High Fidelity Stereo

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Abstract

The primary purpose of a speaker system is to reproduce sound that is faithful to its input signal. A high-fidelity speaker is capable of reproducing sound for the entire range of human hearing, from 20 Hz to 20,000 Hz, identical to its driven signal. This project consisted of designing, constructing, and testing a low-cost, high-fidelity speaker system. Reproducing a faithful signal is highly dependent upon the drivers utilized, the type of enclosure, and the crossover network. The system itself is composed of two sealed, two-way speakers, costing less than $200 in total. A Second-Order Linkwitz-Riley crossover network was utilized with a crossover frequency of 3,000 Hz. The speakers were then tested with a measurement microphone, by recording frequency sweeps and music. A Fast Fourier Transform (FFT) was then performed on the recorded signals to examine the frequency range, as well as its faithful reproduction of the input signal. The speakers were able to accurately reproduce sound from a range of 45 Hz to 20,000 Hz. The FFTs revealed that the speakers were unable to produce enough power below 45 Hz, due to the limited frequency range of the drivers. In addition, the FFTs also showed that the speakers produce a minimal, but prevalent amount of noise. Another important aspect to music is its subjectivity. Although the speakers were unable to accurately reproduce sound for the entire range of 20Hz - 20,000Hz, they ultimately provided a pleasant listening experience.

Introduction

A stereo system is divided in several subcomponents: drivers, crossover network, enclosure, and amplifier.

Drivers are the main components of the speakers that produce sound. They function by converting electrical energy into mechanical energy using a permanent magnet and an electromagnet. The two types of drivers used in this design project are tweeters and woofers. A tweeter reproduces sound at the higher end of human hearing. A woofer reproduces sound at the lower end of human hearing.

Crossover networks are a series of filters that separate the input signal into the frequency ranges required for each type of driver. This project utilized a Second-Order Linkwitz-Riley crossover, characterized by a 12dB/octave rolloff, and a 0dB gain at the cutoff frequency.

A sealed enclosure was designed for this project, as it reproduces a more faithful sound, a key aspect to achieving high-fidelity.

To test the performance of the stereo system, a measurement microphone was utilized. Specifically, a Dayton Audio Umm-6 was used, due to its native connectivity for Windows and Mac devices. The performance testing compared the input audio signal to the recorded output of the speakers.

This project consisted of two iterations of the sealed speakers: one designed during Fall 2019 (denoted as “fall speakers”), and one designed during Spring 2020 (denoted as ‘spring speakers”)

Methods

To ensure that the system was working as intended, the crossover network required testing. MATLAB was used to model the sound pressure response of the circuit. The model is based upon the circuit diagram for this crossover, shown in Figure 1. The values for the inductors and capacitors were determined by the equations below:

$$C = \frac{0.0796}{R*f} \qquad L = \frac{0.3183*R}{f}$$

Where R is the inductance value of the driver and f is the cutoff frequency.

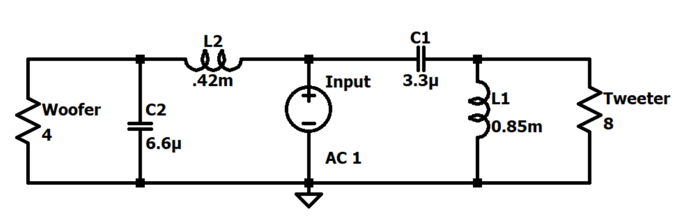


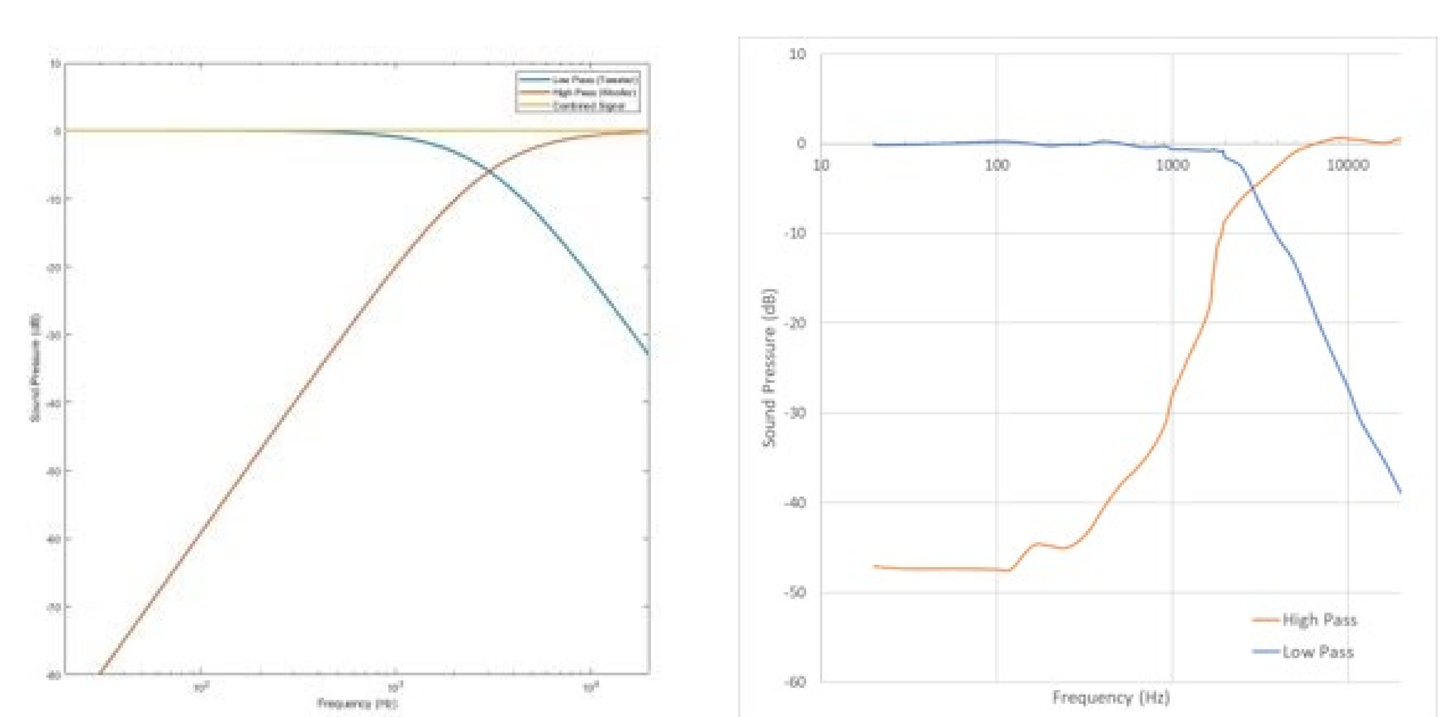
Figure 1. The circuit diagram for the Second-Order Linkwitz-Riley crossover, with the load of the tweeter and woofer shown

Figure 2. The final constructed spring speakers

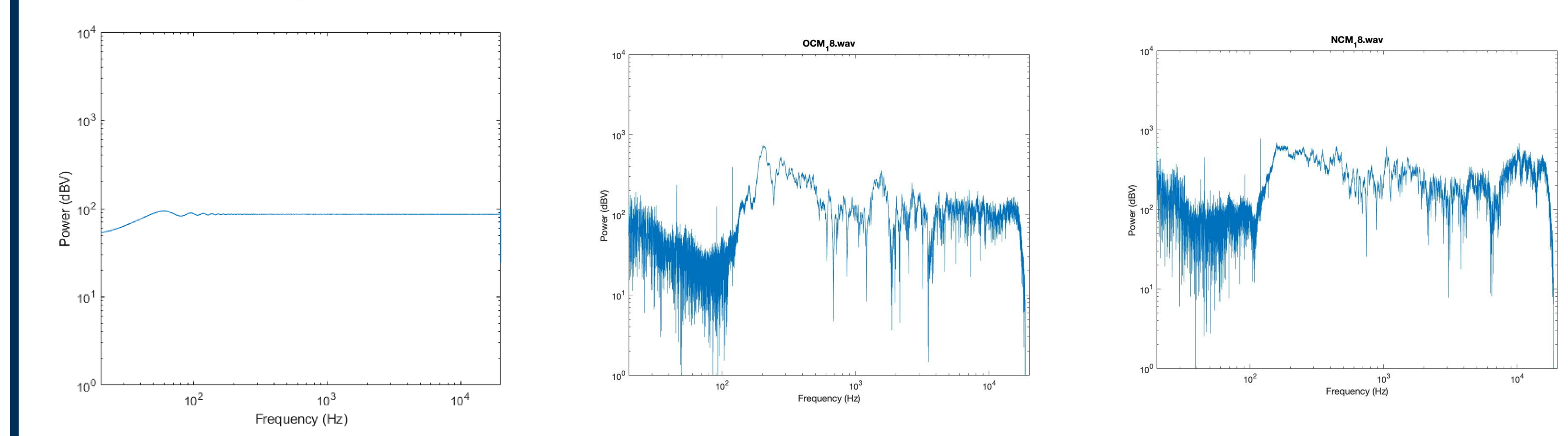
The audio testing procedures were separated into two categories: frequency sweeps and music. To test the speakers for the frequency sweeps, the UMM-6 was placed at three different heights: directly in front of the woofer, directly in front of the tweeter, and between the two drivers. In addition, the UMM-6 was placed at three different distances away from the speakers: 18”, 30”, and 42”. To test the music, the UMM-6 was placed between the two drivers at 42”. The frequency sweep was a 20 second file, with a linear sweep from 20-20,000 Hz

Results

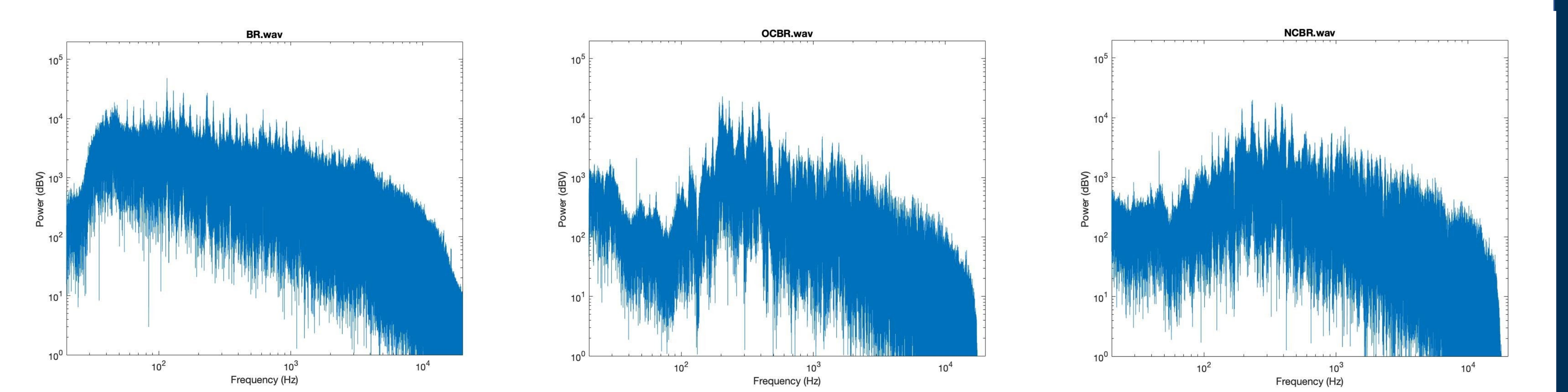
1) Verification of the Second-Order Linkwitz-Riley crossover network. Left, modeled frequency response. Right, measured frequency response



2) FFT plots of a linear frequency sweep from 20Hz – 20,000Hz. Left, FFT of input signal. Middle, FFT of the fall speakers. Right, FFT of the spring speakers



3) FFT plots of *Bohemian Rhapsody* by Queen. Left, FFT of input signal. Middle, FFT of the fall speakers. Right, FFT of the spring speakers



Discussion

The system is inherently limited by the frequency range of the drivers. Specifically, it is limited by the lower range of the woofer, as the spring speakers were unable to reproduce sound lower than 45Hz. Therefore, a “flat” frequency response is essentially impossible without a subwoofer dedicated to reproducing frequencies of 100Hz and below. The FFT for the music tests follow a similar pattern. The output sound did not match the input exactly. However, there is a notable improvement for the spring speaker when compared to the fall speaker. There is a less significant drop in the power at the lower frequencies.

The key aspect to note is that there was both a quantitative and qualitative improvement upon the fall speaker design. Not only does the FFT analysis show that the spring speakers are capable of reproducing audio of a larger frequency range, but they also subjectively sound better. Although there are drop-offs in power in the lowest and highest frequencies, it does not detract from the listening experience. Subjectively, the spring speakers have a pleasant sound, with no hearing fatigue after a few hours of continuous music listening.

Acknowledgements

- Dr. Joseph L. Palladino, Faculty Sponsor
- Andrew Musulin, Engineering Technician
- John Schwenk, WRTC Chief Engineer
- Trinity College Engineering Department