Design and Offset Nulling of a 40 dB Non-Inverting Amplifier

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1. Introduction and Aim

To design and analyze a non-inverting amplifier with a fixed 40 dB gain for precise voltage amplification while maintaining signal integrity and minimizing distortion. Additionally, to minimize or eliminate the offset voltage in the amplifier using offset nulling techniques to ensure accurate amplification with zero output for zero input.

2. Theory

The non-inverting amplifier's gain is determined by the formula

$$A_v = 1 + \frac{R_f}{R_g}.$$

In this experiment, the objective is to achieve a gain of 40 dB (or 100 in linear scale). The principle involves using the operational amplifier in a non-inverting configuration where the input signal is applied to the non-inverting terminal. The feedback network, consisting of R_f and R_g, controls the amplification factor. The output voltage V_o is related to the input voltage V_i by $V_o = A_v V_i$. By varying R_g while keeping R_f fixed, the desired gain can be achieved. The high input impedance of the 741 op-amp ensures minimal loading on the input source, and the low output impedance allows for efficient driving of the load.

Offset voltage in an operational amplifier is caused by internal component mismatches. The 741 op-amp has internal circuitry to address this, but external adjustment is often required. By connecting a potentiometer across specific pins (Pin 1 and Pin 5 in this case) and adjusting it, the offset can be compensated. The principle is to balance the input stage such that the output is zero when the input is zero. This is crucial for applications where accurate amplification of small signals is necessary.

3. Experimental Method and Results

a. Circuit Diagram The circuit diagram is shown in Figure 4. It consists of a 741 operational amplifier with a 50 mV input voltage source V_i, a feedback resistor $R_f =$

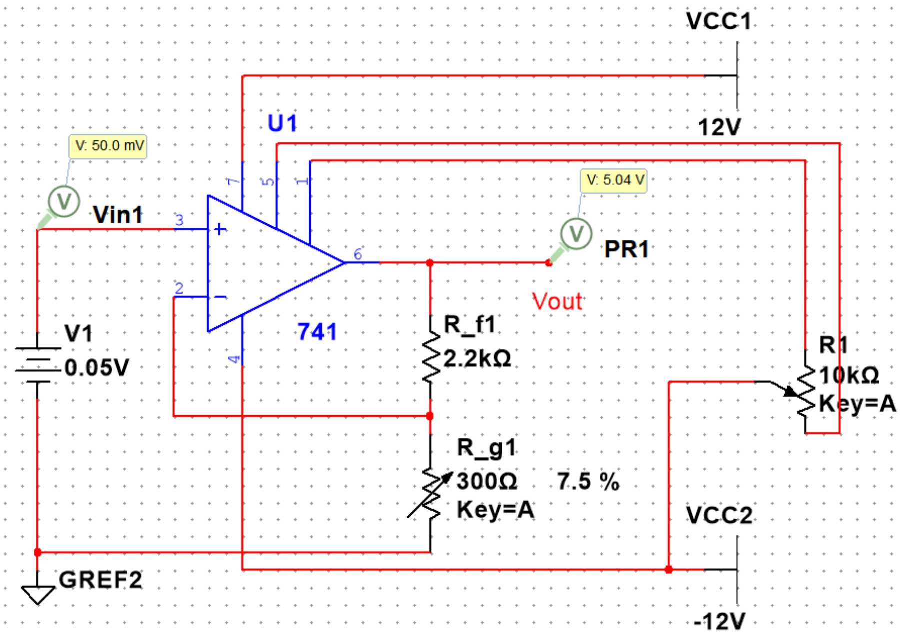

Figure 1: Circuit Diagram

2.2 kΩ, and a variable resistor R_g. The power supply is ±12 V. Additionally, a 10 kΩ potentiometer is connected across Pin 1 and Pin 5 of the op-amp, and the center point of the potentiometer connected to $V_{cc\_}$ for offset nulling. [Insert a photo of your actual circuit setup here if possible.]

b. Experimental Method The circuit was set up as per Figure 4. A DC power supply or signal generator was used to set V_i to 50 mV. R_g was then varied until the gain of the amplifier reached 40 dB, which was determined when $V_o = 5\,\text{V}$. A range of V_i and V_o values were measured and recorded to observe the linear and saturation regions of the transfer characteristic. When approaching saturation, smaller voltage increments were used for accurate mapping. Subsequently, the input voltage was set to $-50\,\text{mV}$ by swapping the power supply leads, and a graph of V_i versus V_o was plotted.

For offset nulling, with V_i set to 0 V, the potentiometer was adjusted until $V_o = 0\,\text{V}$. Then, the input terminal was reconnected to the voltage source, and the potentiometer was varied to set V_i to 50 mV and verify a gain of 100 ($V_o = 5\,\text{V}$). The potentiometer was further varied while measuring V_o for different V_i values, and the results were recorded. Finally, the input voltage was set to $-50\,\text{mV}$ by swapping the leads, and a graph of V_i versus V_o was plotted.

Input Voltage V_i (mV)	Output Voltage V_o (V)
50 (at 40 dB gain)	5
-50	-5
0 (after nulling)	0

Table 1: Measured Values of V_i and V_o

c. Results and Discussion The aim of achieving a 40 dB gain non-inverting amplifier was achieved. The graph of V_i versus V_o showed a linear relationship in the linear region and saturation behavior near the power supply limits. The goal of offset nulling was also achieved. The adjusted circuit provided accurate amplification with zero offset. Deviations from the ideal values occurred due to factors such as the non-ideal characteristics of the op-amp (finite open-loop gain, input offset voltage, etc.) and resistor tolerances. To improve accuracy, higher precision resistors, a more stable power supply, a higher quality potentiometer, and better shielding techniques can be employed.

4. Conclusion

Through the design and offset nulling of the 40 dB non-inverting amplifier, a precise amplification circuit was achieved. The understanding of gain control and offset compensation techniques for the 741 operational amplifier was deepened. The experiments highlighted the importance of considering component non-idealities and provided strategies for improving circuit performance in practical applications.