Lab Report: Custom Weighted Summing & Difference Amplifier, Op-Amp Integrator, and Precision Rectifier

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1 Objective

The purpose of this experiment is to design and implement a custom weighted summing and difference amplifier circuit using an operational amplifier, to study the working of an op-amp integrator, and to analyze the behavior of a precision rectifier (super diode). The circuits perform the following mathematical functions:

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

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

$$V_{out} = -\frac{1}{RC}\int V_{in} dt \tag{3}$$

$$V_{out} = \begin{cases} 0, & V_{in} < 0 \\ V_{in}, & V_{in} > 0 \end{cases} \tag{4}$$

2 Components Required

- Operational amplifier (LM741, TL081, LM358, or equivalent)
- Resistors (values chosen to achieve desired functionality)
- Capacitor (for integration circuit)
- Diode (e.g., 1N4148 for precision rectifier)
- DC power supply ($\pm 15V$)
- Function generator (to provide input signals)
- Oscilloscope (to observe output waveforms)

3 Circuit Design

3.1 Summing and Difference Amplifier

To implement the given equations, the following resistor values are selected:

For $V_{out} = 2V_1 + V_2 - V_3$:

- $R_1 = R_3 = 10k\Omega$
- $R_2 = 20k\Omega$
- $R_f = 20k\Omega$

For $V_{out} = 2V_1 - V_3$:

- $R_1 = 10k\Omega$
- $R_3 = 10k\Omega$
- $R_f = 20k\Omega$
- No R_2 needed (open circuit)

3.2 Op-Amp Integrator

For the integrator circuit, the component values are chosen as follows:

- $R = 10k\Omega$
- $C = 0.1\mu F$

3.3 Precision Rectifier

For the precision rectifier:

- Op-amp (LM358 or TL081)
- Diode (1N4148)
- Resistors (as per design)

4 Experimental Procedure

1. Assemble the circuits on a breadboard as per the schematic.
2. Apply $\pm 15V$ DC power to the op-amp.
3. Use the function generator to apply the appropriate input signals.
4. Observe and record the output waveforms using an oscilloscope.
5. Compare the measured output with the theoretically expected values.

5 Theory and Comparison in Observations

Input Signals	**Expected V_{out}**	**Measured V_{out}**
$V_1 = 5V, V_2 = 3V, V_3 = 3V$	$2(5) + 3 - 3 = 10V$	$9.201V$
$V_1 = 5V, V_3 = 3V$	$2(5) - 3 = 7V$	$7.V$
Square wave input (Integrator)	Triangular wave output	Observed triangular wave
Small AC signal (Rectifier)	Positive half-cycle only	Observed rectified waveform

Table 1: Experimental Results

Operational amplifiers (op-amps) can be used to perform mathematical operations such as addition, subtraction, scaling, integration, and precision rectification.

5.1 Summing and Difference Amplifier

The inverting summing amplifier is used to achieve the desired weighted sum of input voltages. The general equation for an inverting summing amplifier is:

$$V_{out} = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right) \tag{5}$$

By carefully selecting resistor values, the required coefficients in the equation can be achieved. If a non-inverting input is required, a combination of inverting and summing amplifiers can be used.

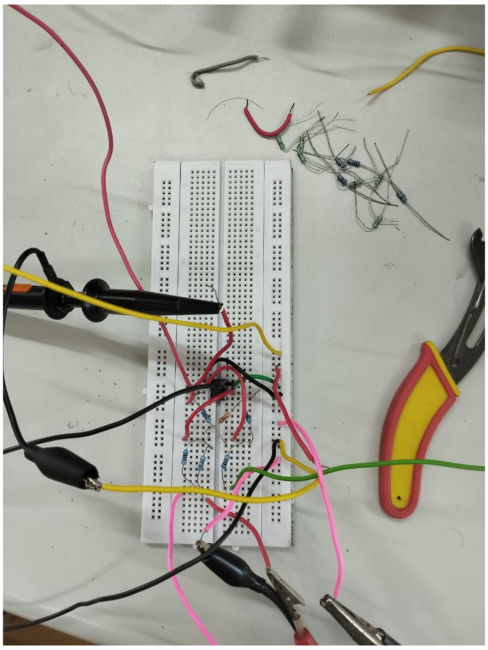

Figure 1: Circuit Diagram In Experiment

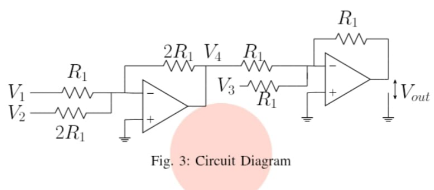

Figure 2: Circuit Diagram

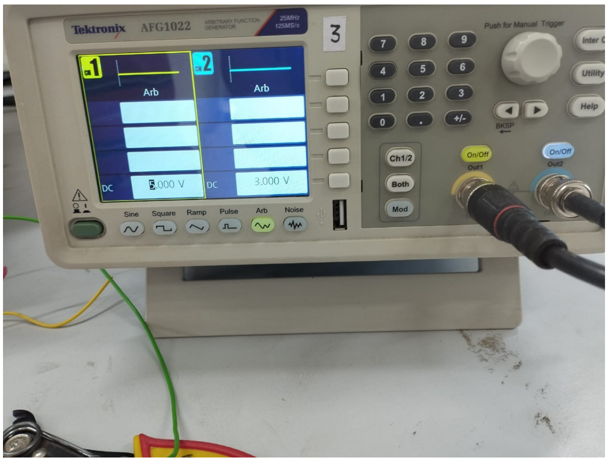

Figure 3: Voltage $V_1 = 5V$ and $V_2 = 3V$ for $2V_1 + V_2 - V_3$

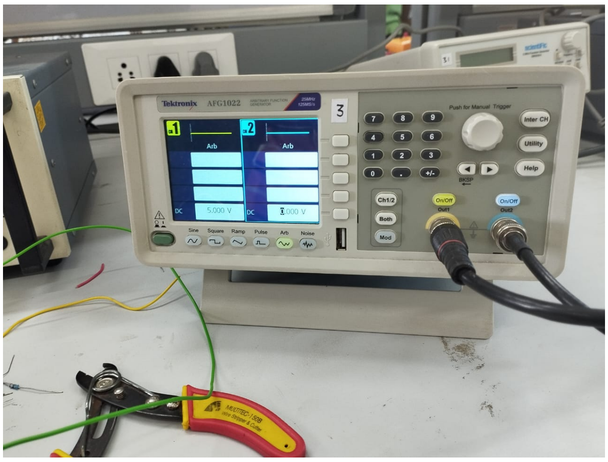

Figure 4: Voltage $V_1 = 5V$ and $V_2 = 0V$ for $2V_1 - V_3$

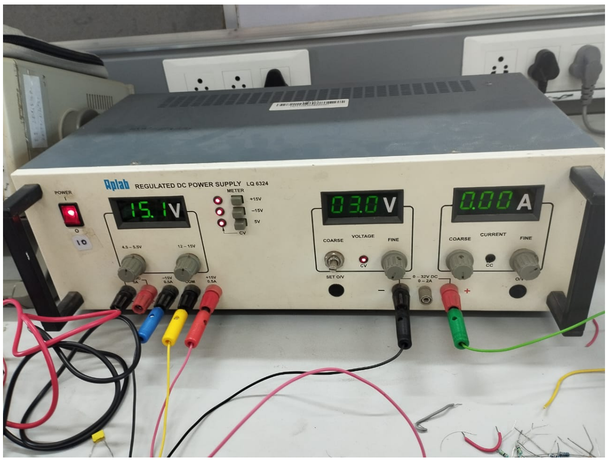

Figure 5: Voltage $V_3 = 3V$

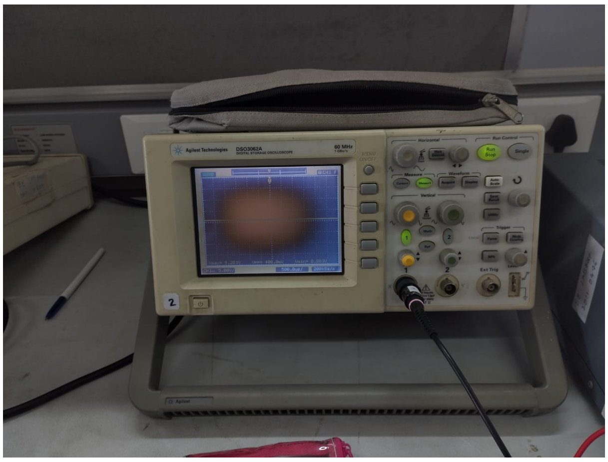

Figure 6: Observed value for $2V_1 + V_2 - V_3$

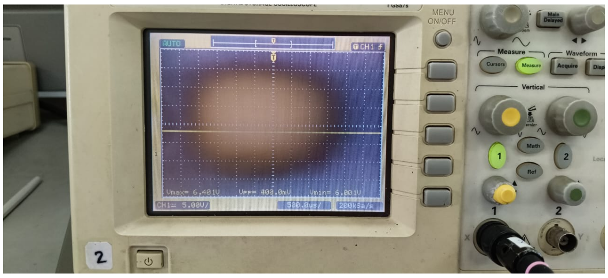

Figure 7: Observed value for $2V_1 - V_3$

5.2 Op-Amp Integrator

The op-amp integrator performs the mathematical integration of an input signal. It consists of an operational amplifier with a capacitor in the feedback path instead of a resistor. The integrator follows the equation:

$$V_{out} = -\frac{1}{RC}\int V_{in}dt \tag{6}$$

This circuit converts a square wave input into a triangular wave output and is widely used in signal processing applications.

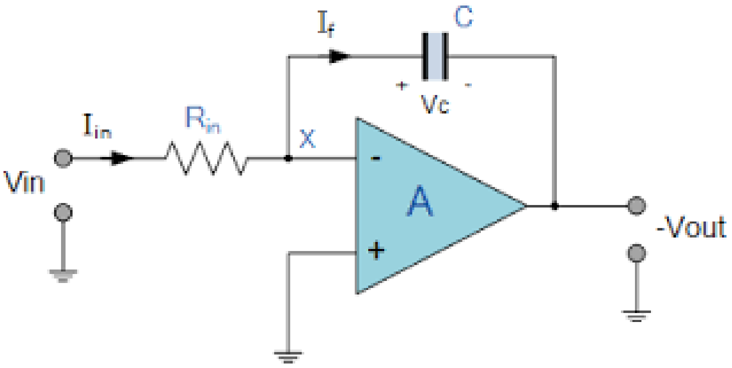

Figure 8: Circuit Diagram

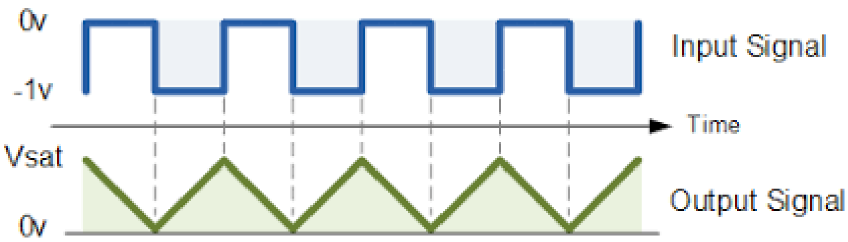

Figure 9: Input and Output Signal for Integrator

Figure 10: Input Signal In function generator

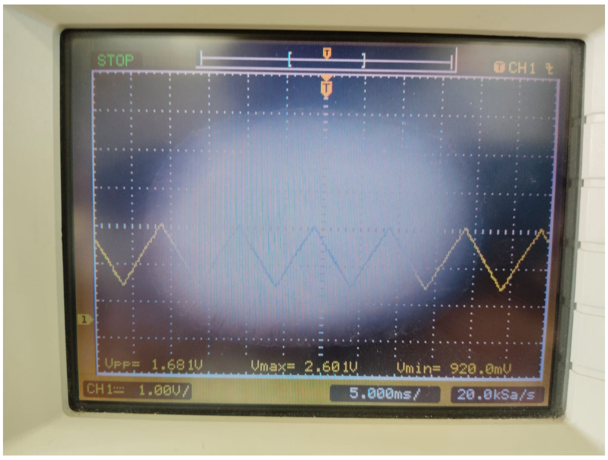

Figure 11: Observed Output Signal

The peak output voltage of an op-amp integrator with a square wave input is:

$$V_{\text{out max}} = \frac{V_{\text{in max}}}{RC} \times \frac{1}{2f}$$

Given:

$$V_{\text{in max}} = 3V, \quad R = 10k\Omega, \quad C = 0.1\mu F, \quad f = 1kHz$$

Substituting the values:

$$\begin{aligned} V_{\text{out max}} &= \frac{3}{(10k\Omega \times 0.1\mu F)} \times \frac{1}{2 \times 1000} \\ &= \frac{3}{(10^4 \times 10^{-7})} \times \frac{1}{2000} \\ &= \frac{3}{10^{-3}} \times \frac{1}{2000} \\ &= 3000 \times \frac{1}{2000} \\ &= 1.5V \end{aligned}$$

Thus, the peak output voltage is:

$$V_{\text{out max}} = 1.5V$$

The observed peak output is $2.6V - 0.92V = 1.68V$.

5.3 Precision Rectifier (Super Diode)

A precision rectifier, or super diode, eliminates the voltage drop problem of conventional diodes, enabling rectification of small AC signals. The circuit consists of an op-amp controlling a diode. For a half-wave rectifier:

$$V_{out} = \begin{cases} 0, & V_{in} < 0 \\ V_{in}, & V_{in} > 0 \end{cases} \tag{7}$$

A full-wave rectifier can be implemented using an additional summing stage to combine the positive and inverted negative portions.

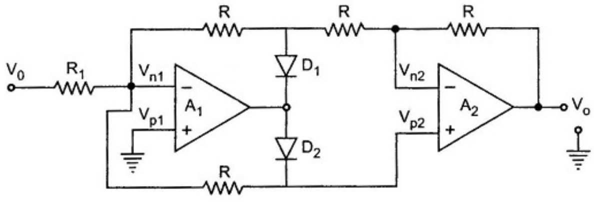

Fig. 2.63 Full wave rectifier

Figure 12: Circuit Diagram for halfwave

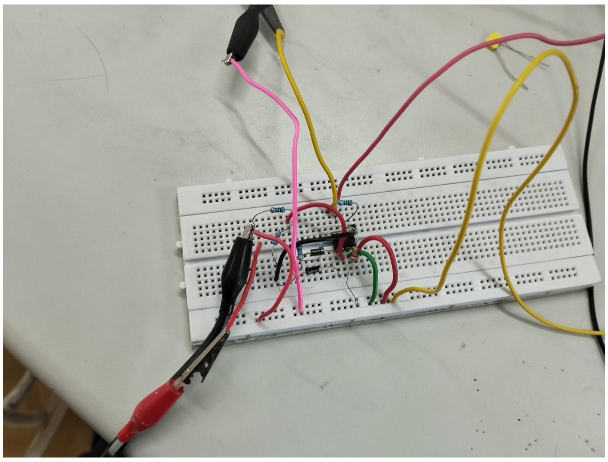

Figure 13: Circuit Diagram In Experiment for fullwave

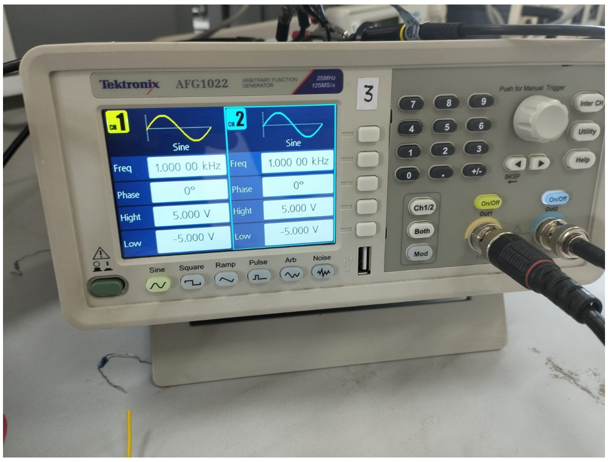

Figure 14: Input Values given by function generator for fullwave

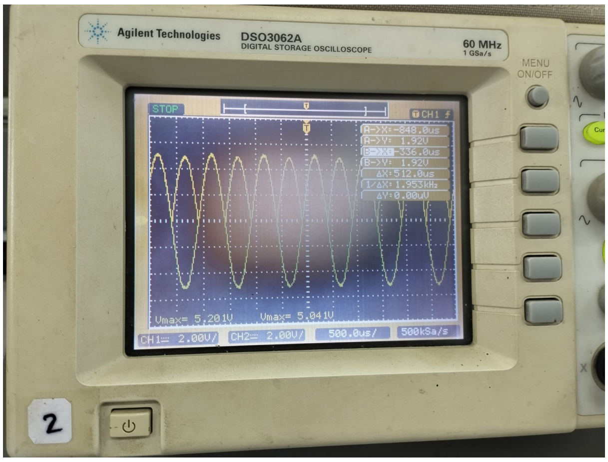

Figure 15: Observed Fullwave Rectification

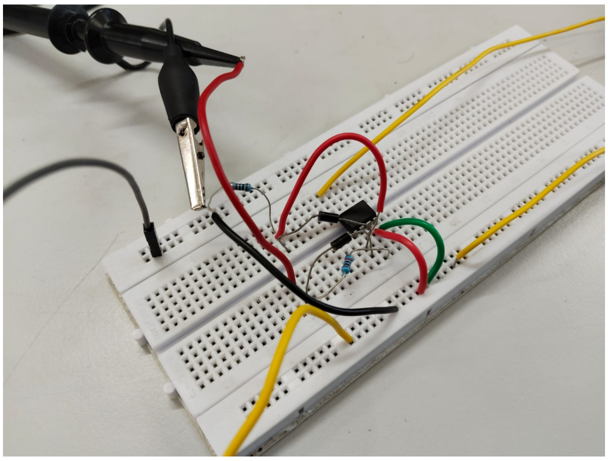

Figure 16: Circuit Diagram In Experiment for halfwave

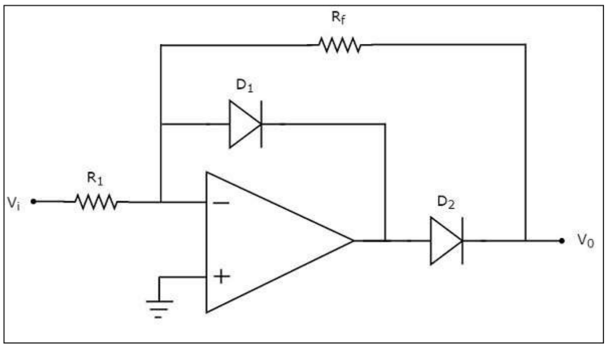

Figure 17: Circuit Diagram for halfwave

Figure 18: Input for Halfwave Rectifier

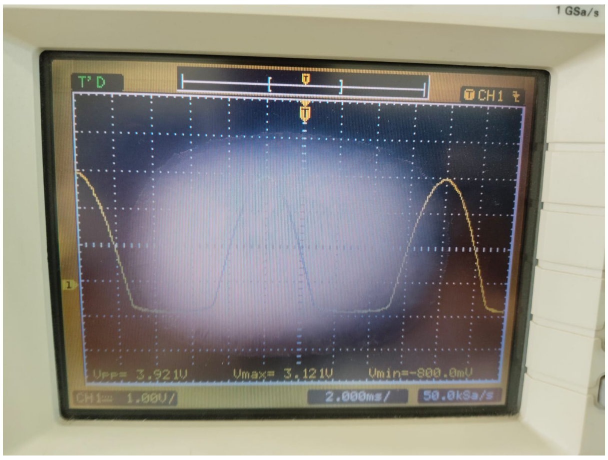

Figure 19: Observed Halfwave Precision Rectification

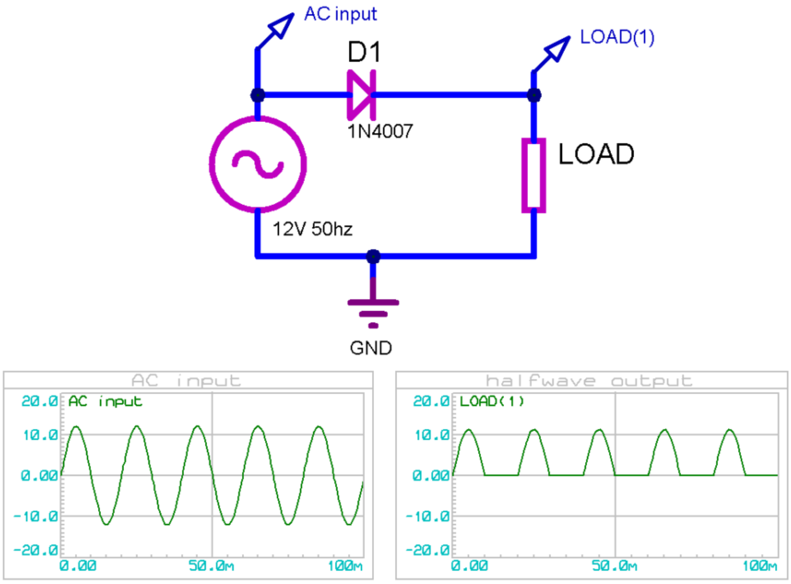

Figure 20: Circuit Diagram for Halfwave Rectification using diode and resistor(values in this are not the one's used for experiment)

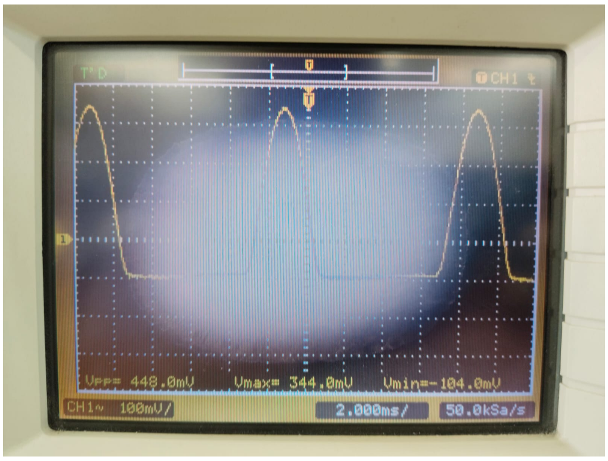

Figure 21: Observed Halfwave Rectification without opamp

There is the 0.7V threshold voltage of diode hence for given input of 1.2V we should get $1.2V - 0.7V = 0.4V$. The observed value is 0.344V.
There is Leakage of current in the diode thats why there is less voltage than theoretical value.

6 Conclusion

The experimental results confirm the correct operation of the summing amplifier, op-amp integrator, and precision rectifier. The precision rectifier successfully eliminates the voltage drop of conventional diodes, enabling accurate rectification of small AC signals.