國立清華大學命題紙

八十六學年度 動力機械 系（所） 乙 組碩士班研究生入學考試

科目 控制系統 科號 2701 共 5 頁第 1 頁 *請在試卷【答案卷】內作答

1. Consider the control system shown in Fig. 1. Let the given plant be

$$G(s) = \frac{10}{(s+10)(s+2)},$$

and assume that the close-loop transfer function has been selected as

$$T(s) = \frac{10(s+4)}{(s+10)(s+2)(s-0.01)+10(s+4)}.$$

Please find out the corresponding compensator D(s). (4%)

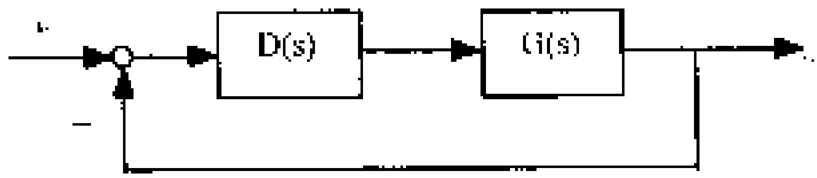


Fig. 1

2. Please draw the root loci of the unity feedback system with a forward loop transfer function

$$L(s) = \frac{s+1}{s(s-1)(s^2+4s+16)}.$$

Please indicate the point(s) where the locus crosses the imaginary axis and where the locus enters into (breaks away from) the real axis. (5%)

3. In the design of a unity feedback control system, a control engineer is asked to achieve the following requirements:

(a) tracking error: $e(j\omega) \le 0.01 \quad \forall \omega \le 0.1$ (rad/sec),

(b) noise attenuation rate:

$$\frac{y_n(j\omega)}{n(j\omega)} \le 1\% \qquad \forall \omega \ge 10 \text{(rad/sec)}.$$

(c) transient performance: overshoot $M_p \le 0.1$ (i.e., 10%).

Is this set of specifications easy to achieve? Why? (10%)

4. A feedback control system is required to satisfy the following specifications: (i) $t_r \approx 1.8/\omega_n \le 0.6\,\text{sec}$, (ii) $t_s \approx 4.6/\zeta\omega_n \le 3\,\text{sec}$, and (iii) the overshoot $M_p \le 10\%$, (iv) the steady state error is less than 0.1%. Please pick out two overall transfer functions which meet all the design requirements from the followings. (6%)

CAUTION: You lose all credit by choosing more than two transfer functions.

$$T_1(s) = \frac{18(s+0.001)}{(s+0.002)(s^2+4.2s+9)}, \quad T_2(s) = \frac{1600}{(s+100)(s^2+8s+16)},$$

$$T_3(s) = \frac{64(s+4.1)}{4.1(s+4)(s^2+6.4s+16)}, \quad T_4(s) = \frac{5000}{(s+200)(s^2+5s+25)},$$

$$T_5(s) = \frac{90}{(s+10)(s^2+4.2s+9)}.$$

Hints: There may be more than one correct answer. Please also notice that the following table gives M_p of three systems with their closed-loop pole-locations.

	ζ	ω_n	$M_p(\%)$
System A	0.1	10	70
System B	0.46	5	20
System C	0.6	2	10

5. Consider the control system shown in Fig. 1. Please pick out five true statements from the followings: (15%)

CAUTION: You lose all credit by choosing more than five statements.

(a) For a plant with a large delay, it is easier to improve the phase margin by using a lag compensator instead of a lead compensator.

(b) The phase margin is always improved if $D(s)$ is a lead compensator.

(c) When $D(0) = 1$, lead compensation is less vulnerable to noise saturation than lag compensation.

(d) One of the most important usages of a lag compensator is to improve steady state performances.

(e) A lead compensator pushes branches of the root loci towards the right-hand-side of the complex plane.

(f) In general, there are more than one $D(s) = K\frac{s+z}{s+p}$ that can 'bend' the root loci such that it pass through the assigned dominant poles, and the best selection is the one that minimizes the difference between p and z.

(g) Compare two loop transfer functions $L_1(s) = G(s)D_1(s)$ and $L_2(s) = G(s)D_2(s)$. If $L_1(s)$ has better transient and steady state responses, it must be more vulnerable to noise saturation than $D_2(s)$.

(h) In real control problems, an infinitely high gain can be achieved if and only if the plant isstable, minimum phase with an order no greater than 2.

(i) A lag compensator always causes phase deterioration to the loop transfer function at all frequencies.

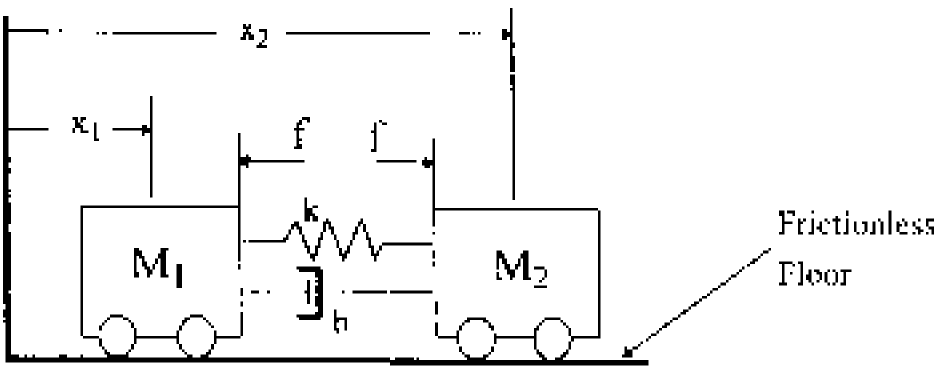
6. The following procedures have been proposed by a research student for the design of a unity feedback control system with a forward compensator $D(s)$ cascaded before a plant $G(s)$:

Step I: Select a closed-loop transfer function $T(s)$ that meets all design requirements,

Step II: Calculate analytically the controller $D(s)$ that corresponds to $T(s)$.

This approach seems to be much more straightforward and attractive than the root locus method and the frequency response method. Please give at least three most important shortages of this approach in dealing with real control problems. (10%)

7. Given a mechanical system with schematic diagram as shown below, where M_1, M_2 are the mass of carts respectively. k and b are the spring and damper that connecting the cats. Two forces with equal amount but opposite direction are applied on carts.

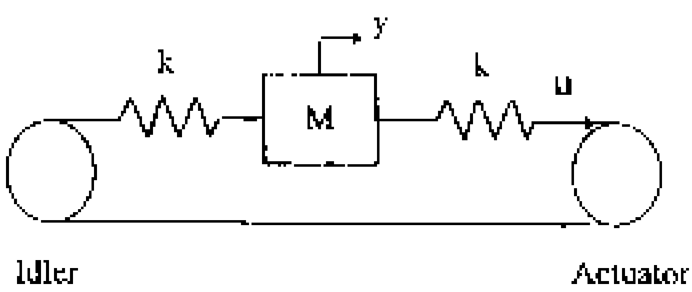


(a) Using x_1, x_2 as state variables, and f as input, write a state space representation for the system. (3 %)

(b) Justify the controllability and observability of the system. (10%)

(c) Provide physical insight(s) of the mechanical system to support your answer in part(b). (2%)

8. A simplified model of a flexible mechanical system is shown as below. The driving force u, is applied by an actuator on the right, while an idler is on the left to maintain the translational motion of the connected mass.



Let both springs have the same spring constant, and k = 1800 N/m, and assuming that they maintain the same value at different positions. And, the transferring mass M = 1 N$\cdot$ s^2/m, the applied force u is in N (Newton).

(a) Write a state space representation for the system, using u as input, while y as output. (5%)

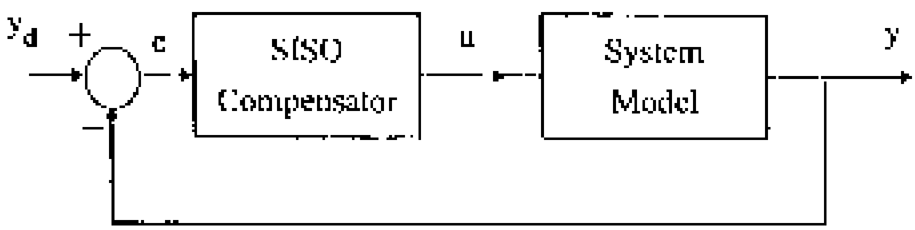
(b) Design a full-state feedback controller with roots at $-20 \pm j20$. (4%)

(c) Design an estimator with roots at $-200 \pm j200$ using y as the only measurement. (4%)

(d) Would it be reasonable to have controller's roots in (b) assigned the same as the estimator's? Give specific viewpoint(s) to support your answer(s) (2%)

(e) If you need to combine the design in (b) and (c) to form a single-input-single-output (SISO) compensator, using yd as the command input. What is the transfer function to be filled-in in the box labeled as SISO compensator in the block diagram as shown below ? (5%)

$e = y_d - y$



9. Consider a nonlinear discrete system described as

$$x(k+1) = x(k)[1 - \alpha\, x(k)],$$

where α is some non-zero real number.

(a) Locate the equilibrium points of this system. (3%)

(b) Find bound(s) of α, such that all the equilibrium points have stable focus(or simply stable equilibrium). (4%)

(c) Using linearization technique to justify your answer in (b). (4%)

(d) Justify your answer in (b) by computing the natural responses for k=1,2,3. approximately, with small perturbation around equilibrium point, x_e, say $x(0) = x_e \pm 0.01$. (4%)