CWC-scale Generators

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NAU NORTHERN ARIZONA UNIVERSITY

Project Description

- Collegiate Wind Competition: Teams compete to make small scale wind turbine
- Wind energy is an important and growing field
  - Wind Energy in US[1]: 2023 - 10% VS 2014 - 4%
- The CWC fosters innovation in the wind energy industry
- Previous generators used were modified drone motors (performed poorly)
- Goal: Create a generator to be modified by CWC Team
- Sponsored by Professor David Willy, +20 years in industry
- Solves multiple problems
  - Design around commercially available vs custom parts
  - Availability and lead times of commercial products
  - Modularity to match aerodynamic requirements

New Client Requirements

- New electrical box
- Arduino
- Shifted schedule
  - No concept generation until week 15
  - Ansys simulations are now week 9

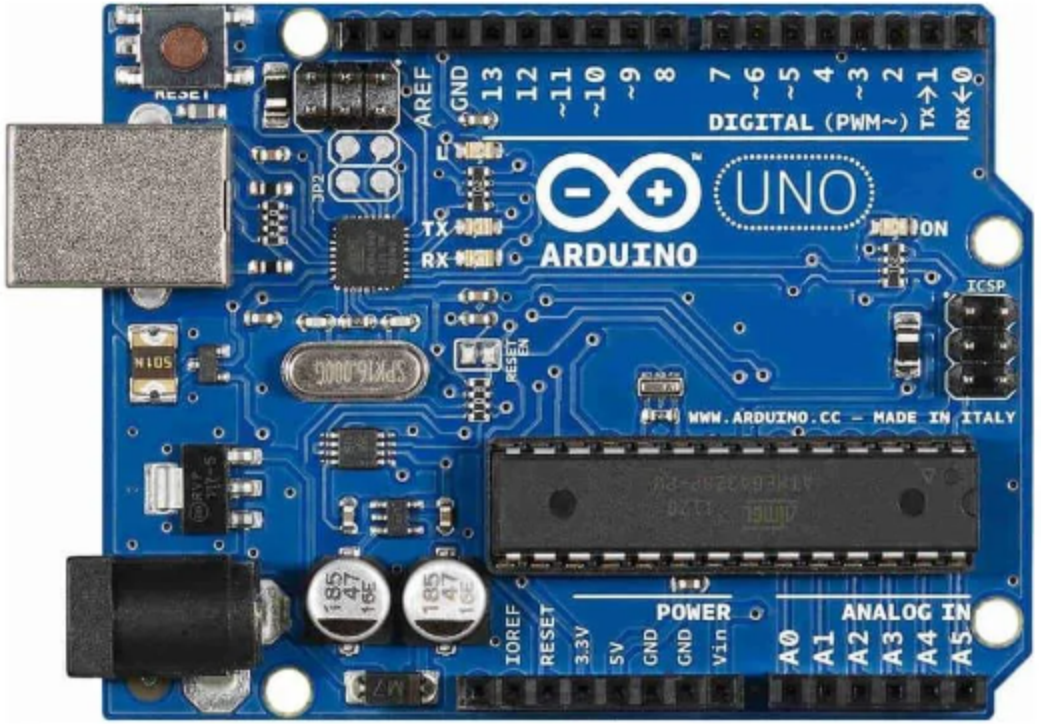


Figure 1: Arduino Uno

Dynamometer

- Electric motor driven
- Power supply
- Programable Load
- Electrical box
  - RPM
  - Torque
  - Current
  - Voltage

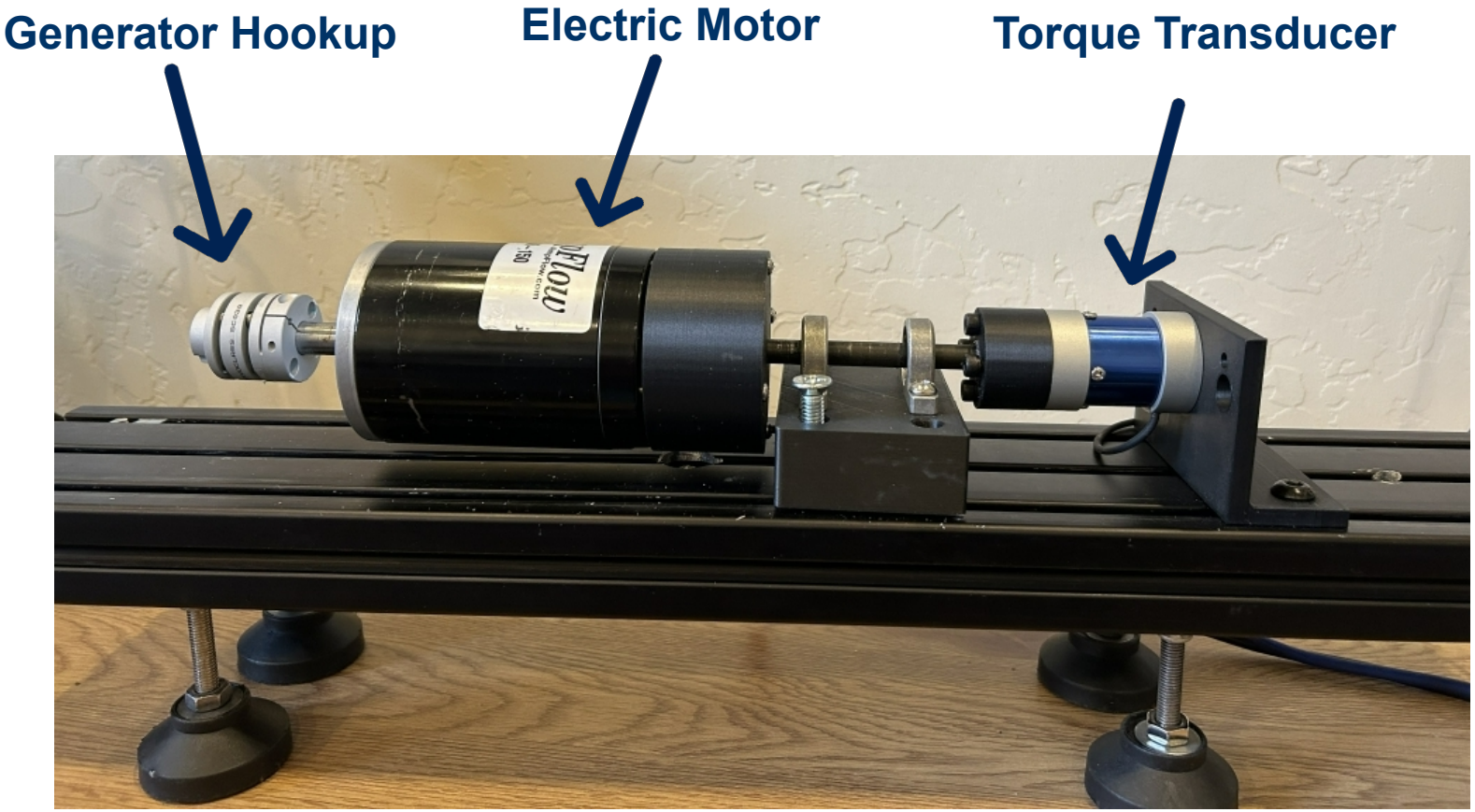
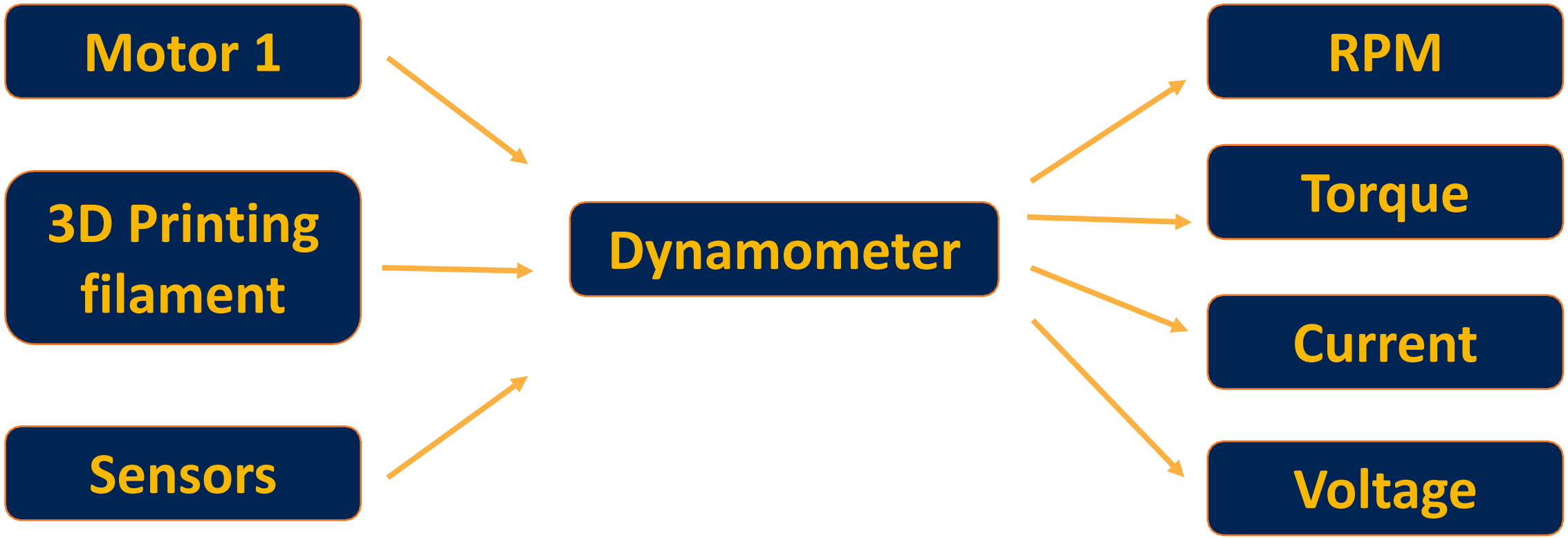


Figure 2: Dynamometer

Blackbox Diagram



QFD

Minimize or Maximize												
House Of Quality			Technical Specifications (How)							Competitive Assessment		
			Dimensions of the electrical box	Current sensor with low error margin	Display screen size	high-presision Torque sensor	Voltage sensor with low error margin	Operating Temperature	Load capacity			
	Customer Requirements (What)	Importance	1	2	3	4	5	6	7	1	2	3
1	Torque measurement	21	3	1	1	9	1	3	3	9	9	9
2	Voltage measurement	21	3	1	1	1	9	3	3	9	9	9
3	Safe	31	9	1	1	1	1	9	9	3	3	3
4	RPM measurement	13	3	1	1	1	1	3	3	9	3	3
5	Current measurement	21	3	9	1	1	1	3	3	9	9	9
6	Transportability	17	9	1	3	1	1	1	1	9	9	9
7	User friendly	29	9	3	9	3	3	1	1	1	1	1
	Target		11 in^3	0.50%	4x20	0.50%	0.50%	-10 - 50 C	0-48V			
	Importance		39	17	17	17	17	23	23			

Obtaining Data for Arduino

- Sending data is not just plug and play
- Most data is sent by voltage (ADC)
  - MUST be less than 5 V
- Needs programming
- Assume Arduino is perfect (5 V)

$$count = \frac{V_{in}}{V_{ref}} * (count_{max}), where\ count_{max} = 1024$$

$$V_{in} = count * \frac{V_{ref}}{count_{max}}\ [V]$$

$count = 893, Digital\ "Voltage"$

$V_{in}, Input\ Voltage\ [V]$

$V_{ref} = 5\ V, Reference\ Voltage\ [V]$

$$\boxed{V_{in} = 4.36\ V}$$

Voltage Divider Method

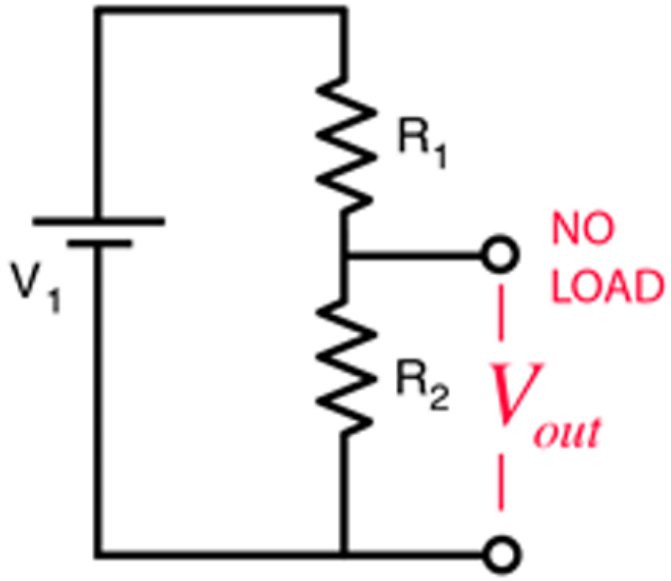
$$V_{out} = V_1 \frac{R_2}{R_1 + R_2} \; [V]$$

$V_{out}, Output\ voltage\ [V]$

$V_1 = 48\ V, Input\ Voltage\ [V]$

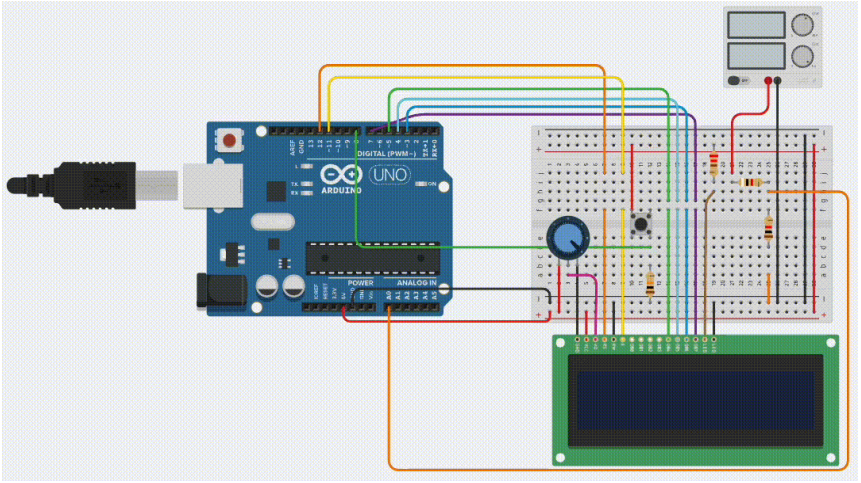
$R = 10\ k\Omega\ \&\ 1k\Omega, Resistance\ [\Omega]$

$$\boxed{V_{out} = 4.36\ V}$$



Obtaining Voltage for Arduino

- Dyno output -> Voltage divider
  - Input MUST be less than 5 V
- Requires count
- Multiplier -> Total voltage



$$M = \frac{R1 + R2}{R2}$$

$$V_{total} = V_{in} * M\ [V]$$

$M, Mulitplier$

$R = 10\ \ k\Omega\ \&\ 1k\Omega, Resistance\ [\Omega]$

$V_{total}, Total\ Voltage\ [V]$

$V_{in} = 4.36\ V, Input\ Voltage\ [V]$

$$M = 11$$

$$V_{total} = 48\ V$$

Infrared (IR) Tachometer

- Inferred light to read the reflective marker
  - Electromagnetic radiation[2]
- Calculates how many times the reflective marker goes by per minute[1]
- Attached to the dynamometer using a 3D printed part to adhere to safety requires

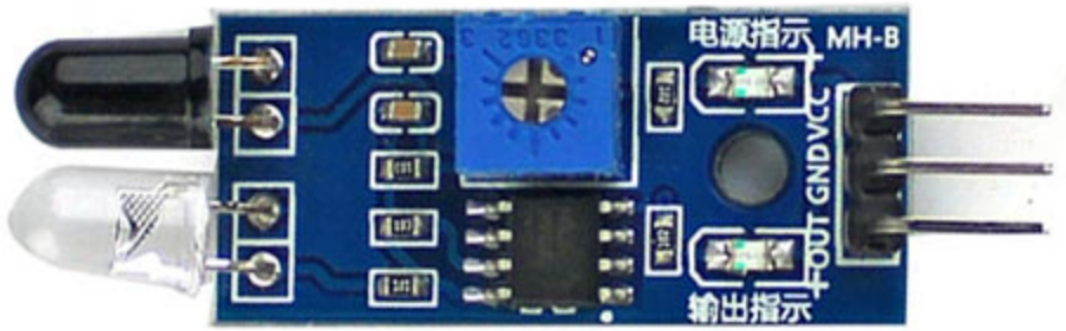


Figure 3: IR Tachometer

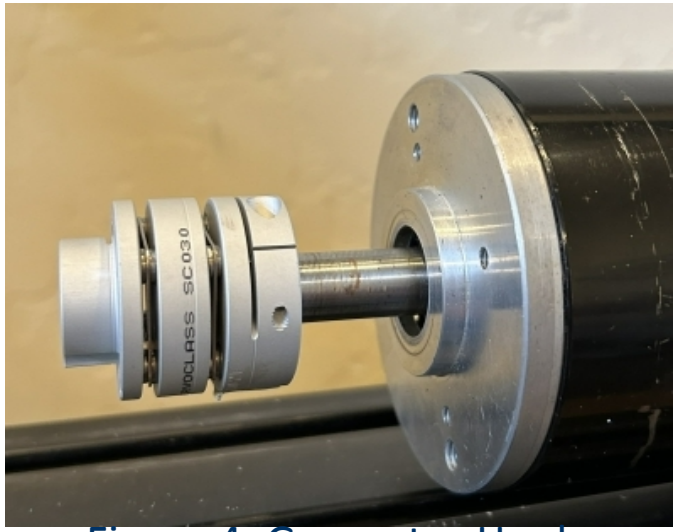


Figure 4: Generator Hookup

IR Tachometer Applied in Arduino

- Ground
  - GND pin
- Power
  - 5 Volt pin
- Signal Output
  - Digital pin

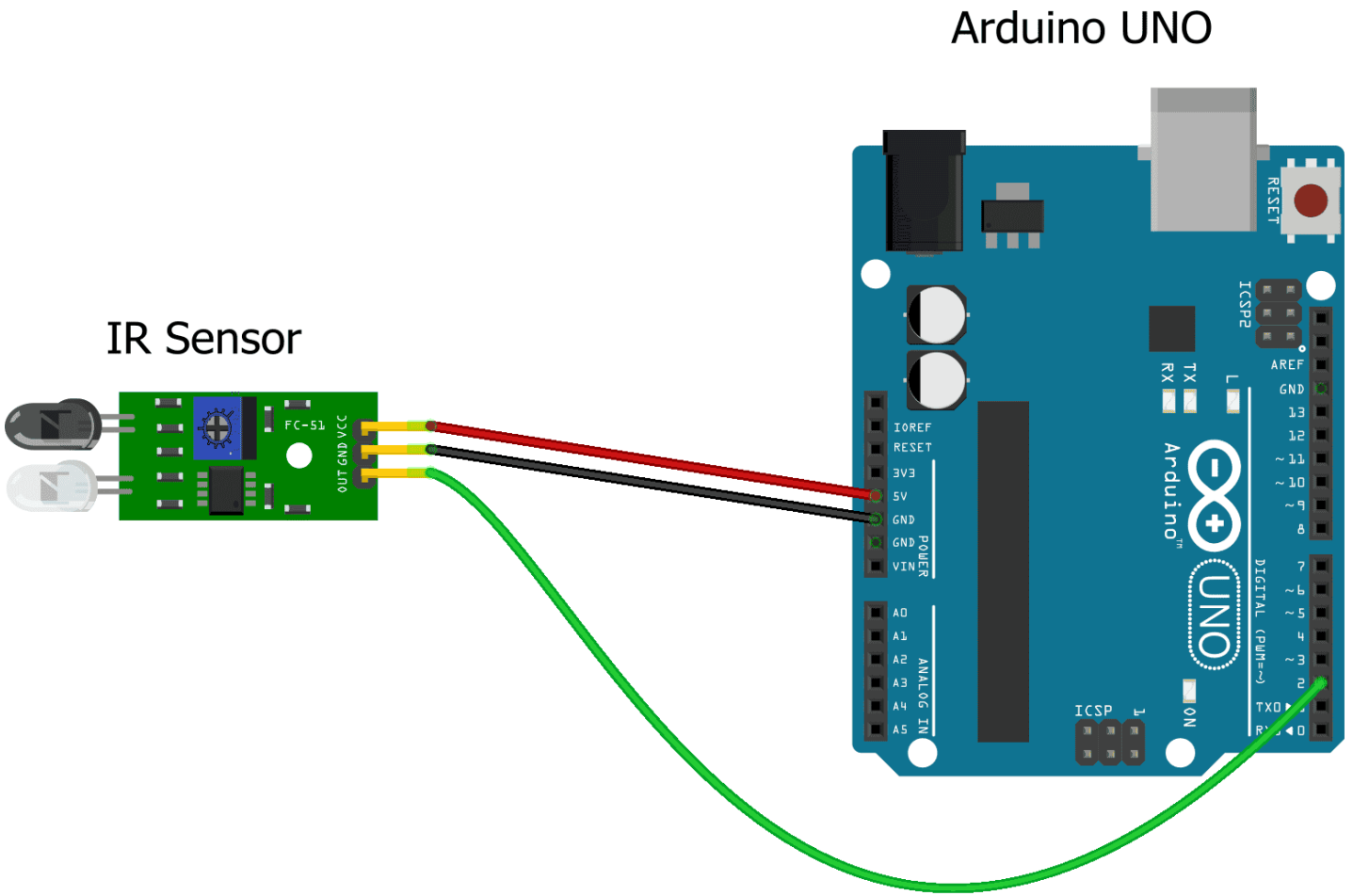


Figure 5: Arduino Diagram of the IR Tachometer

Obtaining RPM for Arduino

- IR sensor
- Counts how many times it "saw" an infrared light
- Timing while using interrupts
  - Interrupts main code to do something else
- Pulses
  - If 3 blade fan, PPR = 3
  - Etc.

$$RPM = \frac{F}{PPR} * (60\ \frac{sec}{min})\ [\frac{rot}{min}]$$

$$RPM, Rotations\ Per\ Minute\ [\frac{rot}{min}]$$

$$F = 30\ Hz, Frequency\ [Hz]$$

$$PPR = 1, Pulse\ Per\ Rotation$$

$$RPM = 1800\ \frac{rot}{min}$$

ACS712 30A Range Current Sensor

- Provides accurate solutions for ac or dc sensing
- Can modify specifications according to needs
- 4.5V-5.5V DC Supply Voltage
- 30A Measured Current Rage
- ~0.66V/A Sensor Sensitivity

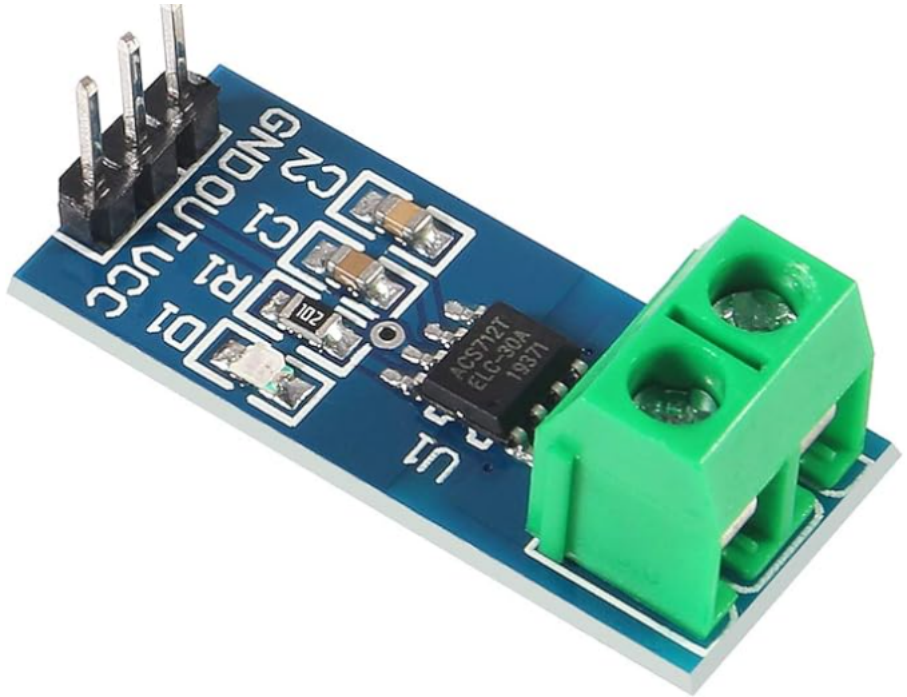


Figure 6: Current Sensor

Current Sensor Applied to Arduino

- Simulation did not have exact current sensor
- Can still be applied in a similar way
- Used LCD 1602 to display reading

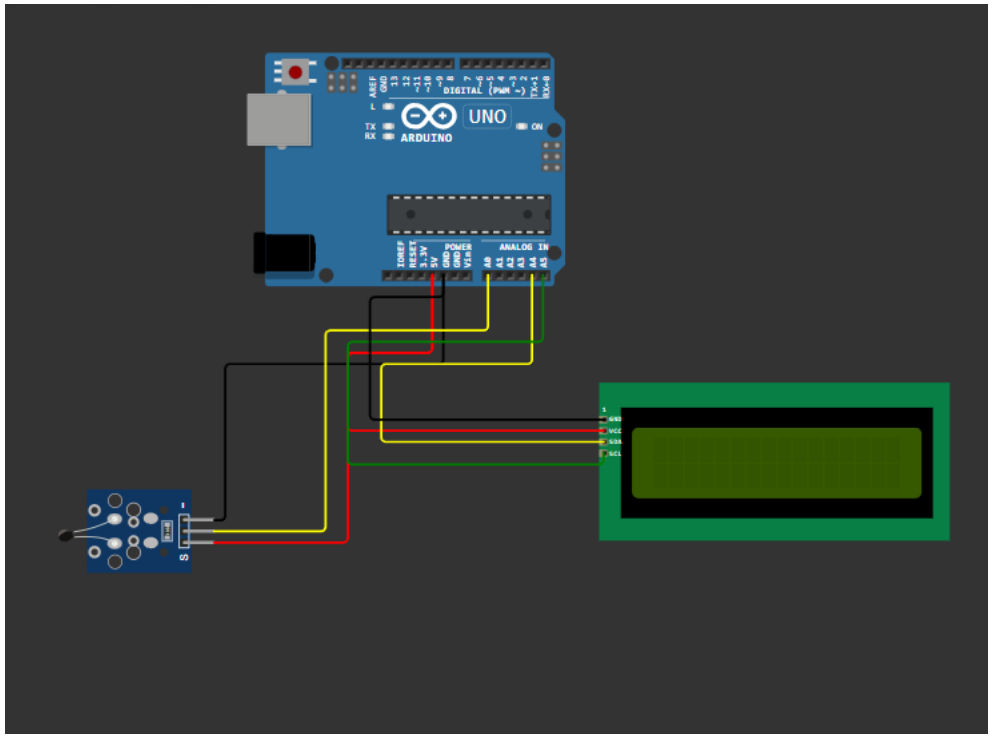


Figure 7: Arduino Diagram of Current Sensor

Obtaining Current for Arduino

- Current sensor
- Requires count
- Dependent on type of current sensor and supply voltage
  - ACS712 **30 A** Range Current Sensor Sensitivities
    - 5 A -> S = 0.185 V/A
    - 20 A -> S = 0.1 V/A
    - **30 A -> S = 0.066 V/A**

$$I = \frac{V_{out} - \frac{V_{cc}}{2}}{S} \; [A]$$

$I, Current \; [A]$

$V_{out} = 3 \; V, Ouput \; Voltage \; from \; Sensor \; [V]$

$V_{cc} = 5 \; V, Supply \; Voltage \; to \; Sensor \; [V]$

$S = 0.066 \frac{V}{A}, Sensitivity \; [\frac{V}{A}]$

$I = 7.57 \; A$

$$\boxed{I = 7.57 \; A}$$

Torque Transducer

- Mechanical input of torque to electrical output, reactionary to motor
  - Strain -> Resistance -> Voltage
- Voltage proportional to strain
- Wheatstone Bridge Circuit

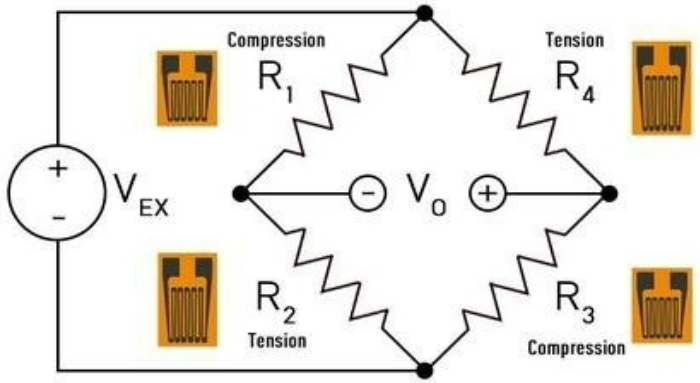


Figure 8: Wheatstone Bridge to measure deformation

Calculations example: $\delta R_1 = +40\,\Omega \quad \delta R_2 = -40\,\Omega \quad \delta R_3 = +40\,\Omega \quad \delta R_4 = -40\,\Omega$

$$E_o = E_i\left(\frac{R_1}{R_1 + R_2} - \frac{R_3}{R_3 + R_4}\right)$$

$$= 50\text{ V}\left(\frac{5040\,\Omega}{5040\,\Omega + 4960\,\Omega} - \frac{8040\,\Omega}{8040\,\Omega + 7960\,\Omega}\right) = +0.0750\text{ V}$$

24 Bit Load Cell Amp

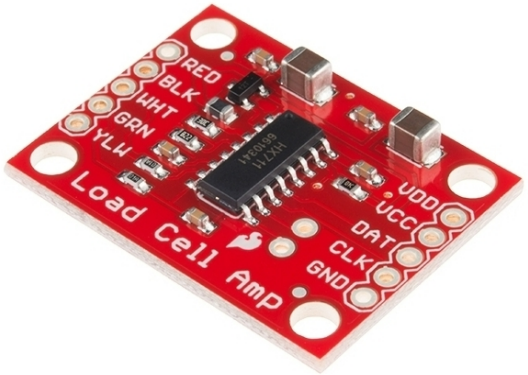


Figure 9: SparkFun Load Cell Amplifier - HX711

- Reads small changes in voltage (millivolts)
- Amplifies with chosen gain (32, 64, 128)
- Converts to digital (24 bit)
  - High resolution so error is insignificant compared to volts converted

FEATURES

- Two selectable differential input channels
- On-chip active low noise PGA with selectable gain of 32, 64 and 128
- On-chip power-on-reset
- Simple digital control and serial interface: pin-driven controls, no programming needed
- Operation supply voltage range: 2.6 ~ 5.5V

Transducer to Arduino

- Arduino reads changes in voltage from Load Cell Amp
- GND – GND; VCC – 5V
- DT (data) and SCK (clock) are data outputs from amp put into Arduino's digital pins
- Arduino can output data via screen or SD card

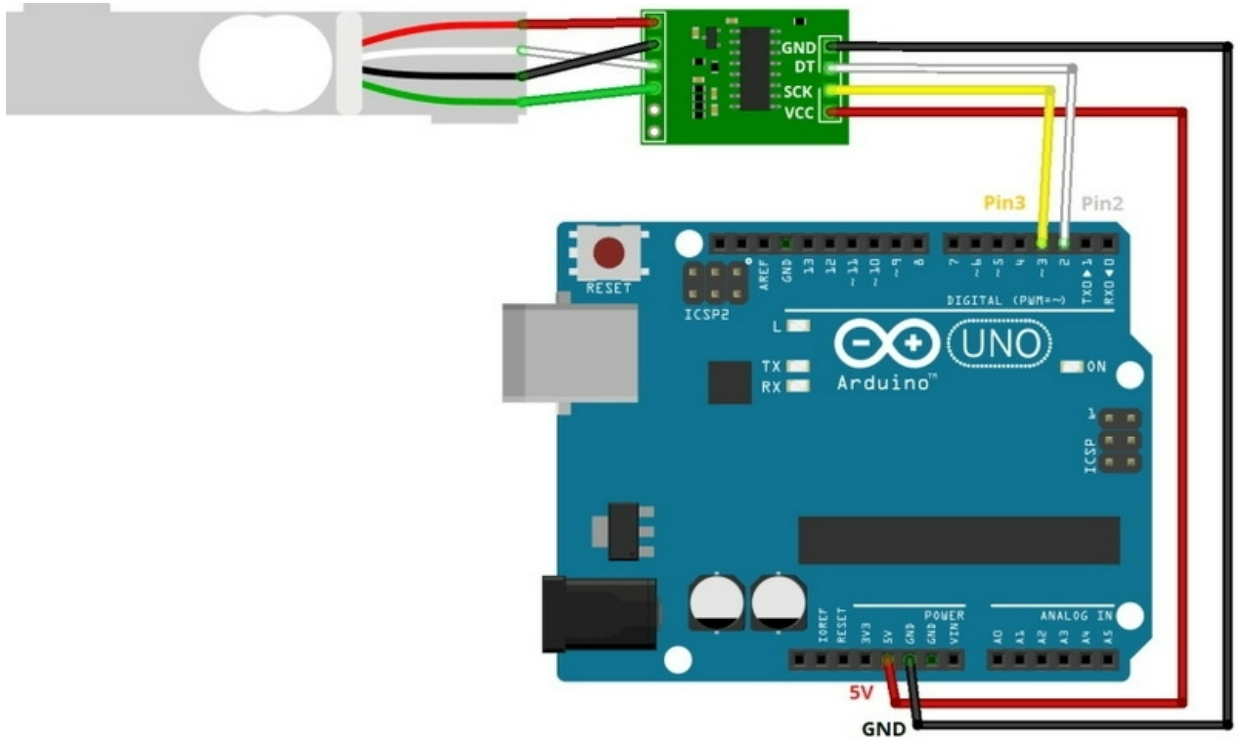


Figure 10: Transducer – Amp – Arduino Connection Diagram

Schematic

- Omitted AC->DC and Dyno connections
- Generator will provide volts between 0 and 48
- Potentiometer for brightness setting on LCD

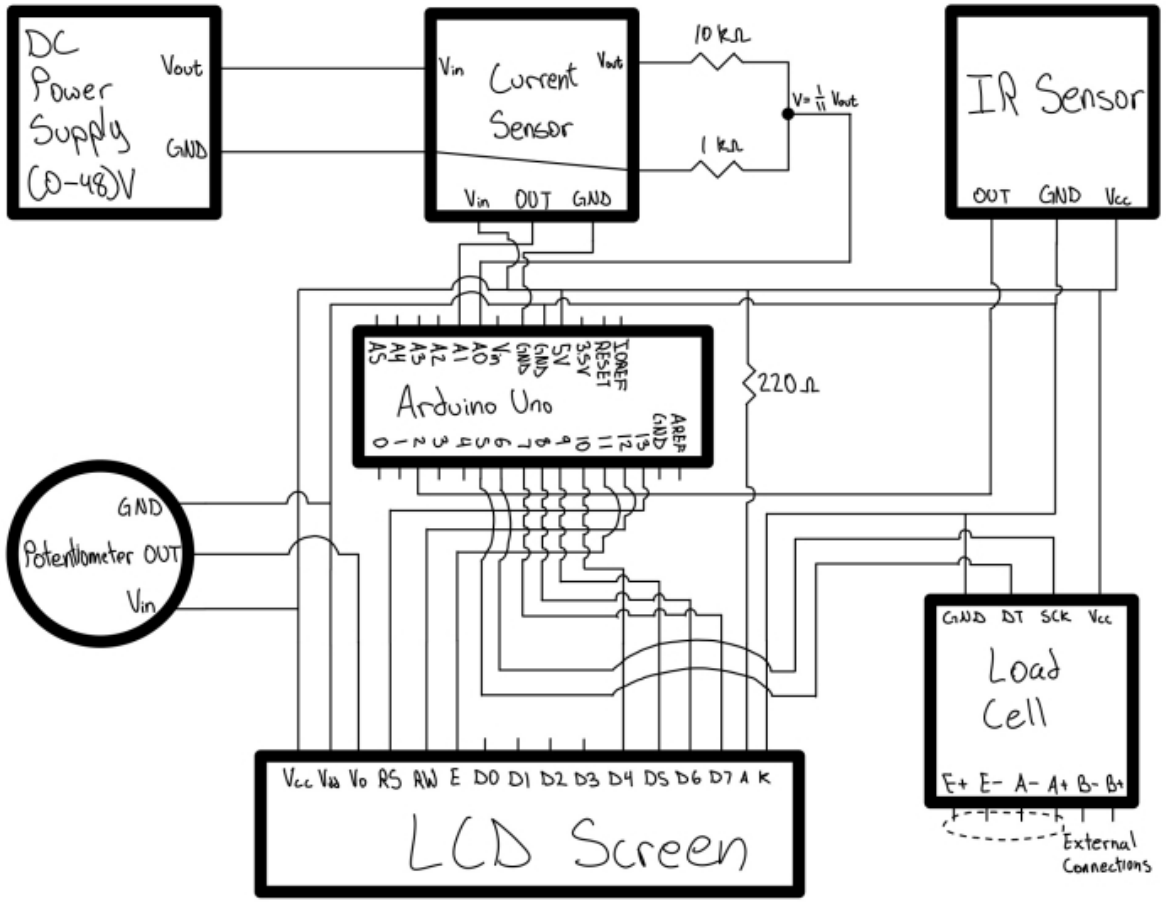


Figure 11: Arduino Schematic

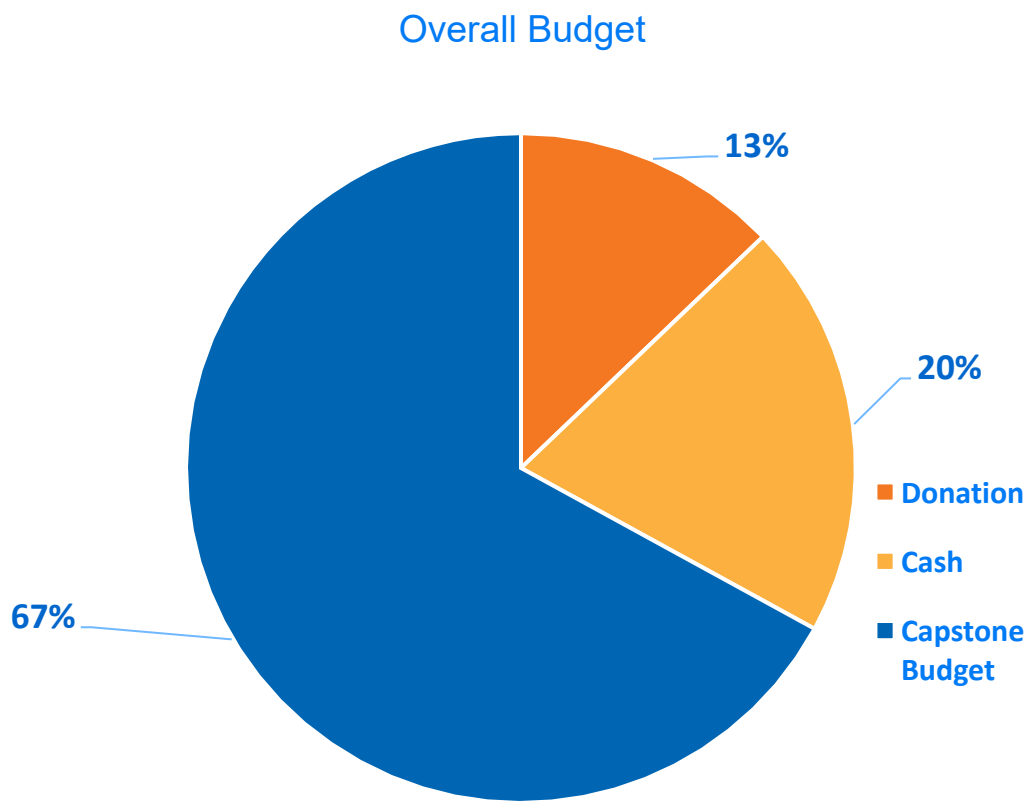
Schedule

- Testing will be pushed back
- Fix Dynamometer
  - Build the Arduino
  - Finish code
- Ansys simulations

Planning and design				
Create schedule	Naomi Echo	100%	2/5/25	2/9/25
Identify deliverables	Naomi Echo	75%	2/7/25	2/12/25
Develop budget	Javan Jake	70%	2/12/25	2/15/25
Finish dyno	Everyone	35%	2/12/25	3/15/25
Solder dyno	Naomi Echo	80%	2/14/25	3/7/25
Replace Dyno Screen	N.E.	100%	2/19/25	2/21/25
Electrical box for dyno	Everyone	0%	2/14/25	3/10/25
4 mm Adaptor to test gen.	Kaitlyn Redman	100%	2/14/25	2/24/25
Tachometer Sensor	Naomi Echo	100%	2/21/25	2/25/25
Voltage Sensor	Javan Jake	100%	2/21/25	2/25/25
Current Sensor	Kaitlyn Redman	100%	2/21/25	2/25/25
Torqe Sensor	Christian Brown	90%	2/21/25	2/25/25
Arduino Code	Alonso Garcia	75%	2/21/25	3/8/25
Make Arduino Schematic	Everyone	100%	2/24/25	3/1/25
Build Ardunio Board	Naomi, Alonso	0%	3/10/25	3/14/25
Ch. 1,6,10	Naomi Echo	100%	2/17/25	3/1/25
Ch. 1,2,7,10	Christian Brown	90%	2/17/25	3/1/25
Ch. 1,8,10	Alonso Garcia	33%	2/17/25	3/1/25
Ch. 1,3,9,10	Javan Jake	75%	2/17/25	3/1/25
Ch. 1,5,10	Kaitlyn Redman	100%	2/17/25	3/1/25
Modify generator	Everyone	0%	3/8/25	3/27/25
Design new generator	Everyone	0%	4/1/25	4/15/25

Budget & Fundraising

Budget & Fundraising			
Find No.	Company:	Description:	Amount:
1	Gofundme	Online donation for capstone team. Can be shared through friends, family, and social media.	$70.00
2	U-Pick-It	2 Alternators Donation	$40.00
3	Chris	Cash Donation	$80.00
4	Amazon	Electric Motor	$9.99
5	Amazon	LCD Screen Display Module Blue Backlight	$19.98
6	Harbor Freight	Chicago Electric 30 Watt Lightweight Soldering Iron	$5.99
7	Harbor Freight	Schneider Sodering Accessory Kit	$19.99
8	Northern Arizona University	Capstone budget	$500.00



Total Cash: $150

Total Donation: $96

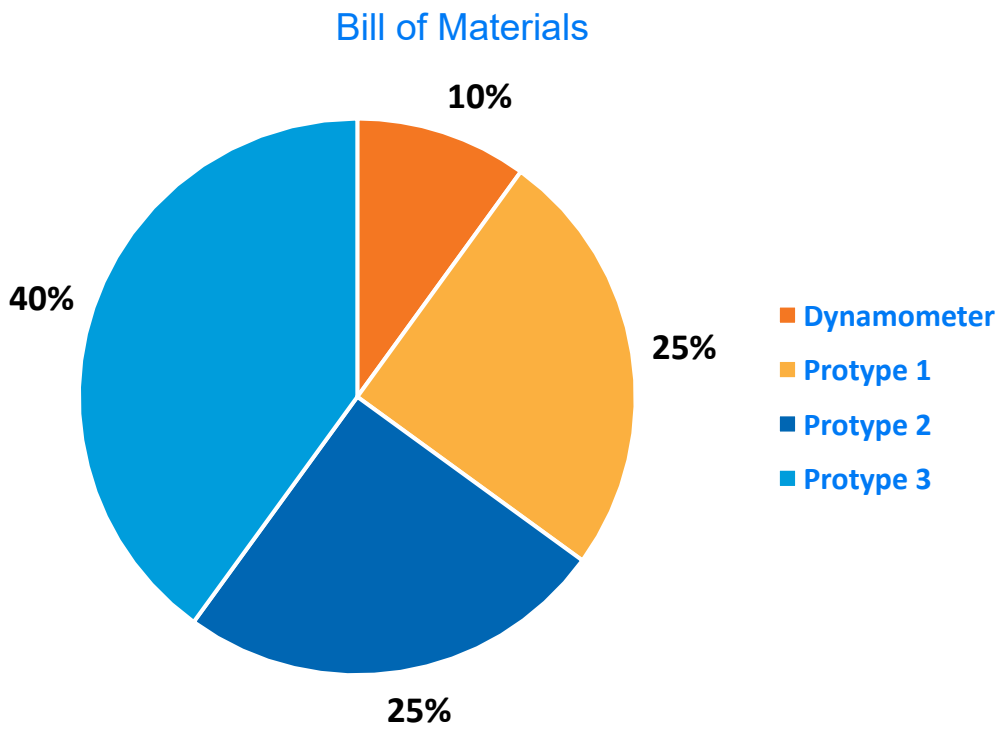
Total Capstone Budget: $500

Total: $746

Bill of Material

Dynamometer

Find No.	Company:	Description:	Cost	Purchase/Not Purchase
1	Amazon	IR Infrared Obstacle Avoidance Sensor IR transmitting Arduino	$9.99	Not Purchase
2	Amazon	5pcs 30A range current Sensor Module Arduino	$11.99	Not Purchase
3	Amazon	Electric Motor	$9.99	Purchase
4	Amazon	LCD Screen Display Module Blue Backlight	$19.98	Purchase
5	AliExpress	10pcs LM358	$0.48	Not Purchase



Total: $52

Moving Forward

Sub-Team 1

- Finish Arduino
  - Converting AC -> DC
  - Load Cell Amp (Measuring Torque)
  - Assembling all components

Sub-Team 2

- ANSYS Simulations
- Test the two generators
- 3D Print Adaptor

Thank you
(Happy Birthday Kaitlyn!!!)

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Any Questions?

References

[1] Climate Central, “A Decade of Growth in Solar and Wind Power: Trends Across the U.S. | Climate Central,” *www.climatecentral.org*, Apr. 03, 2024. https://www.climatecentral.org/report/solar-and-wind-power-2024

[?] rs, Tachometers - A Complete Guide, https://uk.rs-online.com/web/content/discovery/ideas-and-advice/tachometers-guide (accessed Feb. 26, 2025).

[1\2] NASA, “Infrared Waves - NASA Science,” NASA, https://science.nasa.gov/ems/07_infraredwaves/#:~:text=Infrared%20waves%2C%20or%20infrared%20light,warm%20so%20they%20can%20hatch. (accessed Feb. 26, 2025).

https://www.electronicshub.org/interfacing-acs712-current-sensor-with-arduino/#:~:text=Code-,Working,implemented%20in%20code%20as%20follows.