M.I.E.T. ENGINEERING COLLEGE

(Approved by AICTE and Affiliated to Anna University Chennai)

TRICHY – PUDUKKOTTAI ROAD, TIRUCHIRAPPALLI – 620 007

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

COURSE MATERIAL

EE6404 - MEASUREMENTS AND INSTRUMENTAION

II YEAR – IV SEMESTER

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

(SYLLABUS)

Sub. Code : EE6404 **Branch/Year/Sem** : EEE/II/IV

Sub Name : MEASUREMENTS AND INSTRUMENTAION **Staff Name** : S.PANDIARAJAN

EE6404 MEASUREMENTS AND INSTRUMENTATION **L T P C**
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UNIT I INTRODUCTION 9

Functional elements of an instrument – Static and dynamic characteristics – Errors in measurement – Statistical evaluation of measurement data – Standards and calibration.

UNIT II ELECTRICAL AND ELECTRONICS INSTRUMENTS 9

Principle and types of analog and digital voltmeters, ammeters, multimeters – Single and three phase wattmeters and energy meters – Magnetic measurements – Determination of B-H curve and measurements of iron loss – Instrument transformers – Instruments for measurement of frequency and phase.

UNIT III COMPARISON METHODS OF MEASUREMENTS 9

D.C & A.C potentiometers, D.C & A.C bridges, transformer ratio bridges, self-balancing bridges. Interference & screening – Multiple earth and earth loops - Electrostatic and electromagnetic interference – Grounding techniques.

UNIT IV STORAGE AND DISPLAY DEVICES 9

Magnetic disk and tape – Recorders, digital plotters and printers, CRT display, digital CRO, LED, LCD & dot matrix display – Data Loggers.

UNIT V TRANSDUCERS AND DATA ACQUISITION SYSTEMS 9

Classification of transducers – Selection of transducers – Resistive, capacitive & inductive transducers – Piezoelectric, Hall effect, optical and digital transducers – Elements of data acquisition system – A/D, D/A converters – Smart sensors.

TOTAL :45 PERIODS

TEXT BOOKS:

1. A.K. Sawhney, 'A Course in Electrical & Electronic Measurements & Instrumentation', Dhanpat Rai and Co, 2004.
2. J. B. Gupta, 'A Course in Electronic and Electrical Measurements', S. K. Kataria & Sons, Delhi, 2003.
3. Doebelin E.O. and Manik D.N., Measurement Systems – Applications and Design, Special Indian Edition, Tata McGraw Hill Education Pvt. Ltd., 2007.

REFERENCES:

1. H.S. Kalsi, 'Electronic Instrumentation', Tata McGraw Hill, II Edition 2004.
2. D.V.S. Moorthy, 'Transducers and Instrumentation', Prentice Hall of India Pvt Ltd, 2007.
3. A.J. Bouwens, 'Digital Instrumentation', Tata McGraw Hill, 1997.
4. Martin Reissland, 'Electrical Measurements', New Age International (P) Ltd., Delhi, 2001.
5. Alan. S. Morris, Principles of Measurements and Instrumentation, 2nd Edition, Prentice Hall of India, 2003.

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EE6404 MEASUREMENTS AND INSTRUMENTAION

COURSE OBJECTIVES

- To introduce the basic functional elements of instrumentation.
- To introduce the fundamentals of electrical and electronic instruments.
- To educate on the comparison between various measurement techniques.
- To introduce various storage and display devices.
- To introduce various transducers and the data acquisition systems.

COURSE OUTCOMES

- Identify the basic block elements in measuring instruments.
- Explain the significance of electrical and magnetic instruments.
- Demonstrate the working of various bridge circuits.
- Choose the suitable display devices for different applications.
- Illustrate the function of different blocks involved in DAS.
- Compare the performance of electrical and electronic instruments.

Prepared by
Mr. S.PANDIARAJAN

Verified By
HOD

Approved by

PRINCIPAL

UNIT I

INTRODUCTION

Functional elements of an instrument – static and dynamic characteristics – errors in measurement –statistical evaluation of measurement data – standards and calibration.

Instrumentation

Instrumentation is a branch of engineering that deals with the measurement and control of different parameters. Instrumentation is defined as "the art and science of measurement and control". Instrumentation can be used to refer to the field in which Instrument technicians and engineers work, or it can refer to the available methods of measurement and control.

Eg. Pressure, temperature, level, velocity .etc

The measurement of a given parameter or quantity is the act or result of a quantitative comparison between a predefined standard and an unknown quantity to be measured. The physical , chemical, electrical quantity ,properly process, variable or a condition to be measured is referred as measurement.

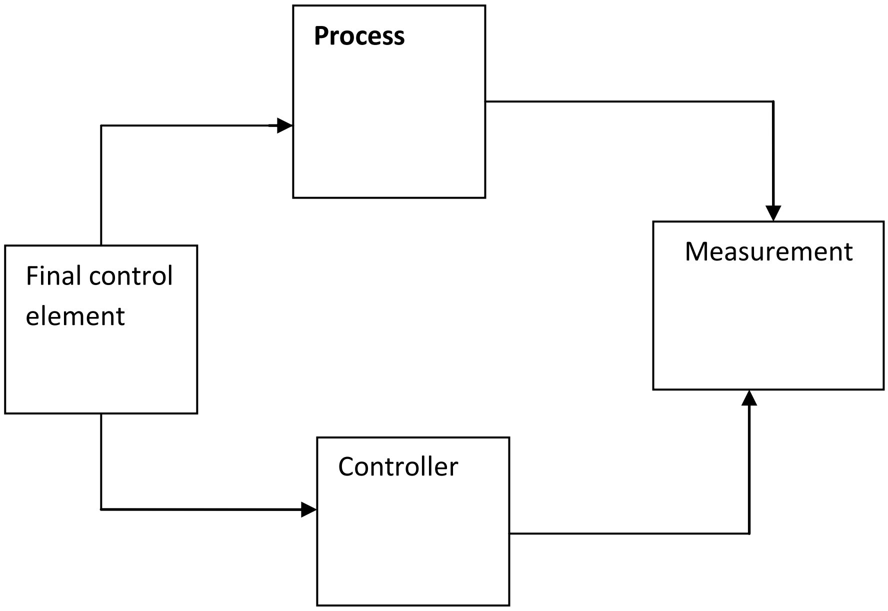
Objectives of engineering measurements

1. Measurements of system parameter information

The result of measurement gives visual indication of parameter(registering/monitoring)or signal for further processing. The collected information gives the current status of physical parameters.

2. Automatic control systems

The measurement systems forms an integral part of automatic control systems in which a variables is to be maintained at a desired value. For keeping a variable at a certain level, the current status of the same must known



3. Simulation means comparison of full scale prototype with a perfect model. T model is translated to the prototype model. Then the experimental results of the model are translated to the prototype. For this measurement of experiment results of the prototype is necessary.

Eg. Testing the model of aerodynamic bodies in controlled air streams and measuring the o/p flow conditions for simulation.

4. Experimental; design

For developing a new products prototype different experiments must be carried out to measure its performance with respect to different inputs.

5. To perform various manipulation

For performing different mathematical manipulations (addition, subtraction, multiplication, division, differentiation etc).

6. Testing of materials and quality control

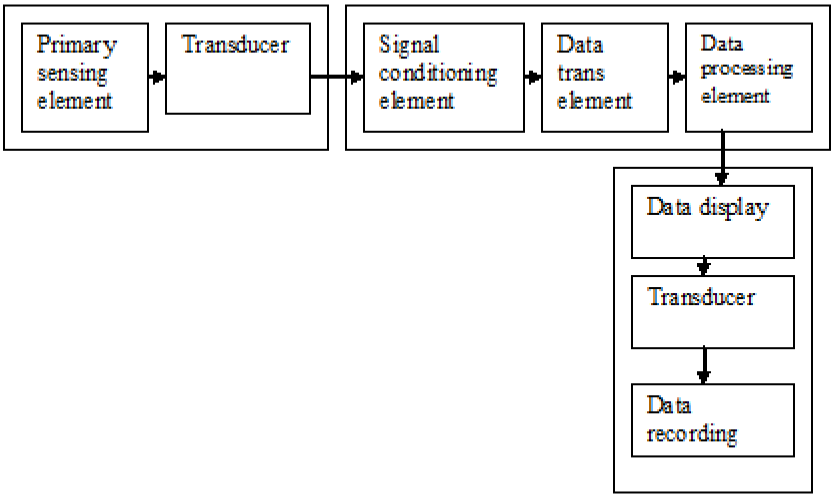
The raw materials for production must be cross checked with standard specification which is also a kind of measurement. Similarly the final product also must be tested against a standard one which comes under quality control.

7. Verification of scientific theories.

To verify scientific theories, experiments are to be conducted which involves measurement of quantities.

Basic measurement system- block diagram

A *measuring system* exists to provide information about the physical value of some variable being measured. In simple cases, the system can consist of only a single unit that gives an output reading or signal according to the magnitude of the unknown variable applied to it. However, in more complex measurement situations, a measuring system consists of several separate elements as shown in Figure. These components might be contained within one or more boxes, and the boxes holding individual measurement elements might be either close together or physically separate. The term *measuring instrument* is commonly used to describe a measurement system, whether it contains only one or many elements, and this term will be widely used throughout this text.



A measurement system consists of 3 fundamental blocks.

1. An input device
2. Signal conditioning and processing device
3. Output device

Every device is composed of one or more functional elements.

1. Input device.

The function of input device is to sense the quantity under measurement. If the measurand is a non electrical quantity, it has to be converted to a proportional electrical quantity; this is done by means of a transducer.

2. Signal conditioning & processing device

The o/p of the first stage may not be suitable for the i/p of the next stage and hence may need to be manipulated. Signal conditioning includes amplification, filtering, attenuating etc.

Data transmitting element: When the elements of an instrument are actually physically separated it becomes necessary to transmit data from one to another. The element that performs this function is called data transmission element. The signals may now be processed for display.

3. Output device

The information about the quantity under measurement has to be conveyed to the personal handling to the instrument or the system to monitoring control or analysis purposes. To monitor data analog or digital indicating instruments like ammeter voltmeter etc may be used. To record data magnetic tape recorders, printers, micro processors may be used. For control and analysis purposes a microprocessor or computer may be used.

Elements of a measurement system

The first element in any measuring system is the primary ***sensor***: this gives an output that is a function of the measurand (the input applied to it). For most but not all sensors, this function is at least approximately linear. Some examples of primary sensors are a liquid-in-glass thermometer, a thermocouple and a strain gauge. In the case of the mercury-in-glass thermometer, the output reading is given in terms of the level of the mercury, and so this particular primary sensor is also a complete measurement system in itself. However, in general, the primary sensor is only part of a measurement system. Variable conversion elements are needed where the output variable of a primary transducer is in an inconvenient form and has to be converted to a more convenient form. For instance, the strain gauge has an output in the form of a varying resistance. The resistance change cannot be easily measured and so it is converted to a change in voltage by a *bridge circuit*, which is a typical example of a variable conversion element. In some cases, the primary sensor and variable conversion element are combined, and the combination is known as a *transducer*.

Signal processing elements exist to improve the quality of the output of a measurement system in some way. A very common type of signal processing element is the electronic amplifier, which amplifies the output of the primary transducer or variable conversion element, thus improving the sensitivity and resolution of measurement. This element of a measuring system is particularly important where the primary transducer has a low output. For example, thermocouples have a typical output of only a few millivolts. Other types of signal processing element are those that filter out induced noise and remove mean levels etc. In some devices, signal processing is incorporated into a transducer, which is then known as a *transmitter*.

In addition to these three components just mentioned, some measurement systems have one or two other components, firstly to transmit the signal to some remote point and secondly to display or record the signal if it is not fed automatically into a feedback control system. Signal transmission is needed when the observation or application point of the output of a measurement system is some distance away from the site of the primary transducer. The signal transmission element has traditionally consisted of single or multi-cored cable, which is often screened to minimize signal corruption by induced electrical noise. However, fibre-optic cables are being used in ever increasing numbers in modern installations, in part because of their low transmission loss and imperviousness to the effects of electrical and magnetic fields.

The final optional element in a measurement system is the point where the measured signal is utilized. In some cases, this element is omitted altogether because the measurement is used as part of an automatic control scheme, and the transmitted signal is

fed directly into the control system. In other cases, this element in the measurement system takes the form either of a signal presentation unit or of a signal-recording unit.

Performance characteristics

Knowledge of the performance characteristics of an instrument is essential for selecting the most suitable instrument for specific measuring jobs. Performance characteristics of an instrument are mainly divided into two.

1. Static characteristics
2. Dynamic characteristics

Static Characteristics

The set of criteria defined for the instrument which is used to measure the quantities that are varying slowly with time or constant is called static characteristics.

Accuracy and inaccuracy (measurement uncertainty)

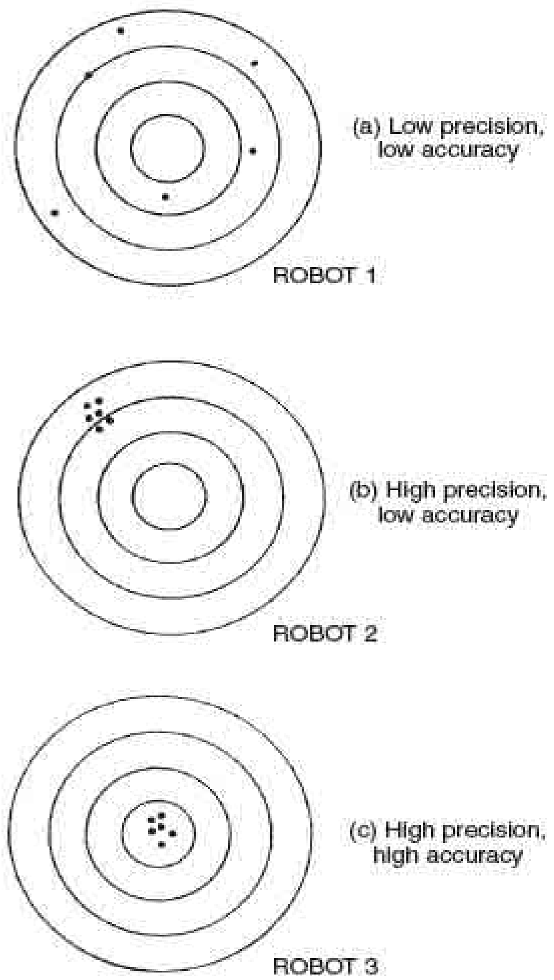
The *accuracy* of an instrument is a measure of how close the output reading of the instrument to the correct value. The measured value invariably differs from the true value because of the effects of disturbing inputs such as temperature, humidity etc. and because of the performance characteristics of the measuring system itself. In practice, it is more usual to quote the *inaccuracy* figure rather than the accuracy figure for an instrument. Inaccuracy is the extent to which a reading might be wrong, and is often quoted as a percentage of the full scale (f.s.) reading of an instrument. If, for example, a pressure gauge of range 0–10 bar has a quoted inaccuracy of 1.0% f.s. (1% of full-scale reading), then the maximum error to be expected in any reading is 0.1 bar. This means that when the instrument is reading 1.0 bar, the possible error is 10% of this value. For this reason, it is an important system design rule that instruments are chosen such that their range is appropriate to the spread of values being measured, in order that the best possible accuracy is maintained in instrument readings. Thus, if we were measuring pressures with expected values between 0 and 1 bar, we would not use an instrument with a range of 0–10 bar. The term *measurement uncertainty* is frequently used in place of inaccuracy.

Precision/repeatability/reproducibility

Precision is a term that describes an instrument's degree of freedom from random errors. If a large number of readings are taken of the same quantity by a high precision instrument, then the spread of readings will be very small. Precision is often, though incorrectly, confused with accuracy.

High precision does not imply anything about measurement accuracy. A high precision instrument may have a low accuracy. Low accuracy measurements from a high precision instrument are normally caused by a bias in the measurements, which is removable by recalibration.

The terms **repeatability** and reproducibility mean approximately the same but are applied in different contexts as given below. *Repeatability* describes the closeness of output readings when the same input is applied repetitively over a short period of time, with the same measurement conditions, same instrument and observer, same location and same conditions of use maintained throughout. ***Reproducibility*** describes the closeness of output readings for the same input when there are changes in the method of measurement, observer, measuring instrument, location, conditions of use and time of measurement. Both terms thus describe the spread of output readings for the same input. This spread is referred to as repeatability if the measurement conditions are constant and as reproducibility if the measurement conditions vary. The degree of repeatability or reproducibility in measurements from an instrument is an alternative way of expressing its precision. Figure illustrates this more clearly. The figure shows the results of tests on three industrial robots that were programmed to place components at a particular point on a table. The target point was at the centre of the concentric circles shown, and the black dots represent the points where each robot actually deposited components at each attempt. Both the accuracy and precision of Robot 1 are shown to be low in this trial. Robot 2 consistently puts the component down at approximately the same place but this is the wrong point. Therefore, it has high precision but low accuracy. Finally, Robot 3 has both high precision and high accuracy, because it consistently places the component at the correct target position.



Tolerance

Tolerance is a term that is closely related to accuracy and defines the maximum error that is to be expected in some value. Whilst it is not, strictly speaking, a static characteristic of measuring instruments, it is mentioned here because the accuracy of some instruments is sometimes quoted as a tolerance figure. When used correctly, tolerance describes the maximum deviation of a manufactured component from some specified value. One resistor chosen at random from a batch having a nominal value 1000W and tolerance 5% might have an actual value anywhere between 950W and 1050 W

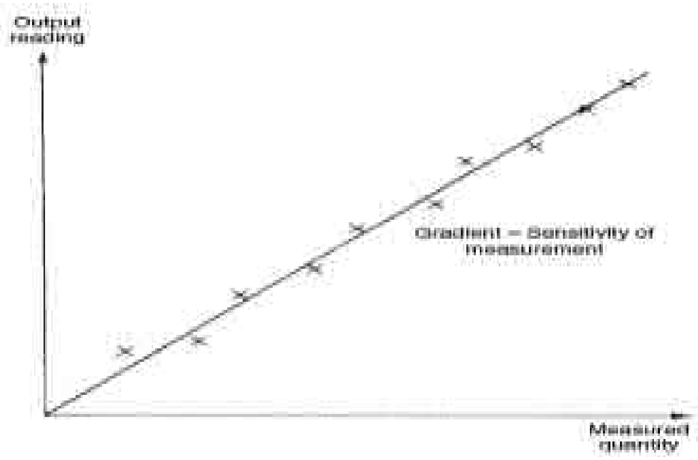
Range or span

The *range* or *span* of an instrument defines the minimum and maximum values of a quantity that the instrument is designed to measure. The range of the indicating instrument is normally from zero to some full scale value and span is simply difference between the full scale and lower scale value. But some instrument operate under a bias so that they start reading, for example, voltages from 150 V to

250 V only. The zero of these instruments is suppressed from indication by means of a bias. In such a case , the range is said to be from 150 V to 250 V and the span is 100 V.

Linearity

Linearity defines the proportionality between the input quantity and output quantity. It is normally desirable that the output reading of an instrument is linearly proportional to the quantity being measured. The Xs marked on Figure show a plot of the typical output readings of an instrument when a sequence of input quantities is applied to it. Normal procedure is to draw a good fit straight line through the Xs, as shown in Figure. (Whilst this can often be done with reasonable accuracy by eye, it is always preferable to apply a mathematical least-squares line-fitting technique.) The non-linearity is then defined as the maximum deviation of any of the output readings marked X from this straight line. Non-linearity is usually expressed as a percentage of full-scale reading.



Sensitivity of measurement

The sensitivity of measurement is a measure of the change in instrument output that occurs when the quantity being measured changes by a given amount. Thus, sensitivity is the ratio of the scale deflection to the value of measurand producing deflection. The sensitivity of measurement is therefore the slope of the straight line drawn on above figure. If, for example, a pressure of 2 bar produces a deflection of 10 degrees in a pressure transducer, the sensitivity of the instrument is 5 degrees/bar (assuming that the deflection is zero with zero pressure applied).

Threshold

Threshold is defined as the minimum input quantity that is necessary to cause a detectable change in the output signal from the zero indication. Manufacturers vary in the way that they specify threshold for instruments. Some quote absolute values, whereas others quote threshold as a percentage of full-scale readings. As an illustration, a car speedometer typically has a threshold of about 15 km/h. This means that, if the vehicle starts from rest and accelerates, no output reading is observed on the speedometer until the speed reaches 15 km/h.

Resolution

Resolution is the smallest increment of the input quantity to which the measuring system responds. Like threshold, *resolution* is sometimes specified as an absolute value and sometimes as a percentage of full scale deflection. One of the major factors influencing the resolution of an instrument is how finely its output scale is divided into subdivisions. Using a car speedometer as an example again, this has subdivisions of typically 20 km/h. This means that when the needle is between the scale markings, we cannot estimate speed more accurately than to the nearest 5 km/h. This figure of 5 km/h thus represents the resolution of the instrument.

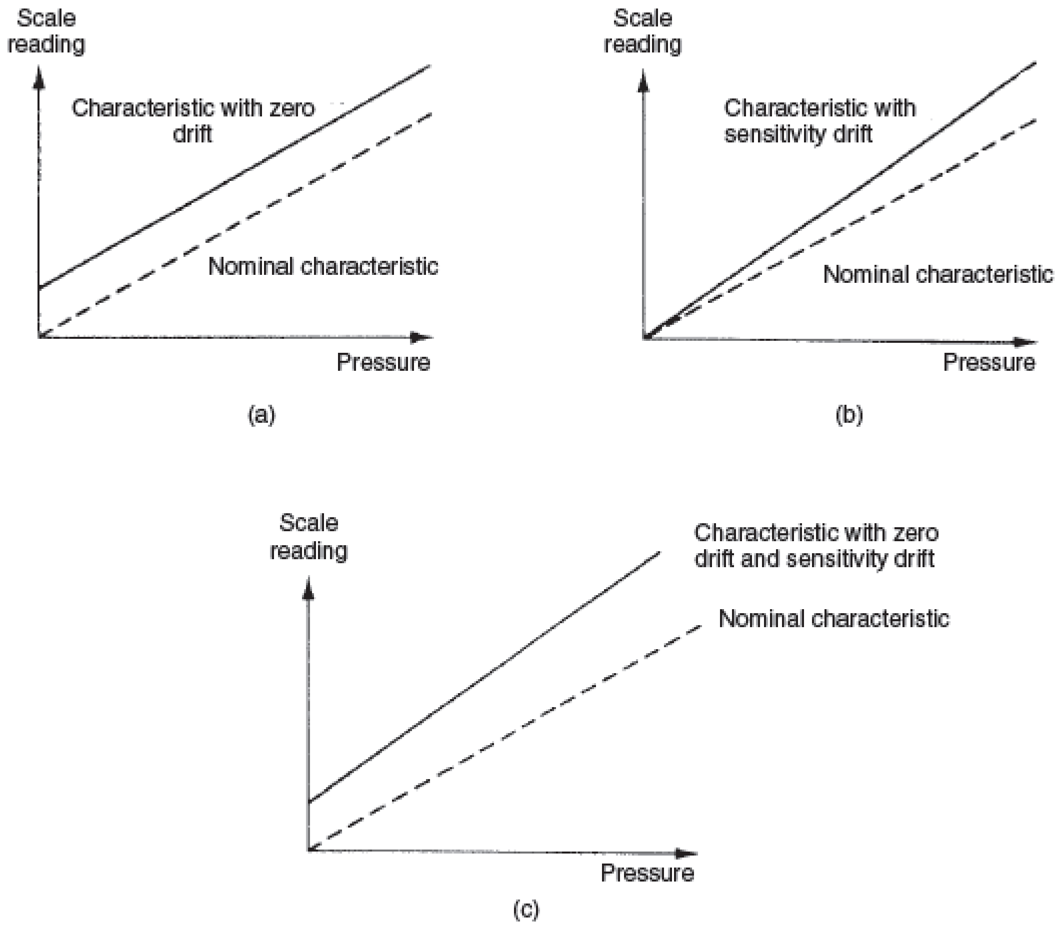
Sensitivity to disturbance

All calibrations and specifications of an instrument are only valid under controlled conditions of temperature, pressure etc. These standard ambient conditions are usually defined in the instrument specification. As variations occur in the ambient temperature etc., certain static instrument characteristics change, and the *sensitivity to disturbance* is a measure of the magnitude of this change. Such environmental changes affect instruments in two main ways, known as *zero drift* and *sensitivity drift*. Zero drift is sometimes known by the alternative term, *bias*.

Zero drift or ***bias*** describes the effect where the zero reading of an instrument is modified by a change in ambient conditions. This causes a constant error that exists over the full range of measurement of the instrument. Zero drift is normally removable by calibration.

Zero drift is also commonly found in instruments like voltmeters that are affected by ambient temperature changes. Typical units by which such zero drift is measured are volts/^{0}C. This is often called the *zero drift coefficient* related to temperature changes. If the characteristic of an instrument is sensitive to several environmental parameters, then it will have several zero drift coefficients, one for each environmental parameter. A typical change in the output characteristic of a pressure gauge subject to zero drift is shown in figure.

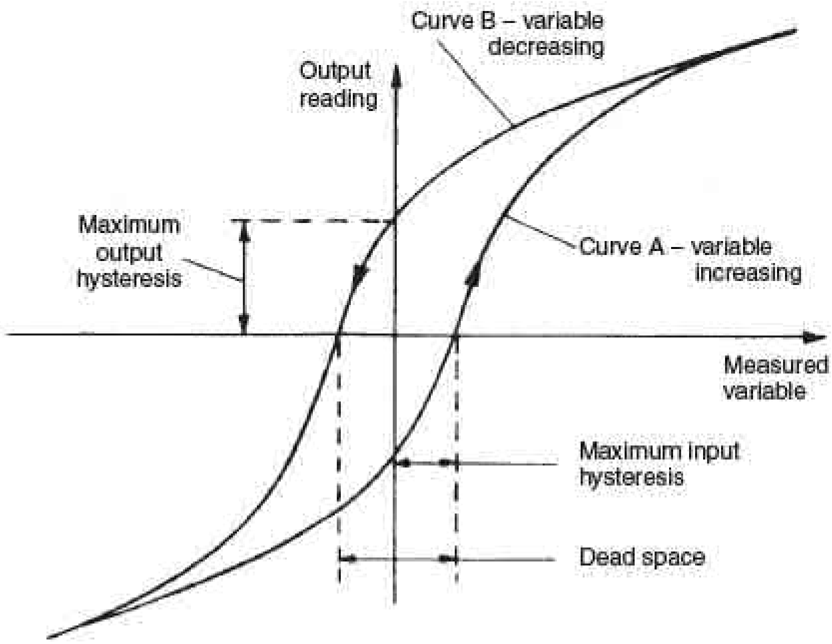
Sensitivity drift (also known as *scale factor drift*) defines the amount by which an instrument's sensitivity of measurement varies as ambient conditions change. It is quantified by sensitivity drift coefficients that define how much drift there is for a unit change in each environmental parameter that the instrument characteristics are sensitive to. Many components within an instrument are affected by environmental fluctuations, such as temperature changes: for instance, the modulus of elasticity of a spring is temperature dependent. Figure b shows what effect sensitivity drift can have on the output characteristic of an instrument. Sensitivity drift is measured in units of the form (angular degree/bar)/^{0}C. If an instrument suffers both zero drift and sensitivity drift at the same time, then the typical modification of the output characteristic is shown in figure c.



Hysteresis effects

Transducer hysteresis is evidenced by a difference in output when a series of inputs is applied first in an ascending or increasing direction and then in a descending or decreasing direction. This occurs as a result of the behavior of the materials used to manufacture the sensing element or as a result of the assembly of these materials. Transducer hysteresis is most evident in sensors that use metal diaphragms, bellows, or spring assemblies in the sensing element. In a pressure transducer, the metal diaphragm is stretched when the pressure is increased and then relaxes when the pressure is reduced. Certain stress levels are built up in the diaphragm material as the pressure is increased, and when the pressure is decreased not all this stress is released. This also means that the diaphragm deflection is not the same for increasing and decreasing pressures.

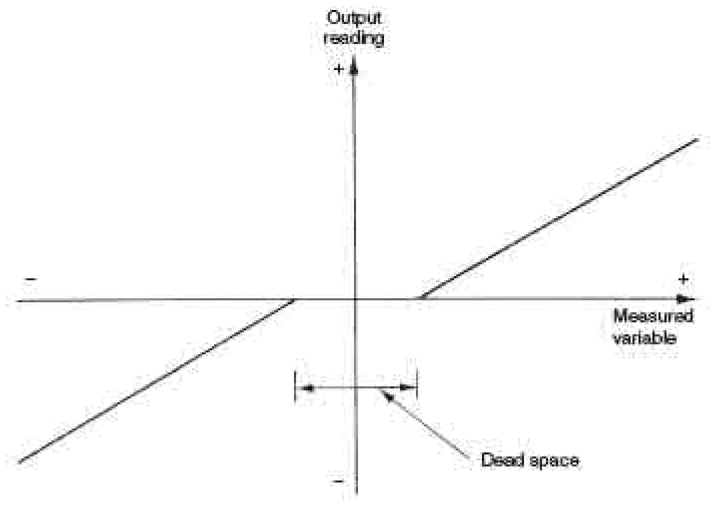
Figure illustrates the output characteristic of an instrument that exhibits *hysteresis*. If the input measured quantity to the instrument is steadily increased from a negative value, the output reading varies in the manner shown in curve (a). If the input variable is then steadily decreased, the output varies in the manner shown in curve (b). The non-coincidence between these loading and unloading curves is known as *hysteresis*. Two quantities are defined, *maximum input hysteresis* and *maximum output hysteresis*, as shown in Figure. These are normally expressed as a percentage of the full-scale input or output reading respectively.



Hysteresis is most commonly found in instruments that contain springs, such as the passive pressure gauge and the Prony brake (used for measuring torque). It is also evident when friction forces in a system have different magnitudes depending on the direction of movement, such as in the pendulum-scale mass-measuring device. Hysteresis can also occur in instruments that contain electrical windings formed round an iron core, due to magnetic hysteresis in the iron. This occurs in devices like the variable inductance displacement transducer, the LVDT and the rotary differential transformer.

Dead space

Dead space is defined as the range of different input values over which there is no change in output value. Dead band is the largest change in input quantity to which the measuring system does not respond. It is primarily caused by friction in the components of the sensor or by gaps in the mating surfaces of moving components such as gears. Dead band is identified by slowly increasing the input signal in small increments until a change of output is noted. The value of input at this point is noted, and the dead band is expressed as that value expressed as a percentage of the transducer span. Some instruments that do not suffer from any significant hysteresis can still exhibit a dead space in their output characteristics, however. Backlash in gears is a typical cause of dead space, and results in the sort of instrument output characteristic shown in figure. Backlash is commonly experienced in gearsets used to convert between translational and rotational motion (which is a common technique used to measure translational velocity).



Static error

It is the algebraic difference between the measured value and true value.

Error =measured value - True value.

Stability

The ability of an instrument to retain its performance throughout its specified operating life is called stability. Transducers and instruments of high stability need not be calibrated frequently. Zero stability defines the ability of instrument to restore to zero reading after the input quantity has been brought to zero, while other conditions remains the same.

2.Dynamic characteristics

Dynamic characteristics of a measuring systems relate to its performance when the measured is a function of time.(dynamic means varying with time). In measurement systems, the dynamic response of instruments must be anaysed because the parameters are functions of time.. The response of instruments or systems to dynamic i/ps are also functions of time.the terms related to dynamic response are

- Over shoot
- Peaktime
- Timedelay
- Time delay
- Setting time
- Time constant

Dynamic characteristics of instruments

The static characteristics of measuring instruments are concerned only with the teadystate

reading that the instrument settles down to, such as the accuracy of the reading etc.

The dynamic characteristics of a measuring instrument describe its behaviourbetween the time a measured quantity changes value and the time when the instrument output attains a steady value in response. As with static characteristics, any values for dynamic characteristics quoted in instrument data sheets only apply when the instrument is used under specified environmental conditions. Outside these calibration conditions, some variation in the dynamic parameters can be expected. In any linear, time-invariant measuring system, the following general relation can be written between input and output for time t > 0:

$$a_n \frac{d^n q_0}{dt^n} + a_{n-1} \frac{d^{n-1} q_0}{dt^{n-1}} + \cdots + a_1 \frac{dq_0}{dt} + a_0 q_0 = b_m \frac{d^m q_i}{dt^m} + b_{m-1} \frac{d^{m-1} q_i}{dt^{m-1}} + \cdots + b_1 \frac{dq_i}{dt} + b_0 q_i \qquad (2.1)$$

where qi is the measured quantity, q0 is the output reading and a0 . . . an, b0 . . . bm are

constants. The reader whose mathematical background is such that the above equation appears daunting should not worry unduly, as only certain special, simplified cases of it are applicable in normal measurement situations. The major point of importance is to have a practical appreciation of the manner in which various different types of instrument

respond when the measurand applied to them varies. If we limit consideration to that of step changes in the measured quantity only, then equation (2.1) reduces to:

$$a_n \frac{d^n q_0}{dt^n} + a_{n-1} \frac{d^{n-1} q_0}{dt^{n-1}} + \cdots + a_1 \frac{dq_0}{dt} + a_0 q_0 = b_0 q_i \qquad (2.2)$$

Zero order instrument

If all the coefficients a1 . . . an other than a0 in equation (2.2) are assumed zero, then:

$$a_0 q_0 = b_0 q_i \quad \text{or} \quad q_0 = b_0 q_i / a_0 = K q_i \qquad (2.3)$$

where K is a constant known as the instrument sensitivity as defined earlier. Any instrument that behaves according to equation (2.3) is said to be of zero order type. Following a step change in the measured quantity at time t, the instrument output moves immediately to a new value at the same time instant t, as shown in Figure 2.10. A potentiometer, which measures motion, is a good example of such an instrument, where the output voltage changes instantaneously as the slider is displaced along the potentiometer track.

First order instrument

If all the coefficients a2 . . . an except for a0 and a1 are assumed zero in

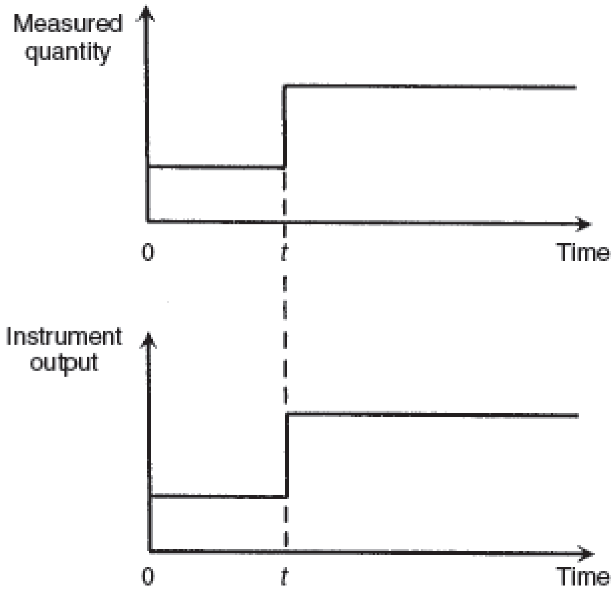
equation (2.2) then

$$a_1 \frac{dq_0}{dt} + a_0 q_0 = b_0 q_i \quad (2.4)$$

Any instrument that behaves according to equation (2.4) is known as a first order

instrument. If d/dt is replaced by the D operator in equation (2.4), we get:

$$a_1 D q_0 + a_0 q_0 = b_0 q_i \quad \text{and rearranging this then gives} \quad q_0 = \frac{(b_0/a_0) q_i}{[1 + (a_1/a_0) D]} \quad (2.5)$$



Zero order instrument characteristic.

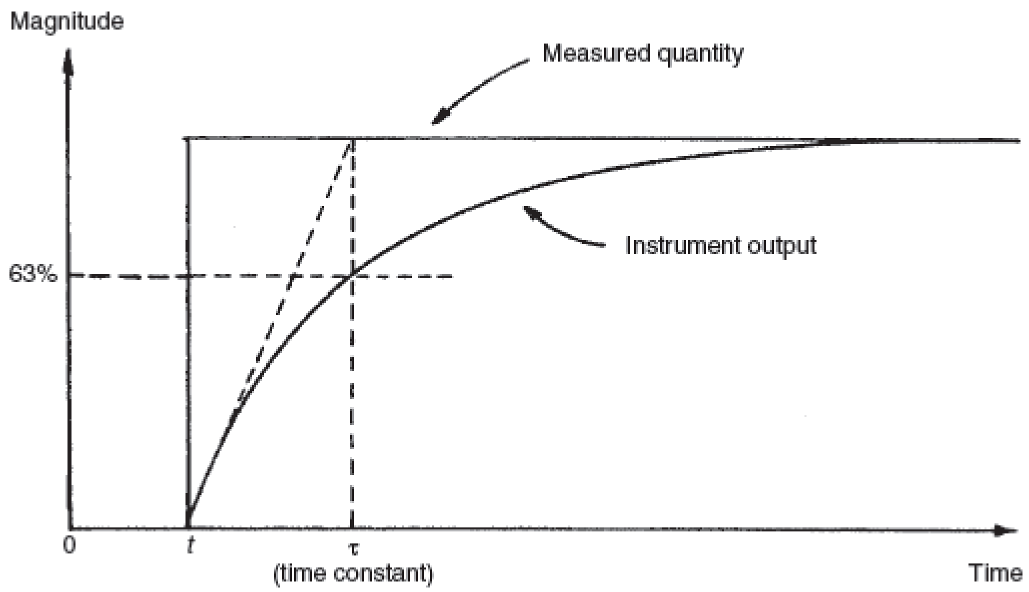
Defining K = b0/a0 as the static sensitivity and D = a1/a0 as the time constant of the system, equation (2.5) becomes:

$$q_0 = \frac{K q_i}{1 + \tau D} \quad (2.6)$$

If equation (2.6) is solved analytically, the output quantity q0 in response to a step change in qi at time t varies with time in the manner shown in Figure 2.11. The time constant _ of the step response is the time taken for the output quantity q0 to reach 63% of its final value. The liquid-in-glass thermometer (see Chapter 14) is a good example of a first order

instrument. It is well known that, if a thermometer at room temperature is plunged into boiling water, the output e.m.f. does not rise instantaneously to a level indicating 100 C, but instead approaches a reading indicating 100 C in a manner similar to that shown in Figure.

A large number of other instruments also belong to this first order class: this is of particular importance in control systems where it is necessary to take account of the time lag that occurs between a measured quantity changing in value and the measuring instrument indicating the change. Fortunately, the time constant of many first order instruments is small relative to the dynamics of the process being measured, and so no serious problems are created.



First order instrument characteristic

Second order instrument

If all coefficients a3 . . . an other than a0, a1 and a2 in equation (2.2) are assumed zero, then we get:

$$a_2\frac{d^2q_0}{dt^2}+a_1\frac{dq_0}{dt}+a_0q_0=b_0q_i \quad (2.7)$$

Applying the D operator again: $a_2D^2q_0+a_1Dq_0+a_0q_0=b_0q_i$, and rearranging:

$$q_0=\frac{b_0q_i}{a_0+a_1D+a_2D^2} \quad (2.8)$$

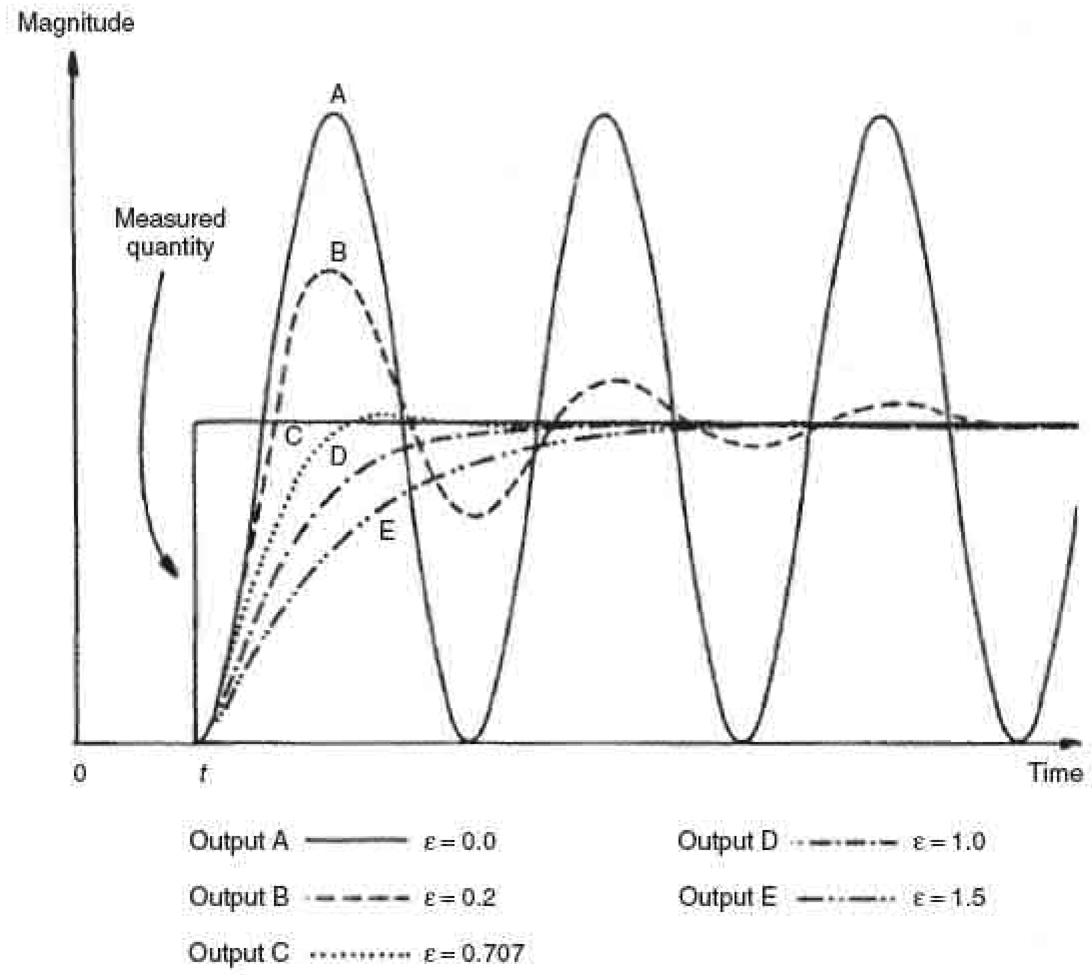
It is convenient to re-express the variables a0, a1, a2 and b0 in equation (2.8) in terms of three parameters K (static sensitivity), ω (undamped natural frequency) and ξ (damping ratio), where:

$$K=b_0/a_0;\quad \omega=a_0/a_2;\quad \xi=a_1/2a_0a_2$$

Re-expressing equation (2.8) in terms of K, ω and ξ we get:

$$\frac{q_0}{q_i}=\frac{K}{D^2/\omega^2+2\xi D/\omega+1} \quad (2.9)$$

This is the standard equation for a second order system and any instrument whose response can be described by it is known as a second order instrument. If equation (2.9) is solved analytically, the shape of the step response obtained depends on the value of the damping ratio parameter _. The output responses of a second order instrument for various values of _ following a step change in the value of the measured quantity at time t are shown. For case (A) where _ D 0, there is no damping and the instrument output exhibits constant amplitude oscillations when disturbed by any change in the physical quantity measured. For light damping of _ D 0.2, represented by case (B), the response to a step change in input is still oscillatory but the oscillations gradually die down. Further increase in the value of _ reduces oscillations and overshoot still more, as shown by curves (C) and (D), and finally the response becomes very overdamped as shown by curve (E) where the output reading creeps up slowly towards the correct reading. Clearly, the extreme response curves (A) and (E) are grossly unsuitable for any measuring instrument. If an instrument were to be only ever subjected to step inputs, then the design strategy would be to aim towards a damping ratio of 0.707, which gives the critically damped response (C). Unfortunately, most of the physical quantities that instruments are required to measure do not change in the mathematically convenient form of steps, but rather in the form of ramps of varying slopes. As the form of the input variable changes, so the best value for varies, and choice of _ becomes one of compromise between those values that are best for each type of input variable behaviour anticipated. Commercial second order instruments, of which the accelerometer is a common example, are generally designed to have a damping ratio somewhere in the range of 0.6–0.8.



Response characteristics of second order instruments

Analog and Digital information

Digital information

1. it is discrete &vary in steps
2. Easier to design
3. storage of information is easy
4. programmed and processed easily
5. not defined for every value of time

Analog information

1. variations/unit time it is in the form of continous or stepless
2. design is not easy
3. storage is difficult
4. difficult to program
5. Analog signals are defined for every value oh time

Errors

Error is the difference between the true value of the variable and the measured value.

Errors are classified as

1. Gross error

2. Systematic error

3. Random errors

Gross error

Gross error mainly occurs due to carelessness or lack of experience of a human being. These cover human mistakes in reading, recording and calculating results. These errors occur due to incorrect adjustments of instruments.

Thers errors can be minimized by

1.taking great care while taking reading, recordings and calculating results.

2. Taking multiple readings preferably by different persons.

Systematic errors

There errors are mainly occur due to the short comings of the instrument such as defective or work parts ageing effects, environmental effects. A constant uniform deviation of the operation of an instrument is known as systematic error.

There are three types of systematic errors as

1. Instrumental errors
2. Environmental errors
3. Observational errors

Instrumental errors

These errors are mainly due to following three reasons

1. Short-comings of instrument

These are because of the mechanical structure of the instruments eg. Friction in the bearings of various moving parts, irregular spring tensions, reduction intension due to improper handlings, hysteresis, gear backlash, variation in air gap etc. These can be avoided by the following methods..

1. Selecting proper instrument and planning the transducer for the measurement.
2. Recognizing the effect of such errors and applying the proper correction factors.
3. Calibrating the instrument carefully against standard.

2. Misuse of instrument

A good instrument if used in abnormal way gives misleading results. Poor initial adjustments, improper zero setting, using leads of high resistance etc are the examples of misuse a good instrument.

3. Loading effects

Loading effects due to the conditions external to the measuring instrument. The various factors that cause these errors are temperature changes, pressure changes, thermal emf., stray capacitance, cross capacitance effect of external fields, aging of equipments and frequency sensitivity of an instrument. Various methods to reduce errors are

1. Using proper correction factors and using information supplied by the manufacturer of the instrument
2. Using the arrangements which will keep the surrounding conditioning, temperature control enclosures etc.
3. Reducing the effect of dust humidity on the components in the instruments.
4. The effects of external fields can be minimized by using the magnetic or electrostatic shields of screens.

Sources of systematic error

Systematic errors in the output of many instruments are due to factors inherent in the manufacture of the instrument arising out of tolerances in the components of the instrument. They can also arise due to wear in instrument components over a period of time. In other cases, systematic errors are introduced either by the effect of environmental

disturbances or through the disturbance of the measured system by the act of measurement.

System disturbance due to measurement

Disturbance of the measured system by the act of measurement is a common source of systematic error.

Errors during the measurement process

Thermometer, which would initially be at room temperature, and plunge it into the water. In so doing, we would be introducing a relatively cold mass (the thermometer) into the hot water and a heat transfer would take place between the water and the thermometer. This heat transfer would lower the temperature of the water. Whilst the reduction in temperature in this case would be so small as to be undetectable by the limited measurement resolution of such a thermometer, the effect is finite and clearly establishes the principle that, in nearly all measurement situations, the process of measurement disturbs the system and alters the values of the physical quantities being measured. A particularly important example of this occurs with the orifice plate. This is placed into a fluid-carrying pipe to measure the flow rate, which is a function of the pressure that is measured either side of the orifice plate. This measurement procedure causes a permanent pressure loss in the flowing fluid. The disturbance of the measured system can often be very significant.

Errors due to environmental inputs

An environmental input is defined as an apparently real input to a measurement system that is actually caused by a change in the environmental conditions surrounding the measurement system. The fact that the static and dynamic characteristics specified for measuring instruments are only valid for particular environmental conditions (e.g. of temperature and pressure) has already been discussed at considerable length in Chapter 2. These specified conditions must be reproduced as closely as possible during calibration exercises because, away from the specified calibration conditions, the characteristics of measuring instruments vary to some extent and cause measurement errors.The magnitude of this environment-induced variation is quantified by the two constants known as sensitivity drift and zero drift, both of which are generally included in the published specifications for an instrument. Such variations of environmental conditions away from the calibration conditions are sometimes described as modifying inputs to the measurement system because they modify the output of the system. When such modifying inputs are present, it is often difficult to determine how much of the output change in a measurement system is due to a change in the measured variable and how much is due to a change in environmental conditions. This is illustrated by the following example. Suppose we are given a small closed box and told that it may contain either a mouse or a rat.

System designers are therefore charged with the task of either reducing the susceptibility of measuring instruments to environmental inputs or, alternatively, quantifying the effect of environmental inputs and correcting for them in the instrument output reading.

Connecting leads

In connecting together the components of a measurement system, a common source of error is the failure to take proper account of the resistance of connecting leads (or pipes in the case of pneumatically or hydraulically actuated measurement systems). For instance, in typical applications of a resistance thermometer, it is common to find that the thermometer is separated from other parts of the measurement system by perhaps 100 metres.

Not only should they be of adequate cross-section so that their resistance is minimized, but they should be adequately screened if they are thought likely to be subject to electrical or magnetic fields that could otherwise cause induced noise. Where screening is thought essential, then the routing of cables also needs careful planning. In one application in the author's personal experience involving instrumentation of an electrical

steel making furnace, screened signal-carrying cables between transducers on the arc furnace and a control room at the side of the furnace were initially corrupted by high amplitude 50 Hz noise. However, by changing the route of the cables between the transducers and the control room, the magnitude of this induced noise was reduced by

a factor of about ten.

Reduction of systematic errors

The prerequisite for the reduction of systematic errors is a complete analysis of the measurement system that identifies all sources of error. Simple faults within a system, such as bent meter needles and poor cabling practices, can usually be readily and cheaply rectified once they have been identified. However, other error sources require more detailed analysis and treatment. Various approaches to error reduction are considered

below.

Careful instrument design

Careful instrument design is the most useful weapon in the battle against environmental inputs, by reducing the sensitivity of an instrument to environmental inputs to as low a level as possible. For instance, in the design of strain gauges, the element should be constructed from a material whose resistance has a very low temperature coefficient (i.e. the variation of the resistance with temperature is very small). However, errors due to the way in which an instrument is designed are not always easy to correct, and a choice often has to be made between the high cost of redesign and the alternative of accepting the reduced measurement accuracy if redesign is not undertaken.

Calibration

Instrument calibration is a very important consideration in measurement systems. All instruments suffer drift in their characteristics, and the rate at which this happens depends on many factors, such as the environmental conditions in which instruments are used and the frequency of their use. Thus, errors due to instruments being out of calibration can usually be rectified by increasing the frequency of recalibration.

Observationtional errors.

These are the errors introduced by the observer. These are many sources of observational errors such as parallax error while reading a scale, selection , the habits of individual observers etc.

To eliminate such errors we should use the instruments with mirrors knife edge pointers etc. Instruments with digital display can also be used.

Errors in measurement systems can be divided into those that arise during the measurement process and those that arise due to later corruption of the measurement signal by induced noise during transfer of the signal from the point of measurement to some other point.

Random errors are perturbations of the measurement either side of the true value caused by random and unpredictable effects, such that positive errors and negative errors occur in approximately equal numbers for a series of measurements made of the same quantity. Such perturbations are mainly small, but large perturbations occur from time to time, again unpredictably. Random errors often arise when measurements are taken by human observation of an analogue meter, especially where this involves interpolation between scale points. Electrical noise can also be a source of random errors. To a large extent, random errors can be overcome by taking the same measurement a number of times and extracting a value by averaging or other statistical techniques. However, any quantification of the measurement value and statement of error bounds remains a statistical quantity. Because of the nature of random errors and the fact that large perturbations in the measured quantity occur from time to time, the best that we can do is to express measurements in probabilistic terms: we may be able to assign a 95% or even 99% confidence level that the measurement is a certain value within error bounds of, say, 1%, but we can never attach a 100% probability to measurement values that are subject to random errors. Finally, a word must be said about the distinction between systematic and random errors. Error sources in the measurement system must be examined carefully to determine what type of error is present, systematic or random, and to apply the appropriate treatment. In the case of manual data measurements, a human observer may make a different observation at each attempt, but it is often reasonable to assume that the errors are random and that the mean of these readings is likely to be close to the correct value. However, this is only true as long as the human observer is not introducing a parallax-induced systematic error as well by persistently reading the position of a needle against the scale of an analogue meter from one side rather than from directly above. In that case, correction would have to be made for this systematic error (bias) in the measurements before statistical techniques were applied to reduce the effect of random errors.

Errors during the measurement process

Manual correction of output reading

In the case of errors that are due either to system disturbance during the act of measurement or due to environmental changes, a good measurement technician can substantially reduce errors at the output of a measurement system by calculating the effect of such systematic errors and making appropriate correction to the instrument readings. This is not necessarily an easy task, and requires all disturbances in the measurement system to be quantified. This procedure is carried out automatically by intelligent instruments.

Intelligent instruments

Intelligent instruments contain extra sensors that measure the value of environmental inputs and automatically compensate the value of the output reading. They have the ability to deal very effectively with systematic errors in measurement systems, and errors can be attenuated to very low levels in many cases.

Quantification of systematic errors

Once all practical steps have been taken to eliminate or reduce the magnitude of systematic errors, the final action required is to estimate the maximum remaining error that may exist in a measurement due to systematic errors. Unfortunately, it is not always possible to quantify exact values of a systematic error, particularly if measurements are subject to unpredictable environmental conditions. Data sheets supplied by instrument manufacturers usually quantify systematic errors in this way, and such figures take account of all systematic errors that may be present in output readings from the instrument.

Statistical analysis of measurements subject to random errors

Mean and median values

Mean:

The average value of a set of measurements of a constant quantity can be expressed as either the mean value or the median value. As the number of measurements increases, the difference between the mean value and median values becomes very small. However, for any set of n measurements x1, x2,…………., xn of a constant quantity, the most likely true value is the *mean* given by:

$$x_{mean} = \frac{x_1 + x_2 + \cdots x_n}{n}$$

This is valid for all data sets where the measurement errors are distributed equally about the zero error value, i.e. where the positive errors are balanced in quantity and magnitude by the negative errors.

Median

The *median* is an approximation to the mean that can be written down without having to sum the measurements. The median is the middle value when the measurements in the data set are written down in ascending order of magnitude. For a set of n measurements x1, x2 , …………. , xn of a constant quantity, written down in ascending order of magnitude, the median value is given by:

$$x_{median} = x_{n+1}/2$$

Thus, for a set of 9 measurements x1, x2, ……..xn arranged in order of magnitude, the

median value is x5.

For an even number of measurements, the median value is midway between the two centre values, i.e. for 10 measurements x1, …….. …, x10, the median value is given by: $(x_5 + x_6)/2.$ Suppose that the length of a steel bar is measured by a number of different observers and the following set of 11 measurements are recorded (units mm). We will call this measurement set A.398, 420, 394, 416, 404, 408, 400, 420, 396, 413, 430, Measurement set A_

mean = 409.0 and

median = 408.

Suppose now that the measurements are taken again using a better measuring rule, and with the observers taking more care, to produce the following measurement set B:

409 406 402 407 405 404 407 404 407 407 408 _Measurement set B_ For these measurements,

mean = 406.0 and

median = 407.

Which of the two measurement sets A and B, and the corresponding mean and median values, should we have most confidence in? Intuitively, we can regard measurement set B as being more reliable since the measurements are much closer together. In set A, the spread between the smallest (396) and largest (430) value is 34, whilst in set B, the spread is only 6. *Thus, the smaller the spread of the measurements, the more confidence we have in the mean or median value calculated*.

Let us now see what happens if we increase the number of measurements by extending

measurement set B to 23 measurements. We will call this measurement set C. 409 ,406 402, 407, 405, 404, 407, 404, 407, 407, 408, 406, 410, 406, 405, 408, 406, 409, 406, 405, 409, 406, 407 _Measurement set C_

Now, mean = 406.5 and median = 406.

This confirms our earlier statement that the median value tends towards the mean value as the number of measurements increases.

Standard deviation and variance

Expressing the spread of measurements simply as the range between the largest and smallest value is not in fact a very good way of examining how the measurement values are distributed about the mean value. A much better way of expressing the distribution is to calculate the variance or standard deviation of the measurements. The starting point for calculating these parameters is to calculate the deviation (error) di of each measurement xi from the mean value xmean:

$$d_i = x_i - x_{\text{mean}}$$

The *variance* (V) is then given by

$$V = \frac{d_1^2 + d_2^2 \cdots d_n^2}{n-1}$$

The *standard deviation* is simply the square root of the variance.

$$\sigma = \sqrt{V} = \sqrt{\frac{d_1^2 + d_2^2 \cdots d_n^2}{n-1}}$$

<u>Example</u>

Calculate σ and V for measurement set.

Solution

First, draw a table of measurements and deviations for set A (mean D 409 as calculated earlier):

Measurement	398	420	394	416	404	408	400	420	396	413	430
Deviation from mean	−11	+11	−15	+7	−5	−1	−9	+11	−13	+4	+21
$(\text{deviations})^2$	121	121	225	49	25	1	81	121	169	16	441

$\sum(\text{deviations}^2) = 1370$; n = number of measurements = 11.
Then, from (3.7), $V = \sum(\text{deviations}^2)/n - 1 := 1370/10 = 137$; $\sigma = \sqrt{V} = 11.7$.

The measurements and deviations for set B are (mean = 406 as calculated earlier):

Measurement	409	406	402	407	405	404	407	404	407	407	408
Deviation from mean	+3	0	−4	+1	−1	−2	+1	−2	+1	+1	+2
$(\text{deviations})^2$	9	0	16	1	1	4	1	4	1	1	4

From this data, using (3.7) and (3.8), $V = 4.2$ and $\sigma = 2.05$.

Note that the smaller values of V and _ for measurement set B compared with A correspond with the respective size of the spread in the range between maximum and minimum values for the two sets.

ž Thus, as V and _ decrease for a measurement set, we are able to express greater confidence that the calculated mean or median value is close to the true value, i.e. that the averaging process has reduced the random error value close to zero. ž Comparing V and _ for measurement sets B and C, V and _ get smaller as the number of measurements increases, confirming that confidence in the mean value increases as the number of measurements increases. We have observed so far that random errors can be reduced by taking the average (mean or median) of a number of measurements. However, although the mean or median value is close to the true value, it would only become exactly equal to the true value if we could average an infinite number of measurements. As we can only make a finite number of measurements in a practical situation, the average value will still

have some error. This error can be quantified as the *standard error of the mean*, which will be discussed in detail a little later. However, before that, the subject of graphical analysis of random measurement errors needs to be covered

UNIT II

ELECTRICAL AND ELECTRONICS INSTRUMENTS

Principle and types of analog and digital voltmeters, ammeters, multi meters – single and three phase wattmeter's and energy meters – magnetic measurements – determination of B-H curve and measurements of iron loss – instrument transformers – instruments for measurement of frequency and phase.

Theory Permanent Magnet Moving Coil (PMMC) Instruments

The general theory of moving-coil instruments may be dealt with considering a rectangular coil of turns, free to rotate about a vertical axis. *N*

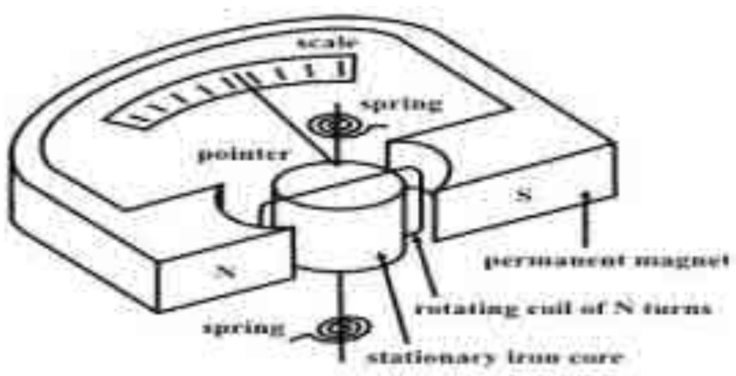


Fig. 42.1(a): Permanent Magnet Moving Coil Instrument.

Fig. 42.1(a) shows the basic construction of a PMMC instrument. A moving coil instrument consists basically of a permanent magnet to provide a magnetic field and a small lightweight coil is wound on a rectangular soft iron core that is free to rotate around

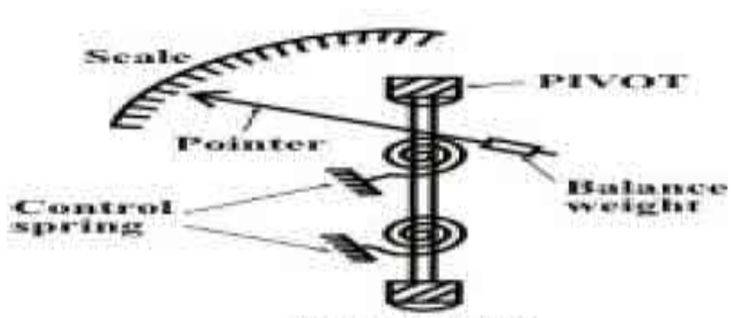


Fig. 42.1(b)

its vertical axis. When a current is passed through the coil windings, a torque is developed on the coil by the interaction of the magnetic field and the field set up by the current in the coil. The aluminum pointer attached to rotating coil and the pointer moves around the calibrated scale indicates the deflection of the coil. To reduce parallax error a mirror is usually placed along with the scale. A balance weight is also attached to the pointer to counteract its weight (see Fig.). To use PMMC device as a meter, two problems must be solved. First, a way must be found to return the coil to its original position when there is no current through the coil. Second, a method is needed to indicate the amount of coil movement. The first problem is solved by the use of hairsprings attached to each end of the coil as shown in Fig. . These hairsprings are not only supplying a restoring torque but also provide an electric connection to the rotating coil. With the use of hairsprings, the coil will return to its initial position when no current is flowing though the coil. The springs will also resist the movement of coil when there is current through coil. When the developing force between the magnetic fields (from permanent magnet and electro magnet) is exactly equal to the force of the springs, the coil rotation will stop. The coil set up is supported on jeweled bearings in order to achieve free movement. Two other features are considered to increase the accuracy and efficiency of this meter movement. First, an iron core is placed inside the coil to concentrate the magnetic fields. Second, the curved pole faces ensure the turning force on the coil increases as the current increases.

It is assumed that the coil sides are situated in a uniform radial magnetic field of flux density2/*Bwbm*, let the length of a coil side (within the magnetic field) be (meter), and the distance from each coil side to the axis be (meter). *lr*

Principle of operation

It has been mentioned that the interaction between the induced field and the field produced by the permanent magnet causes a deflecting torque, which results in rotation of the coil. The deflecting torque produced is described below in mathematical form:

Truly speaking, the equation (42.2) is valid while the iron core is cylindrical and the air gap between the coil and pole faces of the permanent magnet is uniform. This result the flux density B is constant and the torque is proportional to the coil current and instrument scale is linear.

Controlling Torque: The value of control torque depends on the mechanical design of the control device. For spiral springs and strip suspensions, the controlling torque is directly proportional to the angle of deflection of the coil.

..,*ie*Control torque $=C\theta$ (42.3)

where,

θ = deflection angle in radians and = spring constant *C*/.*Nmrad*

Damping Torque: It is provided by the induced currents in a metal former or core on which the coil is wound or in the circuit of the coil itself. As the coil moves in the field of the permanent magnet, eddy currents are set up in the metal former or core. The magnetic field produced by the eddy currents opposes the motion of the coil. The pointer will therefore swing more slowly to its proper position and come to rest quickly with very little oscillation. Electromagnetic damping is caused by the induced effects in the moving coil as it rotates in magnetic field, provided the coil forms part of closed electric circuit.

Deflecting torque:

If the coil is carrying a current of I amp, the force on a coil side B il N (Newton N)

Torque due to both coil side = (2r) (Bil N) (N m)

Where G is the galvanometer constant and is expressed as G=2 r BlN (Nm/amp)

=NBA (Nm/amp)

Where A= 2rl= area of Coil.

N=no of turns of the coil.

B=flux density in Wb/m^2

L=length of the vertical side of the coil,m

2r=breath of the coil.

I=current in ampere.

A= 2rl= area, m^2

Equation of motion : the resulting torque in a coil or motion of a coil in a manganetic filed is due to the combined effect of deflecting torque (T_d) controlling torque($C\theta$) damping torque $D\frac{d\theta}{dt}$ and it is expressed mathematically as

$$j\frac{d^2\theta}{dt^2} = Gi - C\theta - D\frac{d\theta}{dt} = \frac{Jd^2\theta}{dt^2} + \frac{Dd\theta}{dt} + c\theta = G\,I$$

Where J is the moment of inertia of moving parts. One can easily study the dynamic behavior of the above second order system by solving the differential equation

Remarks: When the moving system reached at steady state i.e. at final deflected position, the controlling torque becomes equal and opposite to the deflecting torque. The deflecting angle is directly proportional to the current in the movable coil (see eq). For this reason, the scale of the moving coil instrument is calibrated linearly

Multi-range ammeters and voltmeters

An ammeter is required to measure the current in a circuit and it therefore connected in series with the components carrying the current. If the ammeter resistance is not very much smaller than the load resistance, the load current can be substantially altered by the inclusion of the ammeter in the circuit. To operate a moving coil instrument around a current level 50ma is impractical owing to the bulk and weight of the coil that would be required. So, it is necessary to extend the meter-range shunts (in case of ammeters) and multipliers (in case of volt meters) are used in the following manner.

For higher range ammeters a low resistance made up of managing (low temperature coefficient of resistance) is connected in parallel to the moving coil (see Fig.) and instrument may be calibrated to read directly to the total current.

They are called shunts. The movement of PMMC instrument is not inherently insensitive to temperature, but it may be temperature-compensated by the appropriate use of series and shunt resistors of copper and managing. Both the magnetic field strength and spring-tension decrease with an increase in temperature. On other side, the coil resistance

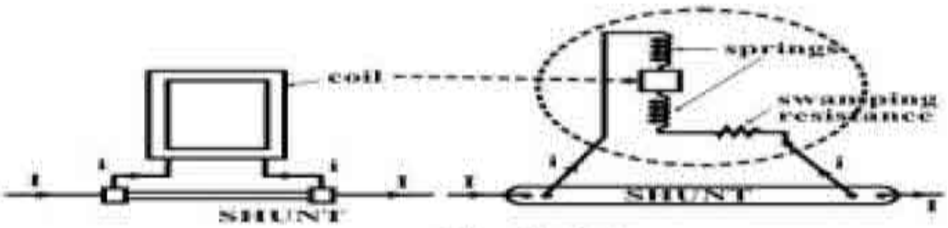


Fig. 42.2(a)

increases with an increase in temperature. These changes lead to make the pointer read low for a given current with respect to magnetic field strength and coil resistance. Use of manganin resistance (known as swamping resistance which has a temperature coefficient practically zero) in series with the coil resistance can reduce the error due to the variation of resistance of the moving coil. The swamping resistance () is usually three times that of coil thereby reducing a possible error of, say, 4% to 1%. A multirange ammeter can be constructed simple by employing several values of shunt resistances, with a rotary switch to select the desired range. Fig. 42.2(b) shows the circuit arrangement. *r*

When an instrument is used in this fashion, care must be taken to ensure shunt does not become open-circuited, even for a very short instant. When the switch is moved from position '*B*' to '*C*' or moved to any positions, the shunt resistance will remain open-circuited for a fraction of time, resulting a very large current may flow through the ammeter and damage the instrument. To avoid such situation, one may use the make-before-break switch as shown in Fig.42.(c).

The wide-ended moving contact connected to the next terminal to which it is being moved before it loses contact with the previous terminals. Thus, during the switching time there are two resistances are parallel with the instrument and finally the required shunt only will come in parallel to the instrument

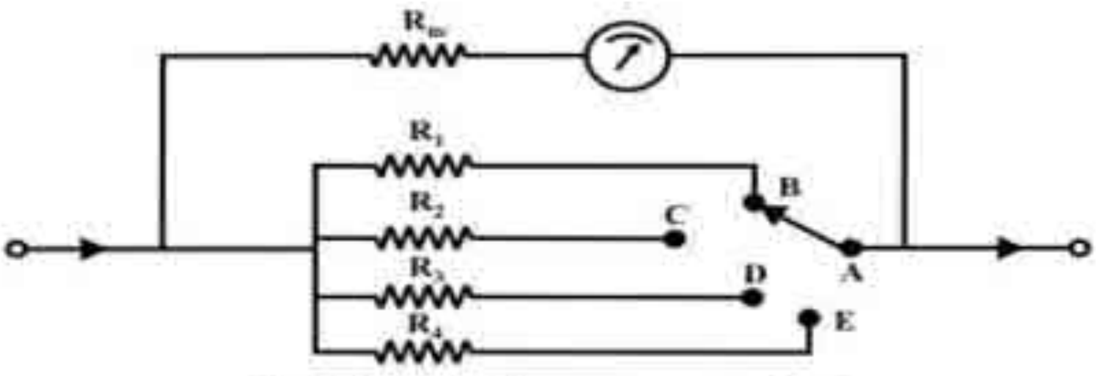


Fig. 42.2(b): Multi-range ammeter circuit

When an instrument is used in this fashion, care must be taken to ensure shunt does not become open circuit, even for a very short instant. When the switch is moved from the position B to C or moved to any position, the shunt resistance will remain open circuit for a fraction of time, resulting a very large current may floe through the ammeter and damage the instrument .to avoid such situation, one may use the make before break switch as shown in fig.

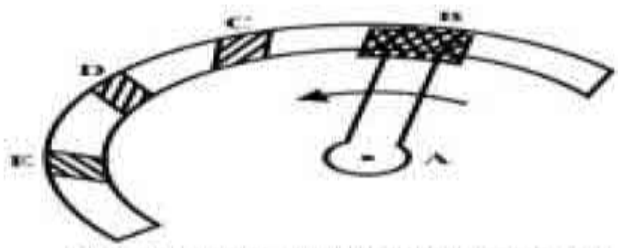


Fig. 42.2(c): Make-before break

Multi-range voltmeter: A dc voltmeter is constructed by a connecting a resistor in series with a PMMC instrument. Unlike an ammeter, a voltmeter should have a very high resistances *R* and it is normally connected in parallel with the circuit where the voltage is to be measured (see Fig.42.4). To minimize voltmeter loading, the voltmeter operating current should be very small i.e., the resistance connected in series with the coil should be high.

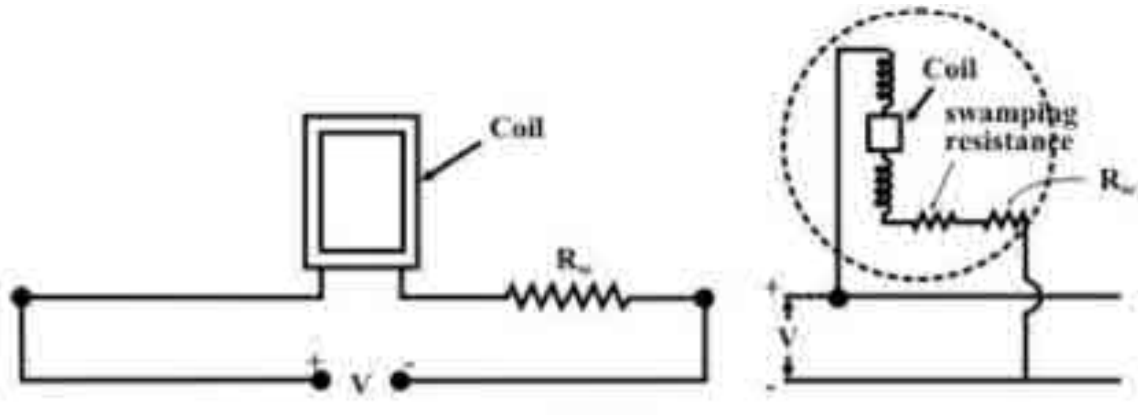


Fig. 42.4

The moving coil instrument can be suitable modified to act either as an ammeter or as a voltmeter. For multi range voltmeter the arrangement is follows as shown in fig. any one of several multiplier resistor is selected by means of rotary switch. Unlike the case of the ammeter, the rotary switch used with the voltmeter should be a break before make, type, that is, moving contact should be disconnect from one terminal before connecting to the next terminal

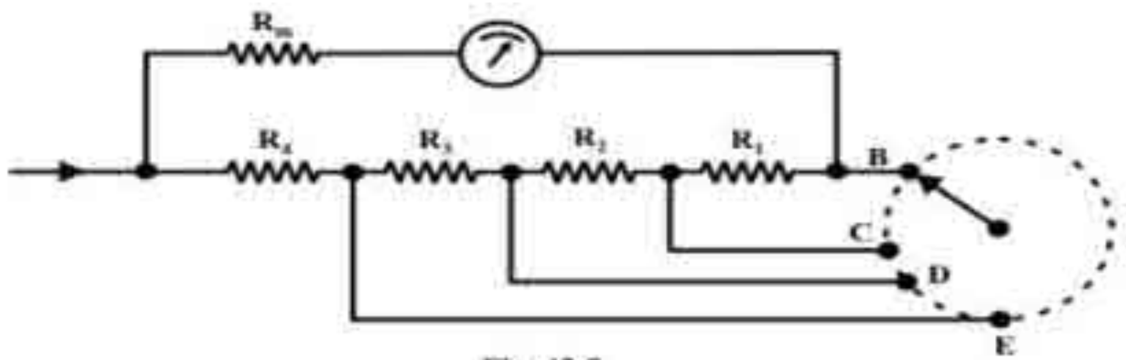


Fig. 42.5

Advantages, Limitations and sources of errors

Advantages:

• The scale is uniformly divided (see at steady state , *sGIC*θ=).

• The power consumption can be made very low (25200*WtoW*μμ).

• The torque-weight ratio can be made high with a view to achieve high accuracy.

• A single instrument can be used for multi range ammeters and voltmeters.

• Error due to stray magnetic field is very small.

Limitations:

• They are suitable for direct current only.

• The instrument cost is high.

• Variation of magnet strength with time.

The Errors are due to:

i) Frictional error, ii) Magnetic decay, iii) Thermo electric error, iv) Temperature error.

Errors can be reduced by following the steps given below:

• Proper pivoting and balancing weight may reduce the frictional error.

• Suitable aging can reduce the magnetic decay.

• Use of managing resistance in series (swamping resistance) can nullify the effect of variation of resistance of the instrument circuit due to temperature variation.

• The stiffness of spring, permeability of magnetic core (Magnetic core is the core of electromagnet or inductor which is typically made by winding a coil of wire around a ferromagnetic material) decreases with increases in temperature.

Ammeter Sensitivity:

Ammeter sensitivity is determined by the amount of current required by the meter coil to produce full-scale deflection of the pointer. The smaller the amount of current required producing this deflection, the greater the sensitivity of the meter. A meter movement that requires only 100 microamperes for full- scale deflection has a greater sensitivity than a meter movement that requires 1 mA for the same deflection.

Voltmeter Sensitivity:

The sensitivity of a voltmeter is given in ohms per volt. It is determined by dividing the sum of the resistance of the meter (R_m), plus the series resistance (R_s), by the full-scale reading in volts.

Construction and Basic principle operation of Moving-iron Instruments

We have mentioned earlier that the instruments are classified according to the principles of operation. Furthermore, each class may be subdivided according to the nature of the movable system and method by which the operating torque is produced. Specifically, the electromagnetic instruments are sub-classes as (i) moving-iron instruments (ii) electro-dynamic or dynamometer instruments, (iii) induction instruments. In this section, we will discuss briefly the basic principle of moving-iron instruments that are generally used to measure alternating voltages and currents. In moving –iron instruments the movable system consists of one or more pieces of specially-shaped soft iron, which are so pivoted as to be acted upon by the magnetic field produced by the current in coil. There are two general types of moving-iron instruments namely (i) Repulsion (or double iron) type (ii) Attraction (or single-iron) type. The brief description of different components of a moving-iron instrument is given below.

• Moving element: a small piece of soft iron in the form of a vane or rod

• Coil: to produce the magnetic field due to current flowing through it and also to magnetize the iron pieces.

• In repulsion type, a fixed vane or rod is also used and magnetized with the same polarity.

• Control torque is provided by spring or weight (gravity)

• Damping torque is normally pneumatic, the damping device consisting of an air chamber and a moving vane attached to the instrument spindle.

• Deflecting torque produces a movement on an aluminum pointer over a graduated scale.

Construction of Moving-iron Instruments

The deflecting torque in any moving-iron instrument is due to forces on a small piece of magnetically ‘soft’ iron that is magnetized by a coil carrying the operating current. In repulsion (Fig.42.7) type moving–iron instrument consists of two cylindrical soft iron vanes mounted within a fixed current-carrying coil. One iron vane is held fixed to the coil frame and other is free to rotate, carrying with it the pointer shaft. Two irons lie in the magnetic field produced by the coil that consists of only few turns if the instrument is an ammeter or of many turns if the instrument is a voltmeter. Current in the coil induces both vanes to become magnetized and repulsion between the similarly magnetized vanes produces a proportional rotation. The deflecting torque is proportional to the square of the current in the coil, making the instrument reading is a true 'RMS' quantity Rotation is opposed by a hairspring that produces the restoring torque. Only the fixed coil carries load current, and it is constructed so as to withstand high transient current. Moving iron instruments having scales that are nonlinear and somewhat crowded in the lower range of calibration. Another type of instrument that is usually classed with the attractive types of instrument is shown in Fig.42.8.

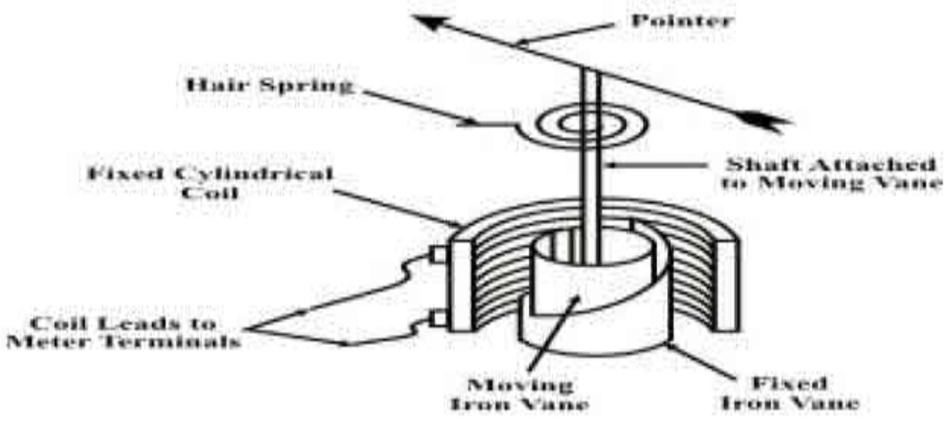


Fig. 42.7: Repulsion type.

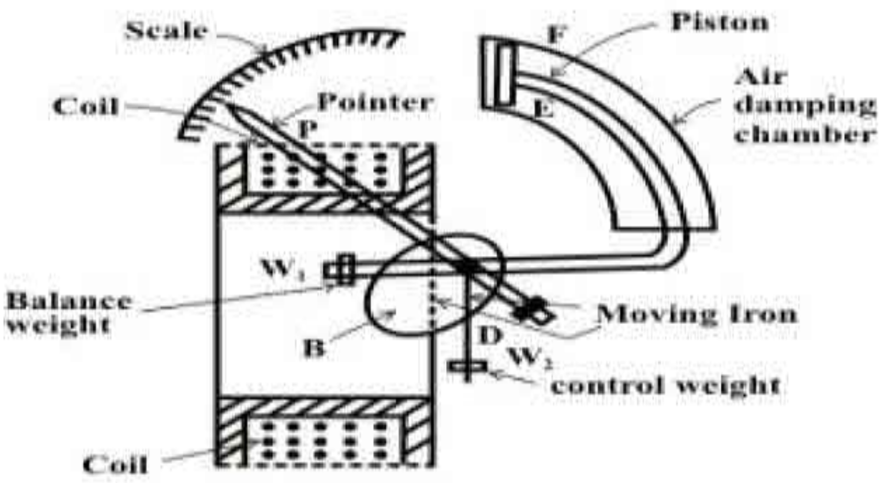


Fig. 42.8: Attraction type

This instrument consists of a few soft iron discs (*B*) that are fixed to the spindle , pivoted in jeweled bearings. The spindle also carries a pointer , a balance weight , a controlling weight and a damping piston (*DDP*1*W*2*WE*), which moves in a curved fixed cylinder . The special shape of the moving-iron discs is for obtaining a scale of suitable form. *F*

Remark: Moving-iron vanes instruments may be used for DC current and voltage measurements and they are subject to minor frequency errors only. The instruments may be effectively shielded from the influence of external magnetic fields by enclosing the working parts, except the pointer, in a laminated iron cylinder with laminated iron end covers.

Torque expression:

Torque expression may be obtained in terms of the inductance of the instrument. Suppose the initial current is I the instrument inductance l and the deflection θ. Then let I change to i+dI being a small change of the current as a result let θ change to (θ+d θ) and the L to (l+dl). In order to get an instrument change in current di there must be an increase in the applied voltage across coil.

The applied voltage $V = \frac{d\boldsymbol{L}I}{dt} = I\frac{dI}{dt} + \boldsymbol{L}\frac{di}{dt}$

The electric energy supplied to the coils in dt is

$$V\,I\,dt = i^2\,dl + I\boldsymbol{L}\,dI$$

Increase in energy stored in the magnetic filed = ½ $(I+dI)^2$ (L+dL)- ½ I^2 L

(Neglecting second and higher order terms in small quantity)

If the T is the value of the control torque corresponding to deflection θ the extra energy stored in the control due to the change d θ to T d θ . The stored increase in stored

energy= $I\boldsymbol{L}\,dI + ½\,i^2\,d\boldsymbol{L} + T\,d\theta$

From the principle of the conversion of energy, one can write the flowing expression

Electric energy drawn from the supply =increases in stored energy + mechanical work done.

Controlling torque

I spring control $T_s=K_s\ \theta$ where K_s is the spring.

II Gravity control $T_G=K_G \sin\theta$

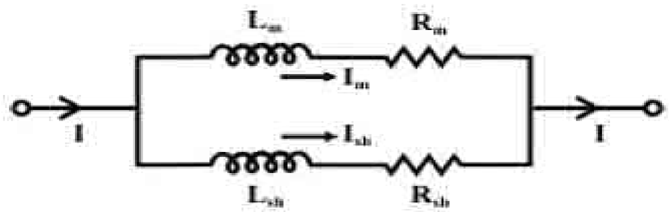
Ranges of Ammeters and Voltmeters

For a given moving-iron instrument the ampere-turns necessary to produce full-scale deflection are constant. One can alter the range of ammeters by providing a shunt coil with the moving coil.

Shunts and Multipliers for MI instruments

For moving –iron ammeters:

For the circuit shown in fig let R_m and L_m are respectively the resistance and inductance of the coil and R_{sh} and L_{sh} the corresponding values for shunt.



The ratio of current in two parallel

$$\frac{Ish}{Im} = \sqrt{\left(\frac{R^2m + (w\,Lm)^2}{R\,2 + (w\,L\,sh)^2}\right)}$$

The above ratio will be independent of the frequency ω provided that he time constants of the parallel two branches are same $\frac{Lm}{Rm} = \frac{Lsh}{Rm}$

In other words $\frac{Ish}{Im} = \frac{Rm}{Rsh}$

Now

$$I = Ish + I\,m = Im\left(\frac{Rm}{Rsh} + 1\right)$$

Multipliers for the shunt = $\left(\frac{Rm}{Rsh} + 1\right).$ It is difficult to design a shunt with the appropriate inductance and shunts are rarely incorporated in moving iron ammeters. thus the multiplier for the shunt = $\left(\frac{Rm}{Rsh} + 1\right).$ it is difficult to design a shunt with the appropriate inductance and shunt are rarely incorporated in moving iron ammeters. Thus the multi range can effectively be obtained by winding the instrument coil in section which may be connected in series ,parallel or series parallel combination which in turn change the total ampere in the magnetizing coil.

For moving –iron voltmeters:

Voltmeter ranges may be altered connecting a resistance in series with the coil. Hence the same coil winding specification may be employed for a number of ranges. Let us considered a high resistance R_{se} is connected in series with the moving coil and it shown in fig.

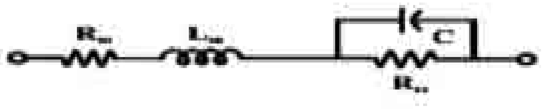
$$V = I_m\sqrt{R_m^{\ 2} + (w\,\boldsymbol{L}_m)^2}$$

$$V = I_m\sqrt{(R_m + R_{se})^2 + (w\,\boldsymbol{L}_m)^2}$$

Multiplier

$$\frac{V}{v} = \sqrt{(R_m + R_{se})^2 + (w\,\boldsymbol{L}_m)^2} \div \sqrt{(R_m^{\ 2} + (w\,\boldsymbol{L}_m)^2)}$$

Note: An ordinary arrangement with a non inductive resistance in series with the fixed coil-result in error that increase as the frequency increases .the change of the impedance of the instrument with change of frequency error; multiplier may be easily shunted by the capacitor.



Advantages:

• The instruments are suitable for use in a.c and d.c circuits.

• The instruments are robust, owing to the simple construction of the moving parts.

• The stationary parts of the instruments are also simple.

• Instrument is low cost compared to moving coil instrument.

• Torque/weight ration is high, thus less frictional error.

Errors:

i. Errors due to temperature variation.

ii. Errors due to friction is quite small as torque-weight ratio is high in moving-iron instruments.

iii. Stray fields cause relatively low values of magnetizing force produced by the coil. Efficient magnetic screening is essential to reduce this effect.

iv. Error due to variation of frequency causes change of reactance of the coil and also changes the eddy currents induced in neighboring metal.

v. Deflecting torque is not exactly proportional to the square of the current due to non-linear characteristics of iron material.

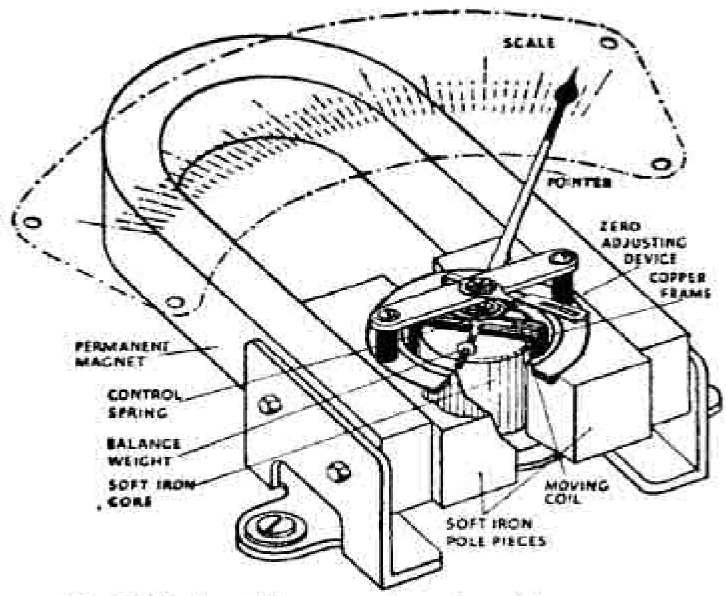


Fig. XII. 4. Diagram of moving coil permanent magnet instrument.

Induction type meters

GENERAL THEORY

Induction type instruments are used only on a.c. circuits. All induction type instruments consist of 2 windings and an aluminum disc. When alternating currents flow through the windings, fluxes ϕ_1 and ϕ_2 are produced. Both these fluxes induce emfs E_1 and E_2 in the disc or drum and circulate eddy currents I_1 and I_2 respectively. Therefore 2 torques are produced by:

1st flux Φ_1 interacting with eddy current I_2 produced by other flux ϕ_2

2nd flux Φ_2 interacting with eddy current I_1 produced by other flux ϕ_1

Total torque is the sum of these 2 torques. Let ϕ_1 and ϕ_2 be instantaneous values of 2 fluxes having a phase difference of α and therefore,

$$\phi_1 = \phi_{m1} \sin wt$$

$$\phi_2 = \phi_{m2} \sin wt$$

Where r.m.s values are,

$\phi_1 = 0.707\phi_{m^1}$

$\phi_2 = 0.707\phi_{m^2}$

Flux □$_1$ produces an emf in the disc by transformer action. The instantaneous value of this emf is,

e$_1$ □ □ □ □ □ d□ □ dt) □ □ □ □ □ □ □ □ d$_{m1}$(sin wt □ □ □ □ □ □ □ □$_{m1}$ cos □ t) □ □ □ □- f □$_{m1}$ cos □ t)

—

dt

Therefore e$_1$ lags flux by 90^o. Let E$_1$ be r.m.s value of emf e$_1$, then

$E_1 \alpha\ 0.707\ (f\ \phi_{m^1})$

$\alpha f\ 0.707\ (f\ \phi_{m^1})\ \alpha\ \phi_1$

If impedance of eddy current path Z, then eddy current,

$$I_1 = \frac{E_1}{Z} = \frac{f\phi}{Z}$$

□ □ lags E$_1$ by an angle□ □ □

Average torque produced by the interaction of □ and I$_1$ is,

$T_{d^1} \alpha \phi_2 I_1 \cos(90^\circ - \beta + \alpha)$

□ □ □ □ □ □ □ □ □ $T_{d^1} \alpha \phi_2 \phi_1 \left(\frac{f}{z}\right) \cos(90^\circ - \beta + \alpha)$

□ □ □ □ □ □ □ □

Similarly,

Average torque produced by the interaction of □ and I_1 is,

$$T_{d2} \alpha \phi_1 I_2 \cos(90^\circ - \beta + \alpha)$$

$$T_{d2} \alpha \phi_2 \phi_1 \left(\frac{f}{z}\right) \cos(90^\circ - \beta + \alpha)$$

Applying Fleming's left hand rule, the two torques act in opposite direction,

$T_d = T_{d1} - T_{d2}$

$$T_d = \left[\phi_2 \phi_1 \left(\frac{f}{z}\right) \cos(90^\circ - \beta + \alpha) - \phi_2 \phi_1 \left(\frac{f}{z}\right) \cos(90^\circ - \beta + \alpha) \right]$$

Solving we get, $T_d \alpha \phi_2 \phi_1 \left(\frac{f}{z}\right) \sin\beta \cos\alpha$

For torque to be large,

(i) Angle Φ1 should is almost zero as possible. For this path of eddy currents is made resistive as possible.

(ii) Angle Φ12should be almost 90^o. Hence two fluxes must be displaced by 90^o.

Induction type energy meter

Energy is the total power delivered or consumed over a time interval, i.e.,

Energy = Power x Time

Electrical energy developed as work or dissipated as heat over an interval of time t is, $W = \int_0^t v\, i\, dt$

Energy is an integrating type of instrument used for measurement of energy in domestic and industrial a.c. circuits.

Single phase induction type energy meter

Construction:

There are 4 main parts:

Driving System:

Consist of 2 electromagnets made of silicon steel laminations

Coil of one of the electromagnet (shunt magnet) is excited by load current known as current coil

Coil of 2^{nd} electromagnet (series magnet) is connected across supply & carries a current proportional to voltage known as pressure coil

Copper shading bands whose position is adjustable are provided on central limb to bring the flux exactly in quadrature with the applied voltage

Moving System:

Consist of an aluminum disc mounted on a light alloy shaft positioned in the air gap between magnets Shaft is pivoted on jewel bearings and a pinion engages it with counting or registering mechanism

Braking System:

Braking Torque is required to control the speed of moving system.

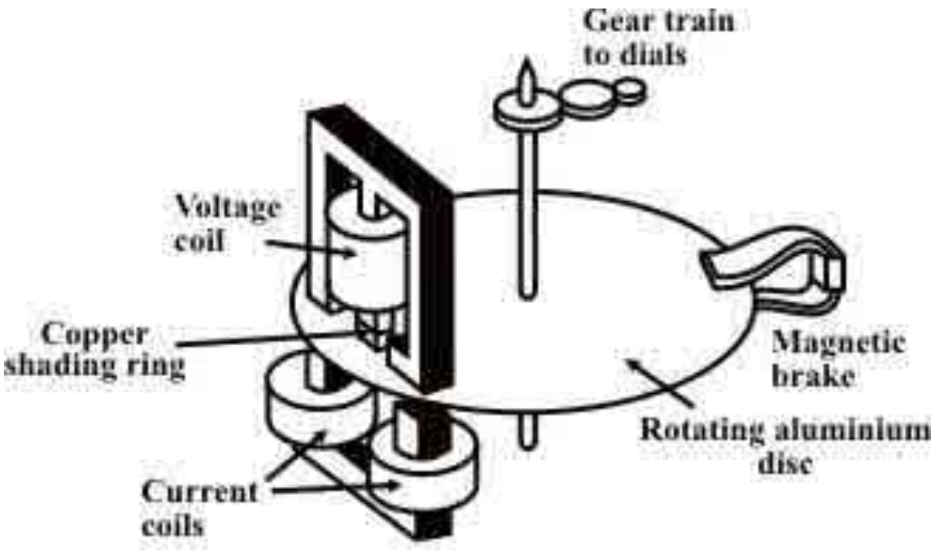
A permanent magnet is positioned near the edge of the aluminium disc to provide braking torque.This magnet induces eddy currents that produces the braking torque proportional to the speed of moving system.

Registering or Counting Mechanism:

Records continuously a no. proportional to a the revolutions made by moving system

Train of gears drives a series of 4 or 5 pointers

There are 2 types of registers – pointer type & cyclometer register



Theory and operation:

Supply voltage V is applied across pressure coil. As pressure coil is highly inductive with a small resistance then current I_p that flow through the coil, lags it by a few degrees less than 90^o. Current I_p produces flux Φ_{pt}, which consist of Φ_g and Φ_p. Flux Φ_g flows across side gaps whereas flux Φ_p links with the disc and eddy emf E_{ep} is induced in it. This in turn produces eddy current I_{ep} which lags E_{ep} by an angle   as the path of eddy current is inductive.

Load current I flows through current coil and produce flux Φ_s proportional to it. This flux induces eddy emf E_{es} in the disc. As a result, eddy current I_{es} flows through it and lags it by an angle Φ

Two torques are produced – T_{d1} by the interaction of Φ_s with I_{ep} and T_{d2} by the interaction of Φ_g with $I_{es,}$ acting in the opposite direction. Net torque is the difference of these two torques.

Let Φ – phase angle of load

Δ- Phase angle between the supply voltage and pressure coil flux

f – Frequency

Z - Impedance of eddy current paths

Net Driving Torque,

$$T_d \alpha \phi_p \phi_s \left(\frac{f}{z}\right) \sin\beta \cos\alpha = K_1 \phi_p \phi_s \left(\frac{f}{z}\right) \sin\beta \cos\alpha$$

Where

K1 is a constant

β was phase angle between fluxes Φ 1 and Φ 2. From phasor diagram, angle between fluxes Φ_p and Δ Φ_s is Φ

$$T_d = K_1 \phi_p \phi_s \left(\frac{f}{z}\right) \sin(\Delta - \phi) \cos\alpha$$

$\phi_p \alpha V$ and $\phi_s \alpha I$

$$T_d = K_2 \phi_p \phi_s \left(\frac{f}{z}\right) \sin(\Delta - \phi) \cos\alpha$$ □ □ □ □ □ □ □ □ □

If f, Z and α □ are constant,

$$T_d = K_3 \phi_p \phi_s I \sin(\Delta - \phi) \cos\alpha$$

Braking Torque, $T_B = K_4 N$ where N is the steady speed

At steady speed, $T_B = T_d$

$$K_4 N = K_3 \phi_p \phi_s I \sin(\Delta - \phi)$$

□ $N = K_3 \div K_4 \phi_p \phi_s I \sin(\Delta - \phi)$

if □ Δ=□ 90□ □ □ then,

N = K VI cos Φ □ =□ K x Power

Total no. of revolutions = ∫N dt

=∫K VI cos Φ □ dt

= K ∫ Power (dt)

= K x Energy

Lag Adjustment / Power Factor Adjustment / Quadrature Adjustment / Inductive load Adjustment:

In order to make the angle between fluxes 90^o, a magnetic shunt circuit known as lag coil is introduced. The pressure coil is excited by voltage V and carries a current I_p which produces an mmf AT_{pt} which in turn produces a flux Φ_{pt} lagging the voltage by an angle 90^o- . But only flux Φ_p links with lag coil. As a result, a voltage E_L is induced in the coil lagging by 90^o and this circulates current I_L through it. The lag coil produces an mmf AT_L. The flux Φ_p that links with the disc is created by the combined action of main mmf AT_{pt} in phase with I_p and lag coil mmf AT_L in phase with I_L. Thus this flux Φ_p will be in phase with the resultant mmf AT_p. By varying mmf of lag coil either in magnitude or in phase we can adjust the phase of flux $\Phi_{p.}$

Arrangements for adjusting the mmf of the lag coil are:

Adjustable resistance:

A few turns of thick wire are placed around central limb of shunt magnet and circuit is closed through a low adjustable resistance. An increase in resistance decreases current and mmf AT_L and hence lag angle □ Φ decreases. Decreases in resistance increases current and mmf ATL and hence lag angle □ increases. Thus angle can be adjusted.

Shading bands:

In this copper shading bands L1 are placed on central limb. When shading bands are moved up the limb it embraces more flux and hence mmf AT_L increases resulting in an increase in θ when shading bands are moved down, mmf AT_L decreases and hence Φ decreases Thus, angle can be adjusted.

Light Load or Friction Compensation:

At light loads, error due to friction is high. Hence a small torque is provided which is independent of the load, and is equal in magnitude to the frictional torque.

For this, a shading loop L_2 is situated between the center pole of the shunt magnet and the disc.

The interaction between the portions of the flux, which are shaded and unshaded by this loop and the current in the disc induce a small driving torque whose value can be adjusted by lateral movement of the loop.

Creep:

- In some meters a slow but continuous rotation is obtained even when only pressure coil is energized. (i.e; there is no current flowing in current coil) . This is called creeping.

- Major cause is overcompensation of friction. This occurs when the friction compensating device is such that it compensates the starting friction (Starting Friction > Running Friction)

- Other causes are excessive voltage across potential coil, vibrations, stray magnetic fields

- To prevent creeping two diametrically opposite holes are drilled in the disc. The disc will come to rest with one of the holes under the edge of a pole of the shunt magnet, the rotation thus limited to a maximum of half revolution. If a hole is under the edge of a pole the eddy current path is distorted and the effective center is A'. As a result there is a force on the disc tending to move A' away from pole axis A. But further rotation of disc is opposed. The magnitude of this opposing torque is not sufficient to rotate the disc in other direction.

- Another method is by attaching a small iron piece to edge of disc. Force of attraction between brake magnet and iron piece prevents creeping.

Overload Compensation:

- When disc revolves continuously in field of series magnet under load conditions, there is a dynamically induced emf in the disc. This causes eddy currents to interact with field of series magnet to produce self - braking torque T_{SB}.

$$T_{SB} = \text{Load Current}^2$$

- To minimize this,

Full load speed of disc is kept low almost 40 rpm.

Φ_s is kept small as compared to Φ_p

Overload compensating device is added which takes the form of a magnetic shunt for the series magnet that diverts flux Φ_s.

Voltage Compensation:

- Energy meters must be compensated for variation in voltage as this can cause errors as shunt magnet flux:is not linear with supply voltage owing to saturation

produces dynamically induced emf that produces self braking torque T_{SB}

$T_{SB} = \square$ Supply Voltage^2

- Compensation is provided using saturable magnetic shunt, which diverts flux or by providing holes in side limbs of shunt magnet

Temperature Compensation:

- Increase in temperature increases resistance of metal parts resulting in:

(i) Decrease in potential coil flux & reduction in angle of lag between V and $\square_p$

(ii) Decrease in torque produced by all shading bands

(iii) Increase in resistance of eddy current paths

(iv) Decrease in angle of lag of eddy currents

- These effects neutralize each other

- Error is serious at low power factors

- Compensation is provided using temperature shunt on brake magnet

Errors:

Errors caused by driving system are:

(i) Incorrect magnitude of fluxes – caused by abnormal values of voltage, current, frequency and change in resistance of coil

(ii) Incorrect phase angles – caused by improper lag adjustments, abnormal frequencies, change in resistance

(iii) Lack of symmetry in magnetic circuit – causes creep

Errors caused by braking system are:

Changes in strength of brake magnets

Changes in disc resistance

Self braking effect

Abnormal friction of moving parts

Adjustments:

Some adjustments are carried out in energy meters so that they read correctly. They are,

Preliminary Light Load Adjustment:

Disc is so positioned that the holes are not underneath the electromagnets

Rated voltage applied to pressure coil with no current in current coil

Light load device adjusted until disc just fails to start

Full load unity power factor adjustment

Rated voltage applied to pressure coil

Rated full load current at upf passed through current coil

Position of brake magnet adjusted so that disc revolves at correct speed

Lag Adjustment (Low power factor Adjustment)

Rated voltage applied to pressure coil

Rated full load current at 0.5 pf lagging passed through current coil

- Lag device adjusted so that disc revolves at correct speed

Full load unity power factor adjustment and Low power factor Adjustment

Rated voltage applied to pressure coil

Rated full load current at upf passed through current coil

Full load unity power factor adjustment & low power factor adjustment done so that disc revolves at correct speed

Light Load Adjustment

Rated voltage applied to pressure coil

Low current passed through current coil at upf

Light Load Adjustment done so that disc revolves at correct speed

Full load unity power factor and Light Load Adjustment are gain done so that disc revolves at correct speed

Performance is rechecked at 0.5 pf lagging

Creep adjustment - Pressure coil is excited by 110% of rated voltage with zero load current. At this condition meter should not creep

Polyphase induction energy meters

Electrical energy in a 'n' conductor system requires 'n-1' measuring elements for measurement of energy. In polyphase wattmeter the elements are mounted on the same spindle, which drives registering mechanism.

These wattmeters may be either muiltidisc type or single disc type.

Multidisc Type: Each element drives a separate disc

Single Disc Type: All elements drive same disc. Disc is slotted or laminated in sectors to prevent interaction between eddy currents produced by one element with flux produced by another element

Two element energy meter

Two element energy meter is used in 3-phase 3 wire system

Provided with 2 discs one for each element

Driving torque of both the elements must be exactly equal for equal amounts of power passing through each. For this an adjustable magnetic shunt is provided on one or both elements and coils are energized from a 1-ϕ supply. Pressure coils are connected in parallel and current coils are connected in series. When energized, torques produced by both elements opposes each other. The magnetic shunt is adjusted such that the two torques are exactly equal and opposite and therefore there is no rotation of disc.

Electrodynamic instruments

Introduction

Electrodynamics type instruments are similar to the PMMC-type elements except that the magnet is replaced by two serially connected fixed coils that produce the magnetic field when energized (see Fig.43.1). The fixed coils are spaced far enough apart to allow passage of the shaft of the movable coil. The movable coil carries a pointer, which is balanced by counter weights. Its rotation is controlled by springs. The motor torque is proportional to the product of the currents in the moving and fixed coils. If the current is reversed, the field polarity and the polarity of the moving coil reverse at the same time, and the turning force continues in the original direction. Since the reversing the current direction does not reverse the turning force, this type of instruments can be used to measure AC or DC current, voltage, or its major application as a wattmeter for power measurement. In the first two cases, the moving and fixed are serially connected. For power measurement, one of the coils (usually the fixed coils) passes the load current and other coil passes a current proportional to the load voltage. Air friction damping is employed for these instruments and is provided by a pair of Aluminum-vanes attached to the spindle at the bottom. These vanes move in a sector shaped chamber. Cost and performance compared with the other types of instruments restrict the use of this design to AC or DC power measurement. Electro-dynamic meters are typically expensive but have the advantage of being more accurate than moving coil and moving iron instrument but its sensitivity is low. Similar to moving iron vane instruments, the electro dynamic instruments are true RMS responding meters. When electro dynamic instruments used for power measurement its scale is linear because it predicts the average power delivered to the load and it is calibrated in average values for AC. Voltage, current and power can all be measured if the fixed and moving coils are connected appropriately. Other parts of the instruments are described briefly below:

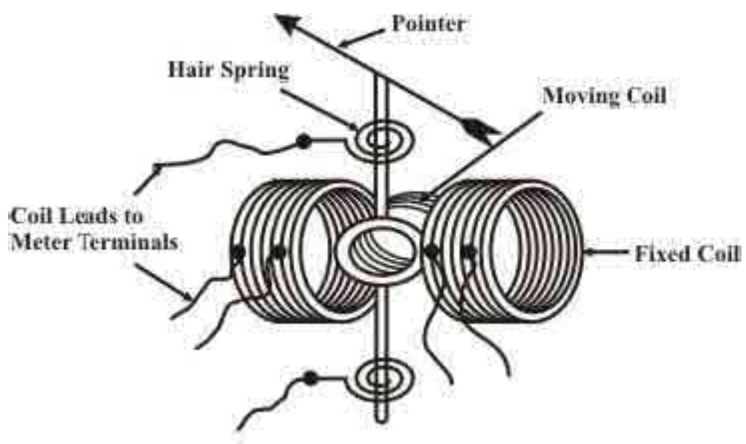


Fig. 43.1(a)

Electro dynamic (or Dynamometer) type Instruments:

Fixed coil: The magnetic field is produced by the fixed coil which is divided into two sections to give more uniform field near the centre and to allow passage of the instrument shaft.

Moving coil: The moving coil is wound either as a self-sustaining coil or else on a non-magnetic former. A metallic former cannot be used, as eddy currents would be induced in it by alternating field. Light but rigid construction is used for the moving coil. It should be noted that both fixed and moving coils are air cored.

Springs: The controlling torque is provided by two control springs. These hairsprings also act as leads of current to the moving coil.

Dampers: Air friction damping is employed for these instruments and is provided by a pair of Aluminum-vanes attached to the spindle at the bottom. These vanes move in a sector shaped chamber.

Shielding: Since the magnetic field produced by fixed coils is weaker than that in other types of instruments, these meters need a special magnetic shielding. Electro-dynamic instruments are effectively shielded from the effects of external magnetic fields by enclosing the mechanism in a laminated iron hollow cylinder with closed ends.

Operating Principle

Let us consider the currents in the fixed and moving coils are *fi* and respectively. The action of electrodynamic instrument depends upon the force exerted between fixed and moving coils carrying current. The flux density produced by the fixed coil is proportional to (fixed coil current). The force on the conductors of the moving coil, for a given strength field, will proportional to (moving coil current) and the number of turns ‘’ of the moving coil. In case of ammeter and voltmeter fixed and moving coils are connected in series and the developed torque is due to the interaction of the magnetic fields produced by currents in the fixed and moving coils and thus it will be proportional to $i^2 \ (i_f = i_m = i)$. Thus, dynamic instruments can be used for dc and ac measurements.

Expression for developed torque:

Let us assume that the fixed and moving coil having self inductance L_f and L_m respectively .further it is assumed that the mutual inductance between the fixed and movable coil is M.

Total energy stored in the magenetic filed of the coil is given by

$$W = \frac{1}{2} l_f i^2_f + \frac{1}{2} l_m i^2_m + M l_f i^2_m$$

Where I_f and I_m are the cureent through the fixed and moving coil. From the above equaton for the torque developed

$$T_d = \frac{dw}{d\theta} = i_f i_m \frac{dm}{d\theta}$$

L eq= L+ Lm+2M

And form mutual inductance between them

$$M = \frac{1}{2}[\boldsymbol{L}_{eq} - (\boldsymbol{L}_f + \boldsymbol{L}_m)]$$

With all deflection type instrument ,mhowever the mutul inductance varies with the relative position of the moving coil abd fixed coil.the maximum value M max of the mutual inductance occure when the axis of the moving and fixed coil ar alined with θ=180 as this postion gives the maximum flux linage between coils. When θ=0' , M=-m max . if the plane of the moving coil is at an angle θ with the direction of the B that produced by the fixed coil . then the muual inductance expressed in M=-Mmax

D.C OPERATION

The developed torque is rewritten by setting $I_f = i_f$ and $I_m = i_m$

$$T_d = I_f \, I_m \, M_{max} \, Sin\, \theta$$

If the control torque is due to spring , the controlling torque is propotional to the angle of the deflecting θ

Contolling torque $=T_c=K_s\,\theta$

Where k_s is the spring constant

$$I_f\, I_m\, \frac{dM}{d\theta} = K_s\, \theta$$

A.C operation

The dynamometer instrument is used to measure alternating current or voltage.the moving coil due to it inertia takes up a position where the average deflecting torque over a complete cycle is balanced by the the restoring of the spiral spring.the deflecting torque is proportional to to the maean value of the squre of the current or voltage and the instrument scale can be therefore be calibtated to read RMS value of alternating current or voltage

$$Tav = \frac{1}{T}\int_0^T i_f(t)\, i_m(t)\, \frac{dM}{d\theta}\, dt$$

Ammeters

Fig. shows that fixed coils and moving coil of a dynamometer instrument connected in series and assumed the current through moving coil does not exceed a certain the upper limit depending on its construction.

The flux direction through the fixed and movable coils due to current is shown in Fig. . it can be noted that the –pole of the moving coil flux is reflected from the adjacent –pole of the fixed coil and on the other side adjacent *S*–poles are also repelled each other. This results the pointer to move clockwise direction from 'zero position' to a steady position depending upon the magnitude of current flowing through the coils. Fig.illustrate the effect of reversing the direction of the current through the coils and shows that the deflecting torque produces movement of the pointer in the same direction. This means that the dynamometer instrument suitable for both dc and ac measurements of current and voltage. The dynamic instrument when uses as a voltmeter, the fixed coils wounded with thin wire are connected in series with the moving coil and a non-inductive resistance Fig. For ammeter application the fixed coils are connected in parallel with the moving coil, and in parallel with a shunt, as required (see Fig.43.4). *NN*

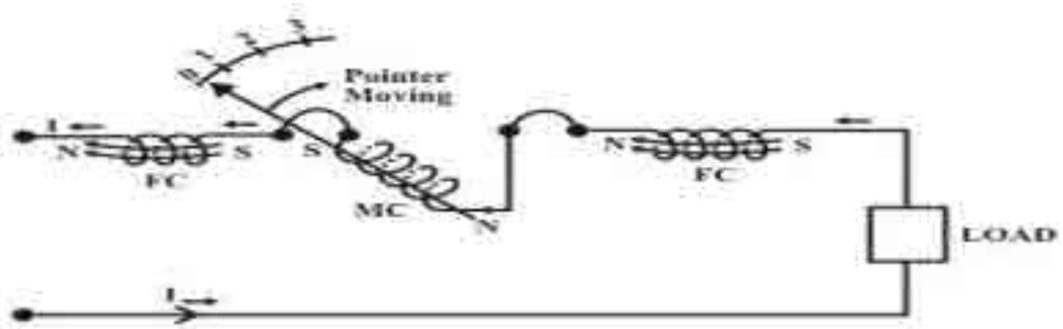


Fig. 43.2(b): Current flowing right to left produces positive deflection again.

Remarks: The scale of the instrument can be conveniently calibrated on dc and then used to measure ac.

Ranges of Ammeters and Voltmeters

Ammeters

A given size of instruments requires a definite number of ampere-turns to be supplied by the fixed and moving coils to obtain a full–scale deflection. Ammeter ranges are altered by changing the number of turns and size of conductor in the fixed and moving coils. A double range instrument may easily be obtained by connecting different coil sections either in series or in parallel. The internal connections are shown in Fig.43.3. The maximum range for which ammeters are usually constructed is dependent on its application. For ammeter use in which only fraction of rated current (say 200 ma) is carried by the moving coil to alter its range by changing the mode of connection of the fixed coils.

Voltmeters: With voltmeters the ranges is altered by changing the number of turns in the coils and the value of series resistances, but the range of a given instrument may be increased by connecting additional resistances in series with it. For example, the range of a given voltmeter may be doubled while connecting in series with it a non–inductive resistance equal in value to the original resistance of the instrument.

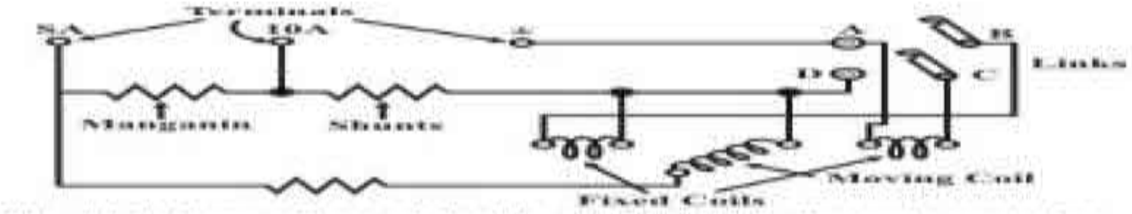


Fig. 43.3: Connections of double-range electro-dynamic ammeter. (For higher range, Fixed coils are in parallel; for lower range, fixed coils are in series).

onnections for ammeter, voltmeter and wattmeter

Ammeter

When ammeters for ranges above about 250 , the moving coil cannot be connected in series with the fixed coil (note the control spring is unsuitable for currents above about 250). Therefore, the moving coil must be connected in parallel with the fixed coils as shown in Fig 43.4. *mAmA*

Here the moving coil current is kept within 200 mA and the rest of current is passed through the fixed coil. Moving coil carries a small fraction of measured current through the moving coil. For extreme accuracy the connection shown in Fig. 43.4 must fulfill the following conditions.

• The resistance/reactance ratio must have the same value (i.e time constant of moving coil = time constant of fixed coil) for each branch.

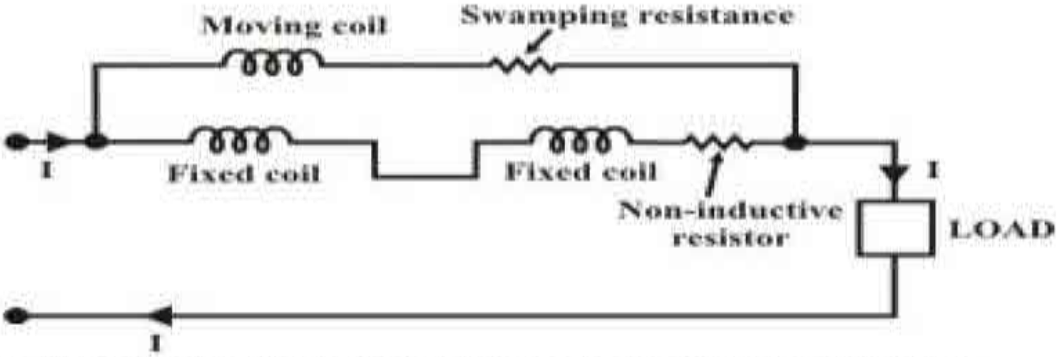


Fig. 43.4: Electro dynamic Ammeter (above 250mA) connection

• The percentage change of resistance with temperature must be the same for the two The connection for use as a voltmeter is shown in Fig. 43.5, in which fixed and oving coils are connected in series with a high series resistance having “zero resistivity co-efficients”.

Voltmeters

Voltmeter: the connection for use as a voltmeter is shown in fig. in which fixed and moving coil are connected in series with a high resistance having ‘Zero resistivity co-efficient.

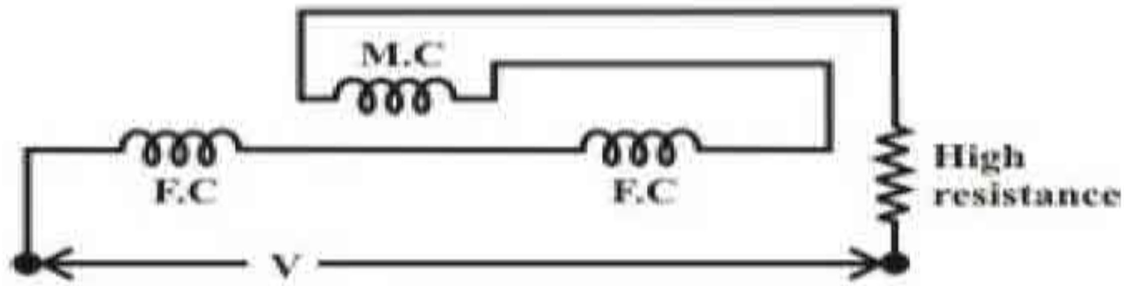


Fig. 43.5: Electro-dynamic voltmeter connection

Remarks: Electro-dynamic meter’s use is much more common for ac voltmeters than for ac ammeters.

Wattmeter: Perhaps the most important use of the electrodynamometer is for the wattmeter. The mechanism of electro dynamic wattmeter closely resembles that of an electro-dynamic ammeter, but the moving coil of wattmeter is connected in series with a high non–inductive resistance.

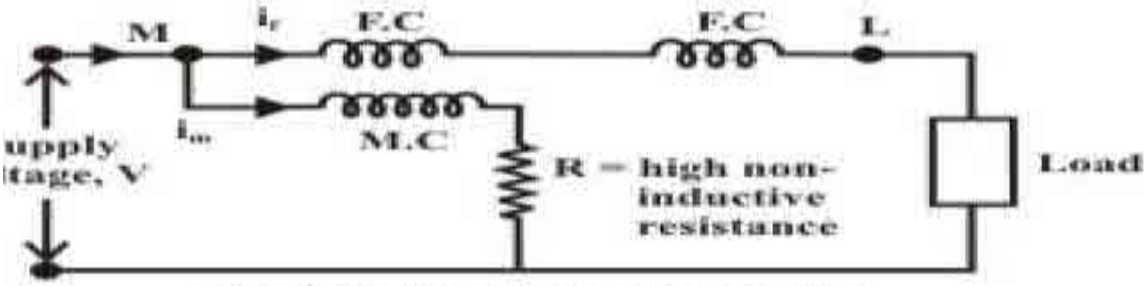


Fig. 43.6: Wattmeter Connection

Advantages and disadvantages of electro-dynamic instruments

Advantages:

i Free from hysteresis and eddy current errors.

ii Applicable to both dc and ac circuits.

iii Precision grade accuracy for 40 Hz to 500 Hz.

iv Electro-dynamic voltmeters give accurate r.m.s values of voltage irrespective of waveforms.

Disadvantages:

i Low torque/weight ratio, hence more frictional errors.

ii More expensive than PMMC or MI instruments.

iii Power consumption higher than PMMC but less than MI instruments.

For these reasons, dynamometer ammeters and voltmeters are not in common use (except for calibration purpose) especially in dc circuits. The most important application of the dynamometer type instruments used as dynamometer wattmeter

Frequency meters

Frequency meters are instruments used to indicate frequency. The different types of frequency meters are:

MECHANICAL RESONANCE TYPE OR VIBRATING REED TYPE FREQUENCY METER

Construction:

Reeds

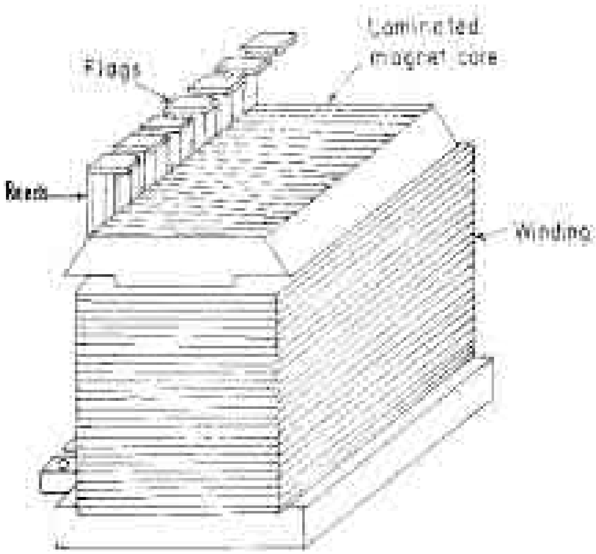
- Thin steel strips called reeds are placed in a row alongside close to an electromagnet.

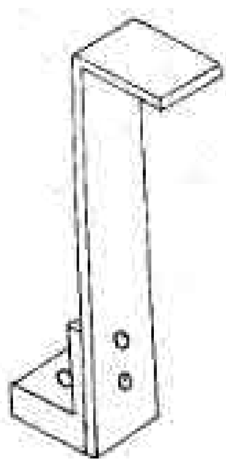
All reeds are similar with their natural frequencies of vibration different (as they have slightly different dimensions) & are arranged in ascending order of frequencies.

- Reeds are fixed at bottom end and are free at top end with a portion bend to serve as flag.

Electromagnet

- Electromagnet has a laminated iron core on which coil is wound. The coil is connected in series across the supply whose frequency is to be measured.



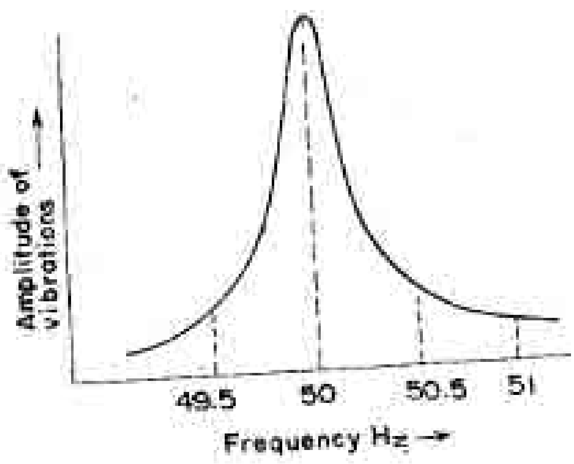


Vibrating Reed

Type Frequency Meter Reed

Operation:

Frequency Meter is connected across the supply whose frequency is to be measured the coil of electromagnet carries a current *i*, which alternates at the supply frequency. The force of attraction between the reeds and the electromagnet is proportional to i^2 and therefore this force varies twice at the frequency supply frequency. Thus, the force exerted on the reeds varies every half cycle. All the reeds tend to vibrate, but the reed whose natural frequency is equal to twice the frequency of supply tends to vibrate the most. Vibration of other reeds is unobservable.



Variation of amplitude of vibrations with frequency

For a frequency exactly midway between that of the reeds, both will vibrate with amplitudes with equal magnitude.

Electrical resonance type

Two types of electrical Resonance Meters are described below:

Ferrodynamic type of frequency meter:

<u>Construction:</u>

Magnetizing Coil

- Consists of a fixed coil called magnetizing coil, which is connected across the supply whose frequency is to be measured

- It is mounted on a laminated iron core

Iron core

- Cross section of iron core varies gradually over the length , being maximum near the end where magnetizing coil is mounted and minimum at the other end.

Moving Coil

- Moving coil is pivoted over the iron core

- A pointer is attached to moving coil

- Terminals of moving coil are connected to a suitable capacitor C

No provision for controlling force

Principle of Operation:

Magnetizing coil carries a current I and produces flux □ in phase with current I. Flux □ □ induces emf E in the moving coil lagging behind it by 90^o. Emf E circulates current I_m in the moving coil. Phase of current I_m depends upon inductance L of the moving coil and capacitance C.

Circuit of moving coil is inductive & therefore current I_m lags behind emf E by an angle □ . The torque acting on the moving coil is,

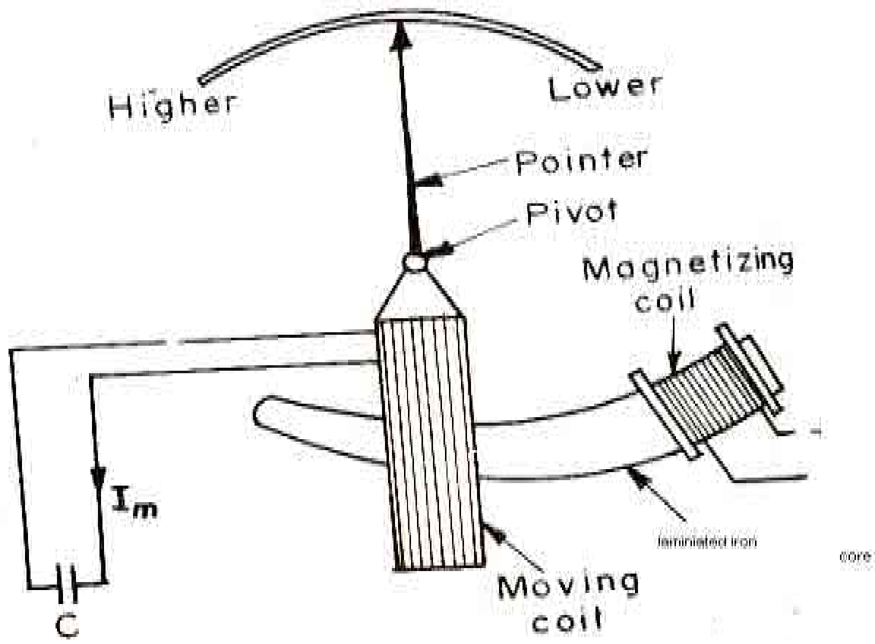
T_d = □ □ I_m I cos $(90^o + \alpha)$

Circuit of moving coil is capacitive & therefore current I_m leads emf E by an angle □ . The torque acting on the moving coil is,

T_d = □ □ I_m I cos $(90^o - \alpha)$□

Inductive reactance of the circuit of moving coil is equal to its capacitive reactance & therefore current I_m is in phase with emf E. The torque acting on the moving coil is,

$T_d = \square \square I_m I \cos 90^o = 0$



Ferro dynamic frequency Meter

Working:

For a fixed frequency, capacitive reactance is constant but inductive reactance of moving coil depends upon the position it occupies on the iron core. Inductive reactance is maximum when moving coil occupies a position close to the magnetizing coil and is minimum at the other end.

The figure shows the position of moving coil at normal frequency. At this position, inductive reactance is equal to the capacitive reactance.

Suppose the frequency increases above its normal value then, $X_L > X_C$ & therefore torque is produced. This torque pulls the moving coil to an equilibrium position i.e., moving coil deflects towards the section of iron core having minimum cross section. So inductive reactance decreases and moving coil comes to rest at a position where $X_L = X_C$.

Suppose the frequency decreases below its normal value then, $X_L < X_C$ & therefore torque is produced. This torque pulls the moving coil to an equilibrium position i.e., moving coil deflects towards the section of iron core having maximum cross section. So inductive reactance increases and moving coil comes to rest at a position where $X_L = X_{C.}$

Advantage:

Great sensitivity

Electrodynamometer type of frequency meter:

Construction:

Fixed coil

Fixed coil is divided into two parts 1 and 2 which forms two separates resonant circuits

- Fixed coil 1 is in series with an inductance L1 and a capacitance C1 forming a resonant circuit of frequency f1.

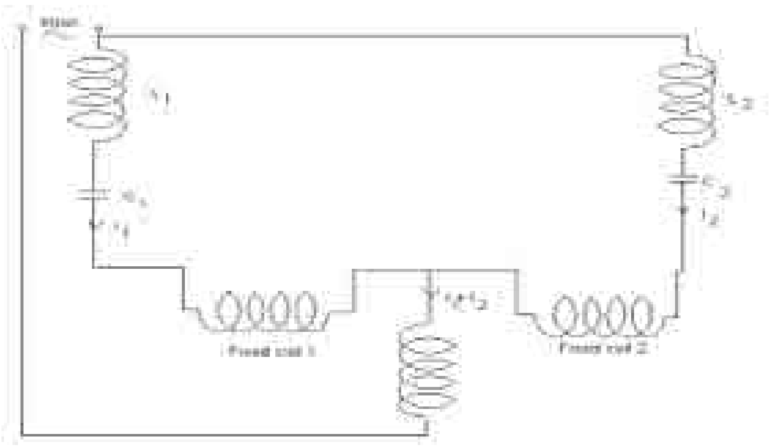
- Fixed coil 2 is in series with an inductance L2 and a capacitance C2 forming a resonant circuit of frequency f2.

Moving Coil

- Current through the moving coil is sum of the currents through the 2 parts of fixed coil

- Torque on the movable element is proportional to the current through the moving coil

A small iron vane mounted on the moving system provides controlling torque.



Electrodynamometer type frequency meter

Operation:

At a particular frequency, the current through circuit of fixed coil 1 lags behind applied voltage (as $X_{L1}>X_{C1}$) while the current through circuit of fixed coil 2 leads applied voltage (as $X_{L2}<X_{C2}$). Therefore torques produced by 2 coils act in opposition on the moving coil. The resultant torque is a function of frequency of the applied voltage.

Application:

- For power frequency measurements

- In power system, for monitoring the frequency

Power factor meters

Power Factor meters indicate directly, the power factor of the circuit to which they are connected.

General Construction:

Current Circuit that carries the current in the circuit whose power factor is to be measured

Pressure Circuit is connected across the circuit whose power factor is to be measured

Pressure circuit is split into 2 parallel paths - one inductive and other non inductive

Operation:

Deflection of pointer depends upon the phase difference (i.e. cos □ □ □ □ between the main current and the currents in the two paths of pressure circuit

Moving system is perfectly balanced at equilibrium position by 2 opposing forces & therefore there is no need for controlling torque. Hence, when a power factor meter is disconnected from a circuit the pointer remains at the position, which it occupied at the instant of disconnection.

The different types of power factor meters are:

Electrodynamometer power factor meter

Single phase electrodynamometer power factor meter

Construction:

Fixed Coil or Current Coil

- Current Coil is split into 2 parts

- It carries current of circuit under test and produces magnetic field proportional to the main current

Pressure Coil or Moving Coil

- There are 2 identical pressure coils A and B connected across the voltage of the circuit

- Pressure coil A has a non-inductive resistance R connected in series with it.

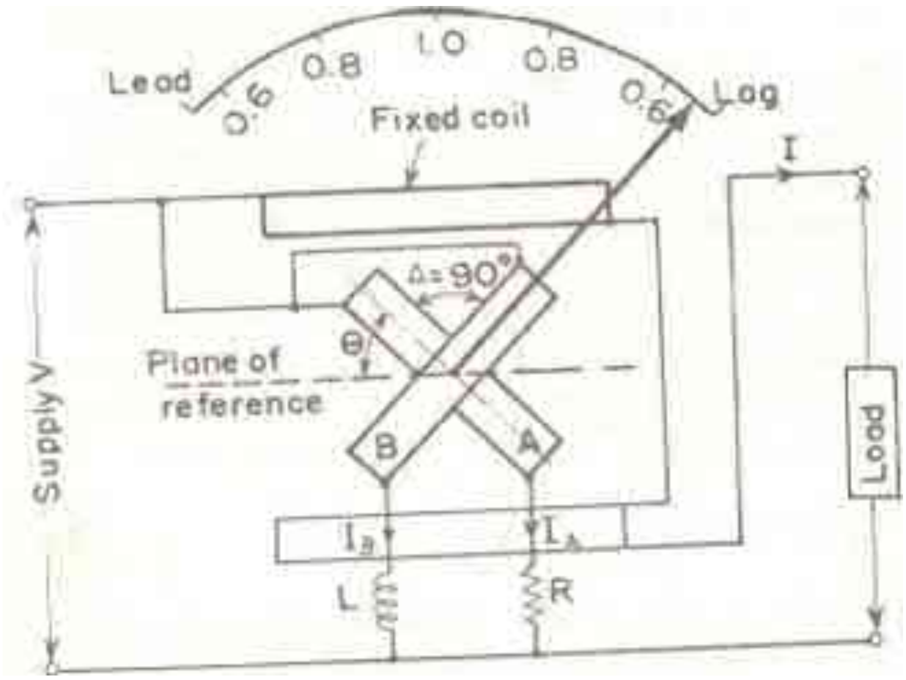
- Pressure coil B has a highly inductive choke coil L connected in series with it.

- Current through coil A is in phase with the circuit voltage while that in coil B lags voltage by an angle △, which is nearly equal to 90^o

- Angle between the plane of the coils A & B is also △

- At normal frequency, values of L and R are such that current through both the coils have same magnitude i.e., R = □ L

- Connections to the moving coils are made through thin silver or gold ligaments



Single Phase Electrodynamometer Power Factor Meter

Operation:

Let’s assume that current through coil B lags the voltage by exactly 90°. Therefore, angle between plane of coils is 90°. Let □ □ be the angular deflection from the plane of reference and M_{max} be the maximum value of mutual inductance. Consider the case of lagging power factor:

Deflecting torque acting on coil A,

$$T_A = K\ V\ I\ M_{max} \cos \Phi \sin \theta$$

Deflecting torque acting on coil B,

$$T_B = K\ V\ I\ M_{max} \cos (90^o - \Phi)\ \sin (90^o + \theta)$$

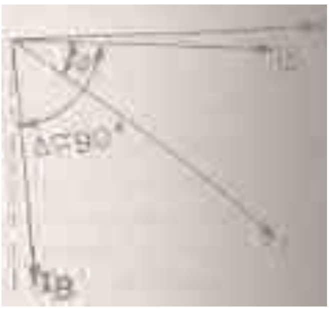
$$T_B = K\ V\ I\ M_{max} \sin \Phi \cos \theta$$

The two torques acts in opposite direction. The coil will take up a position such that the two torques are equal. Hence at equilibrium,

$T_A = T_B$

$K\ V\ I\ M_{max} \cos\theta \sin \square = K\ V\ I\ M_{max} \sin\Phi \cos\theta$

Thus, deflection of the instrument is a measure of phase angle of the circuit. Scale of instrument can be directly calibrated in terms of power factor.



Disadvantage:

Error in the indication may be caused by change in reactance of the coil due to,

change in supply frequency (other than the one it is calibrated at)

presence of harmonics in the supply

Three phase electrodynamometer power factor meter

Construction:

Fixed Coil or Current Coil – similar to that of single phase

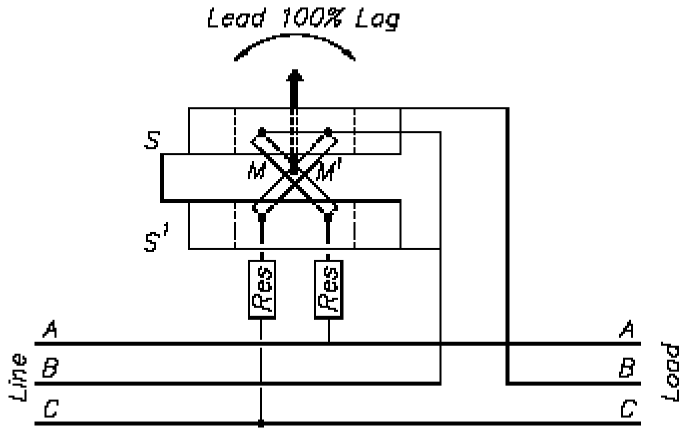
Pressure Coil or Moving Coil

- There are 2 identical pressure coils A and B connected across two different phases of the circuit

- Each coil has only a series resistance & therefore current through both the coils (I_A & I_B) are in phase with applied voltage

- Required phase displacement between current I_A & I_B is obtained from supply itself

- Hence, angle between the plane of the coils is 120^o



3-phase electrodynamometer power factor meter

Operation:

Assume,

V_{12} – voltage applied across coil A

V_{13} – voltage applied across coil B

$V_{12} = V_{13} = \sqrt{3}\, V$

Let □ □ be the angular deflection from the plane of reference and M_{max} be the maximum value of mutual inductance. Consider the case of lagging power factor:

Deflecting torque acting on coil A,

$T_A = K\, V_{12}\, I\, M_{max} \cos(30^o + \Phi) \sin(60^o + \theta)$ □ $= \sqrt{3}\, K\, V\, I\, M_{max} \cos(30^o + \Phi)$ □ $\sin(60^o + \theta)$

Deflecting torque acting on coil B,

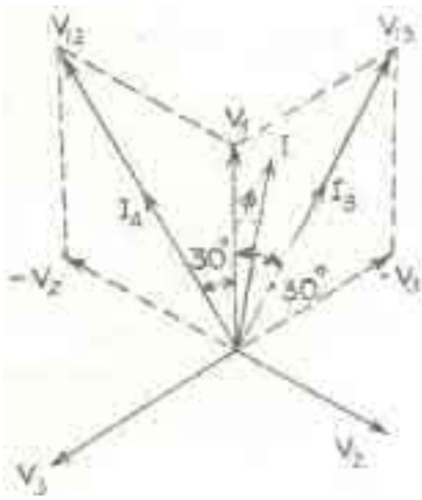
$T_B = K\, V_{13}\, I\, M_{max} \cos(30^o - \Phi)$ □ $\sin(120^o + \theta)$ □ □ □ $\sqrt{3}\, K\, V\, I\, M_{max} \cos(30^o - \Phi)$ □ $\sin(120^o + \theta)$ □

The two torques acts in opposite direction. The coil will take up a position such that the two torques are equal. Hence at equilibrium,

$T_A = T_B \sqrt{3} K V I M_{max} \cos(30^o + \Phi)$ $\sin(60^o + \theta)$ $\sqrt{3} K V I M_{max} \cos(30^o -$ $\sin \Phi) (120^o + \theta)$

Solving,

Thus, deflection of the instrument is a measure of phase angle of the circuit



Advantage:

Error due to change in frequency is eliminated as currents in both the coils are equally affected.

Moving iron power factor meter

According to principle of operation these may be classified as,

Rotating field power factor meter

Three phase rotating field power factor meter

Construction:

Fixed Coils

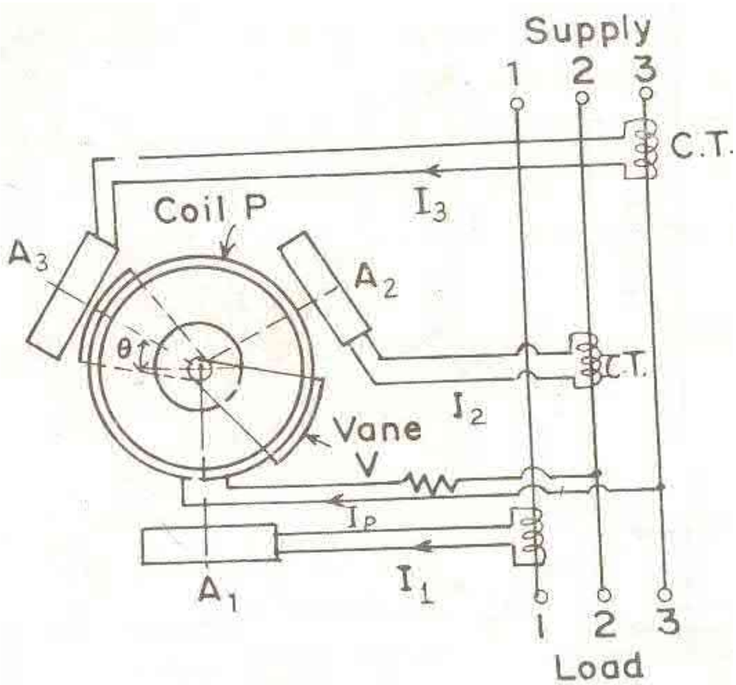
A1, A2, A3 are three fixed coils connected respectively in lines 1, 2 and 3 of 3-phase supply through current transformers Axes of A1, A2 and A3 are120^o displaced from each other and intersecting on the central line of the instrument Equivalent moving coil- Fixed coil P is connected in series with a high resistance across one pair of lines (2 & 3)

Iron cylinder C is placed inside the coil P pivoted on a spindle. Two sector shaped iron vanes 180^o apart are fixed to the cylinder

Spindle also carries damping vanes and a pointer

Iron Cylinder, Vanes and coil P are equivalent electromagnetically to a rectangular moving coil

There are no control springs



Rotating Field Moving Iron Power Factor Meter

Operation:

Current Ip, which is in phase with and proportional to line voltage (due to the large resistance in series), magnetizes coil P and the vanes. The alternating flux produced interacts with the fluxes produced by coils A1, A2 and A3. This causes moving system to take up a position determined by the phase angle of the system.

Total deflecting torque,

T_d □ □ □ □ $I_1 I_p$ cos $(90^o$ – □) sin $(90^o$ + □) + $I_2 I_p$ cos $(330^o$ – □) sin $(210^o$ + □) + $I_3 I_p$ cos $(210^o$ – □) sin $(330^o$ + □)]

For a steady deflection, the total torque must be zero. Also considering system to be balanced i.e., $I_1 = I_2 = I_3$, we have,

cos $(90^o$ – □) sin $(90^o$ + □) + cos $(330^o$ – □) sin $(210^o$ + □) + cos $(210^o$ – □) sin $(330^o$ + □) = 0

Solving □ □ □ □ □

Note:

The three fixed coils A1, A2, A3 produce a rotating magnetic field. In order to prevent induction motor action high resistivity metal is used for the moving irons so as to reduce the values of induced currents.

Single phase rotating field power factor meter

Construction:

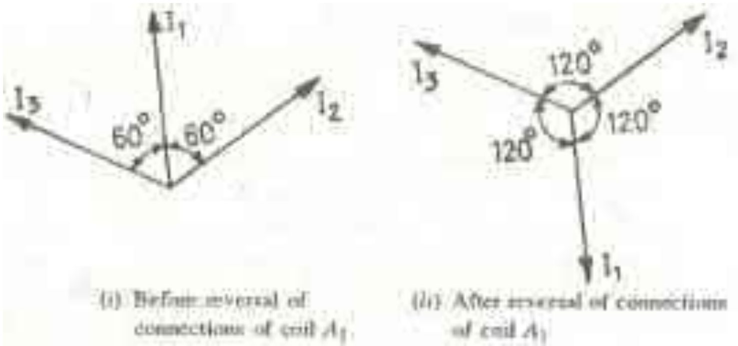
Fixed coils

A1, A2, A3 are three fixed coils connected respectively in lines 1, 2 and 3 of 3-phase supply with resistor R, inductor L and a capacitor C in series with it respectively.

Current in coil A1 is in phase with the line voltage

Current in coil A2 lags by 60^0

Current in coil A3 leads 60^o

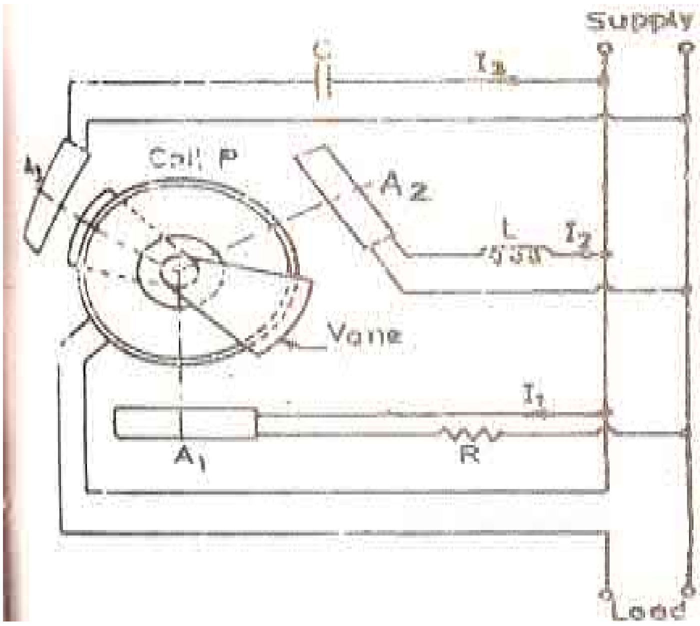


- Connections of coil A1 are reversed w.r.t connections of other coils so that currents in the 3 coils are 120° out of phase with each other

Rest is similar to that of 3-phase power factor meter

Operation:

Similar to that of 3-phase power factor meter



Single phase moving iron power factor meter

Alternating field power factor meter (nalder lipman type)

Construction:

- Moving system comprises of three pairs of iron vanes & cylinders which are fixed to a common spindle pivoted in jewel bearings 7 carries damping vanes & pointer

- Iron vanes are sector shaped with arc subtending $\angle 120^o$ & each pair are fixed 180^o apart. Also 3 pairs of iron vanes are displaced from each other by 120^o

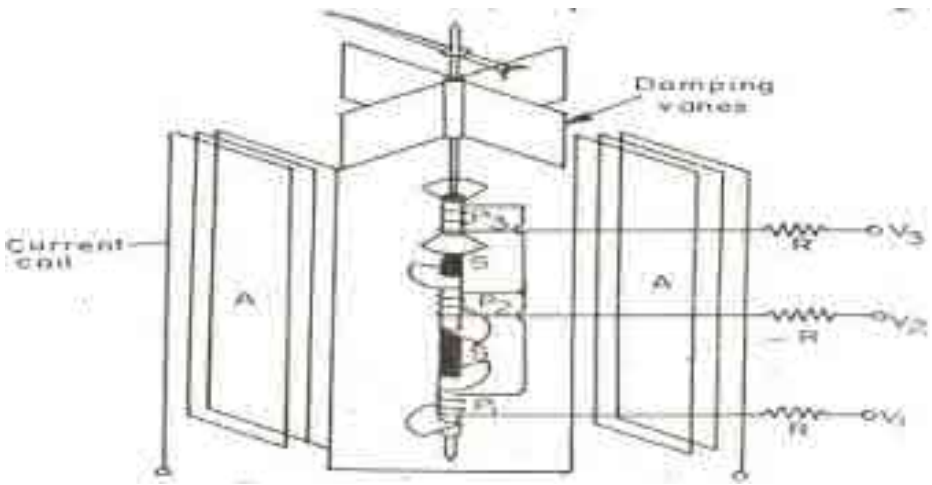
- Cylinders are separated by distance pieces S made of non – magnetic material

- Iron cylinders & the vanes are magnetized by 3 fixed co-axial pressure coils P_1, P_2, P_3 mounted co-axially with the spindle

- Current coil A is wound in two equal parts mounted parallel to each other on opposite sides of the spindle

Operation:

P_1, P_2, P_3 are excited by currents proportional to the phase voltages of the 3-phase system producing 3 fluxes. Coil is supplied with current proportional to current in one of the lines of the 3-phase system and it also produces a flux. Due to the interaction of these fluxes, moving system deflects into such a position that the mea torque on one pair of vanes is neutralized by the other two torques, so that resultant torque is zero. In this steady position, the deflection of the iron vane is equal to phase angle of the circuit.



Nalder Lipman Power Factor Meter

Note:

Its used for balanced currents but it can be modified for use on unbalanced 3-phase circuit & for 2-phase & 1-phase circuits.

No rotating magnetic field is produced here

Advantage of Moving Iron power factor meter

Working forces are very large

All coils are fixed. Hence the use of ligaments is elminated

Scale extends over 360o

Simple & robust in construction

Cheap

Disadvantage of Moving Iron power factor meter

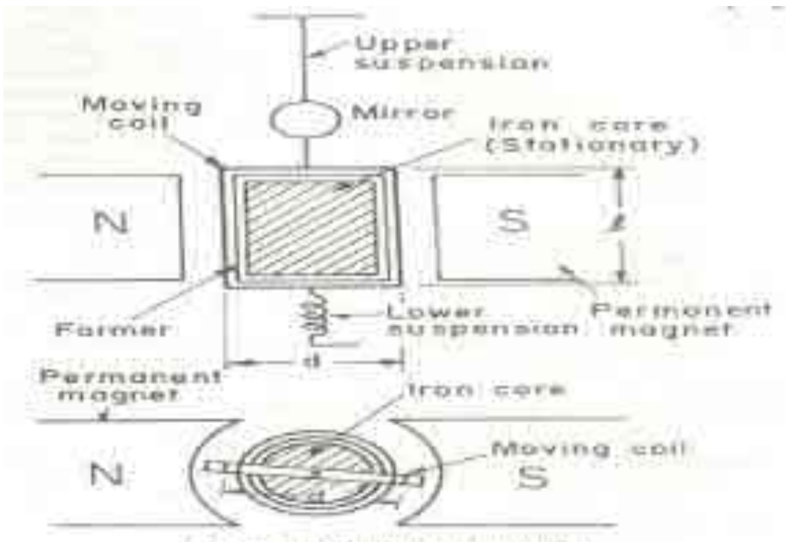
Less accurate due to iron losses

Calibration is affected by variations in supply frequency, voltage & waveform

Magnetic measurements

Ballistic galvanometer

It is used for the measurement of quantity of electricity passed through it. It is due to the result of an instantaneous emf induced in search coil connected across the ballistic galvanometer terminals. The quantity of electricity passing through the galvanometer is proportional to the emf induced and hence to the change in the flux linking with the search coil.



When we pass a current through a galvanometer it does not reach its steady state deflection immediately but there is a time interval or period of transition during which the galvanometer deflects from zero position to final steady position. Dynamic behavior of galvanometer during this period is examined by the equation of motion. The constants of galvanometer are known as intrinsic constants.

The different torque acting on the moving system are

1. **Deflecting Torque (Td):** It is for deflecting the pointer from initial zero position.

Td=BANi

B= Flux density in air gap

A=Area of coil

N= Number of turns

i = Current through the galvanometer.

2. **Inertia Torque (Tj)**: A retarding torque is produced due to inertia of moving system. This torque depends upon the moment of inertia of the moving system and angular acceleration.

$Tj = J\, d^2\theta/dt^2$

J = Moment of inertia of moving system, θ =deflection at any time.

3. Damping Torque (T_D): Damping is provided by the friction due the motion of the coil in air and also by induced electrical effects, if a closed circuit is provided.

$T_D = D\, d\theta/dt$

D= damping constant.

4. **Controlling Torque (Tc):** It is provided due to the elasticity of the system which tries to restore the moving system back to its original position.

$Tc = k\theta$, k= Control constant

Flux meter

It is a special type of ballistic galvanometer in which the controlling torque is very small and the electromagnetic damping is heavy.

The construction is similar to that of a moving coil mille ammeter. A coil of small cross section is suspended from a spring supported by means of a single silk thread. The coil moves in the narrow gap of a permanent magnet. There are no control springs. The current is lead in to the coil with the help of a very loose helices of thin, annealed silver strips. The controlling torque is thus reduced to minimum. The coil is former less and air friction damping is negligible.

The terminals of the flux meter are connected to a search coil. The flux linking with the search coil is changed either by removing the coil from the magnetic field or by reversing the field. Due to the change in the value of the flux linking with the search coil an emf is induced in it. This emf send a current through the flux meter which deflects through an angle depending upon the change in the value of the flux linkages.

If the flux meter permanent magnet field is uniform for all positions of the moving coil, G is a constant. Change in the value of the flux is directly proportional to the change in the deflection. So the instrument have a uniform scale.

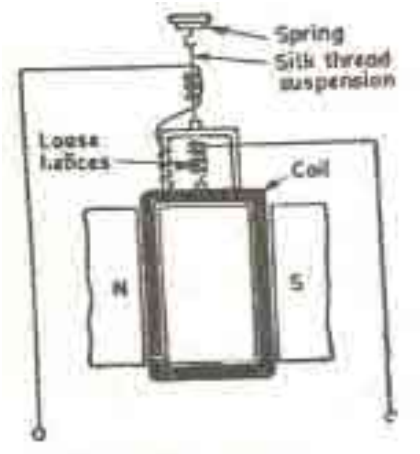


Fig. 8.17. Flux meter.

Lloyd – fisher square

This is the most commonly used magnetic square and therefore it is described in greater details. The strips used are usually 0.25 m long and 50 to 60 mm wide. These strips are built up into four stacks. Each stack is made up of two types of strips one cut in the direction of rolling and other cut perpendicular to the direction of rolling. The stacks or strips are placed inside four similar magnetizing coils of large cross sectional area. These four coils are connected in series to form the primary winding. Each magnetizing coil has two similar single layer coils underneath it. They are called secondary coils. These secondary coils are connected in series in groups of four, one from each core to form two separate secondary windings.

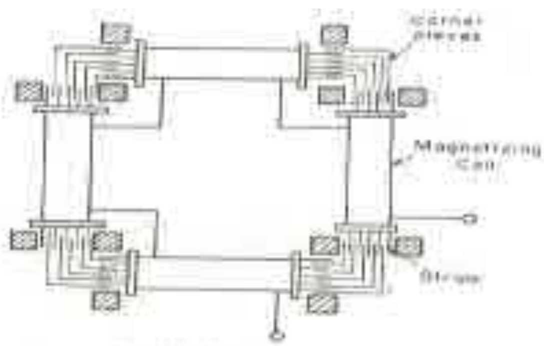


Fig. 10.20. Lloyd Fisher square.

The ends of the strips project beyond the magnetizing coils. The strips are so arranged that plane of each strip is perpendicular to the plane of the square. The magnetic circuit is completed by bringing the four stacks together in the form of a square and joining them at the corners. Measured loss has to be corrected for the loss in the corner pieces.

UNIT- III – COMPARISON METHODS OF MEASUREMENTS

D.C & A.C potentiometers, D.C & A.C bridges, transformer ratio bridges, self-balancing bridges. Interference & screening – Multiple earth and earth loops - Electrostatic and electromagnetic interference – Grounding techniques.

POTENTIOMETRS

The instrument used to measure an voltage comparing it with a known voltage is known as potentiometers.

Advantages

1. High degree of accuracy due to the comparison method.

2. It is independent of source resistance.

3. It is used to measure current with the help of a standard resistance.

4. It is used to calibrate ammeter, voltmeter, wattmeter etc .

SLIDE-WIRE POTENTIOMETERS

It consist of a German sliver or magnanin wire of uniform cross section and stretched between two terminals A&B on a flat board with a scale graduated in mm fixed along side. The extremes A&B are connected to a battery through a variable resistance R with a positive terminal 0f battery connected to end A & negative terminal to end B.

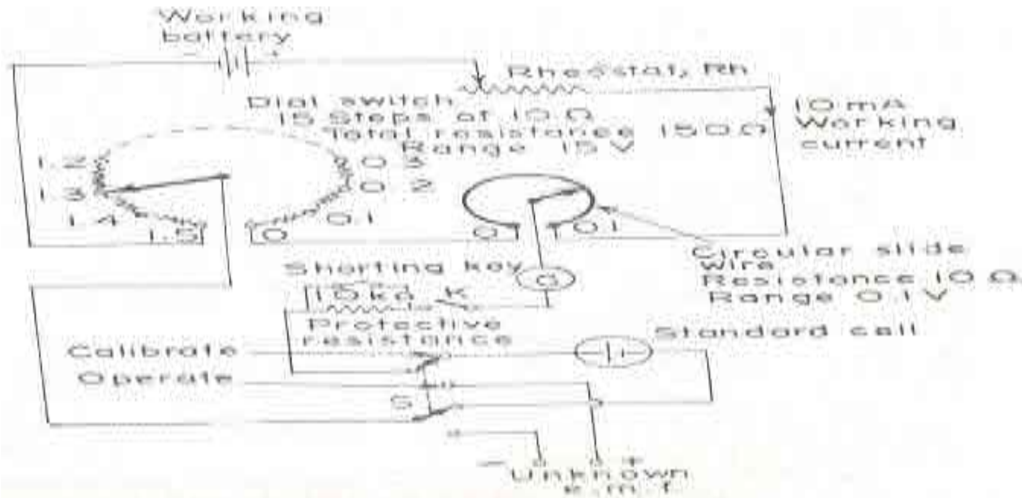
When switch is closed ,a voltage is developed between A&J as AB is a resistor R of length L.Then total resistance/unit length ,r =R/L.The resistance is not a constant but depend on sliding contact as it is varied.

Voltage drop = irl across the resistance.

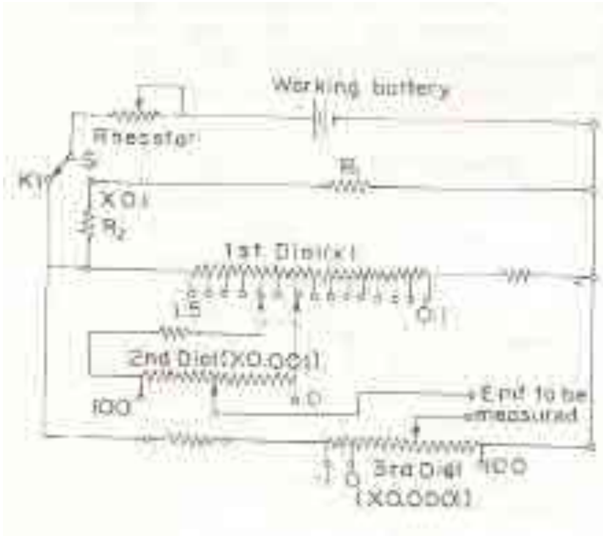
Precision Slide Wire Potentiometer (Compton Potentiometer)

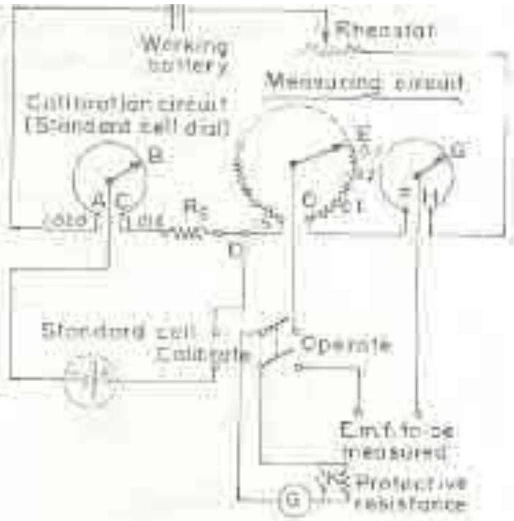
It use calibrated dial resistors and a small circular wire of one or more turns there by reducing the size of the instrument. A dial switch having 16 contact points and a short slide wire .Two moving contacts P1&P2.P1 sliding over the slide wire and contact P2 sliding over he studs connected to the resistance coil. Balance condition more easily and quickly obtained by means of coarse (dial) adjustments and fine (slide wire) adjustment. A battery B of 2V is connected across the potentiometer through the resistors R1&R2 for controlling the current

drawn from the battery .R1 consists of a number of resistance coils connected in sires and is meant for coarse adjustment.R2 is like a slide wire and is meant for fine adjustment .



Vernier Potentiometer





In slide wire potentiometer, the slide wire should be extremely well made so that the variations in contact resistance are not to limit the precision in adjustment of the potentiometer current. This difficulty may be overcome by the use of a shunted dial resistance for the regulator.

The working of Vernier potentiometer is based on Kelvin Varley principle.

APPLICATIONS OF POTENTIOMETERS

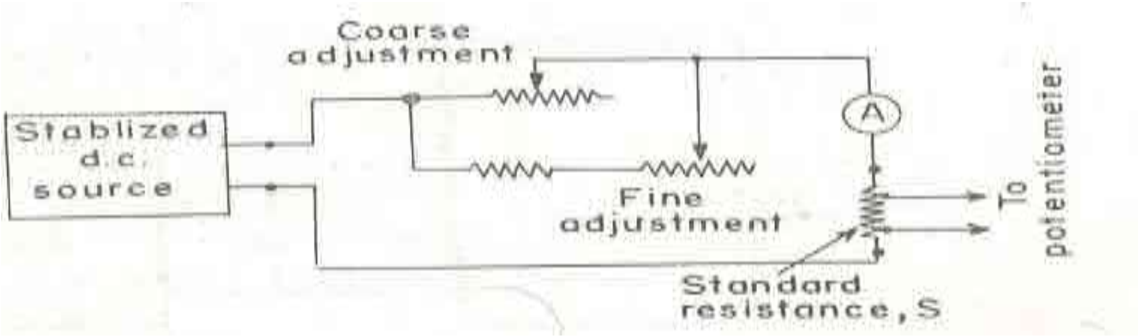
Calibration of Ammeter

Fig shows the circuit for calibrating the ammeter. A standard resistance of suitable value and sufficient current carrying capacity is placed in series with the ammeter under calibraton.The voltage across the standard resistor is measured with the help of potentiometer an the current through the standard resistance can be computed. I

Current $I=V_s/S$

V_s= voltage across the standard resistor

S= standard resistor



Calibration of voltmeter

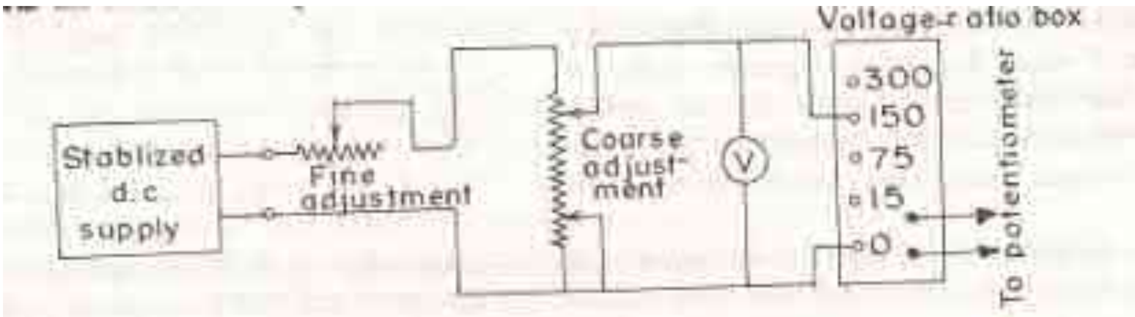
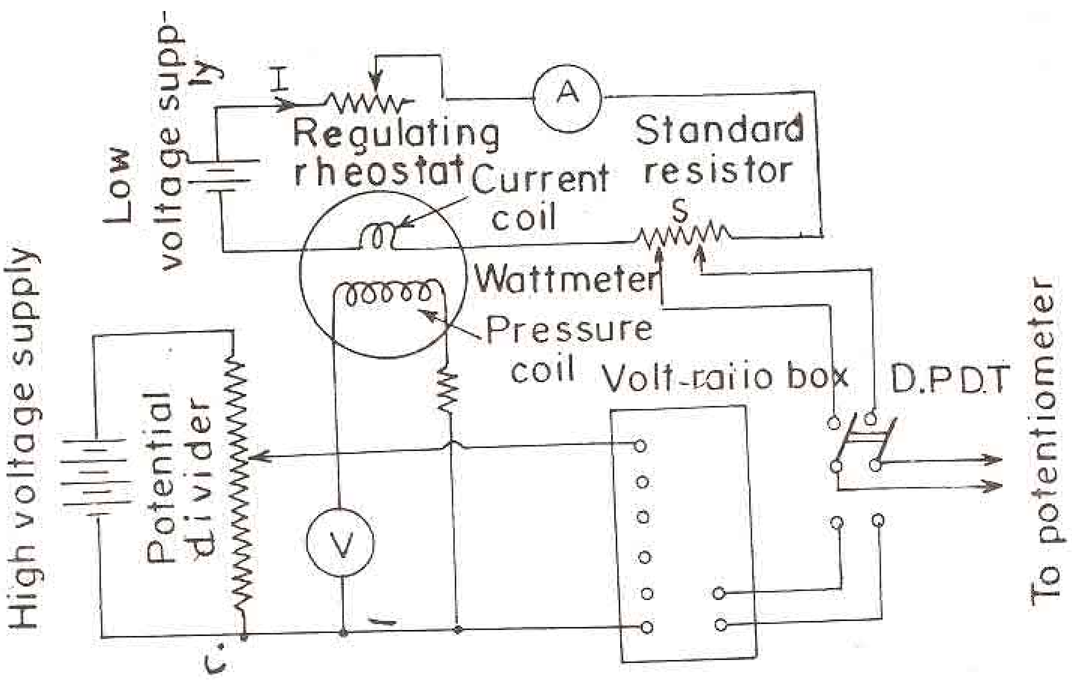


Fig. shows the circuit for calibration of voltmeter. Fig shows a potential divider network consisting of two rheostats one for coarse and other for fine control of calibrating voltage. The potentiometer measures he true value of voltage. If the potentiometer reading does not agree with the voltmeter reading a negative or positive error is indicated. A calibration curve may be drawn with the help of the readings of voltmeter and potentiometer.

Calibration of wattmeter

The arrangement is shown in fig. The current coil of wattmeter is supplied from a low voltage supply and the series rheostat is inserted to adjust the value of current. The voltage ,V, and the current ,I, are measured with the potentiometer employing D.P.D.T switch. The true power is then VI and the wattmeter reading may be compared with this value.

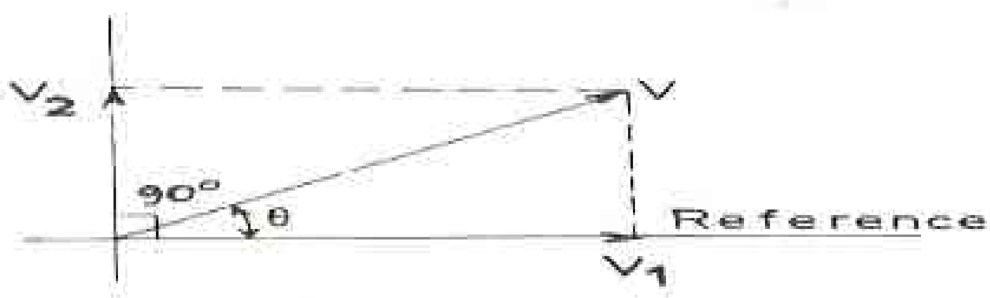


AC POTENTIOMETERS

- Two types of AC potentiometers

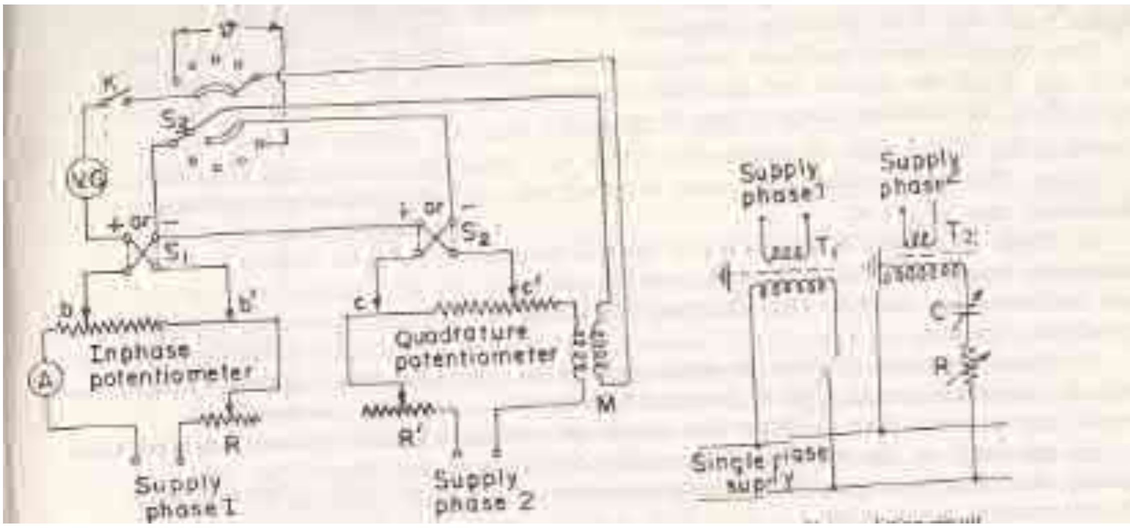
Polar type

In these instruments, the magnitude of the unknown voltage is read from one scale and its phase angle with respect to some reference phasor is read directly from a second scale. Voltage is read in the form V<θ.



Co-ordinate type

These instruments are provided with two scales to read respectively the in phase component V1,and the quadrature component,V2 of the unknown voltage V.These components are 90 degree out of phase with each other.



MEASUREMENT OF RESISTANCE

1. Low resistance

All resistance of the order of 1Ω under may be classified as low resistance.

Eg : Resistance of armature and series windings of large machines

2. Medium Resistance

This class includes resistance from 1Ω upwards to 100KΩ

Eg : Voltmeter resistance, field resistance of motor.

3. High Resistance

Resistance of 100KΩ and upwards may be classified as high resistance.

BRIDGE MEASUREMENT:-

Bridges are used measuring component values and other circuit parameters directly derived from component values.In bridge circuits , the unknown values of an components are compared to that of an accurately known component

A Simply bridge circuit consist of

a)four resitance arms

b)battery

c)null detector

The null detector is usually a galvanometer or other sensitive current meter. The bridge is excited by a DC or AC Source, applied to two opposite junction and a detector connected to the other two junction and a detector connected to the other two junctions.

Bridge circuit are used for measuring component values such as resistance ®, Inductance(L) and capacitance(C), The measurement accuracy is very high

Basically there are two types of bridges,

They are **a)DC Bridge**

b)AC Bridge.

a)DC Bridge

DC bridge are mainly used for measuring DC Resitances .”Wheat stone bridge” is used for measuring medium DC Resistances and kelvin’s double bridge “ is used for measuring low DC Resitances .

b)AC Bridge:-

In AC bridge , its basic form consist of

1) Four arms

2) Source of Excitation and
3) Null detector.

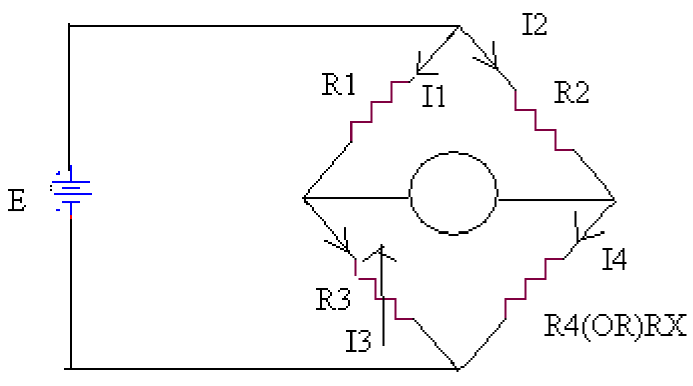
For low frequency measurements , the source of excitation is power line, for high frequency measurement excitation is by oscillator.The null detector is usually a pair of headphones.

“Maxwell’s Bridge and “Hay’s Bridge” are used for measurement of self inductance.

“weins bridge” are “universal impedance Bridge” are used for measurement of frequency.

(i)Wheat stone Bridge.

Wheat stone Bridge is the simplest form of bridge used for measuring resistance



The wheat stone bridge has

a) four resistance arms

b) battery and

c) Galvanometer.

The source (2) is connected to ‘a’ and ‘b’ Galvanometer has a zero centre scale .When there is no current , the voltage between ‘a’ and ‘c’ equals , the voltage between ‘a’ and ‘d’ (or) the voltage between ‘b’ and ‘c’ equals, the voltage between ‘b’ and ‘d’.

so the balance condition

$I_1 R_1 = I_2 R_2$ (OR)

$I_3 R_3 = I_4 R_4$

In general, Resistance R1 and R2 are resistive arms and R3 is called standard arm of the Bridge from fig

For (G) current to be zero, following condition is to be satisfied,

$$I_1 = I_3 = \frac{E}{R1 + R3}$$

$$I_2 = I_4 = \frac{E}{R2 + R4}$$

Substitute I_1 and I_2 in the equation $I_1 R_1 = I2\, R_2$

$$\frac{E}{R1 + R3} \text{ X R1 } = \frac{E}{R2 + R4} \text{ X R2}$$

R1 (R2+R4) = R2 (R1+R3)

R1R2 +R1R4 = R2R1 +R2R3

R4 (OR) RX = $\frac{R2R3}{R1}$

This is the equation for the bridge to be balanced.

In practical, one of the resistances (R3) is made adjustable to permit balancing when the bridge is balanced, the unknown resistance (R4) may be determined by adjusting the value of standard resistor R3, therefore

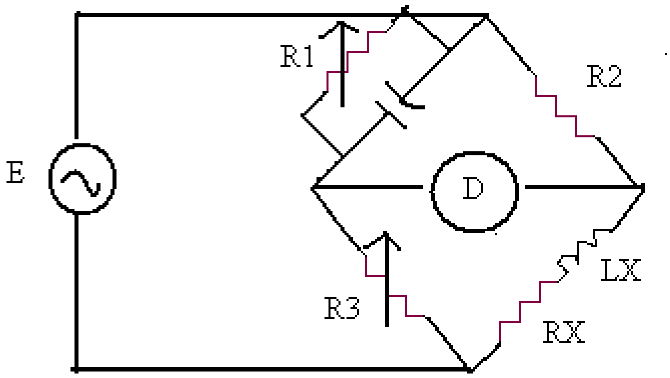
RX = R2 R3/R1

(RX=unknown resistance)

The sensitivity of a Wheatstone bridge is defined as the deflection of a galvanometer per unit current. The amount of deflection is a function of the sensitivity of the galvanometer.

MAXWELL'S BRIDGE

The Maxwell bridge is used for measuring unknown inductance in terms of a known capacitance



Z1==1/Y1 (R1 in parallel with C1)

Y1=1/R1 +jwC

Z2 = R2

Z3 = R3

ZX= RX in series with LX=RX+jwlx

For bridge to be made balanced,

Z1ZX = Z2Z3 ---------(1)

Sub Z1, Z2, Z3 and ZX in equation ---(1)

We get

$$\frac{r1}{1+JWr1c1}(RX \; +jwlx) \; = \; R2R3$$

RX =jwlx = R2R3 (1/R1 +jwC1)

RX +jwlx = $\frac{R2R3}{R1}$ and LX=R2R3C1

For Q =wlx/RX ----(2)

Substitute RX & LX in equation (2)

$$Q= \frac{wR2R3C1R1}{R2R3}$$

Q = w C1R1

In maxwell's bridge circuit , one of the ratio arms has a resitance R1 and capacitance C1 in parallel. The expansion for Q factor is given as "Q=WC1R1"

The resistance is expressed in ohms inductance in henrys and capacitance in farads. This bridge measures inductances from 1 to 1000HZ.

Uses of maxwell's Bridge

a)used for the measurement of low Q values

b) inductance can be measured directly

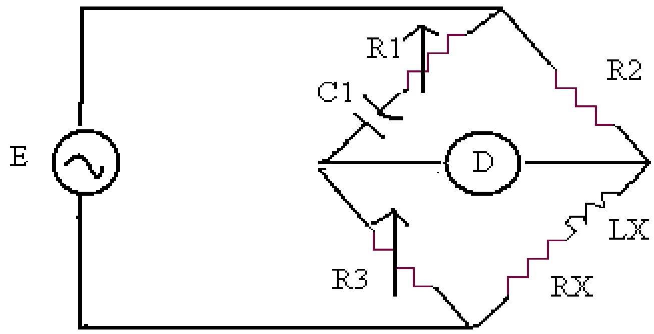
DISADVANTAGE:-

1. There is an interaction between the resistance and reactance balances .If the bridge is used with a fixed capacitor. This can be eliminated by varying the capacitor. This can be eliminated by reactance balance.

2. Limited to measurement of low Q cols.

HAY'S BRIDGE:-

Hay's bridge the modified form of maxwell's bridge uses a resistance uses a resistance in series with the standard capacitor.It is used to measure inductance.



Z1= R1 – j/wC1

Z2 = R2

Z3= R3

Zx = Rx + jwlx

For bridge to be balanced

Z1ZX = Z2Z3-------------------(1)

Sub Z1 , to Z4 in (1)

We get

(R1 – j/Wc1) (Rx + jwLx) = R2R3

R1Rx + R1jwLx – jRx/Wc1 + Lx/Wc1 = R2R3

R1Rx + Lx/ Wc1 – jRx/Wc1 + jwlxR1 = R2R3

Equating real & imaginary parts, we get

R1Rx + Lx/C1= R2R3-------(2)

And

Rx/Wc1 = wLxR1------------(3)

$Rx = W^2 LxR1C1$

Sub Rx in (2) we get,

$R1(W^2 LxR1C1) + Lx/C1 = R2R3$

$W^2 LxR^2 1\ C1 + Lx/C1 = R2R3$

C1 is multiplied in both sides, so we get

$W^2 R1^2 C1^2 Lx = R2R3C1$

$Lx (W^2 R1^2 C1^2 +1) = R2R3C1$

$$Lx = \frac{R2R3C1}{W^2 R1^2 C1^2 + 1}$$

Sub Lx in (3) we get,

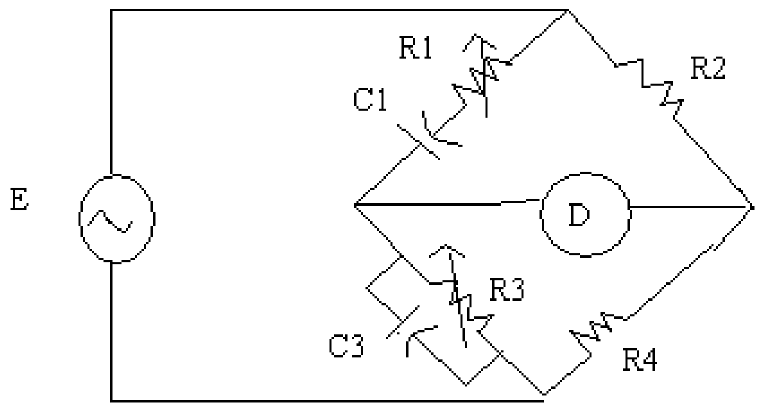
$$Rx/wc1 = wR1 \frac{R2R3C1}{W^2 R1^2 C1^2 + 1}$$

$$Rx = \frac{w^2 C1^2 R1R2R3}{1 + w^2 R1^2 C1^2}$$

The Hay's bridge has a resitance R1 in series with a standard capacitor 'C1'. It is more convenient for measuring high Q coils, because of the value of R1 is very low for large phase angles. For a low value Q coils Maxwell Bridge is preferred.

This circuit is useful for the measurement of high Q inductors (Q>10)

WEIN BRIDGE



- Wein bridge is use to measure frequency .It is an a.c bridge . It is used as a notch filter in the harmonic distortion analyzer.
- It is also used in audio and high frequency oscillators as the frequency determining element
- The figure shows wein's bridge circuit used to measure frequency from figure

$Z1 = R1 - j/Wc1$

$Z2 = R2$

$Z3 = 1/R3 + jwC3$

$Z4 = R4$

For bridge to be made balanced,

$Z1Z4 = Z2Z3$

$Z2 = \frac{Z1Z4}{Z3}$ -----------------(1)

Sub Z1 to Z4 in (1)

We get

R2 = (R1 - j/Wc1) R4($\frac{1}{1/R3 + jwC3}$)

R2 = R4 (R1 - j/Wc1) (1/R3 + jwC3)

R2 = $\frac{R4R1}{R3}$ + $\frac{R4j}{wC1R3}$ + R1R4 jwC3 + $\frac{R4C3}{C1}$

By equating real and imaginary parts,we get

R2 = $\frac{R1+R4}{R3}$ + $\frac{C3+R4}{C1}$ ---------------(2)

And

$\frac{R4}{wC1R3}$ - Wc3r1r4 = 0 -----------------(3)

Rx = w^2 LxR1C1

From equation (2) we get,

$\frac{R2}{R4}$ = $\frac{R1}{R3}$ + $\frac{C3}{C1}$ --------------(4)

From equation (3) we get

1/Wc1r3 = Wc3r1

w^2 = 1/C1R1R3C3

$$w = \frac{1}{\sqrt{C1R1R3C3}}$$

as w = 2Πf ,

$$f = \frac{1}{2Đ\sqrt{C1R1R3C3}} \quad \text{------------------(5)}$$

by choosing R1 = R3 and C1 = C3 , then equation (4) is reduced to

R2/R4 = 2

Therefore the equation has a series RC combination in one arm and parallel RC combination in the adjoining arm, The impedance of arm 1 is Z1 and an admittance of arm 3 is Y3 .For the bridge to get balanced

Z1Z4 = Z2Z3 ,

(ie) $Z2 = \frac{Z1Z4}{Z3}$

The frequency to be found is shown as

F = 1/2ΠRC HZ

USES OF WEIN'S CIRCUIT

1. used for measuring frequency
2. used for measuring capacitances
3. used in harmonic distortion analyzer as a notch filter.
4. used as frequency determining element in audio frequency and RF oscillator
5. Accuracy from 0.5 to 1% can be obtained

ANDERSON'S BRIDGE:-

- This bridge , in fact is a modification of the maxwell's inductance – capacitance bridge .In this method, the self inductance bridge . In this method , the self – inductance is measured in terms of a standard capacitor.
- This method is applicanle for precise measuerement of self inductance over a very wide range of values.
- The fig shows the connections and the phasor diagram of the bridge for balanced condition .

Let L1 = Self inductance to be measured

R1 = Resistance of self –inductor

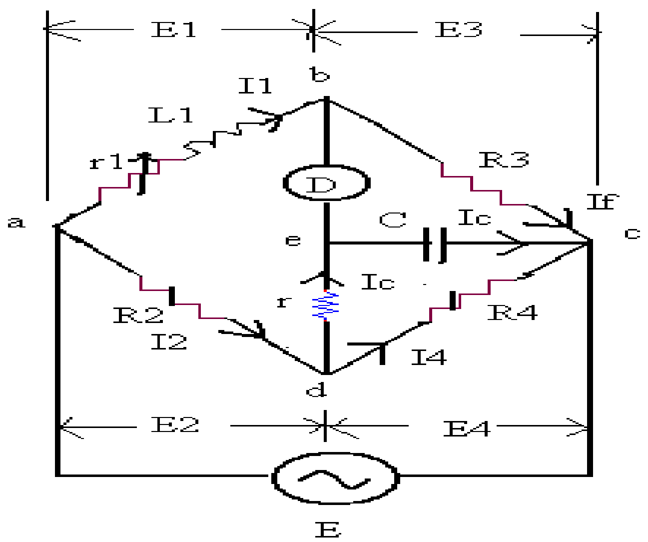
R1 = Resistance connected in series with self-inductor

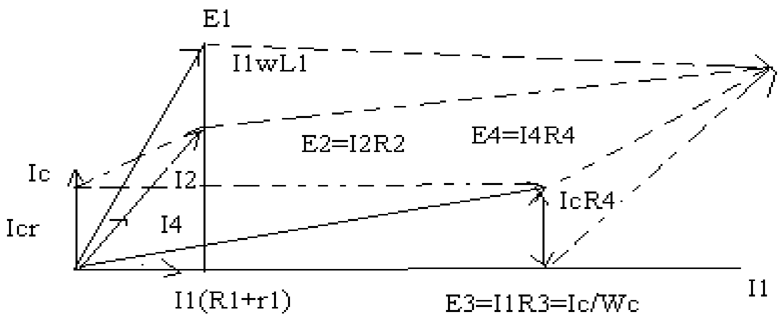
R2, r1,R3,R4 = Known non-inductance resistor

C = fixed standard capacitor

And At Balance , Now I1R3 = Ic x 1/jwC

Ic = I1 jwCR3





Writing the other balance equation

I1(r1 +R1 + jwL1) = I2R2 + Ic r

And

Ic (r + 1/jwC) = (I2 – Ic) R4

Sub the value of Ic in the above equation , we have

I1 = (r1 + R1 + jwL1) = I2R2 + I1 jwCR3r

Or I1(r1 + R1 + jwL1 - jwCR3r) = I2R2—(1)

And jwCR3I1(r + 1/jwC) = (I2 – I1jwCR3)R4 (OR)

I1(jwCR3r + jw (R3R4 + R3) = I2R4—(2)

From equation (1) and (2) we obtain

I1(r1 +R1 + jwL1 - jwCR3r) = I1 (R2R3/R4 + jwCR2R3r/R4 + jwCR3R2)

Equating the real and imaginary parts

R1 = R2R3/R4 – r1

L1 = CR3/R4(r(R4 + R2) + R2R4)

An examination of balance equation reveals that to obtain easy convergence of balance , alternate adjustment of r1 and R2 should be done as they appear in only one of the two balance equations

ADVANTAGES:-

1.In case of adjustments are carried out by manipulating control over r1 and r , they become independent of each other. This is a marked superiority over sliding balance conditions met with low Q coils when measuring with maxwell's bridge

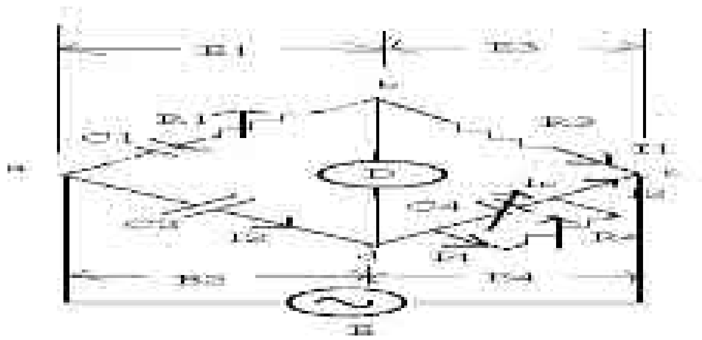
2.This bridge may be used for accurate determination of capacitance in terms of inductance

DISADVANTAGES:-

1.The anderson's bridge is more complex than its prototype maxwell's.The anderson's bridge has more parts and is more complicated to set up and manipulate. The balance equation are not simple and in fact are much more tedious.

2.An additional junction pont increases the difficulty of shielding the bridge. Considering the above complication of Anderson's bridge , in all the cases where a variable capacitor is permissible the more simple maxwell's bridge is used instead of Anderson's bridge.

SCHERING BRIDGE:-



Let C1 = Capacitor whose capacitance is to be determined,

R1 = a series resistance representing the loss in the capacitorC1

C2 = a standard capacitor .This capacitor is either an air (or) a gas capacitor and hence loss free

R3 = a non inductive resistance

C4 = a variable capacitor,

And

R4 = a variable non – inductive resistance in parallel with variable capacitor C4

At balance (r1 + 1/jwC1)(R4/1+ jwC4R4) = R3 /jwC2

(OR) (r1 + 1/jwC1)R4 = R3/jwC2 (1 + jwC4R4)

(OR) r1R4 – Jr4/Wc1 = - Jr3/Wc2 + R3R4C4/C2

Equating the real and imaginary terms , we obtain

r1 = R3C4/C2

and C1 = C2 (R4/R3)

Two independent balance equation are obtained if C4 and R4 are chosen as the variable elements.

Dissipation factor D1 = tan δ = Wc1R1

= w (C2R4/R3) X (R3C4/C2)

= Wc4r4

- Therefore values of capacitance C1 nad its dissipation factor one obtained from the values of bridge elements at balance
- Permanently set up schering bridges are sometimes arranged so that balancing is done by adjustment of R2 and C4 with C2 nad R4 remaining fixed .Since R3 appears in both the balance equation and therefore there is some difficulty in obtaining balance but it has certain advantages.

ADVANTAGES:-

1.The equation for capacitance is C1 = (R4/R3)C2 and since R4 and C2 are fixed , the dial of resistor R3 may be calibrated to read the capacitance directly .

2.Dissipation factor D1 = Wc4R4 and in case the frequency is fixed the dial of capacitor C4 can be calibrated to read the dissipation factor directly.

ELECTROMAGNETIC INTERFERENCE:

Definition:

If the parameter to be measured is at the place at which a measurement is to be displayed. The main one is electrical noise or interference being superimposed on the measurement signal. This is called electromagnetic interference.

Sources of Electromagnetic interference:

Sources of noise and interference include

1) AC power circuits , solenoids switching fluorescent lighting , radio frequency transmitter.
2) Welding equipment
3) Inductive or capacitive coupling.
4) By having earths of slightly different potentials.

Effects of Electromagnetic interference:

Electromagnetic interference often affects instruments signals particularly when very sensitive instruments which are close to equipment that produces a log of electrical noise.

Electromagnetic Compatibility:

The Electromagnetic compatibility regulation are designed to eliminate radio frequency interference emission from electrical machines and to ensure that these are immune to such radiation from external sources.

Earth Loops:

Earth loops from a distinct part of the guarding system of electrical equipments.

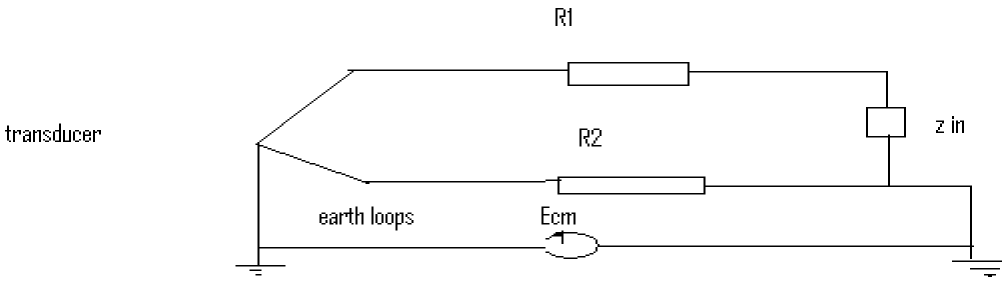
Importance of safety ground:

In a proper installation this ground connection ensures that none of the conducting parts of the instrument when touched can rise a potential above the safety margin with respect to ground.

Earth loop formation:

When two points in a measuring system are connected to ground. A ground loop is formed by the part of the measuring system between the two ground points and the soil between the two points.

The fig shows an example of such an earth loop formed between a grounded transducer and the grounded measuring instrument which are connected by relatively long cables.R_1 and R_2 represented the cable resistance.



The transducer might be a thermocouple or a strain gauge connected to a ground object whereas the instrument can be strip chart recorder impedance bridges an oscilloscope or a data acquisition system.

The ground currents and the soil resistivity create a virtual voltage Sources E cm causing a current to flow through the measuring set up.Thus a constraints arises that accurate measuring system must be designed to reduced or eliminate errors due to ground current flowing below the surface of the earth and ground current associate with the measuring set up it self.

ELECTROSTATIC INTERFERENCE AND SCREENING:

The basics of balancing:

Balanced connection in an audio system are designed to reject both external noise, from power wiring etc,and also internal cross talk from adjacent signal cables. The basic principle of balanced inter connection is to get the signal you want by subtraction using a three wire connection.

In many cases one signal wire sense the actual output of the sending unit while the other sense units output sockets ground, and the difference between them gives the wanted signal. any noise voltage that appear identically on both lines are in theory completely cancelled by the subtraction. In real life the subtraction falls short of perfection as the gains via the hot and cold inputs will not be precisely the same, and the degree of discrimination actually achieved is called the common mode rejection ratio.

Screening:

While two wire carry the signal, the third is ground wire which has the dual duty of both joining the grounds of the interconnected equipment and electro statically screening the two signal wire by being in some way wrapped around them. The wrapping around can mean.

1) A lapped screen with wires laid parrel to the central signal conductor. The screening converge is not perfect, and can be badly degraded as it tends to open up on the outside of the cable bends.
2) A braided screen around the central signal wires. This is more expensive, but opens up less on bends. Screening is not 100% but certainly better than lapped Screen.
3) An over lapping foil screen with the ground wire running down the inside of the foil and in electrical contact with it. This is usually the most effective as the foil cannot open up on the outside of bends, and should give perfect electrostatic screening. However the higher resistance of Al foil compared with copper braid means that RF screening may be worse.

Advantages of Balancing

1) It discriminates against noise and crosstalk.

2) Balanced interconnect allow 6 dB more signal level on the line.

UNIT IV
STORAGE AND DISPLAY DEVICES

Magnetic disk and tape – Recorders, digital plotters and printers, CRT display, digital CRO, LED, LCD & dot matrix display – Data Loggers.

Recorders:

A recorder is a measuring instrument which records time varying quantity, even after the quantity or variable to be measured has stopped. The electrical quantities such as voltage & current are measured directly. The non- electrical quantities are recorded using indirect methods. The non- electrical quantities are first converted to their equivalent voltages or currents, using various transducers.

Electronic recorders may be classified as:

1. Analog recorders
2. Digital recorders

Analog recorders dealing with analog systems can be classified as

1. Graphic recorders
2. Oscillographic recorders
3. Magnetic Tape recorders

Digital recorders dealing with digital output can be classified as

1. Incremental digital recorders
2. Synchronous digital recorders

4.2 Magnetic Disk And Tape

MagneticTapeRecorder

- Ø The magnetic tape recorders are used for high frequency signal recording.
- Ø In these recorders, the data is recorded in a way that it can be reproduced in electrical form any time.
- Ø Also main advantage of these recorders is that the recorded data can be replayed for almost infinite times.
- Ø Because of good higher frequency response, these are used in Instrumentation systems extensively.

Basic Components of Tape Recorder

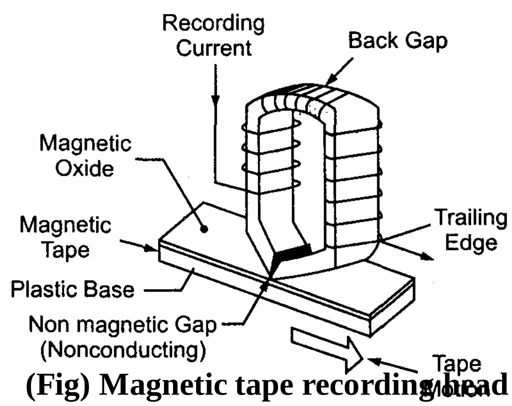
Following are the basic components of magnetic tape recorder

1. Recording Head
2. Magnetic Tape
3. Reproducing Head
4. Tape Transport Mechanism
5. Conditioning Devices

Recording Head

- Ø The construction of the magnetic recording head is very much similar to the construction of a Transformer having a toroidal core with coil.

Ø There is a uniform fine air gap of 5µ m to 15µ m between the head and the magnetic tape.



(Fig) Magnetic tape recording head

Ø When the current used for recording is passed through coil wound around magnetic core, it produces magnetic flux.

Ø The magnetic tape is having iron oxide particles.

Ø When th e tape is passing the head, the flux pr oduced due to recording current gets linked with iron oxide part ices on th e magnetic tape and these particles get magnetized.

Ø This magnetization particle remain as it is, e vent Hough the magnetic tape leaves the gap.

Ø The actual recording takes place at the trailing edge of the air gap.

Ø Any signal is recorded in the form of the patterns.

Ø These magnetic patterns are dispersed anyw here along the length of mag netictape in accordance with the variation in recording current with respect to time.

Magnetic Tape

Ø The magnetic tape is made of thin sheet of tough and dimensionally stable plastic ribbon.

Ø One side of this plastic ribbon is coated by powdered iron oxide particles (Fe_2O_3) thick.

Ø The magnetic tape is wound around a reel.

Ø This tape is transferred from one reel to another.

Ø When the tape passes across air gap magnetic pattern is created in accordance with variation of recording current.

Ø To reproduce this pattern, the same tape with some recorded pattern is passed across another magnetic head in which voltage is induced.

Ø This voltage induced is in accordance with the magnetic pattern.

Reproducing Head

Ø The use of the reproducing head is to get the recorded data played back.

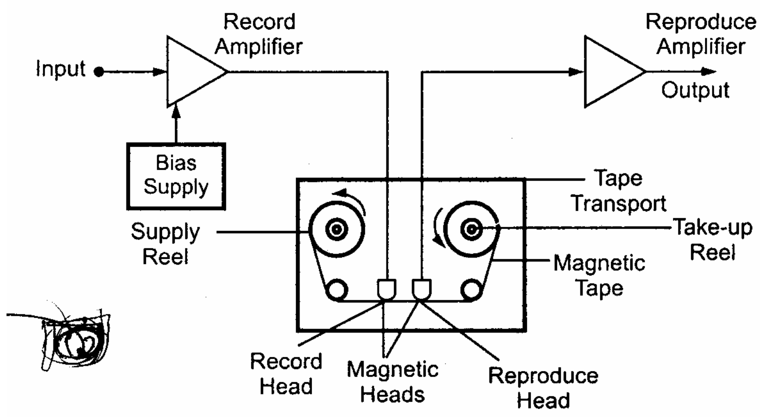
Ø The working of the reproducing head is exactly opposite to that of the recording head.

Ø The reproducing head detects the magnetic pattern recorded on the tape.

Ø The head converts the magnetic pattern back to the original electrical signal.

Ø In appearance, both recording and reproducing heads are very much similar.

Tape Transport Mechanism



(Fig) Basic tape transport mechanism

- Ø The tape transport mechanism moves the magnetic tape along the recording head or reproducing head with a constant speed
- Ø The tape transport mechanism must perform following tasks.
  - It must handle the tape without straining and wearing it.
  - It must guide the tape across magnetic heads with great precision.
  - It must maintain proper tension of magnetic tape.
  - It must maintain uniform and sufficient gap between the tape and heads.
- Ø The magnetic tape is wound on reel.
- Ø There are two reels; one is called as supply & other is called as take-up reel.
- Ø Both the reels rotate in same direction.
- Ø The transportation of the tape is done by using supply reel and take-up reel.
- Ø The fast winding of the tape or the reversing of the tape is done by using special arrangements.
- Ø The rollers are used to drive and guide the tape.

Conditioning Devices

- Ø These devices consist of amplifiers and fitters to modify signal to be recorded.
- Ø The conditioning devices allow the signals to be recorded on the magnetic tape with proper format.
- Ø Amplifiers allow amplification of signal to be recorded and filters removes unwanted ripple quantities.

Principle of Tape Recorders

- Ø When a magnetic tape is passed through a recording head, the signal to be recorded appears as some magnetic pattern on the tape.
- Ø This magnetic pattern is in accordance with the variations of original recording current.
- Ø The recorded signal can be reproduced back by passing the same tape through a reproducing head where the voltage is induced corresponding to the magnetic pattern on the tape.

- Ø When the tape is passed through the reproducing head, the head detects the changes in the magnetic pattern i.e. magnetization.
- Ø The change in magnetization of particles produces change in the reluctance of the magnetic circuit of the reproducing head, inducing a voltage in its winding.
- Ø The induced voltage depends on the direction of magnetisation and its magnitude on the tape.
- Ø The emf, thus induced is proportional to the rate of change of magnitude of magnetisation i.e. e N (dɸ / dt)

  Where N = number of turns of the winding on reproducing head

  ɸ = magnetic flux produced.

  Suppose the signal to be recorded is Vm sin ωt. Thus, the current in the recording head and flux induced will be proportional to this voltage.
- Ø It is given by e= k 1. Vm sin wt, where k1 = constant.
- Ø Above pattern of flux is recorded on the tape. Now, when this tape is passed through the reproducing head, above pattern is regenerated by inducing voltage in the reproducing head winding.
- Ø It is given by e= k2 ωVm cos wt
- Ø Thus the reproducing signal is equal to derivative of input signal & it is proportional to flux recorded & frequency of recorded signal.

Methods of Recording

The methods used for magnetic tape recording used for instrumentation purposes are as follows:

i) Direct Recording
ii) Frequency Modulation Recording
iii) Pulse Duration Modulation Recording

For instrumentation purposes mostly frequency modulation recording is used. The pulse duration modulation recording is generally used in the systems for special applications where large number of slowly changing variables has to be recorded simultaneously.

4.3 Digital Plotters And Printers

PRINTERS

- Ø Printers can be classified according to their printing methodology **Impact printers** and **Non-impact printers**.
- Ø Impact printers press formed character faces against an inked ribbon onto the paper.
- Ø A line printer and dot matrix printer are the examples of an impact printer.
- Ø Non impact printer and plotters use laser techniques, inkjet sprays, xerographic processes, electrostatic methods and e1ectrothermal methods to get images onto the paper.
- Ø A ink-jet printer and laser printer are the examples of non- impact printers.

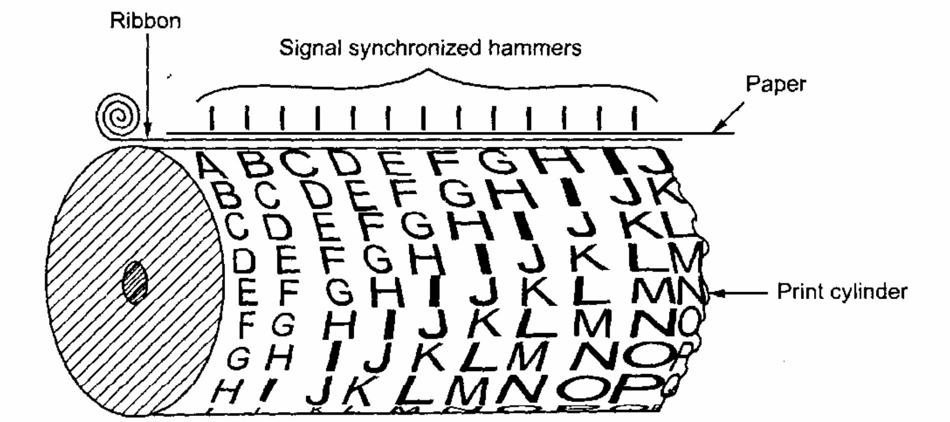
Line Printers

A line printer prints a complete line at a time. The printing speed of line printer varies from 150 lines to

2500 lines per minute with 96 to 100 characters on one line. The line printers are divided into two categories Drum printers and chain printer.

Drum Printers

Drum printer consists of a cylindrical drum. One complete set of characters is embossed on all the print positions on a line, as shown in the Fig. The character to be printed is adjusted by rotating drum.

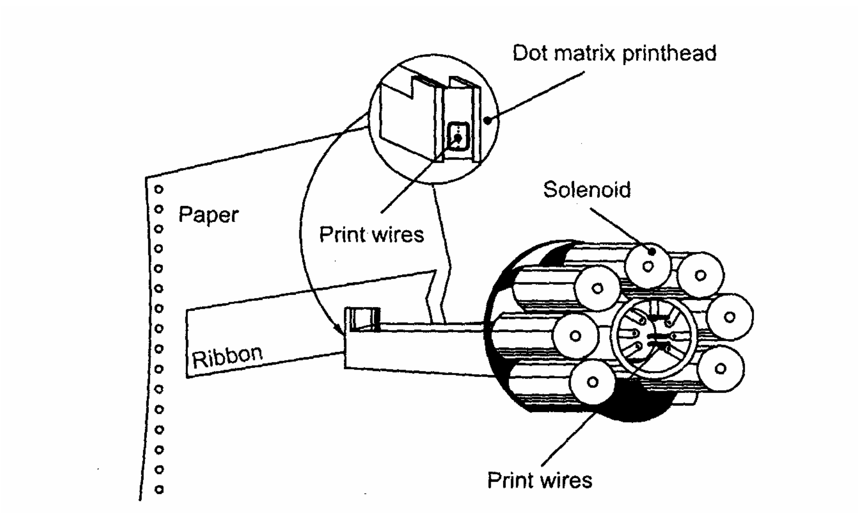


Chain Printers

In these printers chain with embossed character set is used, instead of drum. Here, the character to be printed is adjusted by rotating chain.

Dot Matrix Printers

Dot matrix printers are also called serial printers as they print one character at a time, with printing head moving across a line.



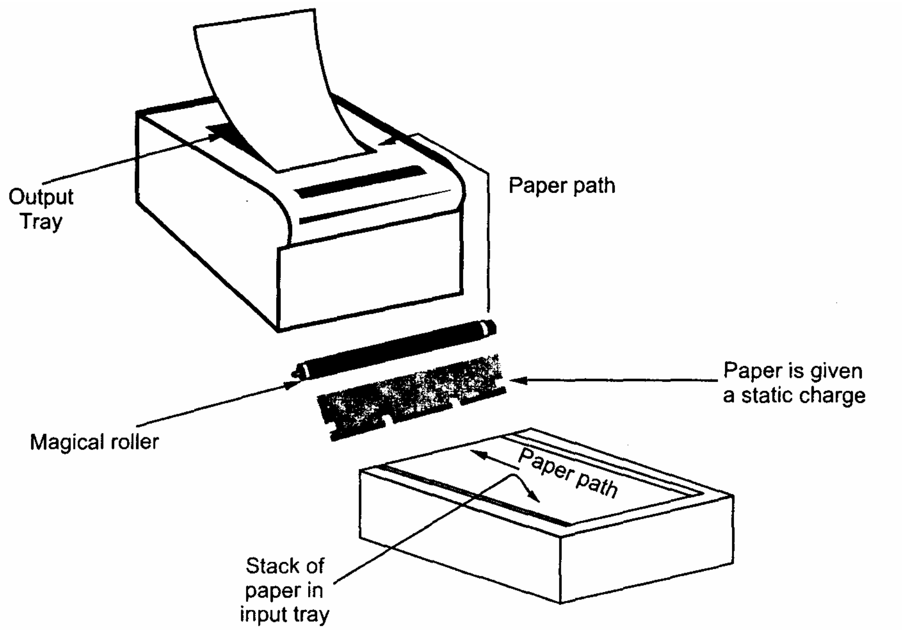
Laser Printer

- The li ne, do t matrix, and ink jet printers need a head movement on a ribbon to print characters.

- This mechanical movement is relatively slow due to the high inertia of mechanical elements.
- In laser printers these mechanical movements are avoided.

- In these printers, an electronically controlled laser beam traces out the desired character to be printed on a photoconductive drum.
- The exposed areas of the drum gets charged, which attracts an oppositely charged ink from the ink toner on to the exposed areas.
- This image is then transferred to the paper which comes in contact with the drum with pressure and heat.

- The charge on the drum decides the darkness of the print.
- When charge is more, more ink is attracted and we get a dark print.



- A colour laser printer works like a single colour laser printer, except that the process is repeated four times with four different ink colours: Cyan, magenta, yellow and black.
- Laser printers have high resolution from 600 dots per inch upto 1200 per inch.
- These printers print 4 to 16 page of text per minute.
- The high quality and speed of laser printers make them ideal for office environment.

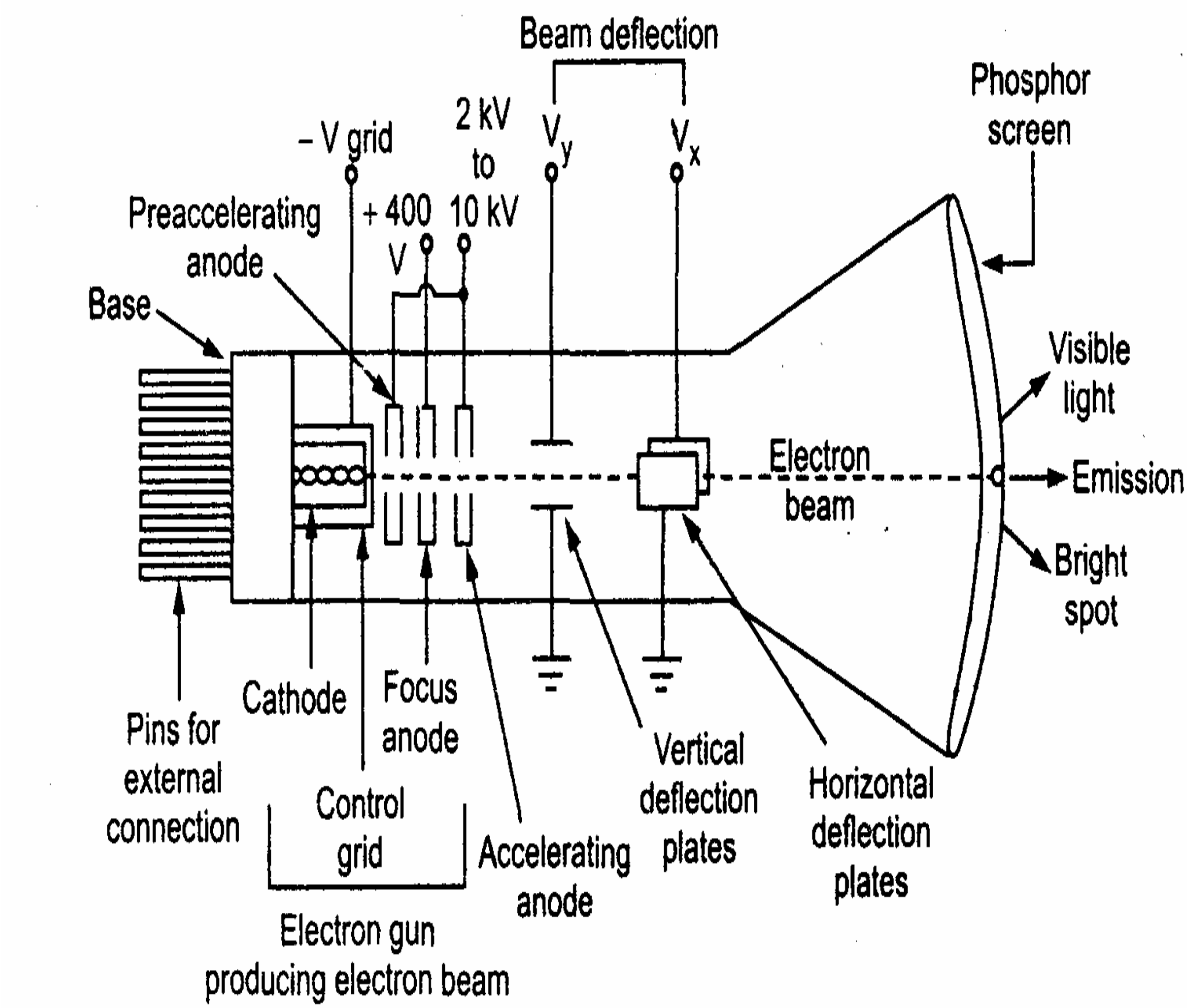
Advantages of Laser printer

- The main advantages of laser printers are speed, precision and economy.
- A laser can move very quickly, so it can "write" with much greater speed than an inket.
- Because the laser beam has an unvarying diameter, it can draw more precisely, without spilling any excess ink.
- Laser printers tend to be more expensive than ink-jet printers, but it doesn't cost as much to keep them running.
- Its toner power is cheap and lasts for longer time.

4.4 CRT Display

The device which allows, the amplitude of such signals, to be displayed primarily as a function of time, is called cathode ray oscilloscope. The cathode ray tube (CRT) is the heart of the C.R.O. The CRT generates the electron beam, accelerates the beam, deflects the beam and also has a screen where beam becomes visible as a spot. The main parts of the CRT are

i) Electron gun
ii) Deflection system
iii) Fluorescent screen
iv) Glass tube or envelope
v) Base



Electron gun

- The electron gun section of the cathode ray tube provides a sharply focused, electron beam directed towards the fluorescent-coated screen.
- This section starts from thermally heated cathode, emitting the electrons.
- The control grid is given negative potential with respect to cathode.
- This grid controls the number of electrons in t beam, going to the screen.
- The momentum of the electrons (their number x their speed) determines the intensity, or brightness, of the light emitted from the fluorescent screen due to the electron bombardment.
- The light emitted is usually of the green colour.

Deflection System

- When the electron beam is accelerated it passes through the deflection system, with which beam can be positioned anywhere on the screen.

Fluorescent Screen

- The light produced by the screen does not disappear immediately when bombardment by electrons ceases, i.e., when the signal becomes zero.
- The time period for which the trace remains on the screen after the signal becomes zero is known as "persistence or fluorescence".
- The persistence may be as short as a few microsecond, or as long as tens of seconds or even minutes.
- Medium persistence traces are mostly used for general purpose applications.
  - Long persistence traces are used in the study of transients.
- Long persistence helps in the study of transients since the trace is still seen on the screen after the transient has disappeared.

Glass Tube

- All the components of a CRT are enclosed in an evacuated glass tube called envelope.

- Ø This allows the emitted electrons to move about freely from one end of the tube to the other end.

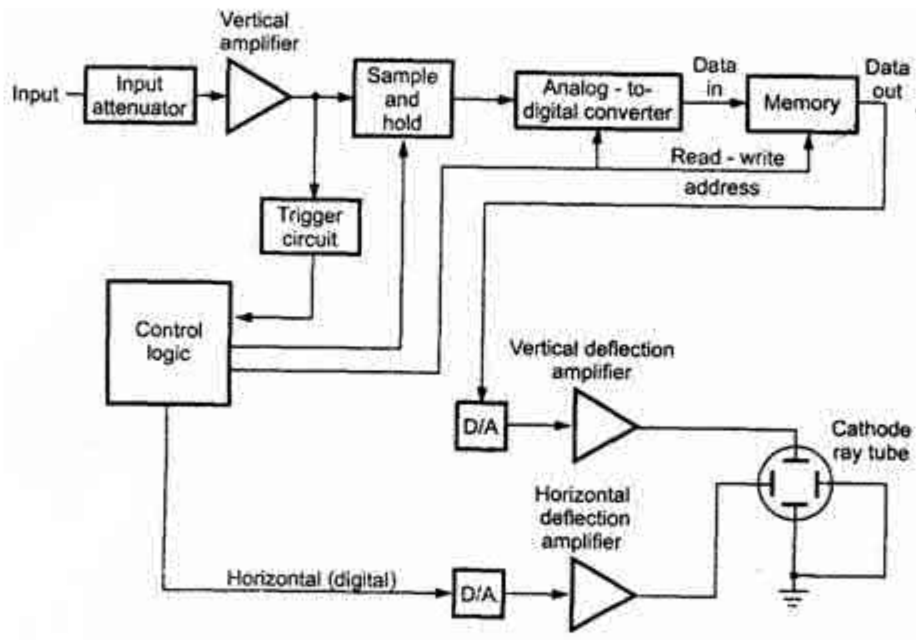
Base

Ø The base is provided to the CRT through which the connections are made to the various parts.

Digital Storage Oscilloscope

Block Diagram

The block diagram of digital storage oscilloscope is shown in the Fig.



Ø The input signal is applied to the amplifier and attenuator section.

Ø The oscilloscope uses same type of amplifier and attenuator circuitry as used in the conventional oscilloscopes.

Ø The attenuated signal is then applied to the vertical amplifier.

Ø To digitize the analog signal, analog to digital (A/D) converter is used.

Ø The output of the vertical amplifier is applied to the A/D converter section.

Ø The successive approximation type of A/D converter is most oftenly used in the digital storage oscilloscopes.

Ø The sampling rate and memory size are selected depending upon the duration & the waveform to be recorded.

Ø Once the input signal is sampled, the A/D converter digitizes it.

Ø The signal is then captured in the memory.
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Ø Once it is stored in the memory, many manipulations are possible as memory can be readout without being erased.

Ø The digital storage oscilloscope has three modes:

1. Roll mode
2. Store mode
3. Hold or save mode.

Advantages

i) It is easier to operate and has more capability. ii) The storage time is infinite.

iii) The display flexibility is available. The number of traces that can be stored and recalled depends on the size of the memory.

iv) The cursor measurement is possible.

v) The characters can be displayed on screen along with the waveform which can indicate waveform information such as minimum, maximum, frequency, amplitude etc.

vi) The X-Y plots, B-H curve, P-V diagrams can be displayed.

vii) The pretrigger viewing feature allows to display the waveform before trigger pulse.

viii) Keeping the records is possible by transmitting the data to computer system where the further processing is possible

ix) Signal processing is possible which includes translating the raw data into finished information e.g. computing parameters of a captured signal like r.m.s. value, energy stored etc.

4.6 DATA LOGGER

Definition

Data logger is an electronic device that records data over time or in relation to location either with a built in instrument or sensor.

Components

Ø Pulse inputs

Counts circuit closing

Ø Control ports

Digital in and out

Most commonly used to turn things on and off

Can be programmed as a digital input

Ø Excitation outputs

Though they can be deployed while connected to a host PC over an Ethernet or serial port a data logger is more typically deployed as standalone devices. The term data logger (also sometimes referred to as a data recorder) is commonly used to describe a self-contained, standalone data acquisition system or device. These products are comprised of a number of analog and digital inputs that are monitored, and the results or conditions of these inputs is then stored on some type of local memory (e.g. SD Card, Hard Drive).

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Examples

Examples of where these devices are used abound. A few of these examples are shown below:

- Ø monitoring temperature, pressure, strain and other physical phenomena in aircraft flight tests (even including logging info from Arinc 429 or other serial communications buses)

- Ø Monitoring temperature, pressure, strain and other physical phenomena in automotive and in-vehicle tests including monitoring traffic and data transmitted on the vehicles CAN bus.

- Ø Environmental monitoring for quality control in food processing, food storage, pharmaceutical manufacturing, and even monitoring the environment during various stages of contract assembly or semiconductor fabrication

- Ø Monitoring stress and strain in large mechanical structures such as bridges, steel framed buildings, towers, launch pads etc.

- Ø Monitoring environmental parameters in temperature and environmental chambers and test facilities.

- Ø A data logger is a self-contained unit that does not require a host to operate.

- Ø It can be installed in almost any location, and left to operate unattended.
- Ø This data can be immediately analyzed for trends, or stored for historical archive purposes.
- Ø Data loggers can also monitor for alarm conditions, while recording a minimum number of samples, for economy.
- Ø If the recording is of a steady-state nature, without rapid changes, the user may go through rolls of paper, without seeing a single change in the input.
- Ø A data logger can record at very long intervals, saving paper, and can note when an alarm condition is occurring. When this happens, the event will be recorded and any outputs will be activated, even if the event occurs in between sample times.
- Ø A record of all significant conditions and events is generated using a minimum of recording hardcopy
- Ø The differences between various data loggers are based on the way that data is recorded and stored.
- Ø The basic difference between the two data logger types is that one type allows the data to be stored in a memory, to be retrieved at a later time, while the other type automatically records the data on paper, for immediate viewing and analysis.
- Ø Many data loggers combine these two functions, usually unequally, with the emphasis on either the ability to transfer the data or to provide a printout of it

Advantages

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Ø A data logger is an attractive alternative to either a recorder or data acquisition system in many applications. When compared to a recorder, data loggers have the ability to accept a greater number of input channels, with better resolution and accuracy.

Ø Also, data loggers usually have some form of on-board intelligence, which provides the user with diverse capabilities.

Ø For example, raw data can be analyzed to give flow rates, differential temperatures, and other interpreted data that otherwise would require manual analysis by the operator the operator has a permanent recording on paper,

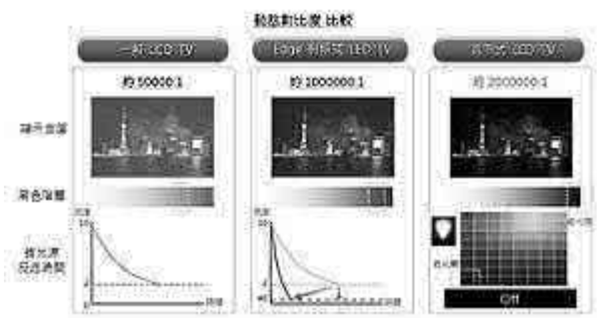
Ø No other external or peripheral equipment is required for operation, and

Ø Many data loggers of this type also have the ability to record data trends, in addition to simple digital data recording

Applications

Ø Temperature sensor
Ø Pressure sensor

4.7 LED-BACKLIT LCD TELEVISION



Comparison of LCD, edge lit LED and LED TV

LED-backlight LCD television (incorrectly called LED TV by (CCFLs) used in traditional LCD televisions. This has a dramatic impact resulting in a thinner panel and less power consumption, brighter display with better contrast levels. It also generates less heat than regular LCD TVs. The LEDs can come in three forms: dynamic RGB LEDs which are positioned behind

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the panel, white Edge-LEDs positioned around the rim of the screen which use a special diffusion panel to spread the light evenly behind the screen (the most common) and full-array which are arranged behind the screen but they are incapable of dimming or brightening individually

LED backlighting techniques

RGB dynamic LEDs

This method of backlighting allows dimming to occur in locally specific areas of darkness on the screen. This can show truer blacks, whites and PRs[*clarification needed*] at much higher dynamic contrast ratios, at the cost of less detail in small bright objects on a dark background, such as star fields

Edge-LEDs

This method of backlighting allows for LED-backlit TVs to become extremely thin. The light is diffused across the screen by a special panel which produces a uniform color range across the screen.

Full Array LEDs

Sharp, and now other brands, also have LED backlighting technology that aligns the LEDs on back of the TV like the RGB Dynamic LED backlight, but it lacks the local dimming of other sets.[6] The main benefit of its LED backlight is simply reduced energy consumption and may not improve quality over non-LED LCD TVs.[7]

Differences between LED-backlit and CCFL-backlit LCD displays

An LED backlight offers several general benefits over regular CCFL backlight TVs, typically higher brightness. Compared to regular CCFL backlighting, there may also be benefits to color gamut. However advancements in CCFL technology mean wide color gamuts and lower power consumption are also possible. The principal barrier to wide use of LED backlighting on LCD televisions is cost.

Applications

The variations of LED backlighting do offer different benefits. The first commercial LED backlit LCD TV was the Sony Qualia 005 (introduced in 2004). This featured RGB LED arrays to offer a color gamut around twice that of a conventional CCFL LCD television (the combined light output from red, green and blue LEDs produces a more pure white light than is possible with a single white light LED). RGB LED technology continues to be used on selected Sony BRAVIA LCD models, with the addition of 'local dimming' which enables excellent on-screen contrast through selectively turning off the LEDs behind dark parts of a picture frame.

Edge LED lighting was also first introduced by Sony (September 2008) on the 40 inch BRAVIA KLV-40ZX1M (referred to as the ZX1 in Europe). The principal benefit of Edge-LED lighting for LCD televisions is the ability to build thinner housings (the BRAVIA KLV-40ZX1M is as thin as 9.9mm). Samsung has also introduced a range of Edge-LED lit LCD televisions with extremely thin housings.

LED-backlit LCD TVs are considered a more sustainable choice, with a longer life and better energy efficiency than plasmas and conventional LCD TVs.[10] Unlike CCFL backlights, LEDs also use nomercury in their manufacture. However, other elements such as gallium and arsenic are used in the manufacture of the LED emitters themselves, meaning there is some debate over whether they are a significantly better long term solution to the problem of TV disposal.

Because LEDs are able to be switched on and off more quickly than CCFL displays and can offer a higher light output, it is theoretically possible to offer very high contrast ratios. They can produce deep blacks (LEDs off) and a high brightness (LEDs on), however care should be taken with measurements made from pure black and pure white outputs, as technologies like Edge-LED lighting do not allow these outputs to be reproduced simultaneously on-screen.

In September 2009 Nanoco Group announced that it has signed a joint development agreement with a major Japanese electronics company under which it will design and develop quantum dots for LED Backlights in LCD televisions.[11] Quantum dots are valued for displays, because they emit light in very specific gaussian distributions. This can result in a display that more accurately renders the colors than the human eye can perceive. Quantum dots also require very little power since they are not color filtered. In September 2010, LG Electronics revealed their new product which claimed as the world's slimmest full LED 3D TV at the IFA consumer electronics trade show in Berlin

4.8 LCD & Dot Matrix Display

LIQUID CRYSTAL DISPLAY

Reflective twisted nematic liquid crystal display.

1. Polarizing filter film with a vertical axis to polarize light as it enters.
2. Glass substrate with ITO electrodes. The shapes of these electrodes will determine the shapes that will appear when the LCD is turned ON. Vertical ridges etched on the surface are smooth.
3. Twisted nematic liquid crystal.

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4. Glass substrate with common electrode film (ITO) with horizontal ridges to line up with the horizontal filter.
5. Polarizing filter film with a horizontal axis to block/pass light.
6. Reflective surface to send light back to viewer. (In a backlit LCD, this layer is replaced with a light source.)

A liquid crystal display (LCD) is a thin, flat electronic visual display that uses the light modulating properties of liquid crystals (LCs). LCs do not emit light directly.

APPLICATIONS

They are used in a wide range of applications including: computer monitors, television, instrument panels, aircraft cockpit displays, signage, etc. They are common in consumer devices such as video players, gaming devices, clocks, watches, calculators, and telephones. LCDs have displaced cathode ray tube (CRT) displays in most applications. They are usually more compact, lightweight, portable, less expensive, more reliable, and easier on the eyes.They are available in a wider range of screen sizes than CRT and plasma displays, and since they do not use phosphors, they cannot suffer image burn-in. LCDs are more energy efficient and offer safer disposal than CRTs.

Overview

LCD alarm clock

Construction

Each pixel of an LCD typically consists of a layer of molecules aligned between two transparent electrodes, and two polarizing filters, the axes of transmission of which are (in most of the cases) perpendicular to each other. With no actual liquid crystal between the polarizing filters, light passing through the first filter would be blocked by the second (crossed) polarizer. In most of the cases the liquid crystal has double refraction.

The surface of the electrodes that are in contact with the liquid crystal material are treated so as to align the liquid crystal molecules in a particular direction. This treatment typically consists of a thin polymer layer that is unidirectionally rubbed using, for example, a cloth. The direction of the liquid crystal alignment is then defined by the direction of rubbing. Electrodes are made of a transparent conductor called Indium Tin Oxide (ITO).

Operation

Before applying an electric field, the orientation of the liquid crystal molecules is determined by the alignment at the surfaces of electrodes. In a twisted nematic device (still the most common

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liquid crystal device), the surface alignment directions at the two electrodes are perpendicular to each other, and so the molecules arrange themselves in a helical structure, or twist. This reduces

the rotation of the polarization of the incident light, and the device appears grey. If the applied voltage is large enough, the liquid crystal molecules in the center of the layer are almost completely untwisted and the polarization of the incident light is not rotated as it passes through the liquid crystal layer. This light will then be mainly polarized perpendicular to the second filter, and thus be blocked and the pixel will appear black. By controlling the voltage applied across the liquid crystal layer in each pixel, light can be allowed to pass through in varying amounts thus constituting different levels of gray. This electric field also controls (reduces) the double refraction properties of the liquid crystal.

LCD with top polarizer removed from device and placed on top, such that the top and bottom polarizers are parallel.

The optical effect of a twisted nematic device in the voltage-on state is far less dependent on variations in the device thickness than that in the voltage-off state. Because of this, these devices are usually operated between crossed polarizers such that they appear bright with no voltage (the eye is much more sensitive to variations in the dark state than the bright state). These devices can also be operated between parallel polarizers, in which case the bright and dark states are reversed. The voltage-off dark state in this configuration appears blotchy, however, because of small variations of thickness across the device.

Both the liquid crystal material and the alignment layer material contain ionic compounds. If an electric field of one particular polarity is applied for a long period of time, this ionic material is attracted to the surfaces and degrades the device performance. This is avoided either by applying an alternating current or by reversing the polarity of the electric field as the device is addressed (the response of the liquid crystal layer is identical, regardless of the polarity of the applied field).

When a large number of pixels are needed in a display, it is not technically possible to drive each directly since then each pixel would require independent electrodes. Instead, the display is multiplexed. In a multiplexed display, electrodes on one side of the display are grouped and wired together (typically in columns), and each group gets its own voltage source. On the other side, the electrodes are also grouped (typically in rows), with each group getting a voltage sink.
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The groups are designed so each pixel has a unique, unshared combination of source and sink. The electronics, or the software driving the electronics then turns on sinks in sequence, and drives sources for the pixels of each sink.

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ILLUMINATION

LCD panels produce no light of their own, they require an external lighting mechanism to be easily visible. On most displays, this consists of a cold cathode fluorescent lamp that is situated behind the LCD panel. Passive-matrix displays are usually not backlit, but active-matrix displays almost always are, with a few exceptions such as the display in the original Gameboy Advance. Recently, two types of LED backlit LCD displays have appeared in some televisions as an alternative to conventional backlit LCDs. In one scheme, the LEDs are used to backlight the entire LCD panel. In another scheme, a set of green red and blue LEDs is used to illuminate a small cluster of pixels, which can improve contrast and black level in some situations. For example, the LEDs in one section of the screen can be dimmed to produce a dark section of the image while the LEDs in another section are kept bright. Both schemes also allows for a slimmer panel than on conventional displays.

Passive-matrix and active-matrix addressed LCDs

A general purpose alphanumeric LCD, with two lines of 16 characters. LCDs with a small number of segments, such as those used in digital watches and pocket calculators, have individual electrical contacts for each segment. A external dedicated circuit supplies an electric charge to control each segment. This display structure is unwieldy for more than a few display elements.

Small monochrome displays such as those found in personal organizers, electronic weighing scales, older laptop screens, and the originalGameboy have a passive-matrix structure employing super-twisted nematic (STN) or double-layer STN (DSTN) technology (the latter of which addresses a colour-shifting problem with the former), and colour-STN (CSTN) in which colour is added by using an internal filter. Each row or column of the display has a single electrical circuit. The pixels are addressed one at a time by row and column addresses. This type of display is called passive-matrix addressed because the pixel must retain its state between refreshes without the benefit of a steady electrical charge. As the number of pixels (and, correspondingly, columns and rows) increases, this type of display becomes less feasible. Very slow response times and poor contrast are typical of passive-matrix addressed LCDs.
Monochrome passive-matrix LCDs were standard in most early laptops (although a few used plasma displays). The commercially unsuccessful Macintosh Portable (released in 1989) was one of the first to use an active-matrix display (though still monochrome), but passive-matrix was the norm until the mid-1990s, when colour active-matrix became standard on all laptops.

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High-resolution colour displays such as modern LCD computer monitors and televisions use an active matrix structure. A matrix of thin-film transistors (TFTs) is added to the polarizing and colour filters. Each pixel has its own dedicated transistor, allowing each column line to access one pixel. When a row line is activated, all of the column lines are connected to a row of pixels and the correct voltage is driven onto all of the column lines. The row line is then deactivated and the next row line is activated. All of the row lines are activated in sequence during a refresh operation. Active-matrix addressed displays look "brighter" and "sharper" than passive-matrix addressed displays of the same size, and generally have quicker response times, producing much better images.

ACTIVE MATRIX TECHNOLOGIES

A Casio 1.8 in colour TFT liquid crystal display which equips the SonyCyber-shot DSC-P93A

Twisted nematic (TN)

Twisted nematic displays contain liquid crystal elements which twist and untwist at varying degrees to allow light to pass through. When no voltage is applied to a TN liquid crystal cell, the light is polarized to pass through the cell. In proportion to the voltage applied, the LC cells twist up to 90 degrees changing the polarization and blocking the light's path. By properly adjusting the level of the voltage almost any grey level or transmission can be achieved.

In-plane switching (IPS)

In-plane switching is an LCD technology which aligns the liquid crystal cells in a horizontal direction. In this method, the electrical field is applied through each end of the crystal, but this requires two transistors for each pixel instead of the single transistor needed for a standard thin-film transistor (TFT) display. Before LGEnhanced IPS was introduced in 2009, the additional transistors resulted in blocking more transmission area, thus requiring a brighter backlight, which consumed more power, and made this type of display less desirable for notebook computers. This newer, lower power technology can be found in the AppleiMac, iPad, and iPhone 4, as well as the Hewlett-Packard EliteBook 8740w. Currently Panasonic is using an enhanced version eIPS for their large size LCD-TV products.Advanced fringe field switching (AFFS)

Known as fringe field switching (FFS) until 2003, advanced fringe field switching is a technology similar to IPS or S-IPS offering superior performance and colour gamut with high

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luminosity. AFFS is developed by HYDIS TECHNOLOGIES CO.,LTD, Korea (formally Hyundai Electronics, LCD Task Force). AFFS-applied notebook applications minimize colour

In 2004, HYDIS TECHNOLOGIES CO.,LTD licenses AFFS patent to Japan's Hitachi Displays. Hitachi is using AFFS to manufacture high end panels in their product line. In 2006, HYDIS also licenses AFFS to Sanyo Epson Imaging Devices Corporation.
HYDIS introduced AFFS+ which improved outdoor readability in 2007.

Vertical alignment (VA)

Vertical alignment displays are a form of LCDs in which the liquid crystal material naturally exists in a vertical state removing the need for extra transistors (as in IPS). When no voltage is applied, the liquid crystal cell remains perpendicular to the substrate creating a black display. When voltage is applied, the liquid crystal cells shift to a horizontal position, parallel to the substrate, allowing light to pass through and create a white display. VA liquid crystal displays provide some of the same advantages as IPS panels, particularly an improved viewing angle and improved black level

Blue Phase mode

Blue phase LCDs do not require a liquid crystal top layer. Blue phase LCDs are relatively new to the market, and very expensive because of the low volume of production. They provide a higher refresh rate than normal LCDs, but normal LCDs are still cheaper to make and actually provide better colours and a sharper image

Military use of LCD monitors

LCD monitors have been adopted by the United States of America military instead of CRT displays because they are smaller, lighter and more efficient, although monochrome plasma displays are also used, notably for their M1 Abrams tanks. For use with night vision imaging systems a US military LCD monitor must be compliant with MIL-L-3009 (formerly MIL-L-85762A). These LCD monitors go through extensive certification so that they pass the standards for the military. These include MIL-STD-901D - High Shock (Sea Vessels), MIL-STD-167B - Vibration (Sea Vessels), MIL-STD-810F – Field Environmental Conditions (Ground Vehicles and Systems),MIL-STD-461E/F –EMI/RFI(Electromagnetic nterference/Radio Frequency Interference), MIL-STD-740B – Airborne/Structureborne Noise, and TEMPEST - Telecommunications Electronics Material Protected from Emanating Spurious Transmissions

Quality control

Some LCD panels have defective transistors, causing permanently lit or unlit pixels which are commonly referred to as stuck pixels or dead pixels respectively. Unlike integrated circuits (ICs), LCD panels with a few defective transistors are usually still usable. It is claimed that it is economically prohibitive to discard a panel with just a few defective pixels because LCD panels are much larger than ICs, but this has never been proven. Manufacturers' policies for the

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acceptable number of defective pixels vary greatly. At one point, Samsung held a zero-tolerance policy for LCD monitors sold in Korea. Currently, though, Samsung adheres to the less restrictive ISO 13406-2 standard. Other companies have been known to tolerate as many as 11 dead pixels in their policies. Dead pixel policies are often hotly debated between manufacturers and customers. To regulate the acceptability of defects and to protect the end user, ISO released the ISO 13406-2 standard. However, not every LCD manufacturer conforms to the ISO standard and the ISO standard is quite often interpreted in different ways. LCD panels are more likely to have defects than most ICs due to their larger size. For example, a 300 mm SVGA LCD has 8 defects and a 150 mm wafer has only 3 defects. However, 134 of the 137 dies on the wafer will be acceptable, whereas rejection of the LCD panel would be a 0% yield. Due to competition between manufacturers quality control has been improved. An SVGA LCD panel with 4 defective pixels is usually considered defective and customers can request an exchange for a new one. Some manufacturers, notably in South Korea where some of the largest LCD panel manufacturers, such as LG, are located, now have "zero defective pixel guarantee", which is an extra screening process which can then determine "A" and "B" grade panels. Many manufacturers would replace a product even with one defective pixel. Even where such guarantees do not exist, the location of defective pixels is important. A display with only a few defective pixels may be unacceptable if the defective pixels are near each other. Manufacturers may also relax their replacement criteria when defective pixels are in the center of the viewing area. LCD panels also have defects known as *clouding* (or less commonly *mura*), which describes the uneven patches of changes in luminance. It is most visible in dark or black areas of displayed scenes

ZERO-POWER (BISTABLE) DISPLAYS

The zenithal bistable device (ZBD), developed by QinetiQ (formerly DERA), can retain an image without power. The crystals may exist in one of two stable orientations ("Black" and "White") and power is only required to change the image. ZBD Displays is a spin-off company from QinetiQ who manufacture both grayscale and colour ZBD devices. A French company, Nemoptic, has developed the BiNem zero-power, paper-like LCD technology which has been mass-produced in partnership with Seiko since 2007.

This technology is intended for use in applications such as Electronic Shelf Labels, E-books, E-documents, E-newspapers, E-dictionaries, Industrial sensors, Ultra-Mobile PCs, etc.

Kent Displays has also developed a "no power" display that uses Polymer Stabilized Cholesteric Liquid Crystals (ChLCD). A major drawback of ChLCD screens are their slow refresh rate, especially at low temperatures. Kent has recently demonstrated the use of a ChLCD to cover the entire surface of a mobile phone, allowing it to change colours, and keep that colour even when power is cut off. In 2004 researchers at the University of Oxford demonstrated two new types of zero-power bistable LCDs based on Zenithal bistable techniques. Several bistable technologies, like the 360° BTN and the bistable cholesteric, depend mainly on the bulk properties of the liquid crystal (LC) and use standard strong anchoring, with alignment films and LC mixtures similar to the traditional monostable materials. Other bistable technologies (i.e. Binem Technology) are based mainly on the surface properties and need specific weak anchoring materials. distortion while maintaining its superior wide viewing angle for a professional display. Colour shift and deviation caused by light leakage is corrected by optimizing the white gamut which also enhances white/grey reproduction.

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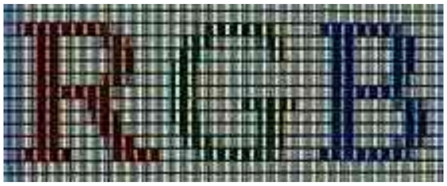
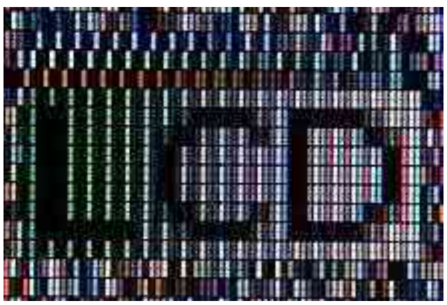
Comparison of the OLPC XO-1 display (left) with a typical colour LCD. The images show
1×1 mm of each screen. A typical LCD addresses groups of 3 locations as pixels. The XO-1 display addresses each location as a separate pixel.



Example of how the colours are generated (R-red, G-green and B-blue)



In colour LCDs each individual pixel is divided into three cells, or subpixels, which are coloured red, green, and blue, respectively, by additional filters (pigment filters, dye filters and metal oxide filters). Each subpixel can be controlled independently to yield thousands or millions of possible colours for each pixel. CRT monitors employ a similar 'subpixel' structures *via* phosphors, although the electron beam employed in CRTs do not hit exact subpixels. The figure at the left shows the twisted nematic (TN) type of LCD.

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UNIT – 5 – TRANSDUCERS AND DATA ACQUISITION SYSTEMS

Classification of transducers – Selection of transducers – Resistive, capacitive & inductive transducers – Piezoelectric, Hall effect, optical and digital transducers – Elements of data acquisition system – A/D, D/A converters – Smart sensors.

Transducer:

- It's a device which convert one form of energy to another form
- Non electrical quantity is converted into an electrical form by a transducer.

Different types transducer:

- Resistive transducers
- Capacitive transducers
- Inductive transducers
- Piezoelectric transducers
- Optical transducers
- Digital transducers

Selection of transducer:

1) Range:

The range of the transducer should be large enough to encompass all the expected magnitude of the measurand.

2) Sensitivity:

The transducer should give a sufficient output signal per unit of measured input in order to yield meaningful data.

3) Electrical output characteristics:

The electrical characteristics the output impendence the frequency response and the response time of the transducer output signal should be compatible with the recording devices and the rest of the measuring system equipment.

4) Physical environment :

The transducer selected should be able to withstand the environment conditions to which it is likely to be subjected while carrying out measurements and test.

Factor influencing choice of the transducer:

1. Operating Principle
2. Sensitivity
3. Operating Range
4. Accuracy
5. Cross sensitivity
6. Errors
7. Transient and frequency response
8. Loading effects.
9. Environmental compatibility
10. Insensitivity to unwanted signals
11. Usage and Ruggedness
12. Electrical aspects
13. Stability and Reliability
14. Static characteristics

1. Operating Principle:

The transducer are many times selected on the basis of operating principle used by them. The operating principle used may be resistive, inductive, capacitive , optoelectronic, piezo electric etc.

2. Sensitivity:

The transducer must be sensitive enough to produce detectable output.

3. Operating Range:

The transducer should maintain the range requirement and have a good resolution over the entire range.

4. **Accuracy:**

High accuracy is assured.

5. Cross sensitivity:

It has to be taken into account when measuring mechanical quantities. There are situation where the actual quantity is being measured is in one plane and the transducer is subjected to variation in another plan.

6. Errors:

The transducer should maintain the expected input-output relationship as described by the transfer function so as to avoid errors.

7. Transient and frequency response :

The transducer should meet the desired time domain specification like peak overshoot, rise time, setting time and small dynamic error.

8. Loading Effects:

The transducer should have a high input impedance and low output impedance to avoid loading effects

9. Environmental Compatibility:

It should be assured that the transducer selected to work under specified environmental conditions maintains its input- output relationship and does not break down.

10. Insensitivity to unwanted signals:

The transducer should be minimally sensitive to unwanted signals and highly sensitive to desired signals

11. Usage and Ruggedness:

The ruggedness both of mechanical and electrical intensities of transducer versus its size and weight must be considered while selecting a suitable transducer.

12. Electrical aspects:

The electrical aspects that need consideration while selecting a transducer include the length and type of cable required.

13. Stability and Reliability :

The transducer should exhibit a high degree of stability to be operative during its operation and storage life.

14.Static Characteristics :

Apart from low static error, the transducer should have a low non- linearity, low hysteresis, high resolution and a high degree of repeatability

Active Transducer:

- Also known as self generating type, develop their own voltage or current from the physical phenomenon being measured.
- Velocity, temperature, light intensity and force can be transducer with the help of active transducer.

Passive Transducer:

- Also known as externally powered transducers, i.e., derive the power required for energy conversion from an external power source.

Resistive Transducer:

- In such a transducer resistance between the output terminals of a transducer gets varied according to the measurand;

- resistive transducer is preferred over other transducer because dc and ac both are suitable for measurements:

$$R = \rho \frac{l}{a}$$

Where

ρ - is the resistivity of the material of conductor in ohm-meter.

L=is the length of the conductor in meters

A= cross sectional area of the conductors in m^2

- Physical phenomenon that is input signal to the transducer causes variation in resistance by changing any one of the quantity ρ, l, and A. for the measurement of the displacement length of the conductor is varied in potentiometer thereby resulting in change in resistance.
- For measurements of force and pressure resistance of the conductor is varied in strain gauge.
- Variation in temperature cause change in the resistivity of the conductor material and so change in resistance take place which is noted for measurements of temperature .with some devices resistance varies with the change in light intensity because of photoconductive effect, while with others resistance varies on exposure to magnetic field due to magneto resistive effect.

POTENTIOMETRS

The instrument used to measure an voltage comparing it with a known voltage is known as potentiometers.

Advantages

1.High degree of accuracy due to the comparison method.

2.it is independent of source resistance.

3.Is is used to measure current with the help of a standard resistance.

4.It is used to calibrate ammeter, voltmeter, wattmeter etc .

SLIDE-WIRE POTENTIOMETERS

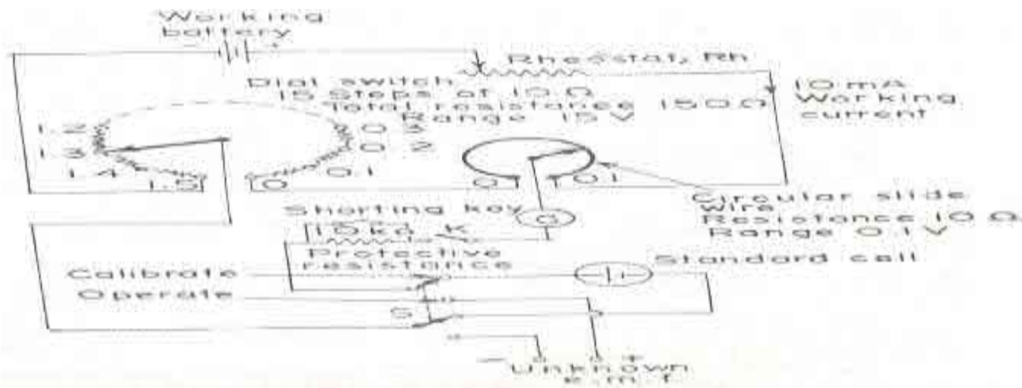
It consist of a German sliver or magnanin wire of uniform cross section and stretched between two terminals A&B on a flat board with a scale graduated in mm fixed along side. The extremes A&B are connected to a battery through a variable resistance R with a positive terminal 0f battery connected to end A & negative terminal to end B.

When switch is closed ,a voltage is developed between A&J as AB is a resistor R of length L.Then total resistance/unit length ,r =R/L.The resistance is not a constant but depend on sliding contact as it is varied.

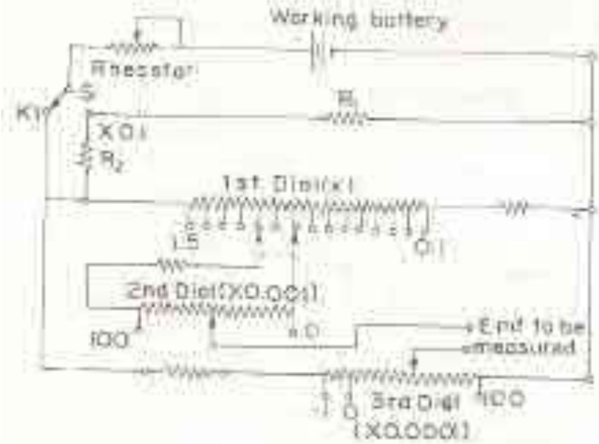
Voltage drop = irl across the resistance.

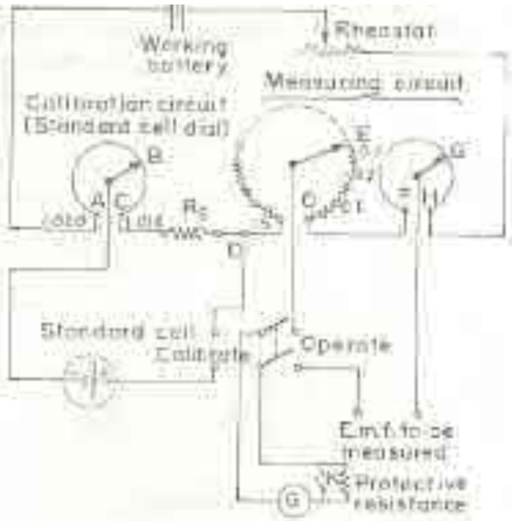
Precision Slide Wire Potentiometer (Compton Potentiometer)

It use calibrated dial resistors and a small circular wire of one or more turns there by reducing the size of the instrument. A dial switch having 16 contact points and a short slide wire .Two moving contacts P1&P2.P1 sliding over the slide wire and contact P2 sliding over he studs connected to the resistance coil. Balance condition more easily and quickly obtained by means of coarse (dial) adjustments and fine (slide wire) adjustment. A battery B of 2V is connected across the potentiometer through the resistors R1&R2 for controlling the current drawn from the battery .R1 consists of a number of resistance coils connected in sires and is meant for coarse adjustment.R2 is like a slide wire and is meant for fine adjustment .



Vernier Potentiometer





In slide wire potentiometer, the slide wire should be extremely well made so that the variations in contact resistance are not to limit the precision in adjustment of the potentiometer current. This difficulty may be overcome by the use of a shunted dial resistance for the regulator.

The working of Vernier potentiometer is based on Kelvin Varley principle.

Merits of potentiometers:

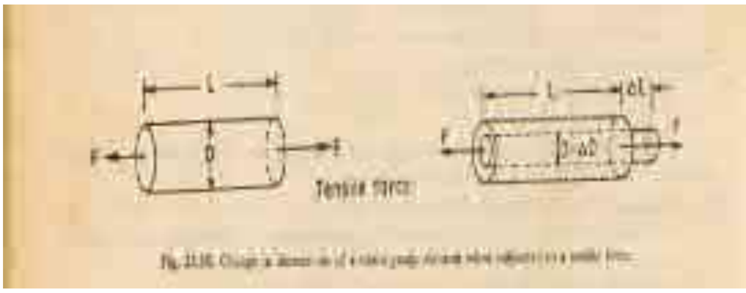
1) The pots are cheap, easy to operate, simple in construction and very useful for simple application.
2) The pots , expect wire wound ones have got very good frequency response and infinite resolution
3) The potentiometer can measure large amplitude of displacement.
4) The potentiometer give very high electrical efficiency and enough output to control circuit for operation.

Demerits of potentiometer:

1) the main draw back with the post is because of wear and tear of wiper and its effect on the life of the transducer.
2) The pots required force are large
3) Large displacement are usually required for moving the slider or wiper along the entire working surface of the pot.
4) The output is insensitive to variation in displacement of movable contact or wiper between two consecutive turns of the pot.

Strain gauge:

- If a metal conductor is stretched or compressed , its resistance changes on account of the fact that both length and diameter of conductor change.
- Also there is a change in the value of resistivity of the conductor when strained and this property is called **piezoresistive effect.**
- **Resistive strain gauges are also known as piezoresistive gauges.**



$$R = \frac{\rho L}{A} - (1)$$

Let a tensile stress s be applied to the wire

$$\frac{dR}{ds} = \frac{\rho}{A}\frac{\partial L}{\partial s} - \frac{\rho L}{A^2}\frac{\partial A}{\partial s} + \frac{L}{A}\frac{\partial \rho}{\partial s} \qquad -(2)$$

Divide equation (2) by

$$\frac{1}{R}\frac{dR}{ds} = \frac{1}{L}\frac{\partial L}{\partial s} - \frac{1}{A}\frac{\partial A}{\partial s} + \frac{1}{\rho}\frac{\partial \rho}{\partial s} \qquad -(3)$$

From (3) , per unit change in resistance is due to

- Per unit change in length=
- Per unit change in Area =
- Per unit change in resistivity =

Area =

$$\frac{\Pi}{4}D^2 , \therefore \frac{\partial A}{\partial s} = 2.\frac{\Pi}{4}D.\frac{\partial D}{\partial s} - (4)$$

$$\frac{1}{A}\frac{\partial A}{\partial s}=\frac{(2\Pi/4)D}{(\Pi/4)D^2}\frac{\partial D}{\partial s}=\frac{2}{D}\frac{\partial D}{\partial s}-(5)$$

Equation (3) can be written as

$$\frac{1}{R}\frac{dR}{ds}=\frac{1}{L}\frac{\partial L}{\partial s}-\frac{2}{D}\frac{\partial D}{\partial s}+\frac{1}{\rho}\frac{\partial \rho}{\partial s} \qquad \text{-(6)}$$

Poisson’s ratio ,

$$v=\frac{\text{lateral strain}}{\text{longitudinal strain}}=-\frac{\partial D/D}{\partial L/L}-(7)$$

$$\partial D/D=-v\text{X}\,\partial L/L-(8)$$

$$\frac{1}{R}\frac{dR}{ds}=\frac{1}{L}\frac{\partial L}{\partial s}+v\frac{2}{L}\frac{\partial L}{\partial s}+\frac{1}{\rho}\frac{\partial \rho}{\partial s} \qquad \text{-(9)}$$

For small variation , the above relationship , can be written as

$$\frac{\Delta R}{R}=\frac{\Delta L}{L}+2v\frac{\Delta L}{L}+\frac{\Delta \rho}{\rho} \qquad \text{-(10)}$$

The gauge factor is defined as the ratio of per unit change in resistance to per unit change in length.

$$G_f=\frac{\Delta \text{R}/R}{\Delta \text{L}/L} \qquad \text{-(11)}$$

$$\text{or } \Delta \text{R}/R=G_f\,\text{X}\,\Delta \text{L}/L$$

$$=G_f\,\text{X}\varepsilon-(12)$$

$$where\ \varepsilon=strain=\Delta \text{L}/L-(13)$$

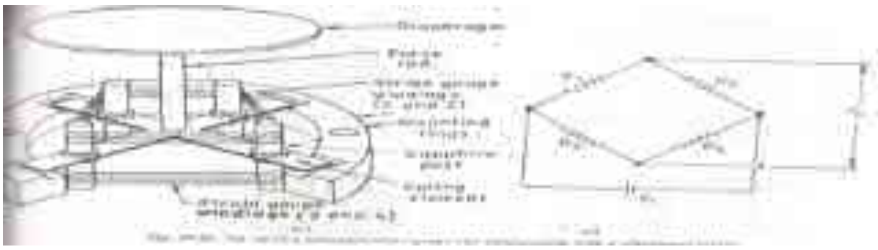
$$G_f = \frac{\Delta R/R}{\Delta L/L} = 1 + 2v + \frac{\Delta\rho/\rho}{\Delta L/L} \qquad -(12)$$

$$G_f = \frac{\Delta R/R}{\Delta L/L} = 1 + 2v + \frac{\Delta\rho/\rho}{\varepsilon} \qquad -(13)$$

Types of strain gauge

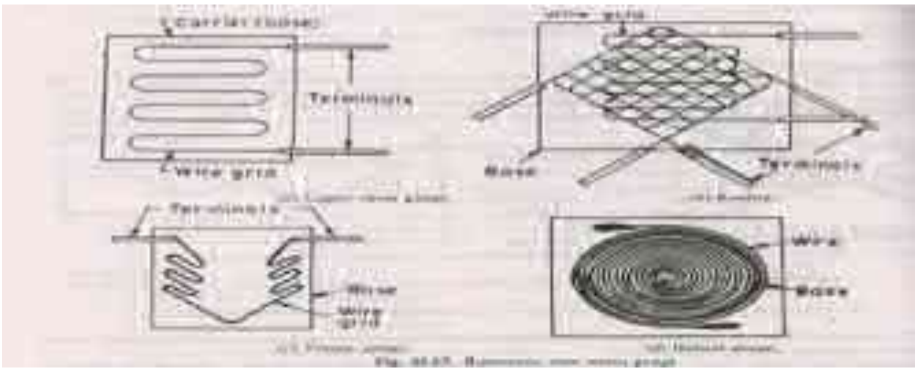
- Unbonded metal strain gauge
- Bonded metal wire strain gauge
- Bonded metal foil strain gauge
- Vacuum deposited thin metal film strain gauges.
- Sputter deposited thin metal film strain gauge.
- Bonded semiconductor strain gauges.
- Diffused metal strain gauge.

Unbounded metal strain gauge:



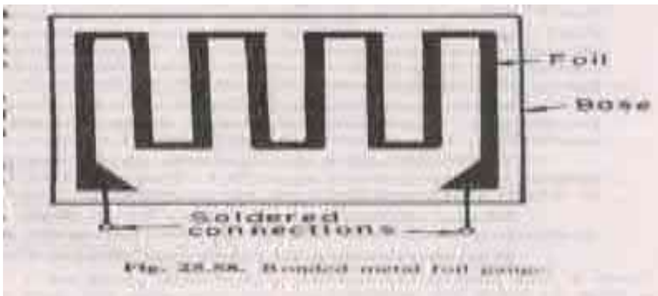
- Used almost exclusively in transducer applications.
- At initial preload , the strains and resistances of the four arms are normally equal, with the result the output voltage of the bridge, e0=0.
- Application of pressure produces a small displacement , the displacement increases tension in 2 wires and decreasing the resistance of the remaining 2 wires.
- This causes an unbalance of the bridge producing an output voltage which is proportional to the input displacement and hence to the applied pressure.

Bonded metal wire strain gauge



- It consist of a grid of fine resistance wire of diameter of about 0.025mm.
- The wire is cemented to a base.
- The base – thin sheet of paper or bakelite.
- Wire is covered with a thin sheet of material so that it is not damaged mechanically.
- The spreading of wire permits a uniform distribution of stress over a grid.

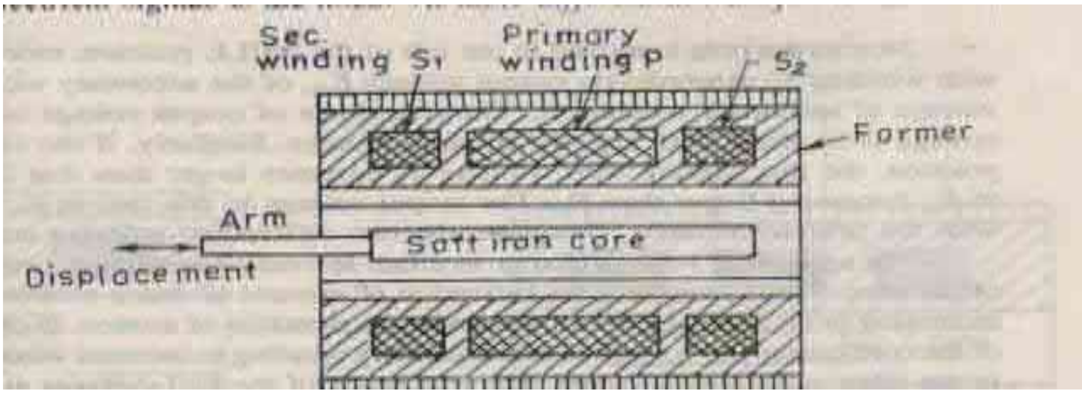
Bonded metal foil strain gauge



- Extension of the bonded metal wire strain gauge.
- The bonded metal wire strain gauge have been completely superseded by bonded foil strain gauge.

LINEAR VARIABLE DIFFERENTIAL TRANSFORMER

Construction



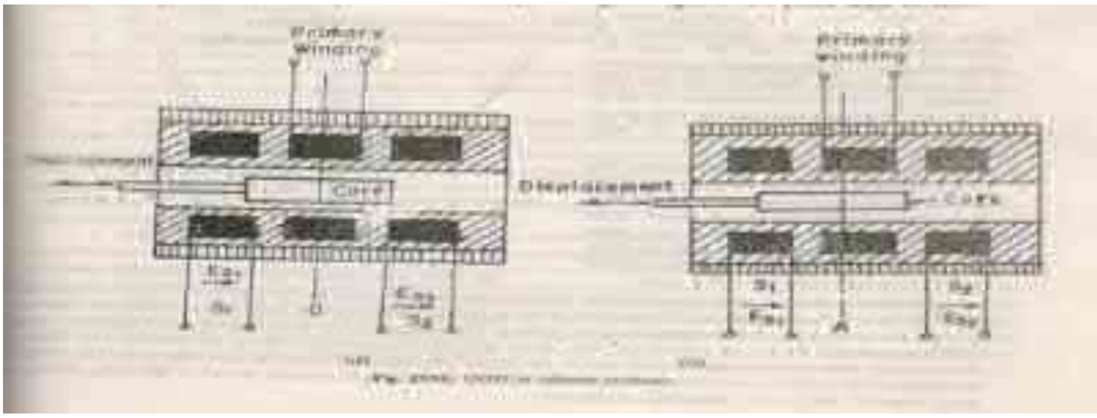
The most widely used inductive transducer to translate the linear motion into electrical signals is the linear variable differential transformer(LVDT).LVDT is a differential transformer consisting of a single primary winding P and two secondary windings S1 and S2 wound over a hallow bobbin of non-magnetic and insulating material.The secondary windings S1 snd S2 have equal number of turns and are identically placed on either side of the primary winding.A movable soft iron core is placed inside the former.The displacement to be measured is applied to the arm attached to the soft iron core.In order to overcome the problem of eddy current losses in the core,nickel-iron alloy is used as core material and is slotted longitudinally.

Working

Primary winding is connected to an ac source of voltage varying from 5 to 25V and of frequency ranging from 50Hz to 20 kHz.Since the primary winding is excited by an alternating current source ,it produces an alternating magnetic field which inturn induces alternating voltages.The output voltage of secondary winding S1 is ES1 and that of secondary winding S2 is ES2.In order to convert the output voltage from S1 and S2 into a single voltage signal the two secondaries S1 and S2 are connected in series opposition as shown in fig.Therefore the output voltage of the transducer is the difference of the two voltages.

Differential output voltage $E_o = E_{s1} – E_{s2}$.

When the core is at its normal position the flux linking with both secondary windings are equal and hence equal emfs are induced in them.Thus at null position Es1=Es2.Since the output voltage of the transducer is the difference of the two voltages,the output voltage Eo is zero at null position.



Now if the core is moved to the left of the null position ,more flux links with windings S1 and less with windings S2.Hence output voltage Es1,of the secondary winding S1,is more than Es2,the output voltage of secondary winding S2.The magnitude of output voltage is thus Eo=Es1 – Es2 and the output voltage is in phase with the primary voltage.

Advantages of LVDT

- The output of LVDT is practically linear for displacements upto 5mm.The LVDTs have a very high range of measurement of displacement.
- LVDT has high sensitivity.It usually varies from 10 mv/mm to 40 v/mm.
- The LVDT gives a high output and many a time there is no need for amplification.
- LVDT has very low hyterisis; hence repeatability is excellent under all conditions.
- LVDT can be used on high frequencies upto 20 kHz.
- Most LVDTs consume less than 1 W of power.

Disadvantages of LVDT

- Large displacements are required for differential output.
- They are sensitive to stray magnetic fields.
- Sometimes the transducer performance is affected by vibrations.
- Temperature affects the performance of the transducer.

Applications

- Displacement.
- Force.
- Weight.
- Pressure.
- Position.

CAPACITIVE TRANSDUCER

The principle of operation of capacitive transducer is based upon the familiar equation for capacitance of a parallel plate capacitor.

$$C = €A/d = €o€rA/ d$$

Where,

A= overlapping area of plates in m^2.

D= distance between two plates in m.

€o= permittivity of free space and is equal to 8.854*10^-12 F/m

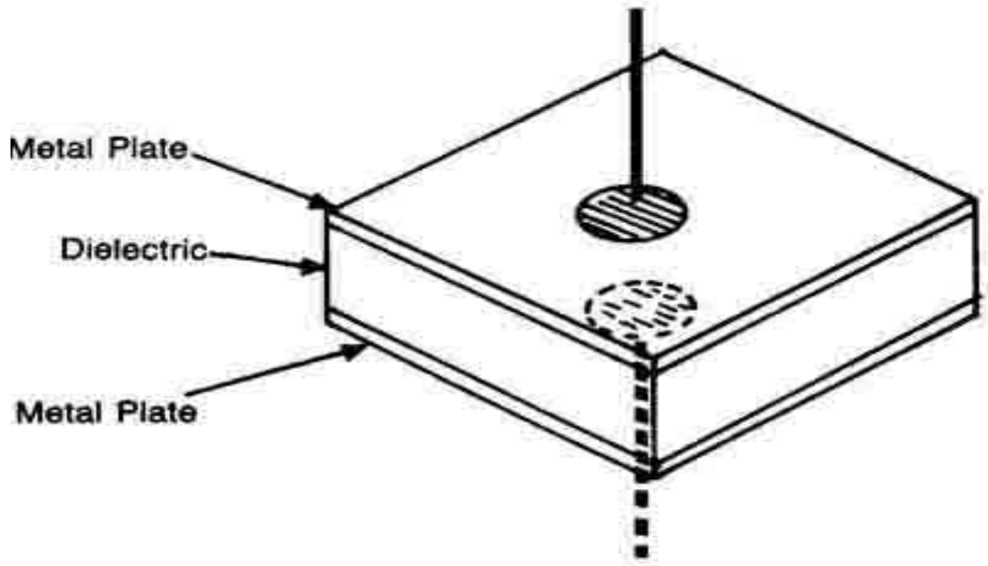
€r = relative permittivity of the dielectric.

The capacitive transducer works on the principle of change of capacitance which may be caused by

- Change in overlapping area A

- Change in the distance d between the plates.
- Change in dielectric constant.

Capacitive transducers-By variation of overlapping area of plates:



We Know $C = \epsilon_o \epsilon_r A / d$

From the above equation it is found that the capacitance is directly proportional to the area A of the plates.Thus the capacitance changes linearly with change in area of plates.

Fig shows two types of capacitive transducers used for the measurement of displacement.The area changes linearly with the displacement and also the capacitance

For a parallel plate capacitor the capacitance is

$C = \epsilon A/d = \epsilon xW/d$ F

Where, x = length of overlapping portion of plates in m.

W = width of overlapping portion of plates in m

Sensitivity $S = \partial C/\partial x = \epsilon W/d$ F/m.

The sensitivity is constant and therefore there is a liner relationship between capacitance and displacement.This type of transducer can be used to measure linear displacement from 1mm to several cm with very high accuracy upto 0.01 percent.

For a cylindrical capacitor the capacitance is

$$C = \frac{2\Pi€x}{Log(D2/D1)} \ F$$

Where,x = is the length of overlapping portion of cylinder in m.

D2 = inner diameter of outer cylindrical electrode in m.

D1 = outer diameter of inner cylindrical electrode in m.

$$\text{Sensitivity } S = \partial C/\partial x = \frac{2\Pi€x}{Log(D2/D1)} \ F/m$$

The principle of variation of capacitance with change in area can also be used to measure angular displacement.Fig shows a two plate capacitor.One plate is fixed and the other is movable.The angular displacement to be measured is applied to movable plate.The angular displacement changes the effective area between the plates and thus the changes the capacitance.The capacitance is maximum when the two plates completely overlap each other i.e.when θ=180°.

Advantages of capacitive transducers

- These transducers have very high impedance and therefore loading effects are minimum.
- These transducers have a good frequency response.This response is as high as 50 kHz and hence they are very useful for dynamic studies.
- These transducers are extremely sensitive.
- A resolution of the order of $2.5*10^3$ mm can be obtained with these transducers.
- These transducers are not affected by stray magnetic fields.

Disadvantages

- Output impedance of capacitive transducer is very high.So its measuring circuit becomes very complicated.
- The cable connecting the transducer to the measuring point is also a source of error.The cable may be source of loading resulting in loss of sensitivity.
- Capacitance of capacitive transducer changes with change in temperature or on account of presence of small external matter e.g.dust particles and moisture etc.
- The instrumentation circuitry used with these transducers is very complex.

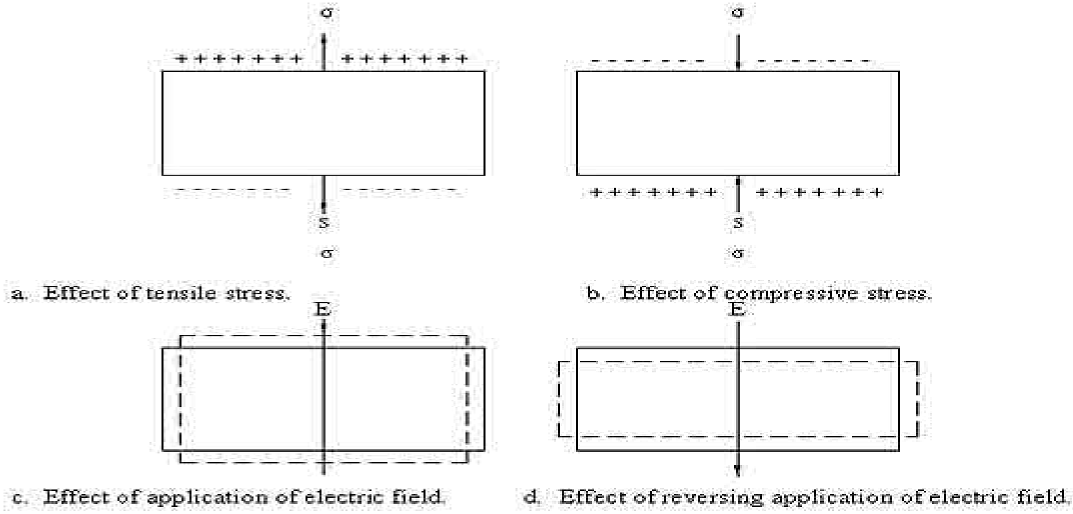
Application

- Capacitive transducers can be used for measurement of both linear and angular displacements.
- Capacitive transducers can be used for the measurement of force and pressure.
- Capacitive transducers can also be employed for measuring pressure directly in all those cases in which permittivity of a medium changes with pressure such as in case of Benzene permittivity varies by 0.5% in the pressure range of 1 to 1000 times the atmosphere pressure.
- Capacitive transducers are commonly used in conjunction with mechanical modifiers for measurement of volume ,density,liquid level,weight etc.

Piezoelectric transducer:

In some crystalline or ceramic material, a potential difference appears across the opposite faces of the material as a result of dimensional changes when a mechanical force applied to it. This is called the piezoelectric effect and such materials are called the piezoelectric materials.

This effect is reversible also that is when a potential difference is applied across the opposite faces of the material, it changes its physical dimensions.



Material for piezoelectric transducer:

Common piezoelectric transducer materials include Rochelle salt , ammonium dihydrogen phosphate (ADP), quartz and ceramics made with barium titanate , potassium dihydrogen phosphate and lithium sulfate and these used in real application.

The piezoelectric effect can be made to respond to mechanical deformation of the material in many different modes. The mode can be

1) thickness expansion
2) transverse expansion
3) thickness shear
4) face shear

The mode of motion employed depends on the shape of the electrodes. A piezoelectric elements used for converting mechanical motion to electrical signal may be thought as charge generator and the capacitor. Mechanical deformation generates a charge and this charge appears a voltage across the electrodes.

The output voltage E_0=Q/C.

The piezoelectric effect is direction sensitive. a tensile force produces a voltage of one polarity while a compressive force produces a voltage of opposite polarity.

A crystal is placed between a solid base and the force summing member. An externally applied force, entering the transducer through its pressure port, applies pressure to the top of the crystal. This produced an emf across the crystal proportional to the magnitude of applied pressure.

The magnitude and the polarity of the induced surface charge are proportional to the magnitude and the direction of the applied force.

$$Q = F * d$$

Where

d=crystal charge sensitivity in coulomb per Newton and is constant for a given crystal cut.

F=applied Force in Newton.

The force f cause a change in thickness of the crystal by Δt in meter and so

$$F = \frac{AE}{t} \Delta t$$

Where A= area of crystal in m^2

E=young’s Modules of elastic in N/m^2

T=thickness of crystal in m

The charge at the electrodes gives rise to an output voltage E_0 and is given by expression

$$E_0 = \frac{Q}{Cp}$$

Where C_p is the capacitance between the electrodes of the crystal.

$$C_p = \frac{\varepsilon 0 \varepsilon r A}{t}$$

$$C_p = \frac{\varepsilon 0 \varepsilon r A}{t}$$

$$E_0 = \frac{dF}{\varepsilon o \varepsilon r A / t} = \frac{F}{A}$$

P=F/A is the pressure in pascals applied on the crystal.

$$E_0 = \frac{d}{\varepsilon o \varepsilon r} tP = gtP$$

Where $g = \frac{d}{\varepsilon o \varepsilon r}$ is the voltage sensitivity of the crystal

Advantages of piezoelectric transducer:

1) Piezoelectric transducer is generally small in size.

2) These transducer are self generating type as they do not need external power.

3) Their outputs are quite large.

Disadvantages of piezoelectric transducer:

1) The output voltage is affected by temperature variation of the crystal.
2) It can be for dynamic measurement only.

Application of piezoelectric transducer:

1) The piezoelectric transducer are mainly used for measurement of force and temperature

2) They are mainly employed in high accelerometer.

Thermocouples:

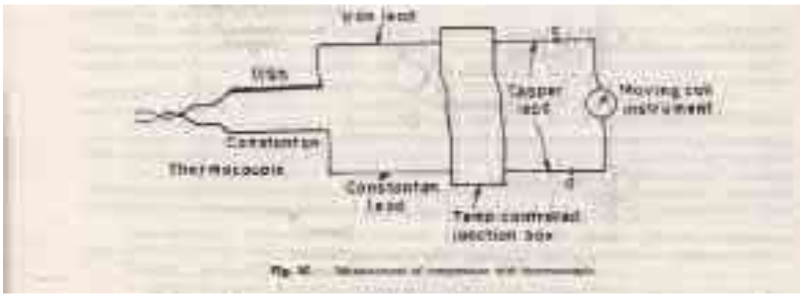
- The basic principle used in thermocouples is called the principle of thermoelectricity which was discovered by Seebeck.
- The principle states that “when the conductors of two different metals A and B are joined together at one end to form a junction is heated to a higher temperature with respect to the free ends, a voltage is developed at the free ends and if these two conductors of metals at the free ends are connected, then the emf set up will established a flow of current.
- The magnitude of net emf will depend upon the magnitude between the temperature of the two junction and the materials used for the conductors.

Thermocouple arrangement for measuring temperature:

- The main parts of a thermocouple arrangement used to measure temperature are as follows
- The thermocouple hot junction J_H which will be introduced into the place where temperature is to be measured.
- The thermocouple cold junction J_C which is maintained at a constant reference temperature.
- A voltage measuring instrument is connected to the free to the ends of the thermocouples.

Operation:

The thermocouple hot junction J_H is introduced into the place where the temperature is to be measured.



- The reference temperature is to be controlled at the constant temperature of 0^0 C.
- Since the two junctions are at different temperature, a voltage is set up at the free ends and since the free ends are connected to a milli voltmeter, the emf set up will establish a flow of current which can be directly measured using the milli voltmeter.
- Since the reference junction is kept at 0^0C the emf measured is a function of the temperature of the temperature of the hot measuring junction. The millivlotmeter is calibrated suitably so that its reading becomes an indication of the temperature.

Advantages:

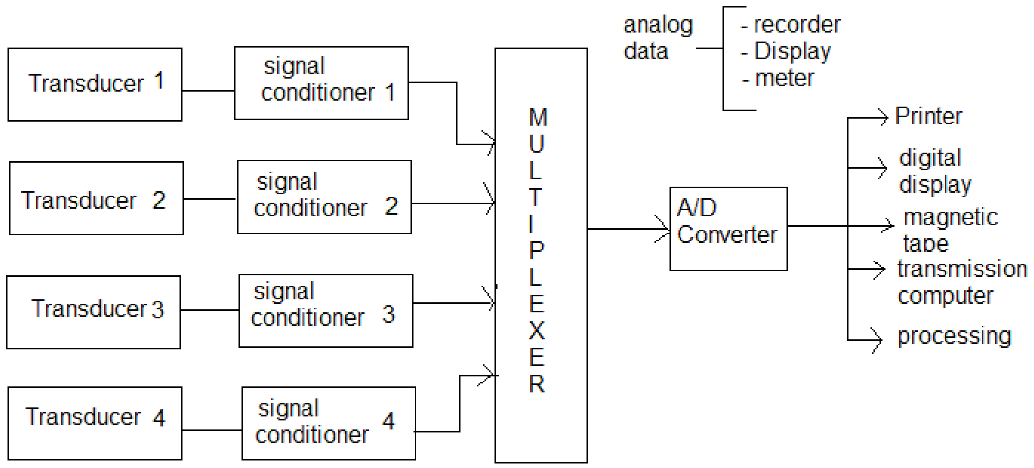
1) These instrument are suitable for very high frequency upto 50 MHz. no other instrument can be measure current and voltages these high frequencies.
2) They indicate the rms values directly.
3) They are not affected by stray magnetic fields.
4) They have good sensitivity.

Disadvantages:

1) The over load capacity is very limited.
2) Considerable power losses due to the poor efficiency of thermal conversion.
3) Low accuracy of measurement.
4) The mill voltmeters used with thermocouple must be necessarily more sensitive and delicate than those used with shunts, and therefore require careful handling.

ELEMENTS OF DIGITAL DATA AQUSITION SYSTEM- INTERFACING OF TRANSDUCER

In order to optimize the characteristics of the system in terms of performance of the system, data handling capacity and cost, different relevant sub-system are combined together. The system used for data processing, data conversion, data transmission, data storage is called data acquisition system.



DIGITAL DATA ACQUISITION SYSTEM

The digital data acquisition system includes all the block shown in fig may use some additional functions block. The essential functions of digital data acquisitions are as follows,

1. It handles the analog signals
2. it performs measurement
3. it converts analog signal into digital data and handles it.
4. it performs internal programming and control.

The various elements of the digital data acquisition system are as follows,

1. **TRANSDUCERS:-**

They convert the physical quantity into a proportional electrical signal which is given as a input to the digital data acquisition system.

2. **SIGNAL CONDITIONERS:-**

They include supporting circuits for amplifying, modifying or selecting certain positions of these signals.

3. **MULTIPLEXERS:-**

The multiplexer accepts multiple analog inputs and connect them sequentially to one measuring instruments.

4. **SIGNAL CONVERTERS:-**

The signal converters are used to translate analog signal to a form which is suitable for the next stage that is analog to digital converter. This block is optional one.

5. ANALOG TO DIGITAL CONVERTER(A/D CONVERTER):-

It converts the analog voltage to its equivalent digital form. The output of the analog to digital converter may be fed to the digital display device for display or to the digital recorders for recording. The same signal may be fed to the digital computer for data reduction or further processing.

6. AUXILIARY EQUIPMENTS:-

The devices which are used for system programming functions are digital data processing are included in the auxiliary equipments. The typical functions of the auxillary equipments include linearization and limit comparison of the signal. These functions are performed by the individual instruments or the digital computer.

7. DIGITAL RECORDER:-

They record the information in digital form. The digital information is stored on punched cards, magnetic tape recorders, type written pages, floppies or combination of these systems. The digital printer used provides a high quality, hard copy for recorders minimizing the operators work.

The data acquisition system is used, now days in increasing, wide fields. These are becoming very much popular because of simplicity, accuracy and the most important reliability of the system. These are widely used in industrial areas, scientific areas, including aerospace, biomedical and telemetry industries.

When the lower accuracy is tolerable or when wide frequency bandwidth is needed, the analog data acquisition systems are used. The digital data acquisition systems are used when the physical quantity being measured has very narrow bandwidth. When the high accuracy with low per channel cost is required, the ultimate solution is to use the digital data acquisition system.

MULTIPLEXING:

In general the process of transmitting more than one information on one channel is called multiplexing

Two types of multiplexing

1. Time division multiplexing

2. frequency division multiplexing

1. **TIME DIVISION MULTIPLEXING:**

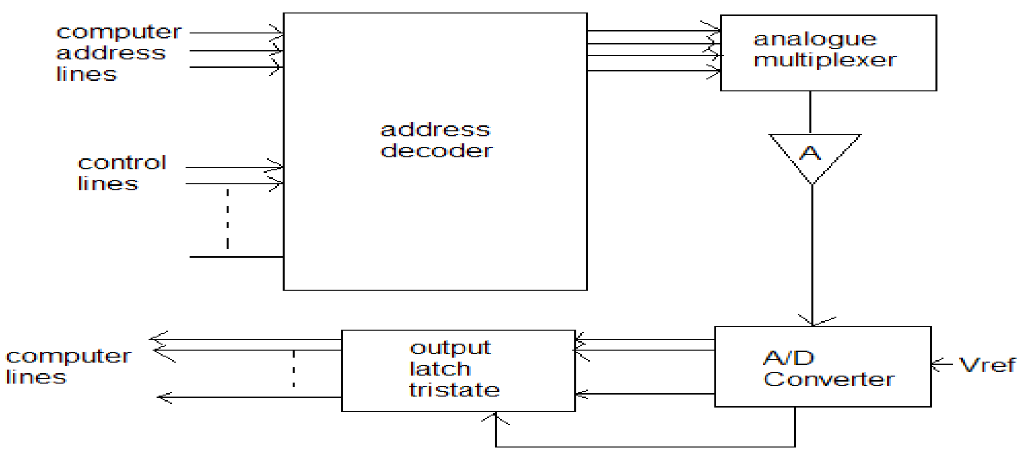
These are cases where analog input channels are multiplexed with the communication channel and signals are transmitted in analog form. In other cases the analog input channels are multiplexed with a digital computer for analysis and/or control. Here an A/D converter is used after the multiplexer. A sample and hold circuit is used before the multiplexer as shown in fig.

A DATA ACQUISITION AND CONVERSION

When simultaneous samples of inputs are required. Before discussing different type of time division multiplexers, we briefly describe an address decoder

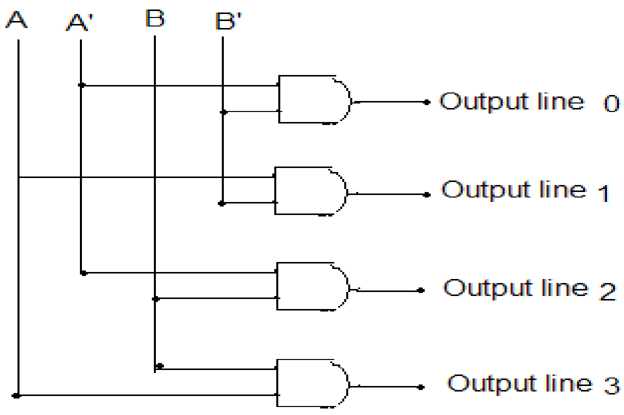
ADDRESS DECODER:

Address decoders receives an input from a computer via address lines that serve to select a particular analog channel to be sampled. The functions of the address decoder are to associate a particular channel a computer address code. A binary code is sent from the computer through special input/ output device to select an analog channel and to the input the data on that channel. A data acquisition system may be as shown in fig.



A TYPICAL ACQUISITION SYSTEM

A two bits, four outputs decoder is shown below, four AND gates with two inputs and four outputs form a decoder.

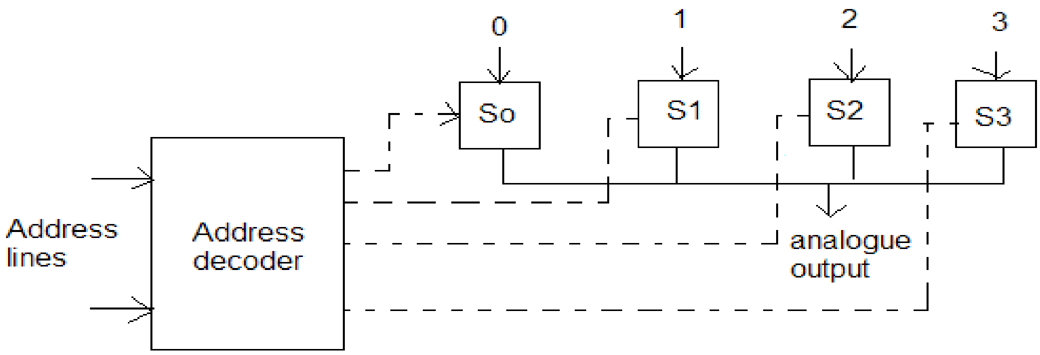


TWO BITS FOUR OUTPUTS DECODER

In the fig, for each two bits binary code, there is one AND gate for which output is one. For e.g. for A =1, and B=0, the output of second gate is 1, since this code represents the decimal number 1, the gate labeled 1 is on and other are off.

ANALOG MULTIPLEXER:-

This is essentially a solid- state switch works according to the decoded address signal and selects the data on the selected channel by closing the switch off the channel. A four channel multiplexer is shown in fig below.



FOUR CHANNEL ANALOGUE MULTIPLEXER

The multiplexer receives an input from the address decoder and uses this to close the appropriate switch. For e.g. an address code channel 10 would detect channel 2. Similarly 00 would select channel 0, 01, channel 1, and 11 channel 3, thus decoder must convert the computer address line to one of these four possibilities. The actual switch elements usually FET. FETs have an 'on' resistance of a few hundred ohm and an 'off' resistance of hundred to thousands of mega ohm.

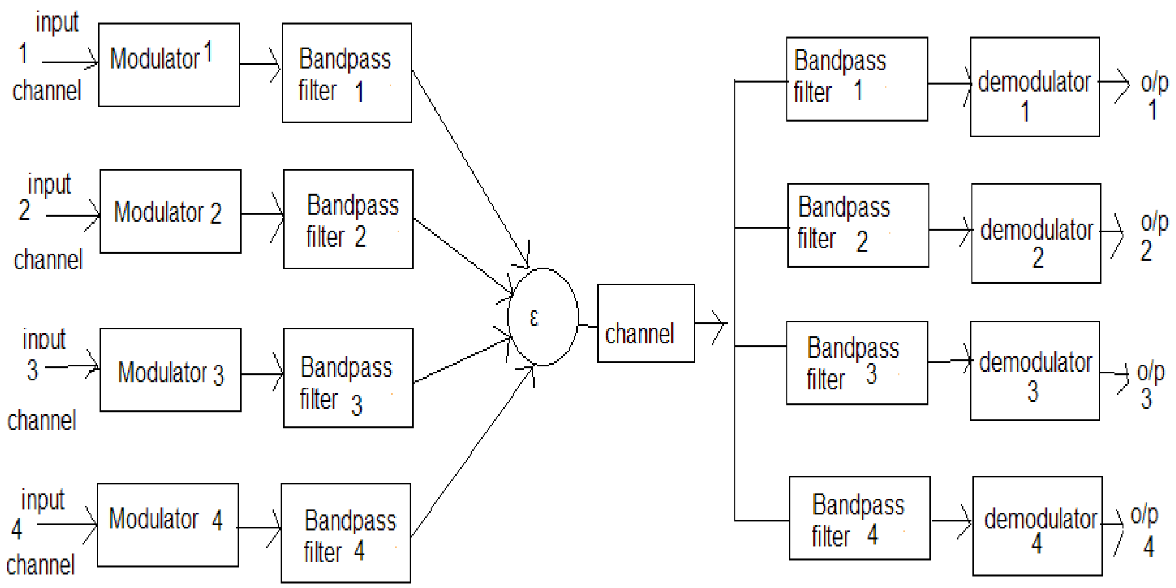
2. FREQUENCY DIVISION MULTIPLEXING:-

The block diagram of a 4 channel FDM system is shown in fig. four input signals are first applied to channel modulators which have different carrier frequencies. The carrier oscillator frequencies are so chosen that they avoid the overlapping of frequency spectrum between each other.

A band pass filter of each channel is used so that only working frequencies around the carrier frequency are allowed to pass.

The harmonics and other spurious frequencies are blocked.

At receiving end, the signals are separated by selective filters and demodulators as shown in fig.



A FREQUENCY DIVISION MULTIPLEXING