EGR 261 Due date: ______________________

Signals and Systems

N261H6

Homework Assignment #6 – Frequency Response

Reading Assignment:

Read the following sections in Electric Circuits, 9th Edition by Nilsson:

Chapter 14, Chapter 15 (Sect. 1-2), Appendix D (The Decibel), and Appendix E (Bode Diagrams)

Section 14.9 in *Linear Signals & Systems, 2nd Ed.* by Lathi

Problem Assignment:

1) Work the following Ch. 14 problems: 3, 4(a-b only), 7, 10(a-b only), 19, 22, 25

   Work the following Ch. 15 problems: 2, 3, 22, 24

   Note: Use R = 1 kΩ for 14.7E

2) Plot the Bode LM plots for the transfer functions below with to the following specifications:
   - use 4 cycle semi-log graph paper (available from instructor's web page)
   - label all levels in dB and all slopes in dB/decade

$$G_1(s) = \frac{500(s+200)}{(s+4{,}000)} \qquad G_2(s) = \frac{500{,}000}{(s+200)(s+1000)}$$

$$G_3(s) = \frac{50(s+2{,}000)(s+5{,}000)}{(s+10{,}000)(s+80{,}000)} \qquad G_4(s) = \frac{5{,}000(s)(s+800)}{(s+200)(s+4{,}000)}$$

$$G_5(s) = \frac{0.5(s+20)^2(s+500)}{s(s+100)}$$

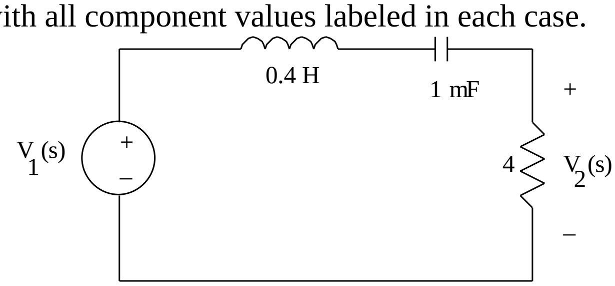
3) Plot the Bode phase plot for $G_1(s)$ and $G_2(s)$ above with the following specifications:
   - use 4 cycle semi-log graph paper
   - label all levels in degrees and all slopes in degrees/decade

4) Plot the **exact** LM and phase plots for $G_1(s)$ and $G_2(s)$ using MATLAB, Excel, or some other graphing software. Include a printout of both the graph and the spreadsheet, equations, etc., used to produce the graph. Compare the graphs to the Bode plots generated for $G_1(s)$ and $G_2(s)$ in problems 2 and 3.

5) For the circuit shown below, $H(s) = V_2(s)/V_1(s)$ is the transfer function of a bandpass filter with a center frequency of w_o = 50 rad/s. Use impedance and frequency scaling on the circuit such that w_o = 20,000 rad/s if

   a) C = 1μF b) L = 1 mH c) R = 1 kΩ

   Draw the scaled circuit with all component values labeled in each case.



MATLAB Problems (Extra Credit):

Put all problems in a single MATLAB program with an initial block of comments (name, course assignment number, etc) and add a comment identifying each part. Include a printout of the program and the output. Check your results to make sure that they are correct.

1) Plot the **exact** LM and phase plots for $G_3(s)$, $G_4(s)$ and $G_5(s)$ using MATLAB. ***Use the abs( ) and angle( ) functions in MATLAB, not tf( ) and bode( ).*** Include a printout of both the graph and the spreadsheet, equations, etc., used to produce the graph. Compare the graphs to the Bode plots generated by hand in problems 2 and 3.

2) Repeat the previous step except ***use the tf( ) and bode( ) functions in MATLAB, not abs( ) and angle( ).*** The results should match with the previous step.

Selected Answers:

14.3) a) $H(s) = \dfrac{\frac{R}{L}}{s + \frac{R + R_l}{L}}$ b) $|H(jw)|_{max}$ occurs when $w = 0$

c) $|H(jw)|_{max} = \dfrac{R}{R + R_l}$ d) $w_C = \dfrac{R + R_l}{L}$

e) $w_c = 20{,}200$ rad/s
$H(j0) = 0.6287 \angle 0°$
$H(jw_c) = H(j20{,}200) = 0.4446 \angle -45°$
$H(j0.3w_c) = H(j6060) = 0.6022 \angle -16.70°$
$H(j3w_c) = H(j60{,}600) = 0.1988 \angle -71.57°$

14.4) a) $w_c = 10{,}000$ rad/s, $f_c = 1591.55$ Hz

b) $H(jw) = \dfrac{10{,}000}{10{,}000 + jw}$
$H(jw_c) = H(j10{,}000) = 0.7071 \angle -45°$
$H(j0.1w_c) = H(j1000) = 0.9950 \angle -5.71°$
$H(j10w_c) = H(j100{,}000) = 0.0995 \angle -84.29°$

14.7) a) $H(s) = \dfrac{\frac{1}{RC}}{s + \frac{R + R_L}{RR_L C}}$ b) $|H(jw)|_{max}$ occurs when $w = 0$

c) $|H(jw)|_{max} = \dfrac{R_L}{R + R_L}$ d) $w_C = \dfrac{1}{RC}\left(1 + \dfrac{R}{R_L}\right)$

e) $w_c = 11{,}000$ rad/s
$H(j0) = 0.9091 \angle 0°$
$H(jw_c) = H(j11{,}000) = 0.6428 \angle -45°$
$H(j0.1w_c) = H(j1{,}100) = 0.9046 \angle -5.71°$
$H(j10w_c) = H(j110{,}000) = 0.0905 \angle -84.29°$

14.10) a) $f_c = 636.62$ Hz

b) $H(jw) = \dfrac{jw}{4000 + jw}$

$H(jw_c) = H(j4000) = 0.7071 \underline{/\ 45°}$

$H(j0.2w_c) = H(j800) = 0.1961 \underline{/\ 78.69°}$

$H(j5w_c) = H(j20{,}000) = 0.9806 \underline{/\ 11.31°}$

14.19) $B = 1.99$ kHz, $f_{c1} = 9.01$ kHz, $f_{c2} = 7.02$ kHz

14.22) a) $w_o = 100$ krad/s

b) $f_o = 15.9$ kHz

c) $Q = 8$

d) $w_{c1} = 93.95$ krad/s

e) $f_{c1} = 14.95$ kHz

f) $w_{c2} = 106.45$ krad/s

g) $f_{c2} = 16.94$ kHz

h) $B = 12.5$ krad/s or 1.99 kHz

14.25) a) $f_o = 3978.87$ kHz

b) $Q = 5$

c) $f_{c1} = 3.60$ kHz

d) $f_{c2} = 4.40$ kHz

e) $B = 795.77$ Hz

15.2) a) $H(s) = \dfrac{-\left(\dfrac{C_1}{C_2}\right)\left(s + \dfrac{1}{R_1C_1}\right)}{s + \dfrac{1}{R_2C_2}}$ b) $H(j0) = \dfrac{-R_2}{R_1}$ c) $H(j\infty) = \dfrac{-C_1}{C_2}$

15.3) a) $H(s) = \dfrac{-\left(\dfrac{1}{R_1C_2}\right)(s)}{\left(s + \dfrac{1}{R_1C_1}\right)\left(s + \dfrac{1}{R_2C_2}\right)}$ b) $H(j0) = 0$ c) $H(j\infty) = 0$

15.22) $L' = 200$ mH, $i_o(t) = [10 - 10e^{-2500t}\cos(2500t)]u(t)$ mA

15.24) $R' = 2546.48\ \Omega$, $L' = 253.3$ uH, $w_{C1} = 1180.6$ krad/s, $w_{C2} = 1337.7$ krad/s, $B = 157.1$ krad/s

5) a) R = 10, L = 2.5 mH, C = 1 μF

b) R = 4, L = 2.5 mH, C = 2.5 μF

c) R = 1000, L = 250 mH, C = 10 nF