FALL 2014
ECEN 457 (ESS)

FINAL EXAM

This is a closed book and notes exam. This exam is worth 20% of your total grade.

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<td>Extra Credit*</td>
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*Provide the list of five fundamental concepts learned in the course.
Problem 1. Design an active-RC circuit, using only one op amp, capable to yield an output voltage for four inputs equals to

\[ V_o = 3V_1 - 4V_2 + \frac{10^6}{s} V_3 - 10^{-6} sV_4 \]

Provide the topology and all the component values.

Hint. Consider a fully balanced circuit with a feedback load of a resistor \( R_F \) and a capacitor \( C_F \) in series.
Problem 2. The relation between GB and $\omega_u$ which the frequency at which $A(j\omega_u) = 1$ is given by

$$\omega_u = \left(GBH^2 - \omega_{3\text{db}}^2\right)^{1/2} = \left(A_o^2 - 1\right)^{1/2} \omega_{3\text{db}}$$

$$\omega_u \bigg|_{A_o} \approx A_o \omega_{3\text{db}} = GB$$

This is valid for

$$A(s) = \frac{A_o \omega_{3\text{db}}}{s + \omega_{3\text{db}}} = \frac{A_o}{1 + s/\omega_{3\text{db}}}$$

Assume $A_0$ is very large. Obtain $\omega_u$ when

$$A(s) = \frac{A_0}{\left(1 + \frac{s}{\omega_d}\right)\left(1 + \frac{s}{\omega_{nd}}\right)}$$
Problem 3. Given the active-RC low pass filter show below:

![Active-RC Low Pass Filter Diagram]

a) Determine the transfer function and $V_o(s)$ when $V_{in}(s) = \frac{V_m}{s}$. Assume the open loop gain of the op amp is characterized by $GB/s$.

b) When the above transfer function’s Q is set to $\frac{1}{\sqrt{2}}$ determine the maximum $\left| \frac{dv_o(t)}{dt} \right|$ for a step $(V_m)$ input. Assume $v_o(0)=0$.

Hint. Use the following relations (Laplace transforms and trigonometric equations):

\[
\mathcal{L}\left[ \frac{df(t)}{dt} \right] = sF(s) - f(0), \quad \mathcal{L}[e^{-at}\sin(\omega_0 t)] = \frac{\omega_0}{(s + a)^2 + \omega_0^2}
\]

\[
A\sin(\omega_0 t) - B\cos(\omega_0 t) = \sqrt{A^2 + B^2}\sin(\omega_0 t - \phi) \text{ where } \tan(\phi) = \frac{B}{A}
\]
Problem 4. Obtain the approximated expression of $V_o(s)$ for the LDO shown below

Note that the pass transistor $M_p$ is a PMOS transistor. In its model assume $r_R \to \infty$ and $R_o = r_o$. 

![LDO Circuit Diagram]
Problem 5. The basic buck converter is illustrated below

Next we show the equivalent circuits, with some non-idealities, during Phase 1 and 2, respectively.

Recall that $v_L = L \frac{di_L}{dt}$, if $v_i$ and $v_o$ do not change during a switch cycle, the expression of $v_L$ can be approximated as $v_L = L \frac{\Delta i}{\Delta t}$.

During Switch 1 (2)  
On (Off)

During Switch 1 (2)  
Off (On)

i) Determine the inductor ripple current $\Delta i_L$

ii) The output voltage expression in steady state

iii) $\Delta i_L$ and $v_o$ for $V_F = V_{SAT} = 0$
EXTRA CREDIT

List the five most fundamental concepts you learned in this course, write in one line for each concept why it is important.

1.

2.

3.

4.

5.