**Aim ↬ To design and verify the operation of OpAmp as an Adder.**

## Equipment Required ↬

Resistors, IC 741 OP-AMP, Function Generator, DSO, Breadboard & Wires.

## Theory ↬

An operational amplifier (OpAmp) adder, also known as a summing amplifier, is a circuit that combines multiple input voltages into a single output. In this configuration, each input voltage is fed through a resistor into the inverting terminal of the OpAmp, while the non-inverting terminal is typically grounded.

### Inverting Summing Amplifier ↴

In an inverting summing amplifier, each input voltage is fed through a resistor into the inverting terminal of the OpAmp, while the non-inverting terminal is typically grounded. The OpAmp's output is proportional to the sum of the input voltages, but with inverted polarity due to the inverting nature of the amplifier. The equation gives the output voltage:

$$V_{out} = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \cdots + \frac{R_f}{R_n}V_n\right)$$

where $V_1, V_2, V_n$ represent the input voltages, and $R_f$ is the feedback resistor connecting the output back to the inverting input.

The negative sign in the equation indicates that the output voltage is an inverted sum of the input voltages. By choosing appropriate resistor values, the output can be made proportional to the desired sum of the inputs. This configuration is widely used in analog signal processing due to its simplicity and precise control.

### Non-Inverting Summing Amplifier ↴

In the non-inverting summing amplifier, the input voltages are applied to the non-inverting terminal of the OpAmp. This configuration allows the output to be a weighted sum of the input voltages without inversion, maintaining the same polarity as the inputs. The circuit is designed by connecting the input voltages through resistors to a voltage divider, which is linked to the non-inverting terminal, while the inverting terminal is connected to the output via a feedback resistor and a resistor to ground. The output voltage for this configuration is given by:

$$V_{out} = \left(1 + \frac{R_f}{R_g}\right)\left(\frac{R_1}{R_1 + R_2 + \cdots + R_n}V_1 + \frac{R_2}{R_1 + R_2 + \cdots + R_n}V_2 + \cdots + \frac{R_n}{R_1 + R_2 + \cdots + R_n}V_n\right)$$

where $R_g$ is the resistor from the inverting terminal to the ground, In this case, there is no inversion of the summed signal, making this configuration useful when maintaining the same polarity is important.

This type of adder circuit finds use in analog signal processing, where combining several input signals into one is required. The simplicity of the design, along with the precise control over the output, makes it a popular choice for applications requiring signal addition in electronics.

### Circuit Diagram ↬

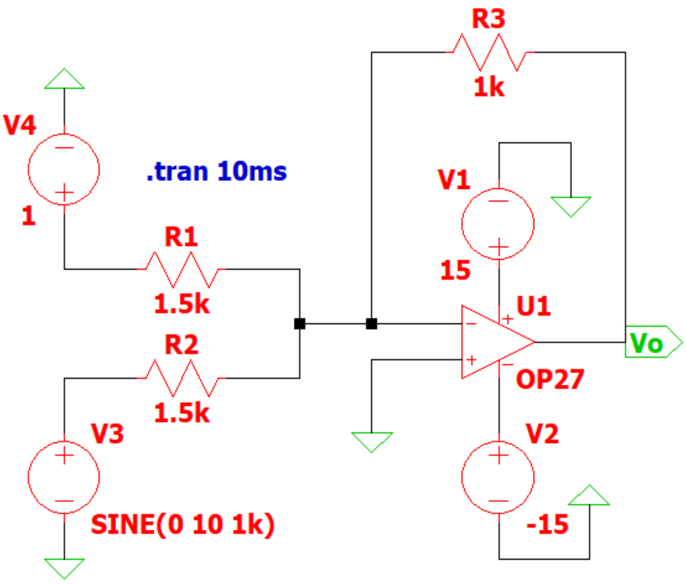


Fig. i) Adder using Inverting OpAmp

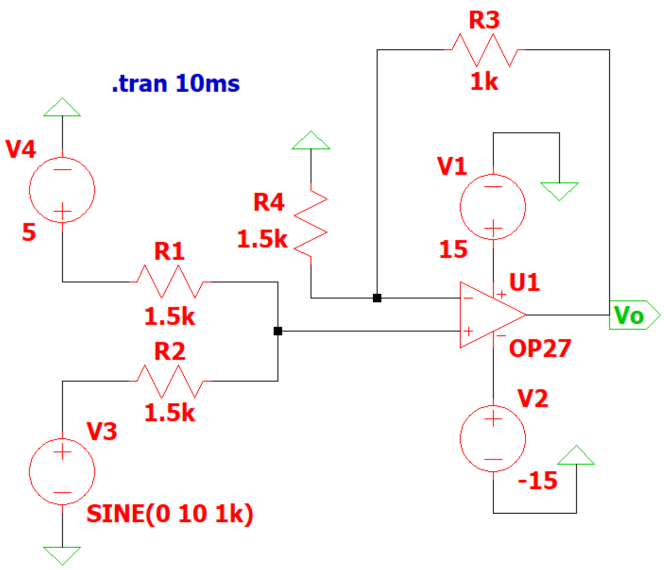


Fig. ii) Adder using Non-Inverting OpAmp

## Graphs ↬

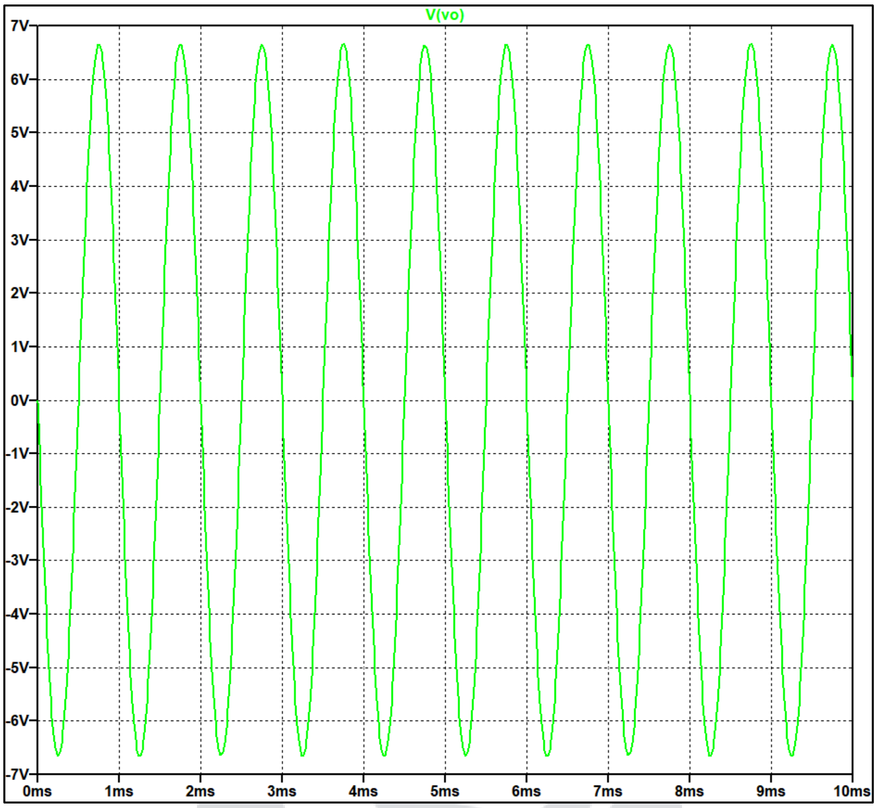


Fig. iii) Adder using Inverting OpAmp with $V_4$=0V

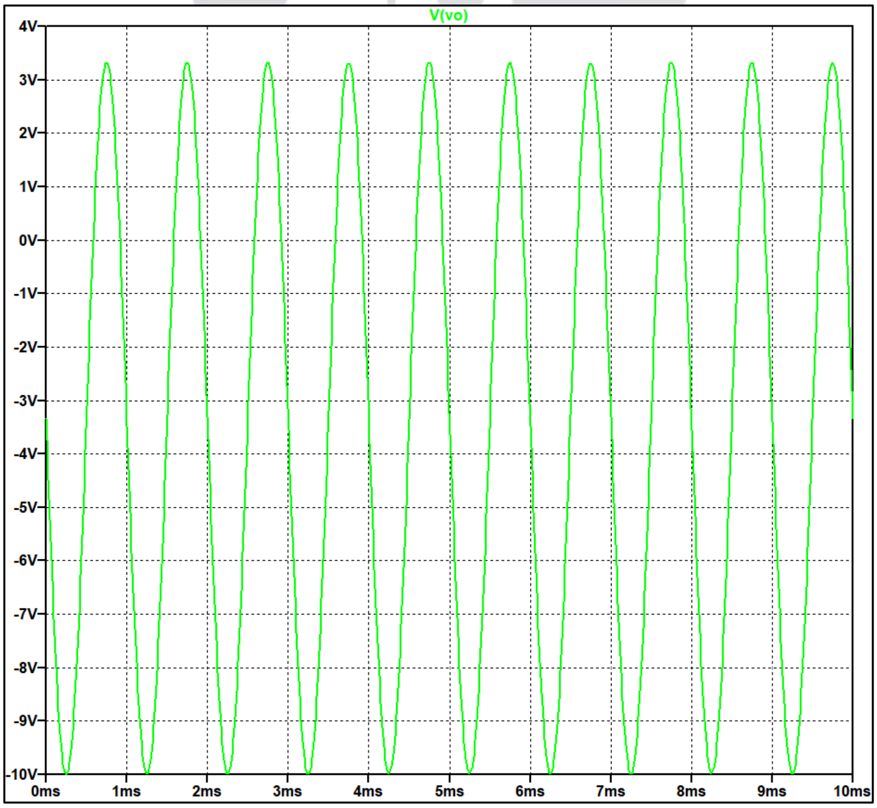


Fig. iv) Adder using Inverting OpAmp with $V_4$=5V

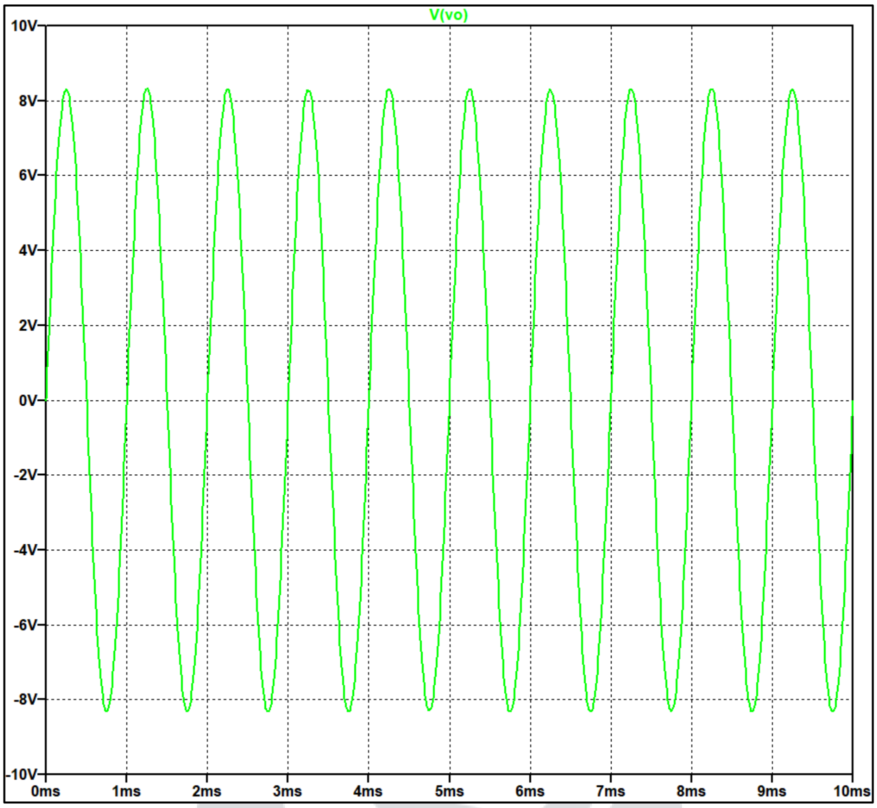


Fig. v) Adder using Non-Inverting OpAmp with $V_4$=0V

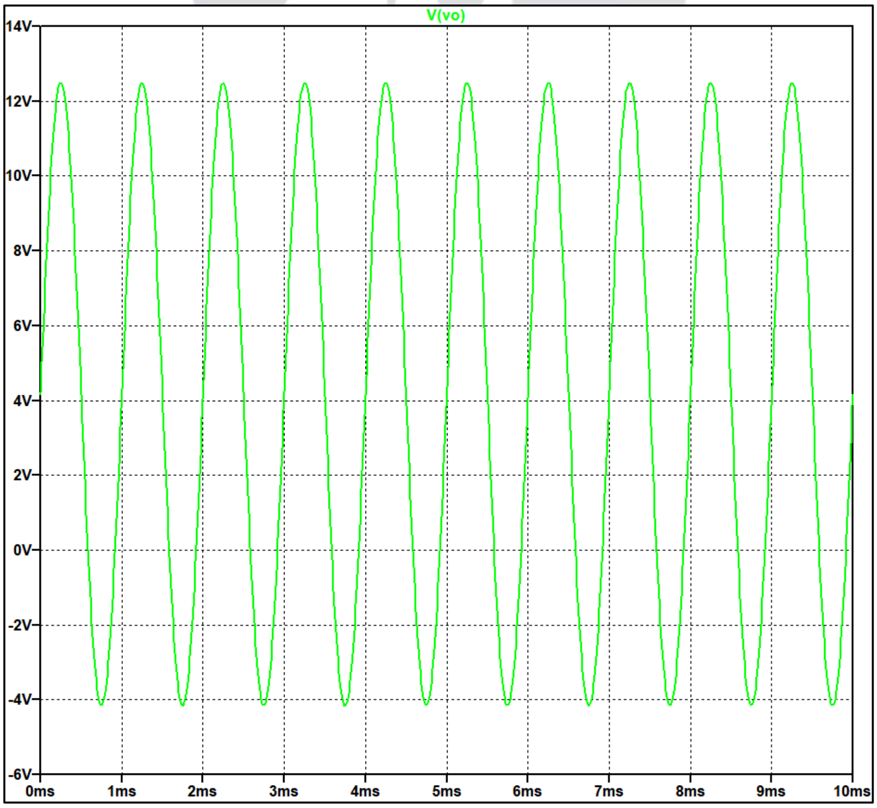


Fig. vi) Adder using Non-Inverting OpAmp with $V_4$=5V

## Output ↬

[The DSO input is amplified for some reason by 10 times ie., $V_1$ & $V_4$ are treated as 10 times the value actually assigned to them]

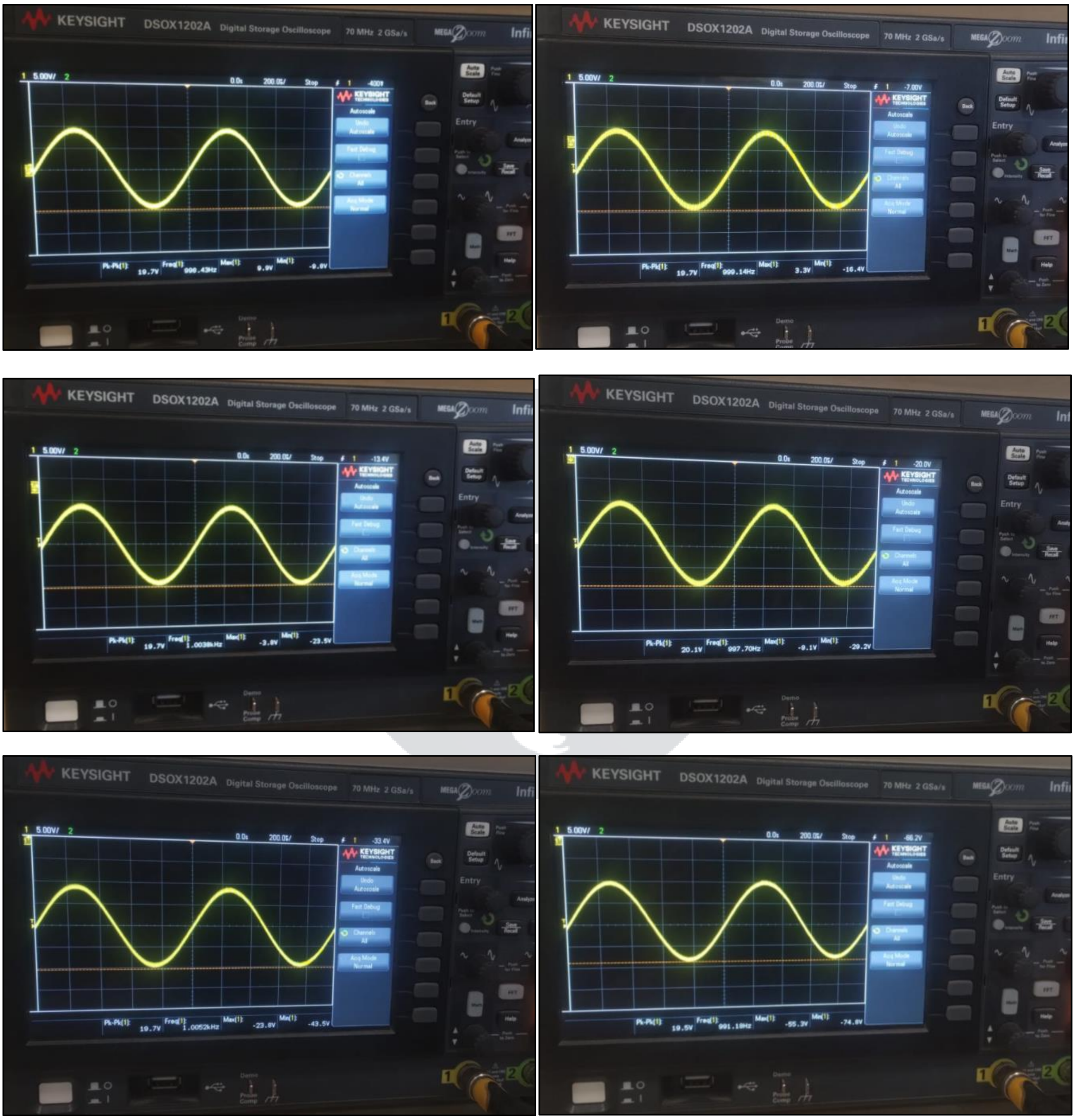


Fig. vii) Adder using Inverting OpAmp with $V_4$=0V, 1V, 2V, 3V, 5V, 10V

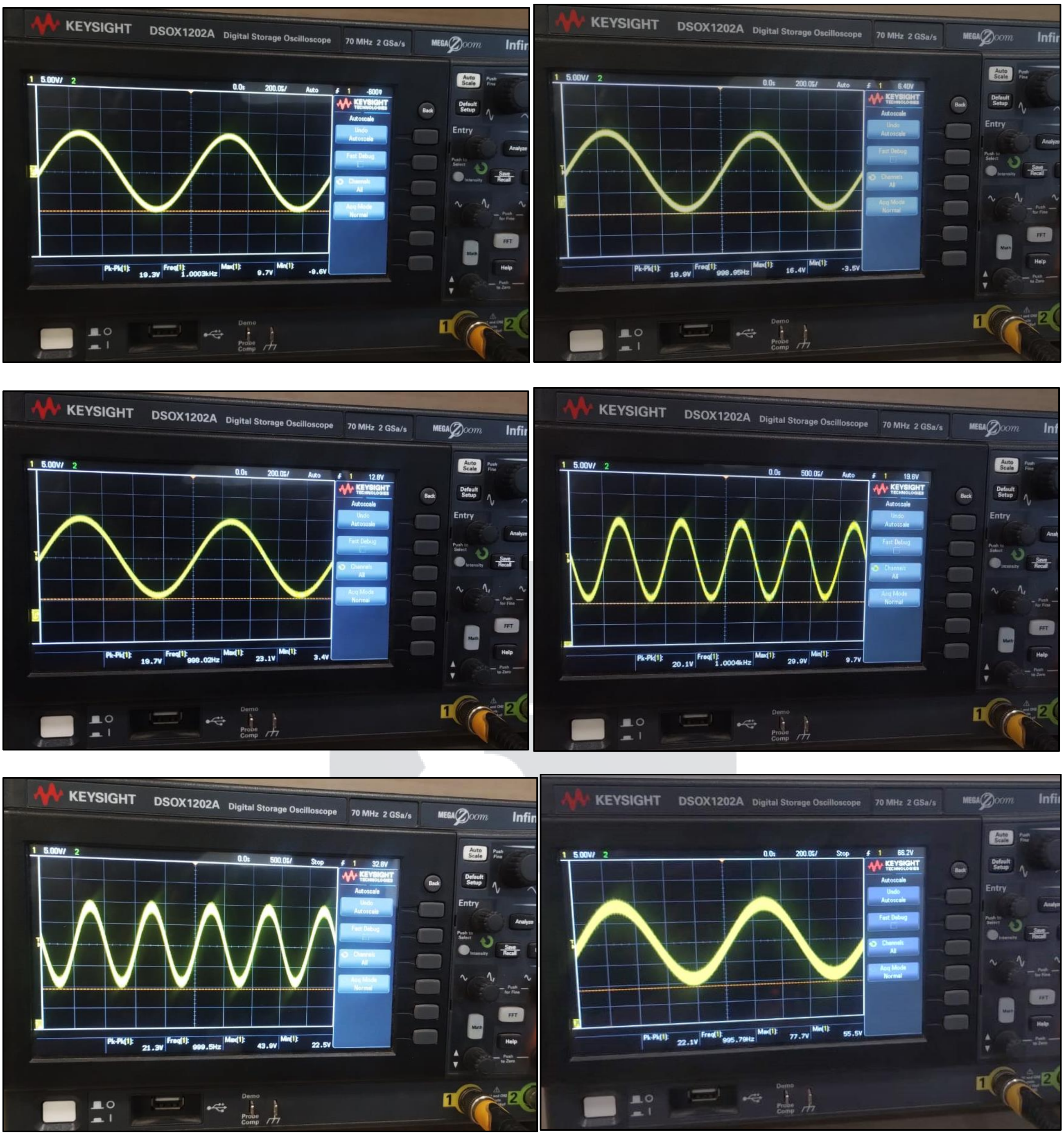


Fig. viii) Adder using Non-Inverting OpAmp with $V_4$=0V, 1V, 2V, 3V, 5V, 10V

## Calculation ↬

$$V_3 = \sin(2\pi f t)\,;\, f = 1kHz \qquad \& \qquad V_4 = 0 \; to \; 10V$$
$$R_1 = 1.489k,\; R_2 = 1.489k,\; R_f = R_3 = 0.981k,\; R_g = R_4 = 1.489k$$

Considering the value of $V_3 = \frac{(V_3)max+(V_3)min}{2}$

And also obtaining the output value of signal as $V_{out} = \frac{(V_{out})max+(V_{out})min}{2}$

**Inverting Summing Amplifier ↴**

$$V_{out} = -\left(\frac{R_3}{R_1}V_3 + \frac{R_3}{R_2}V_4\right)$$

$$V_{out} = -\left(\frac{0.981k}{1.489k} \times 0 + \frac{0.981k}{1.489k} \times V_4\right)$$

$$(V_{out})_0 = -\left(\frac{0.981k}{1.489k} \times 0 + \frac{0.981k}{1.489k} \times 0\right) = 0V$$

$$(V_{out})_1 = -\left(\frac{0.981k}{1.489k} \times 0 + \frac{0.981k}{1.489k} \times 1\right) = -0.659V$$

$$(V_{out})_2 = -\left(\frac{0.981k}{1.489k} \times 0 + \frac{0.981k}{1.489k} \times 2\right) = -1.318V$$

$$(V_{out})_3 = -\left(\frac{0.981k}{1.489k} \times 0 + \frac{0.981k}{1.489k} \times 3\right) = -1.976V$$

$$(V_{out})_5 = -\left(\frac{0.981k}{1.489k} \times 0 + \frac{0.981k}{1.489k} \times 5\right) = -3.294V$$

$$(V_{out})_{10} = -\left(\frac{0.981k}{1.489k} \times 0 + \frac{0.981k}{1.489k} \times 10\right) = -6.588V$$

**Non-Inverting Summing Amplifier ↴**

$$V_{out} = \left(1 + \frac{R_3}{R_4}\right)\left(\frac{R_1}{R_1 + R_2}V_3 + \frac{R_2}{R_1 + R_2}V_4\right)$$

$$V_{out} = \left(1 + \frac{0.981k}{1.489k}\right)\left(\frac{1.489k}{1.489k + 1.489k} \times 0 + \frac{1.489k}{1.489k + 1.489k} \times V_4\right)$$

$$(V_{out})_0 = \left(1 + \frac{0.981k}{1.489k}\right)\left(\frac{0}{2}\right) = 0V$$

$$(V_{out})_1 = \left(1 + \frac{0.981k}{1.489k}\right)\left(\frac{1}{2}\right) = 0.829V$$

$$(V_{out})_2 = \left(1 + \frac{0.981k}{1.489k}\right)\left(\frac{2}{2}\right) = 1.659V$$

$$(V_{out})_3 = \left(1 + \frac{0.981k}{1.489k}\right)\left(\frac{3}{2}\right) = 2.488V$$

$$(V_{out})_5 = \left(1 + \frac{0.981k}{1.489k}\right)\left(\frac{5}{2}\right) = 4.147V$$

$$(V_{out})_{10} = \left(1 + \frac{0.981k}{1.489k}\right)\left(\frac{10}{2}\right) = 8.294V$$

## Result ↬

The OpAmp adder was successfully designed and tested, producing an output that matched the expected inverted sum of the input voltages.

## Conclusion ↬

The circuit operated as predicted, confirming the functionality of the OpAmp as an adder and validating the theoretical calculations.

## Precautions ↬

- Ensure proper placement of resistors and correct wiring of the OpAmp on the breadboard.
- Verify the power supply connections to the OpAmp to avoid damage.
- Make sure input voltage levels do not exceed the specified limits of the IC 741 OpAmp.
- Double-check resistor values for accurate input summing and correct feedback resistor selection.