Electrical Engineering 4CL4: Control System Design

Day Class — Instructor: Dr. I. C. BRUCE
Duration of Examination: 1.5 Hours
McMaster University Midterm Examination — March, 2004

This examination paper includes twelve (12) pages and six (6) questions. You are responsible for ensuring that your copy of the paper is complete. Bring any discrepancy to the attention of your invigilator.

Special Instructions: Use of Casio *fx*-991 calculator only is allowed.
Each question is worth 20 points.
All six (6) questions may be answered, but the maximum total mark is capped at 100 points.
Some equations and tables that may assist you are provided on pages 3–12.

1. A *closed-loop* controller is preferable to an *open-loop* controller for most control problems.
   a. Explain why this is the case.
   b. List under what conditions an *open-loop* controller might be acceptable, and list the advantages of using an open-loop controller as compared to a closed-loop controller in such a case. **(20 pts)**

2. The dynamics of a system are described by the differential equation:

$$\frac{d^3x(t)}{dt^3}+10\frac{d^2x(t)}{dt^2}+31\frac{dx(t)}{dt}+30x(t)=e^{-x(t)}.$$

   a. Linearize this equation for $x(t)$ near 0.
   b. Express the linearized equation from part a. in state-space form, assuming that the output of the state-space model is the variable $x(t)$. **(20 pts)**

3. For a one-d.o.f., unity-feedback control system with the controller and plant transfer functions:

$$C(s)=\frac{K(s+6)}{s(s+1)} \qquad \text{and} \qquad G_o(s)=\frac{1}{s+3},$$

determine the range of values for K that ensures stability. **(20 pts)**

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4. Consider a one-d.o.f., unity-feedback control system with the controller and plant transfer functions:

$$C(s) = 5 \qquad \text{and} \qquad G_o(s) = \frac{1}{(s+3)(s+6)}.$$

If the system has the input disturbance $d_i(t) = 5\sin(6t)$, what does this input disturbance contribute to the plant output $y(t)$ in the steady state? **(20 pts)**

5. A system has the transfer function:

$$H(s) = \frac{-2s+1}{s^2+2s+1}.$$

a. Will the *step response* of this system exhibit undershoot or overshoot? Explain your answer in terms of the locations of the poles and zeros of the transfer function.

b. If the step response does exhibit undershoot or overshoot, find both the *magnitude* and the *time* of maximum undershoot or overshoot. **(20 pts)**

6. The Robust Stability Theorem, as given on page 10 of this exam paper, describes a sufficient condition for the stability of a true feedback control loop in the presence of a plant modeling error. In some situations, the model used for the controller in the design process is somewhat different from the controller than is actually implemented in the true feedback control loop. (For example, a digital PID controller may be used to approximate the behaviour of an analog PID controller that was used in the design process.) Such differences may be considered controller modeling errors.

Describe how you might adapt the Robust Stability Theorem so as to give a sufficient condition for the stability of a true feedback control loop in the presence of a controller modeling error instead of a plant modeling error. **(20 pts)**

THE END

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