Kirchhoff's Laws Applied To Op Amps

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Abstract

In this lab we are utilizing two Op Amp circuits in inverting and noninverting configurations. We are aiming to compare these circuits performances over a range of input voltages in hardware to analytically calculated values for the same circuit. This exercise aims to give experience with using basic Op Amp circuits, applying Kirchhoff's Laws and analyzing results of an experiment.

Equipment

- Extech EX330
- GWINSTEK GPE-3323 Serial: GER901895
- 56, 100, 120 kΩ Resistors
- Inverting, and Non-Inverting Op Amp Discovery circuit board

Procedure

1. Begin by setting up the power supply such that there is a voltage range being supplied between -15 v to +15 v.
2. The circuit board being used has diodes to ensure proper current flow. These diodes have a voltage drop the will effect the voltage range. Record the actual V_{cc-} and V_{cc+} by turn the potentiometer all the way counterclockwise for the minimum voltage supplied and clockwise for the maximum voltage supplied. Measure this value at the V_s pin relative to the Measurements Common.

Part 1:

1. Measure the actual resistances of R_{in} and R_{load}.
2. Measure the actual resistance of the feedback resistor, R_f, and attach this to the terminal block on the circuit board.
3. Begin by setting the input voltage, V_s, to 1 v and measure the output voltage, V_{out}.
4. Continue varying the input voltage between the values of -4 v and +4 v and record the voltage at V_{in-} and V_{out}. Calculate A_v and compare to the gain found in the previous step.
5. Adjust the potentiometer such that 1 v is being supplied. Measure the voltage and current passing through the 3k Ω load resistor

Part 2:

6. Perform steps 1 - 5 utilizing the non inverting Op Amp circuit utilizing a 56 kΩ resistor.
7. Perform steps 1 - 5 utilizing the non inverting Op Amp circuit with a 100 kΩ resistor.

Part 3:

8. Using the ideal op Amp model solve for the closed loop gain of the Op Amp circuits as shown in the following two circuits

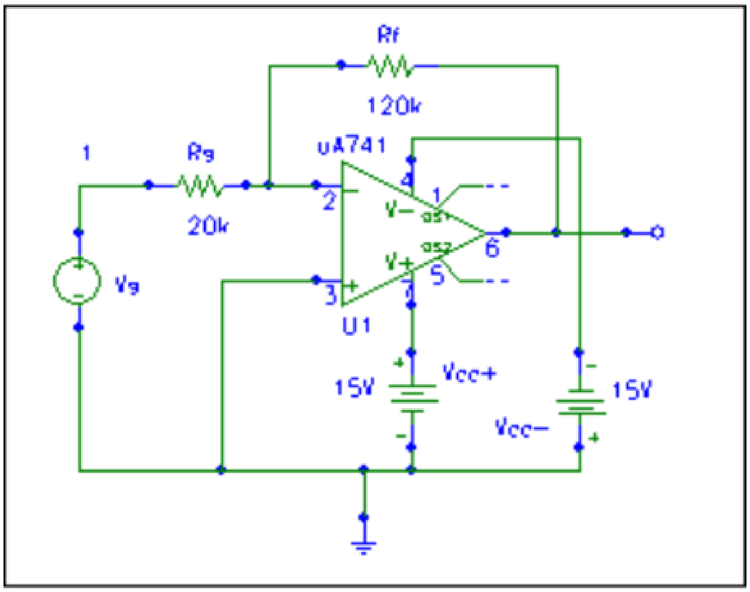


Figure A4

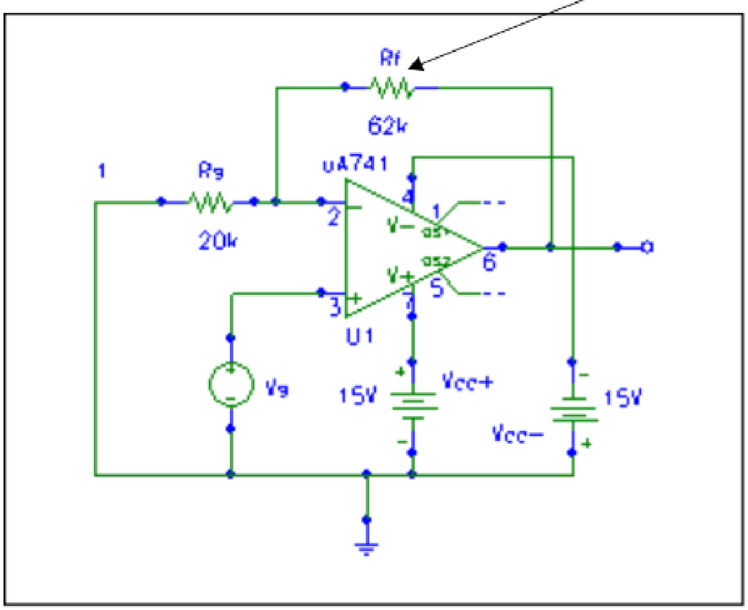


Figure A5

Measurements

Part 1:

Actual $R_{in} = 19.85k\Omega$ Actual $R_{load} = 2.958k\Omega$

Nominal $R_f = 120k\Omega$ Measured $R_f = 117.9k\Omega$

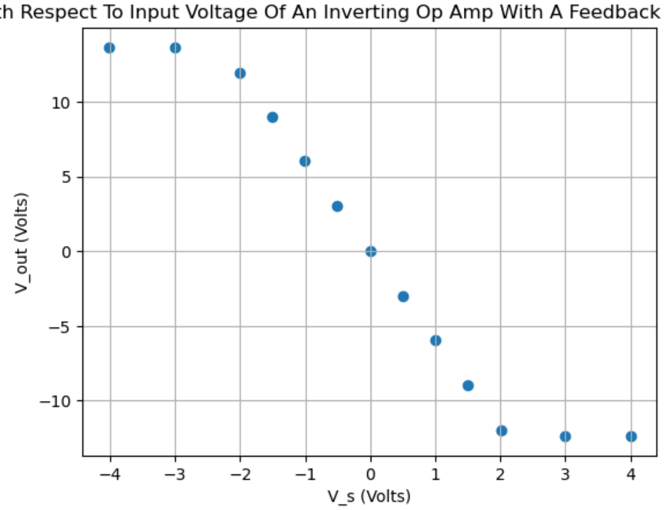
Actual $V_{cc-} = -14.42v$ Actual $V_{cc+} = 14.36v$

$V_s = 1.008v$ $V_{out} = -5.99v$

$V_{load} = -5.96v$ $I_{load} = -2.03mA$

V_s Target (Volts)	V_s Actual (Volts)	V_in- (volts)	V_out (Volts)	A_v = V_out/V_s
-4	-4.02	-1.477	13.65	-3.39552238806
-3	-3.008	-0.614	13.65	-4.53789893617
-2	-2	0	11.94	-5.97
-1.5	-1.503	0	9	-5.988023952096
-1	-1.007	0	6.03	-5.988083416087
-0.5	-0.504	0	3.006	-5.964285714286
0	-0.0008	0	0.0029	-3.625
0.5	0.508	0	-3.011	-5.927165354331
1	1.001	0	-5.95	-5.944055944056
1.5	1.502	0	-8.94	-5.95206391478
2	2.01	0	-11.97	-5.955223880597
3	2.999	0.792	-12.35	-4.118039346449
4	4	1.648	-12.35	-3.0875

Output Voltage With Respect To Input Voltage Of An Inverting Op Amp With A Feedback Resistor Of 117,900 Ohms



Part 2.1:

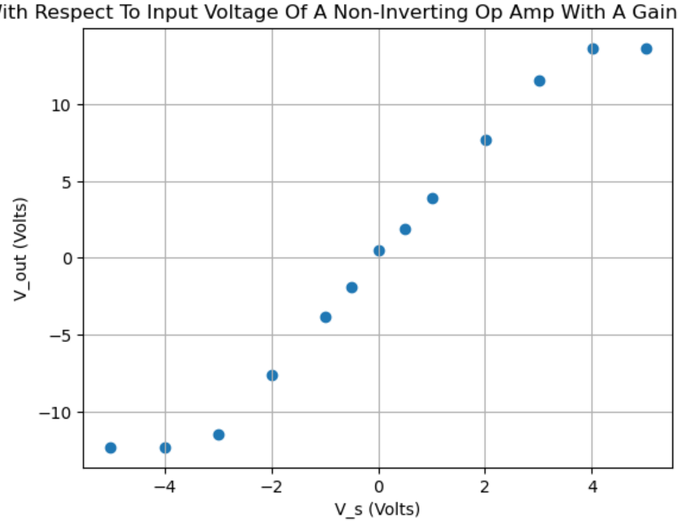
Actual $R_g = 19.7k\Omega$ Actual $R_{load} = 2.962k\Omega$

Nominal $R_f = 56k\Omega$ Measured $R_f = 55.7k\Omega$

Actual $V_{cc-} = -14.40v$ Actual $V_{cc+} = 14.37v$

V_s Target (Volts)	V_s Actual (Volts)	V_in- (volts)	V_out (Volts)	A_v = V_out/V_s
-5	-5.02	-3.214	-12.31	2.4521912350598
-4	-4	-3.215	-12.32	3.08
-3	-3.001	-3.001	-11.48	3.8253915361546
-2	-2	-1.999	-7.62	3.81
-1	-0.995	-0.995	-3.8	3.8190954773869
-0.5	-0.496	-0.496	-1.893	3.8165322580645
0	0.0008	0.0009	0.47	587.5
0.5	0.5	0.5	1.918	3.836
1	1.006	1.007	3.86	3.8369781312127
2	2.003	2.005	7.67	3.8292561158263
3	3.005	3.007	11.51	3.8302828618968
4	4.02	3.56	13.65	3.3955223880597
5	5.01	3.56	13.65	2.7245508982036

Output Voltage With Respect To Input Voltage Of A Non-Inverting Op Amp With A Gain Resistor of 55,700 Ohms

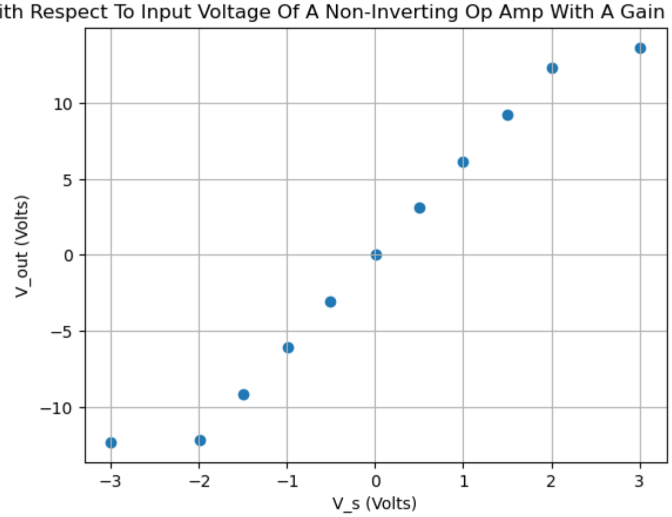


Part 2.2:

Nominal $R_f = 100k\Omega$ Measured $R_f = 100.4k\Omega$

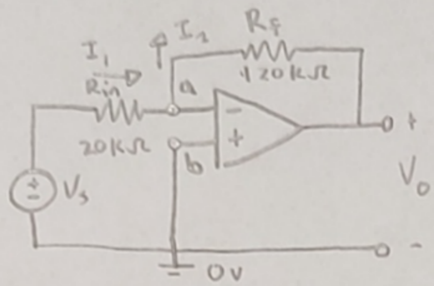
V_s Target (Volts)	V_s Actual (Volts)	V_in- (volts)	V_out (Volts)	A_v = V_out/V_s
-3	-3.001	-2.014	-12.33	4.1086304565145
-2	-1.995	-1.994	-12.19	6.1102756892231
-1.5	-1.501	-1.5	-9.17	6.1092604930047
-1	-0.996	-0.996	-6.08	6.1044176706827
-0.5	-0.506	-0.506	-3.086	6.098814229249
0	0.004	0.0049	0.035	8.75
0.5	0.505	0.506	3.102	6.1425742574258
1	0.999	1	6.12	6.1261261261261
1.5	1.502	1.304	9.2	6.1251664447404
2	2.008	2.01	12.3	6.1254980079681
3	3.007	2.23	13.66	4.5427336215497

Output Voltage With Respect To Input Voltage Of A Non-Inverting Op Amp With A Gain Resistor of 100,400 Ohms



Part 3:

Fig. A4



$V_a = V_b = 0V$

@ a) $\left(\frac{V_s - 0V}{20k\Omega} = \frac{0 - V_o}{120k\Omega}\right) 120k\Omega$

$6V_s = -V_o \rightarrow \boxed{V_o = -6V_s}$

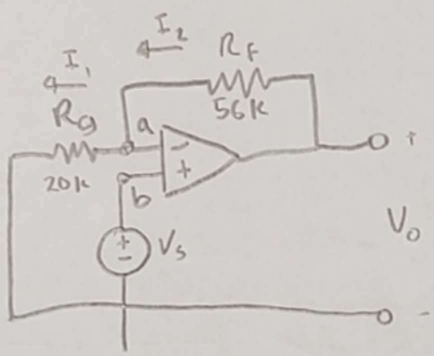
or $\frac{V_o}{V_s} = -\frac{R_f}{R_{in}}$

$\downarrow$

$V_o = -\frac{120k\Omega}{20k\Omega}V_s$

$\boxed{V_o = -6V_s}$

Fig. A5



$V_a = V_b = V_s$

@ a) $\left(\frac{V_a - 0}{20k\Omega} = \frac{V_o - V_a}{56k\Omega}\right) 560k\Omega$

$28V_a = 10V_o - 10V_a$

$10V_o = 38V_a$

$V_o = 3.8V_a \rightarrow \boxed{V_o = 3.8V_s}$

or $\frac{V_o}{V_s} = 1 + \frac{R_f}{R_g}$

$V_o = V_s\left(1 + \frac{56k\Omega}{20k\Omega}\right)$

$\boxed{V_o = 3.8V_s}$

Figure A4 is the analytical model of the circuit tested in part 1. The gain found through testing is approximately -5.958, while the analytical model predicts a gain of -6.

Figure A5 is the analytical model of the circuit tested in part 2. The gain found through testing is approximately 3.825, while the analytical model predicts a gain of 3.8.

The discrepancies in these measurements may have occurred due to several factors - variance of actual resistance in the input and feedback resistors or resistance stemming from the wires themselves.

Conclusion

In this lab we tested two Op Amp circuits, one inverting and one non inverting, for the voltage output measured based on variable voltage inputs. From this we were able to compare our actual values to the predicted values. What we found was that the actual Op Amps performed with an average discrepancy of .058 for the inverting op amp and .025 volts for the non inverting op amp circuits. When graphed we were able to see that as the input voltage reached a target positive voltage or a target negative voltage the op amp reaches saturation and the output voltage remains at the level for any additional increase for the positive or decrease for the negative input voltages.