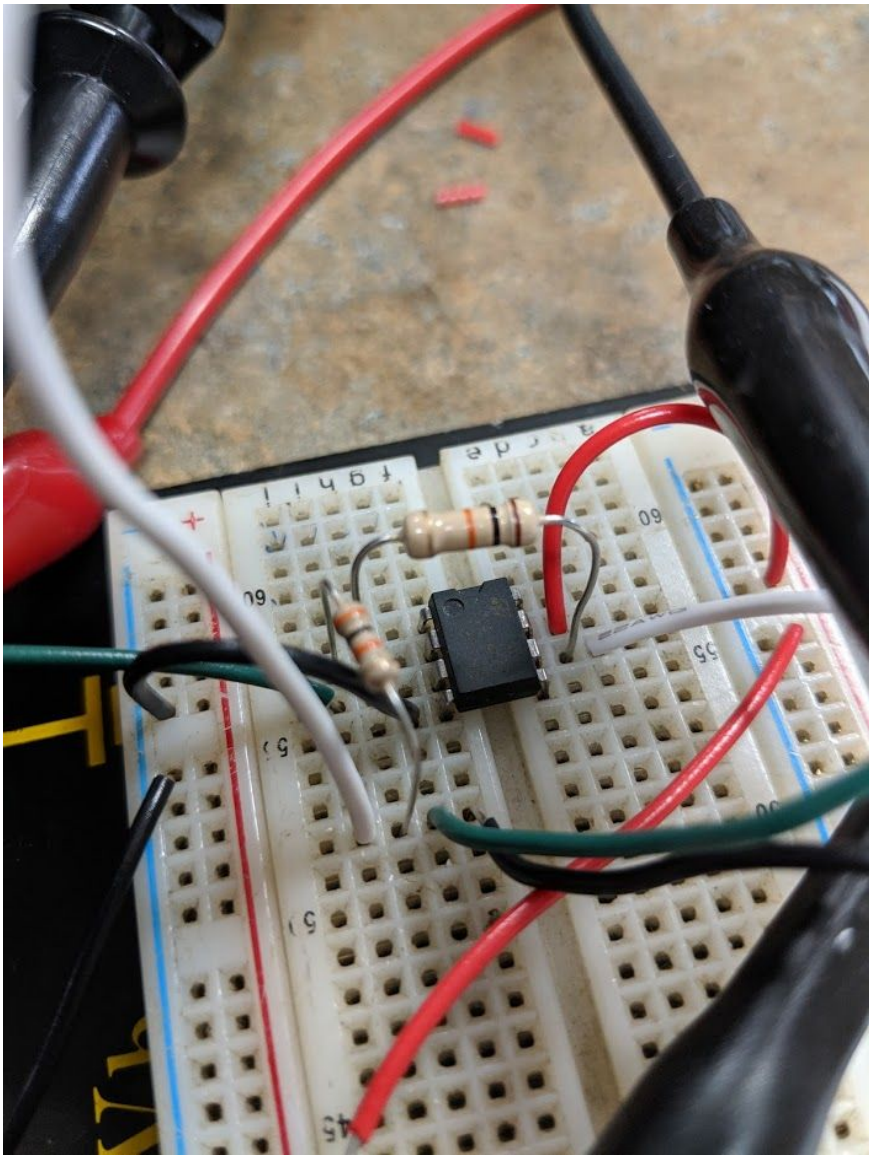
Lab 27

Operational Amplifiers



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Objectives:

The objectives of this lab were to verify experimentally that the gain of an OP AMP can only be made dependent on the external negative feedback loop from the input to the output. Use the op amp as a noninverting amplifier and an inverting summer.

Materials:

- Oscilloscope
- Power supply
- Function generator
- Digital multimeter
- 4 SPST switches
- 741C semiconductor chip
- Two 10K □ resistors

Procedure:

1. To begin this lab a circuit was constructed as shown in Figure 1, where R_1 was set to 10000Ω. The sign wave generator was set to 1000 Hz, and we increased the amplitude of the wave until distortion was seen on the output of the op-amp. The amplitude just before distortion was reached was measured on the oscilloscope, and used as the input voltage. This input voltage was recorded in Table 1 and 6. The output voltage was also measured and placed in Table 1 and 6. The phase shift between the two waves was recorded in the table. This was repeated for each value of R_1 in the tables. The gain was then calculated for each resistor value.
2. Next, the circuit shown in Figure 2 was constructed, where R_1 was set to 10000Ω. We performed the exact same steps that were performed in Step 1, and recorded all of our data in Table 2 and 7.
3. Next, we built the circuit shown in Figure 3. Each 1.5V power supply was in turn removed from the circuit, while the other was replaced in the circuit, and the output voltage value was measured, as shown in Table 3. The "X" value represents which power supply was disabled. Then, both power supplies were put into the circuit, and the output voltage was measured in Table 3 and 8. Next, one of the 1.5V input voltages was inverted and the output voltage was also measured and recorded in Table 3 and 8.
4. The next step was to build a summer with the same two input voltages that would produce a -4.5V output. This was done by replacing R_3 in Figure 3 with a 15kΩ resistor as shown in Figure 4. The values were recorded in the same fashion as step 3 and can be seen in Table 4 and 9.
5. The next step was to build a summer with the same two input voltages that would produce a +1.5V output. This was done by replacing R_3 in Figure 3 with a 5kΩ resistor and inverting the terminals of the output as shown in Figure 5. The values were recorded in the same fashion as step 3 and can be seen in Table 5 and 10.

Table 1: Gain of Inverting Op-amp (Real)					
Resistance Ω		Voltage V p-p		Gain (V_{out}/V_{in})	Phase shift of output compared to input
R_2	R_1	Output	Input		
10,000	10,000	-12.40	12.40	-1.00	180°
	5,100	-12.10	6.20	-1.95	180°
	3,300	-11.80	3.80	-3.11	180°
	20,000	-12.80	25.00	-0.51	180°
	30,000	-8.50	27.00	-0.31	180°

Table 2: Non-Inverting Op-amp (Real)					
Resistance Ω		Voltage Vp-p		Gain (V_{out}/V_{in})	Phase shift of output compared to input
R_2	R_1	Output	Input		
10,000	30,000	15.00	11.00	1.36	0°
	20,000	15.00	9.70	1.54	0°
	10,000	15.00	7.50	2.00	0°
	5,100	15.00	5.00	3.00	0°
	3,300	14.00	3.50	4.00	0°

Table 3: Op-amp as a Summer with -3V Output (Real)						
Condition		Input Polarity		V_{in}		V_{out}
S_3	S_4	V_1	V_2	V_1	V_2	
ON	OFF	+	X	1.50	X	-1.46
OFF	ON	X	+	X	1.50	-1.58
ON	ON	+	+	1.50	1.50	-3.04
ON	ON	-	+	1.50	1.50	.11

Table 4: Op-amp as a Summer with -4V Output (Real)						
Condition		Input Polarity		V_{in}		V_{out}
S_3	S_4	V_1	V_2	V_1	V_2	
ON	OFF	+	X	1.50	X	-2.34
OFF	ON	X	+	X	1.50	-2.31
ON	ON	+	+	1.50	1.50	-4.66
ON	ON	-	+	1.50	1.50	.06

Table 5: Op-amp as a Summer with 1.5V Output (Real)						
Condition		Input Polarity		V_{in}		V_{out}
S_3	S_4	V_1	V_2	V_1	V_2	
ON	OFF	+	X	1.50	X	+.80
OFF	ON	X	+	X	1.50	+.78
ON	ON	+	+	1.50	1.50	+1.58
ON	ON	-	+	1.50	1.50	.02

Table 6: Gain of Inverting Op-amp (Multisim)					
Resistance Ω		Voltage V p-p		Gain (V_{out}/V_{in})	Phase shift of output compared to input
R_2	R_1	Output	Input		
10,000	30,000	-15.84	49.40	-0.32	180°
	20,000	-15.81	32.80	-0.48	180°
	10,000	-15.88	16.60	-0.96	180°
	5,100	-15.86	8.20	-1.93	180°
	3,300	-15.83	5.40	-2.93	180°

Table 7: Non-Inverting Op-amp (Multisim)					
Resistance Ω		Voltage Vp-p		Gain (V_{out}/V_{in})	Phase shift of output compared to input
R_2	R_1	Output	Input		
10,000	30,000	15.99	12.4	1.29	0°
	20,000	15.90	10.8	1.47	0°
	10,000	15.83	8	1.98	0°
	5,100	15.79	5.4	2.92	0°
	3,300	15.83	4	3.96	0°

Table 8: Op-amp as a Summer with -3V Output (Multisim)						
Condition		Input Polarity		V_{in}		V_{out}
S_3	S_4	V_1	V_2	V_1	V_2	
ON	OFF	+	X	1.50	X	-1.50
OFF	ON	X	+	X	1.50	-1.50
ON	ON	+	+	1.50	1.50	-3.00
ON	ON	-	+	1.50	1.50	0.00

Table 9: Op-amp as a Summer with -4.5V Output (Multisim)						
Condition		Input Polarity		V_{in}		V_{out}
S_3	S_4	V_1	V_2	V_1	V_2	
ON	OFF	+	X	1.50	X	-2.26
OFF	ON	X	+	X	1.50	-2.24
ON	ON	+	+	1.50	1.50	-4.49
ON	ON	-	+	1.50	1.50	0.00

Table 10: Op-amp as a Summer with 1.5V Output (Multisim)						
Condition		Input Polarity		V_{in}		V_{out}
S_3	S_4	V_1	V_2	V_1	V_2	
ON	OFF	+	X	1.50V	X	0.747
OFF	ON	X	+	X	1.50	0.747
ON	ON	+	+	1.50	1.50	1.497
ON	ON	-	+	1.50	1.50	0.00

Questions:

1. Does the maximum undistorted sine-wave output of the op amp vary with amplifier gain?Refer to the experimental data to confirm your answer.

No. The maximum undistorted sine-wave output is based on the input voltages applied to the op-amp. The max positive sine-wave peak is usually very close to the applied voltage, and the minimum peak voltage is usually very close to the applied negative voltage.

2. What is the relationship, if any, between the polarity of the output and input voltages in your experimental op amp? Refer to your data.

The output is positive when the sine-wave input is placed on the noninverting input of the op-amp, while the output is negative when the sine-wave is placed on the inverting input of the op-amp.

3. What is the relationship, if any, between experimental inverting amplifier gain and R_F and R_R?

As the resistance of R_R increases the inverted gain decreases as shown in table 1 and 2.

4. Does the data in table 1 bear out the gain formula $-(R_F/R_R)$ in each case? Show your computations.

Yes, using the formula and substituting in each value gets you the proper gain each time.

5. Does the data in table bear out the same formula for non-inverting amplifier in each case?

Yes, when using the formula $1+(R_F/R_R)$

6. In which procedural step was the summer operated as a subtractor.

The summer operated as a subtractor when one input is positive and the other is negative.

Discussion:

For the first experiment, the function generator we were using was unable to reach a peak to peak voltage that would cause the output of the opamp to clip, so we created an amplifier from an op-amp and used that as the input for the other opamp circuit, allowing us to reach much higher voltages that would cause the second op-amp to clip.

Conclusion:

A Op-amp is dependent on the external negative feedback loop from the output to the input since based on the lab results in Tables 1 and 2, as the resistance values of R_1 and R_2 are changed, the gain is directly impacted by a value according to the ratio R_2 / R_1. The op-amp can also be used as a non-Inverting amplifier as shown in Table 2. The gain of the amplifier can be found using the formula: $1+(R_2/R_1)$. A summer was also built in Figures 3, 4, and 5 where the two input voltages were added together and multiplied by a factor of the ratio R_3/R_1 or R_3/R_2.

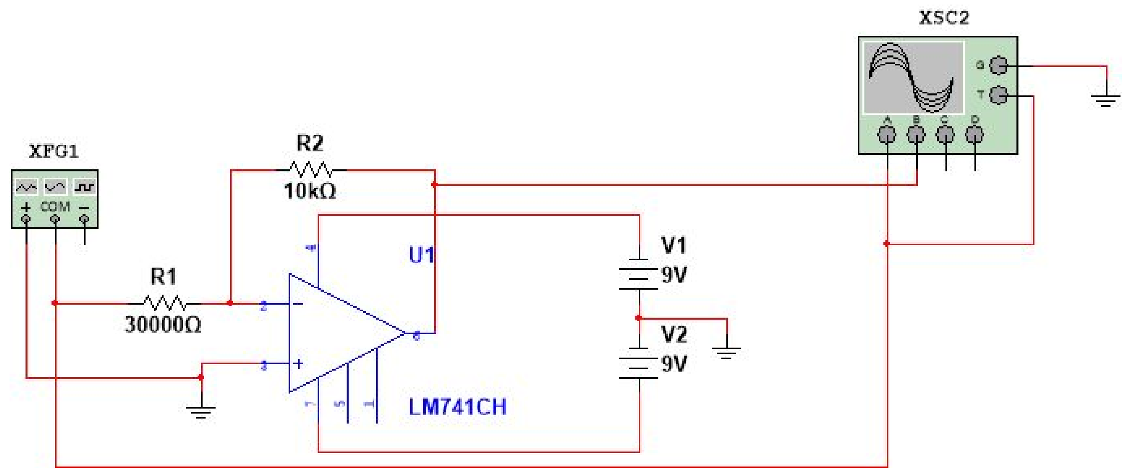

Figure 1: Inverting Op-amp Circuit

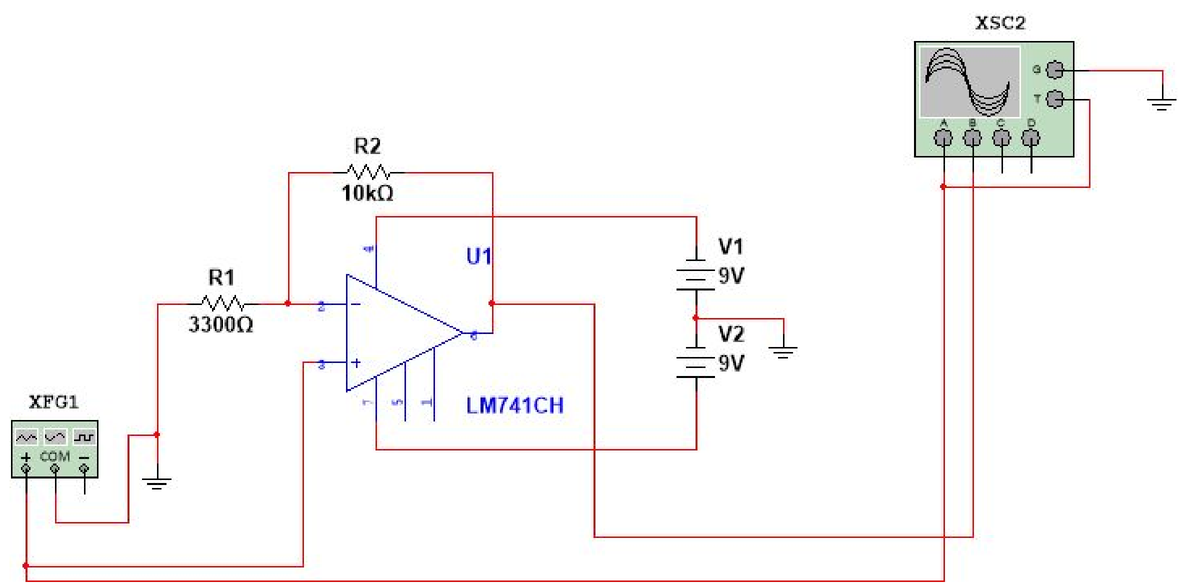

Figure 2: Non-Inverting Op-amp Circuit

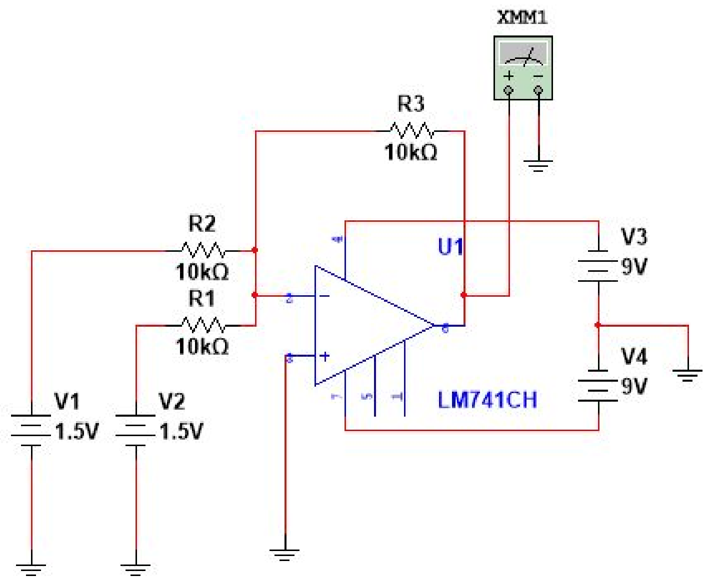

Figure 3: Op-amp as a Summer with -3V Output

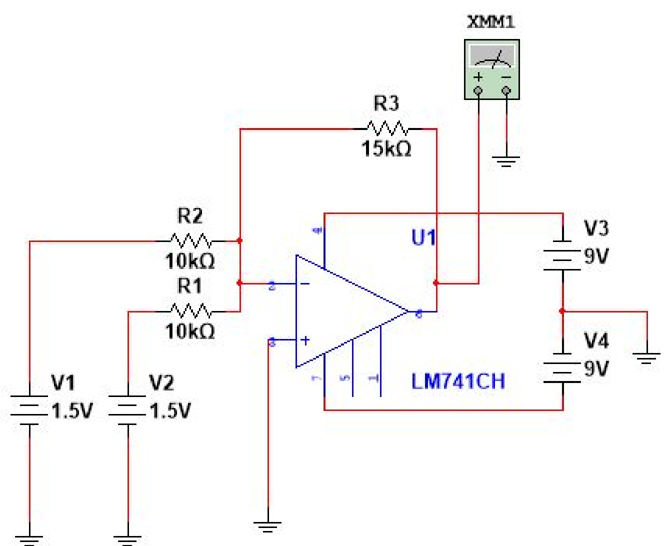

Figure 4: Op-amp as a Summer with -4.5V Output

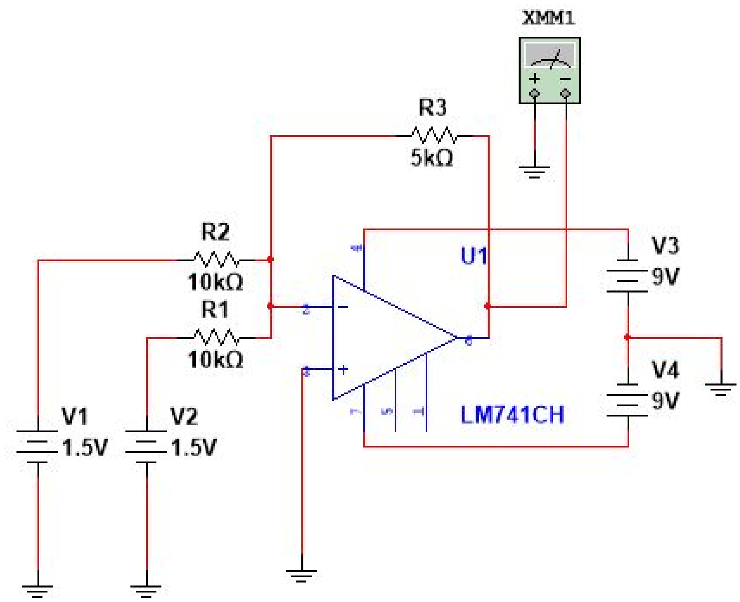

Figure 5: Op-amp as a Summer with 1.5V Output