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UNIT 4 ELECTRONIC MEASUREMENTS

Fundamentals of Cathode Ray Oscilloscope: Block diagram, CRO probes, Delay line, types of Oscilloscopes. Measurement of: Signal voltage, Current, Phase & Frequency using Lissajous patterns, Industrial applications of CRO. DC and AC voltmeter and Ammeter, Ohmmeter, Range Extension, Electronic Multimeters, Types of Voltmeters - Differential type, true RMS type, Vector voltmeter - Wave Analyzer, Spectrum Analyzer and Distortion Analyzer

FUNDAMENTALS OF CATHODE RAY OSCILLOSCOPE

The cathode ray oscilloscope is probably the most versatile tool for the development of electronic circuit and systems and has been one of the most important tools in the development of modern electronics. The cathode ray oscilloscope is a device that allows the amplitude of the electrical signal whether they may be voltage, current, power, etc., to be displayed primarily as a function of time. The oscilloscope depends on the movement of an electron beam, which is then made visible by allowing the beam to impinge on a phosphor surface, which produces a visible spot. If the electron beam is deflected in either of the two orthogonal axes, such as familiar X and Y axes used in conventional graph construction, the luminous spot can be used to create two-dimensional displays.

BLOCK DIAGRAM OF OSCILLOSCOPE:

The major block circuit of general purpose CRO is as follows:

1)CRT

2)Vertical Line

3)Delay line

4)Horizontal amplifier

5)Time base generator

6)Trigger circuit

7)Power Supply.

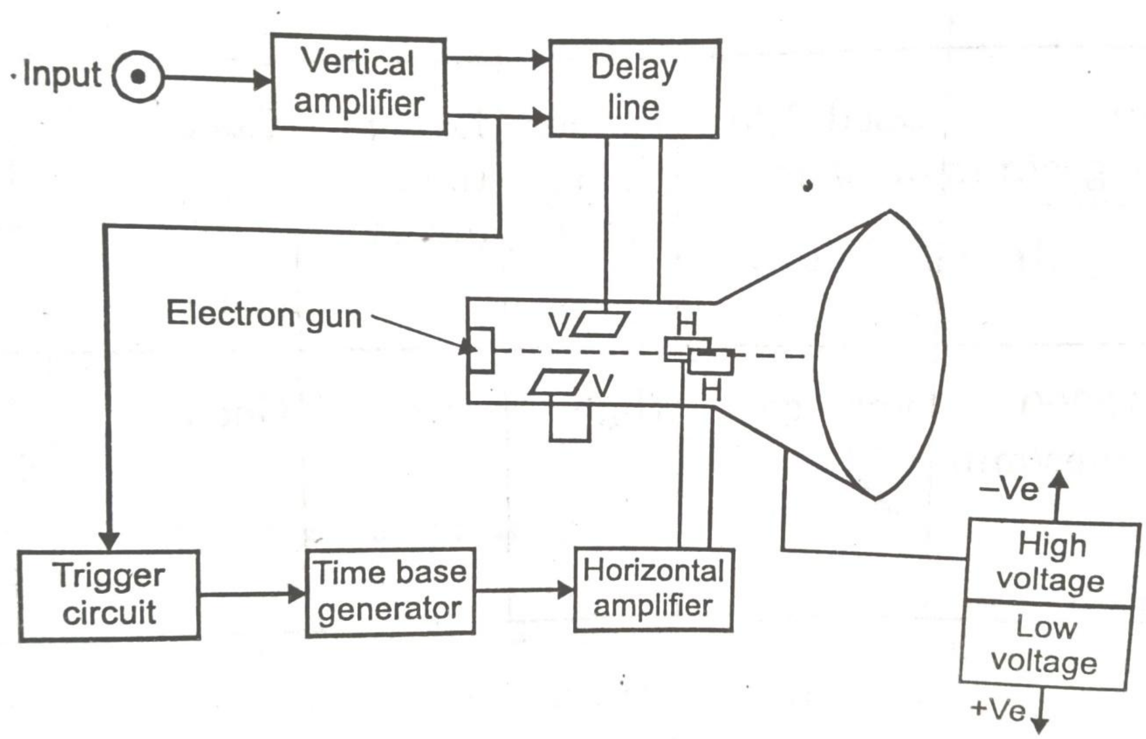


Fig: Block Diagram of oscilloscope

The description is below:

1) Cathode Ray Tube (CRT):

A cathode ray oscilloscope consists of a cathode ray tube (CRT) which is the heart of the oscilloscope, and some additional circuitry to operate the CRT. The main parts of a CRT are:

a)Electron gun assembly.

b)Deflection plate assembly

c)Fluorescent screen

d)Glass envelope

The electron gun assembly produces a sharply focussed beam of electrons which are accelerated to high velocity. This focussed beam of electrons strikes the fluorescent screen with sufficient energy to cause a luminous spot on the screen

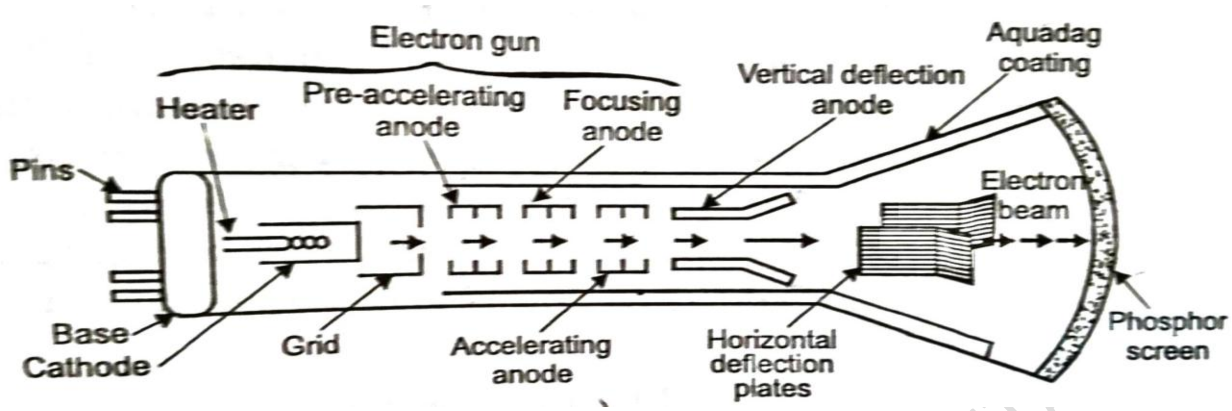


Fig: Internal Structure of CRT

After leaving the electron gun, the electron beam passes through two pairs of "electrostatic deflection plates". Voltages applied to these plates deflect the beam. Voltages applied to one pair of plates move the beam vertically up and down and the voltages applied to the other pair of plates move the beam horizontally from one side to another. Focusing anode is used to focus the beam on the screen, and the accelerating anode makes the electron beam to move with high velocity.

2)Vertical Amplifier:

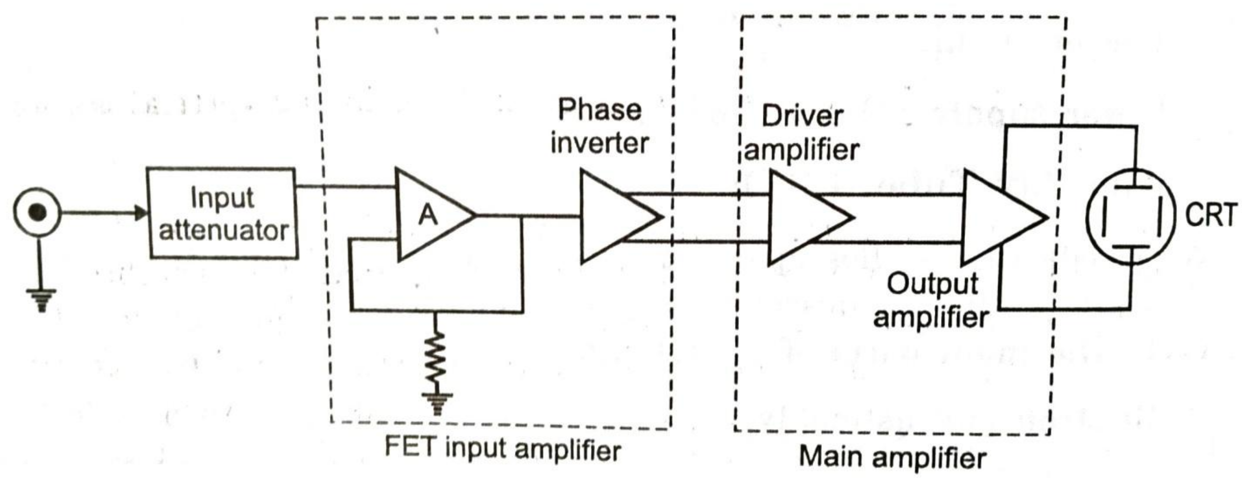


Fig: Vertical Amplifier

This is a wide band amplifier used to amplify signals in the vertical section.

The vertical amplifier consists of several stages, with fixed overall sensitivity or gain expressed in v/divisions. The advantage of fixed gain is that the amplifier can be more easily designed to meet the requirements of stability and between the vertical amplifier is kept within its signal handling capability by proper selection of the input attenuator switch. The first element of the pre-amplifier is the input stage, often consisting of a FET source follower whose high input impedance isolates from the attenuator.

This FET input stage is followed by a BJT emitter followers to match the medium impedance of FET output with the low impedance input of the phase inverter.

The phase inverter provides two anti-phase output signals which are required to operate the push pull output amplifier. The push pull output stage delivers equal signal voltages of opposite polarity to the vertical plates of the CRT.

The advantages of push pull operation on CRO are similar to those obtained from push pull operation. In addition a number of focusing and non-linear effects are reduced, because neither plate is ground potential.

3)Delay Line:

It is used to delay the signal from some time in the vertical section.

Comparing the vertical and horizontal deflection circuits in the oscilloscope block diagram, we observe that the deflection signal is initiated or triggered, by a portion of the output signal applied to the vertical CRT plates. Signal processing in the horizontal channel consists of generating and shaping a trigger pulse that starts the sweep generator, whose output is fed to the horizontal deflection plates. This whole process takes time on the order of 80 ns. To allow the operator to observe the leading edge of the signal waveform, the signal drive for the vertical CRT plates must therefore be delayed by atleast the same amount of time. This is the function of time delay line.

4) Horizontal Amplifier:

The horizontal basically serves two purposes:

a)When the oscilloscope is being in the X-Y node, the signal applied to the horizontal input terminal will be amplified by the horizontal amplifier.

b) When the oscilloscope is being used in the ordinary mode of operation to display a signal applied to the vertical input, the horizontal amplifier will amplify the sweep generator output.

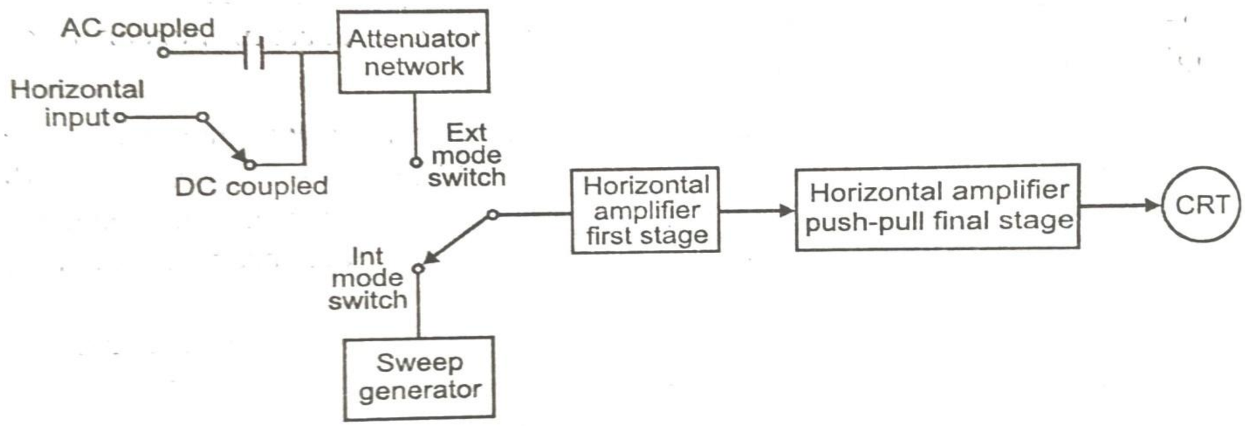


Fig: Horizontal Amplifier

5) Time base generator:

It is used to generate the saw tooth voltage required to deflect the beam in the horizontal section.

6) Trigger circuit:

This is used to convert the incoming signal into trigger pulses that the input signal and the sweep frequency can be synchronised.

7) Power supply:

There are two power supplies, a negative high voltage (HV) supply and a positive low voltage (LV) supply. Two voltages are generated in the CRO. The positive volt supply is from -100V to +1500V. This voltage is passed through a bleeder resistor at a few mA. The intermediate voltages are obtained from the bleeder resistor for intensity, focus and positioning controls.

Screens for CRT's:

When the electron beam strikes the screen of the CRT, a spot light is produced. The screen material on the inner surface of the CRT that produces this effect is the phosphor. The phosphor absorbs the kinetic energy of the bombarding electrons and remits energy at the lower frequency in the visible spectrum. The property of some crystalline materials such as phosphor or zinc oxide to emit light when simulated by radiation is called flourescence. Fluorescent materials have a second characteristic called as phosphorescence which refers to the property of the material to continue light emission even after the source of excitation is cut off. The length of time during which phosphorescence or afterglow occurs is called as the persistence of phosphor.

Phosphor Data Chart:

Phosphor Type	Flourescence	Phosphorescence
P_1	Yellow green	Yellow green
P_2	Blue green	Yellow green
P_4	White	White
P_7	Blue	Yellow green
P_{11}	Purple blue	Purple blue
P_{31}	Yellow green	Yellow green

Applications of Oscilloscope:

Because the oscilloscope is an extremely flexible and versatile instrument, it can be used to measure a number of parameters associated with DC and AC signals. Using a single channel oscilloscope, it is capable of making measurements of voltage, current, time, frequency and rise/fall time. If a dual trace oscilloscope is used, the phase shift between two synchronous signals can be measured.

a)Power Analysis:

Oscilloscopes can be used to measure and analyse the operating characteristics of power conversion devices, circuits and line power harmonics. Differential amplifier probes are needed to this and special software is also offered to make analysis of data easier.

b)Serial data analysis:

Digital data signals are moving to ever-increasing serial data formats. Oscilloscopes are used to analyse and characterize such data formats as USB, SCSI, Ethernet, Serial ATA, Fibre channel, firewire, Rapid I/O, Infiniband, bluetooth and CAN Bus (for automotive industry)

c)Jitter analysis:

Today high bandwidth circuits have extremely fast clocks and signals. Oscilloscopes are used to characterise and debug signal jitter as well as timing for clocks, clock-to-data and data stream analysis.

d)Data storage device testing:

Oscilloscopes are used to test CD/DVD and disk drive designs by measuring disk performance, media noise and optical recording characteristics.

e)Time-domain reflectometry:

Time Domain reflectometry (TDR) is a way to measure impedance values and variations (such as faults) along transmission cables, cable connectors or microstrips on a circuit board.

CRO PROBES

The CRO probe performs the very important function of connecting the test circuit to the oscilloscope without altering, loading or otherwise disturbing the test circuit.

There are three different probes:

a)Direct reading probe, b)circuit isolation probe, c)detector probe.

They are discussed below:

a) Direct reading probe

This probe is the simplest of all probes and it uses a shielded coaxial cable.

It avoids stray pickups which may lead to problems when low level signals are being measured. It is used usually for low frequency and low impedance circuits. However in using the shielded probe, the shunt capacitance of the probe is added to the input impedance and capacity of the scope and acts to lower the response of the oscilloscope to high impedance and high frequency circuits.

b) Isolation probe

Isolation probe is used in order to avoid the undesirable circuit loading effects of shielded probe. The isolation probe which is used along with the capacitive voltage divider, decreases the input capacitance and increases the input resistance of the oscilloscope. This way the loading effects are drastically reduced.

c) Detector probe

When analyzing the response to modulated signals in communication equipment like AM, FM and TV receivers, the detector probe functions to separate the lower frequency modulation component from the higher frequency carrier. The amplitude of the modulator carrier (which is proportional to the response of the receiver to the much high frequency carrier signal) is displayed on the oscilloscope by rectifying and bypassing action. This permits an oscilloscope capable of audio-frequency response to perform signal tracing tests on communication signals in the range of hundreds of Mhz, a range which is beyond the capabilities of all oscilloscopes except the highly specialized ones.

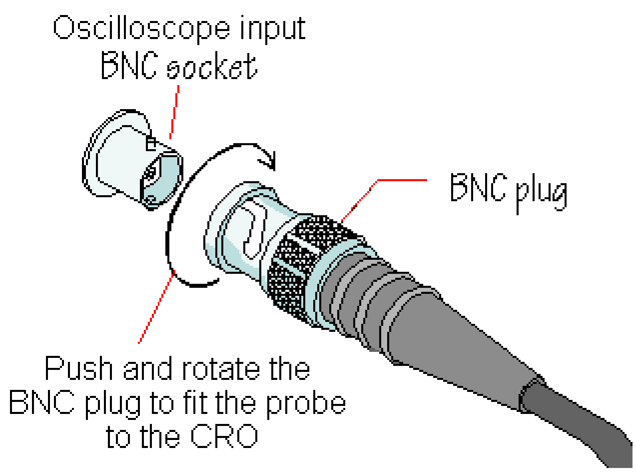


Fig: A CRO Probe

DELAY LINE

The amplitude of the signal is with respect to time and relative position of the sweep generator output signal. When the delay line is not used, the initial part of the signal is lost and only part of the signal is displayed. To counteract this disadvantage, the signal is not applied directly to the vertical plates but is passed through the delay line circuit. This gives time for the sweep to start at the horizontal plates before the signal has passed through the main amplifier. The sweep generator delivers the sweep to the horizontal amplifier and the sweep starts at the horizontal deflection plate after

+80ns. Hence the sweep starts well in time, since the signal arrives at the vertical deflection plate at a time to +200ns.

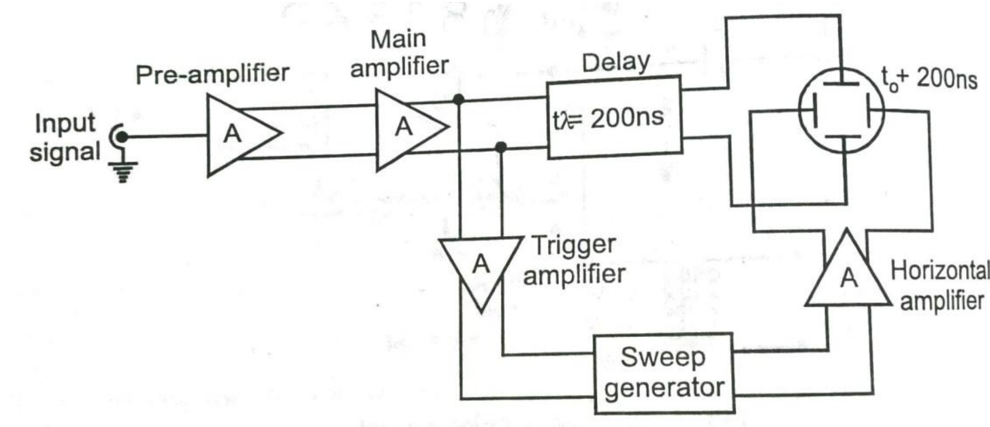


Fig: Delay line circuit

Delay line is packed by inductor and capacitor. This delay is atleast equal to the delay in horizontal.

1)Lumped parameter delay line.

2)Distributor parameter delay line.

They are discussed below:

1) Lumped Parameter delay line:

The lumped parameter delay line was constructed using the T-section. Each T-section produces the delay as follows:

$F_s=\frac{1}{\pi fs}$

where,

f_s=Time delay for the single R_T section.

$f_d=nf_s$

here 'n' is the number of T section.

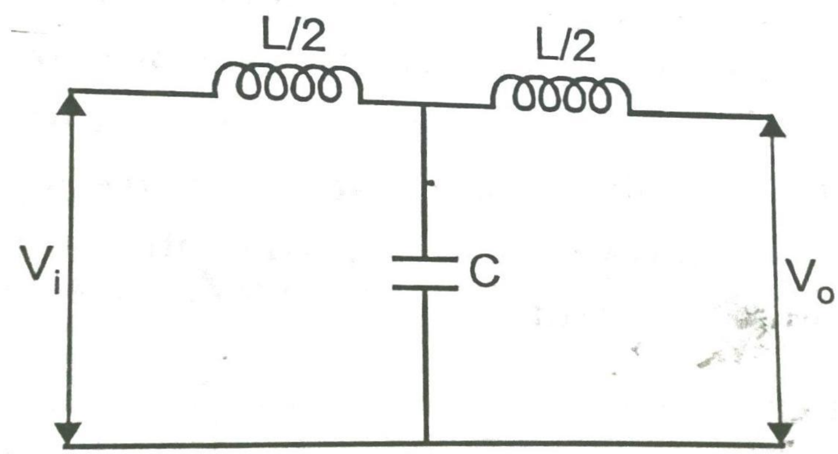


Fig: Lumped parameter delay line

2) Distributed parameter delay line:

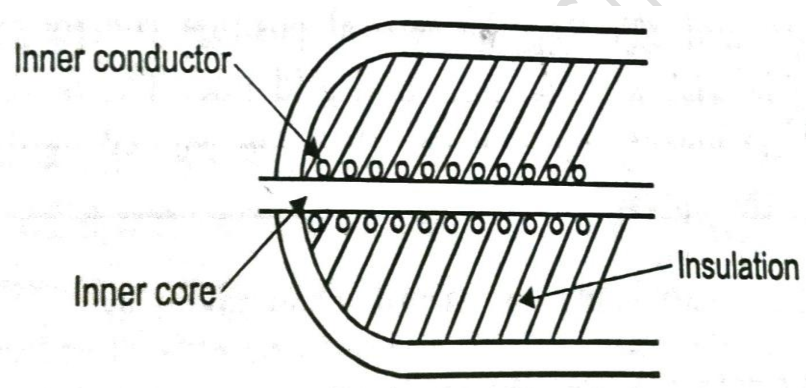


Fig: Distributor parameter delay line

It is a special type of cable. Inner conductor is made up of ferromagnetic core. The inductor coil is wound in the helix shape of the core. Outer core is used to reduce the eddy current loss. We increase the ferromagnetic core that increases the delay line. The coaxial line is advantageous because it does not require the careful adjustment of a lumped-parameter line as it occupies less space.

TYPES OF OSCILLOSCOPES

There are a number of oscilloscopes which are used for special applications. Some of the oscilloscopes are described below:

a)Multiple beam oscilloscopes

In many cases it becomes necessary to compare one signal with that of the other. In such cases Multiple beam oscilloscopes are used. They enclose in a single tube several beam producing systems each with its vertical pair of plates, but mostly with a common time-base. Each Y-channel has its own amplifier. The synchronization or triggering is done from the input of a desired Y-channel or from an external input voltage.

Double beam oscilloscopes use two electron guns within the same cathode ray tube. the electron beam of the two channels are completely independent of each other. The same effect may be produced by a single electron gun, the output from it being split into two independent controllable electron beams.

b) Multiple Trace Oscilloscopes

This oscilloscope uses single electron guns and produces multiple traces by switching the Y-deflection plates from one input signal to another (this means that the Y-channel is time shared by many signals). The eyes interpret this is a continuous simultaneous display of the input signals although it is a sampled display. This method reduces the cost of manufacturing multi-channel oscilloscopes.

c) Sampling oscilloscopes

The oscilloscopes presently can be used for continuous display for frequencies in the 50-300 Mhz range depending upon the design of the oscilloscopes. The display may have upto 1000 dots of luminescence. The vertical deflection for each dot is obtained from progressively later points in each successive cycle of input waveform as shown below:

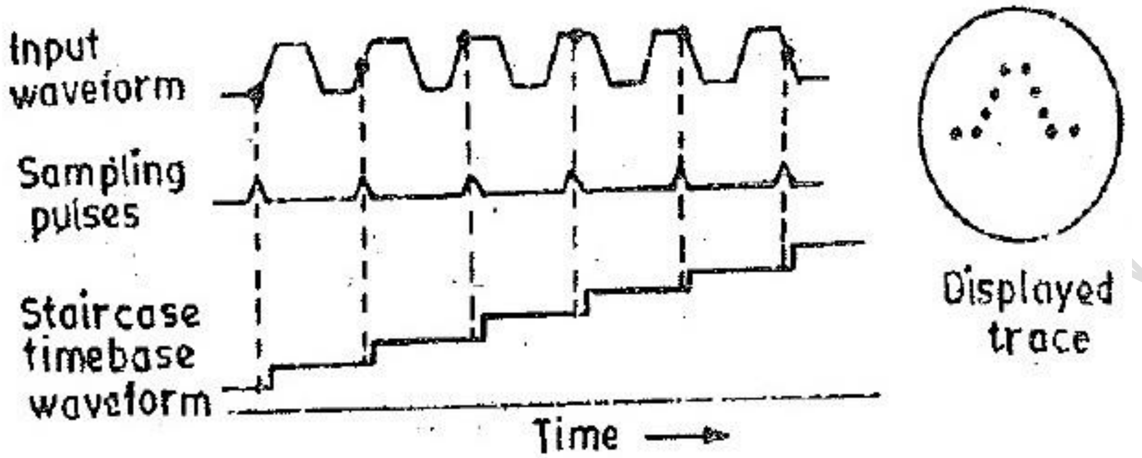


Fig: Principle of Sampling Oscilloscopes.

The horizontal deflection of the electron beam is obtained by applying staircase waveform to X-deflection plates.

The sampling oscilloscope is able to respond and store rapid bits of information and present them in a continuous display. The sampling techniques immediately the input signals into lower frequency domain, where conventional low frequency circuitry is then capable of producing a highly effective display.

This type of oscilloscopes can be used beyond 50Mhz into the UHF range around 500Mhz and beyond upto 10Ghz. It should be noted that the sampling techniques cannot be used the display of transient waveforms.

d) Scanning Oscilloscopes

These oscilloscopes use television tubes. The data to be measured are applied through intensity modulation on the standard screen. Several phenomena can be observed simultaneously on a single screen by using this technique. As a result of large number of factors influencing the quality of recording, experience with the particular camera CRO combination is usually the best guide.

e) Storage type Oscilloscopes

- They are rapidly becoming one of the most useful tools in the presentation of very slowly swept signals and finds many application in mechanical and biomedical fields.

- Usually in conventional CRTs, the persistence of phosphor ranges from microseconds to seconds. In applications where the persistence of the screen is smaller than the rate at which the signal sweeps across the screen, the start of screen will have disappeared before the end of the display is written.
- In storage oscilloscopes, the persistence times are much greater than a few seconds or even hours are available, making it possible to store events on the CRT screen.
- The special CRT of storage oscilloscope contains electron gun, deflection plates, phosphor bronze screen but also it holds many number of special electrodes. The CRT used here is called as storage tube.
- The schematic diagram of Storage CRT below:

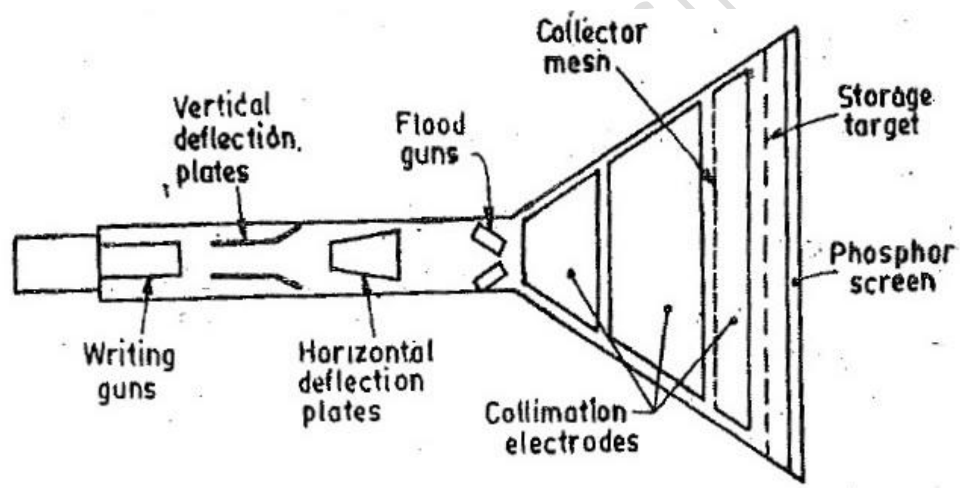


Fig: Schematic diagram of a storage type CRT

- The storage mesh or the storage target is mounted just behind the phosphor screen is a conductive mesh covered with a highly resistive coating of magnesium fluoride.
- The write gun is a high-energy electron gun, similar to the conventional gun giving a narrow focussed beam which can be deflected and used to write the information to be stored.
- Because of the excellent insulating properties of the magnesium fluoride coating, the positively charged pattern remains exactly in the same position on the storage target which it was first deposited.

- The stored pattern may be made available for viewing at a later time by the use of two special electron guns called flood guns. The flood guns are placed inside the CRT in a position between the deflection plates and the storage target and they emit low-velocity electrons over a large area towards the entire screen.
- When the flood guns are switched for viewing mode low energy electrons are sprayed towards the screen. The electron trajectories are adjusted by the collimating electrodes which constitute a low-voltage electrostatic lens system , so that the flood electrons cover the entire screen area.
- To erase the pattern which is etched on the storage mesh, a negative voltage is applied to the storage target, neutralizing the stored positive charge.
- To get variable persistence, the erase voltage is applied in the form of pulses instead of a steady dc voltage. By varying the width of these pulses, the rate of erase is verified.

f) Impulse waveform oscilloscopes

These oscilloscopes are used for the investigation of transient non-period phenomena which occur at high voltages. These oscilloscopes use special types of CRT wherein the plates are mounted on the sides. The voltage to be measured is applied to these plates either directly or through capacitive potential dividers. Simultaneously, an impulse is suddenly applied to the cathode voltage. A very bright display is obtained on account of the high voltage and the high beam current which exist for a very short duration. Therefore, photographic records of the display can be obtained even at very high speeds of upto $50x10^6$ m/s.

MEASUREMENT OF SIGNAL VOLTAGE

Oscilloscopes are best suited for the measurement of peak and peak to peak values of AC voltage waveform, although DC coupled oscilloscopes also permit the display and measurement of an AC signal with a DC component. Before making a voltage measurement, it is important to be sure that the probe is properly compensated and the fine adjustment control of the vertical attenuator is in CAL or "calibrated" position. This control should not be disturbed during a measurement.

The signal to be measured is connected to the vertical input via the probe. The vertical sensitivity, time base, coupling and trigger controls are set to provide a stable display that covers as many vertical divisions as possible without exceeding the limits of the screen. The vertical and horizontal position controls can be used to reposition the traces lightly with respect to the graticule, in order to use the minor divisions of the graticule to the best advantage. If desired, a zero-voltage, or base line reference can be established by switching the vertical input selector switch to ground (GND) and adjusting the vertical position control to make the zero level coincide with the major horizontal grid line. The oscilloscope is a "personalised" instrument which means that the control settings can be adjusted to suit the operator.

AC voltage measurements are easiest when taken as peak-to-peak readings from the oscilloscope screen. A ground reference is established at the mid horizontal graticule line, and then the AC waveform is displayed. Peak-to-peak voltage is read as

v_{p-p} = vertical divisions x volts/divisions x probe attenuation

The number of divisions is the number of major vertical graticule divisions measured between the negative and positive peaks of the waveform. The "volts/divisions" is the setting of the vertical sensitivity control, while probe attenuation depends on the type of the probe such as 1X or 10X. The voltage of an AC with a non-zero DC (average) level can be measured. To obtain the RMS or average values of standard waveforms, it is best to measure the peak to peak value and convert mathematically using the factors like V_{av} and V_{rms} for different types of waveforms.

MEASUREMENT OF CURRENT USING OSCILLOSCOPE

There are two ways to measure current with an oscilloscope. Alternating and direct current can be measured by looking at the voltage across a known value of resistance and applying Ohm's law to the observed trace. Application of this technique is limited by the need for one side of the resistor and oscilloscope to be at ground potential, although some oscilloscopes are equipped with differential preamplifiers that permit viewing the voltage drop across components that have both terminals "floating" above ground. The second method requires the use of the current probe and is only applicable to the measurement of alternating current.

MEASUREMENT OF PHASE AND FREQUENCY USING LISSAJOUS PATTERNS IN AN OSCILLOSCOPE

The patterns that appear on the CRT when sinusoidal voltages are simultaneously applied horizontal and vertical plates. These patterns are called as Lissajous patterns.

When two sinusoidal voltages of equal frequency which are in phase with each other are applied to the horizontal and vertical deflection plates, the pattern appearing on the screen is a straight line as is clear from the figure below:

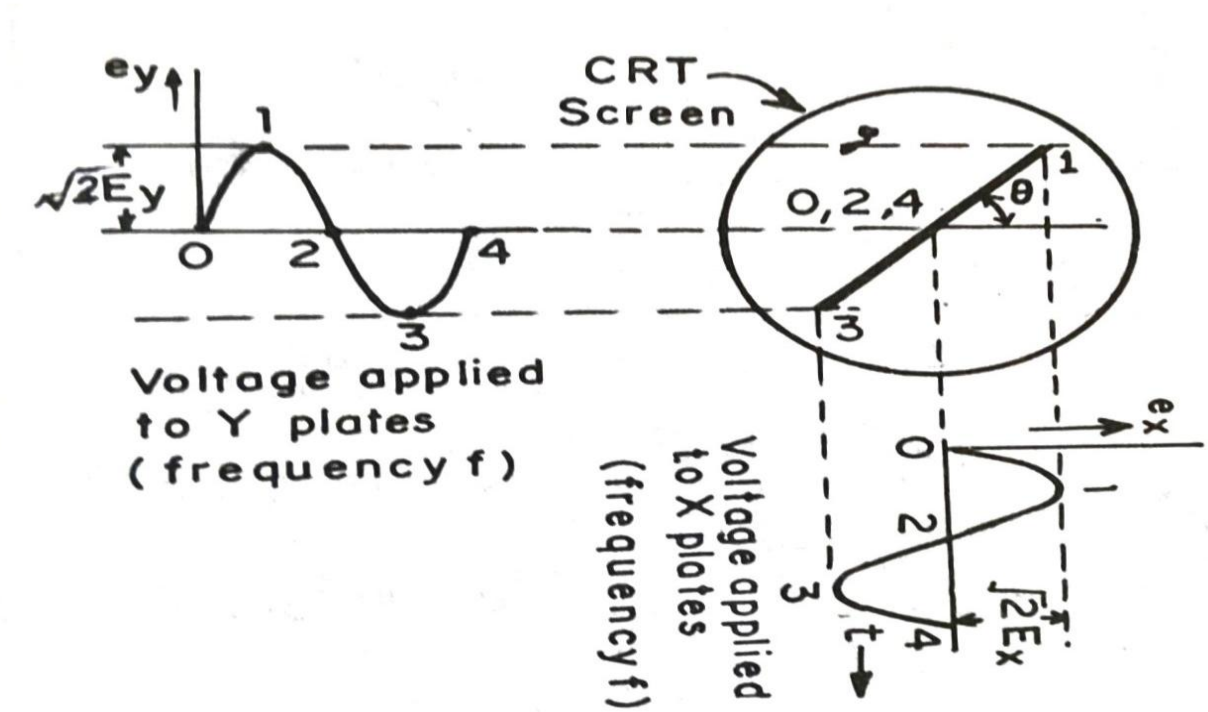


Fig: Lissajous pattern with equal frequency voltages and zero phase shift.

Thus when two equal voltages of equal frequency but with 90^0 phase displacement are applied to a CRO, the trace on the screen is a circle. This is shown below:

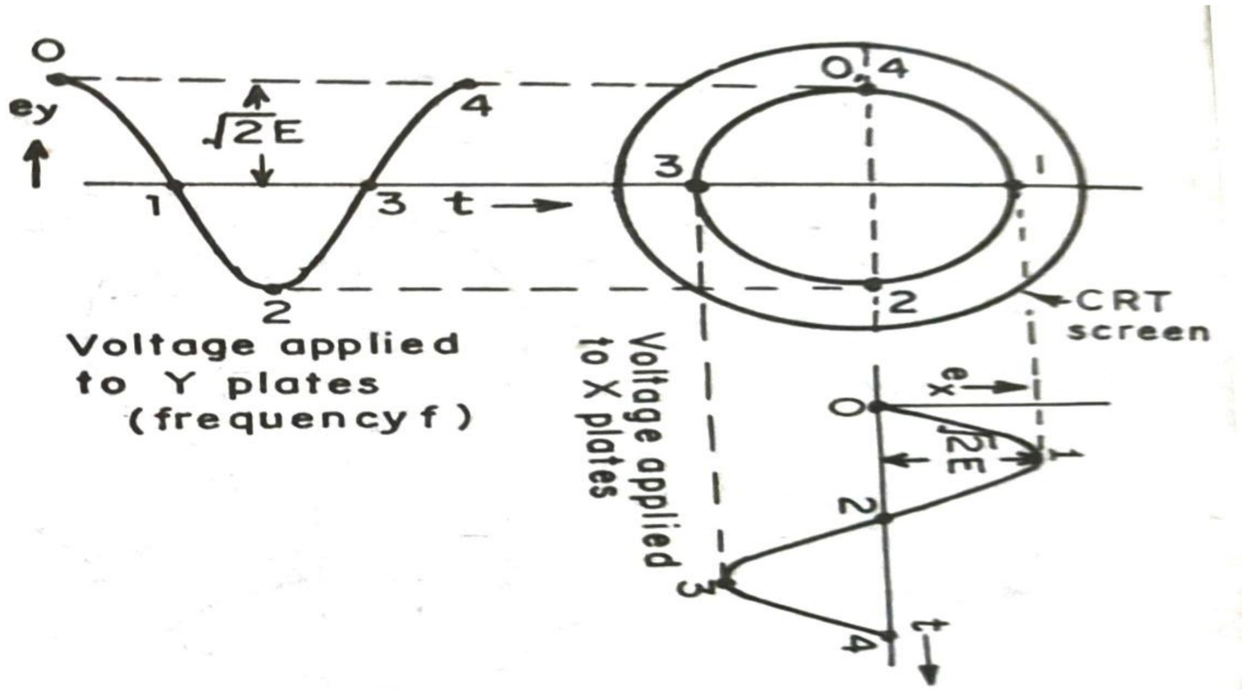


Fig: Lissajous pattern with equal voltages of equal frequency and a phase shift of 90^0

When two equal voltages of equal frequencies but with a phase shift "ϕ" (not equal to 0^0 or 90^0) are applied to a CRO we obtain an ellipse as shown in figure below:

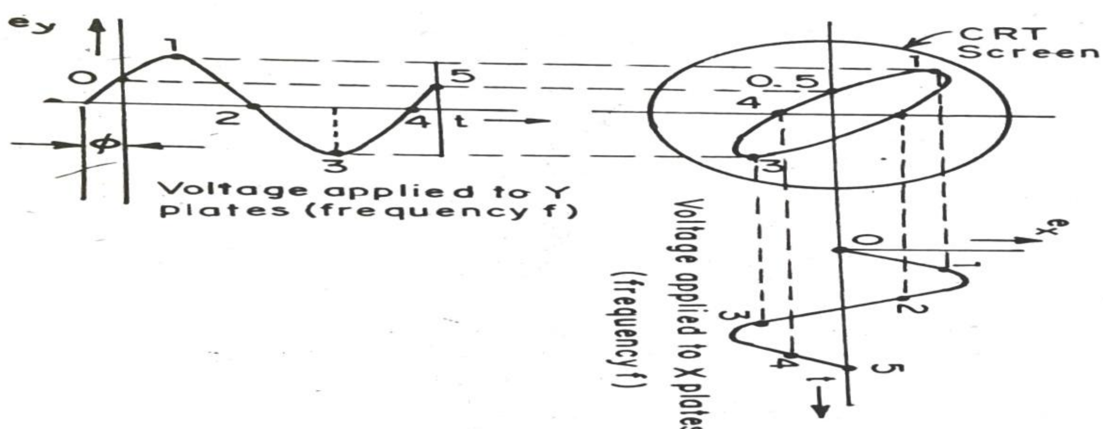


Fig: Lissajous patterns with two equal voltages of same frequencies and phase shift "ϕ"

An ellipse is also obtained when unequal voltages of same frequencies are applied to the CRO.

A number of conclusions can be drawn from the above discussions. When two sinusoidal voltages of same frequencies are applied:

(i) A straight line results when the two voltages are equal and are in either in phase with each other or 180^0 out of phase with each other. The angle formed with the horizontal is 45^0 when the magnitudes of voltages are equal. An increase in the vertical deflection voltage causes the line to have an angle greater than 45^0 with the horizontal. On the other hand a greater horizontal voltages makes the angle less than 45^0 with the horizontal.

(ii) Two sinusoidal waveforms of the same frequency produce a lissajous pattern, which may be a straight line, a circle or an ellipse depending upon the phase and magnitude of the voltages.

A circle can be formed only when the magnitude of the two signals are equal and the phase difference between them is either 90^0 or 270^0. However if the two voltages are not equal and/or out of phase an ellipse is formed. If the 'Y' voltage is larger, an ellipse with vertical major axis is formed while if the X-plate voltage has a greater magnitude, the major axis of the ellipse lies along horizontal axis.

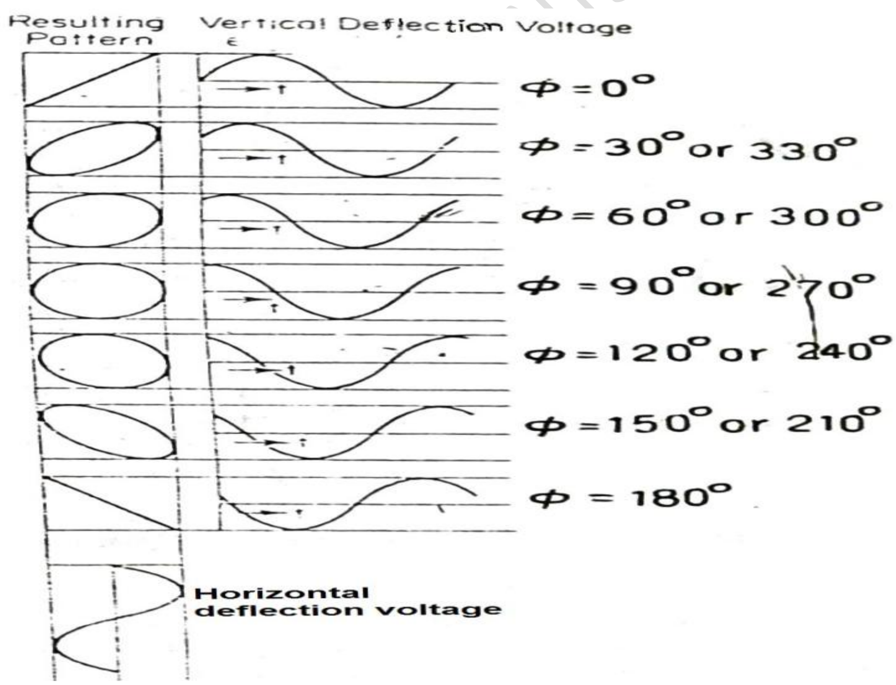


Fig: Lissajous patterns with different phase shifts

It is clear from the above figure that for equal voltages of same frequency, progressive variation of phase voltage causes the pattern to vary from a straight diagonal line to ellipses of different eccentricities and then to a circle, after that through another series of ellipses and finally a diagonal straight line again.

Regardless of the two amplitudes of the applied voltages, the ellipses provides a simple means of finding phase difference between two voltages. Referring to the below figure, the sine of the phase angle between the voltages is given by:

$$\sin \phi = \frac{Y1}{Y2} = \frac{X1}{X2}$$

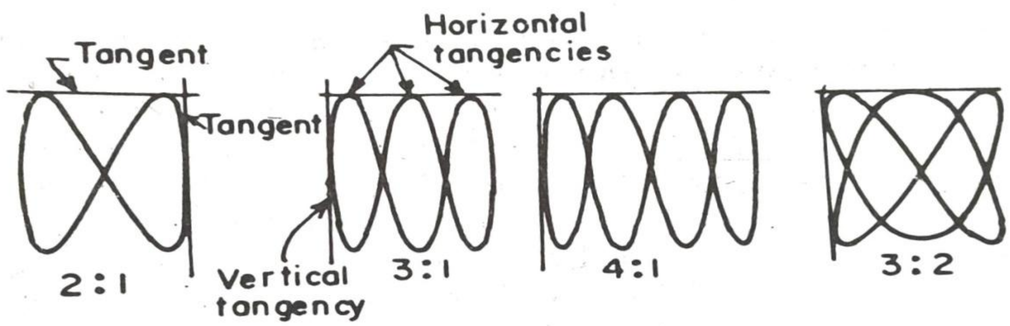


Fig: Lissajous patterns with different frequency ratios.

If the major axis of the ellipse lies in the first and third quadrants (ie., its slope is positive) as shown in figure (a) below, the phase angle is either between 0^0 or 90^0 or between 270^0 to 360^0. When the major axis of the ellipse lies in the second and fourth quadrants, ie., when its slope is negative as in figure (b) below, the phase angle is between 90^0 and 180^0 or between 180^0 and 270^0.

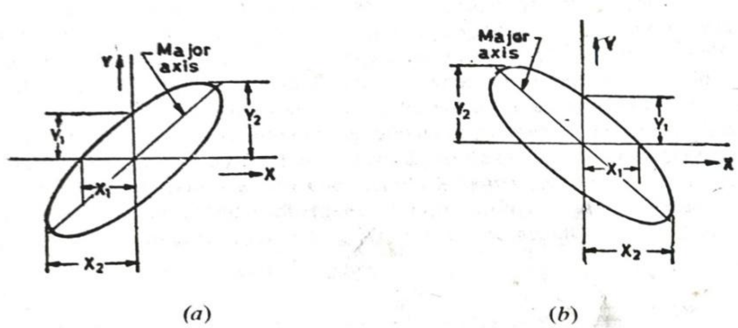


Fig: Determination of angle of phase shifts

FREQUENCY MEASUREMENTS

Lissajous patterns are used for accurate measurement of frequency. The signal whose frequency is to be measured is applied to the 'Y' plates. An accurately calibrated standard variable frequency source is used to supply voltage to the 'X' plates, with the internal sweep generator switched off. The standard frequency is adjusted till the unit pattern appears as a circle or an ellipse, indicating that both signals are of same frequency.

Let us consider an example, suppose sine waves are applied to 'X' and 'Y' plates as shown in figure:

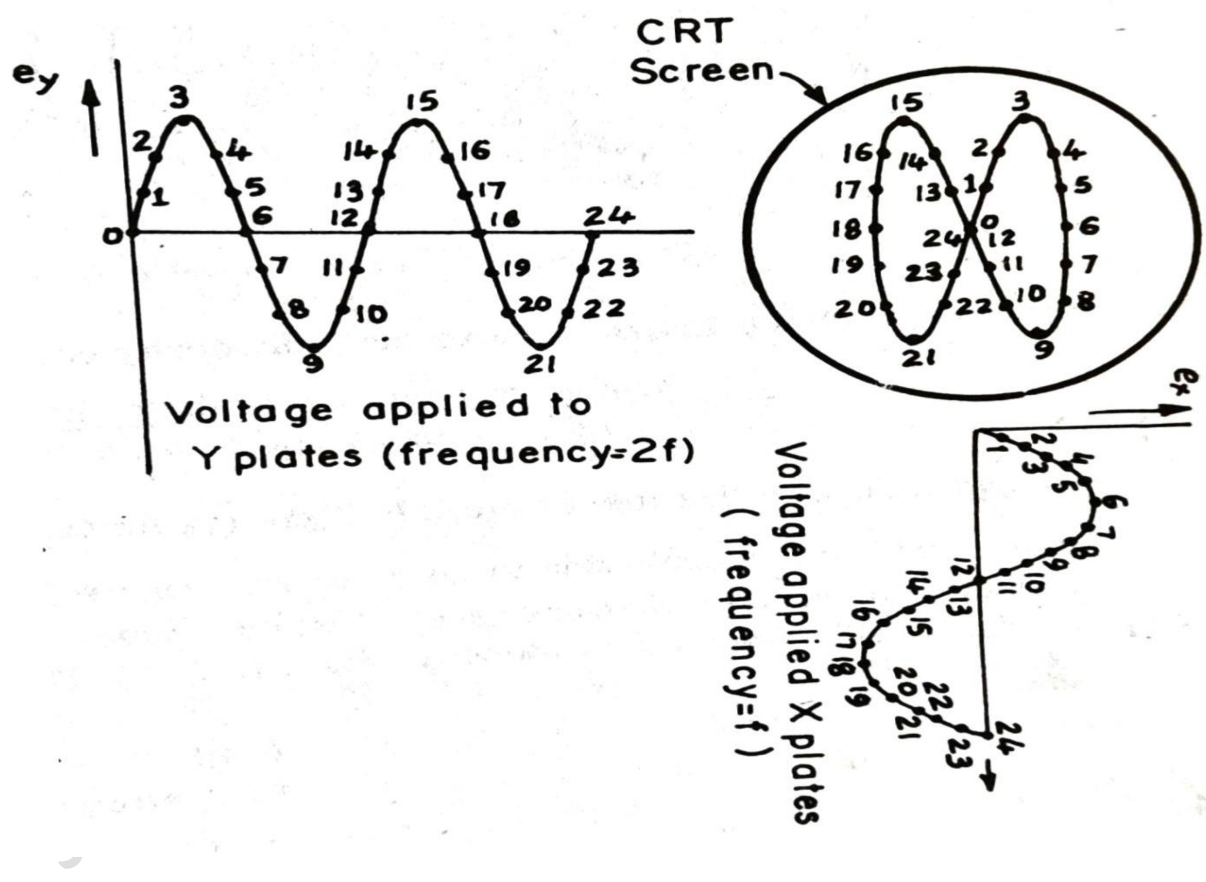


Fig: Lissajous pattern with frequency ratio 2:1

Let the frequency of wave applied to 'Y' plates is twice that of the voltage applied to 'X' plates. This means that the CRT spot travels two complete cycles in the vertical deflection against one in the horizontal direction.

Two waves start at the same instant. Lissajous pattern may be constructed in the usual way and the 8 shaped pattern with the loops is obtained. If the two waves do not start at the same instant we get different patterns for the same frequency ratio. The Lissajous patterns for other frequency ratios can be similarly drawn. Some of these patterns are shown below:

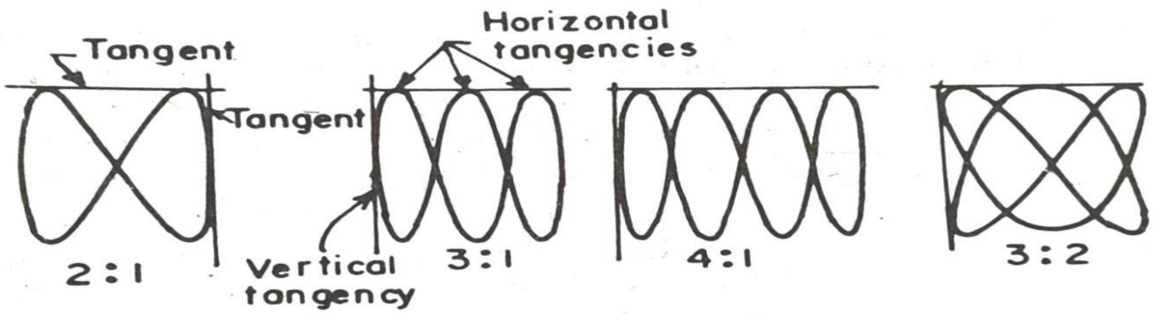


Fig: Lissajous patterns with different frequency ratios

In all the cases, the ratios of the two frequencies are:

$$\frac{fx}{fy} = \frac{Number\ \ of\ times\ tangent\ \ touches\ top\ or\ bottom}{Number\ \ of\ times\ tangent\ \ touches\ either\ side}$$

$$= \frac{number\ \ of\ horizontal\ \ tangencies}{number\ \ of\ vertical\ \ tangencies}$$

where,

f_x= frequency of signal applied to 'Y' plates

f_y= frequency of signal applied to 'X' plates.

INDUSTRIAL APPLICATIONS OF CRO

Because the oscilloscope is an extremely flexible and versatile instrument, it can be used to measure a number of parameters associated with DC and AC signals. Using a single channel oscilloscope, it is capable of making measurements of voltage current, time, frequency and rise/fall time. If a dual trace oscilloscope is used the phase shift between two synchronous signals can be measured.

Other major applications of CRO are listed below:

(A) In Radio Work

1. To trace and measure a signal throughout the RF, IF and AF channels of radio and television receivers.

2. It provides the only effective way of adjusting FM receivers, broadband high-frequency RF amplifiers and automatic frequency control circuits;
3. to test AF circuits for different types of distortions and other spurious oscillations;
4. To give visual display of wave-shapes such as sine waves, square waves and their many different combinations;
5. To trace transistor curves
6. To visually show the composite synchronized TV signal
7. To display the response of tuned circuits etc.

(B) Scientific and Engineering applications:

1.Measurement of ac/dc voltages,
2. Finding B/H curves for hysteresis loop,
3. for engine pressure analysis,
4. for study of stress, strain, torque, acceleration etc.
5. Frequency and phase determination by using Lissajous figures,
6. Radiation patterns of antenna,
7. Amplifier gain,
8. Modulation percentage,
9. Complex waveform as a short-cut for Fourier analysis,
10. Standing waves in transmission lines etc.

DC AND AC VOLTMETERS

Generally AC electromechanical meters are based on two basic movements: those based on DC movement, and those designed for AC use alone. Permanent magnet moving coil (PMMC) meter movement does not work correctly if it is directly connected to alternating current, because the direction of needle movement will change with each half-cycle of AC quantity. Figure 1 shows D'Arsonval meter movement causes useless flutter of the needle while ac is passing through this wire coil. Permanent-magnet meter is a device whose motion depends on the polarity of the applied voltage. In D'Arsonval meter movement, initially the dc current must be rectified through diodes. The diodes act like a one-way valve for electron flow: acting as a conductor for one polarity and an insulator for another. The arrowhead in each diode symbol points against the permitted direction of electron flow. Arranged in a bridge, four diodes serve to steer AC through the meter movement in a constant direction throughout all portions of the AC cycle shown in Figure 2

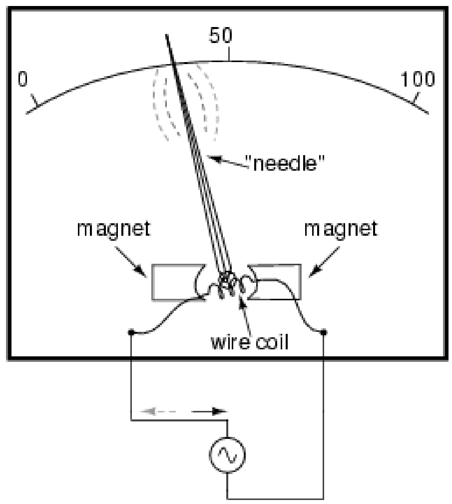


Figure1. PassingAC through this D'Arsonval meter movement causes Useless flutter of the needle.

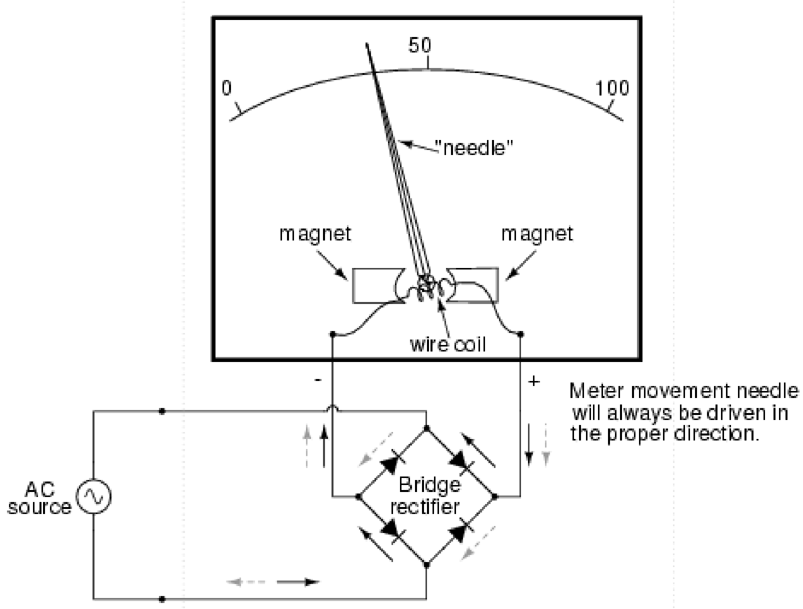


Figure 2 Passing AC through this rectified AC meter movement will drive it in one direction.

Another strategy for a practical AC meter movement is to redesign the movement without the inherent polarity sensitivity of DC types. This means avoiding the use of permanent magnets. The simplest design is to use a non- magnetized iron vane to move the needle against spring tension, the vane being attracted toward a stationary coil of wire energized by the AC quantity to be measured as in Figure 3.

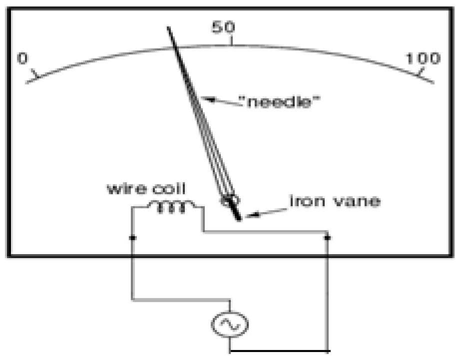


Figure 3 Iron-vane electromechanical meter movement

Electrostatic attraction between two metal plates separated by an air gap is an alternative method for generating a needle-moving force proportional to applied voltage. The forces involved are very small, much smaller than the magnetic attraction between an energized coil and an iron vane, and as such these “electrostatic” meter movements tend to be fragile and easily disturbed by physical movement. This technology possesses high input impedance, meaning that no current need be drawn from the circuit under test. Also, electrostatic meter movements are capable of measuring very high voltages without need for range resistors or other, external apparatus

DC Voltmeter

The DC voltmeter mainly consists of a dc amplifier apart from the attenuator, as shown in Figure 4

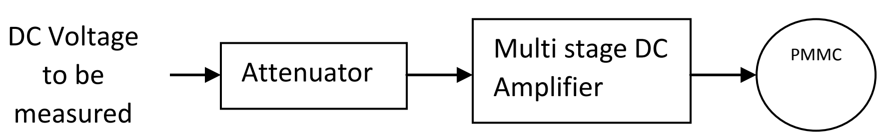


Figure 4 Block diagram of DC voltmeter

DC voltmeters can be divided into two categories.

1. Direct coupled amplifier DC Voltmeter.
2. Chopper type DC Voltmeter.

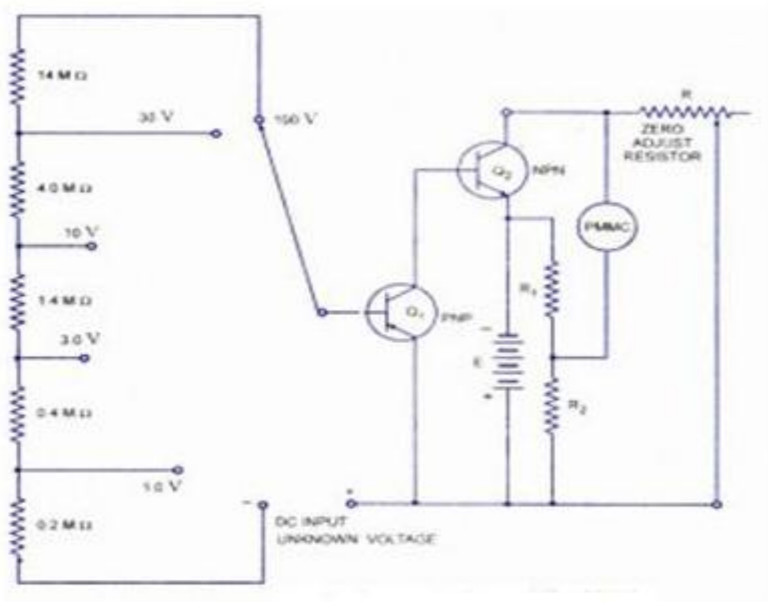


Figure 5 Direct coupled amplifier DC voltmeter

This type of voltmeter is very common because of its low cost. This instrument is used only to measure voltages of the order of milli-volts owing to limited amplifier gain. The circuit diagram for a direct coupled amplifier dc voltmeter using cascaded transistors is shown in Figure 5. An attenuator is used in input stage to select voltage range. A transistor is a current controlled device so resistance is inserted in series with the transistor Q1 to select the voltage range. It can be seen from figure that sensitivity of voltmeter is 200 kilo ohms/volt neglecting small resistance offered by transistor Q1. Other values of range selecting resistors are so chosen that sensitivity remains same for all the ranges. So current drawn from the circuit is only 5micro Ampere.

Two transistors in cascaded connections are used instead of using a single transistor for amplification in order to increase the sensitivity of the circuit. Transistors Q1 and Q2 are taken complement to each other and are directly coupled to minimize the number of components in the circuit. They form a direct coupled amplifier. A variable resistance R is put in the circuit for zero adjustment of the PMMC. It controls the bucking current from the supply E to buck out the quiescent current. The draw-back of such a voltmeter is that it has to work under specified ambient temperature to get the required accuracy otherwise excessive drift problem occurs during operation.

Another circuit diagram of a direct coupled amplifier dc voltmeter using FET in input stage is shown in Figure 6. In this voltmeter, voltage to be measured is firstly attenuated with range selector switch to keep the input voltage of amplifier within its level. FET is used in the input stage of amplifier because of its high input impedance so that is does not load the circuit of which voltage is to be measured and it also keeps the sensitivity of voltmeter very high. As FET is a voltage controlled device so resistance network of attenuator is put in shunt in the circuit. Transistors Q2 and Q3 form the direct coupled dc amplifier whose output is finally supplied to PMMC meter. When transistors work within their operating region, the deflection of meter remains proportional to the applied input voltage. This voltmeter can be used for measurement of voltages of the order of milli-volts because of sufficient gain of amplifier

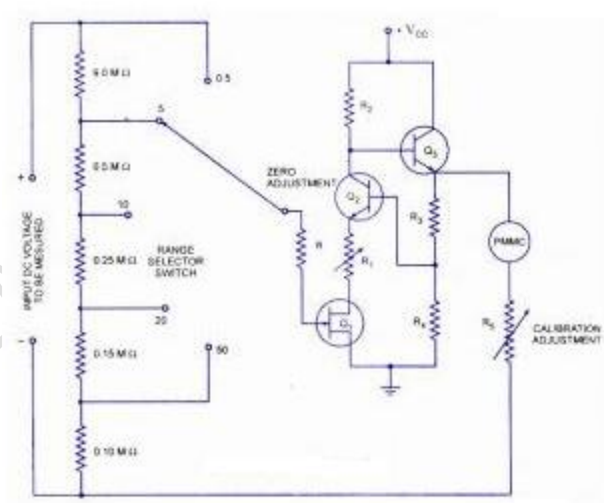
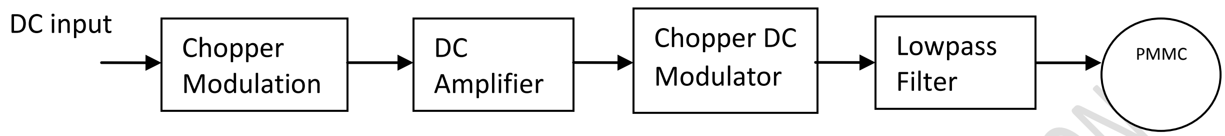


Figure 6 Direct coupled amplifier DC voltmeter using FET

Apart from having high input impedance, this circuit has another advantage that when input voltage exceeds its limit, amplifier gets saturated which limits the current passing through the PMMC meter. So meter does not burn out.

Chopper Type DC Voltmeter

The simple block diagram of the chopper fed DC voltmeter is shown in Figure 7



Chopper type dc amplifier is used in highly sensitive dc electronic volt-meters. Its block diagram is shown in Figure 7. Firstly dc input voltage is converted into ac voltage by chopper modulator and then it is supplied to an ac amplifier, Output of amplifier is then demodulated to a dc voltage proportional to the original input voltage. Modulator chopper and demodulator chopper act in anti-synchronism.Chopper system may be either mechanical or electronic.

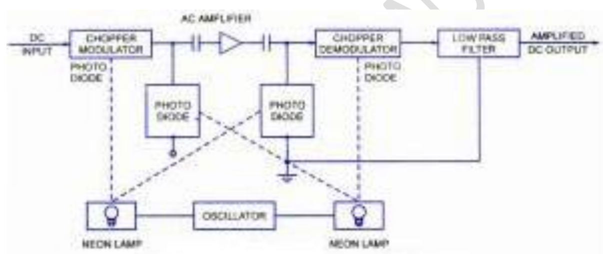


Figure 8 Chopper type DC voltmeter

Circuit diagram of an electronic chopper employing photo diodes is shown in Figure 8. Photo diodes change its resistance under different illumination conditions; this property of photo diode is used in chopper amplifier. Its resistance changes from the order of few mega-ohms to few hundred ohms when it is illuminated by a light source in the dark place. Two neon lamps are used in this circuit which is supplied by an oscillator for alternate half cycles. Two photo diodes are used in input stage which acts as half-wave modulators because of its alternate switching action by the neon lamps at the frequency of oscillator.

Output of chopper modulator is a square wave voltage (proportional to the input signal) which is supplied to the ac amplifier through a capacitor. Amplified output is again passed through a capacitor and then fed to chopper demodulator. Capacitor is used to remove dc drift from the signal. Chopper demodulator gives a dc output voltage (proportional to the input voltage) which is passed through the low pass filter to remove any residual ac component. Now this dc output voltage is supplied to the PMMC meter for measurement of input voltage.

In chopper amplifier dc voltmeter, input impedance is of the order of hundred mega-ohms and it has sensitivity of one micro-volt per scale division.

AC Voltmeter

Sometimes signal is firstly amplified by ac amplifier and then rectified before supplying it to dc meter, as shown in Figure 9. In the former case the advantage is of economical amplifiers and the arrangement is usually used in low priced voltmeters.

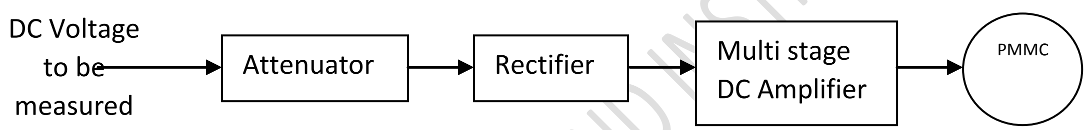


Figure 9 Block diagram of AC voltmeter

Broadly ac voltmeters can be divided into three categories.

1. Average reading AC voltmeters using vacuum tube diode
2. Average reading AC voltmeters using semiconductor diode
3. Peak reading AC voltmeter

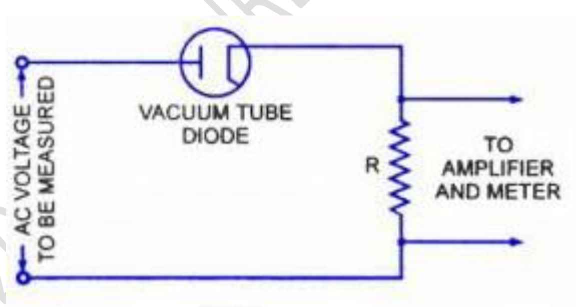


Figure 10 AC voltmeter using vacuum tube diode

Normally ac voltmeters are average responding type and the meter is calibrated in terms of rms values for a sine wave. Since most of the voltage measurements involve sinusoidal waveform so this method of measuring rms value of ac voltages works satisfactorily and is less expensive than true rms responding voltmeters.

However, in case of measurement of non-sinusoidal waveform voltage, this meter will give high or low reading depending on the form factor of the waveform of the voltage to be measured.

The circuit diagram for an average reading voltmeter using a vacuum tube diode is shown in Figure 10. The arrangement requires a vacuum tube diode, an high resistance (of the order of 105 Q.) R and PMMC instrument, all connected in series, as shown in fig. Resistance R is used to limit the current and make the plate The linear plate characteristics are essential in order to make the current directly proportional to voltage. Also because of high series resistance R, plate resistance of vacuum tube diode becomes negligible and therefore variations in plate resistance do not cause non-linearity in voltage-current characteristics. Thus, the scale of PMMC instrument is uniform and independent of variations of tube plate resistance. Voltage across the high resistance is fed to dc amplifier and output of the amplifier is fed to PMMC instrument. Circuit diagram of an average reading ac voltmeter using semi-conductor diode is shown in Figure 11.The diode conducts during the positive half cycle and does not conduct during the -ve half cycle, as shown in figure. The average current through the meter will be given by the expression,

$$I_{av} = V_{av} / 2R = 0.45 * [V_{rms}/R]$$

Vrms is the effective or rms value of applied voltage and 1.11 is the form factor of sinusoidal wave. R is multiplied by 2 because the voltmeter operates on half-wave rectification. It is to be worthnoting that this instrument can be used to indicate dc voltages but in such a case the instrument readings will have to be multiplied by 2 x 1.11, that is, as the diode conducts all the time. Circuit diagram of an average reading ac voltmeter using semi-conductor diodes as a full-wave rectifier is shown in figure. In this case average current through the meter will be Vrms/ 1.11R. Main advantages associated with these voltmeters are that they are simple in construction, have high input impedance, low power consumption and uniform scale. Main disadvantage of these voltmeters is that these operate in audio-frequency range. In radio-frequency range, distributed capacitance of the high resistance R introduces error in the readings.

Another disadvantage of such a voltmeter is that due to non-linear volt-ampere characteristic for lower voltage the readings of the voltmeter at lower voltage are not correct.

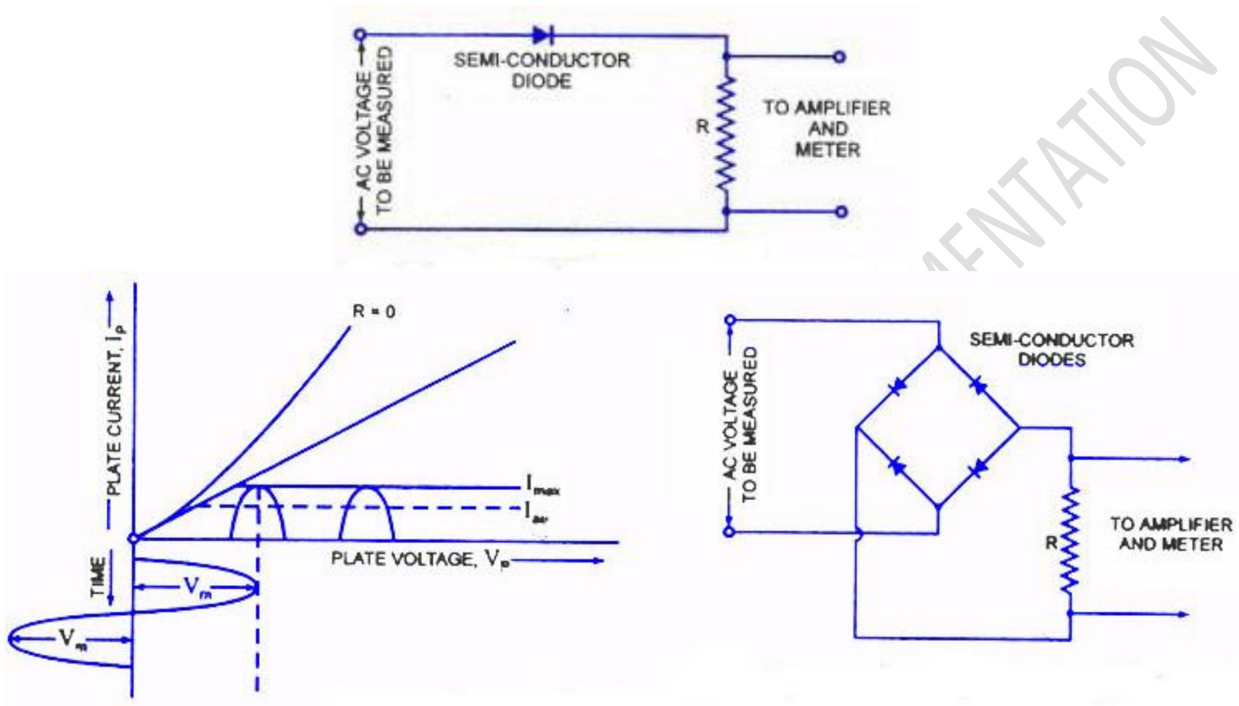
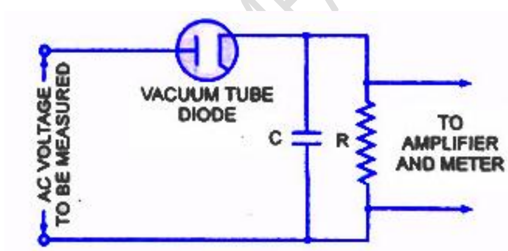
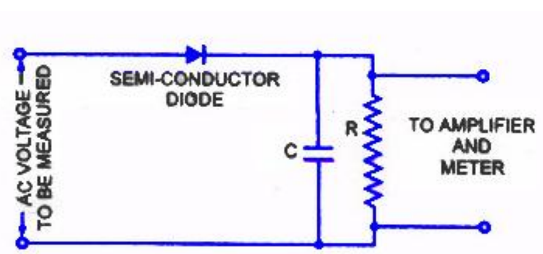


Figure 11 Average Reading AC voltmeter using Semi conductor as half wave rectifier



Peak Reading AC Voltmeter Using Vacuum Tube Diode



Peak Reading AC Voltmeter Using Semi-conductor Diode

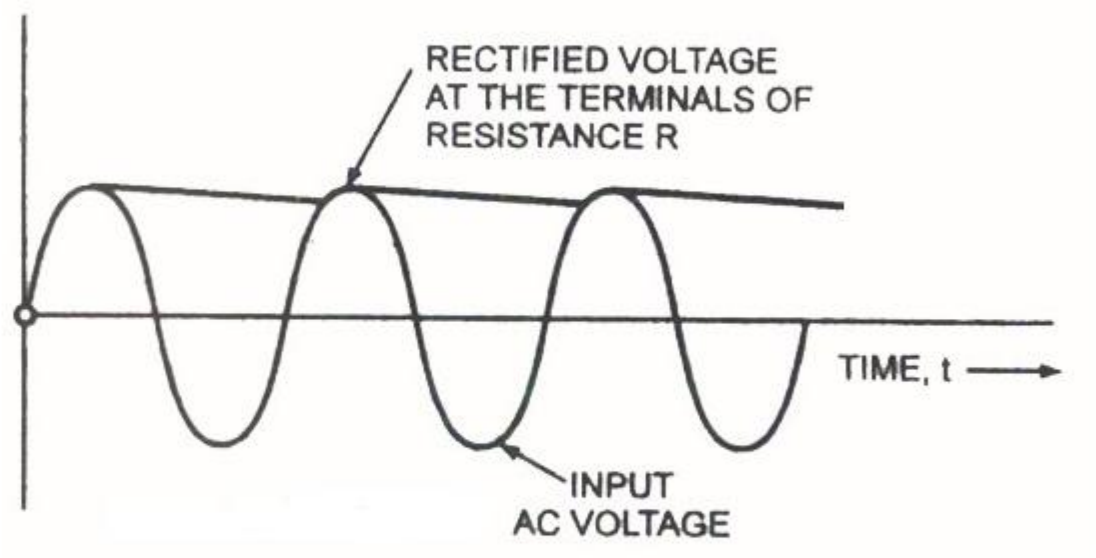


Figure 12 Peak reading AC Voltmeter and its waveform

The circuit diagram for peak reading voltmeter using vacuum tube and semi-conductor diode are shown in figures respectively. In this type of voltmeters capacitor C is charged to the peak value of the applied voltage and capacitor is discharged through high resistance R between two peaks of the wave which results in a small fall in capacitor voltage. But this voltage is again built up during next peak of the wave, as shown in figure. So, voltage across capacitor C and resistance R remains almost constant and equal to peak value of the applied voltage.

Either the average voltage across R or the average current through R, can be used to indicate the peak value of applied voltage. In case the vacuum tube diode (or semi-conductor diode), series resistance R shunted by capacitance C and PMMC are connected in series across the source of unknown voltage, the current through the PMMC will indicate the peak value of applied voltage. In case, the circuit shown in figure making use of rectifying diode, series resistance R, dc amplifier and PMMC is employed, the average voltage across R will indicate the peak value of applied voltage. The high value input resistance also gives more linear relationship between peak applied voltage and the instrument indication. Also the performance of the diode with inputs consisting of pulses and modulated waves is improved.

The dc amplifier associated with the diode rectifier should be provided with stabilizing means in order to prevent drift in the indication of the output meter. Usually a voltage regulated supply combined with a compensating circuit is used. The use of high series resistance R, associated with dc amplifier, no doubt results in a high input resistance but at the same time it implies that an applied voltage of sufficient amplitude is required so that the system acts as a peak voltage device. The main disadvantage of this system is with regards to measurement of low voltage. If the applied voltage is too small, then there is a flow of some current throughout the cycle of the voltage because of high velocity of emission of electrons, and the input resistance may be a few hundred ohms and it defeats the very purpose with which electronic instruments are used.

AMMETER

Ammeter means Ampere-meter which measures ampere value. Ampere is the unit of current so an **ammeter** is a meter or an instrument which measures current.

Types of Ammeter

Depending on the constructing principle, there are many types of ammeter we get, they are mainly -

1. Permanent Magnet Moving Coil **(**PMMC**) ammeter**
2. Moving Iron **(MI) Ammeter**
3. Electrodynamometer type Ammeter
4. Rectifier type Ammeter

Depending on this types of measurement we do, we have-

1. **DC Ammeter.**
2. **AC Ammeter.**

DC Ammeter are mainly PMMC instruments, MI can measure both AC and DC currents, also Electrodynamometer type thermal instrument can measure DC and AC, induction meters are not generally used for ammeter construction due to their higher cost, inaccuracy in measurement.

Description of Different Types of Ammeters

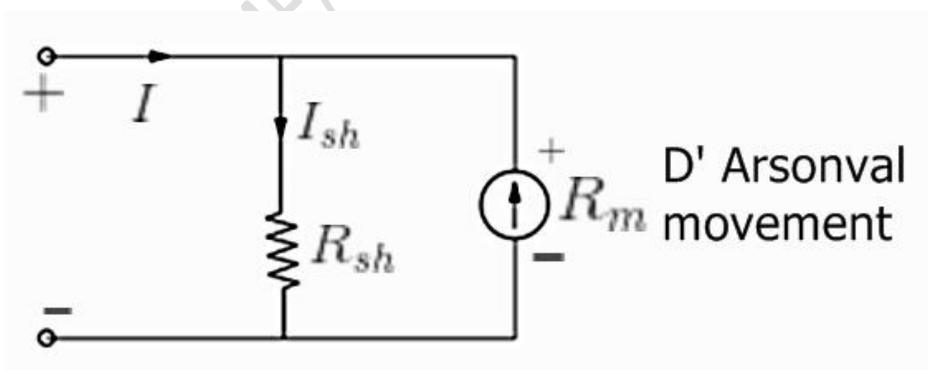
PMMC Ammeter

Principle PMMC Ammeter: When current carrying conductor placed in a magnetic field, a mechanical force acts on the conductor, if it is attached to a moving system, with the coil movement, the pointer moves over the scale. **Explanation:** As the name suggests it has permanent magnets which are employed in this kind of measuring instruments. It is particularly suited for DC measurement because here deflection is proportional to the current and hence if current direction is reversed, deflection of the pointer will also be reversed so it is used only for DC measurement. This type of instrument is called D Arnsonval type instrument. It has major advantage of having linear scale, low power consumption, high accuracy. Major disadvantage of being measured only DC quantity, higher cost etc.

Deflecting torque, $T = BiNlbNm$

Where, B = Flux density in Wb/m². i = Current flowing through the coil in Amp. l = Length of the coil in m. b = Breadth of the coil in m. N = No of turns in the coil.

Extension of Range in a PMMC Ammeter: Now it looks quite extraordinary that we can extend the range of measurement in this type of instrument. Many of us will think that we must buy a new ammeter to measure higher amount of current and also many of us may think we have to change the constructional feature so that we can measure higher currents, but there is nothing like that, we just have to connect a shunt resistance in parallel and the range of that instrument can be extended, this is a simple solution provided by the instrument.



In the figure I = total current flowing in the circuit in Amp. I_{sh} is the current through the shunt resistor in Amp. R_m is the ammeter resistance in Ohm.

$$Then,\ R_{sh} = \frac{R_m}{\frac{I}{I-I_{sh}} - 1}$$

MI Ammeter

It is a moving iron instrument, used for both AC and DC, It can be used for both because the deflection θ propotional square of the current so whatever is the direction of current, it shows directional deflection, further they are classified in two more ways-

1. **Attraction type**.
2. **Repulsion type**.

Its torque equation is:

$$T = \frac{1}{2} I^2 \frac{dL}{d\theta}$$

where I is the total current flowing in the circuit in Amp. L is the self inductance of the coil in Henry. θ is the deflection in Radian.

1. **Attraction Type MI Instrument Principle:** When an unmagnetised soft iron is placed in the magnetic field, it is attracted towards the coil, if a moving system attached and current is passed through a coil, it creates a magnetic field which attracts iron piece and creates deflecting torque as a result of which pointer moves over the scale.
2. **Repulsion Type MI Instrument Principle:** When two iron pieces are magnetized with same polarity by passing a current than repulsion between them occurs and that repulsion produces a deflecting torque due to which the pointer moves. The advantages of MI instruments are they can measure both AC and DC, cheap, low friction errors, robustness etc. It is mainly used in AC measurement because in DC measurement error will be more due to hysteresis.

Electrodynamometer Type Ammeter

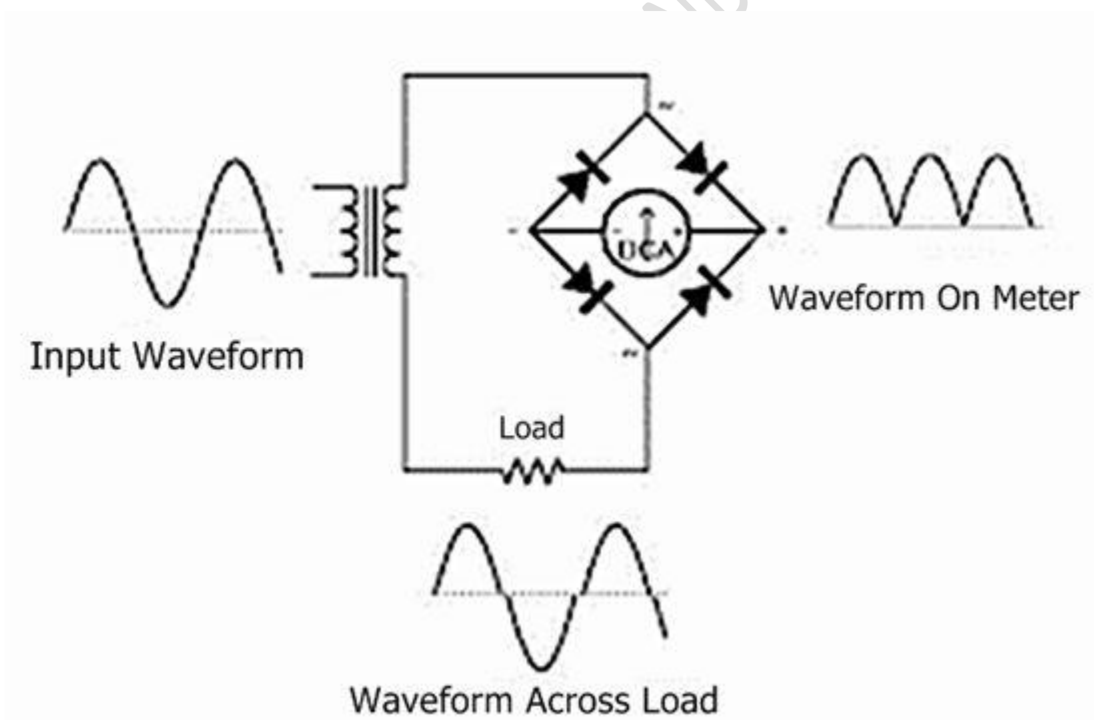
This can be used to measure both i.e. AC and DC currents. Now we see that we have PMMC and MI instrument for the measurement of AC and DC currents, a question may arise - "why do we need Electrodynamometer Ammeter? if we can measure current accurately by other instrument also?". The answer is Electrodynamometer instruments have the same calibration for both AC and DC i.e. if it is calibrated with DC , then also without calibrating we can measure AC. **Principle Electrodynamometer Type Ammeter:** There we have two coils, namely fixed and moving coils . If a current is passed through two coils it will stay in the zero position due to the development of equal and opposite torque. If somehow, the direction of one torque is reversed as the current in the coil reverses, an unidirectional torque is produced. For ammeter, the connection is a series one and φ = 0 Where φ is the phase angle.

$$T = I^2 \frac{dM}{d\theta}$$

Where, I is the amount of current flowing in the circuit in Amp. M = Mutual inductance of the coil.

They have no hysteresis error, used for both AC and DC measurement, the main disadvantages are they have low torque/weight ratio, high friction loss, expensive than other measuring instruments etc.

Rectifier Ammeter



Principle of Rectifier Ammeter: They are used for AC measurement which is connected to secondary of a current transformer, the secondary current is much less than primary and connected with a bridge rectifier to moving coil ammeter. **Advantages**:

1. It can be used in high frequency also.
2. Uniform scale for most of the ranges.

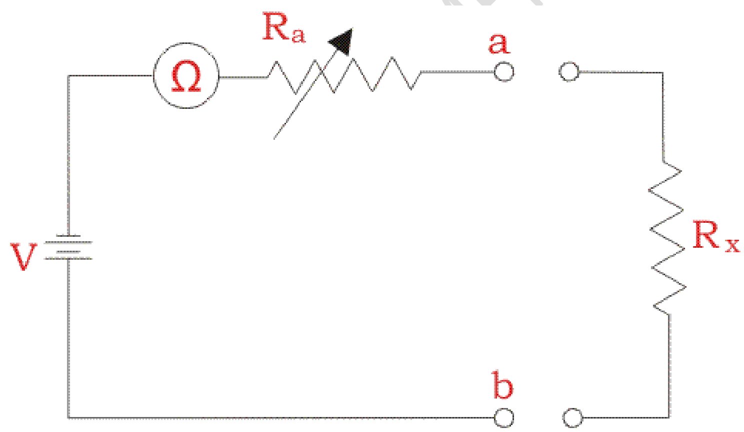
Disadvantages being error due to temperature decrease in sensitivity in AC operation.

OHMMETER

The **ohmmeter** means that it is an instrument which measures resistance of a quantity. Resistance in the electrical sense means the opposition offered by a substance to the current flow in the device. Every device has a resistance, it may be large or small and it increases with temperature for conductors, however for semiconducting devices the reverse is true. There are many types of **ohmmeters** available such as

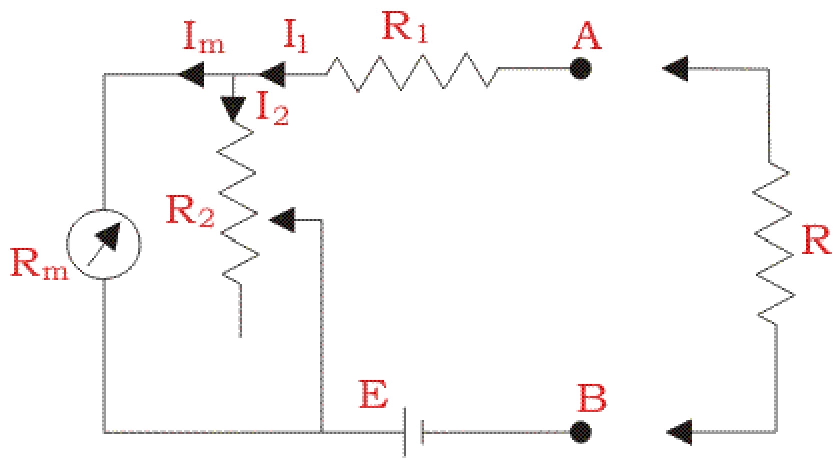
1. Series ohmmeter.
2. Shunt ohmmeter.
3. Multi range ohmmeter.

Working Principle of Ohmmeter



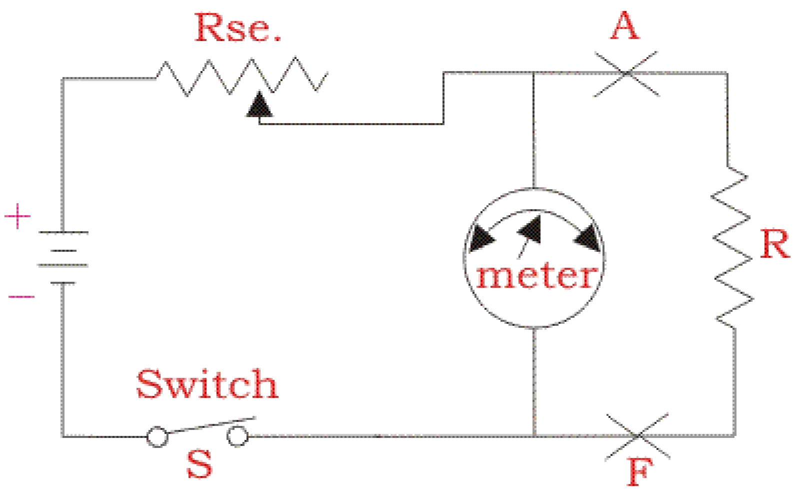
The instrument is connected with a battery, a series adjustable resistor and an instrument which gives the reading. The resistance to be measured is connected at terminal ob. When the circuit is completed by connecting output resistance, the circuit current flows and so the deflection is measured.

Series type Ohmmeter



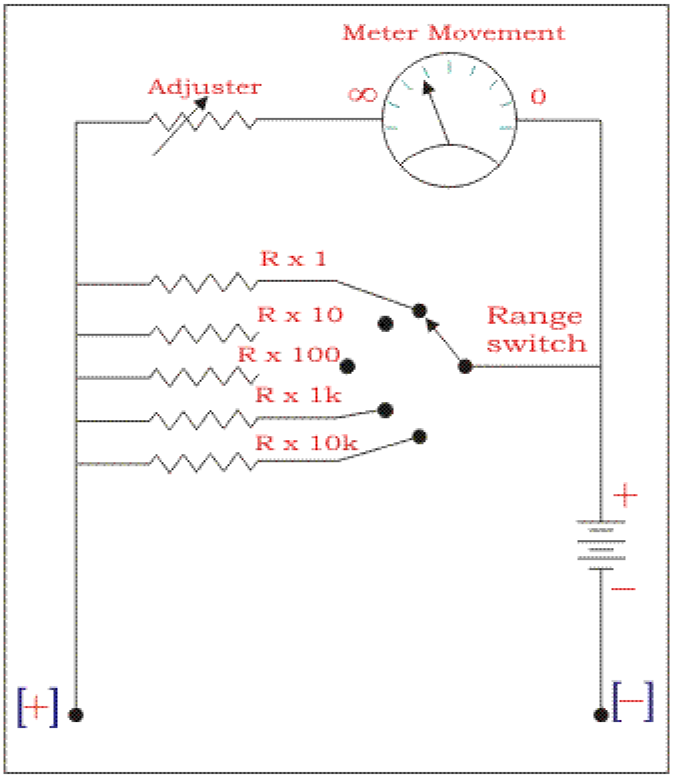
The series type **ohmmeter** consists of a current limiting resistor R1, Zero adjusting resistor R2, EMF source E, Internal resistance of D'Arsonval movement Rm and the resistance to be measured R. When there is no resistance to be measured, current drawn by the circuit will be maximum and the meter will show a deflection. By adjusting R2 the meter is adjusted to a full scale current value since the resistance will be zero at that time. The co-responding pointer indication is marked as zero. Again when the terminal AB is opened it provides very high resistance and hence almost zero current will flow through the circuit. In that case the pointer deflection is zero which is marked at very high value for resistance measurement. So a resistance between zeros to a very high value is marked and hence can be measured. So, when a resistance is to be measured, the current value will be somewhat less than the maximum and the deflection is recorded and accordingly resistance is measured. This method is good but it posses certain limitations such as the decrease in potential of the battery with its use so adjustment must be made for every use. Te meter may not read zero when terminals are shorted, these types of problem may arise which is counteracted by the adjustable resistance connected in series with the battery.

Shunt type Ohmmeter



In this type of meters we have a battery source and an adjustable resistor is connected in series with the source. We have connected the meter in parallel to the resistance which is to be measured. There is a switch by the use of which we can on or off the circuit. The switch is opened when it is not in use. When the resistance to be measured is zero, the terminals A and F are shorted so the current through the meter will be zero. The zero position of the meter denotes the resistance to be zero. When the resistance connected is very high, then a small current will flow the terminal AF and hence full scale current is allowed to flow through the meter by adjusting the series resistance connected with the battery. So, full scale deflection measures very high resistance. When the resistance to be measured is connected between A and F, The pointer shows a deflection by which we can measure the resistance values. In this case also, the battery problem may arise which can be counteracted by adjusting the resistance. The meter may have some error due to its repeated use also.

Multi range Ohmmeter



This instrument provides the reading up to a very wide range. In this case we have to select the range switch according to our requirement. An adjuster is provided so that we can adjust the initial reading to be zero. The resistance to be measured is connected in parallel to the meter. The meter is adjusted so that it shows full scale deflection when the terminals in which the resistance connected is full scale range connected through the range switch. When the resistance is zero or short circuit, there is no current flow through the meter and hence no deflection. Suppose we have to measure a resistance under 1 ohm, then the range switch is selected at 1 ohm range at first. Then that resistance is connected in parallel and the corresponding meter deflection is noted. For 1 ohm resistance it shows full scale deflection but for the resistance other that 1 ohm it shows a deflection which is less than the full load value and hence resistance can be measured. This is the most suitable method of all the **ohmmeters** as we can get accurate reading in this type of meters. So this meter is most widely used now days.

Electronic Multimeters

A multimeter is an electronic instrument which can measure resistances, currents and voltages. It is an indispensable instrument and can be used for measuring d.c. as well as a.c. voltages and currents. Multimeter is the most inexpensive equipment and can make various electrical measurements with reasonable accuracy.

Construction

A multimeter consists of an ordinary pivoted type of moving coil galvanometer. This galvanometer consists of a coil pivoted on jeweled bearings between the poles of a permanent magnet. The indicating needle is fastened to the coil. When electric current is passed through the coil, mechanical force acts and the pointer moves over the scale.

Functions

A multimeter can measure voltages, currents and resistances. To achieve this objective, proper circuits are incorporated with the galvanometer. The galvanometer in a multimeter is always of left zero type i.e. normally its needle rests in extreme left position as compared to centre zero position of ordinary galvanometers.

(i) Multimeter as voltmeter.

When a high resistance is connected in series with a galvanometer, it becomes a voltmeter. Fig. 5 (i) shows a high resistance R connected in series with the galvanometer of resistance G. If I_g is the full scale deflection current, then the galvanometer becomes a voltmeter of range 0 − V volts. The required value of series resistance R is given by:

$$V = I_g R + I_g G$$

$$\text{or } V/I_g = R + G$$

$$\text{or } R = V/I_g - G$$

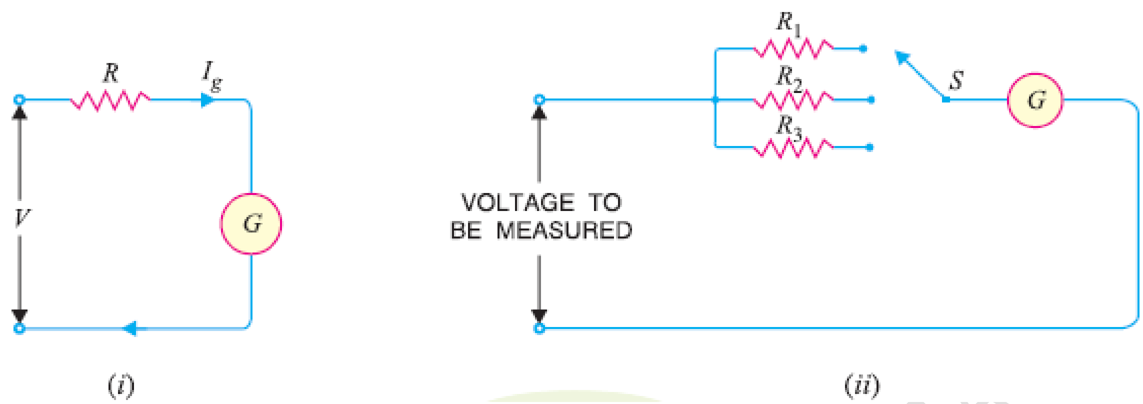


Fig. 5.(i)

For maximum accuracy, a multimeter is always provided with a number of voltage ranges. This is achieved by providing a number of high resistances in the multimeter as shown in Fig.5 (ii). Each resistance corresponds to one voltage range. With the help of selector switch S, we can put any resistance (R1, R2 and R3) in series with the galvanometer. When d.c. voltages are to be measured, the multimeter switch is turned on to d.c. position. This puts the circuit shown in Fig. 5 (ii) in action. By throwing the range selector switch S to a suitable position, the given d.c. voltage can be measured.

The multimeter can also measure a.c. voltages. To permit it to perform this function, a full-wave rectifier is used as shown in Fig. 6. The rectifier converts a.c. into d.c. for application to the galvanometer. The desired a.c. voltage range can be selected by the switch S. When a.c. voltage is to be measured, the multimeter switch is thrown to a.c. position. This puts the circuit shown in Fig. 6 in action. By throwing the range selector switch S to a suitable position, the given a.c. voltage can be measured. It may be mentioned here that a.c. voltage scale is calibrated in r.m.s. values. Therefore, the meter will give the r.m.s. value of the a.c. voltage under measurement.

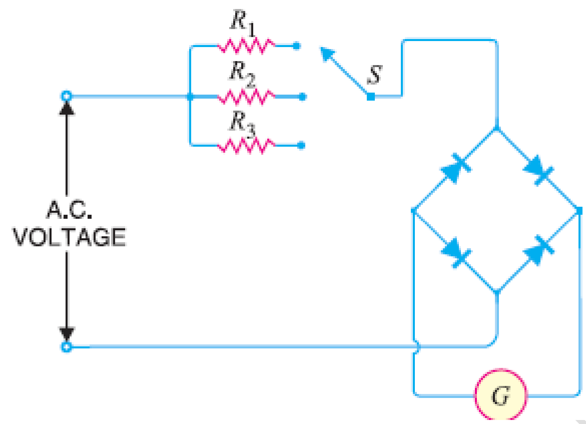


Figure 6. Multimeter Circuit for measuring A.C voltages

(ii) Multimeter as ammeter.

When low resistance is connected in parallel with a galvanometer, it becomes an ammeter. Fig. 7 (i) shows a low resistance S (generally called shunt) connected in parallel with the galvanometer of resistance G. If Ig is the full scale deflection current, then the galvanometer becomes an ammeter of range 0 − I amperes. The required value of shunt resistance S is given by :

$$I_s S = I_g G$$

$$\text{or } I_s/I_g = G/S \text{ or } (I_s/Ig)+1= (G/S)+1$$

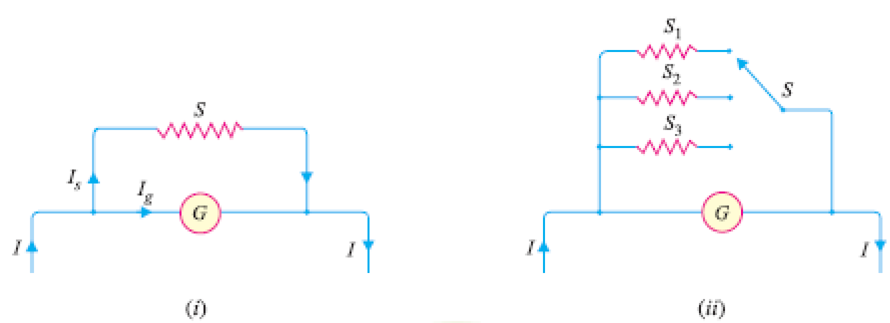


Figure 7 (i) For low resistance (ii) For High resistances

In practice, a number of low resistances are connected in parallel with the galvanometer to provide a number of current ranges as shown in Fig. 7 (ii). With the help of range selector switch S, any shunt can be put in parallel with the galvanometer. When d.c. current is to be measured, the multimeter switch is turned on to d.c. position. This puts the circuit shown in Fig. 7 (ii) in action.

By throwing the range selector switch S to a suitable position, the desired d.c. current can be measured.

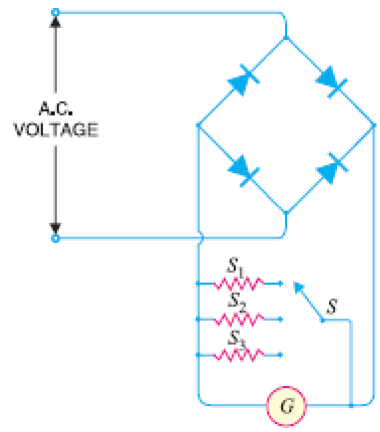


Figure 8. Measuring A.C

The multimeter can also be used to measure alternating current. For this purpose, a full – wave rectifier is used as shown in Fig. 22.4. The rectifier converts a.c. into d.c. for application to the galvanometer. The desired current range can be selected by switch S. By throwing the range selector switch S to a suitable position, the given a.c. current can be measured. Again, the a.c. current scale is calibrated in r.m.s. values so that the instrument will give r.m.s. value of alternating current under measurement.

Applications of Multimeter

It is used

(i) For checking the circuit continuity. When the multimeter is employed as continuity- checking device, the ohmmeter scale is utilised and the equipment to be checked is shut off or disconnected from the power mains.

(ii) For measuring d.c. current flowing through the cathode, plate, screen and other vacuum tube circuits.

(iii) For measuring d.c. voltages across various resistors in electronic circuits.

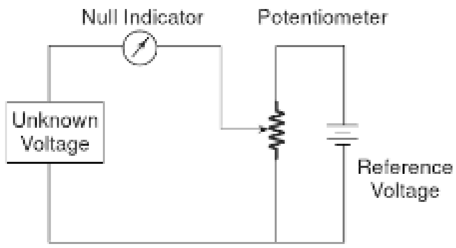
(iv) For measuring a.c. voltages across power supply transformers.

For ascertaining whether or not open or short circuit exists in the circuit under study.

TYPES OF VOLTMETER

DIFFERENTIAL VOLTMETER

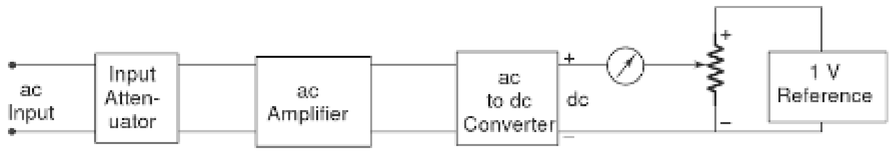
The differential voltmeter technique, is one of the most common and accurate methods of measuring unknown voltages. In this technique, the voltmeter is used to indicate the difference between known and unknown voltages, i.e. an unknown voltage is compared to a known voltage. The figure shows a basic circuit of a differential voltmeter based on the potentiometer method; hence it is also called as a potentiometric voltmeter.



In this method the potentiometer is varied until the voltage across it equals the unknown voltage, which is indicated by the null indicator reading zero. Under null conditions, the meter draws current from neither the reference source nor the unknown voltage source, and hence the differential voltmeter presents infinite impedance to the unknown source. To detect small differences the meter movement must be sensitive, but it need not be calibrated, since only zero has to be indicated. The reference source used is usually a 1 V dc standard source or a zener controlled precision supply. A high voltage reference supply is used for measuring high voltages.

The usual practice, however is to employ voltage dividers or attenuators across an unknown source to reduce the voltage. The input voltage divider has relatively low input impedance, especially for unknown voltages much higher than the reference standard. The attenuation will have a loading effect and the input resistance of voltmeter is not infinity when attenuator is used.

In order to measure ac voltages, the ac voltages must be converted into dc voltage by incorporating precision rectifier circuit as shown in figure



TRUE RMS VOLTMETER

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

AC waveform to be measured is applied to the heating element of the main thermocouple through an ac amplifier. Under absence of any input waveform, output of both thermo-couples are equal so error signal, which is input to dc amplifier, is zero and therefore indicating meter connected to the output of dc amplifier reads zero. But on the application of input waveform, output of main thermo-couple upsets the balance and an error signal is produced, which gets amplified by the dc amplifier and fedback to the heating element of the balancing thermo-couple. This feedback current reduces the value of error signal and ultimately makes it zero to obtain the balanced bridge condition. In this balanced condition, feedback current supplied by the dc amplifier to the heating element of the balance thermo-couple is equal to the ac current flowing in the heating element of main thermo-couple. Hence this direct current is directly proportional to the rms value of the input ac voltage and is indicated by the meter connected in the output of the dc amplifier. The PMMC meter may be calibrated to read the rms voltage directly.

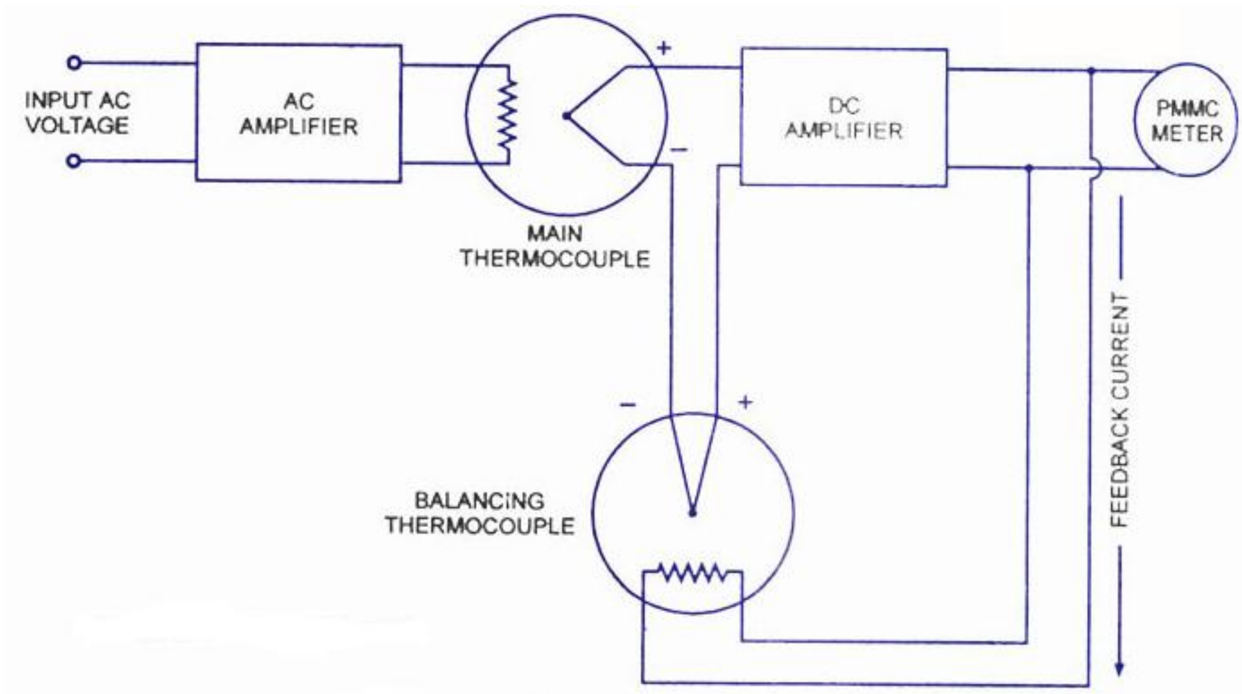
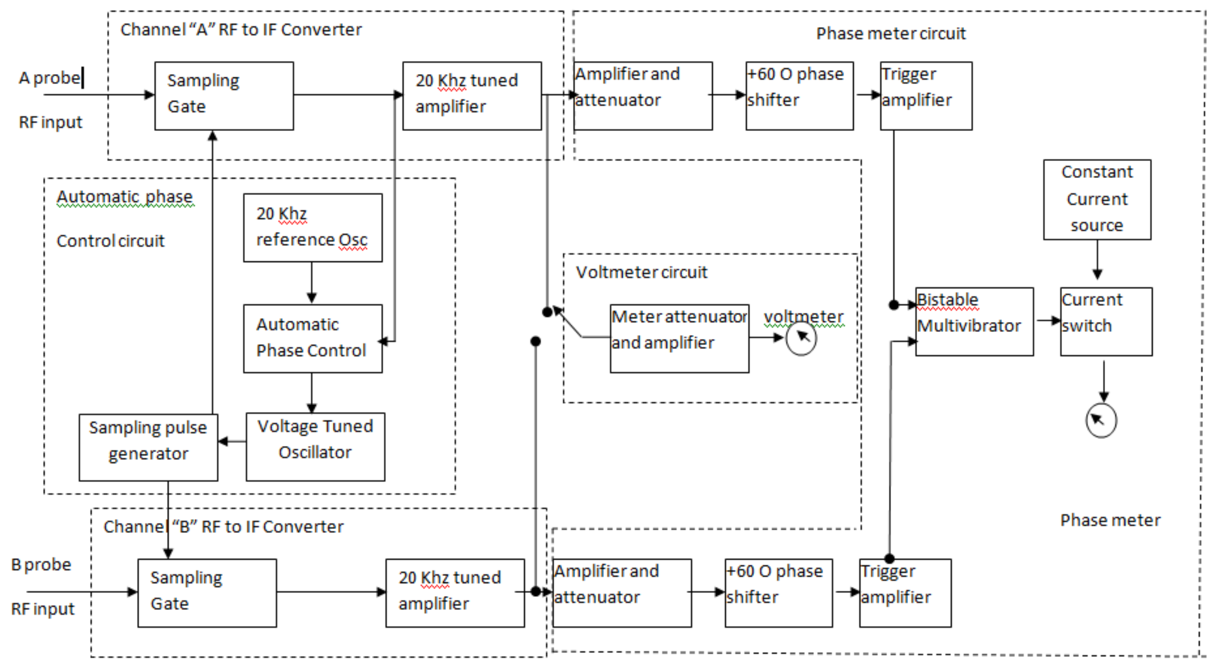


Figure 1. True RMS reading voltmeter

VECTOR VOLTMETER

The vector voltmeter is basically a new type of amplitude and phase measuring device. It uses two samplers to sample the two waves whose amplitude and relative phase are to be measures. It measures the voltages at two different points in the circuit and also measures the phase difference between these voltages at these two points. In this voltmeter, two RF signals of the same fundamental frequency (1MHz to GHz) are converted to two IF signals. The amplitudes, waveforms and the phase relations of IF signals are same as that of RF signals. Thus, the fundamental components of the IF signal have the same amplitude and phase relationships as the fundamental components RF signals. These fundamental components are filtered from the IF signals and are measured by a voltmeter and phase meter.



WAVE ANALYZER

A wave analyzer is an instrument designed to measure relative amplitudes of single frequency components in a complex waveform. It can analysis of waveforms includes the determination of amplitude, frequency and phase angle of the harmonic components.

Types of wave analyzer

1. Frequency selective wave analyzer.
2. Heterodyne wave analyzer.

Frequency selective wave analyzer

The waveform to be analyzed is passed through an adjustable attenuator. This acts as a range multiplier. The driver amplifier feeds the waveform to a high Q filter. This filter consists of cascade arrangement of RC resonant sections and filter amplifiers. The capacitors are used for range changing. The potentiometer is used to change frequency within the selected pass band. The entire AF range is covered in decade steps by the switching capacitors in the RC section The final amplifier stage supplies the selected signal to the meter circuit and to an untuned buffer amplifier. The function of buffer amplifier is to drive the output devices, such as the recorders, electronic counters etc. The analyzer input must have low input distortion. The meter has several voltage ranges as well as decibel scale marked on it. It is driven by an average reading rectifier type detector.

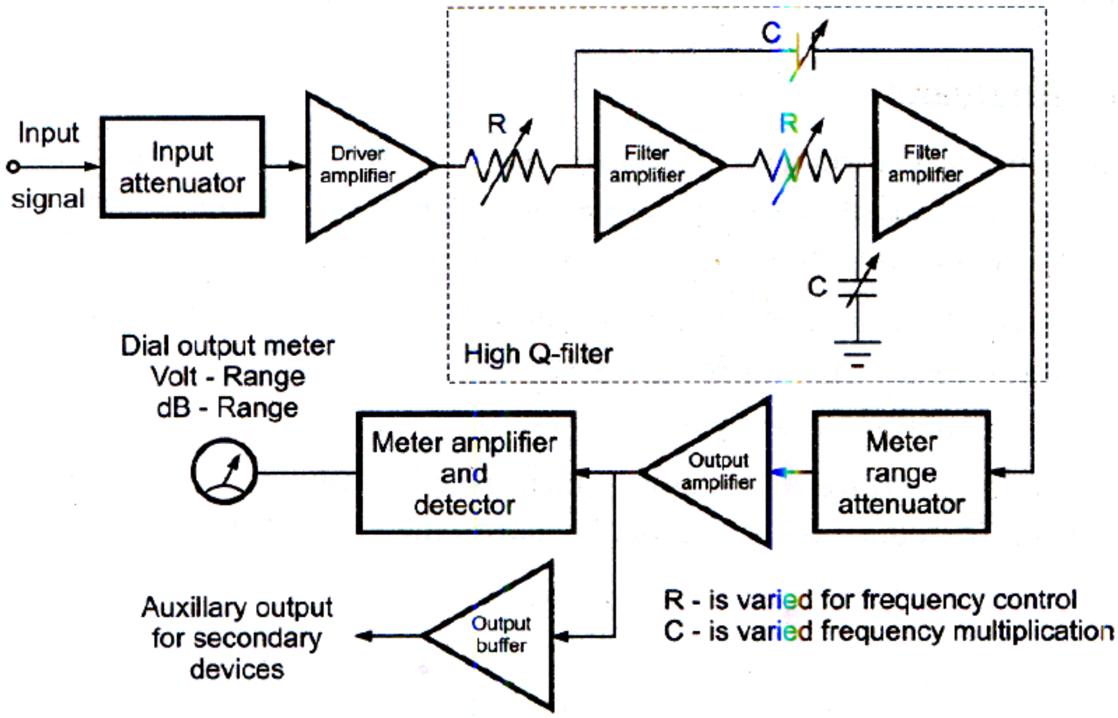


Figure 1. Frequency selective wave analyzer

Heterodyne wave analyzer

This is RF range analyzer works on the principle of mixing i.e. heterodyning. In this type of wave analyzer the input signal is heterodyned to a higher intermediate frequency (IF) by an internal local oscillator. Tuning the local oscillator shifts the various signal frequency components into the pass band of the IF amplifier. The output of the IF amplifier is then rectified and applied to the metering circuit. The input is applied first to the attenuator section. This gives the output frequency in the range of 0 to 18 MHz The untuned amplifier amplifies this signal and gives it to the first mixer. The first mixer heterodynes the input with the frequency from local oscillator. This oscillator has frequency range 30-48 MHz

The output of the first mixer difference frequency of 30 MHz.The IF amplifier amplifies this signal and gives it to the second mixer. The second mixer heterodynes the signal with 30 MHz frequency crystal oscillator. Thus at the output of second mixer the zero difference frequency is obtained. The active filter having controlled bandwidth and symmetrical slopes of 72 dB per octave, then passes the selected component to the meter amplifier and detector. The output from the meter detector is then used to obtain final indication on the output meter which is having a decibel calibrated scale. The output from detector may be applied to a recording device.

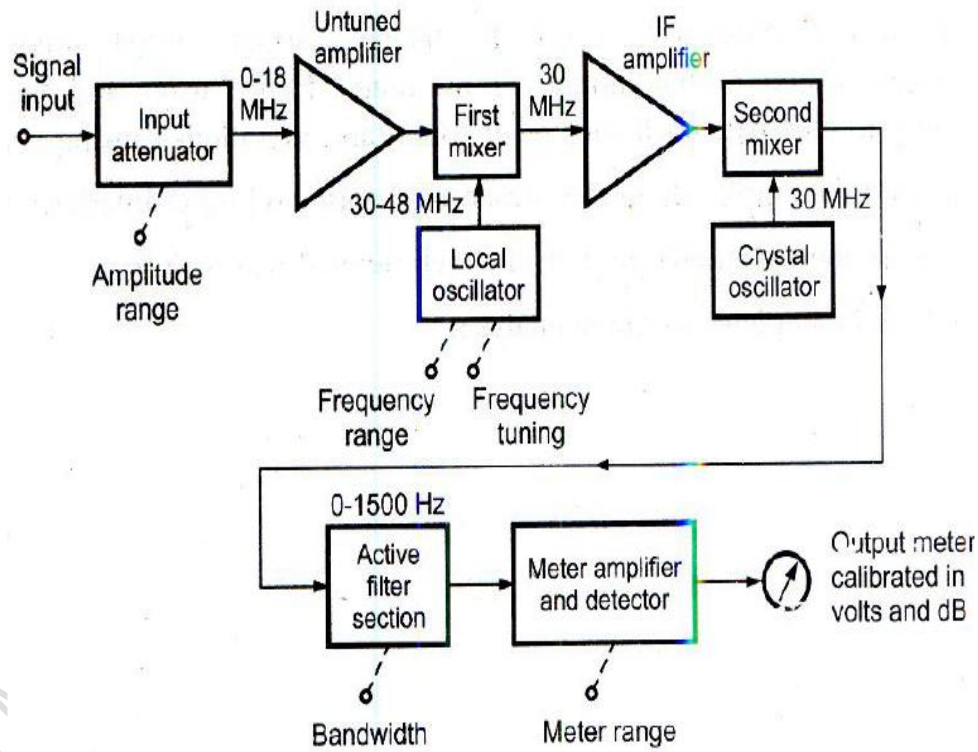


Figure 2. Heterodyne wave analyzer

Applications of wave analyzer

- To measure the harmonic distortion of an amplifier
- To carry out complete harmonic analysis
- To measure the signal energy with the well-defined bandwidth.

SPECTRUM ANALYZERS

Spectrum analysis is defined as the study of energy distribution across the frequency spectrum of a given electrical signal. The spectrum analysis is divided into two major categories on account of instrumentation limitations and capabilities.

They are:

- Audio frequency (AF) analysis, and
- Radio frequency (RF) spectrum analysis.

The RF spectrum analysis covers a frequency range of 10 MHz to 40 GHz, and hence is more important, because it includes the vast majority of communication, navigation, radar, and industrial instrumentation frequency bands. The spectrum analyzers are sophisticated instruments which are capable of portraying graphically the amplitude as a function of frequency in a portion of RF spectrum. These instruments find wide apphcat10ns for measurement of attenuation, FM dev1atton, and frequency in pulse studies

Basic Spectrum Analyzer

The basic spectrum analyzer is designed to represent graphically, a plot of amplitude versus frequency of a selected portion of the frequency spectrum under study. The modern spectrum analyzer basically consists of a narrow band super heterodyne receiver and a CRO. The receiver is electronically tuned by varying the frequency of the local oscillator. A simplified block diagram of a swept frequency spectrum analyzer is shown in Fig 3.

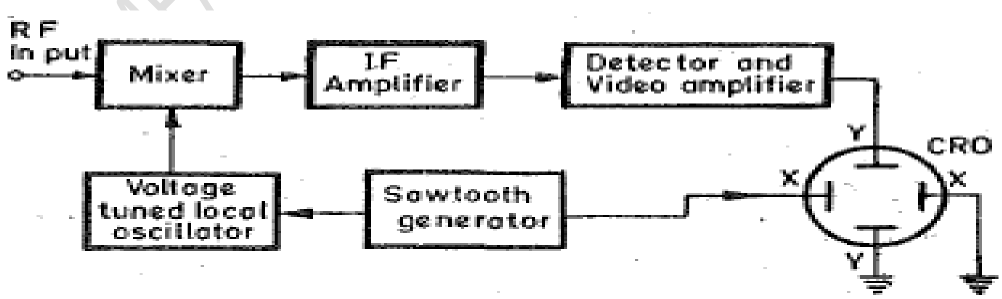


Fig 3. Basic Swept Receiver Spectrum Analyzer:

It consists of a sawtooth generator which supplies a ramp voltage to the frequency control element of the voltage tuned local oscillator. The local oscillator then sweeps through its frequency band at a recurring linear rate. The same sawtooth voltage is simultaneously applied to the horizontal plates of the CRO. The RF signal to be tested is applic4 to the input of the mixer stage.

The sawtooth generator makes the local ·oscillator sweep through it; frequency band to beat with the input signal to produce the desired intermediate frequency (IF). An IF component is produced only when the corresponding component is present in the RF input signal The resulting IF signals are amplified and then detected. After that they are applied to the vertical deflection plates of the CRO, thereby producing a display of amplitude versus frequency on the screen.

DISTORTION ANALYZERS

Generally, the output waveform of an electronic device, such as an amplifier, should become an exact replica of the input waveform. Distortions may be a result of the inherent non-linear characteristics of components used in the electronic circuit. Non-linear behavior of circuit elements introduces harmonics in the output waveform and the resultant distortion is often termed Harmonic Distortion (HD).

Types of Distortion

The various types of distortions which occur are explained below.

1. Frequency Distortion

This distortion occurs due to the amplification factor of the amplifier is different for different frequencies.

2. Phase distortion

This distortion occurs due to the presence of energy-storage elements in the system, which cause the output signal to be displaced in phase with the input signal. If signals of all frequencies are displaced by the same amount, the phase shift distortion would not be observed. However, in actual practice, signals at different frequencies are shifted in phase by different angles and therefore, the phase-shift distortion becomes noticeable.

3. Amplitude Distortion

Harmonic distortion occurs due to the fact that the amplifier generates harmonics of the fundamental of the input signal. Harmonics always give rise to amplitude distortion, for example, when an amplifier is overdriven and clips the input signals.

4. Inter-modulation Distortion

This type of distortion occurs as a consequence of interaction or heterodyning of two frequencies, giving an output which is the sum or difference of the two original frequencies.

5. Cross-over Distortion

This type of distortion occurs in push-pull amplifier due to incorrect bias levels.

6. Total Harmonic Distortion

A non-linear system produces harmonics of an input sine wave, the harmonics consists of a sine wave with frequencies which are multiples of the fundamental of the input signal. The Total Harmonic Distortion (THD) is measured in terms of the harmonic contents of the wave, as given by

$$THD = \frac{[\sum(Harmonics)^2]^{1/2}}{Fundamental} X100\%$$

In a measurement system, noise is read in addition to harmonics, and the total waveform, consisting of harmonics, noise and fundamental, is measured instead of the fundamental alone. Therefore, the measured value of the total harmonic distortion (THDm) is given by

$$THDm = \frac{[\sum(Harmonics)^2 + (Noise^2)]^{1/2}}{[\sum(Fundamental)^2 + (Noise^2)]^{1/2}}$$

Figure 4 shows the block diagram of a harmonic distortion analyser which is used to measure THD. The signal source has very low distortion and this can be checked by reading its output distortion by connecting directly into the analyser. The signal from the source is fed into the amplifier under test. This generates harmonics and the original fundamental frequency. The fundamental frequency is removed by a notch filter. In the manual system, as shown in Figure 4 (a), the switch S is first placed in the position 1 and the total content of fundamental and harmonics (E_T) is measured. Then the switch is moved to the position 2 to measure just the harmonics E_H. The value of THD is then found using following equation:

The meter can be calibrated by putting the switch in the position 1 and adjusting the reading for full scale deflection. With the switch position 2, the meter reading is now proportional to THD. Figure 4(b) shows an alternative arrangement, where the value of ET and EH are read simultaneously and their ratio calculated and displayed as THD on the indicator. For good accuracy, the notch filter must have excellent rejection and high pass characteristics. It should attenuate the fundamental by 100 db or more and the harmonics by less than 1 db. The filter also needs to be tuned accurately to the fundamental of the signal source. This is difficult to achieve manually and most distortion analysers do this automatically. A common form of notch filter is a Wien bridge. This balances at one frequency only and at this frequency, the output voltage at the bridge null detector is minimum.

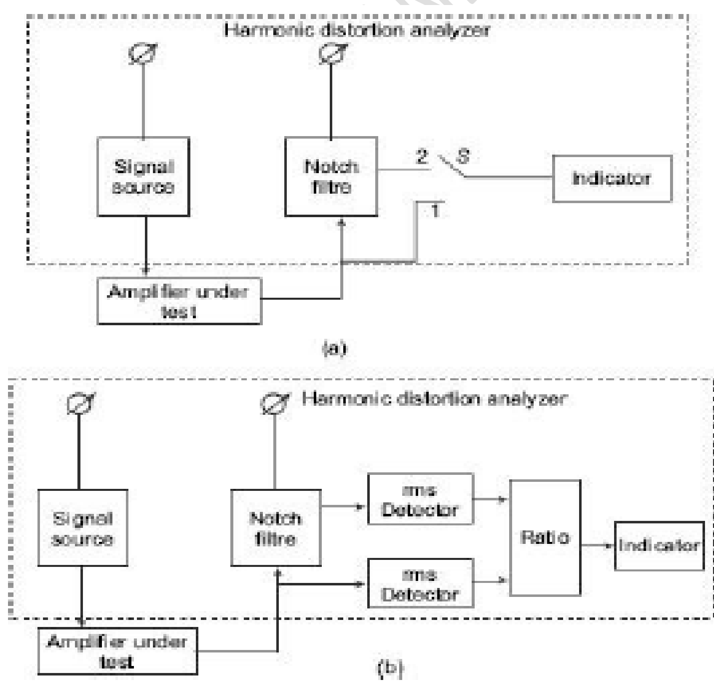


Figure. 4 Simplified block diagrams of fundamental suppression harmonic distortion analysers: (a) Manual reading (b) Ratio reading

$$THD = \frac{Eh}{Et} X100\%$$