Experiment 6: Inverting, Non-Inverting, and Buffer Amplifiers using Op-Amp

Aim/Objective: To design, simulate, and experimentally verify the behaviour of:

- An Inverting Amplifier
- A Non-Inverting Amplifier
- A Voltage Follower (Buffer)

using 741 operational amplifiers and validate their gain and phase relationships

Description:

Operational amplifiers (Op-Amps) are fundamental building blocks in analog circuit design. This experiment explores three common Op-Amp configurations:

1. Inverting Amplifier

Input is applied to the inverting terminal via an input resistor Ri. Non-inverting terminal is grounded. Output is inverted and scaled based on the resistor ratio.

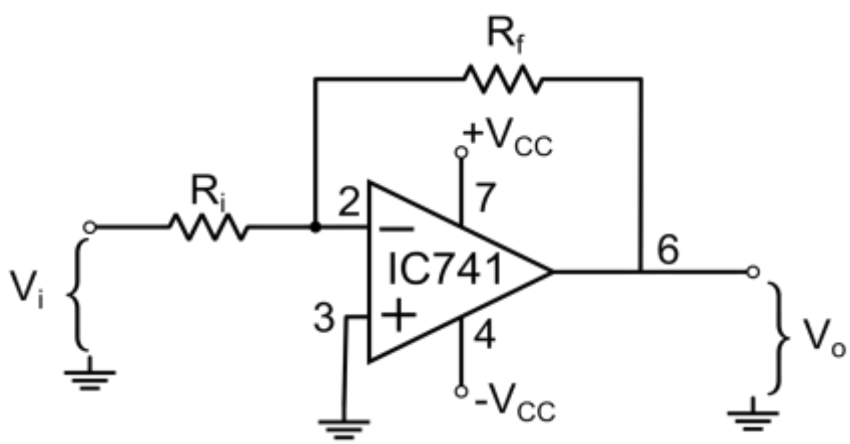


Figure 1: Circuit diagram of an Inverting Opamp using IC 741

Voltage Gain of the Inverting opamp is given as

$$A_V = -\frac{R_f}{R_i}$$

2. Non Inverting Amplifier

Input is applied to the non-inverting terminal. Inverting terminal is connected via feedback to the output

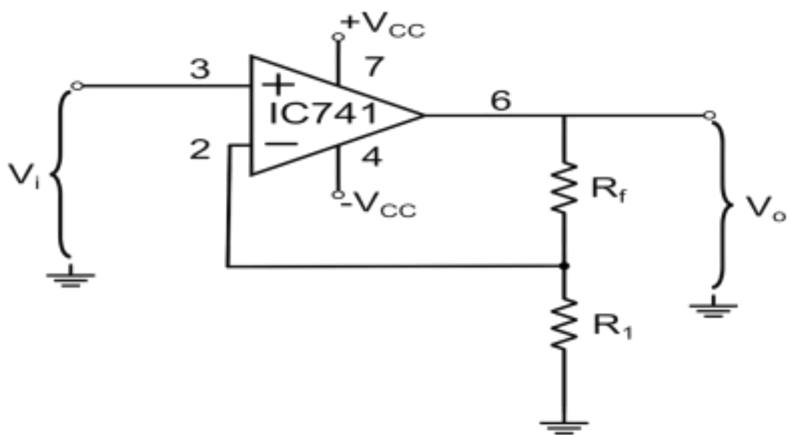


Figure 2: Non-Inverting amplifier using IC741

Voltage gain of the Non inverting opamp is given by

$$A_V = 1 + \frac{R_f}{R_1}$$

3. Voltage Buffer

Input is applied to the non-inverting terminal. Output is connected directly to the inverting terminal (i.e., unity feedback).

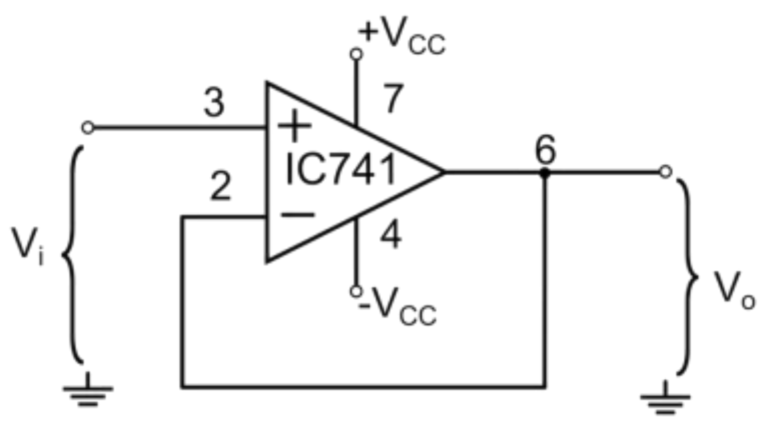


Figure 3: Buffer amplifier using IC741

Voltage gain of the Buffer opamp is given by $A_V = 1$. Hence also called as voltage follower.

Pre-Lab Session

1. List the ideal characteristics of an Op-Amp

2. Why is negative feedback used in Op-Amp circuits?

3. Derive the gain equation of an inverting amplifier.

4. Derive the gain equation of a non-inverting amplifier

MCQ:

1. The input impedance of a voltage follower is:

A) Low

B) Medium

C) High

D) Zero

2. Which of the following statements about a non-inverting amplifier is correct?

A) Output is always 180° out of phase with input

B) Gain is always less than 1

C) Input is connected to the inverting terminal

D) Output is in phase with input and gain is ≥ 1

3. In an inverting amplifier, if the input voltage increases, the output voltage will:

A) Increase with the same polarity

B) Increase with opposite polarity

C) Remain constant

D) Become zero

4. Which parameter of the Op-Amp determines how fast the output can change in response to a rapid input?

A) Slew Rate

B) Bandwidth

C) Input Offset Voltage

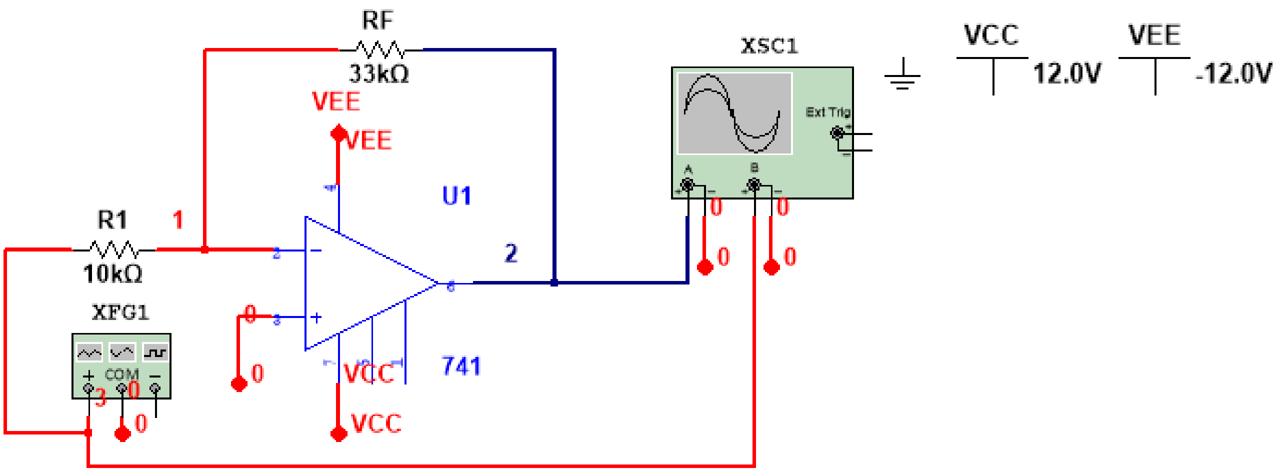
D) Common-Mode Rejection Ratio

5. What is the typical voltage gain of a voltage follower using an ideal Op-Amp?

A) 0 B) 0.5 C) 1 D) Infinite

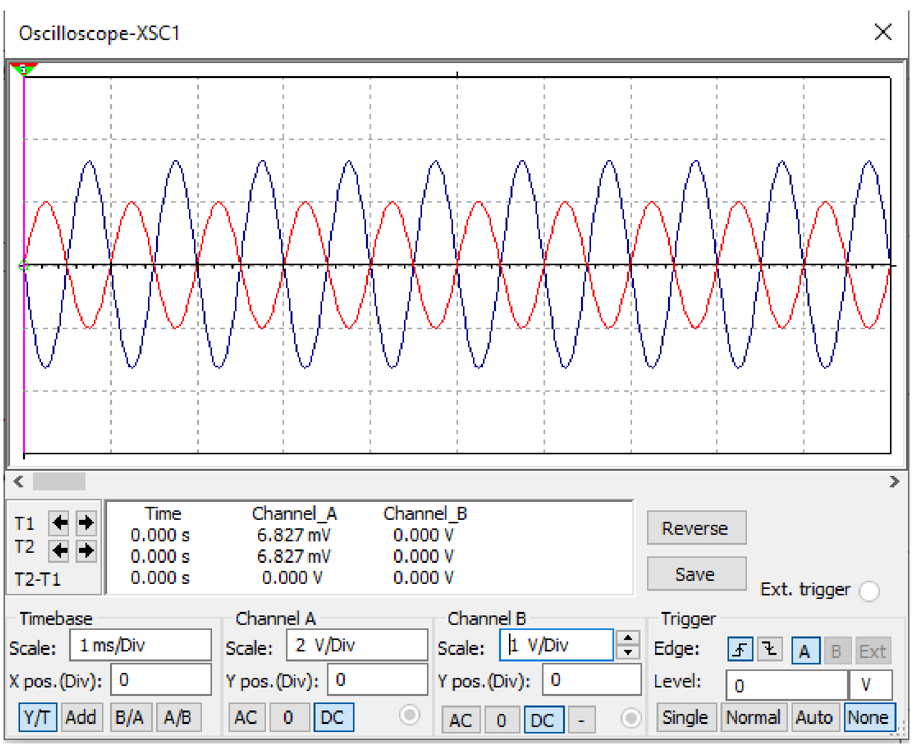
In-Lab Session

Inverting amplifier Circuit Diagram:



Choose the values of Rf and Ri to be 10 kΩ and 1 kΩ respectively. This will lead to a voltage gain of "-10". Apply a sinusoid of 1 kHz frequency and 50mVp-p and check the output waveform. The input and output waveforms will be out of phase by 180 degrees, which is why the amplifier is called as the inverting amplifier. Gradually increase the peak to peak value of the sinusoid as shown in the table below. Observe the output waveform and note down the peak to peak values of the same. Calculate the voltage gain and tabulate below.

Change the frequency of the input sinusoid to 100 Hz and repeat the same exercise. Change **Rf = 330 kΩ and Ri = 10 kΩ** (voltage gain of -33) and repeat the same exercise.

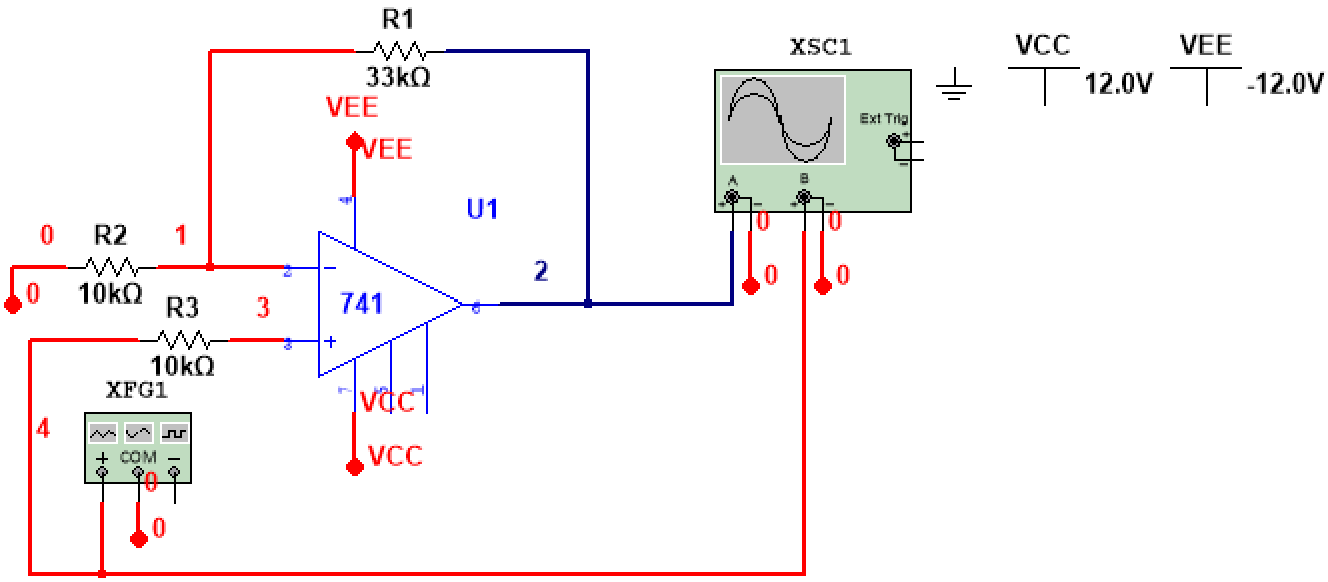


Analysis and Inferences:

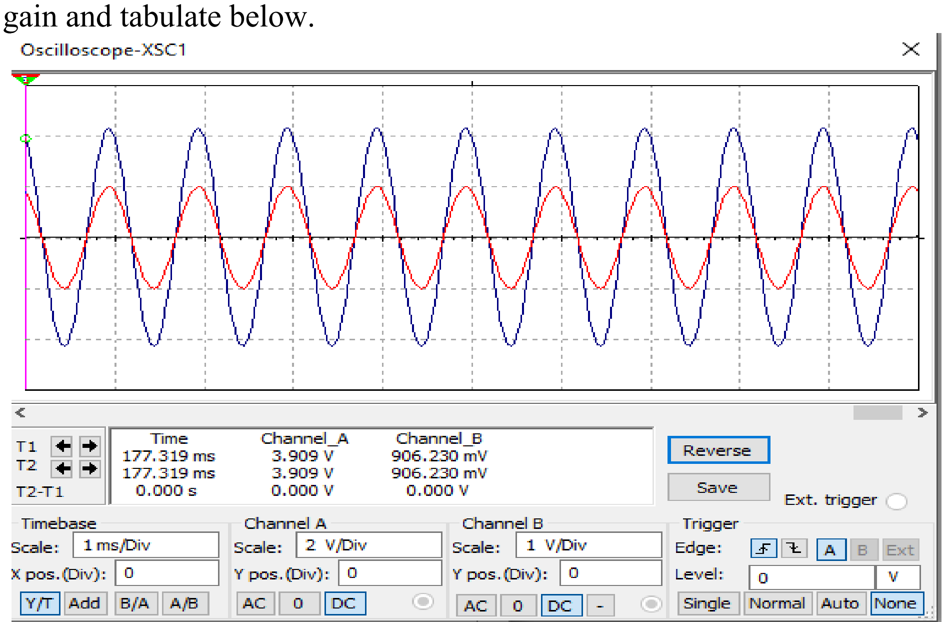
The voltage gain calculated for each input in the tables above, should match or be close to the theoretical gain

$$A_V = -\frac{R_f}{R_i}$$

Non-Inverting amplifier Circuit Diagram:



Choose the values of Rf and R1 to be 10 kΩ and 1 kΩ respectively. This will lead to a voltage gain of "11". Apply a sinusoid of 1 kHz frequency and 50mVp-p and check the output waveform. The input and output waveforms will be in phase, which is why the amplifier is called as the non-inverting amplifier. Gradually increase the peak to peak value of the sinusoid as shown in the table below. Observe the output waveform and note down the peak to peak values of the same. Calculate the voltage gain and tabulate below.

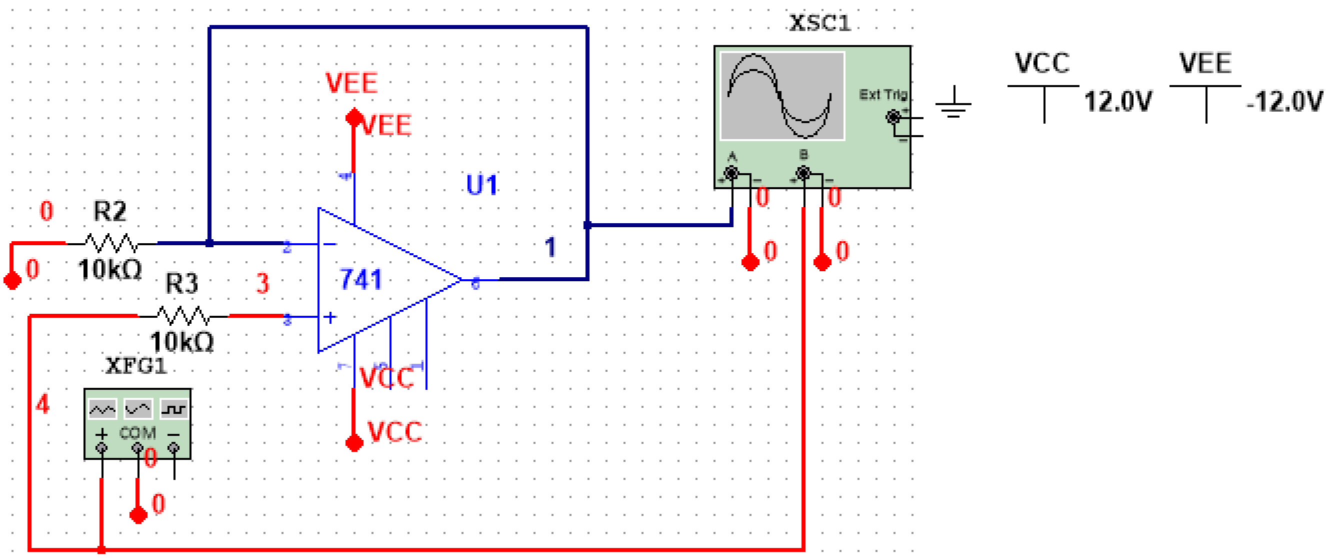


Analysis and Inferences:

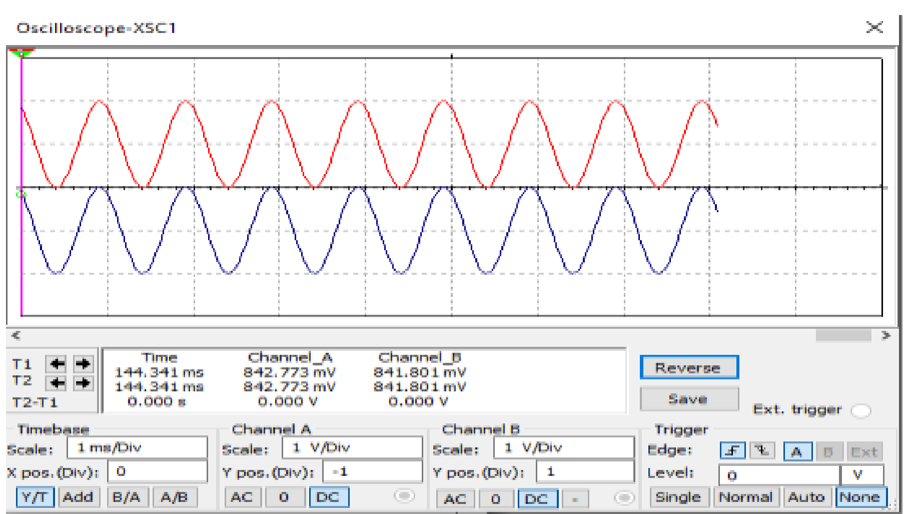
The voltage gain calculated for each input in the tables above, should match or be close to the theoretical gain

$$A_V = 1 + \frac{R_f}{R_1}$$

Voltage Buffer Circuit Diagram:



Assemble the circuit as given in the schematic diagram above. Apply a sinusoid of 100 Hz frequency and 50mVp-p and check the output waveform. The input and output waveforms will be almost same and that is why it is called as voltage buffer. Gradually increase the peak to peak value of the sinusoid as shown in the table below. Observe the output waveform and note down the peak to peak values of the same. Calculate the voltage gain and tabulate below. Change the frequency of the input sinusoid to 1 kHz and repeat the same exercise. Change the frequency of the input sinusoid to 1 MHz and repeat the same exercise.



Analysis and Inferences:

The voltage gain calculated for each input in the tables above, should match or be close to the theoretical gain

$$A_V = 1$$

VIVA-VOCE Questions (In-Lab):

1. The gain of voltage buffer is:
   - A) 0
   - B) 1
   - C) Infinity
   - D) -1

2. In an inverting amplifier, if Rf=10kΩ and Rin=2kΩ, the gain is:
   - A) 5
   - B) -5
   - C) 0.2
   - D) -0.2

3. The input impedance of an ideal non-inverting amplifier is:
   - A) Equal to Rin
   - B) Zero
   - C) Infinite
   - D) Equal to Rf

4. The phase shift in an inverting amplifier is:
   - A) 0°
   - B) 90°
   - C) 180°
   - D) 270°

5. **What happens if the feedback resistor in an inverting amplifier is removed?**
   - A) The gain becomes zero
   - B) The Op-Amp operates in open-loop mode with very high gain
   - C) The output remains at zero
   - D) The input signal is directly passed to output

Data and Results:

Analysis and Inferences:

Result:

The experiment on Inverting, Non-Inverting, and Buffer Amplifiers using Op-Amp has been performed and results have been analyzed.

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