ELECENG 2CF3: Assignment 3

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Exercise #1: *RLC* Series Network At Resonance

1. **Include the complete schematic.**

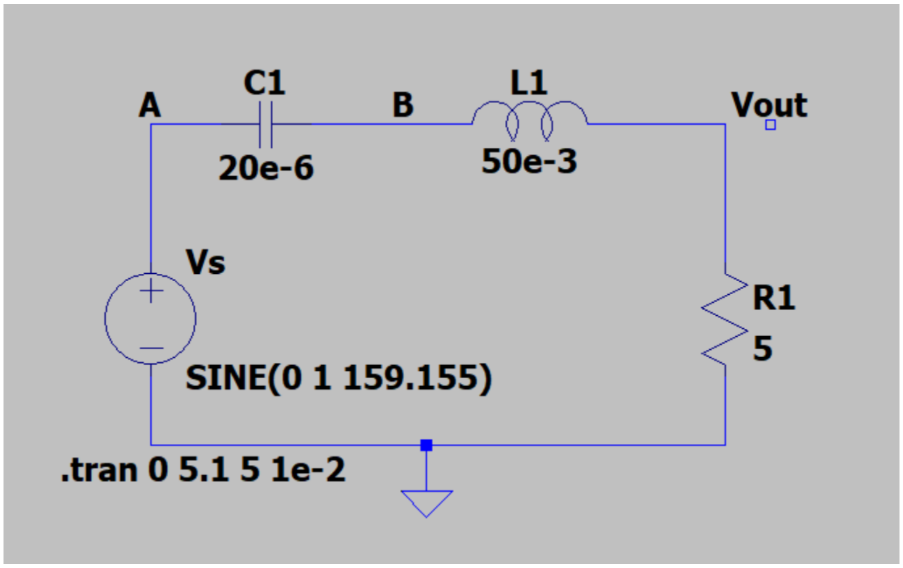

Figure 1: Complete schematic for Exercise 1

2. **Include the complete netlist.**

Vs A 0 SINE(0 1 159.155)
C1 B A 20e-6
L1 B N001 50e-3
R1 N001 0 5
.tran 0 5.1 5 1e-2
.backanno
.end

3. **Include the LTspice file, named properly.**

Exercise1.asc

4. **Include your calculations and final answers for L, Q, f_0, and the phasors V_L and V_C (magnitude and phase).**

$W_0 = 1000$ rad/s $\quad V_s = 1\angle 0°$ $\quad C = 20\,\mu F$ $\quad Z(W_0) = R = 5\Omega$

a) $L = ?$

$$W_0 = \frac{1}{\sqrt{LC}}$$

$$(1000)^2 = \frac{1}{L(20\times10^{-6})}$$

$$L = \frac{1\times10^6}{(1000)^2 \times 20} = 0.05\,H = 50\,mH$$

$$\therefore \boxed{L = 50\,mH}$$

b) $$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

$$= \frac{1}{5}\sqrt{\frac{5\cancel{0}\times10^{-3}}{2\cancel{0}\times10^{-6}}}$$

$$= \frac{1}{5}\sqrt{2.5\times10^3} = \frac{50}{5} = 10$$

$$\therefore \boxed{Q = 10}$$

c) $f_0 = ?$

$\omega_0 = 2\pi f_0 = 2\pi / T_0$

$$f_0 = \frac{W_0}{2\pi}$$

$$= \frac{1000}{2\pi} = 159.155\,Hz$$

$$\therefore \boxed{f_0 = 159.155\,Hz}$$

d) $V_L(j\omega_0) = ?$

$X_L = j\omega_0 L$

$= j(1000)(50\times10^{-3})$

$$\boxed{X_L = 50j\,\Omega}$$

$$X_c = \frac{-j}{\omega_0 C} = \frac{-j}{(1000)(20\times10^{-6})}$$

$$= \frac{-j}{20\times10^{-3}} = \boxed{-50j\,\Omega = X_c}$$

$$V_L(j\omega_0) = V_s\left(\frac{X_L}{X_L + X_c + R}\right) = 1\angle 0^\circ \left(\frac{50j}{\cancel{50j} - \cancel{50j} + 5}\right)$$

$$V_L(j\omega_0) = 10j = 10\angle 90^\circ\ V$$

$$\boxed{\begin{array}{l}\text{magnitude} = 10\ V \\ \text{Phase} = 90^\circ\end{array}}$$

e) $V_c(f_0) = ?$

$$V_c(f_0) = V_s\left(\frac{X_c}{X_L + X_c + R}\right)$$

$$= 1\angle 0^\circ \left(\frac{-50j}{\cancel{50j} - \cancel{50j} + 5}\right)$$

$$= -10j$$

$$= 10\angle -90^\circ$$

$$\therefore \boxed{\begin{array}{l}\text{Magnitude} = 10V \\ \text{Phase} = -90^\circ\end{array}}$$

Figure 2: Calculations for Exercise 1

5. Include the images of the $v_C(t)$ and $v_L(t)$ waveforms resulting from the simulation.

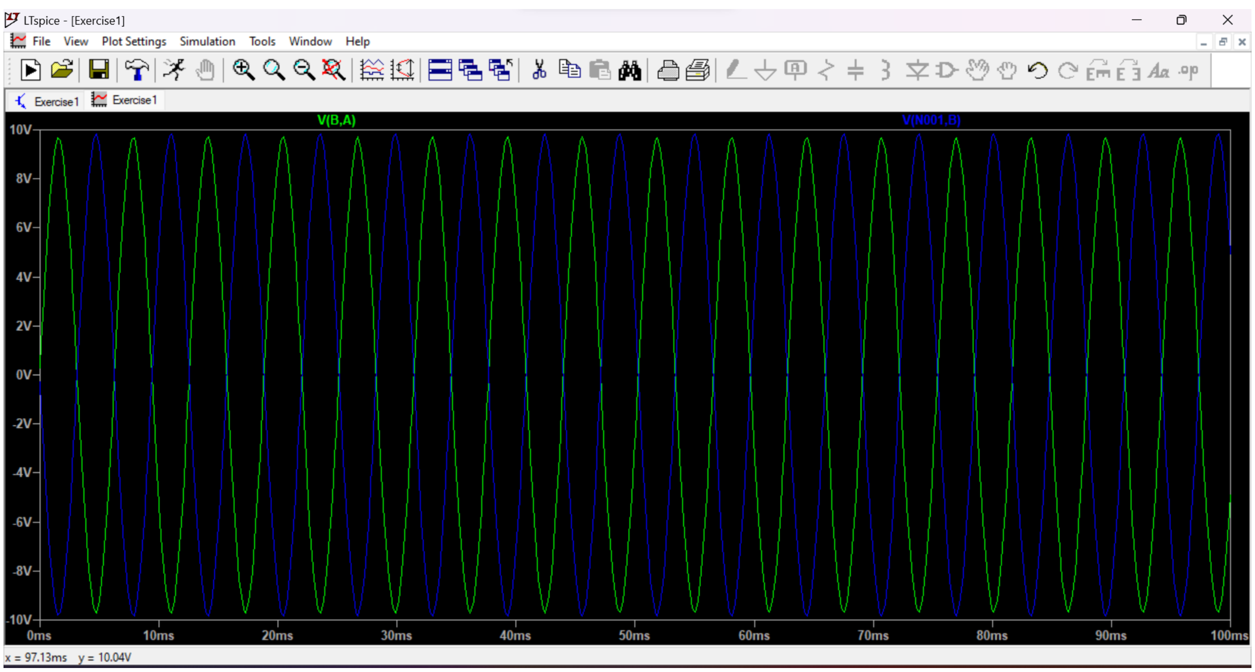

Figure 3: $V_C(t)$ and $V_L(t)$ waveforms resulting from the simulation

The green waveform represents the waveform for the capacitor and the red waveform represents the waveform for the inductor.

6. **Do the simulation results for $v_C(t)$ and $v_L(t)$ at the resonant frequency confirm the magnitude and phase calculation for the phasors V_L and V_C in part 4? Justify your answer.**

   Yes, the simulation results match the calculation for the phasors V_L and V_C. According to the calculation for the voltage phasor for the capacitor, the magnitude is supposed to be 10V and the phase difference is 90º. According to the calculation for the voltage phasor for the inductor, the magnitude is supposed to be 10V and the phase difference is -90º. We can see that both graphs have the same magnitude which is 10V, however, both graphs are inverted with respect to each other. This shows that the green graph (for the capacitor) has a phase angle of 90º and the red graph (for the inductor) has a phase angle of -90º.

Exercise #2: *RLC* Series Network As a Bandpass Filter

1. **Include the complete schematic.**

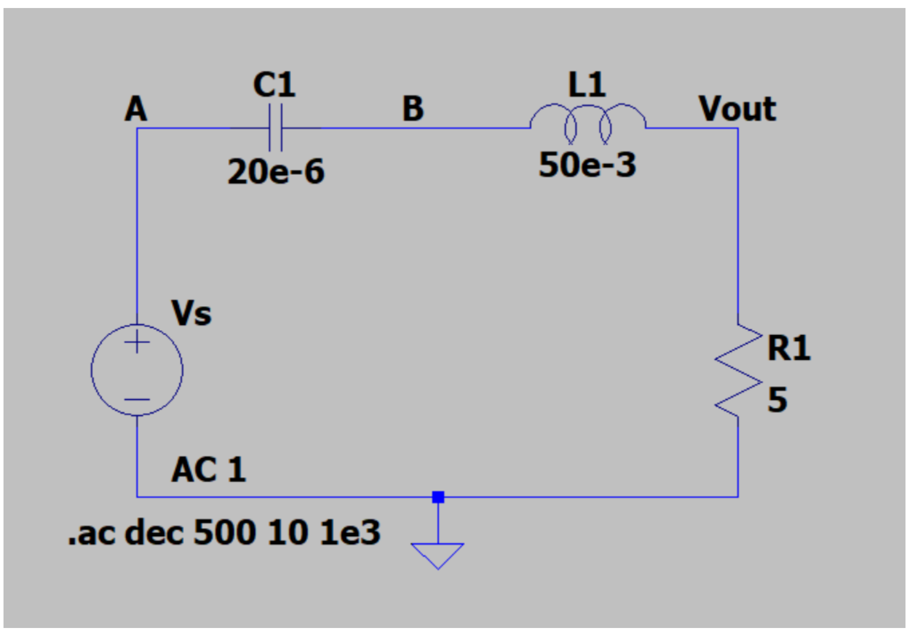

Figure 4: Complete schematic for Exercise 2

2. **Include the complete netlist.**

   Vs A 0 AC 1
   C1 B A 20e-6
   L1 B Vout 50e-3
   R1 Vout 0 5
   .ac dec 500 10 1e3
   .backanno

.end

3. **Include the LTspice file, named properly.**

   Exercise2.asc

4. **Include the calculation of the 3-dB BW, $f_{LO,}$ and f_{HI}.**

$$BW = \frac{W_o}{Q} = \frac{1000 \text{ rad/s}}{10}$$

$$\boxed{BW = 100 \text{ rad/s or } 15.9155 \text{ Hz}}$$

$$f_{Lo} = f_o - \frac{1}{2} BW$$

$$= 159.155 - \frac{1}{2}(15.9155)$$

$$\boxed{f_{Lo} = 151.19725 \text{ Hz}}$$

$$f_{HI} = f_o + \frac{1}{2} BW$$

$$= 159.155 + \frac{15.9155}{2}$$

$$\boxed{f_{HI} = 167.11275 \text{ Hz}}$$

Figure 4: Calculations of the 3-dB BW, $f_{LO,}$ and f_{HI}

5. **Include the magnitude-dB and phase plots of G, versus frequency from the simulation. They can be plotted on a common graph. With the simulation settings suggested above, the frequency axis should be automatically set to a logarithmic scale.**

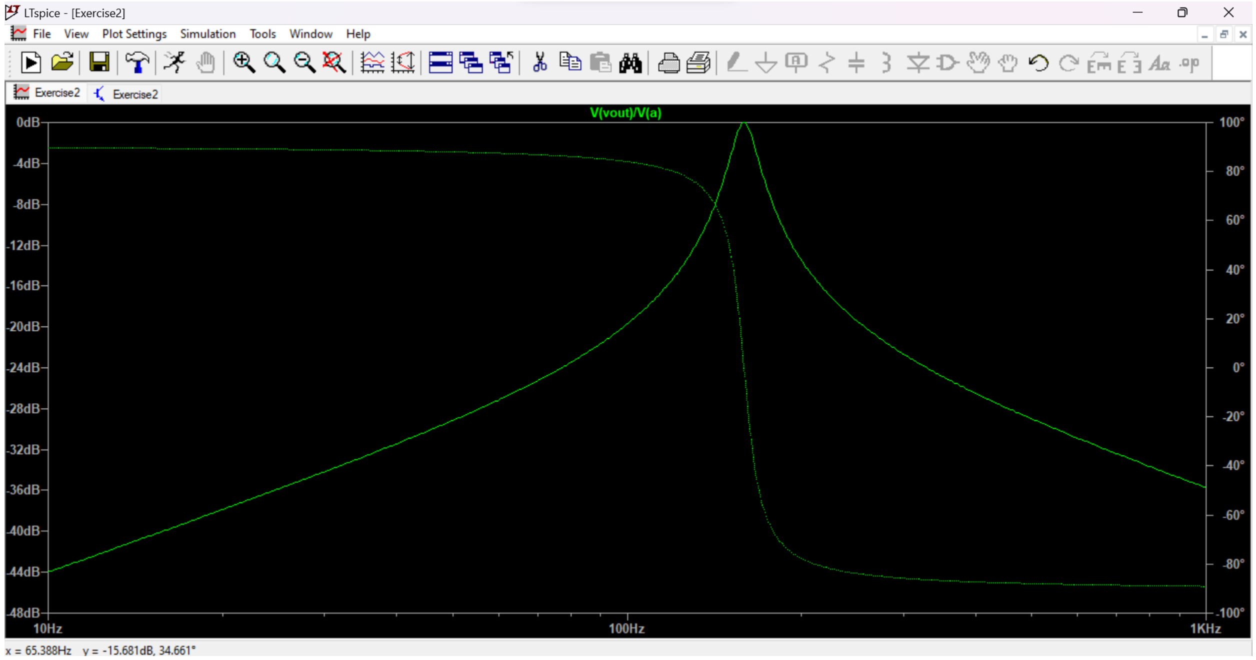

Figure 5: Magnitude-dB and phase plots of G, versus frequency

6. **Does the magnitude-dB plot of G, versus frequency confirm your calculations for BW, f_{LO}, and f_{HI}? To answer this question, you need to read out the values of f_{LO} and f_{HI} from the plot.**

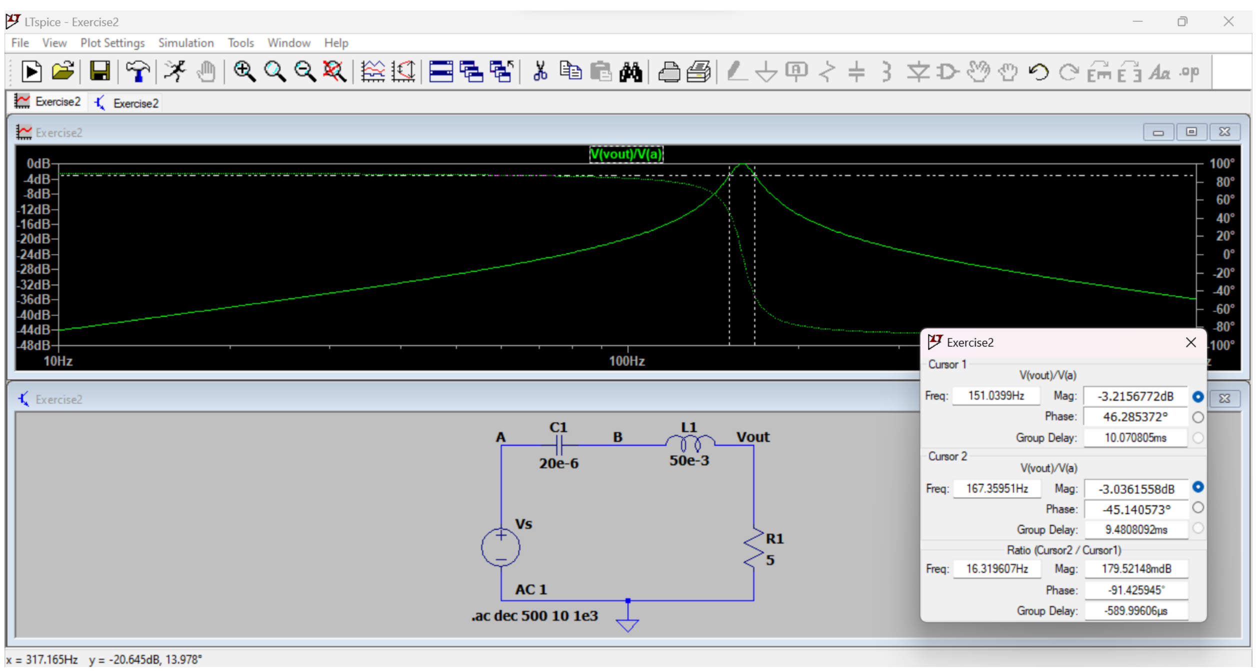

Figure 6: values of BW, $f_{LO,}$ and f_{HI} from the plot

The above figure shows the values of f_{LO} (Frequency of Cursor 1), f_{HI} (Frequency of Cursor 2), and the bandwidth (Frequency of Ratio (Cursor2/Cursor1)). The values do match my calculations with some minor differences in rounding off. These differences could arise due to systematic and simulation errors. However, the values from the plot do approximately match my calculations.

7. **What are the values of the phase of G_v at the resonant frequency f_0 as well as the cut-off frequencies, f_{LO} and f_{HI}, according to the simulation plot? What are these values according to theory? Is there an agreement?**

   The simulation shows the value of G_v has a phase of 0°. The value of the resonant frequency is equal to 159.155 Hz. The cut-off frequencies of f_{LO} and f_{HI} are 151.0399 Hz and 167.3595 Hz respectively. The values of the phase of G_v for f_{LO} and f_{HI} are 46.3° and -45.1° respectively. These values from the simulation plot do match with the expected values from the calculations in theory, however, the simulation does have some minor errors. At resonance, the voltage gain is equal to 0.

Exercise #3: Low-Pass Filter

1. **Include the complete schematic.**

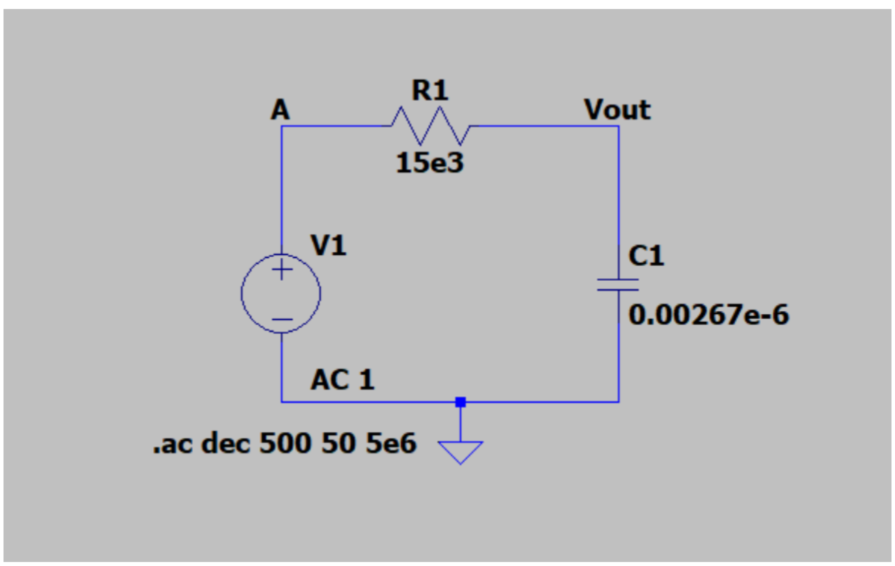

Figure 7: Complete schematic of Exercise 3

2. **Include the complete netlist.**

   V1 A 0 AC 1
   R1 Vout A 15e3
   C1 Vout 0 0.00267e-6
   .ac dec 500 50 5e6
   .backanno

.end

3. **Include the LTspice file, named properly.**

Exercise3.asc

4. **Include the values of R and C. Show the calculation for C.**

$W_o = 25\text{ kHz}$

$R = 15\text{ k}\Omega$

$C = ?$

$$W_o = \frac{1}{RC}$$

$$C = \frac{1}{W_o \cdot R}$$

$$C = \frac{1}{25 \times 15 \times 10^6}$$

$$\boxed{C = 0.00267\ \mu F}$$

Figure 8: Calculation for Capacitance

5. **Include the magnitude-dB plot of the transfer function obtained from the simulation.**

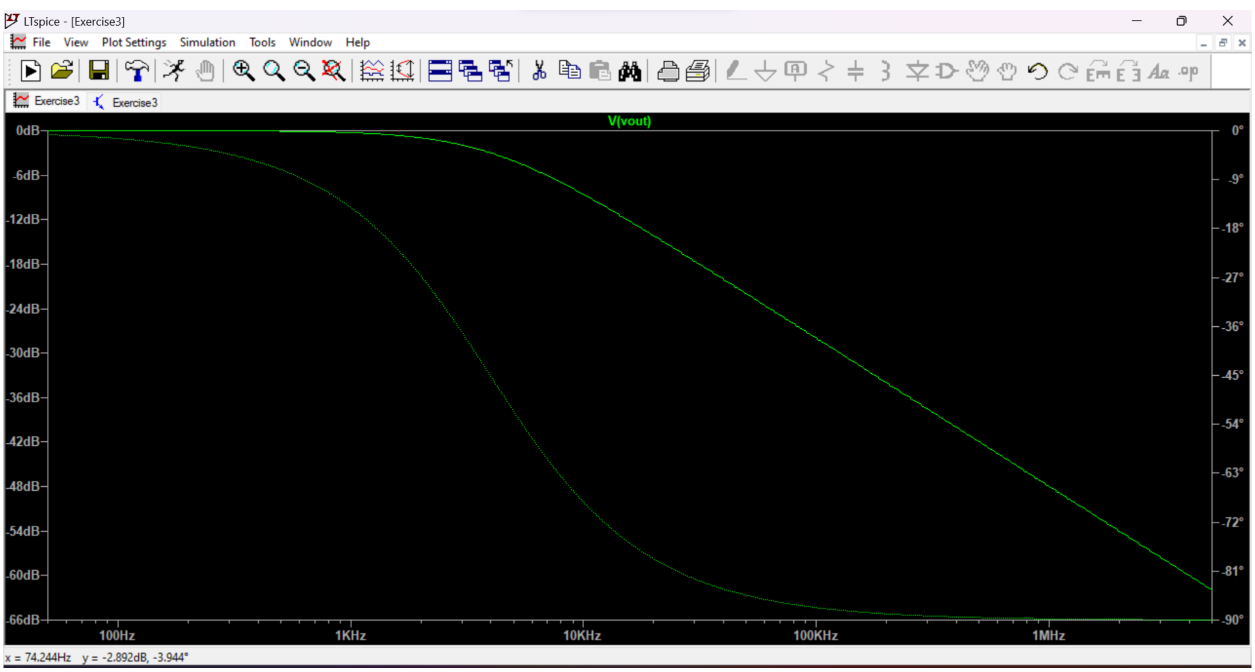

Figure 9: Magnitude-dB plot of the transfer function obtained from the simulation

6. **From the magnitude-dB plot of the transfer function, determine the cut-off frequency. Is it in agreement with the required value of 25 kHz?**

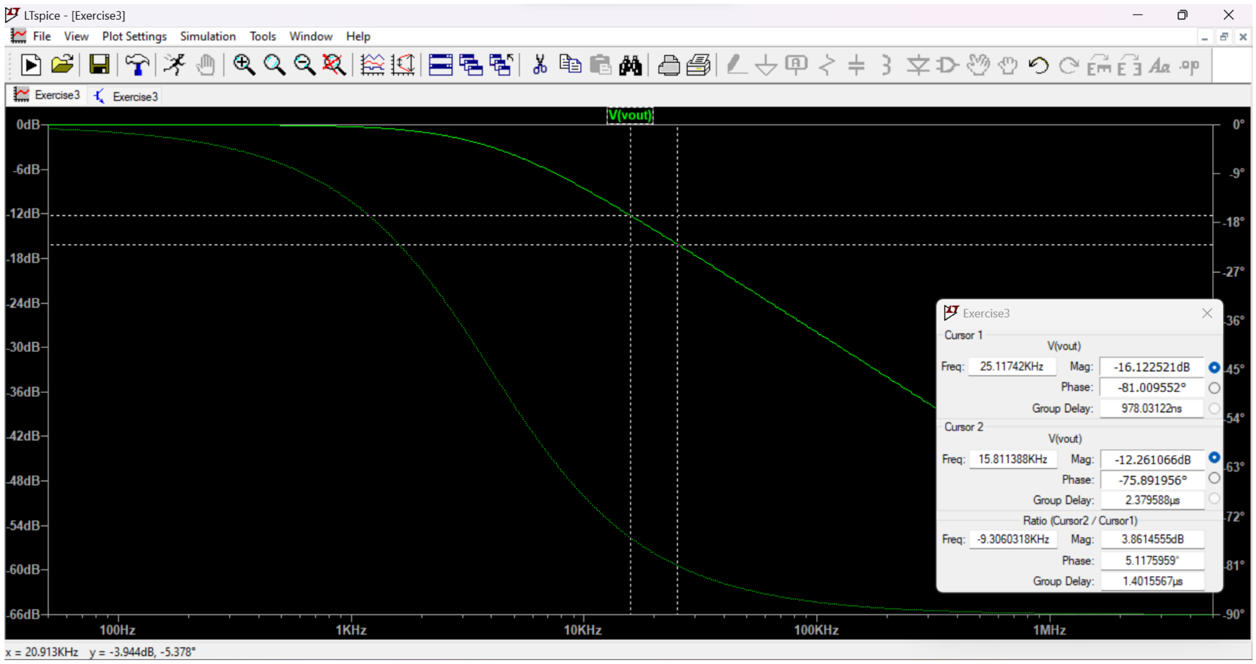

Figure 10: values of BW, $f_{LO,}$ and f_{HI} from the plot

From the magnitude-dB plot of the transfer function, it is seen that the cut-off frequency (Frequency at Cursor 1) is equal to 25.117 kHz. This is in agreement with the required value of 25 kHz.

Exercise #4: High-Pass Filter

1. **Include the complete schematic.**

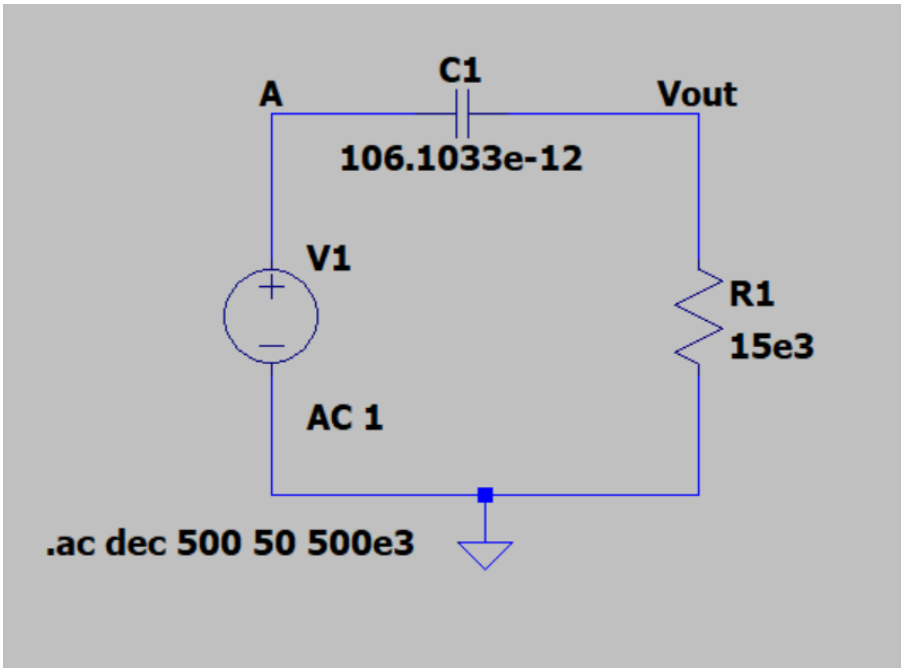

Figure 11: Complete schematic of Exercise 4

2. **Include the complete netlist.**

    V1 A 0 AC 1
    C1 Vout A 106.1033e-12
    R1 Vout 0 15e3
    .ac dec 500 50 500e3
    .backanno
    .end

3. **Include the LTspice file, named properly.**

    Exercise4.asc

4. **Include the values of R and C. Show the calculation for C.**

$$\omega_o = 100\,kHz$$
$$R = 15\,k\Omega$$
$$C = ?$$

$$\omega_o = \frac{1}{2\pi RC}$$

$$C = \frac{1}{\omega_o \cdot 2\pi R} = \frac{1}{(100000)(2\pi)(15000)}$$

$$C = 1.061033 \times 10^{-4} \times 10^{-6}$$

$$\boxed{C = 106.1033\,pF}$$

Figure 12: Calculation for Capacitance

5. **Include the magnitude-dB plot of the transfer function obtained from the simulation.**

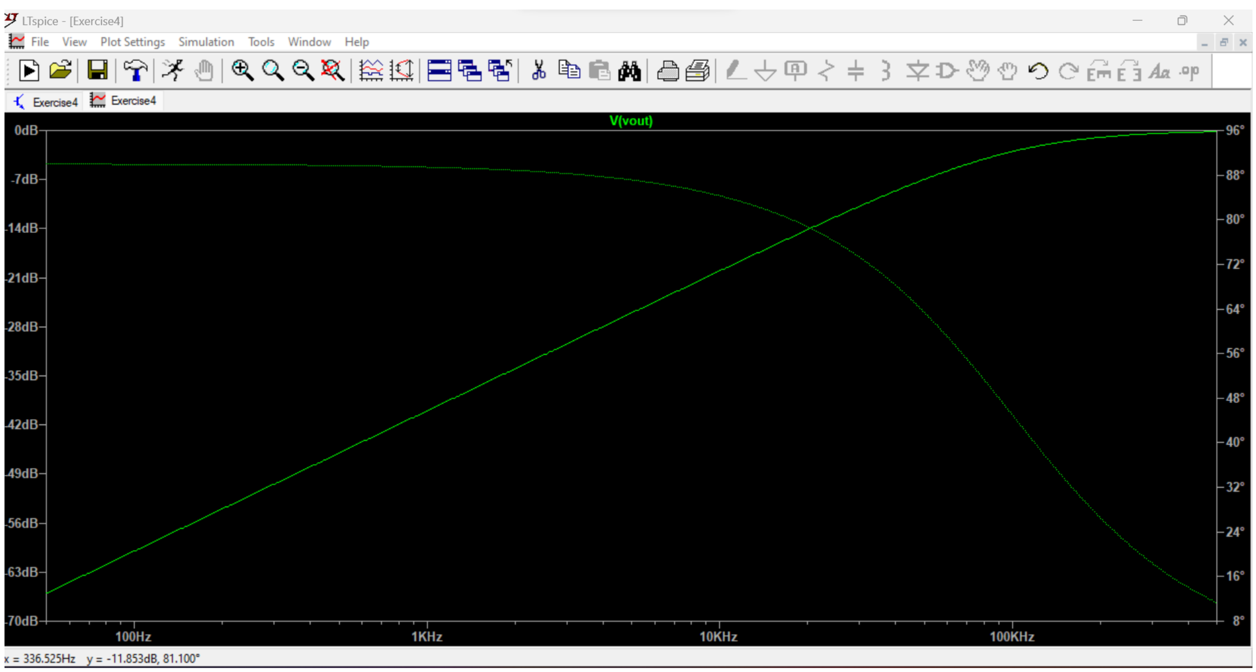

Figure 13: Magnitude-dB plot of the transfer function obtained from the simulation

6. **From the magnitude-dB plot of the transfer function, determine the cut-off frequency. Is it in agreement with the required value of 100 kHz?**

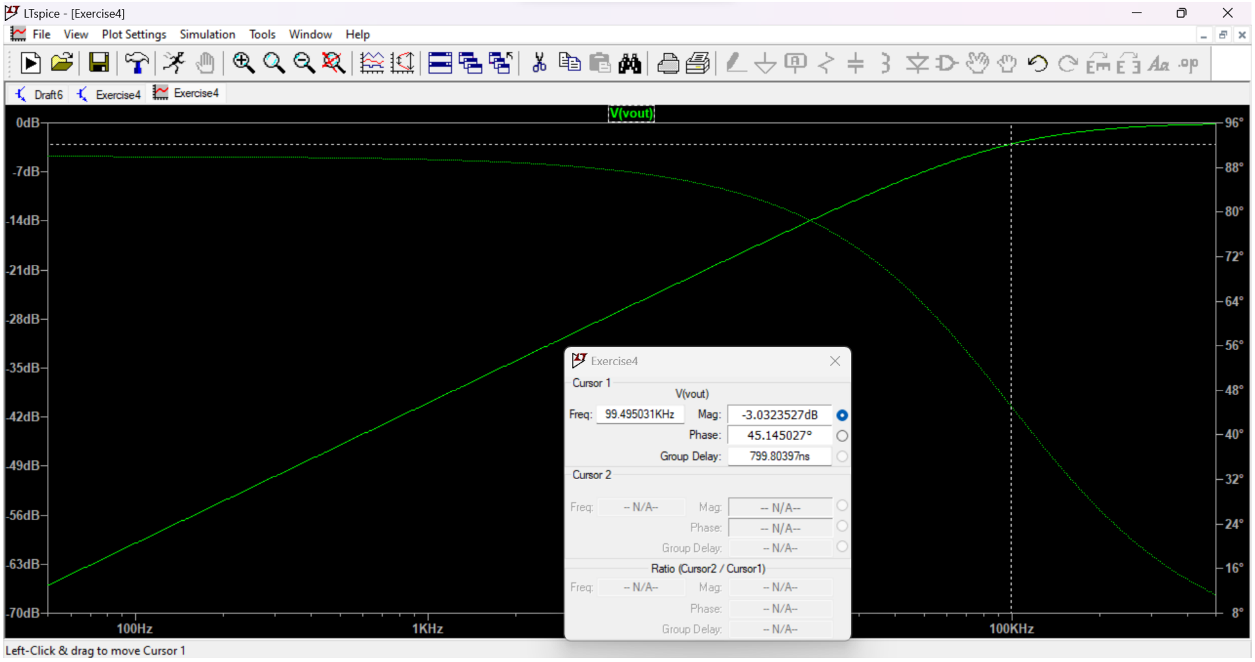

Figure 14: Magnitude-dB plot of the transfer function

From the picture above, it is seen that the value of the cut-off frequency (Frequency of Cursor 1) is equal to 99.495 kHz which is pretty close to the expected value from the calculations which is 100 kHz. The values are still in agreement but the simulation plot has some minor errors.