Exam Number: ________________

Department of Mechanical Engineering

Michigan State University

Ph.D. Qualifying Examination
January 2005
Dynamic Systems and Control

Open Book, Open Notes

Answer All Questions
All Questions Weighted Equally

Exam Prepared by

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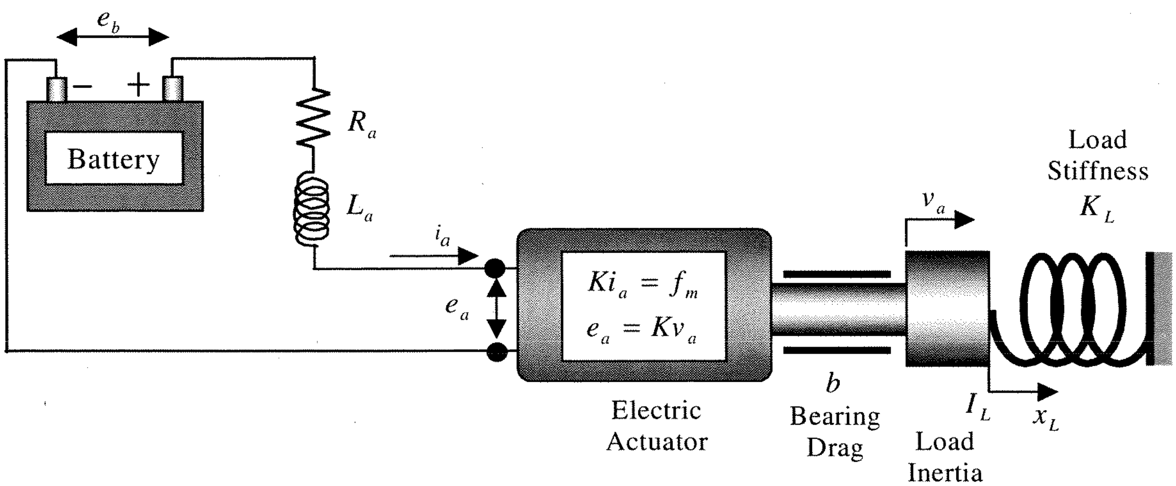
1) Shown below is a schematic diagram for a solenoid actuator with load. The battery drive voltage e_b is applied to the actuator's coil. The actuator's coil has a resistance R_a, and inductance L_a. The actuator's characteristics include a mechanical force f_m proportional to the armature current i_a

$$f_m = Ki_a$$

and an electrical back-emf voltage e_a proportional to the actuator speed v_a

$$e_a = Kv_a.$$

The motor force f_m drives a load that is represented by both viscous friction arising from viscous bearing "drag" $f_{drag} = bv_a$, load inertia I_L and load stiffness K_L.



a) Determine the differential state equation(s) that govern the dynamics of this permanent magnet actuator system model. First, identify the inputs and outputs. Then, write the equations in matrix form.

b) Determine the transfer function from the input $V_b(s) = \mathcal{L}(v_b(t))$ to the output $X_L(s) = \mathcal{L}(x_L(t))$ such that $G(s) = \dfrac{X_L(s)}{V_b(s)}$

Work Problem on this page….

2) An open-loop transfer function is given by the relation

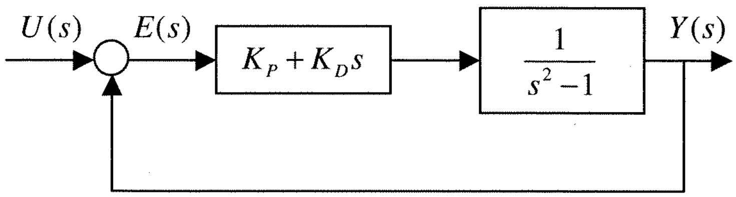
$$KG(s)H(s) = \frac{K(s+3)}{s(s-2)}$$

(a) Sketch the root locus of the system,

(b) Find the value of K for which the closed-loop system is critically damped, and

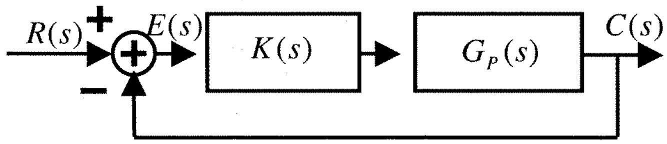
(c) Find the range of K for which the system is stable.

3) Consider the control system below.

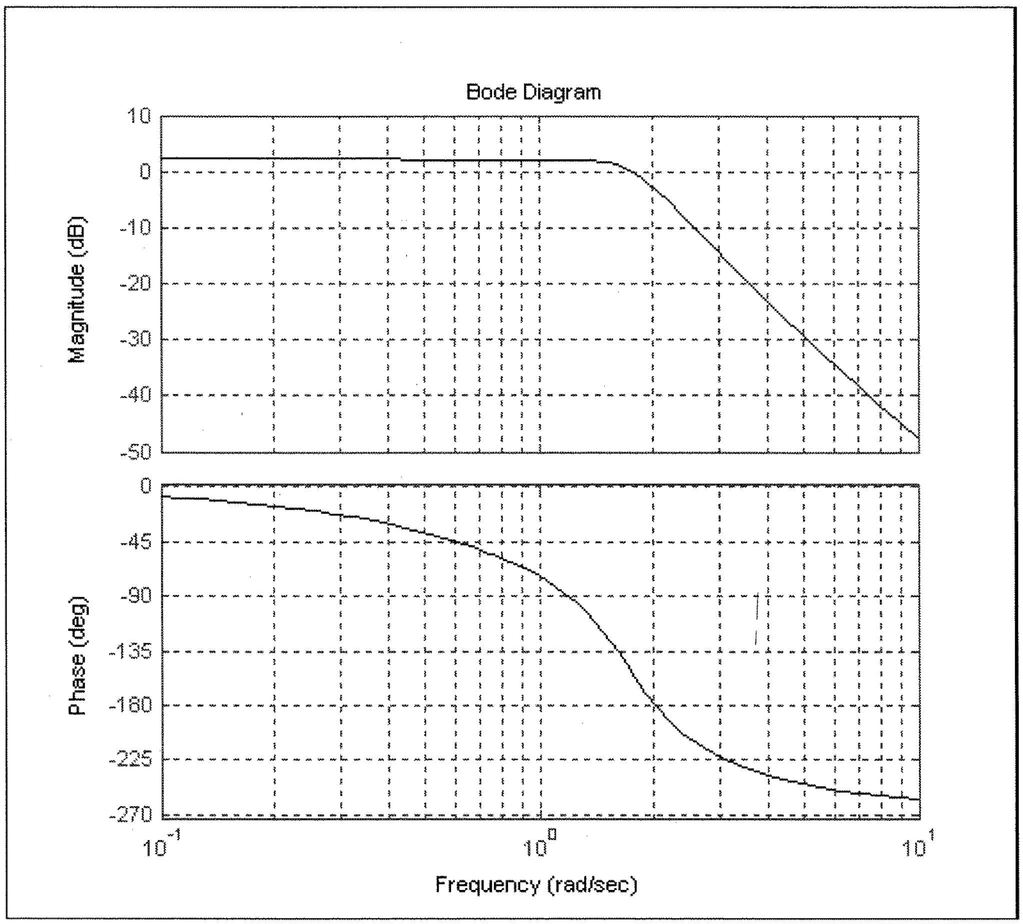


Design the PD controller (compensator) such that the closed loop system has poles at -2 $\pm$ j

4) For the feedback system below,



the Bode diagram $G_P(j\omega)$ for an industrial process that is open-loop stable is drawn below. A Bode diagram is the open-loop system's frequency response.



a) What are the gain and phase margins of this system? Will it be stable when connected in the above feedback system with $K(s) = 1$?

Gain Margin = Phase Margin =	Stable when K(s) =1? Yes or No (Circle one)

b) Design the "best" (widest closed-loop system bandwidth) proportional feedback control system that will yield a phase margin of at least 45° and a gain margin of at least 8 dB.

$K(s) = K_P =$

c) Given the design in part (b) above, what is the expected steady state error of the closed-loop system due to a unit step input $e_{ss} = \lim_{t \to \infty}[e(t)] = \lim_{s \to 0}[sE(s)]$?

Steady-state error =