ELEC ENG 2CF3

Assignment 2
Op-Amp Logic Gates

Areeba Irfan - irfana20 - 400378045

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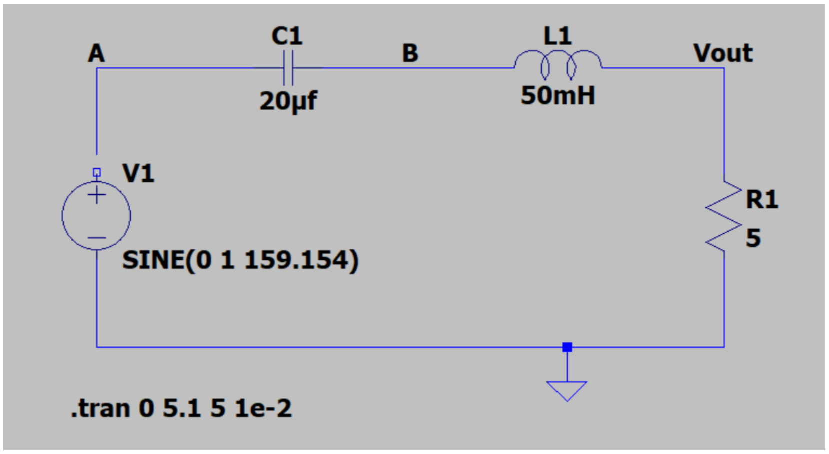
EXERCISE #1: RLC SERIES NETWORK AT RESONANCE

1. Include the complete schematic



2. Include the complete netlist (View→SPICE Netlist)

```
* C:\Users\Areeba\Desktop\winter 2023\2EI4\Draft1.asc
V1 NC_01 0 SINE(0 1 159.154)
C1 B A 20µf
L1 B Vout 50mH
R1 Vout 0 5
.tran 0 5.1 5 1e-2
.backanno
.end
```

3. Include the LTspice (*.asc) file, named properly, e.g., Exercise1.asc.

The name of the file is *excercise1_assignment3.asc*

4. Include your calculations and final answers for L, Q, f0, and the phasors VL and VC (magnitude and phase).

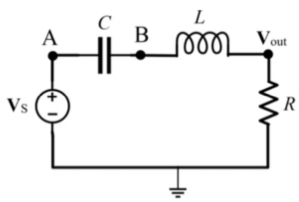


Fig.1. *RLC* series circuit.

$\omega_o = 1000$ rad/s

$V_s = 1\angle 0°$

$C = 20\mu F$

$Z(\omega_o) = 5\Omega$

a) calculate the inductance

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

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

$$L = \frac{1}{\omega_o^2 C}$$

$$= \frac{1}{(1000\,rad/s)^2(20\mu F)}$$

$$= 0.05H$$

b) calculate the quality factor

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

$* R = Z(\omega_o)$

$$\boxed{Q = 10}$$

$$= \frac{1}{5\Omega}\sqrt{\frac{50mH}{20\mu F}}$$

$$= 10$$

c) calculate the resonant frequency f_o in Hz

$$f_o = \frac{\omega_o}{2\pi}$$

$$\boxed{f_o = 159.154\,Hz}$$

$$= \frac{1000\,rad/s}{2\pi}$$

$$= 159.154\,Hz$$

d) calculate the magnitude and phase of inductor & capacitor's voltage

$$X_L(f_o) = \omega_o L j$$

$$= 1000\,rad/s \times 50mH \times j$$

$$= 50\Omega j$$

$$X_C(f_o) = \frac{-j}{\omega_o C}$$

$$= \frac{-j}{1000\,rad/s \times 20\mu F}$$

$$X_C(f_o) = -50j\Omega$$

Voltage division:

$$V_L(f_o) = V_s \times \frac{X_L}{R + X_C + X_L}$$

$$\boxed{V_L(f_o) = 10\angle 90° V}$$

$$= 1\angle 0° \times \frac{50j}{5 - 50j + 50j}$$

$$\boxed{\begin{array}{l} \text{magnitude} = 10V \\ \text{phase} = 90° \end{array}}$$

$$= 10\angle 90° V$$

$$V_C(f_o) = V_s \times \frac{X_C}{R + X_C + X_L}$$

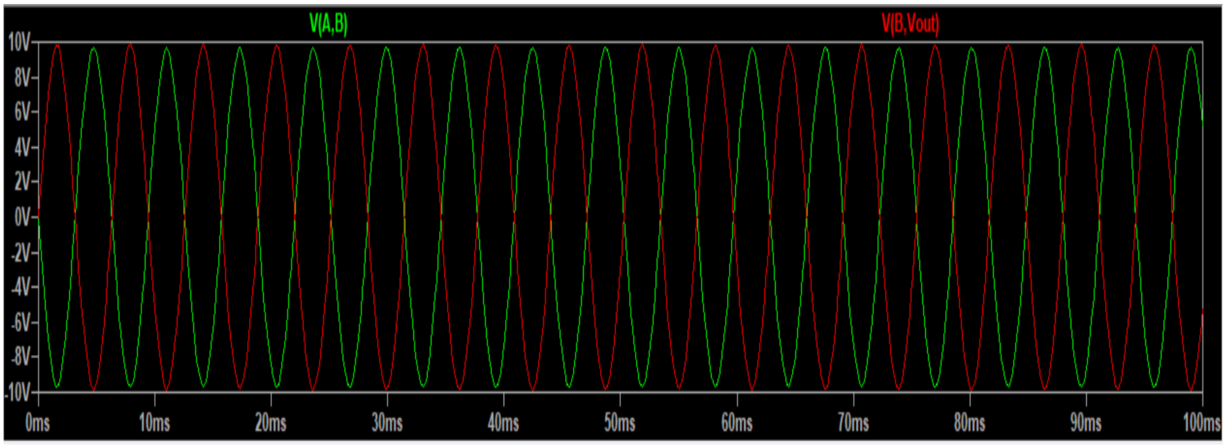
$$\boxed{V_C(f_o) = 10\angle 90° V}$$

$$= 1\angle 0° \times \frac{-50j}{5 - 50j + 50j}$$

$$\boxed{\begin{array}{l} \text{magnitude} = 10V \\ \text{phase} = -90° \end{array}}$$

$$= 10\angle -90° V$$

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

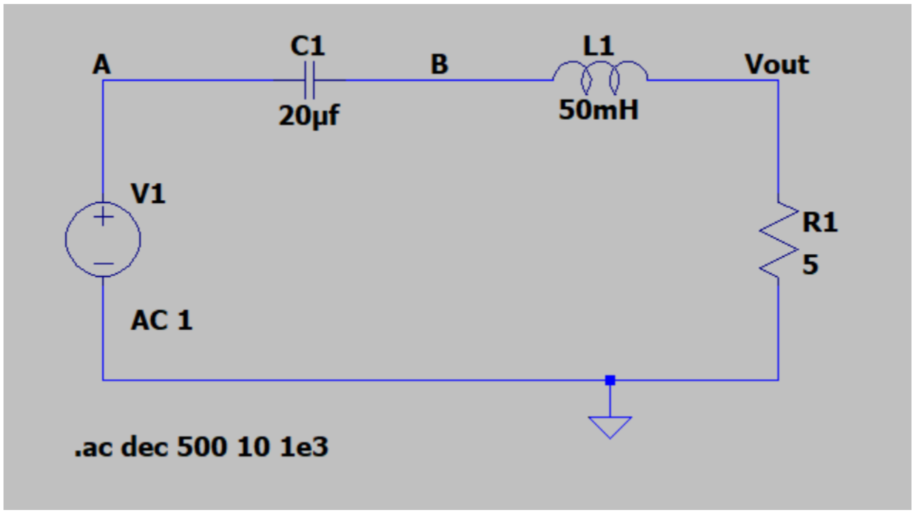


6. Do the simulation results for v_C (t) and v_L(t) at the resonant frequency confirm the magnitude and phase calculation for the phasors VL and VC in part 4? Justify your answer.

Yes, the simulation results for V_C(t) and V_L(t) confirm the calculator for the phasors VL and VC. In theory, at resonance, V_C and V_L are out of phase but with equal strengths. They cancel each other out because they are 180° apart. It can be seen that the amplitude of both waves in the graph is 10 and the phase difference between the two voltages is 180°, which means the graph matches the calculations.

EXERCISE #2: RLC SERIES NETWORK AS A BANDPASS FILTER

1. Include the complete schematic



2. Include the complete netlist

```
* C:\Users\Areeba\Desktop\winter 2023\2CF3\Assignment3\exercise1_assignment3.asc
V1 A 0 AC 1
C1 B A 20µf
L1 B Vout 50mH
R1 Vout 0 5
.ac dec 500 10 1e3
.backanno
.end
```

3. Include the LTspice (*.asc) file, named properly, e.g., Exercise2.asc.

The name of the file is *excercise2_assignment3.asc*

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

calculate the 3dB bandwidth (BW) and the cutoff frequencies f_{OH} & f_{HI} for the voltage gain transfer function $G_V(j\omega) = V_{out}(j\omega)/V_s$

$$\omega_{LO} = \omega_o \left[-\frac{1}{2Q} + \sqrt{\left(\frac{1}{2Q}\right)^2 + 1} \right]$$

$$= 1000\ \text{rad/s} \left[-\frac{1}{2(10)} + \sqrt{\left(\frac{1}{2(10)}\right)^2 + 1} \right]$$

$$= 951.249$$

$$f_{LO} = \frac{\omega_{LO}}{2\pi}$$

$$= 151.396\ \text{Hz}$$

$$\boxed{f_{LO} = 151.396\ \text{Hz}}$$

$$\omega_{HI} = \omega_o \left[\frac{1}{2Q} + \sqrt{\left(\frac{1}{2Q}\right)^2 + 1} \right]$$

$$= 1000\ \text{rad/s} \left[\frac{1}{2(10)} + \sqrt{\left(\frac{1}{2(10)}\right)^2 + 1} \right]$$

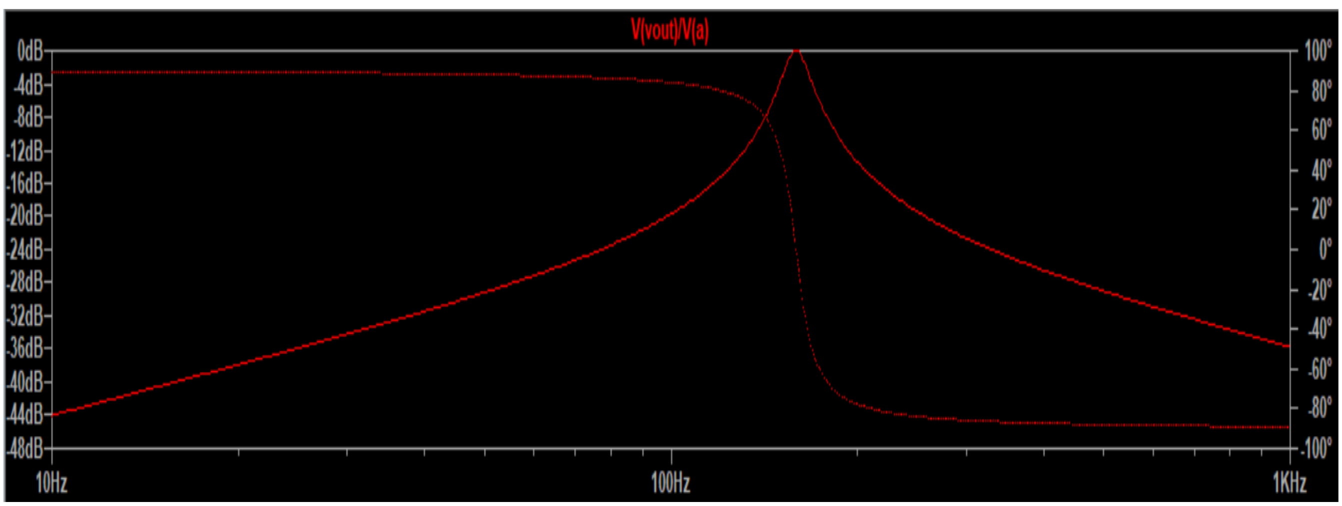
$$= 1051.249$$

$$f_{HI} = \frac{\omega_{HI}}{2\pi}$$

$$= 167.311\ \text{Hz}$$

$$\boxed{f_{HI} = 167.311\ \text{Hz}}$$

5. Include the magnitude-dB and phase plots of G_V versus frequency from the simulation.



6. Does the magnitude-dB plot of G_V versus frequency confirm your calculations for BW, f_{LO} and f_{HI}?

Yes, when observing the graph at the -3db point, the following frequency values on the x-axis confirm the calculation for f_{LO} and f_{HI}.

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?

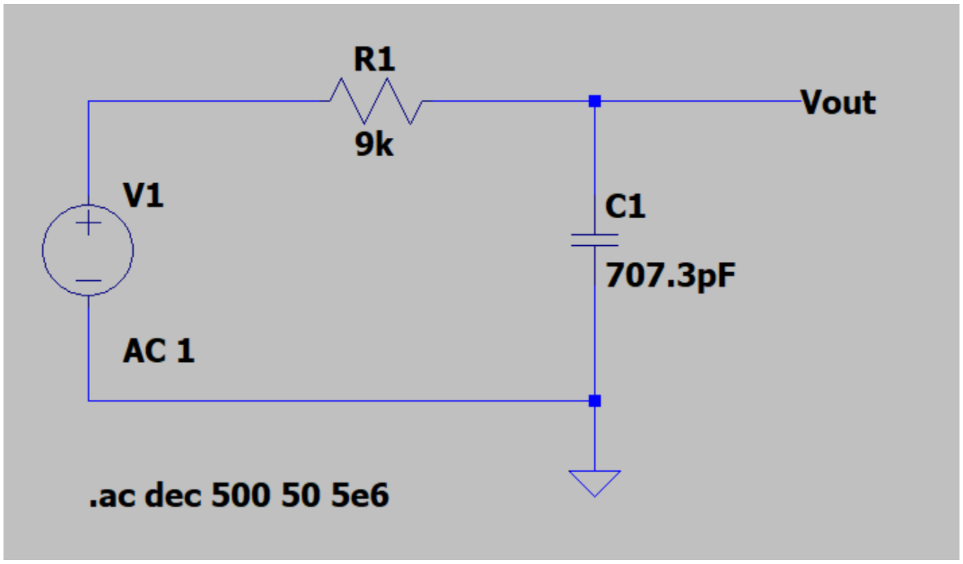
At resonant frequency (159.154 Hz), the phase of G_V was approximately 0°. This is in agreement to theory because the filter's output voltage is in phase with the input voltage, meaning no phase shift.

At f_{LO}, the phase shift was approximately 45°.This is in agreement with the theory because the phase shift at the cutoff frequency is half the phase shift at the resonant frequency. The calculated phase shift at resonant frequency was 90°.

At f_{HI}, the phase shift was approximately -45°.This is in agreement with the theory because, the phase shift at the cutoff frequency is half the phase shift at the resonant frequency. The calculated phase shift at resonant frequency was 90°.

EXERCISE #3: LOW-PASS FILTER

1. Include the complete schematic



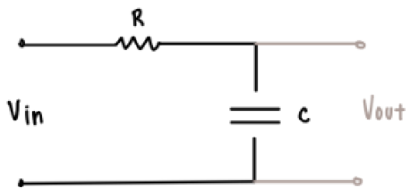
2. Include the complete netlist

```
* C:\Users\Areeba\Desktop\winter 2023\2CF3\Assignment3\Draft1.asc
V1 N001 Vout AC 1
R1 Vout N001 9k
C1 Vout Vout 707.3 pF
.backanno
.end
```

3. Include the LTspice (*.asc) file, named properly, e.g., Exercise3.asc.

The name of the file is *excercise3_assignment3.asc*

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



cutoff frequency $f_o = 25\text{kHz}$

student no. 400378045

$\boxed{R = 9\text{K}\Omega}$

calculate the capacitance

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

$$C = \frac{1}{\omega_o R}$$

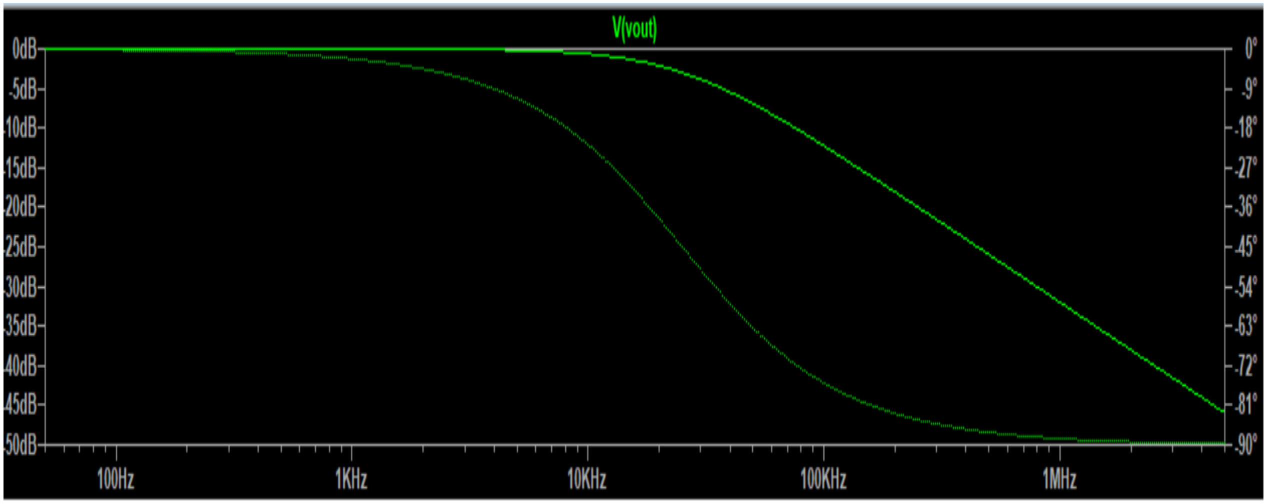
$$= \frac{1}{2\pi f_o R}$$

$$= \frac{1}{2\pi \times 25\text{K} \times 9\text{K}}$$

$$= 7.073 \times 10^{-10}\ \text{F}$$

$\boxed{C = 707.3\text{pF}}$

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

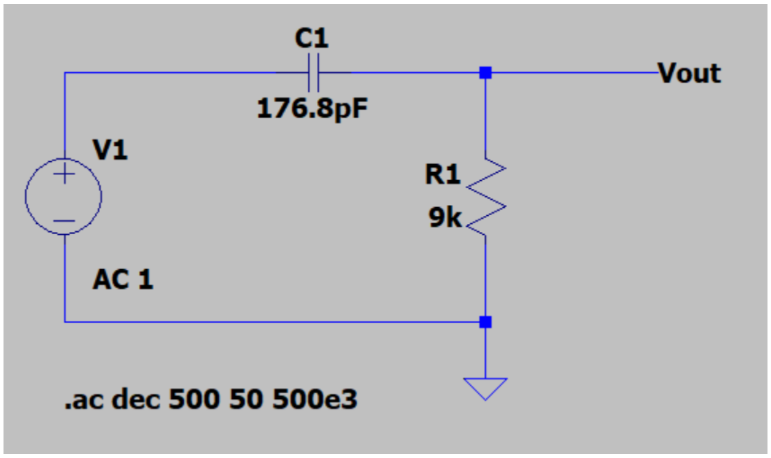


6. From the magnitude-dB plot of the transfer function, determine the cut-off frequency. Is it in agreement with the required value of 25 kHz?

When observing the magnitude-dB plot, it can be determined that the cut-off frequency of the graph is in agreement with 25 kHz. When locating the -3 dB point on the magnitude dB graph, the corresponding frequency on the x-axis is 25 kHz, which is the cut off frequency.

EXERCISE #4: HIGH-PASS FILTER

1. Include the complete schematic



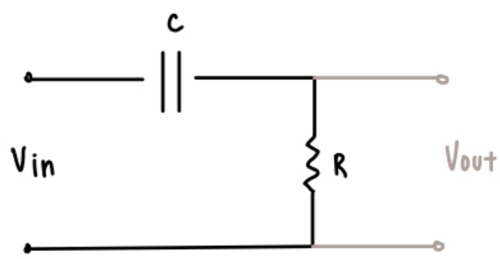
2. Include the complete netlist

```
* C:\Users\Areeba\Desktop\winter 2023\2CF3\Assignment3\Draft3.asc
V1 N001 0 AC 1
R1 0 Vout 9k
C1 Vout N001 176.8pF
.ac dec 500 50 500e3
.backanno
.end
```

3. Include the LTspice (*.asc) file, named properly, e.g., Exercise3.asc.

The name of the file is *excercise4_assignment3.asc*

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



cut off frequency $f_0 = 100\,KHz$

student no. 400378045

$$\boxed{R = 9\,K\Omega}$$

$$\omega_0 = \frac{1}{RC}$$

$$C = \frac{1}{\omega_0 R}$$

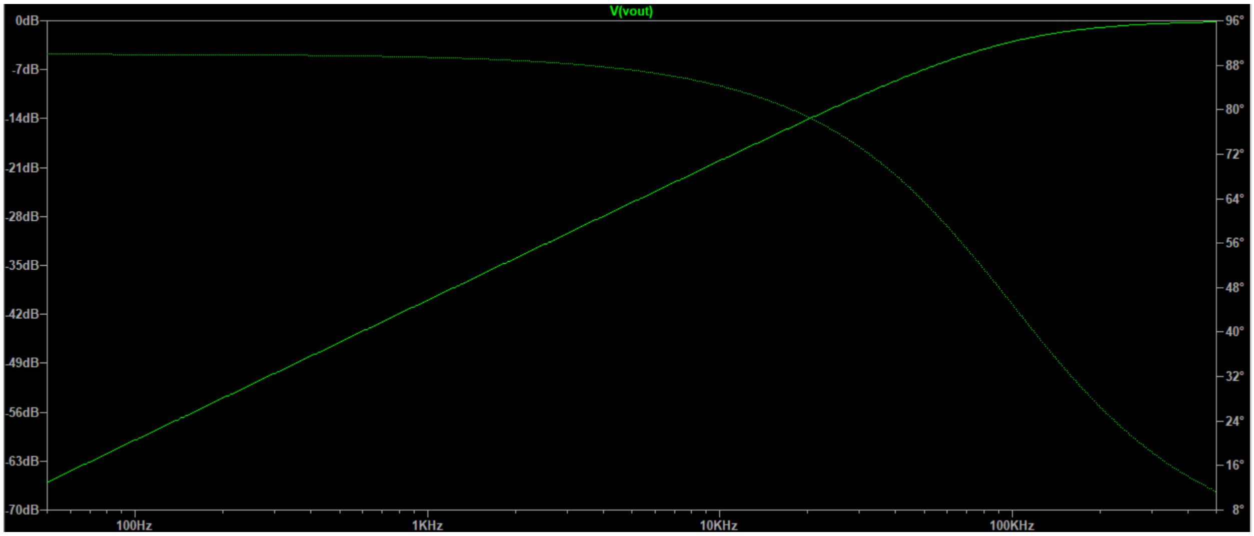
$$= \frac{1}{2\pi f_0 R}$$

$$= \frac{1}{2\pi \times 100k \times 9k}$$

$$= 1.768 \times 10^{-10}\ F$$

$$\boxed{C = 176.8\,pF}$$

5. Include the 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?

When observing the magnitude-dB plot, it can be determined that the cut-off frequency of the graph is in agreement with 100 kHz. When locating the -3 dB point on the magnitude dB graph, the corresponding frequency on the x-axis is 100 kHz, which is the cut off frequency.