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# EC160: Experiment 10
## Basic Properties of Operational-Amplifier

**Objective-:** (i) to study inverting Op-Amp
(ii) to study non-inverting Op-Amp.
(iii) to study gain.

**Theory-:** Operational Amplifier, commonly known as Op-Amp, is a linear electronic device having three terminals, two high impedance input and one output terminal. Op-Amp can perform multiple function when attached to different feedback combinations like resistive, capacitive or both. Generally it is used as voltage amplifier and the output voltage of Op-Amp is the difference between the voltages at its two input terminals.

Ideal and Practical characteristics of Op-Amp.

An ideal Op-Amp is an amplifier with infinite input impedance, infinite open-loop gain, zero output impedance, infinite bandwidth and offset voltage is zero. It has positive and negative inputs which allow circuits that use feedback to achieve a wide range of functions.

In practical Op-Amp, the input impedance is maximum and finite (in the order of 100 k or more), open-loop gain is of the order of thousands, output impedance is low (of the order of hundred ohms) which can be reduced further with the help of negative feedback. The bandwidth of practical op-amp is very small. Practical Op-Amp has non-zero offset voltage. That is, the zerou output is obtained for the non-zero differential input voltage only.

For ideal Op-Amp, no current flows into the input. The practical Op-Amps do have some input currents (of the order of $10^{-6}$ A to $10^{-14}$ A).

Inverting Op-Amp -: An inverting amplifier is a type of Op-Amp circuit which produces an output which is out of phase with respect to its input by 180°.
The open loop gain ($A_0$) of Op-Amp is very high which makes it unstable. To make it stable, a feedback is applied through some external resistor ($R_f$) from its output to input terminal. resulting in reduced gain. So, the voltage at Inverting terminal is now the sum of actual input and feedback voltages, and to seperate both a input resistor ($R_i$) is introduced in the circuit. The non-inverting terminal of Op Amp is grounded, and the inverting terminal behaves like a virtual ground as the junction of input and feedback signal are at same potential.

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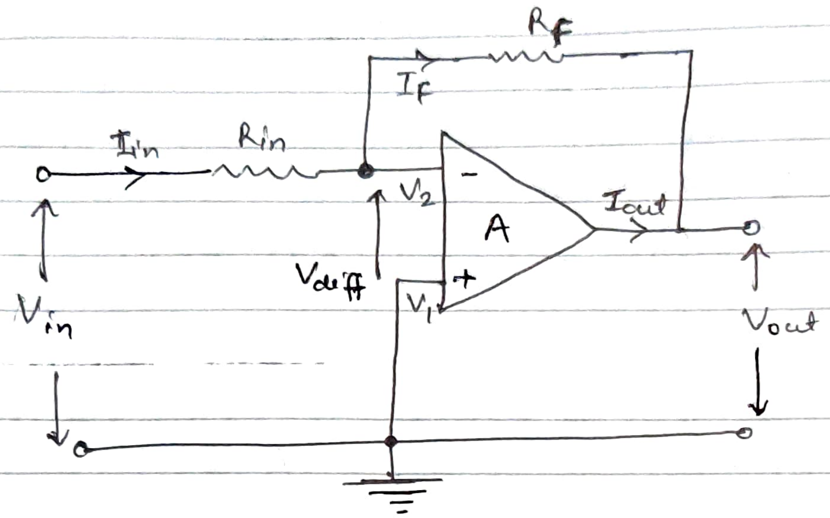
The circuit of an Inverting Op-Amp is given below,




current can be given as,

$$I = \frac{V_{in} - V_{out}}{(R_{in} + R_F)} = \frac{V_{in} - V_2}{R_{in}} = \frac{V_2 - V_{out}}{R_F}$$

$$\therefore \quad \frac{V_{in}}{R_{in}} - \frac{V_2}{R_{in}} = \frac{V_2}{R_F} - \frac{V_{out}}{R_F}$$

$$\frac{V_{in}}{R_{in}} = V_2\left(\frac{1}{R_{in}} + \frac{1}{R_F}\right) - \frac{V_{out}}{R_F}$$

and as $V_2 = 0$

$$I = \frac{V_{in} - 0}{R_{in}} = \frac{0 - V_{out}}{R_F}$$

$$\therefore \quad \frac{R_F}{R_{in}} = -\frac{V_{out}}{V_{in}}$$

$\therefore$ the close loop gain $(A_{CL})$ $= \dfrac{V_{out}}{V_{in}} = -\dfrac{R_F}{R_{in}}$

and, output voltage $V_{out} = -\dfrac{R_F}{R_{in}} \times V_{in}$

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The input resistance with feedback $(R_{if}) = \frac{V_{in}}{I_{in}}$

$$\boxed{\therefore R_{if} = R_{in} + \frac{R_F R_{in}}{R_F + R_{in} + R_{in} A_{CL}}}$$

The output resistance with feedback $(R_{of}) = \frac{V_o}{I_o}$

$$\boxed{R_{of} = \frac{R_o}{1 + A_{CL}\beta} = \frac{R_o}{1 + \frac{A_{CL} R_{in}}{R_{in} + R_F}} = \frac{R_o (R_{in} + R_F)}{R_{in} + R_F + A_{CL} R_{in}}}$$

$\beta$ is gain of feedback circuit and $\beta = \frac{R_{in}}{R_{in} + R_F}$

Non-Inverting Op-Amp :- In this configuration, the input signal is directly fed to non inverting terminal resulting in a positive gain and output voltage in phase with input. To stabilise the circuit a negative feedback is applied through a resistor ($R_f$) and the inverting terminal is grounded with a input resistor $R_2$. This Inverting Op-Amp like layout at the inverting terminal creates a virtual ground at the summing point and make the $R_f$ and $R_2$ a potential divider across inverting terminal, hence determines the gain of the circuit.

The circuit for a Non-Inverting Op-Amp is given below,

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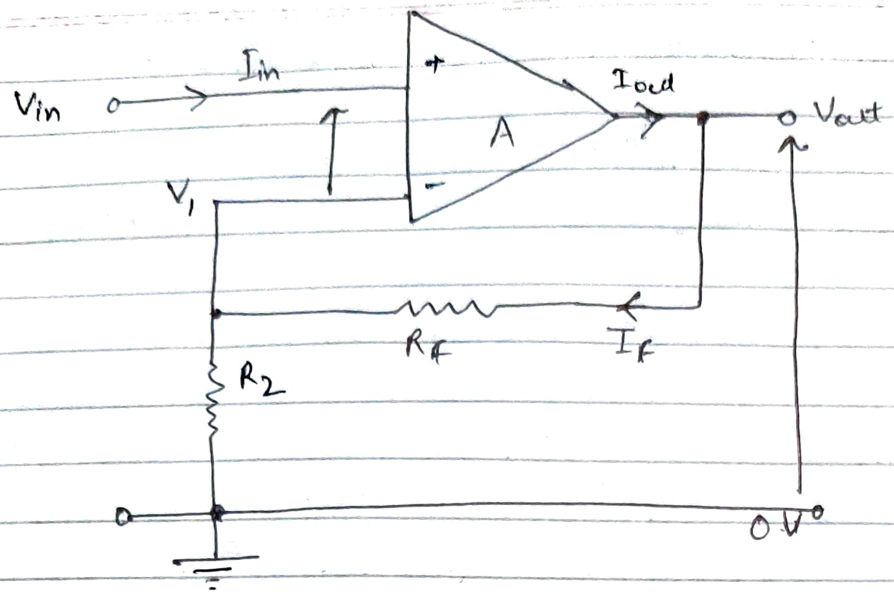


Potential difference $V_1$ can be written as

$$V_1 = \frac{R_2 V_{out}}{R_2 + R_F}$$

in ideal condition $V_1 = V_{in}$, so,

$$V_{in} = \frac{R_2 V_{out}}{R_2 + R_F}$$

Since, close loop gain $(A_{cl}) = \frac{V_{out}}{V_{in}}$

$$\therefore A_{cl} = \frac{R_2 + R_F}{R_2} = 1 + \frac{R_F}{R_2}$$

and, output voltage $(V_{out}) = A_{cl} \times V_{in}$

$$= \left(1 + \frac{R_F}{R_2}\right) \times V_{in}$$

Input resistance with feedback $(R_{if})$,

$$\boxed{R_{if} = 1 + \frac{A_V R_2}{R_2 + R_F} = R_2 (1 + A_V \beta)}$$

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Output resistance with feedback ($R_{of}$),

$$\boxed{R_{of} = \frac{R_o}{1 + A_v \beta}}$$

Procedure for the Experiment

1. Connect the circuit and check if it is a right connection.
2. Set the resistance value ($R_1$) {1 KΩ - 50 KΩ}
3. Set the feedback resistance ($R_f$) value {2 KΩ - 100 KΩ}
4. Set input voltage Vin (-15 to 50 V)
5. Note the output voltage and click on '~~Add~~ Add to Table'.
6. Increase the input voltage by a factor of 2.
7. Click on 'Plot' button to plot the output voltage versus input voltage.

# Simulation Results

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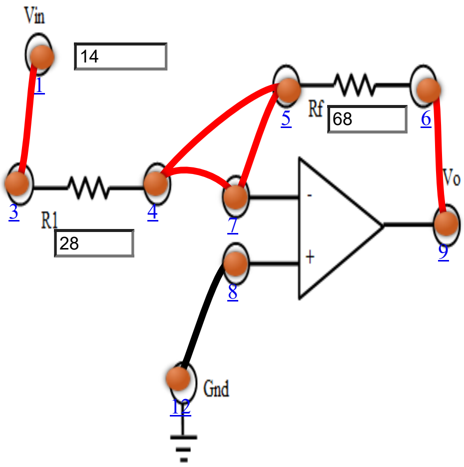
# Inverting Opamp

INSTRUCTION

EXPERIMENTAL TABLE

Resistance: 28 KΩ

| Serial No. | Input Voltage V | Output Voltage V | Current mA |
|---|---|---|---|
| 1 | -15 | 36.4 | -0.0179 |
| 2 | -12 | 29.1 | -0.0143 |
| 3 | -6 | 14.6 | -0.00717 |
| 4 | -2 | 4.86 | -0.00239 |
| 5 | 2 | -4.86 | 0.00239 |



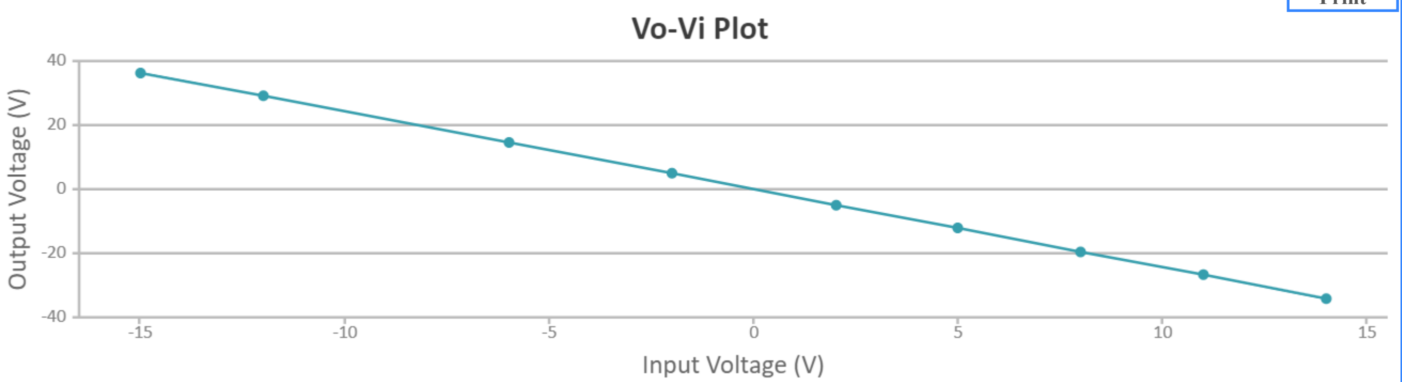

CONTROLS

Input volt : Volt
Resistance ($R_1$) : Kohms
Resistance ($R_f$): Kohms

Add to Table | Plot | Clear
-34.0
0.0167
-2.428571
Check connection | Delete all connection

GRAPH PLOT

Print



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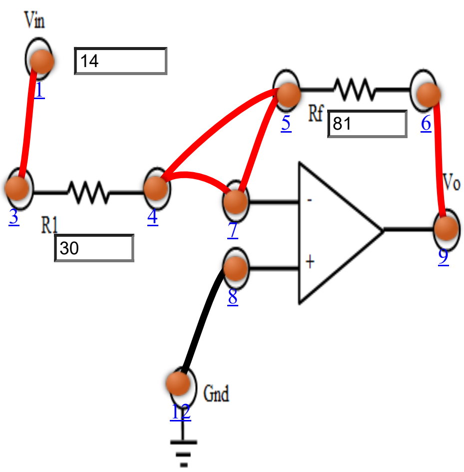
# Inverting Opamp

INSTRUCTION

EXPERIMENTAL TABLE

Resistance: 30 KΩ

| Serial No. | Input Voltage V | Output Voltage V | Current mA |
|---|---|---|---|
| 1 | -15 | 40.5 | -0.0180 |
| 2 | -11 | 29.7 | -0.0132 |
| 3 | -9 | 24.3 | -0.0108 |
| 4 | -7 | 18.9 | -0.00841 |
| 5 | -4 | 10.8 | -0.00480 |




CONTROLS

Input volt : Volt
Resistance ($R_1$) : Kohms
Resistance ($R_f$): Kohms

Add to Table | Plot | Clear

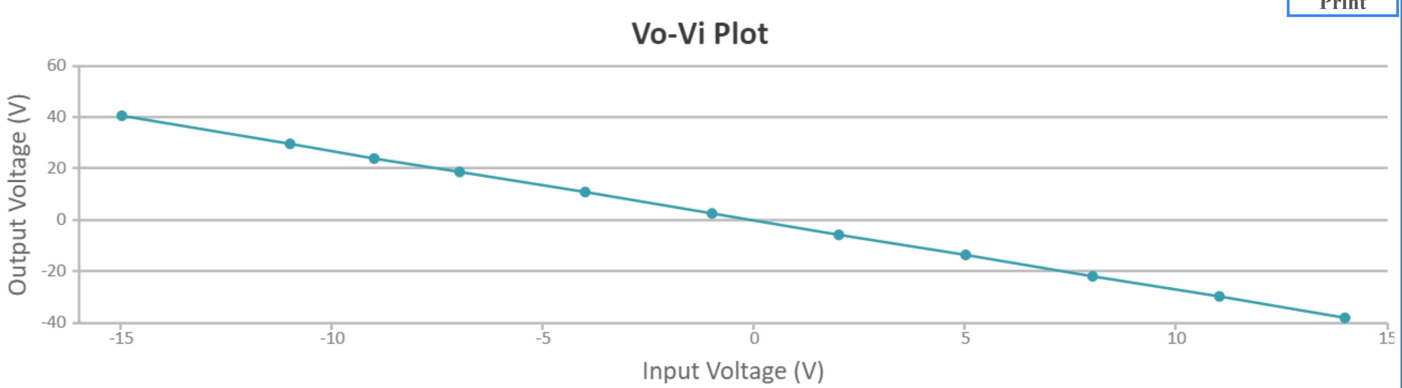
-37.8
Check connection | Delete all connection

0.0168

-2.7

GRAPH PLOT

Print



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# Inverting Opamp

INSTRUCTION

CONTROLS

Input volt : Volt
Resistance ($R_1$) : Kohms
Resistance ($R_f$): Kohms

Add to Table | Plot | Clear

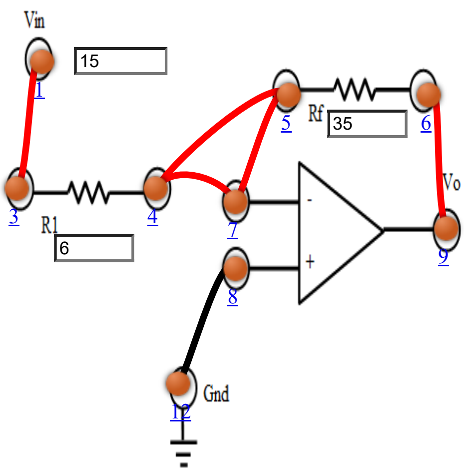
-87.5
0.161
-5.833333

Check connection | Delete all connection

EXPERIMENTAL TABLE

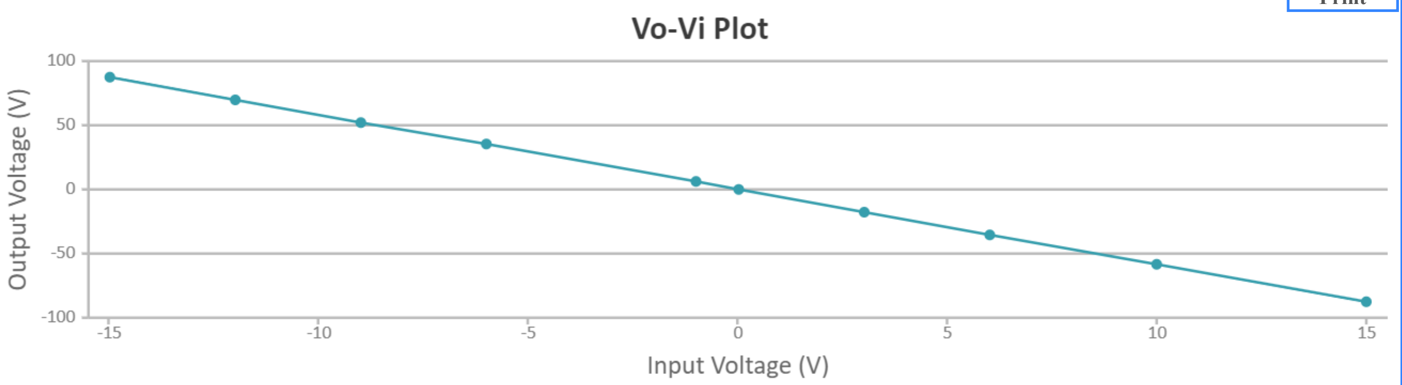
Resistance: 6 KΩ

| Serial No. | Input Voltage V | Output Voltage V | Current mA |
|---|---|---|---|
| 1 | -15 | 87.5 | -0.161 |
| 2 | -12 | 70.0 | -0.129 |
| 3 | -9 | 52.5 | -0.0969 |
| 4 | -6 | 35.0 | -0.0646 |
| 5 | -1 | 5.83 | -0.0108 |




GRAPH PLOT

Print



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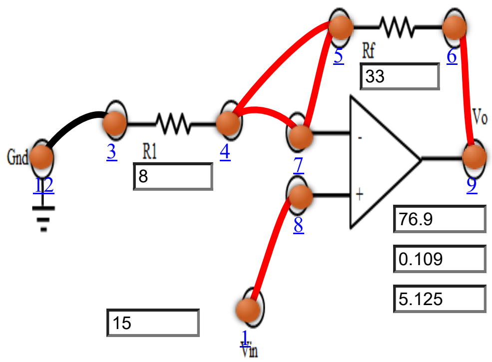
# Non Inverting Opamp

INSTRUCTION

EXPERIMENTAL TABLE

Resistance: 8 KΩ

| Serial No. | Input Voltage V | Output Voltage V | Current mA |
|---|---|---|---|
| 1 | -15 | -76.9 | -0.109 |
| 2 | -13 | -66.6 | -0.0948 |
| 3 | -10 | -51.3 | -0.0732 |
| 4 | -8 | -41.0 | -0.0588 |
| 5 | -5 | -25.6 | -0.0360 |
| 6 | [illegible] | [illegible] | [illegible] |




CONTROLS

Input volt : Volt

Resistance ($R_1$) : Kohms

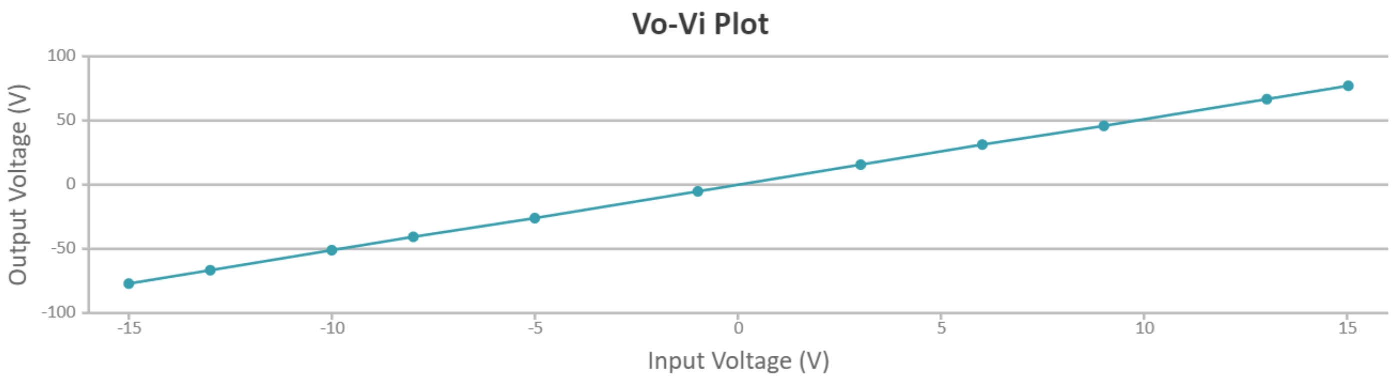
Resistance ($R_f$): Kohms

Add to Table | Plot | Clear | Check connection | Delete all connection

Print It

Take another sets of readings for different R1 and Rf

GRAPH PLOT



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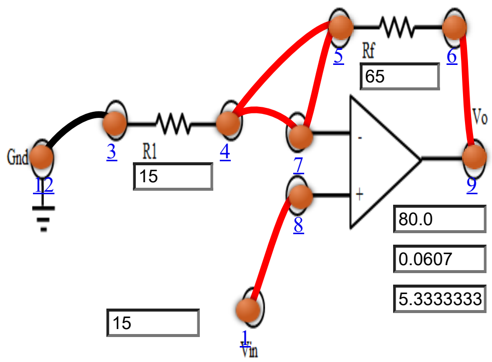
# Non Inverting Opamp

INSTRUCTION

EXPERIMENTAL TABLE

Resistance: 15 KΩ

| Serial No. | Input Voltage V | Output Voltage V | Current mA |
|---|---|---|---|
| 1 | -15 | -80.0 | -0.0607 |
| 2 | -13 | -69.3 | -0.0524 |
| 3 | -10 | -53.3 | -0.0403 |
| 4 | -8 | -42.7 | -0.0319 |
| 5 | -4 | -21.3 | -0.0160 |




CONTROLS

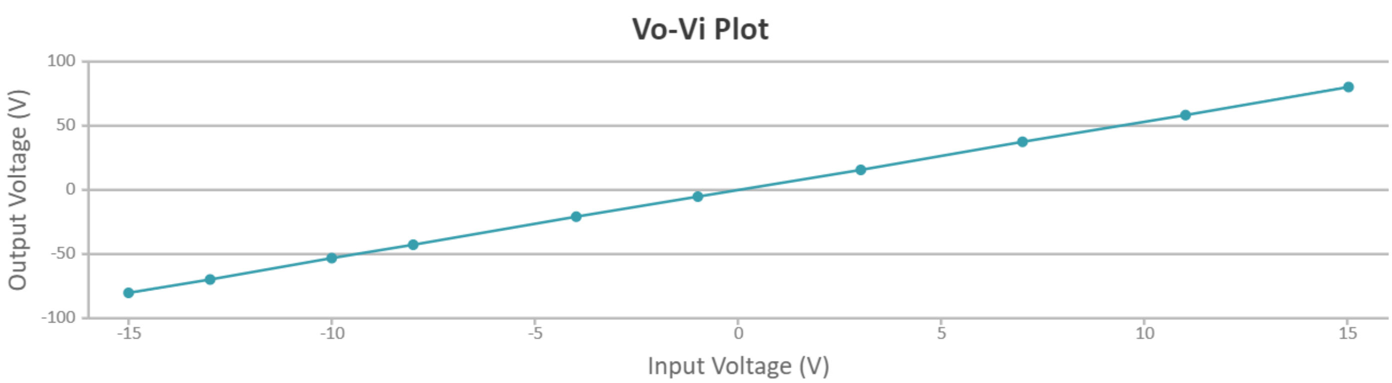
Input volt : Volt
Resistance ($R_1$) : Kohms
Resistance ($R_f$): Kohms

Add to Table | Plot | Clear
Check connection | Delete all connection

Print It

Take another sets of readings for different R1 and Rf

GRAPH PLOT



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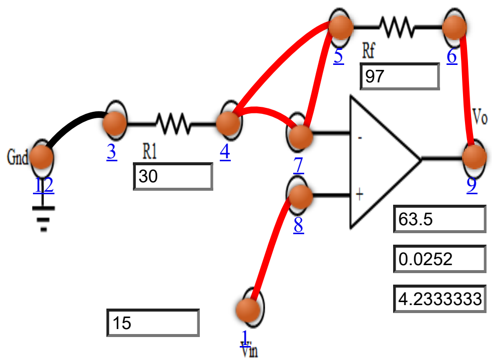
# Non Inverting Opamp

INSTRUCTION

EXPERIMENTAL TABLE

Resistance: 30 KΩ

| Serial No. | Input Voltage V | Output Voltage V | Current mA |
|---|---|---|---|
| 1 | -15 | -63.5 | -0.0252 |
| 2 | -12 | -50.8 | -0.0200 |
| 3 | -8 | -33.9 | -0.0132 |
| 4 | -5 | -21.2 | -0.00840 |
| 5 | -2 | -8.47 | -0.00323 |




CONTROLS

Input volt : Volt
Resistance ($R_1$) : Kohms
Resistance ($R_f$): Kohms

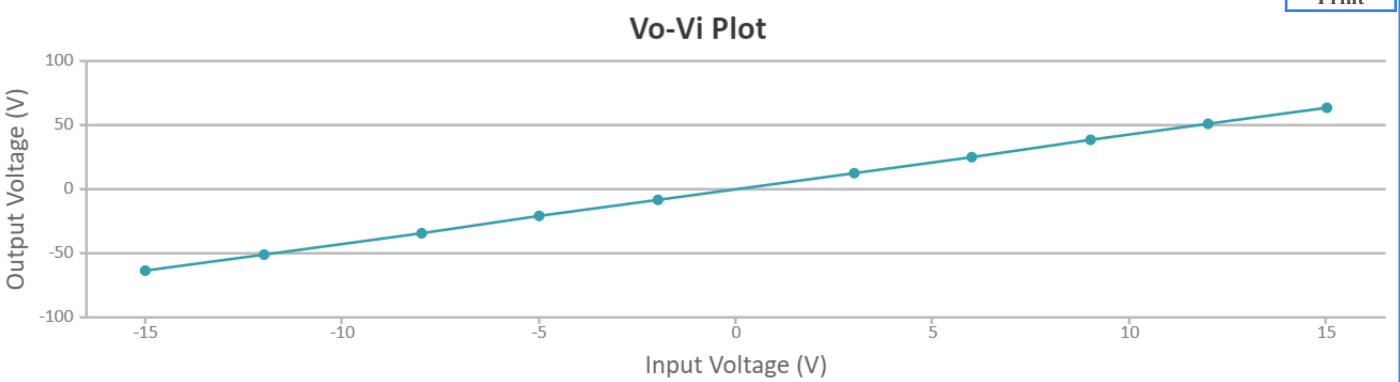
Add to Table | Plot | Clear
Check connection | Delete all connection

Print It

Take another sets of readings for different R1 and Rf

GRAPH PLOT

Print



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**Conclusion**:- Performing the experiment we have studied the following,

i) the characteristics of Ideal and Practical Op-Amp.

ii) the working of Inverting and Non-Inverting Op-Amp.

(iii) the output voltage, feedback factor, input resistance and output resistance with feedback, close loop gain, voltage gain etc. for Inverting and Non-Inverting Op-Amps.