Lab One
Fundamentals of Electronics
EECE2412/3

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Abstract

The purpose of this laboratory experiment is to re-orient individuals with the basics of DC power supplies, function generators, and oscilloscopes. This is done through implementation of operational amplifiers (op-amps), which are integrated into various circuits. The limitations of these op-amps are then investigated through integration of an audio amplifier with a microphone.

KEYWORDS: power supplies, function generators, oscilloscopes, operational amplifier, audio, microphone

Contents

1 Equipment

Available equipment included:

- Basic Circuit Components (Capacitors, Resistors, Inductors, etc.)
- LM741 Operational Amplifiers
- Piezo-electric Speaker
- 8-ohm Speaker
- Basic Microphone
- Keysight EDU36311A Dual DC Power Supply
- Keysight EDU33212A Function Generator
- Keysight DSOX1204G Digital Oscilloscope
- BNC Cables

2 Performing the Experiment

2.1 Physical Circuitry

This laboratory experiment begins with the construction of a basic operational amplifier circuit with input from the function generator and readings obtained from the digital oscilloscope at the input and output of the amplifier at channels one and two, respectively. The circuit can be seen in Figure 1 below:

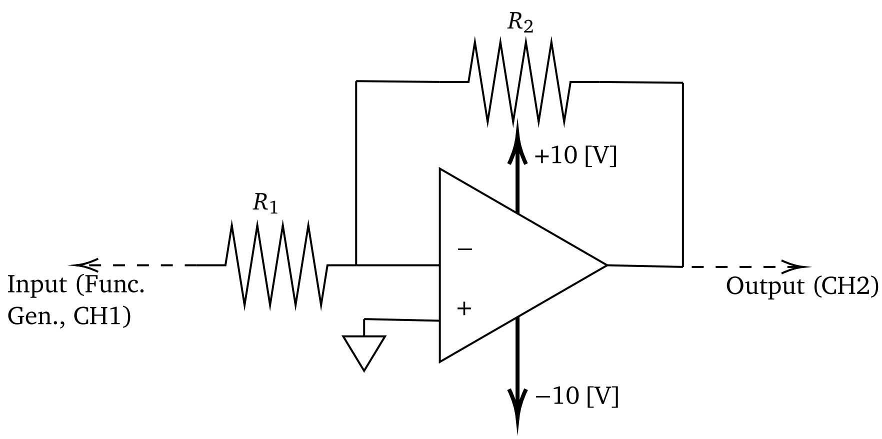

Figure 1: Simple Amplifier Circuit Diagram

Given values of $R_1 = 10[\mathrm{k}\Omega]$ and $R_2 = 100[\mathrm{k}\Omega]$, the above circuit was constructed. Furthermore, an input of $.75[\mathrm{V_{pp}}]$ at $8[\mathrm{kHz}]$ was specified. The resulting circuit is shown in Figure 2 below (Note the connection of two clips, corresponding to the function generator and oscilloscope channel 1, at the input, and the output to oscilloscope channel 2):

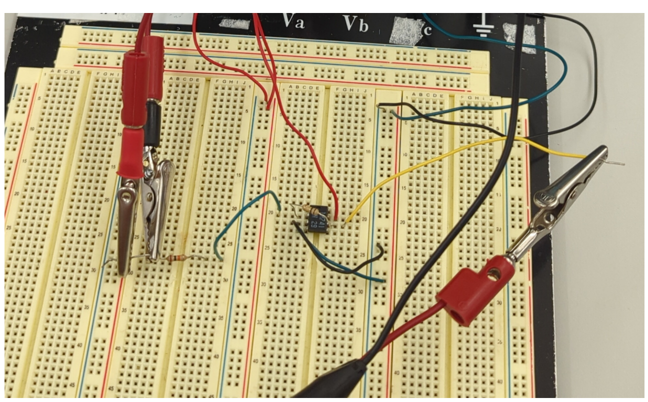

Figure 2: Constructed Circuit Shown in Figure 1

After passing the given signal through the circuit, the following oscilloscope reading was obtained:

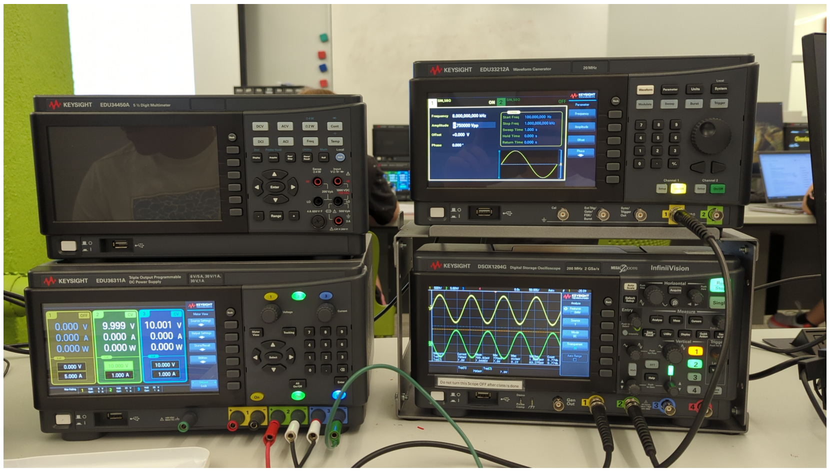

Figure 3: Readings from Circuit Shown in Figure 1

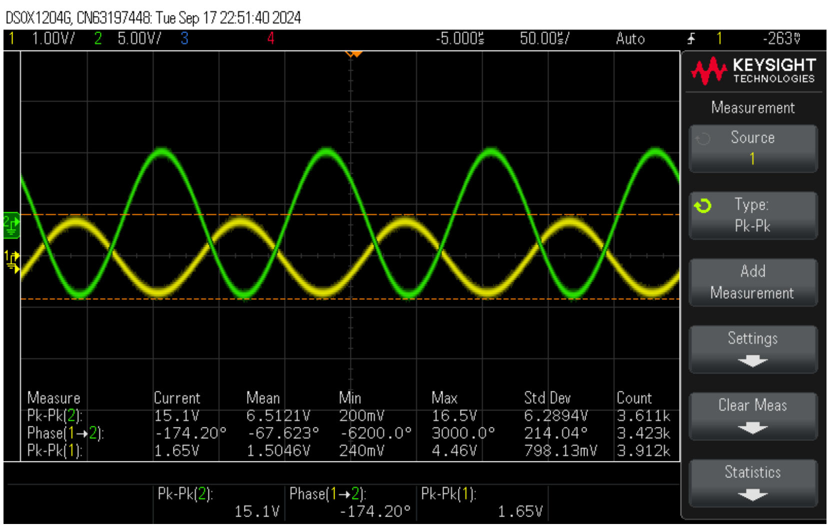

Figure 4: Readings from Circuit Shown in Figure 1

2.1.1 Determining the Phase Shift Visually

Looking at Figures 3 and 4, we may see that the output (green) wave, is a reflection of the input (yellow) wave about the horizontal axis. This corresponds to a phase shift of approximately 180°. This makes sense logically, as the circuit shown in

Figure 1 is an inverting amplifier (as the input flows into the negative terminal). This would result in a gain of magnitude 10, but with the opposite sign.

2.1.2 Determining the Phase Shift Mathematically

The period may be obtained as:

$$T = \frac{1}{8000}$$
$$T = .125[\text{ms}]$$

The time lag between the two waveforms was measured as $6.08 \cdot 10^{-5}[\text{s}]$. We can use this to find the phase shift:

$$\phi = 360\left(\frac{6.08 \cdot 10^{-5}}{.125 \cdot 10^{-3}}\right)$$
$$\phi = 175.1^\circ \approx 180^\circ$$

The delay is approximately 180°, as expected.

2.1.3 Maximum Voltage Output

Using the cursor function on the oscilloscope, the maximum values of the voltage output were obtained as $\pm 7.5[\text{V}]$ (voltage difference of $15[\text{V}]$). Increasing the peak-to-peak voltage results in clipping, as the op-amp voltage supplies are saturated, meaning the output is unable to exceed the supply values.

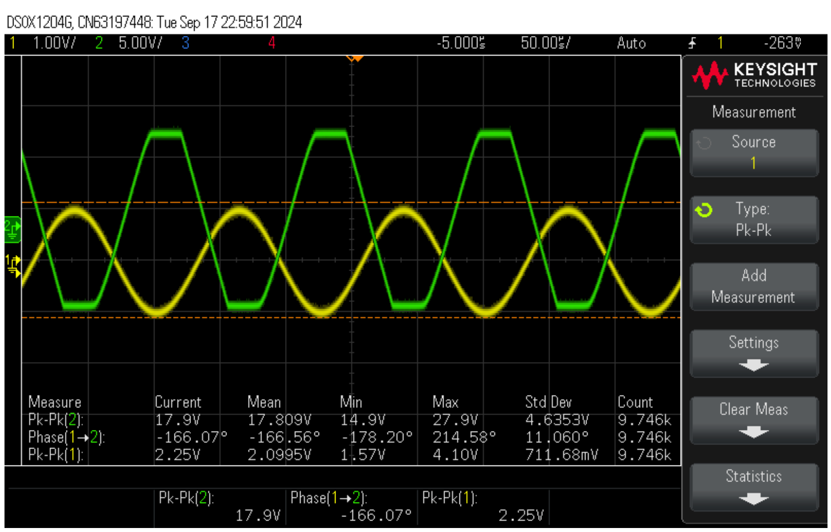

Figure 5: Saturation of the Op-Amp

2.1.4 Voltage Swing

Using the data sheet provided, it was determined that the typical LM741 voltage swing in the given configuration is ±14[V]. Given that the recorded data shows ±15[V], the voltage swing of the circuit is, more or less, as expected.

2.1.5 Using a Square Wave

Integrating a square wave as the input does <u>not</u> result in expected output of a square wave. Instead, the output becomes similar to a triangle wave. This is because the amplitude of a square wave switches abruptly, and the internal capacitance of the amplifier is unable to adjust as quickly. Thus, the capacitors take some time to conform to the voltage accordingly.

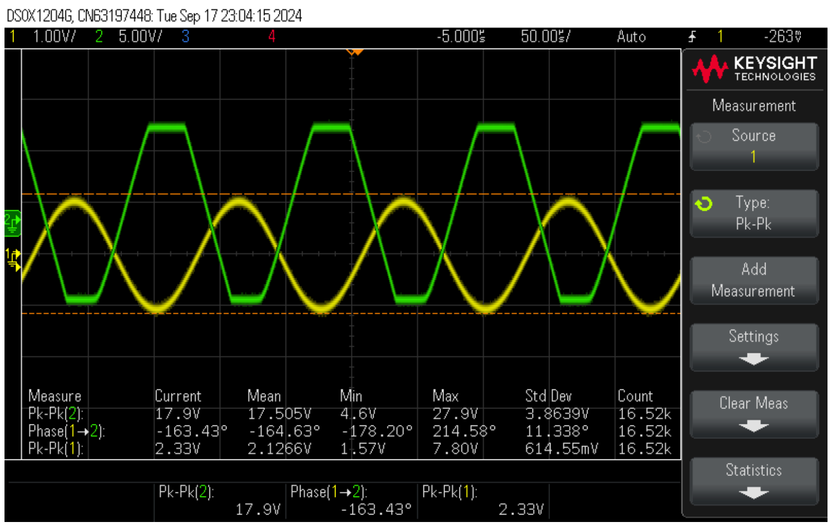

Figure 6: Increased Frequency Wave Input

2.1.6 Increasing the Frequency

Increasing the frequency with a sinusoidal input results more and more in a triangular wave. This is because operational amplifiers face slew rate limitations, meaning that if the signal oscillates too quickly, it is unable to adjust accordingly (this is similar to why the square wave input approaches a triangular wave, see Figures 6 and 7).

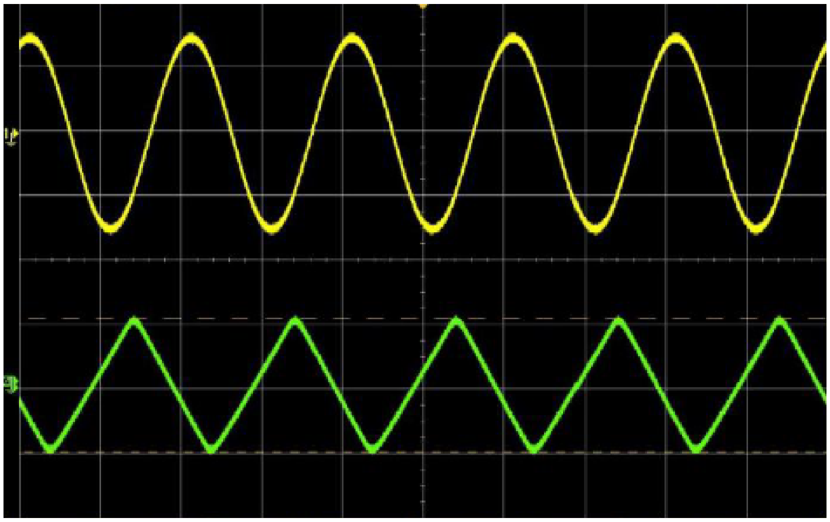

Figure 7: Increased Frequency Wave Input

2.2 Digital Simulation (SPICE)

The circuit from Section 2.1 was reconstructed for digital simulation the schematic is shown in Figure 8 below:

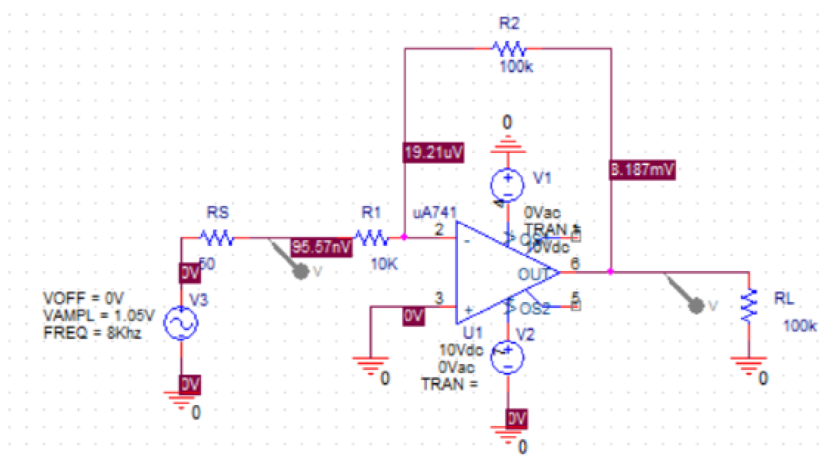

Figure 8: Digital Circuit Schematic

2.2.1 Verifying Experimental Data

Running the simulation produced the following output (Figures 9-11):

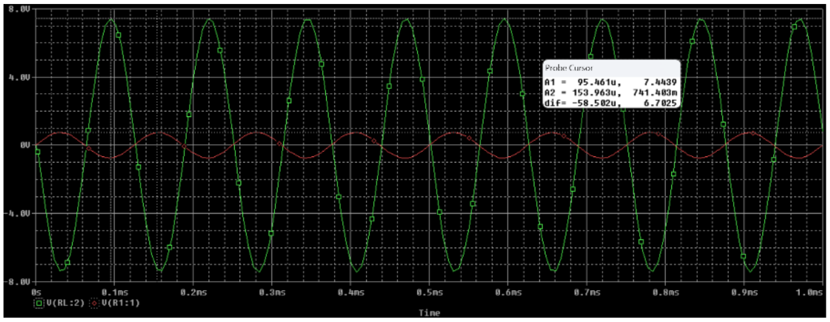

Figure 9: Amplitude and Frequency of Input and Output

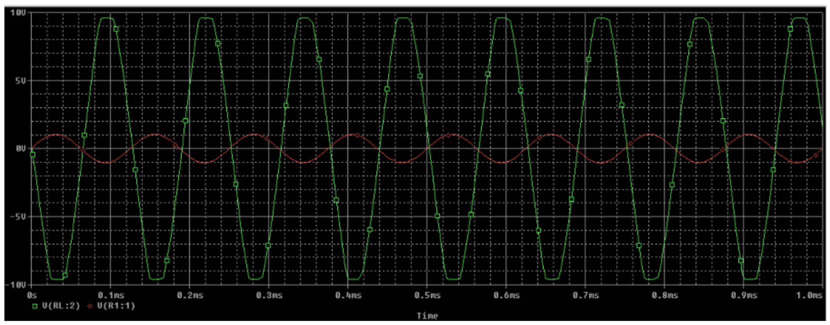

Figure 10: Clipping Beginning at About 1.05[V] Input (Output Magnitude > 10[V])

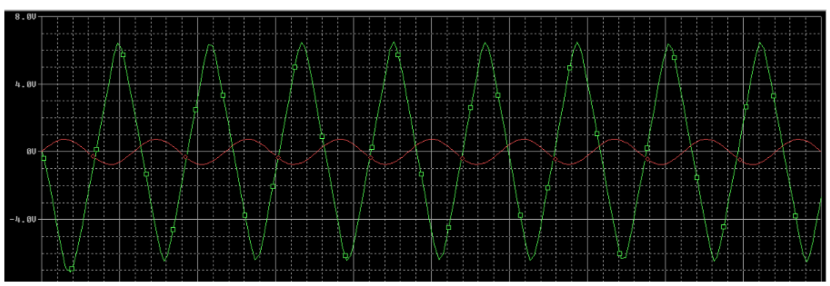

Figure 11: Slew Rate Maximum at Approximately 17[kHz]

It may be observed that the digitally simulated data closely follows the physically acquired data. Specifically, we see that the output has a gain magnitude of 10, with a phase shift of 180° (or gain of -10). Furthermore, because of this gain, clipping occurs when the input voltage is greater than 1[V]. For the simulation, this is visible at 1.05[V]. The slew rate was observed at 17[kHz], which was close to the experimentally obtained value.

2.2.2 Expected Microphone Circuit Data

To prepare for the second part of the physical experiment, a digital schematic mimicking the behaviors of the microphone was constructed. The schematic is shown below, along with the expected gain:

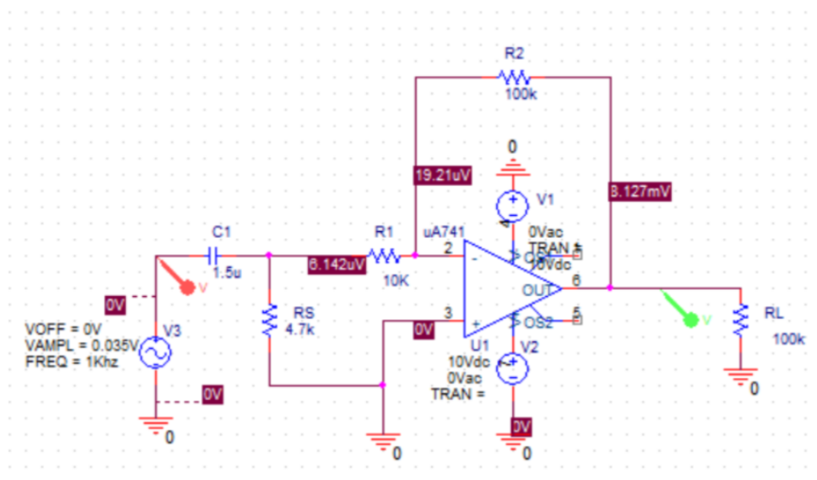

Figure 12: Audio Amplifier Circuit Mock-Up

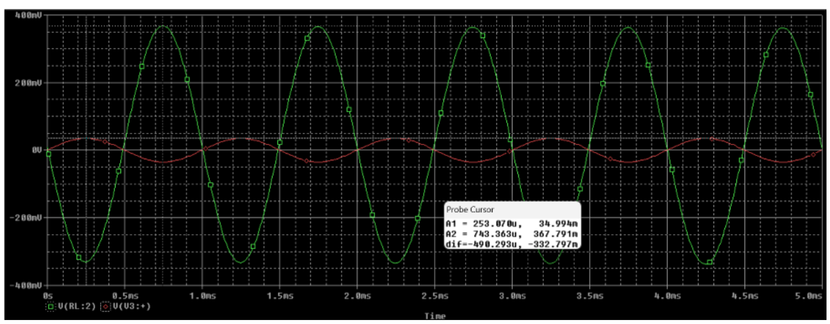

Figure 13: Expected Microphone Gain

The gain may be observed as around −10, as expected. The final step is to plot the 3[dB] frequency:

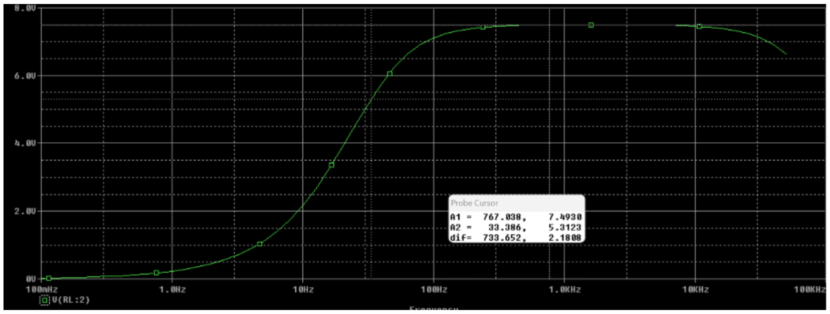

Figure 14: 3dB Frequency

From the simulated values, this is the only one that is different from the obtained data. While the physical circuit showed a critical frequency of 3300[Hz], the simulated data shows 30[Hz], while calculation produces 22[Hz].

2.3 Audio Amplifier Circuit Construction

The constructed amplifier circuit is shown in Figure 15 below:

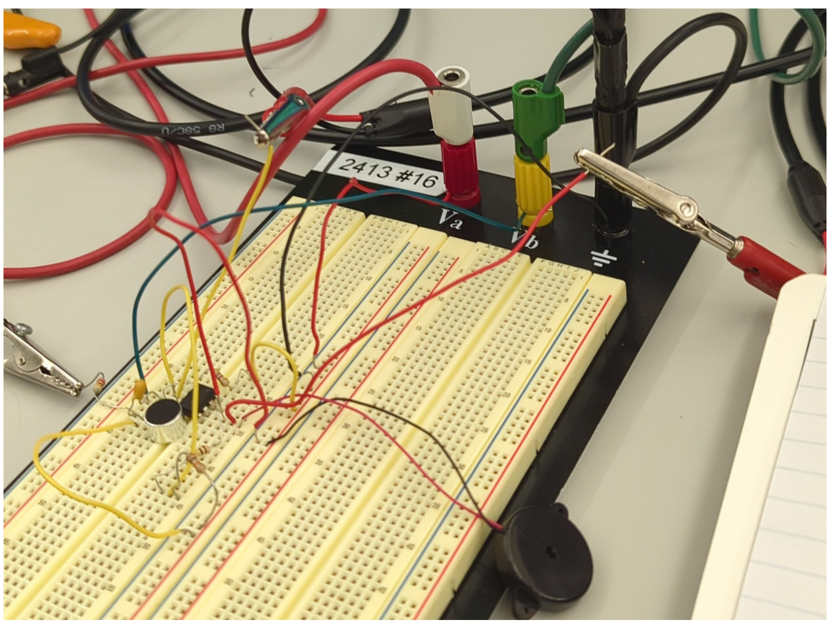

Figure 15: Audio Amplifier Circuit

The amplifier produced the following readings:

Figure 16: Audio Amplifier Circuit Readings

Given that the circuit is reading the analog signal from the microphone, there is significant noise produced at the output (green) wave. Furthermore, due to reflections, the gain magnitude was approximately 5, instead of the expected 10.

2.3.1 Using an 8-ohm Speaker

The implementation of an 8-ohm Speaker resulted in a louder output from the microphone. This is expected, as the speaker has a lower impedance than the piezoelectric speaker, but receives the same current flow. Thus, the perceived volume is louder.

3 Conclusion

Throughout the laboratory experiment, a test circuit was constructed as a refresher on power supplies, waveform generators, oscilloscopes, and operational amplifiers. These concepts were then confirmed virtually through SPICE circuit construction and simulation. Finally, the concepts were synthesized in the construction of a final audio amplifier circuit.