Experiment #3: Frequency Response and Bode Plots

3.1 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, $H(\omega)$, of the network. Plots of $|H(\omega)|$ and $\angle H(\omega)$ 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 $H(\omega)$ is closely related to the transfer function H(s) of the network, as $H(\omega) = H(s = j\omega)$. Both functions are useful in describing different aspects of the behavior of linear networks. While H(s) describes the pole-zero pattern (in the s-plane) of a network's transfer function, $H(\omega)$ 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.

$$H(\omega)_{dB} = 20\mathrm{Log}_{10}|H(\omega)|$$

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.

3.2 Objectives:

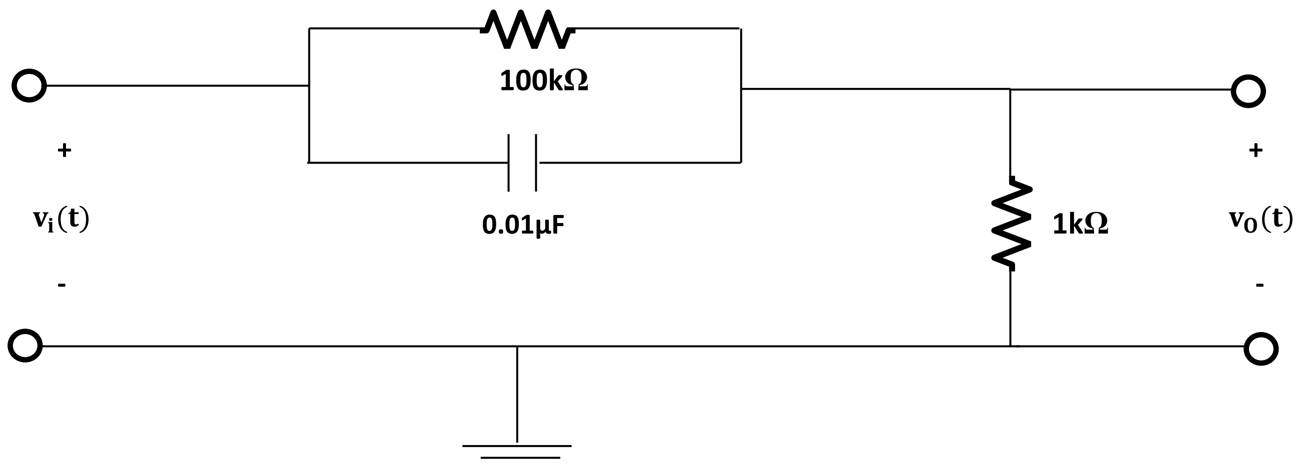
- To draw the asymptotic Bode plots that approximates the frequency-response characteristics of various linear networks.
- To measure and plot the magnitude- and phase-frequency responses of the above-mentioned networks.
- To compare the asymptotic Bode plots and the practical measurements.

3.3 <u>Prelab Assignment (3 marks in total, 1 mark for each step):</u>

Step 1: Consider the network shown in Fig (3.1).

a) Derive the transfer function $H(s) = {}^{V_o}/_{V_i}$, where V_o is the phasor representation of $v_o(t)$ and V_i is the phasor representation of $v_i(t)$.
b) Use Graph (3.1) to draw the asymptotic Bode plots for the frequency-response of the network.

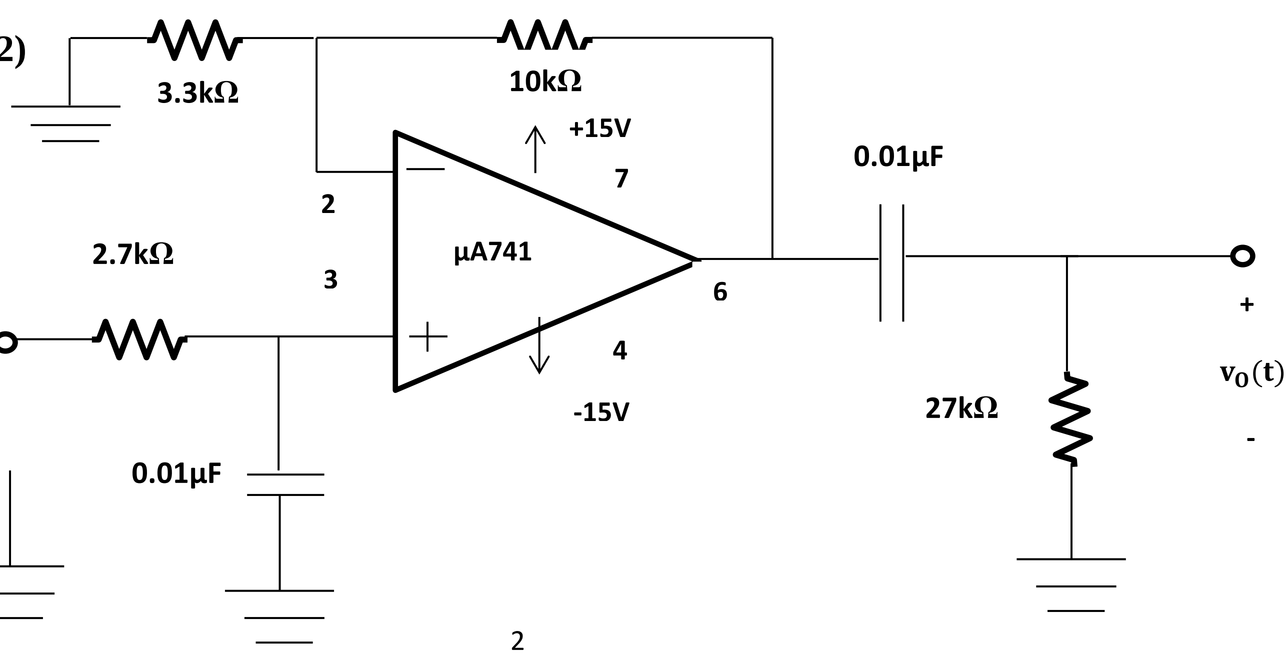
Fig (3.1)



Step 2: Assume that the Op-Amp circuit in Fig (3.2) is working properly.

a) Derive the transfer function $H(s) = {}^{V_o}/_{V_i}$.
b) Use Graph (3.2) to draw the asymptotic Bode plots for the frequency-response of the Op-Amp circuit.

Fig (3.2)



Step 3: Use Multisim to plot the magnitude in dB and phase in degrees of the frequency-responses of each of the above circuits, for 10Hz $\leq$ f $\leq$ 100kHz. Use "AC Sweep" for "Analyses and Simulation" and set the "Start frequency (FSTART)" to 10Hz and "Stop frequency (FSTOP)" to 100kHz.

Components for Fig (3.1) are AC_VOLTAGE (1 V phase 0^o) source, RESISTOR_RATED, CAPACITOR_RATED, INDUCTOR_RATED, and GROUND. "Place" a "Voltage" "Probe" at $v_o(t)$.

Components for Fig (3.2) are UA741CD Op-Amp, AC_VOLTAGE (1 V phase 0^o), DC_POWER, RESISTOR_RATED, CAPACITOR_RATED, and GROUND. "Place" a "Voltage" "Probe" at $v_o(t)$.

(Note: Alternatively, you can also use Simulate->Instruments->Bode Plotter to create the plots using IN for $v_i(t)$ and OUT for $v_o(t)$.)

3.4 Procedure:

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

Step 1: Connect the circuit shown in Fig (3.1).

Connect Channel (A) of the oscilloscope to display $v_i(t)$ and Channel (B) of the oscilloscope to display $v_o(t)$.

Set the trigger source→Channel (A) and rising edge.

Adjust the controls of the function generator to provide a **sinusoidal** input voltage $v_i(t)$ of **5V (peak)** at a frequency of 100Hz.

Step 2: Use "Interactive Simulation" instead of "AC Sweep" mode. Use the oscilloscope displays to measure the phase angle $\angle H(\omega)^o$ in degrees, and use both DMMs to measure the dB-values of V_i and V_o. Evaluate the magnitude $|H(\omega)|$ in dB as: $|H(\omega)|$(in dB)=[V_o(in dB) - V_i(in dB)].

Record your results in Table (3.1).

Step 3: Repeat as in Step 2 for each frequency setting in Table (3.1).

Step 4: Use Graph (3.1) to plot the magnitude $|H(\omega)|$ in dB and phase $\angle H(\omega)^o$ in degrees versus frequency in Hz. Use your plot to determine the locations of the corner frequencies: f_Z and f_P.

f_Z=…………………………………… f_P=……………………………………

Step 5: Demonstrate Step 1 to Step 4 to your TA via ZOOM.

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

Step 6: Connect the circuit shown in Fig (3.2). Connect Channel (A) of the oscilloscope to display $v_i(t)$ and Channel (B) of the oscilloscope to display $v_o(t)$; set the trigger source→Channel (A). Adjust the controls of the function generator to provide a **sinusoidal** input voltage $v_i(t)$ of **0.5V (peak)** at a frequency of 100Hz.

Step 7: Repeat the measurements as in Step 2 and Step 3, and record your results in Table (3.2).

Step 8: Use Graph (3.2) to plot the magnitude $|H(\omega)|$ in dB and phase $\angle H(\omega)$ in degrees versus frequency in Hz. Use your plots to determine the locations of the corner frequencies: f_{P1} and f_{P2}.

f_{P1}=………………………………… f_{P2}=…………………………………

Step 9: Demonstrate Step 6 to Step 8 to your TA via ZOOM.