Exercise #3

PI tuning, continuous time speed controller

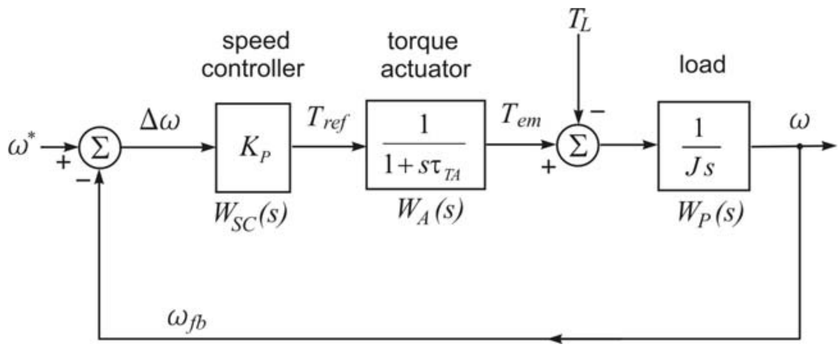

Fig. 3.8. The speed-controlled DC drive system comprising the first-order lag torque actuator $W_A(s)$, inertial load, and the proportional speed controller.

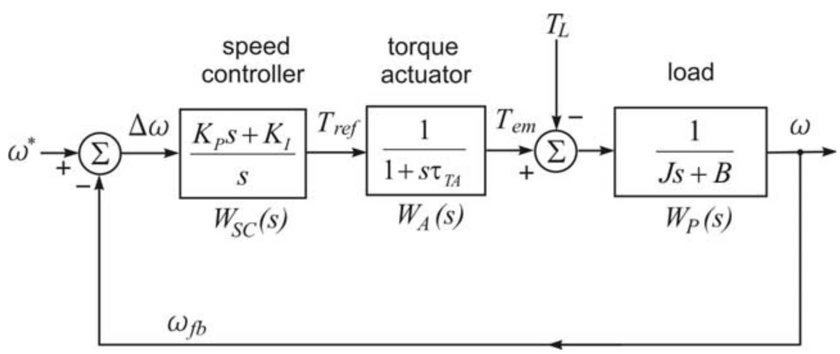

Fig. 3.11. Speed-controlled DC drive with delay τ_{TA} in the torque actuator, with load friction B and load inertia J, and with the PI speed controller.

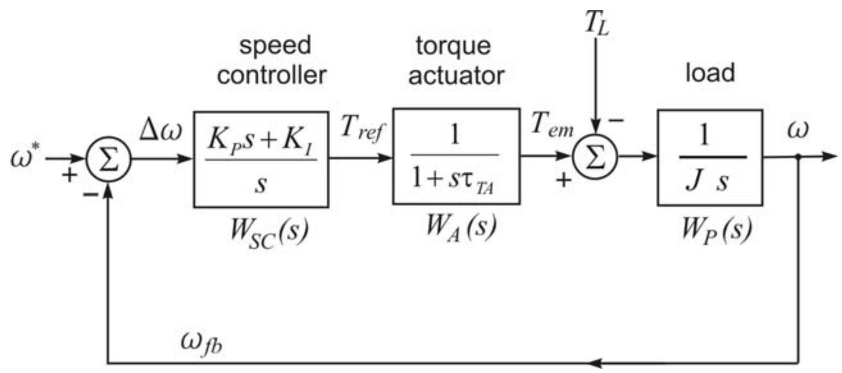

Fig. 3.12. Speed-controlled DC drive with frictionless, inertial load, delay τ_{TA} in the torque actuator, and with the PI speed controller.

P3.1

Consider the closed-loop system with the characteristic polynomial $f(s)$ = $b_0 + b_1 s + b_2 s^2 + b_3 s^3 + b_4 s^4$. Assume that $b_0 = 1$ and $b_1 = b_0$. Determine b_2, b_3, and b_4 according to the *double ratios* design rule:

$$\frac{b_{k+1}}{b_k} \le \frac{b_k}{b_{k-1}} \quad \Rightarrow \quad b_k^2 \ge 2 b_{k-1} b_k$$

Determine the polynomial zeros by using the Matlab function *roots*().

P3.2

(a) Repeat the previous calculation with $b_0 = 10$ and $b_1 = b_0$.
(b) Repeat the previous calculation with $b_0 = 10$ and $b_1 = 10\ b_0$.

P3.3

The speed-controlled DC drive system (Fig. 3.8) comprises a torque actuator that can be modeled as the first-order lag. The friction coefficient B is negligible. The speed controller determines the torque reference $T_{ref} = K_P\ \Delta\omega$ in proportion to the speed error. The system parameters are J = 0.1 kgm^2 and τ_{TA} = 10 ms. Determine the proportional gain K_P so as to obtain the characteristic polynomial in conformity with the *double ratios* design rule. Considering K_M = 1 and K_{FB} = 1, what are the units of K_P ? Calculate the poles of the closed-loop system.

P3.4

For the system in P3.3, determine the closed-loop transfer function. Apply the Matlab command *step*() to obtain the step response to the input disturbance. Estimate the overshoot and the rise time from the plot.

P3.5

The speed-controlled DC drive system (Fig. 3.11) comprises a torque actuator modeled as the first-order lag. The friction coefficient is B = 0.01 Nm/(rad/s). The speed controller comprises the proportional and integral action. The system parameters are J = 0.1 kgm^2 and τ_{TA} = 10 ms. Determine the gains K_P and K_I so as to obtain the characteristic polynomial in conformity with the *double ratios* design rule. Calculate the poles of the closed-loop system.

P3.6

Determine the closed-loop transfer function of the system in P3.5 and obtain the step response by using the Matlab function *step*().

P3.7

The speed-controlled DC drive system (Fig. 3.12) comprises the torque actuator modeled as the first-order lag. The friction coefficient is B = 0. The speed controller comprises the proportional and integral action. The system parameters are J = 0.1 kgm^2 and τ_{TA} = 10 ms. Determine the gains K_P and K_I so as to obtain the characteristic polynomial in conformity with the *double ratios* design rule. Calculate the poles of the closed-loop system.

P3.8

For the system given in P3.7, and with the gain setting calculated in S3.7, determine the open-loop transfer function $W_S(s)$, calculate its poles and zeros, and obtain the *Bode* plot by using the appropriate Matlab command. What is the frequency where $|W_S(j\omega)| = 1$? Why is the parameter setting in Eq. 3.32 to be called the *symmetrical* optimum?

P3.9

Determine the closed-loop transfer function of the system in P3.7 and obtain the step response by using the Matlab function *step*(). What are the overshoot and the rise time?