60

(*University of Choice*)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS 2022/2023 ACADEMIC YEAR

FOURTH YEAR FIRST SEMESTER EXAMINATIONS

FOR THE DEGREE OF BACHELOR OF SCIENCE IN MECHANICAL AND INDUSTRIAL ENGINEERING

COURSE CODE: ECE 413

COURSE TITLE: INSTRUMENTATION

DATE: 20TH DECEMBER, 2022 TIME: 12: 00 PM – 2:00 PM

INSTRUCTIONS TO CANDIDATES

ANSWER QUESTION ONE AND ANY OTHER TWO QUESTIONS.
QUESTION ONE CARRIES 30 MARKS AND ALL OTHERS 20 MARKS EACH.

TIME: 2 Hours

MMUST observes ZERO tolerance to examination cheating

Question One (30mks)

(a) *i)* State and explain the working principle of the following sensors: [5mks]
   i) Load cell
   ii) Polyvinylidene Fluoride tactile sensor
   iii) Thermocouple
   iv) Hall sensor
   v) Pyroelectric infrared sensor

   ii) Highlight five advantages of intelligent instruments over dumb instruments. [5mks]

(b) Describe with the aid of a circuit diagram and waveforms how an analogue output voltage from a sensor can be sampled and held before conversion to digital signal. [5mks]

(c) A linear potentiometric displacement sensor in Fig.1 has a maximum resistance of R_p and a range of 0 *to* 20mm. If the sensor is supplied with a voltage V_s and connected to a digital voltmeter of input resistance R_L at terminals A and B. Determine the ratio of the output to input voltage as a function of the fractional potentiometric resistance x. [5mks]

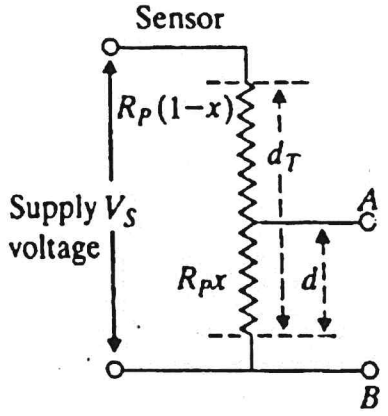

Fig.1

(d) Outline four tasks that can be performed by LabVIEW graphical programming environment. [4mks]

(e) Describe the working of a digital Ramp ADC using a well labelled diagram. [6mks]

Question Two (20mks)

(a) A potentiometer has a total resistance of 12kΩ over the entire length of 24cm. The output voltage is measured by a digital voltmeter with R = 12MΩ connected across the output terminals. If it is supplied by 12V DC and the wiper is at 18cm, calculate: [6mks]

i) the output voltage

ii) the non-linearity error introduced by the digital voltmeter

(b) If the analogue voltage from potentiometer is to fed into a 4-bit successive approximation ADC, through some intermediate circuitry. [9mks]

i) describe how a digital equivalent signal is generated from the value obtained in (a) (i) above.

ii) Draw the circuit used for conversion

(c) Strain in a cantilever beam is monitored using a strain gauge of resistance 1kΩ , GF = 2 and temperature Coefficient of resistance of10^{-5}/°C at room temperature, connected into bridge circuit. At maximum beam deformation, the strain is 4.5. [5mks]

i) Calculate the change in resistance of the gauge if it is strained 0.1%

ii) Calculate the change in effective strain when the room temperature increases by 10°C;

iii) Suggest a way of reducing this temperature effect.

Question Three (20mks)

(a) *i)* Explain the working principle of negative temperature coefficient (NTC) thermistor. [5mks]

ii) An NTC thermistor made of chromium has a resistance of $1k\Omega$ at $T = 100°C$ and $100k\Omega$ at $0°C$. Calculate the resistance at $T = 45°C$.

(b) If the Chromium thermistor (R_0) is connected into a bridge circuit and supplied with $15V$ as shown in Fig. 2. Calculate the voltage that the thermistor must resolve to define 1°C change in temperature. Consider a balanced condition $R_0 = R_a = R_b = R_c = 100k\Omega$ and temperature changes from 0 to 45°C. [4mks]

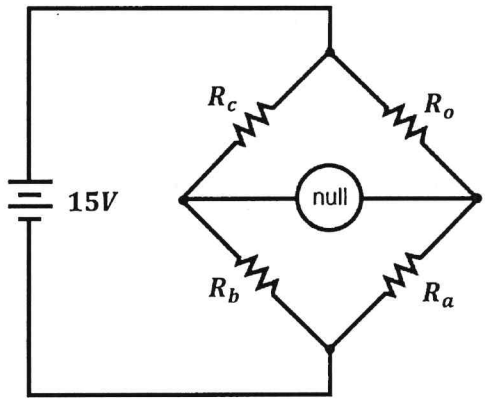

Fig. 2

(c) The differential output voltage from the bridge circuit contains high frequency signals and therefore it's fed into the input of the instrumentation amplifier circuit as shown in Fig. 3. If $R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = 33\ k\Omega$, determine the gain resistance R_G that gives $V_o = 7V$. [4mks]

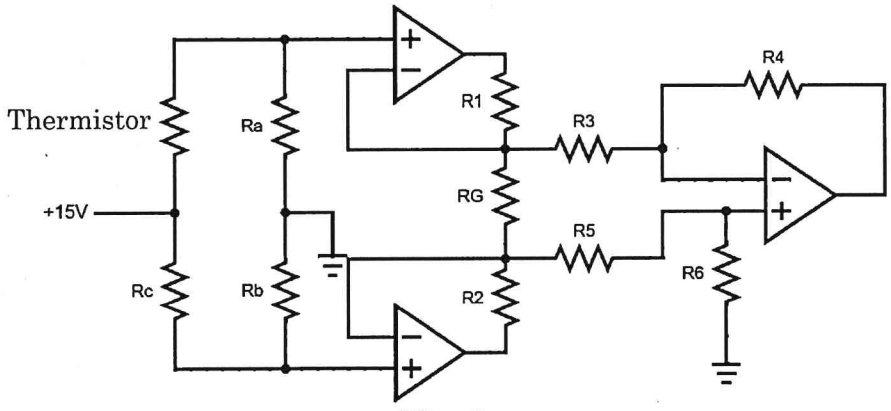

Fig. 3

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

Question 4 (20mks)

(a) The data in the table gives the strain values against differential pressure for a strain gauge bonded to bellows. Pressure ranges from $120kPa$ to $210kPa$. [4mks]

Pressure (kPa)	120	150.3	177.5	210
Strain (μm)	70	85	100	115

Assuming a linear relationship between the minimum and maximum values, determine the non-linearity error as a percentage of full range input at $\varepsilon = 100\mu m$.

(b) With aid of a well labelled diagram, describe the structure of a force sensitive resistor, explain the working principle and give TWO applications. [6mks]

(c) Using well labelled circuit diagrams, explain how voltage-to-frequency converters generate a frequency signal. [5mks]

(d) Describe the working of a variable reluctance tachogenerator. [5mks]

Question 5 (20mks)

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

(b) An LVDT with a range of ±10mm is connected to a 15V voltmeter through an amplifier of gain 250. The voltmeter scale has 100 divisions and can be read up to $1/5^{th}$ of a division. A 0.4mm core displacement produces a differential output of 2mV [5mks]
Calculate:

i) The sensitivity of the LVDT at the amplified output

ii) The output resolution of the instrument

iii) Number of bits required for an ADC when its output is to be digitized

(b) Four Piezoelectric crystals of charge sensitivity $2Pc/N$, area = $1cm^2$, 0.1 cm thickness and $\varepsilon_r = 5$. They are arranged in parallel, and are subjected to a force of 24N. [10mks]
Take $\varepsilon_0 = 8.85 \times 10^{-12}F/m$; $E = 9 \times 10^{10}Pa$
Determine:

i) the voltage across the electrodes for each crystal

ii) the change in crystal thickness

iii) If the output voltage from the sensor is fed through a charge amplifier, into a 16-bit ramp A/D converter with 1.5V resolution. Assuming uniform quantization error of ±0.05125V, calculate the range of possible input signals.