Computer Exercise 1
EL2520 Control Theory and Practice

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Disturbance attenuation

How should the extra poles be chosen in exercise 4.2.1? Motivate!

Control action is needed at least for frequencies where $|G_d(j\omega)| > 1$, i.e. $\omega < \omega_c(\text{for } G_d(s)) = 9.95\text{rad/s}$, in order for disturbances to be attenuated. Therefore, we design $\omega_c = 10$ so that the open loop $|L(jw)| > 1$ at the same frequencies where $|Gd(jw)| > 1$. Then we need to design F_y such that $L(s) \approx \frac{\omega_c}{s}$. However, this will lead to the unrealizable controller due to the fact that the order of the denominator is smaller than that of the numerator. Therefore, we have to add poles at least fulfilling the requirement of "$n(\text{poles}) - n(\text{zeros}) > 0$", in order to let the controller become proper and achievable in real life. Therefore, we need to add at least 3 poles. The value of these three poles should be larger than the cross-over frequency ω_c. Therefore we chose them as $p_1 = p_2 = p_3 = 80\omega_c$, making them the same value for the sake of simplicity.

The feedback controller in exercise 4.2.2 is

$$\begin{aligned} F_y(s) &= \frac{s+\omega_I}{s} \cdot \frac{1}{(\frac{1}{p_1}s+1)\cdot(\frac{1}{p_2}s+1)\cdot(\frac{1}{p_3}s+1)} \cdot G^{-1}(s)G_d(s) \\ &= \frac{s+100}{s} \cdot \frac{1}{(\frac{1}{800}s+1)^3} \cdot \frac{(s+1)((\frac{s}{20})^2+\frac{s}{20}+1)}{20} \cdot \frac{10}{s+1} \end{aligned}$$

where $p_1 = p_2 = p_3 = 80\omega_c$, $\omega_c = 10$ rad/s.

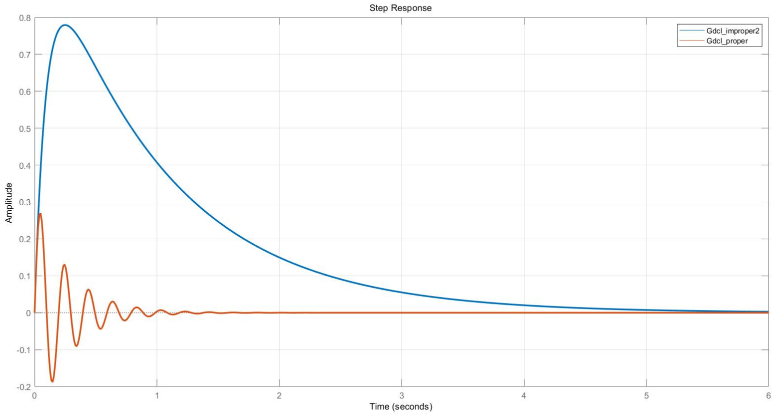

Figure 1: Step disturbance, exercise 4.2.2, where $G_{dcl\_improper2}$ represents the close=loop transfer function which does not include PI controller, while G_{dcl_proper} includes.

The feedback controller and prefilter in exercise 4.2.3 is

$$F_y(s) = \frac{s+100}{s} \cdot \underbrace{\frac{(s+1)((\frac{s}{20})^2+\frac{s}{20}+1)}{20}}_{G(s)^{-1}} \cdot \underbrace{\frac{10}{s+1}}_{G_d(s)} \cdot \frac{1}{(\frac{s}{800}+1)^3} \cdot \underbrace{0.06\frac{0.3s+1}{0.06s+1}}_{F_{\text{lead}}}$$

$$F_r(s) = \frac{1}{1+0.1s}$$

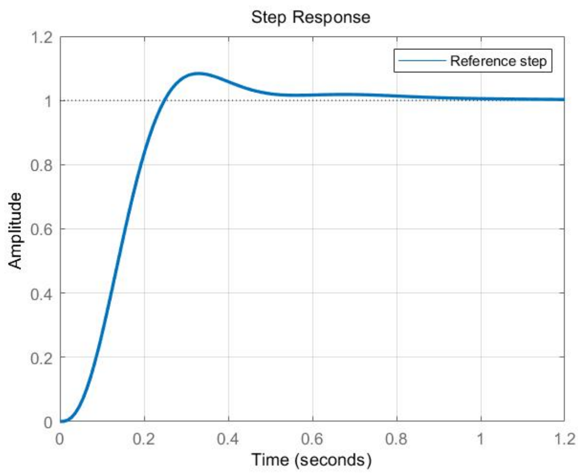

Figure 2: Reference step, exercise 4.2.3

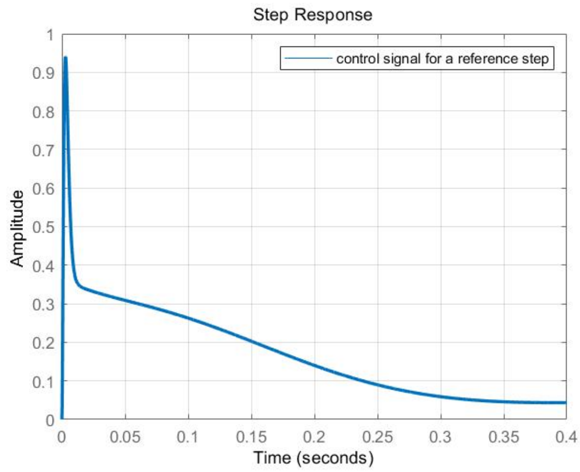

Figure 3: Control signal for a reference step

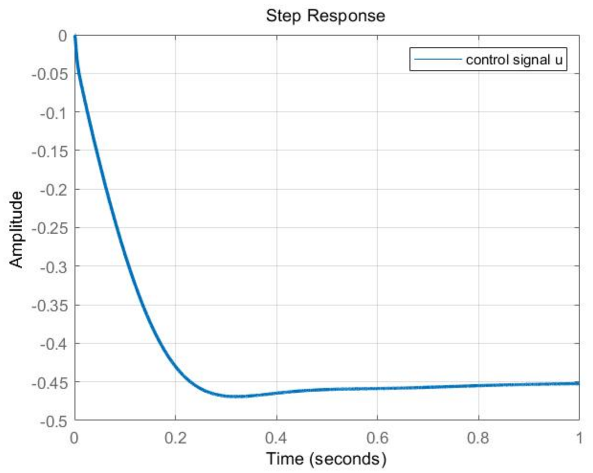

Figure 4: Control signal for a disturbance and a reference step (a combination of these)

Did you manage to fulfill all the specifications? If not, what do you think makes the specifications difficult to achieve?

With the controllers F_y and F_r given above we managed to fulfill all the specifications. In the attached figures, one can see that the requirements are ensured. One challenge was e.g. when increasing the tracking speed, the control input is larger.

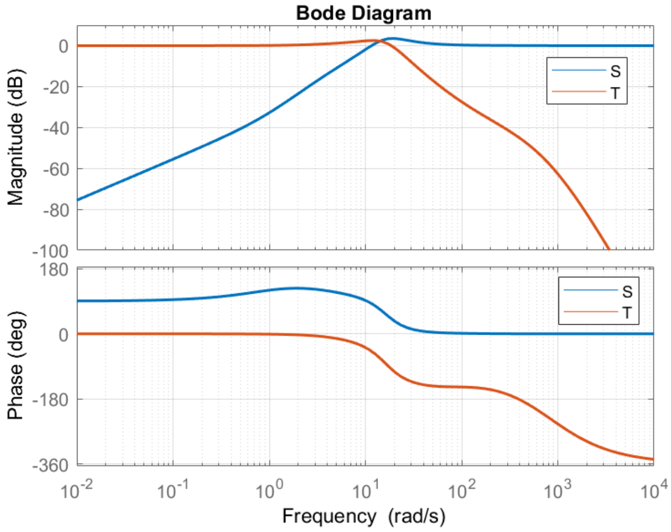

Figure 5: Bode diagram of sensitivity and complementary sensitivity functions, exercise 4.2.4