Group No:

Experiment-01

Study of Op-Amp: Comparator, Inverting Amplifier, Non-Inverting Amplifier

CSE251 - Electronic Devices and Circuits Lab

Objective

1. To understand the basic principles and characteristics of an Operational Amplifier (Op-Amp)
2. To investigate the use of Operational Amplifier (Op-Amp) as Comparator, Inverting Amplifier and Non-Inverting Amplifier

Equipments

1. Op-Amp (uA741)
2. Resistance ($1k\Omega, 2.7k\Omega$)
3. DC power supply
4. Trainer Board
5. Digital Multimeter
6. Breadboard
7. Chords and Wire

Background Theory

Introduction

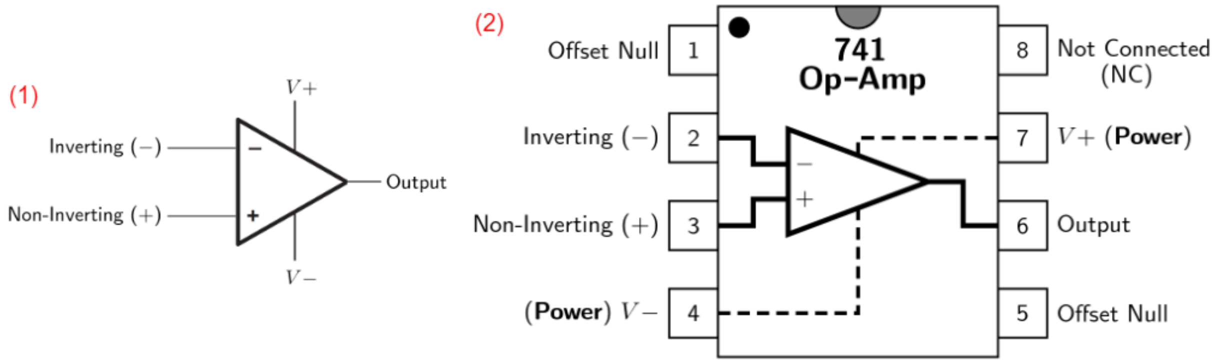
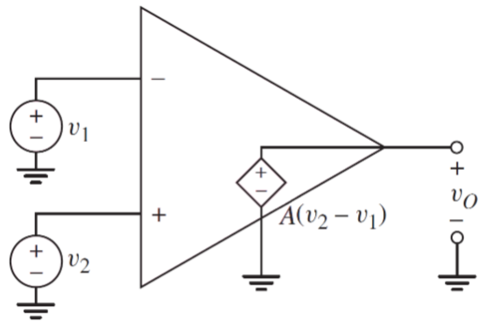


Figure 1: (1) Op-Amp Simplified Circuit Symbol (2) Op-Amp IC Pin Diagram

One of the most widely used electronic devices in linear applications is the Operational Amplifier, commonly known as the Op-Amp. An Op-Amp is an integrated circuit that amplifies the difference between two input voltages and produces a single output. We can also do various mathematical operations like addition, subtraction, multiplication, integration, differentiation etc. with the help of Op-Amp. With the addition of suitable external components, Op-Amp can be used for a variety of applications. Figure 1 shows the simplified circuit symbol of an an Op-Amp. There are 2 terminals for input, 1 terminal for output and 2 terminals for powering up the Op-Amp. Inverting, Non-Inverting are the input terminals and $V+$, $V-$ are the terminals used for powering up the Op-Amp. $V+$ is referred to as 'Positive Supply Voltage' and $V-$ is referred to as 'Negative Supply Voltage'. Figure 1 also shows the IC pin diagram of an Op-Amp where all of the terminals are labeled. The Op-Amp is biased with dc supply voltages, although those connections are seldom explicitly shown.

Ideal Op-Amp



Ideal op-amp equivalent circuit

The ideal Op-Amp senses the difference between two input voltages and amplifies this difference to produce an output voltage. The figure shown above represents the equivalent circuit of an ideal Op-Amp and the circuit configuration is known as Op-Amp open loop configuration. The parameter 'A' shown in the equivalent circuit is the open-loop differential voltage gain of the Op-Amp. In the ideal Op-Amp, the open-loop gain 'A' is very large and approaches infinity and there is no current the the input terminals. But in real Op-Amp, there is a small amount of current that flows into the inverting and non-inverting terminals and the open-loop gain ranges from 10^4 to 10^5 or higher. We will analyze the circuits using the ideal Op-Amp throughout this experiment.

Practical Considerations

Looking into the equation of the output, $v_O = A(v_2 - v_1)$, one may think that, we can get any voltage at the output of the Op-Amp. But the problem is, the output voltage is limited since the Op-Amp is composed of transistors biased in the active region by the dc supply voltages $V+$ and $V-$. When v_O approaches $V+$, it will saturate, or be limited to a value nearly equal to $V+$, since it cannot go above the positive bias voltage. Similarly, when the output voltage approaches $V-$, it will saturate at a value nearly equal to $V-$.

Op-Amp Comparator

The comparator is essentially an op-amp operated in an open-loop configuration, as shown below:

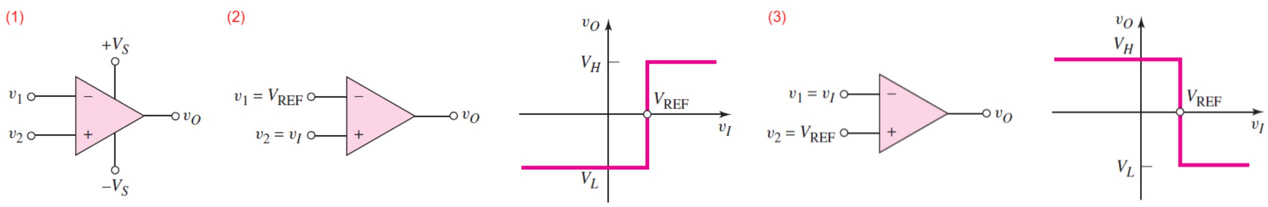
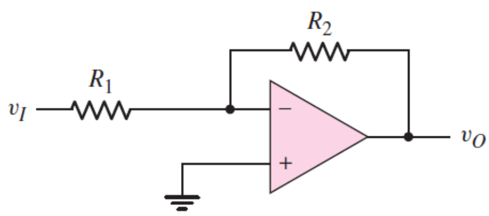


Figure 2: (1) Op-Amp Comparator (2) Noninverting Circuit (3) Inverting Circuit

A comparator compares two voltages to determine which is larger. The comparator is usually biased at voltages $+V_S$ and $-V_S$, although other biases are possible. If non-inverting input > inverting input then $v_O = +V_S$. If inverting input > non-inverting input then $v_O = -V_S$. The figure above shows two comparator configurations along with their voltage transfer characteristics which illustrates the behaviour of a comparator with V_{REF} as reference voltage which can be controlled to get the desired output.

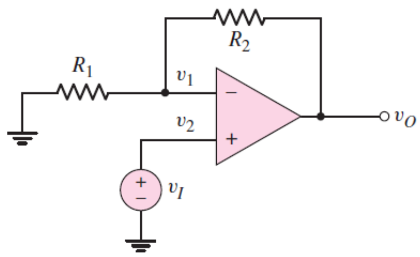
Inverting Amplifier



Inverting amplifier configuration of op-amp is one of the most widely used op-amp circuits. The figure above shows the closed-loop configuration of this circuit. This circuit amplifies the v_I according to the gain which can be controlled by the two resistances R_1 and R_2. It is called inverting amplifier because the output voltage gets inverted here. The following equation shows the relationship of the input and output of the inverting amplifier.

$$v_O = -(\frac{R_2}{R_1}) \times v_I; \ \texttt{where, gain = } -\frac{R_2}{R_1}$$

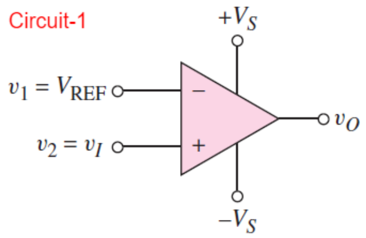
Non-Inverting Amplifier

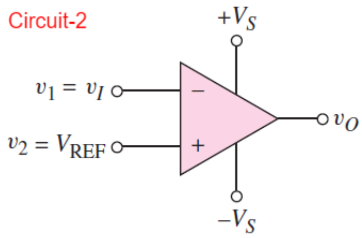


There is another amplifier circuit of op-amp that does not invert the input voltage at the output. It is called the non-inverting amplifier which is shown in the figure above. This circuit also amplifies the v_I according to the gain which can be controlled by the two resistances R_1 and R_2. The following equation shows the relationship of the input and output of the inverting amplifier.

$$v_O = (1 + \frac{R_2}{R_1}) \times v_I; \ \texttt{where, gain = } (1 + \frac{R_2}{R_1})$$

Task-01: Op-Amp Comparator





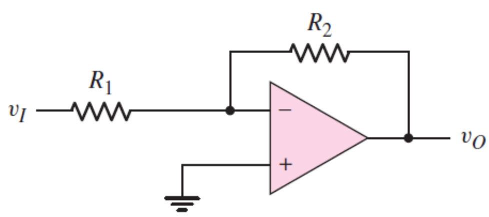
Procedure

1. Construct Circuit-1 with $v_I = 2$ V (p-p), 1 kHz sine wave and $V_{REF} = 0.5$ V. The supply voltage $+V_S$ and $-V_S$ should be +8 V and -8 V respectively which can be taken from the trainer board. **Use this supply voltage throughout the experiment**.

2. Connect the Ch1 and Ch2 of the oscilloscope to v_I and v_O respectively. Observe the input and output waveform and capture them using a camera.

3. Now, construct Circuit-2 and repeat the experiment with same values given above. Observe the input and output waveform and capture them using a camera.

Task-02: Inverting Amplifier

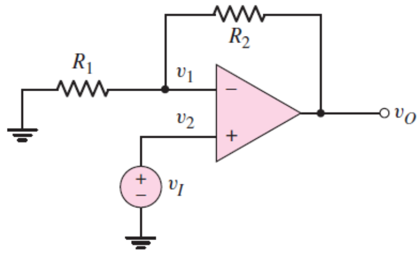


Procedure

1. Construct the circuit with $v_I = 2$ V (p-p), 1 kHz sine wave. Use $R_1 = 1$ kΩ, $R_2 = 2.7$ kΩ.

2. Connect the Ch1 and Ch2 of the oscilloscope to v_I and v_O respectively. Observe the input and output waveform and capture them using a camera.

Task-03: Non-Inverting Amplifier



Procedure

1. Construct the circuit with $v_I = 2$ V (p-p), 1 kHz sine wave. Use $R_1 = 1$ kΩ, $R_2 = 2.7$ kΩ.
2. Connect the Ch1 and Ch2 of the oscilloscope to v_I and v_O respectively. Observe the input and output waveform and capture them using a camera.

Task-04: Report

1. Cover page [include course code, course title, name, student ID, group, semester, date of performance, date of submission]
2. Attach the signed Data Sheet.
3. Answer the questions of the Test Your Understanding section.
4. Add a brief Discussion at the end of the report.

Data Sheet

Task-02:

Input Amplitude from oscilloscope, $v_I =$
Output Amplitude from equation, $v_O = -(\frac{R_2}{R_1}) \times v_I =$
Output Amplitude from oscilloscope, $v_O =$

Task-03:

Input Amplitude from oscilloscope, $v_I =$
Output Amplitude from equation, $v_O = (1 + \frac{R_2}{R_1}) \times v_I =$
Output Amplitude from oscilloscope, $v_O =$

Test Your Understanding

Answer the following questions:

1. You are given an Op-Amp comparator with $v_1 = 4$ V (p-p), sine wave and $v_2 = V_{REF} =$ -1 V. Draw the waveform of v_1, v_2 and v_O in the same graph with proper labels.
2. You are given an inverting amplifier with $v_I = 4$ V (p-p), $R_1 = 1\ k\Omega$, $R_2 = 2.2\ k\Omega$. Draw the waveform of v_I and v_O in the same graph with proper labels.
3. You are given a non-inverting amplifier with $v_I = 4$ V (p-p), $R_1 = 1\ k\Omega$, $R_2 = 2.2\ k\Omega$. Draw the waveform of v_I and v_O in the same graph with proper labels.