Note: 請將題號和答案標示清楚

1. (50%) Considering the motor drive system in Fig. 1, where all the parameters are listed in Table I. Please try to answer the following questions:

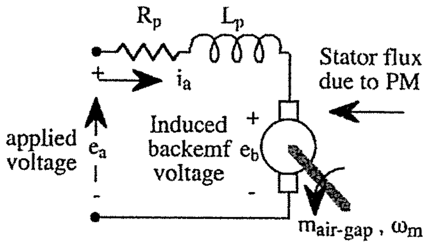
(1) (7%) Derive "two" dynamic equations of motor drive system with (i) the input of applied voltage $e_a(t)$ and the output of armature current, and (ii) the input of armature current and the output of motor velocity $\omega_m(t)$. (show the analytic form without numerical values)

(2) (8%) Show the block diagram of motor drive system in Lapalce domain. The system input is the applied voltage $e_a(t)$ and the output is the motor velocity $\omega_m(t)$. (show the analytic form without numerical values)

(3) (15%) Assuming the motor velocity is measureable, please try to use a proportional control gain, K_p, to design a critical damped dynamic system. You must (i) draw a block diagram to show the closed-loop system with the input of command velocity $\omega_m^*(t)$ in Lapalce domain and output of motor velocity $\omega_m(t)$ in Lapalace domain, and (ii) use the root locus to determine the value of K_p. (use the numerical values to calculate K_p)

(4) (5%) Try to analyze the steady state error ($\omega_m(t=\infty)-\omega_m^*(t=\infty)$)of closed-loop system in (3) with a step velocity input $\omega_m^*(t)=1$. (use the numerical values to calculate the result)

(5) (15%) Please explain why a steady state error occurs on the closed-loop system in (3) and recommend a velocity controller to eliminate the steady state error. You must explain the property of this designed controller which can eliminate the steady state error. (use the numerical values to calculate the result)



$K_e = K_T$ $\quad m_{air\text{-}gap} = K_T \cdot i_a$ $\quad e_b = K_e \cdot \omega_m$

Fig. 1 A PM DC servo drive model

Jp	=	1 Kg-m^2	moment of inertia
K_T	=	0.1 Nm/Amp	torque constant
K_e	=	0.1 volts/rad/sec	backemf constant
Rp	=	2 ohm	armature resistance
Lp	=	4 mH	armature inductance
e_a	=	applied terminal	voltage in volts
i_a	=	armature current in amperes	
mag	=	electromagnetic air-gap torque (moment) = $K_T * i_a$	
e_{bk}	=	induced (back emf) voltage = $Ke*\omega_m$ in volts	
ω_m	=	angular velocity in rad per sec	

Table I Parameters of motor system

2. (50%) Consider a system $G:\begin{cases} \dot{x}=\begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & -1 & 0 \end{bmatrix}x+\begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}u \\ y=\begin{bmatrix} 1 & 0 & 0 \end{bmatrix}x \end{cases}$

(1) (10%) Derive the state response $x(t)$ to an initial state $x(0)=\begin{bmatrix} 1 & 1 & 1 \end{bmatrix}^T$, when $u(t)=0$.

(2) (10%) Derive the transfer function $G(s)$ of the system. Sketch the Bode plot of $G(s)$.

(3) (10%) Sketch the Nyquist plot of $G(s)$. Discuss stability of the closed-loop system of Fig. 2 with $G_C(s)=1$, using the Nyquist Criterion.

(4) (10%) Referring to Fig. 2, is it possible to stabilize the system by PD-control $G_C(s)=K_P+K_Ds\approx\dfrac{K_P+K_Ds}{\tau s+1}$ with sufficiently small τ ? If yes, please design such a controller. If no, please explain the reasons.

(5) (10%) Referring to Fig. 2, design a second-order controller $G_C(s)=\dfrac{b_2s^2+b_1s+b_0}{s^2+a_1s+a_0}$ to allocate the closed-loop poles at $s=-1,-2,-3,-4,-5$.

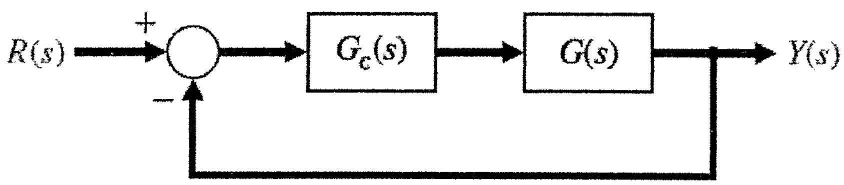


Fig. 2 A closed-loop system.

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