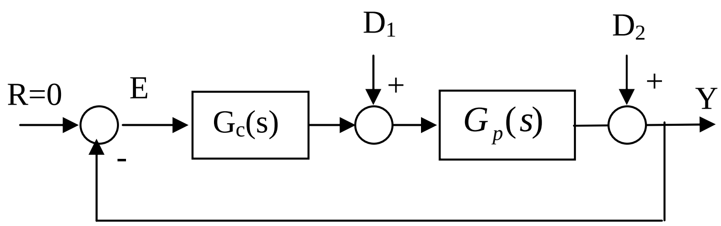
Department of Mechanical Engineering
Massachusetts Institute of Technology
2.14 Analysis and Design of Feedback Control Systems
Fall 2004
Assignment #5
Distributed Wednesday October 13
Due: **Wednesday, October 20** by 5pm in 35-231 Drop Box

Reading: Reading:
Nise 7.1-7.7 (Error)
Chapter 8 (Root locus)

Problem 1

We used the final value theorem to construct a table of errors of a closed loop system with respect to a reference input. Now we want to look at the effect of errors from disturbance.



a) Derive the disturbance – error transfer functions $G_{D_1} = \dfrac{E(s)}{D_1(s)}$ and $G_{D_2} = \dfrac{E(s)}{D_2(s)}$

Now consider a step disturbance for D_2 with D_1= 0

a) What is the expected steady state error if both G_c and G_p are type 0
b) What is the expected steady state error if only G_c is type 1?
c) What is the expected steady state error if only G_p is type 1?

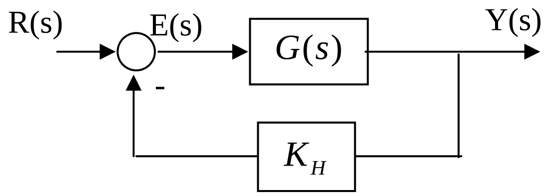
Now reverse the situation and consider a step disturbance for D_1 with D_2= 0

d) What is the expected steady state error if both G_c and G_p are type 0
e) What is the expected steady state error if only G_c is type 1?
f) What is the expected steady state error if only G_p is type 1?

Based on this result and what you know from the error to the reference input
g) State a general rule about the importance of the location of the free integrator in the loop relative to the input of concern.

Problem 2

For the following system:



a) Derive an expression for the input – output error (R-Y) for a given input R(s). (This is sometimes referred to as the "true" error. How does this compare to the case where H(s) = 1?

b) Now assume that G(s) has a steady – stated gain of K_{DC} and is of type 0. Can you find a value of K_H that will make the true error zero?

Problem 3

Nise 8-1 and 8-2

Problem 4

Nise 8-32 (NB: for part d) use matlab to get the step response and compare to a "dominant" 2^{nd} order system assumption from part a)

- Please do not use MATLAB, but instead provide an accurate sketch on graph paper.

Problem 5

Nise 8.43 – You may use matlab and RLTOOL for this question. If you do please provide step response plots.

Problem 6

Returning to the rudder problem, let's see what the root locus tells us about the effect of the zero at s=+z

From the last assignement:

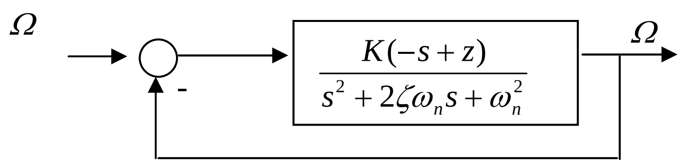
Many ships (and even small boats) exhibit somewhat odd behavior when the rudder angle is suddenly changed This can be rmodeled using linear systems theory as follows:

$$G(s) = \frac{\Omega(s)}{\phi(s)} = \frac{K(-s+z)}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

where Ω is the turning rate in rad/sec and ϕ is the rudder angle in radians .

Assume $\zeta=2$, ω =1 and $z = 1$.

and we want to design a controller gain for the system:



a) Sketch a root locus for this system using the rules given in class. (Be careful is blindly following the rules!)

b) Graphically, find the gain and point of instabiliy and compare it to the value you got last week (it you remember it).

c) Again graphically, find the gain that gives closed-loop roots with damping = 0.707