

Laboratory 2: Amplifiers

Lab Section AA

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EE233 Circuit Theory

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Abstract — In this lab, the characteristics and usage of op-amps were explored through the construction of a voltage-follower and summing amplifier. Further usage of lab equipment for testing/analyzing circuits was conducted. This lab effectively demonstrated the capabilities of op-amps for the overall project of making an audio mixer.

I. INTRODUCTION

In this lab, students will explore op-amps characteristics and usages through the construction of a voltage follower and summing amplifier. This serves as a vital step in the construction of the course's final project: an audio mixer. This lab's focus is on the voltage follower (or buffer) and the summing amplifier. The voltage follower ensures impedance matching between input and output, crucial for signal integrity, while the summing amplifier combines multiple audio sources, enabling control of magnitude, frequency content, dynamics, and panoramic position. By understanding the construction of an audio mixer in small "chunks," it allows the student to engage with the individual components to better understand its role in the overall final project.

II. LAB PROCEDURE

The equipment to construct the different circuits for this lab included a breadboard, LM348N Operational-Amplifier, 100k Ω potentiometer, a 0.22pF capacitor, and jumper wires to connect the components.

The function generator was used to produce different waves required such as a square or sine wave. For the square wave, the function generator was set to a square wave with a frequency of 3 kHz, amplitude of 20.0Vpp. For the sine wave, the

function generator was set to a sine wave with a frequency of 1 kHz, and amplitude of 200mVpp.

The oscilloscope was used to measure output voltage over the capacitor. The cursor function was used to measure time intervals between two points. The measure function was used to precisely calculate rise, fall, and delay times. Two main channels were used from the oscilloscope: Channel 1 and 2. Those channels were connected to the input signal voltages that were supplied by the waveform generator and the various output signal voltages measured across the different circuit components respectively.

III. EXPERIMENTAL PROCEDURE AND ANALYSIS

The Voltage Follower circuit that was constructed is shown in **Error! Reference source not found..**

The power supplies used were $V_{CC} = 12V$ and $V_{EE} = -12V$. The function generator was set to a

square wave with a frequency of 3kHz, 50% duty cycle and amplitude of 10V. A square wave was used as the input signal to the voltage follower.

The waveforms of the output voltage and input voltage is displayed in **Error! Reference source**

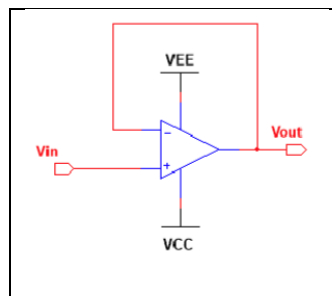


Figure 1. Voltage Follower (note VEE and VCC should be switched).

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Figure 2. The output voltage (green) when the input is a square wave (yellow).

1. From the waveform generated from the oscilloscope, it was found that the time interval for the output to reach a steady state after an input transition was $26.6\mu\text{s}$. Using this value and the voltage peak-to-peak yielded a slew rate of $0.752\text{ V}/\mu\text{s}$, which is like the slew rate found in the datasheet. Comparing the waveforms generated from the oscilloscope yielded very similar results to that of the datasheet and the SPICE program shown in Figure 3. They are nearly identical in terms of output behavior, non-instantaneous rise/fall, and slight delay between input and output.

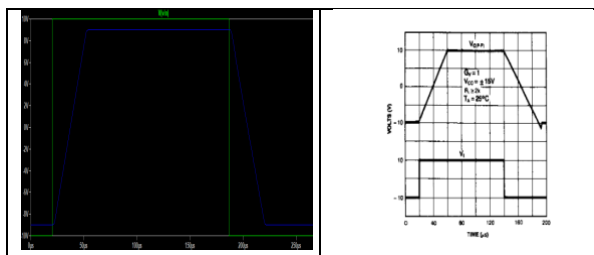


Figure 3. SPICE program waveform (left), Datasheet waveform (right).

The Summing Amplifier circuit that was constructed is shown in Figure 4. The power supplies used were $V_{CC} = 12\text{V}$ and $V_{EE} = -12\text{V}$. The resistors $R_1 = R_2 = R_3 = R_f = 100\text{k}\Omega$ and $C = 22\text{pF}$. The

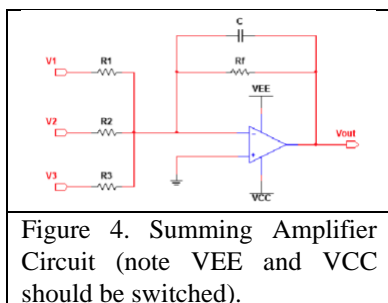


Figure 4. Summing Amplifier Circuit (note VEE and VCC should be switched).

function generator was set to provide $v_1 = \cos(2\pi \times 1000 \times t)\text{ V}$. The frequency of V_1 was slowly adjusted from 10Hz to 1MHz with a sequence of 1-2-5. The output voltage datapoints are shown in Table 1 below.

Table 1

V1 Frequency (Hz)	V_{out} (V)
10	1.05
20	1.05
50	1.05
100	1.05
200	1.05
500	1.05
1000	1.05
2000	1.05
5000	1.05
10000	1.05
20000	960 mV
50000	760 mV
100000	470 mV
200000	270 mV
500000	140 mV
1000000	65 mV

2. According to Figure 5 from the theoretical output from pre-lab3.3.5 and experiment output in Figure 6, they are consistent in waveforms. Both graphs show a drop in the output voltage at similar input frequencies.

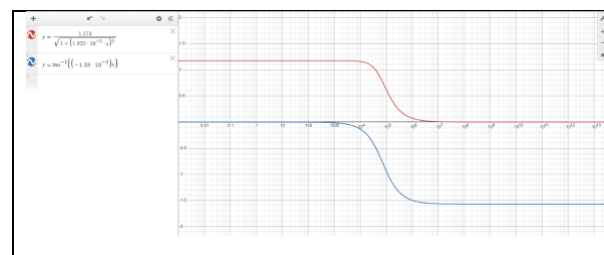


Figure 5. Prelab3.3.5, Magnitude of the output signal from 10Hz to 1MHz .

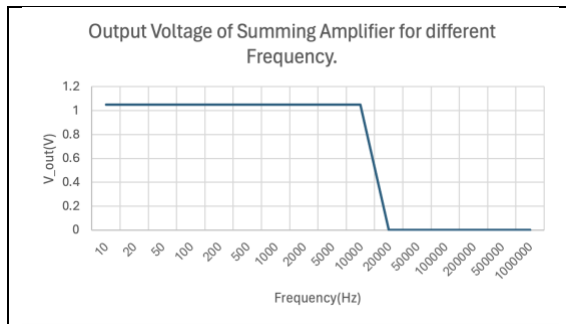


Figure 6. The experiment output signal from 10Hz to 1MHz, based one Table 1.

Next, an audio signal was used as an input signal to V1, V2, and V3. A speaker was connected to V_{out} to play the audio sound. The output signal voltage from the scope display is shown in Figure 7.

- According to Figure , the waveform of the output voltage isn't a pure sinusoidal waveform. Because of this, a 1 kHz signal was tested, causing a sharp high-pitched ring to emit from the speaker. The subsequent



Figure 7. Output voltage (yellow) when a song is played

- The potentiometers that were part of the "input" signals controlled their respective channel's input gain. This meant that adjusting the resistances for a given channel affected the sound coming from that specific channel, the other channels would be unaffected. The potentiometer that was R_f controlled the overall volume of the sound being displayed. As the resistance lowers, the sound will get louder, and vice versa.

IV. CONCLUSIONS

This lab successfully demonstrated the operational characteristics and the applications of op-amps construction and testing of a voltage follower and a summing amplifier. These are critical components for the design and implementation of an audio mixer.

The experimental results confirmed the theoretical predictions for both the voltage follower and summing amplifier circuits.

Measurements such as slew rate and voltage gain were closely aligned with expected values. For example, the voltage follower exhibited a slew rate of $0.752 \text{ V}/\mu\text{s}$, which is closely approximating the datasheet value, thereby verifying our setup. Key observations included a gain of 1 at a low frequency of 10 Hz, with the voltage gain halving at a significantly high frequency of 1700 kHz, slightly differing from the predicted 2290 kHz in SPICE model.

Furthermore, the summing amplifier's performance over various frequencies demonstrated consistent output until a notable decline at higher frequencies, with the output voltage decreasing from 1.05 V at lower frequencies down to 65 mV at 1MHz. In conclusion, this lab successfully achieved its objectives by illustrating both theoretical and practical aspects of the op-amp.

Team Roles

Activity	Student(s) Name
Prelab: Circuit Analysis	Ethan, Junhan, Travis
Prelab: Simulations and Graphs	Ethan, Junhan, Travis
Prelab: Questions	Ethan, Junhan, Travis
Lab: Circuit Construction	Ethan, Junhan, Travis
Lab: Data Collection	Ethan, Junhan, Travis
Lab: Data Analysis	Ethan, Junhan, Travis
Report: Procedure	Ethan, Junhan, Travis
Report: Analysis and Graphs	Ethan, Junhan, Travis
Report: Questions	Ethan, Junhan, Travis