NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester II: 2014/2015)

EE3304 - DIGITAL CONTROL SYSTEMS

April/May 2015 - 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 $D(z) = z - 1$. Hints: $Z\left[\left(\frac{1-e^{-Ts}}{s}\right)\left(\frac{1}{s+2}\right)\left(\frac{1}{s+5}\right)\right] = \frac{0.00398\,z + 0.00315}{(z-0.607)(z-0.818)}$,

$$\frac{Y(z)}{R(z)} = \frac{Z\left[\frac{1-e^{-TS}}{s}\left(\frac{10}{s+5}\right)\right]D(z)}{1+Z\left[\left(\frac{1-e^{-Ts}}{s}\right)\left(\frac{2}{s+2}\right)\left(\frac{10}{s+5}\right)\right]D(z)}$$

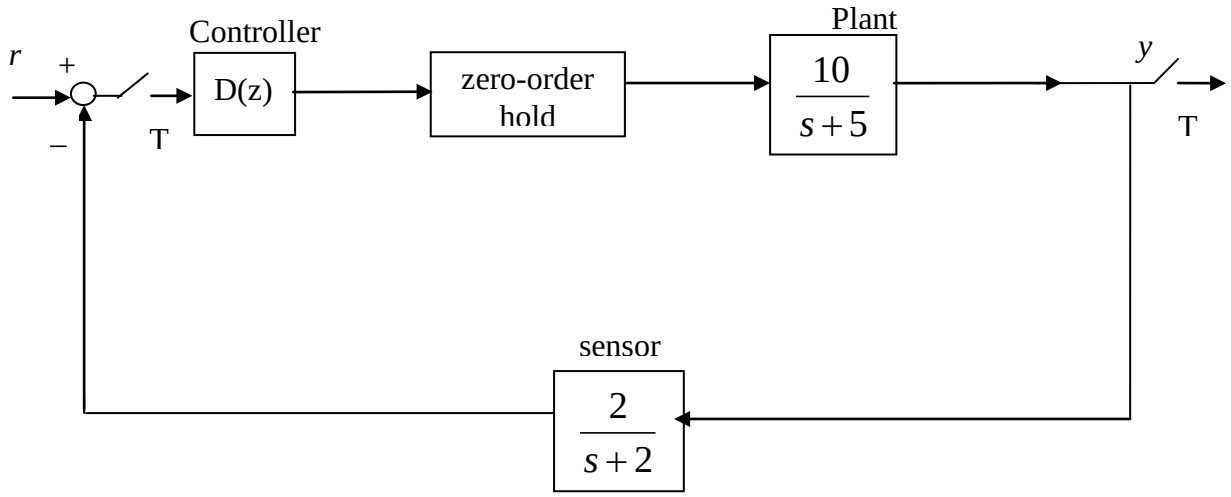

Figure 1

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

(10 marks)

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

(5 marks)

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

(10 marks)

Q.2 (a) A continuous signal,

$$f(t) = \cos t + \cos 2t,$$

is sampled at the sampling frequency of 3 *radian/second.* Give 5 lowest *positive* frequency components in the sampled signal. What is the minimum sampling frequency to avoid aliasing problem?

(8 marks)

(b) Suppose that $y(t) = te^{at}1(t)$ is sampled with the sampling time of *T*, where 1(t) is the unit step function. Obtain the *z*-transform of the sampled signal.

(8 marks)

Q.2 (continued)

(c) It is shown in the class that the bilinear mapping,

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

preserves stability from the continuous one to the discrete one. Prove that the converse is also true, that is, a stable discrete G(z) is always converted to a stable continuous system G(s).

(9 marks)

Q.3 A process model is given by

$$\frac{1}{z-4}.$$

The sampling period is T=1s. The digital controller is designed in a unity 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.

(4 marks)

(b) Is it possible to apply the frequency domain design methods such as phase lead or lag compensators to improve the performance of the system? If yes, then which type of compensator is preferred? Justify your answers.

(3 marks)

(c) Assume that the process model is known, design a digital PI controller to meet following requirements:
1) the maximum overshoot is less than 18%;
2) the settling time is less than 4.6 seconds.
Comment on the potential problem of the performance of the closed-loop system with this type of controller.

(18 marks)

Q.4 A process is described by the transfer function

$$G(z)=\frac{z+0.5}{z^2+1}.$$

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 transfer function from the command signal, $u_c(k)$, to the system output, $y(k)$, follows the reference model, $H_d(z)=\frac{1}{z^2}$.

2) the constant disturbance can be rejected.

(25 marks)

END OF PAPER