Ex/ET/T/424/2019

B. E. Electronics Tele-Communication Engineering Examination, 2019

(4th Year, 2nd Semester)

Instrumentation & Measurements

Time : Three hours Full Marks : 100

Attempt ***any five*** questions
All questions carry equal marks

Marks 14+6

Q.1(a) For the Mass–spring–damper model of an elastic force sensor, deduce the expression of the transfer function G (s) of the system in terms of the damping ratio (ξ) and the undamped natural frequency (ω_n) of the system. Also show the response of the system to a unit step input.

1(b) A force sensor has a mass of 0.5 kg, stiffness of 2×10^2 Nm $^{-1}$ and a damping constant of 6.0 N s m^{-1}. (i) Calculate the steady-state sensitivity, natural frequency and damping ratio for the sensor. (ii) Calculate the displacement of the sensor for a steady input force of 2 N.

Marks 2+10+8

Q.2(a) Explain what you understand by Electrical Loading.
Consider a potentiometric displacement sensor giving resistance proportional to displacement **x as** the output.(R =k**x** ohm). Derive the expression for the voltage displacement relationship for a loaded potentiometer and explain how nonlinearity in the transfer characteristics can arise due to loading effect on the potentiometer.

2(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 5 W 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 non-linear 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.

[Turn over

Marks 10+10

Q.3(a) Explain how internal noise, external noise sources and also interference sources can affect a weak measurement signal obtained from measurement sensors and transducers. Explain how different electrical coupling mechanisms are responsible for reducing the signal-to-noise ratio of a measurement signal.

3(b) A sinusoidal signal of amplitude 1.4 mV and frequency 5 kHz 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) (ii) What is the signal-to-noise ratio in dB?
(iii) Sketch the autocorrelation function for the combined signal and noise.
(iv) (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?
(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?

Marks 14+6

Q4. (a) Define Gauge factor G of a strain gauge in terms of the parameters of the gauge. What is piezoresistive effect? Explain why semiconductor gauges have higher G compared to metallic gauges. Explain how a Semiconductor resistive gas sensor is designed to sense the presence of oxides of nitrogen gas in air.

4.(b) Two strain gauges, each with an unstrained resistance of 120 Ω and a gauge factor of 2.0, are bonded onto a steel bar having cross-sectional area of 10^{-3} m^2, Young's modulus of 2×10^{11} Pa and Poisson's ratio of 0.4. The two gauges are so mounted that one measures the longitudinal strain and the other measures transverse strain. Find the corresponding gauge resistances for the longitudinal and transverse strains.

Marks 12+8

Q5. (a) Explain the principle of measurement of fluid flow using a restriction type flow meter. Explain how an electronic differential pressure transmitter can be used for transmission of information from a process plant to a distant control room for continuous monitoring of flow rate.

5. (b) Explain the theory of flow measurement using a non-restriction type flow meter. Discuss its advantages and disadvantages with respect to a restriction type flow meter.

Marks 10+10

Q6. (a) Explain with diagram the design and operation of a Data Acquisition System (DAS) used in industrial process measurement & remote control.

Q6. (b) Sixteen analogue input voltages, each with a frequency spectrum between 0 and 5 Hz, are input to a time division multiplexer. The multiplexed signal passes to a serial digital

(PCM) transmitter consisting of a sample/hold device, 12-bit binary ADC and a parallel-to-serial converter.

The PCM signal is transmitted to a distant receiver over a link affected by 'white' noise with a power spectral density of 0.2 mW Hz^{-1}.

(i) Suggest a suitable sampling frequency for each input signal.

(ii) What is the corresponding number of samples per second for the multiplexed signal?

(iii) What is the maximum length of time the sample/hold device can spend in the hold state?

(iv) What is the maximum percentage quantization error for the ADC?

(v) Find the bit rate and minimum transmission bandwidth for the PCM signal.

(vi) The first stage of the PCM receiver is a low-pass filter with a bandwidth 'matched' to the frequency spectrum of the PCM signal. Estimate the standard deviation of the noise present at the filter output.

Marks 12+8

Q7. (a) Explain the principle of operation of an optical pyrometer used for high temperature measurements. Discuss its range, accuracy, speed of response and linearity. Explain whether it can be configured for continuous measurement of temperature of a blast furnace in steel plant.

7. (b) Explain how the Resistive metal and semiconductor sensors can be used for temperature measurement. Show their transfer characteristics and the range of temperature over which they can suitably work.

Marks 10 +10

Q8. Write short notes on any **TWO** of the following.

(a) The LVDT and its applications in linear displacement measurement.

(b) The principle of application of capacitive transducer in liquid level measurements

(c) Principle of operation of a Gas Chromatograph for measurement of components of a gas mixture.

(d) Methods of improvement of signal-to-noise ratio of measurement signals.
