Design for Analog Circuits - Laboratory Report

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Assignment 4

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1 Voltage Amplifier

1.1 Aim

To design and simulate a voltage amplifier and obtain its gain, input and output impedances.

1.2 Schematic

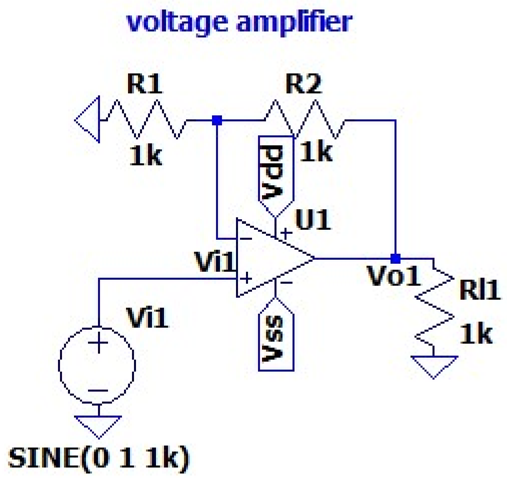

Figure 1: LTSpice schematic of voltage amplifier

1.3 Design

We have chosen $1k\Omega$ resistors in the feedback network as well as the load. The expected gain of the circuit is

$$\frac{V_{o1}}{V_{i1}} = (1 + \frac{R_2}{R_1}) = 2V/V$$

1.4 Transient simulation results

Figure 2 on the next page shows the transient simulation output of the voltage amplifier with 1 V, 1kHz sinewave as input. The amplitude of the output voltage is 1.99941 V. Hence the gain of the amplifier is 1.99941 V/V.

1.5 Input impedance

For obtaining the input impedance we disconnect the load resistance and place a 1 V, 1kHz sinewave current at the input node. The current drawn from the voltage source is $7.5215nA$. So the input impedance obtained is 132.9522 $M\Omega$. Figure 3 below shows the simulation waveforms (it is to be noted that the voltage and current are not in phase).

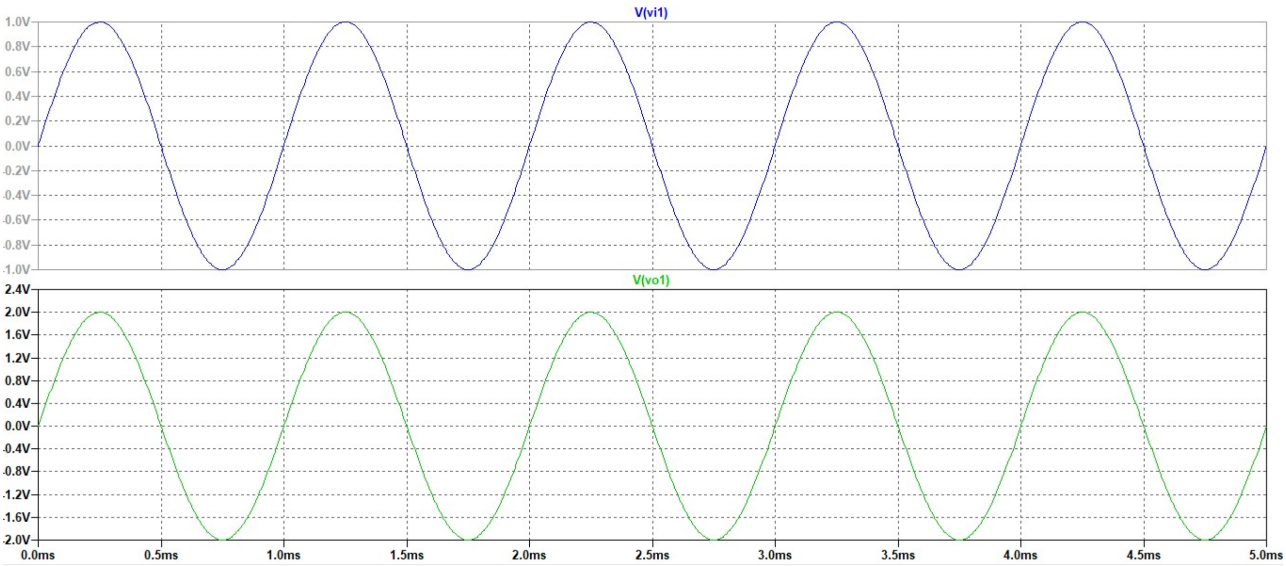

Figure 2: Transient simulation of Voltage amplifier

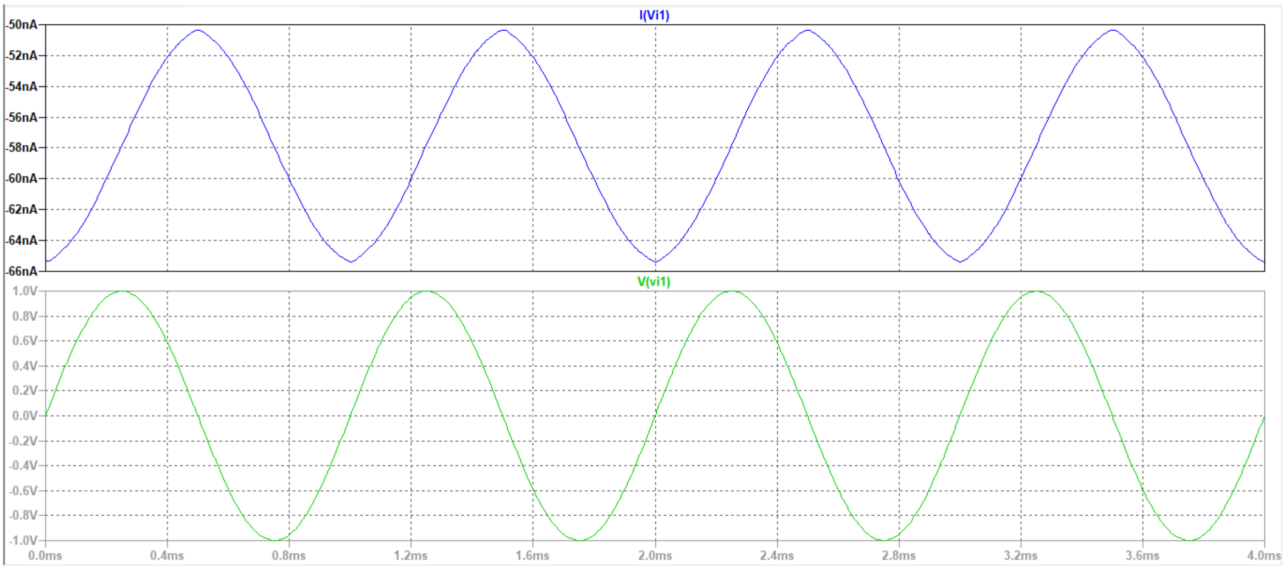

Figure 3: Input Impedance of voltage amplifier

1.6 Output impedance

For obtaining the output impedance we disconnect the load resistance and the input source and inject a 0.1 mA, 1kHz sinewave current at the output node. The voltage across the current source is $36.4815\mu V$. So the output impedance obtained is 0.3648 Ω. Figure 4 below shows the simulation waveforms .

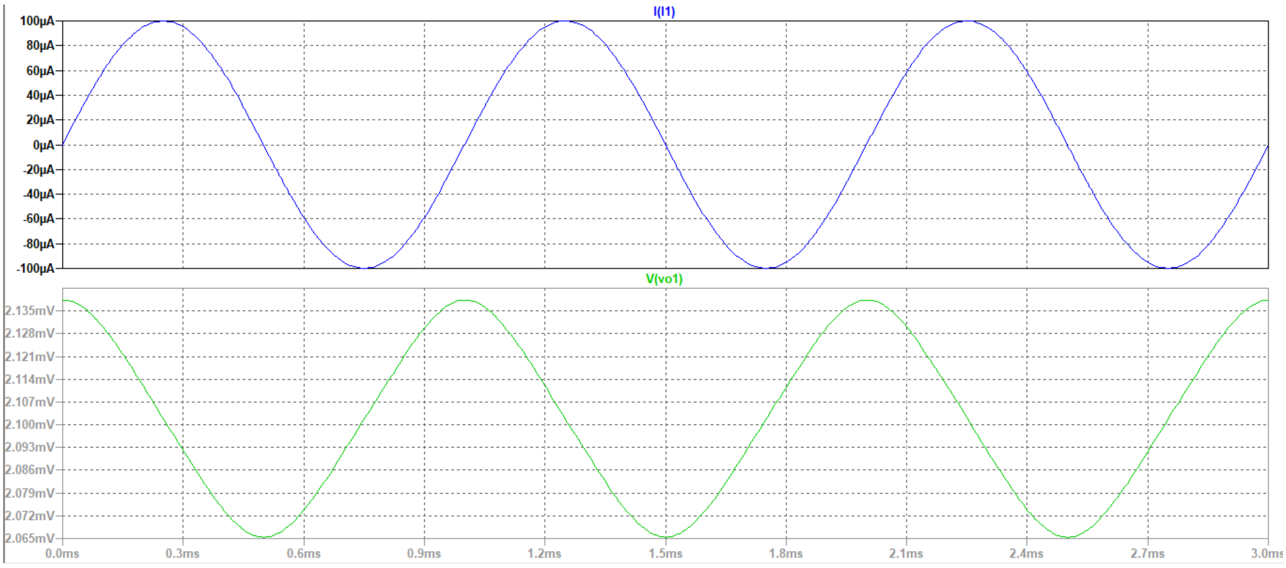

Figure 4: Output Impedance of voltage amplifier

2 Transresistance Amplifier

2.1 Aim

To design and simulate a transresistance amplifier and obtain its gain, input and output impedances.

2.2 Schematic

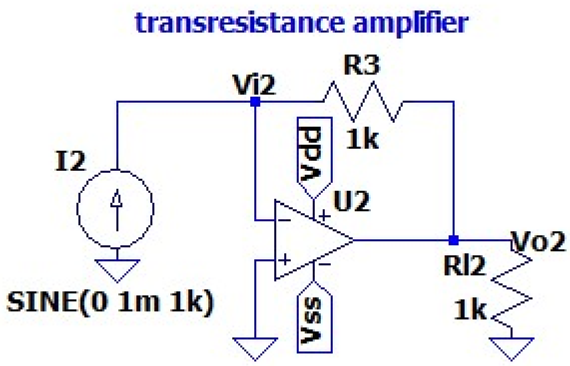

Figure 5: LTSpice schematic of transresistance amplifier

2.3 Design

We have chosen $1k\Omega$ resistors. So, the gain of the amplifier should be

$$\frac{V_{o2}}{I_2} = R_3 = 1V/mA.$$

2.4 Transient simulation results

Figure 6 on the next page shows the transient simulation output of the transresistance amplifier with 1 mA, 1kHz sinewave as input. The amplitude of the output voltage is 0.99967 V. Hence the gain of the amplifier is 0.99967 V/mA.

2.5 Input Impedance

For obtaining the input impedance we disconnect the load resistance and inject a 0.1 mA, 1kHz sinewave current at the input node. The voltage across the current source is $0.1182mV$. So the output impedance obtained is 1.182 Ω. Figure 7 below shows the simulation waveforms.

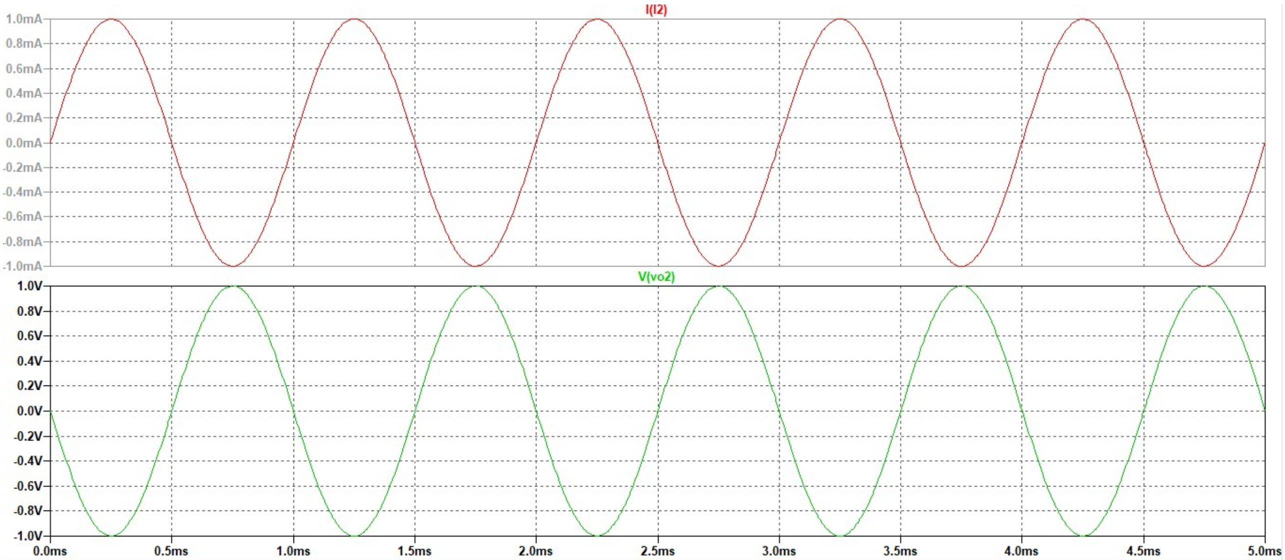

Figure 6: Transient simulation of Transresistance amplifier

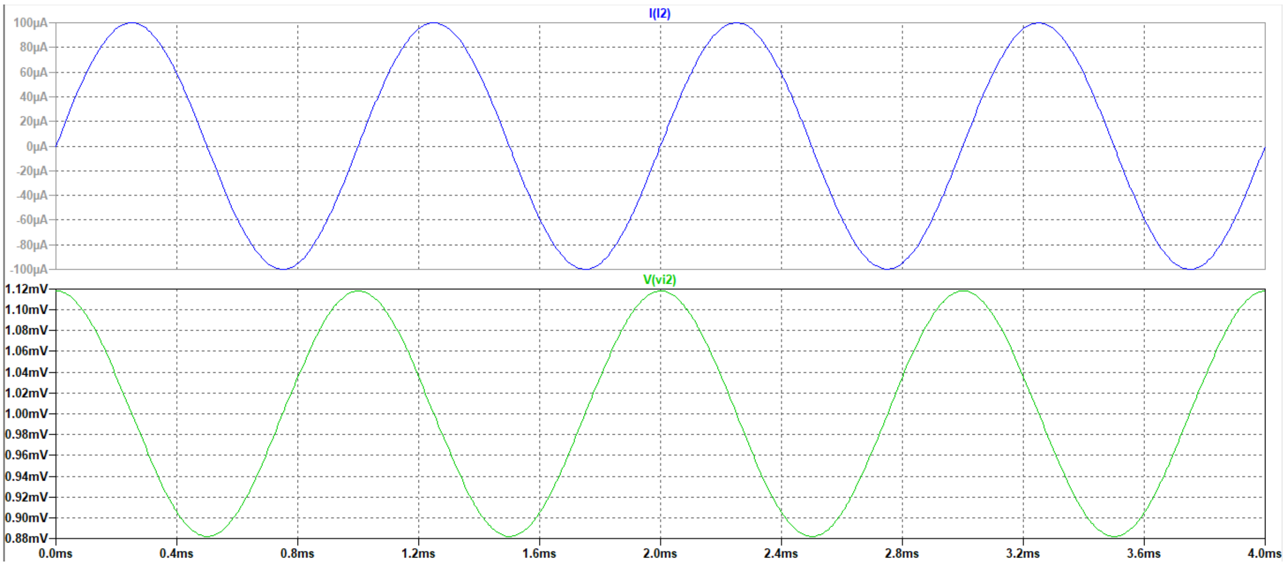

Figure 7: Input impedance of transresistance amplifier

2.6 Output impedance

For obtaining the output impedance we disconnect the load resistance and the input source and inject a 0.1 mA, 1kHz sinewave current at the output node. The voltage across the current source is $18.2734\mu V$. So the output impedance obtained is 0.1827 Ω. Figure 8 below shows the simulation waveforms .

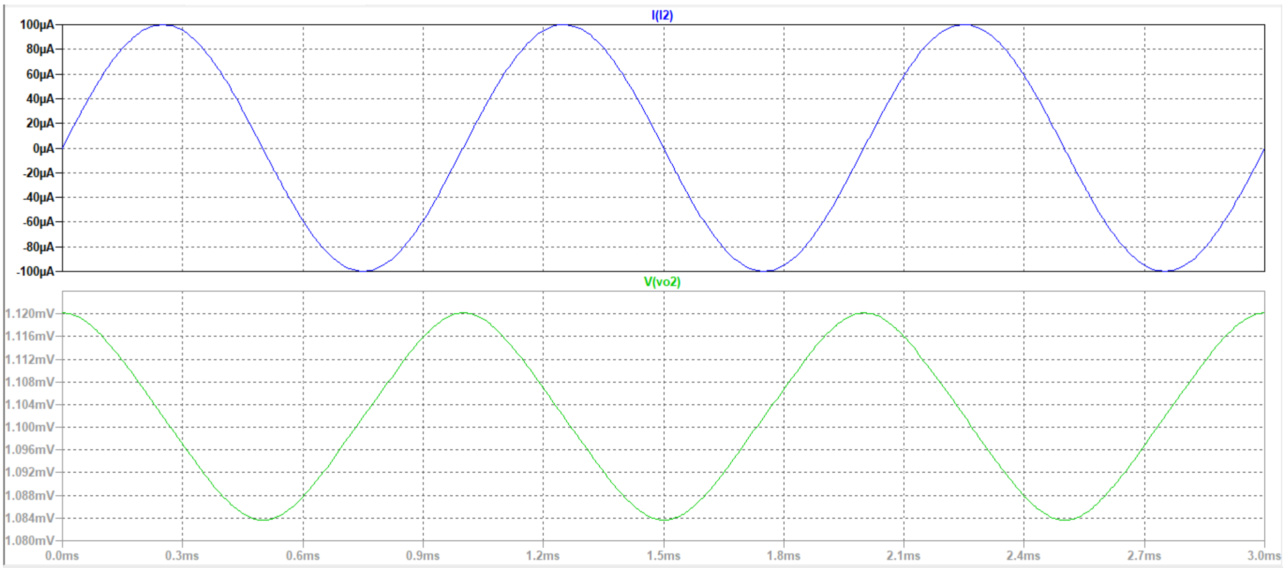

Figure 8: Output Impedance of transresistance amplifier

3 Transconductance Amplifier

3.1 Aim

To design and simulate a transconductance amplifier and obtain its gain, input and output impedances.

3.2 Schematic

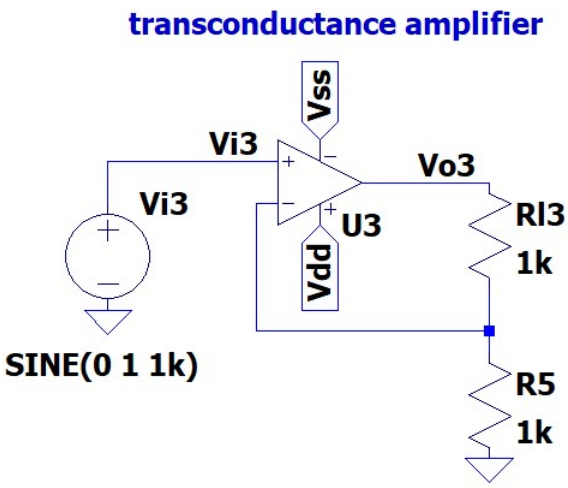

Figure 9: LTSpice schematic of transconductance amplifier

3.3 Design

We have chosen $1k\Omega$ resistors. So, the gain of the amplifier should be

$$\frac{I_{R_{l3}}}{V_{i3}} = \frac{1}{R_5} = 1mA/V.$$

3.4 Transient simulation results

Figure 10 on the next page shows the transient simulation output of the transconductance amplifier with 1 V, 1kHz sinewave as input. The amplitude of the output voltage is 0.99971 mA. Hence the gain of the amplifier is 0.99971 mA/V.

3.5 Input impedance

For obtaining the input impedance we disconnect the load resistance and place a 0.1 V, 1kHz sinewave voltage source at the input. The current drawn from the voltage source is 0.3977 nA. So the output impedance obtained is 251.446 MΩ. Figure 11 below shows the simulation waveforms .

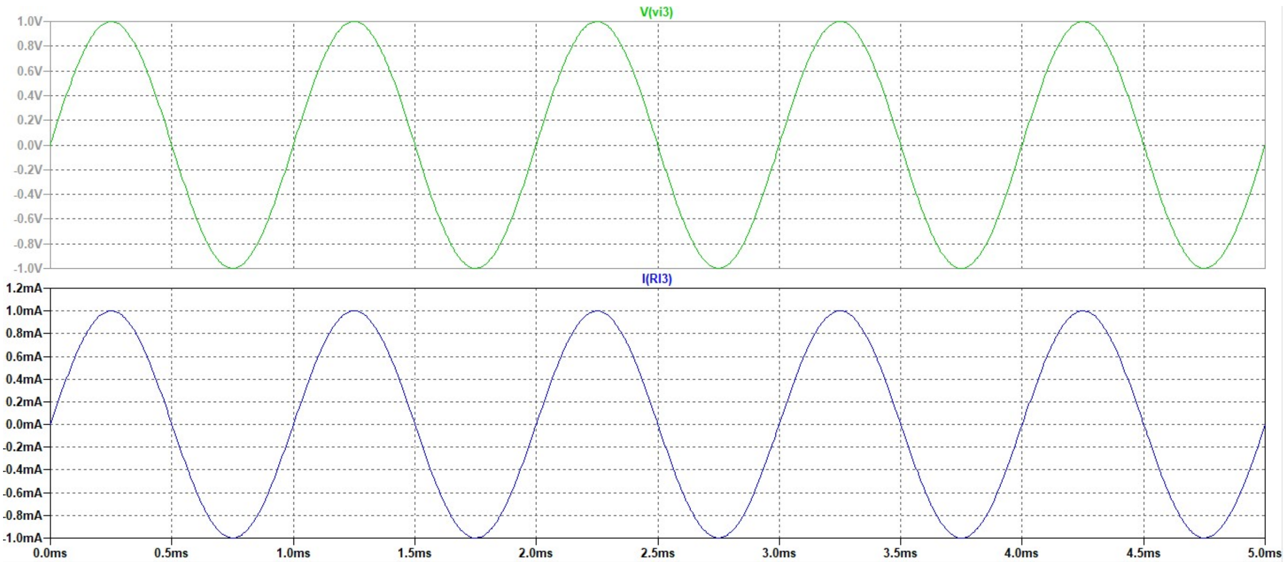

Figure 10: Transient simulation of Transconductance amplifier

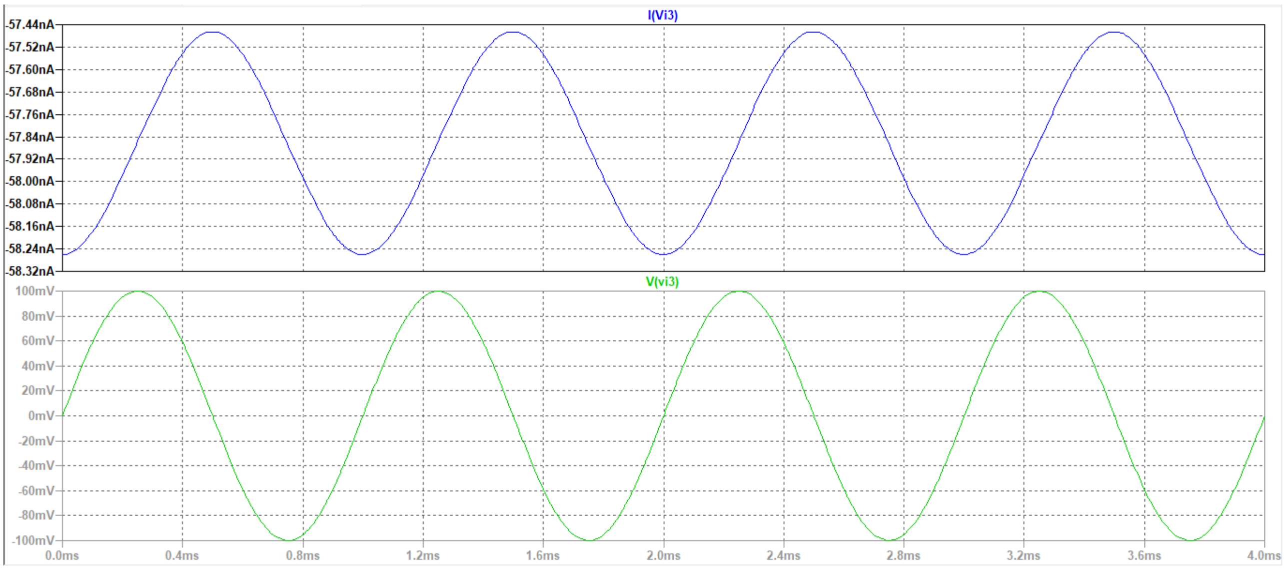

Figure 11: Input Impedance of transconductance amplifier

3.6 Output impedance

For obtaining the output impedance we disconnect the load resistance and the input source and place a 10 mV, 1kHz sinewave voltage source at the output. The voltage across the current source is 10.0305nV. So the output impedance obtained is 996.959 kΩ. Figure 12 below shows the simulation waveforms .

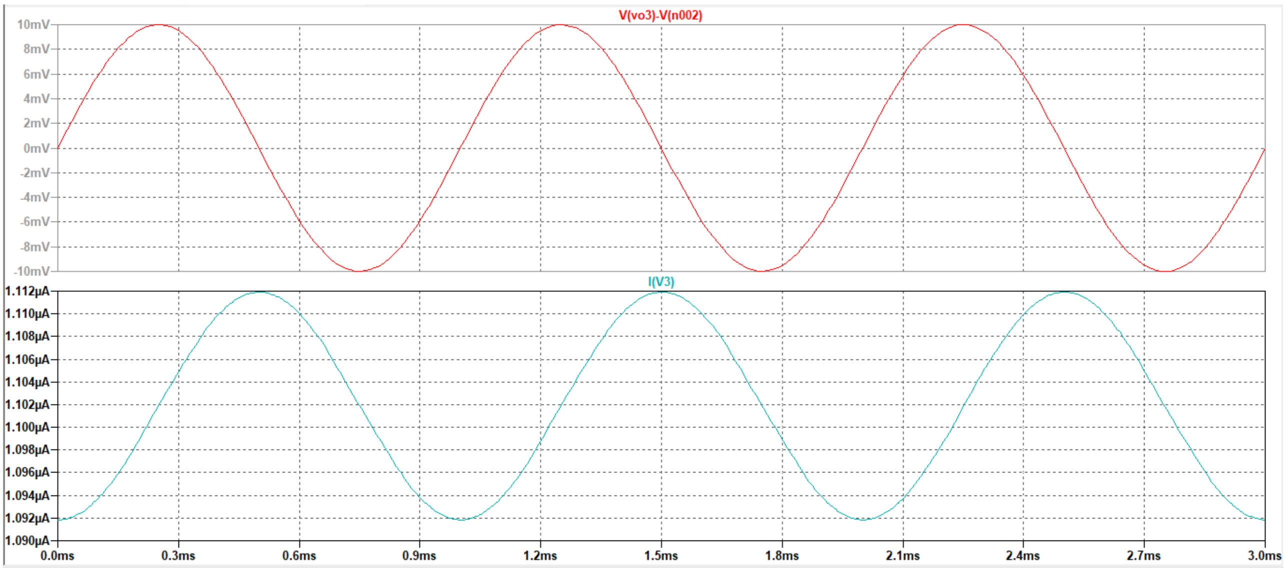

Figure 12: Output Impedance of transconductance amplifier

4 Current Amplifier

4.1 Aim

To design and simulate a current amplifier and obtain its gain, input and output impedances.

4.2 Schematic

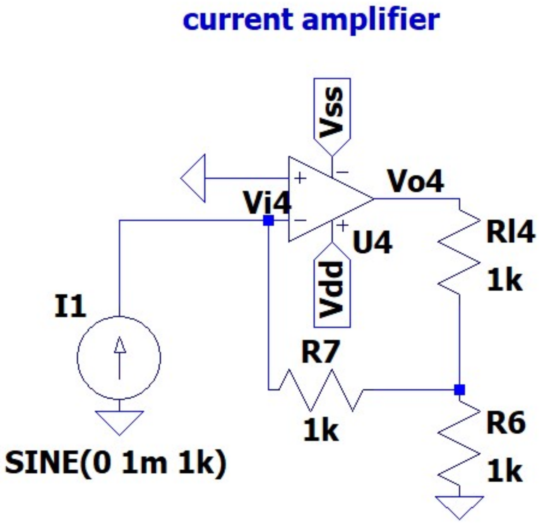

Figure 13: LTSpice schematic of current amplifier

4.3 Design

We have chosen $1k\Omega$ resistors. So, the gain of the amplifier should be

$$\frac{I_{R_{i4}}}{I_1} = -(1 + \frac{R_7}{R_6}) = -2A/A.$$

4.4 Transient simulation results

Figure 14 on the next page shows the transient simulation output of the current amplifier with 1 mA, 1kHz sinewave as input. The amplitude of the output voltage is 1.99935 mA. Hence the gain of the amplifier is -1.99935 A/A.

4.5 Input impedance

For obtaining the input impedance we disconnect the load resistance and place a 0.1 mA, 1kHz sinewave current source at the input. The voltage across the current source is 0.13638 mV. So the input impedance obtained is 1.3638Ω. Figure 15 below shows the simulation waveforms .

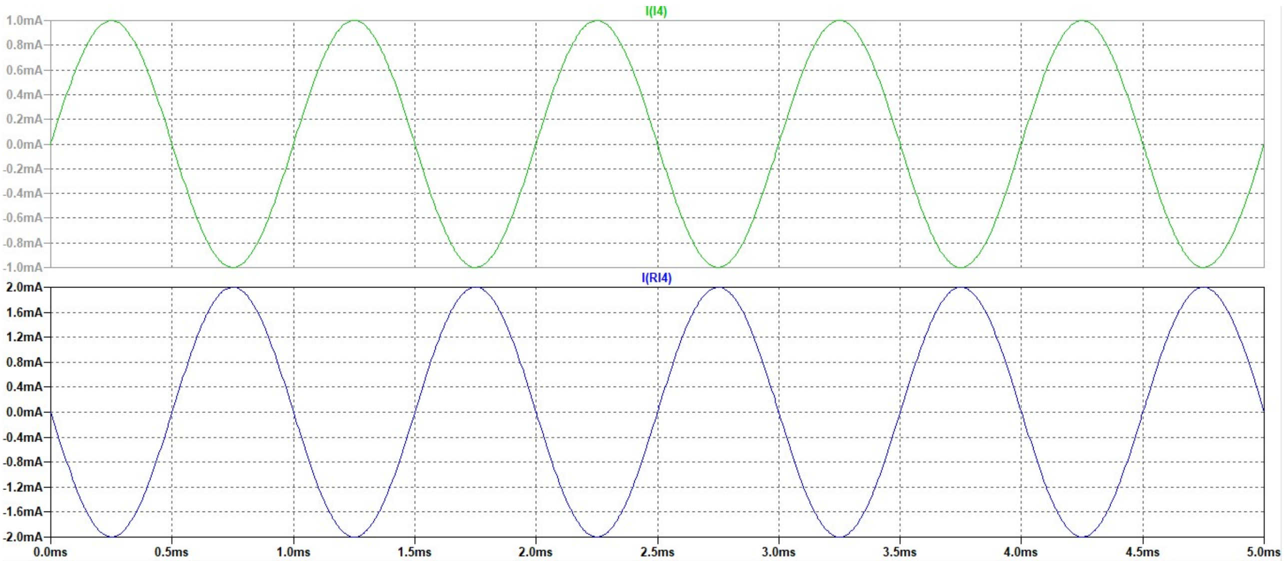

Figure 14: Transient simulation of Current amplifier

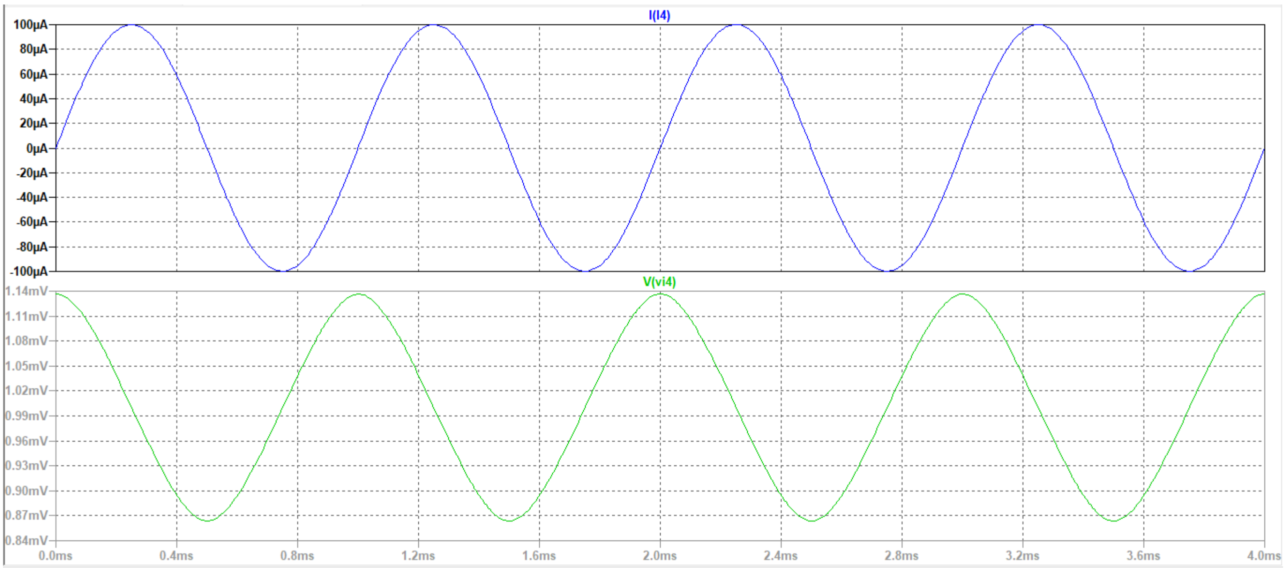

Figure 15: Input Impedance of transconductance amplifier

4.6 Output impedance

For obtaining the output impedance we disconnect the load resistance and the input source and place a 10 mV, 1kHz sinewave voltage source at the output. The voltage across the current source is $10.0659nV$. So the output impedance obtained is 993.453 kΩ. Figure 16 below shows the simulation waveforms .

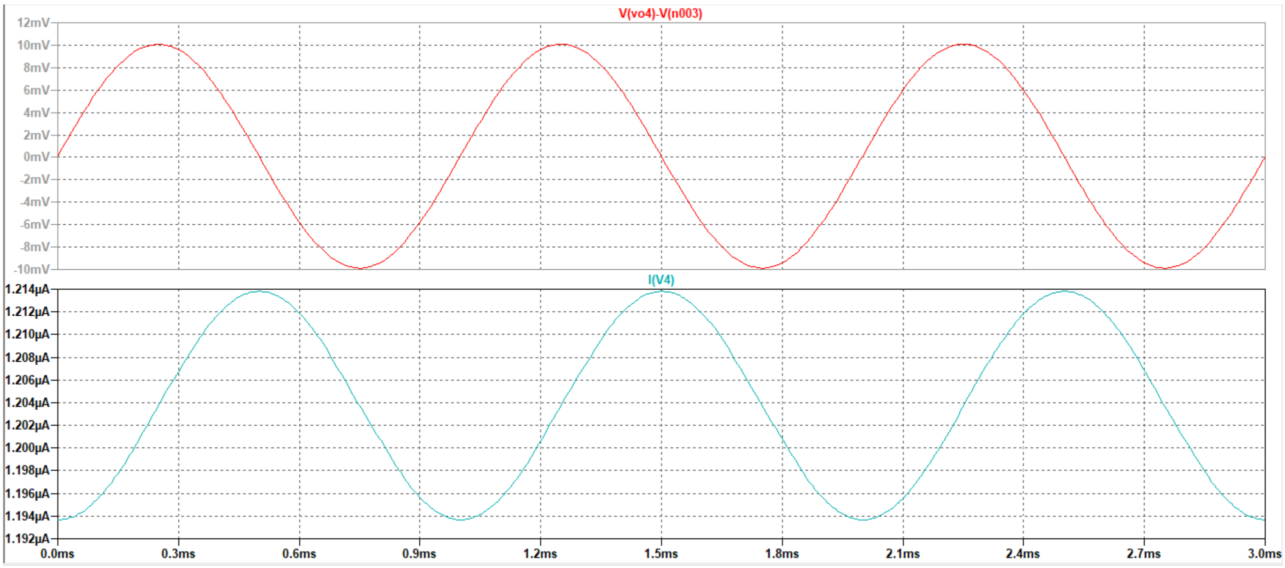

Figure 16: Output Impedance of current amplifier

5 Summary

The gain, input and output impedances of the various amplifiers are tabulated as follows:

Amplifier Type	Gain	Z_{in}	Z_{out}
Voltage	$2.00V/V$	$132.95M\Omega$	0.36Ω
Transresistance	$1.00V/mA$	1.18Ω	0.18Ω
Transconductance	$1.00mA/V$	$251.45M\Omega$	$996.96k\Omega$
Current	$-2.00A/A$	1.36Ω	$993.45k\Omega$

6 Discussion

1. It is known that the closed loop input impedance of series input topology is scaled (1+L) times and that of shunt input topology 1/(1+L) times, L being the open loop gain of the amplifier. Due to IC 741 op-amp internal compensation its gain starts rolling off at 10 Hz at 20 dB/decade, the unity gain cutoff frequency being 1MHz. So, (1+L)≃L at low frequencies and ≃1 at high frequencies. The above effect is reflected in the closed loop input impedances, as evident from Figure 17 below:

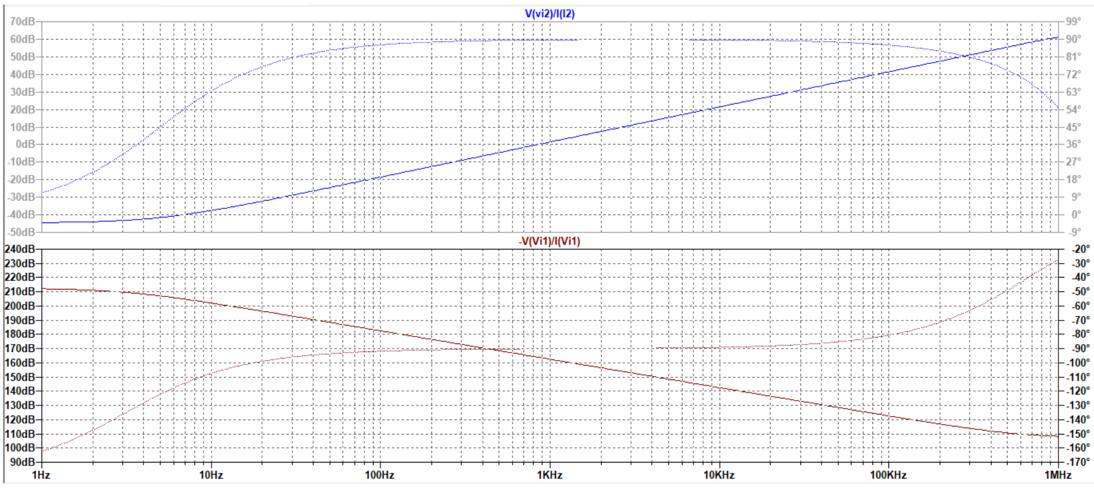

Figure 17: Effect of Op-amp open loop gain variation with frequency on input impedances of series and shunt input topologies respectively

2. A similar effect is observed also in the closed loop output impedances of series and shunt output topologies, as illustrated in Figure 18

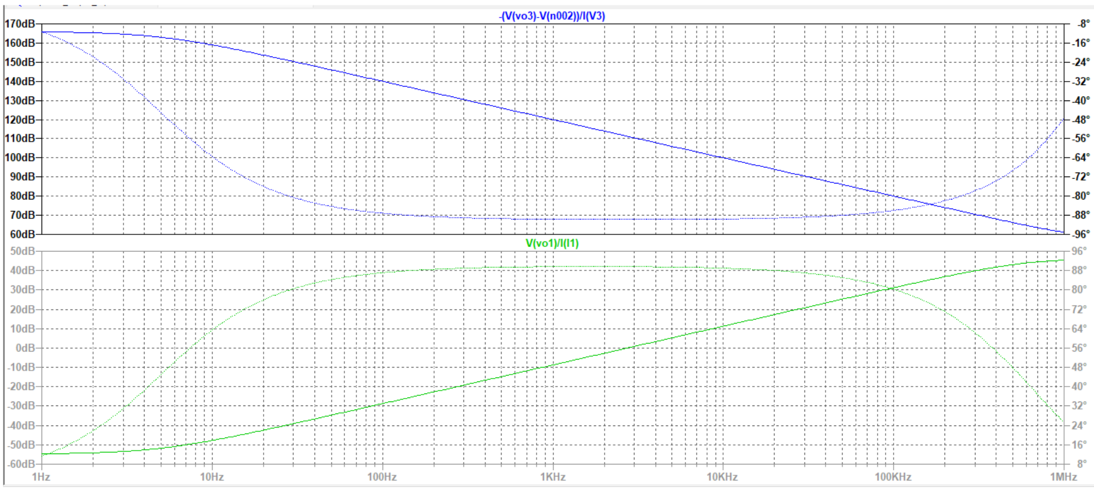

Figure 18: Effect of Op-amp open loop gain variation with frequency on output impedances of series and shunt input topologies respectively