Duke University

Edmund T. Pratt, Jr. School of Engineering

ECE 141 Spring 2010

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 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:________________________________

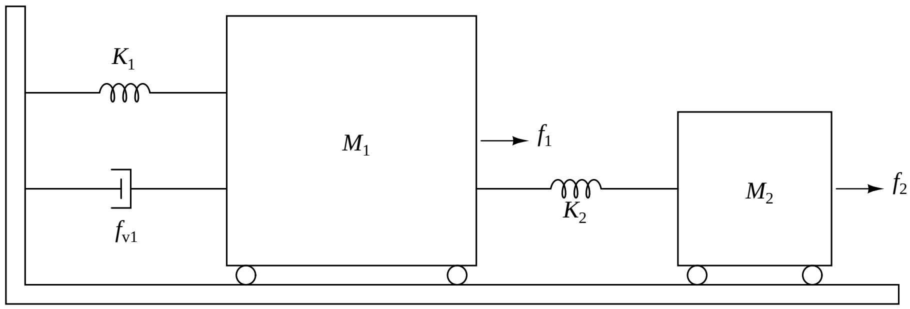
Instructions for Paper-Based Sections

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: [10 pts.] State Space

Given the circuit below:



and assuming f_1, f_2, and the spring, mass, and damper values are known, clearly define your state variables and write the state space equations for the circuit using those variables. The desired output for this system will be the position of mass M_2.

Name (please print):
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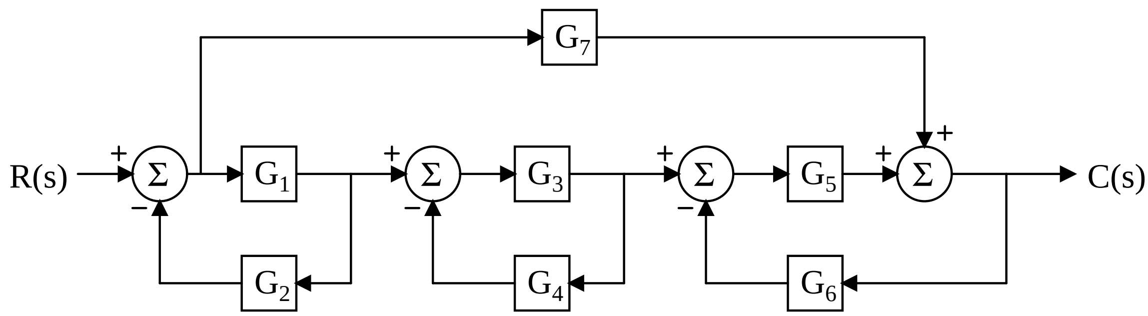
Problem II: [10 pts.] System Simplification

Given the system below:



(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: [20 pts.] System Design and Analysis I

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

$$T(s) = \frac{C(s)}{R(s)} = \frac{K \cdot (s^2 + 10s + 24)}{s^3 + 18s^2 + K \cdot (s^2 + 10s + 24)}$$

For this system:

(a) Clearly, and by hand, generate a Routh array for this system.

(b) Determine the range of stability for the controller.

(c) If this system can be marginally stable, determine the gain value for marginal stability and the frequency of oscillation at marginal stability. If this system cannot be marginally stable, explain why you believe that.

(d) State what type of system this is with respect to steady-state error.

(e) Determine the value(s) of K for which the appropriate finite steady-state error for a unit input is $\frac{1}{3}$. Indicate what kind of unit input this is (i.e. step, ramp, or parabola).

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Problem IV: [25 pts.] System Design and Analysis II

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

$$T(s) = \frac{K}{s^4 + 8s^3 + 19s^2 + 12s + K}$$

(a) Clearly, and by hand, generate a Routh array for this system.

(b) Determine the range of stability for the controller.

(c) If this system can be marginally stable, determine the gain value for marginal stability and the frequency of oscillation at marginal stability. If this system cannot be marginally stable, explain why you believe that.

(d) State what type of system this is with respect to steady-state error.

(e) Assuming K is chosen to keep the system stable, calculate the values of the static error constants with respect to position, velocity, and acceleration.

(f) Assuming K is chosen to keep the system stable, calculate the steady state errors for a step input $u(t)$, a ramp input $t\ u(t)$, and a parabolic input $\frac{1}{2}t^2\ u(t)$.

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Problem V: [35 pts.] System Design and Analysis III

A unity feedback system has a forward transfer function of:

$$G(s) = \frac{s+100}{(s+5)(s+20)}$$

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

(a) Clearly, and by hand, generate a Routh array for this system.

(b) Determine the range of stability for the controller.

(c) If this system can be marginally stable, determine the gain value for marginal stability and the frequency of oscillation at marginal stability. If this system cannot be marginally stable, explain why you believe that.

(d) State what type of system this is with respect to steady-state error.

(e) Determine the value(s) of K for which the second-order poles have a damping ratio of 0.9. For each possible K,

(1) Calculate the damped frequency represented by the system poles,
(2) Calculate the settling time calculated for the poles using the second-order system assumptions, and
(3) State how accurate you believe the second-order assumption will be and why.

(f) Determine the value(s) of K for which the appropriate finite steady-state error for a unit input is $\frac{1}{3}$. Indicate what kind of unit input this is (i.e. step, ramp, or parabola). Furthermore, for this value of K:

(1) Calculate the damping ratio represented by the system poles,
(2) Calculate the natural frequency represnted by the system poles, and
(3) State whether this system is overdamped, underdamped, or critically damped.