EE LAB REPORT-5

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CONTENTS

A. Introduction

An Operational Amplifier (Op-Amp(LM358)) is a high-gain electronic voltage amplifier with differential inputs and a single-ended output. It is widely used in analog circuits for signal amplification, filtering, mathematical operations, and waveform shaping. By configuring external components like resistors and capacitors, op-amps can perform functions such as integration, differentiation, and summation.

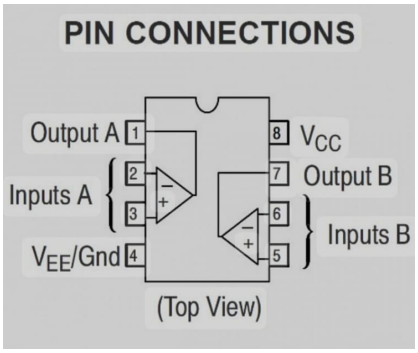


Fig. 1: LM358 connections

The LM358 is a low-power, dual operational amplifier (op-amp) designed for general-purpose applications. It operates with a wide voltage range (3V to 32V) and has low power consumption, making it ideal for battery-powered circuits. The LM358 consists of two independent op-amps in a single package, providing high gain and internal frequency compensation. It is commonly used in signal conditioning, filtering, and amplification circuits.

I. TASK -1

A. Aim

In this experiment, we design and analyze an op-amp-based circuit that produces an output voltage of $2V_1 + V_2 - V_3$, $2V_1 - V_3$, demonstrating the ability of operational amplifiers to perform linear arithmetic operations on input signals.

B. Apparatus Used

- Op-amp(LM358)
- Breadboard.
- DC power supply
- Function generator
- Resistor($10K\Omega$)
- Oscilloscope
- Jumper cables

C. Theory

1) The given circuit is an inverting amplifier using an operational amplifier (op-amp).
2) The current through R_1 and R_2 is same as no current enters the op amp input

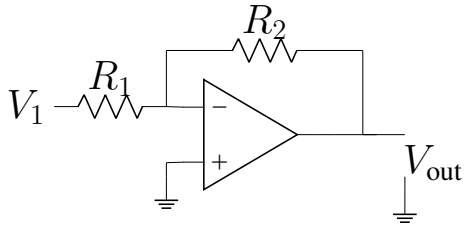


Fig. 2: Operational Amplifier Circuit

3) Applying Ohm's Law and KCL at the inverting terminal:

$$\frac{V_1 - 0}{R_1} = \frac{0 - V_{out}}{R_2} \tag{1}$$

$$V_{out} = -\left(\frac{R_2}{R_1}\right) V_1 \tag{2}$$

D. Circuit diagram

This is the circuit diagram to obtain the desired output as $2V_1 + V_2 - V_3$

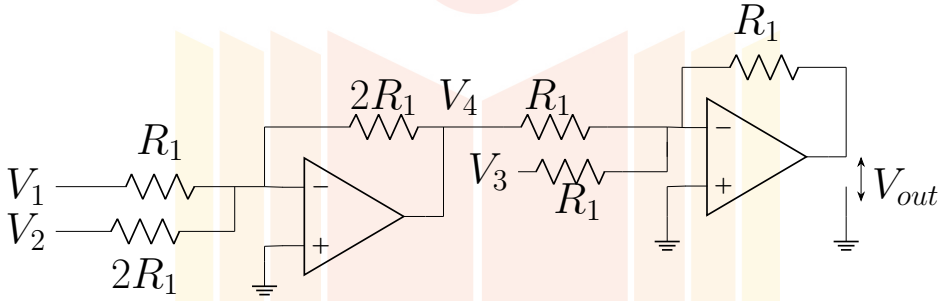


Fig. 3: Circuit Diagram

Quick explanation of what happens in circuit

The output of first op-amp is

$$V_4 = -(2V_1 + V_2)$$

It goes through second Op-amp and gets inverted again and gives final output

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

E. Procedure

1) We need 8 identical resistors and LM358 connect these as in the above circuit.
2) Using a DC power supply, apply the voltages.
3) Measure the voltage V_{out} using a oscilloscope.

F. Precautions

1) **Always connect the COM terminal of the DC power supply as the common ground to ensure proper voltage referencing and circuit stability**
2) Ensure that the LM358 op-amp is powered correctly with V_{cc} =12V and 0V (GND) as the reference to maintain proper functionality and avoid unexpected behavior
3) The output voltage should not exceed 12V due to the saturation limit of the op-amp, which typically operates slightly below the supply voltage.
4) Make sure that the non-inverting input of the op-amp is approximately half of the supply voltage or greater than 2V, but not too close to ground.

G. Results

Circuit Diagram on Breadboard

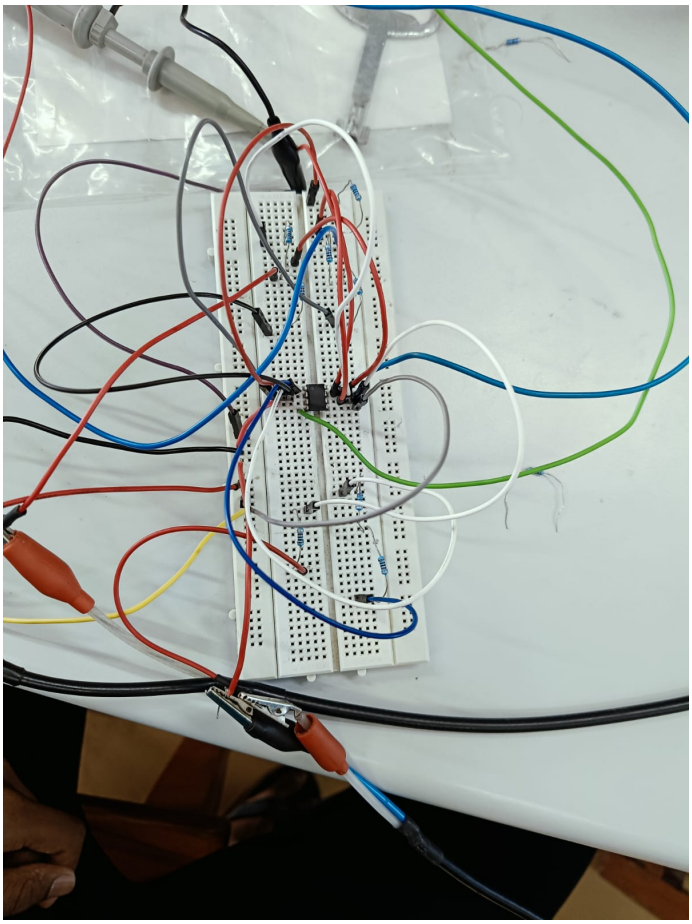
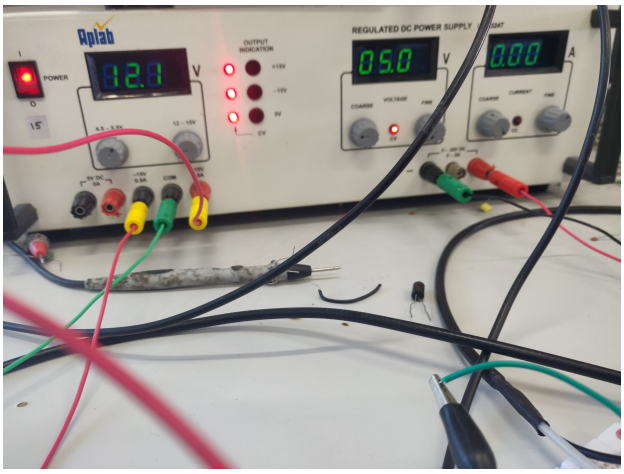
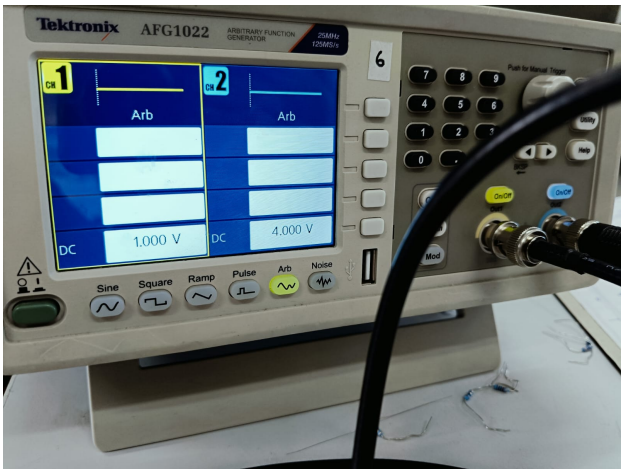


Fig. 4: Caption

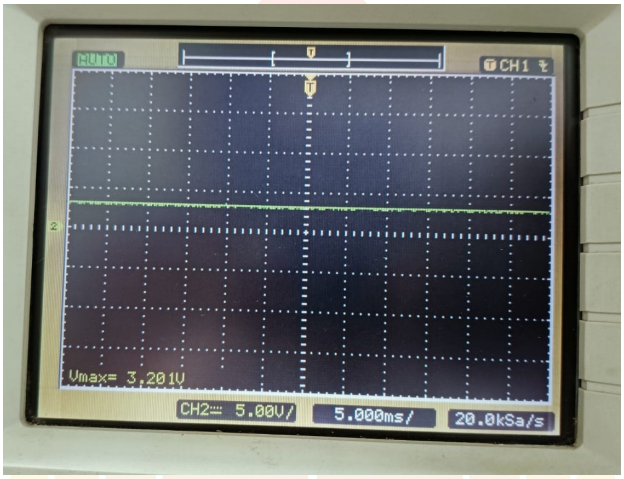
Input Voltages for $2V_1 + V_2 - V_3$



(a) Left side $+V_{CC}$ and right side DC voltage V_2



(b) Voltage V_1 and V_3



(c) Figure 3 caption

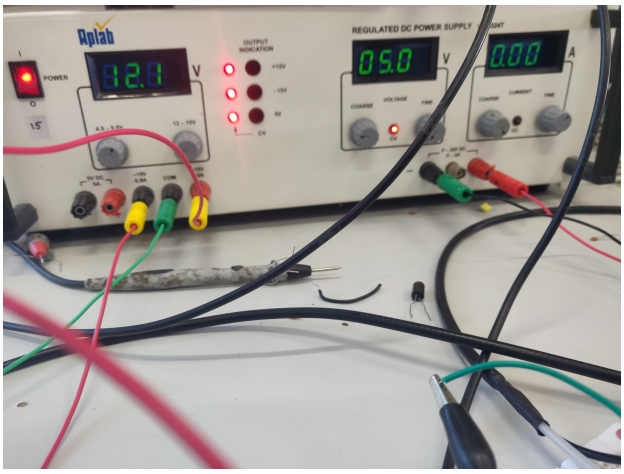
Fig. 5: Output for combination of input voltages V_1 and V_2 and V_3

According to the output equaton we have

$$2V_1 + V_2 - V_3 = 2(1) + 5 - 4$$
$$2V_1 + V_2 - V_3 = 3$$

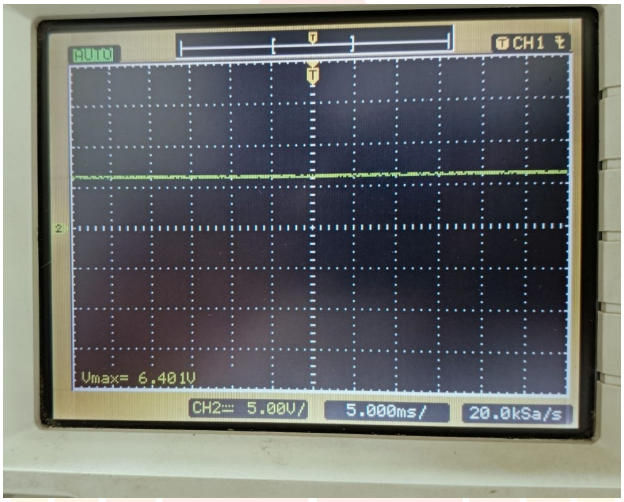
We can see in oscilloscope that we get output as 3.201V which is closer to 3 maybe because of some other factors in Op-amp and wires used

Input Voltages for $2V_1 + V_2 - V_3$



(a) DC voltage V_2

(b) Voltage V_1 and V_3



(c) Figure 3 caption

Fig. 6: Output for combination of input voltages V_1 and V_2 and V_3

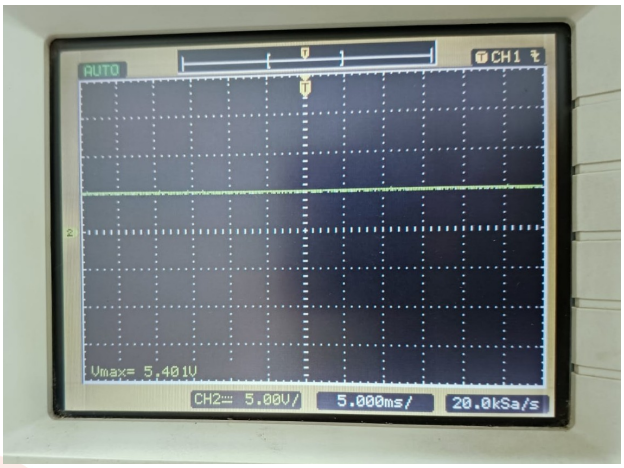
According to the output equaton we have

$$2V_1 + V_2 - V_3 = 2(2) + 5 - 3$$
$$2V_1 + V_2 - V_3 = 6$$

We can see in oscilloscope that we get output as 6.401V which is closer to 6 maybe because of some other factors in Op-amp and wires used

To get output as $2V_1 - V_3$ We need to keep V_2=0 in the original circuit
Input Voltages for $2V_1 - V_3$

(a) Voltage V_1 and V_3



(b) Figure 3 caption

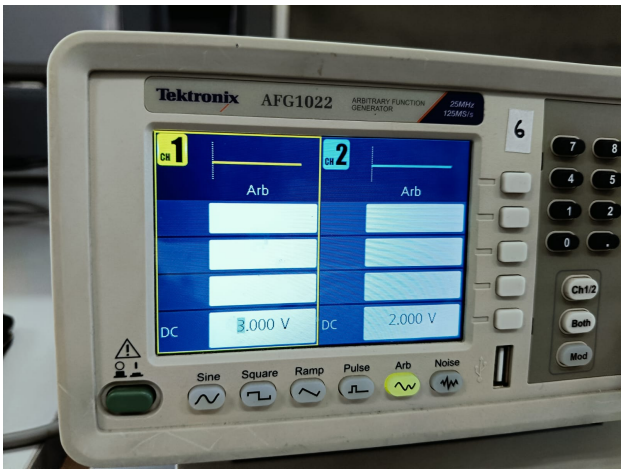
Fig. 7: Output for combination of input voltages V_1 and V_2 and V_3

According to the output equaton we have

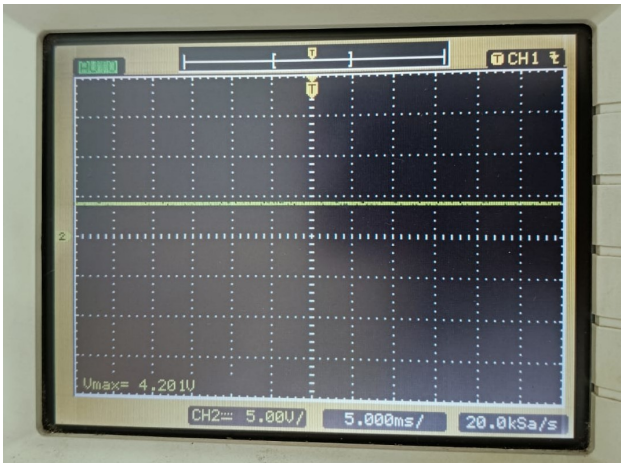
$$2V_1 - V_3 = 2(4) - 3$$
$$2V_1 - V_3 = 5$$

We can see in oscilloscope that we get output as 5.401V which is closer to 5 maybe because of some other factors in Op-amp and wires used

Input Voltages for $2V_1 - V_3$



(a) Voltage V_1 and V_3



(b) Figure 3 caption

Fig. 8: Output for combination of input voltages V_1 and V_2 and V_3

According to the output equaton we have

$$2V_1 - V_3 = 2(3) - 2$$
$$2V_1 - V_3 = 4$$

We can see in oscilloscope that we get output as 4.201V which is closer to 4 maybe because of some other factors in Op-amp and wires used

V_1	V_2	V_3	V_{out}
1V	5V	4V	3V
2V	5V	3V	6V
2V	4V	3V	5V

TABLE I: V_{out} for $2V_1 + V_2 - V_3$

V_1	V_3	V_{out}
4V	3V	5V
3V	2V	4V
3V	3V	3V

TABLE II: V_{out} for $2V_1 - V_3$

II. TASK -2

A. Aim

To design and analyze an op-amp-based integrator circuit using an LM358 operational amplifier. The experiment aims to apply a square wave input and observe the triangular wave output, verifying the integration property of the circuit. The effect of resistor (R) and capacitor (C) values on the output waveform will also be studied.

B. Apparatus used

1) Op-amp(LM358)
2) Resistor(10KΩ)
3) Capacitor(100μF)
4) Oscilloscope
5) Function generator
6) Jumper cables
7) Breadboard

C. Circuit diagram

The circuit diagram is as shown

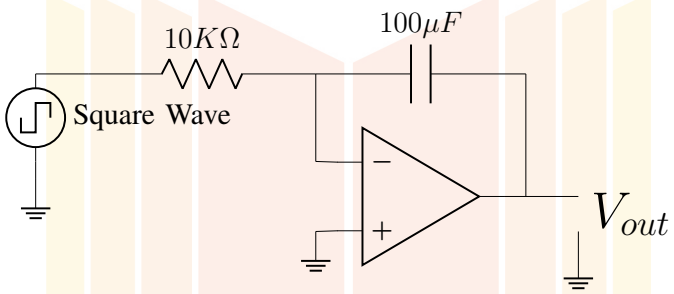


Fig. 9: Op-Amp Integrator Circuit

D. Procedure

1) Here our RC=1 and we will be using square wave of frequency 1Hz and amplitude +5 and -5
2) Using the required apparatus, construct the circuit as shown in the figure above.
3) Apply a square wave of frequency of 1Hz, and an amplitude of $\pm 5V$
4) The desired voltage is given by

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

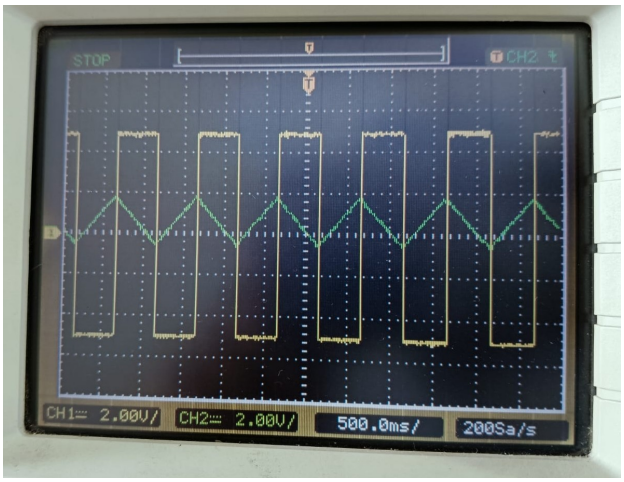
$$V_{out} = -5t \ \ (0 \leq \text{t} \leq 0.5) \tag{3}$$

$$V_{out} = (+5(t-0.5) - 2.5) \ (0.5 \leq \text{t} \leq 1) \tag{4}$$

5) The output triangular wave position depends on where the square wave starts
   Basically it is a triangular wave with period 1 sec

E. Results

(a) Voltage V_1 and V_3



(b) Figure 3 caption

Fig. 10: Output for combination of input voltages V_1 and V_2 and V_3

F. Precautions

a) Always connect the COM terminal of the DC power supply as the common ground to ensure proper voltage referencing and circuit stability.
b) Ensure that the LM358 op-amp is powered correctly with V_{cc} =12V and 0V (GND) as the reference to maintain proper functionality and avoid unexpected behavior.
c) The output voltage should not exceed 12V due to the saturation limit of the op-amp, which typically operates slightly below the supply voltage.

III. TASK -3

A. Aim

The objective of this experiment is to design, implement, and analyze a full-wave rectifier circuit using operational amplifiers and diodes. The experiment aims to demonstrate the working principle of precision rectification, which eliminates the forward voltage drop associated with conventional diode rectifiers, enabling accurate rectification of both positive and negative halves of an AC signal.

B. Appratus used

1) Op-amp(LM-358)
2) Diode
3) Resistor
4) Function generator
5) Oscilloscope
6) Jumper wires

C. circuit diagram

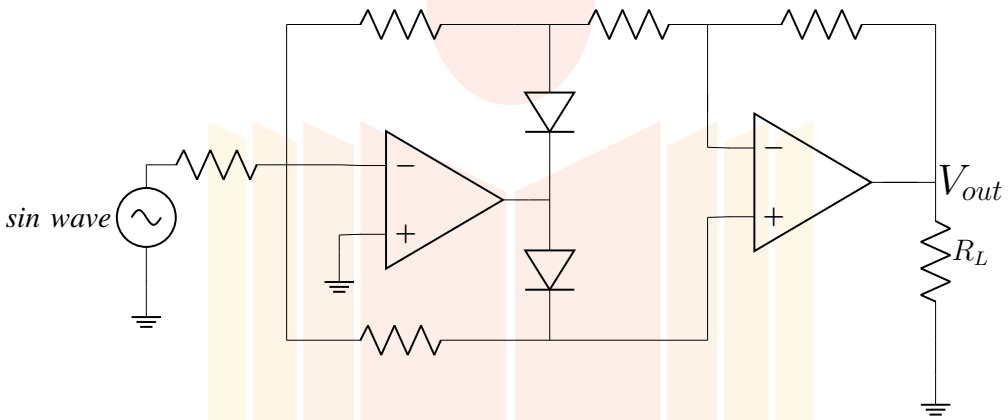


Fig. 11: Full wave rectifier(All resistors are identical)

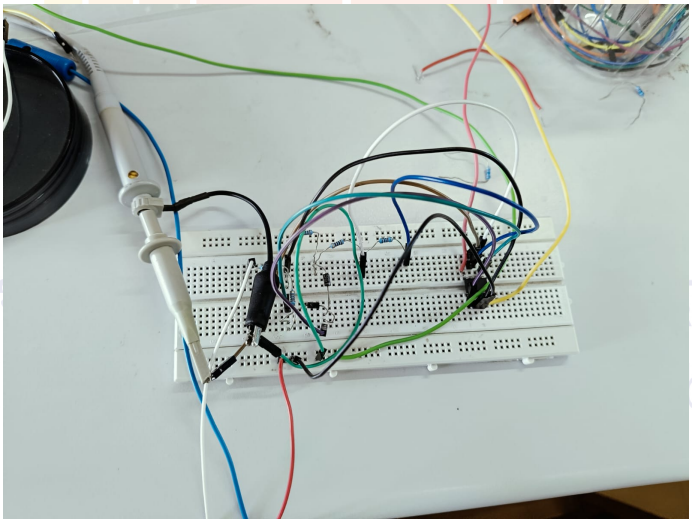


Fig. 12: Full wave circuit on breadboard

D. Theory

Full wave rectifier :- A full-wave rectifier is a circuit that converts an AC (alternating current) signal into a DC (direct current) signal by allowing both the positive and negative halves of the AC waveform to pass, but in the same direction. This makes it more efficient than a half-wave rectifier.

Working principle :-

1) **First Op-amp**
   - During the positive half-cycle, the first op-amp and diode (D1) allow the input to pass.
   - During the negative half-cycle, the op-amp inverts the input voltage and prevents conduction.
2) **Second Op-amp**
   - It takes both the original and inverted signals and combines them.
   - This ensures that both halves of the waveform appear positive at the output.

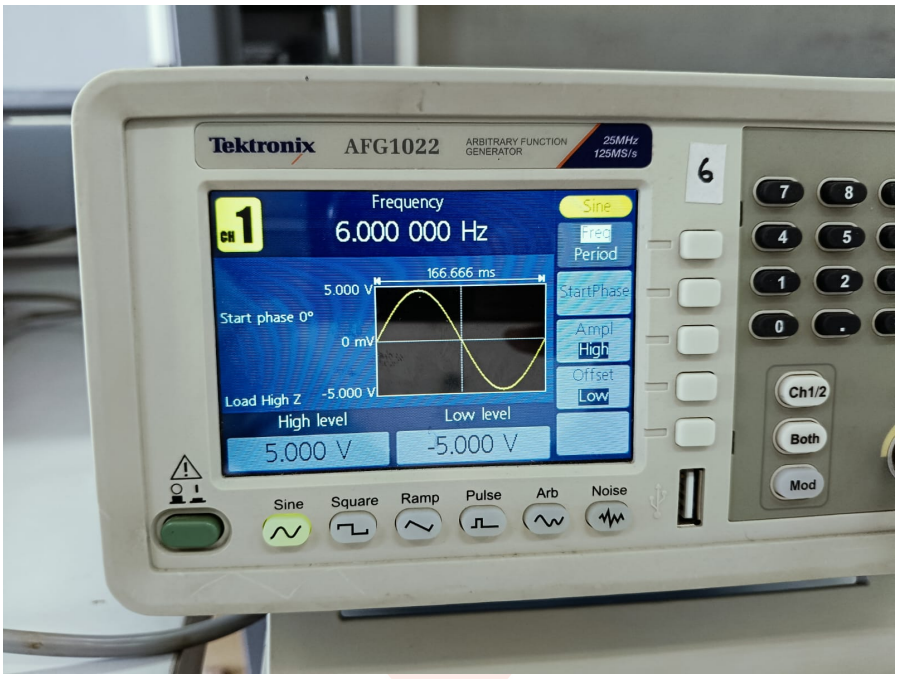
E. Procedure

a) Construct the circuit as shown in the above figure
b) Apply sin wave using function generator

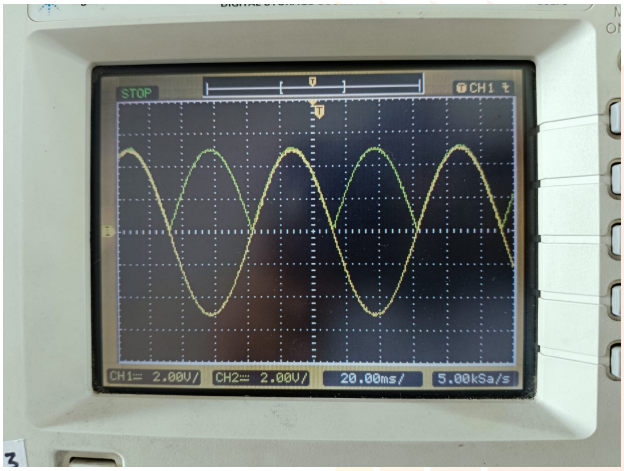
F. Precautions

a) Always connect the COM terminal of the DC power supply as the common ground to ensure proper voltage referencing and circuit stability
b) Ensure that the LM358 op-amp is powered correctly with V_{cc} =12V and 0V (GND) as the reference to maintain proper functionality and avoid unexpected behavior
c) The output voltage should not exceed 12V due to the saturation limit of the op-amp, which typically operates slightly below the supply voltage.

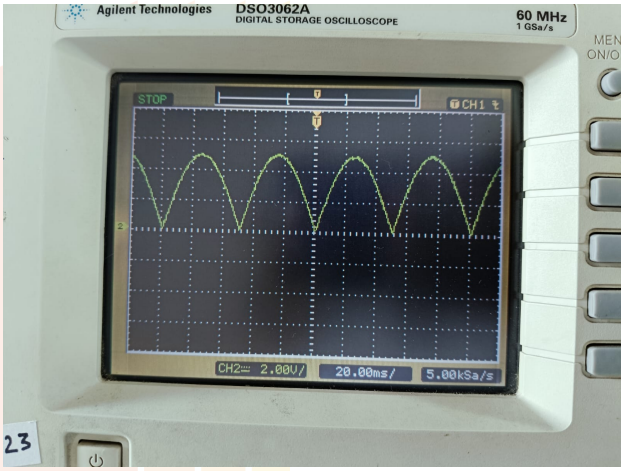
G. Result



(a) Input sine wave for circuit



(b) Output including both input and output of circuit



(c) Output of circuit

Fig. 13: Observation on full wave-rectifier using Op-amps