國立成功大學

110學年度碩士班招生考試試題

編　號：70

系　所：機械工程學系

科　目：自動控制

日　期：0202

節　次：第 1 節

備　註：可使用計算機

 ※ 考生請注意：本試題可使用計算機。 請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

1. **(35%)** The Bell-Boeing V-22 Osprey Tiltrotor is both an airplane and a helicopter. Its advantage is the ability to rotate its engines to 90° from a vertical position for takeoffs and landings. The altitude control system in the helicopter mode is shown in the following figure, where G_1(s) is the controller, G_2(s) is the dynamics of the Osprey Tiltrotor, D (s) is the disturbance, and H(s) is the feedback controller. Answer the followings for $G_1(s)=\frac{K}{s}$, $G_2(s)=\frac{(s+1.5)}{(s+1)(s+10)}$, D (s)=0, H(s)=1.

   (1) (10%) Determine the root locus as K varies and determine the range of K for a stable systems. Also find the oscillation frequency of the system.

   (2) (10%) Determine the value of K so that the system with unit-step input is stable with 1.52% overshoot. Additionally, determine the peak time, and settling time (with a 2% criterion).

   (3) (5%) Determine the steady-state error of the system with the corresponding unit input by using the value of K obtained in part (3).

   (4) (10%) For a unit-step disturbance, D (s)=1/s, design H(s) for the closed-loop system under the same unit input determined in part (3) so that the steady-state error is diminished. Plot the root locus with the new design of H(s).

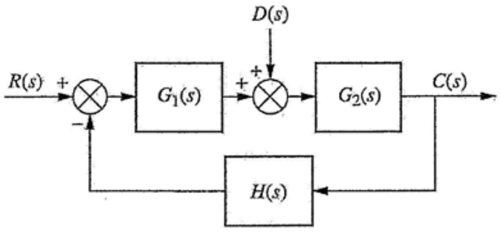


Figure for Problem 1

2. **(15%)** Consider the following state equation and output equation such that

$$\begin{bmatrix}\dot{x}_1\\ \dot{x}_2\\ \dot{x}_3\end{bmatrix}=\begin{bmatrix}-6 & 1 & 0\\ -11 & 0 & 1\\ -6 & 0 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}+\begin{bmatrix}2\\ 6\\ 2\end{bmatrix}u, \quad y=\begin{bmatrix}1 & 0 & 0\end{bmatrix}\begin{bmatrix}x_1\\ x_2\\ x_3\end{bmatrix}$$

   (1) (5%) Show that the state equation can be transformed into the following form by using a proper transformation matrix:

$$\begin{bmatrix}\dot{z}_1\\ \dot{z}_2\\ \dot{z}_3\end{bmatrix}=\begin{bmatrix}0 & 0 & -6\\ 1 & 0 & -11\\ 0 & 1 & -6\end{bmatrix}\begin{bmatrix}z_1\\ z_2\\ z_3\end{bmatrix}+\begin{bmatrix}1\\ 0\\ 0\end{bmatrix}u$$

   (2) (5%) Find the output y in terms of z_1, z_2, and z_3.

   (3) (5%) Determine the transfer function of the aforementioned system.

3. (30%)

A process $G(s)=\dfrac{1}{s(s^2+2s+10)}$ and its control block diagram are shown below.

(1) **(15%)** If the controller $G_c(s)=K$, please use Nyquist plot to determine a K such that the gain margin, G.M., and phase margin, P.M., are at least 6dB and 70° respectively. (please indicate them in your plot clearly)

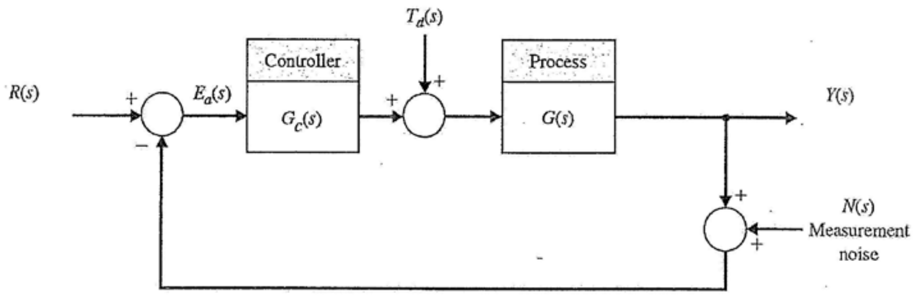
(2) **(15%)** If the controller $G_c(s)=\dfrac{K(s^2+as+b)}{s+c}$, please determine K, a, b, c, to satisfy the design specifications:

DS1 Closed-loop bandwidth is $\omega_B \geq 1Hz$.

DS2 Percent overshoot is $P.O. \leq 15\%$ to a step input.

DS3 Non-dominant pole is 12-times far away from the imaginary axis than the dominant pole.

Useful equations for second-order system:	
1. $P.O.=100\exp(-\zeta\pi/\sqrt{1-\zeta^2})$	(ζ:damping ratio)
2. $\omega_B/\omega_n \cong -1.19\zeta+1.85$	($0.3 \leq \zeta \leq 0.8$; ω_n : natural frequency)



4. (20%)

A control block diagram and its Nichols chart are shown below. Please determine K to satisfy the design specifications:

DS1 The phase margin, P.M., is 30° at least.

(Note: Your Answers should base on the information from the Nichols chart.)

(1) **(5%)** Since setting $K=20$ will cause too large percent overshoot, O.P., we need to set $K=K_3$. What is the value of K_3?

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(2) (5%) When $K=K_3$, what is the maximum magnitude of closed-loop system in dB

(3) (5%) When $K=K_3$, what is the gain margin, G.M. ?

(4) (5%) When $K=K_3$, what is the phase margin, P.M. ?