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

EGR 224 Spring 2014

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.

Your calculator may only be used as a calculation device, not a memory storage unit. Using a calculator for any purpose other than performing "just-in-time" numerical calculations is a violation of the community standard.

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.

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

Problem I: [25 pts.] Basics

The following 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) Make an accurate sketch of the straight-line approximation to the Bode magnitude plot of the transfer function:

$$\mathbb{G}(s) = \frac{s(s+100)}{(s+1)(s+1000)^3}$$

(2) Determine the inverse Laplace transform $p(t)$ of:

$$\mathbb{P}(s) = \frac{2s+4}{s^2+10s+32}$$

(3) If a linear, time invariant system has an output:

$$y_1(t) = 3e^{-5t}u(t)$$

for some input:

$$x_1(t) = e^{-6t}u(t)$$

Determine:

(a) The impulse response for the system, $h(t)$
(b) The step response for the system, $s_{\text{sr}}(t)$
(c) The output to the system $y_2(t)$ if the input is $x_2(t) = e^{-4t}u(t)$

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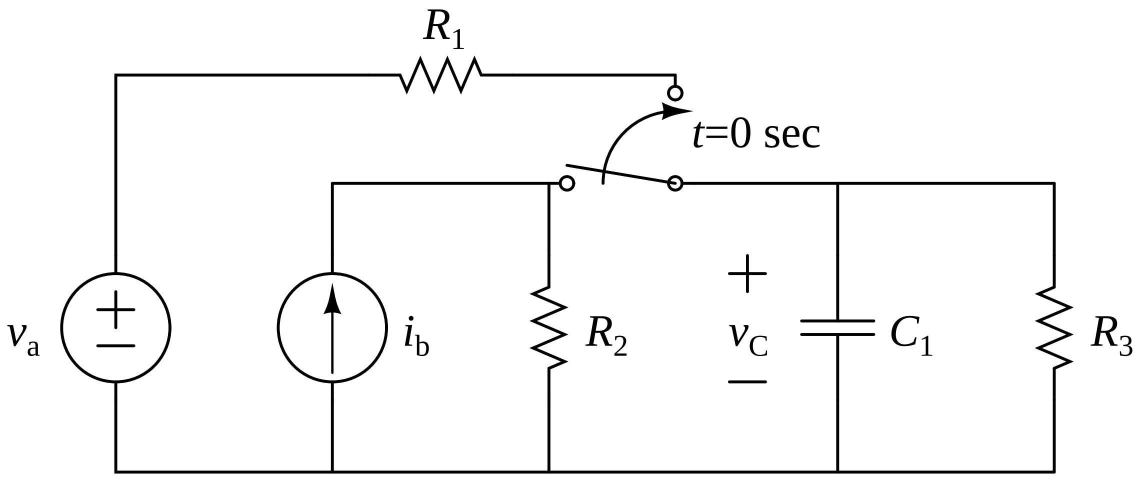
Problem II: [30 pts.] Tour de Switched Circuits

Each of the three parts of this problem involve the exact same circuit:



with the following element values:

$$R_1 = 12\ \text{k}\Omega \qquad C_1 = 1\ \mu\text{F}$$
$$R_2 = 8\ \text{k}\Omega \qquad i_b = 2\ \text{mA}$$
$$R_3 = 4\ \text{k}\Omega$$

Carefully read the conditions for each part of the problem and show your solutions to each.

(1) Assuming the switch had been in its lower position for a very long time before t=0 sec, and assuming $v_a(t)$ is a constant 12 V, find an expression for the capacitor voltage for $t > 0$ sec. Make an accurate sketch of the capacitor voltage for three time constants. Call this $v_{C1}(t)$.

(2) Next, assume the switch had been in its lower position for a very long time before t=0 sec, but that $v_a(t)$ is a decaying exponential $v_a(t) = 7e^{-400t}u(t)$ V. Clearly using Laplace techniques, find an expression for the capacitor voltage for $t > 0$ sec. Call this $v_{C2}(t)$.

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Problem III: [25 pts.] Filter Design

(1) Determine the transfer function for a first-order low-pass filter with a maximum gain of 20 and a cutoff frequency of 1100 rad/s. Then, using only 22 nF capacitors, up to four operational amplifiers, and any reasonably-sized resistors (100 Ω to 100 kΩ) you need, design a voltage-to-voltage circuit that has this transfer function *and* which draws no current from the input voltage.

(2) Determine the transfer function for a second-order band-pass filter with a passband gain of 1, a logarithmic center frequency of $10000 = 1{\times}10^4$ rad/s, and a quality of 0.25. For this filter:

(a) Determine the damping ratio, cutoff (half-power) frequencies, linear center frequency, and bandwidth for the filter. Be sure to clearly indicate which value is which and include units when appropriate.

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

(c) Sketch a Bode plot of the magnitude using straight-line approximations. Be sure to label the axes, including numerical values, along with all slopes and critical frequencies. Also indicate corner frequencies.

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Problem IV: [20 pts.] Operational Amplifiers

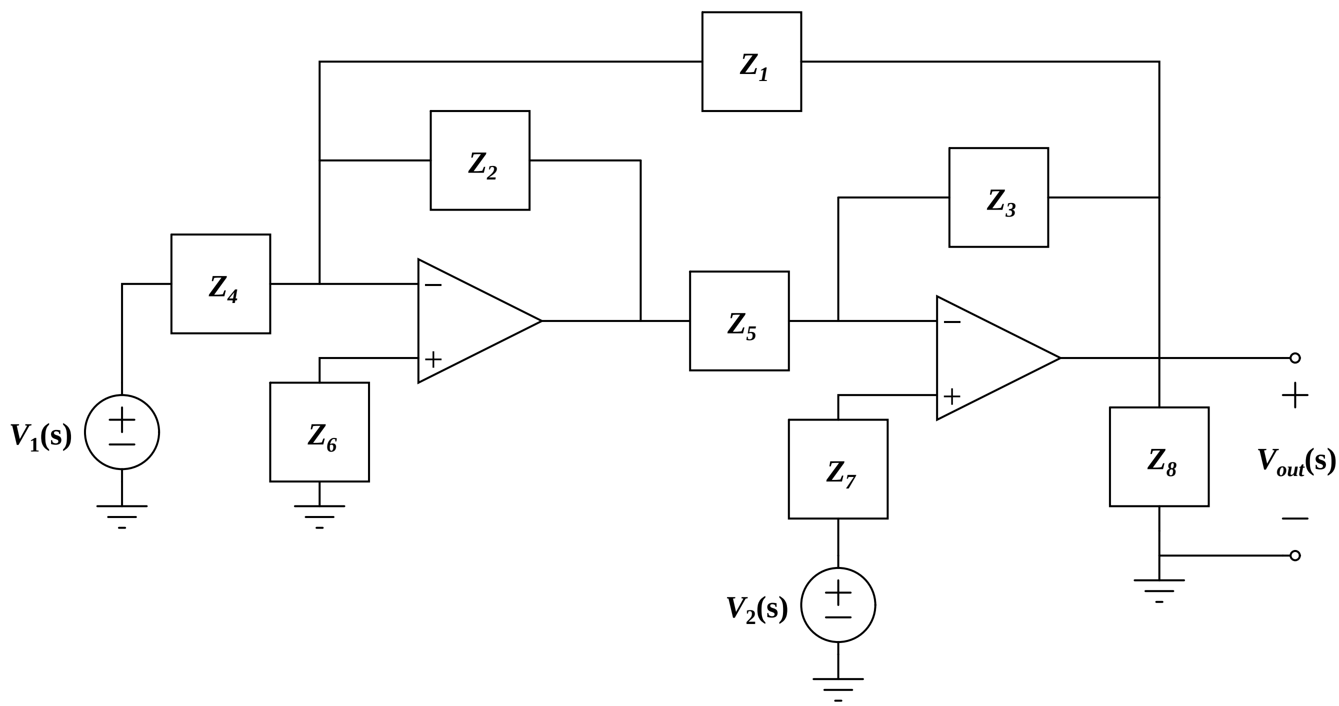
(1) *(a)* Design a circuit using up to three operational amplifiers, reasonably-sized resistors (100 Ω to 100 kΩ), and as many 68 nF = 68×10^{-9} F capacitors as you need that implements the following transfer function:

$$\mathbb{H}(s) = \frac{\mathbb{V}_{\text{out}}(s)}{\mathbb{V}_{\text{in}}(s)} = -\frac{2s}{s+500}$$

(note the sign!) while simultaneously drawing no power from the input voltage source $v_{\text{in}}(t)$. Note that you are *not* allowed to use inductors here.[1]

(b) Determine both the impulse response and the step response to this circuit and clearly label which is which.

(2) Assuming the op-amps in the following circuit are ideal:



clearly label the circuit and determine a set of equations that could be solved to find an expression for the Laplace transform of the output voltage ($\mathbb{V}_{\text{out}}(s)$) as a function of the Laplace transform of the input voltages ($\mathbb{V}_1(s)$ and $\mathbb{V}_2(s)$) and the impedances $\mathbb{Z}_k$. List the total set of unknowns your equations would solve. You are not required to actually solve.

[1]Cue "sad trombone."