EE 2010 Circuit Analysis
Lab 10: Variable-Gain Amplifier via an Op-Amp

Lab Section: **Printed Name (Last, First):**

Learning Objectives:

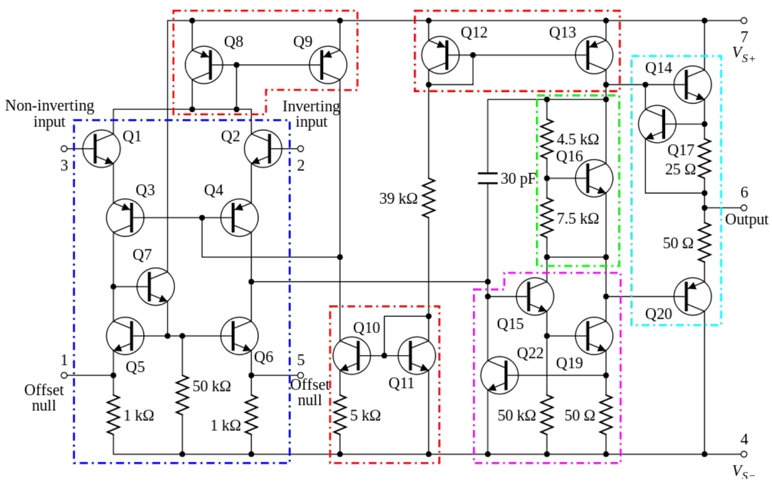
- Understand the basic functionality of an Operational Amplifier (Op-Amp).
- Understand the production of variable gain using a potentiometer/variable resistor.
- Simulate and verify the operation of an Op-Amp, variable-gain amplifier via Multisim.

A. Before coming to lab:

1. Background:

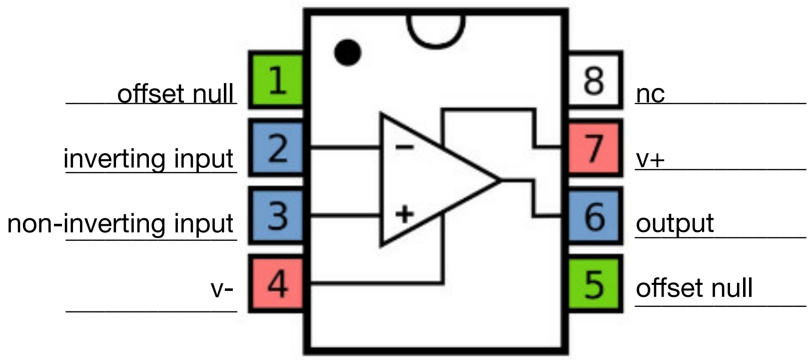
1.1 Find and download a datasheet for the LM741.

1.2 Note the internal structure of the Op-Amp consisting of many passive and active components.



1.3 Use the datasheet to answer the following questions.

1.4 Fill in the pinout diagram with the function of each pin.



1.5 What is the recommended nominal (NOM) Supply Voltage for any of the LM741 series Op-Amps? ±15 V

1.6 What is the typical input resistance? 2 MΩ

2. Understand the Functionality of an Op-Amp

2.1 Read this overview of Op-Amps.

2.2 Take notice of the section on the Internal circuitry of 741-type op-amp.

2.3 We will consider a 741 Op amp in an "inverting amplifier mode."

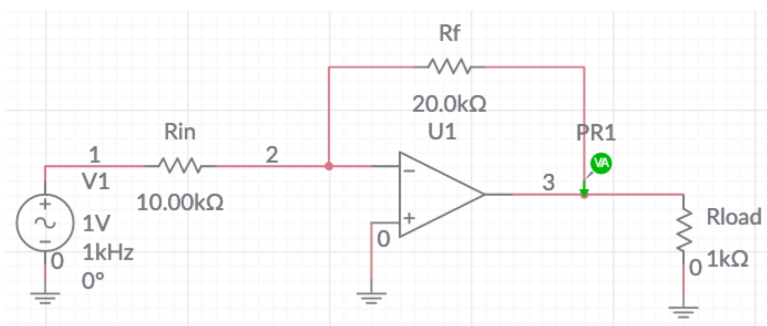


Figure 1: Inverting Op-Amp Configuration

2.4 The Transfer Function (gain) is very simply given by the negative of the ratio of the values of the feedback resistor to the input resistor, i.e.,

$$\frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}} = -\frac{20,000}{10,000} = -2$$

for this particular realization.

2.5 More resources on this configuration may be found here.

3. Simulation in Multisim

We will simulate an Inverting Amplifier configuration with an adjustable-gain. This circuit is often used as a volume control. The gain is controlled using a **potentiometer** as the feedback resistor R_f.

3.1 Read a discussion of Potentiometers here.

3.2 Find the 100K Ω Potentiometer under the Resistor menu.

3.3 Set the Potentiometer percentage to %20 (to achieve a 20kΩ feedback resistance).

3.4 From the left hand menu, select a 3 terminal Op-Amp. Be sure its orientation matches the figure below.

3.5 Set the input sinusoidal voltage input to 1V at 1kHz.

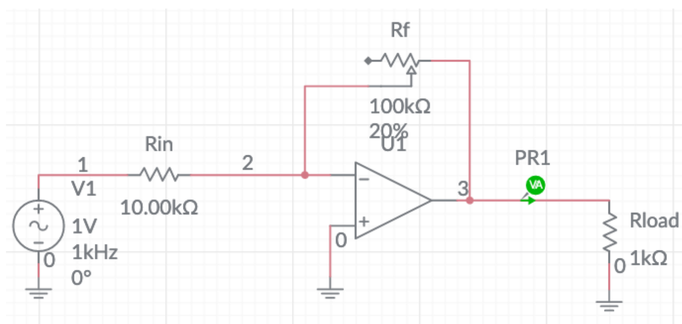


Figure 2: Inverting Amplifier with Feedback Potentiometer

3.6 Take a screen shot of the circuit and upload it to the dropbox on Pilot.

3.7 Observe the “Grapher” results for the input-output waveforms.

3.8 Notice we have realized a gain of 2 as designed.

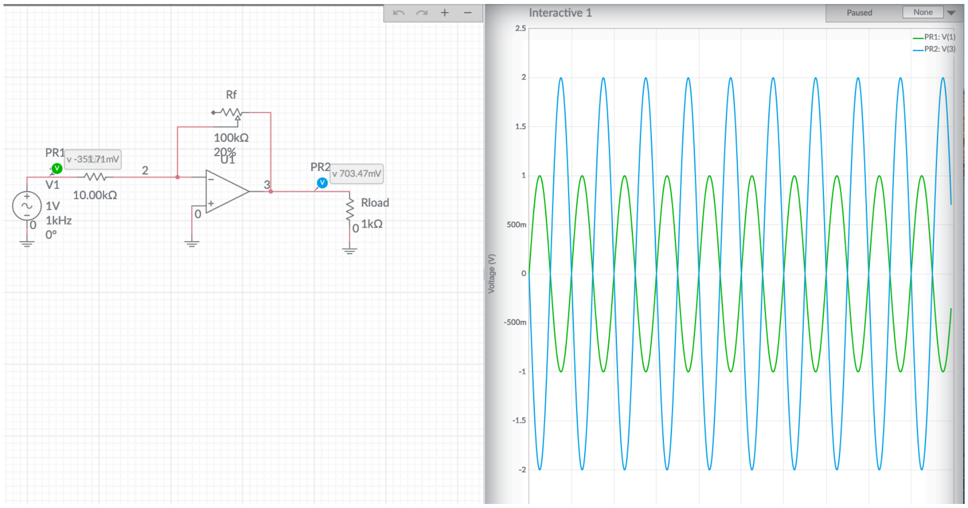
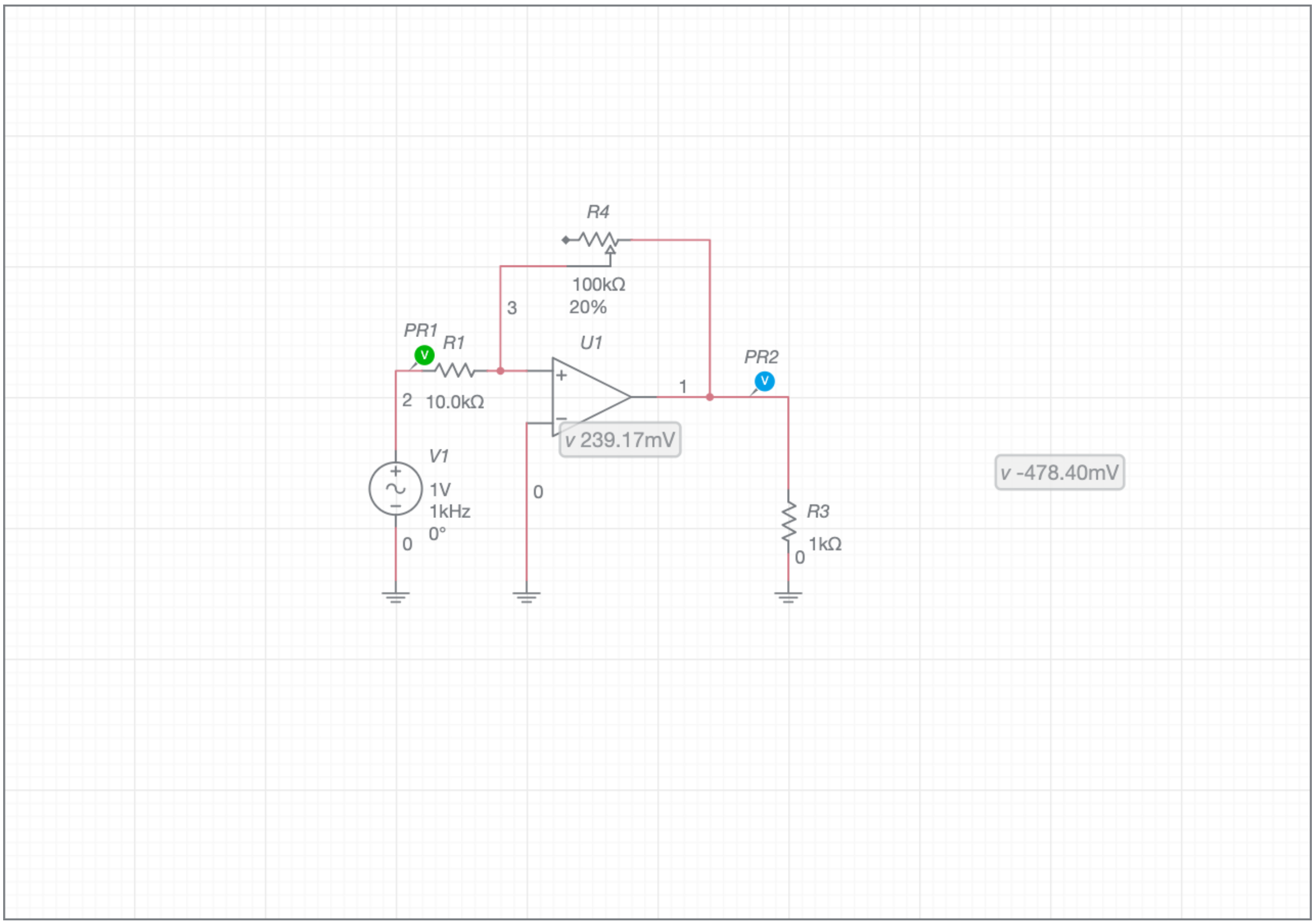


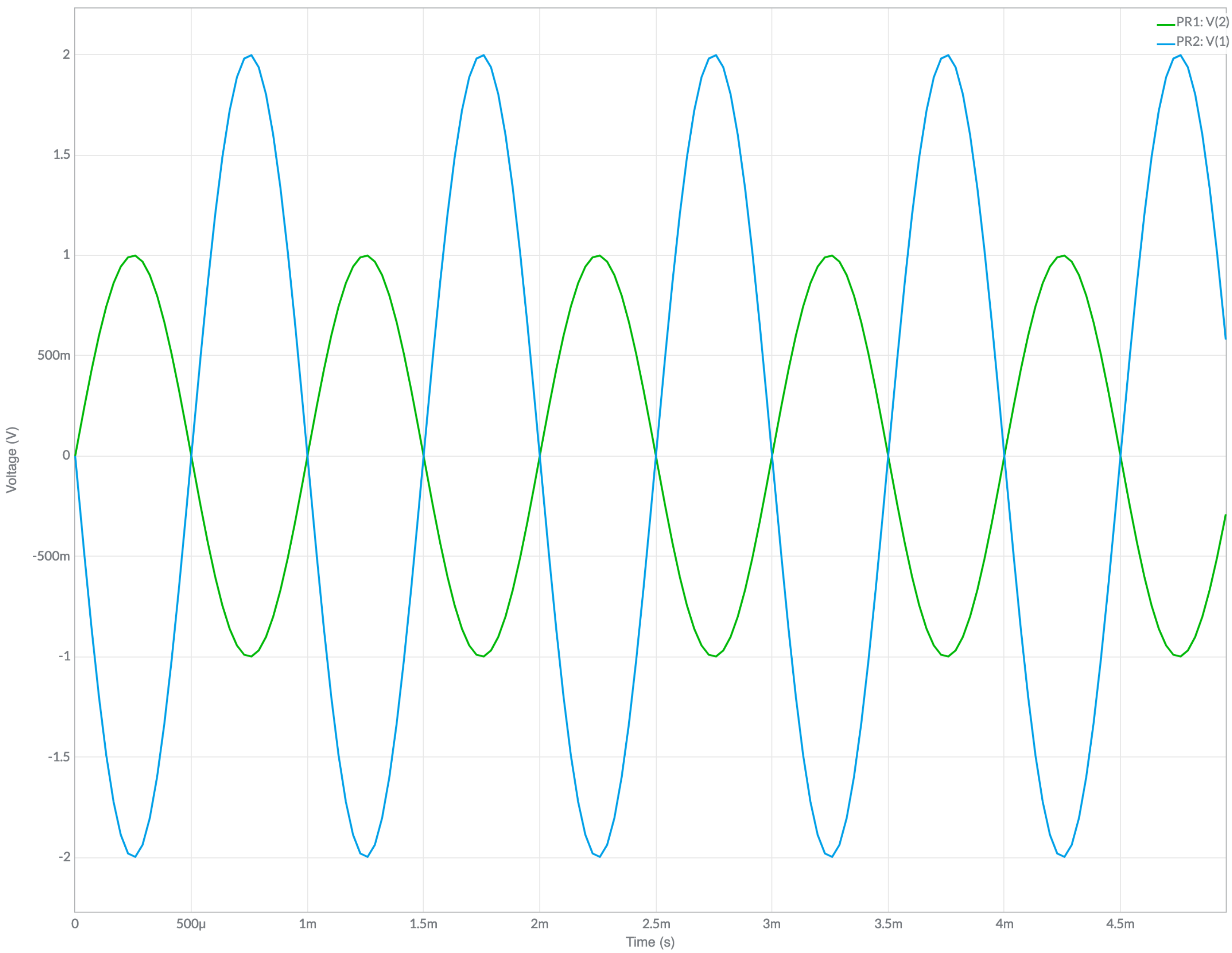
Figure 3: Variable-Gain Inverting Amplifier and Input-Output Waveforms

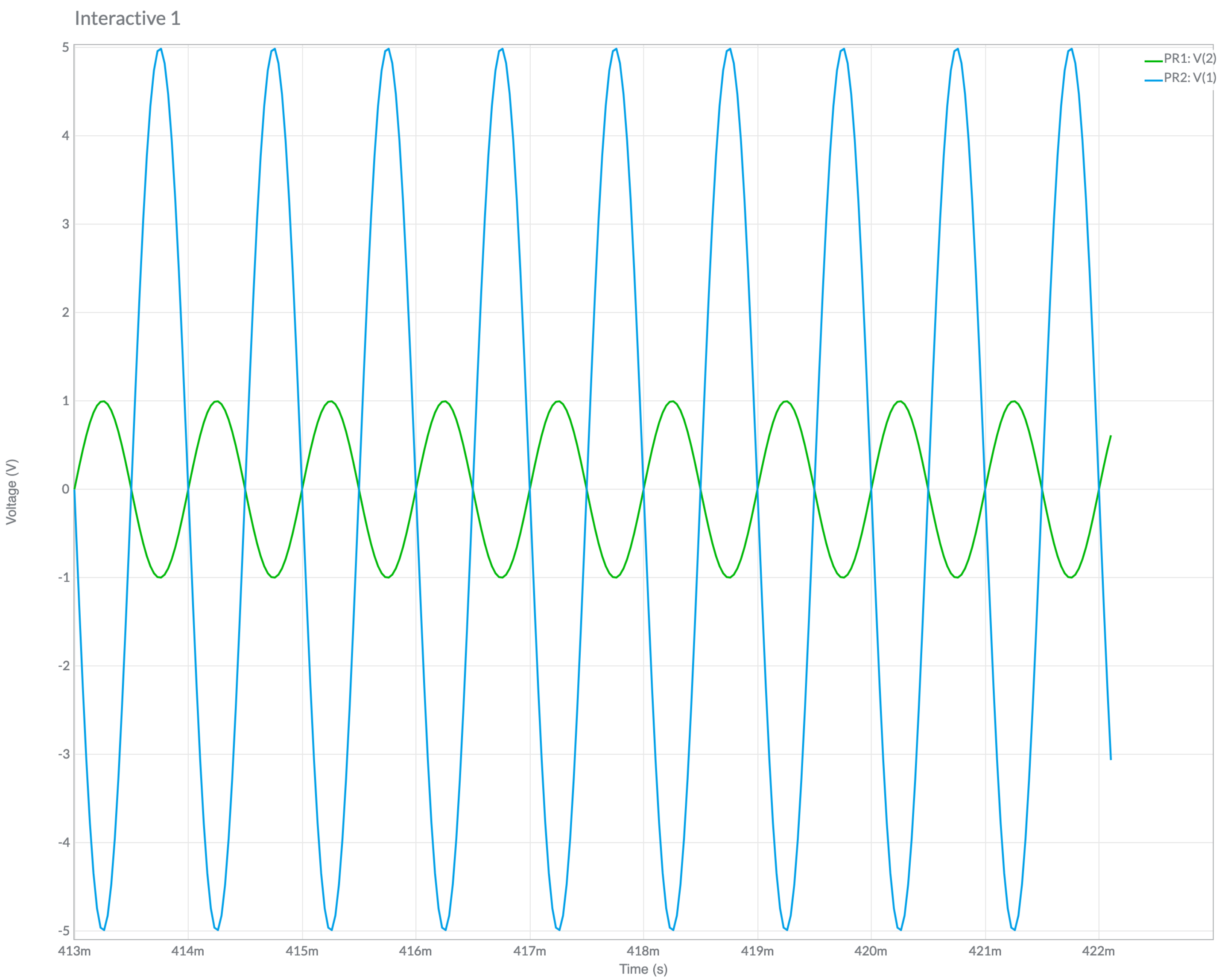
3.9 Simulate again with the feedback resistor set to $50\text{k}\,\Omega$.

3.10 Does the observed gain match the ratio of resistor values? yes


R4
100kΩ
20%
3
PR1
R1
U1
PR2
2
10.0kΩ
1
v 239.17mV
V1
1V
1kHz
0°
0
0
R3
1kΩ
0
v -478.40mV

Interactive 1





Interactive 1
PR1: V(2)
PR2: V(1)
Voltage (V)
5
4
3
2
1
0
-1
-2
-3
-4
-5
413m
414m
415m
416m
417m
418m
419m
420m
421m
422m
Time (s)

B. In-Lab Procedures:

1. The Op-Amp

Figure 4: LM741 Op-Amp

1.1 Refer to the datasheet throughout this project.

1.2 Figure 4 shows the form factor of the 741.

1.3 The **notch** on top or the **dimple** on one corner references the top of the Op-Amp – where the **pin count begins in a counter-clockwise manner**. This notch is visible in the pinout diagram for Pre-Lab. This particular version of the 741 may also have a **white bar** and a **circle** in the top-left corner. An IC could have any of these to signify the top of the chip - where the pin count begins.

1.4 Refer to the datasheet for the pinout for the Op-Amp.

2. The Potentiometer (Pot)

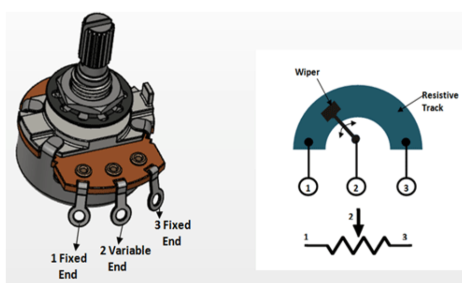


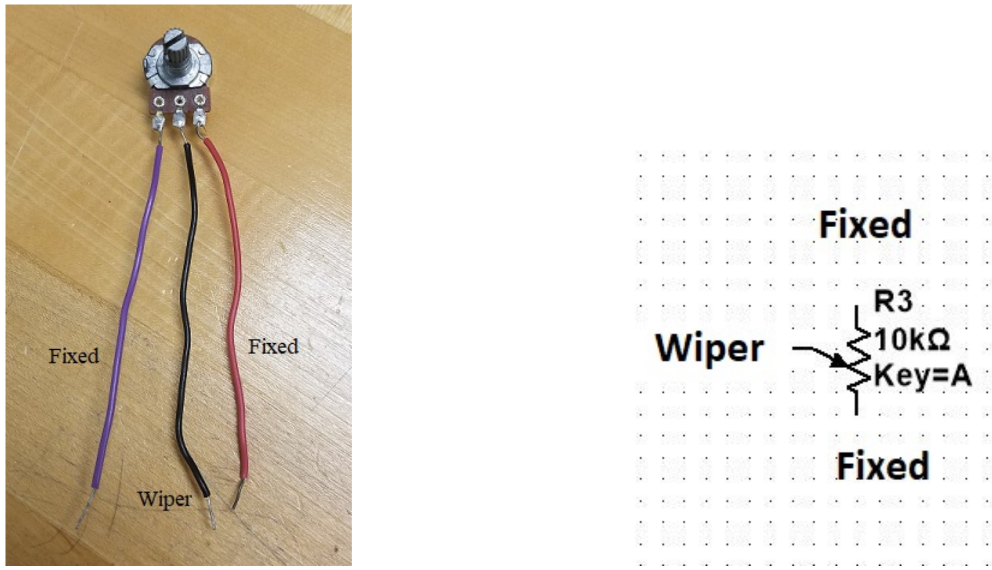
Figure 5: Potentiometer

2.1 Refer to Figure 5 for a graphic and "pin-out" of a potentiometer.

2.2 A potentiometer works by moving a "wiper" across a resistive strip. (For a $100\mathrm{k}\,\Omega$ pot, the strip has a total resistance of $100\mathrm{k}\,\Omega$).

2.3 As the wiper moves across the strip, the resistance between Pins 1 & 2 may be adjusted from $0\,\Omega$ to $100\mathrm{k}\,\Omega$.

2.4 We will use the middle lead (black in the figure) and one of the fixed leads as shown below.



(a) Lab Potentiometer

(b) Multisim Potentiometer

Figure 6: Potentiometers

2.5 Turn the pot in one direction until it stops turning. Use the multimeter to measure the resistance of the potentiometer at both extremes of it's rotation.

2.6 What was the minimum and maximum resistance of the pot?

Min	Max
6	72.3k

3. Constructing the Amplifier

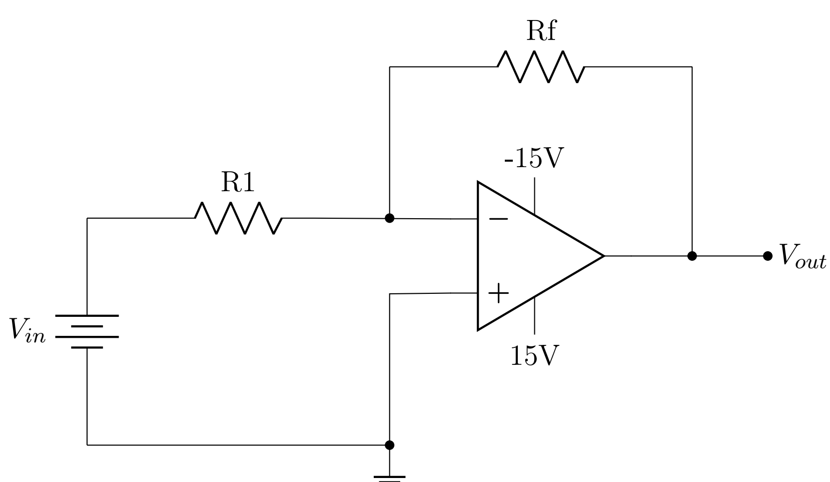


Figure 6: Inverting Amplifier

3.1 Construct the inverting amplifier shown above.

3.2 Select R1 as a 10k Ω resistor and Rf as a 100k Ω potentiometer.

3.3 Connect the potentiometer with the wiper lead connected to the inverting input and one of the fixed leads going to the output of the Op-Amp.

3.4 Use the +6V output terminal on the Power Supply for V_{in}.

3.5 **Set the +6V output to 1V.**

3.6 Use the +25V and -25V outputs to power the Op-Amp.

3.7 **Set the 25V outputs to 15V each**.

3.8 Check the voltages applied to Pins 4 and 7 to be sure **Pin 7 is +VCC (+15V) and Pin 4 is -VCC (-15V).**

3.9 Use the oscilloscope to measure the output voltage of the Amplifier.

3.10 Determine the minimum and maximum output voltage of the Amplifier achievable by adjusting the POT?

Min	Max
-0.6	-8.8

3.11 Since the input is 1V, calculate the min and max gain.

Min	Max
-0.6	-8.8

3.12 Adjust the POT to achieve a convenient (integer) output voltage.

3.13 Turn off the power supply and remove the pot.

3.14 Use the multimeter to measure the resistance of the pot.

3.15 Is the measured resistance of the POT consistent with the Gain equation?

-yes

4. Sinusoidal Signal Input

4.1 If you have time, realize the sinusoidal signal amplifier simulated in pre-lab.

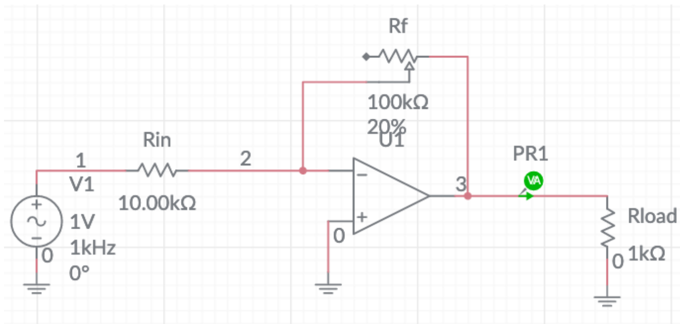


Figure 7: Inverting Amplifier with Feedback Potentiometer

4.2 replace the DC voltage from the +6V output terminal on the Power Supply with a 1kHz, 1V sinusoidal waveform from the function generator for V_{in}.

4.3 Use the oscilloscope to measure both V_{in} and V_{out}.

4.4 Adjust the potentiometer to observe the (inverted) gain at the output.

4.5 If you'd like, switch the function generator to "Triangular Wave" or "Square Wave" excitations and observe the input/output waveforms.

C. Takeaways:

1. The Op-Amp is a useful element that enables straightforward design techniques.
2. The potentiometer is a useful variable resistor.
3. An adjustable-gain amplifier can be easily implemented.