BME Design-Fall 2024 - ALLICIA MOELLER
Complete Notebook

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on

Dec 13, 2024 @08:02 PM CST

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Team contact Information

SIMERJOT KAUR - Sep 06, 2024, 1:31 PM CDT

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Project description

ALLICIA MOELLER - Sep 06, 2024, 1:43 PM CDT

Course Number: BME 400

Project Name: Asymmetrical Force Sensor for Rowing Biomechanics

Short Name: Rowing Biomechanics

Project description/problem statement:

Many college rowing athletes, particularly women, are susceptible to lifelong lower back or hip injuries due to disparate weight distributions on each leg while rowing. This issue can be addressed through gathering real-time data on athlete biomechanics, but this data is often difficult to obtain. Collection and analysis of biomechanical data will enable athletes to adapt their technique towards better performance, and will assist coaches and trainers in preventing injury. The client, Dr. Jill Thein-Nissenbaum, has tasked the team with creating a force plate system that can collect biomechanical data from rowers' lower extremities. The team's goal is to create a wireless sensor system in the rowboat that will capture load distribution during time of use and will assess lower extremity asymmetry to establish risk stratification. Additionally, the team aims to translate the force plate system into a user-friendly interface that will enable coaches and athletes to understand essential biofeedback information, thereby improving both performance and safeguarding against potential injuries.

About the client:

The clients for the project include Dr. Jill Thein-Nissenbaum, Ms. Tricia De Souza, and Ms. Sarah Navin. All three work with and are representing the University of Wisconsin-Madison (UW-Madison) Women's Rowing Team. Dr. Jill Thein-Nissenbaum is a professor in the UW Madison Physical Therapy Program, and is the staff physical therapist for Badger Sports Medicine. She provides consultation and rehabilitation services for all UW Madison sports and works in the Badger Athletic Performance Center analyzing athletic testing performed on UW Madison athletes. Ms. De Souza is a UW-Madison Athletic Trainer; in particular, she provides athletic training services for both the Badgers Men's and Women's Rowing Teams. Finally, Ms. Sarah Navin is a UW Madison Physical Therapy student. She attended UW Madison for undergraduate school and was previously on the Badger Women's Rowing team.

2024/9/13 - Client Meeting 1

ALLICIA MOELLER - Sep 13, 2024, 2:33 PM CDT

Title: Client Meeting 1

Date: 9/13/2024

Content by: Allicia

Present: Allicia, Neha, Emily, Simmi

Goals: To establish clear goals for the semester and year, and finalize the budget

Content:

- Tricia liked the end design in May, didn't like the height adjustment, wants to keep the design simple for integration
  - Less modifications to the rowing style, the better
- Tool for tryouts
- Planning to meet with Dr. Gruben about load cells
  - Jill supports whatever Gruben has to say
- GUI
  - plan is to come up with new GUI designs, have clients send out google form to rowers
  - videos of different GUIs
  - Jill and Tricia can get us a large sample size
- Whatever is left of the $1000 grant - we used $540 last semester
  - If we need a couple hundred more, that can be arranged
- Jill is working on about a paper on lower back injury - could go hand in hand with paper
- Purchasing: we can go through Sue again
- 8 would be ideal - main boat on the water
- October 4, 2024
- Key metrics: peak force, time to peak force, look into "total work" (may not be a priority)
- coaches have TVs, ipads, laptops
  - whatever is easiest for you
  - ideally looking up at eye level
  - using somethin readily available is ideal
  - Tank ergs are tightly packed front-to-back
    - Not able to put screens directly in front of the back 7 ergs.
- Ultimate goal - in the boat
  - Most of the data come from the erg
    - Focus on the erg - priority! - newer ergs
    - If it can be adapted to the tank, that's a plus (not a necessity)
    - It is acceptable to adapt device to the older concept 2 erg

Conclusions/action items:

- Let tricia know when we want to come to boat house to look at the ergs

2024/09/20 - Client Meeting 2

ALLICIA MOELLER - Sep 20, 2024, 11:55 AM CDT

Title: Client Meeting 2

Date: 9/20/2024

Content by: Allicia

Present: Allicia, Simmi, Neha, Tricia, Jill, Emily, Colin

Goals: To clarify the restraints of only measuring vertical component force in the compressive direction

Content:

- Can go down to boat house and talk to the boatmen if we want

-Allicia:

- Clarified what the vertical component of the force is - Jill and Tricia agree that the vertical component of the force alone would be sufficient

- Asked if tensile force is important - currently we are only planning to use compressive force sensors

- Neha:

- talked about the PedarX and Moticon pressure sensors - study done on validity of pressure insoles using boat shoes

- Because of price, it may not be the most feasible - you have to buy the whole data processing kit

- May not be the most appropriate option for us

- Power curve: talking to gruben informed us that finding the power would be difficult and would require motion capture and more kinetic data

    - Jill thinks we do not need it - out of scope

Jill:

- When we start doing research, we should separate data by size

- Okay with $250 for load cells

Conclusions/action items:

- Research price difference between compressive and compressive/tensile load cells - talk to Gruben?

- Set up a time to look at the ergs at the boathouse.

2024/09/20 - Advisor Meeting 2

ALLICIA MOELLER - Sep 20, 2024, 1:17 PM CDT

Title: Advisor Meeting 2

Date: 9/20/2024

Content by: Allicia

Present: Colin, Allicia, Simmi, Emily, Neha, Dr. Appleyard

Goals: To update our advisor on our load cell design and share what we learned from Dr. Gruben

Content:

- Discussed our meeting with Dr. Gruben:

  - Dr. Gruben confirmed that we have a feasible and logical design for isolating the normal component of the rower's applied force.

  - Dr. Gruben suggested an alternative design: add a gap between the footplate and the enclosure and glue a piece of fabric over the entire top plate (membrane design)

- Client interactions:

  - We had a meeting with the clients where we clarified the limitations of our current design (only the vertical component of the force, only compressive)

  - Jill gave us research papers to look into on lower back pain - Jill is in the process of writing her own paper

- Pressure insoles feasibility:

  - Neha went over the idea of using pressure insoles instead of force plates

  - While this would give us more flexibility in attachment style (between various erg models and the boat), it would be less adaptable between rowers (foot size) and potentially too expensive

- GUI design:

  - Neha's goal for next week is to send out a form to rowers with some different visual options for the GUI to get feedback

  - GUI design will be its own design matrix

- Path forward:

  - Tricia (client) is going to chat with some of the other coaches about the importance level of measuring tensile force, if this is not a major concern, we will purchase 4 of the load cells and the instrumentation necessary to get a force reading so that we can start prototyping.

Conclusions/action items:

- Visit the boathouse to look at the different erg models.

09/26/2024 Advisor Meeting 3

ALLICIA MOELLER - Sep 27, 2024, 12:30 PM CDT

Title: Advisor Meeting 3

Date: 09/26/2024

Content by: Allicia

Present: Simmi, Neha, Emily, Allicia

Goals: To update our advisor on our design matrix and chosen design.

Content:

- Notebook updates
  - Neha made 6 GUI designs
    - we're sending 4 of them out to rowers for feedback
    - Ideally, GUIs are modular - rower can switch between them
    - Neha did research on what cues are most helpful for rowing performance
  - Simmi
    - Did research on COP measurements
    - Need total force distribution to calculate COP
    - Wants to ask Dr. Gruben
  - Emily
    - Looked into fabrics for the membrane design
    - Cotton, denim
    - Tensile strength, number of fabric layers
  - Allicia - matrix drawings
- Delrin or acetal - low friction plastic materials that could make a good frictionless surface (alternative to bearings)
- Joann sells grommets - could make attachments for fabric

- PDS
  - Positive feedback from Dr. Appleyard
- Design matrix
  - Specify reliability category (all 3 designs will have same circuitry and will calculate only vertical force)
  - Our design matrix gave us the idea to build up the stationary force plate and test it for accuracy/repeatability

Conclusions/action items:

- Make slides for oral presentation

2014/10/11 - Advisor Meeting

ALLICIA MOELLER - Oct 11, 2024, 12:25 PM CDT

Title: Advisor Meeting

Date: 10/11/2024

Content by: Allicia

Present: Allicia, Neha, Simmi, Colin, Emily, Dr. Appleyard

Goals: To discuss out preliminary presentation/report, and updates to our project.

Content:

- Lab Notebook & Progress
  - Could look into wire wrap as opposed to soldering
  - Looking into materials for footplate - calculate deflections - possible design matrix
  - Talked to Gruben about pre-loading the load cells with tensile springs
  - If we could make an initial prototype out of plywood to assess off-axis loading
- Presentations
- Preliminary draft
- Open questions
- Next weeks meeting
  - May get cancelled

Conclusions/action items:

- Test out basic electrical circuit to assess signal quality
- Talk to makerspace about materials and design for footplate

2024/10/25 - Concept2 Foot Stretcher Dimensions

ALLICIA MOELLER - Oct 25, 2024, 12:02 PM CDT

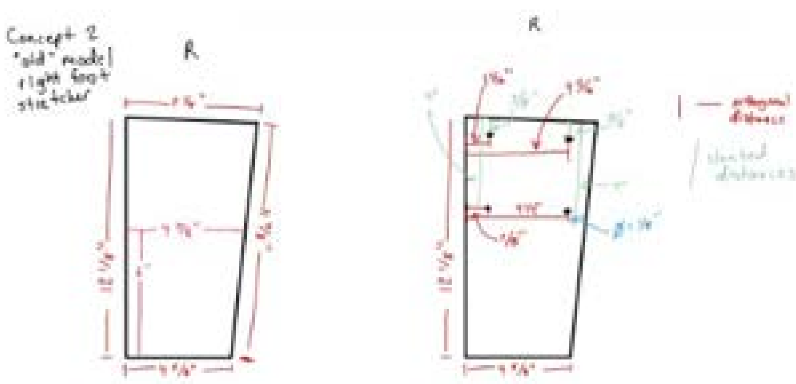
Title: Concept2 Foot Stretcher Dimensions

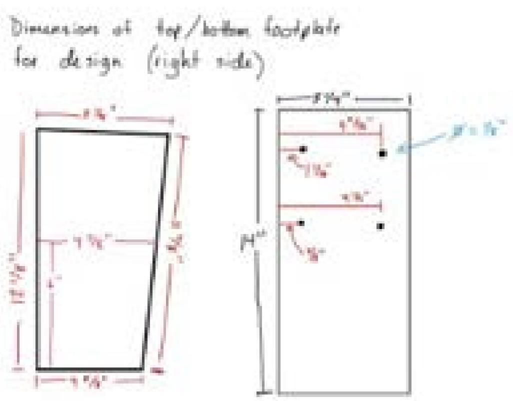
Date: 10/25/2024

Content by: Allicia

Goals: To take careful measurements of the foot stretcher on the old model of the Concept2 ergometer.

Content:





Conclusions/action items:

2024/10/28 - Concept2 New Foot Stretcher Dimensions

EMILY WADZINSKI - Nov 15, 2024, 1:44 PM CST

Title: NEW Concept2 Foot Stretcher Dimensions

Date: 10/28/2024

Content by: Emily

Present: Emily and Allicia

Goals: To take careful measurements of the foot stretcher on the new model D of the Concept2 ergometer.

Content:

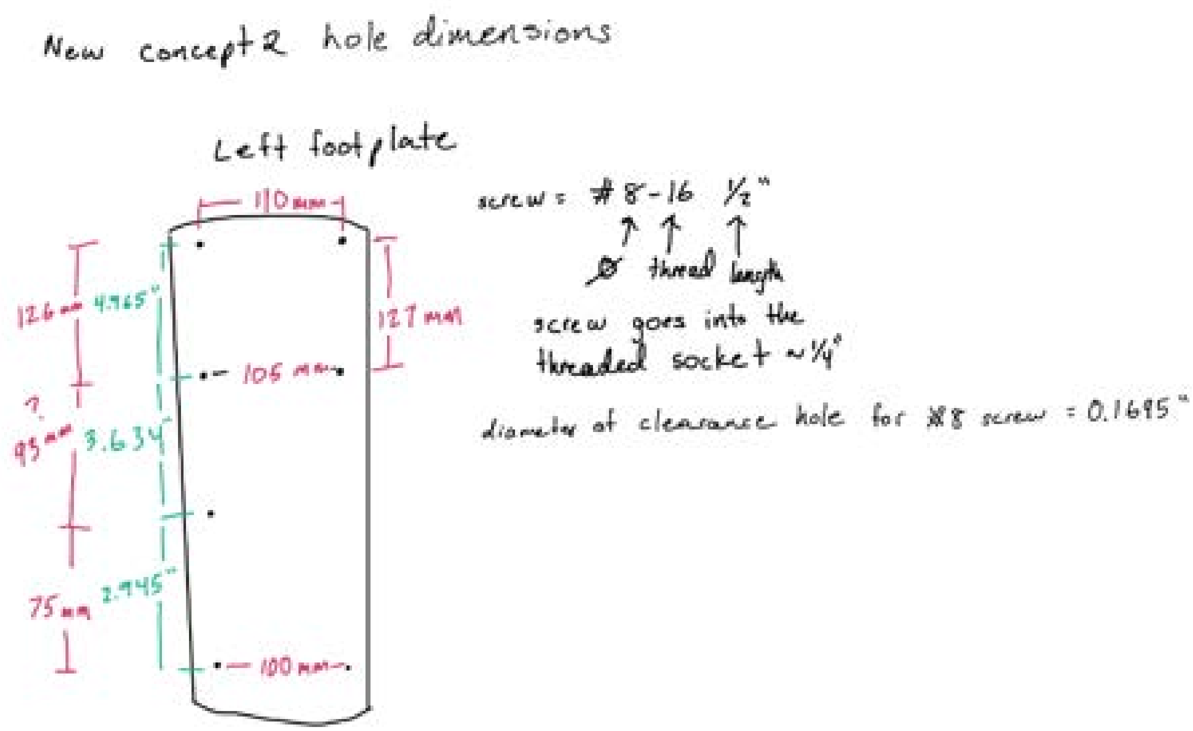
- Allicia and I took a trip to the boathouse to get measurements of the newer model's footplates.

- We took an erg and unscrewed the tops off on both sides.

- Taking a piece of acrylic, we held it over the base and marked where the holes were with sharpie.

- We then measured the base's holes with calipers and the plate's markings to double check alignment.

- Allicia recorded all of the measurements.



Conclusion: Use these measurements for fabrication.

2024/11/25 - Circuit Simulation

ALLICIA MOELLER - Nov 25, 2024, 7:12 PM CST

Title: Circuit Simulation

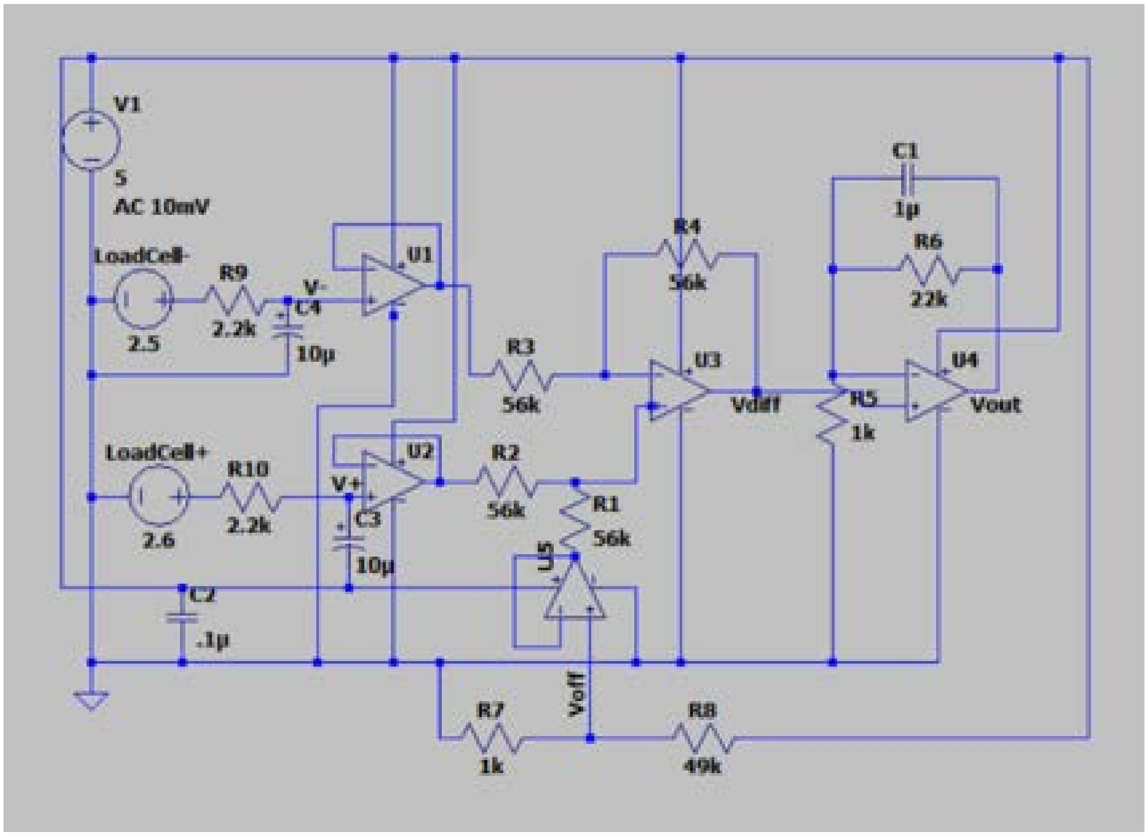
Date: 11/25/2024

Content by: Allicia, Simmi

Goals: To make a spice simulation for a load cell amplifier.

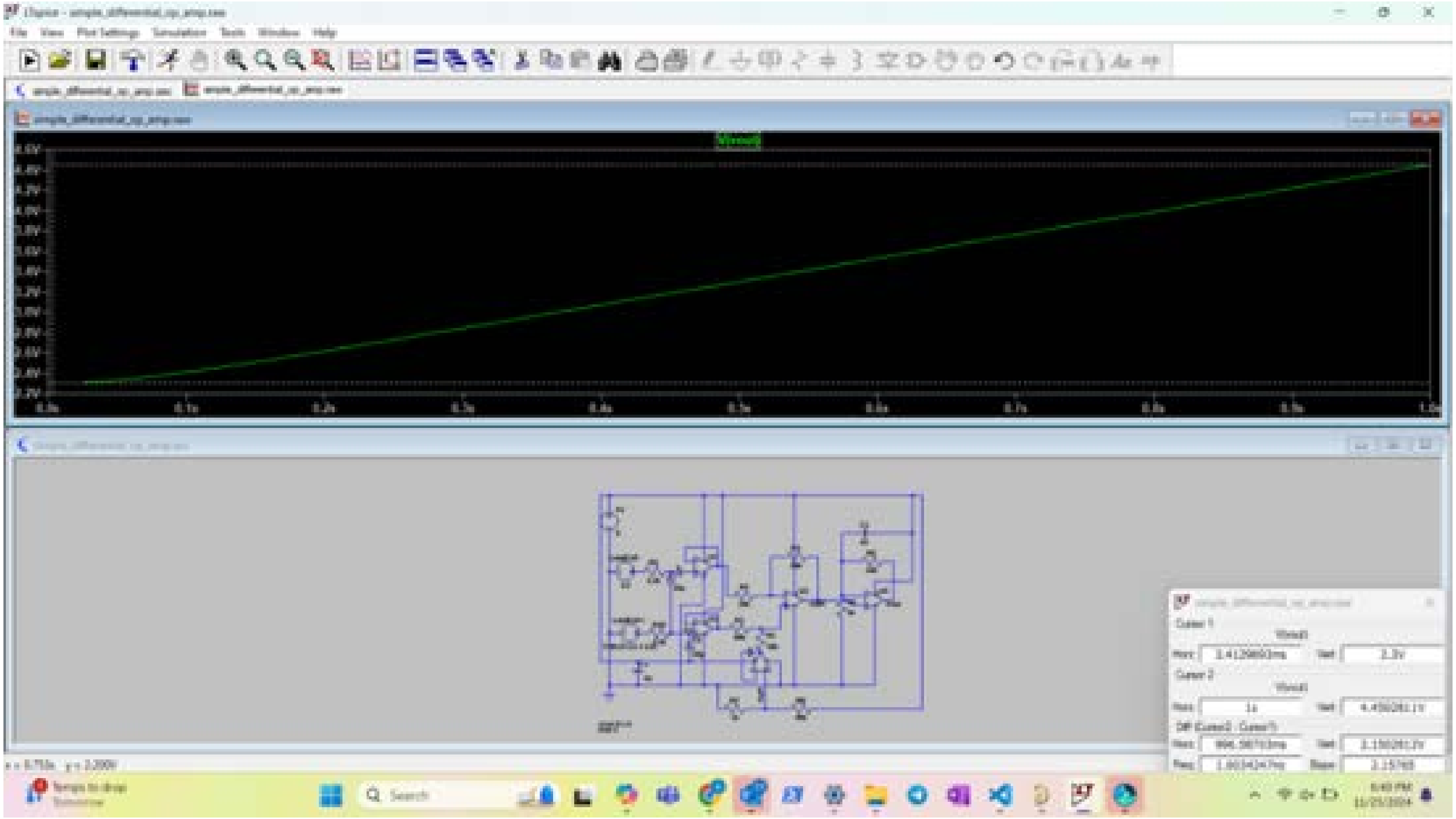
Content:

Circuit schematic:



- V1 = 5V power supply
- Voff = Voltage offset
- Vdiff = LoadCell+ - LoadCell- + Voff
- Vout = (LoadCell+ - LoadCell- + Voff) * Gain
- Gain = 1 + 22/1 = 23

Voltage output when LoadCell- is held at 2.5V and LoadCell+ is varied linearly from 2.5 to 2.6V from 0s to 1s



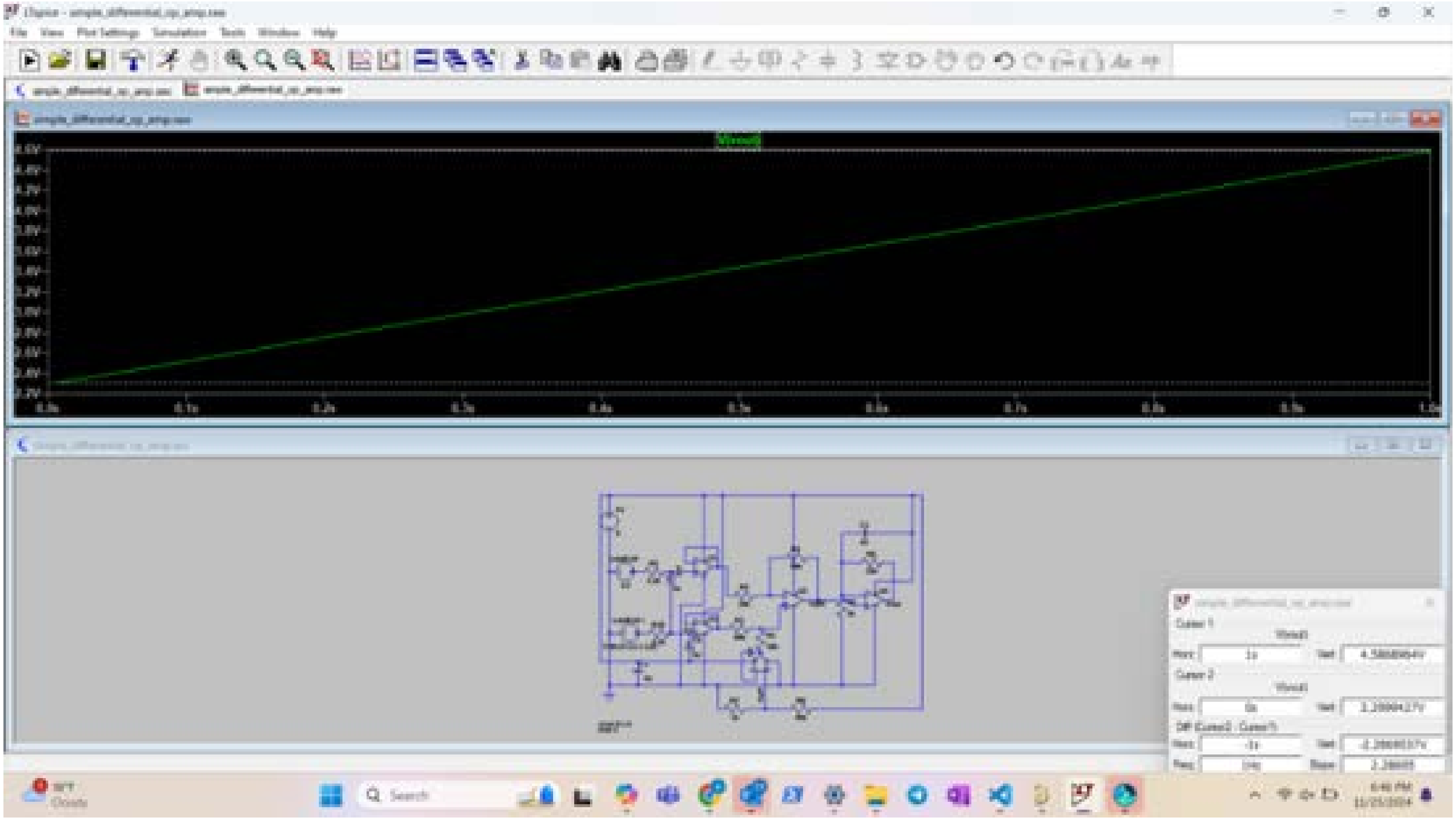
In this simulation, Vout varies from 2.3V to 4.45V.

Vout(Vdiff) = 23*(Vdiff)

When LoadCell+ = 2.5V, Vdiff = 0.1V, so it makes sense that Vout = 2.3V

When LoadCell+ = 2.6V, Viff = 0.2V, so Vout should equal 4.6V

After looking closer at this circuit, I realized that the low pass filter on each load cell input may have a time constant that is causing a delay in the circuit simulation. If I decrease the capacitor on each low pass filter from 10 uF to 1 uF, the time constant will decrease by a factor of 10.



In this simulation:

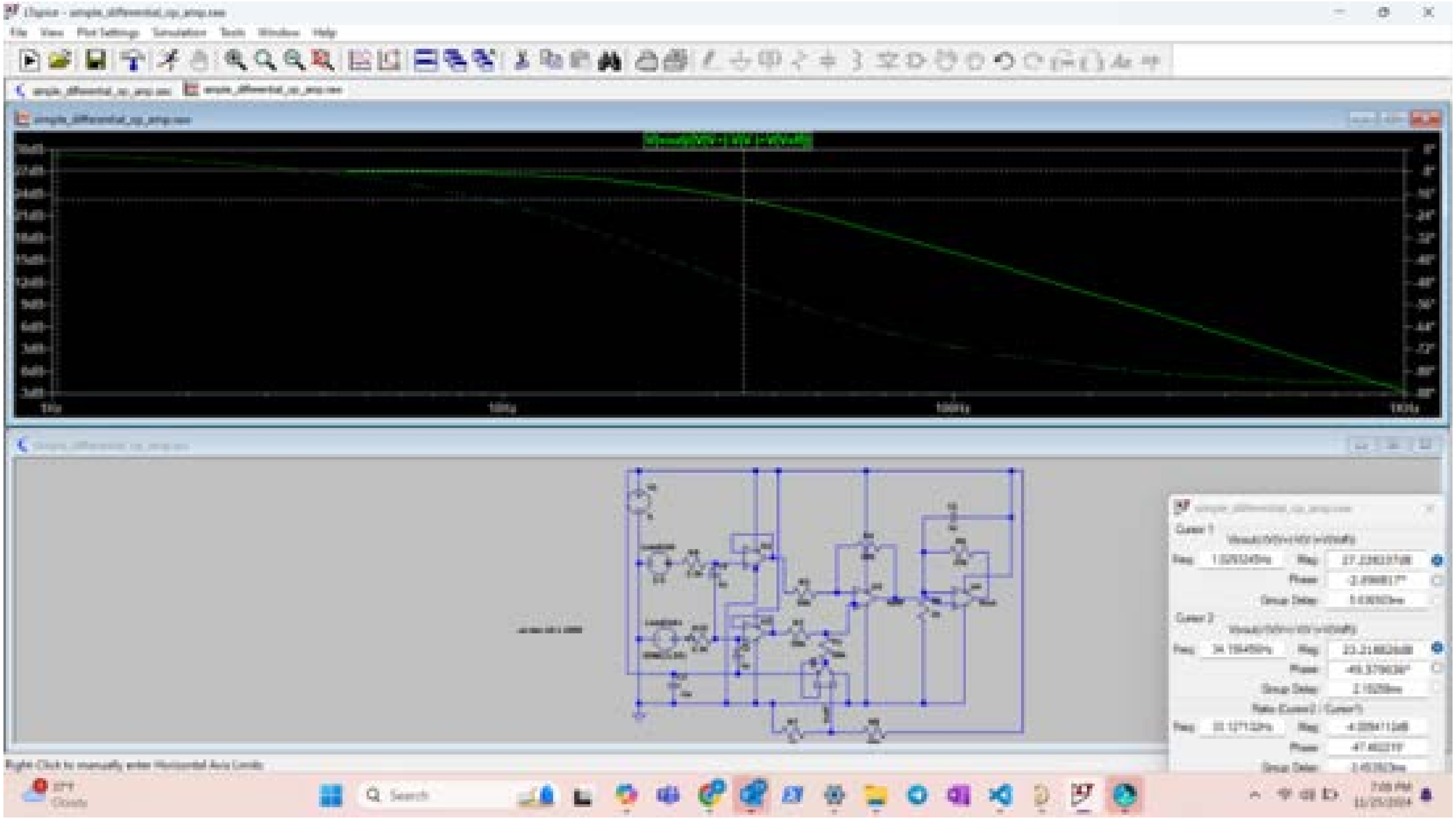
when LoadCell+ = 2.2, Vout = 2.3V

when LoadCell- = 2.6, Vout = 4.587V (much closer to 4.6V)

Because of this discovery, we might desolder the 10 uF capacitors and replace them with 1 uF capacitors.

Cutoff Frequency:

- We would like a low pass cutoff frequency < 60 Hz



With the change to 1 uF capacitors, we see that the cutoff frequency is around 34 Hz, which satisfies our requirement.

Furthermore, the gain at low frequencies is around 27.2 dB

Gain(dB) = 20log(V/V)

27.2 dB corresponds to a voltage gain of 22.9 V/V, which is close to our intended value of 23 V/V.

Conclusions/action items:

- Desolder the 10uF capacitors and replace them with 1 uF capacitors.

2024/11/25 - PCB Layout

ALLICIA MOELLER - Nov 25, 2024, 7:26 PM CST

Title: PCB Layout

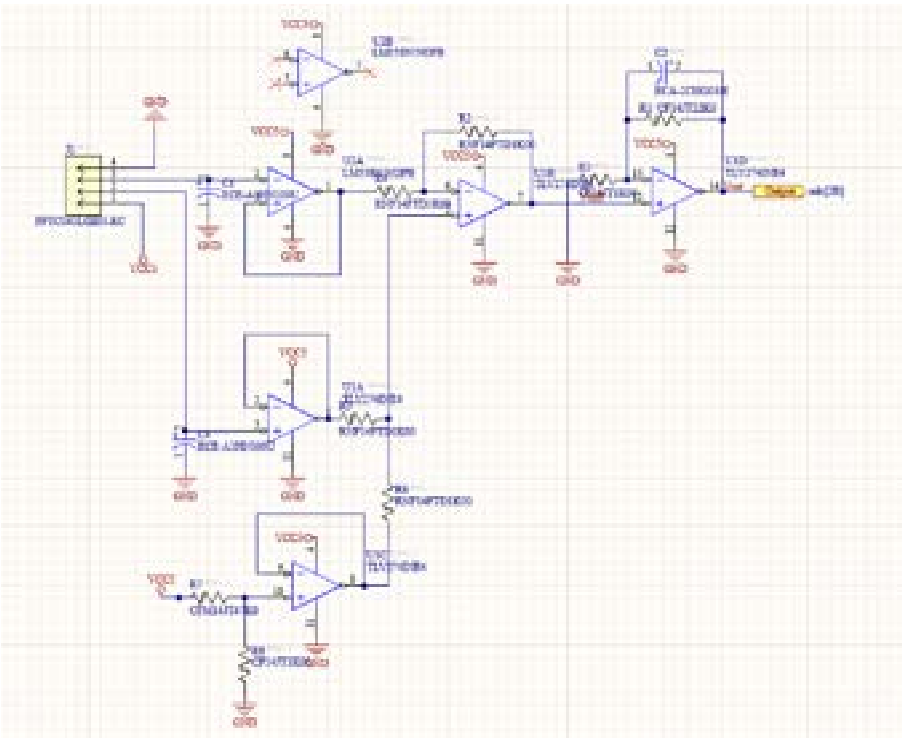
Date: 11/25/2024

Content by: Allicia

Goals: To create a PCB layout in altium to have circuit boards fabricated.

Content:

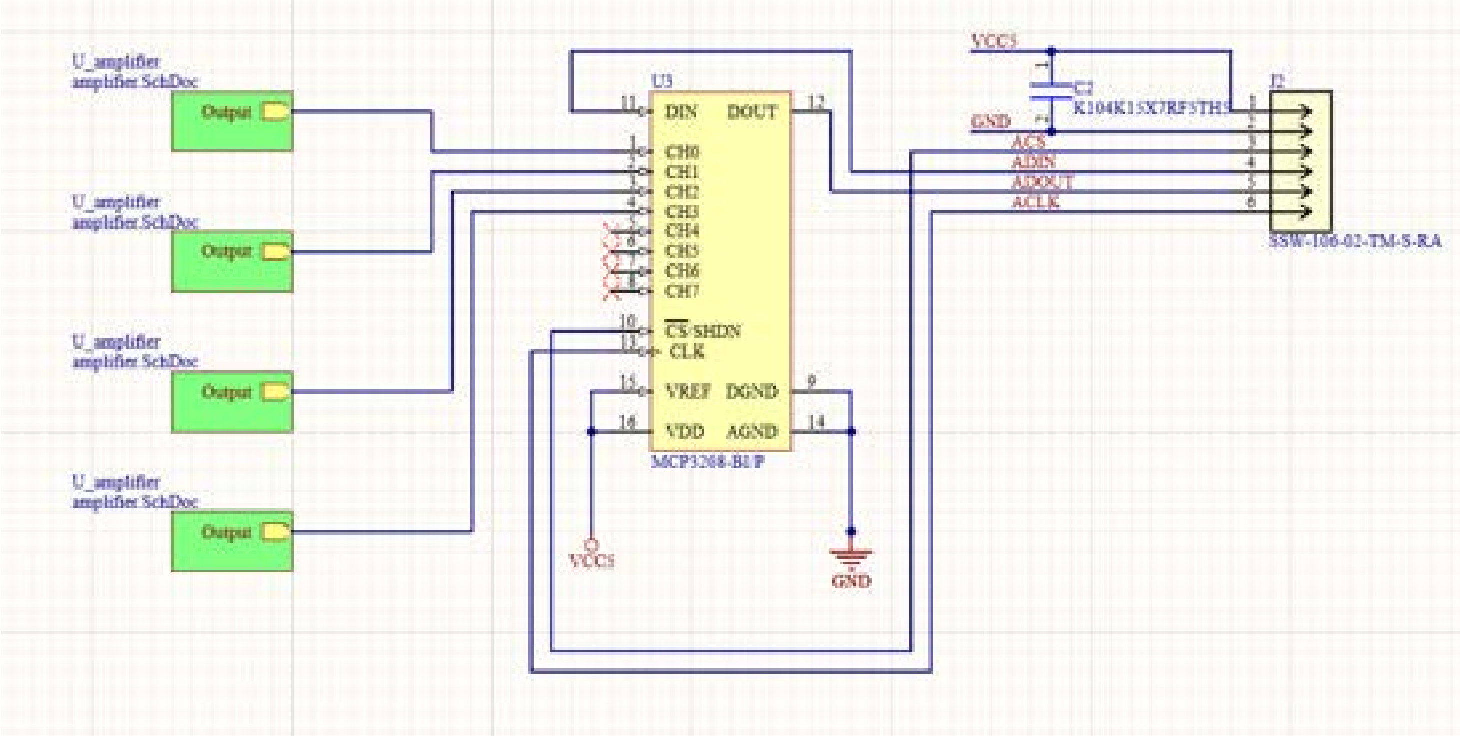
amplifier circuit



J1: connects to one load cell to connect it to 5V and GND and connect its outputs to the amplifier circuit

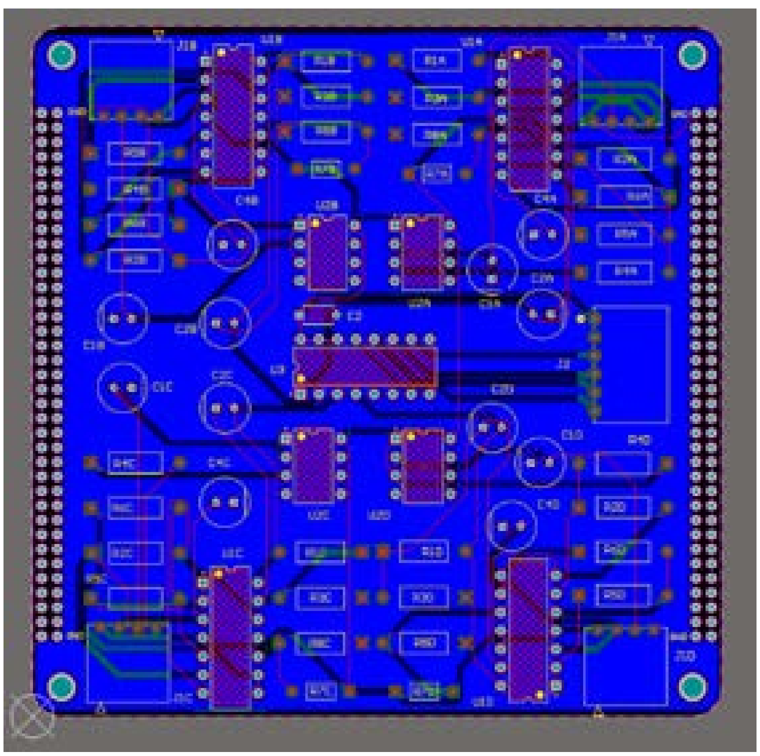
Description of circuitry: The inputs from the load cell go through low pass filters, then go through voltage followers, then they are subtracted by a voltage subtractor with closely-matched resistors. There is a voltage offset of 100 mV (made from a buffered voltage divider R1=47k, R2=1k). The output of this voltage subtractor (with offset) is fed into a non-inverting amplifier (Gain = 23). This amplified output is input into a channel of the ADC.

Overall circuit:



Each green box represents one copy of the amplifier circuity seen above (one per load cell). Each output is fed into the 12-bit ADC. The output of the ADC (4 digital lines) is fed to the 6 pin female socket (J2), which will be connected to the raspberry pi pico (not on PCB). C2 is a decoupling capacitor between power and ground.

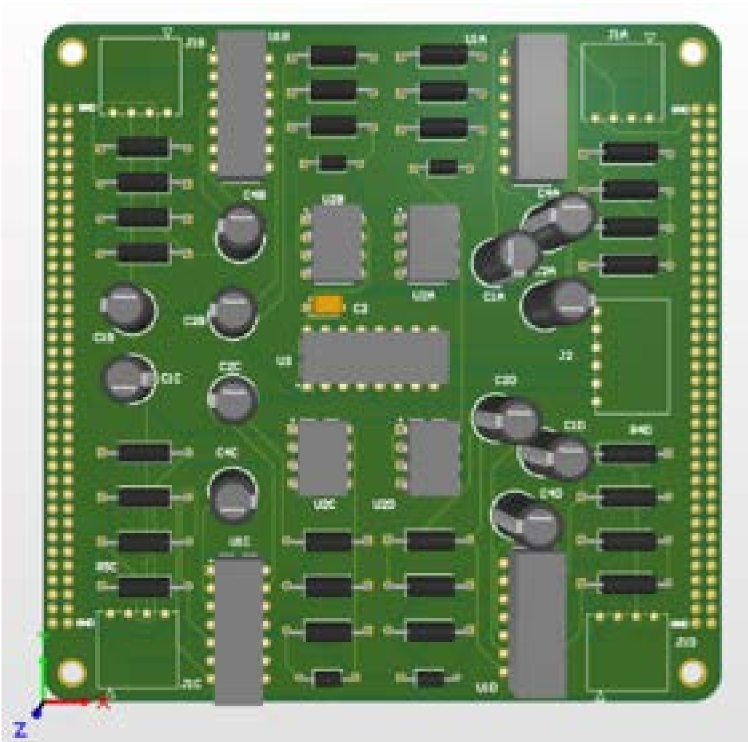
2D PCB Layout



Board dimensions are 95x95mm. The ADC is in the center of the board, the female socket headers are placed around the perimeter of the board (facing outward). I added a few rows of through hole pads to the left and right sides in case we need to make any adjustments post-assembly.

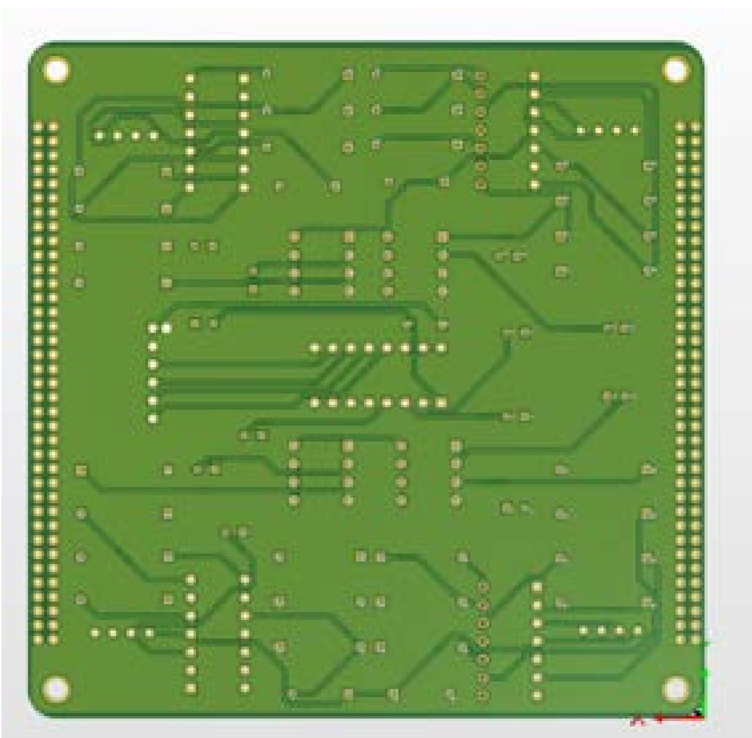
2 layer board with ground polygon pour on the bottom layer.

3D View (top):



note: 3D model of socket headers not available.

3D View (bottom):



I order 5 copies of this board from JLCPCB for $2 + shipping.

We intent to use 2 of them (1 per footplate)

Conclusions/action items:

Assemble PCBs when they arrive.

2024/10/11 - Expense Table (Preliminary)

Neha Kulkarni - Oct 11, 2024, 2:38 PM CDT

Item	Description	Manufacturer	Mft Pt#	Vendor	Vendor Cat#	Date	#	Cost Each	Total	Link
Sensors	Load Cells	TE-Connectivity	FX292X-100A-0100-L	Mouser	824-FX292X-100A0100L	9/26	8	$27.72	$221.76	mouser_load_cells
Raspberry Pi	Microcontroller	Raspberry Pi	Raspberry Pi 4 Model B - 2 GB RAM	Adafruit	4292		1	$45	$45.00	rpi4
ADC	MCP3008 ADC	Bridgold	MCP3008-I/P	Amazon		4/11	1	$13.99	$13.99	mcp3008
								TOTAL:	**$280.75**	

2024/10/15 - DigiKey Order

Title: DigiKey Order

Date: 10/15/2024

Content by: Allicia

Goals: To order some materials for the circuit.

Content:

#	PRODUCT DETAILS	QUANTITY	AVAILABILITY	UI
1	1528-1967-ND 1957 JUMPER WIRE M TO M 6" 28AWG	2	Immediate	1.
2	MCP3008-I/P-ND MCP3008-I/P IC ADC 10BIT SAR 16DIP	1	Immediate	3.
3	296-1395-5-ND LM358P IC OPAMP GP 2 CIRCUIT 8DIP	28	Immediate	0.

Summary

Subtotal:	$12.00
Shipping:	$6.99
Sales Tax:	$1.04
Total:	$20.03

Because we anticipate needed a lot of op amps for out circuit, I ordered 28 through hole op amps to have on hand. Because shipping is the main cost associated with buying small electrical con

Conclusions/action items:

Get reimbursement from Sue.

2024/11/15 - Updated Expenses

Neha Kulkarni - Nov 25, 2024, 12:40 PM CST

Download

Expense_Sheet_Fall_2024_-_Sheet1.pdf (79.5 kB)

2024/10/28 - Load Cell Fixtures

EMILY WADZINSKI - Nov 25, 2024, 12:43 PM CST

Title: Load Cell Holder Iterations

Date: 10/28/2024

Content by: Emily

Present: Emily, Simmi

Goals: To create a fixture to house the load cells

Content:

Load cell holders were 3D printed to fix the load cells onto the footplates. Multiple iterations were made.

Design 1:

- Created by Allicia, located under her design ideas.

- Printed on 10/15 by Emily

- 1 print was done in order to see if the load cell fit and how much clearance it had.

Design 2:

- Created by Simmi, printed by her on 10/28

- 4 prints were done, one for each load cell

- CAD is under her design ideas tab

Conclusion: Use holders for show and tell

2024/10/31 - Prototype Fabrication

EMILY WADZINSKI - Nov 25, 2024, 12:37 PM CST

Title: Prototype Fabrication

Date: 10/31/2024

Content by: Emily, Neha

Present: All

Goals: To create working prototype for show and tell

Content:

We considered metals for a prototype then found some acrylic plates.

Allicia spot drilled holes for pins and bearings on the plates using a mill, then we used a drill press to complete the holes. When drilling through the large holes for the bearings, the acrylic cracked.

Simmi used a block to level and press fit the bearings on the arbor press.

We screwed in the load cell holder fixtures and assembled the plates together with the shoulder screws.

Conclusion:

Use for show and tell, make more iterations

2024/11/15 - Validation of Footplate Measurements

EMILY WADZINSKI - Nov 25, 2024, 12:50 PM CST

Title: Laser Cut Dimensions

Date: 11/15/2024

Content by: Emily

Present: Emily, Colin

Goals: To double check our manual footplate measurements are correct

Content:

- Colin and I went to the makerspace to get our footplate 3D scanned from Jesse's suggestion.

- The makerspace told us we could make a SolidWorks part from our caliper measurements and laser cut that design to see if the holes line ups

- The first outline cut from the laser was not scaled right when the file was uploaded.

- The second outline's holes were also off, most likely due to a scaling issue from the machine.

- Since neither of the outlines were right, we were not confident on our measurements.

Conclusion:

Come back to get the footplate actually 3D scanned

2024/11/22 - Footplate Mill Designs

EMILY WADZINSKI - Nov 25, 2024, 12:24 PM CST

Title: Footplate Mill Designs

Date: 11/22/2024

Content by: Allicia, Emily, Neha, Colin

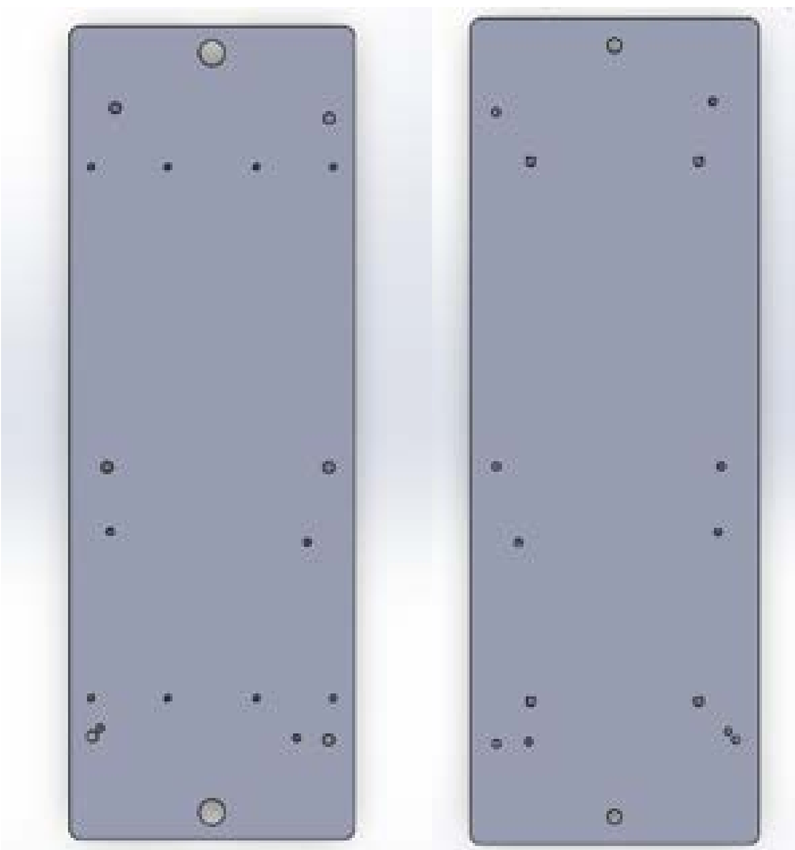
Present: Allicia, Emily, Neha, Colin, Simmi, Jesse Darley, Mike

Goals: To make part files and drawings of the top and bottom footplates.

Content:

This week, we met with Jesse and Mike, and Mike agreed to mill our footplates for us in order to save us time and ensure high quality. We gave him the following files for the top plate and bottom plate.

Note: 2 of each type of plate will be made. The right and left sides are identical, but one will be flipped over so that it is the mirror image of the other. This works because all our threads and holes are through holes.



Top plate features:

- 15 in. x 5.25 in.
- Two holes for sleeve bearings on top and bottom center.

Conclusions/action items:

Get cut plates from Mike

EMILY WADZINSKI - Nov 25, 2024, 12:20 PM CST

Download

BottomPlate3.SLDPRT (186 kB)

EMILY WADZINSKI - Nov 25, 2024, 12:20 PM CST

Download

topplate3.SLDPRT (184 kB)

2024/11/22 - Finished Footplate Assembly

Neha Kulkarni - Nov 25, 2024, 12:25 PM CST

Title: Footplate Mill Designs

Date: 11/22/2024

Content by: Allicia, Emily, Neha, Colin

Present: Allicia, Emily, Neha, Colin, Simmi, Jesse Darley, Mike

Goals: Receive finished footplates and begin to test assembly

Content:

We received the finished footplates from Mike. Observations:

- Bearings on one needed to be press fit so they stick out the other way, we did this on the arbor press
- The 1/16 holes need to be cut larger or we can abandon them and just use the other erg holes
- All Flexfoot holes lined up except one, this is okay because the Flexfoot is still secure

We found that our springs from last year fit really well on our shoulder screws and have a good spring constant for us to use as pre-load springs.

- we did some math to calculate that the spring length needs to 1 in
- we asked Mike to cut the springs down on the grinder for us
- upon assembly we think the springs are still too short, going to ask Mike to re-cut or use washers to create more compression

Conclusions/action items:

Re-evaluate spring length, screw in load cell pins and complete assembly

Neha Kulkarni - Nov 25, 2024, 12:27 PM CST

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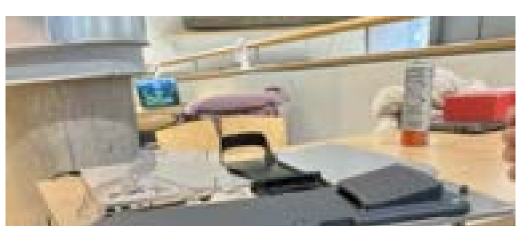
Neha Kulkarni - Nov 25, 2024, 12:28 PM CST



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Neha Kulkarni - Nov 25, 2024, 12:28 PM CST

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IMG_4760_Medium.jpeg (60.8 kB)

Neha Kulkarni - Nov 25, 2024, 12:28 PM CST

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2024/11/25 - Soldering of PCBs

EMILY WADZINSKI - Nov 25, 2024, 2:56 PM CST

Title: PCB Assembly

Date: 11/25/2024

Content by: Emily

Present: Allicia, Emily, Simmi

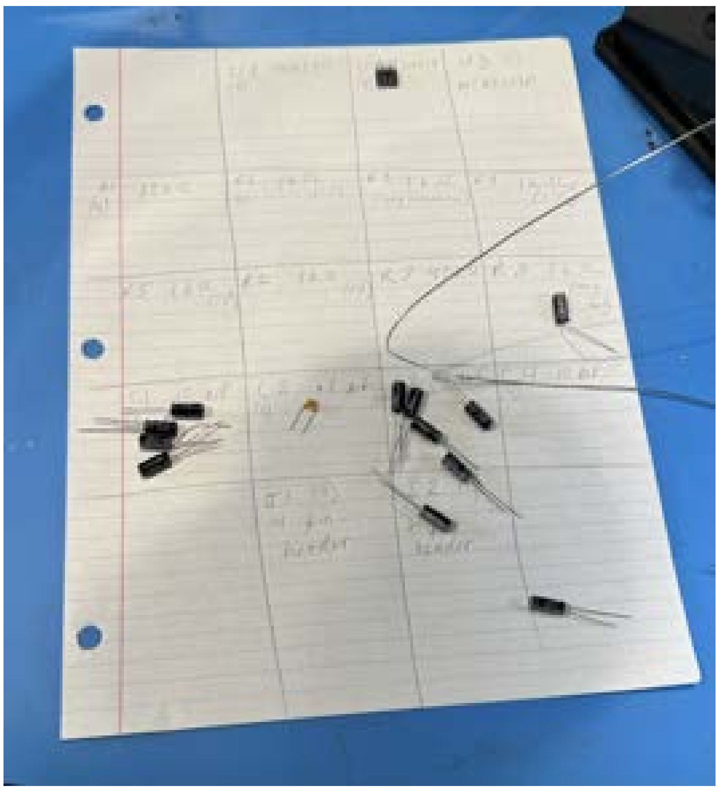
Goals: Soldier our components onto the boards

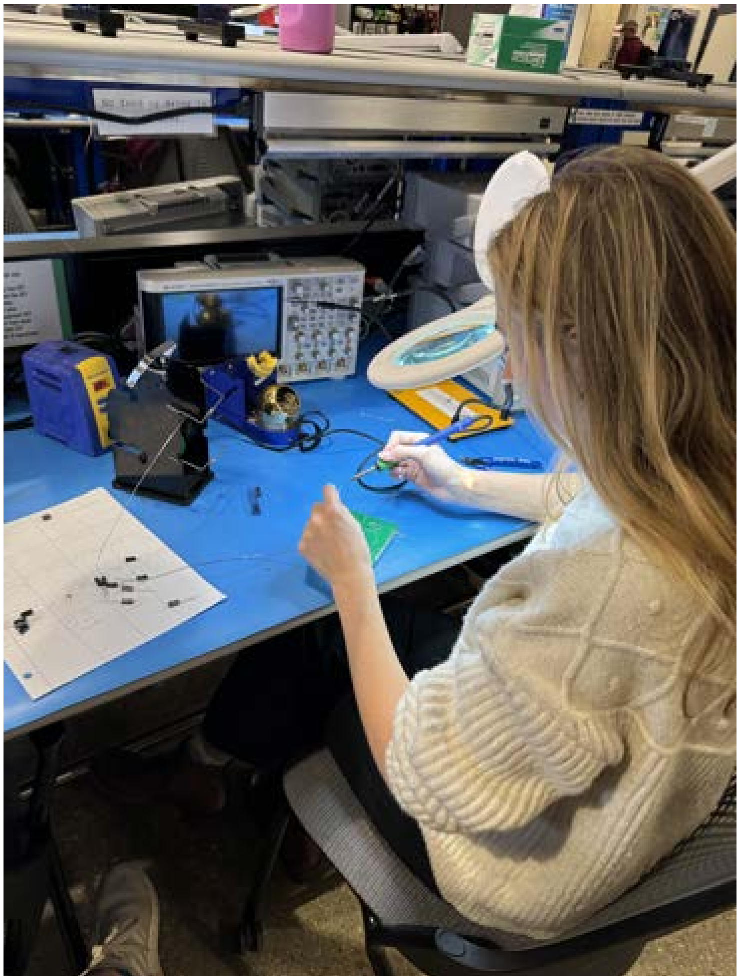
Content:

- components were laid out and organized at the makerspace

- the 1K resistors were sorted and matched together that had differences of 1ohm

- all circuit parts were soldiered onto the two boards, one per foot - we are waiting on a couple op amps to ship in





Conclusion:

Test out the board

2014/12/13-Fabrication Protocol

Neha Kulkarni - Dec 13, 2024, 6:51 PM CST

Title: Final Fabrication Protocol

Date: 12/13/2024

Content by: Team

Present: Team

Goals: Document full fabrication process for entire device.

Content:

Footplates:

1. Use a jigsaw to cut the aluminum plates to 15” x 5.25” x 0.25” as shown in the drawings.
2. Deburr and fillet the edges of the plates using the radius specified in the drawings.
3. Use a CNC mill to drill and tap the holes specified by the drawings for two bottom plates and two top plates.

Circuitry:

1. Obtain a soldering iron and solder wire.
2. Turn on the iron to 750 degrees Fahrenheit.
3. Solder the components to the PCB boards at their corresponding locations (refer to Figure 23).
4. Trim excess wire from the resistors and capacitors.
5. Flatten the capacitors against the board to minimize the height of the board.
6. Repeat with a second PCB board.

Assembly:

1. Unscrew the left and right Concept 2 RowErg Model D Flexfoot from its base.
2. Attach the PCB boards to the center of each bottom aluminum plate using loops of electrical tape.
3. Plug in four load cells to their corresponding spots on each board.
4. Place the load cell housings over each load cell and screw them in with eight M3-0.5 screws per plate.
5. Attach the bottom plates with the circuitry to the existing holes on the ergometer using the screws from the removed FlexFoot.
6. Place the Raspberry Pi Pico between the feet of the erg and connect it to both PCBs.
7. Attach the removed FlexFoots onto the two top aluminum plates with twelve total #10-32 screws.
8. Place the top plates over the bottom plates.

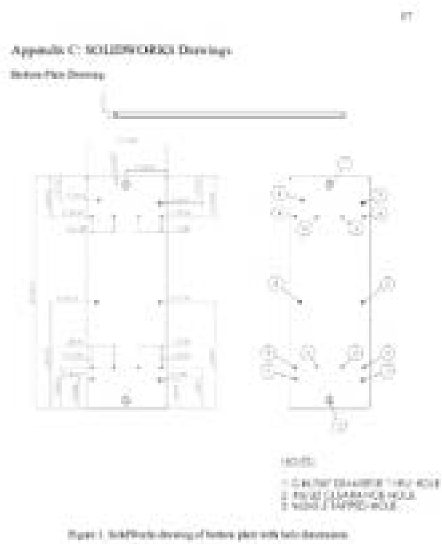
9. Lubricate the shoulder screws with WD-40 and insert them through the bearings of the bottom plate and screw them into the top plate.

10. Connect the Pico to a computer or monitor.

Refer to attached images to see full assembled prototype.

Conclusions/action items: Follow this protocol when fabricating, edit if necessary later on.

Neha Kulkarni - Dec 13, 2024, 6:40 PM CST



Download

drawings.pdf (266 kB)

Neha Kulkarni - Dec 13, 2024, 7:10 PM CST

Download

final_mounted_prototype.HEIC (2.7 MB)

Neha Kulkarni - Dec 13, 2024, 7:11 PM CST

Download

inside_hardware_view.HEIC (2.85 MB)

Neha Kulkarni - Dec 13, 2024, 7:11 PM CST

Download

side_view.HEIC (2.18 MB)

2014/12/13-Testing Protocol

Neha Kulkarni - Dec 13, 2024, 6:48 PM CST

Title: Final Fabrication Protocol

Date: 12/13/2024

Content by: Team

Present: Team

Goals: Document full fabrication process for entire device.

Content:

Refer to pictures for test setup reference.

Calibration Protocol:

1. Place a 1 kN load cell attachment into the MTS machine. Attach the top and bottom compression platens.
2. Move the MTS machine down until the compression platens are 0.2 inches apart (measure with a ruler) and set the emergency stopper.
3. Open the MTS software. Right click on the current force reading and click zero sensor.
4. Attach the FX29 load cell you intend to calibrate to the PCB into the intended channel of use. Attach the PCB to power so that it can print out the raw ADC values of all 4 channels.
5. Make note of the ADC value measured by the load cell when no force is applied to it. This will be the offset value.
6. Move the MTS machine up a few inches and place the FX29 load cell on the bottom compression platen.
7. Very carefully, and very slowly move the top platen down with the fine adjustment wheel while checking the force reading and stop moving the wheel downward once some force is applied. The displacement of the FX29 load cell at 100 lb is 0.03 mm, so it is essential that you move the fine adjustment wheel very carefully as it does not take much displacement to put large amounts of force on the load cell.
8. Use the fine adjustment wheel to adjust the MTS machine until the software reads a force value that is close to 44.5 N. Record the precise force measurement from the MTS software as well as the ADC value of the FX29 load cell.
9. Repeat step 8 with the additional force values listed in Table 2.
10. Once data has been collected for all force values, subtract all the ADC values by the offset value from step 5. Then, run a linear regression using the actual force readings as y-values and the ADC values as x-values, so that the slope of the best fit line provides a calibration coefficient in the form of force/ADC.
11. Repeat steps 4-10 on the remaining 7 sensors, taking care to attach every sensor to its intended channel of use so that the calibration accounts for differences in gain across different channels due to resistor tolerance.

Table 1. Calibration data recording table.

Load Cell:		ADC Offset:	
Ideal Force Values (N)	Actual Force Values (N)	ADC Value	ADC Value - Offset
44.4822			

111.2055

222.411

333.6165

444.822

Testing Protocol:

1. Obtain a set of calibrated weights.
2. Set up one assembled plate on a table with supports, connected to a computer with the code printing force to the nearest tenth.
3. Place a pointed bar onto the middle of the plate that can apply loads while weights are adjusted.
4. Zero out the plate with the bar on it.
5. Place a 0.539 kg weight onto the bar and record the weight.
6. Add another weight of 1.175kg and record the reading.
7. Continue adding weights to the loading mechanism and record the printed readouts in a spreadsheet.
8. Apply a shear load of 2.319 kg using a cable and pulley at the same point of the normal force at five various total weights: 18.841 kg, 31.18 kg, 43.023 kg, 52.044kg, 56.772 kg. Record any differences in printouts.
9. Apply three various weights to the top of the plate and record the plate's readings of 12.339 kg, 24.182 kg, 35.652 kg.
10. Repeat with at the bottom of the plate.

Table 2. Weights Used in Testing Consecutively.

Weight Added (kg)	Total Weight (kg)
0.539	0.539
1.175	1.75
1.16	2.874
2.262	5.109
2.262	7.371
11.47	18.841
12.399	31.18
11.843	43.023

4.377	47.4
4.644	52.044
2.421	54.465
2.307	56.772
2.319	59.091

Conclusions/action items: Analyze data, test further next semester.

Neha Kulkarni - Dec 13, 2024, 6:44 PM CST

Download

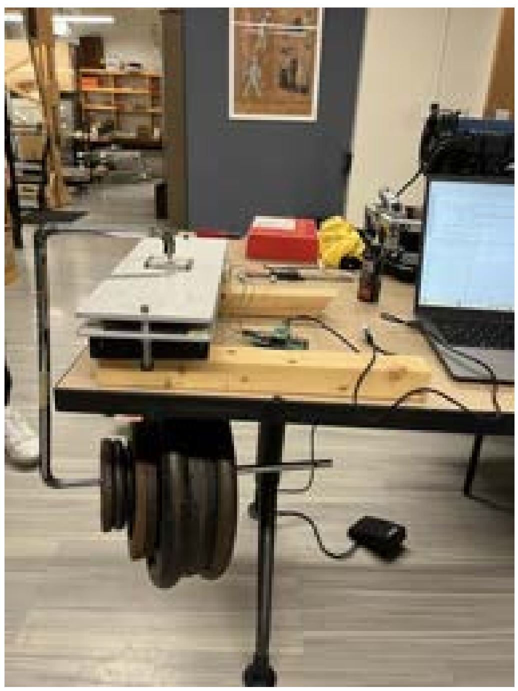
calibration_test_setup.png (1.07 MB)

Neha Kulkarni - Dec 13, 2024, 6:46 PM CST

Download

shear_test_setup.png (1.63 MB)

Neha Kulkarni - Dec 13, 2024, 6:46 PM CST



Download

loading_test_setup.jpg (2.91 MB)

2024/12/2 - Circuit Testing

ALLICIA MOELLER - Dec 02, 2024, 11:03 PM CST

Title: Circuit Testing

Date: 12/2/2024

Content by: Allicia

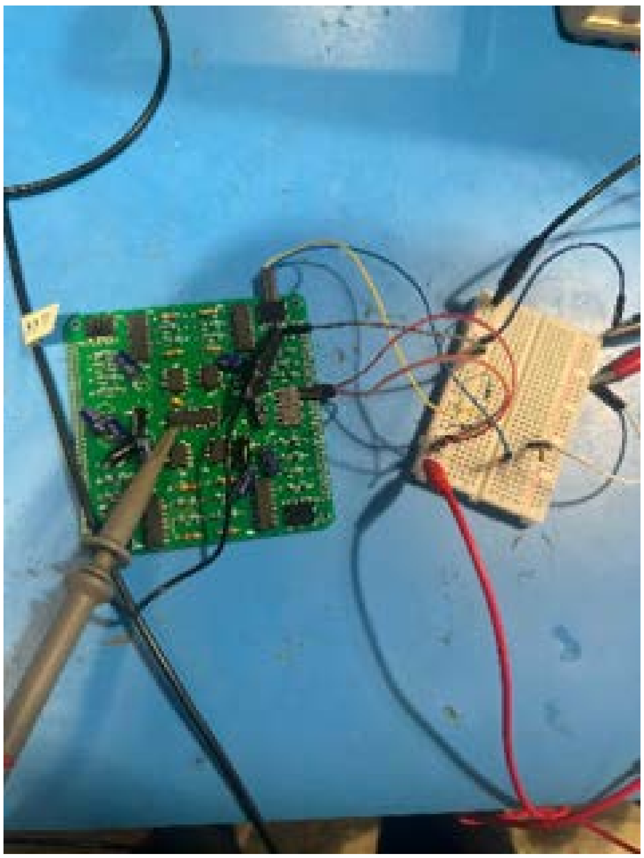
Present: Allicia

Goals: To visualize circuit amplification, linearity, and low pass filtering.

Content:

In order to test the functionality of the PCB amplifier circuit, I mimicked a load cell input with a function generator and viewed the analog output of the amplifier circuit on an oscilloscope.

Test set up:



PCB Power = 5V from power supply

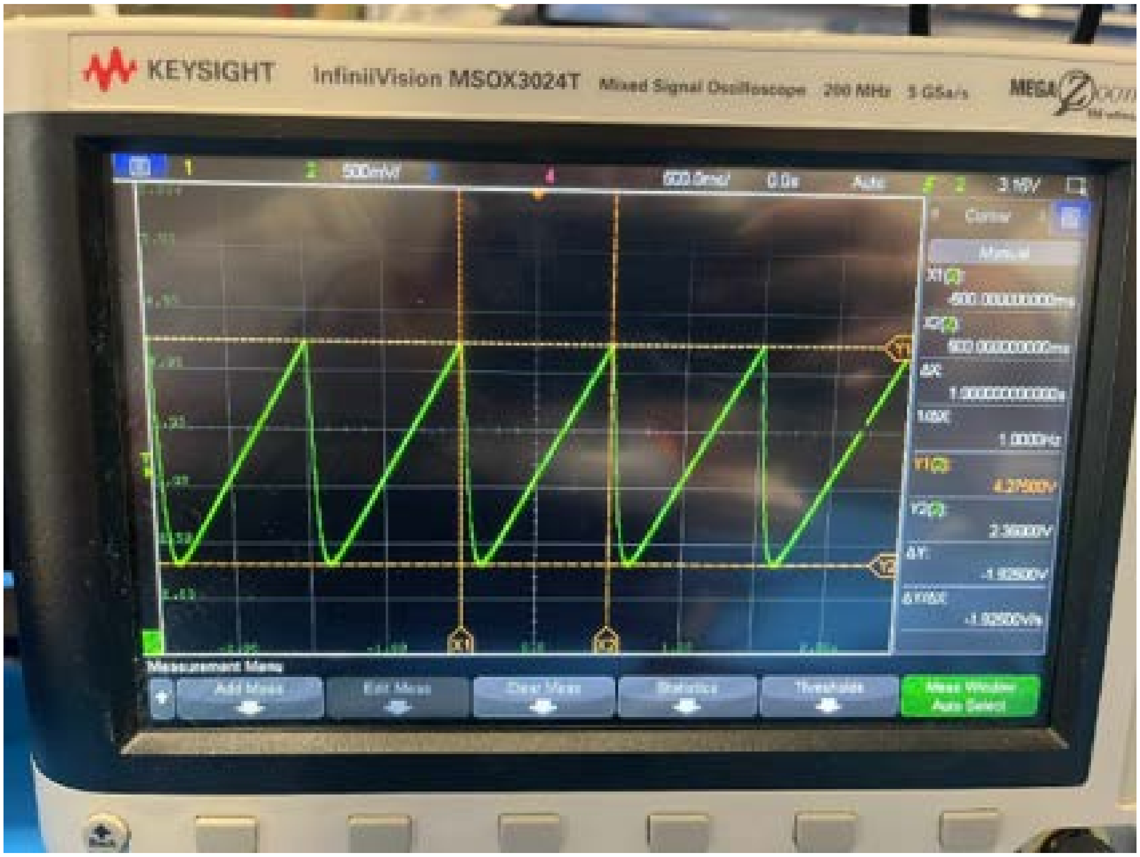
PCB GND = GND from power supply

V- = approx 2.48 V from voltage divider of power supply R1 = R2 = 1kOhm

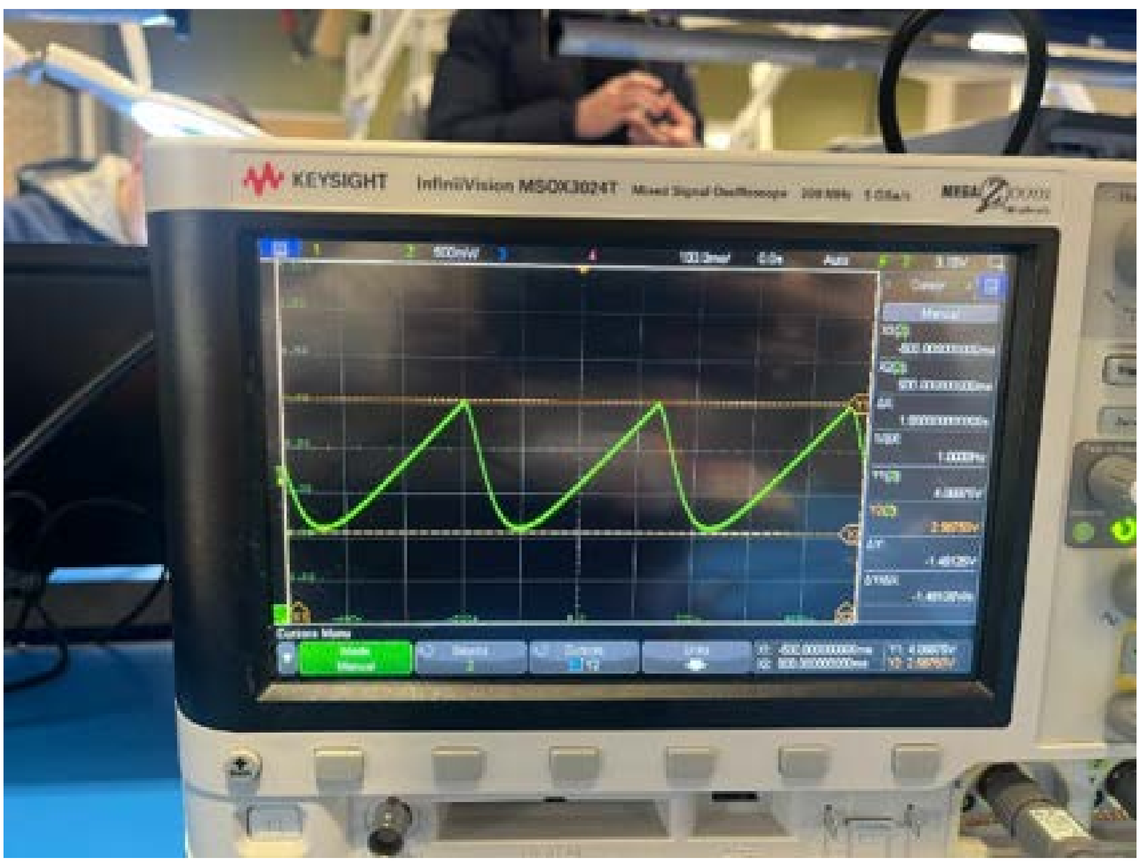
V+ = function generator ramp function varying from 2.48 V to 2.58 V at 1 Hz.

The pk-pk amplitude of V+ is 100 mV because this equates to a 100 lb load on the load cell.

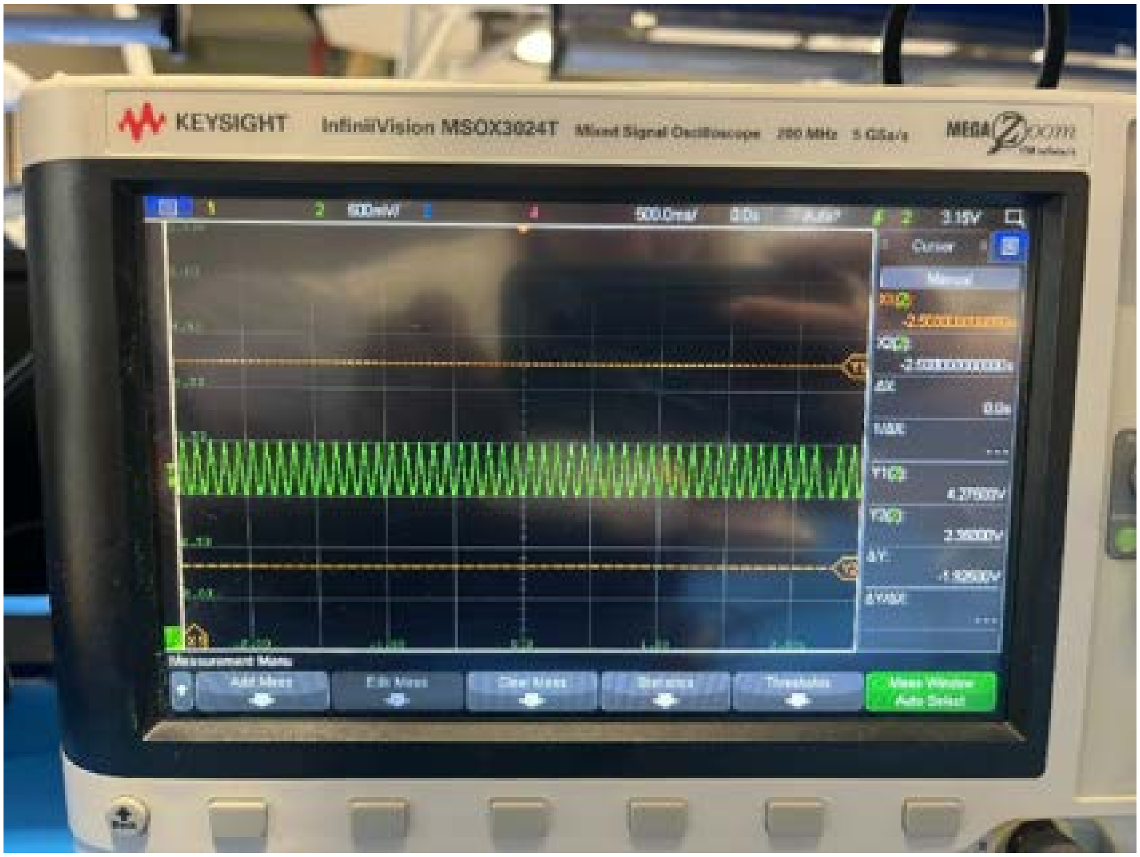
At 1 Hz, the output looks very linear and the pk-pk voltage is 1.925 V. Ideally, this pk-pk voltage would be 2.3 V, but this is still sufficient.



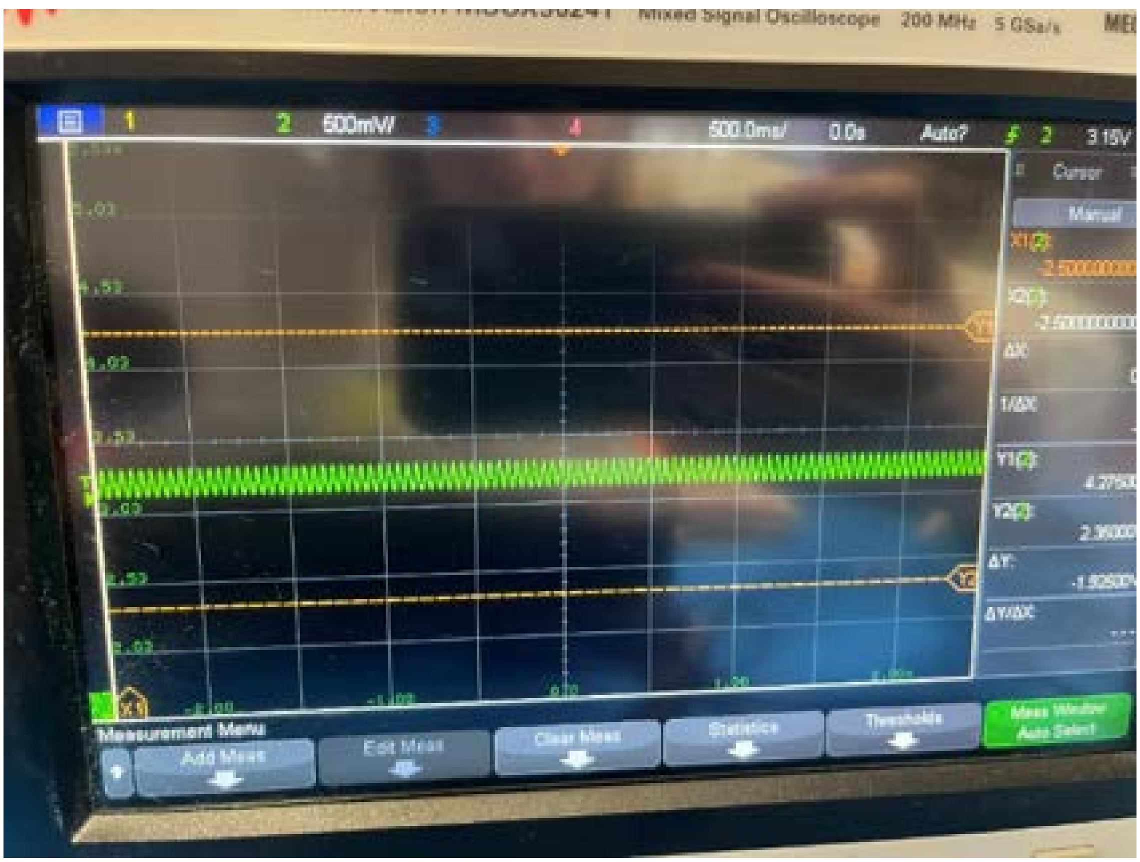
At 3 Hz, the output looks slightly rounded. This is likely due to lag from capacitor charging. I am not too worried about this, but it should be considered as a source of error. It could also be mitigated by decreasing the capacitors of the low pass filters to reduce the time constant.



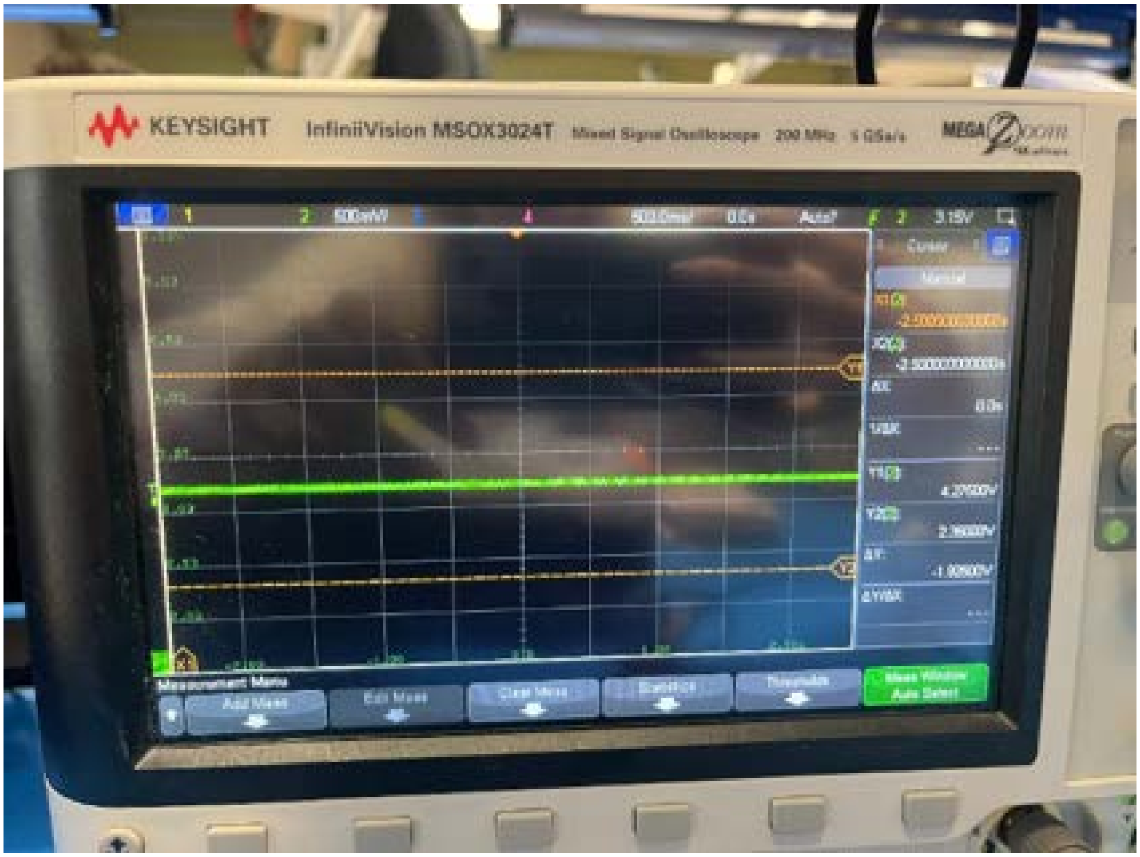
At 10 Hz, the signal is significantly attenuated. The horizontal cursors show the peaks of the ramp at 1 Hz.



At 20 Hz, the signal is even more attenuated.



At 60 Hz, the signal is essentially a flat line.



Conclusions/action items:

The low pass filtering is working very well. The circuit is showing a very linear output at low frequencies. A very change in load could be slightly problematic due to the time constant of the low pass filter, but this could be solved by changing the capacitors. Otherwise, the signal processing done by the PCB amplifier circuit is working correctly.

12/13/2024 - Results

Neha Kulkarni - Dec 13, 2024, 7:45 PM CST

Title: Testing

Date: 12/13/2024

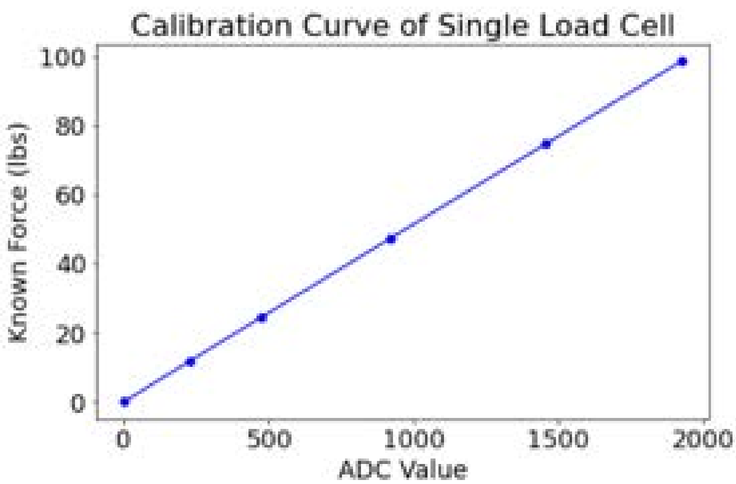
Content by: Team

Present: Team

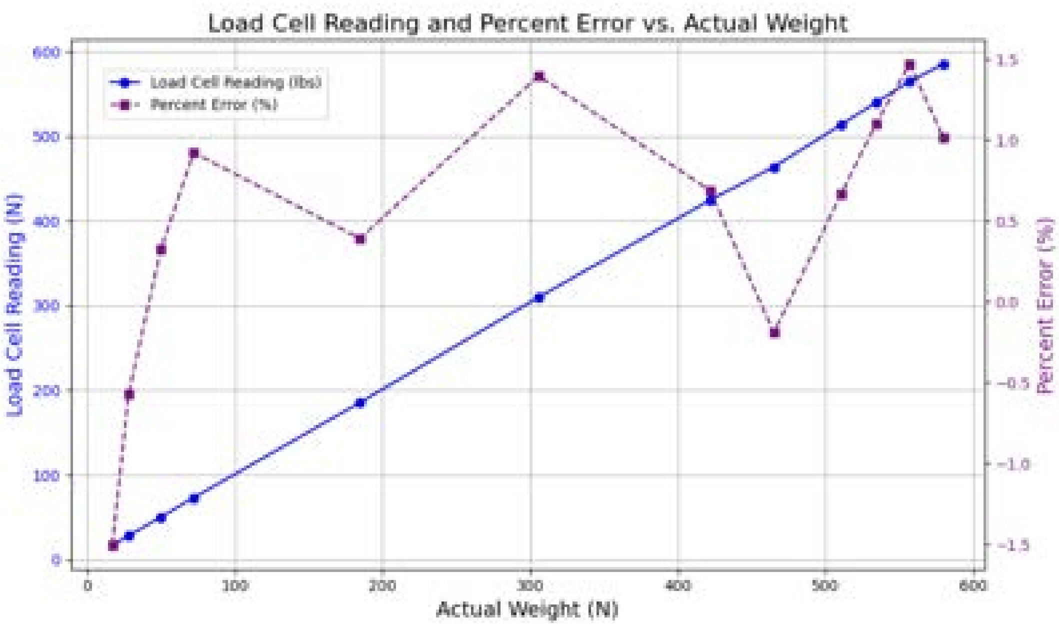
Goals: Analyze data from testing

Content:

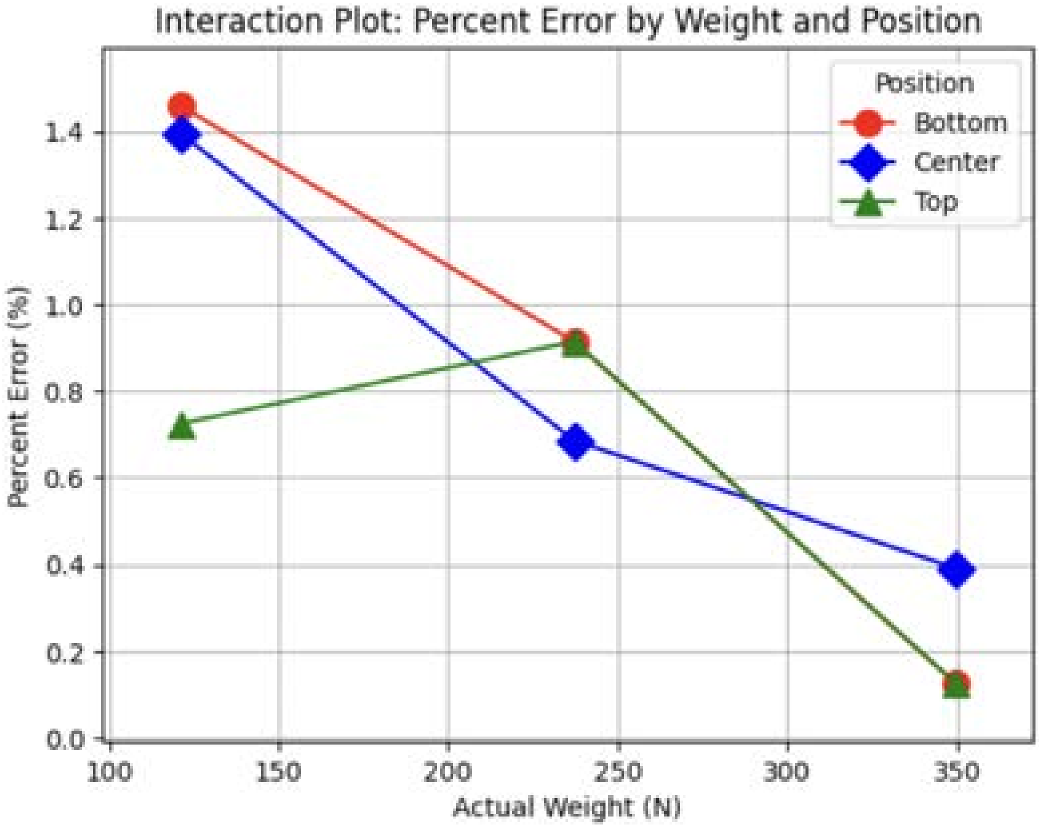
Plotted load vs adc value for each load cell to obtain calibration curve:



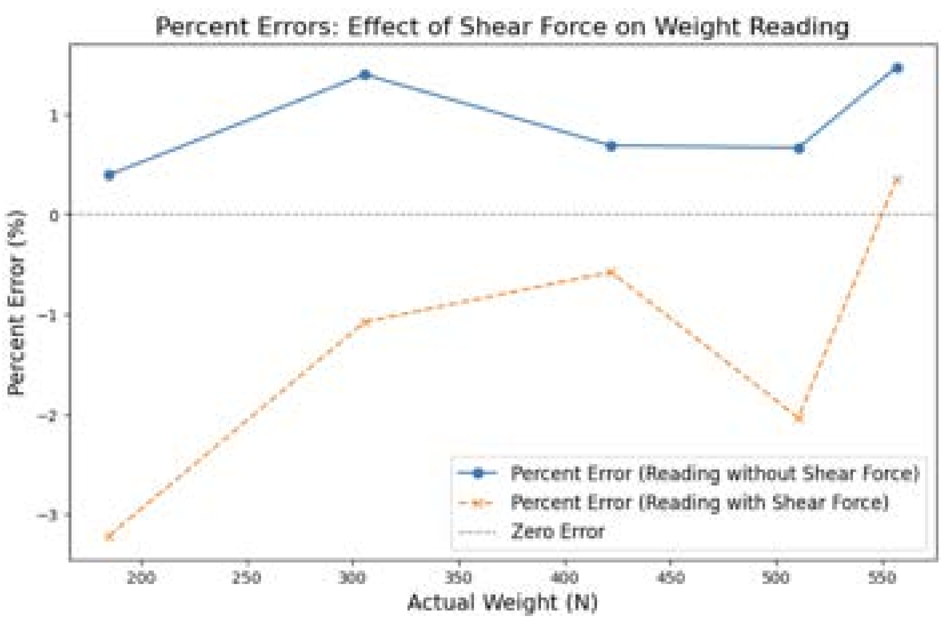
Plotted load cell reading vs actual weight, including % error:



% error vs weight and position:



% error with and without shear:



- stats:
    - p value for load cell readings vs actual weight = 0.49 --> not significant
    - % error was within 5% for all trials --> meets PDS
    - ANOVA p value 0.518 for loading location effects -> not significant
    - p value for for load cell readings vs actual weight with applied shear = 0.0063 --> significant
    - % error with shear within 5% --> meets PDS

Conclusions/action items:

Need more trials to get clearer picture

- need to test with range of shear forces
- need to test with more normal loads
- need to test with dynamic loads

- test on erg vs not on erg
- need to test with rowers

MCP3208 Integration Code

SIMERJOT KAUR - Nov 21, 2024, 7:13 PM CST

Download

MCP3208_Library_Voltage_Reading_Code.py (2 kB)

ALLICIA MOELLER - Nov 22, 2024, 11:18 AM CST

note: ensure baud rate in Thonny micropython code matches the baud rate set for the serial communication in the GUI code. I adapted this code by changing baud rate to 9600.

GUI code

Neha Kulkarni - Nov 25, 2024, 12:59 PM CST

Download

rowing_gui_mainwindow_1_.txt (20 kB)

2024/9/9 - Goal Setting Meeting

ALLICIA MOELLER - Sep 09, 2024, 6:51 PM CDT

Title: Goal Setting Meeting

Date: 9/9/2024

Content by: Allicia

Present: Allicia, Simmi, Emily, Neha, Colin

Goals: To set clear goals for the semester and develop questions to ask our clients.

Content:

End product goal:

- Easily removable device
- Pure force number
- Revisit load cells
  - Cancel out tangential forces
- Revisit pressure sensor insoles
- Have large number of rowers try our product
- Low profile

End of September:

- Demonstrate how the force data will be collected
- Google form of different GUIs to send to rowers

October/November:

- Design and fabricate hardware and mechanical elements

End of semester goal:

- Proof of concept
- Working prototype

Questions for clients:

- What did you like / dislike about last semester's prototype?
- Budget?
- What kind of real-time interface do you want?
- What kind of data do you want to be able to collect?
- Can we see the sunrise? Please, please, please

Conclusions/action items:

Next steps:

- Meet with clients 9/14
- Meet with clients next week

2024/09/17 - Dr. Gruben Preliminary Meeting

Colin Fessenden - Nov 15, 2024, 1:31 PM CST

Title: Dr. Gruben Preliminary Meeting

Date: 9/17/2024

Content by: Allicia

Present: Allicia, Simmi, Emily, Colin, Dr. Gruben

Goals: To get advice from Dr. Gruben on how to implement load cells into our design.

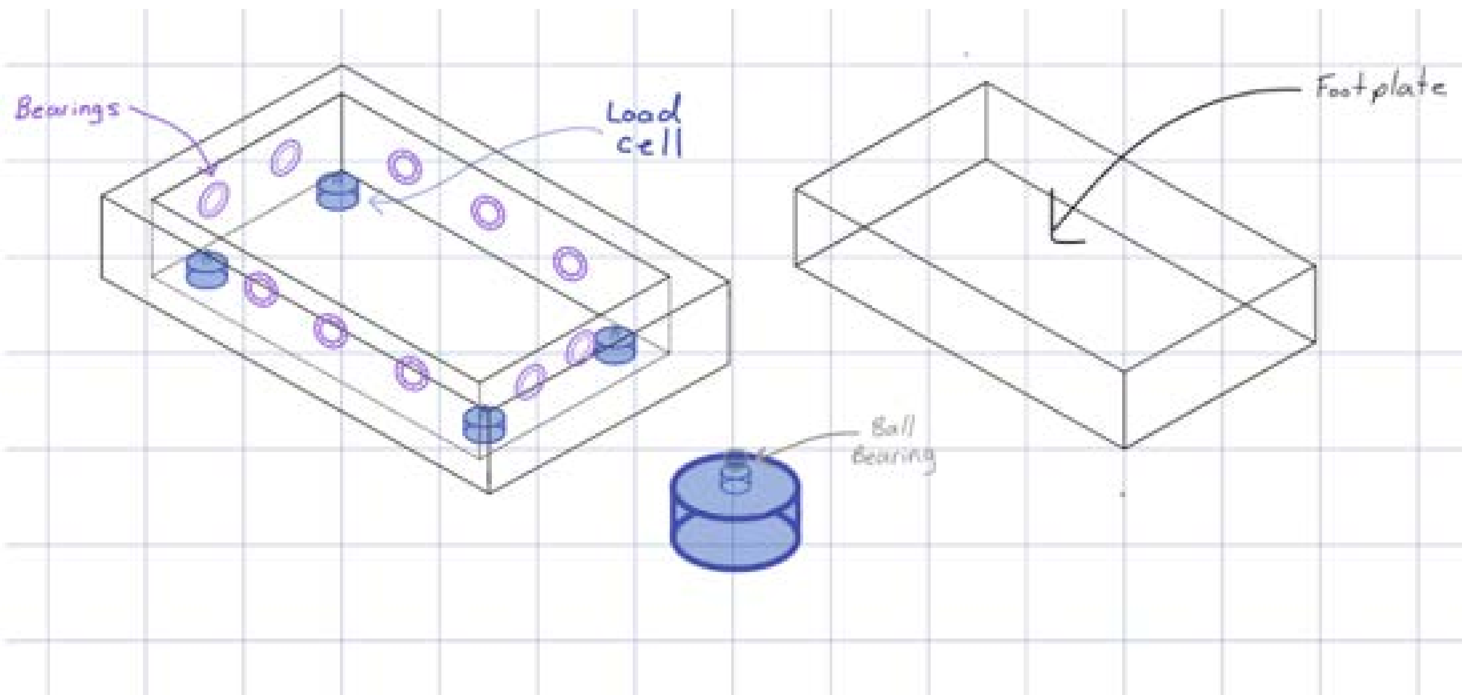
Content:

Why load cells?:

- We would like to revisit the idea of using load cells to make 2 uniaxial force plates to attach to the erg becuase
  - Would provide absolute force data (rather than force difference) which will have important clinical value
  - A static force sensing system would be more comfortable for the rower and more similar to actual rowing/erging (instead of the springs/rotation design)
  - Could be lower profile - less modifications to seat height (clients want to avoid this)

Questions:

- Advice on load cell type? (We're thinking 4 button load cells per plate - 4 corners)
- Is it feasible to shield off tangential forces to reduce off-axis loading of the load cells
  - Best method to do this? bearings? Put the plate on a track? clamping?
- Recommendations on load cell suppliers?
- Explanation of his triaxial force plate with the 18 sensors.
- How cheap can our load cells be?
- Can we test out multiple "force shielding enclosures" or will that cause too much damage to load cell? Will it be obvious if a load cell is damaged?
  - How to determine safe load capacity?
- Considerations when mounting a force plate on an angled surface like the footplate on the erg?
  - Will how we mount it to the erg affect accuracy?



Meeting Notes:

- It's important to recognize that we are isolating the normal component of the force -

-triple axis load cell budget constraint

-This design would inform COP (based on distribution)

- Button load cells are good for this application - $15

- "Measurement specialties" - TE Connectivity - $30 - some come with amplifiers

- building amplification is doable

- could add a (1/4") gap between walls of the footplate and the "shell" - cover entire top with fabric (membrane)

- important to cover and protect the bearings

- could also put springs in the gap (may be too much movement)

- mounting ball bearings: take a piece of foam, punch a hole in it, glue foam to underside of footplate

- capacity for load cells: force from rowers legs can go up to 200lb - load cells have overload capacity - find a load cell that can be protected from max force with overload capacity - lower capacity = better precision

Conclusions/action items:

- Research TE Connectivity load cells

- Make design matrix for enclosure designs

2024/09/24 - Group Meeting Matrix Brainstorming

ALLICIA MOELLER - Sep 24, 2024, 6:43 PM CDT

Title: Group Meeting Matrix Brainstorming

Date: 9/24/2024

Content by: Allicia

Present: Emily, Simmi, Neha, Colin

Goals: Make decisions on our design matrix and decide criteria.

Content:

Neha - made 6 GUI and a form to get feedback on them - nixing the

Neha - design matrix for GUI - absolute force bars, absolute force lines, force different vertical bar, force difference vertical line

Criteria for GUI design matrix:

- aesthetics - visually pleasing
- interpretability - clarity of information, simplicity
- speed of comprehension
- relevance of data
- display use case - is it adaptable to different formats

Force plate design matrix:

- Stationary force plates
- Membrane-bound force plate
- Bearing force plate

Criteria brainstorming:

- Reliability = accuracy and repeatability (off-axis loading)
- Maintenance = how often we would have to repair or recalibrate
- Cost
- Ease of fabrication
- Ergonomics - does it impede the rowers form

Conclusions/action items:

2014/10/10 - Dr. Gruben Meeting 2

ALLICIA MOELLER - Oct 10, 2024, 2:36 PM CDT

Title: Dr. Gruben Meeting 2

Date: 10/10/2024

Content by: Allicia

Present: Allicia, Simmi, Emily, Neha, Dr. Gruben

Goals: To gain insights from Dr. Gruben on load cell mounting, calibration, and circuitry.

Content:

- Load cell mounting:
  - How to attach top plate to load cells - my need more than plate divots because of incline of foot strecher
  - Ideas: squishy foam to go in between and adhere to
  - Clamping top and bottom together - would this interfere with load cell reading or can it be zeroed out?
    - small amount of movement between plates will change force in the clamp (we need near constant force - low spring constant)
  - Foam with large area could provide more force
  - Tensile springs - would hole the plates together and pre-load force sensors
  - Could route the force with a pulley to include a larger spring
  - Could do this with just one spring

- Calibration:
  - Could we find the linear (force/mV) constant for each individual load cell after the plate is assembled with a system of equations?

aV1 + bV2 + cV3 + dV4 = known weight_1

aV1 + bV2 + cV3 + dV4 = known weight_2

aV1 + bV2 + cV3 + dV4 = known weight_3

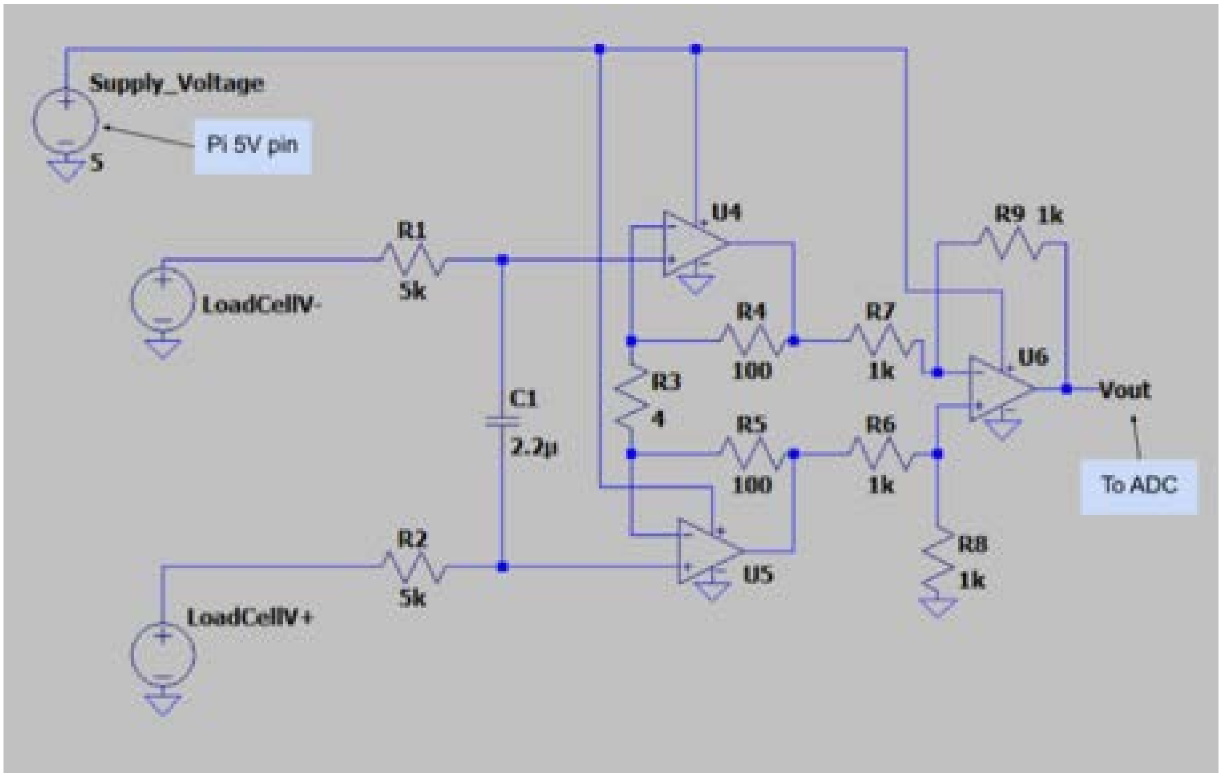
aV1 + bV2 + cV3 + dV4 = known weight_4

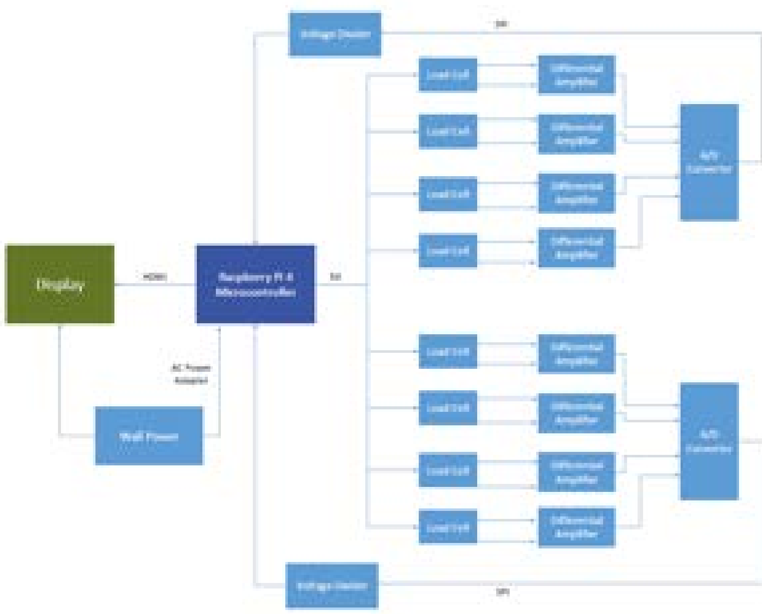
Solve for a,b,c,d

- Should do more than 4 weights - could do an optimization

- Dr. Gruben has calibrated weights and platform for weighing

- Circuitry:
  - Current plan:
    - Design our own circuit and solder components together on perf board
    - Alternative plan: design and order PCBs
  - Watch for ground loops - tie everything back to ground in one place

- 

- 

Conclusions/action items:

- Tensile spring is an ideal solution for our mounting/pre-loading issue. To save vertical space we could mount it sideways with a pulley.

- Circuit should work fine with a soldered perf-board, just be mindful of ground loops

- Gruben has calibrated weights and weighing platform if we want to calibrate our load cells individually.

2024/10/16 - TeamLab Design Consult

ALLICIA MOELLER - Oct 16, 2024, 9:59 PM CDT

Title: Meeting with Jesse from the Team Lab

Date: 10/16/2024

Content by: Emily

Present: Allicia, Simmi, Emily, Colin

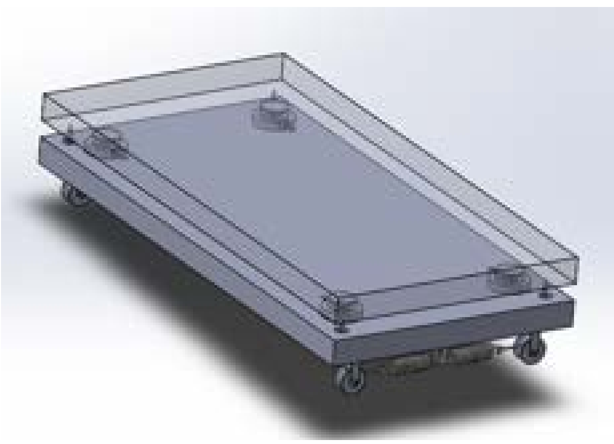
Goals: To help brainstorm footplate design plans with fabrication in mind.

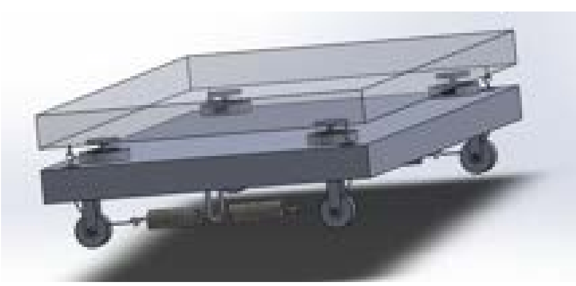
Content:

- The team scheduled a meeting with the team lab for a design consult

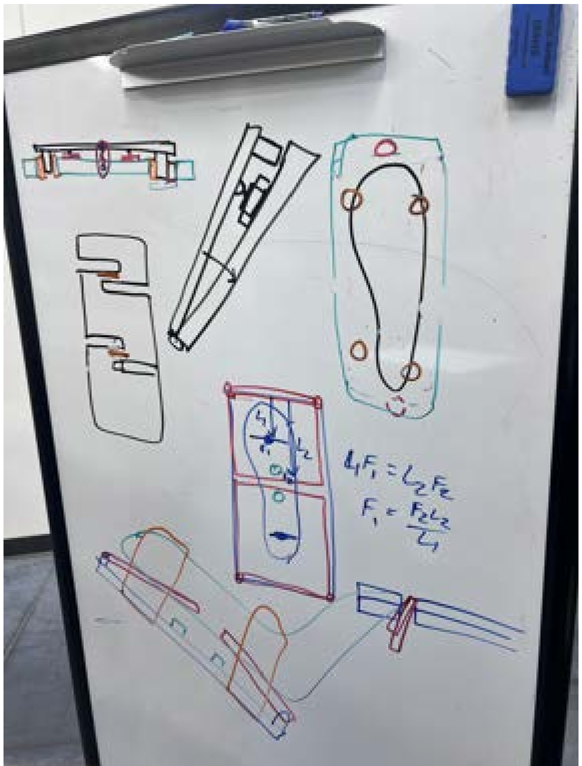
- We explained our footplate ideas to Jesse from the team lab, who helped give us feedback and new ideas

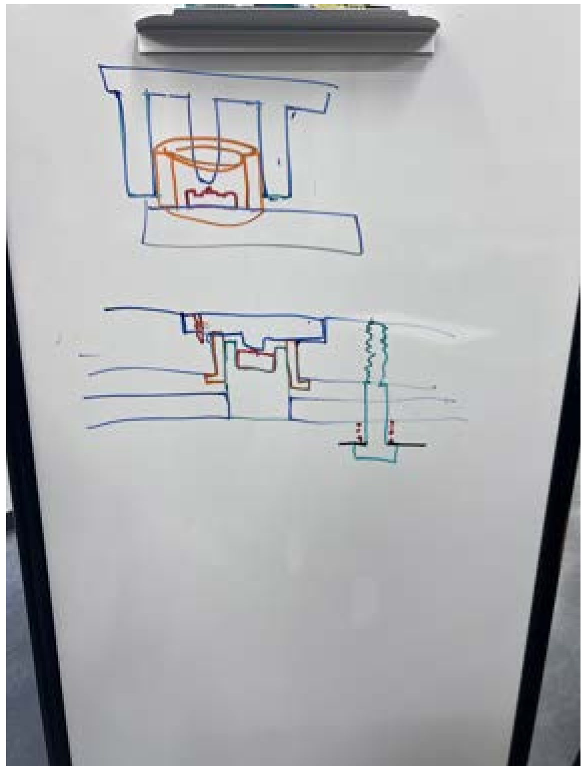
- We explained our need to shield off shearing components from the load cells, and our need to pre-load the load cells. We showed him the following spring-pulley pre-loading mechanism:

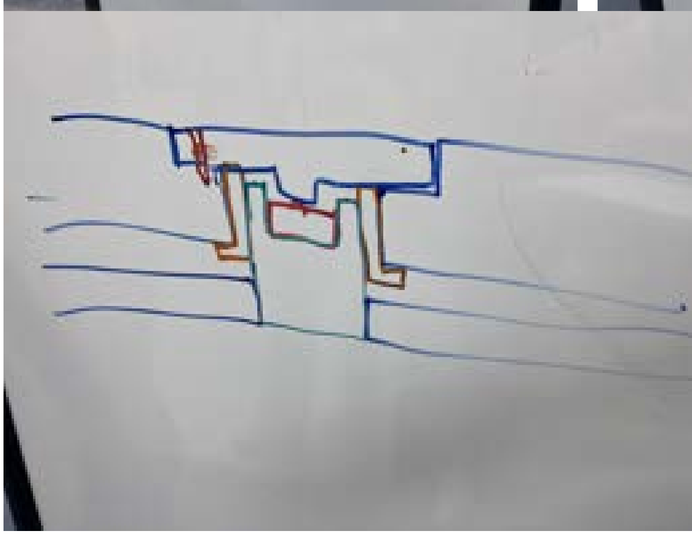




- We went through a couple ideas as shown in these pictures:







Our biggest takeaway was the suggestion of using sleeve bearings to help with the plates vertical movement and sheer forces

- As the top plate presses down, pegs from the top slide through the bearings. A screw and spring on the sides holds the plates together compressively.

- The bearing could either go around the load cell fixture or on the sides of the plate.

- Told us to use bronze bearings, possibly order from the site Igus

ex) https://www.igus.com/product/93?artNr=ZFM-2528-11

- we could use derin on the peg for the load cell if wanted frictionally

- a 0.5' diameter bearing should be thick enough to support if we put the bearings on the outside, otherwise we have to find a bearing larger than the load cell diameter

- a shoulder screw could be used instead of a press fit pin to keep the plates together, with the bearing around the shoulder part.

ex of bearings and shoulder screws)

https://www.mcmaster.com/products/bearings/plain-bearings~/high-load-dry-running-sleeve-bearings/

https://www.mcmaster.com/products/shoulder-bolts/shoulder-screws~/18-8-stainless-steel-shoulder-screws-10/

- if we were to get a 3/8" inner diameter of the bearing, then we'd find a long screw also with a shoulder diameter of 3/8"

Conclusion:

Order one of each to test out

Create a fabrication plan

2024/11/1 - Show and Tell

EMILY WADZINSKI - Nov 25, 2024, 3:11 PM CST

Title: Show and Tell Notes

Date: 11/1/2024

Content by: All

Present: All

Goals: Ask our fellow peers current questions about our prototype

Content:

- We presented our acrylic prototype and asked how we could make the bearings more frictionless, as the plates were not sliding smoothly.

- The main answer we got was to lubricated the bearings with WD-40.

- We also showed a part of our circuit with one load cell with questions on amplification and reducing noise - one person advised us to add decoupling capacitors

- General feedback liked our GUI designs

- Our client attended and Dr. Bell

Conclusion:

Try adding the capacitors to our circuit

2024/11/13 - TeamLab Fabrication Consult

EMILY WADZINSKI - Nov 25, 2024, 3:05 PM CST

Title: Fee-For-Service Fabrication

Date: 11/13/2024

Content by: Emily, Allicia

Present: Allicia, Emily, Colin

Goals: Get a quote from Jesse and ask some design questions

Content:

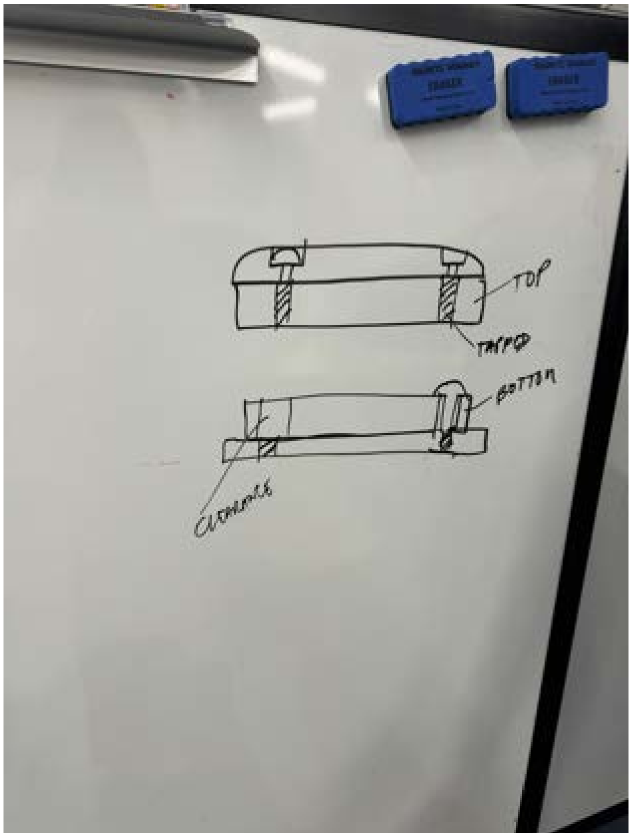
- We presented the newest iteration of our design based on the acrylic prototype, plus the holes for footplate mounting

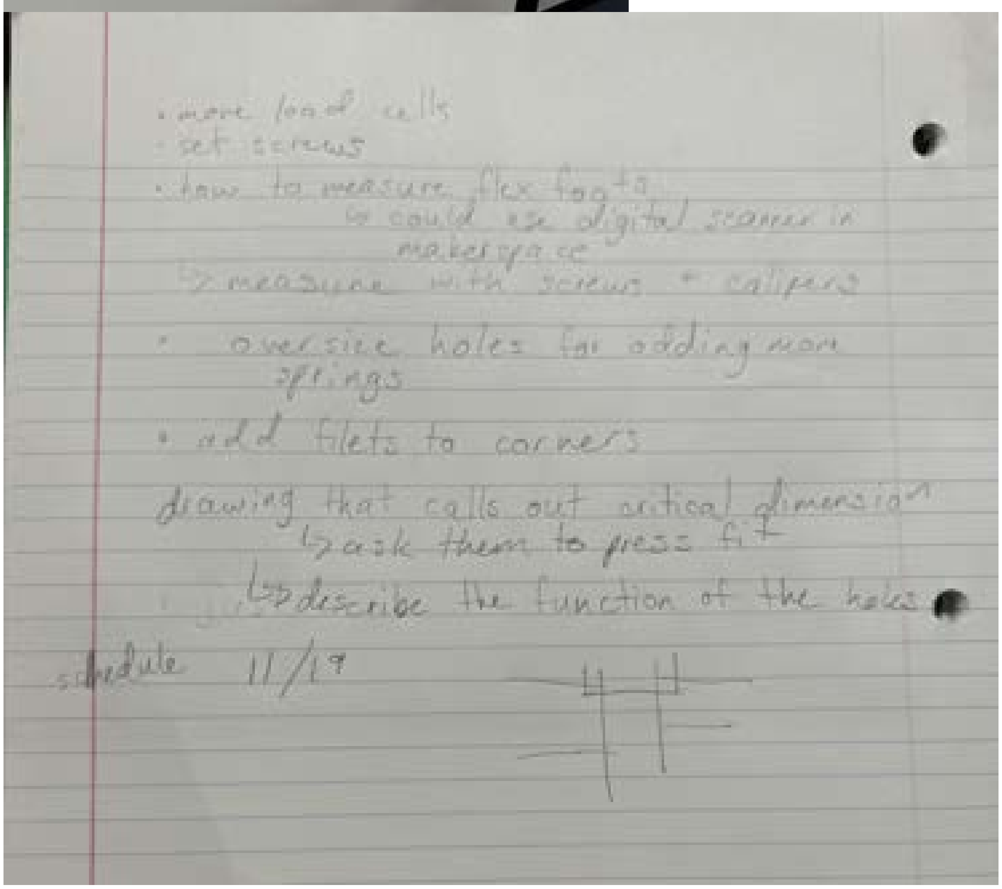
- We asked a few design questions about the number of shoulder screws and simplified our design down to two per plate.

- Allicia took notes

- We scheduled our fabrication for Tuesday, 11/19

- Jesse quoted us for about 2 hours, and it is $75/hr





Conclusion:

Make edits to the SolidWorks design based on what Jesse said - submit our parts/drawings to the shop by Tuesday.

2024/09/12 - Off-Axis Loading

ALLICIA MOELLER - Sep 12, 2024, 6:53 PM CDT

Title: Off-Axis Loading

Date: 09/12/2024

Content by: Allicia

Goals: To better understand off-axis loading and how to mitigate it in load cells.

Citation:

[1] "Off-Axis Loads - Guide To Calculating Side Loads | FUTEK." Accessed: Sep. 12, 2024. [Online]. Available: https://www.futek.com/guide-to-calculating-extraneous-loads

Content:

- Load cells are sensitive to extraneous loads and moments (loads and moments not aligned with the primary axis of the load cell)

- Can damage the load cell
- Can cause inaccurate measurements

- FUTEK Load Cells come with an extraneous loads coeffiients table to determine if the load cell is suitable for different combinations of extraneous loads.

$\sigma max \geq (A)|Fx| + (B)|Fy| + (C)|Fz| + (D)|Mx| + (E)|My| + (F)|Mz|$

- Total stress (axial, torsional, bending, shear) is added with the coefficients from the table, and if the total is less than absolute stress, the load cell can be used for that application.
- Important note: the ultimate fatigue stress is lower than the ultimate static stress. Because rowing is cyclic in nature, we should use the fatigue stress to calculate max strength.

Notes:

- Some load cells advertise "Moment compensation" -> look further into this

Conclusions/action items:

Some load cells are designed to accept off-axis loads. We need to do more research on if there is a load cell with such design in our price range. Otherwise, we need to research how to mechanically shield off extraneous loads and moments.

2024/09/19 - Rowing Kinetics Concept2

ALLICIA MOELLER - Se

Title: Rowing Kinetics Concept2

Date: 9/19/2024

Content by: Allicia

Goals: To learn more about the forces involved in the motion of rowing

Citation:

[1] N. Découfour, F. Barbier, P. Pudlo, P. Gorce, and M. Estivalet, "Forces Applied on Rowing Ergometer Concept2®: a Kinetic Approach for Development (P94)," 2008, pp. 483–490. doi: 10.100

Content:

- The purpose of this study was to optimize the design of a rowing ergometer.
- There are 4 points of contact on the rower: the handle, the seat, and the two foot stretchers
- A mono-directional sensor is used on the handle, and 6-axis force plates were placed under the seat and the two foot stretchers.

2.1.1 Measured and calculated data

a) Kinematics:

- Handle and seat anteroposterior amplitude movements
- Handle: velocity and acceleration allowable (propulsion & recovery)

b) External forces (propulsion & recovery):

- Handle force in 3D space
- Seat forces (medio-lateral (M/L), Anteroposterior (A/P), Vertical (V)).
- Right foot stretcher forces (M/L, A/P, V).
- Centre of mass (CoM) trajectory in sagittal plane of all rower body segments.

-
- Weight capacity of force plates used: 5500 N for M/L and A/P components, 21000 N for the V component. Peak force recorded was 900N.
- External force of foot stretcher:
  - The foot stretchers must absorb the pushing force of the rower during the drive phase, as well as pulling force during the recovery phase\
  - Forces were componentizes into M/L (medio-lateral), A/P (anterior/posterior), and vertical.
  - During the first 50% of the propulsion phase, the vertical force stays relatively constant, while the A/P force doubles. During the recovery phase, the A/P force and vertical force dip negative region then rise (force becomes tensile).

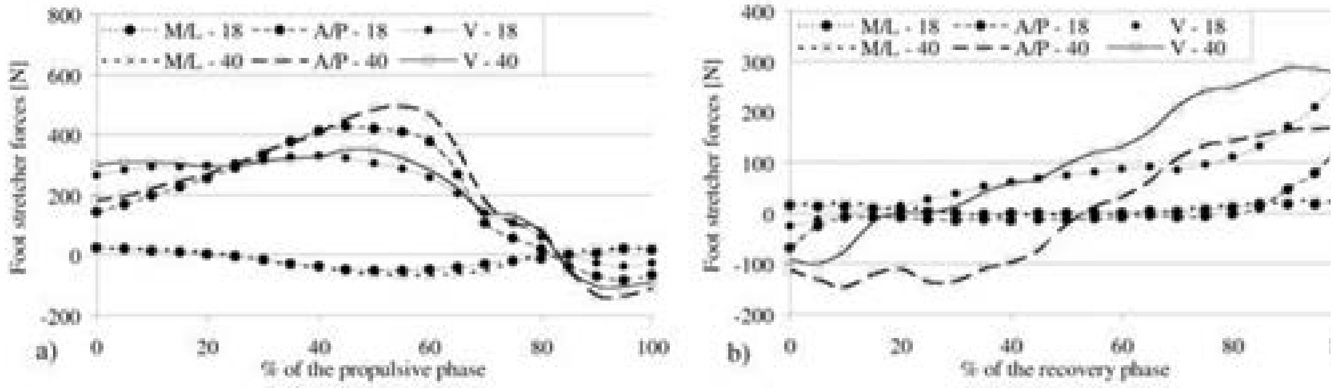


Figure 5 - Force measured under the right foot stretcher during propulsion (a) and reco
(b) rowing phase.

Conclusions/action items:

- Discussion:
  - This research article basically accomplished our ideal scenario (a tri-axis force sensing system under both foot stretchers). The anterior/posterior force graph shows that there is a significant data to be captured along that axis. If we want to go forward with our plan of isolating the vertical force, we need to make it clear to our clients that they will not see the fı of the force applied by the feet.
  - Right now we are planning to buy purely compressive load cells, which will 0 out instead of going negative. This should also be made clear to the clients before purchasing these lo
  - Furthermore, we need to ensure that our enclosure can shield off 500 N of force in the A/P direction.

ALLICIA MOELLER - Sep 19, 2024, 7:10 PM CDT


Forces Applied on Rowing Ergometer Concept2®: a Kinetic Approach for Development (P94)

1- Introduction

Download

Biomechanics_2008_01.pdf (271 kB)

2024/10/8 - Meeting with John

ALLICIA MOELLER - Oct 08, 2024, 2:43 PM CDT

Title: Meeting with John Lombardo

Date: 10/8

Content by: Allicia

Present: Allicia, Simmi, John Lombardo (MakerSpace EE employee)

Goals: To consult John on our circuit, ask for feedback.

Content:

- We showed John our proposed circuit, which includes the rpi providing a 5V power supply to each load cell, then each load cell being fed into a differential amplifier, then into 2 separate multi-channel ADCs and back to the rpi
- First, John suggested we look at OTS load cell amplifiers, but after we explained our limitations of cost and sample rate, we agreed making our own circuitry was a good idea
- He suggested looking into dual amplifier ADC modules with programmable gain, but we have not yet found one with either a high enough sample rate (looking for 100 Hz) or a high enough gain (looking for 50 V/V).
    - Looked at ADS1115
    - Looked at ADS1287D
- Then, John suggested we look into designing our own PCBs for the project
    - JLCPCB is a common PCB manufacturer - have to order at least 5 boards
    - Osh Park is another PCB manufacturer
- We are still open to the idea of finding a dual amplifier/ADC

Conclusions/action items:

- Plan for circuitry: Make a protoboard of an amplifier for 1 load cell - see how reliable it is, how significant noise is - then consider scaling up to a PCB

2024/09/19 - Load Cell Amplification Circuitry

ALLICIA MOELLER - Sep 19, 2024, 6:49 PM CDT

Title: Load Cell Amplification Circuitry

Date: 9/19/2024

Content by: Allicia

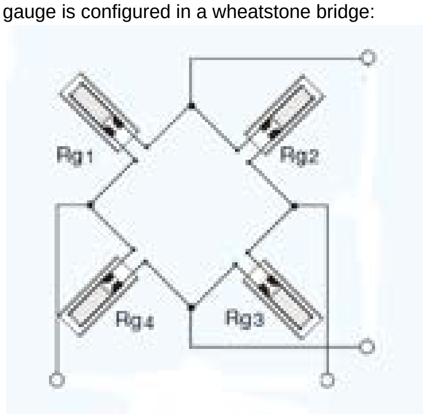
Goals: To research load cell amplification circuitry

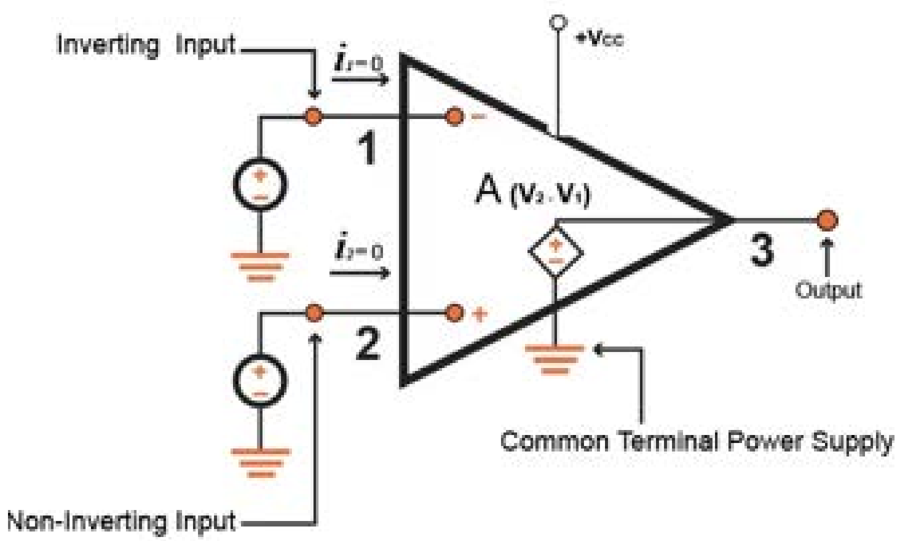
Link: https://predictabledesigns.com/introduction-to-load-cell-conditioning-circuits/

Citation:

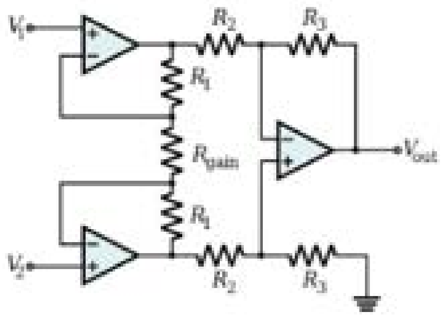
[1] J. Teel, "Introduction to Load Cell Conditioning Circuits," PREDICTABLE DESIGNS. Accessed: Sep. 19, 2024. [Online]. Available: https://predictabledesigns.com/introduction-to-load-cell-conditioning-circuits/

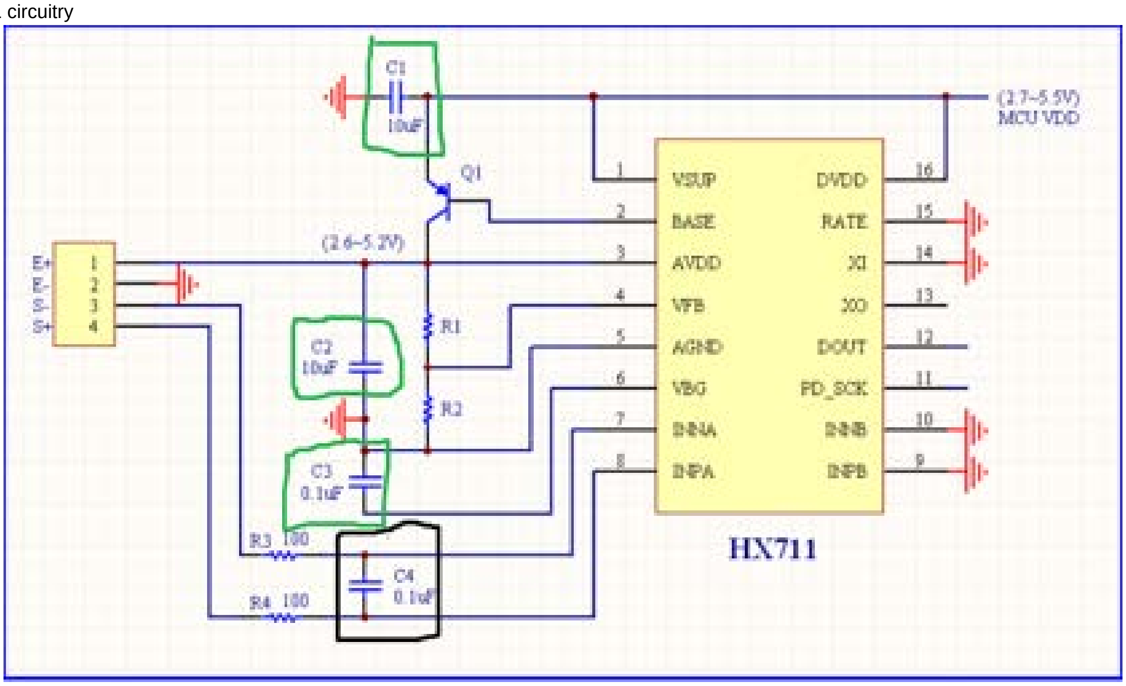
Content:

- Load cell is strain gauge device that converts a mechanical force into an electrical signal
- Strain gauge is configured in a wheatstone bridge:
  - 

- Sensitivity is typically in units of mV/V where the maximum output voltage is the excitation voltage.
- Amplification:
  - The output of the load cell is usually small (on the order of mV) and requires amplification for higher resolution
  - Typical differential amplifier circuit:
  - 

  - "The most efficient type of amplifier to use for the load cell's output signal is the instrumentation amplifier due to its large common-mode rejection ratio, high open-loop gain, low noise, low drift, very low DC-offset and very high input impedances."



- Filtering
    - Filtering removes unwanted noise from the output signal
    - Typically, a low pass filter is implemented into load cell circuitry to attenuate unwanted high frequencies
    - HX711 circuitry
        - 

        - Capacitors have low impedance at high frequencies, so the wires joined together by capacitors are essentially shorted at high frequencies
        - C4 acts as a differential filter because high frequencies present on lines 7 and 8 are shorted, showing no difference in voltage (signal is attenuated).
        - The capacitors in the green boxes provide a stable, noise-free power supply by shorting any high frequencies to ground.

Conclusions/action items:

- Design an amplifier circuit for the 8 load cells we are planning to use in our load cell design
- Research the role of the transistor (Q1) in the HX711 circuit.

2024/09/26 - Design Matrix Drawings

ALLICIA MOELLER - Sep 26, 2024, 3:43 PM CDT

Title: Design Matrix Drawings

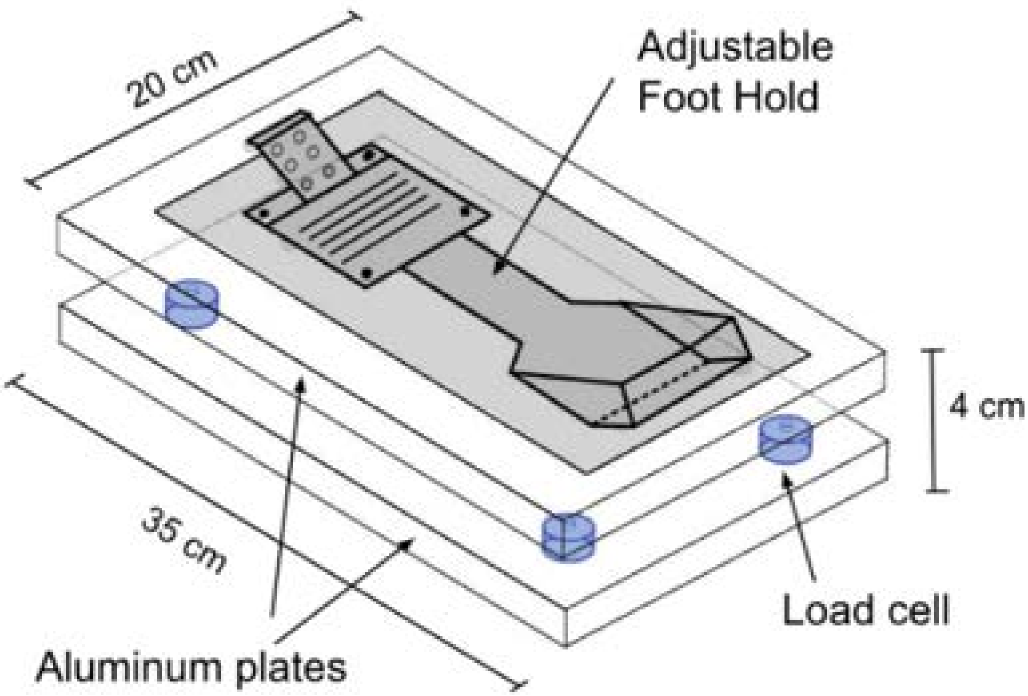
Date: 9/26/2024

Content by: Allicia

Goals: To illustrate our three designs for the design matrix.

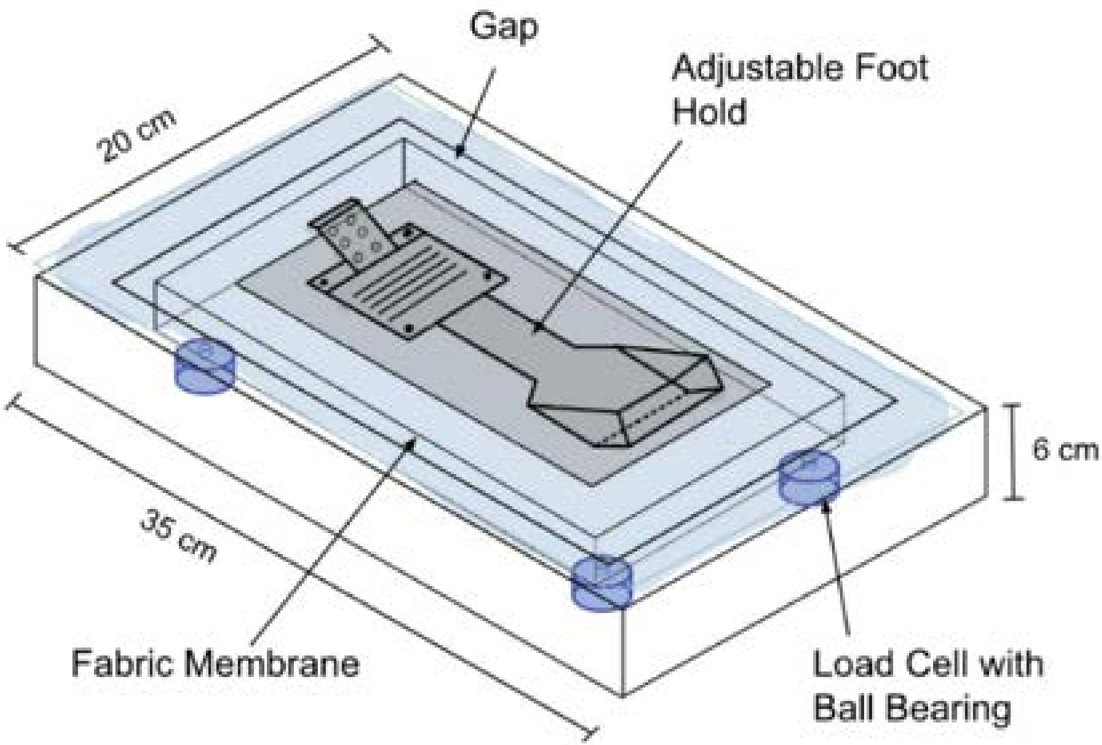
Content:

Stationary force plate:



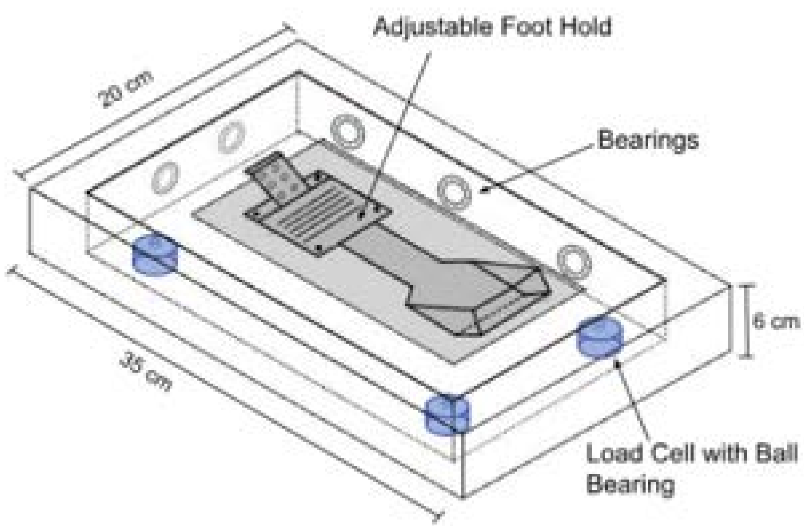
- 4 100 lb load cells mounted between 2 aluminum plates
- One force plate per foot, mounted to ergometer

Membrane-Bound Force Plate



- 4 100lb load cells mounted to the base of an aluminum enclosure
- footplate on top of load cells separated by ball bearings
- Gap between footplate and enclosure is sealed by a fabric membrane which counteracts shearing forces.

Bearing-guided Force Plate



- 4 100 lb load cells mounted on aluminum enclosure
- Footplate is mounted on top of load cells separated by ball bearings
- Bearings line the contact between the side walls of the footplate and enclosure walls to reduce friction in the z direction

Conclusions/action items:

- Build design matrix

2024/10/10 - Load Cell Circuit Schematic

ALLICIA MOELLER - Oct 10, 2024, 3:03 PM CDT

Title: Load Cell Differential Amplifier Circuit

Date: 10/10/2024

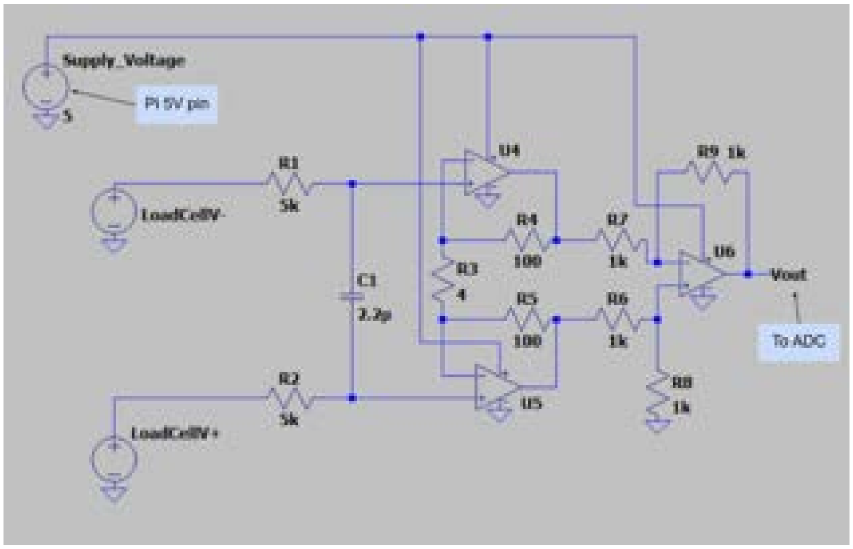
Content by: Allicia

Goals: To design a circuit to filter, buffer, and subtract the two outputs of the load cell.

Content:

In order to save costs on our project, we are opting to build our own circuitry instead of buying an off-the-shelf load cell amplifying - especially considering we need 8 amplifiers!

The schematic below shows a differential voltage amplifier with a gain of 51. There is also a LP differential filter with a cutoff frequency of about 7.5 Hz (see LTSpice bode plot below).



cutoff frequency = 1/(2*pi*2*R*C)

R = 5 kOhms

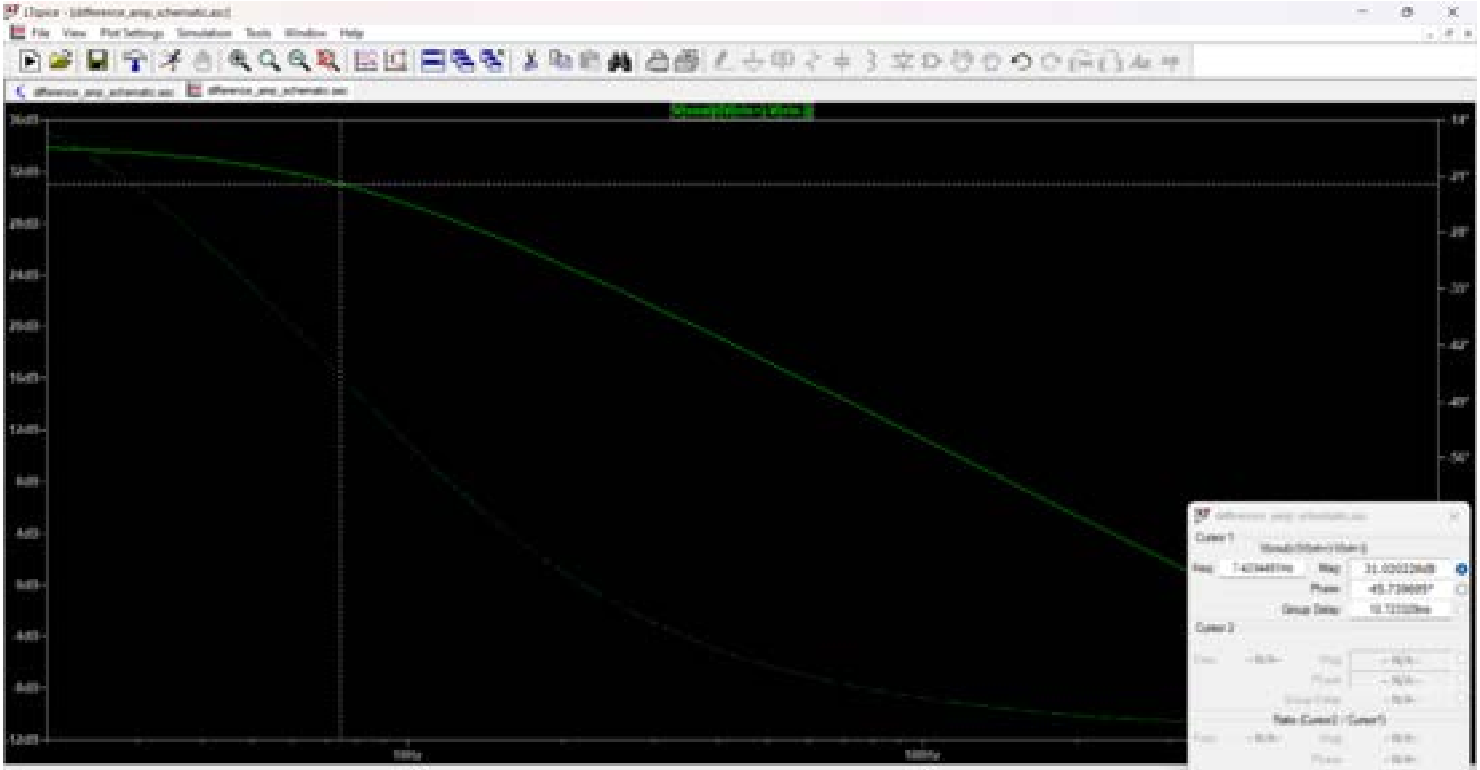
C = 2.2 microFarads

cutoff frequency = 7.235 Hz

gain = (1 + 2*R4/R3) = 1 + 2*100/4 = 51

where R4=R5, R6=R9=R7=R8

gain in dB= 20log(51) = 34.151 dB (see Bode plot at low freq)



Conclusions/action items:

Build up this circuit on a perfboard and solder headers to it for the 4 load cell wires, power, GND, and output for load cell calibration. Decide if we want a higher cutoff freq.

2024/10/15 - CAD Plates with Fixtures

ALLICIA MOELLER - Oct 15, 2024, 9:44 AM CDT

Title: CAD Plates with Fixtures

Date: 10/15/2024

Content by: Allicia

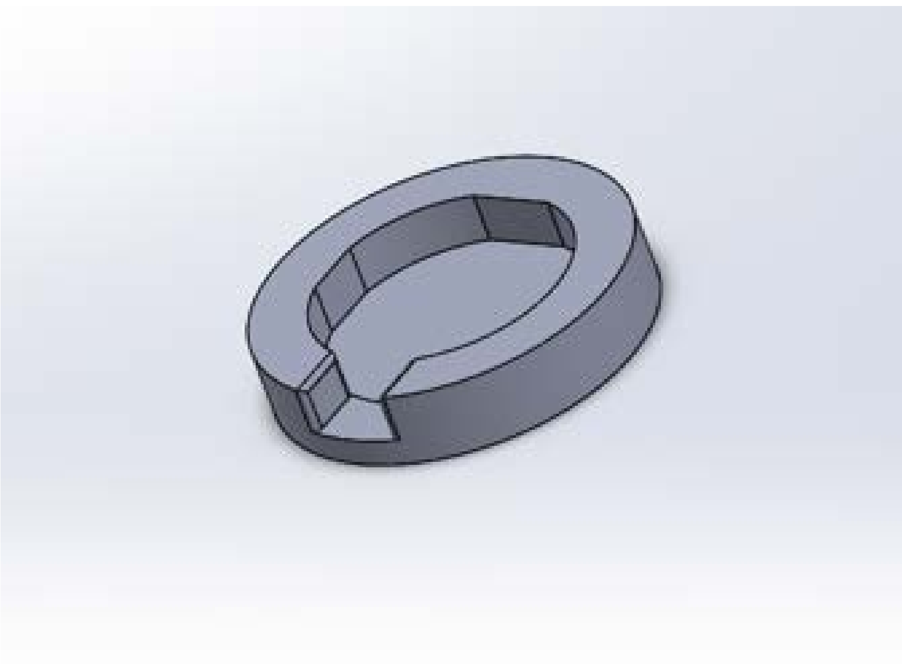
Goals: To make a CAD model describing the fixturing of the load cells to the plates.

Content:

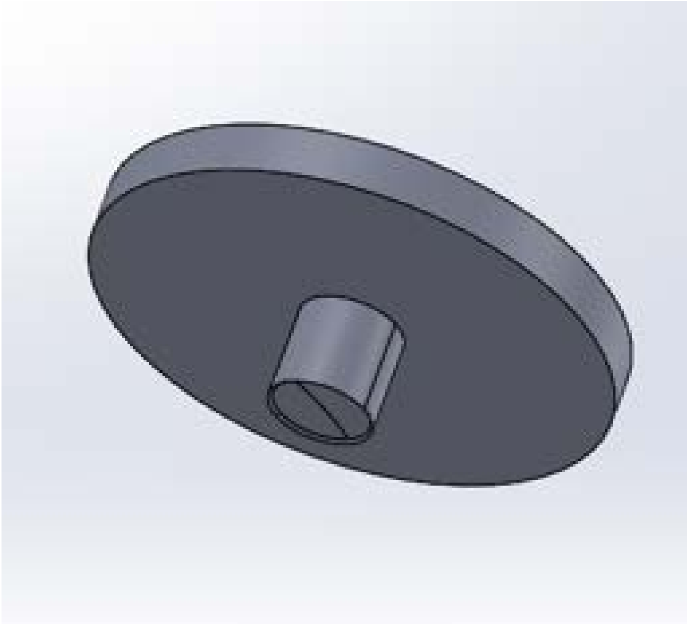
- After discussing with the team, we decided it would make sense to add 2 new components to our design:

1. 4 fixtures to hold the load cells (glue load cells to the base of the fixture) with tapped holes to attach to the bottom plate.

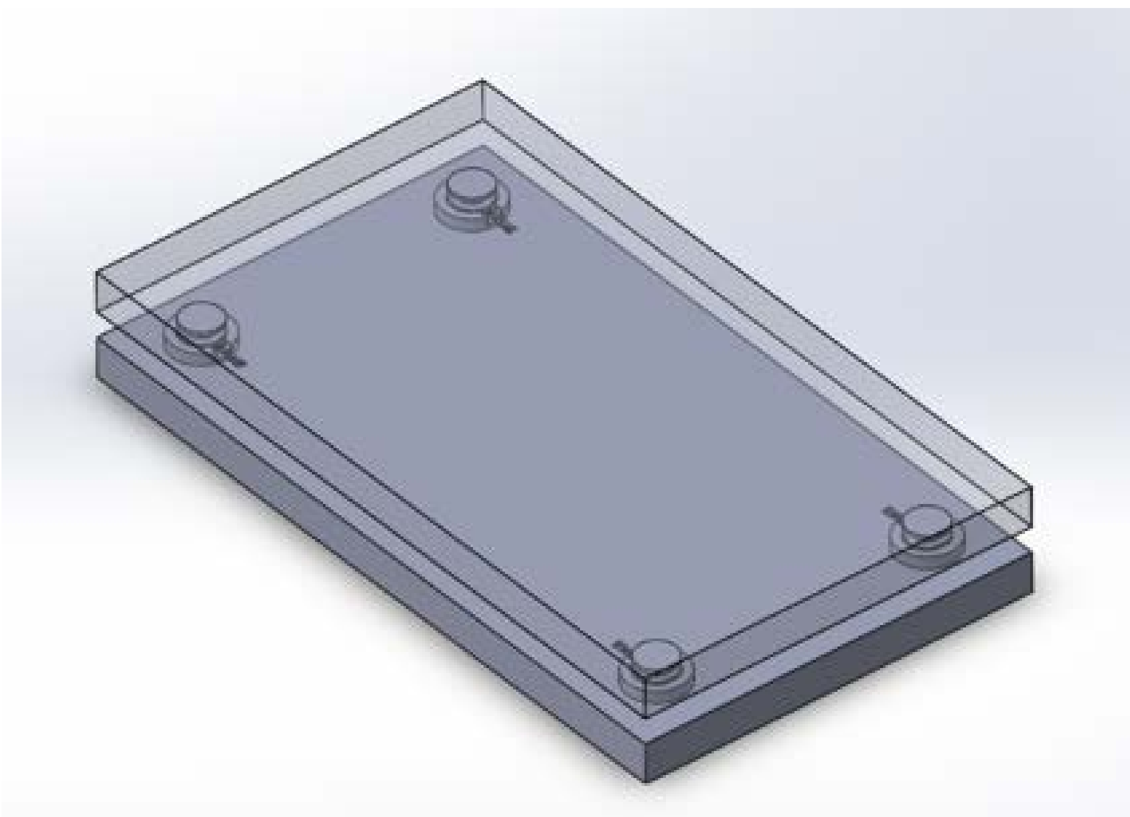
We would fabricate these out of aluminum (likely on the mill)



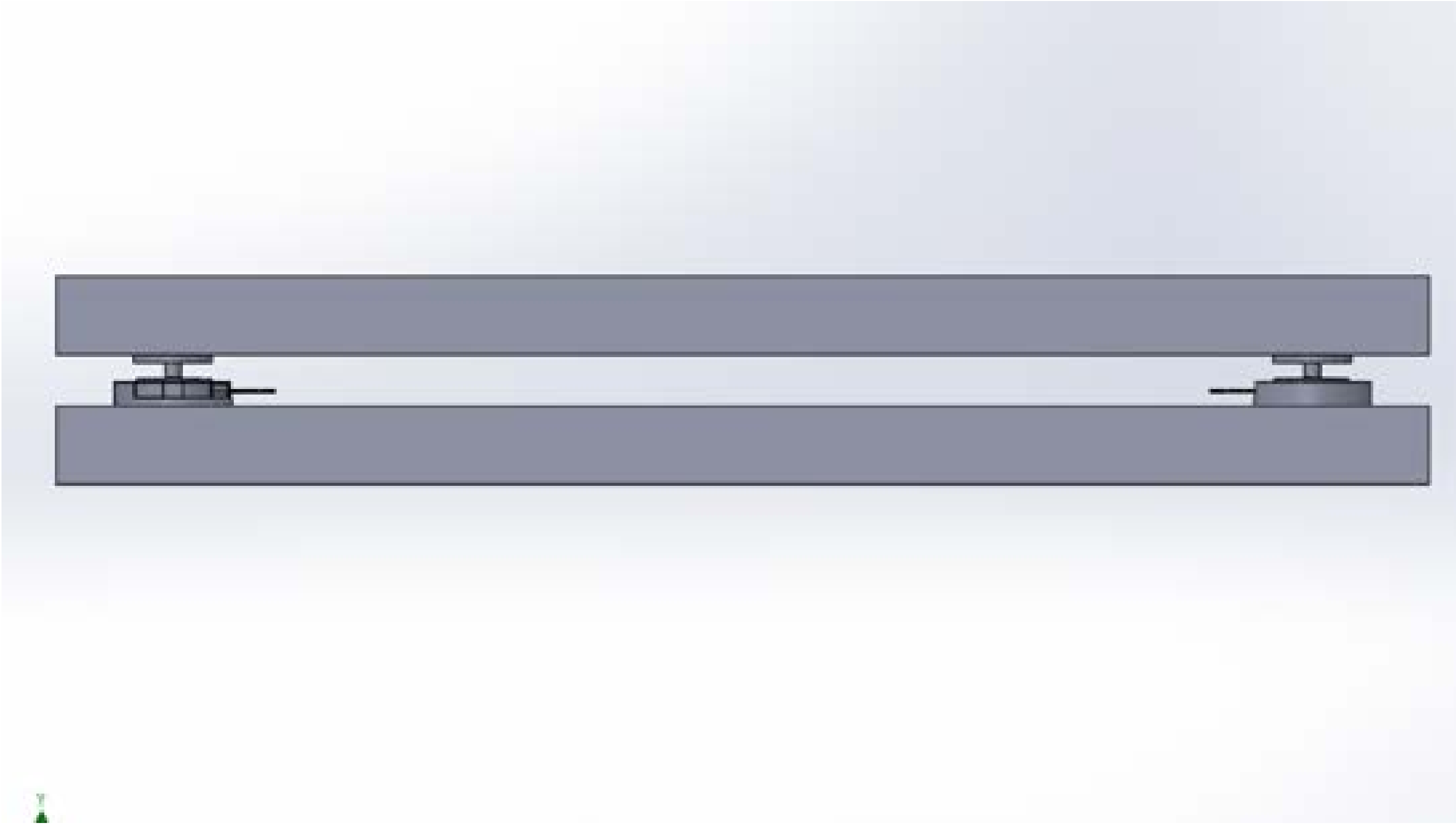
2. Load pin fixtures which are screwed to the top plate (tapped holes) and have a pin that perfectly forms to the force sensing part of the load cell.



Full force plate assembly (attachment mechanisms not shown):



side view:



Conclusions/action items:

Show this design to Jesse in the teamlab to talk about fabrication methods

Add springs/pulleys to this design.

Emily will 3D print 1 copy of the fixture, 1 of the load cell pin to help us gauge dimensions.

ALLICIA MOELLER - Oct 15, 2024, 9:43 AM CDT

Download

fixture_plate_assem.zip (1.56 MB)

2024/10/16 - Pulley Spring Mechanism

ALLICIA MOELLER - Oct 16, 2024, 10:11 PM CDT

Title: Pulley Spring Mechanism

Date: 10/16/2024

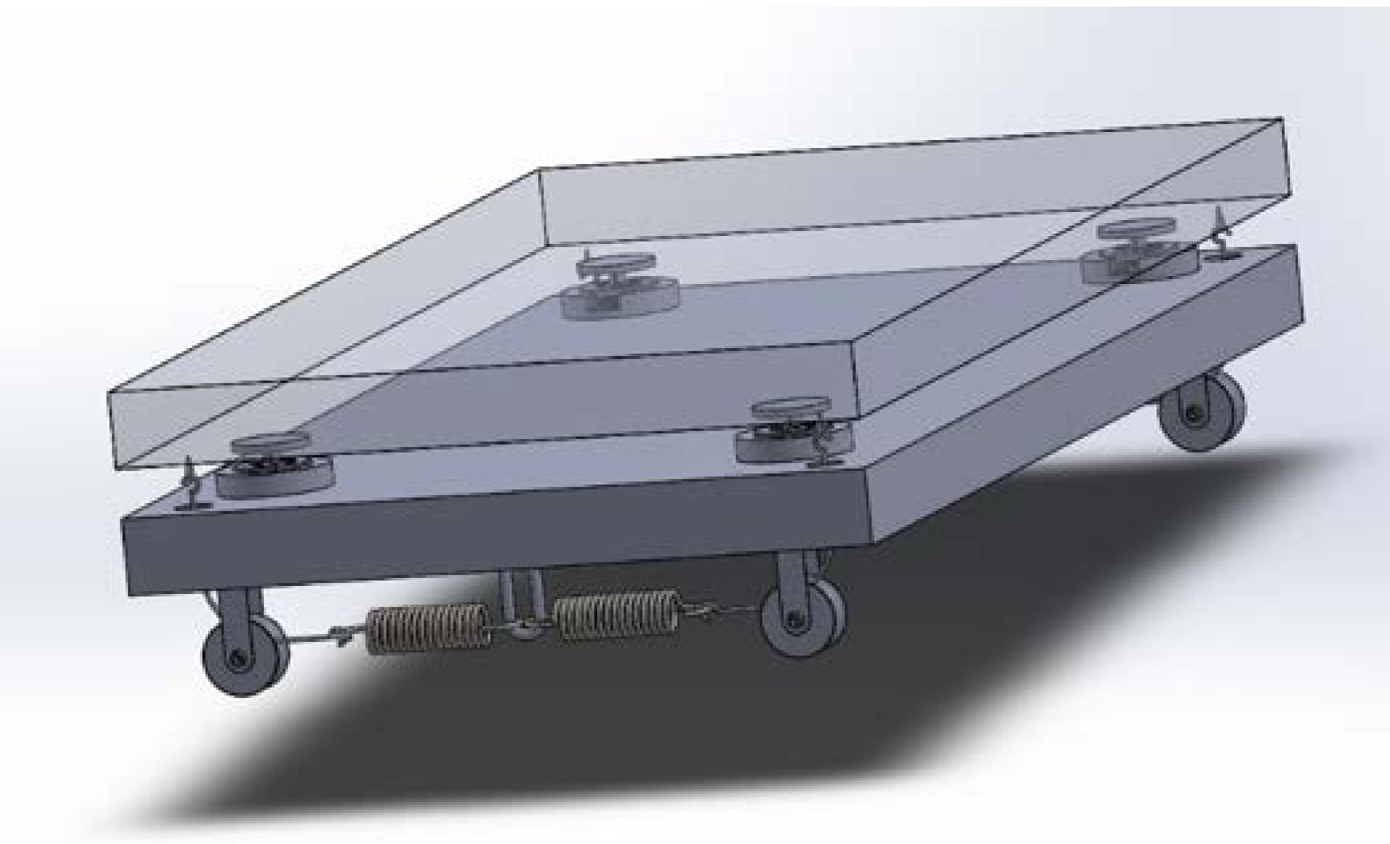
Content by: Allicia

Goals: To make a CAD model of a pulley spring mechanism.

Content:

Problem: We need a mechanism to hold the two plates together as well as put force on the load cells so that we can measure tensile force on the plate as well as compressive.

- Run a cord from top plate through a hole in the bottom plate over a pulley attached to a tension spring.
- Length is added to top/bottom of the plate to make room for the springs.



- If shearing forces are still a significant problem, we would add sidewalls and either utilize the membrane-bound force plate design or the bearing-guided force plate design.

Conclusions/action items:

She these designs to Jesse at the TeamLab to talk about fabrication feasibility.

2024/10/17 - Bushing / Shoulder Screw Idea

ALLICIA MOELLER - Oct 17, 2024, 3:27 PM CDT

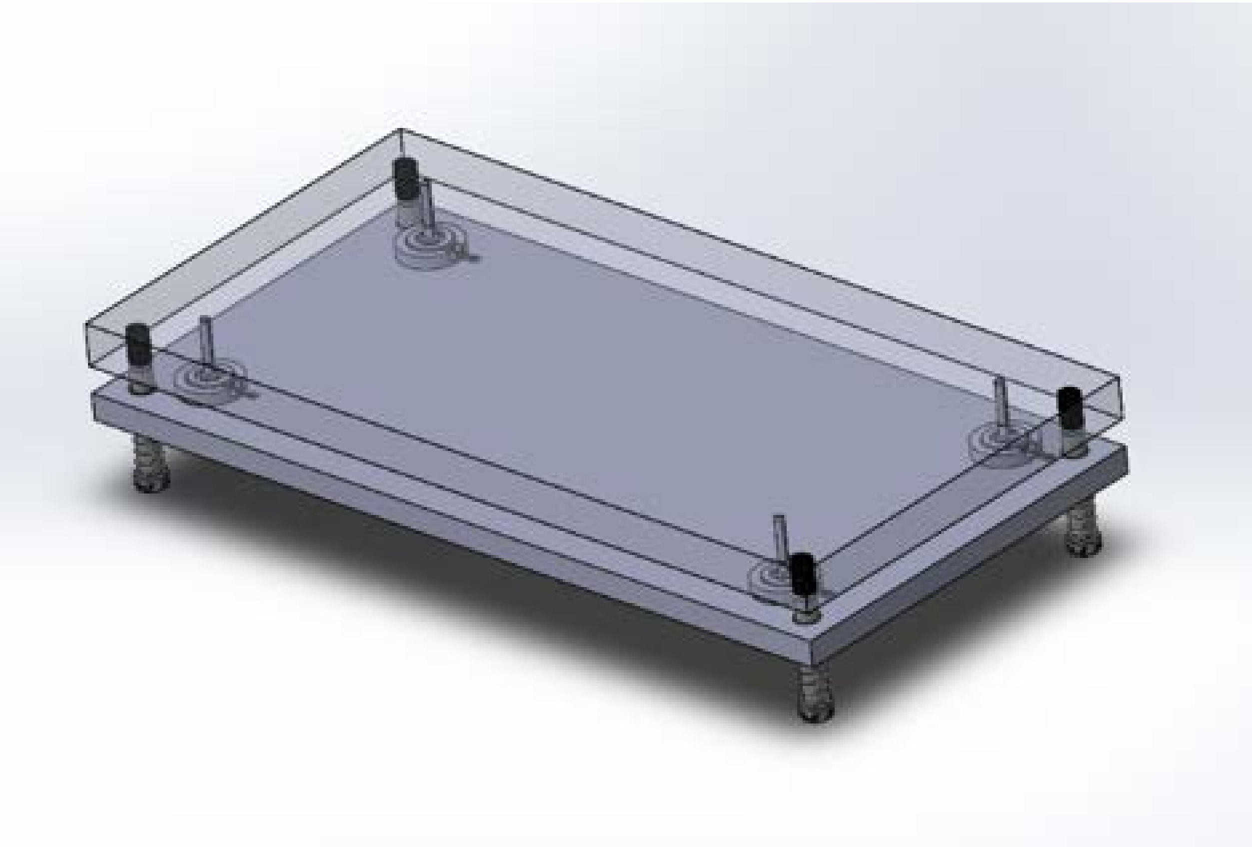
Title: Bushing / Shoulder Screw Idea

Date: 10/17/2024

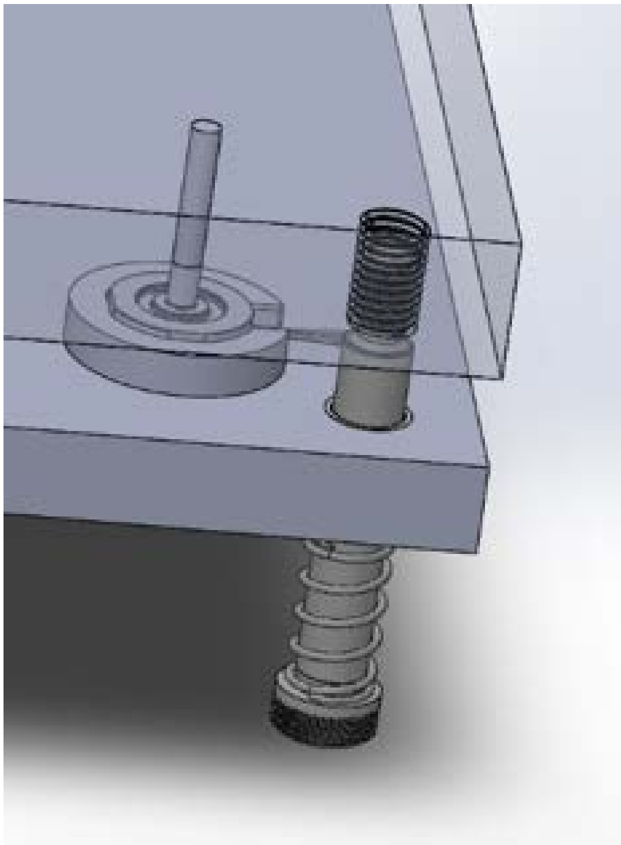
Content by: Allicia

Goals: To make a CAD model of Jesse's bushing/shoulder screw suggestion

Content:



After meeting with Jesse in the teamlab, we decided we want to explore his idea of using shoulder screws and bushings to both shield-off shearing forces, hold the plates together, and pre-load the load cell.



For this design, we will extend the length of the footplates in the anterior/posterior direction to create a small overhang over the top and bottom edge of the foot stretcher to give us more vertical space. We will mill holes in the base plate and press fit sleeve bearings into the holes. We will tap holes in the top plate for the shoulder screws and add holes to press fit the load pins. Then, to attach the plates we'll screw the shoulder screw into the top plate through the bottom plate, placing a compressive spring between the screw head and the bottom plate to compress the load cells.

The load cells are held in place by fixtures we will machine on the mill and screw into the base plate.

For this CAD model, I used:

- High-Load Dry-Running Sleeve Bearing with Steel Shell
  Bronze-Backed PTFE, for 3/8" Shaft Diameter
  Part number
  60695K2
- Alloy Steel Shoulder Screw
  3/8" Shoulder Diameter, 2" Shoulder Length, 5/16"-18 Thread
  Part number
  91259A632

  And a compression spring that roughly fit the dimensions of the CAD model (likely not the same spring we would use for fabrication)

Conclusions/action items:

Buy bushings and shoulder screws to see if friction will cause a problem.

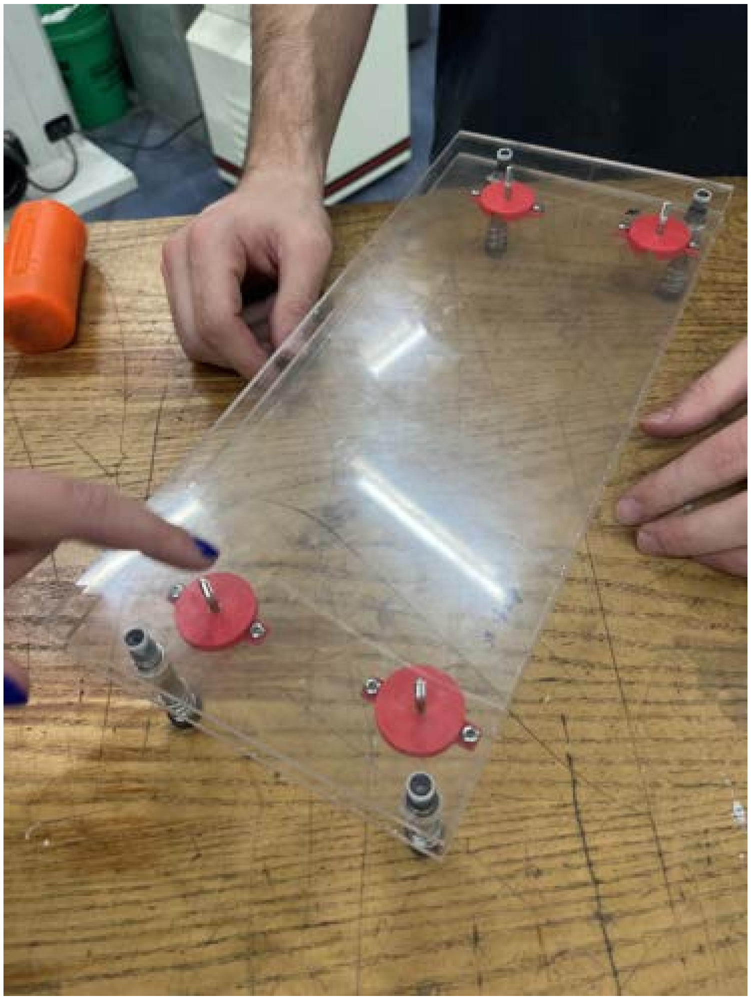
ALLICIA MOELLER - Oct 17, 2024, 3:28 PM CDT

Download

sleeve_bearing.zip (6.04 MB)

EMILY WADZINSKI - Nov 15, 2024, 7:13 PM CST

prototype of design, fabricated 10/31/2024



2024/11/5 - Circuit Troubleshooting

ALLICIA MOELLER -

Title: Circuit Troubleshooting

Date: 11/5/2024

Content by: Allicia

Present: Allicia and Simmi

Goals: To look for sources of error in our circuit.

Content:

- We are trying to build a differential amplifier to connect to one of our our load cells and amplify a voltage difference range of 0-100mV to 0-5V (Gain of 50).
- We built a simple circuit with two unity gain buffers and one differential amplifier with a gain of 47. We noticed that the output of this circuit seemed stuck at a specific non-zero value, ever the load cell (voltage difference should be 0 when no force is applied). After looking at the datasheet for the LM358 op amps we were using, we noticed that the voltage output seemed to voltage swing from the negative output. At first, the output was resting around 0.7 V, but after connecting a 1kOhm resistor from output to ground, the output decreased to about 150 mV. I weren't seeing an change in output voltage when we applied force (0-15lbs) to the load cell.

OUTPUT

V_O	Voltage output swing from rail	Positive Rail (V+)		I_{OUT} = 50 µA	1.:
				I_{OUT} = 1 mA	1
				I_{OUT} = 5 mA(1)	1
		Negative Rail (V-)		I_{OUT} = 50 µA	1(
				I_{OUT} = 1 mA	0.:
			V_S = 5 V, RL ≤ 10 kΩ connected to (V–)	T_A = –40°C to +125°C	

- After speaking to Dr. Nimunkar, he suggested we use a TLV274 quad precision op amp instead. Each chip had 4 op amps, so 2 will be utilized as unity gain buffers, one will be utilized as differential amplifier (voltage subtractor) with closely matched resistors (1% tolerance), and the last op amp will be used as a non-inverting amplifier with gain of 50.

PARAMETER		TEST CONDITIONS		T_A	MIN	TYP	MAX	UNIT
V_{OH}	High-level output voltage	$V_{IC} = V_{DD}/2$, I_{OH} = –1 mA	V_{DD} = 2.7 V	25°C	2.55	2.58		V
				Full range	2.48			
			V_{DD} = 5 V	25°C	4.9	4.93		
				Full range	4.85			
			V_{DD} = ±5 V	25°C	4.92	4.96		
				Full range	4.9			
		$V_{IC} = V_{DD}/2$, I_{OH} = –5 mA	V_{DD} = 2.7 V	25°C	1.9	2.1		
				Full range	1.5			
			V_{DD} = 5 V	25°C	4.6	4.68		
				Full range	4.5			
			V_{DD} = ±5 V	25°C	4.7	4.84		
				Full range	4.65			
V_{OL}	Low-level output voltage	$V_{IC} = V_{DD}/2$, I_{OH} = 1 mA	V_{DD} = 2.7 V	25°C		0.1	0.15	V
				Full range			0.22	
			V_{DD} = 5 V	25°C		0.05	0.1	
				Full range			0.15	
			V_{DD} = ±5 V	25°C		–4.95	–4.92	
				Full range			–4.9	
		$V_{IC} = V_{DD}/2$, I_{OH} = 5 mA	V_{DD} = 2.7 V	25°C		0.5	0.7	
				Full range			1.1	
			V_{DD} = 5 V	25°C		0.28	0.4	
				Full range			0.5	
			V_{DD} = ±5 V	25°C		–4.84	–4.7	
				Full range			–4.65	

- We were still seeing saturation at a non-zero value when we used this configuration. But we got this value down to the order of millivolts when we added a very small resistor from output current away from the output terminal. (low-level output voltage decreases when Ioh is lower according to datasheet). We were then able to see changes in amplified voltage when we pu however, the gain did not seem accurate (we don't have a great way to test this without a calibrated weight at the moment).
- Tomorrow, we are going to attempt repeating this circuit configuration without a pull down resistor, but adding a small voltage offset to the non-inverting side of the op amp so that when th load cell, the output is intentionally non-zero (and above cutoff). Then, we can subtract this offset out in the code after analog-to-digital conversion.
  - The downside to this is that as we shorten the voltage range of the amplified output, we lose precision.

Conclusions/action items:

ALLICIA MOELLER - Nov 05, 2024, 11:19 AM CST

Download

lm358.pdf (4.09 MB)

ALLICIA MOELLER - Nov 05, 2024, 11:19 AM CST

Download

tlv274.pdf (1.75 MB)

2024/11/7 - Circuit with Offset

ALLICIA MOELLER - Nov 07, 2024, 10:19 PM CST

Title: Circuit with Offset

Date: 11/7/2024

Content by: Allicia

Present: Allicia

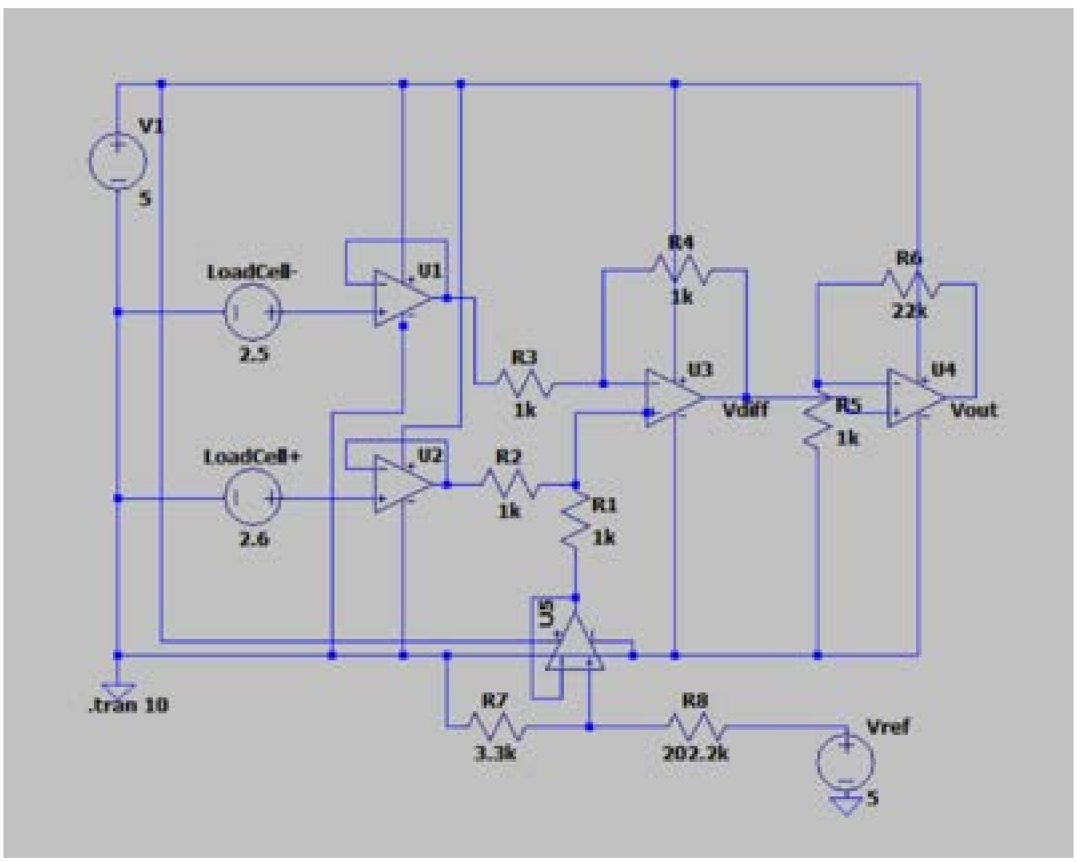
Goals: To build a circuit with an offset to counteract the voltage output swing.

Content:

- One of the issues with the circuit is that the LM358 is not a rail-to-rail, so it has an output swing voltage, and when Vdd- is connected to ground, there will be a non-zero voltage that the output of the amplifier cannot go under (it will saturate).

- Using the TLV274, and separating the amplifier into a voltage subtractor and a non-inverting amplifier, we saw a saturation voltage of about 75 mV. To be able to measure lower force values, we applied an 80mV offset to the non-inverting terminal (ideally, when there is 0 force on the load cell, voltage subtractor should output 80 mV and non-inverting amplifier should output 2.0V. In reality, the 80mV off-set made the voltage subtractor read 95 mV and the non-inverting amplifier read 2.3.

- As long as the relationship between voltage difference and output is still linear, any offset can be zeroed out in the code. To test if our amplifier works with the voltage offset (voltage divider with buffer), I input a function from the wave generator to mimic the load cell output at loads ranging from 0-100lb (0-100mV). To do this, I set the negative output to 2.5V DC and set the positive input to a ramp function ranging from 2.5-2.6V. The output was a perfectly linear ramp function, ranging from 2.07 - 4.41V. This shows us that the circuit is working.



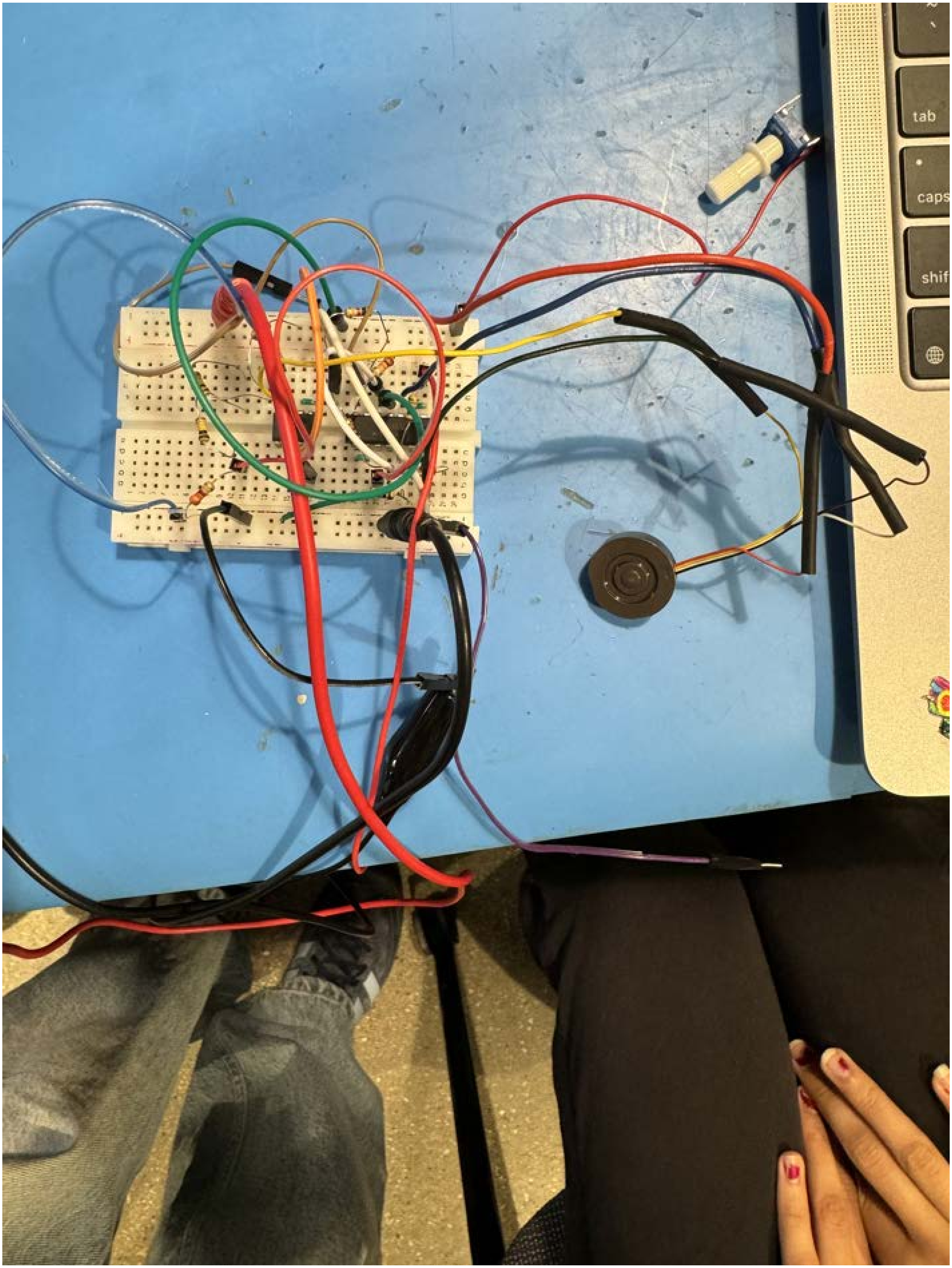
To make the voltage offset more consistent, we will purchase a 4.5V precision voltage reference and use it as the input to the voltage divider as well as the reference voltage for the ADC so that power line fluctuations do not affect accuracy.

Conclusions/action items:

Buy remaining circuit components. Look into PCBs.

EMILY WADZINSKI - Nov 15, 2024, 7:18 PM CST

Picture of current circuit: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9/17/2024 - Insole testing for functional movement

EMILY WADZINSKI - Sep 20, 2024, 11:03 AM CDT

Title: Pressure Insole Testing

Date: 09/17/2024

Content by: Emily

Goals: To determine the accuracy of pressure insoles compared to force plates.

Link/Citation: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10495386/

Content:

These researchers took new pressure insoles off the market and tested them against force plates to compare vGRFs and COP. They used the X4 Foot & Gait Measurement System by XSENSOR. Their website is: https://blog.xsensor.com/tag/x4-foot-gait-measurement-system

Ultimately they found that the numbers were off, and there were numerous discrepancies but probable reasons why. However, they state that even though there were "significant differences in terms of actual values measured", the waveforms and scatterplots of trajectories of the COP, as well as the data patterns for the insoles and force-plates show "high qualitative correlation". This means that you could get a general idea from the data displayed by the insoles for certain clinical applications like walking but may not be used as a accurate replacement to force plates. Insole are a way more accessible option though and still pretty reliable because they have reproducible results.

Conclusion:

Not sure this option will completely work for us as the client wants accurate numbers, not just pattern

9/19/2024 - Insole Options

EMILY WADZINSKI - Sep 27, 2024, 3:49 PM CDT

Title: Different kinds of load cell options

Date: 09/19/2024

Content by: Emily

Goals: To try to get a price point on these

Content:

List of pressure insoles I found: Figuring out their prices is the hardest part. None of them want to say it anywhere on their website. Review page: https://www.theupside.us/p/-upside-force-plate-ecosystems-analysis

1. XO-NANO Smart Insoles

Link: https://www.xonanosmartfoam.com/smart-insole/

"compared with the gold standard force plates and instrumented treadmills with 95% plus accuracy on 3-dimensional forces."

- super accurate

- says they can test and measure GRF and gait analysis

- mentioned in research articles

- price???

- used in research study comparisons with force plates

2. Loadsol by Novel

Links:

https://www.novelusa.com/loadsol

https://www.novelusa.com/insole-chart

- "The loadsol® insole monitors the normal force between the plantar side of the foot and the shoe."

- doesn't matter which part of the shoe the foot is in contact with to get a reading

- Bluetooth, has an smartphone app as well

- can have one or more sensor areas for deeper analysis

- doesn't do local pressure distribution under the foot, but does do peak force, cadence, loading rate, contact time and symmetry which is perfect for us anyways

- spent a lot of time looking at this one, but don't know price

- can add on an IMU too if you want

- Different foot sizes

 from app: 

3. Plantica

https://plantiga.com/our-science

- uses accelerometry, doesn't technically measure pressure or force

- "pro teams can flag lower limb asymmetrical loading strategies after injuries like ACL tears, fractures, ankle sprains, hip injuries, soft tissue injuries, lower back/pelvis injuries. They can also create asymmetry norms/baselines to characterize bandwidth of normal function; They can also flag athletes who exit normal bandwidth by player, position, team and sport."

- can rent out (month, year)

- $30 monthly membership - not bad!

- used by professional sports

- probably the most mainstreamed and used in sports

- can't permanently implement it

- Asked for demo, just got a response on my email from them

4. Salted Smart insole

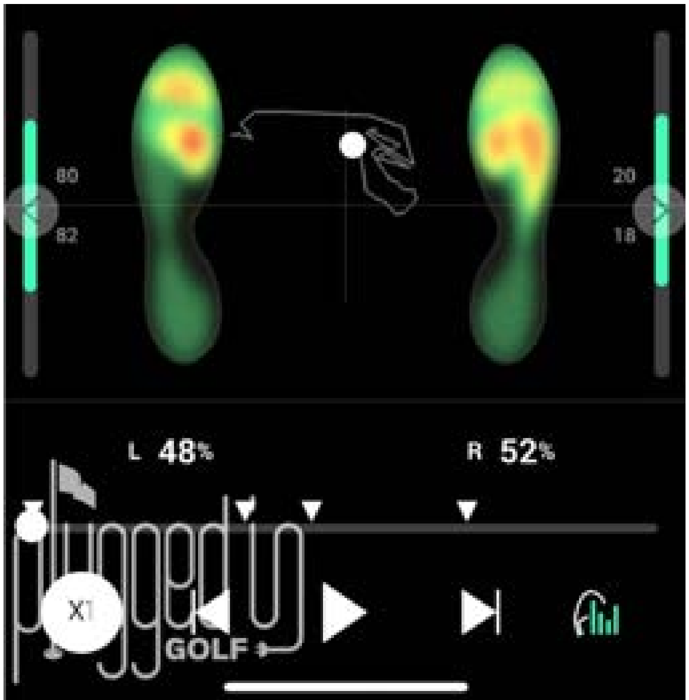
https://sports.salted.ltd/en/product/smart-insole

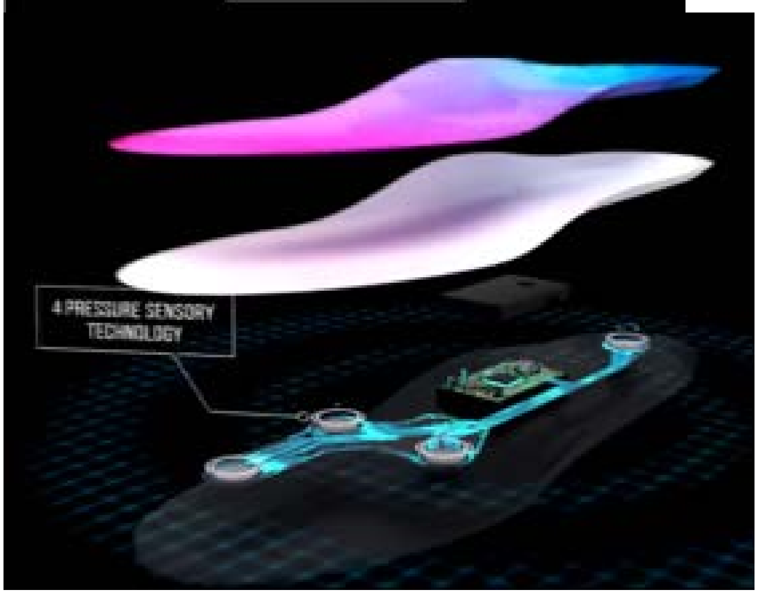
https://mygolfspy.com/we-tried-it/we-tried-it-salted-smart-insole/

- $200! Best price!

- not sure if they're currently on sale

- more balanced based, not reaction forces?





5. Moticon ReGo

https://moticon.com/comparison

https://moticon.com/wp-content/uploads/2024/07/ReGo-Insole3-Specification_01.00_A4_EN.pdf

https://moticon.com/wp-content/uploads/2024/04/ReGo-Pricelist-A4-01.07-EN-USD.pdf

- similar to the others in characteristics

- uses pressure sensors and IMUs

- very popular/known brand

- patented, used clinically

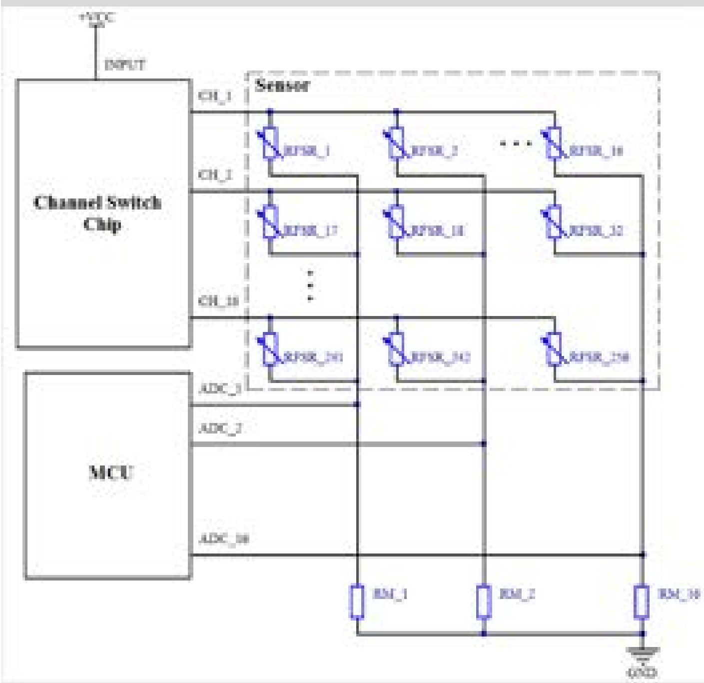
- price list! --> too much, $700 (not as bad as others though)

- has another model called OpenGo, but ReGo is a better fit for our project

6. Tekscan Wearable FSR Sensor

https://www.fsrtek.com/flexible-gait-analysis-piezoresistive-insole-force-sensitive-resistor

- made up of multiple pressure sensors (12 FSRs)
- thinking the force can summate into one total force reading
- Really liked this one
- Emailed and got a response back -- need to inquire data and pricing
- I think we could really implement this into our project to grab various data
- They provide a circuit sheet



7. ZNX-01 flexible thin pressure sensor:

https://www.researchgate.net/publication/381524799_Design_of_Athlete_Plantar_Pressure_Collection_System_based_on_Flexible_Thin_Film_Pressure_Sensor

- made very recently

- uses pressure sensors, microcontroller, HC-06 Bluetooth modules, and a mobile app

- only collects plantar pressure data?

- Can buy on amazonnnnnn: https://www.amazon.com/ZNX-01-Sensing-Pressure-Intelligent-Accessory/dp/B09PF36BGV

- other variations/similar ones on amazon too? Which ones are legit?: https://www.amazon.com/dp/B0836MNNY5/ref=sspa_dk_detail_4?psc=1&pd_rd_i=B0836MNNY5&pd_rd_w=o44Ub&content-id=amzn1.sym.8c2f9165-8e93-42a1-8313-73d3809141a2&pf_rd_p=8c2f9165-8e93-42a1-8313-73d3809141a2&pf_rd_r=MFXEXJD60YK81F3M21EK&pd_rd_wg=iSbSf&pd_rd_r=91b8562d-4db1-4f38-bc20-02104d8b2adb&s=industrial&sp_csd=d2lkZ2V0TmFtZT1zcF9kZXRhaWw

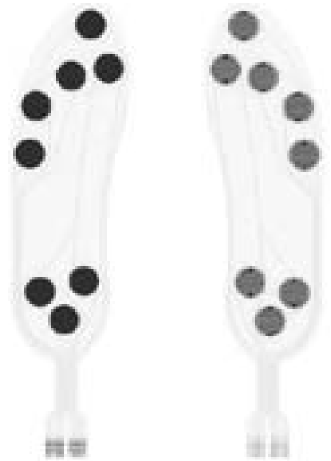


Figure 2. ZNX-01 Flexible Thin Film Pressure Sensor

Conclusion:

Bring up options 6 and 7 to group. I think we could implement #6 well if it meets all of our requirements.

09/26/2024 - Tensile Materials

EMILY WADZINSKI - Sep 27, 2024, 4:35 PM CDT

Title: Different kinds of possible material options

Date: 09/26/2024

Content by: Emily

Goals: To try to figure out what material to get for one of our designs from the design matrix

Content:

https://www.researchgate.net/publication/266148559_Effect_of_fabric_material_and_tightness_on_the_mechanical_properties_of_fabric-cement_composites#pf4

Upon first thoughts of which tensile material to use, my mind went to cotton as it is very versatile and strong, such as 100% denim jeans. In this research article, scientists compared different fabric types and composites. They also compared the number of fabric layers versus tensile stress. The main fabrics they tested were HTPET, polypropylene, and cotton, with HTPET being the strongest in that order.

These graphs show a comparison in stresses:

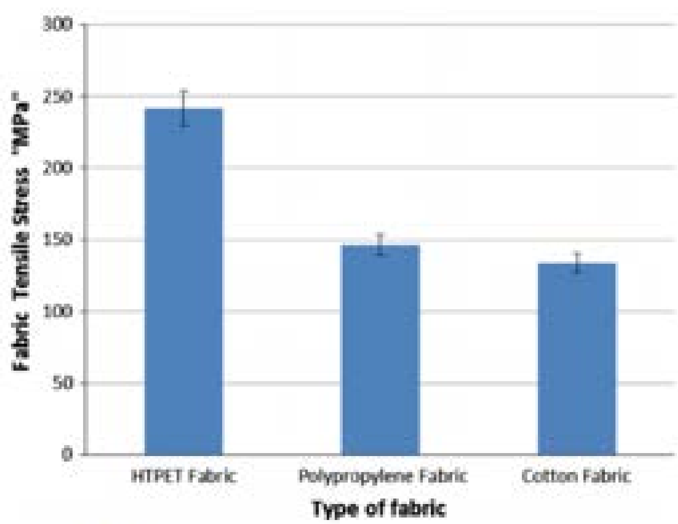


Figure 4 Tensile stress of different types of fabric.

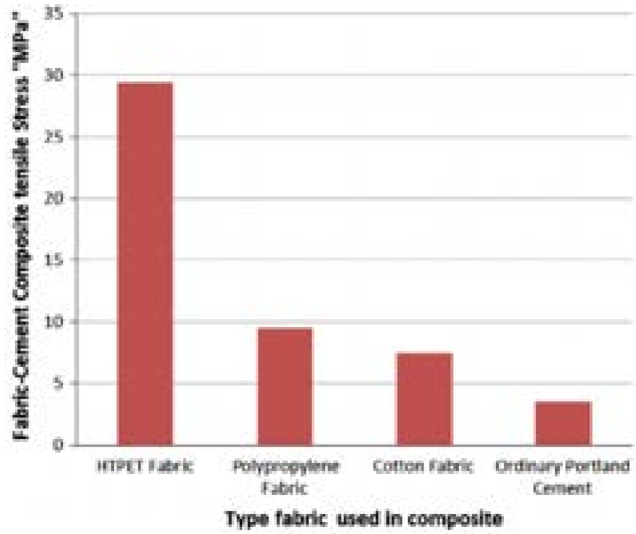


Figure 5 Tensile stress of different fabric–cement composites.

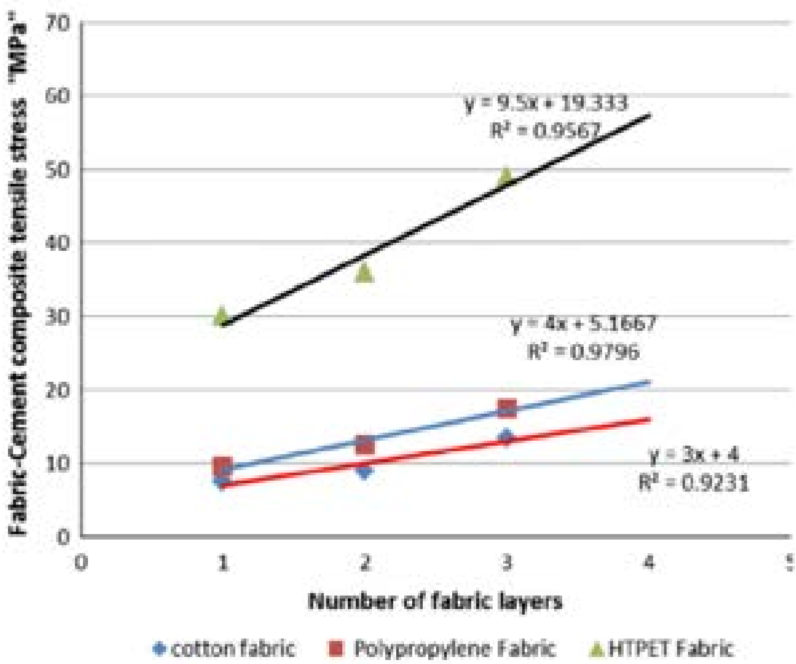


Figure 8 Fabric–cement composite tensile stress versus the fabric number of layers.

In the end, they found that:

- The higher the fabric specific tightness, the lower the tensile strength of fabric-cement composite.

- Higher HTPET fabric tensile strength increases the tensile and bending properties of fabric-cement composites.

- "Preference is given to the use of one fabric layer for the formation of fabric–cement composite with higher tensile properties and lower fabric tightness"

In this article, different types of resistant fabrics are compared (less scientifically) for work clothes:

https://www.oxwork.com/en/blog/resistant-fabric-for-clothing?srsltid=AfmBOopjpY3y3FsxBZZwh6oo3frSAmw4zq9S_EzKQOkOn_0MCSdPR_LM

- states that cotton has low resistance to severe wear --> may be problematic if our device is used for many numerous runs

- wool would be a water resistant option if we decide to move our device

- Kevlar: synthetic material made from PPTA. Superior resistance. Used for fire blankets and safety equipment. Composite made of reinforced fibers for increased resistance. Can handle really high abrasions, good if the device gets a lot of use. (Probably unnecessary)

Conclusion:

Look into the pricing of HTPET fabric? Do we even need Kevlar or the strongest fabric? Would cotton be sufficient?

10/10/2024 - Metal Plate Materials

EMILY WADZINSKI - Oct 11, 2024, 11:50 AM CDT

Title: Footplate Materials

Date: 10/10/2024

Content by: Emily

Goals: To try to figure out what metal to buy for the plates

Content:

mcmaster:

https://www.mcmaster.com/products/metals/aluminum~/

- Definitely aluminum since it's the lightest

- looks like the thicker you go = steep increase in prices

- should go with a bar, sheet sizes don't really work

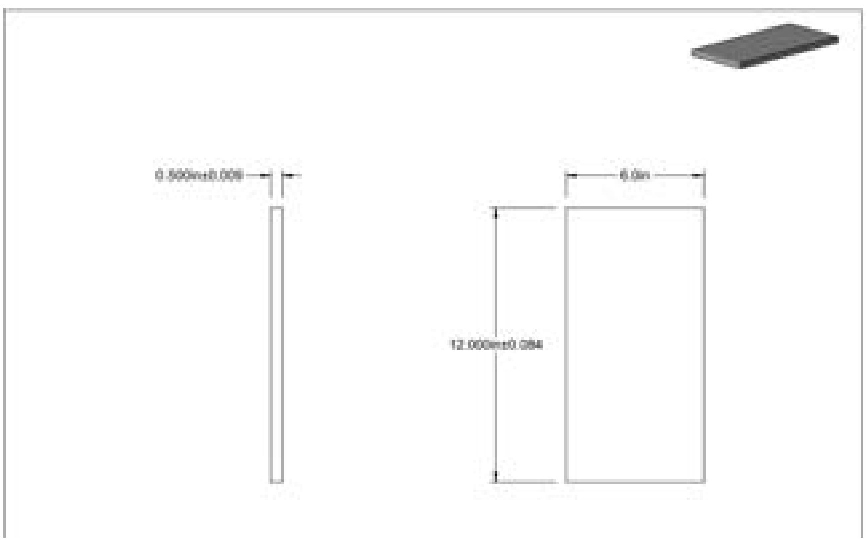
- basic 6061 should be fine, probably cheapest

- Thickness.... what do we need, thinnest possible?

- bars only go to 12" in length - our design drawing is over 13 - so can't get a bar??

3/8" Thick. (-0.008" to 0.008" Tolerance)												
10"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K129	30.63	48.14	89.71	124.72	—	218.80
12"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K154	29.80	51.85	87.27	121.33	—	212.86
3/8" Thick. (-0.003" to 0.003" Tolerance)												
3/8"	Extruded	T6	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8, SAE AMS4150	9447T34	—	—	11.95	—	21.25	26.56
1/2"	Extruded	T6	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8, SAE AMS4150	9447T35	—	—	16.50	—	28.59	36.66
7/16" Thick. (-0.008" to 0.008" Tolerance)												
7/16"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	9008K79	2.76	3.96	7.06	9.82	—	17.23
1/2" Thick. (-0.009" to 0.009" Tolerance)												
1/2"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	9008K81	2.55	4.00	7.46	10.37	—	18.19
3/4"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K610	3.24	5.10	9.50	13.20	—	23.16
1"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K11	4.46	7.01	13.07	18.17	—	31.87
1 1/4"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K473	5.64	8.86	16.50	22.94	—	40.25
1 1/2"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K42	6.80	10.69	19.91	27.68	—	48.57
1 3/4"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K619	7.44	11.69	21.79	30.30	—	53.15
2"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K74	8.83	13.87	25.85	35.94	—	63.06
2 1/2"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K477	11.98	18.82	35.08	48.76	—	85.55
3"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K513	14.42	22.66	42.23	58.71	—	103.00
3 1/2"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K621	14.81	23.27	43.37	60.29	—	105.78
4"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K215	19.29	30.32	56.50	78.55	—	137.80
5"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K217	23.17	36.40	67.84	94.32	—	165.47
6"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K219	25.64	47.45	81.75	113.65	—	199.38
8"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K222	34.07	53.54	99.78	138.72	—	243.36
10"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K106	36.59	57.50	107.16	148.98	—	261.36
12"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	8975K135	34.58	62.03	101.28	140.81	—	247.03
1/2" Thick. (-0.003" to 0.003" Tolerance)												
1/2"	Extruded	T6	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8, SAE AMS4150	9447T36	—	—	17.03	—	30.28	37.85
9/16" Thick. (-0.009" to 0.009" Tolerance)												
9/16"	Extruded	T6511	Hardened	-320° to 300°	ASTM B221, SAE AMS QQ-A-200/8	9008K82	3.51	5.52	10.29	14.31	—	25.10

https://www.mcmaster.com/8975K135/



Conclusions:

could we do a sheet? - then we could go to menards or somewhere local - how rigid does it have to be?

11/18/2024 - 3D Scanning

EMILY WADZINSKI - Nov 25, 2024, 3:31 PM CST

Title: 3D Scan

Date: 11/18/2024

Content by: Emily

Present: Emily

Goals: To get a scan of our plate for accurate measurements

Content:

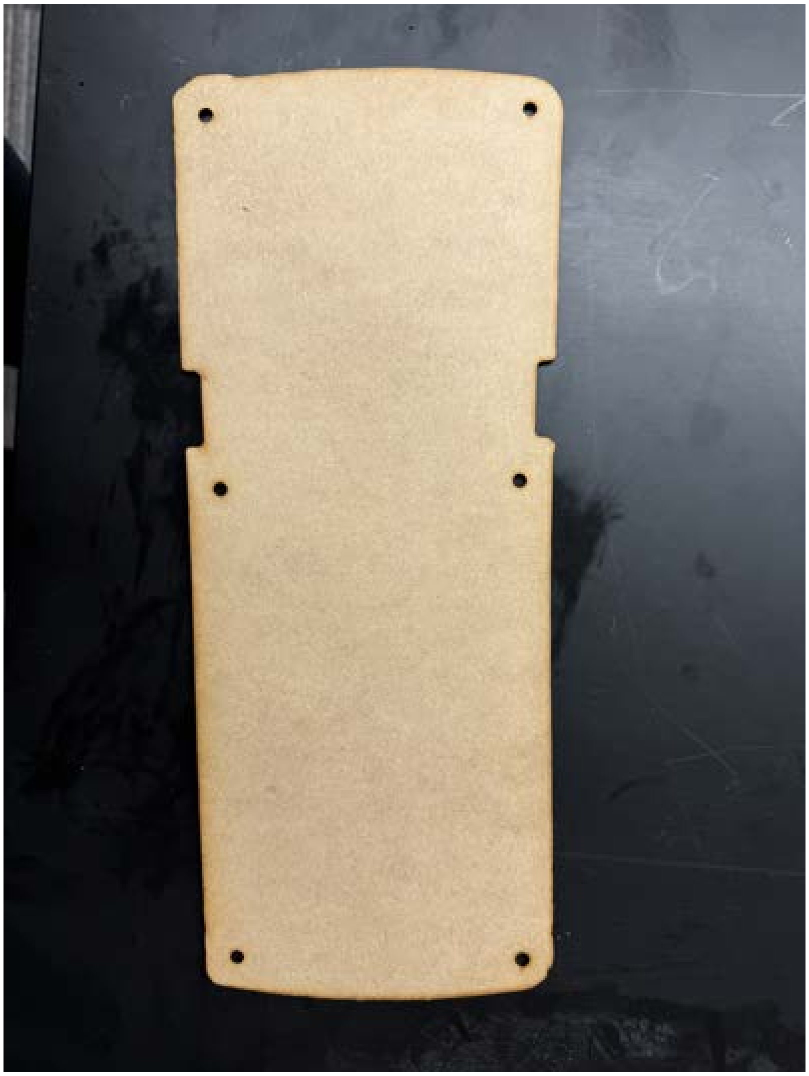
- The right Flexfoot was brought into the makerspace and 3D scanned.

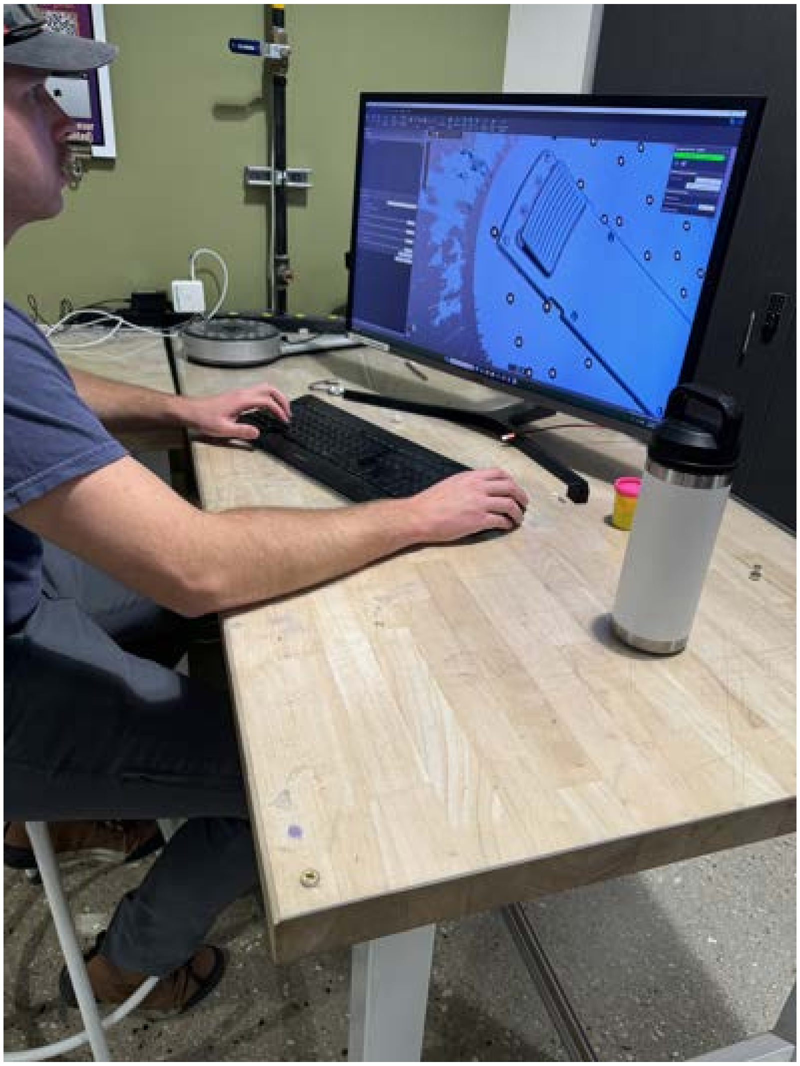
- Locations of the 6 holes were calculated in relation to each other.

- A SolidWorks part was made from the scanner and an stl file

- The part was then laser cut to compare the scan to the actual Flexfoot

- A drawing was made from the part and copy and pasted onto the top and bottom SolidWorks files we had.





Conclusion:

Finalize solidworks and send it in to be machined.

11/18/2024 - Final Solidworks Design

EMILY WADZINSKI - Nov 25, 2024, 4:33 PM CST

Title: SolidWorks Design for CNC

Date: 11/18/2024

Content by: Emily

Present: Emily

Goals: To make a new version of our SolidWorks

Content:

- After meeting with Jesse on 11/13, we needed to update our footplate to 2 shoulder screws per plate and add the holes for the old and new models of the ergometer for mounting

- I first tried to make a copy of Allicia's parts and change the holes, but making edits on her design proved to be challenging

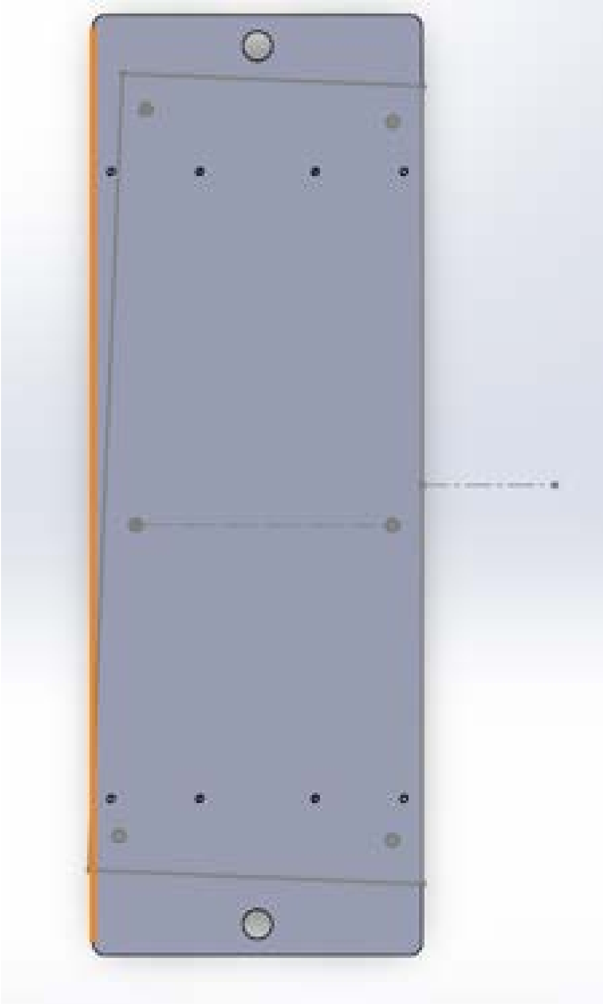
- Colin and I decided to make completely new plates on SolidWorks

- I added the FlexFoot holes based on the measurements Allicia and I got with the calipers, then moved the load cell fixtures/set screws down and in, away from the mounting holes where they were previously in the way of

- Colin and I then added the new bearing holes

- After doing the 3D scan of the Flexfoot, I overlayed a drawing of the scan onto the plates, made new holes using the scan, and deleted the old reference holes

- Then I gave the files over to Allicia who added in 4 holes on each plate for the old erg's foot mounts - the part files of the final plates are under, Team Activities: Group Meetings: 2024/11/13



Conclusion:

Make drawings of the parts for Mike for the CNC machine

EMILY WADZINSKI - Nov 25, 2024, 4:38 PM CST

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BottomPlate2.SLDPRT (164 kB)

EMILY WADZINSKI - Nov 25, 2024, 4:38 PM CST

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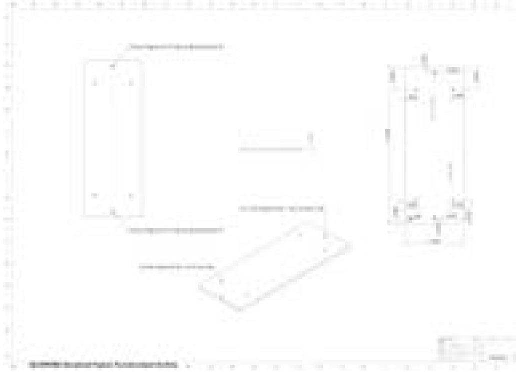

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topplate1.pdf (66.6 kB)

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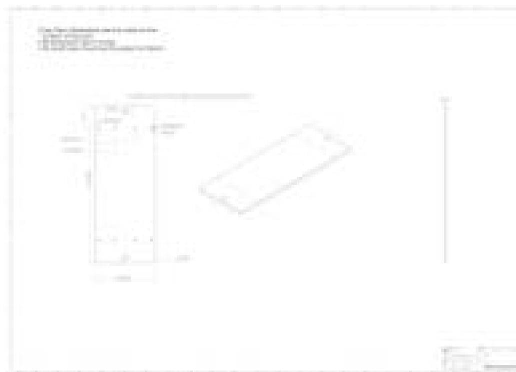

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Revised_BottomPart.pdf (42.9 kB)

2024/09/27 Physics of Rowing

SIMERJOT KAUR - Sep 27, 2024, 11:10 AM CDT

Title: Physics of Rowing

Date: 9/27/2024

Content by: Simmi

Source:

The physics of rowing, https://eodg.atm.ox.ac.uk/user/dudhia/rowing/physics/rowing.pdf (accessed Sep. 27, 2024).

Goals: Learn the basic of force distribution while rowing and determine the possibility of calculating center of pressure.

Content:

- The force distribution in the legs while rowing is a major source of power generation. The rowers are seated on sliding seats, and their feet are attached to the boat by restraints, which allows them to push with their legs to generate propulsion.
- During the drive phase of the rowing stroke, the rower's legs extend, pushing against the footplate. This action is part of a sequence that starts with the legs, then moves to the back, and finally to the arms.
- The force exerted by the legs is transmitted through the body and into the oar handle, which then acts on the oar blade in the water.
- The force distribution in the legs is not uniform throughout the stroke. At the beginning of the stroke, the legs are bent, and the force is minimal. As the rower begins to extend the legs, the force increases, reaching a maximum when the legs are nearly fully extended. This force is then transferred to the oar, which acts as a lever to propel the boat forward.
- The force exerted by the legs is a significant component of the total effort force (E(t)) applied during the stroke. The equation provided in the document describes the relationship between the boat speed (u), the effort force (E(t)), the drag resistance (R(t)), and the accelerations of the rowers' bodies during the power and recovery phases (H1(t) and H2(t)).
- The force curves E(t) for the power phase of the stroke illustrate different patterns of force application. The most energetically efficient is the symmetrical form, where peak pressure is applied during the middle of the stroke. This suggests that the force distribution in the legs should be optimized to achieve this symmetrical force curve, with a smooth and powerful leg drive that peaks at the midpoint of the stroke.

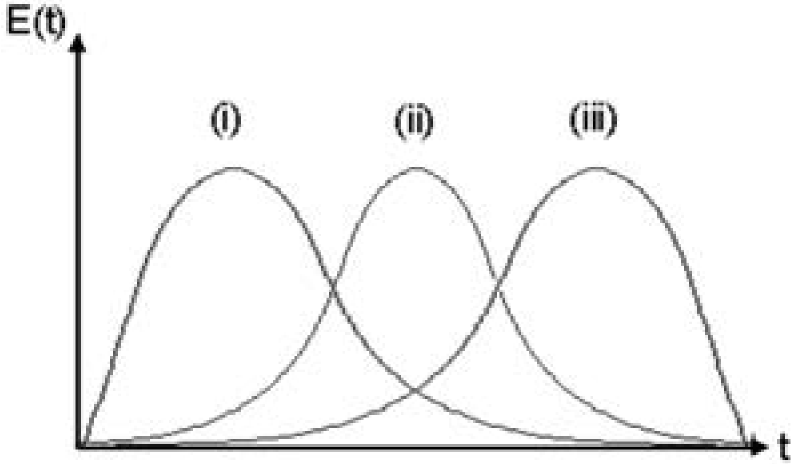


FIG. 2. Force curves *E(t)* for the power phase of the stroke. (i) Peak pressure applied at the beginning of the stroke; (ii) Peak pressure applied during the middle of the stroke, with the effort symmetrical about that point; (iii) Peak force applied at the end of the stroke.

Finding Center of Pressure in the Feet

- Center of pressure: the point where the resultant force acts on the feet, taking into account the distribution of pressure across the footplate.
- To calculate the center of pressure, these are the following variables needed: the total force applied by the rower's legs to the footplate, the distribution of the force across the footplate (with compression only load cells, this might not be possible), this could be measured using pressure sensors, the geometry of the footplate and the position of the feet on it, the angle of the footplate, which affects the direction of the force applied.
- By integrating the pressure distribution over the area of the footplate it is possible to determine the center of pressure but it will require complex methods of finding force distribution

Conclusions/action items:

Overall, I think it is worth looking into how the 4 load cells can help identify what the force distribution is which will help with locating center of pressure.

SIMERJOT KAUR - Sep 27, 2024, 10:55 AM CDT


The Physics of Rowing

[Download](rowing.pdf)

rowing.pdf (346 kB)

9/19/2024 Calculating Power on Erg Using Mechanical Sensors

SIMERJOT KAUR - Sep 20, 2024, 11:44 AM CDT

Title: Calculating Power on Ergometer Using Mechanical Sensors

Date: 9/19/2024

Content by: Simmi

Goals: Understand how power was calculated using mechanical sensors on the ergometer and how that compares in accuracy to the ergometer system.

Source: S. Boyas, A. Nordez, C. Cornu, and A. Guével, “Power responses of a rowing ergometer: Mechanical Sensors vs. Concept2® Measurement System,” *International Journal of Sports Medicine*, vol. 27, no. 10, pp. 830–833, Oct. 2006. doi:10.1055/s-2006-923774

Content:

- Article only calculated power produced by the rower at the handle
- Concept2 ergometers use wind resistance and monitors to display stroke parameters such as speed, pace and power
- Study revealed mean values from the ergometer were 6.8% than the mechanical sensors (the Concept 2 system underestimates power produced by the rower by 25 W)
- Difference between power measurements have not yet been studied in rowing
- Trained rowers have better stroke to stroke consistency compared to beginners so this factor might be affect power measurement accuracy

Power Calculation from Mechanical Sensors

- Mechanical sensors: strain gauge placed near the handle and position sensor installed on the handle which allowed the calculation of the power developed by the rower
- Mechanical sensors allowed the measure of force at the handle and its position variation
- Power developed by the rower was calculated by multiplying the force produced at the handle by its velocity (derivation of position).
- Power was averaged on the whole rowing cycle

Power Calculation from Older Erg Models (Concept 2 Model A)

- Power was calculated as the product of the torque applied to the flywheel by its angular velocity but there aren't any torque sensors in the erg so torque was calculated by finding flywheel deceleration (T = Ja)
- This method calculation doesn't account for changes in friction on the flywheel bearings with or changes in air properties

Power Calculation From Newer Erg Models (Concept 2 Model B & C)

- Power at the level of the flywheel is considered to be the sum of the power dissipated by air resistance and the power developed to accelerate the flywheel between two successive strokes
- More accurate measurement of power

Testing

- 12 rowers - 6 novices: 22+- 2.3 years, 181.3 +- 10.9 cm, 77.3 +- 11.5 kg, 6 experts (rowing for almost a decade): 22.2 +- 2.2 years, 185 +-5.7 cm, 78.2 +- 6.8 kg)
- Tests included having rowers going all out for 15 strokes, initial power was 100 W for both groups and increased every 30 seconds (25 W for beginners, 50W for experts)

Conclusions/action items:

It was really interesting seeing how power was calculated by mechanical sensors and it could possibly be implemented for the lower extremities by adding the load cells on the footplate and putting a position sensor on the seat to calculated power produced by the legs. In conclusion, difference in rowing expertise can be a crucial factor when determining the validation of our force sensor.

SIMERJOT KAUR - Sep 20, 2024, 10:16 AM CDT

[Download](#)

Power_Response_During_Ergometer.pdf (124 kB)

2024/10/15 Load Cell Conditioning

SIMERJOT KAUR - Oct 25, 2024, 11:39 AM CDT

Title: Load Cell Conditioning

Date: 10/15/2024

Content by: Simmi

Source: J. Teel, “Introduction to load cell conditioning circuits,” PREDICTABLE DESIGNS, https://predictabledesigns.com/introduction-to-load-cell-conditioning-circuits/ (accessed Oct. 15, 2024).

Goals: Learn how to properly create a load cell circuit and what elements can be added to increase reading accuracy.

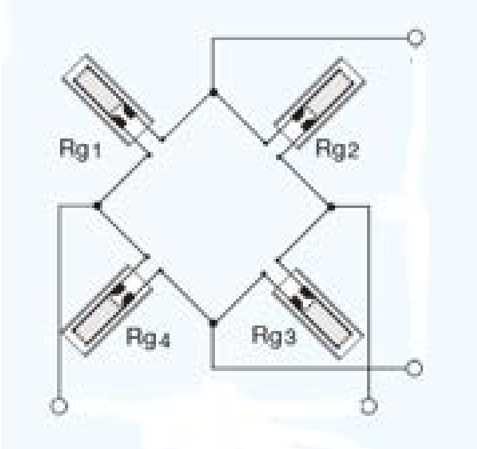
Content:

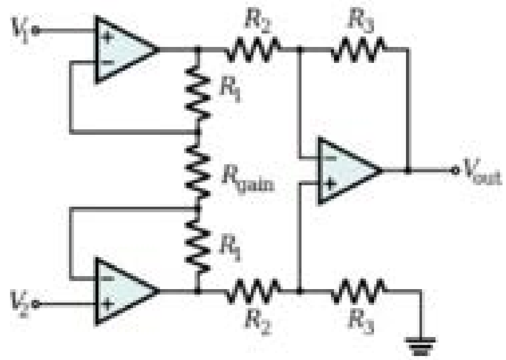
1. To create a load cell circuit with a low-pass filter, use a strain gauge load cell in a Wheatstone bridge setup to generate small voltage signals proportional to the applied force.

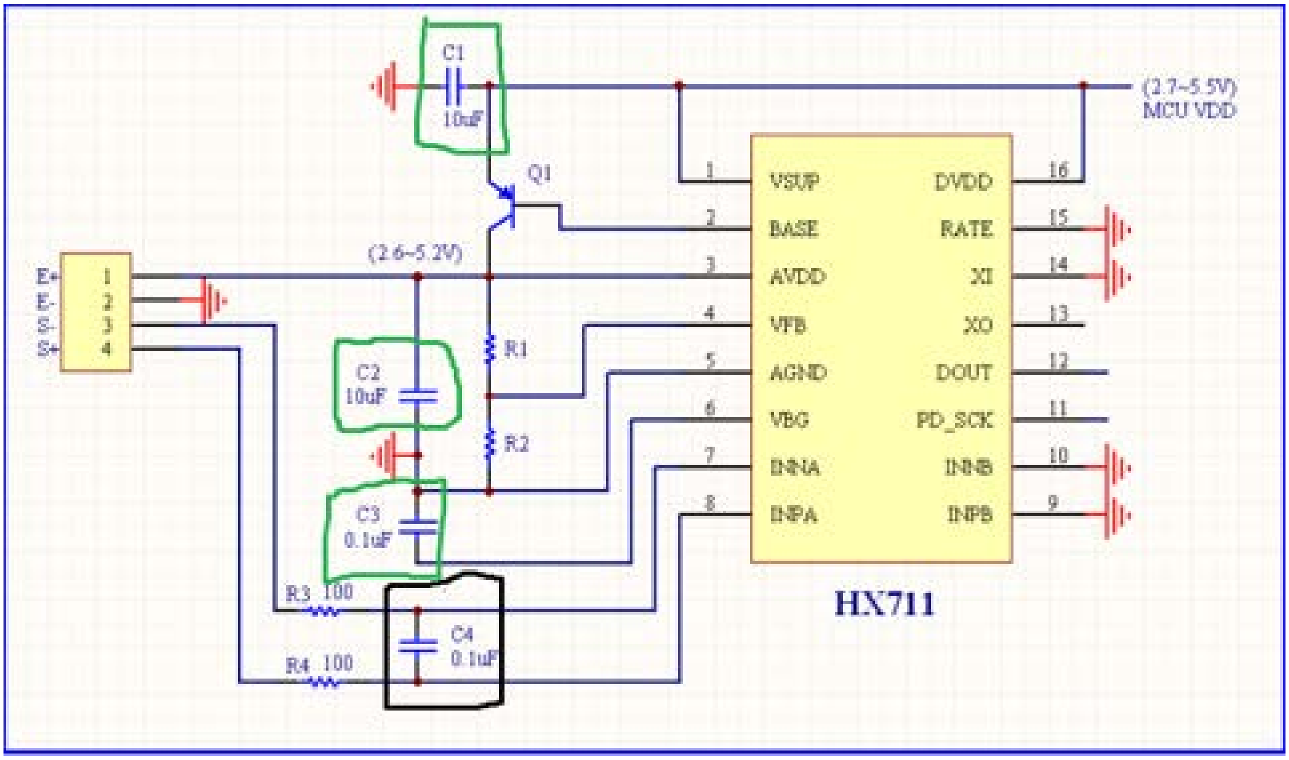
2. Amplify this signal using an instrumentation amplifier for its stability and high precision.

3. Apply a low-pass RC filter with a resistor and capacitor to reduce high-frequency noise, ensuring only the load cell’s low-frequency signal passes.

4 If we need more filtering, we could op-amp-based active filters to refine the signal quality.







The above image is a reference to what our circuit should look like, however instead of an HX711 amplifier we will using a simpler amplifier (3 of them). Two of them will act as voltage buffers and the last one will be used to amplify the difference between the two voltage followers.

Conclusions/action items: In conclusion, it will be necessary to add a low pass filter through the load cells and have a gain of around 50 to amplify the signal from the load cells which is around 50 mv to 0.1 V. Action items are to create the load cells on the breadboard with atleast 4 load cells.

2024/10/23 Load Cell Housing

SIMERJOT KAUR - Oct 25, 2024, 11:47 AM CDT

Title: Load Cell Housing

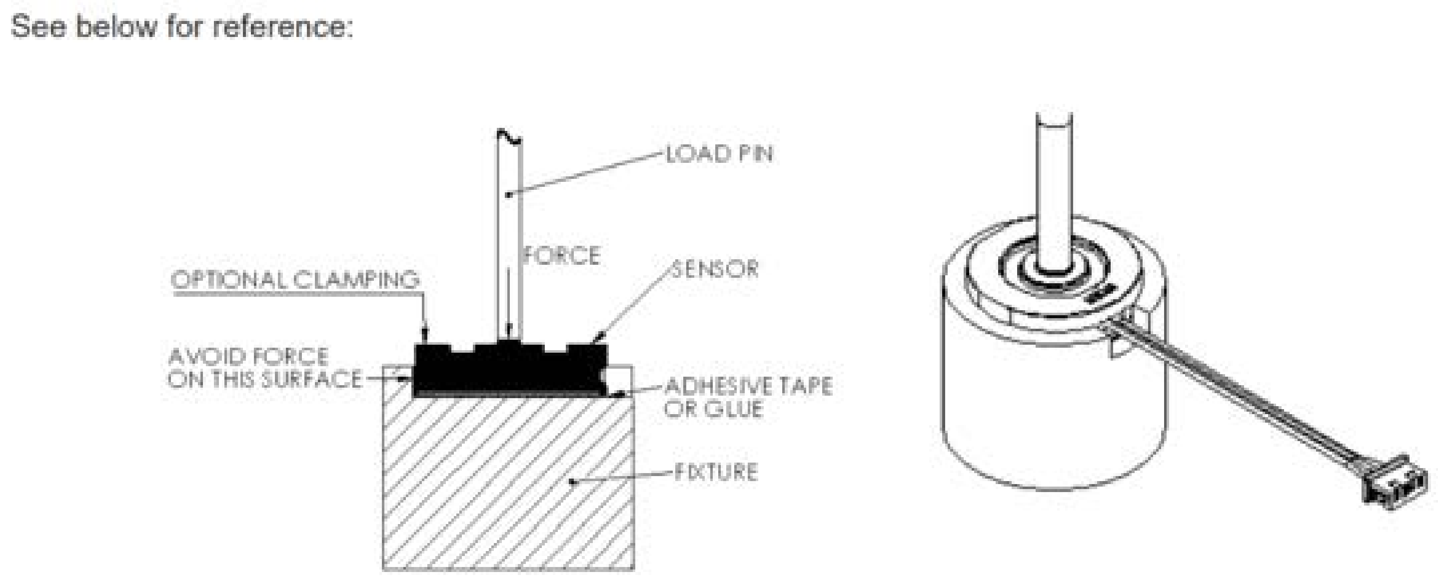
Date: 10/23/2024

Content by: Simmi

Goals: Create a load cell housing fixture to be attached to the bottom plate of the load cell.

Content:

The load cell housing I made consists of a flanges that are screwed on to the bottom plate. The inside of the design is an exact mold of the load cell to better secure the load cell from the top. Below is the image of the load cell mounting instructions from the datasheet:



It is preferred if there is no force on the side of the load which is why the housing will cover the top of the load cell and will minimize force on the sides. Lastly, the load cell housing will only expose the push button feature on the top so the pin can only push onto that surface and this can prevent any possible damage from force on other parts of the load cell.

Insert Image of Design here:

Conclusions/action items: Action items are to 3D print the parts and attach to bottom plate.

Wii Fit Board Concept

Colin Fessenden - Sep 19, 2024, 1:43 PM CDT

Title: Wii Fit Board

Date: 9/19/2024

Content by: Colin Fessenden

Present: N/A

Goals: See if the Wii fit board has any technology inside of it that we could copy/utilize.

Content:

https://pubmed.ncbi.nlm.nih.gov/27735224/

> T. B. Weaver, C. Ma, and A. C. Laing, “Use of the Nintendo Wii Balance Board for Studying Standing Static Balance Control: Technical Considerations, Force-Plate Congruency, and the Effect of Battery Life,” *J Appl Biomech*, vol. 33, no. 1, pp. 48–55, Feb. 2017, doi: 10.1123/jab.2015-0295.

The Nintendo Wii Balance Board (WBB) was used for studying standing static balance. The research examined technical considerations, including the accuracy of the WBB as compared to a force plate, and the influence of battery life on data quality. Results showed that while the WBB offers a cost-effective alternative for balance control studies, its measurements can differ from traditional force plates.

Conclusions/action items:

The Nintendo Wii Balance Board shows potential for balance studies, but care must be taken with calibration, force accuracy, and battery status for reliable results. In terms of measuring force, it may not be vailable.

2024/10/08- Proposed Design CAD Model

Colin Fessenden - Oct 08, 2024, 1:46 PM CDT

Title: CAD Model of Proposed design

Date: 10/8/2024

Content by: Colin Fessenden

Present: N/A

Goals: create digital design using CAD Modeling

Content:

See attached

Conclusions/action items:

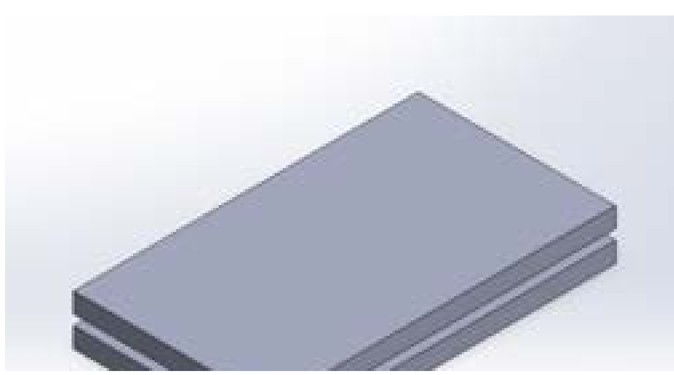
Begin fabrication of footplates

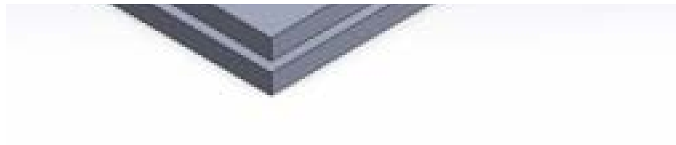
Colin Fessenden - Oct 08, 2024, 1:46 PM CDT

Download

design_1_bottom.png (37.7 kB)

Colin Fessenden - Oct 08, 2024, 1:46 PM CDT





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design_1.png (126 kB)

Colin Fessenden - Oct 08, 2024, 1:46 PM CDT

Download

design1_Assem.SLDASM (248 kB)

Colin Fessenden - Oct 08, 2024, 1:46 PM CDT

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design1_bottom.SLDPRT (68 kB)

Colin Fessenden - Oct 08, 2024, 1:46 PM CDT

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FX292X-100A-0100-L.SLDPRT (369 kB)

09/26/2024 - Internal vs External Cues While Rowing

Neha Kulkarni - Sep 26, 2024, 6:44 PM CDT

Title: Internal vs External Cues While Rowing

Date: 09/26/2024

Content by: Neha

Present: Neha

Goals: Determine efficacy of different types of cues in affecting rowing performance, for application in our GUI

Content:

- internal focus = focus on bodily sensation, internal resources
  - ex. balance, posture, feelings in arms/legs
- external focus = focus on outcome of movement, effect of movement on environment
  - ex. competitors, effect of movement on oars, seat, boat
- hypothesis: external focus best
  - enhances efficiency of movement planning and execution
  - internal focus means movements are consciously controlled, constraining motor system and disrupting muscle memory
- external cue examples:
  - "focus on exerting power through the handles" and "focus on exerting power through the seat"
- internal cue version:
  - "focus on exerting power through the arms" and "focus on exerting power through the legs"
- objective: complete 2000m row in fastest possible time
  - one run all external cues
  - one run all internal cues
  - one run switching cues
- participants filled out questionnaire afterwards
  - how long did you focus on XYZ on a scale of 1-7?
- power, time, stroke rate, heart rate measured
- results
  - stroke rate: no diff
  - heart rate: increased over time (interval-dependent, not cue-dependent)
  - time: significantly fastest when switching cues
  - power: significantly more when switching cues
  - attentional focus: rowers focused significantly more on external cues

Conclusions/action items:

- A rower viewing our GUI could be considered "external" because the OUTCOME of their movement affects the graphic on the screen. Because switching cues is shown to be helpful, coaches may want to prompt rowers with internal cues as a result of the GUI output
  - external-internal translation of cues?

09/08/2024 - Validation of Plantar Pressure and Reaction Force Measured by Moticon Pressure Sensor Insoles on a Concept2 Rowing Ergometer

Neha Kulkarni - Sep 08, 2024, 6:43 PM CDT

Title: Validation of Plantar Pressure and Reaction Force Measured by Moticon Pressure Sensor Insoles on a Concept2 Rowing Ergometer

Date: 09/08/2024

Content by: Neha

Present: Neha

Goals: Understand if sensor insoles can work as a potential route for our design.

Link/Citation: https://www-ncbi-nlm-nih-gov.ezproxy.library.wisc.edu/pmc/articles/PMC8036524/

Content:

- Study conducted with 19 rowers (16F, 3M) on Concept2 erg
  - 4 trials of 500m each for each rower
- Used 2 force sensor insoles, two trials per insole for each rower
  - Moticon Sensor Insole 2 ReGo
  - Novel Pedar-x
- Used FloatPro app to collect data
  - Connected to erg display via bluetooth
- Moticon measures plantar force distribution, 3D acceleration, and reaction force from plantar pressure
  - Wireless
  - More affordable
  - Uses capacitive sensors, MEMS accelerometer
  - 50 Hz sampling frequency
  - Measures 12 plantar regions, 52% of insole area
- Pedar-x measures pressure distribution, calculates reaction force
  - Measures 99 plantar regions (entire insole)
  - 50 Hz sampling frequency
- Attached footplate with rowing shoes, put insoles into rowing shoes
  - This is a good idea, mimics rowing in boat conditions
  - 
- Data exported from software specific to each insole and processed externally in Excel
  - We can do it in MATLAB
- Results/Discussion
  - Pedar-x and Moticon showed significant difference for avg pressure, avg force, and peak force
  - Both insoles display test-retest reliability
  - BUT Moticon is not a valid pressure measuring system when compared to Pedar-X
  - Overestimation of force variables seen bc of sustained contact with insole

Conclusions/action items: Consider insoles as a potential design. Discuss cost/benefits of getting Pedar-x (more accurate) vs Moticon (more affordable, wireless)

09/18/2024 - TE Connectivity Load Cells

Neha Kulkarni - Sep 18, 2024, 9:51 PM CDT

Title: TE Connectivity Load Cells

Date: 09/18/2024

Content by: Neha

Present: Neha

Goals: Investigate specs and feasibility of TE Connectivity Load Cells per Dr. Gruben's recommendation

Link/Citation: https://www.te.com/en/product-CAT-FSE0006.html?n=510876&d=836862&type=products&samples=N&inStoreWithoutPL=false&instock=N

Content:

- TE offers compact compression load cells, good form factor for us
  - 19.4mm diameter, 5.45 mm tall
- Load full scale range (lbf) offered in:
  - 25, 50, 100, 200
  - 100 is probably good for our application given that the load cells won't be loaded directly
- Output signal options
  - 4 V (analog amplified) → probably best for us but more expensive
  - 20 mV/V (analog)
  - 14-bit I2C
- Cable lengths of 40mm or 100mm
- Cost
  - $66 on DigiKey for 100 lbf, 4V amplified analog output, 40mm cable length
    - $66 x 8 = 528 → over budget
  - $32 on DigiKey for 100 lbf, 20 mV/V, 40mm cable length
    - $32 x 8 = 256 → under budget! We could amplify the signal ourselves
- Very detailed datasheets on their website!!

Conclusions/action items:

- Consult team members and client on which load cell to order and order ASAP

Neha Kulkarni - Sep 18, 2024, 9:52 PM CDT

[Download]

ENG_DS_FX29_A7.pdf (774 kB)

09/24/2024 - GUI Designs and Code

Neha Kulkarni - Sep 25, 2024, 9:06 PM CDT

Title: GUI Designs and Code

Date: 09/24/2024

Content by: Neha

Present: Neha

Goals: Play around with pyqt and make some draft GUIs

Link/Citation:

Content:

- data to display:
  - absolute (pure) force
  - force difference
- ways to display
  - line graph
  - bar graph
- for force difference, display horizontally (right diff vs left diff)
- other features
  - color: diff colors for right and left
  - turn red when one is higher than the other
- videos of GUIs
  - absolute force bars
  - absolute force curves
  - force diff bar
  - force diff line
- code is attached in jupyter notebook file

Conclusions/action items:

- Get feedback from clients and rowers on these GUIs
- make rower feedback form

Neha Kulkarni - Sep 25, 2024, 9:06 PM CDT

[Download](#)

sandbox.ipynb (25.1 kB)

09/24/2024 - Rower Feedback Form

Neha Kulkarni - Sep 25, 2024, 9:17 PM CDT

Title: Rower Feedback Form

Date: 09/24/2024

Content by: Neha

Present: Neha

Goals: Create form to get rower feedback on GUI designs

Link/Citation:

Content:

- Ask rowers to rank options
  - want to keep the form short so we get more responses
  - will add one open-ended feedback question
- Criteria to evaluate
  - Aesthetics --> how visually pleasing?
  - interpretability --> is data presented in a way that's understandable?
  - comprehension speed --> will rowers be able to adapt in real-time when presented with a live graph?
  - relevance of data --> how helpful is the data being presented?

Conclusions/action items:

- Send to Jill/Tricia so they can forward to rowing team and coaches
- Evaluate results and make changes to GUIs accordingly
- IDEA: make final application modular to change graphical representation based on desired training outcome

Neha Kulkarni - Sep 25, 2024, 9:18 PM CDT

FORM LINK

2024/10/11 - Footplate materials research

Neha Kulkarni - Oct 11, 2024, 11:00 AM CDT

Title: Footplate materials research

Date: 10/10/2024

Content by: Neha

Present: Neha

Goals: Figure out which materials to use for our footplate that are within our budget

Content:

Material options on Grainger:

- ideal: aluminum
    - All plates are over $100 --> probably not wise to use this material as our top/bottom footplate
    - maybe we could buy less of it and use it as our side walls since we really need those to be rigid
        - for membrane-bound/bearing-guided design
- option: alloy steel
    - cheaper
        - $60 for a 12 x 24 sheet, 2mm thick
    - strong
        - ~60k psi yield strength --> more than enough
    - easy to machine
- option: LDPE plastic
    - strong - Grainger says No Break (?)
    - super cheap
        - probably available at TEAMLab?
    - poor tensile strength
        - don't anticipate that being an issue since that's not the direction it's being loaded in
    - good option for stationary footplate prototype
- for side walls: use U-channels?
    - would be secure
    - can screw into top/bottom so pretty modular
    - can essentially leave stationary footplate as is and add these to make the other designs
    - one issue: bottom plate wouldn't be flush so need to cut/oversize bottom plate

Conclusions/action items:

- order/get LDPE plastic to prototype stationary footplate
- order alloy steel for side walls?

2024/10/22 - MC3008 ADC Python library

Neha Kulkarni - Oct 25, 2024, 2:43 PM CDT

Title: MC3008 ADC Python library

Date: 10/22/2024

Content by: Neha

Present: Neha

Goals: Explore the python library and examples of signal processing from our ADC

Content:

GitHub link

MC3008 link

- library allows for reading raw voltage from a single pin or differential voltage between pins

Conclusions/action items:

- order/get LDPE plastic to prototype stationary footplate
- order alloy steel for side walls?

2024/11/8 - GUI Updates and Features

Neha Kulkarni - Nov 08, 2024, 4:49 PM CST

Title: GUI Features & Updates

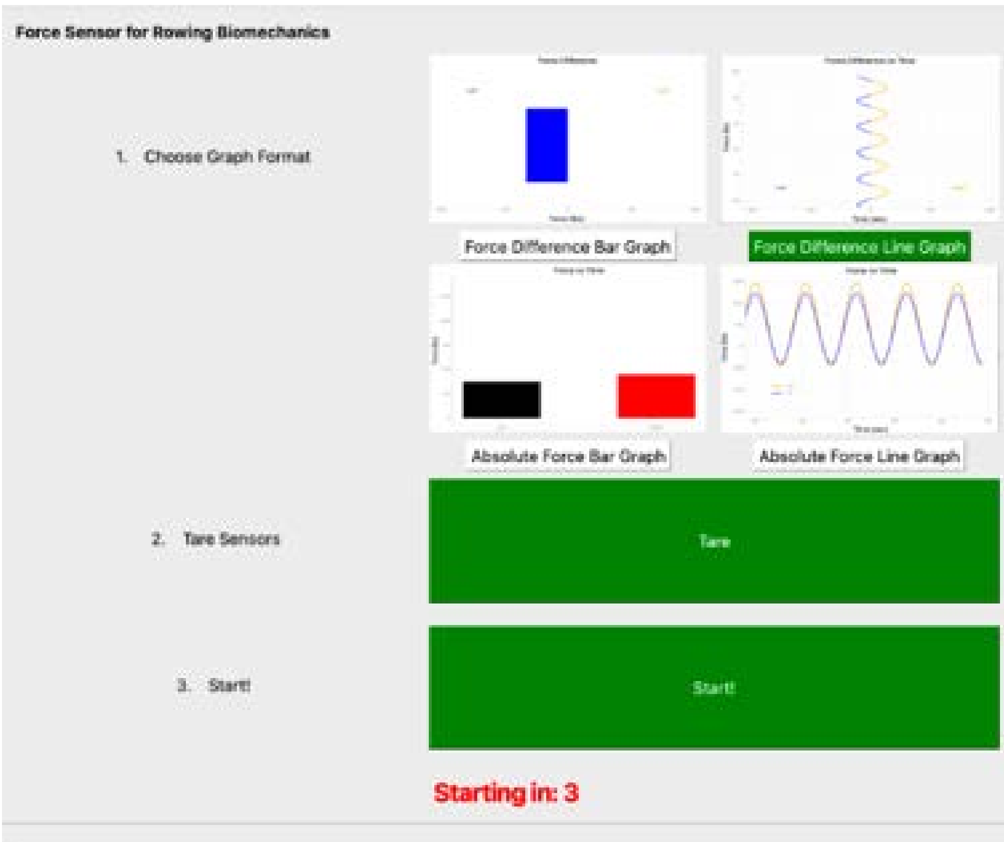
Date: 11/8/2022

Content by: Neha

Present: Neha

Goals: Update the GUI and explore some new features to add

Content:

- added homepage to select graph type, tare sensors, and start
    - counts down from 5 for rower to get set
    - 

- changes to graph setup
    - abs lines is now orange and blue to keep consistency between other graphs
    - abs bars is black and red for clarity
        - harder to interpret two colors (green and red) than one (black and red)
    - got rid of y axis on force diff bar for clarity
- generating random test data instead of reading same csv
    - using np.sin, randomizing parameters every time
    - set sample rate (24 Hz)
    - create time array with np.arange using 1/sample_rate as spacing
        - 30 second trial instead of 10 second
    - set stroke rate using np.random.uniform (selects a sample within a range of values)
        - varies between 28-36 strokes/min ~= 0.45 - 0.6 strokes/sec (multiply by 2pi in function bc np.sin is in rad)
        - can vary stroke rates between feet or set both feet to same stroke rate
    - set a random amplitude for each leg between 100-200 lbs
    - set the vertical offset as about half the amplitude (between 0.45-0.55 times the amplitude) for each leg
        - account for small amount of tension force/lack of tension force
    - set timer interval to 1000ms/sample_rate
- new/potential features

    - allow user to enter rower height/weight
    - graph background turns red when asym > 100 lbs
        - this threshold will have to be adjusted - makes more sense to use a relative value than an absolute one
            - could use % of rower bodyweight?
            - could use clinical 90% threshold? --> when i tried this the constant flashing was really annoying. might adjust parameter to average force asym instead of instantaneous force
    - for abs bars, bars turn green when asym <= 10 lbs
        - this threshold will also have to be adjusted like the above one
    - choose to measure in lbs/newtons?
        - newtons is clinically relevant, lbs is more understandable to rower

Conclusions/action items:

- we'll only know what features make sense after we get a more real dataset
- ask clients about implementing some/all of these features at next meeting

BME Design - Spring 2024 - notebook

ALLICIA MOELLER - Sep 06, 2024, 1:41 PM CDT

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2024_09_06_notebook_66369.pdf (254 MB)

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

Neha Kulkarni - Sep 08, 2024, 6:22 PM CDT

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: