EE-241. Introductory Electronics Laboratory
Handout #5.*

Fall 2009

Amplifier Design Using OP-Amps; Making a Sound System

Objectives

In this experiment you will learn the different parts of a basic audio amplification system. You will learn how to use a mic to convert sound into electricity; an amplifier to magnify the voltage of a feeble audio signal; and a speaker to convert the amplified signal back into sound. This handout is based on experiments 3, 4 and 5 of your textbook [1].

Hearing Signals

Till now you have been using visual aids to learn about currents and voltages in an electric circuit. We will now explore how to deduce some information about electrical signals by hearing the signals over a loudspeaker which is an electroacoustical transducer [1].

1. You will now prepare to hear the waveforms produced by the function generator. Hook up the setup shown in Figure 1 using the loudspeaker provided. Note the polarity marked on the speaker at its back. For now, ignore Z_m in this circuit. If your speaker has a capacitor soldered to it, please use the capacitor in place of Z_m. We will get to the details of this impedance later. Use cables as short as possible, because long cables can act as antennas and can pick up external interference.

2. With the function generator still off, turn its amplitude all the way down and select the frequency to 1 KHz sinusoidal. Turn the generator on. Carefully and gradually increase the generator amplitude until you can hear the tone it produces. Set the oscilloscope to observe the waveform as you listen to it (a few cycles should be visible on the screen). Do you hear anything?

3. Change the waveform shape control on the function generator to other (nonsinusoidal) shapes (square, triangle etc.) and observe the waveform the scope and its effect on the sound. You may observe that the signal distorts quite a bit when you switch to other waveforms. How do you explain this? Recall that the speakers you will be using in the lab have a rating of 8Ω, $0.25W$ or similar.

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[1]A transducer is a device that converts one form of energy into another.

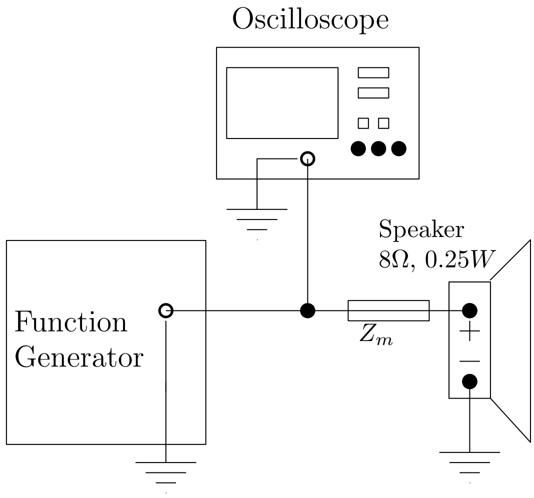

Figure 1: Hearing signals using a speaker.

4. Next connect a 100Ω resistor in series with the speaker in place of Z_l (If there is a capacitor soldered to the speaker, use it as well). Does this improve the signal waveform? If so, why? Try using other values of capacitors, resistors or inductors (if available) to make an impedance matching network. You will see that this too has a limited effect on improving the quality of sound, but it does bring improvement.

5. In other courses, using Fourier analysis, you will be able to show that these other shapes can be represented as sums of sinusoids with frequencies that are multiple of the basic frequency. The difference in sound that you hear can be attributed to such "harmonics." Try to listen to the various waveforms and train your ear to hearing those harmonics (if you can).

6. You may also test your ear's response to various frequencies. Set the function generator waveform to sinusoidal. Now slowly change the frequencies from a few hertz to several thousand. When do you start / stop hearing sounds? This is the frequency response of your ear and it will vary from person to person.

From Sound to Signals

In the previous section, you learned how to convert electrical signals into sound using a speaker. In this section, we will learn to do the opposite using a microphone or "mic." This too is a transducer. You can also call it a *sensor* because it senses sound.

1. Setup the circuit shown in the Figure 2. The type of mic that you will use in the lab is called a *condenser microphone*. Contrast it to a *dynamic microphone*. It needs to be biased by a power supply to work. This is done using the +5V battery and the resistor.

2. Set the coupling of the oscilloscope to AC in order to block the biasing voltage on the mic. Now clap, whistle or speak into the microphone and observe the resulting voltage on an oscilloscope

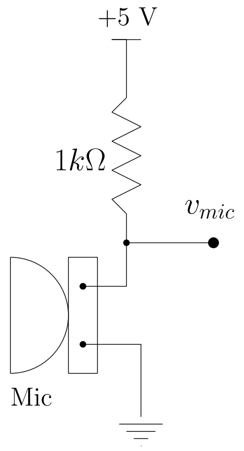

Figure 2: Using a microphone to convert sound into electrical signals.

at v_{mic}. You may also use your cell phone or MP3 player to play a continuous sound into the mic to get a clearer signal.

3. Increase/decrease the voltage sensitivity and sweep of the scope so that you can observe the signal produced by the microphone when you speak into it. Record the peak to peak voltage of the electrical signal produced by the mic.

4. Now think what would happen if you connect v_{mic} directly to a speaker? Is this signal going to be strong enough to drive the speaker? If not, compare it to the peak-to-peak voltage of the signal recorded in the previous section that did produce sound at the speaker.

Clearly, you need to make the signal larger. This requirement is known as *amplification* in electronic circuits. This is precisely what we will do next in our experiment using an OP-AMP.

Designing and testing a voltage amplifier

1. You have learned by now that the signal produced by the microphone was not enough to drive the speakers at a reasonable level. You also know by now, that you would need to amplify the microphone signal by a large factor. Design the circuit of Figure 3 for this purpose so that it gives you a required amplification factor. Recall, from your lab instruction that the amplification factor is given by

$$\frac{v_{OUT}}{v_{IN}} = 1 + \frac{R_2}{R_1}.$$

   Use $R_1 = 1k\Omega$. Select R_2 so that the gain magnitude is approximately as desired.

2. Do not use your circuit to amplify the microphone signal yet. Rather, first investigate the circuit as explained in the next step. Build the circuit using a 741 op amp. The pin assignment for this op amp has been given in Fig. 3(a) of Experiment 4.

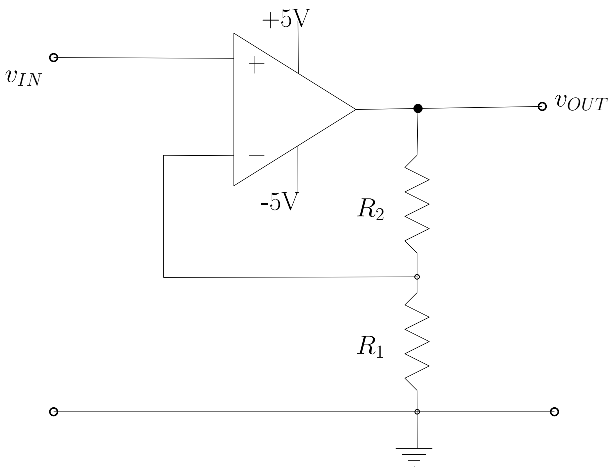

Figure 3: Using an OP-Amp as a voltage amplifier.

3. Measure and plot the DC transfer characteristic (V_{OUT} vs. v_{IN}) for the circuit of Figure 3. Make sure you have enough points in the high-slope region so that you can obtain a relatively accurate plot. If the characteristic does not pass exactly through the origin, do not worry (this is due to an op amp imperfection called DC offset voltage. discussed in the previous Experiment; although this imperfection can cause problems in certain cases if not properly taken into account, it will not cause problems in the circuits we will be using). Determine the slope of this characteristic in the high-slope region, and verify that it is equal to the desired voltage gain. When finished with this step, turn off the power supplies and disconnect the input source from the circuit.

4. By only looking at the plot obtained in the previous step (not by experimenting) answer the following questions:

   (a) What is the input voltage range over which the circuit behaves linearly?

   (b) What is the maximum and minimum output voltage possible?

   (c) If the input voltage were a sinusoid, what would its maximum amplitude be before it would drive the circuit into its nonlinear region?

   (d) What would the shape of the output voltage be if that amplitude were not exceeded?

   (e) What would be the shape of the output voltage if that amplitude were exceeded?

5. To test your preamplifier. drive its input with a 1 kHz sinusoidal signal produced by the function generator. Observe both v_{IN} and v_{OUT} simultaneously, using the two channels of the scope. Try different amplitudes and verify your predictions.

6. Next, replace the function generator by the dynamic microphone as shown in Figure 4. Using the two channels of the scope verify approximately that the microphone signal is amplified by the desired amount. What is the purpose of $3.3k\Omega$ and $10\mu F$ (marked by a dotted box) in this circuit?

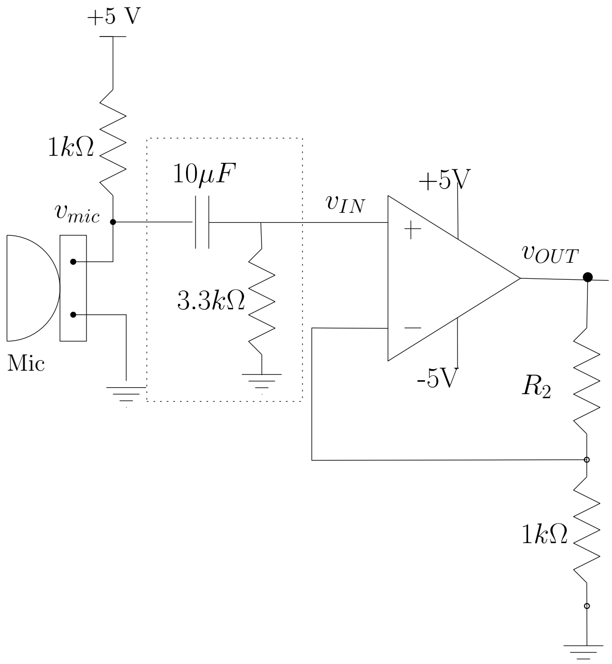

Figure 4: Using an OP-Amp for amplifying mic signal.

A complete sound system

1. You are now ready to use the microphone preamplifier you just designed in a complete sound system. The microphone signal has already been fed to the input of the preamp so that the latter can amplify it and develop a multiple of it at its output. Explore now whether the amplified output can now be fed into the speakers? Use the matching impedance Z_m that you designed in the previous section, if necessary. How loud can you hear the sound now?

2. You will see by now, that the amplifier is still not able to drive the speakers. This is because although the voltage has been amplified, the OP-Amp does cannot provide the current necessary to drive the speakers. For this purpose you will use a *power amplifier.*

3. In this lab, we will use a ready made sound power amplifier $KA2209$ to demonstrate the use of a power amplifier. In later courses you will learn how to design power amplifiers yourself. For now, we will just use it as a black box.

4. Wire the final circuit as shown in Figure 5. You may need to readjust the gain of the preamplifier because the power amplifier we are using also does voltage amplification. For now, keep the gain of the preamplifier to around 1.

5. Keep the microphone away from the speaker. If you hear whistlings. move the microphone further away from the speaker. Speak loudly into lhe microphone. but not loudly enough to distort the sound coming from lhe loudspeaker. If you find that the gain is not enough. you can increase it by adjusting R_1 and R_2.

6. Move the microphone close to the speaker. What do you observe? Can you explain it?

If you have gotten thus far, congratulations on building your first complete electronic system.

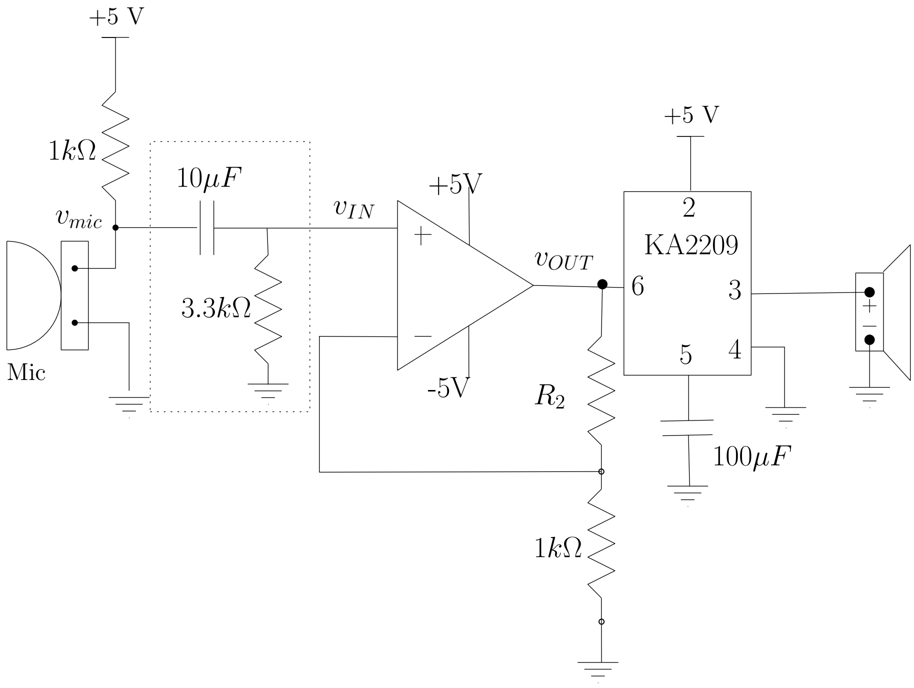

Figure 5: A complete sound system.

References

[1] Y. Tsividis, *A first lab in circuits and electronics,* John Wiley & Sons, 2002.