Ex/ET/T/423/2017(Old)

BACHELOR OF ENGINEERING IN TELE-COMMUNICATION ENGINEERING EXAMINATION, 2017

(4th Year, 2nd Semester)

INSTRUMENTATION & MEASUREMENTS

Time : Three hours Full Marks : 100

Answer any *FIVE* Questions
All question carry equal marks

Marks

14 + 6

Q.1 (a) Derive the expressions of step response of second order elements under the situations of (i) under damped; (ii) critically damped and (iii) over damped.

(b) An elastic force sensor has an effective seismic mass of 0.1kg, a spring stiffness of 10 N m^{-1} and a damping constant of 14 Ns m^{-1}. Calculate the sensor (i) natural frequency, (ii) sensor damping ratio and (iii) transfer function relating displacement and force.

8+ 12

Q.2 (a) What is loading effect in measurements? Explain electrical loading using Thevenin and Norton equivalent circuits.

(b) The motion of a hydraulic ram is to be recorded using a potentiometer displacement sensor connected to a recorder. The potentiometer is 25 cm long and has linear resistance displacement characteristics. A set of potentiometers with maximum power rating of 5W and resistance values ranging from 250 to 2500 Ω in 250 Ω steps is available. The recorder has a resistance of 5000 Ω and the nonlinear error of the system must not exceed 2% of full scale.

Find: -

(i) The maximum potentiometer sensitivity that can be obtained.

(ii) The required potentiometer resistance and supply voltage in order to achieve maximum sensitivity.

10 +10

Q.3 (a) Mention the different noise and interference sources and explain their coupling mechanisms to measurement circuits in industrial environments. Explain important methods of reducing effects of such noise and interference.

(b) A sinusoidal signal of amplitude 1.4 mV and frequency 5kHz is 'buried' in Gaussian noise with zero mean value. The noise has a uniform power spectral density of 100 pW Hz^{-1} up to a cut-off frequency of 1 MHz.

(i) Find the total power, r.m.s value and standard deviation for the noise signal.

(ii) What is the signal-to-noise ratio in dB?

(iii) Sketch the autocorrelation function for the combined signal and noise.

(iv) The combined signal is passed through a band-pass filter with centre frequency 5 kHz and bandwidth 1 kHz. What improvement in signal-to-noise ratio is obtained?

[Turn over

(v) The filtered signal is then passed through a signal averager which averages corresponding samples of 100 sections of signal. What further improvement in signal-to-noise ratio is obtained?

12 + 8

Q.4 (a) Explain with diagram the principle of operation of Linear Variable Differential Transformer (LVDT) as a sensor. Explain how electronically we can extract the phase information of the low level signal when the ferromagnetic plunger have forward and reverse directions of movement. State some applications of the LVDT sensor in industry.

(b) An iron-constantan thermocouple is to be used to measure temperatures between 0 and 300 °C. The emf values are as given below (Table-I).

(i) Find the non-linearity at 100 °C and 200 °C as a percentage of full scale.

(ii) Between 100 and 300 °C the thermocouple emf is given by $E_T = a_1T + a_2 T^2$. Calculate a_1 and a_2.

(iii) The emf is 12500 μV relative to a reference junction of 20 °C and the corresponding reference junction circuit voltage is 1000 μV. Use the result of (ii) to estimate the measured junction temperature.

Table-I

Iron -Constantan Thermocouple (Type-J)	EMF Values (μV)
$E_{100,0}$	5268
$E_{200,0}$	10777
$E_{300,0}$	16325
$E_{500,0}$	27388

10 + 4 + 6

Q.5 (a) Explain the theory of operation of resistive strain gauge. Define the Gauge factor G. Explain why semiconductor strain gauges show high gauge factor G.

(b) A resistance strain gauge has a gauge factor of 2.1 and an unstrained resistance of 120 Ω. What would the resistance of the gauge be if it experienced a strain of 1000 μstrain?

c) Determine the output voltage from the Wheatstone bridge in Fig.1 below when the gauge is subjected to a strain that results in it's resistance increasing to 120.4 Ω.

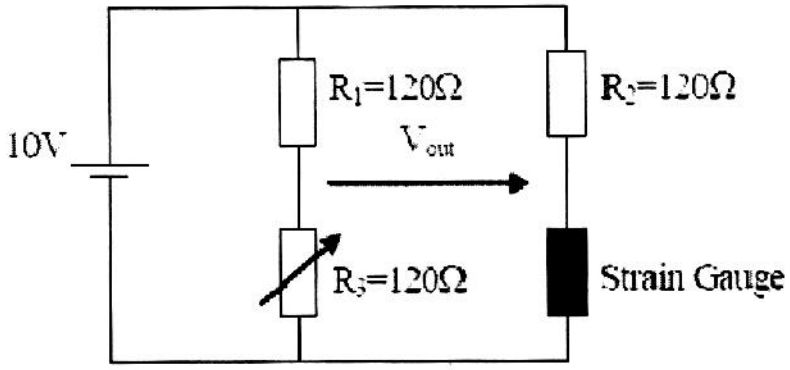

Fig.1

What is the purpose in making R3 a variable resistor?

10 + 10

Q.6 (a) Explain with the aid of a sketch the principle of operation of a Pitot tube flow meter. Derive the following equation that relates velocity (v) to the pressure drop (P_1 - P_2) for the Pitot Tube.

$$v = \sqrt{\frac{2(P_1 - P_2)}{\rho}}$$

ρ = density of fluid

Note: Bernoulli's equation for fluid flow is:

$$P_1 + \rho g h_1 + \frac{\rho v_1^2}{2} = P_2 + \rho g h_2 + \frac{\rho v_2^2}{2}$$

(b) A Pitot tube flow meter is installed in cooling tower water return pipe that has a diameter of 300 mm. A differential pressure reading of 10 mbar is obtained from the sensor.
Determine the following:
(i) the velocity of water in the pipe,
(ii) the volumetric flow rate of water in the pipe,
(iii) and the mass flow rate of water in the pipe.
Note: The density of water is 1000 kg/m3.

10 + 10

Q.7 (a) Discuss with diagrams the principles and basic theory of gas chromatography for measuring the composition of gas mixtures. What is the significance of HETP for a chromatograph column? Show the Van Deemter relation of HETP with the mean carrier gas velocity.

(b) Discuss the principle of operation of Katharometer detector used in gas chromatography. The Katharometer is connected as detector in a chromatograph and explain the subsequent signal processing and operations sequencing needed for obtaining the peak areas of the components in a gas mixture.

10 + 10

Q.8 Write short notes on any ***TWO*** of the following:

(a) Principle of operation of a thermal detector for optical measurements.

(b) Capacitive liquid level and displacement sensors for industrial applications.

(c) Fiber optic temperature sensor for high temperature measurement.

(d) Microcomputer based Data acquisition and communication system for industrial applications.

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