Duke University
Edmund T. Pratt, Jr. School of Engineering

EGR 119 Spring 2011

Test II

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Name (please print)____

In keeping with the Community Standard, I have neither provided nor received any assistance on this test. I understand if it is later determined that I gave or received assistance, I will be brought before the Undergraduate Conduct Board and, if found responsible for academic dishonesty or academic contempt, fail the class. I also understand that I am not allowed to speak to anyone except the instructor about any aspect of this test until the instructor announces it is allowed. I understand if it is later determined that I did speak to another person about the test before the instructor said it was allowed, I will be brought before the Undergraduate Conduct Board and, if found responsible for academic dishonesty or academic contempt, fail the class.

Signature:____

Instructions

First - please turn **off** any cell phones or other annoyance-producing devices. Vibrate mode is not enough - your device needs to be in a mode where it will make no sounds during the course of the test, including the vibrate buzz or those acknowledging receipt of a text or voicemail.

Please be sure to put each problem on its own page or pages - do *not* write answers to more than one problem on any piece of paper and do not use the back of a problem for work on a *different* problem. You will be turning in each of the problems independently. This cover page should be stapled to the front of Problem 1.

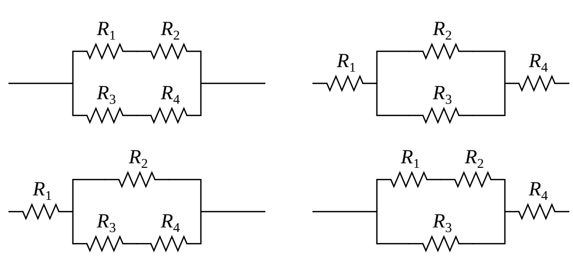
Make sure that your name *and* NET ID are *clearly* written at the top of *every* page, just in case problem parts come loose in the shuffle. Make sure that the work you are submitting for an answer is clearly marked as such. Finally, when turning in the test, individually staple all the work for each problem and place each problem's work in the appropriate folder.

Note that there may be people taking the test after you, so you are not allowed to talk about the test - even to people outside of this class - until I send along the OK. This includes talking about the specific problem types, how long it took you, how hard you thought it was - really anything. Please maintain the integrity of this test.

You may use the || symbol for resistances in parallel and do not need to expand that construction. Be clear with your use of parentheses, however; simply writing something like

$$R_{\text{eq}} = R_1 + R_2 \parallel R_3 + R_4$$

is too vague since it could refer to any of the four combinations below:



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Problem I: [30 pts.] The Basics

The following three items get at the "core" of some of the concepts you have learned in the course. Note however that they are *not* related to each other.

(1) You are given a switched circuit driven by a constant voltage v_{a} and have determined that, for $t > 0$, the voltage v_{x} across one of the elements can be modeled with the equation:

$$6\frac{d}{dt}v_{\text{x}} + 4v_{\text{x}} = 2v_{\text{a}}$$

Furthermore, you have determined that $v_{\text{x}}(0^+) = 3$ V and are given that, for $t > 0$, v_{a}=-18 V.

(a) Determine an expression for the unknown voltage v_{x} as a function of time for $t > 0$ and

(b) Make an accurate sketch of the voltage v_{x} for at least three time constants. Be sure to show any "construction lines" used to make the sketch more accurate.

(2) Design a first-order low-pass voltage-to-voltage filter with a gain of 1, a cutoff frequency of 20000 rad/s, and a slope after the cutoff of 20 dB/decade. Assume that you only have 1 kΩ resistors available to you. You should both give the transfer function for this filter and a possible circuit drawing, clearly showing the input and output votlages.

(3) You have determined that the transfer function for a particular system is given as:

$$\mathbb{H}(s) = \frac{\mathbb{V}_{\text{out}}(s)}{\mathbb{V}_{\text{in}}(s)} = \frac{s + 20}{s^2 + 80s + 2500}$$

Determine the *step* response for the system. Your answer must be a function consisting of all real values in the time domain.

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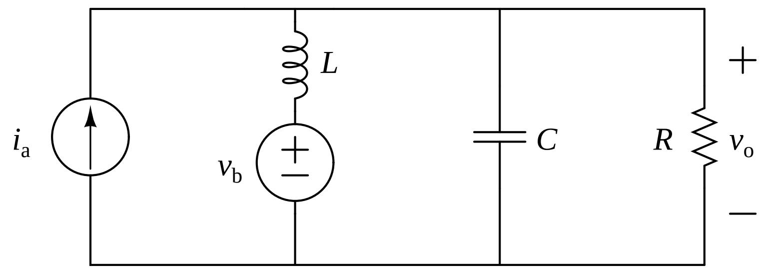
Problem II: [25 pts.] Steady-State Analysis

Given the following circuit:



and assuming that the values for the passive elements and the values for sources i_a and v_b are known,

(1) Assuming v_b is turned off, determine the transfer function between the current source i_a and the voltage v_o across the resistor R:

$$\mathbb{Z}_a(j\omega) = \frac{\mathbb{V}_o(j\omega)}{\mathbb{I}_a(j\omega)}$$

(2) What kind(s) of filter(s) could $\mathbb{Z}_a(j\omega)$ represent? Why do you think that? What would you need to know to be sure?

(3) Assuming i_a is turned off, determine the transfer function between the voltage source v_b and the voltage v_o across the resistor R:

$$\mathbb{H}_b(j\omega) = \frac{\mathbb{V}_o(j\omega)}{\mathbb{V}_b(j\omega)}$$

(4) What kind(s) of filter(s) could $\mathbb{H}_b(j\omega)$ represent? Why do you think that? What would you need to know to be sure?

(5) Assuming the circuit has been in place for a relatively long time with:

$$i_a = 8 + 2\cos(4000t + 10^\circ) \text{ mA} \qquad\qquad v_b = 6 \text{ V}$$

and $R = 1$ kΩ, $L = 400$ mH, and C=2 nF, clearly use phasor analysis to solve for the AC steady-state function for $v_o(t)$. Your solution must be a real-valued function of time.

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Problem III: [20 pts.] Filter Design

In order to both reject ambient electrical noise for a set of measurements and to make sure aliasing does not happen, you need to build a band-pass filter that has a (logarithmic) center frequency of 6000 rad/s and a quality of 0.07. The filter needs to have a 20 dB/dec dropoff or more outside of the pass-band but must have an attenuation of 3 dB or less from the maximum gain inside the pass-band. The maximum gain for your filter needs to be 1 (i.e. 0 dB).

(1) Given the problem statement, determine the maximum gain, quality, natural frequency, damping ratio, linear center frequency, bandwidth, and cutoff frequencies for the filter. Be sure to indicate which value is which.

(2) Write the transfer function for the band-pass filter using one of the two "standard" forms we discussed in class for band-pass filters.

(3) Sketch a Bode plot of the magnitude using straight-line approximations. Be sure to indicate corner frequencies and provide axis labels and values for the independent and dependent axes of the plot.

(4) Assuming you have access to a single 1 kΩ resistor, along with a generous array of capacitors and inductors, design the circuit that has the same transfer function as this filter. Be sure to clearly indicate where the output voltage is as well as what the component values are.

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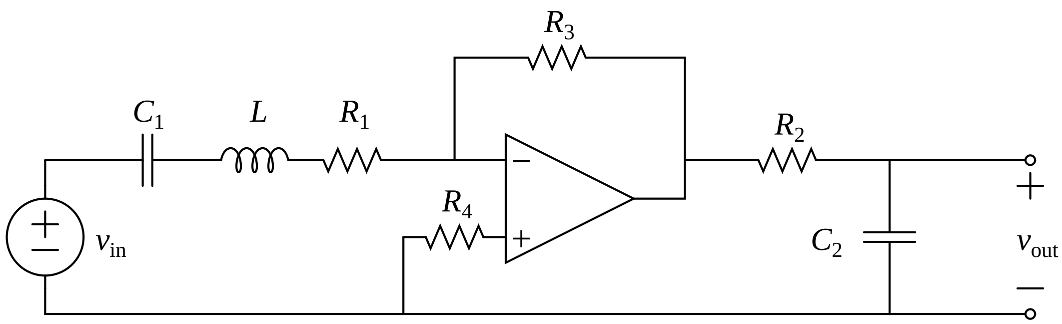
Problem IV: [25 pts.] Operational Amplifiers

(1) Given two voltage sources v_{a} and v_{b}, for which you have access to only their positive terminals, design a practical circuit using operational amplifiers (LM741) and resistors that will not draw any power from either source and will have as an output voltage given by:

$$v_{\mathrm{o}} = 6v_{\mathrm{a}} - 3v_{\mathrm{b}}$$

You may use up to four operational amplifiers.

(2) Given the following circuit:



determine the transfer function

$$\mathbb{H}(s) = \frac{\mathbb{V}_{\mathrm{out}}(s)}{\mathbb{V}_{\mathrm{in}}(s)}$$