Lab Report: Experiment 5

EE1200 - IIT Hyderabad

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Experiment: Op-Amp Applications

भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

Bachelor of Technology

Department of Electrical Engineering

Objective

The objective of this experiment is to analyze and implement three operational amplifier applications:

1. Custom Weighted Summing and Difference Amplifier
2. Op-Amp Integrator
3. Precision Rectifier (Super Diode)

Components Required

- Operational Amplifier (LM 358)
- Resistors (selected for proper weighting)
- DC Power Supply
- Function Generator
- Oscilloscope

Theory and Circuit Design

Custom Weighted Summing and Difference Amplifier

This circuit implements the mathematical functions:

$$V_{out} = 2V_1 + V_2 - V_3 \tag{1}$$

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

An inverting summing amplifier is used with appropriately chosen resistor values to achieve the desired coefficients. The output of an inverting summing amplifier is given by

$$V_{out} = -(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2) \tag{3}$$

By taking $R_f = 2R, R_1 = R$ and $R_2 = 2R$,

$$V_{out} = -(2V_1 + V_2) \tag{4}$$

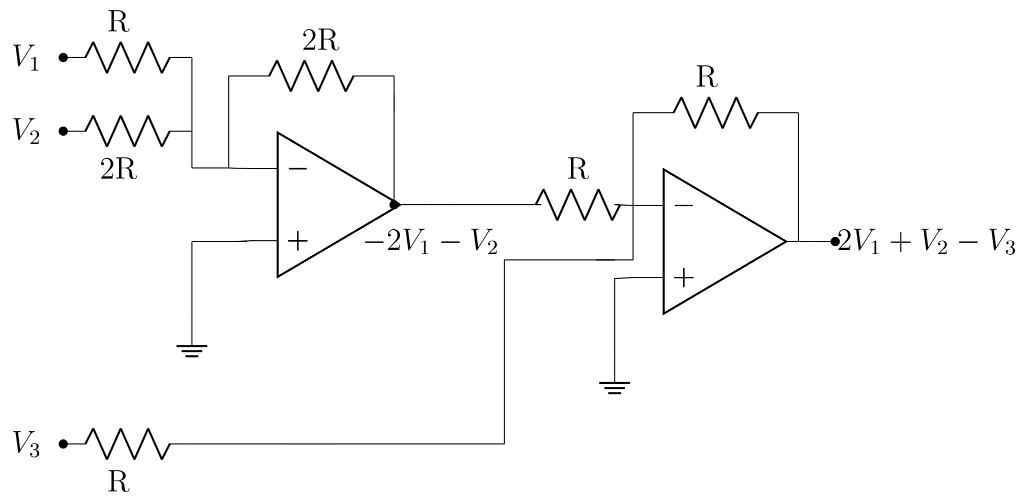
Now by taking the output of this op amp and summing this output with another input voltage V_3 will give us the required output voltage. The output of the second op amp will be,

$$V_{out} = -(\frac{R_f}{R_1}(-2V_1 - V_2) + \frac{R_f}{R_2}V_3) \tag{5}$$

Taking $R_f = R_1 = R_2 = R$,

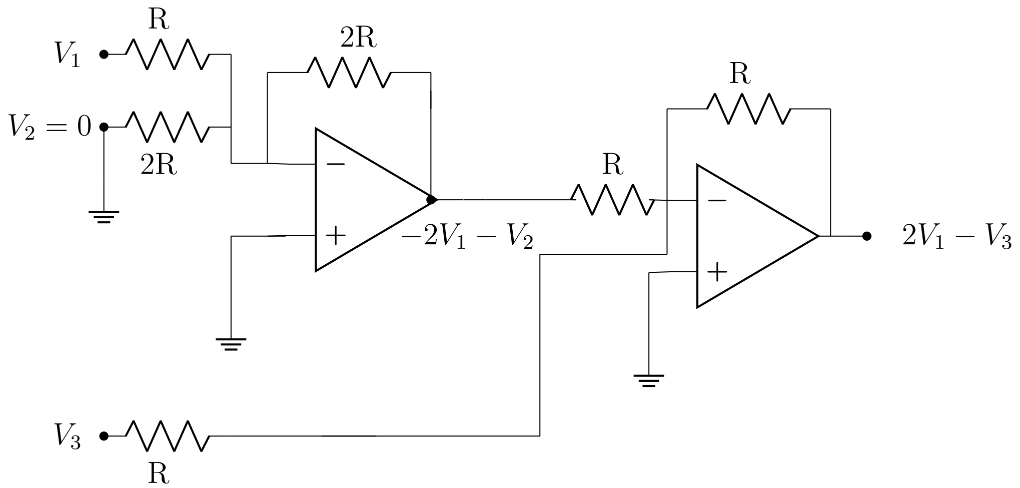
$$V_{out} = (2V_1 + V_2 - V_3) \tag{6}$$

Circuit Diagram



For the second part, to produce output voltage of $2V_1 - V_3$, make $V_2 = 0$, i.e., ground the terminal connecting V_2.

Circuit Diagram



Op-Amp Integrator

This circuit performs mathematical integration:

$$V_{out} = -\frac{1}{RC}\int V_{in}dt \tag{7}$$

In the below circuit, on applying nodal analysis at point A,

$$\frac{V_a - V_{in}}{R} + I_C = 0 \tag{8}$$

$$\frac{V_a - V_{in}}{R} + C\frac{dV_C}{dt} = 0 \tag{9}$$

In case of an ideal op amp, $V_A = 0$,

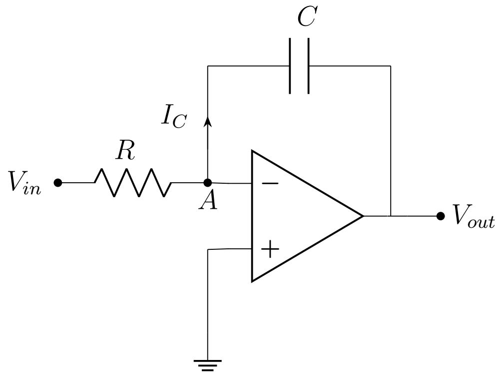
$$\frac{V_{in}}{R} = C\frac{dv}{dt} \tag{10}$$

$$\int dv = \frac{1}{RC}\int V_{in}dt \tag{11}$$

$$0 - V_{out} = \frac{1}{RC}\int V_{in}dt \tag{12}$$

$$V_{out} = -\frac{1}{RC}\int V_{in}dt \tag{13}$$

Circuit Diagram

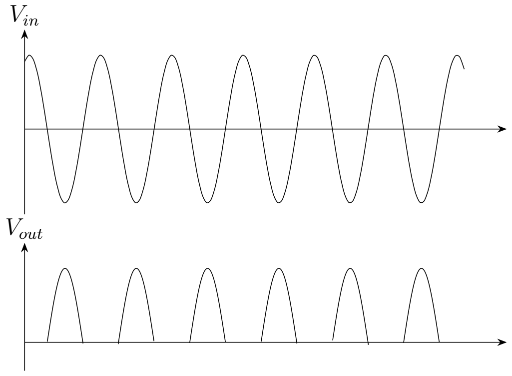


Precision Rectifier

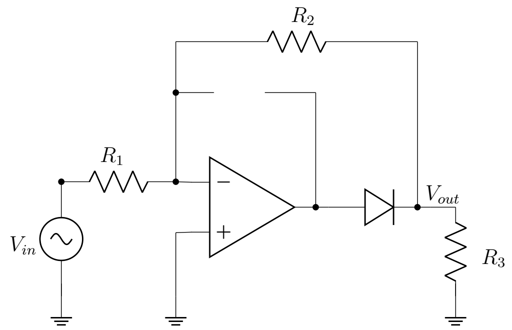
Here, the aim is to use the op amp to control a diode for full-wave rectifier and a half-wave rectifier. The reason why we use the op amp is because the diode has a threshold voltage of $0.7V$. To reduce that voltage to $0V$, we use the op amp. Depending on the amount of load resistance given to the op amp, a full or a half wave rectifier can be achieved.

Circuit Diagram

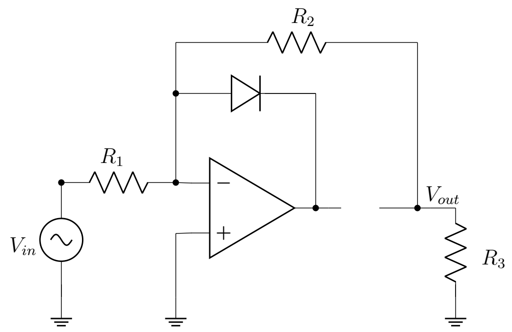
Half wave rectifier



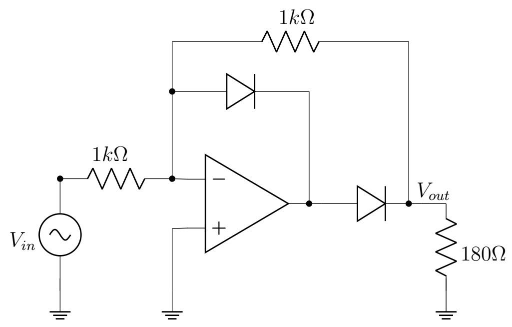
Negative Half Cycle: The upper diode is in reverse-bias condition while the lower diode is in forward-bias condition. This will lead to $V_{out} = -\left(\frac{R_2}{R_1}\right) V_{in}$. Here, $R_2 = R_1$, so $V_{out} = -V_{in}$.



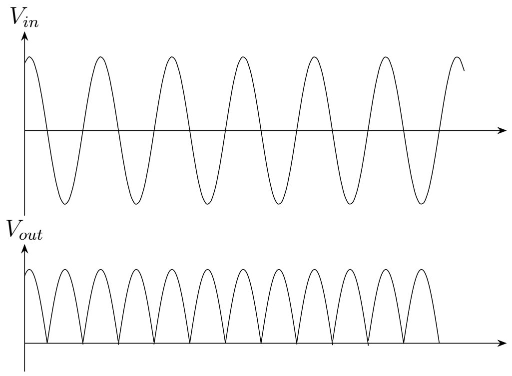
Positive Half Cycle: The lower diode is in reverse-bias condition, while the upper diode is in forward-bias condition. So there is no path for current to flow, so $V_{out} = V_{-} = V_{+} = 0$



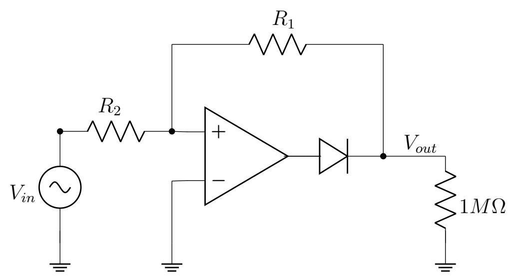
Circuit Diagram



Full wave rectifier

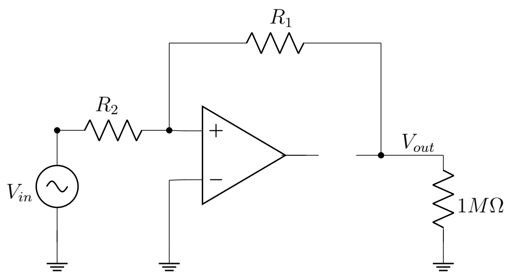


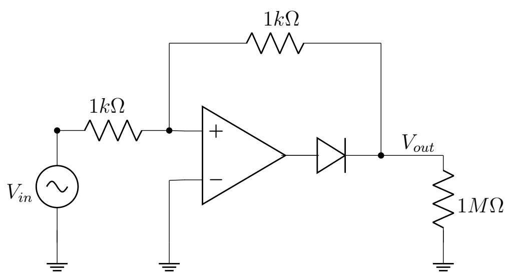
Negative Half Cycle: The diode is in forward-bias condition. This will lead to $V_{out} = -\left(\frac{R_2}{R_1}\right) V_{in}$. Here, $R_2 = R_1$, so $V_{out} = -V_{in}$.



Positive Half Cycle: The diode is in reverse-bias condition. So current flows through the feedback loop, through the $1M\Omega$ resistor, thus forming a loop. Now we can find V_{out} by solving the voltage divider circuit. Here, as $1M\Omega$ is a large resistance, most of the potential drop will be across it, so $V_{out} \approx V_{in}$

Circuit Diagram





Experimental Procedure

1. Set up the required circuit on a breadboard as per the theoretical circuit design.
2. Provide appropriate input signals using a function generator.
3. Observe and record the output waveforms using an oscilloscope.
4. Compare the experimental results with the theoretical predictions.
5. Repeat the process for each circuit configuration.

Results and Observations

Weighted Adder

$2V_1 + V_2 - V_3$

Here, $V_1 = V_3 = 1V, V_2 = 5V$,

$$2V_1 + V_2 - V_3 = 6V$$

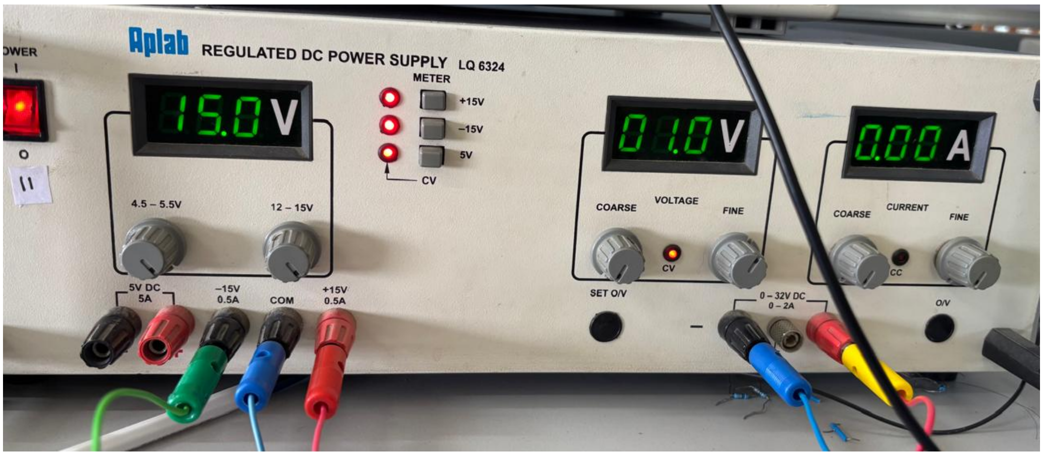
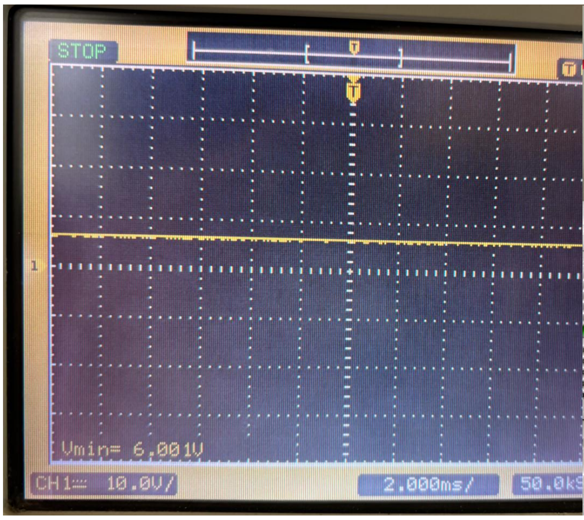
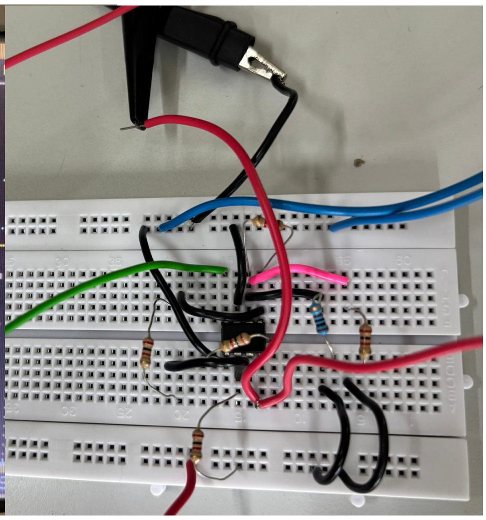


Figure 1: Input

(a) Output



(b) Circuit



$2V_1 - V_3$

Here, $V_1 = 5V, V_3 = 1V$,

$$2V_1 - V_3 = 6V$$

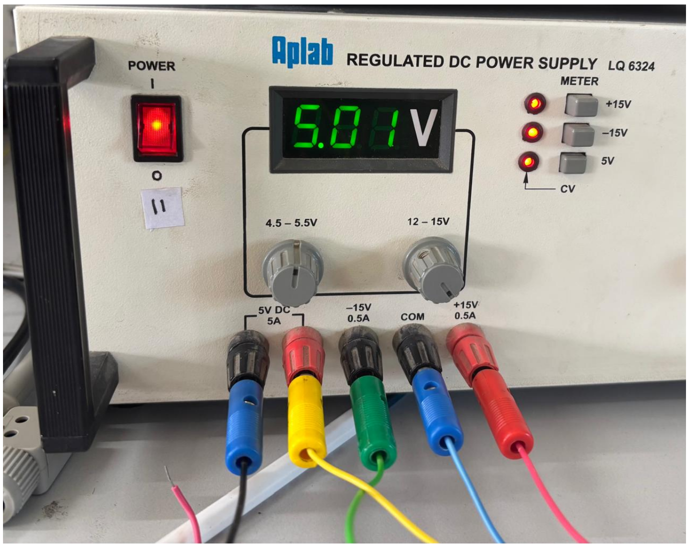
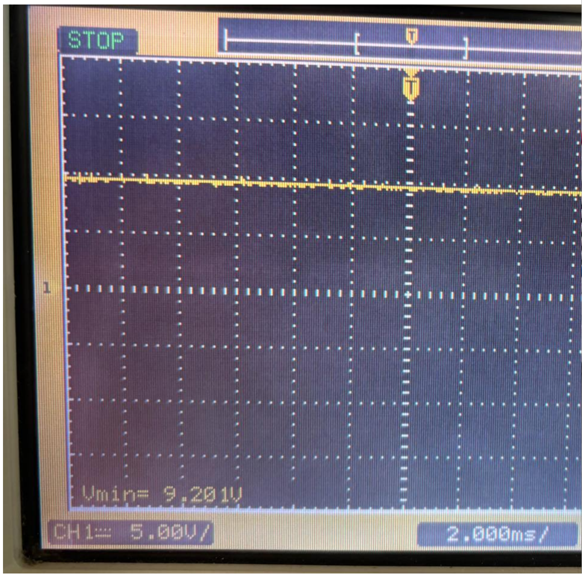
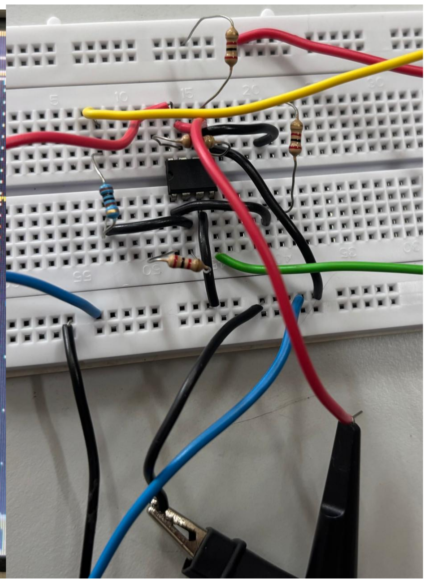


Figure 3: Input

(a) Output



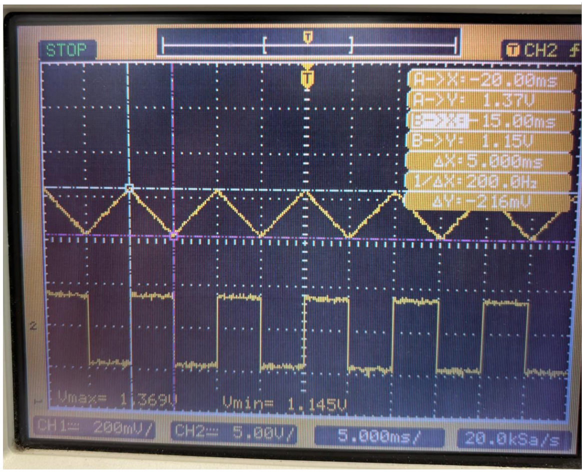
(b) Circuit



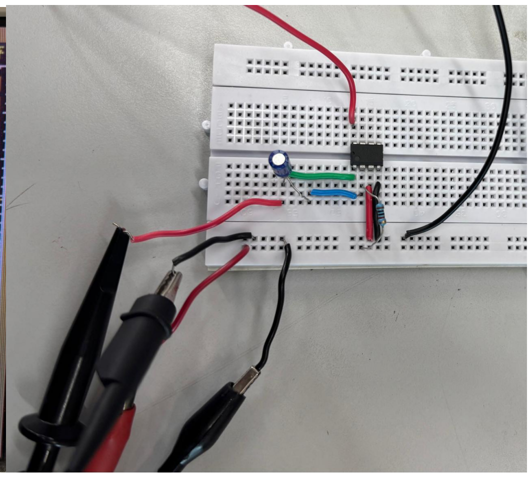
Integrator Op-Amp

Here, input wave is a square wave (triangle), so its integration will result in a triangle wave. Amplitude of triangle wave will be $\frac{t}{2RC}V_{max}$.
Here, $R = 10k\Omega, C = 10\mu F, V_{max} = 4V, t = 10ms$. So, amplitude comes out to be $200mV$

(a) Output vs Input



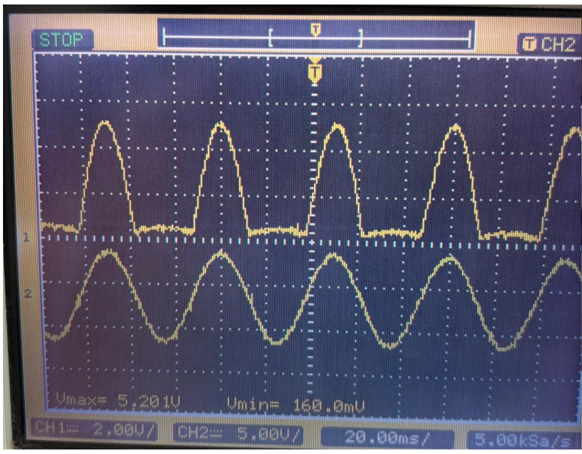
(b) Circuit



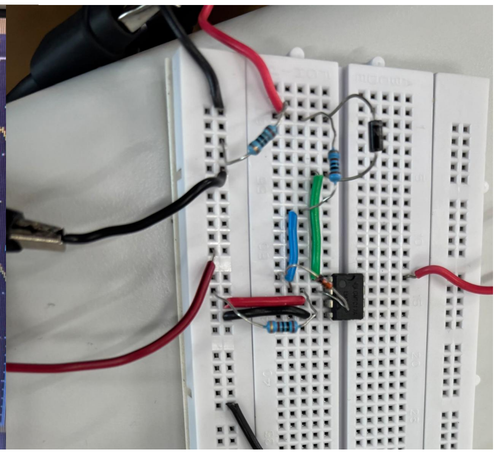
Rectifier

Half-Wave

(a) Output vs Input

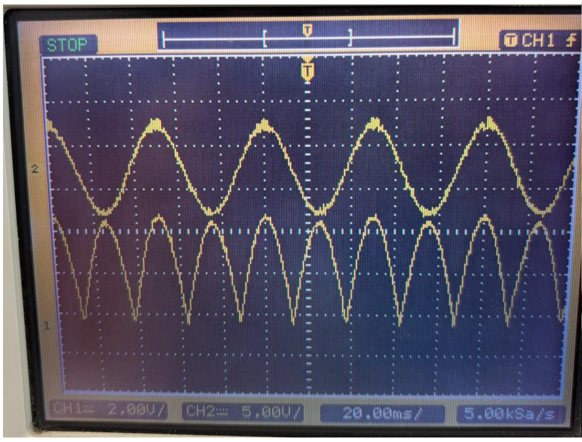


(b) Circuit

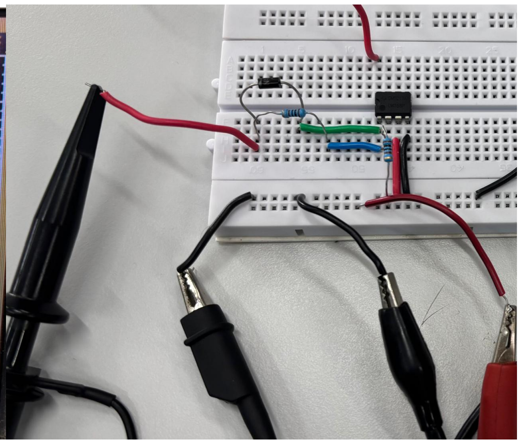


Full-Wave

(a) Output vs Input



(b) Circuit



Conclusion

The experiment successfully demonstrated the functionality of different op-amp applications, including summing and difference amplification, integration, and precision rectification. The observed outputs were consistent with theoretical calculations, validating the practical applications of operational amplifiers.