NE-696: NUCLEAR SYSTEMS DESIGN
Final Examination

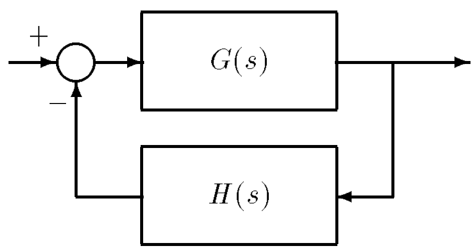
May 8, 1993

Open books and Notes

1. Consider a reactor with a constant source S_o operating at a steady-state power P_o for $t < 0$. You are to design a time-dependent reactivity insertion beginning at $t = 0$ so that the power increases in a purely exponential manner, i.e., $P(t) = P_o\, e^{\alpha t},\ t > 0,\ \alpha > 0$. At the same time the power increases, the source is to be exponentially removed from the core, i.e., $S(t) = S_o\, e^{-\beta t},\ t > 0,\ \beta > 0$.

   For simplicity, assume a one delayed-neutron group model. Derive an expression for the reactivity $k(t)$ and sketch the reactivity transient.

2. Consider the following closed-loop feedback system.



   For this system, the open-loop transfer function is

$$G(s)H(s) = \frac{K(s+a)}{s(s+b)(s+c)(s+d)}, \qquad 0 < a < b < c < d, \qquad K > 0$$

   (a) Sketch the root locus diagram for this system, and determine if the system is stable, unstable, or conditionally stable.

   (b) Sketch Bode gain and phase plots for the open loop transfer function.

   (c) Sketch the Nyquist diagram for the closed-loop system.

   (d) From the characteristic equation for this system, derive an expression for the threshold value of K at which the system becomes unstable. For the special case $a = 1,\ b = 2,\ c = 3$ and $d = 4$, what is the value of this threshold K value?

3. Consider a negative feedback system, such as that of Problem 2, in which the closed-loop transfer function is given by

$$G(s)H(s) = \frac{K\, e^{-s\tau}}{(s+a)(s+b)}, \qquad a, b, \tau, K > 0$$

   (a) Sketch the Nyquist diagram for this system

   (b) You should find that this system is conditionally stable. Explain how you would find the threshold value of K at which the system would become unstable.