

**(Code for Paper) S021/**

**DUBLIN INSTITUTE OF TECHNOLOGY  
KEVIN STREET, DUBLIN 8**

---

**Bachelor of Engineering Technology in Control  
and Automation Systems**

**Bachelor of Engineering Technology in Electrical  
Energy Systems**

**Year 2**

---

**SEMESTER 1 2007-2008**

---

**INSTRUMENTATION**

Mr. Gerard Caffrey.  
Mr. Gavin Duffy.  
Dr. Michael Conlon.  
Dr. Eugene Coyle.

**DAY / MONTH 2007      TIME**

Question 1 is compulsory (40 marks)  
Attempt any two other questions (30 marks per question)

**The following should be available for this examination:**

- Q1.** (a) The angle of a pick and place robot arm is measured using a 2 turn potentiometer. The full scale resistance of the potentiometer is  $10\text{ k}\Omega$ .
- (i) Design a simple transducer which outputs 0 to 5V as the angle of the robot arm rotates from 0 to 720 degrees. **(2 Marks)**
- (ii) What is the sensitivity of the transducer you have designed? **(2 Marks)**
- (iii) If the output voltage reading of the transducer is 3.5V, what is the input angle to the transducer? **(2 Marks)**
- (iv) If an 8-bit A/D converter is used to digitise the output of the transducer, what is the resolution of the transducer in degrees? **(2 Marks)**
- (v) If the A/D converter reads 0000 0000 for an input angle of zero degrees. What is the input angle for an A/D converter reading of 1010 1101? **(2 Marks)**
- (b) (i) A temperature sensor which has a sensitivity of  $20\text{ mV}/^{\circ}\text{C}$  is connected to an amplifier which has a gain of 10. If the sensor temperature is  $50^{\circ}\text{C}$ , determine the amplifier output. **(2 Marks)**
- (ii) Tests on the temperature sensor and amplifier now show that the temperature sensor has an output resistance of  $5\text{ k}\Omega$  while the amplifier has an input resistance  $10\text{ k}\Omega$ . Use the test information to determine the actual amplifier output when the sensor temperature is  $50^{\circ}\text{C}$ . **(3 Marks)**
- (iii) Determine the Norton equivalent model for the general purpose silicon photo-voltaic cell which is stated to have the following specifications:
  - Short Circuit Current for 100 lux is  $180\ \mu\text{A}$ .
  - Open Circuit Voltage for 100 lux is  $330\text{mV}$ .**(2 Marks)**
- (iv) Given that  $1\text{ watt} = 680\text{ lum}$  determine the output of the photo-voltaic cell when the intensity of the sun light on the photo-voltaic cell is  $135\text{ mW}/\text{m}^2$ . **(3 Marks)**

- (c) In terms of instrumentation, explain what is meant by each of the following terms:

Span,  
Offset,  
Resolution,  
Accuracy,

Drift

**(10 Marks)**

- (d) Compare the thermistor, thermocouple and RTD as methods of measuring temperature.

Illustrate your answer by defining the output from each, stating approximate temperature ranges that can be measured and sketching the relationship between temperature and output for each transducer. Also, list some advantages and disadvantages of each one.

**(10 Marks)**

- Q2.** A platinum resistance thermometer is used to monitor the temperature of a liquid which is maintained at a constant temperature of  $310^{\circ}\text{C}$ . The thermometer is specified as having a time constant of 8.2s and its resistance as a function of temperature is given in Table Q2 below.

Temperature $^{\circ}\text{C}$	280	290	300	310	320
Resistance $\Omega$	206	209	212	215	218

Table Q2

- (a) Calculate the time taken for the resistance of the thermometer to change by  $1\Omega$  after an abrupt change of temperature from  $310^{\circ}\text{C}$  to  $300^{\circ}\text{C}$ . **(5 Marks)**
- (b) The thermometer is measuring the temperature of a liquid which is at a temperature of  $310^{\circ}\text{C}$  just before a sudden step change of liquid temperature to  $320^{\circ}\text{C}$ . Determine the resistance of the thermometer 24.6 seconds after the step change in temperature occurs. **(10 Marks)**
- (c) (i) Explain the principle of operation of a cup anemometer connected to a direct current generator to measure wind speed. Describe how the output changes with a change in input and list some of the good and bad features of the device. **(8 Marks)**
- (ii) Explain with the aid of a sketch how a Pitot Tube can be used to determine the equivalent air speed of an airplane. **(7 Marks)**

**(7 Marks)**

**Q3.**

A temperature transducer consists of a sensor, a Wheatstone bridge which has a supply voltage of 5 volts dc and an amplifier. The temperature transducer is to be designed to measure temperature from  $-10^{\circ}\text{C}$  to  $+30^{\circ}\text{C}$ . Tests on the sensor show that its resistance  $R_4$  is related to its temperature  $T$  in degrees Celsius by:

$$R_4 = 10,000(1 + 0.0043T)$$

- (a) Sketch a schematic diagram of your design for the temperature transducer.  
**(5 Marks)**
- (b) Calculate and select suitable values of resistors for the Wheatstone bridge.  
**(5 Marks)**
- (c) Determine the values of the amplifier resistors such the output of the temperature transducer is 0V at  $-10^{\circ}\text{C}$  and + 5V at  $+30^{\circ}\text{C}$ .  
**(10 Marks)**
- (d) If the temperature transducer output is 2.5V, what is the actual temperature of the sensor?  
**(10 Marks)**

**Q.4**

An industrial water storage tank is fitted with a pressure sensor on the side of the tank at its base. The tank has a diameter of 5 m and height of 4 m. The pressure sensor contains a diaphragm with 4 piezoresistors connected in a Wheatstone bridge arrangement with a sensitivity of 10 mV/psi. An instrumentation amplifier is used to amplify this signal to give a 0 to 5 V output range corresponding to an input level range of 0 to 5 m. This voltage signal is connected to the input pin of a microprocessor operating an 8 bit analogue to digital (A/D) conversion.

(a) Describe a piezoresistor. **[4 marks]**

(b) What are the gauge and absolute pressures at the base of the tank when it is full of water?

Note: The density of water is 1000 kg/m<sup>3</sup>.  
Atmospheric pressure = 101,325 Pa

**[6 marks]**

(c) Draw a block diagram of the system showing a block for each component, units and ranges of the input to and output from each block, and the sensitivity of each block.

**[10 marks]**

Note: 1 psi = 6895 Pa = 0.70 m H<sub>2</sub>O.

(d) The overall system was tested and the following data were obtained:

Level (m)	A/D Result
0.0	5
0.5	24
1.0	55
1.5	79
2.0	100
2.5	126
3.0	145
3.5	180
4.0	205
4.5	228

Plot these results and determine the following:

Sensitivity,  
Offset,  
Maximum non linearity.

**[10 marks]**