VANIER COLLEGE - Computer Engineering Technology
247-205 Circuit Analysis and Simulation II

Lab 12 – Application of Op amp

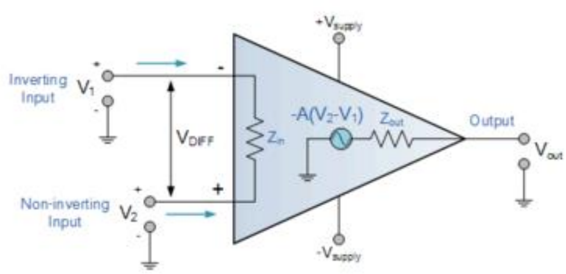
Purpose:

a) To demonstrate the basic operation of operational amplifier.
b) To familiarize with the operation of both inverting and non-inverting amplifier circuit using 741 op amp.
c) To familiarize with the application of op amps as comparator.

To be submitted:

1. **Deadline**: Before your next lab section. If you need more time please let us know.
2. **No formal report required**.
   - Fill in results of all tables. If calculation is involved, clearly indicate basic steps/values used for the calculation.
   - Attach all the 5 screen shots (clearly labelled) as required in the lab.
   - Include a final discussion and conclusion session.

Theory



Operational Amplifiers, or **Op-amps** as they are more commonly called, are one of the basic building blocks of Analogue Electronic Circuits. Operational amplifiers are linear devices that have all the properties required for nearly ideal DC amplification and are therefore used extensively in signal conditioning, filtering or to perform mathematical operations such as add, subtract, integration and differentiation.

Op-amps are fundamentally voltage-amplifying devices designed to be used with external feedback components such as resistors and capacitors between its output and input terminals.

An Op-amp is basically a three-terminal device which consists of

- 2 high impedance inputs
  - ***Inverting Input***, marked with a negative or “minus” sign, (–)
  - ***Non-inverting Input***, marked with a positive or “plus” sign (+).
- The third terminal represents the operational amplifiers output terminal which can both sink and source either a voltage or a current.

Lab Work:

Part 1: Inverting and non-inverting amplifier:

1. Watch the YouTube Video: https://youtu.be/tXLLgtJDvYA

Circuit 1

2. Construct the circuit as shown below. Observe the input and output waveform on an oscilloscope.

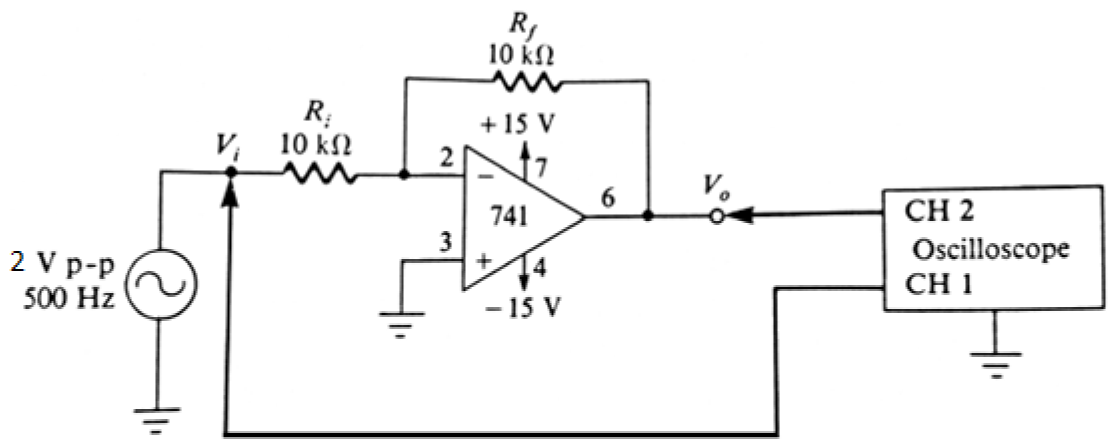
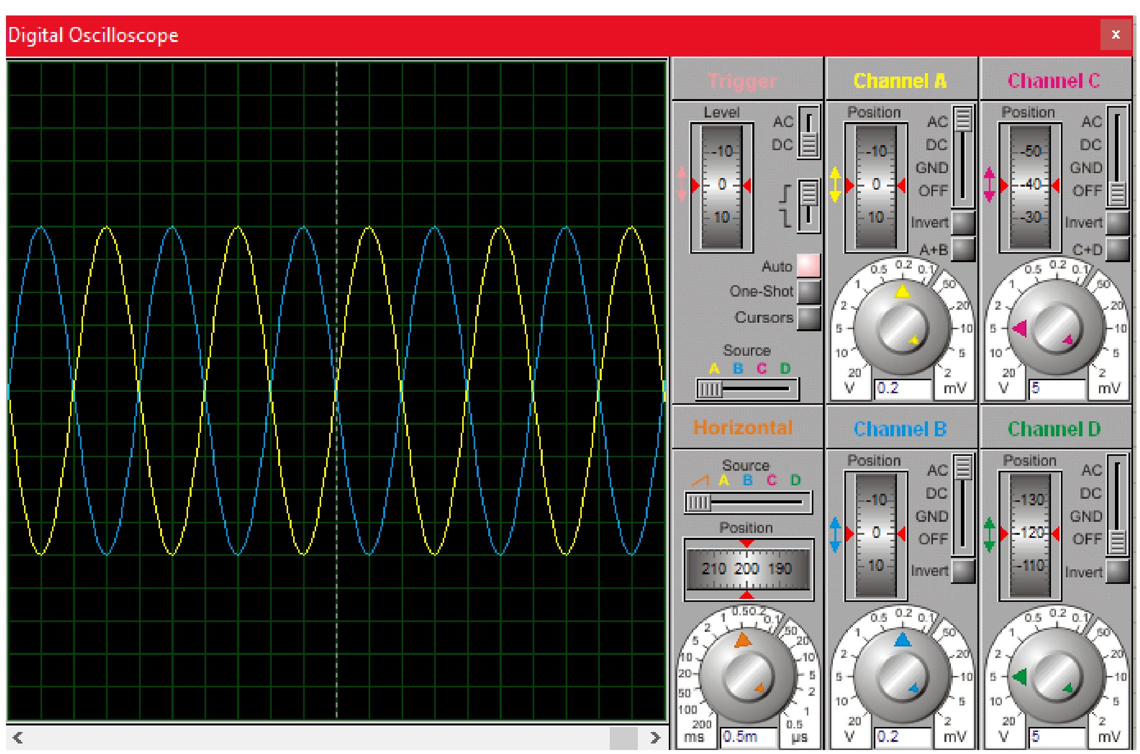
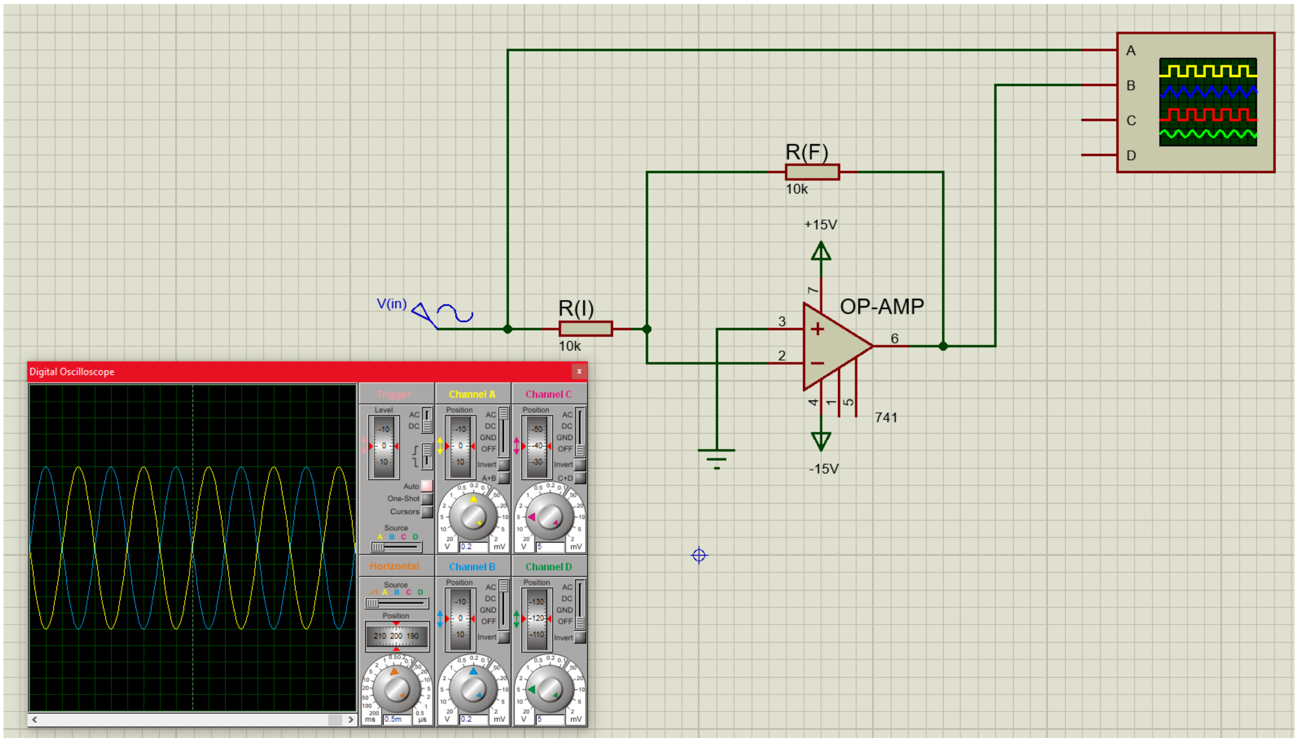


Figure 1: Circuit 1

a. Perform a screen shot of your waveform. Is this configuration functioning as an inverting or a non-inverting amplifier? Explain in a few words.





Without even looking at the circuit configuration, one could say that this is an inverting op-amp. When looking at the scope (screenshot above – yellow = Vin: input, blue = Vout: output) you can see that the output is inverted from the input, therefore this is an inverting op-amp (see complete circuit above).

b. What is the peak-to-peak output voltage, and output gain of this amplifier? What is the theoretical gain? Does this conform to theory calculation?

$$\boldsymbol{V_{PP} = 2v}$$

$$\boldsymbol{A_V = -\frac{R_f}{R_i} = -\frac{10k\Omega}{10k\Omega} = -1\ (calculated)}$$

$$\boldsymbol{A_V = \frac{V_{OUT}}{V_{IN}} = \frac{2V}{2V} = -1\ (measured)}$$

As you can see above, when doing the measurement for the gain of the amplifier, it is the same as my theoretical calculation, therefore my assumption and calculations are correct.

3. Replace R_f with the following resistor values and calculated the corresponding closed-loop voltage gain(theoretical). Show your calculation and record your results in the table as shown below.

R_f	Measured V_o (peak to peak)	Measured gain $A_V = \frac{V_{OUT}}{V_{IN}}$	Calculated gain $A_V = -\frac{R_f}{R_i}$
4.7kΩ	*900 mV*	*-0.45 (900 mV / 2 V)*	*-0.47 (-4.7k / 10k)*
10kΩ	*2 V*	*-1 (2 V / 2 V)*	*-1 (10k / 10k)*
22kΩ	*4.25 V*	*-2.125 (4.25 V / 2 V)*	*-2.2 (22k / 10k)*
47kΩ	*8.9 V*	*-4.45 (8.9 V / 2 V)*	*-4.7 (47k / 10k)*
100kΩ	*20 V*	*-10 (20 V / 2 V)*	*-10 (100k / 10k)*

Table 1: for Circuit 1.

<u>Circuit 2</u>

4. Construct the circuit as shown below

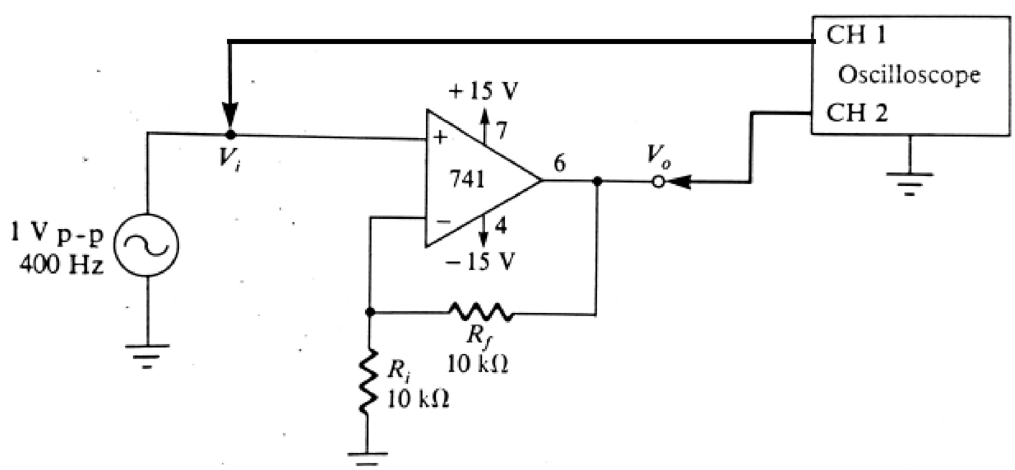
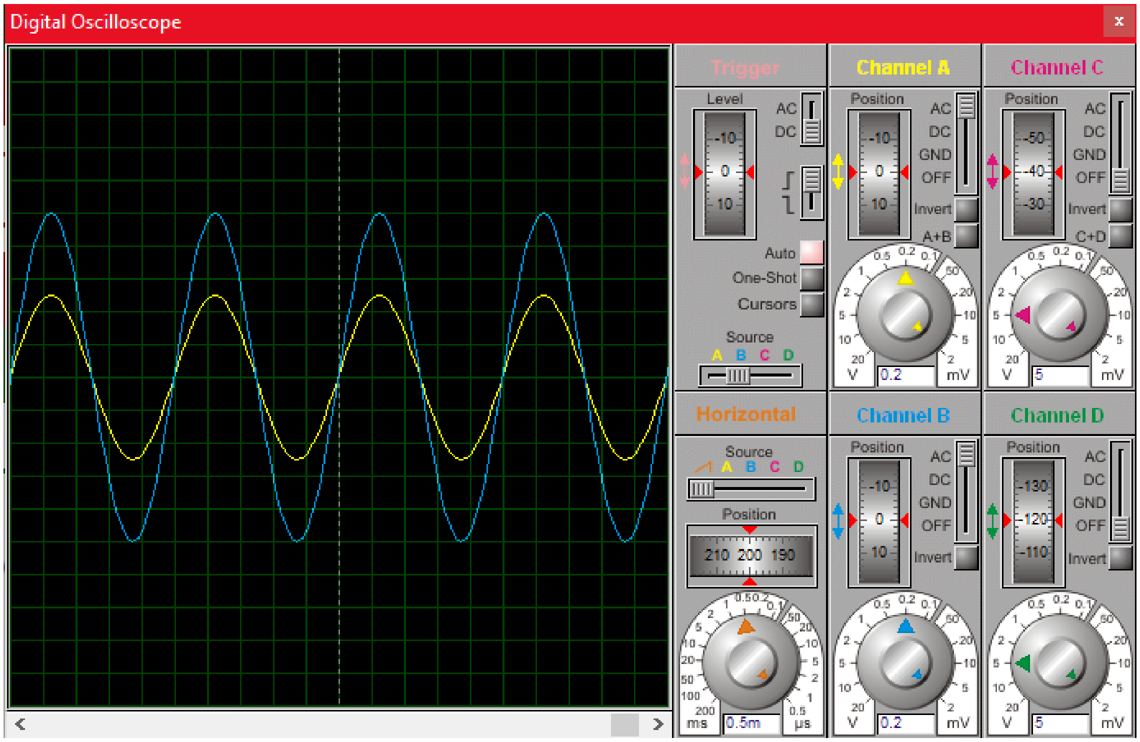
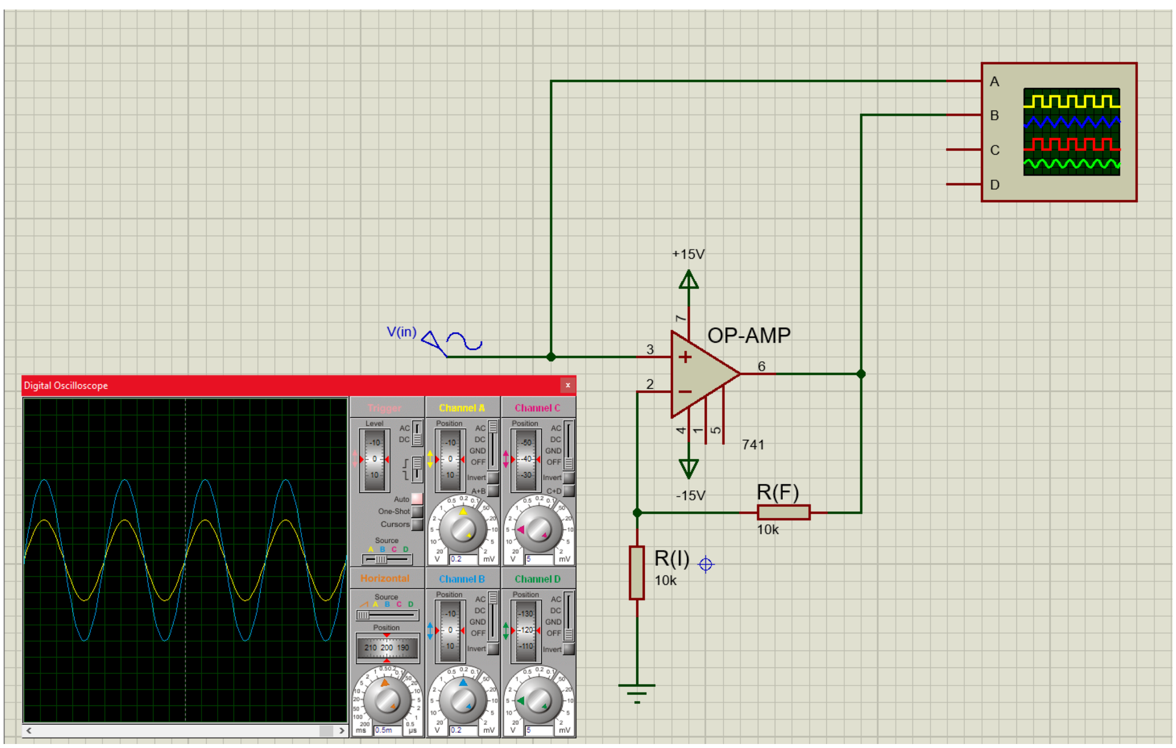


Figure 2 : Circuit 2

a. Perform a screen shot of your waveform. Is this configuration functioning as an inverting or a non-inverting amplifier?





Almost similar to Circuit 1, without looking at the circuit itself and looking at the scope (see screenshot), one could say that this is a non-inverting amplifier. Reason is, the signals (Vin and Vout – yellow and blue graphs) are in perfect phase and are not inverted like in Circuit 1. Here, the scope is the same, yellow: input and blue: output. See complete circuit above.

b. Repeat step 2 above based on this circuit.

R_f	Measured V_o (peak to peak)	Measured gain $A_V = \frac{V_{OUT}}{V_{IN}}$	Calculated gain $A_V = 1 + \frac{R_f}{R_i}$
4.7kΩ	*1.4 V*	*1.4 (1.4 V / 1 V)*	*1.47 (1 + 4.7k / 10k)*
10kΩ	*2 V*	*2 (2 V / 1 V)*	*2 (1 + 10k / 10k)*
22kΩ	*3.1 V*	*3.1 (3.1 V / 1 V)*	*3.2 (1 + 22k / 10k)*
47kΩ	*6 V*	*6 (6 V / 1 V)*	*5.7 (1 + 47k / 10k)*
100kΩ	*11.6 V*	*11.6 (11.6 V / 1 V)*	*11 (1 + 100k / 10k)*

Table 2: for Circuit 2.

Part 2: Comparator

5. Construct the circuit as shown in Figure 3. Observe the input and output waveform on oscilloscope. Perform a screenshot and describe your observation.

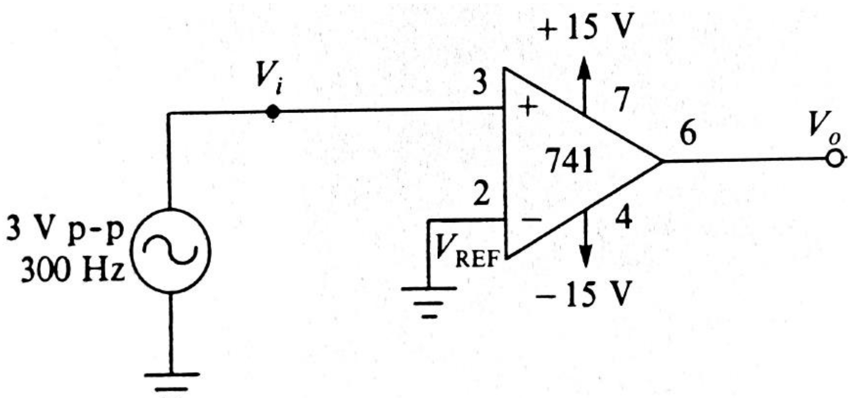
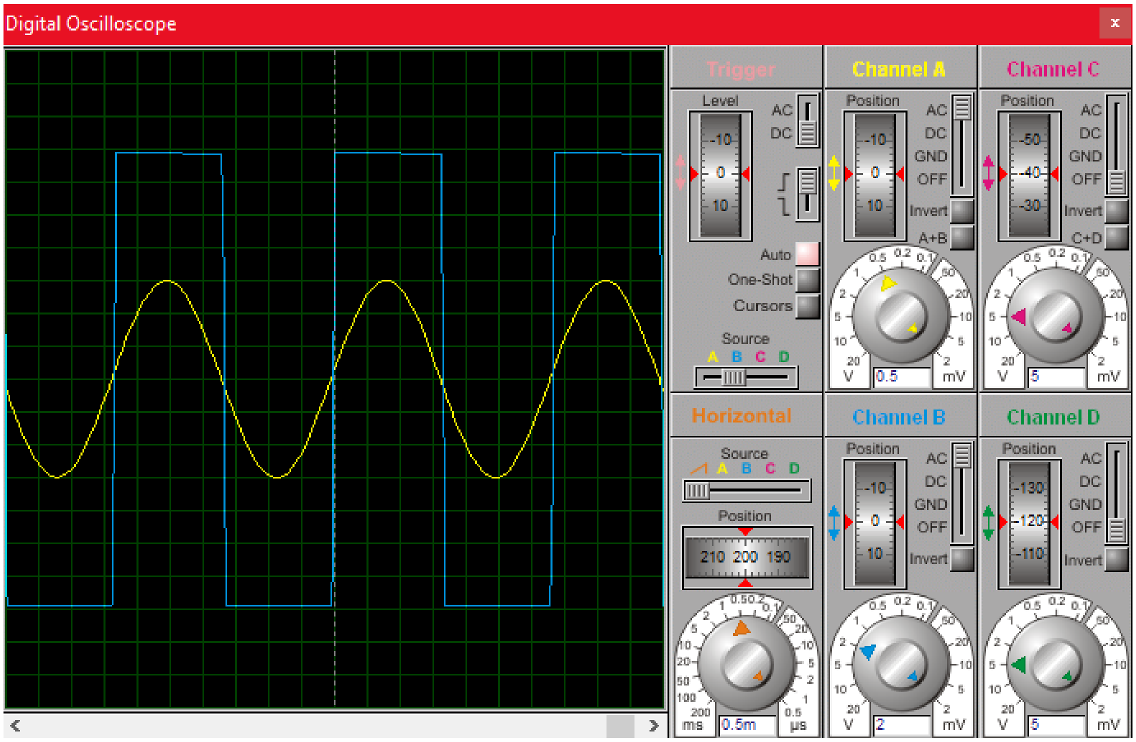
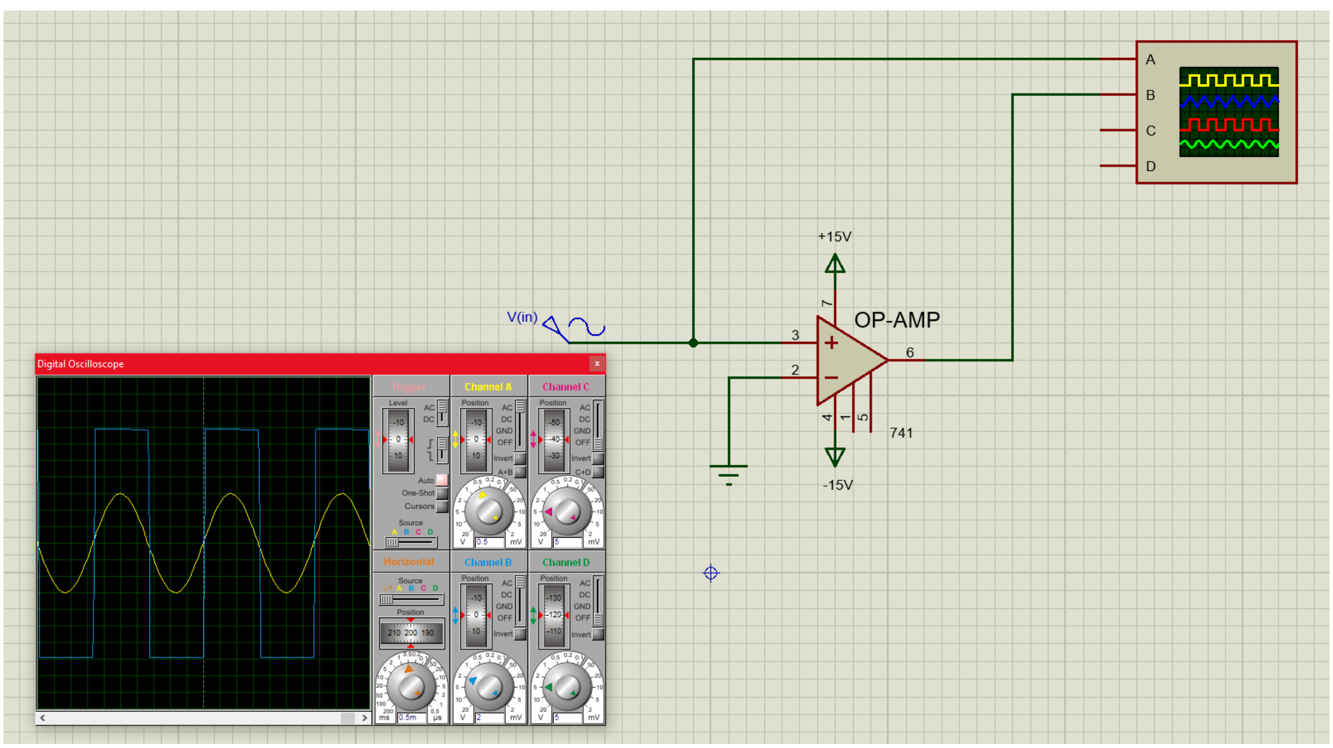


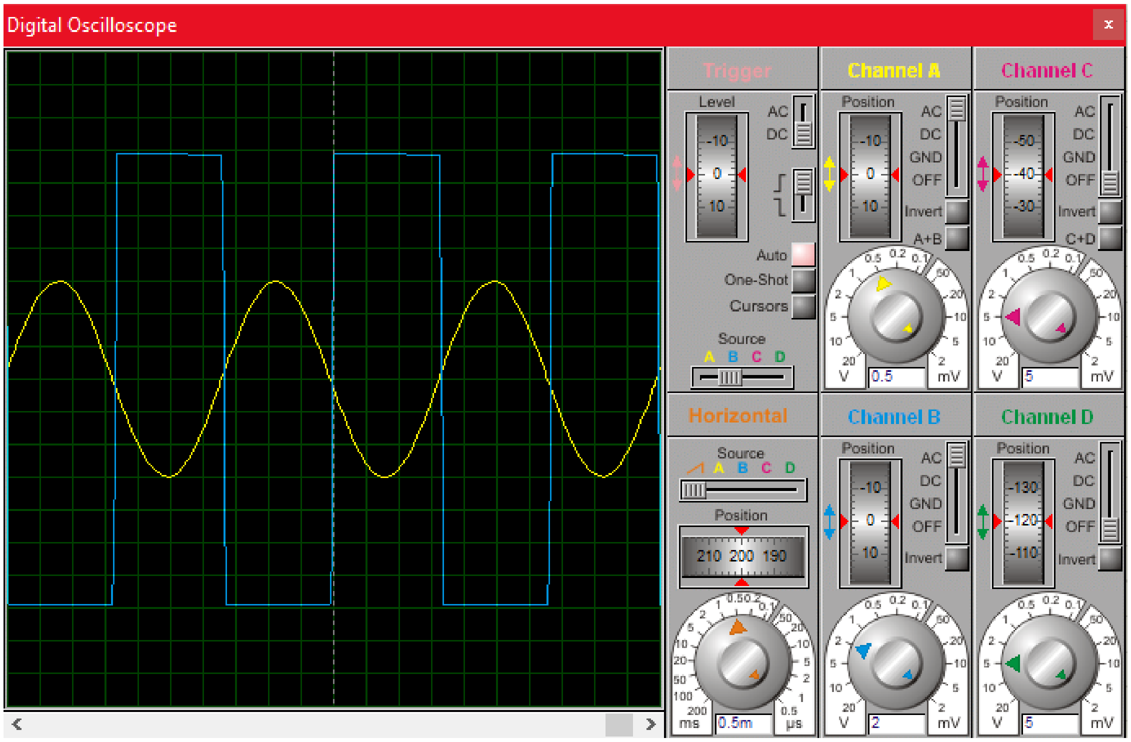
Figure 3 : Voltage-divider biasing

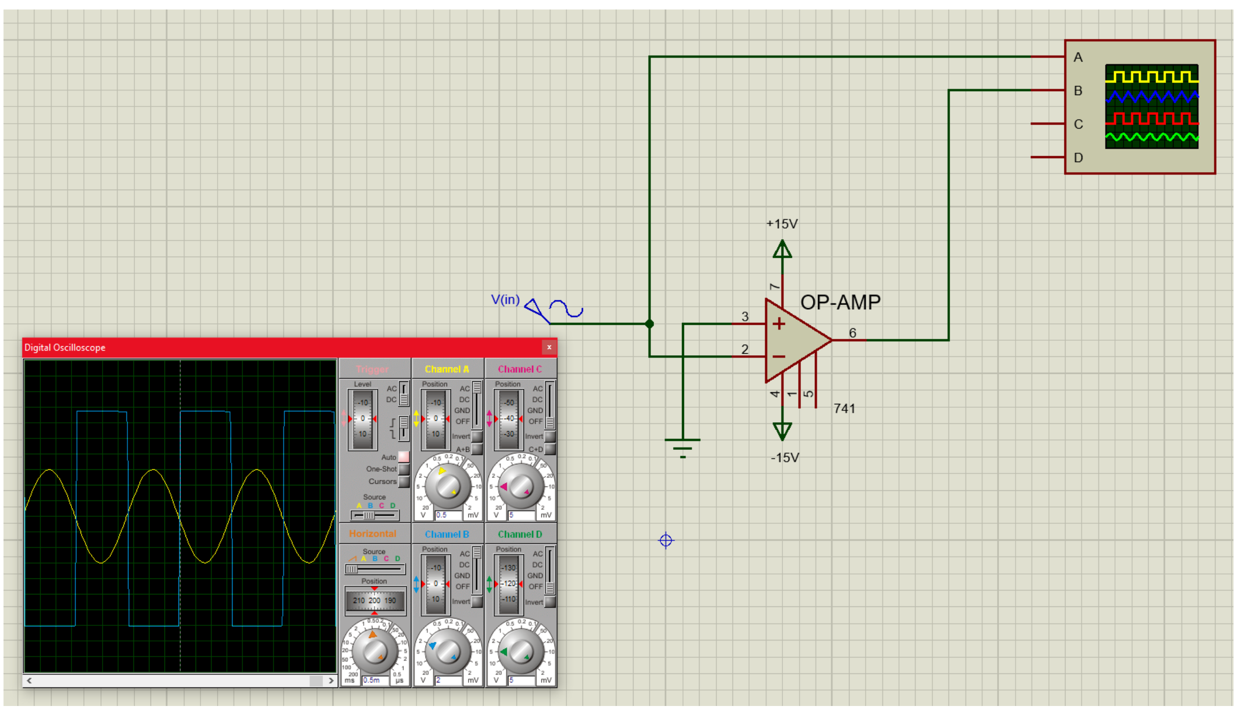

Digital Oscilloscope
Trigger
Channel A
Channel C
Horizontal
Channel B
Channel D
Level
Position
AC
DC
GND
OFF
Invert
A+B
C+D
Auto
One-Shot
Cursors
Source
A B C D
210 200 190
0.5m
ms
µs
V
mV


A
B
C
D
+15V
-15V
V(in)
OP-AMP
741
3
2
6
7
4
1
5
Digital Oscilloscope

Looking at the scope (see screenshot) one could see something a little different compared to the previous scope readings. In this case, there are two different waveform types. The input remains a sine wave (Vin) where the output is now a square wave (Vout). Also, looking a little more closely, the output is non-inverting to the input. Effectively, this is a simple square wave generator. Here, the scope is the same, yellow: input (Vin) and blue: output (Vout). See complete circuit above.

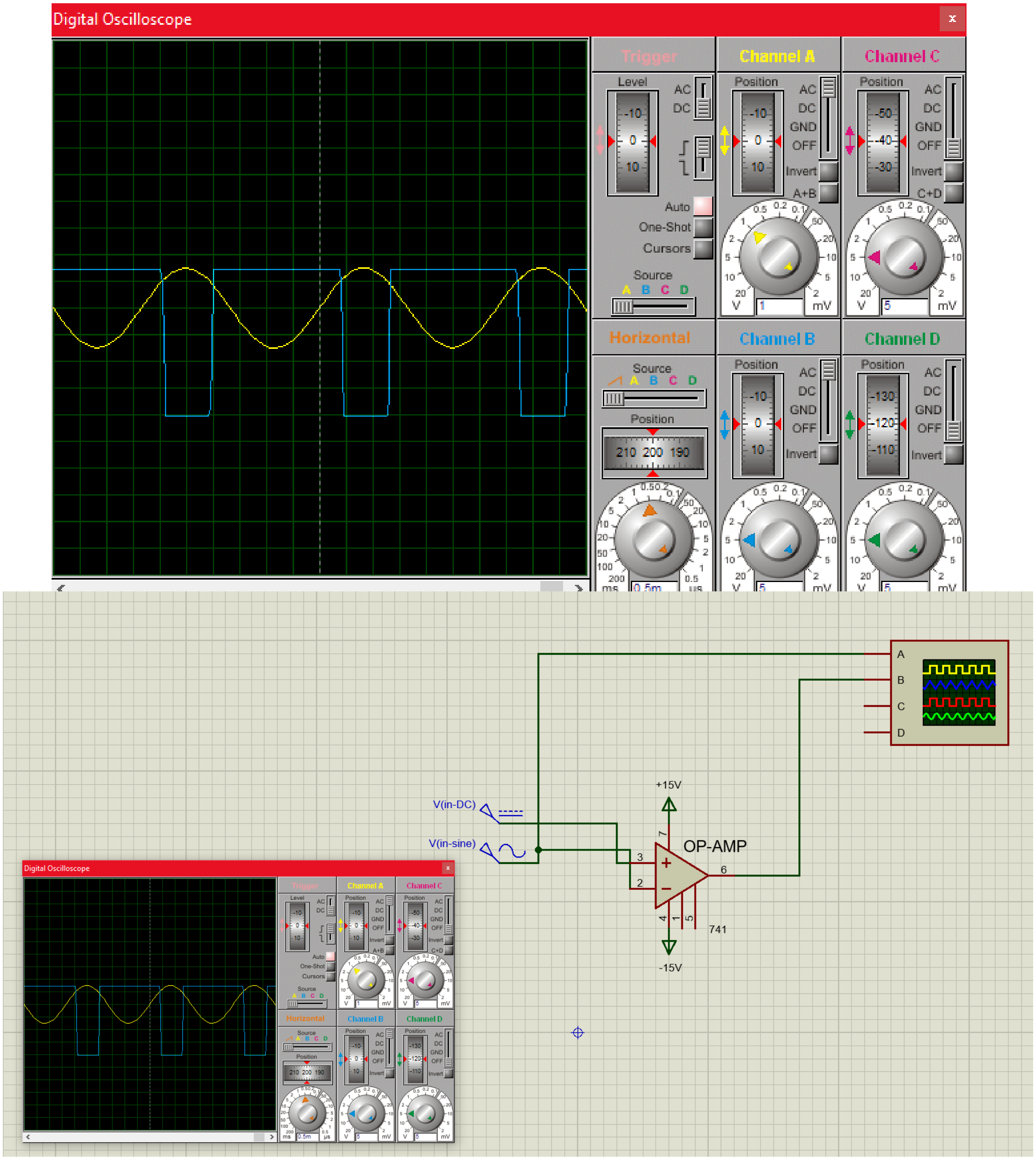
6. Swap your 2 inputs, which means now non-inverting is grounded. Perform a screenshot and describe your observation.





Looking back to the previous question and to the current scope reading (see screenshot), there are not much more things going on in this circuit. The circuit is still acting liking a simple square wave generator. There is one difference, the output waveform is slightly different (square wave - Vout) then the one in the previous question. Here, the square wave is inverted compared to the input (sine wave - Vin). Here, the scope is the same, yellow: input (Vin) and blue: output (Vout). See complete circuit above.

7. Supply a 1V DC voltage to your non-inverting input. Perform a screenshot and describe your observation as compared to output of step 6.



Here, unlike in the two previous questions, there is a noticeable difference when looking at this scope reading (see screenshot). With the addition of the 1V DC supply to the non-inverting input (not included in the previous two), the circuit is still acting like a simple square wave generator but when looking at the scope reading, there is something wrong. The fact that the square wave (Vout) is inverted compared to the input (sine wave – Vin) (like in question 6) isn't the problem here, the problem is that the output (square wave - Vout) seems to be saturated. It's not as "clean" like the square waves in the previous two questions. So essentially, compared to question 6, the square wave (Vout) here is still inverted compared to the input (sine wave - Vin) with the exception that it is now saturated (square wave – Vout). As like with the previous questions, the scope is the same, yellow: input (Vin) and blue: output (Vout). See complete circuit above.

Discussion & Conclusion:

To conclude, this lab focused on the practical application(s) of the operational amplifier where it could be used in various configurations (basic working of op-amp) and focused on some examples where we might see something similar being used today. We used the basic fundamentals about op-amps to perform this lab. We used the 741 op-amp to do our experiments and we used Proteus to do the simulations. There were three distinct simulations / observations done in Proteus. The first being an inverting op-amp. We were asked to calculate and measure various gains of this op-amp (changing the value of Rf). The second simulation was a non-inverting op-amp. Similar to the first simulation, we were asked to calculate and measure various gains of this op-amp (changing the value of Rf). Lastly, the final simulation was an observation of the 741 op-amp being implemented as a comparator. We did some comparisons between the inverting and non-inverting op-amp and did some comparisons with different circuit configurations of the op-amp being used as a comparator.