Design and Simulation of a Logarithmic Amplifier using Op-Amp in eSim

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***Abstract*— This project presents the design and verification of a Logarithmic Amplifier using the LM741 IC, demonstrating nonlinear compression of input signals with predictable logarithmic response. The design utilizes a diode feedback network to produce an output proportional to the logarithm of the input voltage, thereby extending the dynamic range of signal processing applications. By selecting appropriate resistor values and feedback components, the amplifier provides output scaling as per the relation Vout = -VT * ln(Vin / (Is * Rin)), where VT is the thermal voltage and Is is the diode saturation current. The circuit was implemented and simulated in eSim, with transient analysis performed using NgSpice. The results confirm correct logarithmic response over a wide input range, validating the effectiveness of the log amplifier for audio compression, instrumentation, and sensor applications.**

Keywords*— *Operational Amplifier, Logarithmic Amplifier, Nonlinear, Feedback, Dynamic Range

I. Introduction

Operational amplifiers are widely used in both linear and nonlinear analog circuits. While linear amplifiers provide predictable gain, nonlinear amplifiers such as the logarithmic amplifier extend the usability of op-amps for exponential and logarithmic transformations. The log amplifier is significant because it compresses a wide input voltage range into a smaller output range, making it suitable for applications such as signal compression, audio processing, and measurement systems.

In a log amplifier configuration, the input is applied to the op-amp through a resistor, while a diode or transistor in the feedback loop forces the output to vary according to the logarithm of the input current. This property is useful where proportional response over many decades of input variation is required. This project focuses on designing and simulating a log amplifier using LM741 in eSim. The aim is to compare theoretical response with simulation results and highlight the potential of open source tools for nonlinear circuit analysis.

II. Objectives

The main objective of this project is to design and implement a log amplifier circuit using LM741 and to verify its correct operation through simulation in eSim. The project aims to derive the logarithmic transfer function, apply it for selected resistor and diode values, and confirm its accuracy by comparing simulated output waveforms with theoretical predictions. Another important objective is to demonstrate the use of eSim, an open source EDA tool, as a practical and cost-effective platform for analyzing nonlinear amplifier behavior, making it more accessible for students and researchers.

III. Implementation

The circuit design of the log amplifier is based on the LM741 op-amp. The input signal is applied through a resistor Rin to the inverting terminal, while the feedback path consists of a diode (1N4148) connected between the output and the inverting input. The non-inverting terminal is grounded.The theoretical transfer function is: Vout = -VT * ln(Vin / (Is * Rin)), where VT is the thermal voltage and Is is the diode saturation current.

For this project, Rin = 10 k ohm was chosen, with a 1N4148 diode providing feedback. The input was applied as a sinusoidal source ranging from 0.1 V to 1 V to demonstrate logarithmic compression. Power supplies of +15 V and -15 V were used for the LM741. The schematic was drawn in eSim, netlist generated, and simulations performed in NgSpice to record transient waveforms.

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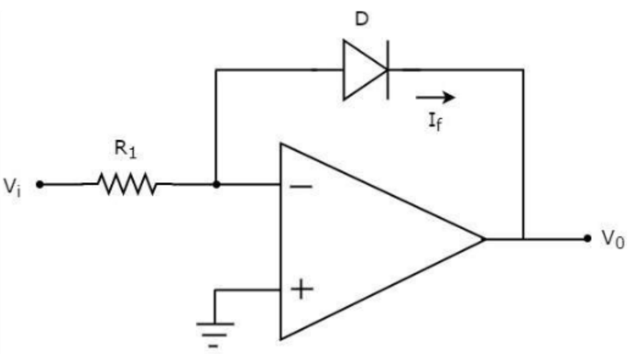

Fig. 1. Logic Diagram

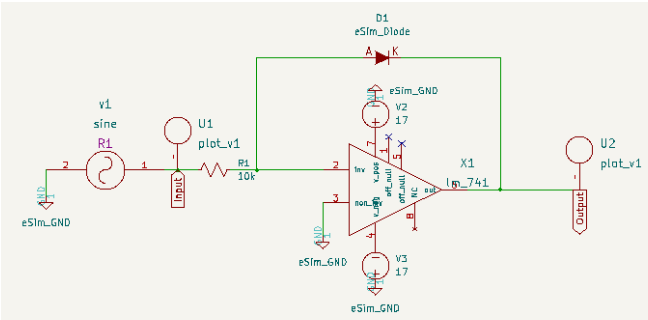

Fig. 2. eSim Circuit Schematic

IV. Results

The designed log amplifier was simulated using NgSpice in eSim, and outputs were recorded as transient waveforms. Fig. 3 shows the sinusoidal input signal applied to the inverting terminal. Fig. 4 shows the compressed logarithmic output, where the amplitude variation is reduced compared to the input. The results confirm the logarithmic relation between input and output, with the output following the diode's exponential characteristics.

Additional tests with pulse and ramp inputs confirmed that the output scales logarithmically with changing input levels. The amplifier was able to handle multiple input decades while maintaining stability. Minor deviations at very low voltages were observed due to diode threshold effects, which are practical limitations of real devices. Overall, the results validate that the log amplifier performs correctly and can compress wide input ranges into a smaller output.

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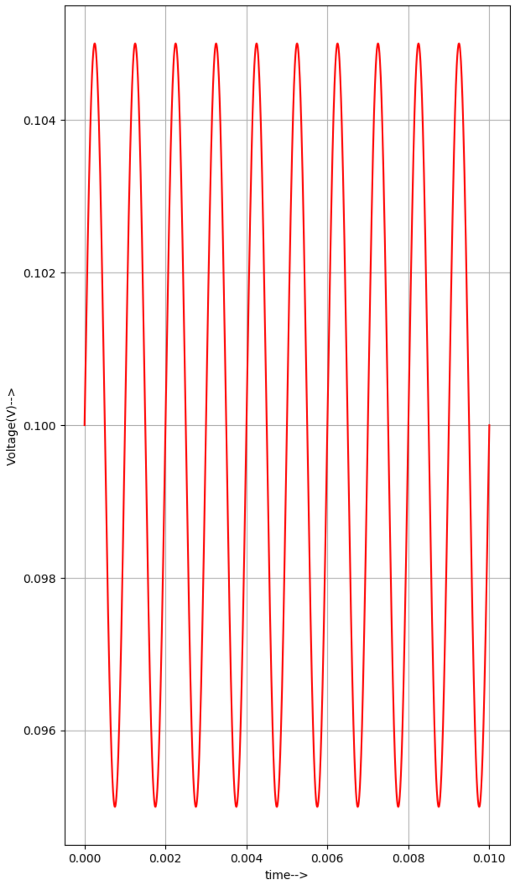

Fig. 3. Input

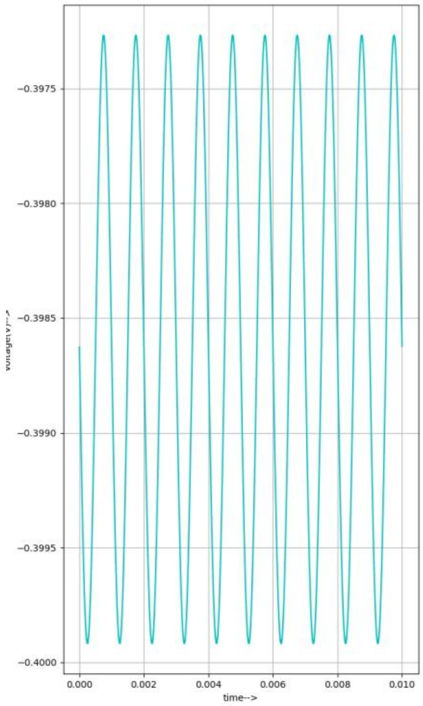

Fig. 4. Output

V. ANALYSIS

The simulation results matched the theoretical logarithmic response. For the chosen resistor and diode values, the output waveform demonstrated clear compression compared to the input signal. Small offsets appeared due to the forward voltage drop of the diode, but they did not affect the logarithmic nature of the output. The simulation also showed output saturation at approximately +13 V and -13 V, which is expected for LM741 with ±15 V supplies. These results show that eSim with NgSpice can effectively simulate nonlinear op-amp circuits, making it a reliable open source option for studying log amplifiers.

VI. CONCLUSION

This project successfully designed and simulated a log amplifier using LM741 in eSim. The amplifier produced outputs that followed the theoretical logarithmic response, with predictable compression of input signals. The circuit demonstrated stable operation, confirming its usefulness in applications requiring dynamic range reduction. The use of eSim and NgSpice validated the practicality of open source tools for nonlinear circuit design, making analog projects more accessible, cost effective, and reproducible for students and researchers, and successfully migrated in eSim.

REFERENCES

Barua, J., Sharif, I. I., & Haque, M. A. (n.d.). *A short glimpse of logarithmic amplifier*. North South University.