Texas A&M University
Department of Electrical and Computer Engineering

ECEN 325 – Electronics

Summer 2012

Exam #1

Instructor: Sam Palermo

- Please write your name in the space provided below
- Please verify that there are 7 pages in your exam
- You may use one double-sided page of notes and equations for the exam
- Good Luck!

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Name: ____________________________

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Problem 1 (30 points)
Plot the magnitude and phase response of the following transfer functions. Label key points and slopes.

a) \[ F(s) = \frac{10^9(s+10^5)}{(s+10^6)(s+10^7)} \]

\[ \text{DC gain} = \frac{10^{14}}{10^{13}} = 10 = 20 \text{dB} \]

\[ \text{HF gain} = 0 \]

\[ 1 \text{ zero at } -10^5 \]

\[ 2 \text{ poles at } -10^6, -10^7 \]

b) \[ F(s) = -\frac{10^9(s+10^5)}{s(s+10^7)} \]

\[ \text{DC gain} = 0 \text{dB} \]

\[ \text{HF gain} = 0 \]

\[ 1 \text{ zero at } -10^5 \]

\[ 2 \text{ poles at } 0, -10^7 \]

\[ \text{Gain at } 10^4 \approx \frac{10^{14}}{10^{11}} = 60 \text{dB} \]

\[ \text{DC phase} = -180^\circ - 90^\circ = -270^\circ -225^\circ \]

\[ \text{inversion} \]
Problem 2 (20 points)
Design an operational amplifier circuit to implement the following transfer function.

\[
\frac{V_o(s)}{V_i(s)} = -\frac{100}{1 + \frac{s}{10^3}}
\]

The circuit should have a **1kΩ input resistance**. Assume that any opamps that you use are ideal.

\[
\frac{V_o}{V_i} = -\frac{R_2}{R_1}\frac{1}{1 + sR_2C}
\]

\[
R_{in} = R_1 = 1kΩ \Rightarrow R_2 = 100kΩ, \quad R_1 = 100kΩ
\]

\[
R_2C = \frac{1}{10^3}
\]

\[
C = \frac{1}{10^3R_2} = \frac{1}{10^3(100kΩ)} = 10nF
\]
Problem 3 (20 points)
Assume for problem 3 that the operational amplifiers is ideal.

\[ V_o = -\left(\frac{Z_{R_3}}{Z_{R_1} + Z_{C_1}}\right) V_{i_1} + \left(\frac{Z_{C_2}}{Z_{R_2} + Z_{C_2}}\right) \left(1 + \frac{Z_{R_3}}{(Z_{R_1} + Z_{C_1}) R_4}\right) V_{i_2} \]

\[ = -\left(\frac{R_3}{R_1 + \frac{1}{sC_1}}\right) V_{i_1} + \left(\frac{sC_2}{R_2 + \frac{1}{sC_2}}\right) \left(1 + \frac{R_3}{R_4} + \frac{sR_2 C_2}{1 + sR_4 C_1}\right) V_{i_2} \]

\[ Z_{i_1}(V_{i_1}) = Z_{R_1} + Z_{C_1} = R_1 + \frac{1}{sC_1} \]

\[ Z_{i_2}(V_{i_2}) = Z_{R_2} + Z_{C_2} = R_2 + \frac{1}{sC_2} \]

\[ V_i = V_{i_1} = V_{i_2} = 0 \Rightarrow \text{Equivalent circuit at output} \]

\[ \text{Ideal Opamp} \quad R_o = 0 \quad \text{All current flows into Opamp} \]

\[ \text{Input} = V_o = 0, \quad i_o = 0 \quad \text{Output} = \frac{V_o}{R_o} = 0, \quad i_o = 0 \]
Problem 4 (20 points)
The operational amplifier used in the remainder of the problem has the following open-loop transfer function

$$A(s) = \frac{10^5}{1 + \frac{s}{10}}$$

a) Sketch the open-loop magnitude response of the operational amplifier. Make sure to label the unity-gain frequency. (5 points)

b) The finite gain-bandwidth operational amplifier from part (a) is used in the following amplifier circuit. Find the expression for the closed-loop transfer function ($v_o/v_i$). (5 points)

c) What is the closed-loop -3dB frequency (bandwidth) of the total amplifier circuit? (5 points)

d) Sketch the closed-loop magnitude response of the amplifier circuit. Make sure to label the unity-gain frequency. (5 points)
Problem 5 (10 points)
The operational amplifier for this problem has a finite slew rate of 1 V/μs.

a) For an output 50kHz triangle wave, what is the maximum amplitude that can be reproduced without distortion? (5 points)

\[ \max \left| \frac{d V_o(t)}{dt} \right| \leq SR \]

\[ \frac{2A}{T/2} \leq 1 \frac{V}{\mu s} \]

\[ A \leq 1 \frac{V}{\mu s} \frac{T}{4} = \frac{1 \frac{V}{\mu s}}{4(50kHz)} \]

\[ A \leq 5V \]

b) For an output 2V amplitude sine wave, what is the maximum frequency that can be reproduced without distortion? (5 points)

\[ \max \left| \frac{d (A \sin \omega t)}{dt} \right| \leq SR \]

\[ \max | A \omega \cos \omega t | \leq SR \]

\[ A \omega \leq SR \]

\[ \omega \leq \frac{SR}{A} = \frac{1 \frac{V}{\mu s}}{2V} = 500 \text{kHz} \]

\[ \omega \leq 500 \text{kHz} \]
Scratch Paper