THE HONG KONG POLYTECHNIC UNIVERSITY

DEPARTMENT OF ELECTRICAL ENGINEERING

Subject Code	:	EE4008A			
Subject Title	:	Applied Digital Control			
Session	:	Semester 2, 2022/23	**Venue**	:	SH2
Date	:	27 April 2023	**Time**	:	15:15 – 18:15
Time Allowed	:	3 Hours	**Subject Examiner(s)**	:	Dr NC Cheung Dr X Yuan

This question paper has a total of __5__ pages (attachments included).

Instructions to Candidates:	Attempt ALL questions. Put your **Part A** answers in the **Green** answer book and **Part B** answers in the **White** answer book.
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.

Part A

Question 1

(a) In implementing a digital controller hardware, two solutions are selected:

(i) Digital controller based on Micro-controller (e.g., embedded processor)
(ii) Digital controller based on Digital Signal Processor (DSP)

For each of the selection above, state what are the advantages of using this selection.
(5 marks)

(b) What are the advantages of using digital control instead of using analogue control? Give 6 reasons. (5 marks)

Question 2

(a) Find the first 3 terms of the digital sequence, by applying long division inverse Z transform to the equation below. (7 marks)

$$\boldsymbol{F(z) = \frac{Z^2+z}{z^2-3z+4}}$$

(b) Find the difference equation *f(k)* by applying partial fraction inverse Z transform to the equation below. (8 marks)

$$F(z) = \frac{Z^2+z}{(Z-0.6)(Z-0.8)(Z-1)}$$

Question 3

Design a ladder logic circuit to implement the function specified below:

Function: Pedestrian crossing traffic light
Inputs: One push button (PB)
Outputs: Three coloured traffic lights of - red, amber, and green
Operation:

1. Initial (after reset) condition – green light on.
2. PB is pressed – amber light on, for 10 seconds.
3. After that, red light (stop the traffic) on, for 45 seconds.
4. After that, the circuit will reset itself, and green light goes on.

Add some explanations to your ladder logic circuit design. (10 marks)

Question 4

Implement the following IIR filter with the minimum hardware: (15 marks)

$$H(z) = \frac{\sum_{n=0}^{M} b(n)z^{-n}}{1+\sum_{n=1}^{N} a(n)z^{-n}} \quad M=3;\ N=3$$

Part B

Question 1

Find the initial and final values of output X(z) in z domain. (10 marks)

$$X(z) = \frac{6}{1-z^{-2}}$$

Question 2

Let $G_c(z) = \frac{z-e^{-1}}{z^2-3z+2}$, $G_P(s) = \frac{s}{(s+1)}$ and $R(z) = \frac{z}{(z-1)}$ (Unit step function as the input). In the digital system, ZOH exists and the sampling time is 1s. Is the overall system stable, unstable or marginally stable? Justify in detail. (10 marks)

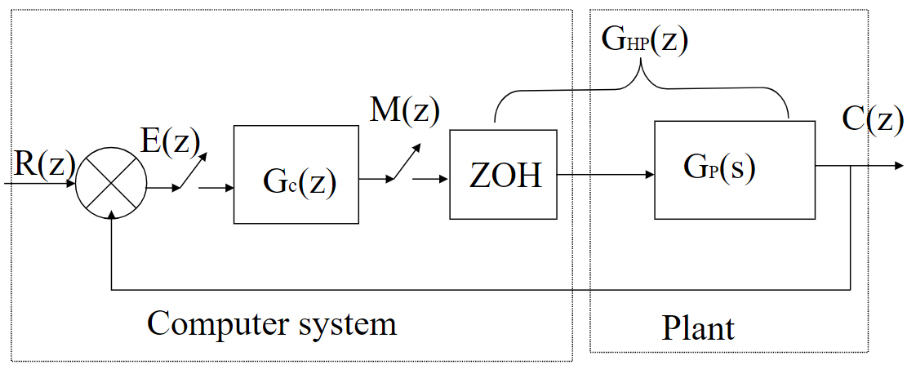

Fig.Q2

Question 3

In the second-order low-pass Butterworth filter $G(s)=\dfrac{\omega_c^2}{s^2+\sqrt{2}\,\omega_c s+\omega_c^2}$, write down the difference equation between the input and output by backward Euler discretization method. The filter cut-off angular frequency is $\sqrt{2}$ rad/s, and the sampling period of the digital system is 1s.

(15 marks)

Question 4

For the PID controller design $G_c(s)$, the plant can be expressed as $G_p(s)=\dfrac{10}{s+10}$. In order to stabilize the overall system, draw the digital PID block diagram in z domain and write down the code to implement the PID controller in a digital unit if the sampling period is 0.1s. (15 marks)

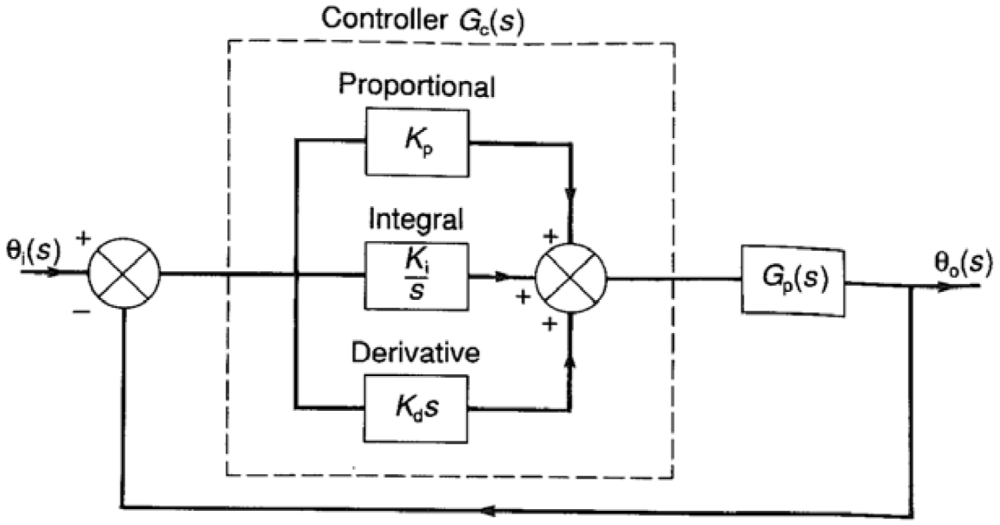

Fig.Q4

----- END OF QUESTIONS-----

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	$\frac{Tz}{(z-1)^2}$
$\frac{1}{s^3}$	$\frac{t^2}{2}$	$\frac{T^2 z(z+1)}{2(z-1)^3}$
$\frac{1}{s+a}$	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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