UNIVERSITY OF JOHANNESBURG

PROGRAM	: *BACHELOR OF ENGINEERING TECHNOLOGY*: ELECTRICAL
SUBJECT	: **Sensors and Devices – Main Exam**
CODE	: **SENELA2**
DATE	: May/June 2019
DURATION	: 180 minutes (3 hours)
FULL MARKS	: 100

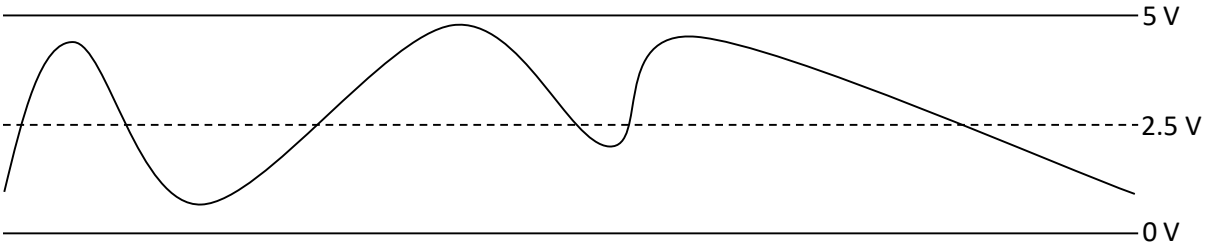
ASSESSOR	: Mr. J Venter
MODERATOR	: Dr JW Lambrechts
NUMBER OF PAGES	:
INSTRUCTIONS	: ONLY ONE POCKET CALCULATOR PER CANDIDATE MAY BE USED. FILL IN ANSWERS ON THE PAPER

QUESTION 1 [15]

1.1 In any communication channel, there is a sender, a channel (or medium) and a receiver. Relate this to a project presentation phase of a project. Specifically state who is what in this relation. (3)

1.2 How many voltage levels does an analogue signal and a digital signal have respectively? (4)

1.3 For the given analogue signal, draw the digital signal from an inverting operational amplifier where the reference input is at 2.5 V (4).

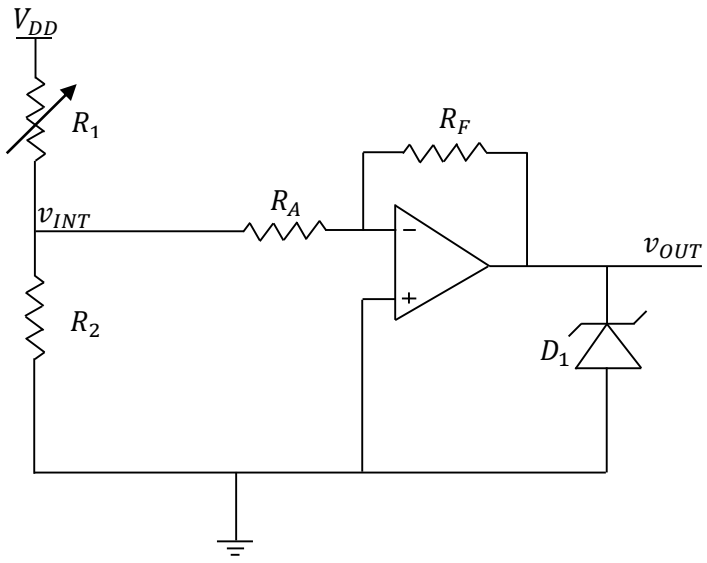


1.4 When characterising a sensor or device, why would one almost never have datapoints that follow an exact line or equation? (2)

1.5 The voltage-current relationship of a Ge infrared detector (light sensitive diode) is given by the following transfer function: $y = mx + C$. Explain the significance of C. (2)

QUESTION 2 [26] – Temperature sensing

2.1 Consider the circuit below. R_2 = 20 kΩ, R_F = 1.5 kΩ, R_A = 1 kΩ, V_{DD} = 12 V. R_1 is a NTC sensor with a temperature coefficient of 500 Ω/°C. The supply voltage to the operational amplifier is 15 V (not shown in the figure). The circuit specification requires operation between 20 °C and 100 °C. At 100 °C, the NTC sensor resistance is 10 kΩ.



2.1.1 What will the maximum and minimum output voltage be when D_1 is removed? (10)

2.1.2 What will the minimum and maximum output voltage be when D_1 is included with $V_{Z_{D1}}$ = 9 V? (2)

2.1.3 Calculate and specify the temperature range of the circuit if D_1 is included. (7)

2.2 Calculate the change in temperature when 0.001 MJ of energy is injected into 100 gram of mercury? The specific heat capacity of mercury 138 J/kg/˚C. (3)

2.3 What is the resistance of a nickel-based RTD detector at 0 ˚C with the following specifications? (α=0.00672 Ω/Ω/˚C, ΔT= 50 ˚C, R_T = 100 Ω). (4)

QUESTION 3 [22] – Light sensing

3.1 What is the advantage of using a phototransistor over a photodiode for light sensing? (3)

3.2 Describe the 4 elements/devices/components that make up an infrared non-contact temperature sensor. (8)

3.3 Describe the working principle of a photoresistor/Light Dependent Resistor. Also refer to the bandgap properties that make conduction in these devices possible. (5)

3.4 List 6 of the 8 characteristics of a light sensor operating in photoconduction mode. (6)

QUESTION 4 [5] – Sound sensing

4.1 What is the primary function of a piezoelectric crystal? (2)

4.2 What is the Doppler effect? Make specific reference to any variations that may occur in the frequency (3)

QUESTION 5 [15] – Magnetic sensing

5.1 Sketch a graph that relates the number of turns of a solenoid with the number of turns for a toroid where the radius of the toroid is 5 cm and the same current must flow through both. The number of turns in the toroid must not exceed 100 and at least 5 points must be shown on the graph. The coordinates of the 5 points must be provided. (15)

Consider the following parameters: Mutual inductance 2 mH, coupling factor 75% and $\mu_0 = 4\pi \times 10^{-7}$ H/m

The following equations may be of use.

$B = \frac{\mu_o}{2\pi}\frac{i_o N}{r}\ toroid$ $B = \mu_o i_o N\ solenoid$ $M = k\sqrt{L_S L_T}$ $L = \frac{N \times B}{i_o}$

QUESTION 6 [17] – Devices

6.1 Draw the equivalent circuit model of a Zener diode (including orientation). (2)

6.2 List 4 of the 7 electrical characteristics of a Zener diode. (4)

6.3 Draw the symbols of a TRIAC and an IGBT. (4)

6.4 Why is the reverse recovery time of a Schottky diode less than a conventional diode? (2)

6.5 What are the primary grain elements in a Metal Oxide Varistor composed of? (2)

6.6 With regards to output characteristics, what does an IGBT present that cannot be obtained by one single device? (3)