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2.004 Dynamics and Control II  
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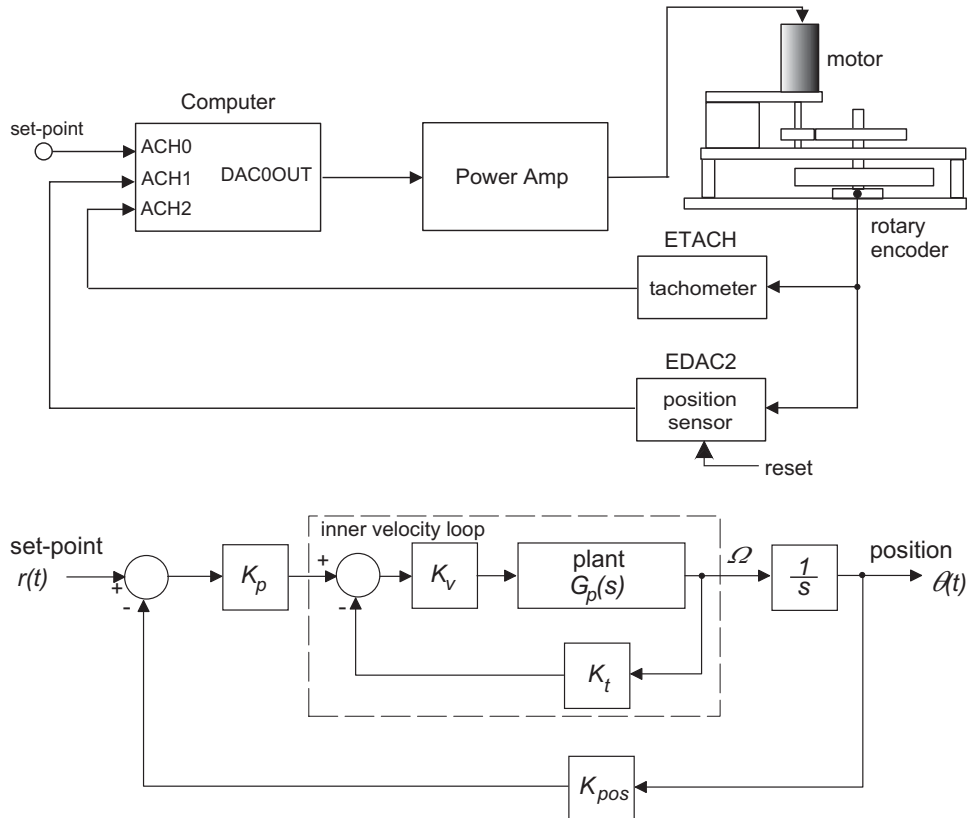
*2.004 Dynamics and Control II*

**Laboratory Session 7:  
Closed-Loop Position Control using Position and Velocity Feedback.<sup>1</sup>**

**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:



<sup>1</sup>April 6, 2008

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.

**The Task:** Your task is to design and implement a closed-loop position control system for the rotational plant, to meet the following specifications:

- Percentage overshoot  $\%OS = 5\%$ .
- Time to peak,  $T_p = 1$  sec.

You should use the multi-loop structure shown above to do this.

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  $K = K_a K_m / N$  under PD control, that is

$$G_c(s) = K_p + K_d s$$

was shown to have a closed loop transfer function

$$\begin{aligned} G_{cl}(s) &= \frac{G_c(s)G_p(s)}{1 + K_{pos}G_c(s)G_p(s)} \\ &= \frac{K(K_p + K_d s)}{Js^2 + (B + KK_d K_{pos})s + KK_p K_{pos}}. \end{aligned}$$