הטכניון—מכון טכנולוגי לישראל, הפקולטה להנדסת מכונות
TECHNION—Israel Institute of Technology, Faculty of Mechanical Engineering

Advanced Control Laboratory (034406)

Spring Semester, 2019/2020 Academic Year

Preparatory Work 2

Question 1 (15%)

Assume that the 1000 rotary encoder measures rotation angle of a DC motor rotor. The rotor is connected to the arm through a gearbox with 5 : 1 gear ratio (5 rotor turns into one arm rotation). Obtain analytically the constant that converts the encoder pulses to the arm rotation angle in degree units.

Question 2 (85%)

Neglecting the dynamics of an electric circuit, the behavior of a DC motor with an inertial load can be described by the following transfer function (assumes that the input to the system is the supplied to the motor voltage and the output is the load turn angle):

$$P(s) = \frac{k_p}{s(\tau_p s + 1)}$$

Time constant τ_p and static gain k_p are positive and defined by the motor and load parameters (see Lab 2 for more details). The motor and the load are controlled by a proportional controller k_c as in Figure 1.

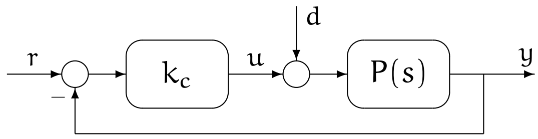

Figure 1: The closed loop with a proportional controller

Answer the following questions:

1. (8%) Is the $P(s)$ stable? What is the range of k_c that stabilizes the closed loop?
2. (12%) What is a steady-state error to the unit steps in reference r and disturbance d as functions of τ_p, k_p, and k_c?
3. (15%) Simulate in Simulink the closed loop in Figure 1 under $\tau_p = 0.04$, $k_p = 1.2$, reference $r = 1(t)$, disturbance $d = 0$, and the following controller gains $k_c = 5, 10, 40$. After the simulation, plot in MATLAB the system response (y) under the controller gains above. Utilize the block *Scope* to save signals with respect to simulation time. How does the value of the proportional controller influence on the closed loop system response (overshoot, rise time, and settling time)? Use Nyquist plot and root locus to explain your answer.

   Note: set up the sample time of $0.001\,[s]$ in "Simulation/Model Configuration Parameters" of your Simulink file to achieve smooth responses.
4. (15%) Assume $k_p = 1.2$ and $\tau_p = 0.04$, and find the value of proportional controller which satisfies the overshoot of 5%.
5. (17%) The file named `Data.mat` contains the noised response in a finite time range t for $r = (1 - e^{-80t})$ and $d = 0$ of the closed loop system when $k_c = 0.2$ (the first column is the time vector t, and the following column is the output vector y). Write the program in MATLAB to obtain the values of k_p and τ_p in

accordance with the given response. The solution should include the code in MATLAB, and the response plot which proves the correctness of the result.

Hint: the given closed loop system is the second order system with static gain 1 so there are two parameters only: ω_n and ζ. Write MATLAB program that systematically assign values to ω_n and ζ, obtain a response of the corresponding second order system (use MATLAB function `lsim`), compare the response above to the given one, and finally choose the optimal values of ω_n and ζ (determine the optimality criterion in this case). Then the values of k_p and τ_p should be calculated from the obtained ω_n and ζ values.

6. (12%) Repeat the previous section, but utilize MATLAB function `tfest` for an estimation of the closed loop transfer function. The description of this function is `sys = tfest(data,np,nz)`. It estimates a continuous-time transfer function, `sys`, using time-domain data, `data`, and contains `np` poles, `nz` zeros. The time-domain data is specified by `data = iddata(y,r,Ts)` which creates an iddata object containing a time-domain output signal `y` and input signal `r`, respectively. `Ts` is the sample time of the experimental data.

7. (6%) Compare the values of k_p and τ_p obtained from the two previous sections.