2.004 Dynamics and Control II
Spring 2008

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Laboratory Objectives: This week’s lab is an open-ended design exercise. You are given a feedback control scheme to analyze, evaluate through simulation, and then implement on the rotational plant.

(i) To investigate the use of multiple feedback loops, using both position and velocity feedback.

(ii) To investigate the manipulation of closed-loop dynamic response through the use of multiple loops.

(iii) To compare your experimental results with a Simulink digital simulation.

Introduction: In this week’s lab session you will use both the tachometer (ETACH) and position sensor (EDAC2) to form a control system with two loops as shown below:
A new controller, _PosVelController_, is available in the 2.004 Lab Software for this session. It allows you to set the two gains $K_p$ and $K_v$ in the block diagram above.

<table>
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<th>The Task: Your task is to design and implement a closed-loop position control system for the rotational plant, to meet the following specifications:</th>
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<td>• Percentage overshoot $%OS = 5%$.</td>
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<td>• Time to peak, $T_p = 1$ sec.</td>
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<td>You should use the multi-loop structure shown above to do this.</td>
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We want you to proceed as you would as a practicing engineer in industry, that is analyze the system and choose controller gains, perform a simulation of the closed-loop behavior to verify your design, and only then implement the hardware controller.

**Procedure:**

(a) Develop the closed-loop transfer function for the system as shown in the block diagram.

(b) Choose values for $K_p$ and $K_v$ that will meet the system specification. (Appendix A might help).

(c) Develop a Simulink model, based on the block diagram. You might use the existing PI model (in the 2.004 Class Locker) as a starting point. Use your simulation to confirm that you have met the system specifications. Include a display of the motor current, so that you can be sure that you will not saturate the Power Amplifier.

(d) When you are satisfied with your controller design, invoke the PosVel Controller, set your values of $K_p$ and $K_v$ on the controls, and run the system to generate a step response. Compare the response to that of your Simulink model, and check it against the specifications given above.

(e) Finally, compare the response of this control scheme with that of PD control (as in Lab 6). (The closed-loop PD transfer function is given in Appendix B.)

- Determine the PD controller gains to generate the same characteristic polynomial as you used in your experiments above,
- Load the PID Controller (you should not have to change any connections, although you can disconnect the tachometer if you wish).
- Measure the step response with PD control. Use a step size of 0.25 v.
- Compare the step responses of the two control schemes, and explain any differences.
Appendix A: System Transient Response Specifications

For the step response of the second-order system

\[ G(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2} \]

the time to the first peak \( T_p \) is

\[ T_p = \frac{\pi}{\omega_d} = \frac{\pi}{\omega_n \sqrt{1 - \zeta^2}} \]

and the percentage overshoot is

\[ \%OS = e^{-\zeta\pi\sqrt{1 - \zeta^2}} \times 100. \]

See Nise, Sec. 4.6.

Appendix B: PD Control Action

In Lab. 6, the second-order system with a transfer function

\[ G_p(s) = \frac{K}{Js^2 + Bs} \]

where \( K = K_aK_m/N \) under PD control, that is

\[ G_c(s) = K_p + K_ds \]

was shown to have a closed loop transfer function

\[ G_{cl}(s) = \frac{G_c(s)G_p(s)}{1 + K_{pos}G_c(s)G_p(s)} = \frac{K(K_p + K_ds)}{Js^2 + (B + KK_dK_{pos})s + KK_pK_{pos}}. \]