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MANIPAL INSTITUTE OF TECHNOLOGY
MANIPAL
(A constituent unit of MAHE, Manipal)

V SEMESTER B.TECH (ELECTRICAL & ELECTRONICS ENGINEERING)
END SEMESTER EXAMINATIONS, NOVEMBER 2022

MEASUREMENTS AND INSTRUMENTATION [ELE 3153]

REVISED CREDIT SYSTEM

Time: 3 Hours **Date: 29 NOVEMBER 2022** **Max. Marks: 50**

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.

1A. A transformer generating primarily a magnetic field is located 10cm from a shielding structure. The shielding structure is made from a 1cm thick sheet of copper. Estimate the shielding effectiveness of this structure at 1.5 kHz. Given, σ = 5.7x10 S/m for copper. ***(03)***

1B. A resistance manufacturer constructs a resistance anywhere between 1.14 kΩ and 1.26 kΩ and classifies them to be 1.2 kΩ resistance. Determine the tolerance to be stated. If the resistance values are specified at 25°C, determine the maximum resistance possible at 75°C, given temperature coefficient of +500 ppm/^{0}C ***(03)***

1C. You have been hired to an electrical machine manufacturing firm as a replacement to another engineer who left the company. The first task on arrival is to critically review and determine the current flowing in a designed circuit which is connected to a DC motor. The engineer's journal had the following observations:

a) DC current flowing through the circuit is measured by a PMMC based ammeter and backed up by an Electrodynamometer based ammeter.

b) The PMMC instrument contains 100 turns of coil with the flux density in the air gap being 0.2Wb/m^2 with the coil area being 0.8 cm^2.

c) The electrical characteristics of the employed electrodynamometer-based ammeter was:

Deflection (degree)	30	50	90	120	150
Mutual Inductance (H)	0.015	0.025	0.045	0.06	0.075

d) Spring constants for both the ammeters were determined to be the same.

e) The deflection in both the meters when tested were found to be the same.

If the target design DC current to the DC motor is 3.5A, determine the % error (of current measurement) in the existing circuit design. What should be the sensitivity of the electrodynamometer so that the % error is zero? ***(04)***

2A. A 3.45kW, 230V separately excited DC motor was subjected to a Maxwells Bridge to test its armature inductance and resistance as shown in Fig 2A.

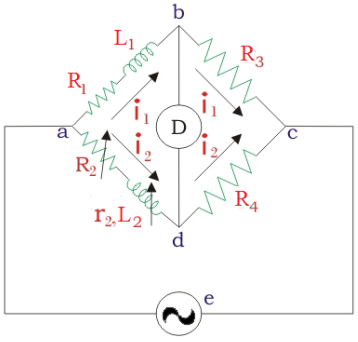

Fig 2A ***(03)***

Upon conducting experimentation, it was revealed that the current through D was zero when R_4=1.2Ω, R_3=1Ω, r_2=0.1Ω, R_2=0.5Ω and L_2= 10mH. Calculate the following

1. The armature inductance and Resistance
2. The time constant of the motor

Draw the trajectory of the full load current with time, clearly marking the steady state value, time constant and settling time.

2B. A capacitive transducer is made up of two concentric cylindrical electrodes. The outer diameter of the inner cylindrical electrode is 3mm and the dielectric medium is air. The inner diameter of the outer electrode is 3.1mm. The length of electrodes is 20mm. Calculate the change in capacitance if the inner electrode is moved through distance of 2mm. Also calculate the dielectric stress when a voltage of 100V is applied across the electrodes and determine if it is within safe limits assuming the breakdown strength of air to be 3 kV/mm. ***(03)***

2C. With a neat diagram, describe how the linear motion of the core of an inductive transducer is transduced to electrical signals. The output of an LVDT is connected to a 5V voltmeter through an amplifier having an amplification factor of 250. An output of 2mV appears across the terminals of LVDT when the core moves through a distance of 0.5 mm. Calculate the sensitivity of the LVDT and that of the instrument. The milli-voltmeter scale has 100 divisions. The scale can be read to $1/5^{th}$ of a division. ***(04)***

3A. Mention any four main functions of signal conditioning circuit. Design an active signal conditioning circuit using OPAMP to be interfaced with AD590 temperature transducer IC so as to produce 0V at 0°C and 10V at 100°C. The rate of conversion of AD590 is 1μA/^{0}K. ***(03)***

3B. A state variable filter circuit design is as shown in the Fig.3B. Analyze the circuit and determine the transfer function of a low-pass filter $\left(\frac{V_{LP}}{V_{IN}}\right)$ from the design. Also, determine the cutoff-frequency and quality factor of the design.

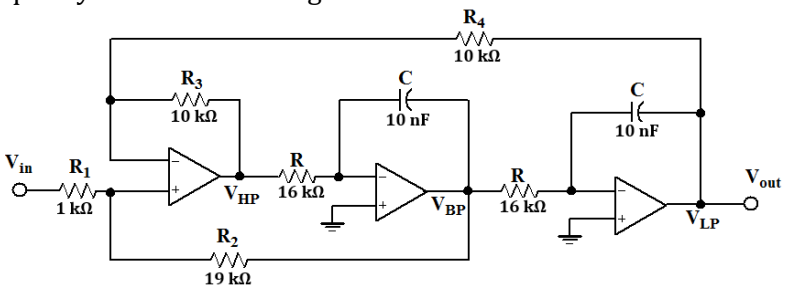

Fig 3B ***(03)***

3C. With a neat diagram, explain the operation of analog signal isolation in the photo-conductive mode. An active signal isolation circuit (photo-conductive mode) has the following specifications: $V_{cc} = +5V$; servo gain = forward gain = 0.004; forward current = $15mA$. Design suitably, the circuit components that will ensure an amplified (as well as isolated) voltage output of $0 - 4V$ for an existing voltage input of $0 - 2V$. With the help of a neat final schematic, evaluate your design and prove that it meets the required amplified voltage output. ***(04)***

4A. As part of an instrumentation design challenge organized by your firm, you are required to evaluate the design solutions of three finalist student teams. The problem statement for the design challenge is as follows:

"A vibration sensor is mounted on the flaps of a passenger aircraft to analyze the fatigue of aircraft flaps during its maintenance checkup. The vibration sensor output is linear and in the range of -50mV to +50mV. The entire range of signal must be suitable to be fed to an onboard ADC of range 0V to +5V. Due to external and internal factors that may lead to high frequency noises to the sensor data, the signals of frequency more than 30Hz should considered as noise signals and need to be eliminated." ***(03)***

The schematics of the two submitted design solutions are as shown in Fig 4A. Evaluate and comment on the design for correctness with appropriate justification.

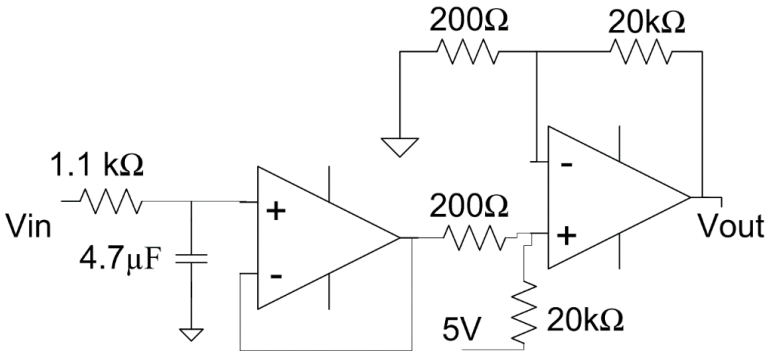

Fig.4A: Design A

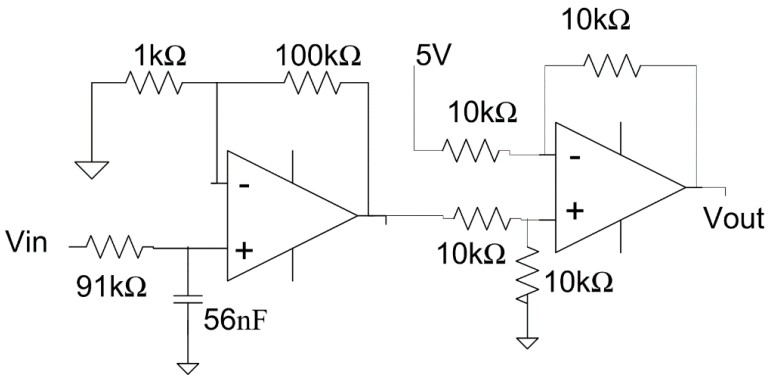

Fig.4A: Design B

4B. A 4-bit binary weighted D/A converter shown in the Fig4B has R=10kΩ; R_f=5kΩ and V_{ref}=-10V, and an input binary word of 1101. Analyze the working of the schematic shown and determine the following:

a. Resolution

b. Current through the MSB switch

c. Output voltage

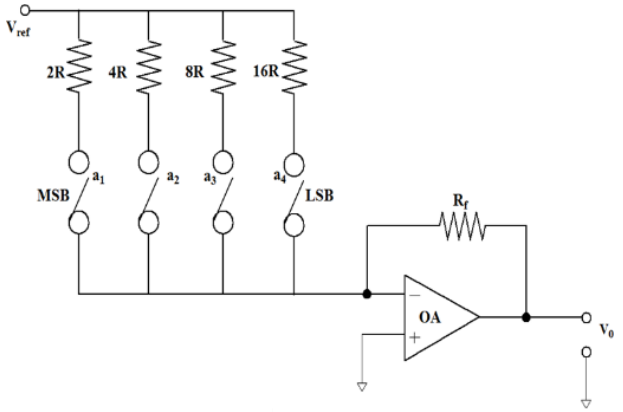

Fig 4B **(03)**

4C. An RTD with its signal conditioning circuit to give corresponding output voltage (Vout) is shown in the Fig 4C. The design is such that Vout is zero for a temperature of 25^{0}C and RTD gives a resistance (Rt) of 1kΩ at rated temperature of 25^{0}C. Find the temperature when the output (Vout) is changed to 3V.

Assume Vdc=5V, Temperature coefficient of RTD is 0.00393Ω/^{0}C, Ra=Rb=Rc=R2=R=1kΩ and R3=10kΩ **(04)**

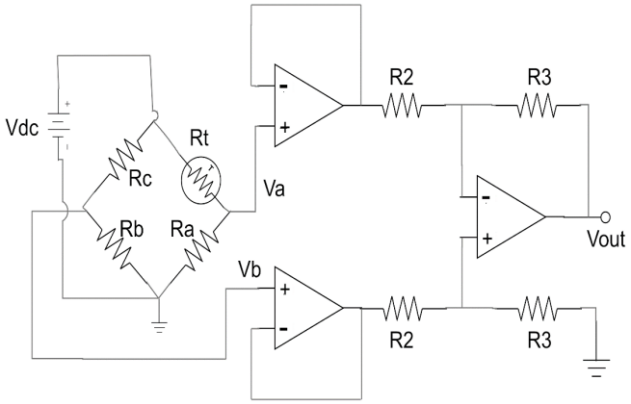

Fig. 4C

5A. A force measurement system contains force transducer and embedded signal conditioning circuit such that the variation in force is converted to voltage of range 0V to 10V. The analog input from the force measurement system is connected to a microcontroller using successive approximation register (SAR) based 4-bit ADC. Draw the connection diagram for the interface and analyse the working of the SAR based ADC with a reference voltage of 10V for an input of 7.7V from the force measurement system and determine the equivalent digital output. Support the ADC conversion using SAR with relevant explanations and calculations. ***(03)***

5B. Describe exhaust after treatment system in vehicles and comment on the importance of such a system. List and explain the specific usage and importance of any two sensors used in a Denoxtronics system. List any two existing Emission Standards/Norms in India to be followed considering impact on environment from vehicle emissions. ***(03)***

5C. Design a charge mode amplifier circuit with suitable signal conditioning for a pressure based piezo-electric transducer. Design should be such that the output voltage from the setup needs to be acquired by a microcontroller with ADC in the range of 0 to 5V corresponding to an input pressure range of 0 to 10 N/m^2. The output voltage needs to be realized for a frequency band of 59Hz to 318Hz. The pressure-to-charge sensitivity of the selected piezo material is 13.5 pC/Nm^{-2}. The values of piezo shunt resistance and capacitance are 10GΩ and 4nF respectively. The connecting cable capacitance is found to be 1nF. Assume the charge amplifier feedback resistance to be 10kΩ. Draw the complete system circuit and compute the equivalent output for an input pressure of 6 N/m^2 ***(04)***