

# BME Design-Spring 2019 - Stephan Blanz Complete Notebook

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on

May 01, 2019 @02:21 PM CDT

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## Team Contact Information

- Stephan Blanz - Feb 10, 2019 @12:08 PM CST

Last Name	First Name	Role	E-mail
Rogers	Jeremey	Advisor	jeremy.rogers@wisc.edu
Dingle	Aaron	Client	dingle@surgery.wisc.edu
Blanz	Stephan	Leader	blanz@wisc.edu
John	Beckman	Communicator	jbeckman3@wisc.edu
Oakes	Royal	BSAC /BWIG	soakes@wisc.edu
Guo	Rick	BPAG	jguo77@wisc.edu





## Project Description

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- Stephan Blanz - Feb 10, 2019 @12:10 PM CST

**Course Number:**

BME 402

**Project Name:**

Somatosensory stimulation apparatus for rodent cages

**Short Name:**

Hindlimb Stimulator

**Project description/problem statement:**

Peripheral nerve injuries are common, debilitating and costly. Approximately 2.8%-5% of all trauma patients in the US sustain such an injury with nearly 100,000 peripheral nerve repairs being performed annually costing approximately 150 billion dollars. The most important clinical outcome following nerve repair, is functional ability, and despite advances in microsurgical technique, poor functional outcomes are frequent. Unfortunately, the cause for outcome variability is unknown and functional outcome is difficult to assess and measure experimentally.

The goal of this project is to design and validate an experimental apparatus that can provide somatosensory stimulation (i.e. vibration) to the hindlimb of a rodent would greatly improve the ability to assess nerve regeneration in rats for a wide range of studies- including but not restricted to, surgical repair methods, tissue engineering and neural interfacing.

**About the client:**

Dr. Aaron Suminski is a scientist with the University of Wisconsin, Department of Biomedical Engineering. He collaborates with Dr. Aaron Dingle, a post-doctoral researcher, with the University of Wisconsin, Department of Surgery, Poore lab. The Poore lab's research focus is clinical and experimental microsurgery, with an emphasis on peripheral nerve regeneration and repair. Together they are researching the effectiveness of various treatments and methods of nerve repair.



## 2019/02/01-Advisor Meeting

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- Stephan Blanz - Feb 01, 2019 @01:51 PM CST

**Title:** Advisor Meeting

**Date:** 2/1/19

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

**Goals:** Planning

**Content:**

**Action Items:**

Contact Dr. P for access to 1036 Lab. Mention as alternative to have access to oscilloscope with wave gen feature.

Find out why speakers weren't working for last group.

Ways to measure amplitude: mechanical transducers (have to look into frequency and bandwidth)

Email Dr. T. Puccinelli about outreach plan, rough draft as well as what places we could do it.

**Things to think about:**

Perception space of amplitude/ frequency coupling

Energy, frequency, coupling, (mass of plate) can do first order analysis of **speakers**.

Look at SWAP for ordering parts

**Conclusions/action items:**

If using speakers is feasible, switch over from vibrational motor to speaker. Possible pitfalls: being able to run speakers at low frequencies.



## 2019/02/15-Advisor Meeting

---

- Stephan Blanz - Feb 15, 2019 @01:30 PM CST

**Title:** Advisor Meeting 2/15/18

**Date:** 2/15/19

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, Rick Guo, Royal Oakes, John Beckman

**Goals:** Establish future progress

**Content:**

- Make sure to get outreach done.
- Progress:

Using a voice coil is good since it simplifies some aspects

Consider specifications (not hobby time in the garage)

Energy/Power considerations and calculations that go in amplitude and what it corresponds to at the plate.

Think about using a distance measurement to measure amplitude. Put something at a certain standoff and get measurement for when transducer hits the standing surface.

Waterproofing: Think about what needs to be waterproofed and sanitation. The platform itself may not need to be sealed if you can just isolate and seal the speaker.

- Presentations:

Props add to presentation

Scales on axes were too small. Also, units of amplitude. (trick: specify in figure what font size is)

Presenting pitfalls as a positive experience: what did you learn.

**Conclusions/action items:**

Start thinking engineering design with voice coils.

Start testing voice coils.



## 2019/02/22-Advisor Meeting

---

- Stephan Blanz - Feb 24, 2019 @03:11 PM CST

**Title:** Advisor Meeting 2/15/18

**Date:** 2/15/19

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, Rick Guo, Royal Oakes, John Beckman

**Goals:** Establish future progress

**Content:**

Get amplitude from caliper measurement:

Get current measurement in line, get voltage measurement see which changes

OCT measures: 1000 samples/sec up to 110,000 samples/sec

Get frequency with microphone

Look into physics of inertia and coupling.

Measurement of amplitude of pad vs speaker alone. Maybe get some calculations.

Thinking about mechanics of infinite mass (fixed to cage)

To Do:

Design of attachment of motor to base (this needs to be thought of first for testing purposes)

Two forms of measurement

Look up atomic force microscopy.

Could be used to deflect laser and take amplitude measurements.

If one end is free and another is on a pad, most movement is on bottom.

What we did last week

What we plan to do next week

Any Difficulties

Timeline

Table of Hours

**Conclusions/action items:**

Fix weekly report.

Implement "design concepts" in process. Conduct initial mathematical / physics analysis of problem and design from that point forward.



## 2019/03/01-Advisor Meeting

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• Steven Oakes • Mar 07, 2019 @06:48 PM CST

**Title:** Adviser Meeting

**Date:** Friday, March 1, 2019

**Content by:** Royal Oakes

**Present:** Royal, Rick, John

**Goals:** Adviser Meeting

**Content:**

Linear regression/line fit of frequency data to show that frequency in is the same as frequency out.

Dr. Rogers does not know much about using force transducer to measure amplitude. But it seems like the best option.

A direct measurement of amplitude (in distance) would be a good sanity check for the indirect measurement. We need to figure out the expected amplitude to understand what the best way to measure it.

**Conclusions/action items:**

Testing.



## 2019/03/08-Advisor Meeting

- Stephan Blanz - Mar 09, 2019 @05:34 PM CST

**Title: Adviser Meeting**

**Date:** Friday, March 1, 2019

**Content by:** Stephan Blanz

**Present:** Stephan, Royal, Rick

**Goals:** Adviser Meeting

**Content:**

Immediate goals:

Base Design

Progress: Have concept of a design

Disadvantages: Not made a priority

Outreach (John)

Progress: None

Disadvantages: Slow progress, may need to rethink idea

**Feedback:** Backup and generalize more. Make a device that can monitor something. Think about relating to what we're doing using vibration, microphones, speakers. (how low of an amplitude can you detect but not here, etc...)

*Important part:* finding a solution to something there is no template for. Ie here's a box of items, design something that can do xyz (broad question with not a known correct answer)

MATLAB code (Rick)

Progress: code that can produce a frequency and amplitude

Disadvantages: coding skills

Amplitude testing (Stephan)

Progress: new part received

Disadvantages: Standoff needs to be manufactured

Frequency Testing (Royal)

Progress: baseline readings across one model

Disadvantages: only one model tested to date

**General Feedback:**

Think about film to cover gap of stand.

Option: open mat that's glued down (or loose) to cage floor everywhere. If it's not cleanable, it needs to be replaceable.

Have gap and allow things to come through and encapsulate / isolate below.

**Conclusions:**

Shift priorities to design platform.

Testing to be performed: Correlation/MSE between input and output frequency





## 2019/03/15-Advisor Meeting

---

- Stephan Blanz - Mar 15, 2019 @01:32 PM CDT

**Title: Adviser Meeting**

**Date:** Friday, March 1, 2019

**Content by:** Stephan Blanz

**Present:** Stephan, Royal, Rick

**Goals:** Adviser Meeting

**Content:**

Fix caliper to ground. Place base on transducer. Measure position of lower lip of base at 0V and various other inputs.

Measure Voltage and amplitudes at various frequencies.

Still continue load cell testing

Think about alternatives to 3D printing.

**Notes on Report:**

Abstract does not describe the device. For final report make the abstract reflect the device (at least a few sentences)

Question that might be worth addressing: why is sensation the target / metric used and how does the sciatic nerve play into this, and why is vibration a benefit. Why isn't muscle control; is there a physiological rationale?

Good thing: 70-100 Hz... with references good use of text

Use PMMA instead of plexiglass.

For images, use labels instead of numbers if possible.

For Royal's image label the items in drawing.

Equation parts need a little more connection and rigor. (Different masses and bridge gaps how different parameters influence design and frame with conceptually, what are the design constraints and how are these influencing the outputs and how the equations connect them)

**General Feedback:**

Think about film to cover gap of stand.

Option: open mat that's glued down (or loose) to cage floor everywhere. If it's not cleanable, it needs to be replaceable.

Have gap and allow things to come through and encapsulate / isolate below.

**Conclusions:**

Shift priorities to design platform.

Testing to be performed: Correlation/MSE between input and output frequency





## 2019/04/05-Advisor Meeting

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• Stephan Blanz • Apr 05, 2019 @01:03 PM CDT

**Title: Adviser Meeting**

**Date:** 5/5/19

**Content by:** Stephan Blanz

**Present:** Stephan, Royal

**Goals:** Adviser Meeting

**Content:**

**Load Cell Measurement:**

Measures strain.

Keep in back of mind that this measurement can have limitations due to moving air and dissipations. Drives a certain amount of energy into sound rather than deflecting beam.

Also that displacement can be limited due to the beam not bending as much.

Think about using a camera in macro mode to get displacement measurements.

**This would give a measurement that is not affected by the mode of measurement.**

**Conclusions:**

Have labarchives ready for next meeting.



## 2019/04/12-Advisor Meeting

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- John Beckman - Apr 12, 2019 @01:00 PM CDT

**Title:** Advisor Meeting

**Date:** 2019/04/12

**Content by:** John Beckman

**Present:** All

**Goals:** Discuss weekly progress of the project

**Content:**

- Covered outreach
- Another transducer went out, ordered 8 more.
- Mechanical problem inside the transducer.
- Talking about amplifier:
  - recommended for use with our speakers
  - driving at a voltage from 4-20 V
  - 20 V may be way to high
- Cell phone camera for displacement measurement matches preliminary caliper measurements
- Using ImageJ
- Matlab could pull in images and average over 10 second window to give an average displacement.

**Priorities:**

- Experiment/Data
- Don't make up stuff to do for the sake of doing it.
- Reasonably quick and repeatable.
- Error bar on the measurements to a degree, ruler measurement remove and replace to determine the accuracy of our measurements
- Application of this:
  - Uncoupled transducer.
  - Test different weights attached to the end of the transducer to determine how amplitude voltage and frequency vary with weights attached as well.
  - No understanding of how it will act/integrate with the rat.
- 1. Uncoupled amplitude and frequency
- 2. Coupled to cage amplitude and frequency
- 3. Added weights to test viability with an animal
- NOTEBOOK!

**Conclusions/action items:**

Make sure that we are updating notebook every time we are meeting, or working on things, or researching for the project. Also plan going forward is the numbered section above, as well as bolded priorities section.



## 2019/02/25-Stand for Speakers

• Stephan Blanz - May 01, 2019 @06:45 AM CDT

**Title:** Stand for Speaker

**Date:** Monday, February 25, 2019

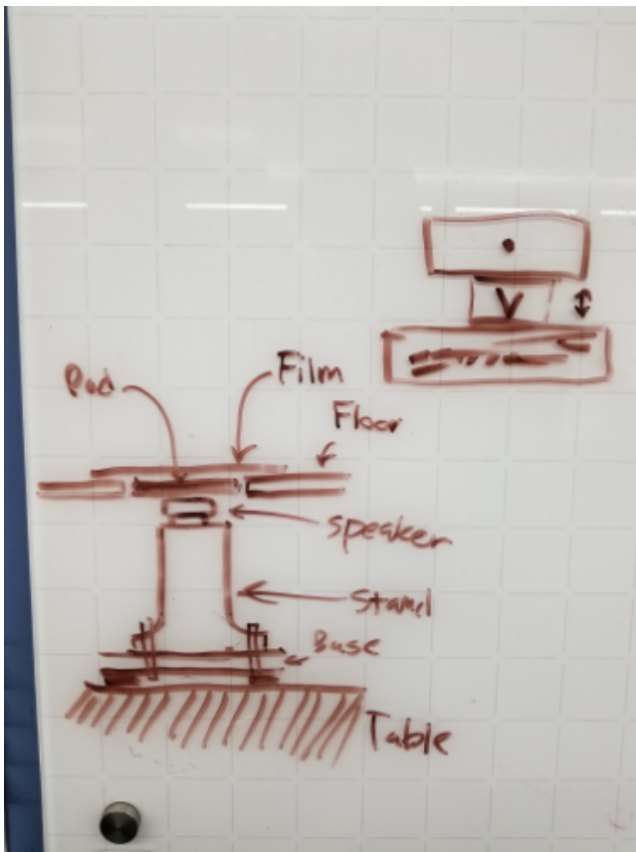
**Content by:** Steven Royal Oakes

**Present:** Stephan Blanz, Rick Guo

**Goals:** Describe an idea for the cage

**Content:**

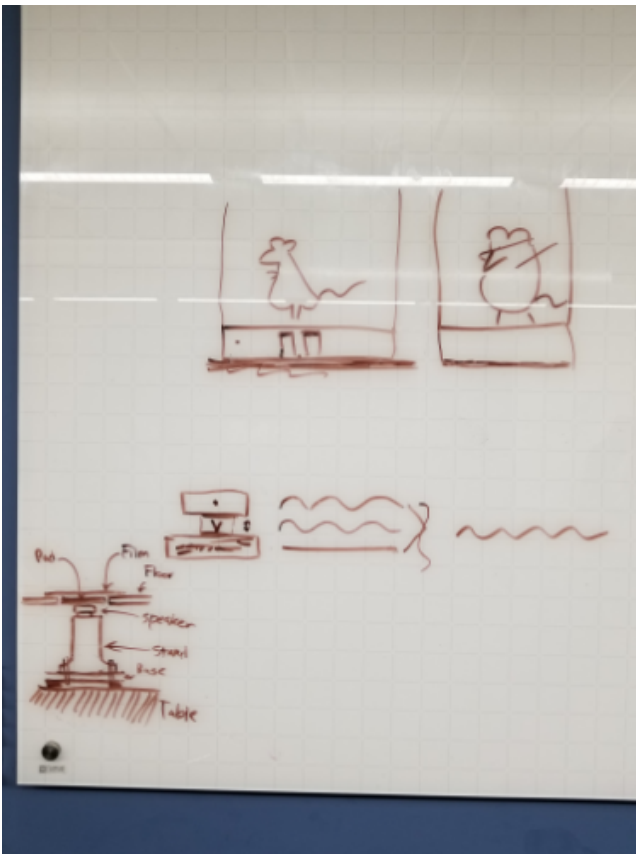
We decided to use a speaker to apply vibrations to the rat's feet. We need a way to couple the vibrations from the speaker to the rat's feet while preserving the signal from the speaker. This is my idea. There will be a stand that couples the speaker to the base of the cage:



**Figure 1:** The stand for the speaker. The speaker is attached to a stand which is attached to the base of the cage. There is a pad that is connected to the speaker which will transmit the vibrations to the rat's feet. There is a film that will prevent urine from leaking onto the speaker.

An important factor of this design is that the mass of the stand will be much larger than that of the pad and rat. This will prevent motion from the stand from interfering with the vibrations of the speaker. The stand will need to be tightly coupled to the base of the cage and the base of the cage itself will need to be flush with the table for this to work. A piece of rubber or foam may be needed to make the base of the cage flush with the table. This will make the effective mass of the stand to be infinite to the speaker.

Another image:



**Figure 2.** The full whiteboard. The squiggly lines indicate the vibrations that the rat will see when the mass of the stand is infinite. There will be a compartment below that cage which houses that stands and speaker. The rats in the cage are having a good time.

**Conclusions/action items:**

Design and fabricate the stands/cage. Take test the cage to make sure that the frequency is accurate.



## 2019/02/26-Using Lasers as a Measuring Device

• Stephan Blanz - May 01, 2019 @06:44 AM CDT

### Title: Brainstorming the Feasibility of Measuring Displacement with a Laser

Date: 02/26/2019

Content by: Stephan Blanz

Present: Team

Goals: Brainstorm laser measurement options

#### Content:

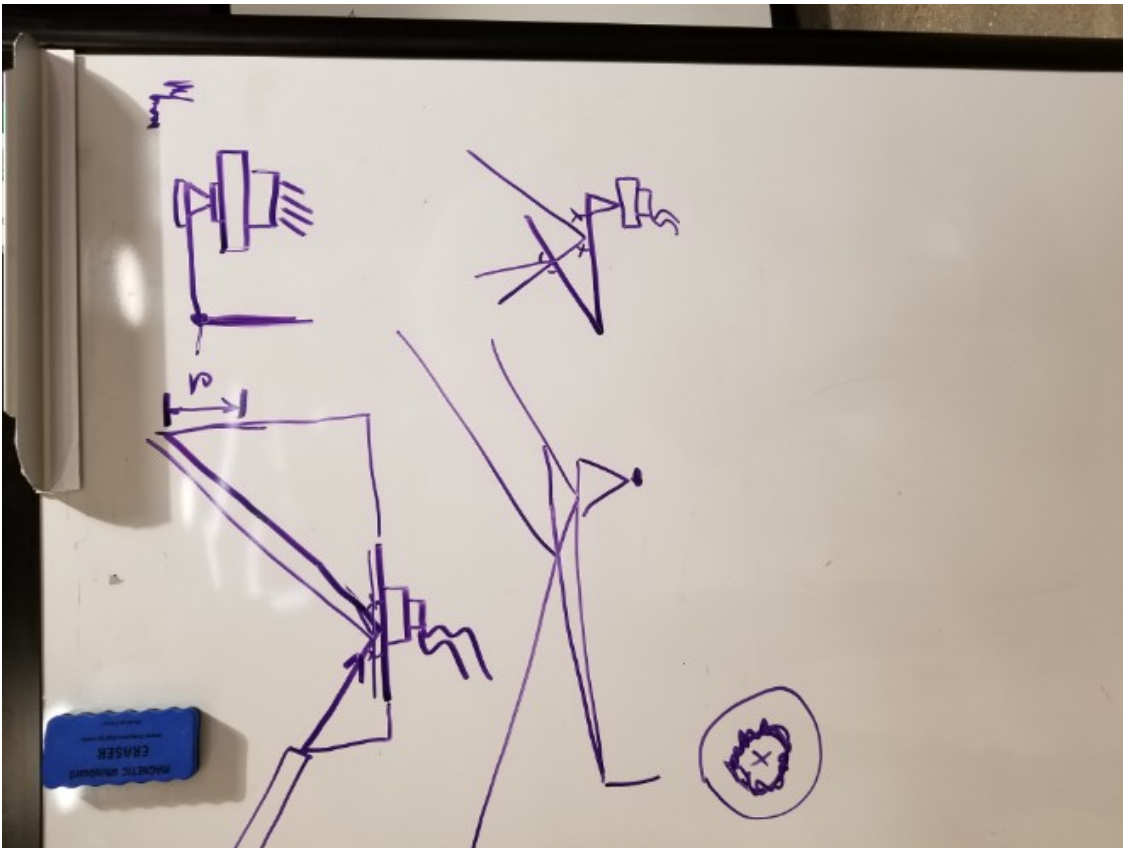
The problem is the transducer creates very small movements. Also, it appears that the transducer oscillates around a vertical position  $y_1$ , different from its resting position  $y_0$  (when not powered). This has made measuring displacement very difficult.

Two methods were considered:

1. Shining a laser directly on the surface of the transducer and then measuring the displacement of the reflected beam.
2. Using a cantilever beam, placed on top of the transducer as a reflection point. This would ensure the displacement measured from the reflective beam would be an amplified measurement of the original displacement simply calculated by basic trigonometry.

Downsides:

1. Did not create a scaled version of the displacement. Would still be difficult to measure.
2. Material consideration. We would need a very light and very rigid material which would not bend or buckle when coupled with the transducer.



#### Conclusions/action items:

If using a laser to measure device, the material used in the cantilever must be very rigid and light to both ensure accurate measurements and not influence the oscillations produced by the transducer.



## 3/12/2019 Expenses

• jinyuxuan guo • Mar 12, 2019 @07:14 PM CDT

**Title:** Expenses

**Date:** 3/12/2019

**Content by:** Jinyuxuan Guo

**Present:** N/A

**Goals:**

**Content:**

Description	Price	Quantity	Cost
Dayton Audio DAEX-9-4SM Skinny Mini Exciter Audio and Haptic Feedback 9mm 1W 4 Ohm	\$2.75	2	\$5.50
Dayton Audio DAEX-13-4SM Skinny Mini Exciter Audio and Haptic Feedback 13mm 3W 4 Ohm	\$2.90	2	\$5.80
Dayton Audio DAEX13CT-4 Coin Type 13mm Exciter 3W 4 Ohm	\$3.33	2	\$6.66
Dayton Audio DAEX13CT-8 Coin Type 13mm Exciter 3W 8 Ohm	\$3.33	2	\$6.66
Dayton Audio DTA-1 Class D AC/DC Battery Powered Mini Amplifier 15 WPC	\$29.80	1	\$29.80
SparkFun Load Cell Amplifier - HX711	\$9.95	1	\$9.95
Mini Load Cell - 100g, Straight Bar (TAL221)	\$8.95	1	\$8.95
Total			\$91.68

**Conclusions/action items:**



## 2019/04/18: Rubber Mat Adhesion

• Steven Oakes • Apr 18, 2019 @06:42 PM CDT

**Title:** Rubber Mat Adhesion

**Date:** Thursday, April 18, 2019

**Content by:** Royal Oakes

**Present:** N/A

**Goals:** Describe how the rubber mat was adhered to the bottom of the cage.

**Content:**

We needed to attach a rubber mat to the bottom of the cage to prevent feces, urine, and cleaning supplies from dripping onto the speaker and electronics below the cage.

The bottom of the cage is 10 in by 11 in. I cut a 1/32 in thick rubber mat to be 10.5 in by 11.5 in and removed a 0.25 in square from each corner. This would allow the mat to sit on the bottom of the cage and allow the four "leaves" to go up the sides of the cage to protect the edges of the cage. Rubber cement was used to adhere the rubber mat to the cage.



Above is an image of the bottom of the cage after the application of rubber cement and rubber mat. Rubber cement was applied to both the rubber mat and the bottom of the cage before being pressed together. This was done to increase the strength of the bond.





Above is an image of how the "leaves" of the rubber mat were adhered to the side of the cage. Rubber cement was applied to both the mat and the walls of the cage. Then they were pressed together using a heavy wooden block for several minutes. The vice was added to increase the weight of the wooden block.



Above is an image of the rubber mat attached to the bottom of the cage.



The bottom of the cage was very smooth and was not roughened before adhesion. This may lead to adhesion problems in the future. However, researchers may want to replace the rubber mat in the future. So this decreased strength of the bond may be beneficial. Moreover, if researchers want to improve the strength of the bond, they may remove the rubber mat, roughen the surface, and reapply the adhesive.

**Conclusions/action items:**

The rubber mat was not applied perfectly. The corners of the mat and the bottom of the cage do not line up properly. However, this should not have a large impact on the effectiveness of the barrier because so much of the cage is covered (most importantly the holes in the middle of the cage).



## 2019/04/20-Rubber Mat Adhesion Part 2

• Stephan Blanz • Apr 30, 2019 @10:25 PM CDT

**Title:** Rubber Mat Adhesion

**Date:** 4/30/2019

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, Rick Juo, John Beckman

**Goals:** create neater looking floor cover



**Content:**

While Royal did an excellent job of covering the floor with the rubber mat, the overhanging lip gave a not-so-neat appearance.

Considering the nature of presentations where poor aesthetic often assumes poor function, we designed to trim this lip. Also, we noticed that the previous mat had not adhered to all locations, so we made sure to apply weight to as many points as possible.

**Conclusions/action items:**

When using rubber cement it might be beneficial to cut out the approximate area with wood. Place the wood on top of the rubber and then place weights on top of wood to ensure uniform adhesion.



## 2019/04/25-Painting Enclose

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• Stephan Blanz - May 01, 2019 @06:08 AM CDT

**Title:** Painting the Enclose

**Date:** 04/25/19

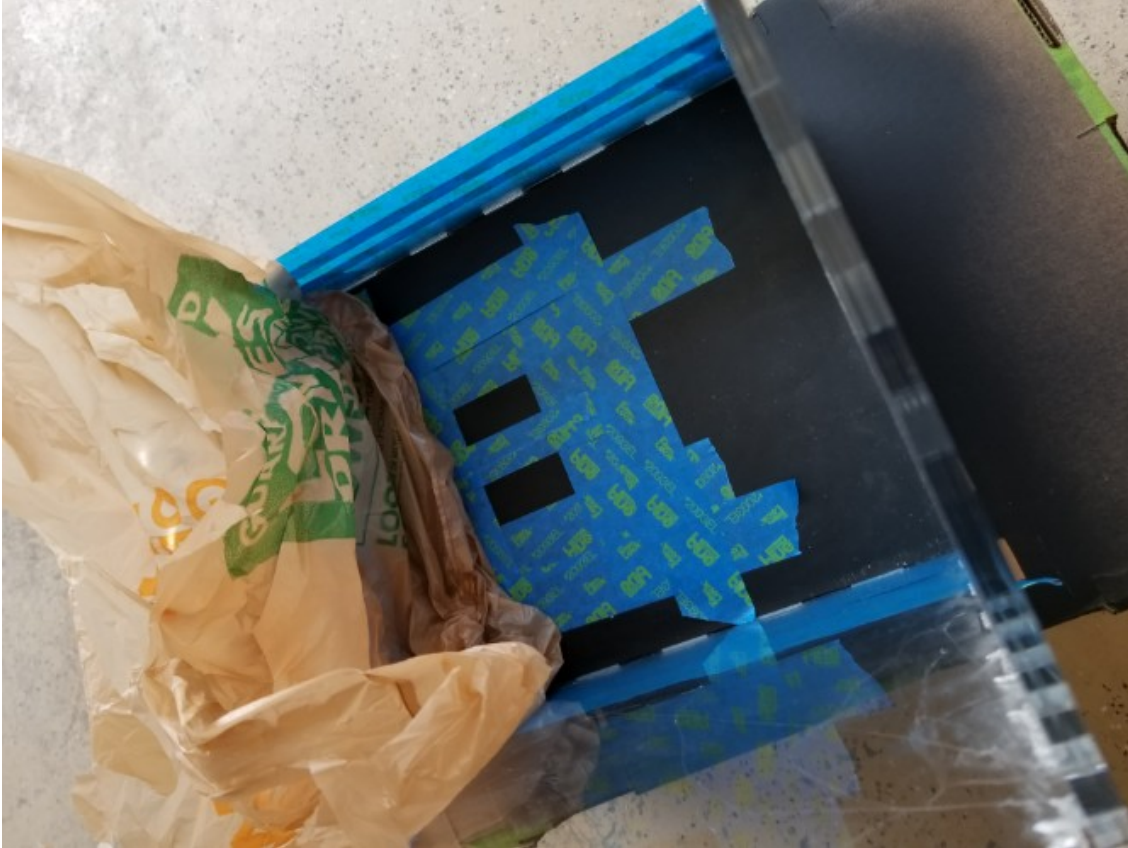
**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Create a visually appealing look for the enclosure

**Content:**

While the top portion (enclosure) should remain visible, it would be more aesthetically pleasing the paint the bottom portion housing the electronics. Additionally, painting the foot placement marks is needed. Spraypaint and tape was used to accomplish both.



**Conclusions/action items:**

While the spray-paint worked very well on the acrylic, it did not stick very well to the rubber mat, and pulling the tape off resulted in pulling some of the paint with it. Would consider different paint options for future iterations.



## 2019/04/27-Electronics Assembly Build

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• Stephan Blanz - May 01, 2019 @06:24 AM CDT

**Title:** Building the Electronics Assembly

**Date:** 04/27/2019

**Content by:** Stephan Blanz

**Present:** All

**Goals:** Building the electronics Assembly

**Content:**

22ga single strand wires were soldered onto transducers.

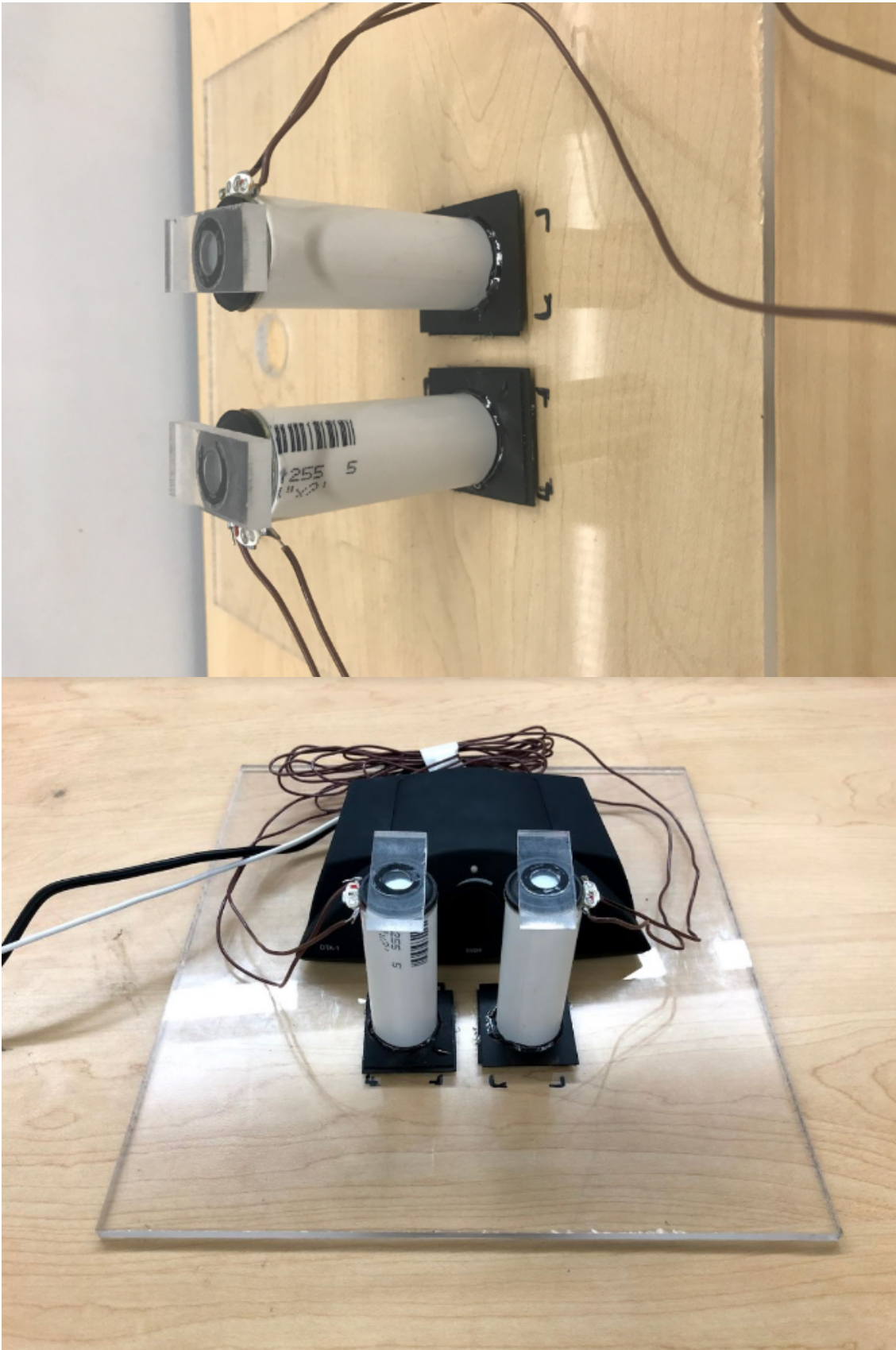
Transducers were attached to pvc/concrete columns with superglue.

1/4" thickness acrylic cutouts were attached to the transducers with the 3M adhesive tape already on the transducers from the manufacturer.

Rubber pads were attached to the bottom of the cage with rubber cement to create absorption pads. Two layers were needed to ensure correct total vertical height.

PVC column with transducers was attached to the rubber absorption pads using a two part epoxy.





The wire was neatly coiled and attached to the amplifier, placed behind the columns

**Conclusions/action items:**

Electronics Assembly Complete.

This is attached to the bottom of the enclosure.

This ensures the transducers have infinite mass.





## 2019/04/28-Final Design

• Stephan Blanz - May 01, 2019 @08:07 AM CDT

**Title:** Final Design

**Date:** 4/28/19

**Content by:** Stephan Blanz

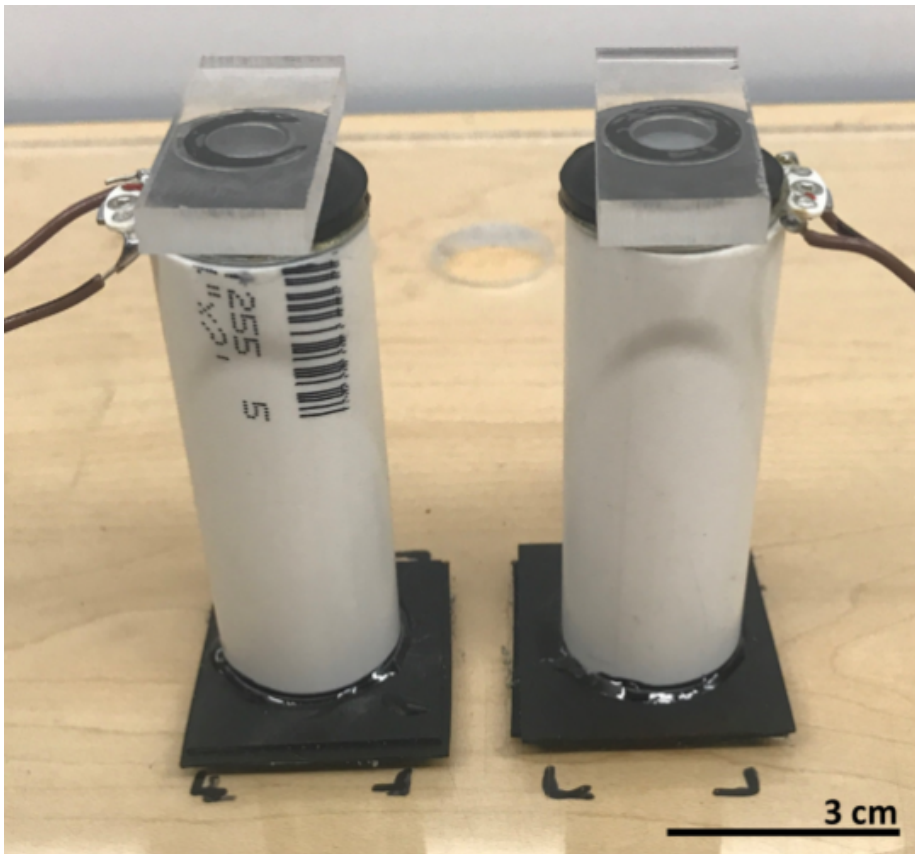
**Present:** Team

**Goals:** Display Final Design

**Content:**







pruebasnido

- □ ×



Figure 1 (Top). A plexiglass cage with holes cut out of the bottom where the transducers will couple with rubber mat on the bottom of the cage. Included in the cage is a water resistant rubber mat in case of rodent waste. Additionally, the circuitry and transducers will be safe from harm underneath the cage, with the only cords coming out of this section of the enclosure being an 3.5 mm headphone jack, as well as a power cord for the amplifier. The transducers are also in this bottom section of the enclosure where they are coupled to the rubber mat due to the cement and PVC standoffs built for them so that the transducers fit properly into the platform cutouts in the bottom of the cage.

Figure 1 (Middle). The standoff, transducers, and acrylic platforms, which together provide the vibrational stimulus to the enclosure. This set up allows the platforms to properly sit in the cut outs at the bottom of the cage where the rodent's feet will be placed while in the enclosure.

Figure 1 (Bottom). The graphical user interface (GUI) was created in MATLAB. The GUI allows the user to modify the frequency of the vibration from 50 to 200 Hz and the relative amplitude from 0 to 0.2. Additionally, the user can select if a single transducer or both transducers will produce the desired stimulus.

**Conclusions/action items:**

The final design along with GUI window.



## 2019/02/26: Frequency Testing by Sound Waves

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• Steven Oakes • Mar 07, 2019 @06:04 PM CST

**Title:** Frequency Testing by Sound Waves

**Date:** Tuesday, February 26, 2019

**Content by:** Royal Oakes

**Present:** Stephan Blanz

**Goals:** Determine the accuracy of the frequency produced by the speakers.

**Content:**

We purchased a few speakers from Dayton Audio. We need to test these speakers to make sure that they produce sound that matches the frequency of the sound driving the speaker.

For this experiment we used a headset to measure frequency of the speaker. The speaker was taped to a table using masking tape such that the tape was not in contact with the moving component of the speaker. The microphone of the headset was placed between 0.5 in to 1 in away from the surface of the speaker. A cardboard box was placed on top of the headset and speaker to decrease ambient noise. Two coats were placed on top of the cardboard box to increase the noise insulation.

We then played various frequencies through the speaker using an online tone generator. We recorded 6 seconds of audio from each trial and the saved files were in .m4a format. These files were converted to .wav format so that they could be processed in MATLAB. The files were processed using the MATLAB fast Fourier transform function. Then we examined the graphs to find peaks near the expected frequency. We measured the amplitude and exact frequency of the peak.

**Conclusions/action items:**

See data in the experimentation folder.



## 2019/01/31 - Applying Sine wave to LRA Motor

---

- John Beckman - Jan 31, 2019 @05:59 PM CST

**Title:** Applying a variable voltage to the LRA motor and looking for variable amplitude and frequency

**Date:** 1/31/19

**Content by:** John Beckman

**Present:** Stephan, Rick, Royal

**Goals:** To determine whether or not it is feasible to control voltage and frequency of the LRA motor by using AC as opposed to DC

**Content:**

By applying a sine wave function with varying frequencies, and simultaneously running an FFT on the system, there appears to be a one to one correlation between applied voltage frequency and measured. Which we would expect to see. However, we did not have access to the lab long enough today to begin testing vibrational frequency and amplitude.

**Conclusions/action items:**

We will return in the next week to begin testing the vibrational frequency and amplitudes of the LRA motor. To do this we will use the FFT code created last semester written by Royal. This should allow us to create multiple FFTs of the different vibrational modes we can achieve with the given motor, and from there we should be able to proceed with creating a user friendly program to manipulate the motor.



## 2019/02/01 - Testing Sine Wave input to LRA Motor

---

• John Beckman • Feb 01, 2019 @02:02 PM CST

**Title:** Applying a variable voltage to our LRA motors and measuring vibrational output

**Date:** 2/1/19

**Content by:** John Beckman

**Present:** Stephan, Royal, Rick

**Goals:** To measure the vibrational output of our LRA motors given various low frequency voltage inputs

**Content:**

This spreadsheet shows the three highest amplitude peaks after having gone through a FFT. The spreadsheet has recorded the frequencies as well as the amplitudes at the given frequency. In addition the spreadsheet contains the input voltage frequency at a constant peak to peak voltage input of 3.6V centered at 1.8V.

**Conclusions/action items:**



## 2019/02/26: Frequency Measurement by Sound Data

• Stephan Blanz • Apr 30, 2019 @09:58 PM CDT

### Title: Frequency Measurement by Sound Data

**Date:** Tuesday, February 26, 2019

**Content by:** Royal Oakes

**Present:** Royal Oakes, Stephan Blanz

**Goals:** Describe the data from the experiment.

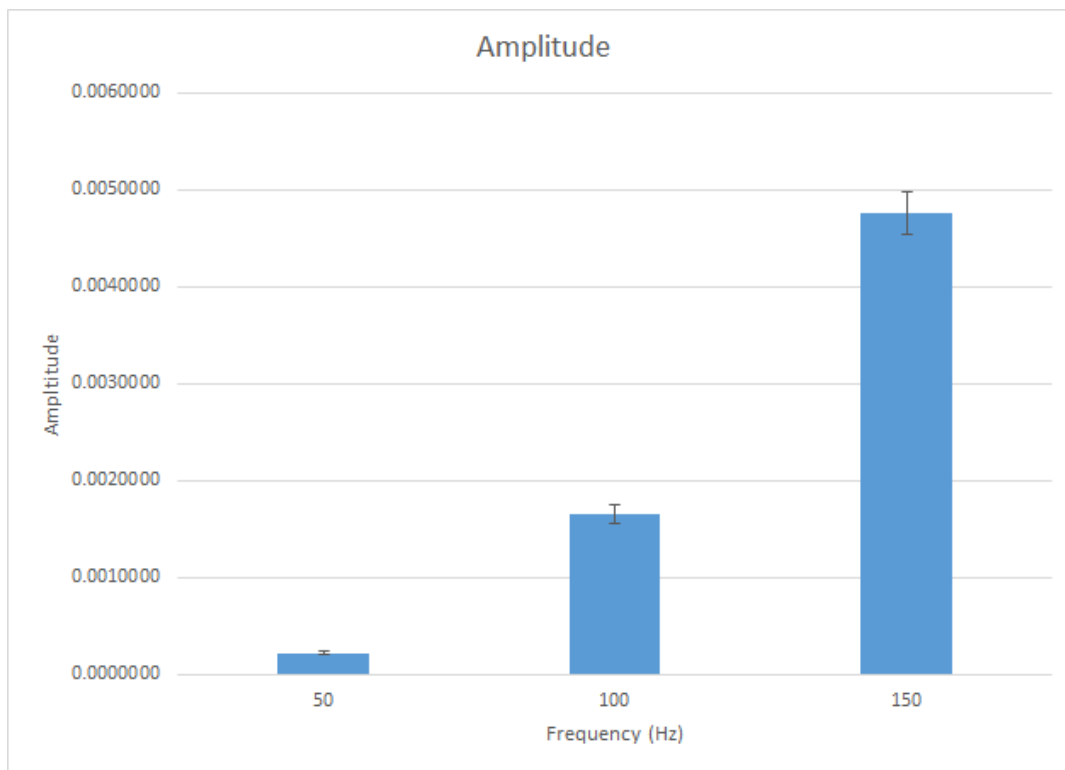
### Content:

The data from the experiment is attached to this page:

- WAVE files are the raw sound data from the experiment. The title has the format *<Frequency>\_<Trial>.wav*. Frequency is the applied frequency to the speaker and trial is self explanatory.
- XLSX file contains the data from the FFT of the WAVE files.
- MATLAB file is the program that was used to make plots of the FFTs of the WAVE files.

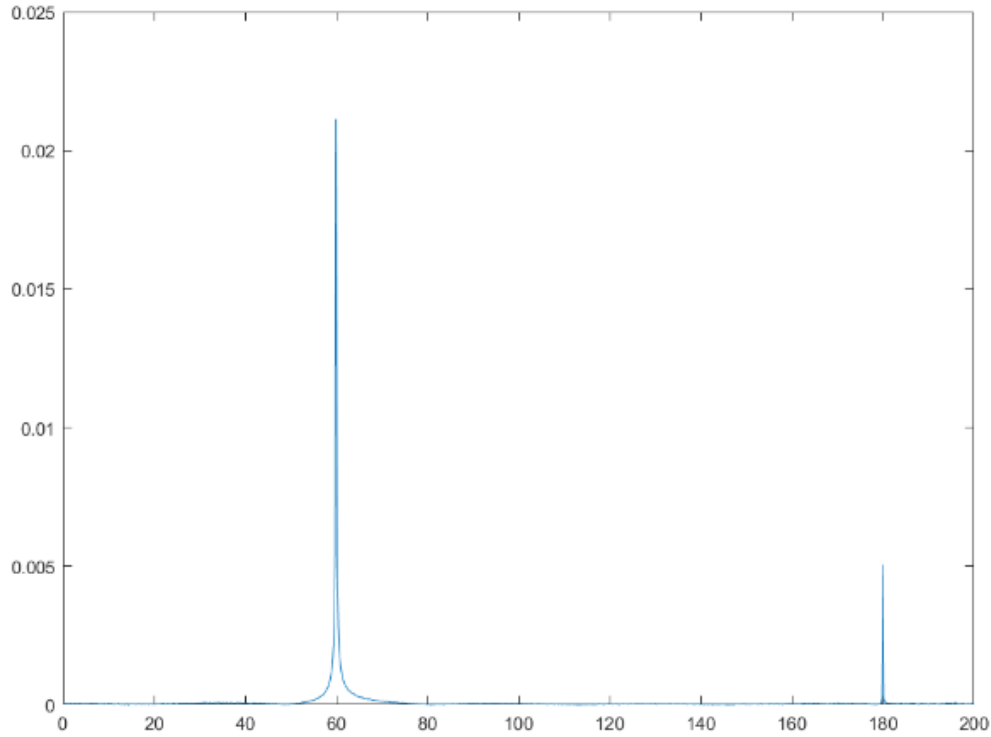
We found that the measured frequency on the FFT was always within 0.11 Hz of the applied frequency. This indicates that the applied frequency and the output frequency of the speaker are very similar in tone. This is to be expected since speakers are designed to have very accurate tones. The slight variation of the measured frequency may be due to the frequency resolution of the FFT.

We found that the amplitude of the sound wave decreased significantly with frequency. See graph below. Error bars are +/- 1 standard error of the mean. There are 5 samples in each group.



We did not do any statistical tests on the data because this is preliminary data. However, visual inspection reveals that there is a significant difference.

In addition, there was very strong background noise in this experiment. See graph below where a representative FFT of ambient noise is shown (NoSound\_01.wav). This noise might be due to the poor quality of the headset microphone and the ambient sound. The noise is several factors higher than the applied sound.



**Conclusions/action items:**

Perform testing to determine the lowest frequency can be applied. Ideally the testing will be done using a method other than sound to add confidence that this data is accurate.

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



100Hz\_04.wav(1.1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



100Hz\_05.wav(1.1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



150Hz\_01.wav(1.1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



150Hz\_02.wav(1.1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



150Hz\_03.wav(1.1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



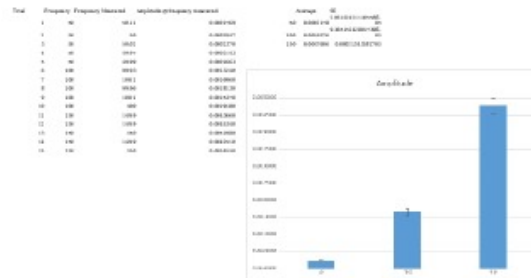
150Hz\_04.wav(1.2 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



150Hz\_05.wav(1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



BME402\_SpeakerTesting\_2019-02-26.xlsx(14.7 KB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



NoSound\_01.wav(980.1 KB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



NoSound\_02.wav(1 MB) - [download](#)



• Steven Oakes • Mar 07, 2019 @06:07 PM CST



NoSound\_03.wav(1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST

```
[y,fs] = audioread('NoSound_03.wav');
y1 = y(1, :);
% dt = 1/fs;
% t = 0:dt:(length(y)-dt);
% plot(t, y1);
% xlabel('seconds');
% ylabel('Amplitude');
y = y1(:);
T = length(y);
L = length(y1);
F2 = abs(V/L);
P1 = P2(1:L/2+1);
P1(2:end-1) = 2*P1(2:end-1);
f = FS*(0:(L/2)/L);
plot(f, P1);
axis([0 2000 0 0.005]);
```

VisualizeWav.m(329 Bytes) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



50Hz\_01.wav(1.1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



50Hz\_02.wav(1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



50Hz\_03.wav(1.1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



50Hz\_04.wav(1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



50Hz\_05.wav(1.1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



100Hz\_01.wav(1.1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



100Hz\_02.wav(1 MB) - [download](#)

• Steven Oakes • Mar 07, 2019 @06:07 PM CST



100Hz\_03.wav(1.1 MB) - [download](#)



## 2019/04/17-Displacement test

• jinyuxuan guo • Apr 30, 2019 @10:57 PM CDT

**Title:** Dispalcement test

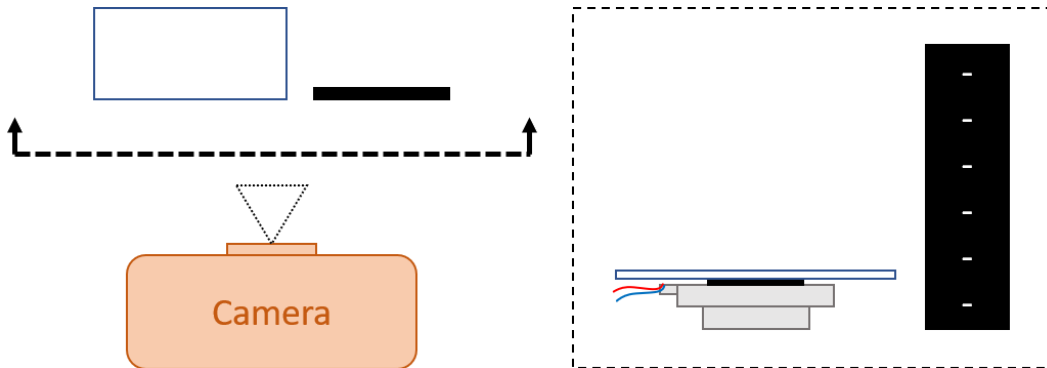
**Date:** 04/17/2019

**Content by:** Jinyuxuan Guo

**Present:** Team

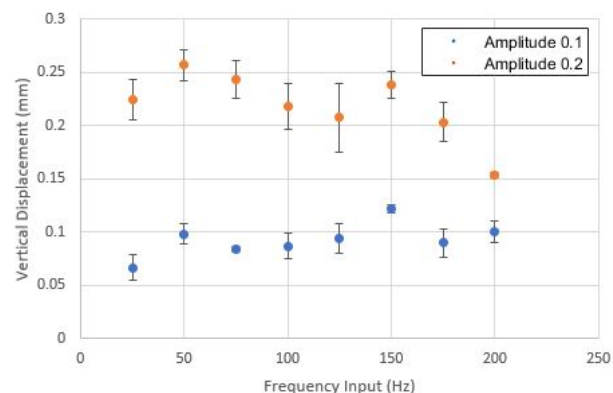
**Goals:** To check the relationship between amplitude and frequency

**Content:**



A test was performed to determine the displacement of the transducer at various input frequencies and voltages. A thin white plate was placed on top of the transducer to provide contrast with a dark background. A ruler was placed next to the transducer to provide a reference. A camera was used to take a 32 to 36 second video of the transducer while it was producing vibrations. The video was processed in MATLAB by averaging all the frames in the video to a single image. The resulting blur was then measured in ImageJ for its thickness to determine peak-to-peak displacement.

**Conclusions/action items:**



From the displacement test, the displacement data at amplitude 0.1, 0.2 and frequencies from 25 Hz to 200 Hz was collected. To find out the relationship between frequency and amplitude, two Chi-square test is conducted on the results at 0.1 and 0.2 amplitude of the displacement test. The vertical displacement at an amplitude of 0.1 and 0.2 was computed at frequencies between 25 Hz and 200 Hz at 25 Hz intervals (n=3 for each trial). The Chi-square test is then conducted to check whether there is significant difference between observed results and the expected value. In this case, the observed results are displacement data at different frequency

and the expected value will be the overall average displacement at 0.1 and 0.2 amplitude. The null hypothesis is that there is no significant difference between displacement results obtained from different frequency and overall average displacement, the alternative hypothesis is there are significant differences. Both of the results of the two Chi-square test at 0.1 and 0.2 amplitude support our null hypothesis. There is no statistically significant difference in displacement at various frequencies at 0.1 amplitude,  $\chi^2$  (df = 7, N = 24) = 0.01858,  $p > 0.99$ , or at 0.2 amplitude,  $\chi^2$  (df = 7, N = 24) = 0.03269,  $p > 0.99$ .



## 2019/04/19-Frequency test

• jinyuxuan guo • Apr 30, 2019 @10:57 PM CDT

**Title:** Frequency test

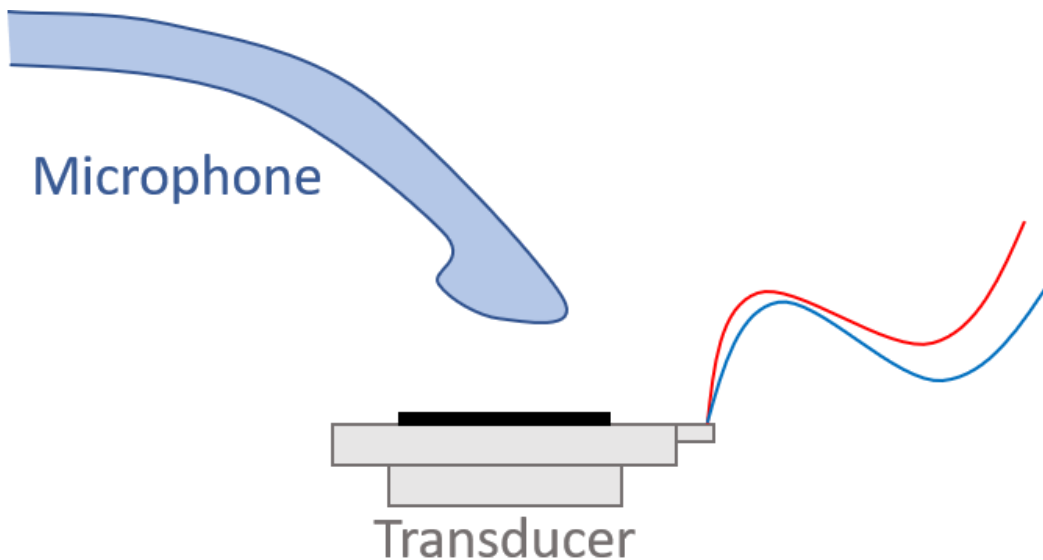
**Date:** 2019/04/19

**Content by:** Jinyuxuan Guo

**Present:** Team

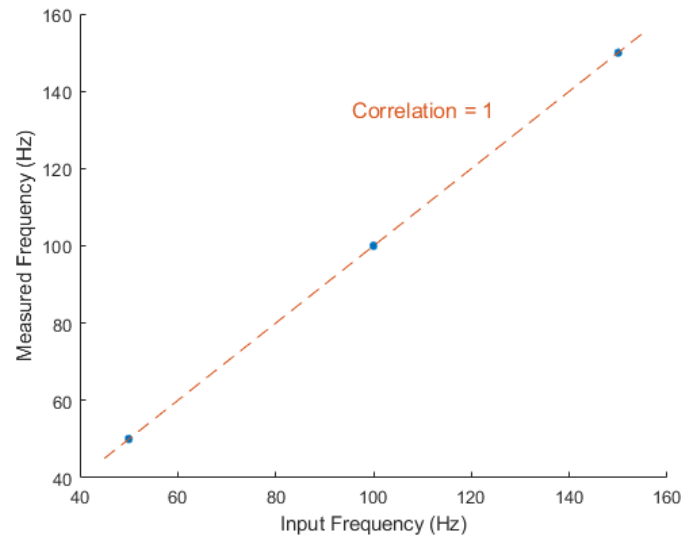
**Goals:** To make sure that the output frequency matches the input frequency.

**Content:**



A test was performed using a Logitech H390 USB Headset to determine the relationship between input and output frequency of the transducer. The microphone from the Logitech headset was placed 1/4 inch above the surface of the transducer. Frequencies of 50, 100, and 150 Hz were used as inputs and 6 seconds of audio was captured for each frequency. The audio file was analyzed using MATLAB's Fast Fourier Transform (FFT) to determine major frequency components.

**Conclusions/action items:**



In order to justify that the output frequency is similar or equal to the input frequency, the frequency verification test is designed and accomplished. The transducer is running at 50 Hz, 100 Hz and 150 Hz while this signal is recorded. A MATLAB code is then used to measure the output frequency of the transducer through FFT. The measured average frequency is 50 Hz at 50 Hz input frequency, 100 Hz at 100 Hz input frequency and 150 Hz at 150 input frequency. The out frequency is positively correlated with the input frequency. The pearson's correlation coefficient is 1.



# 2019/04/20-Loaded Displacement Test

• Stephan Blanz - May 01, 2019 @07:09 AM CDT

**Title:** Testing displacement under load

**Date:** 04/20/2019

**Content by:** Stephan Blanz

**Present:** Team

**Goals:** Collect preliminary data to determine if displacement varies with load

**Content:**

Assume: male rat weighs 400 g. Half the weight on each transducer = 200g

Test were conducted with a 200 g weight on the transducer and measured similar to the original displacement test.

Preliminary data indicates we have similar results between a loaded transducer and an unloaded transducer.

More data is needed to determine how the transducer will react at all parameters.

**Conclusions/action items:**

Preliminary data indicates displacement measurements recorded of an unloaded transducer apply to

Collected more data to determine statistical significance.

• Stephan Blanz - May 01, 2019 @07:09 AM CDT

F	W	L	SD	D
20	0.200	0.000	0.000	0.1
30	0.200	0.000	0.000	0.1
40	0.200	0.000	0.000	0.1
50	0.200	0.000	0.000	0.1
60	0.200	0.000	0.000	0.1
70	0.200	0.000	0.000	0.1
80	0.200	0.000	0.000	0.1
90	0.200	0.000	0.000	0.1
100	0.200	0.000	0.000	0.1
110	0.200	0.000	0.000	0.1
120	0.200	0.000	0.000	0.1
130	0.200	0.000	0.000	0.1
140	0.200	0.000	0.000	0.1
150	0.200	0.000	0.000	0.1
160	0.200	0.000	0.000	0.1

Displacement\_With\_200g\_Load.xlsx(9.3 KB) - [download](#)







## 2019/04/23-Bleed test

• jinyuxuan guo • Apr 30, 2019 @10:57 PM CDT

**Title:** Bleed test

**Date:** 04/24/2019

**Content by:** Jinyuxuan Guo

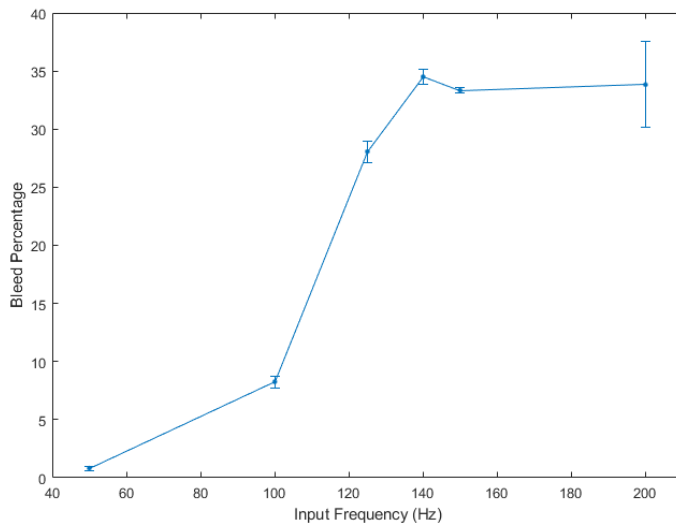
**Present:** Team

**Goals:** To understand how much off-target stimulation exists

**Content:**

A test was performed in the final design cage to determine the amount of off-target stimulation produced when stimulating a single hindlimb. A Sparkfun ADXL335 accelerometer was placed directly on the platform being vibrated (direct-target configuration) and recorded using an Arduino. Sampling was at 1000 Hz for 0.6 seconds. Then testing was repeated with the accelerometer on the platform adjacent to the platform being vibrated (off-target configuration). The magnitude of the acceleration vector was computed and was analyzed using MATLAB's FFT. At each input frequency, the amplitude of the FFT data for the off-target configuration was divided by the amplitude of the FFT data for the direct-target configuration to obtain the bleed percentage.

**Conclusions/action items:**



Another parameter that needs to be tested is the isolation of the vibrations from two pedals. This is very important because the device should be able to stimulate only one of the rodent's hindlimbs without stimulating the other. A bleedover test is conducted to see how much vibration exists on non-vibrating pedal. The results are shown on the figure. Each data point represents the off-target stimulation at that frequency, normalized by the on-target stimulation at the same frequency. At frequencies under 100 Hz, the bleed percent is under 10%, while the bleed percent can go over 30% at frequencies above 125 Hz. Bleed percent increases as the input frequency becomes higher. At high frequencies over 100 Hz, the isolation of vibrations from two pedals is partially lost.



## 2019/03/29: Show and Tell

---

• Steven Oakes • Apr 02, 2019 @05:47 PM CDT

**Title:** Show and Tell Notes

**Date:** Friday, March 29, 2019

**Content by:** Royal Oakes

**Present:** Royal, Rick, Stephen

**Goals:** Describe feedback we received during the show and tell.

**Content:**

We received no feedback on our design.

**Conclusions/action items:**

None.



## 2019/02/10-Exciter Panel Backing

• Stephan Blanz • Apr 28, 2019 @01:14 PM CDT

**Title:** Exciter Panel Backing

**Date:** 2/10/19

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, Royal Oakes

**Goals:** Determine suitable materials for exciter backing to ensure vibrations are in desired frequency range

**Content:**

HEAVIER MATERIAL = LOWER FREQUENCIES

Excellent materials to use for exciter mounting include:

- Aluminum, Nomex/Kevlar, or resin-impregnated paper honeycomb sandwich composites
- Structural or syntactic foam sandwich composites (e.g. Rohacell)
- Fabric-reinforced phenolic plastic panels
- Fiberglass-reinforced resin panels
- Corrugated or honeycomb cardboard sheet
- Corrugated plastic 'signboard' material
- Foam-core poster board with paper backing

Other materials which are less ideal but still workable include:

- Unreinforced plastic panels
- Mylar sheet
- Plexiglas or Lexan sheet
- Glass windows
- Mirrors
- Acoustic drop-ceiling tiles
- Wallboard
- Plywood/MDF/OSB sheets

Materials which may not give desirable results:

- Metal panels
- Metal structural members
- Concrete
- Wooden beams
- Soil

Source: <https://www.parts-express.com/resources-buyers-guide-exciters>

**Conclusions/action items:**

When testing choose from various materials and weights to determine ideal frequency response (heavier weight = lower frequencies).



## 2019/02/10-Exciter Product Comparison

- Stephan Blanz - Feb 10, 2019 @02:22 PM CST

**Title:** Exciter Product Comparison

**Date:** 2/10/19

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, Royal Oakes

**Goals:** Compare various commercially available products

**Content:**

Name	Diameter (mm)	Diameter (inches)	< 1 Frequency Fs	Cost	Link	Optional	Magnet Type	Impedance	Power	dA/dF (db to Freq response)	Purchase
DAEX-9-4SM	11.8	0.46456718	1200	5.99		(Haptic also)	Neodymium	4 Ohm	1 Watt	0 < 80 Hz; 1 > 80 HZ, Linear	**
DAEX-13-4SM	18.6	0.73228386	950	5.99		(Haptic also)	Neodymium	4 Ohm	3 Watt	1, Linear	**
DAEX9CT-4	20.9	0.82283509	1200	5.99		(Haptic also)	Neodymium	4 Ohm	0.5 Watt	5, Linear	
DAEX13CT-4	26.3	1.03543363	650	2.99		(haptic also)	Neodymium	4 Ohm	3 Watt	0.1, Linear	**
DAEX13CT-8	26.3	1.03543363	775	3.99			Neodymium	8 Ohm	3 Watt	.2, Linear	**
DAEX19CT-4	33	1.2992133	637	7.99			Neodymium	4 Ohm	5 Watt	Unkown in range, possibly 0	
DAEX19SL-4	33	1.2992133	630	7.99		(haptic also)		4 Ohm	4 Watt	1, Linear	
DAEX25X4-4	52.5	2.06693025	285								
DAEX25CT-4	56	2.2047256	306								
DAEX25VT-4	58.1	2.28740281	230								
DAEX25FHE-4	58.3	2.29527683									
DAEX32Q-4	60.7	2.38976507									
DAEX32Q-8	61	2.4015761	580								
DAEX25W-8	72.5	2.85433225				Waterproof					

**Conclusions/action items:**

We will purchase 2x DAEX-9-4SM, 2x DAEX-13-4SM, 2x DAEX13CT-4 and 2x DAEX13CT-8 based on product size, high resonance frequency and linearity of amplitude/frequency coupling.



# 2019/02/22-Lidar as Measurement

- Stephan Blanz - Feb 22, 2019 @12:26 PM CST

**Title:** LIDAR speed of measurement

**Date:** 2/22/2019

**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Determine Feasibility of Lidar

**Content:**

Measurement +  
Friday, February 22, 2019 10:50 AM

1. Can light measure fast enough?

$$f_s = \frac{c}{\lambda} = \frac{3 \cdot 10^8 \text{ m/s}}{750 \cdot 10^{-9} \text{ m}} = 400 \cdot 10^{12} \text{ Hz}$$

Yes!  $f_s \gg 2 \cdot f$

2. Can the receiving end of the detector detect changes  $< 1 \text{ mm}$ ?

$f = 100 \text{ Hz}$   
 $f_s = 400 \text{ Hz}$

$700 \text{ Hz} = \frac{200 \text{ samples}}{1 \mu\text{s}}$   
 $1 \mu\text{s} \approx 1 \text{ mm}$   
 $700 \text{ Hz} = \frac{200 \text{ samples} \cdot 1 \text{ mm}}{1 \mu\text{s}}$   
 $= 200 \text{ mm}/\mu\text{s}$   
 $= 200 \text{ mm}/10^{-6} \text{ s}$   
 $= 2 \cdot 10^8 \text{ mm/s}$

$\frac{200 \text{ mm}}{1 \cdot 10^{-6} \text{ s}} = 2 \cdot 10^8 \text{ mm/s}$   
 $= 300 \text{ ns}$   
 $= \frac{1}{3 \cdot 10^9} = 3 \cdot 10^8$   
 $3 \cdot 10^8 \text{ mm/s}$

$\text{Must see } \approx 300 \text{ mm} \cdot (1/3 \mu\text{s})$   
 $= 700 \text{ mm every second}$

**No!**

**Conclusions/action items:**

Do not use LIDAR. Can't capture measurements fast enough.



## 2019/02/22-Microphone as Measurement

• Stephan Blanz • Feb 22, 2019 @12:28 PM CST

**Title:** Using a Microphone as measurement

**Date:** 2/22/19

**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Code for FFT of microphone

**Content:**

```
import ddf.minim.analysis.*;
import ddf.minim.*;

Minim minim;
AudioSource in;
FFT fft;

void setup() {
  size(512, 200);

  //handle audio input
  minim = new Minim(this);
  in = minim.getLineIn();
  fft = new FFT( in.bufferSize(), in.sampleRate() );
}

void draw() {
  background(0);
  stroke(255);

  // perform a forward FFT on the samples in jingle's mix buffer,
  // which contains the mix of both the left and right channels of the file
  fft.forward( in.mix );

  for(int i = 0; i < fft.specSize(); i++) {
    // draw the line for frequency band i, scaling it up a bit so we can see it
    line( i, height, i, height - fft.getBand(i)*8 );
  }
}
```

Source: [https://gist.githubusercontent.com/AlexLamson/8fe64eff543394ef06083a9f24bc5a32/raw/926f42228cacac5d4abd362ccf2df2b7e9d68920/minim\\_microphone\\_fft.pde](https://gist.githubusercontent.com/AlexLamson/8fe64eff543394ef06083a9f24bc5a32/raw/926f42228cacac5d4abd362ccf2df2b7e9d68920/minim_microphone_fft.pde)

**Conclusions/action items:**

If using microphone, this can give a real time FFT useful for validating system.



## 2019/02/27-Load Cell Research

• Stephan Blanz • Apr 30, 2019 @09:36 PM CDT

**Title:** Load Cell Research

**Date:** 2/27/19

**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Find Out How a Load Cell Works

**Content:**

Load cells convert **Force** into a measurable electrical output. The force exerted on the load cell is measured relative to the strain felt by strain gauges in the beam of the cell [1].

I'm expecting the load cell to produce no more than (50 g) ( $9.81\text{m s}^{-2}$ ) of Force. Doubling that for a safety consideration should make the 100 g load cell ideal. Sparkfun sells one at: <https://www.sparkfun.com/products/14727> [2]

Additionally, the load cell will require an amplifier <https://www.sparkfun.com/products/13879> [3]

## References

[1]"Load Cells", <https://www.omega.ca/en/>, 2019. [Online]. Available: <https://www.omega.com/en-us/resources/load-cells>. [Accessed: 01- May- 2019].

[2]"Mini Load Cell - 100g, Straight Bar (TAL221) - SEN-14727 - SparkFun Electronics", *Sparkfun.com*, 2019. [Online]. Available: <https://www.sparkfun.com/products/14727>. [Accessed: 01- May- 2019].

[3]"SparkFun Load Cell Amplifier - HX711 - SEN-13879 - SparkFun Electronics", *Sparkfun.com*, 2019. [Online]. Available: <https://www.sparkfun.com/products/13879>. [Accessed: 01- May- 2019].

**Conclusions/action items:**

We have identified a device (load cell) with which we should be able to obtain measurements based on Force produced by the transducers.



## 2019/03/05-Load Cell Circuit and Arduino Code

• Stephan Blanz • Apr 30, 2019 @09:56 PM CDT

**Title:** Building the Load Cell Circuit and Arduino Code

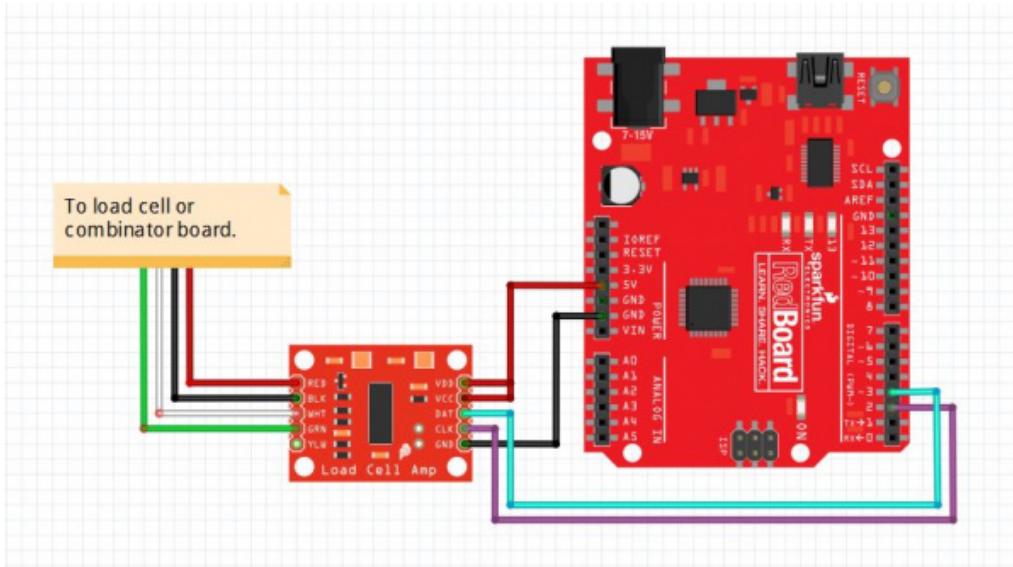
**Date:** 03/05/2019

**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Create a working circuit for the load cell

**Content:**



The circuit is very straightforward. The website provided a sample code for calibrating the load cell once connected to the arduino.

During testing, I found the code was not capable of small calibrations and modified it as follows:

```
#include <HX711.h>
```

```
/*
```

```
*
```

Source code provided by

By: Nathan Seidle

SparkFun Electronics

Date: November 19th, 2014

License: This code is public domain but you buy me a beer if you use this and we meet someday (Beerware license).

Expanded by:

Stephan Blanz

This is the calibration sketch. Use it to determine the calibration\_factor that the main example uses. It also outputs the zero\_factor useful for projects that have a permanent mass on the scale in between power cycles.

Setup your scale and start the sketch WITHOUT a weight on the scale

Once readings are displayed place the weight on the scale

Press +/- or a/z to adjust the calibration\_factor until the output readings match the known weight

Use this calibration\_factor on the example sketch



This example assumes pounds (lbs). If you prefer kilograms, change the `Serial.print(" lbs");` line to `kg`. The calibration factor will be significantly different but it will be linearly related to lbs (1 lbs = 0.453592 kg).

Your calibration factor may be very positive or very negative. It all depends on the setup of your scale system and the direction the sensors deflect from zero state

This example code uses bogde's excellent library: <https://github.com/bogde/HX711>

bogde's library is released under a GNU GENERAL PUBLIC LICENSE

Arduino pin 2 -> HX711 CLK

3 -> DOUT

5V -> VCC

GND -> GND

Most any pin on the Arduino Uno will be compatible with DOUT/CLK.

The HX711 board can be powered from 2.7V to 5V so the Arduino 5V power should be fine.

```
*/
#include "HX711.h"

#define DOUT 3
#define CLK 2

HX711 scale;

float calibration_factor = 11800; // 11800 in cage for g

void setup() {
  Serial.begin(9600);
  Serial.println("HX711 calibration sketch");
  Serial.println("Remove all weight from scale");
  Serial.println("After readings begin, place known weight on scale");
  Serial.println("Press + or a to increase calibration factor");
  Serial.println("Press - or z to decrease calibration factor");

  scale.begin(DOUT, CLK);
  scale.set_scale();
  scale.tare(); //Reset the scale to 0

  long zero_factor = scale.read_average(); //Get a baseline reading
  Serial.print("Zero factor: "); //This can be used to remove the need to tare the scale. Useful in permanent scale projects.
  Serial.println(zero_factor);
}

void loop() {
  scale.set_scale(calibration_factor); //Adjust to this calibration factor

  Serial.print("Reading: ");
  Serial.print(scale.get_units(), 1);
  Serial.print(" g"); //Change this to kg and re-adjust the calibration factor if you follow SI units like a sane person
  Serial.print(" calibration_factor: ");
  Serial.print(calibration_factor);
  Serial.println();

  if(Serial.available())
  {
    char temp = Serial.read();
    if(temp == '+' || temp == 'a')
      calibration_factor += 25;
    else if(temp == '-' || temp == 'z')
      calibration_factor -= 25;
    else if(temp == 'w')
      calibration_factor += 100;
    else if(temp == 's')
```

```

    calibration_factor -= 100;
    else if(temp == 'e')
    calibration_factor += 1000;
    else if(temp == 'd')
    calibration_factor -= 1000;
    else if(temp == 't')
    scale.tare();
}
}

```

This came out to have a **calibration factor of 11800**

Once the calibration factor is established, it can be hard coded and then run in a continuous monitoring:

```

/*
Example using the SparkFun HX711 breakout board with a scale
By: Nathan Seidle
SparkFun Electronics
Date: November 19th, 2014
License: This code is public domain but you buy me a beer if you use this and we meet someday (Beerware license).

```

This example demonstrates basic scale output. See the calibration sketch to get the calibration\_factor for your specific load cell setup.

This example code uses bogde's excellent library: <https://github.com/bogde/HX711>  
 bogde's library is released under a GNU GENERAL PUBLIC LICENSE

The HX711 does one thing well: read load cells. The breakout board is compatible with any wheat-stone bridge based load cell which should allow a user to measure everything from a few grams to tens of tons.

Arduino pin 2 -> HX711 CLK  
 3 -> DAT  
 5V -> VCC  
 GND -> GND

The HX711 board can be powered from 2.7V to 5V so the Arduino 5V power should be fine.

```

*/
#include "HX711.h"

#define calibration_factor 11800.0 //This value is obtained using the SparkFun_HX711_Calibration sketch

#define DOUT 3
#define CLK 2

HX711 scale;

void setup() {
  Serial.begin(9600);
  // Serial.println("HX711 scale demo");

  scale.begin(DOUT, CLK);
  scale.set_scale(calibration_factor); //This value is obtained by using the SparkFun_HX711_Calibration sketch
  scale.tare(); //Assuming there is no weight on the scale at start up, reset the scale to 0

  // Serial.println("Readings:");
}

void loop() {
  Serial.print(scale.get_units(), 1); //scale.get_units() returns a float
  // Serial.print(" g"); //You can change this to kg but you'll need to refactor the calibration_factor

```

```
Serial.println();  
}
```

**Conclusions/action items:**

Calibration factor: 11800



## 2019/03/30-PVC Pedestals

• Stephan Blanz • Apr 05, 2019 @12:11 PM CDT

**Title:** Base Leg Manufacturing

**Date:** 3/30/19

**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Manufacture Legs out of PVC / Concrete

**Content:**

Concrete was mixed in accordance with packaging instructions. Slightly more water was used than recommended to make pouring into small PVC opening easier.

Concrete mix was poured in 3" length PVC with 1/2" ID.

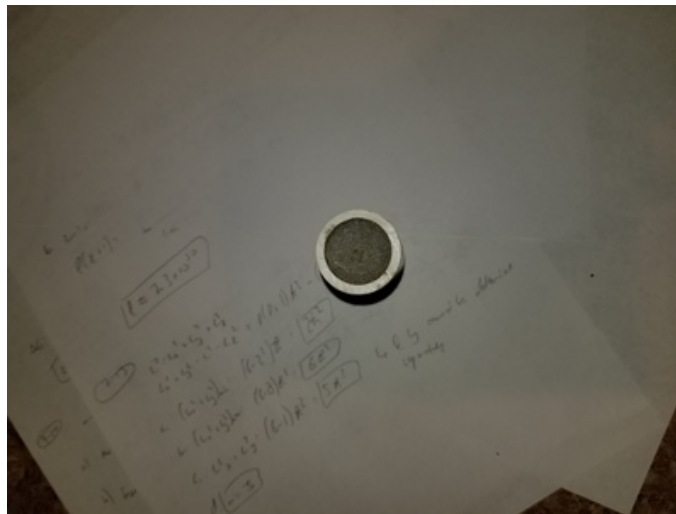
PVC/ Concrete platform was allowed to dry for 48 hours.

Weights were measured and determined to be: 81g, 81g, 81g, 83 g.

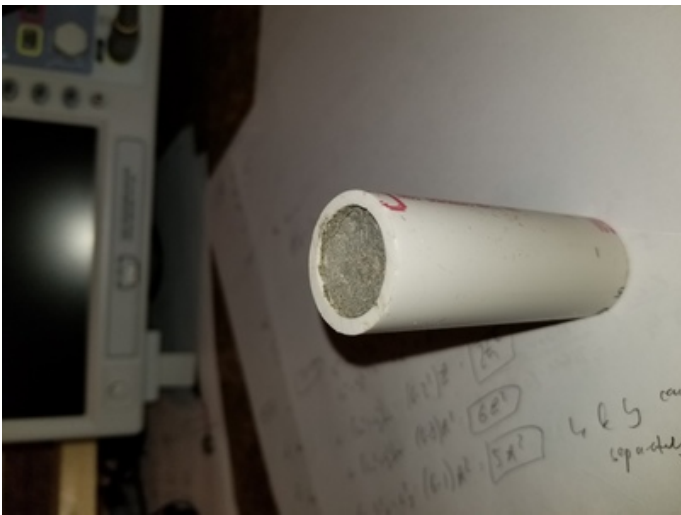
**Conclusions/action items:**

We now have 3 PVC/ Concrete stations of equal weight and density. Two of these will be used to support the transducers.

• Stephan Blanz • Apr 30, 2019 @10:04 PM CDT



20190430\_220130.jpg(3.7 MB) - [download](#)



20190430\_220137.jpg(3.6 MB) - [download](#)





## 2019/04/07-Camera Capture Attempt

---

• Stephan Blanz • Apr 30, 2019 @10:18 PM CDT

**Title:** Camera Capture Attempt

**Date:** 4/30/19

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, Royal Oakes

**Goals:** Try to capture displacement via lab camera

**Content:**

We went to Royal's lab to try and capture the transducer oscillating. However, the camera was intended to be used with a microscope and did not have a focal point conducive to testing without a microscope.

The Camera used was: CoolSNAP DYNO CCD 2.8 MP camera

**Conclusions/action items:**

Use a camera designed to capture images at close distances, but not meant to be coupled with a microscope.



## 2019/04/14-Movie Averager

• Stephan Blanz • May 01, 2019 @08:51 AM CDT

**Title:** Matlab code to take averages

**Date:** 4/14/19

**Content by:** Stephan Blanz

**Present:** Stephan Blanz

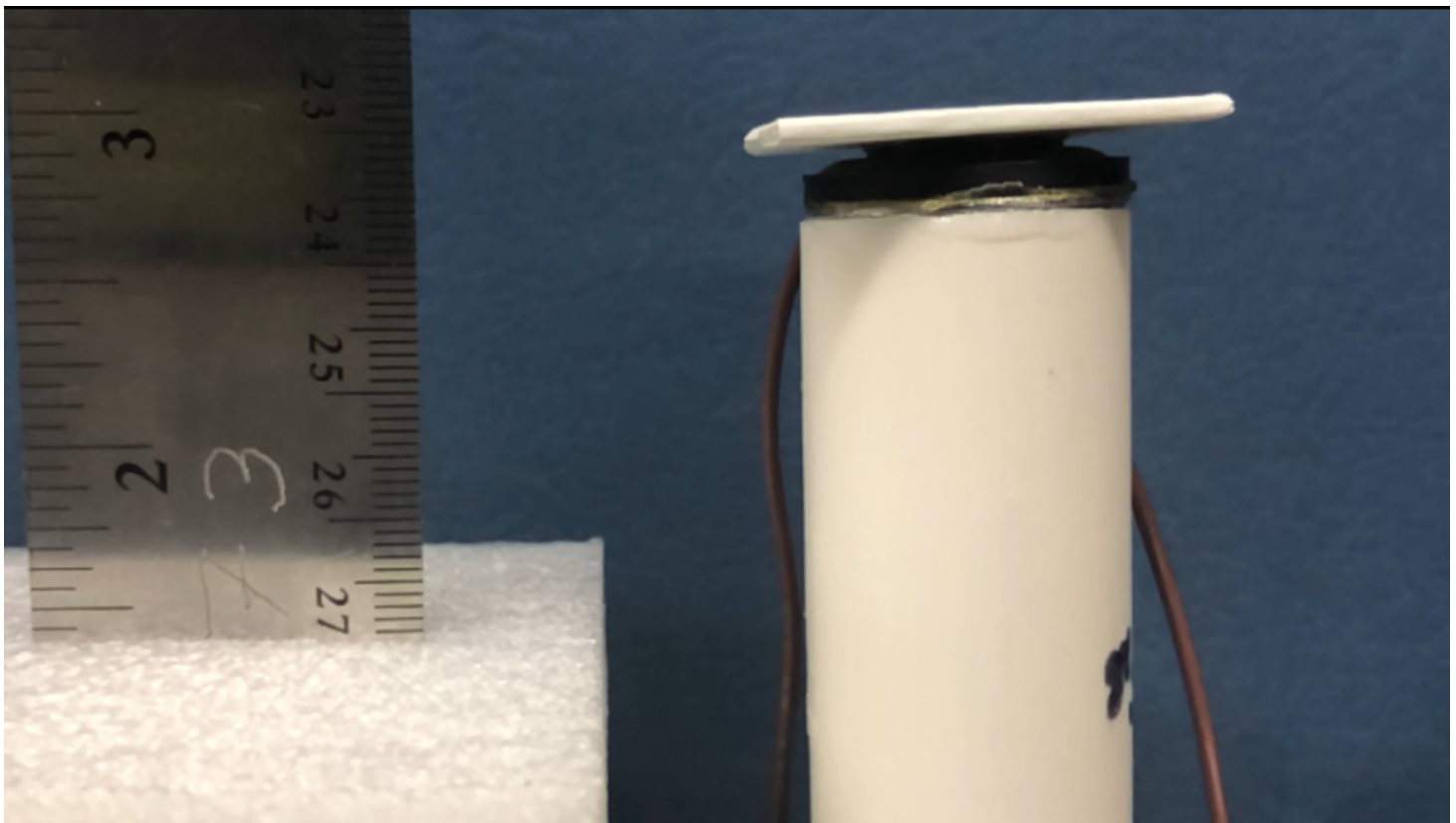
**Goals:** Write Matlab code that can generate a mean frame from a movie to analyze motion

**Content:**

This code will ask the user to select a file. The program will then average the frames and both display and save the mean frame as well as an index frame (which can be selected by the user in the code).

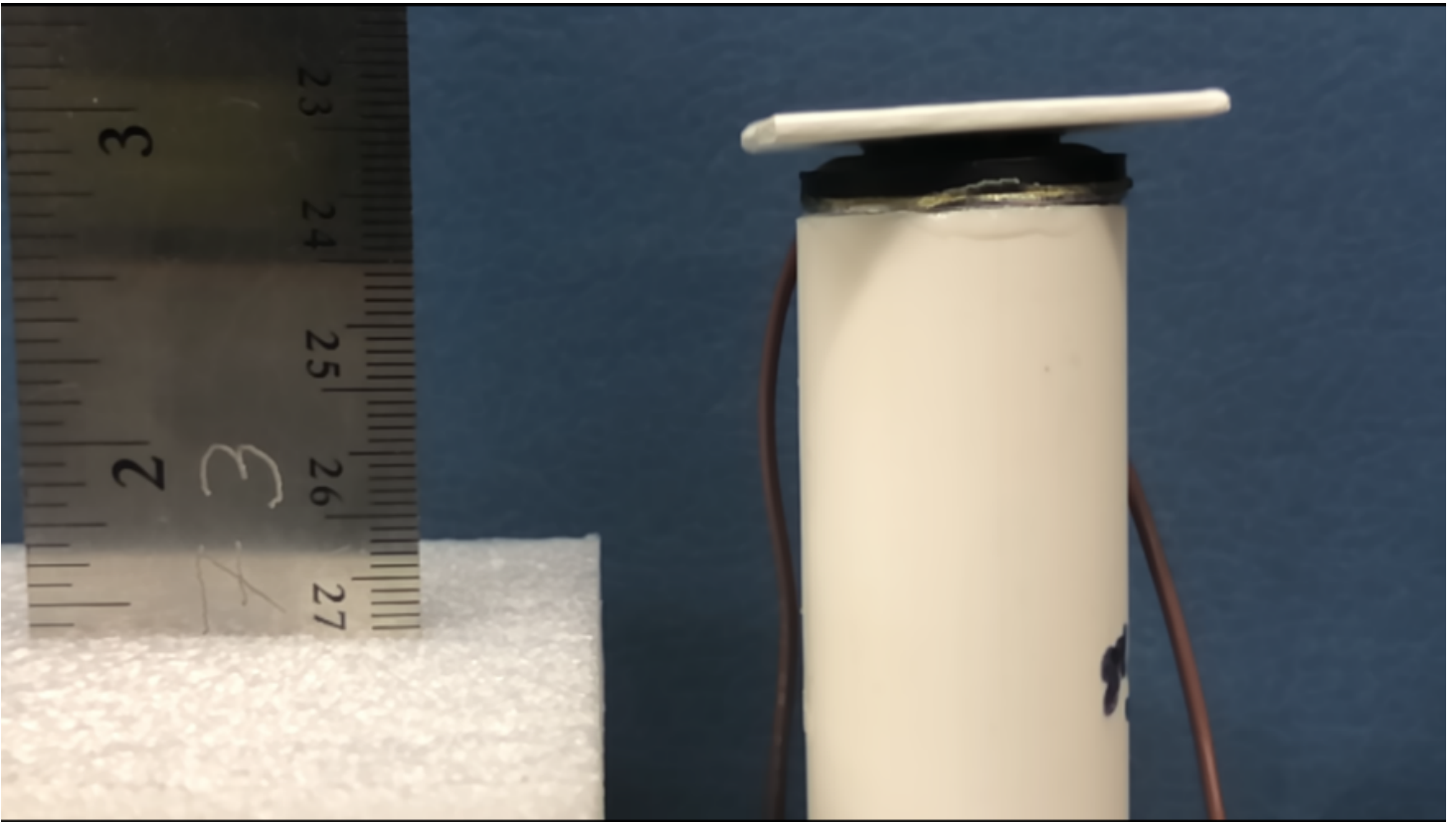
It is not recommended to use the matlab generated pictures for imageJ analysis as I have found there seems to be a compression that causes blur. It is also not recommended to use matlab to zoom in on generated pictures, but to let imageJ do this instead, as this has also been observed to cause blur.

This program will show the images more as a sanity check than an analytical tool. Ensure you have selected the correct file and that your reference frame is free of blue and conversely, your mean frame has blur.



**Figure 1.** Index Frame used as baseline measurement. No blur.





**Figure 2.** Mean frame with visible blur.

**Conclusions/action items:**

Matlab is great, but don't rely on its figure function. (Don't save the figure and then apply image analysis techniques.) Instead, have MATLAB save the image to the drive and then load that image in ImageJ and apply image analysis.

**Code:**

```
%% Movie Averager
% By: Stephan Blanz
% Portions of code found at: https://ww2.mathworks.cn/matlabcentral/answers/59194-reading-video-file-to-matlab?s\_tid=gn\_loc\_drop

% This code will ask the user to select a file. The program will then
% average the frames and both display and save the mean frame as well as an
% index frame (which can be selected by the user in the code).
%
% It is not recommended to use the matlab generated pictures for imageJ
% analysis as I have found there seems to be a compression that causes
% blur. It is also not recommended to use matlab to zoom in on generated
% pictures, but to let imageJ do this instead, as this has also been
% observed to cause blur.
%
% This program will show the images more as a sanity check than an
% analytical tool. Ensure you have selected the correct file and that your
% reference frame is free of blue and conversely, your mean frame has blur.

%%
clc; % Clear the command window.
close all; % Close all figures (except those of imtool.)
imtool close all; % Close all imtool figures.
clear; % Erase all existing variables.
workspace; % Make sure the workspace panel is showing.

% Set this to the index of the frame you want to use as reference. Recommend
% to use one shortly before start of video since there is no motor motion
```

```

% yet and also no artifact from pushing record
indexGrabLocation = 5;

strErrorMessage = sprintf('Please select a file you want to analyze. ');
response = questdlg(strErrorMessage, 'Choose a File', 'Select File', 'Cancel', 'Select File');
if strcmpi(response, 'Select File')
    [baseFileName, folderName, FilterIndex] = uigetfile('*.mp4'); % Change this if using a different file format
    if ~isequal(baseFileName, 0)
        movieFullFileName = fullfile(folderName, baseFileName);
    else
        return;
    end
else
    return;
end

try
    videoObject = VideoReader(movieFullFileName)
    % Determine how many frames there are.
    numberOfFrames = videoObject.NumberOfFrames;
    vidHeight = videoObject.Height;
    vidWidth = videoObject.Width;

    numberOfFramesWritten = 0;

    % Loop through the movie, getting mean frame.
    for frame = 1 : numberOfFrames
        % Extract the frame from the movie structure.
        thisFrame = read(videoObject, frame);

        % Uncomment if you want to go frame by frame and watch
        % WARNING: TAKES REAAAAALLY LONG.
        % % % Display it
        % % hImage = subplot(1, 2, 1);
        % % image(thisFrame);
        % % axis('on', 'image');
        % % caption = sprintf('Frame %4d of %d.', frame, numberOfFrames);
        % % title(caption, 'FontSize', fontSize);
        % % drawnow; % Force it to refresh the window.

        % Calculate the mean frame.
        if frame == 1
            sumFrame = double(thisFrame);
        elseif frame == 5
            indexFrame = thisFrame;
        else
            sumFrame = sumFrame + double(thisFrame);
        end
        meanFrame = uint8(sumFrame / frame);
        % % Uncomment this to plot as you go
        % % Plot the mean gray levels.
        % hPlot = subplot(1, 2, 2);
        % imshow(meanFrame);
        % axis('on', 'image');
        % caption = sprintf('Mean of %d frames', frame);
        % title(caption, 'FontSize', fontSize);
        % drawnow;
        %
        % % Update user with the progress. Display in the command window.
        % progressIndication = sprintf('Processed frame %4d of %d.', frame, numberOfFrames);

```

```
% disp(progressIndication);
end

hImage = figure(1);
imshow(indexFrame);
% Uncomment if you want it zoomed in. Not recommended for image
% processing as MATLAB screws with the formatting and you get a blur
%axis([1000 2000 700 1000]);
caption = sprintf('%s  Index Frame', baseFileName);
title(caption);

hPlot = figure(2);
imshow(meanFrame);
%axis([1000 2000 700 1000]);
caption = sprintf('%s  Mean of %d frames', baseFileName, frame);
title(caption);

%axis([hImage hPlot],[370 570 190 250],'on','image')

% IMPORTANT: This is where images are stored.
fileName1 = sprintf('IndexFrame_%s.png', baseFileName);
fileName2 = sprintf('MeanFrame_%s.png', baseFileName);
imwrite(indexFrame,fileName1);
imwrite(meanFrame,fileName2);

% Alert user that we're done.
finishedMessage1 = sprintf('Done! It processed %d frames of\n  "%s"', numberOfFrames, movieFullFileName);
finishedMessage2 = sprintf('Files saved as\n "%s" \n and \n "%s"', fileName1, fileName2);
disp(finishedMessage1); % Write to command window.
uiwait(msgbox(finishedMessage1)); % Also pop up a message box.
uiwait(msgbox(finishedMessage2)); % Also pop up a message box.

catch ME
% Some error happened if you get here.
strErrorMessage = sprintf('Error extracting movie frames from:\n\n%s\n\nError: %s\n\n', movieFullFileName, ME.message);
uiwait(msgbox(strErrorMessage));
end
```



## 2019/04/25-Determining Distance of Gap after Transducer

• Stephan Blanz • May 01, 2019 @08:51 AM CDT

**Title:** Determining the most efficient distance for conducting the least amount of sound / vibration between foot rest and cage

**Date:** 04/25/2019

**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Get an ideal distance.

**Content:**

**Stable's Law (Sound Travel)**

$$d = \frac{2 \rho c v^2}{3 \rho U^2}$$

$$A(d) = A_0 e^{-\alpha d}$$

where  $\alpha$ : rate of decay  
 $\rho$ : dynamic viscosity coefficient  
 $A_0$ : amplitude at gap  
 $U$ : speed of sound in medium  
 $N(\alpha)$ : amplitude as a function of distance

$$\alpha = \frac{2(1.377)(20.5)^2}{3(1.184)(243)^2} = 2.572 \cdot 10^{-7} \text{ s}^{-1}$$

$$\frac{\alpha}{2\text{mils}} = .0021443$$

$$\frac{\alpha}{1\text{mils}} = .032002$$

**Best case Assumptions:**

- Sound is a point source
- Point source is at maximum distance from other plates at  $z = .0508\text{m}$
- $A_0 = 1$

$$A(.0508) = \exp(-\alpha(.0508))$$

$$A(.0508) = .99877$$

$$A(.0002) = .99876$$

**Take-aways:**

Sound slows more in air than acrylic.

Even under best case assumption, the amplitude lost is less than 0.2%

Given this, even the smallest gap will have virtually an undetectable difference from the largest theoretical (not practical) gap.

**Conclusions/action items:**

Creating any kind of gap is the best we can do. At these distances the size of the gap will have virtually no impact on the amplitude of vibrations.



## 04/24/19 - Video Displacement Test Analysis

- John Beckman - Apr 29, 2019 @10:55 PM CDT

**Title:** Video Displacement ImageJ Processing

**Date:** 04/24/19

**Content by:** John Beckman

**Present:** N/A

**Goals:** To record the displacements of all the tests done using camera to record displacement data

**Content:**

An excel spreadsheet will be attached which contains data from all of the different video tests completed in different scenarios. With 200 g weight on top of just the transducer, with no weight no coupling, and with a weight coupled in the cage. Also there is another spreadsheet in the excel document which contains the results from earlier analysis in which each team member analyzed two sets of data (6 data points for each set) as well as one data point from the sets above and below their own. This was done to ensure each team member knew and understood how to analyze these results.

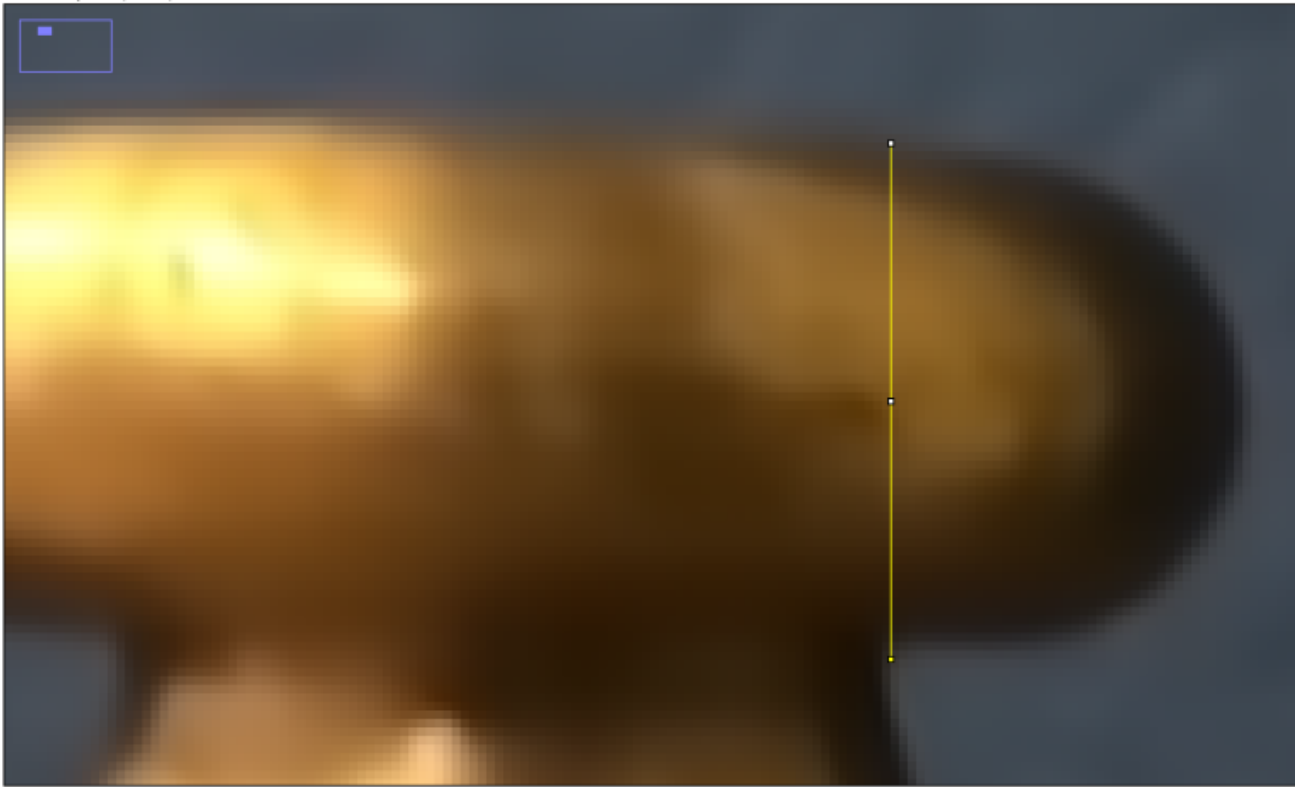
IndexFrame\_LOAD 25 0.1.mp4.png (600%)  
960x544 pixels; RGB; 2MB



This Image shows the index frame and the line used to measure the height of the index frame. There is a machine ruler located to the right of this zoomed image of the index frame which was used to determine the actual value for the size of the item being measured.

MeanFrame\_LOAD 25 0.1.mp4.png (600%)

960x544 pixels; RGB; 2MB



This image shows the zoomed in measured frame. this measurement paired with the index frame was used to determine the displacement of the transducer at each different variable amplitude (voltage peak - peak).

**Conclusions/action items:**

Now we must analyze the collected data, and use different statistical tests to determine the significance of these data points.

• John Beckman • Apr 29, 2019 @10:56 PM CDT

**Overview**

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**Sheet 1: Uncoupled**

Frequency	Amplitude	Unit	Avg	StdDev	Min/Max	Max Min	Var Min
10	0.1	g	1.300	1.320	0.000		
15	0.1	g	1.301	1.300	0.000		
20	0.1	g	1.301	1.299	0.000		
25	0.1	g	1.300	1.299	0.000		
30	0.1	g	1.300	1.299	0.000		
35	0.1	g	1.300	1.299	0.000		
40	0.1	g	1.300	1.299	0.000		
45	0.1	g	1.300	1.299	0.000		
50	0.1	g	1.300	1.299	0.000		
55	0.1	g	1.300	1.299	0.000		
60	0.1	g	1.300	1.299	0.000		
65	0.1	g	1.300	1.299	0.000		
70	0.1	g	1.300	1.299	0.000		
75	0.1	g	1.300	1.299	0.000		
80	0.1	g	1.300	1.299	0.000		
85	0.1	g	1.300	1.299	0.000		
90	0.1	g	1.300	1.299	0.000		
95	0.1	g	1.300	1.299	0.000		
100	0.1	g	1.300	1.299	0.000		
105	0.1	g	1.300	1.299	0.000		
110	0.1	g	1.300	1.299	0.000		
115	0.1	g	1.300	1.299	0.000		
120	0.1	g	1.300	1.299	0.000		
125	0.1	g	1.300	1.299	0.000		
130	0.1	g	1.300	1.299	0.000		
135	0.1	g	1.300	1.299	0.000		
140	0.1	g	1.300	1.299	0.000		
145	0.1	g	1.300	1.299	0.000		
150	0.1	g	1.300	1.299	0.000		
155	0.1	g	1.300	1.299	0.000		
160	0.1	g	1.300	1.299	0.000		
165	0.1	g	1.300	1.299	0.000		
170	0.1	g	1.300	1.299	0.000		
175	0.1	g	1.300	1.299	0.000		
180	0.1	g	1.300	1.299	0.000		
185	0.1	g	1.300	1.299	0.000		
190	0.1	g	1.300	1.299	0.000		
195	0.1	g	1.300	1.299	0.000		
200	0.1	g	1.300	1.299	0.000		

[Video\\_Displacement\\_Final.xlsx\(42.5 KB\) - download](#)



## 03/03/19 - Stethoscope Outreach Activity

• John Beckman • Apr 29, 2019 @09:21 PM CDT

**Title:** Stethoscope Outreach Activity

**Date:** 3/03/19

**Content by:** John Beckman

**Present:** N/A

**Goals:** Create an activity guide and proposal for our stethoscope outreach activity

**Content:**

The Activity we had in mind was to have the students design a stethoscope for a "client" with a very limited budget. The students would be given a list of materials as well as prices for the different items. Total budget of \$10, and varying prices for the materials from \$1-3. See the proposal attached.

**Conclusions/action items:**

Send Tracy Puccinelli the outreach guide and ask her opinion. From there discuss where to perform this activity and who to reach out to.

• John Beckman • Apr 29, 2019 @09:16 PM CDT

### Proposal for a stethoscope building outreach activity

Location:

Our team of 4, would like to go to Madison West High School on April 5<sup>th</sup> for the AVID/TOPI group.

Team:

John Beckman, Stephen Bost, Emmanuel Gao, and Royal Oates

Our roles:

Students will learn more about the human heart and circulatory system with an emphasis on how biomedical engineers have interbed with the diagnostic system in the past using examples such as: Pacemakers, Replacement valves, and stents. Then we will have them design a stethoscope given 35 and a variety of different priced supplies. Next, we will have them use their stethoscope to measure resting heart rate of their team members. Also, we will discuss the different heart sounds, what they represent, and finally compare stethoscope measurement to measurement using wrist pulse.

Presentations:

Our presentation will focus on the heart and circulatory system, especially looking at ways that biomedical engineers have helped in the past when this complex system fails. We will take a look at pacemakers and replacement heart valves as well as the benefits these devices can have on a patient in need of them. Also, we will talk about stents and the benefit of these in certain scenarios, such as those used following stroke, to unblock blocked off blood arteries. Finally we will show the improvements that have been made in these technologies over time.

Activity:

We will allow the students to separate into teams of 2-4, then provide them with a theoretical \$5 to purchase materials to build another stethoscope. We will look for one engine for simplicity sake, in addition we can talk to the students about some of the design process and restrictions that are placed on the engineers most of the time. From there we will take place some basic design specifications and allow them to ask any questions they have about the activity.

Item	Quantity	Cost	Location
Disc cup	1 of 300	\$5.49	Amazon
Black foam net	2 of 4	\$0.27	Amazon
Scrap PVC tubing	1 of 20 ft	\$50.99	Amazon
Rubber bands	1 of 0.5 lb	\$5.49	Amazon
Disc Tape	1 1/2 ft	\$3.99	Amazon
White Cotton	1 of 300	\$5.93	Amazon
Black Whip	1 1/2 ft	\$3.99	Amazon
Vinyl PVC Tubing	1 of 20 ft	\$50.99	Amazon
<b>Total Cost:</b>		<b>\$92.14</b>	

[Outreach\\_Proposal.docx\(14.8 KB\) - download](#)



## 03/14/19 - Pill Dissolving Outreach Activity

- John Beckman - Apr 30, 2019 @12:04 AM CDT

**Title:** Pill Dissolving outreach Activity

**Date:** 03/14/19

**Content by:** John Beckman

**Present:** N/A

**Goals:** To create a better activity that is less obvious to those solving the problem/participating in the activity.

**Content:**

This activity is more of a demo for students to better understand ways in which engineers can simulate environments of the human body. To do this vinegar will be used to simulate the acidic environment inside the human stomach. From there they will observe the dissolution of three different types of pills, such as chalk, and gel encased.

**Conclusions/action items:**

Again, send Tracy the new activity guide for feedback, and continue working on setting up a date/time for this activity.

- John Beckman - Apr 30, 2019 @12:04 AM CDT

D E P A R T M E N T O F  
**Biomedical Engineering**  
College of Engineering University of Wisconsin-Madison

**How Biomedical Engineers Simulate In vivo Environments**

Organization: University of Wisconsin-Madison Department of Biomedical Engineering

Contact person/s: (names)  
Contact information: (email)

**General Description**

**Type of activity**

For this activity, the participants will get together in groups of 2-4, and explore how biomedical engineers create in vitro environments that simulate environments from the human body. To start we will discuss some of the challenges with creating environments that accurately represent those of the human body, and we dedicate some of the time to discuss mechanisms are. From there we will transition into discussing how to simulate the environment inside the human stomach, as well as how this environment is conducive for the breakdown of food. This activity will allow students to examine the breakdown of different types of pills in this environment. Specifically we will show a couple of other (see more) different types of pills advertising the fastest absorption or release into the system. Then we will provide the students with vinegar, simulated stomach acid, and some different types of pills to examine which one absorbs the quickest. Afterwards, we will discuss how this simulated environment could be useful for an engineer attempting to test a device that is meant to be implemented into the human body.

**Program Objectives**

**Big idea:** The team wants to help expand student's knowledge of in vitro environments and how they can be used to help engineers test their designs. In addition we will discuss other ways in which an engineer can simulate in vitro environments, specifically discussing our BME 301 class in which an environment is used to test a bone graft.

**Learning goals:**

As a result of participating in this program, visitors will be able to:

1. Expand participants knowledge of Biomedical Engineering and how we interact with the human body.
2. Teach participants how to analyze the human body and create a simulated environment with which to test a design.
- 3.

**Table of Contents**

**BME\_Outreach\_Activity.docx(72.2 KB) - download**





## 04/08/19 - Final Outreach Activity Guide

- John Beckman - Apr 29, 2019 @11:39 PM CDT

**Title:** Broken Wrist Outreach Simulation

**Date:** 04/08/19

**Content by:** John Beckman

**Present:** Rick, Royal

**Goals:** To create an activity guide for the final outreach activity

### Content:

The new activity guide will be similar to the original stethoscope activity, however rather than a budget they will just be given 3 different materials to use to fix a simulated broken wrist. The broken wrist will be a cut piece of wood, wrapped in foam, to simulate the skin and muscles in a simple/cheap way. See the activity guide below for full information on how the event will be run.

### Conclusions/action items:

Again send this outreach guide to Tracy for feedback. Also still need to set a date for this event, have reached out to a couple of other contacts, potential for a Sunday school event with Royal and his mothers church.

• John Beckman - Apr 29, 2019 @11:39 PM CDT

DEPARTMENT OF  
**Biomedical Engineering**  
College of Engineering University of Wisconsin-Madison

---

**How Biomedical Engineers Simulate In vivo Environments**

Organization: University of Wisconsin-Madison Department of Biomedical Engineering  
 Contact person/s: John Beckman  
 Contact information: jbeckman@wisc.edu

---

**General Description**

*Type of activity*

For this activity, the participants will get together in small groups and be given a small piece of wood that is either broken or cut in half. The students will be told that this piece of wood is a bone that has been broken, and that it is their job to design a cast or cuff for this bone that needs to be repaired. Then they will be shown a list of around 10 different materials that they can use to hold this bone in place while it heals. The students will only be allowed to take 3 items from the list to build their cast, we will explain that they are given a limited budget and can only afford 3 of the items on the list. From their the students will be given approximately 10-15 minutes to decide which materials they would like to use, then they will be given time to build their cast/cuff. To test their designs, we will use small weights, 2.5, 5, and 10-pound kettlebells to test both the compression and bending of their design. We will test the different designs with a bending load, and the team with the "strongest" design will be given a candy reward. After all the designs have been tested, we will ask the students what changes they would make if they were tasked with this project from a client.

---

**Program Objectives**

**Big idea:** The team wants to help expand student's knowledge of the design process, and what being a Biomedical Engineer is all about. Also, we will teach the students about bone fractures and the bone healing process.

**Learning goals:**  
 As a result of participating in this program, visitors will be able to:

1. Briefly explain Biomedical Engineering and the design process.
2. Expand participants knowledge of the human body and its resilience.
3. Describe how engineers could doctors in the repair of broken bones.
4. Have fun!

[BME\\_Outreach\\_Activity\\_3.docx\(44 KB\) - download](#)



## 2019/02/10: Speaker Design Research

• Steven Oakes • Feb 10, 2019 @01:29 PM CST

**Title:** Speaker Design Research

**Date:** Sunday, February 10, 2019

**Content by:** Royal Oakes

**Present:** Royal Oakes, Stephan Blanz

**Goals:** Describe the properties of speakers.

**Content:**

There is a chance that we may use a speaker to generate the vibrations on the rodent's hindlimbs for this semester's design. It would be beneficial to understand the properties of speakers and the equations that govern their action.

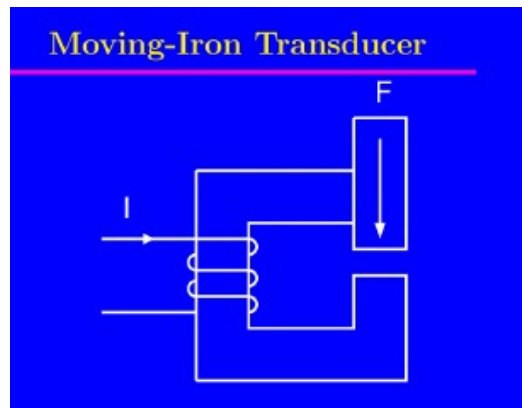
I have gathered material relating to the mechanics of speakers and attached them to this page. Below is a short description of each file:

- **LoudspeakerEqns.pdf:** This file contains an equation for the displacement of a voice coil in a speaker.
- **LoudspeakerExplanation.html:** This file contains an explanation of the parameters in the LoudspeakerEqns.pdf. It was taken from a physics forum so the interpretations may not be completely accurate. Taken from [\[link\]](#).
- **LoudspeakerParameters.pdf:** This file contains detailed information about the construction of speakers and the parameters that govern their action. It does not provide many equations, but it is still useful background information.
- **LoudspeakerForceEqn.html:** Contains a useful formula for the mechanical force generated by a voice coil. Taken from [\[link\]](#).

**Conclusions/action items:**

Write summary of what I have learned.

• Steven Oakes • Feb 10, 2019 @01:15 PM CST



BME402\_LoudspeakerEqns.pdf(80.4 KB) - [download](#)

• Steven Oakes • Feb 10, 2019 @01:15 PM CST



BME402\_LoudspeakerExplanation.html(139.4 KB) - [download](#)

## Loudspeaker Parameters

D. G. Meyer  
School of Electrical & Computer  
Engineering

**BME402\_LoudspeakerParameters.pdf(651.4 KB) - download**

• Steven Oakes • Feb 10, 2019 @01:24 PM CST



### SPEAKERS

QUESTIONS/COMMENTS

**AUTHOR:** Roman M. Luz III

**E-MAIL:** [rluz@mit.edu](mailto:rluz@mit.edu)

**COURSE:** 2

**CLASS/SECTION:** 2

**MAIN FUNCTIONAL REQUIREMENT:** Convert electric signal into audible sound.

**DESIGN PARAMETER:** Loudspeaker (there are other types of speakers...)

**GEOMETRY STRUCTURE:**

**BME402\_LoudspeakerForceEqn.html(21.5 KB) - download**



## 2019/02/25: Stand for Speaker

• Steven Oakes • Feb 25, 2019 @06:19 PM CST

**Title:** Stand for Speaker

**Date:** Monday, February 25, 2019

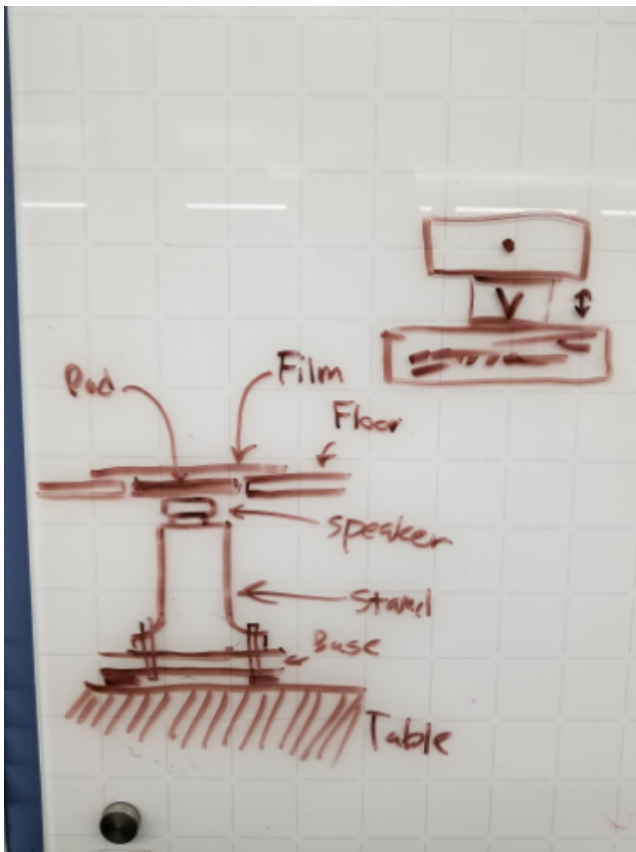
**Content by:** Steven Royal Oakes

**Present:** Stephan Blanz, Rick Guo

**Goals:** Describe an idea for the cage

**Content:**

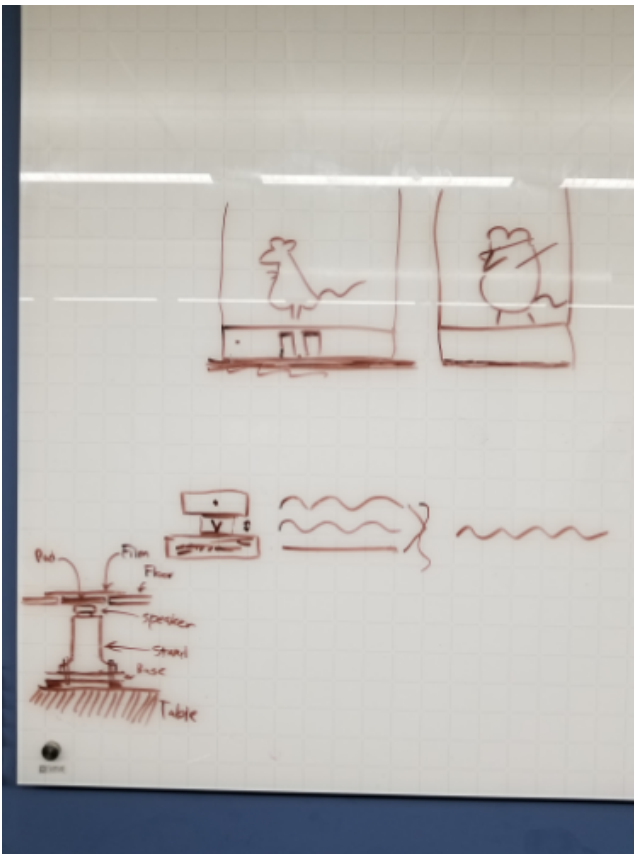
We decided to use a speaker to apply vibrations to the rat's feet. We need a way to couple the vibrations from the speaker to the rat's feet while preserving the signal from the speaker. This is my idea. There will be a stand that couples the speaker to the base of the cage:



**Figure 1:** The stand for the speaker. The speaker is attached to a stand which is attached to the base of the cage. There is a pad that is connected to the speaker which will transmit the vibrations to the rat's feet. There is a film that will prevent urine from leaking onto the speaker.

An important factor of this design is that the mass of the stand will be much larger than that of the pad and rat. This will prevent motion from the stand from interfering with the vibrations of the speaker. The stand will need to be tightly coupled to the base of the cage and the base of the cage itself will need to be flush with the table for this to work. A piece of rubber or foam may be needed to make the base of the cage flush with the table. This will make the effective mass of the stand to be infinite to the speaker.

Another image:



**Figure 2.** The full whiteboard. The squiggly lines indicate the vibrations that the rat will see when the mass of the stand is infinite. There will be a compartment below that cage which houses that stands and speaker. The rats in the cage are having a good time.

**Conclusions/action items:**

Design and fabricate the stands/cage. Take test the cage to make sure that the frequency is accurate.



## 2019/04/02: Outreach Activity Idea

• Steven Oakes • Apr 18, 2019 @07:06 PM CDT

### Title: Outreach Activity Idea

**Date:** Tuesday, April 2, 2019

**Content by:** Royal Oakes

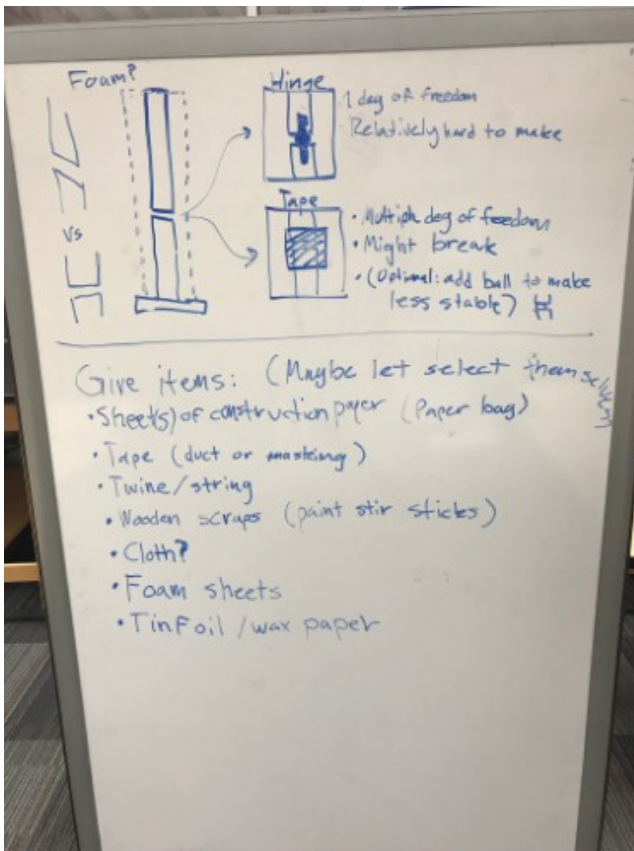
**Present:** N/A

**Goals:** Describe my idea for the outreach activity.

### Content:

Our team needs to do an outreach activity to graduate. This is my idea for an activity for kids to have fun.

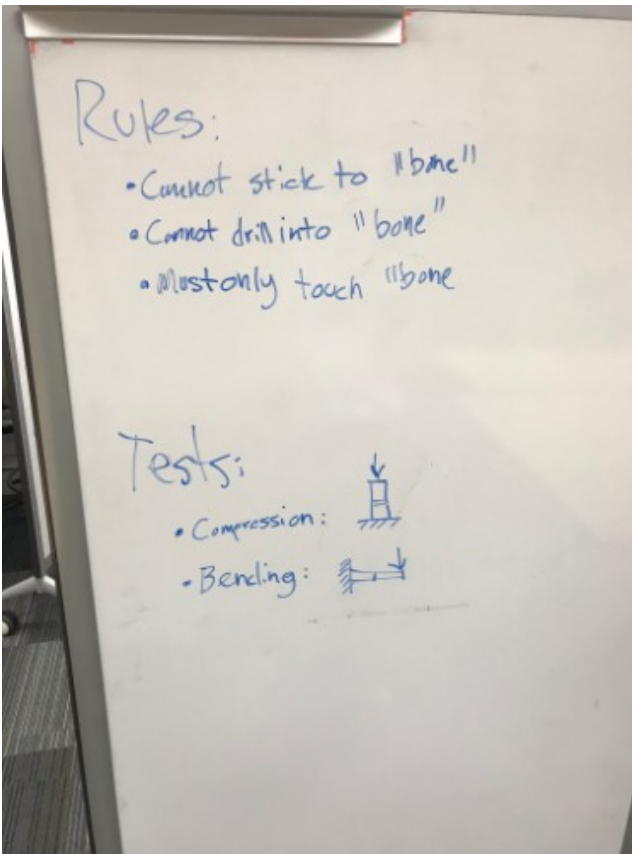
We will simulate a broken forearm and allow the participants to design a splint/cast to immobilize the fracture. The broken forearm will be modeled using two wooden sticks loosely attached to one another at the ends. See the top section of the image below. We could use a hinge, tape, or wrap the sticks in a layer of foam to attach the sticks. This would give the sticks some degree of freedom while not allowing them to separate completely.



The participants will be given (or allowed to select) several items to make their cast. See the bottom half of the above image. I believe that allowing the teams to select their items will be more engaging for the participants. The following items for the activity should be cheap and widely available:

- Construction paper (or paper bags)
- Tape (duct, masking, or scotch)
- Twine or string
- Wooden paint stirring sticks
- Cloth
- Foam sheets
- Tin foil
- Wax paper

Also participants should be allowed to use scissors.



There should be some rules to make testing easier and prevent the faux-forearm from being damaged. See the above image. Some potential rules are,

- No drilling into the forearm
- The splint must only touch the forearm

We can test the cast using a bending test where the forearm is attached cantilever-style and a load is applied to the free end. See the above image. We can measure displacement to determine which of the participants' designs is the best. We will not be using compression testing because bending testing is easier to measure and we will only have time to do one test. The best designs will be rewarded with candy or something else.

#### **Conclusions/action items:**

Order and prepare materials for the activity.

We ended up using this idea for the outreach activity. The participants enjoyed it.



**Title:** Vibration Research

**Date:** 9/18/18

**Content by:** Rick Guo

**Present:** Rick Guo

**Goals:** To find a proper frequency range to stimulate the rodents' hindlimbs

**Content:**

What I found is that vibrations on hindlimbs at 35 Hz(according to article 1 below) to 90 Hz(according to article 2 below) can do good to rats' intervertebral disk and strengthen their hindlimbs' muscle. Therefore, I believe vibrations at 35 to 90 Hz will be safe to use on rats. And also according to a article found by Stephan, vibrations with a frequency of 50 to 150 Hz can stimulate the rodents effectively.

Here are the articles:

Local vibration enhanced the efficacy of passive exercise on mitigating bone loss in hindlimb unloading rats.

<https://www-sciencedirect-com.ezproxy.library.wisc.edu/science/article/pii/S009457651630875X>

Low-intensity vibrations partially maintain intervertebral disc mechanics and spinal muscle area during deconditioning

<https://www-sciencedirect-com.ezproxy.library.wisc.edu/science/article/pii/S152994301300123X?via%3Dihu>

**Conclusions/action items:**

According to the research, a frequency ranges from 35 Hz to 93 Hz may be appropriate to stimulate the rodents without hurting them.





## Client meeting notes

---

• jinyuxuan guo • Oct 10, 2018 @03:50 PM CDT

**Title:** Client meeting notes

**Date:** 9/21/18

**Content by:** Rick Guo

**Present:** Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

**Goals:** Meet with clients to discuss project

**Content:**

The clients want a device that can hold one rodent and use vibration to stimulate one of its hindlimbs.

It should be:

Fit on a laboratory bench

Has controllable frequency

Stimulates only one leg

Does not injure rodents

Computer controlled

Hold one rodent at a time

Waterproof and easily sanitizable

**Conclusions/action items:**

Meet with client



## 2018/12/02 Research for Force testing

• jinyuxuan guo • Dec 04, 2018 @07:47 PM CST

**Title:** research for force testing

**Date:**12/2/1018

**Content by:** Jinyuxuan GUO

**Present:** Jinyuxaun GUO

**Goals:** To find out the force that our motor can generate

**Content:**

According to a tutor video found online,  $F = m r \omega$ , where  $F$  is force generated,  $m$  is the mass of the eccentric disk,  $r$  is the distance from the spinning rod to the center of mass of the eccentric disk and  $\omega$  is the angular velocity. From the data sheet of the motor, I got the diameter of the eccentric disk is 6mm and the motor is operating at 14000 RPM. Then, I weight the eccentric disk and it is 0.2 grams. See calculations below:

Force generated

$$F = m r \omega^2$$

$\omega = 2\pi \cdot \frac{\text{RPM}}{60}$   
 The distance from the spinning rod to the center of mass of the eccentric disk  
 The mass of the eccentric disk

---

$m = 0.2 \text{ g}$      $\text{RPM} = 14000 \Rightarrow \omega = 2\pi \cdot \frac{14000}{60} \approx 1466 \text{ rad/s}$

center of mass of a semicircle  
 $r = \frac{2d}{3\pi} = \frac{2 \cdot 6\text{mm}}{3\pi} = 1.273 \text{ mm}$

$F = 0.2 \times 10^{-3} \text{ kg} \cdot 1.273 \times 10^{-3} \text{ m} \cdot 1466 \text{ rad/s} = 3.73 \times 10^{-4} \text{ N}$

Link of the website: <https://www.precisionmicrodrives.com/vibration-motors/>

**Conclusions/action items:**

The result of force generated by the motor is  $3.73 \times 10^{-4} \text{ N}$ . Then, we can use this number to calculate the acceleration of whole device due to this force.



## 2018/12/4 Acceleration of the whole device

---

• jinyuxuan guo • Dec 04, 2018 @07:32 PM CST

**Title:** Acceleration of the whole device

**Date:** 12/4/2018

**Content by:** Jinyuxuan Guo

**Present:** Jinyuxuan Guo

**Goals:** To calculate the acceleration of the whole device due the force generated by the motor

**Content:**

Last time, the force generated by the motor is calculated and the result is  $3.73e-4$  N. According to Newton's Second Law of Motion,  $F = ma$ , the acceleration of the whole device can be calculate if the weight data of the whole device is obtained. The team weighted the two parts that make up the device, the motor and the pedal. The motor is 2.63 grams and the pedal is 14 grams, so the total weight of the device is 16.63 grams. Thus, the acceleration of the whole device is the force generated by the motor over the mass of the whole device, which is  $3.73e-4$  N /  $16.63e-3$  kg, and the results is  $0.02243$  m/s<sup>2</sup>. That is  $2.289e-3$  G.

**Conclusions/action items:**

**The acceleration of this device is  $2.289e-3$  G.**



## 2019/02/10 Alternative frequency-testing method

---

• jinyuxuan guo • Feb 10, 2019 @03:52 PM CST

**Title:** Alternative frequency-testing method

**Date:**2019/02/10

**Content by:** Jinyuxuan Guo

**Present:** Jinyuxuan Guo

**Goals:** To find an alternative frequency-testing method

**Content:**

Link: <https://simplemotor.com/motor-speed-measurement/>

In this website, the author give us a method to measure the frequency of a motor in Hz. There is a nice youtube video showing how to build this project. However, the limitation is that this method only works for ERM motors.

**Conclusions/action items:**

During the last group meeting, we used our accelerometer to test the frequency of the motors. However, we keep seeing the constant results no matter how we change the voltage. Thus, we would like to have an alternative frequency-testing method to compare with, in order to see the two results are similar or not.



## competing design research

---

• jinyuxuan guo • Oct 10, 2018 @03:46 PM CDT

**Title:** Competing design research

**Date:** 9/16/18

**Content by:** Rick Guo

**Present:** Rick Guo

**Goals:** To find out designs that compete with our project

**Content:**

There are different types of rodent cages in the market currently. Most of them are not be able to stimulate the rodents. Some of them that can stimulate the rodents mainly uses electric shots or heat. However, cages that can stimulate rodent limbs through vibrations, as required by the clients, are not found. Since the cage will have to fulfill the unique and specific needs of the clients' experiments, competition of this project is limited.

**Conclusions/action items:** Very Limited competing designs(especially using vibrations to stimulate the rodents)



## Micro cell phone vibration motor

• jinyuxuan guo • Oct 10, 2018 @03:35 PM CDT

**Title:** Micro cell phone vibration motor

**Date:** 9/27/18

**Content by:** Rick Guo

**Present:** Rick Guo

**Goals:** To come up with a design idea

**Content:**

Cell Phone Micro Vibration Motor.

Retrieved from: [https://www.amazon.com/uxcell-9000RPM-Yellow-Micro-Vibration/dp/B016VQSZ7Q/ref=pd\\_sbs\\_60\\_4?\\_encoding=UTF8&pd\\_rd\\_i=B072L7SRRS&pd\\_rd\\_r=8a9f34bd-c676-11e8-ac03-51a7059c8938&pd\\_rd\\_w=XL7Ej&pd\\_rd\\_wg=DZII7&pf\\_rd\\_i=desktop-dp-sims&pf\\_rd\\_m=ATVPDKIKX0DER&pf\\_rd\\_p=53dead45-2b3d-4b73-bafb-fe26a7f14aac&pf\\_rd\\_r=PKTM989KJF13PWXBNRDW&pf\\_rd\\_s=desktop-dp-sims&pf\\_rd\\_t=40701&refRID=PKTM989KJF13PWXBNRDW&th=1](https://www.amazon.com/uxcell-9000RPM-Yellow-Micro-Vibration/dp/B016VQSZ7Q/ref=pd_sbs_60_4?_encoding=UTF8&pd_rd_i=B072L7SRRS&pd_rd_r=8a9f34bd-c676-11e8-ac03-51a7059c8938&pd_rd_w=XL7Ej&pd_rd_wg=DZII7&pf_rd_i=desktop-dp-sims&pf_rd_m=ATVPDKIKX0DER&pf_rd_p=53dead45-2b3d-4b73-bafb-fe26a7f14aac&pf_rd_r=PKTM989KJF13PWXBNRDW&pf_rd_s=desktop-dp-sims&pf_rd_t=40701&refRID=PKTM989KJF13PWXBNRDW&th=1)

1. Produces a vibration through the spin of a head with unbalanced weight
2. Can only work with fixed frequency, 3 motors are needed to control frequency(53Hz 86Hz 150Hz).
3. Cheap, about 1.2 dollars each

**Conclusions/action items:**

one possible way to develop a vibrational platform using this motor



# 11/27/2018 Arduino code design to get fft from accelerometer

- Stephan Blanz - Dec 12, 2018 @01:29 PM CST

Title:

Date: 11/27/2018

Content by: Jinyuxuan Guo

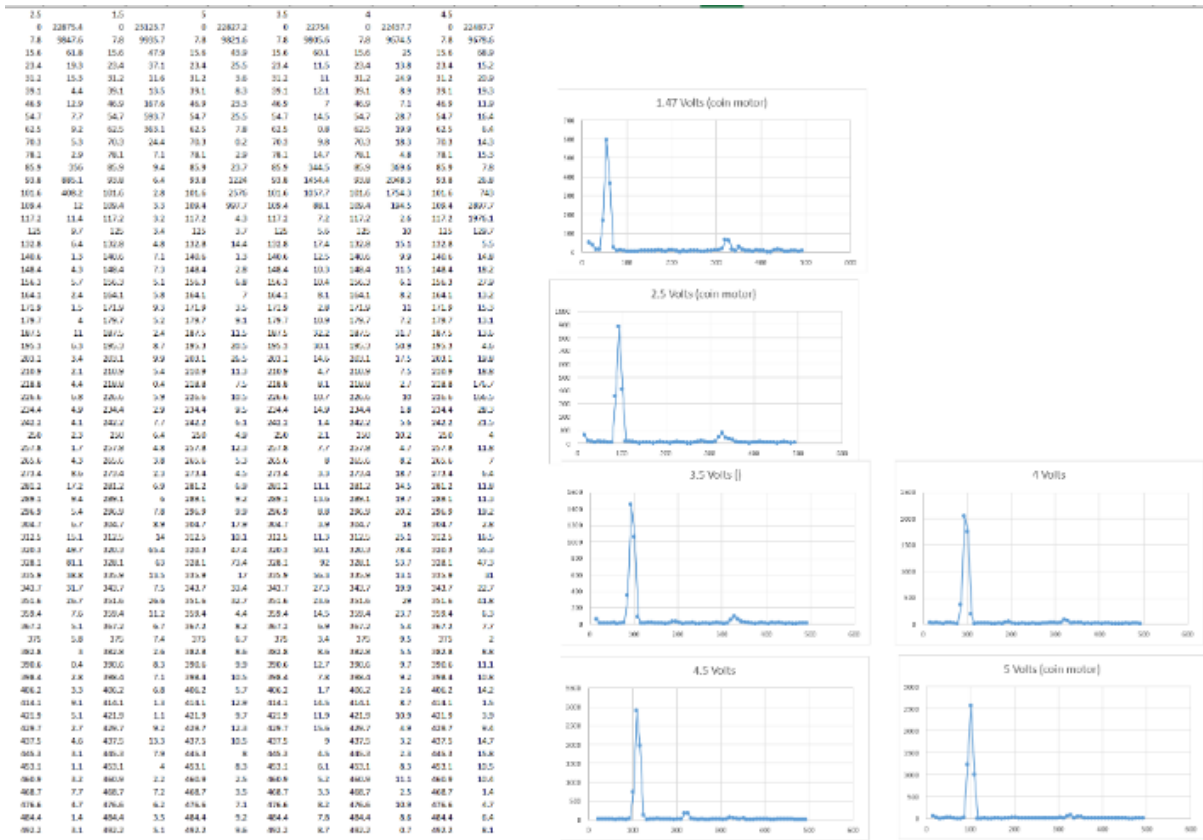
Present: Jinyuxuan Guo, Stephan Blanz

Goals: Design a code that can give us the frequency that the motor is vibrating at

Content:

I did some research on how to use arduino to give us fft under the help of a accelerometer. I used a code template from the arduino library and modify the parameters of the code. Basically, what it will do is that, it can give us a high magnitude at the frequency that the motor is working at. Using this code, we are able to test the motors with different voltages to see the the motor's performance under various conditions.

Conclusions/action items:



I put the raw data in excel to see the dominant frequency. The results are 50 Hz at 1.5 V, 90 Hz at 2.5 V, 100 Hz at 3.5 V and 110 Hz at 4.5 V.

- jinyuxuan guo - Dec 11, 2018 @08:24 PM CST



## 03/19/2019 Speaker broken

---

• jinyuxuan guo • Mar 29, 2019 @01:15 PM CDT

**Title:** Speaker broken

**Date:** 03/29/2019

**Content by:** Jinyuxuan Guo

**Present:** Stephan, Royal and Rick

**Goals:** None

**Content:**

The speaker is broken during the show and tell.

It broke at conditions below:

Frequency: 200Hz

GUI amplitude: 5

Computer volume: 50

**Conclusions/action items:**

The speak broke at this condition. Avoid reaching these again.





## 04/09/2019 Recording videos for displacement test

---

• jinyuxuan guo • Apr 30, 2019 @10:43 PM CDT

**Title:** Recording videos for displacement test

**Date:** 04/09/20149

**Content by:** JInyuxuan Guo

**Present:** Jinyuxuan & John

**Goals:** To record all the videos for displacement test.

**Content:**

Last semester when we were working with motors, we found that the amplitude will increase as the frequency goes up. This time we work with transducers. We need to verify that there no correlation between amplitude and frequency when we use the transducers to generate the vibration. Our place is record videos of a running transducer at different amplitude and frequency. Analyze each video using a software call ImageJ(It can give us the displacement of the transducer by counting pixels). Today, my job is to record all the videos.

The test is setup as such: A thin white plate was placed on top of the transducer to provide contrast with a dark background. A ruler was placed next to the transducer to provide a reference. A camera was used to take a 32 to 36 second video of the transducer while it was producing vibrations.

We took 3 videos per trial, at amplitude of 0.1, 0.2 and frequencies at 25, 50, 75, 100, 125, 150, 175 and 200 Hz. There were 48 videos in total. I used an Iphone X as the camera and took all the videos in slow motion mood. They are all stored in my phone and they will be uploaded to our googledive later

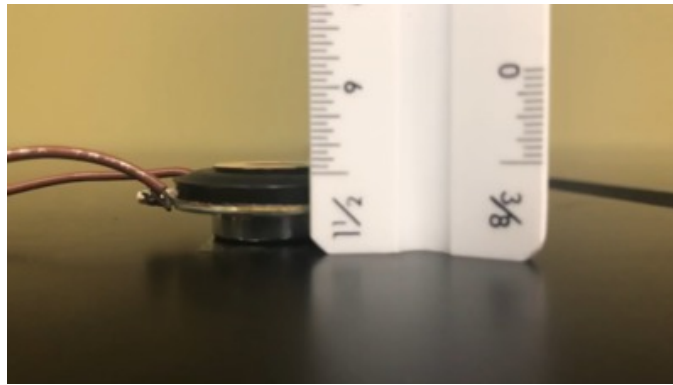
**Conclusions/action items:**

**All the videos are ready for analysis. This test will give us insight on the relationship between amplitude and frequency of our transducer.**



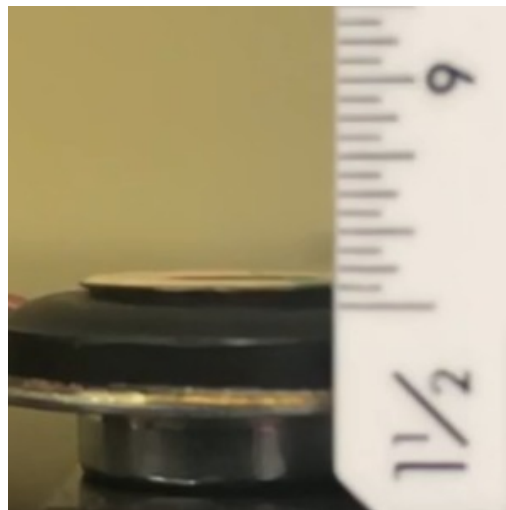
## 4/17/2019 Data analysis of speaker displacement

- jinyuxuan guo • Apr 17, 2019 @03:34 AM CDT



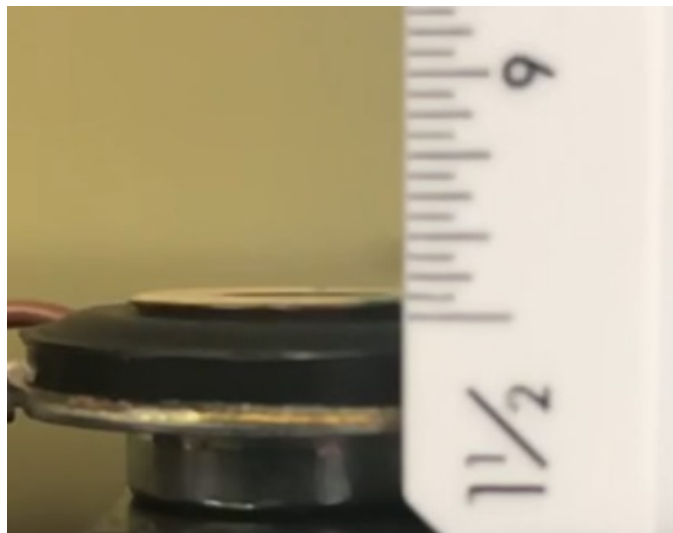
**50\_0.1\_MIN.PNG(307.7 KB)** - [download](#) This is the data analysis of speaker displacement when it is working. The images are the max and min position of the speaker captured from the testing video. The txt file is the result.

- jinyuxuan guo • Apr 17, 2019 @03:34 AM CDT



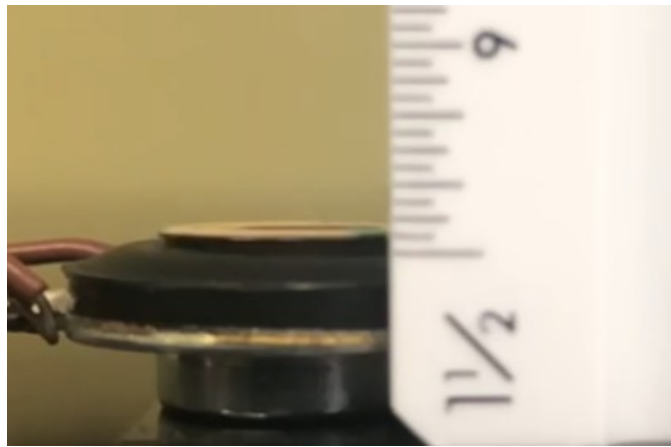
**50\_0.2\_max.PNG(116.1 KB)** - [download](#) This is the data analysis of speaker displacement when it is working. The images are the max and min position of the speaker captured from the testing video. The txt file is the result.

- jinyuxuan guo • Apr 17, 2019 @03:34 AM CDT



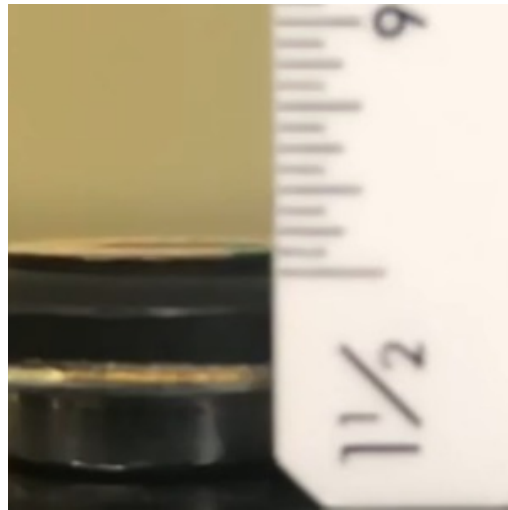
**50\_0.2\_min.PNG(130 KB)** - [download](#) This is the data analysis of speaker displacement when it is working. The images are the max and min position of the speaker captured from the testing video. The txt file is the result.

• jinyuxuan guo • Apr 17, 2019 @03:34 AM CDT



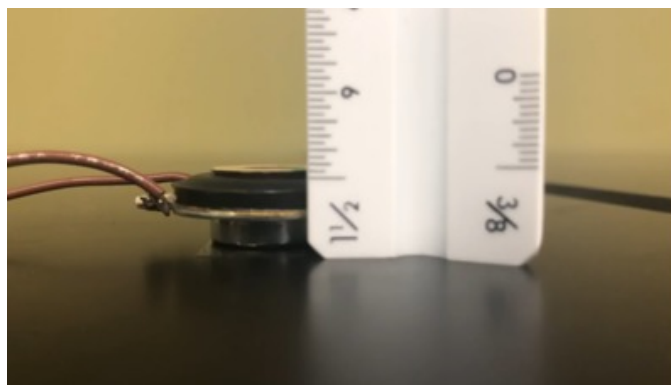
**100\_0.1\_max.PNG(102.4 KB)** - [download](#) This is the data analysis of speaker displacement when it is working. The images are the max and min position of the speaker captured from the testing video. The txt file is the result.

• jinyuxuan guo • Apr 17, 2019 @03:34 AM CDT



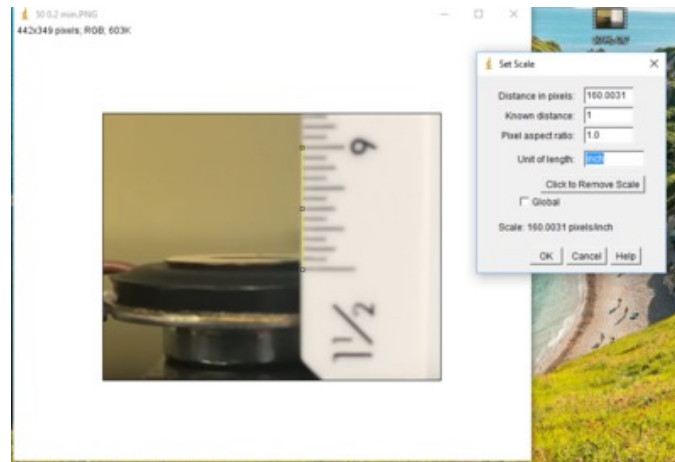
**100\_0.1\_min.PNG(89.9 KB)** - [download](#) This is the data analysis of speaker displacement when it is working. The images are the max and min position of the speaker captured from the testing video. The txt file is the result.

• jinyuxuan guo • Apr 17, 2019 @03:34 AM CDT



**50\_0.1\_MAX.PNG(305.2 KB)** - [download](#) This is the data analysis of speaker displacement when it is working. The images are the max and min position of the speaker captured from the testing video. The txt file is the result.

• jinyuxuan guo • Apr 17, 2019 @03:34 AM CDT



**Capture.PNG(390.5 KB) - download** This is the data analysis of speaker displacement when it is working. The images are the max and min position of the speaker captured from the testing video. The txt file is the result.

• jinyuxuan guo • Apr 17, 2019 @03:34 AM CDT

```

S0 0.1
Min: 42.2%
Max: 44.7%
Diff: 2.4%

S0 0.2
Min: 42.2%
Max: 46.2%
Diff: 3.7%

I00 0.1
Min: 41.4%
Max: 43.2%
Diff: 1.8%
  
```

**Rick.txt(126 Bytes) - download** This is the data analysis of speaker displacement when it is working. The images are the max and min position of the speaker captured from the testing video. The txt file is the result.



# 04/23/2019 Chi-square test on the results of displacement test.

• jinyuxuan guo • Apr 28, 2019 @10:29 AM CDT

**Title:** Chi-square test on the results of displacement test.

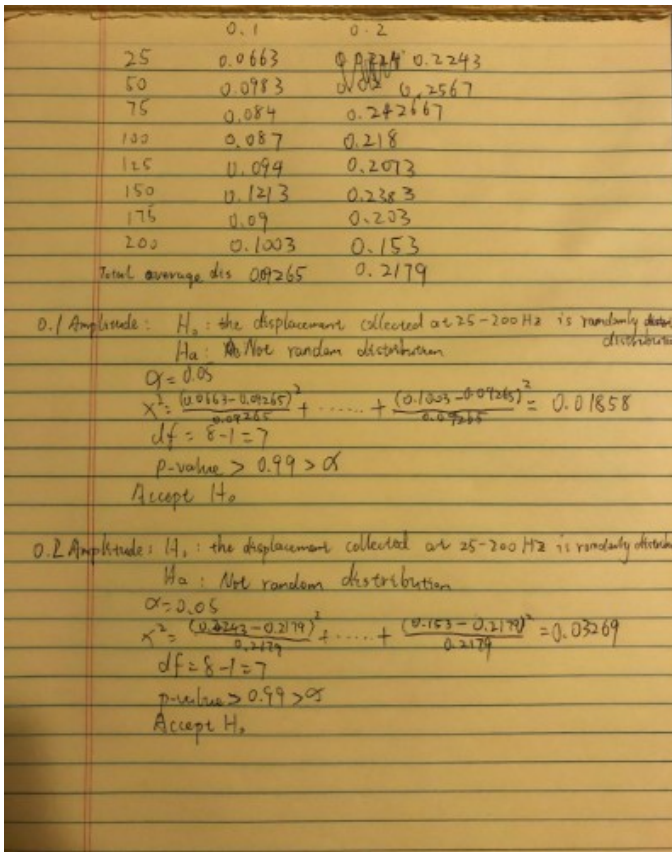
**Date:** 04/23/2019

**Content by:** Jinyuxuan Guo

**Present:** Jinyuxuan

**Goals:** To find out the relationship between frequency and amplitude

**Content:**



**Conclusions/action items:**

To find out the relationship between frequency and amplitude, two Chi-square test is conducted on the results at 0.1 and 0.2 amplitude of the displacement test. The vertical displacement at an amplitude of 0.1 and 0.2 was computed at frequencies between 25 Hz and 200 Hz at 25 Hz intervals (n=3 for each trial). There is no statistically significant difference in displacement between frequencies at 0.1 amplitude,  $\chi^2(7, N = 24) = 0.01858, p > 0.99$ , or at 0.2 amplitude,  $\chi^2(7, N = 24) = 0.03269, p > 0.99$ . However, there is a statistical significance between the 0.1 and 0.2 amplitude samples ( $p < 0.0001$ ). Error bars represent  $\pm 1$  SE.



## 04/24/2019 MATLAB GUI code finished

---

• jinyuxuan guo • Apr 28, 2019 @12:11 PM CDT

**Title:** MATLAB GUI code finished

**Date:** 03/14 - 04/24

**Content by:** Jinyuxuan Guo

**Present:** Jinyuxuan Guo

**Goals:** To create an user friendly software that can control the parameters of the vibration

**Content:**

According to the requirement by our clients, they would like to have a software that can control the vibration easily through a pc. After discussion with the team, this task is assigned to me and I

**Conclusions/action items:**



## 2014/11/03-Entry guidelines

---

• John Puccinelli • Sep 05, 2016 @01:18 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.



**Title:**

**Date:**

**Content by:**

**Present:**

**Goals:**

**Content:**

**Conclusions/action items:**





## Team contact Information

• Stephan Blanz • Oct 10, 2018 @11:33 AM CDT

Last Name	First Name	Role	E-mail
Rogers	Jeremey	Advisor	jeremy.rogers@wisc.edu
Dingle	Aaron	Client	dingle@surgery.wisc.edu
Blanz	Stephan	Leader	blanz@wisc.edu
John	Beckman	Communicator	jbeckman3@wisc.edu
Oakes	Royal	BSAC /BWIG	soakes@wisc.edu
Guo	Rick	BPAG	jguo77@wisc.edu



## Project description

---

• Stephan Blanz • Oct 09, 2018 @10:35 PM CDT

**Course Number:**

BME 400

**Project Name:**

Somatosensory stimulation apparatus for rodent cages

**Short Name:**

Hindlimb Stimulator

**Project description/problem statement:**

Peripheral nerve injuries are common, debilitating and costly. Approximately 2.8%-5% of all trauma patients in the US sustain such an injury with nearly 100,000 peripheral nerve repairs being performed annually costing approximately 150 billion dollars. The most important clinical outcome following nerve repair, is functional ability, and despite advances in microsurgical technique, poor functional outcomes are frequent. Unfortunately, the cause for outcome variability is unknown and functional outcome is difficult to assess and measure experimentally.

The goal of this project is to design and validate an experimental apparatus that can provide somatosensory stimulation (i.e. vibration) to the hindlimb of a rodent would greatly improve the ability to assess nerve regeneration in rats for a wide range of studies- including but not restricted to, surgical repair methods, tissue engineering and neural interfacing.

**About the client:**

Dr. Aaron Suminski is a scientist with the University of Wisconsin, Department of Biomedical Engineering. He collaborates with Dr. Aaron Dingle, a post-doctoral researcher, with the University of Wisconsin, Department of Surgery, Poore lab. The Poore lab's research focus is clinical and experimental microsurgery, with an emphasis on peripheral nerve regeneration and repair. Together they are researching the effectiveness of various treatments and methods of nerve repair.



## 2018/09/21-Client Meeting

• Stephan Blanz • Oct 09, 2018 @10:41 PM CDT

**Title:** Advisor Meeting Notes

**Date:** 9/21/18

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, Royal Oaks, Rick Guo

**Goals:** Initial Meeting with client. Determine immediate priorities and set expectations

**Content:**

Injured nerves leads to a level of disability.

Rodents have historically been a model for nerve repair.

Vibrational stimulation of varying magnitudes

Old design: 3 nose poke holes (yes, no, maybe; left, right, don't know)

Design -> cause injury to nerve, test progress of rehabilitation

Next step: implant electrodes that replace function (artificial signal in nerve through electrode)

Look into foot physiology for sense

Independently vibrate two feet. Isolate to only feet, not other parts of the body.

Be able to get into device by themselves. (can put whatever in device to fix them in desired position)

Two alternative forced choice experiment

Come up with repeatable, reliable computer stimulation

Interface needs to be on a computer (think about TTL input)

Cleaning think bleach safe.

**Conclusions/action items:**

- Research rodent hindlimb anatomy to determine which **vibrations** it is sensitive to
- When frequencies have been determined, ensure that the product can be **user controlled** over the range of frequencies



## 2018/09/14-Advisor Meeting Notes

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• Stephan Blanz • Sep 21, 2018 @01:52 PM CDT

**Title:** Advisor Meeting Notes

**Date:** 9/14/18

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

**Goals:** Meet with advisor to discuss progress

**Content:**

In **progress reports**, highlight pertinent changes.

Have prepared agenda for **client meeting**. Think: design specifications, quantitative metrics, IP concerns. Do background research on relevant literature and existing devices. Brainstorm on how to solve the problem. Think about emailing agenda to the client.

**Conclusions/action items:**

Meet with client



## 2018/09/21-Advisor Meeting Notes

---

• Stephan Blanz • Sep 21, 2018 @01:54 PM CDT

**Title:** Advisor Meeting Notes

**Date:** 9/14/18

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

**Goals:** Meet with advisor to discuss progress

**Content:**

Update website with group picture, progress reports and deliverables as required.

On progress reports if there is not much change, highlight it. Put important info in an email as well.

Progress report should show a trajectory of progress. Both where you are and where you plan on going.

Use as a tool to schedule. Set overall deadlines and then work your way back to where you are to establish schedules.

Ask if the vibrations from limb could be felt elsewhere in the body at certain points during client meeting – would this influence design specifications.

Think about which stimuli we would like to use on rodent.

Continuous stimulation vs tap for stimulation.

Could we use cold to stimulate?

**Conclusions/action items:**

Meet with client and develop PDS.



## 2018/09/28-Advisor Meeting Notes

---

• Stephan Blanz • Oct 09, 2018 @10:45 PM CDT

**Title:** Advisor Meeting Notes

**Date:** 9/28/18

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

**Goals:** Meet with advisor to discuss progress

**Content:**

Advisor agrees with defining short term goal of vibrational stimulation. Plan to find several commercially available devices that can achieve this and use these for a design matrix. Use pictures in design matrix.

**Conclusions/action items:**

- Determine range of vibrations
- Find suitable commercial product that an end-user can manipulate the output within the prescribed range



## 2018/10/12-Advisor Meeting

---

• Stephan Blanz • Dec 12, 2018 @01:22 PM CST

**Title:** Advisor Meeting Notes

**Date:** 10/12/18

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

**Goals:** Meet with advisor to discuss progress

**Content:**

### Advisor Meeting 10/12/18

Feedback for improvement on presentation:

- Practice with clicker beforehand. Practice how to recover if something happens
- Practice the presentation as a team. Makes the individual portion as well as the transition go smoother. Also verify all props are in place at the beginning.
- Take out overview slide
- Make a point to introduce client, and client's background and why propose product
- Be more specific and **highlight and emphasize** key points in talk, ie. Cell phone vibrator would need three different motors. Member's of audience didn't understand differences. Or methods of stimulation.
- Try to anticipate audience and where gaps between presentation and audience knowledge would exist, and fill those gaps in early in presentation
- Engage the audience. Be enthusiastic. Smile! Fake it until you make it.

Comments on project moving forward:

- Identify which components of the project require precision. Amplitude, vibration?
- Isolate vibration. Figure out best method for doing so.
- Think about cuffs to vibrate. That way you could have independent vibration and rodents could be independently moving. Think about piezo buzzers.

### Conclusions/action items:

- Take feedback on presentation and ensure future success



## 2018/10/19-Advisor Meeting Notes

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• Stephan Blanz • Dec 12, 2018 @01:24 PM CST

**Title:** Advisor Meeting Notes

**Date:** 10/12/18

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

**Goals:** Meet with advisor to discuss progress

**Content:**

### **Advisor Meeting 10/19/18**

Look into piezo with leads coming off. Might be able to find one with leads coming off it.

Downside of piezo: they are voltage driven, require high voltage.

Thor labs has very small piezo speakers.

Also, voice coils might be viable options. Bottom line, there are small things that can work with a cuff.

Recommend getting a set of cheap earbuds and seeing if they produce an amplitude high enough to feel (voice coil).

For Arduino, look at implantable light transceiver.

### **Conclusions/action items:**

- Explore piezo as vibrational motor





## 2018/10/26-Advisor Meeting Notes

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• Stephan Blanz • Dec 12, 2018 @01:26 PM CST

**Title:** Advisor Meeting Notes

**Date:** 10/12/18

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

**Goals:** Meet with advisor to discuss progress

**Content:**

### **Advisor Meeting 10/26/18**

Voice Coil: Still needs to be researched more. Play with amplitude (volume) and frequency. It is possible to make an audio file that will do this.

Is it possible to break apart a headset and preserve voice coil?

Client: Keep client updated on progress and the investigation of various methods.

Design / Fabricate Platform should be the next step. Can order motors from amazon and start testing platform design.

Think about materials and mill a component with those materials.

Be sure to attend show and tell and Tong lecture in upcoming weeks.

**Conclusions/action items:**

- Consider Milling a platform



## 2018/11/02-Advisor Meeting Notes

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• Stephan Blanz • Dec 12, 2018 @01:28 PM CST

**Title:** Advisor Meeting Notes

**Date:** 10/12/18

**Content by:** Stephan Blanz

**Present:** Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

**Goals:** Meet with advisor to discuss progress

**Content:**

### **Advisor Meeting Notes 11/2/18**

Think about testing. There will be a lot of variables to test. Break problem down to testing the device in various ways vs testing with rat. Collect data on subcomponents: amplitude of vibration, frequency of vibration, energy input, energy output. Ultimately you want to stimulate. Be able to report data on stimulation parameters (amplitude and frequency).

Apply design principles: mass that is off-centered by a certain amount, what kind of energy would get out? Energy in vs energy out? How is it coupling to rat? Inertia transfer to platform. How much are you coupling into rat's foot.

### **Comments on Notebook**

Make sure to document work you're doing. Put in entries as you're doing.

### **Comments on Report**

Ensure all team members read entire notebook. Can use track changes to edit sections other than own.

Try to use the same voice throughout paper.

Background section: relevant physiology and biology.

Could use short introductory paragraph talking about relevant pieces of information. Bridge in between that talks about link between two needs to be evaluated.

Beef up sections in include more detail on everything.

Be sure to relate pictures (CAD drawing of cam) to what it does and how it does it.

Keep in mind for figures and captions that they should be able to stand alone against the paper.

References should mostly be journals and scientific articles.

Next Meeting Times: Monday morning, or between 3 and 5. Tuesday before 11 and Wednesday Afternoon.

Thanksgiving week: Monday other than noon.

### **Conclusions/action items:**

- Try to bridge relevant pieces of the paper to show relevance / importance in a unifying context



## 2018/10/4-Design Matrix

• Stephan Blanz • Oct 10, 2018 @12:16 AM CDT

**Title:** Design Matrix Creation

**Date:** 10/4/18

**Content by:** Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

**Present:** Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

**Goals:** Create Design Matrix Criteria

**Content:**

Each motor was rated according to the following criteria (weights in parentheses):

**Segregation of Stimulation (25):** The degree to which the vibrational stimulation is localized to one hindlimb of the rat. A score of 5 would imply that any vibration applied to one hind-leg platform would be undetectable in the other hind-leg platform. A score of 3 would imply that when vibration is applied to one hind-leg platform there is a measurable vibration in the other hind-leg platform between 0 and 0.1 times the amplitude of the applied vibration. A score of 1 would imply that when a vibration is applied at one hind-leg platform there is a measurable vibration at the other hind-leg platform between 0.5 and 1 times the applied vibration.

**Frequency Range (20):** How closely the vibration range of the motor matches the desired vibration range. A score of 5 would imply that the motor has a range larger than but including 70 Hz to 100 Hz. A score of 3 would imply that the motor has a range of 70 Hz to 100 Hz but has limited resolution within this range. A score of 1 would imply the motor does not produce vibrations within the 70 Hz to 100 Hz range.

**Ease of Integration (15):** The ease of creating an interface between the motor and the rat. A score of 5 would imply that the interface could be designed within two weeks. A score of 3 would imply the interface could be designed within a month. A score of 1 would imply that it would take more than one month to design the interface.

**Size (15):** The design must be able to fit on a laboratory bench and hold one adult rat. The cage has a minimum size of 30 cm × 30 cm × 60 cm. A score of 5 would imply the motor could be used with a cage of dimensions 30 cm × 30 cm × 60 cm. A score of 3 would imply the motor could be used with a cage of dimensions 35 cm × 35 cm × 60 cm. A score of 1 would imply the motor requires a cage larger than 40 cm × 40 cm × 60 cm.

**Ease of Achieving Desired Effect (5):** The ease of controlling the motor. We will need to create code that will manipulate the motor. A score of 5 would imply that there is a sufficient amount of documentation on how to control the motor. A score of 3 would imply that there is some documentation on how to control the motor. A score of 1 would imply that there is little to no documentation on how to control the motor.

**Safety (5):** The safety of the design. The design should not harm or cause discomfort for the user or rat. A score of 5 would imply that there is little to no chance that the rat or user will be harmed. A score of 3 would imply that there is some chance that the rat or user will be harmed. A score of 1 would imply that there is a high likelihood that the rat or user will be harmed.

Criteria	(Weight)	Linear Actuator		Micro Vibration Motor		Precision Vibration Motor	
		Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Segregation of stimulation	25	5/5	25	4/5	20	4/5	20
Frequency range	20	3/5	12	3/5	12	5/5	20
Ease of integration	15	3/5	9	2/5	6	3/5	9
Size	15	3/5	9	4/5	12	5/5	15
Ease of achieving desired effect	5	5/5	5	3/5	3	4/5	4
Cost	5	3/5	3	5/5	5	4/5	4
<b>Total</b>	<b>85</b>		<b>63</b>		<b>58</b>		<b>72</b>

**Conclusions/action items:**

- Precision Vibration Motor wins



## 2018/12/02: Motor Testing

• Steven Oakes • Dec 12, 2018 @10:41 AM CST

### Title: Motor Testing

Date: 12/2/2018

Content by: Royal Oakes

Present: Stephan Blanz, John Beckman, Rick Guo

Goals: Describe the testing procedure for the motors.

### Content:

An experiment was conducted to determine the response of the linear resonant actuator (LRA) motor and eccentric rotating mass (ERM) motor under different conditions. Each of the two motors were placed into three different positions with an accelerometer (Figure 1). The direct placement configuration was used to determine the motor's response to different voltages, since there may be discrepancies in actual performance from the datasheet. The dampened configuration was used to determine what the rodent might perceive from the leg being stimulated by the motor during use of the cage. The off-target configuration was used to determine what the rodent might perceive from the leg not being stimulated during use of the cage.

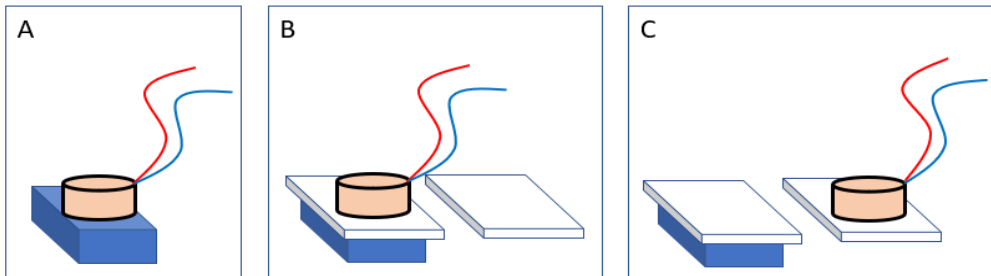


Figure 1. The configurations of the accelerometer (blue) and the motor (beige) used in our experiment. (A) The direct placement configuration. (B) The dampened configuration. There is a foam pad (white) separating the accelerometer and the motor. (C) The off-target stimulation configuration. The motor is placed on the adjacent foam pad to the accelerometer.

In each configuration, a motor was vibrated at various voltages. The voltages tested in each motor spanned the range specified in the motor's datasheet at 0.5 V increments. Each motor was powered using a PWM signal with a max voltage of 5 V. Thus, a 2.5 V signal in this experiment corresponds to a duty cycle of 50% and a 3.5 V signal corresponds to a 70% duty cycle

Data was collected from the accelerometer using an Arduino UNO and was sent to MATLAB for processing as described in Royal Oakes' design ideas. First, the motor was powered and 128 samples of the acceleration vector were collected from the accelerometer at 1 kHz. This number of samples was chosen due to memory limitations of the Arduino UNO. Second, the data was imported to MATLAB. Third, the magnitude of the acceleration vector was computed. Fourth, the Fourier transform of the accelerometer magnitude was computed using the MATLAB fast Fourier transform [1]. This method was used rather than sending the data one sample at a time because literature suggests that our method leads to more accurate data [2].

[1] "Fast Fourier transform - MATLAB fft." [Online]. Available: <https://www.mathworks.com/help/matlab/ref/fft.html>. [Accessed: 12-Dec-2018].

[2] A. Hjort, M. Holmberg, V. Ziemann, and K. Gajewski, "Measuring mechanical vibrations using an Arduino as a slave I/O to an EPICS control system," 2015.

### Conclusions/action items:

Complete the testing of the motors and record their data.

Finish the report and final presentation.



## 2018/12/02: Motor Testing Raw Data

• Steven Oakes • Dec 12, 2018 @10:50 AM CST

### Title: Motor Testing Raw Data

**Date:** 12/2/2018

**Content by:** Royal Oakes

**Present:** N/A

**Goals:** Present the Raw Data from the Motor Testing

### Content:

The legend for the raw data is presented below. The data was collected as described in the Motor Testing Protocol page. The coin motor is the linear resonant actuator (LRA) motor and the cylindrical motor is the eccentric rotating mass (ERM) motor.

=== Definitions ===

<type> is the measured value from the accelerometer:

- "mag" is the magnitude of the acceleration vector.

- "xData" is the acceleration along the x axis of the accelerometer.

<value> is the pwm voltage applied to the motor. The voltage can be solved for by  $\text{voltage} = (\text{value}/255) * 5$ .

=== Legend ===

<type>\_<value> -> The direct placement of the coin motor on the accelerometer.

noise\_<type>\_<value> -> The cylindrical motor on a different pad in rodent cage.

noise1\_<type>\_<value> -> The cylindrical motor on the same pad in rodent cage.

coin\_direct\_<type>\_<value> -> The coin motor on the same pad in the rodent cage.

coin\_noise\_<type>\_<value> -> The coin motor on a different pad in the rodent cage.

cyl\_dir\_<type>\_<value> -> The cylindrical motor directly on the accelerometer.

### Conclusions/action items:

None.

• Steven Oakes • Dec 12, 2018 @10:46 AM CST



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## 2018/09/07-Sense Feeling

• Stephan Blanz • Oct 09, 2018 @10:55 PM CDT

**Title:** Research Notes on Sensory Cells

**Date:** 9/7/18

**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Determine the effects various cells have on "feeling"

**Content:**

**How do we sense feeling?**

The [tactile corpuscles](#) (also known as Meissner corpuscles) respond to light touch, and adapt rapidly to changes in texture (vibrations around 50 Hz).

The [bulbous corpuscles](#) (also known as Ruffini endings) detect tension deep in the skin and [fascia](#).

The [Merkel nerve endings](#) (also known as Merkel discs) detect sustained pressure.

The [lamellar corpuscles](#) (also known as Pacinian corpuscles) in the skin and fascia detect rapid vibrations (of about 200–300 Hz).

- The **Rapidly Adapting (RA) or [Meissner corpuscle end-organ mechanoreceptor](#)** underlies the perception of flutter<sup>[6]</sup> and slip on the skin.<sup>[7]</sup> They have small receptive fields and produce transient responses to the onset and offset of stimulation.
- The **[Pacinian corpuscle or Vater-Pacinian corpuscles or Lamellar corpuscles](#)**<sup>[8]</sup> underlie the perception of high frequency vibration.<sup>[6][9]</sup> They also produce transient responses, but have large receptive fields.

**Conclusions/action items:**

- Two frequency ranges: ~ 50Hz and 200 - 300 Hz
- Document contains hyperlinks in case I need a refresher



## 2018/09/28-Hindlimb Stimulation methods

• Stephan Blanz • Oct 09, 2018 @10:53 PM CDT

**Title:** Research Notes on Techniques Currently Used to Stimulate Rodents

**Date:** 9/28/18

**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Determine what is currently being used to stimulate rodents

**Content:**

### Hindlimb stimulation

via 50 ms air-puff [1]

thin acupuncture needles (0.14 mm) were inserted into the paws and a 0.2–1 mA, 1 ms electrical pulse was delivered [2]

10-150 Hz [3]

g.USBamp (g.tec) and the coin motor (YBI027,  $\Phi=10$  mm, YB motors, Republic of Korea) for stimulation system is operated through NI cDAQ operation of the vibration motor is managed by Data Acquisition Toolbox (MathWork, U.S.A.) 4 second stimulation in anesthetized mice [4]

Typically, the sensation of warm is elicited at temperatures of 34–37°C, while the sensation of pain is elicited at temperatures of 42–48°C [5]

The sensation of pleasant or innocuous cooling is typically elicited at temperatures of ~23–29°C, while the sensation of cold pain is significantly variable, with multimodal distribution of the cold pain threshold recently reported, corresponding to modal threshold temperatures of 23.7°C, 13.2°C and 1.5°C, respectively [5]

[1] M. Murayama and M. E. Larkum, "Enhanced dendritic activity in awake rats.," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 106, no. 48, pp. 20482–6, Dec. 2009.

[2] M. H. Mohajerani *et al.*, "Spontaneous cortical activity alternates between motifs defined by regional axonal projections.," *Nat. Neurosci.*, vol. 16, no. 10, pp. 1426–35, Oct. 2013.

[3] J. H. Edwards and G. C. Reilly, "Vibration stimuli and the differentiation of musculoskeletal progenitor cells: Review of results in vitro and in vivo.," *World J. Stem Cells*, vol. 7, no. 3, pp. 568–82, Apr. 2015.

[4] C. Yeon, D. Kim, K. Kim, and E. Chung, "Sensory-evoked potential using a non-invasive flexible multi-channel dry EEG electrode with vibration motor stimulation," in *IEEE SENSORS 2014 Proceedings*, 2014, pp. 519–522.

[5] J. R. Deuis, L. S. Dvorakova, and I. Vetter, "Methods Used to Evaluate Pain Behaviors in Rodents.," *Front. Mol. Neurosci.*, vol. 10, p. 284, 2017.

### Conclusions/action items:

- Using Vibration: 10-150 Hz
- Refer back to this in case we decide to stimulate using other methods





## 2018/10/04-Touch Screen

• Stephan Blanz • Oct 09, 2018 @11:32 PM CDT

**Title:** Touch Screen Chamber

**Date:** 10/4/18

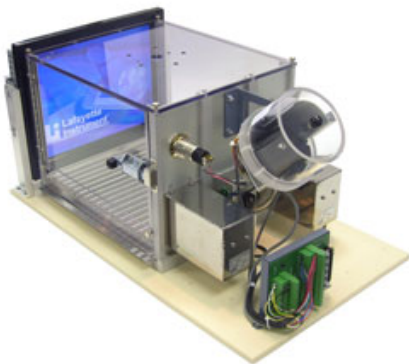
**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Competition Research

**Content:**

Lafayette instruments provides various rodent enclosures for use in training. They have one in particular where the rat can be trained to touch a "touch screen." However, they have no product that stimulates hindlimbs.



Link: <http://lafayetteneuroscience.com/products/rat-touch-screen-chamber>

**Conclusions/action items:**

- We have a novel item.
- We might be able to incorporate an existing product for additional features



## 2018/11/22-Vibration Mechanics in Various Motors

• Stephan Blanz • Dec 12, 2018 @12:47 PM CST

**Title:** Vibration Mechanics in Various Motors

**Date:** 11/22/18

**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Vibration Calculations and Determining Best Fit for Project

**Content:**

Three motors are commonly used to create vibration.

**LRA** (Linear resonant actuator): Have a more narrow frequency range. Amplitude is somewhat variable [1]. The page shows how to calculate amplitude based on mass.

**ERM** (Eccentric rotating mass): Have a wider frequency range. However, amplitude is coupled with frequency [2].

**Piezoelectric Motors:** Have both variable amplitude and frequency. However, from datasheet these appear to be too fragile for our needs [3].

**Conclusions/action items:**

Forward the video to Rick so he can begin calculations.

Piezoelectric motors may be too sensitive for our needs.

Consider using a combination of LRA and ERM motors.

**References:**

[1] "Linear Resonant Actuators – LRAs," *Precision Microdrives*. [Online]. Available: <https://www.precisionmicrodrives.com/vibration-motors/linear-resonant-actuators-lras/>. [Accessed: 12-Dec-2018].

[2] "Vibration Motors – ERMs and LRAs," *Precision Microdrives*. [Online]. Available: <https://www.precisionmicrodrives.com/vibration-motors/vibration-motors-erms-and-lras/>. [Accessed: 12-Dec-2018].

[3] TDK, "PiezoHapt™ Actuators," *Electric Double-Layer Capacitors (EDLC / Supercapacitors) | TDK Product Center*. [Online]. Available: [https://product.tdk.com/info/en/products/sw\\_piezo/haptic/piezo\\_hapt/technote/tpo/index.html](https://product.tdk.com/info/en/products/sw_piezo/haptic/piezo_hapt/technote/tpo/index.html). [Accessed: 12-Dec-2018].



## 11/27/18-Coding Guidelines

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• Stephan Blanz • Dec 12, 2018 @02:23 PM CST

**Title:** Coding Guidelines

**Date:** 11/27/18

**Content by:** Stephan Blanz

**Present:** Rick, Royal

**Goals:** Establish guidelines/ objectives to adhere to while coding

**Content:**

I found an article that basically did exactly what we want in terms of gaining accelerometer readings, through an accelerometer and arduino and then found the FFT in MATLAB.

Additionally, I analyzed the code Rick used to create readings in one dimensions, and created an excel diagram from that data. When comparing this graph with the data we collected using Royal's program including 3 accelerometers, we had significantly different results. I believe the code Rick found to be insufficient, also he was unable to tailor it to our applications so we will proceed with Royal's code and use 3 axis accelerometer measurements.

One of the things this code did however was only sampled the arduino in one axis, which I thought was a poor choice.

However, the group did find that by collecting the data on the arduino and sending it in batches, that they achieved better results than by sending the data as soon as it's collected [1].

**Conclusions/action items:**

Record accelerometer on all 3 axes.

Don't use code you don't understand.

Send data in batches.

**References:**

[11] A. Hjort, M. Holmberg, V. Ziemann, and K. Gajewski, "Measuring mechanical vibrations using an Arduino as a slave I/O to an EPICS control system," 2015.



## 2018/10/04-Precision Vibration Motor

• Stephan Blanz • Oct 09, 2018 @11:16 PM CDT

**Title:** Advisor Meeting Notes

**Date:** 10/4/18

**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Potential Source of Vibration

**Content:**

Precision Microdrives has a motor that seems to operate within the frequency range our preliminary research has led us to believe we'll see a rodent response.

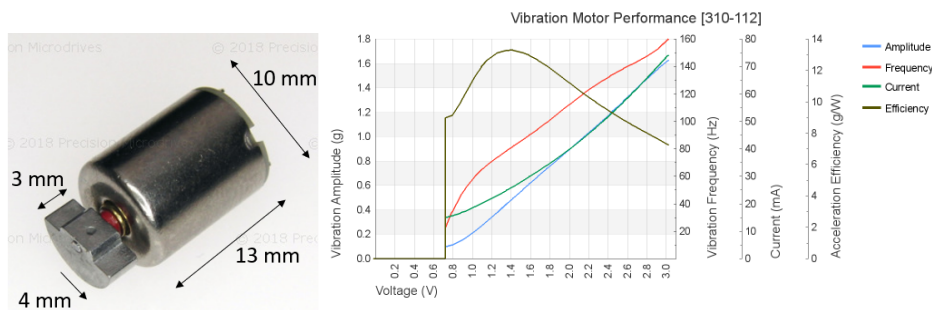


Figure 1 a(left) Vibrational motor based on rotating weight which creates vibrations when spun. b(right) Frequency vs Voltage curve will be used to establish ranges when testing.

**Conclusions/action items:**

- Produces ~30 Hz to ~160 Hz vibrations



## 2018/10/05-Slide-in for Vibrational Motor

• Stephan Blanz • Oct 09, 2018 @11:08 PM CDT

**Title:** Possible Design Idea for Securing Motor

**Date:** 10/05/18

**Content by:** Stephan Blanz

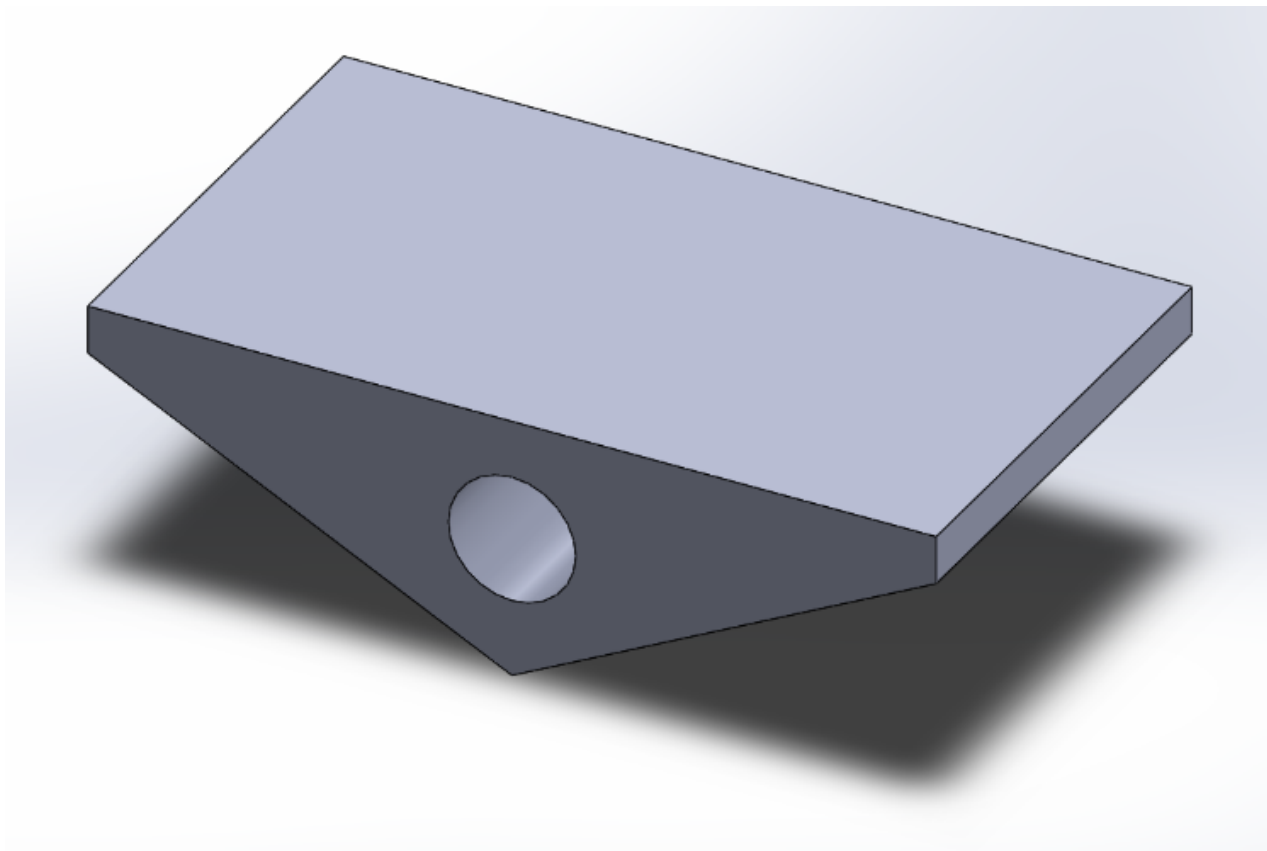
**Present:** Stephan Blanz

**Goals:** Design and evaluate a method of attaching motor

**Content:**

After finding the motor, I wanted to create a method of attaching this to the platform. Since the motor functions by rotating a semi-circular weight, it should be possible to create a platform with a cylindrical cut-out in which the motor could slide into. The vibrations of the motor would be transferred on contact to the platform.

Limitations are it might not be a 1:1 transfer.



Also, dimensions at this point are still variable. However, should be small enough to fit a rodent foot pad.

**Conclusions/action items:**

- If used, need to test that vibrations are transferred 1:1. If not, create tuning curve.



## 2018/11/25-Earphone Standoff

• Stephan Blanz • Dec 12, 2018 @01:49 PM CST

**Title:** Earphone Standoff

**Date:** 11/25/18

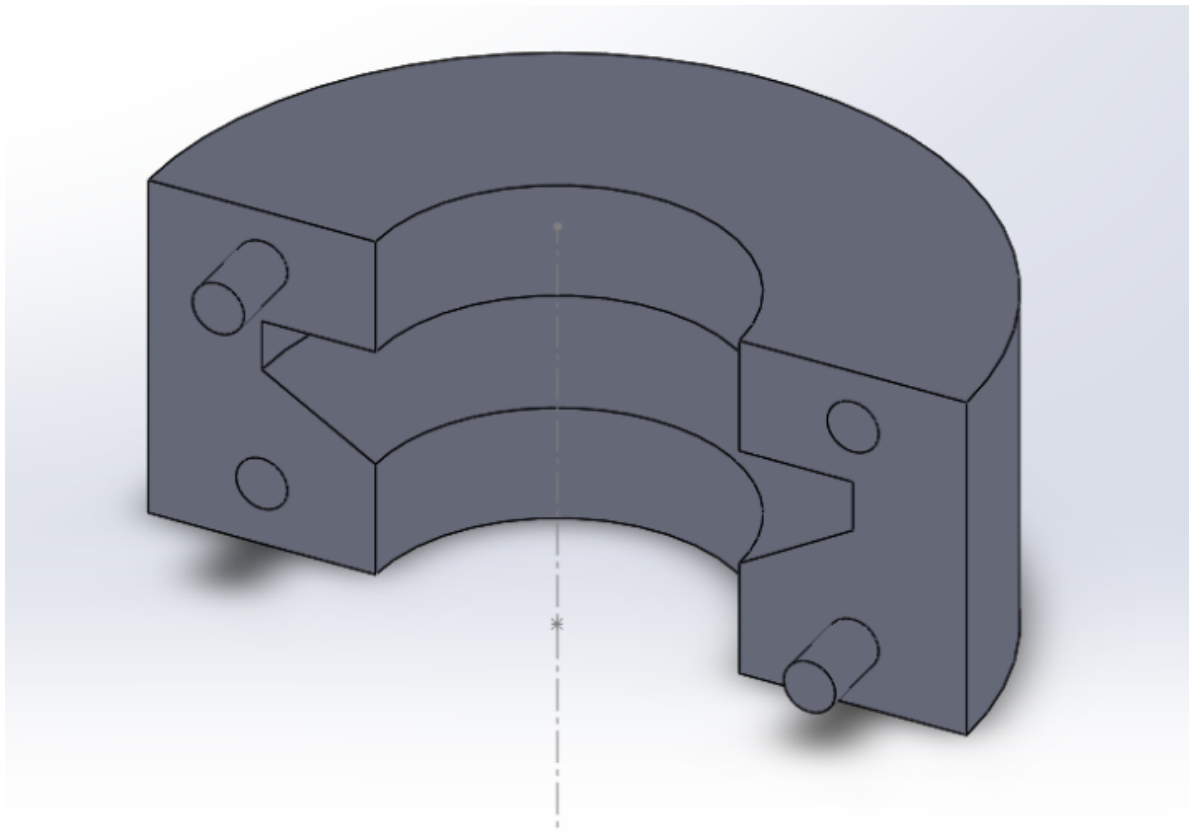
**Content by:** Stephan Blanz

**Present:**

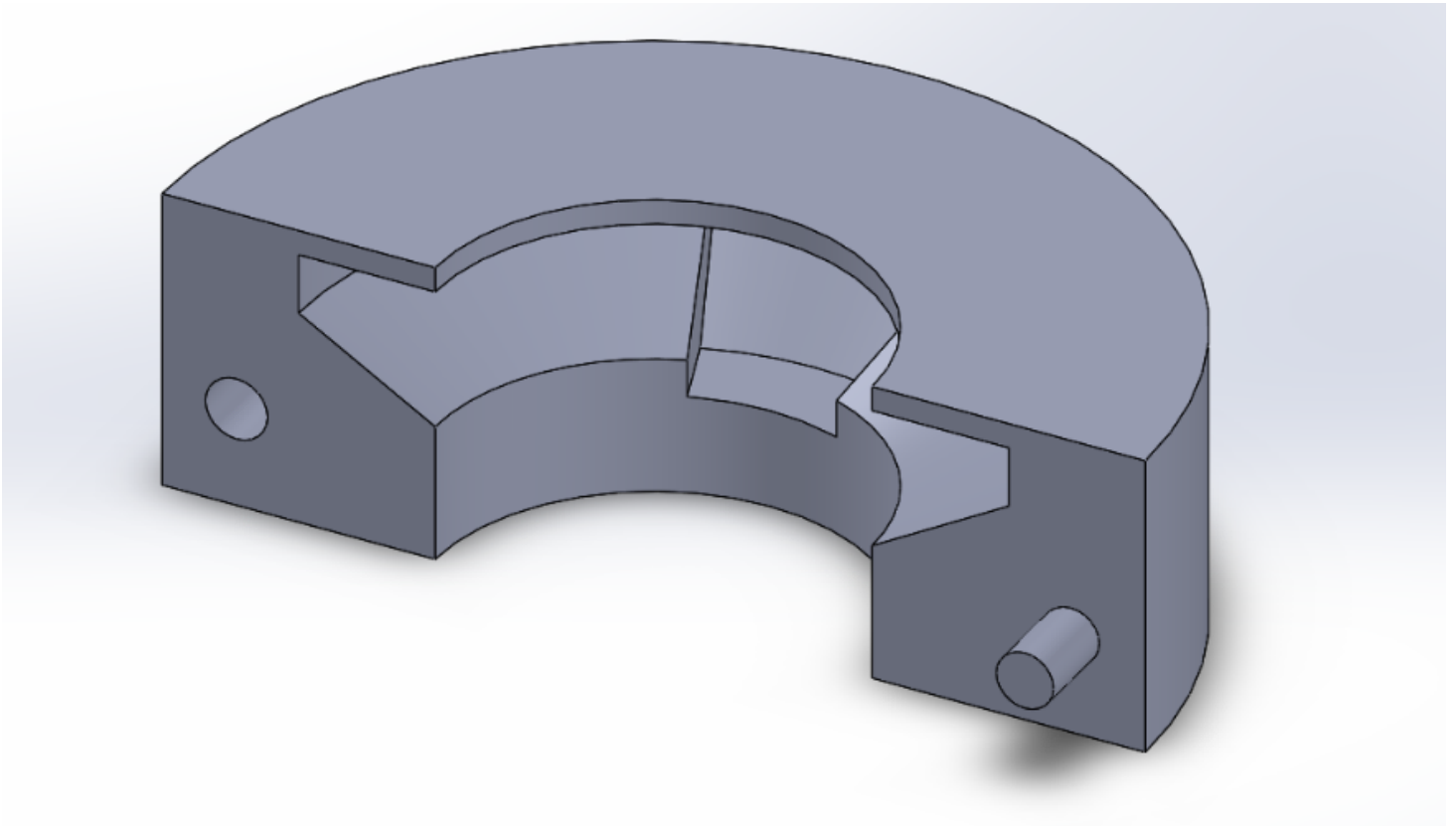
**Goals:** Create a standoff for headphones so they can be attached to the rodent

**Content:**

The first version of the designed needed a cutout to accommodate the wires coming off the headphone. It also needed a smaller standoff between the cradle and the outer surface. Below are versions 1 and 2 of the design.



**Figure 1.** Initial design features a cradle for the earphones and a standoff



**Figure 2.** Improvements to original design featuring a cradled cutout for the earphone and a small standoff to transmit the vibrations.

**Conclusions/action items:**

This is an alternative to the current vibrational motor that we are using.



## 2018/11/25-Slide-in Part 2

• Stephan Blanz • Dec 12, 2018 @01:52 PM CST

**Title:** Possible Design Idea for Securing Motor

**Date:** 11/25/18

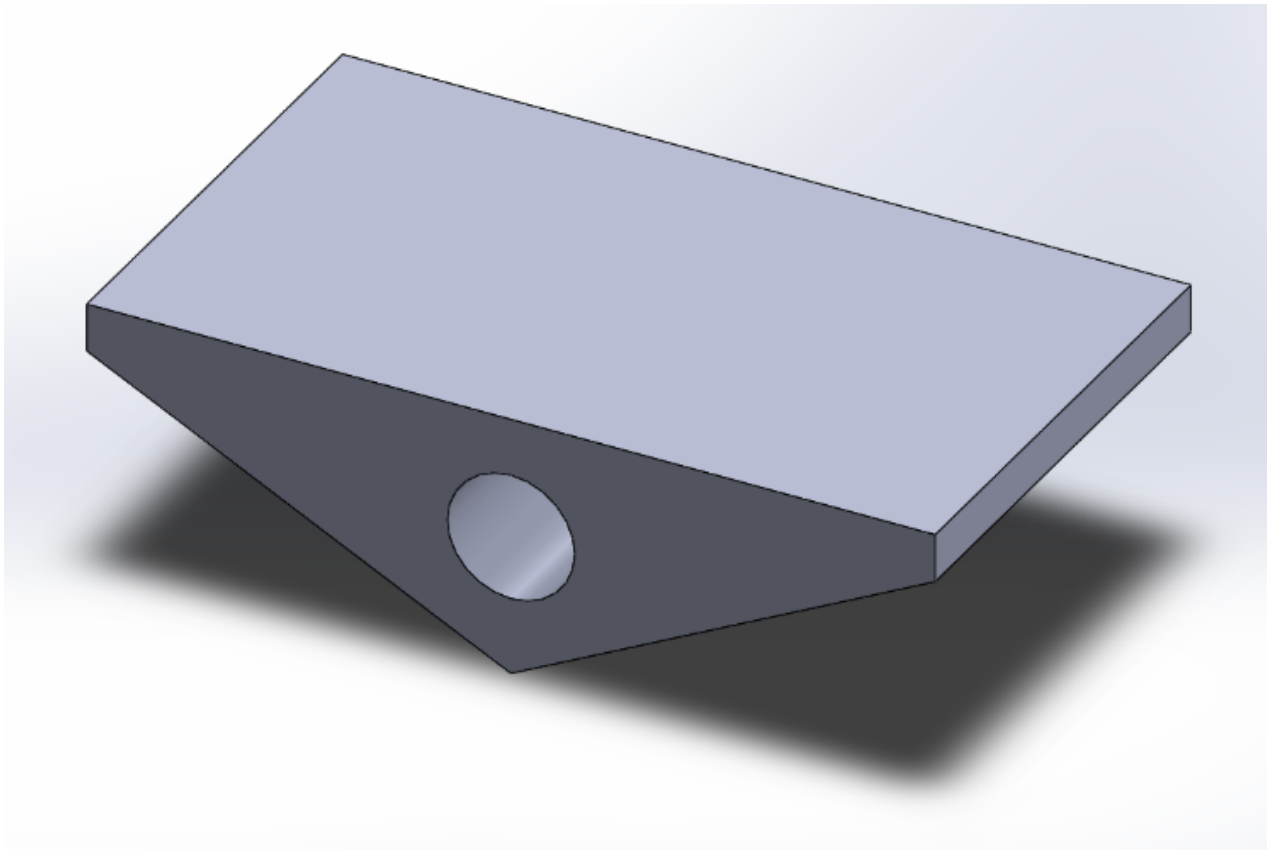
**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Design and evaluate a method of attaching motor

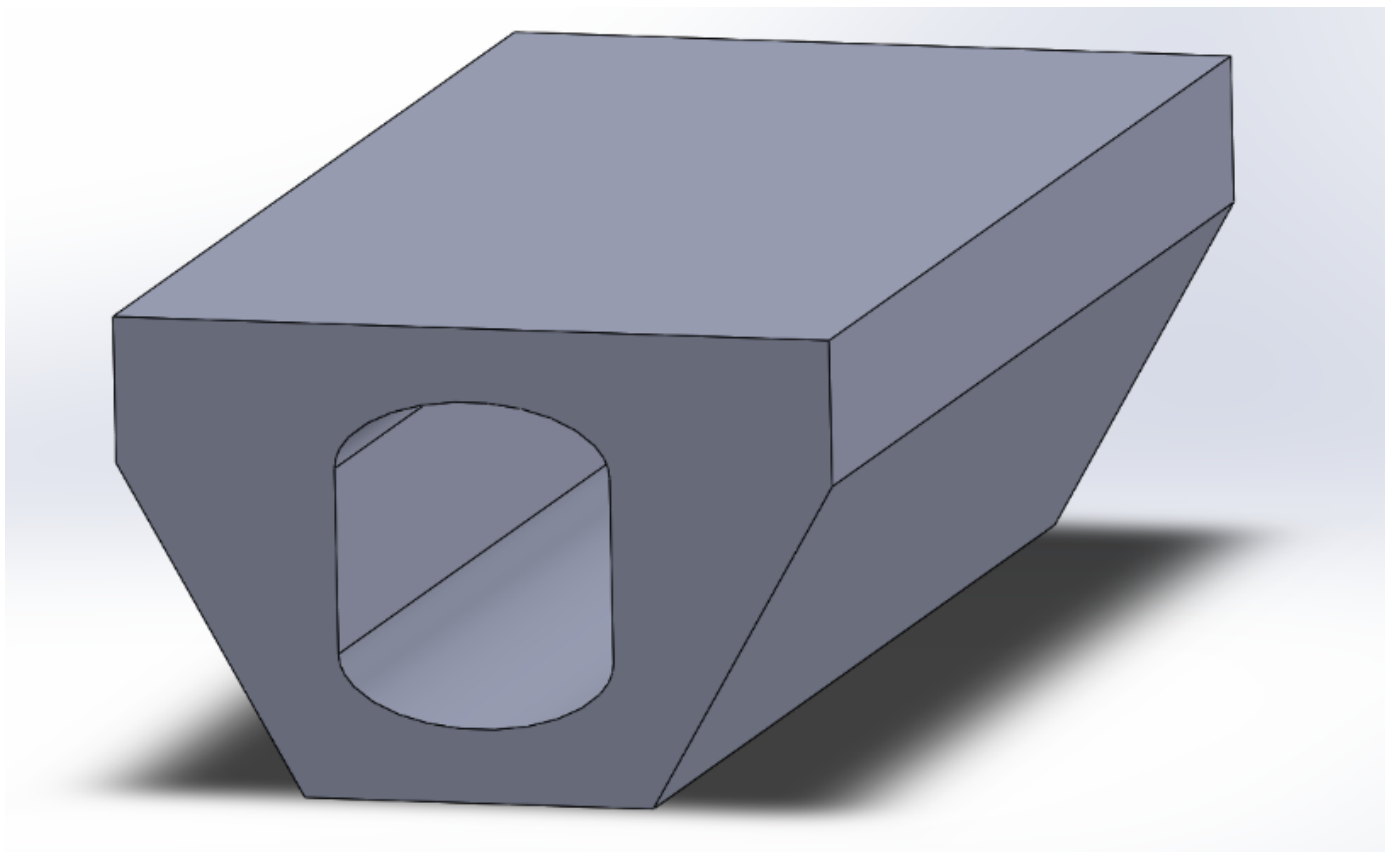
**Content:**

Create an updated model to the first version of the platform.



**Figure 1.** First platform concept, featuring circular cutout for vibrational motor.





**Figure 2.** Features a cylindrical shaft with rounded edges that snugly accommodates the ERM motor we purchased. Also features a flat bottom part to stick LRA motor to.

**Conclusions/action items:**

- If used, need to test that vibrations are transferred 1:1. If not, create tuning curve.



## 2018/10/09-As of this Date RARC Classes

• Stephan Blanz • Oct 09, 2018 @10:58 PM CDT

**Title:** RARC Training Completed as of this date

**Date:** 10/9/2018

**Content by:** Stephan Blanz

**Present:** Stephan Blanz

**Goals:** Proof of Training

**Content:**

- RARC Classes		
Completed		
Class	Supplemental Materials	Date
Mouse -- Covers: mouse c : mus	yes	02/07/18
Lab Animal Surgery		02/01/18
Rat -- Covers: rat c : rattus	yes	01/10/18
LAS Aseptic Technique		12/12/17
LAS Anesthesia		12/12/17
Anesthesia Machine User Guide		12/12/17
Medical Records		12/12/17
Controlled Substances		12/12/17
Animal User Orientation		12/04/17

**Conclusions/action items:**

None



## 9/14 - Neural Regeneration

---

- John Beckman - Oct 10, 2018 @01:24 PM CDT

**Title:** Mammalian Neural Regeneration

**Date:** 9/14/18

**Content by:** John Beckman

**Present:** N/A

**Goals:** To better understand how Neural Regeneration works in a mammals nervous system

**Content:**

- Neural Regeneration is almost impossible in the CNS due to the glial scar tissue that forms following nerve damage in the CNS. This is because of the Astrocytes that will cut off the damaged nerve from the rest of the CNS.
- In the PNS however, through a series of processes, Wallerian Degeneration, and axon regeneration allows for the damaged nerves to be encapsulated in the myelin of a Schwann cell. These Schwann cells will also release growth factors after the macrophages clean all the debris out of the space between the damaged neuron and the cell body.

S. Rotshenker, "Wallerian degeneration: the innate-immune response to traumatic nerve injury.," *J. Neuroinflammation*, vol. 8, p. 109, Aug. 2011.

E. Huebner and S.M. Strittmatter, "Axon Regeneration in the Peripheral and Central Nervous Systems," N.p., 27, Mar. 2010. Web.

**Conclusions/action items:**

The clients are studying how effective nerve regeneration surgery is. For in some situations the nerve is significantly more damaged, and requires a more invasive surgical procedure. Surgery can be used to help guide the axons to the cell body.



## 9/20 - Surgical Repair of PNS nerves

---

- John Beckman - Oct 10, 2018 @02:13 PM CDT

**Title:** Advisor Meeting Notes

**Date:** 9/20/18

**Content by:** John Beckman

**Present:** N/A

**Goals:** Research how surgical repair of neurons is different than the process of wallerian degeneration

**Content:**

There are four main steps to surgical repair of nerves in the peripheral nervous system

1. Preparation: removal of necrotic tissue leaving the ends as two normal looking nerve ends.
2. Approximation: The nerve ends are mobilized and brought together leaving a minimal gap by applying appropriate tension. Tensionless repairs have shown to have better results.
3. Alignment: The blood vessels must be aligned, and proper rotational alignment undertaken.
4. Maintenance: Sutures are placed in the epineurium, which is where they are held together. The sutures need to be properly inserted to avoid malrotation of the nerves.

G. M F, M. M, H. S, and W. S. Khan, "Peripheral nerve injury: principles for repair and regeneration.," *Open Orthop. J.*, vol. 8, pp. 199–203, 2014.

**Conclusions/action items:**

This form of nerve repair is slightly different than wallerian degeneration, and requires a significant amount of invasive operations to complete. However the general procedure is similar, removal of necrotic tissue, followed by growth to the opposite end. The major difference occurs in the lack of growth occurring in the surgical repair, which can lead to a less successful repair than Wallerian Degeneration can provide.



## 10/01 - Linear Actuator

- John Beckman - Oct 10, 2018 @02:31 PM CDT

**Title:** Linear Actuator Motor for vibrational stimulus

**Date:** 10/01/18

**Content by:** John Beckman

**Present:** N/A

**Goals:** Find a potential motor to create the desired vibrational stimulus

**Content:**

A linear actuator or linear servo will allow for a direct linear motion. Utilizing coding to power the actuator we could use a delay to create a varying vibrational frequency.

Some example Linear actuators or servos can be seen below.



**Conclusions/action items:**

Add this design to the design matrix, and then evaluate all of the other motors to determine which best meets our design specifications.



## 11/09 - Headphone voice coil

---

• John Beckman • Dec 12, 2018 @01:14 PM CST

**Title:** Alternate stimulus source from an ear bud

**Date:** 11/09/2018

**Content by:** John Beckman

**Present:** N/A

**Goals:** Determine if using a voice coil from a headphone is a viable alternative source of stimulation

**Content:**

After taking apart a pair of apple headphones, I took the membrane off of the voice coil itself. The membrane no longer vibrated at all. Additionally, online tone generators can be found which send a sinusoidal sine wave at a given frequency to the ear bud. Seems like a reasonable mode of stimulation which also allows for variable amplitude and frequency.

**Conclusions/action items:**

There are a few issues with the voice coil that will need to be addressed, a standoff must be built so that the vibration is not blocked by too much force applied to the membrane. Also, a means of attaching the coil to the rats foot must be created, could be as simple as a small elastic band. Additionally, the plastic housing for the headphones must be removed somehow.



## 12/02 - Motor Wire Soldering

---

• John Beckman • Dec 12, 2018 @01:21 PM CST

**Title:** Soldering connections for platform fit

**Date:** 12/02/2018

**Content by:** John Beckman

**Present:** Stephan, Royal, and Rick

**Goals:** Solder motor wires to allow for long range connection to the Arduino

**Content:**

Soldered wires to ERM connections, then put heat shrink tubing around the body of the motor and the wires to allow for a stable connection and to make it easier to slide into the platform.

Soldered wires to LRA to allow for longer than 2 inch connections to this motor. Then attached it to the bottom of the platform using the adhesive on the motor itself.

**Conclusions/action items:**

Ready to test frequency of the different motors in many different ways. including offset of the alternate pad during stimulation to test if we can accurately stimulate one limb isolated.



## 2018/10/09: Vibration Effects On Rats

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• Steven Oakes • Oct 09, 2018 @11:23 PM CDT

**Title:** Vibration Effects on Rats

**Date:** 10/09/2018

**Content by:** Royal Oakes

**Present:** NA

**Goals:** Describe the effects of vibrations on rats.

**Content:**

For this project we need to design a rat cage that can stimulate the hind limbs of the rodent with vibrations. It seems appropriate that I conduct preliminary research to understand what frequencies of vibration can elicit a behavioral response from rats. This page will contain citations to the article in IEEE format followed by bullet points indicating important points from the article.

A. M. Garner, J. N. Norton, W. L. Kinard, G. E. Kissling, and R. P. Reynolds, "Vibration-induced Behavioral Responses and Response Threshold in Female C57BL/6 Mice," Sep-2018. [Online]. Available: <https://www-ingentaconnect-com.ezproxy.library.wisc.edu/contentone/aalas/jaalas/2018/00000057/00000005/art00003>. [Accessed: 30-Sep-2018].

- Rats were subjected to a range of frequencies between 20-190Hz. The greatest behavioral response came from frequencies between 70-100Hz.
- All four limbs of the rats were stimulated.
- Behavioral changes included freezing, hunched posture, and surveying the cage.

**Conclusions/action items:**

Find more sources on the effect of vibrations on rats.





## 2018/11/27: Arduino MATLAB Serial Communication

• Stephan Blanz • Dec 12, 2018 @01:28 PM CST

**Title:** Arduino MATLAB Serial Communication

**Date:** 11/27/2018

**Content by:** Royal Oakes

**Present:** Stephan Blanz

**Goals:** Describe research regarding MATLAB Arduino communication.

**Content:**

We will be using an Arduino to record data from an accelerometer. However, the arduino has limited memory and, thus, it is beneficial to use MATLAB to process the data.

There is an Arduino-MATLAB communication toolkit which allows Arduino devices to interface with MATLAB. (<https://www.mathworks.com/hardware-support/arduino-matlab.html>)

- Communication can be opened using the MATLAB commands `serial()` and `fopen()` and the Arduino command `Serial.begin()`.
- MATLAB can read data from the Arduino using `fscanf()`.
- Arduino can write data to MATLAB using `Serial.println()`.

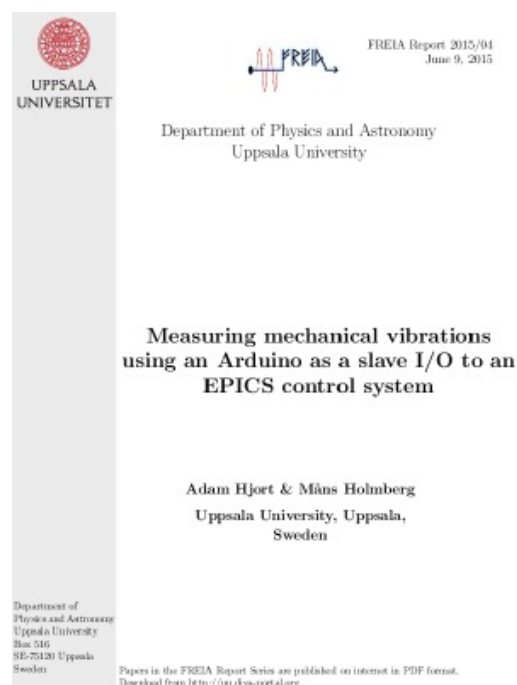
A. Hjort, M. Holmberg, V. Ziemann, and K. Gajewski, "Measuring mechanical vibrations using an Arduino as a slave I/O to an EPICS control system," 2015.

- This paper describes an optimal method for transmitting accelerometer data from Arduino to MATLAB. Rather than sending data as it is recorded to MATLAB, the Arduino will store data and then transmit the data in batches. This supposedly makes the measurements more accurate because there are unpredictable delays associated with serial communication. If these delays are interspersed with readings, it can lead to samples not being recorded at a constant frequency.

**Conclusions/action items:**

Implement the method described in A. Hjort *et al.* Perform testing of the motors.

• Steven Oakes • Dec 12, 2018 @11:03 AM CST



FULLTEXT01.pdf(3.8 MB) - [download](#)



## 2018/11/27: Design of Testing Code

• Steven Oakes • Dec 12, 2018 @10:41 AM CST

**Title:** Design of Testing Code**Date:** 11/27/2018**Content by:** Royal Oakes**Present:** N/A**Goals:** Describe the code that was used to test the motors.**Content:**

We received two motors from Amazon. One was an eccentric rotating mass (ERM) motor and the other was a linear resonant actuator (LRA) motor. Since these motors were very cheap, there may be discrepancies between the specifications of the motors in their respective datasheets and the actual performance of the motors. To test the actual performance of the motors, as well as to test the motors in the rat cage we have designed, I created code which is able to read information from an accelerometer, transmit that code to MATLAB, and compute the Fourier transform of the data. I have attached the code to this page: sketch\_nov25a.ino for the arduino code, and MatlabSerialArduino.m for the MATLAB code.

The Arduino code was designed to take a certain number of samples from the accelerometer at 1000 Hz. The data read from the accelerometer was a vector of three integers, meaning each sample was 12 bytes. For all our experiments, we used 128 samples due to memory limitations of the Arduino. After the 128 samples were collected, the Arduino would then send all 128 samples to MATLAB through serial communication at 9600 baud.

The MATLAB code would receive the 128 samples from the Arduino. Then the norm of each vector was computed. The Fourier transform of the magnitude of the acceleration vectors was then computed. This data was then saved and used to produce graphs.

**Conclusions/action items:**

One issue with the Arduino and MATLAB code is that if the number of samples were to change, the Arduino and MATLAB code would both have to be changed to reflect the new number of samples. It would be beneficial for future experiments to only have to change one aspect of the code to change these fundamental values. Future work could involve having the arduino send the important information like number of samples to MATLAB, so the values in the MATLAB and Arduino code do not need to be coordinated by a human.

We will need to use this code for testing in the future.

• Steven Oakes • Dec 12, 2018 @10:14 AM CST



sketch\_nov25a.ino(1.2 KB) - [download](#)

```

clear
close all
clc

% The number of samples in a single package from the Arduino.
PACKAGE_SIZE = 128;
% The number of packages received from the Arduino.
PACKAGE_NUM = 1;
% The number of values in each sample from the Arduino.
SAMPLE_NUM = 3;

xyzData = zeros(PACKAGE_SIZE, SAMPLE_NUM);
xData = zeros(PACKAGE_SIZE * PACKAGE_NUM, 1);
yDataFFT = zeros(PACKAGE_SIZE * PACKAGE_NUM, 1);
t = 1:PACKAGE_SIZE;
mag = zeros(PACKAGE_SIZE * PACKAGE_NUM, 1);
magFFT = zeros(PACKAGE_SIZE * PACKAGE_NUM, 1);

% Initialize communication with Arduino.
try
    s = serial('COM3', 'baudrate', 9600);
    fopen(s);
    fscanf(s); % Get the first byte to acknowledge Arduino.
catch
    warning('Could not establish connection with Arduino.');
```

```

end

% Get data from Arduino a certain number of times.
for n = 1:PACKAGE_NUM
    try
        % Send a signal to the Arduino to get another data set.
        fprintf(s, '%d', 'uLatid');
        fscanf(s);

        % Read data from Arduino.
        for i = 1:PACKAGE_SIZE
            for j = 1:SAMPLE_NUM
                val = fscanf(s);
                xyzData(i,j) = str2double(val([1:length(val) - 2]));
            end
        end

        % Get the magnitude of the acceleration vectors.
        for i = 1:PACKAGE_SIZE
            mag([((i-1)*PACKAGE_SIZE) + 1]) = norm(xyzData(i, :));
        end

        xData([((i-1)*PACKAGE_SIZE) + 1]) = xyzData(i,1);
        yDataFFT = fft(mag);
        xDataFFT = fft(xData);
    end
end

fclose(s); % Close serial communication with Arduino.

```

**MatlabSerialArduino.m(1.8 KB) - download**



## 2018/11/29: MATLAB Code for Plots

• Steven Oakes • Dec 12, 2018 @10:41 AM CST

**Title:** MATLAB Code for Plots

**Date:** 11/29/2018

**Content by:** Royal Oakes

**Present:** N/A

**Goals:** Describe the code to make the MATLAB plots.

**Content:**

We used MATLAB to compute the Fourier transform of our magnitude data from the accelerometer. This script is designed to take the FT data from the MatlabSerialArduino.m script and make plots from it.

The first iteration of the MATLAB code to make plots was called PlotsPlotsPlots.m. This script would require the user to input the names of all the CSV files containing FT data that they want to display on the same axis. Then the script would compute the values for the frequency axis and plot the magnitude of the FT data on the same axis. The plotting was done in such a way that the first CSV file chosen would receive the same color each time the script executed. This allowed the script to create separate plots that had the same color for the same voltage values easily.

The second iteration of the MATLAB code to make plots was called Multiplots.m. This script would execute the same steps from the PlotsPlotsPlots.m script, but could be used to create multi-plots, images with multiple plots. The user would specify which CSV files they wanted to read and which plot the data would be plotted on. This allowed the creation of the plots that will be used in future presentations.

**Conclusions/action items:**

Use the scripts to make plots for the preliminary presentation and final report.

• Steven Oakes • Dec 12, 2018 @10:30 AM CST

```
% The number of samples in a single package from the Arduino.
PACKAGE_SIZE = 128;
% The number of packages received from the Arduino.
PACKAGE_NUM = 1;
% The number of values in each sample from the Arduino.
SAMPLES = 2;

% x1 = abs(fftshift(cnormaf('mag_102.csv')));
% x2 = abs(fftshift(cnormaf('mag_127.csv')));
x3 = abs(fftshift(cnormaf('cyl_dir_mag_152.csv')));
x4 = abs(fftshift(cnormaf('cyl_dir_mag_177.csv')));
x5 = abs(fftshift(cnormaf('cyl_dir_mag_202.csv')));
x6 = abs(fftshift(cnormaf('cyl_dir_mag_227.csv')));
x7 = abs(fftshift(cnormaf('cyl_dir_mag_252.csv')));

% y1 = abs(fftshift(cnormaf('cmln_direct_mag_102.csv')));
% y2 = abs(fftshift(cnormaf('cmln_direct_mag_127.csv')));
y3 = abs(fftshift(cnormaf('mss6L_mag_152.csv')));
y4 = abs(fftshift(cnormaf('mss6L_mag_177.csv')));
y5 = abs(fftshift(cnormaf('mss6L_mag_202.csv')));
y6 = abs(fftshift(cnormaf('mss6L_mag_227.csv')));
y7 = abs(fftshift(cnormaf('mss6L_mag_252.csv')));

% z1 = abs(fftshift(cnormaf('cmln_noise_mag_102.csv')));
% z2 = abs(fftshift(cnormaf('cmln_noise_mag_127.csv')));
z3 = abs(fftshift(cnormaf('mss6L_mag_152.csv')));
z4 = abs(fftshift(cnormaf('mss6L_mag_177.csv')));
z5 = abs(fftshift(cnormaf('mss6L_mag_202.csv')));
z6 = abs(fftshift(cnormaf('mss6L_mag_227.csv')));
z7 = abs(fftshift(cnormaf('mss6L_mag_252.csv')));

freq = ((0:(length(x7)-1))/(PACKAGE_SIZE/2)) ./ (0.001*PACKAGE_SIZE);

figure
subplot(3,3,1);
hold on
% plot(freq, x1, 'color', [ 85/255 85/255]);
% plot(freq, x2, 'color', [ 178/255 178/255]);
plot(freq, x3, 'color', [ 178/255 188/255]);
plot(freq, x4, 'color', [215/255 188/255]);
plot(freq, x5, 'color', [118/255 118/255]);
plot(freq, x6, 'color', [85/255 252/255]);
plot(freq, x7, 'color', [0.0000 118/255 14/255]);
hold off

title('Direct Placement')
legend('3.0V', '2.5V', '2.0V', '1.5V', '1.0V')
axis([0 250 0 500])

subplot(3,3,2);
hold on
% plot(freq, y1, 'color', [ 85/255 85/255]);
% plot(freq, y2, 'color', [ 178/255 178/255]);
plot(freq, y3, 'color', [ 178/255 188/255]);
plot(freq, y4, 'color', [215/255 188/255]);
plot(freq, y5, 'color', [118/255 118/255]);
plot(freq, y6, 'color', [85/255 252/255]);
plot(freq, y7, 'color', [0.0000 118/255 14/255]);
hold off

title('Amplified')
xlabel('Amplitude')
axis([0 250 0 1000])
```

[Multiplots.m\(2.7 KB\) - download](#)

```

% The number of samples in a single package from the Arduino.
PACKAGE_SIZE = 128;
% The number of packages received from the Arduino.
PACKAGE_NUM = 1;
% The number of values in each sample from the Arduino.
SAMPLES = 5;

% x1 = abs(fftshift(csummat("cyl_dir_weg_100.csv")));
% x2 = abs(fftshift(csummat("cyl_dir_weg_127.csv")));
% x3 = abs(fftshift(csummat("cyl_dir_weg_152.csv")));
% x4 = abs(fftshift(csummat("cyl_dir_weg_177.csv")));
% x5 = abs(fftshift(csummat("cyl_dir_weg_202.csv")));
% x6 = abs(fftshift(csummat("cyl_dir_weg_227.csv")));
% x7 = abs(fftshift(csummat("cyl_dir_weg_252.csv")));

freq = ((0:(length(x7)-1))-(PACKAGE_SIZE/2)) ./ (0.001*PACKAGE_SIZE);

figure
hold on
% plot(freq, x1, 'color', [ 85/255 85/255 1])
% plot(freq, x2, 'color', [ 170/255 170/255 1])
% plot(freq, x3, 'color', [ 255/255 100/255 1])
% plot(freq, x4, 'color', [215/255 100/255 1])
% plot(freq, x5, 'color', [130/255 130/255 1])
% plot(freq, x6, 'color', [80/255 255/255 0])
% plot(freq, x7, 'color', [0.0008 115/255 14/255])
hold off

legend('3.0V', '3.5V', '4.0V', '4.5V', '5.0V')
axis([0 250 0 50])
xlabel('Frequency [Hz]')
ylabel('Amplitude')

```

[PlotsPlotsPlots.m\(1.1 KB\) - download](#)



**Title:** Vibration Research

**Date:** 9/18/18

**Content by:** Rick Guo

**Present:** Rick Guo

**Goals:** To find a proper frequency range to stimulate the rodents' hindlimbs

**Content:**

What I found is that vibrations on hindlimbs at 35 Hz(according to article 1 below) to 90 Hz(according to article 2 below) can do good to rats' intervertebral disk and strengthen their hindlimbs' muscle. Therefore, I believe vibrations at 35 to 90 Hz will be safe to use on rats. And also according to a article found by Stephan, vibrations with a frequency of 50 to 150 Hz can stimulate the rodents effectively.

Here are the articles:

Local vibration enhanced the efficacy of passive exercise on mitigating bone loss in hindlimb unloading rats.

<https://www-sciencedirect-com.ezproxy.library.wisc.edu/science/article/pii/S009457651630875X>

Low-intensity vibrations partially maintain intervertebral disc mechanics and spinal muscle area during deconditioning

<https://www-sciencedirect-com.ezproxy.library.wisc.edu/science/article/pii/S152994301300123X?via%3Dihu>

**Conclusions/action items:**

According to the research, a frequency ranges from 35 Hz to 93 Hz may be appropriate to stimulate the rodents without hurting them.



## Client meeting notes

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• jinyuxuan guo • Oct 10, 2018 @03:50 PM CDT

**Title:** Client meeting notes

**Date:** 9/21/18

**Content by:** Rick Guo

**Present:** Stephan Blanz, John Beckman, Royal Oaks, Rick Guo

**Goals:** Meet with clients to discuss project

**Content:**

The clients want a device that can hold one rodent and use vibration to stimulate one of its hindlimbs.

It should be:

Fit on a laboratory bench

Has controllable frequency

Stimulates only one leg

Does not injure rodents

Computer controlled

Hold one rodent at a time

Waterproof and easily sanitizable

**Conclusions/action items:**

Meet with client



## 2018/12/02 Research for Force testing

• jinyuxuan guo • Dec 04, 2018 @07:47 PM CST

**Title:** research for force testing

**Date:**12/2/1018

**Content by:** Jinyuxuan GUO

**Present:** Jinyuxaun GUO

**Goals:** To find out the force that our motor can generate

**Content:**

According to a tutor video found online,  $F = m r \omega$ , where  $F$  is force generated,  $m$  is the mass of the eccentric disk,  $r$  is the distance from the spinning rod to the center of mass of the eccentric disk and  $\omega$  is the angular velocity. From the data sheet of the motor, I got the diameter of the eccentric disk is 6mm and the motor is operating at 14000 RPM. Then, I weight the eccentric disk and it is 0.2 grams. See calculations below:

Force generated

$$F = m r \omega^2$$

$\omega = 2\pi \cdot \frac{\text{RPM}}{60}$   
 The distance from the spinning rod to the center of mass of the eccentric disk  
 The mass of the eccentric disk

---

$m = 0.2 \text{ g}$      $\text{RPM} = 14000 \Rightarrow \omega = 2\pi \cdot \frac{14000}{60} = 1466 \text{ rad/s}$

center of mass of a semicircle  
 $r = \frac{2d}{3\pi} = \frac{2 \cdot 6\text{mm}}{3\pi} = 1.273 \text{ mm}$

$F = 0.2 \times 10^{-3} \text{ kg} \cdot 1.273 \times 10^{-3} \text{ m} \cdot 1466 \text{ rad/s} = 3.73 \times 10^{-4} \text{ N}$

Link of the website: <https://www.precisionmicrodrives.com/vibration-motors/>

**Conclusions/action items:**

The result of force generated by the motor is  $3.73 \times 10^{-4} \text{ N}$ . Then, we can use this number to calculate the acceleration of whole device due to this force.





## 2018/12/4 Acceleration of the whole device

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• jinyuxuan guo • Dec 04, 2018 @07:32 PM CST

**Title:** Acceleration of the whole device

**Date:** 12/4/2018

**Content by:** Jinyuxuan Guo

**Present:** Jinyuxuan Guo

**Goals:** To calculate the acceleration of the whole device due the force generated by the motor

**Content:**

Last time, the force generated by the motor is calculated and the result is  $3.73e-4$  N. According to Newton's Second Law of Motion,  $F = ma$ , the acceleration of the whole device can be calculate if the weight data of the whole device is obtained. The team weighted the two parts that make up the device, the motor and the pedal. The motor is 2.63 grams and the pedal is 14 grams, so the total weight of the device is 16.63 grams. Thus, the acceleration of the whole device is the force generated by the motor over the mass of the whole device, which is  $3.73e-4$  N /  $16.63e-3$  kg, and the results is  $0.02243$  m/s<sup>2</sup>. That is  $2.289e-3$  G.

**Conclusions/action items:**

**The acceleration of this device is  $2.289e-3$  G.**



## competing design research

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• jinyuxuan guo • Oct 10, 2018 @03:46 PM CDT

**Title:** Competing design research

**Date:** 9/16/18

**Content by:** Rick Guo

**Present:** Rick Guo

**Goals:** To find out designs that compete with our project

**Content:**

There are different types of rodent cages in the market currently. Most of them are not be able to stimulate the rodents. Some of them that can stimulate the rodents mainly uses electric shots or heat. However, cages that can stimulate rodent limbs through vibrations, as required by the clients, are not found. Since the cage will have to fulfill the unique and specific needs of the clients' experiments, competition of this project is limited.

**Conclusions/action items:** Very Limited competing designs(especially using vibrations to stimulate the rodents)



## Micro cell phone vibration motor

• jinyuxuan guo • Oct 10, 2018 @03:35 PM CDT

**Title:** Micro cell phone vibration motor

**Date:** 9/27/18

**Content by:** Rick Guo

**Present:** Rick Guo

**Goals:** To come up with a design idea

**Content:**

Cell Phone Micro Vibration Motor.

Retrieved from: [https://www.amazon.com/uxcell-9000RPM-Yellow-Micro-Vibration/dp/B016VQSZ7Q/ref=pd\\_sbs\\_60\\_4?\\_encoding=UTF8&pd\\_rd\\_i=B072L7SRRS&pd\\_rd\\_r=8a9f34bd-c676-11e8-ac03-51a7059c8938&pd\\_rd\\_w=XL7Ej&pd\\_rd\\_wg=DZII7&pf\\_rd\\_i=desktop-dp-sims&pf\\_rd\\_m=ATVPDKIKX0DER&pf\\_rd\\_p=53dead45-2b3d-4b73-bafb-fe26a7f14aac&pf\\_rd\\_r=PKTM989KJF13PWXBNRDW&pf\\_rd\\_s=desktop-dp-sims&pf\\_rd\\_t=40701&refRID=PKTM989KJF13PWXBNRDW&th=1](https://www.amazon.com/uxcell-9000RPM-Yellow-Micro-Vibration/dp/B016VQSZ7Q/ref=pd_sbs_60_4?_encoding=UTF8&pd_rd_i=B072L7SRRS&pd_rd_r=8a9f34bd-c676-11e8-ac03-51a7059c8938&pd_rd_w=XL7Ej&pd_rd_wg=DZII7&pf_rd_i=desktop-dp-sims&pf_rd_m=ATVPDKIKX0DER&pf_rd_p=53dead45-2b3d-4b73-bafb-fe26a7f14aac&pf_rd_r=PKTM989KJF13PWXBNRDW&pf_rd_s=desktop-dp-sims&pf_rd_t=40701&refRID=PKTM989KJF13PWXBNRDW&th=1)

1. Produces a vibration through the spin of a head with unbalanced weight
2. Can only work with fixed frequency, 3 motors are needed to control frequency(53Hz 86Hz 150Hz).
3. Cheap, about 1.2 dollars each

**Conclusions/action items:**

one possible way to develop a vibrational platform using this motor



# 11/27/2018 Arduino code design to get fft from accelerometer

- Stephan Blanz - Dec 12, 2018 @01:29 PM CST

Title:

Date: 11/27/2018

Content by: Jinyuxuan Guo

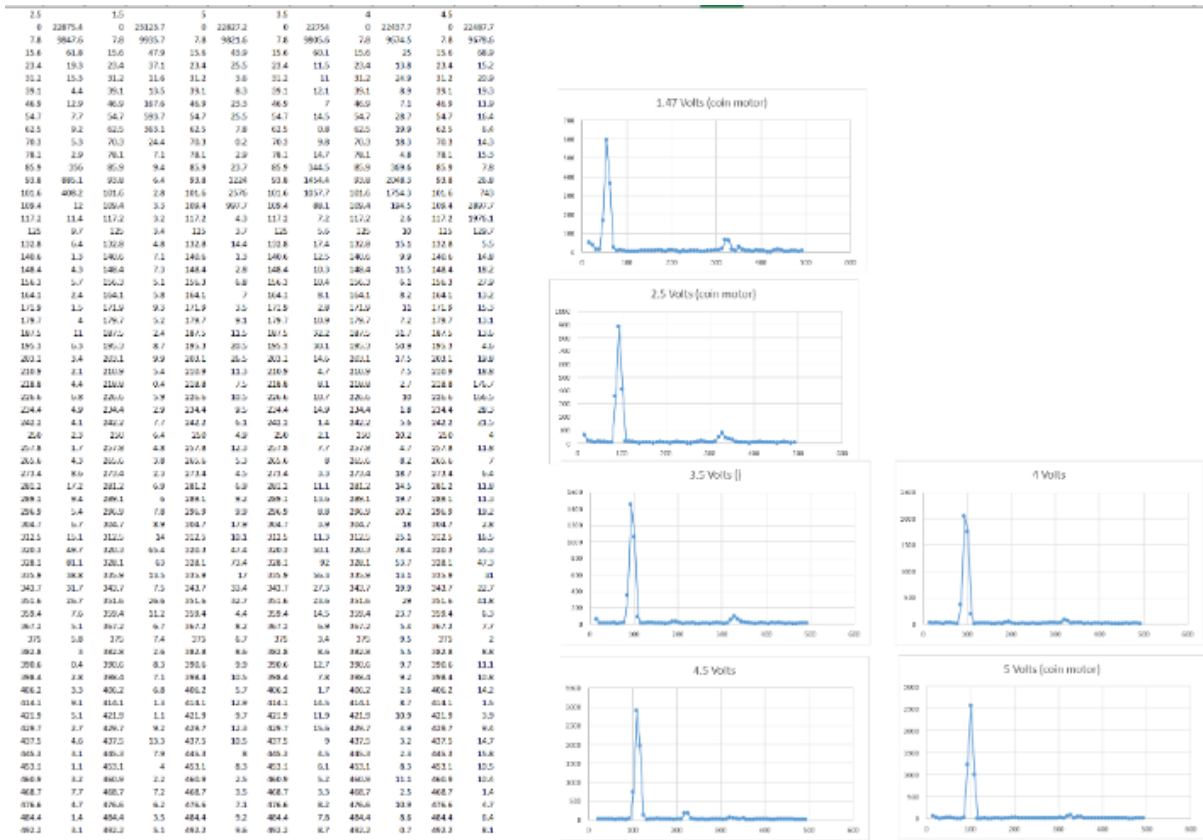
Present: Jinyuxuan Guo, Stephan Blanz

Goals: Design a code that can give us the frequency that the motor is vibrating at

Content:

I did some research on how to use arduino to give us fft under the help of a accelerometer. I used a code template from the arduino library and modify the parameters of the code. Basically, what it will do is that, it can give us a high magnitude at the frequency that the motor is working at. Using this code, we are be able to test the motors with different voltages to see the the motor's performance under various conditions.

Conclusions/action items:



I put the raw data in excel to see the dominant frequency. The results are 50 Hz at 1.5 V, 90 Hz at 2.5 V, 100 Hz at 3.5 V and 110 Hz at 4.5 V.

- jinyuxuan guo - Dec 11, 2018 @08:24 PM CST



## 2016/09/05-Entry guidelines

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• John Puccinelli • Sep 05, 2016 @01:18 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

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• jinyuxuan guo • Dec 02, 2018 @05:57 PM CST

**Title:**

**Date:**

**Content by:**

**Present:**

**Goals:**

**Content:**

**Conclusions/action items:**