EGERTON UNIVERSITY

UNIVERSITY EXAMINATIONS

NJORO CAMPUS

SECOND SEMESTER 2012/2013

THIRD YEAR EXAMINATIONS FOR THE DEGREE OF BACHELOR OF SCIENCE IN INSTRUMENTATION AND CONTROL ENGINEERING

ICEN 323: PRINCIPLES OF MEASUREMENT SYSTEMS I

STREAM: Y5S2 B.Sc. ICEN **TIME:** 2 HOURS

DAY: FRIDAY, 12.00 – 2.00 P.M. **DATE:** 17/05/2013

INSTRUCTIONS:

1. Attempt any **FOUR** questions.
2. You need the following for this examination
   (i) Answer book
   (ii) Calculator
   (iii) Ordinary linear graph paper
   (iv) Drawing set

Q1.

(a) Explain the four basic elements of a measurement system. (6 marks)

(b) (i) Sketch a labeled diagram of a weight measurement system.

(ii) Explain how the signal propagates through the system. (10 marks)

(c) Define the following terms:

(i) Static Characteristics

(ii) Dynamic characteristics (4 marks)

Q2.

(a) Explain with the aid of sketches the following terms:

(i) Non-linearity

(ii) Sensitivity

(iii) Resolution

(iv) Hysteresis (8 marks)

(b) The e.m.f. $E(T)\ \mu V$ and junction temperature T^oC of a Copper/Constantan thermocouple junction is approximately given by:

$E(T) = 38.74T + 0.0332T^2 + 0.000207T^3$ for the range $0\ ^oC$ to $400\ ^oC$.

If $E = 0\mu V$ at $T = 0^oC$ and $E = 20870\mu V$ at $T = 400^oC$:

Sketch the ideal straight line graph and determine;

(i) The slope and the equation for E_{IDEAL} that describes the ideal straight line.

(ii) The equation for the sensitivity, $\frac{dE}{dT}$

(iii) The non-linearity equation $N(T) = E(T) - E_{IDEAL}$

(6 marks)

(c) A platinum resistance thermometer has a resistance of 100.00Ω at 0 °C, 138.50Ω at 100 °C and 175.83 Ω at 200 °C.

(i) Design a Wheatstone bridge that will give an output of 0 to 100 mV between 0 and 200 °C.

(ii) Determine the bridge output voltage and non-linearity at 100 °C. (6 marks)

Q3.

(a) Define the term **error** and differentiate between **random** and **systematic** errors. ((3 marks)

(b) A measurement system is arranged to measure the volume of water passing through a pipe at an interval of 100 seconds. The readings are: 54, 48, 52, 50, 49, 49 53, 48, 50, 51 and 53 cm^3. Determine:

(i) The mean volume

(ii) The standard deviation

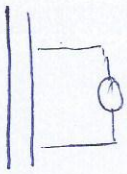
(iii) The volume estimate at 68% and 95% confidence level (10 marks)

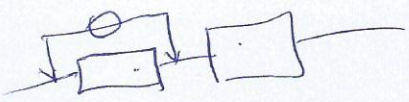
(c) A voltmeter having an input resistance of 100kΩ is connected across a load of 10 kΩ. If the load is in series with another circuit having a resistance of 10 kΩ, determine the percentage fractional error. (4 marks)

(d) A displacement measurement system has a sensor with a linearity error of ± 0.25% and a repeatability error of ± 0.25% of the reading. The system is to be used with a voltmeter display which has an accuracy of ± 0.15% of the reading. Calculate:

(i) The worst possible error

(ii) The overall error (3 marks)





Q4.

(a) Explain with the aid of sketches the principle of operation of:

(i) A Linear Variable Differential Transformer (LVDT).

(ii) A Resistance Temperature Detector (RTD). (10 marks)

(b) A capacitive sensor consists of two plates in air. The plates are 50 mm square and are separated by a distance of 1.2 mm. A sheet of a dielectric material of 50 mm square and 1 mm thick can slide between the plates. If the dielectric is displaced so that 50% of it is between the capacitor plates, determine the capacitance of the sensor. (The relative permmitivities of the dielectric material and air are 5 and 1 respectively). (3 marks)

(c) A variable reluctance sensor has a U-shaped ferromagnetic core and an armature both having a cross-sectional area of 400 mm^2 and a relative permeability of 50. Between the two cores there is a variable air gap of relative permeability of 1.

Before any displacement of the armature, the mean length of the flux path in the ferromagnetic material is 360 mm.

The magnetomotive force is provided by a current of 1.5A flowing through a coil of 1000 turns wound round the core.

Draw a labeled sketch of the arrangement and determine the flux when the two air gaps are **each** 5mm. (7 marks)

Q5.

(a) A platinum resistance temperature sensor with a resistance of 120 Ω at 0^oC is connected to one arm of a Wheatstone bridge. At 0^oC, the bridge is balanced with each of the other arms being 120 Ω. If the supply voltage to the bridge is 5 volts and the temperature coefficient of the platinum sensor is 0.0039 K^{-1}, determine the output voltage from the bridge for a temperature change of 25^oC. (3 marks)

(b) (i) State at least 6 characteristics of an ideal OPAMP.

(ii) Draw a sketch and derive the expressions for the gains of:

(I) A three-input summation OPAMP

(II) An integrating OPAMP (9 marks)

(c) (i) State the Nyquist sampling theorem

(ii) Explain the term aliasing

(iii) Explain with the aid of a block diagram the operation of a successive approximation ADC (8 marks)

Q6.

(a) Draw a line diagram that shows the classification of data presentation elements. (2 marks)

(b) (i) An L.E.D. requires a forward voltage and current of 1.6 volts and 20mA respectively to display a logic 1. If the supply voltage is to be 6.0 volts, determine the resistance required.

(ii) Show how letters A, C, E, F , H and J can be displayed using the 7-segment

a b c d e f g code.

(iii) State the following:

(I) The advantage of a 7*5 dot matrix over the seven segment character format.

(II) The advantages of large scale displays over the small-scale Alpha-numeric displays.

(III) The difference between a monitor and a V. D. U. (12 marks)

(c) A closed loop chart recorder incorporates an a.c. position servomechanism which is described by the equation shown below:

$$\frac{\Delta y}{\Delta E_{TH}} = \frac{K_D K_A K_i}{LIs^3 + [RI + L(K_v + b)]s^2 + R(K_V + b)s + K_T K_A K_i}$$

Use the data given to determine;

(i) The recorder transfer function

(ii) The steady state sensitivity (6 marks)

Chart recorder data:

Amplifier gain $K_A = 10^2$

Control winding resistance $R = 10\Omega$

Control winding inductance $L = 100mH$

Moment of inertia of rotor and pulley $I = 10^{-4} kgm^2$

Mechanical damping constant $b = 5 \times 10^{-4} Nmsrad^{-1}$

Slope of torque-speed curve $K_v = 5 \times 10^{-4} Nmsrad^{-1}$

Slope of torque-current curve $K_i = 8 \times 10^{-4} NmA^{-1}$

Sensitivity of displacement sensor $K_T = 0.5Vrad^{-1}$

Sensitivity of pulley system $K_D = 10mrad^{-1}$

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