B.E.

Sixth Semester Examination, December-2007

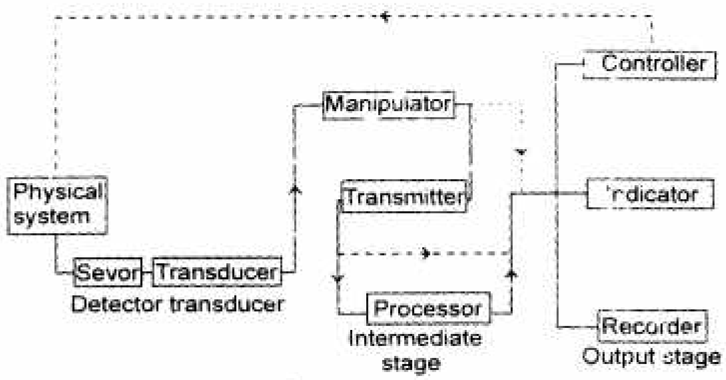
Measurement & Instrumentation (ME-310-E)

Time : 3 Hrs.] **[M.M. : 100**

Note : Attempty any five questions.

Q.1. (a) What are the basic blocks of a generalized measurement system ? Draw them and explain their functions. **10**

Ans.



Generalised Measurement System

The basic components are shown in block diagram in a generalised measurement system.

Most of measurement system contain three main functional elements :

(i) Primary sensing element

(ii) Variable conversion element

(iii) Data Presentation element.

(i) Primary Sensing Element : The quantity under measurement makes its first contact with the primary sensing element of a measurement system. This act is then immediately followed by the conversion of measurand into an analogous electrical signal. This is done by a transducer. A transducer, in general, is defined as a device which converts energy from one form to another. The physical quantity to be measured, in the first place is sensed and detected by an element which gives the output in a different analogous form. This output is then converted into an electrical signal by a transducer. This is true of most of the cases but is not true for all. In many cases the physical quantity is directly converted into an electrical quantity by a tranceducen. The first stage of a measurement system is known as a detector transducer stage.

(ii) Variable Conversion Element : The output of the primary sensing element may be electrical signal of any form. It may be a voltage, a frequency or some other electrical parameter. Sometimes this output is not suited to the system. For the instrument to perform the desired function, it may be necessary to convert this output to some other suitable form while preserving the information content of the original signal.

(iii) Data Presentation Element : The information about the quantity under measurement has to be conveyed to the personal handling the instrument or the system for monitoring, control, or analysis purposes.

Q. 1. (b) Describe the merits of electronic instruments over mechanical and electrical instruments. **10**

Ans. These days most of the scientific and industrial measurements require very fast responses. The necessity to step up response time and also the detection of dynamic changes in certain panametens, which require the monitoring time of the order of ms and many a times, have led to the design of today's electronic instruments and their associated circuitry. Since in electronic devices, the only movement involved is that of electrons, the response time is extremely small on account of very small inertia of electrons. Another advantage of using electronic devices is that very weak signals can be detected by using pre-amplifiers and amplifiers. The most important use of electronic instruments is their usage in measurement of non-electrical quantities, where the non-electrical quantity is converted into electrical form through the use of transducers communications is a field which is entirely dependent upon the electronic instruments and associated apparatus. In general electronic instruments have (i) a higher sensitivity (ii) a faster response (iii) a greater flexibility (iv) lower weight (v) lower power consumption and (vi) a higher degree of reliability than their mechanical or purely electrical counterparts.

Q.2. Derive the equations for time response of a first order system subjected to ramp input. Draw the response curve and find steady state error. Give some example. **20**

Ans. The applied input is a unit ramp

$$r(t) = t \quad \text{or} \quad R(s) = \frac{1}{S^2}$$

∴ Output

$$C_{(s)} = G_{(s)} R_{(s)} = G_{(s)} = \frac{1}{S^2 (1 + \tau_s)}$$

$$= \frac{1}{S^2} - \frac{\tau}{S} + \frac{\tau^2}{1 + \tau_s}$$

Taking the inverse Laplace transform,
we get,

$$C(t) = t - \tau[1 - \exp(1 - t/\tau)] \qquad \text{....(i)}$$

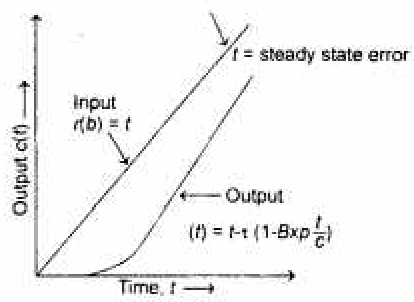
The dynamic response of a first order system to a ramp input is shown in fig.
The dynamic error is

$$e_m(t) = r(t) - C(t)$$
$$= \tau[1 - \exp(1 - t/\tau)] \qquad \text{...(ii)}$$

The final steady state error is,

$$e_{ss} = \lim_{t \to \infty} e_m(t) = \tau \qquad \text{...(iii)}$$

Thus, the first order system will track the unit ramp input with a steady state error τ which is equal to the time constant of the system.



Ramp response of Ist order

If the system is subjected to a ramp input $r(t) = At$,

Then the output is,

$$C(t) = A[t - \tau(1 - \exp)(-t/\tau)] \quad \text{...(iv)}$$

the dynamic error,

$$e_d(t) = r(t) - C(t) = A\tau[\exp(-1t/\tau)] \quad \text{...(v)}$$

and final steady state error $e_{ss} = A\tau$.

Q. 3. List the different means normally used for torque measurements. Describe the procedure you would like to follow to mount four strain gauges on a mild steel circular shaft for torque measurement. **20**

Ans. The different means normally used for torque measurement are :

(1) Strain gauge torque meters

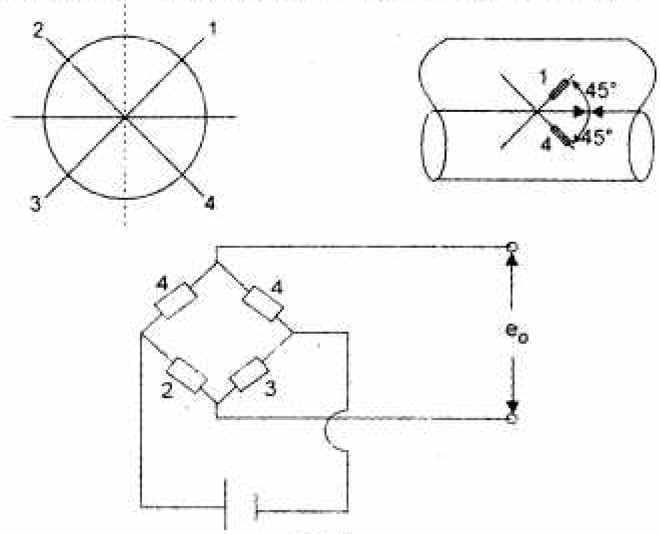
(2) Stroboscopic method

(3) Inductance torque transducer

(4) Digital method

(5) Magneto-strictive transducers.

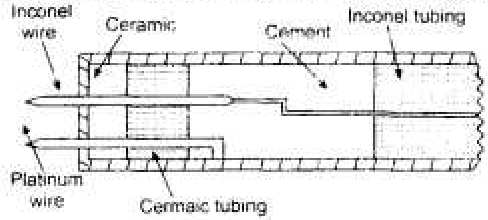
The strain in the shaft may be measured by means of strain gauges attached to its surface. The gauges should be so mounted that they give maximum sensitivity to the strains produced by torsion. The normal method is to mount a complete strain gauge bridge on the shaft. The strain bridge configuration generally used for measurement of torque is shown in fig. In this arrangement two strain gauges are subjected to tensile stresses while the other two experience compressive stresses. The gauges must be precisely at 45° with the shaft axis. Gauges 1 and 3 must be diametrically opposite as must gauges 2 and 4.



Bridge

Q. 4. What is a hot wire anemometer ? Describe its construction and principle of working. **20**

Ans. Hot wire anemometers are hot wire resistance transducers which are used for measurement of flow rates of fluids. Flow rates of non-conducting liquids in open channels and closed pipes and of gases in closed pipes can be measured very conveniently by suitably locating this transducer which is in the form of a wire filament. The hot wire filament is usually a fire wire of plantinum or tungsten, and is mounted in the flow channel, by means of supports. The transducer is in the form of a probe as shown in fig.



Hot wire anemometer

The diameter and length of wire depends upon the size of the pipe and the maximum flow rate which has to be measured. The diameter of wire varies from 5 µm to 300 µm and length is approximetely equal to half the diameter of the pipe. The probe is located at the centre of the pipe with direction of wire perpendicular to the direction of fluid flow.

The method can be used for measurement velocities. The hot wire probe can be placed in small sized pipes without causing any pressure drop in the fluid stream. However, it can measure only the average velocity of flow. The method is unsuitable for velocity measurements if the fluid is conducting liquid. The main applications of hot wire anemometers are for gas flow and wind velocity measurements and in the laboratory for flow measurements of non conducting liquids and gases.

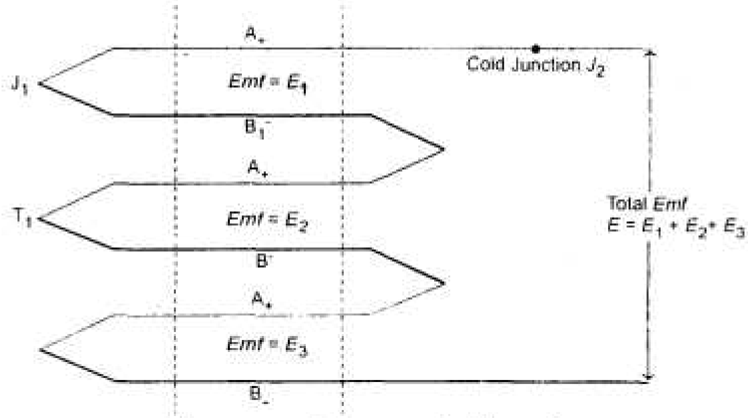
Q. 5. Describe the series and parallel connections of thermocouples and explain under what situations they should be used ? **20**

Ans. (1) Series Connection : Fig. shows three thermocouples connected in series. In such an arrangement, the total emf is the sum of the emfs developed by individual thermocouples. For a general case, when n thermocouples are connected in series, the total emf is

$$E = E_1 + E_2 + E_3 + \ldots\ldots + E_n$$

In case all the thermocouples are indentical and they work under identical conditions, $E_1 = E_2 = E_3 \ldots\ldots E_n$ and therefore, $E = nE_1$ or resultant emf is n times the emf of an individual thermocouple.

Such an arrangement is called a thermopile. The use of a thermopile gives a very high sensitivity owing to its high output. Therefore, it is well suited for applications when difference in temperatures of measuring and reference junctions is small.



Thermocouples connected in series

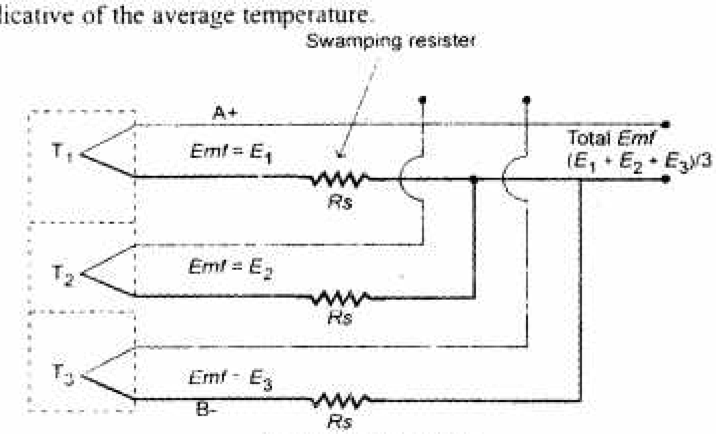
Temperature difference can be measured easily by connection thermocouples in series but with reversed polarities with the result that their values an substractive. The net emf in this case is

$$E = E_1 - E_2$$

(2) Parallel Connection : Thermocouples may be connected in parallel to measure average temperature as shown in fig. The thermocouples used may not have equal resistances and in order to minimize the effects of unequal resistances in individual thermocouples and their lead wires to the point of parallel connection at the measuring instrument a swamping resistance is put in series with each thermocouple. The swamping resistors prevent current flow between thermocouples which would, in the absence of these resistors produce measurement errors. For parallel connection shown in fig, the total emf is :

$$E = \frac{E_1 + E_2 + E_3}{3}$$

Which is indicative of the average temperature.



Parallel connection

Q. 6. What do you mean by Wheatstone bridge ? Derive an expression for its sensitivity in case of a voltage sensitive bridge with different resistances in each arm and simplify the expression when all the arms are having equal resistances. 20

Ans. It is the most commonly used D.C. bridge for measurement of resistance. This bridge is used for measurement of small resistance changes that occur in passive resistive transducers like strain gauges, thermistors and resistance thermometers.

With refer to fig. Let us assume that the input impedance of the meter is infinite and therefore $i_m = 0$.

Hence, $i_1 = i_3$ and $i_2 = i_4$, output voltage e_0 = voltage across terminals b and $d = iR_1 - i_2R_2$

But $$i_1 = \frac{e_i}{R_1 + R_3} \text{ and } i_2 = \frac{e_i}{R_2 + R_4}$$

$$\therefore \quad e_0 = \left[\frac{R_1}{R_1 + R_3} - \frac{R_2}{R_2 + R_4}\right] e_i = \left[\frac{R_1R_4 - R_2R_3}{(R_1 + R_3)(R_2 + R_4)}\right] e_i$$

Suppose now R_1 changes by an amount ΔR_1.

This causes a change Δe_0 in the output voltage. Thus,

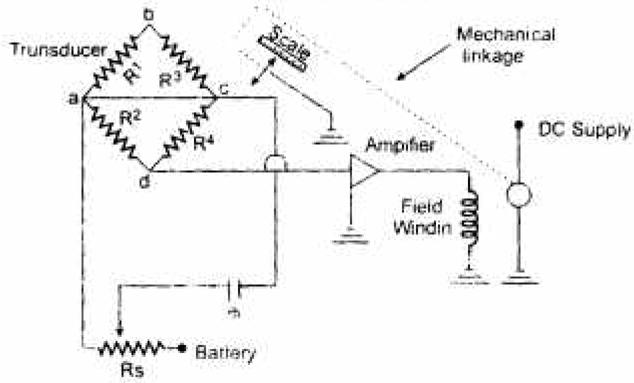
$$e_0 + \Delta e_0 = \left[\frac{(R_1 + \Delta R_1)R_4 - R_2R_3}{(R_1 + \Delta R_1 + R_3)(R_2 + R_4)}\right] e_i$$

$$= \left[\frac{1 + \Delta R_1 / R_1 - R_2 R_3 / R_1 R_4}{\{1 + (\Delta R_1 / R_1) + R_3 / R_1\}\{1 + R_2 / R_4\}} \right]$$

If all the resistance comprising the bridge are eqal *i.e.*,

$$R_1 = R_2 = R_3 = R_4 = R$$

then $$e_0 = 0 \text{ and } \Delta e_0 = \left[\frac{(\Delta R / R)}{4 + 2(\Delta R / R)} \right] e_i$$



Self balancing bridge

Q. 7. (a) Explain, with example, the method of rejection of test data based upon confidence intervals. **10**

Ans. Rejection of Data based upon Confidence Intervals : A criterion used for discarding a data point is that its deviation from the mean exceeds four times the probable error of a single reading. This results in discarding a data outside a confidence interval for a single reading at a confidence level of 0.993.

A better criterion which does not involve the evaluation of probable error when the set of data points is small and standard deviation is not accurately known, is to discard a reading that lies outside the interval corresponding to confidence level of 0.99 for a single observation. On this basis not more than 1 reading in 100 would lie outside this range.

A still better method is to use the confidence interval corresponding to a confidence level of 0.95 in order to scrutinize the measurement proceducer adopted.

Q. 7. (b) Prove that the algebraic sum of the deviations of a set of observations from their arithmetic mean is zero. **10**

Ans. Deviation is departure of the observed reading from the arithmetic mean of the group of reading x_1 be d_1 and that of reading x_2 be d_2, etc.

Then,
$$d_1 = x_1 - \bar{x}$$
$$d_2 = x_2 - \bar{x}$$
$$d_n = x_n - \bar{x}$$

and
$$\bar{x} = \frac{\Sigma(x_n - d_n)}{n}$$

Algebraic sum of deviations

$$= d_1 + d_2 + d_3 + \dots + d_n$$
$$= (x_1 - \bar{x}) + (x_2 - \bar{x}) + (x_3 - \bar{x}) + \dots + (x_n - \bar{x})$$

$$= (x_1 + x_2 + x_3 + \ldots + x_n) - n\bar{x} = 0$$
$$\text{as } x_1 + x_2 + x_3 + \ldots + x_n = n\bar{x}$$

Therefore the algebragic sum of deviations is zero.

Q. 8. Write short notes on the following : **20**

(i) Cathode Ray Oscilloscope (CRO),

(ii) Digital to Analog (D-A) Converters :

Ans. (i) Cathode Ray Oscilloscope (CRO) : The cathode ray oscilloscope (CRO) is a very useful and versatile laboratory instrument used for display, measurement and analysis of waveforms and other phenomena in electrical and electronic circuits. CROs are in fact very fast $X - Y$ plotters, displaying an input signal versus another signal or versus time. The "stylus" of this "plotter" is a luminous spot which mores over the display area in response to an input voltage. The luminous spot is produced by a beam of electrons striking a flourescent screen.

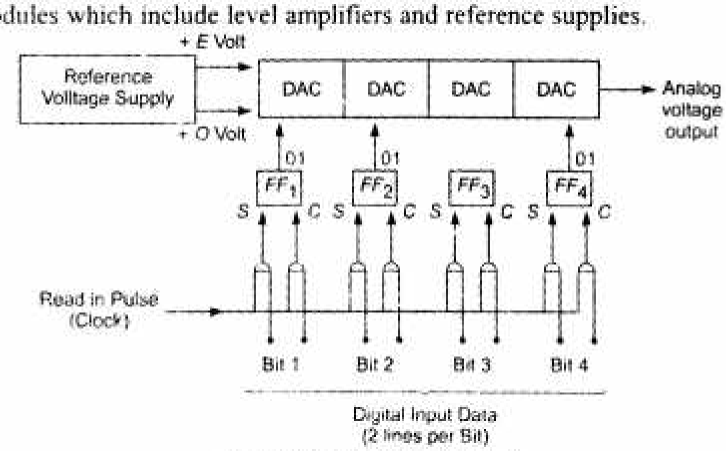
The extremely low inertia effects associated with a beam of electrons enables such a beam to be used for following the changes in instantaneous values of rapidly varying voltages.

The normal form of a CRO uses a horizontal input voltage which is an internally generated ramp voltage called "Time Base". This horizontal voltage moves the luminous spot periodically in a horizontal direction from left to right over the display area or screen. The vertical input to the CRO is the voltage under investigation. The vertical input voltage moves the luminous spot up and down in accordance with the instantaneous value of the voltage. The luminous spot thus traces the waveform of the input voltage with respect to time. When the input voltage repeats itself at a fast rate, the trace (display) on the screen appears stationary on the screen. The CRO thus provides a means of visualizing time varying voltages. As such, the CRO has become a universal tool in all kinds, of electrical and electronic investigations.

(ii) Digital to Analog (D-A) Converters : A practical digital to analog converter is shown in fig. The basic components are :

(i) Flip flow (FF) Register.

(ii) DAC modules which include level amplifiers and reference supplies.



Analog to digital converter

The digital signals are dropped into the register by a read in pulse (usually a clock pulse). These pulses are automatically converted by the DAC network to analog voltage.