THE HONG KONG POLYTECHNIC UNIVERSITY

DEPARTMENT OF ELECTRICAL ENGINEERING

Subject Code	:	EE4008A			
Subject Title	:	Applied Digital Control			
Session	:	Semester 2, 2021/22	**Venue**	:	Online Examination
Date	:	10-May-2022	**Time**	:	15:15 – 18:15
Time Allowed	:	3 Hours	**Subject Examiner(s)**	:	Dr N.C. Cheung

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This question paper has a total of 6 pages (attachments included).

Instructions to Candidates: Attempt ALL Questions

Physical Constants: Nil

Other Attachments: Z Transform Table

Available from Invigilator: Nil

DO NOT TURN OVER THE PAGE UNTIL YOU ARE TOLD TO DO SO.

Question 1

(a) What is the meaning of a "multivariable plant"?
(b) Suggest one example of a "multivariable plant".
(c) Draw the control block diagram of a "multivariable plant" being converted to digital form, and being controlled by state variable feedback control.

(10 marks)

Question 2

Design the Programmable Logic Controller ladder network program for a rotary gate entrance system as shown in Fig Q2. The gate entrance system has the following specifications:

- When a user wishes to go through the gate, he needs to activate the start button with a staff card.
- When activated, the gate will unlock.
- When the person passes through the optical switch path, it will reset and lock again.
- Or when activated, but nobody goes through after 10 seconds, the gate will reset and lock again.

(10 marks)

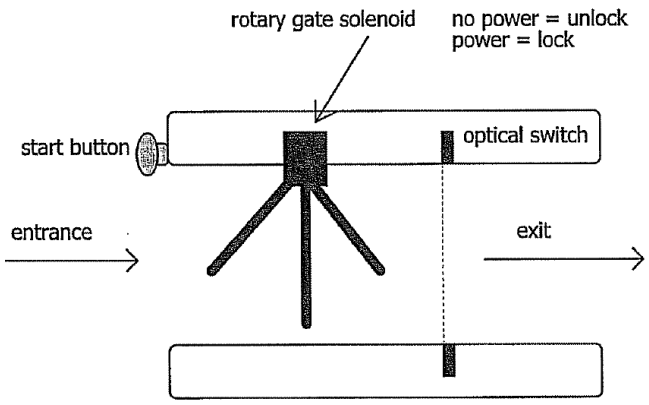

Fig. Q2

Question 3

Find the z inverse transform of the function given below by using the partial fraction method.

$$G(z) = \frac{8z^2}{(2z-1)(4z-1)}$$

(15 marks)

Question 4

By using a IIR digital filter as an example, explain why it is more preferrable to implement:

(a) Direct Form II than to implement Direct Form I.

(10 marks)

(b) Direct Form II transposed than to implement Direct Form II

(5 marks)

Question 5

In a step-by-step manner, explain how you could obtain the P, I, D values of a control system via Ziegler Nichols step response tuning strategy. (10 marks)

Question 6

Convert the following filter function H(s) into digital form, by using bi-linear transformation. Let the sampling time be 0.1 seconds. (10 marks)

$$H(s) = \frac{1}{S+7}$$

Question 7

Design a nuclear power plant monitoring system that can handle two important functions.

The first function is to monitor the security breach of the plant (detect any unauthorized person entering the nuclear reactor area). This event is triggered by any one of the occupancy detectors located around the nuclear power plant. If this happens a flashing yellow lamp and a siren will be activated.

The second function is to monitor whether the nuclear reactor has reached an over-heated temperature. This event can be detected by the temperature sensors installed around the nuclear core and the cooling system. This function has a higher priority over the previous function. If this happens a flashing red lamp and a siren will be activated.

Use a Direct Digital Controller (DDC) to perform the above tasks. Your design should include the following components.

(a) A system diagram to describe your overall system hardware. (3 marks)
(b) The sequence of operations for the monitoring system. (3 marks)
(c) The I/O summary. (3 marks)
(d) The mode summary table. (3 marks)
(e) The complete flow diagram of the system. (3 marks)

Question 8

Fig. Q8 shows the state feedback control of a thermal power plant. In a recent survey, it was found that a sensor to connection $x_2(t)$ is not feasible. With the help of a diagram, explain how you could still use state feedback control without using a sensor signal from $x_2(t)$.

(15 marks)

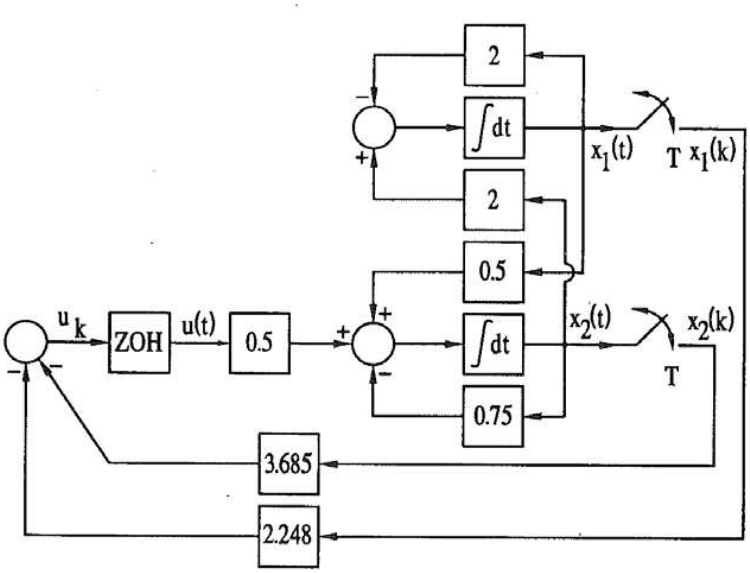

Fig. Q8

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z-transform Table

Laplace Transform $F(s)$	Time function $f(t)$, $t\geq 0$	z-transform $F(z)$
e^{-nTs}	$\delta(t-nT)$	z^{-n}
$e^{-nTs}F(s)$	$f(t-nT)$	$z^{-n}F(z)$
	$f(t+nT)$	$z^{n}F(z)-z^{n}f(0)-z^{n-1}f(1)-\ldots-zf(n-1)$
$F(s+a)$	$e^{-at}f(t)$	$F(e^{aT}z)$
$\frac{1}{s}$	unit step $H(t)$	$\frac{z}{z-1}$
$\frac{1}{s^2}$	unit ramp t	$\frac{Tz}{(z-1)^2}$
$\frac{1}{s^3}$	$\frac{t^2}{2}$	$\frac{T^2z(z+1)}{2(z-1)^3}$
$\frac{1}{s+a}$	e^{-at}	$\frac{z}{z-e^{-aT}}$
$\frac{1}{(s+a)(s+b)}$	$\frac{1}{b-a}\left(e^{-at}-e^{-bt}\right)$	$\frac{1}{b-a}\left(\frac{z}{z-e^{-aT}}-\frac{z}{z-e^{-bT}}\right)$
$\frac{\omega}{s^2+\omega^2}$	$\sin\omega t$	$\frac{z\sin\omega T}{z^2-2z\cos\omega T+1}$
$\frac{s}{s^2+\omega^2}$	$\cos\omega t$	$\frac{z(z-\cos\omega T)}{z^2-2z\cos\omega T+1}$

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