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

ECE 141 Spring 2009

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 Judicial 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:____

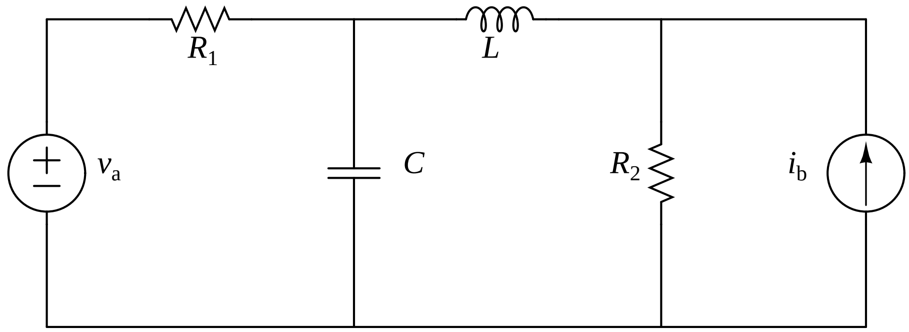
Instructions for Paper-Based Sections

Be sure to put your name on **each page** of the test of any scratch paper you are turning in. Clearly indicate where each part is solved. You will be turning the test in as individual problems. This cover sheet should be stapled along with Problem I - every other part will consist of the page from the test and any extra pieces of paper used. For this reason, it is critical that you have no more than one problem's work on any given page. To turn in the test, you will check to make sure your name is on every page, then staple together any relevant scratch work, and finally you will turn in the six piles to the folders in the front of the room.

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

Problem I: [15 pts.] State Space

Given the circuit below:



and assuming v_a, i_b, and the passive element values are known, clearly define your state variables and write the state space equations for the circuit using those variables.

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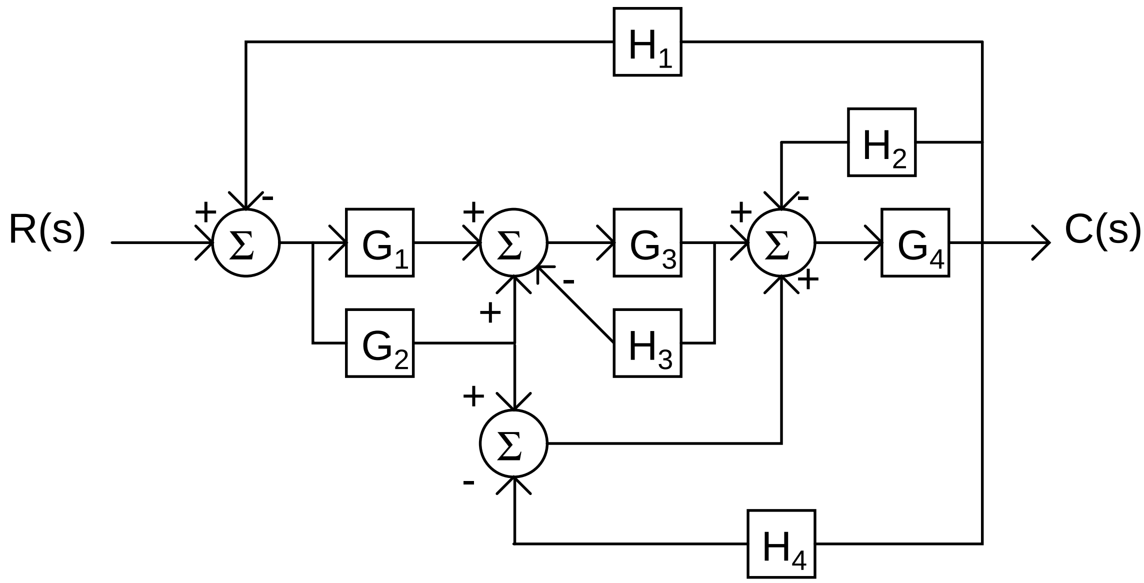
Problem II: [10 pts.] System Simplification

Given the system below (adapted from Nise 5.7):



(a) Clearly draw a signal flow diagram for the system. Be sure to indicate where each node is on the system.

(b) Use Mason's Rule to determine the overall transfer function $T(s) = C(s)/R(s)$. Note that once you define components in terms of the individual transfer functions, you do *not* need to simplify nor do you need to substitute them into the final result.

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Problem III: [15 pts.] System Stability

(1) The overall transfer function for a system is determined to be:

$$T(s) = \frac{s^2+2}{s^5+4s^4+2s^3+8s^2+4s+1}$$

(a) Clearly, and by hand, generate a Routh array for this system.
(b) Based on the array, where are the poles for this system?

(2) The forward gain for a unity feedback system with gain control is given as:

$$G(s) = \frac{K(s+3)}{(s-1)(s+2)(s+6)(s+8)} = \frac{K(s+3)}{s^4+15s^3+60s^2+20s-96}$$

(a) Clearly, and by hand, generate a Routh array for this system.
(b) Determine the range of stability for the controller.
(c) Determine the gain value(s) for marginal stability and the frequency of oscillation at marginal stability.

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Problem IV: [20 pts.] System Design I

A unity feedback system has a forward transfer function of:

$$G(s) = \frac{1}{(s+1)(s+10)}$$

A gain block with gain K is placed in the forward path between the summation block and $G(s)$.

(a) What type of system is this?
(b) Over what range of K is the system stable?
(c) What is the value of the appropriate finite static error constant with respect to K?
(d) What is the value of the steady state position error for a unit input with respect to K?
(e) Are there value of K that will yield an underdamped system with a settling time of 2 sec or longer? If so, what are they? If not, why do you believe that?
(f) Is there a value of K that will yield an underdamped response such that the %OS is 15? If so, what is it? If not, why do you believe that?
(g) Is there a value of K that will produce a steady state position error that is 1% assuming a unit input? If so, what is it? If not, why do you believe that?

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Problem V: [20 pts.] System Design II

A system is found to have an overall transfer function of:

$$T(s) = \frac{C(s)}{R(s)} = \frac{K}{(s+20)(s^2+6s+10)}$$

For this system:

(a) Find the poles and zeros of the transfer function.

(b) Estimate $\%OS$, T_s, T_p, and T_r. How accurate do you believe these values are, any why?

(c) Assuming K is unknown, what type of system does this represent with respect to steady state error? (be careful! and complete...)

(d) Determine the appropriate finite static error constant and steady state error as functions of K, assuming unit input.

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Problem VI: [20 pts.] System Design III

The forward transfer function of a unity feedback system with gain control is given as:

$$G(s) = \frac{K\ (s+1)}{s^2(s^2+14s+58)}$$

For this system:

(a) Determine the range of K that will keep the system stable.

(b) What type of system does this represent?

(c) Determine the appropriate interesting (i.e. nonzero and finite) static error constant and steady state error as functions of gain assuming unit input.

(d) Determine the value of K that will produce a steady state position error of 25% relative to a unit input.

(e) Determine the value(s) of K that will produce a marginally stable system as well as the frequency of oscillation of the system given that gain.