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: Inverting Amplifier Circuit

In this laboratory exercise, you will use a bread board to construct an *inverting* amplifier using the LM301 operational amplifier (op-amp) chip. You will construct the op-amp circuit shown in Figure 2 using R_1 = 1 kΩ. You will then measure V_{out} as a function of the other resistor R_2 using the values in Table 1. The gain of the inverting amplifier is given by the equation

$$\frac{|V_{out}|}{|V_{in}|} = -\frac{R_2}{R_1}. \tag{1}$$

Please refer to the pin out diagram shown below in Fig. 1 to aid you in the construction of your circuit.

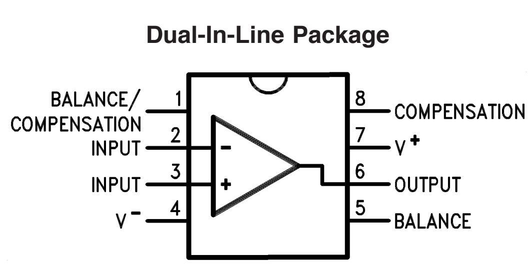

Figure 1 - Pin-out for the LM301 op-amp chip.

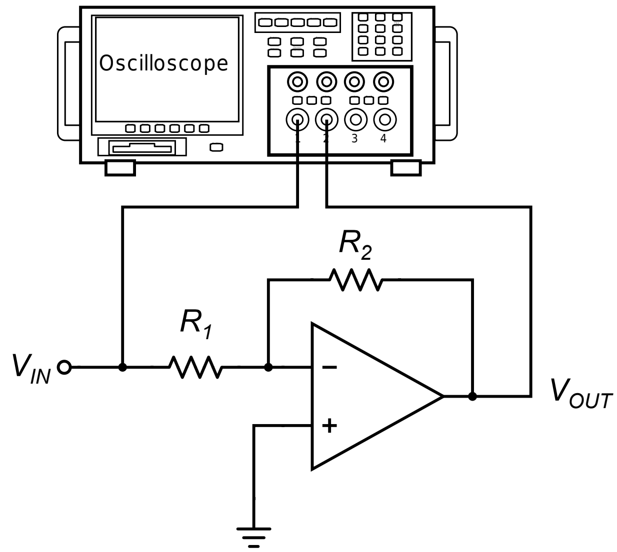

Figure 2 – A schematic of the inverting amplifier with input and output connected to the oscilloscope. The input signal V_{IN} comes from the function generator. (Note that the +15V and –15V power inputs have been omitted in this drawing, but they are still necessary.)

1. Copy the pin-out shown in Fig. 1 into your lab notebook.
2. Copy the circuit diagram shown in Fig. 2 into your lab notebook.
3. Turn on the breadboard. Set the adjustable – and + 15V power supplies to -10V and +10V by turning the knobs. Then, turn off the breadboard.
4. Insert the LM301 into the breadboard so that it is straddling one of the vertical trenches running down the breadboard.
5. Connect the ground, 0 - 15V terminals at the top of the breadboard to the various red and blue vertical columns. You should have a column to the right of the IC at +10V, a column on the left of the IC at -10V, and a third column at ground.
6. Give power to the amplifier IC by connecting the -10V column to the V- pin and the +10V column to the V+ pin. (Refer to pin-out in Fig. 1.)

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.

7. **Insert the 33 pF capacitor between pins 1 and 8.** This capacitor will reduce high frequency noise and increase stability.
8. Ground the non-inverting input (pin 3) of the amplifier.
9. Copy Table 1 into you lab notebook with a column for R_2 and a column for V_{OUT}.
10. Take a 10kΩ resistor from the set. Measure its resistance and record the value in the table in your lab notebook.

Table 1			
$R_2(\Omega)$	$R_2\,(\Omega)$	$\lvert V_{out}\rvert$ (V)	$\lvert V_{in}\rvert$ (V)
10k			
5.6k			
4.7k			
1k			
470			

11. Insert this resistor into proto board as R_2 to form the circuit shown in Fig. 2. One end should be connected to the inverting input (pin 2) and the other end connected to the op-amp output (pin 6).
12. 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.
13. Connect the output 'T' on the function generator to CH1 of the oscilloscope.
14. Connect the other side of 'T' to a BNC cable with minigrabbers on the other end. This cable will connect the output of the function generator to the input of the circuit.
15. 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_1 in the op-amp circuit. Carefully, insert it into the breadboard in the correct position. One end should be connected to inverting input (pin 2), the other end should be connected to the function generator via the red minigrabber.
16. Connect CH2 of the oscilloscope to the *output* of the circuit V_{OUT} using a different BNC-to-minigrabber cable. Remember, the black mini-grabbers should always be connected to ground.
17. Compare the circuit on your breadboard to the circuit in Figures 1 and 2. Check to make sure that it is
18. Turn on the breadboard.
19. Set the output of the function generator to be a 1 kHz sine wave with a peak-to-peak amplitude of $1V_{pp}$, and press the "Output ON" button.
20. Press the "auto set" button on the right hand side of the oscilloscope. You should see a sine wave appear. Measure the amplitude of CH1 and CH2 on the scope and these values in the table next to the value of R_1.
21. Measure the peak-to-peak amplitude $|V_{out}|$ and $|V_{in}|$ as a function of R_2 by swapping out the resistor until you have completely cycled through the resistors in the Table 1.
22. Turn off the breadboard and disconnect the minigrabbers from your circuit.
23. **Return all resistors to the proper bins.**

Part II: 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.

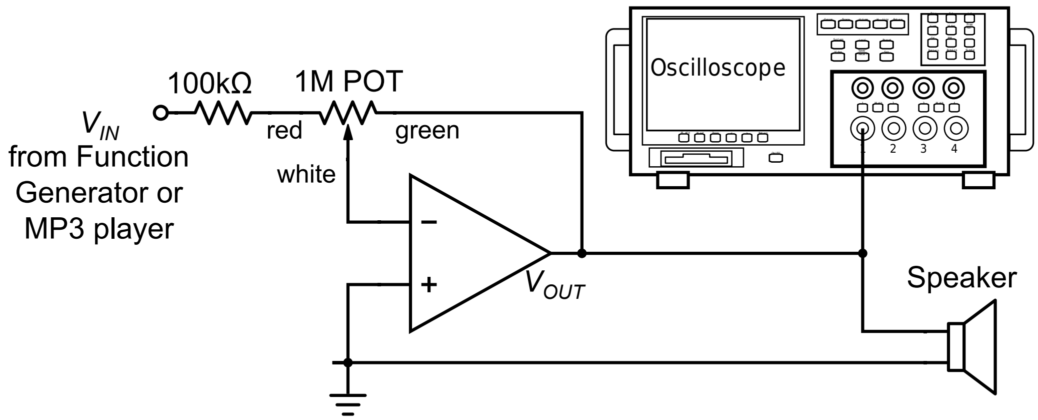

Figure 3 – A schematic of the inverting amplifier with input and output connected to audio equipment. Note that the +15V and –15V power inputs have been omitted, but they are still necessary.

1. Copy the circuit diagram shown in Fig. 3 into your lab notebook.
2. 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!
3. Connect the Extech handheld DMM to the leads of the potentiometer and measure its resistance. Turn the knob and see if the resistance changes. Try this with various combinations of leads to get a sense for how it works.
4. Remove the BNC 'T' from the functions generator and plug it into CH1 on the oscilloscope.
5. Replace the two resistors R_1 and R_2 with the 100kΩ resistor and 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 the 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. Pick a song, press play, 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_2 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