## EE322 Fall 08 Homework Problem Set 37 (PS37)

Be sure to show your work.

1. Given the frequency response below, rewrite the equation for H(jω) in the standard form for Bode analysis.

$$H(j\omega)=\frac{1000(j\omega+1000)}{(j\omega+10)(j\omega+10{,}000)} = \frac{10^3 \cdot 10^3\left(1+\frac{j\omega}{10^3}\right)}{10\left(1+\frac{j\omega}{10}\right)\cdot 10^4\left(1+\frac{j\omega}{10^4}\right)}$$

$$= \frac{10\left(1+\frac{j\omega}{10^3}\right)}{\left(1+\frac{j\omega}{10}\right)\left(1+\frac{j\omega}{10^4}\right)}$$

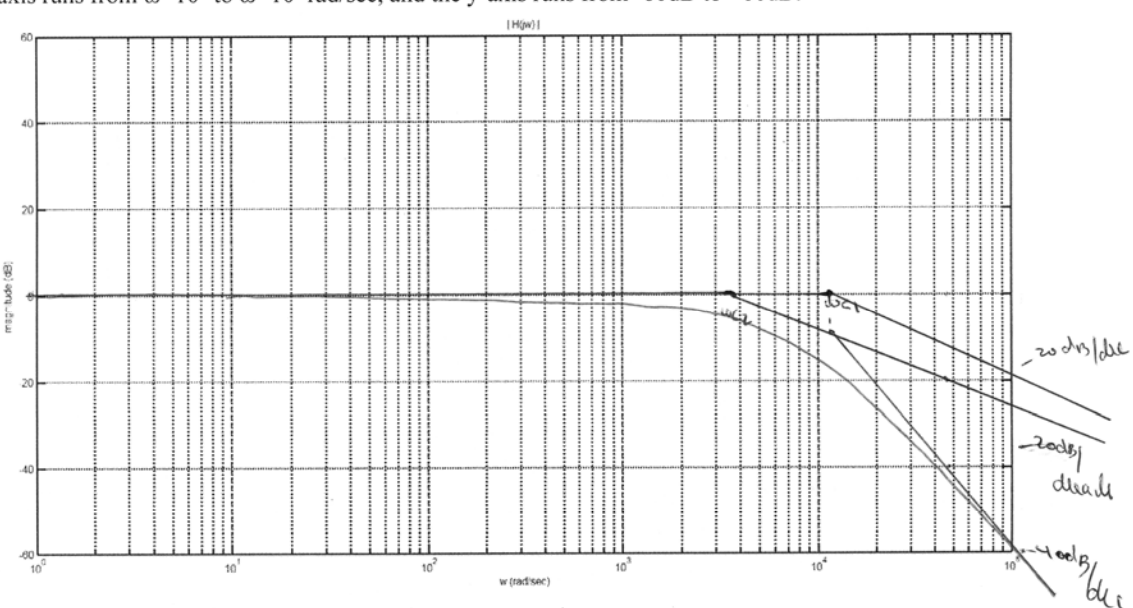
Indicate the following values from your answer to problem 3:

Gain term (constant) = 1

Zero(s) at ω = ∞

Pole(s) at ω = $2.61 \cdot 10^4$ rad/s & $0.38 \cdot 10^4$ rad/s

On the axis that follows, plot the asymptotic Bode magnitude of H(jω). If the axes are hard to read, the x-axis runs from ω=$10^0$ to ω=$10^5$ rad/sec, and the y-axis runs from -60dB to +60dB.

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2. Text, problem 12-35. Use a constant gain term of +20dB and a cutoff frequency of 10 kHz, with a capacitor value of 0.01 μF.

3. Text, problem 12-37c. Let all resistors = 100 Ω, and all capacitance = 1 μF. Determine the equation for the frequency response, then plot the magnitude and phase in MATLAB. For the plotting, you can either:
    - use the *abs*/*angle* functions with a semilogx plot for frequency, and convert magnitude to dB;
    - or use the *bode* function.

Pb12-35


$$H(j\omega) = \frac{-R_F}{R_i + \frac{1}{j\omega C_i}}$$

$$\boxed{f_c = \frac{1}{2\pi R_i C_i} = 10\ \text{KHz}}$$

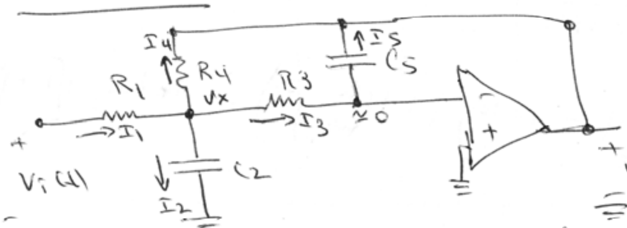
High frequency gain $= |H(\infty)| = R_F/R_i \Rightarrow 20\log\left(\frac{R_F}{R_i}\right) = 20\,\text{dB}$

$$\Rightarrow \frac{R_F}{R_i} = 10 \Rightarrow \boxed{R_F = R_i \times 10}$$

2 equations, 2 unknowns $\Rightarrow R_i = \frac{1}{2\pi \cdot 10^4 \cdot 10^{-8}} = \frac{10^4}{2\pi} \approx 1.6\,\text{K}\Omega$

$$\boxed{R_F = 16\,\text{K}\Omega}$$

Pb 12.37C




① $I_1 = I_2 + I_3 + I_4$

② $I_3 = I_5$

① $$\frac{V_i - V_x}{R_1} = V_x(j\omega)C_2 + \frac{V_x - V_o}{R_4} + \frac{V_x}{R_3}$$

$$\frac{V_i}{R_1} = \frac{V_x}{R_1} + V_x(j\omega)C_2 + \frac{V_x}{R_4} - \frac{V_o}{R_4} + \frac{V_x}{R_3}$$

$$\boxed{V_i = V_x + V_x(j\omega)R_1C_2 + V_x\frac{R_1}{R_4} - V_o\frac{R_1}{R_4} + \frac{V_x R_1}{R_3}} \quad ①$$

② $$\frac{V_x}{R_3} = (0 - V_o)(j\omega)C_5 = -V_o(j\omega)C_5 \Rightarrow$$

$$\boxed{V_x = -V_o(j\omega)R_3C_5}$$

Substitute (2) in (1)

$$V_i = -V_o\left[(j\omega)R_3C_5 + (j\omega)^2R_1R_3C_2C_5 + (j\omega)\frac{R_1}{R_4}R_3C_5 + \frac{R_1}{R_4} + (j\omega)\frac{R_1}{\cancel{R_3}}\cancel{R_3}C_5\right]$$

$$V_i = \frac{-V_o}{R_4}\left[(j\omega)^2R_1R_3R_4C_2C_5 + (j\omega)C_5\left(R_3R_4 + R_1R_3 + R_1R_4\right) + R_1\right]$$

$$\boxed{H(j\omega) = \frac{V_o}{V_i} = -\frac{R_4}{(j\omega)^2R_1R_3R_4C_2C_5 + (j\omega)C_5\left(R_3R_4 + R_1R_3 + R_1R_4\right) + R_1}}$$

For $R_1 = R_4 = R_3 = R$ & $C_2 = C_5 = C$

$$H(j\omega) = -\frac{R}{(j\omega)^2R^3C^2 + (j\omega)C\,3R^2 + R} = \frac{-1}{(j\omega)^2R^2C^2 + 3RC(j\omega) + 1}$$

For $R = 100\,\Omega$ and $C = 1\mu F \Rightarrow RC = 10^{-4}$

$$H(j\omega) = \frac{-1}{(j\omega)10^{-8} + 3\cdot10^{-4}(j\omega) + 1} = \frac{-1}{10^{-8}\left(j\omega + 2.61\cdot10^{+4}\right)\left(j\omega + 0.38\cdot10^{4}\right)}$$

$$= \frac{-1}{\left(1 + \frac{j\omega}{\underbrace{2.61\cdot10^{4}}_{\omega_{c1}}}\right)\left(1 + \frac{j\omega}{\underbrace{0.38\cdot10^{4}}_{\omega_{c2}}}\right)}$$

$$20\log\left|H(j\omega)\right| = \underbrace{20\log|-1|}_{0} - 10\log\left(1 + \left(\frac{\omega}{\omega_{c_1}}\right)^2\right) - 10\log\left[1 + \left(\frac{\omega}{\omega_{c_2}}\right)^2\right]$$

**This is a low pass filter…when w=0, H(jw)=1 and when w=∞, | H(jw) | = 0.**