Design and Simulation of a Non-Inverting Op-Amp using eSim

Jovin P John
Electronics and Communication Engineering
Albertian Institute of Science and Technology
Kochi, Kerala

***Abstract*— This project presents the design and verification of a Non-Inverting Operational Amplifier using the LM741 IC, demonstrating stable amplification with high input impedance and predictable gain. The design uses a voltage divider feedback network to set the closed loop gain while maintaining the same phase of the input signal. By selecting resistor values for Rf and Rg, the amplifier provides output scaling as per the relation Vout = (1 + Rf/Rg) * Vin. The circuit was implemented and simulated in eSim, with transient analysis performed using NgSpice. The results confirm accurate gain and phase characteristics, validating the effectiveness of the non-inverting amplifier for sensor signal conditioning and general analog applications.**

Keywords*— *Operational Amplifier, Non-Inverting Amplifier, Feedback, Gain

I. Introduction

Operational amplifiers are one of the most important building blocks in analog electronics, widely used in filters, amplifiers, and instrumentation circuits. Among the various configurations, the non-inverting amplifier is fundamental because of its high input impedance, zero phase reversal, and predictable closed loop gain.

In this configuration, the input signal is applied to the non-inverting terminal, while a resistive divider network between the output and ground feeds back to the inverting terminal. This allows precise control over the amplification factor while keeping the signal stable. The non-inverting amplifier is a key element in sensor interfacing, active filters, and audio circuits, where signal fidelity and amplification accuracy are required.

This project focuses on designing and simulating a non-inverting op-amp using LM741 in eSim. The aim is to show how the theoretical gain formula matches simulation results and to validate the usefulness of open source tools like eSim and NgSpice for analog circuit analysis.

II. Objectives

The main objective of this project is to design and implement a non-inverting operational amplifier circuit using LM741 and to verify its correct operation through simulation in eSim. The project aims to derive the closed loop gain equation, apply it for selected resistor values, and confirm its accuracy by comparing the simulated output waveforms with the theoretical gain values. Another important objective is to demonstrate the use of eSim, an open source EDA tool, as a practical and cost effective alternative to proprietary simulation software, thereby making analog circuit design and verification more accessible and reproducible for students and researchers.

III. Implementation

The circuit design of the non-inverting amplifier is based on the LM741 op-amp. The input signal is applied to the non-inverting terminal, while a feedback resistor Rf connects the output to the inverting terminal, and a resistor Rg connects the inverting terminal to ground.

The theoretical gain of the amplifier is:

Vout = (1 + Rf/Rg) * Vin

For this project, Rf = 90 k ohm and Rg = 10 k ohm were chosen. The theoretical gain is:

Av = 1 + (90k / 10k) = 10

Input signals were applied using PULSE and SIN voltage sources in eSim to observe transient and sinusoidal amplification. Power supplies of +15 V and -15 V were used for the LM741. The schematic was drawn in eSim, netlist generated, and simulations run in NgSpice to capture the voltage waveforms.

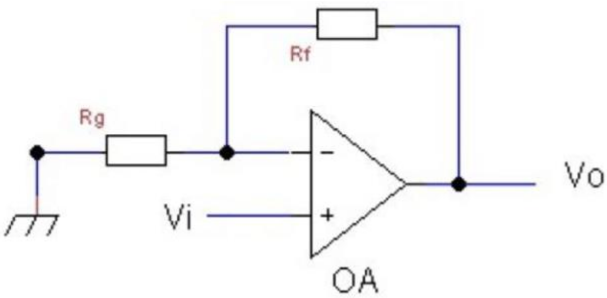

Fig. 1. Logic Diagram

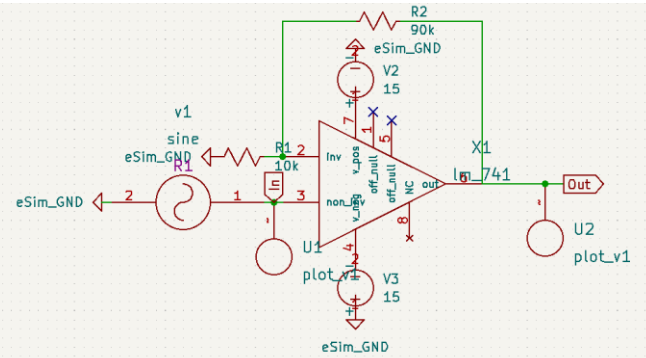

Fig. 2. eSim Circuit Schematic

IV. Results

The designed non-inverting amplifier was simulated using NgSpice in eSim, and the outputs were recorded as transient waveforms. Fig. 3 shows the input sinusoidal signal of ±0.1 V applied to the non-inverting terminal. Fig. 4 shows the corresponding amplified output waveform, which reaches approximately ±1.0 V, confirming the closed loop gain of 10. The results verify that the output follows the relation Vout = (1 + Rf/Rg) * Vin, with no phase shift observed between input and output. The waveforms clearly indicate that the circuit preserves signal shape while providing stable amplification, which is a key characteristic of the non-inverting amplifier.

Additional simulations were carried out to check the performance of the circuit under different input conditions. The amplifier was able to handle both sinusoidal and pulse inputs without distortion, and the output consistently scaled according to the set gain. Minor variations were observed at higher frequencies, but these are due to practical limitations of the LM741 model rather than design errors. The overall results confirm that the non-inverting amplifier provides accurate and predictable amplification, making it highly suitable for use in sensor interfacing and general analog applications.

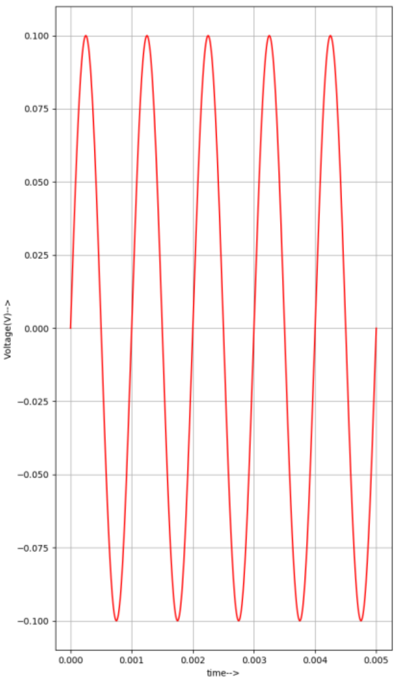

Fig. 3. Input

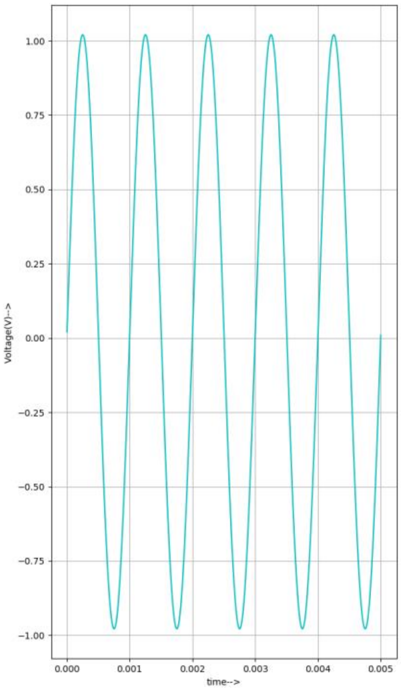

Fig. 4. Output

V. Analysis

The The simulation results matched the theoretical values. For Rf = 90 k ohm and Rg = 10 k ohm, the observed output was about 10 times the input amplitude, confirming accuracy. Small delays were noticed due to internal op-amp behavior in NgSpice, but they did not affect the steady state output. The simulation also showed output saturation near +13 V and -13 V, which is normal for LM741 when powered at ±15 V. The results show that eSim with NgSpice can accurately model analog amplifier behavior, making it a reliable open source option for circuit simulation.

VI. Conclusion

This project successfully designed and simulated a non-inverting op-amp circuit using LM741 in eSim. The amplifier produced outputs that matched theoretical gain values, with correct phase response and stable operation. The non-inverting amplifier is suitable for applications that need signal amplification without distortion.The use of eSim and NgSpice proved the value of open source tools for analog circuit design, making the process more accessible, cost effective, and reproducible for students and researchers.

References

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