(University of Choice)

MASINDE MULIRO UNIVERSITY OF SCIENCE AND TECHNOLOGY (MMUST)

MAIN CAMPUS

UNIVERSITY EXAMINATIONS 2021/2022 ACADEMIC YEAR

FOURTH YEAR FIRST SEMESTER SPECIAL/SUPPLEMENTARY EXAMINATIONS

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

COURSE CODE: ECE 413

COURSE TITLE: INSTRUMENTATION

DATE: Monday, 3rd October, 202 TIME: 3-5pm

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 4 Printed Pages. Please Turn Over.

Question 1 (30mks)

(a) i) State three characteristics of instrumentation amplifiers [3mks]

ii) With regards to signal conditioning, define the following terms: [4mks]

i) Multiplexing:

ii) Quantization

iii) Quantization error

iv) Resolution of an Analogue-to-Digital Converter:

(b) i) State the principle of operation of piezoelectric sensors and explain the working of piezo-electric accelerometers with the aid of a well labelled diagram. [6mks]

ii) Show that the output voltage (V) of a piezoelectric crystal is proportional to applied pressure P. [2mks]

(c) With the aid of a block diagram, describe the internal structure of a smart sensor. [6mks]

(d) The level of Hydrogen peroxide ($\rho = 1450\ kg/m^3$) in a cylindrical vessel with a diameter of $2.5m$ and weight $w = 100\ kg$, can vary from 0 to $3m$. The minimum variation in level that can be detected is $10cm$. Design 4 load cells that can be used to measure the variations in height. [Take $g = 9.8N/kg$] [4mks]

(e) With the aid of a diagram, describe the working of a ramp ADC converter. [5mks]

Question 2 (20mks)

(a) i) State the working principle of pyroelectric sensor and explain using a sketch how it behaves as a *charge generator* when subjected to incident infrared radiation. [5mks]

ii) Describe the application of pyroelectric sensors in detecting human motion. [5mks]

(b) i) 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 $T = 40°C$. [4mks]

ii) The thermistor (R_0) is connected into a bridge circuit and supplied with $15V$ as shown in Figure 1. At balanced condition, $R_0 = R_a = R_b = R_c = 100k\Omega$. At $T = 40°C$, calculate the voltage that the thermistor must resolve to define 1°C change in temperature. [3mks]

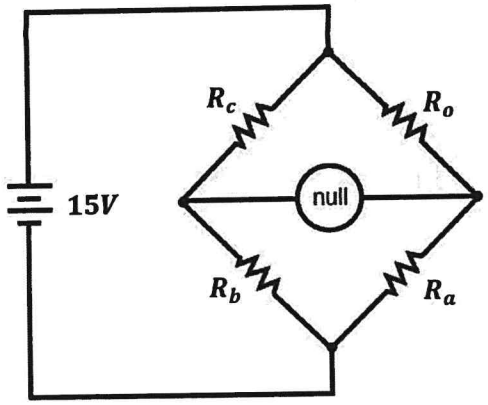

Figure 1

iii) 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 Figure 2. If $R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = 33\,k\Omega$, determine R_G so that the corresponding output $V_o = 10V$. [3mks]

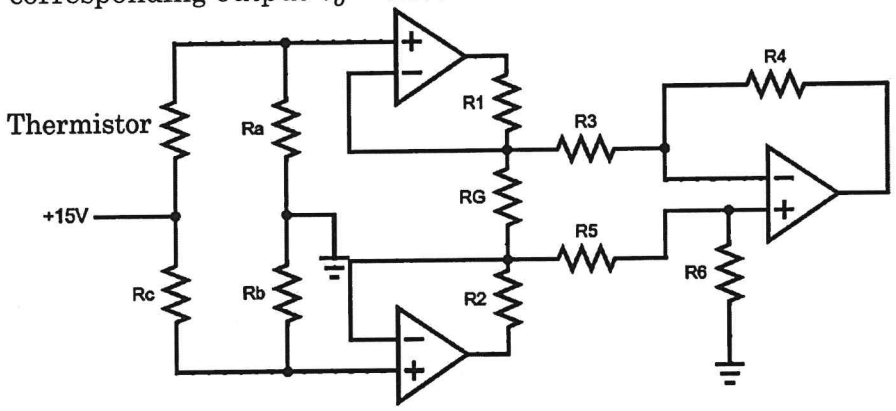

Figure 2

Question 3 (20mks)

(a) Explain the working principle of magnetoresistive effect and give two applications. [5mks]

(b) i) A 2.5 mm thick quartz piezoelectric crystal having a voltage sensitivity of 0.055Vm/N is subjected to a pressure of 1.4MN/m^2. If the permittivity of quartz is 40.6×10^{-12}F/m, Calculate; [4mks]
   i) The output voltage
   ii) Charge sensitivity

   ii) If the output voltage from the sensor is fed through a charge amplifier, into a ramp A/D converter with a 16-bit precision and a maximum quantization error of $\pm 0.05125V$. Assuming uniform quantization error, calculate: [3mks]
   i) The quantization interval
   ii) Range of possible input signals if the minimum input is 0V.

(c) State five advantages of intelligent instruments over dumb instruments. [5mks]

(d) A 10kΩ NTC thermistor has a β value of 3455 between the [3mks]

temperature range of 25°C and 100°C. Calculate its resistive value at 25°C and at 100°C.

Question 4 (20mks)

(a) With the aid of a well labelled circuit diagram, describe how a LVDT transducer can be used with a bellows to measure changes in pressure levels. [8mks]

(b) Highlight five functions performed by data acquisition software. [5mks]

(c) A potentiometer has a total resistance of $15.5k\Omega$ over the entire length of 24cm. It is excited by 10V DC. The output voltage is measured by an analogue voltmeter with an input resistance $R_L = 35k\Omega$, connected as load of the potentiometer. If the wiper is at 16cm, calculate: [8mks]

i) the output voltage indicated by the analogue voltmeter

ii) the non-linearity error introduced by the analogue voltmeter and compare with the error caused if a digital voltmeter with $R_L = 12M\Omega$ was used.

Question 5 (20mks)

(a) Using well labelled circuit diagrams, explain the working of voltage-to- frequency converters. [7mks]

(b) A platinum resistance temperature detector (RTD) is connected as shown in the Figure 3. The buffer $A1$ decouples the voltage divider from the inverting Op-Amp. The parameters of the RTD are; $\alpha = 0.01/°C$, $T_0 = 0°C, R_0 = 100k\Omega$. The circuit parameters are $V_s = 5V$, $R_1 = 3R_0, V_{out} = \pm 10V$. Calculate the measurable interval of temperature when V_{out} changes from 0V to $-10V$. [4mks]

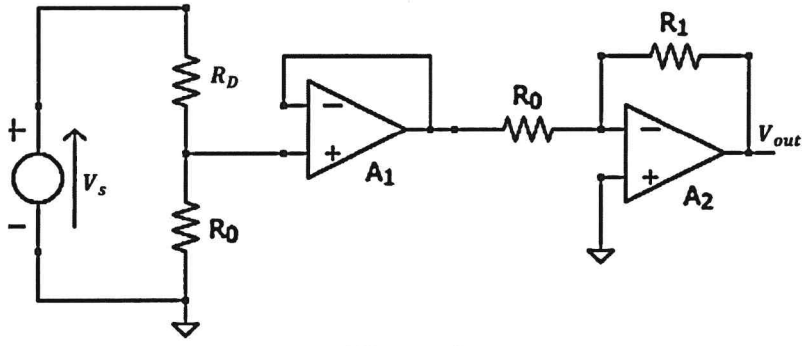

Figure 3

(c) i) Explain by use of a well labelled diagram how a capacitive accelerometer can be used for triggering airbags in automobiles. [3mks]

ii) A capacitance transducer has two plates of area $500mm^2$, separated by a distance of $0.2mm$. A linear displacement reduces the gap to 0.18mm. If the dielectric is air having a permitivity of $8.85 \times 10^{-12} F/m$. Calculate; [3mks]

i) the change in capacitance.

ii) the sensitivity of the capacitive transducer [3mks]