

Construction of Speaker and Crossover Unit

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1. Introduction

Speakers, themselves, prove to be an incredible milestone in the history of physics. However, there are certain problems that can be improved upon. The development of the crossover unit, which allows for an array of speakers, has revolutionized the modern day audio industry. The crossover unit separates frequencies in audio signals and can direct them to certain speakers. This allows for specialized speakers to create quality sound waves. The audible spectrum of sound wave frequencies is rather large. With this in mind, having one speaker output this entire range would produce a less desirable sound quality. However, having speakers play specific ranges within this spectrum can improve quality of sound substantially. This project delves into the basics of creating a speaker system that includes specialized speakers and a crossover unit to direct signals to the appropriate speakers.

2. Speaker Design

The first step in the design process of speakers is the decision of which speaker type to use. There are two types of speakers. The first uses a coil that remains stationary with a magnet attached to a material capable of creating audible sound waves from vibrations. A music source outputs a varying current that is run through the coil. This current creates a varying magnetic field which, by the Lorentz force, interacts with the magnet. The interaction between the magnet and the coil produces movement upwards and downwards depending on the variation of the current. These movements are transferred to the material, which creates sound waves. The second type of speaker operates with the same principles. However, in this design the magnet remains stationary and the coil is free to move when it experiences the Lorentz force. The varying current is run through the coil creating a changing magnetic field, which interacts with the stationary magnet. The Lorentz force of this interaction creates the movement of the coil, and

the resulting vibrations create sound waves. The project discussed in this paper uses the second design. The reason for using this design is because of the mass being moved by magnet-coil interaction. By having a free-moving coil, the mass that must be moved to create vibrations is significantly less than one with a free-moving magnet. Because the free-moving coil is less massive, the vibrations are larger which makes the speaker sound louder.

The construction of the speakers uses basic materials. Considering the amp to be used is rated at 4 ohms, the speakers are designed to each carry about 8 ohms. Having the speakers run in parallel, the system will have an equivalent resistance of roughly 4 ohms. This is done to have matching impedance ratings of the speaker system and amp to ensure quality sound. The following construction methods are taken from Jose Pino's 2008 article, "Styrofoam Plate Speaker" in *Make Magazine* with a few revisions to the process [1]. A lightweight styrofoam plate serves as the cone, while thick construction paper suspends the cone and attached coil above a cardboard base. The coil uses 28-gauge enameled copper magnet wire from Radioshack. The wire is wrapped around a rolled paper cylinder, which is glued to the back of the styrofoam cone. The larger speaker (subwoofer) is wrapped with 170 turns while the smaller (tweeter) is wrapped 200 times. The magnet, which is a basic ceramic magnet, is glued permanently to the cardboard base. The cylinder-cone unit is placed over the magnet and the paper supports are secured (Figure 1.).

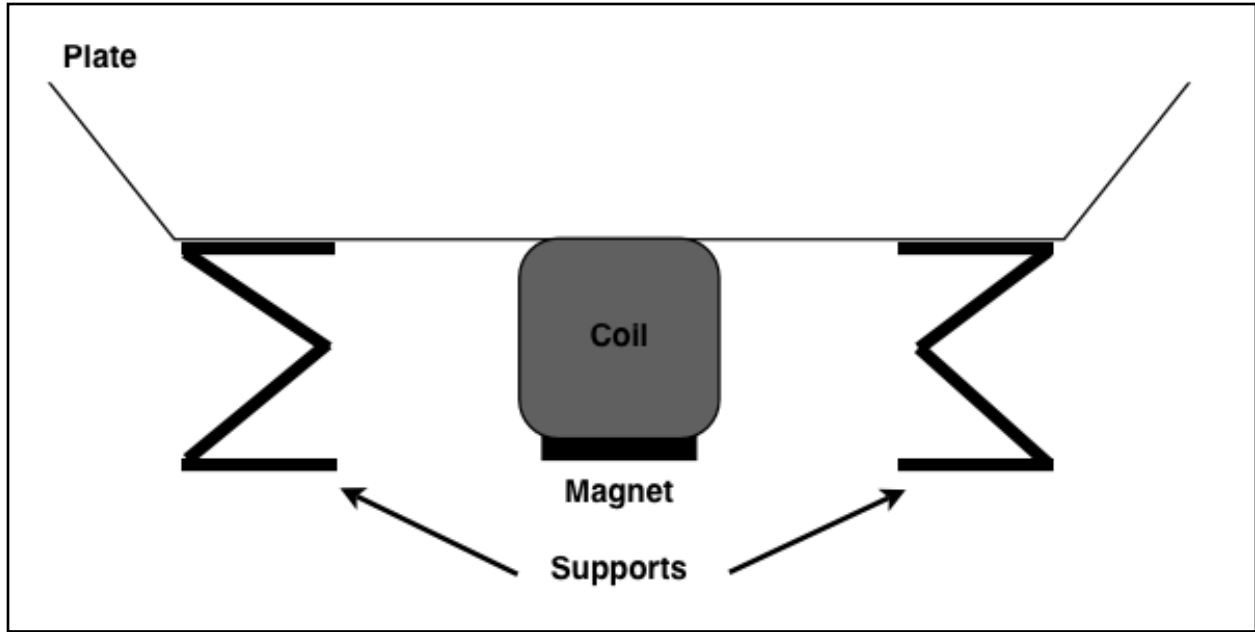


Figure 1. Speaker

3. Crossover Unit

The crossover unit of a speaker system is a combination of two elements: a high pass filter and a low pass filter. The crossover unit is frequency-based and allows speakers to be more specialized for a range of frequencies. The crossover unit will be designed to produce frequencies well within the range of the audible spectrum.

3.1 High Pass Filter

The high pass filter element of a crossover “only allows high frequency signals from its cutoff frequency, F_c point and higher to infinity to pass through while blocking those any lower” [2]. With this in mind, it is apparent that this element will correspond to a speaker specialized to output high frequency sounds. There are many different designs of high pass filters, however, the simplest is a combination of a resistor and a capacitor in series [3]. This is the method used in this project design. The capacitor and speaker will be placed in series. Considering the low pass element alone should be 8 ohms, the speaker should have a resistance of 8 ohms. Through trial and error, the speaker, when wrapped with 200 turns of the copper magnet wire, produced a

resistance of roughly 8 ohms. With the resistance determined to be 8 ohms, the capacitor's capacitance must be calculated in order to provide the appropriate cutoff frequency. The cutoff frequency for the high pass filter is found using the following equation: [2]

$$F_c = \frac{1}{2\pi RC}$$

Where R is the impedance rating (resistance) of the speaker (8 ohms) and C is the value of the capacitance. The equation allows for the selection of a particular F_c (cutoff frequency) and solving for the necessary C . For a 6kHz cutoff frequency, a capacitor of 3.3 μ F is chosen. This high pass arrangement allows only high frequency (treble) signals to pass to the smaller speaker. The high pass element can be seen in figure 2. This circuit and the following circuits were created using a circuit modeling programming called Cadence® Pspice®.

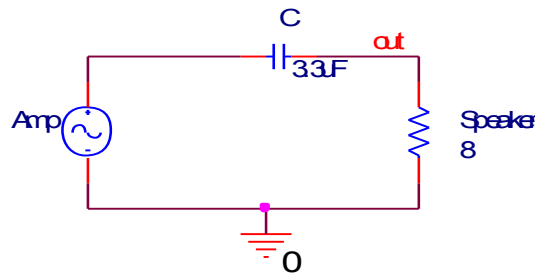


Figure 2. High Pass Filter Circuit

3.2 Low Pass Filter

The low pass filter is the element of the crossover which “only allows low frequency signals from 0Hz to the cut-off frequency, F_c point to pass while blocking those higher” [3]. The low pass is created following the same methods as the high pass with the exception of the order of the resistor and capacitor. For the low pass, the resistor is placed in series with the capacitor and the output is taken over the capacitor only [3]. Considering the output must go to the speaker, this element will hold two resistors: the speaker and one placed in series before the capacitor. With this in mind, the speaker must be designed appropriately to allow the addition of

another resistor in the element. A 1-ohm resistor is selected to make the capacitance calculations for cutoff frequency simple. The speaker in use is wrapped 170 times and provides approximately 7 ohms resistance. Together with the additional resistor, the equivalent resistance of the speaker is 8 ohms. Again, the only component left to calculate is the capacitance in order to provide the appropriate cutoff frequency. Like the high pass circuit, the low pass cut off frequency is governed by the following equation: [3]

$$F_c = \frac{1}{2\pi RC}$$

The resistor value 1 ohms was selected to simplify the calculation of the capacitance.

$$1.5kHz = \frac{1}{2\pi * 1\Omega * C}$$

$$C = \frac{1}{2\pi * 1\Omega * 1.5kHz} = 106 \mu F$$

A capacitor with the value of 106 μ F is not commonly produced, therefore a capacitor of 100 μ F is chosen. This arrangement sends only signals of low frequency to the larger speaker or subwoofer. The low pass element is outlined in Figure 3 below.

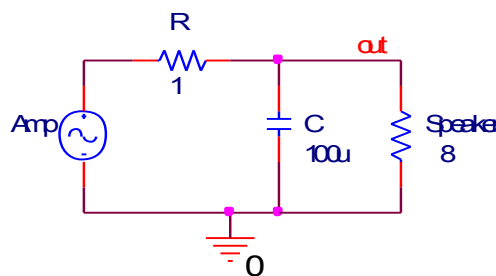


Figure 3. Low Pass Filter Circuit

3.3 Incorporating the High and Low Pass Filters

To create the speaker system, the crossover unit must incorporate both elements. The complete crossover unit is diagrammed in Figure 4. In order to have a subwoofer and tweeter work together, the crossover unit must appropriately send frequencies to the correct speaker. With the connected elements, the music source will output a varying current into the crossover unit. Here, the signals will be directed to both elements. Signals that enter the low pass filter will be filtered to only low frequency signals and, therefore, the subwoofer will play deeper sounds. Likewise, the signals entering the high pass filtered will have all low frequency signals filtered out and the tweeter will play high sounds. Together, the unit will play an array of frequencies in the audible spectrum but with much better quality than a single speaker receiving the same signals.

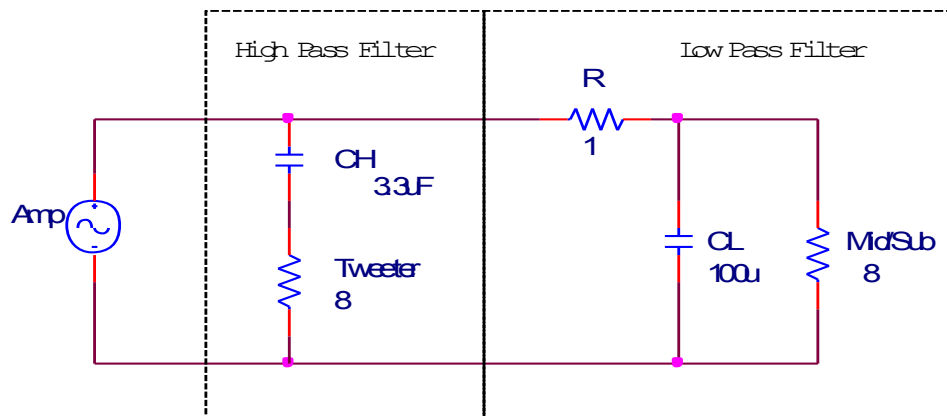


Figure 4. Completed Crossover Circuit

4. Conclusion

In the end, the speaker and crossover system performs its function. When the system is connected to a music source, both speakers play the music, with the high frequencies going to the “tweeter” and the low frequencies going to the “subwoofer”. The system uses the principles of

the Lorentz force and the properties of high and low pass filters to play the different frequencies through the speakers. The combined effect of the speakers improves the quality of the music and allows a larger variety of sounds to be played through the sound system.

5. Citations

1. Jose Pino, "Styrofoam Plate Speaker," Make Magazine, February 29, 2008, 131, accessed November 5, 2012, <http://www.makezine.com/12>.
2. Wayne Storr. "High Pass Filter," Last Modified November, 2012, http://www.electronics-tutorials.ws/filter/filter_3.html.
3. Wayne Storr. "Passive Low Pass Filter," Last Modified November, 2012, http://www.electronics-tutorials.ws/filter/filter_2.html.