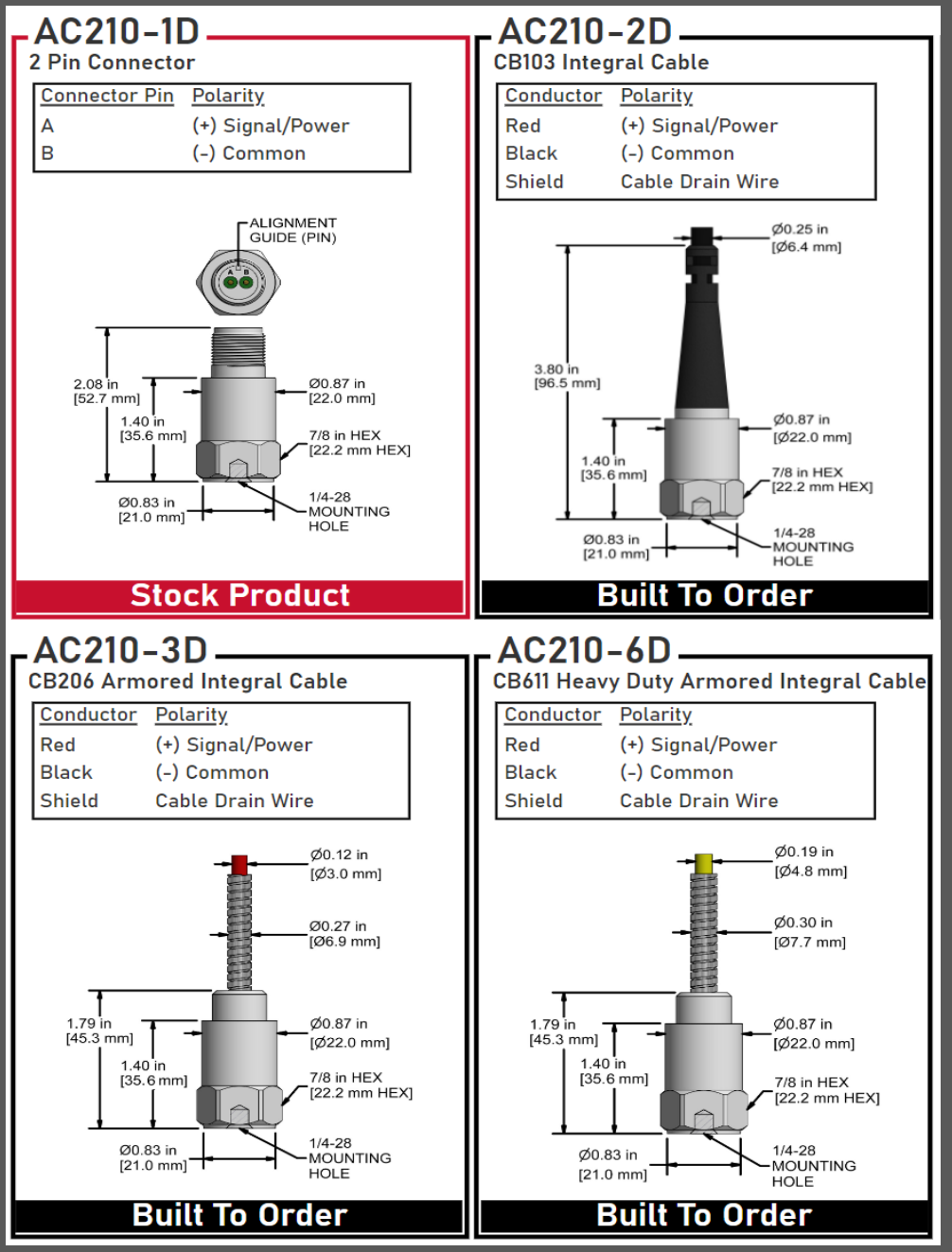
Accelerometer

https://ctconline.com/products/ctc-line/industrial-accelerometers/100-mv-g-standard-size/?prd=AC210

Can choose different cable attachments:

- No cable
- Integral Cable
- Armored Integral Cable
- Heavy Duty Armored Integral Cable

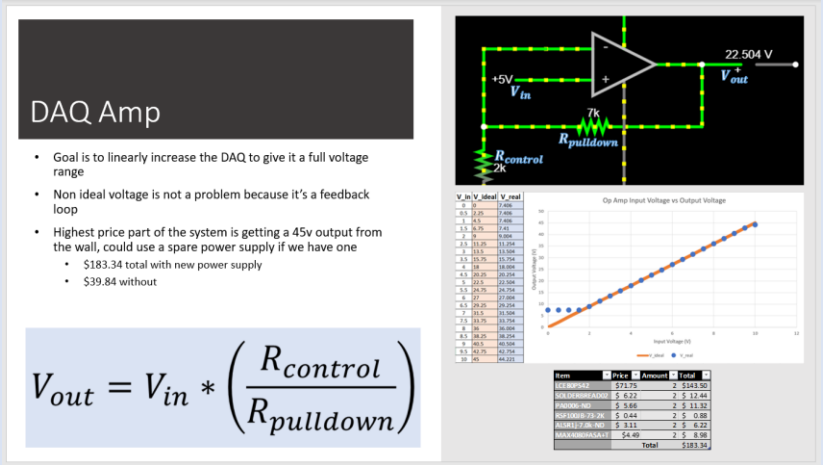




Week 4

Pricing and Lead Time

Category	Item	Column	Cost (USD)	Cost (CAD)	Lead Time
Accelerometer	Accelerometer	AC210-2D	$ 388.37	$ 501.00	5 weeks
Accelerometer	Accelerometer	AC210-2D	$ 388.37	$ 501.00	6 weeks
Accelerometer	Shipping		$ 73.64	$ 95.00	7 weeks
EM Brake	EM Brake	AHB-5	$ 800.00	$ 1,032.00	2 weeks
EM Brake	EM Brake Controller	ICS2000	$ 160.00	$ 206.40	2 weeks
EM Brake	EM Brake Coupling		$ 50.00	$ 64.50	2 weeks
EM Brake	Shipping		$ 200.00	$ 258.00	2 weeks
EM Brake	Air Supply	???	???	???	???
DAQ Amp	Components		$ 142.12	$ 183.34	1 week



Refer back to week 3 slide

Mfr Part #	Quantity Available	Price
AD22035Z ACCELEROMETER 18G ANALOG 8CLCC *Analog Devices Inc.*	100 In Stock	1 : $45.66000 Tube
805-0050 ACCELEROMETER 50G IEPE TO5-3 *TE Connectivity Measurement Specialties*	21 In Stock	1 : $198.67000 Bulk
805M1-0020 ACCELEROMETER 20G ANALOG TO5-3 *TE Connectivity Measurement Specialties*	304 In Stock	1 : $198.67000 Bulk
805M1-0020-01 ACCELEROMETER 20G ANALOG TO5-3 *TE Connectivity Measurement Specialties*	51 In Stock	1 : $205.68000 Bulk
805-0050-01 ACCELEROMETER 50G IEPE TO5-3 *TE Connectivity Measurement Specialties*	20 In Stock	1 : $215.65000 Bulk
310A-80 GENERAL INDUSTRIAL VIBRATION SEN *Senther Technology*	49 In Stock	1 : $276.16000 Bulk

Not needed dependent on experiment run time and applied load; need to know what the actual numbers are

Pricing and Lead Time

Category	Item	Column	Cost (USD)	Cost (CAD)	Lead Time
Accelerometer	Accelerometer	AC210-2D	$ 388.37	$ 501.00	5 weeks
Accelerometer	Accelerometer	AC210-2D	$ 388.37	$ 501.00	6 weeks
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EM Brake	EM Brake Coupling		$ 50.00	$ 64.50	2 weeks
EM Brake	Shipping		$ 200.00	$ 258.00	2 weeks
EM Brake	Air Supply	???	???	???	???
DAQ Amp	Components		$ 142.12	$ 183.34	1 week

Mfr Part #	Quantity Available	Price
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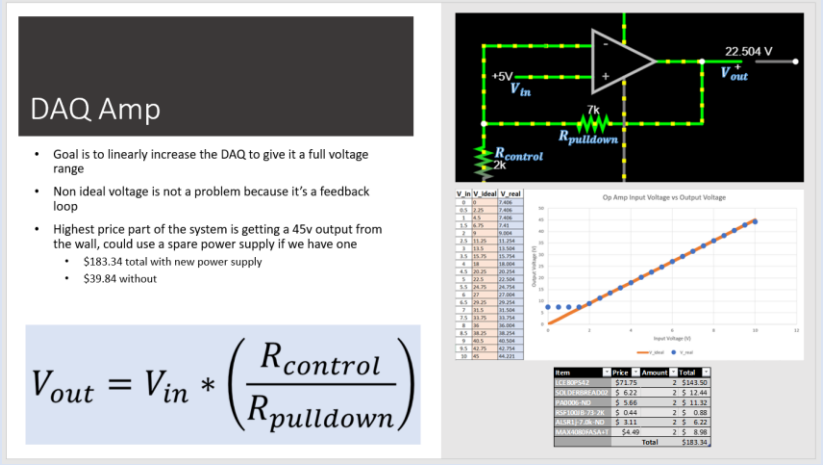
310A-80 GENERAL INDUSTRIAL VIBRATION SEN *Senther Technology*	49 In Stock	1 : $276.16000 Bulk



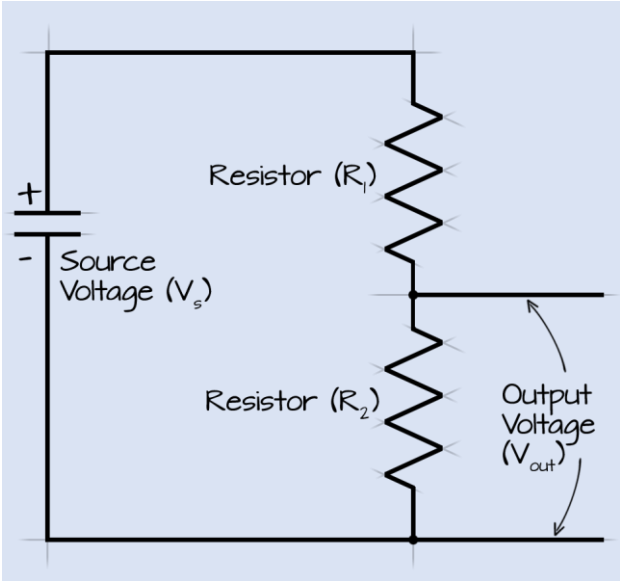
Refer back to week 3 slide

Not needed dependent on experiment run time and applied load; need to know what the actual numbers are

Week 5

Voltage Divider

- Goal is to make the 42V line power the 24V items without needing another power supply
- Accomplished with a simple voltage divider
- Want to make it low power (low amperage)



$$V_{out} = V_s\left(\frac{R_2}{R_1 + R_2}\right) \rightarrow R_1 = \frac{V_s * R_2}{V_{out}} - R_2$$

Rearrange voltage divider equation

$$R_1 = \frac{V_s * R_2}{V_{out}} - R_2 = \frac{42\ V\ * 10{,}000\ \Omega}{24\ V} - 10{,}000\ \Omega = 7{,}500\ \Omega$$

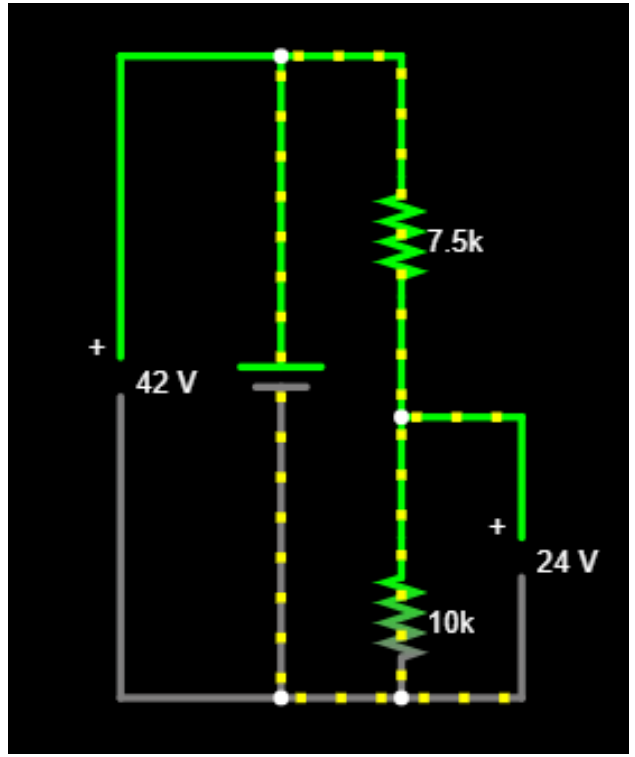
Calculate the Two Resistors Needed

$$i = \frac{V}{R} = \frac{42\ V}{7{,}500\ \Omega + 10{,}000\ \Omega} = 0.0024\ A$$

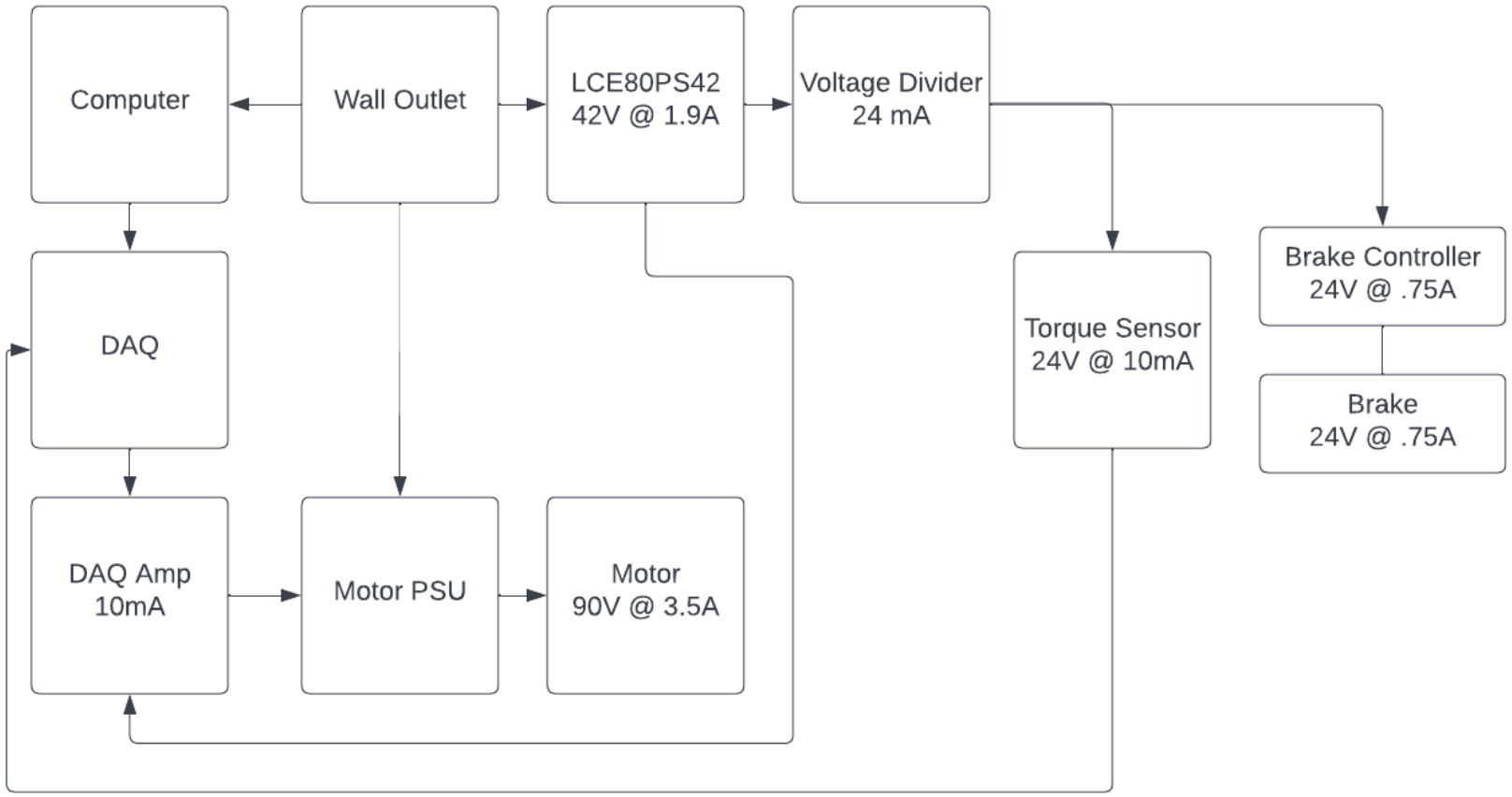
Amperage Used By Resistors

$$P = V * i = 42\ V\ * 0.0024\ A = 0.1\ W$$

Power Used By Resistors



Full Circuit



Notes:

- All wiring will be done on a protoboard
- Accelerometers will be on a separate circuit (with a separate DAQ) due to restrictions of myDAQ
- Should see no issues going forward

Air Brake Consumption

Air Consumption $= 425\frac{L}{min}$ @ $620\ kpa = 112.3\frac{gal}{min}$ @ $90\ psi$

Assuming pipe is laminar, can use the Poiseuille Equation to calculate the flow rate:

$$Q = \frac{\pi D^4 \Delta P}{128 \mu \Delta x}, Q' = Q * c, \therefore Q' = \frac{\pi D^4 \Delta P}{128 \mu \Delta x} * c$$

Known Variables:

$\Delta P = pressure = 90\ psi = 620{,}528.4\ Pa$

$\mu = viscosity = 18.6\ \mu Pa * s = 0.0000186\ Pa * s$

$c = Conversion\ Rate = 15.8503\frac{gal/min}{l/s}$

Assumed Variables

$D = Pipe\ Diameter = 0.004\ m$

Unknown Variables

$\Delta x = Pipe\ Length = m$

$Q = Flow\ Rate = \frac{l}{s}$

$Q' = Flow\ Rate = \frac{gal}{min}$

$$Q' = \frac{\pi D^4 \Delta P}{128 \mu \Delta x} * c = \frac{\pi (0.004\ m)^4 * 620528.4\ Pa}{128 * (0.0000186\ Pa * s) * \Delta x} * 15.8503\frac{gal/min}{l/s}$$

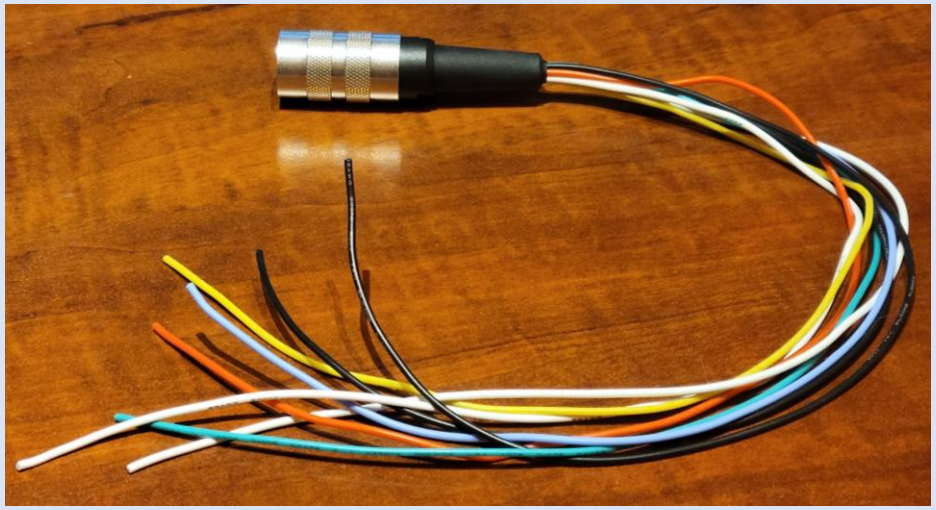
$$\Delta x = \frac{\pi D^4 \Delta P}{128 \mu Q'} * c = \frac{\pi (0.004\ m)^4 * 620528.4\ Pa}{128 * (0.0000186\ Pa * s) * 112.3\frac{gal}{min}} * 15.8503\frac{gal/min}{l/s}$$

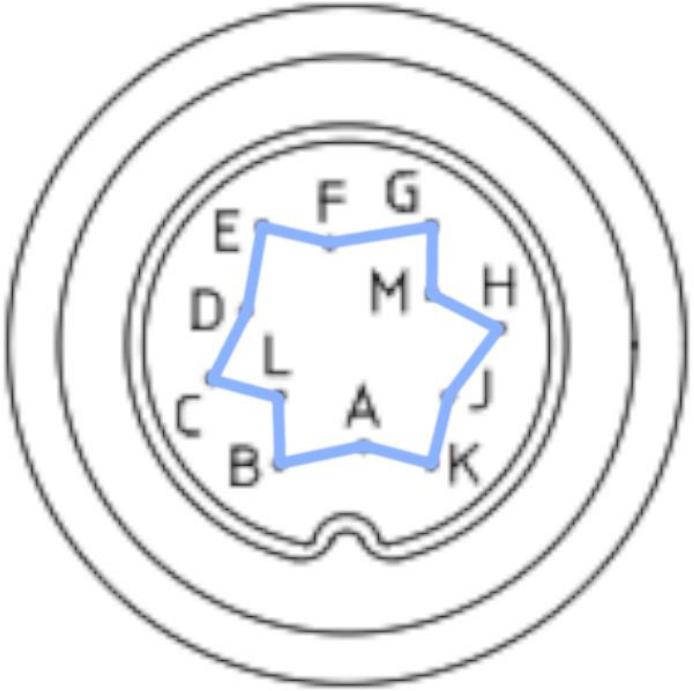
$\Delta x = 0.03\ m$

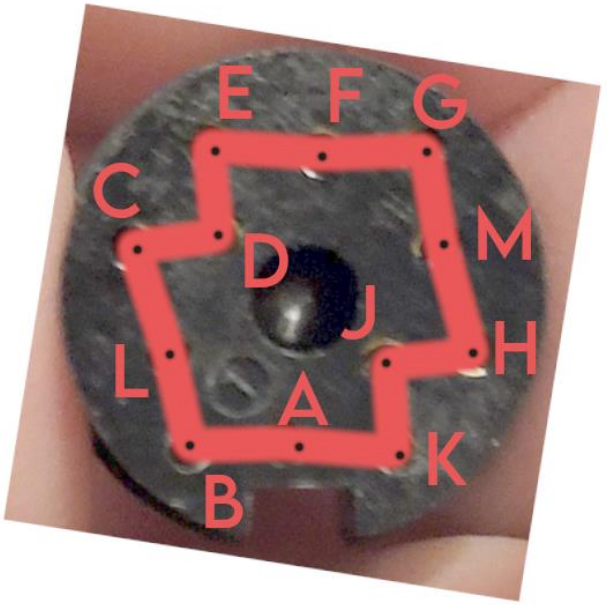
Week 6

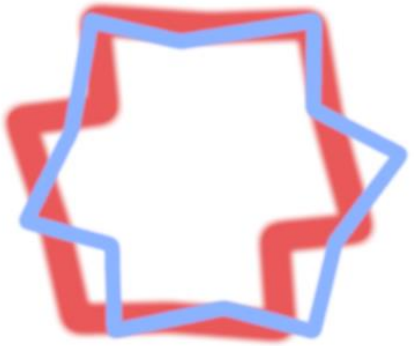
Cable Building

- I don’t know who made the diagram, but it’s not accurate
- Gave me a headache for a few minutes trying to figure it out
- Soldering was a pain

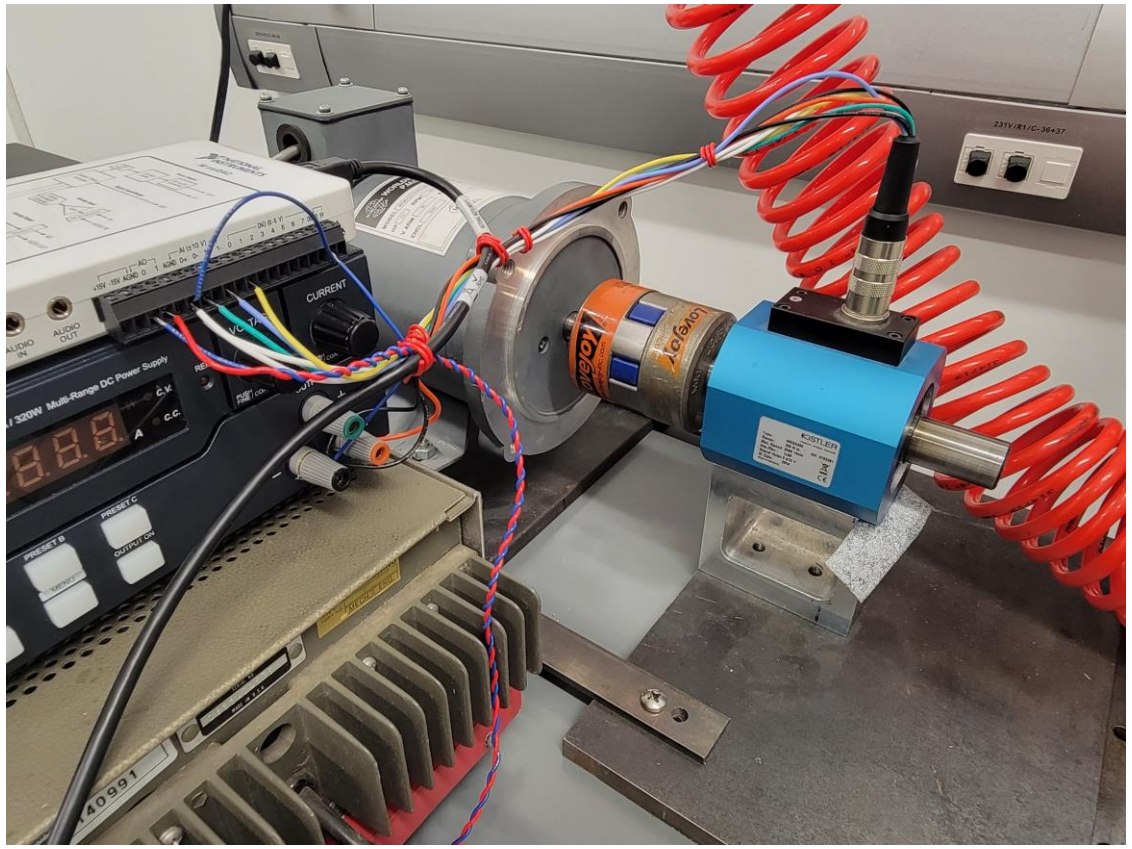


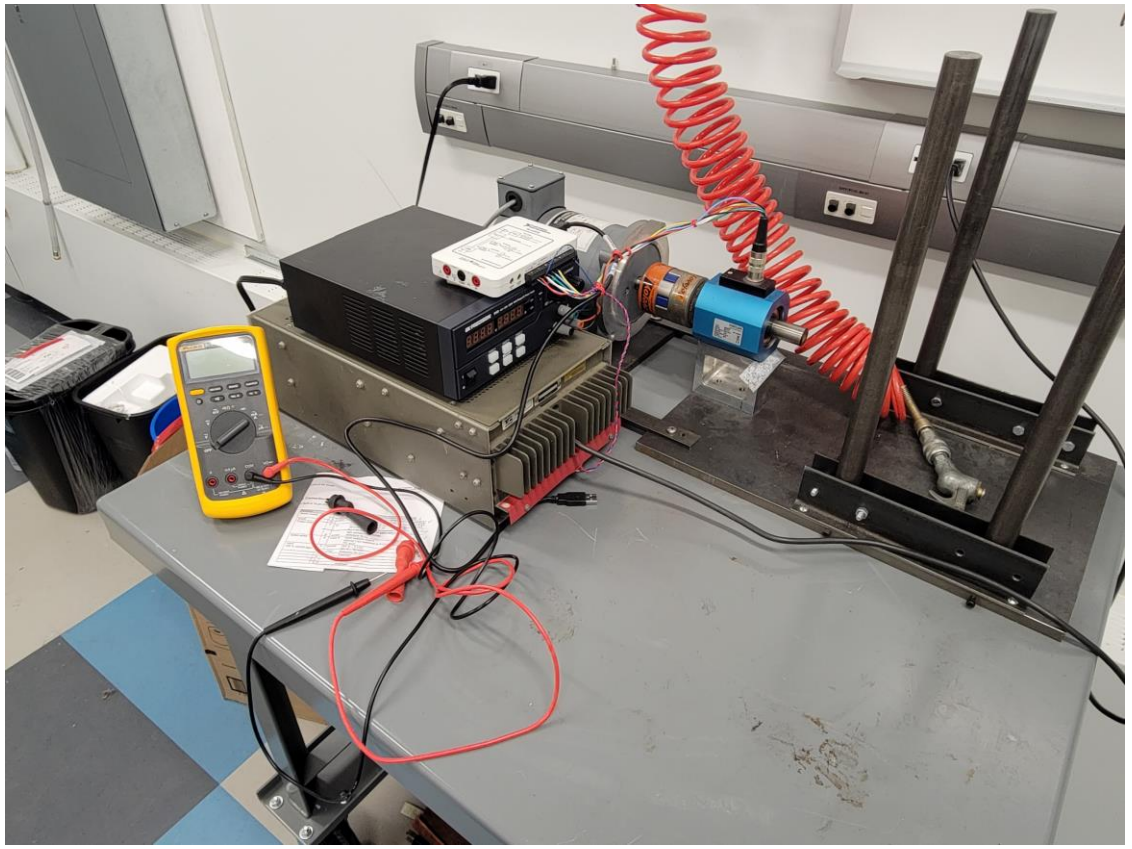






Wiring


CURRENT
AUDIO IN
AUDIO OUT
Multi-Range DC Power Supply
PRESET B
PRESET C
KISTLER



Air Supply

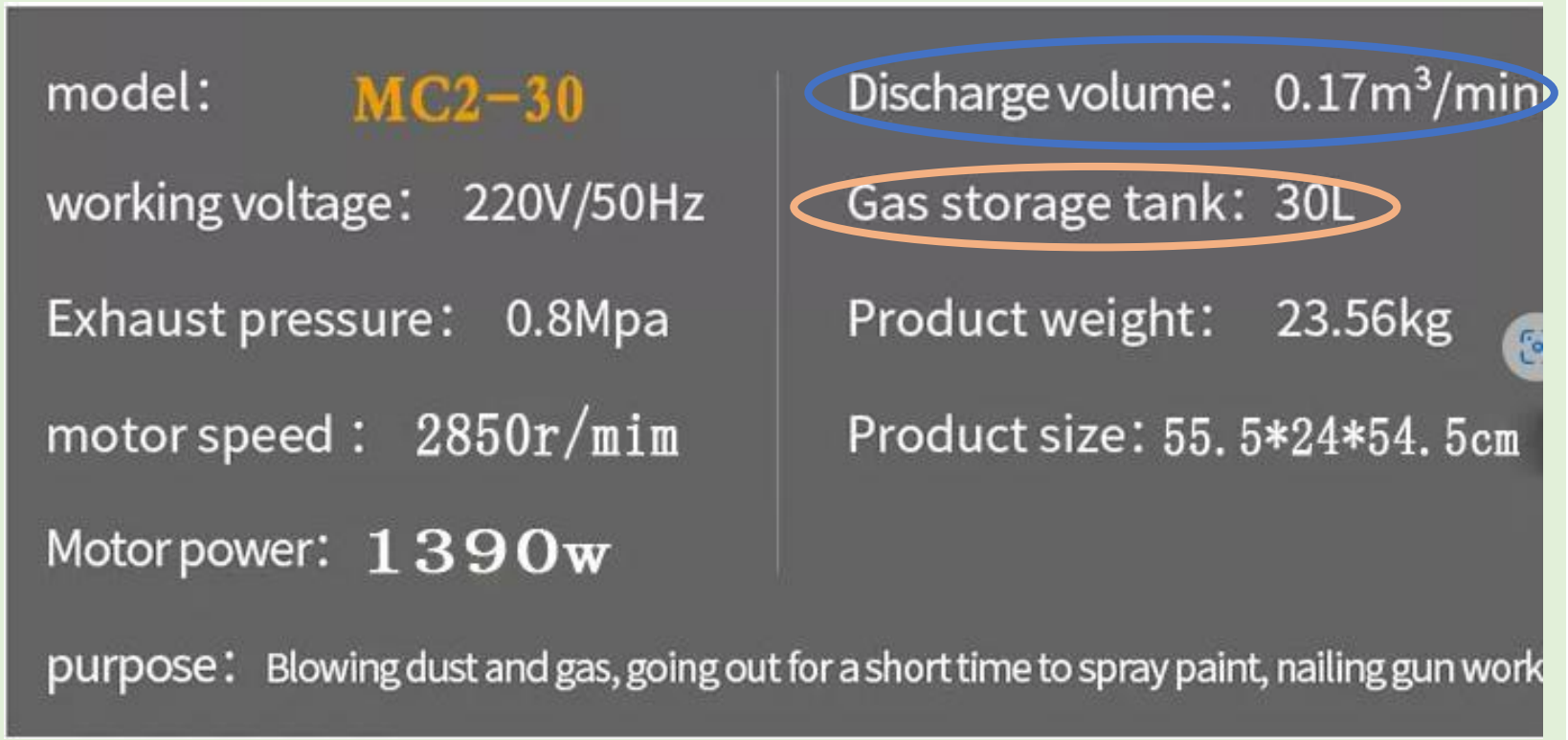
What air brake manufacturer said:

- Air Consumption is "$112.3 \frac{gal}{min}$ @ 90 psi"
- "May use it without the compressed air supply under 1000W for 5 mins or 200W continuously"

The air supply recommended is no where near this

Idea: Use building air supply at 90psi and monitor temperature on set up

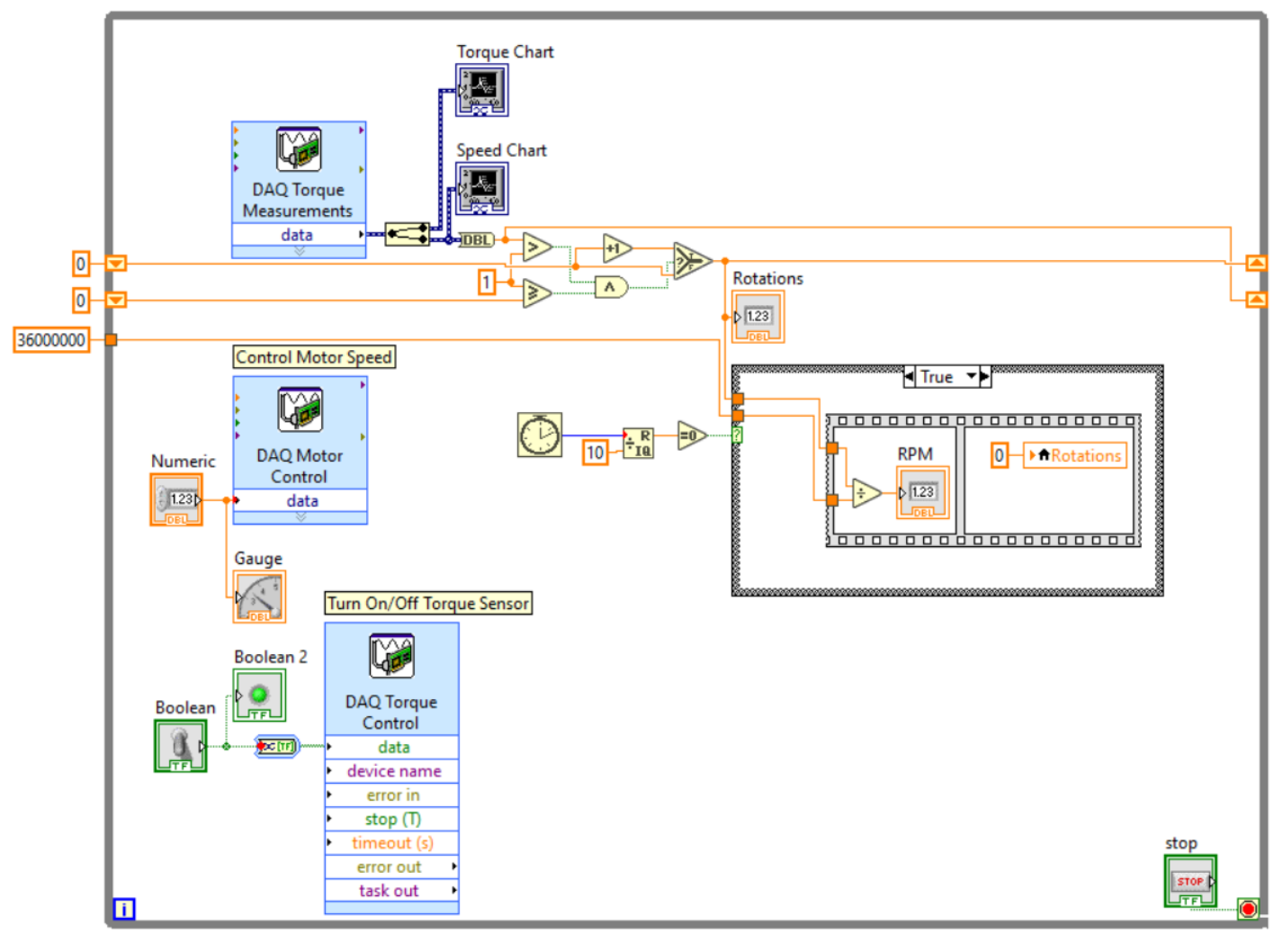
Problem: No idea how long we want to run this, and I'm also having trouble with the math due to my lack of mechanical / chemical background



Flow Rate: $0.17 \frac{m^3}{min} = 0.748 \frac{gal}{min} \neq 112.3 \frac{gal}{min}$

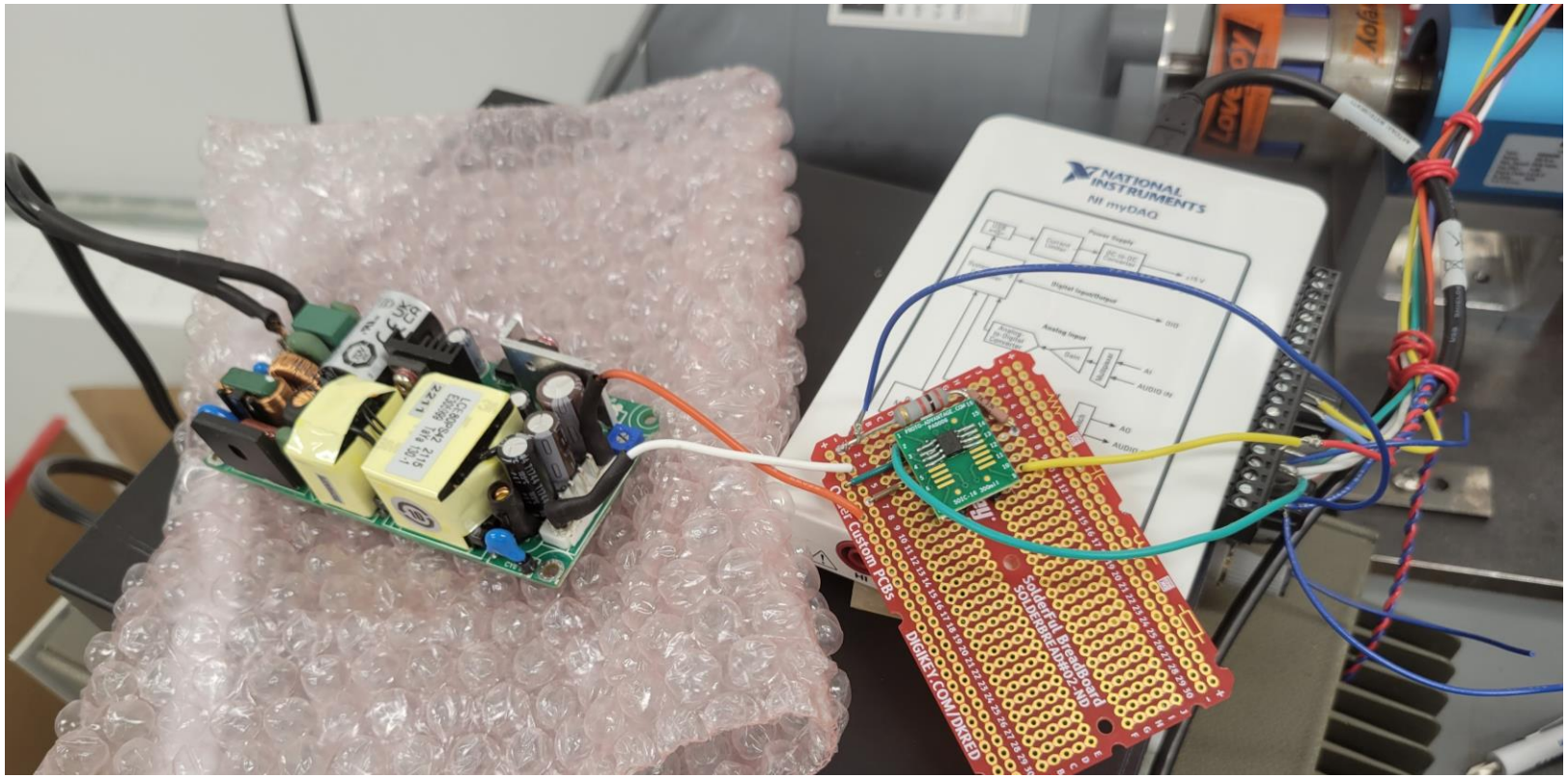
How long it can be used: $0.03\ m^3 * \frac{1\ min}{0.17\ m^3} = 0.17\ min = 11.6 sec$

Week 7



Draft One of the Software is Done

Draft One of The Electrical Is Done



- Theory behind it works
- Need to order a different OpAmp
- Need to clean up and make safer
- THE MOTOR ACTUALLY GOES

Powering The Brake

Voltage Divider

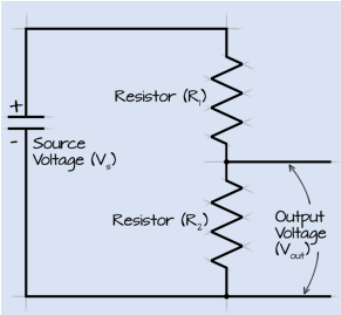
- Goal is to make the 42V line power the 24V items without needing another power supply
- Accomplished with a simple voltage divider
- Want to make it low power (low amperage)

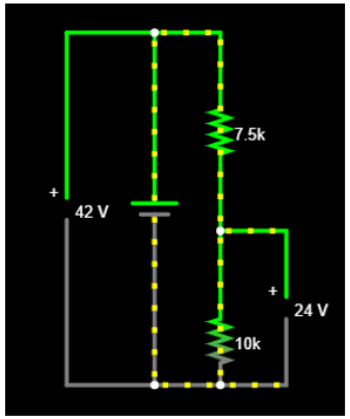
$$V_{out} = V_s\left(\frac{R_2}{R_1 + R_2}\right) \rightarrow R_1 = \frac{V_s * R_2}{V_{out}} - R_2$$ Rearrange voltage divider equation

$$R_1 = \frac{V_s * R_2}{V_{out}} - R_2 = \frac{42\ V\ * 10{,}000\ \Omega}{24\ V} - 10{,}000\ \Omega = 7{,}500\ \Omega$$ Calculate the Two Resistors Needed

$$i = \frac{V}{R} = \frac{42\ V}{7{,}500\ \Omega + 10{,}000\ \Omega} = 0.0024\ A$$ Amperage Used By Resistors

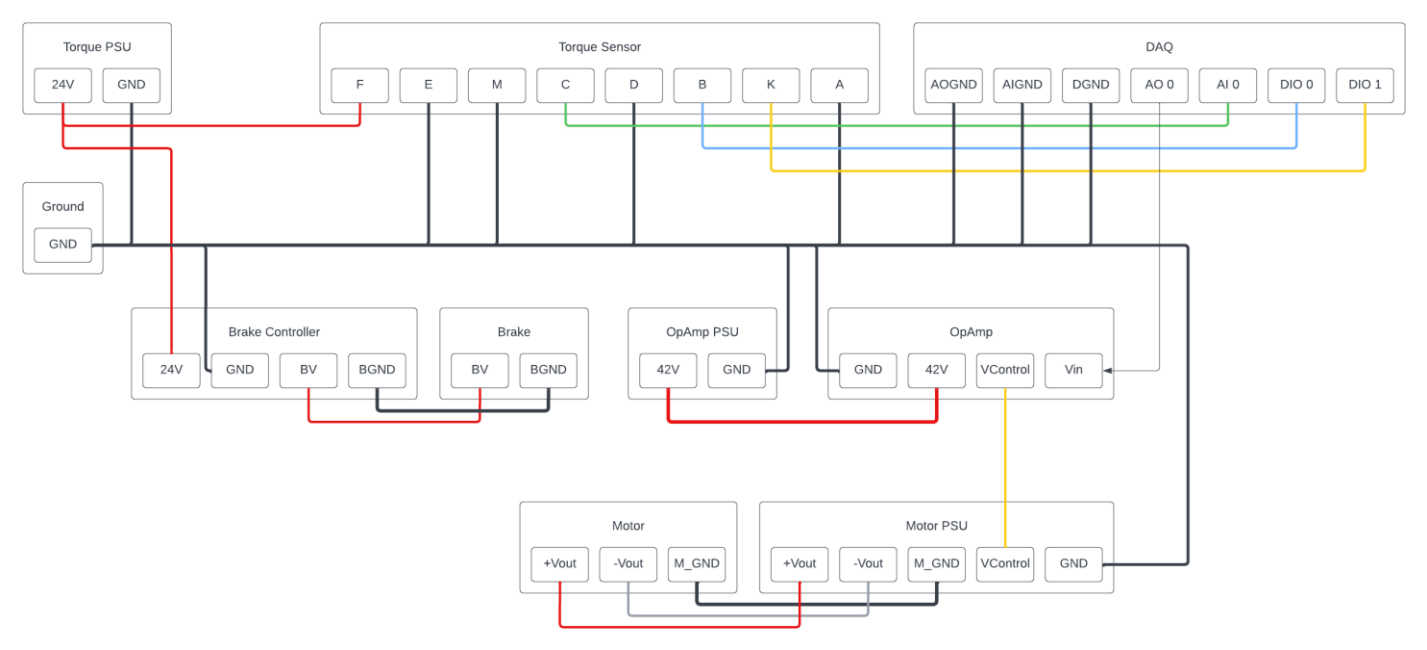
$$P = V * i = 42\ V\ * 0.0024\ A = 0.1\ W$$ Power Used By Resistors





- Update on Brake Voltage Divider: Can't actually just use voltage divider,
- Need to use actual voltage regulator for 24v stuff; don't need to get right now because we have a spare PSU

Electrical Wiring Box

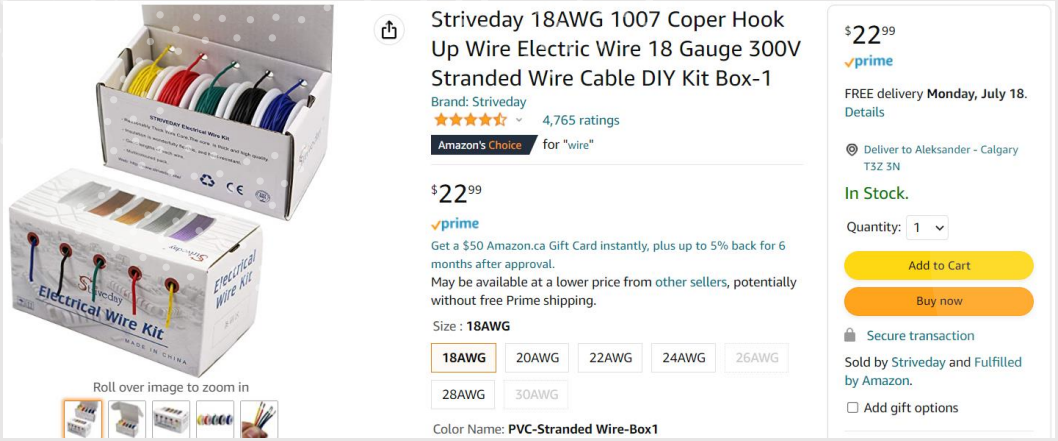


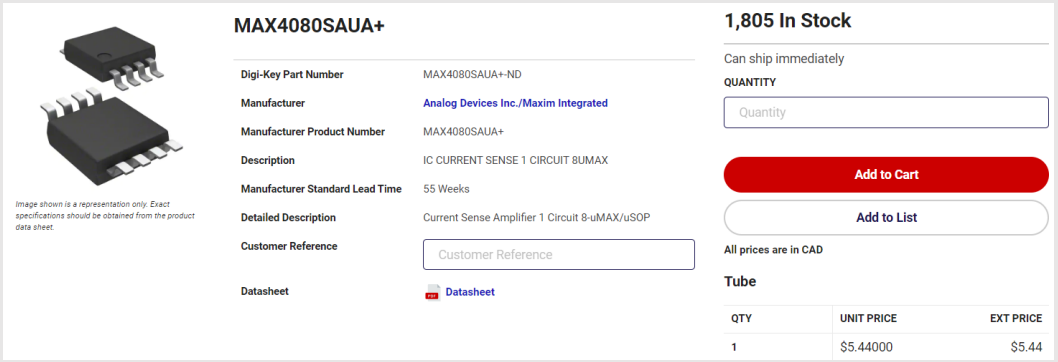
- Going to make a single box that everything connects into
- For cleanliness and safety
- Using BNC connectors when possible
- **D-plug or serial cable - Unsure what type of connector to use when more than 2 wires (such as between Torque Sensor and DAQ)**

What I Need Ordered

- Striveday 18AWG 1007 Coper Hook Up Wire Electric Wire 18 Gauge 300V Stranded Wire Cable DIY Kit Box-1, Electrical Wire - Amazon Canada

- MAX4080SAUA+ Analog Devices Inc./Maxim Integrated | Integrated Circuits (ICs) | DigiKey





Item	Cost/Unit	Quantity	Cost
MAX4080SAUA+	$ 5.49	2	$ 10.98
Wire 18 Gauge	$ 22.99	1	$ 22.99
		TOTAL	$ 33.97

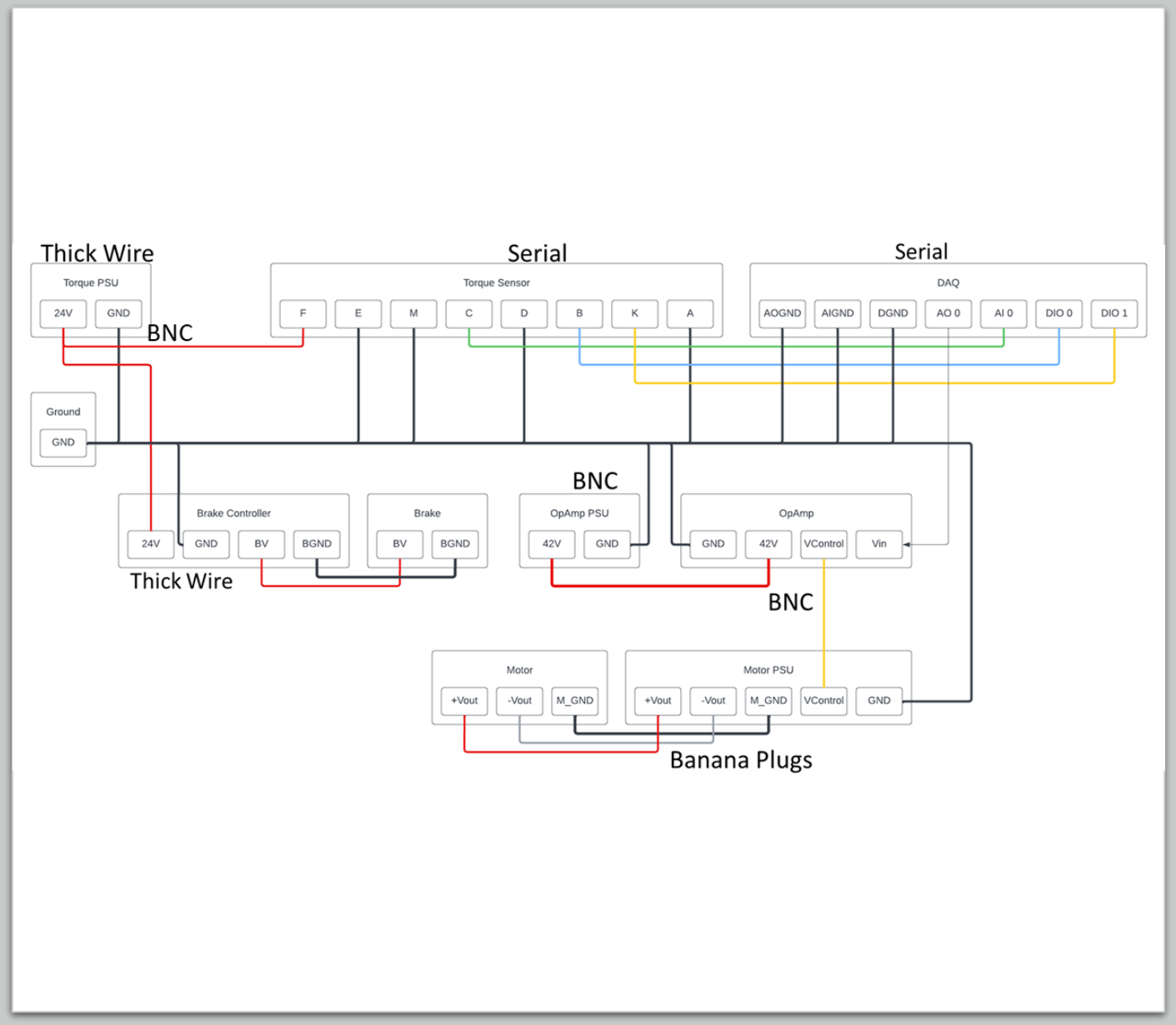
What's Next

- Order parts
- Figure out connections needed for a wire box
- Order all parts for wire box
- Make wire box
- 3D Print Casing for converter, solder board, and wire box
- Resolder torque sensor wire and opamp boards to be nicer
- Assemble
- More software things

Week 8

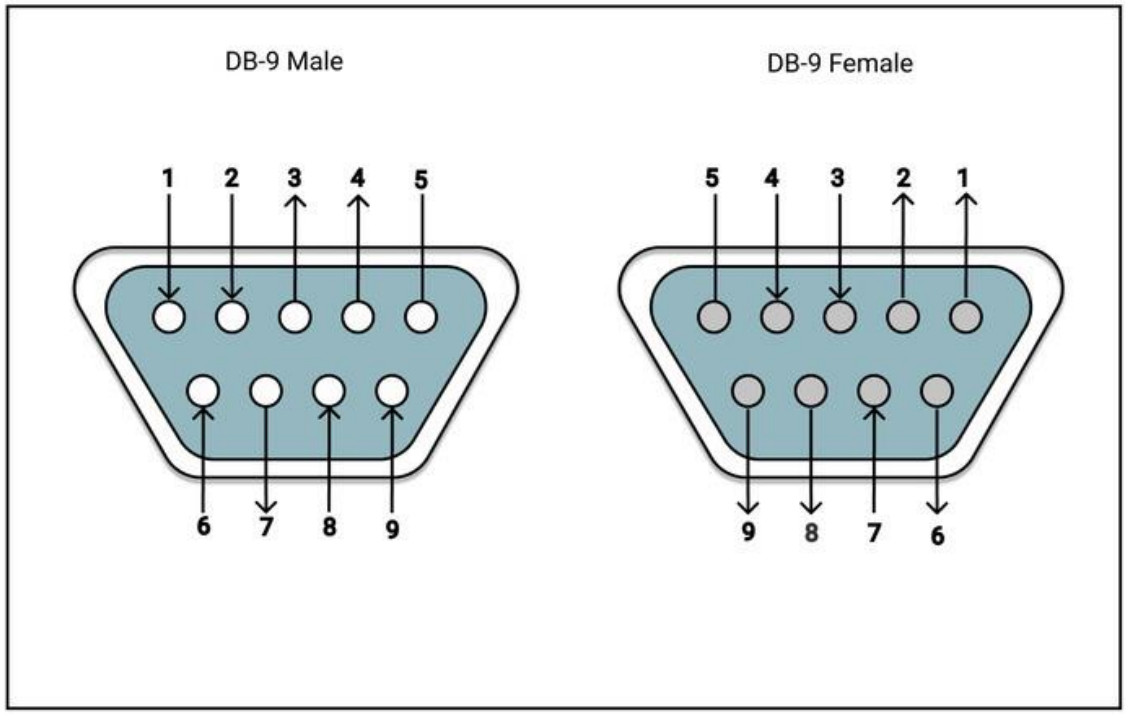
Plug Layout

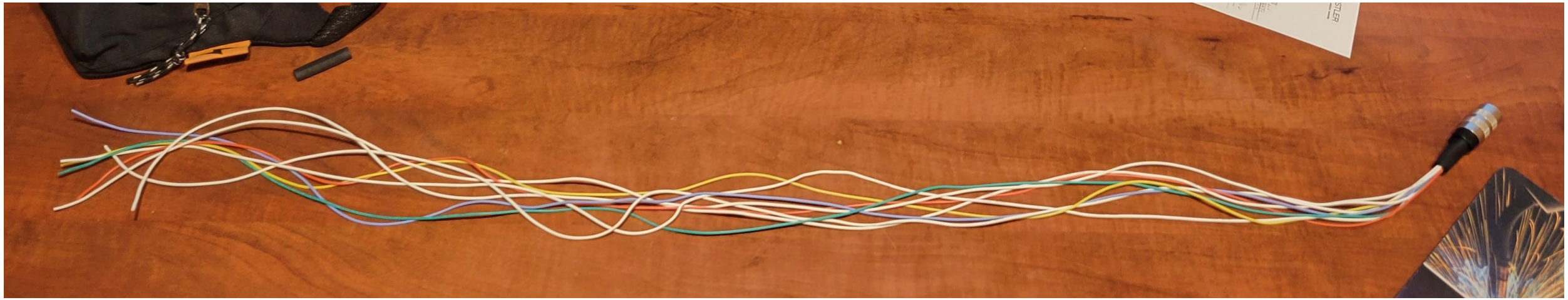
- 2x Serial
  - 2x Cable to Female
  - 2x Male to Breakout
- 3x BNC
  - 3x Female BNC to Wire
  - 3x Male BNC to Wire
- 1x Banana
  - Already have them



Resoldering Cable To Be Longer And Serial

Function	Pin	Description	Net	Color	DB-9 Pin
Power Supply	F	+U_B, 18…26 VDC	None	Red	6
	E	Reference for U_B	GND	White	1
Shield	M	Connected to case	GND	White	2
Torque output	C	U_A, +/- 10VDC	None	Yellow	7
	D	Reference for U_A	GND	White	3
Speed Sensor	B	Track A	None	Blue	8
Input	K	Control, 0…2 VDC OFF or 5…30 ON	None	Green	9
	A	Reference for Control	GND	White	4





DAQ Is Also Going To Be Serial

DAQ Pin	DB-9 Pin
AOGND	1
AIGND	3
DGND	5
AO 0	6
AI 0	7
DIO 0	8
DIO 1	9