科目：控制系統(5008)　　校系所組：清大電機工程學系丁組、動力機械工程學系乙組

1. Choose from the followings TEN INCORRECT statements, and briefly explain why. (2.5% each)

(a) It is possible to improve the tracking performance by an open-loop control system.

(b) It is possible to achieve disturbance rejection by an open-loop control.

(c) As compare with a P control, a PI controller improves the steady state error at the cost of a smaller damping ratio when the bandwidth of the control system is about the same.

(d) If the control system has two right-half plane zero, then it causes only time delay but no undershoot in step responses.

(e) In a feedback control system, if the plant has a pure integrator and the controller also has a pure integrator, then the steady state error tracking a parabola command is bounded.

(f) A control system with too large a stability margin must satisfy its transient and/or steady state performance.

(g) A D-term should be introduced into a *PID* controller when the response speed is too slow.

(h) The *PID* parameters obtained from the *Z-N* tuning formula results in an over-damped control system (i.e., $\varsigma > 1$).

(i) The performance of a feedback system is insensitive to plant uncertainty, but sensitive to sensor nonlinearity.

(j) A *PI* controller pushes the root locus of a control system towards the right-hand-side on the complex plane (as compared with a *P*-control).

(k) An unstable plant may become stable when feedback control is introduced, and the undershoot effect in a plant can also be removed by feedback.

(l) When saturation occurs to a control system, the equivalent DC gain of the loop transfer function (i.e., open-loop system transfer function) tends to decrease.

(m) In a real control system where G(s) represents the plant (including the sensor and the actuator) with a bandwidth about 10 rad/sec and $D(s) = K\dfrac{1+(s/z)}{1+(s/p)}$ represents the controller to be implemented by a micro-processor, K can be chosen as large as 100 in order to yield a close-loop bandwidth of around 100 rad/sec.

(n) A Phase lead controller improves the phase plot of the loop transfer function, but not necessarily the resultant phase margin.

(o) To apply the Nyquist stability criterion, we need to know the number and locations of right-half-plane (RHP) poles and RHP zeros of the plant.

(p) The plant in a control system can be conceived as a low-pass filter, hence sensor noises generally cause no trouble to a control system.

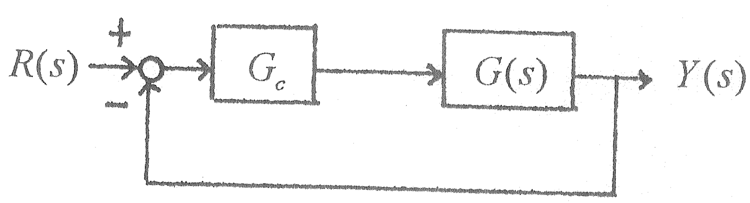
(q) When we design a control system using the root locus method, it concerns only the transient performances related to the damping ratio ζ and the natural frequency ω_n of a system. As regards the steady state performances and noise saturation, there is nothing we can do using the root locus method.

(r) The inclusion of a RHP poles and/or zeros into a controller always deteriorate the performance of a control system. Therefore, unless there is no other way to stabilize a feedback control system, the controller should be of minimal phase.

(s) When a control system is designed on the Bode plots, it can handle not only the transient performance related to the damping ratio ζ and the natural frequency ω_n, but also the steady state performances and noise attenuation.

(t) The undershoot effect caused by a RHP zero in the plant can easily be removed by pole-zero cancellation in a practical control system.

2. Consider the system shown below.



$$G(s) = \frac{1}{(s+2)(s+3)}$$

(a) When G_c is a P controller, i.e., G_c=K, and the damping ratio ζ of the system is varied continuously from 0.5 to 0.7, find the corresponding range of K. (5%)

(b) When G_c is a P controller, i.e., G_c=K, and K varies continuously in the range as obtained in (a), find the corresponding range of steady state error for unit step input. (5%)

(c) When G_c is a PI controller, i.e., $G_c = K_p(1+\frac{K_I}{s})$, find the conditions in terms of K_p and K_I to ensure the stability of the system. (5%)

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(d) Let $G_c = K_p(1+\frac{20}{s})$. Draw the root locus roughly for K_p varying from 0 to ∞ and find the poles of the system when the root locus crosses the imaginary axis. (5%)

(e) If $G_c = 1+\frac{20}{s}$, draw the Bode diagram for $G_cG(s)$ and designate in your plot the gain margin and the phase margin. (5%)

3. Use the state space pole-placement method to design a compensator for the third-order system with transfer function

$$G(s) = 10/ s(s+2)(s+8)$$

Please use state space description in observer canonical form and place the control poles at -1.42 and -1.04±2.14j and observer poles at -4.25 and -3.13± 6.41j.

(25%)

4. A plant to be controlled is given as: (25%)

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

where $X = [x_1 \; x_2]^T$, $A = \begin{bmatrix} -6 & 2 \\ 2 & -6 \end{bmatrix}$, $B=[2 \; 0]^T$, $C=[1 \; 0]$.

(1) Find the eigenvalues of A and the corresponding eigenvectors.
(2) Derive and prove the controllability and observability of this system.
(3) Find a transformation matrix S, i.e., $Z= SX$, $Z = [z_1 \; z_2]^T$ to diagonalize the system matrix A.
(4) For the resulted transformed plant:

$$\dot{Z} = A'Z + B'u$$
$$y = C'Z$$

(a) Find: A', B' and C'.
(b) The closed-loop poles of the transformed plant are to be located at -8 and -10 via state feedback control $u = r - GZ = r - g_1z_1 - g_2z_2$, find g_1 and g_2.
(c) Find the closed-loop tracking transfer function from $r(t)$ to $y(t)$, the zero of this transfer function, and the steady-state value of the output $y(t)$ due to unit-step input of $r(t)$.