Department of Electrical, Computer, & Biomedical Engineering
Faculty of Engineering & Architectural Science

Course Title:	ELE302 Electric Networks
Course Number:	ELE302
Semester/Year (e.g.F2016)	F2024

Instructor:	S. Jassar

Assignment/Lab Number:	3
Assignment/Lab Title:	Frequency Response and Bode Plots

Submission Date:	Friday Nov 1st, 2024
Due Date:	

Student LAST Name	Student FIRST Name	Student Number	Section	Signature*
Malik	Hamza	501112545	26	HamzaMalik

*By signing above you attest that you have contributed to this written lab report and confirm that all work you have contributed to this lab report is your own work. Any suspicion of copying or plagiarism in this work will result in an investigation of Academic Misconduct and may result in a "0" on the work, an "F" in the course, or possibly more severe penalties, as well as a Disciplinary Notice on your academic record under the Student Code of Academic Conduct, which can be found online at: http://www.ryerson.ca/senate/current/pol60.pdf

Toronto Metropolitan University
Department of Electrical, Computer, & Biomedical Engineering
Faculty of Engineering & Architectural Science

ELE 302
Laboratory #3

Frequency Response and Bode Plots

1.0 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 | H(ω)| and ∠H(ω) 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 H(ω)= H(s=jω). 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(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(ω)| in dB and ∠H(ω) in degrees versus frequency [log scale] are said to be the asymptotic Bode plots of the frequency response characteristics.

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

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.

2.0 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.

3.0 REQUIRED LAB EQUIPMENT & PARTS:

- DC Power Supply (PS), Function Generator (FG) and Oscilloscope.
- ELE202 Lab Kit and ELE302 Lab Kit: various components, breadboard, wires and jumpers.

4.0 PRE-LAB ASSIGNMENT (3 marks with 1.5 marks for each step):

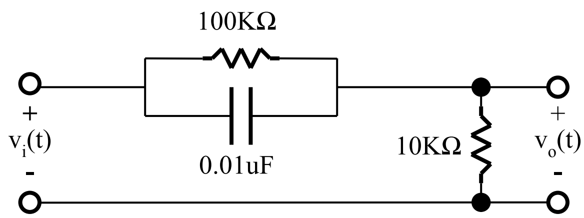
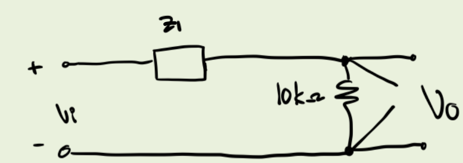


Figure 1.0: An One Pole-One Zero Circuit

(a) Step 1: Consider the network shown in **Figure 1.0**.

i) 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 $v_i(t)$.

Pre-Lab workspace (show your analysis here)



Use Voltage Division

$$V_o = \frac{10k}{Z_1 + 10k}(V_i)$$

$$V_o = \frac{10K\ V_1}{\left(\frac{10^{13}}{100j\omega+10^8}\right)+10k}$$

$$\frac{V_o}{V_1} = \frac{(10k)(100k\ j\omega+10^8)}{10k(100k\ j\omega+10^8)+10^{13}}$$

$$\frac{V_o}{V_1} = \frac{1000\mu(j\omega+1000)}{1000\mu(j\omega+101000)}$$

$$\frac{V_o}{V_1} = \frac{(j\omega+1000)}{(j\omega+101000)}$$

$$Z_1 = R // C$$

$$= \frac{1}{\frac{1}{j\omega C}+\frac{1}{R}}$$

$$Z_1 = \frac{R}{j\omega CR+1}$$

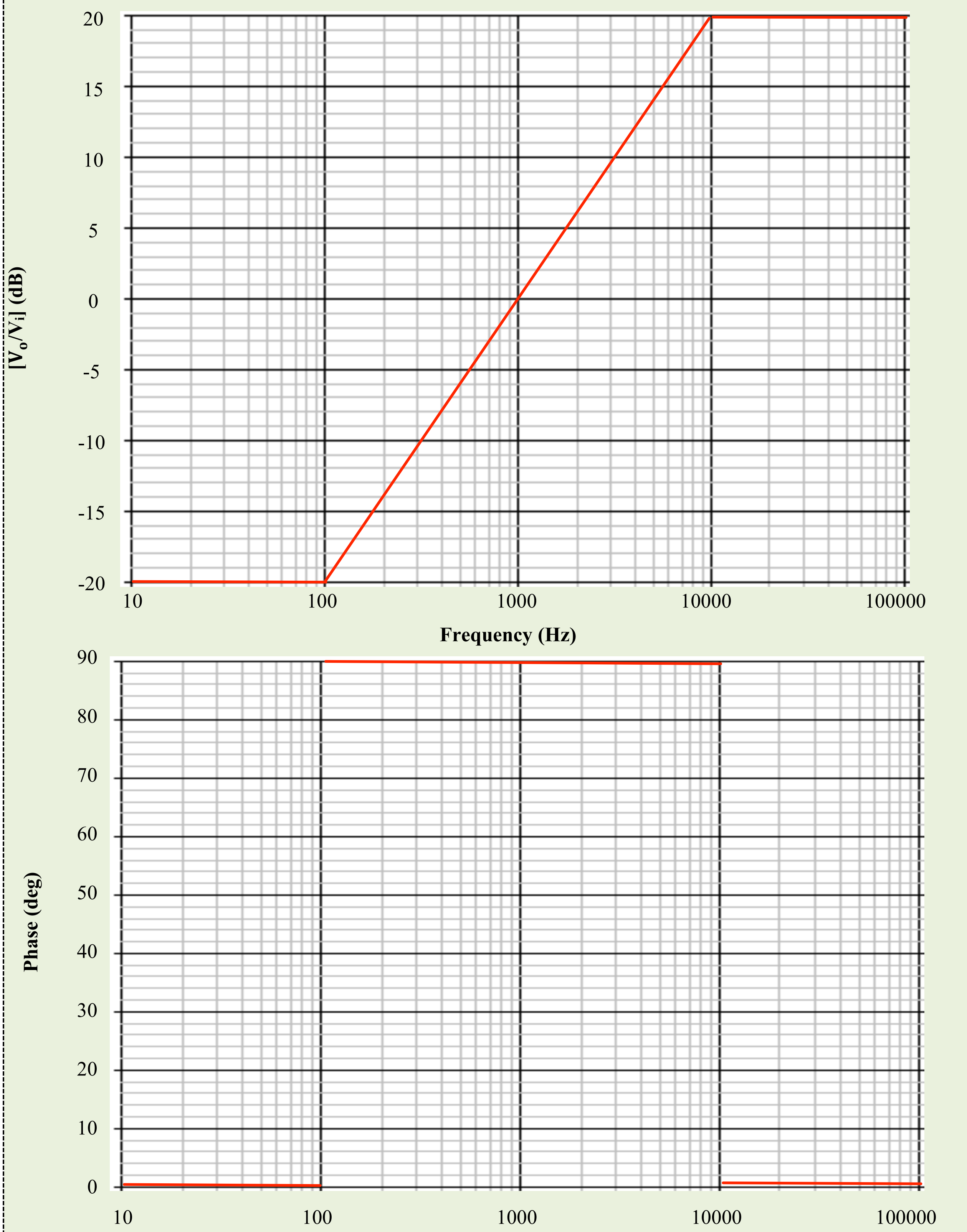
$$Z_1 = \frac{100k}{j\omega(0.01\mu)(100k)+1}$$

$$Z_1 = \frac{10^{13}}{100k\ j\omega+10^8}$$

$$\frac{V_o}{V_i} = \frac{1000\left(1+\frac{j\omega}{1000}\right)}{101000\left(1+\frac{j\omega}{101000}\right)}$$

$$20\log_{10}(9.9\times10^{-3}) = -40.1$$

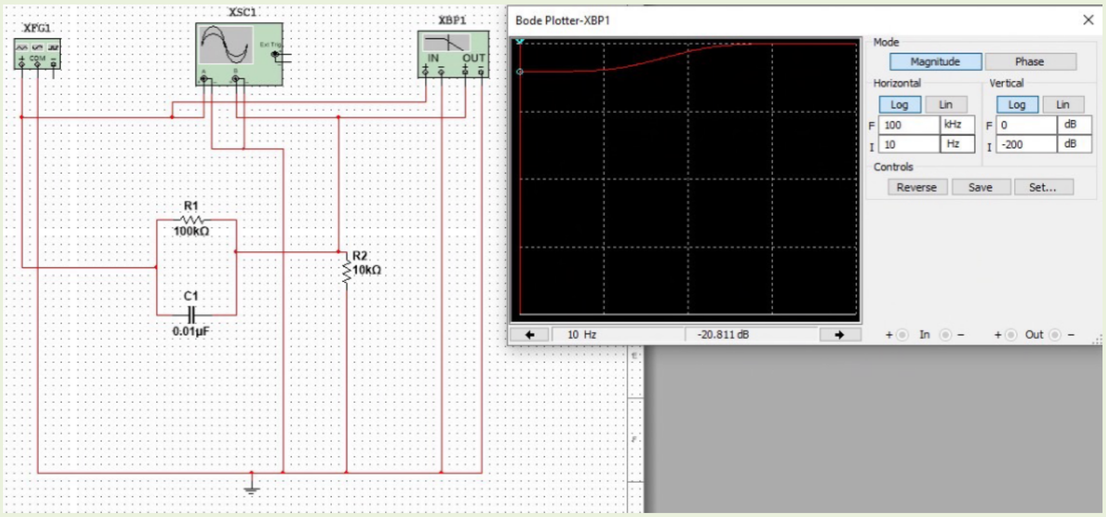
ii) Use **Graph 1.0** to draw the asymptotic Bode plots for the frequency-response of the network.

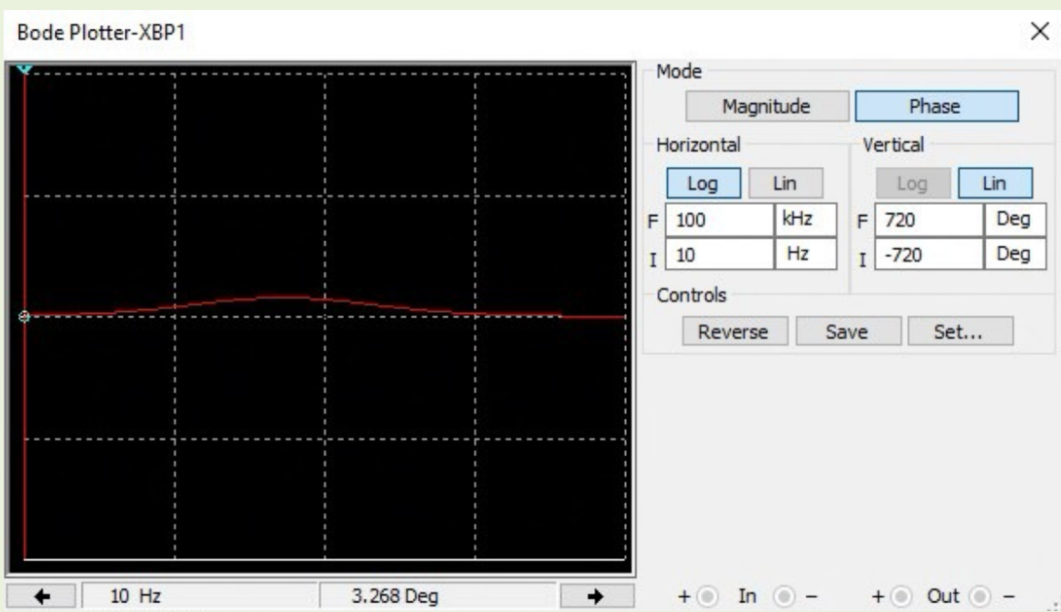


Graph 1.0

iii) Use Multisim to plot the magnitude in dB and phase in degrees of the frequency-responses of the above circuits, for 10Hz ≤ f ≤ 100kHz. (Note: Simulate->Instruments->Bode Plotter can be used in creating the plots).

Pre-Lab workspace (show your analysis here)





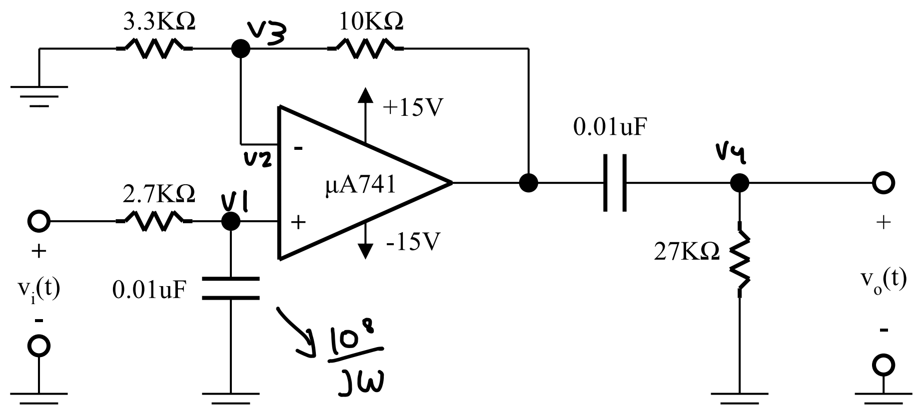


Figure 2.0: A Two Poles-One Zero Circuit

(b) Step 2: Assume that the Op-Amp circuit in **Figure 2.0** is working properly.

i) Derive the transfer function H(s) = V_o/V_i.

Pre-Lab workspace (show your analysis here)

$s \to j\omega$

KCl @ V1

$$\frac{V_i - V_1}{2.7k} = V_1(1\times10^{-8}/s)$$

$$\frac{V_i}{2.7k} - \frac{V_1}{2.7k} = V_1\, 10^{-8}/s$$

$$\frac{V_i}{2.7k} = V_1(1 + 2.7k\times10^{-11}/s)$$

$$V_1 = \frac{V_i}{1+2.7\times10^{-11}s}$$

KCl @ V4

$$(V_4 - V_o)(sL) = \frac{V_4}{27k}$$

$$V_4 - V_o = \frac{V_4}{27ks}$$

$$V_4 = \frac{V_o}{27ks} + V_o$$

KCl @ V3

$$\frac{V_1}{10k} = \frac{V_3 - V_4}{10k + 10^{-8}/s}$$

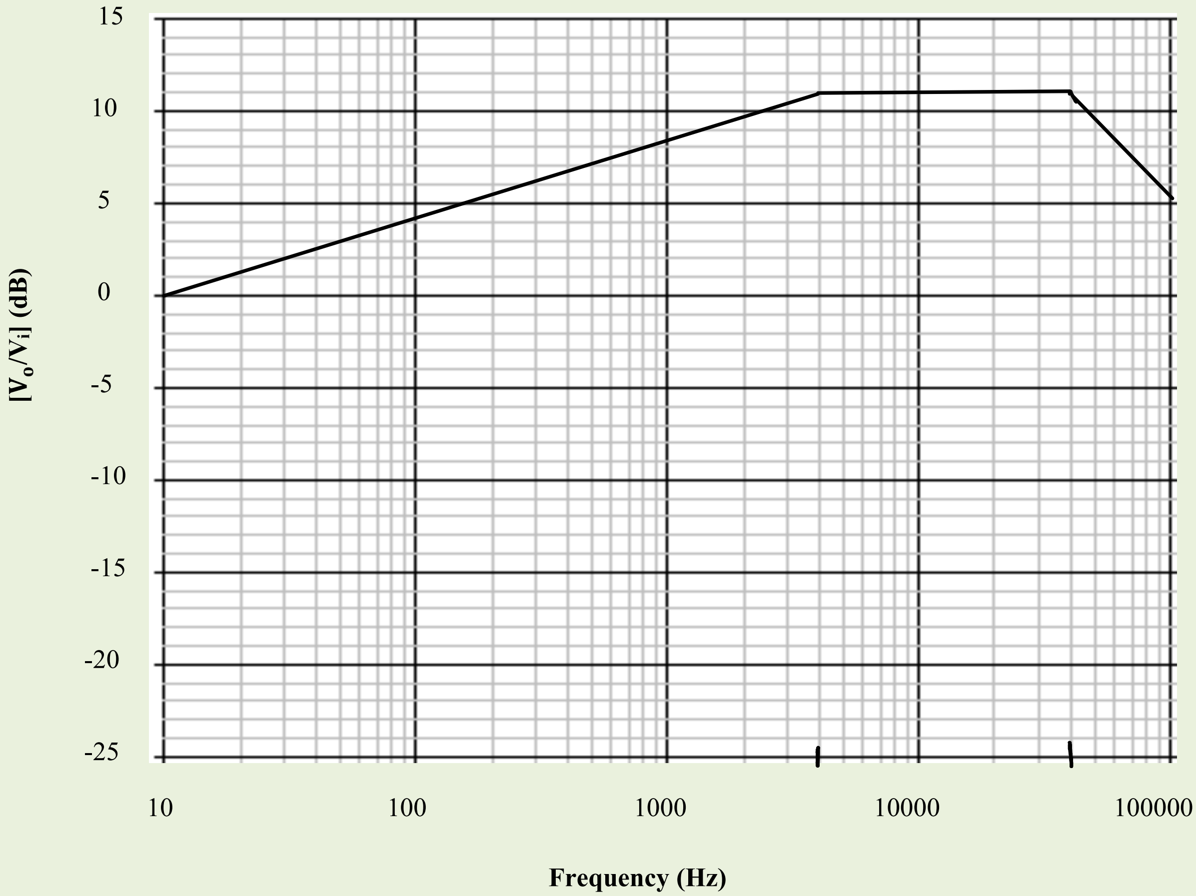
$$\frac{V_i}{10k + 2.7\times10^{-7}/s} = \frac{V_o}{27ks}$$

$$\frac{27k}{10k + 2.7\times10^{-7}/s} = \frac{V_o}{V_i}$$

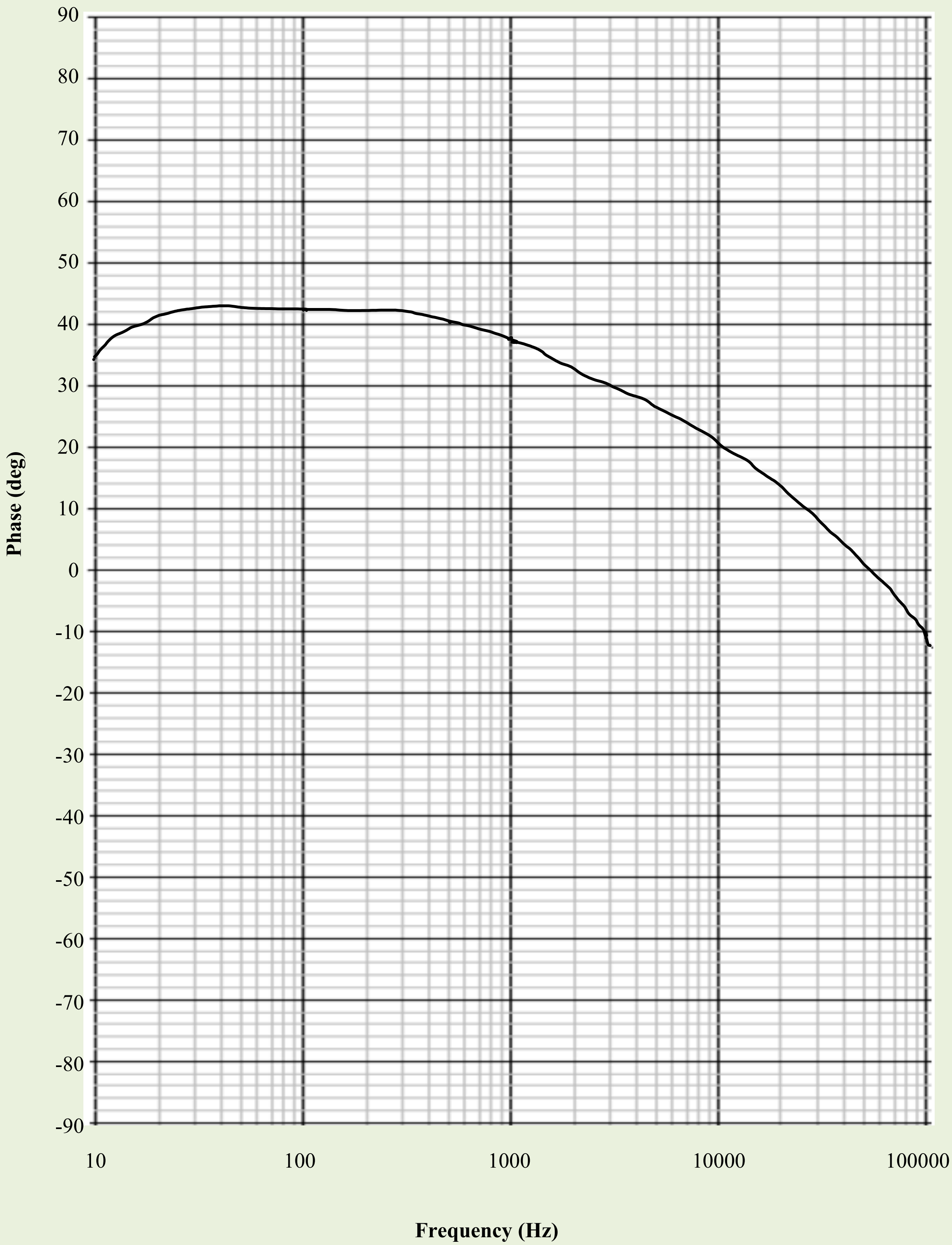
$$\frac{V_4}{V_i} = \frac{27k}{10k(1+2.7\times10^{-4})}$$

$$\frac{V_o}{V_i} = \frac{2.7}{(1+2.7\times10^{-11}s)}$$

ii) Use **Graph 2.0** to draw the asymptotic Bode plots for the frequency-response of the circuit:



Graph 2.0 (*Gain*)



Graph 2.0 (*Phase*)

iii) Use Multisim to plot the magnitude in dB and phase in degrees of the frequency-responses of the above circuits, for 10Hz ≤ f ≤ 100kHz. (Note: Simulate->Instruments->Bode Plotter can be used in creating the plots).

Pre-Lab workspace (show your analysis here)