MODULE 5

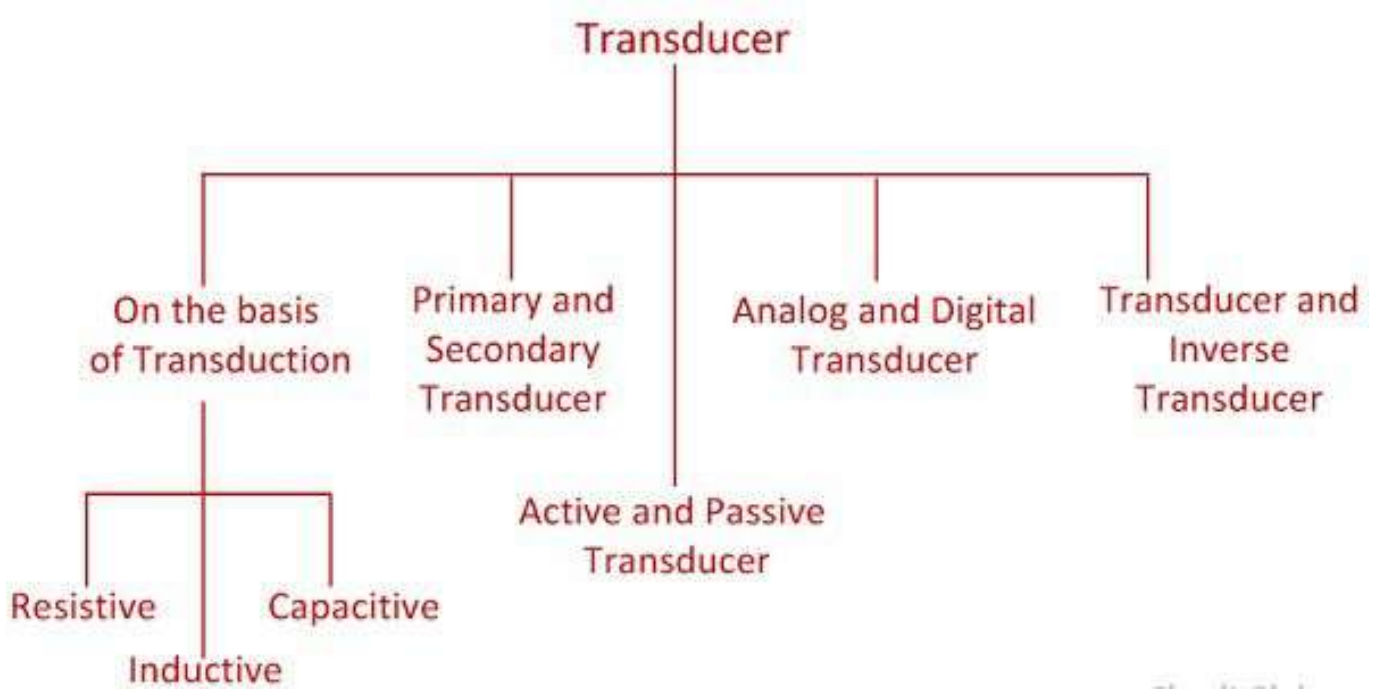
SYLLUBUS

- Transducers - Definition and classification. LVDT, Electromagnetic and Ultrasonic flowmeters, Piezoelectric transducers-modes of operation-force transducer, Load cell, Strain gauge.
- Oscilloscopes- Principal of operation of general purpose CRO- basics of vertical and horizontal deflection system, sweep generator etc. DSO-Characteristics-Probes and Probing techniques.
- Digital voltmeters and frequency meters using electronic counters, DMM, Clamp on meters.
- Phasor Measurement Unit (PMU) (description only).
- Introduction to Virtual Instrumentation systems- Simulation software’s (description only)

TRANSDUCER

- The broad definition of a transducer is that it is a device which converts the energy from one form to another.
- An **electrical transducer** is a device which is capable of converting physical quanties into a proportional electrical quantity such as voltage or electric current.
- This physical quantity which is to be measured can be pressure, temperature, displacement etc.
- The transducer is of many types, and they can be classified by the following criteria.
  - By transduction used.
  - as a primary and secondary transducer
  - as a passive and active transducer
  - as analog and digital transducer
  - as the transducer and inverse transducer

CLASSIFICATION OF TRANSDUCERS



CLASSIFICATION OF TRANSDUCERS

1. Classification based on the Principle of Transduction

- The transducer is classified by the transduction medium.
- The transduction medium may be resistive, inductive or capacitive depends on the conversion process that how input transducer converts the input signal into resistance, inductance and capacitance, respectively.

CLASSIFICATION OF TRANSDUCERS

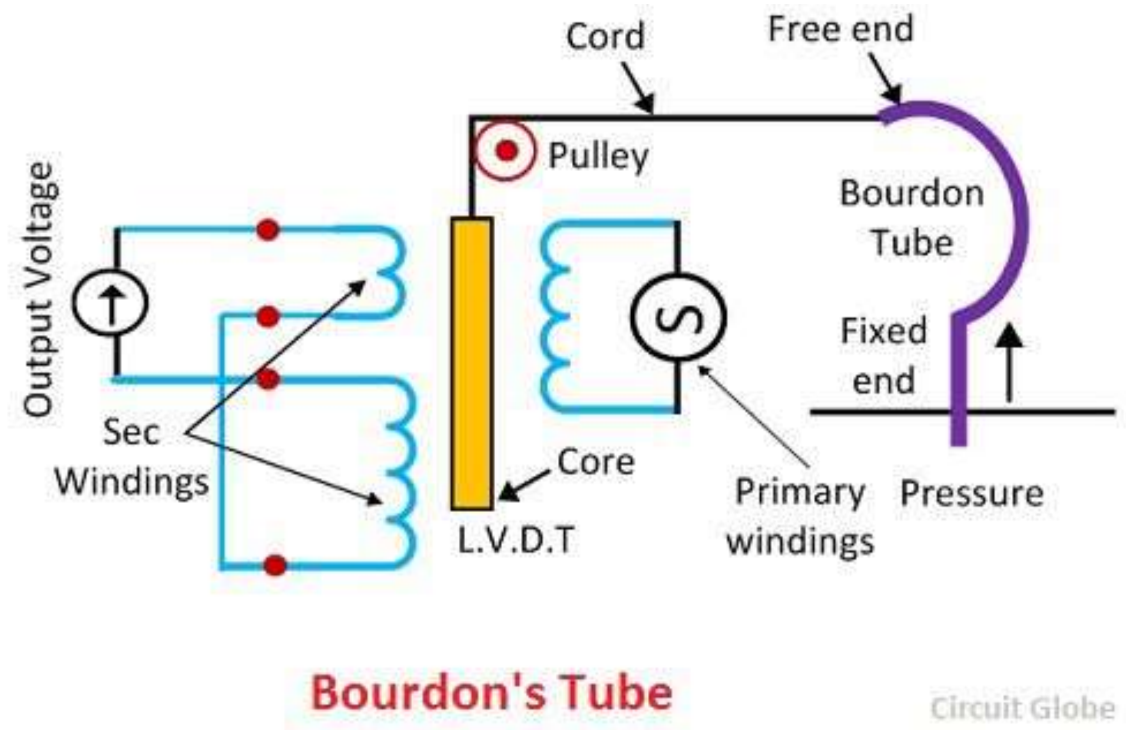
2. Primary and secondary transducer

- **Primary Transducer** – The transducer consists the mechanical as well as the electrical devices. The mechanical devices of the transducer change the physical input quantities into a mechanical signal. This mechanical device is known as the primary transducers.
- **Secondary Transducer** – The secondary transducer converts the mechanical signal into an electrical signal. The magnitude of the output signal depends on the input mechanical signal.

CLASSIFICATION OF TRANSDUCERS

- **Example of Primary and Secondary Transducer**
  - Consider the Bourdon's Tube shown in the figure below. The tube act as a primary transducer. It detects the pressure and converts it into a displacement from its free end. The displacement of the free ends moves the core of the linear variable displacement transformer. The movement of the core induces the output voltage which is directly proportional to the displacement of the tube free end.
  - Thus, the two type of transduction occurs in the Bourdon's tube. First, the pressure is converted into a displacement and then it is converted into the voltage by the help of the L.V.D.T.

CLASSIFICATION OF TRANSDUCERS



3.Active and passive transducers

- Active transducers are those which do not require any power source for their operation. They work on the energy conversion principle. They produce an electrical signal proportional to the input (physical quantity).
- For example, a thermocouple is an active transducer.
- Transducers which require an external power source for their operation is called as a passive transducer.
- For example, a photocell is a passive transducer which will vary the resistance of the cell when light falls on it. This change in resistance is converted to proportional signal with the help of a bridge circuit. Hence a photocell can be used to measure the intensity of light.

4. Analog and Digital Transducer

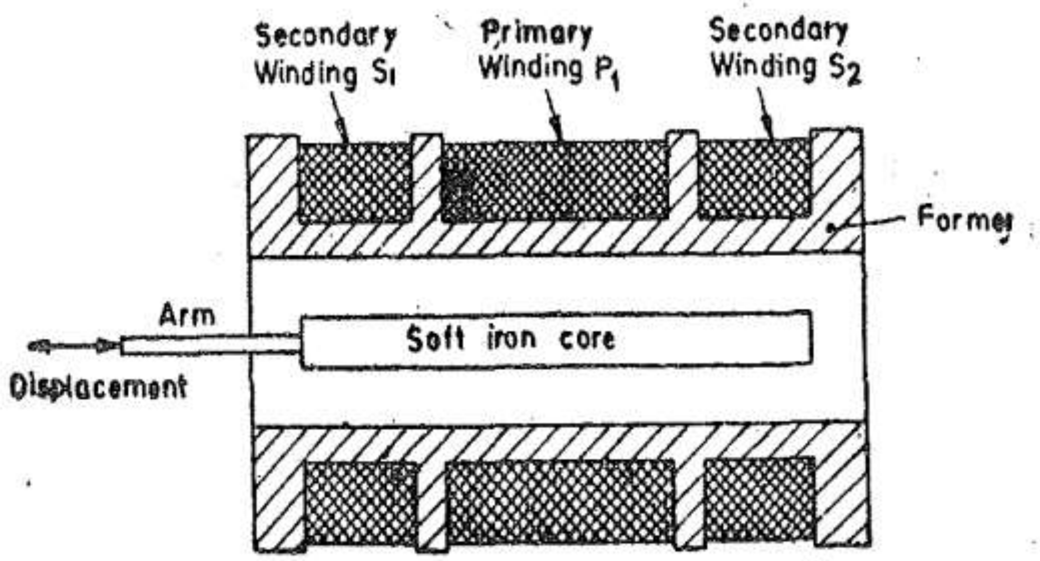
- Analog transducers converts input signal into output signal, which is a continuous function of time such as thermistor ,strain gauge, LVDT , thermocouple etc.
- Digital transducers converts input signal into the output signal in the form of pulses .It gives discrete output. These transducers are becoming more popular nowadays because of advantages associated with digital measuring instruments and also due to the fact that digital signals can be transmitted over a long distance without causing much distortion due to amplitude variation and phase shift.

5. Transducers and inverse transducers

- Transducer is a device that converts a non electrical quantity into an electrical quantity. Normally a transducer and associated circuit has a non electrical input and an electrical output. For example : a thermocouple , photo conductive cell, pressure gauge , strain gauge.
- Inverse transducer is a device that converts an electrical quantity into a non electrical quantity . For example a piezoelectric crystal and translational and angular moving coil elements can be employed as inverse transducers.

LVDT

- The most widely used inductive transducer to translate the linear motion into electrical signal is the **linear variable differential transformer (LVDT).**
- The basic construction of the LVDT h given below.



LVDT

- The transformer consists of a single primary winding P1 and two secondary windings S1 and S2 wound on a cylindrical former.
- The secondary windings have equal number of turns and are identically placed on either side of the primary winding.
- The primary winding is connected to an alternating current source. A movable soft iron core is placed inside the former.
- The displacement to be measured is applied to an arm attached to the soft iron core.
- In practice the core is made of nickel iron alloy which is slotted longitudinally to reduce eddy current losses.

LVDT

- The frequency of a.c. applied to primary windings may be between 5O Hz to 20 kHz.
- The output voltage of secondary, S1 is Es1 and that of secondary, S2, is *Es2.*
- When the core is in its normal (NULL) position equal voltages are induced in two secondary windings.
- In order to convert the outputs from s1, and S2 into a single voltage signal, the two secondaries S1 and S2 are connected in series opposition as shown in Fig. 25·38 (b).
- Thus the output voltage of the transducer is the difference of the two voltages·

LVDT

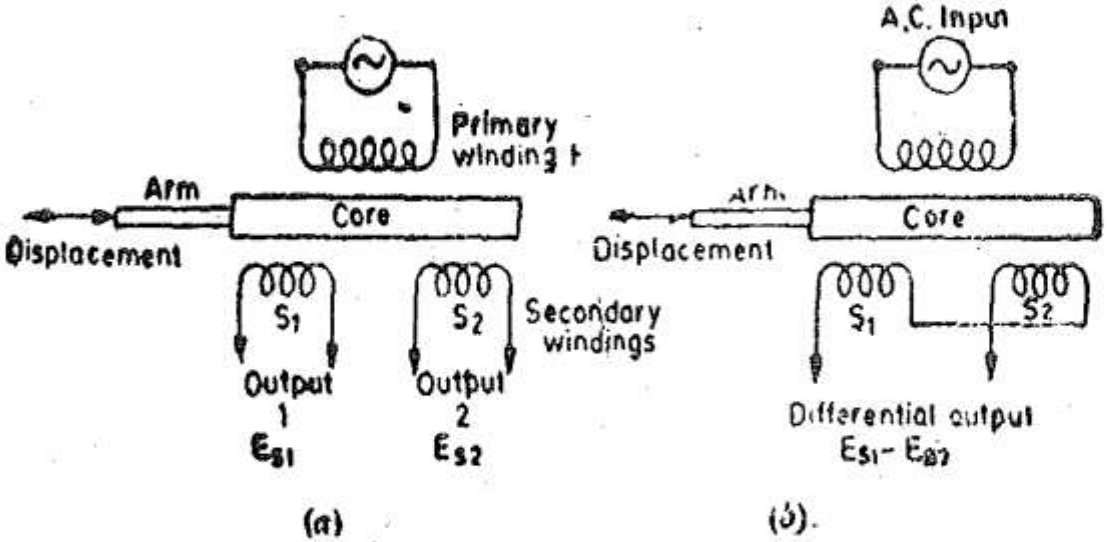


Fig. 25·38. Circuits of an LVDT.

- Differential output voltage Eo= Es1-Es2

LVDT

- When the core is at null position , the flux linking the primary and secondary is equal and equal e.m.f is induced in them.
- Thus at null position Es1=Es2
- Since the output voltage of the transducer is the difference of the two secondary voltages it is zero at null position.
- Now if the core is moved to the left of the NULL position, more flux links with winding S1 and less with winding S2. Accordingly output voltage Es1 of the secondary winding S1 is more than Es2,the output voltage of secondary winding S2.

LVDT

- The magnitude of output voltage is, thus Es1- Es2 and the output voltage is in phase with Es1.
- Similarly, if the core is moved to the right of the null position, the flux linking with winding s2 becomes larger than that linking with winding S1. This results is Es2 becoming larger than Es1.
- The output voltage in this case is Eo= Es2-Es1 and is in phase with Es2.
- The amount of voltage change in either secondary winding is proportional to the amount of movement of the core .
- Hence, we have an indication of amount of linear motion.
- By noting which output voltage is increasing or decreasing, we can determine the direction of motion.

LVDT

- The output voltage of an LVDT is a linear function of core displacement within a limited range of motion, say, about *5 mm* from the null position.
- Figure shows the variation of output voltage against displacement for various positions of core.

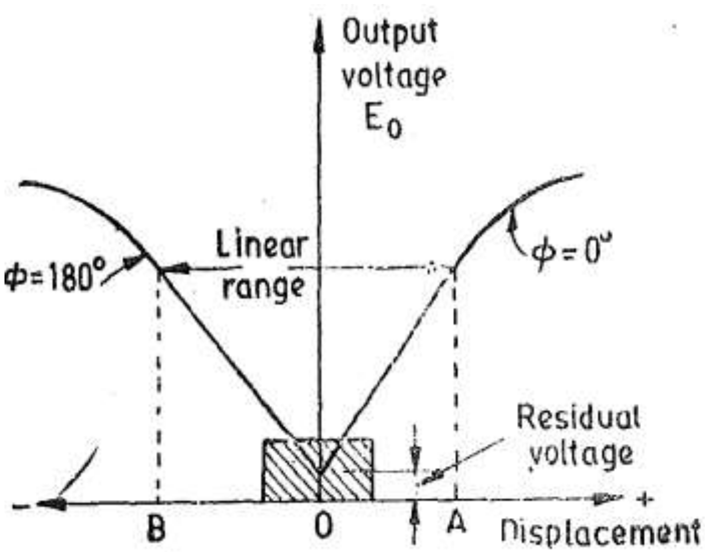


Fig. 25·39. Variation output voltage with linear displacement for an LVDT.

•The curve is practically linear for small displacements (upto about 5 mm). Beyond this range of displacement, the curve starts to deviate from straight line

LVDT

- Ideally the output voltage at the null position should be equal to zero. However, in actual practice there exist a small voltage at the null position.
- **Advantages**
  - Linearity:-The output voltage of this transducer is practically linear for displacements up to 5 mm. A linearity of 0.05% is available in commercial LVDTs.
  - Infinite resolution:-It is possible to build a transducer with a resolution as fine as 1 x 10^-3 mm.
  - High output:-It gives a high output and therefore many a times there is no need for intermediate amplification devices

LVDT

- Ruggedness:- These transducers can usually tolerate a high degree of shock and vibration.
- Less friction:- There are no sliding contacts and hence there is less friction and less noise.
- Low hysteresis:- This transducer shows a low hysteresis and hence repeatability is excellent under all conditions.
- Low power consumption:- Most of the LVDTs consume a power of less than 1 W.

LVDT

- **Disadvantages of LVDTs.**
  - Relatively large displacements are required for appreciable differential output
  - They are sensitive to stray magnetic fields but shielding is possible.
  - The receiving instrument must be selected to operate on a.c. signals
  - The transducer performance is affected by vibrations
  - Temperature affects the performance of the transducer

PIEZO-ELECTRIC TRANSDUCERS

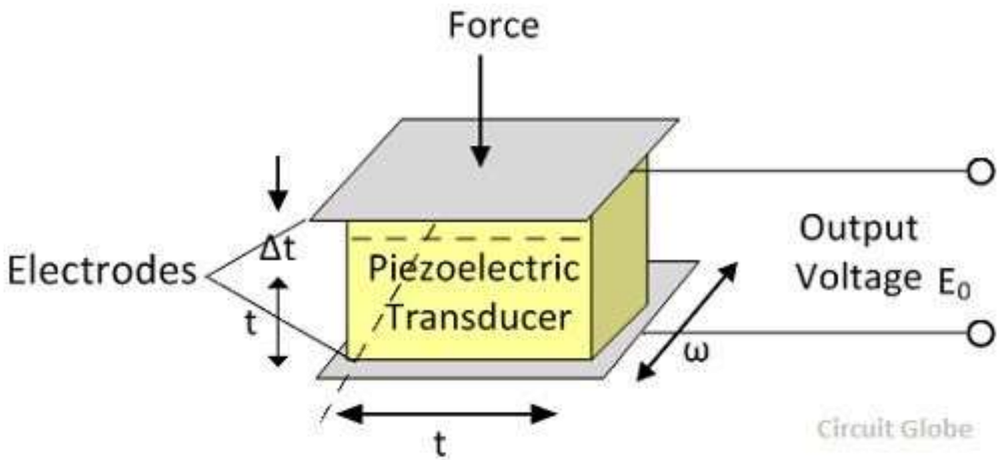
- The Piezoelectric transducer is a transducer used for conversion of pressure or mechanical stress into an alternating electrical force.
- It is used for measuring the physical quantity like force, pressure, stress, etc.
- The piezoelectric transducer uses the piezoelectric material.
- The word piezoelectric means the electricity produces by the pressure.
- A piezo-electric material is one in which an electric potential appears across certain surfaces of a crystal if the dimensions of the crystal are changed by the application of a mechanical force.

PIEZO-ELECTRIC TRANSDUCERS

- This potential is produced by the displacement of charges.
- The effect is reversible, *i.e.,* conversely, if a varying potential is applied to the proper axis of the crystal, it will change the dimensions of the crystal thereby deforming it. This effect is known as piezo -electric effect.
- Elements exhibiting piezo-electric qualities are sometimes are called as electro-resistive elements.
- Quartz is the examples of the natural piezoelectric crystals, whereas the Rochelle salts, lithium sulphate, dipotassium tartrate are the examples of the man made crystals. The ceramic material is also used for piezoelectric transducer.
- The ceramic material does not have the piezoelectric property. The property is developed on it by special polarizing treatment.

PIEZO-ELECTRIC TRANSDUCERS

- Theory of Piezo-Electric Transducer



  - A piezo-electric element used for converting mechanical motion to electrical signals may be thought as charge generator and a capacitor.
  - Mechanical deformation generates a charge and this charge appears as a voltage across the electrodes. The voltage is ,

$$E = Q/C.$$

PIEZO-ELECTRIC TRANSDUCERS

- The piezo-electric effect is direction sensitive.
- A tensile force produces a voltage of one polarity while a compressive force produces a voltage of opposite polarity.
- The magnitude and polarity of the induced surface charges are proportional to the magnitude and direction of the applied force *F*.

$$Charge\ Q = d \times F\ Coulomb$$

Where, d – charge sensitivity of the crystals

F – applied force in Newton

PIEZO-ELECTRIC TRANSDUCERS

- The force changes the thickness of the crystals.

$$F = \frac{AE}{t} \Delta t \, Netwon$$

Where A – area of crystals in meter square
t – the thickness of crystals in meter
E – Young's modulus N/m^2

The young modulus is,

$$E = \frac{stress}{strain} = \left(\frac{F}{A}\right) . \frac{1}{\Delta t / t}$$

$$E = \frac{Ft}{A \Delta t} N/m^2$$

$$A = \omega l$$

where ω – width of crystals in meter
l – the length of crystals in meter

PIEZO-ELECTRIC TRANSDUCERS

∴ From Eqns. 25·63 and 25·64, we have, charge :

$$Q = d\frac{AE}{t}\Delta t \text{ coulomb}$$

The charge at the electrodes gives rise to an output voltage E_0,

Voltage $$E_0 = \frac{Q}{C_p} \text{ volt}$$

where C_p = capacitance between electrodes ; F.

Capacitance between electrodes $C_p = \epsilon_r \epsilon_0 A/t$

From Eqns. 25·63 and 25·67 we have :

$$E_0 = \frac{dF}{\epsilon_r \epsilon_0 A/t} = \frac{dt}{\epsilon_r \epsilon_0} \cdot \frac{F}{A}$$

PIEZO-ELECTRIC TRANSDUCERS

But $\dfrac{F}{A}=P=$ pressure or stress in N/m^2.

$$\therefore \qquad E_0=\frac{d}{\epsilon_r\epsilon_0}t\,P \qquad ...(25{\cdot}69)$$

$$=g\,t\,P \qquad ...(25{\cdot}70)$$

where
$$g=\frac{d}{\epsilon_r\epsilon_0} \qquad ...(25{\cdot}71)$$

'g' is the voltage sensitivity of the crystal. This is constant for a given crystal cut. Its units are Vm/N.

Now
$$g=\frac{E_0}{t\,P}=\frac{E_0/t}{P} \qquad ...(25{\cdot}72)$$

But $E_0/t=$ electric field strength, V/m, Let $\epsilon=E_0/t=$ electric field

$$\therefore \qquad g=\frac{\text{electric field}}{\text{stress}}=\frac{\epsilon}{P} \qquad ...(25{\cdot}73)$$

From Eqn. 25·71,

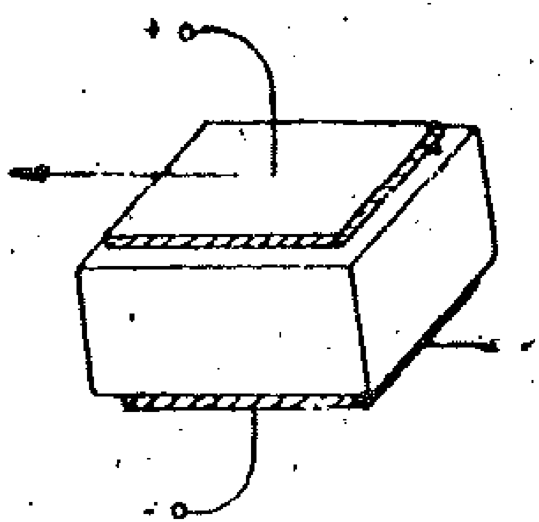
Charge sensitivity
$$d=\epsilon_r\,\epsilon_0\,g \quad \text{F/N} \qquad ...(25{\cdot}74)$$

MODES OF OPERATION OF PIEZO-ELECLRIC CRYSTALS

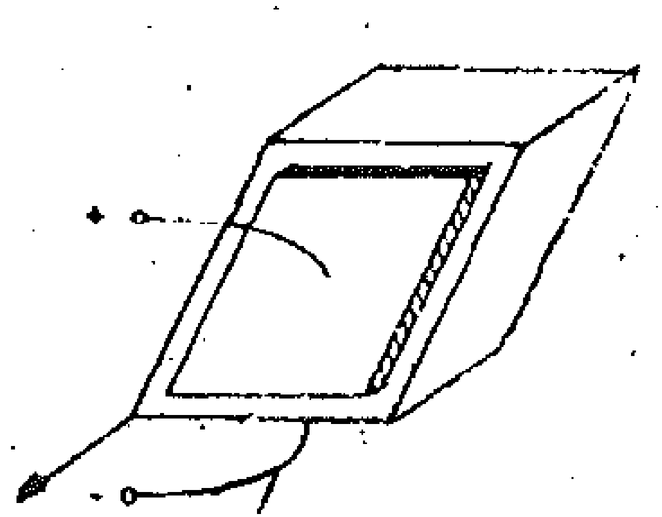
- The piezo-electric crystals are used in many modes. These modes are :

  (i) Thickness shear

  ii) Face shear



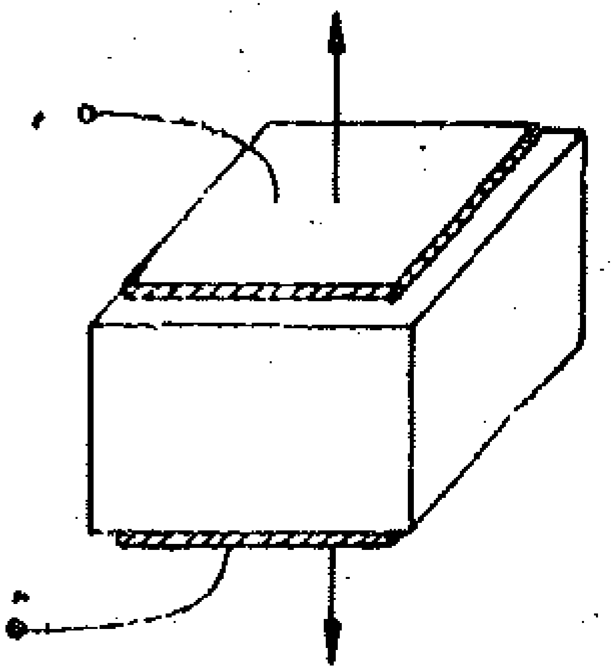
a) Thickness shear



b) Face shear

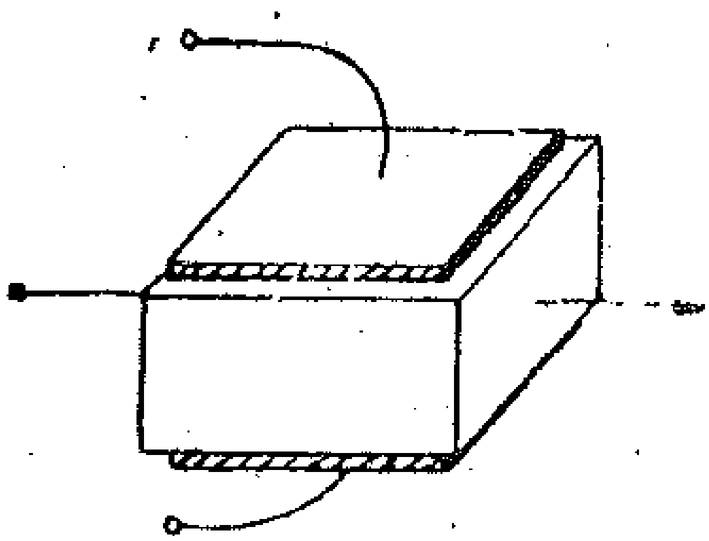
MODES OF OPERATION OF PIEZO-ELECLRIC CRYSTALS

(iii) Thickness expansion



c) Thickness expansion

(iv) Transverse expansion



d) Transverse expansion

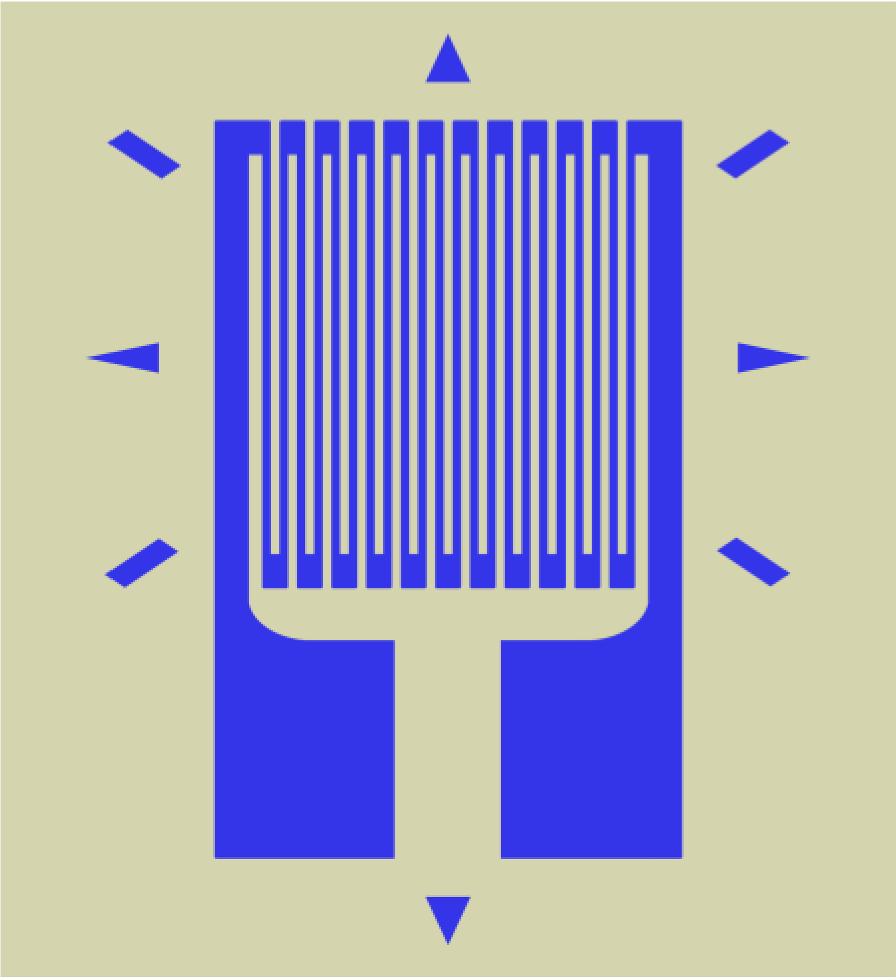
PROPERTIES OF PIEZO- ELECTRIC CRYSTAL

- The piezoelectric material has high stability.
- It is available in various shapes and sizes.
- The piezoelectric material has output insensitive to temperature and humidity.

STRAIN GAUGES

- If a metal conductor is stretched or compressed, its resistance changes on account of the fact that both length and diameter of conductor change.
- Also there is a change in the value of resistivity of the conductor when it is strained and this property is called piezo resistive effect.
- Therefore, resistance strain gauges are also known as piezo resistive gauges.
- The strain gauges are used for measurement of strain and associated stress in experimental stress analysis.
- Secondly, many other detectors and transducers like load cells, torque meters, pressure gauges, temperature sensors, accelerometers and flow meters, employ strain gauges as secondary transducers.

STRAIN GAUGES



STRAIN GAUGES

- Theory of strain gauges
  - If a strip of elastic material is subjected to tension, or in other words positively strained, its longitudinal dimension will increase while there will be a reduction in the lateral dimension .
  - So when a gauge is subjected to a positive strain, its length increases while its area of cross-section decreases.
  - Since the resistance of a conductor is proportional to its length and inversely proportional to its area of cross section, the resistance of the gauge increases with positive strain.

STRAIN GAUGES

- The change in the value resistance of strained conductor is more than what can be accounted for an increase in resistance due to dimensional changes.
- The extra change in the value of resistance is attributed to a change in the value of resistivity of a conductor when strained.
- Let us consider a strain gauge made of circular wire . The wire has the dimensions ; length=L, area= *A, diameter=D before being strained. The material of the wire has a resistivity ρ.

  :. Resistance of unstrained gauge R=pL/A.
- Let a tensile stress *be applied to the wire. This produces a positive strain causing the length* to increase and area to decrease. Thus when the wire is strained there are changes in its dimensions.

STRAIN GAUGES

- Let ΔL=change in length, ΔA =change in area, ΔD=change in diameter and Δ R= change in resistance,

In order to find how ΔR depends upon the meterial physical quantities, the expression for R is differentited with respect to stress s. Thus we get :

$$\frac{dR}{ds}=\frac{\rho}{A}\frac{\partial L}{\partial s}-\frac{\rho L}{A^2}\frac{\partial A}{\partial s}+\frac{L}{A}\frac{\partial \rho}{\partial s} \qquad \ldots(25{\cdot}20)$$

Dividing Eqn. 25·20 throughout by resistance $R=\rho L/A$, we have

$$\frac{1}{R}\frac{dR}{ds}=\frac{1}{L}\frac{\partial L}{\partial s}-\frac{1}{A}\frac{\partial A}{\partial s}+\frac{1}{\rho}\frac{\partial \rho}{\partial s} \qquad \ldots(25{\cdot}21)$$

It is evident from Eqn. 25·21, that the per unit change in resistance is due to :

(*i*) per unit change in length$=\Delta L/L$. (*ii*) per unit change in area$=\Delta A/A$.

Area $\quad A=\frac{\pi}{4}D^2 \qquad \therefore \quad \frac{\partial A}{\partial s}=2.\frac{\pi}{4}D.\frac{\partial D}{ds} \qquad \ldots(25{\cdot}22)$

or

$$\frac{1}{A}\frac{dA}{ds}=\frac{(2\pi/4)D}{(\pi/4)D^2}\frac{\partial D}{\partial s}=\frac{2}{D}\frac{\partial D}{\partial s} \qquad \ldots(25{\cdot}23)$$

STRAIN GAUGES

$\therefore$ Eqn. 25·21 can be written as :

$$\frac{1}{R}\frac{dR}{ds}=\frac{1}{L}\frac{\partial L}{\partial s}-\frac{2}{D}\frac{\partial D}{\partial s}+\frac{1}{\rho}\frac{\partial \rho}{\partial s} \quad ...(25·24)$$

Now, Poisson's ratio $\nu=\frac{\text{lateral strain}}{\text{longitudinal strain}}=-\frac{\partial D/D}{\partial L/L}$ ...(25·25)

or $\partial D/D=-\nu\times\partial L/L$

$$\therefore \quad \frac{1}{R}\frac{dR}{ds}=\frac{1}{L}\frac{\partial L}{\partial s}+\nu\frac{2}{L}\frac{\partial L}{\partial s}+\frac{1}{\rho}\frac{\partial \rho}{\partial s} \quad ...(25·26)$$

For small variations, the above relationship can be written as :

$$\frac{\Delta R}{R}=\frac{\Delta L}{L}+2\nu\frac{\Delta L}{L}+\frac{\Delta\rho}{\rho} \quad ...(25·27)$$

STRAIN GAUGES

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

Gauge factor $$G_f = \frac{\Delta R/R}{\Delta L/L} \quad \text{...(25·28)}$$

or $$\frac{\Delta R}{R} = G_f \frac{\Delta L}{L} = G_f \times \epsilon \quad \text{...(25·29)}$$

where $$\epsilon = \text{strain} = \frac{\Delta L}{L}$$

The gauge factor can be written as :

$$G_f = \frac{\Delta R/R}{\Delta L/L} = 1 + 2\nu + \frac{\Delta \rho/\rho}{\Delta L/L} = 1 + 2\nu + \frac{\Delta \rho/\rho}{\epsilon} \quad \text{...(25·30)}$$

The strain is usually expressed in terms of microstrain. 1 microstrain = 1 μm/m.

If the change in the value of resistivity of a material when strained is neglected, the gauge factor is :

$$G_f = 1 + 2\nu \quad \text{...(25·31)}$$

STRAIN GAUGES

- The equation 25.30 is valid only when. *change in resistivity due to strain is* almost negligible (Piezoresistive Effect *is negligible)*.

PROBLEM

Example 25'7. A resistance wire strain gauge uses a soft iron wire of small diameter. The gauge factor is +4'2. Neglecting the piezoresistive effects, calculate the Poisson's ratio.

Solution. The gauge factor is given by Eqn. 25'30, $G_f = 1 + 2\nu + \frac{\Delta\rho/\rho}{\epsilon}$

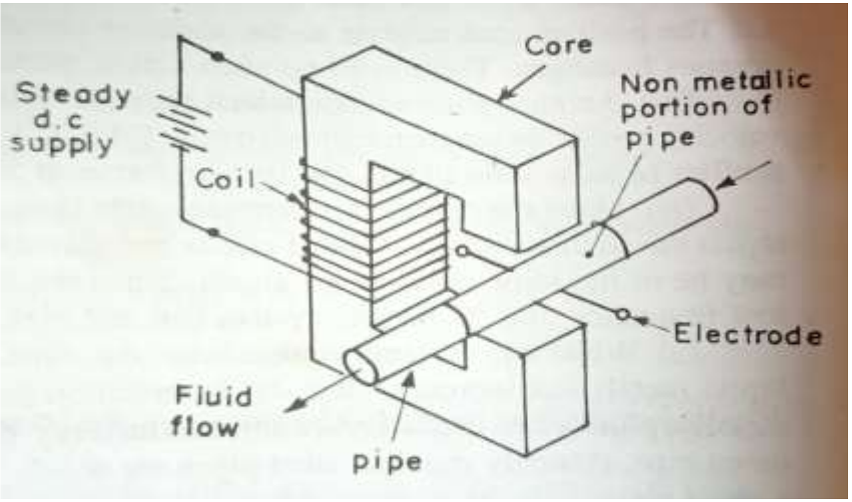
If piezoresistive effect is neglected, the gauge factor is given by Eqn. 25'32 as : $G_f = 1 + 2\nu$

$\therefore$ Poisson's ratio $\nu = \frac{G_f - 1}{2} = \frac{4'2 - 1}{2} = 1'6.$

ELECTROMAGNETIC FLOW METERS

- Electromagnetic Flow Meters, simply known as mag flow meter is a volumetric flow meter which is used for flow measurements of slurries ,sludge and any electrically conducting liquid
- Magnetic flow meters works based on Faraday's Law of Electromagnetic Induction. According to this principle, when a conductive medium passes through a magnetic field B, a voltage E is generated which is proportional to the velocity v of the medium, magnetic flux density and length of the conductor.

ELECTROMAGNETIC FLOW METERS



- It consist of a pair of electrodes connected in the opposite sides of a non-magnetic non-conducting pipe carrying the liquid whose flow is to be measured.
- The pipe is surrounded by an electromagnet which produces a magnetic field.
- The liquid flowing through the pipe acts as the conductor and this induces a voltage across the electrodes which is proportional to the average flow velocity.

ELECTROMAGNETIC FLOW METERS

- Mathematically, we can state Faraday's law as E= Blv
- E is the voltage generated in a conductor, V is the velocity of the conductor, B is the magnetic field strength and l is the length of the conductor.
- It is very important that the liquid flow that is to be measured using the magnetic flow meter must be electrically conductive.
- If magnetic field is assumed to be constant, then then the voltage appearing across the electrode will be directly proportional to velocity.

ELECTROMAGNETIC FLOW METERS

- Advantages
  - If powerful magnetic field is provided, it can be used to measure flow of pipe in any size.
  - There is now obstruction to flow that may cause pressure drops
  - Output voltage is linearly rated to the input.
  - Output is unaffected by changes in characteristics of liquid such as viscosity, pressure and temperature

ELECTROMAGNETIC FLOW METERS

- Limitations of electromagnetic Flow Meters
  - The substance being measured must be conductive. Therefore, it can’t be employed for metering the flow rate of gases and steam, petroleum products and similar liquids having very low conductivity.
  - It is a very expensive device.

ULTRASONIC FLOW METER

29.40.5. Ultrasonic Flow Transducer. Basically an ultrasonic transducer for flow rate consists of two piezoelectric crystals in the liquid or gas separated by a distance. One of crystal acts as a transmitter and ther other as a receiver.

The transmitter emits an ultrasonic pulse which is received at the receiver a time Δt later. The transit time in the direction of flow is,

$$\Delta t_1 = \frac{d}{c + v} \qquad \text{...(29.80)}$$

where
d = distance between transmitter and receiver ; m)
c = velocity of sound propagation in medium ; m/s,
v = linear velocity of flow ; m/s.

When the signal is travelling in the opposite direction against the flow

$$\Delta t_2 = \frac{d}{c - v} \qquad \text{...(29.81)}$$

ULTRASONIC FLOW METER

Similarly a sinusoidal signal of frequency f Hz travelling in the flow direction has a phase shift of :

$$\Delta\phi_1 = \frac{2\pi f d}{c + v} \text{ rad} \quad \text{...(29.82)}$$

and that travelling against the direction of flow has a phase shift of :

$$\Delta\phi_2 = \frac{2\pi f d}{c - v} \text{ rad} \quad \text{...(29.83)}$$

Velocity can, therefore, be determined by either measuring the transit time or the phase shift.

Fig. 29.87 shows a system which can be used external to the pipe carrying the liquid. T and R are respectively transmitting and receiving crystals. They are either pressed to the exterior of pipe or are immersed in the liquid so that the signal is transmitted through the liquid.

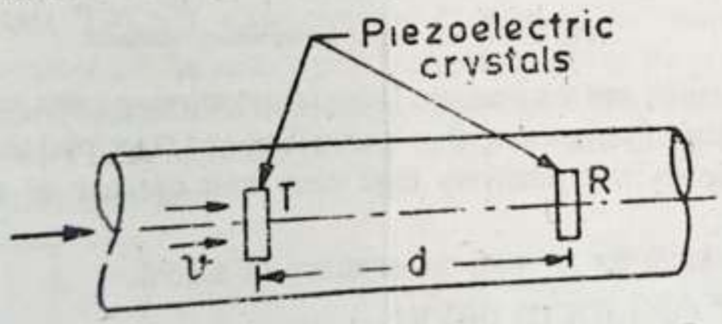


Fig. 29.87. Ultrasonic method for measurement of flow.

ULTRASONIC FLOW METER

The oscillator provides a sinusoid signal of about 100 kHz to crystal T whereas crystal R acts as the receiver. The functions of T and R are reversed periodically by a commutating switch.

The difference in transit times is,

$$\Delta t = \Delta t_2 - \Delta t_1 = \frac{2dv}{c^2 - v^2} \qquad \text{...(29.84)}$$

This is measured by a phase sensitive detector driven synchronously with the commutator. Usually $c >> v$.

$$\therefore \qquad \Delta t \approx \frac{2dv}{c^2} \qquad \text{...(29.85)}$$

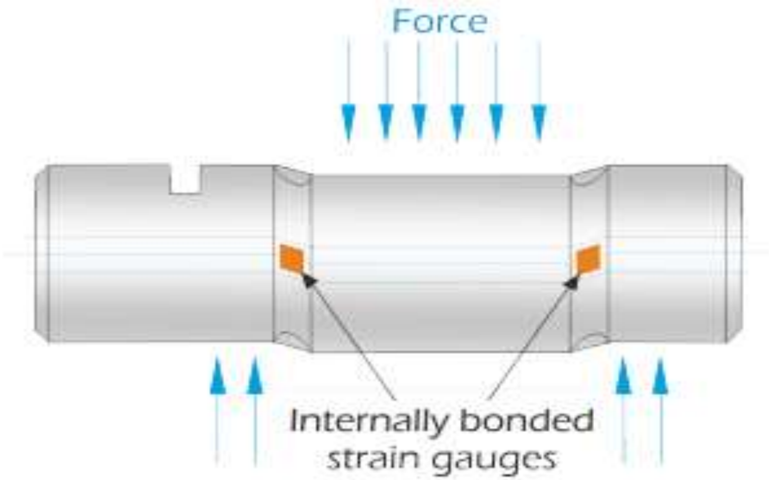
Hence, time Δt is linearly proportional to flow velocity v. This system, though gives a linear relationship,

LOAD CELL

- A load cell is a highly accurate device that is used to measure weight or force in a number of different applications.
- They can be used to measure compression, tension, bending or shear forces.
- Within the load cell structure is an area, or group of areas, which are designed to be stressed when a load/force is applied, normally in a linear fashion.
- Strain gauges manufactured from metal foil are bonded to these areas to sense the strain in the load cell structure under the applied load or pressure, and then provide a electrical output signal proportional to the strain when excited by a regulated voltage or current source.

LOAD CELL

•This signal is usually only a few millivolts and usually requires amplification before it can be read.



CATHODE RAY OSCILLOSCOPE (CRO)

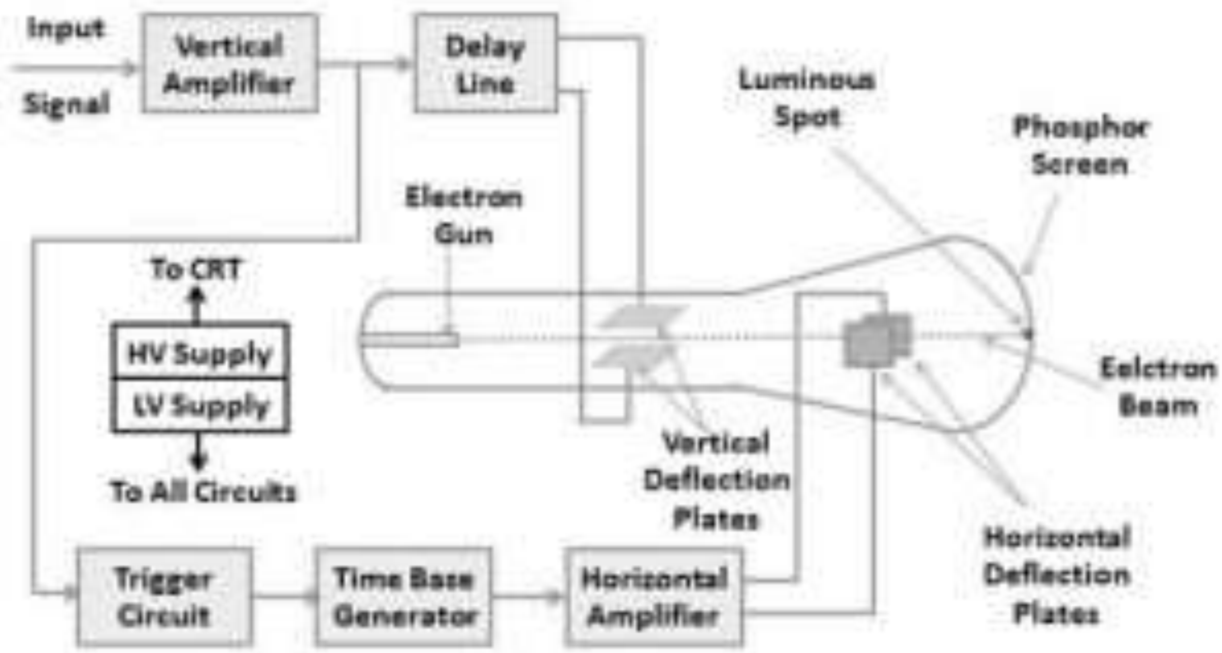
- The cathode ray oscilloscope (CRO) is a type of electrical instrument which is used for showing the measurement and analysis of waveforms and others electronic and electrical phenomenon.
- It is a very fast X-Y plotter shows the input signal versus another signal or versus time.
- The CROs are used to analyse the waveforms, transient, phenomena, and other time varying quantities from a very low-frequency range to the radio frequencies.

CATHODE RAY OSCILLOSCOPE (CRO)

- The CRO is mainly operated on voltages. Thus, the other physical quantity like current, strain, acceleration, pressure, are converted into the voltage with the help of the transducer and thus represent on a CRO.

CATHODE RAY OSCILLOSCOPE (CRO)

- The following **block diagram shows the general-purpose CRO**



CATHODE RAY OSCILLOSCOPE (CRO)

- The instrument employs a **cathode ray tube** (CRT), which is the heart of the oscilloscope.
- It generates the electron beam, accelerates the beam to a high velocity, deflects the beam to create the image, and contains a phosphor screen where the electron beam eventually becomes visible.
- For accomplishing these tasks various electrical signals and voltages are required, which are provided by the power supply circuit of the oscilloscope.
- Low voltage supply is required for the heater of the electron gun for generation of electron beam and high voltage, of the order of few thousand volts, is required for cathode ray tube to accelerate the beam.
- Normal voltage supply, say a few hundred volts, is required for other control circuits of the oscilloscope.

CATHCATHODE RAY OSCILLOSCOPE (CRO)

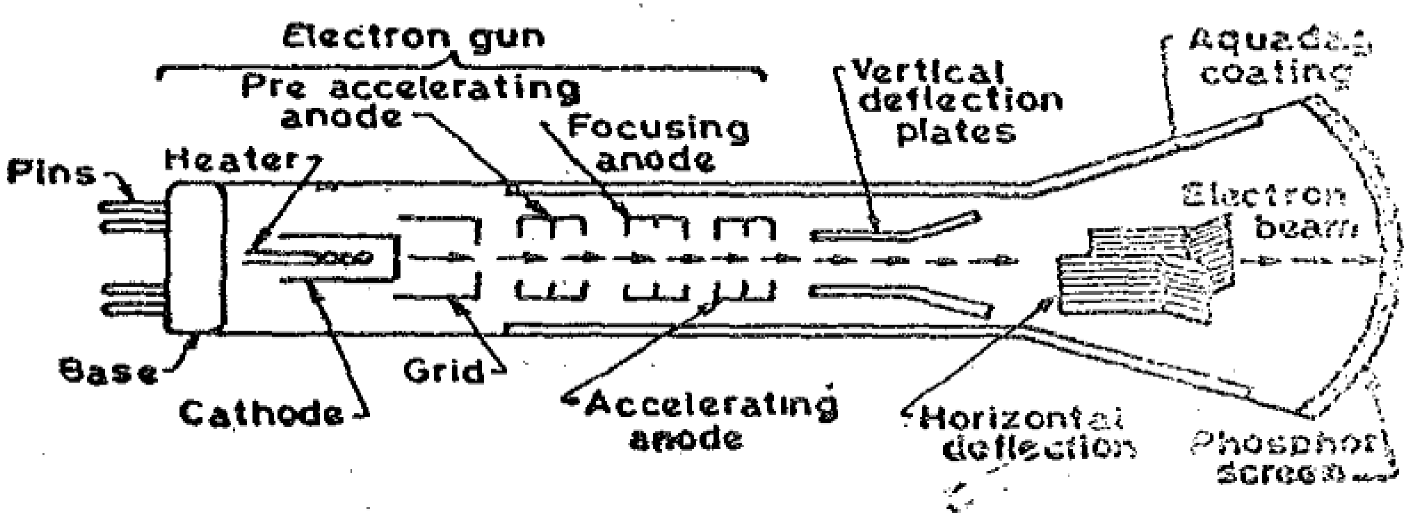


Fig. 21·1. Internal structure of a CRT.

- A cathode ray oscilloscope consists of a cathode ray tube (CRT), which is the heart of the tube, and some additional circuitry to operate the CRT.

CATHODE RAY OSCILLOSCOPE (CRO)

- The main parts of a CRT are :
  - (i) Electron gun assembly,
  - (ii) Deflection plate assembly,
  - (iii) Fluorescent screen,
  - (iv) Glass envelope,
  - (v) Base, through which connections are made to various parts.

CATHODE RAY OSCILLOSCOPE (CRO)

- The source of focused and accelerated electron beam is the electron gun.
- The electron gun, which emits electrons and forms them into a beam.
- It consists of a heater, a cathode, a grid, a pre-accelerating anode, a focusing anode and an accelerating anode.
- Electrons are emitted from the indirectly heated cathode. A layer of barium and strontium oxide is deposited on the end of the cathode-which is a cylinder-to obtain high emission of electrons at moderate temperatures.
- These electrons pass through a small hole in the "control grid".

CATHODE RAY OSCILLOSCOPE (CRO)

- This control grid is usually a nickel cylinder, with a centrally located hole,-co-axial with the CRT axis.
- The intensity of electron beam depends upon the number of electrons emitted from the cathode.
- The grid with its negative bias controls the number of electrons emitted from the cathode and hence the intensity is controlled by the grid.
- The electrons, emitted from the cathode and passing through the hole in the control grid are accelerated by the high positive potential which is applied to the "pre-accelerating" and "accelerating anodes“.

CATHODE RAY OSCILLOSCOPE (CRO)

- The electron beam is focused by the "focusing anode".
- The accelerating and focusing anodes are cylindrical in form, with small openings located in the centre of each electrode, coaxial with the tube axis.
- After leaving the focusing anodes, the electron beam passes through the vertical and horizontal deflection plates and then goes on to the fluorescent screen.
- There are two methods of focusing an electron beam :
  - (i) Electrostatic focusing and
  - (ii) Electromagnetic focusing.
- The CRO uses electrostatic method of focusing.

CATHODE RAY OSCILLOSCOPE (CRO)

- Horizontal and vertical deflection plates are fitted between electron gun and screen to deflect the beam according to input signal.
- Electron beam strikes the screen and creates a visible spot. This spot is deflected on the screen in horizontal direction (X-axis) with constant time dependent rate.
- This is accomplished by a time base circuit provided in the oscilloscope.
- The signal to be viewed is supplied to the vertical deflection plates through the vertical amplifier, which raises the potential of the input signal to a level that will provide usable deflection of the electron beam.

CATHODE RAY OSCILLOSCOPE (CRO)

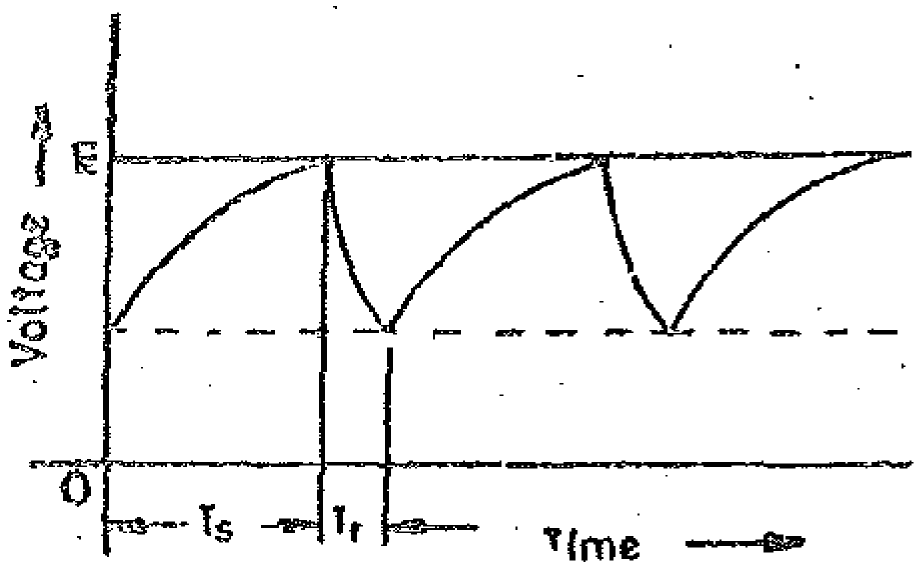
- Now electron beam deflects in two directions, horizontal on X-axis and vertical on Y-axis.
- A triggering circuit is provided for synchronizing two types of deflections so that horizontal deflection starts at the same point of the input vertical signal each time it sweeps.
- The front of the CRT is called the face plate.
- The internal surface of the faceplate is coated with the phosphor. The phosphorous converts the electrical energy into light energy.
- The energy level of the phosphorous crystal raises when the electron beams strike on it.
- The light which is emitted through phosphorous excitation is called fluorescence. When the electron beam stop, the phosphorous crystal regain their original.

TIME BASE GENERATORS/ SWEEP GENERATORS

- Most of the CRO applications involve measurement or display of a quantity which varies with respect to time.
- This requires that the CRT spot move across the screen from left to right with a constant velocity.
- In order that the beam deflect linearly from left to right, ramp voltages are applied to horizontal deflection or *X plates.*
- *The circuits which develop* these ramp voltage are called time base generators or sweep generators.
- The output of a sweep generator is called a sweep voltage.

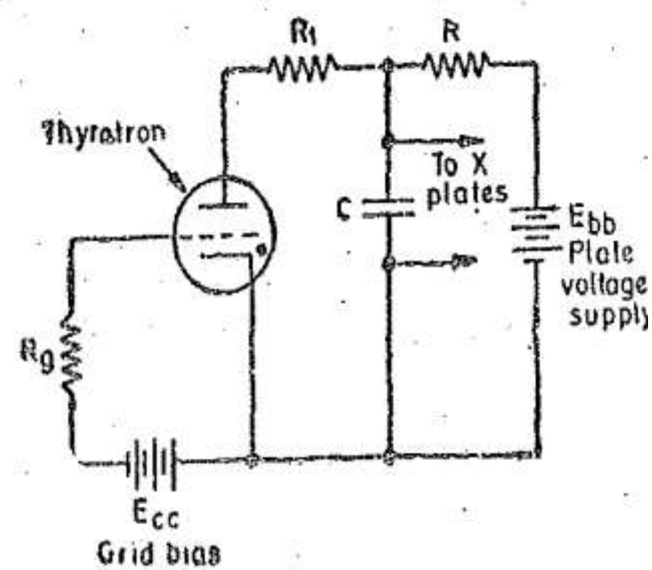
TIME BASE GENERATORS/ SWEEP GENERATORS

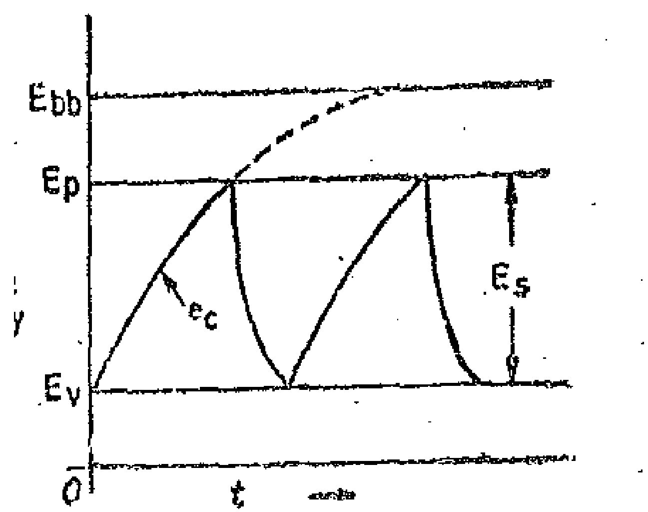
- This voltage, starting from some initial value, increases linearly with time, to a maximum value, after which it again returns to its initial value.
- Time Ts is called the sweep time while time Tr is called the retrace time or flyback time.



TIME BASE GENERATORS/ SWEEP GENERATORS

- A simple sweep generator uses an RC circuit wherein a switch is used to charge and discharge a capacitor.
- The switch may be a vacuum tube, a gas filled tube, a SCR, a transistor or any other semi-conducting device depending upon the application, speed required, and many other factors.

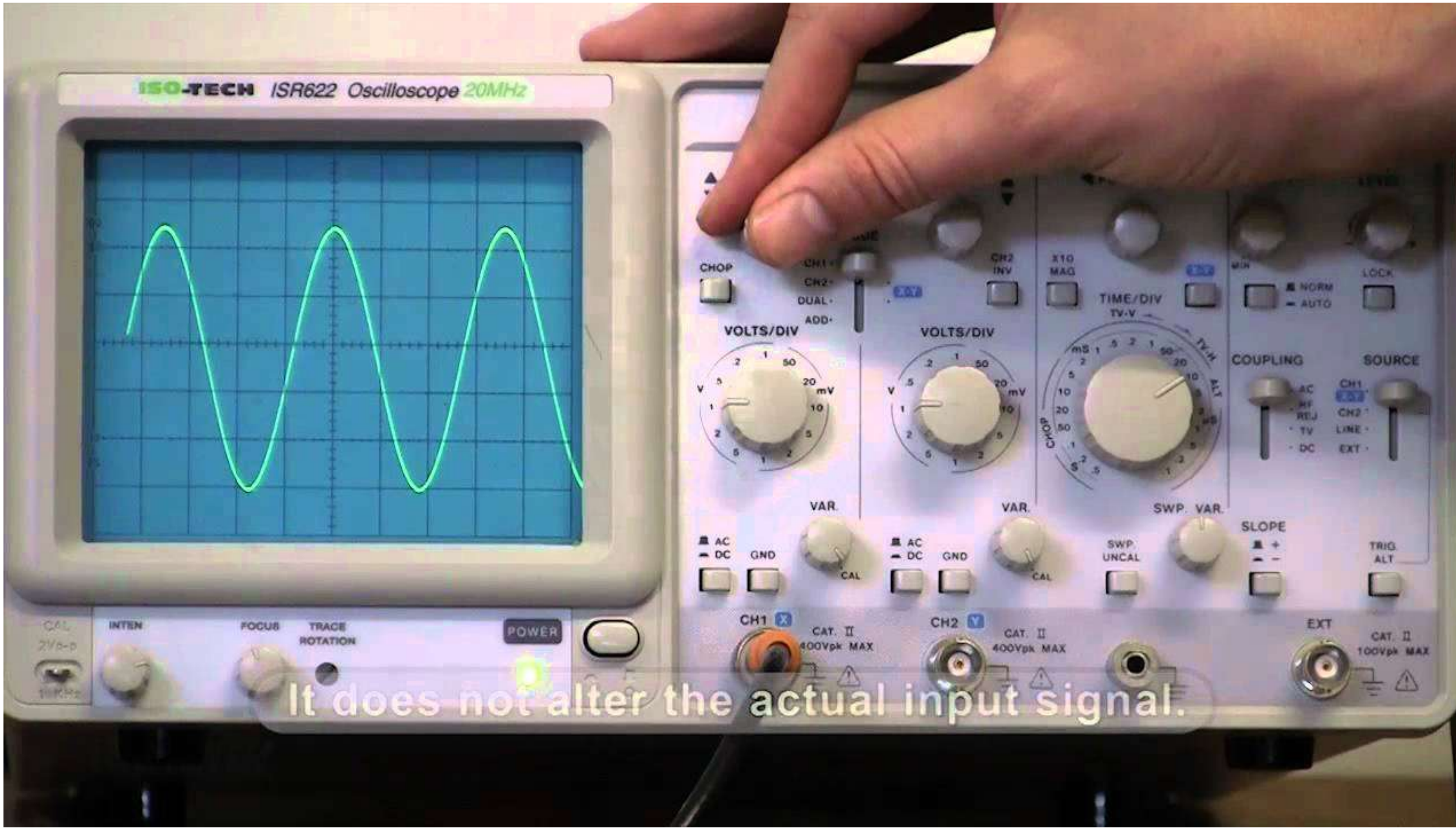




TIME BASE GENERATORS/ SWEEP GENERATORS

- Figure shows a sweep generator using a thyratron. Capacitor C charges exponentially through R, approaching the supply voltage Ebb .
- When the plate voltage reaches a value Ep which corresponds to breakdown voltage, the thyratron ionizes and conducts heavily.
- The capacitor discharges rapidly through the tube and resistance R1 till the capacitor voltage drops to a value Ev, which is the ionization potential of the thyratron.
- At this voltage the thyratron stops conducting and presents an infinite resistance and the capacitor starts charging again through resistance R.
- When its voltage reaches Ep, it discharges again. This process repeats itself, and the voltage ec, across the capacitor is a saw tooth wave. This voltage is fed to the X plates.

MEASUREMENT OF VOLTAGE,CURRENT AND FREQUENCY USING CRO



MESUREMENT OF PHASE-LISSAJOUS PATTERN

- The patterns that appear on the screen of a CRT when sinusoidal voltages are simultaneously applied to horizontal and vertical plates are called '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.

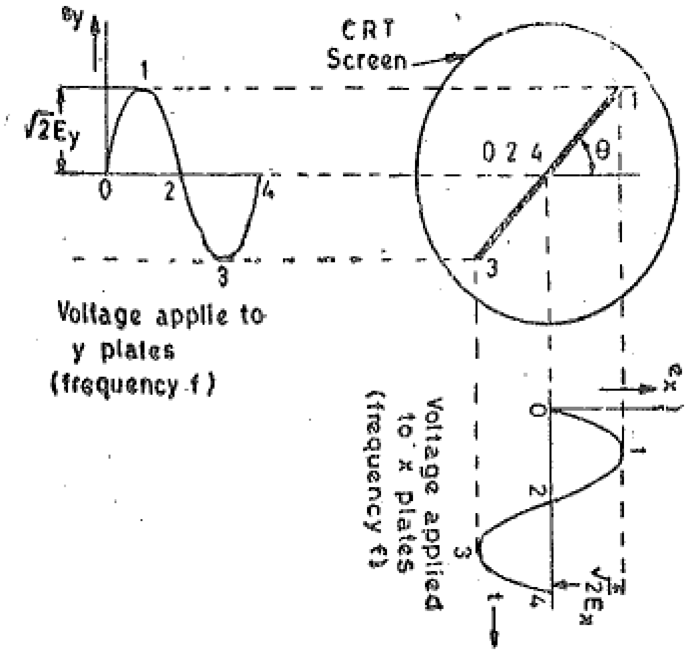


Fig. 21'12. Lissajous pattern with equal frequency voltages and zero phase shift.

MESUREMENT OF PHASE-LISSAJOUS PATTERN

- Thus when two equal voltages of equal frequency but with 90° phase displacement are applied to a CRO, the trace on the screen is a circle.

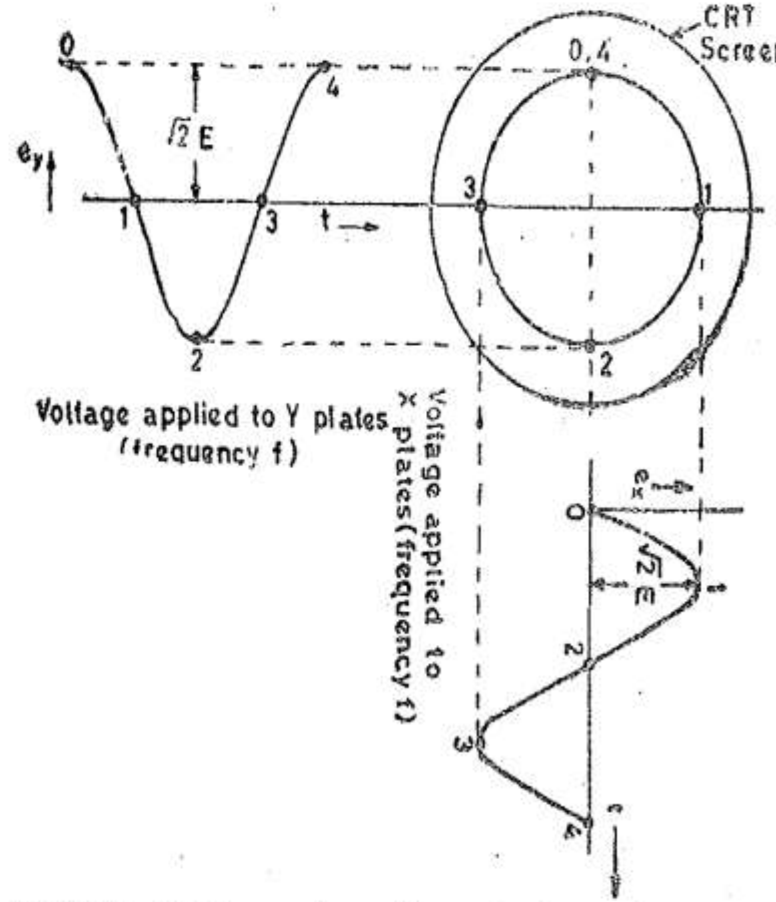


Fig 21·13. Lissajous pattern with eqral voltages of equal frequency and a phase shift of 90°.

MESUREMENT OF PHASE-LISSAJOUS PATTERN

- When two equal voltages of equal frequency but with a phase shift ϕ (not equal to 0° or 90°) are applied to a CRO we obtain an ellipse.
- An ellipse is also obtained when unequal voltages of same frequency are applied to the CRO.
- 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.

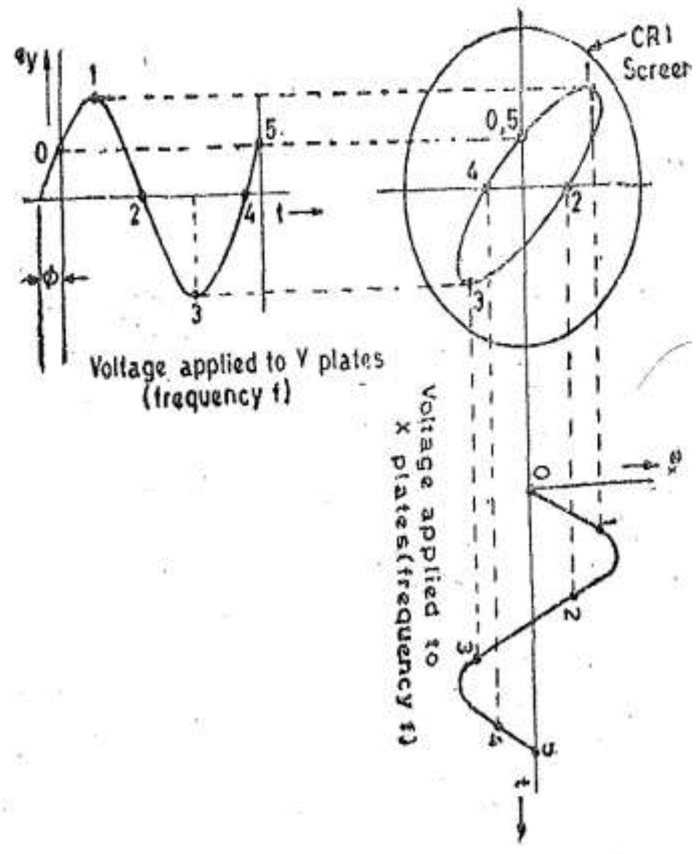


Fig. 21·14. Lissajous pattern with two equal voltages of same frequency and phase shift of ϕ.

MESUREMENT OF PHASE-LISSAJOUS PATTERN

- Regardless of the two amplitudes of the applied voltages the ellipse provides a simple means of finding phase difference between two voltages.
- Sinϕ=Y1/Y2=X1/X2
- If the major axis of the ellipse lies in the first and third quadrants (i.e.its slope is positive) the phase angle is either between 0° to 90° or between 270° or 360°.
- When the major axis of ellipse lies in second and fourth quadrants i.e, when its slope is negative, the phase angle is either between 90 ° and 180° or between 180° and 270 °.

MESUREMENT OF PHASE-LISSAJOUS PATTERN

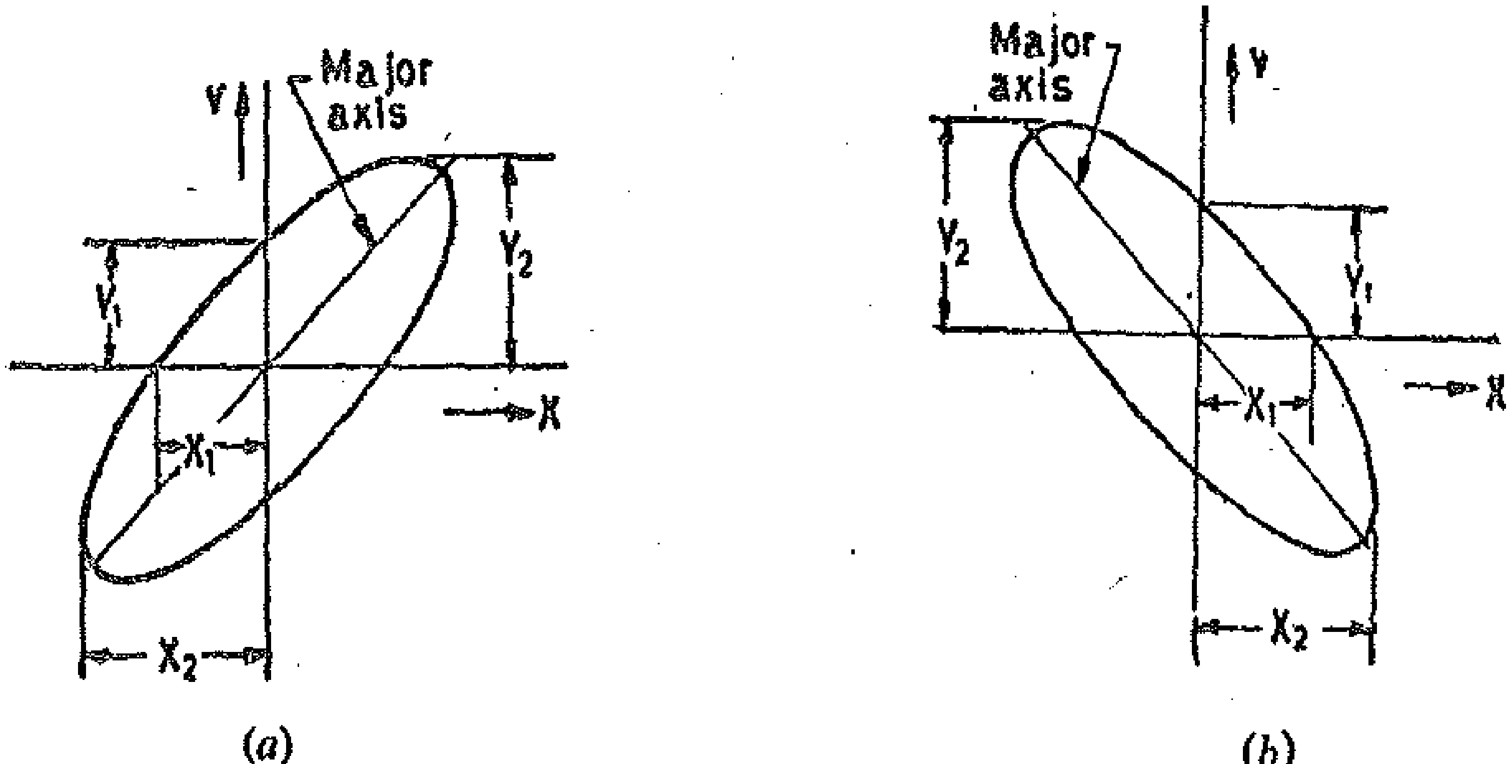


Fig. 21·16. Determination of angle of phase shift.

Example 21·6. The sketches shown in Fig. 21·22 display Lissajous patterns for cases where voltages of same frequency but of different phase are connected to Y and X plates of the oscilloscope. Find the phase difference in each case. The spot generating the patterns moves in a clockwise direction. Calculate the angles if the spot generating the patterns moves in the anticlockwise direction.

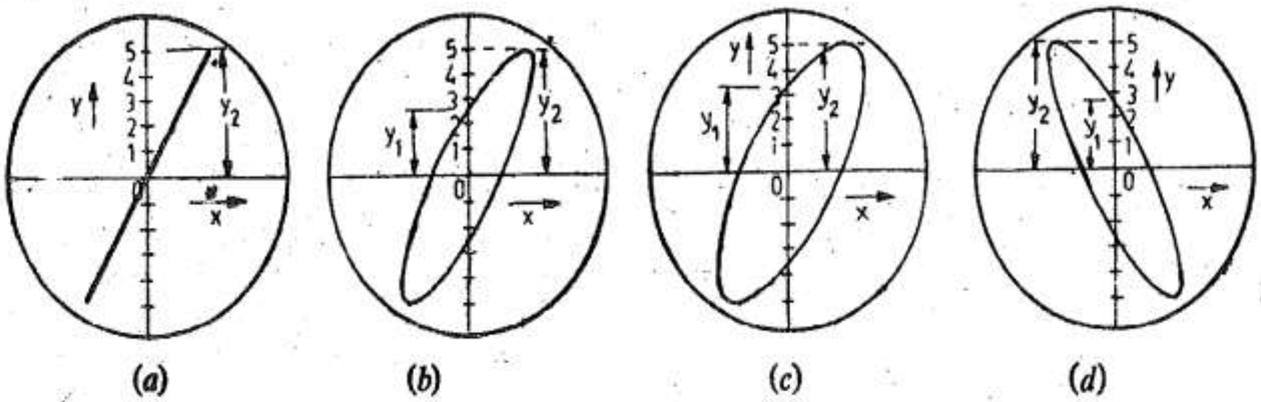


Fig. 21·22

Solution. The spot generating the patterns moves in clockwise direction.

(*a*) $\text{Sin } \phi = \frac{Y_1}{Y_2} = \frac{0}{5} = 0$

$\therefore$ $\phi = 0°$ (as the Lissajous pattern is in 1st and 3rd quadrants).

(*b*) $\text{Sin } \phi = \frac{2·5}{5} = 0·5$

$\therefore$ $\phi = 30°$ (as the major axis of the pattern is in 1st and 3rd quadrants).

(*c*) $\text{Sin } \phi = \frac{3·5}{5} = 0·7$

$\therefore$ $\phi = 45°$ (as the major axis of the pattern is in 1st and 3rd quadrants).

(*d*) $\text{Sin } \phi = \frac{2·5}{5} = 0·5$

$\therefore$ $\phi = 180 - 30° = 150°$ (as the major axis is in 2nd and 4th quadrants).

If the spot generating the patterns moved in the counter clockwise direction, the angles would be :

(*a*) 180°, (*b*) $-30°$, (*c*) $-45°$, (*d*) $180 + 30 = 210°$

MEASUREMENT OF FREQUENCY-LISSAJOUS PATTERN

- Lissajous patterns may be 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 until the pattern appears as a circle or an ellipse, indicating that both signals are of the same frequency.
- Where it is not possible to adjust the standard signal frequency to the exact frequency of the unknown signal, the standard is adjusted to a multiple or a sub multiple of the frequency of the unknown source so that the pattern appears stationary.

ASUREMENT OF FREQUENCY- LISSAJOUS PATTERN

- Let us consider an example. Suppose sine waves are applied to *X and Y plates as* shown in Fig.
- 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 direction against one in the horizontal direction.

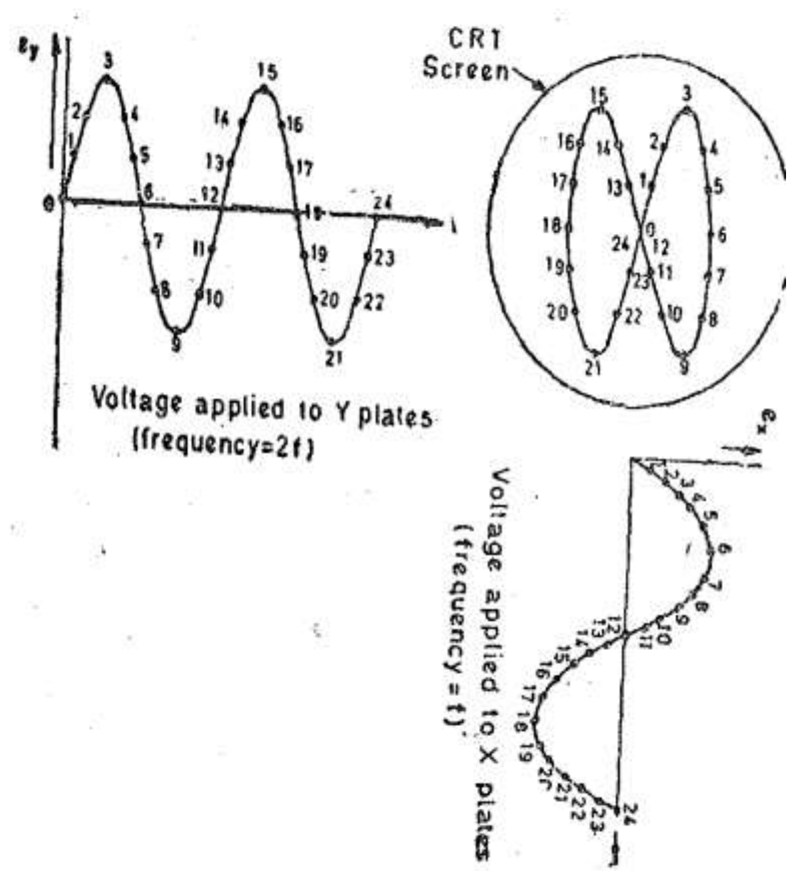


Fig. 21·17. Lissajous pattern with frequency ratio 2 : 1.

ASUREMENT OF FREQUENCY-LISSAJOUS PATTERN

- The two waves start at the same instant. Lissajous pattern may be constructed in the usual way and a 8 shaped pattern with two loops is obtained.
- If the two waves do not start at the same instant we get different patterns for the same frequency ratio.

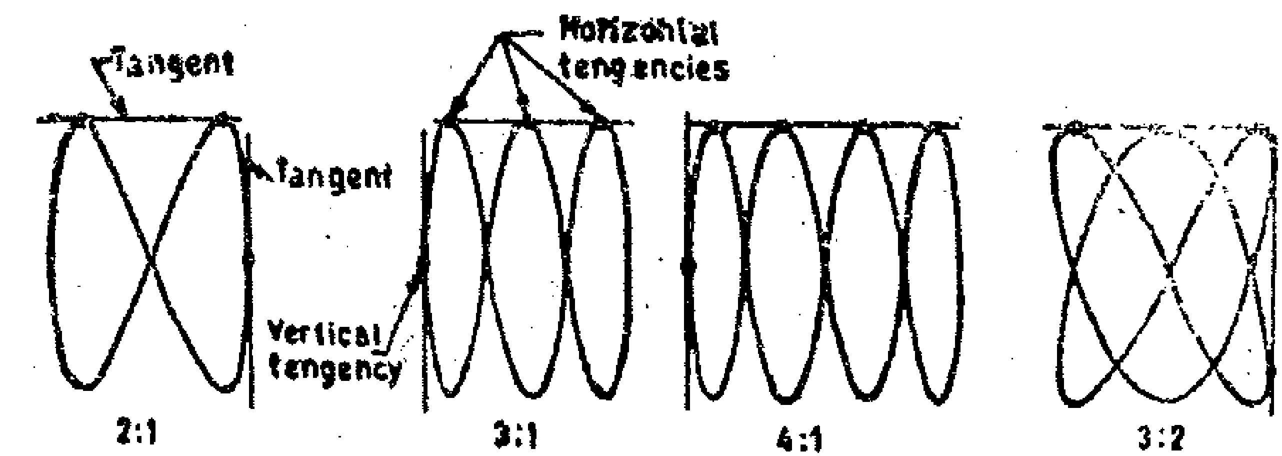


Fig. 21·18. Lissajous patterns with different frequency ratios.

ASUREMENT OF FREQUENCY-LISSAJOUS PATTERN

$$\frac{f_y}{f_x} = \frac{\text{number of times tangent touches top or bottom}}{\text{number of times tangent touches either side}}$$

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

f_y = frequency of signal applied to Y plates.

f_x = frequency of signal applied to X plates.

ASUREMENT OF FREQUENCY-LISSAJOUS PATTERN

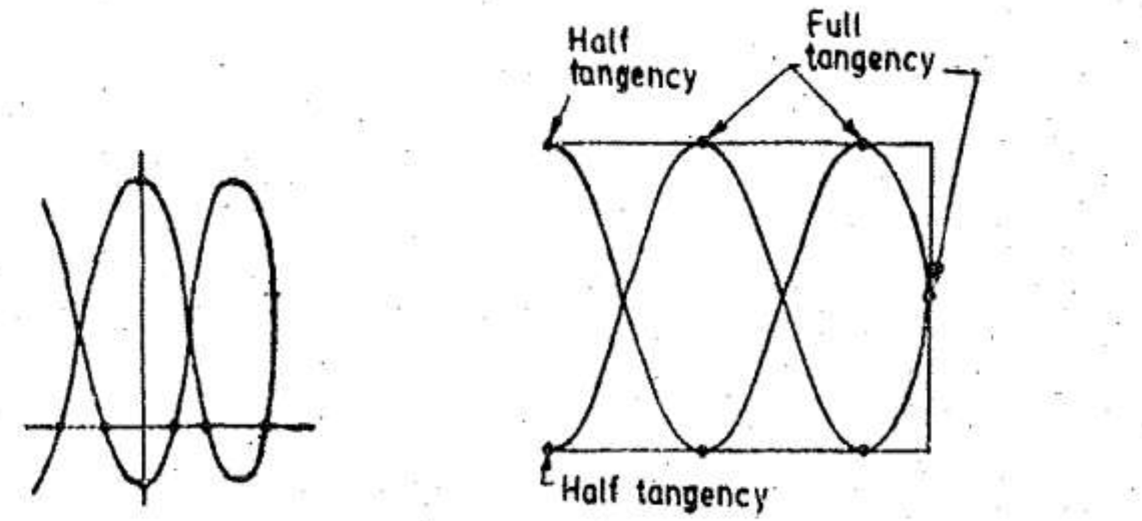
- The above rule, however, does not hold for the Lissajous pattern with free ends.
- Two lines are drawn, one horizontal and the other vertical so that they do not pass through any intersections of different parts of the Lissajous curve. The number of intersections of the horizontal and the vertical lines with the Lissajous curve are individually counted.
- The frequency ratio is given by :

$$\frac{f_v}{f_x} = \frac{\text{number of intersections of the horizontal line with the curve}}{\text{number of intersections of the vertical line with the curve}}$$

- The modified rule is applicable in all cases whether the Lissajous pattern is open or closed.

ASUREMENT OF FREQUENCY-LISSAJOUS PATTERN

- The ratio of frequencies when open ended Lissajous patterns are obtained can also be found by treating the open ends as half tangencies.



(a) Fig. 21·19 (b)

$$\frac{f_v}{f_h} = \frac{\text{number of horizontal tangencies}}{\text{number of vertical tangencies}} = \frac{2+1/2}{1} = \frac{5}{2}$$

PROBES

- The probe performs the very important function of connecting the test circuit to the oscilloscope without alterin g, loading, or otherwise disturbing the test circuit.
- The probes are of three different types :

  (i) Direct reading probe,

  (ii) circuit isolation probe,

  (iii) detector probe.

PROBES

- **Direct Probe-** The probe in simplest of all the probes and uses a shielded co-axial cable. It avoids stray pick-ups which may create problems when low level signal are being measured . It is usually used for low frequency or low impedance circuits. However using the shielded probe, the shunt capacitance of the probe and cable is added to the input impedance and acts to lower the response of the oscilloscope
- **Isolation Probe-** Isolation probe is used in order to avoid the undesirable circuit loading effects of the shielded probe. The isolation decreases the input capacitance and increases the input resistance of the oscilloscope. This way the loading effects are drastically reduced.

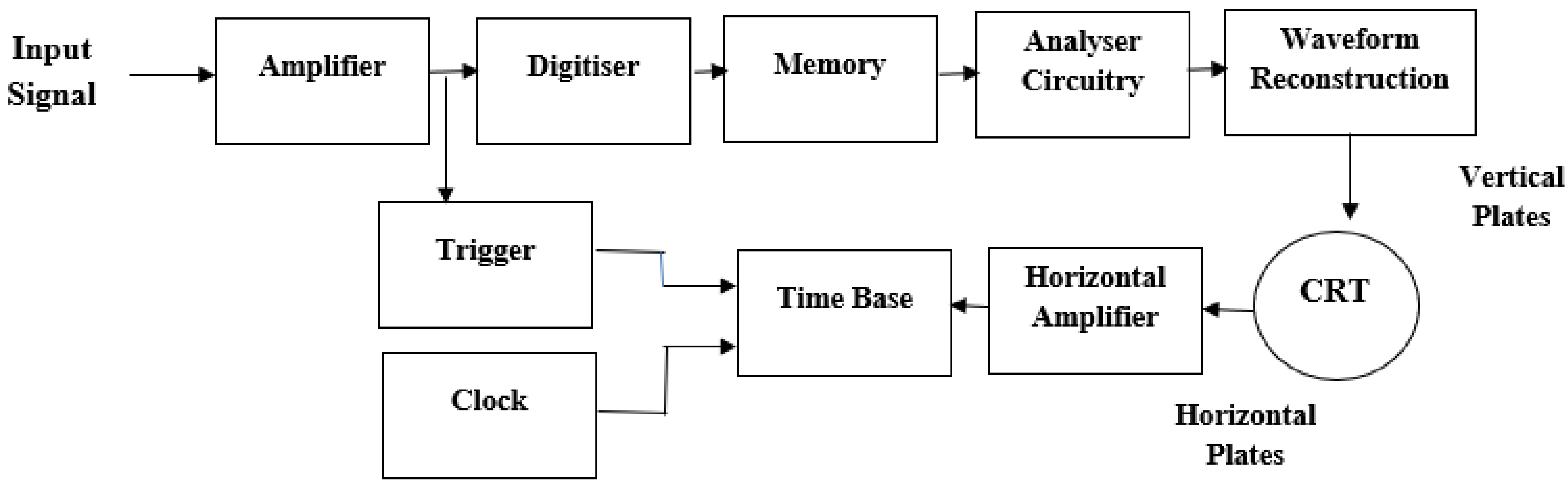
PROBES

- **Detector probe.**
  - When analyzing the response to modulated signals used in communication equipment like AM, FM and TV receivers, the detector probe functions to separate the low frequency modulation component from the high frequency carrier.

DIGITAL STORAGE OSCILLOSCOPE (DSO)

- A digital storage oscilloscope (DSO) is an oscilloscope which stores and analyses the signal digitally rather than using analog techniques.
- It is now the most common type of oscilloscope in use because of the advanced trigger, storage, display and measurement features which it typically provides.
- It displays the signal visually as well as numerically

BLOCK DIAGRAM OF DSO



DIGITAL VOLTMETER (DVM)

- A digital voltmeter (DVM) displays the value of ac or dc voltages being measured directly as discrete numerals in the decimal number system.
- Numerical read out of DVMs is advantageous since it eliminates observational errors committed by operators.
- The errors on account of parallax and approximations are entirely eliminated.
- The use of digital voltmeters increases the speed with which readings can be taken.
- Also the output of digital voltmeters can be fed to memory devices for storage and future computations.

DIGITAL VOLTMETER (DVM)

- For the same accuracy, a digital voltmeter now is less costly than its analog counterpart.
- The decrease in size of DVMs on account of use of ICs, the portability of the instruments has increased.
- The various types of DVM are

  (i) Ramp type DVM,

  (ii) Integrating type DVM,

  (iii) Potentiometric type DVM,

  (iv) Successive approximation type DVM,

  and (v) Continuous balance type DVM.
- These classification is based on voltage measuring principles on which these instruments operate.

RAMP TYPE DVM

- The operating principle of a ramp type digital voltmeter is to measure the time that linear ramp voltage takes to change from level of input voltage to zero voltage (or vice versa).
- This time interval is measured with an electronic time interval counter and the count is displayed as a number of digits on electronic indicating tubes or the output readout of the voltmeter.
- The conversion of a voltage value to a time interval is shown in the timing diagram.

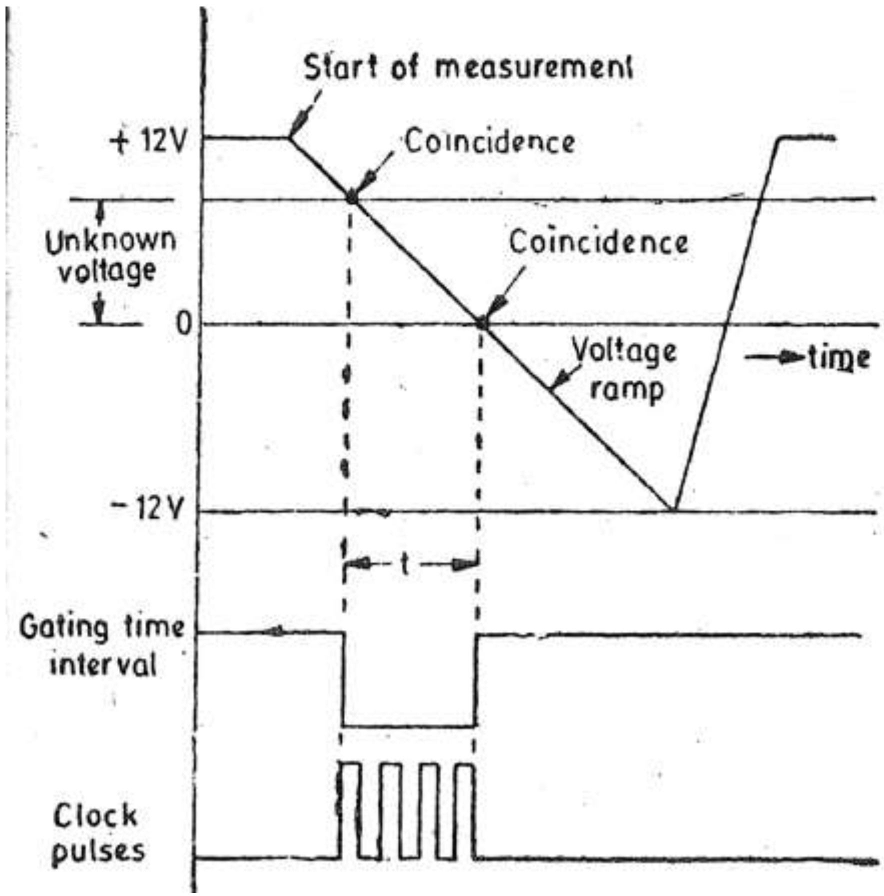
RAMP TYPE DVM

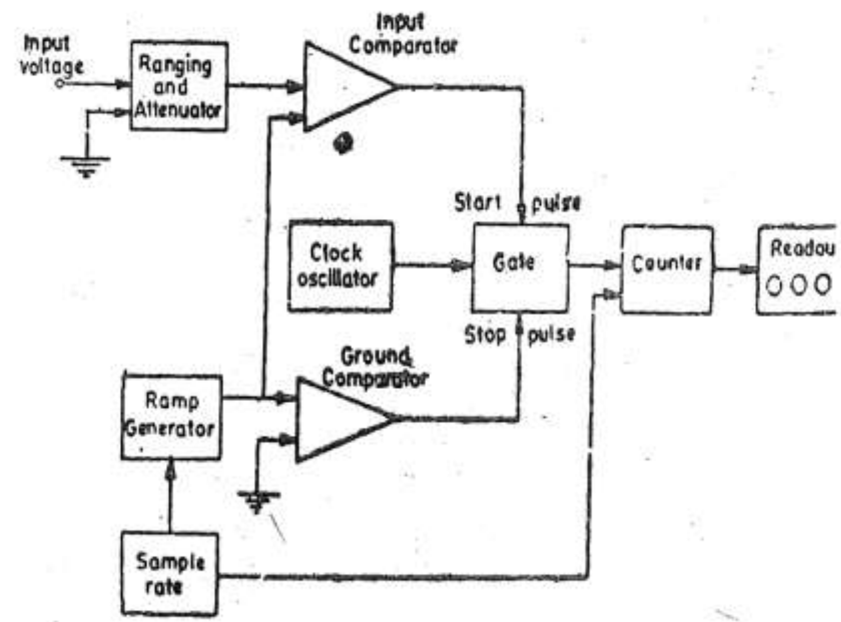
- At the start of measurement a ramp voltage is initiated.
- A negative going ramp is shown ,but a positive going ramp may also be used.
- The ramp voltage value is continuously compared with the voltage being measured (unknown voltage).
- At the instant the value of ramp voltage is equal to that of unknown voltage a coincidence circuit, called an input comparator generates a pulse which opens a gate.
- The ramp voltage continues to decrease till it reaches ground level(zero voltage).
- At this instant another comparator called ground comparator generates a pulse and closes the gate.

RAMP TYPE DVM

- The time elapsed between opening and closing of the gate is t in indicated.
- During this time interval pulses from a clock pulse generator pass through the gate and are counted and displayed.
- The decimal number as indicated by the readout is a measure of the value of input voltage.
- The sample rate multivibrator determines the rate at which the measurement cycles are initiated. The sample rate circuit provides an initiating pulse for the ramp generator to start its next ramp voltage.
- At the same time it sends a pulse to the counters which set all of them to 0.
- This momentarily removes the digital display of the readout.

RAMP TYPE DVM





ltage

Fig. 28·42. Block diag am of a ramp DVM.

DIGITAL FREQUENCY METER

- Principle of Operation
  - The signal whose frequency is to be measured is converted into a train of pulses, one pulse for each cycle of the signal .Then the number of pulses appearing in a definite interval of time is counted by means of an electronic counter.
  - Since the pulses represent the cycles of unknown signal, the number appearing on the counter is a direct indication of frequency of the unknown signal.
  - Since the electronic counters are extremely fast, the frequency of high frequency signals may be known.

DIGITAL FREQUENCY METER

- The block diagram of the basic circuit of a digital frequency meter is shown.

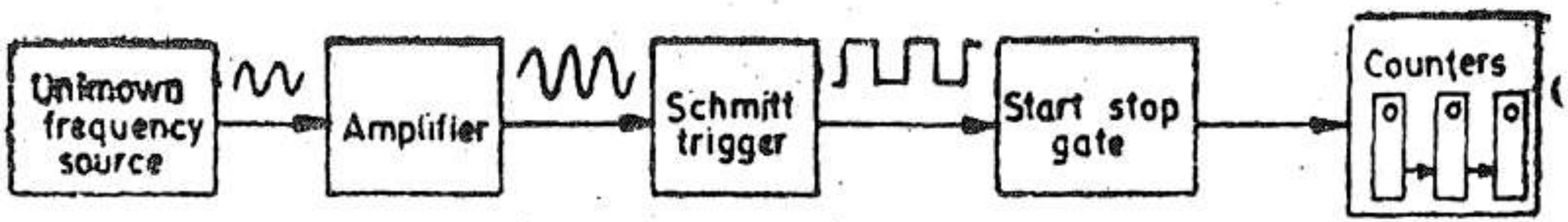


Fig. 28 33. Basic circuit of a digital frequency meter.

- The unknown frequency signal is fed to a Schmitt trigger.
- The signal may be amplified before being applied to Schmitt trigger.

DIGITAL FREQUENCY METER

- In a Schmitt trigger, the signal is converted into a square wave with very fast rise and fall time then differentiated and clipped.
- As a result, the output from a Schmitt trigger is a train of pulses, one pulse, for each cycle of the signal.
- The output pulses from the Schmitt trigger are fed to start stop gate. · When this gate opens (start)the input pulses pass through this gate and are fed to an electronic counter which starts registering the input pulses.
- When the gate is dosed (stop), the input of pulses to counter ceases and it stops counting.

DIGITAL FREQUENCY METER

- The counter displays the number of pulses that have passed through it in the time interval between start and stop.
- If this interval is known, the pulse rate and hence the frequency of the input signal can be found.
- Suppose *f is the frequency of unknown signal, N the number of counts* displayed by counter and t is the time interval between start and stop of gate,

  Frequency of unknown signal f= N/t

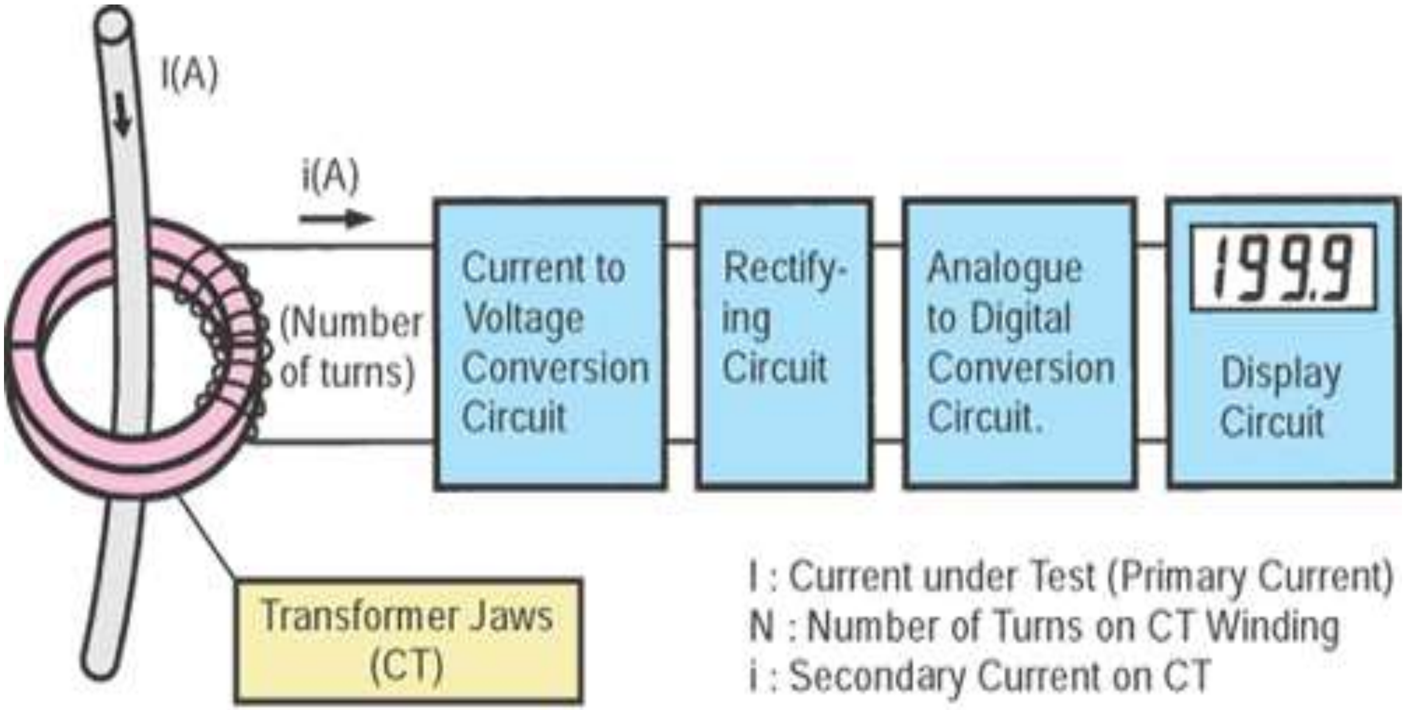
CLAMP METER

- A clamp meter is one kind of test equipment and it is also known as Tong Tester.
- This equipment is very simple to use and operate. The main function of this device is to measure a live conductor in the circuit without damage or power loss.
- By using this equipment, one can measure the high-value current without turning off the circuit while testing.
- The main drawback of this meter is, the long tester accuracy is significantly low.

CLAMP METER

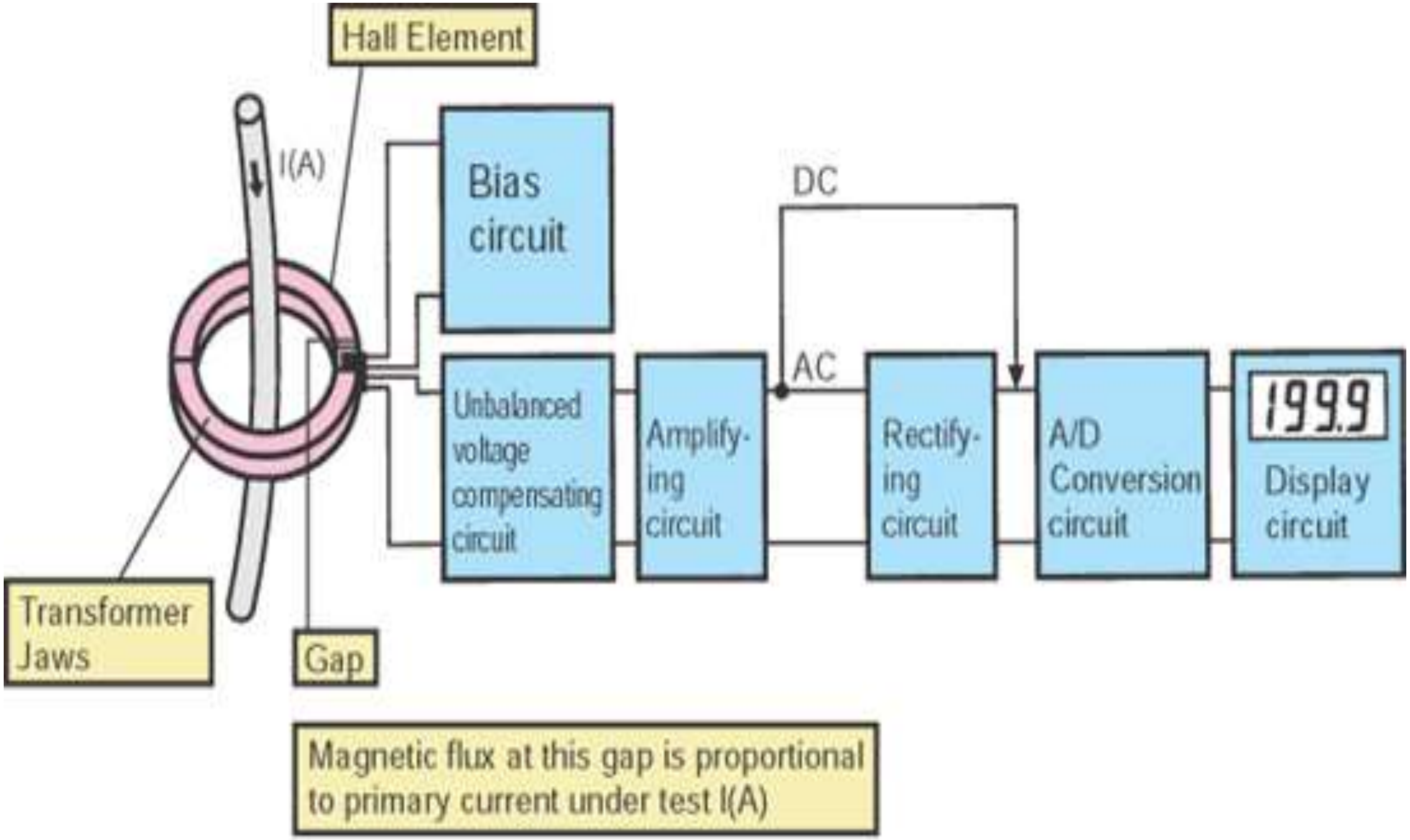
- A device that is used to measure current in an efficient, convenient, and safe manner without using test leads is known as clamp meter.
- Magnetic field can occur when the current flows throughout a conductor. So by using this device, the magnetic field can be detected to provide the reading of the corresponding current.

CLAMP METER



$$i = \frac{I}{N} \text{ (A)}$$

CLAMP METER

- 

Hall Element
I(A)
Bias circuit
DC
AC
Unbalanced voltage compensating circuit
Amplify-ing circuit
Rectify-ing circuit
A/D Conversion circuit
199.9
Display circuit
Transformer Jaws
Gap
Magnetic flux at this gap is proportional to primary current under test I(A)

CLAMP METER


Parts Of Clamp Meter
Transformer Clamps
Clamp Opening Trigger
Function Rotary Switch
Power Switch
Back Light
Hold Button for keeping the last reading on Display
LCD
Negative/ Ground Input Terminal
Positive Input Terminal for Volt, Resistance, Diode, Temperature and Continuity Test
www.electricalfundablog.com

CLAMP METER

- **Jaws/Transformer Clamps**
  - Transformer clamps or Jaws are used to detect the magnetic field while the current flowing in the conductor
- **Clamp Opening Trigger**
  - A clamp opening trigger is used to open or close the clamps
- **Power Switch**
  - The power switch is used to switch on or off the meter.

CLAMP METER

- **Back Light Button**
  - The backlight button is used to activate the LCD display to read the displayed value easily at night or in dark places.
- **Hold Button**
  - Hold button mainly holds the final value on the LCD display.
- **Negative or Ground Input Terminal**
  - The ground input terminal is used for connecting the ground jack or negative of the meter cable.

CLAMP METER

- **Positive Input Terminal**
  - This terminal is used for connecting the positive jack in the meter cable
- **LCD Display**
  - The LCD display is used to show the measured value.
- **Functional Rotary Switch**
  - This switch is used to choose the current based on the range & type being measured

DIGITAL MULTIMETER -DMM

- **Digital multimeter** is a test equipment which offers several electronic measurement task in one tool.
- The standard and basic measurements performed by multimeter are the measurements of amps, volts, and ohms.

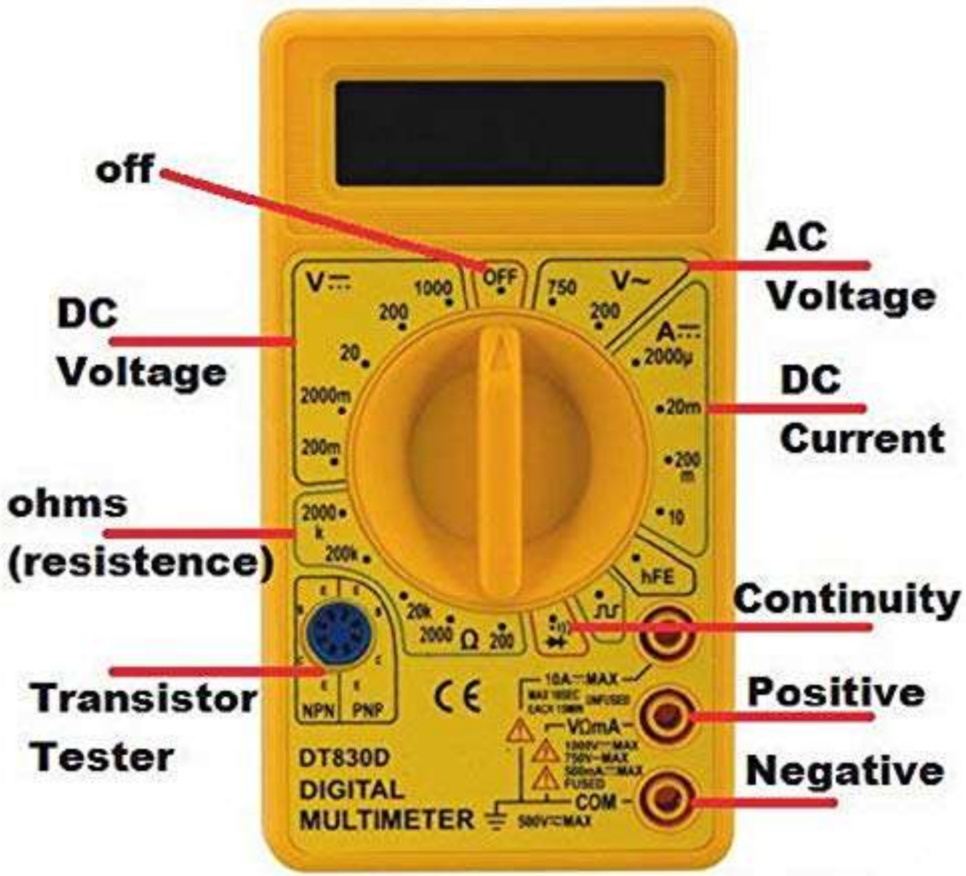
➢ **Parts of Digital Multimeter**

  – **Display screen**-It has illuminated display screen for better visualization. It has five digits display screen; one represent sign value and the other four are for number representation.

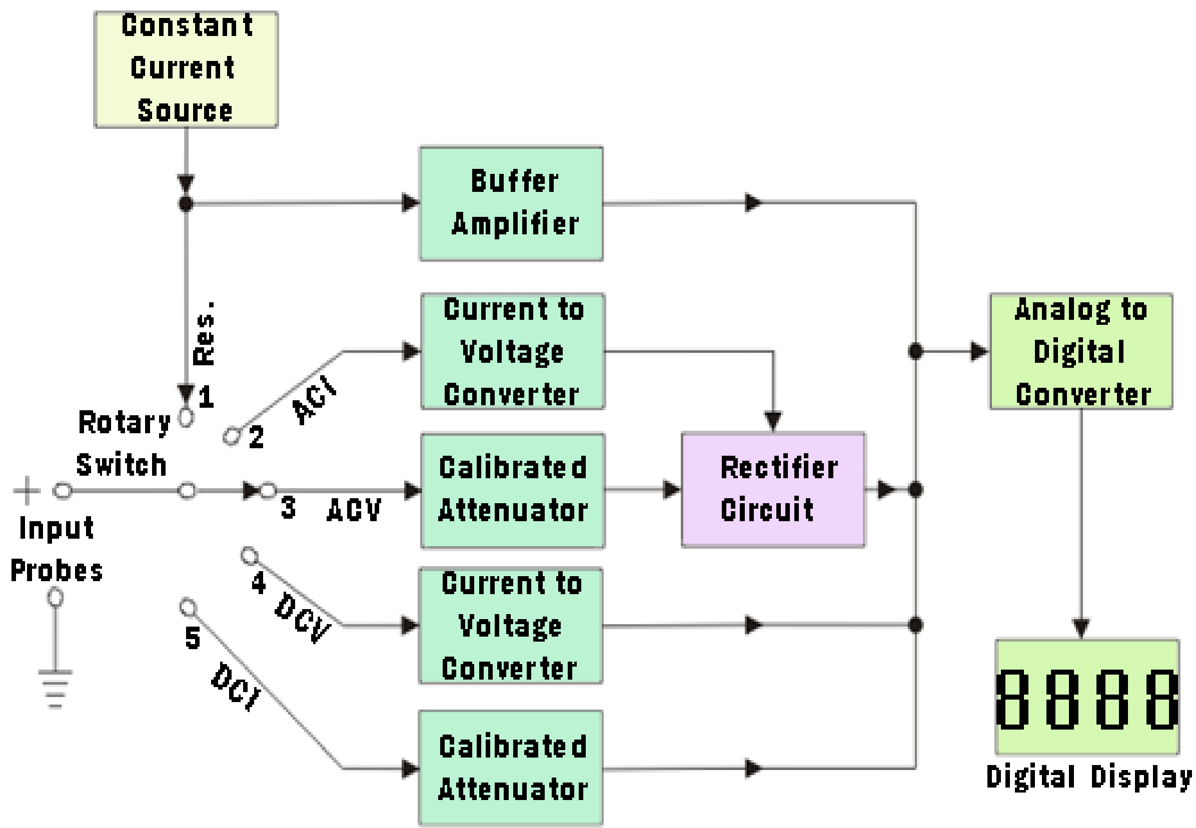
DIGITAL MULTIMETER -DMM

- **Selection knob-** A single multimeter performs so many tasks like reading voltage, resistance, and current. The selection knob allows the user to select the different job.
- **Port**- There are two ports on the front of the unit. One is the mAVΩ port which allows the measurement of all the three units: current up to 200 mA, voltage, and resistance. The red probe is plugged into this port. The other is COM port which means common and it normally connected to –ve of a circuit and black probe is plugged into it. There is one particular port is 10A, which is use to measures large current in the circuit.

DIGITAL MULTIMETER -DMM



DIGITAL MULTIMETER -DMM



PHASOR MEASUREMENT UNIT (PMU)

- A **phasor measurement unit** (PMU) is a device used **to estimate the magnitude and phase angle of an electrical phasor quantity** (such as voltage or current) in the electric grid using a common time source for synchronization.
- **Time synchronization is usually provided by GPS** and allows synchronized real-time measurements of multiple remote points on the grid.
- **PMUs are capable of capturing samples from a waveform in quick succession** and reconstructing the phasor quantity, made up of an angle measurement and a magnitude measurement.
- The resulting measurement is known as a ***synchrophasor***. These time synchronized measurements are important because if the grid's supply and demand are not perfectly matched, frequency imbalances can cause stress on the grid, which is a potential cause for power outages.

PHASOR MEASUREMENT UNIT (PMU)

- PMUs can also be **used to measure the frequency** in the power grid.
- A typical commercial PMU can report measurements with very high temporal resolution in the order of **30-60 measurements per second**. This helps engineers in analyzing dynamic events in the grid which is not possible with traditional **SCADA measurements** that generate one measurement every **2 or 4 seconds.**
- Therefore, PMUs equip utilities **with enhanced monitoring and control capabilities** and are considered to be one of the most important measuring devices in the future of power systems.
- A PMU can be a dedicated device, or the PMU **function can be incorporated into a protective relay** or other device.

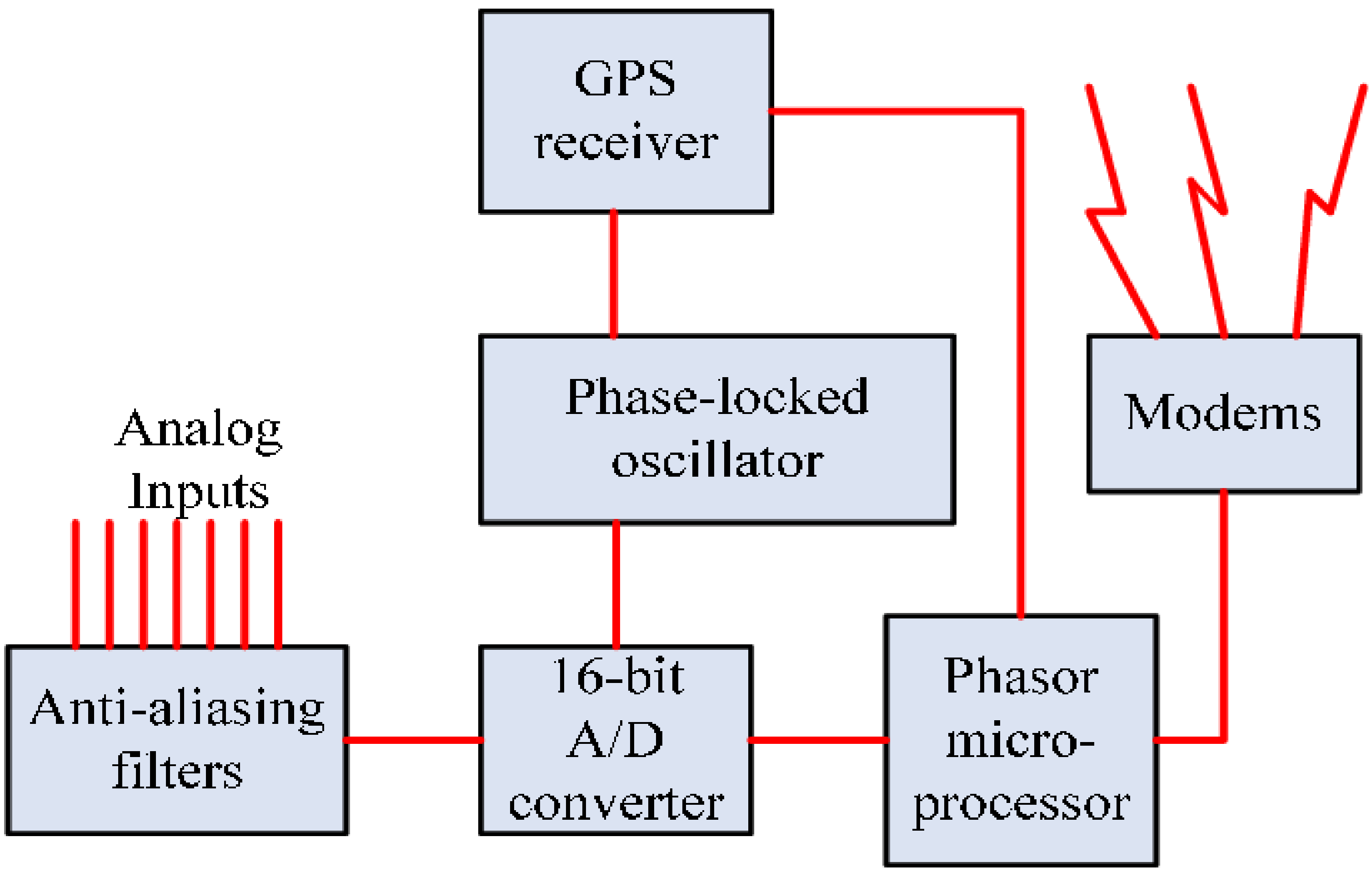
WHY PMU?

- PMU an essential component of Smart Grids.
- It **provides Synchrophasor data**
- **Reports Magnitude, Phase and Frequency** of an AC waveform
- **Makes the grid observable** due to high reporting rates
- **Preventive actions** can be taken

THE MAIN COMPONENTS OF PMU

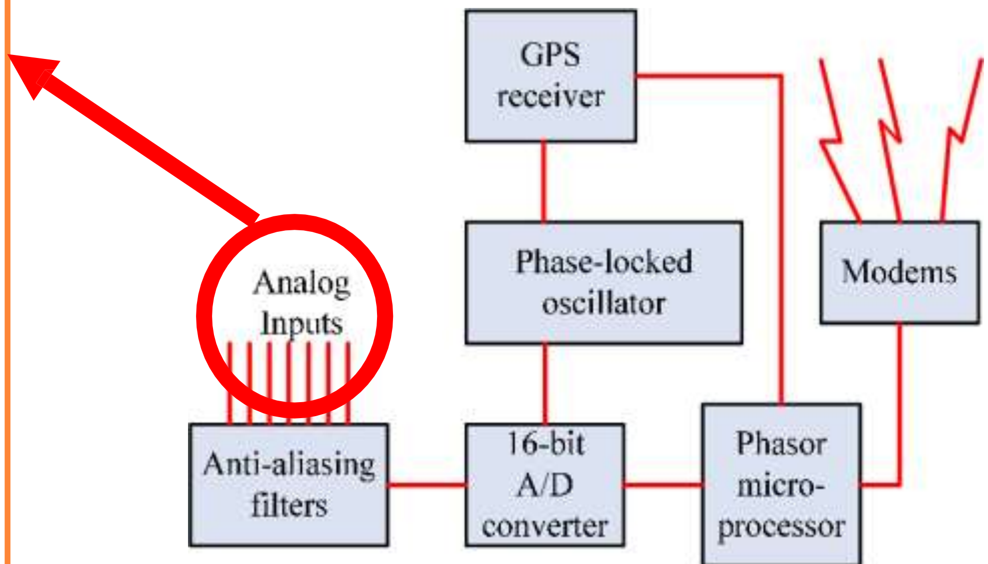
- Analog Inputs
- GPS receiver
- Phase locked oscillator
- A/D converter
- Anti-aliasing filters
- Phasor micro-processor
- Modem

BLOCK DIAGRAM OF PMU



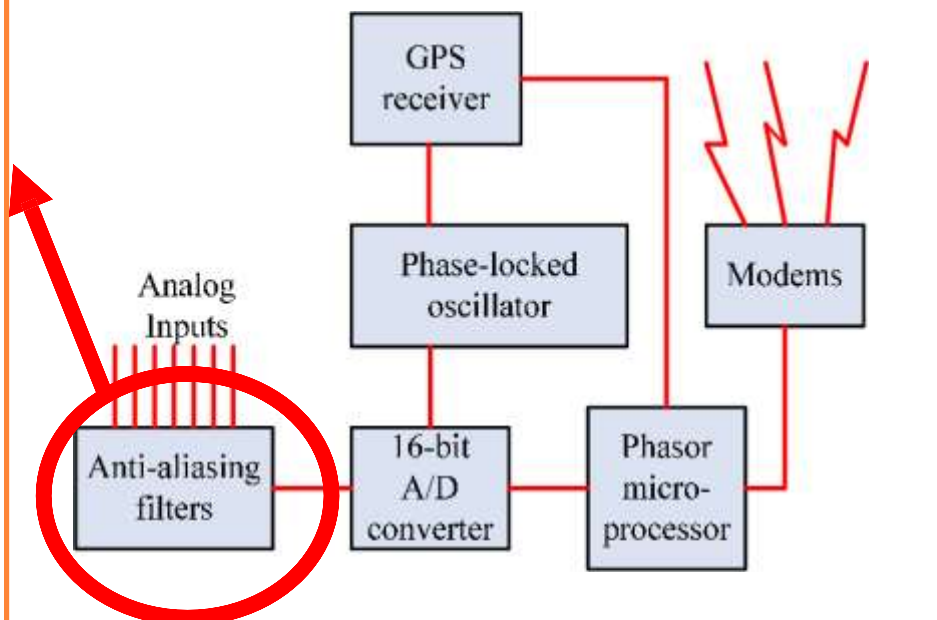
ANALOG INPUTS

- Current and potential transformers are employed at substation for measurement of voltage and current.
- The analog inputs to the PMU are the voltages and currents obtained from the secondary winding of potential and current transformers.



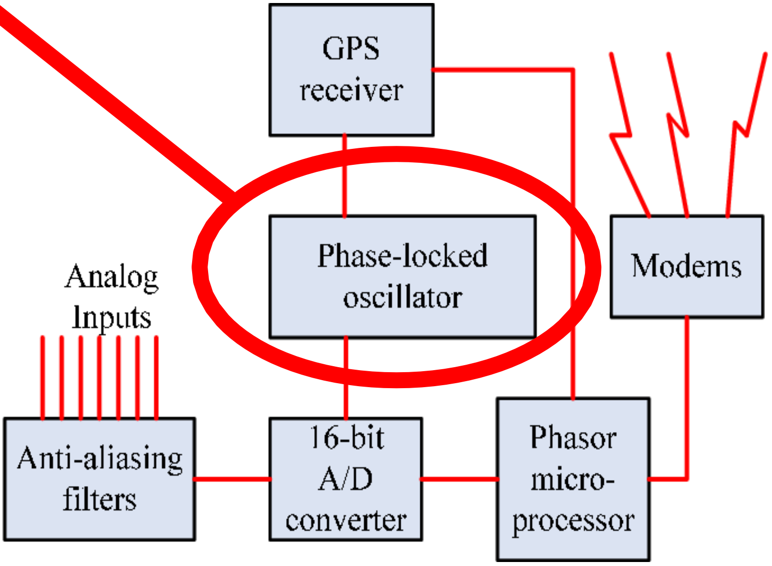
ANTI-ALIASING FILTERS

- Anti-aliasing filter is an analog low pass filter which is used to filter out those components from the actual signal whose frequencies are greater than or equal to half of nyquist rate to get the sampled waveform.
- Nyquist rate is equal to twice the highest frequency component of input analog signal.
- If anti aliasing filters are not used, error will be introduced in the estimated phasor



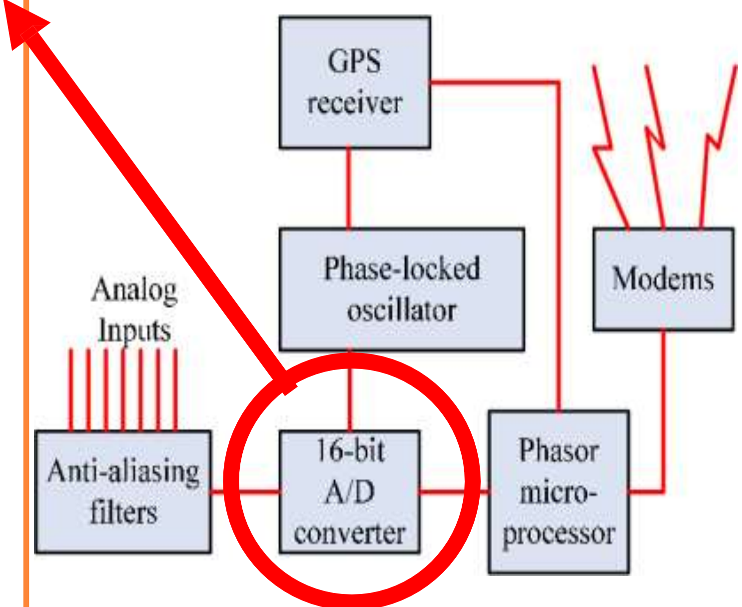
Phase lock oscillator

- Phase lock oscillator along with Global Positioning System reference source provides the needed high speed synchronized sampling.
- Global Positioning System (GPS) is a satellite-based system for **providing position and time.**



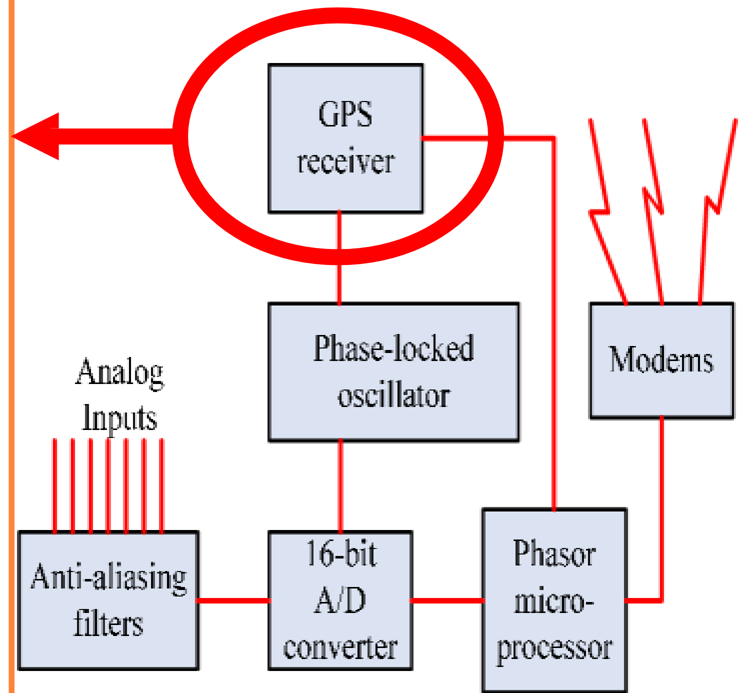
A/D CONVERTER

- It converts the analog signal to the digital signal.
- The output of ADC is a sequence of digital values that convert a continuous time and amplitude analog signal to a discrete time and discrete amplitude signal.



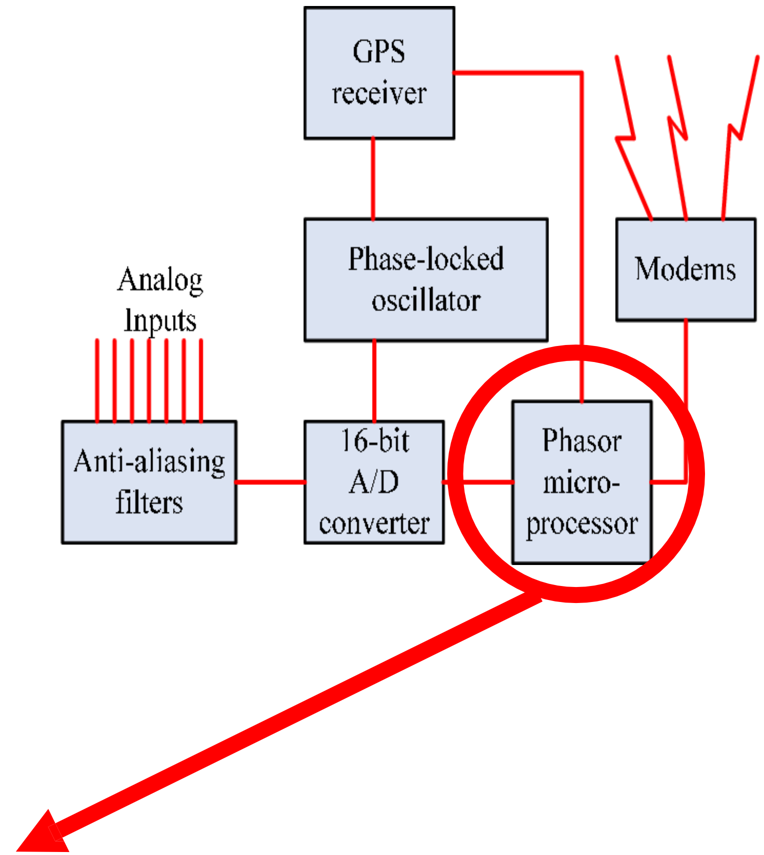
GLOBAL POSITIONING SYSTEM

- The synchronized time is given by GPS **uses the high accuracy clock from satellite technology.**
- Without GPS **providing the synchronized time**, it is hard to monitor whole grid at the same time.
- The GPS satellites **provide a very accurate time synchronization signal**, available, via an antenna input, throughout the power system. This means that that voltage and current recordings from different substations can be directly displayed on the same time axis and in the same phasor diagram.



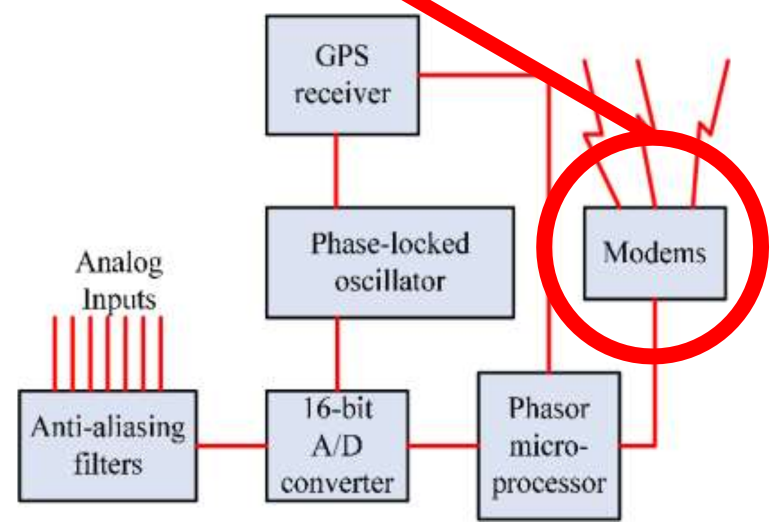
PROCESSOR

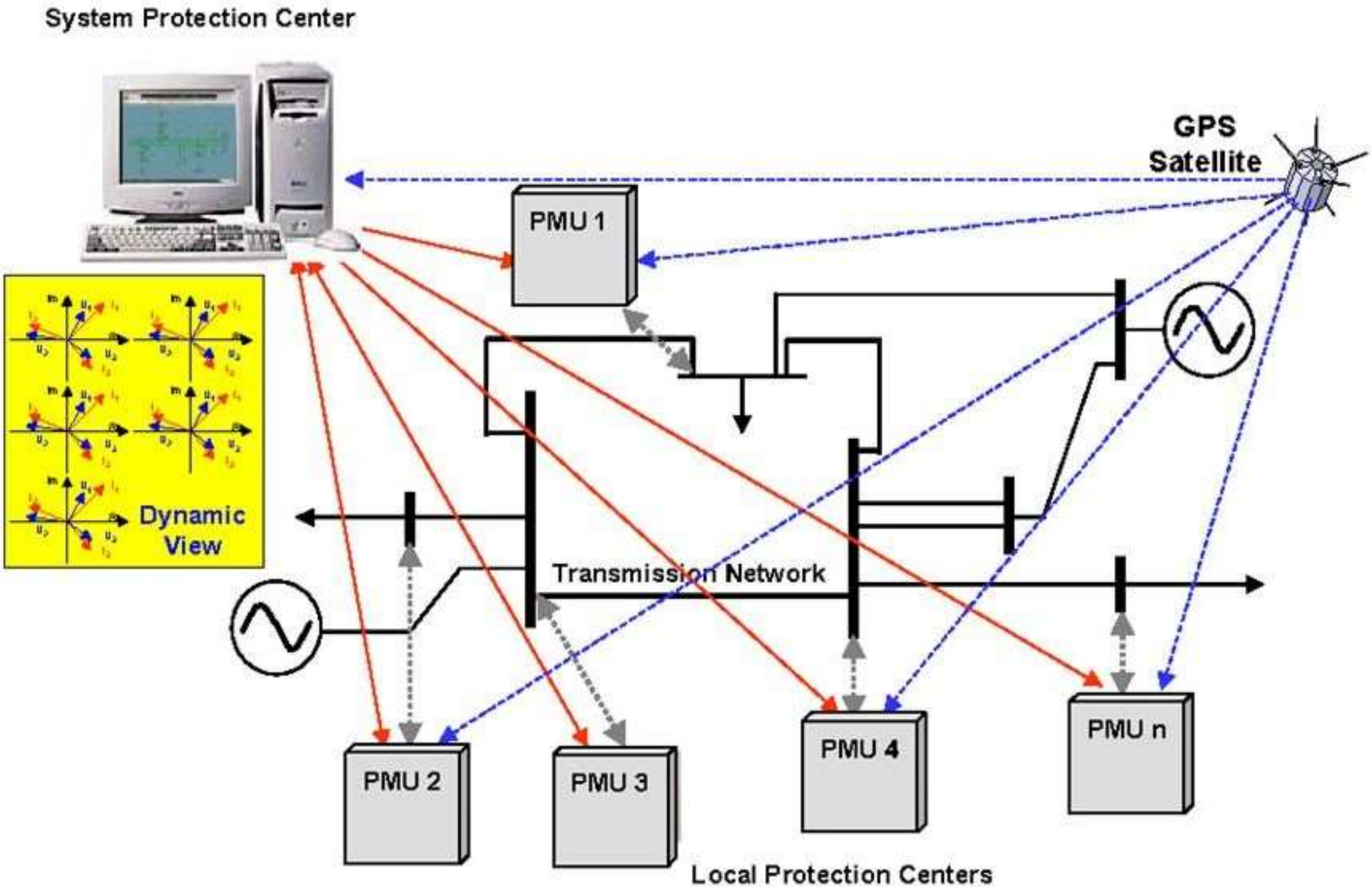
- The microprocessor **calculates all the current and voltage signals using the DFT techniques.**
- **Certain other estimates of interest are frequency and rate of change of frequency measured** locally, and these also are included in the output of the PMU.
- The timestamp is created from two of the signals derived from the GPS receiver.



Modem

- The objective of modem is to produce a signal that can be transmitted and decoded to make a replica of the original digital data.




System Protection Center
GPS
Satellite
PMU 1
Dynamic
View
Transmission Network
PMU 2
PMU 3
PMU 4
PMU n
Local Protection Centers

VIRTUAL INSTRUMENTATION

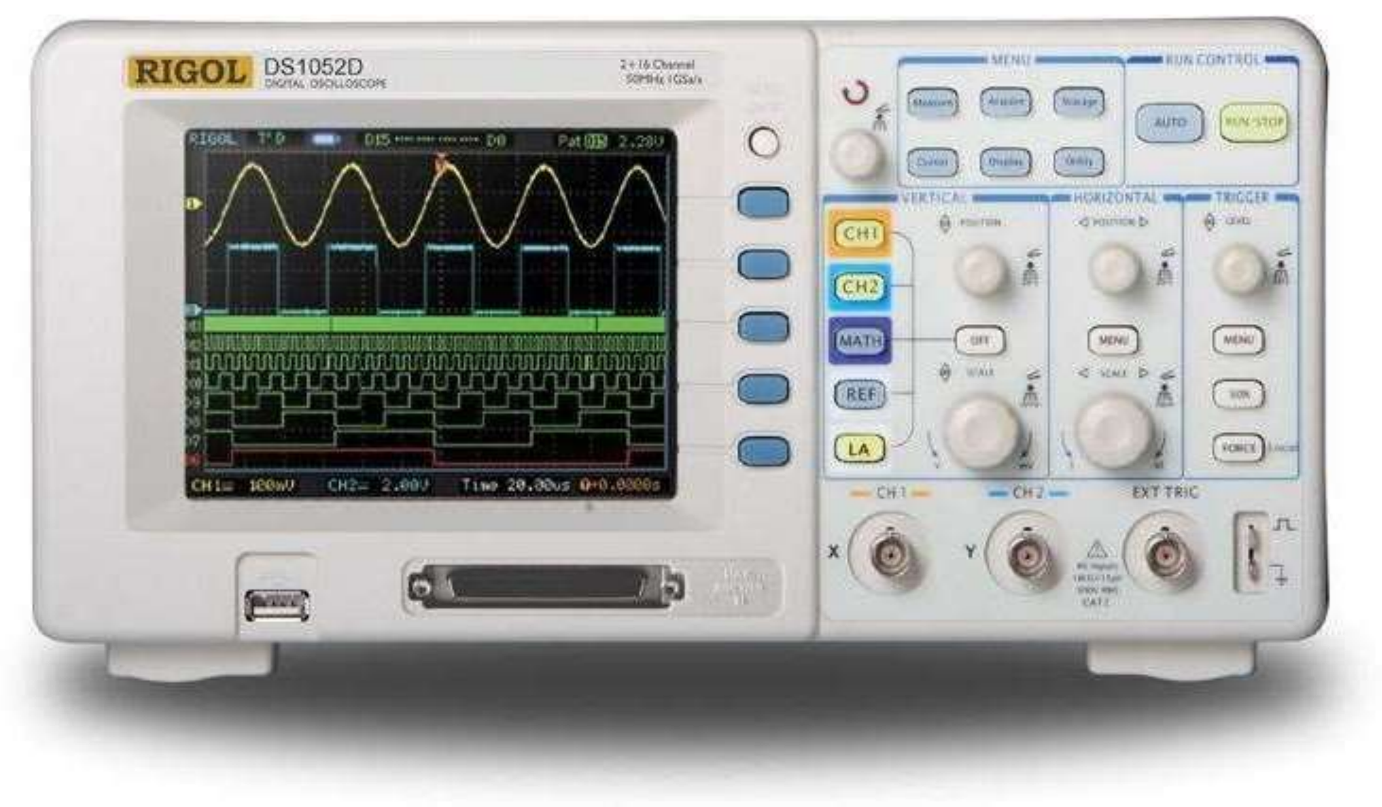
- Virtual instrumentation is an interdisciplinary field
- It merges sensing, hardware and software technologies.
- Used to create flexible and sophisticated instruments for control and monitoring applications.

HISTORY

- The concept of *was born in late 1970s.*
- *when microprocessor* technology enabled a machine's function to be more easily changed by changing its software.
- The flexibility is possible as the capabilities of a virtual instrument depend very little on dedicated hardware.

The first phase:

- It is represented by early "pure" analog measurement devices, such as oscilloscopes etc.
- They were completely closed dedicated systems.



The Second phase

- It is started in 1950s, as a result of demands from the industrial control field.

- Instruments started to digitalize measured signals, allowing digital processing of data.

The third phase

- Measuring instruments became computer based.

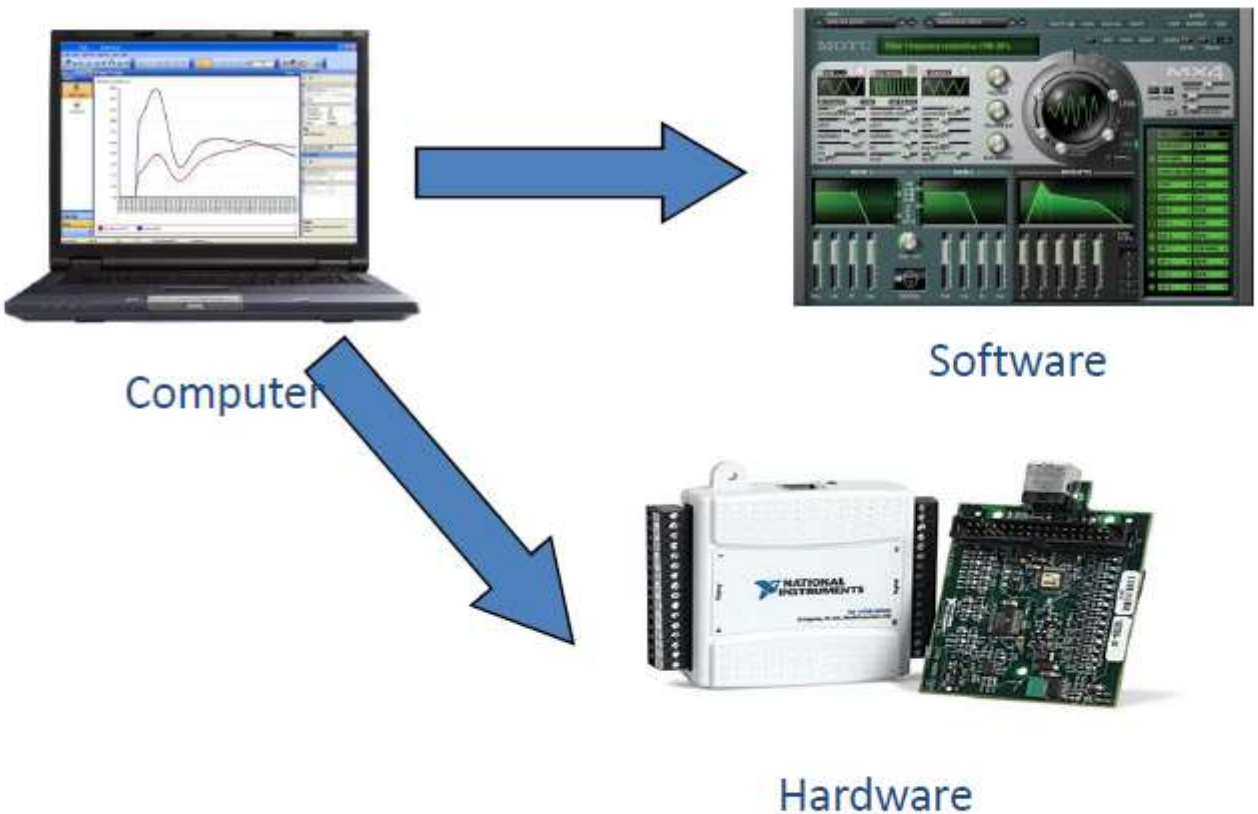
- They begun to include interfaces that enabled communication between the instrument and the computer.

- As a result, virtual instrumentation made possible decrease in price of an instrument.
- As the virtual instrument depends very little on dedicated hardware, a customer could now use his own computer.

Virtual Instrument Architecture

A virtual instrument is composed of the following blocks:

- Sensor module
- Processing Module
- Output


Software
Computer
Hardware

SENSOR MODULE

- A sensor module principally consists of three main parts:
  - input
  - the signal conditioning part
  - the A/D converter

INPUT

- Real World Data.

- According to the type of connection, sensor interfaces can be classified as *wired* and *wireless*.

- *Wired Interfaces are usually standard parallel interfaces, such as General Purpose Interface Bus*

- *Wireless Interfaces are increasingly used because of convenience.*

SIGNAL CONDITIONING

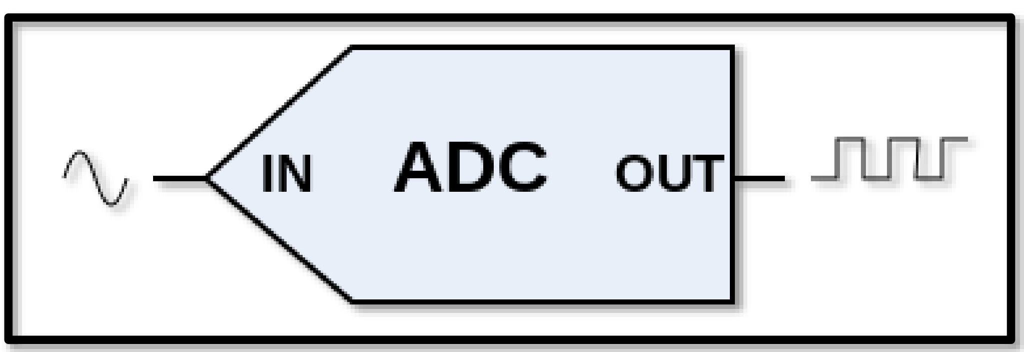
- It is the techniques used to convert immeasurable or unworkable signal into useful or functional form.

Example:

- **Example:**
  - Some sensors give signal in micro volts which needs to be amplified in order to use in the circuit.
  - If the signal has high amplitude then it needs to be attenuated in order to use it.

ANALOG TO DIGITAL CONVERTER

- Real world data is then converted in digital form by using ADC.
- Analog data is converted in the form which a computer can easily understand.



Processing Module

- It allows flexible implementation of sophisticated processing functions.

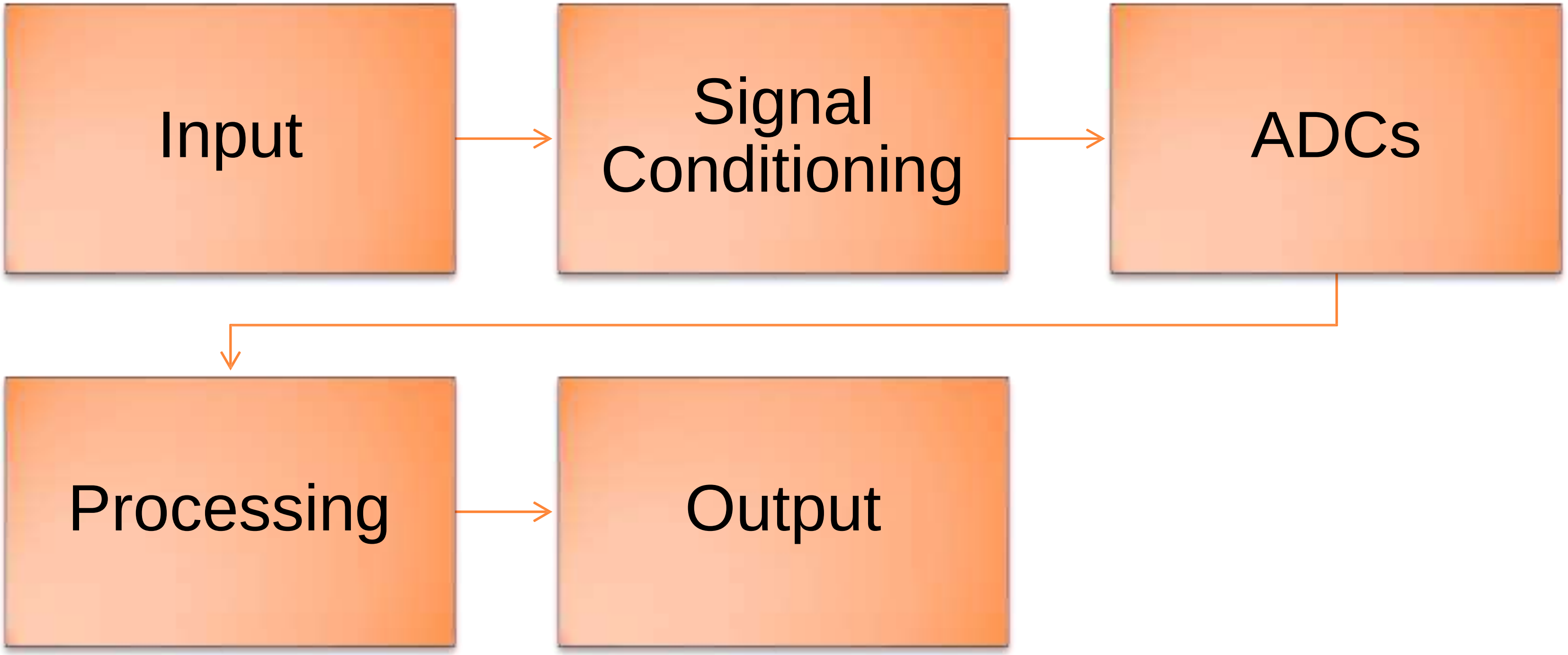
- A virtual instrument depends very little on dedicated hardware, which principally does not perform any complex processing.

- Functionality and appearance of the virtual instrument may be completely changed utilizing different processing functions.

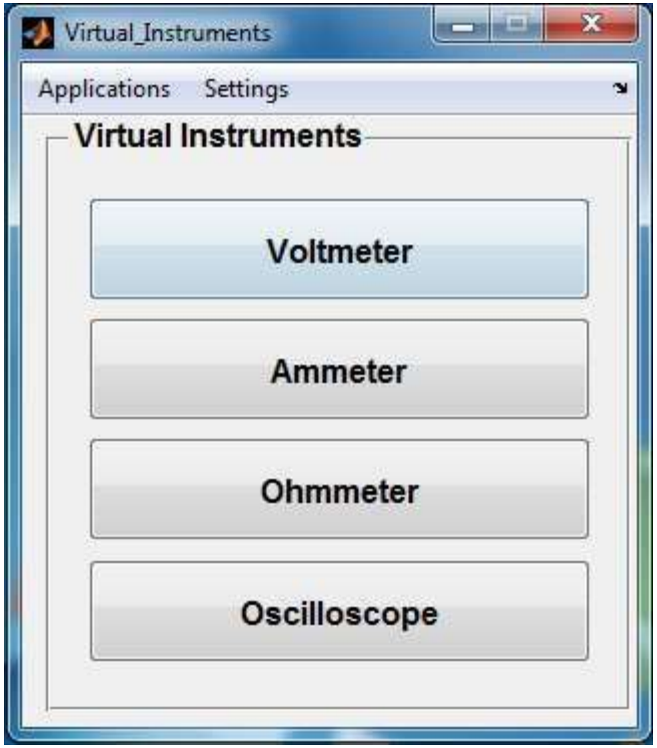
OUTPUT PRESENTATION

- Computer's user interfaces are much easier
- it is possible to employ more presentation effects and to customize the interface for each user.

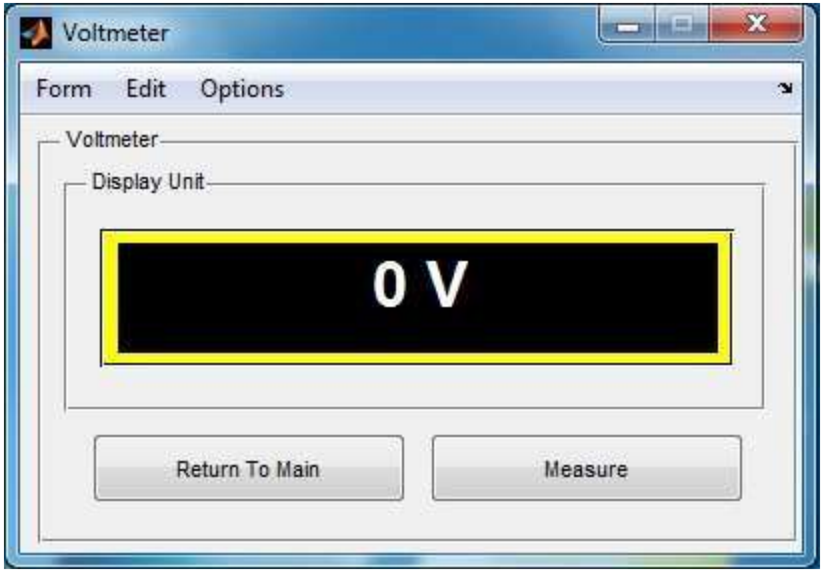
BLOCK DIAGRAM



APPLICATIONS

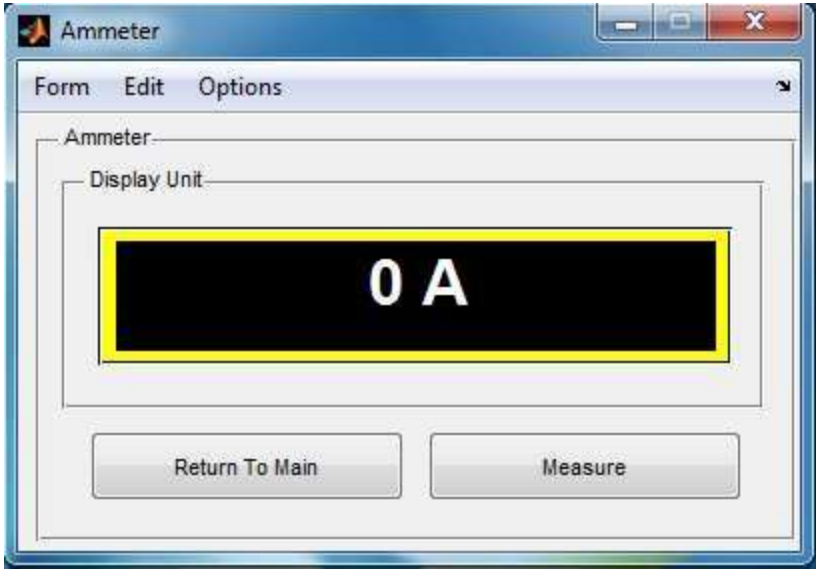


Main Form to Select Virtual Instrument



Voltmeter

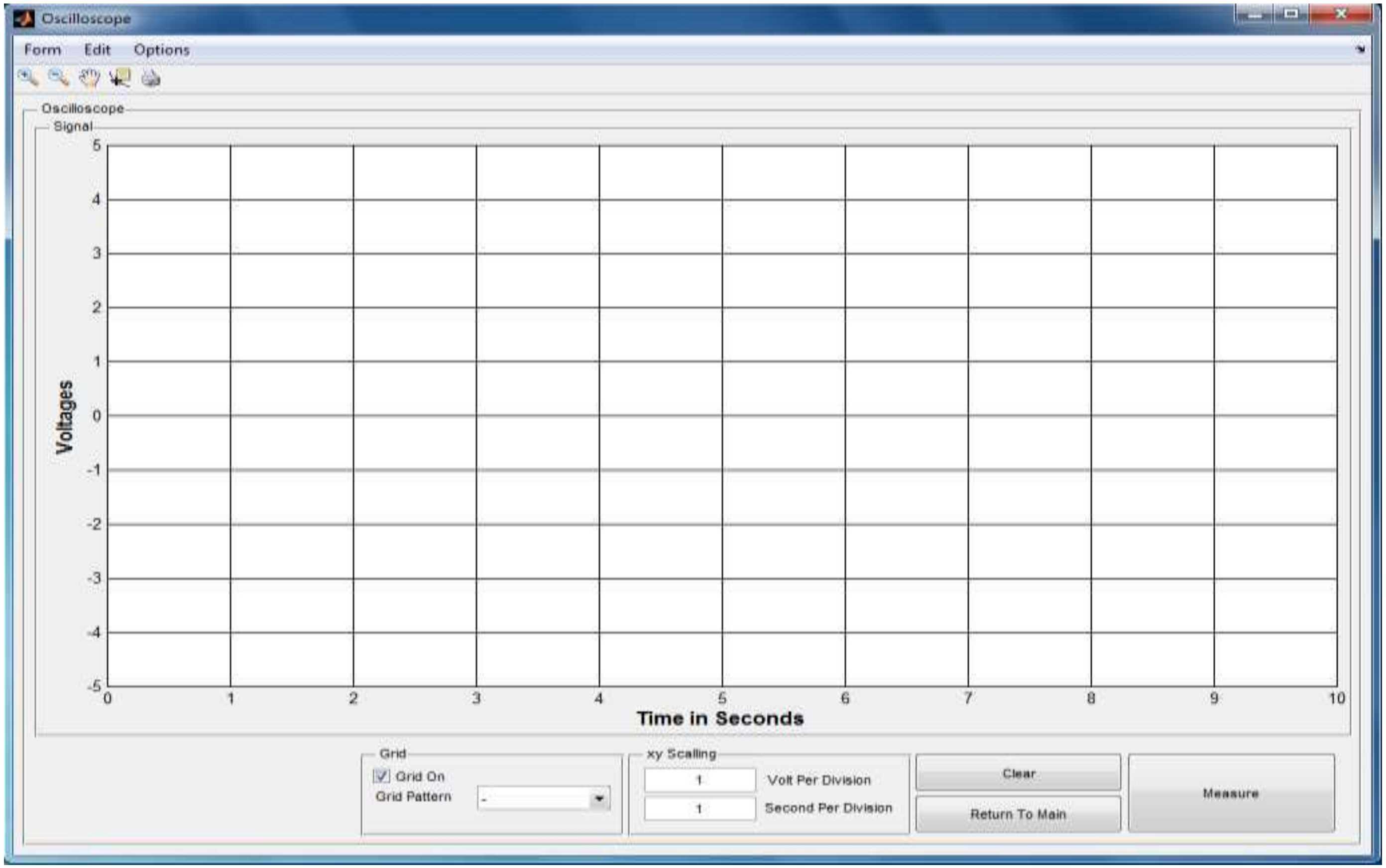
APPLICATIONS



Ammeter

Ohmmeter

APPLICATIONS



Oscilloscope

ADVANTAGES

- **Lower cost of instrumentation**
- **Easy-to-use graphical user interface**
- **Portability between various computer platforms**
- **Increases the utility of computer**
- **Flexibility**

DISADVANTAGES

- <u>Security</u>

Sensitive information may be accessible to public users.

- <u>Power Consumption</u>

VI demands that many devices run simultaneously and can consume a lot of power. Each computer will consume a large amount of power in addition to any external hardware.