



Pick-up Coils

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Abstract

In our project, we explore Faraday's Law and its applicability to guitar pickups. We:

- Test validity of a model of guitar string/pickup
- Experiment with Noise Reduction using Humbucker coil

and find that our initial model is insufficient to represent a true guitar string. We also find that Humbucker coils do indeed reduce noise in output.

Introduction



What are we doing?

Experiment A

We want to verify our pick-up model by experiment results.

Experiment B

We want to check how noise is reduced with two opposite sides of pickup coils compared to one.



Motivation



PICKUP

- Guitar string is cool!
- Faraday is awesome!
- Want to explore the functionality of pickup coils
- Want to check how noise is reduced with humbucker coils
- Last but not least... Want to play with pickup coils

Theory



Faraday's Law

$$\vec{B}(t) = B_0 e^{-\beta t} \cos(\omega t + \phi) \hat{z}$$

Then we have:

$$\begin{aligned} \epsilon &= - \frac{\partial \Phi}{\partial t} = - A \frac{\partial B}{\partial t} = A(B_0 \beta e^{-\beta t} \cos(\omega t + \phi) - B_0 \omega e^{-\beta t} \sin(\omega t + \phi)) \\ &= AB_0 e^{-\beta t} (\beta \cos(\omega t + \phi) - \omega \sin(\omega t + \phi)) \end{aligned}$$



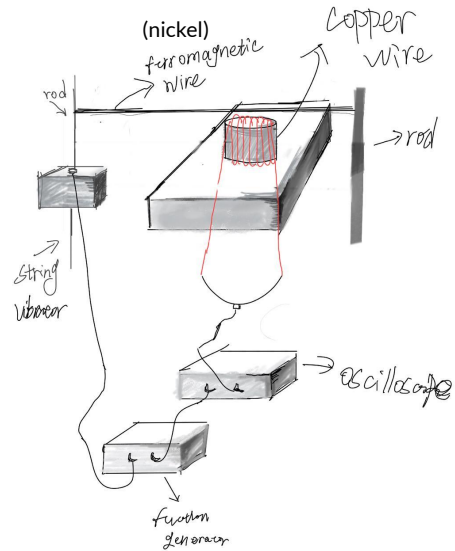
Methods and Challenges

Design of Experiment A

Story of failures

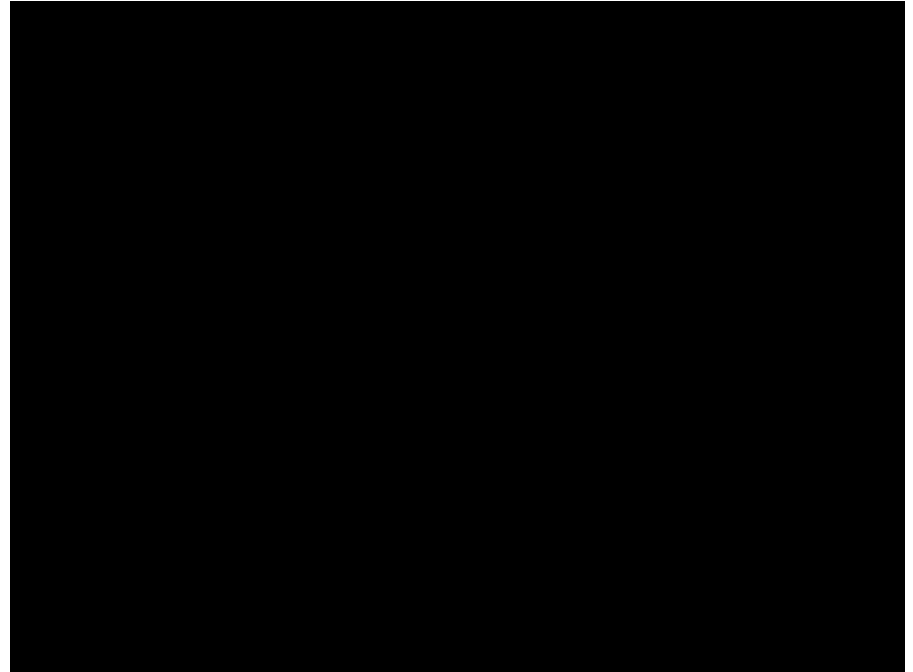
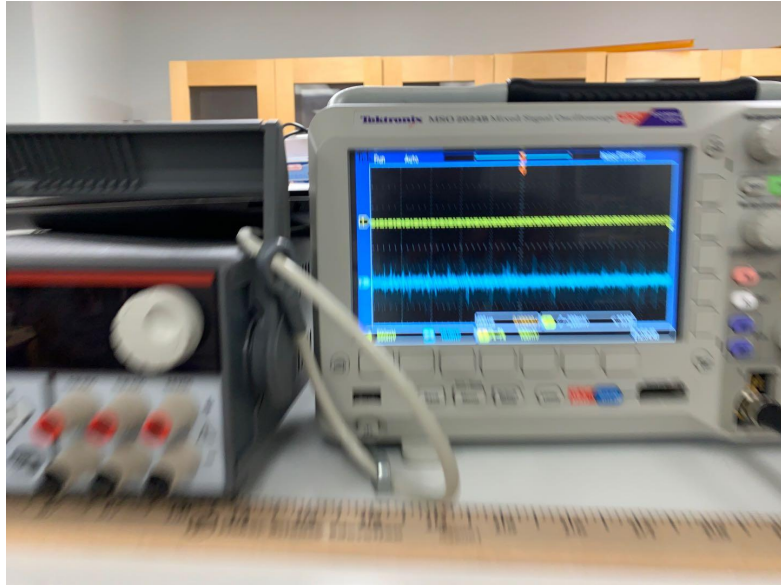


Initial Design---Oscilloscope+Function Generator

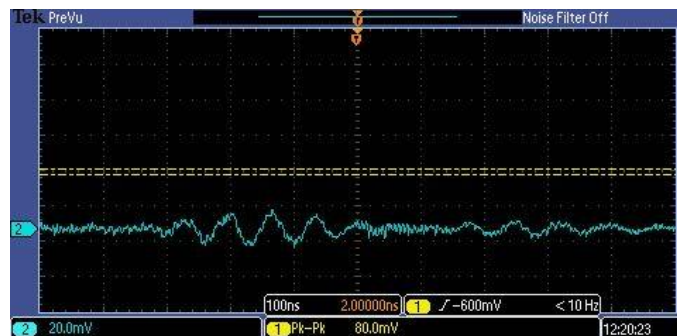
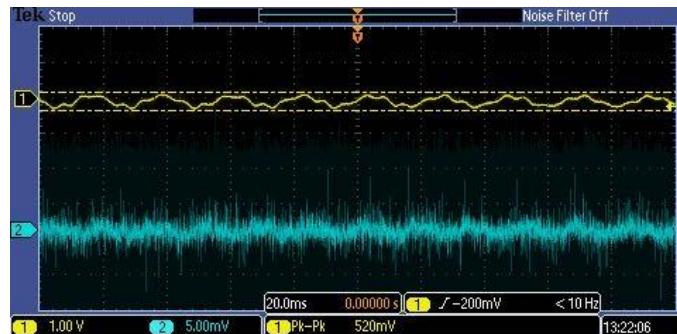
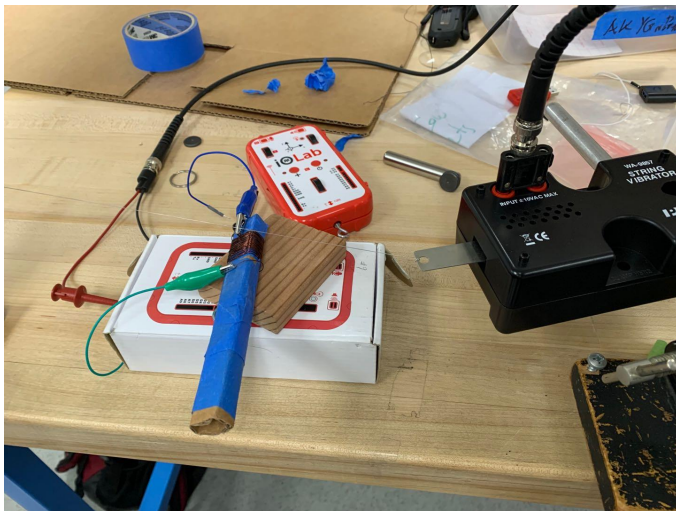


But Failed

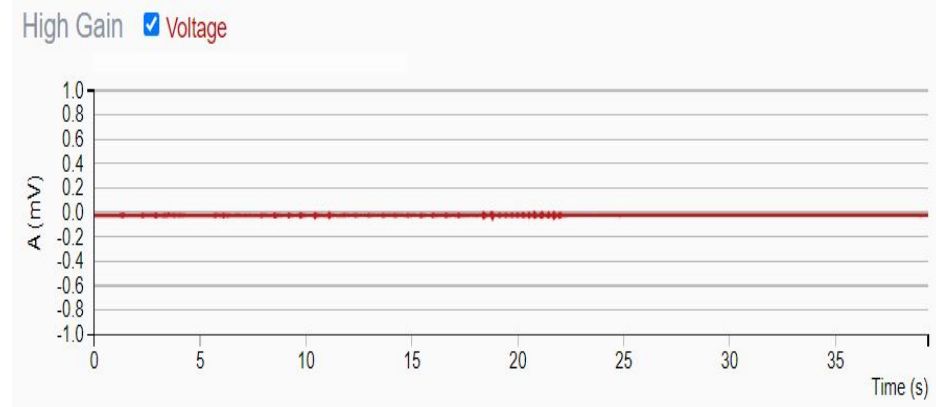
The oscilloscope didn't record anything, but...



Redesign Coil—Failed

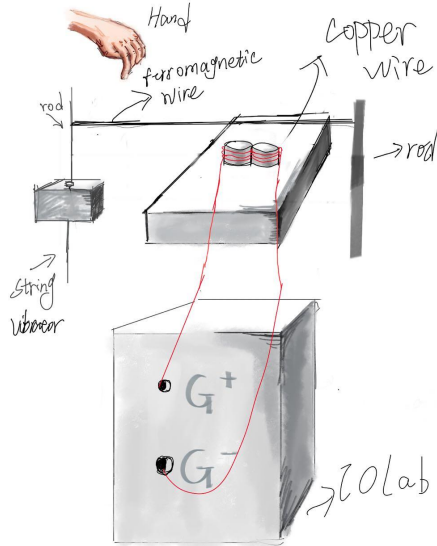


Redesign—IO Lab+Function Generator+New Coil

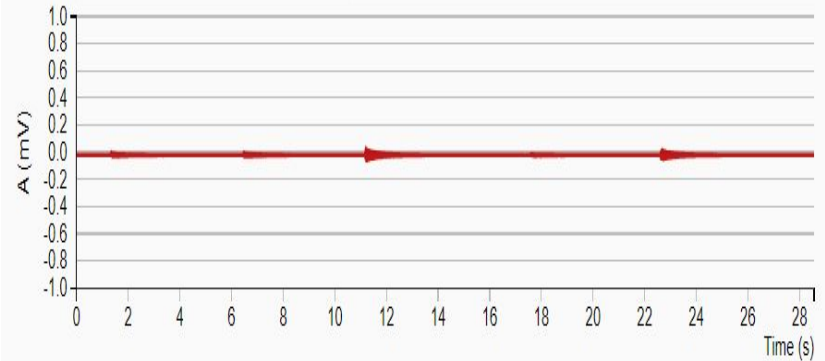


But Failed again...

re-re-Redesign—Hand Plucking



High Gain Voltage



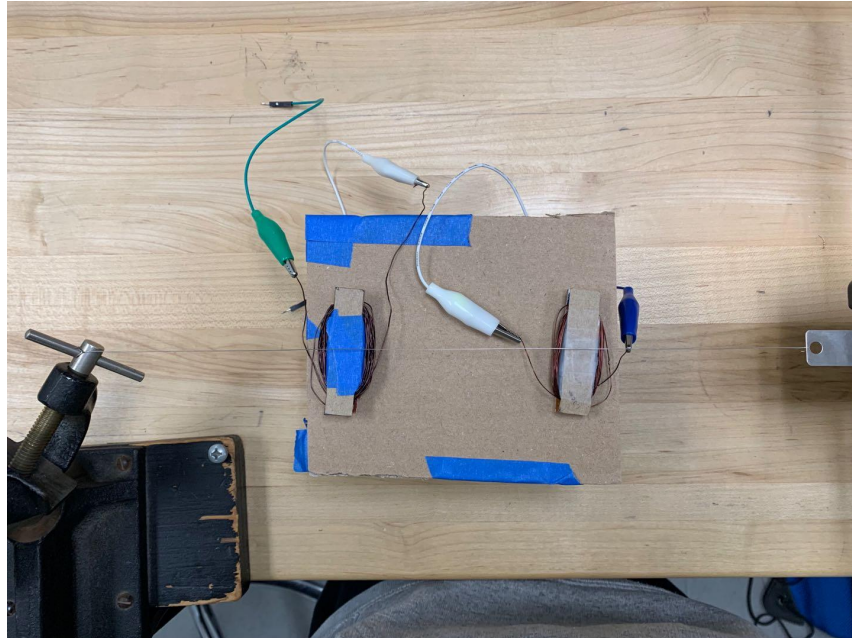
Design of Experiment B

How good will the noise be reduced

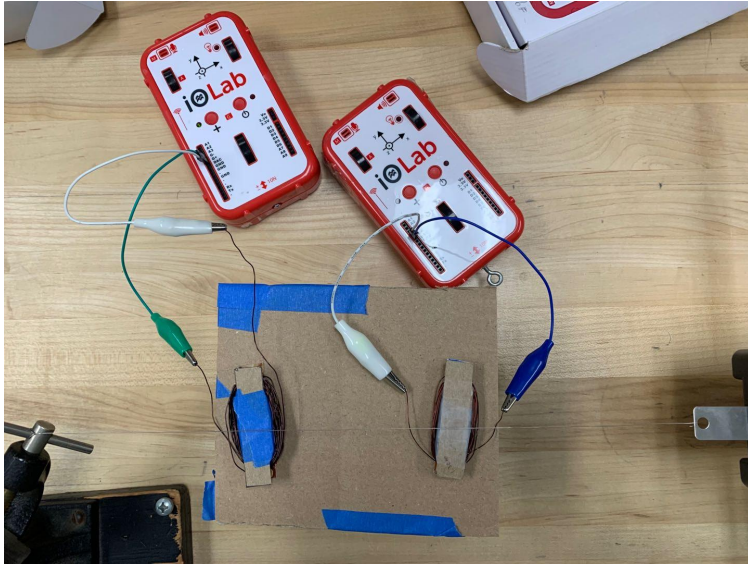




Coils in Series—Failed



Redesign—Two Individual Coils





Some Measurements ()"

Quantity	Measurement	Device
Magnet Diameter	1.280 ± 0.005 cm	Calipers
Cardboard Pickup Outer Length	5.740 ± 0.005 cm	Calipers
Cardboard Pickup Inner Length	3.330 ± 0.005 cm	Calipers
Cardboard Pickup Outer Width	1.300 ± 0.005 cm	Calipers
Coil Major Axis	4.445 ± 0.005 cm	Calipers
Coil Minor Axis	2.080 ± 0.005 cm	Calipers
Height of Wire	9.51 ± 0.05 cm	Meter Stick
Height of Vibrator	6.10 ± 0.05 cm	Meter Stick

Data Reduction and Analysis

Easier to cover both at once since we had two parts.

Part 1



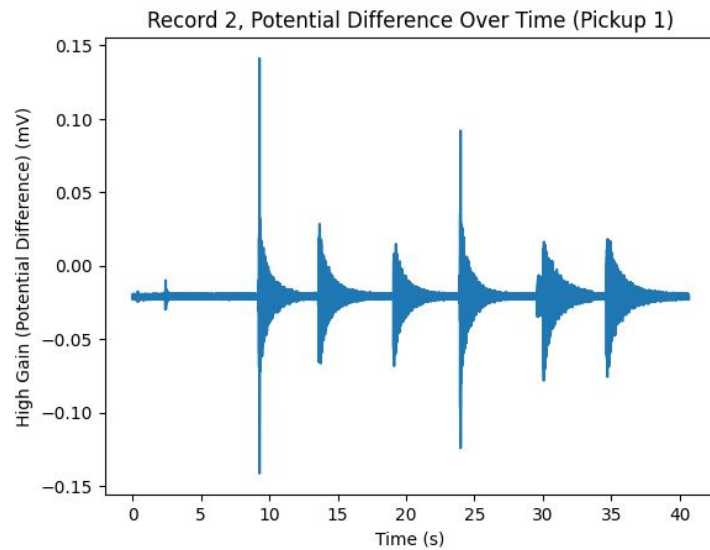
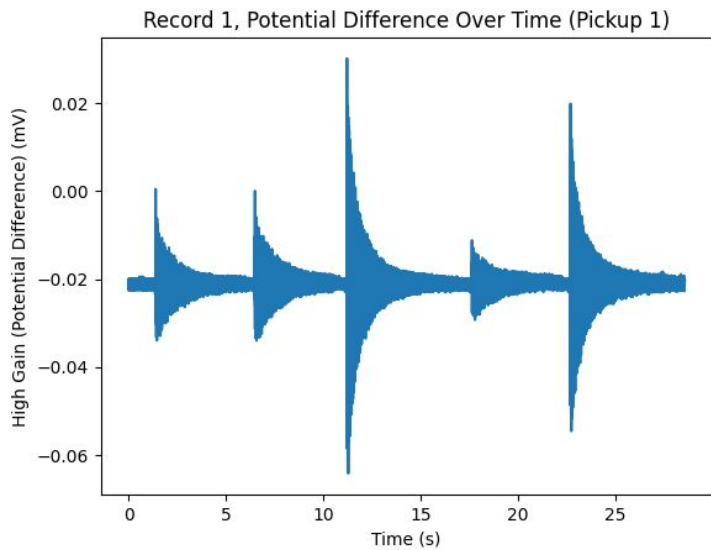


Methods for Data Reduction

- FFT of a Segment
- Dominant FFT Plot Whole Curve Over Time
 - “Segmentize” the curve and find dominant frequency for each segment
- Audio File Recovery and Qualitative Check

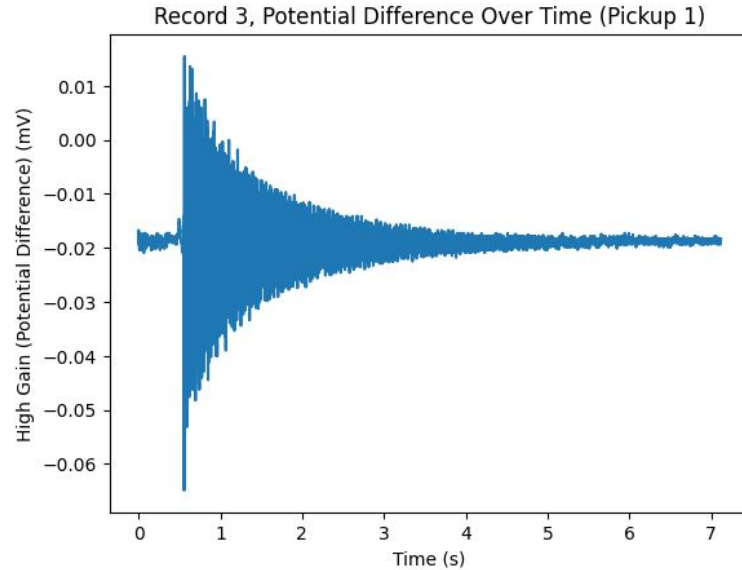


Plotting the Strings



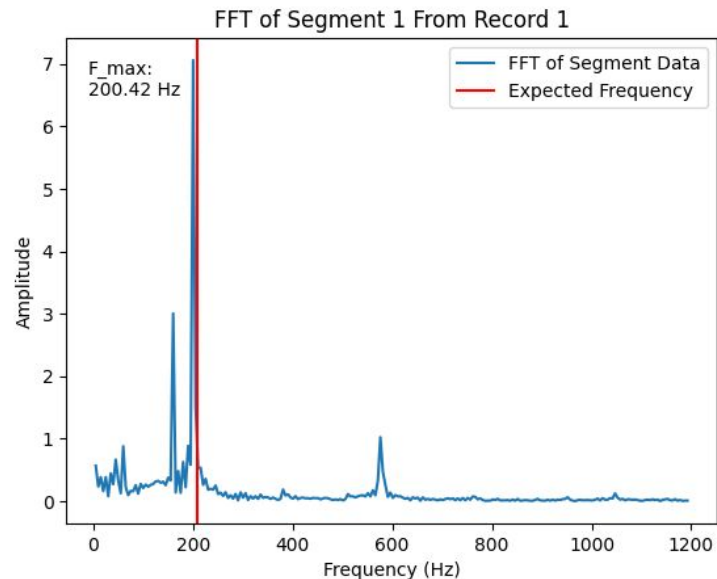
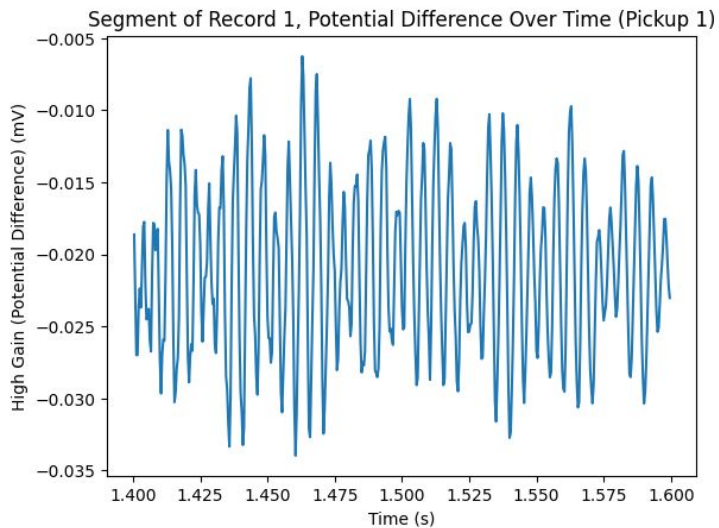


Plotting the Strings Cont.





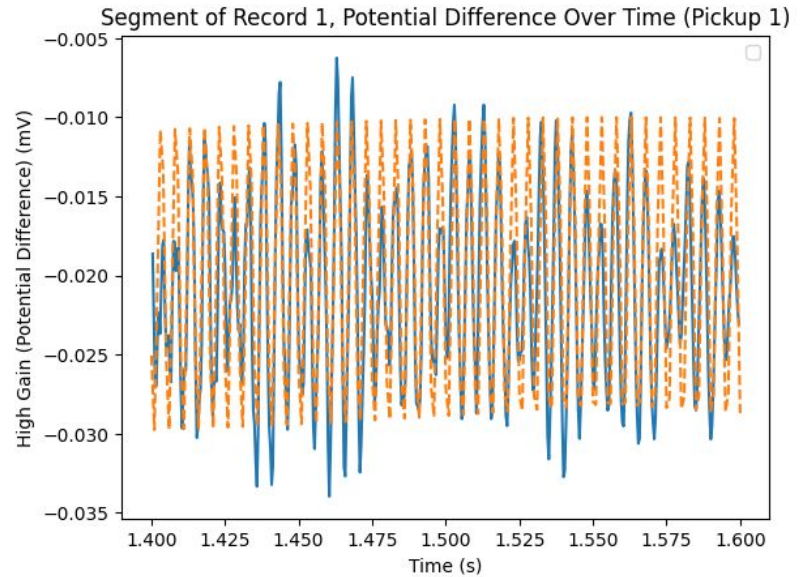
Record 1: FFT of Segments



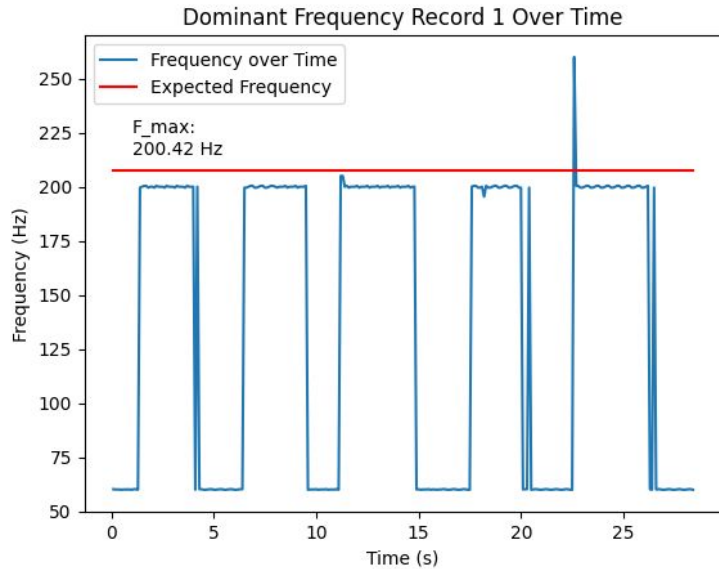
Relative Error:

What Does FFT Do?

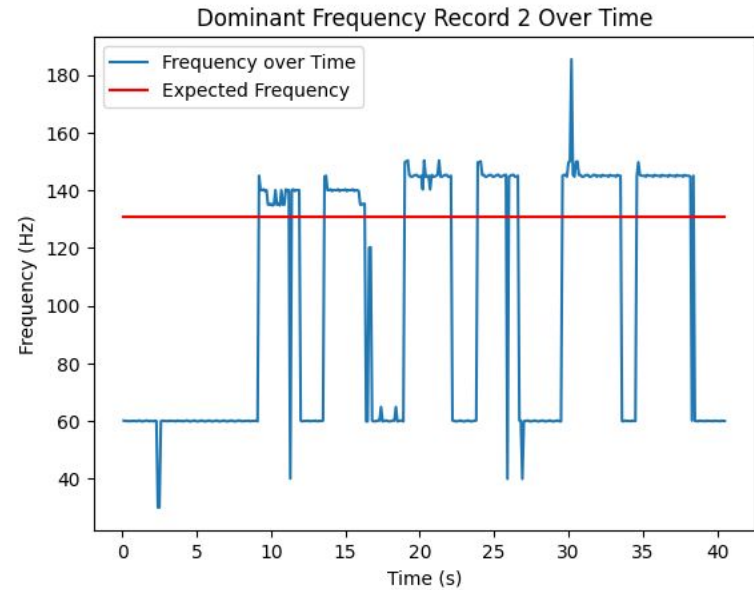
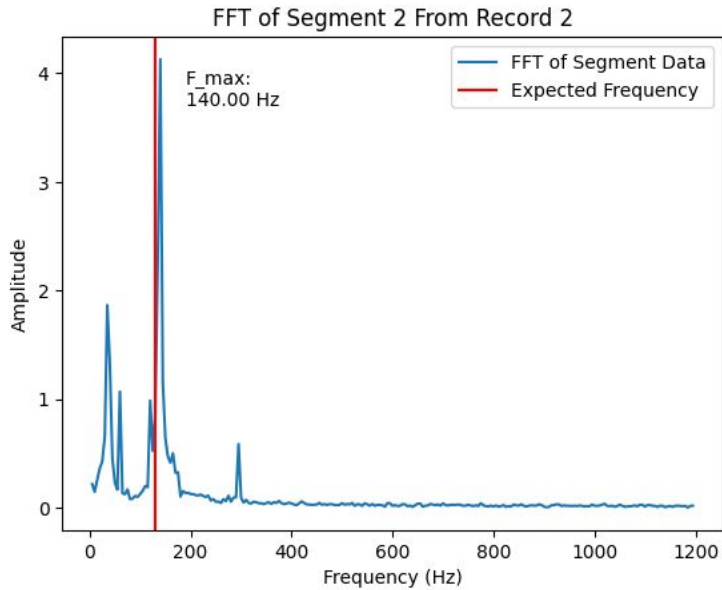
- Breaks down the signal
- Original model is not powerful enough



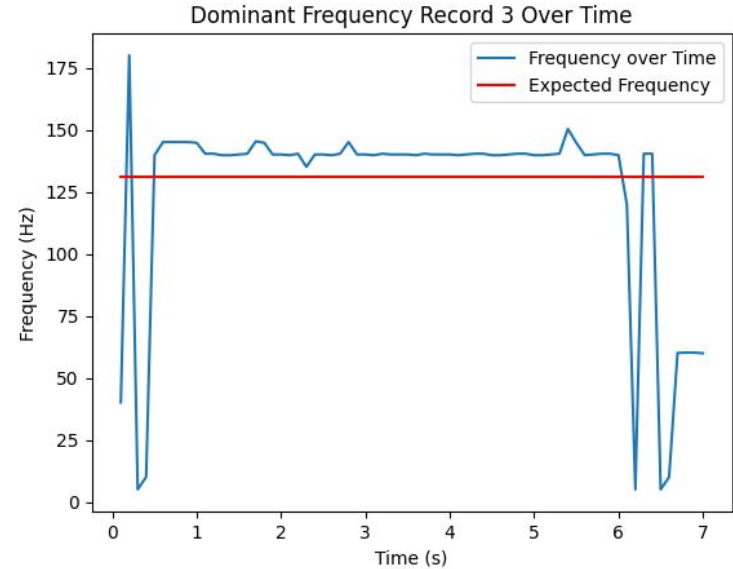
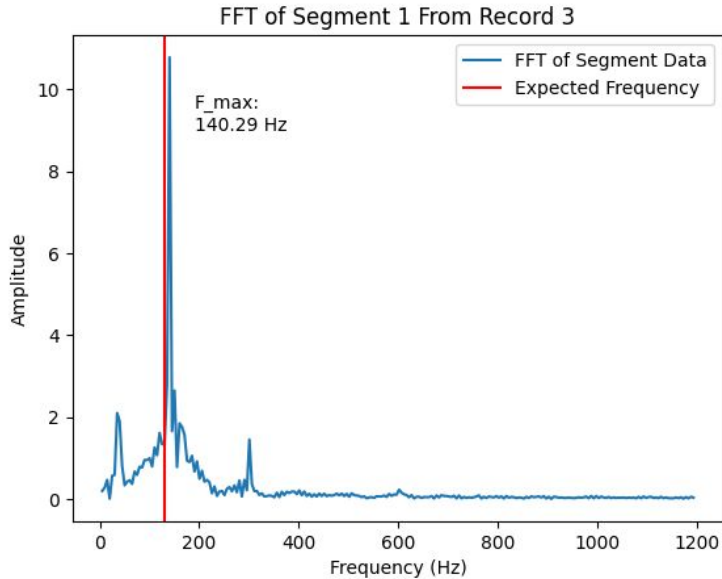
FFT Dominant Frequency over Time



Data Reduction for Record 2

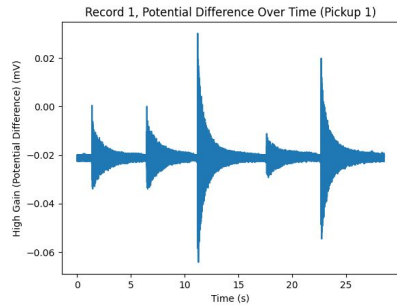


Data Reduction for Record 3





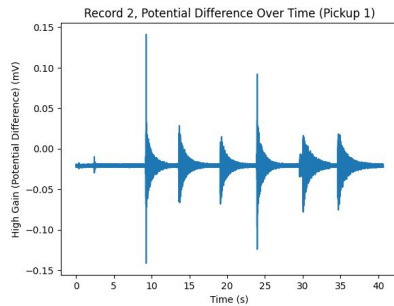
Audio Regeneration (The Fun Part)



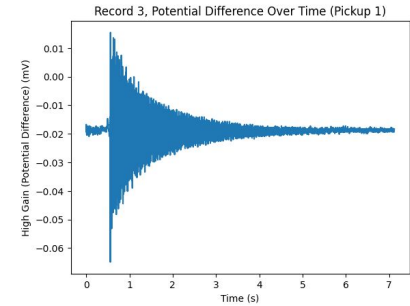
Record 1



Record 2



Record 3

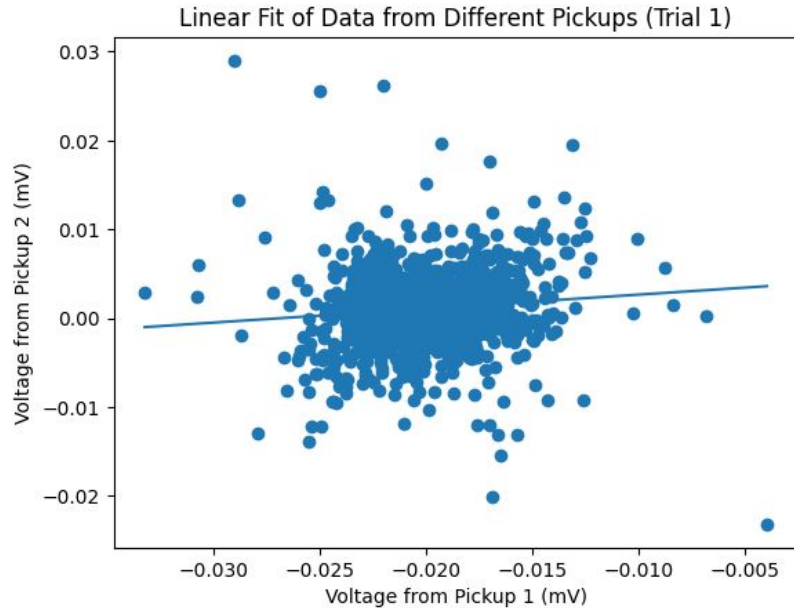


Part 2





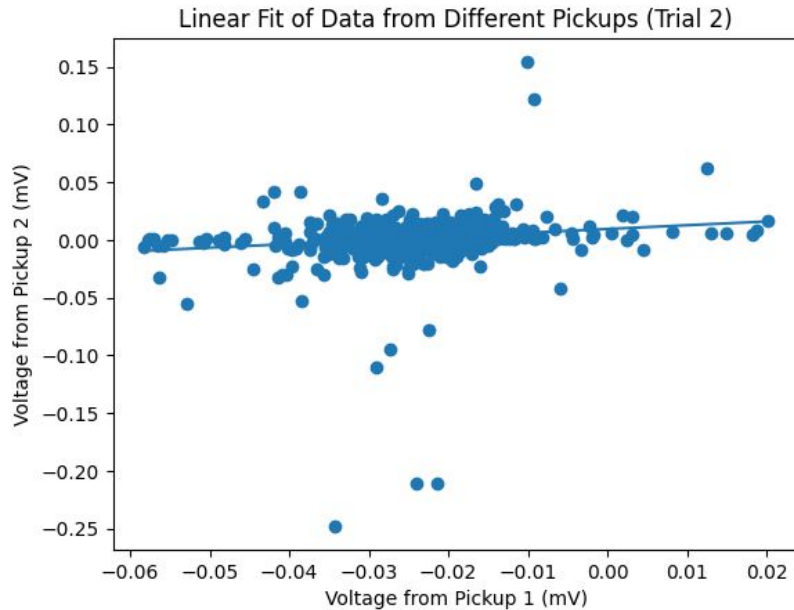
Faraday's Law Allowing Noise Reduction



- Clearly not a good fit
- Data does not appear to be linear



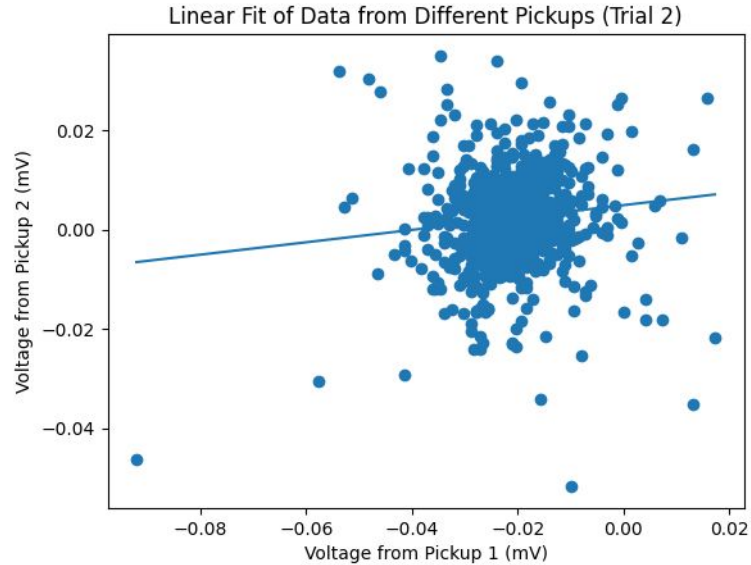
Noise Reduction



- Mmmm... much better?
- Seemingly linearish data



Noise Reduction

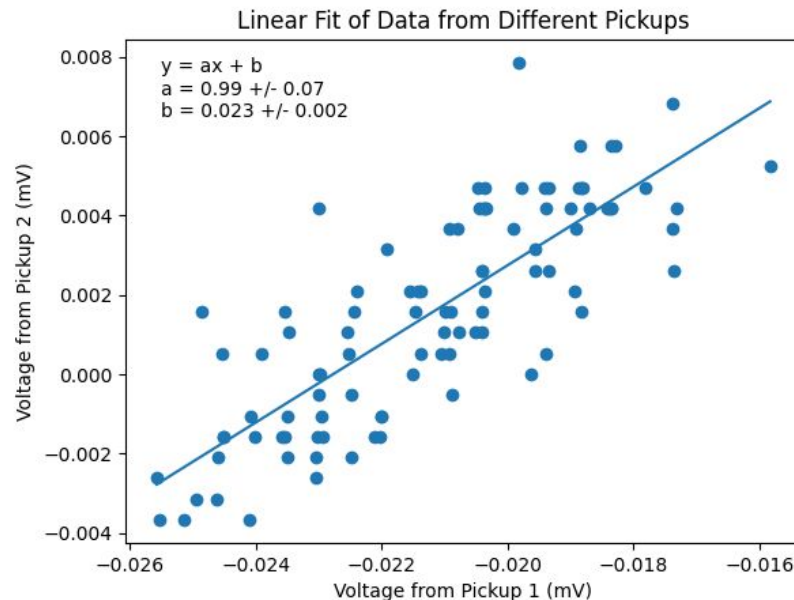
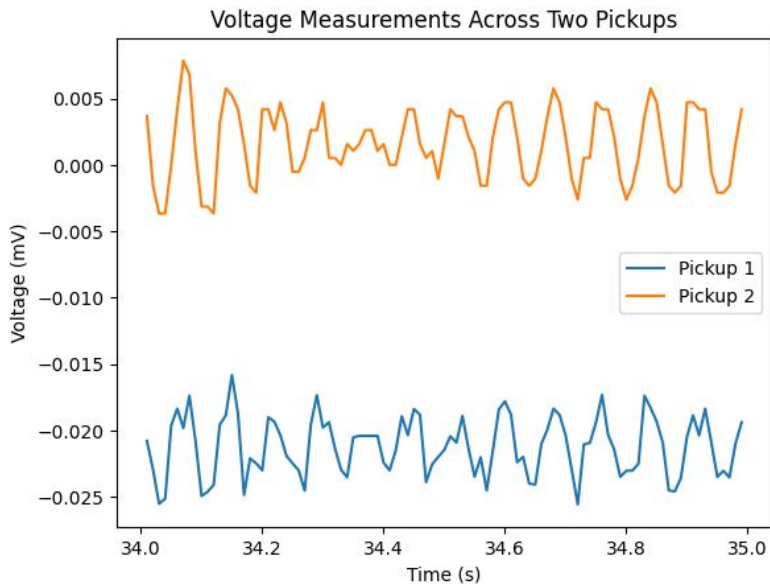


- Clearly not a good fit
- Data does not appear to be linear



Noise Reduction on Segment Data

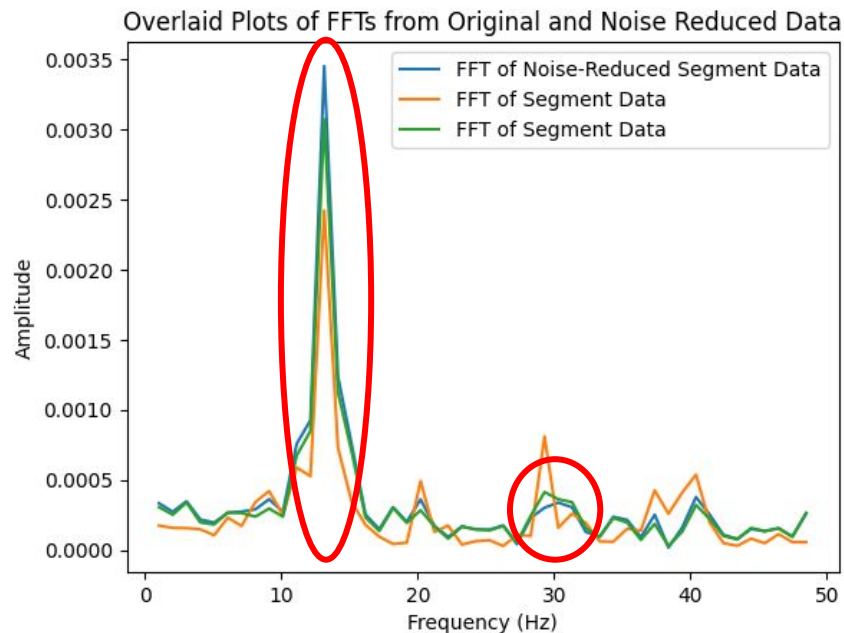
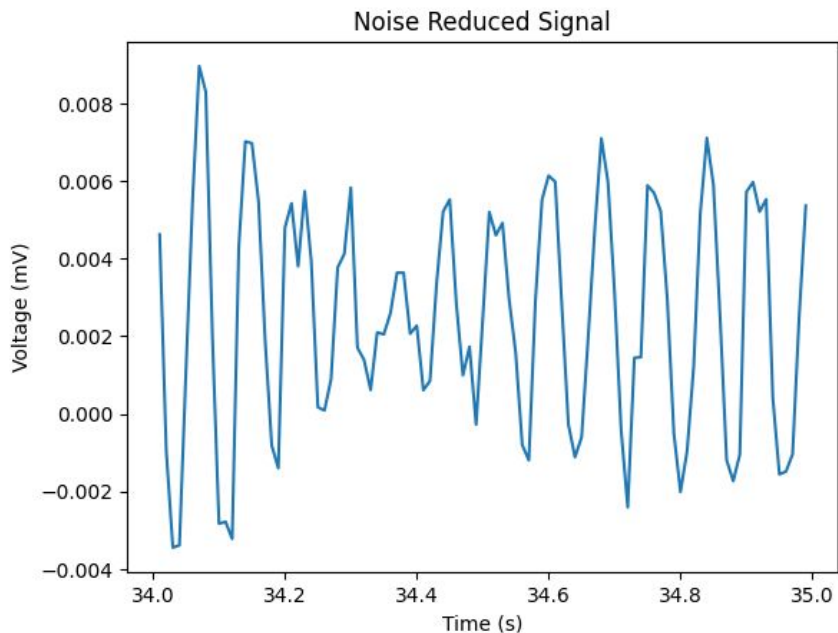
Error Data Unknown, Estimates
⇒ Chi Squared: ~10.12
⇒ Data-Driven Model



Pay Attention To: (since we added the signals)

- Where Blue > Green, Orange (Signal was Increased)
- Where Blue < Green, Orange (Signal was Reduced)

Voila...? 🧐



```
func = lambda a, b : a * segment['Voltage (mV)'] + b + segment['Voltage (mV)'.1']
```

Why do the Frequencies look wrong?



Sources of Errors

- Human Errors: Plucking too hard (impacting the tuning of the string or the distance between the string and the magnets)
- Noise and systematic errors in wires, iOLab Device, Calipers/Ruler
- Strong magnet in close proximity to wire could cause wire to oscillate differently



Closing Up



Future Directions

- Improving model for guitar string
- Reducing Errors
 - Implement better method for keeping string tight
 - Improved measurement tools with less systematic error
 - Better coils
- Comparing Sound Quality of Reduced Noise with Pickups vs. Digital Noise Reduction



Summary and Conclusions

We:

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- Experiment with Noise Reduction using Humbucker coil

and find that our initial model is insufficient to represent a true guitar string. We also find that Humbucker coils do indeed reduce noise in output.