UNIVERSITI TUN HUSSEIN ONN MALAYSIA

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SEMESTER II
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KERTAS SOALAN INI MENGANDUNGI SEMBILAN (9) MUKA SURAT

Q1 (a) A system G(z) defined by

$$G(z) = \frac{Y(z)}{X(z)} = \frac{0.5z^{-1} - 0.3z^{-2}}{1 - 2z^{-1} + 7z^{-2}}$$

Assume that $x(k)$, the input to the system G(z), is the Kronecker delta function $\delta_0(kT)$, where

$$\delta_0(kT) = 1, \quad \text{for } k = 0$$
$$= 0 \quad \text{for } k \neq 0$$

y(k) is the output of the system G(z).

Using the MATLAB approach, write the program to obtain $y(k)$ up to k 50.

(7 marks)

(b) The discrete-time unity-feedback control system (with sampling period $T = 1$ second) has an open-loop pulse transfer function:

$$G(z) = \frac{K(0.3679z + 0.2642)}{(z - 0.3679)(z - 1)}$$

(i) Using the Jury Stability Test, determine the range of gain K for stability.

(12 marks)

(ii) Determine the frequency of the sustained oscillation, ω_d.

(6 marks)

(Note: • *The sustained oscillations exist at the output when the system becomes critically stable.*

• $\omega_d = \frac{\omega_s}{2\pi} \angle z$ rad/sec, *Where* ω_s *Sampling frequency)*

Q2 (a) From Figure Q2(a), prove that the output C(z) is given by:

$$C(z) = \frac{GR(z)}{1 + GH(z)}$$

(6 marks)

(b) G(s) in Figure Q2(a) consist of a continuous plant preceded by a zero-order hold (ZOH). The continuous plant is given by $\frac{1}{5s+5}$. The feedback function, $H(s) = \frac{1}{s}$.

(i) Obtain and sketch the output sequence c(kT) for the first four samples, of the system when it is subjected to a unit-step input. Assume that the sampling period T is 1 second.

(15 marks)

(ii) By using the initial and final value theorem, calculate the initial and the final values of the output c(kT).

(4 marks)

Q3 The open loop pulse transfer function of a digital closed-loop system with a unity feedback is given by

$$G(z) = \frac{K(z+1)}{(z-0.6065)(z-1)}$$

The sampling period is T = 0.1 second.

(i) Plot the root locus as the gain K is varied from 0 to ∞. (Please use the graph scale 5 cm : 1 unit)

(12 marks)

(ii) Determine the range of the gain K for the system to be stable.

(3 marks)

(iii) Obtain the value of the gain K that yield a damping ratio ζ of the closed-loop poles equal to 0.5.

(6 marks)

(iv) With the gain K set to yield $\zeta = 0.5$, determine the number of samples per cycle of damped sinusoidal oscillation.

(4 marks)

Note that any point on the locus of constant ζ on the z plane is given by

$$Log\, e^{r} = \frac{-\zeta\theta}{\sqrt{(1-\zeta^{2})}}$$

where r and θ are the magnitude and phase of the point respectively with reference to the origin.

Q4 The transfer function of a continuous plant preceded by a zero order hold is given by

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

Design a digital controller such the response of the closed loop system with unity feedback to a unit step input will reach steady-state when $t = 0.4$ second with zero error. Obtain and sketch this response for the first four samples only. The sampling period is assumed to be 0.2 second. By using the initial and final value theorems, calculate the initial and the final values of the sampled output.

(25 marks)

Q5 The transfer function of a continuous plant preceded by a zero order hold is given by

$$G_p(s) = \frac{1}{s^2}$$

A digital proportional-plus-derivative controller with a pulse transfer

$$G_D(z) = K_p + K_D(1 - z^{-1})$$

is to be designed by using the root locus method. It is desired that the damping ratio ζ of the dominant closed-loop poles be 0.5 and the undamped natural frequency be 4 rad/sec. The sampling period is of this closed-loop system with a unity feedback is assumed to be 0.1 second. Determine the values of K_P and K_D.

(25 marks)

Q6 Consider the following discrete-time system:

$$\mathbf{x}(k+1) = G\mathbf{x}(k) + Hu(k)$$

where

$$G = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -0.5 & -0.2 & 1.1 \end{bmatrix}, \quad H = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}$$

(a) Determine a suitable state feedback gain matrix **K** such that when control signal is given by $u(k) = -\mathbf{K}\mathbf{x}(k)$, the closed-loop system will have poles at $z_1 = 0.25$, $z_2 = 0.5 + j0.5$ and $z_3 = 0.5 - j0.5$.

(13 marks)

(b) Determine a suitable state feedback gain matrix **K** such that when control signal is given by $u(k) = -\mathbf{K}\mathbf{x}(k)$, the closed-loop system exhibits the dead-beat response to any non-zero initial states $\mathbf{x}(0)$. Obtain the state response $\mathbf{x}(k)$ and verify that the response is indeed deadbeat.

(12 marks)

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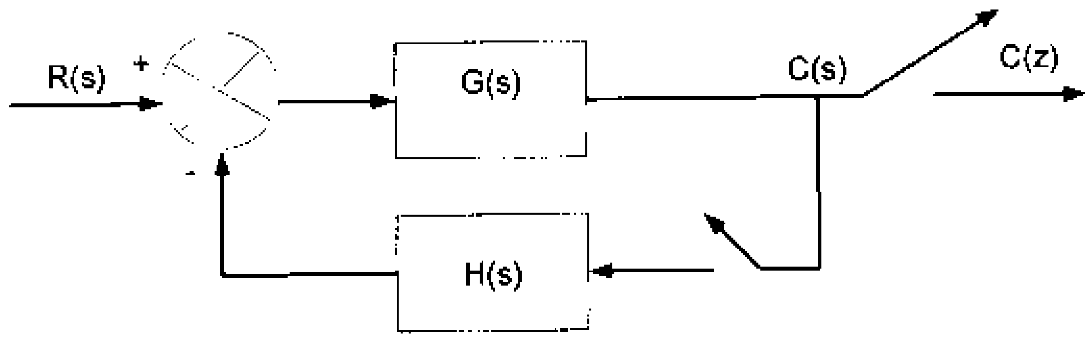

FIGURE Q2(a)

Table 1: Table of z Transform

	$X(s)$	$x(t)$	$x(kT)$ or $x(k)$	$X(z)$
1.	—	—	Kronecker delta $\delta_0(k)$ $1, \quad k = 0$ $0, \quad k \neq 0$	1
2.	—	—	$\delta_0(n-k)$ $1, \quad n = k$ $0, \quad n \neq k$	z^{-k}
3.	$\frac{1}{s}$	$1(t)$	$1(k)$	$\frac{1}{1-z^{-1}}$
4.	$\frac{1}{s+a}$	e^{-at}	e^{-akT}	$\frac{1}{1-e^{-aT}z^{-1}}$
5.	$\frac{1}{s^2}$	t	kT	$\frac{Tz^{-1}}{(1-z^{-1})^2}$
6.	$\frac{2}{s^3}$	t^2	$(kT)^2$	$\frac{T^2z^{-1}(1+z^{-1})}{(1-z^{-1})^3}$
7.	$\frac{6}{s^4}$	t^3	$(kT)^3$	$\frac{T^3z^{-1}(1+4z^{-1}+z^{-2})}{(1-z^{-1})^4}$
8.	$\frac{a}{s(s+a)}$	$1-e^{-at}$	$1-e^{-akT}$	$\frac{(1-e^{-aT})z^{-1}}{(1-z^{-1})(1-e^{-aT}z^{-1})}$
9.	$\frac{b-a}{(s+a)(s+b)}$	$e^{-at}-e^{-bt}$	$e^{-akT}-e^{-bkT}$	$\frac{(e^{-aT}-e^{-bT})z^{-1}}{(1-e^{-aT}z^{-1})(1-e^{-bT}z^{-1})}$
10.	$\frac{1}{(s+a)^2}$	te^{-at}	kTe^{-akT}	$\frac{Te^{-aT}z^{-1}}{(1-e^{-aT}z^{-1})^2}$
11.	$\frac{s}{(s+a)^2}$	$(1-at)e^{-at}$	$(1-akT)e^{-akT}$	$\frac{1-(1+aT)e^{-aT}z^{-1}}{(1-e^{-aT}z^{-1})^2}$

	$X(s)$	$x(t)$	$x(kT)$ or $x(k)$	$X(z)$
12.	$\frac{2}{(s+a)^3}$	$t^2 e^{-at}$	$(kT)^2 e^{-akT}$	$\frac{T^2 e^{-aT}(1+e^{-aT}z^{-1})z^{-1}}{(1-e^{-aT}z^{-1})^3}$
13.	$\frac{a^2}{s^2(s+a)}$	$at-1+e^{-at}$	$akT-1+e^{-akT}$	$\frac{[(aT-1+e^{-aT})+(1-e^{-aT}-aTe^{-aT})z^{-1}]z^{-1}}{(1-z^{-1})^2(1-e^{-aT}z^{-1})}$
14.	$\frac{\omega}{s^2+\omega^2}$	$\sin \omega t$	$\sin \omega kT$	$\frac{z^{-1}\sin \omega T}{1-2z^{-1}\cos \omega T+z^{-2}}$
15.	$\frac{s}{s^2+\omega^2}$	$\cos \omega t$	$\cos \omega kT$	$\frac{1-z^{-1}\cos \omega T}{1-2z^{-1}\cos \omega T+z^{-2}}$
16.	$\frac{\omega}{(s+a)^2+\omega^2}$	$e^{-at}\sin \omega t$	$e^{-akT}\sin \omega kT$	$\frac{e^{-aT}z^{-1}\sin \omega T}{1-2e^{-aT}z^{-1}\cos \omega T+e^{-2aT}z^{-2}}$
17.	$\frac{s+a}{(s+a)^2+\omega^2}$	$e^{-at}\cos \omega t$	$e^{-akT}\cos \omega kT$	$\frac{1-e^{-aT}z^{-1}\cos \omega T}{1-2e^{-aT}z^{-1}\cos \omega T+e^{-2aT}z^{-2}}$
18.			a^k	$\frac{1}{1-az^{-1}}$
19.			a^{k-1} $k=1,2,3,\ldots$	$\frac{z^{-1}}{1-az^{-1}}$
20.			ka^{k-1}	$\frac{z^{-1}}{(1-az^{-1})^2}$
21.			$k^2 a^{k-1}$	$\frac{z^{-1}(1+az^{-1})}{(1-az^{-1})^3}$
22.			$k^3 a^{k-1}$	$\frac{z^{-1}(1+4az^{-1}+a^2z^{-2})}{(1-az^{-1})^4}$
23.			$k^4 a^{k-1}$	$\frac{z^{-1}(1+11az^{-1}+11a^2z^{-2}+a^3z^{-3})}{(1-az^{-1})^5}$
24.			$a^k \cos k\pi$	$\frac{1}{1+az^{-1}}$
25.			$\frac{k(k-1)}{2!}$	$\frac{z^{-2}}{(1-z^{-1})^3}$
26.			$\frac{k(k-1)\cdots(k-m+2)}{(m-1)!}$	$\frac{z^{-m+1}}{(1-z^{-1})^m}$
27.			$\frac{k(k-1)}{2!}a^{k-2}$	$\frac{z^{-2}}{(1-az^{-1})^3}$
28.			$\frac{k(k-1)\cdots(k-m+2)}{(m-1)!}a^{k-m+1}$	$\frac{z^{-m+1}}{(1-az^{-1})^m}$

Table 2: z Transform of $x(k+m)$ and $x(k-m)$

Discrete function	z Transform
$x(k+4)$	$z^4X(z) - z^4x(0) - z^3x(1) - z^2x(2) - zx(3)$
$x(k+3)$	$z^3X(z) - z^3x(0) - z^2x(1) - zx(2)$
$x(k+2)$	$z^2X(z) - z^2x(0) - zx(1)$
$x(k+1)$	$zX(z) - zx(0)$
$x(k)$	$X(z)$
$x(k-1)$	$z^{-1}X(z)$
$x(k-2)$	$z^{-2}X(z)$
$x(k-3)$	$z^{-3}X(z)$
$x(k-4)$	$z^{-4}X(z)$