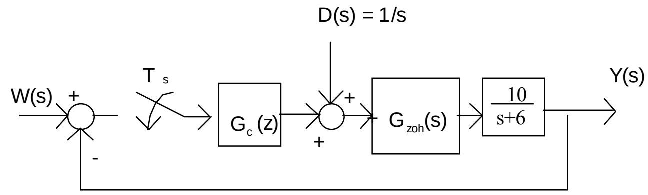
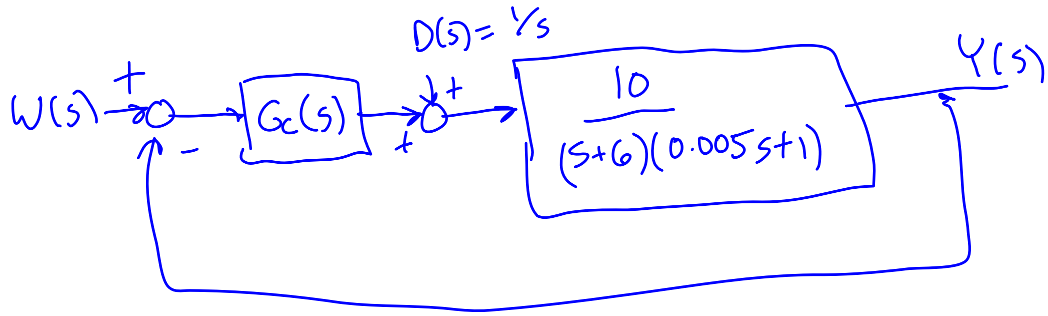
Due Wednesday, February 20 EE/MFS599 HW#8



T_s = 10 msec

1. a) Re-write the problem so it is completely in the s-domain

Solution: Gzoh = 1/[(Ts/2)s+1] = 1/[0.005s+1]



b) Make the disturbance zero and let Gc(s) = K. Find the sensitivity of Y(s)/W(s) to the gain K for both the open-loop and unity feedback case when the nominal value is K=100 and the input is a unit step.

Open-loop: $S_K^{Y/W} = \frac{\partial Y/W}{\partial K}\cdot\frac{K}{Y/W}\Big|_{Nom} = G_{ZOH}G\cdot\frac{K}{KG_{ZOH}G} = 100\%$

Closed-loop $S_K^{Y/W} = \frac{\partial Y/W}{\partial K}\cdot\frac{K}{Y/W} = \frac{\partial}{\partial K}\frac{KG_{ZOH}G}{1+KG_{ZOH}G}\cdot\frac{K}{\frac{KG_{ZOH}}{1+KG_{ZOH}G}}\Big|_{Nom}$

$= \frac{G_{ZOH}G(1+KG_{ZOH}G)-G_{ZOH}(KG_{ZOH}G)}{(1+KG_{ZOH}G)^2}\cdot\frac{K}{\frac{KG_{ZOH}G}{1+KG_{ZOH}G}} = \frac{1}{1+KG_{ZOH}G}\Big|_{Nom}$

For the nominal case of $s=0$ and $K=100$, $S_K^{Y/W} = \frac{1}{1+100(\frac{10}{6})} = 0.6\%$

c) Predict how the steady-state response will change if K increases by 10% for both the open-loop and closed-loop configurations.

Open-loop: 10% change in K will cause a 10% change in steady-state response

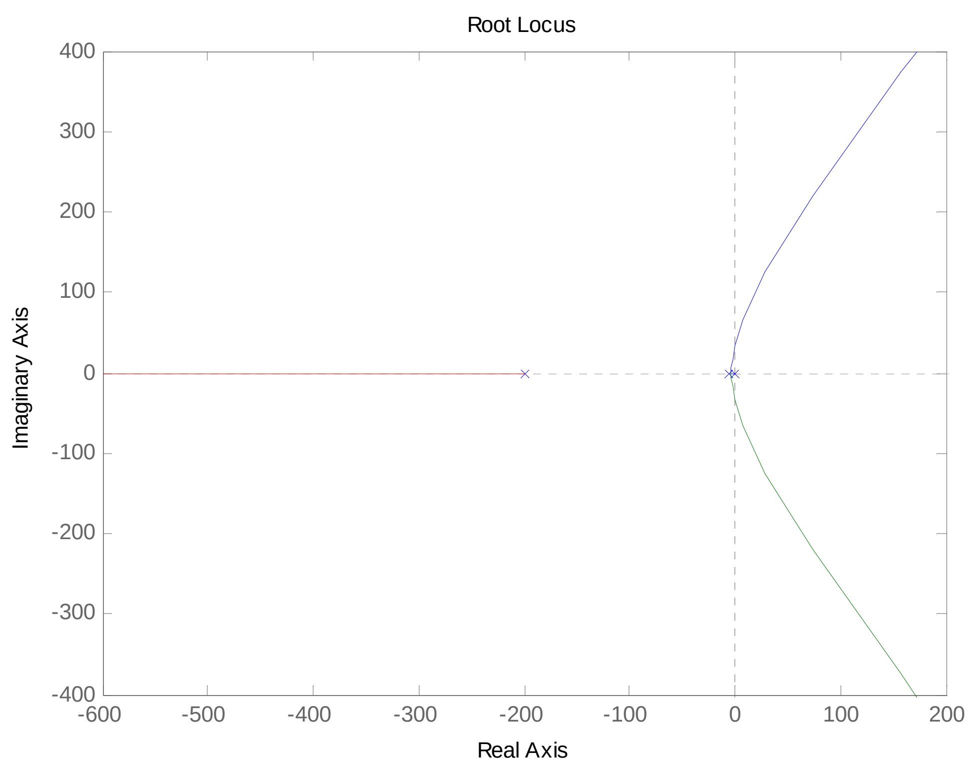
0.06% change

Closed-Loop: 10% change in K will cause a

in Steady-State

2. a) Let the disturbance be a unit step (constant). Design a <u>Robust</u> digital compensator, Gc(z), which will meet the following specifications
    1. Closed-loop system is stable
    2. t_s due to a step is less than 2 seconds
    3. e_{ss} due to a step is zero
    4. $M_p < 5\%$ (remember Mohannad's 4.32% means $\zeta = 0.707$
    5. Steady-state error due to the constant disturbance d(t)=u(t) is minimized

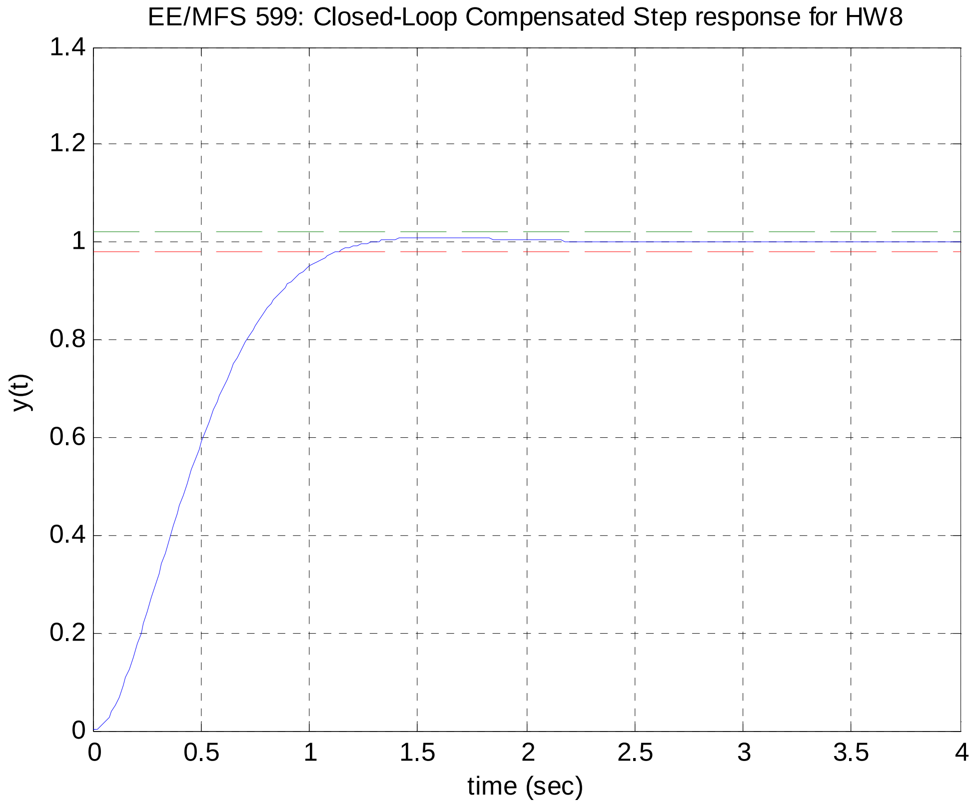
We should address the disturbance and ess specs first. We currently have a Type 0 system. We need a minimum of a Type 1 system to meet ess specs. We also need an integrator to reject the disturbance. We should try Gc(s) = num(s)/s. If we lump the 1/s term in with GzohG(s) to obtain 10/(s(s+6)(0.005s+1)) and draw the root locus, we find:



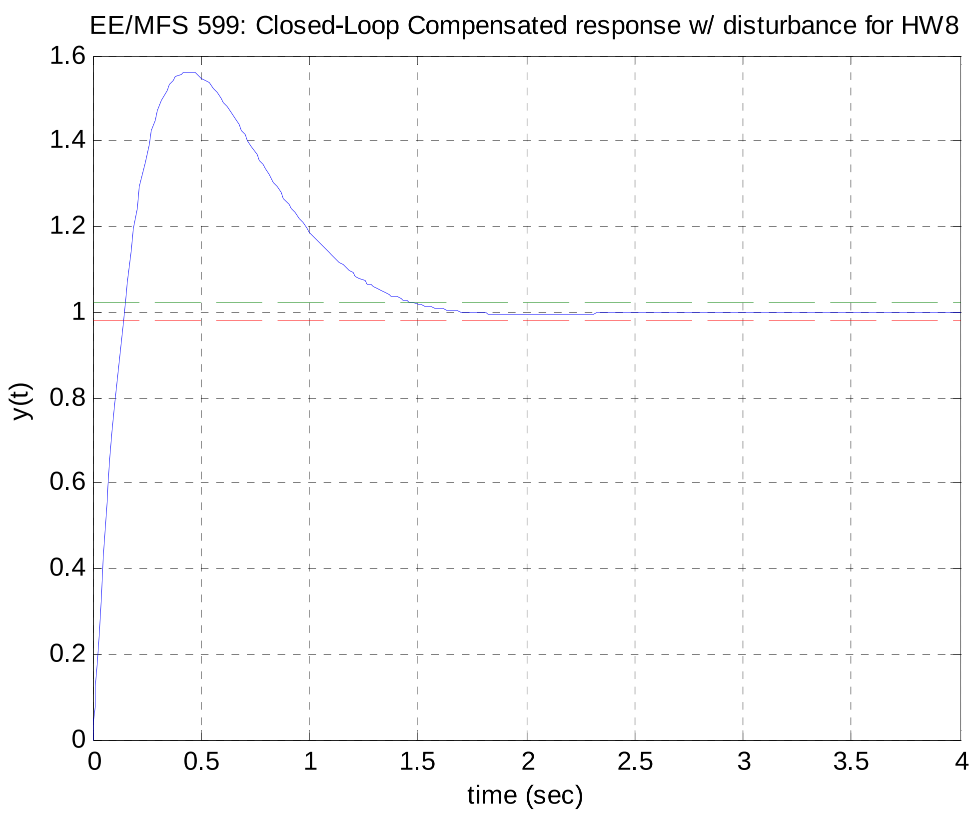
From the transient specifications, we have s1 = -3+j2 will easily meet the specifications. We note that the root locus passes very close to these dominant poles. We can let the num(s) = K and find K from K=-1/(GzohG(s1)/s1) = 1.28. Thus, a compensator which will meet all the above requirements is Gc = 1.28/s

b) Use Simulink to verify your design (in the s-plane using Gc(s)). Initially, set the disturbance to zero and measure your transient (t_s and M_p) and steady-state error specs. Then, set the disturbance to a unit step and verify that its effect is negligible

Ans: Here is the compensated step response with no disturbance. As you can see, the system settles in about 1.2 seconds and has less than 2% over shoot (nice response!)

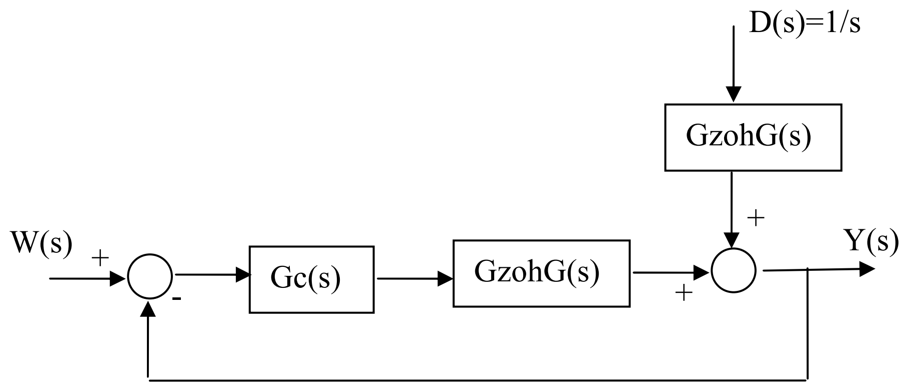


Here is the response with the step disturbance turned on. As you can see, the system rejects the disturbance in steady-state and returns to a final value of 1.

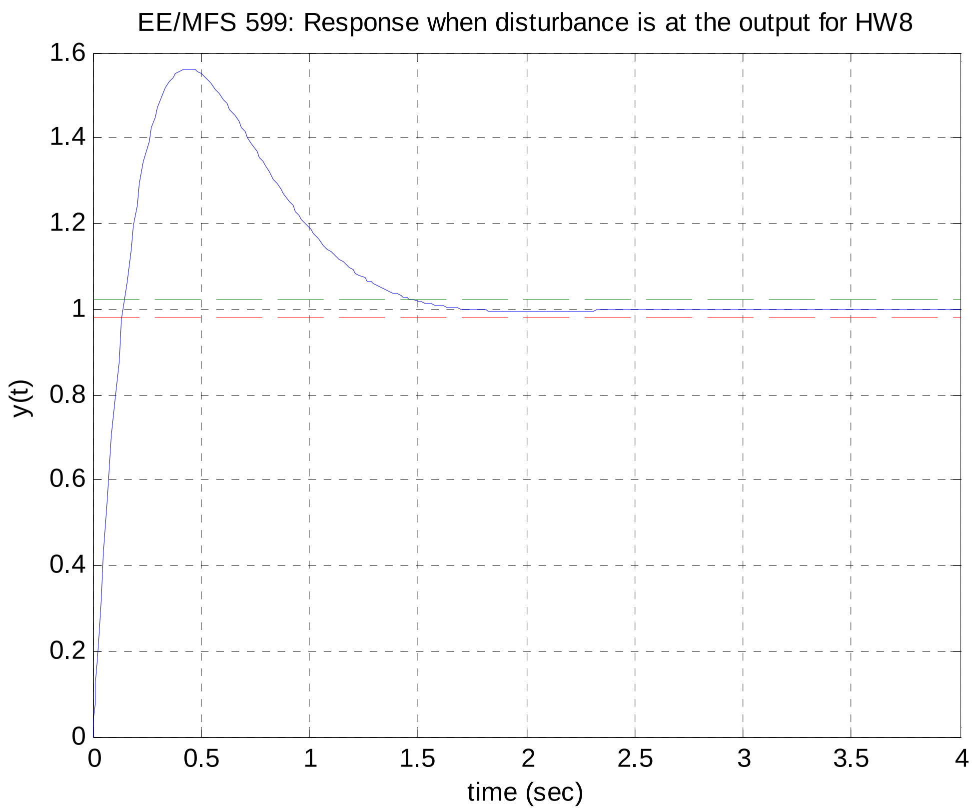


c) Your book discusses the case when your disturbance occurs at the output. I made the statement in class that the model we use is the same as the model in the book if we simply put GzohG(s) as a pre-filter to the output disturbance. Implement the following diagram on

Simulink using your values of GzohG(s) and Gc(s) to verify the output is the same as in part b)



Ans: The following is the Simulink simulation for the above block diagram. It is identical to the response we obtained in part c)



d) Find Gc(z) using any method you wish (since there is no derivative term, we can use the bilinear transform).

Gc(z) = 1.28/(2(z-1)/[Ts(z+1)] = 25,600 [z-1]/[z+1] using the bilinear transformation