xDI - Cartilage Bioreactor

Client: Prof. Corinne Henak
Faculty Consultant: Prof. Corinne Henak (ME); Prof. Paul Campagnola (BME)
Team: Jeffery Guo (ME Admin & Accountant)
Emilio Lim (BME BWIG & BSAC)
Griffin Radtke (ME Operational Leader & Communicator)
Sydney Therien (BME Operational Leader & Communicator)

Status

Report Date: 04/12/2024
Next Milestone: Final Report
Deadline: 04/29/24
Status: on schedule

Technical Summary

This week, the team continued progress on fabricating housing components and circuitry reference materials. On the housing end, the PTFE rods are completely fabricated and ready to be incorporated into the bioreactor. Inserts for the aluminum rods that will connect them to the voice coils have been designed and one was 3D printed. Progress was also made on the fastener setup for the sample tray as it needs to be easily removed and reattached for sample imaging. A breadboard circuit diagram was also created for reference by Henak Lab personnel so that more actuators can be incorporated in the future. Load cell test data will also be analyzed and the team will look to purchase parts such as the DAQ, power supply, and circuit components. The team will continue to fabricate the bioreactor next week and hope to have it assembled relatively soon, ideally before Monday April 22nd.

New Tasks

Task Name	Description and Concrete Outcome	Owner	Est. Time [hrs]
Finish PTFE fabrication	Threaded the PTFE and obtained the correct fasteners for the cylinders.	ST	1
Ideate sample tray connection/removal strategies	Brainstormed how to best attach the sample tray to the lid in a way that can be secure but also easily removable	ST	2
Complete Breadboard circuit	Design a breadboard circuit diagram for ease of building in future	EL	1
Finish VCA Attachment Components	Made slight additional modifications and 3D-printed press-fit, biocompatible attachments to the bearing shaft.	GR	2
Review load cell test data and order parts	Review last week's testing data from the load cell and get ready to purchase parts	JG	1

Technical Section

Author: Sydney Therien
Editor: N/A

Finish PTFE fabrication	Threaded the PTFE and obtained the correct fasteners for the cylinders.	ST	1

In order to finish full fabrication of the PTFE rods, the inside of the drilled holes needed to be threaded. This was accomplished on a lathe using an M6 bit. Additionally, all the fasteners were swapped out to be the same length. As of now, the PTFE is 100% ready to be assembled into the bioreactor housing.

Author: Sydney Therien
Editor: N/A

Ideate sample tray connection/removal strategies	Brainstormed how to best attach the sample tray to the lid in a way that can be secure but also easily removable	ST	2

In order to make the bioreactor's samples easily accessible for imaging by Dr. Henak and her lab personnel, the sample tray needs to be completely removable from the bioreactor. This will require some strategic thought about fastener locations and methods. There were two main ways to do this that came to mind. The first of which requires eight bolts and wingnuts that attach to the lid and base modules, shown in Figure 1 below. Four bolts go into the lid and four go into the base, and a pair of them attaches each corner. The force applied by these bolts would be directly perpendicular to the surface they are drilled through. This method would require the acrylic and sample tray holes to be threaded.

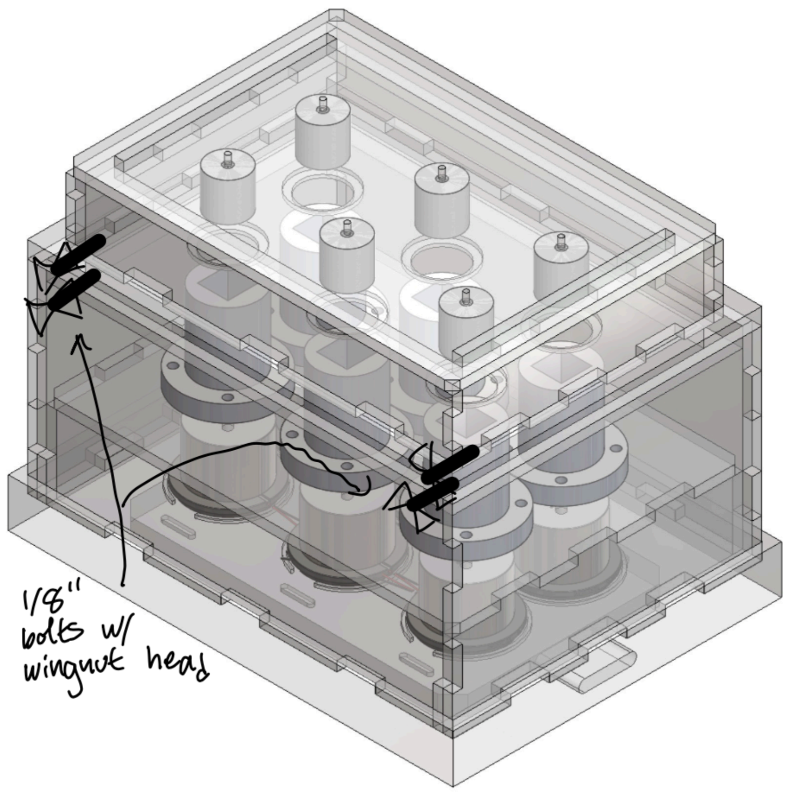


Figure 1: A schematic bioreactor with one face of wingnut attachment shown.

The second method to fasten the lid involves utilizing eight dowels and four cable clamps. The dowels will go in the same (non-threaded this time) holes and stick out for about half an inch. This will provide two points for a Cable Clamp to go around and hold the dowels together. If you are unfamiliar with what a Cable Clamp is, it's essentially a reusable zip-tie. An example can be found in Figure 2. This method would be much faster of an assembly since adding eight dowels and four Cable Clamps would be more easily done than twisting eight wingnuts.

Figure 2: Some examples of Cable Clamps in open and closed configurations.

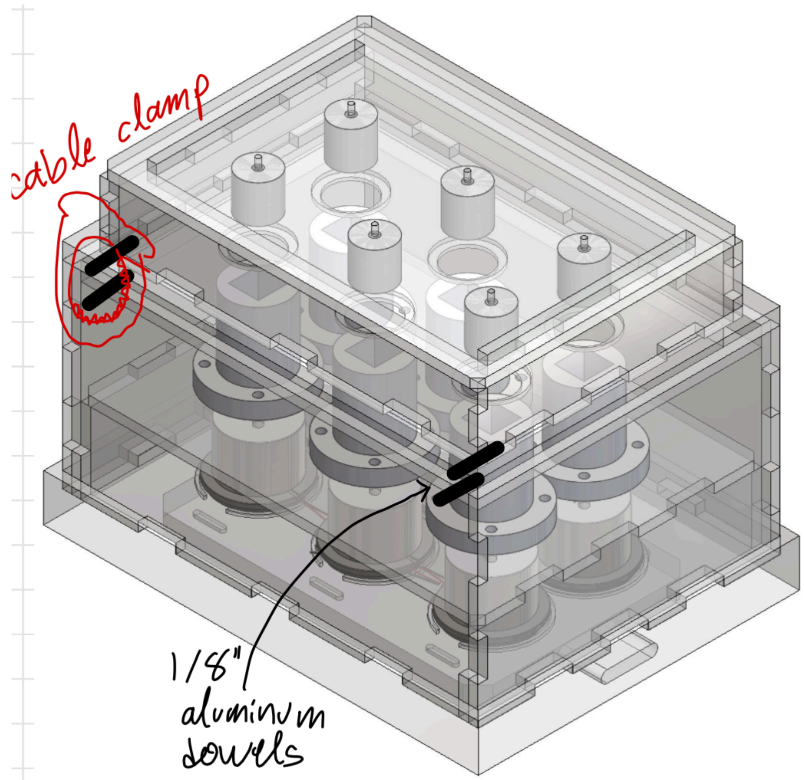


Figure 3: A schematic bioreactor with one face of dowel and Cable Clamp shown.

The potential issue with this design is the bending introduced by the Cable Clamps pulling on the dowels and creating a bending moment. In order to decide what to do moving forward regarding attaching the sample tray, SolidWorks simulations will be run after Sydney and Griffin discuss potential alternate methods of achieving this connection. There were alternatives discussed at this week's client meeting that will need to be evaluated, but the decision on this will be made quickly due to the ever-decreasing amount of time left in the semester.

Author: Emilio Lim
Editor: N/A

Complete Breadboard circuit	Design a breadboard circuit diagram for ease of building in future	EL	1

For the ease of building the circuit in the future, Dr Henak requested a breadboard diagram on top of the LTSpice schematic. The schematic was made using different components as it was not available on the software I was using. From figure 4 below, the 9V battery represents a power supply and the Arduino represents the MyDAQ. The ports of the Arduino and the MyDAQ are exactly the same. Other components include a NMOS transistor, diode, 1kΩ, 1MΩ, and a motor. While the components differ slightly to the actual design, the cable and connections are accurate. During the meeting with Dr Henak, it was explained that the circuit shown below can only power one VCA. To power all 6 VCAs, we would need to duplicate the exact circuit 5 times exactly.

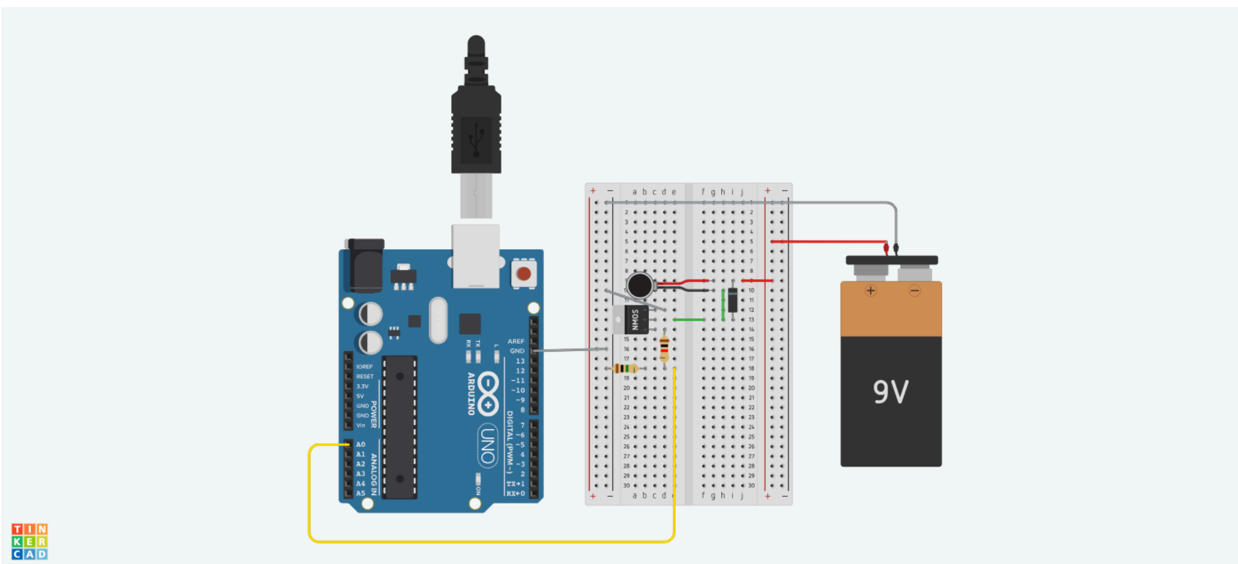


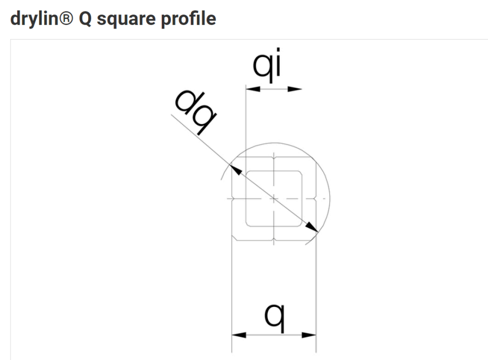
Figure 4: Breadboard circuit schematic.

Author: Griffin Radtke

Editor: N/A

Finish VCA Attachment Components	Made slight additional modifications and 3D-printed press-fit, biocompatible attachments to the bearing shaft.	GR	2

As the drawing for the drylinQ aluminum shaft isn't dimensioned particularly well (namely, the inner radius - Figure 5), I made a few slight adjustments to the previous CAD to ensure successful press-fit after receiving the sample parts from Sydney. Following those revisions, both adaptive components (see previous work) were 3D-printed with FL BioMed Clear resin. The plunger component was then press-fit (see Figure 6), with machining of the shaft (i.e., likely with a drop-saw) to the necessary length needed prior to press-fitting of the VCA-shaft/square profile attachment.



Art.-Nr.	AWMQ-10
q	7.5 mm
Ø dq	10.0 mm
qi	5.0 mm

Figure 5: Note the missing inner radial dimensions (the outer radius is not filleted while the inner is, interestingly enough).

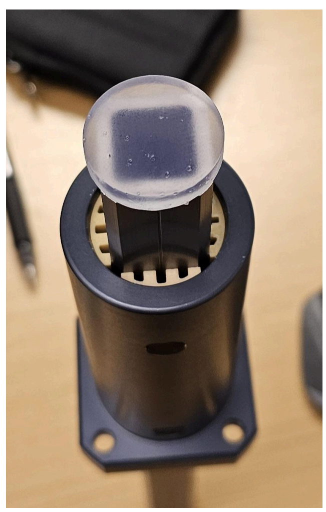


Figure 6: Press-fit plunger (i.e., which will contact the sample dish).

Author: Jeffery Guo
Editor: N/A

Review load cell test data and order parts	Review last week's testing data from the load cell and get ready to purchase parts	JG	1

Last week, Jeff and Emilio ran the VCA under the Henak Lab load cell to analyze the force profile and how it may or may not change over longer test durations. Initial review of the results seems to suggest that there could possibly be minor fluctuations or changes in the load over time scales of 15-30 minutes. More specific results and numbers quantifying behavior such as overshoot, which will be included in the final report and posters. The force profile was a square wave, and its square-like profile could be partially attributed to the base of the load cell being magnetic. We will also prepare to place purchase orders for a NI DAQ, power supply, and circuit components.

Gantt Chart

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Jan		Feb				Mar				Apr				
Task	24	31	7	14	21	28	6	13	20	27	3	10	17	24	1
Individual Presentations					X										
Bioreactor Housing and Bearings															
Control with One VCA								X							
Working Prototype										O					O
Full Bioreactor CAD Model				X											
Fabricated Bioreactor									X						
Circuitry with All Six VCAs															
Final Review										O					O
Design Specification Validation															
Bioreactor Assembly with Circuitry															

X = Completed Tasks, O = Milestone Deadlines

Old Tasks

Task Name	Description and Concrete Outcome	Owner	Est. Time
Integrate MyDAQ with motor controller or other circuitry to get desired output	Experiment with different circuit components (e.g., MOSFET, power op amp, H-bridge, etc.) to obtain a force of 6N at 1Hz using the myDAQ and/or Maxon motor controller	EL/JG	3
Finalize bearing options	Flesh out bearing design matrix with all final options and quantitative specs.	ST	3
CAD Refinement & Analysis	Run SolidWorks FE static simulation to verify feasibility of compressive interface, refine model graphics	GR	3
Troubleshoot myDAQ	Troubleshoot potential errors in the myDAQ	JG	2
Work with Arduino and current regulator	See if some codes of the arduino can be used to generate a sine wave in lieu of the current regulator from the ME library	EL	2
Design consultation with TeamLab regarding fabrication and bearings	Met with TeamLab personnel to ask about the cost/feasibility of fabricating the device and solicited their opinion on what bearings to use.	ST	1
New CAD with fabrication feedback from TeamLab	Turned the TeamLab's recommendations for the bioreactor into a full SolidWorks file which will be possible to machine.	ST	7.5
Estimate 3D-Print Costs	Calculate exact costs of 3D-printing previous model, itemize budget	GR	1
Test and develop working system of circuitry/electronics to operate VCA	Continue experimenting with electronics/other components (e.g., motor controller, H-bridge, power supply, myDAQ, Arduino) to develop functioning system that can operate the VCA	JG/EL	3
Develop rough calibration curve for voltage input and force applied	Create a rough calibration curve for voltage input for the VCA vs. force outputted by the VCA using the triangle PCB	JG/EL	1

Estimate friction and impact of wear for Drylin Q Flange bearing	Pulled numbers from Drylin website and made plots to get a sense of how long the bearing could be in operation and how much of an issue friction would be.	ST	2.5
Continue testing H-bridge	Continue testing H-bridge to get a triangle output	JG/EL	3
Revamp CAD for Machining	Make modifications to existing CAD for machining-purposes	GR	6
Finalize prototype CAD and manufacture prototype parts	Put finishing touches on the actual 3D model and create SolidWorks drawings that can be laser cut. Use Makerspace facilities to 3D print and laser cut the parts for the prototype.	ST	3
Prepare presentation for prototype demonstration	Administrative – working to concisely present physical and analytical work.	All	2+
Continue developing working electronics/circuitry	Continue developing the circuit and electronics to operate the VCA	JG/EL	2
Draw a circuit diagram	Use LTSpice to draw out the circuit diagram	EL	0.25
Temp. Analysis of Compressive Lid	Verified acrylic's stability under thermal expansion at incubator-like conditions.	GR	1.5
Request sample of bearing and shaft from Igus.	Ordered one bearing and 9-12in of hard-anodized aluminum square hollow shaft on a sample form available on Igus.com.	ST	0.5
Modifying CAD for prototype presentation	Added bearings, compressive interface PTFE, and VCAs to the CAD used for prototype fabrication.	ST	1
Finalize circuitry and mode of operation	Finalize the circuit and choose on either using the Arduino or MyDAQ	EL/JG	3
Force Sanity Check	Conducted finite element simulation of cartilage plug sample under loading conditions expected within the bioreactor.	GR	1.5

VCA-Compatible Components	Designed (and will be 3D-printing) components compatible with the drylinQ bearing system.	GR	2
Received bearing and shaft sample from Igus (!)	Unpacked the samples that arrived from Igus over spring break.	ST	0
Machined PTFE (almost complete)	Used a bandsaw and lathe to cut the PTFE pillars, face them, and drill holes that still need to be tapped.	ST	4
Force test	Used a load cell to test the consistency of the force output	EL/JG	2

Previous Work

Author: Sydney Therien
Editor: N/A

Request sample of bearing and shaft from Igus.	Ordered one bearing and 9-12in of hard-anodized aluminum square hollow shaft on a sample form available on Igus.	ST	0.5

After going to the Igus website to get information for filling out the order form, I noticed that there was a new “request sample” button on the page. I filled this out for one Drylin Q square flange and one for 9-12in of hard-anodized aluminum square hollow shaft. The total value of these products is about $70, so I’ll watch my inbox for either a confirmation of shipment or a message that says this is too expensive to sample. If I don’t hear anything from them by the end of spring break, I’m going to assume that my request won’t be granted and I’ll then fill out purchasing forms for these items.

After the prototype presentation, the team had a discussion about how we were going to finish out the semester. We’ve decided to validate our design and circuitry for one actuator and present our client with a working system rather than rush buying everything to build the design in its entirety. Ideally, we end the semester with a single actuator/bearing/plunger system that runs in a 3D print/¼” acrylic housing prototype. This housing will use the same acrylic panels as the current prototype, but the base and sample tray modules will be re-printed after some CAD modifications in a higher-quality biocompatible and autoclavable resin. The bioreactor could still be used for experiments in this state, but there would be many easy ways for the client to improve the device if she should choose to. If she wants to invest in the bioreactor fully, she could choose to hire the TeamLab to get the housing machined out of aluminum and order the other five units-worth of actuators, bearings, and shaft. The team is of the opinion that it would be more valuable to have a single working proof of concept that could then simply be multiplied than it would be to blow the entire budget in a rush to get a fully finished product.

Author: Sydney Therien
Editor: N/A

Modifying CAD for prototype presentation	Added bearings, compressive interface PTFE, and VCAs to the CAD used for prototype fabrication.	ST	1

To properly convey what the eventual design will look like, the CAD files used for fabrication of the prototype needed to be filled out with the rest of the design’s components. This involved adding compressive interface PTFE cylinders, ThorLabs voice coils, and Igus Drylin Q flange bearings to the SolidWorks assembly. Photos were taken for the design review that split the device into its modules, which can be seen below.

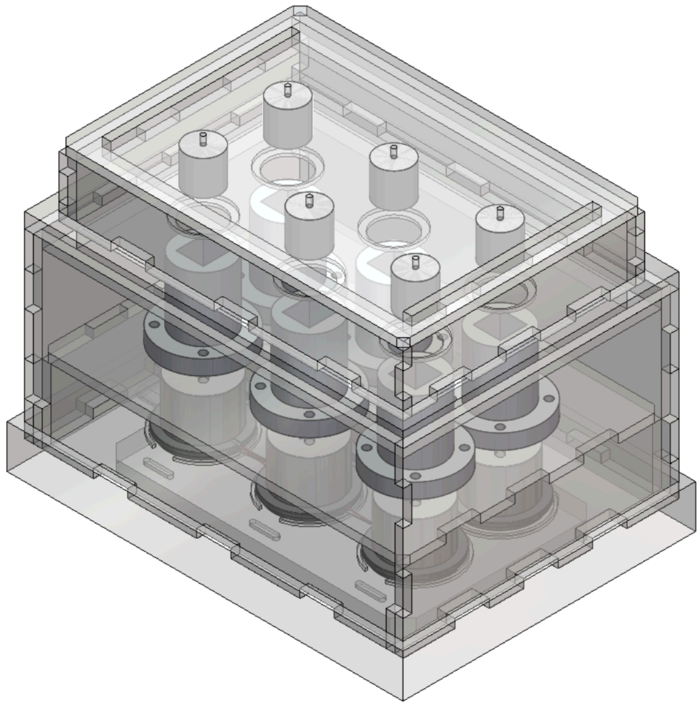


Figure 1: The full prototype in CAD complete with the purchased components.

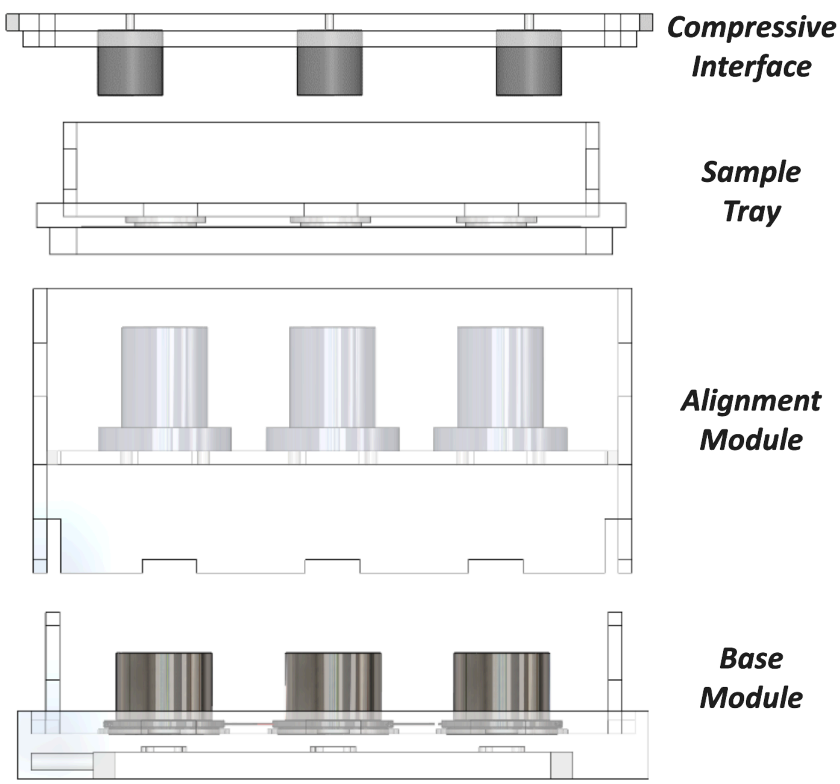


Figure 2: The labeled modular CAD of the prototype as it was presented.

Author: Emilio Lim
Editor: Jeffery Guo

Finalize circuitry and mode of operation	Finalize the circuit and choose on either using the Arduino or MyDAQ	EL/JG	3

We recorded some data from the MakerSpace using the MyDAQ and the Arduino. We found that when using the MyDAQ, the noise of 51dB from the Arduino due to the carrier frequency can be fully eliminated. When using the MyDAQ, we also found that the resulting voltage output across the VCA is a wave more similar to a square wave rather than a triangular wave. The voltage outputs when using the Arduino and MyDAQ are depicted below in Figures 3 and 4, respectively. To make the final decision, an overall summary was made to compare Arduino and MyDAQ using LabView.

After several discussions with Dr. Henak, we ultimately decided to use the MyDAQ instead of the Arduino which Dr. Henak has been supportive of. The circuit, however, will remain the same.

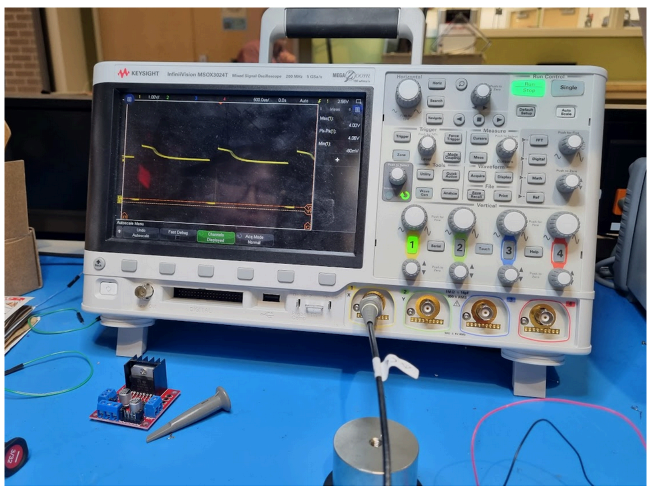


Figure 3: The voltage output across the VCA when using the Arduino to supply the input signal

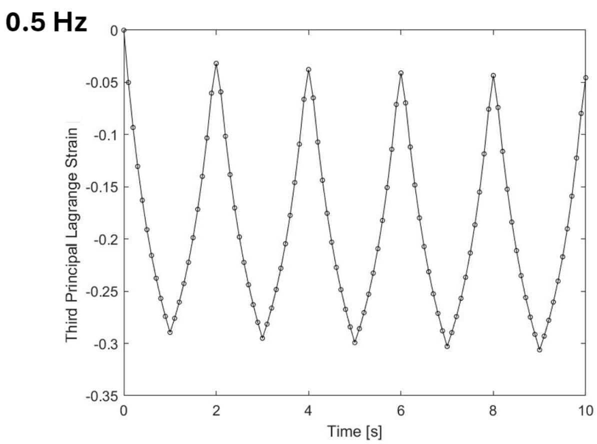
Figure 4: The voltage output across the VCA when using the MyDAQ to supply the input signal

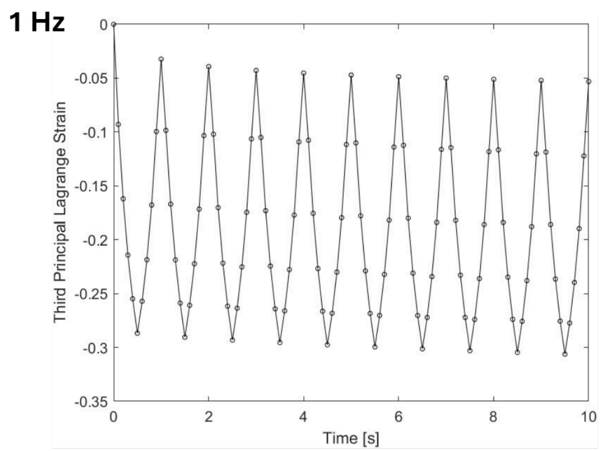
Author: Griffin Radtke

Editor: N/A

Force Sanity Check	Conducted finite element simulation of cartilage plug sample under loading conditions expected within the bioreactor.	GR	1.5

To ensure our initial force estimate (many, many weeks ago) was accurate to a more realistic model of articular cartilage, I ran a finite element simulation within FEBio of a ¼ symmetry cartilage plug (with our sample dimensions) via the biphasic solver, using properties previously discussed with Dr. Henak.With a triangular force input of -5.65 N (at 0.5 and 1 Hz) applied for 10 s, the third principal Lagrange strain was extracted and compared to our nominal ~-0.2 engineering strain approximation (showing alignment between our initial Hooke's Law approximation and our actual simulated output).





Author: Sydney Therien
Editor: N/A

Estimate friction and impact of wear for Drylin Q Flange bearing	Pulled numbers from Drylin website and made plots to get a sense of how long the bearing could be in operation and how much of an issue friction would be.	ST	2

After the TeamLab consultation steered the team in the direction of using the Drylin Q flange bearing (essentially for cost/lower complexity reasons), I wanted to see whether or not use of this bearing would fulfill the design specifications. This involved assessing the friction force that would be produced between the walls and the shaft, and the lifetime of the product using wear resistance.

To assess friction, I first called igus to see if the CoFs on the website were static or dynamic (it did not say). They said that the values would be comparable between the two, so for estimation purposes, I used the provided values for low and high loads (I'm fairly certain this is a low-load application, but I wanted to visualize both). Using Ff = mu*N and a range of normal forces from 0-3N (hopefully much more than we would hope to experience) and multiplying by four for the number of walls that experience the friction, I produced this plot.

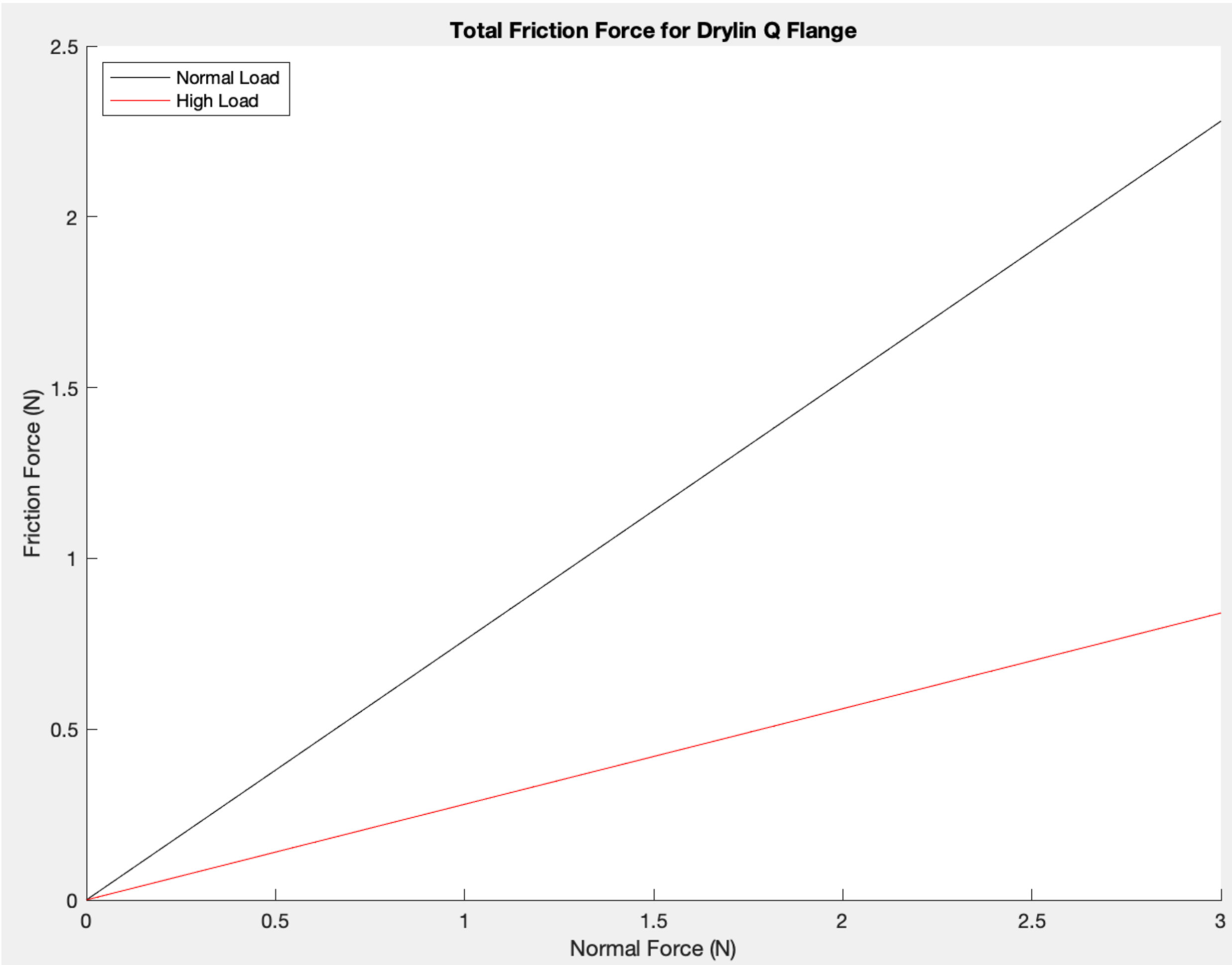


Figure 1: Plot describing the total friction force opposing actuator output force for the Drylin Q flange bearing over a range of normal forces.

Since the force output range for the VCA goes up to ~12N, this friction force is easily compensated for if the device is calibrated properly. However, the normal force fluctuates depending on the amount that the walls with low-friction gliding material are worn down. I wanted to assess how fast this process happened to both see how often the device would need to be recalibrated and how long the bearings would last before the low-friction gliding material wore down enough to necessitate replacement.

I pulled wear coefficients from the Drylin website. These were given in um/km, which I interpreted as "the gliding material will wear down this many microns if 1 km of shaft slides across it." These wear coefficients were given for many shafts, the lowest two of which for our gliding material (iglide J) were hard-anodized aluminum and hard-chromed. Drylin sells a [hard-anodized aluminum shaft](#) compatible with this bearing for $101.19/m. I assumed that with each actuation, the shaft travels along the entire length of gliding material (which is a significant overestimate but provides us with a solid factor of safety). Using the wear coefficients, the distance of gliding material covered in one second (twice the length of how much is inside the bearing), and some basic math, I calculated how long the bioreactor could be in operation. This is shown below.

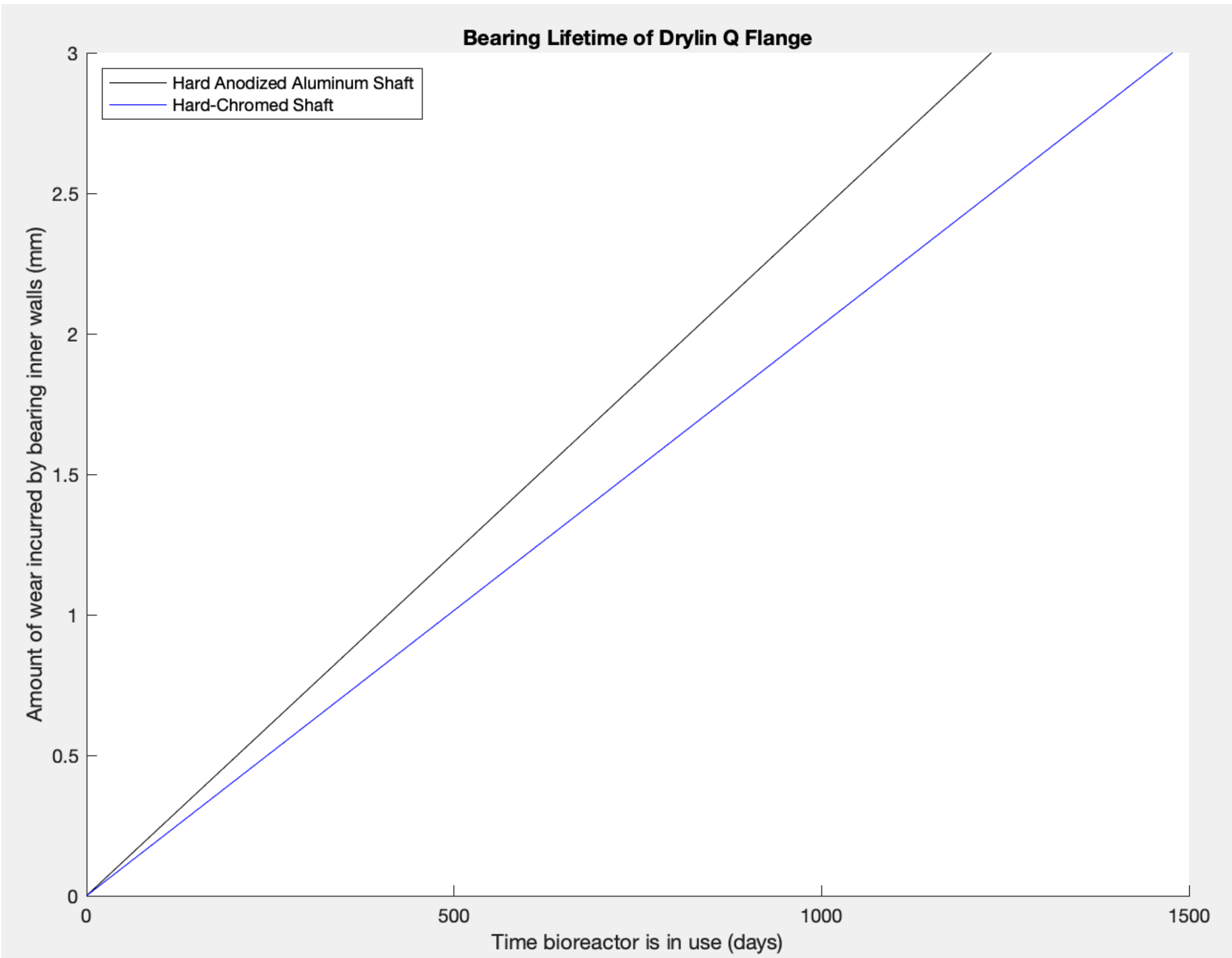


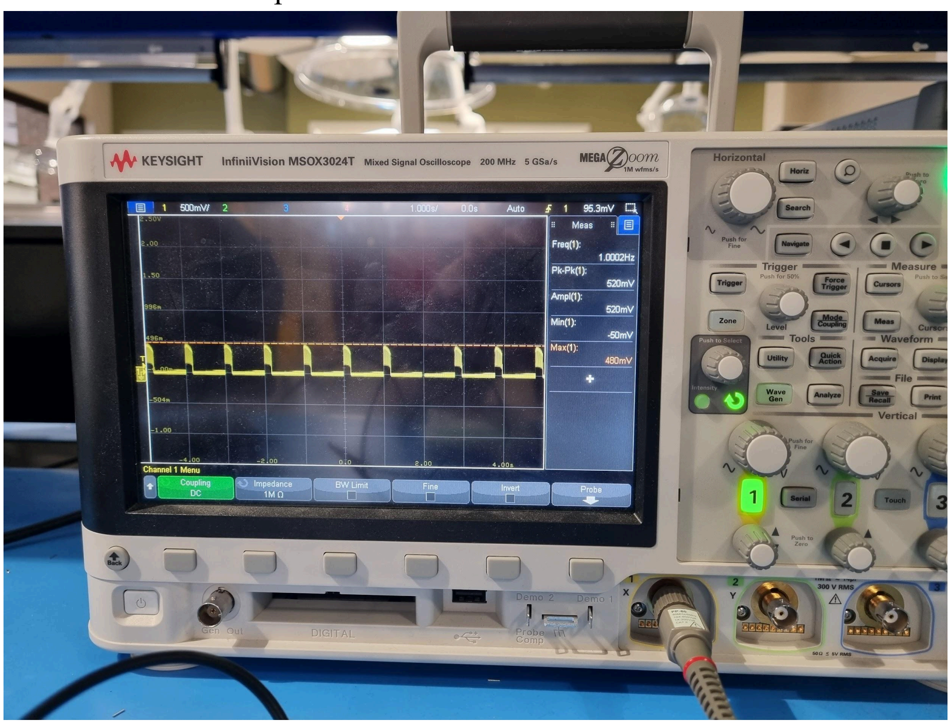
Figure 2: Plot describing how long the bioreactor is in continuous operation versus how much that operation wears down the walls made of gliding material.

What Figures 1 and 2 show is that the Drylin bearings have a much longer life than previously thought and seem to be a fitting bearing for the bioreactor. With this information, I hope that the team can be more confident moving forward with incorporating them into the design. I also sent igus an email summarizing what I did in these calculations with these plots and asked for anything they had on how long the bearings would last under our conditions, so I'm watching my inbox for their reply and hopefully they have some information or maybe even some feedback on these plots for me.

Author: Emilio Lim
Editor: Jeffery Guo

Continue testing H-bridge	Continue testing H-bridge to get a triangle output	JG/EL	3

This week Emilio and Jeffery continued to test the VCA using the H-bridge from the L298N motor controller. We were successful in getting an output with sufficient current to allow the VCA to oscillate at 1Hz, following a square wave output. When we were trying to change the voltage output from the H-bridge by changing the value of the enable pins, we found that the VCA makes a high pitched siren-like noise. This noise could not be heard when the enable pin is set to the max value. A clearly defined square wave output can also be seen when the enable is set to max value from the oscilloscope. Any value lesser than 255, which is the max value, would produce the siren-like sound and a square wave with some noise as seen in the picture below. A short video of the experiment is uploaded onto the drive under media > testing 3/6.
To continue moving forward, we will need to be able to change the voltage output, ensure the output signal generated is a triangle-like wave, and make sure there is no additional sound. Patrick suggested we look into finding a setting that would allow a triangle wave output by changing the value of the enable pin.



Author: Griffin Radtke

Editor: N/A

Revamp CAD for Machining	Make modifications to existing CAD for machining-purposes	GR	6

After further discussion regarding the plan(s) for fabrication going forward, we've decided to proceed in two separate directions: Sydney will work on an acrylic model, while I'll make slight modifications to the existing design to repurpose it for machining (i.e., the previous model was designed w/ 3D-printing intent, hence the non-machinable architecture at certain points). Along with slight revisions in design intent, several elements within the model are removed, as the improvements in tolerancing offered by machining make several features in the prior design redundant. Overall, timeliness of machining/fabrication is now the main concern, which is reflected in several of the design modifications.

Looking forward, after discussion with the team, analysis of the CAD will be prioritized during the faculty & TA meetings, with – assuming approval/consensus in both – an order for fabrication to be placed by the end of the week (3/15).

Author: Sydney Therien
Editor: N/A

Finalize prototype CAD	Put finishing touches on the actual 3D model and create SolidWorks drawings that can be laser cut.	ST	2

In preparation for the upcoming prototype presentation, the CAD model that had been created based on TeamLab manufacturability feedback had to be finalized and converted into a file type that could be manufactured. This involved first making sure that everything fit together in the SolidWorks parts assembly and that there wasn't any overlap of pieces hiding anywhere, as well as making sure the design itself was 100% good to print/cut. Then, a SolidWorks drawing was made of the pane pieces that will make up the box walls. This was done in such a way that the tongues and grooves fit into each other as much as possible to save space on the acrylic sheet.

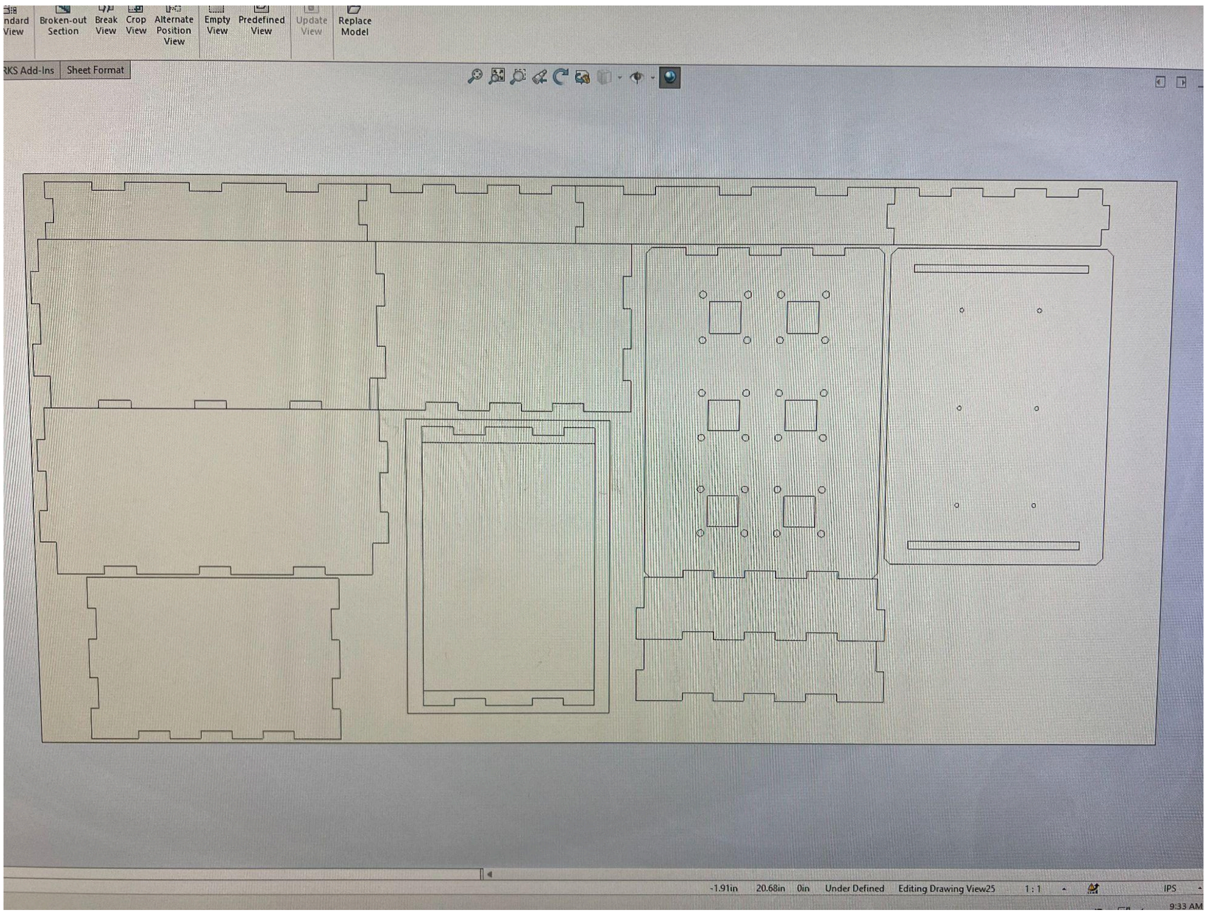


Figure 1: A picture of the computer screen that had the final SolidWorks drawing.

The file shown in Figure 1 was then converted to .dxf and cut on a 24x36 in clear acrylic sheet that is ¼" thick purchased at the Makerspace for $36.50. There were no problems with the cut, the pieces were to scale, and it fit together well.

Figure 2: Testing the tongues and grooves of the cut acrylic pieces to see how they fit together (no adhesive has been used yet).

The 3D printed parts, the base and the sample tray, are both printing currently. They should be done by the end of today (Friday 3/15). They were printed with white PLA with 20% infill on the tray and 10% infill on the base (to save money). The print cost was $41.35, with the base costing $23.30 and the tray costing $18.05. This brings the total cost of this prototype to **$77.85** including the acrylic. Once the base and tray are finished printing, the paper will come off the acrylic pieces and the prototype can be assembled. It will make its debut on Monday at the next client meeting!

Author: Jeffery Guo
Editor: Emilio Lim

Continue developing working electronics/circuitry	Continue developing the circuit and electronics to operate the VCA	JG/EL	2

Over this past week, Jeffery and Emilio continued to work on developing the appropriate circuitry to operate the VCA. **We created a circuit capable of supplying a triangle wave to**

operate the VCA at 1 Hz. With the input of Makerspace staff, we decided to use an N-channelMOSFET instead of an H-bridge, because H-bridges are better suited for applications requiring bidirectional actuation, which we do not require, so an N-channel MOSFET would be better for our case. We purchased the [Infineon IRFZ44N](), at an affordable price of $1.00 from the Makerspace, which can handle the voltages and currents required to operate the VCAs.

In summary, the circuit we developed (with the wonderful help of friendly Makerspace staff), depicted in Figure 3 below, works by receiving a PWM triangular input signal at the desired frequency (i.e., 1 Hz) from an Arduino and an input voltage from a power supply. The circuit also contains a diode and resistors which function to protect various components such as the MOSFET. The force output is controlled by adjusting the power supply's voltage. The maximum current the VCA drew was roughly 700 mA. Video documentation of our functional circuit and VCA is available [**here**]().

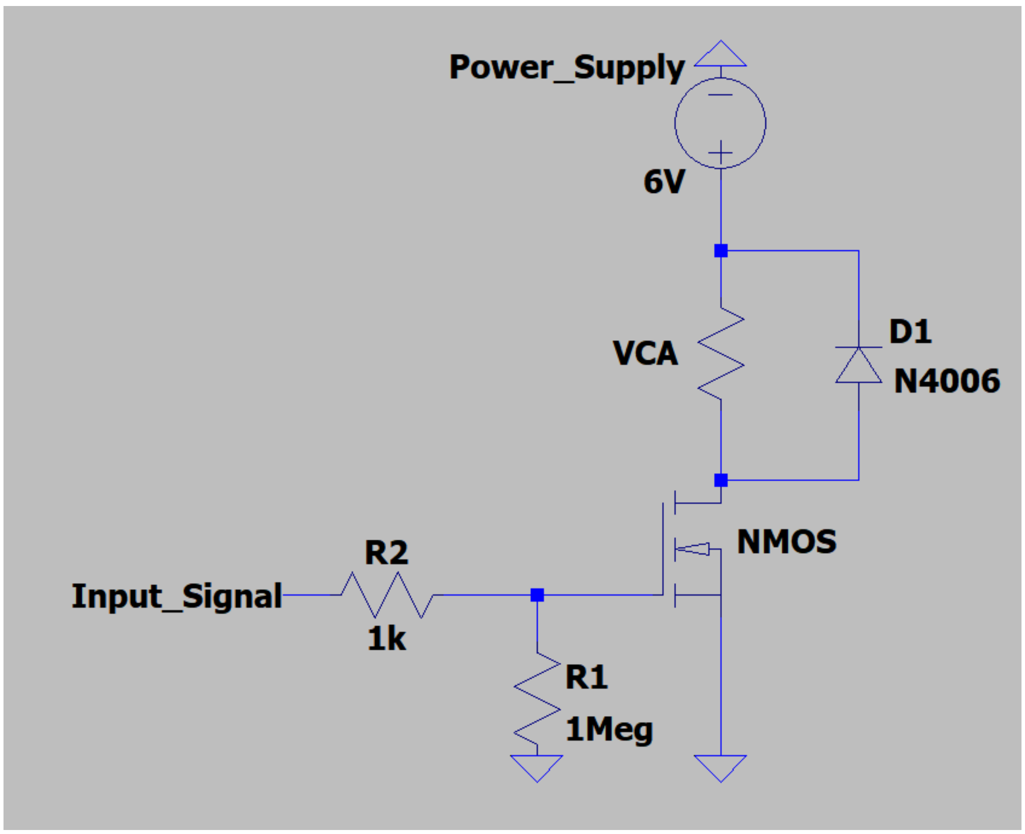


Figure 3: Circuit schematic.

For our next steps, we will look to test our circuit using a NI DAQ/myDAQ in place of an Arduino to provide the input signal. We will also need to verify sufficient force output using our newly developed circuit and develop a calibration curve of power supply voltage vs. force applied. With the prototype bioreactor housing nearly complete, we're also excited to see how the VCA(s) will physically fit and sit securely in the housing. Soon, whenever appropriate, we'll look to purchase the last five VCAs and the additional circuit components we need to control all

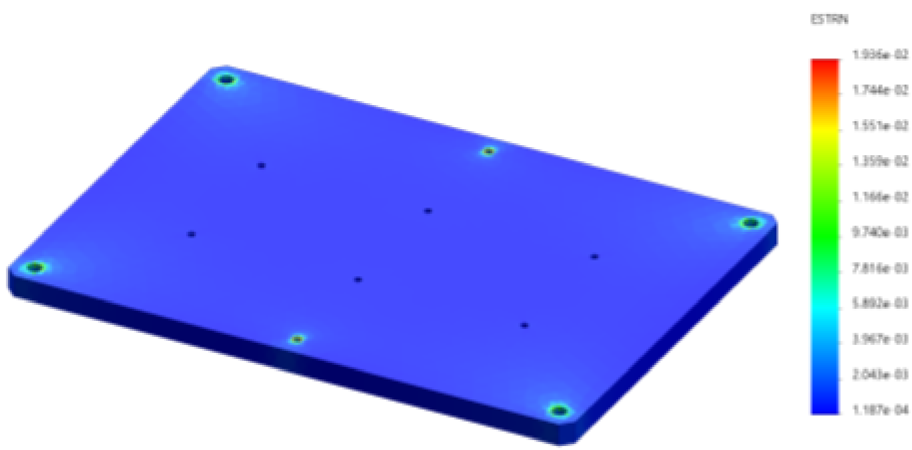
VCAs. With this in mind, we will also find and purchase a power supply capable of supplying enough current to power all 6 VCAs, roughly 6-7 A maximum.

Author: Griffin Radtke

Editor: N/A

Temp. Analysis of Compressive Lid	Verified acrylic's stability under thermal expansion at incubator-like conditions.	GR	1.5

As discussed in prior reports, the final design will almost certainly rely on a 10 [mm]-thick laser-cut acrylic lid structure to 'deliver' the compressive load. While the loading itself has been simulated, with no risk of failure (i.e., ~4x F.O.S. calculated), temperature has yet to be analyzed; although, intuitively, little-to-no warping is expected *within the lid* as a result of the temperature increase (i.e., to 37C) to incubator conditions, verification, analysis of strain is obviously necessary as a final proof.



Thermal simulation results, with strain analyzed to verify minimal deflections with a Δ=15 [C]. Strain is minimal within the bulk of the material, although potential singularities arising from the mesh exist about the bolt locations.

Author: Emilio Lim

Editor: N/A

Force test	Used a load cell to test the consistency of the force output	EL/JG	2

Emilio and Jeffery went to Dr Henak's lab to test for the consistency of the force output from the VCA. Dr Henak was able to install LabVIEW on the lab computer, thus, we used LabVIEW to generate the signal for the circuit. The power supply was taken from the design lab. The experimental procedure involves data collection for a 30 minute span using a load cell. We tested the force at 0.5Hz, 1Hz, and 2Hz, with a voltage of 6.63V.
We observed a square like wave when the expected waveform is a triangle wave. The reason that might cause this is the magnetic base of the platform. This caused a delay in the extension of the VCA. Since it requires a certain amount of force to overcome the magnetic force, it tends to shoot up upon exiting the magnetic field instead of slowly extending upwards. This shoot up also caused a spike in the force output. We observed a spike of 8N when the expected force is around 6N. We expect to see a more triangular force output when the entire setup is tested. We also noticed the force being applied non-uniformly.

Furthermore, the force output was not entirely constant throughout the experiment. It decreased from 6N to 5N, then back up to 5.5N. It was found to be quite steady (at 5.5N) after 20 minutes. Another observation we made is that the VCA applies force in one direction, causing the load cell to deflect sideways. This problem should be effectively tackled by utilizing the bearings. Thus, we will rerun our test with the bearing and housing when it is assembled.

Author: Sydney Therien
Editor: N/A

Received bearing and shaft sample from Igus (!)	Unpacked the samples that arrived from Igus over spring break.	ST	0

It turns out that Igus fulfilled my request for the bearing and shaft samples, though I never received any kind of email confirmation. The package was waiting in my mail room after returning from spring break. In it was 0.33m of shaft and one bearing, however, the bearing was the "twin" size and not the single that I had requested.

Figure 1: 0.33m of 20mm square hard-anodized aluminum shaft and Drylin Q square twin flange bearing (twice the height of what is required).

This means we can't use it in the bioreactor, but it still has utility for preliminary testing and getting a general feel of the product. There is more resistance inside the bearing than anticipated when it was casually tested with adding the shaft and moving it around, but this is likely because the bearing has twice the amount of sliding element, which were observed to be slightly misaligned (perhaps why this unit was provided as a sample), giving rise to higher friction. A properly-sized bearing and some more shaft have been ordered and should be arriving soon.

Author: Sydney Therien
Editor: N/A

Machined PTFE (almost complete)	Used a bandsaw and lathe to cut the PTFE pillars, face them, and drill holes that still need to be tapped.	ST	4

The next step of the fabrication process was to begin machining the PTFE for eventual installation as the compressive interface in the lid. All fabrication was done in the TeamLab. It was first cut into 1in segments using the bandsaw. Then the belt sander was used to level the segments. Unfortunately, the segments were too short to use the tool that preserves a 90deg angle with a perpendicular side. Because of this, it was realized that a higher level of precision was needed to fabricate the pillars to the quality required for interfacing with tissue samples. If there is a slant on the pillars, a nonuniform force distribution will be created on the sample face. The pillars were taken to a lathe to face the sides and make them as similar in height as possible. After this process, they were all within 0.008in of each other in height. It isn't essential for the pillars to be exactly the same height since they are controlled by different actuators, but it is good practice to make them as close as possible to eliminate differences between bioreactor slots. Also using a lathe, the pillars were drilled with an M5x1 drill bit in the center. The holes were drilled approximately 0.6in into the PTFE. The holes still need to be tapped with an M6 tap, and this will be done early next week.

Figure 2: All six PTFE pillars after cutting and drilling side-by-side to visualize their height similarity.

Figure 2: One individual PTFE pillar with the M5 hole shown.

Figure 3: The fasteners to be used to attach the pillars (one of them is the wrong size and will be swapped). They were acquired from the TeamLab free of charge.

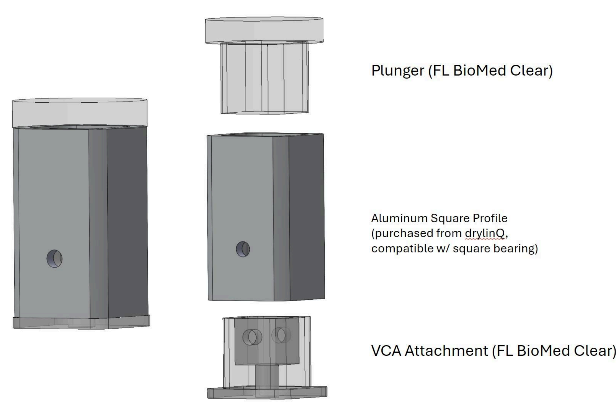
One pillar became slightly deformed by the lathe jaws when it heated up and melted slightly. This should not impact the function of the pillar in the bioreactor, but if the client thinks it prudent, it would not be a problem to remake. After refamiliarizing myself with how to use the lathe, any further PTFE-related fabrication steps will go much faster.

Author: Griffin Radtke

Editor: N/A

VCA-Compatible Components	Designed (and will be 3D-printing) components compatible with the drylinQ bearing system.	GR	2

As discussed in prior meetings, attachment parts are required to fasten the VCA to a square profile compatible with that of the square bearing and also impact/lift the sample dish upward into the PTFE rods. Both will be press-fit, with the lower also having two bolt locations: one, an M6, for attachment to the VCA, and another, an



M4, to further fasten the part (i.e., the VCA attachment) to the square profile. Both parts will be 3D-printed with BioMed Clear on Monday and inserted within the sample square profile obtained from the manufacturer.