TWEETERS: HIGH-PASS FILTERS

Introduction

Audio Treble (vocals that you hear in music) is one of the main focuses of audio engineers. Car receivers often have equalizer settings to enhance or amplify the high frequency parts of an audio signal. One example would be amplifying the voice of your favorite singer, especially if the voice has a higher frequency aspect to it. Speakers that can handle the high audio frequencies emitted are commonly called tweeters.

You will soon see that passing an audio signal through a high pass filter is how tweeters are fabricated. A high-pass filter is a filter that passes and amplifies high-frequency signals but cuts out lower frequencies or heavy bass sounds such as those generated by a bass guitar or drum. In this lab you will observe the frequency and gain characteristics of a high-pass filter and how they are utilized to filter out low frequency portions of audio signals and amplify the high frequency sections. We hope this lab provides you with insight on how your car audio system and home stereo function.

Procedure

Figure 1 shows the pin layout of the TL074CN chip. We will use this figure to create a simple high-pass filter. We will pass an audio signal (song) through the filter and observe how the signal at the output of the op-amp differs from the one at the input. Also, how changing resistor and capacitor values in the circuit change the filter quality.

PIN CONNECTIONS (top view)

You can find more information about the specification of the TL074CN op-amp circuit at: http://www.datasheetcatalog.org/datasheet/stmicroelectronics/2297.pdf
Note on the speakers:

Make sure to use powered speakers for this lab, we are using powered speakers so you won’t have to worry about impedance matching, where the input impedance of the audio source matches the output impedance of the speakers. Impedance matching maximizes the power transferred to the load but requires a more complicated circuit. Using powered speakers allows you to focus more on the theory of signals and not the tweeter design process.

Step 1: Powering the filter

![Image: Battery & Power setup for TL074CN](image1)

1. Place the TL074CN chip on your protoboard. Notice on one side of the chip is a half-circle; this lets you know the location of each pin. Refer to Figure 1 for pin descriptions and locations, notice chip in the picture possesses the same half-circle.

2. Using one of the 9V batteries, connect the positive terminal (Vcc+) to Pin 4 of the TL074CN chip and use the negative terminal to create part of the Ground connection similar to the one in Figure 2.

3. Using the second 9V battery, connect the negative terminal (Vcc-) to Pin 11 of the chip and use the positive terminal to complete the Ground connection. Your circuit should now look similar to Figure 2.

![Image: TL074CN Chip and Batteries](image2)
Step 2: Constructing High-pass filter

1. Leaving the power setup you created in the previous step, using Figures 3 & 4, build the high-pass filter as pictured in Figure 4. Figure 3 is the diagram of the high-pass filter and Figure 4 is its physical representation. As you can see from Figure 1, there are 4 op-amps in the chip, **CHOOSE ONE**. Referring to Figure 1, looking at the half-circle on the edge of the chip, we will use the first op-amp (op-amp at the top, just left of the half-circle) to create the high-pass filter.

**Figure 3: Diagram of high-pass filter**

**Figure 4: High-Pass filter on protoboard**
2. Look at the speaker wires in Figure 5 and identify the left and right speaker wires as well as the speaker ground. Connect the left and right speakers to the output pin of op-amp 1 (Pin1). This plays the audio signal produced by the filter through the speakers. Also don’t forget to connect the green cable (ground) to the ground connection on your board. Your connection should look similar to Figure 4.

Figure 5: Speaker wires

3. Look at Figure 6 this is the audio cord that connects to the headphone jack of your MP3 player or computer and the stripped wires that connect to the input of the filter. This is what enables the song from your device to be passed through the filter. Identify the ground connection for the audio source and the audio input for the op-amp. Connect the audio input to the filter, like in Figure 4. Connect the ground wire to the same Ground connection that you created in Step1. Connect the headphone plug to the headphone jack of the mp3 player or computer.

4. Play a song. If you don’t have any music files on your computer or MP3 player, visit an online radio station or Pandora.com.

Figure 6: Audio cord
NOTE: Your circuit should look very similar to the one constructed in Figure 4. If your circuit does not appear to be working properly try setting up the circuit exactly as pictured in Figure 4.

5. Listen to the song that you have playing. Now replace R2 with a 0 → 22KΩ potentiometer (resistor that’s able to vary its resistance). Set the potentiometer to the previous value R2 = 10KΩ. Now increase the resistance value of your filter by changing to Rf = 20KΩ (20,000Ω). What happens to treble quality? Does it appear to increase or decrease?

6. Now vary the potentiometer between 0 → 9KΩ. Does the bass appear to increase or decrease?

7. Try changing the value of the capacitance C1 and C2 (matching). Note down the results and your conclusion on how the changes affect the circuit.

8. Using the experience you’ve received so far when it comes to configuring the op-amp, come up with the best performance that can be achieved using the parts you have available with you (use the potentiometer and different capacitor values). Compare your speaker output quality with other team members and see what they did differently and how it affected their output. Note the

**Circuit Theory (High-pass filter)**

Many of the concepts to understand filter functions are shown in the Low-pass filter lab (which you should have completed before this one). The cutoff frequency is set by the equation below. Use them to help solve the questions above.

\[
F_c = \frac{1}{2\pi \sqrt{(R_1 * R_2 + C_1 + C_2)}}
\]

Where \( R_1 = R_2 \), \( C_1 = C_2 \), simplifies the equation to:

\[
F_c = \frac{1}{2\pi \sqrt{R + C}}
\]

**Conclusion**

You have observed that passing an audio signal through a high pass filter is how tweeters are fabricated. You observed the frequency characteristics of a high-pass filter and how they are utilized to filter out low frequency portions of audio signals (bass) and amplify the high frequency sections (vocals). We hope this lab provided you with insight on how your car audio and home stereo systems function.