MEL740 Instrumentation and Automatic Control

2 hr Major 5/05/2007.

One A4 size paper with your own handwriting allowed in the exam hall

Q1 Apply Routh's stability criterion to determine the range of K for stability of the characteristic equation $s^4 + s^3 + Ks^2 + s + 1 = 0$. (6)

Q2 A capacitor of nominal value C at gap length d is used to measure displacement over a range $0.75d$ to $1.25d$.

a) Sketeh the change in eapacitance as a fraction of the nominal capacitance against x/d where x is the displacement over the specified range.
b) Derive the equation for the line which denotes the endpoint fit over the range.
c) What is the nonlinearity error using an endpoint fit? (2 + 2 + 2)

Q3 A second order system has 12% overshoot and a settling time of 0.6 seconds. Find the transfer function for the system. (6)

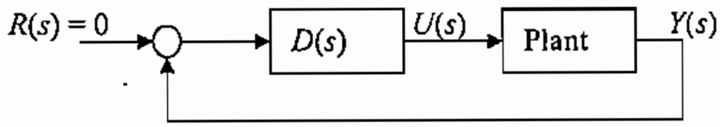
Q4 A cruise eontrol is used to drive a ear at a set specd without the accelerator being manipulated by the driver. Consider a car of mass 1000 kg which requires a traction force (f)of 500 N to overcome the aerodynamic drag (proportional to the velocity, b) at a steady speed of 10 m/s.

$$m\dot{v} + bv = f$$

i) What is the plant transfer function $\dfrac{V(s)}{F(s)}$?
ii) Draw a block diagram showing the plant, with force as the input and velocity as the output for a unity feedback system with a cascaded gain of K.
iii) Sketch the root locus for the system.
iv) The task is to design a controller such that the rise time is limited to 5 s and %overshoot to 10%. Show the boundaries of the region on the root locus where these criterion are satisfied.
v) Determine a reasonably small value of K, the proportional control that satisfies thc design condition above using the root locus.
vi) What is the steady state error to a step input?
vii) Sketch the step response and determine if the design conditions have been met with respect to rise time and overshoot.
viii) Steady state error is to be less that 2%. Design a lag controller (pole-zero) to reduce the SS error.
ix) Design for appropriate gain and state the value of the gain.
x) Verify if the second order assumption is valid.
xi) Plot the transient response to a step input of the modified system.
xii) For the cruise control problem, the output is very clearly the velocity of the car which has to be regulated. What is the input?

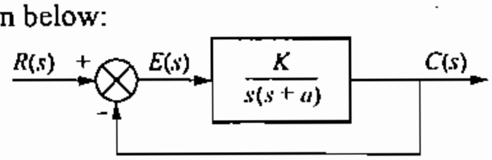
(1 + 1 + 2 + 2 + 1 + 1 + 2 + 2 + 1 + 1 + 1 + 1)

Q5. A regulator system (reference input = 0 for this problem) has the plant $\dfrac{Y(s)}{U(s)} = \dfrac{1}{s^2}$



a) Taking $x_1 = y$ and $x_2 = \dot{y}$ as state variables, derive the state variable model of the plant.
b) Compute k such that $u = \mathbf{k}\mathbf{x}$ gives closed-loop characteristic roots with $\omega_n = 1$, $\zeta = \sqrt{2}/2$
c) Design a full-order observer that estimates x_1 and x_2 given measurement of x_1. Pick the characteristic roots of the state error equation with $\omega_n = 5$, $\zeta = 0.5$.
d) Find the transfer function of the compensator, D(s) obtained by combining (b) and (c).
e) Why is $D(s)$ be different from $-\dfrac{Y(s)}{U(s)}$ (2 + 4 + 4 + 6 + 1)

Q6. For the system shown below:



a) Determine the sensitivity of the steady-state error to parameter a if a step input is given.
b) Plot the sensitivity as a function of the parameter a. (6 + 3)