Instrumentation-I (Tutorial-1)

Chapter -1 Instrumentation System

1. Explain the function of different stages of the measuring system with the help of the block diagram.
2. What is an electrical transducer? How can it be classified, explain with suitable example.
3. Discuss the analog and digital system of measurement.

Chapter-2 Theory of Measurement

1. Explain the following terms.
   a. Accuracy
   b. Precision
   c. Resolution
   d. Sensitivity
   e. Linearity
2. Discuss the different between the terms accuracy and precision in measuring process.
3. Explain briefly the dynamic performance parameter of an instrument.
4. What are the general classes of measurement errors? Explain how can they be eliminated?
5. Discuss the different statistical tools used in the analysis of the measuring system.
6. Using statistical evaluation of random errors or data of measurement, explain how probable error in a measurement can be obtained.
7. A Voltmeter whose accuracy is 2% of the full scale reading is used on its 0-50V scale. The voltage measured by the meter is 15V and 42V. Calculate the possible percentage error of both readings. Comment on your result. [Ans: 6.67%, 2.38%]
8. Eight measurements of current in a branch yield values of 50.2, 50.6, 49.7, 51.1, 50.3, 49.9, 50.3 and 51.0 mA. Assuming only the random errors are present in the measurement system, Calculate:
   a. The average value. [Ans: 50.38 mA]
   b. The standard deviation. [Ans: 0.5]
   c. The probable error of the reading. [Ans: 0.33725]
9. A moving coil ammeter has a uniform scale with 50 divisions and gives full scale reading of 5A. The instrument can read upto one-fourth of the full scale division with fair degree of certainty. Determine the resolution of the instrument in mA. [Ans: 25mA]
10. Calculate the relative error in power factor if the relative error in power, current and voltage are respectively 0.5%, 1%, 1%. [use pf=P/(VI)] [Ans: $\pm$2.5%]

Instrumentation-I (Tutorial-2)

1. Following reading were obtained in respect of measurement of a capacitor: 1.003, 0.998, 1.001, 1.009, 1.005, 0.991, 0.996, 0.997, 1.008 and 0.994 μF.
   a. Arithmetic mean
   b. Deviation from the mean
   c. Average deviation
   d. Standard deviation
   e. Variance
   f. Range
   g. Probable error of one reading
   h. Probable error of the mean
2. A 10,000 Ω variable resistance has a linearity of 0.1% and the movement of contact arm is 320^0
   a. Determine the maximum position deviation in degrees and the resistance deviation in ohm.
   b. If this instrument is to be used as a potentiometer with a linear scale of 0 to 1.6V. Determine the maximum voltage error. [Ans: (a)0.32^0, 10 Ω (b)1.6mV]
3. A balanced AC bridge has the following constants
   Arm AB : R= 1000Ω in parallel with C = 0.5 μF
   Arm BC : R=1000Ω in series with C = 0.5 μF
   Arm CD: R=200 Ω in series with L = 30 mH
   Find the constant of arm DA. Express the result as a pure R in (a) parallel (b) series with pure L or C. Given frequency =1kHz.
4. An ac bridge has following constants:
   Arm AB: Capacitor of 0.55 μF in parallel with 1 kΩ resistance
   Arm AD: resistance of 2kΩ
   Arm BC: capacitance of 0.5 μF
   Arm CD: unknown capacitance C_x and R_x in series
   Frequency – 1kHz
   Determine the unknown resistance, capacitance and dissipation factor. [ans: 2200Ω, 0.249 μF 3.455]
5. A multimeter having a sensitivity of 2000 Ω/V is used for the measurement of voltage across a circuit having an output resistance of 10 kΩ. The open circuit voltage of the circuit is 6V. Find the reading of the multimeter when it is set to its 10V scale. Also find the % error. If the output resistance of the circuit is 1000 Ω and open circuit voltage is 6V at its 10V scale, find the % error and comment upon your result. [33% , 4.8%]

Instrumentation-I (Tutorial-3)

1. Explain the 'loading effect' on the accuracy of a resistance potentiometer transducer when used for the measurement of displacement.
2. Show how 'loading effect' causes a non-linear relationship between the input and output in measurement made by a potentiometer. Derive the relation of e_0/e_i versus R_p/R_m for a potentiometer transducer where e_0 is the output voltage of a potentiometer, e_i is the input voltage of the potentiometer, R_p is the potentiometer resistance and R_m is the meter resistance. B
3. A linear resistance potentiometer is 50mm long and is uniformly wound with a wire of total resistance of 20kΩ. Under normal conditions, the slider is at the center of the potentiometer. Determine the linear displacement when the resistances of the potentiometer, as measured by Wheatstone bridge are 1550Ω and 5600Ω. Are the two displacements in the same direction? If it is possible to measure a minimum value of 10Ω resistance with the above arrangement, determine the resolution of the potentiometer in mm.[Ans: 21.125mm, 11mm, yes, 0.025mm]
4. A variable potential divider has a total resistance of 2kΩ and is fed from a 10V dc supply. The output is connected to a load resistance of 5kΩ. Determine the loading errors for the wiper positions corresponding to k=0, 0.25, 0.5, 0.75 and 1.0. Use your results to plot a graph of error versus K.
5. A potentiometer has a resistance of 5kΩ and is rated at 3W. What is the maximum allowable excitation voltage? Calculate the sensitivity and resolution if the length of the potentiometer is 0.1m and there are 200 turns. Also calculate the % loading error at 0.65 of the travel if a meter of 5kΩ is connected across the potentiometer. [Ans: 122.47]
6. A voltage dividing potentiometer is used to measure an angular displacement. The angle of displacement is 60^0 and total angle of travel of potentiometer is 355^0. Calculate the voltage output on open circuit if the potentiometer is excited by 60V source. Calculate the actual value of the output voltage at this setting if a voltmeter of 1MΩ is connected across the output. The resistance of the potentiometer is 1kΩ and the turns are uniformly distributed. Also calculate the % error. [10.140845V, 10.139421V, 0.014%]
7. In a resistive potentiometer the maximum % error is $15R_p/R_m$ where R_p and R_m are the resistance of potentiometer and the load respectively. A position measurement may have a maximum non-linearity of 0.5% while driving a load of 10kΩ. Find out the maximum value of resistance of the potentiometer. [Ans: 333.33 Ω]
8. Choose a potentiometer that has the greatest possible sensitivity and meets the non linearity requirement of 2% (minimum) from available potentiometers having a thermal rating of 5 watts and resistances ranging from 200Ω to 5000Ω in steps of 50 Ω. The output of the potentiometer is to be measured with a device of 4000Ω input resistance. Determine also the maximum excitation voltage that can be employed with this potentiometer.

Instrumentation-I (Tutorial-4)

1. Define the gauge factor of a resistance strain gauge and obtain the expression for the same.
2. Distinguish bonded and unbonded strain gauges and comment upon their suitability for measurement of physical quantities.
3. A thin circular wire of soft iron has a gauge factor of 3.8. Determine the Poisson's ratio for the soft iron. [Ans:1.4]
4. The wire in strain gauge is 0.1m long and has an initial resistance of 120Ω. On application of force the wire length increases by 0.1mm and resistance increases by 0.21Ω. Determine the Gauge factor of this device.[1.75]
5. An SG having a resistance of 500Ω and a gauge factor 3 is bonded onto a member of a structure under tensile stress. Determine the percentage strain suffered by the member if the change in resistance of the gauge accurately measured is 1.5 Ω. [Ans: 0.001]
6. A resistance gauge is used to measure stress on steel. The steel is stressed to 1400kg/cm^2. Assume Young's modulus of steel $2.1*10^6$ kg/cm^2. Calculate the percentage change of resistance of a strain gauge assuming gauge factor equal to 2 and poisson's ratio.[Ans: 0.067%, 0.5]
7. A strain gauge having a resistance of 200Ω and gauge factor 2.5 is connected in series with blast resistance of 400Ω across 24V. Determine the change in output voltage when a stress of 140MN/m^2 is applied. The modulus of elasticity is 200GN/m^2. [Ans: 9.33mV]
8. In order to measure the strain in a cantilever beam, a single strain gauge of resistance 1k ohm and gauge factor 2 and temperature coefficient $10*10^{-6}/^0$C is mounted on the beam and connected to one arm of the bridge circuit. The outer arms of the bridge have a resistance of 1000Ω each. The bridge detector resistance is 100 ohm and its sensitivity is 10mm/μA. Calculate the detector deflection for 0.1% strain and the change in effective strain indicated when the room temperature increases by 10^0C. The supply to the bridge circuit is 10V.[Ans: 44.5mm]
9. Explain the construction and working principle of a linear variable differential transformer.
10. Discuss the factor limiting the bandwidth and sensitivity of a linear variable differential transformer.
11. An LVDT is used for measuring the deflection of a bellows. The sensitivity of LVDT is 40V/mm. The bellows is deflected by 0.125mm by a pressure of $0.8*10^6$N/m^2. Determine the sensitivity of LVDT in V per N/m^2 and the pressure when the voltage output of an LVDT is 3.5V.[Ans: $6.25*10^{-6}$ V per N/m^2, $5.6*10^5$N/m^2]
12. The output of an LVDT is connected to a 5V voltmeter through an amplifier whose amplification factor is 250. An output of 2mV appears across the terminals of LVDT when the core moves through a distance of 0.5mm. Calculate the sensitivity of the LVDT and that of the whole setup. The mili-voltmeter scale has a 100 divisions. The scale can be read to 1/5 of division. Calculate the resolution of the instrument in mm.
13. An LVDT with a secondary voltage of 5V has a range of $\pm$ 25mm. Find the output voltage when the core is -18.75mm from center. Plot the core position versus output for a core movement going from +18.75mm to -10mm.[Ans: -3.75V, 3.75V to -2V linearly]

Instrumentation-I (Tutorial-5)

1. Explain the principle of operation of capacitive displacement transducers. How do you obtain a linear characteristic between the capacitance and displacement when displacement is measured in terms of change in overlapping area? Also discuss the sensitivity of the transducer.
2. Discuss how capacitive transducers can be used to measure displacement with the chance in term of movement of dielectric material between the plates. Also mention the sensitivity of the transducers.
3. Explain how can the response of the capacitive transducer, which works on the principle of variation of capacitance with displacement between two plates, be made linear. Also give the sensitivity and resolution of such an arrangement.
4. A displacement capacitive transducer uses a differential arrangement with two outer plates which are fixed and central plate which is movable. The distance between the fixed and movable plate is 5mm when no displacement is applied. A voltage of 1000V a.c. is applied across the fixed plates. Find the differential output voltage if a displacement of 0.01mm is applied to the central plate. Find also the sensitivity of the transducer. [Ans: 2V, 200V/mm]
5. A capacitive transducer is made up of two concentric cylindrical electrodes. The outer diameter of the inner cylindrical electrode is 3mm and the dielectric medium is air. The inner diameter of the outer electrode is 3.1mm. Calculate the dielectric stress when a voltage of 100V is applied across the electrodes. Is it within safe limits? The length of the electrode is 20mm. Calculate the change in capacitance if the inner electrode is moved through a distance of 2mm. The breakdown strength of air is 3kV/mm.[2kV/mm, 3.4pF]
6. Show how the resistance temperature characteristics of thermistor look and explain its suitability for temperature measurement.
7. Explain how resistive transducer can be designed and used for the measurement of the relative humidity of air and gases. What is the basic limitation of the arrangement?
8. The resistance of a thermistor is 200kΩ at -100^{0}C. Find the value of resistance at 400^{0}C. Also find the ratio of two resistances for platinum over the same temperature and comment upon your answers. Platinum has a resistance temperature coefficient of 0.0039/^{0}C. The value of β is 4000K for thermistor.[Ans: $6.93*10^{-3}$ ohm, 2.95]
9. A gauge is made of a material having a temperature coefficient of $12*10^{-6}$/^{0}C. It has a gauge factor of 2. It is connected in a bridge circuit having resistance of 120Ω. The bridge is balanced in ambient temperature. Supporting there is change in temperature of 20^{0}C in the temperature of the gauge. A) Find the output voltage of the bridge if the input voltage is 10V. B) What is the equivalent strain represented by the change in temperature. If dummy strain gauge is to replace one resistance of the bridge for the temperature compensation, show where should it be placed in the bridge? [Ans: 0.6mV, 12 micro strain]
10. A bridge circuit has two fixed resistors and two strain gauges all of which have a resistance of 120Ω. The gauge factor is 2.04 and strain applied to twin strain gauge, one is tensile and other is compression is $165*10^{-6}$. If the battery current is 50mA; Determine a) voltage output of the bridge b) sensitivity in volt/strain. If the galvanometer connected to two output terminals reads 100μV per scale division if 1/10th of a division can be read with confident, determine the resolution. [Ans; 0.0202V, 1.225mV/μs, 0.008μs]

Instrumentation-I (Tutorial-6)

1. A barium titanate piezoelectric pick-up has dimension of 6mm*6mm*1.5mm and a voltage sensitivity of 0.012Vm/N. Relative permittivity of barium titanate is 1400 and modulus of elasticity of barium titanate is $12*10^{10}N/m^2$. Determine i) the output voltage ii) Charge sensitivity iii) Strain iv) Charge generated v) The capacitance of the pick-up. The force applied to pick-up is 10N.[Ans: 5V, 148.7pC/N, $2.315*10^{-6}$ 1487pC, 297.4pF]
2. The output of an LVDT is 1.25V at maximum displacement. At a load of $0.75M\Omega$, the deviation from the linearity is maximum and it is $\pm 0.0025V$ from the straight line through origin. Determine the linearity at the given load.[Ans: 0.2%]
3. An LVDT is used for measuring the deflection of a bellows. The sensitivity of LVDT is 40V/mm. The bellows is deflected when the voltage output of LVDT is 3.5V. [$6.25*10^{-6}$V/N per m^2, $5.6*10^5N/m^2$].
4. A thermistor has resistance of 3980Ω at the ice point and 794Ω at 50^0C. The resistance-temperature relationship is given by $R_T = aR_0e^{\frac{b}{T}}$. Calculate the constants 'a' and 'b'. Calculate the range of resistance to be measured in case the temperature varies 40^0C to 100^0C.[Ans: $a=3*10^{-5}$, b=2842.8K]
5. The output of a potentiometer is to be read by a recorder 10kΩ input resistance. The non-linearity must be held to 1%. A family of potentiometer having thermal ratings of 5W and resistances ranging from 100Ω to 10kΩ in step of 100Ω are available. Choose from the family of potentiometer, a potentiometer that has the greatest possible sensitivity and which meets the non-linearity requirement. Find the maximum excitation voltage permissible with this potentiometer. What is the sensitivity if the potentiometer is single turn? [Ans: 600 ohms, 0.152V/degree]
6. Hall effect element is used for the measurement of magnetic flux of $0.8wb/m^2$. The thickness of element is 2.5mm. If the current passed through the element is 4A. Calculate the Hall emf developed. Given that $K_H=5*10^{-7}$ [Ans: $6.4*10^{-4}$V]
7. A piezoelectric pressure transducer having sensitivity of $2*10^{-12}$C/N is connected to a charge amplifier, the gain being set to 5mV/pC. The amplifier output is connected to a ultraviolet chart recorder, whose sensitivity is set to 25mm/V. Determine the overall sensitivity and deflection of the chart due to a force of 200N. [0.25mm/N, 50mm]
8. A series connected thermopile is made up of copper-constantan thermocouples with T_1 at 150^0C and its net effect is 3.3mV for the arrangement of three junction pairs as shown in figure. Calculate the value of temperature T_2, taking the sensitivity of each junction as $50\mu V/^0C$. [Ans: 172^0C or 128^0C]

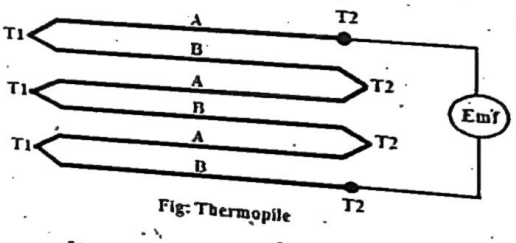


Fig: Thermopile

9. For thermistor T_0=300K, β=3420K, R_0=1kΩ and R=2kΩ, calculate the value of T. Also find the sensitivity $(s) = \frac{\partial R}{\partial T}$. [Ans: 282.8K, 85.53Ω/K]
10. An LVDT has secondary voltage of 5V for a displacement of $\pm 12.5mm$. Determine the output voltage for a core displacement of 8mm from its central position. [Ans: 3.2V]

Instrumentation I

Converter Resolution

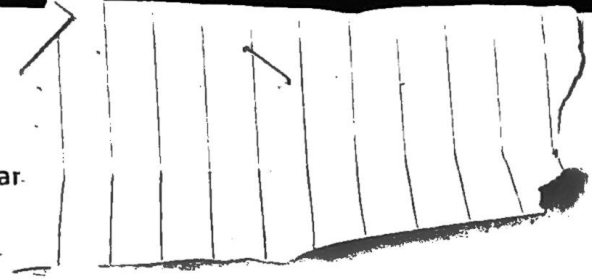
1. What is the percentage resolution of a 5-bit converter?[3.23%]
2. What is the resolution and percentage resolution of a 12-bit DAC whose output varies between +50 to -50 V?[0.0244 V, 2.44%]
3. The basic steps of a 9 bit DAC is 10.3 mV. If 000000000 represents 0 volt, what output will be produced if the input is 101101111?[3.78 volts]
4. Calculate the values of LSB, MSB and full scale output voltage for an 8 bit DAC for the 0-10 V range. [39 mV, 5 V, 9.96V]
5. A 10 bit ADC has an input voltage if -10 V to +10 V. What is the resolution and percentage resolution of the converter?[19.5 mV,1.95%]
6. A good quality analog transducer having an input 0-8V is able to distinguish a change of 1 mV in its input signal. Calculate the number of bits.[13]
7. A 6-bit ADC has a maximum precision supply voltage of 20 V. Provide the following information for the unit.
   a. What voltage change does each bit represent?[0.317 V]
   b. What voltage does 100110 represent?[12.06 volts]

R-2R converter

1. An 8 bit R-2R DAC has a reference voltage of 12 V. Find the minimum value of resistance so that the output current of the ladder doesn't exceed 10 mA. Also find the smallest value of current.
2. Show how R-2R ladder can be used to generate a sequence of current. What would be the output voltage of the circuit when the input code is 1001?

$(dv/dt)_{max}$ and f_{max}

1. Given an 11 bit ADC converter with conversion time 0.1 sec and V_{FS} =10V. Find the maximum rate of change that the analog input signal may have in order that the converter can resolve the input signal into an 11-bit number in a single conversion time.[0.05 V/s]
2. Given a 12 bit , 10V full scale ADC that has a 20 microseconds conversion time and is used without a sample and hold circuit. Find the maximum rate of change in input signal and maximum input frequency that will still allow the ADC to operate at full resolution.[125%,2Hz]
3. If a sample and hold circuit with an aperture time of 3 ns is used together with the ADC described in example 2, calculate the maximum rate of change of voltage and signal frequency that can be applied while still allowing the converter to fully resolve the input signal. [0.8V/microsec, 14 Hz]
4. Given a sample and hold amplifier with an aperture time of 50 ns, which is connected to an 8 bit ADC, find the highest frequency of sinewave that can be digitalized within an error of 1 LSB.[12.4 kHz]



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Instrumentation I

Assignment 2

1. What are the advantages of inverted R-2R DAC over other DAC? Derive the output expression for R-2R DAC.
2. What will be the 6-bit approximation digital output for the analog input 6.127V if V_R is 8V?
3. Show how R-2R ladder network can be used to generate a binary weighted sequence of current.
4. A 3-bit DAC has a voltage range of (0-12)V. Calculate the
   a. Weight of LSB
   b. Weight of MSB
   c. Exact range of the converter
   d. Percentage error

   If now, the bit of the converter is increased to 6, show by how much percentage the error is increased or decreased? Justify your answer.
5. Explain how analog to digital conversion can be carried out using a flash type ADC.
6. Consider a 6-bit digital to analog converter with a resistance of 20 kΩ in MSB position. The converter is designed with weighted resistive network. The reference voltage is 12 V. the output of the resistive network is connected to an operational amplifier with a feedback resistance of 10kΩ. What is the analog output for a binary input of 101011?
7. The basic step of a 9 bit DAC is 10.3 mV. If (000000000) represents 0 V, what output is produced if the input is (101101111)? Write the advantage of R-2R ladder type DAC over WRN type.
8. Describe in detail the successive approximation method of analog to digital (A/D) conversion taking an example of 4-bit converter having full range of 5V and input of 3.215 V.
9. A 6-bit DAC has 20 kΩ resistance in MSB position. The converter is designed with weighted resistive network. The reference voltage is 12 V. The output of the resistive network is connected to an operational amplifier with a feedback resistance of 5 kΩ. What will be the analog output for a binary input of 101101.
10. A 6-bit DAC has a reference voltage of 9 V if it uses
    a. R-2R ladder network
    b. Weighted resistive network

    Find the minimum value of resistance in both the cases such that the output current does not exceed 10mA.
11. Explain with suitable example how analog to digital conversion is carried out using successive approximation type ADC.
12. An 8 bit ADC has a maximum supply voltage of 18 volts. Find
    a. What voltage change does LSB represent?
    b. What voltage does 101011 represent?
13. State and explain Nyquist Criterion. Also explain the phenomenon of aliasing and the way to eliminate it.

14. What do you mean by sample and hold circuit? Explain its functioning with the help of a circuit diagram and also discuss about its characteristics to define its specification. What is the purpose of using sample and hold circuit in analog to digital conversion system?
15. A 10 bit, 10 V successive approximation converter has 20 microseconds conversion time. Find the maximum rate of change of input signal and maximum input frequency.
16. What is a data acquisition system? What are the components of a digital DAS? Explain the working of a multiplexer with 4 input, 2 control and 1 output signal.
17. Explain briefly the different components of digital data acquisition system.

Assignment 3

1. Explain the operating principle of electrical resonance type frequency meter in detail.
2. Show how the instrument transformers are used to measure high voltage and current. Also explain why the secondary of current transformers should not be kept open circuited when primary is energized.
3. Explain the construction detail and operating principle of a single phase induction type energy meter. Show that the total number of revolutions made by its disc during a particular time is proportional to the energy consumed.
4. List out the different types of frequency meters. Explain the construction and working principle of any of them to measure the frequency.
5. Explain the construction and working principle of single phase electro dynamometer type of wattmeter and derive the expression of the deflection, for both ac and dc operation.

(1)(b) Explain the characteristics of instrumentation amplifier & derive the expression for its gain (5)

Instrumentation-I
BCT II/II

F.M: 40
Time:-