EE 141 – Final

03/21/2014
Duration: 2 hours and 50 minutes

The final is closed book and closed lecture notes. No calculators.
You can use a single page of handwritten notes.
Please carefully justify all your answers.

Problem 1: The linearized equations describing the vertical motion of a hot-air balloon are given by:

$$\begin{aligned} \tau_1 \dot{T} &= -T + u \\ \tau_2 \ddot{z} + \dot{z} &= aT + w \end{aligned}$$

where T represents the hot-air temperature, z represents the altitude of the balloon, u represents the burner heating rate, and w is the wind speed. In what follows we will assume that $w = 0$ and to simplify the computations the parameters τ_1, τ_2, and a will assume the following unrealistic values:

$$\tau_1 = 0.02 \qquad \tau_2 = 0.5 \qquad a = 10$$

1. Compute the transfer function from the input u to the balloon's altitude.
2. Design a controller for a unity-feedback loop so that the step response has no overshoot and the rise time is no greater than 0.9 seconds.

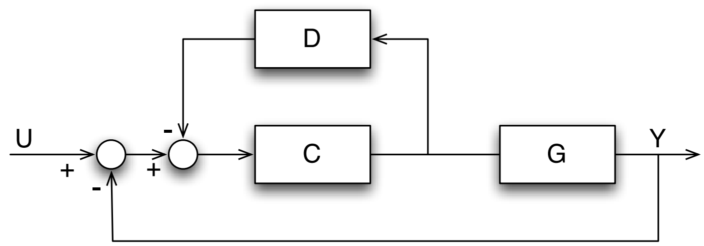

Figure 1: Block diagram for Problem 2.

Problem 2

1. Compute the transfer function $H(s) = Y(s)/U(s)$.
2. Assume that:

$$D(s) = 0, \quad C(s) = 10^6, \quad G(s) = \frac{s+1}{(s^2+10s+100)(s+100)^2},$$

   and sketch the bode plot for the open-loop transfer function.
3. Knowing that H is a stable transfer function for $D(s) = 0$ and $C(s) = 10^6$, design $D(s)$ so that the gain margin becomes 30dB.

Problem 3: Consider the following closed-loop transfer function:

$$G(s) = \frac{s^3 + 6s^2 - 4s - 24}{s^3 + (k+6)s^2 + (4k-4)s + 5k - 24}.$$

1. Sketch the root locus with respect to the parameter k knowing that one of the zeros is located at -6.
2. Mark on your root-locus where you would place the closed-loop poles to minimize the settling time while ensuring there is no overshoot?
3. Which value of k would you use to place one pole at -1?