Experiment 5: Op-Amp Applications

Abhimanyu Koushik (EE24BTECH11024),
Agamjot Singh (EE24BTECH11002)
IIT Hyderabad

March 3, 2025

Abstract

This experiment explores three key applications of operational amplifiers (op-amps): custom weighted summing and difference amplifiers, op-amp integrators, and precision rectifiers. The mathematical principles, circuit designs, and working mechanisms are analyzed. Experimental results validate the theoretical predictions and demonstrate the versatility of op-amps in signal processing.

1 Introduction

Operational amplifiers (op-amps) are versatile components widely used in analog signal processing. This experiment focuses on three applications: 1. Custom weighted summing and difference amplifier. 2. Op-amp integrator. 3. Precision rectifier (super diode).

Each application is implemented using appropriate circuit designs to perform mathematical operations or signal conditioning tasks.

2 Custom Weighted Summing & Difference Amplifier

Objective To implement mathematical functions such as:

$$V_{\text{out}} = 2V_1 + V_2 - V_3$$

$$V_{\text{out}} = 2V_1 - V_3$$

Circuit Design The circuit uses an inverting summing amplifier with carefully chosen resistors to achieve desired weighting coefficients. If a non-inverting input is required, a combination of inverting and summing amplifiers can be used.

Components Required - Op-amp (e.g., LM741, TL081) - Resistors (precisely selected for weighting) - DC power supply - Function generator (for input signals) - Oscilloscope

Equation Derivation For an inverting summing amplifier:

$$V_{\text{out}} = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right)$$

By selecting appropriate resistor values (R_f, R_1, R_2, R_3), the desired coefficients for V_1, V_2, V_3 can be achieved.

—

3 Op-Amp Integrator

Objective To design a circuit that performs mathematical integration:

$$V_{\text{out}} = -\frac{1}{RC} \int V_{\text{in}} \, dt$$

Circuit Design The circuit uses an operational amplifier with a capacitor in the feedback path instead of a resistor. This configuration enables the op-amp to act as a continuous-time integrator.

Components Required - Op-amp (e.g., LM741, TL081) - Resistor (R) - Capacitor (C) - DC power supply - Function generator - Oscilloscope

Working Principle The op-amp integrator converts a square wave input into a triangular wave output. It acts as a continuous-time integrator in signal processing applications.

—

4 Precision Rectifier (Super Diode)

Objective To design a precision rectifier capable of rectifying small AC signals without the voltage drop issue of standard diodes.

Circuit Design The circuit uses an op-amp to control a diode for full-wave or half-wave rectification. The op-amp eliminates the $0.7\,V$ threshold voltage of conventional diodes.

Components Required - Op-amp (e.g., LM358, TL081) - Diode (e.g., 1N4148) - Resistors - AC signal generator - Oscilloscope

Equation Derivation For a half-wave rectifier:

$$V_{\text{out}} = \begin{cases} 0 & V_{\text{in}} < 0 \\ V_{\text{in}} & V_{\text{in}} > 0 \end{cases}$$

For a full-wave rectifier, an additional summing stage is used to combine the positive portion with the inverted negative portion of the input signal.

—

5 Results and Observations

Custom Weighted Summing Amplifier The experimental results confirmed that the circuit accurately implemented the mathematical functions: 1. $V_{\text{out}} = 2V_1 + V_2 - V_3$ 2. $V_{\text{out}} = 2V_1 - V_3$

The output voltages measured on the oscilloscope matched theoretical predictions.

Op-Amp Integrator The integrator successfully converted square wave inputs into triangular wave outputs. The observed waveforms were consistent with theoretical expectations.

Precision Rectifier The precision rectifier effectively rectified small AC signals without any noticeable voltage drop. Both half-wave and full-wave configurations were tested and verified.

—

6 Conclusion

This experiment demonstrated three key applications of operational amplifiers: 1. Weighted summing and difference amplifiers were implemented using resistor networks. 2. The op-amp integrator performed real-time integration of input signals. 3. The precision rectifier eliminated voltage drop issues associated with conventional diodes.

These applications highlight the versatility of op-amps in performing mathematical operations and signal conditioning tasks in electronic circuits.

—