GEBZE TECHNICAL UNIVERSITY

ELECTRONIC ENGINEERING

ELEC-237

ELECTRONICS LABORATORY-I

EXPERIMENT 1

Operational-Amplifier Basics

Prepared by
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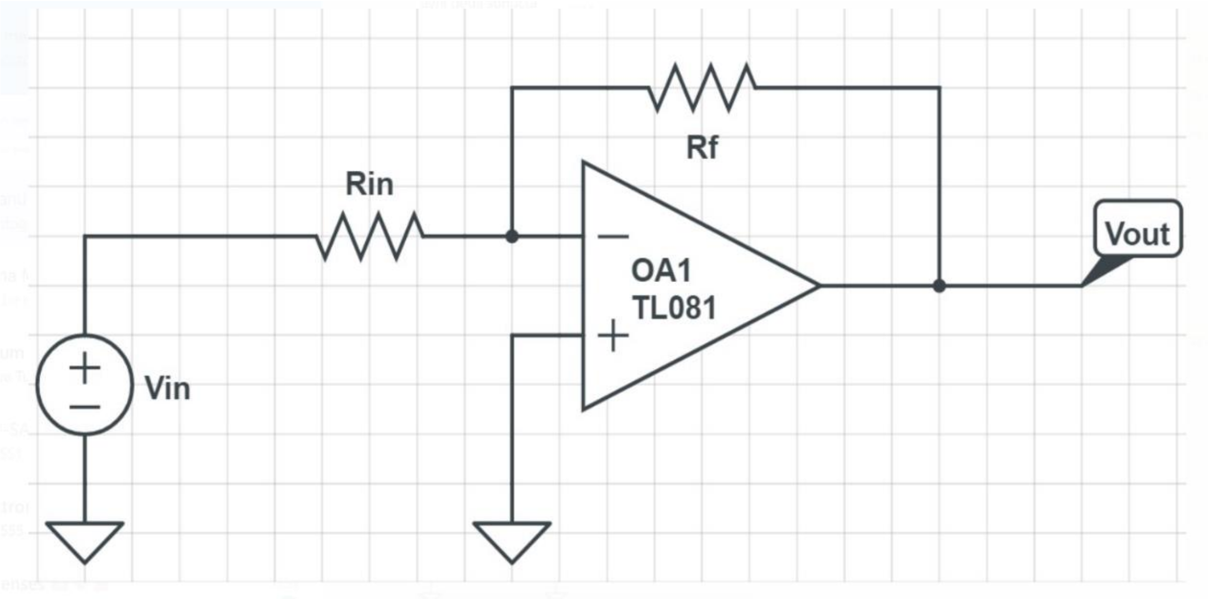
1.The Inverting Amplifier

1.1 DC Voltages and Gain:



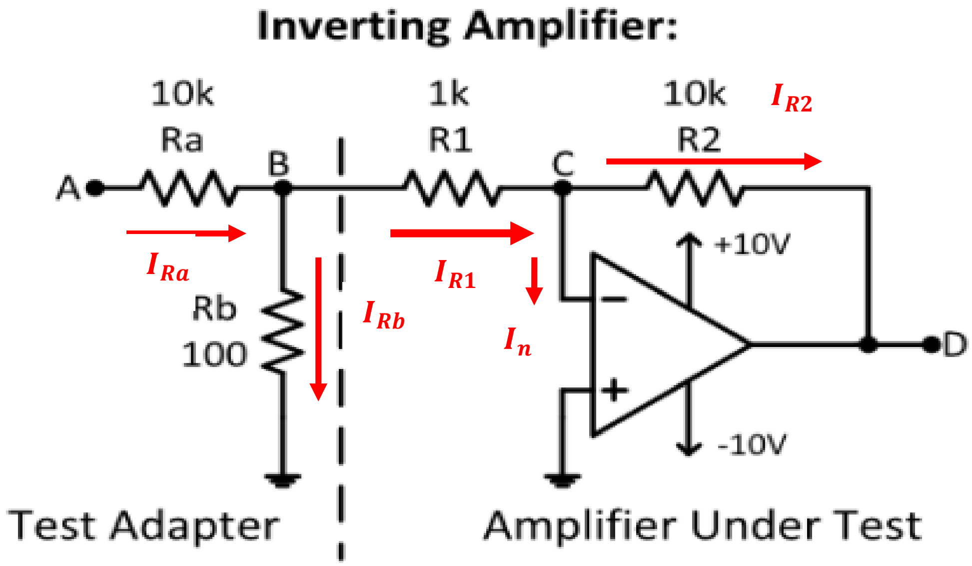
Şekil 1:A basic patern of an operational amplifier

In the inverting amplifier circuit, the input voltage Vin is applied to the negative side of the operational amplifier with the resistor Rin. The positive terminal is grounded. The resistor R_f connected between the input and output terminals is referred to as the feedback resistor.
Before analyzing our circuit, let's remember the opamp features:

- There is no potential difference between the inverting (-) and non-inverting (+) inputs. In short, the voltage difference is zero.
- A small current flows into the opamp from the inverting (-) and non-inverting (+) terminals. Since this current is very small, it can be neglected.

It doesn't matter if the signal applied to the input is AC or DC, both are amplified. Since the potential difference between the (-) end and the (+) end of the opamp is zero, the (-) end of the opamp in the inverting amplifier circuit is at ground potential.

ANALYSIS OF THE CIRCUIT



$$I_{Ra} = I_{Rb} + I_{R1}$$

In this equation, according to the Kirchhoff current rule, the currents entering a point are equal to the sum of the total outgoing currents. The only current entering point B is I_Ra, and the outgoing currents are I_rb and I_r1.

$$\frac{V_A - V_B}{R_A} = \frac{V_B}{R_B} + \frac{V_B - V_C}{R_1}$$

The following equation is written over the equality of both cases by writing the currents from Ohm's law in terms of I = V/R.

$$\frac{V_A}{R_A} - \frac{V_B}{R_A} = \frac{V_B}{R_B} + \frac{V_B}{R_1} - \frac{V_C}{R_1}$$

$V_C = 0$ -> Even though the negative input is not connected to the opra, it behaves like ground when its voltage is zero. This is called virtual ground. vc is also virtual ground. Therefore Vc=0 . In ideal opamps, the voltages of the positive and negative inputs are always equal.(Vc ->(-))

$$\frac{V_A}{R_A} = \frac{V_B}{R_B} + \frac{V_B}{R_1} + \frac{V_B}{R_A}$$

$$\frac{V_A}{R_A} = V_B\left(\frac{1}{R_A} + \frac{1}{R_1} + \frac{1}{R_A}\right)$$

$$V_B = \frac{V_A}{R_A\left(\frac{1}{R_B} + \frac{1}{R_1} + \frac{1}{R_A}\right)}$$

With the simplified equation we wrote above, the voltage at node B is found.

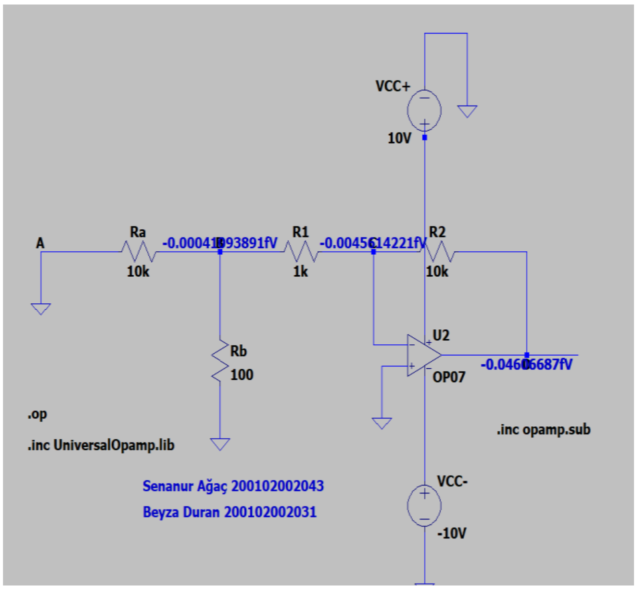
$$I_{R1} = I_{R2} + I_n$$

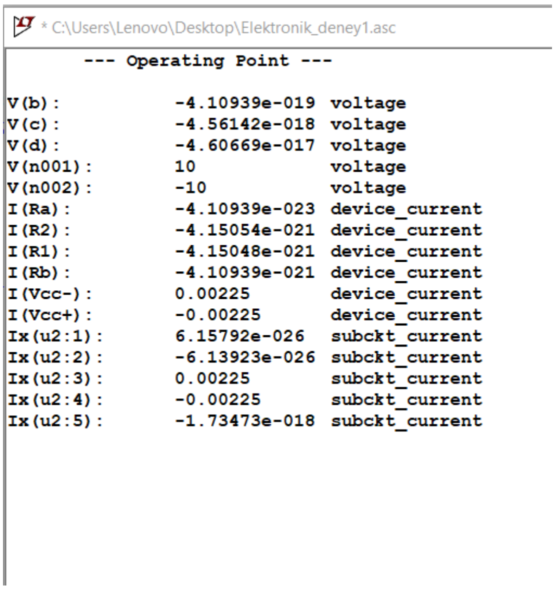
$$I_{R1} = I_{R2}$$

The current entering the opamp from both positive and negative inputs is zero; or in other words, no direct current flows from the inputs to the opamp. Ip=In=0. According to Kirchoff's current rule, the sum of currents entering a point is equal to the sum of outgoing currents. The only current entering the virtual ground point is Ir1, the outgoing currents are In and Ir2.

$$\frac{V_B - V_C}{R_1} = \frac{V_C - V_D}{R_2} \quad V_C = 0 \rightarrow \frac{V_B}{R_1} = \frac{-V_D}{R_2}$$

$$V_D = -\frac{V_A}{R_A\left(\frac{1}{R_B} + \frac{1}{R_1} + \frac{1}{R_A}\right)} \times \frac{R_2}{R_1}$$





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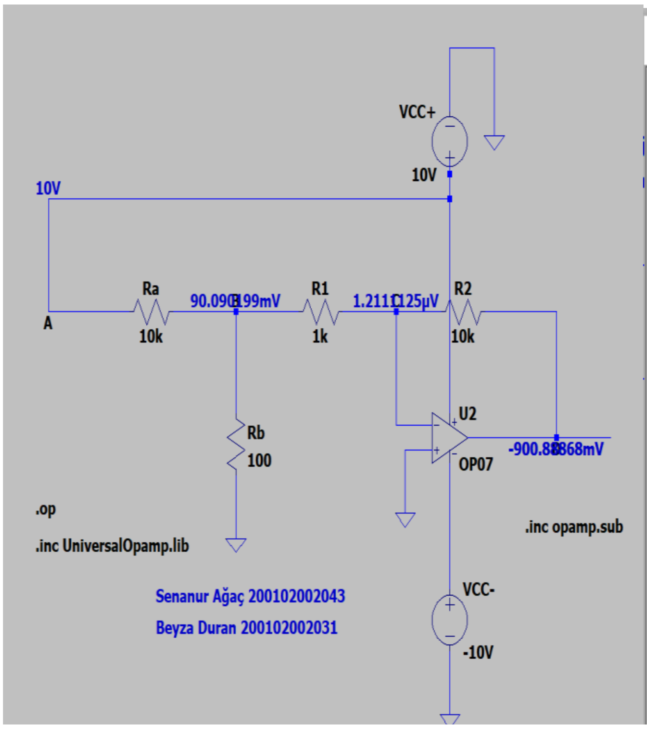
```
       --- Operating Point ---

V(b):          -4.10939e-019  voltage
V(c):          -4.56142e-018  voltage
V(d):          -4.60669e-017  voltage
V(n001):       10             voltage
V(n002):       -10            voltage
I(Ra):         -4.10939e-023  device_current
I(R2):         -4.15054e-021  device_current
I(R1):         -4.15048e-021  device_current
I(Rb):         -4.10939e-021  device_current
I(Vcc-):       0.00225        device_current
I(Vcc+):       -0.00225       device_current
Ix(u2:1):      6.15792e-026   subckt_current
Ix(u2:2):      -6.13923e-026  subckt_current
Ix(u2:3):      0.00225        subckt_current
Ix(u2:4):      -0.00225       subckt_current
Ix(u2:5):      -1.73473e-018  subckt_current
```

Figure 1: VA=0



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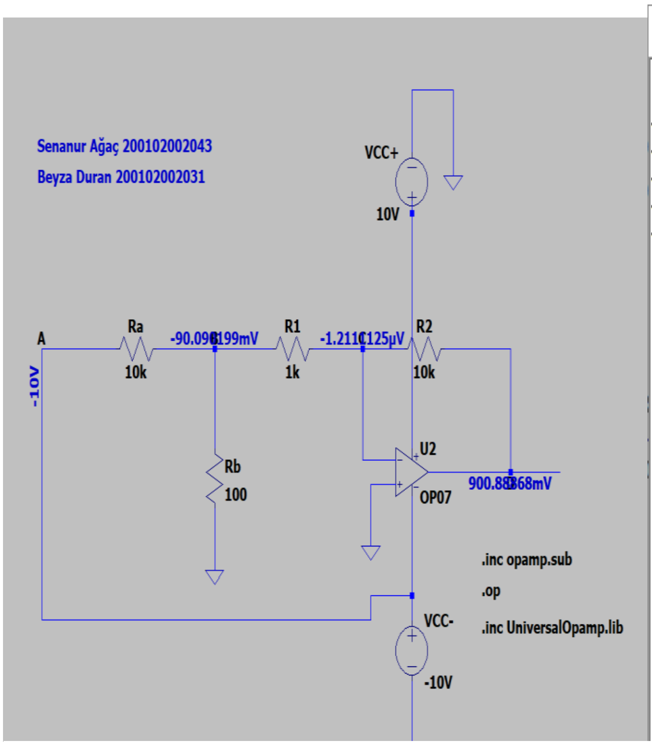
```
--- Operating Point ---

V(b):         0.0900902       voltage
V(c):         1.21111e-006    voltage
V(d):         -0.900889       voltage
V(a):         10              voltage
V(n001):      -10             voltage
I(Ra):        -0.000990991    device_current
I(R2):        -9.0089e-005    device_current
I(R1):        -9.0089e-005    device_current
I(Rb):        0.000900902     device_current
I(Vcc-):      0.00229527      device_current
I(Vcc+):      -0.00319617     device_current
Ix(u2:1):     -1.635e-014     subckt_current
Ix(u2:2):     1.63522e-014    subckt_current
Ix(u2:3):     0.00220518      subckt_current
Ix(u2:4):     -0.00229527     subckt_current
Ix(u2:5):     9.0089e-005     subckt_current
```

Figure 3:VA= 10V



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```
--- Operating Point ---

V(b):         -0.0900902      voltage
V(c):         -1.21111e-006   voltage
V(d):         0.900889        voltage
V(a):         -10             voltage
V(n001):      10              voltage
I(Ra):        0.000990991     device_current
I(R2):        9.0089e-005     device_current
I(R1):        9.0089e-005     device_current
I(Rb):        -0.000900902    device_current
I(Vcc-):      0.00319617      device_current
I(Vcc+):      -0.00229527     device_current
Ix(u2:1):     1.635e-014      subckt_current
Ix(u2:2):     -1.63522e-014   subckt_current
Ix(u2:3):     0.00229527      subckt_current
Ix(u2:4):     -0.00220518     subckt_current
Ix(u2:5):     -9.0089e-005    subckt_current
```

Figure 2:VA= -10 V

Table 1: LTspice measurements

Va	Vb	Vc	Vd
0 v	-0.004fV	-0.0045fV	-0.046fV
V 10	90.1 mV	1.21µV	-900.8 mV
V -10	-90,1 mV	-1.21 µV	900.8 mV

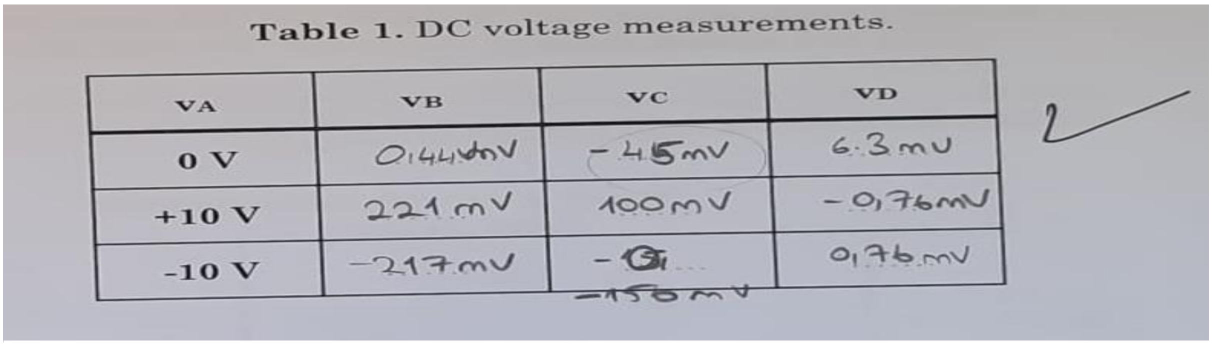


Table 1. DC voltage measurements.

VA	VB	VC	VD
0 V	0,44mV	-45mV	6.3mV
+10 V	221 mV	100mV	-0,76mV
-10 V	-217mV	-[illegible] -150mV	0,76mV

Figure 4: Values measured during the experiment

Conclusion: In this part of the experiment, it was observed that the LTspice results and the values measured in the experiment were different. However, since these differences were very small, it was predicted that the experiment would be completed.

1.2 Quick Changes of Gain:

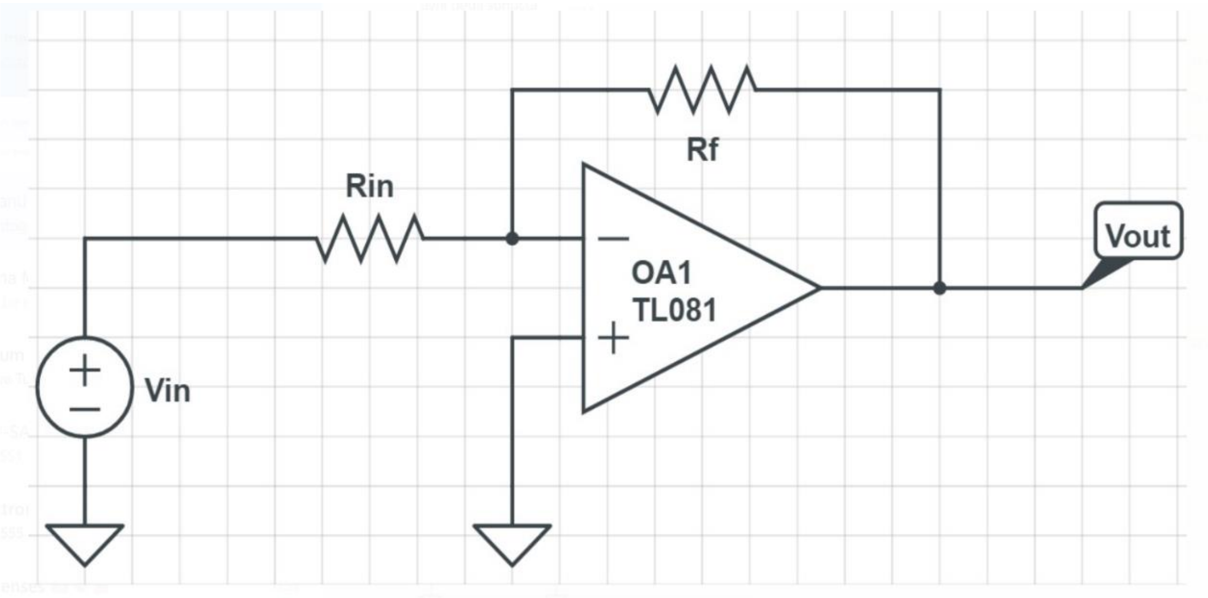


Figure 7: A basic patern of Inverting Amplifier

In the above circuit, we find the gain as follows:

$$A_V = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

The negative sign in the equation indicates an inversion of the output signal with respect to the input as it is 180° out of phase. This is due to the feedback being negative in value

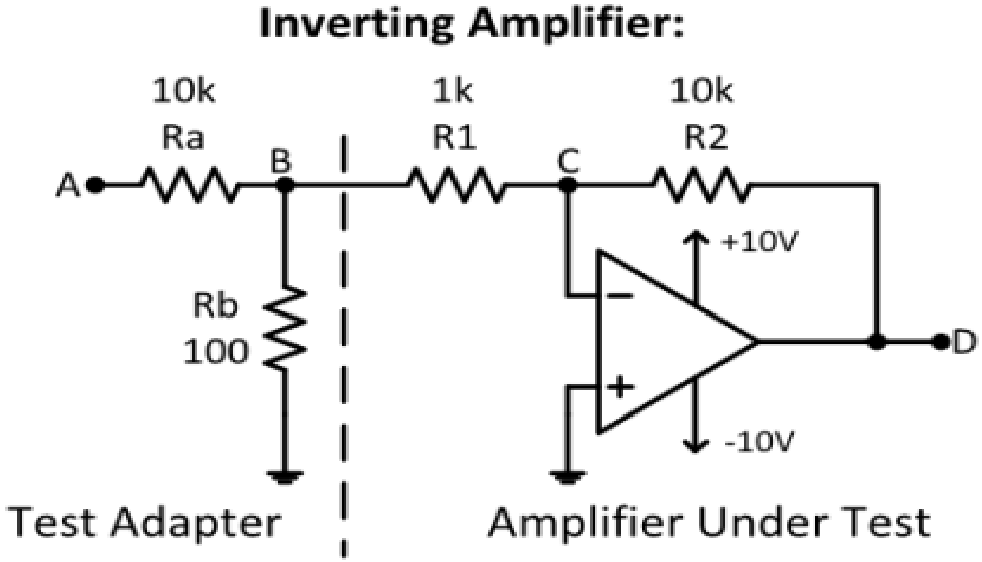


Figure 8: Our circuit

In our circuit, the gain was found as follows:

$$A_V = \frac{V_D}{V_B} = -\frac{R_2}{R_1}$$

a) Shunt resistor R2 by one of equal value to reduce the gain by a factor of 2. Measure the DC Voltages at nodes B, C, and D. Write gain of the circuit. Put your measurement results to Table 2, column a).

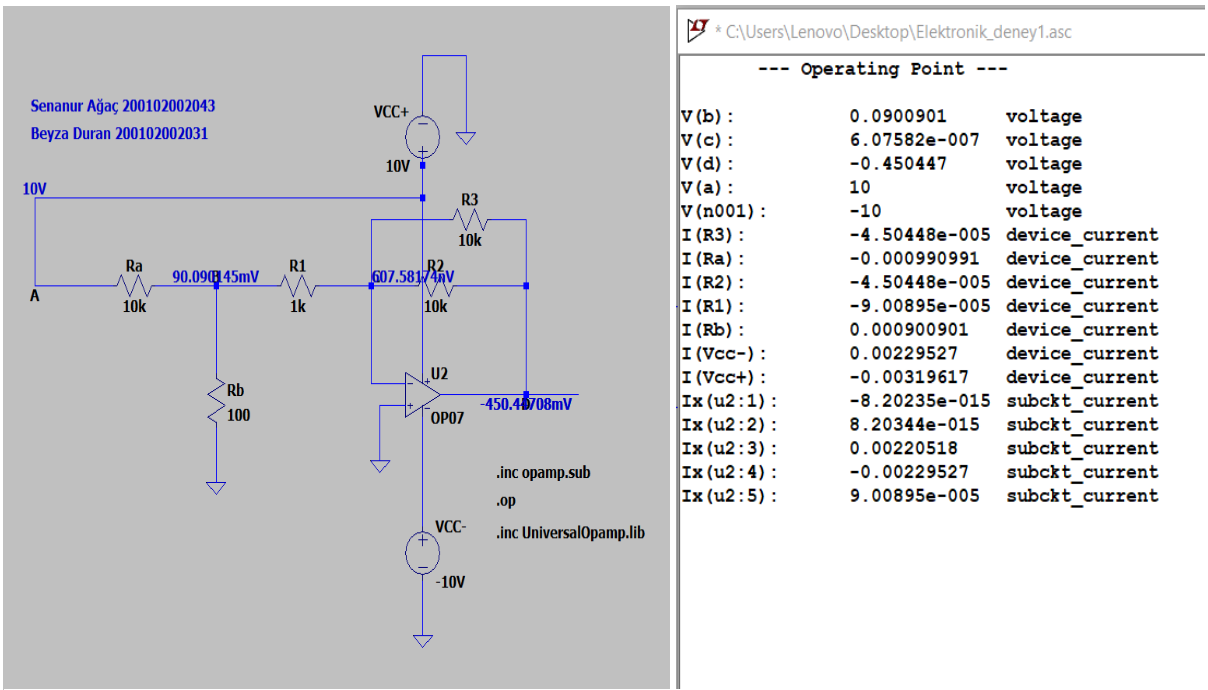


Figure 9: Simulation results when equivalent shunt resistor is added to resistor R2

As seen in the simulation result above, the gain of the opamp is:

$$A_V = \frac{V_D}{V_B} = \frac{-450\ mV}{90\ mV} = -\frac{R_{2(eq)}}{R_1} = -\frac{5k}{1k} = -5$$

) Shunt resistor R1 by one of equal value to raise the gain by a factor of 2. Measure the DC Voltages at nodes B, C, and D. Write gain of the circuit. Put your measurement results to Table 2, column b).

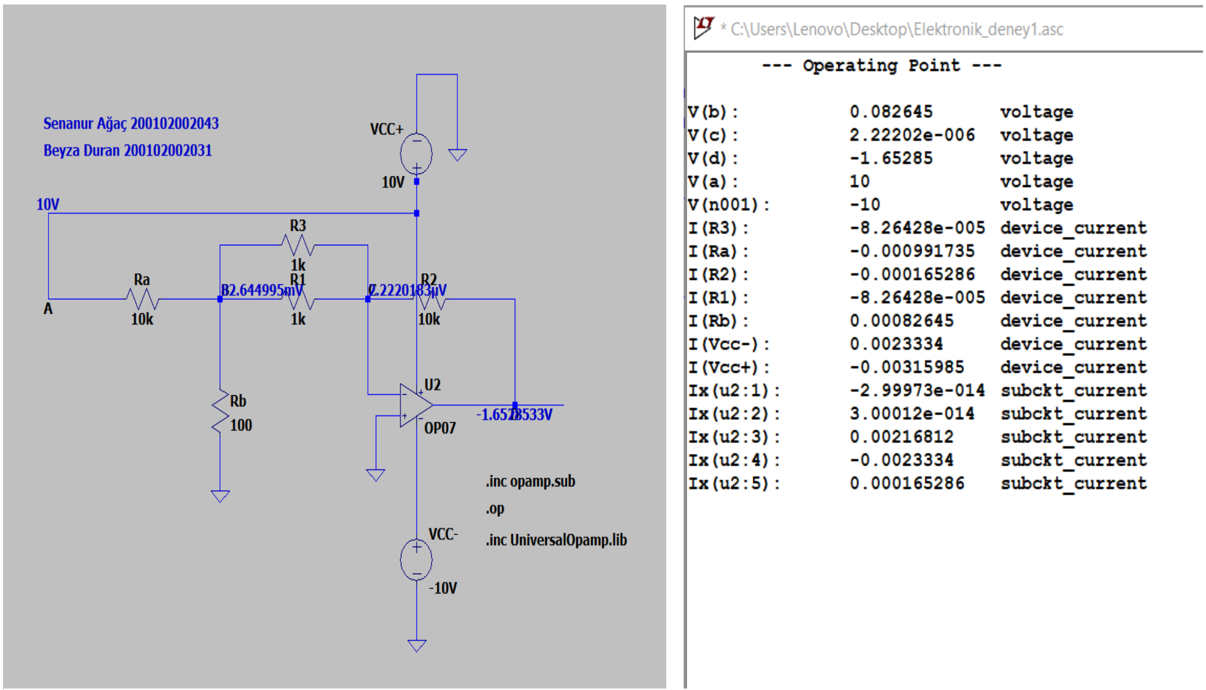


Figure 10: Simulation results when equivalent shunt resistor is added to resistor R1

As seen in the simulation result above, the gain of the opamp is:

$$A_V = \frac{V_D}{V_B} = \frac{-1.65V}{82.64\ mV} = -19.96 \qquad and \qquad -\frac{R_2}{R_{1(eq)}} = -\frac{10k}{0.5k} = -20$$

c) Open the connection of R1 to node B, and add a resistor in series with R1, of equal value, joined to R1 at a new node to be called X. Measure the DC Voltages at nodes B, C, D, and X. Write gain of the circuit. Put your measurement results to Table 2, column c).

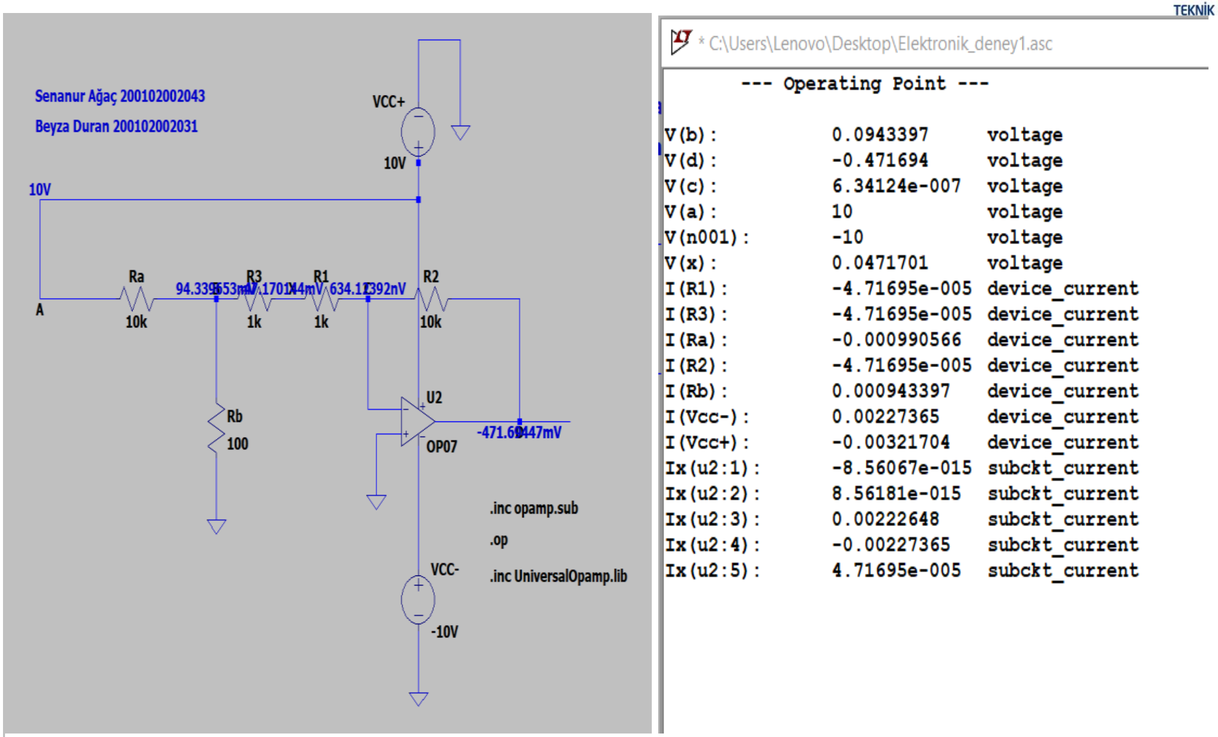


Figure 11: Simulation results when an equivalent series resistor is added to resistor R1

$$A_V = \frac{V_D}{V_B} = \frac{-471mV}{94\ mV} = -5.01 \qquad and \qquad -\frac{R_2}{R_{1(eq)}} = -\frac{10k}{2k} = -5$$

Tablo 2: LTspice measurements

$V_A = +10$ V	a)	b)	c)
V_B	90 mV	82.64 mV	94 mV
V_C	607 nV	2.22 µV	634 nV
V_D	- 450 mV	- 1.65 V	- 475 mV
V_X	N/A	N/A	47.2 mV
Gain = V_D / V_B	- 5	- 19.96	- 5,01

Table 2. DC gain changes.

$V_A = +10$ V	a)	b)	c)
VB	137 mV	250 mV	150 mV
VC	5 mV	150 mV	-98 mV
VD	-0,39 mV	-1,46 V	-0,142 V
VX	N/A	N/A	73 mV
Gain= VD/ VB	-2,9	-5,84	-2,84

Figure 12: Values measured during the experiment

Conclusion: Some of the results we obtained in the experiment did not come out as they should be, so some values in the gain part were irrelevant. There may be incorrect measurements made in the experiment or a connection error in the designed circuit.

: 1.3 AC Gain and Overload:

Problem :

Use the same circuit above with Ra = 1kΩ and node A is connected to a waveform generator.

a) Adjust the waveform at node A for 2 Vpeak (at 1 kHz). Measure the DC and peak-to-peak (Vpp) values and relative phase of the signals. Put your measurement results to Table 3.

b) Short-circuit resistor Ra. Measure the DC and peak-to-peak (Vpp) values and relative phase of the signals. Put your measurement results to Table 3.

Note that loading effect requires the readjustment of the signal source so that the desired amplitude can be obtained at node A.

Result of the problem :

In the circuit, the R_a resistance is adjusted to 1 Ω and the circuit is fed with an AC source. The gain is calculated as V_{dpp} / V_{app}. Calculate the table using the formulas below.

- $V_{pp} = V_{DC} \times \sqrt{2}$
- $\Phi = f \times 360 \times (t_2 - t_1)$

t2-t1 value is reached with cursor from oscilloscope

a)

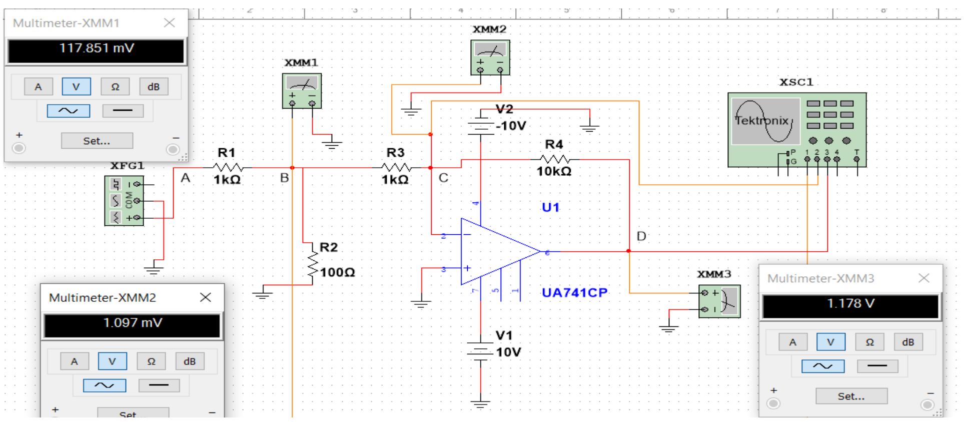


Figure 4

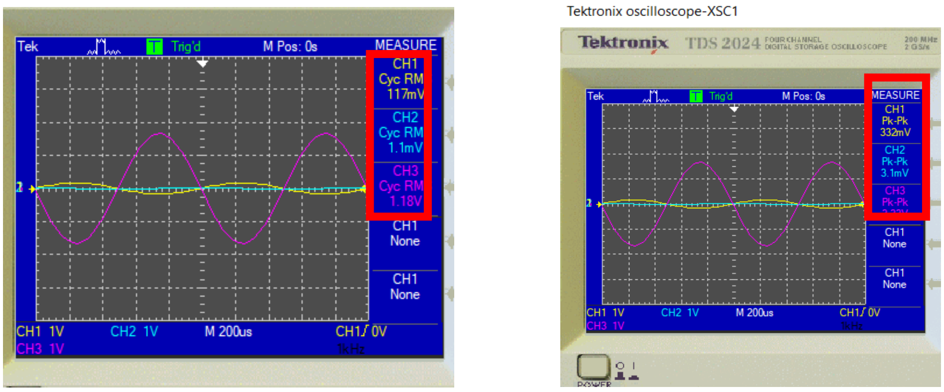


Figure 5 :

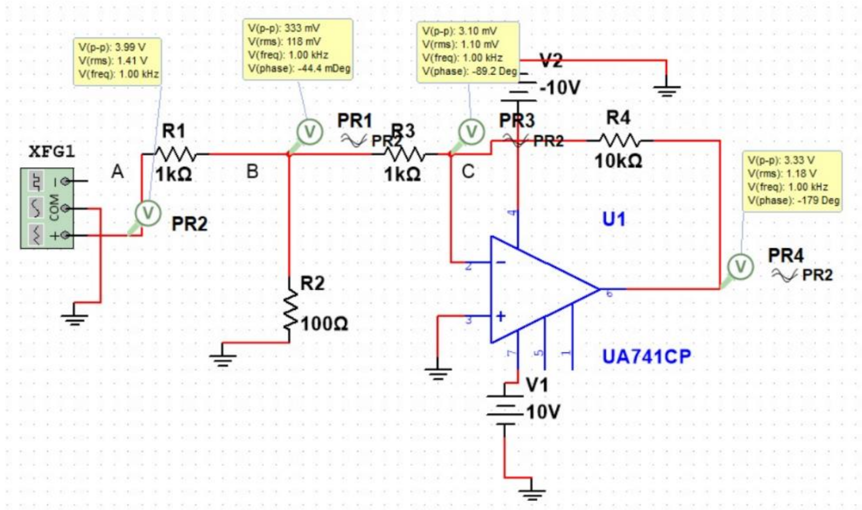


Figure 6

In Figure 5, the circuit was drawn over the multisim and the Vpp Vdc values were reached via the oscilloscope and the t2-t1 value was found. In Figure 6, there is a general drawing with all values. When V_{dpp}/ V_{app} value is found, it is seen that the gain is 0.8325.

$$Gain = \frac{V_{D-pp}}{V_{a-pp}} = \frac{3.33}{4.0} = 0.8325$$

b) The R_a resistor is short-circuited and the circuit is fed by AC Source.

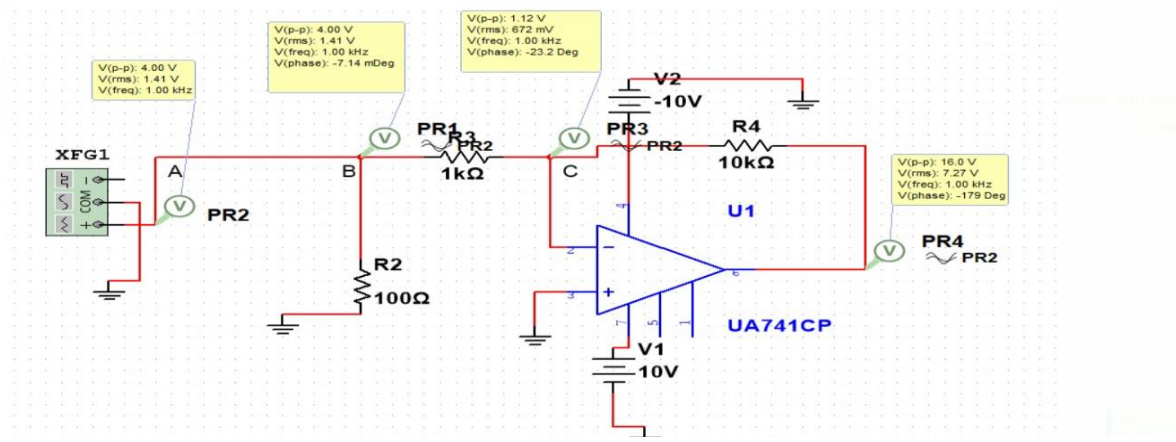


Figure 7

The gain of the circuit should come from the formula (R1/R2). Since Va-pp = 4 V, Vd-pp is expected to be 40. However, since the opamp is supplied with 10 V, it cannot reach this value and the circuit does not work correctly.

Conclusion :

Tablo 3

V_a = 2sin(2π1kt)	Ra=1 kΩ			Ra= 0		
	V_{DC}	V_{PP}	Φ	V_{DC}	V_{PP}	Φ
V_b	117.851 Mv	332 mV	0.440°	1.41 V	4.00 V	0.007 °
V_c	1.097 mV	3.1 mV	89.2°	672 mV	1.12 V	23.2 °
V_d	1.178 V	3.33V	179°	7.27 V	16.0 V	179°

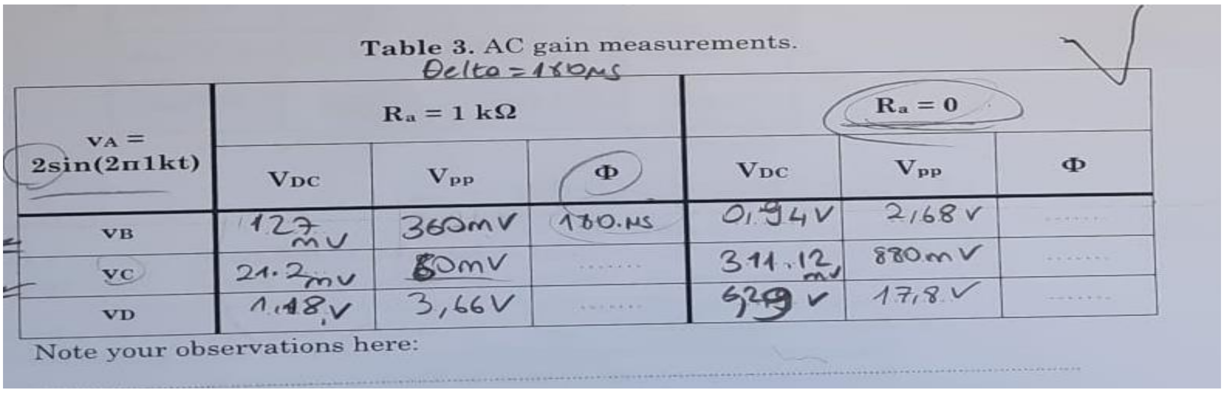


Table 3. AC gain measurements.
Delta = 180µs

VA = 2sin(2π1kt)	Ra = 1 kΩ			Ra = 0		
	VDC	VPP	Φ	VDC	VPP	Φ
VB	127 mV	360mV	180.µs	0,94V	2,68 V	....
VC	21.2mV	80mV	....	311,12 mV	880mV	....
VD	1,48 V	3,66V	....	6,29 V	17,8 V	....

Note your observations here:

Figure 8

The differences between the test and simulation results are due to the noise generated by the cables used. Noises were observed on the oscilloscope during the measurement and an average was applied. The opamp circuit was built using an AC source and the experiment was carried out in the simulation environment. V_{dc}, V_{pp} Φ measurements were made and the relationship between them is given in the equations. The differences between the test and simulation results are due to the noise generated by the cables used. Noises were observed on the oscilloscope during the measurement and an average was applied.

2.1.4. Virtual Ground

Problem:

Use the same circuit above including the input and Ra = 1kΩ. While displaying nodes B and D on your oscilloscope screen, shunt node C to ground with a resistor of various values, in turn 1kΩ, 100Ω, and 10Ω. Put your measurement results to Table 4.

Result of the Problem :

The voltage across Vc is 0 according to the assumptions accepted in the ideal opamp. Since the voltage value at the other end of the added resistor is 0, it does not contribute to the circuit.

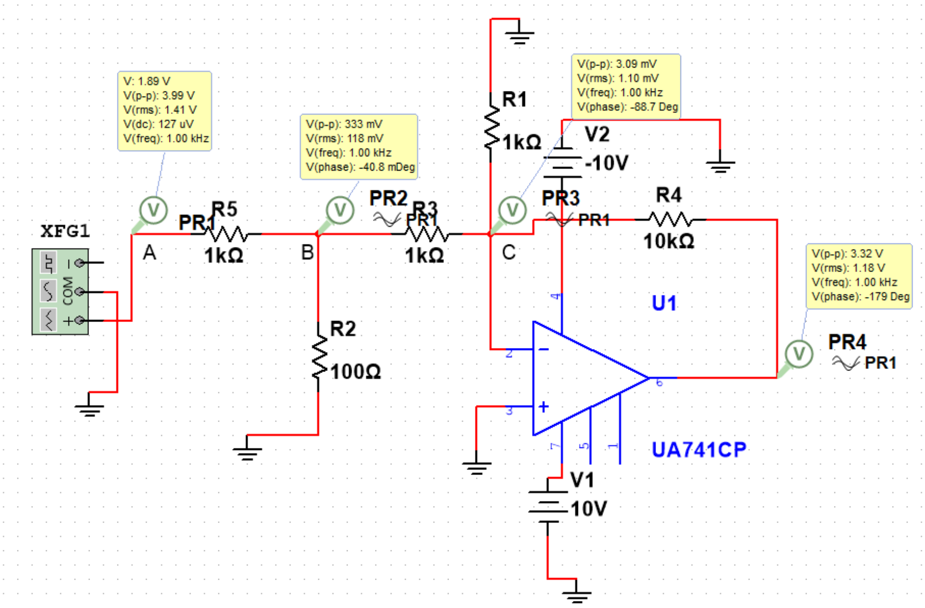


Figure 9

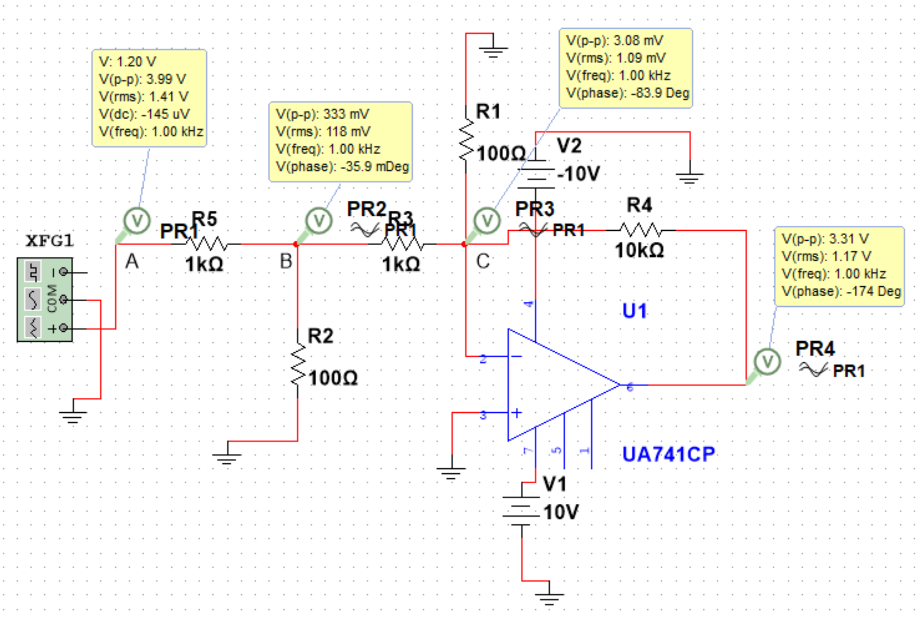


Figure 10

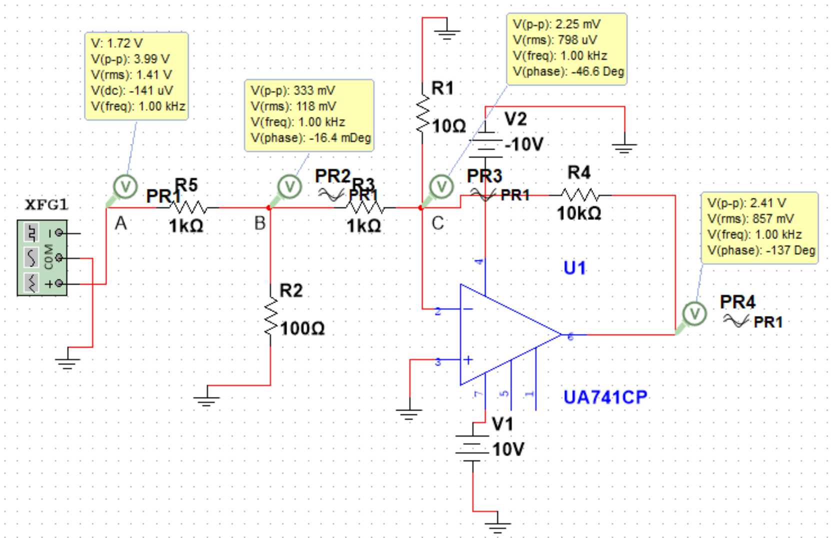


Figure 11

Conclusion :

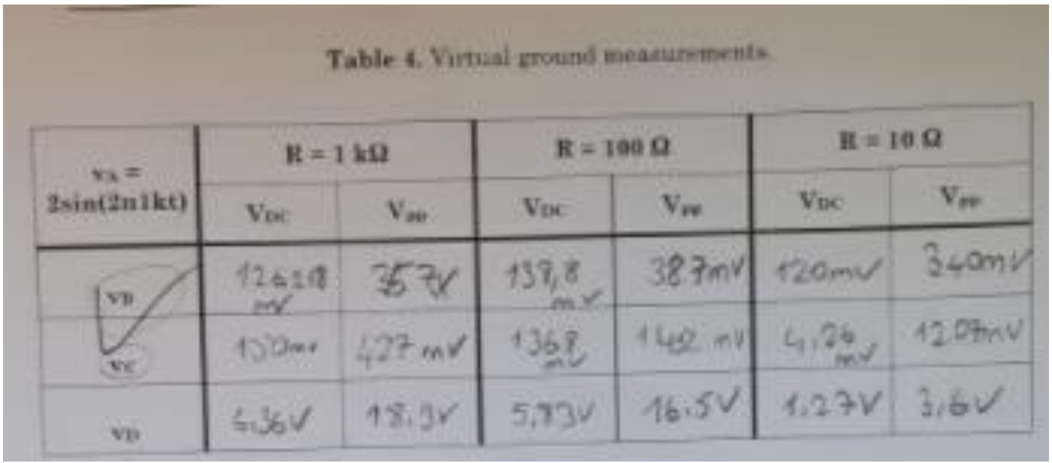


Table 4. Virtual ground measurements.

v_A = 2sin(2π1kt)	R = 1 kΩ		R = 100 Ω		R = 10 Ω	
	V_{DC}	V_{PP}	V_{DC}	V_{PP}	V_{DC}	V_{PP}
VB	126,18 mV	357V	139,8 mV	38.7mV	120mV	340mV
VC	130mV	427 mV	136,8 mV	142 mV	4,26 mV	12.09mV
VD	4,36V	18,3V	5,73V	16,5V	1,27V	3,6V

Figure 12

Tablo 4

V_a = 2sin(2π1kt)	Ra= 1kπ		Ra= 100π		Ra= 10π	
	V_{DC}	V_{PP}	V_{DC}	V_{PP}	V_{DC}	V_{PP}
V_b	118 mV	333 mV	118 mV	333 mV	118 mV	333 mV
V_c	1.10 mV	3.09 mV	1.09 mV	3.08 mV	798 uV	2.25 mV
V_d	1.18 V	3.32 V	1.17 V	3.31 V	857 mV	2.41 V

32.The Non-Inverting Amplifier

1.1 DC Voltages and Gain:

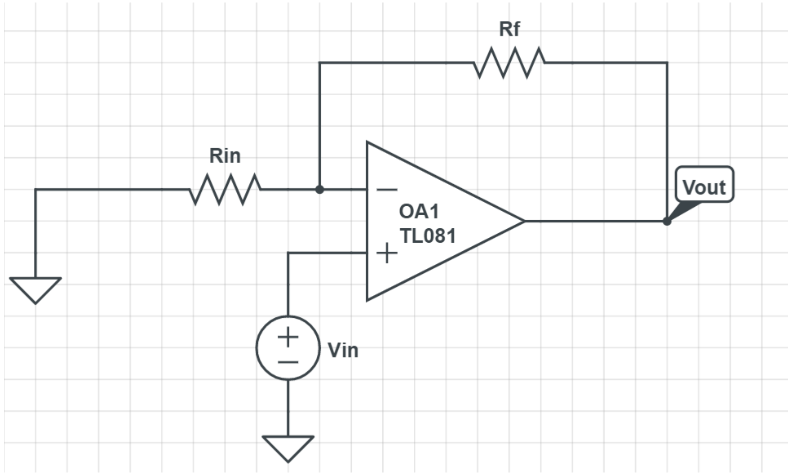


Figure 13

In the Non-Inverting Amplifier circuit, unlike the Inverting Amplifier circuit, the Vin signal is applied to the (+) terminal of the opamp as shown in Figure 14. The ground is connected to the (-) terminal of the opamp.

- Gain = $\frac{V_{out}}{V_{in}} = 1 + \frac{R_2}{R_1}$

Analysis of the circuit

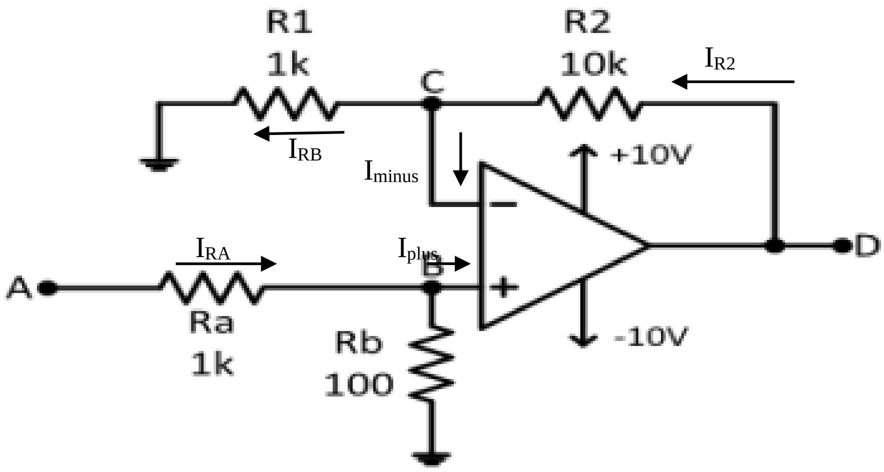


Figure 14

We assume that the rules given below are correct for the ideal opamp.

- $I_{minus} = I_{plus} = 0$ A
- $V_c = V_B$

Using these assumptions, we arrive at the connection between V_A-V_D by solving the following equations.

Since the current passing through I_{minus} does not pass, the current passing through R1 and the current passing through R2 are equal to each other.

- $I_{R1} = I_{R2}$

The following equation is written over the equality of both cases by writing the currents from Ohm's law in terms of I = V/R.

- $I_{R1} = \frac{V_C - 0}{R_1} = I_{R2} = \frac{V_D - V_C}{R_2}$

The equation is simplified and written as

- $V_D = V_C \left(\frac{R_2 + R_1}{R_1}\right)$ (1.1)

The voltage equations according to the resistors connected to the (-) end of the opamp are written as above.

The equation can be established by using the R_a and R_b resistors connected to the (+) end of the opamp. Ideal Opamp, I_{plus} current is considered to be 0. Accordingly, the equation

- $I_{Ra} = I_{Rb}$

is written.

- $I_{Rb} = \frac{V_A - 0}{R_b} = I_{R2} = \frac{V_A - V_B}{R_a}$

The equation is simplified and written as

- $V_B = V_A \times \frac{R_B}{R_A + R_B}$ (1.2)

Since we accept the equality of Vc= Vb in the ideal opamp, the following last equation is written according to equations (1.1) and (1.2).

- $V_D = V_A \times \frac{R_B}{R_A + R_B} \times (1 + \frac{R_2}{R_1})$ (1.3)

(Vout and Vin) The equation between Input and Output is given in 1.3.

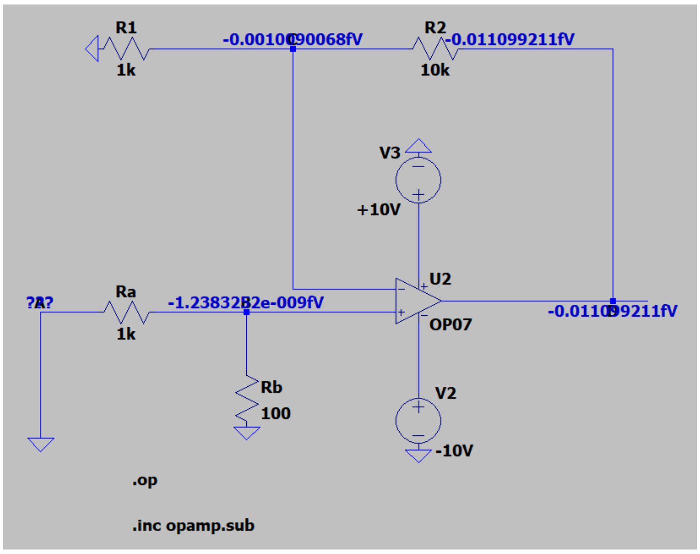
Gain $= \frac{V_D}{V_B} = 1 + \frac{R_2}{R_1}$ (1.4)

Problem:

Assemble the circuit as shown in Figure 3. 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 grounded (0 V) or left open is effectively the same case. Put your measurement results to Table 5.

Result of the problem:

For Va = 0v ;

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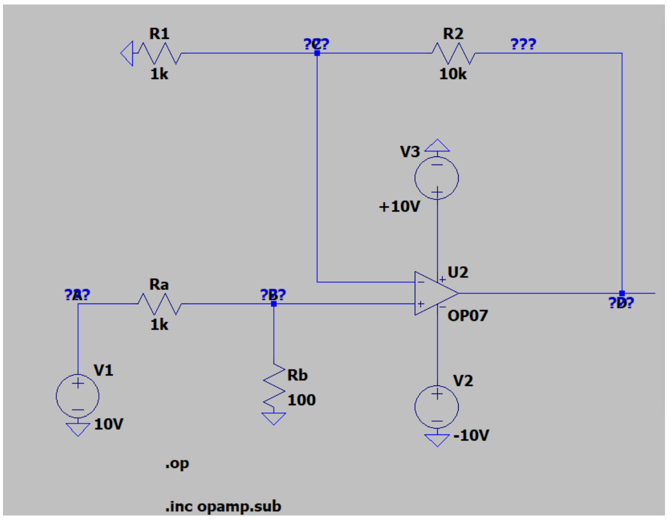
* C:\Users\senaa\OneDrive\Masaüstü\Draft3.asc
        --- Operating Point ---

V(c):           -1.00901e-018  voltage
V(d):           -1.10992e-017  voltage
V(b):           -1.23833e-024  voltage
V(n002):        -10            voltage
V(n001):        10             voltage
I(Ra):          -1.23833e-027  device_current
I(Rb):          -1.23833e-026  device_current
I(R2):          -1.00902e-021  device_current
I(R1):          -1.00901e-021  device_current
I(V3):          -0.00225       device_current
I(V2):          0.00225        device_current
Ix(u2:1):       1.36216e-026   subckt_current
Ix(u2:2):       -1.45403e-026  subckt_current
Ix(u2:3):       0.00225        subckt_current
Ix(u2:4):       -0.00225       subckt_current
Ix(u2:5):       1.73472e-018   subckt_current
```

Figure 15

For Va = +10v ;




```
* C:\Users\senaa\OneDrive\Masaüstü\Draft3.asc
        --- Operating Point ---

V(c):           0.821915       voltage
V(d):           9.04105        voltage
V(b):           0.909091       voltage
V(a):           10             voltage
V(n002):        -10            voltage
V(n001):        10             voltage
I(Ra):          -0.00909091    device_current
I(Rb):          0.00909091     device_current
I(R2):          0.000821913    device_current
I(R1):          0.000821915    device_current
I(V3):          -0.00267608    device_current
I(V2):          0.00186084     device_current
I(V1):          -0.00909091    device_current
Ix(u2:1):       1.1785e-009    subckt_current
Ix(u2:2):       -1.17541e-009  subckt_current
Ix(u2:3):       0.00267608     subckt_current
Ix(u2:4):       -0.00186084    subckt_current
Ix(u2:5):       -0.000821913   subckt_current
```

Figure 16

For Va = -10v ;

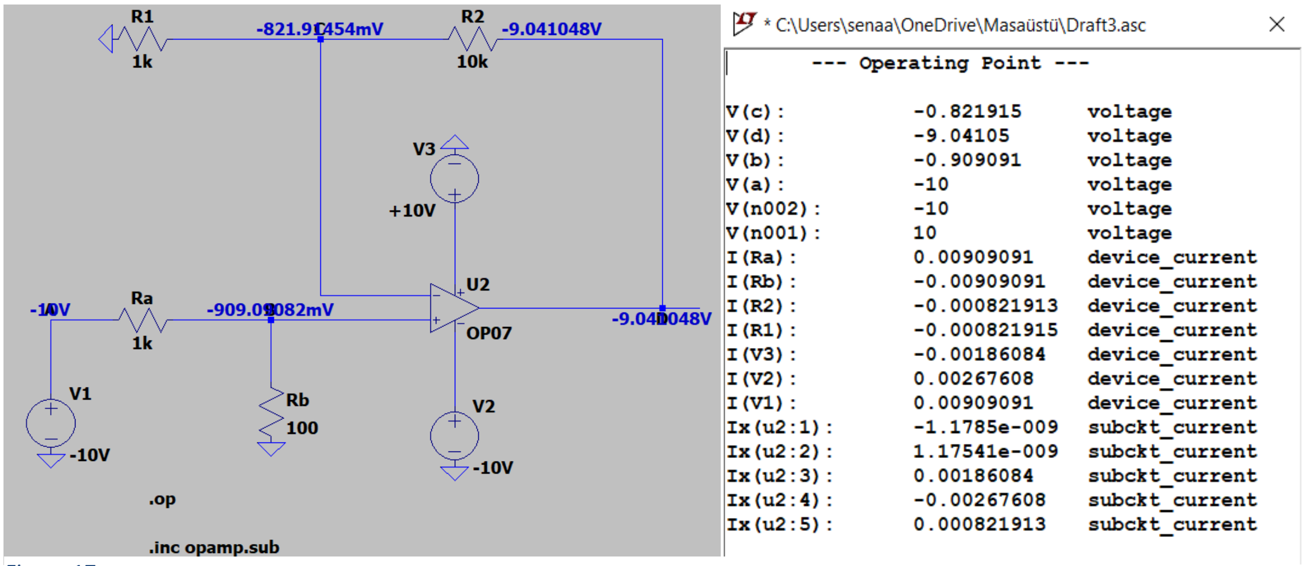


Figure 17

Tablo 5

V_a	V_b	V_c	V_d
0 V	0 V	0 V	0 V
+10 V	99.008 mV	99.008 mV	1.089 V
-10 V	-99.008 mV	-99.008 mV	-1.089 V

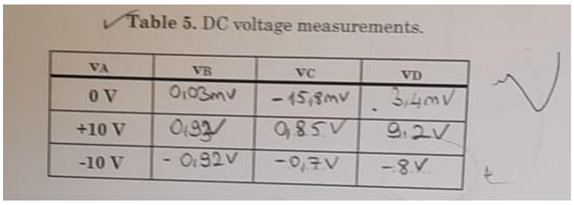


Table 5. DC voltage measurements.

VA	VB	VC	VD
0 V	0,03mV	-15,8mV	3,4mV
+10 V	0,93V	0,85V	9,2V
-10 V	- 0,92V	-0,7V	-8V

Figure 18

Comparison of the test results and simulation results can be seen in table 5 and figure x. The reasons for the error values occurring in between may be due to the energy losses experienced during the experiment, the UA741CP opamp used, and the noise caused by the jumpers.

According to the formulas 1.3 and 1.x, the gain should be 10(R_2/R_1 = 10k/1k) in this experiment. As a result of the simulation, it was seen that it was approximately 10.

2.2 Quick Changes of Gain:

PROBLEM :

Use the same circuit above with vA = +10 V.

a) Shunt resistor R2 by one of equal value. Measure the DC Voltages at nodes B, C, and D. Put your measurement results to Table 6, column a).

b) Shunt resistor R1 by one of equal value. Measure the DC Voltages at nodes B, C, and D. Put your measurement results to Table 6, column b).

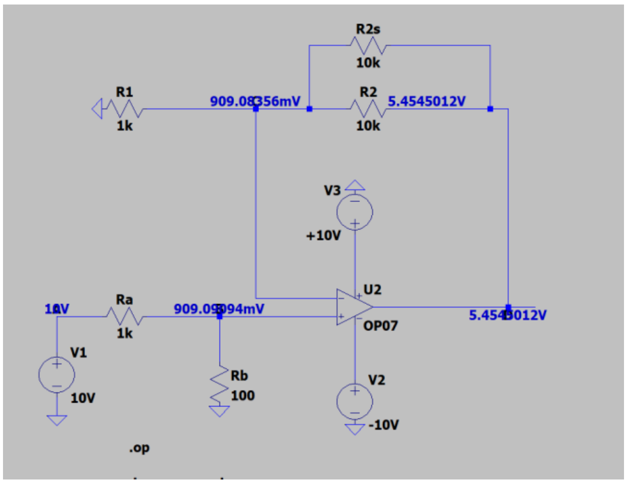
c) Short-circuit resistor R2. Measure the DC Voltages at nodes B, C, and D. Put your measurement results to Table 6, column c).

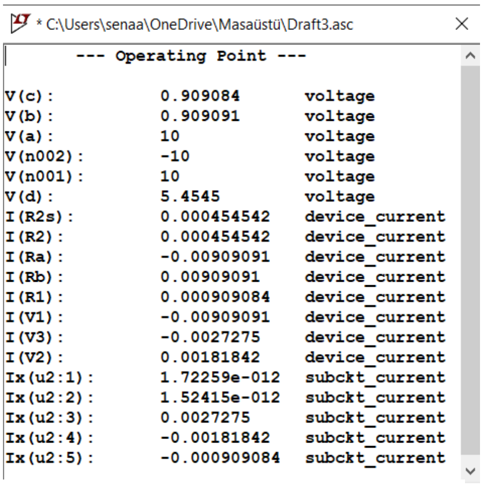
Result of the problem :

What is required in this question is to make new comments about the gain by making additions to the circuit as desired in options a, b and c.

a) In this case, as requested from us, we attach another parallel resistor to R2 in the simulation program and experiment. As a result of this addition, the new value of total R2 becomes 5k(10k//10k). When the calculations are made according to the equation given below, it is seen that the gain is 6. The Vd/Vb result also confirms this value.

Gain = $1 + \frac{R_2}{R_1} = 1 + \frac{5k}{1k} = 6$





* C:\Users\senaa\OneDrive\Masaüstü\Draft3.asc

--- Operating Point ---

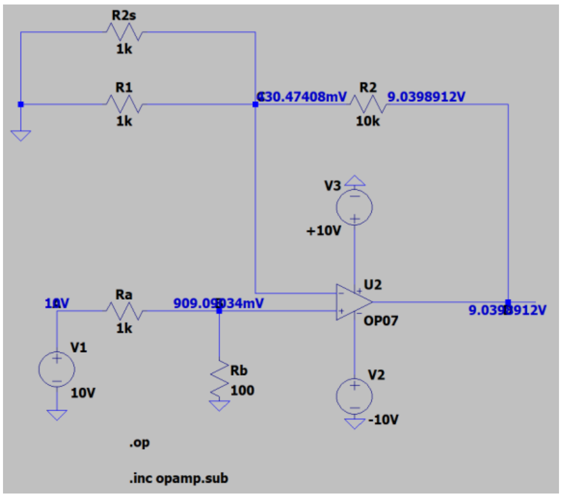
V(c):	0.909084	voltage
V(b):	0.909091	voltage
V(a):	10	voltage
V(n002):	-10	voltage
V(n001):	10	voltage
V(d):	5.4545	voltage
I(R2s):	0.000454542	device_current
I(R2):	0.000454542	device_current
I(Ra):	-0.00909091	device_current
I(Rb):	0.00909091	device_current
I(R1):	0.000909084	device_current
I(V1):	-0.00909091	device_current
I(V3):	-0.0027275	device_current
I(V2):	0.00181842	device_current
Ix(u2:1):	1.72259e-012	subckt_current
Ix(u2:2):	1.52415e-012	subckt_current
Ix(u2:3):	0.0027275	subckt_current
Ix(u2:4):	-0.00181842	subckt_current
Ix(u2:5):	-0.000909084	subckt_current

Figure 19

$$\frac{V_D}{V_B} = \frac{5.4545\ V}{909.0994\ mV} = \ 5{,}9999$$

b) In this case, as requested from us, we attach another parallel resistor to R1 in the simulation program and in the experiment. As a result of this addition, the new value of total R1 becomes 1k(1k//1k). When the calculations are made according to the equation given below, it is seen that the gain is 21. The Vd/Vb result also confirms this value.

Gain = $1 + \frac{R_2}{R_1} = 1 + \frac{10k}{1k} = 11$




```
* C:\Users\senaa\OneDrive\Masaüstü\Draft3.asc
--- Operating Point ---

V(c):          0.430474        voltage
V(b):          0.90909         voltage
V(a):          10              voltage
V(n002):       -10             voltage
V(n001):       10              voltage
V(d):          9.03989         voltage
I(R2s):        0.000430474     device_current
I(R2):         0.000860942     device_current
I(Ra):         -0.00909091     device_current
I(Rb):         0.0090909       device_current
I(R1):         0.000430474     device_current
I(V1):         -0.00909091     device_current
I(V3):         -0.00269723     device_current
I(V2):         0.00184329      device_current
Ix(u2:1):      6.46294e-009    subckt_current
Ix(u2:2):      -6.46055e-009   subckt_current
Ix(u2:3):      0.00269723      subckt_current
Ix(u2:4):      -0.00184329     subckt_current
Ix(u2:5):      -0.000860942    subckt_current
```

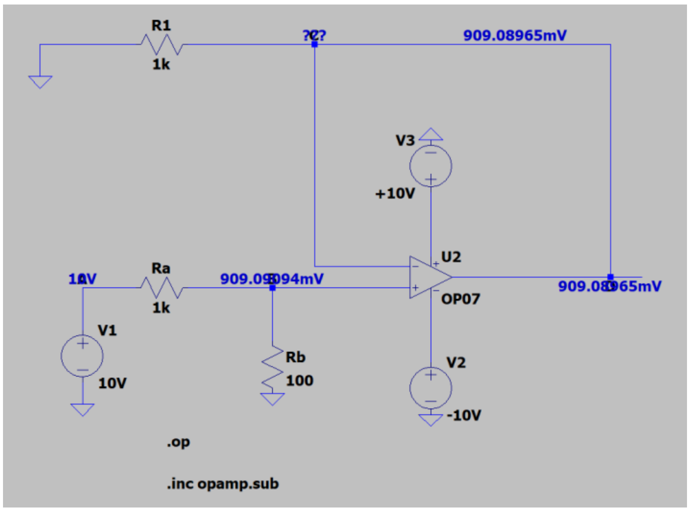
Figure 21

$$\frac{V_D}{V_B} = \frac{9.03989\ V}{909.0994\ mV} = 9.9537$$

c)

In this case, R_2 resistor was short-circuited in the simulation program and experiment as requested. After this change, it is seen that the Vin value, where the opamp has no gain, and the Vout value are equal.

Gain $= 1 + \frac{R_2}{R_1} = 1 + \frac{0k}{1k} = 1$




```
* C:\Users\senaa\OneDrive\Masaüstü\Draft3.asc
--- Operating Point ---

V(d):          0.90909         voltage
V(b):          0.909091        voltage
V(a):          10              voltage
V(n002):       -10             voltage
V(n001):       10              voltage
I(Ra):         -0.00909091     device_current
I(Rb):         0.00909091      device_current
I(R1):         0.00090909      device_current
I(V1):         -0.00909091     device_current
I(V3):         -0.0027275      device_current
I(V2):         0.00181841      device_current
Ix(u2:1):      1.64037e-012    subckt_current
Ix(u2:2):      1.60638e-012    subckt_current
Ix(u2:3):      0.0027275       subckt_current
Ix(u2:4):      -0.00181841     subckt_current
Ix(u2:5):      -0.00090909     subckt_current
```

Figure 22

$$\frac{V_D}{V_B} = \frac{909.089\ V}{909.098\ mV} = 0.9999$$

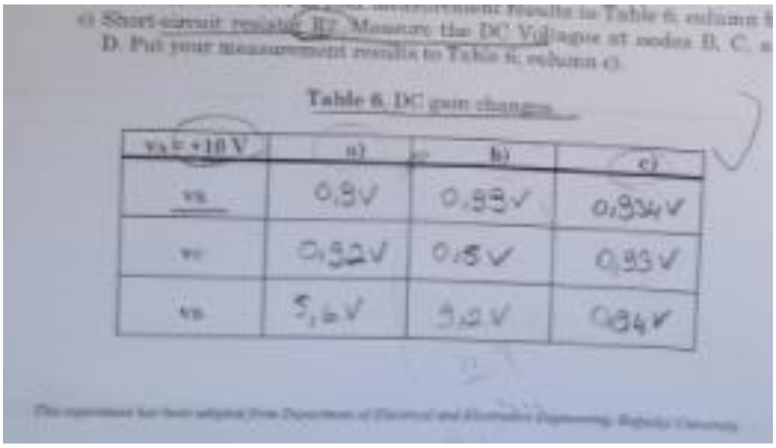
Conclusion :

Connections, analyzes and equations of Non-Inverting Amplifier opamps have been understood with the experiments. Gain equations were written and these calculations were made according to the changes in the resistors. The simulation results and experiment results written in the table are in agreement. Minor differences may be due to the experimental environment, noise due to the jumpers used.

Table 6

V_a = +10v	a)	b)	c)
V_b	$909.0994\ mV$	909.0994 mV	909.098 mV
V_c	909.008 mV	0.43 V	909.099 mV
V_d	5.4545 V	9.03989 V	909.089 mV

Figure 23



c) Short-circuit resistor R2. Measure the DC Voltage at nodes B, C, a[illegible]
D. Put your measurement results to Table 6, column c).

Table 6. DC gain changes

VA = +10 V	a)	b)	c)
VB	0,9V	0,93V	0,934V
VC	0,92V	0,5V	0,93V
VD	5,6V	9,2V	0,84V

2.3 AC Gain and Overload:

Problem:
Use the same circuit above with Ra = 1kΩ and node A is connected to a waveform generator.

a) Adjust the waveform at node A for 5 Vpeak (at 1 kHz). Measure the peak-to-peak (Vpp) values and relative phase of the signals. Put your measurement results to Table 7.

b) Shunt both OPAMP input terminals individually with resistors Rx = 1 kΩ. Measure the peak-to-peak (Vpp) values and relative phase of the signals. Put your measurement results to Table 7.

c) Insert a series resistor Rs = 100 kΩ between node B and resistor Ra while the Rx's are still in place as shown in Figure 4. Measure the peakto-peak (Vpp) values and relative phase of the signals. Put your measurement results to Table 7.

Result of the problem :

a)
When the circuit is filled as the instructions given in the option, the simulation results are taken as follows.

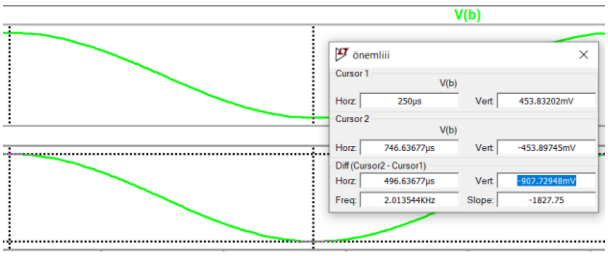


Figure 24

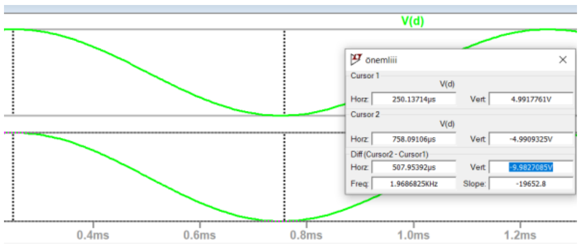


Figure 25

Figure 26

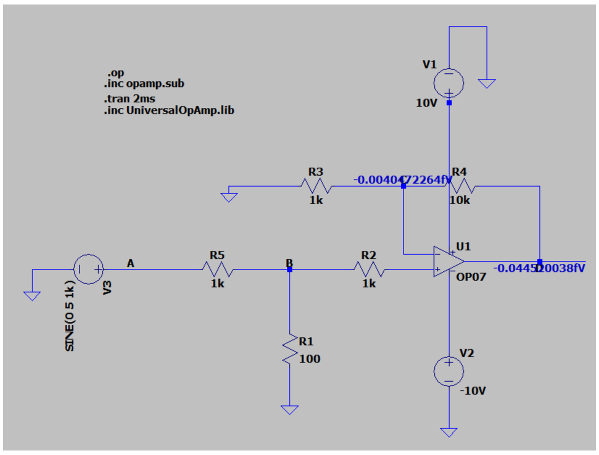


Figure 27

b)

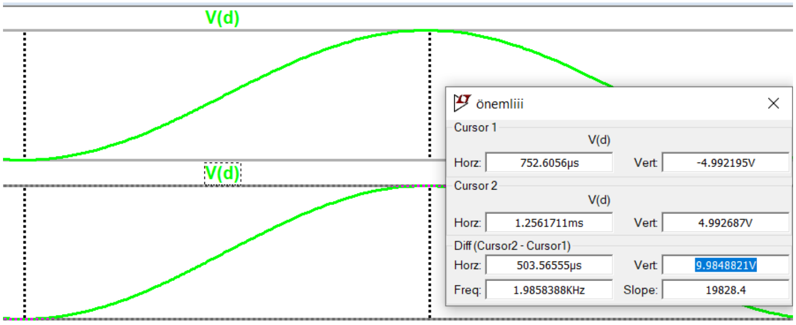


Figure 28

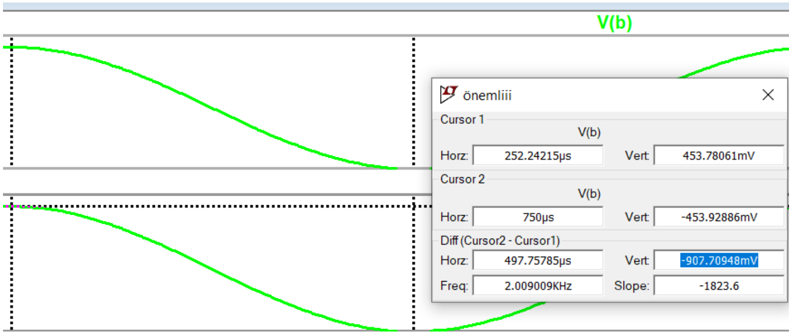


Figure 29

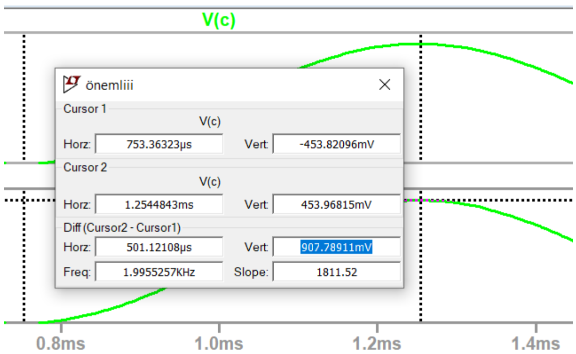


Figure 30

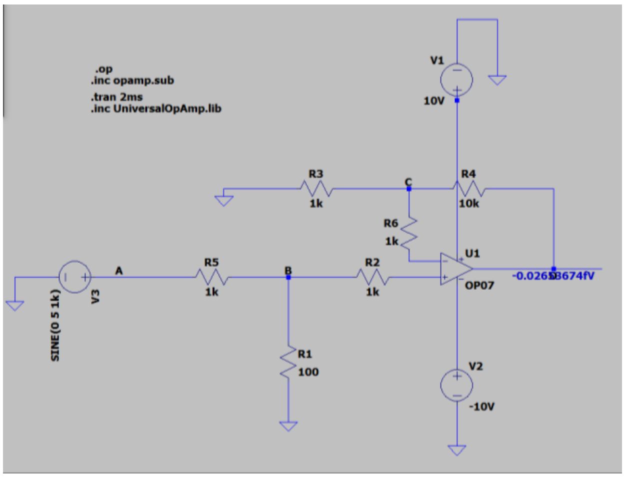


Figure 31

c)

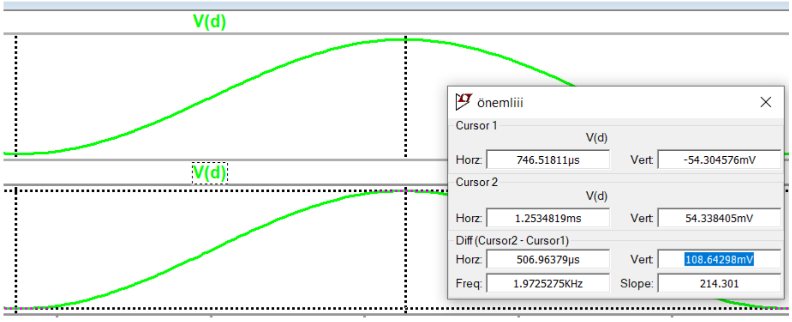


Figure 32

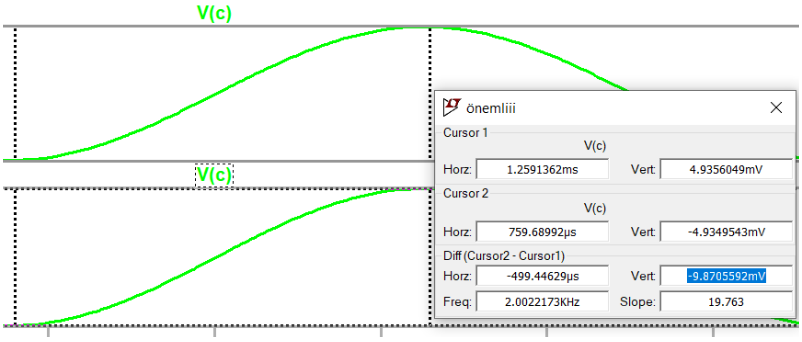


Figure 33

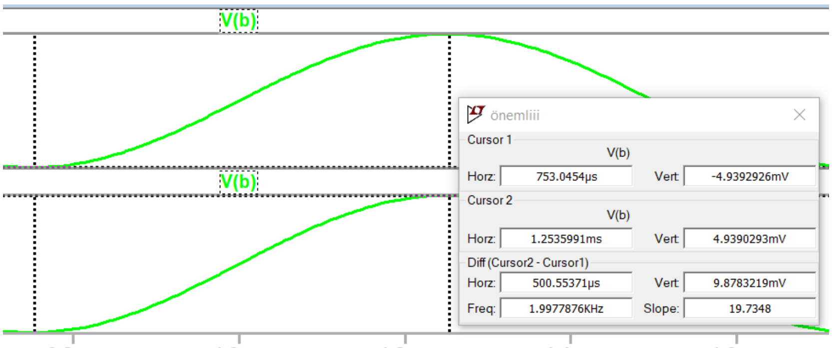


Figure 34

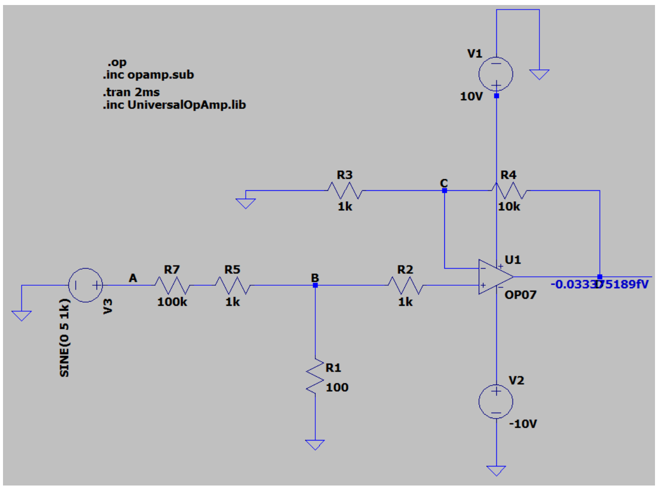


Figure 35

Conclusion :
When the table is examined, it is seen that the Rx resistance has no effect on the results. The effect of the resistor Rs is found to be .fghj.. and the result is in agreement with the equations found during the analysis of the circuit.

Table 6

V_a 5sin(2π1kt)	Rx = ∞ Rs = 0	Rx = 1 kΩ Rs = 0	Rx = 1 kΩ Rs = 100 kΩ
	V_{PP}	V_{PP}	V_{PP}
V_b	907.8 mV	907.8 mV	9.87 mV
V_c	907.8 mV	907.8 mV	9.87 mV
V_d	9.97V	9.98V	108.64 mV
Gain	1.0001	1.0109	

3.General-Purpose Amplifier Topology

3.1 Individual Inputs, Difference Gains:

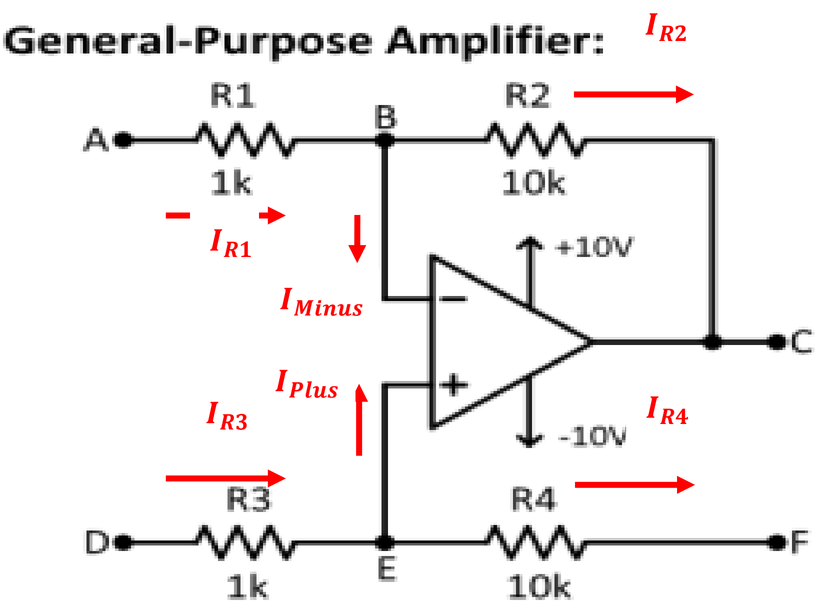


Figure 36

$$I_{R1} = I_{R2} + I_{Minus}$$

$$I_{Minus} = 0 \rightarrow I_{R1} = I_{R2} \rightarrow \frac{V_A - V_B}{R_1} = \frac{V_B - V_C}{R_2}$$

$$V_C = V_B\left(1+\frac{R_2}{R_1}\right) - V_A\,\frac{R_2}{R_1}$$

$$I_{R3} = I_{R4} + I_{Plus}$$

$$I_{Plus} = 0 \rightarrow I_{R3} = I_{R4} = \frac{V_D - V_E}{R_3} = \frac{V_E - V_F}{R_4}$$

$$V_E = \frac{\dfrac{V_D}{R_3} + \dfrac{V_F}{R_4}}{\dfrac{1}{R_3} + \dfrac{1}{R_4}}$$

PROBLEM 1:
Assemble the circuit as shown in Figure 5. Adjust the power supplies to ±10V. Adjust the waveform at node A for 100mV peak (at 1 kHz). The other nodes are connected to ground. Measure the peak-to-peak (Vpp) values and relative phase of the signals.

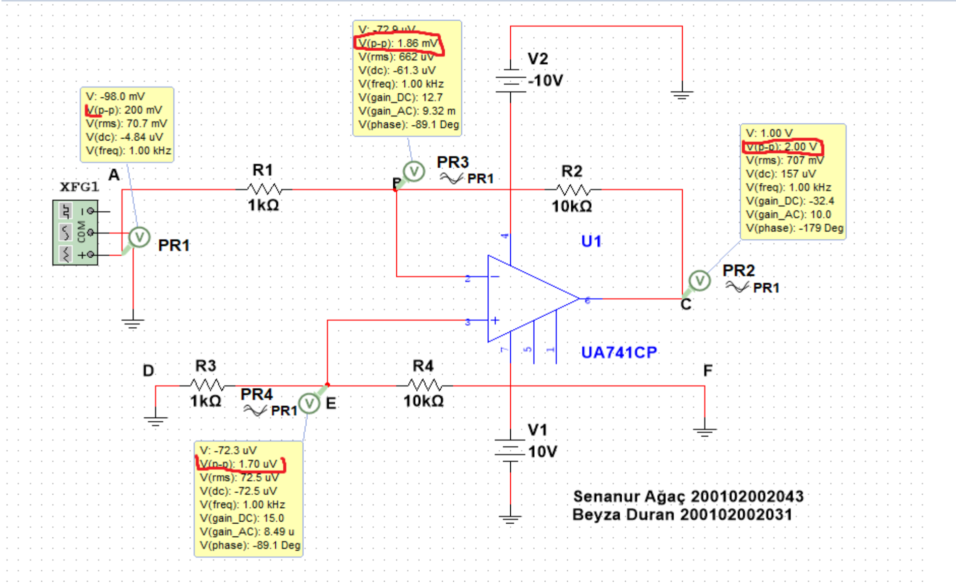


Figure 37: If +200 mV peak-to-peak voltage is given from node A, circuit and values

PROBLEM 2:
Then, connect the 100mV signal to node D and the other nodes to ground and measure the peak-to-peak (Vpp) values and relative phase of the signals.

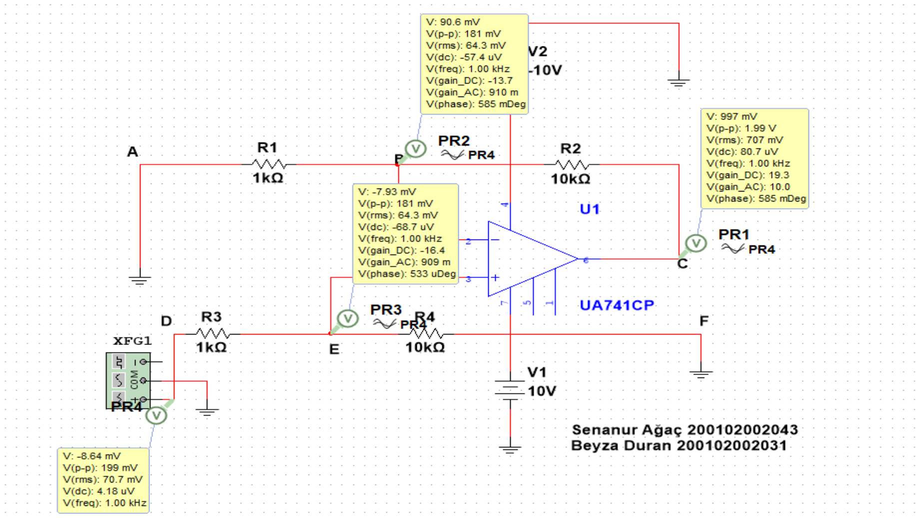


Figure 208: If +200 mV peak-to-peak voltage is given from node D, circuit and values

PROBLEM 3:

Finally, connect the 100mV signal to node F and the other nodes to ground and measure the peak-to-peak (Vpp) values and relative phase of the signals. Put your measurement results to Table 8.

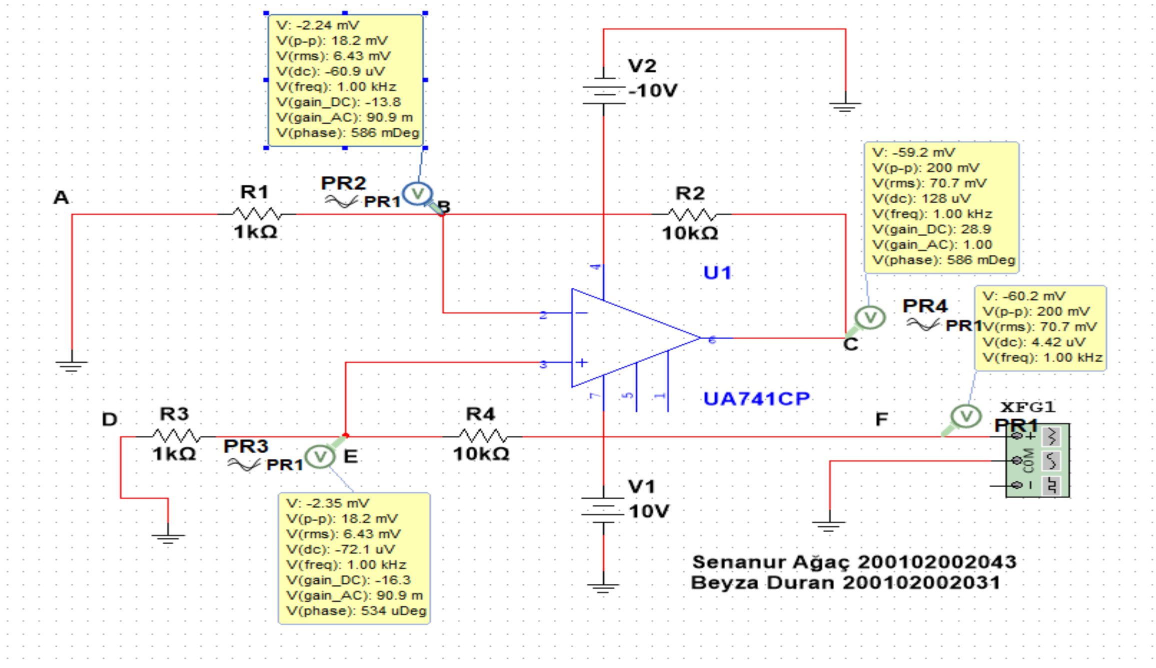


Figure 39: If +200 mV peak-to-peak voltage is given from node F, circuit and values

Table 6: Multisim simulation results

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	2 V	1.99 V	200 mV
V_B	1.86 mV	181 mV	18.2 mV
V_E	1.70µV	181 mV	18.2 mV

Conclusion:

We couldn't do it because we didn't have enough time for Table 8. That's why we were able to simulate and do this part later. The simulation results are consistent with the theoretical equations.

3.2 Common- Mode Gains:

PROBLEM 1:

a) Connect the waveform generator to provide a 5 V peak signal to both A, D with F at ground. Measure the peak-to-peak (Vpp) values and relative phase of the signals. Put your measurement results to Table 9.

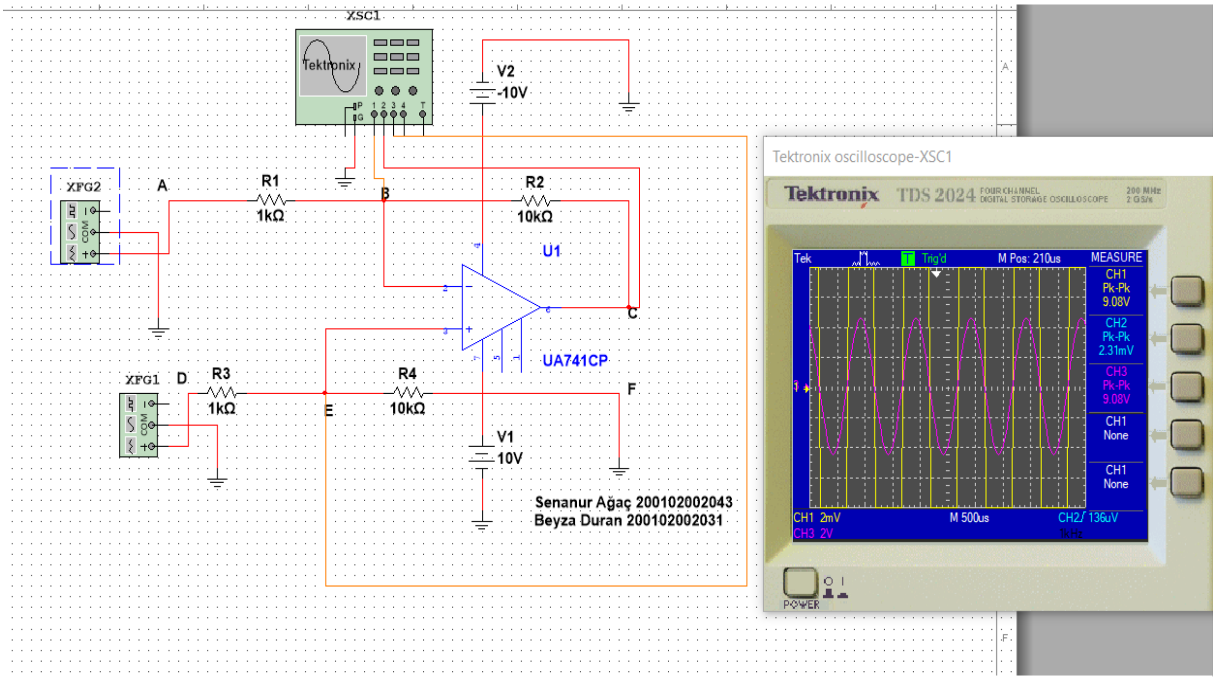


Figure 40 : The voltages obtained at nodes C , B and E when 10 V peak to peak is given to nodes A and D

PROBLEM 2:

b) Connect the waveform generator to provide a 5 V peak signal to A, D, and F. Measure the peak-to-peak (Vpp) values and relative phase of the signals. Put your measurement results to Table 9.

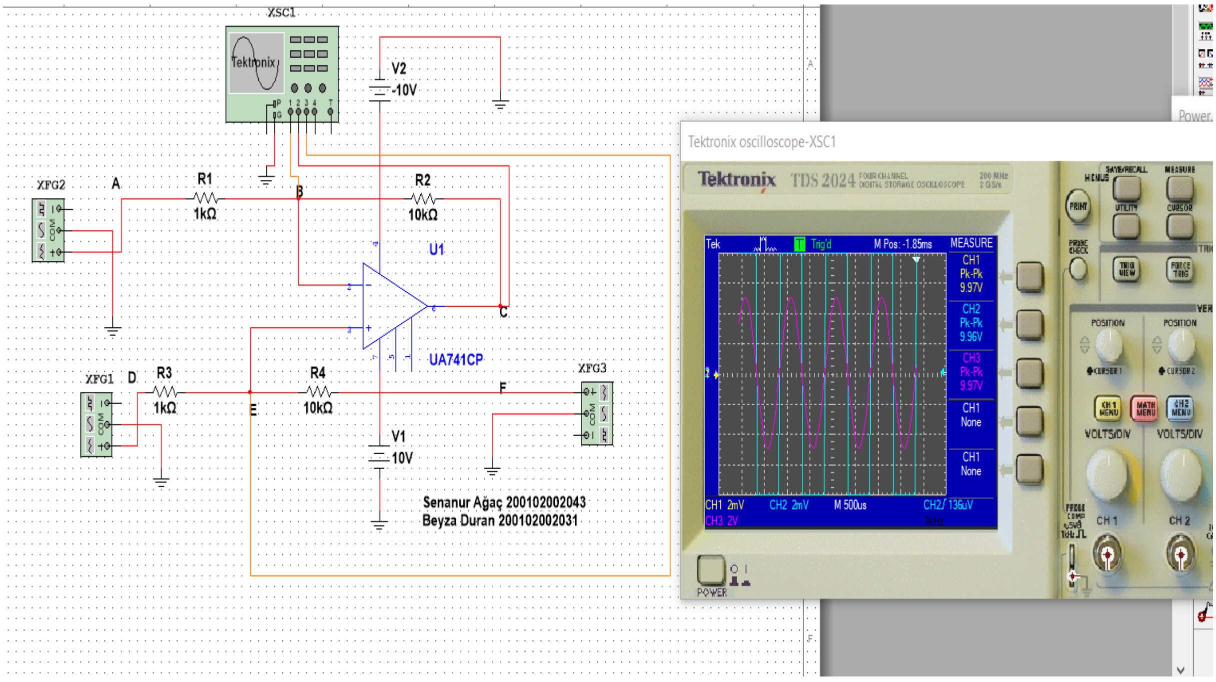


Figure 41 : The voltages obtained at nodes C , B and E when 10 V peak to peak is given to nodes A , D and F

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	2.31 mV	9.96 V
V_B	9.08 V	9.96 V
V_E	9.08 V	9.97 V

Tablo 7: MULTISIM simulation results

Conclusion: Since we could not reach this part of the experiment, the results could not be obtained. but the table is filled by simulating with Multisim.