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

ECE 141 Spring 2006

# 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:________________________________________

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## Problem I: [10 pts.] Pole Location

Use a Routh table to determine how many poles of the following system $T(s)$ are in the left-half plane, how many are in the right-half plane, and how many are on the $j\omega$ axis. Briefly explain how you determined your answer. *Note:* merely solving for the roots and stating where they are will give you no credit.

$$T(s) = \frac{C(s)}{R(s)} = \frac{s^2+3s+2}{s^7+2s^6-2s^5+2s^4+6s^2-9s}$$

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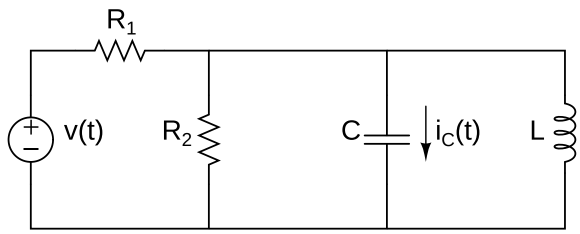
## Problem II: [15 pts.] State Variables

Given the circuit below,




Assuming the voltage source $v(t)$ is the input and the current through the capacitor $i_C(t)$ is the output, write the system using a state equation. Be sure to indicate what your states are and present the final answer in matrix form.

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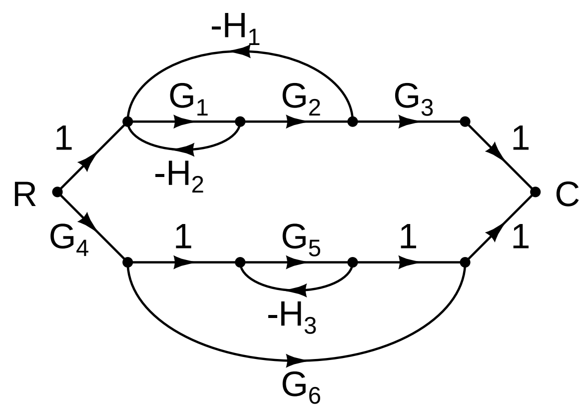
## Problem III: [20 pts.] Signal Flow and Mason's Rule

Given the signal flow diagram below:




use Mason's rule (showing your work clearly) to determine the transfer function

$$T(s) = \frac{C(s)}{R(s)}$$

Do not multiply terms out (please!).

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## Problem IV: [25 pts.] Stability

A standard negative feedback system has the following parameters:

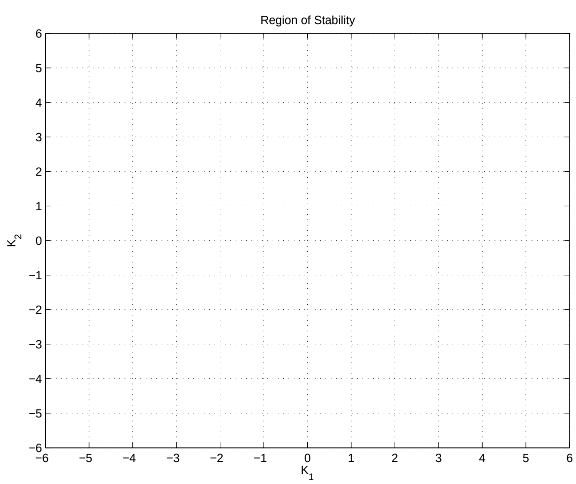
$$G(s) = \frac{1}{s^4 + 4s^3 + 3s^2 + 4s + 4} \qquad\qquad H(s) = K_1 s^2 + K_2$$

*(a)* Determine the values of $K_1$ and $K_2$ for which the system will be stable. *Note:* one of the equations will require both variables.

*(b)* On the graph below, shade in the area that describes values of $K_1$ and $K_2$ that would present a stable system. Note that the borders of this area will represent some form of marginal stability.

*(c)* Assuming that $K_1 = 0$, determine the value of $K_2$ that will cause marginal stability for a non-trivial system, then determine the frequency of oscillation for that value of $K_2$.

*(d)* Assuming that $K_2 = 0$, determine the value of $K_1$ that will cause marginal stability for a non-trivial system, then determine the frequency of oscillation for that value of $K_1$.



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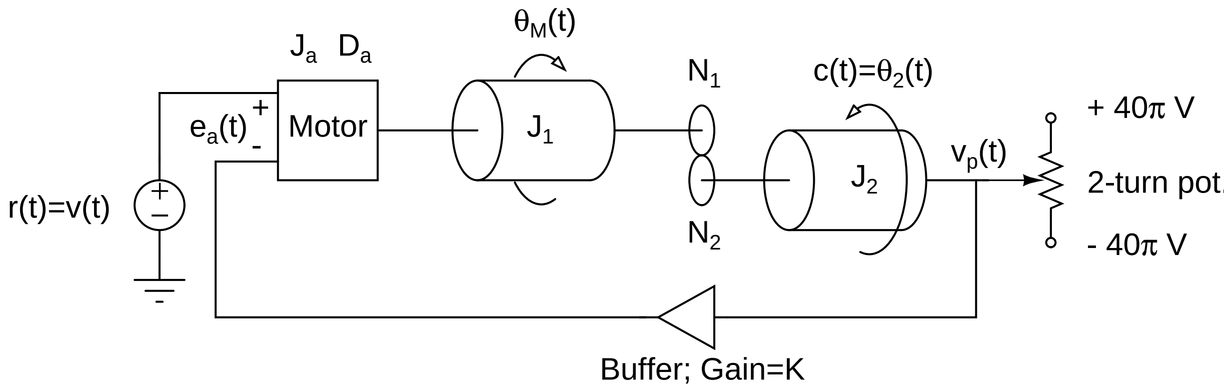
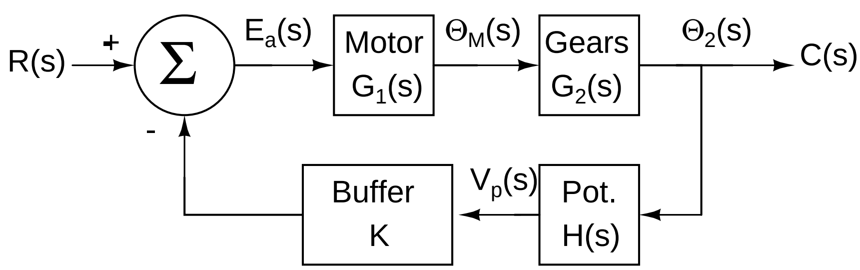
## Problem V: [30 pts.] Electromechanical Systems

Given the system below (represented both as a model and a block diagram):




Assuming $K_t/R_a$=8, $K_b = 0.125$, $J_a = 1$, $J_1 = 1$, $J_2$=200, $N_1$=1, $N_2$=10, $D_a$=3:

*(a)* Determine the following transfer functions:

**(1)** Motor: $G_1(s) = \frac{\Theta_M(s)}{E_a(s)}$

**(2)** Gears: $G_2(s) = \frac{\Theta_2(s)}{\Theta_M(s)}$

**(3)** Potentiometer: $H(s) = \frac{V_p(s)}{\Theta_2(s)}$

*(b)* Determine the overall transfer function, $T(s) = \frac{C(s)}{R(s)}$.

*(c)* Determine the values of buffer gain $K$ that will yield a stable system.

*(d)* Assuming $r(t) = u(t)$ V and $K$=1, determine the settling time, rise time, natural frequency, damping ratio, and %OS for the output.

*(e)* Assuming you want a 10% OS, what value of $K$ should be used?