UPII Honors Project

Assembly of an Electromagnetic Pickup and the Observation of its Electromagnetic Properties

By

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April 25, 2011

The goal of this project was to build an electromagnetic pickup and to incorporate it into the use of an acoustic guitar. The type of guitar pickup built uses a single coil to generate an electric current, which travels to the amplifier where the current is converted from electrical energy to mechanical energy. A single-coil pickup typically consists of several thousand turns of very thin, insulated copper wire wound around a plastic bobbin that provides a surface for the coil to wrap around as well as an enclosure for several permanent magnets (Brain 2002). I decided to use a broken pickup that I had previously used in another guitar as a template to assemble this one. After the pickup was built, I had to build a simple electric circuit for the current to flow and modify the acoustic guitar to allow it to be connected to an amplifier through a stereo cable.

Part 1. The Bobbin

The guitar coil starts out as a simple bobbin. The bobbin already had the magnets inside waxed into place, so I decided to leave them in their original orientation. This bobbin had a row of six magnets in the center, and also a bar magnet underneath (this was most likely to strengthen the total field of the small magnets combined). Using a magnetic compass, the permanent magnets alignment pointed from north (bottom) to south (top). The bar magnet on the bottom also pointed in the same direction, which strengthens the existing magnetic field.

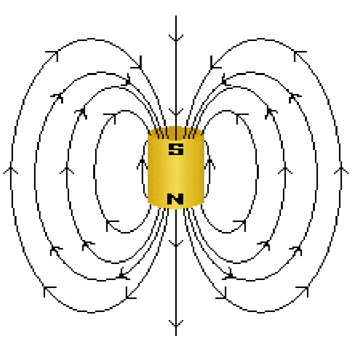

Figure 1: Magnetic Field of the Individual Bar Magnet (Obtained from Google Images.)

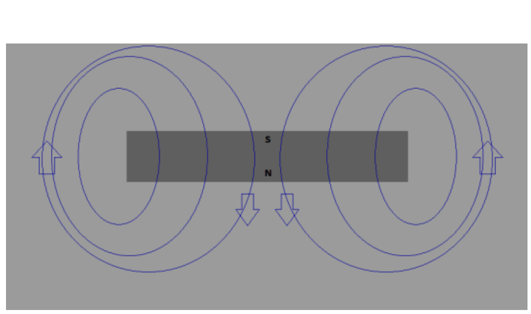

Figure 2: Magnetic Field of the Bottom Bar Magnet (MS Paint)

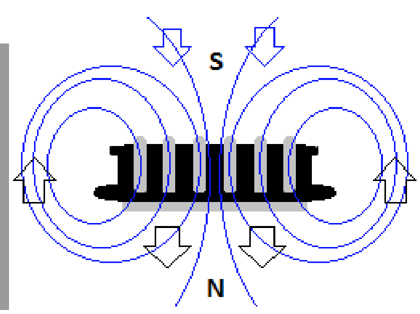

Figure 3: Magnetic Field of the Bobbin (MS Paint)

Part 2. The Coil

Winding the coil was the most time-consuming part of the construction process. There are machines that can do the winding and counting by itself, but because of time and money constraints, I decided to build the pickup using a makeshift winder. The winder consisted of a drill clamped down with a vise grip that had a magnet attached to the drill bit. The spool was on a bar that allowed it to rotate. The drill would rotate the bobbin, which would reel the wire from the spool to the coil. The counting was next to impossible, so to calculate the number of winds, I used the proportional relationship between the number of wraps and the resistance of the coil.

Figure 4: Winding Apparatus Setup

Figure 5: The Finished Coil

Winding the coil the first time took about two hours. The wire used was 42 AWG (.06 mm), which is almost as small as a strand of human hair. After winding the coil, I used a multimeter to test the resistance of the coil. The DC resistance read 0 ohms, which indicated a broken wire. After attempting to repair the inner strand of wire, it broke off completely from the inside and I had to rewind the coil from the beginning. Subsequent to the second coil, I was able to obtain a resistance of 945 ohms. Using a ratio of one turn of wire to 8 in., I measured the resistance of a single wound of copper to be about .9 ohms. Using this relationship, I estimated the number of turns of wire to be approximately 1050, ±100 turns. This is around the lowest number of turns used in electric guitars. Most commercial pickups are wrapped over 1000 times and have a resistance between 1 to 7 K ohms (Brain 2002).

After the coil was finished, each end of the coil was soldered to two sheathed wires. This is done so that the pickup will be able to become part of an electric circuit.

Part 3. The Electric Circuit

The next part of building the guitar pickup is to build an electric circuit. With the guitar strings in the magnetic field, the ferromagnetic strings form their own magnetic dipoles. When the strings are plucked, they vibrate, and these vibrations cause a changing magnetic flux. This produces an emf in the coil. This induced current is fed through the guitar to the amplifier to produce sound (Serway 2006). I made a simple electric circuit that would be able to carry the current to the amp, as shown in the left. Faraday's Law states that a changing magnetic flux through the surface enclosed by a stationary path causes a net electric field around the path (Stewart 2010). Because each string is magnetized, and therefore part of the magnetic field, a vibration of a string causes the same frequency change in current. The voltage oscillates, creating an alternating current. In this instance, the guitar strings can be counted as infinite wires, and the field of each wire and magnet would look similar to the diagram on the left.

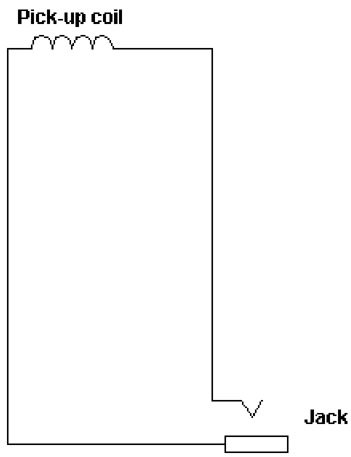

Figure 7: Pickup Schematic (Google Images. Modified with MS Paint)

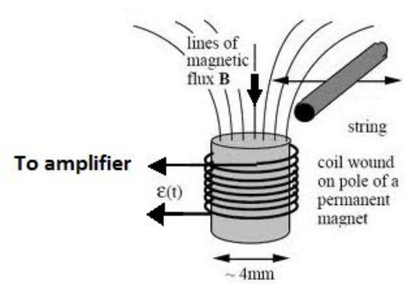

Figure 8: Coil of a Permanent Magnet (Google Images. Edited with MS Paint)

Part 4. Final Modifications

Because the guitar being used was acoustic, there were a few modifications that I had to make to its design. The strings on an acoustic guitar are steel. This allows for a louder sound and longer string oscillation time, but since the field will not pick up steel vibration, I used the nickel-plated strings that are found on electric guitars. This allows the strings to still vibrate well while being able to be magnetized by the coil. I also had to add an output jack for the amplifier cable, and a couple of screws to hold the pickup in place on the guitar.

Figure 9: Finished Pickup

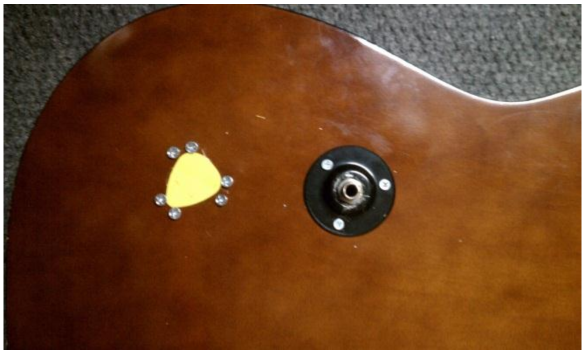

Figure 10: Output Jack (Back of Guitar)

After testing the guitar using two different amplifiers, the pickup produced the amount of current needed to be heard out of the amp. The volume is substantially lower on the amp due to the small number of turns, but the output is still noticeable.

Part 5. Conclusion

Using basic principles of induction and electromagnetism, I was able to construct a guitar pickup and successfully use it in an acoustic guitar. During the process, I was able to learn a lot of valuable information about Faraday's Law and generators. One of the main determining factors in the output of a guitar is the number of turns. A greater turn of wires allows a greater flux and a greater change in voltage. The easiest way for the most amount of turns is to have a small diameter of wire, which is why thin gauged wire is used in the construction of guitar pickups.

Works Cited

Brain, Marshall. "How Electric Guitars Work" 01 July 2002. HowStuffWorks.com. <http://entertainment.howstuffworks.com/electric-guitar.htm> 25 April 2011.

Serway, Raymond A. and Jewett, John W., *Principles of Physics: A Calculus-Based Text*, 2006. Cengage Learning, 2011.

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