Experiment #4: Frequency Response and Bode Plots

4.1 Introduction:

The sinusoidal-steady-state response of a linear network is a sinusoid of the same frequency as the input excitation, but with different amplitude and phase angle. The ratio of the response-phasor to the excitation-phasor is frequency-dependent, and is called the **frequency-response function H(ω)** of the network. Plots of $|\mathbf{H(\omega)}|$ and $\angle\mathbf{H(\omega)}$ versus frequency are often used to describe the frequency-selective characteristics of various linear networks such as feedback amplifiers and filters.

The frequency-response function H(ω) is closely related to the **transfer function H(s)** of the network, as $\mathbf{H(\omega)= H(s = j\omega)}$. Both functions are useful in describing different aspects of behavior of linear networks. While H(s) describes the pole-zero pattern (in the s-plane) of a network's transfer function, H(ω) describes the frequency-selective characteristics associated with such a pattern. Clearly, a change in the pole-zero patterns of H(s) will yield a corresponding change in the frequency-response characteristics for the network.

To quickly visualize how the pole-zero pattern of the transfer function of a network affects the frequency-response characteristics, electrical engineers often use a **straight-line approximation** technique (known as the **Bode method**) to simplify the analysis and design of linear networks. Through quick analysis, the designer is then able to evaluate various possibilities before deciding on a suitable network. The Bode method is a conceptual technique that reduces the complete frequency-response characteristics to a sum of elementary straight-line approximations. The straight-line approximations of $|H(\omega)|$ in **dB** and $\angle H(\omega)$ in **degrees** versus frequency [**log scale**] are said to be the **asymptotic Bode plots** of the frequency response characteristics.

$$\mathbf{H(\omega)_{dB} = 20Log_{10}|H(\omega)|}$$

This experiment examines the frequency-response characteristics of various linear networks. It also demonstrated the effectiveness of the Bode method in providing a quick visualization of the frequency-response for these networks.

4.2 Objectives:

- To draw the asymptotic Bode plots that approximates the frequency-response characteristics of various linear networks.
- To measure and plot the magnitude- and phase-frequency responses of the above-mentioned networks.
- To compare the asymptotic Bode plots and the practical measurements.

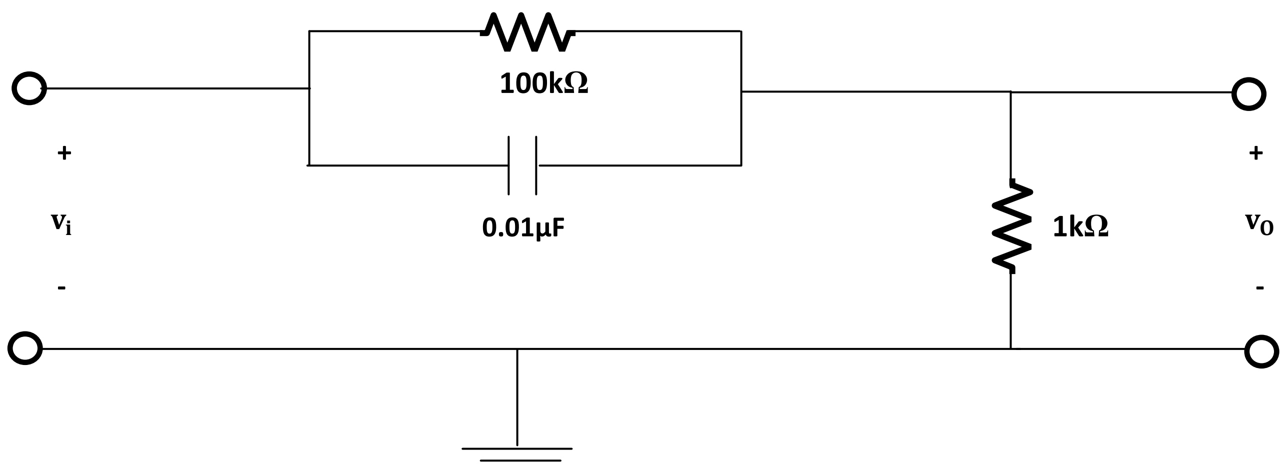
4.3 Prelab Assignment:

Step 1: Consider the network shown in **Fig (4.1)**.

a) Derive the transfer function H(s) = $^{V_o}/_{V_i}$.

b) Use **Graph (4.1)** to draw the asymptotic Bode plots for the frequency-response of the network.

Fig (4.1)

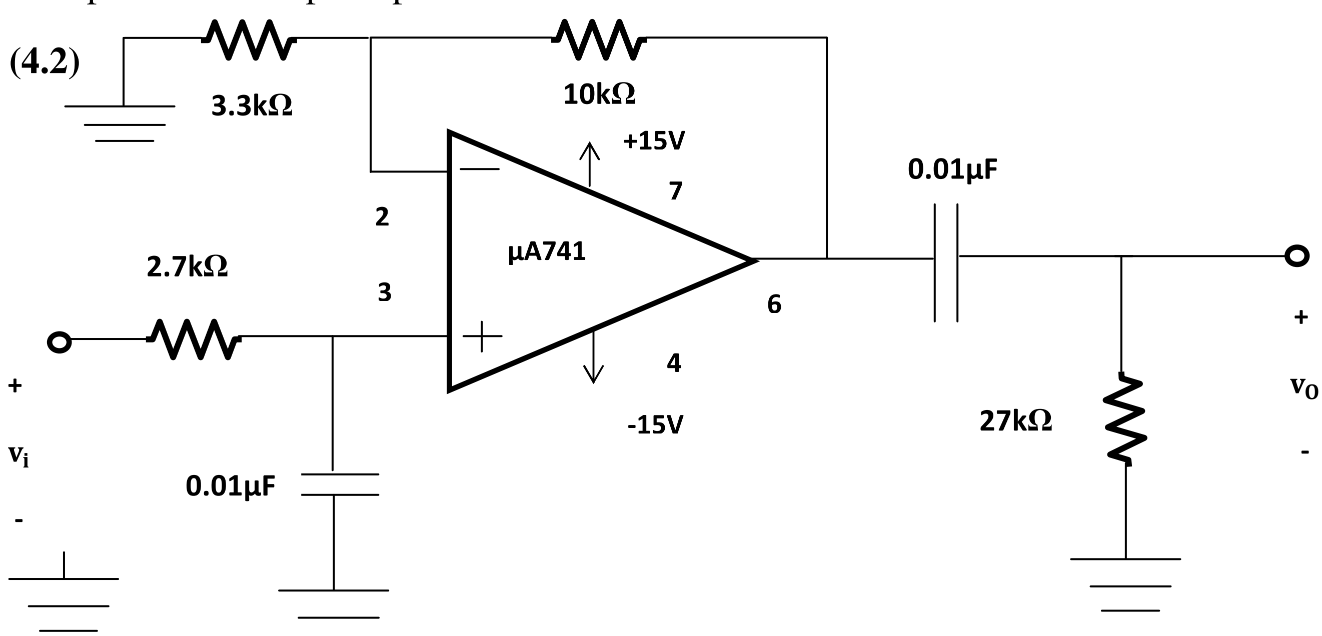


Step 2: Assume that the Op-Amp circuit in **Fig (4.2)** is working properly.

a) Derive the transfer function H(s) = $^{V_o}/_{V_i}$.

b) Use **Graph (4.2)** to draw the asymptotic Bode plots for the frequency-response of the Op-Amp circuit.

Fig (4.2)



Step 3: Use **SPICE** software (please read Section 14.10 of Fundamentals of Electric Circuits 5th Edition) to plot the magnitude (**dB**) and phase (degrees) frequency-responses of each of the above circuits, for **$10Hz \le f \le 100kHz$**.

4.4 Procedure:

Part I: The Frequency Response Associated With [One Pole-One Zero] Transfer Function

Step 1: Connect the circuit shown in Fig (4.1). Connect channel (A) of the oscilloscope to display $\mathbf{V_i}$ and channel (B) of the oscilloscope to display $\mathbf{V_o}$; set the trigger source→A. Adjust the controls of the function generator to provide a sinusoidal input voltage $\mathbf{V_i}$ of **5V (peak)** at a frequency of **100Hz**.

Step 2: Use the oscilloscope displays to measure the phase angle $\angle H(\omega)^0$, and use both DMMs to measure the dB-values of $\mathbf{V_i}$, $\mathbf{V_o}$, and the frequency, and evaluate the magnitude $|H(\omega)|$ in dB as: **$|H(\omega)|dB = [\ V_o$ (in dB) - V_i (in dB)]**.

Record your results in Table (4.1).

Step 3: Repeat as in Step 2 for each frequency setting in Table (4.1).

Step 4: Use **Graph (4.1)** to plot the magnitude $|H(\omega)|$ (dB) and phase $\angle H(\omega)^0$ versus frequency in Hz. Use your plot to determine the locations of the corner frequencies: $\boldsymbol{f_Z}$ and $\boldsymbol{f_P}$.

$\boldsymbol{f_Z}$ = ………………………… And $\boldsymbol{f_P}$ = ……………………………

Part II: The Frequency Response Associated with [Two Poles-One Zero] Transfer Function

Step 5: Connect the circuit shown in **Fig (4.2)**. Connect channel (A) of the oscilloscope to display $\mathbf{V_i}$ and channel (B) of the oscilloscope to display $\mathbf{V_o}$; set the trigger source→A. Adjust the controls of the function generator to provide a sinusoidal input voltage $\mathbf{V_i}$of **0.5V (peak)** at a frequency of 100Hz.

Step 6: Repeat the measurements as in Step 2 and Step 3, and record your results in **Table (4.2)**.

Step 7: Use **Graph (4.2)** to plot the magnitude $|H(\omega)|$ (dB) and phase $\angle H(\omega)^0$ versus frequency in Hz. Use your plots to determine the locations of the corner frequencies: $\boldsymbol{f}_{\mathbf{P1}}$ and $\boldsymbol{f}_{\mathbf{P2}}$.

$\boldsymbol{f}_{\mathbf{P1}}$ = ………………………………………… and

$\boldsymbol{f}_{\mathbf{P2}}$ = …………………………………………