NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester II: 2013/2014)

EE3304 - DIGITAL CONTROL SYSTEMS

April/May 2014 - Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

(a) This examination paper contains **FOUR (4)** questions, and comprises **FOUR (4)** 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 The block diagram of a digital control system is given in Figure 1. Let $T = 0.1s$ and

$$D(z) = 50\frac{z}{z-1}.$$

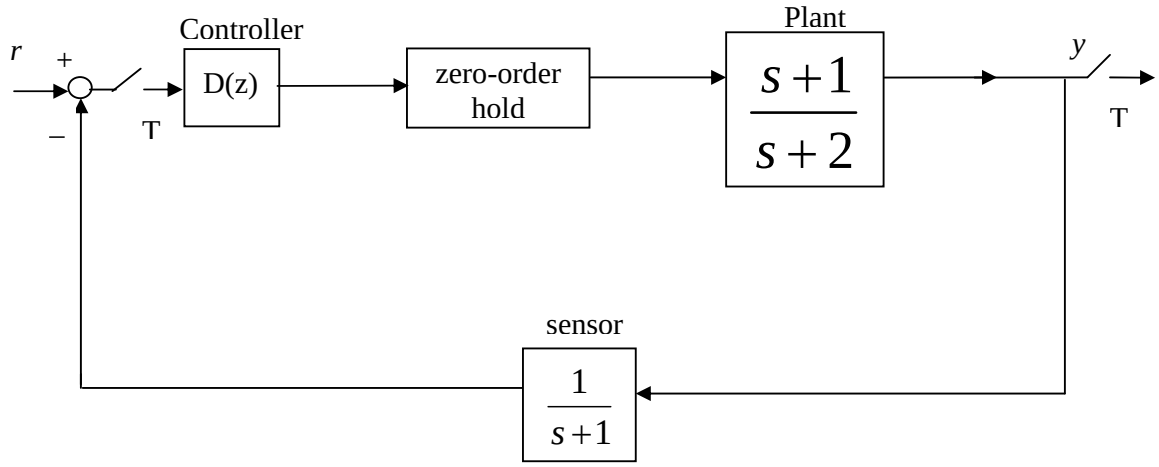

Figure 1. Block diagram for Q1.

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

(12 marks)

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

(8 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

$$f(t) = \cos 2t + \cos 3t + \cos 5t.$$

Give 5 lowest *positive* frequency components in the sampled signal if the sampling frequency is 6 *radian/second*. What is the minimum sampling frequency to avoid aliasing problem?

(9 marks)

(b) Obtain the *z*-transform of $f(k) = ka^k 1(k)$, where 1(k) is the unit step function.

(8 marks)

(c) Show that the bilinear mapping,

$$z = \frac{1+\frac{Ts}{2}}{1-\frac{Ts}{2}},$$

preserves stability.

(8 marks)

Q.3 The Bode diagram of a process is given in Fig. 2. Assume that the sampling period is T=0.1s. The digital controller is to be designed in a unit feedback configuration to improve the performance of the system.

(a) Design a digital lead compensator to meet the following requirements:
1) the closed-loop has a damping ratio around $\zeta = 0.6$;
2) the steady state error of the closed-loop for step reference input is less than 10%.

(20 marks)

(b) Design a digital PI controller. Use the Ziegler-Nicholes (ZN) second method, i.e. the stability limit method, to choose the proportional and integral gains.

(10 marks)

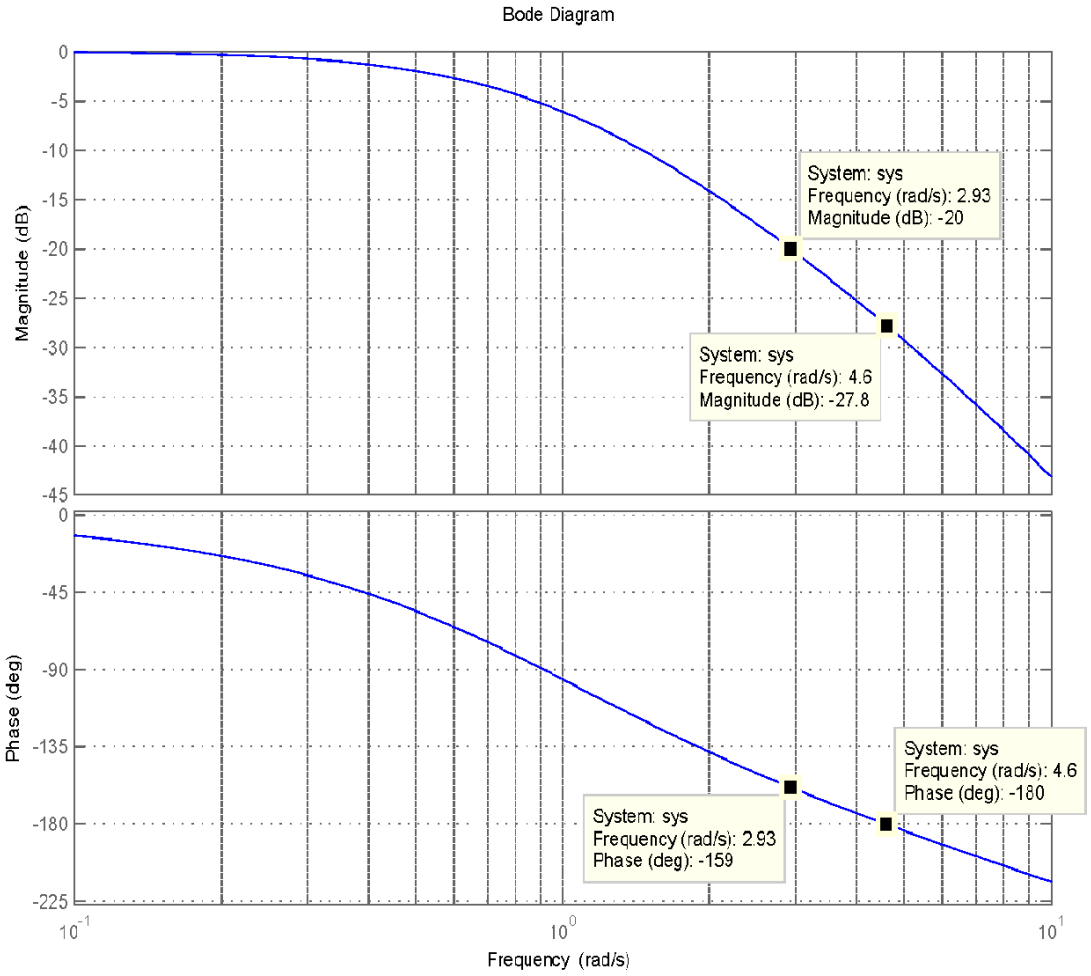

Figure 2. Bode plot for Q3.

Q.4 A process is described by the transfer function

$$H(z) = \frac{z+2}{z^2}.$$

The sampling period is T=1s. Design a pole placement controller in the form of

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

to meet the following performance requirements:
1) the maximum overshoot is less than 18%;
2) the settling time is less than 9.2 seconds.

(20 marks)

END OF PAPER