Lab 7

Getting started with Operational Amplifier Circuits

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1 Introduction

Operational amplifiers (op-amps) are fundamental components in modern electronics, widely used for signal amplification, filtering, and mathematical operations in various applications. Their versatility stems from high input impedance, low output impedance, and the ability to provide significant gain. This lab focused on gaining practical experience with basic op-amp circuits, specifically the inverting and summing amplifier configurations. These configurations serve as the building blocks for more complex analog signal processing systems.

The primary objective of this experiment was to explore the behavior of the inverting op-amp circuit and the summing inverting amplifier. By constructing these circuits and measuring their performance under various input conditions, a deeper understanding was gained of how op-amps manipulate signals in terms of gain, polarity, and signal combination. Additionally, the lab introduced the importance of selecting appropriate resistor values to achieve desired circuit gains and explored the effect of adding a DC offset to an AC signal using summing amplifiers.

Through the assembly of the circuits on a protoboard and the use of measurement tools such as oscilloscopes, the relationship between input and output signals was observed and experimental results were compared with theoretical expectations. This lab provided an essential foundation for mastering the use of op-amps in real-world electronic applications.

2 Results

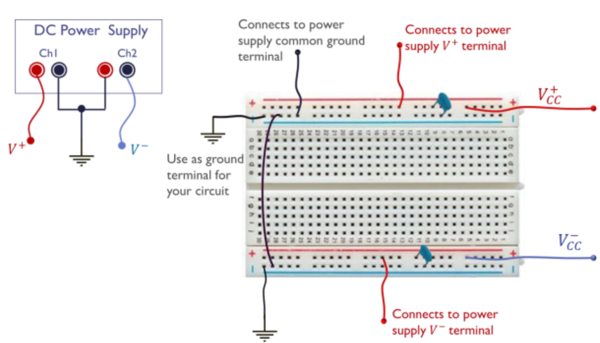

Figure 1: DC Power Supply Connections on Breadboard

An inverting op-amp circuit was constructed. First the DC power supply was connected to the breadboard as shown in Figure 1. The two capacitors used had a capacitance of 10 μF.

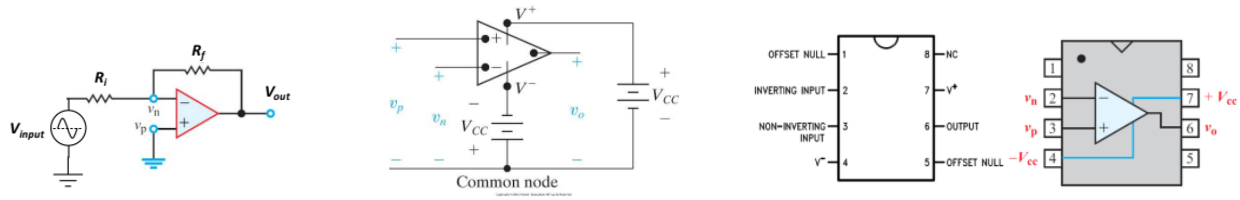

Figure 2: Inverting Op-Amp Circuit

The inverting op-amp circuit was constructed as shown in Figure 2. The gain of the circuit is chosen to be -10. The equation for the gain of the inverting op-amp circuit is given by

$$G = -\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_i}$$

Since we want a reistor value of 10 kΩ for R_i, we can choose R_f to be 100 kΩ. The circuit was built on the breadboard in Figure 3.

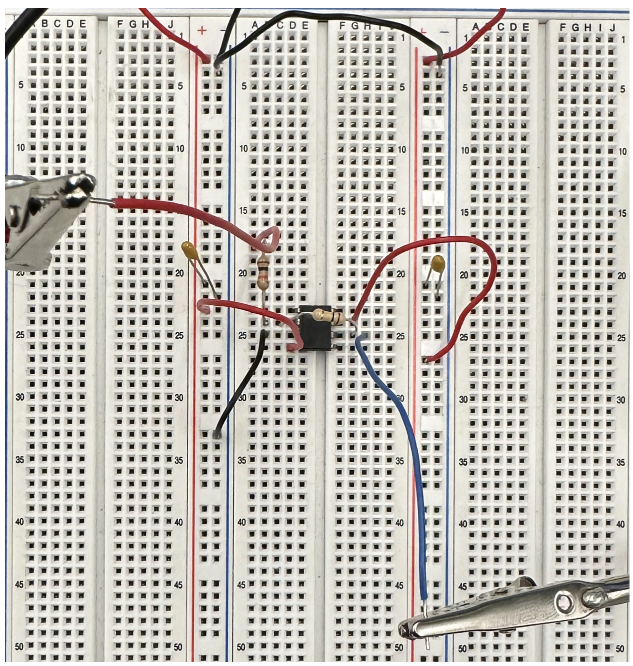

Figure 3: Inverting Op-Amp Circuit on Breadboard

The actual values of R_f and R_i were measured to be 98.876 kΩ and 9.975 kΩ respectively. The circuit was then connected to a function generator which was set to produce a 1 kHz sine wave with an amplitude of 0.5 V peak-to-peak. An oscilloscope was connected to the output of the op-amp circuit to measure the output voltage. The oscilloscope was also connected directly to the function generator to measure the input. The input voltange and output voltage were measured to be 1.11 V and 10.9 V, respectively. The gain of the circuit was calculated to be -9.82, which is close to the expected value of -10. The gain of the circuit is negative, because the output sine wave has its phase shifted by π. The input sine wave had the amplitude increased to 1.2V peak-to-peak. The output sine wave, is measured to be 17.5 V with its peaks clipped. This is due to the op-amp reaching its maximum output voltage of ±10 V. If the voltage cap was removed, then the amplitude would be 24 V.

The inverting op-amp circuit was then modified to include a DC offset. This is called a summing inverting amplifier.

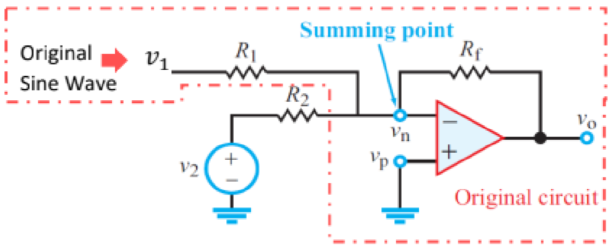

Figure 4: Summing Inverting Amplifier

The circuit seen in Figure 4 was built on a breadboard. The equation for the output voltage of the summing inverting amplifier is given by the equation:

$$V_{out} = -\frac{R_f}{R_1}V_1 - \frac{R_f}{R_2}V_2$$

The original circuits gain is $-\frac{R_f}{R_1} = -10$. Thus, the resistor value for R_2 can be calculated through this equation:

$$-\frac{R_f}{R_2}v_2 = -1 = -\frac{100\ k\Omega}{R_2} \cdot 10\ V \implies R_2 = 1M\Omega$$

The circuit was built on a breadboard as shown in Figure 5. The actual values of the R_2 was measured to be 0.912 $M\Omega$

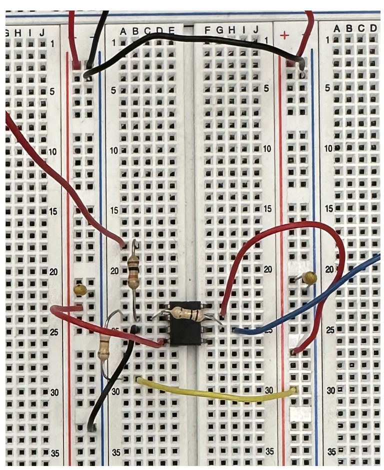

Figure 5: Summing Inverting Amplifier on Breadboard

The function generator was set to produce a 1 kHz sine wave with an amplitude of 0.5 V peak-to-peak. The DC power supply was set to 5 V. In order to get the 10 V for V_{out}, V_2

is connected to V_{cc}^{+}. The oscilloscope was connected to the output of the op-amp circuit to measure the output voltage. The output voltage wasd measured to be 3.750 V peak-to-peak. This is to be expected since the gain of the circuit is -10 and the DC offset is -1 V.

3 Discussion and Conclusion

In conclusion, this lab provided valuable hands-on experience with operational amplifiers, particularly inverting and summing inverting amplifier configurations. Through the construction and testing of these circuits, we observed how operational amplifiers manipulate input signals by controlling gain and polarity. The measured gain values were close to the theoretical predictions, demonstrating a solid understanding of circuit design and the influence of resistor values on gain.

In the inverting amplifier configuration, the expected gain of -10 was confirmed experimentally, with minor deviations due to component tolerances. The phase inversion characteristic of the inverting amplifier was clearly observed. The output clipping at high input signal amplitudes highlighted the importance of considering the op-amp's output voltage limits in practical circuit design.

The summing amplifier experiment further demonstrated the ability of op-amps to combine AC and DC signals. By introducing a DC offset, we successfully modified the output signal, reinforcing the utility of op-amps in applications requiring signal conditioning.

Overall, this lab established foundational knowledge of operational amplifier circuits, which will be crucial for more advanced analog electronics applications.

4 References

[1] Dr. Iman Salama. "Lab 7 – Getting started with Operational Amplifier Circuits" Northeastern University. 25 October 2024.