

## EE443L Lab 4: Closed Loop Motor Speed Control

### Introduction:

The concept of closed loop control is introduced in this laboratory for the objective of DC motor speed control. Open loop control was investigated last week and will be compared to proportional closed loop control this week to demonstrate the advantages and disadvantages of closed-loop control as well as response types and metrics.

### Prelab:

Proportional closed loop control is depicted in Figure 1 where it is noted that the controller has knowledge of both the desired input and system output. Thus, the DC motor input voltage  $V_a(s)$  is varied based on the difference (error) between the desired speed  $s\theta_d(s)$  and actual speed  $s\theta(s)$ .

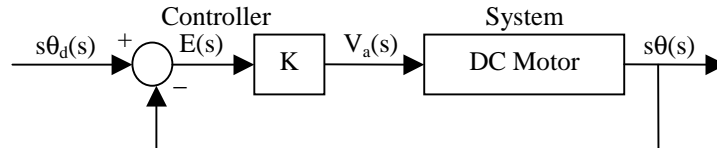


Figure 1: Proportional Closed Loop Motor Speed Control Diagram

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

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

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

$$K =$$

3. Can the closed loop controller give us the flexibility to vary the type of response, i.e., the transient response by varying  $K$ ? Why or why not?
4. How do we adjust  $K$  to compensate for motor parameter variations, e.g., changes in inertia, friction, etc.?
5. With the help of Matlab, Maple, or Simulink, find two sample values of  $K$  between 0.0 and 0.375 that will yield very little (if any) overshoot and a fair amount of overshoot using the motor parameters determined in the motor characterization lab. Simulate the system with Simulink for  $\dot{\theta}_d(t) = 40u(t)$  rad/sec and these values of  $K$  and turn in plots of these two responses.

## Laboratory Procedure:

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

1. Modify your open loop controller VI from last week so that it becomes proportional closed loop control with closed loop controller gain  $K$  as shown in Figure 1.

**Important note:** One important closed loop characteristic to remember is that the maximum effective voltage we can apply to the motor via PWM is the power supply voltage  $V_{\text{SUPPLY}}$ . Therefore, the largest controller gain  $K$  we can accommodate without voltage saturation affecting our system response is  $K = V_{\text{SUPPLY}} / e_{\text{max}}$  with  $e_{\text{max}}$  the maximum error  $e(t)$  value. This limitation is most often encountered when step responses are required since the initial (and most often maximum) error is the value of the desired speed minus zero if the motor starts at rest. Using  $V_{\text{SUPPLY}} = 15\text{V}$  and  $\dot{\theta}_d = 40u(t)$  rad/sec, we find that our maximum gain should not exceed 0.375 to avoid voltage clipping. This is why the gain range of 0.0 to 0.375 was specified in the prelab.

2. Using the proportional closed loop controller, implement the closed loop gains  $K$  determined in the prelab to achieve little and a fair amount of overshoot in the DC motor speed step responses. Plot the motor step responses for a desired motor speed of 40rad/sec, note the corresponding gains, and whether the gains were varied from those determined in the prelab.
3. Measure the step response peak time  $T_p$ , percent overshoot P.O., settling time  $T_s$ , rise time  $T_r$ , and steady state error  $e_{ss}$  for both step responses.
4. Create a table of performance metrics including those from the open loop response as well as both closed loop responses. Compare these and comment on the various apparent advantages and disadvantages of each approach/response.