M. Tech. Intelligent Automation and Robotics, 1st Year 2nd Semester, 2018

ADVANCED DIGITAL CONTROL SYSTEMS

Time: 3 Hours Full Marks: 100

Answer any **FOUR** questions.

1. a) Define Lyapunov function. [3]

   b) State the condition for stability by Lyapunov analysis for both continuous and discrete systems. [6]

   c) What is an autonomous system? State the state equation for an autonomous system. [4]

   d) Determine the condition for stability of an autonomous system in state-space. [4]

   e) For A= $\begin{pmatrix} 0.5 & 0 \\ 0 & 0.2 \end{pmatrix}$ and Q=I, determine P satisfying the condition for stability of the autonomous system, where P and Q have standard meanings. [8]

2. a) For a system governed by $x(k+1) = A\, x(k) + B\, u(k)$, find the optimal control signal u(k) by Lyapunov's theorem. [10]

   b) For A= $\begin{pmatrix} 0.5 & 0 \\ 0 & 0.2 \end{pmatrix}$ and B= $[1 \quad 1]^T$ obtain the optimal u(k). [6]

   c) Draw the state diagram of the complete system including the state and equation and the control equation. [9]

3. a) Realize the following system by parallel mode.

   $$u(z)/e(z) = K_1 Z^{-1}/(1 - b_1 Z^{-1}) + K_2 Z^{-1}/(1 - b_2 Z^{-1})$$ [4]

   b) Find u(kT) as a function of e(kT), where u(kT) is the control signal and e(kT) is the error. [4]

   c) Realize $u(z)/e(z) = (1-Z^{-1})/(3Z^{-2} - 8Z^{-1} + 4)$ as direct and parallel realization. Which one is more efficient? [8]

   d) Draw the complete position control scheme of an antenna dish using a microcomputer. Also explain the scheme. [6]

   e) Write the P-I-D control law in continuous time domain and discretize it. [3]

4. a) Show that the mean and variance of quantization noise due to truncation is $-q/2$ and $q^2/12$ respectively. [8]

b) Develop a scheme to determine the word-length of an ADC. [9]

c) The incoming signal to an ADC has a saturation to threshold ratio of 250 (corresponding to 0.4% resolution). The allowed signal to noise is 40 dB. Determine the word-length of the ADC. [8]

5. a) State Perseval's theorem for computation of noise variance at the output of the controller from the input quantization noise-variance. [6]

b) For the given control algorithm:

$$u(kT)=e(kT) + b\, u((k-1)T),\ b>1,$$

find $D(Z)= u(Z)/e(Z)$. [4]

c) If the input quantization noise associated with error is $q^2/12$, find the quantization noise associated with control signal $u(Z)$ using Perseval's theorem. [6]

d) For the controller:

$$u(Z)/e(Z)= 0.5/(1- 0.2\, Z^{-1}) + 0.6/(1- 0.3\, Z^{-1}),$$

show the input and output multiplication error in the parallel realization of the controller. [9]

6. a) Justify the importance of phase-lead and phase-lag controller-Explain with Bode plots. [6]

b) State the steps of Phase-lead controller design. [9]

c) Given the transfer function of an uncompensated plant as

$$G(S)= 39.453\, K/S.\,(S+ 8.871) \text{ with } K=10.$$

Design a phase-lead controller to ensure 45^{O} phase-margin. [10]

7. a) Compute the transfer function of a Zero-Order Hold circuit. [6]

b) Show that a Zero-Order Hold circuit acts like a Low-Pass Filter. [6]

c) Obtain the Z-transform of $N(S)/D(S)= 1/ (S +2).\,(S+3)$ [6]

d) Compute $f(kT)$ when $F(Z) = Z(1 - e^{-aT})/(Z-1)\,(Z- e^{-aT})$ [7]