AV-241 : Instrumentation and Control Lab

Instrumentation Lab-1

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SC22B146

Experiment -3

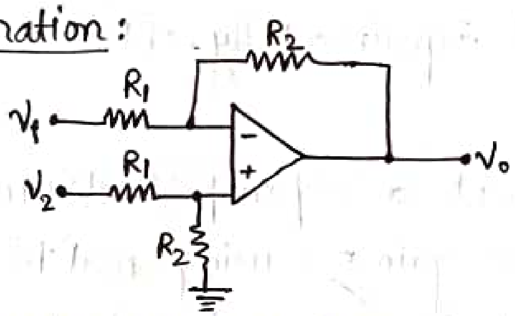
Aim: Design and implement two important OP-AMP based measurement circuits :

(a) Difference Amplifier
(b) Instrumentation Amplifier using 3 opamps.

Components and Equipments Required :

- Opamp IC OP07
- Variable resistance boxes / Potentiometers
- DC power supply
- Multimeter.

Brief Explanation :



Output voltage is given as

$$V_o = (V_2 - V_1)\frac{R_2}{R_1}$$

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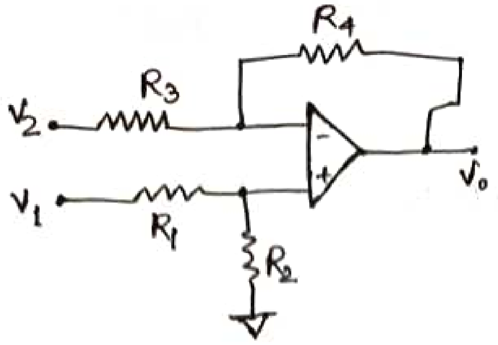
Difference amplifier amplifies the difference of the input voltages V_1 and V_2.

The objective of this experiment difference amplifier circuits is to further understand the concepts of difference modes signals and CMRR.

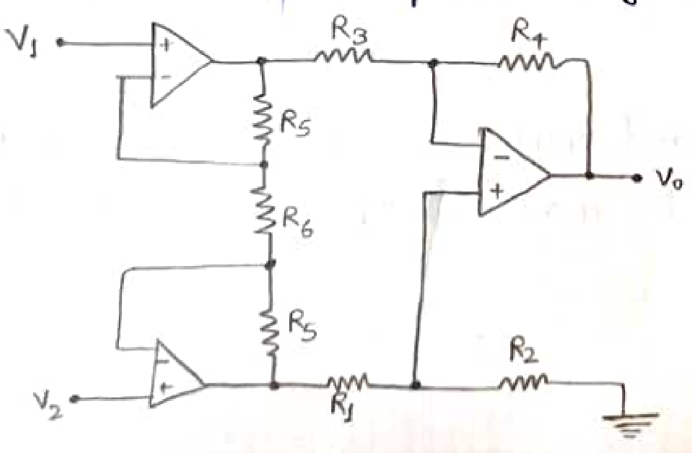
Part A: Design and implement a difference amplifier of unity difference gain using matched 10 KΩ resistors.



Measure the output of the difference amplifier for:
(i) $V_1 = 0.5V$ and $V_2 = -0.5V$,
(ii) $V_1 = V_2 = 1V$.

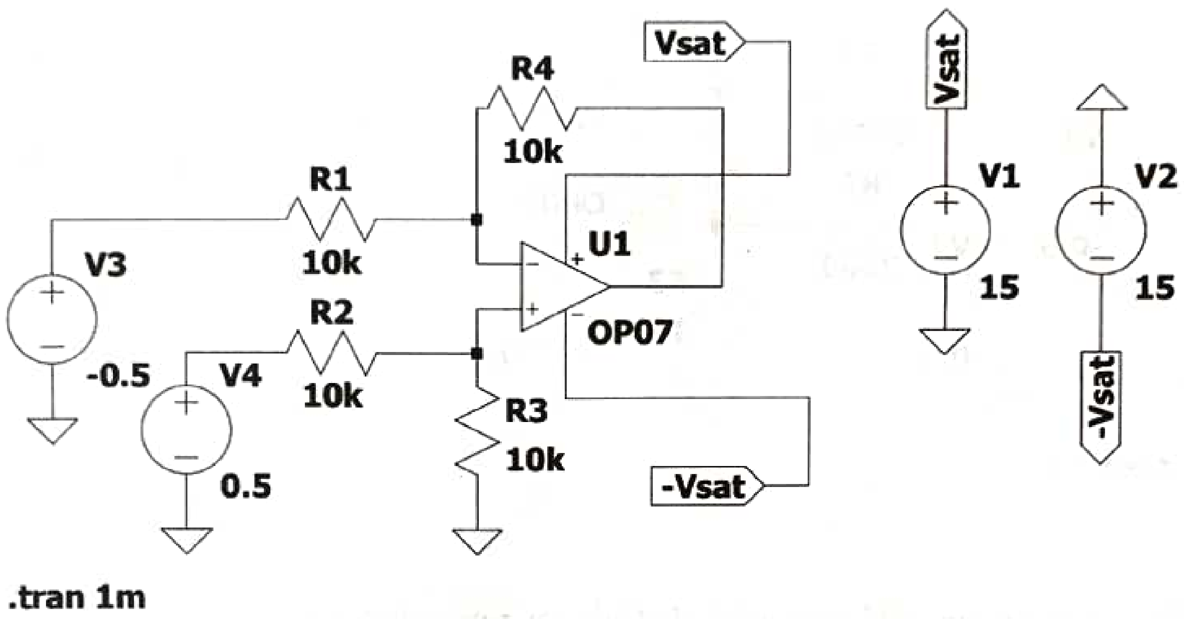
Compute CMRR using the above measured outputs.
Now, find the 1% mismatch of the resistors of the difference amplifiers and find experimentally the minimum value of CMRR for this circuit.
Repeat the experiment for 2% tolerance as well. Check the similari[ty] between the theoretical and experimentally-obtained values of CMRR.

Part B: Design and implement a 3-opamp Instrumentation amplifier (IA) of difference gain =3 using matched 10 kΩ resistors. Compute CMRR using the above measured outputs.
Now, find the 1% mismatch to the resistors of the difference amplifier in the IA and find experimentally the minimum value of CMRR for this circuit.
Repeat the experiment for 2% tolerance as well. Check the similarity between the theoretical and experimentally-obtained values of CMRR.

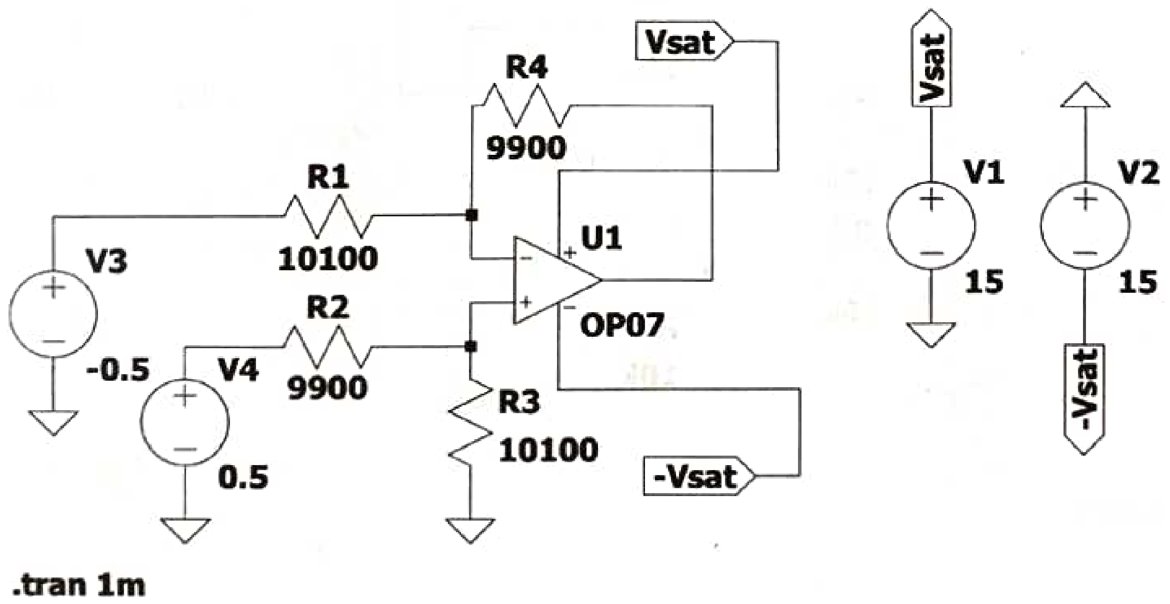


Differential Amplifier Experiment Simulation:

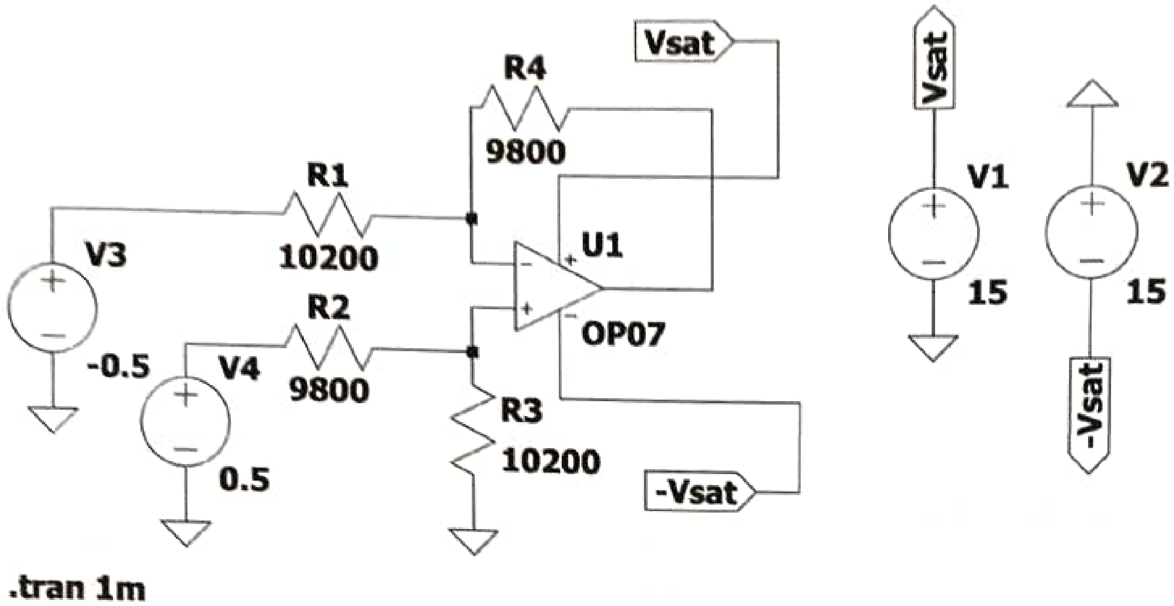
A) Measurement of Differential Gain for **zero** tolerance



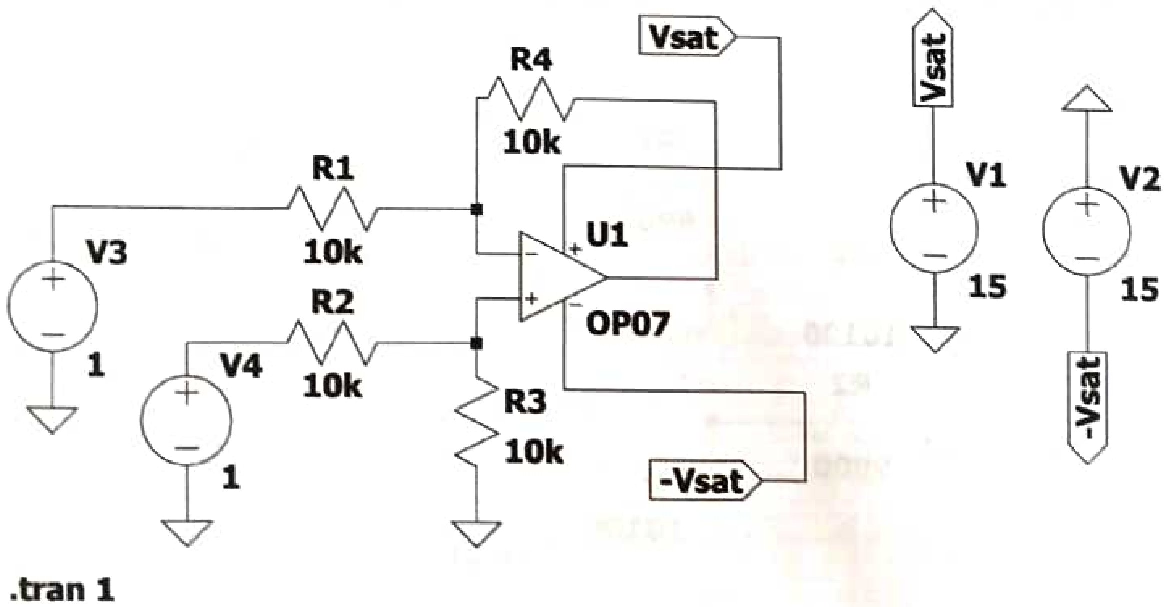
B) Measurement of Differential Gain for **one percentage** tolerance



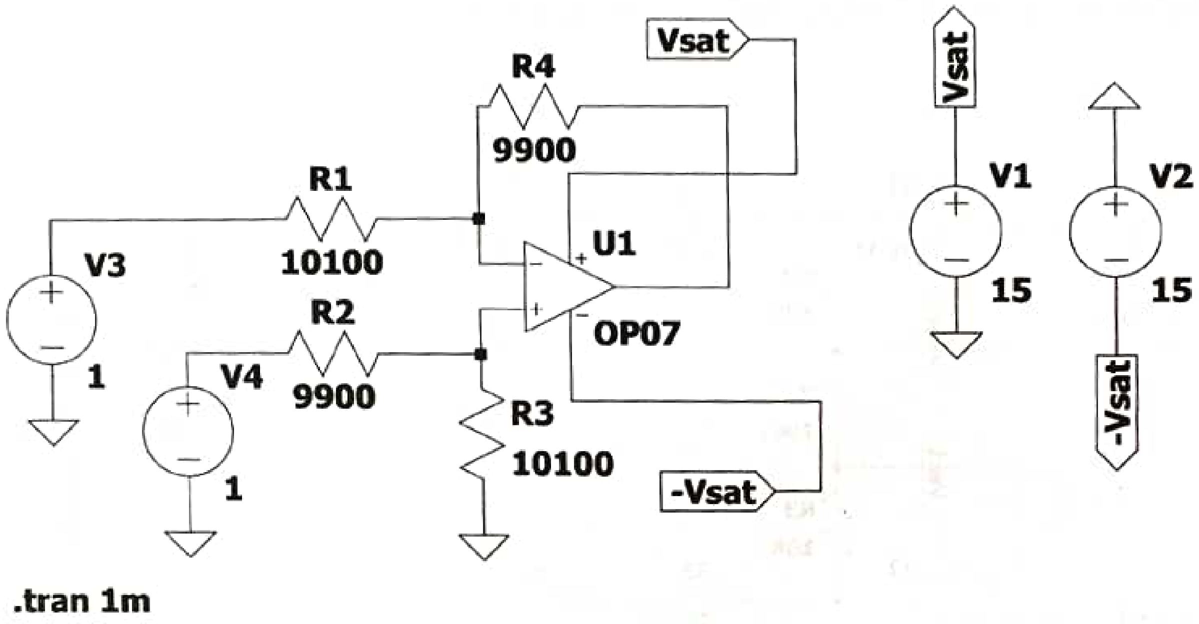
C) Measurement of Differential Gain for **two percentage** tolerance



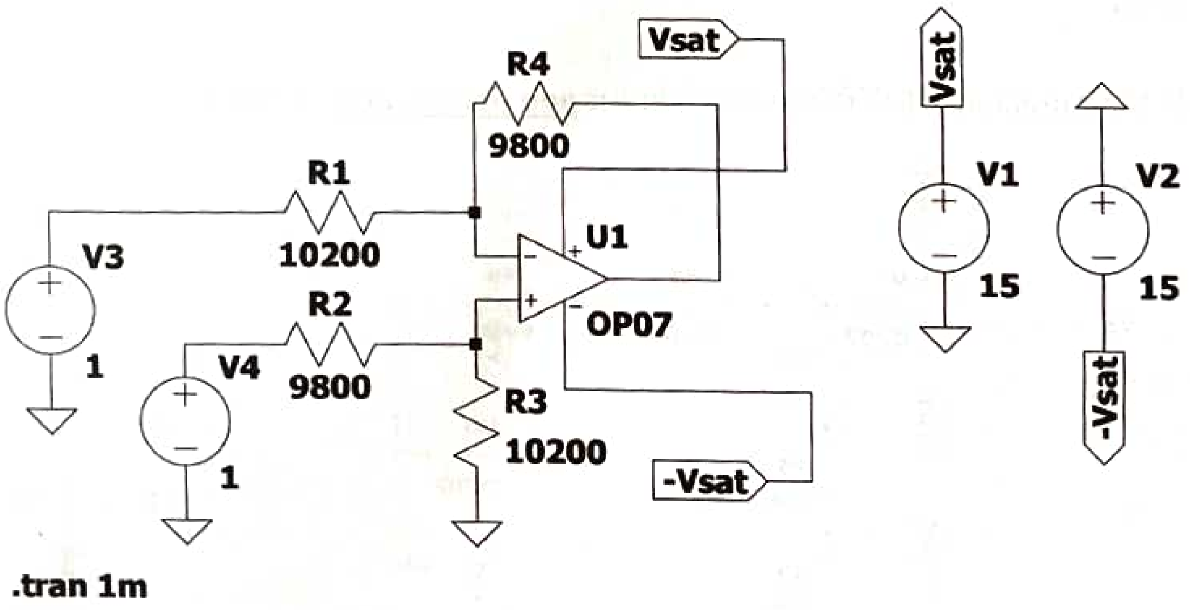
A) Measurement of Common Mode Gain for **zero** tolerance



B) Measurement of Common Mode Gain for **one percentage** tolerance

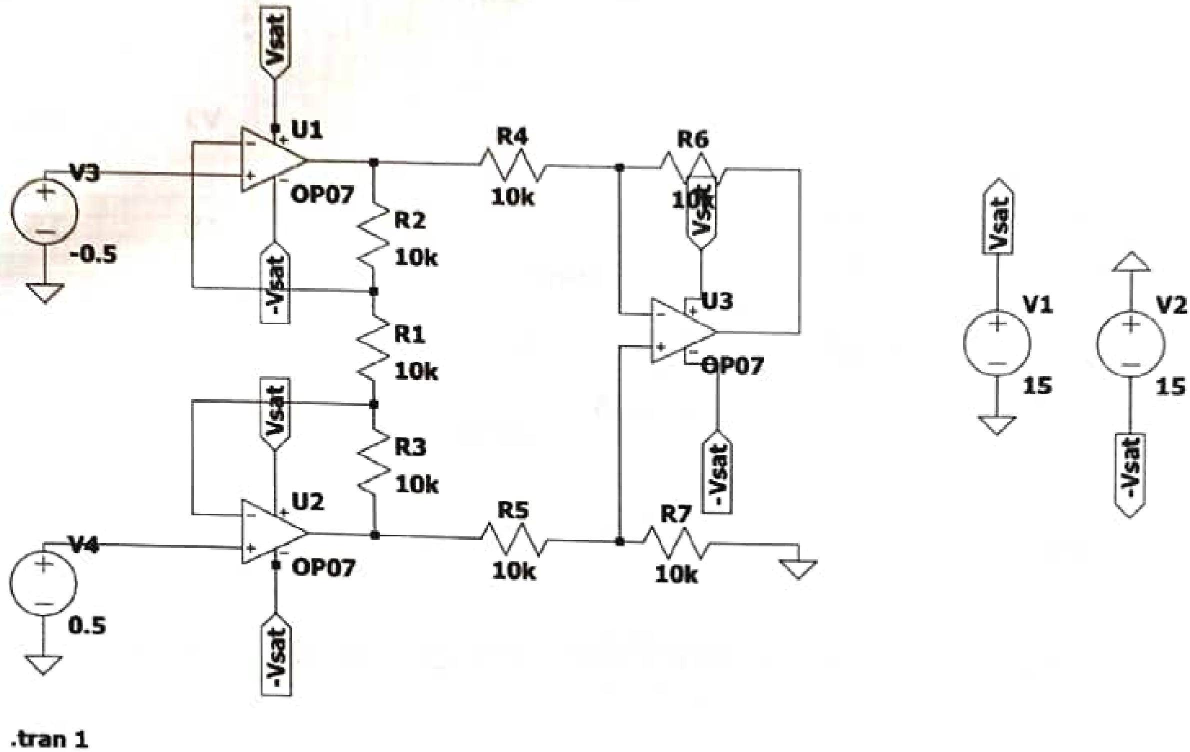


C) Measurement of Common Mode Gain for **two percentage** tolerance

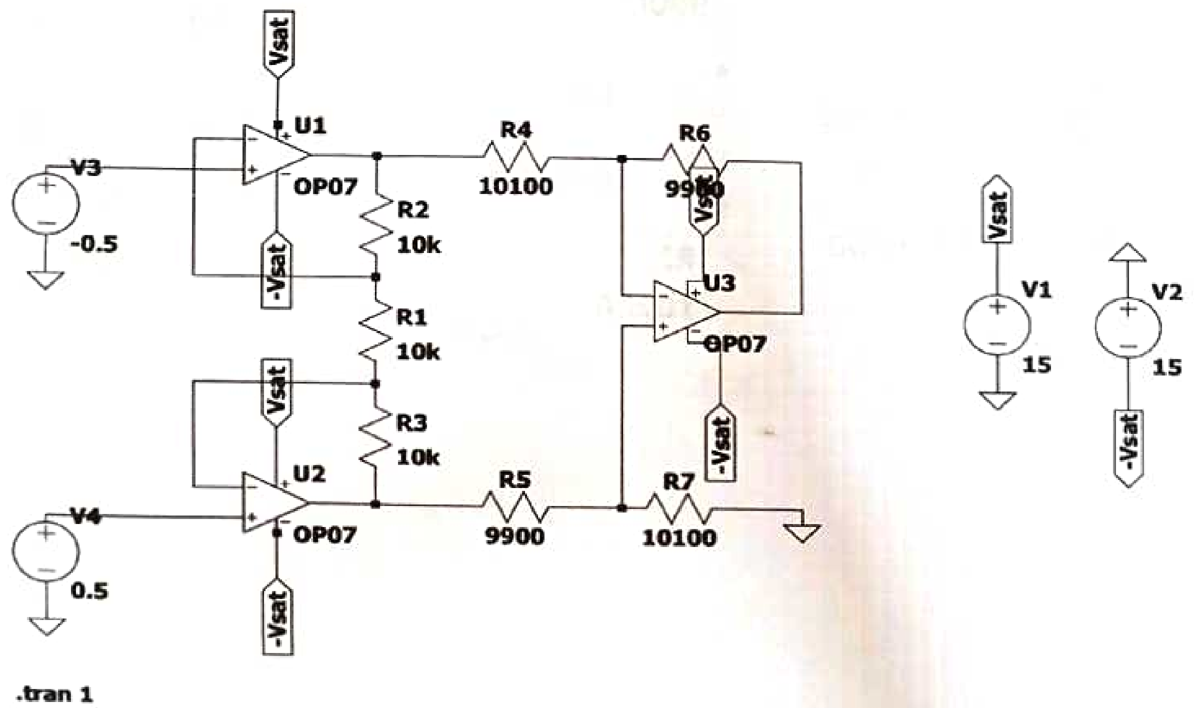


Instrumental Amplifier Experiment Simulation:

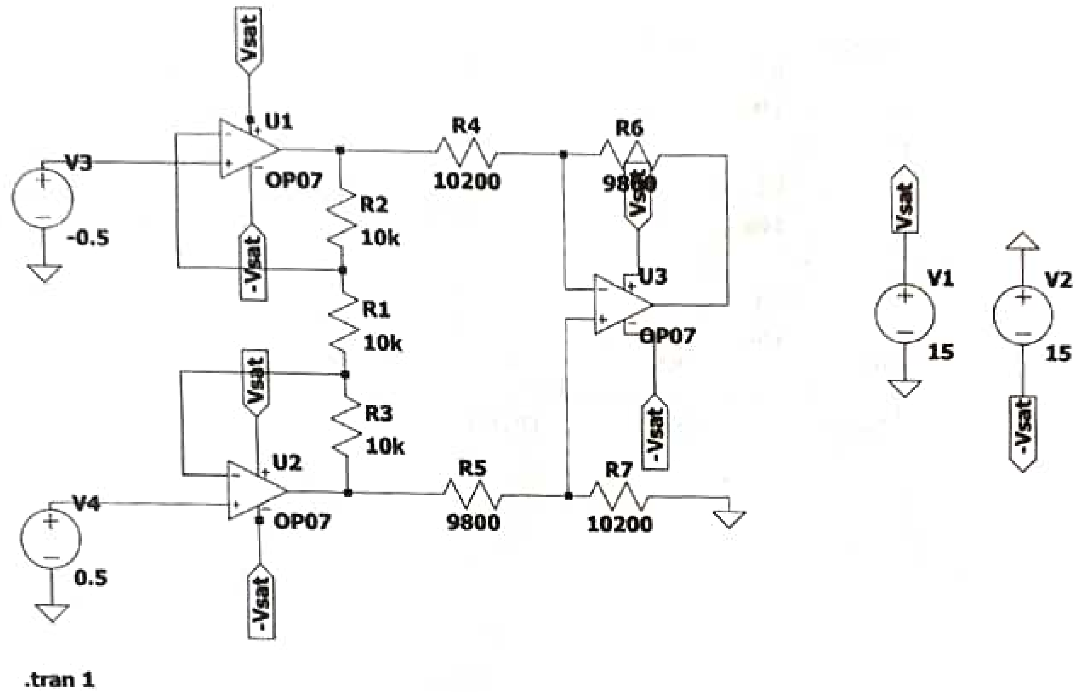
A) Measurement of Differential Gain for **zero** tolerance



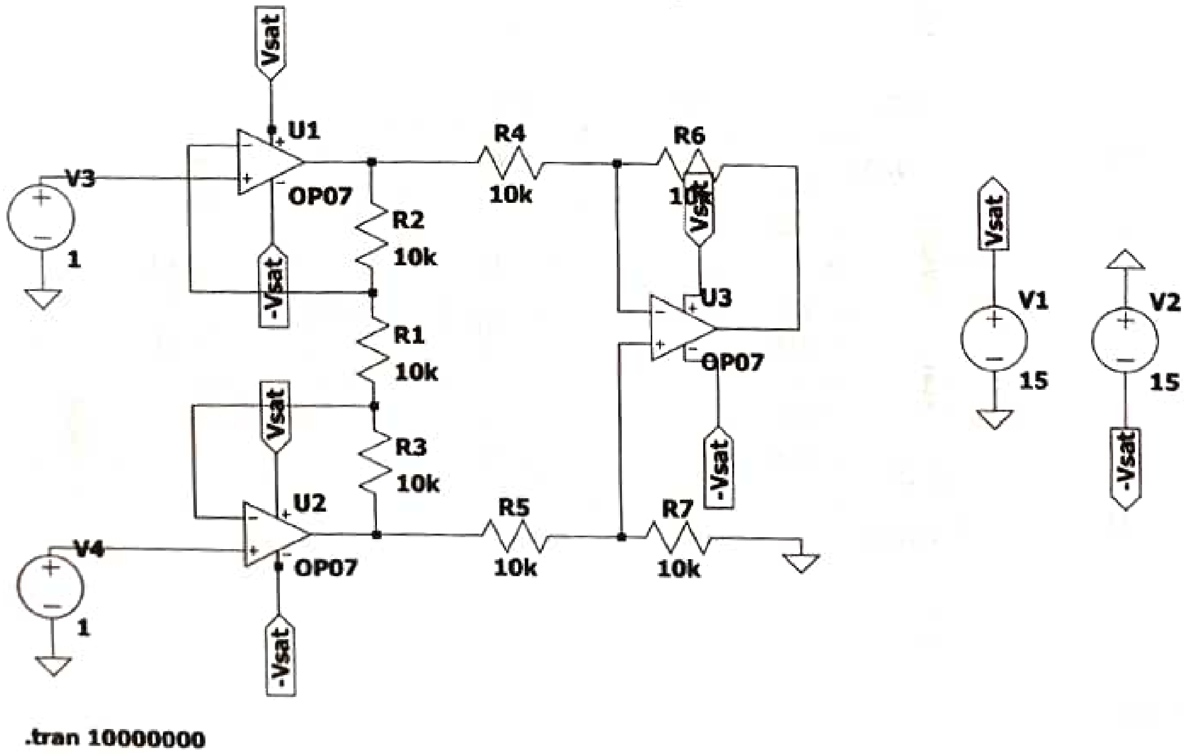
B) Measurement of Differential Gain for **one percentage** tolerance



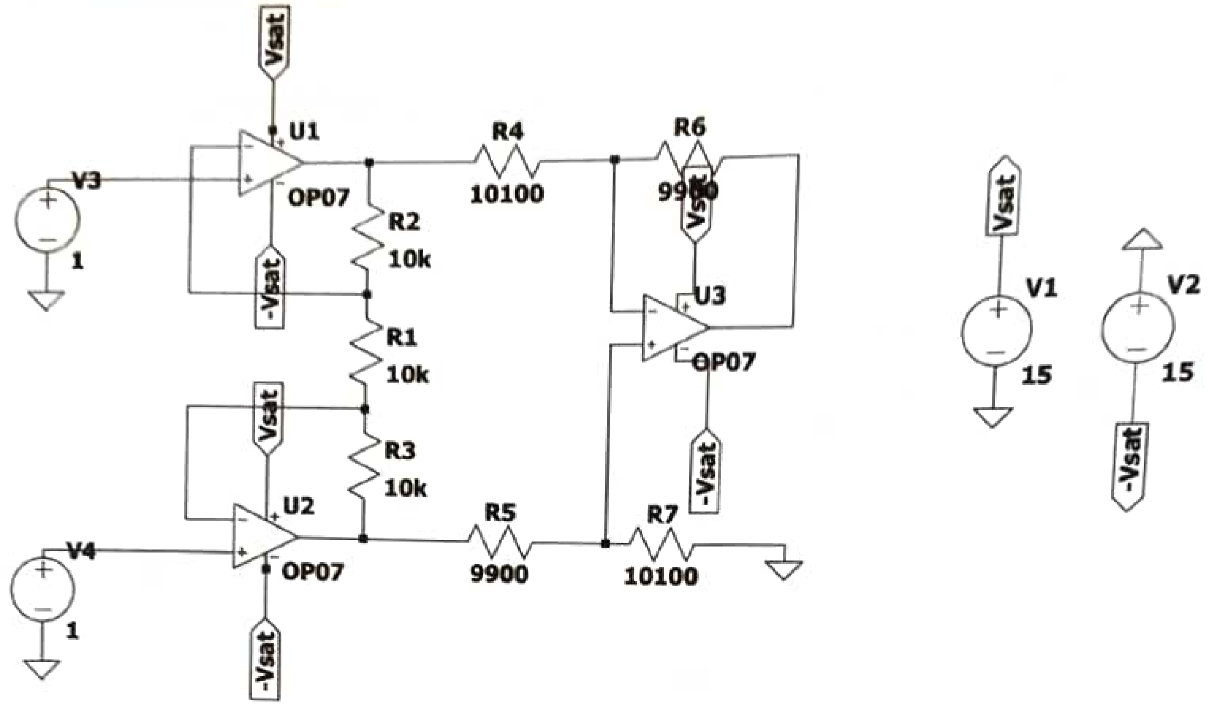
C) Measurement of Differential Gain for **two percentage** tolerance



A) Measurement of Common Mode Gain for **zero** tolerance



B) Measurement of Common Mode Gain for **one percentage** tolerance



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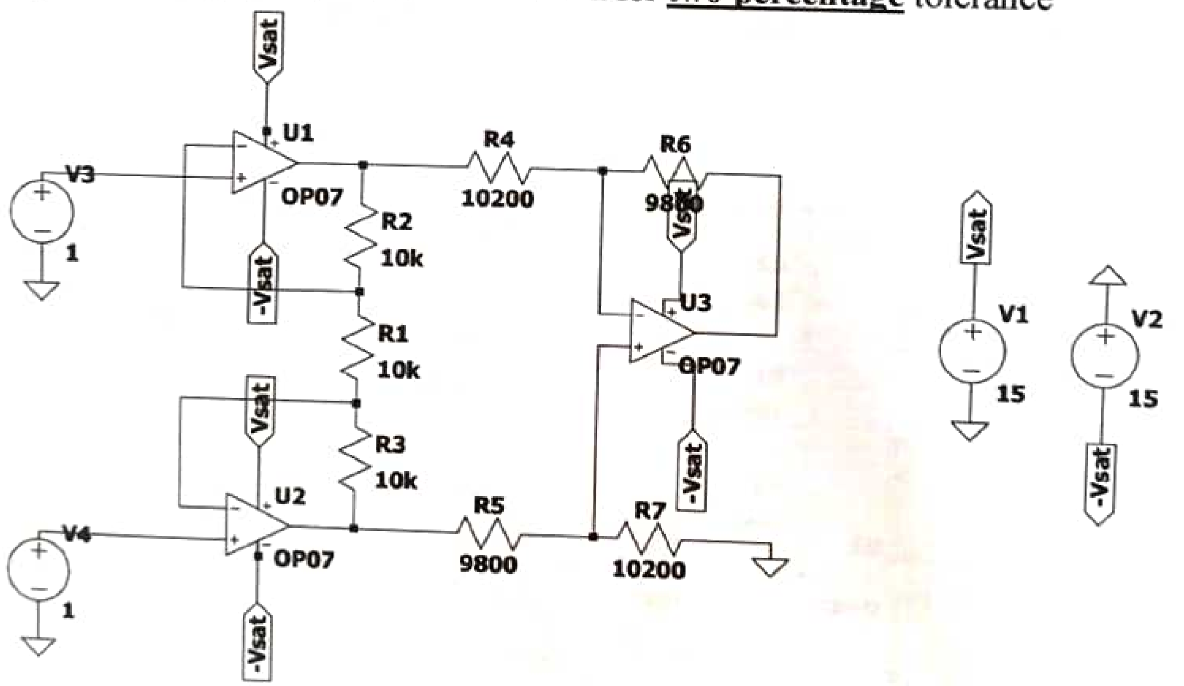
C) Measurement of Common Mode Gain for **two percentage** tolerance



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Exp 3A

Simulation of Difference Amplifier:

For Differential Gain:

Gain 0% tolerance: 999.99 mV/V
Gain 1 % tolerance: 990.3 mV/V
Gain 2% tolerance: 980.39 mV/V

For Common Mode Gain:

Gain 0% tolerance: 4.489 nV/V
Gain 1 % tolerance: 19.80 mV/V
Gain 2% tolerance: 39.21 mV/V

Minimum CMRR:

CMRR 0% tolerance: 166.956 dB
CMRR 1 % tolerance: 33.98 dB
CMRR 2% tolerance: 27.96 dB

Exp 3B

Simulation of Instrumentation Amplifier:

For Differential Gain:

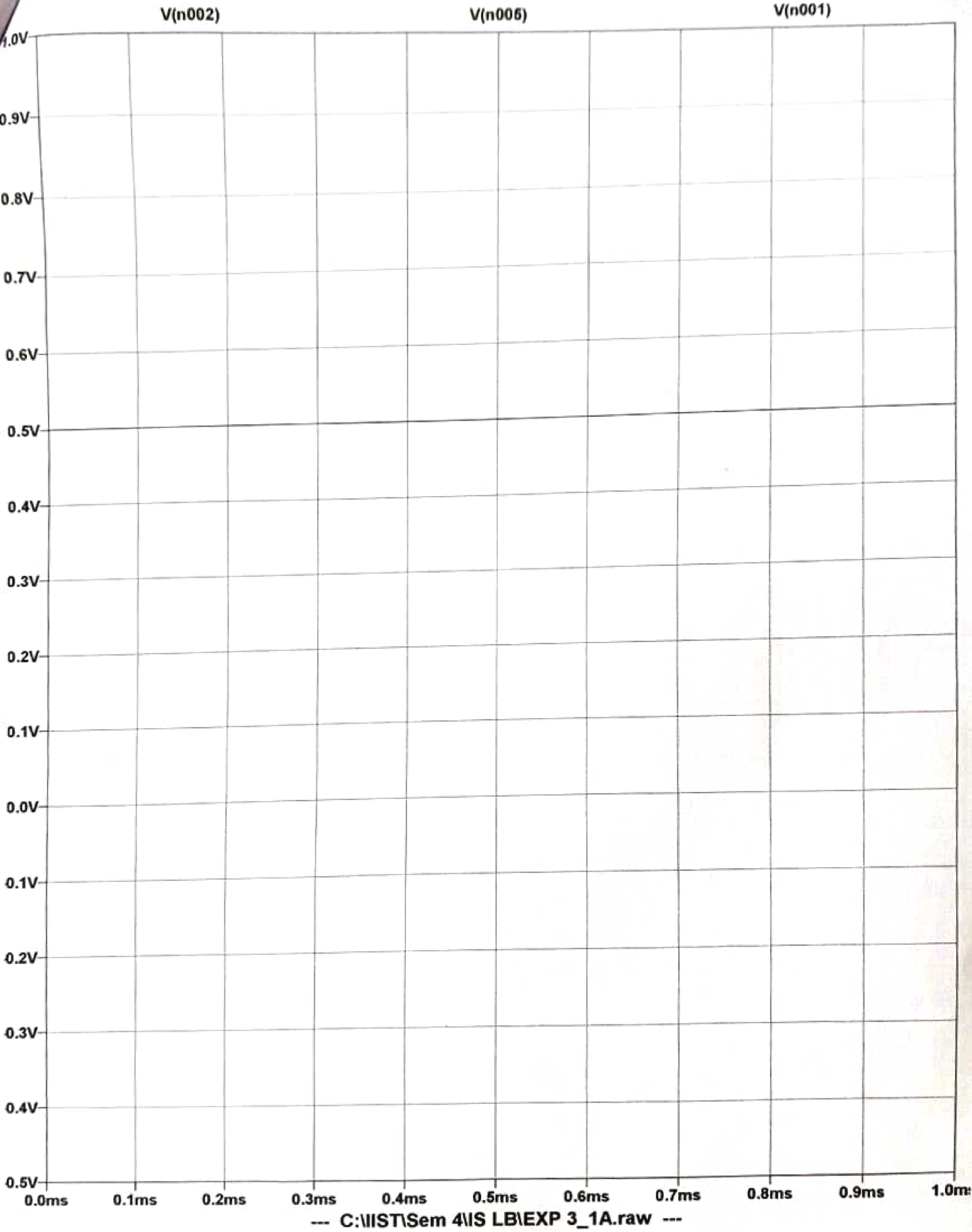
Gain 0% tolerance: 2.99 V/V
Gain 1 % tolerance: 2.97 V/V
Gain 2% tolerance: 2.941 V/V

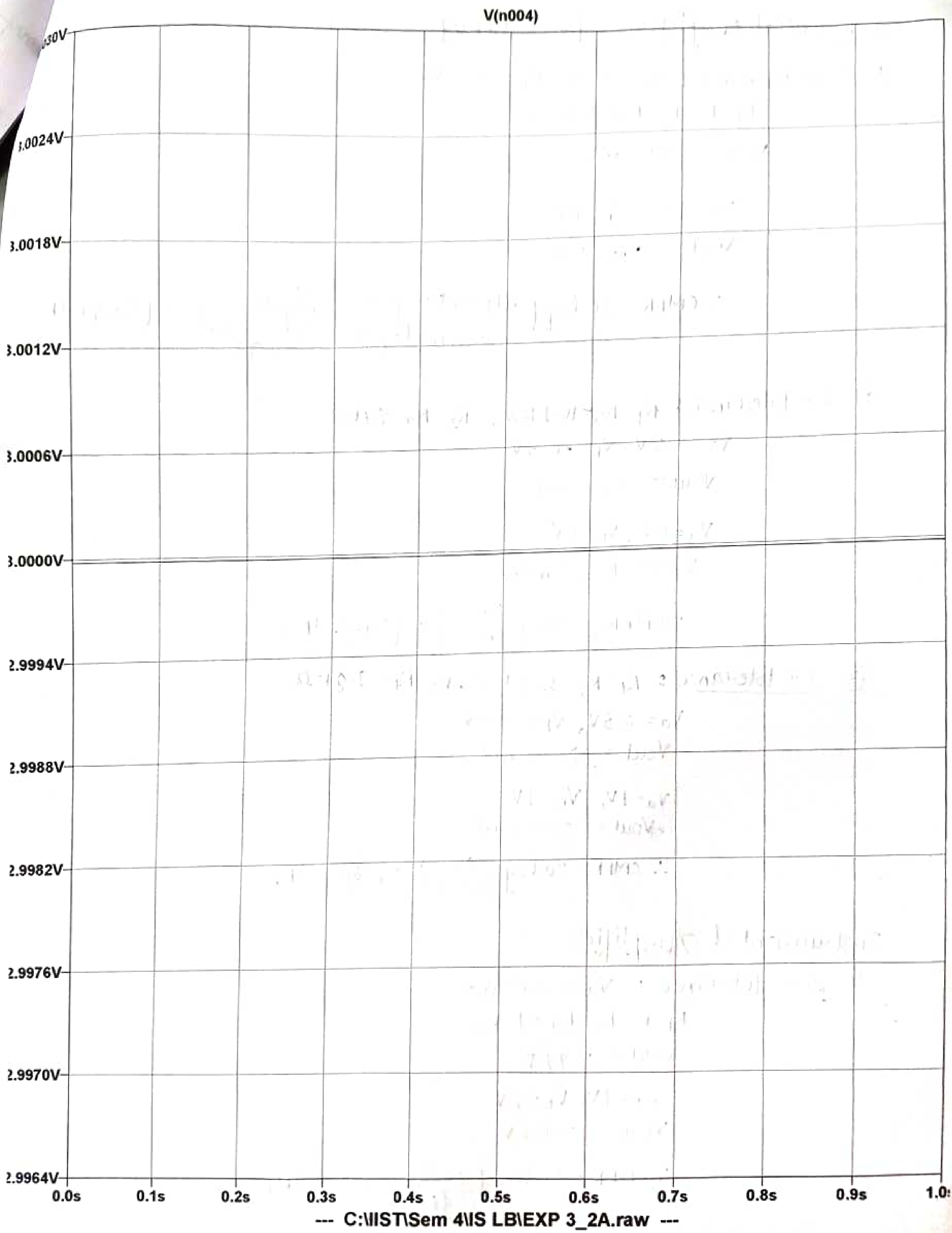
For Common Mode Gain:

Gain 0% tolerance: 4.50 nV/V
Gain 1 % tolerance: 19.80 mV/V
Gain 2% tolerance: 39.215 mV/V

Minimum CMRR:

CMRR 0% tolerance: 176.478 dB
CMRR 1 % tolerance: 43.521 dB
CMRR 2% tolerance: 37.500 dB


V(n002)
V(n006)
V(n001)
1.0V
0.9V
0.8V
0.7V
0.6V
0.5V
0.4V
0.3V
0.2V
0.1V
0.0V
-0.1V
-0.2V
-0.3V
-0.4V
-0.5V
0.0ms
0.1ms
0.2ms
0.3ms
0.4ms
0.5ms
0.6ms
0.7ms
0.8ms
0.9ms
1.0ms
--- C:\IIST\Sem 4\IS LB\EXP 3_1A.raw ---


V(n004)
3.0030V
3.0024V
3.0018V
3.0012V
3.0006V
3.0000V
2.9994V
2.9988V
2.9982V
2.9976V
2.9970V
2.9964V
0.0s
0.1s
0.2s
0.3s
0.4s
0.5s
0.6s
0.7s
0.8s
0.9s
1.0s
--- C:\IIST\Sem 4\IS LB\EXP 3_2A.raw ---

Results:

Differential Amplifier [$V_{cc} = \pm 15V$]

① Zero tolerance: $V_a = 0.5V$, $V_b = -0.5V$

$R_1 = R_2 = R_3 = R_4 = 10K\Omega$

$V_{out} = 999.0\,mV$

$V_a = 1V$, $V_b = 1V$

$V_{out} = 0.001\,V$

$\therefore CMRR = 20\log\left(\frac{\text{differential gain}}{\text{common mode gain}}\right) = 20\log\left(\frac{999}{\frac{0.001}{1000}\times}\right) = \boxed{59.99\,dB}$

② 1% tolerance: $R_1 = R_3 = 10.1\,K\Omega$, $R_2 = R_4 = 9.9\,K\Omega$

$V_a = 0.5V$, $V_b = -0.5V$

$V_{out} = 990.0\,mV$

$V_a = 1V$, $V_b = 1V$

$V_{out} = 19.02\,mV$

$\therefore CMRR = 20\log\left(\frac{990}{19.02}\right) = \boxed{34.33\,dB}$

③ 2% tolerance: $R_1 = R_3 = 10.2\,K\Omega$, $R_2 = R_4 = 9.8\,K\Omega$

$V_a = 0.5V$, $V_b = -0.5V$

$V_{out} = 980.2\,mV$

$V_a = 1V$, $V_b = 1V$

$V_{out} = 38.01\,mV$

$\therefore CMRR = 20\log\left(\frac{980}{38.01}\right) = \boxed{28.22\,dB}$

Instrumental Amplifier

① Zero tolerance: $V_a = 0.5V$, $V_b = 0.5V$

$R_1 = R_2 = R_3 = R_4 = 10K\Omega$

$V_{out} = 2.99\,V$

$V_a = 1V$, $V_b = 1V$

$V_{out} = 0.001\,V$

$\therefore CMRR = 20\log\left(\frac{2.99}{1/1000}\right) = \boxed{69.51\,dB}$

② 1% tolerance: $R_1 = R_3 = 10.1\ k\Omega$, $R_2 = R_4 = 9.9\ k\Omega$.

$V_a = 0.5V$, $V_b = 0-0.5V$

$V_{out} = 2.96V$

$V_a = 1V$, $V_b = 1V$

$V_{out} = 18.8\ mV$

$\therefore CMRR = 20\log\left(\frac{2.91 \times 1000}{18.8}\right) = \boxed{43.94\ dB}$

③ 2% tolerance: $R_1 = R_3 = 10.2\ k\Omega$, $R_2 = R_4 = 9.8\ k\Omega$

$V_a = 0.5V$, $V_b = -0.5V$

$V_{out} = 2.93\ V$

$V_a = 1V$, $V_b = 1V$

$V_{out} = 36\ mV$

$\therefore CMRR = 20\log\left(\frac{2.93 \times 1000}{36}\right) = \boxed{38.21\ dB}$