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EE 316-08
Electric Circuits & Electronics Design Lab

Lab 2: Inverting and Noninverting OP-Amp Circuits

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1. Introduction:

Over the course of this lab, I will introduce and analyze inverting and noninverting Op-Amp configurations for both DC and AC inputs. I will insert both a inverting and noninverting Op-Amp into multisim in the Simulation portion of this lab report. Continually, under the results and discussions section, I will examine closed loop voltage gains and the effects load resistances have on output voltage. This data will come straight from the simulations, however the simulations will not cover every instance of my findings and just an example.

2. Theoretical Analysis:

2.1 Operation Amplifiers:

Op-Amps for short, are devices tasked with amplifying input voltage. They are designed to be used with external feedback components such as resistors and capacitors between its output and input terminals. They consist of 3 of these terminals, 2 input and out output. The inputs and outputs are typically read in voltages, so we will limit our discussion to just voltages. The outputs signal is the difference between the signals being applied to its two individual inputs.

2.2 Inverting Op-Amp:

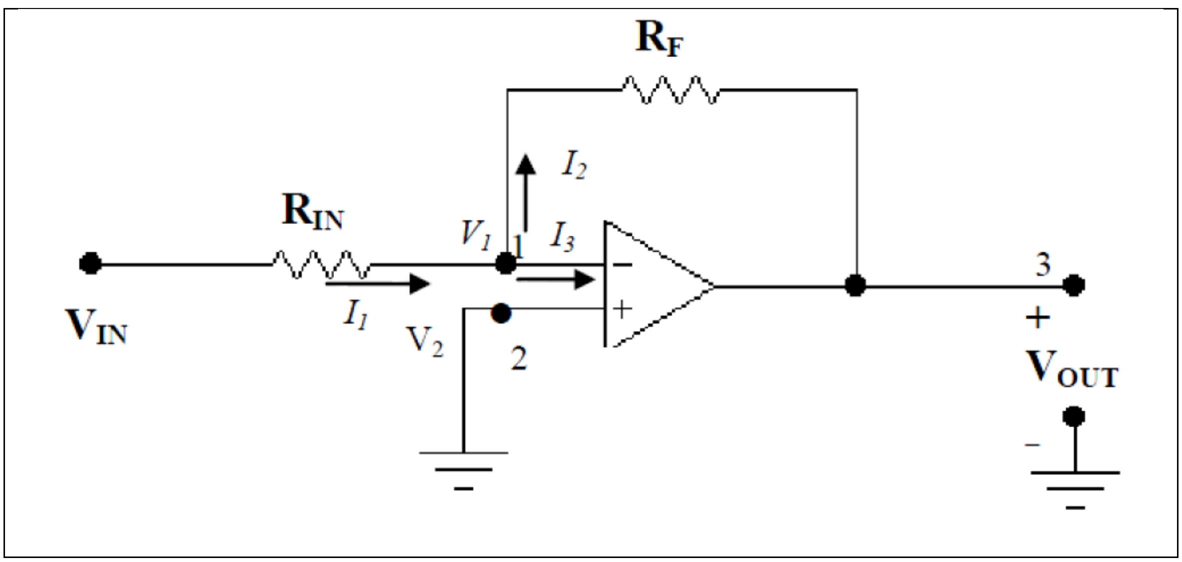


Figure 1: Inverting Amplifier

These inverting amplifiers receive feedback from the output. If they're ideal, the voltage at the inverting terminal is equal to the non-inverting terminal. The difference between the two input terminals is very small. The voltage gain formula is shown below:

$$\boxed{G = \frac{V_{OUT}}{V_{IN}} = \frac{-R_F}{R_{IN}}}$$

2.3 Non-Inverting Op-Amp:

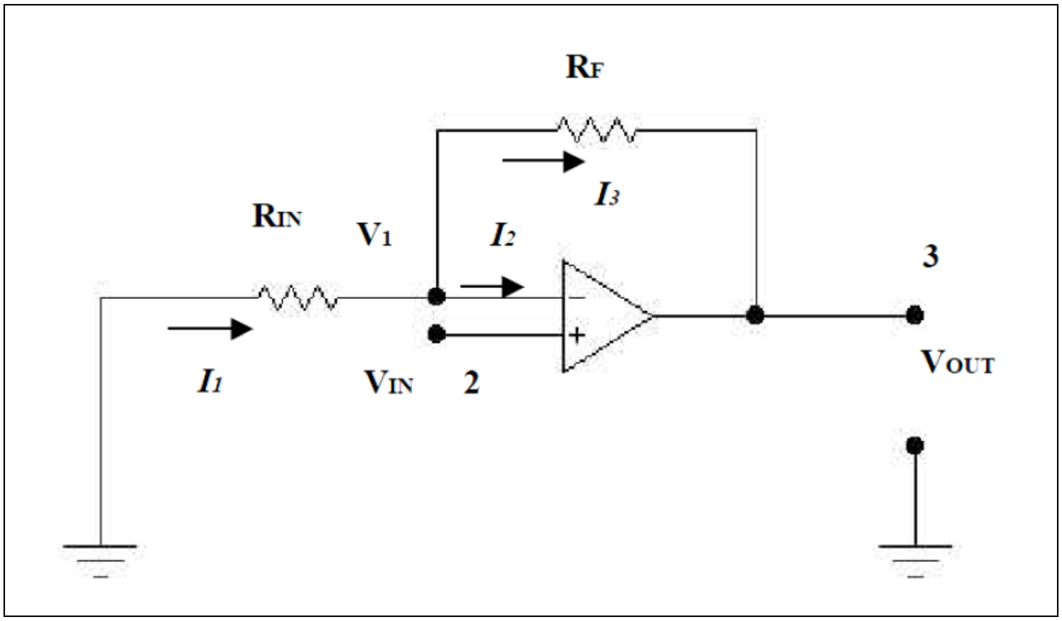


Figure 2: Non-inverting Op-Amp

On the other hand, a Non-inverting Op-Amps' output is in phase with respect to the input in which the feedback is applied at the inverting input. The gain of a non-inverting amplifier is high and the formula is shown below:

$$\boxed{G = \frac{V_{OUT}}{V_{IN}} = 1 + \frac{R_F}{R_{IN}}}$$

3. Simulations:

I will now show the Multisim implementation of figures one and two.

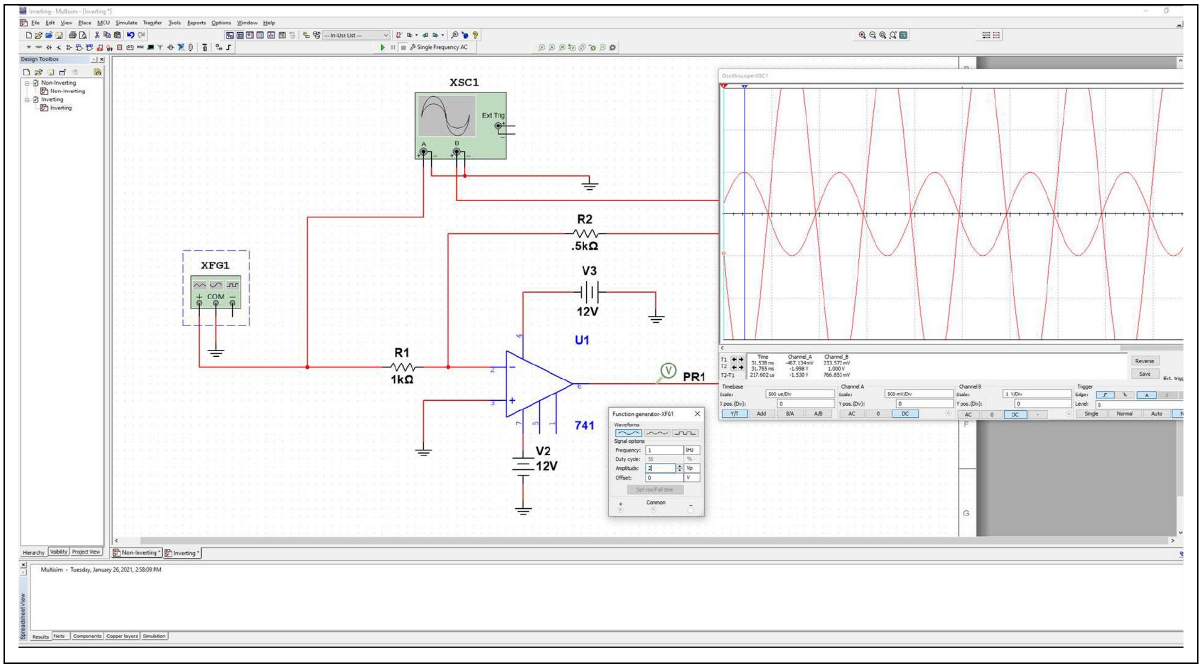


Figure 3: Figure 1 in Multisim with Oscilloscope readings (INVERTING)

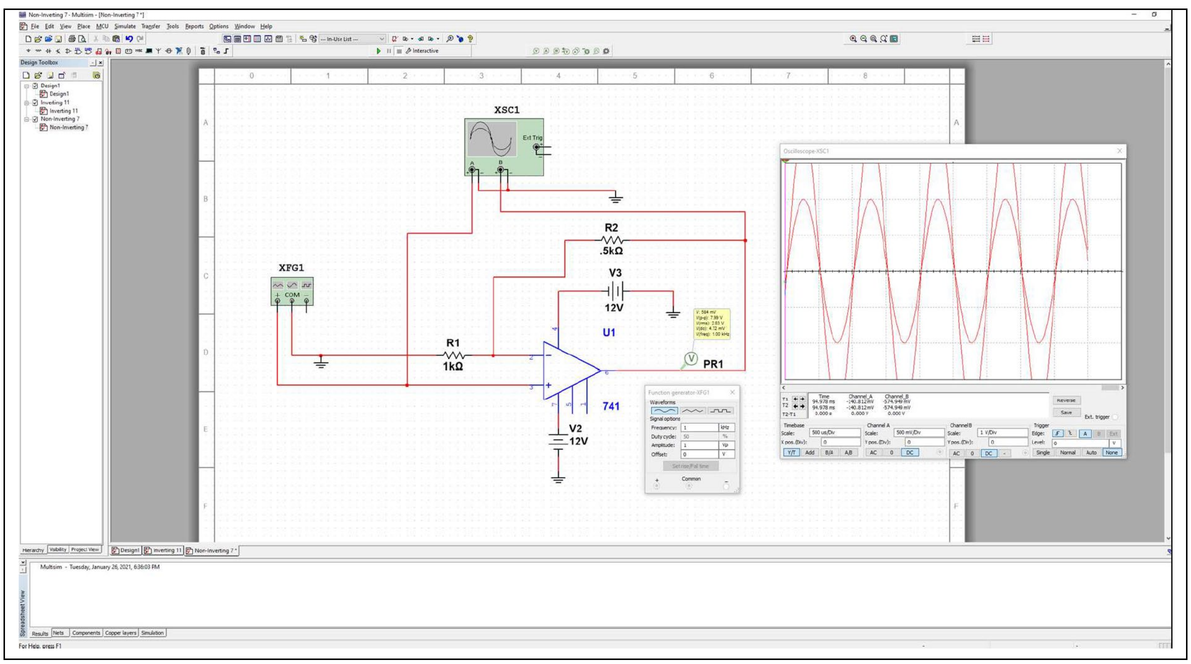
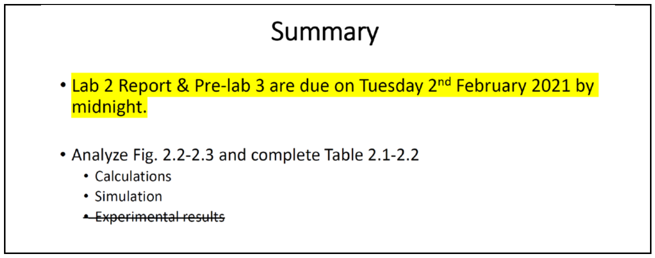


Figure 4: Figure 3 in Multisim with oscilloscope readings (NON-INVERTING)

As you can see in both, I have attached a Oscilloscope to monitor the inputs and outputs on channels A and B respectively. The function generator (XFG1) is also put into place to provide input on both terminals.

~~4. Experimental:~~

We were not instructed to provide experimental results for this lab, see the following screenshot.



5. Results and Discussion:

I will now discuss my findings from multisim for both non-inverting and inverting configurations of Op-Amps. Up first is the Inverting configuration,

Vin (V)	Rin(kOhm)	Rf (kOhm)	Vout (V) Oscilloscope	Gain V/v	Vout (v) Volt Meter
2	1	0.5	1	-0.5	0.354
2	1	1	2	-1	0.707
2	1	2	4	-2	1.41
2	1	3	6	-3	2.12
2	1	4	8	-4	2.83

Table 1: Results from Figure 2 in Multisim (Inverting configuration, effects of load resistors on output voltage)

Vin (V)	Rin(kOhm)	Rf (kOhm)	Vout (V) Oscilloscope	Gain V/v	Vout (v) Volt Meter
2	1	0.5	3	1.5	1.06
2	1	1	4	2	1.41
2	1	2	6	3	2.12
2	1	3	8	4	2.83
2	1	4	10	5	3.54

Table 2: Results from Figure 4 in Multisim (Non-Inverting configuration, effects of load resistors on output voltage)

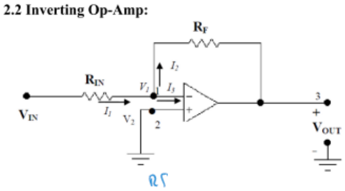
6. Conclusion:

In conclusion, this lab helped me to better understand the purpose and functionality of Op-Amps. It was very interesting to see how it all worked, and especially the waveforms in the oscilloscope. Continually, it was helpful to understand how the different measurements were taken in Multisim and took some time to set up properly. Overall, this lab was very useful in applying and furthering my knowledge of Op-Amps.

7. Appendix:

Let R_{IN} = 1 kΩ, R_F = 0.5, 1, 2, 3 and 4 kΩ, and the input voltage be a 2 V_{pp} (2 volt peak-to-peak) sinusoidal waveform at 1kHz frequency.

2.2 Inverting Op-Amp:



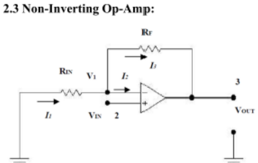
$V_{IN_{pp}}$ (V)	R_{IN} (kΩ)	R_F (kΩ)	$V_{OUT_{pp}}$ (V) O-scope	Gain (V/V)	$V_{OUT_{rms}}$ (V) DMM
2	1	0.5	1	-0.5	.353
		1	2	-1	.706
		2	4	-2	1.402
		3	6	-3	2.118
		4	8	-4	2.824

Gain $(-{}^{RF}/_{Rin})$	Vout-O-Scope $(Vin \cdot G)$	Vout-Dmm $(\frac{1}{2\sqrt{2}} \cdot VoutPP)$
$G = \frac{-0.5}{1} = -0.5\ V/V$	$V_{outpp} = \lvert -.5 \times 2 \rvert = 1\ V$	$\frac{1}{2\sqrt{2}} = 0.353(1) = .353\ V$
$G = \frac{-1}{1} = -1\ V/V$	$V_{outpp} = \lvert -1 \times 2 \rvert = 2\ V$	$.353 \times 2 = .706\ V$
$G = \frac{-2}{1} = -2\ V/V$	$V_{outpp} = \lvert -2 \times 2 \rvert = 4\ V$	$.353 \times 4 = 1.402\ V$
$G = \frac{-3}{1} = -3\ V/V$	$V_{outpp} = \lvert -3 \times 2 \rvert = 6\ V$	$.353 \times 6 = 2.118\ V$
$G = -\frac{4}{1} = -4\ V/V$	$V_{outpp} = \lvert -4 \times 2 \rvert = 8\ V$	$.353 \times 8 = 2.824\ V$

Figure A1: Hand calculations for solving Figure 1.

Let R_{IN} = 1 kΩ, R_F = 0.5, 1, 2, 3 and 4 kΩ, and the input voltage be a 2 V_{pp} (2 volt peak-to-peak) sinusoidal waveform at 1kHz frequency.

2.3 Non-Inverting Op-Amp:



$V_{IN_{pp}}$ (V)	R_{IN} (kΩ)	R_F (kΩ)	$V_{OUT_{pp}}$ (V) O-scope	Gain (V/V)	$V_{OUT_{rms}}$ (V) DMM
2	1	0.5	3	1.5	1.059
		1	4	2	1.412
		2	6	3	2.118
		3	8	4	2.842
		4	10	5	3.53

Gain $(1 + {}^{RF}/_{Rin})$	Vout-O-Scope $(Vin \cdot G)$	Vout-Dmm $(\frac{1}{2\sqrt{2}} \cdot VoutPP)$
$G = 1 + \frac{.5}{1} = 1.5\ V/V$	$Vout = 2 \times 1.5 = 3\ V$	$Vout = .353 \times 3 = 1.059\ V$
$G = 1 + \frac{1}{1} = 2\ V/V$	$Vout = 2 \times 2 = 4\ V$	$Vout = .353 \times 4 = 1.412\ V$
$G = 1 + \frac{2}{1} = 3\ V/V$	$Vout = 2 \times 3 = 6\ V$	$Vout = .353 \times 6 = 2.118\ V$
$G = 1 + \frac{3}{1} = 4\ V/V$	$Vout = 2 \times 4 = 8\ V$	$Vout = .353 \times 8 = 2.824\ V$
$G = 1 + \frac{4}{1} = 5\ V/V$	$Vout = 2 \times 5 = 10\ V$	$Vout = .353 \times 10 = 3.53\ V$

Figure A2: Hand calculations for solving Figure 2.