Winding Single-Coil Pickups for a Fender Stratocaster Electric Guitar

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Abstract

The goal of this project is to construct three single-coil guitar pickups that recreate 50s & early 60s Stratocaster's pickups. Then these pickups will be used to replace all three pickups on my 2010 American made Fender Stratocaster. Properties of each self-made pickup will be measured, as well as that of the original pickups on my Stratocaster. The final step is to compare the data sets to see if the self-constructed pickups outperform the original pickups on my Stratocaster, or if they do not match up with the quality of the original pickups, then what improvements can be made.

This report describes the process of making single-coil pickups in detail, which involves basic setup, coil winding, potting and magnetizing. The necessary tools and useful techniques will be explained in each step of the pickup construction. Each step is equally important and it is crucial to do each part correctly in order to construct a pickup with decent quality and to avoid possible reconstruction. Finally, this report will compare the measurements of the electromagnetic properties of self-made pickups and original pickups; the results show that the self-made pickups have similar properties to that of the original pickups. As a result, this project is a success in general and only minor improvements need to be made.

Construction of a Single-coil Pickup

Fender Stratocaster single-coil pickups have the following components: two pieces of flatwork (bottom and top), six Alnico 5 pole pieces (with different heights and one for each string of a guitar), wire for the pickup coil (I used poly-coated 42AWG copper wire), a pickup cover and hookup wires (to connect the pickup to the guitar). Also, two mounting screws and two spring tubes are necessary to mount each of the pickups onto the pickguard. Pickup kits and wires can be purchased online. I bought the Stratocaster pickup kits from Stew-Mac and the pickup wire from Amazon at reasonable prices.

Figure 1: Materials Needed for Single-Coil Pickups

Basic Setup

The basic setup is the first step in constructing a single-coil guitar pickup, and it includes three parts: prepare the flatwork, install the pole pieces, and then install the top flatwork. The basic setup is quite simple, yet it is very important. If it is not done correctly, it will affect the following steps of the pickup construction.

Prepare the Flatwork

Round the edges of the fiber flatwork very carefully with fine-grit sandpaper, in order to remove any roughness that may catch the thin wire during the coil winding process. Note that winding the coil wire is a work of zero-tolerance. If the wire is broken during winding of the pickup coil, then everything done is in vain and a new winding needs to take place. On the bottom piece, countersink the underside of the eyelet hole, in order to better fit the eyelet and allow it to expand and grip more securely to the flatwork. Insert the eyelet into the underside of the flatwork. The small end of the eyelet will be facing up for setting.

Install the Pole Pieces

For a Fender Stratocaster, each pickup kit contains six pole pieces of three different heights. They are for the six different strings of the Stratocaster. In standard guitar tuning, the two longest pole pieces are for the D and G strings, and the shortest is for the B string. The remaining three are the same length, they are for the E, A, E strings (as shown in figure 2). Detailed installation of the pole pieces is described in the following section – install the top flatwork.

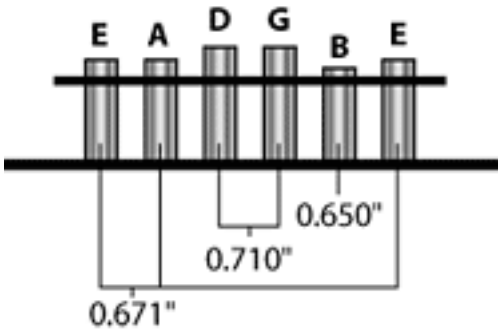


Figure 1: Basic Setup

Install the Top Flatwork

When installing the top flatwork, it is important to leave a 7/16"-15/32" gap between the top and bottom flatwork for the pickup coil. The pole piece holes on the flatwork, especially that of the top flatwork, are a little tight for the pole pieces to fit in. I used a plastic hammer to hammer the pole pieces into the flatworks. Do not use a steel hammer because the fiber flatworks are quite fragile. One of the flatworks was bent over when I hammered it too hard, and I needed to buy a new flatwork to replace it. Hammer down the pole pieces so that at they are flush with the bottom surface of the bottom flatwork, as shown in figure 2. It is recommended to do this step on a flat, rigid plate.

Pickup Winding

After finishing the basic setup, the next step is to wind the pickup with wire. In my opinion, pickup winding requires the longest time and the most technique. I spent almost three hours winding the first pickup, but as my experience increased and winding technique improved, the winding of the second and third pickups took me 100 minutes and 50 minutes, respectively.

The description of how to wind a single-coil pickup is as follows: The coil wire I chose to use was poly-coated 42AWG copper wire. Since the diameter of this wire is only 0.0027 inches and can be easily snapped, extra care is needed when dealing with such wire. We used a motorized coil winding machine to wind the wire. The coil winding machine has two sides, which give clockwise and counter-clockwise coil winding sense. Since I chose to wind all three pickups with clockwise winding sense, the pickups needed to be magnetized with different polarity in order to create a humbucking effect (I discuss magnetizing the pickups later). The coil winding machine also has a counter, to counts the number of turns wound on each pickup coil. A speed control is located on top of the coil winding machine. Usually, the speed control knob is set at the eleven o'clock direction for "normal" winding speed. Back tension on the wire is also needed in order to hold the wire in place on the pickup coil, and so that it does not fly around during the winding process and get snapped.

Figure 3: Pickup Winding

The most important part of winding a pickup is to direct the wire by hand such that the wire winds uniformly onto the pickup. As shown in figure 3, there are two limit screws on the winding machine; each limit screw should be adjusted to the inner width of the top/bottom flatwork, which also must be parallel to each other. This determines the position of the limit screws such that when we direct the wire by hand, the wire will not go beyond the inner width of the top/bottom flatwork. When winding the pickups, I used the thumb and index finger to hold the wire carefully and directed the wire between the two limit screws with constant speed. It also helps a lot to keep one's hands dry and clean, such that one's fingers do not give too much tension on the wire – then the pickup coil winding will proceed smoothly. The other hand is used to control the speed of the winding machine, in case unexpected things happen (e.g. the wire goes beyond the flatwork), the winding machine can then be stopped at a gradual pace.

Each pickup coil needed 8,000 turns of wire for a 50s & early 60s Fender Stratocaster pickup. When winding one of the pickups, the wire snapped at 6000 turns, and the frustration was evident, but the happy moments came when a pickup was successfully wound, no matter how long it took. So do not rush when winding a pickup, be patient.

Potting the Pickups with Wax

After winding, Professor Errede and I soldered the signal lead and ground wires of the pickup coil to their respective eyelets (middle pickup with opposite lead polarity for hum-cancelling) and then potted the pickups with wax. The purpose of potting a pickup is to make the wires of the pickup coil stay in place such that they cannot vibrate in the sound field of the guitar amp and produce microphonic feedback. A small glass jar containing a mixture of 80% paraffin + 20% beeswax (by weight) was placed inside a crock pot filled with water, which is used to heat the jar of wax. A cooking thermometer was placed inside the jar of wax in order to closely monitor the temperature (note that the flash point of the paraffin wax – beeswax mixture is ~ 395^{o} F). An appropriate (and safe) temperature for potting pickups is around 160 degree Fahrenheit. When the pickup potting setup reached this temperature, we immersed the pickup in the small jar of now-melted wax. Air bubbles from the pickup start rising to the surface of the liquid wax. When there were no more air bubbles coming out, the potting was finished. Potting a pickup usually took around 25 minutes.

The pickup potting setup is shown in Figure 4. After potting, it is necessary to take some time to leave the pickups in a safe place to cool down.

Figure 2: Potting Pickups with Wax

Magnetizing/Charging the Pickups

The final step to complete the construction of a single-coil pickup is magnetization. With all three pickup coils wound clockwise, they needed to have different magnetic polarity in order to work properly, hum-cancelling wise. For a Fender Stratocaster, in this case, the bridge and neck pickups should both have the same magnetic polarity (south polarity in top view), and the middle pickup should have the opposite magnetic polarity (north polarity in top view). The setup for magnetizing a pickup is shown in Figure 5.

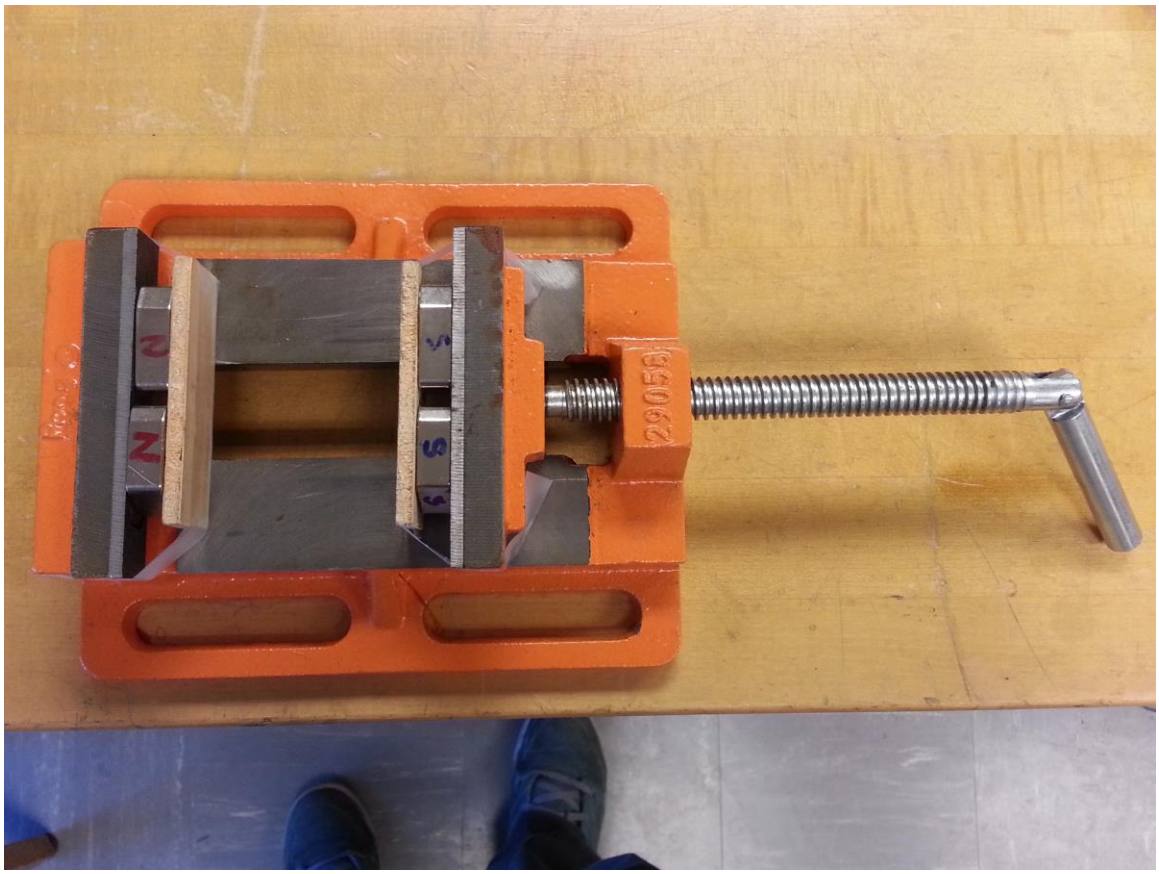


Figure 3: Magnetizing a Pickup

Two pairs of very strong rare-earth magnets, each with south and north polarity were attached to the inside of a steel machine vise as shown in Figure 5. The spacing between the rare-earth magnets needs to be a slightly wider than the actual width of the pickup (i.e. the space between top and bottom flatworks). It is also important that the pole pieces of the pickup do not directly contact the powerful rare-earth magnets (very difficult to pull them apart}. We used 1/8" thick plywood shims to accomplish this. Once the vice was set up properly, we slowly put a pickup into the space between the rare-earth magnets, oriented properly for the desired magnetic polarity - facing the corresponding north or south magnet and then slowly closed the vice. A single-coil pickup was thus constructed!

Pickup Data Measurements and Comparison

Upon finishing the pickups, Professor Errede helped me take important measurements of these self-made pickups and the original pickups on my Stratocaster, as we wanted to compare the results to see how well the self-made pickups performed. Figure 6 shows the setup that we used to take measurements and other tables and graphs show the data sets. For comparison, these tables and graphs will be categorized as neck, middle and bridge pickups, with each containing the data from the self-made and the original pickups. Some important pickup properties that we measured were the DC resistance of the pickup, the resonant frequency f, the quality factor $Q = f/\Delta f$ and the pickup impedance at resonance, $Z(f)$.

Figure 4: Setup for Measurements, the pickup is placed inside the hole.

Table 1: Neck Pickup, self-made vs. original

Neck Pickup	DC Resistance (KΩ)	Resonant Frequency (KHz)	Quality Factor (Q)	Z at Resonance (KΩ)
Self-made	6.04	8.215	6.04	869.06
Original	5.99	8.235	8.07	932.42

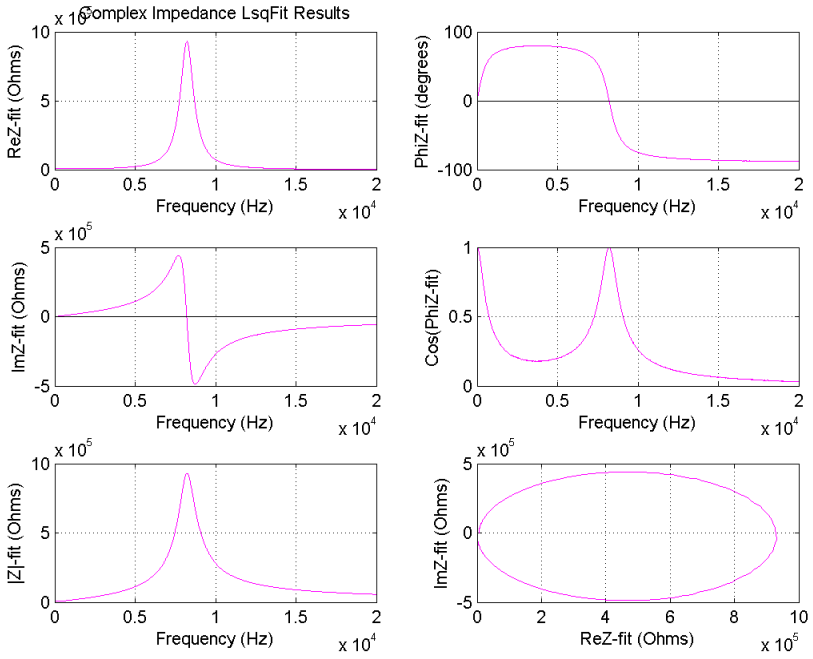
Table 2: Middle Pickup, self-made vs. original

Middle Pickup	DC Resistance (KΩ)	Resonant Frequency (KHz)	Quality Factor (Q)	*Z* at Resonance (KΩ)
Self-made	6.03	8.185	5.95	823.98
Original	6.05	7.965	7.41	832.16

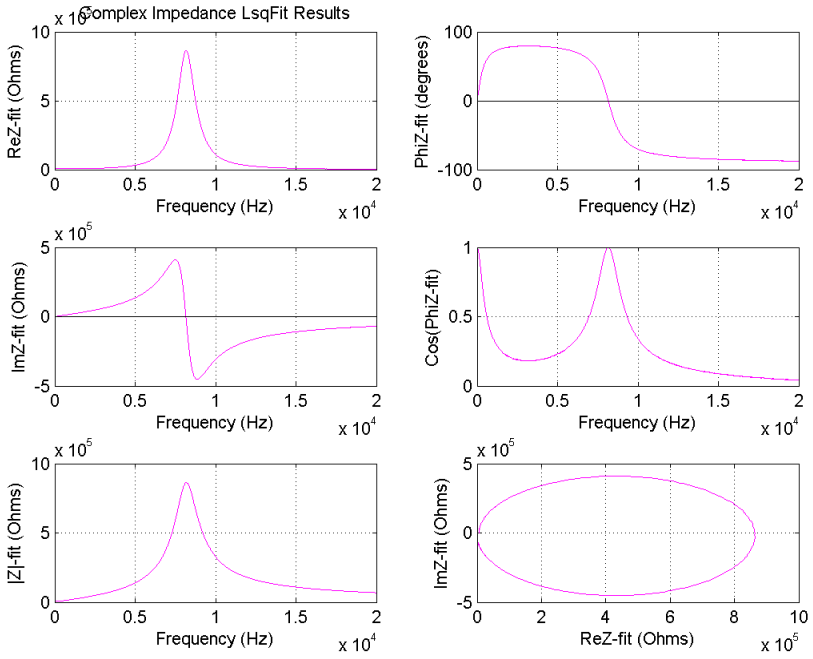
Table 3: Bridge Pickup, self-made vs. original

Bridge Pickup	DC Resistance (KΩ)	Resonant Frequency (KHz)	Quality Factor (Q)	*Z* at Resonance (KΩ)
Self-made	6.01	8.725	5.92	918.73
Original	7.40	6.855	7.03	1141.07

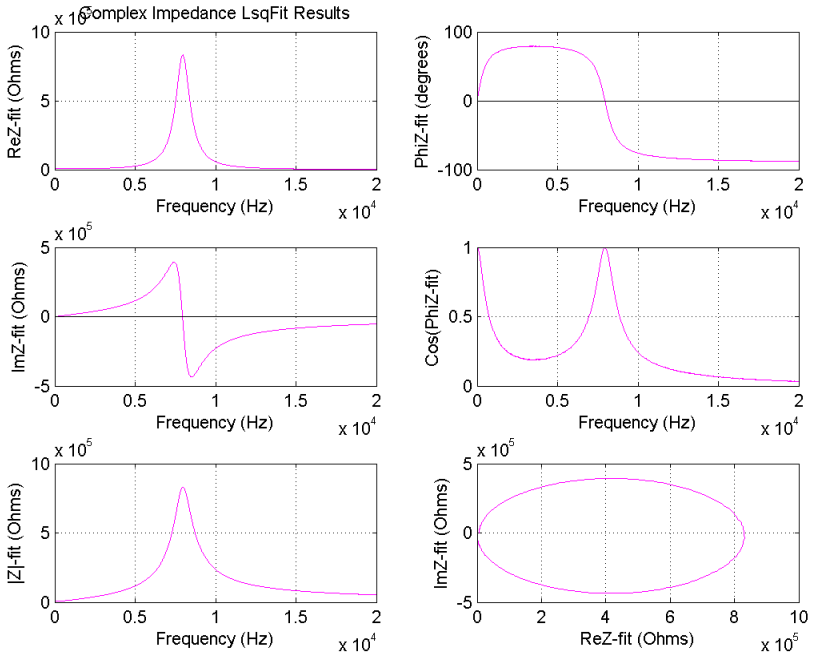
The above results show that the self-made and the original pickups have similar properties in terms of DC resistance, resonant frequency and quality factor. Now let's take a closer look at the least square fit graphs of complex impedance, which is correlated to the actual output of the pickup.



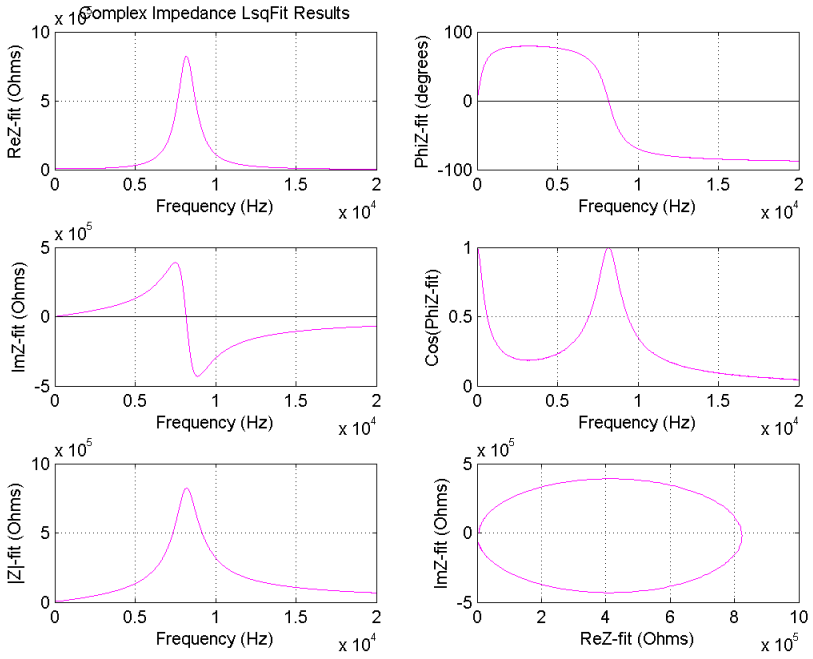
Graph 1: Impedance LsqFit Results, Original Neck Pickup



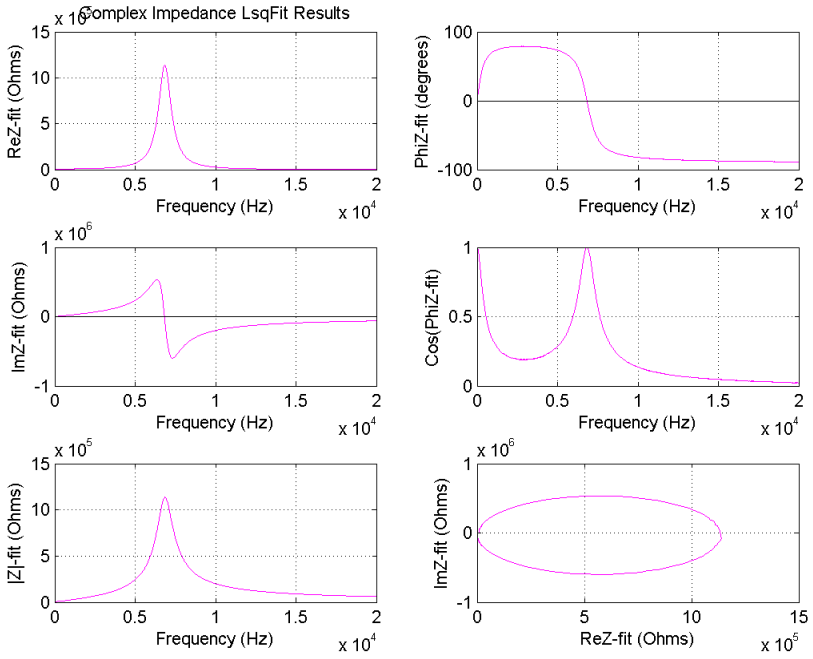
Graph 2: Impedance LsqFit Results, Self-made Neck Pickup



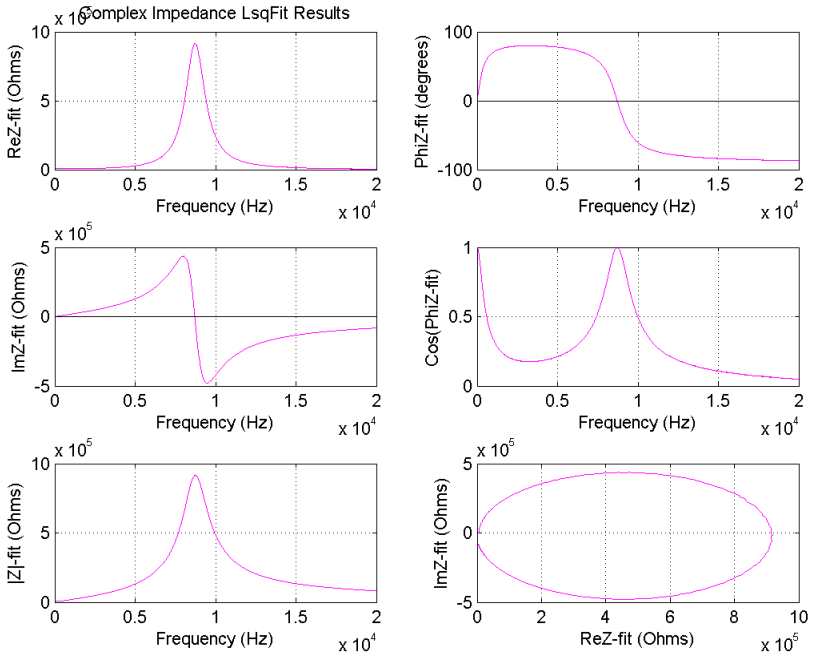
Graph 3: Impedance LsqFit Results, Original Middle Pickup



Graph 4: Impedance LsqFit Results, Self-made Middle Pickup



Graph 5: Impedance LsqFit Results, Original Bridge Pickup



Graph 6: Impedance LsqFit Results, Self-made Bridge Pickup

Results

From the complex impedance least square fit graphs, it can be seen that the self-made pickups are quite similar to the original pickups on the 2010 American Standard Fender Stratocaster. The maximum outputs of self-made pickups on the resonant peaks are a little bit smaller than that of the original pickups. However, in graphs for self-made pickups, the widths of the resonances Δf are significantly wider than that of the original pickups, which means that the pickups will produce a warmer, mid-rangier sound when picking the higher frets on the guitar. When Professor Errede and I played the guitar, this point was indeed proven. Overall, this project was successful, i.e. we were able to construct pickups similar to the sound of the 50s & early 60s Fender Stratocaster pickups.

Finally, credits are given to Professor Errede. Thanks to his help during the construction and measurement of the pickups.