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IMPERIAL COLLEGE LONDON

Design Engineering MEng EXAMINATIONS

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

SAMPLE EXAMINATION PAPER

(with numerical answers)

This paper contains EIGHT questions and lasts for 1.5 hours

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. An electrical signal is represented mathematically by the equation:

$$x(t) = 2.35\sin(3142t + 30°) + 0.65 \text{ volts}$$

(i) What is the average value of *x(t)*?

[2]

(ii) What is the frequency in Hz and phase angle in radians of the signal?

[3]

(iii) What are its maximum and minimum values?

[4]

(iv) Rewrite x(t) in exponential instead of sinusoidal form.

[3]

(v) Sketch the amplitude spectrum of *x(t)*.

[3]

2. The signal in Q1 is to be sampled by a microprocessor system with an analogue to digital converter (ADC).

(i) What is the minimum sampling frequency that you must use in order not to corrupt the converted signal? In practice, what sampling frequency would you choose to use and why?

[8]

(ii) It is known that the converted digital signal requires an accuracy of 0.1%. How many bits of resolution is required of the ADC to achieve this accuracy?

[4]

3. Figure Q3 shows a motor with a hall effect sensor detecting the rotational speed of a motor. The circular magnet attached to the motor's axle has 12 pairs of magnetic poles. The output of the hall effect sensor produces a series of pulses, one pulse for every N-S pair of the circular magnet, which is counted by the microprocessor system.

   (i) If C is the number of pulses counted over a period of 100 msec, write down the equation relating the speed of the motor S in revolution/minute (rpm) to the pulse count C.

[6]

   (ii) The pulses could be counted by the microprocessor using the method of polling or interrupt. Explain in no more than 100 words the advantages and disadvantages of these two methods.

[6]

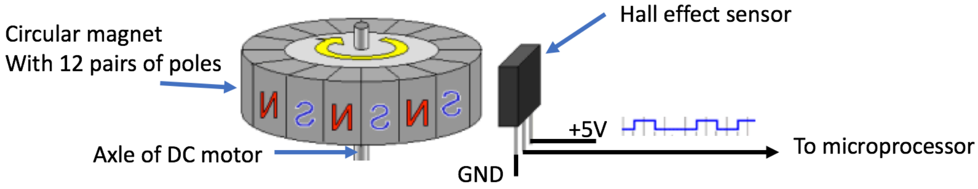


Figure Q3

4. A second order system has a transform function given as:

$$H(s) = \frac{2000}{s^2 + 2s + 1000}$$

   (i) Derive the poles of the system.

[6]

   (ii) Given that a generic 2nd order system can be described by the following expression in s-domain:

$$K\frac{\omega_0{}^2}{s^2 + 2\zeta\omega_0 s + \omega_0{}^2}$$

where ζ is the damping factor and ω_0 is the natural frequency, drive the value of K, the dimpling factor and the natural frequency for H(s).

[6]

5. A system with input x(t) and output y(t) is characterised by the following differential equation:

$$2\frac{d^2y}{dt^2} + 2y(t) = \frac{dx}{dt}$$

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

[6]

(ii) What are the poles and zeros of the system?

[6]

6. A discrete-time system is characterised by the z-domain transfer function:

$$H(z) = \frac{Y(z)}{X(Z)} = \frac{1}{1 - 0.2Z^{-1}}$$

where X(z) and Y(z) are the z transforms of the input x[n] and output y[n] respectively.

(i) Derive the difference equation relating x[n] to y[n].

[5]

(ii) Assuming that the input is causal and that y[0] = 0, derive the first 8 samples of the system's impulse response.

[5]

(iii) By substituting $z = e^{j\Omega}$, derive the frequency response of this discrete-time system in terms of the discrete frequency Ω.

[5]

7. Draw, in block diagram form, a complementary filter for deriving pitch or roll angles measured with an Inertia Measurement Unit (IMU). Briefly explain why we need such a filter to find the angle of the IMU.

[8]

8. Figure Q8 show a simple proportional feedback system to control the motor speed s(t) in response to the set-point r(t) in the s-domain.

(i) Derive the close-loop transform function of the system Y(s)/R(s).

[5]

(ii) Modify the system block diagram in Q8 to include a derivative term.

[5]

(iii) Explain the impact on the dynamic response of the system with the addition of this derivative component to the feedback system.

[4]

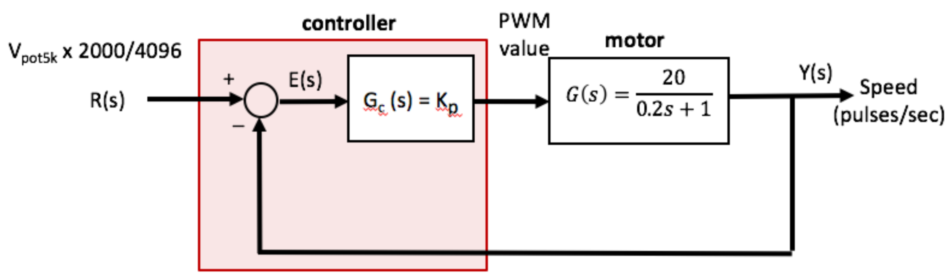


Figure Q8

Numerical answers to the Sample Paper

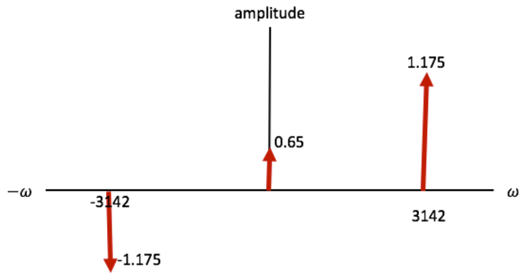
1. (i) 0.65v

   (ii) 500Hz, $\frac{\pi}{6}\ rad/\sec\ at\ t = 0$

   (iii) 3v and -1.7v

   (iv) $x(t) = 0.65 + \frac{1.175}{j}\left(e^{j(3142t+\frac{\pi}{6})} - e^{-j(3142t+\frac{\pi}{6})}\right)$

   (v)



2. (i) Fs(min) = 1kHz, in practice, use at least 2.5 x Fs(min) or higher, i.e. 2.5kHz. Otherwise would need perfect low pass filter to reconstruct the analogue signal.

   (ii) Need accuracy of 1 part in 1000. Therefore requires 10 bits ADC – 1 part in 1024.

3. (i) S = 50 x C rpm

   (ii) Bookwork – see notes or other materials.

4. (i) Poles at $s = -1 \pm j\sqrt{31.6}$

   (ii) K = 2 $\omega_0 = 31.6$ $\zeta = 0.0316$

5. (i)

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

   (ii) zero = 0, poles = ±j

6. i)

$$y[n] = x[n] + 0.2y[n-1]$$

(ii)

n	0	1	2	3	4	5	6	7
x[n]	1	0	0	0	0	0	0	0
y[n]	1	0.2	0.04	0.008	0.0016	0.00032	0.000064	0.0000128

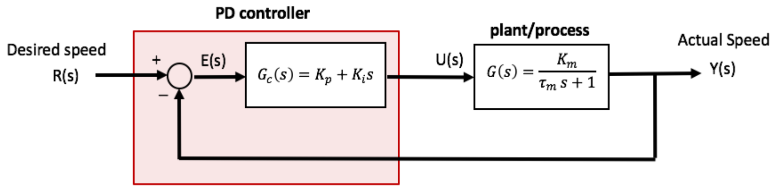
(iii)

$$\left|H(e^{j\Omega})\right| = \sqrt{\frac{1}{(1.04 - 0.1\cos(\Omega))}}$$

7. Book work. See notes and tutorials.

8. (i) $H_{CL}(s) = \frac{20K_p}{1+20K_p+0.2s}$

(ii)



(iii) Bookwork.