ASIA PACIFIC UNIVERSITY TECHNOLOGY & INNOVATION

EE009-3-1 INSTRUMENTATION AND MEASUREMENT LAB MANUAL

TITLE: POTENTIOMETER, WHEATSTONE BRIDGE, AND OPERATIONAL AMPLIFIERS

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POTENTIOMETER

1. OBJECTIVES

- ✓ Demonstrate how a potentiometer varies resistance.
- ✓ Construct a potentiometric circuit.
- ✓ Conduct an experiment to determine the effect of meter loading on a potentiometric circuit.

1. INTRODUCTION

In our daily life, we use potentiometer frequently, as they allow us to control the functions of some devices, such as turning up and down the volume of a music player, a sound amplifier or an electric guitar.

It is normal to wonder what a potentiometer is. It is basically a variable resistor, therefore, it is used to control the intensity that passes through an electrical circuit of low power, generally less than 1W. Thus, we can say that potentiometers allow us to set the output level in many of the devices we commonly use.

As for the unit of measurement, the maximum resistance value is measured in ohms, so the potentiometer symbol is the Greek omega Ω, as is the case with other types of electrical resistors. Thus, a 50 kilo-ohms potentiometer offers a variable resistance from 0 ohms to 50,000 ohms. The most usages potentiometers are 10, 100, 250 and 500 kilo ohms, but there are other options. However, potentiometers should not be confused with rheostats, as the latter are indicated for high-power circuits, from 1 W and up.

A potentiometer consists of a resistor of constant total value along which a cursor moves, which is a movable contact that divides the total resistance into two resistors of variable value and whose sum is the total resistance, so that when the cursor is moved one increases and the other decreases. When connecting a potentiometer, the value of its total resistance or that of one of the variable resistors can be used, since potentiometers have three terminals, two of them at the ends of the total resistors and the other attached to the cursor.

2. MATERIALS FOR THE EXPERIMENT

- ✓ Power supply
- ✓ Multi meter
- ✓ Resistors
- ✓ Potentiometer
- ✓ Jumper wires

3. STEPS FOR POTENTIOMETER EXPERIMENT

- ✓ Set the power supply to 5V. Use this input voltage for the potentiometric circuit in Figure 1. Measure this voltage and record it. This must be held constant throughout the experiment.

- ✓ Shift the position on the scale until the voltage reaches zero.

- ✓ Measure the potentiometer voltage (to the nearest millivolt) for every 10% increment on the linear input scale until 100%. Take the same 10 readings as the percentage is decreased from 100% down to 0%.

- ✓ Analyze the linearity, repeatability and hysteresis of your potentiometer based on your results.

- ✓ Add a 10K resistor between the wiper (output voltage) and ground. This simulates a load on the sensor. See Figure 2.

- ✓ Tabulate the data using the same method as in steps 1-3.

- ✓ Calculate the percent linearity (worst case) for this set of data. How does it differ from the unloaded case? At what angle does the largest non-linearity occur?

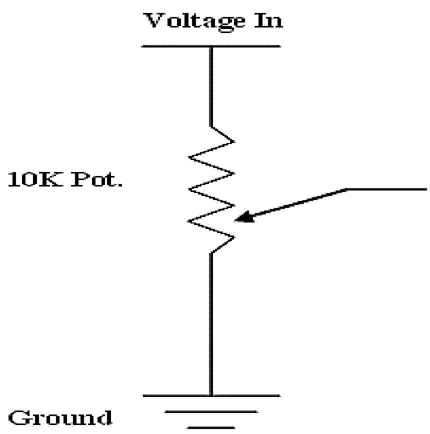


FIGURE 1

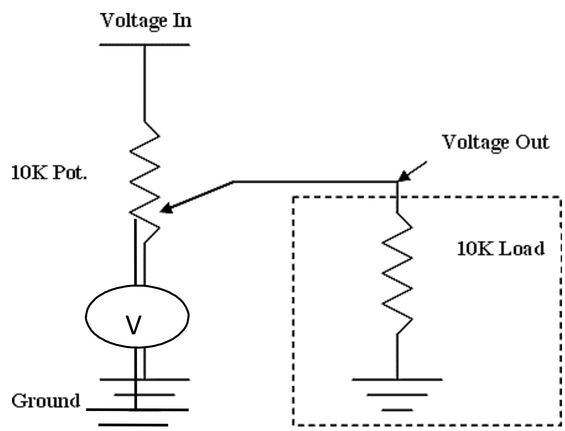


FIGURE 2

4. RESULTS

Table 1: Potentiometer voltage for 0° to 100%

Input(%)	Voltage
0	0.00
10	0.5
20	1.00
30	1.50
40	2.00
50	2.50
60	3.00
70	3.50
80	4.00
90	4.50
100	5.00

Table 2: Potentiometer voltage for 100% to 0%

Input(%)	Voltage
100	5.00
90	4.50
80	4.00
70	3.50
60	3.00
50	2.50
40	2.00
30	1.50
20	1.00
10	0.5
0	0.00

Table 3: Voltage 0% to 100% with loading

Input(%)	Voltage
0	0.00
10	0.459
20	0.862
30	1.24
40	1.61
50	2.00
60	2.42
70	2.89
80	3.45
90	4.13
100	5.00

Table 4: Voltage from 100% to 0% with loading

Input(%)	Voltage
100	5.00
90	4.13
80	3.45
70	2.89
60	2.42
50	2.00
40	1.61
30	1.24
20	0.862
10	0.459
0	0.00

5. DISCUSSION

In the experiment I was able to calculate the value of the potentiometer for each 5 volt increment. For example, in Table 1 and 2, using Tinkercad, the percentage value input 10 equals 5 on the potentiometer needle. Using the potentiometer and counting to five, I have obtained the value of the voltage that equals 0.5V as shown in figure Q.

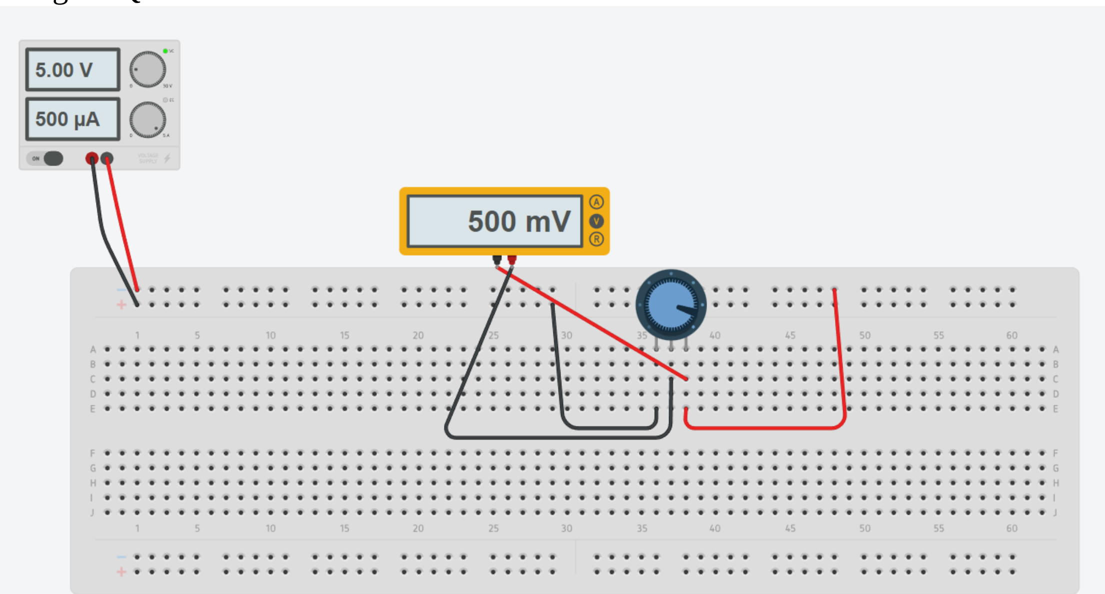


FIGURE Q

On the other hand regarding table 3 and 4 I have used a different circuit where I have as you can see in the figure s. In this circuit I have used the same process of obtaining the result at each increment of 5 volts. For example, for the 10% percentage input I got 0.459 volts as shown in figure S.

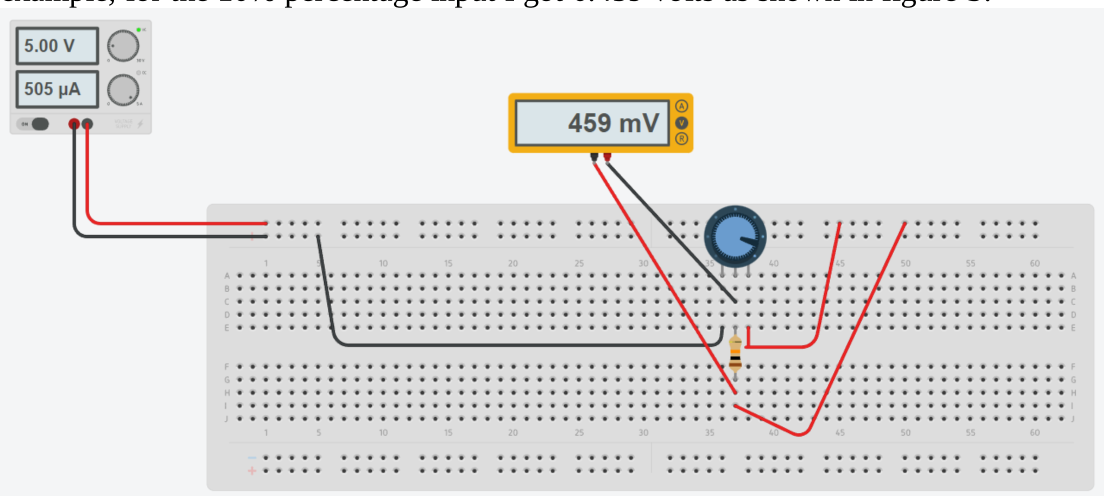
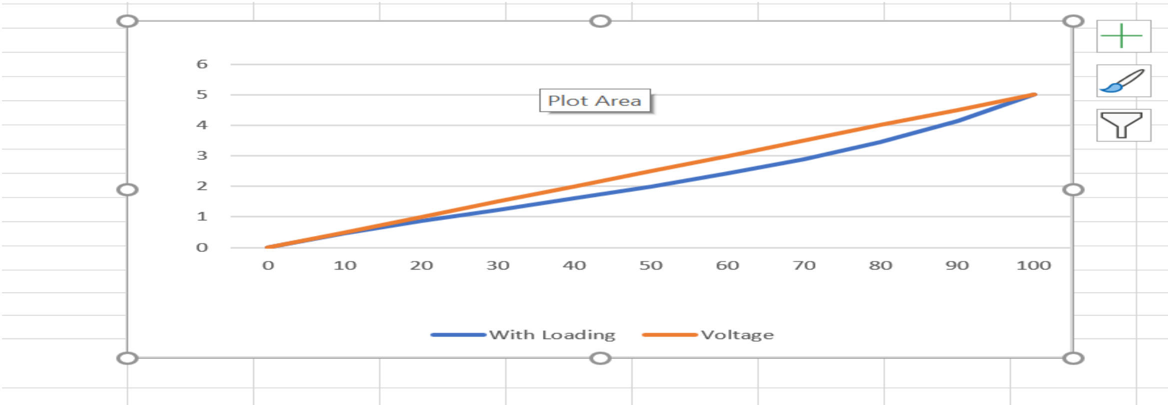


FIGURE S



Graph S

6. CONCLUSION

In conclusion from the results obtained in the experiment, it can be seen how the voltage varies in each 5V increment. The potentiometer is a variable or manipulable resistor that can be varied and as the potentiometer is varied you can also see a change in the multimeter in terms of voltage.

7. REFERENCES

WHEATSTONE BRIDGE

2.1 OBJECTIVES

After performing this experiment, students should be able to:

- Construct a Wheatstone bridge circuit using 3 fixed resistors and a potentiometer.
- Demonstrate the balance and unbalanced conditions of a Wheatstone bridge.
- Varying the resistance on one arm in a Wheatstone bridge circuit.
- Conduct and experiment to determine the appropriate value of resistance to balance a bridge.

2.2 INTRODUCTION

The Wheatstone bridge is a circuit designed to accurately measure the value of an electrical resistance. It consists of four resistors R1, R2, R3 and R4 connected as shown in Figure No. 1. This bridge is used to find the unknown resistance very accurately by comparing it to a known value of resistors. In this bridge, the unbalanced or balanced condition is used to find the resistance.

For this bridge, the balanced voltage at points a and b must be equal. Therefore, no current flows through the multimeter. To obtain the balanced condition, one of the resistors must be variable.

In conclusion a Wheatstone bridge is widely used to measure electrical resistance. This circuit is constructed with two known resistors, an unknown resistor and a variable resistor connected in the form of a bridge. When the variable resistor is adjusted, then the current in the galvanometer becomes zero, the ratio of two unknown resistors is equal to the ratio of the value of the unknown resistor and the adjusted value of the variable resistor. By using a Wheatstone bridge, the unknown value of electrical resistance can be easily measured.

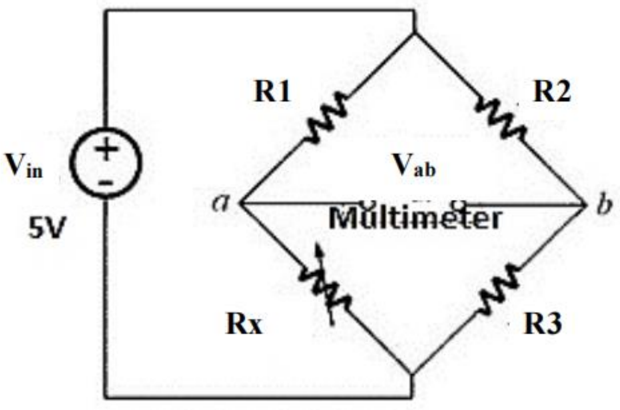


Figure 1: Wheatstone bridge circuit

2.3 MATERIALS LIST

1. Power supply
2. Multi meter
3. Resistors
4. Potentiometer
5. Jumper wires

2.4 STEPS OR PROCEDURE FOR UNBALANCED CONDITION

1. Select three fixed resistors, R1, R2, R3 and one potentiometer Rx. Note down these values down in Table 1 as the measured values (The value of the three fixed resistors, R1, R2, R3 remain the same throughout the experiment.)
2. Set the power supply to 5V.
3. Connect the circuit as shown in Figure 1
4. Set the potentiometer to a small value eg. 1kΩ
5. Calculate the expected value of V_{ab}. Note this value down in Table 2.
6. Measure using a voltmeter the output voltage across a-b, V_{ab}. Note down this value in your table.
7. Vary the potentiometer value by xΩ such that the new value of Rx is now 1k + xΩ
8. Measure the output voltage across a-b, V_{ab}.
9. Repeat steps 6 -7 while varying the potentiometer values with fixed increments of xΩ.
10. Tabulate Table 2.
11. Discuss your findings and show all relevant simulations calculations in your report.

2.4.1 STEPS OR PROCEDURE FOR BALANCED CONDITION

1. Select three fixed resistors, R1, R2, R3 and one potentiometer Rx. Note down these values down in Table 2 as the measured values
2. Set the power supply to 5V.
3. Connect the circuit as shown in Figure 1
4. Calculate the expected value of Rx when the bridge is in a balance state, $V_{ab} = 0$.
5. While measuring the output voltage across a-b, V_{ab}, tune the potentiometer, Rx, until V_{ab} is zero. Note down this value of Rx in your table.
6. Select three different values of R1, R2, R3. Note down these values down in Table 2.
7. Repeat steps 3-6. Populate Table 1.
8. Discuss your findings and show all relevant simulations and calculations in your report

2.5 RESULTS

Table 1 balance Bridge condition

	R1 in Ω	R2 in Ω	R3 in Ω	Vab (measured)	Rx calculated in Ω	Rx measured in Ω
1	50	40	80	0	64	64
2	10	30	50	0	150	150
3	0.50	1.5	3.2	0	9.6	9.6
4	5000	4000	8000	0	6400	6400
5	3	8	5	0	13.33	13.33

Validated by:

Table 2 unbalanced Bridge condition

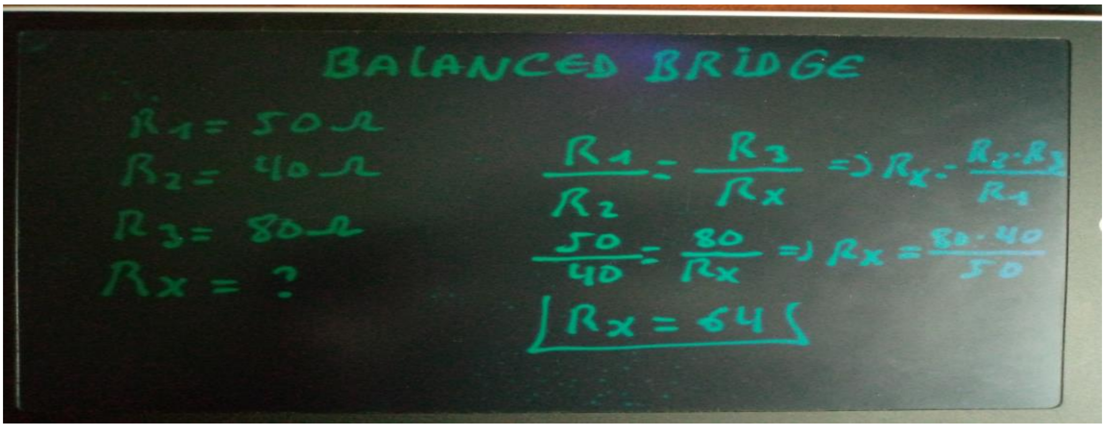
	R1 in Ω	R2 in Ω	R3 in Ω	Rx measured in Ω	Vab (calculated)	Vab (measured)
1	2000	2000	2000	1000	-833	-833
2	2000	2000	2000	2000	0	0
3	2000	2000	2000	3000	0.5	0.5
4	2000	2000	2000	4000	0.833	0.833
5	2000	2000	2000	5000	1.07	1.07
6	2000	2000	2000	6000	1.25	1.25
7	2000	2000	2000	7000	1.39	1.39
8	2000	2000	2000	8000	1.50	1.50
9	2000	2000	2000	9000	1.59	1.59
10	2000	2000	2000	10000	1.67	1.67

Validated by:

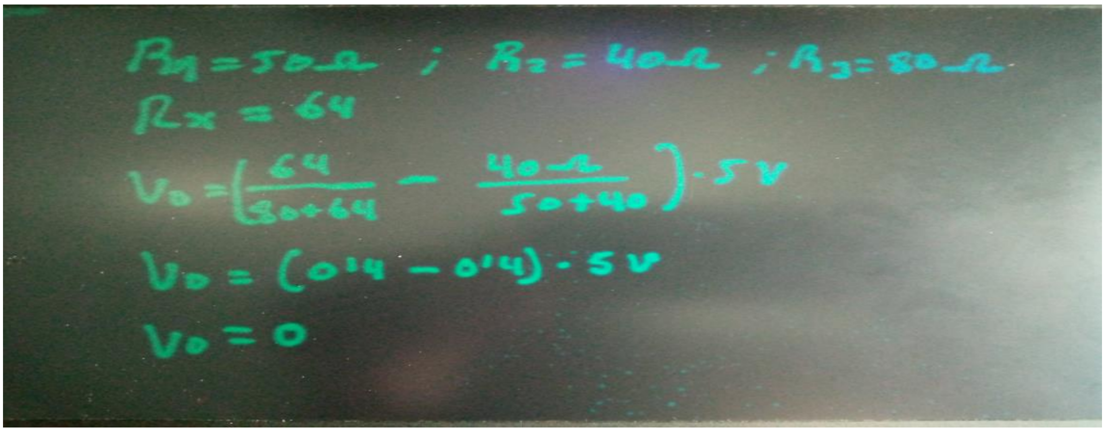
2.6 DISCUSSION

This experiment is basically focused on calculating balance bridges as well as unbalanced bridges. As you can see in the table of the results, starting with the first one where I have calculated balanced bridge. The balanced bridge has a value of Vab which is equal to zero. By setting different values to the three resistors I have obtained the value of Rx with the potentiometer, where the condition of zero voltage(ab) has been fulfilled.It is showed in figure T.

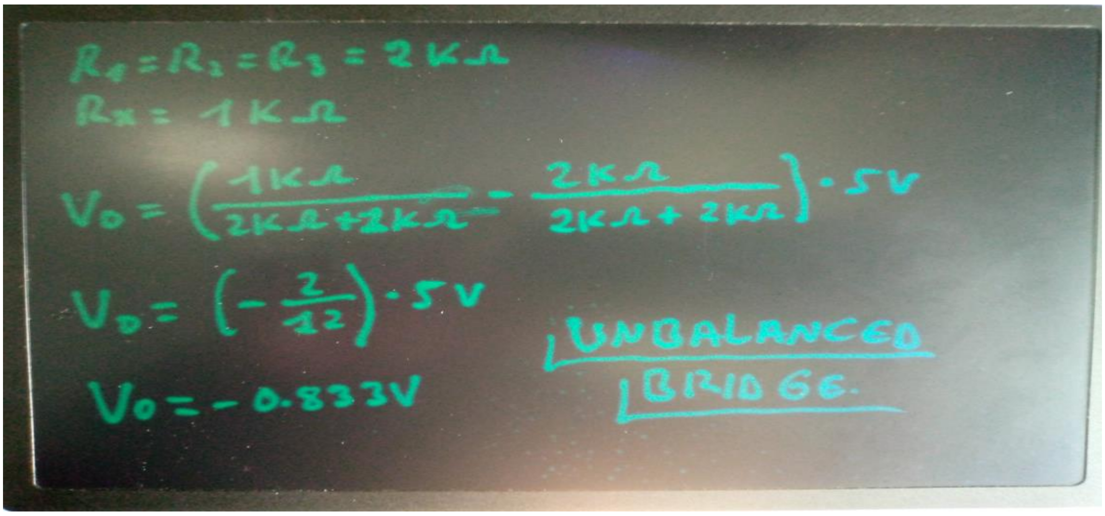
FIGURE T



Now in this case if we take the new Rx value 64 ohms and apply it to the output voltage formula we get zero as shown in the figure below.



On the other hand in the Wheatstone bridge table in the following table (table 2), where all three resistors keep the same value. In the potentiometer the value starts from 1 kilo Ohms up to 10 kilo Ohms. In this experiment the results we get in the voltage go progressively from a lower number to a higher number as you can see in table 2 (unbalanced bridge). An example would be the following:



The voltage result -833 volts equals the amount of current through Vab in the Wheatstone Bridge circuit.

Here are some formulas for WHEATSTONE BRIDGE:

$$V_1 = \frac{R_2}{R_1 + R_2} V_S \qquad V_2 = \frac{R_4}{R_3 + R_4} V_S$$

$$\boxed{V_O = V_2 - V_1 = \left(\frac{R_4}{R_3 + R_4} - \frac{R_2}{R_1 + R_2} \right) V_S}$$

2.7 CONCLUSION

In this experiment I have understood many concepts about how the Wheatstone Bridge works through theoretical fundamentals as well as how to obtain data or calculations. Basically, Balanced condition and Unbalanced condition are two types of conditions that can occur in Wheatstone Bridge and the difference is in what you get in the voltage. When the voltage is zero, it is a balanced bridge and when the voltage is non-zero, it is an unbalanced bridge. This can be calculated by application formulas or by using Tinkercad to verify the results.

2.8 REFERENCES

OPERATIONAL AMPLIFIERS

3.1 OBJECTIVES

After performing this experiment, students should be able to:

1. Construct a simulated circuit that uses 741 operational amplifiers.
2. Demonstrate the practical limitations of operational amplifiers
3. Conduct a simulation to experiment using operational amplifiers to amplifly voltage signals.
4.

3.2 INTRODUCTION

An amp op(figure a) is a high gain amplifier with two input terminals, a single output terminal and an internal direct coupling. It is represented by the symbol in figure 1-1a and its circuit in figure 1-1b. The output voltage V is the difference of the input voltages applied to each of the input terminals. A positive signal applied to the positive (+) input terminal causes a positive change in the output. For this reason, the (+) terminal is known as a non-inverting input. On the other hand, the positive signal applied to the negative (-) input terminal produces a negative change in the output, so the (-) terminal is called the inverting input.

Inverting Amplifier(figure 1)

With the inverting amplifier the signal that we enter through Ve will be amplified by a factor called gain. This gain can be greater or less than one, so the input signal can also be reduced. It is represented by the following figure: (-R2/R1)

Non-inverting amplifier(figure 2)

The non-inverting amplifier only amplifies the input signal, it cannot reduce its amplitude, and the gain is given by the following formula: (1 + (R2/R1))

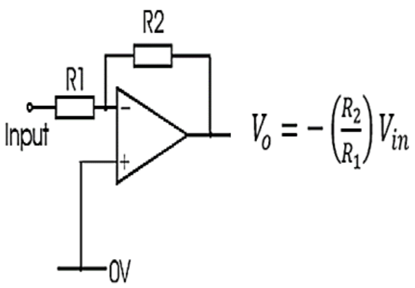


FIGURE 1

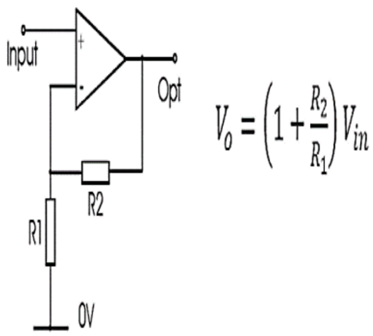
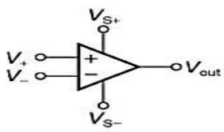
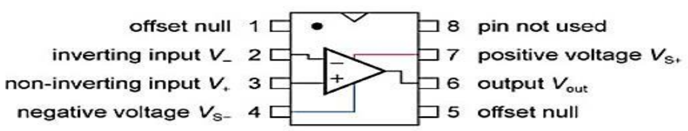


FIGURE 2



(a)

(b)



3.3 MATERIALS

1. Power supply
2. Multimeter
3. Function generator
4. Operational Amplifiers
5. Resistors
6. Breadboard
7. Jumper wires

*All the above are simulation-based components

3.4 STEPS FOR OPERATIONAL AMPLIFIERS

1. Select resistors values for R1 and R2 such that the following conditions are met:
a. R1 > R2
b. R1 < R2
c. R1 = R2
2. Calculate the gain using the measured values of the resistors chosen, insert into table.
3. Configure the circuit using a suitable software as shown in Figure 1 with resistors R1 =…Ohms and R2 =…Ohms
4. Set the DC supply to +/-12V. Connect to the +/-V_{cc} pins of the op-amp.
5. Set up a function generator to provide a sine wave with amplitude of 0.50V (1.0V peak-to-peak) at 50 Hz. Connect the function generator to the input of the op-amp circuit.
6. Connect the oscilloscope (OSC) to display the input and output waveforms.
7. Calculate the gain of the circuit (V_o/V_{in}) using the output and input values on the OSC display.
8. Measure and record the amplitude of the input and output signal for each R_1 and R_2 condition. Note the wave forms obtained.
9. Tabulate all results for the calculated and measured values using the format given in Table 1.
10. Repeat steps 1 – 10 for Figure 2.

NOTE:
How do outputs of the inverting and non-inverting op-amps differ? If shown just the output waveforms from the oscilloscope screens, how would you differentiate between the two configurations? What is the effect on the output for both amplifier configurations if R_1 is larger than R_2 or vice versa, and if they are equal? Effect of having supply voltage supplied at pins 4 and 7 on the output? What limits the output? Cut-off voltage?

3.5 RESULTS

Table 1 for Inverting Opam

Resistor values R1 (Ω)	Resistor values R2 (Ω)	Input amplitude from OSC Vin	Output amplitude from OSC Vo	Measured from OSC display(Vo/Vin)	Calculated gain - (R2/R1)
5	2	0.5	0.2	0.4	-0.4
2	5	0.5	1.25	2.5	-2.5
6	6	0.5	0.5	1	-1

Table 1 for non- Inverting Opam

Resistor values R1 (Ω)	Resistor values R2 (Ω)	Input amplitude from OSC Vin	Output amplitude from OSC Vo	Measured from OSC display(Vo/Vin)	Calculated gain (1 +R2/R1)
5	2	0.5	0.7	1.4	1.4
2	5	0.5	1.75	3.5	3.5
6	6	0.5	1	2	2

3.6 DISCUSSION

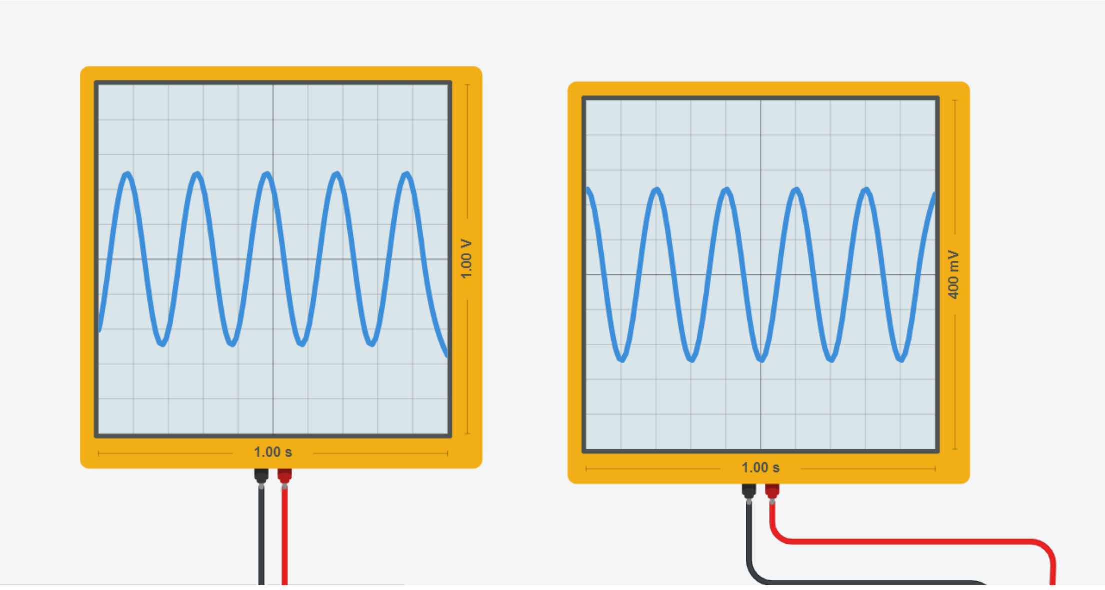


FIGURE F

As the results are reflected in the two tables of the inverted and non-inverted. I could observe that in the Non Inverting opam table the oscilloscope output has higher values as well as measured OSC display in spite of sharing the same resistor values. On the other hand, when resistor 1 in the Inverting table is higher than resistor 2, taking into account the Gain values, it can be seen that electrons have been gained in the circuit. Figure F shows the oscilloscope waveform for the first example in the inverted Opamp table where it has been verified that the output is equal to 0.2 observing the oscilloscope waveform.

3.7 CONCLUSION

In this experiment, I have managed to understand quite a few concepts about operational amplifiers. I can now differentiate between the inverted part and the non-inverted part and I can interpret the oscilloscope for the reading and the behaviour of the oscilloscope waveforms.

3.8 REFERENCE