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(*University of Choice*)
MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS 2023/2024 ACADEMIC YEAR

FOURTH YEAR FIRST SEMESTER MAIN EXAMINATIONS

FOR THE DEGREE OF BACHELOR OF SCIENCE IN ELECTRICAL AND COMMUNICATIONS ENGINEERING

COURSE CODE: ECE 413

COURSE TITLE: INSTRUMENTATION

DATE: **FRIDAY 15/12/2023** **TIME: 12: 00 PM – 2:00 PM**

INSTRUCTIONS TO CANDIDATES

Question ONE (1) is compulsory
Answer Any Other TWO (2) questions

TIME: 2 Hours

MMUST observes ZERO tolerance to examination cheating

This Paper Consists of 5 Printed Pages. Please Turn Over.

QN 1 [30mks]

(a) *i)* Briefly explain the elements of data acquisition system, citing examples for each element. [4mks]

ii) State FIVE roles of driver software in data acquisition. [5mks]

iii) List FIVE criteria for choosing the most suitable measuring instrument for a given application. [5mks]

iv) State two conditions by which an emf is generated in thermocouples. [2mks]

(b) *i)* Highlight FIVE features of intelligent instruments [5mks]

ii) Describe the architecture of an intelligent sensor. [3mks]

(c) State the importance of the following signal conditioning techniques:

i) Amplification [2mks]

ii) Isolation [2mks]

iii) Analogue to digital conversion [2mks]

QN 2 [20mks]

(a) Give TWO differences between resistance temperature detectors and thermistors. [2mks]

(b) The bridge circuit shown contains a thermistor $\boldsymbol{R_3}$, whose parameters are $\beta = 4100, T_0 = 273.15K, and\ R_0 = 5k\Omega$. The other arms of the bridge are $R_1 = 150\Omega, R_x = 125\Omega$. The bridge is balanced by variable resistor R_2.

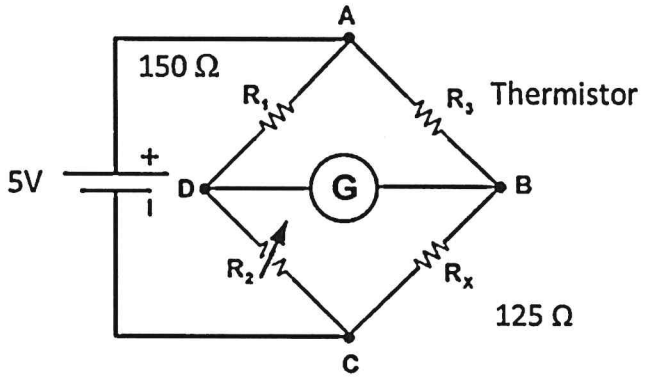

Fig. 1

Calculate:

i) the value of R_2 required to balance the bridge at 75°C. [4mks]

ii) the temperature reading for a voltage output of $V_{BD} = 0.25V$. [4mks]
[Assume $R_2 = 110\Omega$]

(c) The differential output voltage from the bridge circuit contains common mode signals and hence fed into the instrumentation amplifier circuit shown in **Fig. 2.**

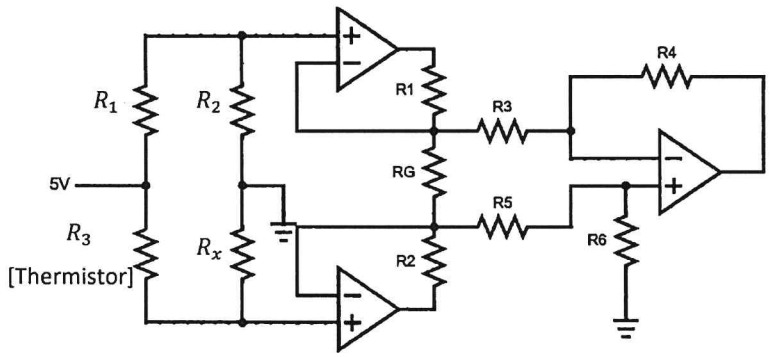

Fig. 2

Given that $R_1 = R_2 = 30\ k\Omega$, and the difference amplifier has a fixed gain of 10, determine the gain resistance R_G that gives $V_o = 5V$. [3mks]

(d) The 5V analogue output from the instrumentation amplifier is converted to a digital word by a 3-bit Flash ADC. Describe using a circuit diagram how the digital conversion occurs. [7mks]

QN 3 [20mks]

(a) A strain gauge of gauge factor 40.5 and unloaded resistance $R_G = 200\ \Omega$ at room temperature is bonded on a load cell made of steel of diameter $d = 5.5cm$ and $E = 200\ GN/m^2$ and connected into a bridge circuit with a supply voltage of $V_{in} = +15V$.
Resistors $R_1 = 150\Omega, R_2 = 100\Omega, R_3 = 300\text{k}\Omega$.

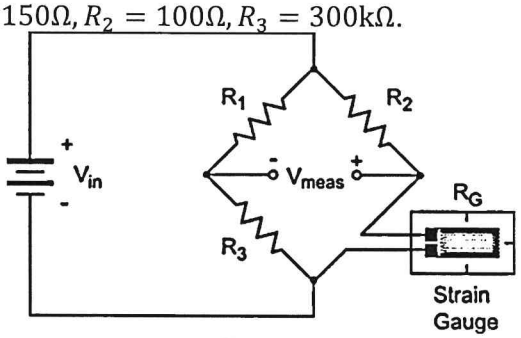

Fig. 3

If an object of weight 4.5kN is applied on the loadcell, determine:

i) The strain in each load cell. [2mks]

ii) The change in resistance. [1mk]

iii) The offset voltage of the bridge. [2mks]

(b) *i)* If the temperature coefficient of resistance for the strain gauge is $10^{-5}/°\text{C}$, determine the change in strain in the gauge when the room temperature increases by 10°C. [2mk]

ii) A dummy strain gauge (not affected by strain due to loading) is introduced to avert errors in measurement due to temperature effect. By analysis, suggest which resistor should be replaced to ensure: [3mks]

- Null offset voltage when unloaded and the room temperature increases by 10°C

- Offset voltage approximately equal to one obtained in (a) (iii) under a loading of 4.5kN when the room temperature increases by 10°C.

(c) If the analogue offset voltage from the bridge is amplified by a gain of 5000 and fed into a 4-bit successive approximation ADC:

i) Describe how a digital equivalent signal is generated after amplification of the value obtained (a) (iii) above. [6mks]

ii) Draw the circuit used for conversion [4mks]

QN 4 [20mks]

(a) Explain the working principle of Eddy current sensors using a well labelled diagram. [6mks]

(b) Distinguish between Eddy current and Hall effect sensors [2mks]

(c) *i)* Explain the working principle of Hall effect sensors using a well labelled diagram. [5mks]

ii) A silicon plate of thickness $1mm$, width $10mm$, length $100mm$ and Hall coefficient $3.66 \times 10^{-4} m^3/C$ is placed in magnetic field of $0.5\ Wb/m^2$ acting perpendicularly. If a current of $10^{-2} A$ flows through the plate, calculate the Hall voltage developed. [3mks]

iii) Give FOUR applications of Hall effect sensors. [4mks]

QN 5 [20mks]

(a) With the aid of a well labelled circuit diagram, describe how an LVDT sensor can be used with a bellows to measure gauge pressure. [5mks]

(b) An LVDT sensor has a core displacement of range $\pm 10mm$ and produces a differential output of $\pm 5mV\ (rms)$.

The data in the table gives the core displacement values against differential voltages due to differential pressure for an LVDT connected to bellows. The values are obtained from the null position.

Core displacement (mm)	Differential voltage (mV)
0.05	0.025
1.20	0.90
2.21	1.90
3.20	3.00
4.22	4.10
7.46	3.72
8.49	4.21
10.00	5.00

i) Assuming a linear relationship between the null position and maximum values, determine the non-linearity error as a percentage of full range output at a core displacement of $4.22mm$. [5mks]

ii) Determine the sensitivity of the LVDT sensor [1mk]

iii) If the output of the LVDT accelerometer is measured by a digital voltmeter with a resolution of 0.015mV, calculate the resolution of the accelerometer. [1mk]

iv) The output of the LVDT accelerometer is to be converted to digital form by a digital Ramp ADC of resolution $0.015mV$. Determine the number of bits required. [3mks]

(c) Describe the working of a **digital Ramp ADC** using a well labelled diagram. [5mks]