Design for Analog Circuits - Laboratory Report

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Assignment 1

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1 BJT Amplifier

1.1 Aim

To design a BJT Amplifier with a gain of 5-6.

1.2 Schematic

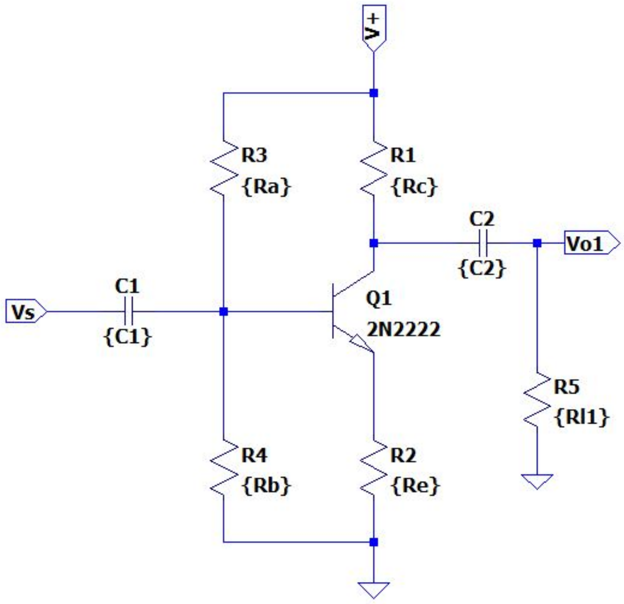

Figure 1: LTSpice Schematic of the BJT Amplifier Circuit

1.3 Calculation of Component Values

We shall design the amplifier for R_L=10kΩ ,$F = 1kHz$ and gain=6.67 (to account for attenuation due to loading) taking the following design assumptions:

1. $V_c = 0.5 \times V_+ = 5V$
2. $R_L = 10 \times R_C \implies R_C = 1k\Omega$
3. $I_{R_a} = 10 \times I_b$
4. $I_{R_a} = I_{R_b}$
5. $I_C = I_E$
6. $V_{BE(on)}$ of BJT = 0.7 V

We have chosen NPN transistor (Part No. 2N2222) with β=200.

$$\text{DC value of collector current}(I_C) \quad = \quad \tfrac{5}{1} = 5mA$$

$$
\begin{aligned}
\text{Emitter Resistor}(R_E) &= \frac{R_C}{\text{gain}} = 150\Omega \\
\text{Emitter Voltage}(V_E) &= I_C \times R_E = 0.75V \\
\text{Base current}(I_B) &= \frac{I_C}{\beta} = 25\mu A \\
\text{Current through } R_a(I_{R_a}) &= 10 \times I_B = 0.25mA \\
\text{Voltage across } R_b(V_{R_b}) &= V_{BE} + V_E = 1.45V \\
R_b &= \frac{V_{R_b}}{I_{R_a}} = 5.8k\Omega \\
R_a &= \frac{V_+ - V_{R_b}}{I_{R_a}} = 34.2k\Omega
\end{aligned}
$$

The component values are used for initial simulation and have been tuned for getting better results.

1.4 DC Operating Point Simulation

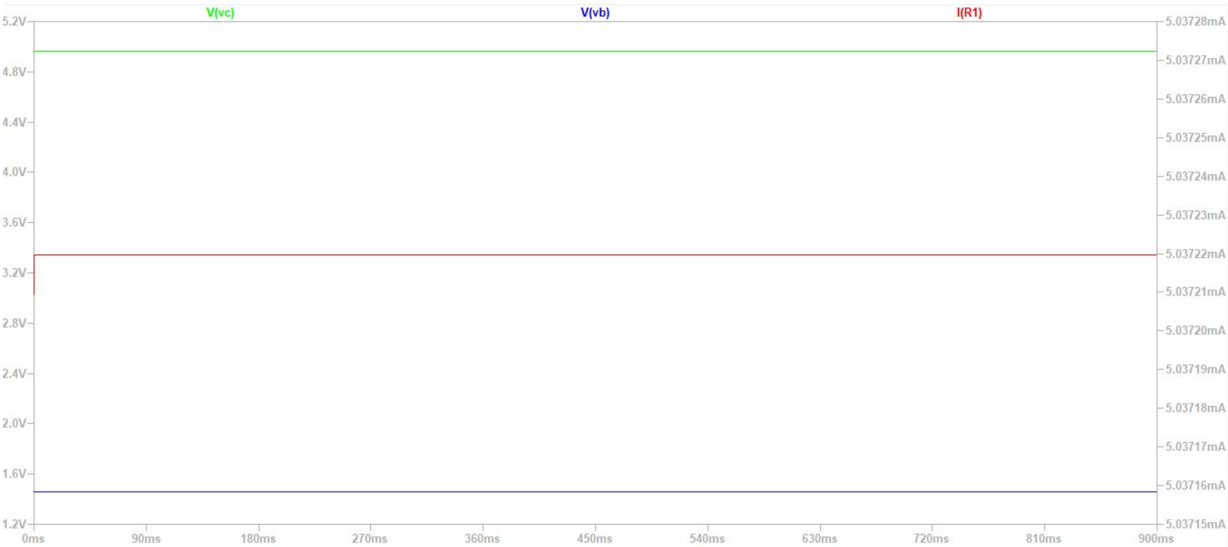

Figure 2: DC operating point simulation of BJT amplifier

The following table shows the DC operating point values of the amplifier as obtained from simulation using $R_L = 10k\Omega, Rc = 1k\Omega, Re = 0.15k\Omega, Ra = 34.8k\Omega, Rb = 6.6k\Omega$:

Parameter	Value
I_C	$5.04mA$
V_C	$4.96V$
V_E	$0.76V$
I_{R_a}	$0.25mA$
V_{R_b}	$1.46V$

1.5 Input and Output Coupling Capacitor Selection

The input capacitor C_i and output capacitor C_o are chosen such that their reactance is less than 10% of the input impedance and load impedance of the amplifier respectively.

$$\begin{aligned}
\text{Input Impedance of the amplifier}(R_{in}) &= R_a||R_b||\beta R_E = 4.68k\Omega \\
\text{Load Impedance of the amplifier}(R_L) &= 10k\Omega \\
\text{Input Capacitor Reactance}(X_{C_i}) &= 0.468k\Omega \\
\text{Output Capacitor Reactance}(R_L) &= 1k\Omega
\end{aligned}$$

So we have

$$C_i = \frac{1}{2\pi F X_{C_i}} = 0.34\mu F$$

$$C_o = \frac{1}{2\pi F X_{C_o}} = 0.16\mu F$$

1.6 AC Simulation Without R_L

Figure 3 shows the AC simulation (magnitude and frequenly response) of the amplifier gain with no-load. We obtain a gain of 16.1 dB = 6.39. Since the amplifier is on no-load, the observed gain is higher than the design gain. The lower cutoff frequency obtained from the simulation is 100 Hz and upper cutoff frequency is 34.4 MHz.Figure 4 shows the waveforms at output when 0.2 V p-p 1kHz sinewave is supplied to the amplifier input.

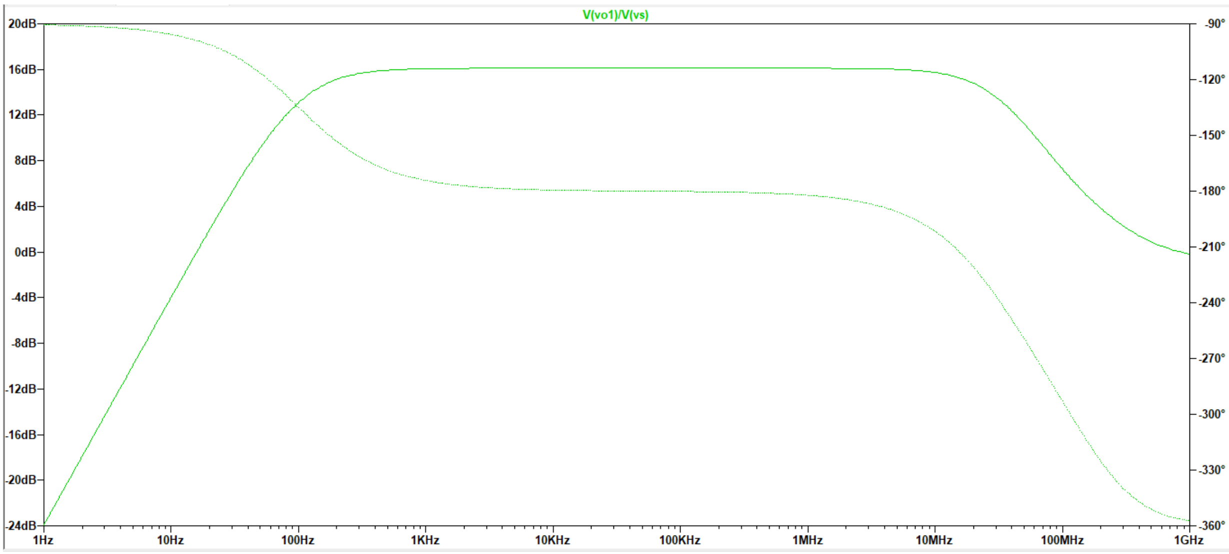

Figure 3: AC simulation of BJT amplifier without R_L.

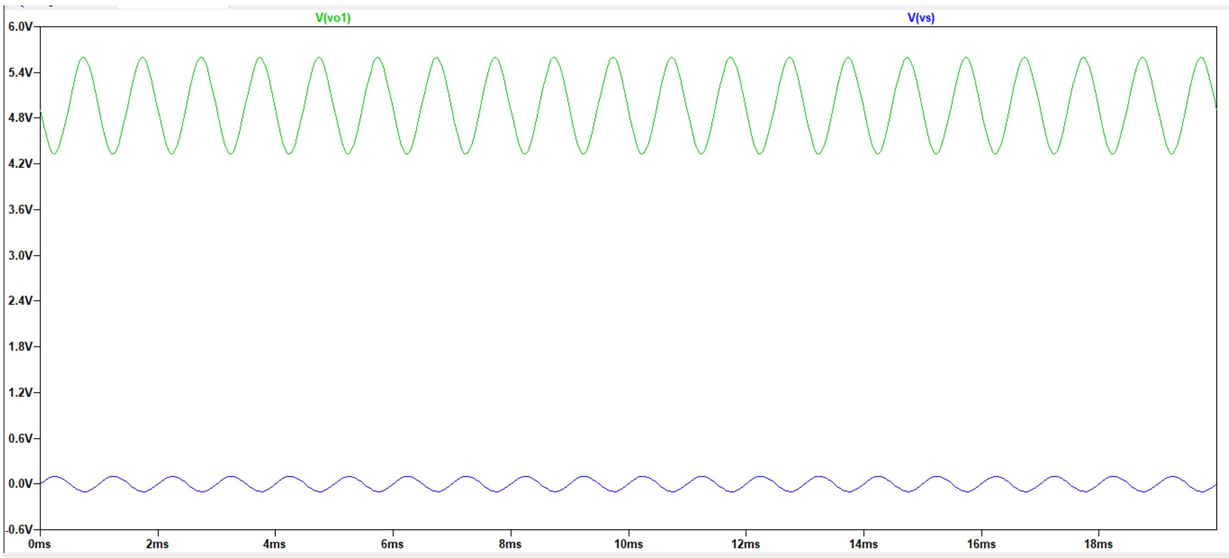

Figure 4: BJT amplifier output for 0.2 V p-p sinewave without R_L.

1.7 AC Simulation With $R_L = 10k\Omega$

Figure 5 shows the AC simulation (magnitude and frequency response) of the amplifier gain. We obtain a gain of 15.28 dB = 5.8 which satisfies the requirement. The lower cutoff frequency obtained from the simulation is 148 Hz and upper cutoff frequency is 37.9 MHz. Figure 6 shows the waveforms at output when 0.2V p-p 1kHz sinewave is supplied to the amplifier input.

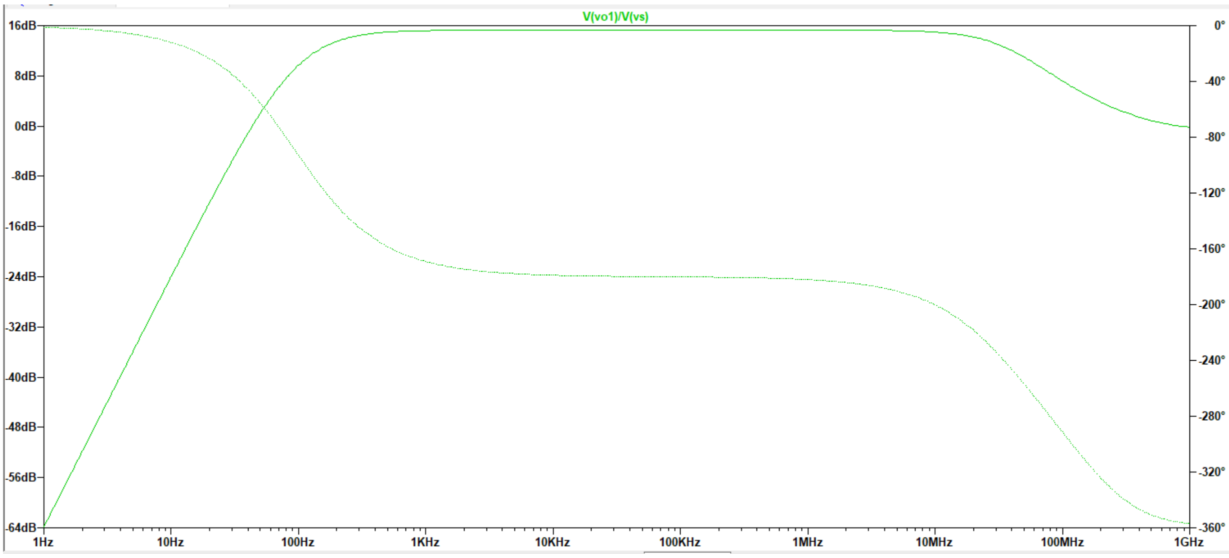

Figure 5: AC simulation of BJT amplifier with $R_L = 10k\Omega$.

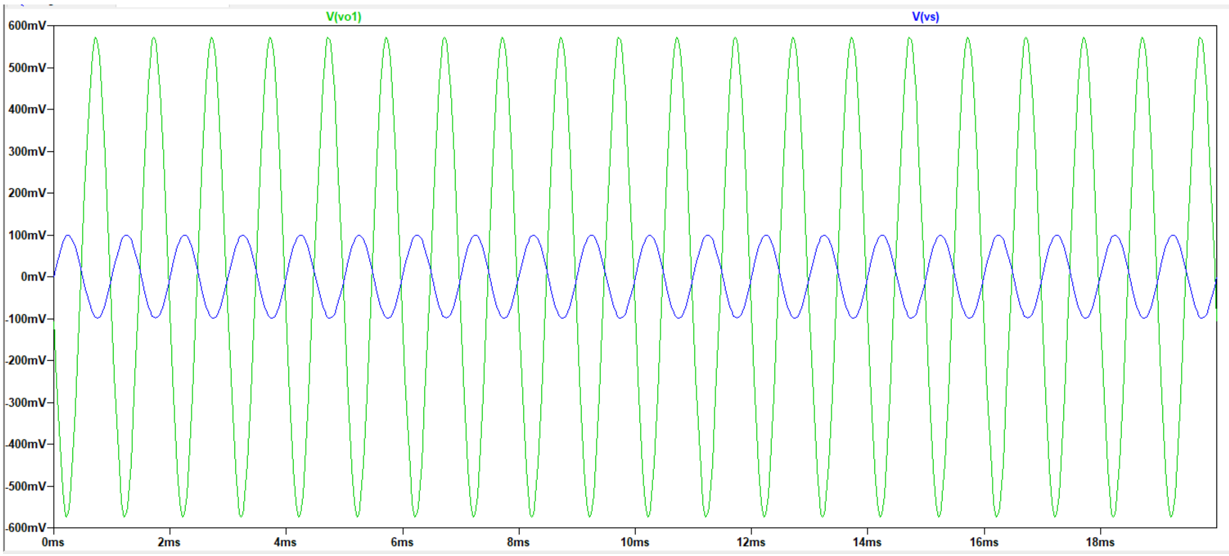

Figure 6: BJT amplifier output for 0.2V p-p 1kHz sinewave and $R_L = 10k\Omega$.

2 Non-Inverting Amplifier

2.1 Aim

To design a non-Inverting amplifier(using op-amp) with a gain of 5-6.

2.2 Schematic

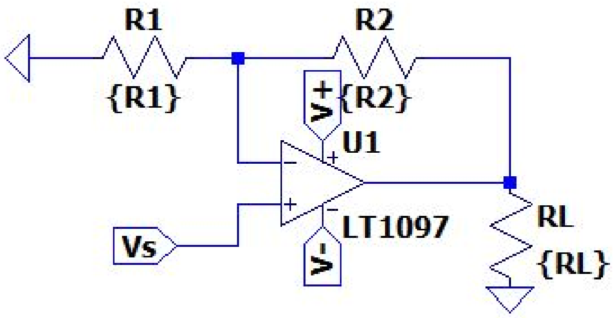

Figure 7: LTSpice Schematic of the Non-inverting Amplifier Circuit

2.3 Calculation of Component Values

We shall design the amplifier for R_L=10kΩ and gain=6. We have chosen Op-Amp (Part No. LT1097) for this design. We know that for a non-inverting amplifier

$$\text{gain } G = \frac{R_2 + R_1}{R_1}$$

We choose R_1=1 kΩ and R_2=5 kΩ to get a gain of 6..

2.4 AC Simulation Without R_L

Figure 8 shows the AC simulation (magnitude and frequency response) of the amplifier gain with no-load. We obtain a gain of 15.56 dB = 6.00. The bandwidth of the amplifier obtained from the simulation is 105.2 kHz.Figure 9 shows the waveforms at output when 0.2 V p-p 1kHz sinewave is supplied to the amplifier input.

Figure 8: AC simulation of non-inverting amplifier without R_L.

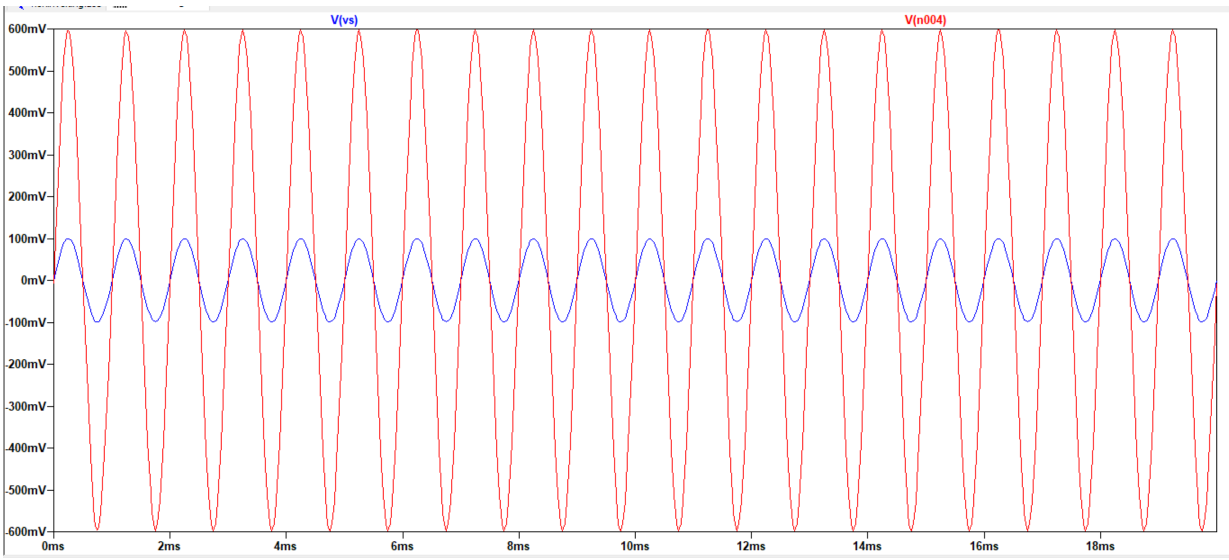

Figure 9: Non-inverting amplifier output for 0.2 V p-p sinewave without R_L.

2.5 AC Simulation With $R_L = 10k\Omega$

Figure 10 shows the AC simulation (magnitude and frequency response) of the amplifier gain. We obtain a gain of 15.56 dB = 6.00. The bandwidth obtained from the simulation is 95.3 kHz. Figure 11 shows the waveforms at output when 0.2 V p-p 1kHz sinewave is supplied to the amplifier input.

Figure 10: AC simulation of non-inverting amplifier with $R_L = 10k\Omega$.

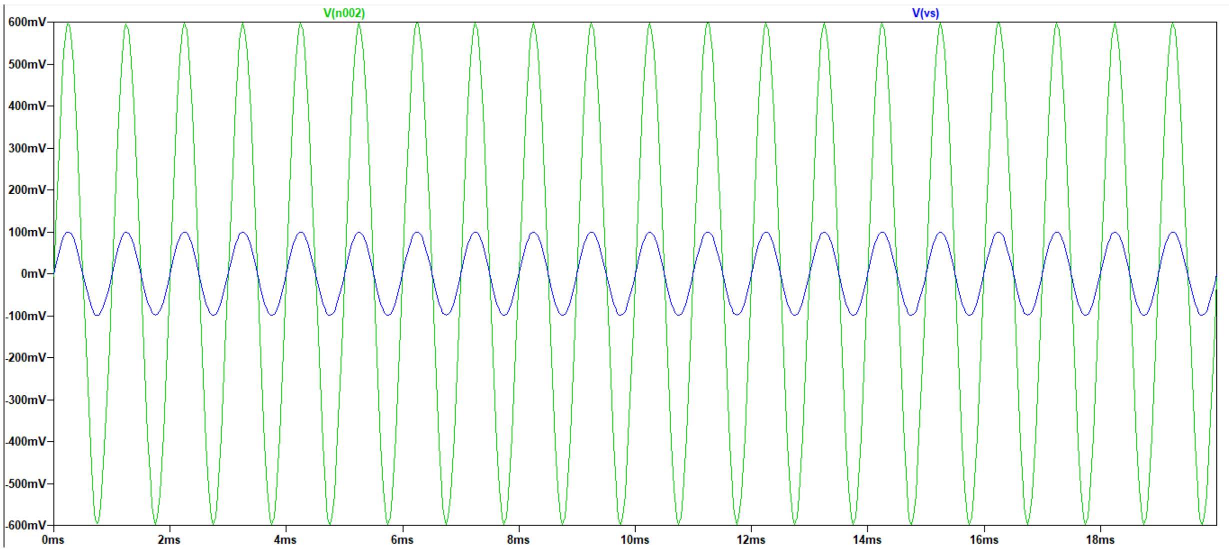

Figure 11: Non-inverting amplifier output for 0.2 V p-p sinewave with $R_L = 10k\Omega$.

3 Op-amp Buffer Amplifier

3.1 Aim

To design a Op-amp Buffer Amplifier.

3.2 Schematic

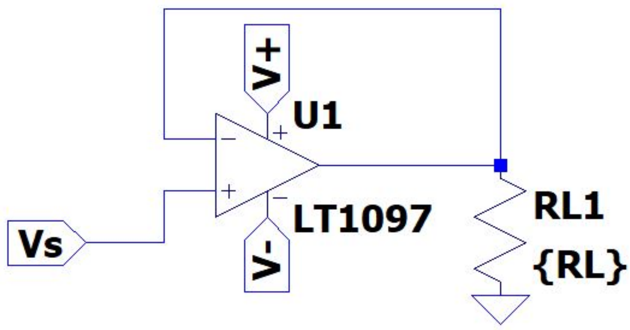

Figure 12: LTSpice Schematic of the op-amp (LT1097) Buffer Circuit

3.3 AC Simulation Without R_L

Figure 13 shows the AC simulation (magnitude and frequency response) of the buffer gain with no-load. We obtain a gain of 0 dB. The bandwidth of the buffer obtained from the simulation is 1.06 MHz.Figure 14 shows the waveforms at output when 10V p-p 1kHz sinewave is supplied to the buffer input.

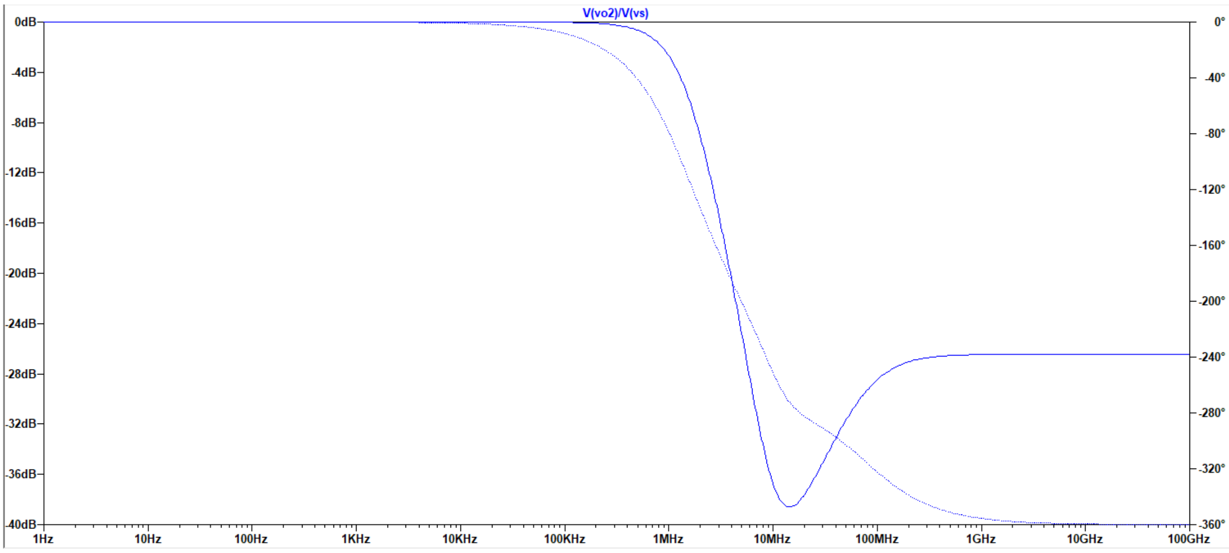

Figure 13: AC simulation of buffer without R_L.

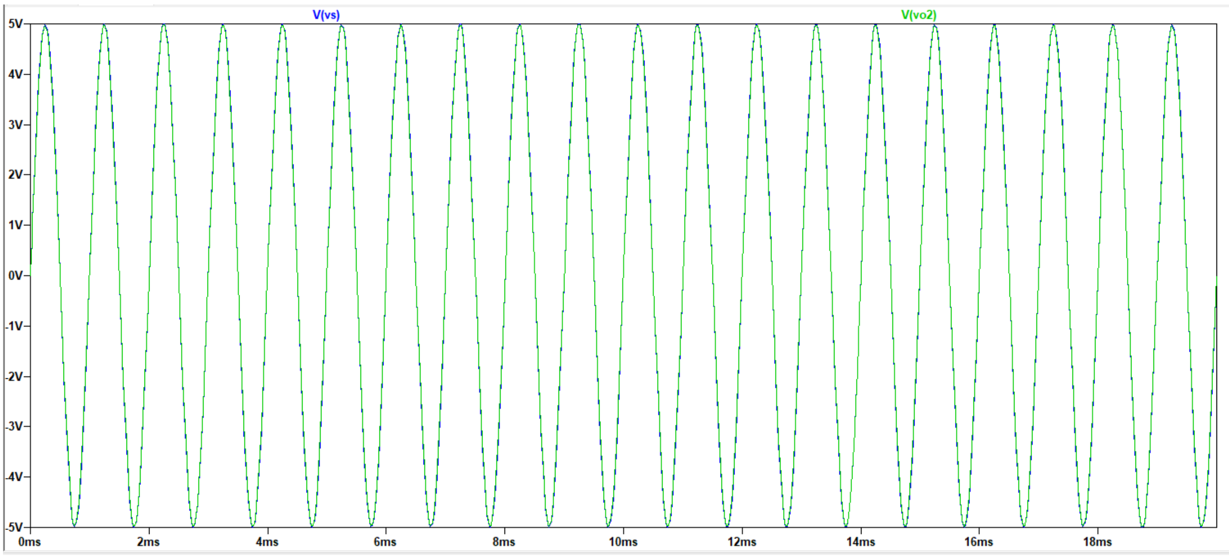

Figure 14: Buffer output for 10 V p-p sinewave without R_L.

3.4 AC Simulation With $R_L = 10k\Omega$

Figure 15 below shows the AC simulation (magnitude and frequency response) of the amplifier gain. We obtain a gain of 0 dB . The bandwidth of the buffer obtained from the simulation is 0.94 MHz. Figure 16 shows the waveforms at output when 10 V p-p 1kHz sinewave is supplied to the buffer input.

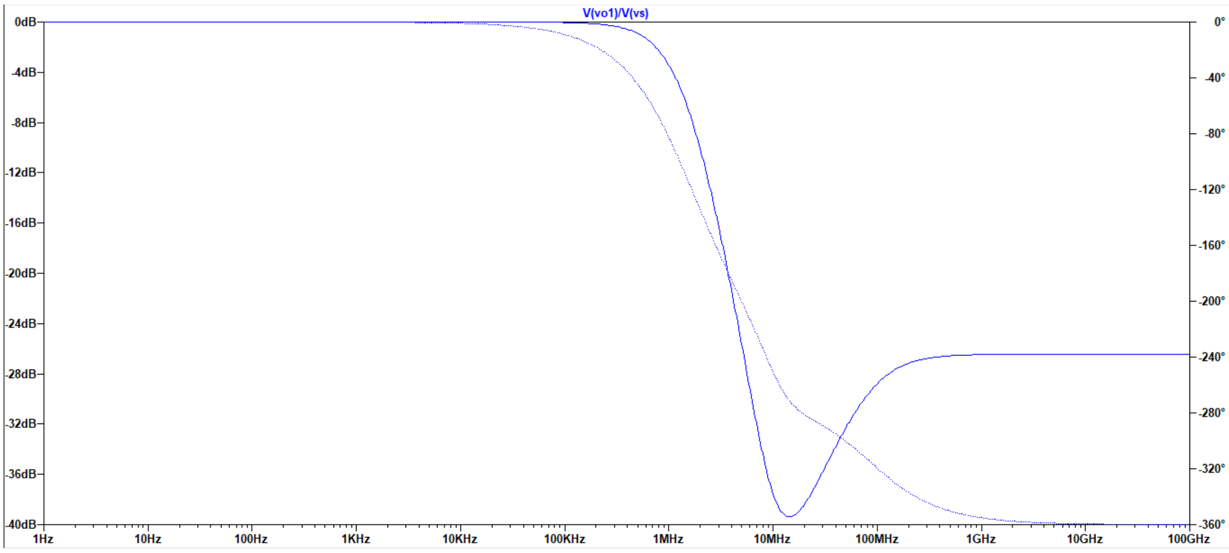

Figure 15: AC simulation of buffer with $R_L = 10k\Omega$.

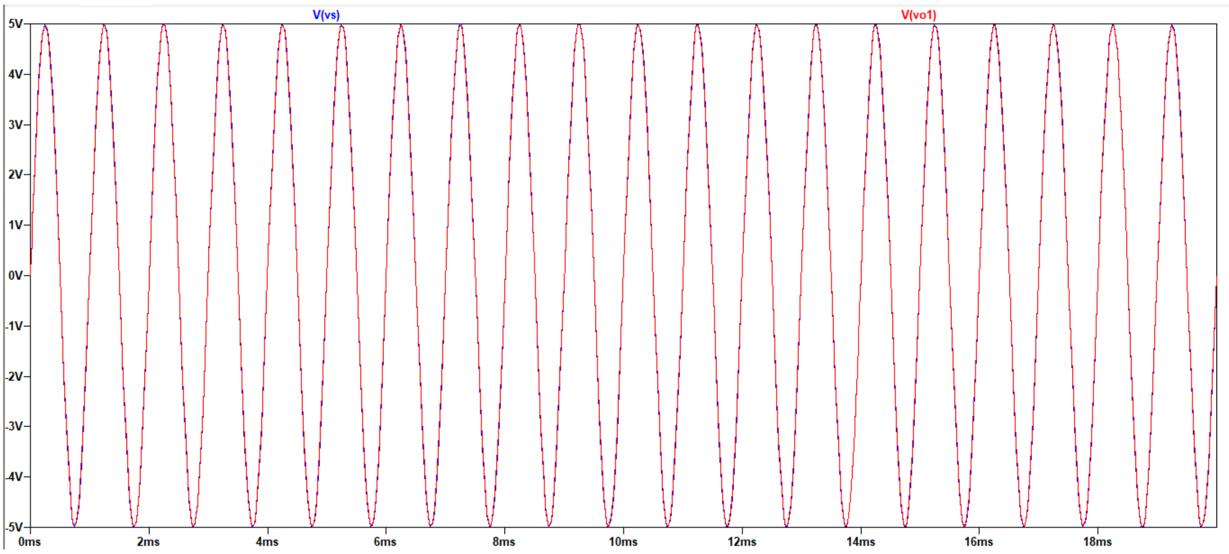

Figure 16: Buffer output for 10 V p-p sinewave with $R_L = 10k\Omega$.

4 Conclusions

1. The output impedance of the BJT amplifier is higher than that of the OP-AMP based amplifiers, so the gain values with and without load are considerably different.

2. The BJT amplifier has a very large bandwidth compared to the OP-AMP amplifiers.

3. At low frequencies (below 100 Hz) the BJT amplifier will not function as intended, because the reactance of the input coupling capacitor increases, which causes signal attenuation at the amplifier input.