Group No: 01

Experiment-02

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

CSE251 - Electronic Devices and Circuits Lab

Objective

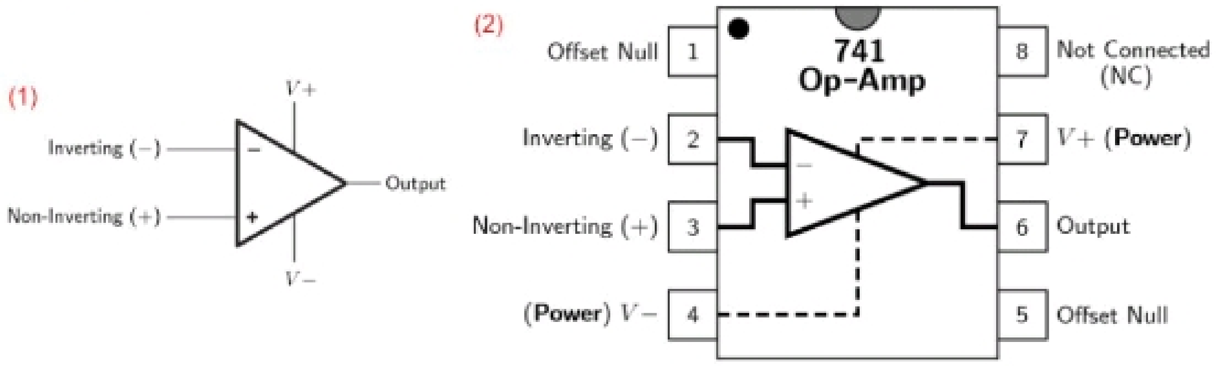
1. To understand the basic principles and characteristics of an Operational Amplifier (Op-Amp)
2. To investigate the use of Operational Amplifier (Op-Amp) as Comparator, Non-Inverting Amplifier, Inverting Amplifier and Inverting Summing Amplifier

Equipment

1. Op-Amp (uA741)
2. Resistance ($1k\Omega, 2.7k\Omega, 10k\Omega$)
3. DC Power Supply
4. Function Generator
5. Trainer Board
6. Digital Multimeter
7. Breadboard, Chords and Wires

Background Theory

Introduction

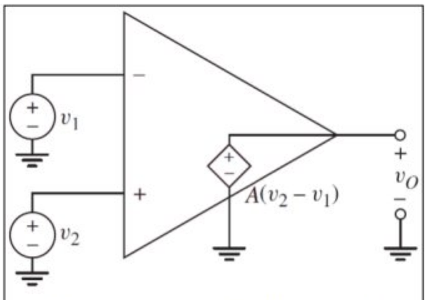


(1) Op-Amp Simplified Circuit Symbol (2) Op-Amp IC Pin Diagram

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. The figure above shows the simplified circuit symbol of 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_S^+, V_S^- are the terminals used for powering up the Op-Amp. V_S^+ is referred to as 'Positive Supply Voltage' and V_S^- is referred to as 'Negative Supply Voltage'. The IC pin diagram of an Op-Amp is also shown where all of the terminals are labeled. Op-Amp is biased with dc supply voltages, although those connections are seldom explicitly shown.

Ideal Op-Amp

The ideal Op-Amp senses the difference between two input voltages and amplifies the difference to produce an output voltage. The figure shown on the right side represents the equivalent circuit of an ideal Op-Amp and the circuit configuration is known as the open-loop configuration of Op-Amp. The parameter 'A' shown in the equivalent circuit is the open-loop differential voltage gain of the Op-Amp. In an ideal Op-Amp, the open-loop gain 'A' is very large value approaching infinity and there is no current flowing into the the input terminals. But in a real Op-Amp, a small amount of current flows into the input 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.



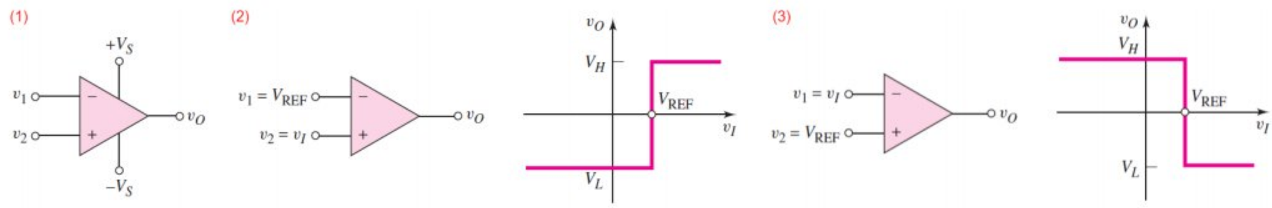
Ideal op-amp equivalent circuit

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 output voltage is limited since the Op-Amp is composed of transistors biased in the active region by the dc supply voltages V_S^+ and V_S^-. When v_O approaches V_S^+, it will saturate, or be limited to a value almost equal to V_S^+, since it cannot go beyond the positive bias voltage. Similarly, when the output voltage approaches V_S^-, it will saturate at a value almost equal to V_S^-.

Op-Amp Comparator

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



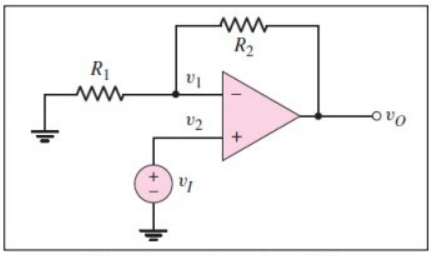
(1) Op-Amp Comparator (2) Non-inverting Circuit (3) Inverting Circuit

A comparator compares two voltages to determine which one is larger. Comparator is usually biased at voltages V_S^+ and V_S^- , although other biases are also possible. When, non-inverting input > inverting input then, $v_O = V_S^+$. When, inverting input > non-inverting input, i.e. $v_1 > v_2$ then, $v_O = V_S^-$. The figures above show two comparator configurations along with their voltage transfer characteristics to illustrate the behaviour of a comparator with V_{REF} as reference voltage which can be controlled to get the desired output.

Non-Inverting Amplifier

The amplifier circuit of an op-amp that does not invert the input voltage at the output is called the non-inverting amplifier. This circuit amplifies the input voltage, v_I according to the gain which can be controlled by the resistances R_1 and R_2. The following equation shows the relation between the input and output of a non-inverting amplifier:

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

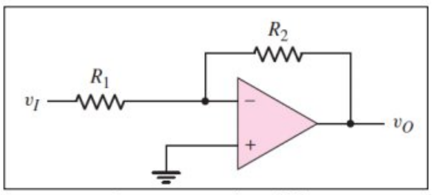


Non-inverting Amplifier

Inverting Amplifier

Inverting amplifier configuration of an op-amp is one of the most widely used op-amp circuits. It amplifies the input voltage, v_I according to the gain which can be controlled by the resistances R_1 and R_2. The input voltage gets inverted at the output, hence the name inverting amplifier. The following equation shows the relation between the input and output of an inverting amplifier:

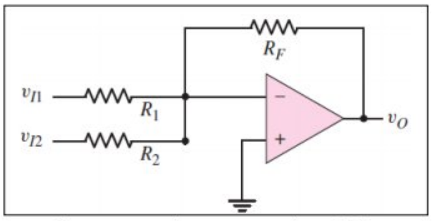
$$v_O = -(\frac{R_2}{R_1}) \times v_I; \texttt{ where, gain = } -\frac{R_2}{R_1}$$



Inverting Amplifier

Inverting Summing Amplifier

The figure shows the circuit configuration of an op-amp known as inverting summing amplifier that does the job of weighted summation. The input voltages are added according to their weight and gets inverted at the output. The weight of each input voltage during the summing operation can be controlled by the resistances R_1, R_2 and R_F. The following equation shows the relation between input and output of the circuit:



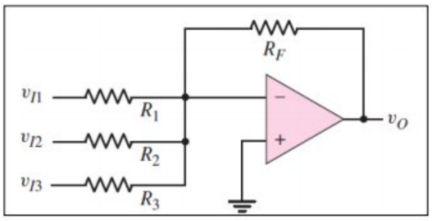
Inverting Summing Amplifier

$v_O = -(\frac{R_F}{R_1} \times v_{I1} + \frac{R_F}{R_2} \times v_{I2})$; `where, gain for` v_{I1} `=` $-\frac{R_F}{R_1}$`, gain for` v_{I2} `=` $-\frac{R_F}{R_2}$

The inverting summing amplifier circuit has 2 inputs which can be extended to as many inputs as we want and the equation will change accordingly. Let's say, we need to add another input, v_{I3}. The equation will become:

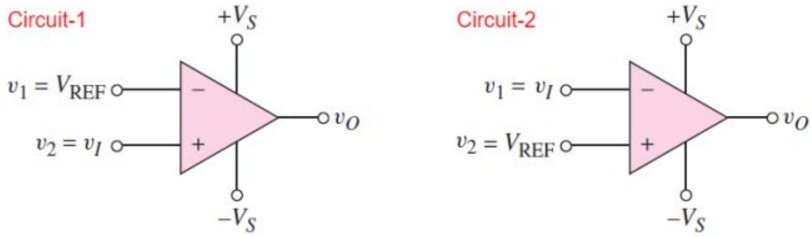
$$v_O = -(\frac{R_F}{R_1} \times v_{I1} + \frac{R_F}{R_2} \times v_{I2} + \frac{R_F}{R_3} \times v_{I3})$$

`where, gain for` v_{I1} `=` $-\frac{R_F}{R_1}$`, gain for` v_{I2} `=` $-\frac{R_F}{R_2}$
`gain for` v_{I3} `=` $-\frac{R_F}{R_3}$



3-input Inverting Summing Amplifier

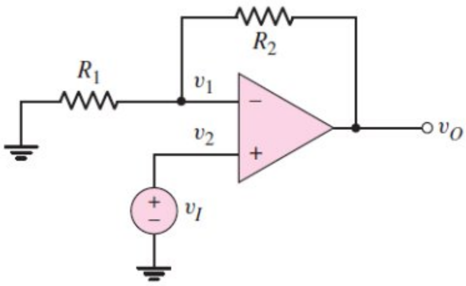
Task-01: Op-Amp Comparator



Procedure

1. Construct ***Circuit-1*** with $v_I = 2$ V (p-p), 1 kHz sine wave and $V_{REF} = 0.5$ V. Use the trainer board for the supply voltages, $V_S^+ = +8V$ and $V_S^- = -8V$ and **use these supply voltages for the next tasks**.
2. **The ground of the oscilloscope, trainer board and function generator should be connected**.
3. Connect 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.
4. 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.

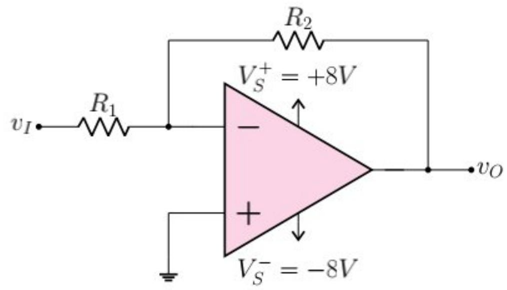
Task-02: Non-Inverting Amplifier



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.

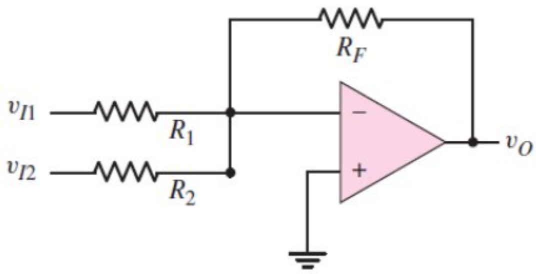
Task-03: Inverting Amplifier



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: Inverting Summing Amplifier



Procedure

1. Construct the circuit using the Ch-1 and Ch-2 of the DC Power Supply for $v_{I1} = 1$ V and $v_{I2} = 2$ V respectively.
2. Use $R_1 = 10$ kΩ, $R_2 = 10$ kΩ and $R_F = 10$ kΩ.
3. Use the digital multimeter to measure the output voltage v_O and write down the values in the data sheet.

Task-05: 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. Attach the captured photos of all the waveforms you have observed in the oscilloscope.
4. Answer the questions of the Test Your Understanding section.
5. Add a brief Discussion at the end of the report.

Data Sheet

for Task-02:

Value of R_1 using multimeter = 1k
Value of R_2 using multimeter = 2.61k
Input Amplitude from oscilloscope (use the **Measure** button), v_I = 1.88V
Output Amplitude from equation, $v_O = (1 + \frac{R_2}{R_1}) \times v_I$ = 6.787v
Output Amplitude from oscilloscope (use the **Measure** button), v_O = 6.21V

~~for Task-03~~:

Value of R_1 using multimeter = 1k
Value of R_2 using multimeter = 2.61k
Input Amplitude from oscilloscope (use the **Measure** button), v_I = ~~0.96V~~ 1.88V
Output Amplitude from equation, $v_O = -(\frac{R_2}{R_1}) \times v_I$ = ~~-1.93V~~ -4.91V
Output Amplitude from oscilloscope (use the **Measure** button), v_O = ~~-0.18V~~ -3.56V ??

for Task-04:

Value of R_1 using multimeter = 9.78k
Value of R_2 using multimeter = 9.84k
Value of R_F using multimeter = 9.61k
from multimeter, v_{I1} = 1.98 v
from multimeter, v_{I2} = 1.01 v
Output Amplitude from equation, $v_O = -(\frac{R_F}{R_1} \times v_{I1} + \frac{R_F}{R_2} \times v_{I2})$ = -2.93v
~~Output Amplitude from multimeter, v_O~~ = -2.82 v

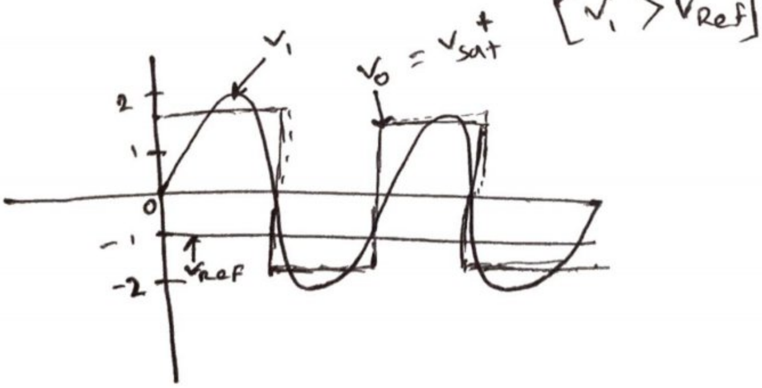
Farhan Sadiq
07/02/24

Signature of the lab faculty

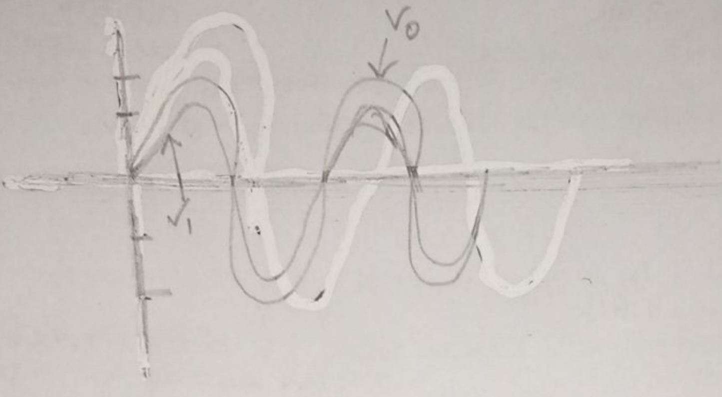
Test Your Understanding

Answer the following questions:

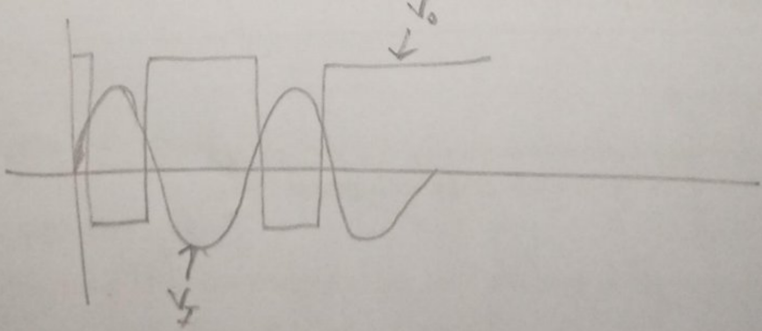
1. You are given an Op-Amp comparator with v_1 = 4 V (p-p) sine wave and $v_2 = V_{REF}$ = -1 V. Draw the waveform of v_1, v_2 and v_O in the same graph with proper labels.
   Answer:



2. You are given an inverting amplifier with $v_I = 4$ V (p-p) sine wave, $R_1 = 1\ k\Omega$, $R_2 = 2.2\ k\Omega$. Draw the waveform of v_I and v_O in the same graph with proper labels.
<u>**Answer:**</u>



3. You are given a non-inverting amplifier with $v_I = 4$ V (p-p) sine wave, $R_1 = 1\ k\Omega$, $R_2 = 2.2\ k\Omega$. Draw the waveform of v_I and v_O in the same graph with proper labels.
<u>Answer:</u>



Discussion

All oven from Exp 2, ~~It~~ it is clean that OP Amp ~~react~~ specifically difenant in ~~are~~ specific cincuit module. Moneoven, an OPAmp's ~~I~~ ideology specifies that, it can only be usable in a specific satunation voltage.

It was the first lab of using trainer Board.