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

V SEMESTER B. TECH (ELECTRICAL & ELECTRONICS ENGINEERING)
END SEMESTER ON-LINE PROCTORED EXAMINATIONS
DECEMBER 2021

MEASUREMENTS AND INSTRUMENTATION [ELE 3153]

REVISED CREDIT SYSTEM

Time: 75 Minutes + 10 Minutes **Date: 28 December 2021** **Max. Marks: 20**

Instructions to Candidates:

- Answer **ALL** the questions.
- Missing data may be suitably assumed.
- Time: 75 minutes for writing + 10 minutes for uploading.

1A. 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 needs to be eliminated."

The schematics of the three submitted design solutions are as shown in **Fig Q1A (Design A, Design B and Design C)**. Evaluate and select the optimum design with appropriate justification.

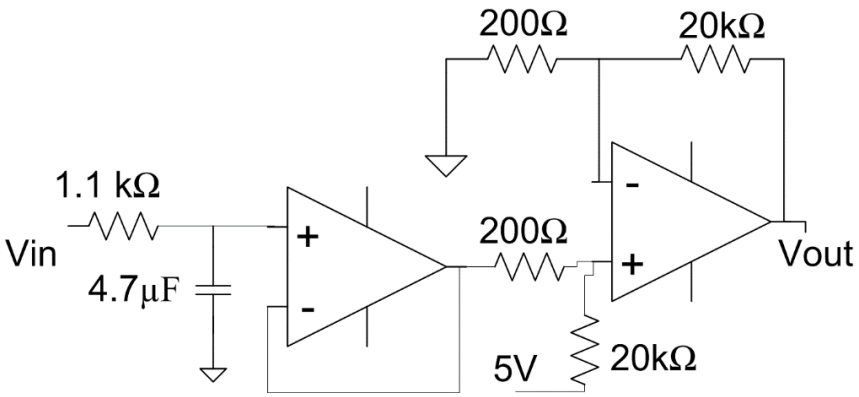

Fig Q1A Design A ***(05)***

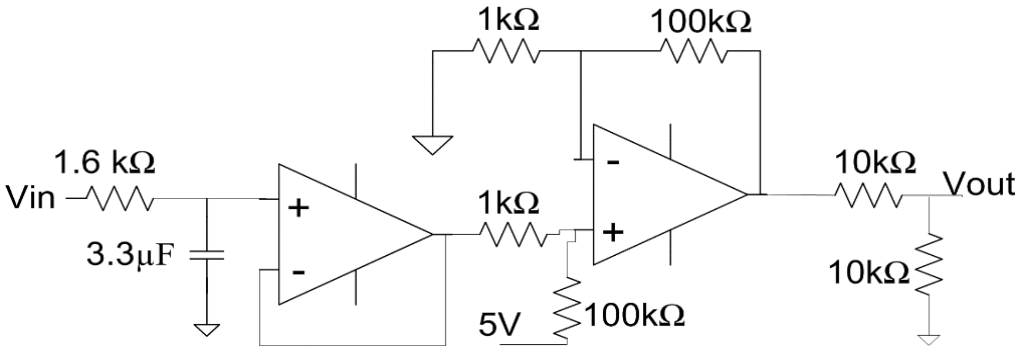

Fig Q1A Design B

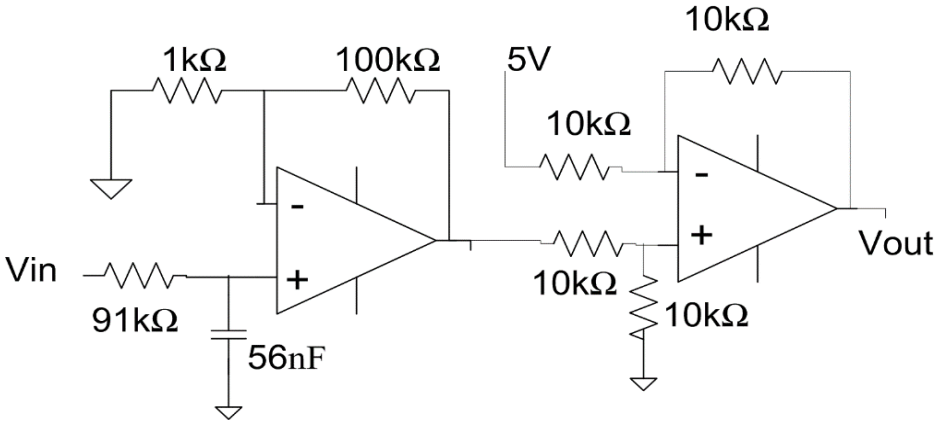

Fig Q1A Design C

1B. An AC Bridge as shown in the **Fig Q1B**, is used to measure an unknown inductance L_x, which has inherent resistance R_x. The bridge parameters are $R_1 = 20k\Omega$; $R_2 = 50k\Omega$; $C_2 = 0.0037\mu F$. The operating frequency $\omega = 10^5 rad/sec$. C_1 is adjustable from 10pF to 150pF and R_4 is adjustable from 0 to 10kΩ. Derive expressions for R_x and L_x to show that resistive and reactive balance are independent of each other. Further through appropriate analysis, determine the largest values of R_x and L_x that can be measured with given parameters.

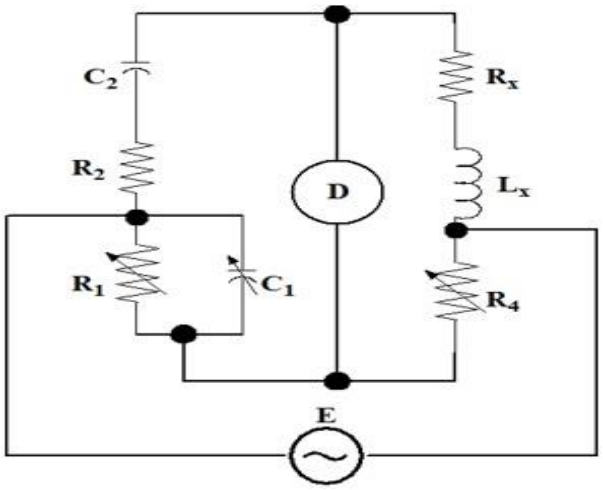

Fig Q1B ***(03)***

1C. A thermocouple shown in **Fig Q1C**. has a transfer function linking its voltage output V and temperature input of T as:

$$G(s) = \frac{30 * 10^{-6}}{10s + 1} volts/℃$$

Determine and plot to scale the response of the system when it is suddenly immersed in a water bath at 100^0C. From the response, comment on its dynamic characteristics.

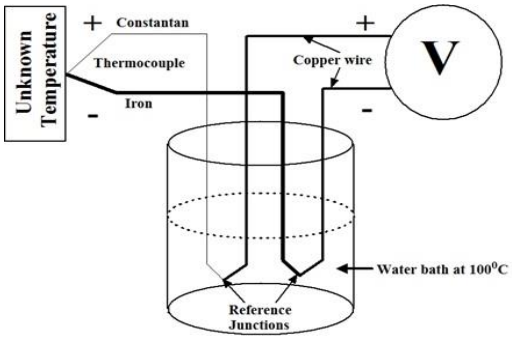

Fig Q1C ***(02)***

2A. Design a charge mode amplifier circuit with suitable signal conditioning for a pressure based piezo-electric transducer such that the output voltage from the setup needs to be acquired by a microcontroller via an 4bit-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. The output of the signal conditioning circuit is connected to a successive approximation register (SAR) based 4bit-ADC. Draw the complete system circuit which generates the appropriate digital output. Further, compute the digital equivalent output from the ADC for an input pressure of 6 N/m^2. ***(05)***

2B. In an electrodynamometer instrument the total resistance of voltage coil circuit is 8.2kΩ and mutual inductance changes from -173μH at zero deflection to +175μH at full scale deflection of 95°C. If 100V potential difference is applied across voltage circuit, current of 3A at a power factor of 0.75 is passed through current coil. What will be the deflection if the spring constant is 4.63X10^{-6} N-m/rad. ***(03)***

2C. A linear resistance potentiometer is used to measure linear displacement. It is $50\,mm$ long and is uniformly wound with a wire having a resistance of $10{,}000\,\Omega$. Under normal conditions, the slider is at the center of the potentiometer.

a) Calculate the linear displacement when the resistance of the potentiometer as measured by a Wheatstone bridge is $3{,}850\,\Omega$.
b) Calculate the linear displacement when the resistance of the potentiometer is $7{,}560\,\Omega$.
c) Comment on the direction of the displacements.
d) If it is possible to measure a minimum value of resistance of $10\,\Omega$ with the above arrangement, find the resolution of the potentiometer in mm. ***(02)***