DEPARTMENT OF ELECTRONICS AND COMMUNICATION

ENGINEERING

ELECTRONIC MEASURING INSTRUMENTATION

B.TECH ECE
(IV YEAR – I SEM)
(2023-24)

J.B.I.E.T

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B.Tech. ECE **L T-P-D C**
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ELECTRONICMEASUREMENTSANDINSTRUMENTATION

Module-1
UNIT-I:
Block Schematics of Measuring Systems: Performance characteristics, Static characteristics, Accuracy, Precision, Resolution, Types of Errors, Gaussian Error, Root Sum Squares formula, Dynamic Characteristics, Repeatability, Reproducibility, Fidelity, , Lag; Measuring Instruments: DC Voltmeters, D' Arsonval Movement, DC Current Meters, AC Voltmeters and Current Meters, Ohmmeters.
UNIT-2:
Multimeters, Meter Protection, Extension of Range, True RMS Responding Voltmeters, Specifications of Instruments. Electronic Voltmeters, Multimeters, AC,DC Meters, Digital Voltmeters: Ramp Type, Staircase Ramp, Dual Slope Integrating type, Successive Approximation Type,Autoranging,31/2,33/4 Digit Display, Pico ammeter, High Resistance Measurements, Low current Ammeter, Applications.
Module-2

UNIT - I: Signal Generators: AF, RF Signal Generators, Sweep Frequency Generators, Pulse and Square wave Generators, Function Generators, Arbitrary waveform Generator, Video Signal Generators, and Specifications.
UNIT - II: Signal Analyzers, AF, HF Wave Analyzers, Harmonic Distortion, Heterodyne wave Analyzers, Spectrum Analyzers, Power Analyzers, Capacitance-Voltage Meters, Oscillaors.

Module-3
UNIT -I:
DC and AC Bridges: Wheat Stone Bridge, Kelvin Bridge, AC Bridges, Maxwell, Hay, Schering, Wien, Anderson Bridges.
UNIT -II:
Resonance Bridge, Similar Angle Bridge, Wagner’s ground connection, Twin T, Bridged T Networks, Detectors
Module-4
UNIT - I:
Oscilloscopes: CRT, Block Schematic of CRO, Time Base Circuits, Lissajous Figures, CRO Probes, High Frequency CRO Considerations, Delay lines, Applications, Specifications.
UNIT -II:
Special Purpose Oscilloscopes: Dual Trace, Dual Beam CROs, Sampling Oscilloscopes, Storage Oscilloscopes, Digital Storage CROs, Frequency Measurement, Period Measurement, Errors in time/Frequency Measurements, universal counters, Extension of range; Recorders: Strip chart, X-Y, oscillographic recorders
Module-5
UNIT -I:
Transducers: Classification, Strain Gauges, Bounded, unbounded; Force and Displacement Transducers, Resistance Thermometers, Hotwire Anemometers, LVDT, Thermocouples, Synchros, Special Resistance Thermometers, Digital Temperature sensing system, Piezoelectric Transducers, Variable Capacitance Transducers, Magneto Strictive Transducers.
UNIT -II:

Measurement of Physical Parameters: Flow Measurement, Displacement Meters, Liquid level Measurement, Measurement of Humidity and Moisture, Velocity, Force, Pressure - High Pressure, Vacuum level, Temperature - Measurements, Data Acquisition Systems.

TEXT BOOKS: 1. Electronic Measurements and Instrumentations by K. Lal Kishore, Pearson Education - 2010.

2. Electronic instrumentation: H.S.Kalsi - TMH, 2nd Edition 2004. 213

REFERENCE BOOKS: 1.Electronic Instrumentation and Measurements - David A. Bell, Oxford Uiv. Press, 1997.

2. Modern Electronic Instrumentation and Measurement Techniques: A.D. Helbincs, W.D. Cooper: PHI, 5th Edition, 2003.

3. Electronic Measurements and Instrumentation: B. M. Oliver, J. M. Cage TMH Reprint.

4. Industrial Instrumentation: T. R. Padmanabham Spiriger 2009.

Course Outcomes: The Student will be able to

1. Describe the fundamental concepts and principles of electronic instrumentation.
2. Illustrate the operation of various instruments required in measurements.
3. Identify and use the selected cathode ray oscilloscope for measurement of parameters.
4. Examine the AC and DC bridges for the measurement of resistance, inductance, capacitance, and frequency.
5. Identify various transducers for the measurement of physical quantities like temperature, pressure, distance, and displacement.

CO-PO Mapping														
CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	2		2									2	2	
CO2	2		2		1							1	1	
CO3	1	2	2									1		1
CO4	1	2			2							2		1
CO5	2		2									2		2

MODULE-1

Block Schematics of Measuring Systems

Introduction:

The measurement of any quantity plays very important role not only in science but in all branches of engineering, medicine and in almost all the human day to day activities.

The technology of measurement is the base of advancement of science. The role of science and engineering is to discover the new phenomena, new relationships, the laws of nature and to apply these discoveries to human as well as other scientific needs. The science and engineering is also responsible for the design of new equipments. The operation, control and the maintenance of such equipments and the processes is also one of the important functions of the science and engineering branches. All these activities are based on the proper measurement and recording of physical, chemical, mechanical, optical and many other types of parameters.

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 major problem with any measuring instrument is the error. Hence, it is necessary to select the appropriate measuring instrument and measurement procedure which minimizes the error. The measuring instrument should not affect the quantity to be measured.

An electronic instrument is the one which is based on electronic or electrical principles for its measurement function. The measurement of any electronic or electrical quantity or variable is termed as an electronic measurement.

Advantages of Electronic Measurement

The advantages of an electronic measurement are

1. Mostofthequantitiescanbeconvertedbytransducersintotheelectricalorelectronicsignals.
2. Anelectricalorelectronicsignalcanbeamplified, filtered, multiplexed, sampledand measured.
3. Themeasurementcaneasilybeobtainedinorconvertedintodigitalformforautomatic analysis and recording.

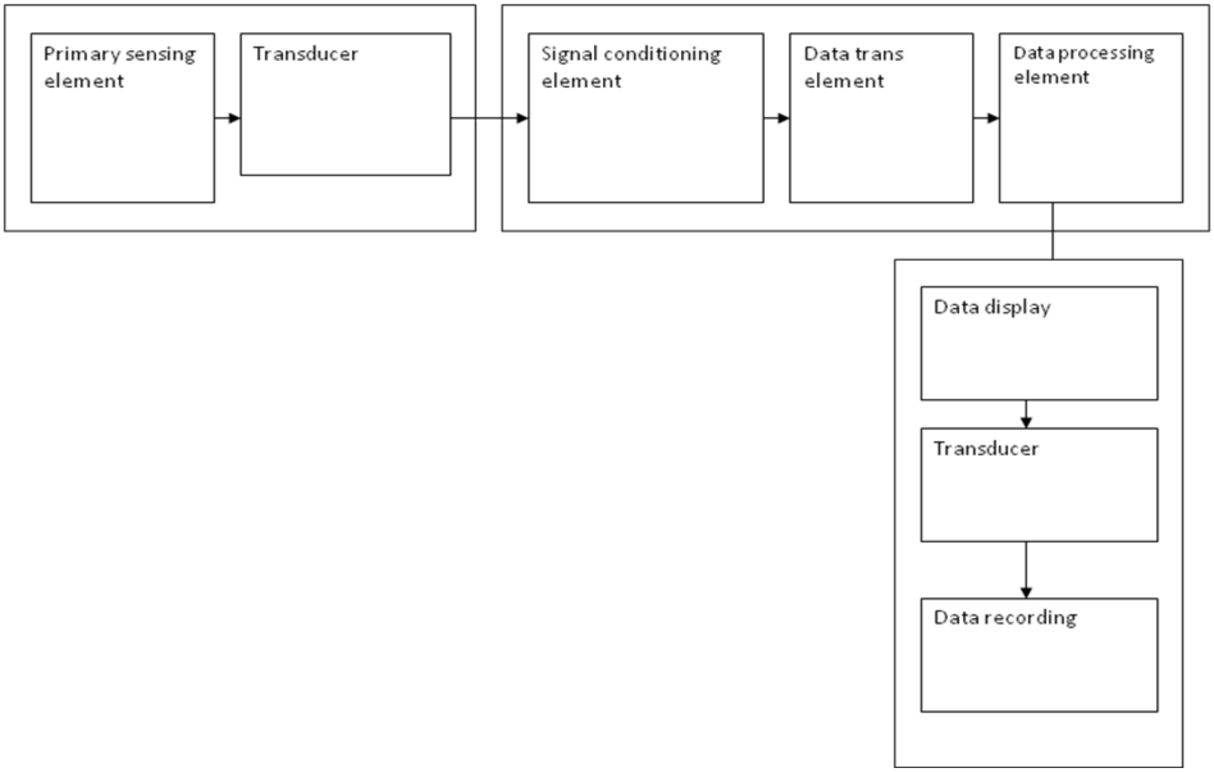
4Themeasuredsignalscanbetransmittedoverlongdistanceswiththehelpofcablesorradio links, without any loss of information.

5. Manymeasurementscanbecarriedeithersimultaneouslyorinrapidsuccession.
6. Electroniccircuitscandetectandamplifyveryweaksignalsandcanmeasuretheeventsofvery short duration as well.
7. Electronic measurement makes possible to build analog and digital signals. The digital signals are very much required in computers. The modern development in science and technology are totally based on computers.
8. Higher sensitivity, low power consumption and a higher degree of reliability are the important features of electronic instruments and measurements. But, for any measurement, a well defined set of standards and calibration units is essential. This chapter provides an introduction to different types of errors in measurement, the characteristics of an instrument and different calibration standards.

Functional elements of an instrument:

Any instrument or a measuring system can be described in general with the help of ablock diagram. While describing the general form ofa measuring system,it is not necessary togo into the details of the physical aspects of a specific instrument. The block diagram indicates the necessary elements and their functions in a general measuring system.

- **Primary sensing element:** which senses the quantity under measurement
- **Variable conversion element:** which modifies suitably the output of the primary sensing element
- **Variable Manipulation Element:** The signal gets manipulated here preserving the original nature of it
- **DataTransmissionElement:**Thetransmissionofdatafromoneanotherisdonebythe data transmission element
- **Datapresentationelement**: Thedisplayorreadoutdeviceswhichdisplaytherequired information about the measurement.



Static characteristics:

As mentioned earlier, the static characteristics are defined for the instruments which measure the quantities which do not vary with time. The various static characteristics are accuracy, precision, resolution, error, sensitivity, threshold, reproducibility, zero drift, stabilityand linearity.

Accuracy:

It is the degree of closeness with which the instrument reading approaches the true value of the quantity to be measured. It denotes the extent to which we approach the actual value of the quantity. It indicates the ability of instrument to indicate the true value of the quantity. The accuracy can be expressed in the following ways.

1) Accuracyas'PercentageofFullScale Reading:Incaseofinstrumentshavinguniform scale,the accuracy can be expressed as percentage of full scale reading.

Forexample,theaccuracy ofaninstrument havingfullscale readingof50unitsmaybeexpressed as ± 0.1% of full scale reading. From this accuracy indication, practically accuracy is expressed in terms of limits of error. So forthe accuracy limits specified above, there will be ± 0.05units error in any measurement. So for a reading of 50 units, there will be error of ± 0.05 units i.e. ± 0.1 % while for a reading of 25 units, there will be error of ± 0.05 units in the reading i.e. ± 0.2%. Thusas reading decreases, error in measurement is ± 0.05 units but net percentage error is more. Hence, specification of accuracy in this manner is highly misleading.

2) Accuracy as 'Percentage ofTrue Value' :This is the best methodofspecifying the accuracy. It is to be specified in terms of the true value of quantity being measured. For example, it can be specified as ± 0.1% of true value. This indicates that in such cases, as readings get smaller, error also gets reduced. Hence accuracy of the instrument is better than the instrument for which it is specified as percent of full scale reading.

Precision:

Itisthemeasureofconsistencyorrepeatabilityof measurements.

Let us see the basic difference between accuracy and precision. Consider an instrumenton which, readings upto 1/1000th of unit can be measured. But the instrument has large zero adjustment error. Now every time reading is taken, it can be taken down upto'1000th of unit. So as the readings agree with each other, we say that the instrument is highly precise. But, though the readings are precise upto 10100th of unit, the readings are inaccurate due to large zero adjustment error. Every reading will be inaccurate, due to such error. Thus a precise instrument may not be accurate. Thus the precision means sharply or clearly defined and the readings agree among themselves. But there is no guarantee that readings are accurate. An instrument having zeroerror,if calibrated properly,can giveaccuratereadingsbut inthat casestill,the readingscan beobtaineddownupto1/10th ofunit only.Thus accuracy canbe improvedbycalibrationbutnot the precision of the instrument.

Theprecisioniscomposedoftwocharacteristics:
Conformityand
Numberofsignificantfigures.

Conformity:

Consider a resistor having true value as 2385692.0Ω, which is being measured by an ohmmeter. Now, the meter is consistently measuring the true value of the resistor. But the reader, can read consistently,avalueas2.4MΩduetononavailabilityofproperscale.Thevalue2.4MΩis estimated by the reader from the available scale. There are no deviations from the observed value. The error created due to the limitation of the scale reading is a precision error.

SignificantFigures:

The precision of the measurement is obtained from the number of significantfigures, in which the reading is expressed. The significant figures convey the actual information about the magnitude and the measurement precision of the quantity.

Resolution:

It is the smallest increment of quantity being measured which can be detected with certainty by an instrument.

So if a nonzero input quantity is slowly increased, output reading will not increase until some minimum change in the input takes place. This minimum change which causes the change in the output is calledresolution. The resolutionofaninstrument is alsoreferredtoas discrimination of the instrument. The resolution can affect the accuracy of the measurement.

Errors:

Staticerror=measuredvalue–true value

Themostimportantstaticcharacteristics ofaninstrumentis itsaccuracy,whichisgenerally expressed in terms of the error called static error.

Mathematicallyitcanbeexpressedas,e=A_t-AmJ

where e = Error

A_m = Measured value of the quantity

A_t = True value of the quantity

In this expression, the error denoted as e is also called absolute error. The absolute error doesnot indicate precisely the accuracy of the measurements. For example, absolute error of ± 1 V is negligible when the voltage to be measured is of the order of 1000 V but the same error of ±1 V becomes significant when the voltage under measurement is 5 V or so. Hence, generally instead of specifying absolute error, the relative or percentage error is specified.

Sensitivity:

Thesensitivityisalwaysexpressedbythemanufacturersastheratioofthe magnitude ofquantity being measuredtothe magnitude ofthe response. Actually,this definitionis the reciprocalofthe sensitivity is called inverse sensitivity or deflection factor. But manufacturers call this inverse sensitivity as a sensitivity.

$$\text{Inverse sensitivity} = \text{Deflection factor}$$

$$\therefore \quad \boxed{\text{Deflection factor} = \frac{1}{\text{Sensitivity}} = \frac{\Delta q_i}{\Delta q_o}}$$

The units of the sensitivity are millimeter per micro-ampere, millimeter per ohm, counts per volt,

Drift : Gradual shift in the meassured value ,over an extended period, when there is no change in input.

Threshold: Theminimumvalue ofinput forwhichthedevicejuststartstorespond.

Range/Span: Theminimumandmaximumvalueofquantitysothatthedeviceiscapableof measuring.

Repeatability: A measure of how well the output returns to a given value when the same precise input is applied several times. Or The ability ofan instrument to reproduce a certain set of reading within a given accuracy.

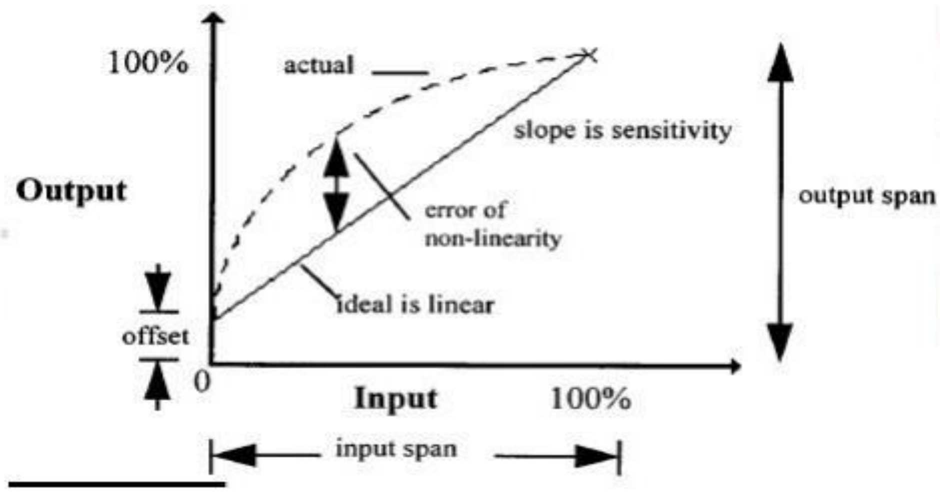
Linearity: Inputoutputrelationshipofadevicemustbe linear.

But practical systems shows small deviations from the linear shape (allowed within the specified limits)

Hysteresis: Inputisincreasedfromnegativevalue,outputincreasesasindicatedbycurve1

• Then the input is steadily decreased , output does not follow the same path , but lag by a certain value as indicated by curve 2 •

ThedifferencebetweenthetwocurvesiscalledHysterisis.



DYNAMICCHARACTERISTICS:

TheresponseofinstrumentsorsystemstodynamicI/Psarealsofunctionsoftime. Instruments rarely

respond instantaneously to changes in the measured variables.

Instead,theyexhibitslownessorsluggishnessduetosuchthingsasmass,thermalcapacitance, fluid capacitance or electric capacitance.

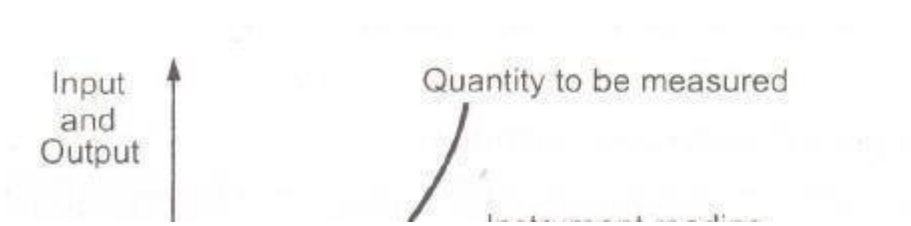
- **SpeedofResponse**:Itistheabilityofasystemtorespondtoasuddenchangesintheinput signal/quantity

- **Fidelity**: It is the degree to which an instrument indicates the changes in the measured variable without dynamic error (Indication of how much faithfully system responds to the changes ininput).

Lag: It is the retardation or delay in the response of an instrument to changes in the measured variable. Two types : Process lag(process) and Control lag (Instrument)

Dynamicerror:

Itisthedifferencebetweenthetruevalue ofthevariabletobe measured,changingwithtime andthevalue indicatedby the measurementsystem,assuming zerostaticerror. TheFig. 1.13 shows the dead time, i.e. time delay and the dynamic error.



Typesoferrors:

The static erroris defined earlieras the difference betweenthe true value ofthe variable andthe valueindicated bythe instrument.The staticerrormayariseduetonumberofreasons.Thestatic errors are classified as:

1) Grosserrors

2) Systematicerrors

3) Randomerrors

Gross errors:

The gross errors mainly occur due to carelessness or lack of experience of a human being. These coverhuman mistakes inreadings,recordings and calculating results. These errors also occurdue to incorrect adjustments of instruments. These errors cannot be treated mathematically. These errors are also calledpersonal errors. Some gross errors are easily detectedwhile others are very difficult todetect.

Systematicerrors:

The systematic errors are mainly resulting due to the shortcomings of the instrument and the characteristics of the material used in the instrument, such as defective or worn parts, ageing effects, environmental effects, etc.

Aconstantuniformdeviationofthe operationofaninstrument isknownasasystematic error.
There are three types of systematic errors as

1)Instrumentalerrors2)Environmentalerrors3)Observationalerrors

Instrumentalerrors:

Theseerrorsaremainlyduetofollowingthreereasons

• Short-comingsofinstrument

These are because of the mechanical structure of the instruments eg. Friction in the bearings of various moving parts, irregular spring tensions, hysteresis, gear backlash, variation in air gap etc.

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. Elimination: Use the instrument intelligently & Correctly

• LoadingeffectsLoadingeffects duetoImproperwayofusingthe instrument

• **Ellimination.**

– Selectingproperinstrumentandthetransducerforthemeasurement.

– Recognizetheeffectofsucherrorsandapplythepropercorrectionfactors.

– Calibratetheinstrumentcarefullyagainststandard.

EnvironmentalErrors(duetotheExternalConditions)

• The various factors : Temperature changes,Pressure,vibratons, Thermal emf.,stray capacitance, cross capacitance, effect of External fields, Aging of equipments and Frequency sensitivity of an instrument.

Elimination • Using proper correction factors and using the instrument Catalogue • Using Temperature & Pressure control methods etc. • Reducing the effect of dust, humidity on the components in the instruments. • The effects of external fields can be minimized by using the magnetic or electrostatic shields of screens.

ObservationalErrors:

Errorintroducedbytheobserver

Few souces are:

• Parallaxerrorwhilereadingthemeter,

• wrongscaleselection,

• habitsofindividualobsever

• Eliminatio

n Use the

• instrumentwithmirrors,

• instrumentwithknifeedgepointers,

• Instrumenthavingdigitaldisplay

Randomerrors:

Some errors still result, though the systematic and instrumental errors are reduced or atleast accounted for. The causes of such errors are unknown and hence, the errors are called **random** errors. These errors cannot be determined in the ordinary process of taking the measurements.

Absoluteandrelativeerrors:

When the error is specified interms of an absolute quantity and not as a percentage, then it is called an absolute error.

Thus the voltage of 10± 0.5V indicated ± 0.5Vas an absolute error. Whenthe error is expressed as a percentage or as a fraction of the total quantity to be measured, then it is called relative error.

Generallytherelativeerrorincaseofresistancesisspecifiedaspercentageoftolerances.Another method of expressing error is by specifying it as parts per million (ppm), relative to the total quantity. Soit is arelative error specification . Generally change in resistance withtemperature is indicated in ppm/ °C shows the variation in resistance with Temperature temperature. Thus if a resistance of100k**Ω**. has atemperature coefficient of50 *ppm/C* means 50 parts per millionth per degree celcius. Thus one millionth of 100 kohm. is 0.1 ohm and 50 such parts means 5 D.

Limitingerrors:

The manufacturers specify the accuracy of the instruments within a certain percentage of full scale reading. The components like the resistor, inductor,capacitorare guaranteedtobe withina certain percentage of rated value. This percentage indicates the deviations from the nominal or specified value of the particular quantity. These deviations from the specified value are called **Limiting Errors.** These are also called **Guarantee Errors.**

Thustheactualvaluewiththelimitingerrorcanbeexpressedmathematicallyas,

$$\boxed{A_a = A_s \pm \delta A}$$

where A_a = Actual value

A_s = Specified or rated value

δA = Limiting error or tolerance

Relativelimitingerror:

Thisisalsocalledfractionalerror.Itistheratiooftheerrortothespecifiedmagnitudeofa quantity.

Thus $$\boxed{e = \frac{\delta A}{A_s}}$$

where e = Relative timing error

From the above equation, we can write,

$$\delta A = e \cdot A_s$$

and

$$A_a = A_s \pm \delta A$$

$$= A_s \pm e\, A_s$$

$$\therefore \quad \boxed{A_a = A_s [\, 1 \pm e \,]}$$

The percentage relative limiting error is expressed as

$$\boxed{\% e = e \times 100}$$

The relative limiting error can be also be expressed as,

$$\boxed{e = \frac{\text{Actual value } (A_a) - \text{Specified value } (A_s)}{\text{Specified value } (A_s)}}$$

Voltmetersandmultimeters:

Basicmeter:

A basic d.c. meter uses a motoring principle for its operation. It stntes that any current carrying coil placed in a magnetic field experiences a force, which is proportional to the magnitude of current passing through the coil. This movement of coil is called D'Arsonval movement and basic meter is called D'Arsonval galvanometer.

D.Cinstruments:

a) Usingshuntresistance,d.c.currentcanbemeasured.Theinstrumentisd.c.microammeter, milliammeter or ammeter.

b) Usingseriesresistancecalledmultiplier,d.c.voltagecanbemeasured.Theinstrumentisd.c. millivoltmeter, voltmeter or kilovoltmeter.

c) Usingabatteryandresistivenetwork,resistancecanbemeasured.Theinstrument is ohmmeter.

A.Cinstruments:

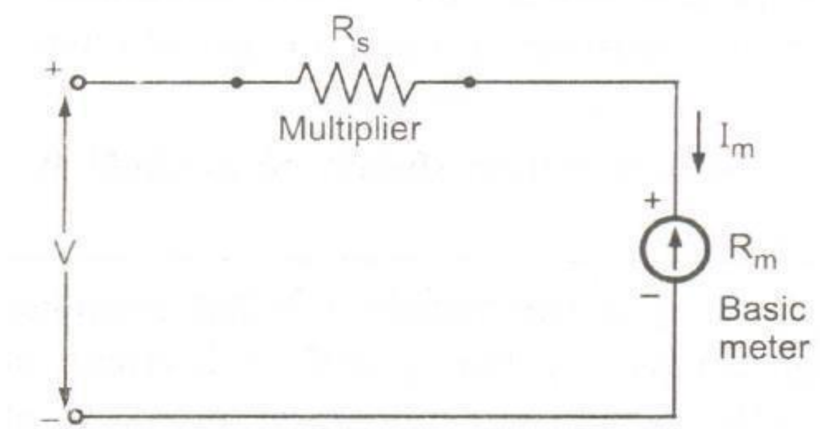
a) Usingarectifier,a.c.voltagescanbemeasured,at powerandaudiofrequencies.The instrument is a.c. voltmeter.

b) Usingathermocoupletypemeterradiofrequency(RF)voltageorcurrentcanbemeasured.

c) Usingathermistorinaresistivebridgenetwork,expandedscaleforpowerlinevoltagecanbe obtained.

BasicDCvoltmeter:

The basic d.c. voltmeter is nothing but a permanent magnet moving coil (PMMC) 0' Arsonval galvanometer. The resistance is required to be connected in series with the basic meter to use it as a voltmeter. This series resistance is called a **multiplier.** The main function of the multiplier is to limit the current through the basic meter so that the meter current does not exceed the full scale deflection value. The voltmeter measures the voltage across the two points of a circuit or a voltage across a circuit component. The basic d.c. voltmeter is shown in the Fig.



The voltmeter must be connected across the two points or a component, to measure the potential difference, with the proper polarity.

Themultiplierresistancecanbecalculatedas:

Let R_m = internal resistance of coil i.e. meter

R_s = series multiplier resistance

I_m = full scale deflection current

V = full range voltage to be measured

From Fig. 2.1, $\therefore V = I_m(R_m + R_s)$

$$\therefore \quad V = I_m R_m + I_m R_s$$

$$\therefore \quad I_m R_s = V - I_m R_m$$

$$\therefore \quad \boxed{R_s = \frac{V}{I_m} - R_m}$$

Themultiplyingfactorformultiplieristhe ratioof fullrangevoltagetobemeasuredandthedrop across the basic meter.

Let v = drop across the basic meter $= I_m R_m$

$\therefore$ m = multiplying factor $= \dfrac{V}{v}$

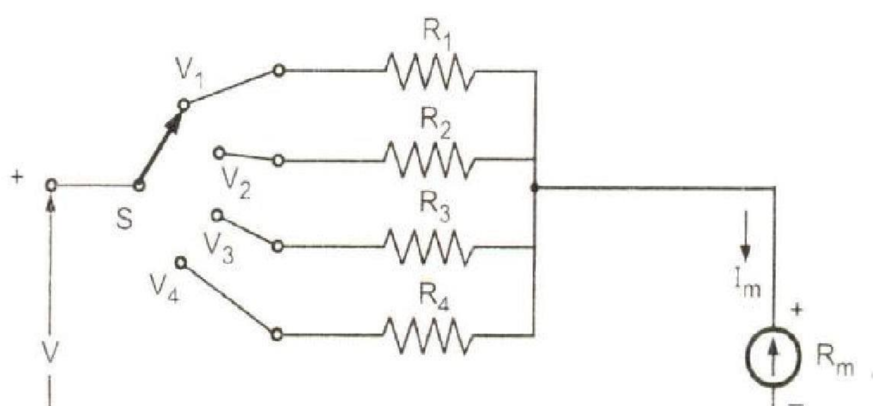
$$= \frac{I_m(R_m + R_s)}{I_m R_m}$$

Hence multiplier resistance can also be expressed as,

$$R_s = (m-1) R_m$$

Multirangevoltmeters:

Therangeofthebasicd.c.voltmetercanbeextendedbyusingnumberofmultipliersclnda selector switch. Such a meter is called **multirange** voltmeter.



The R1, R2, R3 and R4 are the four series multipliers. When connected in series with the meter, they can give four different voltage ranges as V1, V2, V3, and V4. The selector switch S is multiposition switch by which the required multiplier can be selected in the circuit.

Themathematicalanalysisofbasicd.c.*voltmeter*isequallyapplicableforsuchmultirange *voltmeter*.Thus,

$$R_1 = \frac{V_1}{I_m} - R_m \qquad R_2 = \frac{V_2}{I_m} - R_m \qquad \text{and so on.}$$

Sensitivityofvoltmeters:

Inamultirangevoltmeter,the ratioofthetotalresistanceRttothevoltagerangeremains same.

Thisratioisnothingbutthereciprocalofthefullscaledeflectioncurrent ofthemeteri.e.1/101. This value

is called sensitivity of the voltmeter. Thus the sensitivity of the voltmeter is defined,

$$S = \frac{1}{\text{Full scale deflection current}}$$

$$\boxed{S = \frac{1}{I_m}\ \Omega/V \text{ or } k\Omega/V}$$

Loadingeffect:

While selecting a meter for a particular measurement, the sensitivity rating IS very important. A low sensitive meter may give the accurate reading in low resistance circuit but will producetotally inaccurate reading in high resistance circuit.

The voltmeter is always connected across the two points between which the potential differenceis to be measured. If it is connected across a low resistance then as voltmeter resistance is high, most of the current will pass through a low resistance and will produce the voltage drop which will be nothing but the true reading. But if the voltmeter is connected across the high resistance then due to two high resistances in parallel, the current will divide almost equally through thetwo paths. Thus the meter will record the voltage drop across the high resistance which will be much lower than the true reading. Thus the low sensitivity instrument when used in high resistance circuit 'gives a lower than the true reading. This is called loading effect of the voltmeters. It is mainly caused due to low sensitivity instruments.

A.Cvoltmetersusingrectifier:

The PMMC movement used in d.c. voltmeters can be effectively used in a.c. voltmeters. The rectifier is used to convert a.c. voltage to be measured, to d.c. This d.c., if required is amplified andthen given tothe PMMC movement. The PMMC movement gives the deflection proportional to the quantity to be measured.

The r.m.s. value of an alternating quantity is given by that steady current (d.c.) which whenflowing through a given circuit for a given time produces the same amount of heat as producedbythealternatingcurrentwhichwhenflowingthroughthesamecircuitfor thesametime.The r.m.s value is calculated by measuring the quantity at equal intervals for one complete cycle.Then squaring each quantity, the average of squared v,llues is obtained. The square root of this average value is the r.m.s. value. The r.m.s means root-mean square i.e. squaring, finding the mean i.e. average and finally root.

If the waveform is continuous then instead of squaring and calculating mean, the integratioll is used. Mathematically the r.m.s. value of the continuous a.c. voltage having time period T is given by,

$$\boxed{V_{rms} = \sqrt{\frac{1}{T}\int_0^T V_{in}^2\, dt}}$$

The $\frac{1}{T}$ term indicates the mean value or average value.

For **purely sinusoidal quantity,**

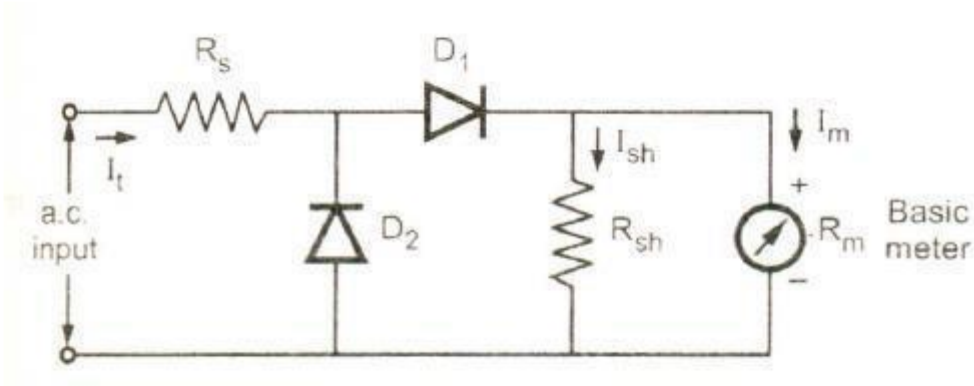
$$V \quad 0.707\ V$$

Ifthea.c.quantityiscontinuousthenaveragevaluecanbeexpressedmathematicallyusing integration as,

Theformfactor istheratioofr.m.s.valuetotheaveragevalueofanalternatingquantity.

$$\boxed{K_f = \frac{\text{r.m.s. value}}{\text{average value}} = \text{form factor}}$$

Basicrectifiertypevoltmeter:

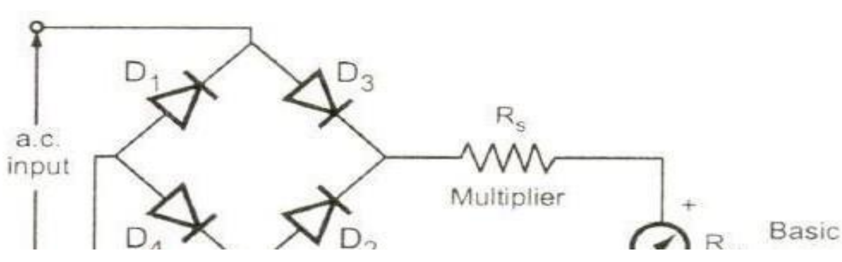


The diodes D1 and D2 are used for the rectifier circuit. The diodes show the nonlinear behaviour for the low currents hence to increase the current through diode D1, the meter is shunted with a resistance Rsh' This ensures high current through diode and its linear behaviour.

When the a.c. input is applied, for the positive half cycle, the diode 01 conducts and causes the meter deflection proportional to the average value of that half cycle. In the negative cycle, the diode D2 conducts and D1 is reverse biased. The current through the meter is in opposite direction and hence meter movement is bypassed. Thus due to diodes, the rectifying action produces pulsating d.c. and lile meter indicates the average value of the input.

A.Cvoltmeterusingfullwaverectifier:

The a.c. voltmeter using full wave rectifier is achieved by using bridge rectifier consisting of four diodes, as shown in the Fig



OHMMETER (SERIES TYPE OHMMETER)

A D'Arsonval movement is connected in series with a resistance R_1 and a battery which is connected to a pair of terminals A and B, across which the unknown resistance is connected. This forms the basic type of series ohmmeter, as shown in Fig. 4.30 (a).

The current flowing through the movement then depends on the magnitude of the unknown resistance. Therefore, the meter deflection is directly proportional to the value of the unknown resistance.

Referring to Fig. 4.30 (a)

R_1 = current limiting resistance
R_2 = zero adjust resistance
V = battery
R_m = meter resistance
R_x = unknown resistance

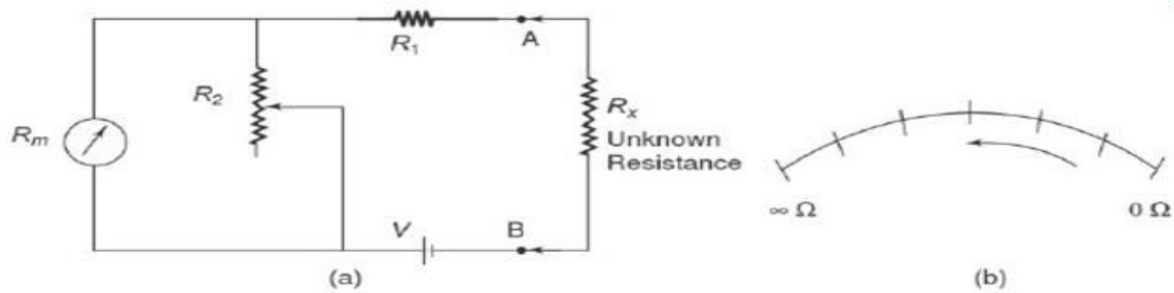


Fig. 4.30 (a) Series type ohmmeter (b) Dial of series ohmmeter

Calibration of the Series Type Ohmmeter

To mark the "0" reading on the scale, the terminals A and B are shorted, i.e. the unknown resistance $R_x = 0$, maximum current flows in the circuit and the shunt resistance R_2 is adjusted until the movement indicates full scale current (I_{fsd}). The position of the pointer on the scale is then marked "0" ohms.

Similarly, to mark the "∞" reading on the scale, terminals A and B are open, i.e. the unknown resistance $R_x = \infty$, no current flow in the circuit and there is no deflection of the pointer. The position of the pointer on the scale, is then marked as "∞" ohms.

By connecting different known values of the unknown resistance to terminals A and B, intermediate markings can be done on the scale. The accuracy of the instrument can be checked by measuring different values of standard resistance, i.e. the tolerance of the calibrated resistance, and noting the readings.

A major drawback in the series ohmmeter is the decrease in voltage of the internal battery with time and age. Due to this, the full scale deflection current drops and the meter does not read "0" when A and B are shorted. The variable shunt resistor R_2 across the movement is adjusted to counteract the drop in battery voltage, thereby bringing the pointer back to "0" ohms on the scale.

It is also possible to adjust the full scale deflection current without the shunt R_2 in the circuit, by varying the value of R_1 to compensate for the voltage drop. Since this affects the calibration of the scale, varying by R_2 is much better solution. The internal resistance of the coil R_m is very low compared to R_1. When R_2 is varied, the current through the movement is increased and the current through R_2 is reduced, thereby bringing the pointer to the full scale deflection position.

The series ohmmeter is a simple and popular design, and is used extensively for general service work.

Therefore, in a series ohmmeter the scale marking on the dial, has "0" on the right side, corresponding to full scale deflection current, and "∞" on the left side corresponding to no current flow, as given in Fig. 4.30 (b).

Values of R_1 and R_2 can be determined from the value of R_x which gives half the full scale deflection.

$$R_h = R_1 + R_2 \parallel R_m = R_1 + \frac{R_2 R_m}{R_2 + R_m}$$

where R_h = half of full scale deflection resistance.

The total resistance presented to the battery then equals $2R_h$ and the battery current needed to supply half scale deflection is $I_h = V/2\ R_h$.

To produce full scale current, the battery current must be doubled.

Therefore, the total current of the ckt, $I_t = V/R_h$

The shunt current through R_2 is given by $I_2 = I_t - I_{fsd}$

The voltage across shunt, V_{sh}, is equal to the voltage across the meter.

Therefore $\quad V_{sh} = V_m$

$$I_2 R_2 = I_{fsd} R_m$$

Therefore $\quad R_2 = \dfrac{I_{fsd} R_m}{I_2}$

But $\quad I_2 = I_t - I_{fsd}$

$\therefore \quad R_2 = \dfrac{I_{fsd} R_m}{I_t - I_{fsd}}$

But $\quad I_t = \dfrac{V}{R_h}$

Therefore $\quad R_2 = \dfrac{I_{fsd} R_m}{V/R_h - I_{fsd}}$

Therefore $\quad R_2 = \dfrac{I_{fsd} R_m R_h}{V - I_{fsd} R_h}$

As $\quad R_h = R_1 + \dfrac{R_2 R_m}{R_2 + R_m}$

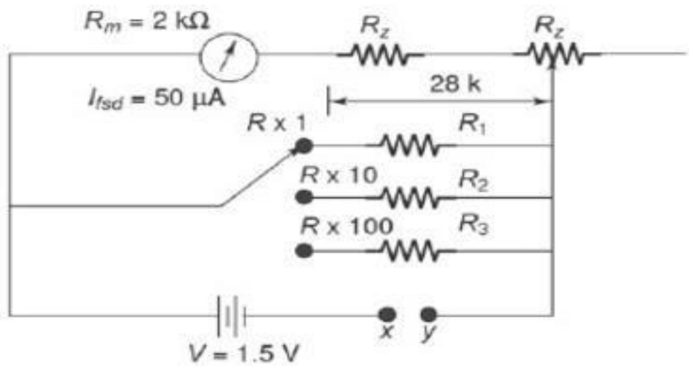
Therefore $\quad R_1 = R_h - \dfrac{R_2 R_m}{R_2 + R_m}$

Hence $$R_1 = R_h - \frac{\dfrac{I_{fsd} R_m R_h}{V - I_{fsd} R_h} \times R_m}{\dfrac{I_{fsd} R_m R_h}{V - I_{fsd} R_h} + R_m}$$

Therefore $$R_1 = R_h - \frac{I_{fsd} R_m R_h}{V}$$

Hence, R_1 and R_2 can be determined.

Multirange Ohmmeter The ohmmeter circuit shown in Fig. is only for a single range of resistance measurement. To measure resistance over a wide range of values, we need to extend the ohmmeter ranges. This type of ohmmeter is called a multirange ohmmeter, shown in Fig. 4.31.



SHUNT TYPE OHMMETER

The shunt type ohmmeter given in Fig consists of a battery in series with an adjustable resistor R_1, and a D'Arsonval movement

The unknown resistance is connected in parallel with the meter, across the terminals A and B, hence the name shunt type ohmmeter.

In this circuit it is necessary to have an ON/OFF switch to disconnect the battery from the circuit when the instrument is not used.

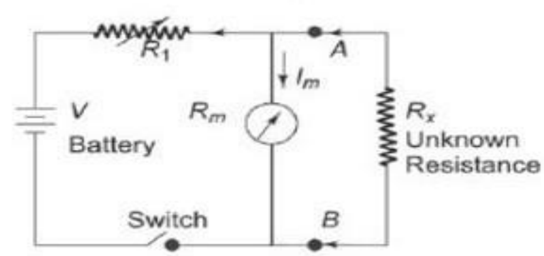


Fig. Shunt type ohmmeter

Calibration of the Shunt Type Ohmmeter

To mark the "0" ohms reading on the scale, terminals A and B are shorted, i.e. the unknown resistance $R_x = 0$, and the current through the meter movement is zero, since it is bypassed by the short-circuit. This pointer position is marked as "0" ohms.

Similarly, to mark "∞" on the scale, the terminals A and B are opened, i.e. $R_x = \infty$, and full current flows through the meter movement; by appropriate selection of the value of R_1, the pointer can be made to read full scale deflection current. This position of the pointer is marked "∞" ohms. Intermediate marking can be done by connecting known values of standard resistors to the terminals A and B.

This ohmmeter therefore has a zero mark at the left side of the scale and an ∞ mark at the right side of the scale, corresponding to full scale deflection current as shown in Fig.

Fig. Dial of shunt type ohmmeter

The shunt type ohmmeter is particularly suited to the measurement of low values of resistance. Hence it is used as a test instrument in the laboratory for special low resistance applications.

CALIBRATION OF DC INSTRUMENT

The process of calibration involves the comparison of a given instrument with a standard instrument, to determine its accuracy. A dc voltmeter may be calibrated with a standard, or by comparison with a potentiometer. The circuit in Fig. is used to calibrate a dc voltmeter; where a test voltmeter reading V is compared to the voltage drop across R. The voltage drop across R is accurately measured with the help of a standard meter. A rheostat, shown in Fig. is used to limit the current.

A voltmeter tested with this method can be calibrated with an accuracy of ±0.01%.

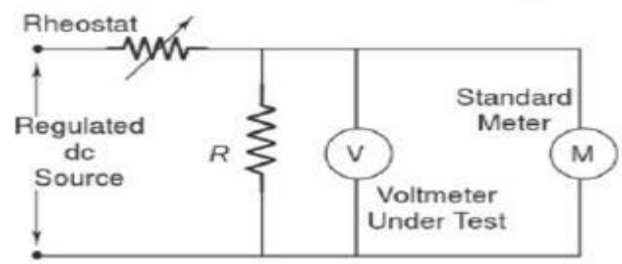


Fig. Calibration of voltmeter

Electronicmultimeter:

For the measurement of d.c. as well as a.c. voltage and current, resistance, an electronic multimeter is commonly used. It is also known as Voltage-Ohm Meter (VOM) or multimeter The important salient features of YOM are as listed below.

1) Thebasiccircuit ofYOMincludesbalancedbridged.c.amplifier.

2) Tolimitthemagnitudeoftheinputsignal,RANGEswitchisprovided.Byproperlyadjusting input attenuator input signal can be limited.

3) Italsoincludesrectifiersectionwhichconvertsa.c.inputsignaltothe d.c.voltage.

4) Itfacilitatesresistancemeasurementwiththe helpofinternalbatteryandadditional circuitry.

5) Thevariousparametersmeasurementispossiblebyselectingrequiredfunctionusing FUNCTION switch.

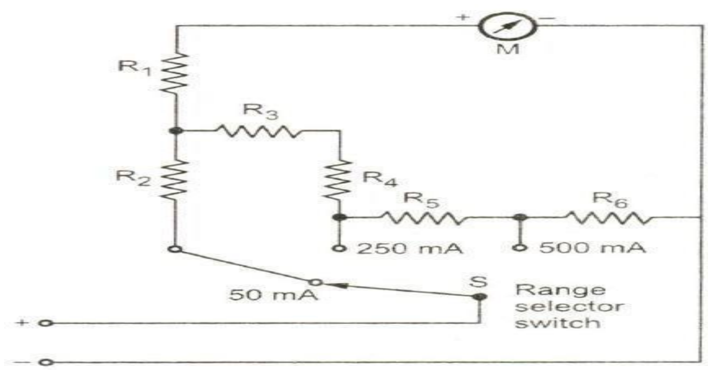
6) ThemeasurementofvariousparametersisindicatedwiththehelpofindicatingMeter.

UseofmultimeterforD.Cmeasurement:

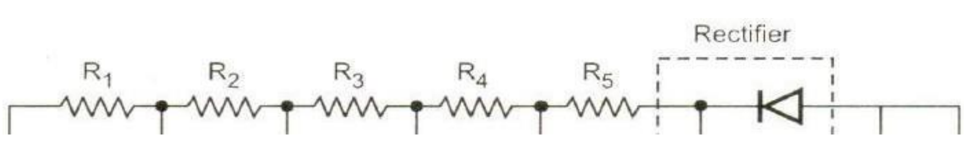
Forgetting different ranges of voltages,different series resistances are connected inseries which can be put in the circuit with the range selector switch. We can get different ranges to measure the d.c. voltages by selecting the proper resistance in series with the basic meter.

Useofmultimeterasammeter:

To get different current ranges, different shunts are connected across the meter with the help of range selector switch. The working is same as that of PMMC ammeter



UseofmultimeterformeasurementofA.Cvoltage:

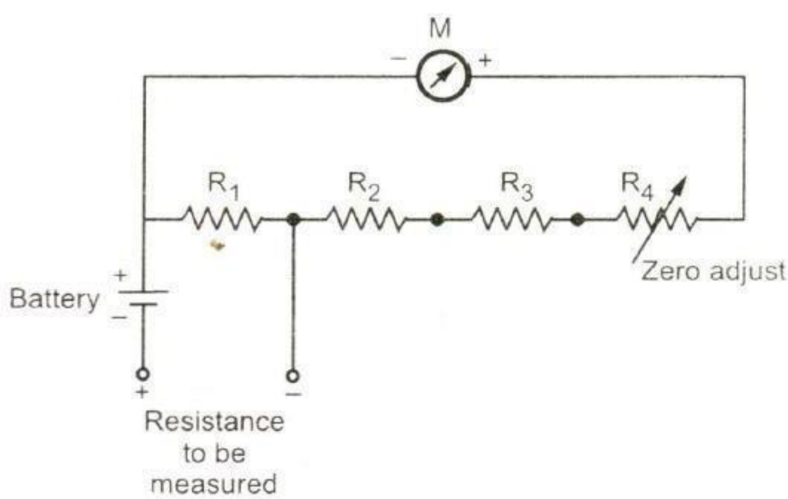


Therectifierusedinthecircuitrectifiesa.c.voltageintod.c.voltageformeasurement ofa.c.

voltagebeforecurrentpassesthroughthemeter. Theotherdiodeisusedfortheprotection purpose.

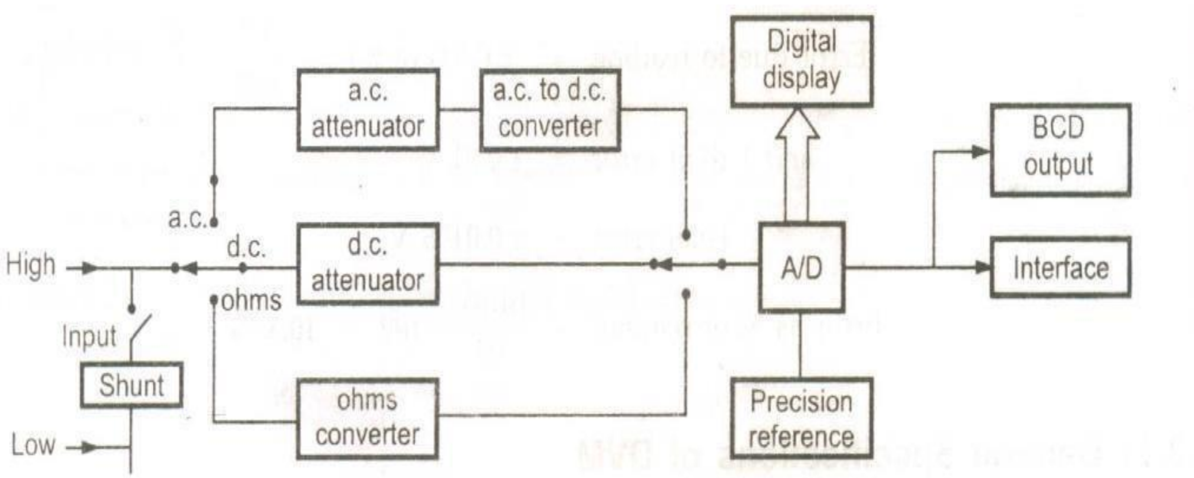
Useofmultimeterforresistancemeasurement:

The Fig shows ohmmeter section of multimeter for a scale multiplication of 1. Before any measurement is made, the instrument is short circuited and "zero adjust" control is varied until the meterreads zeroresistance i.e. it shows fullscale current. Now the circuit takes the form ofa variation of the shunt type ohmmeter. Scale multiplications of 100 and 10,000 can also be used for measuring high resistances. Voltages are applied the circuit with the help of battery.



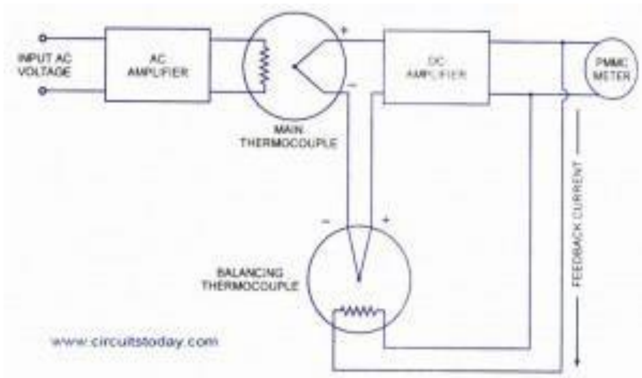
Digitalmultimeters:

Thedigitalmultimeterisaninstrumentwhichiscapableofmeasuringa.c.voltages,d.c.voltages, a.c. andd.c. currents and resistances *over* several ranges. The basic circuit of a digital multimeter is always a d.c. voltmeter as shown in the Fig



The current is convertedto voltage by passing it through low shunt resistance. The a.c. quantities are *converted* to d.c. by employing various rectifier and filtering circuits. While for the resistance measurements the meter consists of a precision low current source that is applied across the unknown resistance while gives d.c. voltage. Allthe quantities are digitizedusing analog todigital converter and displayed in the digital form on the display.The basic building blocks of digital multimeter are several *AID* converters, counting circuitry and an attenuation circuit. Generally dual slope integration type ADC is prefprred in the multimeters. The single attenuator circuit is used for both a.c. and d.c. measurements in many commercial multimeters.

TrueRMSReading Voltmeter



Block Diagram of True RMS Reading Voltmeter

TrueRMSRespondingVoltmeters

RMS value of the sinusoidal waveform is measured by the**average reading voltmeter**of whichscale is calibrated in terms of rms value. This method is quite simple and less expensive. But sometimes rms value of the non-sinusoidal waveform is required to be measured. For such a measurement a true rms reading voltmeter is required. True rms reading voltmeter gives a meter indication by sensing heating power of waveform which is proportional to the square of the rms value of the voltage.

Thermo-couple is used to measure the heating power of the input waveform of which heater is supplied by the amplified version of the input waveform. Output voltage of the thermocouple is proportional to the square of the rms value of the input waveform. One more thermo-couple, called the balancing thermo-couple, is used in the same thermal environment in order toovercome the difficulty arising out of non-linear behaviour of the thermo-couple. Non-linearity of the input circuit thermo-couple is cancelled by the similar non-linear effects of the balancing thermo-couple. These thermo-couples form part ofa bridge inthe input circuit ofa dcamplifier,as shown in block diagram.

AC waveform tobe measured is applied tothe heating element ofthe mainthermocouple through an ac amplifier. Under absence of any input waveform, output of both thermo-couples are equalso error signal, which is input to dc amplifier, is zero and therefore indicating meter connected to theoutputof dcamplifier readszero.Buton theapplication ofinputwaveform, outputofmain thermo-couple upsets the balance and an error signal is produced, which gets amplified by the dc amplifierandfedbacktotheheatingelementofthebalancingthermo-couple.Thisfeedback current reducesthevalueoferrorsignalandultimatelymakesitzerotoobtainthebalanced bridge condition. In this balanced condition, feedback current supplied by the dc amplifier to the heating element of the balance thermo-couple is equal to the ac current flowing in the heating element of mainthermo-couple.Hence this directcurrent is directly proportionaltothe rmsvalue ofthe input ac voltage and is indicated by the meter connected in the output of the dc amplifier. The PMMC meter may be calibrated to read the rms voltage directly.

Bythismethod,rmsvalueofanyvoltagewaveformcanbemeasuredprovidedthatthepeak excursions of the waveform do not exceed the dynamic range of the ac amplifier.

MODULE-2

AFWaveanalyzer

The wave analyzer consists of a very narrow pass-band filter section which can Be tuned to a particular frequency within the audible frequency range (20Hz to 20 KHz)). The block diagram ofa wave analyzer is as shown in fig 1.

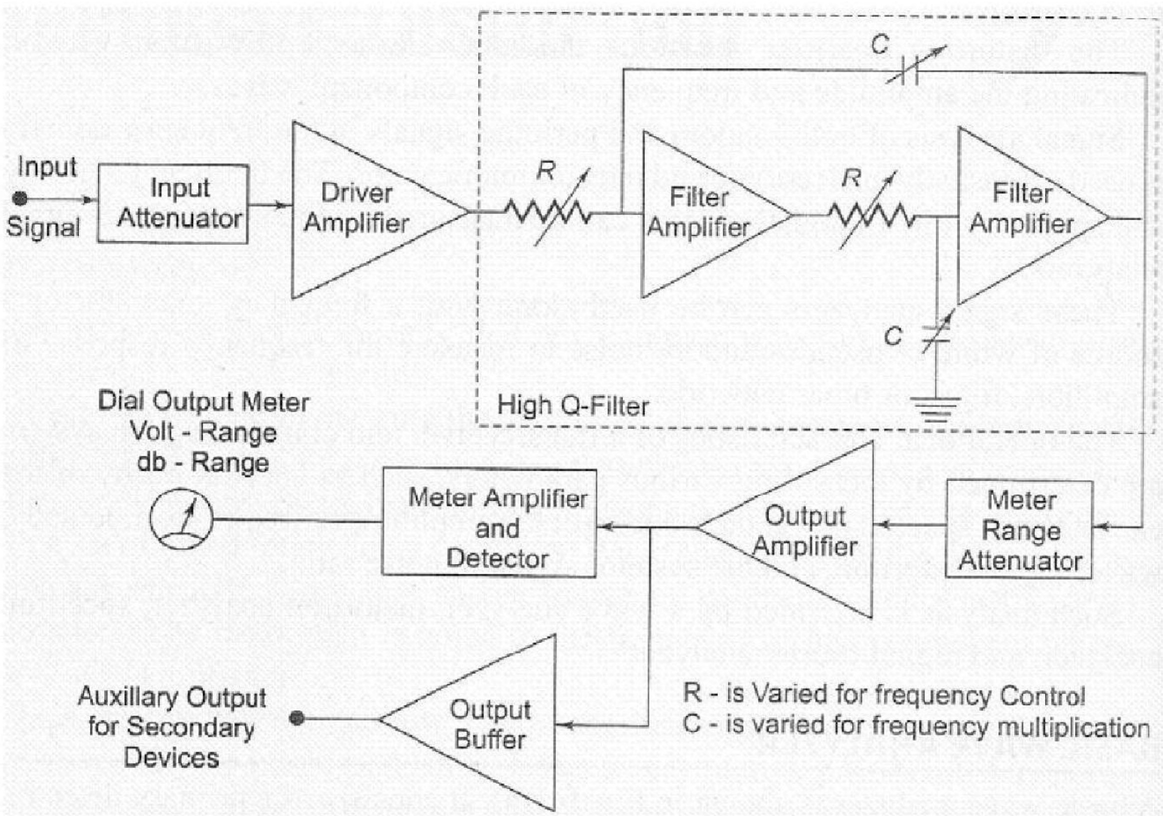


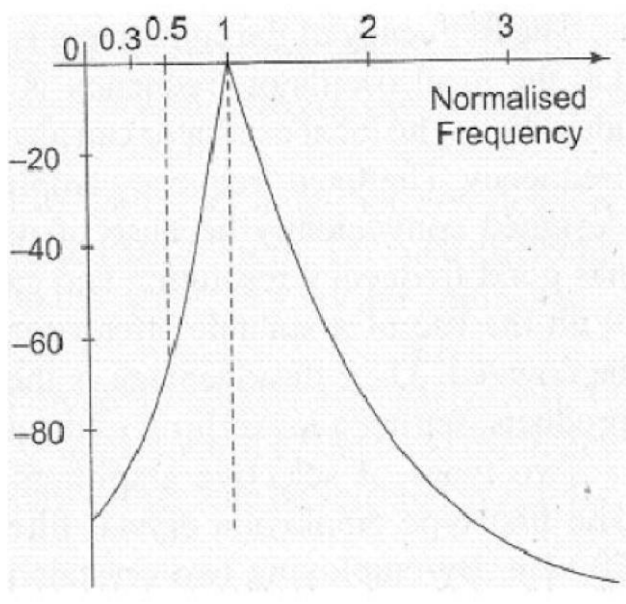
Fig1:Frequencywaveanalyzer

The complex wave to be analyzed is passed through an adjustable attenuator which serves as a range multiplierandpermits a large range ofsignalamplitudes tobe analyzedwithout loading the amplifier.

The output of the attenuator is then fed to a selective amplifier, which amplifies the selected requency. The driveramplifierapplies the attenuated input signal toa high-Q active filter. This high-Q filter is a low pass filterwhichallows the frequency whichis selectedtopass andreject allothers. The magnitude ofthis selectedfrequency is indicated by the meterandthe filtersection identifies the frequency of the component. The filter circuit consists of a cascaded RC resonant circuit and amplifiers. For selecting the frequency range, the capacitors generally used are of the closed tolerance polystyrene type and the resistances used are precision potentiometers. The capacitors are used for range changing and the potentiometer is used to change the frequency within the selected pass-band, Hence this wave analyzer is also called a Frequency selective voltmeter.TheentireAFrangeiscovered indecadestepsbyswitchingcapacitorsintheRCsection.

The selected signal output from the final amplifier stage is applied to the meter circuit and to an unturned buffer amplifier. The main function of the buffer amplifier is to drive output devices, such as recorders or electronics counters.

The meter has several voltage ranges as well as decibel scales marked on it. It is driven by an average reading rectifier type detector. The wave analyzer must have extremely low input distortion, undetectable by the analyzer itself. The band width of the instrument is very narrow typically about 1% of the selective band given by the following response characteristics shows in fig.1.2



Applicationofwaveanalyzer:

1. Electricalmeasurements

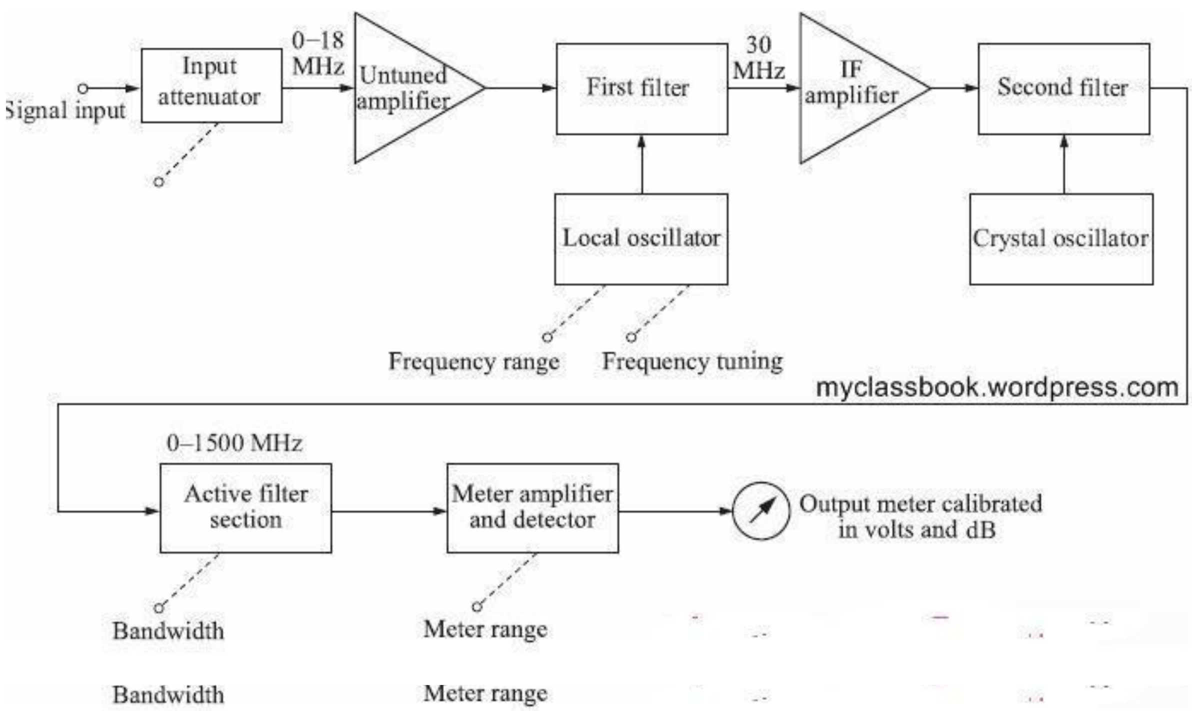
2. Soundmeasurements

3. Vibrationmeasurements.

In industries there are heavy machineries which produce a lot of sound and vibrations, it is very important to determine the amount of sound and vibrations because if it exceeds the permissible level it would create a number of problems. The source of noise and vibrations is first identified by wave analyzer and then it is reduced by further circuitry.

Heterodynewaveanalyzer

A wave analyzer,in fact, is an instrument designedtomeasure relative amplitudes of single frequency components in a complex waveform. Basically, the instrument acts as a frequency selective voltmeter which is used to the frequency of one signal while rejecting all other signal components. The desired frequency is selected by a frequency calibrated dial to the point of maximum amplitude. The amplitude is indicated either by a suitable voltmeter or CRO.This instrument is used in the MHz range. The input signal to be analysed is heterodyned to a higher IF byaninternallocaloscillator. Tuningthe localoscillatorshiftsvarioussignalfrequencycomponents into the pass band of the IF amplifier. The output of the IF amplifier is rectified and is applied tothe metering circuit. The instrument using the heterodyning principle is called a *heterodyning tuned voltmeter*.



The block schematic of the wave analyser using the heterodyning principle is shown in fig. above. The operating frequency range of this instrument is from 10 kHz to 18 MHz in 18 overlappingbands selected by the frequency range control of the local oscillator. The bandwidth is controlled by an active filter and can be selected at 200, 1000, and 3000 Hz.

Waveanalyzershaveveryimportantapplicationsinthefollowingfields:

1) Electricalmeasurements
2) Soundmeasurementsand
3) Vibrationmeasurements.

The wave analyzers are applied industrially inthe field of reductionofsoundandvibrations generated by rotating electricalmachines andapparatus. The source ofnoise and vibrations is first identified by wave analyzers before it can be reduced or eliminated. A fine spectrum analysis with the wave analyzer shows various discrete frequencies and resonances that can be related to the motion of machines. Once, these sources of sound and vibrations are detected with the help of wave analyzers, ways and means can be found to eliminate them.

Harmonicdistortion:

The**totalharmonicdistortion(THD)**isameasurementoftheharmonicdistortion presentin a signal and is defined as the ratio of the sum of the powers of all harmonic components to the powerofthefundamentalfrequency.**Distortionfactor**,acloselyrelatedterm,issometimesused as a synonym.

In audio systems, lower distortion means the components in a loudspeaker, amplifier or microphoneorotherequipmentproduceamoreaccuratereproductionofanaudiorecording.

To understand a system with an input and an output, such as an audio amplifier, we start with an idealsystemwherethetransferfunctionislinear andtime-invariant. Whenasignalpassesthrough a non-ideal, non-linear device, additional content is added at the harmonics of the original frequencies. THD is a measurement of the extent of that distortion.

Whenthemainperformance criterionisthe ″purity″oftheoriginalsinewave(inotherwords,the contribution of the original frequency with respect to its harmonics), the measurement is most commonly defined as the ratio of the RMS amplitude of aset of higher harmonic frequencies to the RMS amplitude of the first harmonic, or fundamental, frequency

$$\mathrm{THD_F} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots}}{V_1}$$

where$V_n$istheRMS voltageofthe$n$thharmonicand$n$ =1 isthefundamentalfrequency.

SpectrumAnalyzer

The modern spectrum analyzers use a narrow band super heterodyne receiver. Supereterodyne is nothing but mixing of frequencies in the super above audio range. The functional block diagram of super heterodyne spectrum analyzer or RF spectrum nalyzer as shown in the Figure

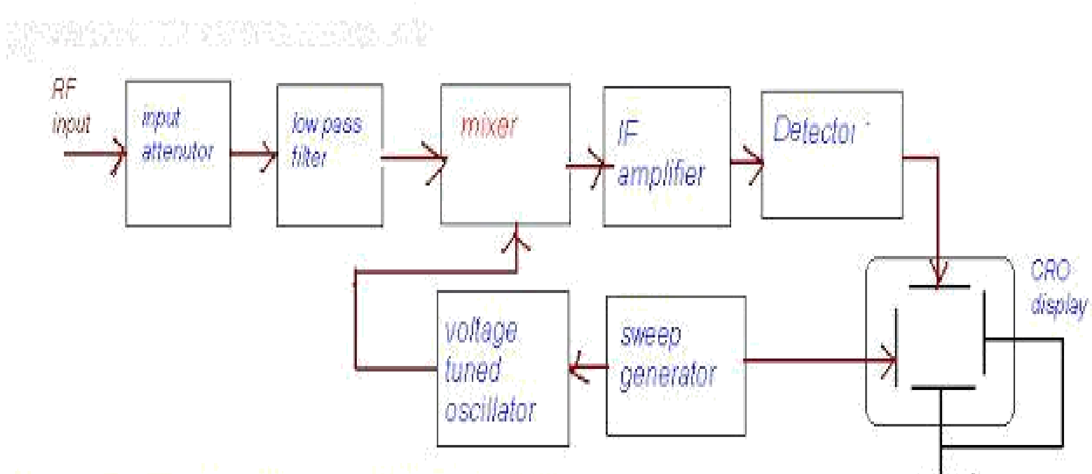


fig.: super hertodyne spectrum analyzer or RF spectrum analyzer

The RF input to be analyzed is applied to the input attenuator. After attenuating,the signal is fed to low pass filter. The low pass filter suppresses highfrequency components and allows low frequency components to pass through it. The output of the low pass filter is given to the mixer, where this signal is fixed with the signal coming from voltage controlled or voltage tunedoscillator.

This oscillator is tuned over 2 to 3 GHz range. The output of the mixer includes two signals whose amplitudes are proportional to the input signal but their frequencies are the sum and difference of the input signal and the frequency of the local oscillator.

Sincethe frequency rangeoftheoscillatoristunedover2to3GHz,the IFamplifieristuned to a narrow band of frequencies of about 2 GHz. Therefore only those signals which are separated from the oscillator frequency by 2 GHz are converted to Intermediate Frequency (IF) band. This IF signalis amplifiedby IF amplifierand then rectifiedby the detector. Aftercompleting amplification and rectification the signal is applied to vertical plates of CRO to produce a vertical deflection on the CRT screen. Thus, when the saw tooth signal sweeps, the oscillator also sweeps linearly from minimum to maximum frequency range i.e., from 2 to 3 GHz.

Here the saw tooth signal is applied not only to the oscillator (to tune the oscillator) but also to the horizontal plates of the CRO to get the frequency axis or horizontal deflection on the CRTscreen. Onthe CRT screen the vertical axis is calibrated in amplitude and the horizontal axis is calibrated in frequency.

FFTspectrumanalyzer

A spectrum analyzer, which uses computer algorithm and an analog to digital conversion phenomenon and produces spectrum of a signal applied at its input is known as digital Fourier or digital FFT or digital spectrum analyzer

Principle

When the analog signal to be analyzed is applied, the A/D converter digitizes the analog signal (i.e., converts the analog signal into digital signal). The digitized signal, which is nothing but the set of digital numbers indicating the amplitude of the analog signal as a function of time is stored in the memory of the digital computer. From the stored digitized data, the spectrum of the signal is computed by means of computer algorithm.

Description:

The block arrangement of a digital Fourier analyzer is illustrated in the figure above .The analog signal to be ana1ysed is applied to the low pass filter, which passes only low frequency signals and rejects high pass spurious signals. This filter section is used mainly, to prevent aliasing. Theoutputoflowpassfilterisgiventotheattenuator.Theattenuatorisavoltagedividing network whose function is to set the input signal to the level of the A/D converter. The use of attenuator prevents the converter from overloading. The function of A/D converter is to convert the samples of analog data into digital i.e. ., to digitize the analog signal. When the output of A/D converter is applied to the digital computer, the computer analyzes the digitized data and adjusts the attenuator setting accordingly in order to obtain the maximum output from the inverter without any overloading. As soon as the entire analog signal is sampled and digitized by the A/D converter) computer performs calculations on the data according to the programmed algorithm and the calculated spectral components are stored in the memory of the computer

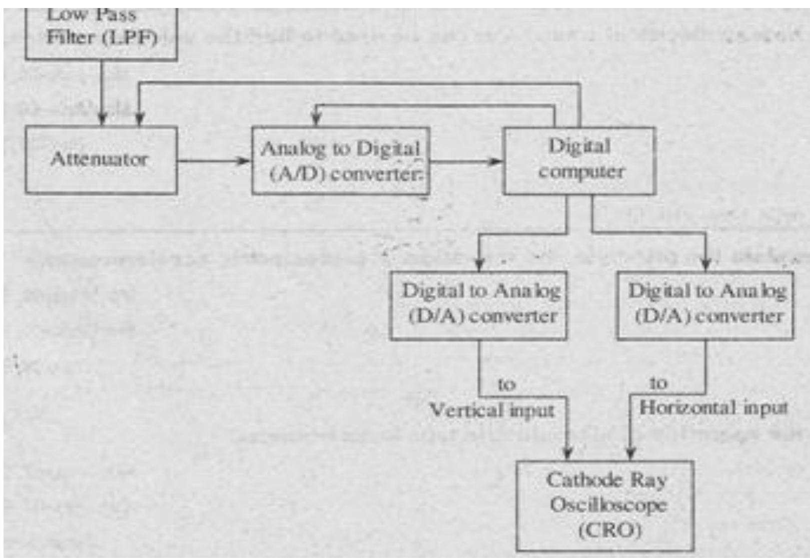


Fig Digital Fourier Analyzer

Ifthespectraldisplayis tobeviewedontheoscilloscope,thedigitalvaluesofspectralcomponents stored in the computer memory are converted into analog by using D/A converters and then appliedtotheCRO. Thus thespectraldisplay of theinputwaveformis obtained on theCRTscreen.

Advantages

1. The use of computer avoids most of the hardware circuitry such as electronic switches, Filtersand PLLs. The use of less hardware reduces the cost of the analyzer.
2. Moremathematicalcalculationscanbe carried-outonthespectraldisplay.
3. Therateofsamplinganalogsignalcan bemodifiedinordertoobtainbetterspectraldisplay.

STANDARDSIGNALGENERATOR:-

Astandardsignalgeneratorproducesknownandcontrollablevoltages.Itisusedaspower sourceforthemeasurement ofgain,signal tonoiseratio (SN),bandwidthstandingwaveratioand otherproperties.

Itisextensivelyusedinthemeasuringofradioreceiversandtransmitter instrument isprovidedwithameansofmodulatingthe carrierfrequency,whichisindicatedbythedialsetting on the front panel.

Themodulationisindicated byameter.The outputsignalcan be AmplitudeModulated(AM)or FrequencyModulated(FM).Modulationmaybe donebya sinewave,Square,rectangular,ora pulse wave.

Theelementsofaconventionalsignalgenerator:

1)RFOsillator

(2) Widebandamplifier.

(3) ExternalOsillator.

4) ModulationOsillator

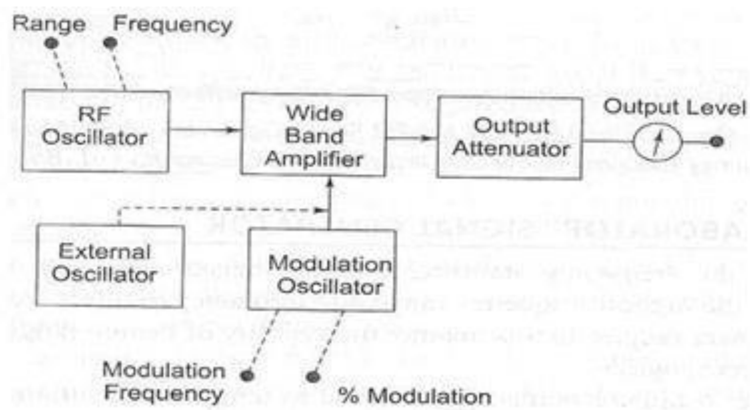
(5)Outputattenuator.

The carrier frequency is generated by a very stable RF oscillator using an LC tank circuit, havingaconstantoutputoveranyfrequencyrange.Thefrequencyofoscillationsis indicatedby thefrequency range control and the venire dial setting. AM is provided by an internal sine wavegenerator or from an external source.

The signal generator is called an oscillator. A Wien bridge oscillator is used in this generator.TheWienbridgeoscillatoristhebestoftheaudiofrequency range.Thefrequencyof oscillations can be changed by varying the capacitance in the oscillator.

Thefrequencycanalsobechangedinstepsbyswitchingtheresistorsofdifferentvalues. TheoutputoftheWienbridgeoscillatorgoestothefunctionswitch.

Thefunctionswitchdirectstheoscillatoroutputeithertothesine waveamplifierortothe square wave shaper. At the output, we get either a square or sine wave.The output is varied by means of an attenuator**.**



The instrument generates a frequency ranging from 10 Hz to 1 MHz continuously vV (rms).The outputistakerthrougha push-pullamplifier.Forlowoutput,theimpedance is 6000.Thesquare wave amplitudes can be varied from 0 - 20 v (peak). It is possible to adjust the symmetry of the square wave from 30 -70%. The instrument requires only 7W of power at 220V 50Hz.

Thefrontpanel ofasignalgenerator consistsofthe following.

l.Frequencyselector:Itselectsthefrequency indifferentrangesandvariesitcontinuouslyin a ratio

of 1: 11. The scale is non-linear.

2. Frequencymultiplier:Itselectsthefrequencyrangeover5decadesfrom10Hzto7MHz

3. Amplitudemultiplier:Itattenuatesthesinewavein3decades,xlx0.1andx 0.01.

4. Variableamplitude:Itattenuatesthesinewaveamplitudecontinuously

5. Symmetrycontrol:Itvariesthesymmetryofthesquarewavefrom30%to70%.

6. Amplitude:Itattenuatesthesquarewaveoutputcontinuously.

7. Functionswitch:Itselectseithersinewaveorsquareoutput.

8. Outputavailable:Thisprovidessinewaveorsquarewaveoutput.

9. Sync:Thisterminalisusedtoprovidesynchronizationoftheinternalsignal withanexternal signal.

10. On-OffSwitch

SweepGenerator

It provides a sinusoidal output voltage whose frequency varies smoothly and continuously overan entire frequency band, usually at an audio rate. The process of frequency modulation may be accomplished electronically or mechanically. It is done electronically by using the modulating voltage to vary the reactance of the oscillator tank circuit component, and mechanically by means of a motor driven capacitor, as provided for in a modern laboratory type signal generator. Figure shows a basic block diagram of a sweep generator. The frequency sweeper provides a variablemodulatingvoltagewhichcausesthecapacitanceofthemasteroscillatortovary.A representativesweepratecouldbeoftheorderof20sweeps/second.Amanualcontrolallows independent adjustment of the oscillator resonant frequency. The frequency sweeper provides a varying sweep voltage synchronization to drive the horizontal deflection plates of the CRO. Thustheamplitude oftheresponseofatestdevicewillbelockedanddisplayedonthescreen.

To identify a frequency interval, a marker generator provides half sinusoidal waveforms at any frequency within the sweep range. The marker voltage can be added to the sweep voltage of the CROduringalternatecyclesofthesweepvoltage,andappearssuperimposedonthe responsecurve.

The automatic level control circuit is a closed loop feedback system which monitors the RFlevelatsomepoint inthe measurementsystem.Thiscircuitholdsthepowerdeliveredtothe

loadortestcircuitconstantandindependentofrequencyandimpedancechanges.Aconstant

powerlevelpreventsanysourcemismatchandalsoprovidesaconstantreadoutcalibrationwith frequency.

SQUAREANDPULSEGENERATOR:-

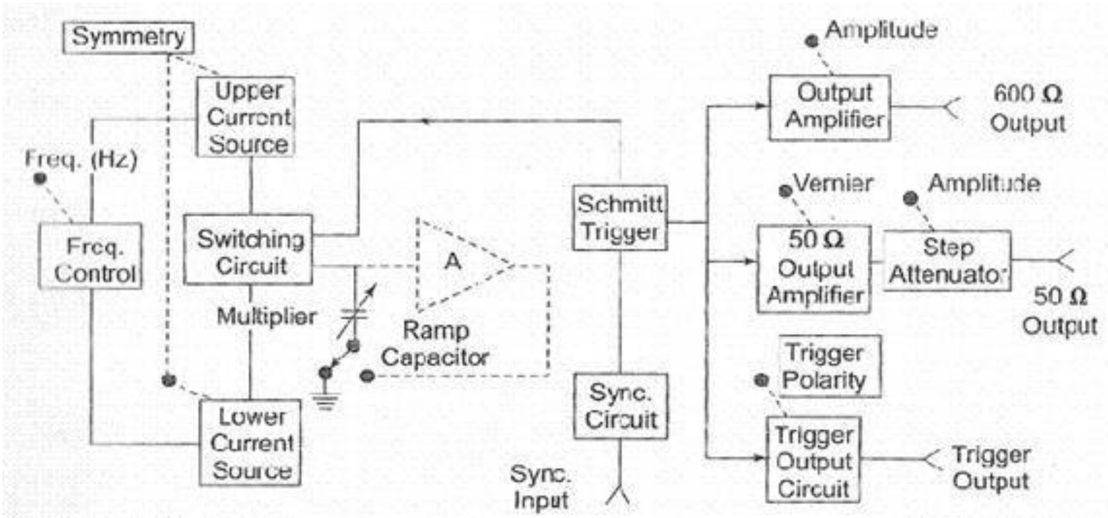
ThesegeneratorsareusedasmeasuringdevicesincombinationwithaCRO.Theyprovideboth quantitative and qualitative information of the system under test. They are made use of in transientresponsetestingofamplifiers.Thefundamentaldifferencebetweenapulsegenerator and a square wave generator is in the duty cycle.

Dutycycle=Asquarewavegeneratorhasa500/odutycycle.

RequirementsofaPulse

1. Thepulseshouldhaveminimumdistortion,sothatanydistortion,inthedisplayissolelydue to the circuit under test.
2. Thebasic characteristicsofthepulsearerisetime,overshoot,ringing,sag,andundershoot.
3. Thepulseshouldhavesufficientmaximumamplitude,ifappreciableoutputpowerisrequiredby the test circuit, e.g. for magnetic core memory. At the same time, the attenuation range shouldbe adequate to produce small amplitude pulses to prevent over driving of some test circuit.
4. The range of frequency control of the pulse repetition rate (PRR) should meet the needs of theexperiment. For example, a repetition frequency of 100 MHz is required for testing fast circuits.Othergeneratorshaveapulse-burstfeaturewhichallowsatrainofpulsesratherthana continuous output.
5. Some pulse generators can be triggered by anexternally applied triggersignal;conversely, pulsegeneratorscanbeusedtoproducetriggersignals,whenthis output ispassedthrougha differentiator circuit.
6. The output impedance of the pulse generator is another important consideration. In a fast pulsesystem,the generatorshould be matched to the cable and the cable to the test circuit. A mismatchwouldcauseenergytobe reflectedbacktothegeneratorbythetestcircuit,andthis may be rereflected by the generator, causing distortion of the pulses.
7. DCcouplingofthe outputcircuit isneeded,whendcbiaslevelistobe maintained. The basic circuit for pulse generation is the asymmetrical multi-vibrator.

AlaboratorytypesquarewaveandpulsegeneratorisshowninFig6.1



Thefrequencyrangeoftheinstrumentiscoveredinsevendecadestepsfrom1Hzto10 MHz, with a linearly calibrated dial for continuous adjustment on all ranges.

The duty cycle can be varied from 25 - 75%. Two independent outputs are available, a 50Ω sourcethatsupplies pulseswitha riseandfalltimeof5nsat 5Vpeakamplitude anda 600Ωsource which supplies pulses with a rise and fall tme of 70 ns at 30 V peak amplitude. The instrument can beoperatedasafreerunninggenenratoror,itcanbesynchronizedwithexternalsignals.

The basic generating loop consists of the current sources, the ramp capacitor, the Schmitt triggerand the current switching circuit as shown in the fig

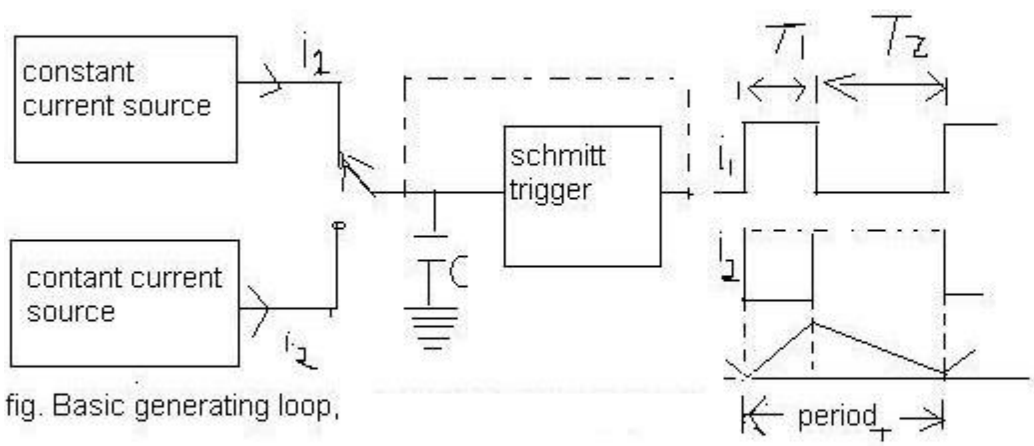


fig. Basic generating loop,

Theuppercurrentsourcesuppliesaconstantcurrenttothecapacitorandthecapacitor voltageincreaseslinearly.Whenthepositiveslope oftherampvoltage reachestheupperlimitset by theinternal circuit components, the Schmitt trigger changes state. The trigger circuit output becomesnegative and reverses the condition of the current switch. The capacitor discharges linearly, controlled by the lower current source.

When the negative ramp reaches a predeterminedlower level,the Schmitt triggerswitches back to its original state. The entire process is then repeated.

The ratio i1/i2 determines the duty cycle, and is controlled by symmetry control. The sumofi1and i2determines thefrequency.The sizeofthecapacitoris selectedby themultiplierswitch. The unit is powered by an intenal supply that provides regulated voltages for all stages of the instrument.

Theprecautionarymeasurestobetakeninasignalgenerator application:-

A signalgeneratoris aninstrument,whichcanproduce various types ofwave forms suchas sinewave, square wave, triangular wave, saw tooth wave, pulse trains etc. As it can generate a varietyof waveforms it is widely used in applications like electronic troubleshooting anti development, testing the performance of electronic equipments etc. In such applications a signal generator is used to provide known test conditions (i.e., desired signals of known amplitude and frequency

Hence, the following precautionary measures should be taken while using a signal generator for an application.

1. Theamplitudeandfrequencyoftheoutputofthesignalgeneratorshouldbemadestable and well known.

2. Thereshouldbeprovisionforcontrollingtheamplitudeofsignalgeneratoroutputfromvery small to relatively large values.

3. The output signalofgeneratorshouldnot containany distortionandthus,it shouldpossess very low harmonic contents.

4. Also,theoutputofthesignalgeneratorshouldbeless spurious.

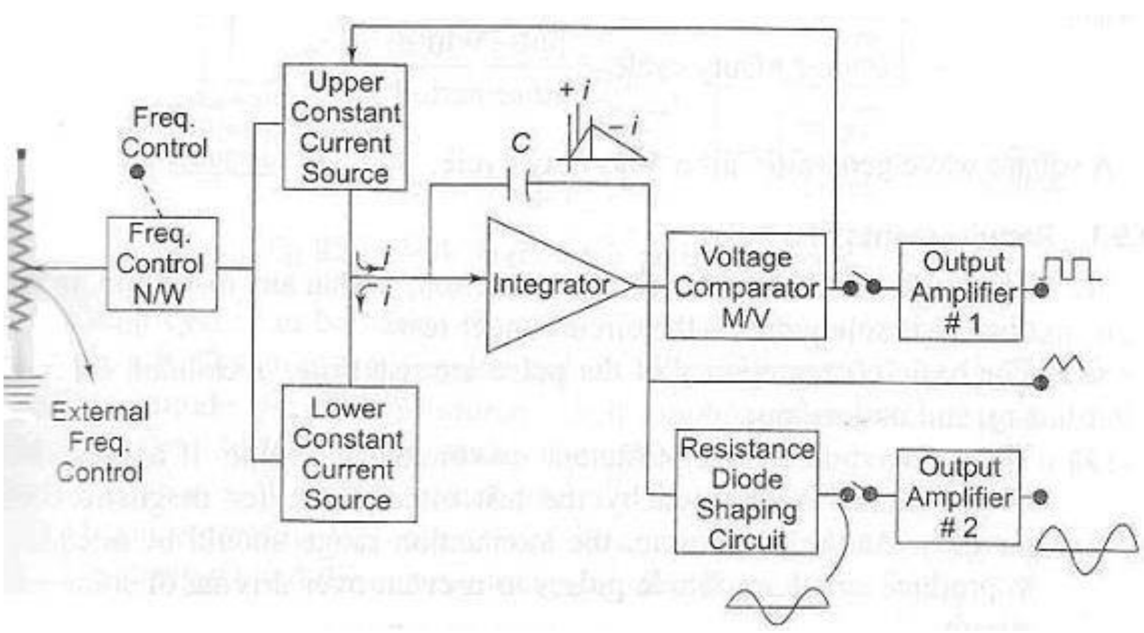
FUNCTIONGENERATOR

A function generator produces different waveforms of adjustable frequency. The common outputwaveforms are the sine, square, triangular and saw tooth waves. The frequency may be adjusted,from a fraction ofa Hertz to severalhundred kHzlie variousoutputsofthe generator can bemade available at the same time. For example, the generator can provide a square wave to testthe linearity of a rectifier and simultaneously provide a saw tooth to drive the horizontal deflection amplifier of the CRO to provide a visual display.

Capability of Phase Lock the function generator can be phase locked to an external source. One function generator can be used to lock a second function generator, and the two output signals can be displaced in phase by adjustable amount. In addition, the fundamental frequency of onegeneratorcanbe phase locked toa harmonic ofanothergenerator,byadjustingthe amplitude and phase of the harmonic; almost any waveform can be generated by addition.

Thefunctiongeneratorcanalsobephaselockedtoafrequencystandardandits output waveforms will then have the same accuracy and stability as the standard source.

Theblock diagramofafunctiongenerator:



Theblockdiagramofafunctiongeneratoris illustratedinfig.Usuallythe frequencyis controlled by varying the capacitorinthe LC orRC circuit. Inthe instrument the frequency is controlledbyvaryingthemagnitudeofcurrentwhichdrivestheintegrator.Theinstrument produces sine, triangular and square waves with a frequency range of 0.01 Hz to 100 kHz.

The frequency controlled voltage regulates two current sources. The upper current source supplies constant current to the integrator whose output voltage increases linearly with time, according to the equation of the output signal voltage. An increase or decrease in the currentincreases or decreases the slope of the output voltage and hence controls the frequency. Thevoltagecomparatormulti-vibratorchangesstatesatapre-determinedmaximumlevelof theintegratoroutputvoltage.Thischangecutsofftheuppercurrentsupplyandswitcheson thelower current supply. The lower current source supplies a reverse current to the integrator, so thatitsoutputdecreaseslinearlywithtime.Whentheoutputreachesapre-determined minimum level, the voltage comparator again changes state and switches on the Lower current source. The output of the integrator is a triangular waveform whose frequency is determined by themagnitudeofthecurrentsuppliedbytheconstantcurrentsources.Thecomparatoroutput delivers a square wave voltage of the same frequency.

e=-1/C∫idt

The resistance diode network alters the slope of the triangular wave as its amplitude changes and produces a sine wave with less than 1% distortion.

ArbitraryWaveformGenerator, AWG

The waveforms produced by arbitrary waveform generators, AWGs can be either repetitive or sometimes just a single-shot. If the AWG waveform is only a single shot, then a triggering mechanism is needed to trigger the AWG and possibly the measuring instrument.

The AWG is able to generate an arbitrary waveform defined by a set of values, i.e. "waypoints" entered to set the value of the waveform at specific times. They can make up a digitalor even an analogue waveform.

As a result an arbitrary waveform generator is a form of test equipment that is able to produce virtually any waveshape that is required.

ArbitraryWaveformGeneratortechniques

There are a number of ways of designing arbitrary waveform generators. They are based around digital techniques, and their design falls into one of two main categories:

- ***Direct Digital Synthesis, DDS:***This type of arbitrary waveform generator is based around the DDS types of frequency synthesizer, and sometimes it may be referred to as an Arbitrary Function Generator, AFG.
- ***Variable-clock arbitrary waveform generator***The variable clock arbitrary function generator is the more flexible form of arbitrary waveform generator. These arbitrary waveform generators are generally more flexible, although they do have some limitations not possessed by the DDS versions. Sometimes these generators are referred to as just arbitrary waveform generators, AWGs rather than arbitrary function generators.
- ***Combined arbitrary waveform generator***This format of AWG combines both ofthe other forms including the DDS and variable clock techniques. In this way the advantages of both systems can be realised within a single item of test equipment.

Arbitrarywaveformgeneratorresolutionandspeed:

Two of the main specifications for an arbitrary waveform generator are their resolution and also the speed. These two parameters determine the precision with which the waveform can be reproduced. They are governed by different elements within the arbitrary waveform generator circuit.

The amplitude resolution is governed by the resolution of the digital to analogue converter (D/A or D2A). This is described in terms of the number of bits. A 12 bit resolution provides 4096 amplitude steps.

The speed of the arbitrary waveform generator is also very important. The maximum repetition rate for the waveform is governed by two factors: the length of the waveform in terms of the number of samples required to simulate the waveform and the maximum clock frequency. For example if the arbitrary waveform generator had a maximum clock frequency of 25 MHz and the waveform had 1000 points, then the maximum repetition rate would be 25 kHz. If a higherrepetition rate was required, then it would be necessary to decrease the number of samples as it would not be possible to increase the clock frequency in the arbitrary waveform generator!

Arbitrarywaveformgeneratorapplications:

AWGs are used in many applications where specialised waveforms are required. These can be within a whole variety of sectors of the electronics industry.

To give a view of some of the AWG applications, it is possible for DDS-based arbitrary waveform generators is to create signals with precisely controlled phase offsets or ratio-related frequencies. This enables the generation of signals like polyphase sine waves, I-Q constellations, or simulation of signals from geared mechanical systems such as jet engines. Complex channel-channel modulations are also possible.

The arbitrary waveform generator may not be the most widely used of items of test instrumentation, but they can be immensely useful in a variety of applications. Modern arbitrary waveformgenerators are very flexible and can be used to create veryspecific waveforms for use in testing a variety of applications.

Direct digital synthesizer, DDS technology lends itself to being used within arbitrary waveform generators, AWGs. Those AWGs that use DDS technology are often referred to as arbitrary function generators, or AFGs.

The reason for being called arbitrary function generators is that they often appear as an extension of the function generator test instruments that are available.

Arbitrary waveform generators using direct digital synthesis technology are able to benefit from the technology, while not adding unwanted additional complexity and cost. DDS technology has developed considerably in recent years and this makes thema veryattractive option to form the basis of a waveform generator. As a result arbitrary function generators are relatively widely used.

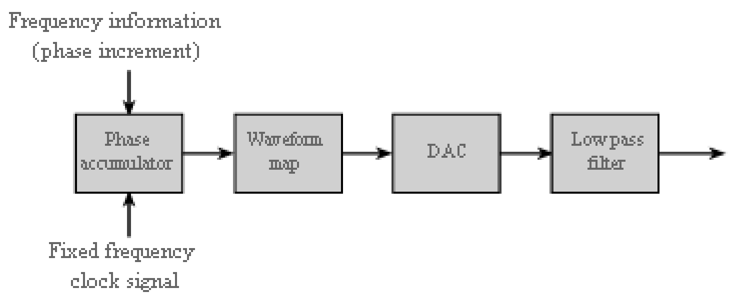
Arbitraryfunctiongeneratorbasics:

As mentioned, this type of arbitrary waveform generator is based around the DDS types of frequency synthesizer, and sometimes it may be referred to as an Arbitrary Function generator,AFG.

The arbitrary function generator uses integrated circuits intended for direct digital frequency synthesizers, but enables an arbitrary waveform generator circuit to be created relatively easily and for an economic price.

To look at how anarbitraryfunctiongenerator works, it is necessaryto look at the operation of a direct digital synthesizer.

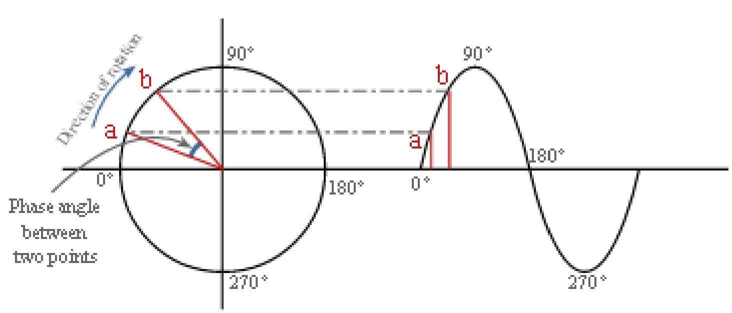
This circuit operates bystoring the pointsofa waveformindigitalformat, andthenrecalling them to generate the waveform. These points can be on any form of repetitive waveform that is required. The rate at which the DDS completes one waveform governs the frequency. The basic block diagram of the DDS based arbitrary waveform generator is shown below.



DDS frequency synthesizer as used in an arbitrary function generator, AFG

The operation of the DDS within the arbitrary function generator can be envisaged by looking at the waythat phase progresses over the course of one cycle of the waveform.

The phase is often depicted as a line of phasor rotating around a circle. As the phase advances around the circle, this corresponds to advances in the waveform. The faster is progresses, the sooner it completes a cycle and the hence the higher the frequency.



Phase angle of points on a sine wave

The direct digital synthesizer operates bystoring various points ofthe required waveform in digital format in a memory. These can then be recalled to generate the waveform as they are required.

To simulate the phase advances a phase accumulator is used. This takes in phase increment information, and clock pulses from a clock. For each clock pulse, the phase will advance a certain amount.The greaterthe increment,the larger the phase advance, and hence the higherthe frequency generated.

At each clock pulse the phase information is presented to the memory and the relevant location is accessed, proving the waveform information for that particular phase angle.

It can be seen that any waveform can be loaded into the memory; although a sine wave is shown on the diagram, the actual waveform could be anything.

While it is possible to load certain preset waveforms into the memory, it is also possible to load user generated ones inas well. These make thetest instrument anarbitrarywaveformgenerator or arbitrary function generator rather than a standard function generator.

Advantagesanddisadvantages ofAFG:

While the arbitrary function generator or DDS based version of the arbitrary waveform generator, has many advantages, there are also some disadvantages that should also be taken into account when choosing what type of signal generator to use.

Arbitraryfunctiongeneratoradvantages

- ***Sub Hz frequency resolution:***By using a long word length phase accumulator in the phase accumulator of the DDS, it is possible to achieve sub-Hertz frequency resolution levels.
- ***Down sampling:***Waveforms are automatically truncated by sampling to allow repetition rates above the clock frequency.
- ***Digitalmodulation:*** Itispossibletoadddigitalmodulationwordstothephase accumulator to provide a means of providing digital modulation.

Arbitraryfunctiongeneratordisadvantages

- ***Waveform jitter:***Waveform jitter is an issue with arbitrary function generators because frequencies are up-sampled or down-sampled and this results in missing samples and hence jitter. Only frequencies equaltothe clock frequency dividedby the waveform lengthandits sub multiples are not sampled and therefore they do not suffer from this problem

- ***Single waveform capability:*** It is only possible to generate a single waveform at a time because memory segmentation and waveform sequencing is not possible using a DDS arbitrary function generator

The arbitrary function generator is the ideal instrument where a variety of programmed waveforms are required without the added flexibility and complexity of the more expensive variable clock arbitrary waveform generator. For most laboratory applications, the arbitrary function generator is an ideal choice.

MODULE-3

Oscilloscopes

Introduction:

In studying the various electronic, electrical networks and systems, signals which are functions of time, are often encountered. Suchsignals may be periodic or non periodic in nature. The device which allows, the amplitude of such signals, to be displayed primarily as " function of time, is called **cathode ray** oscilloscope, commonly known as C.R.O. The CR.O gives the visual representation of the time varying signals. The oscilloscope has become an universal instrument andis probably most versatile tool for the development ofelectronic circuits andsystems. It is an integral part of electronic laboratories.

The oscilloscope is, in fact, a voltmeter. Instead of the mechanical deflection of a metallic pointer as used in the normal voltmeters, the oscilloscope uses the movement of an electron beam against a fluorescent screen, which produces the movement of a visible spot. The movement of such spot on the screen is proportional to the varying magnitude of the signal, which is under measurement.

BasicPrinciple:

The electron beam can be deflected in two directions : the horizontal or x-direction and the vertical or y-direction. Thus an electron beam producing a spot can be used to produce two dimensionaldisplays,Thus CRO. can be regarded as a fast x-y plotter. The x-axis andy-axis can be used to study the variation of one voltage as a function of another. Typically the x-axis of the oscilloscope represents the time while the y-axis represents variation of the input voltage signal. Thus if bhe input voltage signal applied to the y-axis of CRO. is sinusoidally varying and if x-axis represents the time axis, then the spot moves sinusoidally, and the familiar sinusoidal waveform can be seenonthe screenofthe oscilloscope. The oscilloscope is sofast device that it can display the periodic signals whose time period is as small as microseconds and even nanoseconds. The CRO. Basically operates on voltages, but it is possible to convert current, pressure, strain, acceleration and other physical quantities into the voltage using transducers and obtain their visual representations on the CRO.

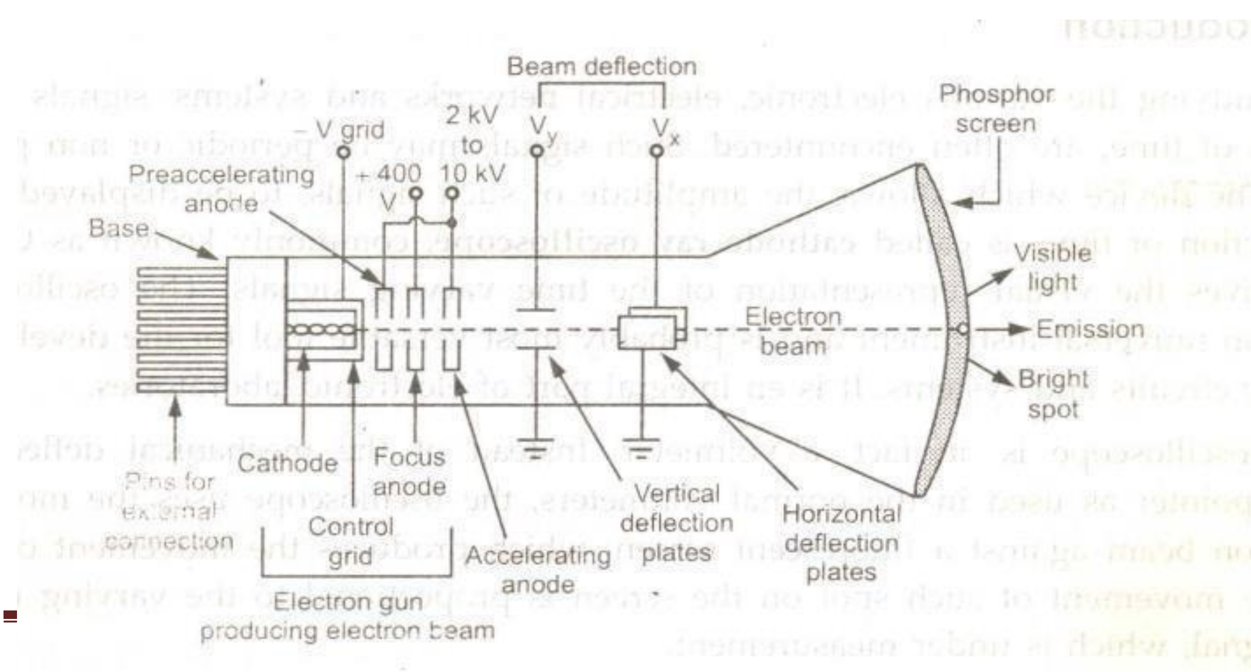
CathodeRayTube(CRT):

Thecathoderaytube(CRT)istheheart oftheCR.O.theCRTgeneratestheelectron 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)Electrongunii)Deflectionsystemiii)Fluorescentscreen

iv) Glasstubeorenvelopev) Base

AschematicdiagramofCRT,showingitsstructureandmaincomponents isshownin the Fig.



ElectronGun:

The electron gun section of the cathode ray tube provides a sharply focused electron beam directed :towards the fluorescent-coated screen. This sectionstarts from theql1ally heated cathode, limiting the electrons. The control grid is give!! negative potential with respect to cathode dc. This grid controls the number of electrons in the beam, going to the screen.

The momentum of the electrons (their numberx theirspeed) determines the intensity,or brightness, of the light emitted from the fluorescent screen due to the electron bombclrdl1lent. The light emitted is usually of the green colour. Because the electrons are negatively charged, a repulsive force is created by applying a negative voltage to the control grid (in CRT, voltages appliedtovariousgridsarestatedwithrespectto cathode,whichis takenascommonpoint).This negative control voltage can be made variable.

DeflectionSystem:

When the electron beam is accelerated it passes through the deflection system, with which beam can be positioned anywhere on the screen. The deflection system of the cathode- ray-tube consists of two pairs of parallel plates, referred to as the vertical and horizontal deflectionplates.Oneofthe plates'ineach setis connectedtoground (0V),Tothe other plateof each set, the

externaldeflectionvoltageisappliedthrough an internal adjustable gainamplifierstage,Toapply the deflection voltage externally, an external terminal, called the Y input or the X input, is available.

As shown in the Fig. , the electron beam passes through these plates. A positive voltage applied to the Y input terminal (Vy) Causes the beam to deflect vertically upward due to the attraction forces,while a negative voltage applied to. the Y input terminal will cause the electron beam to deflect vertically downward, due to the repulsion forces. When the voltages are applied simultaneouslytoverticalandhorizontcl1deflectingplates,the electronbeamis deflecteddue to the resultant-of these two voltages.

FluorescentScreen:

The light produced by the screen does not disappearimmediately when bombardment by electrons ceases,i.e.,when the signalbecomes zero. The time periodforwhichthe trace remains onthe screenafter the signalbecomes zero is knownas "persistence". The persistence may be *jS* short as a few microsecond, or as long as tens of seconds and minutes.

Long persistencetraces are used inthe 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.

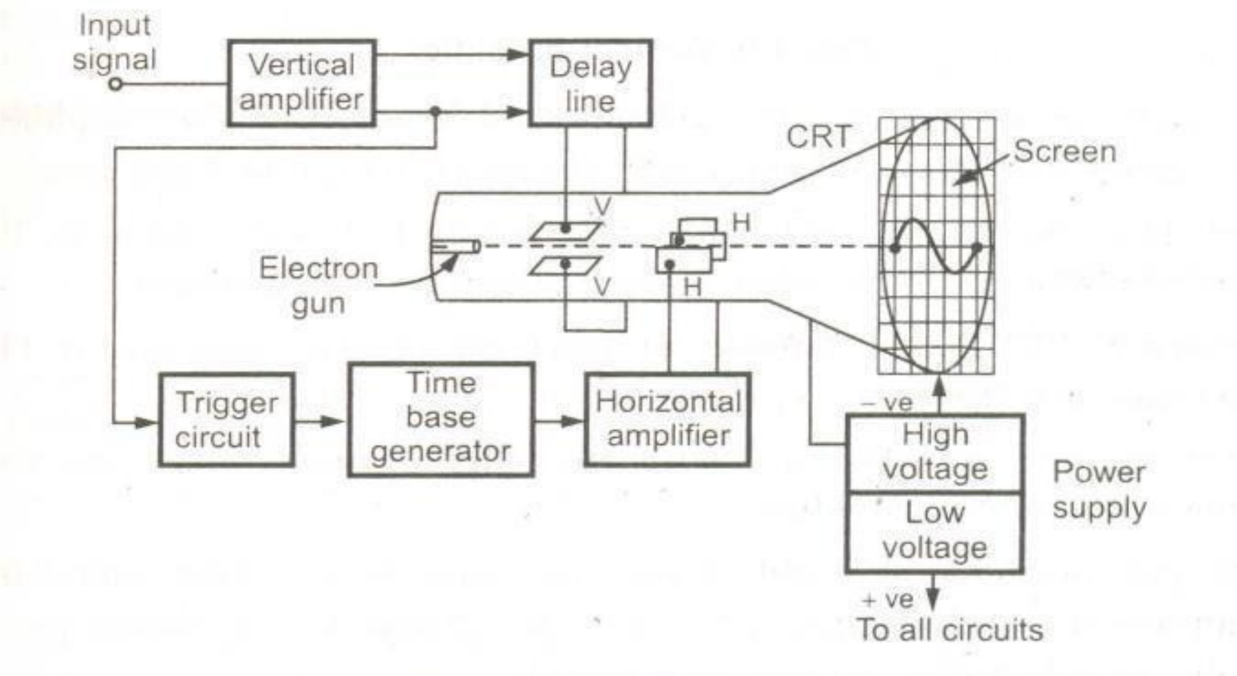
Phosphorscreencharacteristics:

Manyphosphormaterialshavingdifferent excitationtimesandcoloursaswellasdifferent phosphorescence times are available. The type PI, P2, PI1 or P3I are the short persistence phosphors and are used for the general purpose oscilloscope

Medical oscilloscopes require a longer phosphor decay and hence phosphors like P7 and P39 are preferred for such applications. Very slow displays like radar require long persistence phosphors to maintain sufficient flicker free picture. Such phosphors are P19, P26 and, P33.

The phosphors P19, P26, P33 have low burn resistance. The phosphors PI, P2, P4, P7, Pll have medium burn resistance while PIS, P3I have high burn resistance.

Blockdiagramofsimpleoscilloscope:

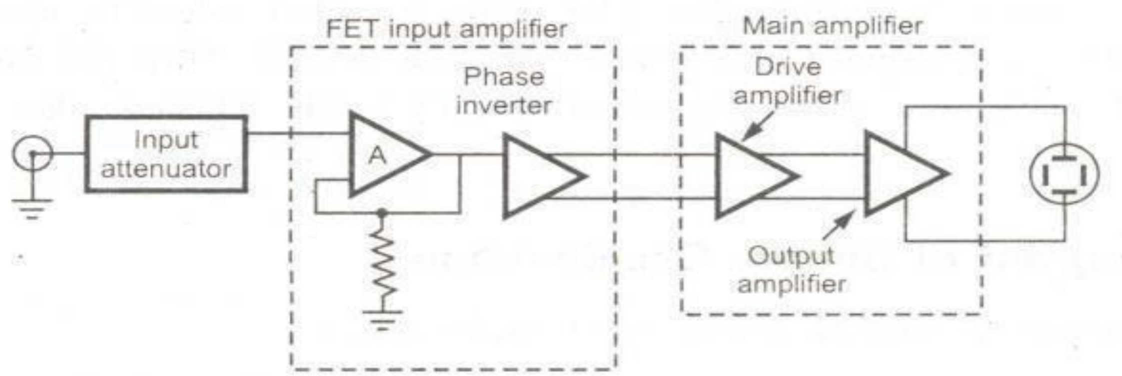


CRT:

This isthecathoderaytubewhichistheheart of CR.O.Itis'usedtoemitthe rlectrons requiredto strike the phosphor screen to produce the spot for the visual display of the signals.

VerticalAmplifier:

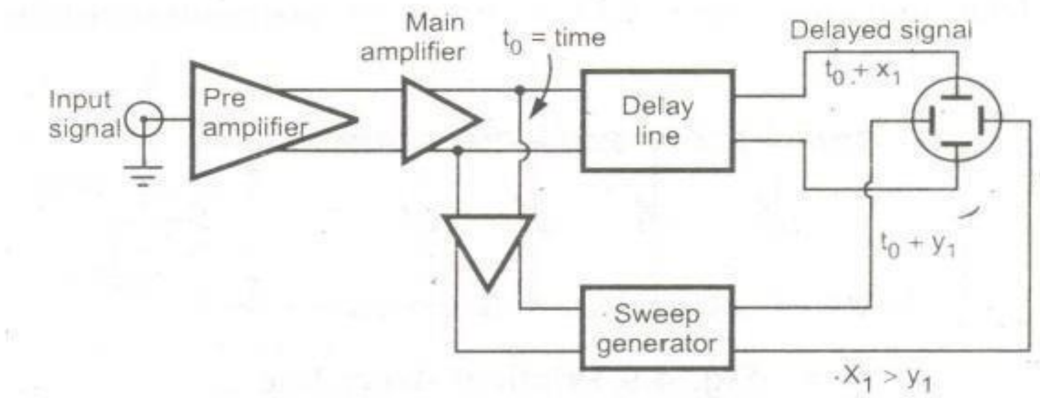
The input signals are generally not strong to provide the measurable deflection on the screen. Hence the vertical amplifier. stage is used Jo amplify the input signals. The amplifier stages used are generally wide band amplifiers so as to pass faithfully the entire band of frequencies to be measured. Similarly it contains theattenuatorstages as well. Theattenuators areusedwhenvery highvoltagesignalsareto beexamined,to bringthesignalswithin theproperrangeof operation.



It consists ofseveralstages withoverall fixedsensltivity. The amplifiercan be designed forstabilityandrequired bandwidthveryeasilyduetothe fixed gain.Theinputstagecolrtsists ofan attenuator followed by FETsource follower. It has vel' highinput impedance required to isolate the amplifier from the attenuator. It is followed by BJT emitter follower to match the output impedance of FET output With input of phase inverter. The phase inverter providestwo antiphase output signals which are required to operate the push pull output amplifier.The push pull operation has advantages like better hum voltage cancellation, even harmonic suppression especially large 2nd harmonic, greater power output per tube and reduced number of defocusing and nonlinear effects.

Delayline:

The delay line is used to delay the signal for some time in the verticClI sections. When the delay line is not used, the part of the signal gets lost. Thus the input signal is not applied directly to the vertical plates but is delClyed bv some time using a delay line cu-cuit as shown in the Fig.



If the trigger pulse is picked off at a time t = to after the signal has passed through the main amplifierthensignalis delayedbyXI nanosecondswhilesweeptakesYInanosecondstoreach. The designofdelay line is such that the delay time XI is higher thanthe time YI' Generally XI is

200. nsecwhiletl;1.eYIis 80ns,thusthesweepstartswellintimeandnopartofthesignalis lost. There are two types of delay lines used in CR.O. which are:

i) Lumpedparameterdelayline

ii) Distributedparameterdelayline

Trigger circuit:

It is necessary that horizontal deflection starts at the same point of the input vertical signal, each time it sweeps. Hence to synchronize horizontal deflection with vertical deflection a synchronizing or triggering circuit is used. It converts the incoming signal into the triggering pulses, which are used for the synchronization.

Timebasegenerator:

The time base generator is used to generate the sawtooth voltage, required to deflect the beam in the horizontal section. This voltage deflects the spot at a constant time dependent rate. Thus the x-axis' on the screen can be represented as time, which, helps to display and analyse the time varying signals.

Oscilloscopeprobes

Oscilloscopes are widely used for test and repair ofelectronics equipment ofall types. However it is necessary to have a method of connecting the input of the oscilloscope to the point on the equipment under test that needs monitoring.

To connect the scopetothe point to be monitoredit is necessaryto usescreened cable to prevent any pick-up of unwanted signals and in addition to this the inputs to most oscilloscopes use coaxial BNC connectors. While it is possible to use an odd length of coax cable with a BNC connectoronone end and openwires withcrocodile / alligator clips ontheother, this is not ideal and purpose made oscilloscope probes provide a far more satisfactory solution.

Oscilloscope probes normally comprise a BNC connector, the coaxial cable (typically around a metre in length) and what may be termed the probe itself. This comprises a mechanical clip arrangement so that the probe can be attached to the appropriate test point, and an earth orground clip to be attached to the appropriate ground point onthe circuit under test.

Care should be taken when using oscilloscope probes as they can break. Although they are robustly manufactured, any electronics laboratory will consider oscilloscope probes almost as "life'd" items that can be disposed of after a while when they are broken. Unfortunately the fact that they are clipped on to leads of equipment puts a tremendous strain on the mechanical clip arrangement. This is ultimately the part which breaks.

X1andX10oscilloscope probes

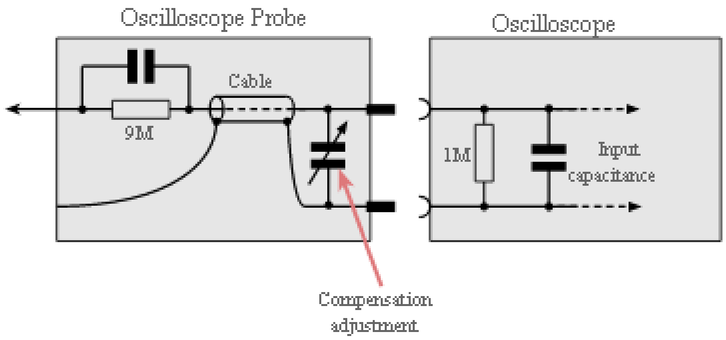
There are two maintypes ofpassive voltage scope probes. Theyare normallydesignated X1 and X10, although1X and 10Xaresometimesseen. The designationrefersto the factorbywhichthe impedance of the scope itelf is multiplied by the probe.

The X1 probes are suitable for many low frequency applications. They offer the same input impedance of the oscilloscope which is normally 1 MΩ. However for applications where better accuracy is needed and as frequencies start to rise, other test probes are needed.

To enable better accuracy to be achieved higher levels of impedance are required. To achievethis attenuators are built into the end of the probe that connects with the circuit under test. The most commontype ofprobe witha built inattenuatorgivesanattenuationoften, and it isknown as a X10 oscilloscope probe. The attenuation enables the impedance presented to the circuitunder test to be increased by a factor of ten, and this enables more accurate measurements to be made.

As the X10 probe attenuatesthe signal by a factor often, the signal entering the scope itself will be reduced. Thishasto betaken into account.Someoscilloscopesautomaticallyadjust the scales according to the probe present, although not all are able to do this. It is worth checking before making a reading.

The10X scopeprobeusesaseriesresistor(9MOhms)toprovidea 10:1attenuationwhen itis used with the 1 M Ohm input impedance of the scope itself. A 1 M Ohm impedance is the standardimpedanceused for oscilloscopeinputs andthereforethisenablesscope probestobe interchanged between oscilloscopes of different manufacturers.



Oscilloscope probe circuit

The scope probe circuit shown is a typical one that might be seen - other variants with the variable compensation capacitor at the tip are just as common.

In addition to the X1 and X10 scope probes, X100 probes are also available. These oscilloscope probes tend to be used where very low levels ofcircuit loading are required, and where the high frequenciesarepresent. Thedifficultyusingthe isthefactthatthe signalisattenuatedbya factor of 100.

X10oscilloscopeprobecompensation

The X10 scope probe is effectivelyan attenuator and this enables it to load the circuit under test far less. It doesthis by decreasing he resistive and capacitive loading on the circuit. It also has a much higher bandwidth than a traditional X1 scope probe.

The x10 scope probe achieve a better high frequency response than a normal X1 probe for a varietyofreasons. It doesthis by decreasing the resistive and capacitive loading on the The X10 probe can often be adjusted, or compensated, to improve the frequency response.

Typicaloscilloscopeprobe

For manyscope probes there is a single adjustment to provide the probe compensation, although there can be two on some probes, one for the LF compensation and the other for the HF compensation.

Probes that have only one adjustment, it is the LF compensation that is adjusted, sometimes the HF compensation may be adjusted in the factory.

To achieve the correct compensation the probe is connected to a square wave generator in the scope and the compensation trimmer is adjusted for the required response - a square wave.

CompensationadjustmentwaveformsforX10oscilloscopeprobe.

Ascanbeseen,theadjustment isquiteobviousandit isquick andeasytoundertake.It shouldbe doneeachtimetheprobeis moved fromone inputtoanother,oronescopetoanother. It doesnot hurt to check it fromtime to time, even if it remains on the same input. As in most laboratories, things get borrowed and a different probe may be returned, etc . .

A note ofcaution: manyoscilloscope probes include a X1/X10 switch. This is convenient, but it must be understood that the resistive and capacitive load on the circuit increase significantly in the X1 position. It should also be remembered that the compensation capacitor has no effect when used in this position.

As an example of the type of loading levels presented, a typical scope probe may present a load resistance of10MΩ along with a load capacitance of15pF to the circuit in the X10 position. For the X1 position the probe may have a capacitance of possibly 50pF plus the scope input capacitance. This may end up being of the order of 70 to 80pF.

Othertypes ofprobe

Apart from the standard 1X and 10X voltage probes a number of other types of scope probe are available.

- ***Current probes:***It is sometimes necessary to measure current waveforms on an oscilloscope. This can be achieved using a current probe. This has a probe that clips around the wire and enables the current to be sensed. Sometimes using the maths functions on a scope along with a voltage measurement on another channel it is possible to measure power,

- ***Active probes:***As frequencies rise, the standard passive probes become less effective. The effect of the capacitance rises and the bandwidth is limited. To overcome these difficulties active probes can be used. They have an amplifier right at the tip of the probe enabling measurements with very low levels of capacitance to be made. Frequencies of several GHz are achievable using active scope probes.
- ***Differential scope probes:***In some instances it may be necessary to measuredifferential signals. Low level audio, disk drive signals and many more instances use differential signals and these need to be measured as such. One way of achieving this is to probe both lines of the differential signal using one probe each line as if there were two single ended signals, and then using the oscilloscope to add then differentially (i.e. subtract one from the other) to providethedifference.

  Using two scope probes in this way can give rise to a number of problems. The main one is that single ended measurements of this nature do not give the required rejection of any common mode signals (i.e. Common Mode Rejection Ratio, CMMR) and additional noise is likely to be present. There may be a different cable length on each probe that may lead to a time differences and a slight skewing between the signals.

  To overcome this a differential probe may be used. This uses a differential amplifier at the probing point to provide the required differential signal that is then passed along the scope probe lead to the oscilloscope itself. This approach provides a far higher level of performance.

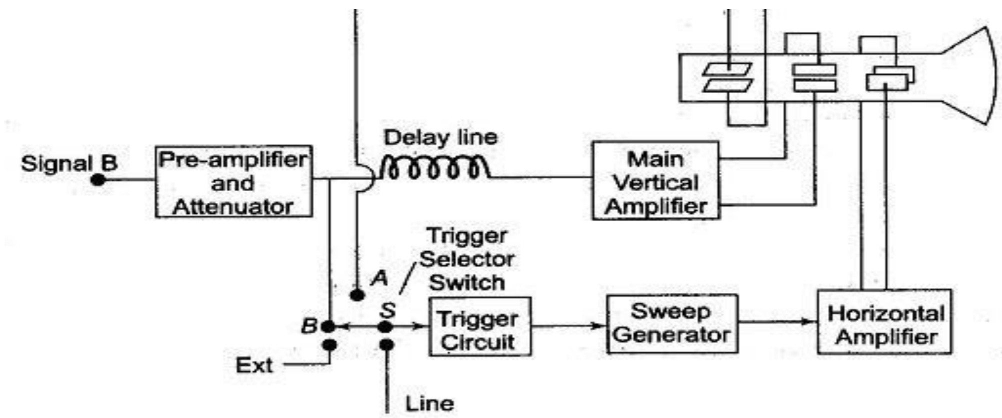
- ***High voltage probes:***Most standard oscilloscope voltage probes like the X1 or X10 are only specified for operation up to voltages of a few hundred volts at most. For operation higher than this a proper high voltage probe with specially insulated probe is required. Italso will step down the voltage for the input to the scope so that the test instrument is not damaged by the high voltage. Often voltage probes may be X50 or X100.

<u>SpecialPurposeOscilloscopes</u>

DualBeam CRO

Thedual trace oscilloscope has one cathode ray gun, and an electronic switchwhich switches two signals to a single vertical amplifier. The dual beam CRO uses two completely separate electron beams, two sets of VDPs and a single set of HDPs. Only one beam can be synchronised at one time, since the sweep is the same for both signals, i.e. a common timebase is used for both beams. Block diagram of a Dual Beam CRO.

Therefore,the signals must have the same frequency ormust be relatedharmonically, in order to obtain both beams locked on the CRT screen, e.g. the input signal of an amplifier can beusedassignalAanditsoutputsignalassignal



B. **Fig. 7.18** Dual Beam CRO

DUALTRACEOSCILLOSCOPE

ThisCRO hasa single electron gun whose electron beamissplit into two byanelectronicswitch. There is one control for focus and another for intensity. Two signals are displayed simultaneously. The signals pass through identical vertical channelsor vertical amplifiers. Each channel has its own calibrated input attenuator and i positioning control, sothat the amplitude of each signal can be ndependpntly adjusted.

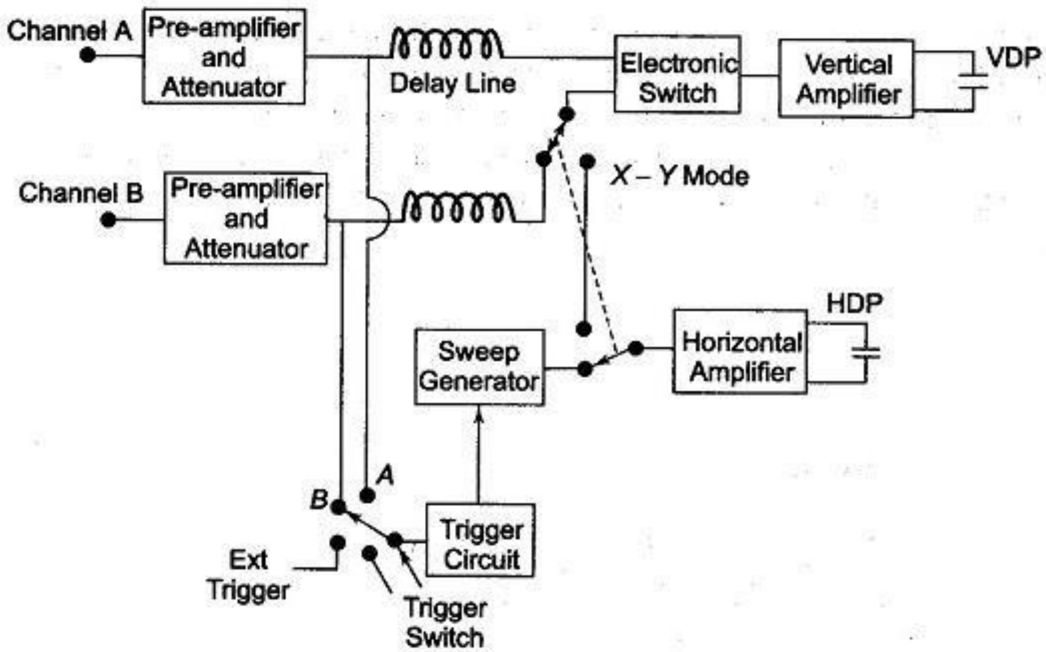


Fig. 7.19 (a) Dual Trace Oscilloscope

Amode controlswitch enablesthe electronic switchto operateintwo modes.Wheritheswitch is in ALTERNATE position, the electronic switch feeds each signal alternately to theverticalamplifier. Theelectronic switchalternately connects the mainvertical amplifierto channels A and**B**and adds a different dc component to each signal; this dc component directs the beam alternately to the upper or lower half of the screen. The switching takes place at the start of each new sweep of the sweep generator. The switching rate of theelectronic switch is synchronised to the sweep rate, so that the CRT spot traces the channel A signal on one sweep and the channel B signal on the succeeding sweep [Fig. 7.19 (b)]

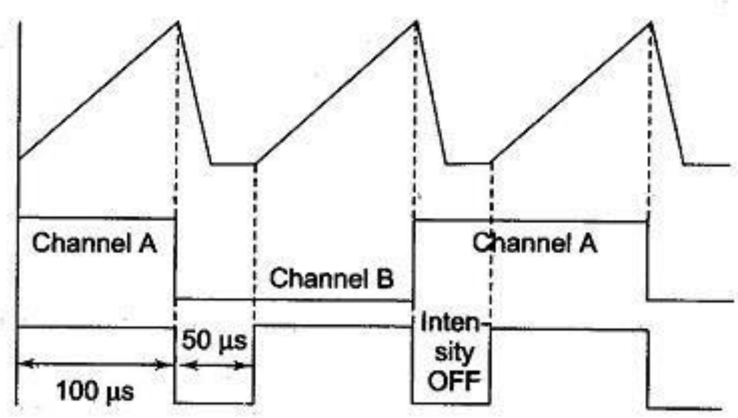


Fig. 7.19 (b) Time Relation of a Dual-Channel Vertical Amplifier in Alternate Mode

The sweep trigger signal is available from channels A or B and the trigger pick-off takes place before theelectronic switch. This arrangement maintains the correct phase relationship between signals A and B.

When the switch is in the CHOP mode position, the electronic switch is free running at the rate of 100-500 kHz, entirely independent of the frequency of the sweep generator. The switch successively connects small segments of A and B waveforms to the main vertical amplifierat a relativelyfastchoppingrateof500kHze.g.1i.tssegments ofeachwaveformarefed totheCRT display (Fig. 7.19 (c)).

If the chopping rate is slow, the continuity of the display is lost and it is better to use the alternate mode of operation. In the added mode of operation a single image canbe displayed by the addition of signal from channels A and B, i.e. (A + B), etc. In the X— Y mode ofoperation, thesweep generator is disconnected and channel B is connected to the horizontal amplifier. Since both preamplifiers are identical and have the same delay time, accurate X — Y measurements can be made.

<u>DualtraceOscilloscope(0-15MHz)</u>

BlockDescriptionY-Channels

A and B vertical channels are identical for producing the dual trace facility. Each comprises an inputcouplingswitch,aninputstepattenuator,asourcefollowerinputstagewithprotection circuit,a pre-amplifierfrom whicha triggersignalis derived anda combined finalamplifier. The input stage protection circuit consists of a diode, which prevents damage to the FET transistors thatcouldoccurwithexcessivenegativeinput potentials,anda resistornetworkwhichprotects the input stage from large positive voltage swings.

As the transistors are the balanced pre-amplifier stage, they share the same IC block. The resulting stabilisationprovides a measure of correction to reduce the drift inherent in highgain amplifiers. The triggerpick-offsignalis takenfrom one side ofthe balanced pre-amplifiertothe triggermode switch,whereeitherchannelA orchannel **B**triggeringcanbe selected.The supply fortheoutputofthe pre-amplifierstageisderivedfroma constantcurrentsourcecontrolled by thechannelswitchinglogic.Underthecontrolofchannelswitching,signalsfromA and**B**channels are switched to the final amplifier. The combined balanced final amplifier is a direct coupled one to the Y-plates of the CRT (refer to Fig. 7.20).

ChannelSwitching

The front panel A and B channel selection (push button or switch), controls an oscillator in the CHOP mode. For channel switching electronic switching logic and a F/F is used. When either A or B channels are selected, the F/F is switched to allow the appropriate channel.

In the ALTERNATE mode, a pulse from the sweep-gating multivibrator via the electronic switching logic, switches the F/F, thus allowing A and B channels for alternate sweeps.

IntheCHOPmode,the oscillatorisswitchedvia thelogicstagetoprovide rapidswitching ofthe channels via the F/F.

Triggering

A triggering signal can be obtained from the vertical amplifier of Channels A and**B**from an external source or internally from the mains supply (LINE triggering). The triggering signal is selected and normally fed via the amplifier stage to the pulse shaper, which supplies well defined trigger pulses to the sweep-gating multivibrator for starting the sawtooth generator.

Triggering fromthe TV line andframesignals can beobtainedfromthe syncseparatorandpeak detector stages. The latter stage is switched into circuit in the TOP position.

Time Base

Thetimebasegeneratorcircuitoperatesontheconstantcurrentintegrator principle.

The sweep-gating multivibrator, triggered by pulses from the differentiator and auto circuits, starts the sawtooth generator. Sweep signals are fed to the final X-amplifier.

A gate pulse is supplied by the sweep-gating multivibrator for unblanking the CRT during the forward sweep. Inaddition this pulse is supplied toan externalsocket for probe adjustment via a diode network.

X–Channel

Under the control of diode switching from the TIME/DIV switch, the X- amplifier receives its input signal from either the time base sawtooth generator or from an external source (X-EXT input socket via the **X**and triggerpre-amplifier). The X-MAGN(x 5) circuit is incorporated inthe X-final amplifier. The output of this amplifier is direct coupled to the horizontal deflectionplates of the CRT.

Cathode–RayTubeCircuitandPowerSupply

The high voltages required for the CRT, which has an acceleration potential of 1.5 kV, are generatedby a voltage multiplier circuit controlledby a stabilised power supply. The CRT beam current is controlled by:

The intensity potentials network across the Extra High Tension (EHT) supply. During flyback (movement ofelectron beamfrom right to left) by the blanking pulses coming from the sawtooth generator via the beam blanking stages to blank the trace during right to left movement of the electron.

Regulation of the mains input voltage is achieved by a diode clipper network controlled by a signal fed back from an LED in the + 14 V rectifier supply.

SAMPLINGOSCILLOSCOPE(VHF)

An ordinary Sampling Oscilloscope has a B.W. of10MHz. The HF performance canbe improved by means of sampling the input waveform and reconstructing its shape from the sample, i.e.the signal to be observed is sampled and after a few cycles the sampling point is advanced and anothersampleistaken.Theshapeofthewaveformisreconstructedbyjoiningthesample levels together. The sampling frequency may be as low as 1/10th of the input signal frequency (if the input signal frequency is 100 MHz, the bandwidth of the CRO vertical amplifier can be as low as 10 MHz). As many as 1000 samples are used to reconstruct the original waveform.

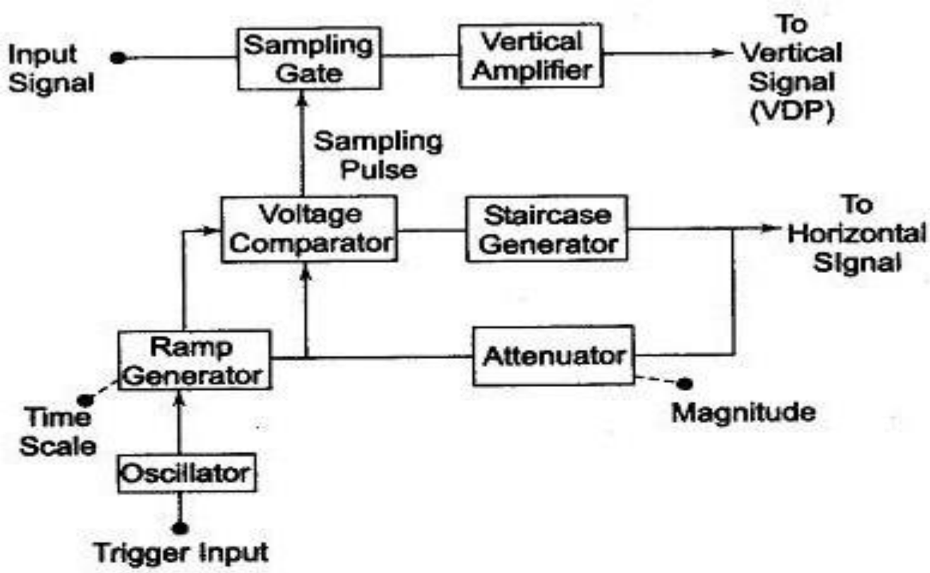


Fig. 7.24 Sampling Oscilloscope

Figure 7.24 shows a block diagram of a sampling oscilloscope. The input waveform is appliedtothe sampling gate. The input waveform is sampledwhenevera sampling pulse opens the sampling gate. The sampling must be synchronised with the input signal frequency. The signal is delayed in thevertical amplifier, allowing the horizontal sweep to be initiated by the input signal. The waveforms are shown in Fig. 7.25.

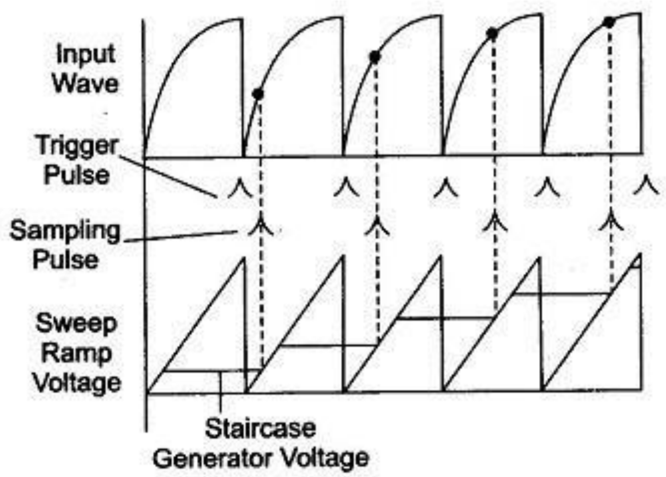


Fig. 7.25 Various Waveforms at Each Block of a Sampling Oscilloscope

At the beginning of each sampling cycle, the trigger pulse activates an oscillator and a linear ramp voltage is generated. This ramp voltage is applied to a voltage comparator which compares the ramp voltage to a staircase generator. When the two voltages are equal in amplitude,the staircase advances one step anda sampling pulse is generated,which opens the sampling gate for a sample of input voltage.

The resolution of the final image depends upon the size of the steps of the staircase generator.The smaller the size of the steps the larger the number of samples and higher the resolution of the image.

STORAGEOSCILLOSCOPE

Storage targets can be distinguished from standardphosphor targets by their ability to retain a waveform pattern for a long time, independent of phosphor peristence. Two storagetechniques are used in oscilloscope CRTs, mesh storage and phosphor storage.

A mesh-Storage Oscilloscope uses a dielectric material deposited on a storage mesh as the storage target. This mesh is placed between the deflection plates and the standardphosphor target in the CRT. The writing beam, which is the focussed electron beam of thestandardCRT, charges the dieletric material positively where hit. The storage target is then bombarded with low velocity electrons from a flood gun and the positively charged areas of the storage target allowtheseelectronstopassthroughtothe standardphosphortargetandtherebyreproduce the stored image on the screen. Thus the mesh storage has both a storage target and a phosphor display target. The phosphor Storage Oscilloscope uses a thin layer of phosphor to serve both as the storage and the display element.

MeshStorage

It is used to display Very Low Frequencies (VLF) signals and finds many applications in mechanical and biomedical fields. The conventional scope has a display with a phosphor peristence ranging from a few micro seconds to a few seconds. The persistence can be increased to a few hours from a few seconds.

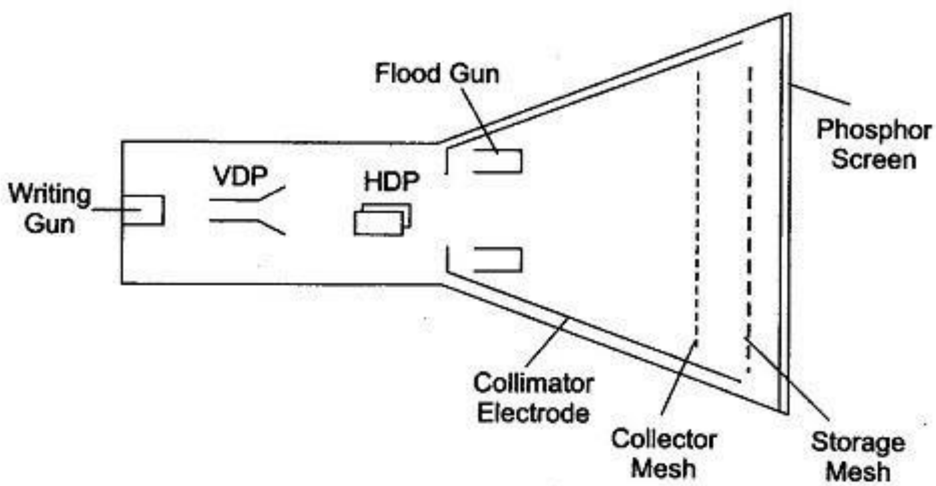


Fig. 7.26 Basic Elements of Storage Mesh CRT

A meshStorage Oscilloscope, shown in Fig. 7.26, contains a dielectric material deposited on a storagemesh, acollector mesh,flood gunsandacollimator,inadditiontoall theelementsof astandardCRT. Thestoragetarget,athindepositionofa dielectricmaterialsuchasMagnesium Fluoride on the storage mesh, makes use of a property known as secondary emission. The writing gun etches a positively charged pattern on the storage mesh or target by knocking off secondary emission electrons. Because of the excellent insulating property of the Magnesium Fluoride coating, this positively charged pattern remains exactly in the position where it is deposited. In order to make a pattern visible, a special electron gun, called the flood gun, is switched on (even after many hours).

The electron paths are adjusted by the collimator electrode, which constitutes a low voltage electrostaticlenssystem(tofocusthe electronbeam),asshowninFig.7.27.Mostofthe electrons are stopped and collected by the collector mesh. Only electrons near the stored positive charge are pulled tothe storage target withsufficient force to hit the phosphorscreen. The CRT will now display the signal and it will remain visible as long as the flood guns operate. To erase the pattern on the storage mesh,a negative voltage is applied to neutralise the stored positive charge.

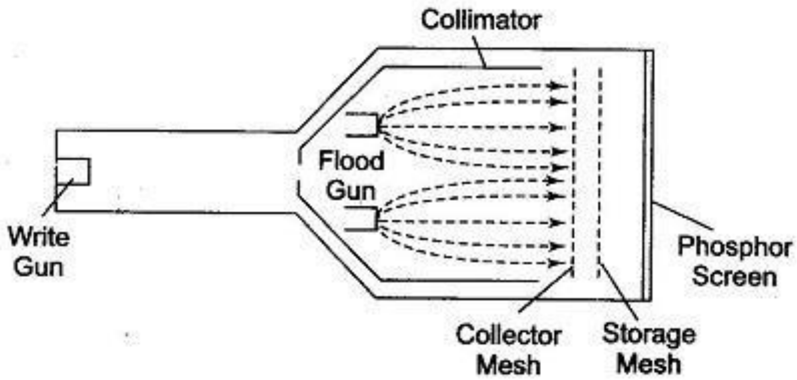


Fig. 7.27 Storage Mesh CRT

Since the storage mesh makes use of secondary emission, between the first and second crossover more electrons are emitted than are absorbed by the material, and hence a net positive charge results.

Below the first crossover a net negative charge results, since the impinging electrons do not have sufficient energy to force an equal number to be emitted. In order to store a trace,assume that the storage surface is uniformly charged and write gun (beam emission gun) willhit the storage target. Those areas of the storage surface hit by the deflecting beam lose electrons, which are collected by the collector mesh. Hence, the write beam deflection pattern is traced on the storage surface as a positive charge pattern. Since the insulation of the dielectric material is high enough to prevent any loss of charge for a considerable length of time, the pattern is stored. To view, the stored trace, a flood gun is used when the write gun is turned off.

The flood gun, biased very near the storage mesh potential, emits a flood of electrons which move towards the collector mesh, since it is biased slightly more positive than the deflection region. The collimator, a conductive coating on the CRT envelope with an applied potential, helpstoalignthefloodelectronssothattheyapproachthestoragetargetperpendicularly.

When the electrons penetrate beyond the collector mesh, they encounter either a positively charged region on the storage surface or a negatively charged region where no trace has been stored.

The positively charged areas allow the electrons to pass through to the post accelerator region and the display target phosphor. The negatively charged region repels the flood electrons back to the collector mesh. Thus the charge pattern on the storage surface appears reproduced on the CRT display phosphor just as though it were being traced with a deflected beam.

Figure7.28showsadisplayofthestoredchargepatternonmeshstorage.

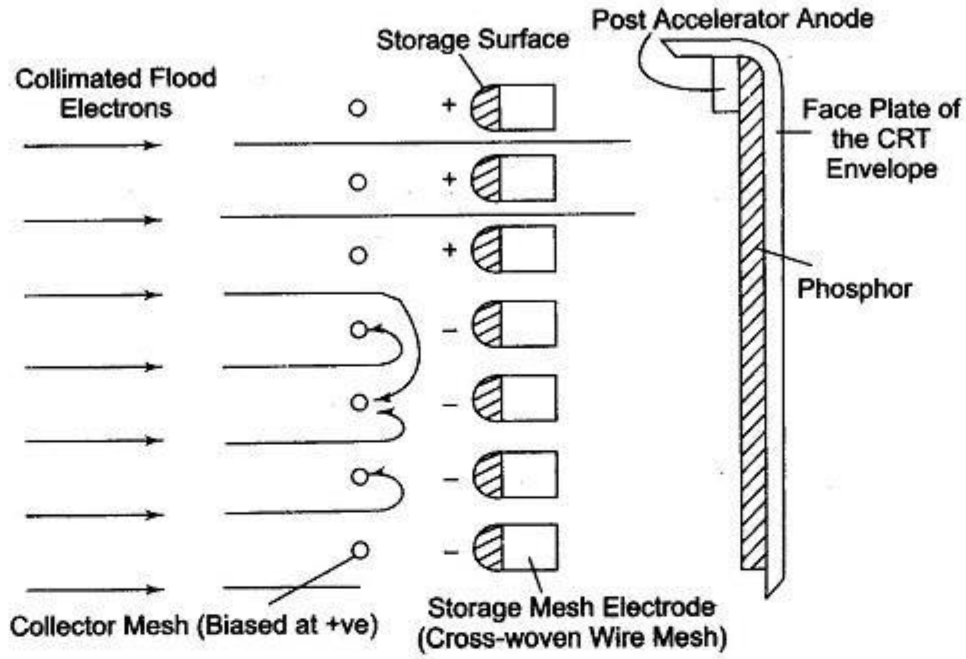


Fig. 7.28 Display of Stored Charged Pattern on a Mesh-storage

DigitalStorageOscilliscope

Digital Storage Oscilliscopes are available in processing and non-processing types. Processing types include built in computing power, which takes advantage of the fact that all data is already in digital form.

The inclusion of interfacing and a microprocessor provides a complete system for information acquisition, analysis and output. Processing capability ranges from simple functions (such as average, area, rms, etc.) to complete Fast Fourier Transform (FFT) spectrum analysis capability.

Non–processing digital scopes are designed as replacements for analog instruments for both storage and non-storage types. Their many desirable features may lead to replace analog scopes entirely (within the Bandwidth range where digitization in feasible).

The basic principle of a digital scope is given in Fig. 7.51. The scope operating controls are designedsuchthatallconfusingdetailsareplacedonthe backside andoneappearstobe using a conventional scope. However, some digital scope panels are simpler also; most digital scopes provide the facility of switching selectable to analog operation as one of the operating modes.

The basic advantage of digital operation is the storage capability, the stored waveform can be repetitively read out, thus making transients appearrepetitively and allowing their convenient displayonthescopescreen.(TheCRTusedin DigitalStorageOscilliscope isanordinaryCRT,not a storage type CRT.)

Furthermore, the voltage and time scales of display are easily changed after the waveform has been recorded, which allows expansion (typically to 64 times) of selected portions, to observe greater details.

A cross-hair cursor can be positioned at any desired point on the waveform and the voltage/time values displayed digitally on the screen, and/or readout electrically.

Some scopes use 12 bit converters, giving 0.025% resolution and 0.1% accuracy on voltage and time readings, which are better than the 2-5% of analog scopes.

Split screen capabilities (simultaneously displaying live analog traces and replayed stored ones) enable easy comparison of the two signals.

Pretriggercapabilityisalsoasignificantadvantage.Thedisplayofstoreddata ispossible inboth amplitude versus time and X- Y modes. In addition to the fast memory readout used for CRT display, a slow readout is possible for producing hard copy with external plotters.

When more memory than the basic amount (typically 4096 points/words) is needed, amagnetic disk accessory allows expansion to 32,000 points.

AllDigital Storage Oscilliscope scopes are limited in bandwidth by the speed of their A/D converters. However, 20 MHz digitizing rates available on some scopes yield a 5 MHz bandwidth, which is adequate for most applications.

Consider a single channnel of Fig. 7.51. The analog voltage input signal is digitised in a 10 bitA/D converter witha resolution of0.1% (1 part in 1024) and frequency response of 25 kHz. The total digital memory storage capacity is 4096 for a single channel, 2048 for two channels each and 1024 for four channels each.

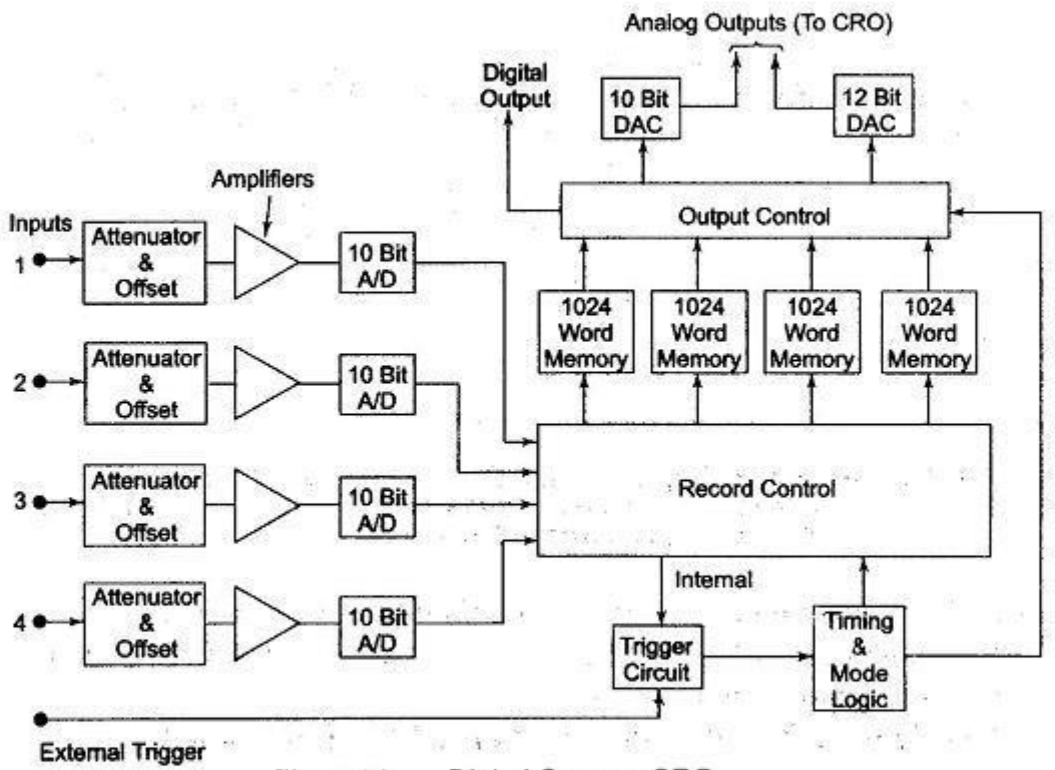


Fig. 7.51 Digital Storage CRO

The analog input voltage is sampledat adjustable rates (upto100,000samples persecond)and datapointsare readontothe memory.A maximumof4096pointsarestorable inthisparticular instrument. (Sampling rate and memory size is selected to suit the duration and waveform of the physical event being recorded.)

Once the sampled record of the event is captured in memory, many useful manipulations are possible, since memory can be read out without being erased.

If the memory is read out rapidly and repetitively, an input event which was a single shot transient becomes a repetitive or continuous waveform that can be observed easily on an ordinary scope (not a storage scope). The digital memory also may be read directly (without going through DAC) to, say, a computer where a stored program can manipulate the data in almost any way desired.

Pre-triggering recording allows the input signal preceding the trigger points to be recorded. In ordinary triggering the recording process is started by the rise of the input (or some external triggering) above some preset threshold value.

Asindigitalrecorder,DSOcanbesettorecordcontinuously(new datacoming intothememory pushes out olddata, once memory is full),untilthe triggersignalis received;thenthe recording is stopped, thus freezing data received prior to the trigger signal in the memory.

An adjustable trigger delay allows operator control of the stop point, so that the trigger may occur near the beginning, middle or end of the stored information.

DigitalStorageOscilliscope Features

1. Sampling rate20Mega-samplespersecondperchannel.Max.(simultaneous)capture of both channels.
2. Pre-trigger:25%,50%,75%,forSingleShot,Rollnormal.
3. Rollmode:(ContinuousandSingleShotwithPre-triggerof 25%,50%,75%)
4. Singleshot(0.5p.sSingleshot@10pts./divresolutionwithpre-trigger25%,50%,75%)
5. DigitalSweeprate:0.5.µs/cmto50sec/cm,(eventaslongas8.33minutescanbe captured)
6. ComputerbuiltinInterface:(RS232SerialportandCentronicsParallelinterface).

MODULE-5

Transducers

Transducer is a device that converts energy in one form of energy to another form of energy. This converts non-electrical quantity into electrical quantity.

A transducer is defined as a device that receives energy from one system and transmits it to another, often in a different form.

Broadly defined, the transducer is a device capable of being actuated by an energising input from one or more transmission media and in turn generating a related signal to one or more transmission systems. It provides a usable output in response to a specified input measurand, which may be a physical or mechanical quantity, property, or conditions. The energy transmitted by these systems may be electrical, mechanical or acoustical.

The nature of electrical output from the transducer depends on the basic principle involved in the design. The output may be analog, digital or frequency modulated.

Basically, there are two types of transducers, electrical, and mechanical. Transducer is a device that converts energy in one form of energy to another form of energy. This converts non-electrical quantity into electrical quantity.

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Basically,thereare twotypesoftransducers,electrical,andmechanical.

ElectricalTransducerDefinition

An electrical transducer is a sensing device by which the physical, mechanical or opticalquantity to be measured is transformed directly by a suitable mechanism into an electricalvoltage/current proportional to the input measurand.

Anelectricaltransducermusthavethefollowingparameters:

ElectricalTransducerDefinition

An electrical transducer is a sensing device by which the physical, mechanical or opticalquantity to be measured is transformed directly by a suitable mechanism into an electricalvoltage/current proportional to the input measurand.

Anelectricaltransducermusthavethefollowingparameters:

1. **Linearity:**The relationship between a physical parameter and the resulting electrical signal must be linear.
2. **Sensitivity:**This is defined as the electrical output per unit change in the physical parameter (for example V/°C for a temperature sensor). High sensitivity is generally desirable for a transducer.
3. **Dynamic Range:** The operating range of the transducer should be wide, to permit its use under a wide range of measurement conditions.
4. **Repeatability:**Theinput/outputrelationshipforatransducershouldbepredictableover a long period of time. This ensures reliability of
5. **Physical Size:**TheElectrical Transducer Definitionmust have minimal weight and volume, so that its presence in the measurement system does not disturb the existing conditions.

AdvantagesofElectricalTransducer

The main advantages of electrical transducer (conversion of physical quantity into electrical quantities) are as follows:

1. Electricalamplificationandattenuationcanbeeasilydone.
2. Mass-inertiaeffectsareminimised.
3. Effectsoffrictionareminimised.
4. Theoutputcanbeindicatedandrecordedremotelyatadistancefromthesensingmedium.
5. The output can be modified to meet the requirements of the indicating or controlling units. Thesignal magnitude can be related in terms of the voltage current. (The analog signal information can be converted in to pulse or frequency information. Since output can be modified, modulated or amplified at will, the output signal can be easily used for recordingon any suitable multichannel recording device.)
6. The signal can be conditioned or mixed to obtain any combination with outputs of similar transducers or control signals.

7. Theelectricalorelectronicsystemcanbecontrolledwithaverysmallpower level.
8. Theelectricaloutputcanbeeasilyused,transmittedandprocessedforthepurposeof measurement.

Electricaltransducercanbebroadlyclassifiedintotwomajorcategories,

Classificationoftransducers

- ***PrimaryandSecondaryTransducers***
- ***AnalogandDigitalTransducers***
- ***ActiveandPassiveTransducers***
- ***TransducersandInverse Transducers***

- ***PrimaryandSecondaryTransducers***

When the input signal is directly sensed by the transducer and physical phenomenon is converted into the electrical form directly then such a transducer is called the primary transducer.

Example: The thermistor senses the temperature directly and causes the change in resistance with the change in temperature.

When the input signal is sensed first by some detector or sensor and then its output being of some form other than input signals is given as input to a transducer for conversion into electrical form, then such a transducer falls in the category of secondary transducers.

For example, in case of pressure measurement, bourdon tube is a primary sensor which converts pressure first into displacement, and then the displacement is converted into an output voltage by an LVDT.

- ***AnalogandDigitalTransducers***

Analog transducerconverts inputsignalintooutputsignal,which is acontinuous functionof time such as thermistor, strain gauge, LVDT, thermo-couple etc.

Digitaltransducerconvertsinputsignalintotheoutputsignaloftheformofpulsee.g.it gives discrete output.

- ***TransducersandInverse Transducers***

Transducer, as already defined, is a device that converts a non-electrical quantity into an electrical quantity.

Normally a transducer and associated circuit has a non-electrical input and an electrical output, for example a thermo-couple, photoconductive cell, pressure gauge, strain gauge etc.

An inverse transducer is a device that converts an electrical quantity into a non-electrical quantity.

Example:piezoelectricoscillator

- ***ActiveandPassiveTransducers***

An**active transducer** generates an electrical signal directly in response to the physical parameter and does not require an external power source for its operation. Active transducers are self generating devices, which operate under energy conversion principle and generate an equivalent output signal (for example from pressure to charge or temperature to electricalpotential).

Typical example of active transducers are piezo electric sensors (for generation of charge corresponding to pressure) and photo voltaic cells (for generation of voltage in response to illumination).

Passive transduceroperate underenergycontrolling principles, which makes it necessary to use an external electrical source with them. They depend upon the change in an electrical parameter (R, L and C).

Typicalexamplearestraingauges(for resistancechangeinresponsetopressure),and thermistors (for resistancechange corresponding to temperature variations).

Electrical transducer is used mostly to measure non-electrical quantities. For this purpose a detector or sensing element is used, which converts the physical quantity into a displacement. This displacement actuates an electric transducer, which acts as a secondary transducer and givesanoutputthatiselectricalinnature.Thiselectricalquantityismeasuredbythestandardmethod used for electrical measurement. The electrical signals may be current, voltage, or frequency; their production is based on R, L and C effects.

A transducer which converts a non-electrical quantity into an analog electrical signal may be considered as consisting of two parts, the sensing element, and the transduction element.

The sensing or detector element is that part of a transducer which responds to a physical phenomenon or to a change in a physical phenomenon. The response of the sensing element must be closely related to the physical phenomenon.

The transduction element transforms the output of a sensing element to an electrical output. This, in a way, acts as a secondary transducer.

Transducers may be further classified into different categories depending upon the principle employed by their transduction elements to convert physical phenomena into output electricalsignals.

SelectingaTransducer

Thetransducerorsensorhastobephysicallycompatiblewithitsintendedapplication.The following should be considered while selecting a transducer.

1. **Operatingrange:** Chosentomaintainrangerequirementsandgood
2. **Sensitivity:**Chosentoallowsufficientoutput.
3. **Frequencyresponseandresonantfrequency:**Flatovertheentiredesiredrange.

4. **Environmental compatibility:** Temperature range,corrosive fluids, pressure,shocks, interaction, size and mounting restrictions.
5. **Minimumsensitivity:**Toexpectedstimulus,otherthanthemeasurand.
6. **Accuracy:**Repeatability and calibration errors as well as errors expected due to sensitivity to other stimuli.
7. **Usage and ruggedness:** Ruggedness, both of mechanical and electrical intensities versus size and weight.
8. **Electricalparameters:** Lengthandtypeofcablerequired,signaltonoiseratiowhen combined with amplifiers, and frequency response limitations.

ResistiveTransducer

Resistive Transducers are those in which the resistancechanges due to a change in some physical phenomenon. The change in the value of the resistancewith a change in the length of the conductor can be used to measure displacement.

Strain gauges work on the principle that the resistanceof a conductor or semiconductor changes when strained. This can be used for the measurement of displacement, force and pressure.

The resistivity of materials changes with changes in temperature. This property can be used for the measurement of temperature.

$$\boxed{R = \frac{\rho L}{A}}$$

Potentiometer(DisplacementTransducer)

A resistive potentiometer (pot) consists ofa resistanceelement providedwitha sliding contact, called a wiper. The motion of the sliding contact may betranslatoryor rotational. Some have a combination of both, with resistive elements in the form of a helix, as shown in Fig. 13.1(c). They are known as helipots.

Translatory resistive elements, as shown in Fig. 13.1(a), are linear (straight) devices. Rotational resistive devices are circular and are used for the measurement of angular displacement, as shown in Fig. 13.1(b).

Helical resistive elements are multi turn rotational devices which can be used for the measurement of either translatory or rotational motion. A potentiometer is a passive transducer since it requires an external powersource for its operation.

AdvantageofPotentiometers

1. Theyareinexpensive.
2. Simpletooperateandareveryusefulforapplicationswheretherequirementsarenot particularly severe.
3. Theyareusefulforthemeasurementoflargeamplitudesofdisplacement.
4. Electricalefficiencyisveryhigh,andtheyprovidesufficientoutputtoallowcontrol operations.

Disadvantagesof Potentiometers

1. Whenusingalinearpotentiometer,a largeforce isrequiredtomovethesliding contacts.
2. Theslidingcontactscanwearout,becomemisalignedand generatenoise.

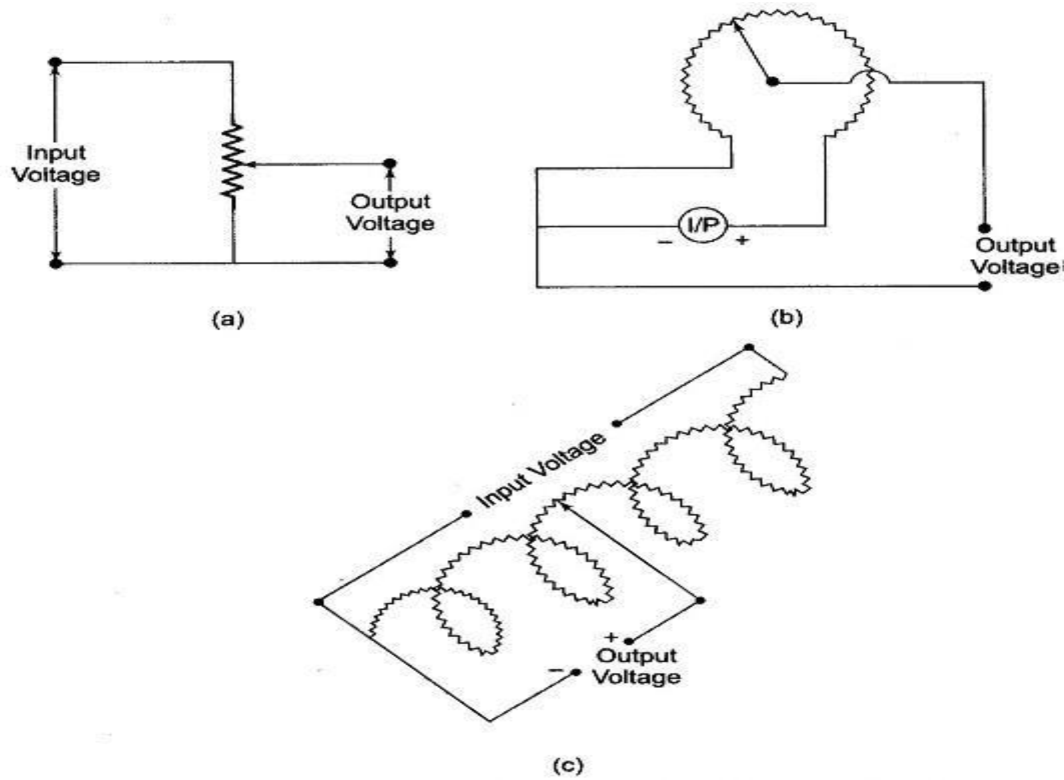

Fig. 13.1 (a) Translatory Type (b) Rotational Type (c) Helipot (Rotational)

Straingauges

The strain gauge is an example of a passive transducer that uses electric resistance variation in wires to sense the strain produced by a force on wires. It is a very versatile detector and transducer for measuring weight, pressure, mechanical force, or displacement.

The construction of a bonded strain gauge (see figure) shows a fine wire element looped back and forth on a mounting plate, which is usually cemented to the member undergoing stress. A tensile stress tends to elongate the wire and thereby increase its length and decrease its cross-sectional area.

Bondedtypestraingaugesarethreetypes,namely

1. **WireStrainGauges**

2. FoilStrainGauge

3. SemiconductorStrain Gauge

1. WireStrainGauges:

WireStrainGaugeshasthreetypesnamely,

1. Gridtype
2. Rossettetype
3. Torquetype
4. Helicaltype

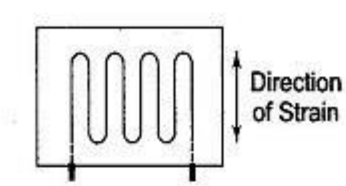

Fig. 13.6 Grid Type Strain Gauge

The grid arrangement of the wire element in a bonded strain gauge creates a problem not encountered in the use of unbonded strain gauges. To be useful as a strain gauge, the wire element must measure strain along one axis. Therefore complete and accurate analysis ofstrain in a rigid member is impossible, unless the direction and magnitude of stress are known. The measuring axis of a strain gauge is its longitudinal axis, which is parallel to the wire ele- ment, as shown in Fig. 13.6.

When a strain occurs in the member being measured, along the transverse axis of the gauge, it also affects the strain being measured parallel to the longitudinal axis. This introduces an error in the response of the gauge.

In most applications, some degree of strain is present along the transverse axis and the transverse sensitivity must be considered in the final gauge output. Transverse sensitivity cannotbecompletelyeliminated,andinhighlyaccuratemeasurementsthe resultant gaugeerror must be compensated for.

Iftheaxisofthestraininа component isunknown, StrainGaugeTransducerTypesmaybe used to determine the exact direction. The standardprocedure is to place several gauges at a point on the member’s surface, with known angles between them. The magnitude of strain in each individual gauge is measured, and used in the geometrical determination of the strain in the member.

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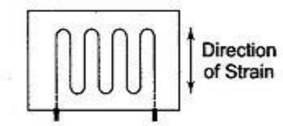


Fig. 13.6 Grid Type Strain Gauge

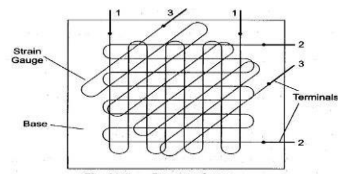


Fig. 13.7 Rossette Gauge

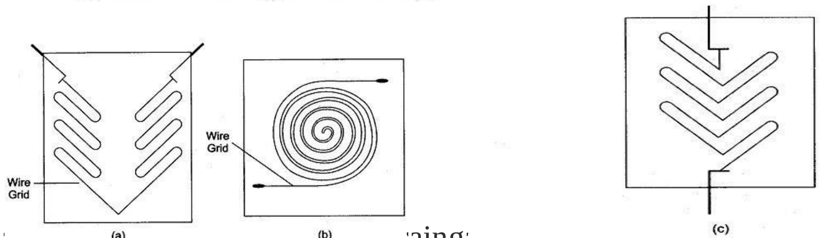


Fig. 13.8 (a) and (c) Torque Type Gauge (b) Helical Gauge

Characteristics of a resistance wire strain gauge

- TheStrain Gauge Transducer Types should have a high value of gauge factor (a high valueofgaugefactorindicates a largechangeinresistanceforparticularstrain,implying high sensitivity).
- Theresistanceofthe straingauge shouldbe as highas possible,since this minimizes the effectsofundesirablevariationsof resistanceinthemeasurementcircuit.A high resistance value results in lower sensitivity.
- Thestraingaugeshouldhavealowresistancetemperaturecoefficient.
- Thestraingaugeshouldnothavehysteresiseffectsinitsresponse
- Thevariationinresistanceshouldbealinearfunctionofthe strain.
- Straingaugesarefrequentlyusedfordynamicmeasurementsandhencetheirfrequency response should be good.
- Leadsusedmustbeofmaterialswhichhavelowandstableresistivityand lowresistance temperature coefficient.

FoilStrain Gauge

This class of strain gauges is an extension of the resistancewire strain gauge. The strain is sensed with the help of a metal foil. The metals and alloys used for the foil and wire are nichrome, constantan (Ni + Cu), isoelastic (Ni + Cr + Mo), nickel and platinum.

Foil gauges have a much greater dissipation capacity than wire wound gauges, on account of their larger surface area for the same volume. For this reason, they can be used for a higher operating temperature range. Also, the large surface area of foil gauges leads to betterbonding.

Foil typeStrain Gauge Transducer Typeshave similarcharacteristics towire straingauges. Their gauge factors are typically the same.

The advantage of foil type Strain Gauge Transducer Typesis that they can be fabricated on a large scale, and in any shape. The foil can also be etched on a carrier.

Etched foil gauge construction consists of first bonding a layer of strain sensitive material to a thin sheet of paper or bakelite. The portion of the metal to be used as the wire element is covered with appropriate masking material, and an etching solution is applied to the unit. The solution removes that portion of the metal which is not masked, leaving the desired grid structure intact.

This method of construction enables etched foil strain gauges to be made thinner than comparable wire units,as shown inFig. 13.9. This characteristic,togetherwitha greaterdegree of flexibility,allows the etched foil to be mounted in more remote and restricted places and on a wide range of curved surfaces. The resistancevalue of commercially available foil gauges is between 50 and 1000 Ω

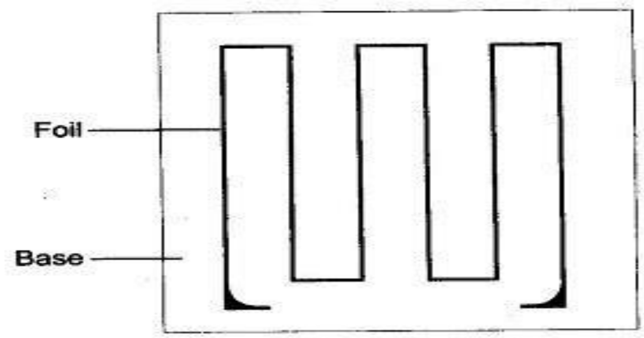


Fig. 13.9 Foil Type Strain Gauge

SemiconductorStrainGauge

To have a high sensitivity, a high value of gauge factor is desirable. A high gauge factor means relatively higher change inresistance, which can be easily measured with a good degree of accuracy.

Semiconductor strain gauges are used when a very high gauge factor is required. They have a gaugefactor50timesashighaswirestraingauges.Theresistanceof the semiconductor changes with change in applied strain.

Semiconductor straingauges depend for theiractionuponthe piezo resistive effect, i.e. change invalueoftheresistanceduetochangeinresistivity,unlikemetallicgaugeswherechange inresistance is mainly due to the change in dimension when strained. Semiconductor materials such as germanium and silicon are used as resistive materials.

A typical strain gauge consists of a strain material and leads that are placed ina protective box, as shown in Fig. 13.10. Semiconductor wafer or filaments which have a thickness of 0.05 mm areused.Theyarebondedonsuitableinsulatingsubstrates,suchasTeflon.

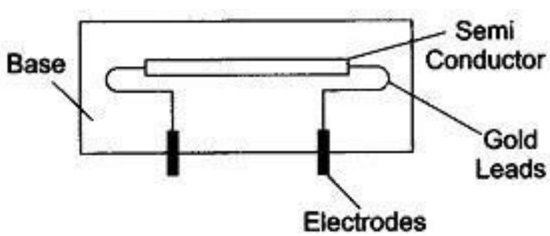


Fig. 13.10 Semiconductor Strain Gauge

Gold leads are generally used for making contacts. These strain gauges can be fabricated along with an IC Op Amp which can act as a pressure sensitive transducer. The large gauge factor is accompaniedbya thermalrate ofchangeofresistanceapproximately 50timeshigherthanthat for resistive gauges. Hence, a semiconductor strain gauge is as stable as the metallic type, but has a much higher output.

Simple temperature compensation methods can be applied to semiconductor strain gauges, so that small values of strain, that is micro strains, can also be measured.

AdvantagesofSemiconductorStrain Gauge

1. Semiconductor strain gauges have a high gauge factor of about + 130. This allows measurement of very small strains, of the order of 0.01 micro
2. Hysteresischaracteristicsofsemiconductorstraingaugesareexcellent,e.lessthan0.05%.
3. Lifeinexcessof10x10^6operationsandafrequencyresponseof10^{12}HZ.
4. Semiconductorstraingaugescanbeverysmallinsize,ranginginlengthfrom0.7to7.0mm.

DisadvantagesofSemiconductorStrain Gauge

1. Theyareverysensitivetochangesintemperature.
2. Linearity ofsemiconductorstraingaugesispoor.
3. Theyaremoreexpensive.

TemperatureTransducers

- ResistanceTemperatureDetectors(RTD)
- Thermocouples
- Thermistor

ResistanceTemperatureDetector(RTD)

Detectors of wire resistance temperature common employ platinum, nickel or resistance wire elements,whoseresistancevariationwithtemperaturehashighintrinsicaccuracy.Theyare available in many configurations and size and as shielded or open units for both immersion and surface applications.

Therelationshipbetweentemperature andresistanceofconductorscanbecalculatedfrom the equation:

$$R = R_O \quad (1 + \alpha \Delta T)$$

where

R =theresistanceofthe conductorat temperature t(^{0}C)

R0 =theresistanceatthereferencetemperature,usually20^{0}C α=

the temperature coefficient of resistance

ΔT =thedifferencebetweentheoperatingandthereferencetemperature

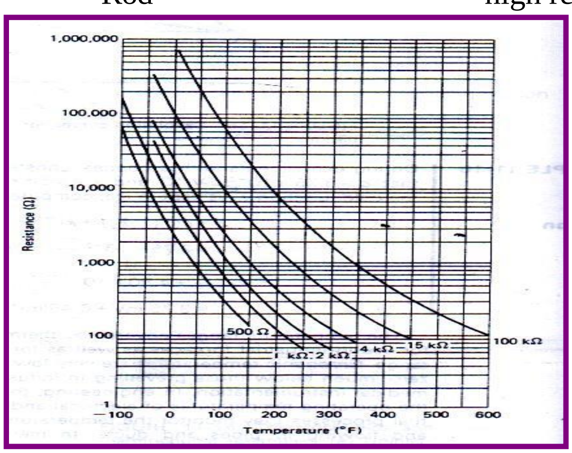
Thermistor

Athermistorisasemiconductormadebysinteringmixturesofmetallicoxide,suchasoxidesofmanganes e, nickel, cobalt, copper and uranium.

Termistorshavenegativetemperaturecoefficient(NTC).Thatis,theirresistancedecreasesastheir temperature rises.

Types of thermistor

	Resistance
Disc	1 to 1MΩ
Washer	1to 50kΩ
Rod	high resistance



This figure shows resistance versus temperaturefor a family thermistor. The resistance value marked at the bottom end of each curve is a value at 25^0C

Theresistancedecreasesastheirtemperaturerises-NTC

Advantagesof thermistor

- Smallsizeandlowcost
- Fastresponseovernarrowtemperature range
- GoodsensitivityinNegativeTemperatureCoefficient (NTC) region
- Coldjunctioncompensationnotrequiredduetodependence of resistance on absolute temperature.
- Contactandleadresistanceproblemsnotencountereddue to large resistance

Limitationsofthermistor

- Nonlinearityinresistancevstemperaturecharacteristics
- Unsuitableforwidetemperaturerange
- Verylowexcitationcurrenttoavoidsself heating
- Needofshieldedpower lines,filters,etcduetohighresistance

Thermocouples

It consists of two wires of different metals are joined together at one end, a temperature difference between this end and the other end of wires produces a voltage between the wires. The magnitude of this voltage depends on the materials used for the wires and the amount of temperature difference between the joined ends and the other ends.

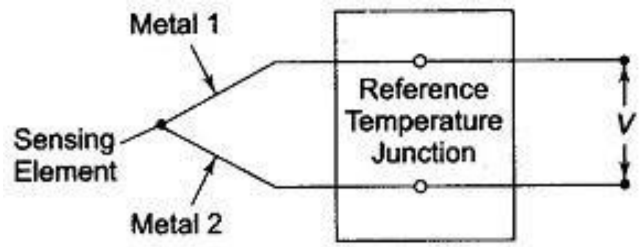


Fig. 13.41 Basic Thermocouple Connection

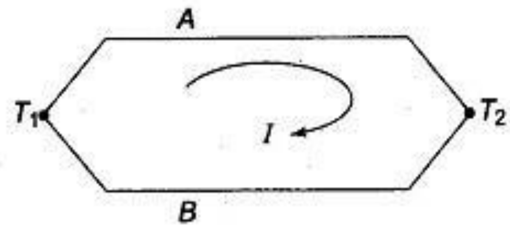


Fig. 13.42 Current through Two dissimilar Metals

A current will circulate around a loop made up of two dissimilar metal when the two junctions are at different temperatures. When this circuit is opened, a voltage appears that is proportional to the observed seeback current. The Thomson and Peltier emfs originate fromthe fact that, within conductors, the density of free charge carriers (electrons and holes) increases with temperature.

- If the temperature of one end of a conductor is raised above that of the other end, excess electrons from the hot endwill diffuse to the cold end. This results in an inducedvoltage, the**Thomson effect**, that makes the hot end positive with respect to the cold end.

Conductors made up of different materials have different free-carriers densities even when at the same temperature. When twodissimilarconductors are joined, electrons will diffuse across the junction from the conductor with higher electron density. When this happens theconductor losing electronsacquire a positive voltage with respect to the other conductor. This voltage is called the **Peltier emf.**

- When the junction is heated a voltage is generated, this is knownas seeback effect. The seeback voltage is linearly proportional for small changes in temperature.
- The magnitude of this voltage depends on the material used for the wires and the amount of temperature difference between the joined ends and the other ends. The junction of the wires of the Thermocouple Circuit is called the **sensing junction.**
- The temperature at this end of the Thermocouple Circuitwire is a reference temperature, this function is known as the reference, also called as the cold junction.
- When the reference end is terminated by a meter or a recording device, the meter indication will be proportional to the temperature difference between the hot junction and the reference junction.
- The magnitude of thethermalemf depends on the wire materials used and in the temperature difference between the junctions.
- Thermalemfsforsomecommonthermocouplematerials.

The thermocouple (TC) is a temperature transducerthat develops an emf that is a function ofthe temperature difference between its hot and cold junctions.

- **Type 'E'**Thermocoupleunits useChromel alloy as the positiveelectrodeandconstantan alloy as the negative electrode.
- **Type 'S'**Thermocouple produces the least output voltage but can be used over greatest temperature range.
- **Type'T'**usescopperandconstantan.

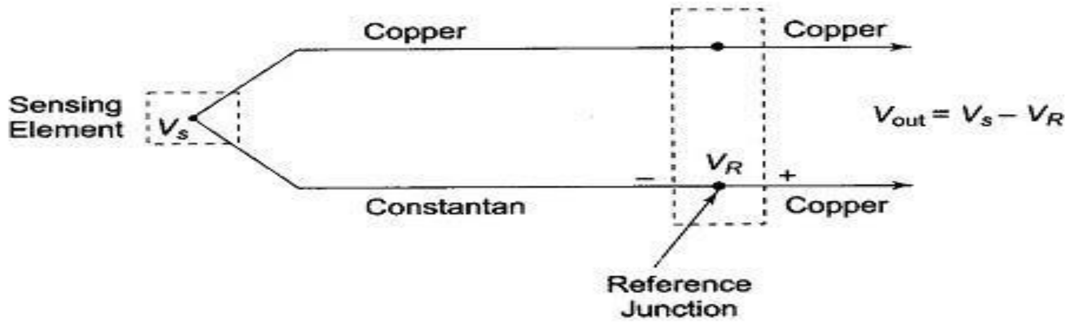


Fig. 13.44 **A Type T Thermocouple with Reference Junction**

Theemfofthethermocouple: E

$= c(T_1 – T_2) + k(T_1^2 – T_2^2)$

Where

c and k =constantofthethermocouplematerials T_1

=The temperature of the "hot" junction

T_2 =Thetemperatureofthe"cold"or"reference" junction

Advantagesof Thermocouple

- Ithasruggedconstruction.
- Ithasatemperaturerangefrom—270°C-2700°C.
- Usingextensionleadsandcompensatingcables,longdistancestransmissionfor temperature measurement is possible.
- Bridgecircuitsarenotrequiredfortemperaturemeasurement.
- Comparativelycheaperin cost.
- Calibrationcheckscanbeeasily performed.
- Thermocouplesoffergoodreproducibility.
- Speedofresponseishighcompared tothefilledsystemthermometer.
- Measurementaccuracyisquitegood.

DisadvantagesofThermocouple

- Coldjunctionandothercompensationisessentialforaccurate
- Theyexhibitnon-linearityintheemfversustemperaturecharacteristics.

- Toavoidstrayelectricalsignalpickup,properseparationofextensionleadsfrom thermocouple wire is essential.
- Strayvoltagepick-upsarepossible.
- Inmanyapplications,thesignalsneedtobeamplified.

CapacitiveTransducer

Thecapacitanceofaparallelplatecapacitorisgivenby

$$C = \frac{kA\varepsilon_0}{d}(Farads)$$

where

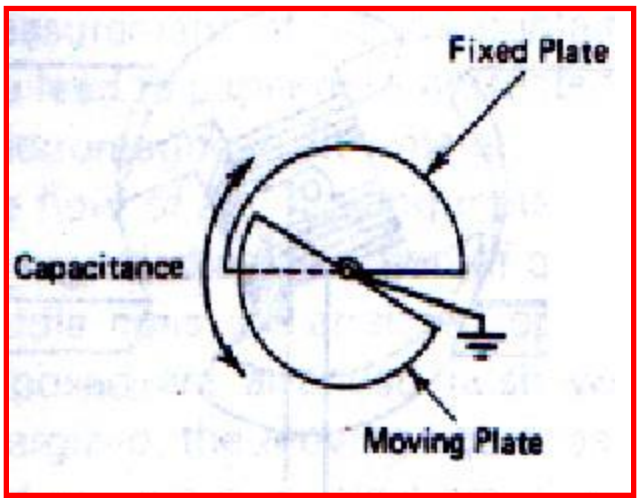
k =dielectric constant

A =theareaoftheplate,inm^2εo

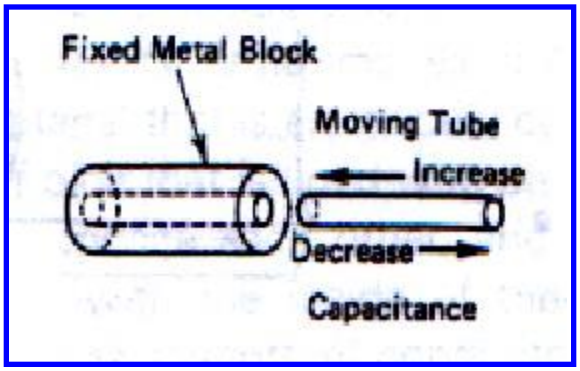
= 8.854×10^{-12} F/m

d =theplateplacinginm

The capacitance of this unit proportional to the amount of the fixed plate that is covered,thatshaded by moving plate.This type of transducer will give sign proportionalto curvilinear displacement or angular velocity.

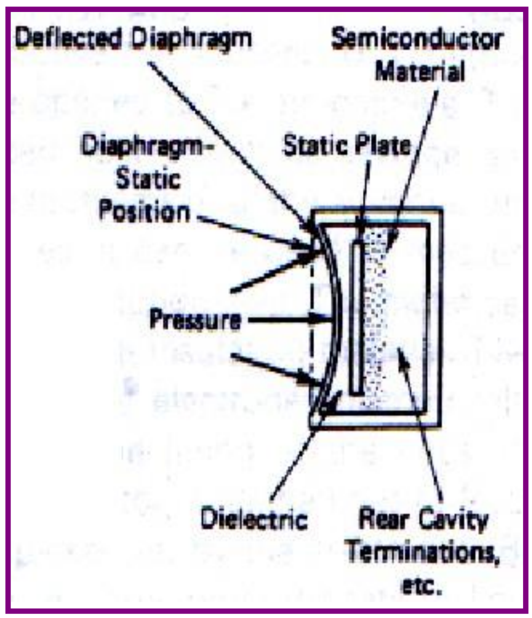


It consists of a fixed cylinder and a moving cylinder. These pieces are configured so the moving piece fits inside the fixed piece but insulated from it.



CapacitivePressureTransducer

Atransducerthatvariesthespacing betweensurfaces.Thedielectriciseitherairorvacuum. Often used as Capacitance microphones.



InductiveTransducer

Inductive transducers may be either of the self generating or passive type. The self generating type utilises the basic electrical generator principle, i.e, a motion between a conductor and magnetic field induces a voltage in the conductor (generator action). This relative motion between the field and the conductor is supplied by changes in the measurand.

An inductive electromechanical transducer is a device that converts physical motion (position change) into a change in inductance. Transducers of variable inductance type work upon one of the following principles:

1.VariationofselfinductanceandVariationofmutualinductance

Inductive transducers are mainly used forthe measurement of displacement. The displacement to be measured is arranged to cause variation in any of three variables

- **Numberofturns**
- **Geometricconfiguration**
- **Permeabilityofthemagneticmaterial**

$$L = \frac{e}{di/dt} = \frac{N^2}{R} \qquad (13.10)$$

ChangeinSelfInductancewithNumbersofTurns

The output may be caused by a change in the number of turns. Figures 13.14(a) and (b) are transducers used for, the measurement of displacement of linear and angular movement respectively.

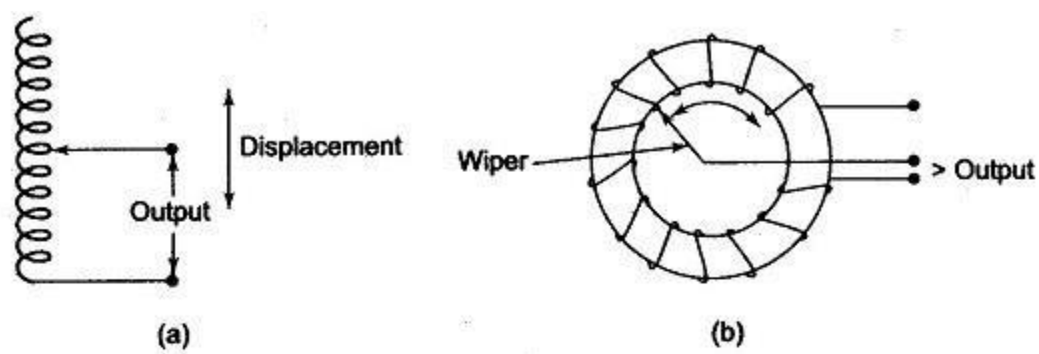


Fig. 13.14 (a) Linear Inductive Transducer (Using Air Core) (b) Angular Inductive Transducer (Using Ferrite Core)

Transducer Working on the Principle of Change in Self Inductance with Change inPermeability

Figure 13.15 shows anInductive Transducer Definition which works on the principle of the variation of permeability causing a change in self inductance. The iron core is surrounded by a winding. If the iron core is inside the winding, its permeability is increased, and so is the inductance. When the iron core is moved out of the winding, the permeability decreases, resulting in a reduction of the self inductance of the coil. This transducer can be used for measuring displacement.

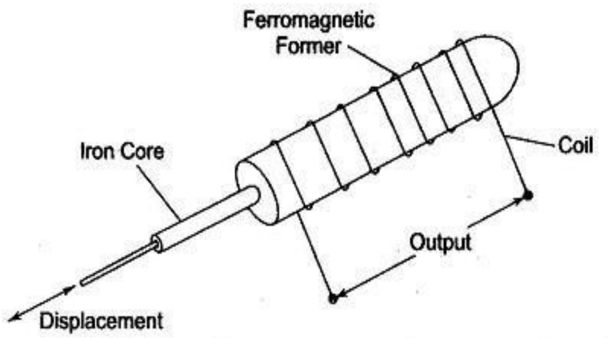


Fig. 13.15 Inductive Transducer Working on the Principle of Variation of Permeability

VariableReluctanceTypeTransducer

A transducer of the variable type consists of a coil wound on a ferromagnetic core. The displacement which is tobe measured is appliedtoa ferromagnetictarget. The target does not have any physical contact with the core on which it is mounted. The core and the target are separated by an air gap, as shown in Fig. 13.16(a)

The reluctance of the magnetic path is determinedby the size of the airgap. The inductance of the coil depends upon the reluctance of the magnetic circuits. The self inductance of the coil is given by

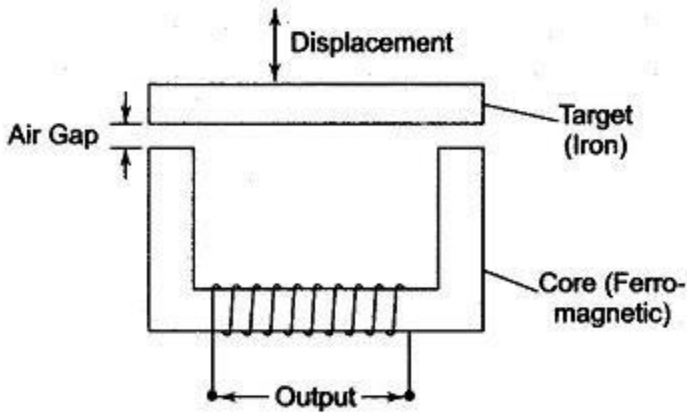


Fig. 13.16(a) Variable Reluctance Transducer

$$L = \frac{N^2}{R_i + R_g} \qquad (13.11)$$

where N = number of turns

R_i = reluctance of iron parts

R_g = reluctance of air gap

Butreluctanceoftheairgapisgivenby

$$R_g = \frac{l_g}{\mu_o \times A_g} \qquad (13.13)$$

Where

lg=lengthoftheair gap

Ag=areaofthefluxpaththroughair μ_o =

permeability

Rgisproportionalto lg,as$\mu_o$andAgareconstants.

Hence L is proportionalto l/lg, i.e. the self inductance ofthe coilis inversely proportionaltothe length of the air gap.

DifferentialOutputTransducer

- The inductance of one part increases from L to L + ΔL, while that of the other part decreases from L to L — ΔL. The change is measured as the difference of the two, resulting inanoutput of2ΔL insteadofΔL,when onewindingisused. This increasesthe sensitivity and also eliminates error.

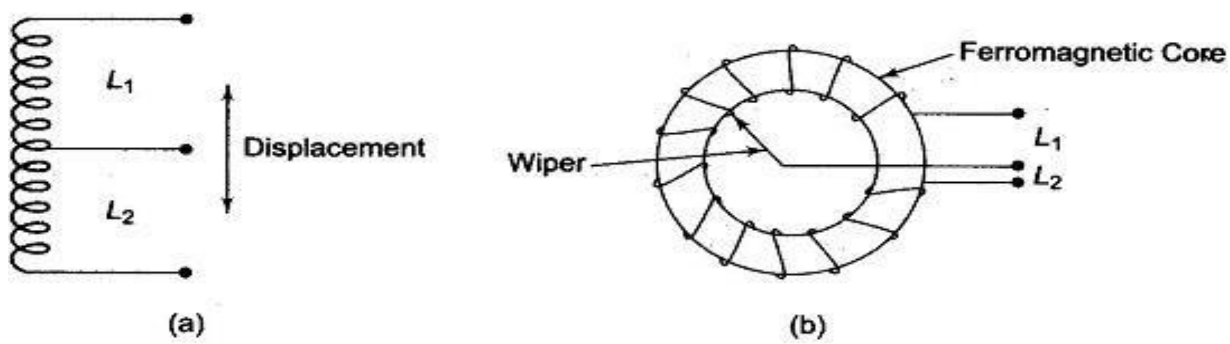


Fig. 13.17 (a) Linear Differential Output Transducer
(b) Angular Differential Output Transducer

LinearVariableDifferentialTransducer(LVDT)

- Thedifferentialtransformerisapassiveinductivetransformer.Itisalsoknownasa Linear Variable Differential Transducer(LVDT).

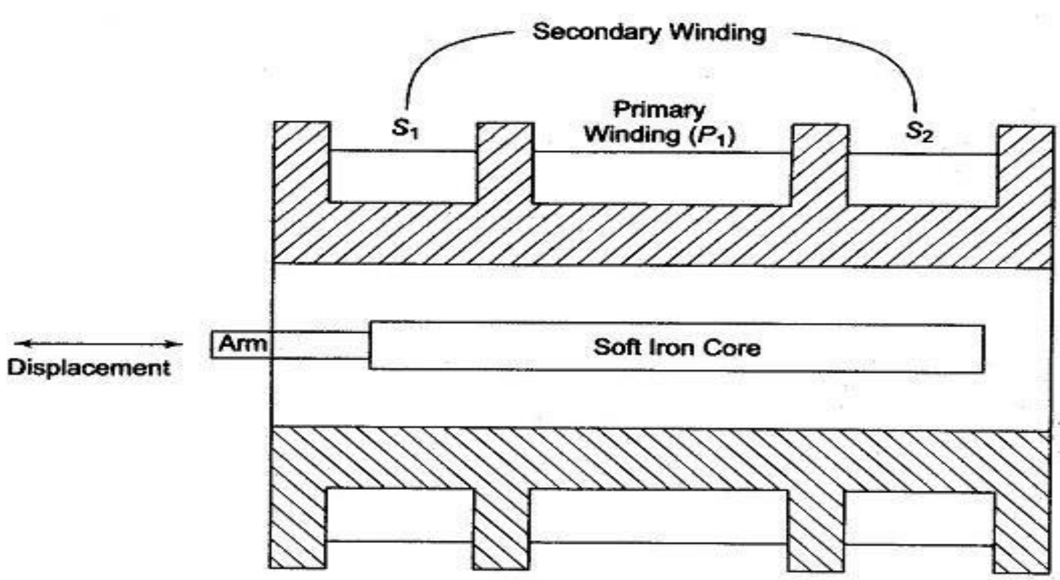


Fig. 13.19 Construction of a Linear Variable Differential Transducer (LVDT)

- ThetransformerconsistsofasingleprimarywindingP1andtwosecondarywindings S1and S2wound on ahollowcylindricalformer.Thesecondarywindingshavean equal number of turns and are identically placed on either side of the primary windings. The primary winding is connected to an ac source.

- Anmovablesoftironcoreslideswithinthehollowformerandthereforeaffectsthemagnetic couplingbetween the primary and the two secondaries. The displacement to be measured is applied to an arm attached to the soft iron core.
- When the core is in its normal (null) position, equal voltages are induced in the two secondary windings. The frequency of the ac applied to the primary winding rangesfrom 50 Hz to 20 kHz.
- TheoutputvoltageofthesecondarywindingsS1isEs1andthatofsecondarywinding S2is Es2.
- In order to convert the output from S1 to S2 into a single voltage signal, the two secondaries S1and S2are connected in series opposition,

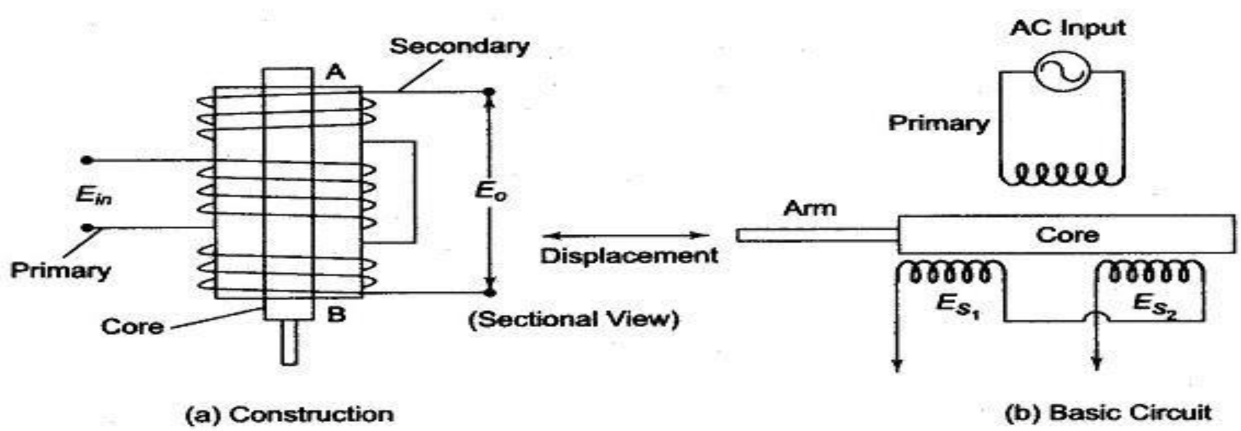


Fig. 13.20 Secondary Winding Connected for Differential Output

- Hence the output voltage of the transducer is the difference of the two voltages. Therefore the differential output voltage Eo=Es1~Es2.
- When the core is at its normal position, the fluxlinking with both secondary windings is equal, and hence equal emfs are induced inthem. Hence, at null position Es1= Es2. Since the output voltage of the transducer is the difference of the two voltages, the output voltage Eois zero at null position.
- Now,ifthecoreismovedtotheleftofthenullposition,morefluxlinkswithwinding S1 and less with winding S2. Hence, output voltage Es1 of the secondary winding S1 is greater than Es2 . The magnitude of the output voltage of the secondary is then Es1—Es2, in phase with Es1(the output voltage of secondary winding S1).

- Similarly, if the core is moved to the right of the null position, the flux linking with windingS2becomesgreaterthanthatlinkedwithwindingS1.Thisresultsin E_{S2} becoming larger than E_{S1}. The output voltage in this case is $E_o = E_{S2} - E_{S1}$ and is in phase with E_{S2}.

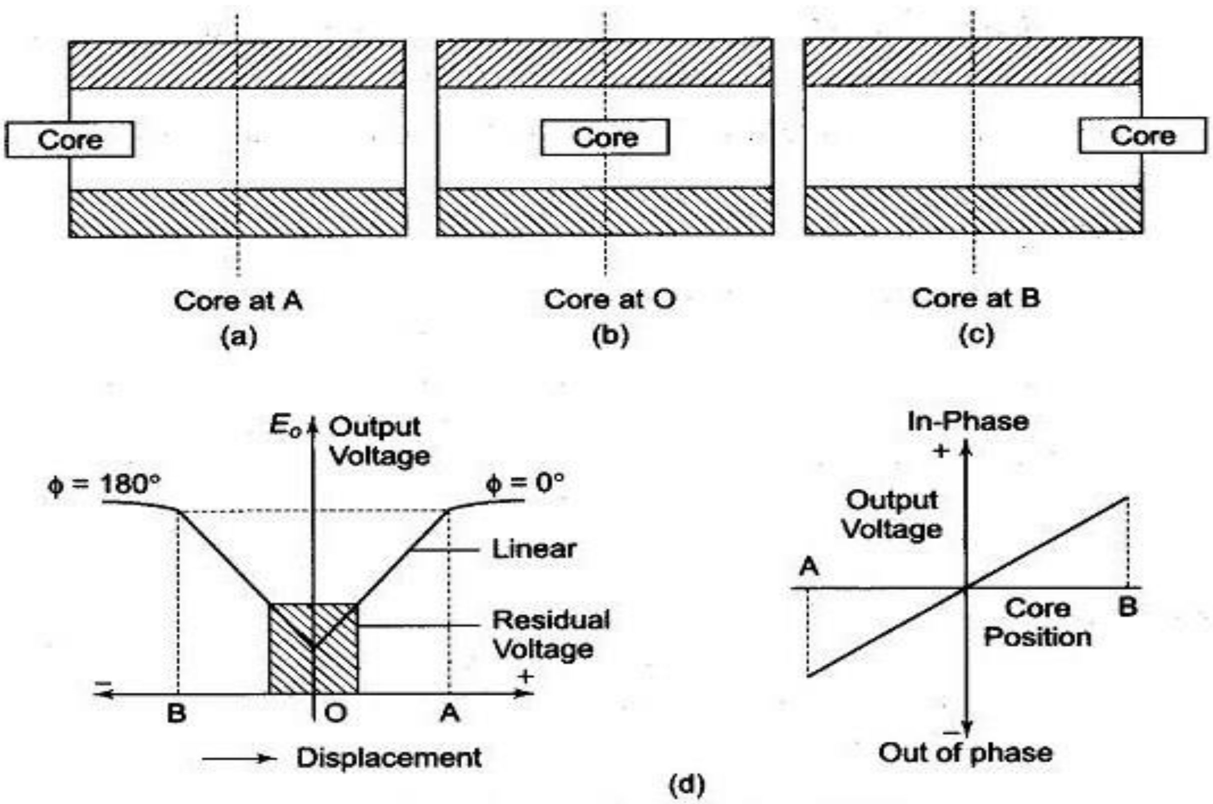


Fig. 13.21 (a), (b), (c) Various Core Position of LVDT
(d) Variation of Output Voltage vs Displacement

Advantages

- **Linearity:**Theoutputvoltageofthistransducerispracticallylinearfordisplacements upto 5 mm (a linearity of 0.05% is available in commercial LVDTs).
- **Infiniteresolution:**Thechangeinoutputvoltageisstepless.Theeffectiveresolution depends more on the test equipment than on the
- **Highoutput:**Itgivesahighoutput(thereforethereisfrequentlynoneedfor intermediate amplification devices).
- **Highsensitivity:**Thetransducerpossessesasensitivityashighas40 V/mm.
- **Ruggedness:**Thesetransducerscanusuallytolerateahighdegreeofvibrationand shock.
- **Lessfriction:**Thereare nosliding contacts.

- **Lowhysteresis:** Thistransducerhasalowhysteresis,hencerepeatabilityisexcellent under all conditions.
- **Lowpower:**consumptionMostLVDTsconsume lessthan1W

Disadvantages

- Largedisplacementsarerequiredforappreciabledifferentialoutput.
- Theyaresensitivetostraymagneticfields(butshieldingispossible).
- The receiving instrument must be selected to operate on ac signals, or ademodulatornetwork must be used if a dc output is required.
- Thedynamic responseis limitedmechanically by themass ofthe coreandelectrically by the applied voltage.
- Temperaturealsoaffectsthetransducer.

PiezoelectricTransducer

- A Symmetrical crystalline materials such as Quartz, Rochelle salt and Barium titanate produceanemfwhen they are placed under stress. This property is used in PiezoelectricTransducer Working Principle, where a crystal is placed between a solid base and the force-summing member.

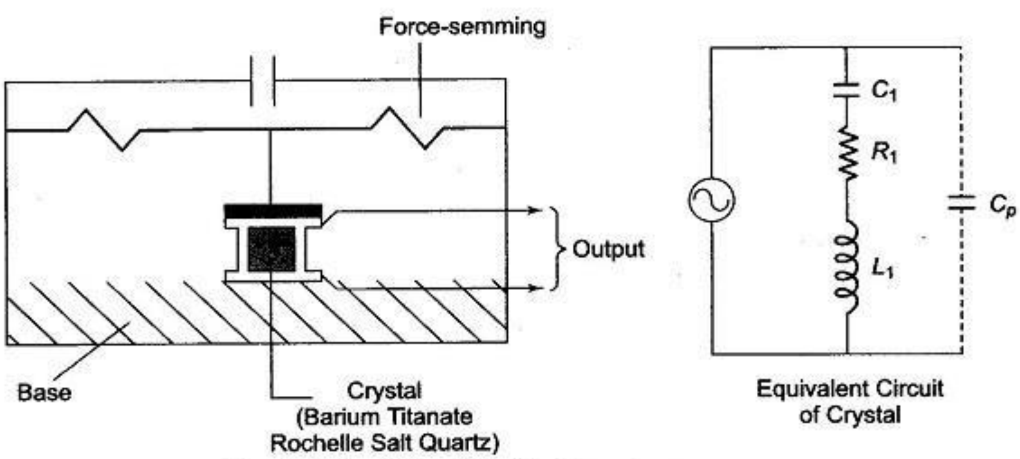


Fig. 13.31 Piezo Electric Transducer

- For a Piezoelectrical Transducer element under pressure, part of the energy is,converted to anelectric potentialthat appears on opposite faces of the element, analogoustoachargeontheplatesofacapacitor.Therestoftheapplied energyis converted to mechanical energy, analogous to a compressed spring. When the pressure is removed, it returns to its original shape and loses its electric charge.

Fromtheserelationships,thefollowingformulashavebeenderivedforthecoupling coefficient K

$$K = \frac{\text{Mechanical energy converted to electrical energy}}{\text{Applied mechanical energy}}$$

or

$$K = \frac{\text{Electrical energy converted to mechanical energy}}{\text{Applied electrical energy}}$$

- Analternating voltageapplied to a crystal causes it to vibrate at its natural resonance frequency. Since the frequency is a very stable quantity, Piezoelectrical Transducer crystals are principally used in HF accelerometers.
- The principal disadvantage is that voltage will be generated as long as the pressure applied to the piezo electric element changes.

Synchros

wherein a change in the inductance of a sensing element is produced by a pressure change PressureInductiveTransducer.ASynchrocanbeanangularpositiontransducerworking onPressure Inductive Transducer principle, wherein a variable coupling between primary and secondary winding is obtained by changing the relative orientation of the windings.A Synchro appears like anAC motorconsisting of a rotor and a stator.They have a rotor with one or three windings capable of revolving inside a fixed stator. There are two common types of rotors, the salientpole and the wound rotor.

- The stator has a3-phase winding with the windings of the3-phase displaced by 120°.The synchro may be viewed as a variable coupling transformer.

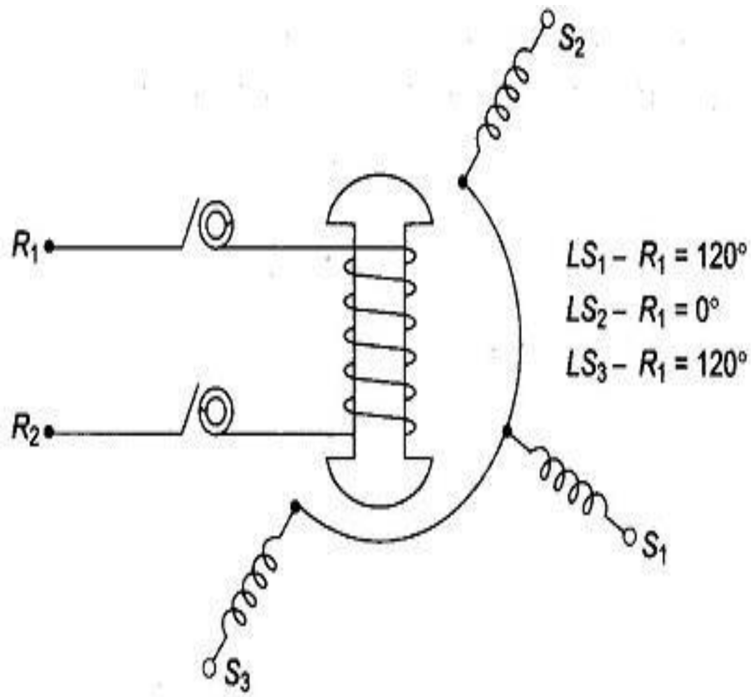


Fig. 13.23 Basic Synchro

- The rotor is energized by an ac voltage and coupling between rotor and stator windings varies as a trigonometric or linear function of the rotor position.

A Synchro system formed by interconnection of the devices called the Synchro transmitter andSynchro control transmitter is perhaps the most widely usederror detector in feedback control system. It measures and compares two angular displacements and its outputvoltage is approximately linear with angular displacement.

Whenanacexcitationvoltageisappliedtotherotor,theresultantcurrentproduces a magnetic field and by transformer action induces voltages in the stator coils.

The effective voltage induced in any stator coil depends upon the angular position of thecoil axis with respect to the rotor axis.

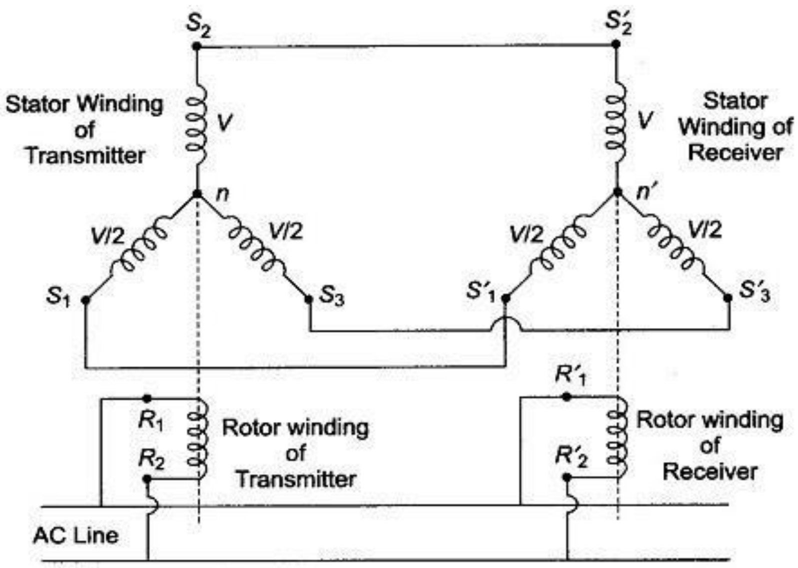
Suppose the voltage is V, the coupling between S1 and S2 of the stator and primary (rotor) winding is a cosine function. In general if the rotor is excited by 50 Hz ac, also called reference voltage, the voltage induced in any stator winding will be proportional to the cosine of the angle between the rotor axis and the stator axis.

Forexample,ifareferencevoltageVsinωtexcitestherotorofasynchro(R_1—R_2),the stator terminals will have a voltage of the following form:

ThesevoltagesareknownasSynchroformat voltages.

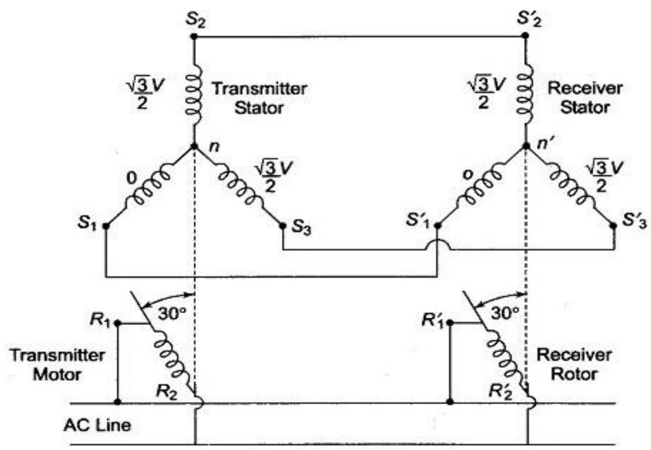
$$V(S_1 - S_2) = V \sin \omega t \sin \theta$$
$$V(S_1 - S_2) = V \sin \omega t \, (\sin \theta + 120°)$$
$$V(S_2 - S_3) = V \sin \omega t \, (\sin \theta + 240°)$$

- ThesevoltagesareknownasSynchroformat voltages.



(a)

(a) Torque Transmission Using Synchro Trans



(b)

Fig. 13.24 (b) Follow Up Conditions of Transmitter-Receiver System

A Synchro system formed by interconnection of the devices called the Synchro transmitter and Synchro control transmitter is perhaps the most widely used error detector in feedback control system. It measures and compares two angular displacements and its output voltage is approximately linear with angular displacement.

The conventional Synchro transmitter (TX) uses a salient pole rotor with sleeved slot. When an acexcitationvoltage is appliedtothe rotor,the resultant current produces a magneticfieldand bytransformeractioninducesvoltagesinthestatorcoils.Theeffectivevoltageinducedin anystator coildepends upon the angular position of the coil axis with respect to the rotor axis (when the coil voltage is known, the induced voltage at any angular displacement can be determined).

Initially winding S2 of the stator of transmitter is positioned for maximum coupling with the rotor winding as shown in Fig. 13.24(a). Suppose the voltage is V, the coupling between S1and S2ofthe statorandprimary (rotor) winding is a cosine function. Ingeneralifthe rotoris excited by 50 Hz ac, also called reference voltage, the voltage induced in any stator winding will be proportional to the cosine of the angle between the rotor axis and the stator axis. The voltages inducedacrossanypairofstatorterminals (S1—S2,SI—S3,orS2—S3)willbesum or difference, depending on the phase of the voltage measured across the coils.

For example, if a reference voltage V sin ωt excites the rotor of a synchro (R1— R2), the stator terminals will have a voltage of the following form:

$$V(S_1 - S_2) = V \sin \omega t \sin \theta$$
$$V(S_1 - S_2) = V \sin \omega t (\sin \theta + 120°)$$
$$V(S_2 - S_3) = V \sin \omega t (\sin \theta + 240°)$$

whereθistheshaftangle.

ThesevoltagesareknownasSynchroformat voltages.

Therefore, the effective voltages in these windings are proportional to cos 60° or they are V/2 each. So long as the rotors of the transmitterand receiver remains in this position, no current will flow between the stator windings because of the voltage balance.

When the rotor of the transmitter is moved to a new position, the voltage balance is disturbed or changed. Assuming that the rotor of the transmitter is moved through 30° as shown in Fig. 13.24(b), the stator winding voltages of the transmitter will be changed to 0,√3/2 V and √3/2 V respectively.

Hence,a voltage imbalanceoccurs betweenthestatorwindingsofthetransmitterandreceiver. This voltage imbalance between the windings causes current to flow between the windings producing a torque that tends to rotate the rotor of the receiver to a new position where the voltage balance is again restored. This balance is restored only ifthe receiverturns throughthe same angle as the transmitter and also the direction of rotation is the same as that of the transmitter. Hence a Synchrocan be usedto determine the magnitude and direction ofangular displacement.

MagnetostrictiveTransducer

- Magnetostrictive materials transducer converts magnetic energy to mechanical energy andvice versa. As a magnetostrictive material is magnetized,it strains; that is it exhibits a change in length per unit length.

- Conversely, if an external force produces a strain in a magnetostrictive material, the material's magneticstatewillchange. This bi-directional coupling betweenthemagnetic and mechanical states of a magnetostrictive material provides a transduction capability that is used for both actuation and sensing devices.

Magnetostrictionisaninherentmaterialpropertythatwillnotdegradewithtime.

HotWireAnemometer

BasicPrinciple:

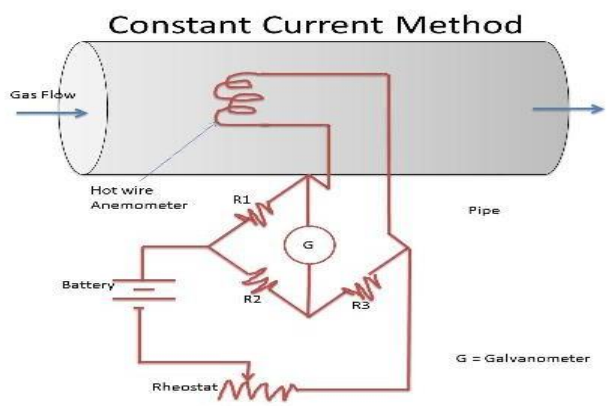
- When an electrically heated wire is placed in a flowing gas stream, heat is transferred from the wire to the gas and hence the temperature of the wire reduces, and due to this, the resistance of the wire also changes. This change in resistance of the wire becomes a measure of flow rate.
- Thereare twomethods ofmeasuring flow rateusing aanemometer bridgecombination namely:

Constantcurrentmethod

- Constanttemperaturemethod

Constant current method

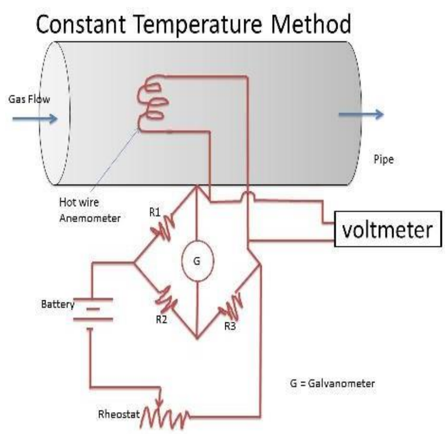
- The bridge arrangement along with the anemometer has been shown in diagram. Theanemometer is kept in the flowing gas stream to measure flow rate.



- A constant current is passed through the sensing wire. That is, the voltage across the bridge circuit is kept constant, that is, not varied.
- Due to the gas flow, heat transfer takes place from the sensing wire to the flowing gas and hence the temperature of the sensing wire reduces causing a change in the resistance of the sensing wire. (this change in resistance becomes a measure of flow rate).
- Due to this, the galvanometer which was initially at zero position deflects and this deflection of the galvanometer becomes a measure of flow rate of the gas when calibrated.

Constanttemperaturemethod

- The bridge arrangement along with the anemometer has been shown in diagram. The anemometer is kept in the flowing gas stream to measure flow rate.
- Acurrentisinitially passedthroughthe wire.



- Due to the gas flow, heat transfer takes place from the sensing wire to the flowing gas and this tends to change the temperature and hence the resistance of the wire.
- The principle in this method is to maintain the temperature and resistance of the sensing wire at a constant level. Therefore, the current through the sensing wire is increased to bring the sensing wire to have its initial resistance and temperature.
- The electrical current required in bringing back the resistance and hence the temperature of the wire to its initial condition becomes a measure of flow rate of the gas when calibrated

UNIT-5

BRIDGES

Twotypes ofbridgecircuitsareusedinmeasurement:

1) DCbridge:

a) wheatstonebridge

b) kelvin bridge

2) ACbridge:MaxwellBridge

wheatstone bridge: The Wheatstone bridge is an electrical bridge circuit used to measure resistance.It consists of a voltage source and a galvanometer that connects two parallel branches,containing fourresistors. One parallelbranchcontains one known resistance andone unknown; the other parallel branch contains resistors of known resistances.

In the circuit at right, $R4$ is the unknown resistance; $R1$, $R2$ and $R3$ are resistors of known resistance where the resistance of $R3$ is adjustable. How to determine the resistance oftheunknownresistor,R4?"Theresistancesoftheotherthreeareadjustedandbalanced until the current passing through the galvanometer decreases to zero".

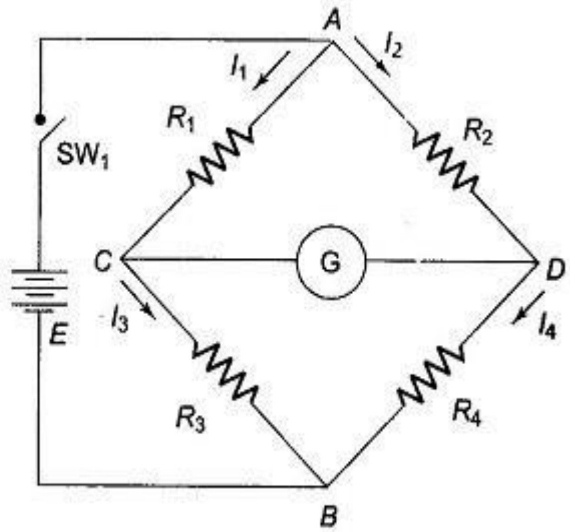


Fig. 11.1 Wheatstone's Bridge

*R*3isvarieduntilvoltagebetweenthetwomidpoints(**B**and**D**)willbe**zero**and nocurrentwill flow through the galvanometer.

Whenthe bridgeisinbalancecondition(nocurrentflowsthroughgalvanometerG),weobtain; voltage drop across R1 and R2 is equal,

I1R1=I2R2

voltagedropacrossR3andR4isequal,

I3R3=I4R4

Forthegalvanometercurrenttobezero,thefollowingconditionsshouldbesatisfied

$$I_1 = I_3 = \frac{E}{R_1 + R_3} \qquad (11.2)$$

$$I_2 = I_4 = \frac{E}{R_2 + R_4} \qquad (11.3)$$

SubstitutinginEq.

$$\frac{E \times R_1}{R_1 + R_3} = \frac{E \times R_2}{R_2 + R_4}$$

$$R_1 \times (R_2 + R_4) = (R_1 + R_3) \times R_2$$

$$R_1 R_2 + R_1 R_4 = R_1 R_2 + R_3 R_2$$

$$R_4 = \frac{R_2 R_3}{R_1}$$

UnbalancedWheatstone'sBridge

- To determine the amount of deflection that would result for a particular degree of unbalance,generalcircuitanalysiscanbeapplied,butweshalluseThevenin'stheorem.

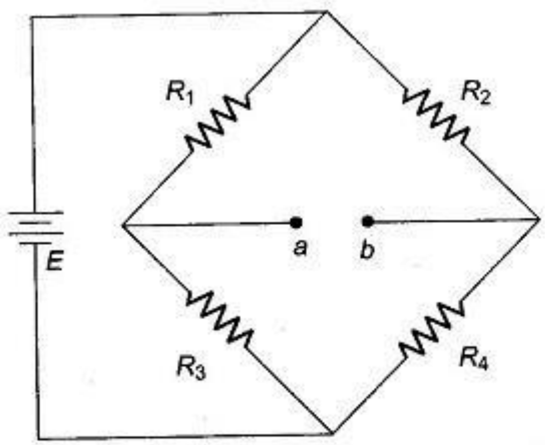


Fig. 11.2 Unbalanced Wheatstone's Bridge

Applying the voltage divider equation, the voltage at point a can be determined as follows

$$E_a = \frac{E \times R_3}{R_1 + R_3} \quad \text{and at point } b, \quad E_b = \frac{E \times R_4}{R_2 + R_4}$$

Therefore, the voltage between a and b is the difference between E_a and E_b, which represents Thevenin's equivalent voltage.

$$E_{th} = E_{ab} = E_a - E_b = \frac{E \times R_3}{R_1 + R_3} - \frac{E \times R_4}{R_2 + R_4}$$

Therefore

$$E_{ab} = E\left(\frac{R_3}{R_1 + R_3} - \frac{R_4}{R_2 + R_4}\right)$$

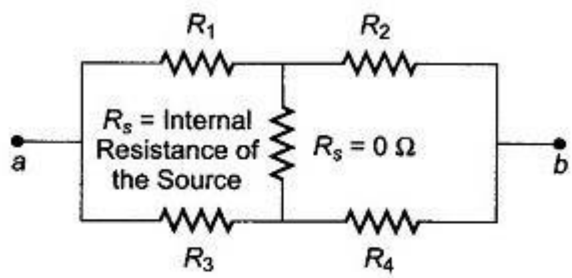


Fig. 11.3 Thévenin's Resistance

The equivalent resistance of the circuit is $R_1//R_3$ in series with $R_2//R_4$ i.e. $R_1//R_3 + R_2//R_4$.

$$R_{th} = \frac{R_1\ R_3}{R_1 + R_3} + \frac{R_2\ R_4}{R_2 + R_4}$$

Therefore, Thevenin's equivalent circuit is given in Fig. 11.4. Thevenin's equivalent circuit for the bridge, as seen looking back at terminals a and b in Fig. 11.2, is shown in Fig. 11.4.

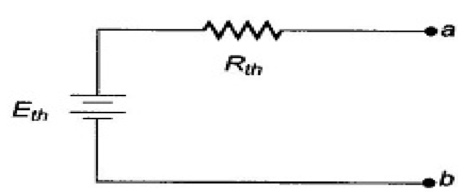


Fig. 11.4 Thévenin's Equivalent

$$I_g = \frac{E_{th}}{R_{th} + R_g} \qquad (11.5)$$

Kelvin'sbridge

Kelvin'sbridgeisamodificationofWheatstone'sbridgeandis usedtomeasurevalues ofresistancebelow1Ω.Inlowresistancemeasurement,theresistanceofthe leadsconnecting the unknown resistanceto the terminal of the bridge circuit may affect the measurement.

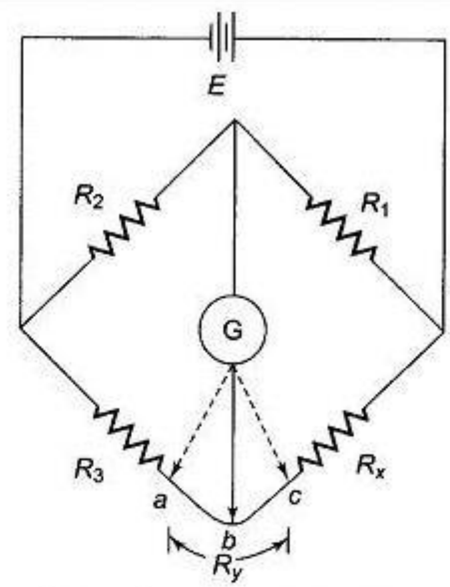


Fig. 11.10 Kelvin's Bridge

$$\frac{R_{cb}}{R_{ab}} = \frac{R_1}{R_2} \qquad (11.6)$$

and the usual balance equations for the bridge give the relationship

$$(R_x + R_{cb}) = \frac{R_1}{R_2}(R_3 + R_{ab}) \qquad (11.7)$$

$$R_{ab} + R_{cb} = R_y \text{ and } \frac{R_{cb}}{R_{ab}} = \frac{R_1}{R_2}$$

$$\frac{R_{cb}}{R_{ab}} + 1 = \frac{R_1}{R_2} + 1$$

$$\frac{R_{cb} + R_{ab}}{R_{ab}} = \frac{R_1 + R_2}{R_2}$$

i.e.

$$\frac{R_y}{R_{ab}} = \frac{R_1 + R_2}{R_2}$$

$$R_{ab} = \frac{R_2 \ R_y}{R_1 + R_2} \quad \text{and as} \quad R_{ab} + R_{cb} = R_y$$

$$R_{cb} = R_y - R_{ab} = R_y - \frac{R_2 \ R_y}{R_1 + R_2}$$

$$R_{cb} = \frac{R_1 \ R_y + R_2 \ R_y - R_2 \ R_y}{R_1 + R_2} = \frac{R_1 \ R_y}{R_1 + R_2}$$

SubstitutingforRabandRcbinEq.(11.7),we have

$$R_x + \frac{R_1 R_y}{R_1 + R_2} = \frac{R_1}{R_2}\left(R_3 + \frac{R_2 R_y}{R_1 + R_2}\right)$$

$$R_x + \frac{R_1 R_y}{R_1 + R_2} = \frac{R_1 R_3}{R_2} + \frac{R_1 R_2 R_y}{R_2 (R_1 + R_2)}$$

$$R_x = \frac{R_1 R_3}{R_2} \tag{11.8}$$

<u>MaxwellBridge:</u>

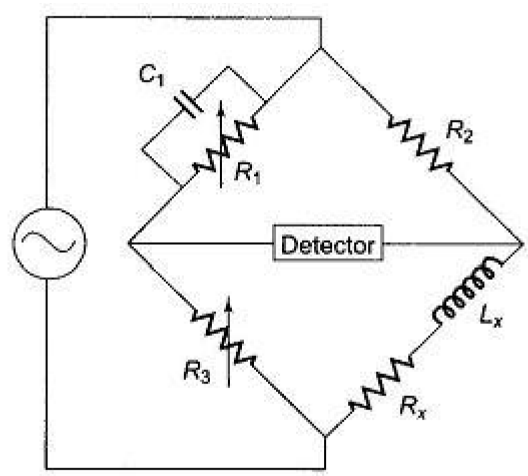


Fig. 11.21 Maxwell's Bridge

Thegeneralequationforbridgebalanceis

Z1Z3=Z2Z4

Maxwell'sbridgeislimitedtothe measurementoflow Qvalues(1 —10).The measurement is independent of the excitation frequency. The scale of the resistance canbecalibratedtoread inductancedirectly.

The Maxwellbridge using a fixed capacitorhas the disadvantage that there is an interaction between theresistanceand reactance balances. This can be avoided by varying the capacitances, instead of R2and R3, to obtain a reactancebalance.

$$Z_1 Z_x = Z_2 Z_3$$

i.e.
$$Z_x = \frac{Z_2 Z_3}{Z_1} = Z_2 Z_3 Y_1$$

Where $Z_1 = R_1$ in parallel with C_1 i.e. $Y_1 = \frac{1}{Z_1}$

$$Y_1 = \frac{1}{R_1} + j\omega C_1$$

$$Z_2 = R_2$$

$$Z_3 = R_3$$

$Z_x = R_x$ in series with $L_x = R_x + j\omega L_x$

$$R_x + j\omega L_x = R_2 R_3 \left(\frac{1}{R_1} + j\omega C_1 \right)$$

$$R_x + j\omega L_x = \frac{R_2 R_3}{R_1} + j\omega C_1 R_2 R_3$$

Equating real terms and imaginary terms we have

$$R_x = \frac{R_2 R_3}{R_1} \text{ and } L_x = C_1 R_2 R_3$$

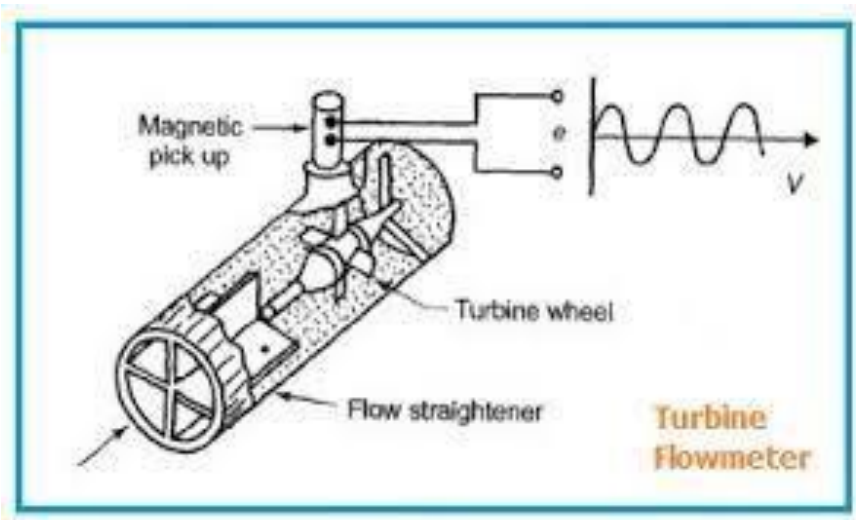
$$Q = \frac{\omega L_x}{R_x} = \frac{\omega C_1 R_2 R_3 \times R_1}{R_2 R_3} = \omega C_1 R_1$$

<u>MeasurementofPhysicalparametersFlow</u>

<u>Measurement</u>

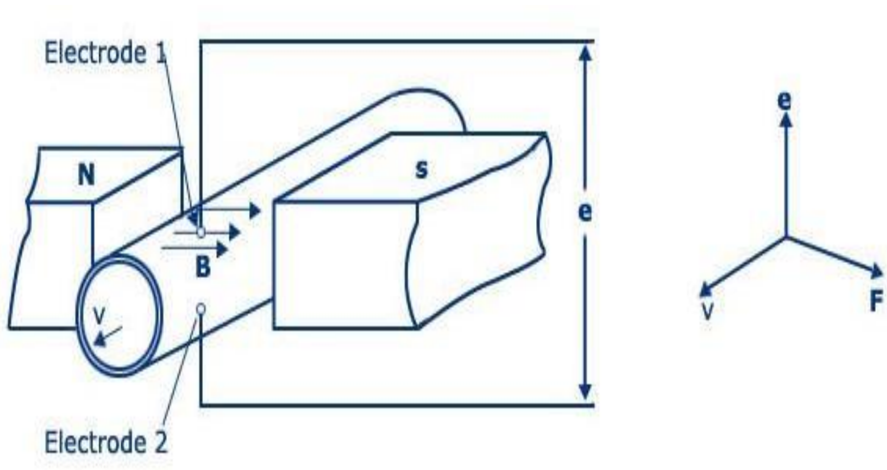
- Turbineflowmeter
- electromagneticflowmeter
- UltrasonicFlowMeter

Turbineflowmeter:



The turbine flow metertranslates the mechanical action ofthe turbine rotating inthe liquid flow around an axis into a user-readable rate of flow (gpm, lpm, etc.). The turbine tends to have all the flow traveling around it.The turbine wheel is set in the path of a fluid stream. The flowing fluid impinges onthe turbine blades, imparting a force to the blade surface and setting the rotor in motion. When a steady rotation speed has been reached, the speed is proportional to fluid velocity. Turbine flow meters are used for the measurement of natural gas and liquid flow. These are less accurate.

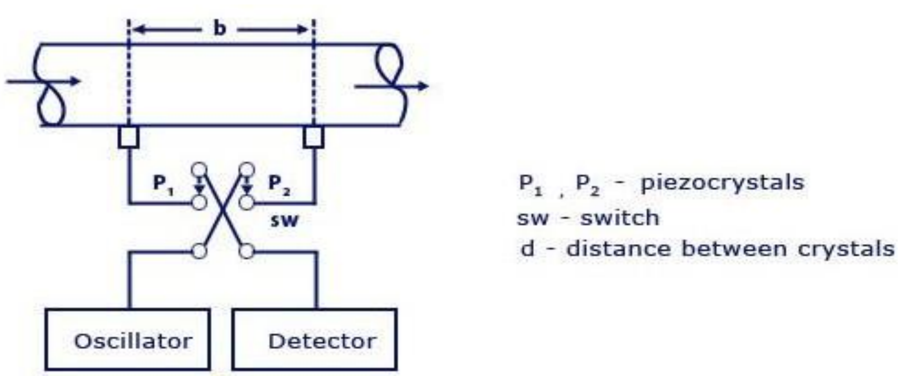
Electromagneticflowmeter:



An electromagnetic flow meter can be used to measure the flow of fluids. According to Faraday’slaw,a voltage‘e’isinduced ina conductoroflength‘l’meterswhichis dependent on the flux density and liquid flowing velocity ‘v’m/sThe parameter used for the measurement of flow is the speed of flow, and is measured in terms of the potential difference induced when the moves in a tubing/pipe with a transverse magnetic field impressed.

$$E=B.l.v$$

UltrasonicFlowMeter:



When pressure waves are released into the flowing fluid, their velocity and amplitudeareaffectedbythefluidvelocity.Ultrasonicflowmetershelpinmeasuringthese pressure wave changes, especially in the ones having frequencies greater than 20KiloHertz using specializedtechniques. There are twotypes ofultrasonic flow meters. One of them is based on the measurement of phase shift between the waves directed downstream and upstream alternately.

The other one is based on the measurement of separation of frequency of oscillation directed downstream and upstream simultaneously.

Liquidlevelmeasurement

- Resistivemethod
- Floatmethod
- Capacitancemethod
- Ultrasonicmethod

Humidity

The presence of moisture (water vapor, an invisible gas) in the atmosphere is measured by the humidity of the air.

Humidity and condensation are closely related as condensation inevitably occurs when the air is saturated with moisture (100% humidity).

Absolute humidity measures the amount of water vapor in air. Grams H_2O/m^3 of air. Thiswater is a gas, water vapor.

Relativehumiditymeasurestheamountofwatervaporinairrelativetothemaximum amount of water vapor the air could hold at that temperature.

Relativehumidity increases withincreasing watervaporordecreasing temperature. Coldair can’t “carry” as much water vapor as warm air.

The **dew point** is the temperature to which a given parcel of humid air must be cooled, atconstant barometric pressure, for water vapor to condense intoliquid water.

A hygrometer is a sensor that senses the amount of evaporated water in air by a mechanical or electronic method. A hygrometer is an instrument used for measuring the moisture content in the atmosphere.

Themorehumiditythat istheairthe longerthehairis.The lessthehumiditythetighterand shorter the hair gets. This transducers the amount of humidity into a force which can then be converted into an electronic or other mechanical signal.where salt water conducts electricitytoturna lightonisutilized inaelectronic resistivesensor.As humidity decreases, the salt concentration increases causing the resistivity of the circuit to decrease.

Thus, resistance is directly proportional to humidity. Since voltage changes are muchsmaller when dealing with small humidity differences, precise measurement equipment must be used making these sensors less practical. Temperature variation also produces varied results during constant humidity and must be taken into account when measuring from this sensor.

ElectrolyticHygrometer:

It utilizesa cell coated with a thin film of phosphorous pentoxide. Which absorbs water from the sample gas.The cell has a bifilar winding of inert electrodes on a fluorinated hydrocarboncapillary.Directvoltageappliedtotheelectrodes dissociatesthewaterwhichis absorbed by the P2O5 into hydrogen and oxygen.

Two electrons are required for electrolyzing each water molecule and so the current in the cell represents the no.of molecules dissociated.Based on the fliow rate tempeqature and current yields the humidity in ppm

Aluminiumoxidehygrometer:

It is formed by depositing a layer of aluminum oxide on a conductive substrate and then coating the oxide with a thin film of gold.The conductive base and gold layer become the capacitor electrodes and aluminium oxide coating becomes capacitors dielectric.

Watervapourpenetrates intothe gold layer and is absorbed by the oxidation layer. The no. of water molecules absorbed determines the impedance of the capacity which is measureof Relative humidity.

ResistiveHygrometer:

These are electrical transducers to measure Relative humidity. Insulative substrate coated with a lithium chloride solution of a controlled concentration. where salt water conducts electricitytoturna lightonisutilized inaelectronic resistivesensor.As humidity decreases, the salt concentration increases causing the resistivity of the circuit to decrease.

Thehygroscopicnatureofsaltmakesittotakeupwatervapourfromthesurrounding atmosphere.

Moisture

Itisdefined astheamount ofwaterabsorbedby asolidorliquid. Thestandardmethodis Gravimetric method. Moisture measurement involve electrical measurement. Electrical quantities like conductivity orcapacitance ofmaterial change withthe moisture content. The materials like coffee,grain,flour ,wood,coal,oil etc are used to measure moisture. conductivity andcapacitancevary from material to material.

Moisture Content (MC): a measure of the amount of water in wood

$$MC = \left[\frac{\text{Weight of Wood plus Water} - \text{Oven Dry Weight of Wood}}{\text{Oven Dry Weight of Wood}} \right] \times 100$$

$$= \left[\frac{\text{Weight of Water}}{\text{OD Weight}} \right] \times 100$$

Since MC calculation is based on OD weight, it can have values greater than 100%

VELOCITYMEASUREMENTS

MEASUREMENTOFLINEARVELOCITY

- Velocityisthefirstderivativeofdisplacement.
- Linearvelocityisdefined asthe rateof change of the position vector withtimeatan instant in time.
- Themethodsusedformeasurementoflinearvelocity

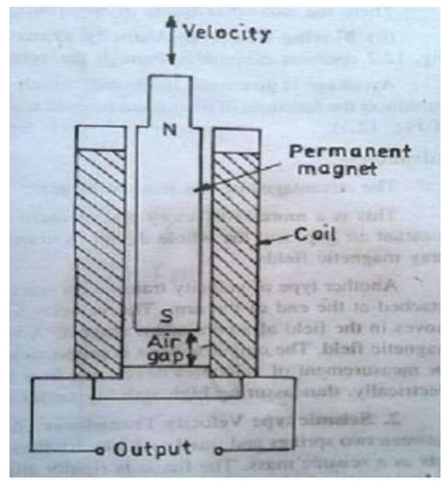
❑ Electro-magnetictransducers.

Thistransducerutilizesthevoltageproducedinacoilonaccountofchangeinflux linkages resulting from change in reluctance

- Movingmagnettype
- MovingCoilType

MOVINGMAGNETTYPETRANSDUCER:

Thesensingelementisarodtypepermanentmagnetthatisrigidlycoupledtothe devicewhosevelocityisbeingmeasured.Thereisacoilsurroundingthepermanent magnet.The motion of the magnet induces a voltage in the coil and theamplitude of the voltage isdirectly proportional to the velocity.The polarity of the output voltage determines the direction of motion.



- Foracoilplacedinmagneticfieldthevoltagegeneratedis:

$$e0=B.A.N.v$$

B=fluxdensity;Wb/m2, A=
area of coil;
N=Numberofturnsof coil,
v=relativevelocityofmagnetwithrespecttocoil

$$e0=Kv$$

K=BAN=aconstant

- **ADVANTAGES**

1. The maintenance requirements ofthese transducers are negligible, because there are no mechanical surfaces or contacts.

2. Theoutputvoltageislinearlyproportionaltovelocity.

- **DISADVANTAGES**

1. The performance of these transducers is adversely affected by stray magnetic fields. These fields can cause noise.
2. Thefrequency responseisusuallylimitedandisstated.
3. These transducers are not very useful for measurement of vibrations because their calibration deteriorates as contact with steel tools etc. leads to progressive demagnetization.

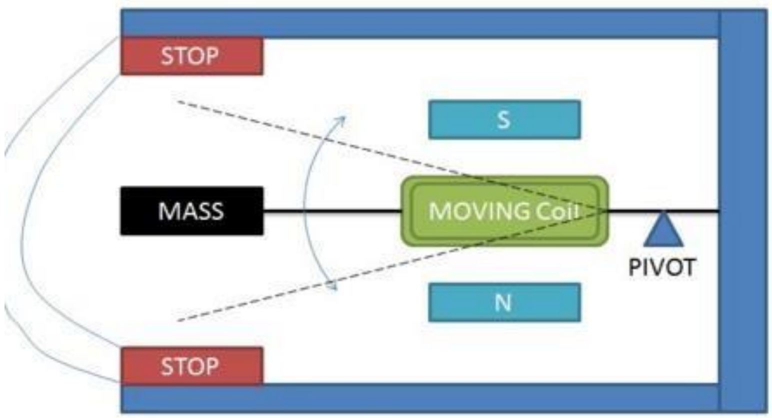
MOVINGCOILTYPEVELOCITYTRANSDUCER:

It operates essentially through the action of a coil moving in a magnetic field. A voltage is generated in the coil which is proportional to the velocity of the coil. The velocity to be measured is applied to the arm and therefore the coil moves in the field of permanent magnet.A voltage is generated on account of motion of the coil in the magnetic field.

Theoutputvoltageisproportionaltothevelocity.

ADVANTAGES

1. This is a more satisfactory arrangement as the system now forms a closed magnetic circuit with a constant air gap, and the whole device is contained in an antimagneticcase which reduces the effects of stray magnetic fields.
2. Theinstrumenthaspermanentpolepieceswhichgeneratethemagneticfield.
3. There is a pivoted arm on which a coil is mounted. There is a mass attached to the endof the coil.The whole device is contained in an antimagnetic case.



MEASUREMENTOFANGULARVELOCITY

- Themeasurementofangularvelocitymaybemadewithatachometer.
- Thetachometer(MechanicalTransducer)maybedefinedas:

i. An instrument used for measure of angular velocity , as of shaft , either by registering the total number of revolutions during the period of contact, or by indicating directly the number of revolutions per minute.

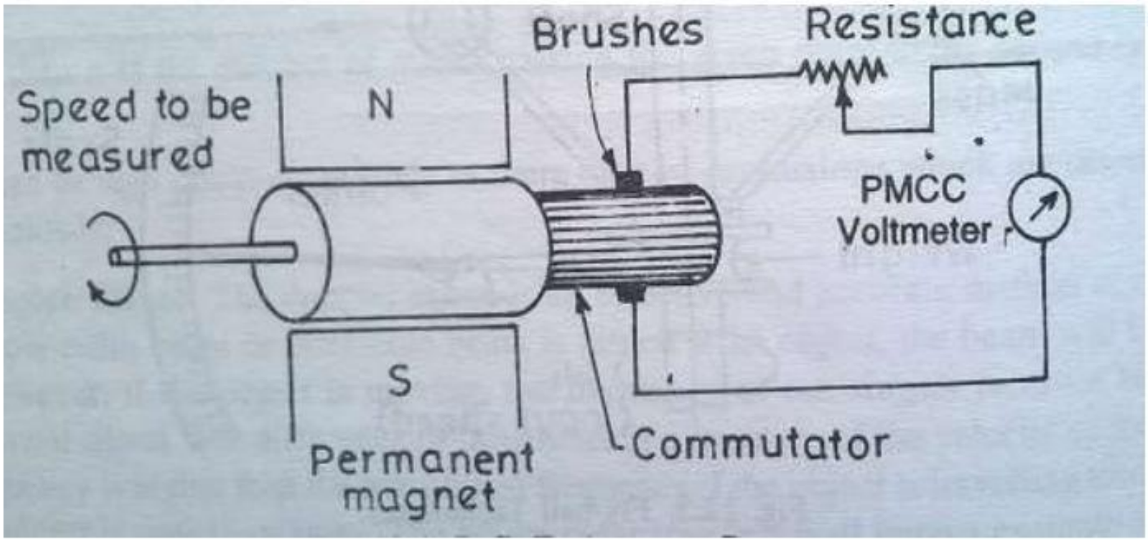
ii. An instrument which either continuously indicates the value of rotary speed or continuously displays a reading of average speed over rapidly operated short intervals of time.

ELECTRICALTACHOMETERS:

- **D.C.TachometerGenerators**

They consist of a small armature which is coupled to the machine whose speed is to be measured. This armature revolves in a field of permanent magnet. The emf generated is proportional to the product of flux and speed. Since the flux of the permanent magnet is constant, the voltage generated is proportional to speed. The polarity of output voltage indicates the direction of rotation. This emf is measured with the help of a moving coil voltmeter having a uniform scale and calibrated directly in terms of speed.

A series resistance is used in the circuit for the purpose of limiting the current from the generator in the event of a short circuit on the output side.



- **Advantages**

i. Thedirectionofrotationisdirectlyindicatedbythepolarityoftheoutputvoltage.

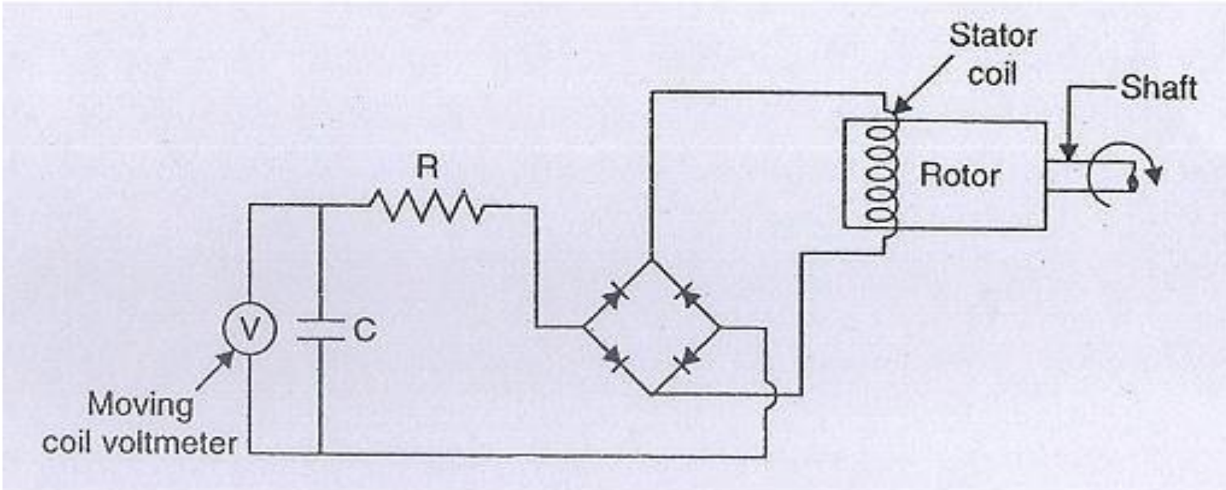
ii. Theoutputvoltageistypically10mv/rpm

- **Disadvantages**

i. Brushes of small tachometer generators often produce maintenance problems, as their contact resistance may vary and produce appreciable error. Thus the commutator and the brushes require periodic maintenance.

ii. The input resistance of meter should be very high as compared with output resistance of generator. This is required to limit the armature current to small value. If the armature current is large, the field of the permanent magnet is distorted giving rise to non-linearity.

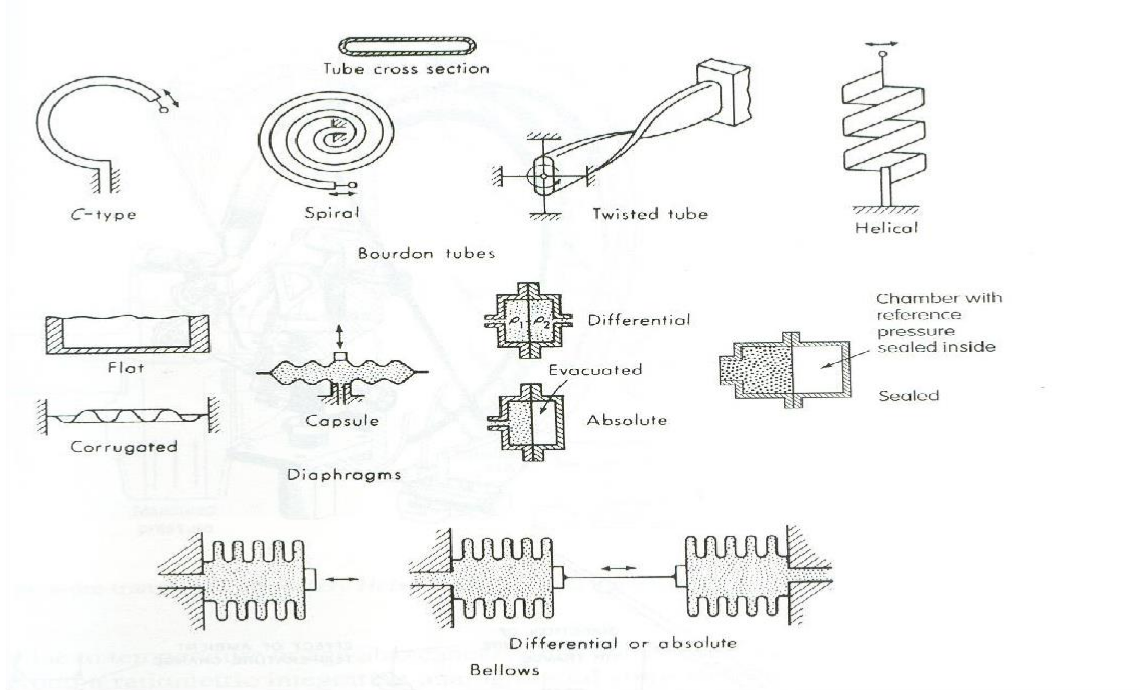
A.C.TachometerGenerator



It consists of, like an alternator, a stationary armature (stator) and a rotating field system (rotor). Owing to the generation of e.m.f in a stationary coil on a stator, commutation problems no longer exist.The alternating e.m.f. induced in the stationary coil is rectified,and the output D.C. voltage is measured with the help of a moving coil voltmeter (V).

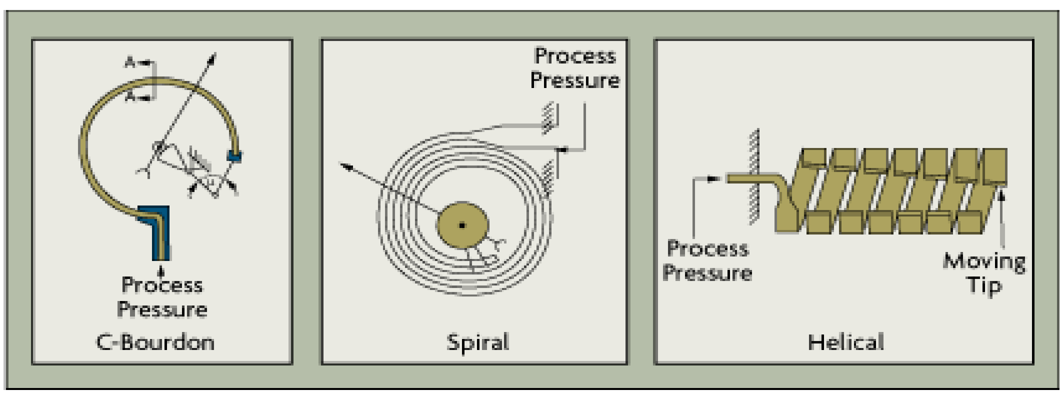
The ripple content of the rectified voltage is smoothened by the capacitor filter (C).As the speed depends on both the amplitude of the voltage and frequency, anyone of themcan be used as a measure of the speed. In an A.C. tachometer, it is the induced voltage that is considered as the required parameter.

Varioustypesofpressuregauges



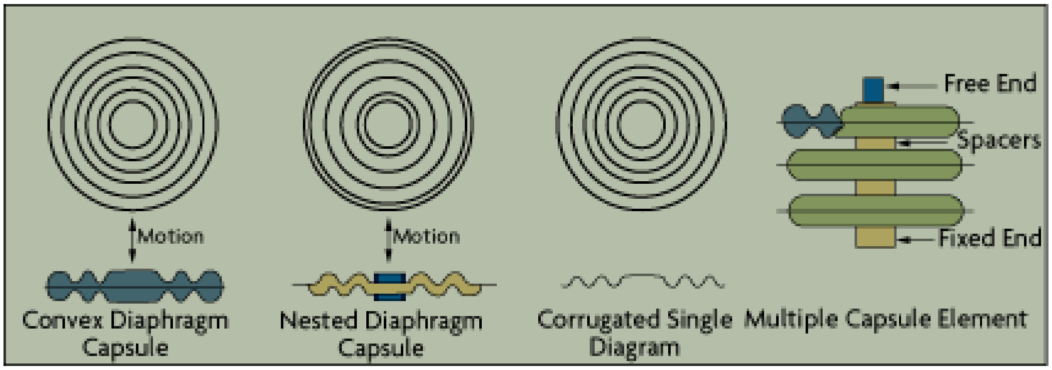
BourdonType:

Flexible element used as sensor. Pressure changes cause change in element position. Element connected to pointer to reference pressure.



DiaphragmandBellowsElement:

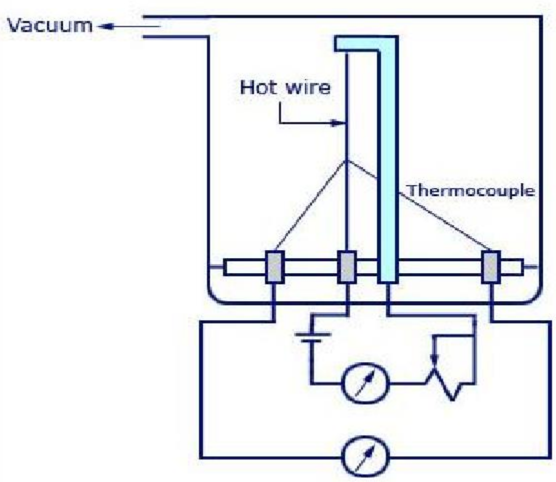
- Similar concept to Bourdon type. Widely used because they require less space and can be made from materials that resist corrosion.



THERMOCOUPLEGAUGE

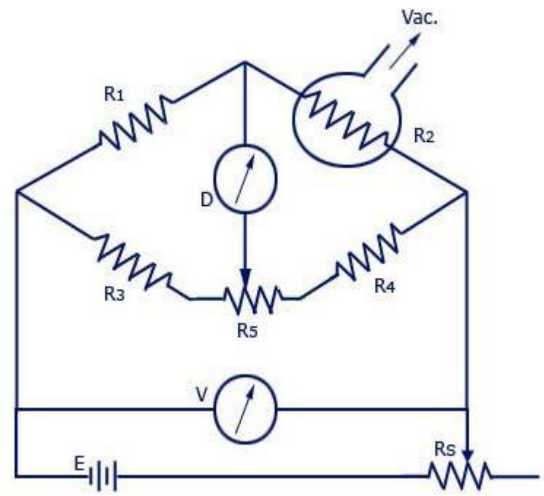
A Thermocouple is kept in contact with the heated wire and the temperature of the wire is directly measured as a measure of pressure. For different pressures, the temperature is measured by the fine-wire thermocouple, the hating current being initially fixed by the resistance as shown in the figure. This device is usually used for comparison purposes. The sensitivity of such an instrument depends on the pressure and the wire current.

Two sets of thermocouples are used to measure temperatures of heater wires in the two chambers and oppose each other. When there is a difference in pressures, there occurs an unbalance which is measured by a potentiometer circuit. Instead of a single thermocouple per wire, a thermopile is often chosen to increase sensitivity. The thermocouple gauge is also composition dependent and needs empirical calibration for the high vacuum range.



Piranigauge:

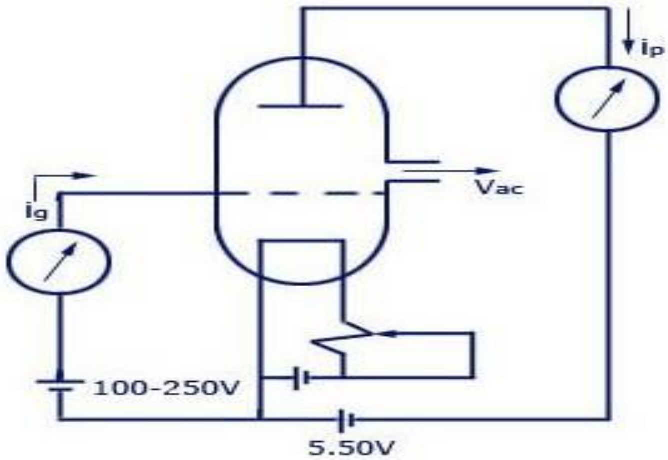
A basic pirani gauge consists of a fine wire of tungsten or platinum of about 0.002 cm in diameter. This wire is mounted in a Tube and then connected to the system whose vacuum is to be measured. The temperature range is around(7-400) degree Celsius and the heating current is between (10-100) mA.A bridge circuit is also used for greater accuracy.



When the pressure changes,there will be a change in current. For this,the voltage V has to be kept constant. The resistance R2ofthe gauge is measured,by keeping the gauge current constant. The null balance of the bridge circuit is maintained by adjusting the voltage or current. This change is made with the help of a potentiometer and the change brought will be a measure of the pressure produced.

IonizationGauge

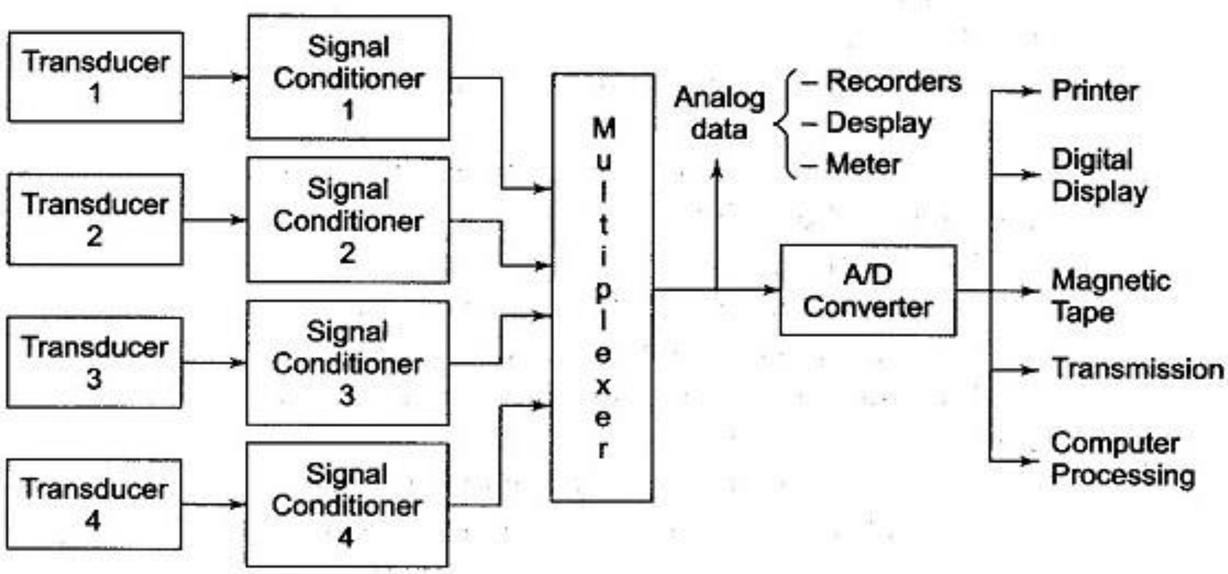
Theconstructionofahotcathode typeionizationgaugeconsistsofabasicvacuum triode.



The grid is maintained at a large positive potential with respect to the cathode and the plate. The plate is at a negative potential with respect to the cathode. This method is also known as the external control type ionization gauge as the positive ion collector is external to the electron collector grid with reference to the cathode. The positive ions available between the grid and the cathode will be drawn by the cathode, and those between thegrid and the plate will be collected by the plate.

Dataacquisitionsystem

AschematicblockdiagramofaGeneralDataAcquisitionSystem(DAS).



- AtypicalDataAcquisitionSystemconsists ofindividualsensors withthenecessary signal conditioning, data conversion, data processing, multiplexing, data handling and associated transmission, storage and display systems.

ObjectivesofDataAcquisitionSystem:

- Itmustacquirethenecessarydata,atcorrectspeedandatthecorrect
- Useofalldataefficientlytoinformtheoperatorabouthestateofthe
- It must monitor the complete plant operation to maintain on-line optimum and safe operations.
- It must provide an effective human communication system and be able to identify problemareas,therebyminimising unit availabilityandmaximising unitthroughpoint at minimum cost.
- It must be able to collect, summarise and store data for diagnosis of operation and record purpose.
- Itmustbeabletocomputeunitperformance indicesusingon-line,real-timedata.
- Itmustbeflexibleandcapableofbeingexpandedforfuturerequire
- Itmustbereliable,and nothaveadowntimegreaterthan0.1%.

The important factors that decide the configuration and sub systems of thedataacquisitionsystemare as follows.

- Accuracyandresolution
- Numberofchannelstobemonitored
- Analogordigitalsignal
- Singlechannelor multichannel
- Samplingrateperchannel
- Signalconditioningrequirementsofeach channel
- Cost

Thevariousgeneralconfigurationsincludethefollowing.

- **Singlechannelpossibilities**
- Directconversion
- Pre-amplificationanddirectconversion

- Sampleandhold,andconversion
- Pre-amplification,signalconditioningandany oftheabove
- **Multichannelpossibilities**
- Multiplexingtheoutputsofsinglechannelconverters
- Multiplexingtheoutputofsample-holdcircuits
- Multiplexingtheinputsofsample-holdcircuits
- Multiplexinglowleveldata

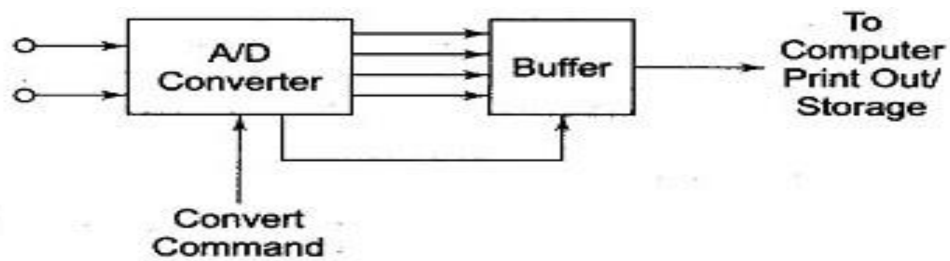


Fig. · Single Channel DAS

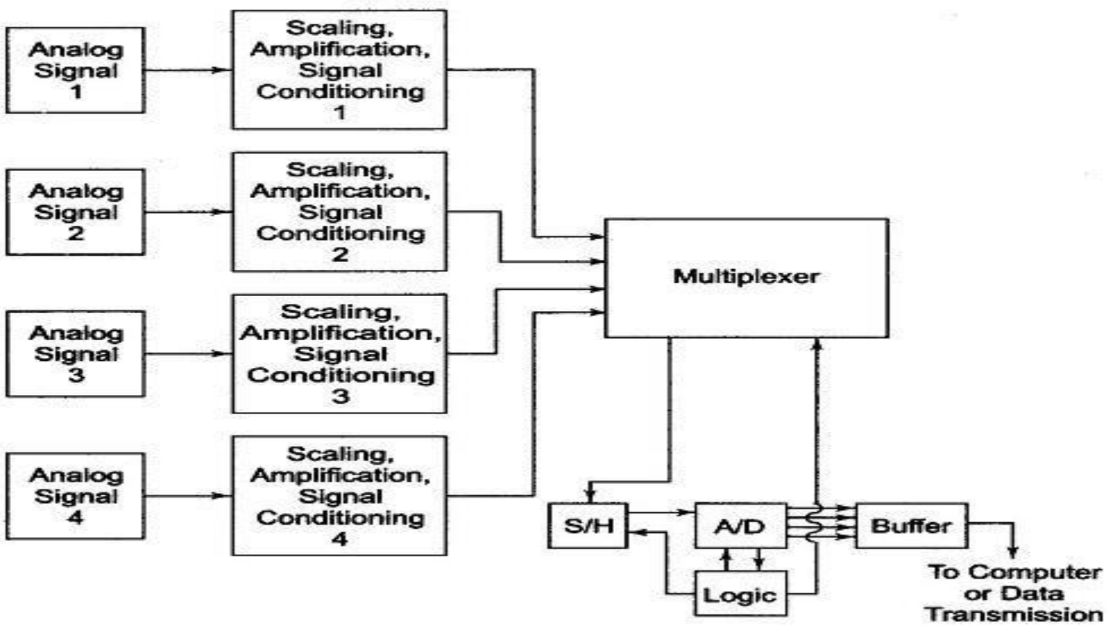


Fig. 17.5 Multi-channel DAS (A/D Preceded by a Multiplexer)