UNIVERSITY OF SWAZILAND
SUPPLEMENTARY EXAMINATION, JULY 2017

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER:	**INSTRUMENTATION SYSTEMS**
COURSE NUMBER:	**EE521**
TIME ALLOWED:	**THREE HOURS**

INSTRUCTIONS:

1. There are four questions in this paper. **Answer all four questions.**
2. Each question carries 25 marks.
3. Marks for different sections are shown on the right hand margin.
4. Show the steps clearly in all your calculations including any assumptions made.

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THIS PAPER HAS FIVE (5) PAGES INCLUDING THIS PAGE

QUESTION 1 *(25 marks)*

(a) A temperature measurement system consists of an RTD (Resistance Temperature Detector) sensor excited by a constant current source. Explain how the following can cause errors in the temperature measurement:

(i) Self-heating of the sensor *(2 marks)*

(ii) Lead wire resistance. *(2 marks)*

(b) An RTD with a nominal resistance of 250 Ω is excited with a 10 mA current source. The RTD is packaged in a material which has a thermal resistance of $40°C/W$.

(i) Determine the temperature measurement error due to self-heating? *(5 marks)*

(ii) The two wire lead to the RTD sensor is 30 m long with a wire resistance of $1.028\times10^{-3}\ \Omega/m$. The sensor has a temperature coefficient of resistance (thermal response) of $0.00385\ \Omega/\Omega/°C$. Determine temperature measurement error caused by the resistance of the two lead wires.

(6 marks)

(c) Explain, giving illustrative examples where applicable, how the RTD measurement system described in (b) may be improved so as to reduce:

(i) the measurement error due to self-heating. *(4 marks)*

(ii) the measurement error due to the lead wires. *(6 marks)*

QUESTION 2 *(25 marks)*

(a) List any five distinct electronic functions (or operations) which are normally carried out during sensor 'conditioning'. *(5 marks)*

(b) Why are 'bridge' circuits used in sensor circuits? *(2 marks)*

(c) Define the terms 'strain' and 'gauge factor' as used in strain gauge sensors. . *(5 marks)*

(d) A measurement system consists of a strain gauge connected to one arm of a quarter bridge circuit. The bridge output is connected to the input of an instrumentation amplifier.

(i) Draw the circuit diagram (not a block diagram) of the measurement system showing the bridge, sensor and a three-opamp version of the instrumentation amplifier . *(4 marks)*

(ii) The strain gauge has a gauge factor of 2, nominal resistance of 120 Ω and, in the measurement, the strain gauge experiences a strain ranging from -10^{-4} to $+10^{+4}$. It is desired that the resulting output voltage from the instrumentation amplifier be in the range -5 V to $+5$ V.

Determine the gain required in the instrumentation amplifier, assuming that the bridge excitation voltage is +15 V. **Do not design the instrumentation amplifier itself.**

(9 marks)

QUESTION 3 *(25 marks)*

(a) What are the differences between each of the following sets of terms:

(i) 'Sensitivity' and 'Cross sensitivity' as used in description of sensors. *(2 marks)*

(ii) 'Accuracy' and 'Precision' as used in measurement. *(2 marks)*

(iii) 'The piezo-resistive effect' and' the piezo-electric effect' as used in sensors. *(2 marks)*

(iv) 'Static' and 'Dynamic' properties as used in description of instruments. *(2 marks)*

(v) 'Contact' and 'Non-contact' measurement methods. *(2 marks)*

(b) In this question you are expected to design a **four-pole Butterworth lowpass filter** with a lower cut-off frequency f_C of 5 kHz. You are given that for the equal-component value, Sallen-Key, 4-pole, lowpass filter shown in Fig. Q3a, the components may be found using the following normalized data:

Poles	$k_3 = RC\omega_C$	G
4	1.000	1.152
	1.000	2.235

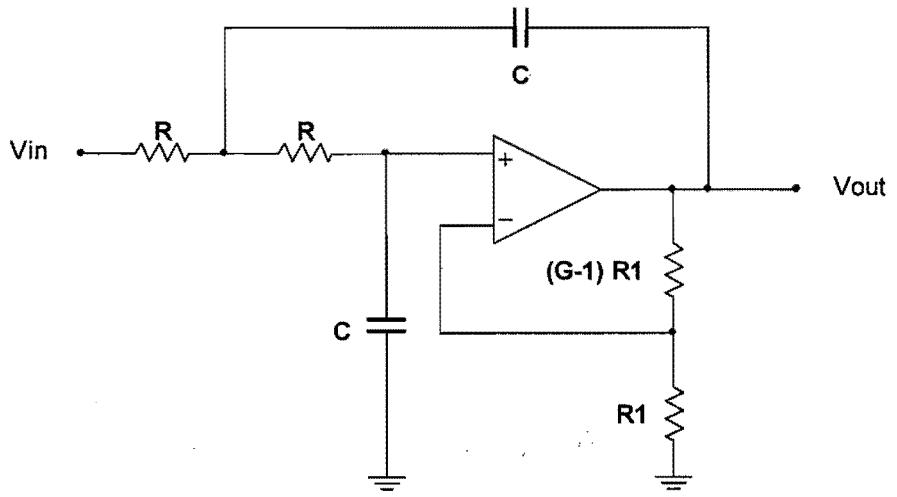

Fig. Q3a

(i) Determine the values of all the components in your circuit. *(12 marks)*

(ii) Draw a circuit schematic diagram showing all components values of your diagram.

(3 marks)

QUESTION 4 ***(25 marks)***

(a) **(i)** What is an **'isothermal block'**? *(2 marks)*

(ii) Explain why and how an isothermal block is used in electronic measurements using thermocouples. *(5 marks)*

(b) A sensor used in a measurement system produces a signal with a minimum value of 1.8 V and a maximum value of 2.6 V. A circuit is required which changes this sensor signal to the range 0 V to 5 V for feeding into an ADC input of a microcontroller with maximum possible resolution, so that the sensor signal fills the entire input range of the ADC.

(i) By means of a diagram, suggest a circuit which can used to realize the required change in signal levels. *(4 marks)*

(ii) Design the circuit, calculating the values of all the required components. *(14 marks)*

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