EECS 40, Fall 2009
Bonus Points Quiz

Dec 8, 2009
Total Time Allotted: 60 minutes

DO ALL WORK ON EXAM PAGES
(Exam paper has a total of 8 pages including cover page)

1. Closed book exam. You are allowed to bring two sheets (8.5" x 11") of notes.
2. You can use a calculator. NO cell phone or computer.
3. If you put down the wrong answer, partial credits will be given only if you show the correct steps.
4. Points will be taken off for answers without units.
5. **Bonus points = 0.5*Quiz points*[120 - (midterm1 score+midterm2 score)]/120**
   If your (midterm1+midterm2) score is > 120, do not take this exam.. Otherwise, ***negative*** bonus points will be recorded.

Last (Family) Name:_____

First Name: _____

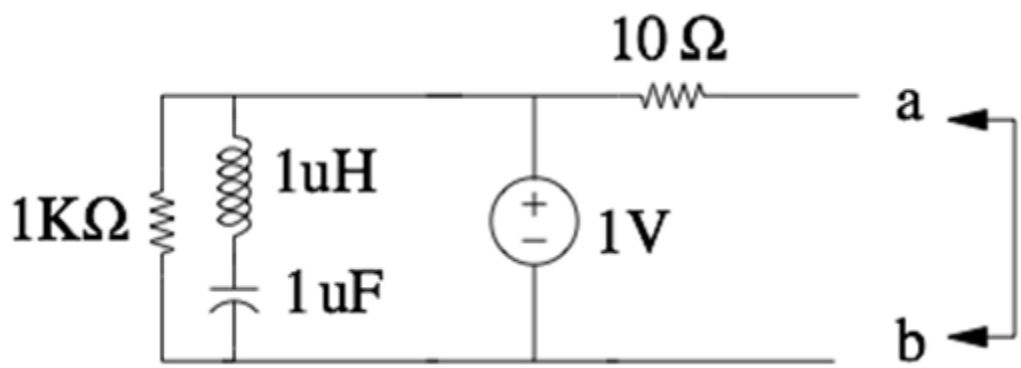
Student ID: _____Discussion Session (# or TA): _____

Signature: _____

Problem 1 (10 points)	
Problem 2 (20 Points)	
Problem 3 (15 Points)	
Problem 4 (15 Points)	
Problem 5 (20 Points)	
Problem 6 (20 points)	
TOTAL (100 points)	

Problem 1 Impedance (10 points)

Find the Thevenin equivalent impedance at 60Hz for the following circuit across terminals a and b. Give numerical answers for both the real and imaginary parts.



Answer

Small-signal analysis: short the voltage source and apply a test source between terminals *a* and *b*. The stuff on the left is shorted out; only the 10 Ω resistor remains. Therefore,

$$Re(Z) = \mathbf{10\,\Omega}$$

$$Im(Z) = \mathbf{0}$$

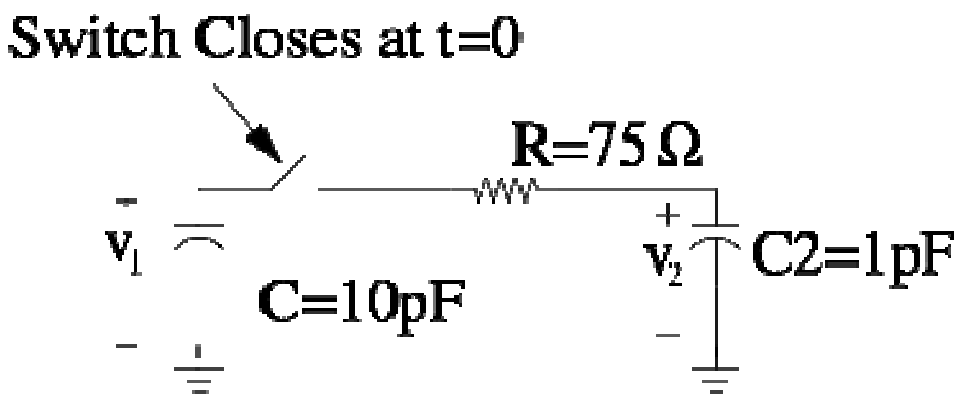
The most common error was failing to short the voltage source, treating it as a current source. In this case, the correct impedance would have been:

$$Re(Z_{wrong}) = 866\,\Omega$$

$$Im(Z_{wrong}) = -330\,\Omega$$

Problem 2 First Order Transient (20 points)

Consider the circuit shown in figure below. Prior to t=0 , v_1=8V and v_2=12 V.



(a) (5 points) Immediately after the switch is closed, what is the value of the current (i.e. $i(0^+)$) ?

The voltages across the capacitors is continuous, so the values at 0^+ are the same as at 0^-. Therefore, the current is:

$$i(t=0^+) = \frac{v_1 - v_2}{R}$$

$$= \frac{v_1}{R} = \frac{8\ \text{V}}{75\ \Omega} = \mathbf{-53.3\ mA}$$

(b) (5 points) Use KCL to write a differential equation for this circuit at t > 0. Do not solev this differential equation.

Acceptable answers include:

$$C_1 \frac{dv_1}{dt} = -C_2 \frac{dv_2}{dt}$$

$$-C_1 \frac{dv_1}{dt} = C_2 \frac{dv_2}{dt}$$

(c) (5 points) What is the time constant of this circuit?

The equivalent capacitance can be calculated using the mathematical formula for parallel impedances:

$$\tau = R(C_1 \| C_2) = R \frac{C_2 C_1}{C_2 + C_1}$$

$$= 75\ \Omega \cdot 0.909\ \mathrm{pF} = \mathbf{68.2\ ps}$$

(d) (5 points) What value does v_2 approach as t becomes very large?

Use conservation of charge. As *t* becomes very large, the voltages become equal; call this value v_f.

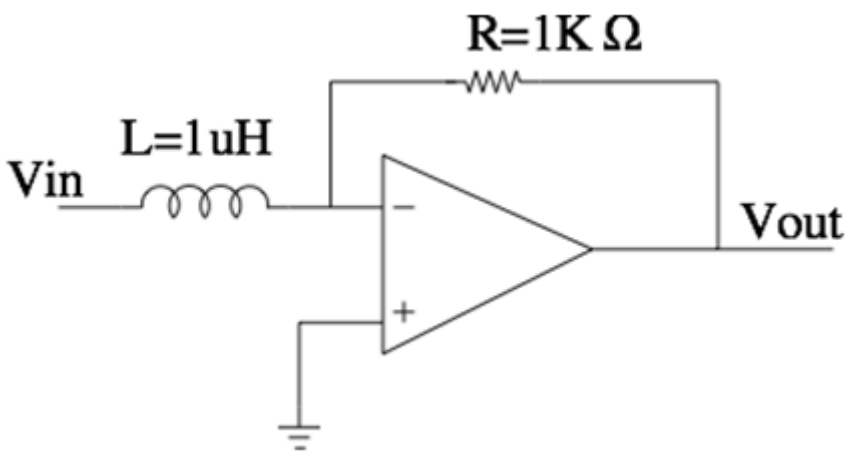
$$v_1 C_1 + v_2 C_2 = v_f (C_1 + C_2)$$

$$\Rightarrow v_f = \frac{v_1 C_1 + v_2 C_2}{C_1 + C_2}$$

$$\Rightarrow v_f = \mathbf{8.36\ V}$$

Problem 3: Op Amp Circuit Transfer Function (15 points total)

(a) (10 points) Find the complex transfer function $\mathbf{V_{out}}(\omega)/\mathbf{V_{in}}(\omega)$ of the following op-amp circuit. Assume the op-amp is ideal. Watch your units!



This is an inverting amplifier. The gain of an inverting amplifier is:

$$A(\omega) = -\frac{Z_1}{Z_2}$$

In this case,

$$Z_1 = R$$

$$Z_2 = j\omega L$$

$$\Rightarrow A(\omega) = -\frac{R}{j\omega L} = \frac{jR}{\omega L}$$

$$= \frac{j \cdot 10^9 \text{ rad/s}}{\omega}$$

(b) (5 points) Describe *in 10 words or less* what will happen to the op amp circuit when $\omega = 0$ (i.e. V_{in} is a DC voltage).

Acceptable answers include:

- V_{out} will reach V_{rail}. Virtual short condition not valid.
- Gain magnitude approaches infinity
- It becomes a transresistance amplifier

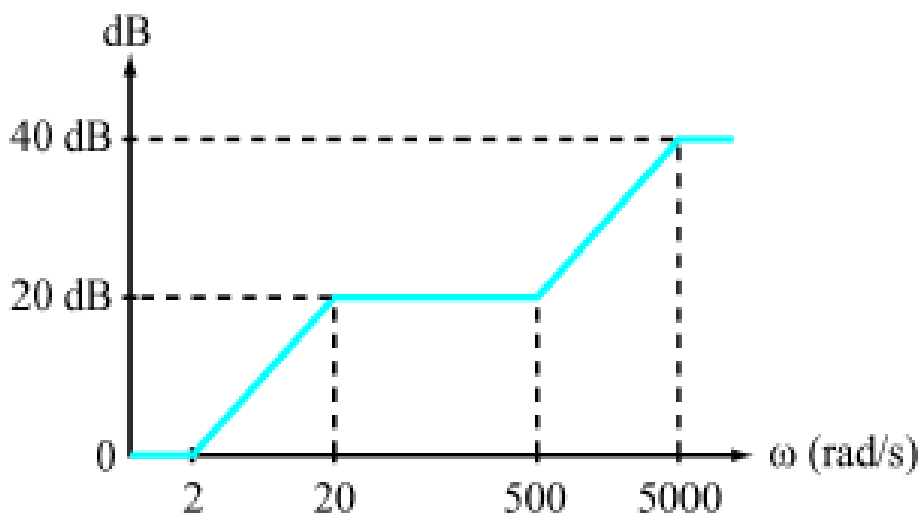
Problem 4 Bode Plots (15 points)

A circuit has the following transfer function

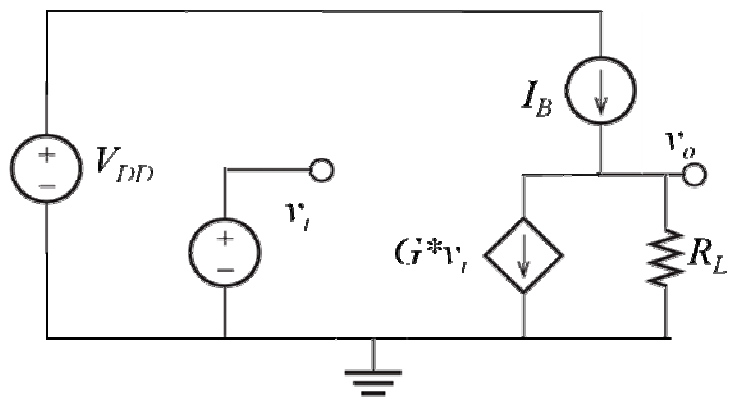
$$H(\omega) = \frac{j\left(1+\frac{j\omega}{2}\right)\left(1+\frac{j\omega}{500}\right)}{\left(1+\frac{j\omega}{20}\right)\left(1+\frac{j\omega}{5000}\right)}$$

Sketch the Magnitude Bode Plot, Label all corner frequencies and slopes

Ans



Problem 5 Dependent Source Circuit Analysis (20 points)



Let V_{DD} = 5 V, R_L = 1 kΩ, G = 7 mS.
Please give both analytical and numerical answers.

a) Find the current I_B so that when $v_i = 0$, $v_o = 2$ V. (10 pts)

When $v_i = 0$, the current in the dependent source is zero. If we define the DC current I_L downward through R_L, we can apply KCL to find:

$$I_L = I_B$$

$$\Rightarrow v_o = I_B \cdot R_L$$

$$\Rightarrow I_B = \frac{v_o}{R_L} = 2 \text{ mA}$$

b) Find the gain $A = v_o/v_i$ of this circuit for $I_B = 0$. (10 pts)

We know the current in the dependent source is $G*v_i$. Note that it all flows into the resistor. If we define the AC current i_L downward through R_L, we can apply KCL to find:

$$i_L = -G \cdot v_i$$

$$\Rightarrow v_o = -G \cdot R_L \cdot v_i$$

$$\Rightarrow A = -G \cdot R_L = -7$$

Many erroneous solutions used V_{DD} in the calculations, such as in KVL loops. V_{DD} does not participate in either part of this small-signal analysis.

Problem 6 Boolean Algebra and Karnaugh Maps (20 points total)

(A) A 3-variable Karnaugh map is shown below.

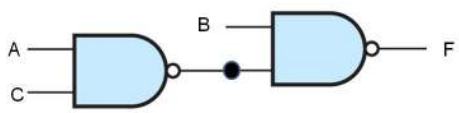
A \ BC	00	01	11	10
0	1	1	0	0
1	1	1	1	0

(i) (5 points) Write down the Boolean expression with sum of products.

$$\mathbf{F = \overline{B} + AC}$$

(ii) (5 points) Implement the function with NAND gates only. Draw your circuit.

$$\mathbf{F = \overline{B} + AC = \overline{B\,\overline{AC}}}$$



(B) The truth table of a logic function F is shown below.

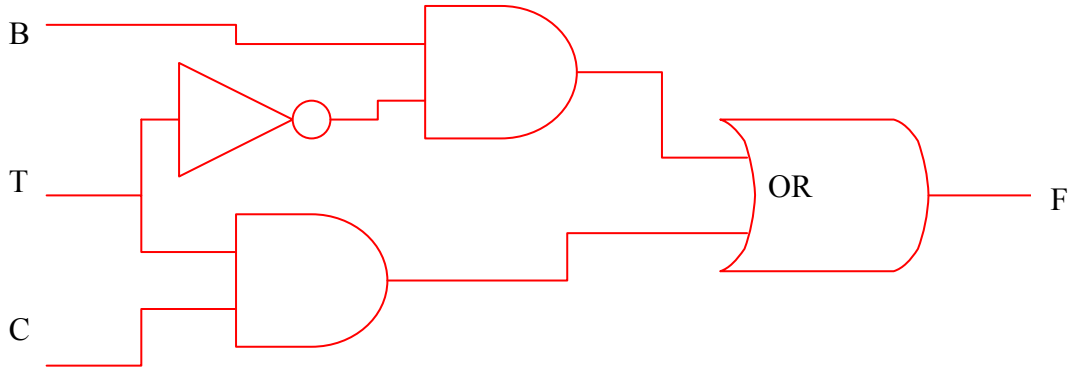
B	T	C	F
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	1
1	0	1	1
1	1	0	0
1	1	1	1

(i)(5 points) Simplify the logic function ***F*** using the sum of products method.

The following uses the SOP method:

$$F = \bar{B}TC + B\bar{T}\bar{C} + B\bar{T}C + BTC$$

$$= (\bar{B} + B)TC + B\bar{T}(C + \bar{C})$$

$$F = TC + B\bar{T}$$

(ii)(5 points) Implement your ***F*** function using the logic gates AND, OR, NOT. (5 pts)