Experiment A8
Electronics III
Procedure

Deliverables: checked lab notebook, plots

Overview

Electronics have come a long way in the last century. Using modern fabrication techniques, engineers can now print billions of transistors onto a piece of silicon the size of a postage stamp. These *integrated circuits* (ICs) have drastically improved nearly every aspect of human civilization, from communications to banking, and have generated a tremendous amount of wealth for many savvy engineers.

In this lab, you will use an IC chip to amplify signals. Electronic amplification is important for measurements, as it increases the **signal-to-noise ratio**. That is, it allows you to distinguish a signal from any unwanted background noise.

Part I: Non-inverting Amplifier Circuit

In this laboratory exercise, you will use a bread board to construct a non-inverting amplifier using an LM301 integrated circuit (IC). The primary purpose of this lab is to teach you how to implement an IC chip in a circuit. You will construct the op-amp circuit shown in Figure 1 using $R_2 = 1$ kΩ. You will then measure V_{out} as a function of the other resistor R_1 using the values in Table 1. The gain of the non-inverting amplifier is given by the equation

$$\frac{|V_{out}|}{|V_{in}|} = 1 + \frac{R_1}{R_2}. \qquad (1)$$

Please refer to the pin out diagram shown in Figure 2 to aid you in the construction of your circuit.

Table 1

R_1 (Ω)	R_1 (Ω)	V_{out} (V)	V_{in} (V)
100			
470			
1k			
2k			
10k			

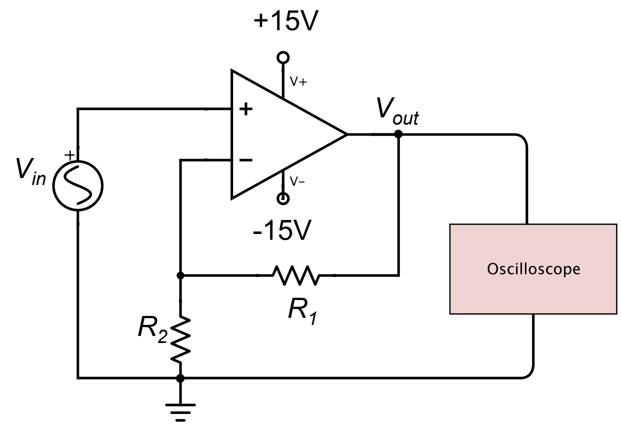

Figure 1 - Circuit diagram for the non-inverting amplifier.

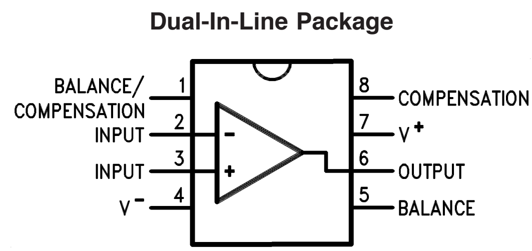

Figure 2 - Pin-out for the LM301 op-amp chip.

Please refer to the pin out diagram shown in Figure 2 to aid you in the construction of your circuit. A step-by-step guide to constructing the circuit is provided below. Ask the TA to check your circuit before turning on the power supply.

1. Copy the circuit diagram and pinout (Figures 1 and 2) into your lab notebook.
2. Insert the LM301 chip into the proto board as demonstrated during lecture. Orient the Op-amp such that the dot is in the upper left corner. **If you are at all uncertain about this or any of the following steps, ask the TA or lab instructor for help!**
3. Refer to the pin-out (Fig. 2). Using different colored wires, connect pins 4 and 7 to the -15V DC and +15V DC, respectively, power supplies on the proto board.

Pro-tip: Try to avoid having long loops of wire in your circuit. Long loops of wire will pick up electromagnetic noise and make you circuit difficult to see.

4. **Insert the 33 pF capacitor between pins 1 and 8.** This capacitor will reduce high frequency noise and increase stability.
5. Pick a 1 kΩ resistor from the resistor set. Using the Extech handheld DMM, measure its resistance and record the value in your lab notebook. This resistor will be used for R_2 in the op-amp circuit. Carefully, insert it into the proto board in the correct position. One end should be connected to ground, and the other end should be connected to inverting input (pin 2).
6. Connect the output 'T' on the function generator to the non-inverting input of the circuit using a BNC-to-minigrabber cable by doing the following: Connect a wire to the non-inverting input (pin 3), and grab onto it with the red minigrabber. Connect another wire to ground and grab onto it with the black minigrabber.
7. Turn on the function generator. Press the "sine" button, then "output menu", then "load impedance", then "High Z", then press "Top Menu" to exit to the main menu.
8. Connect the other side of 'T' on the function generator to CH1 of the oscilloscope.

9. Connect CH2 of the oscilloscope to the *output* of the circuit using a different BNC-to-minigrabber cable.
10. Copy Table 1 into you lab notebook with a column for R_1 and a column for V_{out}. Take a 100 Ω resistor from the set. Measure its resistance and record the value in the table in your lab notebook.
11. Insert this resistor into proto board as R_1 to form the circuit shown above. One end should be connected to the output (pin 6), and the other end should be connected to inverting input (pin 2).
12. Turn on the function generator and set the output to be a 1 kHz sine wave with a peak-to-peak amplitude of $1V_{pp}$.
13. Press the "auto set" button on the right hand side of the oscilloscope. You should see a sine wave appear. Measure the peak-to-peak amplitude of both CH1 and CH2 on the scope and the values in the table next to the value of R_1.
14. Repeat steps 11 – 13 until you have completely cycled through the resistors provided and filled out the table.
15. Make a plot of the measured gain G as a function of R_1 with the theoretical curve on top.

Part II: Inverting Amplifier Circuit

In this laboratory exercise, you will use a bread board to construct a *inverting* amplifier using the LM301 IC. You will construct the op-amp circuit shown in Fig. 3 using $R_2 = 1\ \text{k}\Omega$. You will then measure V_{out} as a function of the other resistor R_1 using the values in Table 1. The gain of the inverting amplifier is given by the equation

$$\frac{|V_{out}|}{|V_{in}|} = -\frac{R_2}{R_1} \,. \tag{2}$$

Please refer to the pin out diagram shown in Fig. 2 to aid you in the construction of your circuit.

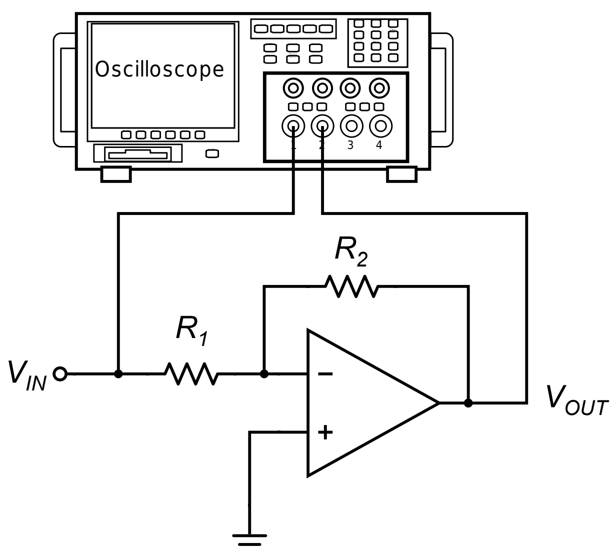

Figure 3 – A schematic of the inverting amplifier with input and output connected to the oscilloscope. Note that the +15V and –15V power inputs have been omitted, but they are still necessary.

Table 2

R_1 (Ω)	R_1 (Ω)	V_{out} (V)	V_{in} (V)
100			
470			
1k			
2k			
10k			

1. Remove the resistors from Part I, but leave the rest of the circuit intact.
2. Copy the circuit diagram shown in Fig. 3 into your lab notebook.
3. Turn off the breadboard and disconnect the minigrabbers.
4. Pick a 1 kΩ resistor from the resistor set. Using the Extech handheld DMM, measure its resistance and record the value in your lab notebook. This resistor will be used for R_2 in the op-amp circuit. Carefully, insert it into the proto board in the correct position.
5. Ground the non-inverting input (pin 3) of the amplifier.
6. Connect CH2 of the oscilloscope to the *output* of the circuit V_{OUT} using a different BNC-to-minigrabber cable.
7. Copy Table 2 into you lab notebook with a column for R_1 and a column for V_{OUT}. Take a 10kΩ resistor from the set. Measure its resistance and record the value in the table in your lab notebook.
8. Insert this resistor into proto board as R_1 to form the circuit shown above. One end should be connected to the input from the function generator, and the other end should be connected to inverting input (pin 2).
9. Make sure one end of the output 'T' on the function generator is still connected to the input of the circuit V_{IN} using BNC-to-minigrabber cables.
10. Make sure the other end of the output 'T' on the function generator is still connected to CH1 on the oscilloscope.
11. **Make sure the breadboard in on.**
12. Turn on the function generator and set the output to be a 1 kHz sine wave with a peak-to-peak amplitude of $1V_{pp}$.
13. Press the "auto set" button on the right hand side of the oscilloscope. You should see a sine wave appear. Measure the peak-to-peak amplitude of CH1 and CH2 on the scope and these values in the table next to the value of R_1.
14. Repeat steps 7 – 13 until you have completely cycled through the resistors provided.
15. Make a plot of the measured gain G as a function of R_1 with the theoretical curve on top.

Part III: Audio Pre-Amp

You will now use the LM301 to build an amplifier for your favorite music. Please use the step-by-step instructions below to construct the inverting amplifier circuit below.

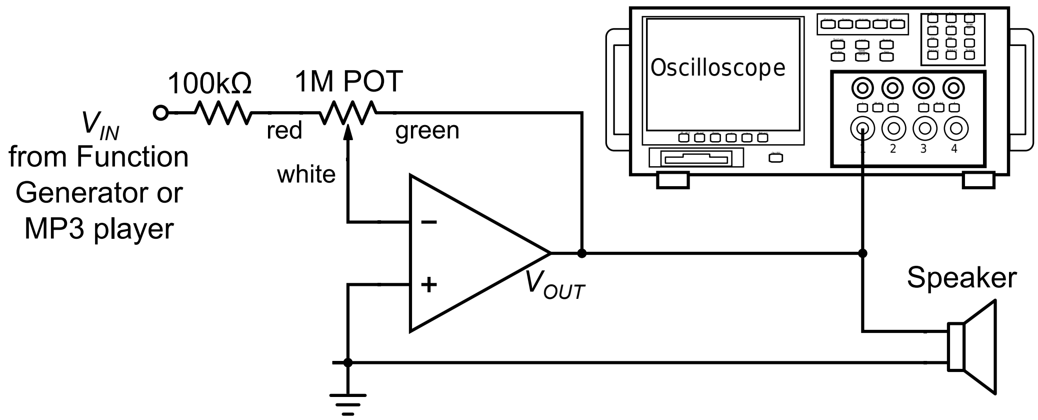

Figure 4 – A schematic of the inverting amplifier with input and output connected to audio equipment. Note that the +15V and –15V power inputs have been omitted, but they are still necessary.

1. Copy the circuit diagram shown in Fig. 4 into your lab notebook.
2. Turn off the breadboard and disconnect the minigrabbers from your circuit.
3. Remove the BNC 'T' from the functions generator and plug it into CH1 on the oscilloscope.
4. Locate the 1MΩ potentiometer. You may notice that there is something very special about the knob on the potentiometer—it goes all the way up to 11!
5. Replace the two resistors R_1 and R_2 with the 1MΩ potentiometer as shown in the schematic above.
6. The function generator should be connected to a 100kΩ resistor in series with the red wire on the potentiometer.
7. Connect the other BNC-to-minigrabber cable to a T on CH1 of the oscilloscope. Connect the red minigrabber to the output of the Op-amp and the black minigrabber to ground.
8. Connect the plain BNC coaxial cable to the other side of the T on CH1. Use the 3.5mm audio adapter to connect the other end of the cable to the speaker.
9. Turn on the function generator set it to output a 100 Hz sine wave at $1V_{pp}$. You should hear a sound coming from the speaker. Press the "autoset" button on the oscilloscope, and you should see a sine wave appear on CH1.
10. Turn the knob on the potentiometer. You should hear the speaker get louder or softer and see the waveform change size on the oscilloscope.

11. Play with the frequency on the function generator to play different tones on the speaker.

Not too loud, though!

12. Ask the lab instructor or TA for the MP3 player. Disconnect the BNC cable from the function generator and use another 3.5mm audio adapter to connect it to the mp3 player.

Caution: If you choose to use you phone instead of the MP3 player, you do so at your own risk!

13. Press play on the mp3 player and crank it up!
14. Demonstrate your circuit to the TA or lab instructor. They must sign off on it before you leave.
15. Clean up you lab bench and restore it to its initial condition. Disconnect all BNC coaxial cables. Remove any jumper cables from the breadboard. **Return all resistors to the proper bins.**

Data Analysis and Deliverables

Please make the following plots in Matlab, import them into a LaTeX or MS Word document, and give them concise, intelligent captions. Make sure the axes are clearly labeled with units. Plots with multiple data sets on them should have a legend. **Additionally, write a paragraph separate from the caption describing what you did in lab and how it relates to the plot.**

1. For Part I, make a plot of the measured gain G as a function of R_1 with the theoretical curve on top for the non-inverting amplifier.
2. For Part II, make a plot of the measured gain G as a function of R_1 with the theoretical curve on top for the inverting amplifier.

Appendix A

Equipment

- Tektronix AFG3021C Function Generator
- Tektronix MDO3012 Digital Oscilloscope
- Powered Breadboard
- Breadboard Solder-less Connectors
- National Semiconductor Operational Amplifier; MFR# LM301AN
- Socket, IC, 08 PIN; MFG# 6100-8-R
- BNC connector to red /black grabberss – 2' length
- BNC Cables (qty. – 3) 3' – 4' in length
- BNC – "T" connector
- BNC connector - Red and Black banana end to BNC
- Resistors
- 33pF Capacitors
- 2 BNC to 3.5mm male audio adapters
- WSA-8612 Wireless Desktop Speak
- AGPTEK Badge-ZOOM MP3 Player