Texas A&M University
Department of Electrical and Computer Engineering

ECEN 325 – Electronics

Spring 2009

Exam #1

Instructor: Sam Palermo

- Please write your name in the space provided below
- Please verify that there are 5 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:  
SAM PALERMO

UIN:
Problem 1 (30 points)
Plot the magnitude and phase response of the following transfer functions:

a) \[ F(s) = \frac{10^{10}(s+10^6)}{(s+10^7)(s+10^8)} \]

\[ \angle \omega \rightarrow 20 \] \[ 20 | \omega | \angle F(s) \] \[ -20 \text{dB/dec} \] \[ 10^6 \text{ to } 10^8 \] \[ 10^7 \text{ to } 10^9 \]

b) \[ F(s) = -\frac{10^{10}(s+10^6)}{s(s+10^8)} \]

\[ \angle \omega \rightarrow 20 \] \[ 20 | \omega | \angle F(s) \] \[ -20 \text{dB/dec} \] \[ 10^6 \text{ to } 10^8 \] \[ 10^7 \text{ to } 10^9 \]
Problem 2 (40 points)
Assume for problem 2 that all operational amplifiers are ideal.

a) Design an operational amplifier circuit which implements a low-pass filter with gain (Lossy Integrator). Design the circuit to achieve 10kΩ input impedance, -2V/V (6dB) dc gain, and 10kHz -3dB frequency. (15 points)

\[ R_1 = R_2 = 10kΩ \]
\[ DC \ Gain = \frac{-R_2}{R_1} = -2 \Rightarrow R_2 = 20kΩ \]
\[ \omega_{-3dB} = 2\pi f_{-3dB} = \frac{1}{R_2 C} = \frac{2\pi}{10kHz} \]
\[ \frac{1}{C} = \frac{1}{2\pi(2kHz)} \]
\[ = \frac{1}{800μF} \]

\[ Gain = 0dB @ 2kHz \]

c) For the following circuit obtain the expression for \( v_o \) as a function of \( v_{i1}, v_{i2}, \) and \( v_{i3} \).
Hint: apply superposition. (20 points)

\[ v_A = -v_{i1} + \frac{Z_c}{Z_R + Z_c} v_{i2} \]
\[ v_o = -\frac{Z_c}{Z_R} v_{i3} + \frac{1}{2} \left( 1 + \frac{Z_c}{Z_R} \right) v_A \]
\[ = -\frac{Z_c}{Z_R} v_{i3} + \frac{1}{2} \left( 1 + \frac{Z_c}{Z_R} \right) \left( -v_{i1} + 2 \frac{Z_c}{Z_R + Z_c} v_{i2} \right) \]
\[ = -\frac{1}{2} \frac{Z_R + Z_c}{Z_R} v_{i1} + \frac{Z_c}{Z_R} v_{i2} - \frac{Z_c}{Z_R} v_{i3} \]

\[ v_o = -\frac{1 + 5RC}{52RC} v_{i1} + \frac{1}{5RC} v_{i2} - \frac{1}{5RC} v_{i3} \]
Problem 3 (20 points)

a) The operational amplifier used in part (b) of this problem has a dc gain of $10^5$ and a -3dB frequency of 10rad/s. 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. (5 points)
Problem 4 (10 points)
The operational amplifier for this problem has a finite slew rate of 1V/µs.
a) For an output 100kHz triangle wave, what is the maximum amplitude that can be reproduced without distortion? (5 points)

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

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

\[ A \leq 1 \frac{V}{\mu s} \left( \frac{T}{4} \right) = \frac{1 \frac{V}{\mu s}}{4(100 \text{kHz})} \]

\[ A \leq 2.5 \text{V} \]

b) For an output 10V amplitude sine wave, what is the maximum frequency that can be reproduced without distortion? (5 points)

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

\[ \text{max} | A \omega \cos \omega t | \leq SR \]

\[ A \omega \leq SR \]

\[ \omega \leq \frac{SR}{A} = \frac{1 \frac{V}{\mu s}}{10 \text{V}} = 100 \text{krad/s} \]

\[ \omega \leq 100 \text{krad/s} \]