CID No: ________________________

IMPERIAL COLLEGE LONDON

Design Engineering MEng EXAMINATIONS 2018

For Internal Students of the Imperial College of Science, Technology and Medicine
This paper is also taken for the relevant examination for the Associateship or Diploma

Engineering Analysis EA 2.3 – Electronics 2

3rd May 2018: 10.00 to 11.30 (one hour thirty minutes)

This paper contains EIGHT questions.
Attempt ALL questions.

The numbers of marks shown by each question are for your guidance only; they indicate approximately how the examiners intend to distribute the marks for this paper.

This is a CLOSED BOOK Examination.

1. You are designing an electronic system to measure breathing of a patient with a breathing frequency of up to 40 breaths/minute. However, the diagnostic technique measures turbulence in the flow that would be up to 100 times faster than the breathing frequency. Furthermore, the medical team told you that they need your system to have a measurement accuracy of 0.05%. You are required to pick an analogue to digital converter (ADC) to turn your transducer measurements, which ranges from 0 to 3.3V, to digital samples.

   (i) What would you choose as the sampling frequency for the ADC? Why?

   [4]

   (ii) How many bits must the ADC have as converted values? Why? What is the resolution of the ADC in volts?

   [4]

   (iii) You were also told that the transducer could pick up interference of unknown frequencies from its surrounding. State with justifications and assumptions how you may avoid your captured signal being corrupted by such interference.

   [4]

2. A signal $x(t)$ can be modelled mathematically as:

$$x(t) = \cos(62.8t) + 0.5\sin(125.6t + \frac{\pi}{2})$$

   (i) Sketch the waveforms $\cos(62.8t)$ and $0.5\sin(125.6t + \frac{\pi}{2})$ for $0 \leq t \leq 0.2$. Hence sketch the signal $x(t)$ for $0 \leq t \leq 0.2$.

   [8]

   (ii) Rewrite $x(t)$ in exponential form. (There is no need to simplify the equation.)

   [5]

   (iii) Sketch the amplitude spectrum $|X(j\omega)|$ of the signal.

   [3]

3. In designing a real-time electronic system, you are given the choice of using polling or interrupt to handle some external events.

   (i) State the limitations of polling when compared with using interrupts.

   [2]

   (ii) Describe the sequence of action that a microprocessor takes when an interrupt occurs.

   [4]

   (iii) What guidelines must you follow when writing an interrupt service routine?

   [4]

4. The following differential equation describes the relationship between the output y(t) and the input x(t) of a linear system:

$$7\frac{d^2y}{dt^2}+\frac{dy}{dt}10=\frac{d^2x}{dt^2}+2\frac{dx}{dt}-4y(t)$$

(i) What is the order of this system?

[2]

(ii) Given that Y(s) and X(s) are the Laplace Transforms of y(t) and x(t) respectively, write down the transfer function H(s) = Y(s)/X(s) for the system.

[4]

5. A system H consists of two circuits A and B connected in series with each other as shown in Figure Q5. The transfer function for circuit A is P(s) and for circuit B is Q(s), and they are known to be:

$$P(s)=\frac{1}{0.5s+1} \qquad Q(s)=\frac{100}{s^2+2ks+100}$$

where k is a constant.

(i) Derive the s-domain equation for the transfer function H(s) of the entire system?

[5]

(ii) What is the natural or resonant frequency of the system?

[3]

(iii) It is known that when k = 10, the system is critically damped. Sketch the step response of the system. Explain your answer.

[4]

(iv) If k is 1, sketch the step response of the system. Explain your answer.

[4]

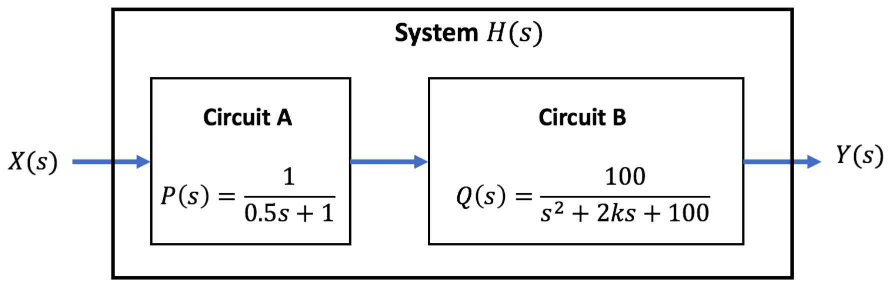

Figure Q5

6. The block diagram of a discrete-time shift-invariant system G is shown in Figure Q6. The input to the system is $x[n]$ and the output is $y[n]$, where $n = 0,1,2,3, \ldots$ etc. The system is assumed to be casual, i.e. $x[n] = y[n] = 0$, for $n < 0$.

   (i) Derive the difference equation for the system.

   [4]

   (ii) Derive the output sequence $y[0], y[1], \ldots \ldots, y[9]$ given that $\alpha = 0.8$, $\beta = 0.2$, $x[0] = 0$ and $x[n] = 10$ for $n \geq 1$.

   [4]

   (iii) Find the transfer function $G[z]$ of the system given that $\alpha = 0.8$, $\beta = 0.2$.

   [4]

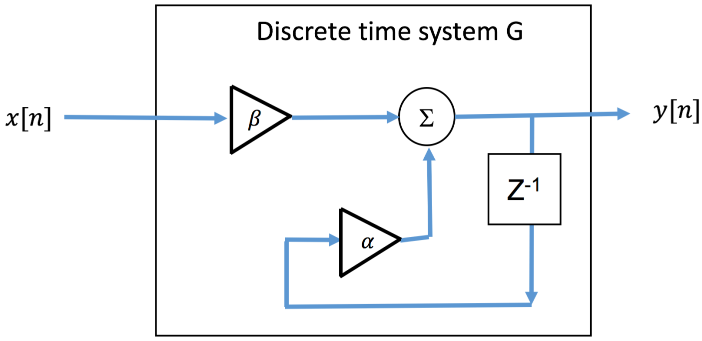

Figure Q6

7. For the group project, you used an IMU to derive the pitch angle of the mini-segway vehicle.

   (i) Explain the principle used by the accelerometer to measure the pitch angle.

   [4]

   (ii) Why is it not sufficient to rely on the accelerometer alone to provide the pitch angle measurement?

   [4]

   (iii) What does a gyroscope measure, and how can the gyroscope reading be used to measure the pitch angle? What is its limitations?

   [4]

   (iv) How did you combine the two types of measurement to provide a better estimate of the pitch angle?

   [4]

8. Figure Q8 shows a proportional -derivative (PD) controller with a transfer function of C(s) controlling the behaviour of a first order system with a transfer function of P(s) in a close-loop feedback arrangement. It is known that:

$$P(s) = \frac{1}{1 + 0.1s}$$

(i) Write down the transfer function of *C(s)* in terms of the proportional gain K_p and the derivative gain K_d of the controller.

[3]

(ii) If $K_d = 0$, derive the close-loop transfer function *H(s)* of the system where

H(s) = Y(s)/R(s).

[5]

(iii) Explain the effect of the proportional gain K_p and the derivative gain K_d of the controller on the close-loop response of the system.

[4]

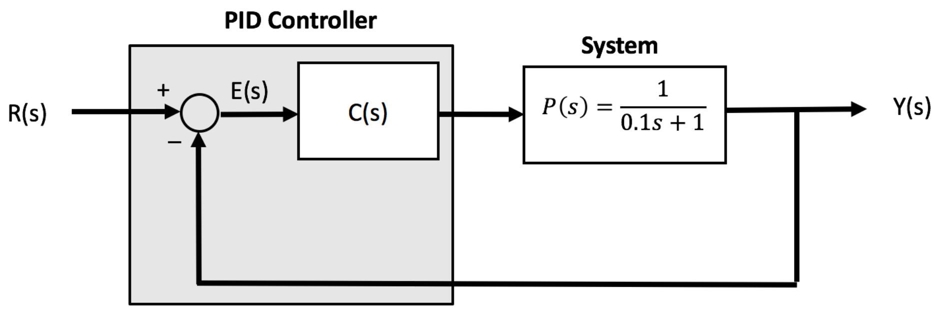

Figure Q8

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