ELECTRONICS INSTRUMENTATION AND MEASUREMENT

By Anju

MEASUREMENT

- The measurement is the result of the comparison of standard and the unknown quantity. The result of the measured quantity is generally expressed in numeric forms. In other words, the measurement is the process through which the physical parameters like heat, displacement, force etc. is converted into the easily readable numeric value.

METHOD OF MEASUREMENT

1. **Direct Method:**
   - This is the simplest method of measurement in which the value of the quantity to be measured is obtained directly without any calculations, e.g. measurements by scale, calipers & micrometers.
   - It involves contact or non contact type of inspections.
2. **Indirect Method:**
   - The value of the quantity to be measured is obtained by measuring other quantities, which are related to required value.
   - E.g. density calculation by measuring mass & volume.
3. **Absolute Method:**
   - Also called fundamental method & is based on the measurement of the base quantities used to define a particular quantity.

TYPES OF INSTRUMENTS

Absolute / Primary Instruments

These are the **instruments** which give the value of the quantity measured according to the constants of the **instrument** and its deflection. **Primary instruments** are mostly used in standard laboratories and as a standardizing in various institutions and research organizations. The example of **absolute instruments** are Rayleigh current balance, absolute electrometer and **tangent galvanometer**. Tangent Galvanometer gives the value of the current according to the tangent of deflection angle Θ, the earth's magnetic field and the radius and the number of turns of the wire used in it. These instruments do not require comparison with other standards.

SECONDARY INSTRUMENTS

- **Secondary instruments** are the **instruments** in which the value of the **electrical quantity** is measured and is determined from the **deflection of the instruments**. These instruments provide the **magnitude** of the electrical quantity which is to be measured. These instruments are already calibrated as compared to **absolute instruments**.

SPECIFICATIONS OF INSTRUMENTS

- **Accuracy** can be defined as the amount of uncertainty in a measurement with respect to an absolute standard. Accuracy specifications usually contain the effect of errors due to gain and offset parameters.
- **Precision** describes the reproducibility of the measurement. For example, measure a steady state signal many times. In this case if the values are close together then it has a high degree of precision or repeatability.

Cont.

- **Sensitivity** is an absolute quantity, the smallest absolute amount of change that can be detected by a measurement.
- **Resolution** is the ratio between the maximum signal measured to the smallest part that can be resolved - usually with an analog-to-digital (A/D) converter.
- It is the degree to which a change can be theoretically detected, usually expressed as a number of bits.

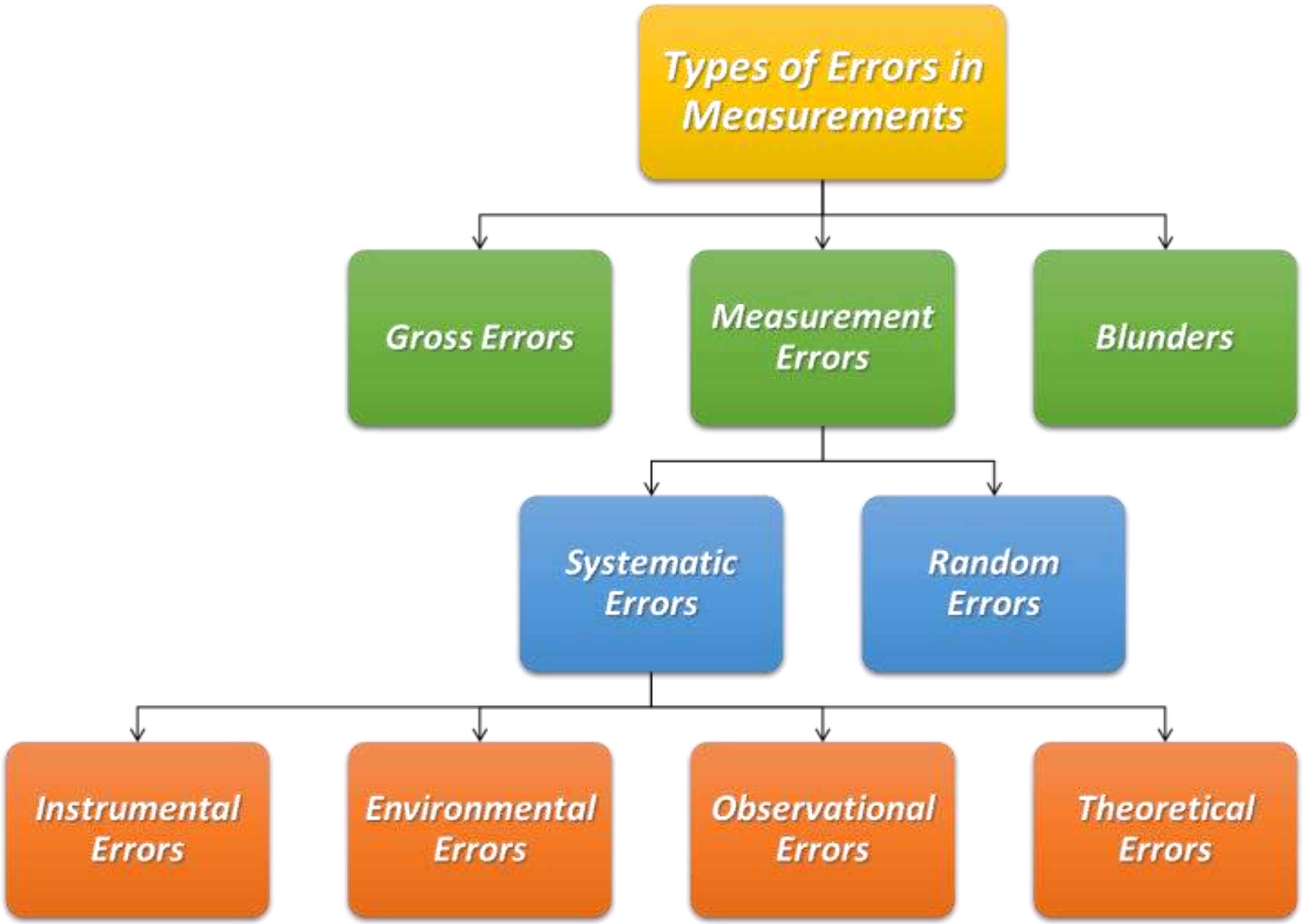
Cont.

- **Range**
- The range or span of an instrument defines the minimum and maximum values of a quantity that the instrument is designed to measure.

ERRORS IN MEASUREMENT

- Measurement Error (also called Observational Error) is the difference between a measured quantity and its true value. It includes random error (naturally occurring errors that are to be expected with any experiment) and systematic error (caused by a mis-calibrated instrument that affects all measurements).
- Error = Measured Value – True Value
- **Types of Errors:**
- Gross Errors
- Systematic Errors
- Random Errors

TYPES OF ERRORS IN MEASUREMENT



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- **Absolute Error:** the amount of error in your measurement. For example, if you step on a scale and it says 150 pounds but you know your true weight is 145 pounds, then the scale has an absolute error of 150 lbs – 145 lbs = 5 lbs.
- **Greatest Possible Error:** defined as one half of the measuring unit. For example, if you use a ruler that measures in whole yards (i.e. without any fractions), then the greatest possible error is one half yard.
- **Instrument Error:** error caused by an inaccurate instrument (like a scale that is off or a poorly worded questionnaire).

Cont.

- **Margin of Error:** an amount above and below your measurement. For example, you might say that the average baby weighs 8 pounds with a margin of error of 2 pounds (± 2 lbs).
- **Measurement Location Error**: caused by an instrument being placed somewhere it shouldn't, like a thermometer left out in the full sun.
- **Operator Error**: human factors that cause error, like reading a scale incorrectly.
- **Percent Error:** another way of expressing measurement error. Defined as:

$$\text{Percent Error} = \frac{(\text{measured value - actual value})}{\text{actual value}}$$

- **Relative Error:** the ratio of the absolute error to the accepted measurement.
- As a formula, that's:

$$E_{\text{relative}} = \frac{E_{\text{absolute}}}{E_{\text{measured}}}$$

SOURCES OF ERROR

While dealing with any kind of measurements, it is important to identify the possible sources of error. It helps to maintain the accuracy of physical measurement in both fields and labs. There are mainly three possible sources of errors.

Instrumental

The imperfection or faulty adjustment of the measurement instrument may cause errors. Such errors, produced from the equipment, is known as instrumental error. Example: a long or short tape, an angle measurement instrument without proper adjustment.

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Personal

Error may also arise due to imperfection of human sight in observation and of touch in manipulating instruments. These man made errors are known as personal error. Example: Taking wrong level reading, taking wrong reading of an angle of circle of a theodolite.

Natural

Variation of natural phenomena is also a possible source of error. Variation of temperature, humidity, gravity, wind, refraction, magnetic declination etc. are most common natural phenomena which may cause measurement errors. If they are not properly observed while taking measurements, the results will be incorrect. Example: Length error of tape or chain due to temperature change.

LIMITING ERRORS

- Limiting Error is defined as the maximum deviation either in positive side or negative side in the measurement by an instrument from the nominal value or true value. Let us assume that the true value or nominal value of a quantity is A_s and the measured value by the instrument is A_a, then Limiting Error $\delta A = (Aa – As)$.
  The measured value may be greater than true value As or less than As. Thus δA will be either positive or negative. This is why Limiting Error is specified as $\pm \delta A$. This error is also known as Guarantee Error as the error in measurement is guaranteed to be within specified limits.

LOADING EFFECTS

The output of a sensor device may deviate from the correct value due to loading effect.

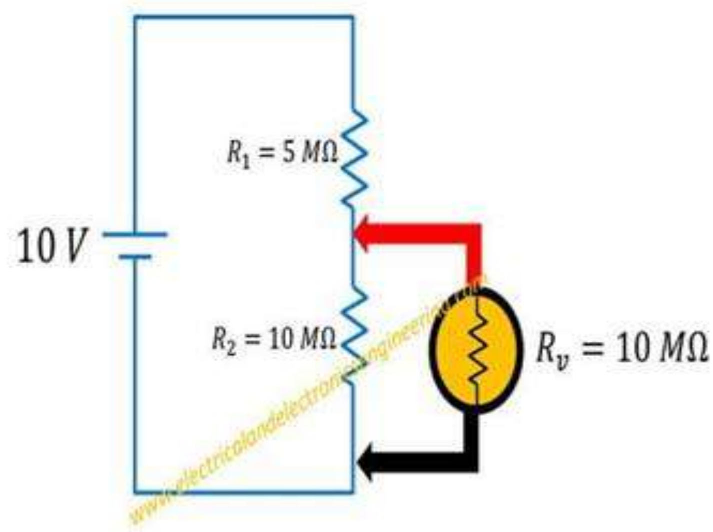
We can categorize two types of loading effect:

- Inter element loading A given element in the system may modify the characteristics of the previous element.
- Process loading The introduction of the sensing element into the process or system being measured causes the value of the measured variable to change.

LOADING EFFECT IN VOLTMETER

Loading effects of voltmeter

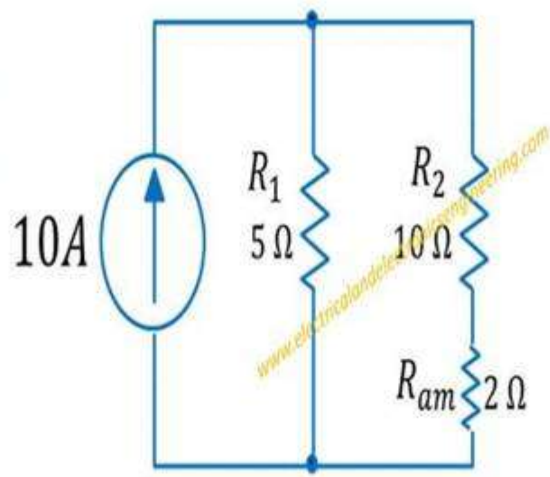
Loading effect of the voltmeter is the difference between actual voltage that exists in the circuit without connecting the voltmeter and the voltage that appears after connecting voltmeter.



LOADING EFFECT IN AMMETER

Loading effects of ammeter

The extent by which an ammeter connected to a branch of circuits effects the actual reading of current is known as loading effect of that ammeter



CALIBRATION

Calibration is **important** because it helps ensure accurate measurements, and accurate measurements are foundational to the quality, safety and innovation of most products and services we use and rely on every day. Few people realize the
critical **role** and **importance** of **calibration** in their daily lives.

- The main reasons for calibration are to ensure the reliability of the instrument, that it can be trusted. To determine the accuracy of the instrument and to ensure the readings are consistent with other measurements.

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- Considering the costs arising from legal action for damages that might be filed against you, the expenses for proper calibration and adjustment are minor in comparison. Companies who take their responsibility seriously and wish to establish long-term business relationships therefore need to calibrate their equipment regularly. It could also void your warranty if your instrument is not calibrated.

No quantitative data – no quality assurance

Calibration and adjustment

One-point or multiple-point calibration

Five-point calibration as manufacturer standard

STANDARDS OF MEASUREMENT

- The international prototype meter and the international yard are considered to be perfect or master standards. These cannot be used for general purposes. For practical and shop floor measurements, there is need of working standards. For Example, micrometers, rules etc. are required for measurement in workshop.

STANDARDS OF MEASUREMENT

Thus depending upon the degree of accuracy required for the work, the standards are subdivided into following four categories or grades:

1. Primary Standards (Master Standards):

The primary standard is also known as Master Standard, and is preserved under the most careful conditions. These standards are not commonly in use. They are used only after long internals. They solely used for comparing the secondary standards. Sometimes it is also called Reference Standards.

2. Secondary Standards (Calibration Standards):

The secondary standard is more or less similar to the primary standard. They are nearly close in accuracy with primary standards. The secondary standard is compared at regular intervals with primary Stands and records their deviation. These Standards are distributed to a number of places where they are kept under safe custody. They are used occasionally for comparing the territory standards.

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3. Tertiary Standards (Inspection Standards):

The Tertiary standard is the first standard to be used for reference purpose in workshops and laboratories. They are used for comparing the working standards. These are not used as frequently and commonly as the working standards but more frequency than secondary standards. Tertiary standards should also be maintained as a reference for comparison at intervals for working standards.

4. Working Standards (Workshop Measuring Standards):

The working standard is used for actual measurement in workshop or laboratories by the workers. These standards should also be as accurate as possible to the tertiary standard. But sometimes, lower grades of materials can be used for their manufacturing to reduce cost.

PERMANENT MAGNET MOVING COIL INSTRUMENT

Permanent Magnet Moving Coil: Principle of Working

When a current carrying conductor is placed in a magnetic field, it experiences a force and tends to move in the direction as per Fleming’s left-hand rule.

Fleming left-hand rule:

If the first and the second finger and the thumb of the left hand are held so that they are at right angle to each other, then the thumb shows the direction of the force on the conductor, the first finger points towards the direction of the magnetic field and the second finger shows the direction of the current in the wire.

Equation involved

The interaction between the induced field and the field produced by the permanent magnet causes a deflecting torque, which results in the rotation.

The three important torque involved in this instrument are:

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Deflecting torque:

The force F which will be perpendicular to both the direction of the current flow and the direction of magnetic field as per Fleming's left hand rule can be written as

F = NBIL

where N: turns of wire on the coil

B: flux density in the air gap

I: current in the movable coil

L: vertical length of the coil

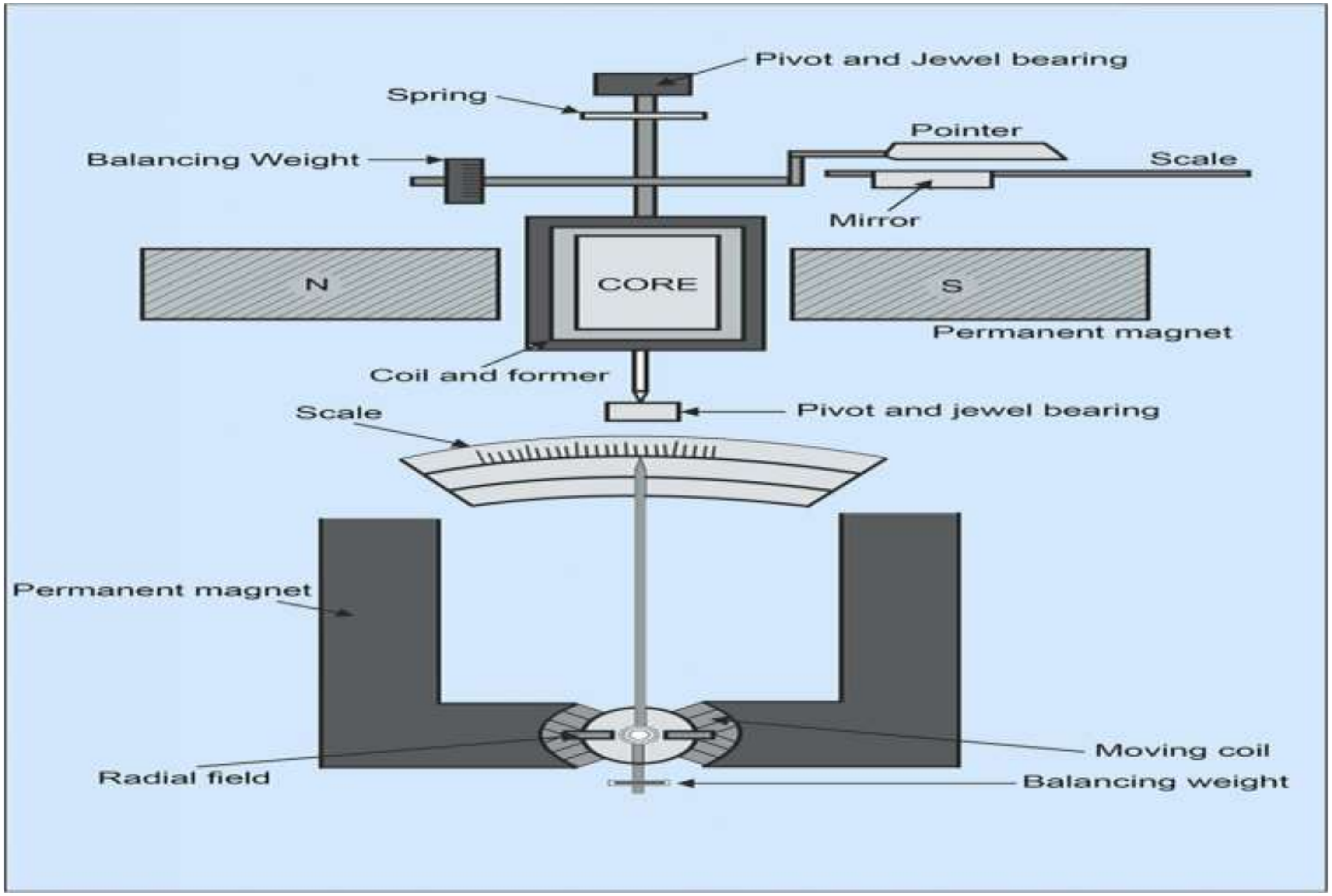
Theoretically, the torque (here electro-magnetical torque) is equal to the multiplication of force with distance to the point of suspension.

Hence Torque on left side of the cylinder T_L = NBIL x W/2 and torque on right side of the cylinder T_R = NBIL x W/2

Therefore the total torque will be = $T_L + T_R$

T = NBILW or NBIA where A is effective area (A= LxW)

PMMC DIAGRAM



CONTROLLING TORQUE

- This torque is produced by the spring action and opposes the deflection torque so as the pointer can come to rest at the point where these two torques are equal (Electromagnetic torque = control spring torque). The value of control torque depends on the mechanical design of spiral springs and strip suspensions.
  The controlling torque is directly proportional to the angle of deflection of the coil.
  Control torque $C_t = C\theta$ where, θ = deflection angle in radians and C = spring constant Nm /rad .

DAMPING TORQUE

This torque ensures the pointer comes to an equilibrium position i.e. at rest in the scale without oscillating to give an accurate reading. In PMMC as the coil moves in the magnetic field, eddy current sets up in a metal former or core on which the coil is wound or in the circuit of the coil itself which opposes the motion of the coil resulting in the slow swing of a pointer and then come to rest quickly with very little oscillation.

CONSTRUCTION

- A coil of thin wire is mounted on an aluminum frame (spindle) positioned between the poles of a U shaped permanent magnet which is made up of magnetic alloys like alnico.
  The coil is pivoted on the jeweled bearing and thus the coil is free to rotate. The current is fed to the coil through spiral springs which are two in numbers. The coil which carries a current, which is to be measured, moves in a strong magnetic field produced by a permanent magnet and a pointer is attached to the spindle which shows the measured value.

WORKING

When a current flow through the coil, it generates a magnetic field which is proportional to the current in case of an ammeter. The deflecting torque is produced by the electromagnetic action of the current in the coil and the magnetic field.

When the torques are balanced the moving coil will stop and its angular deflection represents the amount of electrical current to be measured against a fixed reference, called a scale. If the permanent magnet field is uniform and the spring linear, then the pointer deflection is also linear.

The controlling torque is provided by two phosphorous bronze flat coiled helical springs. These springs serve as a flexible connection to the coil conductors.

Damping is caused by the eddy current set up in the aluminum coil which prevents the oscillation of the coil.

APPLICATIONS

- The PMMC has a variety of uses onboard ship. It can be used as:
- 1) **Ammeter**:
- When PMMC is used as an ammeter, except for a very small current range, the moving coil is connected across a suitable low resistance shunt, so that only small part of the main current flows through the coil.
- The shunt consists of a number of thin plates made up of alloy metal, which is usually magnetic and has a low-temperature coefficient of resistance, fixed between two massive blocks of copper. A resistor of the same alloy is also placed in series with the coil to reduce errors due to temperature variation.
- 2) **Voltmeter**:
- When PMMC is used as a voltmeter, the coil is connected in series with a high resistance. Rest of the function is same as above. The same moving coil can be used as an ammeter or voltmeter with an interchange of above arrangement

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- 3) **Galvanometer**:
- The galvanometer is used to measure a small value of current along with its direction and strength. It is mainly used onboard to detect and compare different circuits in a system.
- 4) **Ohm Meter**:
- The ohm meter is used to measure the resistance of the electric circuit by applying a voltage to a resistance with the help of battery. A galvanometer is used to determine the flow of current through the resistance. The galvanometer scale is marked in ohms and as the resistance varies since the voltage is fixed, the current through the meter will also vary.

ADVANTAGES

- The PMMC consumes less power and has great accuracy.
- It has a uniformly divided scale and can cover an arc of 270 degrees.
- The PMMC has a high torque to weight ratio.
- It can be modified as ammeter or voltmeter with suitable resistance.
- It has efficient damping characteristics and is not affected by stray magnetic field.
- It produces no losses due to hysteresis.

DISADVANTAGE

- The moving coil instrument can only be used on D.C supply as the reversal of current produces a reversal of torque on the coil.
- It’s very delicate and sometimes uses AC circuit with a rectifier.
- It’s costly as compared to moving coil iron instruments.
- It may show an error due to loss of magnetism of permanent magnet.

MOVING-IRON INSTRUMENTS

- Moving-iron instruments are generally used to measure alternating voltages and currents. In moving-iron instruments the movable system consists of one or more pieces of specially-shaped soft iron, which are so pivoted as to be acted upon by the magnetic field produced by the current in coil.

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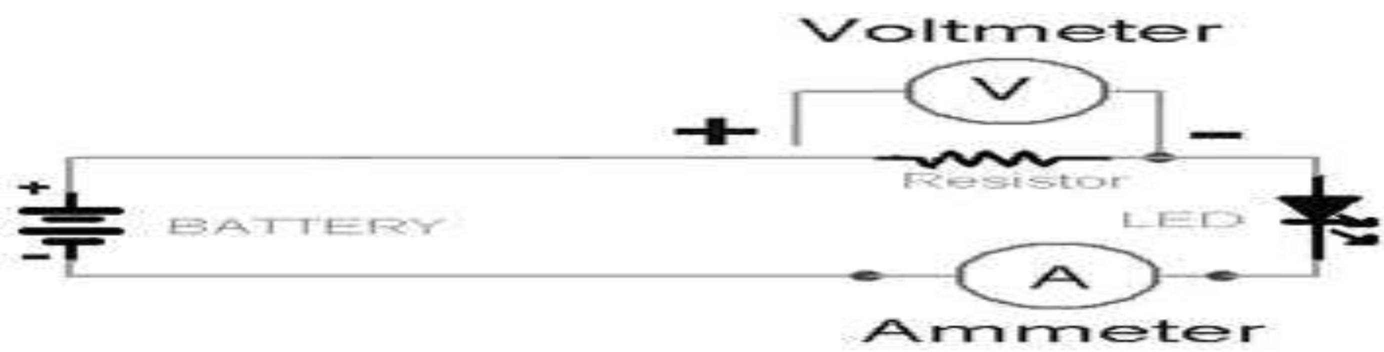
- **There are two general types of moving-iron instruments namely:**
- **Repulsion** (or double iron) type
- **Attraction** (or single-iron) type
- The brief description of different components of a moving-iron instrument is given below:
- **Moving element:** a small piece of soft iron in the form of a vane or rod.
- **Coil:** to produce the magnetic field due to current flowing through it and also to magnetize the iron pieces.
- **In repulsion type**, a **fixed** vane or rod is also used and magnetized with the same polarity.
- **Control torque** is provided by spring or weight (gravity).
- **Damping torque** is normally pneumatic, the damping device consisting of an air chamber and a moving vane attached to the instrument spindle.
- **Deflecting torque** produces a movement on an aluminum pointer over a graduated scale.

HOW IT WORKS?

- The deflecting torque in any moving-iron instrument is due to forces on a small piece of magnetically ‘soft’ iron that is magnetized by a coil carrying the **operating current**. In repulsion type moving–iron instrument consists of two cylindrical soft iron vanes mounted within a fixed current-carrying coil.



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- One iron vane is held fixed to the coil frame and other is free to rotate, carrying with it the pointer shaft. Two irons lie in the magnetic field produced by the coil that consists of only few turns if the instrument is an ammeter or of many turns if the instrument is a voltmeter.
- Current in the coil induces both vanes to become magnetized and repulsion between the similarly magnetized vanes produces a proportional rotation. Moving iron instruments having scales that are nonlinear and somewhat crowded in the lower range of calibration.

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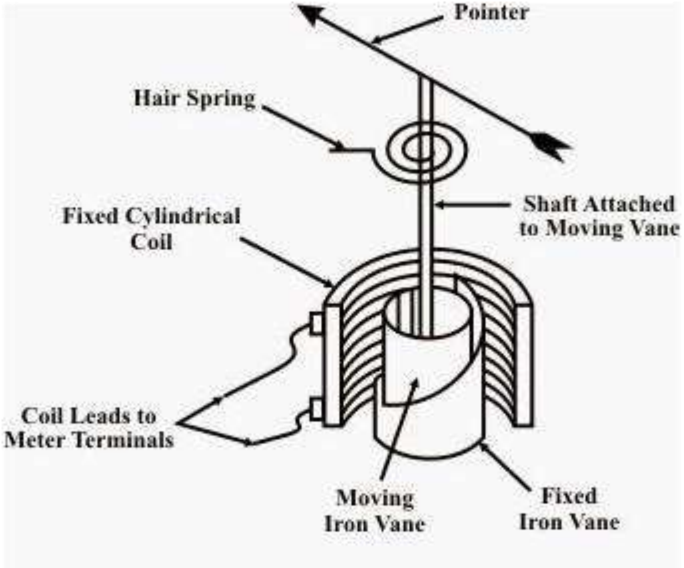
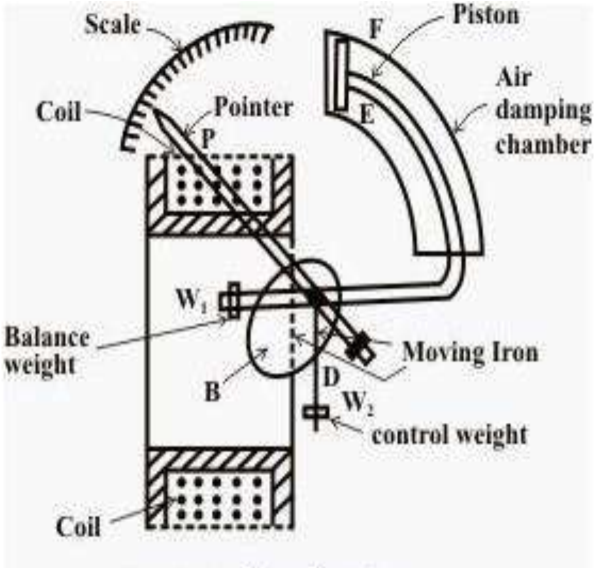


Repulsion type.



Attraction type

MEASUREMENT OF ELECTRIC VOLTAGE AND CURRENT

- Moving iron instruments are used as Voltmeter and Ammeter only.
- Both can work on AC as well as on DC.
- **Ammeter**
- Instrument used to measure current in the circuit.
- Always connected in series with the circuit and carries the current to be measured.
- This current flowing through the coil produces the desired deflecting torque.
- It should have low resistance as it is to be connected in series.
- **Voltmeter**
- Instrument used to measure voltage between two points in a circuit.
- Always connected in parallel.
- Current flowing through the operating coil of the meter produces deflecting torque.
- It should have high resistance. Thus a high resistance of order of kilo ohms is connected in series with the coil of the instrument.

RANGES OF AMMETER AND VOLTMETER

- For a given moving-iron instrument the ampere-turns necessary to produce full-scale deflection are constant.
- One can alter the range of ammeters by providing a shunt coil with the moving coil.
- Voltmeter range may be altered connecting a resistance in series with the coil. Hence the same coil winding specification may be employed for a number of ranges.

ADVANTAGES

- The instruments are suitable for use in AC and DC circuits.
- The instruments are robust, owing to the simple construction of the moving parts.
- The stationary parts of the instruments are also simple.
- Instrument is low cost compared to moving coil instrument.
- Torque/weight ratio is high, thus less frictional error.

ERRORS

- Error due to variation in temperature.
- Error due to friction is quite small as torque-weight ratio is high in moving coil instruments.
- Stray fields cause relatively low values of magnetizing force produced by the coil. Efficient magnetic screening is essential to reduce this effect.
- Error due to variation of frequency causes change of reactance of the coil and also changes the eddy currents induced in neighbouring metal.
- Deflecting torque is not exactly proportional to the square of the current due to non-linear characteristics of iron material.

CATHODE RAY OSCILLOSCOPE

A **Cathode Ray Oscilloscope** (CRO) is an instrument generally used in a laboratory to display, measure and analyze various waveforms of electrical circuits. A cathode ray oscilloscope is a very fast X-Y plotter that can display an input signal versus time or another signal.

Cathode ray oscilloscopes use luminous spots which are produced by striking the beam of electrons and this luminous spot moves in response variation in the input quantity. At this moment one question must be arise in our mind that why we are using only an electron beam? The reason behind this is low effects of beam of electrons that can be used for following the changes in the instantaneous values of rapidly changing input quantity. The general forms of cathode ray oscilloscope operate on voltages. So the input quantity that we have talked above is voltage. Nowadays, with the help of transducers it is possible to convert various physical quantities like current, pressure, acceleration etc to voltage thus it enable us to have a visual representations of these various quantities on **cathode ray oscilloscope**. Now let us look at the constructional details of the cathode ray oscilloscope.

CONSTRUCTION AND WORKING OF CATHODE RAY TUBE(CRT)

- The main part of cathode ray oscilloscope is cathode ray tube which is also known as the heart of cathode ray oscilloscope.
  Let us discuss the construction of cathode ray tube in order to understand the **construction of cathode ray oscilloscope**. Basically the cathode ray tube consists of **Five main parts:**
  - Electron gun
  - Deflection plate system
  - Fluorescent screen
  - Glass envelope
  - Base

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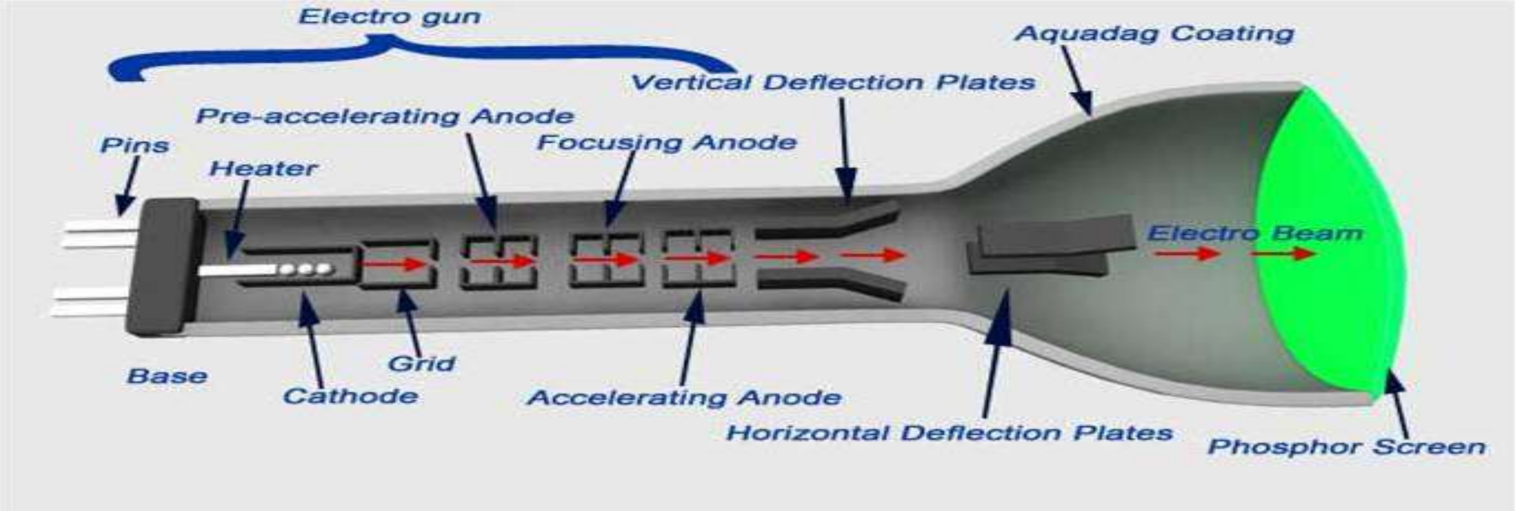

Internal Structure of CRT

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- **Electron Gun**:
  It is the source of accelerated, energized and focused beam of electrons. It consists of six parts namely heater, a cathode, a grid, a pre-accelerating anode, a focusing anode and an accelerating anode. In order to obtain the high emission of electrons the layer of barium oxide (which is deposited on the end of cathode) is indirectly heated at moderate temperature. The electrons after this passes through a small hole called control grid which is made up of nickel. As the name suggests the control grid with its negative bias, controls the number of electrons or indirectly we can say the intensity of emitted electrons from cathode. After passing through the control grid these electrons are accelerated with the help of pre-accelerating and accelerating anodes. The pre-accelerating and accelerating anodes are connected to a common positive potential of 1500 volts. Now after this the function of the focusing anode is to focus the beam of the electrons so produced. The focusing anode is connected to adjustable voltage 500 volts. Now there are two methods of focusing the electron beam and are written below:

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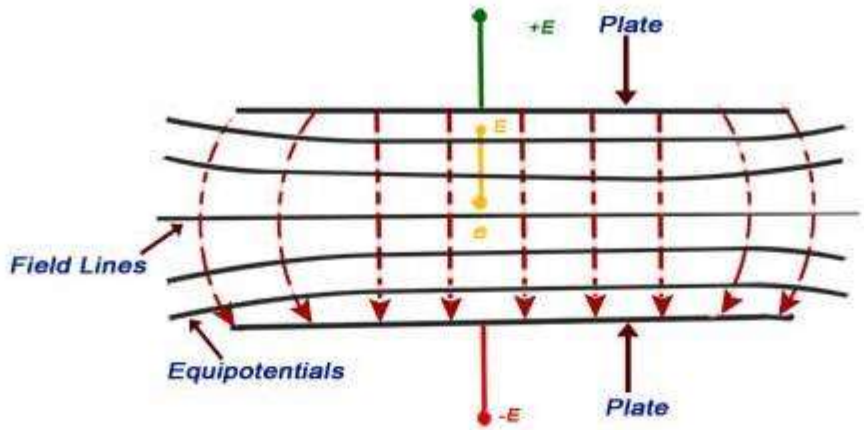
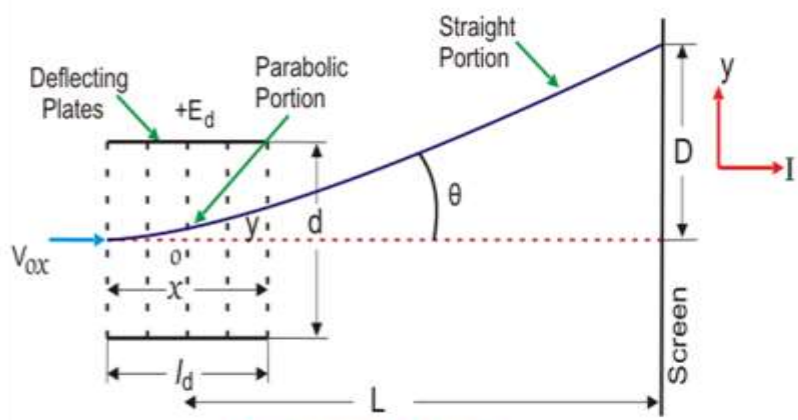


Electric field between parallel Plates



Electrostatic Deflection

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- **Fluorescent Screen in CRT**
- Fluorescence is the property of some crystalline materials like phosphor or zinc oxide to emit light when stimulated by light radiation.
- Phosphorescence is the property of fluorescent materials to continue light emission even after the source that exited is withdrawn.
- Persistence of the phosphor is the time duration for which the after glow or phosphorescence occurs. The screen of the cathode ray tube is coated with material called phosphor that will emit light when bombarded by electrons. There are many possible phosphors that differ in colour, persistence, efficiency etc. One of the commonest is willemite. This is a composition of zinc orthosilicate, $ZnO + SiO_2$, with traces of manganese as an "activator". This produces the greenish trace of small general purpose cathode ray tubes. Compounds of zinc, cadmium, magnesium, and silicon are the other useful materials for the screens. Presence of metals like silver, manganese, copper and chromium in proportions as small as 1 part in 105 will increase the light output of the screen by a factor 10 to 100 and will also affect the colour. When used these materials are called activators.

Cont.

- **Glass Envelope**
- The inner wall of CRT between the neck and **screen** are usually coated with a conducting material known as aquadag. This coating is electrically connected to the accelerating anode so that the electrons which accidentally strike the walls are returned to the anode.

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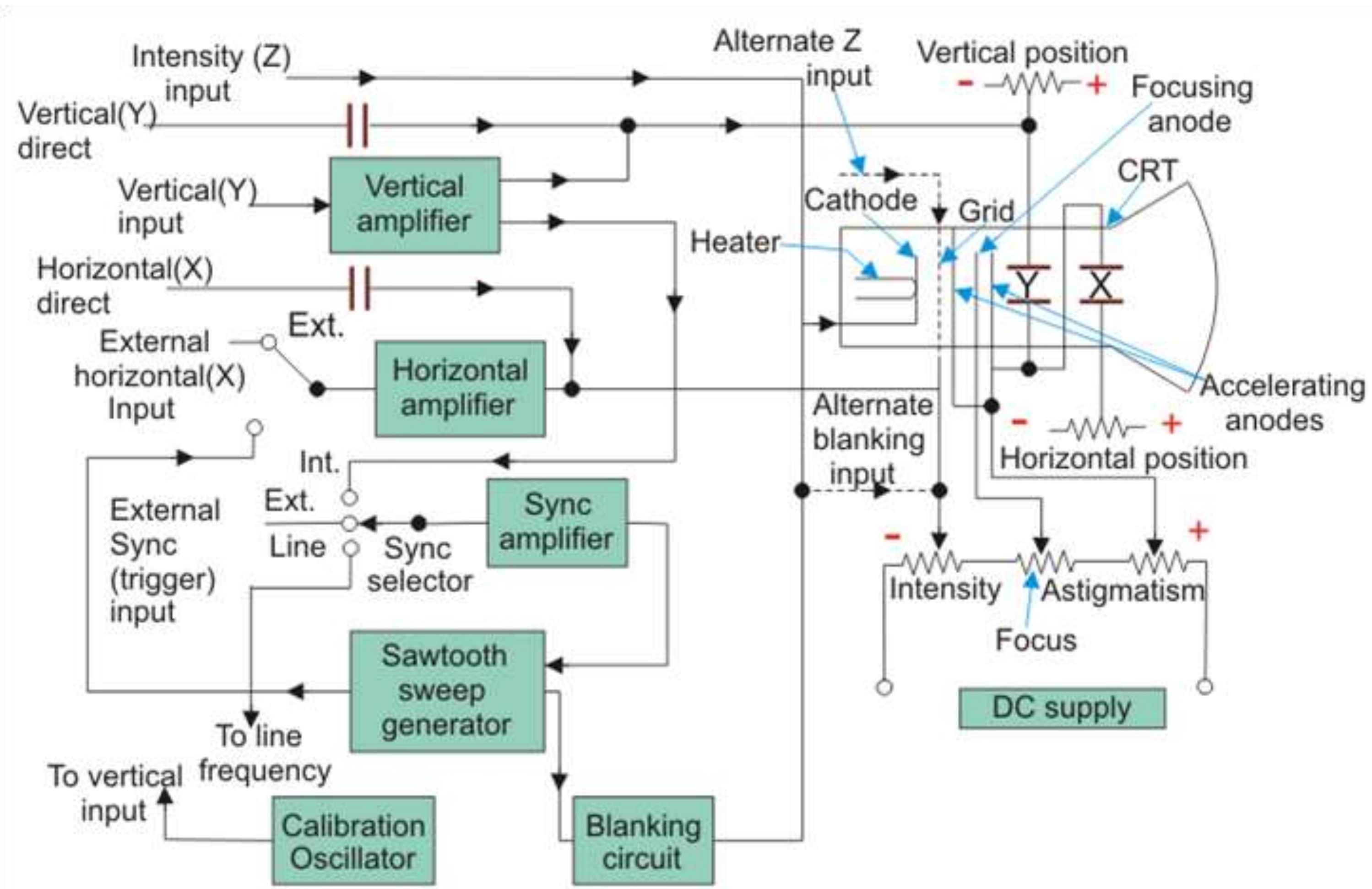


Intensity (Z) input
Vertical(Y) direct
Vertical(Y) input
Vertical amplifier
Horizontal(X) direct
Ext.
External horizontal(X) Input
Horizontal amplifier
Int.
Ext.
Line
External Sync (trigger) input
Sync selector
Sync amplifier
Sawtooth sweep generator
To line frequency
To vertical input
Calibration Oscillator
Blanking circuit
Alternate Z input
Vertical position
Focusing anode
CRT
Cathode
Grid
Heater
Y
X
Accelerating anodes
Alternate blanking input
Horizontal position
Intensity
Astigmatism
Focus
DC supply

Cont.

- Now we will study the basic circuit diagram of **cathode ray oscilloscope** under the following main parts.
- **Vertical Deflection System:**
  The input signal for examining are fed to the vertical deflection system plates with the help of input attenuator and a number of amplifier stages. The main function of these amplifiers is to amplify the weak the weak signals so that the amplified signal can produce the desirable signals.
- **Horizontal Deflection System:**
  Like the vertical system horizontal system also consists of horizontal amplifiers to amplify the weak input voltage signals but in contrast to vertical deflection system, horizontal deflection plates are fed by a sweep voltage that provides a time base as shown above. As shown in the circuit diagram, the saw tooth sweep generator is triggered by the synchronizing amplifier when the sweep selector switch is in the internal position and thus the triggered saw tooth generator gives input to the horizontal amplifier by following this mechanism.

Cont.

- Now there are four types of sweeps:
  - Free Running or Recurrent Sweep
    As the name suggests, the saw tooth waveform is repetitive i.e. a new sweep is started immediately after the previous sweep.
  - Triggered Sweep
    Some time the waveform to be observed may not be periodic so it is desired that the sweep circuit remain inoperative and the sweep be initiated by the waveform under examination. In such cases we use triggered sweep.
  - Driven Sweep
    Generally a driven sweep is used where the sweep is free running but triggered by the signal under test.
  - Non Saw Tooth Sweep
    This is used for finding the phase difference between the two voltages. Another important application is that we can compare frequency of input voltages using non saw tooth sweep.

SYNCHRONIZATION

There must be synchronization between the sweep and the signal being measured. Synchronization is done to produce stationary pattern. There are three sources of synchronization which can be selected by synchronization selector and they are written below:

- Internal
  In this trigger is obtained from the signal being measured through vertical amplifier.
- External
  In this trigger an external trigger source is required.
- Line
  In this method trigger is obtained power supply.
- Intensity Modulation
  Intensity modulation can be done by inserting the signal between the ground and the cathode. Intensity modulation causes the brightening of the display.

Cont.

- Positioning Controls
  Position can be control by applying small independent internal direct voltage sources to the deflecting plates and with the help of potentiometer (using it as voltage divider) we can control the position of signal.
- Focus Control
  Focus can be controlled by changing the focal length of the focusing electrode which acts like a lens and focal length can be changed by the changing potential of the focusing anode.
- Intensity Control
  The intensity can be varied by changing the grid potential with respect to cathode.
- Calibration Circuit
  Calibrating voltage has a square shape which is usually internally generated of known amplitude.
- Astigmatism
  By adjusting the focus the spot can be made sharp in order to avoid the problem of astigmatism.

FRONT PANEL OF AN CRO

CONTROLS

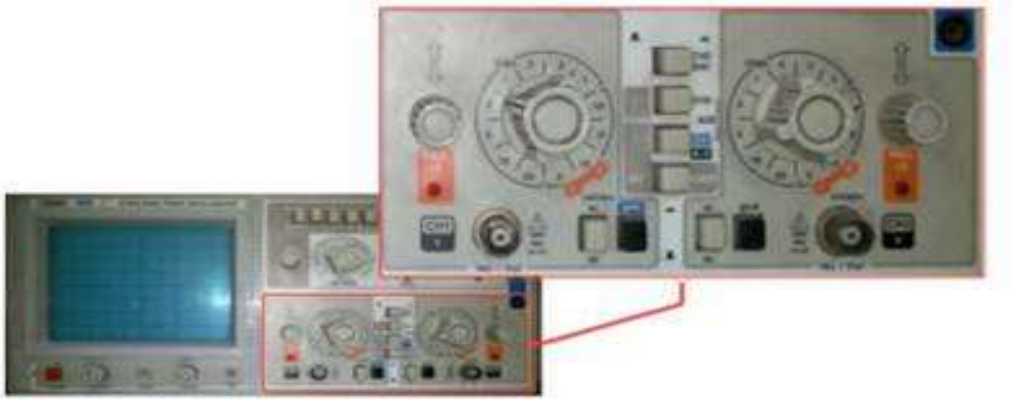
- DISPLAY CONTROLS
- Common display control includes:
- **An intensity control** is used to adjust the brightness of the waveform. As the sweep speed is increased, there is a need to increase the intensity level.
- **A focus control** is used to adjust the sharpness of the waveform.
- **A trace control** is used to rotate the trace on the CRO screen.
- **A calibration point** is used to calibrate the CRO. It gives a steady square wave at a particular set frequency and voltage. It allows the accurate scaling of the trace. The standard calibration signal is 0V-2V at 1KHz.

Cont.

Display controls

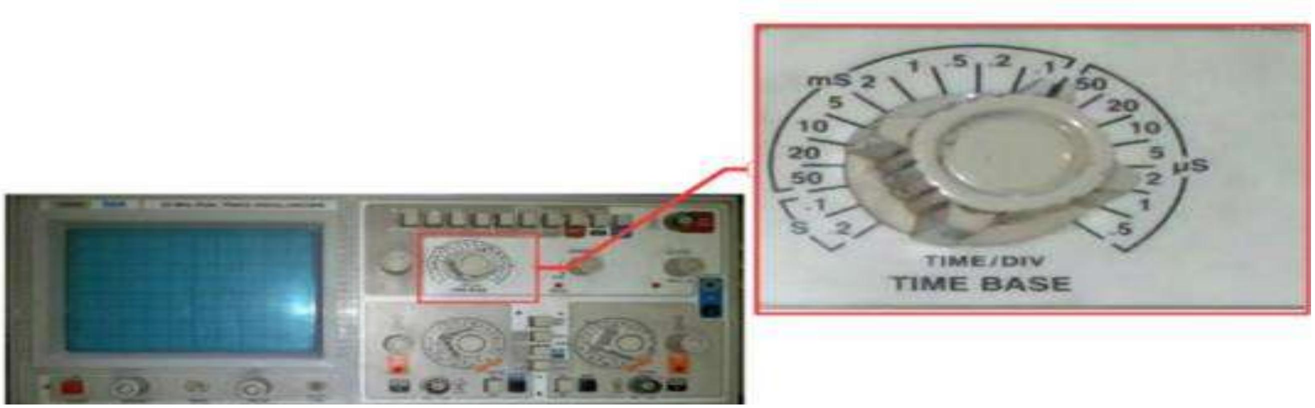
VERTICAL CONTROLS

- Vertical controls are used to position and scale the wave form vertically.
  Volts/div.: For selecting desired voltage sensitivity of the vertical amplifier to obtain the proper wave form on the screen.
  Volts/div. Variable: Provides continuously variable voltage sensitivity. Calibrated position is fully clockwise.
  Position: Controls horizontal position of trace on screen.
  Vertical Position knob: To move the trace up or down the on the screen.



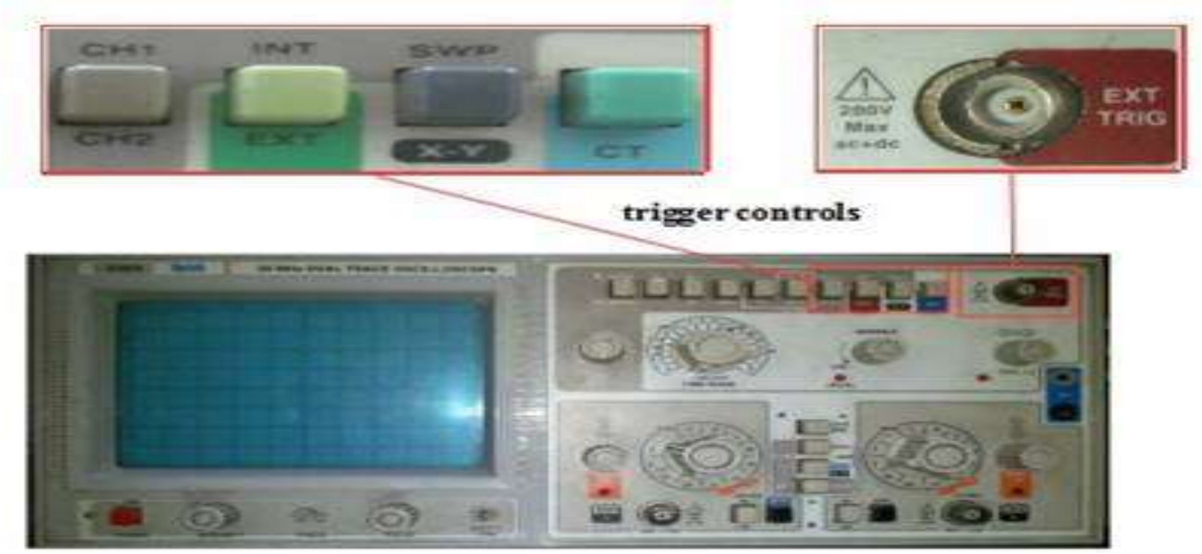
HORIZONTAL CONTROLS

- Horizontal controls are used to position and scale the wave form horizontally.
- **Sweep time/cm:** For selecting desired sweep rate from calibrated steps or admits external signal to horizontal amplifier.
- **Sweep time/cm Variable:** Provides continuously variable sweep rates. Calibrated position is fully clockwise.
- **Position:** Controls horizontal position of trace on screen.
- **Horizontal Variable:** Controls the attenuation (reduction) of signal applied to horizontal amplifier through External Horizontal connector.



TRIGGER CONTROLS

- The trigger selects the timing of the beginning of the horizontal sweep.
- **Slope:** Selects whether triggering occurs on a rising or falling edge of trigger signal.
- **Coupling:** Selects whether triggering occurs at a specific amount of DC or AC level.
- **Level:** Selects the voltage point on the triggering signal at which sweep is triggered. It also allows automatic (auto) triggering of allows sweep to run free (free run).



INPUT COUPLING

Coupling is used to connect an electrical signal from one circuit to another. When the input coupling is the connection from circuit to the oscilloscope. The coupling can be set to DC, AC.

- DUAL BUTTON
- The oscilloscope has a capability to display both channel signals on the screen at the same time. This is known as DUAL MODE.
- It is usually used to measure phase difference between two signals.

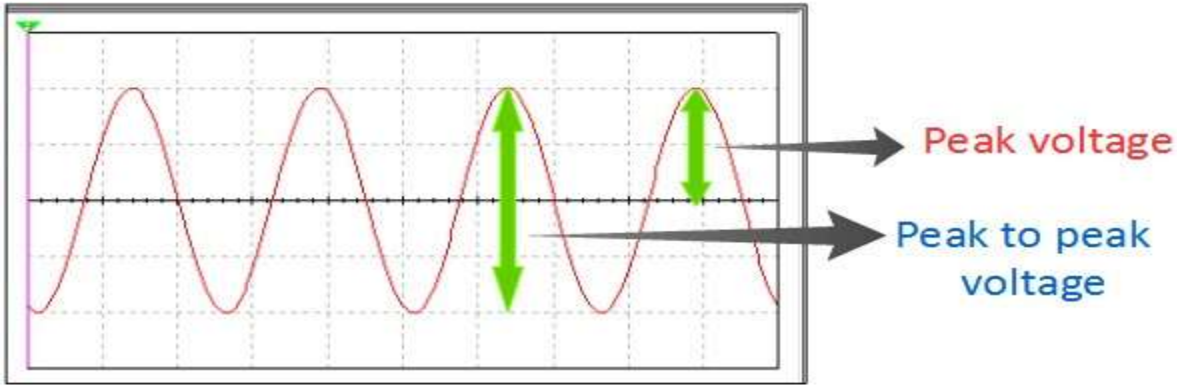
ALTERNATE AND CHOP BUTTONS

- Multiple channels are displayed using either an alternate or chop mode.
- Chop mode causes the oscilloscope to draw small parts of each signal back and forth between them, the switching rate is too fast so that the waveform looks like a continuous signal.

MEASUREMENT TECHNIQUES

- The objective of observing a signal on the oscilloscope screen is to make voltage and time measurements.
- These measurements may be helpful in understanding the behavior of a circuit component, or the circuit itself, depending on what has to be measure.
- The oscilloscope screen consists of the grids which can be external or internal to the screen of CRO, which divides both the horizontal axis (voltage) and the vertical axis (time) into divisions which will be helpful in making the measurements.
- These values are determined by two variables namely the time/div and the volt/div both of which can be adjusted from the relevant buttons available on the front panel of the oscilloscope. MEASUREMENT OF A.C. VOLTAGE
-

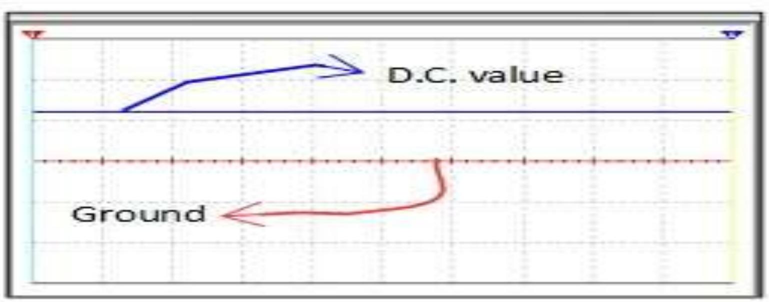
MEASUREMENT OF A.C. VOLTAGE



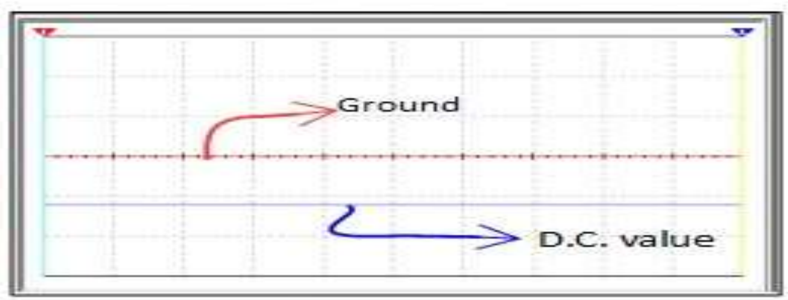
- **Measurement of peak-to-peak voltage and peak voltage:**
- To measure the ac. voltage of sinusoidal waveform. The input ac. signal is applied from the signal generator to a channel of CRO. The voltage/div switch (Y-plates) and time base switch (X-plates) are adjusted such that a steady picture of the waveform is obtained on the screen.
- The vertical height (L) i.e. peak-to-peak height is measured. When this peak-to-peak height (L) is multiplied by the voltage/div. (voltage deflection sensitivity 'n') we get the peak-to-peak voltage (2Vo). From this we get the peak voltage (Vo). The rms voltage Vrms is equal to. This rms voltage Vrms is verified with rms voltage value, measured by the multimeter.

MEASUREMENT OF D.C. VOLTAGE

- The trace(horizontal line) is adjusted such that it lie on the X-axis of the screen. The d.c. input voltage to be measure is then fed to the input channel of the CRO in the d.c. mode. The shift of trace from the horizontal line occurs which gives the measure of the magnitude of the d.c. voltage.



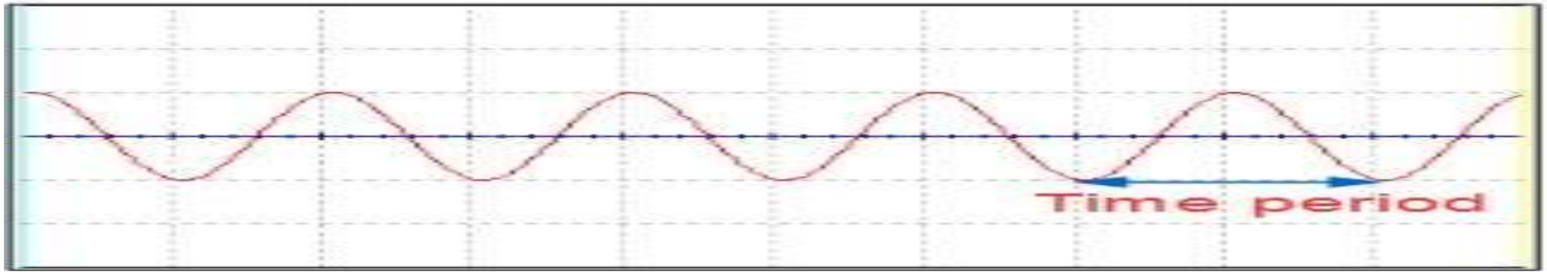
Depicting the positive DC voltage



Depicting the negative DC voltage

USING TIME-PERIOD:

- From the trace the time period of the input signal is equal to ‘t’ times the value of time/div setting.
- Suppose that the time period of the input signal is T. As we know frequency is the reciprocal of time period.
- Then, the frequency of the signal =1/T



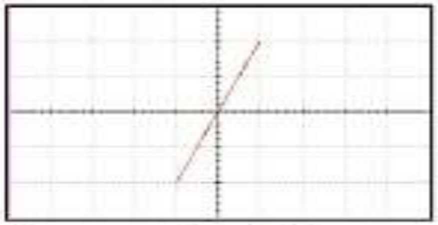
USING LISSAJOUS FIGURE

- When two signals having some frequency are applied to input terminal of CRO and get superimposed perpendicularly (when A/B or B/A is pressed), then a pattern of closed figure is obtained which is known as LISSAJOUS FIGURE.
- This is easily done on an oscilloscope in XY mode.
- The signal whose frequency to be measured is given on vertical plate and signal whose frequency is given to horizontal plate.
- Now the known frequency is adjusted such that a Lissajous pattern can be obtained, which depends on the ratio of the two frequencies.
- Let f_y be the frequency of unknown signal (applied at vertical plate) and f_x be the frequency of known signal (applied at horizontal plate)
- Then tangents are drawn on horizontal and vertical side of the Lissajous pattern, which gives the measure of:

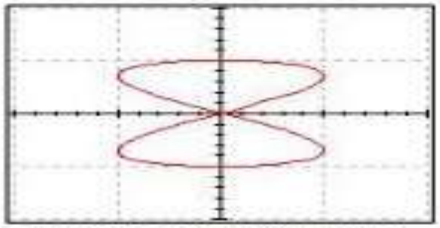
$$\frac{f_x}{f_y} = \frac{\text{no. of } \cap \text{ at horizontal side of Lissajous pattern}}{\text{no. of } \cap \text{ at vertical side of Lissajous pattern}}$$

where $\cap$ means intersection

Cont.

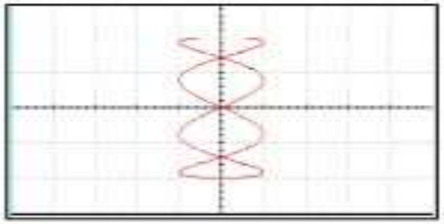


Frequency of vertical wave is same as the frequency of horizontal wave.



Frequency of vertical wave is twice the frequency of horizontal wave.

Frequency of vertical wave is thrice the frequency of horizontal wave.

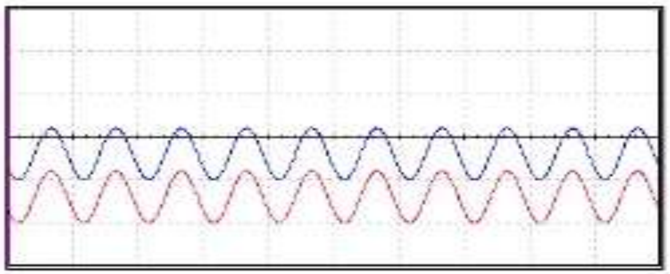


Frequency of vertical wave is four times the frequency of horizontal wave.

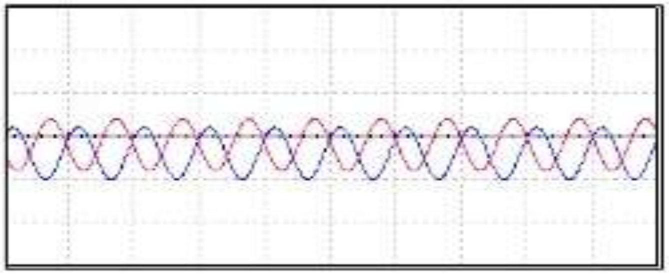
MEASUREMENT OF PHASE DIFFERENCE

If two or more signals are being monitored simultaneously, a time delay may occur between the signals (that is one signal may lead the other or vice-verse), called as phase difference. Two waves that have the same frequency, have a phase difference that is constant (independent of t).

When the phase difference is zero, the waves are said to be in phase with each other. Otherwise, they are out of phase with each other.



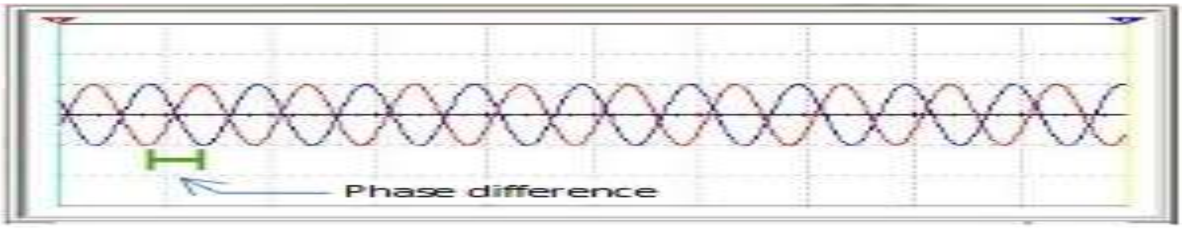
In phase waveform



Out of phase waveform

If the phase difference is 180º (radians), then the two signals are said to be in anti-phase. If the peak amplitudes of two anti-phase waves are equal, their sum is zero at all values of time, t.

The phase difference is expressed in terms of radians or degrees. **In Dual Mode**, the phase difference can be calculated as follows it depicting the two signals having the same frequency:

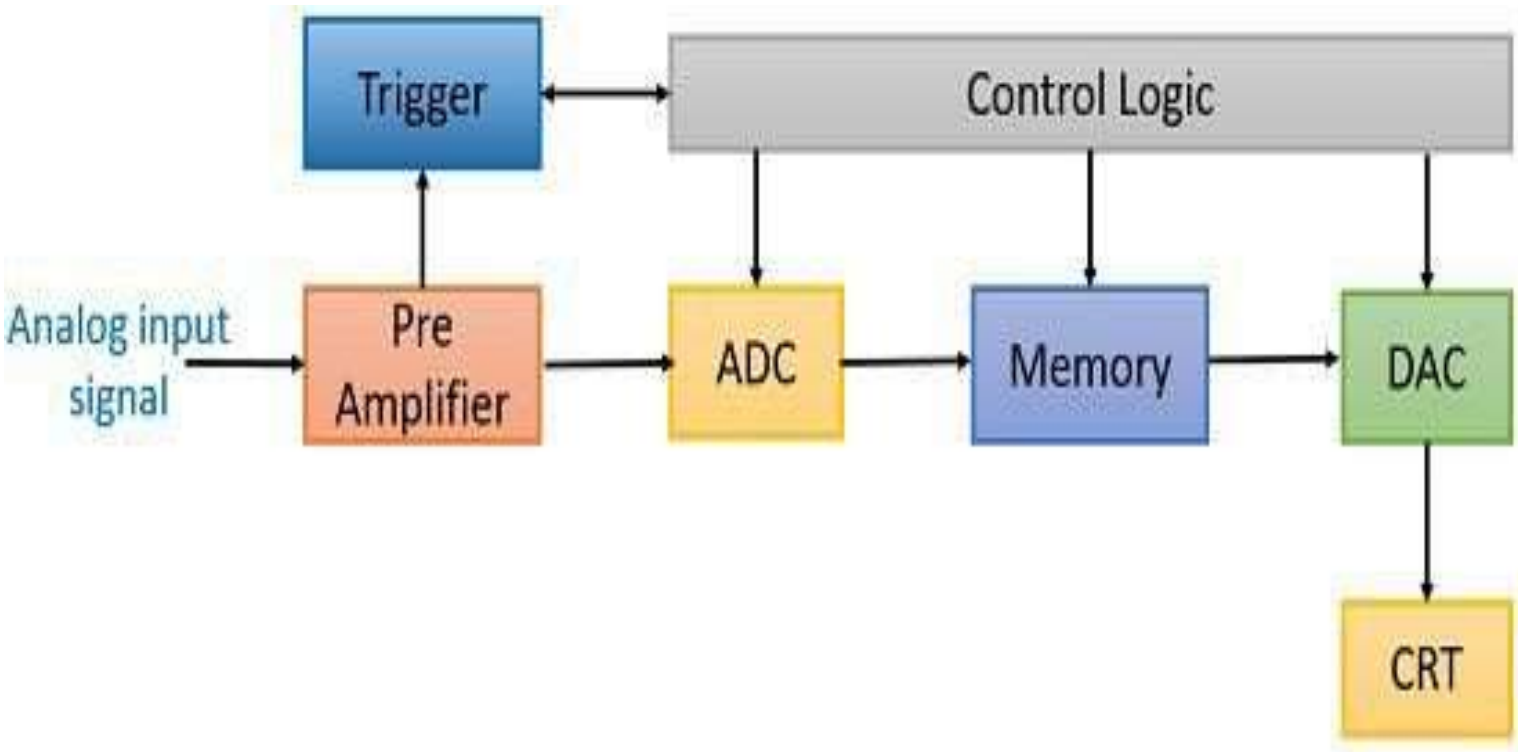


The phase difference between the signals can also be determined in XY mode of the dual slope oscilloscope. In the XY mode, the x-axis data is taken on one channel, y-axis data is taken on the other. In that way, Channel I is related with Channel II which is presented by means of graph, so that the variation of a signal with respect to another can be observed. In XY mode, the two signals having a constant phase difference.

DIGITAL STORAGE OSCILLOSCOPE

Digital Storage Oscilloscope is an instrument that **analyses the signal digitally** and **stores the data in the electronic digital memory**. By examining the stored traces in memory, it can display **visual** as well as **numerical values**.
It digitizes the input signal in order to have subsequent digital signals. The input is stored in digital memory in the form of **0** and **1**. This stored digitized signal is then viewed on the **CRT screen** after the signal reconstruction in analog form.
Here, the digital copy of input waveform is stored and further analyzed using **Digital Signal Processing techniques**.
The **maximum frequency** that can be measured by using Digital Oscilloscope basically **depends** on **sampling rate** and **nature of converter**.
Sometimes people misconstrue in between digital voltmeter and digital storage oscilloscope.
A digital voltmeter records fluctuation in voltage. On contrary, Digital oscilloscope displays a graphical representation of the signal. It also helps to determine unexpected voltage source.

Block Diagram of Digital Storage Oscilloscope



Block diagram of Digital Storage Oscilloscope

WORKING OF DIGITAL STORAGE OSCILLOSCOPE

From the figure shown above, we can see that an analog input signal is fed into the pre-amplifier unit. This unit amplifies the input so as to raise the level of the amplitude of the signal.

This signal is then fed to an analog to digital converter (ADC) and the trigger detector. As the voltage crosses the **threshold value**, the device starts recording on the application of the signal sent by the trigger unit.

The output of the pre-amplifier is sampled by the ADC at regular intervals. The **digital outpu**t provided by the ADC is **stored in memory** at consecutive locations. The recording of signal continues until the memory is full.

The **DAC** employed in the circuit **produces analog signal** to be displayed in CRT.

Any further changes in the applied input, re-triggers the oscilloscope which causes the memory to reset. That means the memory is overwritten with the new upcoming data unless the system is in **HOLD mode**.

By the application of **HOLD mode**, the signal traces can be analysed by the user according to the user’s choice.

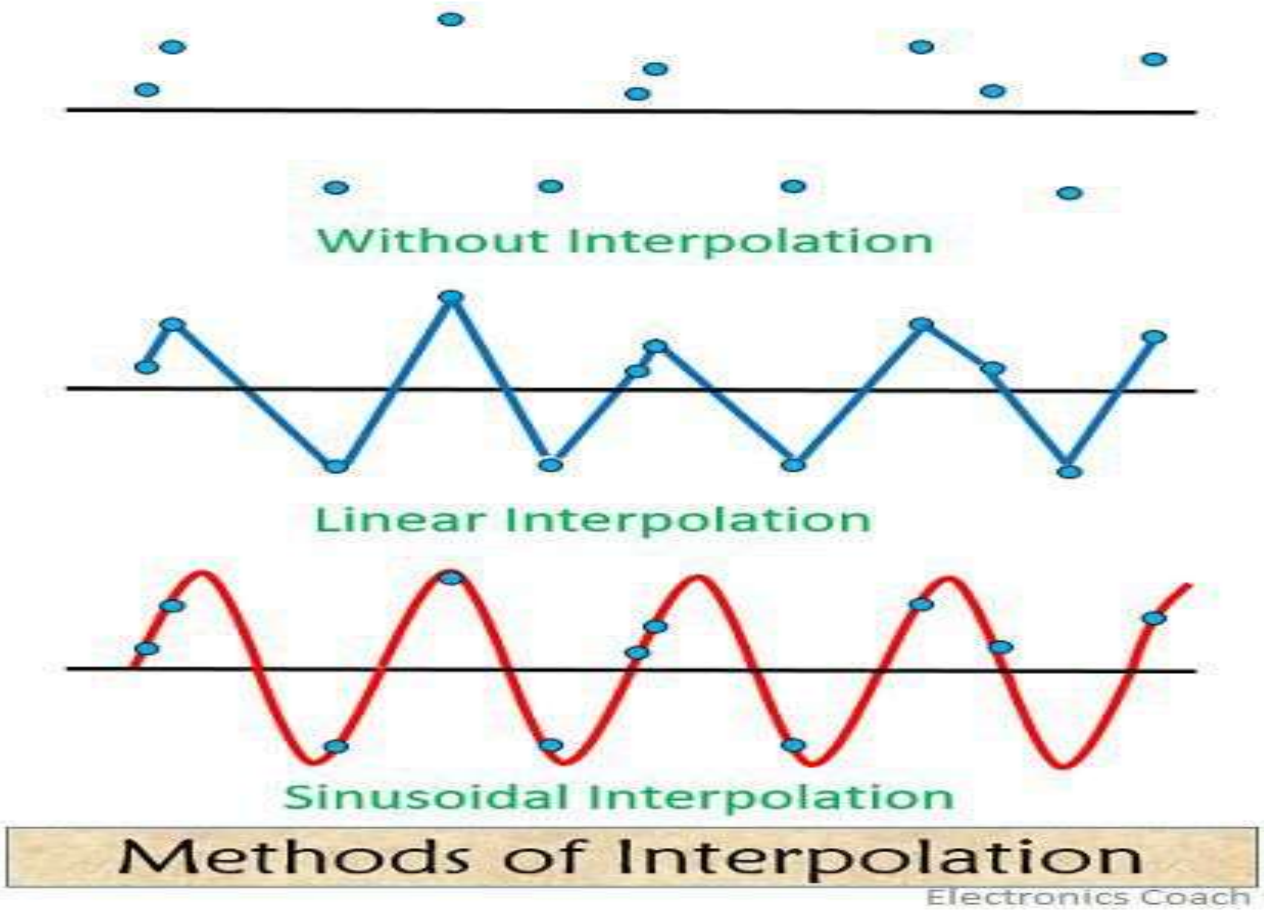
Cont.

The **size of the memory** unit determines the **number of samples stored** in it. One can alter the length of recording by changing the sampling frequency of ADC.
In the case of the digital oscilloscope, many different input channels are used. But, the memory available to each channel gets reduced. When all the channels share a common store. This is done through multiplexing.
Here, **40 channels** oscillator are obtainable commercially having storage capability of **25000 dots**. Many oscillators employ floppy disc storage capability.
At the time of digitization in order to make sure that no information is lost, according to Sampling Theory, the sampling rate must be twice as fast as the highest frequency of input signal. Failing of which will give rise to aliasing effect.

WAVEFORM RECONSTRUCTION

- Although the input is sampled according to sampling theory, aliasing effect can still occur. This is so because the output is present as series of dots, that corresponds to the sampled value.
- Digital storage oscilloscope uses **interpolation technique**, for visualization of final waves.
- Interpolation is a technique that creates new data points with the help of a discrete set of known data points. It is basically of two types-
- **Linear interpolation**
- **Sinusoidal interpolation**

LET'S HAVE A LOOK AT THE FIGURE ILLUSTRATING INTERPOLATION METHODS-



Cont.

- In **linear interpolation**, the dots are connected together by a **straight line**. It can be used in **pulsed or square wave generation** but not in case of sinusoidal waves.
- On contrary, in **sinusoidal interpolation**, the dots are connected so as to form **sinusoidal waveform**. But it is not suitable for square or pulse waves.
- Sampling technique gives rise to another problem when used in digital oscilloscopes. The transient or glitches that exist in between the sample points can be missed out.
- The problem is solved by **envelope mode oscilloscopes** can be used. It employs special logic circuitry due to which the sample and digitizing circuitry run at high speed. The functioning of which is independent of the setting of display time.
- In this, each sample value is compared with the previous one and resultantly the higher one is stored in memory.

Cont.

- **Advantages**
- They possess infinite storage time.
- It can be easily operated.
- Digital storage oscilloscope allows flexible display property.
- **Applications**
- It is used in audio and video recording.
- It is used in radio broadcasting for signal testing.
- In circuit debugging, it is used for testing of the voltage of the signal.
- In case of digital storage oscilloscope, the replacement of internal equipment is more **economical**. This is so because it employs CRT which is cheaper than analog storage oscilloscope.

BRIDGES

- Bridge circuits are mainly used to measure unknown quantities in electronics such as resistance, capacitance, impedance and admittance.
- Abridge circuit consists of 4 arms with a DC source.
- The unknown component to be measured is place in one arm. The component in other arm is adjusted till the detector reads zero. At this condition the bridge is said to be balanced. Then the unknown value is found from the known value of the arm component.

ADVANTAGES OF BRIDGE CIRCUIT

- a. High measurement accuracy
- b. The accuracy is independent of null detector's characteristics
- c. The balance equation is independent of magnitude of input voltage
- d. The interchange of source and detector does not affect the balance condition,
- e. The bridge circuit can be used in control circuits

TYPES OF BRIDGES

- 1) DC Bridges
- These bridges are mainly used for measurement of resistances
- a) Wheatstone bridge
- 2) AC Bridges
- These types of bridges are used to measure impedance consisting of capacitance and inductance.
- a) Maxwell’s Bridge (Inductance and Capacitance)
- b) Hay’s Bridge
- c) De-Sauty’s bridge

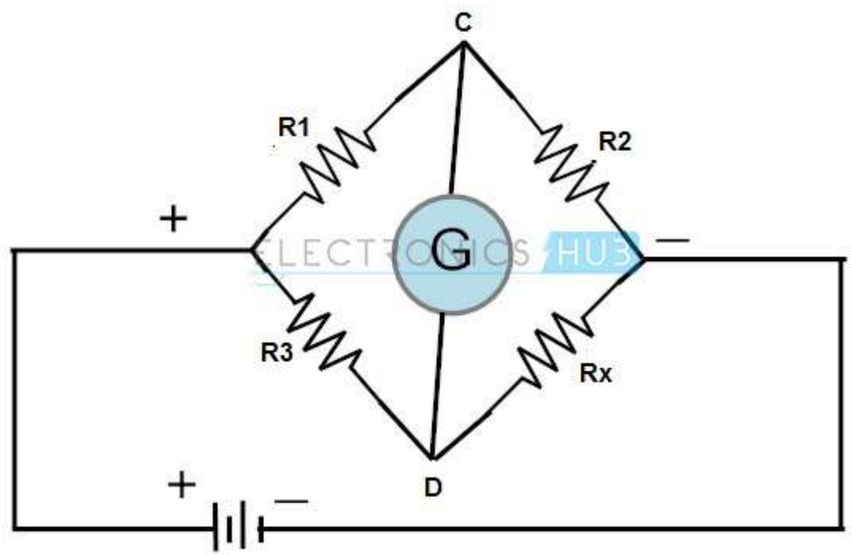
WHEATSTONE BRIDGE

- The most common and simplest bridge network to find the resistance is the Wheatstone Bridge. This bridge is used where small changes in resistance are to be measured like in sensor applications. This is used to convert a resistance change to a voltage change of a transducer.

WHEATSTONE BRIDGE

- A Wheatstone bridge consists of four resistors that are connected in the shape of a diamond with the supply source and indicating instruments as shown in figure

This bridge is used to find the unknown resistance very precisely by comparing it with a known value of resistances. In this bridge null or balanced condition is used to find the resistance



WHEATSTONE BRIDGE

- For this bridge balanced condition voltage at points C and D must be equal. Hence, no current flows through the galvanometer. For getting the balanced condition one of the resistors must be variable

- The voltage at point D $V_D = \frac{E*R_X}{R_3+R_X}$

- The voltage at point C $V_C = \frac{E*R_2}{R_1+R_2}$

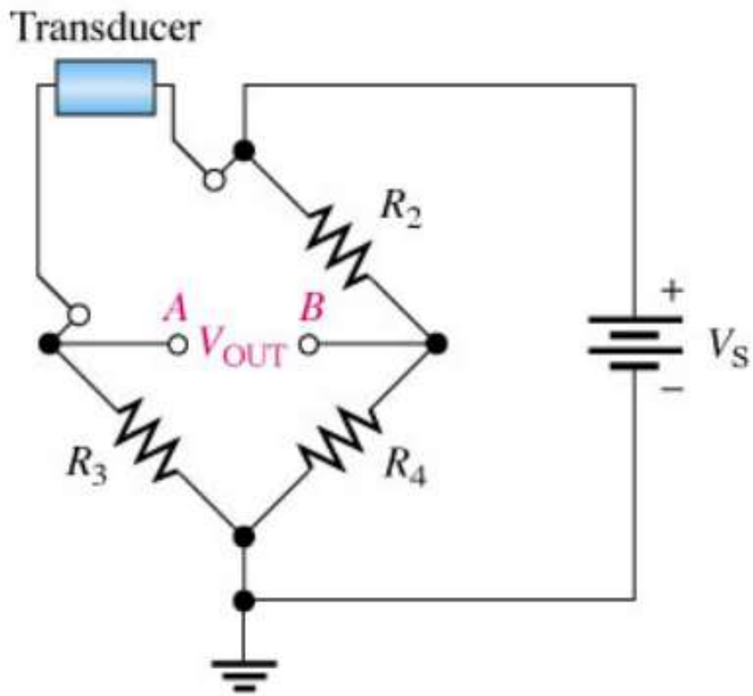
Cont.

- The voltage (V) across galvanometer or between C and D is:
- $V_{CD} = V_D - V_C \Longrightarrow \frac{E*R_X}{R_3+R_X} - \frac{E*R_2}{R_1+R_2}$
- When the bridge is balanced $V_{CD} = 0$
- $\frac{E*R_X}{R_3+R_X} - \frac{E*R_2}{R_1+R_2} = 0$
- $\frac{E*R_X}{R_3+R_X} = \frac{E*R_2}{R_1+R_2} \Longrightarrow R_X(R_1 + R_2) = R_2(R_3 + R_X)$
- $R_X = \frac{R_2 R_3}{R_1}$

UNBALANCED WHEATSTONE BRIDGE

- The unbalanced bridge is used to measure some transducer quantities, such as strain, temperature, or pressure.
- The bridge is balanced at a known point, then the amount of deviation, as indicated by the output voltage, indicates the amount of change in the parameter being measured.

- The value of the parameter being measured can be determined by the amount that the bridge is unbalanced.
- Tiny changes in transducer resistance will unbalance the bridge, thereby providing a measurement reading



Example:-

Consider using a Wheatstone bridge having R1 = 200 Ω and R2 = 2000 Ω to measure a resistance Rm . The bridge is balanced by adjusting R3 until R3 = 250 Ω . What is the value of Rm ?

Solution:

$$R_m = \frac{R_2}{R_1} R_3 = \frac{2000}{200} 250 = 2500\ \Omega$$

Example:-

Consider using a Wheatstone bridge having $R1 = 200\ \Omega$ and $R2 = 2000\ \Omega$ to measure a resistance, Rm , of a temperature sensor. Suppose the resistance of the temperature sensor, Rm , in Ω, is related to the temperature T, in °C, by the equation

$$Rm = 1500 + 25T$$

The bridge is balanced by adjusting R3 until $R3 = 250\ \Omega$. What is the value of the temperature?

SOLUTION

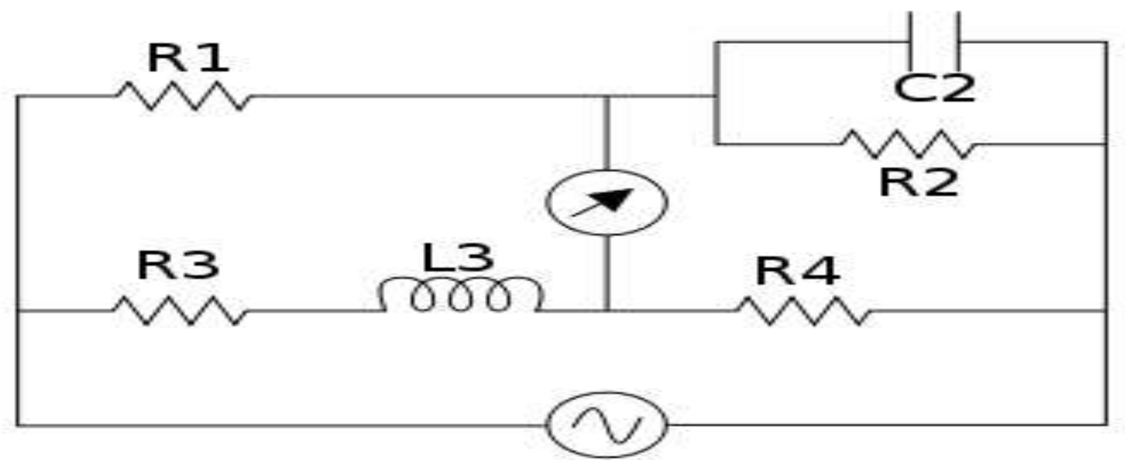
$$R_m = \frac{R_2}{R_1} R_3 = \frac{2000}{200} 250 = 2500\ \Omega$$

Next, the temperature in °C is given by

$$T = \frac{R_m - 1500}{25} = \frac{2500 - 1500}{25} = \frac{1000}{25} = 40\ ^\circ\mathrm{C}$$

MAXWELL BRIDGE

- A Maxwell bridge is a modification to a Wheatstone bridge used to measure an unknown inductance (usually of low Q value) in calibrated resistance and inductance or resistance and capacitance. The bridge is known as a Maxwell-Wien bridge when the calibrated components are a parallel resistor and capacitor. It is named for James C. Maxwell, who first described it in 1873.



Cont.

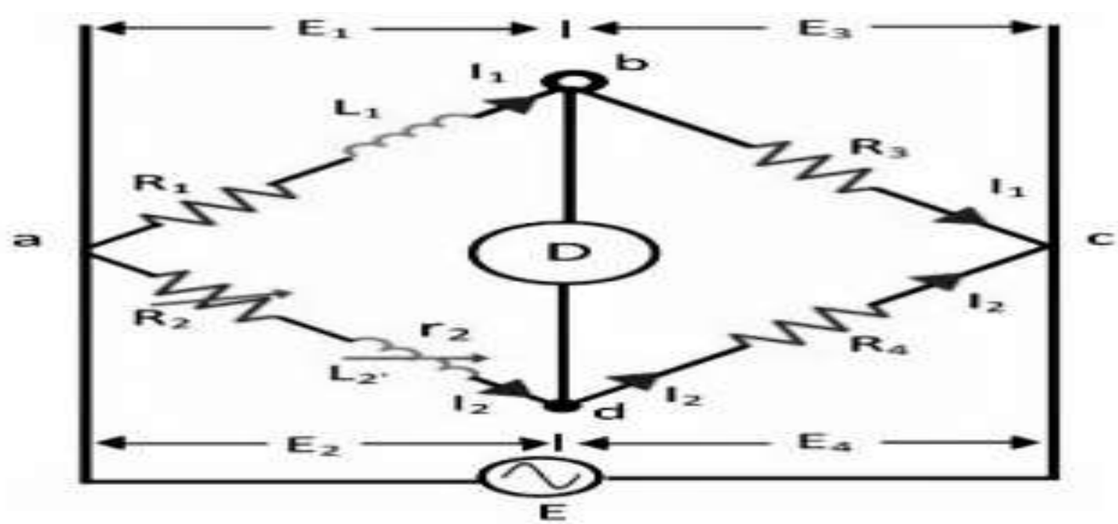
- It uses the principle that the positive phase angle of an inductive impedance can be compensated by the negative phase angle of a capacitive impedance when put in the opposite arm and the circuit is at resonance; i.e., no potential difference across the detector (an AC voltmeter or ammeter)) and hence no current flows through it. The unknown inductance then becomes known in terms of this capacitance.
- Regarding the picture, in a typical application R_1 and R_4 are known fixed entities, and R_2 and C_2 are known variable entities. R_2 and C_2 are adjusted until the bridge is balanced. R_3 and L_3 can then be calculated based on the values of the other components

TYPES OF MAXWELL'S BRIDGE

- Two methods are used for determining the self-inductance of the circuit. They are
- Maxwell's Inductance Bridge
- Maxwell's inductance Capacitance Bridge

MAXWELL'S INDUCTANCE BRIDGE

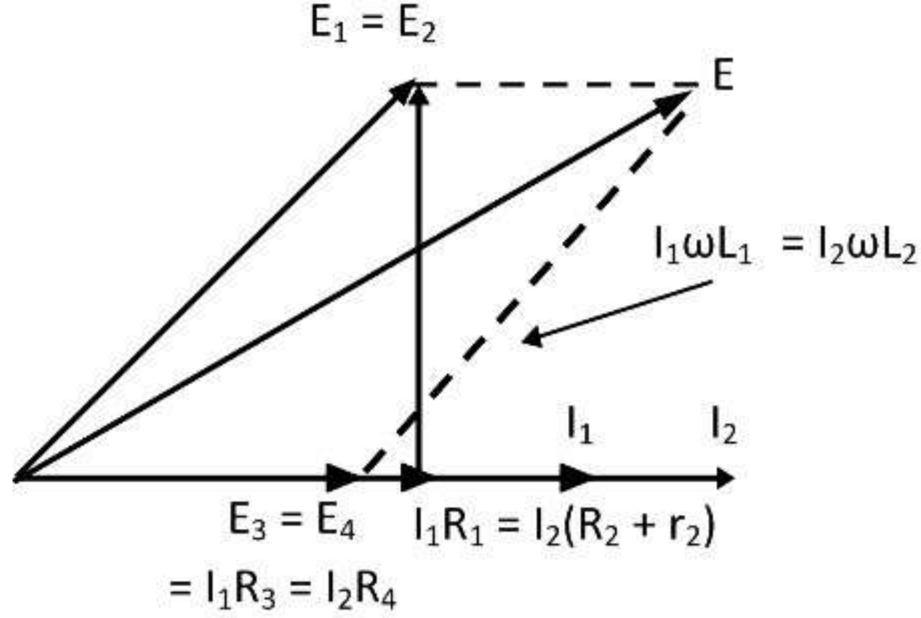
- In such type of bridges, the value of unknown resistance is determined by comparing it with the known value of the standard self-inductance. The connection diagram for the balance Maxwell bridge is shown in the figure below.



Cont.

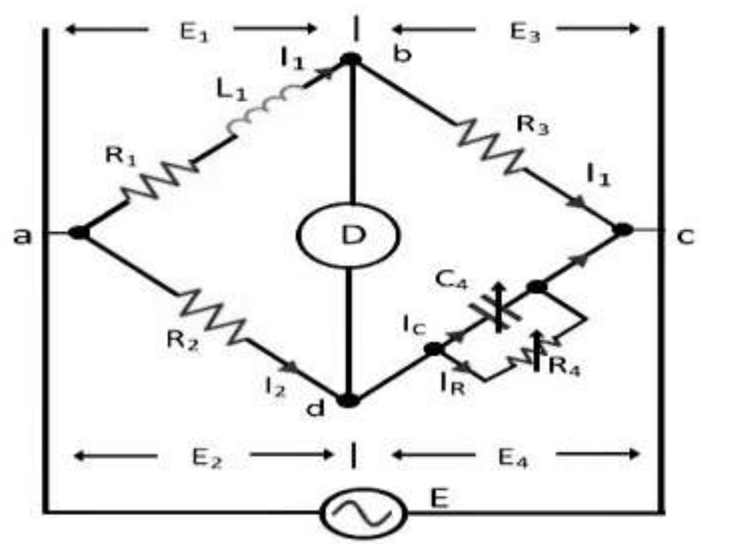
- Where, L1 – Unknown inductance of resistance R1.
  L2 – Variable inductance of fixed resistance r2.
  R2 – Variable resistance connected in series with inductor L2.
  R3, R4 – Known non-inductance resistance.
- At balance,
- L1=R3/R4L2
- R1=R3/R4(R2+r2)
- The value of the R3 and R4 resistance varies from 10 to 1000 ohms with the help of the resistance box. Sometimes for balancing the bridge, the additional resistance is also inserted into the circuit.

Cont.

- The phasor diagram of Maxwell's inductance bridge is shown in the figure below.
- 

MAXWELL'S INDUCTANCE CAPACITANCE BRIDGE

- In this type of bridge, the unknown resistance is measured with the help of the standard variable capacitance. The connection diagram of the Maxwell Bridge is shown in the figure below.



Cont.

For balance condition,

$$(R1 + j\omega L_1)\left(\frac{R4}{1 + j\omega C_4 R_4}\right) = R2R3$$

$$R_1R_4 = j\omega L_1 R_4 = R_2R_3 + j\omega C_4 R_4 R_2 R_3$$

By separating the real and imaginary equation we get,

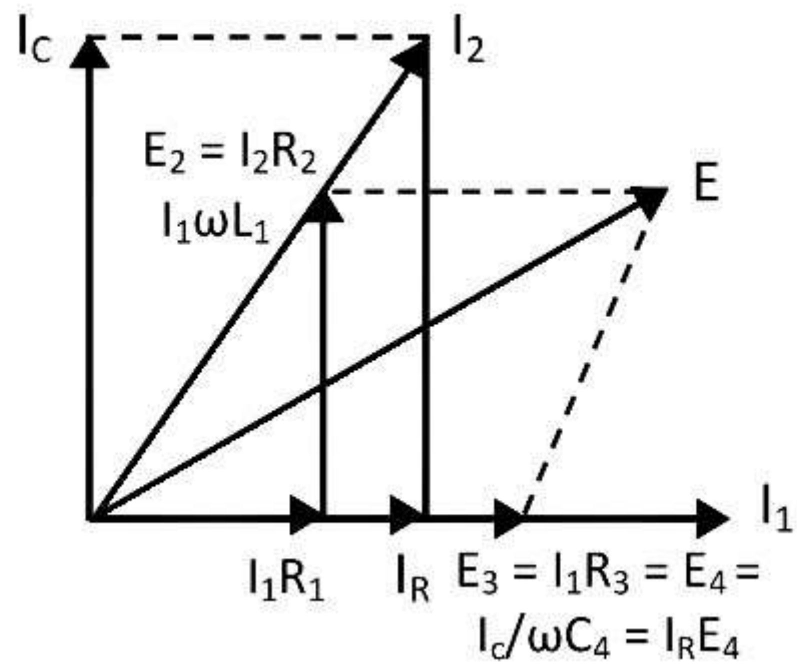
$$R_1 = \frac{R_2R_3}{R_4}$$

$$L_1 = R_2R_3C_4$$

The above equation shows that the bridges have two variables R_4 and C_4 which appear in one of the two equations and hence both the equations are independent. The circuit quality factor is expressed as

$$Q = \frac{\omega L_1}{R_1} = \omega C_4 R_4$$

THE PHASOR DIAGRAM OF MAXWELL'S INDUCTANCE CAPACITANCE BRIDGE IS SHOWN IN THE FIGURE BELOW



ADVANTAGES OF THE MAXWELL'S BRIDGE

- The following are the advantages of the Maxwell bridge-
- The balance equation of the circuit is free from frequency.
- Both the balance equations are independent of each other.
- Maxwell's inductor capacitance bridge is used for the measurement of the high-range inductance.

DISADVANTAGES OF THE MAXWELL'S BRIDGE

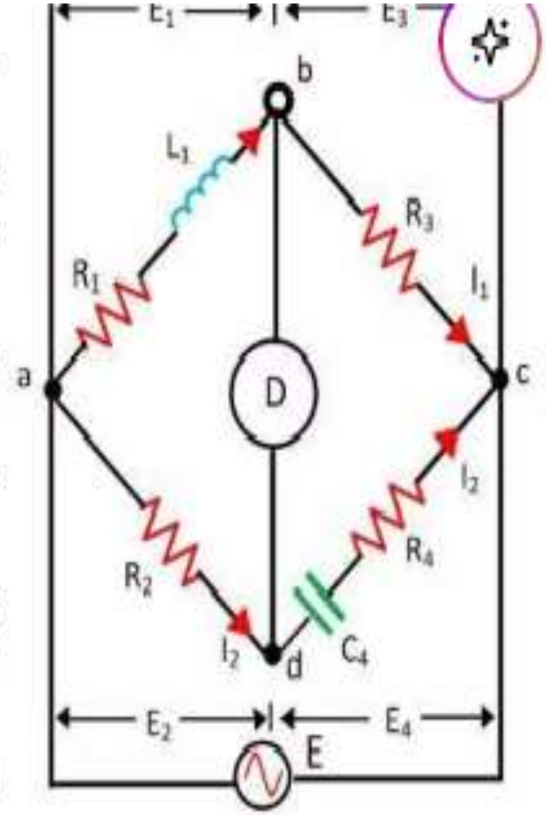
- The main disadvantages of the bridge are
- The Maxwell inductor capacitance bridge requires a variable capacitor which is very expensive. Thus, sometimes the standard variable capacitor is used in the bridges.
- The bridge is only used for the measurement of medium-quality coils.

HAY'S BRIDGE

- The **Hay's bridge** is used for determining the self-inductance of the circuit. The bridge is the advanced form of Maxwell's bridge.
- The Maxwell's bridge is only appropriate for measuring the medium quality factor.
- Hence, for measuring the high-quality factor the Hays bridge is used in the circuit.
- In Hay's bridge, the capacitor is connected in series with the resistance, the voltage drop across the capacitance and resistance are varied.
- And in Maxwell bridge, the capacitance is connected in parallel with the resistance.
- Thus, the magnitude of a voltage pass through the resistance and capacitor is equal.

CONSTRUCTION OF HAY'S BRIDGE

- The unknown inductor L_1 is placed in the arm **ab** along with the resistance R_1.
- This unknown inductor is compared with the standard capacitor C_4 connected across the arm **cd**. The resistance R_4 is connected in series with the capacitor C_4.
- The other two non-inductive resistor R_2 and R_3 are connected in the arm **ad** and **bc** respectively.
- The C_4 and R_4 are adjusted for making the bridge in the balanced condition.
- When the bridge is in a balanced condition, no current flows through the detector which is connected to point **b** and **c** respectively.
- The potential drops across the arm **ad** and **cd** are equal and similarly, the potential across the arm **ab** and **bc** are equal.



Hay's Bridge

HAY'S BRIDGE THEORY

- Let,
  L_1 – unknown inductance having a resistance R_1
  R_2, R_3, R_4 – known non-inductive resistance.
  C_4 – standard capacitor
- At balance condition,

$$(R_1 + j\omega L_1)(R_4 - j/\omega C_4) = R_2 R_3$$

$$R_1 R_4 + \frac{L_1}{C_4} + j\omega L_1 R_4 - \frac{jR_1}{\omega C_4} = R_2 R_3$$

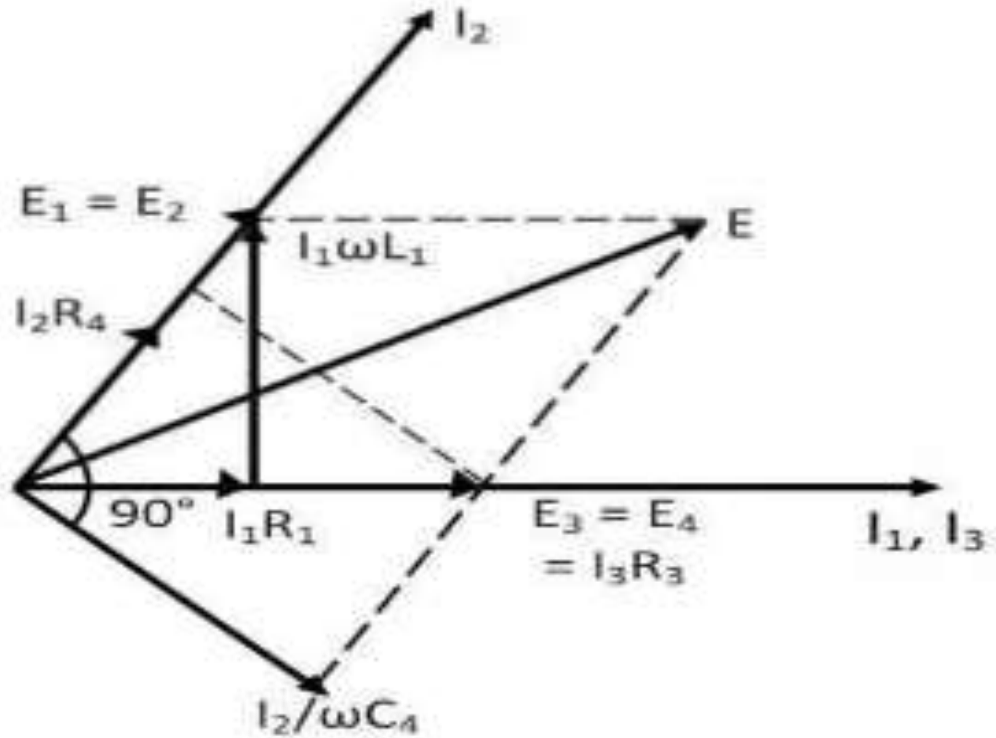
$$(R_1 + j\omega L_1)(R_4 - j/\omega C_4) = R_2 R_3$$

$$R_1 R_4 + \frac{L_1}{C_4} + j\omega L_1 R_4 - \frac{jR_1}{\omega C_4} = R_2 R_3$$

- At last ,by simplifying all equation, we get,

$$L_1 = R_2 R_3 C_4$$

PHASOR DIAGRAM OF HAY'S BRIDGE

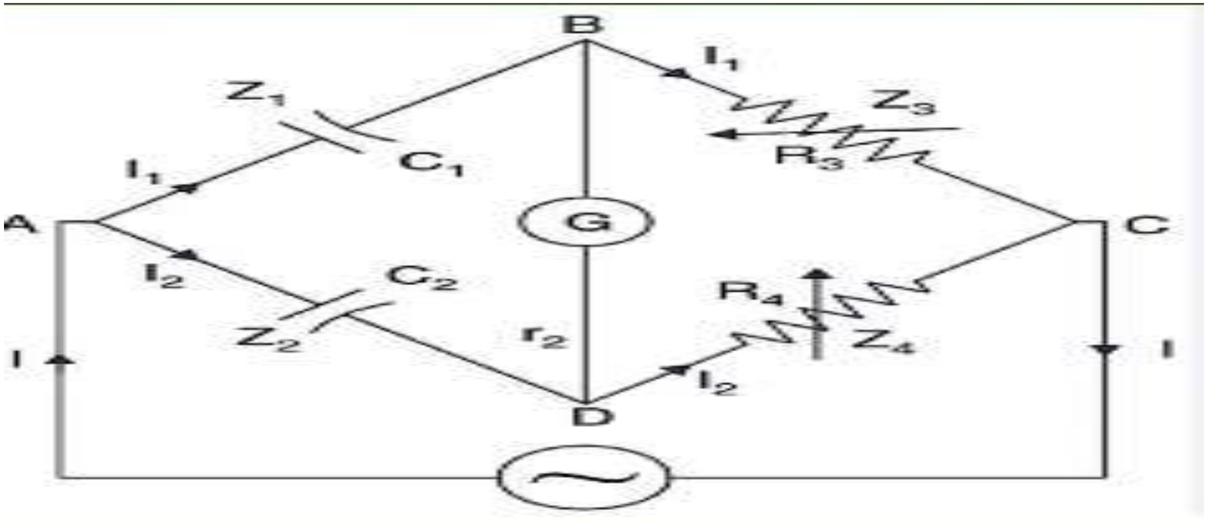


DE-SAUTY'S BRIDGE

- De-Sauty's bridge is the simplest AC bridge circuit used for the measurement of unknown capacitance. The bridge gives a fair degree of accuracy for measuring capacitance over a wide range. It can also be used for comparing two capacitances.

CONSTRUCTION OF DE-SAUTY'S BRIDGE

- The bridge consists of four branches or arms. Two capacitors **C_1** and **C_2** are placed in branches **AB** and **AD** respectively. The branches **BC** and **CD** consist of resistors **R_3** and **R_4** respectively. An AC source is connected between terminals **A** and **C**. The circuit diagram of the bridge is shown in the figure.
- A null indicator is connected across terminals **B** and **D**, which indicates null deflection when the bridge is balanced.



Cont.

- **Let,**
- **C_1** = Unknown capacitance
- **C_2** = Known standard capacitance
- **R_3** = Known standard non-inductive resistance
- **R_4** = Known standard non-inductive resistance
- **Balance Condition of De-Sauty's Bridge**
- When the bridge is balanced, we have:

$$Z_1 = \frac{1}{j\omega C_1}$$

$$Z_2 = \frac{1}{j\omega C_2}$$

$$Z_3 = R_3$$

$$Z_4 = R_4$$

- It is the easiest method for the measurement of capacitance as it has a simple circuit and only one variable element. In order to bring the bridge into a balanced condition, either **R_3** or **R_4** can be chosen as a variable element.

Cont.

- **Advantages of De-Sauty's Bridge**
- The advantage of this bridge is its simplicity to obtain a perfect balance.
- The calculations are very easy.
- **Disadvantages of De-Sauty's Bridge**
- If both capacitors are not free from dielectric loss, it is not possible to obtain the balance condition. This method is therefore used only for air capacitors, which are more or less loss-free.

Q-METER

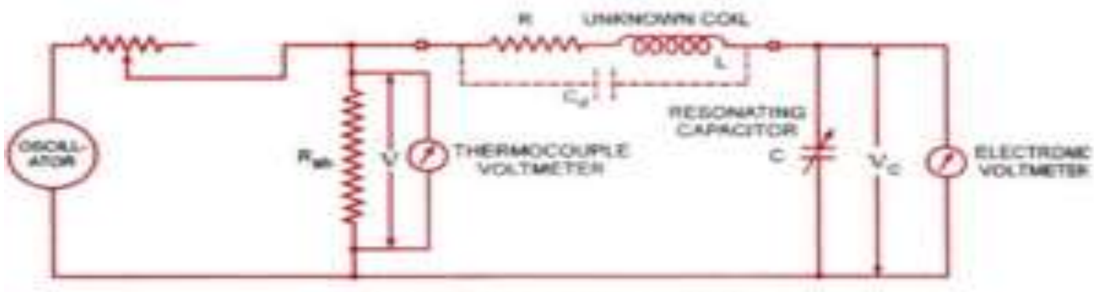
- A **Q meter** is a testing instrument used for measuring the quality factor (Q) of electrical circuits at radio frequencies. Although modern impedance measuring devices have largely replaced it in professional laboratories, it remains popular among radio amateurs for educational and experimental purposes.
- The Q meter measures the **storage factor** or **quality factor** of an electrical circuit, which indicates the relationship between stored and dissipated energy. The higher the Q value, the lower the energy loss within the circuit. The instrument helps evaluate the characteristics of coils and capacitors, especially in RF applications.

WHAT IS THE QUALITY FACTOR OF A COIL?

- The **quality factor (Q)** of a coil is defined as the ratio of its inductive reactance to its effective resistance:
- Q = XL / R
- where XL is the inductive reactance and R is the effective resistance of the coil.

CIRCUIT DIAGRAM

- The Q meter operates on the **principle of series resonance**. When an AC series circuit reaches resonance, the voltage across the capacitor is equal to the applied voltage multiplied by the quality factor of the circuit. A voltmeter connected across the capacitor can be calibrated to read the Q value directly.



Circuit Diagram of a Q-meter

- In a practical Q meter circuit, the oscillator is tuned to the desired frequency, and the tuning capacitor (C) is adjusted to its maximum value. The input voltage is kept constant, and the voltage across the capacitor (Vc) is measured and calibrated to directly indicate the Q value. The measured value represents the Q of the entire circuit rather than just the coil, with minor errors due to shunt resistance and distributed capacitance.

WORKING PRINCIPLE

- The Q meter works on the **series resonant principle**. Resonance occurs when the reactances of the capacitance and inductance are equal in magnitude but opposite in phase, allowing energy to oscillate between the electric and magnetic fields of the capacitor and inductor respectively. The instrument primarily depends on the capacitance, inductance, and resistance of the resonant circuit.

APPLICATIONS

- Measures the **quality factor (Q)** of coils and circuits.
- Determines **effective resistance, inductance,** and **capacitance**.
- Measures **bandwidth** and **resonant frequency** of RF circuits.
- Used for evaluating **component characteristics** in laboratories.
- Helpful in **educational and research experiments** involving tuned circuits.

FIXED AND VARIABLE AF OSCILLATOR

- Signal generators are the sources of electrical signals used for the purpose of testing and operating different kinds of electrical equipment. A signal generator provides different types of waveforms such as sine, triangular, square, pulse etc., whereas an oscillator provides only sinusoidal signal at the output.
  The AF oscillators are divided into two types. They are as follows
  1. Fixed frequency AF oscillator
  2. Variable frequency AF oscillator.

FIXED FREQUENCY AF OSCILLATOR

Many instrument circuits contain oscillator as one of its integral parts to provide output signal within the specified fixed audio frequency range. This specified audio frequency range can be 1 kHz signal or 400 Hz signal.

The 1 kHz frequency signal is used to execute a bridge circuit and 400 Hz frequency signal is used for audio testing. A fixed frequency AF oscillator employs an iron core transformer. Due to this a positive feedback is obtained through the inductive coupling placed between the primary winding and secondary winding of the transformer and hence fixed frequency oscillations are generated.

VARIABLE FREQUENCY AF OSCILLATOR

- It is a general purpose oscillator used in laboratory. It generates oscillations within the entire audio frequency range i.e. from 20 Hz to 20 kHz. This oscillator provides a pure, constant sine wave output throughout this AF range. The examples of variable AF oscillators used in laboratory are RC feedback oscillator, beat frequency oscillator.

THE FRONT PANEL OF A SIGNAL GENERATOR CONSISTS OF THE FOLLOWING.

1. 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 1 MHz.
3. Amplitude multiplier It attenuates the sine wave in 3 decades, x 1, 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 wave output.
8. Output available This provides sine wave or square wave output.
9. Sync This terminal is used to provide synchronisation of the internal signal with an external signal.
10. On-Off Switch

STANDARD SIGNAL GENERATOR

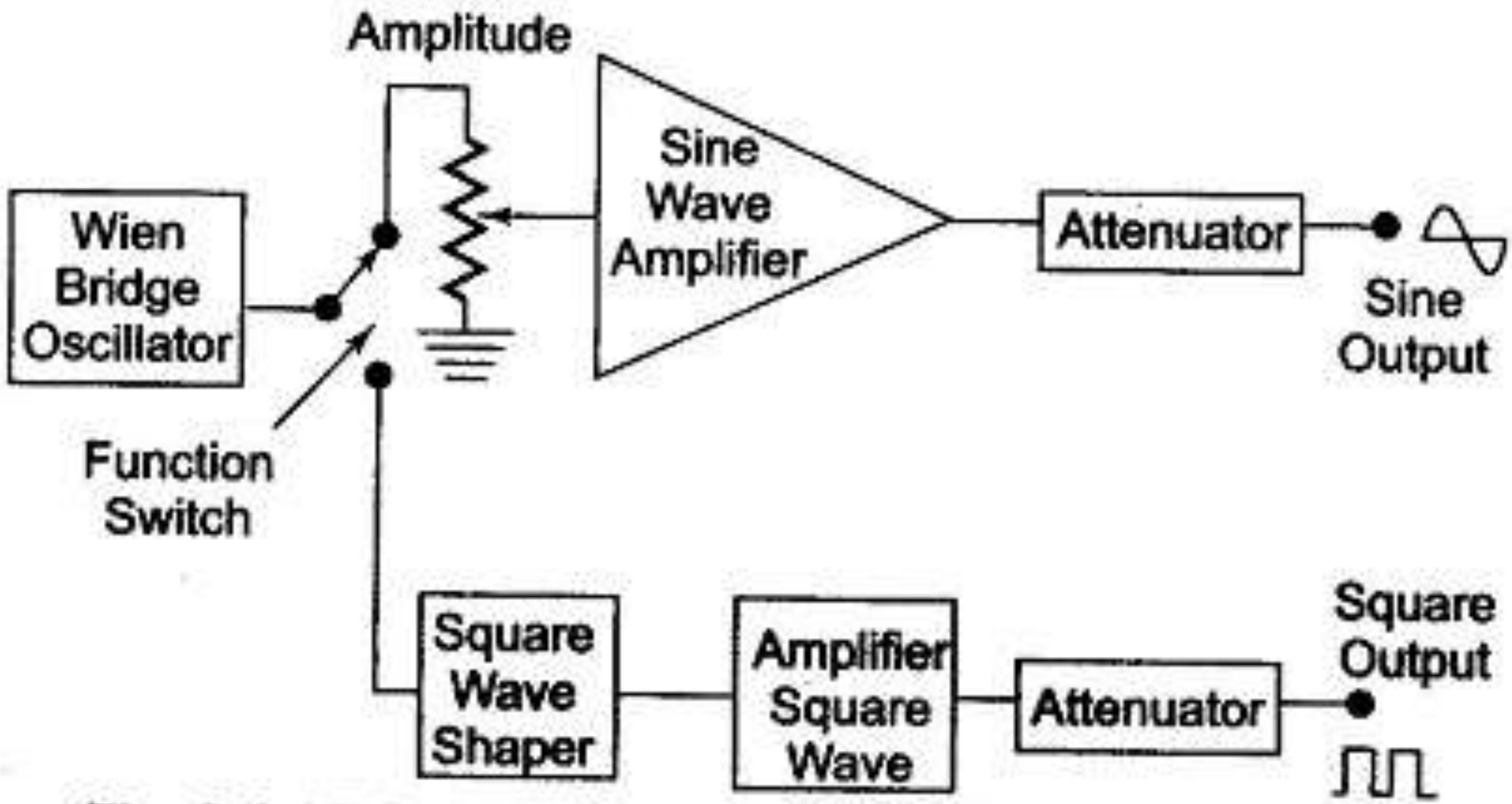


Fig. 8.4 AF Sine and Square Wave Generator

SQUARE AND PULSE GENERATOR:

- 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. A square wave generator has a 50% duty cycle.
- used as measuring devices in combination with a CRO.

Requirements of a Pulse Generator

- The pulse should have minimum distortion.
- The basic characteristics of the pulse are rise time, overshoot, ringing, sag, and undershoot.
- The pulse should have sufficient maximum amplitude.
- The range of frequency control of the pulse repetition rate (PRR) should meet the needs of the experiment.

  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.

Cont.

- 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.
- The output impedance of the pulse generator is another important, In a fast pulse system, 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 re-reflected by the generator, causing distortion of the pulses.
- DC coupling of the output circuit is needed.

A LABORATORY TYPE SQUARE WAVE AND PULSE GENERATOR IS SHOWN IN FIG. 8.6.

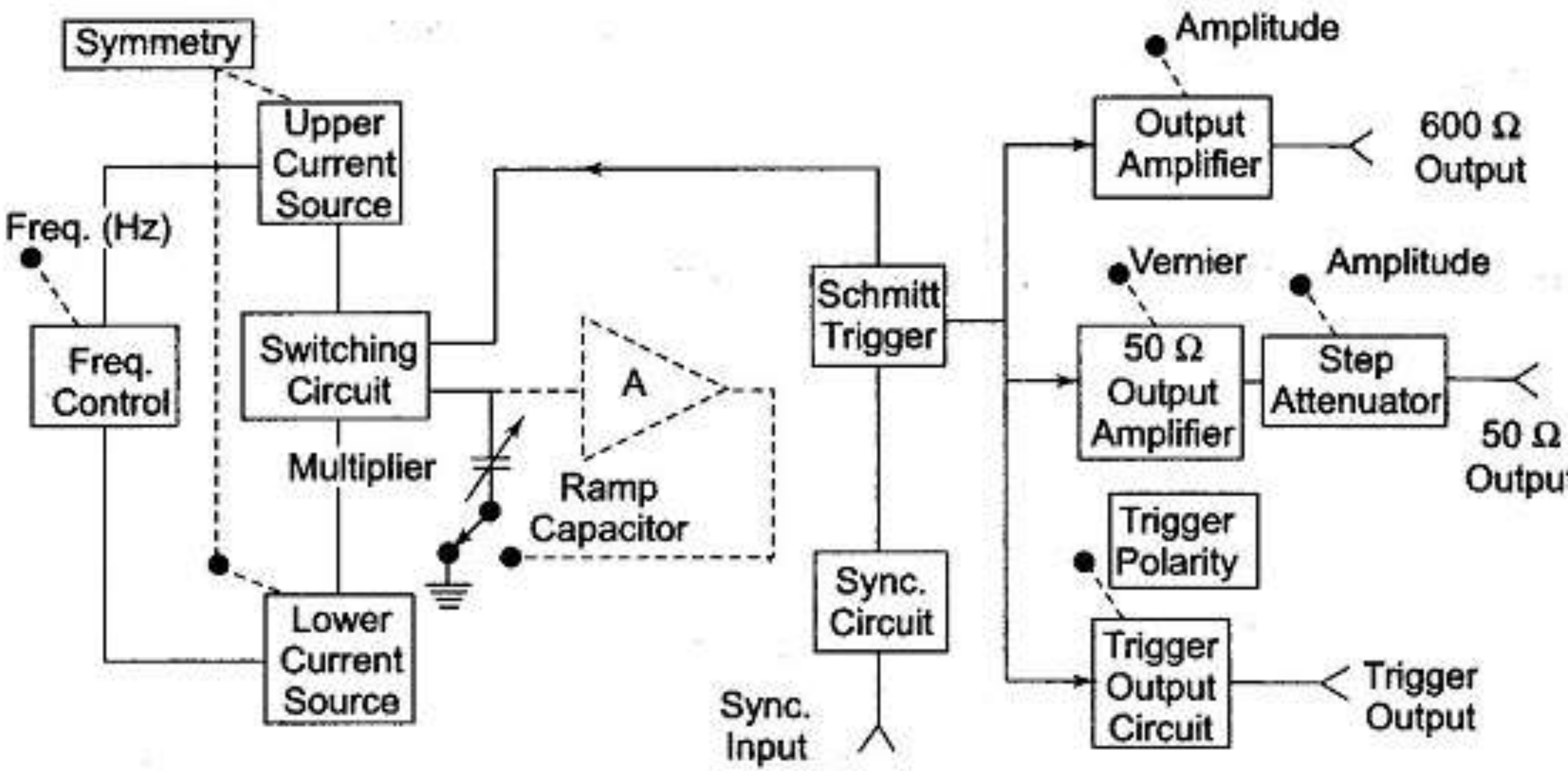


Fig. 8.6 Block Diagram of a Pulse Generator

RANDOM NOISE GENERATOR:

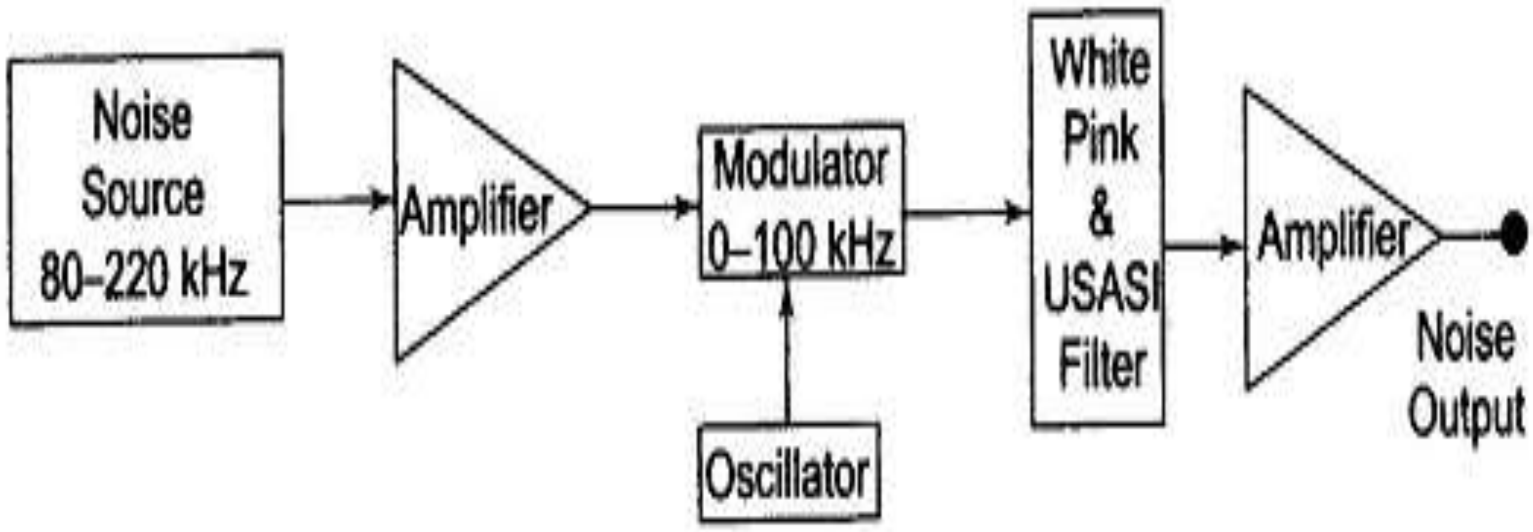


Fig. 8.8 Random Noise Generator

RANDOM NOISE GENERATOR:

The instrument offers the possibility of using a single measurement to indicate performance over a wide frequency band, instead of many measurements at one frequency at a time.

The spectrum of random noise covers all frequencies and is referred to as White noise, i.e. noise having equal power density at all frequencies (an analogy is white light).

Cont.

- ✓ The method of generating noise is usually to use a semi conductor noise diode, which delivers frequencies in a band roughly extending from 80 — 220 kHz.
- ✓ The output from the noise diode is amplified and heterodyned down to the audio frequency band by means of a balanced symmetrical modulator.
- ✓The filter arrangement controls the bandwidth and supplies an output signal in three spectrum choices, white noise, pink noise and USASI noise.

RANDOM NOISE GENERATOR

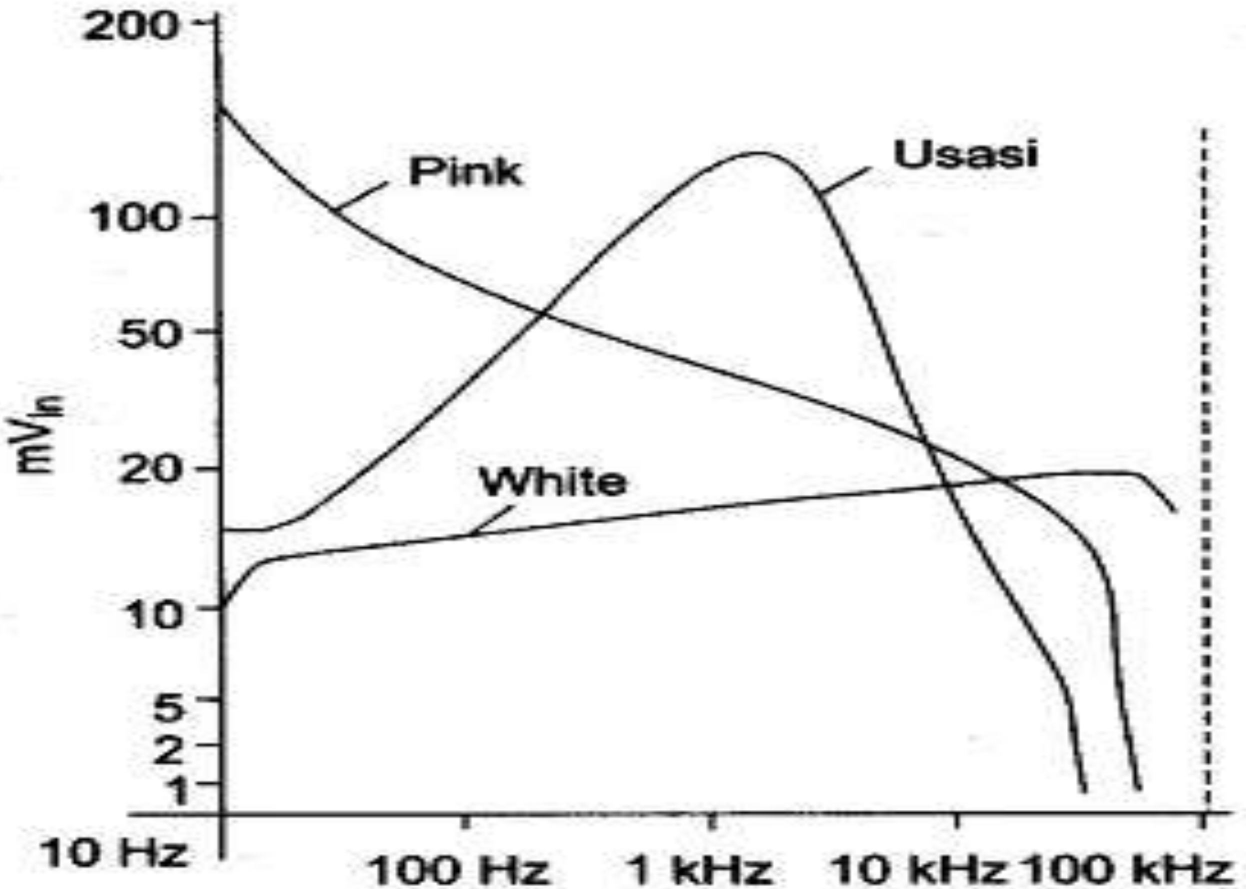


Fig. 8.9 Frequency Response

RANDOM NOISE GENERATOR

- It is seen that white noise is flat from 20 Hz to 25 kHz and has an upper cutoff frequency of 50 kHz with a cutoff slope of —12 dBs/ octave.
- Pink noise is so called because the lower frequencies have a larger amplitude, similar to red light. Pink noise has a voltage spectrum which is inversely proportional to the square root of frequency and is used in bandwidth analysis.
- Usasi noise ranging simulates the energy distribution of speech and music frequencies and is used for testing audio amplifiers and loud speakers.

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 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.

SWEEP GENERATOR

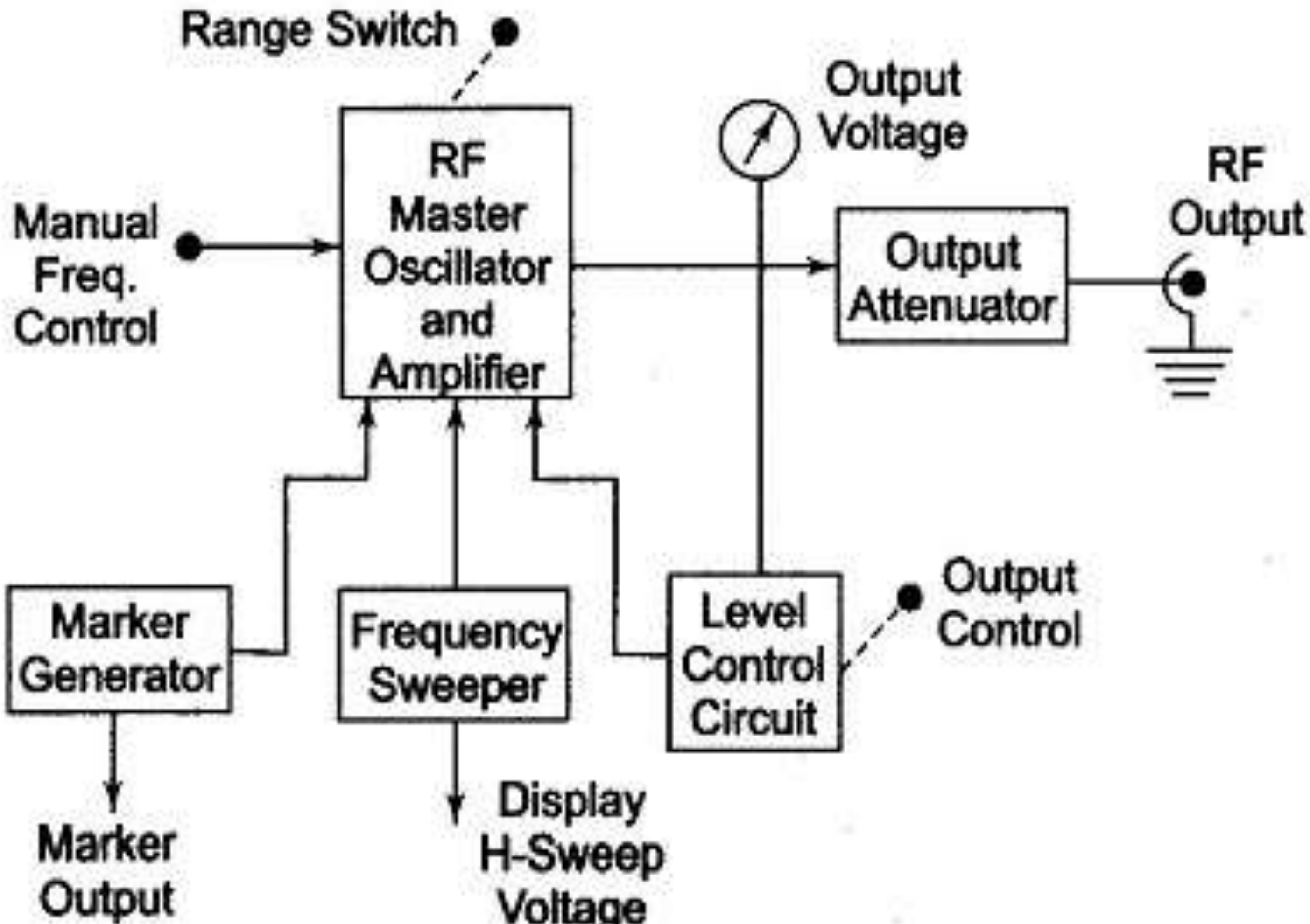


Fig. 8.10 Sweep Generator

Comparison of Analog and Digital Instruments

Analog Instruments	Digital Instruments
Output is continuous value.	Output is in discrete numerical
Indication is by pointer and scale.	Indication is by numeric display (LED
Less accurate due to parallax error.	More accurate, no parallax error
Resolution is low.	Resolution is high
Difficult to read precisely.	Easy and clear reading
Slower response	Less affected by environmental changes
Simple construction	Complex construction
Used in traditional measuring instruments	Used in modern electronic instruments

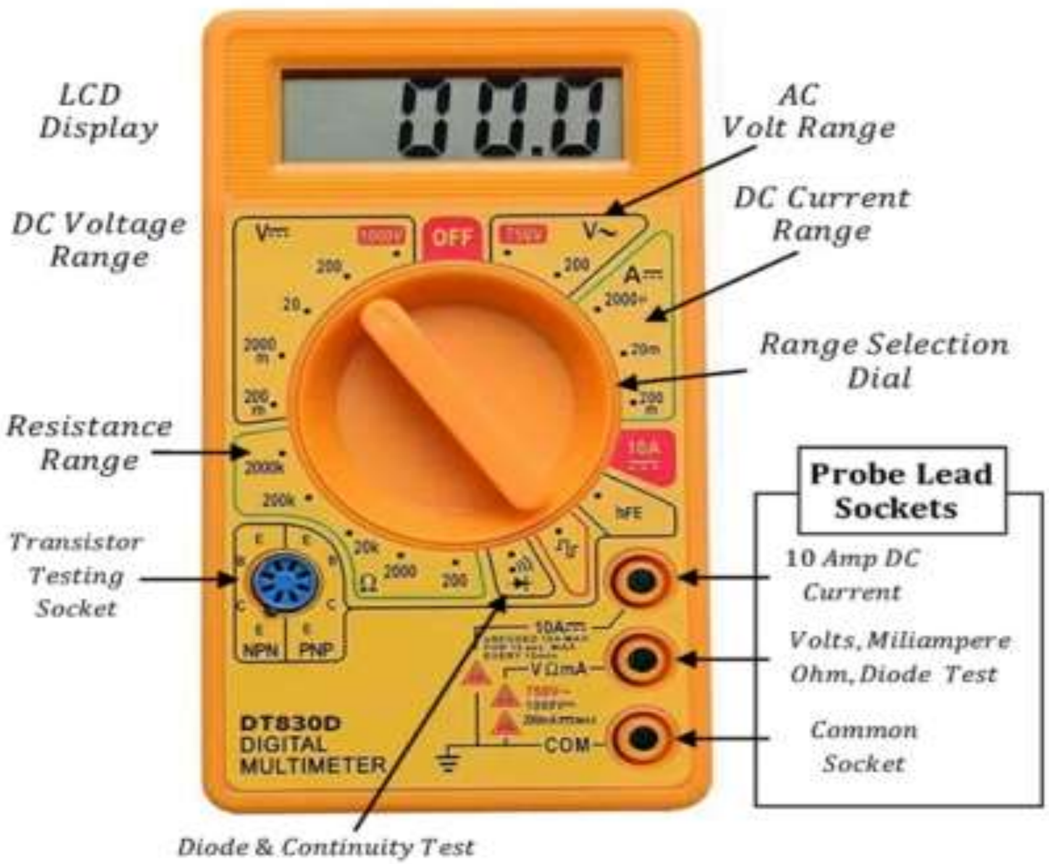
DIGITAL MULTIMETER (DMM)

- A **Digital Multimeter** is an electronic measuring instrument used to measure **DC voltage, AC voltage, DC current, AC current, resistance**, and other parameters like **continuity and diode test**.

WORKING OF DIGITAL MULTIMETER

- The unknown electrical quantity (voltage/current/resistance) is applied to the **input terminals**.
- The **range selector** sets the appropriate measurement range.
- For AC measurements, the signal is converted into DC by the **AC/DC converter**.
- The **signal conditioning circuit** processes the signal.
- The **ADC** converts the analog signal into a digital signal.
- The processed digital data is displayed on the **digital display** as a numerical value.

DIGITAL MULTIMETER (DMM)



APPLICATIONS OF DIGITAL MULTIMETER (DMM)

- Used to measure **DC and AC voltage.**
- Used to measure **DC and AC current.**
- Used to measure **resistance**.
- Used for **continuity testing** of wires and connections.
- Used for **diode and transistor testing.**
- Used in **fault finding and troubleshooting** of electronic circuits.
- Used in **laboratories, workshops, and industries**.
- Used for **maintenance and testing** of electrical and electronic equipment.

LIMITATIONS OF DIGITAL MULTIMETER (DMM)

- Requires a **power source (battery)** for operation.
- **Not suitable for very high-frequency measurements**.
- More **expensive** than analog meters.
- Sensitive to **overload and improper connections**.
- Display response may be **slow for rapidly varying signals**.
- Accuracy may be affected if the **battery is weak**.

LOGIC PROBE

- A **logic probe** is a digital test instrument used to detect the **logic state (HIGH, LOW, or PULSE)** at a point in a digital circuit.
- Logic Probes typically have 3 LED indicators that show the status of the test point.
- A logic high state (“1”) is normally shown by a red LED turning on.
- A logic low state (“0”) is normally shown by a green LED turning on.
- Digital Pulses: Some logic probes have pulse detection. When this happens, a third amber LED lights up.
- A tri-state test point (three states): Some probes also detect when the point under test does not have a defined logic state. This can happen when the circuit under test has a digital output off and there is no measurable logic level. To indicate this situation, many logic probes turn off all LEDs.

LOGIC PULSER

- A **logic pulser** is a digital test instrument used to **inject test pulses** into a digital circuit for troubleshooting.
- **Working Principle**
- The logic pulser is connected to the **power supply** of the digital circuit.
- When the **push button** of the pulser is pressed, it generates a **short-duration logic pulse**.
- The pulse can be either:
  - **Logic HIGH pulse**, or
  - **Logic LOW pulse**
- The generated pulse is applied to the **input of the digital circuit**.
- If the circuit is working correctly, the pulse will propagate through the circuit and can be observed at the output using a **logic probe or CRO**.
- If the pulse does not propagate properly, the faulty section can be identified.