Department of Electrical Engineering
College of Engineering and Petroleum
Kuwait University

EE 234 Section A4

Electronics 1 Laboratory

Operational Amplifier II

Applications

Experiment #2

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Introduction

This report focuses mainly on Operational Amplifiers and some of their applications. Operational Amplifiers (Op-Amps) are used in many ways and in most electronic devices. Amplifiers are electronic devices that enhance the power of a signal, often used in audio equipment, broadcasting, and communication systems to produce a larger output signal without altering its original characteristics. Knowing how these parts work in the circuit and what they contribute to is essential for theoretical and experimental implementations. This report explores 2 types of Op-Amps, the Difference OP-Amp and the Integrator Op-Amp.

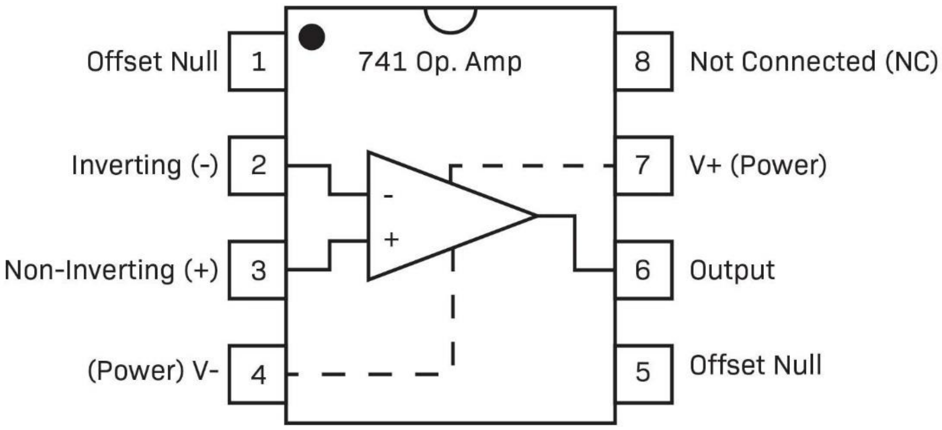

Figure 1 - Digital Representation of OP-AMP

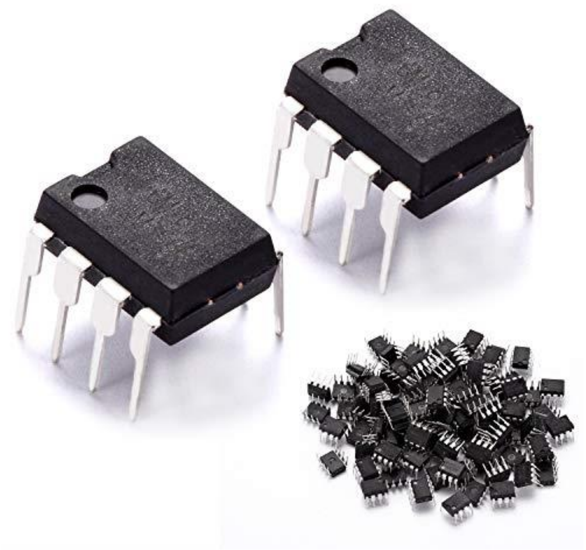

Figure 2 - Physical Representation of OP-AMP

Amplifier Structure:

- Input Terminal: Receives the input signal.
- Amplification Circuit: Increases the strength of the input signal.
- Output Terminal: Delivers the amplified signal to the load.
- Power Supply: Provides the necessary electrical power for amplification (AC or DC).
- Feedback Loop: Controls gain and enhances stability.

Amplifier Applications:

- Audio Amplification
- Signal Conditioning
- Control Systems

i. The Difference Amplifier:

A difference amplifier, also known as a differential amplifier, amplifies the difference between two input voltage signals, rejecting common signals. It's useful for noise reduction and precise signal measurement in instrumentation and sensor interfacing. Often built using operational amplifiers, it's crucial in analog computing and electronic circuits for accurate differential signal amplification. [1]

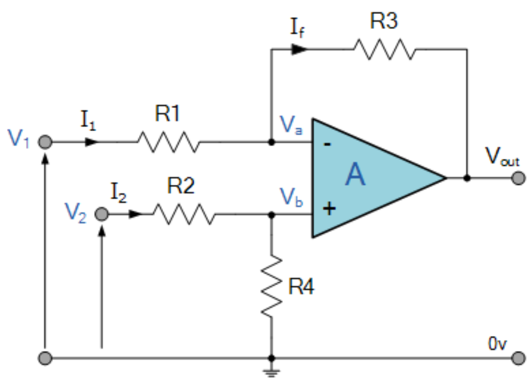

Figure 3 - Op-Amp Differential Circuit

To find the voltage output (Vo) the Difference Law can be used as follows [3]:

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

ii. The Integrator Amplifier:

An integrator op-amp is a configuration where an inverting operational amplifier performs mathematical integration of an input voltage signal, typically with a capacitor in the feedback loop. This results in an output voltage proportional to the input voltage's time-integral, facilitating electronic calculus operations. [2]

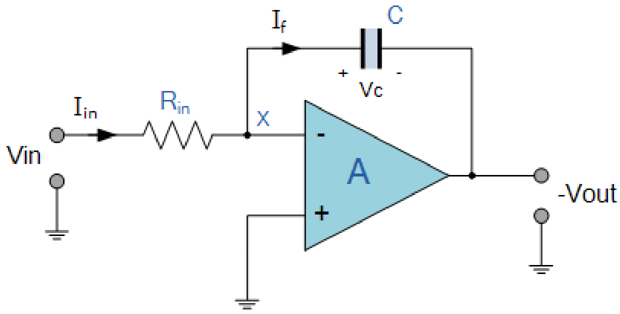

Figure 4 - Op-Amp Integrator Circuit

For the Integrator Op-Amp the output voltage can be calculated as follows:

$$Vo = -\frac{1}{R_{in} * C}\int_0^t V_{in}\,dt = -\int_0^t V_{in} * \frac{dt}{R_{in} * C}$$

Objectives

The experiment aims to:

1- Familiarize the Op-Amps

2- Understanding the different types of Op-Amps and their uses

List of Equipment & Components

- Breadboard
- DDM
- Multiple Resistors
- Capacitor
- Op-Amp
- A set of wires
- oscilloscope (CRO)
- Function Generator

Experiment Methods & Procedure

i. PART (A): DC Analysis for The Different Op-Amp

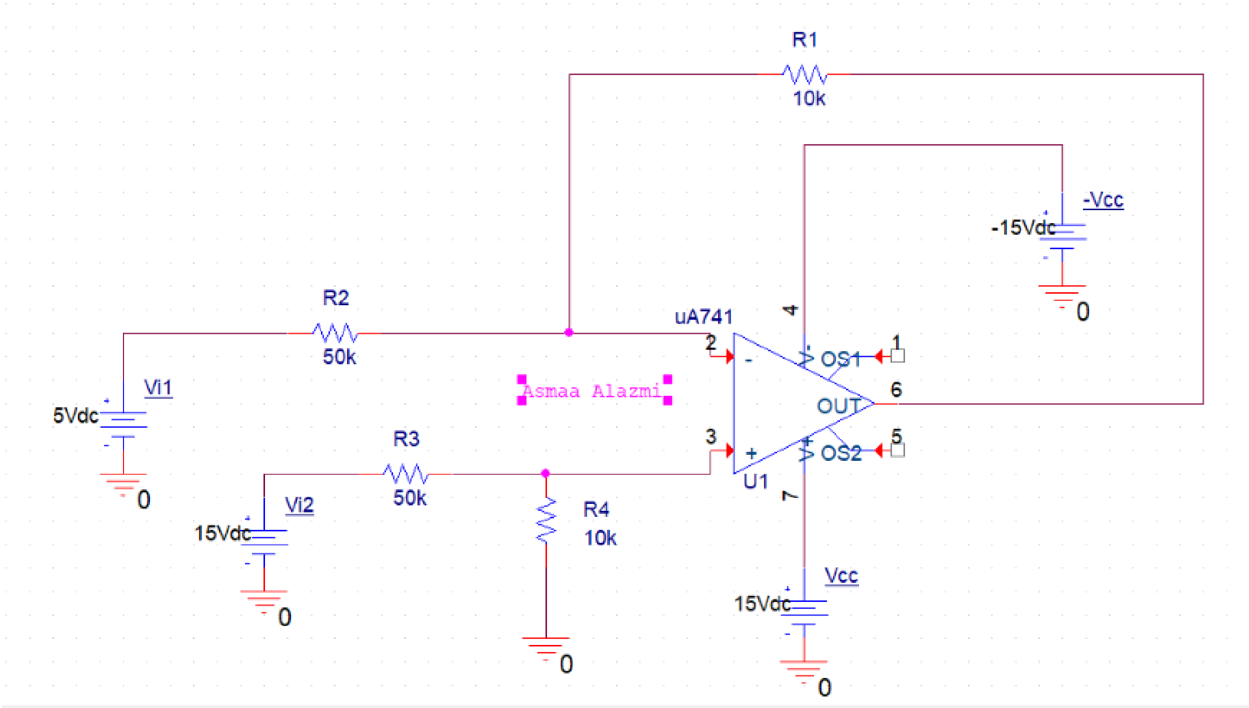

Figure 5 - Op-Amp Difference Circuit Experiment

1- Circuit of Fig.5 was set on the breadboard.
2- The Value of R1, R2, R3 and R4 were set to 10K, 50K, 50K, 10K ohm respectively.
3- The resistors were measured using the DDM to assure accuracy.
4- The DC voltages of V1, V2, -Vcc and Vcc were set to 5V, 15V, -15V, 15V respectively.
5- The DC voltages were measured using the DDM.
6- Connect an oscilloscope (CRO) to measure and display both the input and output waveforms.
7- Convert the oscilloscope to DC voltage and configure other settings.
8- Adjust the settings of the oscilloscope for proper waveform visualization.
9- Plot (Vo only) vs time.
   i. P-Spice Simulator: use time domain (transient) analysis with run time = 2 m with start saving data =0 and max step size =1u).
   ii. Analysing the waveform from the oscilloscope plot it by hand (measure Vmax).
10- Shorten the Vi2 by setting it to 0V or connecting R3 to the ground directly.
11- Plot Vo1 versus time for Vi1:
   i. P-Spice Simulator: use time domain (transient) analysis with run time = 2 m with start saving data =0 and max step size =1u).

ii. Analysing the waveform from the oscilloscope plot it by hand (measure Vmax).

12- Reconnect the power supply to Vi2.

13- Shorten the Vi1 by setting it to 0V or connecting R2 to the ground directly.

14- Plot Vo2 versus time for Vi1:

i- P-Spice Simulator: use time domain (transient) analysis with run time = 2 m with start saving data =0 and max step size =1u).

ii- Analysing the waveform from the oscilloscope plot it by hand (measure Vmax).

i. PART (B): AC Analysis for The Integrator Op-Amp

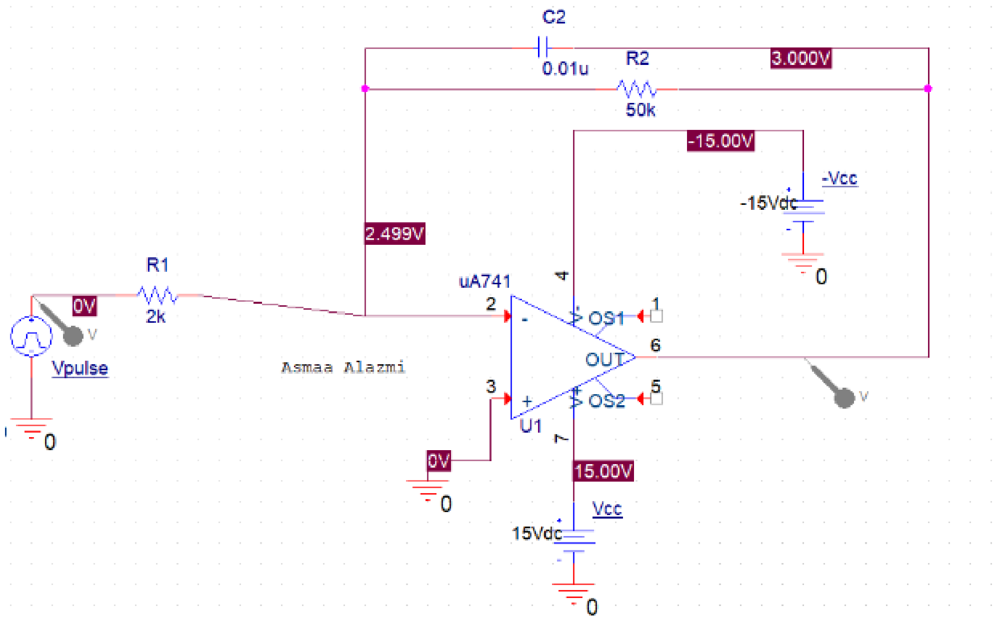

Figure 6 - Op-Amp Integrator Circuit Experiment

1- Circuit of Fig.6 was set on the breadboard.

2- The Value of R1 and R2 were set to 2K, 50K ohm respectively.

3- The resistors were measured using the DDM to assure accuracy.

4- Connect a 0.01u Capacitor in parallel with R2.

5- The AC power supply to triangle wave (Vpulse):

i. For the P-Spice Simulation it was set to:

- V1 = 1
- V2 = -1
- TD = 0
- TR = 1f
- TF = 1f

- PW = 0.25m
- PER = 0.5m

ii. For the practical experiment V:

- Vin = 1V

6- The DC voltages of -Vcc and Vcc were set to -15V, 15V respectively.
7- The DC voltages were measured using the DDM.
8- Connect an oscilloscope (CRO) to measure and display both the input and output waveforms.
9- Convert the oscilloscope to AC voltage and configure other settings.
10- Adjust the settings of the oscilloscope for proper waveform visualization.
11- Plot (Vi & Vo) vs time.

i- P-Spice Simulator: Vi square wave use V pulse /source & use time domain (transient) analysis with run time = 3m with start saving data =1m, max step size =1u and click box for skip the initial bias point).

ii- Analysing the waveform from the oscilloscope plot it by hand.

12- Prepare to measure the slope by getting Delta-t, from the oscilloscope select X/Y then move both cursers to the right location (edge of min and edge of max).
13- Then to get the Delta-V from the oscilloscope select X/Y then move both cursers to the right location.
14- Get the slope by doing the following calculation: $\frac{Delta-v}{Delta-t}$
15- Set the AC power supply to sin wave.
16- Plot (Vi & Vo) vs time.

i- P-Spice Simulator: Vi sin wave use V pulse /source (Voff = 0, Vampl = 1, Freq = 2K, AC = 0) & use time domain (transient) analysis with run time = 3m with start saving data =1m, max step size =1u and click box for skip the initial bias point).

ii- Analysing the waveform from the oscilloscope plot it by hand after setting the VP-P to 2V and increasing the frequency to 2KHz.

17- Analyse the Theta (angle) by using the following calculation: $\frac{Delta-t}{T} * (360) = angle\ in\ degree$
18- Move the Y cursers to the cross point of the x-axis with the signal for both waves, then get Delta-t.
19- Select ‘Measure’ > ‘Time’ > ‘Period’ on the oscilloscope to get T.
20- Set the AC power supply to triangle wave (Vpulse).

i. For the P-Spice Simulation it was set to:

- V1 = 1
- V2 = -1
- TD = 0
- TR = 0.25m

- TF = 0.25m
- PW = 1f
- PER = 0.5m

ii. For the practical experiment V:

- Vin = 1V

21- Plot (Vi & Vo) vs time.

i. P-Spice Simulator: Vi square wave use V pulse /source, use time domain (transient) analysis with run time = 3m with start saving data =1m, max step size =1u and click box for skip the initial bias point).

ii. Analysing the waveform from the oscilloscope plot it by hand.

22- Get the voltage gain by applying the following calculation: $Av = \frac{Vo}{Vi}$

Observation & Results

i. PART (A): DC Analysis for The Different Op-Amp

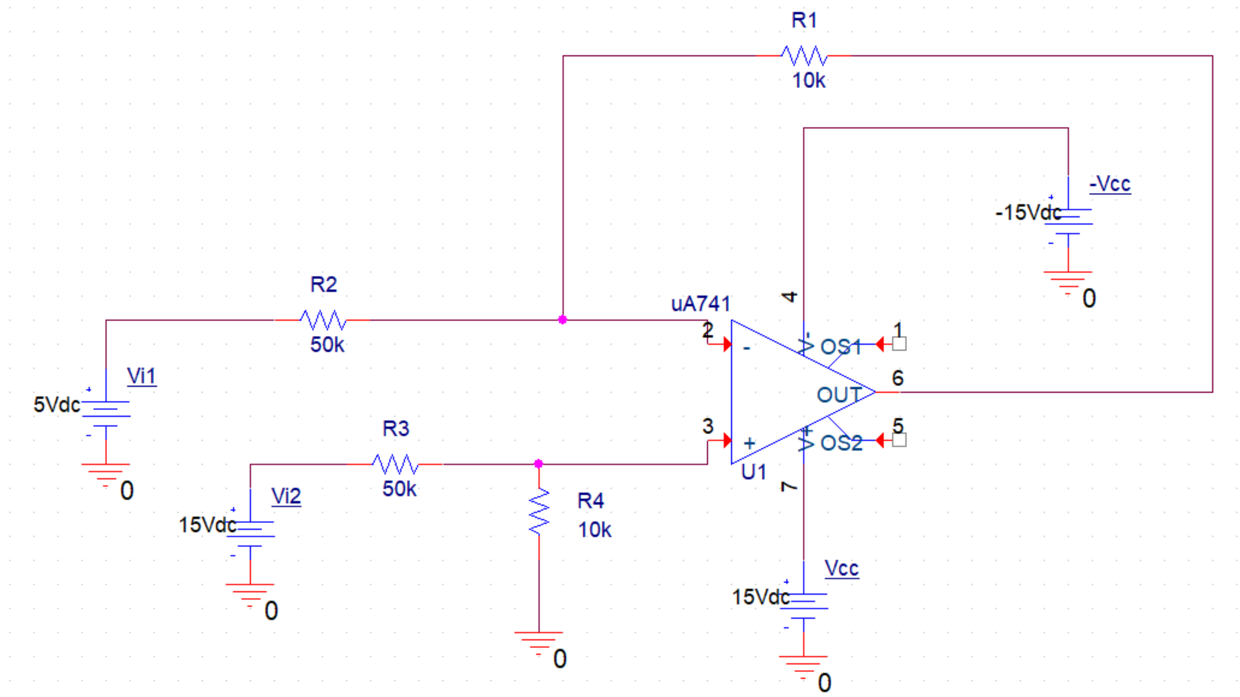

Figure 7 – PART A: Difference Op-Amp

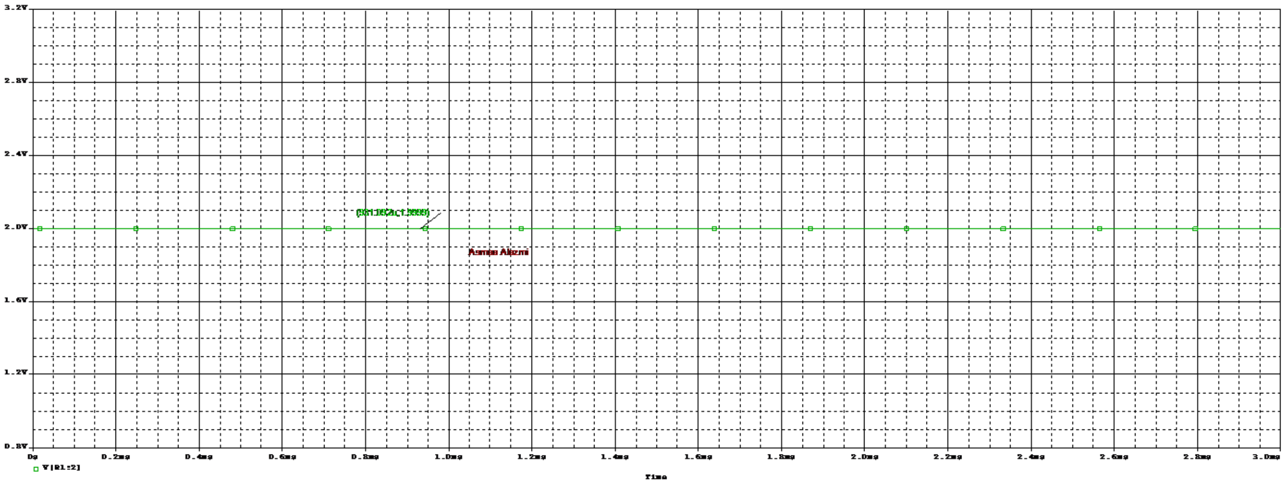

Figure 8 - PART A: Simulated Vo Vs Time

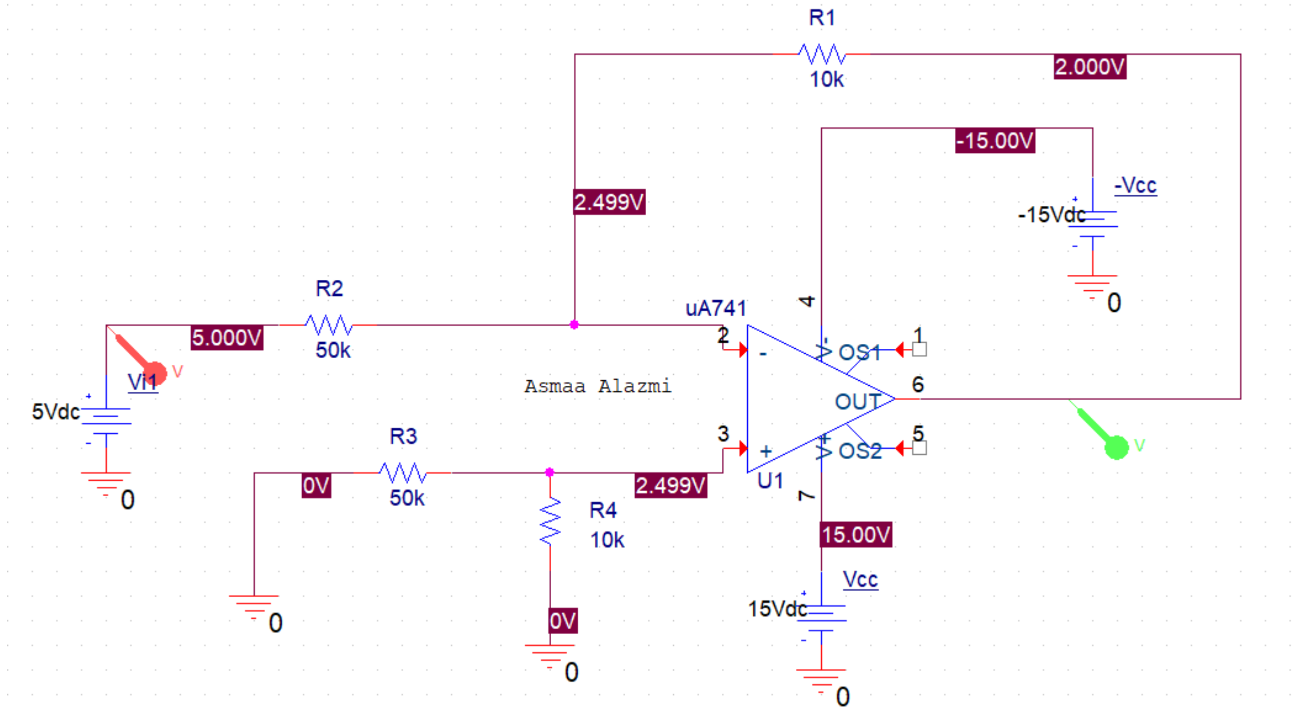

Figure 9 - PART A: Simulated Vi2 Short

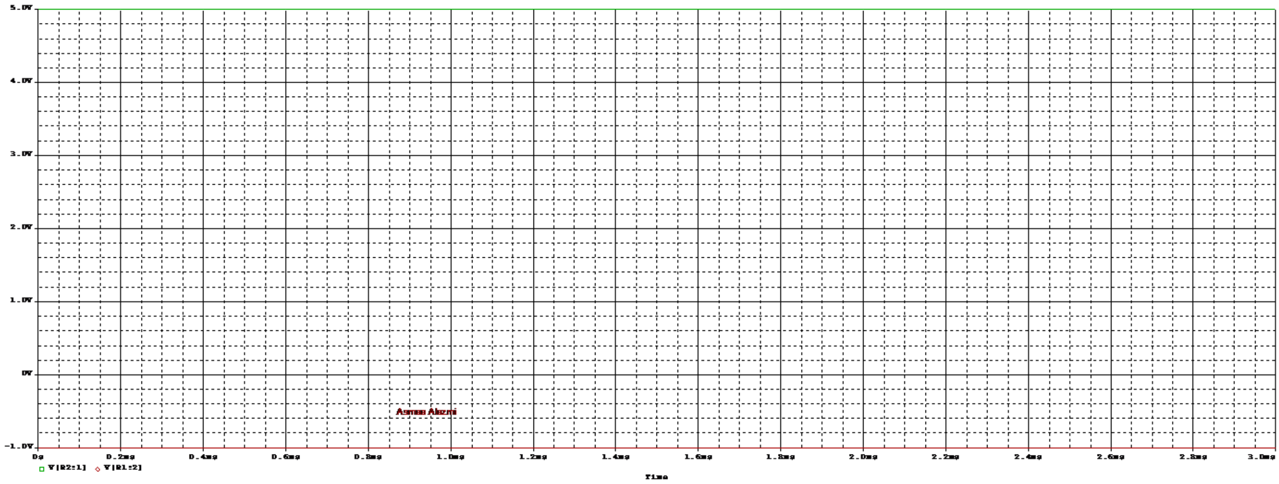

Figure 10 - PART A: Simulated Vo1 Vs Time for Vi2 Short

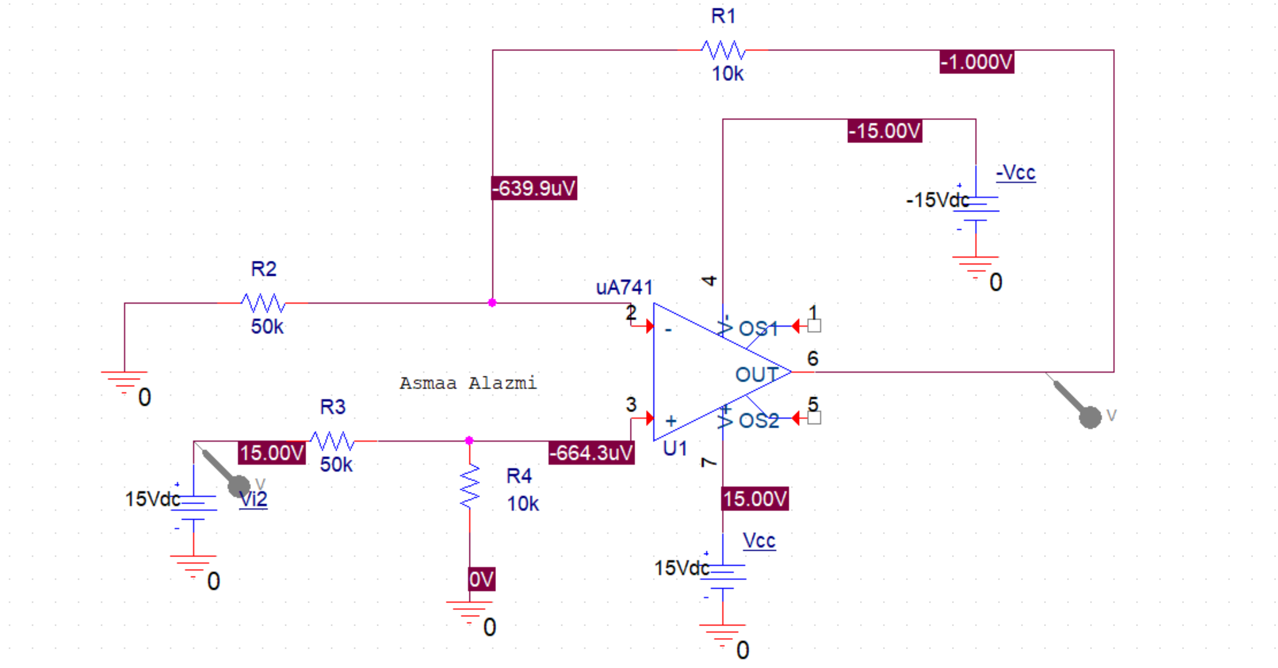

Figure 11 - PART A: Simulated Vi1 Short

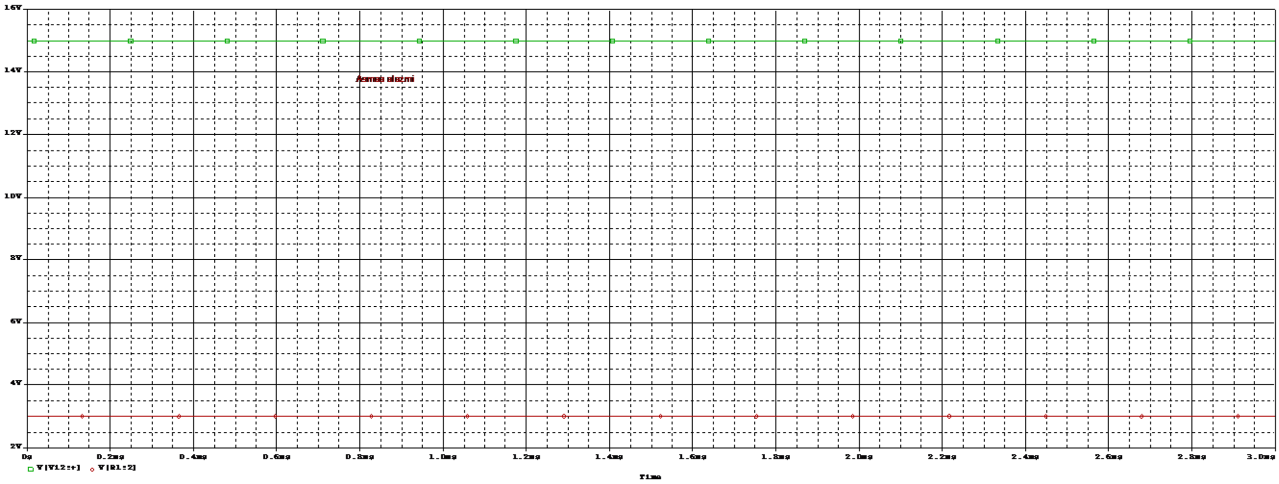

Figure 12 - PART A: Simulated Vo2 Vs Time for Vi1 Short

ii. PART (B): DC Analysis for The Different Op-Amp

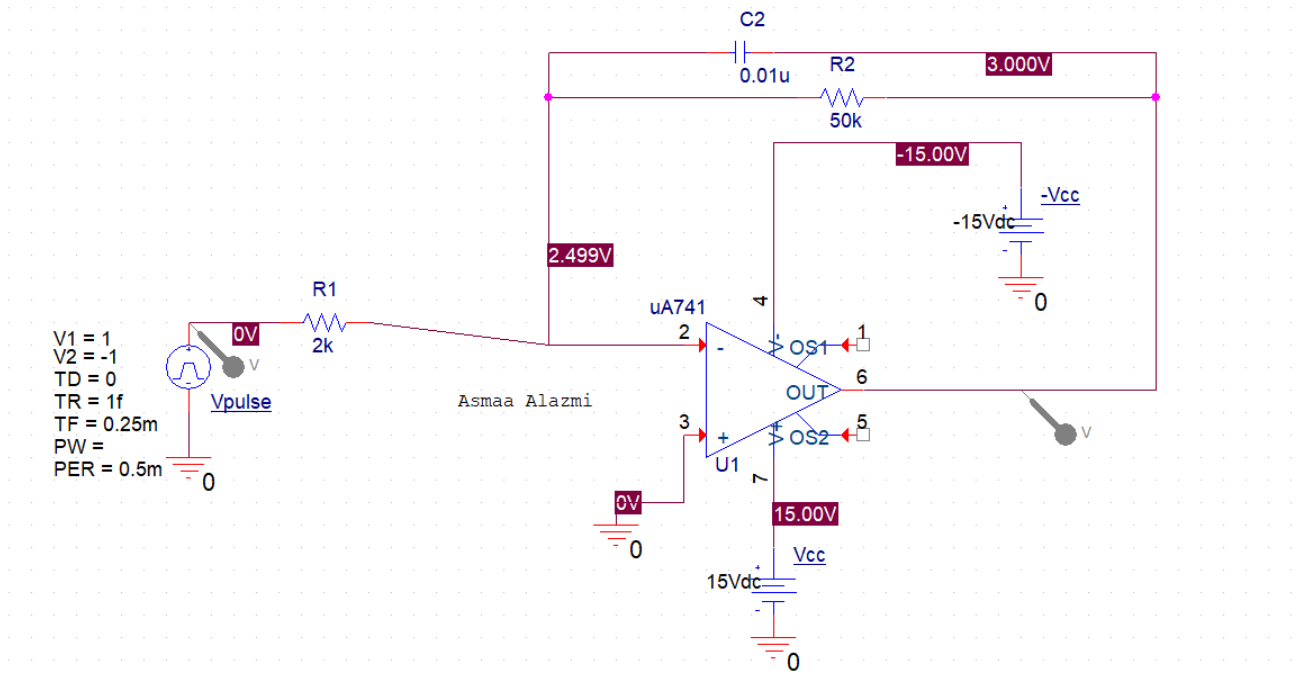

Figure 13 – PART B: Integrator Op-Amp

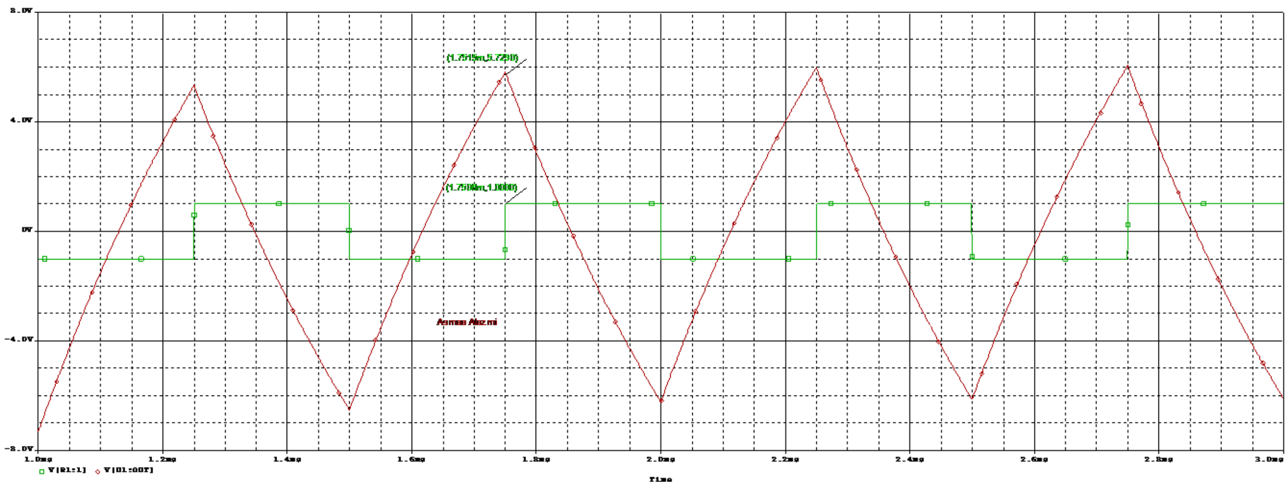

Figure 14 - PART B: Simulated Vi & Vo Vs Time

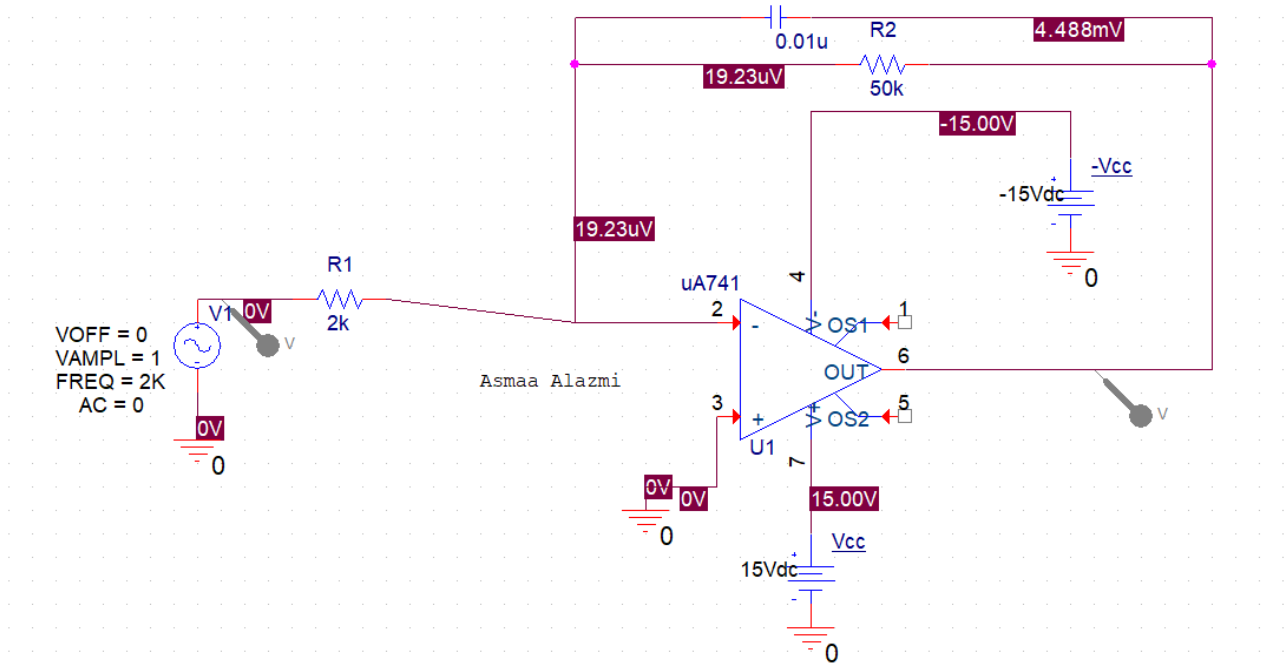

Figure 15 – PART B: Simulate Vi Sin Wave

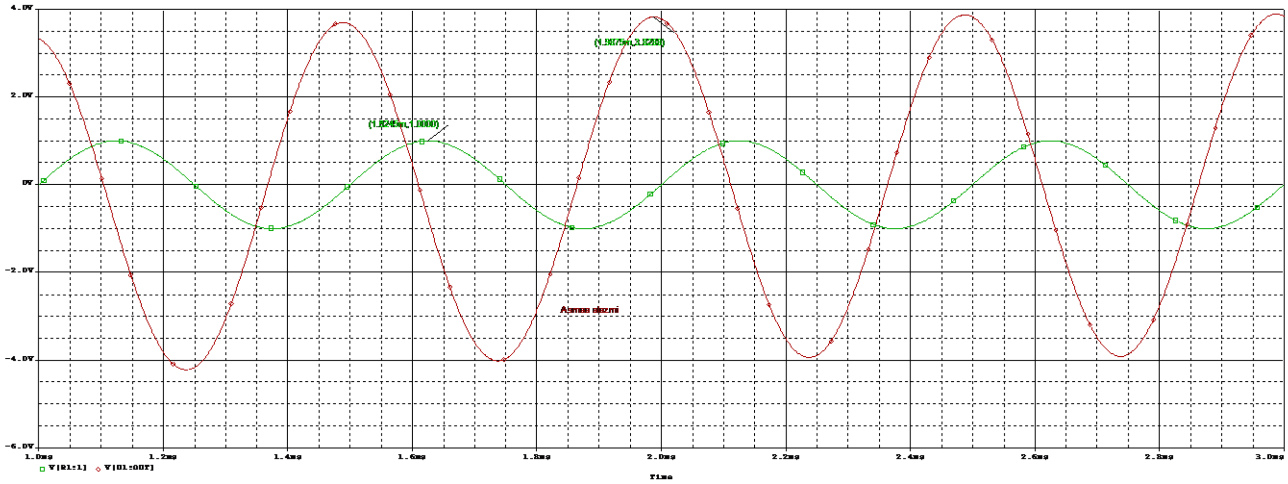

Figure 16 – PART B: Simulate Vi & Vo Vs Time

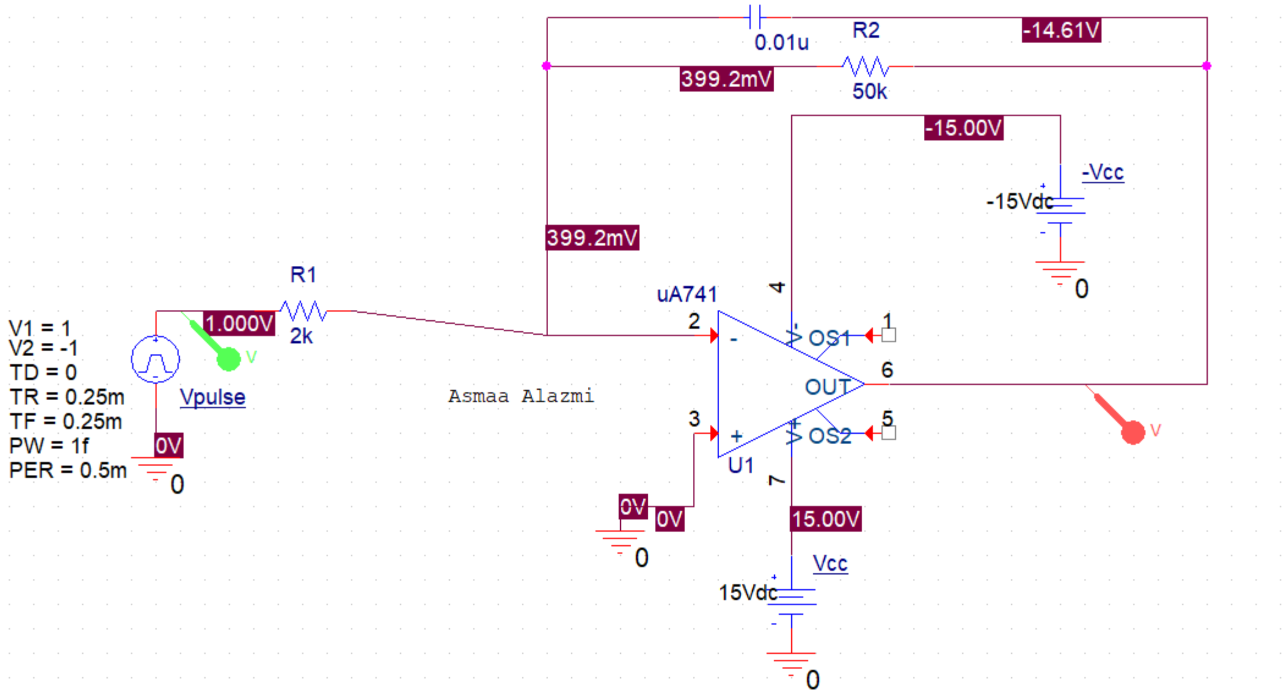

Figure 17 - PART B: Simulate Vi Triangle Wave

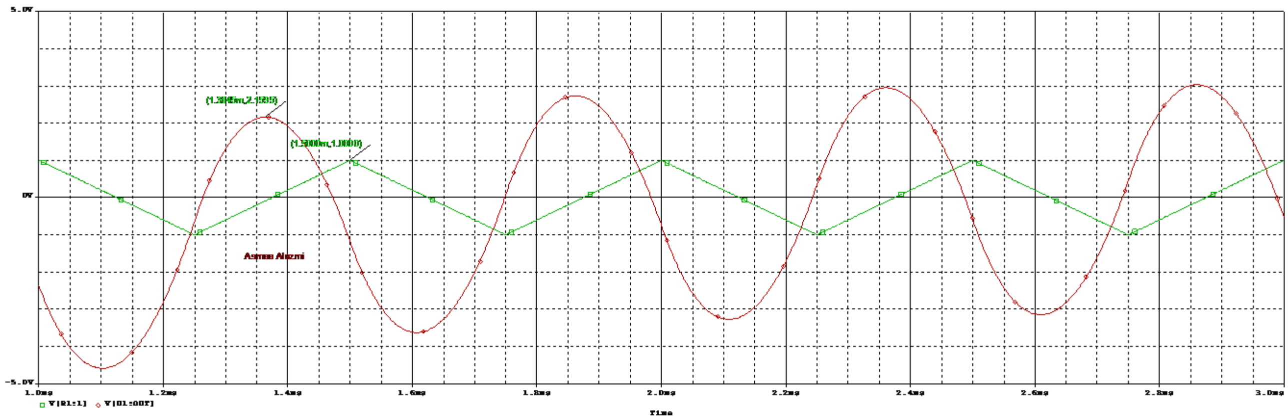

Figure 18– PART B: Simulate Vi & Vo Vs Time

Data & Results

Table 1 - PART A: Results

	P-Spice Simulation	Practical
Fig.7: Vo	1.9999V	2V
Fig.9: Vo1 and Vi1	-1V and 5V	-1V and 5V
Fig.11: Vo2 and Vi2	2.9999V and 15V	3V and 15V

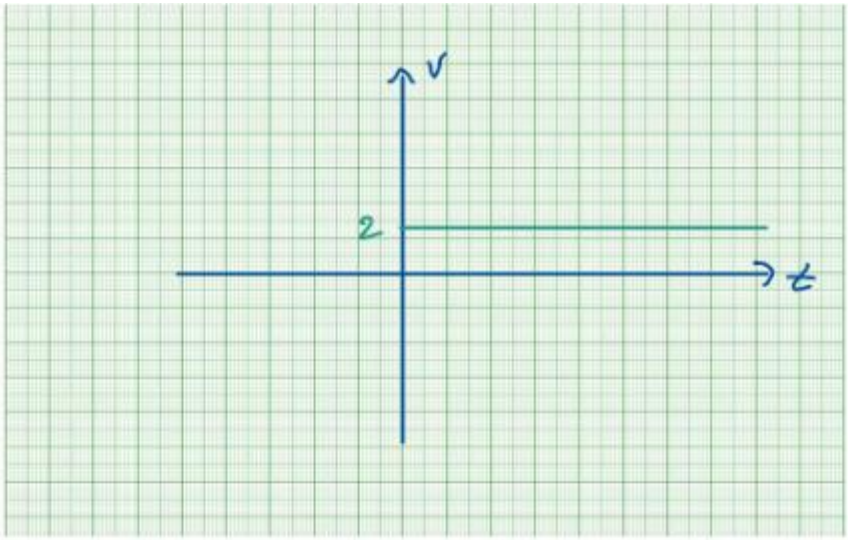

Figure 19 - PART A: Practical Plot 1

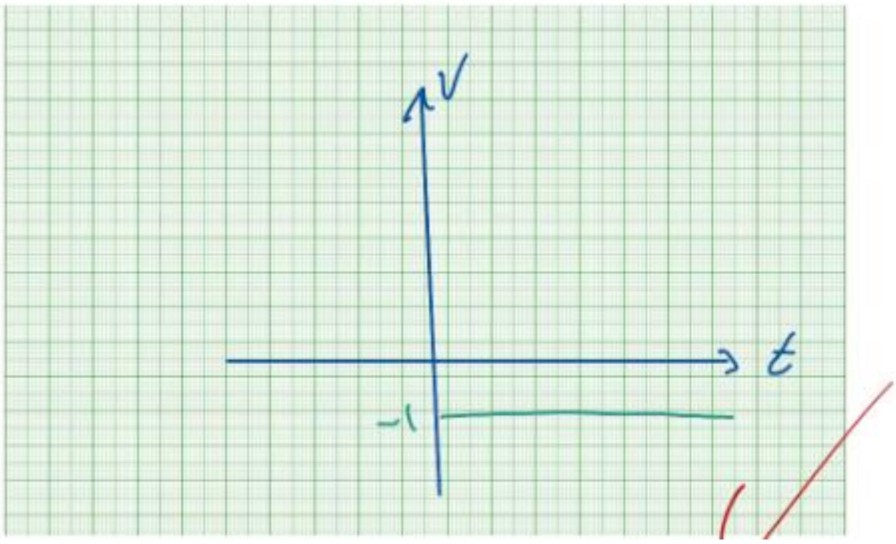

Figure 20 - PART A: Practical Plot 2

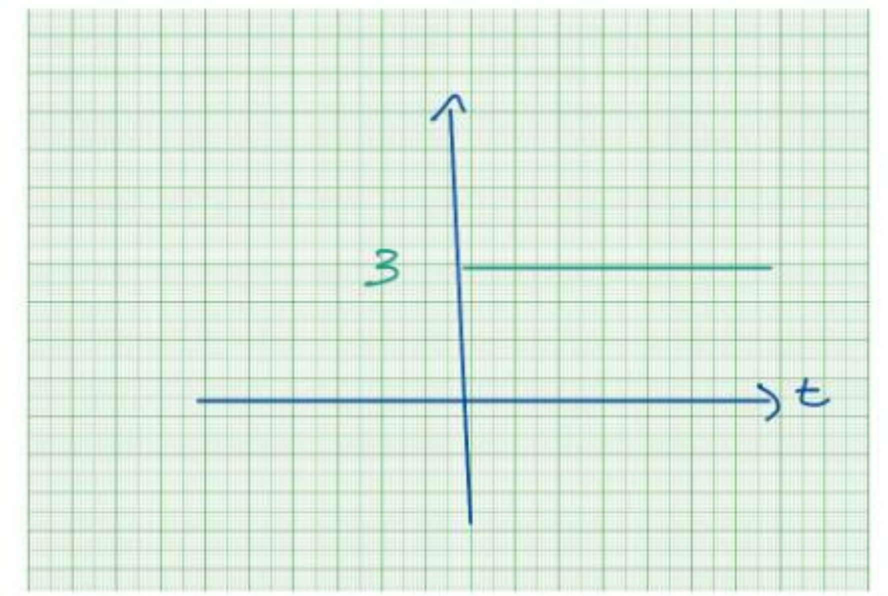

Figure 21 - PART A: Practical Plot 3

Table 2 - PART B: Results

	P-Spice Simulation	Practical
Fig.13: Vi and Vo (p-p)	2V and 11V	2V and 10.6V
Fig.15: Vi and Vo (p-p)	-2V and 6V	-2V and 5.9V
Fig.17: Vi and Vo (p-p)	2V and 6V	1.8 V and 5.6V

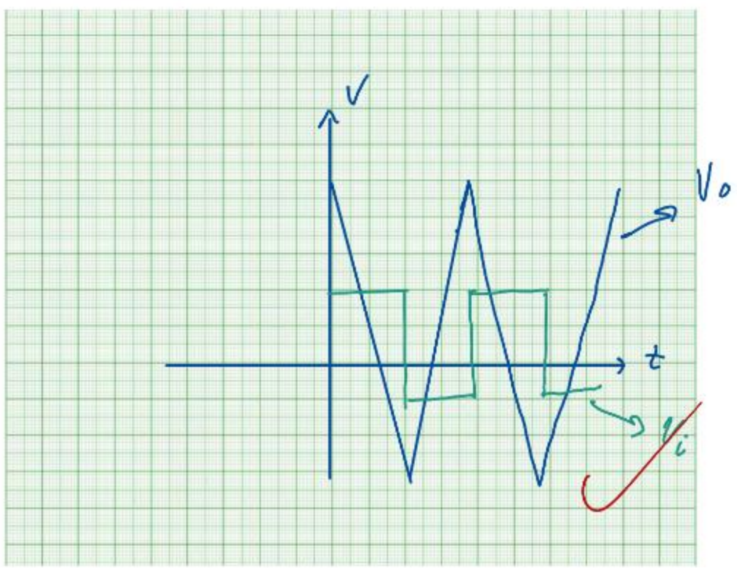

Figure 22 - PART B: Practical Plot 1

- The Slope = $\frac{Delta-v}{Delta-t} = \frac{11}{264u} = 41666.66$

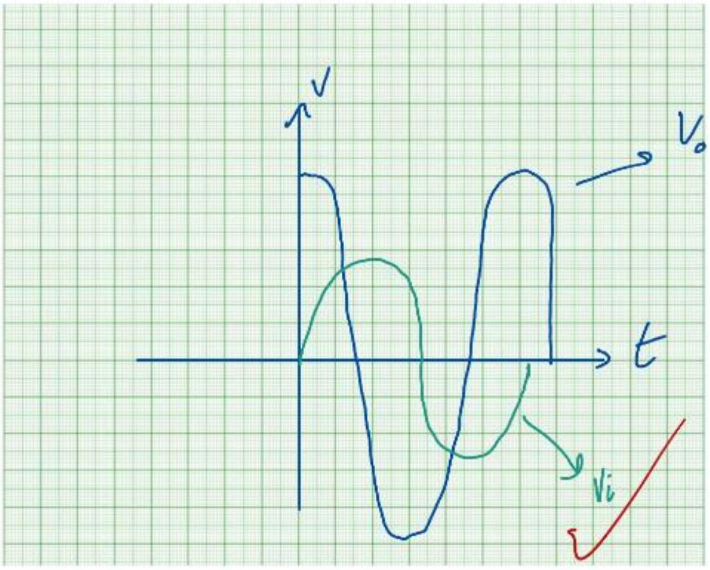

Figure 23- PART B: Practical Plot 2

- Theta (angle) = $\frac{Delta-t}{T} * (360) = \frac{120u}{520u} = 83\ degree$

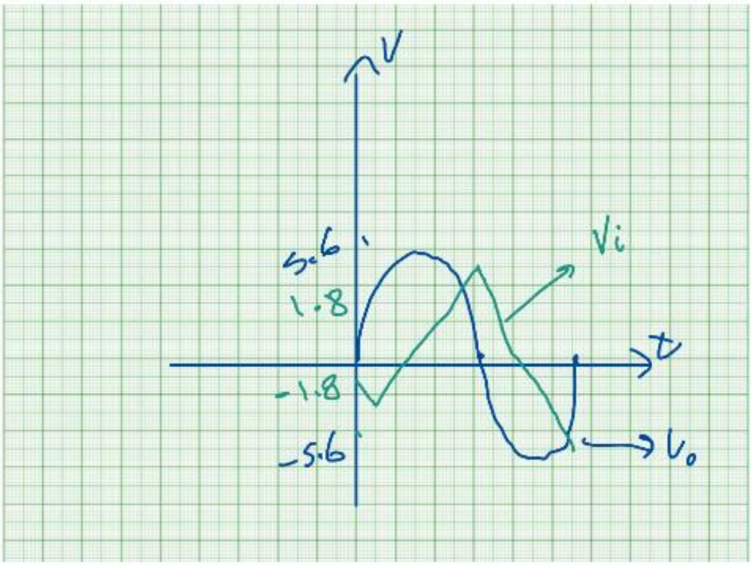

Figure 24- PART B: Practical Plot 3

- Av (voltage gain) = $\frac{Vo}{Vi} = \frac{5.6}{1.8} = 3.111V$

Discussion of Results

The Operational Amplifier II applications showed that the difference op-amp effectively amplifies the difference between two input signals, proving useful in precise signal processing tasks. The integrator op-amp, using sine and triangle waves as inputs, produced cosine and parabolic waves, confirming its function in integration on varying input signals. Both configurations showed stable and predictable behavior, demonstrating their versatility in analog circuit applications.

Conclusion

1- The difference op-amp effectively amplifies the difference between two input signals, making it suitable for applications requiring precise signal differentiation.
2- The integrator op-amp successfully transformed a sine wave input into a cosine wave and a triangle wave input into a parabolic wave, demonstrating its real-time integration capabilities.
3- The stability of both difference and integrator op-amp configurations in various analog circuit applications was confirmed, demonstrating their reliability and versatility.

Questions & Problems

1- Calculate Vo1, Vo2 & Vo theoretically of the circuits in PART A, Fig.5?

Using the difference law:

$$V_{oT} = \frac{R_2}{R_1 * (V_2(+Ve\ input) - V_1(-Ve\ input))}$$

$$Vo = \frac{10K}{50K * (15 - 5)} = 2V$$

Vo1 for Vi1 = Av * Vi1 = $\frac{R_2}{R_1 * V_{i1}} = \frac{-10K}{50K*5} = -1V$

Vo2 for Vi2 = Av * Vix = $\frac{1+R_2}{R_1} * V_x = \frac{1+10K}{50K} * 15\ (\frac{10K}{50K+10k}) = 3V$

$$V_{oT} = 3 - 1 = 2V$$

2- Derive expressions theoretically for the output voltage of the circuits in Fig 6?

$$Vc = \frac{Q}{C}, \qquad Vc = Vx - Vout = 0 - Vout$$

$$so, -\frac{dVout}{dt} = \frac{dQ}{Cdt} = \frac{dQ}{C\,dt}$$

$$Iin = \frac{Vin - 0}{Rin} = \frac{Vin}{Rin}$$

$$I_f = C\frac{dVout}{dt} = C\frac{dQ}{Cdt} = \frac{dVout\,.\,C}{dt}$$

$$I_{in} = I_f = \frac{Vin}{Rin} = \frac{dVout\,.\,C}{dt}$$

$$so, \frac{Vin}{Vout}\,.\,\frac{dt}{Rin\,.\,C} = 1$$

$$Vout = -\frac{1}{Rin\,.\,C}\int_0^t Vin\,dt = -\int_0^t Vin\,.\,\frac{dt}{Rin\,.\,C}$$

References

[1] Wikipedia contributors. (2023, June 27). Differential amplifier. In *Wikipedia, The Free Encyclopedia*. Retrieved from https://en.wikipedia.org/wiki/Differential_amplifier

[2] Electronics Tutorials. (n.d.). *Operational amplifier integrator*. Retrieved June 27, 2024, from https://www.electronics-tutorials.ws/opamp/opamp_6.html

[3] Electronics Tutorials. (n.d.). *Operational amplifier basics*. Retrieved June 27, 2024, from https://www.electronics-tutorials.ws/opamp/opamp_5.html

[4] D. M. Alsaif, "EXPERIMENT # 2: Operational Amplifier II Applications," Kuwait, 2024.

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Lab Report Evaluation Form

Experiment:
Course Number and Title:
Date:
Student Name(s):

Assign a weight (W) for each criterion to be evaluated. Sum of weights is 20.
Rank each criterion by assigning a numerical grade (G) from lowest 1 to highest 5.

Criterion	Weight (W)	Grade (G)	W*G
1. Experiment Title page with student Name and Due date	1	0 1 2 3 4 5	
2. Table of Contents	0.5	0 1 2 3 4 5	
2. Design and setup experiments, conduct and data analysis.			
a. Objectives.	1.5	0 1 2 3 4 5	
b. Theory of Experiment.	*3*	0 1 2 3 4 5	
c. Equipment and Components Used.	*1*	0 1 2 3 4 5	
d. Experimental procedures.	*1*	0 1 2 3 4 5	
e. Experimental Data and Results.	*4*	0 1 2 3 4 5	
f. Solving Discussion	*4*	0 1 2 3 4 5	
g. *Conclusion and Comments*	2	0 1 2 3 4 5	
4. Written Communication.			
a. Structure/Organization/plots.	1	0 1 2 3 4 5	
b. Grammar/Rhetoric.	1	0 1 2 3 4 5	

GRADE = Σ (W* G) = ________ %

Comments: