The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Mechanical Engineering

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Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	: **DMX6305 Modern Control Systems**
Academic Year	: 2021/22
Date	: 22nd February 2023
Time	: 13:30 – 16:30 hrs.
Duration	: **3 hours**

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **seven (7)** questions in **four (04)** pages.
3. Answer **five (05)** questions and each question should commence from a new page.
4. Relevant charts/codes are provided.
5. This is a **Closed Book Test** (CBT).
6. Answers should be in clear handwriting and do not use Red colour pen.
7. Clearly state your assumptions, if any.

Q1 Figure Q1 shows that a ballistic missile is required to follow a predetermined flight path by adjusting its angle of attack α (the angle between its axis and its velocity vector v). The angle of attack is controlled by adjusting the thrust angle δ (the angle between the thrust direction and the axis of the missile).

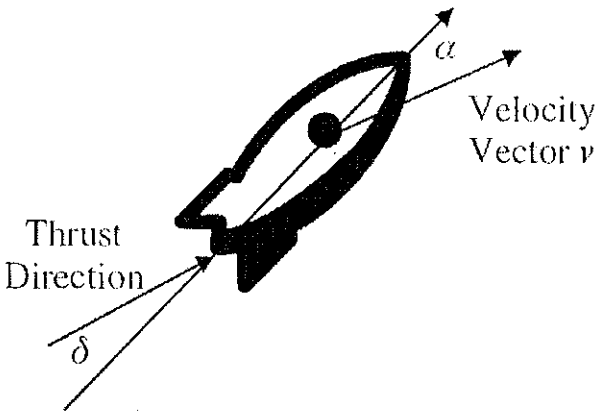

Figure Q1

(a) Describe the main components and connections of a digital control block diagram for ballistic missiles. [10]

(b) Draw a block diagram for a digital control system for the angle of attack, including a gyroscope to measure the angle α and a motor to adjust the thrust angle δ. [10]

Q2 Figure Q2 shows an unit feedback control system. The system is digitally controlled with a sampling period of 0.02s. G(S) and C(Z) are given in below.

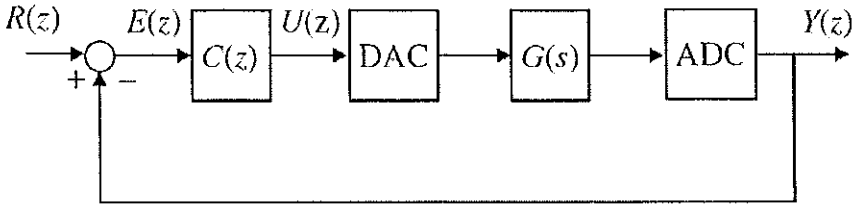

Figure Q2

(a) Find the z-transfer function for the analog subsystem with DAC and ADC. [07]

(b) Find the closed-loop transfer function and characteristic equation. [07]

(c) Find the steady-state error for a sampled unit step and a sampled unit ramp input. Comment on the effect of the controller on steady-state error. [06]

Q3 A system is modeled by the differential equation.

$$\dddot{y}(t) + 13\ddot{y}(t) + 56\dot{y}(t) + 80y(t) = \dddot{u}(t) + 8\ddot{u}(t) + 17\dot{u}(t) + 6u(t)$$

(a) Determine the system's state space model [A, B, C, D]. [8]

(b) Determine the poles of the system. [6]

(c) Find the observability and controllability of the system. [6]

Q4

(a) Explain stability in the context of Lyapunov's theory. [10]

(b) The following equations describe a non-linear system.

$$\dot{x_1} = -x_1 + 2x_2$$
$$\dot{x_2} = 3x_1 - 2x_2 - x_2^3$$

Determine the stability of the non-linear system. [10]

Q5

(a) Consider a discrete-time LTI system whose system function H(z) is given by

$$H(z) = \frac{z}{z-0.5} \qquad |z| > \frac{1}{2}$$

i. Find the step response s[n]. [5]

ii. Find the output y[n] to the input x[n]=nu[n] [5]

(b) The open loop transfer function of second order system is given below.

$$GH(z) = \frac{0.3K(z+0.7)}{(z-1)(z-0.3)}$$

i. Obtain the root locus plot. [5]

ii. Find the critical gain. [5]

Q6

The state-space model of a system is given by;

$$\dot{X} = Ax + Bu$$

$$Y = Cx$$

Where,

$$A = \begin{vmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -5 & -6 \end{vmatrix}$$

$$B = \begin{vmatrix} 0 \\ 1 \\ 1 \end{vmatrix}$$

It is desired to have close loop poles at $s = (-1 \pm j3)$and $s = -7$ by using a state feedback control $\boldsymbol{u} = -\boldsymbol{KX}$. Determine the necessary feedback gain matrix $\boldsymbol{K}$ and the control signal $\boldsymbol{u}$.

[20]

Q7

A closed loop sampled data system is shown in Figure Q7. The sample rate is $10Hz$.

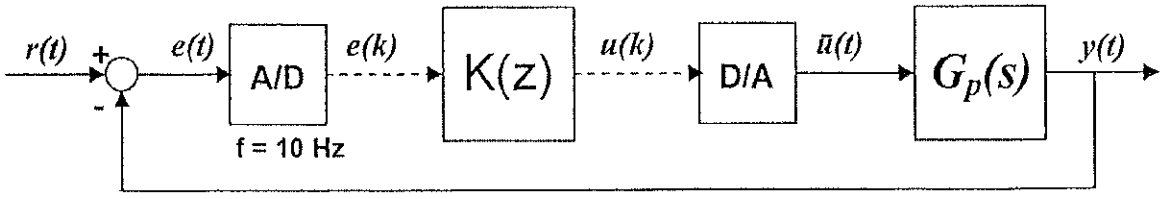

Figure Q7

The following equations represent the digital controller and the continues time plant respectively.

$$u(k) = u(k-1) + 2e(k-1) \qquad \dot{y}(t) = -5y(t) + 4\bar{u}(t)$$

(a) Determine the $K(z)$ and $G_p(s)$. [10]

(b) The D/A converter is ZOH. Find the closed loop transfer function $T(z) = Y(z)/R(z)$ of the equivalent discrete time system.

[10]

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