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

ECE 141 Spring 2008

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

For each of these problems, there will be some groundwork in using or finding transfer functions for systems. Be sure to indicate which part of a problem you are answering and put your name on the paper. If you need extra pieces of paper, make sure that you only do work from one problem on a page - you will be turning in the problems as individual entities, much like the homework. Make sure your name and NET ID appear on *each page* and that you staple the relevant pages together before turning them in. Staple this signed cover page to the top of Problem I.

Instructions for Computer-Based Sections

All your files for this test will be placed in a directory on your OIT account. There are two scripts you will be running to set everything up. The first - `StartTest2` - will create a folder called `ECE141TEST2` in your account and then set the permissions such that I can look at the files. You *must* make sure all your scripts, worksheets, and graphs end up in this folder. The second - `EndTest2` - will send me a snapshot of the directory contents and lock the directory from further changes. After I receive the e-mail, I will copy the directory contents to another location. I will release the originals after the test has been returned.

Be sure to use the stated names for files in those problems requiring computational solutions. Also, if you use MATLAB or Maple to generate answers for problems, you should write a script or worksheet called `ScratchProblemN.whatever` where N is the problem number and `whatever` is the appropriate extension for the program (generally `.m`, `.mw`, or `.mws`).

To run the `StartTest2` script, log into your UNIX account and type:

```
~mrg/public/ECE141S08/StartTest2
```

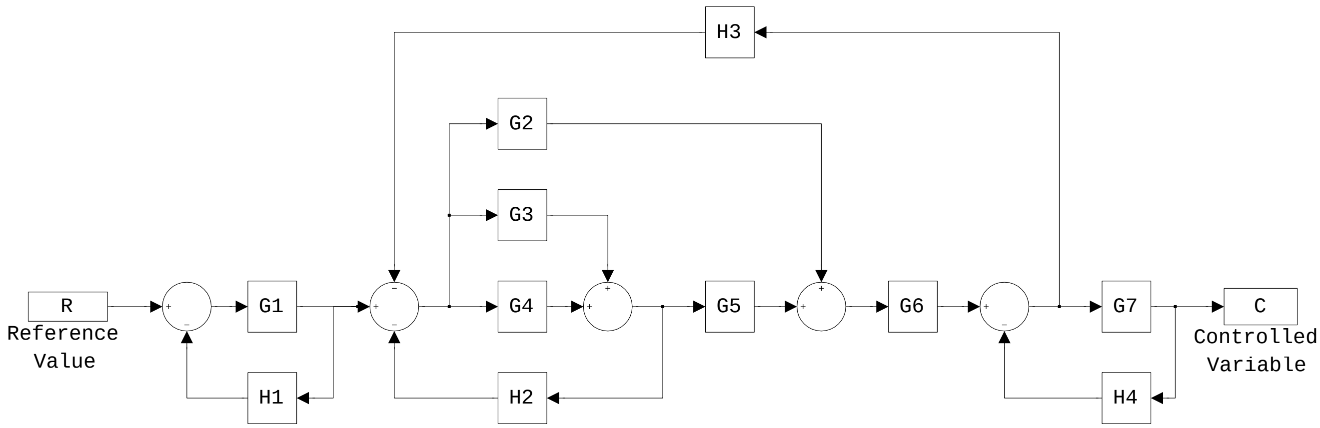
Similarly, when you are finished and ready to lock your directory, type:

```
~mrg/public/ECE141S08/EndTest2
```

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

Problem I: [15 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 $T(s) = C(s)/R(s)$. Remember that once you have defined a particular path or loop function, you do *not* need to substitute in later.

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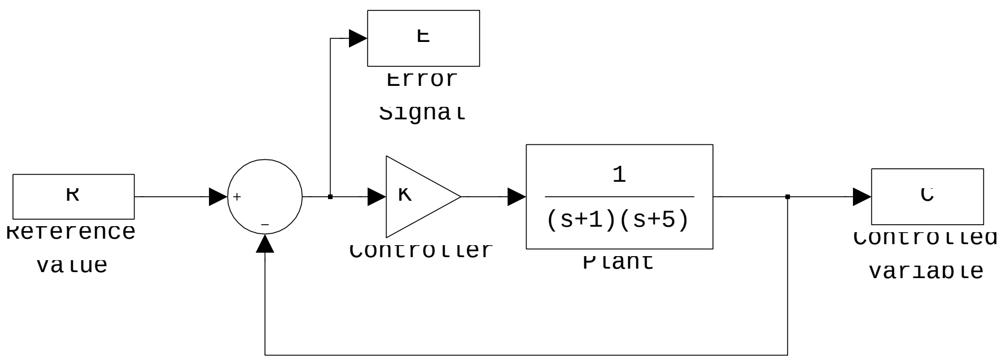
Problem II: [30 pts.] System Design I

This problem works with a system that has the following block diagram:



For this system:

(a) Determine the overall transfer function $T = \frac{C}{R}$

(b) Determine the values of K that keep the system stable. Be sure to provide supporting documentation.

(c) Is there a value of K for which the system is marginally stable? If there is, find it and also find the frequency of oscillation for the marginally stable system.

(d) For what value of K is the system critically damped?

(e) For what values of K is the system underdamped?

(f) Assuming K is such that the system is underdamped, determine ω_n and ζ as functions of K.

(g) The system is found to be underdamped when $K = 10$. Determine where the poles are for this value of K.

(h) Calculate estimates for the rise time, peak time, %OS, and settling time when $K = 10$. How much confidence do you have in your predictions, and why?

(i) Assuming $K > 0$: with respect to steady state error, what type of system is this, and why?

(j) Assuming $K > 0$: which is the appropriate finite static error constant, and what is its value as a function of K?

(k) Assuming $K > 0$: what is the steady state value of the error signal e, as a function of K, when the input is:

(a) $r(t) = 10\, u(t)$

(b) $r(t) = 10\, t\, u(t)$

(c) $r(t) = 10\, t^2\, u(t)$

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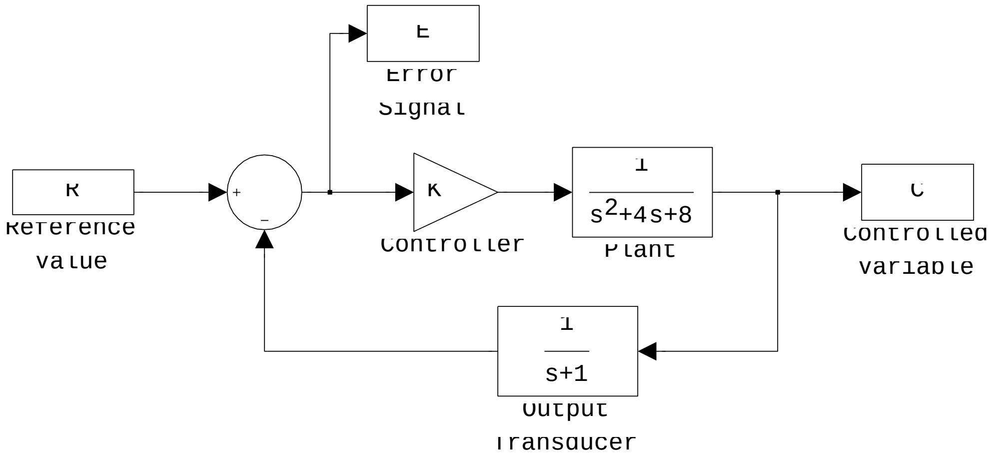
Problem III: [25 pts.] System Design II

This problem works with a system that has the following block diagram:



For this system:

(a) Determine the overall transfer function $T = \frac{C}{R}$

(b) Determine the values of K that keep the system stable. Be sure to provide supporting documentation.

(c) Is there a value of K for which the system is marginally stable? If there is, find it and also find the frequency of oscillation for the marginally stable system.

(d) The system is found to be stable when $K = 15$. Determine where the poles are for this value of K, then predict the peak time and %OS for this particular gain. How much confidence do you have in your predictions, and why?

(e) With respect to steady state error: what type of system is this, and why?

(f) What is the appropriate finite static error constant, and what is its value as a function of K?

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Problem IV: [30 pts.] System Design III

A system with gain control K in the forward path is found to have an overall transfer function of:

$$T = \frac{K(s^2 - 4s + 3)}{s^3 + 8s^2 + 15s + Ks^2 - 4Ks + 3K}$$

For this system:

(a) Determine the values of K that keep the system stable. Be sure to provide supporting documentation.

(b) Is there a value of K for which the system is marginally stable? If there is, find it and also find the frequency of oscillation for the marginally stable system.

(c) With respect to steady state error: what type of system is this, and why?

(d) What is the appropriate finite static error constant, and what is its value as a function of K?

(e) What is the steady state value of the error signal e when the input is:

- (a) $r(t) = 3\,u(t)$
- (b) $r(t) = 3\,t\,u(t)$
- (c) $r(t) = 3\,t^2\,u(t)$

(f) The system is shown to be stable when $K = 2$. Determine where the poles are for this value of K, then predict the peak time and %OS for this particular gain. How much confidence do you have in your predictions, and why?

(g) Use MATLAB to simulate the output of this system for 20 seconds when the gain is 2 and the input is a unit step function. Determine the simulated peak time and %OS graphically and report this on the test. Save the code for this to a file called `Sys3step.m` and save the plot as a PostScript file using the command:

```
print -deps Sys3StepPlot
```

(h) Use MATLAB to simulate the output of this system for 20 seconds when the gain is 2 and the input is a unit ramp ($r(t) = t\,u(t)$) function. Save the code for this to a file called `Sys3ramp.m` and save the plot as a PostScript file using the command:

```
print -deps Sys3RampPlot
```