NE 696: Nuclear Systems Design
Final Examination

Open Books and Notes Monday, May 11, 1992

1. Consider a source-free reactor operating at a steady power level of P_o. At $t = 0$, the reactivity is varied in such a way as to cause the reactor power to exponentially decrease as

$$P(t) = P_o \exp(-\lambda t), \qquad t > 0.$$

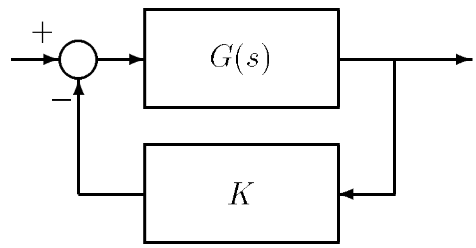
Here λ is the decay constant for the delayed neutrons (assume a one delayed-neutron group in your analysis). Find and sketch the reactivity as a function of time that would produce this power transient. Neglect any feedback effects. *(15 points)*

2. Sketch the Bode plots for both positive and negative values of K for the following transfer function

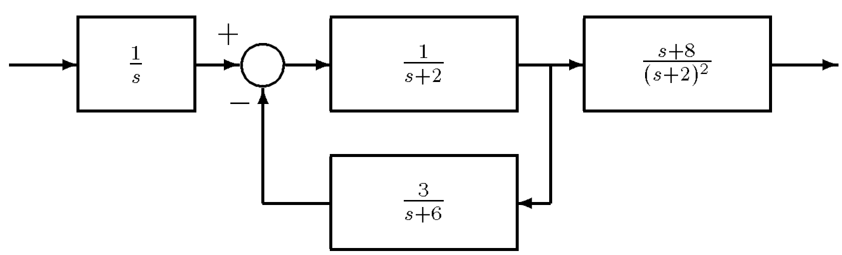
$$G(s)H(s) = \frac{K(s+1)(s+100)}{(s+10)^2(s+1000)}.$$

Sketch two feedback systems for which this would be the closed-loop transfer function. *(10 points)*

3. Consider the following system with a constant feedback gain $K(>0)$



in which the subsystem denoted by $G(s)$ is constructed as



Sketch the root locus diagram for this system and estimate the value of K for the onset of instability. *(20 points)*

4. Construct the Nyquist diagram for and determine the stability of a system with negative feedback for which the closed-loop transfer function is given by

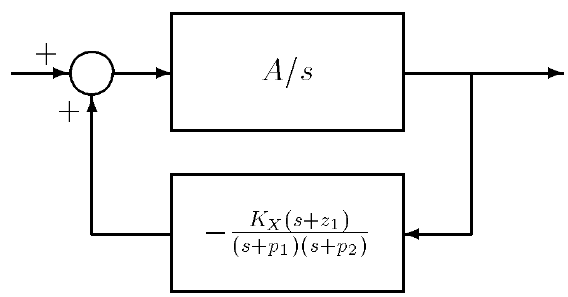
$$G(s)H(s) = \frac{100\,(s+10)}{s^2(s+100)}.$$

Is this system stable? *(15 points)*

5. Consider a reactor with xenon feedback but for which there is no temperature feedback. (You knew we had to have a xenon problem).

   (a) Show that for low frequencies the zero power transfer function $Z(s) \simeq A/s$ where the constant $A > 0$. Obtain an expression for A. *(4 points)*

   (b) With the xenon reactivity feedback transfer function derived in class, the reactor at low frequencies can thus be modeled as



   What is the characteristic equation for this system? *(4 points)*

   (c) Construct the Routh array for this system, and derive a criterion on AK_X for stability. *(8 points)*

   (d) Sketch root locus diagrams for this system as AK_X varies in magnitude, one for $\phi_o < (\phi_o)_{crit}$, and one for $\phi_o < (\phi_o)_{crit}$. Indicate how the root locus diagrams change as ϕ_o increases. What can you say about the stability of this reactor from each diagram? *(8 points)*

   (e) Sketch pairs of Bode plots of the open-loop transfer function for this system, one pair for $\phi_o < (\phi_o)_{crit}$, and one pair for $\phi_o < (\phi_o)_{crit}$. *(8 points)*

   (f) Sketch Nyquist diagrams for this system, one for $\phi_o < (\phi_o)_{crit}$, and one for $\phi_o < (\phi_o)_{crit}$. What can you say about the stability of this reactor from each diagram? *(8 points)*