# Op-Amp Applications

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## 1 Objective

- Implementing a custom weighted summing and difference amplifier.
- Implementing an Op-amp integrator.
- Rectification of AC signals without the voltage drop issue of a diode.

# 2 Structure and Working of Op-Amp

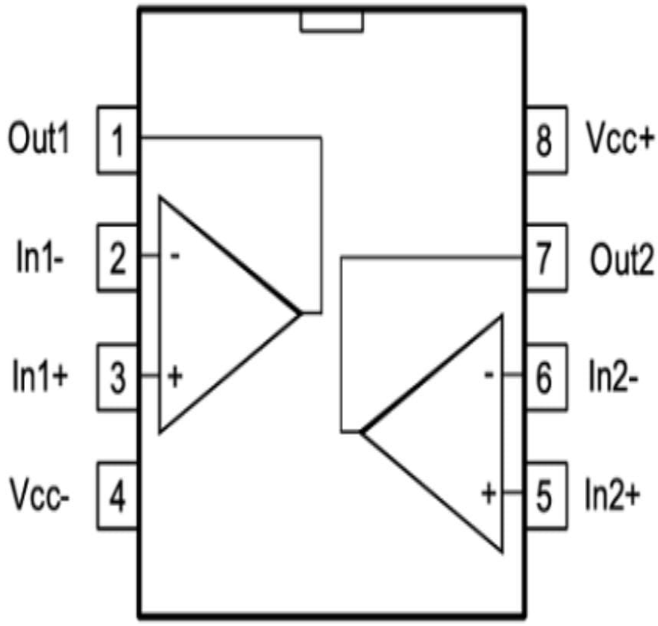



Figure 1: Op-Amp design

| | | |
|---|---|---|
| 1 | OUTPUT1 | This pin is the output of first operational amplifier |
| 2 | INPUT1- | This pin is the inverting input of first op-amp |
| 3 | INPUT1+ | This pin is the non-inverting input of first op-amp |
| 4 | VEE, GND | This pin is the non-inverting input of first op-amp |
| 5 | INPUT2+ | This ground or negative supply to op-amp |
| 6 | INPUT2- | This pin is the non-inverting input of second op-amp |
| 7 | OUTPUT2 | This pin is the output of the second op-amp |

Figure 2: Op-Amp design

$V_{cc}$ : This pin is the positive voltage supply to the Op-Amp.

# 3 Custom weighted summing and difference amplifier

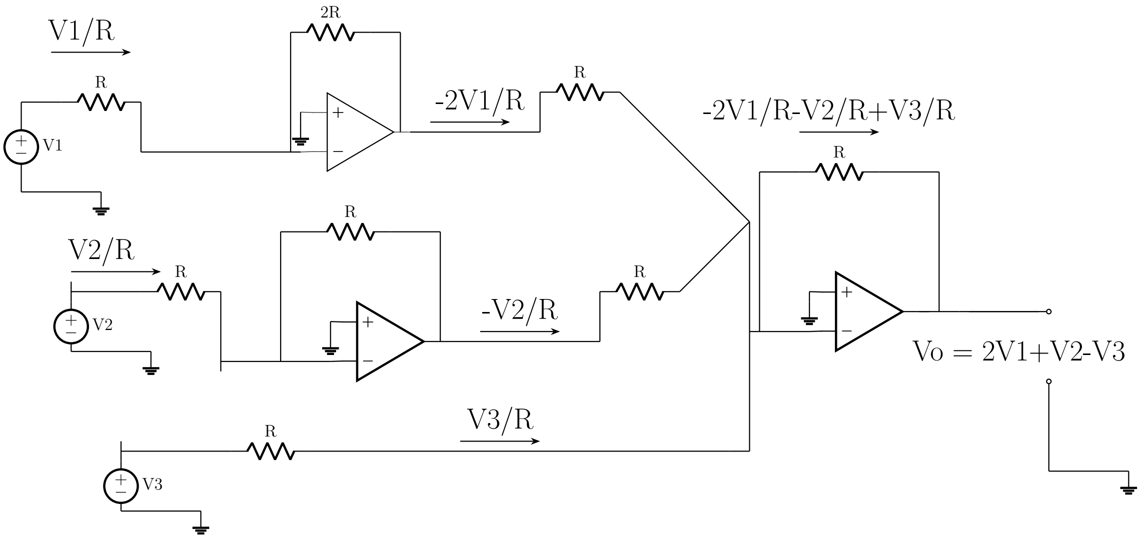
## 3.1 Materials Required

- Op-Amp(LM358)-2
- Resistors(10kΩ)-9
- DC power supply
- Function Generator
- Oscilloscope
- Jumper wires

## 3.2 Circuit Design

- Connect the Op-Amps and resistors as shown in the figure below.
- Give $V_{cc}$ a positive input and GND a negative voltage.
- Give voltage input for $V_1$, $V_2$ and $V_3$ from the DC power supply and Function Generator.
- Measure the output voltage at the output pin of the third Op-Amp using the oscilloscope probe.

## 3.3 Circuit Diagram



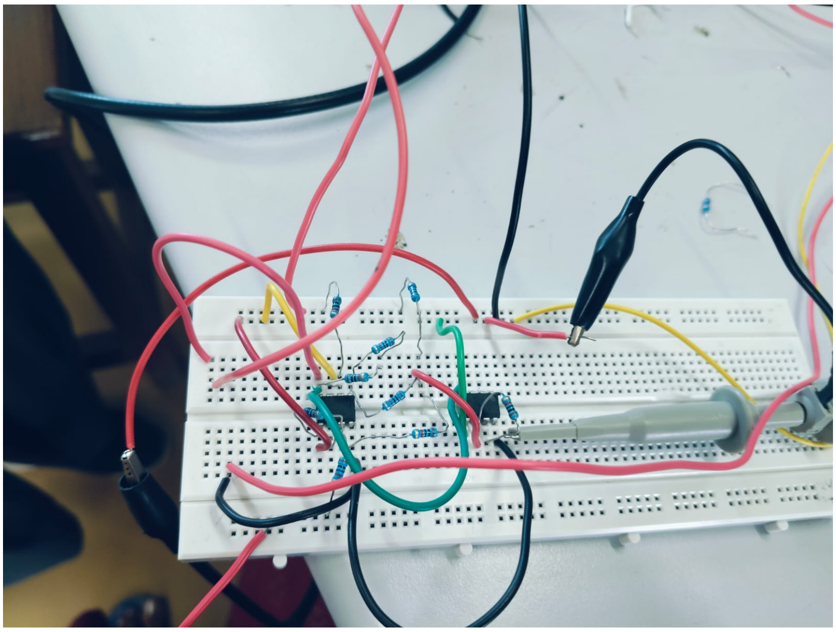



Figure 3: Caption describing the image

## 3.4 Working Principle

The given circuit consists of two inverting op-amps used to modify voltage signs and a summation amplifier to combine the signals. The circuit operates as follows:

1. **First Inverting Op-Amp**
    - The first operational amplifier (Op-amp) is configured as an inverting amplifier with a gain of $-2$.
    - It takes the input voltage $V_1$ and produces an output of $-2V_1$.
2. **Second Inverting Op-Amp**
    - The second op-amp is also an inverting amplifier but with a gain of $-1$.
    - It inverts the input voltage $V_2$, giving an output of $-V_2$.
3. **Summing Amplifier**
    - The outputs of the first and second inverting amplifiers, along with $V_3$, are fed into a **summing amplifier**.
    - The summing amplifier performs a weighted addition of the inputs:

    $$V_o = 2V_1 + V_2 - V_3$$

    - This means the final output voltage is a combination of the amplified and inverted signals from the previous stages.

## 3.5 Observations

In our case,

$$V_1 = 5, V_2 = 3, V_3 = 5$$

$$V_{cc} = 12V, GND = -12V$$

Thus we get our output voltages as:

- $V_0 = 2V_1 + V_2 - V_3 = 2(5) + 3 - 5 = 8V$

- $V_0 = 2V_1 - V_3 = 5V$

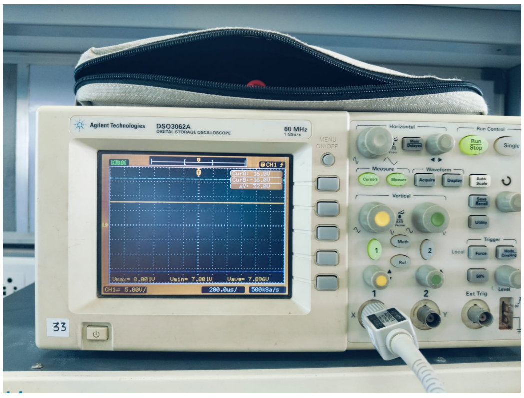



Figure 4: Output Voltage-1


Figure 5: Output Voltage-2

### 3.6 Precautions

1. Ensure all the connections are firm and tight.
2. Ensure that the resistors don't touch each other.
3. Ensure that the resistors don't touch the Op-amp pins.
4. Check the data sheet for the Op-amp being used for the maximum and minimum inputs it can handle.

## 4 Op-amp integrator

### 4.1 Materials Required

- Op-Amp (LM-358)
- Resistors (10 k$\Omega$, 100 k$\Omega$)
- Capacitor (220 nF)
- Function Generator
- Oscilloscope
- Jumper wires

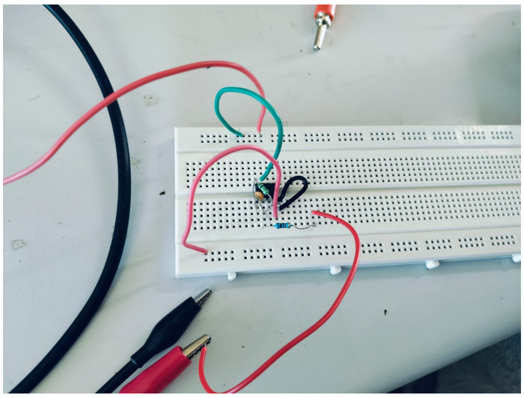
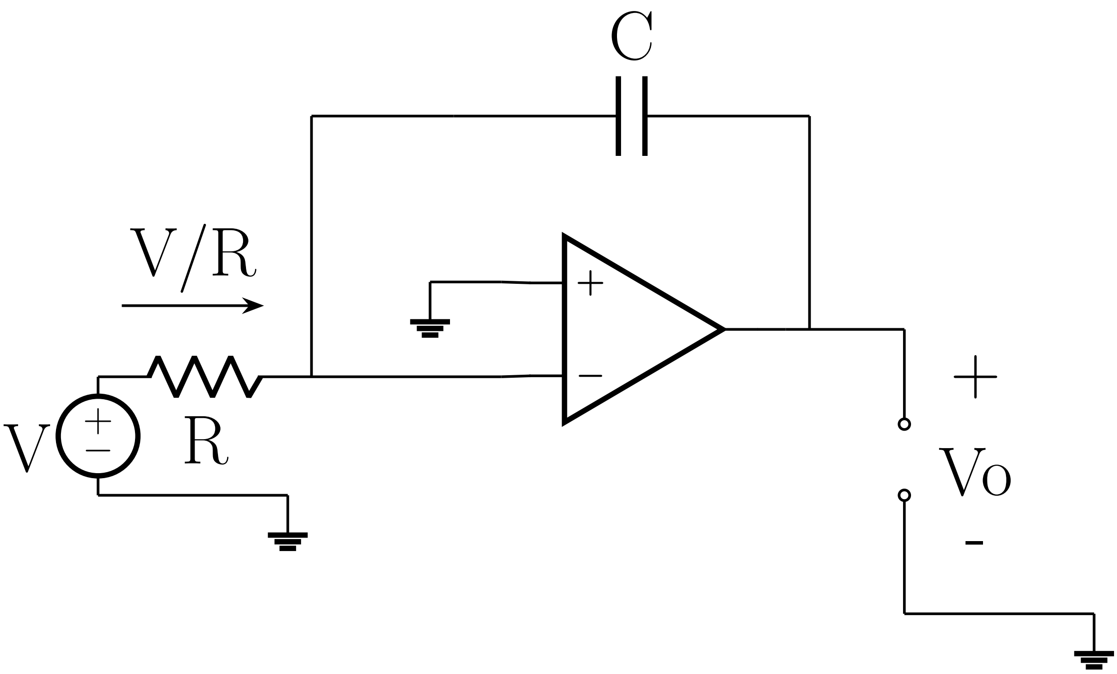


Figure 6: Circuit-Integrator

### 4.2 Circuit Diagram




### 4.3 Working Principle

An operational amplifier (op-amp) integrator is a circuit that performs mathematical integration of the input voltage with respect to time.
The circuit consists of an op-amp with a capacitor in the feedback path and a resistor at the input.

1. **Capacitor Charging and Feedback**

- Since the op-amp maintains virtual ground, the current through $R$ is given by Ohm's law:

$$I = \frac{V_{in}}{R}$$

- This current cannot flow into the op-amp's input and is forced to flow through the feedback capacitor $C$.
- The voltage across a capacitor is given by:

$$V_C = \frac{1}{C} \int I \, dt$$

- Substituting $I = \frac{V_{in}}{R}$:

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

## 4.4 Observations

The output voltage $V_o$ is the negative integral of the input voltage. Since the input is a square wave, we get the output wave as a trangular wave.

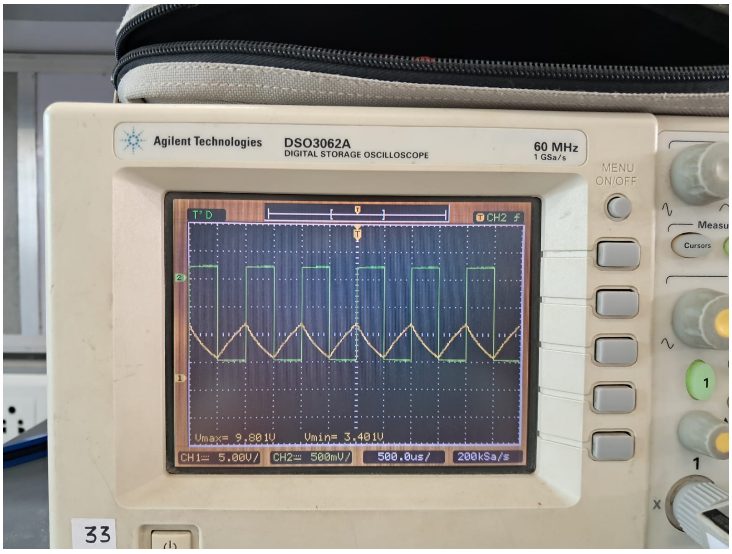



Figure 7: Output signal

# 5 Precision Rectifier

## 5.1 Materials Required

- 2 Op-Amps (LM-358)
- 2 diodes (1N4148)
- Breadboard
- Connecting wires
- Resistors of $10k\Omega$-5
- AC power supply
- Oscilloscope with probes

## 5.2 Circuit Diagram

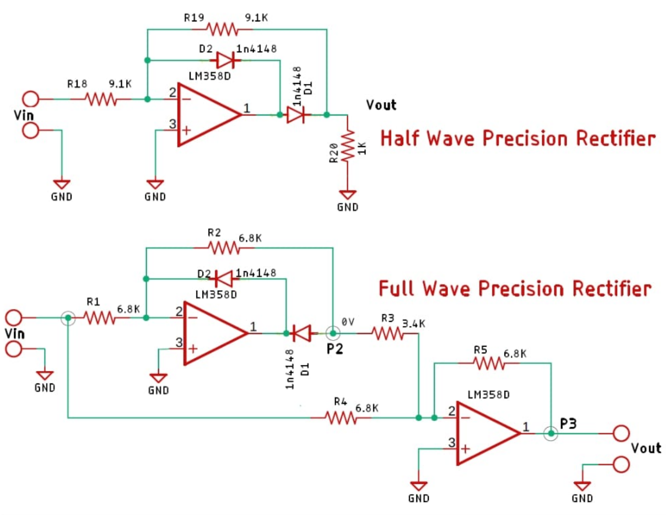



Figure 8: Half-wave and Full-wave rectifier

## 5.3 Working Principle

**Half-Wave Precision Rectifier:**
This circuit consists of 2 diodes and a single Op-Amp. When the signal's at a certain time between 0 to $\frac{T}{2}$, the current passes through the circuit as shown in the following picture, due to the fact that the diodes are forward

biased in this situation.

When the signal's at a certain time between $\frac{T}{2}$ to $T$[insert mage], the current flows through the feedback resistor path, and thus the Op-Amp inverts the negative voltage and gives off positive voltage as the output.
Hence only the part of the sine wave that has negative amplitude, ranging from 0 to 2 volts is inverted and passed and recorded by the oscilloscope as shown in the figure (observation).
**Full-Wave Precision Rectifier:**
For the circuit used for Full-Wave Rectification, the diodes in Half-Wave Rectifier circuit are reversed followed by giving both $V_1$ and $V_o$ of half wave rectifier to the $V^-$ pin of another Op-Amp.

One important thing to note is that in this circuit between $V_o$ of sub-circuit and $v^-$ pin of 2nd Op-Amp, a resistance of $5k\Omega$ is connected by putting 2 $10k\Omega$ in parallel connection.
From the point, P2 to point P3 is the summing amplifier, the output from the precision rectifier is fed to the summing amplifier through the resistor R3. The value of the resistor R3 is half of R5 or you can say it's R5/2=$5k\Omega$ that is how we are setting a 2X gain out of the op-amp.
The input from the point P1 is also fed to the summing amplifier with the help of the resistor R4, the resistors R4 and R5 are responsible for setting the gain of the op-amp to 1X.
Since the output from the Point P2 is fed directly to the summing amplifier with the gain of 2X, that means the output voltage will be 2-times the input voltage. Let's assume the input voltage is 2V peak, so we will get a 4V peak at the output. At the same time, we are directly feeding the input to the summing amplifier with a gain of 1X. [insert image] This working principle ensures that the entire sinusoidal wave is rectified.

## 5.4 Observations

**Half-wave rectifier:**

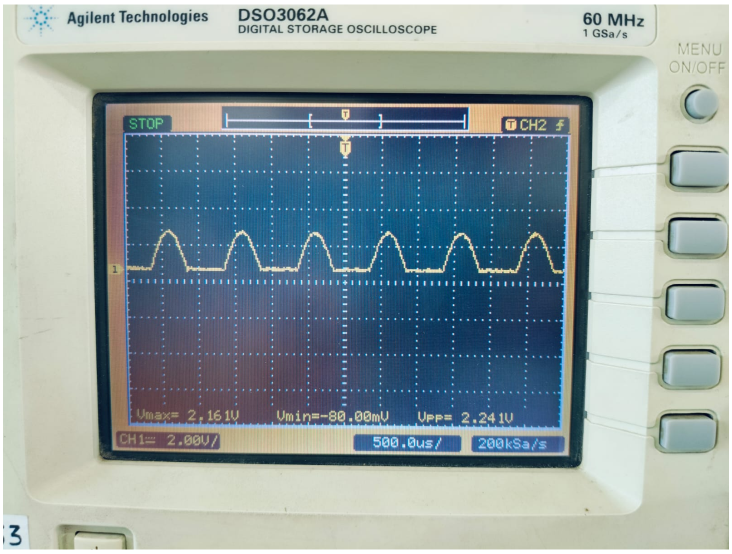



Figure 9: Half-wave rectified response of sinusoidal wave

**Full-wave rectifier:**

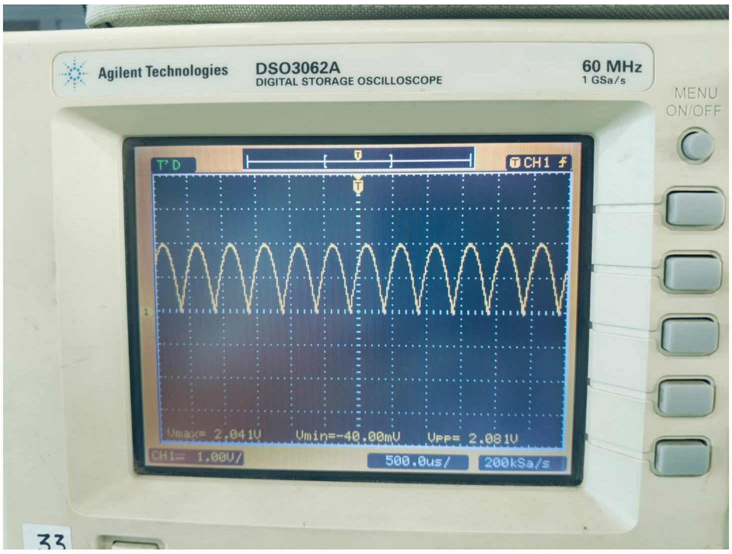



Figure 10: Full-wave rectified response of sinusoidal wave

## 5.5 Precautions

1. Ensure that all the connections are strong and tight.
2. Ensure that the resistors do not touch each other.

3. Ensure that Op-Amp and diodes are functioning properly.

# 6 Final Conclusion

By performing Experiment-5, we understood the functionality of Op-Amps and diodes. We also understood the principle behind implementing a custom weighted summing and difference amplifier, implementing an Op-Amp integrator, and rectification of AC signals without the voltage drop issue of a diode.