ELECTRONICS INSTRUMENTATION AND MEASUREMENTS

LECTURE NOTES

B. TECH 3RD YEAR – 5TH SEM (2024-25)

DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

MODERN ENGINEERING

&

MANAGEMENT STUDIES

Electronics Instrumentation & Measurements

Module-I (12 Hours)

Basics of Measurements: Accuracy, Precision, resolution, reliability, repeatability, validity, Errors and their analysis, Standards of measurement. Bridge Measurement: DC bridges- wheat stone bridge, AC bridges – Kelvin, Hay, Maxwell, Schering and Wien bridges, Wagner ground Connection. Electronic Instruments for Measuring Basic Parameters: Amplified DC meter, AC Voltmeter, True- RMS responding Voltmeter, Electronic multi-meter, Digital voltmeter, Vector Voltmeter.

Module-II (12 Hours)

Oscilloscopes: Cathode Ray Tube, Vertical and Horizontal Deflection Systems, Delay lines, Probes and Transducers, Specification of an Oscilloscope. Oscilloscope measurement Techniques, Special Oscilloscopes – Storage Oscilloscope, Sampling Oscilloscope, Signal Generators: Sine wave generator, Frequency – Synthesized Signal Generator, Sweep frequency Generator. Pulse and square wave generators. Function Generators.

Module-III (10 Hours)

Signal Analysis: Wave Analyzer, Spectrum Analyzer. Frequency Counters: Simple Frequency Counter; Measurement errors; extending frequency range of counters Transducers: Types, Strain Gages, Displacement Transducers.

Module-IV (6 Hours)

Digital Data Acquisition System: Interfacing transducers to Electronics Control and Measuring System. Instrumentation Amplifier, Isolation Amplifier. An Introduction to Computer-Controlled Test Systems.IEEE-488 GPIB Bus

Books:

1].Modern Electronics Instrumentation & Measurement Techniques, by Albert D.Helstrick and William D.Cooper, Pearson Education.

[2]. Elements of Electronics Instrumentation and Measurement-3rd Edition by Joshph J. Carr. Pearson Education.

[3]. Electronics Instruments and Instrumentation Technology – Anand, PHI

[4] Doebelin, E.O., Measurement systems, McGraw Hill, Fourth edition, Singapore, 1990.

[5] A Course in Electrical and Electronic Measurements and Instrumentation, A K Sawhney, Puneet Swhney, Dhanpat Rai & Co

1. INSTRUMENT AND MEASUREMENT INSTRUMENT It is a device for determining values or magnitude of a quantity or variable through a given set of formulas. MEASUREMENT It is a process of comparing an unknown quantity with an accepted standard quantity.

1. ELECTRONIC MEASUREMENT &INSTRUMENTATION It is the branch of Electronics which deals with the study of measurement and variations of different parameters of various instruments. Why measurement of parameters and study of variations for a particular instrument are required? The measurement of parameters and its variations for a particular instrument is required because it helps in understanding the behavior of an instrument.

2. CONDITION FOR A MEASURING INSTRUMENT The measuring instrument must not affect the quantity which is to be measured.

MEASUREMENT SYSTEM PERFORMANCE: The performance of the measurement system/instruments are divided into two categories. (a) Static Characteristics. (b)Dynamic Characteristics.

ACCURACY- It is defined as the ability of a device or a system to respond to a true value of a measure variable under condition.

2. PRECISION-Precision is the degree of exactness for which an instrument is design or intended to perform.

3. REPEATABILITY- The repeatability is a measuring device may be defined as the closeness of an agreement among a number of consecutive measurements of the output for the same value of the input under save operating system.

4. REPRODUCIBILITY- Reproducibility of an instrument is the closeness of the output for the same value of input. Perfect reproducibility means that the instrument has no drift.

5. SENSITIVITY- Sensitivity can be defined as a ratio of a change output to the change input at steady state condition.

6. RESOLUTION- Resolutions the least increment value of input or output that can be detected, caused or otherwise discriminated by the measuring device.

7. TRUE VALUE-True value is error free value of the measure variable it is given as difference between the Instrument Reading and Static error. Mathematically, True value= Obtained Instrument reading – static error

DYNAMIC CHARACTERISTICS OF INSTRUMENT The Dynamic Characteristics are those which change within a period of time that is generally very short in nature.

1. SPEED OF RESPONSE-It is the rapidity with which an instrument responds to the changes to in the measurement quantity.

2. FIDELITY-The degree to which an instrument indicate the measure variable without dynamic error.

3. LAG-It is retardation or delay in the response an instrument to the changes in the measurement.

4. ERROR The deviation or change of the value obtained from measurement from the desired standard value. Mathematically, Error = Obtained Reading/Value – Standard Reference Value. There are three types of error. They are as follows:

1. GROSS ERRORS-This are the error due to humans' mistakes such as careless reading mistakes in recoding observation incorrect application of an instrument.

A. SYSTEMATIC ERROR-A constant uniform deviation of an instrument is as systematic error. There are two types of systematic error.

a) STATIC ERROR The static error of a measuring instrument is the numerical different between the true value of a quantity and its value as obtained by measurement.

b) DYNAMIC ERROR 1. It is the different between true value of a quantity changing with and value indicated by the instrument.

The Dynamic Errors are caused by the instrument not responding fast enough to follow the changes in the measured value.

B. RANDOM ERROR-The cause of such error is unknown or not determined in the ordinary process of making measurement. TYPES OF STATIC ERROR

i. INSTRUMENTAL ERROR- Instrumental error are errors inherent in mastering instrument because of the mechanical construction friction is bearing in various moving component. It can be avoided by

a. Selecting a suitable instrument for the particular measurement.

b. Applying correction factor after determining the amount of Instrumental error.

ii. ENVIROMENTAL ERROR –Environmental error are due to conditions external to the measuring device including condition al in the area surrounding the instrument such as effect of change in temperature , humidity or electrostatic field it can be avoided a. Providing air conditioning. b. Use of magnetic shields.

iii. OBSERVATIONAL ERRORThe errors introduced by the observer. These errors are caused by habits of the observers like tilting his/her head too much while reading a "Needle – Scale Reading".

Measurement

Measurement is the foundation for all experimental science. All the great technological development could not have been possible without ever-increasing levels of accuracy of measurements. The measurement of an amount is based on some international standards, which are completely accurate compared with others. Just like your vegetable vendors, measurements are taken by comparing an unknown amount with a known weight. Every measurement carries a level of uncertainty which is known as an error. This error may arise in the process or due to a mistake in the experiment. So 100% accurate measurement is not possible with any method.

An error may be defined as the difference between the measured and actual values. For example, if the two operators use the same device or instrument for measurement. It is not necessary that both operators get similar results. The difference between the measurements is referred to as an ERROR.

To understand the concept of measurement errors, you should know the two terms that define the error. They are true value and measured value. The true value is impossible to find by experimental means. It may be defined as the average value of an infinite number of measured values. The measured value is a single measure of the object to be as accurate as possible.

Types of Errors

There are three types of errors that are classified based on the source they arise from; They are:

- Gross Errors
- Random Errors
- Systematic Errors

Gross Errors

This category basically takes into account human oversight and other mistakes while reading, recording, and readings. The most common human error in measurement falls under this category of measurement errors. For example, the person taking the reading from the meter of the instrument may read 23 as 28. Gross errors can be avoided by using two suitable measures, and they are written below:

- Proper care should be taken in reading, recording the data. Also, the calculation of error should be done accurately.
- By increasing the number of experimenters, we can reduce the gross errors. If each experimenter takes different readings at different points, then by taking the average of more readings, we can reduce the gross errors

Random Errors

The random errors are those errors, which occur irregularly and hence are random. These can arise due to random and unpredictable fluctuations in experimental conditions (Example: unpredictable fluctuations in temperature, voltage supply, mechanical vibrations of experimental set-ups, etc, errors by the observer taking readings, etc. For example, when the same person repeats the same observation, he may likely get different readings every time.

This article explored the various types of errors in the measurements we make. These errors are everywhere in every measurement we make. To find more articles, visit BYJU’S. Join us and fall in love with learning.

Systematic Errors:

Systematic errors can be better understood if we divide them into subgroups; They are:

- Environmental Errors
- Observational Errors
- Instrumental Errors

Environmental Errors: This type of error arises in the measurement due to the effect of the external conditions on the measurement. The external condition includes temperature, pressure, and humidity and can also include an external magnetic field. If you measure your temperature under the armpits and during the measurement, if the electricity goes out and the room gets hot, it will affect your body temperature, affecting the reading.

Observational Errors: These are the errors that arise due to an individual's bias, lack of proper setting of the apparatus, or an individual's carelessness in taking observations. The measurement errors also include wrong readings due to Parallax errors.

Instrumental Errors: These errors arise due to faulty construction and calibration of the measuring instruments. Such errors arise due to the hysteresis of the equipment or due to friction. Lots of the time, the equipment being used is faulty due to misuse or neglect, which changes the reading of the equipment. The zero error is a very common type of error. This error is common in devices like Vernier callipers and screw gauges. The zero error can be either positive or negative. Sometimes the scale readings are worn off, which can also lead to a bad reading.

Instrumental error takes place due to :

- An inherent constraint of devices
- Misuse of Apparatus
- Effect of Loading

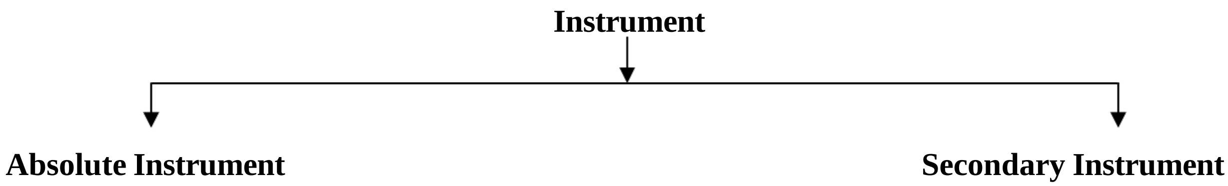
Precision and accuracy are two ways that scientists think about error. Accuracy refers to how close a measurement is to the true or accepted value. Precision refers to how close measurements of the same item are to each other. Precision is independent of accuracy.

Precision refers to the level of detail and accuracy in measurement or calculation. In other words, precision is how close multiple measurements or calculations are to each other, and how much variability there is between them.

MEASURING INSTRUMENTS

1.1 Definition of instruments

An instrument is a device in which we can determine the magnitude or value of the quantity to be measured. The measuring quantity can be voltage, current, power and energy etc. Generally instruments are classified in to two categories.



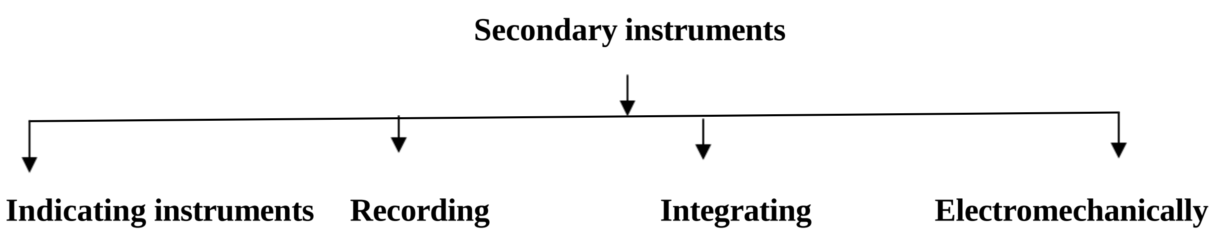
1.2 Absolute instrument

An absolute instrument determines the magnitude of the quantity to be measured in terms of the instrument parameter. This instrument is really used, because each time the value of the measuring quantities varies. So we have to calculate the magnitude of the measuring quantity, analytically which is time consuming. These types of instruments are suitable for laboratory use. Example: Tangent galvanometer.

1.3 Secondary instrument

This instrument determines the value of the quantity to be measured directly. Generally these instruments are calibrated by comparing with another standard secondary instrument.

Examples of such instruments are voltmeter, ammeter and wattmeter etc. Practically secondary instruments are suitable for measurement.



1.3.1 Indicating instrument

This instrument uses a dial and pointer to determine the value of measuring quantity. The pointer indication gives the magnitude of measuring quantity.

1.3.2 Recording instrument

This type of instruments records the magnitude of the quantity to be measured continuously over a specified period of time.

1.3.3 Integrating instrument

This type of instrument gives the total amount of the quantity to be measured over a specified period of time.

1.3.4 Electromechanical indicating instrument

For satisfactory operation electromechanical indicating instrument, three forces are necessary. They are

(a) Deflecting force

(b) Controlling force

(c) Damping force

1.4 Deflecting force

When there is no input signal to the instrument, the pointer will be at its zero position. To deflect the pointer from its zero position, a force is necessary which is known as deflecting force. A system which produces the deflecting force is known as a deflecting system. Generally a deflecting system converts an electrical signal to a mechanical force.

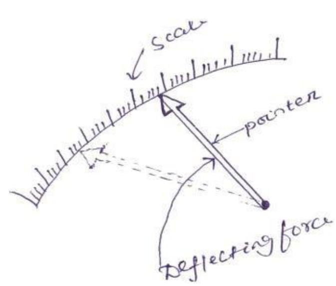


Fig. 1.1 Pointer scale

1.4.1 Magnitude effect

When a current passes through the coil (Fig.1.2), it produces a imaginary bar magnet. When a soft-iron piece is brought near this coil it is magnetized. Depending upon the current direction the poles are produced in such a way that there will be a force of attraction between the coil and the soft iron piece. This principle is used in moving iron attraction type instrument.

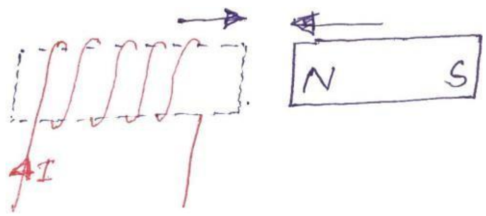


Fig. 1.2

If two soft iron pieces are place near a current carrying coil there will be a force of repulsion between the two soft iron pieces. This principle is utilized in the moving iron repulsion type instrument.

1.4.2 Force between a permanent magnet and a current carrying coil

When a current carrying coil is placed under the influence of magnetic field produced by a permanent magnet and a force is produced between them. This principle is utilized in the moving coil type instrument.

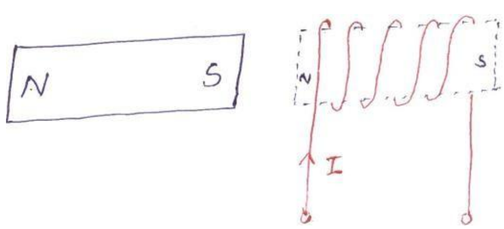


Fig. 1.3

1.4.3 Force between two current carrying coil

When two current carrying coils are placed closer to each other there will be a force of repulsion between them. If one coil is movable and other is fixed, the movable coil will move away from the fixed one. This principle is utilized in electrodynamometer type instrument.

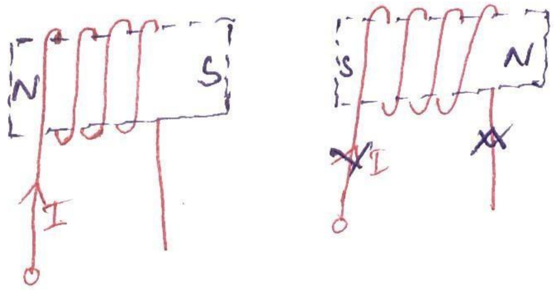


Fig. 1.4

1.5 Controlling force

To make the measurement indicated by the pointer definite (constant) a force is necessary which will be acting in the opposite direction to the deflecting force. This force is known as controlling force. A system which produces this force is known as a controlled system. When the external signal to be measured by the instrument is removed, the pointer should return back to the zero position. This is possibly due to the controlling force and the pointer will be indicating a steady value when the deflecting torque is equal to controlling torque.

$T_d \square T_c$ (1.1)

1.5.1 Spring control

Two springs are attached on either end of spindle (Fig. 1.5).The spindle is placed in jewelled bearing, so that the frictional force between the pivot and spindle will be minimum. Two springs are provided in opposite direction to compensate the temperature error. The spring is made of phosphorous bronze.

When a current is supply, the pointer deflects due to rotation of the spindle. While spindle is rotate, the spring attached with the spindle will oppose the movements of the pointer. The torque produced by the spring is directly proportional to the pointer deflection□ .

$T_C \square \square$ (1.2)

The deflecting torque produced T_d proportional to ‘I’. When $T_C \square T_d$, the pointer will come to a steady position. Therefore

$\square \square I$ (1.3)

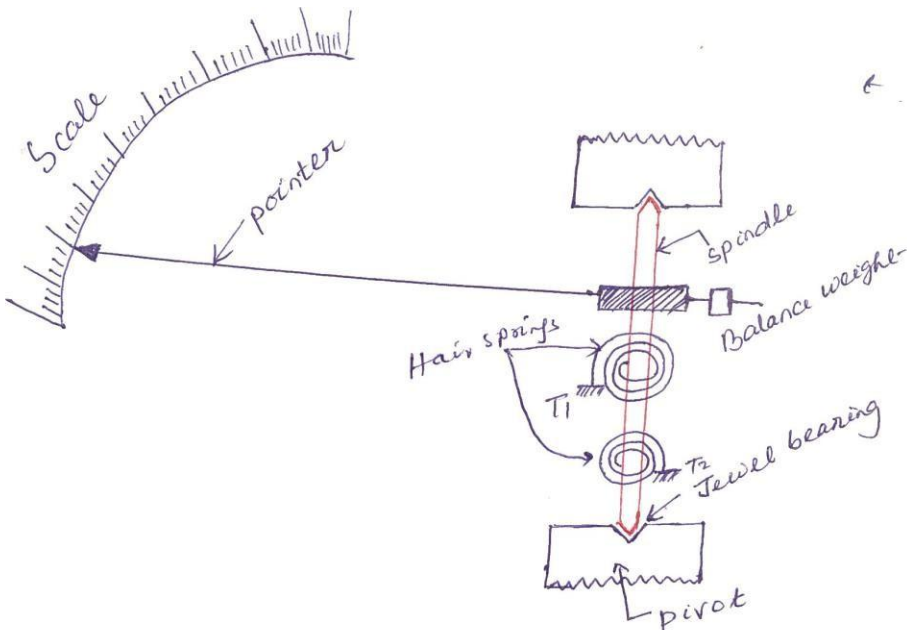


Fig. 1.5

Since, □ and I are directly proportional to the scale of such instrument which uses spring controlled is uniform.

1.6 Damping force

The deflection torque and controlling torque produced by systems are electro mechanical. Due to inertia produced by this system, the pointer oscillates about it final steady position before coming to rest. The time required to take the measurement is more. To damp out the oscillation is quickly, a damping force is necessary. This force is produced by different systems.

(a) Air friction damping
(b) Fluid friction damping
(c) Eddy current damping

1.6.1 Air friction damping

The piston is mechanically connected to a spindle through the connecting rod (Fig. 1.6). The pointer is fixed to the spindle moves over a calibrated dial. When the pointer oscillates in clockwise direction, the piston goes inside and the cylinder gets compressed. The air pushes the piston upwards and the pointer tends to move in anticlockwise direction.

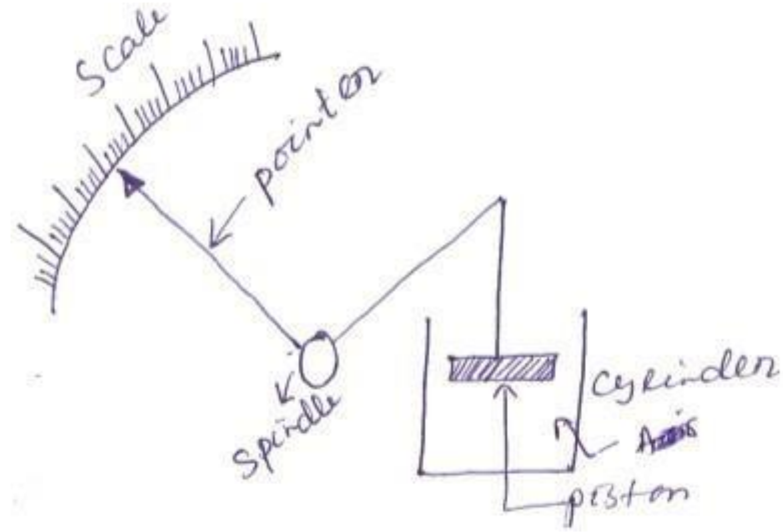


Fig. 1.6

If the pointer oscillates in anticlockwise direction the piston moves away and the pressure of the air inside cylinder gets reduced. The external pressure is more than that of the internal pressure. Therefore the piston moves down wards. The pointer tends to move in clock wise direction.

1.6.2 Eddy current damping

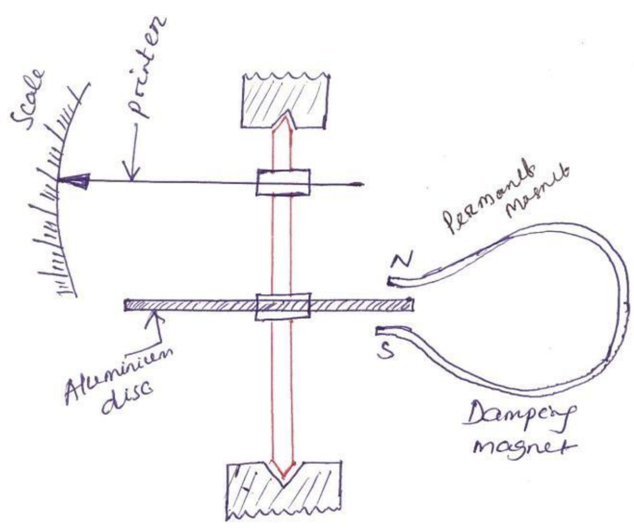


Fig. 1.6 Disc type

An aluminum circular disc is fixed to the spindle (Fig. 1.6). This disc is made to move in the magnetic field produced by a permanent magnet.

When the disc oscillates it cuts the magnetic flux produced by damping magnet. An emf is induced in the circular disc by faradays law. Eddy currents are established in the disc since it has several closed paths. By Lenz's law, the current carrying disc produced a force in a direction opposite to oscillating force. The damping force can be varied by varying the projection of the magnet over the circular disc.

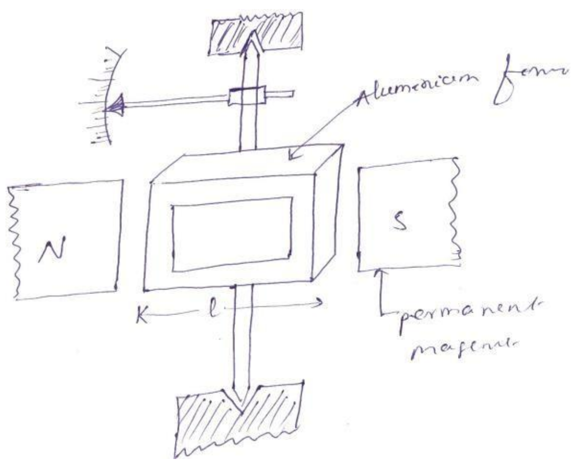
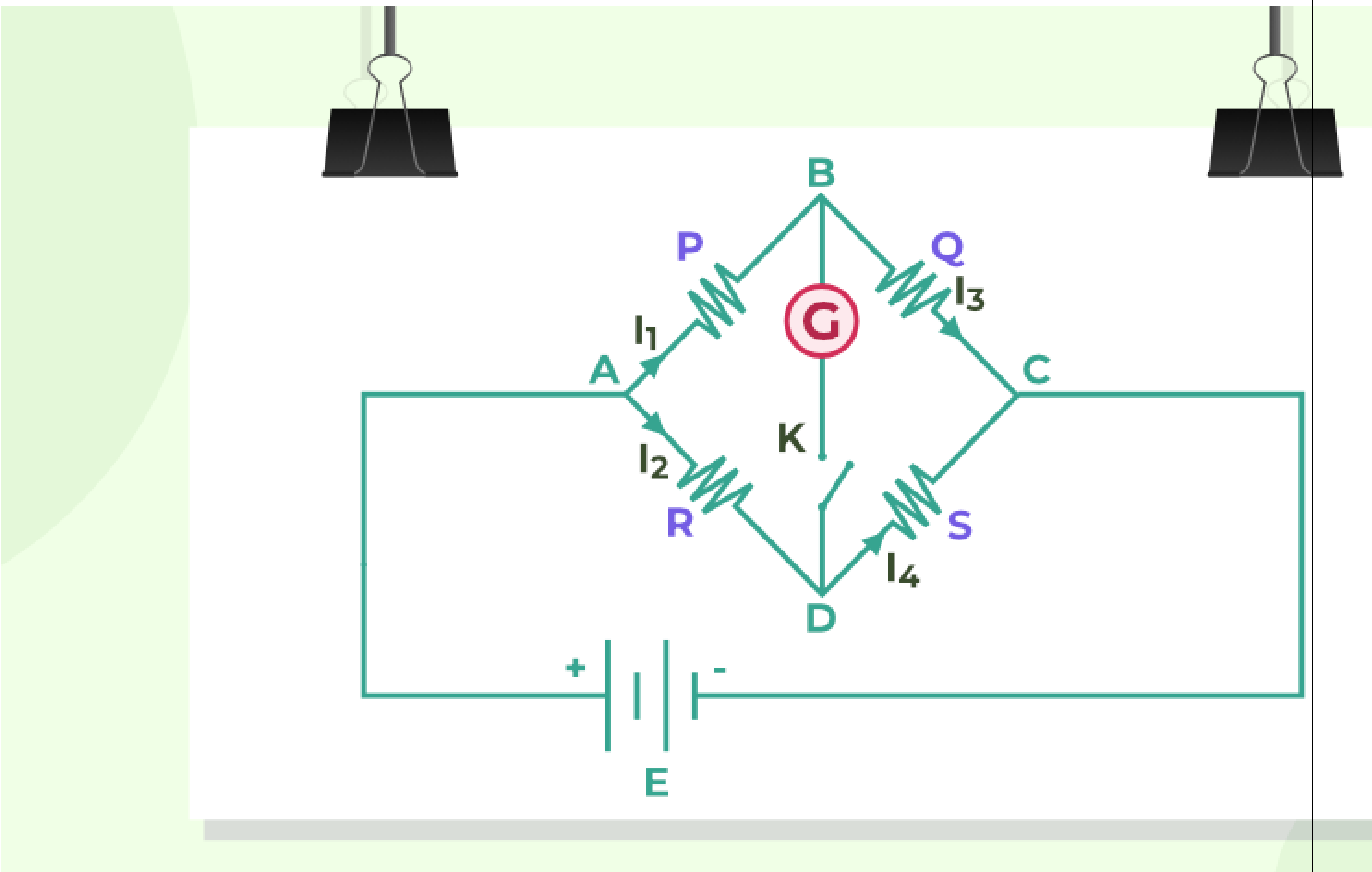


Fig. 1.6 Rectangular type

Wheatstone Bridge

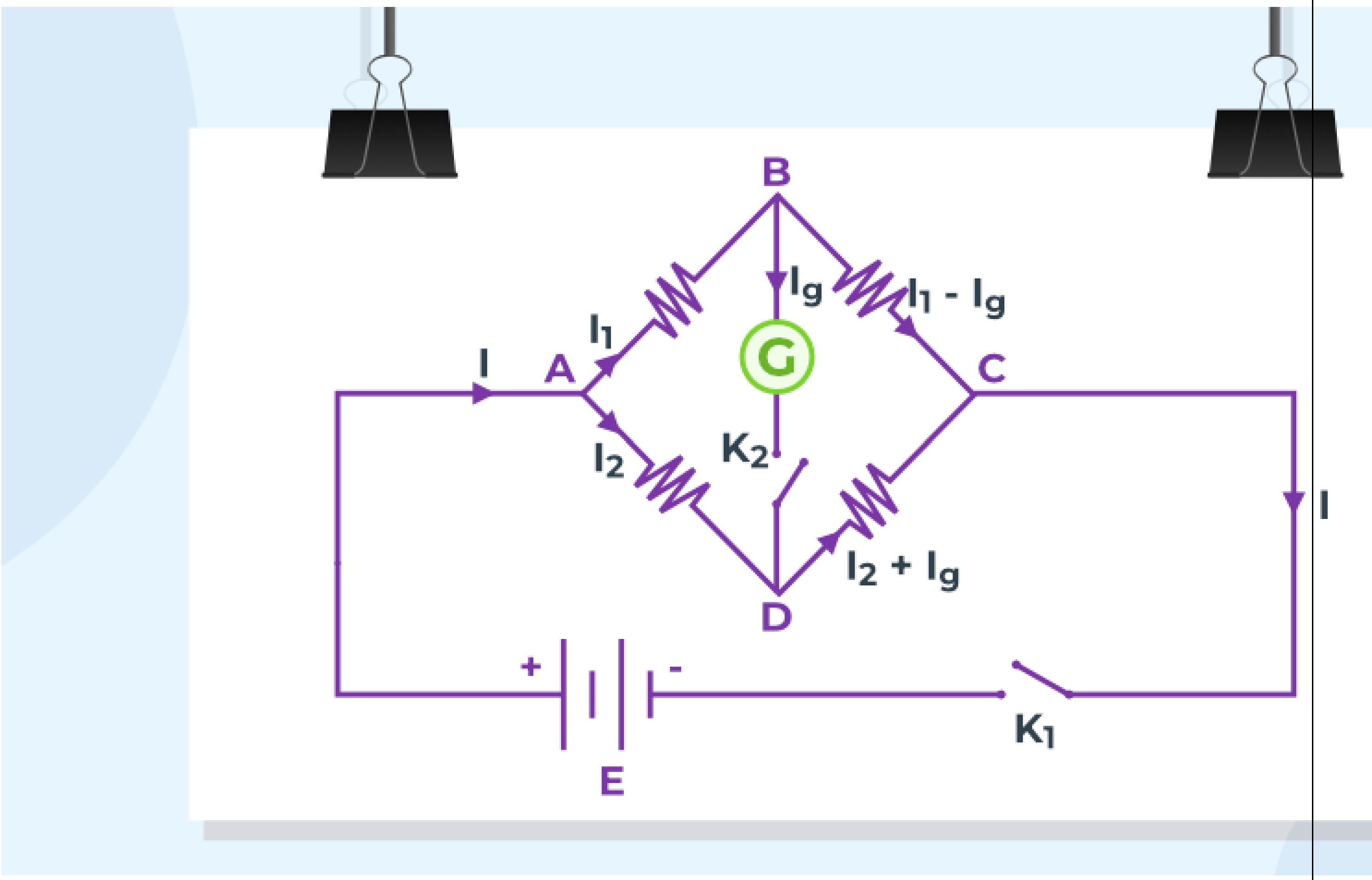
Wheatstone Bridge Definition

Wheatstone Bridge is an instrument designed to measure unknown resistance in electrical circuits. It calculates the unknown resistance by balancing the two legs of the bridge circuit where one leg contains both known resistors and the other leg contains one known (variable) and one unknown resistor. Since it estimates unknown resistance in an electric circuit, it is also known as a resistance bridge. Wheatstone bridge is a very reliable instrument as it measures the resistance very precisely.



Wheatstone Bridge Principle
Wheatstone Bridge works on the principle of null deflection i.e., there is no current flowing through the galvanometer, and its needle shows no deflection, hence the name null deflection. In the unbalanced state of the Wheatstone bridge i.e., when the potential across the galvanometer is different, the galvanometer shows the deflection, and as the bridge becomes balanced by changing the variable resistor, the potential difference across the galvanometer becomes zero i.e., the equilibrium state of Wheatstone bridge.

Construction of Wheatstone Bridge
Construction of Wheatstone Bridge requires four resistors P, Q, R, and S that are placed in the form of four sides AB, BC, AD, and DC of a quadrilateral ABCD. A cell E and key K1 are placed between the A and C ends of this quadrilateral, and a sensitive galvanometer G and key K2 is placed between the B and D ends. Clearly, the potential of point A will be equal to the potential of the positive plate of the cell and the potential of point C will be equal to the potential of the negative plate of the cell.
It is clear from the figure that the resistances P and Q are in series when the key K2 is open. Similarly, resistances R and S are in series, but P and Q together (arm ABC) and R and S together (arm ADC) are connected in parallel to each other. Since the side BD of the galvanometer is placed like a bridge over the sides ABC and ADC of the quadrilateral, this circuit is called a bridge.



When the bridge is in an equilibrium state, that is, there is no deflection in the galvanometer. That is, in the equilibrium state of the bridge, the ratio of the resistances of any two adjacent arms is equal to the ratio of the remaining two adjacent sides.

Wheatstone Bridge Derivation

Suppose, on pressing the cell key K1, a current I flows through the cell, which splits into two parts at the end A. One part I1 flows through the resistance P in arm AB and the other part I2, through the resistance R in arm AD. The current I1 again comes to end B and gets divided into two parts. One part of it Ig flows through the galvanometer in arm BD and the remaining part (I1- Ig) flows through resistance Q in arm BC. At the end D, the current I2 from arm AD and the current Ig from arm BD, so the current flowing through the resistance S in arm DC will be (I2 + Ig).

So according to Kirchhoff's law, in closed path ABDA,

$$I_1P + I_gG - I_2R = 0 \quad ...(1)$$

And in closed path BCDB,

$$(I_1 - I_g)Q - (I_2 + I_g)S - I_gG = 0 \quad ...(2)$$

The values of the resistors P, Q, R, and S are taken in such a way that no current flows through the galvanometer G when the key K2, is pressed. This is called the ***equilibrium state of the bridge****, that is, in the equilibrium state of the bridge, the deflection in the galvanometer is zero (Ig = 0).*

Putting Ig = 0, in the above equations,

$I_1P = I_2R$ and $I_1Q = I_2S$

or

$I_1P / I_1Q = I_2R / I_2S$

or

$P / Q = R / S$

This is the necessary condition for the balance of the Wheatstone Bridge. With the help of the above formula, knowing the values of three resistors P, Q, and R, the value of the fourth resistance S can be found.

Wheatstone Bridge Formula

The Wheatstone Bridge Formula for the calculation of the unknown resistor is as follows:

R = PS/Q

where,

***P** and **Q** is the resistance of ratio arm*

***S** is the known resistance of the standard arm*

***R** is the unknown resistance*

Advantages of Wheatstone's Bridge

Various advantages of the Wheatstone's Bridge are,

- *With the help of Wheatstone's Bridge, we can build a Meter bridge.*
- *The biggest advantage of Wheatstone's Bridge is to accurately measure the electric resistance instead of using costly instruments.*
- *We can measure minute changes in the bridge, even in m ohm.*
- *It is very easy to find out the unknown resistance as the rest of the three are easily known.*
- *We can measure strain and pressure using a Wheatstone bridge.*

Disadvantages of Wheatstone's Bridge

Various disadvantages of the Wheatstone's Bridge are,

- *The result of Wheatstone's Bridge can be easily affected by temperature and EMF cells.*
- *Wheatstone bridge may also get affected if the galvanometer is not of good quality.*
- *Wheatstone Bridge fails if it is not in a balanced condition.*
- *We can't measure large resistance with the help of Wheatstone's Bridge.*
- *The cost of maintaining the Wheatstone Bridge is very high.*

AC BRIDGES

2.1 General form of A.C. bridge

AC bridge are similar to D.C. bridge in topology(way of connecting).It consists of four arm AB,BC,CD and DA .Generally the impedance to be measured is connected between ‘A’ and ‘B’. A detector is connected between ‘B’ and ’D’. The detector is used as null deflection instrument. Some of the arms are variable element. By varying these elements, the potential values at ‘B’ and ‘D’ can be made equal. This is called balancing of the bridge.

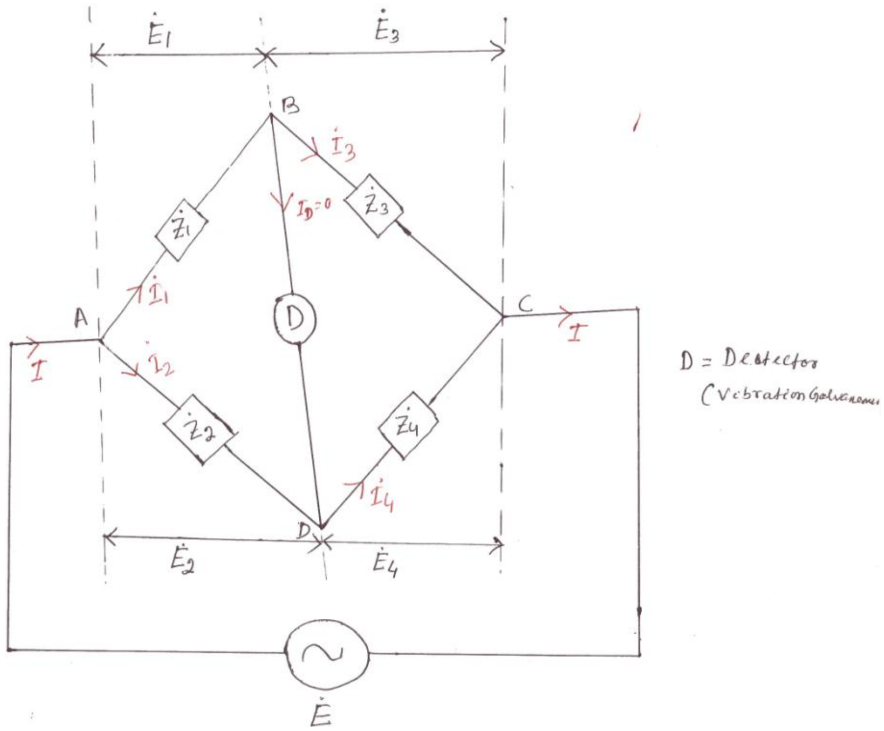


Fig. 2.1 General form of A.C. bridge

At the balance condition, the current through detector is zero.

$$\therefore \dot{I}_1 = \dot{I}_3$$

$$\dot{I}_2 = \dot{I}_4$$

$$\therefore \frac{\dot{I}_1}{\dot{I}_2} = \frac{\dot{I}_3}{\dot{I}_4} \qquad (2.1)$$

At balance condition,

Voltage drop across ‘AB’=voltage drop across ‘AD’.

$$\dot{E}_1 = \dot{E}_2$$

$$\therefore \dot{I}_1 \dot{Z}_1 = \dot{I}_2 \dot{Z}_2 \qquad (2.2)$$

Similarly, Voltage drop across ‘BC’=voltage drop across ‘DC’

$$\dot{E}_3 = \dot{E}_4$$

$$\therefore \dot{I}_3 \dot{Z}_3 = \dot{I}_4 \dot{Z}_4 \qquad (2.3)$$

From Eqn. (2.2), we have $\therefore \frac{\dot{I}_1}{\dot{I}_2} = \frac{\dot{Z}_2}{\dot{Z}_1}$ (2.4)

From Eqn. (2.3), we have $\therefore \frac{\dot{I}_3}{\dot{I}_4} = \frac{\dot{Z}_4}{\dot{Z}_3}$ (2.5)

From equation -2.1, it can be seen that, equation -2.4 and equation-2.5 are equal.

$$\therefore \frac{\dot{Z}_2}{\dot{Z}_1} = \frac{\dot{Z}_4}{\dot{Z}_3}$$

$$\therefore \dot{Z}_1 \dot{Z}_4 = \dot{Z}_2 \dot{Z}_3$$

Products of impedances of opposite arms are equal.

$$\therefore |Z_1| \angle\theta_1 |Z_4| \angle\theta_4 = |Z_2| \angle\theta_2 |Z_3| \angle\theta_3$$

$$\Rightarrow |Z_1||Z_4| \angle\theta_1 + \theta_4 = |Z_2||Z_3| \angle\theta_2 + \theta_3$$

$$|Z_1||Z_4| = |Z_2||Z_3|$$

$$\theta_1 + \theta_4 = \theta_2 + \theta_3$$

* For balance condition, magnitude on either side must be equal.

* Angle on either side must be equal.

Summary

For balance condition,

- $\dot{I}_1 = \dot{I}_3, \quad \dot{I}_2 = \dot{I}_4$
- $|Z_1||Z_4| = |Z_2||Z_3|$
- $\theta_1 + \theta_4 = \theta_2 + \theta_3$
- $\dot{E}_1 = \dot{E}_2$ & $\dot{E}_3 = \dot{E}_4$

2.2 Types of detector

The following types of instruments are used as detector in A.C. bridge.

- Vibration galvanometer
- Head phones (speaker)
- Tuned amplifier

2.2.1 Vibration galvanometer

Between the point ‘B’ and ‘D’ a vibration galvanometer is connected to indicate the bridge balance condition. This A.C. galvanometer which works on the principle of resonance. The A.C. galvanometer shows a dot, if the bridge is unbalanced.

2.2.2 Head phones

Two speakers are connected in parallel in this system. If the bridge is unbalanced, the speaker produced more sound energy. If the bridge is balanced, the speaker do not produced any sound energy.

2.2.3 Tuned amplifier

If the bridge is unbalanced the output of tuned amplifier is high. If the bridge is balanced, output of amplifier is zero.

2.3 Measurements of inductance

2.3.1 Maxwell's inductance bridge

The choke for which R_1 and L_1 have to measure connected between the points 'A' and 'B'. In this method the unknown inductance is measured by comparing it with the standard inductance.

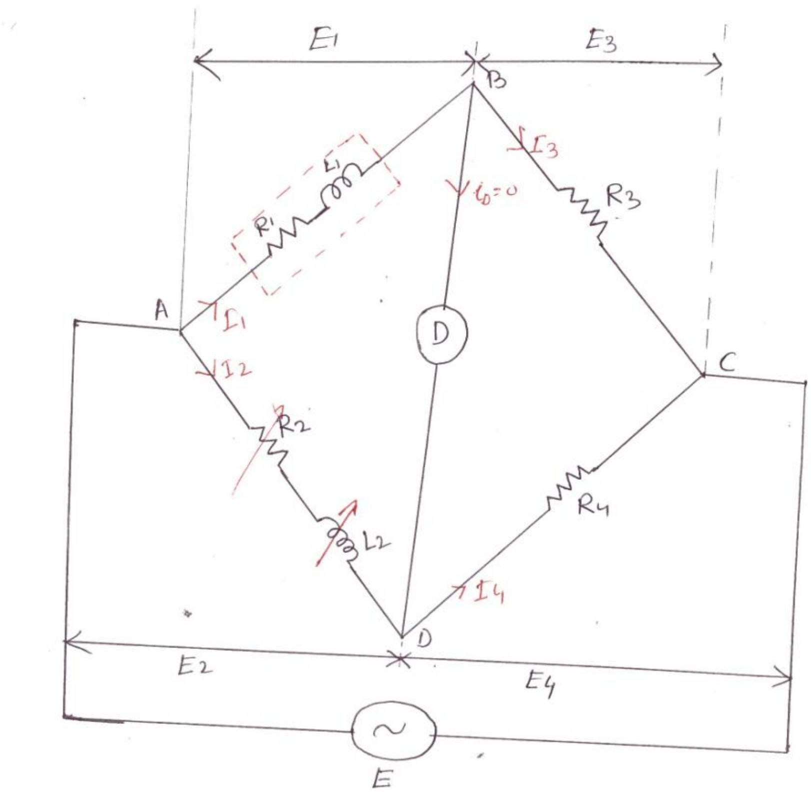


Fig. 2.2 Maxwell's inductance bridge

L_2 is adjusted, until the detector indicates zero current.

Let R_1= unknown resistance

L_1= unknown inductance of the choke.

L_2= known standard inductance

R_1,R_2,R_4= known resistances.

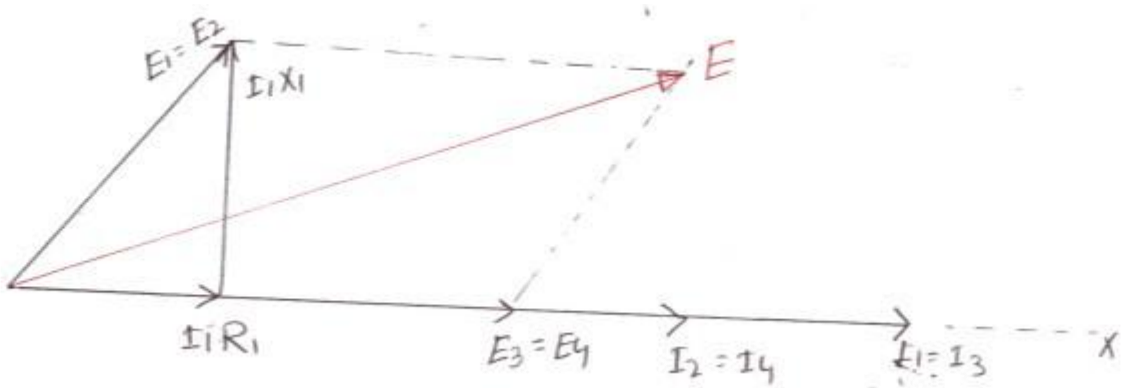


Fig 2.3 Phasor diagram of Maxwell's inductance bridge

At balance condition, $Z_1 Z_4 = Z_2 Z_3$

$(R_1 + jXL_1)R_4 = (R_2 + jXL_2)R_3$

$(R_1 + jwL_1)R_4 = (R_2 + jwL_2)R_3$

$R_1R_4 + jwL_1R_4 = R_2R_3 + jwL_2R_3$

Comparing real part,

$R_1R_4 = R_2R_3$

$$\therefore R_1 = \frac{R_2R_3}{R_4} \qquad (2.6)$$

Comparing the imaginary parts,

$wL_1R_4 = wL_2R_3$

$$L_1 = \frac{L_2R_3}{R_4} \qquad (2.7)$$

Q-factor of choke, $Q = \frac{WL_1}{\quad} = \frac{WL_2R_3R_4}{\quad}$

$R_1 \qquad R_4 R_2 R_3$

$$Q = \frac{WL_2}{R_2} \tag{2.8}$$

Advantages

- ✓ Expression for R_1 and L_1 are simple.
- ✓ Equations area simple
- ✓ They do not depend on the frequency (as w is cancelled)
- ✓ R_1 and L_1 are independent of each other.

Disadvantages

- ✓ Variable inductor is costly.
- ✓ Variable inductor is bulky.

2.3.2 Maxwell's inductance capacitance bridge

Unknown inductance is measured by comparing it with standard capacitance. In this bridge, balance condition is achieved by varying 'C_4'.

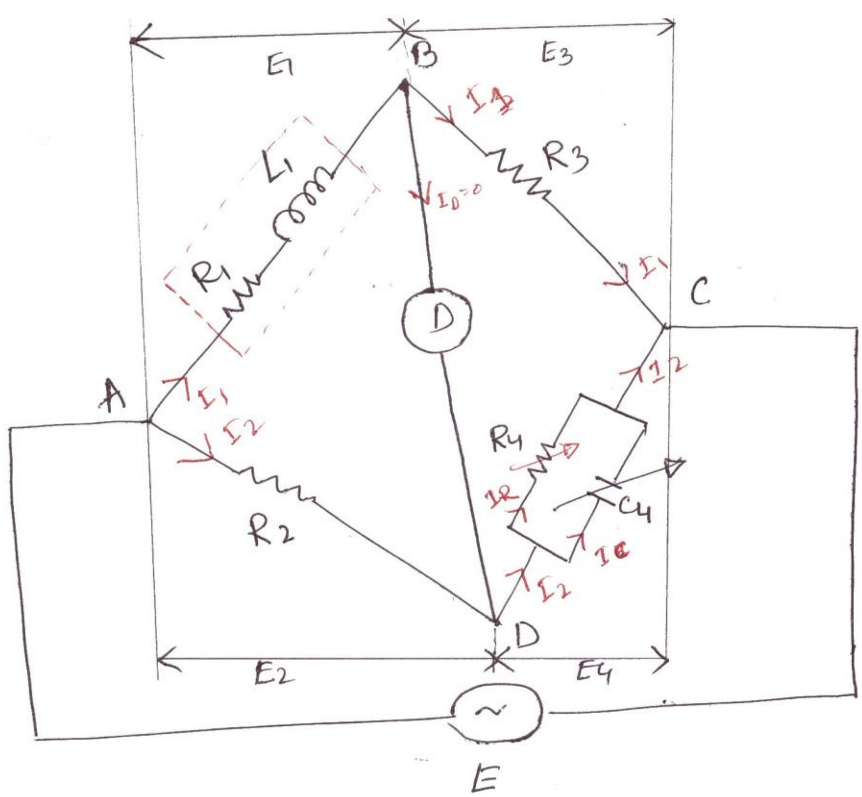


Fig 2.4 Maxwell's inductance capacitance bridge

At balance condition, $Z_1Z_4=Z_3Z_2$ (2.9)

$$Z_4 = R_4 \,||\, \frac{1}{jwC_4} = \frac{R_4 \times \dfrac{1}{jwC_4}}{R_4 + \dfrac{1}{jwC_4}}$$

$$Z_4 = \frac{R_4}{jwR_4C_4 + 1} = \frac{R_4}{1 + jwR_4C_4} \qquad (2.10)$$

$\therefore$ Substituting the value of Z_4 from eqn. (2.10) in eqn. (2.9) we get

$$(R_1 + jwL_1) \times \frac{R_4}{1 + jwR_4C_4} = R_2R_3$$

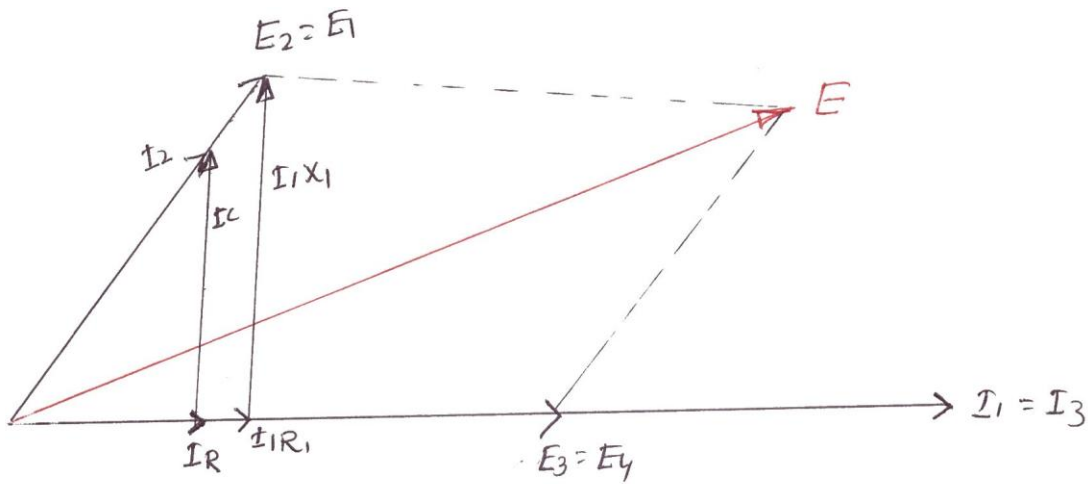


Fig 2.5 Phasor diagram of Maxwell's inductance capacitance bridge

$$(R_1 + jwL_1)R_4 = R_2R_3(1 + jwR_4C_4)$$

$$R_1R_4 + jwL_1R_4 = R_2R_3 + jwC_4R_4R_2R_3$$

Comparing real parts,

$$R_1 R_4 = R_2 R_3$$

$$\Rightarrow R_1 = \frac{R_2 R_3}{R_4} \tag{2.11}$$

Comparing imaginary part,

$$wL_1 R_4 = wC_4 R_4 R_2 R_3$$

$$L_1 = C_4 R_2 R_3 \tag{2.12}$$

Q-factor of choke,

$$Q = \frac{WL_1}{R_1} = w \times C_4 R_2 R_3 \times \frac{R_4}{R_2 R_3}$$

$$Q = wC_4 R_4 \tag{2.13}$$

Advantages

- ✓ Equation of L_1 and R_1 are simple.
- ✓ They are independent of frequency.
- ✓ They are independent of each other.
- ✓ Standard capacitor is much smaller in size than standard inductor.

Disadvantages

- ✓ Standard variable capacitance is costly.
- ✓ It can be used for measurements of Q-factor in the ranges of 1 to 10.
- ✓ It cannot be used for measurements of choke with Q-factors more than 10.
  We know that $Q = wC_4R_4$

For measuring chokes with higher value of Q-factor, the value of C_4 and R_4 should be higher. Higher values of standard resistance are very expensive. Therefore this bridge cannot be used for higher value of Q-factor measurements.

2.3.3 Hay's bridge

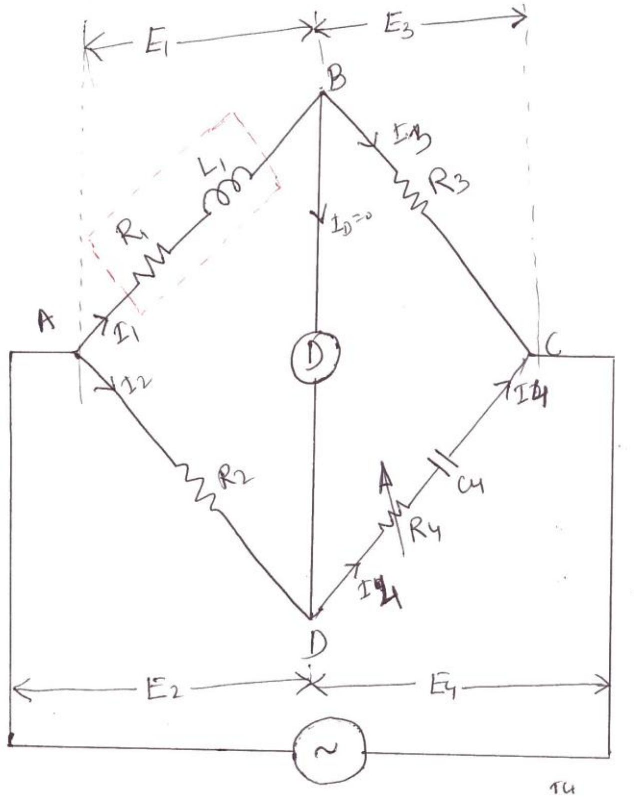


Fig 2.6 Hay's bridge

- $\dot{E}_1 = \dot{I}_1 R_1 + j\dot{I}_1 X_1$
- $\dot{E} = \dot{E}_1 + \dot{E}_3$
- $\dot{E}_4 = \dot{I}_4 R_4 + \dfrac{I_4}{jwC_4}$
- $\dot{E}_3 = I_3 R_3$

$$Z_4 = R_4 + \frac{1}{jwC_4} = \frac{1 + jwR_4C_4}{jwC_4}$$

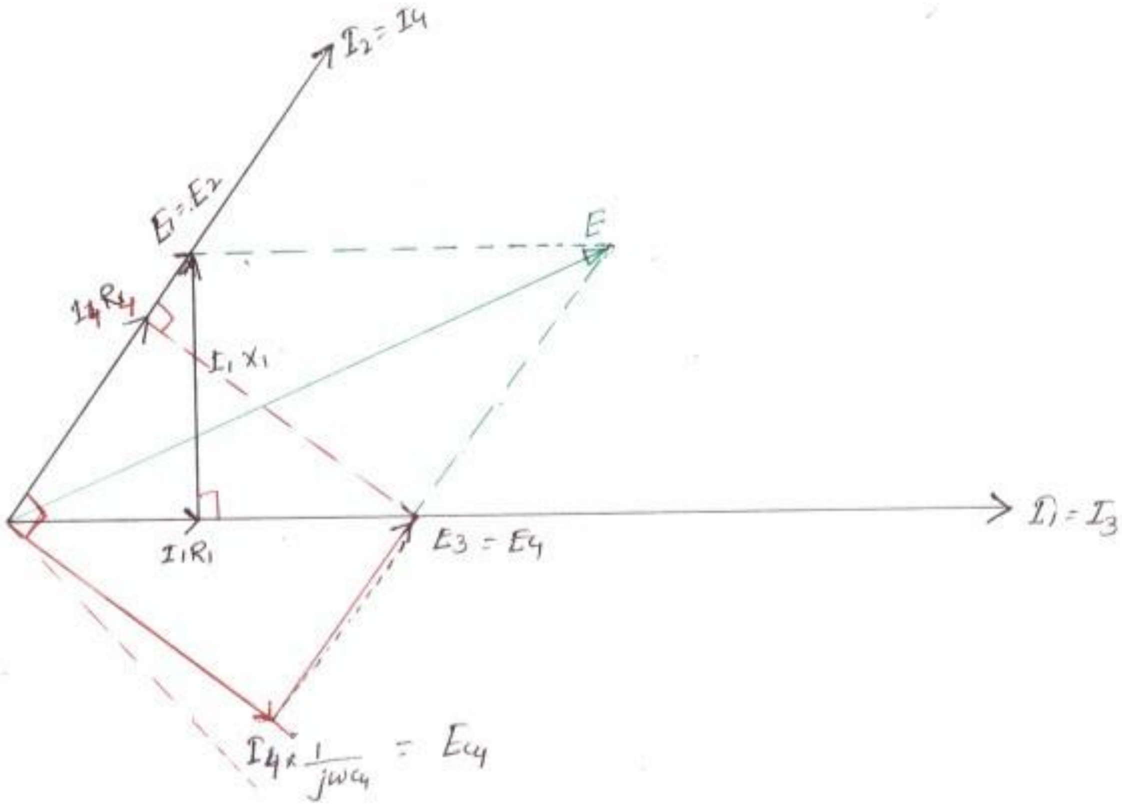


Fig 2.7 Phasor diagram of Hay's bridge

At balance condition, $Z_1Z_4=Z_3Z_2$

$$(R_1 + jwL_1)\left(\frac{1+ jwR_4C_4}{jwC_4}\right) = R_2R_3$$

$$(R_1 + jwL_1)(1+ jwR_4C_4) = jwR_2C_4R_3$$

$$R_1 + jwC_4R_4R_1 + jwL_1 + j^2w^2L_1C_4R_4 = jwC_4R_2R_3$$

$$(R_1 - w^2L_1C_4R_4) + j(wC_4R_4R_1 + wL_1) = jwC_4R_2R_3$$

Comparing the real term,

$$R_1 - w^2L_1C_4R_4 = 0$$

$$R_1 = w^2L_1C_4R_4 \qquad (2.14)$$

Comparing the imaginary terms,

$$wC_4R_4R_1 + wL_1 = wC_4R_2R_3$$

$$C_4R_4R_1 + L_1 = C_4R_2R_3$$

$$L_1 = C_4R_2R_3 - C_4R_4R_1 \tag{2.15}$$

Substituting the value of R_1 fro eqn. 2.14 into eqn. 2.15, we have,

$$L_1 = C_4R_2R_3 - C_4R_4 \times w^2L_1C_4R_4$$

$$L_1 = C_4R_2R_3 - w^2L_1C_4{}^2R_4{}^2$$

$$L_1(1 + w^2L_1C_4{}^2R_4{}^2) = C_4R_2R_3$$

$$L_1 = \frac{C_4R_2R_3}{1 + w^2L_1C_4{}^2R_4{}^2} \tag{2.16}$$

Substituting the value of L_1 in eqn. 2.14 , we have

$$R_1 = \frac{w^2C_4{}^2R_2R_3R_4}{1 + w^2C_4{}^2R_4{}^2} \tag{2.17}$$

$$Q = \frac{wL_1}{R_1} = \frac{w \times C_4R_2R_3}{1 + w^2C_4{}^2R_4{}^2} \times \frac{1 + w^2C_4{}^2R_4{}^2}{w^2C_4{}^2R_4R_2R_3}$$

$$Q = \frac{1}{wC_4R_4} \tag{2.18}$$

Advantages

- ✓ Fixed capacitor is cheaper than variable capacitor.
- ✓ This bridge is best suitable for measuring high value of Q-factor.

Disadvantages

- ✓ Equations of L1and R1 are complicated.
- ✓ Measurements of R_1 and L_1 require the value of frequency.
- ✓ This bridge cannot be used for measuring low Q- factor.

2.3.4 Owen's bridge

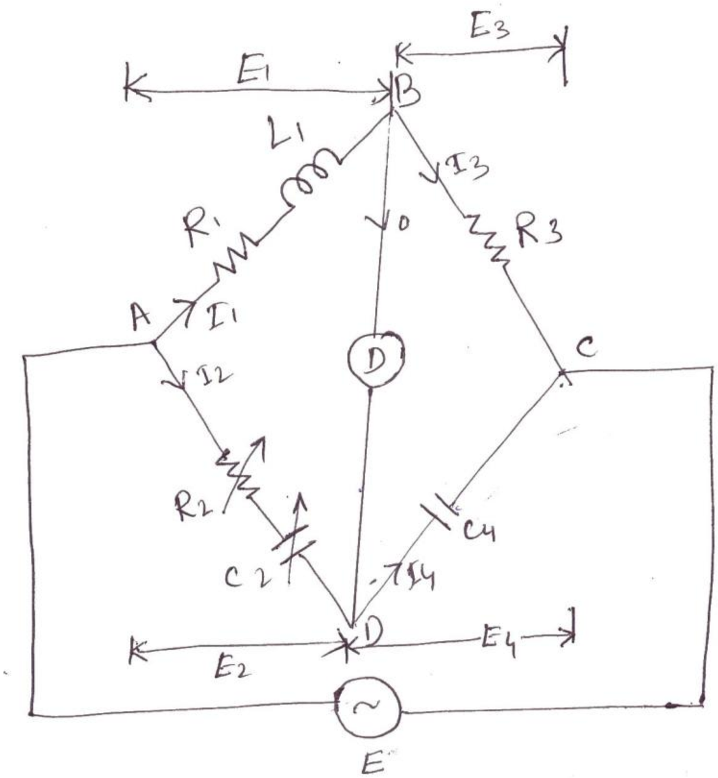


Fig 2.8 Owen's bridge

- $E_1 = I_1 R_1 + jI_1 X_1$
- I_4 leads E_4 by 90^0

➢ $\dot{E} = \dot{E}_1 + \dot{E}_3$

➢ $\dot{E}_2 = I_2 R_2 + \frac{I_2}{jwC_2}$

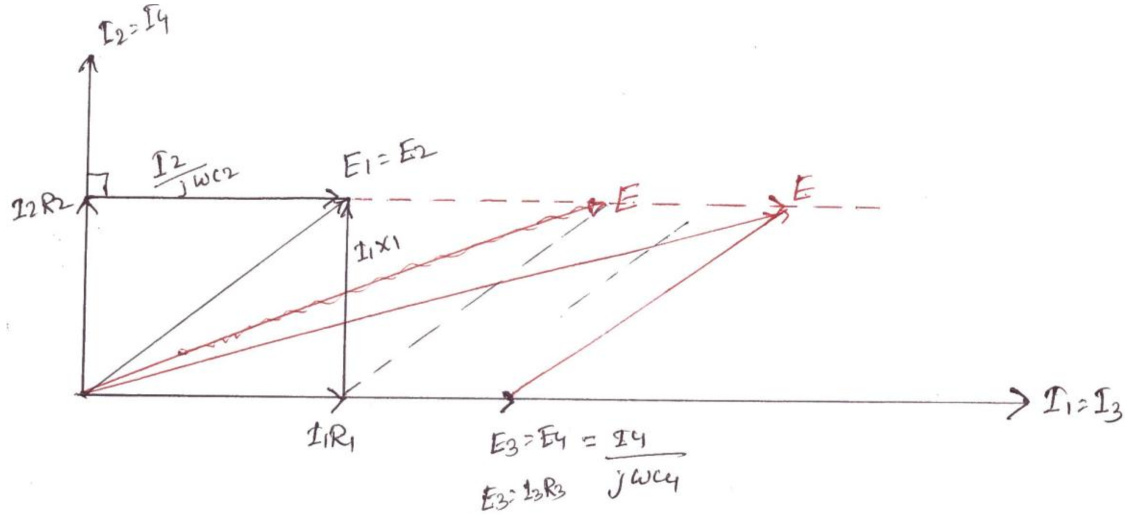


Fig 2.9 Phasor diagram of Owen's bridge

Balance condition, $\dot{Z}_1 \dot{Z}_4 = \dot{Z}_2 \dot{Z}_3$

$$Z_2 = R_2 + \frac{1}{jwC_2} = \frac{jwC_2R_2 + 1}{jwC_2}$$

$$\therefore (R_1 + jwL_1) \times \frac{1}{jwC_4} = \frac{(1 + jwR_2C_2) \times R_3}{jwC_2}$$

$$C_2(R_1 + jwL_1) = R_3C_4(1 + jwR_2C_2)$$

$$R_1C_2 + jwL_1C_2 = R_3C_4 + jwR_2C_2R_3C_4$$

Comparing real terms,

$$R_1C_2 = R_3C_4$$

$$R_1 = \frac{R_3C_4}{C_2}$$

Comparing imaginary terms,

$$wL_1C_2 = wR_2C_2R_3C_4$$

$$L_1 = R_2R_3C_4$$

$$\text{Q- factor} = \frac{WL_1}{R_1} = \frac{wR_2R_3C_4C_2}{R_3C_4}$$

$$Q = wR_2C_2$$

Advantages:

- ✓ Expression for R_1 and L_1 are simple.
- ✓ R_1 and L_1 are independent of Frequency.

Disadvantages

- ✓ The Circuits used two capacitors.
- ✓ Variable capacitor is costly.
- ✓ Q-factor range is restricted.

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DC Amplifier : Circuit Diagram, and Applications

An Amplifier circuit can be described as, a circuit which is used to increase the input signal. But, not every amplifier circuit is the same due to their type of circuit configuration as well as operation. In electronic circuits, a small signal amplifier can be used because it amplifies a small input signal. There are different types of amplifier circuits like operational amplifiers, power amplifiers, and small signal to large signal amplifiers. The amplifiers classification can be done based on the signal size, configuration and process of the input signal which means the relationship among the flow of current within the load as well as an input signal. This article discusses an overview of DC amplifiers.

A **DC amplifier (direct coupled amplifier)** can be defined as is a kind of amplifier where the one stage output of the amplifier can be connected to the next stage input for allowing the signals without frequency. So this is named as the direct current which passes from input to output. The DC amplifier is another type of coupling amplifier and this amplifier is particularly used for amplifying low-frequencies like thermocouple current otherwise photoelectric current.

This type of amplifier can be used for both DC (direct current) signals as well as AC (alternating current) signals. The DC amplifier's frequency response is the same as LPF (low pass filter). The direct current amplification can be achievable only by using this amplifier, therefore later it turns into the basic building block of the differential as well as operational amplifier. In addition, monolithic IC (integrated circuit) technology does not permit the production of large coupling capacitors.

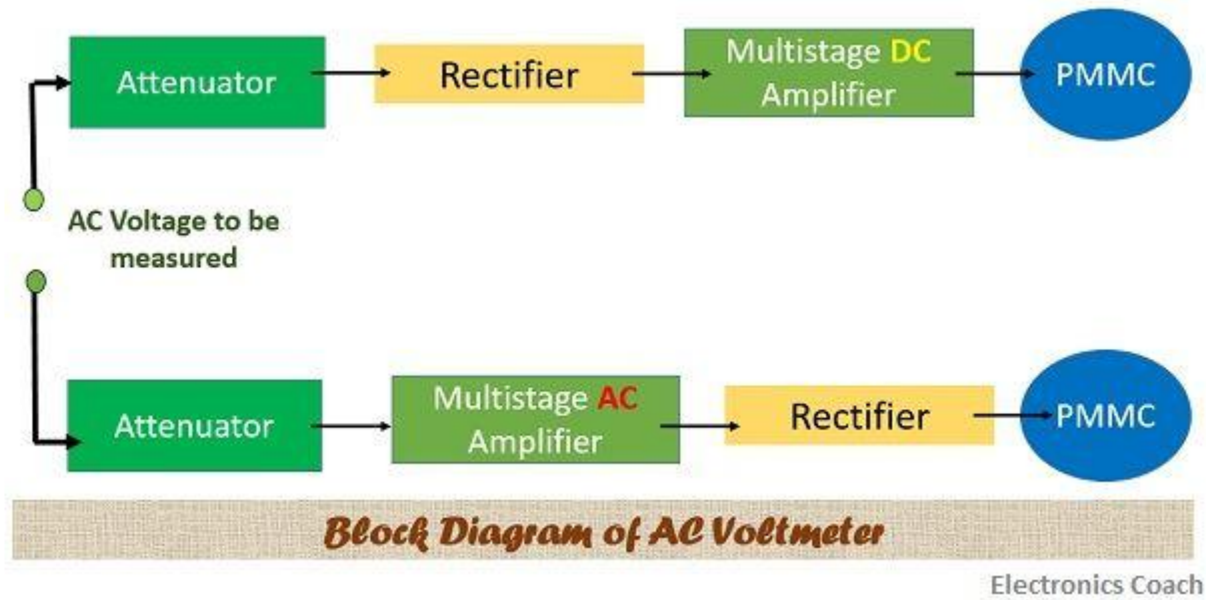
AC Voltmeter:

Definition: AC voltmeters are designed in a manner so that they can measure the AC voltage under measurement. The main difference between AC voltmeter circuit and DC voltmeter circuit is the usage of a **rectifier.** The rectifier is used in order to transform the AC voltage into DC voltage.

Block Diagram of AC Voltmeter

To develop a basic understanding of AC voltmeter, it is crucial to have a brief idea of the block diagram of AC voltmeter circuit. The block diagram of AC voltmeter resembles the block diagram of DC voltmeter except the fact that rectifier is used in case of AC voltmeter.

The input to be measured is given to the **attenuator circuit** which performs the operation of selection of a particular range of voltage. The output of attenuator is given to rectifier which converts the AC voltage into pulsating DC voltage. Then the final output of DC amplifier is given to the PMMC meter.



The rectifier can be used before the **multistage amplifier** or after the amplifier. This depends on the type of amplifier used in AC voltmeter. If we are using multistage AC amplifier, then the rectifier circuit will be used after the amplifier. On the contrary, if the multistage amplifier used is DC, then the rectifier should be used before it.

The amplifier is a vital component because it amplifies the signal which got attenuated during the measurement procedure. The usage of the amplifier increases the cost of the circuit. If the designing needs to be economical, then we should use multistage DC amplifier.

True RMS Voltmeter:

True RMS Voltmeter – Complex waveform are most accurately measured with an rms voltmeter. This instrument produces a meter indication by sensing waveform heating power, which is proportional to the square of the rms value of the voltage. This heating power can be measured by amplifying and feeding it to a thermocouple, whose output voltages is then proportional to the $E_{rms.}$

However, thermocouples are non-linear devices. This difficulty can be overcome in some instruments by placing two thermocouples in the same thermal environment.

Figure 4.25 shows a block diagram of a true rms responding voltmeter.

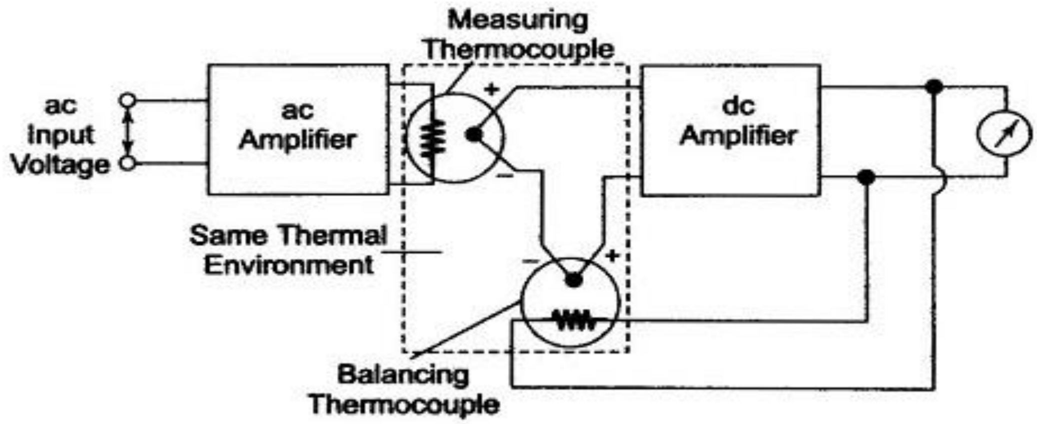


Fig. 4.25 True RMS Voltmeter (Block Diagram)

The effect of non-linear behavior of the thermocouple in the input circuit (measuring thermocouple) is cancelled by similar non-linear effects of the thermocouple in the feedback circuit (balancing thermocouple). The two couples form part of a bridge in the input circuit of a dc amplifier.

The unknown ac voltage is amplified and applied to the heating element of the measuring thermocouple. The application of heat produces an output voltage that upsets the balance of the bridge.

The dc amplifier amplifies the unbalanced voltage; this voltage is fed back to the heating element of the balancing thermocouple, which heats the thermocouple, so that the bridge is balanced again, i.e. the outputs of both the thermocouples are the same. At this instant, the ac current in the input thermocouple is equal to the dc current in the heating element of the feedback thermocouple. This dc current is therefore directly proportional to the effective or rms value of the input voltage, and is indicated by the meter in the output circuit of the dc amplifier. If the peak amplitude of the ac signal does not exceed the dynamic range of the ac amplifier, the true rms value of the ac signal can be measured independently.

True RMS Meter:

There exists a fundamental difference between the readings on a normal ac meter and on a true rms meter. The first uses a D' Arsonval movement with a full or half wave rectifier, and averages the values of the instantaneous rectified current.

The rms meter, however, averages the squares of the instantaneous current values (proportional, for example, to the instantaneous heating effect). The scale of the true rms meter is calibrated in terms of the square roots of the indicated current values. The resulting reading is therefore the square root of the average of the squared instantaneous input values, which is the rms value of the measured alternating current.

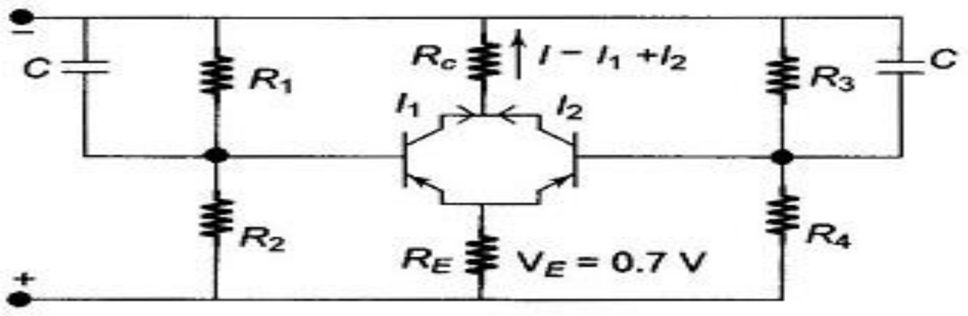


Fig. 4.26 Squaring Device

A true rms meter is always a combination of a normal mean value indicating meter and a squaring device whose output at any instant is proportional to the instantaneous squared input. It can be shown that the ac component of the voltage developed across the common collector resistors of two transistors that are connected in parallel, and between the bases of which a small ac voltage is applied, is proportional to the square of the applied input voltage.

Multimeter Types and Their Applications

Most of the engineers, as well as technicians in the electronics field, know the measurement device namely a multimeter. Multimeters are available in different forms in the market based on the characteristics. A multimeter is an essential measurement instrument, used in any engineering workshop or any lab. The main function of this device is to measure the electrical properties of tools as well as wiring in industries. At present, multimeters are used for different purposes based on the requirements like to deal with electricity, laboratories, power sources & circuits. The different electrical parameters in the multimeter can be selected using a dial or a rotary switch on the front side of the instrument. This article discusses an overview of multimeter types.

A Multimeter is an electronic instrument, every electronic technician and engineer's widely used piece of test equipment. A multimeter is mainly used to measure the three basic electrical characteristics of voltage, current, and resistance. It can also be used to test continuity between two points in an electrical circuit. This post mainly introduces the basic information of multimeters, applications, and types of multimeters are in. Let's see all of these.

The multimeter has multi functionalities like, acts like ammeter, voltmeter, and ohmmeter. It is a handheld device with positive and negative indicator needles over a numeric LCD digital display. Multimeters can be used for testing batteries, household wiring, electric motors, and power supplies.

How to use a Multimeter?

The function and operation of a multimeter are similar for both analog and digital types. This instrument includes two leads or probes namely red and black & three ports. The black color lead is used to plug into the common port, whereas the red color leads plug into other ports based on the requirement.

Once the leads are plugged in, the knob can be switched ON in the center of the instrument so that the appropriate function can be done for the specific component test. For instance, once the knob is situated to 20V DC, then the multimeter will notice DC voltage up to 20V. To calculate low voltages, then set the knob in the multimeter to the 2V/200mV range.

To obtain a reading from the meter, you need to touch the end of each probe to the end of the terminals of components. Types of multimeter devices are very safe to utilize on devices and circuits to provide the current or voltage that does not go above the highest rating of the meter.

While measuring, we must be very cautious so don't touch the bar ends of the metal in the tester when activated otherwise you will get an electrical shock.

Functions of Multimeters

These instruments are capable of different readings based on the model. So basic types of multimeter are mainly used to measure amperage, resistance, voltage, checks continuity and a complete circuit can be tested like the following.

- Resistance in Ohms
- Capacity in Farads
- The temperature in Fahrenheit/ Celsius
- AC Voltage & Amperage
- Inductance Henrys
- DC Voltage & Amperage

- Frequency in Hz
- Conductance in Siemens
- Decibels
- Duty Cycle

To some types of multimeters, special sensors or accessories can be attached for extra readings like acidity, light level, alkalinity, wind speed & relative humidity.

Digital Multimeter :

A Digital Multimeter can measure variety of electrical functions such as Current, Voltage, Resistance etc.

We encounter digital multimeter or DMM in electronics or electrical study every then and now. You might have used or saw an electrician using it to find fault in a connection.

Here I am going with easy step by step explanation with diagrams to make you understand its working and different features.

What is a Digital Multimeter

A **digital multimeter** or **DMM** is a test equipment used for resistance, voltage, current measurement, and other electrical parameters as per requirement and displaying the results in the mathematical digits form on an LCD or LED readout. It is a type of multimeter which functions digitally rather giving an analog output.

Digital multimeters are widely accepted worldwide as they have better accuracy levels and ranging from simple 3 ½ to 4 ½ digit handheld DMM to very special system DMM.

Features of Digital Multimeter

The Digital multimeter is the most advanced measuring instrument that makes use of modern Integrated circuits for making electrical measurements.

Some of its features which make it famous in the eyes of professional technicians are:

1. It is light in weight.
2. Capable of giving more accurate readings.
3. It measures lots of physical quantities like voltage, current, resistance, frequency, etc.
4. It is less costly.
5. It measures different electrical parameters at high frequencies with the help of special probes.

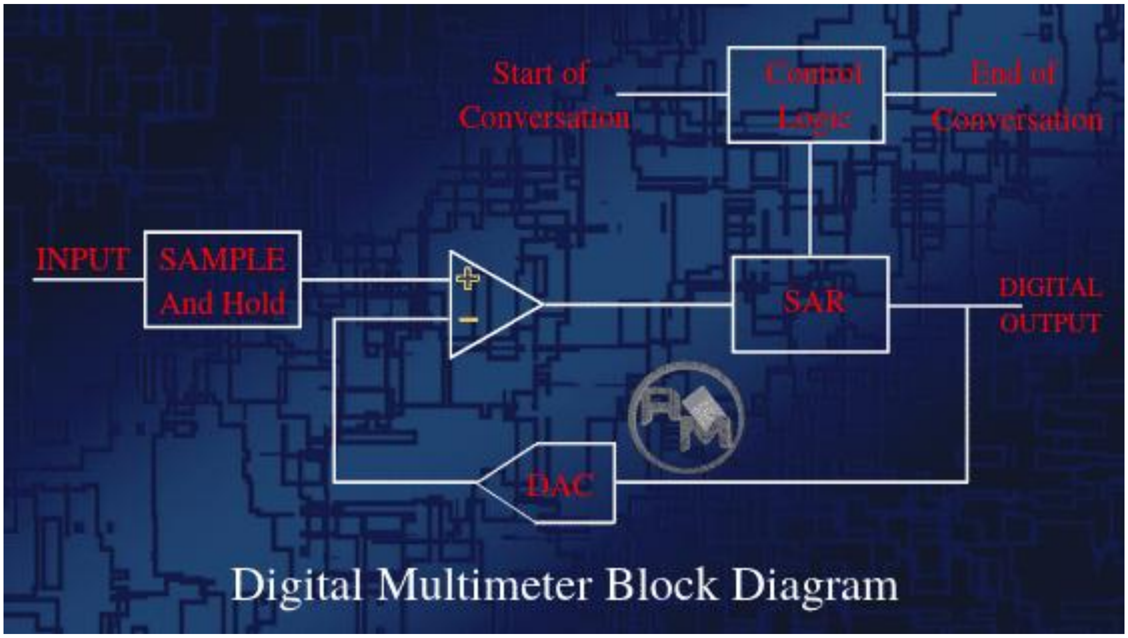
Block diagram of Digital multimeter

The Key process that occurs within a Digital multimeter for any measurement that takes place is that of voltage measurement. If you measure voltage then you can easily measure other electrical parameters with the help of mathematical formulas.

To understand how digital multimeter works, first of all, we have to understand this process.

As we know, Digital multimeters gave output in numeric form due to ADC registers present inside these multimeters. One that is most widely used in digital multimeters, DMMs is known as the successive approximation register or SAR. For better accuracy, these SAR ADCs may have resolution levels of 12 bits.

Generally, a Digital multimeter has resolution levels of 16 bits with speeds of 100k samples per second. These levels of speed are more than adequate for most DMM applications, that's why we are using these registers depending upon the requirement.



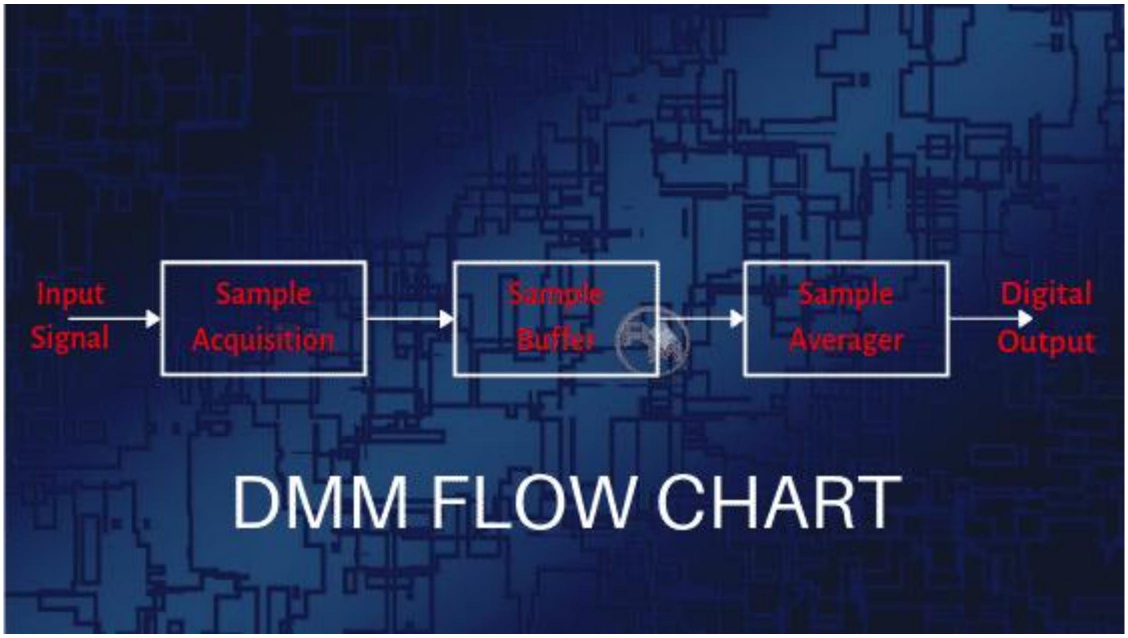
As shown in the diagram, the first stage of the process is a sample and hold used to sample the voltage at the input of the Digital multimeter and then to hold it steady. The output of the first stage becomes one of the inputs of the operational amplifier and another input of the op-amp is digital output feedback through the DAC.

The output obtained becomes the input of the SAR which generates results in digital form with a good resolution level. With a steady input voltage, the resister starts at half its full-scale value. It basically sets the most significant bit, MSB to “1” and all the remaining ones to “0”.

To see how it works take the simple example of a 4-bit SAR. Its output will start at 1000. If the voltage is less than half the maximum capability the comparator output will be low and that will force the register to a level of 0100. If the voltage is above this, the register will move to 0110, and so on.

Operation of Digital multimeter

The flow chart given below shows the operation flow of the digital multimeter.



As shown above, sample acquisition is done with the help of the sample and hold circuit. Inside the sample and hold circuit the capacitor is present which gets charge to match the input analog voltage known as the acquisition process.

When the capacitor is released from the acquisition circuit then the voltage is considered to be sampled. After this, the noise generally comes which will adversely affect the accuracy of the digital multimeter. To overcome this, we buffered and averaged the samples to achieve high accuracy and resolution.

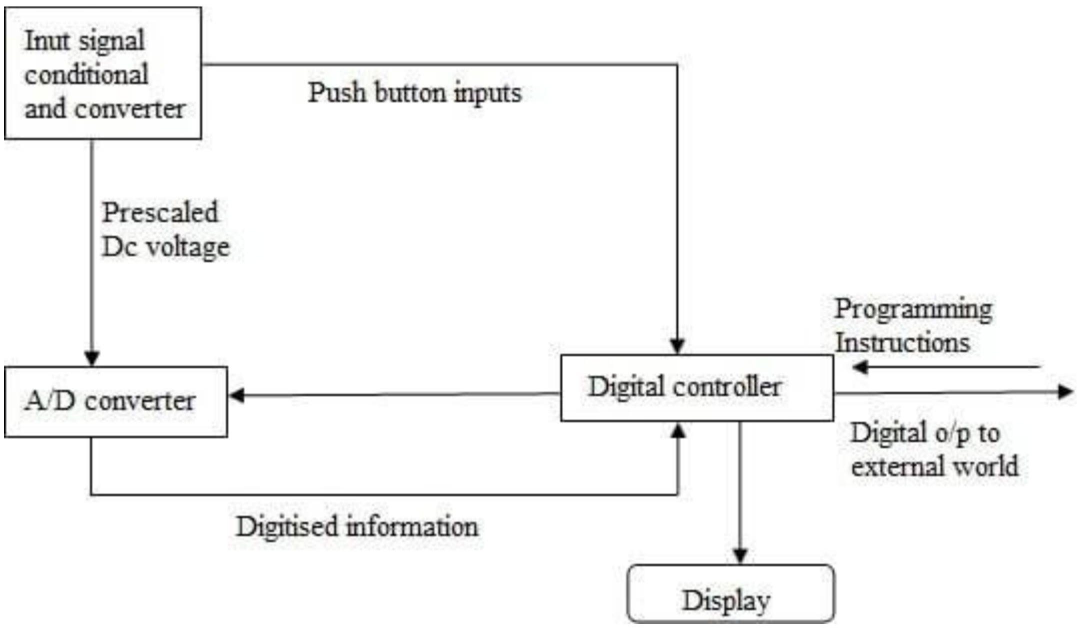
After knowing this you can easily use a Digital multimeter for measurements of electrical parameters like Ac & Dc voltage, current, Resistance, capacitance etc.

Working Principle of Digital Multimeter

As shown in the block diagram, in a typical Digital multimeter the input signal i.e. ac or dc voltage, current, resistance, temperature, or any other parameter is converted to dc voltage within the range of the ADC. The analog to digital converter then converts the pre-scaled dc voltage into its equivalent digital numbers which will be displayed on the display unit.

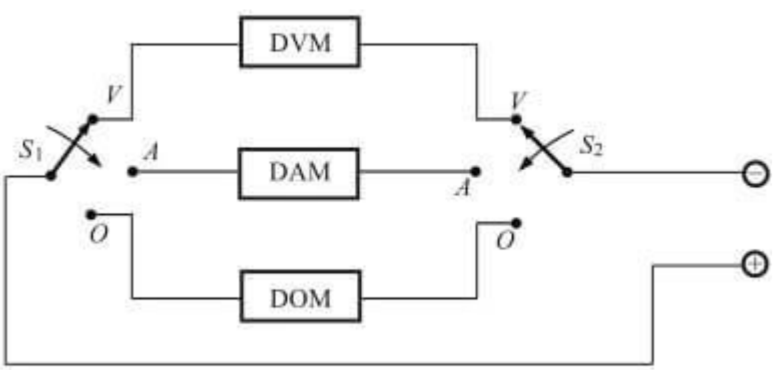
Sometimes, a digital controller block is implemented with a microcontroller or a microprocessor to manage the flow of information within the instrument. This block will coordinate all the internal functions as well as transferring information to external devices such as printers or a personal computer.

In the case of some handheld multimeter, some or all of these blocks may be implemented in a VLSI circuit while the A/D converter and display driver can be in the same IC.



Digital Multimeter as Voltmeter, Ammeter and Digital Ohmmeter

In digital multimeter, we can incorporate many types of meters like ohmmeter, ammeter, a voltmeter for the measurement of electrical parameters. Its block diagram is shown below in the figure. Let us have a look at its working and specification one by one.



vector voltmeter :

A vector voltmeter is a specialized instrument that measures both the amplitude and phase difference between two signals, unlike a regular voltmeter which only measures amplitude. It uses two samplers to capture the two signals, converting them into intermediate frequency (IF) signals that maintain the amplitude and phase relationships of the original signals. These IF signals are then filtered and measured by a voltmeter and phase meter. Essentially, it's a more sophisticated amplitude and phase measuring device.

Here's a more detailed breakdown:

1. Signal Acquisition:

- The vector voltmeter receives two input signals, which can be RF or other electrical signals.
- These signals are sampled by two samplers.

2. Signal Conversion:

- The samplers convert the input signals into intermediate frequency (IF) signals.
- These IF signals retain the amplitude and phase relationships of the original signals.

3. Signal Filtering and Measurement:

- The IF signals are then filtered to extract the fundamental components.
- These fundamental components are then measured by a voltmeter and a phase meter.
- The voltmeter measures the amplitude of the signals, and the phase meter measures the phase difference between them.

4. Phase Measurement:

- The vector voltmeter determines the phase difference between the two input signals.
- This phase difference is crucial for understanding the relationship between the two signals, particularly in circuits where phase relationships are important.

5. Application:

- Vector voltmeters are used in various applications, including:
  - Measuring the phase difference between the signals in an amplifier circuit.
  - Characterizing the performance of power amplifiers.
  - Testing RF and microwave components.
  - Measuring the phase and amplitude of signals in telecommunications systems.

MODULE-II

Oscilloscopes

Introduction:

In studying the various electronic, electrical networks and systems, signals which are functions of time, are often encountered. Such signals 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 and is probably most versatile tool for the development of electronic circuits and systems. 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.

Basic Principle:

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 dimensional displays, Thus CRO. can be regarded as a fast x-y plotter. The x-axis and y-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 seen on the screen of the oscilloscope. The oscilloscope is so fast 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.

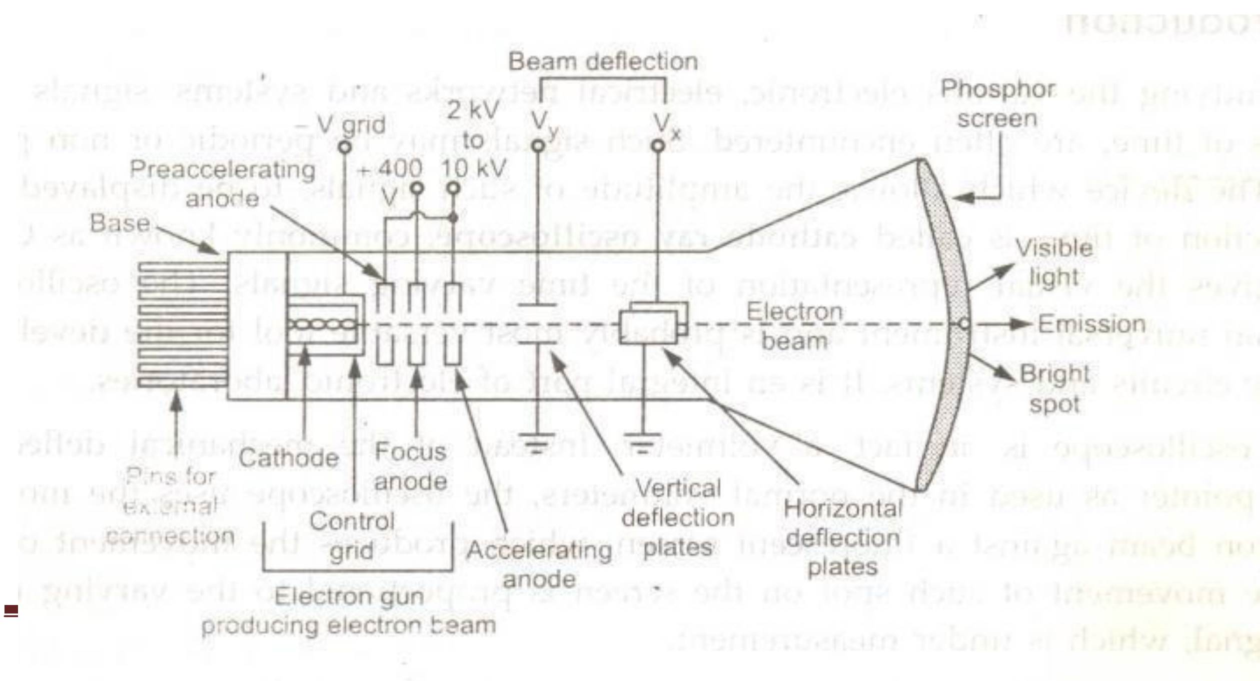
Cathode Ray Tube (CRT):

The cathode ray tube (CRT) is the heart of the CR.O. the CRT generates the electron beam, ,accelerates the beam, deflects the beam and also has a screen where beam becomes visible ,as a spot. The main parts of the CRT are:

i) Electron gun ii) Deflection system iii) Fluorescent screen

iv) Glass tube or envelope v) Base

A schematic diagram of CRT, showing its structure and main components is shown in the Fig.



Electron Gun:

The electron gun section of the cathode ray tube provides a sharply focused electron beam directed :towards the fluorescent-coated screen. This section starts from 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 number x their speed) 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 applied to various grids are stated with respect to cathode, which is taken as common point). This negative control voltage can be made variable.

Deflection System:

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 deflection plates. One of the plates' in each set is connected to ground (0 V), To the other plate of each set, the

external deflection voltage is applied through an internal adjustable gain amplifier stage, To apply 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 simultaneously to vertical and horizontcl1 deflecting plates, the electron beam is deflected due to the resultant-of these two voltages.

Fluorescent Screen:

The light produced by the screen does not disappear immediately when bombardment by electrons ceases, i.e., when the signal becomes zero. The time period for which the trace remains on the screen after the signal becomes zero is known as "persistence". The persistence may be *jS* short as a few microsecond, or as long as tens of seconds and minutes.

Long persistence traces are used in the study.. of transients. Long persistence helps in the study of transients since the trace is still seen on the screen after the transient has disappeared.

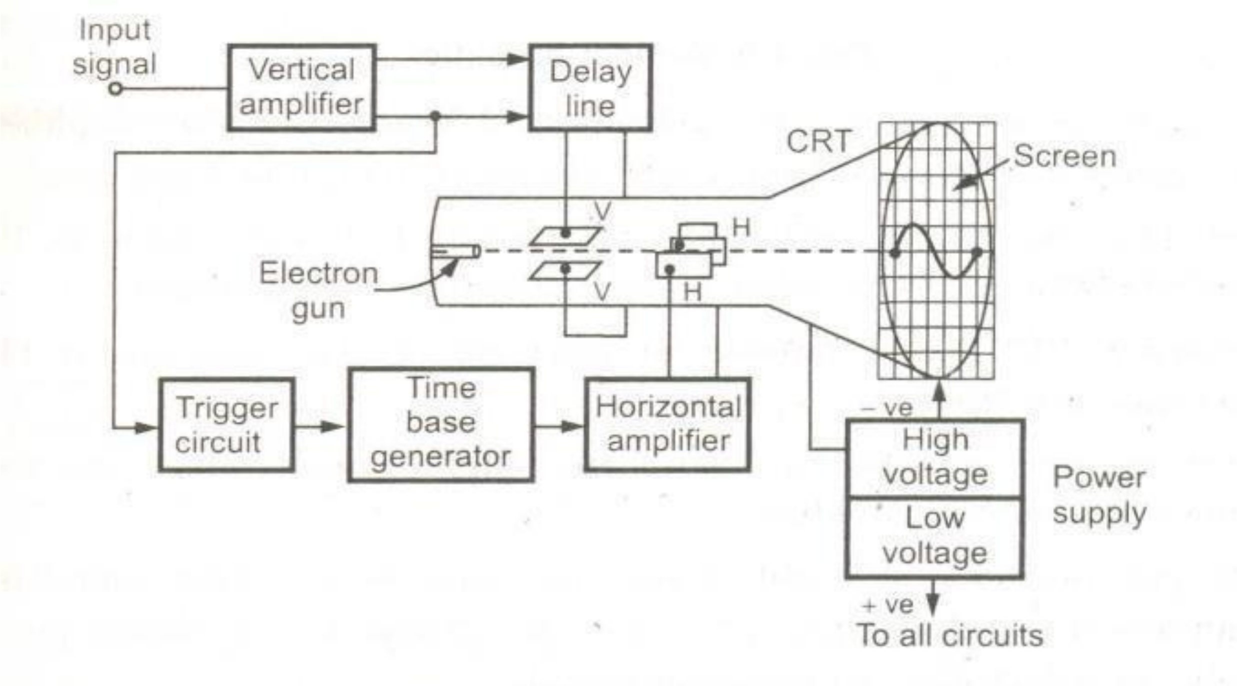
Phosphor screen characteristics:

Many phosphor materials having different excitation times and colours as well as different 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.

Block diagram of simple oscilloscope:

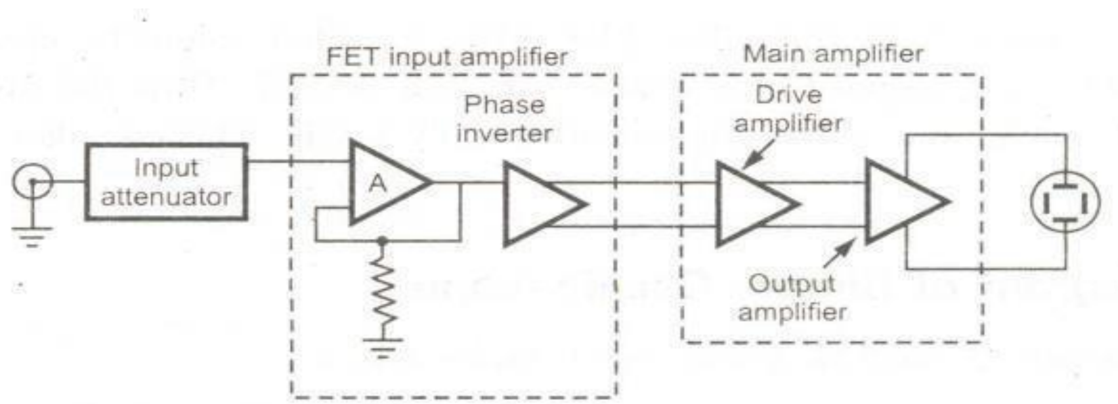


CRT:

This is the cathode ray tube which is the heart of CR.O. It is' used to emit the rlectrons required to strike the phosphor screen to produce the spot for the visual display of the signals.

Vertical Amplifier:

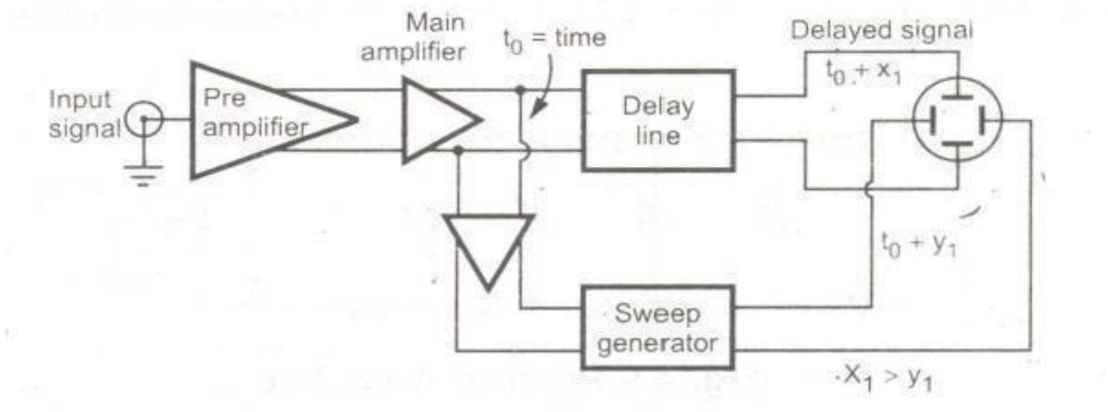
The input signals are generally not strong to provide the measurable deflection on the screen. Hence the vertical amplifier. stage is used Jo amplify the input signals. The amplifier stages used are generally wide band amplifiers so as to pass faithfully the entire band of frequencies to be measured. Similarly it contains the attenuator stages as well. The attenuators are used when very high voltage signals are to be examined, to bring the signals within the proper range of operation.



It consists of several stages with overall fixed sensltivity. The amplifier can be designed for stability and required bandwidth very easily due to the fixed gain. The input stage colrtsists of an attenuator followed by FET source follower. It has vel' high input 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 provides two 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.

Delay line:

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 amplifier then signal is delayed by XI nanoseconds while sweep takes YI nanoseconds to reach. The design of delay line is such that the delay time XI is higher than the time YI' Generally XI is

200. nsec while tl;1.eYI is 80 ns, thus the sweep starts well in time and no part of the signal is lost. There are two types of delay lines used in CR.O. which are:

i) Lumped parameter delay line

ii) Distributed parameter delay line

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.

Time base generator:

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.

Oscilloscope probes

Oscilloscopes are widely used for test and repair of electronics equipment of all 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 scope to the point to be monitored it is necessary to use screened 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 connector on one end and open wires with crocodile / alligator clips on the other, 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 or ground clip to be attached to the appropriate ground point on the 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.

X1 and X10 oscilloscope probes

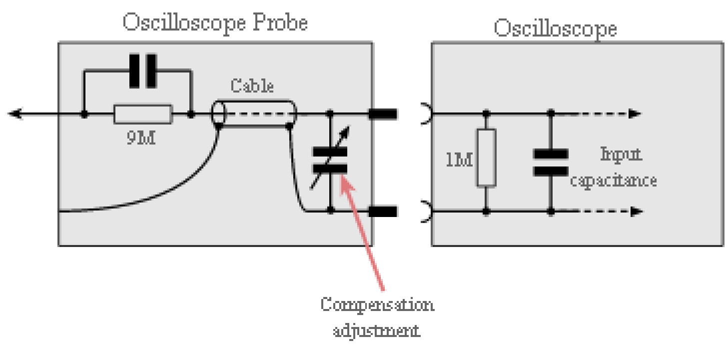
There are two main types of passive voltage scope probes. They are normally designated X1 and X10, although 1X and 10X are sometimes seen. The designation refers to the factor by which the impedance of the scope itelf is multiplied by the probe.

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 achieve this attenuators are built into the end of the probe that connects with the circuit under test. The most common type of probe with a built in attenuator gives an attenuation of ten, and it is known as a X10 oscilloscope probe. The attenuation enables the impedance presented to the circuit under test to be increased by a factor of ten, and this enables more accurate measurements to be made.

As the X10 probe attenuates the signal by a factor of ten, the signal entering the scope itself will be reduced. This has to be taken into account. Some oscilloscopes automatically adjust the scales according to the probe present, although not all are able to do this. It is worth checking before making a reading.

The 10X scope probe uses a series resistor (9 M Ohms) to provide a 10 : 1 attenuation when it is used with the 1 M Ohm input impedance of the scope itself. A 1 M Ohm impedance is the standard impedance used for oscilloscope inputs and therefore this enables scope probes to be 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 of circuit loading are required, and where the high frequencies are present. The difficulty using the is the fact that the signal is attenuated by a factor of 100.

X10 oscilloscope probe compensation

The X10 scope probe is effectively an attenuator and this enables it to load the circuit under test far less. It does this 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 variety of reasons. It does this by decreasing the resistive and capacitive loading on the The X10 probe can often be adjusted, or compensated, to improve the frequency response.

Typical oscilloscope probe

For many scope 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.

Compensation adjustment waveforms for X10 oscilloscope probe.

As can be seen, the adjustment is quite obvious and it is quick and easy to undertake. It should be done each time the probe is moved from one input to another, or one scope to another. It does not hurt to check it from time 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 of caution: many oscilloscope 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 of 10MΩ along with a load capacitance of 15pF 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.

Other types of probe

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 measure differential 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.

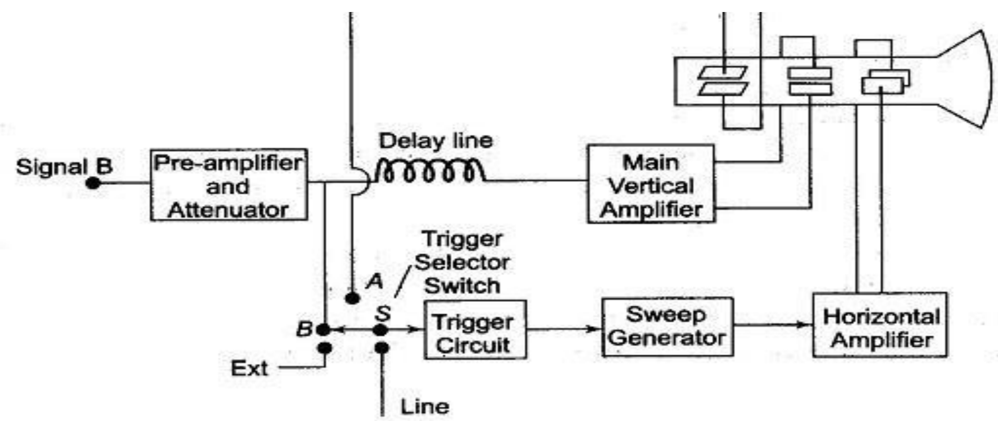
- ***High voltage probes:*** Most standard oscilloscope voltage probes like the X1 or X10 are only specified for operation up to voltages of a few hundred volts at most. For operation higher than this a proper high voltage probe with specially insulated probe is required. It also will step down the voltage 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.

Special Purpose Oscilloscopes

Dual Beam CRO

The dual trace oscilloscope has one cathode ray gun, and an electronic switch which 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 time base is used for both beams. Block diagram of a Dual Beam CRO.

Therefore, the signals must have the same frequency or must be relatedharmonically, in order to obtain both beams locked on the CRT screen, e.g. the input signal of an amplifier can be used as signal A and its output signal as signal



B.

Fig. 7.18 Dual Beam CRO

DUAL TRACE OSCILLOSCOPE

This CRO has a single electron gun whose electron beam is split into two by an electronic switch. There is one control for focus and another for intensity. Two signals are displayed simultaneously. The signals pass through identical vertical channels or vertical amplifiers. Each channel has its own calibrated input attenuator and i positioning control, so that the amplitude of each signal can be ndependpntly adjusted.

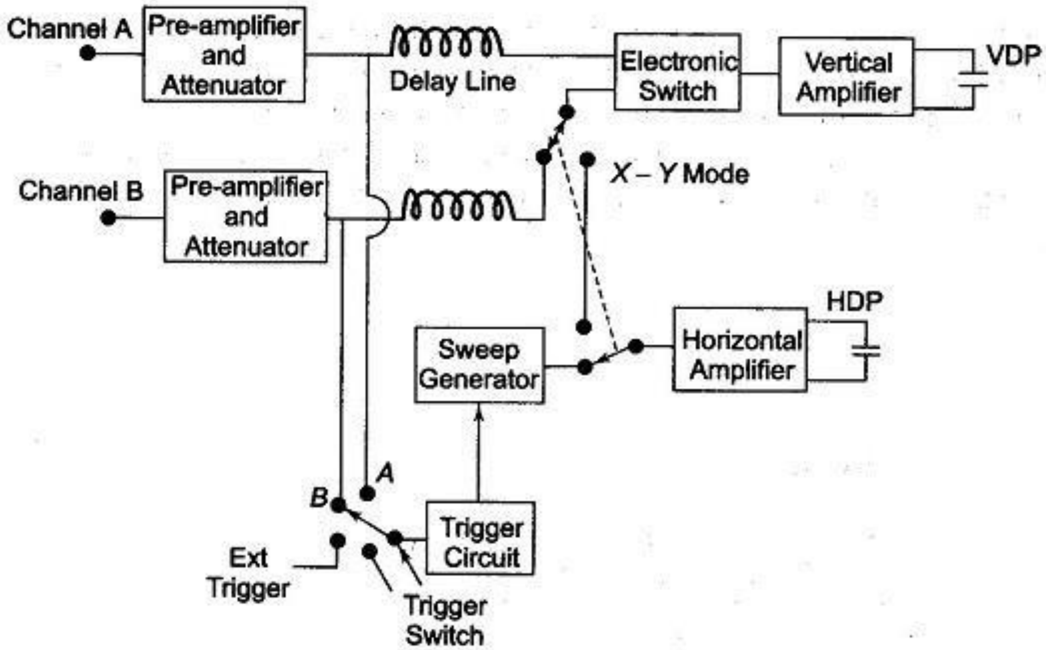


Fig. 7.19 (a) Dual Trace Oscilloscope

A mode control switch enables the electronic switch to operate in two modes. Wheri the switch is in ALTERNATE position, the electronic switch feeds each signal alternately to the vertical amplifier. The electronic switch alternately connects the main vertical amplifier to 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)]

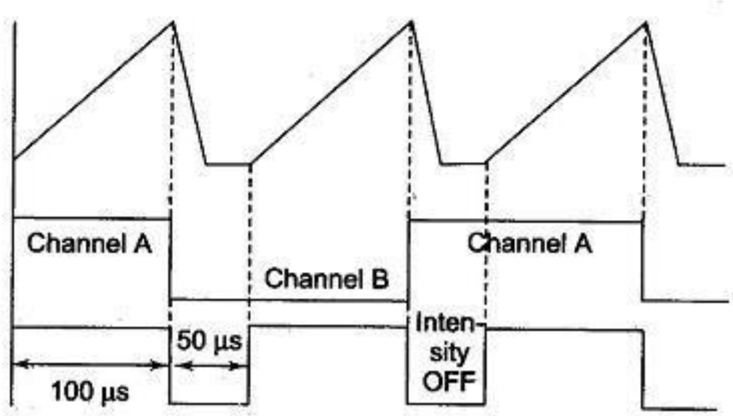


Fig. 7.19 (b) Time Relation of a Dual-Channel Vertical Amplifier in Alternate Mode

The sweep trigger signal is available from channels A or B and the trigger pick-off takes place before the electronic 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 amplifier at a relatively fast chopping rate of 500 kHz e.g. 1 i.ts segments of each waveform are fed to the CRT 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 can be displayed by the addition of signal from channels A and B, i.e. (A + B), etc. In the X — Y mode of operation, the sweep 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>Dual trace Oscilloscope(0-15MHz)</u>

Block Description Y-Channels

A and B vertical channels are identical for producing the dual trace facility. Each comprises an input coupling switch, an input step attenuator, a source follower input stage with protection circuit, a pre-amplifier from which a trigger signal is derived and a combined final amplifier. The input stage protection circuit consists of a diode, which prevents damage to the FET transistors that could occur with excessive negative input potentials, and a resistor network which protects 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 stabilisation provides a measure of correction to reduce the drift inherent in high gain amplifiers. The trigger pick-off signal is taken from one side of the balanced pre-amplifier to the trigger mode switch, where either channel A or channel **B** triggering can be selected. The supply for the output of the pre-amplifier stage is derived from a constant current source controlled by the channel switching logic. Under the control of channel switching, signals from A 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).

Channel Switching

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.

In the CHOP mode, the oscillator is switched via the logic stage to provide rapid switching of the 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 from the TV line and frame signals can be obtained from the sync separator and peak detector stages. The latter stage is switched into circuit in the TOP position.

Time Base

The time base generator circuit operates on the constant current integrator 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. In addition this pulse is supplied to an external socket 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 trigger pre-amplifier). The X-MAGN (x 5) circuit is incorporated in the X-final amplifier. The output of this amplifier is direct coupled to the horizontal deflection plates of the CRT.

Cathode–Ray Tube Circuit and Power Supply

The high voltages required for the CRT, which has an acceleration potential of 1.5 kV, are generated by a voltage multiplier circuit controlled by 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 of electron beam from 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.

SAMPLING OSCILLOSCOPE (VHF)

An ordinary Sampling Oscilloscope has a B.W. of 10 MHz. The HF performance can be 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 another sample is taken. The shape of the waveform is reconstructed by joining the sample 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.

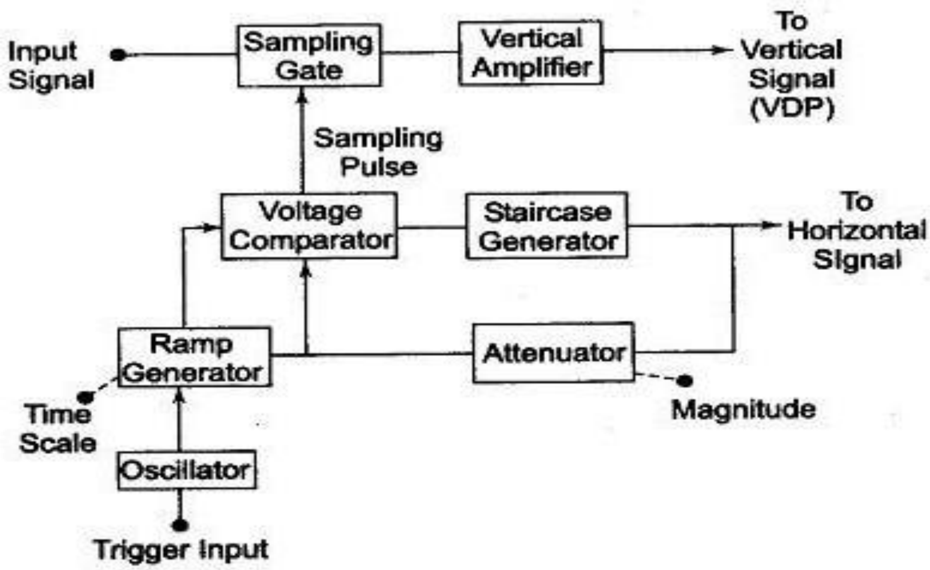


Fig. 7.24 Sampling Oscilloscope

Figure 7.24 shows a block diagram of a sampling oscilloscope. The input waveform is applied to the sampling gate. The input waveform is sampled whenever a 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.

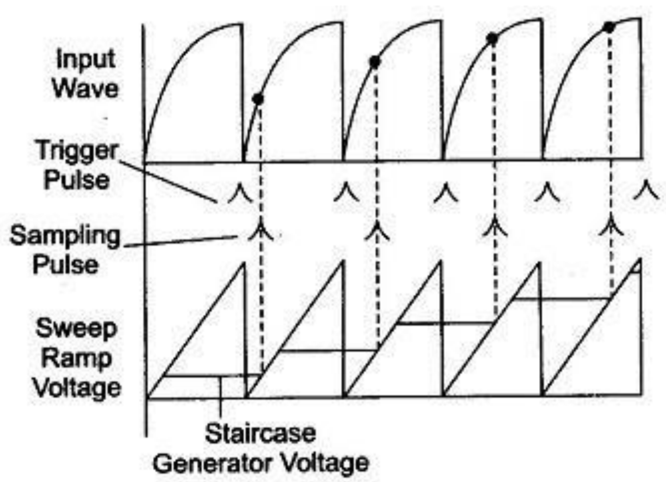


Fig. 7.25 Various Waveforms at Each Block of a Sampling Oscilloscope

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 and a 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.

STORAGE OSCILLOSCOPE

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 storage techniques 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 standard phosphor target in the CRT. The writing beam, which is the focussed electron beam of the standard CRT, 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 allow these electrons to pass through to the standardphosphor target and thereby reproduce 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.

Mesh Storage

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.

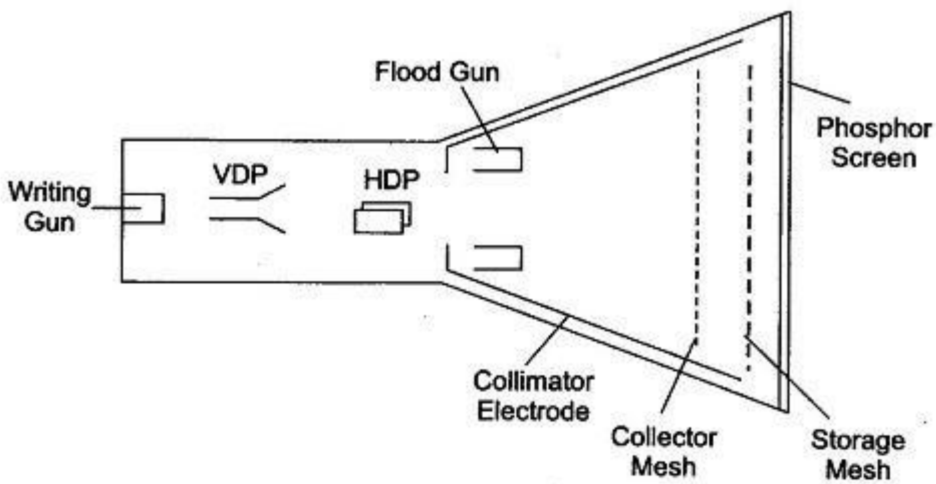


Fig. 7.26 Basic Elements of Storage Mesh CRT

A mesh Storage Oscilloscope, shown in Fig. 7.26, contains a dielectric material deposited on a storage mesh, a collector mesh, flood guns and a collimator, in addition to all the elements of a standard CRT. The storage target, a thin deposition of a dielectric material such as Magnesium 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 electrostatic lens system (to focus the electron beam), as shown in Fig. 7.27. Most of the electrons are stopped and collected by the collector mesh. Only electrons near the stored positive charge are pulled to the storage target with sufficient force to hit the phosphor screen. 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.

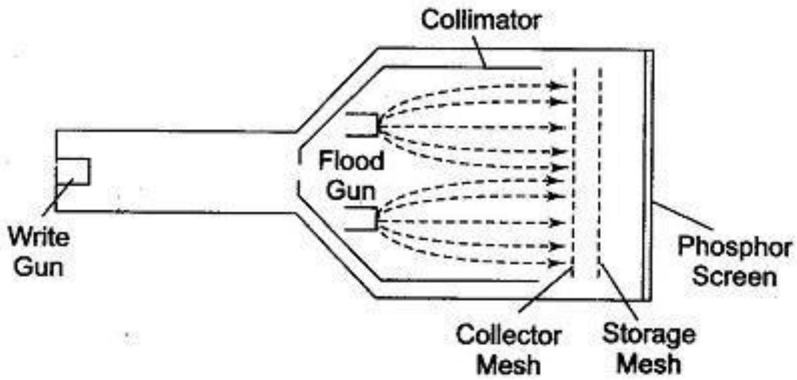


Fig. 7.27 Storage Mesh CRT

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) will hit 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, helps to align the flood electrons so that they approach the storage target perpendicularly.

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.

Figure 7.28 shows a display of the stored charge pattern on mesh storage.

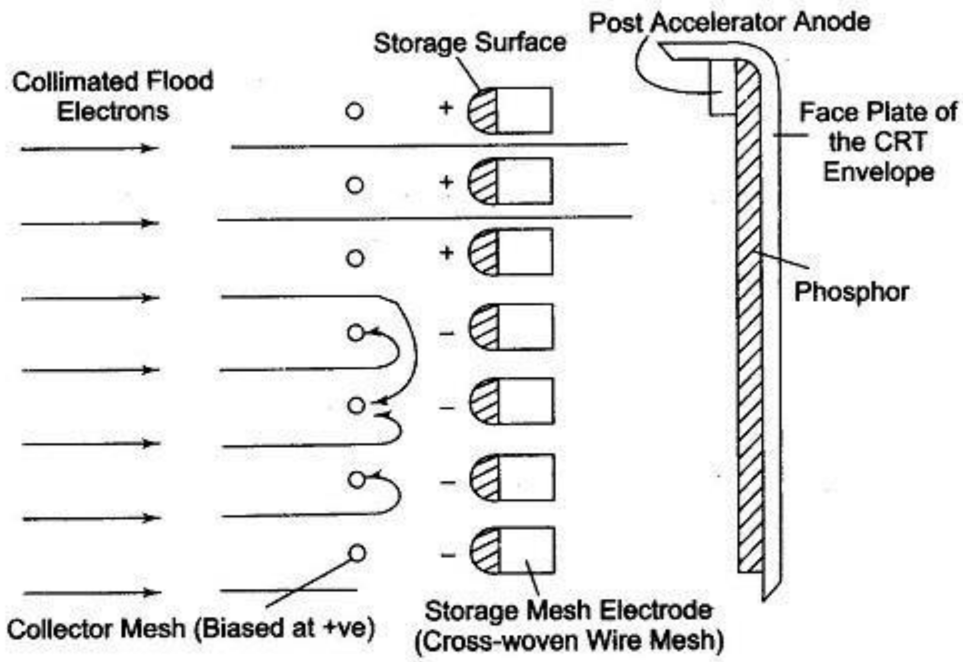


Fig. 7.28 Display of Stored Charged Pattern on a Mesh-storage

Digital Storage Oscilliscope

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 designed such that all confusing details are placed on the back side and one appears to be 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 appear repetitively and allowing their convenient display on the scope screen. (The CRT used in Digital Storage Oscilliscope is an ordinary CRT, 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.

Pretrigger capability is also a significant advantage. The display of stored data is possible in both 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, a magnetic disk accessory allows expansion to 32,000 points.

All Digital 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 bit A/D converter with a resolution of 0.1% (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.

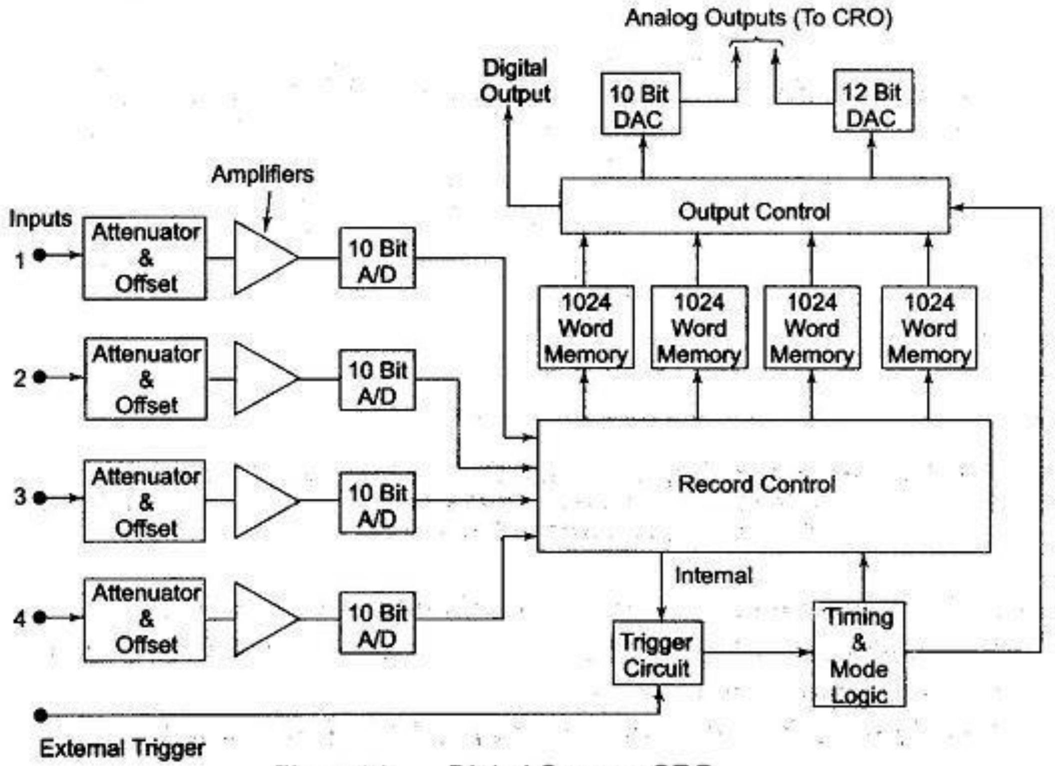


Fig. 7.51 Digital Storage CRO

The analog input voltage is sampled at adjustable rates (up to 100,000 samples per second) and data points are read onto the memory. A maximum of 4096 points are storable in this particular 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.

As in digital recorder, DSO can be set to record continuously (new data coming into the memory pushes out old data, once memory is full), until the trigger signal is received; then the 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.

Digital Storage Oscilliscope Features

1. Sampling rate 20 Mega-samples per second per channel. Max. (simultaneous) capture of both channels.
2. Pre-trigger: 25%, 50%, 75%, for Single Shot, Roll normal.
3. Roll mode: (Continuous and Single Shot with Pre-trigger of 25%, 50%, 75%)
4. Single shot (0.5 p.s Single shot @ 10 pts. /div resolution with pre-trigger 25%, 50%, 75%)
5. Digital Sweep rate: 0.5. μs/cm to 50 sec/cm, (event as long as 8.33 minutes can be captured)
6. Computer built in Interface: (RS 232 Serial port and Centronics Parallel interface).

MODULE-III

AF Wave analyzer

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 of a wave analyzer is as shown in fig 1.

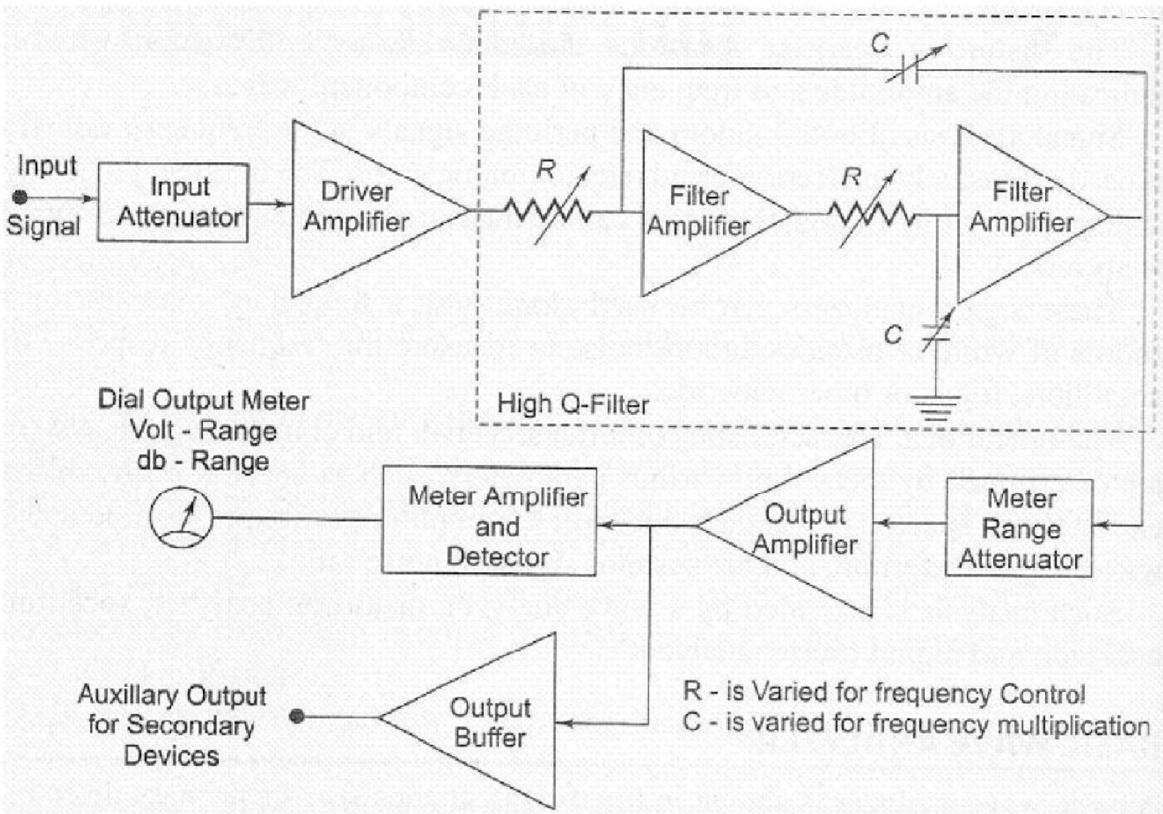


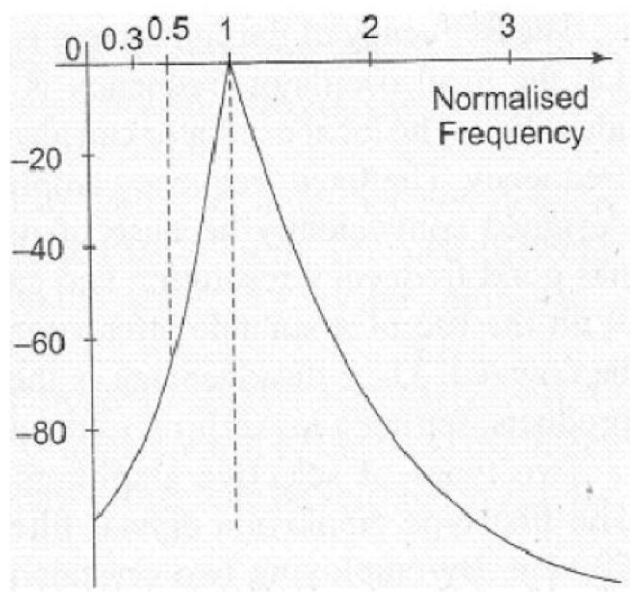
Fig 1: Frequency wave analyzer

The complex wave to be analyzed is passed through an adjustable attenuator which serves as a range multiplier and permits a large range of signal amplitudes to be analyzed without loading the amplifier.

The output of the attenuator is then fed to a selective amplifier, which amplifies the selected requency. The driver amplifier applies the attenuated input signal to a high-Q active filter. This high-Q filter is a low pass filter which allows the frequency which is selected to pass and reject all others. The magnitude of this selected frequency is indicated by the meter and the filter section 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. The entire AF range is covered in decade steps by switching capacitors in the RC section.

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



Application of wave analyzer:

1. Electrical measurements

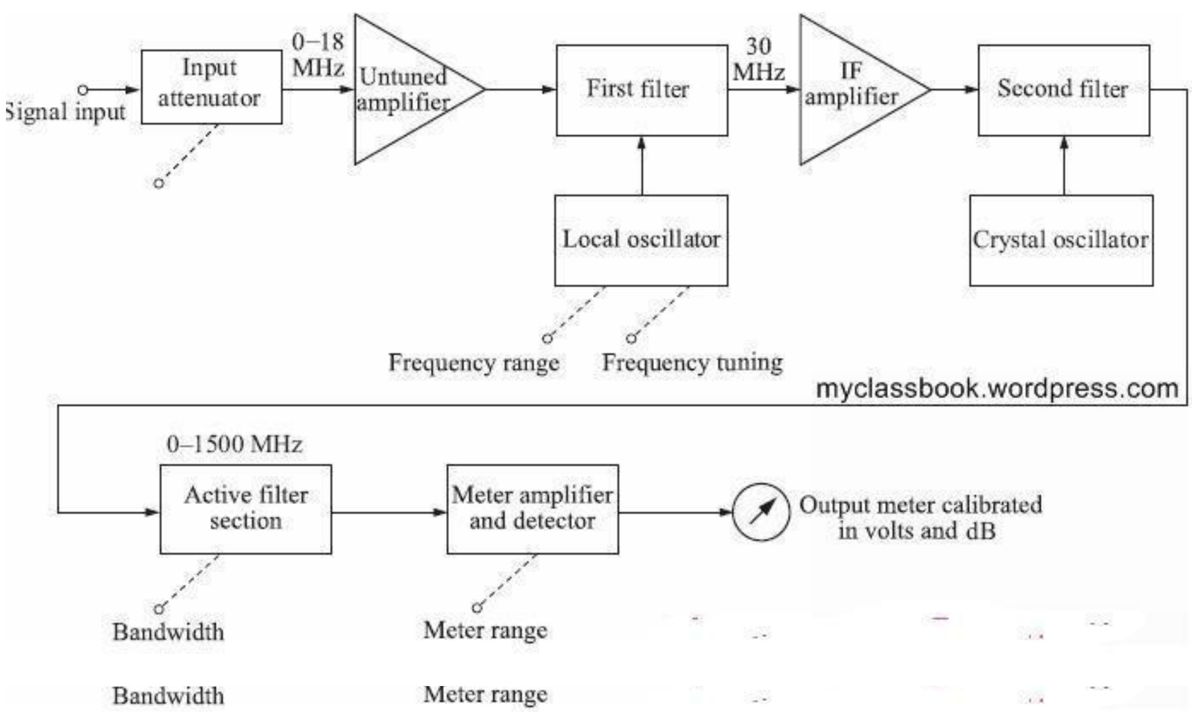
2. Sound measurements

3. Vibration measurements.

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.

Heterodyne wave analyzer

A wave analyzer, in fact, is an instrument designed to measure 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 by an internal local oscillator. Tuning the local oscillator shifts various signal frequency components into the pass band of the IF amplifier. The output of the IF amplifier is rectified and is applied to the 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 overlapping bands 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.

Wave analyzers have very important applications in the following fields:

1) Electrical measurements
2) Sound measurements and
3) Vibration measurements.

The wave analyzers are applied industrially in the field of reduction of sound and vibrations generated by rotating electrical machines and apparatus. The source of noise 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.

Harmonic distortion :

The **total harmonic distortion (THD)** is a measurement of the harmonic distortion present in

a signal and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. **Distortion factor**, a closely related term, is sometimes used as a synonym.

In audio systems, lower distortion means the components in a loudspeaker, amplifier or microphone or other equipment produce a more accurate reproduction of an audio recording.

To understand a system with an input and an output, such as an audio amplifier, we start with an ideal system where the transfer function is linear and time-invariant. When a signal passes through 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.

When the main performance criterion is the ″purity″ of the original sine wave (in other words, 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 a set of higher harmonic frequencies to the RMS amplitude of the first harmonic, or fundamental, frequency

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

where V_n is the RMS voltage of the nth harmonic and $n = 1$ is the fundamental frequency.

Spectrum Analyzer

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

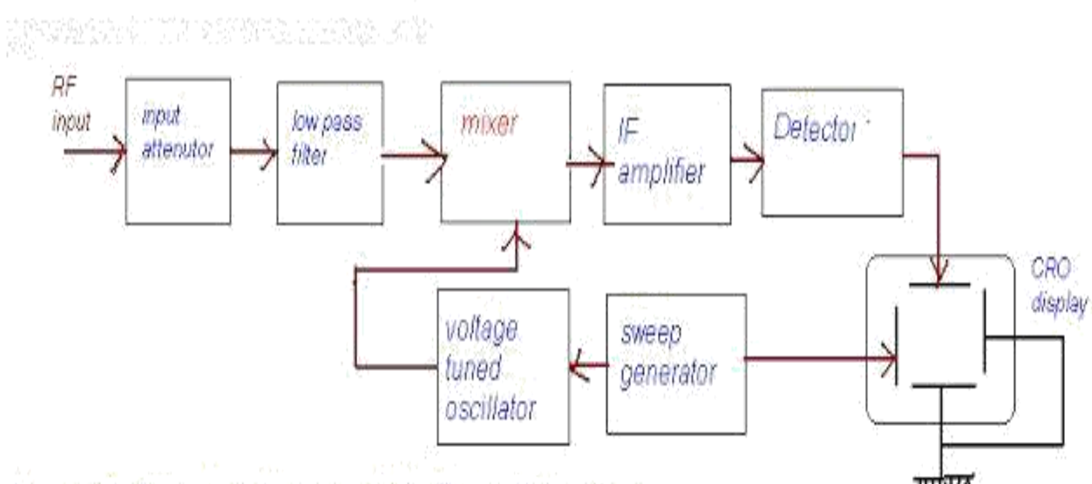


fig.: super hertodyne spectrum analyzer or RF spectrum analyzer

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 high frequency 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 tuned oscillator.

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.

Since the frequency range of the oscillator is tuned over 2 to 3 GHz, the IF amplifier is tuned 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 signal is amplified by IF amplifier and then rectified by the detector. After completing 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 CRT screen. On the CRT screen the vertical axis is calibrated in amplitude and the horizontal axis is calibrated in frequency.

FFT spectrum analyzer

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. The output of low pass filter is given to the attenuator. The attenuator is a voltage dividing 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

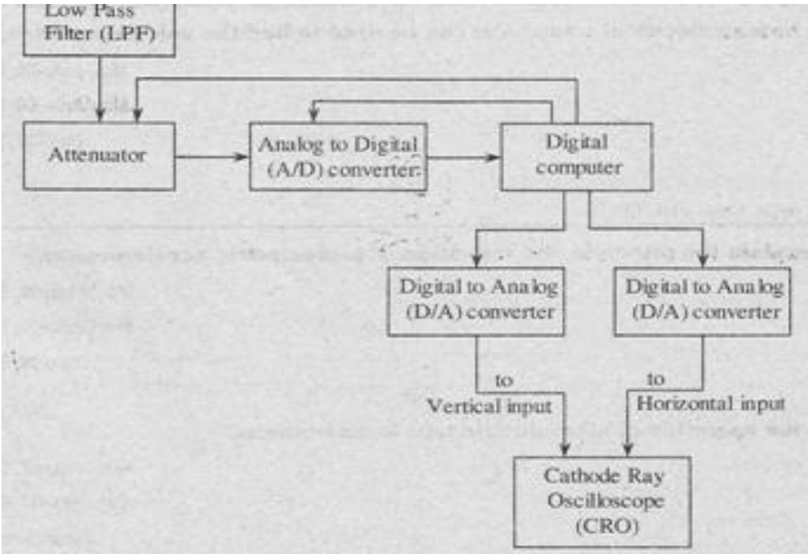


Fig Digital Fourier Analyzer

If the spectral display is to be viewed on the oscilloscope, the digital values of spectral components stored in the computer memory are converted into analog by using D/A converters and then applied to the CRO. Thus the spectral display of the input waveform is obtained on the CRT screen.

Advantages

1. The use of computer avoids most of the hardware circuitry such as electronic switches, Filters and PLLs. The use of less hardware reduces the cost of the analyzer.
2. More mathematical calculations can be carried-out on the spectral display.
3. The rate of sampling analog signal can be modified in order to obtain better spectral display.

STANDARD SIGNAL GENERATOR:-

A standard signal generator produces known and controllable voltages. It is used as power sourcefor the measurement of gain, signal to noise ratio (SN), bandwidth standing wave ratio and other properties.

It is extensively used in the measuring of radio receivers and transmitter instrument is provided with a means of modulating the carrier frequency, which is indicated by the dial setting on the front panel.

The modulation is indicated by a meter. The output signal can be Amplitude Modulated (AM) or Frequency Modulated (FM). Modulation may be done by a sine wave, Square, rectangular, or a pulse wave.

The elements of a conventional signal generator:

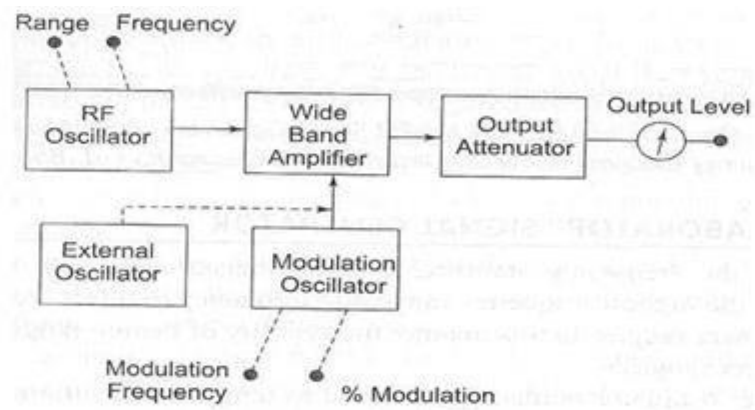
1) RF Osillator
(2) Wide band amplifier.
(3) External Osillator.
4) Modulation Osillator
(5) Out put attenuator.

The carrier frequency is generated by a very stable RF oscillator using an LC tank circuit, having a constant output over any frequency range. The frequency of oscillations is indicated by 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.The Wien bridge oscillator is the best of the audio frequency range. The frequency of oscillations can be changed by varying the capacitance in the oscillator.

The frequency can also be changed in steps by switching the resistors of different values. The output of the Wien bridge oscillator goes to the function switch.

The function switch directs the oscillator output either to the sine wave amplifier or to the 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 output is taker through a push-pull amplifier. For low output, the impedance is 6000. The square 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.

The front panel of a signal generator consists of the following.

l. Frequency selector: It selects the frequency in different ranges and varies it continuously in

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

2. Frequency multiplier: It selects the frequency range over 5 decades from 10 Hz to 7 MHz

3. Amplitude multiplier: It attenuates the sine wave in 3 decades, x l x 0.1 and x 0.01.

4. Variable amplitude: It attenuates the sine wave amplitude continuously

5. Symmetry control: It varies the symmetry of the square wave from 30% to 70%.

6. Amplitude: It attenuates the square wave output continuously.

7. Function switch: It selects either sine wave or square output.

8. Output available: This provides sine wave or square wave output.

9. Sync: This terminal is used to provide synchronization of the internal signal with an external signal.

10. On-Off Switch

Sweep Generator

It provides a sinusoidal output voltage whose frequency varies smoothly and continuously over an 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 variable modulating voltage which causes the capacitance of the master oscillator to vary. A representative sweep rate could be of the order of 20 sweeps/second. A manual control allows 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. Thus the amplitude of the response of a test device will be locked and displayed on the screen.

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 CRO during alternate cycles of the sweep voltage, and appears superimposed on the responsecurve.

The automatic level control circuit is a closed loop feedback system which monitors the RF level at some point in the measurement system. This circuit holds the power delivered to the load or test circuit constant and independent o frequency and impedance changes. A constant power level prevents any source mismatch and also provides a constant readout calibration with frequency.

SQUARE AND PULSE GENERATOR:-

These generators are used as measuring devices in combination with a CRO. They provide both quantitative and qualitative information of the system under test. They are made use of in transient response testing of amplifiers. The fundamental difference between a pulse generator and a square wave generator is in the duty cycle.

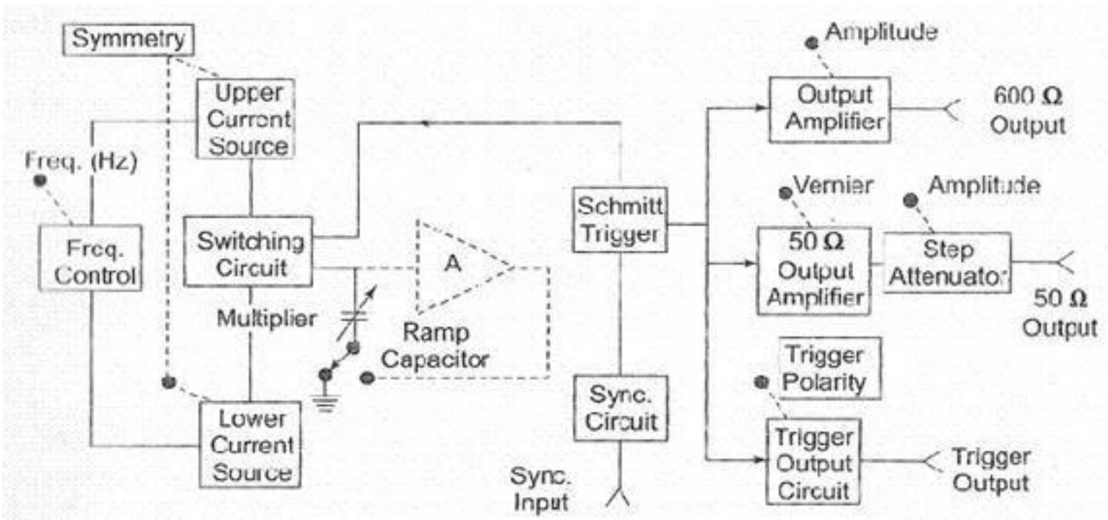
Duty cycle = A square wave generator has a 500/o duty cycle.

Requirements of a Pulse

1. The pulse should have minimum distortion, so that any distortion, in the display is solely due to the circuit under test.
2. The basic characteristics of the pulse are rise time, overshoot, ringing, sag, and undershoot.
3. The pulse should have sufficient maximum amplitude, if appreciable output power is required by 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.Other generators have a pulse-burst feature which allows a train of pulses rather than a continuous output.
5. Some pulse generators can be triggered by an externally applied trigger signal; conversely, pulse generators can be used to produce trigger signals, when this output is passed through a differentiator circuit.
6. The output impedance of the pulse generator is another important consideration. In a fast pulsesystem, the generator should be matched to the cable and the cable to the test circuit. A mismatch would cause energy to be reflected back to the generator by the test circuit, and this may be rereflected by the generator, causing distortion of the pulses.
7. DC coupling of the output circuit is needed, when dc bias level is to be maintained.

The basic circuit for pulse generation is the asymmetrical multi-vibrator.

A laboratory type square wave and pulse generator is shown in Fig 6.1



The frequency range of the instrument is covered in seven decade steps from 1Hz to 10 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 source that supplies pulses with a rise and fall time of 5 ns at 5V peak amplitude and a 600Ω source which supplies pulses with a rise and fall tme of 70 ns at 30 V peak amplitude. The instrument can be operated as a freerunning genenrator or, it can be synchronized with externalsignals. The basic generating loop consists of the current sources, the ramp capacitor, the Schmitt triggerand the current switching circuit as shown in the fig

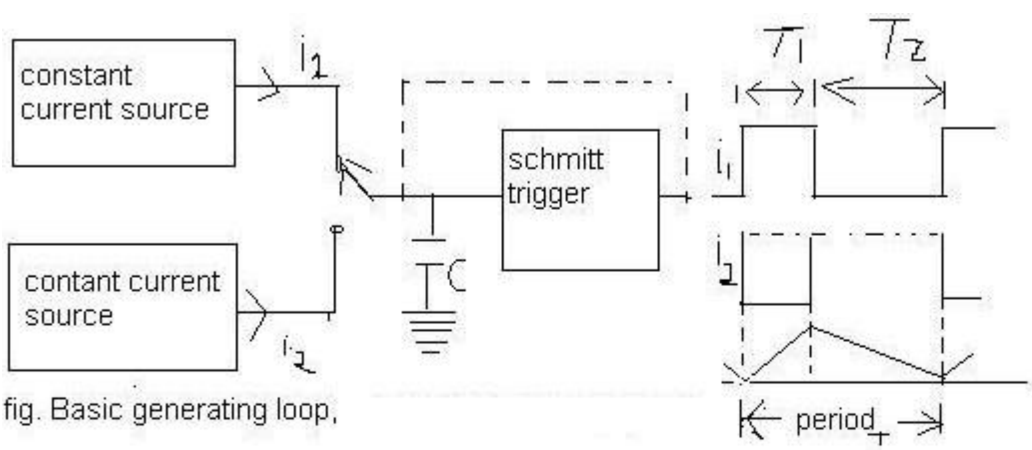


fig. Basic generating loop,

The upper current source supplies a constant current to the capacitor and the capacitor voltage increases linearly. When the positive slope of the ramp voltage reaches the upper limit set 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 predetermined lower level, the Schmitt trigger switches 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 sum of i1 and i2 determines the frequency. The size of the capacitor is selected by the multiplier switch. The unit is powered by an intenal supply that provides regulated voltages for all stages of the instrument.

The precautionary measures to be taken in a signal generator application:-

A signal generator is an instrument, which can produce various types of wave forms such as sine wave, square wave, triangular wave, saw tooth wave, pulse trains etc. As it can generate a variety of 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. The amplitude and frequency of the output of the signal generator should be made stable and well known.

2. There should be provision for controlling the amplitude of signal generator output from very small to relatively large values.

3. The output signal of generator should not contain any distortion and thus, it should possess very low harmonic contents.

4. Also, the output of the signal generator should be less spurious.

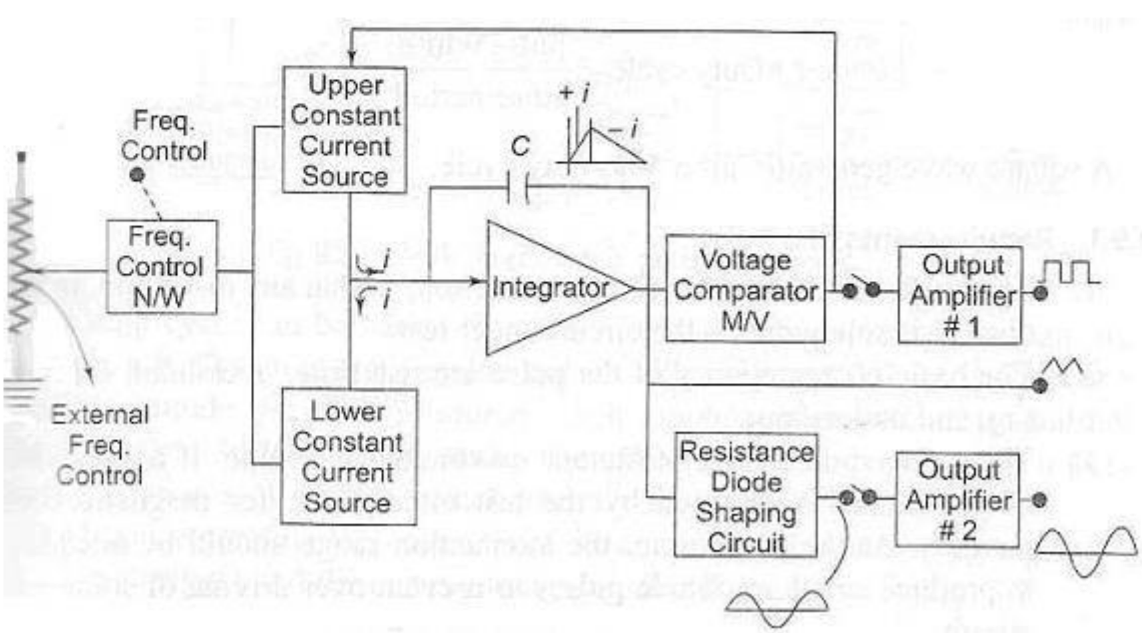
FUNCTION GENERATOR

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 of a Hertz to several hundred kHz lie various outputs of the 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 one generator can be phase locked to a harmonic of another generator, by adjusting the amplitude and phase of the harmonic; almost any waveform can be generated by addition.

The function generator can also be phase locked to a frequency standard and its output waveforms will then have the same accuracy and stability as the standard source.

The block diagram of a function generator:



The block diagram of a function generator is illustrated in fig. Usually the frequency is controlled by varying the capacitor in the LC or RC circuit. In the instrument the frequency is controlled by varying the magnitude of current which drives the integrator. The instrument 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. The voltage comparator multi-vibrator changes states at a pre-determined maximum level of the integrator output voltage. This change cuts off the upper current supply and switches on the lower current supply. The lower current source supplies a reverse current to the integrator, so that its output decreases linearly with time. When the output reaches a pre-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 the magnitude of the current supplied by the constant current sources. The comparator output delivers a square wave voltage of the same frequency.

$e = - 1/C \int idt$

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.

Arbitrary Waveform Generator, 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 digital or 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.

Arbitrary Waveform Generator techniques

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 of the 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.

Arbitrary waveform generator resolution and speed:

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 higher repetition 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!

Arbitrary waveform generator applications:

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 waveform generators are very flexible and can be used to create very specific 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 them a very attractive option to form the basis of a waveform generator. As a result arbitrary function generators are relatively widely used.

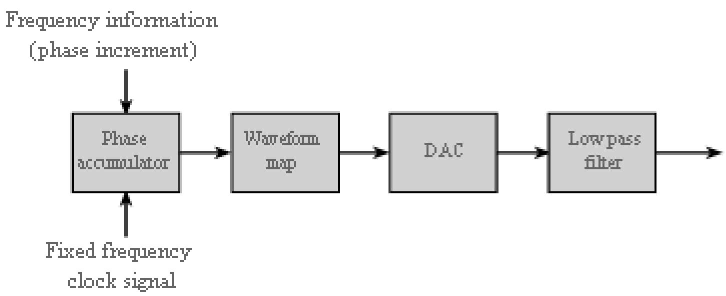
Arbitrary function generator basics:

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 an arbitrary function generator works, it is necessary to look at the operation of a direct digital synthesizer.

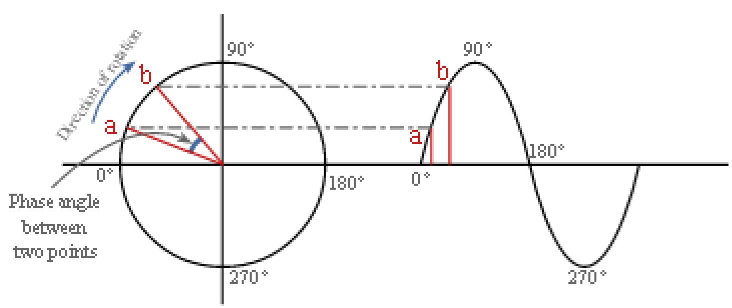
This circuit operates by storing the points of a waveform in digital format, and then recalling them to generate the waveform. These points can be on any form of repetitive waveform that is required. The rate at which the DDS completes one waveform governs the frequency. The basic block diagram of the 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 way that 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 by storing various points of the 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 greater the increment, the larger the phase advance, and hence the higher the 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 in as well. These make the test instrument an arbitrary waveform generator or arbitrary function generator rather than a standard function generator.

Advantages and disadvantages of AFG:

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.

Arbitrary function generator advantages

- ***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.
- ***Digital modulation:*** It is possible to add digital modulation words to the phase accumulator to provide a means of providing digital modulation.

Arbitrary function generator disadvantages

- ***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 equal to the clock frequency divided by the waveform length and its 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.

Displacement Transducer : Circuit, Types, Working & Its Applications

The position sensor is a type of device used to monitor & measure a change within the position of an object in a device/ machine or in certain vicinity & changes into signals which are appropriate for transmission, processing, or control. There are different kinds of position sensors available where displacement transducer is one specific kind of position sensor. Generally, normal sensors sense the existence of the object whereas displacement sensors simply detect the displacement once any object moves from one location to another. So, the amount of displacement detection simply allows you to determine the object's thickness & height. This article discusses an overview of a **displacement transducer** – working with applications.

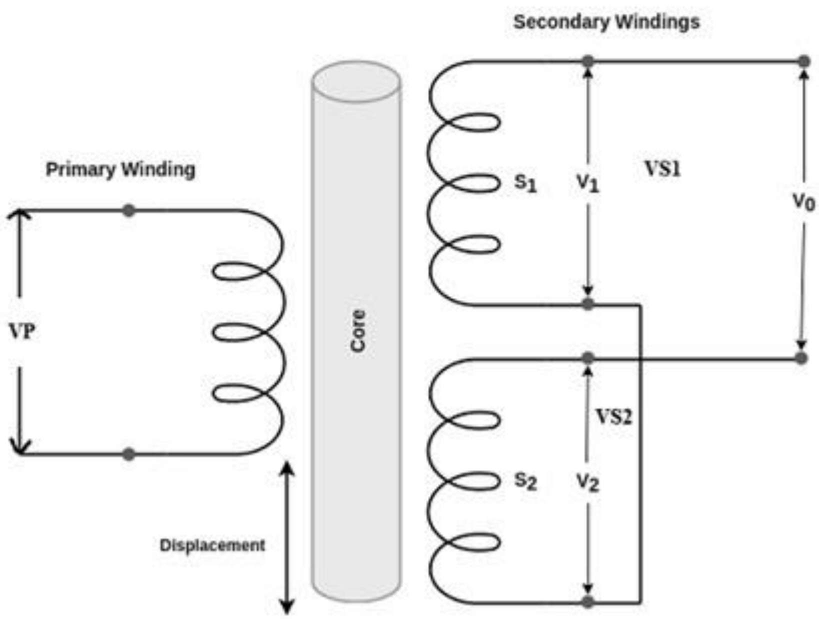
A displacement transducer is an electromechanical device used to convert the motion of an object into electrostatic, electromagnetic, or magnetoelectric signals which are read & interpreted into data. There is a wide range of displacement transducers like linear & rotary. These transducers are also helpful in measuring the physical distance between the sensor & a target. Most displacement transducers measure static & dynamic displacements, so they are frequently used for measuring the vibration of an object. The measured displacements range from micro inches to a few feet.

Displacement Transducer

The displacement transducer working principle is based on the extremely reliable inductive measurement principle. These transducers are rugged, very easy to use & can attain high precision. Displacement transducers give reliable measurement results in different areas of production, research & development.

Displacement Transducer Circuit Diagram

The displacement transducer used in the below circuit is an inductive transducer. This circuit is used to measure displacement with an Inductive transducer.



Displacement Transducer Circuit

In the above circuit, the transformer includes a primary winding & two secondary windings. The two secondary winding's endpoints are connected together thus, we can declare that these two windings are simply connected within series opposition.

The 'VP' voltage is applied at the transformer's primary winding, let the voltage developed across every secondary winding be $VS1$ & $VS2$. So, the 'V0' output voltage is received across the first points of secondary windings. So the output voltage can be written as V0 = VS1 – VS2. The transformer used in the above circuit is the differential transformer because it generates an o/p voltage, which is the dissimilarity between VS1 & VS2.

If the core is positioned at the central point, then the induced voltages across two windings S1 & S2 are equivalent. So, the output voltage V0=0. In this condition, we say that there is no displacement.

If the core is displaced above the central position, then the emf generated within coil S1 is more i.e, V1>V2.

In the same way, if the core is displaced below the central position, then the emf generated within the S2 coil is more i.e, V2>V1.

So in these two cases, we have two displacements upward & downward. In these two cases, the magnitude of output voltage 'V0' will be proportional to the core position relative to the center.

Thus, if we want to measure the displacement of the body then we must connect the body to the central core. Therefore, once the body shifts in a straight line, then the middle point of the core changes, so, the o/p voltage like 'V0' also varies accordingly. In this condition, we can get the displacement by simply measuring the o/p voltage. So, the phase and magnitude of the output voltage signify the displacement and direction of the body correspondingly.

MODULE-IV

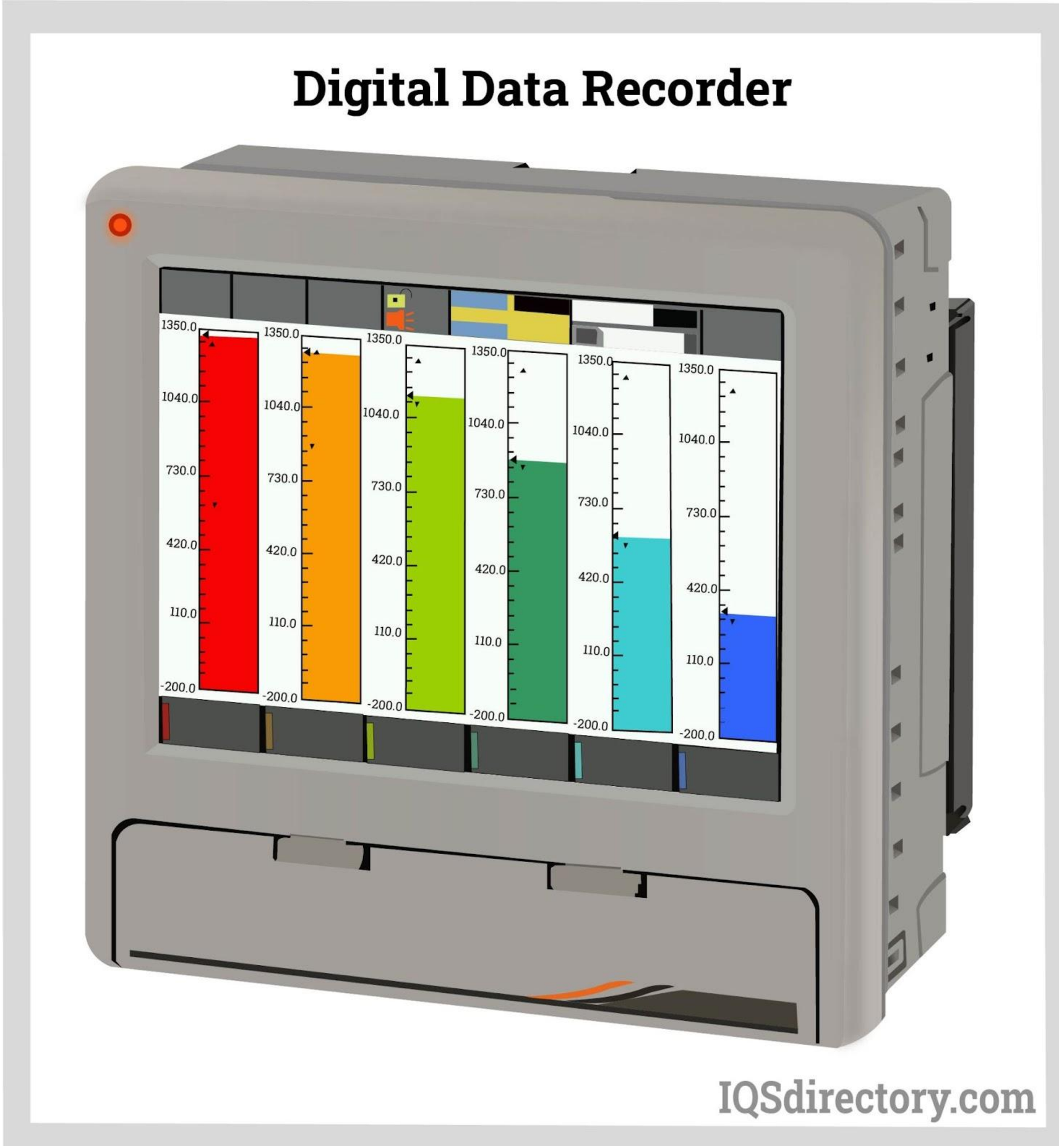
Data Acquisition Systems: Types, Principles and Applications

Introduction

This article will take an in-depth look at data acquisition systems.

The article will bring more information to topics such as:

- Principles of Data Acquisition Systems
- Data Acquisition Systems Measurements, Modules & Methods
- Types of Data Acquisition Systems and Data Acquisition Signals
- Applications and Benefits of Data Acquisition Systems
- And Much More…



The Core Principles of Data Acquisition Systems

This chapter delves into the foundational aspects of data acquisition systems, discussing their essential components and the processes involved in gathering and analyzing data.

Defining a Data Acquisition System

A data acquisition system is a cohesive assembly made up of sensors, measurement tools, and computers. Its primary function is to collect and analyze data to provide insights into electrical or physical phenomena, offering a thorough interpretation of the gathered information.

To comprehend how a data acquisition system functions, it is essential to understand its data processing and recording mechanisms. For example, data acquisition systems can measure the temperature of a heating coil, ensuring it heats an object to a precise temperature. This assessment of the coil's efficiency is achieved by examining its temperature, a process termed data acquisition, enabled by the system. Similarly, these systems measure voltage drops across electrical resistors.

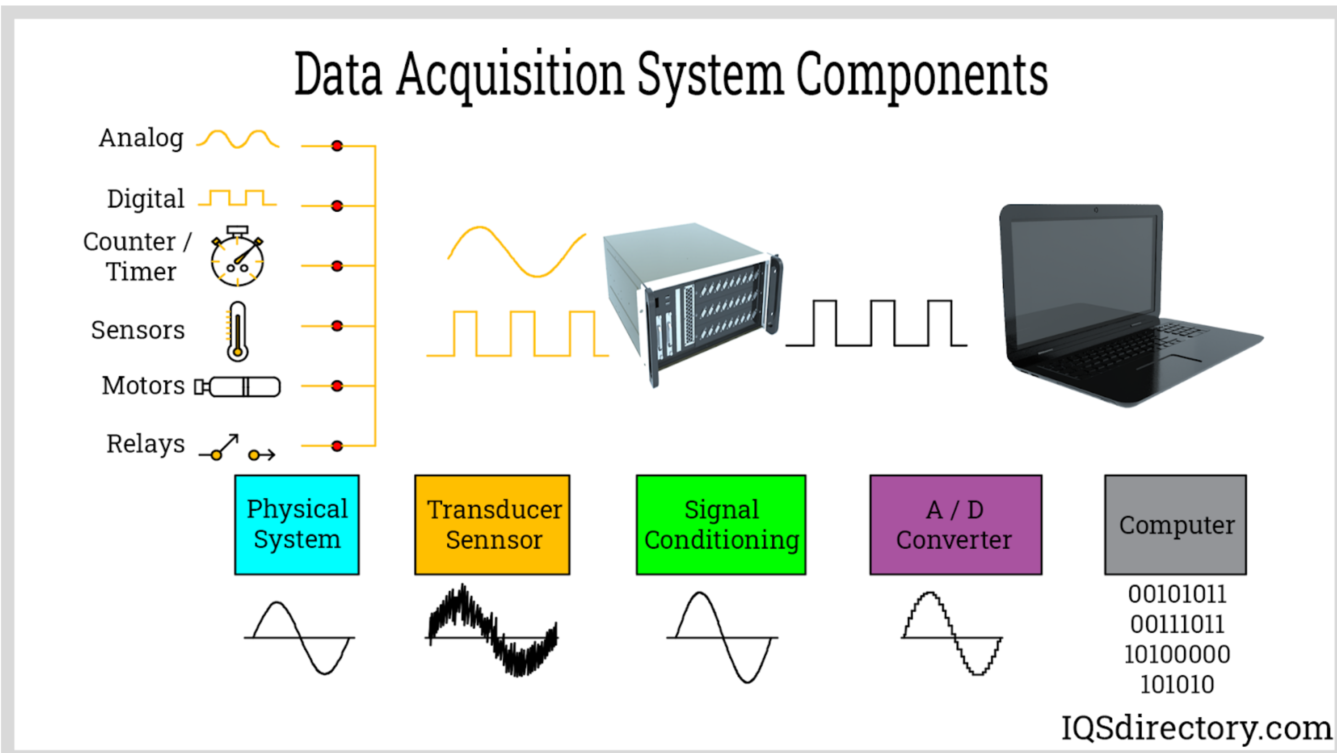
The key objective of recording and measuring electrical and physical phenomena via data acquisition systems is to facilitate in-depth analysis. Utilizing specialized software, these systems can efficiently process and store data in various user-friendly formats. They capture real-world data and preserve it for further scientific or engineering evaluation.

Data acquisition systems come in handheld and remote variants. Handheld models are ideal when direct interaction with the specimen is feasible, while remote systems are suitable when in-person interaction is not possible or needed, allowing measurements from afar.

Essential Components of a Data Acquisition System

The data collection process starts by identifying the physical attributes to measure. Measurements could involve temperature, light intensity, vibration, pressure, fluid dynamics, and force, among others. Any physical property measured first needs conversion into a format suitable for the data acquisition system to sample.

This conversion occurs through sensors. A data acquisition system integrates both hardware and software to measure or manage real-world physical properties. A comprehensive system includes DAQ hardware, sensors, actuators, signal conditioning equipment, and computers running DAQ software. If timing precision is necessary, especially in event-mode DAQ systems, an independent timing mechanism might be essential.



Sensors

Sensors, or transducers, facilitate interaction with the measured subject, either directly or indirectly. They convert physical values into electrical signals. Various sensors are employed in data acquisition systems, depending on the application. For instance, a temperature sensor measures heat, while a photovoltaic sensor measures light.

All sensors serve the common purpose of transforming analog signals—like temperature, light, and speed—into digital signals for computer processing. The high quality of sensors in DAQ systems ensures precise readings with minimal noise or disruption.

Signal Conditioners

Sensor-derived electrical signals might include noise or interference and may need modification for use. Often, these signals are too weak for accurate measurement by the data acquisition system. To counteract these issues, a signal conditioner is used. Signal conditioning refines and optimizes signals for precise measurement and trustworthy data collection.

Signal conditioners utilize filter circuits to separate noise from genuine signals and amplification circuits to strengthen weak signals. These functions are essential to the role of signal conditioners. Additionally, a well-designed circuit can perform tasks such as linearization, calibration, and excitation. The appropriate choice of conditioning circuit aligns closely with sensor characteristics in the DAQ system.

Data Acquisition Hardware

Serving as a bridge between sensors and computers, data acquisition hardware connects to computers via USB ports or PCI-express slots. This hardware receives signals from sensors and converts them into a digital format that computers can interpret, enabling data processing and analysis.

Instrumentation Amplifier, Circuit Diagram, Advantages, and Applications

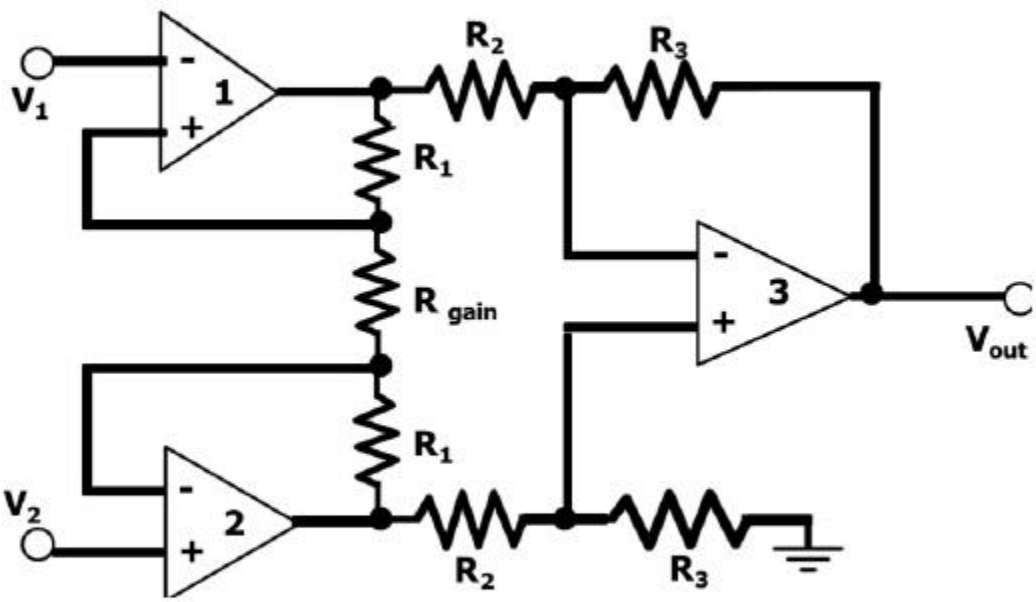
An **instrumentation amplifier** is one kind of **IC (integrated circuit)**, mainly used for amplifying a signal. This amplifier comes under the family of the differential amplifier because it increases the disparity among two inputs. The main function of this amplifier is to diminish surplus noise that is chosen by the circuit. The capacity to refuse noise is familiar to every IC pins which are known as the **CMRR (common-mode rejection ratio)**. The **instrumentation amplifier IC** is an essential component in the designing of the circuit due to its characteristics like high CMRR, open-loop gain is high, low drift as well as low DC offset, etc.

An instrumentation amplifier is used to amplify very low-level signals, rejecting noise and interference signals. Examples can be heartbeats, blood pressure, temperature, earthquakes and so on. Therefore, the essential characteristics of a good instrumentation amplifier are as follows.

- Inputs to the **instrumentation amplifiers** will have very low signal energy. Therefore the instrumentation amplifier should have high gain and should be accurate.
- The gain should be easily adjustable using a single control.
- It must have High Input Impedance and Low Output Impedance to prevent loading.
- The Instrumentation amplifier should have High CMRR since the transducer output will usually contain common mode signals such as noise when transmitted over long wires.
- It must also have a High Slew Rate to handle sharp rise times of events and provide a maximum undistorted output voltage swing.

Instrumentation Amplifier using Op Amp

The **instrumentation amplifier using op-amp circuit** is shown below. The **op-amps** 1 & 2 are non-inverting amplifiers and op-amp 3 is a **difference amplifier**. These three op-amps together, form an instrumentation amplifier. Instrumentation amplifier's final output Vout is the amplified difference of the input signals applied to the input terminals of op-amp 3.Let the outputs of op-amp 1 and op-amp 2 be Vo1 and Vo2 respectively.



Then, **Vout = (R3/R2)(Vo1-Vo2)**

Look at the input stage of the instrumentation amplifier as shown in the figure below. The **instrumentation amplifier derivation** is discussed below.

The potential at node A is the input voltage V1. Hence the potential at node B is also V1, from the virtual short concept. Thus, the potential at node G is also V1.

The potential at node D is the input voltage V2. Hence the potential at node C is also V2, from the virtual short. Thus, the potential at node H is also V2.

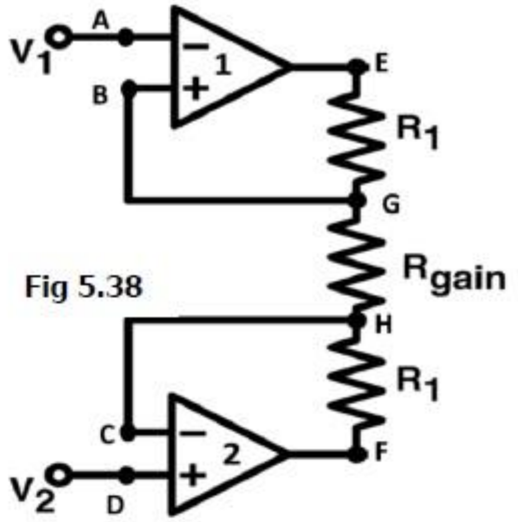


Fig 5.38

Input Stage of the Instrumentation Amplifier

The **working of the instrumentation amplifier** is, Ideally the current to the input stage op-amps is zero. Therefore the current I through the resistors R1, Rgain, and R1 remain the same.
Applying **Ohm's law** between nodes E and F,

I = (Vo1-Vo2)/(R1+Rgain+R1) ……………………….(1)
I = (Vo1-Vo2)/(2R1+Rgain)
Since no current is flowing to the input of the op-amps 1 & 2, the current I between the nodes G and H can be given as,

I = (VG-VH) / Rgain = (V1-V2) / Rgain……………………….(2)
Equating equations 1 and 2,

(Vo1-Vo2)/(2R1+Rgain) = (V1-V2)/Rgain
(Vo1-Vo2) = (2R1+Rgain)(V1-V2)/Rgain ……………………….(3)
The output of the difference amplifier is given as,

Vout = (R3/R2) (Vo1-Vo2)
Therefore, **(Vo1 – Vo2) = (R2/R3)Vout**
Substituting **(Vo1 – Vo2)** value in equation 3, we get
(R2/R3)Vout = (2R1+Rgain)(V1-V2)/Rgain
i.e. **Vout = (R3/R2){(2R1+Rgain)/Rgain}(V1-V2)**
This above equation gives the output voltage of an instrumentation amplifier.

The overall gain of the amplifier is given by the term **(R3/R2){(2R1+Rgain)/Rgain}**.
The overall voltage gain of an **instrumentation amplifier** can be controlled by adjusting the value of resistor Rgain.
The common mode signal attenuation for the instrumentation amplifier is provided by the difference amplifier.

Advantages of Instrumentation Amplifier

The **advantages of the instrumentation amplifier** include the following.

- The gain of a three op-amp **instrumentation amplifier circuit** can be easily varied by adjusting the value of only one resistor Rgain.
- The gain of the amplifier depends only on the external resistors used.
- The input impedance is very high due to the emitter follower configurations of amplifiers 1 and 2
- The output impedance of the instrumentation amplifier is very low due to the difference amplifier3.
- The CMRR of the **op-amp** 3 is very high and almost all of the common mode signal will be rejected.

Isolation Amplifier Working and Its Applications

An isolation amplifier or a unity gain amplifier provides isolation from one fraction of the circuit to another fraction. So, the power cannot be drawn, used and wasted within the circuit. The main function of this amplifier is to increase the signal. The same input signal of the op-amp is passed out exactly from the op-amp as an output signal. These amplifiers are used to give an electrical safety battier as well as isolation. These amplifiers protect the patients from the outflow of current. They crack electrical signal's ohmic continuity among input & output and isolated power supply can be provided for both the input and output. So, the low-level signals can be amplified.

An isolation amplifier can be defined as, an amplifier which doesn't have any conductive contact among input as well as output sections. Consequently, this amplifier gives ohmic isolation among the i/p & o/p terminals of the amplifier. This isolation must have less leakage as well as a high amount of dielectric breakdown voltage. The typical resistor and capacitor values of amplifier among the input & output terminals are resistor should have 10 Tera Ohms and capacitor should have 10 picofarads.

isolation-amplifier

These amplifiers are frequently used when there is extremely huge common-mode voltage disparity among input & output side. In this amplifier, the ohmic circuitry is not there from input ground to output ground.

Isolation Amplifier Design Methods

There are three kinds of design methods are used in isolation amplifiers which include the following.

- Transformer Isolation
- Optical Isolation
- Capacitive Isolation

1). Transformer Isolation

This type of isolation uses two signals like PWM or frequency modulated. Internally, this amplifier includes 20 KHz oscillator, rectifier, filter, and transformer to give supply to every isolated stage.

- The rectifier is used as an input to the main op-amp.
- Transformer links the supply.
- The oscillator is used as an input to the secondary op-amp.
- An LPF is used for removing the components of other frequency.

The advantages of transformer isolation mainly include high CMRR, linearity, and accuracy.

The applications of transformer isolation mainly include medical, nuclear and industrial.

What is IEEE 488 Bus or GPIB : Working & Its Applications

During the 1960s, HP developed many different tests and measuring devices like logic analyzers and multimeters. In order to achieve smoother interconnection between controllers and measuring instruments, the HP-IB was introduced (HP Interface Bus). HPIB is the original name for GPIB (General Purpose Interface Bus), whereas later it got many other names. Finally, the Institute of Electrical and Electronics Engineers has provided a specification number to GPIB which is 488 in the year 1978. From then, GPIB was also termed IEEE 488 or IEEE 488 bus. Today, this article helps us in understanding the detailed concept regarding the **basics of GPIB**, its architecture, working principles, and advantages & disadvantages.

What is GPIB or IEEE 488 Bus?

The IEEE 488 (GPIB) bus is an 8-bit parallel multi-master interface bus that is used for short-distance communications. As the bus became the key interface meeting multiple standards, it was termed as General Purpose Interface Bus. Because of its flexibility, the data transmission can take place between any instruments present in the bus having a speed appropriate for the slowest active instrument.

Achieve proper communication between the devices in GPIB requires three components which are:

Talker – This holds the ability to transmit device-dependent information from one device to another device on the bus when it is addressed to talk. On the whole device, only one GPIB instrument can function as an active talker at a time.

Listener – It is responsible to receive device-dependent information from another device present in the bus when it is addressed to listen. On the whole device, more number of GPIB instruments can function as active listeners at a time.

Controller – The name of the controller itself signifies that it is an entity that manages the entire functionality of the bus. The controller is generally a computer that provides the signal to the instruments to execute multiple activities making sure that no issues take place in the bus. When two talker devices try to talk at the same time instant, it leads to data corruption and shows the impact on the entire system.

IEEE 488 bus allows different controllers to share a similar bus whereas only one controller will be active at any specific time.

GPIB bus consists of eight data lines in order to transmit 8 bits of data at a single instance. And command messages work with seven bits out of 8 and the message format is shown below:

7	6	5	4	3	2	1	0
0	TA	LA	GPIB Primary Address				

Message Format

Bits 0 through 4 indicate the primary address of the device, for which the Talker/Listener assignment is intended. If bit 5 is high, the device should listen. If bit 6 is high, the device should talk. Bit 7 is a "don't care" bit. Its value is ignored, so it is interpreted as a value of zero in command messages.

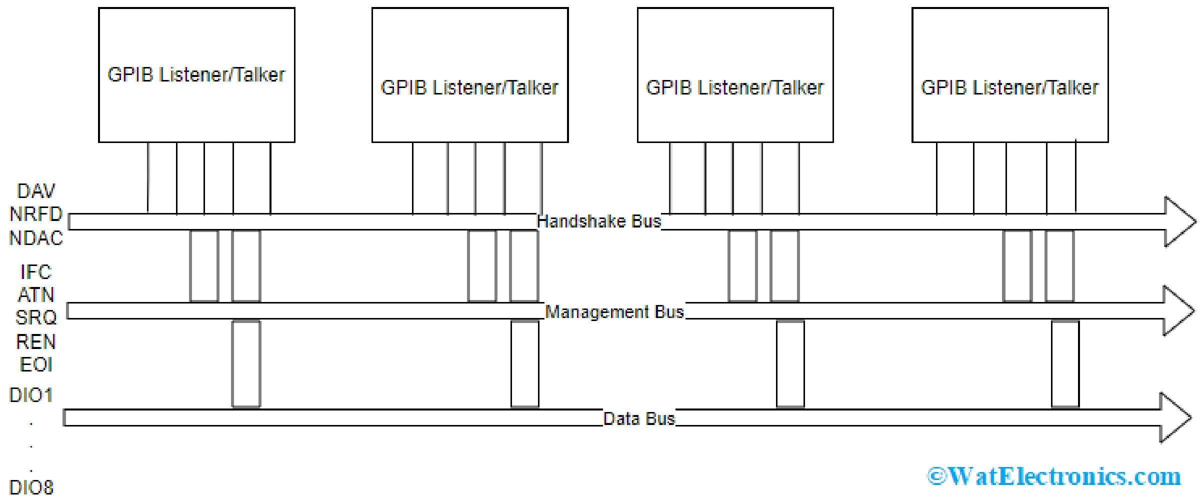
IEEE 488 Bus Features

As the main functionality of GPIB is to establish interconnection between various instruments and devices, it is recommended to know the features of the IEEE 488 bus. A few of those are:

1. The transaction between the messages is a hardware three-wire-handshake.
2. Communication happens in digital format and it transmits only one byte of data at a time.
3. To a single IEEE 488 bus, approximately 15 devices can be connected at a time.
4. The bus length can be 20 meters, but the distance between each device can be 2 meters.
5. The maximum data rates can be up to 1 Megabyte/second.
6. The width of the data bus is 8 lines.
7. The connector used in GPIB is a 24-pin Amphenol or sometimes a D-type connector is also used.
8. The bus can support 31 5-bit primary devices which are addressed from 0-to 30 by assigning a unique address for every device.
9. The topology used in GPIB is linear or forked type.
10. The protocol supports both **half-duplex and full-duplex communication modes** so that two devices can send data while at the same time receiving data from each other simultaneously

IEEE 488 Bus Block Diagram

The **IEEE 488 bus architecture**, consists of 16 signaling lines that are used to carry information and allow to pass commands between various devices that have connections with the bus. These 16 signals are classified into three groups which are



IEEE 488 Bus Architecture

Data Bus – 8 lines, Data Byte Transfer Control Bus – 3 lines,s, and General Interface Management Bus – 5 lines.

All three functional groups explain the **IEEE 488 bus working principle**.

Data Bus

The data bus acts as a channel for data transmission and passage of commands across the device connected to the GPIB device. The 8 signals are named DIO 1 to DIO 8 which are bidirectional in nature and active low lines. The data transmission using the commands takes place in bit-parallel and byte-serial approaches which correspond that only one data byte can be transmitted at a time. DIO 1 is the LSB bit and DIO 8 is the MSB bit.

Every byte which is placed in the data bus denotes either a data byte or a command. At the time of data transmission, when the ATN pin is TRUE, then the data bus carries a command that is to be received by each device in the GPIB bus. Whereas when the ATN is FALSE while data transmission, then the data bus carries a data byte. Here, only the active listeners are able to receive the carried byte.