Duke University

Edmund T. Pratt, Jr. School of Engineering

Controls Fall 2015

Test II

Michael R. Gustafson II

Name and NetID (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.

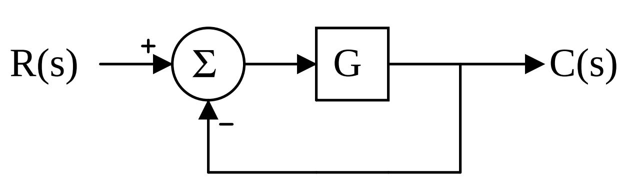
Please be sure to put each problem on its own page or pages - do *not* write answers to more than one problem on any piece of paper and do not use the back of a problem for work on a *different* problem. You will be turning in each of the problems independently. This cover page should be stapled to the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

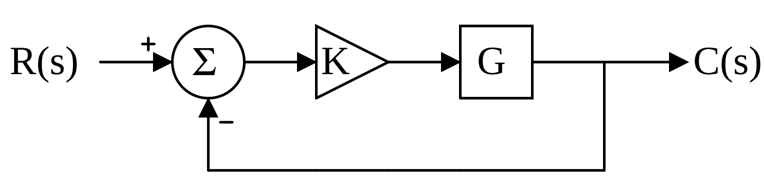
Make sure that your name *and* NetID are *clearly* written at the top of *every* page, just in case problem parts come loose in the shuffle. Make sure that the work you are submitting for an answer is clearly marked as such. Finally, when turning in the test, individually staple all the work for each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

If you create some intermediate variable that is defined in terms of other known variables, you do *not* need to back-substitute later. For instance, if you have some $R_{\text{eq}} = R_1 + R_2$, from that point forward, you can use R_{eq} without having to expand it out.

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.

Note: The following represent the block diagrams for unity feedback systems and unity feedback systems with cascaded proportional (gain) control, respectively:





Name (please print):
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Problem I: [30 pts.] Transient Characteristics

While your work for these problems may go on other pages, your final answers should go in the space provided below the prompts.

(1) Determine the steady-state value and the settling time of the step response for a system that has an overall transfer function of:

$$T_{\mathrm{w}}(s) = \frac{7}{s+3}$$

(2) Determine the steady-state value and the settling time of the step response for a unity feedback system that has a forward transfer function of:

$$G_{\mathrm{x}}(s) = \frac{7}{s+3}$$

(3) Determine the settling time and %OS of the step response for a system that has an overall transfer function of:

$$T_{\mathrm{y}}(s) = \frac{15}{s^2+3s+12}$$

(4) Determine the settling time and %OS of the step response for a unity feedback system that has a forward transfer function of:

$$G_{\mathrm{z}}(s) = \frac{15}{s^2+3s+12}$$

(5) A first-order system is found to have a step response with a steady state value of 3 and a settling time of 5 seconds. What is that system's overall transfer function?

(6) An underdamped second-order system is found to have a step response with a steady state value of 0.5; the transient includes a maximum 25% overshoot that occurs 2 seconds after the step input begins. What is that system's overall transfer function?

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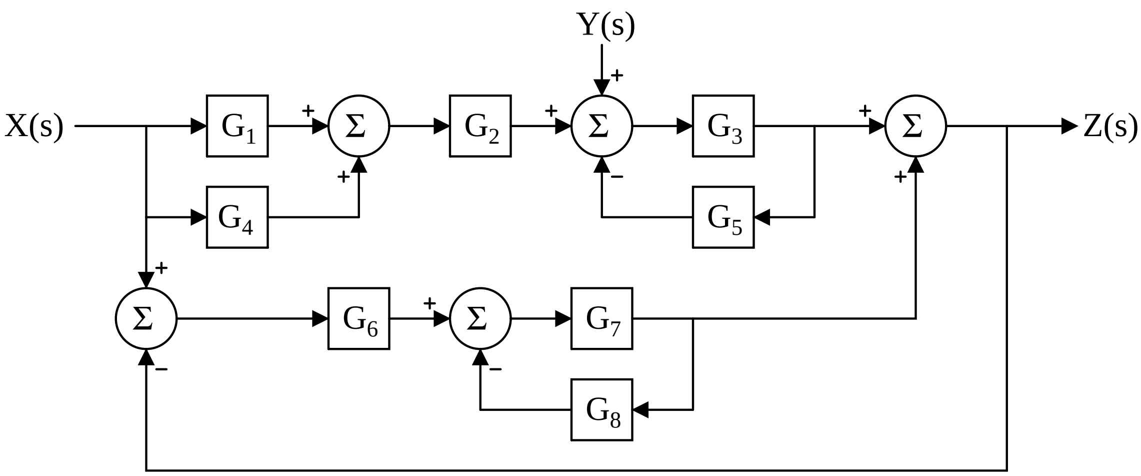
Problem II: [15 pts.] System Simplification

Given the system below:



(1) Clearly draw a signal flow diagram for the system. Be sure to indicate where each node is on the diagram - *especially* **X**, **Y**, and **Z**.

(2) Clearly use Mason's Rule to determine the overall transfer function $T_x(s) = Z(s)/X(s)$. 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.

(3) Clearly use Mason's Rule to determine the transfer function $T_y(s) = Z(s)/Y(s)$. 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. If you re-use any components defined for $T_x(s)$ above, simply state that.

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Problem III: [25 pts.] Stability

While your work for these problems - including the Routh arrays - may go on other pages, your final answers should go in the space provided below the prompts. Clearly use a Routh array to support your conclusions for the following problems:

(1) A unity feedback system has a forward transfer function of:

$$G_{\mathrm{w}}(s) = \frac{500}{s^3 + 28s^2 - 140s - 400}$$

How many left, right, and $j\omega$ poles does the overall system have?

(2) A system has an overall transfer function of:

$$T_{\mathrm{x}}(s) = \frac{30}{s^5 - 2s^4 - s^3 + 2s^2 - 6s + 12}$$

How many left, right, and $j\omega$ poles does the overall system have?

(3) A system has an overall transfer function of:

$$T_{\mathrm{y}}(s) = \frac{p}{s^3 + 5s^2 + (p+2)s + 3p - 8}$$

where p is some real-valued parameter. What are the values of p that produces a stable system?

(4) A unity feedback system has a controller K in cascade with a plant:

$$G_{\mathrm{z}}(s) = \frac{s^2 - 8s + 17}{s^2 + 12s + 20}$$

What are the values of K that produces a stable system? What value or values of K make the system marginally stable? For the case or cases where the system is marginally stable, what is the frequency of oscillation of the steady state step response?

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Problem IV: [30 pts.] Steady State Analysis

While your work for these problems may go on other pages, your final answers should go in the space provided below the prompts.

(1) A unity feedback system has a gain controller K in cascade with a plant:

$$G_{\mathrm{y}}(s) = \frac{5}{(s+2)(s+3)}$$

(a) What system type does this represent?

(b) Circle the appropriate statement or statements for each of the static error constants and line through the incorrect statements in the table below:

K_{p}	K_{v}	K_{a}
is 0	is 0	is 0
is ∞	is ∞	is ∞
is neither 0 nor ∞	is neither 0 nor ∞	is neither 0 nor ∞

(c) For any of the above where you circled "is neither 0 nor ∞" calculate the finite value as a function of K.

(d) For any of the above where you circled "is neither 0 nor ∞" find the gain K that would produce a position error of exactly 25%. Also determine the input signal for which that 25% error would represent an absolute position error of 2.

(e) What range of K makes the system overdamped?

(f) What value of K would produce an underdamped system with a 20% overshoot for its dominant poles?

(2) A system has an overall transfer function of:

$$T_{\mathrm{z}}(s) = \frac{20K(s+2)}{s^3+6s^2+(20K+13)s+40K}$$

(a) What system type does this represent?

(b) Circle the appropriate statement or statements for each of the static error constants and line through the incorrect statements in the table below:

K_{p}	K_{v}	K_{a}
is 0	is 0	is 0
is ∞	is ∞	is ∞
is neither 0 nor ∞	is neither 0 nor ∞	is neither 0 nor ∞

(c) For any of the above where you circled "is neither 0 nor ∞" calculate the finite value as a function of K.

(d) For any of the above where you circled "is neither 0 nor ∞" find the gain K that would produce a position error of exactly 25%. Also determine the input signal for which that 25% error would represent an absolute position error of 2.