University of California Merced
School of Engineering
Department of Electrical Engineering

ENGR 065 Circuit Theory

Lab #8: The Operational Amplifier

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Objectives

- To learn how to use an operational amplifier (OpAmp). Three different amplifier circuits will be simulated: an inverting amplifier, a non-inverting amplifier, and a difference amplifier.

- To learn how the component values affect behavior of OpAmp circuits.

- To learn how to simulate amplifier circuits with SPICE.

1. Introduction

An operating amplifier is designed to be used with external feedback elements similar as Resistors and/or Capacitors between it's input and outputs. Op-amps have a wide variety of uses in electronics similar as signal exertion, perform mathematical operations similar as add, subtraction, etc. Currently numerous op-amps are being used in consumer devices. There are three forms of op-amps that we're simulating in today's lab reversing amplifier, non-inverting amplifier and difference amplifier.

2. Methods & Procedures

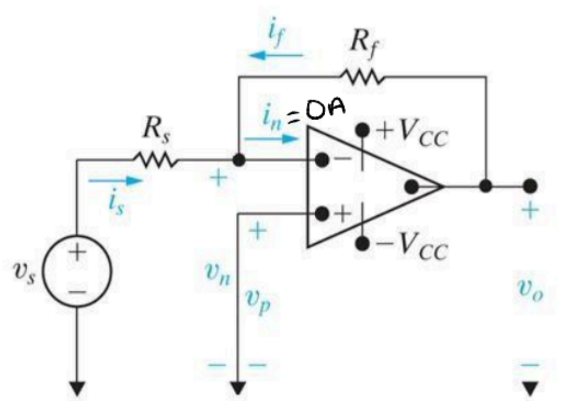
This lab concentrated on the use of an functional amplifier (op-amp) in circuits. The three different forms that were looked at were the flipping amplifier, non-inverting amplifier, and difference amplifier. The values of the circuits were kept fairly alike so that the main change that was detected was in the way that the amplifiers were connected to the circuit. Thus the main thing was for us to observe how the output values of each individual circuit is affected by its structure and element values.

In this lab we were given the task of creating three different circuits, specifically centering on the arrangement of amplifiers within a circuit. The instructions were devoted towards navigating the simulation within the PSPICE environment. Each time making sure to outline what values should be imputed for the resistors, Vdc, Vsin, Voff, Vampl, and so on as required by the circuit arrangement. From there we were instructed to fill in the tables, each time making sure that we changed the values of the circuit to match to the values.

3. Results & Discussion

Part A. The Inverting Amplifier

The first objective of this assignment is to simulate the behavior of the following inverting amplifier circuit:



Variables:

- $v_s = 2V$ is the input voltage source
- v_n = voltage of the inverting terminal
- v_o = output voltage
- V_{cc}=12V is the positive voltage supply
- $-V_{cc}$ is the negative voltage supply
- $R_s = 1k\Omega$ is a resistance connected to v_s
- $R_f = 1k\Omega$ is the "feedback" resistance

Figure 1:

	R_f(kΩ)	0.1	0.5	1	4	6	8	10
Theoretical values (ideal OpAmp assumption)	$v_s(V)$	2V	2V	2V	2V	2V	2V	2V
	v_n (V)	0V	0V	0V	0V	0V	0V	0V
	v_o (V)	-0.2V	-1V	-2V	-8V	-12V	-16V	-20V
	v_o/v_S (gain)	-0.1	-0.5	-1	-2	-3	-4	-5
Simulated values (from SPICE)	$v_s(V)$	2	2	2	2	2	2	2
	v_n (V)	-998μ	-994μ	-989μ	-959μ	-939μ	439m	722m
	v_o (V)	-0.2V	-1	-2	-8	-12	-12	-12
	v_o/v_S (gain)	-0.1	-0.5	-1	-4	-6	-6	-6

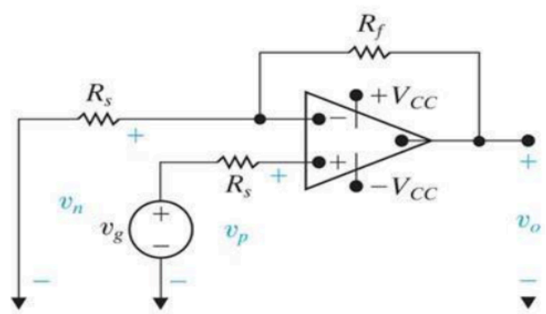
- As we look at the data we can see the Vs stays the same with 2 volts for all of the resistance values. As this is so because it is before any other resistor and so it will not be affected by any of the values. Along with this when the resistor is greater than 6kΩ we can conclude that the voltage is -12v.

	R_f(kΩ)	0.1	0.5	1	4	6	8	10
Theoretical values (ideal OpAmp assumption)	$i_s(mA)$	2mA	2mA	2mA	2mA	2mA	2mA	2mA
	i_f(mA)	-2mA	-2mA	-2mA	-2mA	-2mA	-2mA	-2mA
Simulated Values (from SPICE)	$i_s(mA)$	2mA	2mA	2mA	2mA	2mA	2mA	2mA
	i_f(mA)	-2mA	-2mA	-2mA	-2mA	-2mA	-2mA	-2mA

- So to find the data above the table we used Ohm's Law. Therefore the value of is is constant because both Is and If remain the same.

Part B. The Noninverting Amplifier

The second objective of this assignment is to simulate the behavior of the following noninverting amplifier circuit:



Variables and Values

- $v_g = 2V$ is the input voltage source
- $v_n =$ voltage of the inverting terminal
- v_o is the output voltage
- V_{cc}=12V is the positive voltage supply
- $-V_{cc}$ is the negative voltage supply
- $R_f = 1k\Omega$ is the "feedback" resistance
- $R_s = 1k\Omega$

If the OpAmp is ideal, then the output voltage is $v_o = (1 + \frac{R_f}{R_s})v_g = Kv_g$, where $K = 1 + \frac{R_f}{R_s}$ is the closed-loop gain of the circuit.

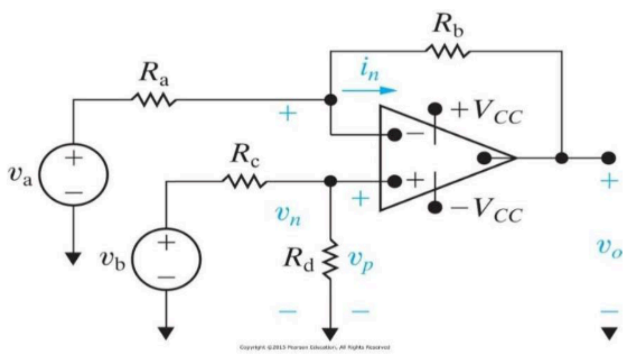
Figure 2:

	R_f(kΩ)	0.1	0.5	1	4	6	8	10
Theoretical values (ideal OpAmp assumption)	v_g (V)	2V	2V	2V	2V	2V	2V	2V
	v_n (V)	0V	0V	0V	0V	0V	0V	0V
	v_o (V)	2.2V	3V	4V	10V	14V	18V	22V
	v_o/v_g (gain)	1.1	1.5	2	5	7	9	11
Simulated values (from SPICE)	v_g (V)	2	2	2	2	2	2	2
	v_n (V)	1.99	1.99	1.99	1.99	1.72	1.34	1.09
	v_o (V)	2.19	2.99	3.99	9.99	12.05	12.05	12.05
	v_o/v_g (gain)	1.095	1.49	1.99	4.95	6.03	6.03	6.03

- We can see that as the Rf increases, the complementary Vo(V) and gain increases as well, whilst the Vg(V) and Vn(V) stay the same.

Part C. The Difference Amplifier

The third objective of this assignment is to simulate the behavior of the following difference-amplifier circuit:



Variables and Values

- $v_a = 1V, v_b = 0.5V$ are the (default) input voltage sources
- v_o is the output voltage
- v_n = voltage of the inverting terminal
- v_p = voltage of the non-inverting terminal
- V_{cc}=12V is the positive voltage supply
- $-V_{cc}$ is the negative voltage supply
- $R_a = R_b = R_c = R_d = 1k\Omega$

Figure 3:

	$v_a(V)$	0.5	0.5	0.5	0.5	0.5	0.5
	$v_b\ (V)$	-0.5	0	0.5	1	5	15
Theoretical values (ideal OpAmp assumption)	$v_n\ (V)$	0.25V	0V	-0.25V	-0.5V	-2.5V	-7.5V
	$v_p\ (V)$	0.25V	0V	-0.25V	-0.5V	-2.5V	-7.5V
	$v_o(V)$	-1V	-0.5V	0V	0.5V	4.5V	14.5V
	$\frac{v_o}{v_b - v_a}$ (Gain)	1	1	1	1	1	1
Simulated values (from SPICE)	$v_n\ (V)$	0.249	0.249	0.249	0.249	0.249	1.53
	$v_p\ (V)$	0.25	0.25	0.25	0.25	0.25	0.25
	$v_o(V)$	0.998	0.498	-2.03	-0.5	-4.5	-11.93
	$\frac{v_o}{v_b - v_a}$ (Gain)	-0.99	-0.99	$\frac{-2.03}{0}$	-1	-1	-0.823

- In this table ,we can see that the Vn(V) and Vp(V) values both match each other in their voltage outputs. Likewise, the Vo(V) follows a pattern of increasing. The G(closed-gain) value stays the same as the voltage increases.

4. Conclusion and Recommendations

- During this lab we learned three different ways of amps inverting amplifier, non-inverting amplifier and difference amplifier. As we observed from the tables in the analysis portion the tables displayed that Vs stayed the same across the circuit due to being not affected by the modification in resistors' value. In table two we noticed that Vg stayed the same across until we reached certain calculations which made the values alter. While completing this lab, it was intriguing to see the different amplifiers interact with the environment (simulated circuit) and give us a new view on how they work.