NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester II: 2012/2013)

EE3304 - DIGITAL CONTROL SYSTEMS

April/May 2013 - Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

(a) This examination paper contains **FOUR (4)** questions, and comprises **THREE (3)** pages.

(b) All questions are compulsory. Answer **ALL** questions.

(c) This is a CLOSED book examination. Each student is allowed to bring **ONE** (1) sheet of A4 size paper.

(d) Programmable calculators are not allowed.

Q.1 Consider a DC motor control system given in Figure 1. Let $T = 0.1s$ and $D(z) = z/(z-1)$.

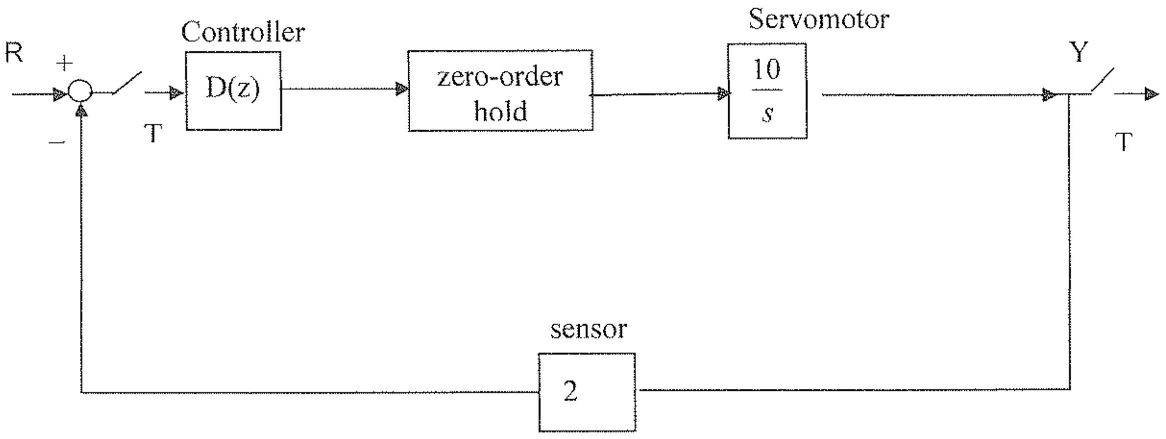

Figure 1

(a) Determine the discrete-time transfer function of the closed-loop system, $\frac{Y(z)}{R(z)}$.

(13 marks)

(b) Find the output time response when the input is a unit pulse and sketch the response.

(7 marks)

(c) Is the closed-loop stable and why?

(5 marks)

Q.2 (a) A continuous signal (t is in the unit of second) to be sampled is

$$f(t) = \cos 3t + \cos 5t.$$

Find six lowest positive frequency components in the sampled signal if the sampling frequency is 6 *radian/second.* Choose a suitable sampling frequency to avoid aliasing problem.

(8 marks)

(b) Determine the z-transform, $X(z)$, of a sequence given by

$$x(k) = \{1, 0, -1, 0, 1, 0, -1, 0, 1, 0, -1, 0, ...\}.$$

You may assume that the first sample corresponds to $k=0$ and that the sub-sequence, {1, 0, -1, 0} repeats for all k.

(8 marks)

(c) Show that $[G(s)E^*(s)]^* = G^*(s)E^*(s)$, where $G^*(s)$ stands for Laplace transform of $g(k)$.

(9 marks)

Q.3 A process model is given by

$$\frac{1}{s+1}.$$

The digital controller is designed in a unit feedback configuration to improve the performance of the system.

(a) Assume that the model is not known and the PID controller is used, is it possible to use the Ziegler-Nicholes (ZN) auto-tuning methods to design the control parameters for the PID controller? If yes, then which ZN method can be applied? Justify your answers.

(5 marks)

(b) Assume that the process model is known and the sampling period T=1, design a first order digital controller to meet following requirements:
1) the closed-loop has a damping ratio, $\zeta = 0.5$, and natural frequency, ω_n=1;
2) the closed-loop achieves a finite steady state error for a ramp input.

(15 marks)

(c) Is the controller designed in (b) equivalent to a PID controller? Justify your answer.

(5 marks)

Q.4 (a) A process is described by the transfer function

$$G(z) = \frac{z+\alpha}{z^2 - z}.$$

Design a pole placement controller in the form of

$$U(z) = \frac{T(z)}{R(z)}U_c(z) - \frac{S(z)}{R(z)}Y(z)$$

such that the closed loop transfer function from the command signal, $u_c(k)$, to the system output, $y(k)$, follows the reference model, $\frac{1}{z^2}$. Discuss the condition on the parameter α such that the inputs are guaranteed to be bounded.

(15 marks)

(b) A nonlinear process is described by

$$y(k+1) = y(k) + u(k-1)y^2(k-1) + \beta u(k-1)$$

where β is a constant parameter.

Design a one-step-ahead controller to make the output of the system, $y(k)$, follow any arbitrary desired output, $r(k)$. Discuss the condition on the parameter β such that the resulting control input, $u(k)$, is always bounded.

(10 marks)

END OF PAPER