EE443L Lab 3: Open Loop Motor Speed Control

Introduction:
The concept of open loop control is introduced in this laboratory for the objective of DC motor speed control. Speed control involves developing a controller that will influence the DC motor such that it spins at a desired speed. Open loop control will be investigated this week and proportional closed loop control next week to demonstrate the advantages of closed-loop control as well as response types and metrics.

Prelab:
Open loop control is depicted in Figure 1 where it is noted that the controller has knowledge of only the desired input and thus acts as a system gain that modifies the system such that the output can be made equal to the input.
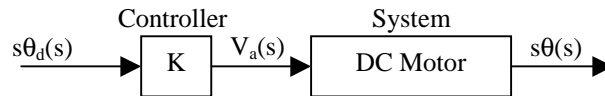
Controller   System

$s\theta_d(s)$ → [K] $V_a(s)$ → [DC Motor] $s\theta(s)$ →

Figure 1: Open Loop Motor Speed Control Diagram

1. Using the DC motor model discussed both in class and lab, determine the transfer function $G_{OL}(s)$ = $s\theta(s)/ s\theta_d(s)$ without specific motor parameters applied, i.e., the general result.

$$G_{OL}(s) = s\theta(s)/ s\theta_d(s) =$$

2. Realizing a unity DC gain $G_{OL}(0) = 1$ will correspond to the steady-state value of the motor speed $\dot{\theta}(t)$ in rad/sec and a constant desired speed $\dot{\theta}_d(t)$ in rad/sec being equal, determine the value of the controller gain K for which this happens.

$$K =$$

3. Compute a numerical value for K found above using the motor parameters determined in the motor characterization lab and simulate the open loop control system with the motor model developed in the motor characterization lab for $\dot{\theta}_d(t) = 50u(t)$ rad/sec. Include a plot of the simulation result demonstrating the success of your open loop controller.

$$K =$$

4. Can the open loop controller give us the flexibility to vary the type of response, i.e., the transient response, by varying K?

5. How do we adjust K to compensate for motor parameter variations, e.g., changes in resistance, friction, etc.?

Laboratory Procedure:

    Open loop control will be implemented and investigated through the approach shown in Figure 1 and discussed in the prelab.

1. Begin the lab by downloading the LabVIEW VI *lab3.vi* (and its associated subVI *Altera_Clock_Source.vi*) found at N:\ee443l\Lab 3\ that is set up to vary the PWM duty cycle through a virtual knob and plot motor speed from frequency to voltage converters and Altera counters. Ensure you understand the operation of the VI and that it correctly drives the motor when the supply voltage is set to 15V.

2. Use open loop control and the open loop gain K determined in the prelab to provide DC motor speed control through LabVIEW. Plot the motor response and compare to the simulink results for $\dot{\theta}_d(t) = 50u(t)$ rad/sec. Note several considerations will need to be taken into account when implementing the open loop controller. These include conversion of armature voltage to duty cycle, limit duty cycle to ±127, include h-bridge drop out voltage (approximately 0.4V), and convert frequency-to-voltage converter voltage and Altera counter values to actual speed. Include a printout of your LabVIEW open loop control VI.

3. Adjust the open loop gain K, so $\dot{\theta}_d(t) \approx \dot{\theta}(t)$ and plot responses for $\dot{\theta}_d(t) = 50$rad/sec, 80rad/sec. Measure the response peak time T_p, percent overshoot P.O., settling time T_s, rise time T_r, and steady state error e_{ss} as shown in Figure 2 and discussed in Table 1. Which of these measured response parameters can be varied with the controller gain K?
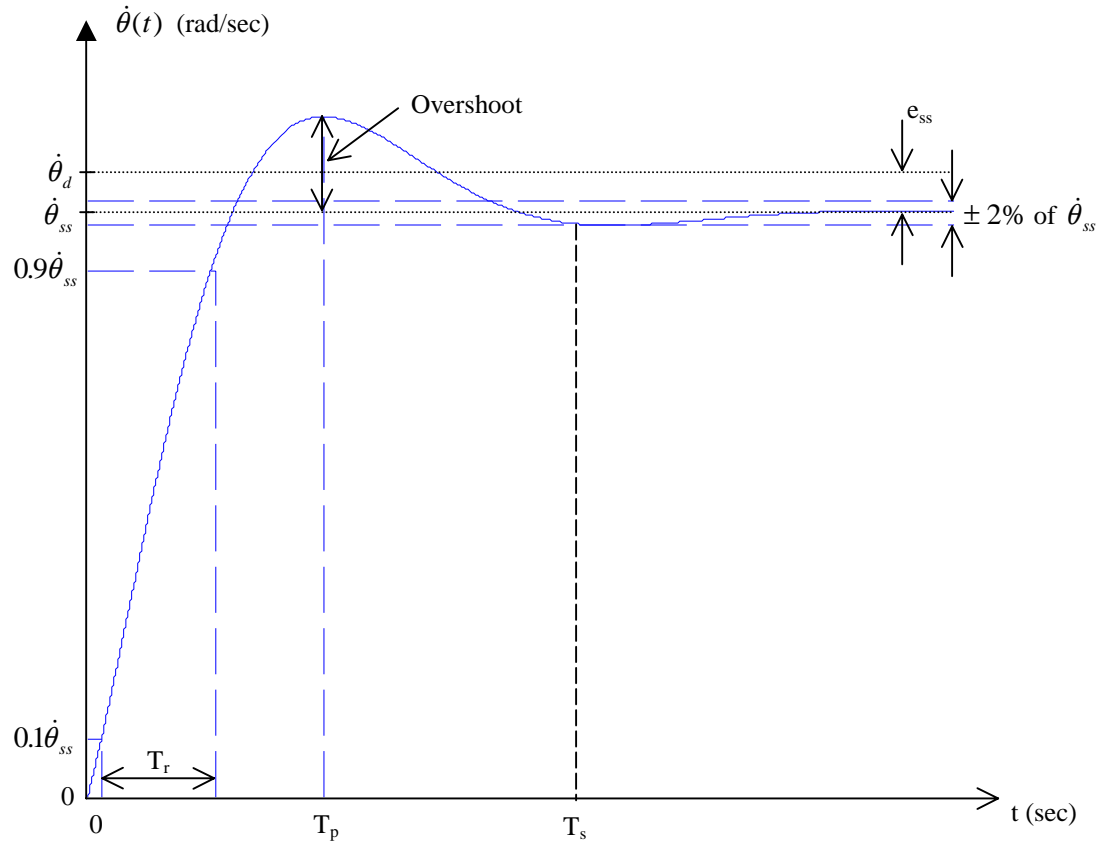
Figure 2: Performance Metrics for Control System Step Responses

Table 1: Description of Step Response Performance Metrics

Performance Metric	Description
T_p (peak time)	time for response to rise to a peak (maximum)
P.O. (percent overshoot)	100%(peak value - steady state value) / steady state value
T_s (settling time)	time required for response to settle within $\pm$ 2% of its steady state value
T_r (rise time)	time for response to rise from 10% to 90% of its steady state value
e_{ss} (steady state error)	difference between desired and actual responses after transients have decayed