The Pickup Project (HU-3910) [C21]

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Overview

Our project for this humanities practicum was to create and experiment with magnetic pickups intended for use in an electric guitar. A pickup is a device that generates an electric signal from the motion of guitar strings, thus allowing it to be amplified and played through speakers. The goal of this project is to experiment with the materials and techniques used to create guitar pickups and measure their effects on electrostatic properties, frequency response, and generated sound.

Theory

Lenz's Law: The metal strings over the pickup, when vibrating, cause changes to the magnetic field of the pickup. Because of Lenz's law, this change in the magnetic field induces a current in the wire coiled around the magnets. This current is what is amplified and eventually played through an amp.

Initial Assembly(w/ magnets)

- *Overview:* In this stage, the overall structure of the pickup is made, and the magnets secured in place.
- *Variables:*
    - Magnets used (Standard: Alnico V)
- *Summary:* We worked with stratocaster pickups (strat pickups) throughout this term. A stratocaster pickup has a single coil around magnets that correspond to each of the strings

of the electric guitar.

We worked with kits provided to use in the music lab, which contained sets of these magnets as well as two plates to put them into. We followed the instruction booklet for the placement of each magnet, and then used a combination of the drill press and hammers found within the lab to secure each of the magnets in place.

- *Q/A:*

  Q: Does the orientation of the magnets matter?

  A: Yes, it is extremely important that all the magnets have the same polarity. For the kits, the set of matching sides on each magnet are marked with a blue dot.

  Q: Is there a specific spacing to maintain between the two plates?

  A: Yes, check the instruction booklet. The kits come with rubber spacers that are this exact length if you wish to use them.

  Q: The magnets are different lengths, does it matter which magnets go to which strings?

  A: Yes, the instruction booklet explains this orientation in detail. In general, the longest magnets go in the middle, while shorter magnets go on the outsides.

Winding

- *Overview:* The wire to take advantage of Lenz's law is wound around the structure created in the assembly step.
- *Variables:*
    - Wire gauge (Standard: 42 AWG)
    - # Of Turns (Standard: ~6k)
    - The wind itself
- *Summary:* This process uses the pickup winder found in the lab. To set up the pickup winder, first mount the pickup into it. This is done over the screw on the part of the device that rotates. Secure it into place with another piece of metal and a lock nut.

  Begin fastening the string to the pickup now. Through one of the holes in the pickup, coil the string approximately 8 times. Then, give it a few manual turns around the pickup in the desired direction. Align the coil of wire below the machine, and ensure the wire goes up and over the metal bar on the pickup and then feeds into your pickup. Ensure that this metal bar (the one with lock collars) has its lock collars tightened in line with the edges of the two plates of the pickup, to prevent the wire from slipping off of the pickup.

  Now, plug the pickup machine in, and turn it on. Program the machine to do the desired number of turns in the direction that matches how you have set up the pickup. Begin winding slowly at first, and pick up speed as you go.

As you wind, work the wire back and forth, making the coil grow outwards evenly. The "Perfect Lay" would be a wind that is exactly even. This would entail a lot of problems from electrostatic problems, but making it too asymmetrical may lead to problems as well. Keeping a balance of randomness and evenness is what gives each pickup different audio qualities.

The machine should stop automatically once finished. Toggle the run off, turn the speed dial down to 0, turn the machine off, and unplug it for safety. Then, cut the wire at a reasonable length and make 8 coils through the other hole in the pickup. Remove the pickup from the machine.

- *Q/A:*

  Q: Why does the coil go below the machine?

  A: The wire can be uncoiled from the top and bottom of a coil, the edges are designed so that this is possible without cutting the wire. Doing it in other configurations would necessitate the coil itself moving, and thus having torque applied to it by the wire. The wire is exceedingly thin, and this would instantly snap it in most cases.

  Q: Is there a correct direction to wind the pickup?

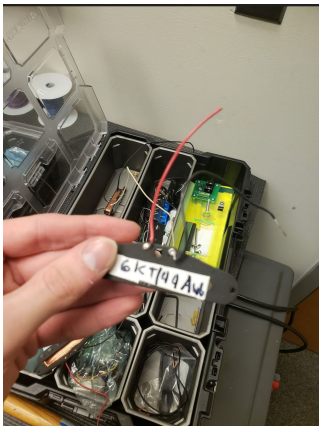
  A: No, just keep it consistent for convenience so that your hot wires all align across multiple pickups.

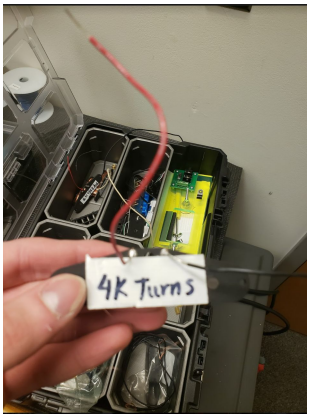
  Q: How fast is too fast?

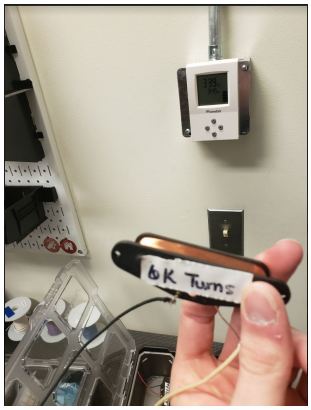
  A: Go as fast as you are comfortable with, so long as you can get a generally even wind on the pickup.

  Q: What should I do if the wire snaps or falls off the edge of a pickup.

A: If this is not immediately fixable, it's most likely beyond salvage. Dismount the pickup, use a cutting device to remove the wire currently coiled on, and retry.







Soldering

- *Overview:* Solder leads into the pickup.
- *Variables:*
    - N/a
- *Summary:* To prepare, materials, locate the fan (for removing toxic fumes) and place it over the area you will be working. Get the wires you will use as leads (preferably two different colors to more easily distinguish the two outputs. Strip the wires using a wire stripper in the lab.

  You will solder individual components, and then reflow the solder to combine them. First start with both places the wire is wrapped ~8 times on the pickup. Use the soldering iron to heat up the metal coil, and then touch the solder to it. When the wire/terminal is hot enough, the heat will melt the solder over it. Generally, it is ideal to heat the target of

the solder to the point of melting the solder, instead of directly melting the solder.

Now, do the same for one end of both wires you have selected. Finally, heat the terminals on the pickup to reflow the solder, while pressing the soldered end of the wires into these terminals (one at a time). This should reflow the solder and cause the wire and terminal to become fused.

- *Q/A:*

  Q: Should I wait between soldering the same component?

  A: Yes, you should wait until it has fully cooled off. Some materials, if soldered repeatedly in quick succession, may char and/or become damaged in some way.

Testing

- *Overview:* Once the pickups have been soldered with different colored wires attached, various dependent variables are tested.
- *Variables (Dependent):*
    - Sound
    - Frequency Response
    - Resistance
    - Inductance
    - Capacitance
- *Summary:* First, measure the resistance, inductance, and capacitance of the pickup using the LCR meter. Connect the leads to the matching alligator clips from the LCR meter. For inductance and capacitance, measure them for both the 120 Hz setting and the 1k Hz setting.

  Moving onto the frequency response, you will need a function generator, an oscilloscope, and a resistor with magnitudes more resistance than the resistance of the pickup. Attach the function generator to one end of the resistor. To the other end, place the hot ends of both the oscilloscope and the pickup. Attach all of the ground leads together (function generator, oscilloscope, and pickup). We did not use a breadboard to do this, but doing so may make the process easier. We then tested various frequencies on the function generator, and measured the peak to peak voltage on the oscilloscope. Later, we graphed these values and fit them with an x^3 fit.

Finally, we utilized the pickup tester in the lab to produce audio. We mounted the pickup tester such that when the pickup was laid on top of it, it was just barely hovering over the wires of an electric guitar. We used alligator clips to connect the leads of the pickup to the terminals on the tester, which then allowed us to directly plug in an amp cord. We plugged the amp cord into an amp within the lab, and recorded the generated sounds when plucking the guitar strings.

- *Q/A:*

  Q: My numbers do not seem entirely correct, what could be wrong?

  A: The LCR meter has two different modes, series and parallel. Ensure it is in series mode.

  Q: How many values should I measure for the frequency response?

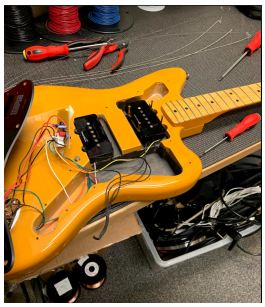
  A: Bob Palmieri told us that we could double the frequencies until it began dropping off, to ascertain the frequency response in terms of octaves. Feel free to measure more, the goal is to find where the response peaks.

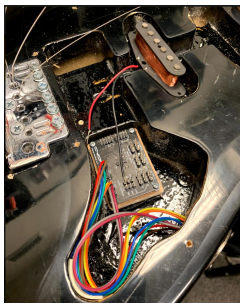
  Q: Where should the pickup be mounted over a guitar for the best audio output?

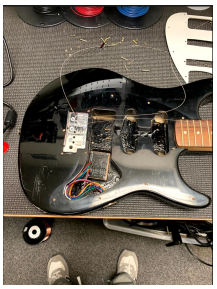
  A: Try to keep it away from other pickups as best you can, to avoid having their magnetic fields interact.

Installing and Future Work

The next step for the team following our progress should begin to work on integrating the pickups we've designed into a Stratocaster Electric guitar. Our team attempted to install our designed pickups into two different electric guitars, but because they were not Stratocasters, this task did not come to fruition. The next team should focus on properly installing the pickups we have made into a guitar that accepts the single-coil fender pickups, most likely a stratocaster or telecaster. It is important to sample the sound a pickup makes when installed within a guitar, because different parts of guitar string create different audio artifacts. In addition to installing pickups into a guitar, continuing testing while focusing on different variables of the pickup are essential to advancing this project. Testing variables like magnet type and direction should be tested using the same AC voltage measurement while increasing frequency to compare these variables and evaluate the optimal pickup parameters.







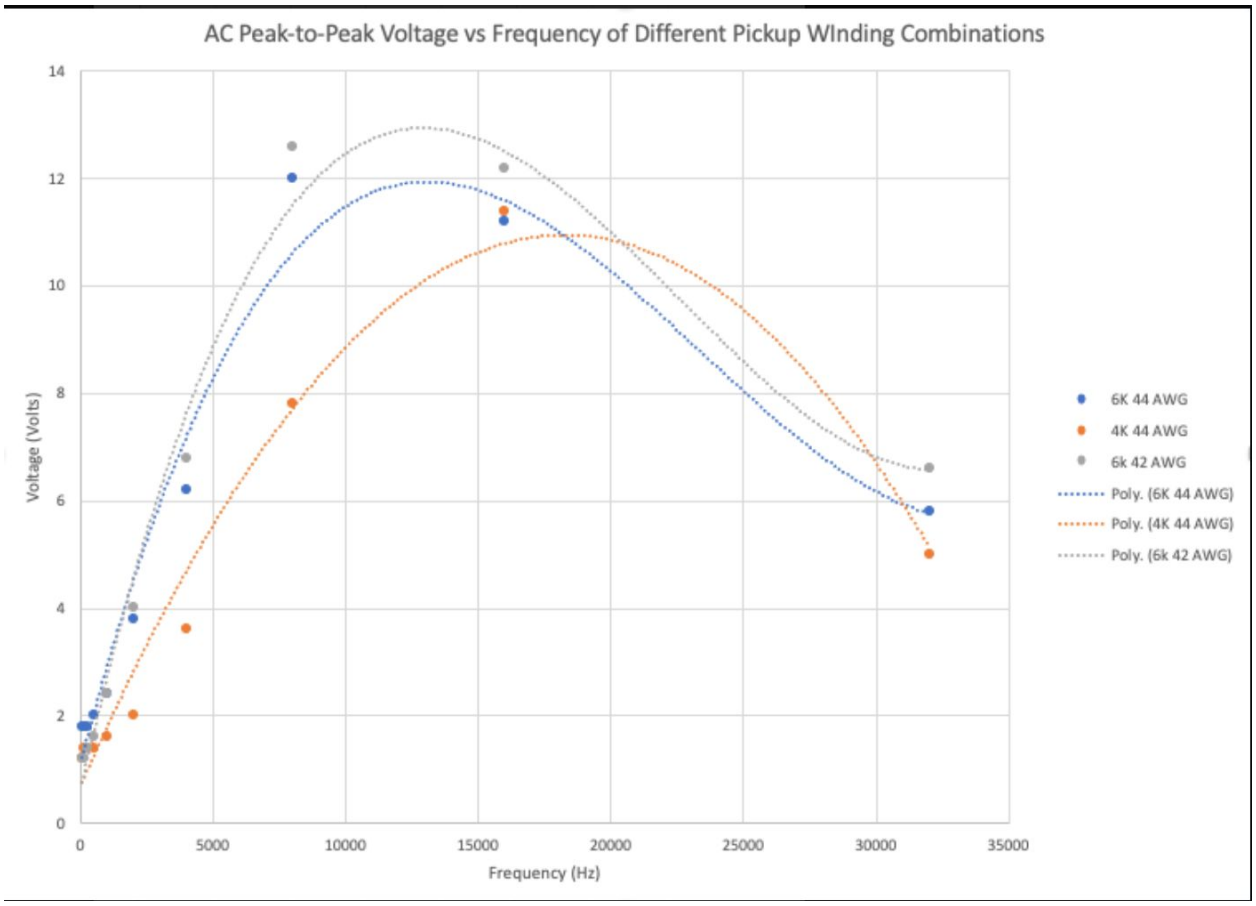
Figures

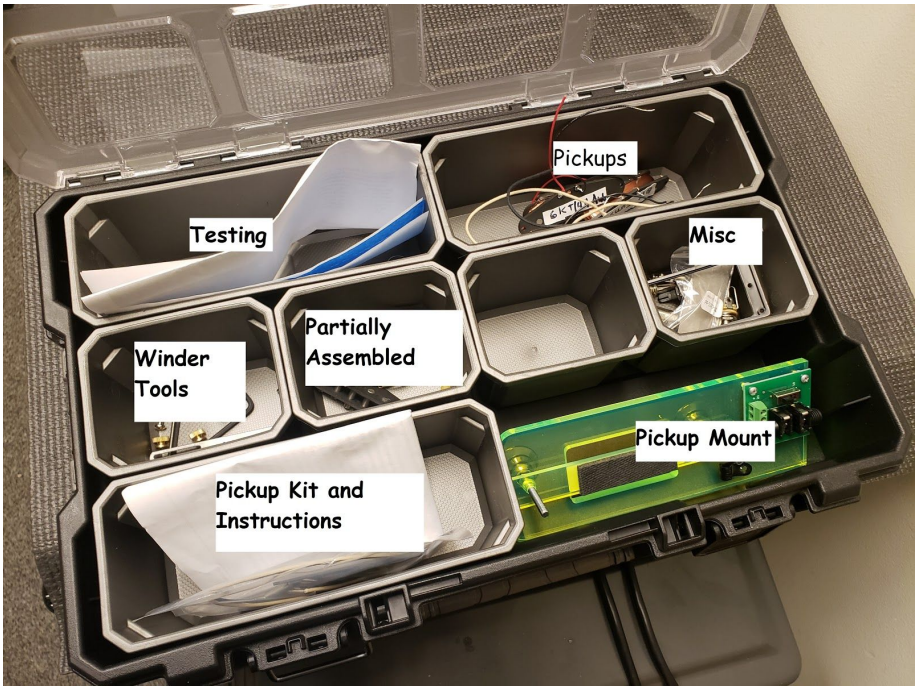
	4k Coils (44 AWG)	6k Coils #1 (44 AWG)	6k Coils #2 (42 AWG)	
Resistance AC (120)	4.4 kΩ	6.7 kΩ	4.3 kΩ	

Resistance AC (1K)	4.4 kΩ	6.7 kΩ	4.3 kΩ	
Inductance (120) s	0.56 H	1.3 H	2.4 H	
Inductance (1k) s	0.56 H	1.3 H	1.7 H	
Capacitance (120)	3.0 mF	1.4 nF	1.3 mF	
Capacitance (1k)	46 nF	21 nF	20. nF	

Below: Measured across a 62k Ohm Resistor (Blue Red Orange Gold)										
	60	120	250	500	1000	2000	4000	8000	16000	32000
6k 44 AWG P2P	1.8V	1.8V	1.8V	2V	2.4V	3.8V	6.2V	12V	11.2V	5.8V
4k 44 AWG P2P	1.2V	1.4V	1.4V	1.4V	1.6V	2V	3.6V	7.8V	11.4V	5V
6k 42 AWG P2P	1.2V	1.2V	1.4V	1.6V	2.4V	4V	6.8V	12.6V	12.2V	6.6V

Frequency	Voltage		
60	1.8	1.2	1.2
120	1.8	1.4	1.2
250	1.8	1.4	1.4
500	2	1.4	1.6
1000	2.4	1.6	2.4
2000	3.8	2	4
4000	6.2	3.6	6.8
8000	12	7.8	12.6
16000	11.2	11.4	12.2
32000	5.8	5	6.6


AC Peak-to-Peak Voltage vs Frequency of Different Pickup WInding Combinations
Voltage (Volts)
Frequency (Hz)
0
2
4
6
8
10
12
14
0
5000
10000
15000
20000
25000
30000
35000
6K 44 AWG
4K 44 AWG
6k 42 AWG
Poly. (6K 44 AWG)
Poly. (4K 44 AWG)
Poly. (6k 42 AWG)


Pickups
Testing
Misc
Partially Assembled
Winder Tools
Pickup Mount
Pickup Kit and Instructions