GEBZE TECHNICAL UNIVERSITY

ELECTRONICS ENGINEERING DEPARTMENT

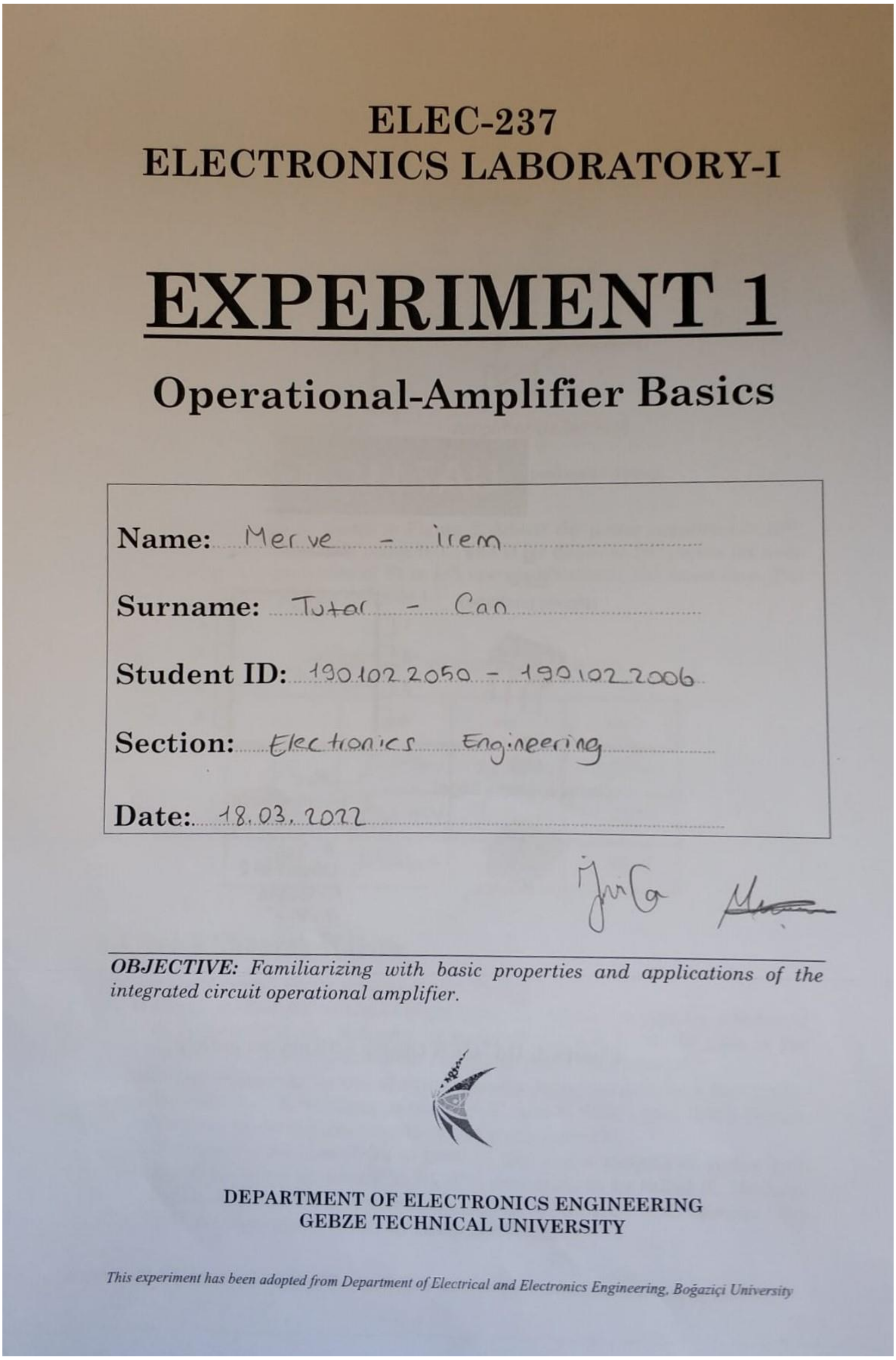
ELEC 237

EXPERIMENT – 1 REPORT

PREPARED BY

IREM CAN	1901022006
MERVE TUTAR	1901022050

INGREDIENTS



ELEC-237
ELECTRONICS LABORATORY-I

EXPERIMENT 1

Operational-Amplifier Basics

Name: Merve - irem

Surname: Tutar - Can

Student ID: 1901022050 - 1901022006

Section: Electronics Engineering

Date: 18.03.2022

OBJECTIVE: Familiarizing with basic properties and applications of the integrated circuit operational amplifier.

DEPARTMENT OF ELECTRONICS ENGINEERING
GEBZE TECHNICAL UNIVERSITY

This experiment has been adopted from Department of Electrical and Electronics Engineering, Boğaziçi University

Figure 1. Cover page of the leaflet

1. Introduction

Inverting and non-inverting of an op-amp in this experiment conditions were examined. Each of these circuits contains an operational amplifier. Op Amp circuits are integrated circuits with very high signal amplification power, used to increase the functionality of electronic circuits. They are fed with DC (direct current) and provide current and voltage gain. Accordingly, they also perform power amplification and impedance conversion tasks.

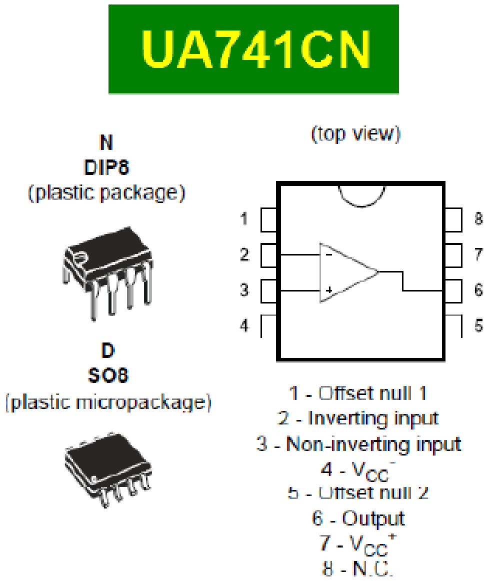


Figure 3. UA741CN Opamp with pin connections.

1. Experiment

2.1. The Inverting Amplifier

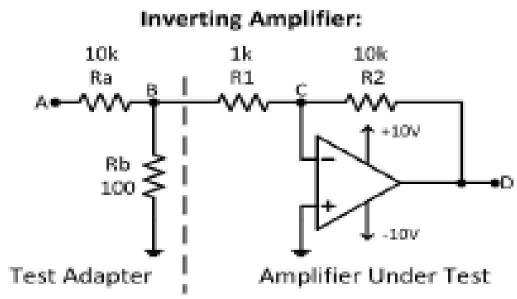


Figure 4. Inverting Amplifier experiment setup.

Figure 4. (inverting amplifier);

- ⇨ The non-inverting input terminal is connected directly to ground. This means that we have 0 V at the non-inverting terminal and at the inverting terminal.
- ⇨ VIN is applied to R_1 and generates a current of V_{IN}/R_1 flowing toward the inverting input terminal.
- ⇨ Since assume that current cannot flow into the input terminal, all that current travels around the op-amp and flows to the output node through R_2. The voltage drop across R_2 will be $V_{IN}R_2/R_1$.
- ⇨ The left side of R_2 is at 0V, and since current is flowing from left to right, the voltage on the right side of R_2 must be lower than the voltage on the left side. Thus, the voltage at the output node will be 0V minus the voltage drop across R_2: $V_{OUT} = 0 – VINR_2/R_1$.

Based on this analysis, can express the closed-loop gain (G_{CL}) of the inverting configuration as follows:

$$\frac{V_{OUT}}{V_{IN}} = G_{CL} = -\frac{R_2}{R_1}$$

2.1.1. DC Voltages and Gain

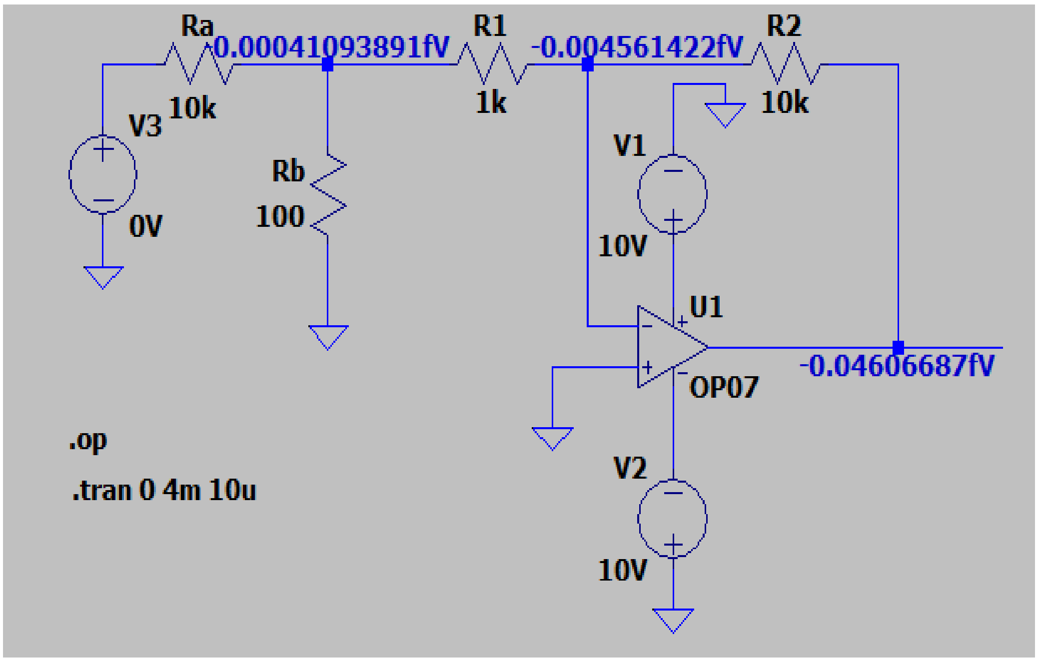


Figure 5. LTspice results from V_A = 0V

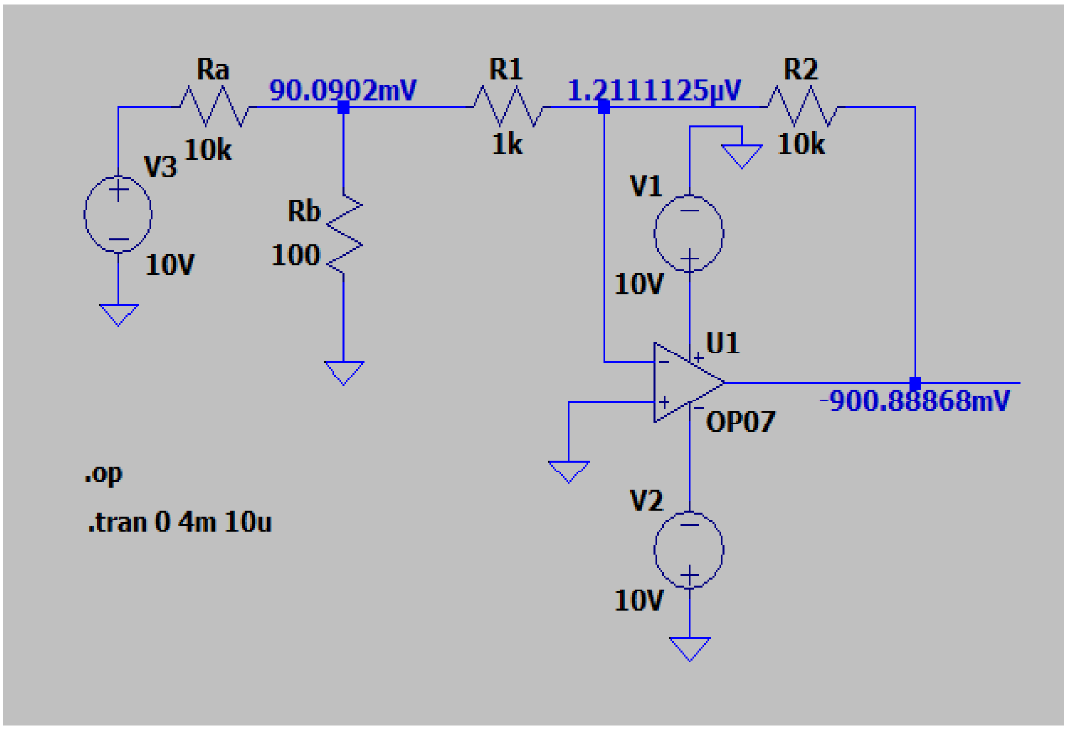


Figure 6. LTspice results from V_A = 10V

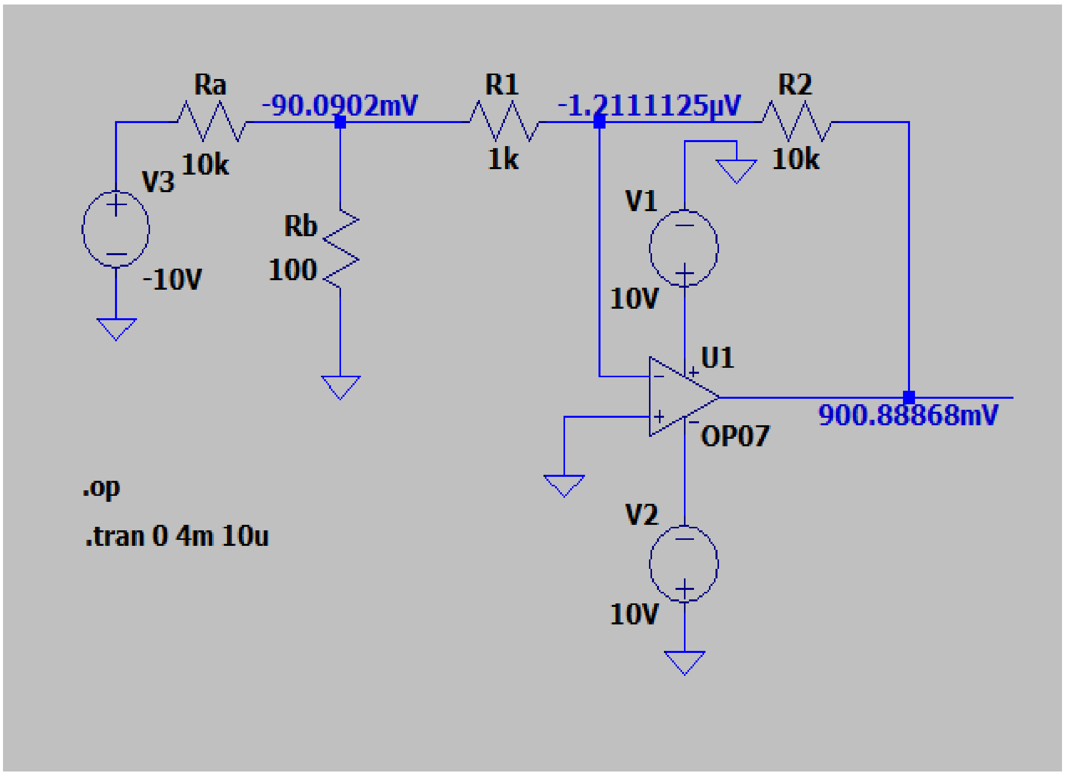
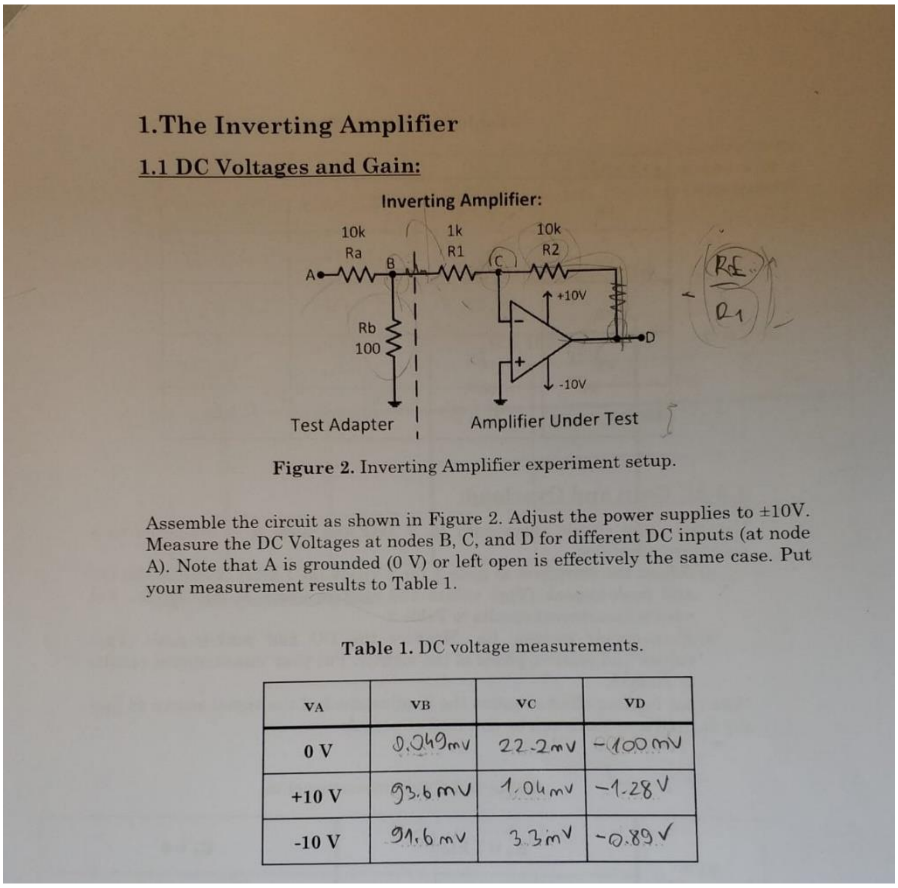


Figure 7. LTspice results from V_A = -10V

Table 1. DC voltage measurements

V_A	V_B	V_C	V_D
0 V	-0.00041 fV	-0.00456 fV	-0.46 fV
+10 V	90.09 mV	1.21 µV	-900.9 mV
-10 V	-90.09 mV	-1.21 µV	900.9 mV



1.The Inverting Amplifier

1.1 DC Voltages and Gain:

Figure 2. Inverting Amplifier experiment setup.

Assemble the circuit as shown in Figure 2. Adjust the power supplies to ±10V. Measure the DC Voltages at nodes B, C, and D for different DC inputs (at node A). Note that A is grounded (0 V) or left open is effectively the same case. Put your measurement results to Table 1.

Table 1. DC voltage measurements.

VA	VB	VC	VD
0 V	0.049mV	22.2mV	-100 mV
+10 V	93.6 mV	1.04 mV	-1.28 V
-10 V	91.6 mV	3.3 mV	-0.89 V

Figure 8. DC voltage measurements during the experiment

The results obtained during the experiment and the data obtained when the simulation results are compared do not match. It is observed that the simulation outputs give accurate results.

2.1.2 Quick Changes of Gain

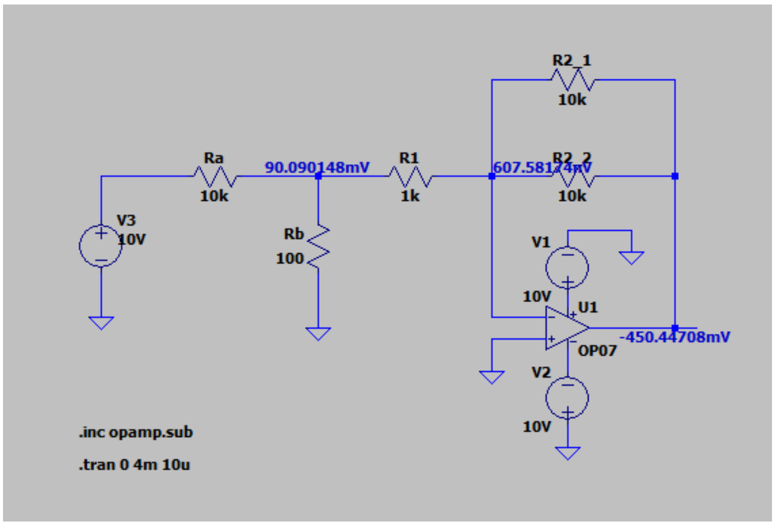


Figure 9. LTspice results when gain reduced by 2 times

In order for reduce the gain by a factor of 2, the R_2 resistance must decrease by two times, so the circuit has been updated with two parallel connected R_2 resistors.

First gain:

$$-\frac{R2}{R1} = -\frac{10k}{1k} = -10$$

Calculated gain:

$$-\frac{R2//R2}{R1} = -\frac{5k}{1k} = -5$$

Gain has been reduced by fifty percent.

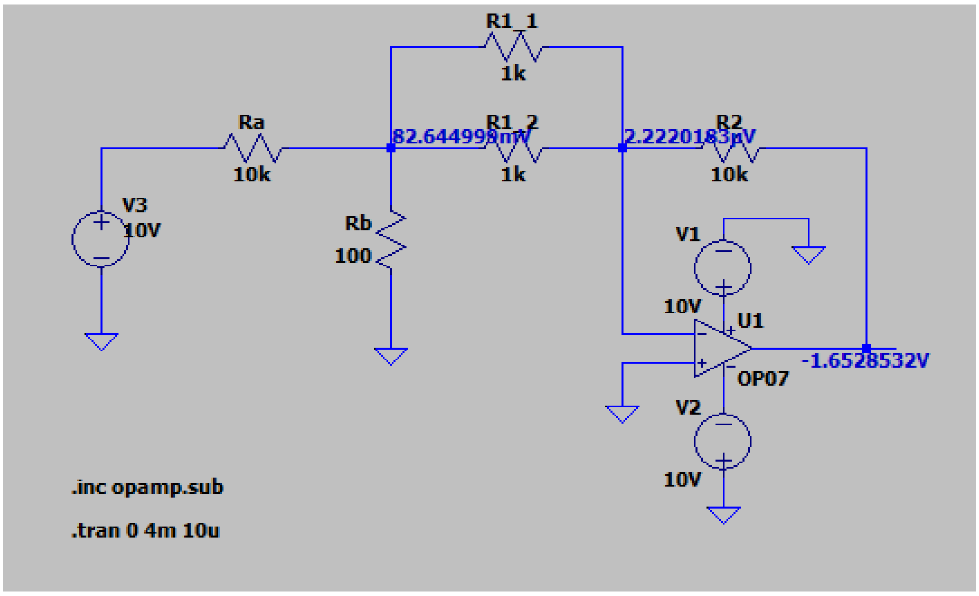


Figure 10. LTspice results when gain increase by 2 times

In order for raise the gain by a factor of 2, the R_1 resistance must decrease by two times, so the circuit has been updated with two parallel connected R_1 resistors.

First gain:

$$-\frac{\mathrm{R2}}{\mathrm{R1}} = -\frac{10\mathrm{k}}{1\mathrm{k}} = -10$$

Calculated gain when R_2 doubles:

$$-\frac{\mathrm{R2}}{\mathrm{R1//R1}} = -\frac{10\mathrm{k}}{0.5\mathrm{k}} = -20$$

Gain has been raised by fifty percent.

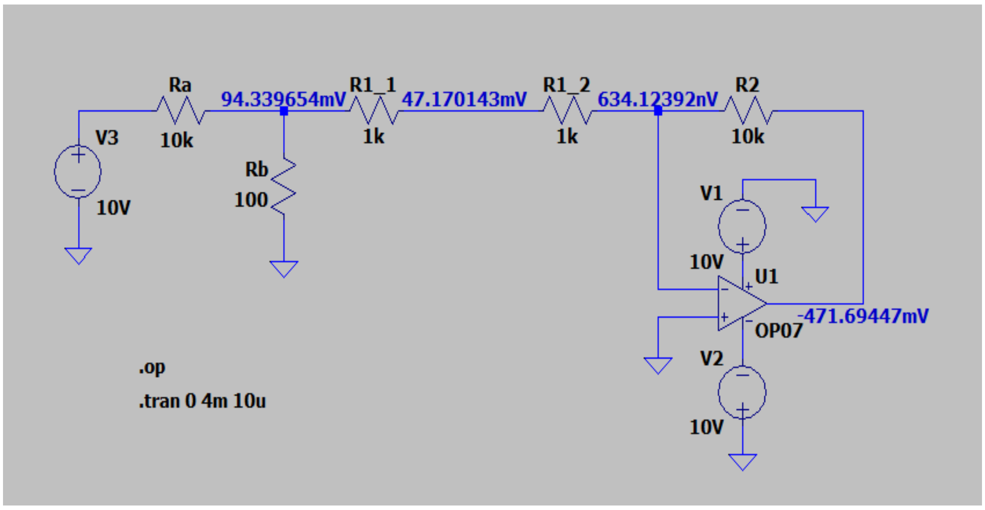


Figure 11. LTspice results after adding node X

The connection of R_1 to node B was opened and a resistor equal to R_1 (1k) was added to the circuit in series. Then, the circuit analysis was performed with LTspice.

Table 2. DC gain changes

V_A = +10V	**a)**	**b)**	**c)**
V_B	90.1 mV	82.6 nV	94.3 mV
V_C	607.6 nV	2.2 µV	634.12 nV
V_D	-450.4 mV	-1.65 V	-471.69 mV
V_X	N/A	N/A	47.17 mV
Gain = V_D/V_B	-5	-19.97	-5.0

Table 2. DC gain changes.

$V_A = +10$ V	a)	b)	c)
VB	99.8 mV	95.9 mV	98.1 mV
VC	3.4 V	12.4 mV	9.9 mV
VD	-0,44 V	- 1.40 V	-0.63 V
VX	N/A	N/A	112 mV
Gain= VD/ VB	4.40	1.46	6.42

Figure 12. DC gain changes measurements during the experiment

2.1.3. AC Gain and Overload

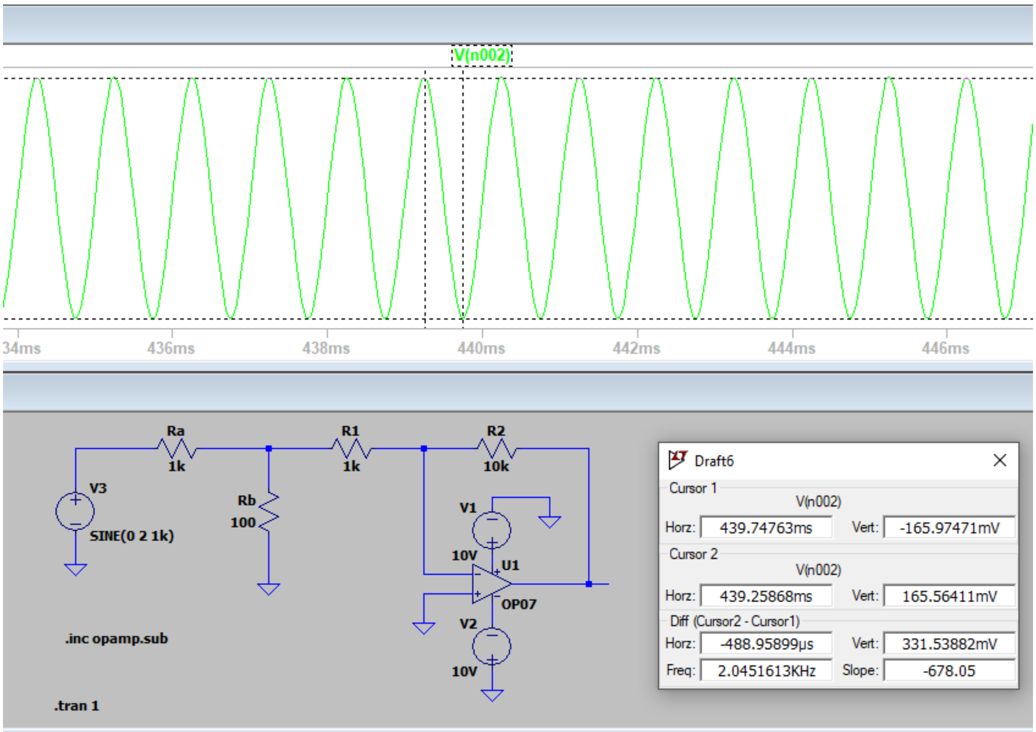


Figure 13. LTspice AC voltage measurement

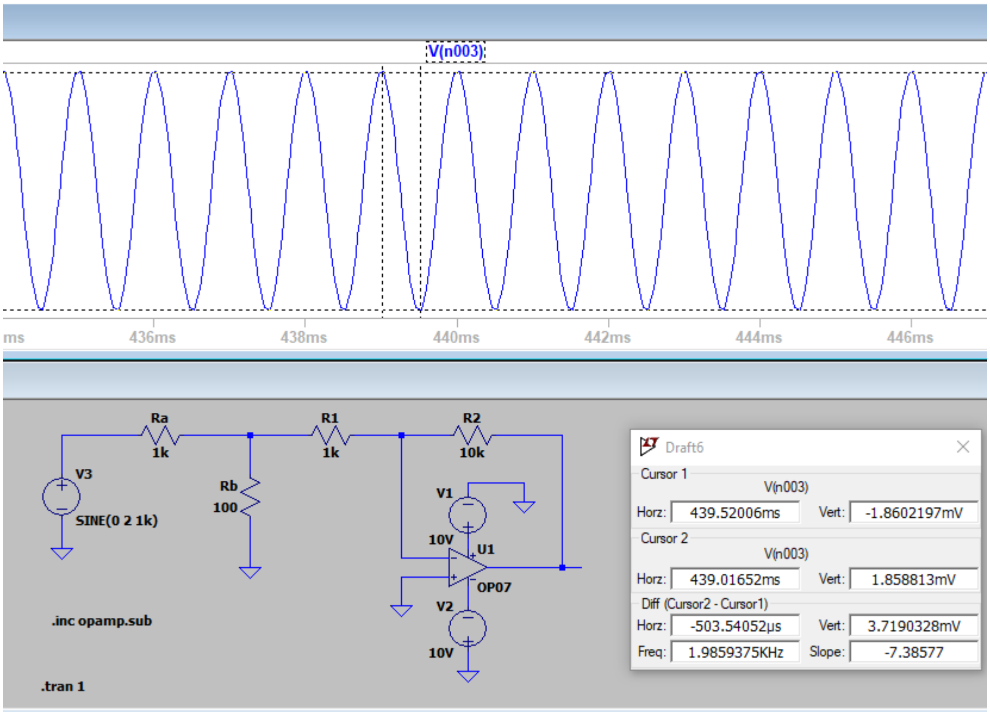


Figure 14. LTspice AC voltage measurement

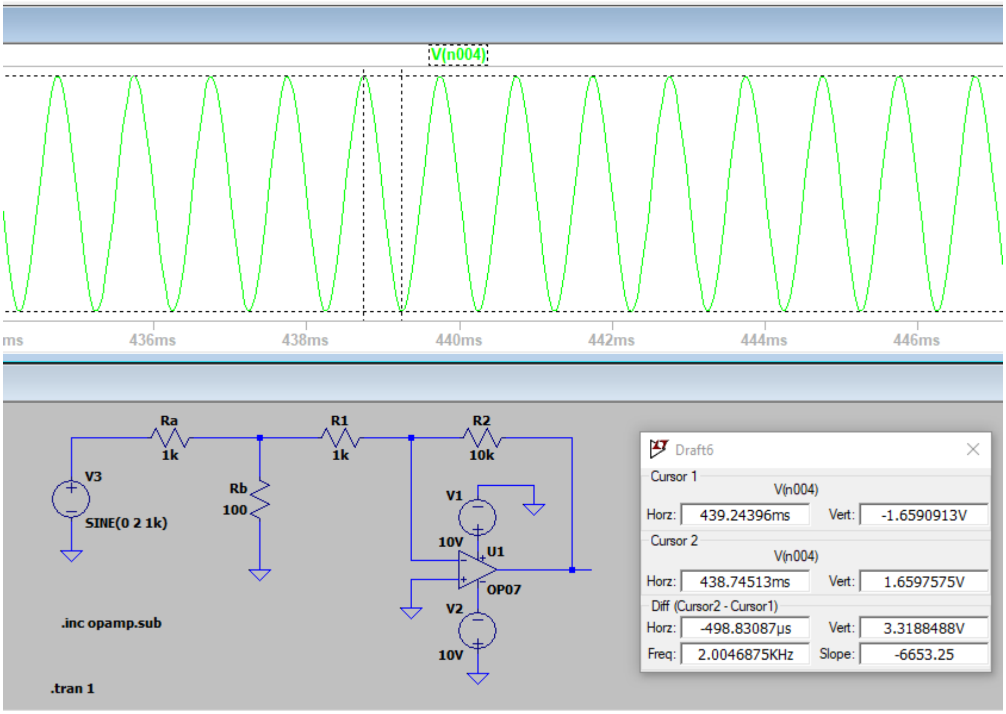


Figure 14. LTspice AC voltage measurement

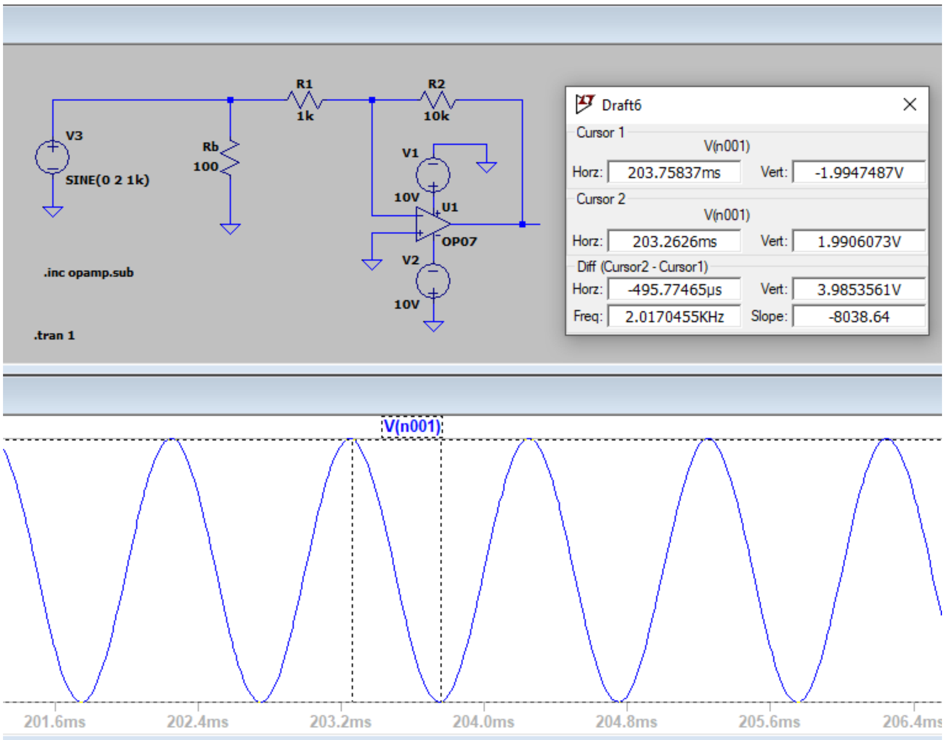


Figure 15. LTspice AC voltage measurement

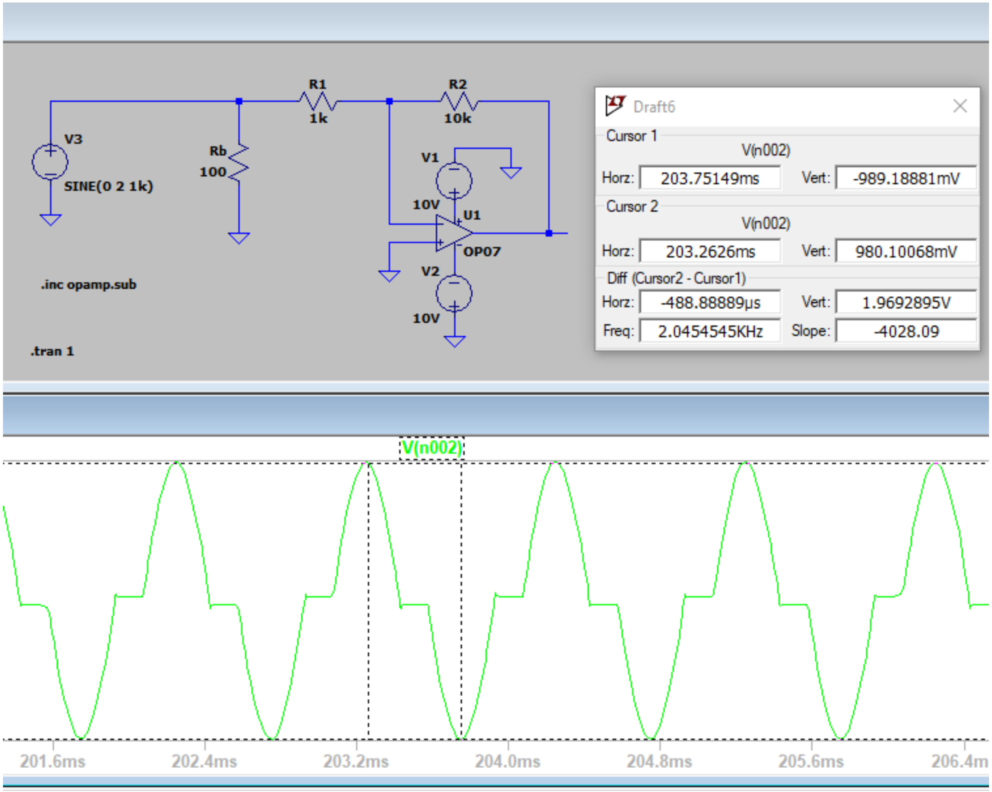


Figure 16. LTspice AC voltage measurement

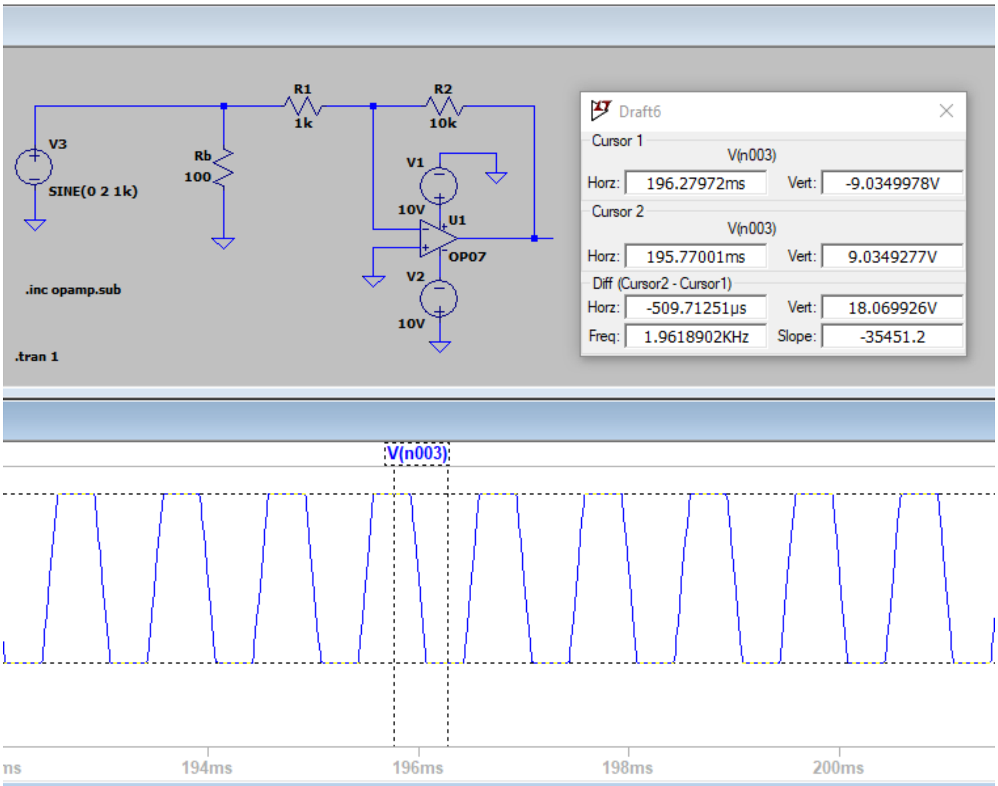


Figure 16. LTspice AC voltage measurement

Table 3. AC gain measurements

$V_A = 2\sin(2k\pi t)$	$R_a = 1\ k\Omega$			$R_a = 0$		
	V_{DC}	V_{PP}	Φ	V_{DC}	V_{PP}	Φ
V_B	117.2 mV	331.5 mV	0	1.38 V	3.9 V	-
V_C	1.32 mV	3.72 mV	87.84	0.7 V	1.97 V	0
V_D	1.17 mV	3.32 V	180	6.4 V	18.07 V	180

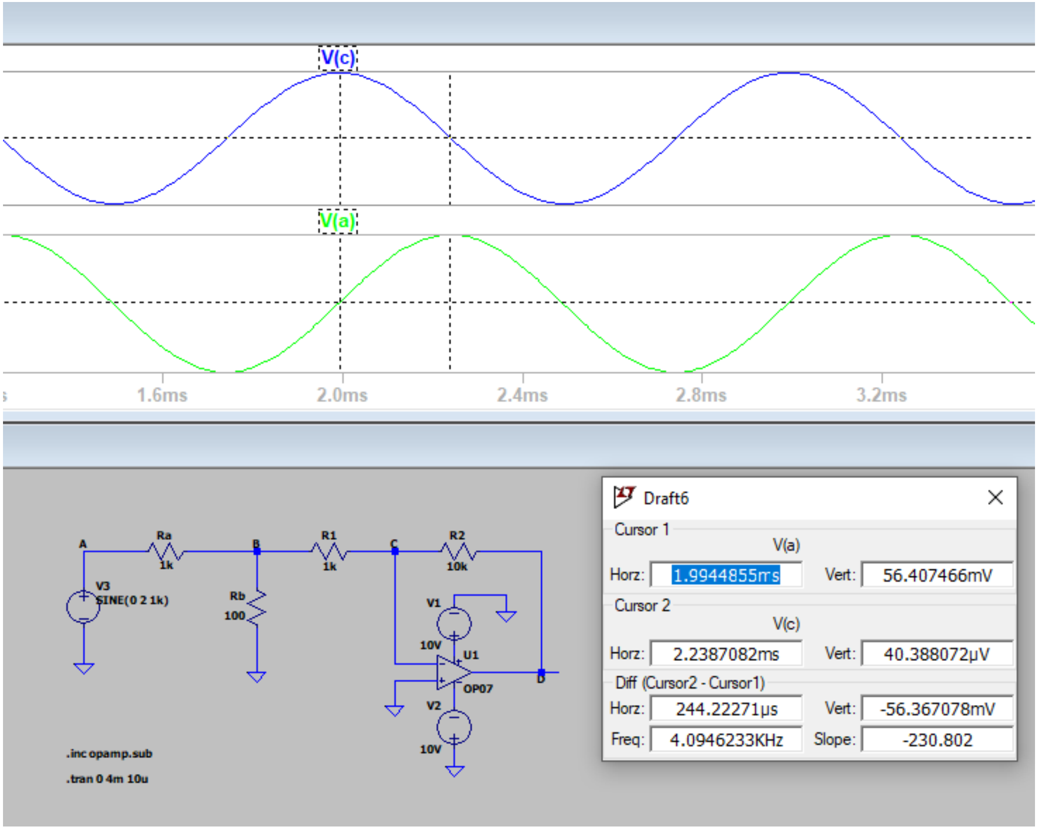


Figure 17. LTspice phase angel measurement

For example, if a measurement is to be made for V_C when measuring the phase angle, as shown in Figure 17., it is necessary to find the phase difference for V_C and V_A. the ΔT value is reached by the difference V_C-V_A between the cursor and the wave peaks.

To reach the phase angle:

$$\Phi = 2 * \pi * f * \Delta T$$

$$\Rightarrow \quad \Phi = 2 * 360 * 1x10^3 * 224x10^{-6} = 87.84$$

2.1.4. Virtual Ground

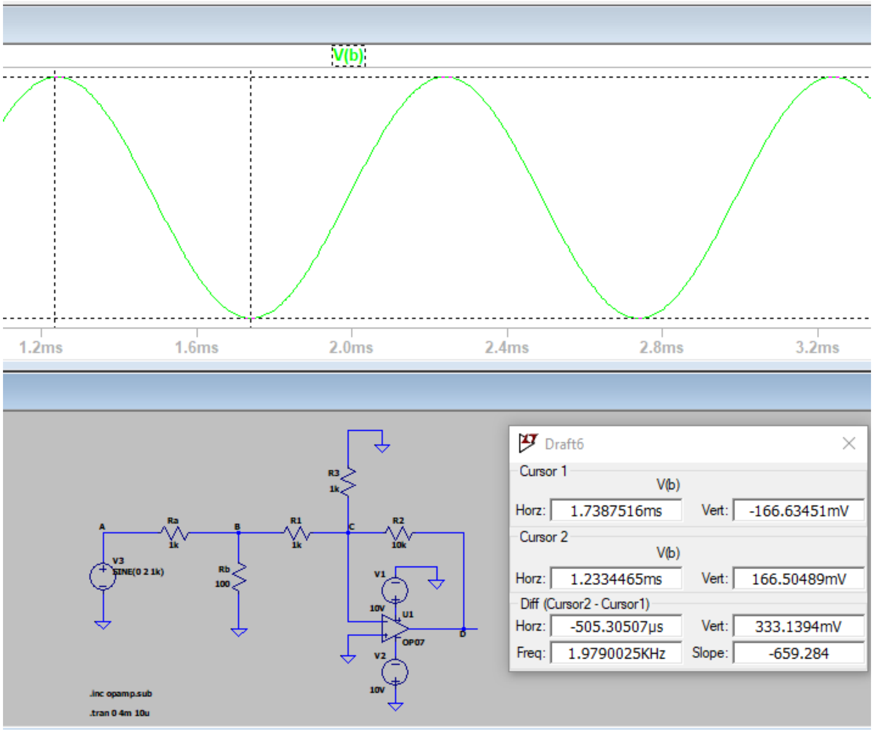


Figure 18. LTspice AC voltage measurement

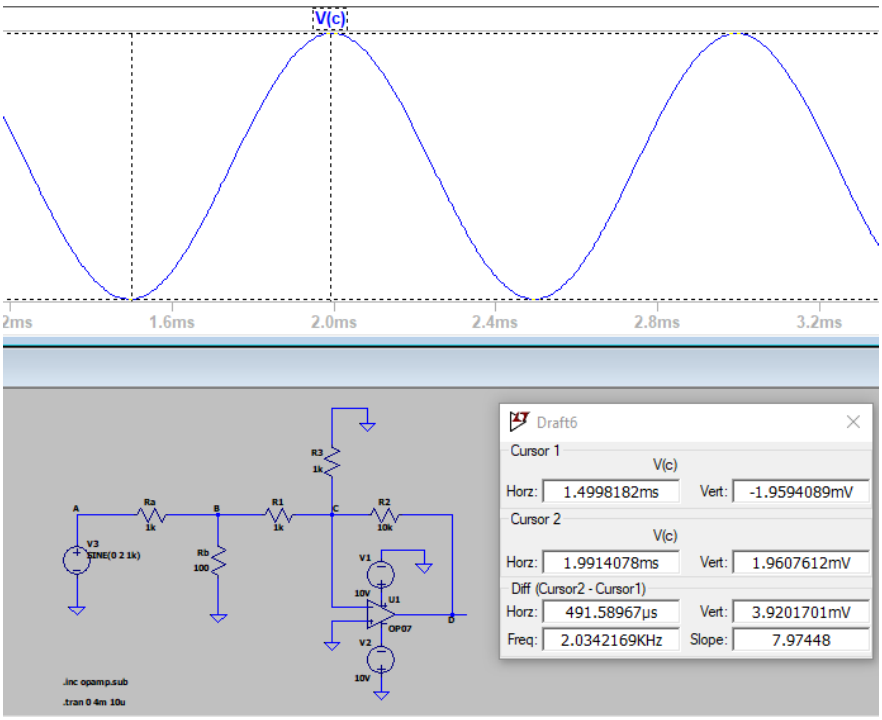


Figure 19. LTspice AC voltage measurement

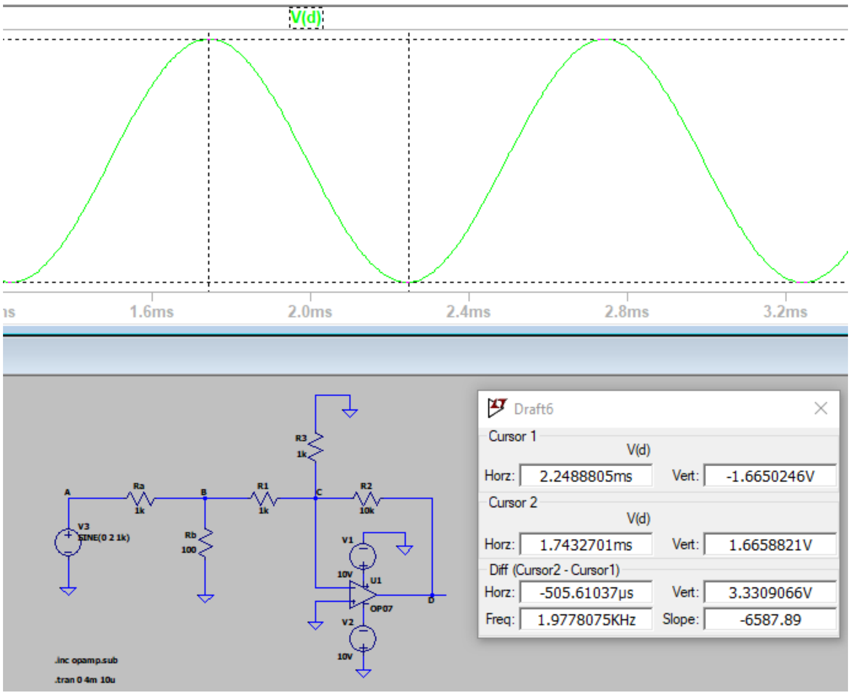


Figure 20. LTspice AC voltage measurement

For R = 1 kΩ, 100 Ω, 10 Ω values, the measured values were added to the corresponding parts of the table using the LTspice program in the steps shown in the figures above.

Table 4. Virtual ground measurements.

V_A = 2sin(2kπt)	R = 1 kΩ		R = 100 Ω		R = 10 Ω	
	V_{DC}	V_{PP}	V_{DC}	V_{PP}	V_{DC}	V_{PP}
V_B	117.8 mV	333.1 mV	117.8 mV	333.3 mV	117.8 mV	333 mV
V_C	1.38 mV	3.9 mV	1.38 mV	3.9 mV	0.9 mV	2.5 mV
V_D	1.17 mV	3.3 V	1.17 mV	3.3 V	0.7 V	2.1 V

The RMS voltage is also known as the equivalent DC voltage because the RMS value gives the amount of AC power drawn by a resistor similar to the power drawn by a DC source. RMS value of any signal is the equivalent DC signal that when passed through a resistor produces same amount of heat that the AC signal would have produced. The RMS voltage (VRMS) of a sinusoidal waveform is determined by dividing the peak voltage value by the square root of one (1/√2). Since 2 Vpeak is given in the question, the calculation is made by multiplying 1/2√2.RMS voltage, also called the effective value, depends on the size of the waveform and is not a function of the waveform frequency or phase angle.in a nutshell, RMS represents the equivalent DC.

2.2. The Non-Inverting Amplifier

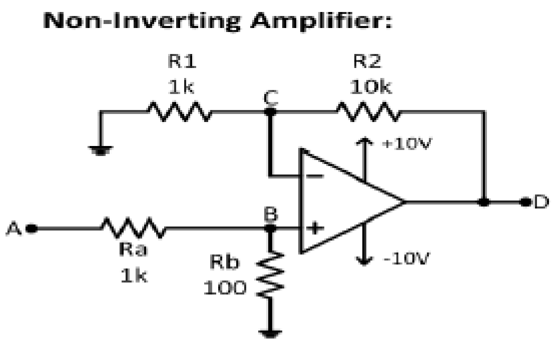


Figure 21. Non-Inverting Amplifier experiment setup.

Figure 21. (non-inverting amplifier);

- ⇨ The input voltage V_{IN} is applied to the non-inverting input terminal, and the virtual short assumption allows to transfer this input voltage directly to the inverting input terminal.
- ⇨ V_{IN} at the inverting input terminal generates a current of V_{IN}/R_1 flowing toward ground.
- ⇨ Assume that no current flows into or out of the op-amp's input terminals, and consequently, the current flowing through R_2 must be equal to the current flowing through R_1: $I_{R2} = V_{IN}/R_1$. This current is flowing away from the op-amp's output terminal.
- ⇨ The voltage drop across R_2 is $I_{R2} \times R_2 = (V_{IN}R_2)/R_1$.
- ⇨ Since the lower-voltage terminal of R_2 is connected to the inverting input terminal, the output voltage is equal to V_{IN} plus the voltage across R_2: $V_{OUT} = V_{IN} + (V_{IN}R_2)/R_1 = V_{IN}(1 + R_2/R_1)$.

Based on this analysis, can express the closed-loop gain (G_{CL}) of the non-inverting configuration as follows:

$$\frac{V_{OUT}}{V_{IN}} = G_{CL} = 1 + \frac{R_2}{R_1}$$

2.2.1. DC Voltages and Gain

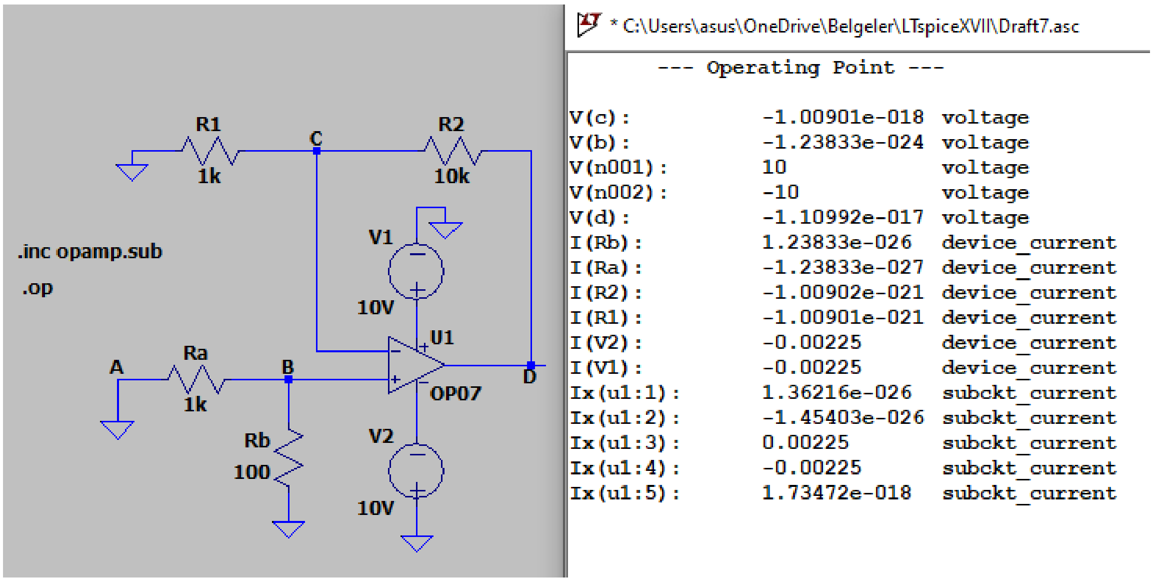


Figure 22. LTspice results from V_A = 0V

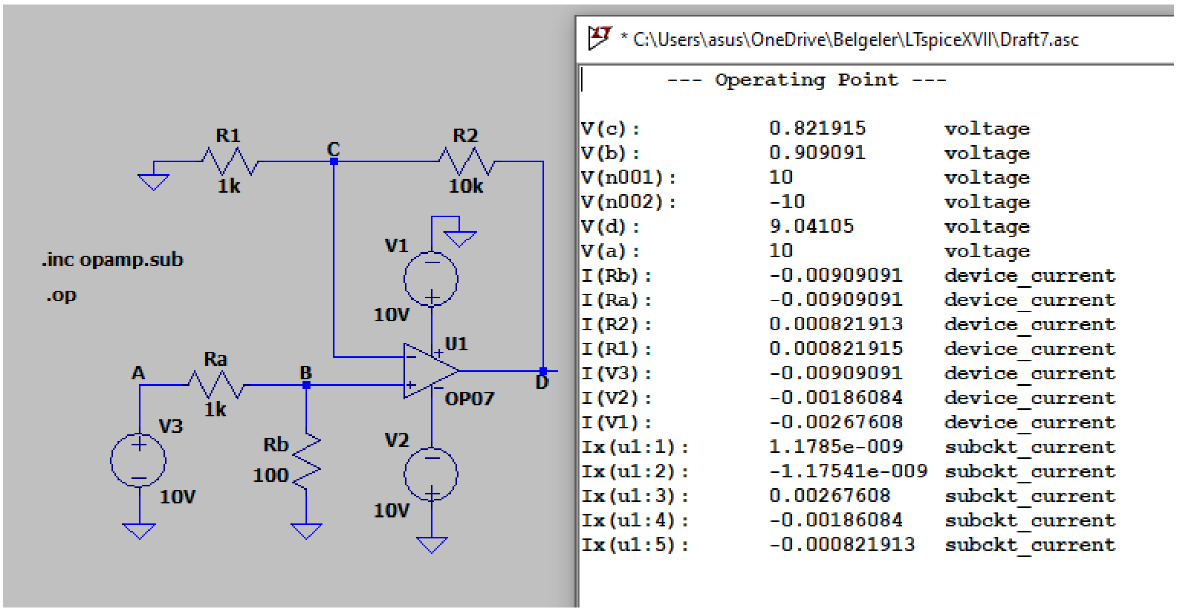


Figure 23. LTspice results from V_A = +10V

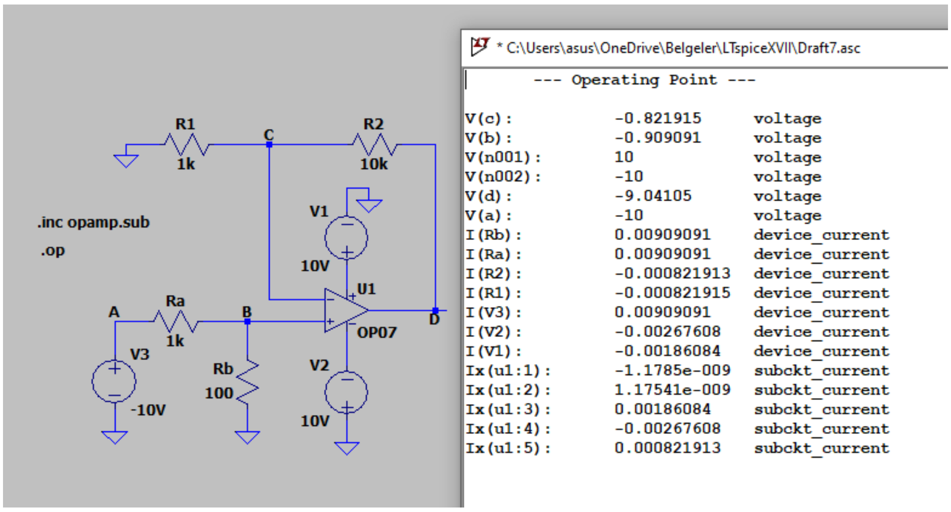


Figure 24. LTspice results from V_A = -10V

Table 5. DC voltage measurements

V_A	V_B	V_C	V_D
0 V	-1.24 fV	-0.001 fV	-0.01 fV
+10 V	0.9 V	0.8 V	9.04 V
-10 V	-0.9 V	-0.8 V	-9.04 V

The measurements in the figures (22-23-24) are listed in the table.

2.2.2. Quick Changes of Gain

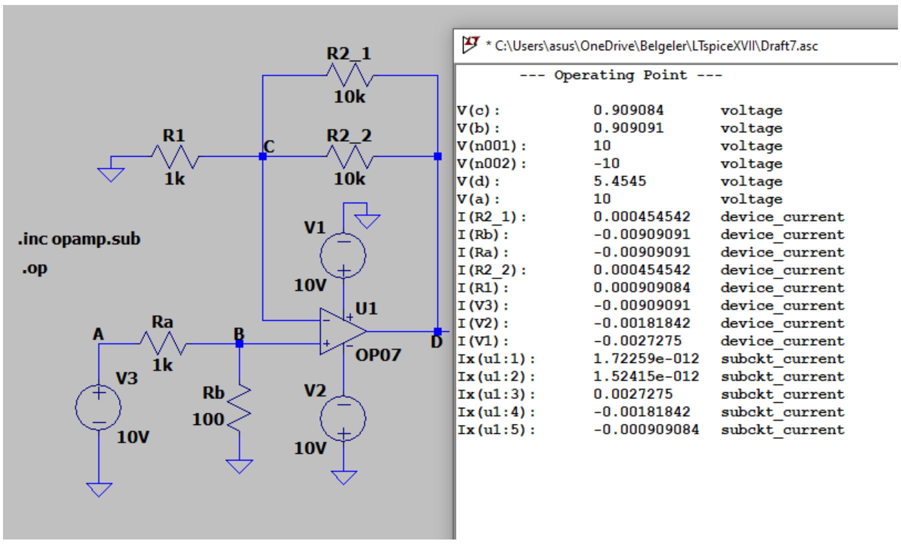


Figure 25. The parallel circuit of the resistor R_2

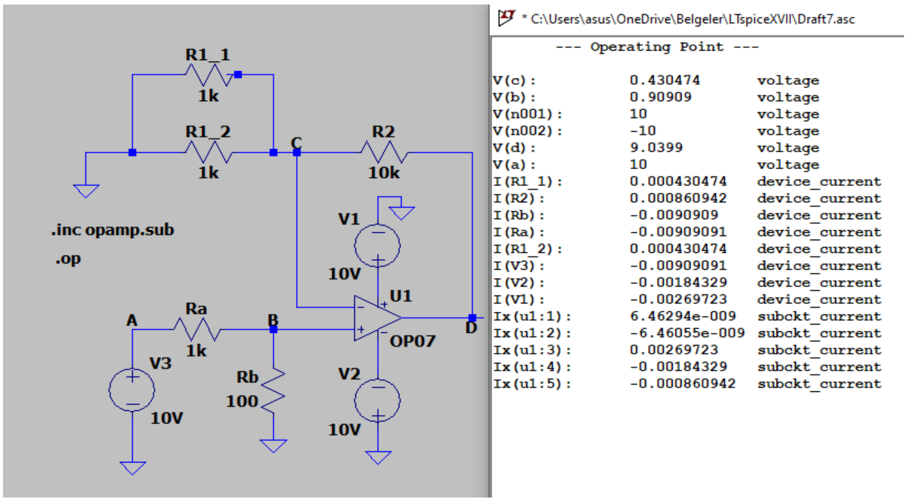


Figure 25. The short-circuit state of the resistor R_2

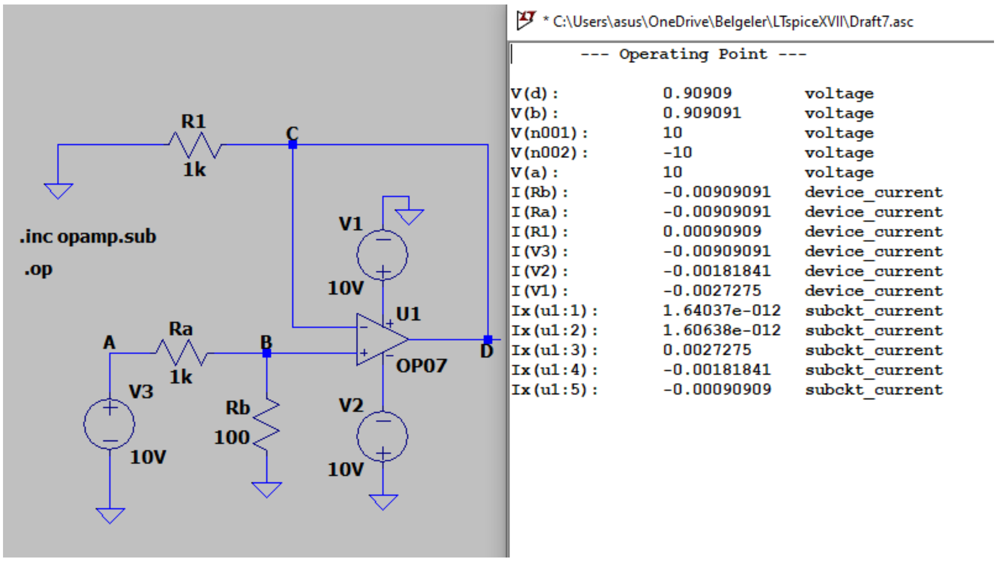


Figure 26. The parallel circuit of the resistor R_2

Table 6. DC gain changes

V_A = +10 V	a)	b)	c)
V_B	0.9 V	0.9 V	0.9 V
V_C	0.9 V	0.43 V	0.9 V
V_D	5.45 V	9.0 V	0.9 V

As can be seen from Table 6. b), in non-invetring circuits, the voltages on the arms of the two input terminals are not always equal. That means the feedback system failed to get enough current or voltage from the output to balance against the input.

2.2.3. AC Gain and Overload

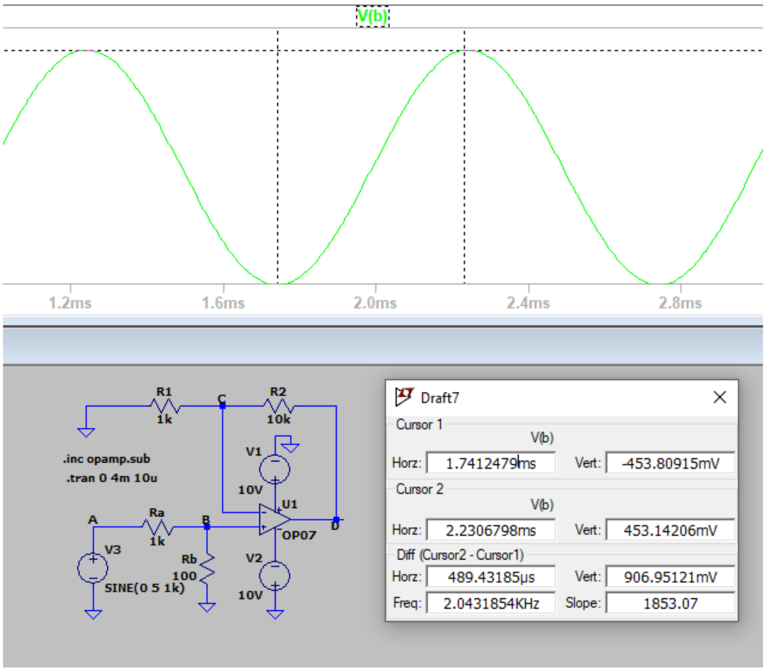


Figure 27. Node A for 5 Vpeak, V_B voltage value

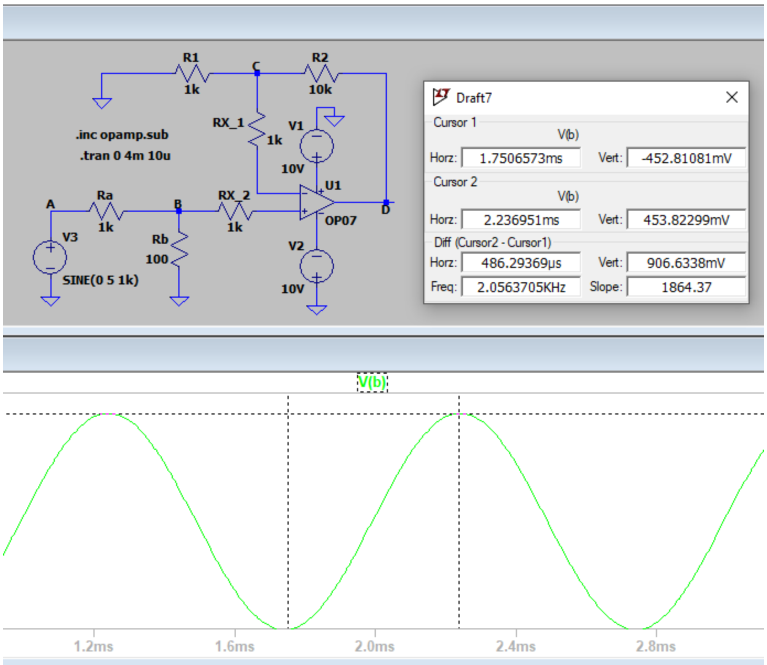


Figure 28. Shunt $R_X = 1k\Omega$, V_B voltage value

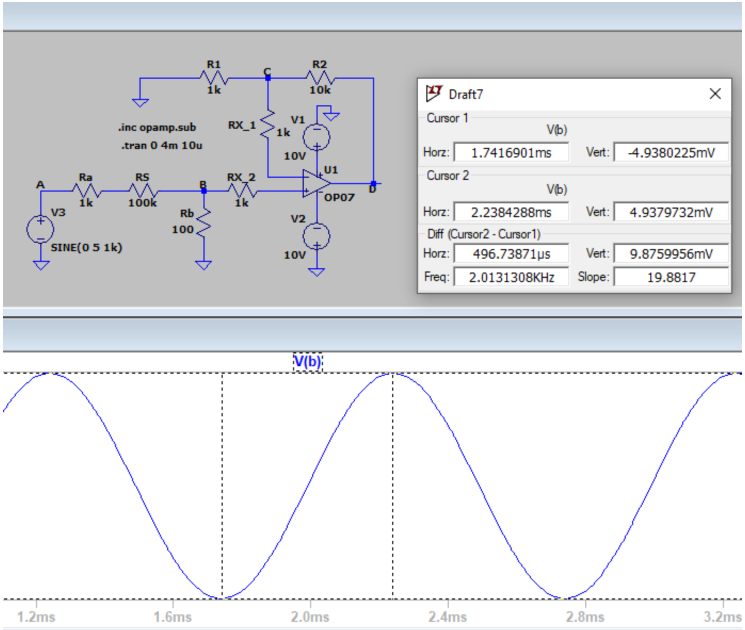


Figure 29. R_S resistor is added to the circuit, V_B voltage value

Like the voltage V_B measurements made in the given figures, V_C and V_D measurements were made and added to the relevant sections in the table.

Table 7. AC gain measurements.

$V_A = 5\sin(2\pi 1kt)$	**Rx = ∞** **Rs = 0**	**Rx = 1 kΩ** **Rs = 0**	**Rx = 1 kΩ** **Rs = 100 kΩ**
	V_{PP}	V_{PP}	V_{PP}
V_B	905.96 mV	906.7 mV	9.88 mV
V_C	907.5 mV	907.4 mV	9.88 mV
V_D	9.98 V	9.98 V	108.6 mV
Gain	11.02	11.0	10.99

A shunt resistor (or shunt) is defined as a device that creates a low resistance path to force most of the electric current through the circuit to flow through this path. When the R_X resistor is added to the input terminals of the op amp as a shunt, it can be seen that the volt values have not changed by looking at the data in Table 7. this circuit summarizes the use of the shunt resistor.

2.3. General-Purpose Amplifier Topology

2.3.1. Individual Inputs, Difference Gains

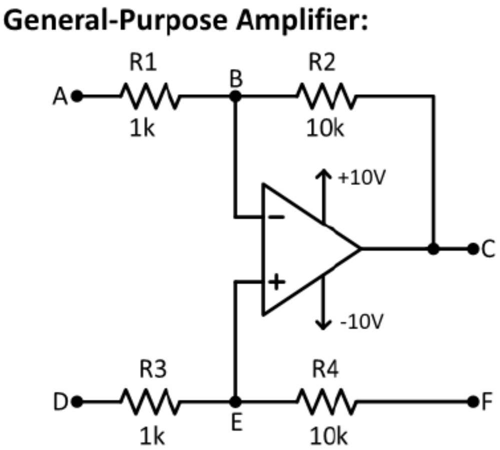


Figure 30. General-Purpose Amplifier experiment setup.

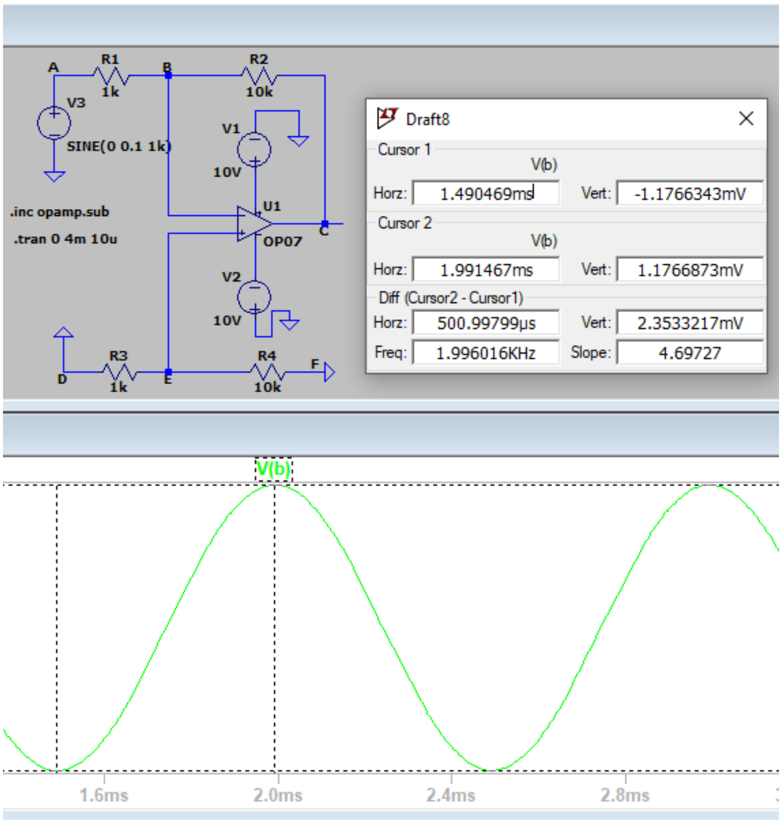


Figure 31. Node A for 100mV peak (at 1 kHz), voltage V_B value

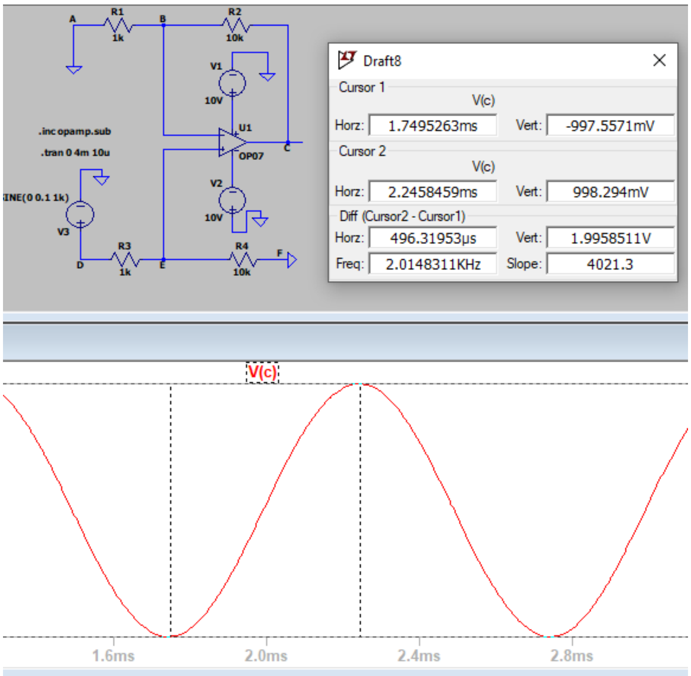


Figure 32. Node D for 100mV peak (at 1 kHz), voltage V_C value

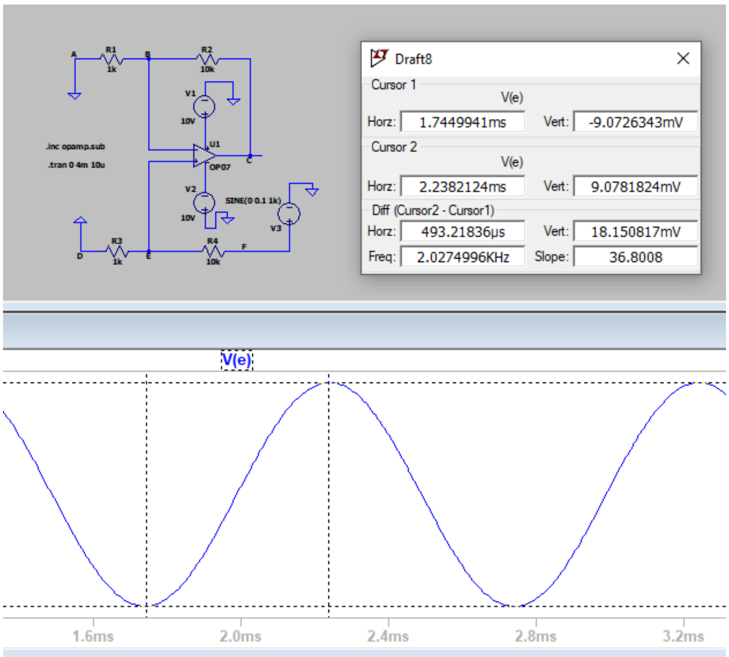


Figure 32. Node F for 100mV peak (at 1 kHz), voltage V_E value

Nodes A, B and C are separately supplied with a 100mV peak (at 1 kHz) AC source. The V_B, V_E and V_D volt values are measured and the simulation is presented in the images. The measured values are transferred to Table 8.

Table 8. AC gain measurements.

SIN = 0.1sin(2π1kt)	**V_A = SIN** **V_D = 0** **V_F = 0**	**V_A = 0** **V_D = SIN** **V_F = 0**	**V_A = 0** **V_D = 0** **V_F = SIN**
	V_{PP}	V_{PP}	V_{PP}
V_C	1.9 V	1.9 V	9.88 mV
V_B	2.35 mV	181.4 mV	9.88 mV
V_E	31.8 nV	181.3 mV	108.6 mV

2.3.2. Common-Mode Gain

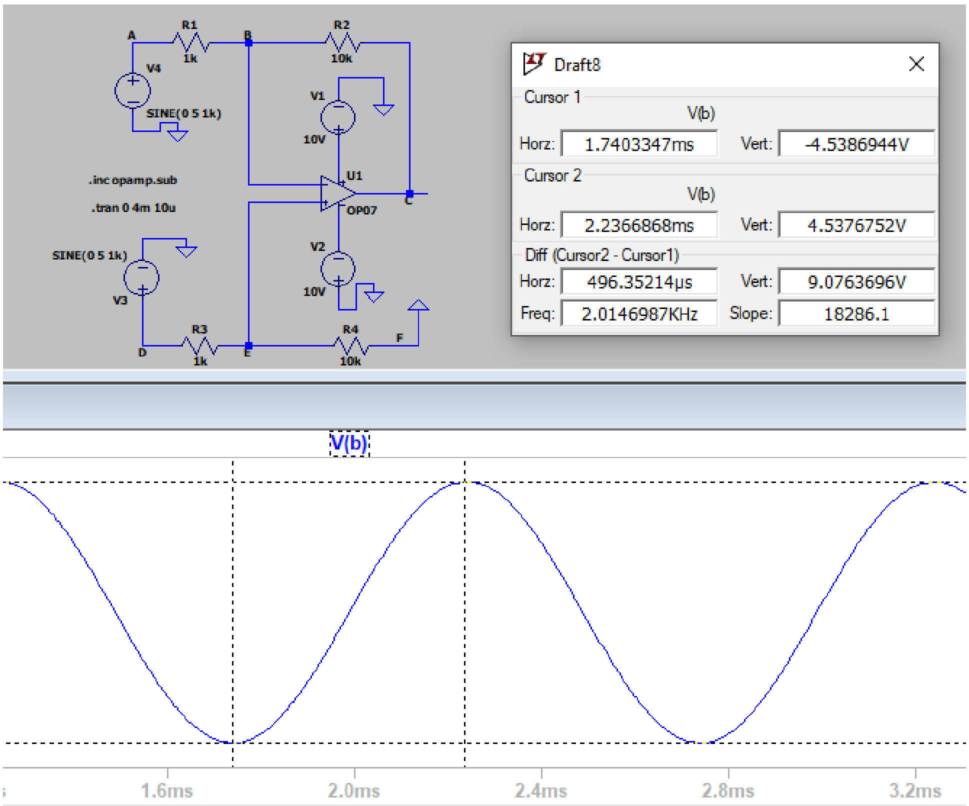


Figure 33. Node A and D for 5 V peak signal, voltage V_E value

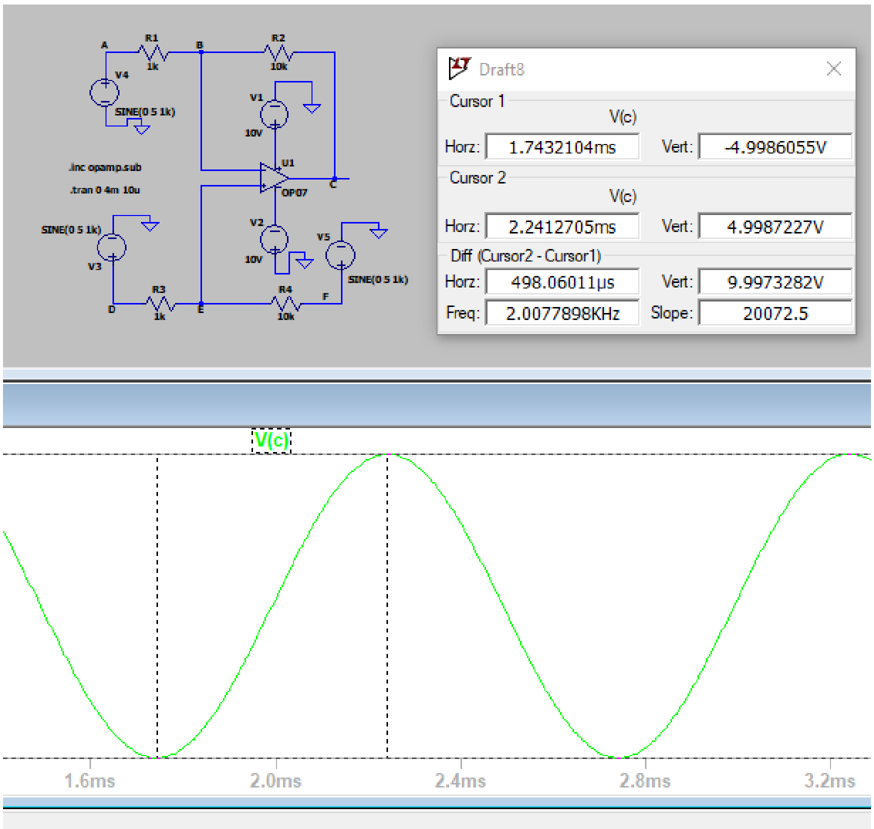


Figure 33. Node A, D and F for 5 V peak signal, voltage V_E value

Table 9. Common-mode gain measurement.

SIN = 5sin(2π1kt)	V_A = SIN V_D = SIN V_F = 0	V_A = SIN V_D = SIN V_F = SIN
	V_{PP}	V_{PP}
V_C	390.5 µV	9.9 V
V_B	9.1 V	9.9 V
V_E	9.1 V	9.9 V

It has been observed that when a 100mV peak (at 1 kHz) AC source is connected to points A and D, the voltage values of V_B and V_E are equal, and when an AC source is connected to points A, D and F, the volt values of V_B, V_C, V_E are equal.

3. Conclucion

In this experiment, Operational-Amplifier Basics is used.We used concepts such as opamp,inverting input,non-inverting input,gain,peak to peak and phase.

We learned from our applications in this experiment that in a circuit like the one above, as the value of Rf increases, the gain increases, and as the value of Rin increases, the gain decreases. It was observed that when a shunt resistor was added to the Rf value, the gain decreased and when a shunt resistor was added to the Rin value, the gain increased.

We observed the voltages at the nodes by giving different dc voltages. When we used ac source, we also measured the dc value, peak to peak values and phase angles of the signals.

After adding different resistance values to the circuit, the RMS voltage (VRMS) of a sinusoidal waveform was determined by dividing the peak voltage value by the square root of one ($1/\sqrt{2}$).

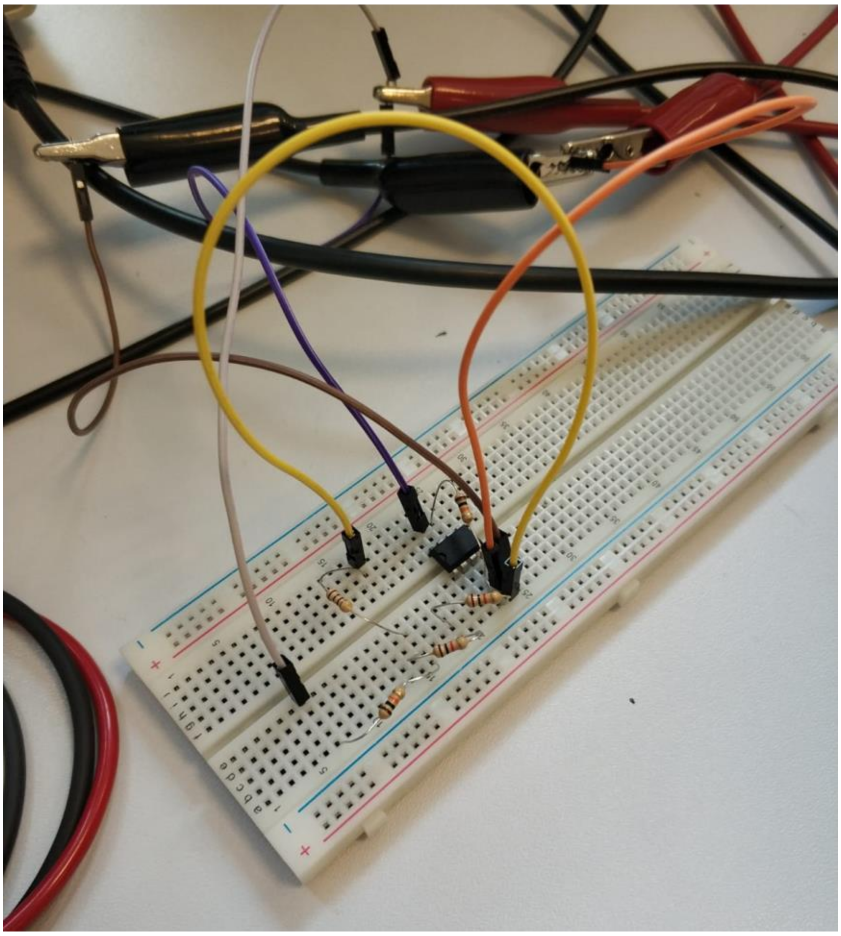


Figure 34. The circuit established during the experiment

We set up the experimental circuit and connections as above. While measuring the volt values at the nodes during the experiment, we measured many different values at the same node. We think that this is because the opamp may be broken.

We could not progress in the experiment and wasted time, as we had to constantly rewind to get a constant correct value.

4. References

[1] https://www.quora.com/What-if-its-not-possible-to-get-the-voltage-difference-between-the-inverting-and-non-inverting-terminals-equal-to-zero-of-an-op-amp

[2] https://www.electrical4u.com/shunt-resistors/