Duke University

Edmund T. Pratt, Jr. School of Engineering

EGR 119 Spring 2010

Test II

Michael R. Gustafson II

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 Judicial 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.

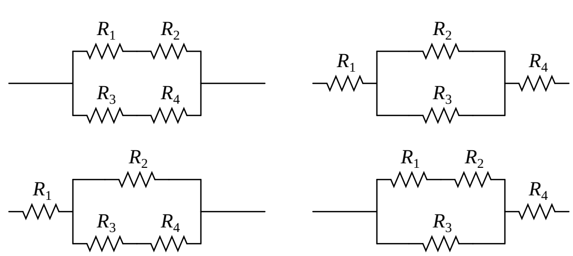
Make sure that your name *and* NET ID are *clearly* written at the top of *every* page, just in case problem parts come loose in the shuffle. Make sure that the work you are submitting for an answer is clearly marked as such. Finally, when turning in the test, individually staple all the work for each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

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

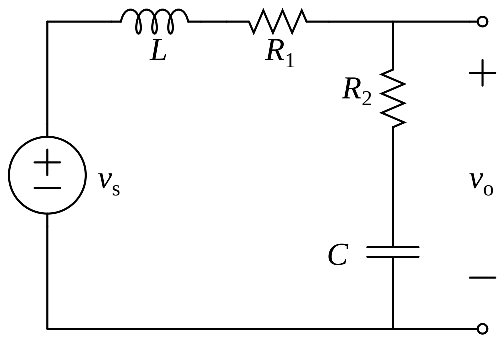
is too vague since it could refer to any of the four combinations below:



Name (please print):
Community Standard (print ACPUB ID):

Problem I: [15 pts.] Transfer Functions

Given the following circuit:



(1) Clearly re-draw the circuit in the frequency domain.

(2) Determine the transfer function:

$$\mathbb{G}(j\omega) = \frac{\mathbb{V}_{\mathrm{o}}(j\omega)}{\mathbb{V}_{\mathrm{s}}(j\omega)}$$

and write it as a ratio of polynomials in $j\omega$.

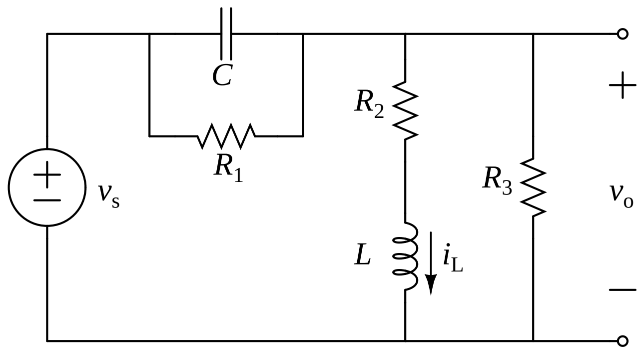
(3) Write the differential equation that relates the output voltage $v_{\mathrm{o}}(t)$ to the input voltage $v_{\mathrm{s}}(t)$.

(4) What kind of filter do you think this might be? Why do you think that? What else would you want to know to be sure?

Name (please print):
Community Standard (print ACPUB ID):

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

Given the following circuit:



(1) Assuming the circuit has been in place for a long time and

$$v_\mathrm{s} = V$$

where V is some constant voltage, re-draw the circuit using the steady state approximations for the elements and then determine the value of the output voltage v_o and the inductor current i_L.

(2) Assuming the circuit has been in place for a long time and

$$v_\mathrm{s} = (6 + 10\cos(5t))\ \mathrm{V} \qquad L = 1\ \mathrm{H} \qquad C = 1\ \mathrm{F}$$
$$R_1 = 1\ \Omega \qquad R_2 = 2\ \Omega \qquad R_3 = 3\ \Omega$$

determine an expression for the value of the output voltage v_o and an expression for the inductor current i_L. Your expressions must use only real-valued numbers. Be sure to include units where needed. Clearly show your process - especially once you substitute in numbers - so that minor calculation mistakes can be distinguished from major process errors.

Name (please print):
Community Standard (print ACPUB ID):

Problem III: [15 pts.] Filter Design I

Given a desired transfer function of:

$$\mathbb{H}(j\omega) = \frac{\mathbb{V}_{\text{out}}(j\omega)}{\mathbb{V}_{\text{in}}(j\omega)} = \frac{(j\omega)^2}{(j\omega + 10)(j\omega + 1000)}$$

(1) 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.

(2) What kind of filter do you think this might be? Why do you think that? What else would you want to know to be sure?

(3) Design a circuit that has this transfer function. Assume the only resistors you can find in the lab are 1 kΩ, but that you have access to inductors and capacitors of any size you need as well as a few op-amps. You know. Just in case.

Name (please print):
Community Standard (print ACPUB ID):

Problem IV: [25 pts.] Filter Design II

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 half-power frequencies of 500 rad/s and 50000 rad/s. 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 10 (i.e. +20 dB).

(1) Given the problem statement, determine the maximum gain, quality, natural frequency, damping ratio, linear center frequency, 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.

Name (please print):
Community Standard (print ACPUB ID):

Problem V: [20 pts.] Operational Amplifiers

There are several methods for communicating color information to electronic displays. One method - RGB - sends information about the amount of Red, Blue, and Green there should be in an element. Another method - YPbPr - sends the luma (Y), blue-difference (Pb), and red-difference (Pr) values. The luma is essentially the brightness of an element and can be related to the necessary RGB values for a device with:

$$Y = K_r\ (R - G) + K_b\ (B - G) + G, \text{ or alternately}$$
$$Y = K_r\ R + (1 - K_r - K_b)\ G + K_b\ B$$

where Y is the luma value, R is the red value, G is the green value, B is the blue value, and K_r and K_b are two constants which are related to how exactly that particular device emits light.

Your job will be to build a circuit that takes as inputs the voltages on the R, G, and B wires coming from some device and has as an output the luma voltage. For some systems, the K_r value is 0.2126 and the K_b value is 0.0722. Your circuit must *not* draw power from the inputs. Note that if you use ideal operational amplifier assumptions, your component values must work with the LM741 op-amps we discussed in class (i.e. $A \approx 2e5$, $r_{\text{i}} \approx 2$ MΩ, and $r_{\text{o}} \approx 75\ \Omega$). Also, while you are not required to determine the absolute *minimum* number of elements required to reproduce the relationship above, assume you have only 6 op amps at your disposal. Finally, for the three inputs R, G, and B, you only have access to their positive terminal; their negative terminal is already connected to ground. That is, the following three items should show up somewhere in your circuit: