BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
First Semester 2023-2024
Mid Semester Exam (Closed book)
Transducers and Measurement Techniques (INSTR F312)

Time: *90 Minutes* *Max Marks:60* *Date:09 Oct 2023*
Note: *This question paper has 2 (TWO) printed pages. Assume and clearly specify any missing data suitably. Marks are indicated against each question.*

Q1. A system is to be designed for a robotic application where a DC shunt motor whose input voltage is proportional to torque and this torque is proportional to angular displacement θ (rad). The stiffness Ks of the spring can vary by ±10% about the nominal value of 0.05 rad N $^{-1}$ m $^{-1}$. **[12 M]**
Given that the following are available:
(i) An amplifier of gain 1000, **(ii)** a voltage error detection unit, **(iii)** POT of sensitivity 100 V/rad **(iv)** A DC shunt motor with sensitivity 0.2 N-m V $^{-1}$ **(v)** A Spring with stiffness Ks (rad N $^{-1}$ m $^{-1}$), and **(vi)** A stable angular displacement transducer of sensitivity 100 V rad $^{-1}$

(a) Draw a block diagram of the system, ***(i)*** open loop, ***(ii)*** closed loop using above mentioned components.
(b) Determine the value of angular displacement if input voltage is 100 V in case of open loop and close loop system. Comment on their values.
(c) calculate the effect of a 10% *decrease* in Ks on the sensitivity of the closed loop system over open loop system.

Q2. A platinum resistance sensor is used to interpolate between the triple point of water (0 °C), the boiling point of water (100 °C) and the freezing point of zinc (419.6 °C). The corresponding resistance values are 100.0 Ω, 138.5 Ω and 253.7 Ω. The algebraic form of the interpolation equation is $R_T = R_0(1 + \alpha T + \beta T^2)$, where R_T (Ω) = resistance at T °C, R_0 (Ω) = resistance at 0°C. Find the numerical form of the interpolation equation. **[8 M]**

Q3. A capacitive transducer consists of two triangular plates placed side by side with a negligible gap between them and a rectangular plate moving laterally with a uniform air gap of 1 mm between the rectangular plate and triangular plate, as shown in Fig. Q3. **[15 M]**
(a) Calculate the value of C_1 and C_2
(b) Find the displacement sensitivity of C_1 and C_2 with respect to 'x'.

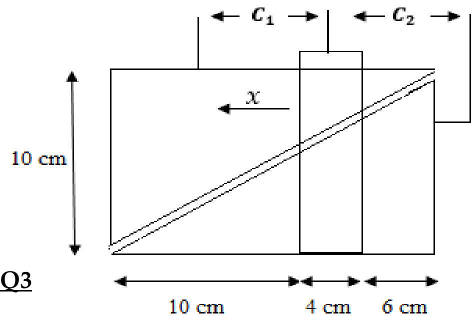

Fig. Q3

Q4. An unbonded strain gauge based accelerometer with a natural frequency of 150 Hz is shown in Fig. Q4(a). The magnitude of the strain due to prestressing (e_o) is 2.5 times of the maximum strain developed due to applied acceleration. If the strain due to applied acceleration is sinusoidal in nature with $e = 10\sin(t) \times 10^{-4}$, then, **[18 M]**

(a) Find the output voltage (V_o) generated from bridge circuit (Fig. Q4(b)) for a maximum DC supply voltage $\widehat{V_S}$ volts.
(b) Find the maximum output voltage (V_o) generated from the bridge circuit, if $V_S = \widehat{V_S}\sin(20t)$ volts. Also draw the typical output voltage waveform for this case.
(c) Now assume that the signal generated from bridge is corrupted by a zero-mean white gaussian noise with σ = 20 mV. If the corrupted signal is averaged for 50 sections, calculate the in SNR (in dB) before and after averaging.

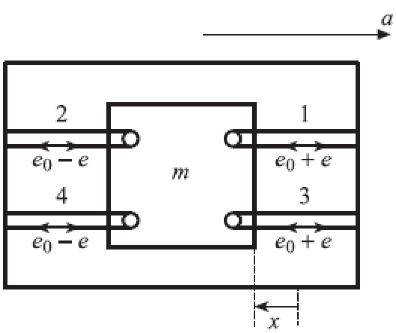

Fig. Q4 (a)

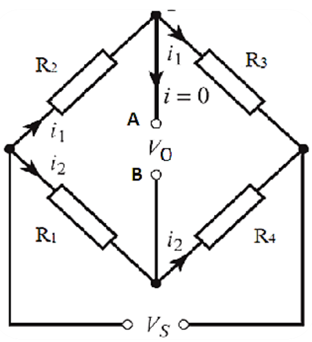

Fig. Q4 (b)

Strain Gauge data

Resistance	= 120 Ω
Gauge factor	= 2.1
Maximum current	= 50 mA
Length at zero acceleration	= 2.3 cm

Q5. Read the following statement from research paper, J.A. Rodriguez-Manfredi *et al.* "The Mars Environmental Dynamics Analyzer, MEDA. A Suite of Environmental Sensors for the Mars 2020 Mission," Space Science Reviews, pp. 217-248, 2021.

"The dynamic range of the Humicap® (a humidity sensor (HS)) changes with temperature, and the sensor also becomes logarithmically slower with decreasing temperature, its time constant is about 0.1 s at 293 K, but for example at -40 ℃ it is about 30 s and at -70 ℃ about 450 s. **[7 M]**

(a) What will be frequency range for the Humicap®, for which the amplitude inaccuracies will be limited to $\pm$ 5% for **(*i*)** 20 ℃ and **(*ii*)** -70℃.

(b) Suggest a method to compensate for this variation in time constant at different temperatures.

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