Electrical Engineering 42/100
Summer 2012
Instructor: Tony Dear

Department of Electrical Engineering and Computer Sciences
University of California, Berkeley

Midterm Exam: Monday, July 16, 2012

Last Name: ______________________ First Name: ______________________

SID: ______________________

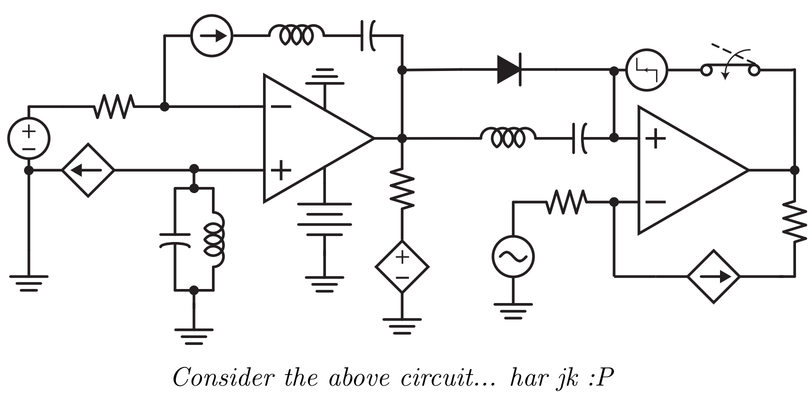
Discussion (circle one): 9-11am (Jerry) 10-12pm (John) 12-2pm (William) 2-4pm (Dennis)

Notes and Instructions

1. Fill out the information above as clearly and accurately as possible.
2. You have 110 minutes to complete this exam.
3. This exam contains five questions, on a total of sixteen pages (including this one).
4. Do all your work and **box** all answers on the provided paper; do not hand in loose papers.
5. None of the questions require long-winded calculations. Show your work clearly and concisely; partial credit will be given, but unclear or unnecessarily complicated work may be penalized.
6. One sheet of notes may be used on this exam.
7. You may not communicate with anyone else during the course of the exam, nor are electronic computational devices allowed. Academic dishonesty policies will be enforced.
8. Don't panic... and may the force be with you. :)

I have read all of the above instructions and agree to comply with them. All of the work on this exam is my own, and I had no prior knowledge of the exam contents.

Signature: ______________________________



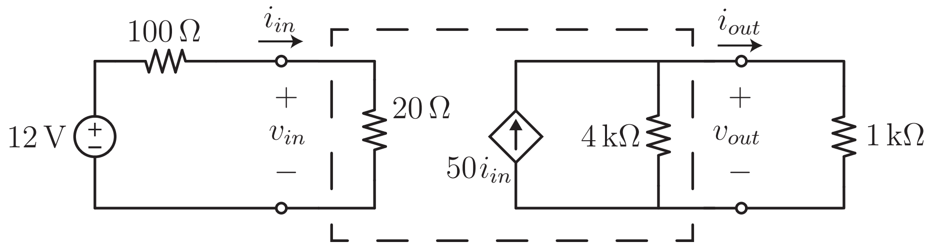
Consider the above circuit... har jk :P

Question	Q. 1	Q. 2	Q. 3	Q. 4	Q. 5	Total
Score	/25	/15	/15	/25	/20	/100

This page intentionally left blank

1. **Answer ALL the questions!**

   (a) *(5 points)* In the following circuit, we pass an input signal through a current amplifier. Evidently, it is nonideal with finite input and output impedances. The output is attached to a load $R_L = 1\,\mathrm{k}\Omega$.

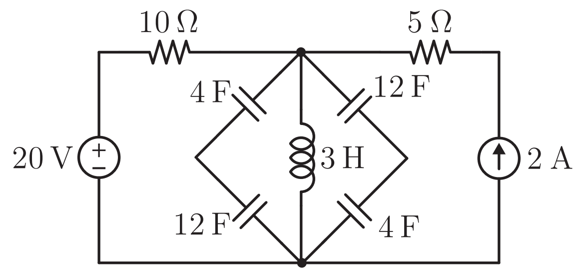


   i. Calculate the power P_{in} at the input of the amplifier.

   ii. Calculate the power P_{out} at the output of the amplifier.

   iii. What is the power gain G of the amplifier?

(b) *(10 points)* Consider the following circuit.

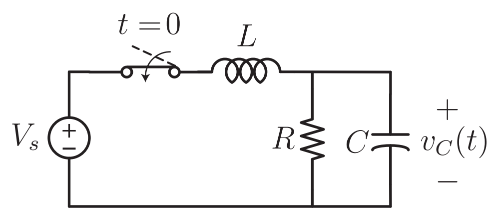


i. Simplify the circuit by applying all possible series and parallel combinations to any resistors, capacitors, inductors.

ii. Assuming DC steady state, calculate the powers of the sources and state whether each is supplying or absorbing energy.

iii. Find the energy stored in the inductor assuming DC steady state conditions.

(c) *(10 points)* Consider the following RLC circuit. The capacitor is initially uncharged. Express all results below in terms of the given circuit parameters.



i. Derive the ODE governing $v_C(t)$ for $t > 0$ (V_s is a DC source).

ii. Assuming *underdamped* behavior, qualitatively describe the behavior of $v_C(t)$ over time. You may sketch plots to supplement your explanation.

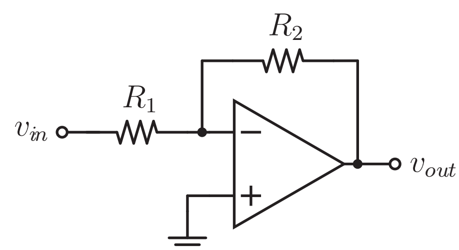
iii. Find an expression for the energy stored in the capacitor after a very long time.

2. **OVER 9000!!!**

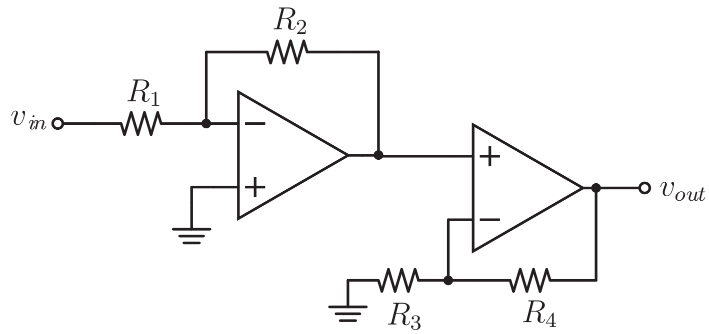
Today you will be helping Jerry design an amplifier circuit to meet some specifications that Tony has given him (be sure to use only KCL or Jerry will not be very happy).

(a) *(1 point)* Tony wants as much gain as possible. Since an ideal op amp has infinite open-loop gain, Jerry does not see why negative feedback would be useful, seeing as it drastically reduces the gain. Name one benefit of negative feedback, other than the ability to apply the summing-point constraint.

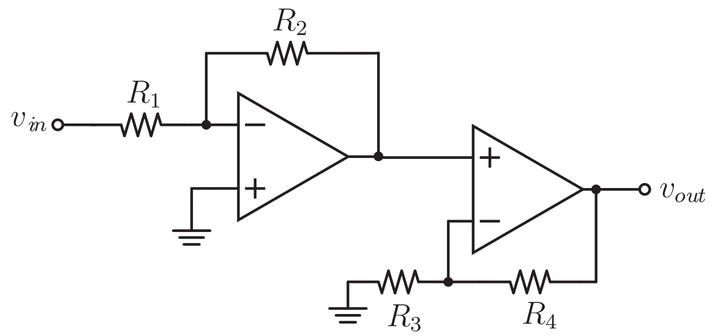
(b) *(2 points)* Jerry believes you and agrees to use negative feedback configurations. Tony wants a gain of over -9000, so Jerry confidently designs an inverting amplifier with a gain of -10000, shown below. Help Jerry choose resistor values such that he achieves that gain.



(c) *(4 points)* Now Tony comes over and says that the lab only has resistor values between $100\,\Omega$ and $10\,\mathrm{k}\Omega$ due to budget cuts. "No problem!" says Jerry. He decides to add a noninverting stage after the first amplifier. Choose new values for all resistors so that we still have a gain of over -9000.



(d) *(2 points)* Jerry builds his circuit and finds that it doesn't work. But of course, he has forgotten to power the amplifier! He attaches supply rails of $\pm 15\,\mathrm{V}$ to both op amps. Using the resistance values that you chose above, what is the voltage input range for which amplifier operation remains linear?

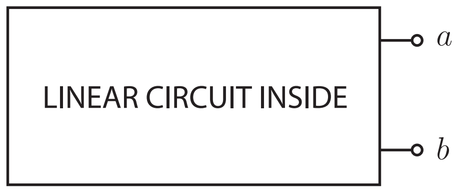


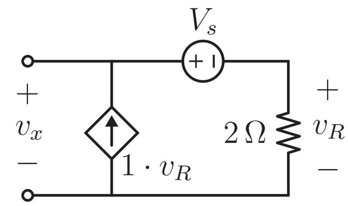
(e) *(3 points)* Just as Jerry finishes his new design, Tony comes over and says, "Oh btw, the source resistances for the inputs will be on the order of $10\,\mathrm{k}\Omega$." Find the input resistance of the circuit using your resistance values and explain why this is problematic.

(f) *(3 points)* Tired of the constant spec changes, Jerry ragequits and leaves the problem for Dennis to fix. Help Dennis rectify the new problem by adding another stage to the amplifier circuit to make the input resistance as high as possible without changing the gain.

3. **Probing Thévenin with a Device (twss)**

William has stumbled across a mysterious electronic box labeled "LINEAR CIRCUIT INSIDE." Hearing a ticking sound coming from inside, he has decided that it would be unsafe to open it up. However, he's still very curious about what the circuit looks like inside, so he probes the two terminals sticking out of the box (for some reason this seemed perfectly okay, even though opening it was not).





Instead of having a multimeter like normal people, John has the above whack measuring device (shown on the right). The device can be attached across two terminals of any circuit. The value of V_s can be twiddled with, and the device will then report the voltage v_x.

(a) *(12 points)* William decides to use John's device to probe the box. He makes two measurements and observes the following:

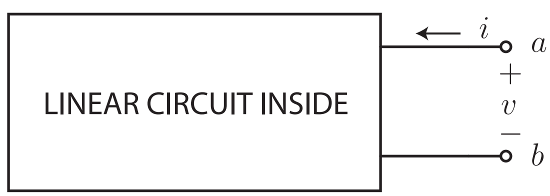
$$V_s = 5\,\text{V} \rightarrow v_x = -3\,\text{V}$$
$$V_s = 6\,\text{V} \rightarrow v_x = 0\,\text{V}$$

Using this information, help William find the Thévenin and Norton equivalent circuits of the box.

Hint: Pick one equivalent circuit to focus on first. You can get the second one easily afterward.

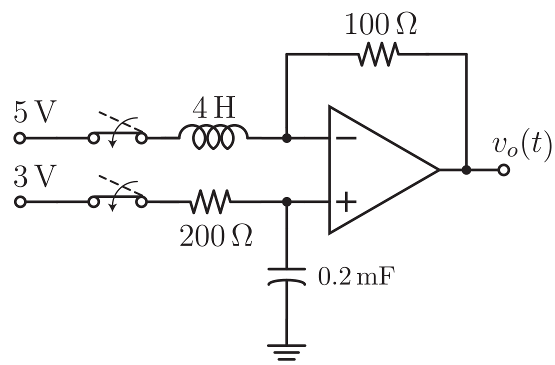
More space for part (a)...

(b) *(3 points)* While William has only performed two measurements, he now essentially knows the black box's current output for any voltage input (or vice-versa). For the references shown below, plot the box's i-v characteristic. Label axes, intercepts, and slopes.

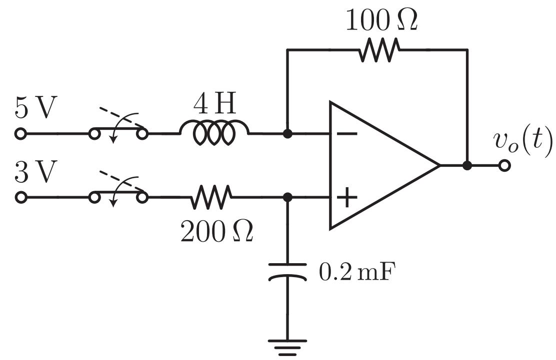


4. **What Is This I Don't Even**

In an attempt to troll the students, Dennis has constructed the following monstrosity. Both switches close at $t = 0$, and the capacitor is uncharged prior to the switch actions. **Assume that the op amp is ideal with no rail limitations and that negative feedback holds**.

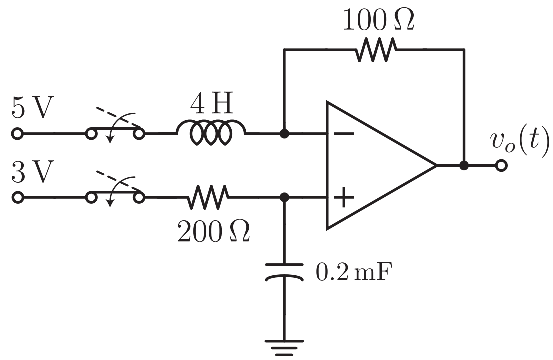


(a) *(8 points)* Find $v_+(t)$ at the noninverting input for $t > 0$.



(b) *(3 points)* Write an equation for $v_o(t)$ in terms of $v_-(t)$, the voltage at the inverting input.

(c) *(6 points)* Use your results from (a) and (b) to solve for $v_o(t)$.

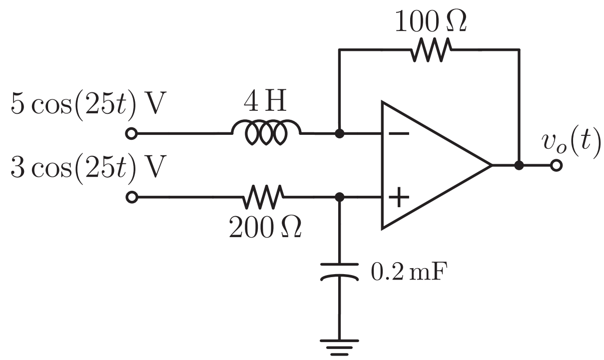


(d) *(4 points)* Does $v_-(t)$ ever reach a steady-state value? If so, find the value; if not, explain why this circuit does not allow for this to happen.

(e) *(4 points)* Does $v_o(t)$ ever reach a steady-state value? If so, find the value; if not, explain why this circuit does not allow for this to happen.

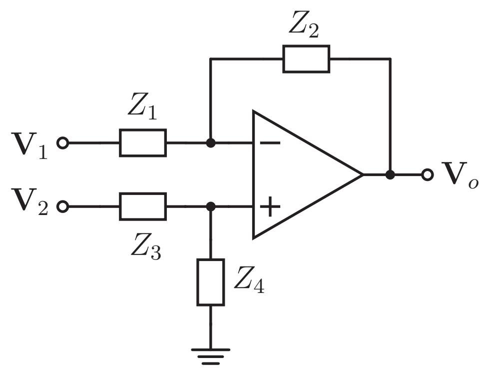
5. **Not Sure If Wrong Figure... Or If GSIs Just Got Lazy**

John takes Dennis's circuit and replaces the input voltages with sinusoidal sources, both with frequency $\omega = 25$ rad/sec. He also wants to find $v_o(t)$, though he doesn't care about the transient response.



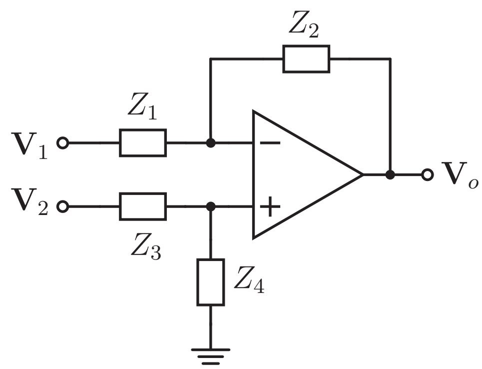
(a) *(5 points)* Help John thwart Dennis's ODE trolling plan by redrawing the circuit with all elements converted to the phasor domain.

(b) *(7 points)* Dennis accidentally lets slip that this amplifier is actually a difference amplifier, though with impedances instead of resistances. John takes the opportunity to redraw the circuit as follows:



Show that the gain for a general difference amplifier is

$$\mathbf{V}_o = \left(\frac{Z_4}{Z_3 + Z_4}\right)\left(\frac{Z_1 + Z_2}{Z_1}\right)\mathbf{V}_2 - \left(\frac{Z_2}{Z_1}\right)\mathbf{V}_1$$



$$\mathbf{V}_o = \left(\frac{Z_4}{Z_3 + Z_4}\right)\left(\frac{Z_1 + Z_2}{Z_1}\right)\mathbf{V}_2 - \left(\frac{Z_2}{Z_1}\right)\mathbf{V}_1$$

(c) *(4 points)* Using the gain given above, derive an expression for $\mathbf{V}_\text{o}$, the phasor form of $v_o(t)$.

(d) *(4 points)* Perform the final conversion back to the time domain to obtain an expression for $v_o(t)$.

This page is not graded. No fun questions this time because we know that most of you will probably not want to waste your precious time. If you actually do finish early, feel free to use the space below to write, compose, rant, complain, draw, create, etc. We'll find it encouraging when grading your midterms deep into the night.

We'll start you off with a Pikachu.