Experiment - 4

Operational Amplifier Circuits

NAME - ANINDYA VIJAYVARGEEYA

ROLL NO - 200010015

INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
Department of Electronics & Electrical Engineering
EE102: Basic Electronics Laboratory

Expt.No. 4: Operational Amplifier Circuits

Objectives:

1. To study the comparator circuit realized using an Op-Amp.
2. To study inverting and non-inverting amplifier circuits realized using an Op-Amp.
3. To study a practical integrator circuit realized using an Op-Amp.

Materials Required:

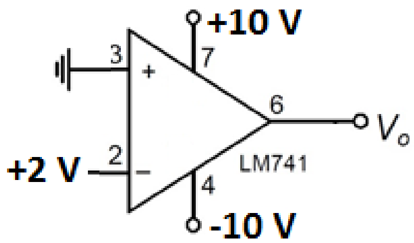
1. Equipment: Breadboard, Function Generator, Oscilloscope, DC Power Supply
2. Components: LM741 Op Amp (One), 10kΩ (Two), 39kΩ (One), 68kΩ (One), 100kΩ (One), 2.2nF (One)

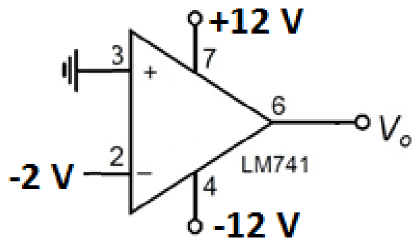
Precautions and Guidelines:

1. The Op-Amp generally works on split power supply (e.g. ±12 V). Both positive and negative power supplies must be present whenever op-amp is powered.
2. The range of power supply is from ±5 V to ±15 V. Do not forget to connect the common terminal of the power supply to the ground on the breadboard.
3. The Op-Amp will not function properly if only one side of power supply is connected or positive and negative power supplies are interchanged.

Pre-Lab Work:

1. For the op-amp circuits given below, predict the ideal outputs in each case.

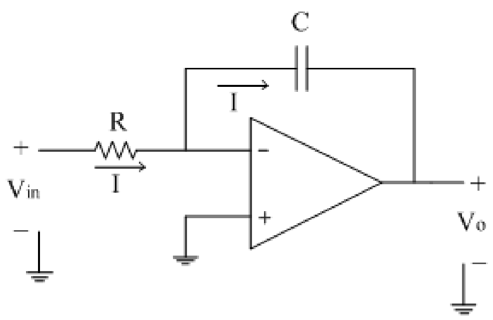




2. Derive the input-output relationship (Vo/Vi) for the circuit in Part B.

3. Derive the input-output relationship (Vo/Vi) for the circuit in Part C.

4. For the ideal integrator circuit shown below, derive the input-output relationship (V_o/V_{in}).



Part A: Comparator

1. Assemble the circuit as shown in Fig.1. Set the DC power supply voltage to ±12 V. Make sure that the DC power supply ground is connected to the circuit ground.
2. Apply a 500 mV_{p-p}, 500 Hz sine wave as input (V_i) from the function generator. Connect Ch1 of the oscilloscope to V_i and Ch2 to output (V_o).
3. Observe V_o and V_i and note down the peak-to-peak value of V_o.
4. Now, change the DC power supply voltage values to ±10 V and ±14 V. Note down the peak-to-peak values of V_o for each case.

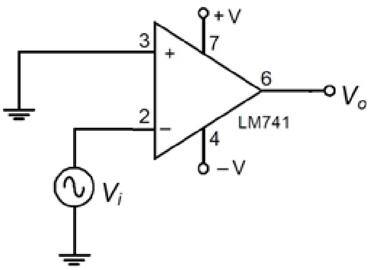


Fig. 1

DC Supply (in Volt)	Peak-to-peak of V_o (in Volt)
±12	
±10	
±14	

Part B: Inverting Amplifier

1. Assemble the circuit shown in Fig.2 with R_1 = 100 kΩ and R_2 = 10 kΩ. Set the DC power supply voltage to ±12 V. Make sure the power supply ground is connected to the circuit ground.
2. Apply a 200 mV_{p-p}, 1 kHz sine wave at V_i from the function generator and see the output V_o.
3. Observe V_o and V_i, and determine the voltage gain of Op-Amp, $A = V_o/V_i$.
4. Change R_1 to 10 kΩ, 39 kΩ and 68 kΩ and find the voltage gain for each case.

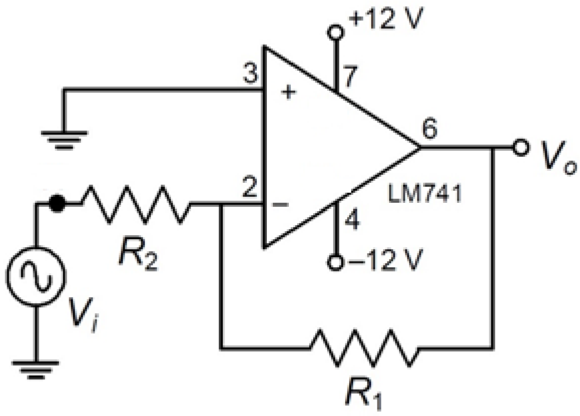


Fig. 2

Part C: Non-Inverting Amplifier

1. Assemble the circuit shown in Fig.3 with R_1 = 100 kΩ and R_2 = 10 kΩ. Set the DC power supply voltage to ±12 V. Make sure the power supply ground is connected to the circuit ground.
2. Apply a 200 mV_{p-p}, 1 kHz sine wave at V_i from the function generator and see the output V_o.
3. Observe V_o and V_i, and determine the voltage gain of Op-Amp, $A = V_o/V_i$.
4. Change R_1 to 10 kΩ, 39 kΩ and 68 kΩ and find the voltage gain for each case.

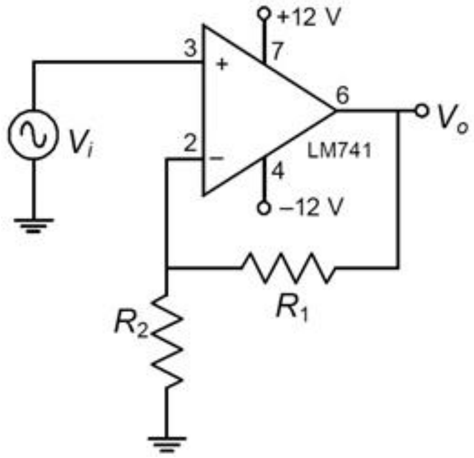


Fig.3

Part D: Practical Integrator

An ideal integrator suffers from two main limitations:

(i). The output of the integrator is inversely proportional to the time constant τ = RC. The larger the time constant τ, the longer it takes to saturate the integrator.

(ii). The second limitation is the presence of offset voltage even for zero input. It may be only a few millivolts, but it gets integrated over time and eventually drives the Op-Amp output to saturation. To prevent this from occurring, a large resistor is added in parallel with the capacitor.

1. Assemble the circuit shown in Fig.4. Set the DC power supply voltage to ±12 V. Make sure the power supply ground is connected to the circuit ground.
2. Apply a 1 V_{p-p}, 10 kHz square wave at V_i from the function generator.
3. Connect Ch1 of oscilloscope to the input (V_i) and Ch2 to the output (V_o) of the circuit.
4. Set the time base of the oscilloscope to 20 µs/div and voltage scales of each channel to 500 mV/div.
5. Observe the waveforms and sketch V_i and V_o, one below the other with identical time and amplitude axes.

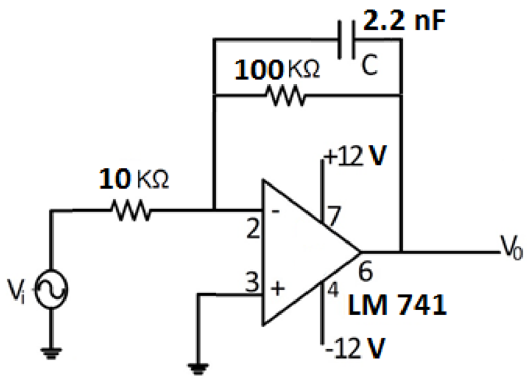


Fig.4

Part D: Lab Report

Prepare and submit a lab report as specified in the general instructions regarding the lab. Include the answers to the following questions in the report:

1. For a source with high internal impedance which configuration (inverting or non-inverting) will be suitable for designing a good amplifier?

Prelab 4

200101015
Anindya Vijayvargeeya

Ans1

Since in the first circuit $V_+ < V_-$

$V_o = -V_{cc} = -10V$

in the second circuit $V_+ > V_-$

$V_o = +V_{cc} = 12V$

Ans2

$V_2 \simeq V_3 = 0$

applying KCL at node 2,

$$\frac{V_i - V_2}{R_2} = \frac{V_2 - V_o}{R_1} \quad (\& \; V_2 = 0)$$

$$\boxed{\frac{V_o}{V_i} = -\frac{R_1}{R_2}}$$

Ans 3

$$V_2 \simeq V_3 = V_i$$

applying KCL at node 2

$$\frac{V_i - 0}{R_2} = \frac{V_o - V_i}{R_1}$$

$$\boxed{\frac{V_o}{V_i} = \left(1 + \frac{R_1}{R_2}\right)}$$

Ans 4

$$V_- \simeq V_+ = 0$$

applying ~~KCL~~ KVL,

$$V_{in} - IR - \frac{1}{C}\int I\,dt = V_o$$

Since $V_- = 0$, $I = \frac{V_{in}}{R}$

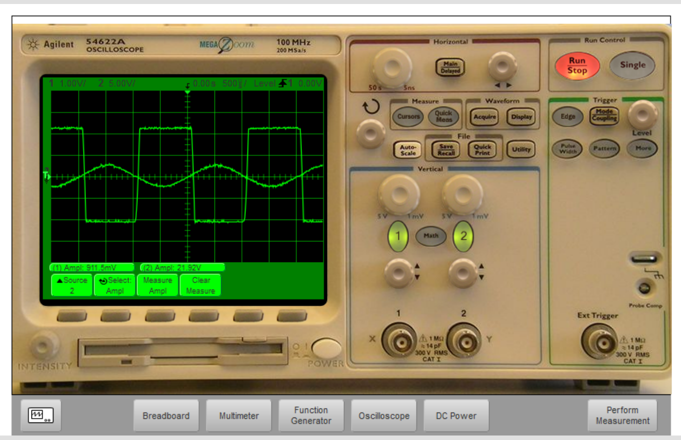
$$\boxed{V_o = -\frac{1}{RC}\int V_{in}\,dt}$$

Observations

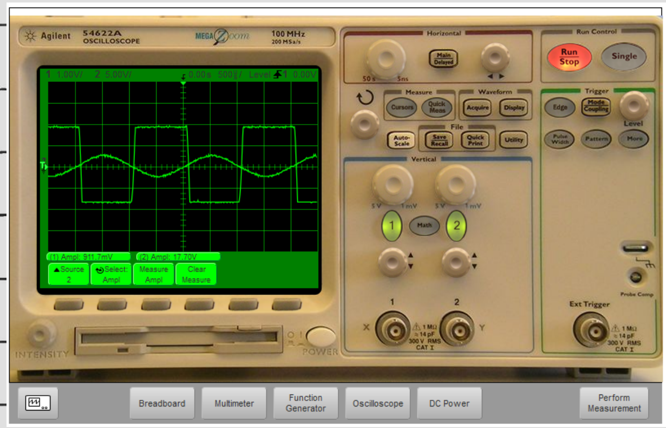
Part A :

DC Supply (in Volt)	P-P V_o (in Volt)
±12	21.92
±10	17.70
±14	26.00

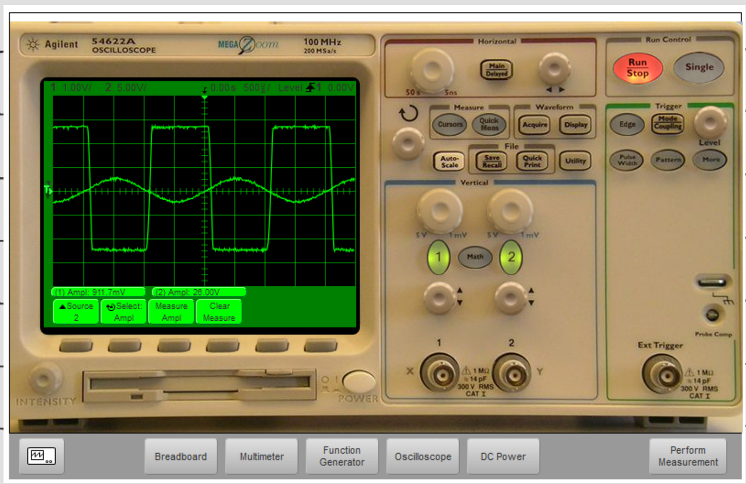
12V



10V



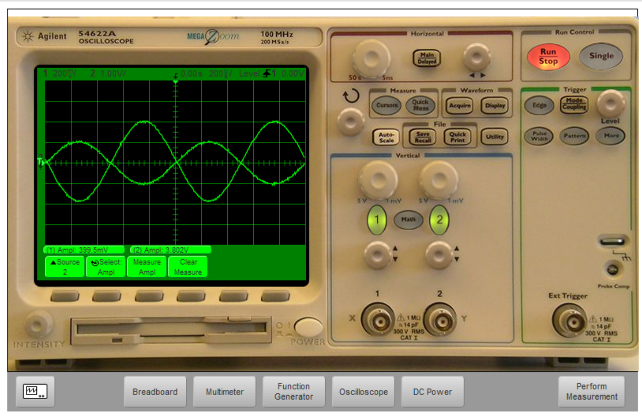
14V



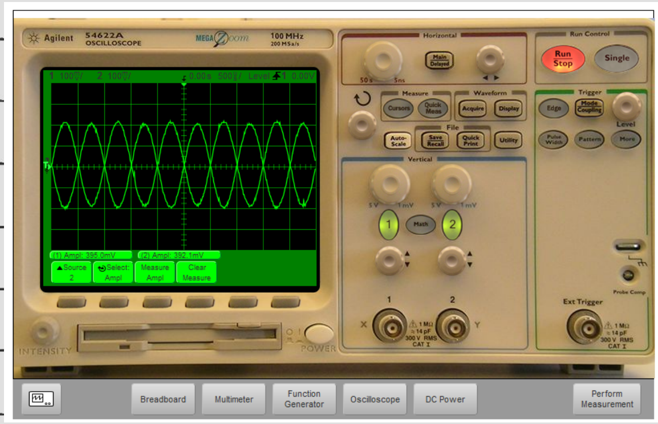
Part B:

Value of R_1 (in Ω)	V_i (in Volt)	V_o (in Volt)	Voltage gain (V_o/V_i)
100k	399.5m	3.802	−9.516
10k	395.0m	392.1m	−0.993
39k	369.8m	1.5668	−4.234
68k	388.0m	2.790	−7.195

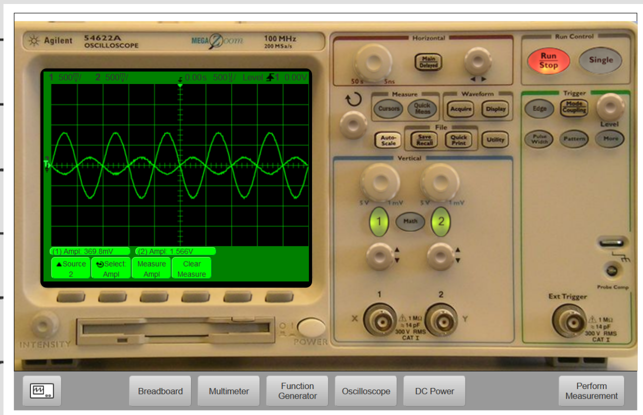
100k



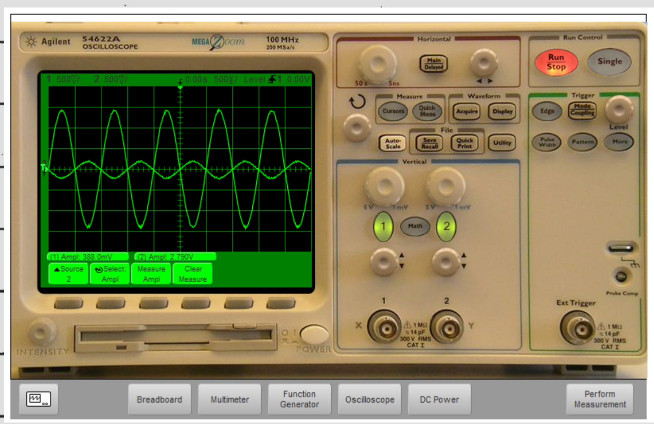
10k



39k



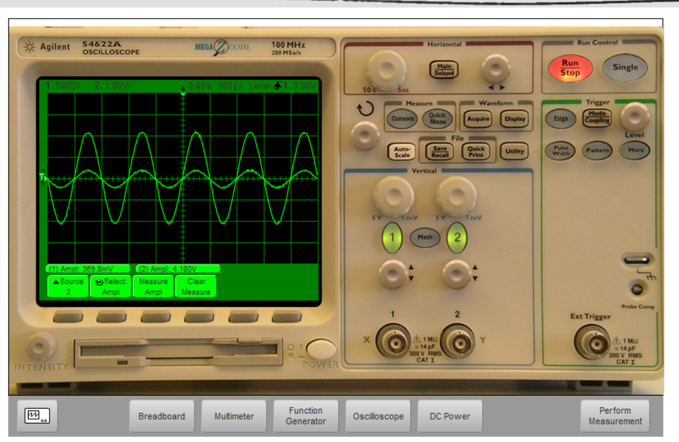
68k



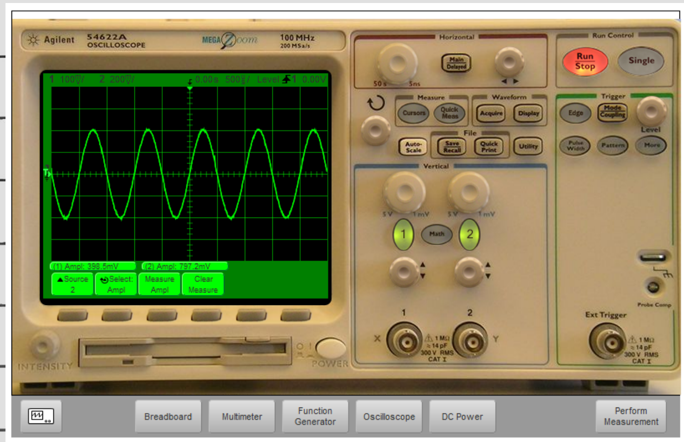
Part C:

Value of R_1 (in Ω)	V_i (in Volt)	V_o (in Volt)	Voltage gain (V_o/V_i)
100k	369.8m	4.180	11.303
10k	398.5m	797.2m	2.001
39k	392.6m	1.999	5.092
68k	399.4m	3.187	7.979

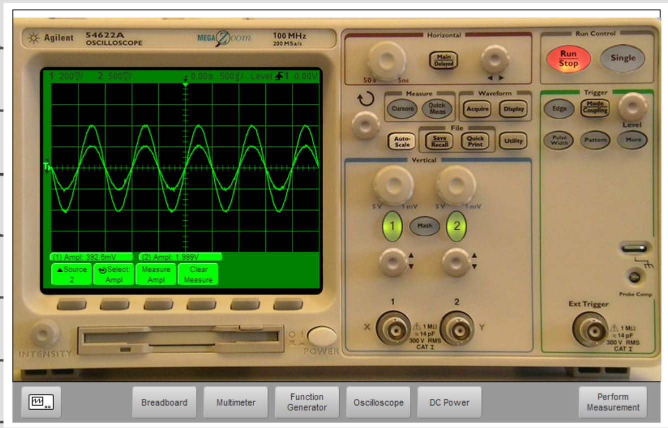
100k



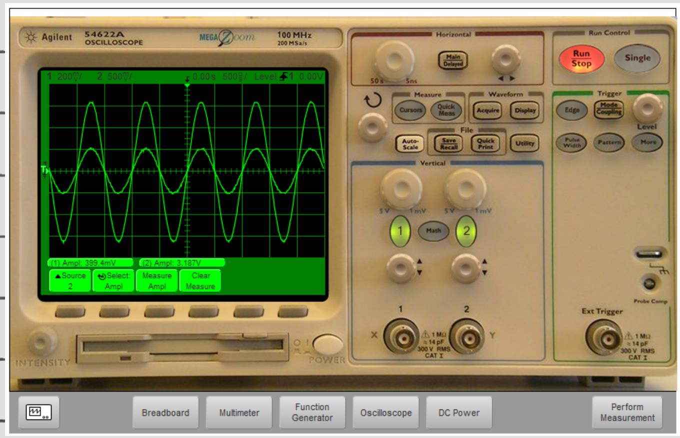
10k



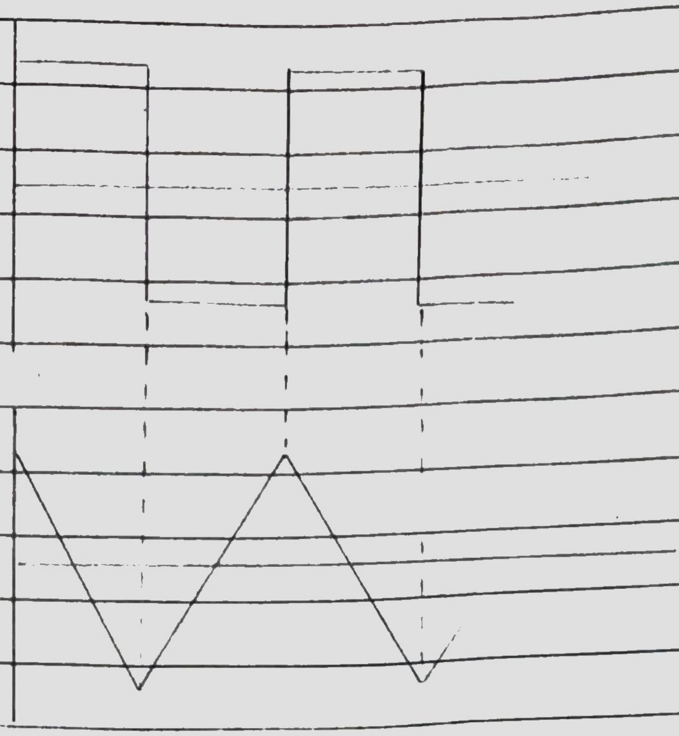
39k

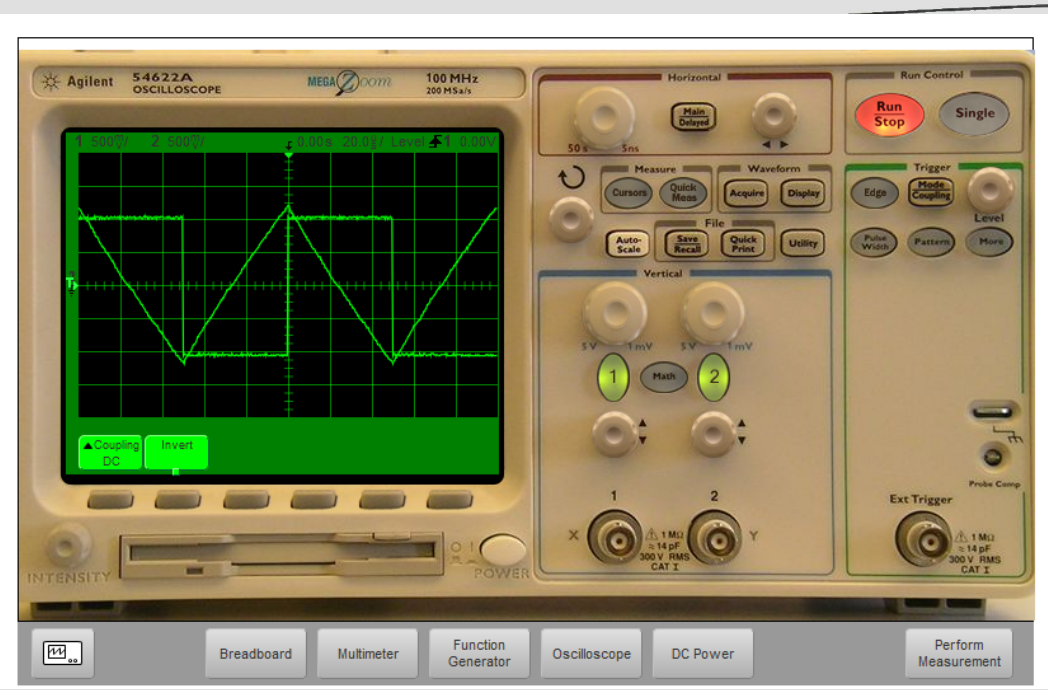


68k



Part D:

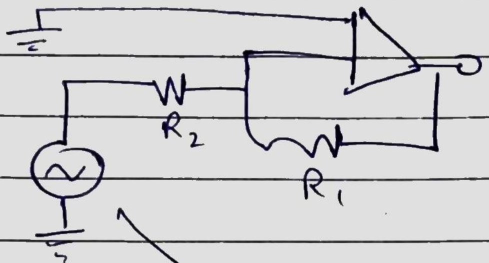


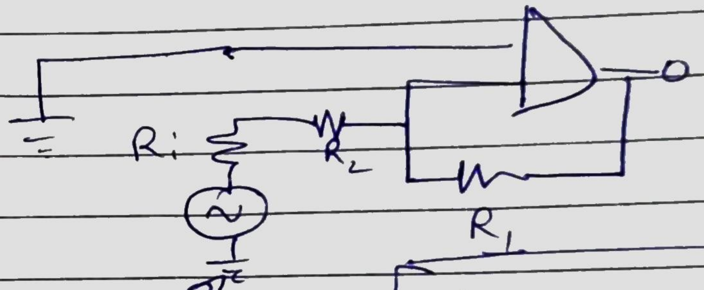

Agilent
54622A
OSCILLOSCOPE
100 MHz
Horizontal
Run Control
Run
Stop
Single
Measure
Cursors
Quick Meas
Waveform
Acquire
Display
File
Auto-Scale
Save Recall
Quick Print
Utility
Trigger
Edge
Mode Coupling
Level
Pulse Width
Pattern
More
Vertical
Math
Coupling
DC
Invert
Ext Trigger
Probe Comp
INTENSITY
POWER
Breadboard
Multimeter
Function Generator
Oscilloscope
DC Power
Perform Measurement

Answers

To obtain a good amplifier circuit it would be better to use non-inverting configuration, as:

→ having high internal impedance in inverting configuration would mean adding to the ~~increasing~~ value of R_2 and thus decreasing the ~~out~~ voltage gain $\left(V_o/V_i = \frac{-R_1}{R_2} \right)$.



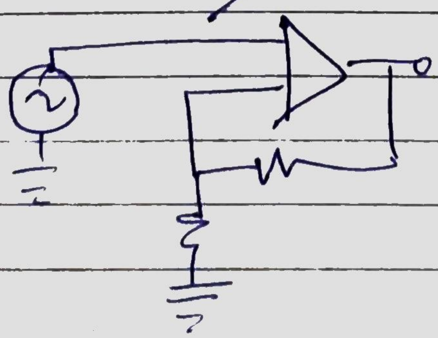


Source with internal impedance can be replaced with ideal source with ext. impedance

Thus, here

$$\frac{V_O}{V_i} = \frac{-R_1}{R_2 + R_i}$$

→ having high internal impedance in non-inverting configuration would not change the voltage gain at all



no current flows through this wire so potential drop across the source ~~is~~ remains unchanged.