POHANG UNIVERSITY OF SCIENCE AND TECHNOLOGY
Department of Electrical Engineering
2010 Automatic Control Qualifying Exam
Aug. 2010

(제어필수는 반드시 풀고 제어선택과 전력전자 중 한 분야를 선택해서 푸시오)

제어필수

1. Consider a single-input single-output LTI system below;

$$\dot{X}(t) = AX(t) + Bu(t)$$
$$y(t) = CX(t)$$

a) Let

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -6 & -11 & -6 \end{bmatrix}.$$

Then find the similarity transformation matrix P such that $X(t) = P\overline{X}(t)$ for diagonalization of A.

Find also the diagonalized matrix $\overline{A}$.

b) Show that the transfer function of the above LTI system is invariant under the similarity transformation.

제어선택

1. $\dot{x}(t)=\begin{bmatrix}2 & 1\\ 0 & 1\end{bmatrix}x(t)+\begin{bmatrix}b_1\\ b_2\end{bmatrix}u(t), \quad y(t)=\begin{bmatrix}c_1 & c_2\end{bmatrix}$

1) 이 시스템이 완전히 제어가능(controllable)하고 관측가능(observable)하기 위하여 위한 $b_1,\ b_2,\ c_1,\ c_2$ 가 만족해야 할 조건을 구하시오. (10)

2) $b_1=0,\ b_2=1,\ c_1=1,\ c_2=0$ 일 때 state feedback $u=-Kx+pv=-[k_1\ \ k_2]x+v$ 를 이용하여 closed loop system의 eigenvalue가 -2에 두 개가 되는 $K=[k_1\ \ k_2]$를 구하시오. (10)

3) $v(t)=\sin t$ 일 때 정상상태 출력 $y_s(t)$를 구하시오. (20)

4) closed loop system의 상태천이행렬(state transition matrix)을 구하시오.(10)

전력전자 문제

1. (20 points)
Draw the circuit model of the transformer and explain its elements. Also show the conditions of the perfect transformer.

2. Consider the buck-boost dc-to-dc converter. Its input voltage and output voltage are V_o and V_d, respectively. The duty ratio and switching period are also D and T_s. (30 points)

1) Draw the circuit of the buck-boost dc-to-dc converter and explain its operation principle.
2) Derive the input-output voltage relation in the continuous conduction mode.
3) Derive the voltage stress across the switch of the buck-boost converter during the off interval.

POHANG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Department of Electrical Engineering

2009 Automatic Control Qualifying Exam

Aug. 2009

(제어필수는 반드시 풀고 제어선택과 전력전자 중 한 분야를 선택해서 푸시오)

제어필수

1. Consider a Magnet-Ball-Suspension system. The objective of the system is to control the position of the steel ball by adjusting the current in the electromagnet through the input voltage e(t).

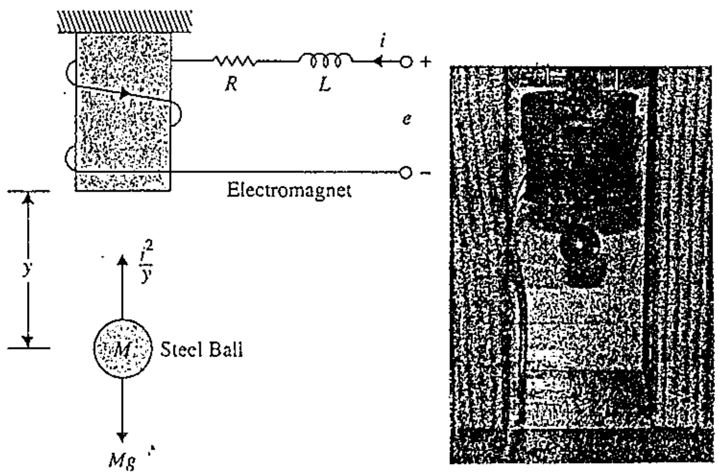


Figure 4-54 Magnetic-ball-suspension system.

a) Find the differential equations of the system.

b) Let us define the state variables as $x_1(t) = y(t)$, $x_2(t) = dy(t)/dt$, and $x_3(t) = i(t)$.

   Establish a state equations of the system.

c) Desired steel ball position is $y(t) = y_0$.

   Fine the equilibrium state $X_0 = [x_{10}, x_{20}, x_{30}]^T$.

d) Linearize the system and write system matrices A and B.

제어선택

Consider a DC Motor.

$i_a(t) =$ armature current, $L_a = 0.1H$ armature inductance,

$R_a = 1\,ohm$ armature resistance, $e_b(t)$ =back emf, $e_a(t) =$ armature voltage,

$K_b = 1\ \ V/rad/s$ back emf constant, $T_L = 0$ Load torque, $T_m =$ motor torque,

$\omega_m(t) =$ rotor angular velocity, $\theta_m(t) =$ rotor angular position,

$J_m = 0.1\ \ N-m-s^2$ motor inertia, $B_m = 0.01\ N-m-s$ viscous damping constant,

$K_i = 1\ \ N-m/A$ motor torque constant.

1. Let us define the state variables as $x(t) = [i_a(t), \omega(t),\ \theta(t)]^T$, the input variable as $u(t) = e_a(t)$ and the output variable as $y(t) = \theta_m(t)$. Write a state equation and an output equation of the DC motor.
$(\dot{x}(t) = Ax(t) + Bu(t),\quad y(t) = Cx(t))$
2. Find the transfer function $H(s) = \dfrac{Y(s)}{U(s)}$.
3. Write the controllable canonical form(phase-variable canonical form) dynamic equation of $H(s)$.
$(\dot{\overline{x}}(t) = \overline{A}\overline{x}(t) + \overline{B}u(t),\quad y(t) = \overline{C}\overline{x}(t))$
4. Find a nonsingular matrix P satisfying $x(t) = P\overline{x}(t)$.

전력전자 문제

1. Consider the boost dc-to-dc converter. Its input voltage and output voltage are V_d, and V_o respectively. The duty ratio, the switching period and the load are also D, T_s, and R. (30 points)

1) Draw the circuit of the boost dc-to-dc converter and explain its operation principle.
2) Derive the switch utilization factor of the boost dc-dc converter and draw with respect to the duty ratio D.
3) Derive the voltage ripple of the output voltage.

2. Consider the flyback converter. (20 points)

1) Draw its circuit, explain its operation principle, and derive its voltage transfer ratio in the continuous conduction mode.
2) Derive the voltage stress across the switch of the flyback convert- ter during the off interval.

POHANG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Department of Electrical Engineering

2008 Automatic Control Qualifying Exam

Nov. 2008

(제어필수는 반드시 풀고 제어선택과 전력전자 중 한 분야를 선택해서 푸시오)

제어필수

1. Consider that the loop transfer function of a closed-loop control system is

$$L(s) = \frac{0.5}{s(1+2s)(1+4s)}.$$

a) Sketch the Bode diagram and find out the gain margin.

b) Sketch the Nyquist diagram.

c) Suppose that zero at s=-1 is added to the loop transfer function L(s). What is the general effect of addition of zero to the loop transfer function.

d) Sketch the Nyquist diagram for the zero added system and show the effect of adding zero in terms of gain margin.

제어선택

1. $\dot{x}(t) = Ax(t) + bu(t), \quad y(t) = cx(t)$ (선형시불변시스템)

a) Controllability 와 Observability 의 정의를 정확히 기술하시오.

b) $\bar{x} = Px, \quad P$: nonsingular square matrix. $\bar{x}$의 상태방정식을 구하고 observability가 같음을 보이시오.

c) BIBO(Bounded Input Bounded Output) stability의 정의를 정확히 기술하시오.

d) A의 모든 eigenvalue가 negative real part를 가지면 BIBO stable 함을 보이시오. 그러나 역은 성립하지 않음을 보이시오.

전력전자 문제

1. (20 points)

   Draw the circuit model of the transformer and explain its elements. Also show the conditions of the ideal transformer.

2. Consider the boost dc-to-dc converter. Its input voltage and output voltage are V_d, and V_o respectively. The duty ratio and switching period are also D and T_s. (30 points)

1) Derive the input-output voltage relation in the continuous conduction mode.
2) Explain the power factor correction circuit using the boost converter in the critical conduction mode.
3) Derive and draw the switch utilization factor (SUF) of the boost dc-dc converter with respect to the duty ratio D.

POHANG UNIVERSITY OF SCIENCE AND TECHNOLOGY
Department of Electrical Engineering
2007 Automatic Control Qualifying Exam

Aug. 17, 2007

(제어필수는 반드시 풀고 제어선택과 전력전자 중 한 분야를 선택해서 푸시오)

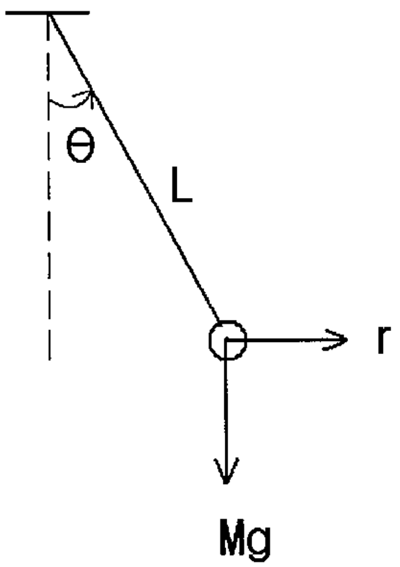
제어필수

1. Consider the following simple pendulum. The objective of the system is to control the position of the mass M by adjusting the external force r(t). Let us define

   $x_1(t) = \theta(t), x_2(t) = \dot{\theta}(t)$, and the equilibrium point be

   $\theta_0(t) = x_{01}(t) = \frac{\pi}{6}, \ \ \dot{\theta}_0(t) = x_{02}(t) = 0.$

   and $M=1, L=1, g=9.8$



a) Write the state equation of the system.
b) Find the nominal value of r(t)
c) Linearize the state equation about the equilibrium point.

제어선택

1. 다음 용어들의 정의를 정확히 기술하시오.(20)

relaxed system at t_0 causal system

Stable in the sense of Lyapunov Asymptotically stable

2. (20점) 플랜트의 전달함수 $G_P(s) = \dfrac{(s+1)}{(s^2+2s+1)(s+2)}$ 이다.

i) 3차의 controllable canonical form의 state space realization

$\dot{x} = Ax + bu, \quad y = cx$ 를 구하시오. (15)

ii) 위 realization이 observable 한가? (5)

iii) $u = -Kx + pv = -[k_1, k_2, k_3]x + pv$ 를 이용하여 closed loop system의 eigenvalue가 $-4 \pm j3,\ -5$ 이고 v가 단위계단함수일 때 정상상태 오차가 영이 되는 K 와 p 를 구하시오. (10)

전력전자 문제

1. Consider the single-phase full-wave phase-controlled rectifier. Assume that the load current i_o is constant as an inductive load. V_s and α are the rms voltage and firing angle, respectively.(30 points)
1) Draw the waveforms of the PCR output voltage v_o and input current at α = 45 [degree].
2) Derive the average output voltage V_o.
3) Derive the power factor and total harmonic distortion (THD) of the converter.

2. Consider the buck-boost dc-to-dc converter. Its input voltage and output voltage are V_o and V_d, respectively. The duty ratio and switching period are also D and T_s. (20 points)
1) Explain the operation principle of the buck-boost converter and derive the input-output voltage relation in the continuous conduction mode.
2) Derive the critical inductor value for the critical conduction mode.

POHANG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Department of Electrical Engineering

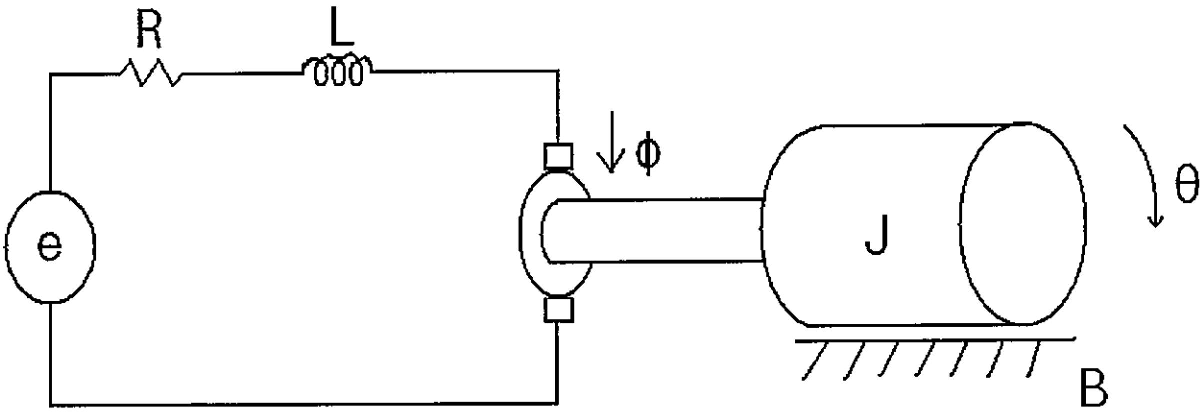
2006 Automatic Control Qualifying Exam

Aug. 14, 2006

(제어필수는 반드시 풀고 제어선택과 전력전자 중 한 분야를 선택해서 푸시오)

제어필수

1. Consider the following PM DC motor position control system.



$e(t) = input$
$\theta(t) = output$

a) Find the mathematical model using differential equation.
b) Construct a Block diagram.
c) Find the state equation.
d) Find the transfer function.
e) Find the output $\theta(t)$ for $e(t) = \delta(t)$ with zero initial conditions. ($\delta(t)$ is unit impulse function. Assume inductance L is negligible.)

제어선택

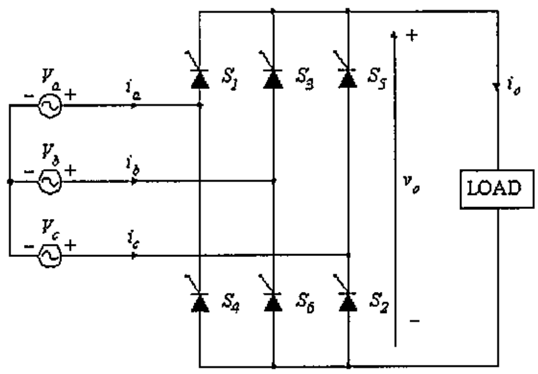
1. $\dot{x}(t) = Ax(t) + Bu(t)$, $y(t) = Cx(t)$, $x(t) \in R^n$, $u(t) \in R^m$, $y(t) \in R^m$.   (I)
위 시스템에서 완전상태가제어성(complete state controllability)과 완전상태가관측성(complete state observability)의 정의를 기술하시오.(20)

2. 시스템 (I)에서 $A = \begin{bmatrix} 0 & 6 & -5 \\ 1 & 0 & 2 \\ 3 & 2 & 4 \end{bmatrix}$, $B = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$ 이고 A의 고유치는
$\lambda_1 = 1$, $\lambda_2 = 1$, $\lambda_3 = 2$ 이다. 각각의 고유치에 대한 고유벡터 또는 일반고유벡터 p_1, p_2, p_3를 구하시오.(15)

3. $x = P\bar{x} = [p_1\ p_2\ p_3]\bar{x}$의 변환으로 얻은 시스템의 $\overline{A}, \overline{B}$를 구하고 변환된 시스템이 completely controllable한지 판단하시오.(15)

전력전자 문제

1. Consider the following three-phase full-converter. (30 points)



Assume that the load current i_o is constant during the period. V_s and α are the rms phase voltage and firing angle, respectively.

1) Draw the waveforms of the PCR output voltage v_o and phase currents.
2) Derive the average output voltage V_o.
3) Derive the power factor of the converter.
4) Derive the total harmonic distortion (THD) of the converter.

2. Consider the boost dc-to-dc converter. Its input voltage and output voltage are V_o and V_d, respectively. The duty ratio and switching period are also D and T_s. (20 points)

1) Derive the input-output voltage relation in the continuous conduction mode.
2) Derive the critical inductor value for the critical conduction mode.

2005년도 자동제어 박사과정 QE 문제
Oct. 26, 2005

(제어필수는 반드시 풀고 제어선택과 전력전자중 한 분야를 선택해서 푸시오.)

제어필수

Consider that a single-loop feedback control system has the loop transfer function

$$L(s) = G(s)H(s) = \frac{K}{s(s+2)(s+10)}.$$

a) Find the K for Gain Margin of 10 db.
b) Sketch the Nyquist plot for above K.
c) Sketch the Bode plot for above K.
d) Specify the Phase Margin on the above Bode plot.

제어선택

1-1. z-plane 과 s-plane 사이의 관계는 $z = e^{sT}$ (T는 샘플링 간격) 으로 표시된다. s-plane에서 constant damping ratio line 을 z-plane 에 도시하시오. (10)

1-2. z 변환을 이용하여 다음 차분방정식의 해를 구하라. (10)

$$x(k+2) - x(k+1) + 0.1x(k) = u_s(k)$$

$$x(0) = 0,\ x(1) = 0,\ \ u_s(k):\ \textit{unit step function}$$

2. $\dot{x}(t) = Ax(t) + Bu(t), \quad y(t) = Cx(t), \quad x(t) \in R^n,\ u(t) \in R^m,\ y(t) \in R^m. \qquad (I)$

   1) $\bar{x}(t) = Px(t)$, P is a nonsingular square matrix.

   $$\dot{\bar{x}}(t) = \bar{A}\bar{x}(t) + \bar{B}u(t), \quad y(t) = \bar{C}\bar{x}(t) \qquad (II)$$

   $\bar{A}$, $\bar{B}$, $\bar{C}$ 를 A, B, C, P 로 표시하시오. (10)

   2) 시스템 (I)과 시스템(II)의 전달함수가 같음을 보이시오. (10)

   3) 시스템 (I)이 제어가능하면 시스템 (II)도 제어가능함을 보이시오. (10)

전력전자 문제

1. Consider the three-phase half-wave converter which is composed up of three thyritor switches S_1, S_2, and S_3. Assume that the load current i_o is constant during the period. V_s and α are the rms phase voltage and firing angle, respectively. (20 points)

1) Draw the waveforms of the PCR output voltage v_o and phase currents.

2) Derive the average output voltage V_o and power factor of the conver- ter.

2. (30 points)

1) Explain the operation principle of the flyback converter and derive its voltage transfer ratio in the continuous conduction mode. (20 points)

2) Derive the voltage stress across the switch of the flyback converter during the off interval. (10 points)

2004. 11. 3

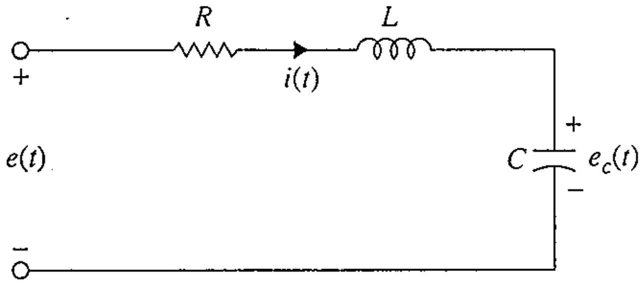
POHANG UNIVERSITY OF SCIENCE AND TECHNOLOGY
Department of Electrical Engineering
2004 Automatic Control Qualifying Exam

Nov. 3, 2004

(제어필수는 반드시 풀고 제어선택과 전력전자 중 한 분야를 선택해서 푸시오)

제어필수

1. Consider the following spring-damper system.



(a)

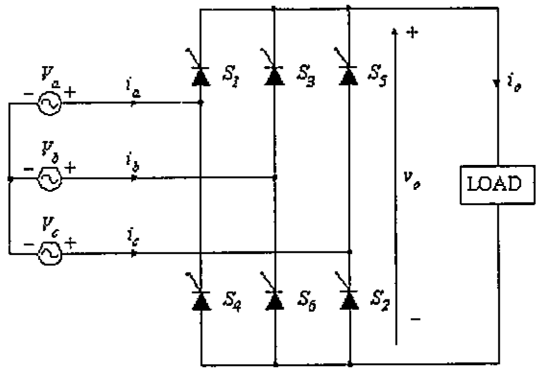
$L=1$, $R=3$, $C=0.5$

$e(t) = input$
$e_c(t) = output$

a) Find the differential equation and find the state equation and output equation.
b) Find the transfer function from the state equation and output equation.
c) Find the fundamental matrix and state transition matrix.
d) Prove that the state transition matrix $\Phi(t_2-t_1)\Phi(t_1-t_0)=\Phi(t_2-t_0)$ using the definition of state transition matrix.
e) Find the output $y(t)$ for $f(t)=\delta(t)$ with zero initial conditions. $\delta(t)$ is unit impulse function.

전력전자 선택 문제

1. Consider the following three-phase full-converter. (30 points)



Assume that the load current i_o is constant during the period. V_s and α are the rms phase voltage and firing angle, respectively.

1) Draw the waveforms of the PCR output voltage v_o and phase currents.
2) Derive the average output voltage V_o.
3) Derive the power factor of the converter.

2. Consider the boost dc-to-dc converter. Its input voltage and output voltage are V_o and V_d, respectively. The duty ratio and switching period are also D and T_s. (20 points)

1) Derive the input-output voltage relation in the continuous conduction mode.
2) Derive the critical inductor value for the critical conduction mode.

Control Part

(제어 선택)

1. Given system matrices,

$$A = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}, \quad C = \begin{bmatrix} 1 & 1 \end{bmatrix},$$

   a. Is it controllable? Verify your answer.

   b. Is it observable? Verify your answer.

   c. Is it stable? Verify your answer.

   d. Show the transfer function.

2. Compute

$$\begin{bmatrix} 5 & 4 & 4 & 4 \\ 4 & 5 & 4 & 4 \\ 4 & 4 & 5 & 4 \\ 4 & 4 & 4 & 5 \end{bmatrix}^{-1} \begin{bmatrix} 2 \\ 2 \\ 2 \\ 2 \end{bmatrix}.$$

   Hint: Rewrite it as $(I + ab^T)^{-1}a$ and compute it with scalar inversion instead of matrix inversion.

3. **(Zero-Order-Holder)**

   a. What is the impulse response of the ZOH with T-sec duration?

   b. Find the transfer function of the ZOH.

   c. When the ZOH is connected in cascade with a linear process with transfer function, what is the resulting z-transform of the combination?

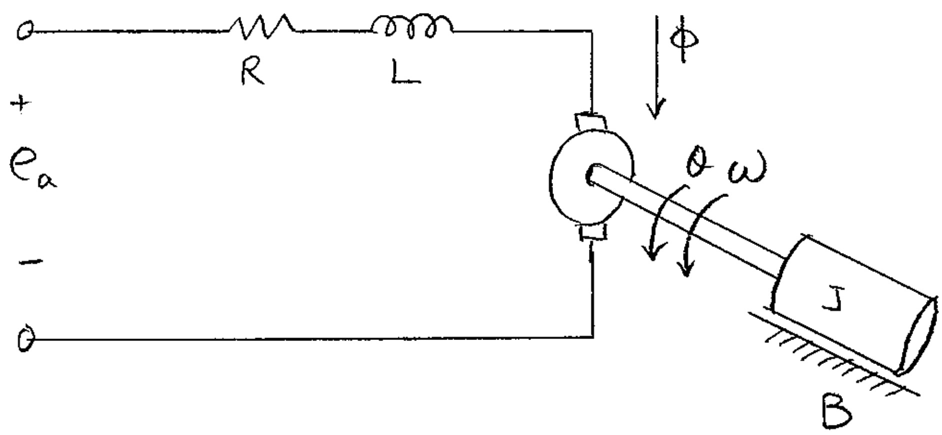
2003년도 자동제어 박사과정 QE 문제

(제어필수는 반드시 풀고 제어선택과 전력전자중 한 분야를 선택해서 푸시오.)

제어필수

1. A PM dc server motor variables and parameters are defined as follows.

i_a = armature current
R = armature resistance
e_b = back emf
T = motor torque
θ = rotor displacement
J = load inertia
B = viscous friction coefficient
L_a = armature inductance
e_a = applied voltage
K_b = back emf constant
ϕ = magnetic flux in the air gap
w = rotor angular velocity
K_i = torque constant



a. Write the state equation using i_a, w, and θ as the state variables

b. Find the transfer function $G(s)=\dfrac{\theta}{e_a}$

2. Consider that a single loop feedback control system has the loop transfer function

$$L(s) = G(s)H(s) = \frac{24}{s(s+2)(s+10)}$$

a. Sketch the Nyquist plot
b. What is the gain margin?

제어선택

1. $G(s) = \dfrac{2}{(s+3)(s+2)}$ 이고 sampling interval $T = 0.1$ sec일 때

   1) ZOH (zero order hold) equivalent ($G_{zoh}(z)$)를 구하시오. (10)
      (exp(-0.3)=0.7408, exp(-0.2)=0.8178)

   2) 1)에서 구한 이산시간 전달함수를 G(z)라 하고 G(z)의 controllable canonical form의 state space realization
      $x(k+1) = Ax(k) + bu(k)$, $y(k) = cx(k)$ 를 구하시오. (10)

2. $\dot{x}(t) = \begin{bmatrix} 0 & 1 \\ -2 & -3 \end{bmatrix} x(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t)$

   1) 상태천이행렬(state transition matrix)를 구하시오. (10)
   2) 위 시스템이 제어가능한지 판별하시오. (10)
   3) $u(t) = -[k_1 \ k_2]x(t)$ 일 때 폐루우프 시스템의 극점이
      $-4 \pm j4$ 이 되는 k_1, k_2를 구하시오. (10)

전력전자 선택

1. Consider the full-bridge dc-to-dc converter. (20 points)
1) Explain (or define) the power factor of the converter with harmonic current components.

2) Explain and compare the unipolar and bipolar PWM switchings for its voltage control.

2. Consider the 3-phase PWM inverter. (30 points)

1) Determine the switch utilization factor (SUF) of the 3-phase inverter with the sinusoidal PWM switching.

2) Explain the advantages of the space vector modulation comparing with the sinusoidal PWM (SPWM).

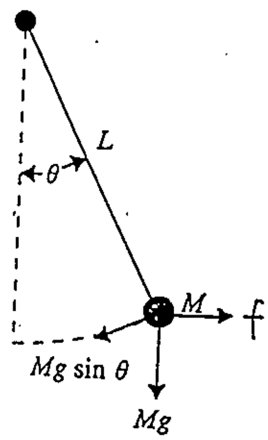
2003년도 자동제어 박사과정 QE 문제

(제어필수는 반드시 풀고 제어선택과 전력전자중 한 분야를 선택해서 푸시오)

제어필수

1. Consider a pendulum given below. $\theta(t)$ is supposed to be controlled to maintain the angle $\theta_0 = \frac{2\pi}{36}$.

Let M = 1, L = 1, G = 9.8, $x_1 = \theta$, $x_2 = \dot{\theta}$



a) Find the state equation.
b) Linearize the system about the equilibrium point.

2. Consider a system below.

$$\dot{X} = AX + Bu$$
$$y = CX$$

where $A = \begin{bmatrix} 1 & 1 \\ -2 & -3 \end{bmatrix}$, $B = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$, $C = [1 \;\; 0]$

Find the similarity Transformation matrix T for diagonal form and find the transformed matrices $\overline{A}, \overline{B}, \overline{C}$.

제어선택

1. 플렌트의 전달함수 $G_P(s) = \dfrac{2}{(s+1)(s+2)}$ 이다.

i) Bilinear transformation을 이용하여 discrete equivalent $G(z)$를 구하시오.

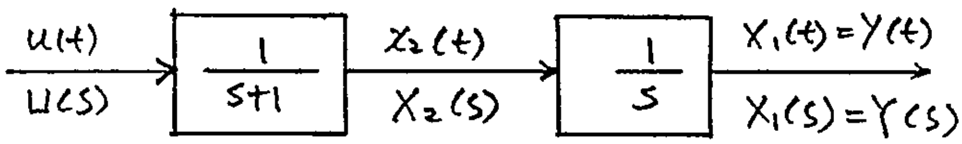
(sampling interval = 0.1 sec.) (exp(-0.2)=0.819, exp(-0.1)=0.905)

ii) G(z)의 controllable canonical form의 state space realization $x(k+1) = Ax(k) + bu(k)$, $y(k) = cx(k)$ 를 구하시오.

iii) $u(k) = -Kx(k) + r(k) = -[k_1, k_2]x + r(k)$ 를 이용하여 closed loop system의 eigenvalue가 $0.6 \pm j0.5$ 이 되는 K를 구하시오.

iv) r(k)가 단위계단함수일 때 정상상태에서의 y 값을 구하시오.

2. 다음과 같이 Motor System Model이 주어져 있다.



여기서 초기조건은 $x_1(0) = 1$ 이고, $x_2(0) = 0$ 이다.

1) $x_1(t)$, $x_2(t)$ 그리고 y(t)를 $x_1(0)$, $x_2(0)$ 및 u(t)를 이용하여 구하라.

2) 1초만에 $x_1(1) = 0$, $x_2(1) = 0$ 이 되도록 만들어 주는 u(t) ($0 \le t \le 1$)를 구하라.

전력전자 문제

1. Consider the three-phase half-wave converter which is composed up of three thyritor switches S_1, S_2, and S_3. Assume that the load current i_o is constant during the period. V_s and α are the rms phase voltage and firing angle, respectively. (30 points)

1) Draw the waveforms of the PCR output voltage v_o and phase currents.
2) Derive the average output voltage V_o and power factor of the conver- ter.
3) Explain advantages of the PLL technique for the phase-controlled rectifier.

2. Consider the six-step inverter with dc link voltage V_d. (20 points)

1) Draw the waveforms of the gating signals, line voltage, and phase voltage. (10 points)
2) What is the line-to-line voltage ? (5 points)
3) What is the rms value of the fundamental component of the line-to- line voltage ? (5 points)

2002년도 자동제어 박사과정 QE 문제

(제어필수는 반드시 풀고 제어선택과 전력전자중 한 분야를 선택해서 푸시오.)

제어필수

1. (30점) Consider a system whose open loop transfer function is given below.

$$G(s) = \frac{4500K}{s(s+361.2)}$$

Design a PD controller such that the resulting system satisfies the following performance specifications;

i) Steady-state error due to unit-ramp input $\leq$ 0.000443
ii) Maximum overshoot $\leq$ 5 percent
iii) Rise time tr $\leq$ 0.005 sec

2. (20점) Gain margin과 phase margin을 정확히 정의하고, 제어기 설계할 때 이들의 값이 어느 정도 이상이 되도록 하는 이유를 설명하시오.

제어선택

1. (30점) 플랜트의 전달함수 $G_P(s) = \frac{2500}{s(s+25)}$ 이다.

i) Bilinear transformation을 이용하여 discrete equivalent $G_D(z)$를 구하시오. (sampling interval = 0.01 sec.) 또는 Zero order hold equivalent $G_{zoh}(z)$를 구하시오. (exp(-0.25)= 0.7788)
ii) i)에서 구한 이산시간 전달함수를 G(z)라 하고 G(z)의 controllable canonical form의 state space realization $\dot{x} = Ax + bu, \quad y = cx$ 를 구하시오.
iii) $u = -Kx = -[k_1, k_2]x$ 를 이용하여 closed loop system의 eigenvalue가 $0.4 \pm j0.3$ 이 되는 K를 구하시오.

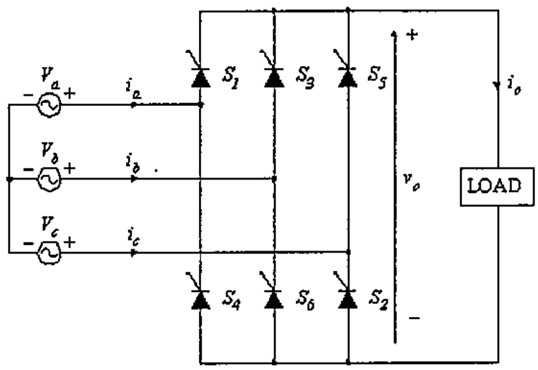
2. (20점) Prove that, for BIBO (Bounded-Input-Bounded-Output) stability, the poles of the system transfer function must all lie in the open left-half s-plane.

전력전자

1. (20 points)

   Draw the circuit model of the transformer and explain its elements. Also show the conditions of the perfect transformer.

2. Consider the following three-phase full-converter. (30 points)



   Assume that the load current i_o is constant during the period. V_s and α are the rms phase voltage and firing angle, respectively.

1) Draw the waveforms of the PCR output voltage v_o and phase currents.
2) Derive the average output voltage V_o.
3) Derive the power factor of the converter.
4) Derive the total harmonic distortion (THD) of the converter.

QE for Control group

Oct. 27, 2000

- Solve 2 basic problems and solve 2 advanced problems out of 4 advanced problems.

I. Basic problems.

1. Consider the loop transfer function

$$G(s)H(s) = \frac{K(s+1)}{S(s+4)(s + 2s+2)}$$

Sketch the root locus.

2. Consider that single-loop feedback control system has the loop transfer function

$$L(s) = G(s)H(s) = \frac{24}{s(s+2)(s+10)}$$

Sketch the Nyquist plot and find the gain margin.

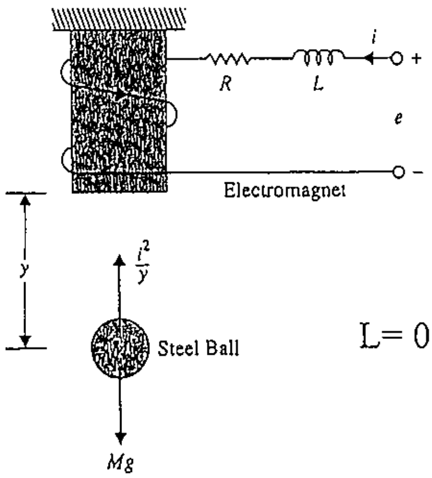
3. $G(s)=\dfrac{2}{(s+1)(s+2)}$ 이고 sampling interval $T=0.1$ sec 일 때 다음의 방법을 사용하여 discrete equivalent를 구하시오.

1) bilinear transform ($G_b(z)$)

2) ZOH (zero order hold) equivalent ($G_{zoh}(z)$)

(exp(-0.1)=0.9048, exp(-0.2)=0.8178)

4. Consider the magnetic-ball-suspension system shown below. Write the state equations and linearize the system about the equilibrium point $y_0(t)$ = 0.2.



L= 0.1, R=100, M=100, and g=9.8.

II. Advanced problems

1. a) Show that the average rectified voltage is given by $\frac{3}{\pi}\sqrt{2}V_{LL}$ in the three phase diode rectifier, where the source is a balanced three phase system and $v_{ab} = \sqrt{2}V_{LL}\cos\omega t$.
b) Draw the full bridge thyristor rectifier of a single phase system $v_s = \sqrt{2}V_s\cos\omega t$. Show that the average rectified voltage is given by $\frac{2\sqrt{2}}{\pi}V_s\cos\alpha$, where $\alpha(rad) > 0$ is the firing angle.

2. a) Draw the DC motor equivalent circuit using armature inductance L_a, armature resistance R_a, back emf e_a, and armature voltage v_a.
b) When torque constant is k_T, the flux of field winding is Φ, and the motor speed is ω, how they are related to the back emf e_a?
c) If we let $R_a \approx 0$, then the torque constant k_T is equal to the back emf constant k_b. Prove it using the fact that the mechanical power is equal to the electrical power.
d) If the rotor plus load inertia is equal to J, the damping coefficient is B, and the external load torque is T_L, obtain an equation between the motor torque T and J, B, T_L, ω.
e) Using the above information, construct a motor (with load) block diagram using Laplace operator s.
f) Add a speed loop with a PI controller and a closed loop transfer function. But, in obtaining the transfer function use the fact that the current dynamic block can be replaced by $1/R_a$, since the current dynamics is much faster than that of the mechanical dynamics.

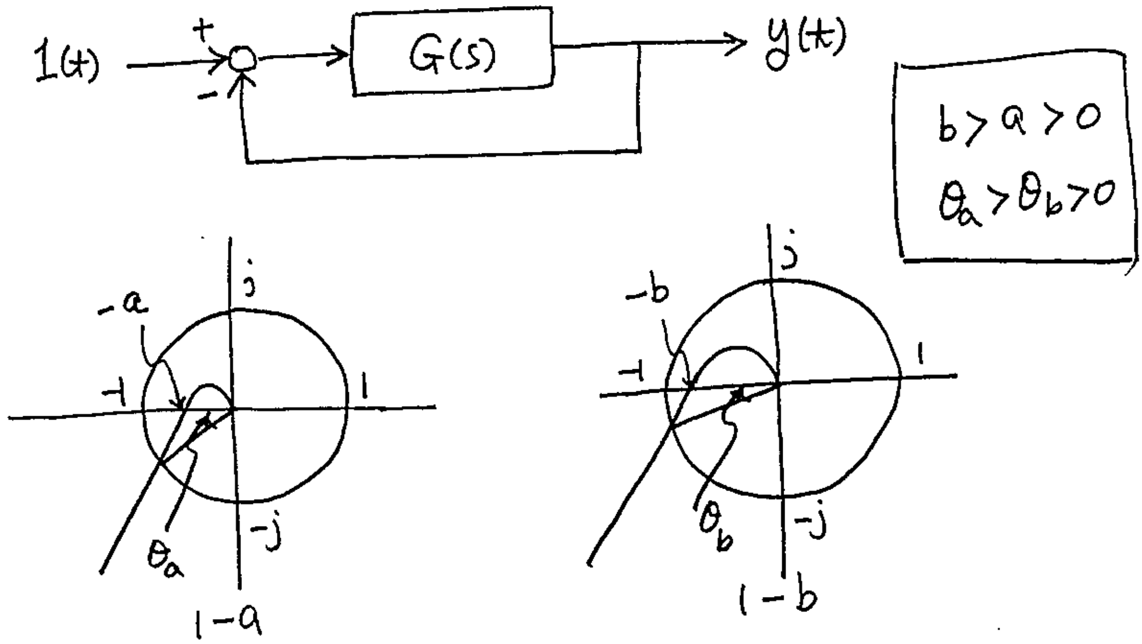
1999. 10. 29

제어분야 박사 자격 시험

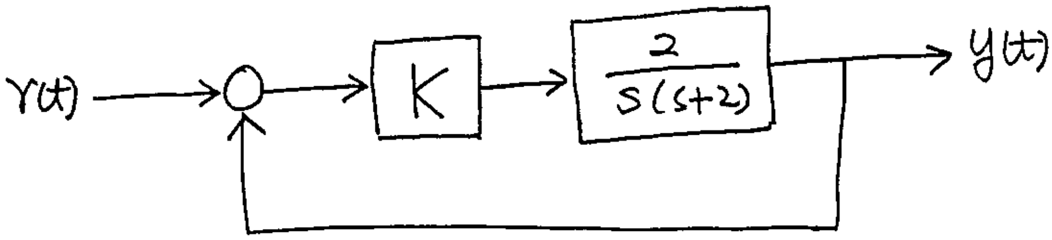
제어필수

1.1 Open Loop 시스템이 안정한 최소위상이고 다음과 같은 Nyquist plot을 갖는다. 두 시스템을 비교하여 Unit Step Input에 대한 각각의 응답을 그리시오. (20)

1.2 이득여유와 위상여유를 설명하고 그림 1-a에서 이득여유와 위상여유를 구하시오. (10)



2.



2.1 Damping ratio가 0.5가 되는 K를 구하시오. (10)

2.2 Unit ramp function이 입력일 때 정상상태오차가 0.1 이하가 되는 K의 범위를 구하시오. (10)

제어선택

1.

$$(\Sigma_1) \quad \dot{x} = Ax + Bu, \quad y = Cx$$

$$\bar{x} = Tx, \quad det(T) \neq 0$$

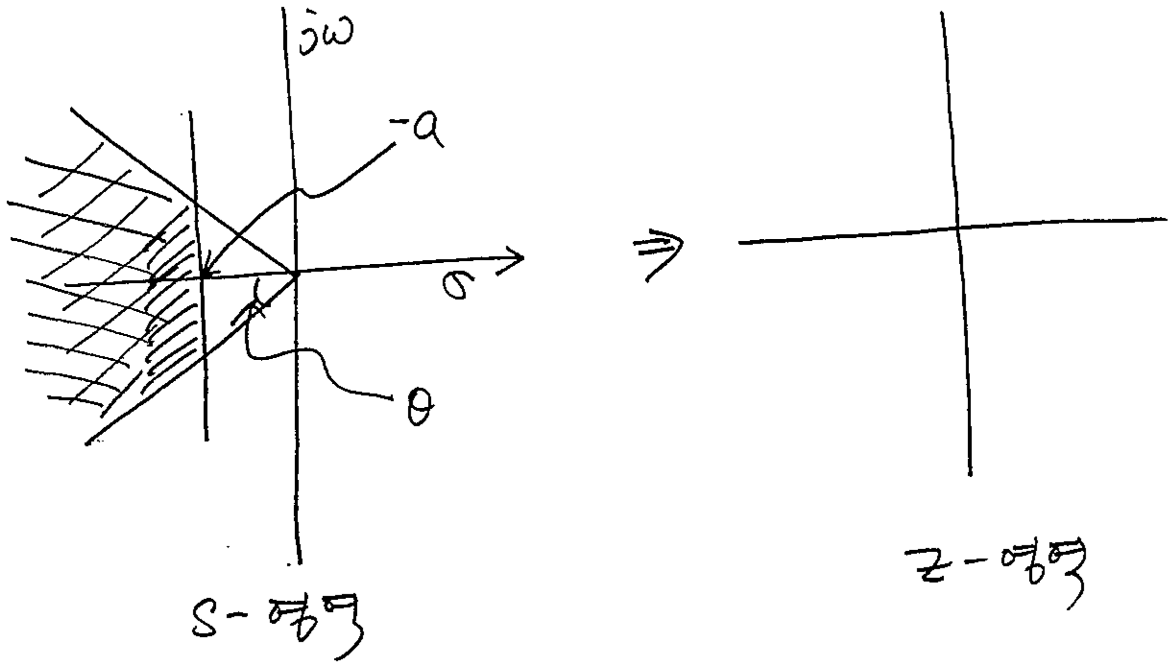
$$(\Sigma_2) \quad \dot{\bar{x}} = \bar{A}\bar{x} + \bar{B}u, \quad y = \bar{C}\bar{x}$$

1.1 $\bar{A}$, $\bar{B}$, $\bar{C}$ 를 A, B, C, T 로 표시하시오. (10)

1.2 시스템 Σ_1 과 Σ_2 의 전달함수가 같음을 보이시오. (10)

1.3 시스템 Σ_1 이 completely controllable 하면 시스템 Σ_2 도 completely controllable 함을 보이시오. (10)

2. 다음의 s-영역을 z-영역에 표시하시오. (20)



1999.10.29

전력전자

1. Consider the three-phase half-wave converter which is composed up of three thyristor switches S_1, S_2, and S_3. Assume that the load current i_o is constant during the period. V_s and α are the rms phase voltage and firing angle, respectively. (30 points)

1) Draw the waveforms of the PCR output voltage v_o and phase currents.

2) Derive the average output voltage V_o and power factor of the converter.

3) Explain the cosine-wave crossing method as a control technique of the phase-controlled rectifier.

2. (20 points)

1) Explain simply the operation principle of the buck-boost converter and derive the input-output voltage relation in the continuous conduction mode.

2) Explain the unipolar PWM in the full-bridge dc-to-dc converter.

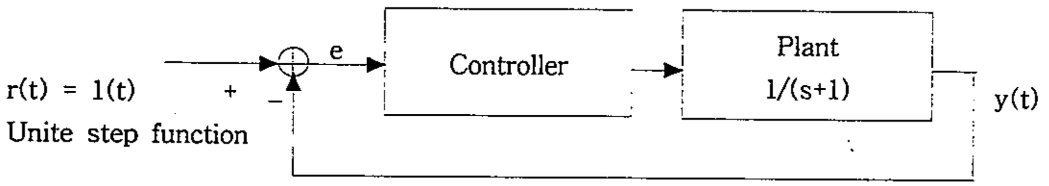
98.10.23

제어 및 전력전자 QE for 99' Ph.D candidates

> 6문제 중 4문제를 선택하시오. (제어·전력전자 공통 필수 2문제는 반드시 선택, 나머지 2 문제는 제어 분야 2문제를 선택하거나, 전력전자 분야 2문제를 선택) 제어와 전력전자를 혼용하여 선택할 수 없음에 유의하시오.

제어 및 전력전자 공통 필수 문제

1. (제어 및 전력전자 공통 필수) Controller Design



위의 block diagram에서

(i) the steady-state error is zero (i.e. $\lim_{t\to\infty}(r-y) = \lim_{t\to\infty} e = 0$)

(ii) the closed-loop system poles are at $-1 \pm j$

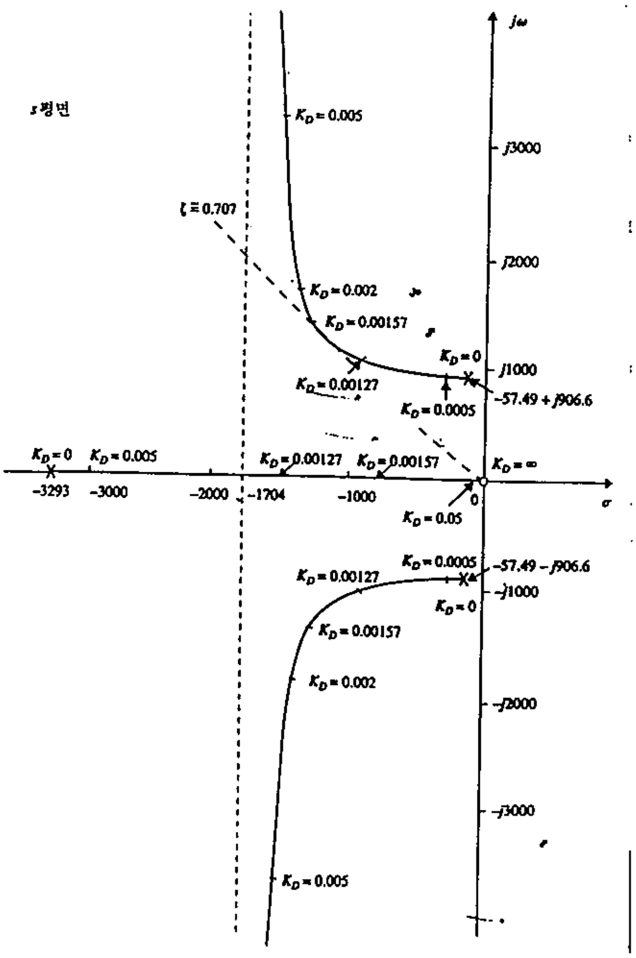
의 spec.을 만족하는 제어기를 하나 제안하시오.

2. (제어 및 전력전자 공통 필수)

We shall consider a 3rd-order aircraft attitude control system. With the **PD** controller, the resulting **forward-path** transfer function of the system is

$$G_c(s) = \frac{2.718\times10^9 (K_p + K_D s)}{s(s^2 + 3408.3s + 1204000)}$$

Setting K_p=1 and varying K_D from zero to infinity, **the closed loop system root contours** are given in the right side. Describe the variation of 1) **maximum overshoot** 2) **rising time** 3) **settling time** as K_D increases from zero to infinity. (Hint: the behavior of the system **dominantly** depends on the **complex poles,** rather than the real-axis pole and the zero.)



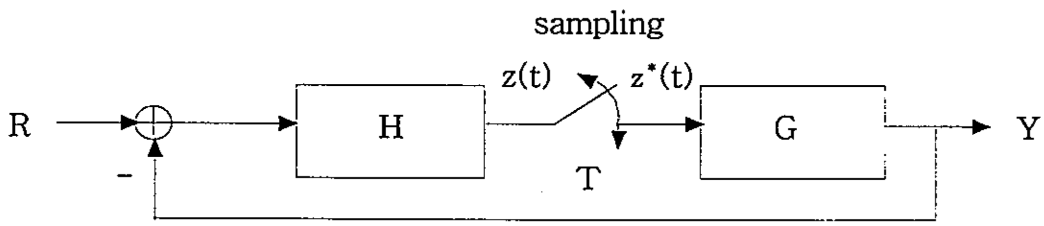
제어 문제

1. (On sampled data systems)
Let us define the following notations given a signal a(t) and a sample period T.

A ≡ Laplace transform of a(t)

A* ≡ Sampled expressin of A defined by
Laplace transform of a*(t) $\left(\equiv \sum_{k=-\infty}^{\infty} a(t-kT)\right)$

1) Represent Y* in terms of R, H, G and their combined and/or sampled expressions.



2) Calculate the transfer function from R* to Y* **if possible.** Otherwise, explain which condition allows us to do so. [Hint: Which condition of A allows us to separate A* and B* from (AB)*, i.e. (AB)* = A*B* for any B?]

2. (On similarity transformation)

$$(S_1)\qquad \dot{x}(t)=Ax(t)+Bu(t),\quad y(t)=Cx(t)$$

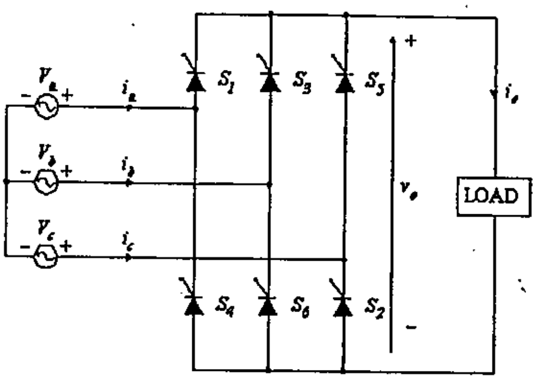
$$\downarrow \qquad \bar{x}(t)=Px(t),\quad P\in R^{n\times n},\quad P \text{ 는 nonsingular}$$

$$(S_2)\qquad \dot{\bar{x}}(t)=\bar{A}\,\bar{x}(t)+\bar{B}u(t),\quad y(t)=\bar{C}\,\bar{x}(t)$$

① $\bar{A}$, $\bar{B}$, $\bar{C}$ 를 A, B, C, P 로 표시하시오.
② 시스템 (S_1)이 controllable하면 시스템 (S_2)도 controllable함을 보이시오.
③ 시스템 (S_1)의 eigenvalue와 pole을 정의하고 그 차이를 기술하시오.

전력전자 문제

1. Consider the following three-phase full-converter. (30 points)



Assume that the load current i_o is constant during the period. V_s and α are the rms phase voltage of the source voltage and firing angle, respectively.

1) Draw the waveforms of the PCR output voltage v_o and phase currents.
2) Derive the average output voltage V_o.
3) Derive the power factor of the converter.

2. (20 points)

Draw and explain the equivalent model of the transformer, and explain the conditions of the ideal transformer.

제어분야 자격시험문제

1. 전달함수 $H(s)=\dfrac{(s-1)}{(s+1)(s+2)(s+3)}$ 의 controllability 와 observability에 대하여 논의하라. (10 점)

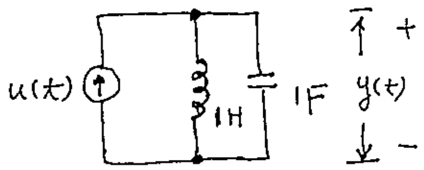
2. obsever 설계에 있어서 seperation principle에 대하여 논의하라. (10 점)

3. 행렬 $A=\begin{bmatrix} 2 & 1 \\ 1 & 3 \end{bmatrix}$ 일때 A^n 의 고유치를 구하라. (단 n은 자연수이다) (10 점)

4. 디지탈 제어기 C(z) 를 구현함에 있어서 parameter의 round-off error가 pole 에 미치는 영향을 상세히 설명하고 대응책을 제시하시요. (10 점)

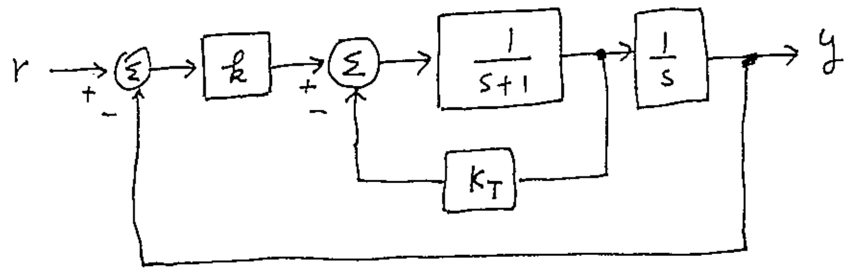
5. $G(s)=\dfrac{1}{s(s+1)}$ 의 Discrete equivalent G(z) 를 zero-order hold equivalent로 구하시요. (10 점)

6. 다음의 시불변 시스템을 생각하라. (20 점)



(1) 이 시스템의 BIBO stability 를 증명하라.
(2) 이 시스템이 BIBO stable 하지 않다면 unbounded output를 내는 bounded input을 구하라.

7. 아래 그림은 position servomechanism의 block diagram이다. 아래 물음에 답하라. (30 점)



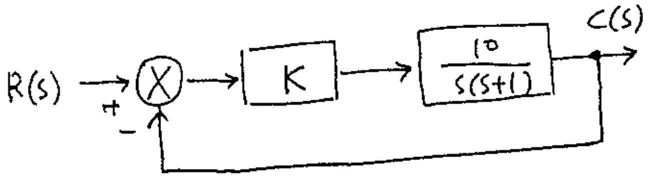
(a) tachometer feedback $k_T = 0$ 으로 놓고 $0 < k < \infty$ 으로 변할 때 root locus를 그리시요.

(b) $k = 4$ 로 놓고 $0 < k_T < \infty$ 으로 변할 때 root locus를 그리시요.

(c) $k = 4$ 인 경우 overshoot 가 5% 정도 (damping ratio = 0.707) 되도록 k_T 를 정하시요.

자동제어

1. 다음과 같은 feedback system을 생각하라.

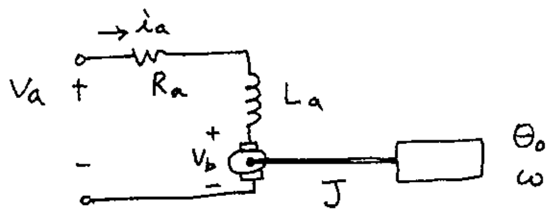


(1) 이 시스템의 상태방정식을 써라.

(2) 근궤적 (root locus)를 이용하여 이 시스템을 안정화시키는 K의 영역을 찾아라.

(3) r(t)가 unit ramp input일때 출력 c(t)의 정상상태 값을 구하라.

2. 다음과 같은 position control system을 생각하라. 여기서 입력 변수는 armature voltage $V_a(t)$ 이고 출력변수는 $\theta_o(t)$이다.



θ_o: motor position
ω_a: motor speed
J : motor 측으로 환산된 motor 와 load의 total inertia

(1) 이러한 motor 시스템의 전압방정식, 토크방정식, 유기기전력을 표현하라. (필요하면 motor coefficient는 정의하여 사용하시요.)

(2) 미분방정식으로 부터 상태방정식을 써라.

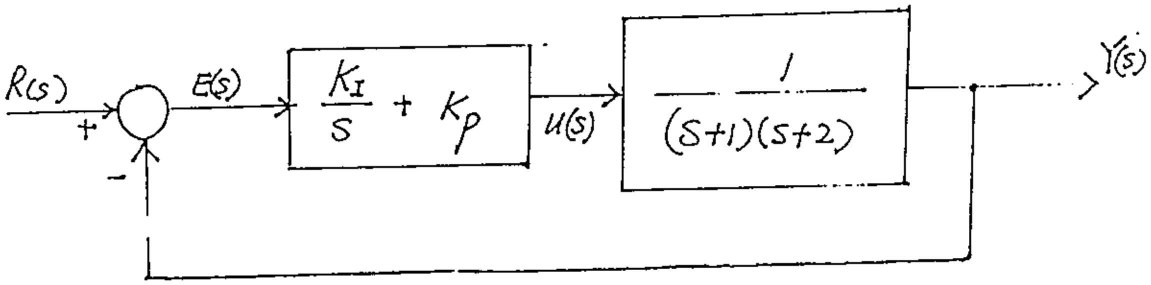
(3) State transition matrix를 구하라.

(4) 이 시스템의 controllability와 observabilty에 대하여 설명하라.

(5) 이시스템의 변수 i_a가 측정가능하지 않을때 estimate하는 observer를 구성하라.

Qualifying Examination (제어-전공)

1. 다음과 같은 Feedback System 을 생각해 보자.



$K_p > 0, \quad K_I > 0$

(1) 전달함수 (transfer function) $H(s) = \frac{Y(s)}{R(s)}$ 를 구하시오.

(2) step input 에 대한 steady-state error 를 구하시오.

(3) 전체 system 을 다음과 같이 state-space representation 으로 표시하시오.

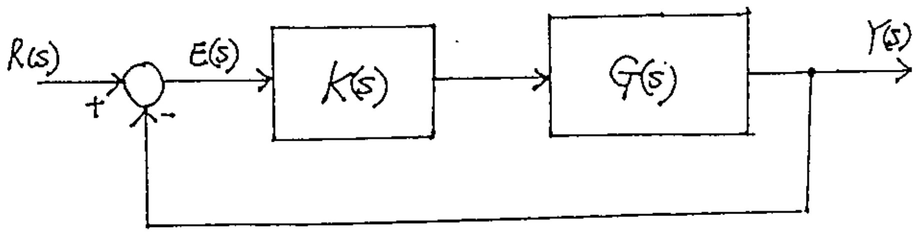
$$\begin{cases} \dot{x}(t) = Ax(t) + Bu(t) \\ y(t) = Cx(t) \\ u(t) = Dx(t) + Fr(t) \end{cases}$$

2. 선형 system 의 특성방정식이 다음과 같이 주어져 있다.

$$s^4 + 2s^3 + s^2 + 2ks + 5k = 0.$$

$0 \le K < \infty$ 범위에서 이 특성 방정식의 root locus 를 그려보시오.

3. 다음과 같은 Feedback System 을 생각해 보자.



$G(s) = \frac{5}{s(s+1)(s+2)}$ 이다.

(1) $K(s) = k$ 일때 closed-loop system 을 안정하게 하는 k 의 범위는?

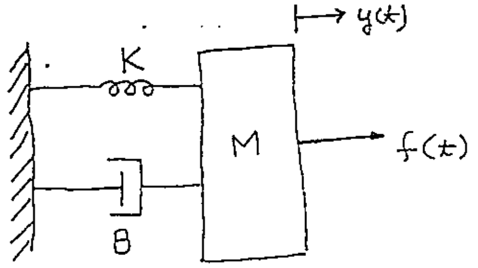
(2) $K(s) = e^{j\theta}$ 일때 closed-loop system 을 안정하게 하는 θ 의 범위는?

(3) $K(s) = ke^{j\theta}$ 에서 k 와 θ 가 동시에 변화할 때 closed loop system 의 안정성은 어떻게 영향받는지 설명하시오.

자동제어 자격시험문제 94/4/2

1. 다음의 mechanical system을 생각하라. 여기서 K는 스프링상수, B는 viscous friction 계수, M은 mass, f(t)는 force, y(t)는 변위를 나타낸다.

33



1) 이 시스템의 force equation을 구하라
2) 상태변수를 정의하여 상태방정식을 구하라
3) 이 시스템의 state diagram 을 그려라

2. (1) $G(s)= 10(s+2)/[s(s+1)(s+3)^2]$ 일 때 g(t)를 구하고 최종치정리 (final value theorem) 을 이용하여 $\lim_{t\to\infty} g(t)$ 를 구하라

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(2) S : $\dot{x}(t) = Ax(t)+Bu(t)$, $y(t) = Cx(t)$ 일 때 유사변환 P (det (P)≠0) 를 이용하여 $x_N(t) = Px(t)$ 를 정의하였다. 변환된 시스템을 S_N: $\dot{x}_N(t) = A_Nx_N(t) + B_Nu(t)$, $y(t) = C_Nx_N(t)$ 로 표시했을 때 A_N, B_N, C_N 를 구하고 시스템 S와 S_N의 전달함수가 같음을 보여라.

(3) (2)에서 시스템 S가 controllable 하면 시스템 S_N 도 controllable 함을 보여라.

3. Consider a phase-lag controller of the form $E_2(s)/E_1(s) =(1+aTs)/(1+Ts)$.

33

(1) Using passive elements (resistors and capacitors), realize the controller and find it's transfer function.

(2) Sketch a pole-zero configuration of the transfer function on the complex s-plane.

(3) Sketch a Bode plot of the controller.

bonus 1점.

자동제어 QE

1. 아래 그림과 같은 시스템에서 process는 다음과 같다.

$$\dot{x}(t) = \begin{pmatrix} 0 & 1 \\ 0 & -2 \end{pmatrix} x(t) + \begin{pmatrix} 0 \\ 1 \end{pmatrix} u(t)$$

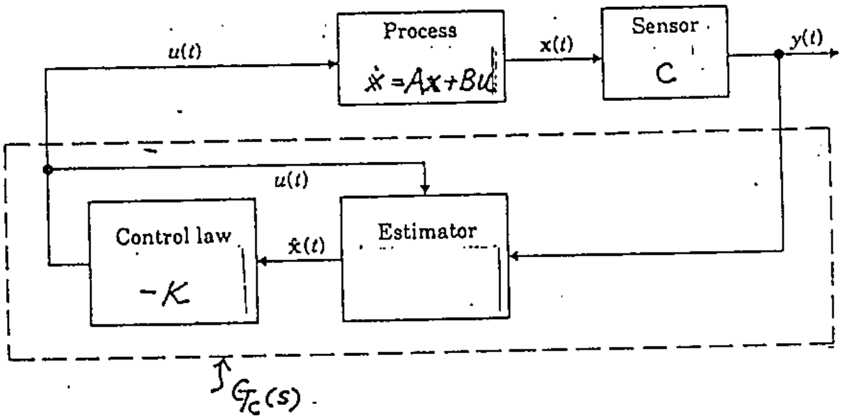
$$y(t) = [\ 1 \quad 0\ ]x(t)$$

i) 주어진 시스템은 1) u(t)가 없는 경우 안정한가? 2) completely controllable 한가?
3) completely observable 한가?

ii) desired controller의 근이 $-\frac{1}{2} \pm j\frac{\sqrt{(3)}}{2}$에 위치하도록 하는 state feedback gain K를 구하시오.

iii) desired estimate의 근이 $-\frac{\sqrt{(2)}}{2} \pm j\frac{\sqrt{(2)}}{2}$에 위치하도록 하는 estimator gain L과 estimator 식을 구하시오.

iv) 위의 estimator와 controller가 통합된 compensator $G_c(s)$ 를 구하시오.



2.1 플랜트의 전달함수 $G(s) = \frac{10}{s(s+10)}$ 일 때 zoro-order hold 를 이용한 discrete equivalent G(z)를 구하시오. Sampling interval은 T = 0.1 초 이고 다음 식들을 이용하시오. (10)

$$Z(\frac{1}{s}) = \frac{z}{z-1},\quad Z(\frac{1}{s^2}) = \frac{Tz}{(z-1)^2},\ Z(\frac{1}{s^3}) = \frac{T^2 z(z+1)}{2(z-1)^3},\quad Z(\frac{1}{s+a}) = \frac{z}{z-e^{-aT}},$$

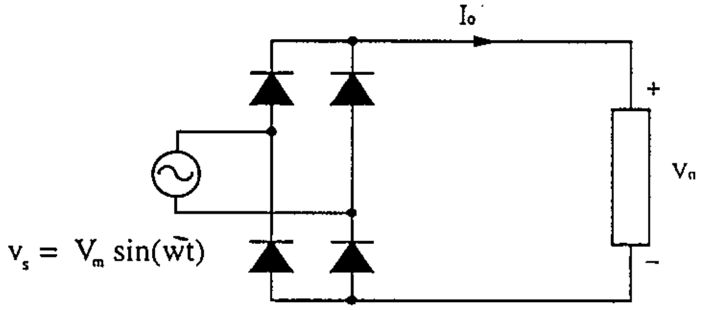
$$e^{-0.1} = 0.905,\quad e^{-1} = 0.368,\quad e^{-2} = 0.135\quad e^{-3} = 0.0498,\quad e^{-10} = 0.454x10^{-4}.$$

2.2 문제 2.1의 플랜트 G(z)에 단위펄스함수 (unit pulse function, $\delta(k) = 1$ for $k = 0$ 이고 $\delta(k) = 0$ for $k > 0$ 임) 가 인가되었을 때 출력 y(k)를 구하시오. 모든 초기조건은 0 이다. (10)

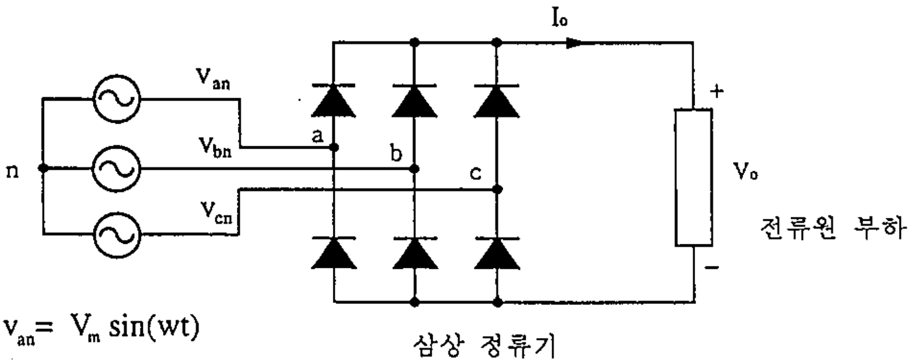
2.3 Digital제어기 설계시에 Quantization 오차 및 Roundoff 오차가 시스템의 성능에 미치는 영향을 기술하고 대책을 제시하시오. (10)

3. 다이오드로 구성된 다음의 단상 및 삼상 정류기를 생각하라. 단상 정류기에서 최대 첨두전압과 삼상 정류기에서 상전압의 최대 첨두전압은 Vm 이며 각속도는 w 이다. 정류기의 부하는 인덕티브 부하인 전류원 부하로서 Io 이다. Vo 는 출력전압을 나타낸다.

3.1) 단상 정류기에서 출력전압의 파형을 그리고 평균 출력전압을 구하라.
3.2) 삼상 정류기에서 출력전압의 파형을 그리고 평균 출력전압을 구하라.
3.3) 삼상 정류기에서 입력전류의 파형을 그려라.



단상 정류기

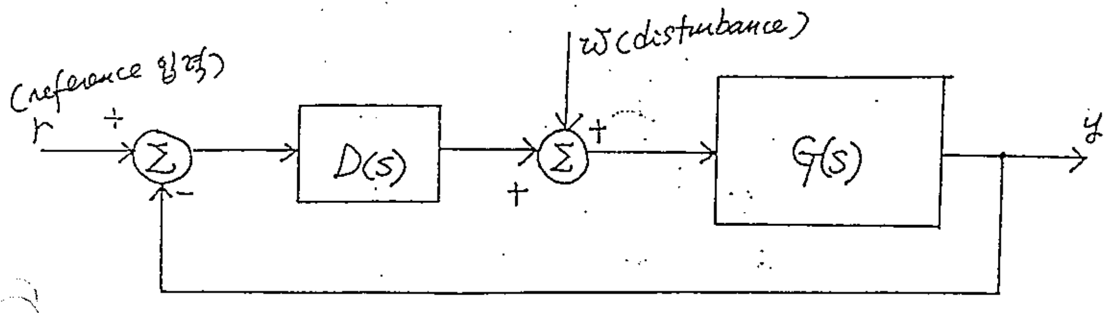


삼상 정류기

1993 Control Ph.D. Qualifying Exam.

[30pt]Prob. #1

아래 그림은 모터제어를 위한 closed-loop system 이며 $G(s) = \frac{1}{s(5s+1)}$ 는 모터의 전달함수이며, $D(s) = K_1 + K_2 s$ 는 PD 형의 제어기 이다. 아래 주어진 spec. 을 만족하도록 K_1 과 K_2 를 구하라. 아래 (A), (B), (C), (D) 순서를 따라 풀 것.



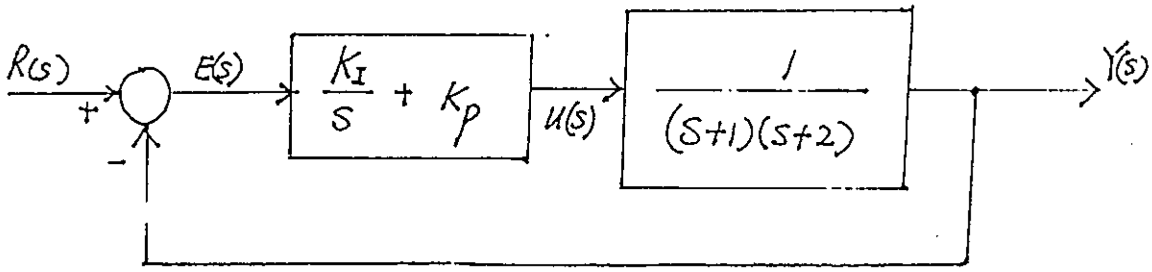
(공통) (A) $r(t) = t \cdot 1(t)$ ($1(t)$: unit step function) 일 경우 이에 대한 steady state error 를 구하라.

(공통) (B) $w(t) = 1(t)$ 일 경우 이에 대한 steady-state error 를 구하라.

(공통) (C) 복소수 평면 상에서 overshoot (M_p) ≤ 0.05 이고 1% 오차에 대한 Settling time (t_s) $\le$ 1 (sec) 를 만족하는 영역을 그리시오.
(Hint: $t_s \cong \frac{4.6}{\zeta\omega_n}$ 이며, $M_p \cong 0.05$ 는 대략 $\zeta \cong 0.7$)

Qualifying Examination (제어 분야)

1. 다음과 같은 Feedback System 을 생각해 보자.



$K_p > 0, \quad K_I > 0$

(1) 전달함수(transfer function) $H(s) = \frac{Y(s)}{R(s)}$ 를 구하시오.

(2) step input 에 대한 steady-state error 를 구하시오.

(3) 전체 system 을 다음과 같이 state-space representation 으로 표시하시오.

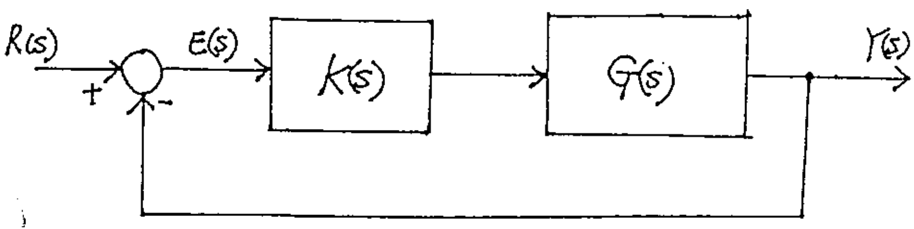
$$\begin{cases} \dot{x}(t) = Ax(t) + Bu(t) \\ y(t) = Cx(t) \\ u(t) = Dx(t) + Fr(t) \end{cases}$$

2. 선형 system 의 특성방정식이 다음과 같이 주어져 있다.

$s^4 + 2s^3 + s^2 + 2Ks + 5K = 0.$

$0 \le K < \infty$ 범위에서 이 특성 방정식의 root locus 를 그려 보시오.

3. 다음과 같은 Feedback System 을 생각해 보자.



$G(s) = \frac{5}{s(s+1)(s+2)}$ 이다.

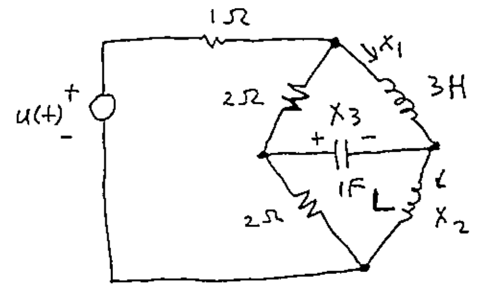
(1) $K(s) = k$ 일때 closed-loop system 을 안정하게 하는 k 의 범위는?

(2) $K(s) = e^{j\theta}$ 일때 closed-loop system 을 안정하게 하는 θ 의 범위는?

(3) $K(s) = ke^{j\theta}$ 에서 k 와 θ 가 동시에 변화할 때 closed loop system 의 안정성은 어떻게 영향받는지 설명하시오.

박사자격 시험 제어 및 전력전자 Adv. Level 문제
(93/3/30 (火))

1. Consider the circuit. The output is the voltage across the capacitor. The state equation is found as follows after some calculations.



$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -\frac{2}{5} & \frac{4}{15} & \frac{1}{3} \\ \frac{4}{5L} & -\frac{6}{5L} & -\frac{1}{L} \\ -1 & +1 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} \frac{2}{15} \\ \frac{2}{5L} \\ 0 \end{bmatrix} u(t)$$

$$y = \begin{bmatrix} 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

(1) Find the controllability matrix. What happens when L=3 and L≠3 henries ?

(2) Find the observability matrix. Discuss the situation.

(3) Find the transfer function when L= 3 henries. What is the meaning of the result ?

2. Consider the six-step three-phase inverter.

(1) Draw the waveform of the gating signals, line voltage and phase voltage.

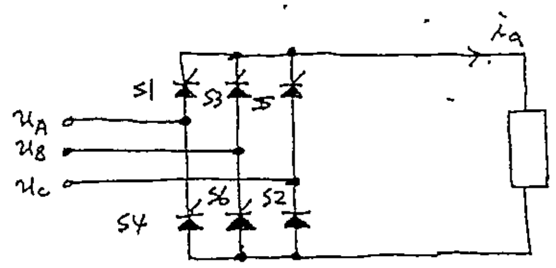
(2) What is the line-to-line rms voltage ?

(3) What is the rms value of fundamental component of the line-to-line voltage ?

3. Find 3x3 rotation matrix $R_{r,\phi}$ that represents the rotation of ϕ angle about the vector $r= (1,1,1)^T$.

박사 자격 시험 제어 및 전력전자 Advanced Level 문제. 92/9/29

1. Consider the following full-wave converter.



$u_A = \sqrt{2} V_s \sin \omega t$
V_s: phase voltage

Assume that the load current i_a is continuous and constant during the period.

(1) Draw the waveforms of the PCR output voltage and phase currents.

(2) Derive the average output voltage.

(3) What is the rms value of the phase current ?

(4) What is the power factor of the full-wave converter ?

2. 다음과 같은 선형 시불변 시스템을 생각하자.

FE: $\dot{x} = Ax + Bu$, $x(to)$는 주어짐

$y = Cx$

2.1 상태 가제어성(controllability)와 가관측성(observability)를 자세히 설명하시오.

2.2 등가변환 $\bar{x} = Px$를 이용하여 FE는 다음과 같이 변환된다. (P는 non- singular 행렬임)

FE1: $\dot{\bar{x}} = \bar{A}\bar{x} + \bar{B}u$, $x(to)$는 주어짐

$y = \bar{C}\bar{x}$

여기서 $\bar{A} = PAP^{-1}$, $\bar{B} = PB$, $\bar{C} = CP^{-1}$ 임. 시스템 FE와 FE1의 controllability특성이 같음을 보여라. (Controllability matrix의 rank가 같음을 보인다.)

2.3 FE가 uncontrollable한 경우 등가변환 $\bar{x} = Px$에 의하여 다음과 같이 변환됨을 보여라. (P는 non-singular 행렬임)

FE2: $\begin{bmatrix} \dot{x}1 \\ \dot{x}2 \end{bmatrix} = \begin{bmatrix} A11 & A12 \\ 0 & A22 \end{bmatrix} \begin{bmatrix} x1 \\ x2 \end{bmatrix} + \begin{bmatrix} B1 \\ 0 \end{bmatrix} u$ $x: P'$ PAP'

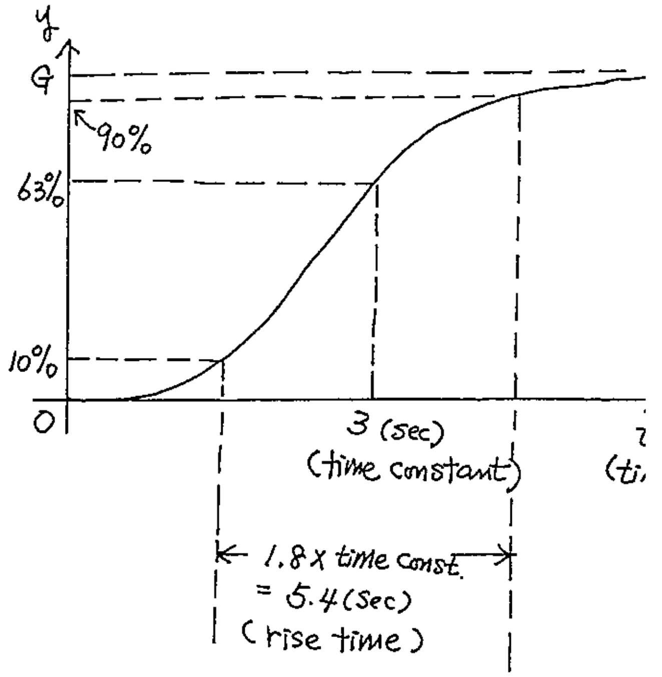
여기서 (A11, B1)은 controllable하다.

2.4 (2.3)의 결과를 이용하여 상태궤환 $u = -Kx$에 의하여 controllability 특성이 변하지 않음을 보여라. 즉 (A,B)의 제어성과 (A-BK,B)의 제어성이 같음을 보여라. (controllable한 경우와 uncontrollable한 경우로 나누어 증명할 것)

박사 자격 시험 자동제어 문제

92/9/29 (火)

문 1) 주어진 System 에 unit step 입력을 가하여 옆 그림과 같은 출력을 얻었다.



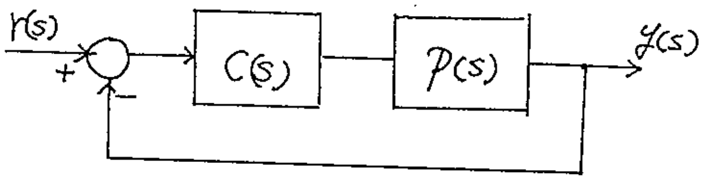
(10) ① system 의 전달함수 $P(s)$ 를 구하라.

(30) ② 아래 그림과 같이 제어기를 달아서 다음의 Performance Specifications 를 만족시키고자 한다. 이를 만족 시키는 제어기 $C(s)$ 를 구하라.

(i) 정상 상태 오차 = 0

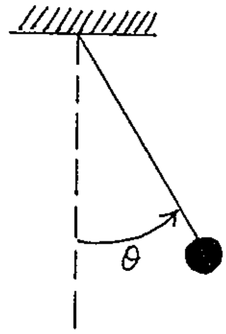
(ii) overshoot = 0 %

(iii) rise-time ≤ 2 (sec)



(hint: rise-time ≅ 1.8 x time constant of the system)

(문 2) 옆 그림과 같은 간단한 Pendulum 의 운동 방정식이 $\ddot{\theta} + \omega^2\theta = u$ 와 같다.



(10) ① state space 형으로 위의 방정식을 나타 내시오.

(10) ② 모든 state 를 측정할 수 있을 경우 closed-loop system 의 pole 이 $s = -4 \pm 4j$ 에 있도록 state feedback 제어기 (즉 K) 를 설계하라. (단 $\omega = 5$ rad/sec)

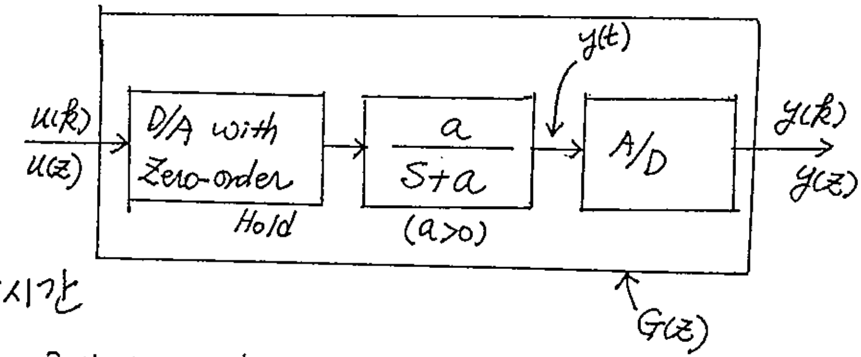
(10) ③ θ 만을 측정할 수 있을 경우 모든 state 를 추측할 수 있도록 observer 를 설계하라. 단 $\omega = 5$ rad/sec 라 놓고 observer 의 극이 $s = -10 \pm 10j$ 에 있도록 하라.

박사 자격 시험 자동제어 문제

92/9/29 (火)

(문 3) (20) ① $P(s) = \dfrac{K}{(S+5)^2}$ 가 주어졌을 때 system 의 gain margin 을 20dB 로 하는 K 값과 phase margin 을 45° 로 만들어 주는 K 값을 구하라.

(10) ② 옆 그림 에서와 같이 system 이 주어 졌을 때 이산시간 전달함수 G(z) 를 구하라. (단 Sample period T = 1 (sec))



(10) ③ $P(s) = \dfrac{1}{S^2+\sqrt{2}S+1}$ 에서 bandwidth (rad/sec) 를 구하라.

91. 2

박사 자격시험

AUTOMATIC CONTROL

1. For a transfer function given below,

$$\frac{C(s)}{R(s)} = \frac{a_0 s^2 + a_1 s + a_2}{b_0 s^2 + b_1 s + b_2}$$

a) Draw the State Diagram (Block diagram) by direct decomposition.

b) write the state equation in vetor-matrix form.

2. Consider that a control system with single feedback loop has the loop transfer function

$$G(s)H(s) = \frac{K(s - 1)}{s(s + 1)}$$

where $K > 0$.

a) Sketch the complete Nyquist path and corresponding Nyquist plot.

b) Discuss the stability associated with feedback gain K.

Automatic Control Field

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1. In the time-invariant single-input, single-output second order control system shown below, it was observed that

$$y(t) = 1 - \frac{4}{\sqrt{3}} e^{-\frac{1}{2}t} \cos\left(\frac{\sqrt{3}}{2}t - \frac{\pi}{6}\right) \quad \text{for } t \geq 0$$

when unit step input u(t) was applied.

$$u(t) \longrightarrow \boxed{\frac{1}{s^2 + as + b}} \longrightarrow y(t)$$

a) Find a and b.

b) Design a controller such that

$y(t) = y_{ref}$

in steady state for any given constant y_{ref} .

c) Write a state equation in matrix form for the system in b).

2. Consider a linear time invariant continuous system shown below.

$$\dot{X}(t) = AX(t) + Bu(t)$$

$$Y(t) = CX(t)$$

a) Discretize the system and find the discrete state equation in the vector-matrix form as

$$X[(k+1)T] = DX(kT) + Eu(kT)$$

$$Y(kT) = FX(kT)$$

b) Find the solution by means of the Z-transformation method.

91 . 2 학기 박사 자격 시험.

Ph.D Qualifying Exam.
1991. Summer

Automatic Control

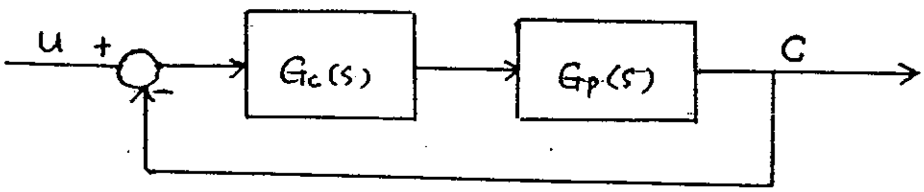
1. Given the Z-transform function

$$R(z) = \frac{(1 - e^{-aT})\, z}{(z - 1)(z - e^{-aT})}$$

   a) Find the inverse Z-transform r(kT).

   b) Explain the Final-Value theorem completely and find the $\lim_{k \to \infty} r(kT)$

2. Consider a feedback control system below



where $G_p(s) = \dfrac{4}{s(s^2 + 4s + 6)}$, $G_c(s) = \dfrac{K(1 + Ts)}{s}$

   a) Find the values of K and T so that the following specifications are satisfied :

      1) Ramp error constant Kv = 4

      2) The magnitude of the imaginary parts of the complex characteristic equation roots of the closed-loop system must not be greater than 4 rad/sec.

   b) Sketch the root locus of the closed-loop characteristic equation with the value of T which determined above.

3. Describe the Frequency-domain analysis method and motivations of conducting control system analysis in frequency domain.

3. For a given Homogeneous Transformation matrix of PUMA 560 wrist:

$$
{}^{0}T_{6} = \begin{bmatrix} 0.3062 & 0.9186 & 0.2500 & 10.2500 \\ 0.8839 & 0.1768 & -0.4330 & 10.2500 \\ 0.3536 & 0.3536 & 0.8660 & 1.0000 \\ 0. & 0. & 0. & 1.0000 \end{bmatrix}
$$

(a) Find three Euler Angles ϕ, θ, φ.

(b) Comment on your solution and discuss other inverse kinematic solution techniques.