University of Toronto
Department of Electrical and Computer Engineering
ECE 356S – System and Signal Analysis II 1999
Exp 2: CONTROLLER DESIGN FOR THE DC MOTOR

1 Purpose

The purpose of this lab is to design and simulate two different feedback controllers for the DC motor system. The first one is a proportional (P) controller, the second a proportional + integral (PI) controller. The simulation is done using MATLAB.

2 Introduction

Proportional Controller

A proportional controller generates an actuating signal proportional to the error signal. For our DC motor system, the control law is therefore

$$v_m = K_P(w_d - w),$$

where w_d is the desired motor speed and K_P is the proportional gain. Since $v_t = K_t w$, we are led to define the desired tachometer output voltage $v_d := K_t w_d$, and then we get the control law

$$v_m = \frac{K_P}{K_t}(v_d - v_t).$$

Defining $K_P' := K_P/K_t$, we have the block diagram shown in Fig. 1. The closed-loop transfer

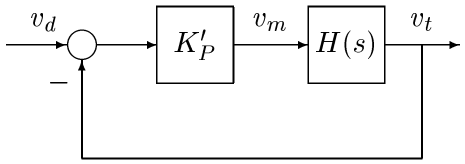

Figure 1: Proportional Control of Motor.

function from v_d to v_t is still first-order.

Proportional + Integral Controller

In a PI controller there is an additional term in the actuating signal that is proportional to the integral of the error signal. The PI control law for the DC motor is

$$v_m = \left(K_P + \frac{K_I}{s}\right)(w_d - w).$$

Defining $K_I' := K_I/K_t$, we have the block diagram shown in Fig. 2. The transfer function of the closed-loop system from v_d to v_t is now second-order.

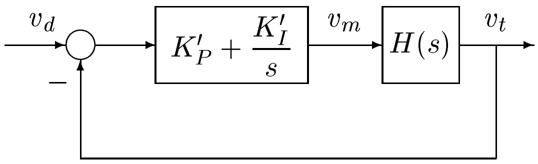

Figure 2: PI Control of Motor.

3 Design Procedure

Use the transfer function $H(s)$ obtained in Exp. 1 for the unloaded case.

3.1 Proportional Controller

1. Design a proportional controller so that the time constant of the closed-loop transfer function $H_{CL}(s)$ from v_d to v_t equals 0.005 s. Does the DC gain of $H_{CL}(s)$ depend on K'_P? Comment: The desired DC gain is 1, for then v_t asymptotically perfectly tracks a step v_d.

2. Using MATLAB, plot the step response and the frequency response of $H_{CL}(s)$. Also, plot the step response of v_m and infer what the magnitude of v_d can be so that the saturation constraint $|v_m| \leq 5$ isn't violated.

3.2 Proportional + Integral Controller

1. Design a PI controller so that the poles of the closed-loop transfer function $H_{CL}(s)$ are $-200 \pm 204j$. This corresponds to $\zeta = 0.7$ and $\omega_n = 285.7$.

2. Repeat the plots and re-determine the maximum allowed magnitude of v_d.

4 Results and Discussion

1. For the proportional and the PI controllers, what are the closed-loop DC gains? Will v_t track a step v_d exactly?

2. Discuss the advantages and limitations of the two controller structures.

3. The motor, considered as a system from v_m to v_t, is stable. The process of experimentally determining its parameters (DC gain and time constant in this case) is called *identification*. How might you identify an unstable system, that is, experimentally determine its parameters? For example, the system $K/(\tau s - 1)$.