UNIVERSITY OF ESWATINI

MAIN EXAMINATION, DECEMBER 2018

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. **Answer All Questions.**
2. Each question carries 20 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 FOUR (4) PAGES INCLUDING THIS PAGE

QUESTION 1 *(20 marks)*

(a) Distinguish between the following terms as used in measurements:

(i) Dynamics and static characteristics. *(2 marks)*

(ii) Accuracy and precision. *(2 marks)*

(iii) Sensitivity and resolution. *(2 marks)*

(iv) Span and range. *(2 marks)*

(v) Zero drift and sensitivity. *(2 marks)*

(b) A distance meter to be used to measure length in the range 0 to 12 m was tested and gave the following output voltages:

Length, m	0.0	2.0	4.0	6.0	8.0	10.0	12.0
Output, mV	6.24	7.30	8.48	9.72	10.72	12.04	13.03

(i) Calculate the sensitivity and zero offset of the distance meter. A calculator in linear regression mode may be used and units must be stated. *(3 marks)*

(ii) The output of this distance meter is to be fed into an analogue-to-digital converter (ADC) chip which has an input analogue signal range of 0 V to 5V. Design a suitable circuit to interface the distance meter to the ADC. *(5 marks)*

QUESTION 2 *(20 marks)*

a. A circuit of a simple differential amplifier is shown in Fig. 1.

(i) Explain why differential amplifiers are widely used in instrumentation. *(2 marks)*

(ii) Show that the output voltage v_o and the input voltages v_1, and v_2 are related by:

$$v_0 = \left(1+\frac{R_2}{R_1}\right)\left(\frac{\frac{R_4}{R_3}}{1+\frac{R_4}{R_3}}\right)v_2 - \frac{R_2}{R_1}v_1$$ *(3 marks)*

(iii) We usually assume that $\frac{R_2}{R_1} = \frac{R_4}{R_3}$. Why is this assumption used? *(2 marks)*

(iv) If due to poor matching of resistors $\frac{R_2}{R_1} = 10$ and $\frac{R_4}{R_3} = 11$, calculate the CMRR of the opamp. (**Hint: Let** $v_1 = v_{cm} + \frac{v_{dm}}{2}$ **and** $v_2 = v_{cm} - \frac{v_{dm}}{2}$) *(3 marks)*

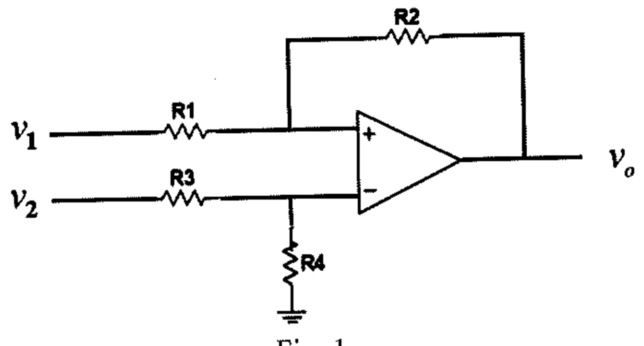

Fig. 1.

b. Consider the equal-component Sallen-Key **low pass** filter shown in Fig. 2.

(i) Name two uses of filters in instrumentation circuits. *(2 marks)*

(ii) Draw a **highpass** version of this filter. *(3 marks)*

(iii) Using your version in part (b) as the basis, design a **fourth order highpass** Butter worth filter with cut off frequency of 1.2 kHz. You are given that for a 4^{th} order Butterworth lowpass or highpass filter K= 1.152 and 2.235. Capacitors available for use have values of 100nF, 22 nF or 10nF. Resistors used should have the +1% tolerance values given in the table 1. *(5 marks)*

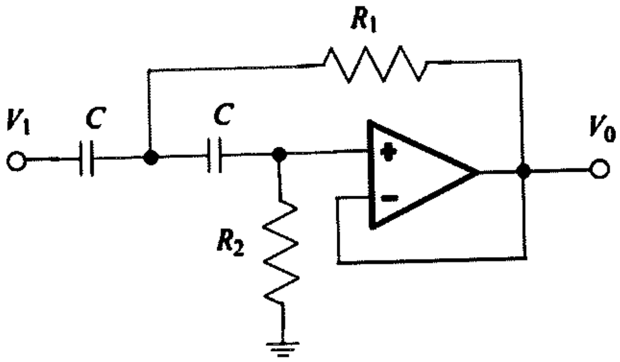

Fig. 2

QUESTION 3 ***(20 marks)***

a. Consider the half bridge circuit shown in Fig. 3

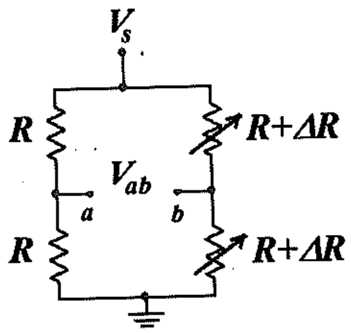

Fig. 3

(i) Derive an expression for the output voltage V_{ab} of the half bridge circuit. *(3-marks)*

(ii) Describe using an appropriate sketch how this circuit may be used to remove the temperature error in load measurements based on bending of beams. *(3-marks)*

b. Calculate the temperature (in Celsius) measured by a thermistor when the resistance is 2,500 Ω. Assume that the thermistor has the following coefficients for the Steinhart-Hart equation: A = 1.1252 x 10-3/K, B = 2.3478 x 10-4/K, and C = 3.5262 x 10-8/K. given that Steinhart- Hart equation:

$$\frac{1}{T} = A + B \ln R + C(\ln R)^3 \quad \text{where } T = \text{Absolute temperature } (K)$$

R = resistance of the thermistor *and A, B* and *C* are constants and 0K = -273.15 °C. *(6-marks)*

c. A CdS cell (LDR) has a dark resistance of 120 kΩ and its resistance in a light beam of 18 mW/cm^2 is 40 kΩ. The cell has a first-order response time constant of 60 ms. If we want to trigger a comparator with a threshold voltage of 1.5 V within 20 ms of the interruption of 18 mW/cm^2 beam shone on the cell. Design a circuit to trigger the comparator. *(8-marks)*

QUESTION 4 *(20 marks)*

a. Explain the following terms as used in communication between measurement devices:
   (i) Half duplex and full duplex communication, *(3-marks)*
   (ii) Asynchronous and Synchronous transmission, and *(3-marks)*
   (iii) Balanced and unbalanced interfaces. *(3-marks)*

b. Design a circuit to transmit -2V to 5V analogue signal over a 5mA to 20mA current transmission loop. Assume that load is grounded and that amplifiers saturate at ±12V. What are limits of the load resistance at the receiver? *(11-marks)*

QUESTION 5 *(20 marks)*

Design a transmitter and a receiver for a system which converts a sound signal from a microphone into light transmission through an optical fibre link and then converts the optical signal back into sound via a loud speaker. Assume the following items can be used in your design:

- A microphone which produces a maximum differential signal of 100 mV p-p at maximum sound intensity.
- The microphone wires have 50 Hz pick up 10 10 mV which is common-mode.
- A light emitting diode at one end of the fibre that should driven 100 mA p-p when the microphone signal is maximum.
- A photo diode at the other end of the fibre that produces 1 mA p-p when the LED is producing maximum signal of 100 ma p-p.
- A loud speaker of 10 Ω impedance which should be driven at 10 V p-p at maximum signal.
- There are non-linearities in the system so that sound is not distorted.
- Diodes only conduct current in one direction only therefore appropriate offsets must be applied to the signal whenever required.

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VALUES OF STANDARD 1% TOLERANCE RESISTORS

100	140	196	274	383	536	750
102	143	200	280	392	549	768
105	147	205	287	402	562	787
107	150	210	294	412	576	806
110	154	215	301	422	590	825
113	158	221	309	432	604	845
115	162	226	316	442	619	866
118	165	232	324	453	634	887
121	169	237	332	464	649	909
124	174	243	340	475	665	931
127	178	249	348	487	681	953
130	182	255	357	499	698	976
133	187	261	365	511	715	
137	191	267	374	523	732	