# Industrial Instrumentation

## 328355(28)

**Course Instructor:**

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# Marks Distribution

- Theory: ESE = 80 + TA = 20; Total = 100

| Attendance | Assignment | Viva/Presentation | Total |
|---|---|---|---|
| 5 | 10 | 5 | 20 |

| CO-1 | CO-2 | CO-3 | CO-4 | CO-5 | Total |
|---|---|---|---|---|---|
| 4 | 4 | 4 | 4 | 4 | 20 |

# Marks Distribution

- Practical (Lab): ESE = 40 + TA = 20
- 10 Experiments to be performed.
- For Each Experiment marking will be:

  Practical & Viva = 10 + Report = 10
- 10 x 20 = 200 marks will be normalised to final 20 marks.

# Course Objectives

1. To study the Basic Measurement System.
2. To understand Basics of Transducers and Primary Sensing Elements.
3. To understand different types of Transducers relating with Non Electrical Parameter.
4. To study Temperature and Pressure measurement.
5. To study different phenomena of Flow measurement and Photo Electricity.

# Unit 1

Measurement Systems

Government Engineering College, Raipur (CG)

# Syllabus

- **Introduction** to measurement system
- Elements of Generalised measurement systems
- **Cathode Ray Oscilloscope (CRO)**
- Block Diagram of CRO
- Measurement of Phase & Frequency using Lissajous Pattern
- Dual Trace Oscilloscope
- Sampling Oscilloscope
- Digital Storage Oscilloscope
- **Display Devices:** LED, LCD

# Books

1. Electrical and Electronic Measurements and Instrumentation by A.K. Sawhney, Dhanpat Rai & Co., 18e
2. Mechanical Measurements & Control by D.S. Kumar, Metropolitan Book Co., 5e

# Introduction

- **Measurement**: The measurement of a quantity is an act of comparison between the unknown quantity and a pre-defined standard.
- The result is usually expressed in form of Numerical values.
- In fact, the measurement is a process in which we convert physical parameter into meaningful numbers.
- This numerical measure is followed by a Unit, which identifies a particular characteristic or property of the quantity under measurement.

# Introduction

- For a meaningful measurement following conditions must be met:

1. The Standard used must be accurately defined and should be commonly acceptable.
2. The apparatus used and the method adopted must be provable.

# Methods of Measurement

- There are 2 broad classification
  1. Direct Methods
  2. Indirect Methods

# Methods of Measurement

- **Direct Methods**: In these methods the unknown quantity (a.k.a. measurand) is directly compared against a standard. The result is expressed as a numerical number followed by a unit.
- Direct methods are most common methods for measurement of any quantity such as length, mass, time etc.
- These methods are not preferable due to human involvement, less accuracy, and less sensitivity. Also these methods are not always practical and feasible.

# Methods of Measurement

- **Indirect Methods**: In these methods the unknown quantity is measured by indirect comparison with secondary standards through calibration.
- The measurand is first converted into an analogous signal which is then fed to a device which gives the result of measurement.
- These methods avoids direct and frequent handling of the standards.

# Generalised Measurement System

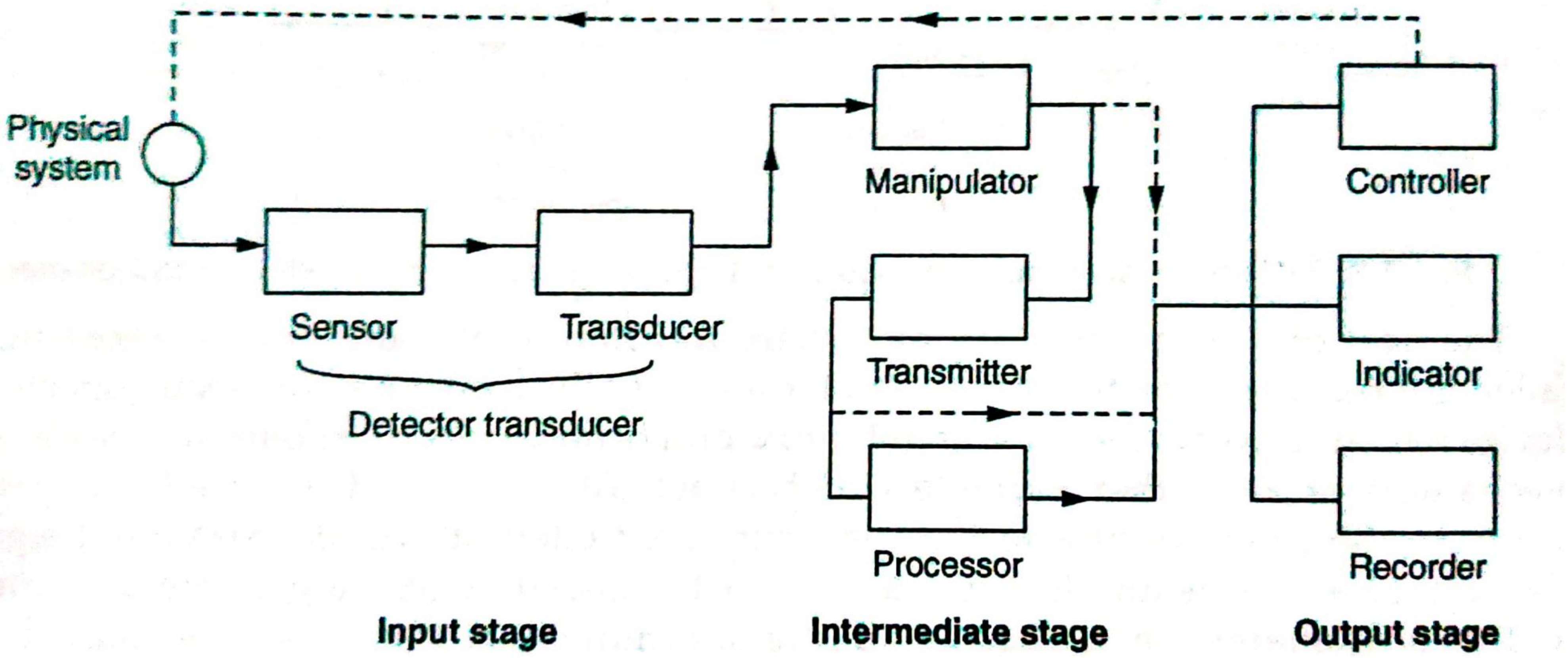



**Figure 1**

# Generalised Measurement System

- **Primary Sensing Element**: It sense the condition, state or value of the measurand by extracting a small amount of energy from it and then it produces an output which reflects this condition, state or value.
- Because of extraction of small energy (a.k.a. loading effect), the measurand is disturbed by the act of measurement and so a perfect measurement is not possible.
- A good instrument is designed to reduce the loading effect.

# Generalised Measurement System

- **Transducer or Variable Conversion Element**: It converts the signal from one physical form into another, without changing the information content.
- The signal after transduction becomes more suitable for measurement and control.
- Ex. – Bourdon tube converts pressure into displacement, Thermocouple converts temperature into emf, flow meters converts flow into pressure etc.

# Generalised Measurement System

- **Manipulation Element**: This operates on the signal according to some mathematical rule, without changing the physical nature of the variable.

[input] x Constant = [output]

- Ex. – The Odometer of an automobile measures the distance travelled by following formula:

[revolution] x (kilometer / revolution) = kilometer

# Generalised Measurement System

- **Data Processing Element**: It modifies the data before it is finally displayed or recorded.
- Data processing is used for purposes such as:

1. Correction to the measured physical variable to compensate for scaling, nonlinearity, zero offset, etc.
2. Perform operations such as addition, subtraction, multiplication or division of two or more variables.
3. Converting data into useful form.
4. Separate signal from noise, distortion etc.
5. Collect average, logarithmic etc. values.

# Generalised Measurement System

- **Data Presentation Element**: This element provides an indication or record of the output from data processing element.
- This element may serve following functions: Transmitting, Signalling, Indicating, Recording, Registering.

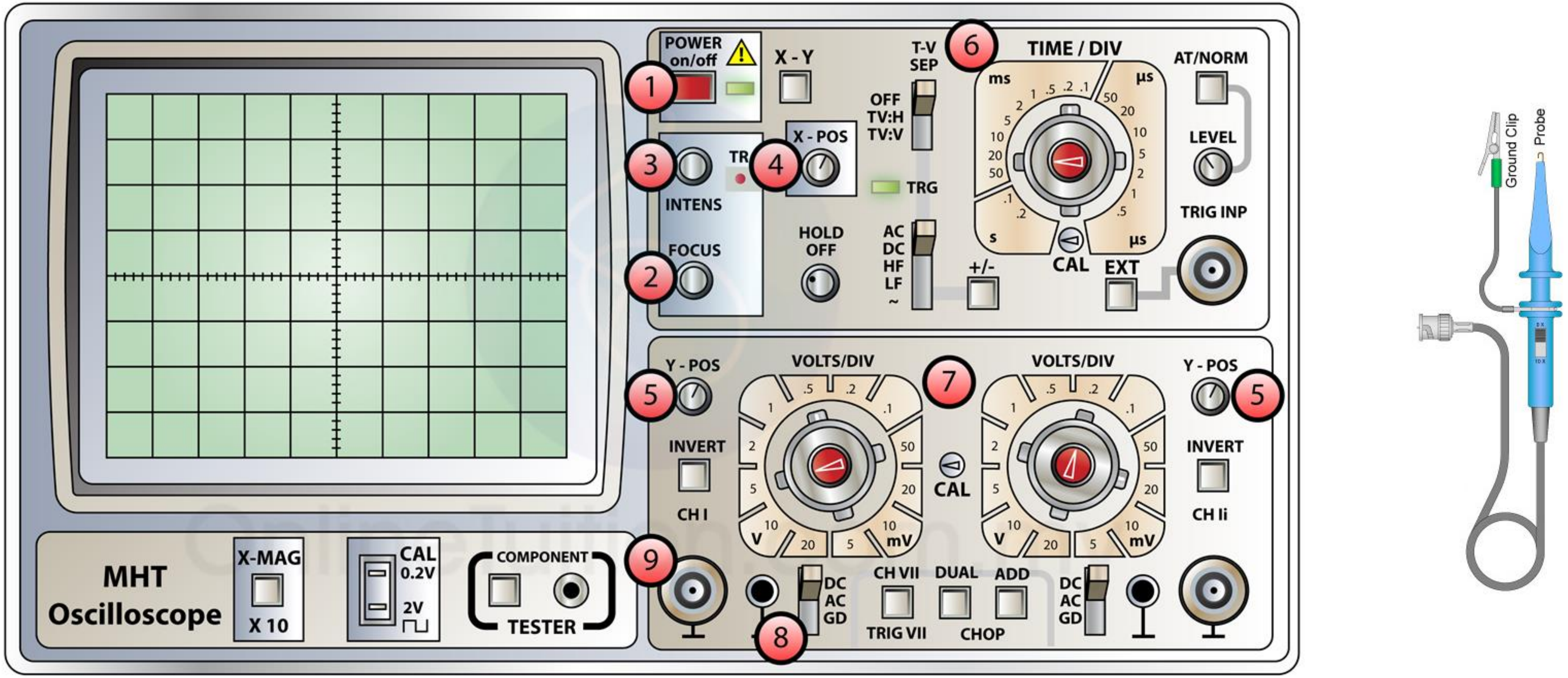
# CRO

- CRO stands for Cathode Ray Oscilloscope.
- An 'oscilloscope', previously called an 'oscillograph’, and informally known as a scope or o-scope, CRO (for cathode-ray oscilloscope), or DSO (digital storage oscilloscope), is a type of electronic test instrument that graphically displays varying signal voltages, usually as a two-dimensional plot of one or more signals as a function of time.
- Oscilloscopes display the change of an electrical signal over time, with voltage and time as the Y- and X-axes, respectively, on a calibrated scale.

# CRO

- Other signals (such as sound or vibration) can be converted to voltages and displayed.
- The waveform can then be analyzed for properties such as amplitude, frequency, rise time, time interval, distortion, and others. Calculation of these values required manually measuring the waveform against the scales built into the screen of the instrument.
- Modern digital instruments (DSO) may calculate and display these properties directly.

# CRO



POWER on/off
X - Y
T-V SEP
TIME / DIV
AT/NORM
OFF TV:H TV:V
X - POS
TR
TRG
LEVEL
INTENS
TRIG INP
FOCUS
HOLD OFF
AC DC HF LF ~
+/-
CAL
EXT
ms
µs
s
Y - POS
VOLTS/DIV
VOLTS/DIV
Y - POS
INVERT
INVERT
CAL
CH I
CH Ii
V
mV
MHT Oscilloscope
X-MAG
X 10
CAL 0.2V 2V
COMPONENT
TESTER
DC AC GD
CH VII
DUAL
ADD
TRIG VII
CHOP
1
2
3
4
5
6
7
8
9
Ground Clip
Probe


**Figure 2**

# DSO

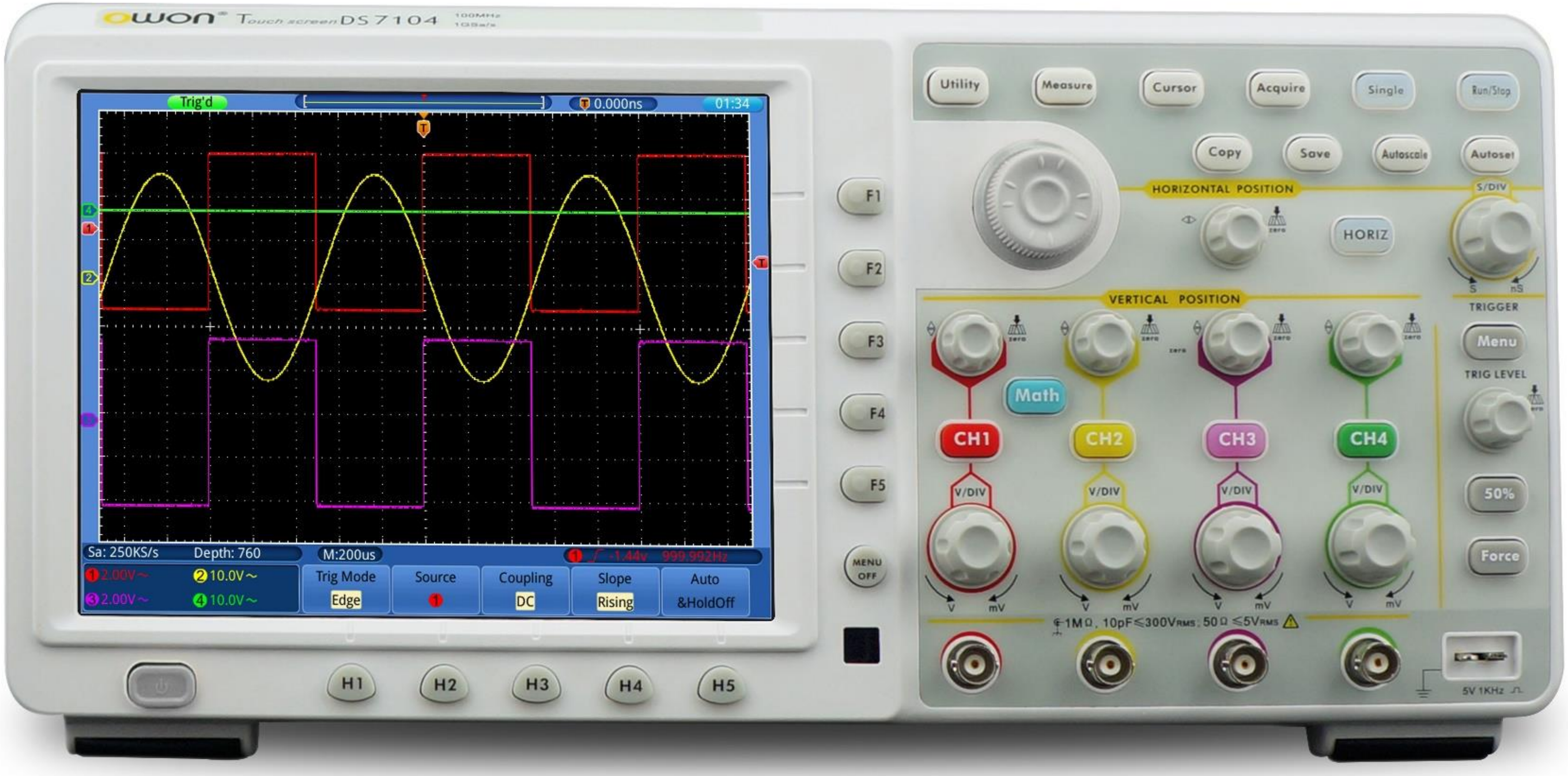

OWON
Touch screen DS7104
Trig'd
0.000ns
01:34
Sa: 250KS/s
Depth: 760
M:200us
2.00V
10.0V
Trig Mode
Edge
Source
Coupling
DC
Slope
Rising
Auto
&HoldOff
F1
F2
F3
F4
F5
MENU OFF
H1
H2
H3
H4
H5
Utility
Measure
Cursor
Acquire
Single
Run/Stop
Copy
Save
Autoscale
Autoset
HORIZONTAL POSITION
HORIZ
S/DIV
VERTICAL POSITION
TRIGGER
Menu
TRIG LEVEL
Math
CH1
CH2
CH3
CH4
V/DIV
50%
Force
5V 1KHz

**Figure 3**

# CRO

- The luminous spot is produced by a beam of electrons striking a fluorescent screen.
- The normal form of a CRO uses a horizontal input voltage which is an internally generated ramp voltage, called **Time Base**.
- This horizontal voltage moves the luminous spot periodically in a horizontal direction from left to right over the display area or screen.
- The vertical input to the CRO is the voltage under investigation.

# CRO

- The vertical input voltage moves the luminous spot up and down in accordance with the instantaneous value of the voltage.
- The luminous spot thus traces the waveform of the input voltage with respect to time.
- When the input voltage repeats itself at a fast rate, the trace (display) on the screen appears stationary on the screen.
- CROs operate on voltages. However, it is possible to convert current, strain, acceleration, pressure and other physical quantities into voltages with the help of transducers.

# CRO

- Range: CROs can –measure frequencies upto 1 GHz, and observer events as small as 20 Hz in duration.
- Most present day oscilloscopes are capable of accepting two or more inputs & displaying them simultaneously.
- Storage oscilloscope can be used to store the waveform to inbuilt memory, external memory or to a computer connected to it via serial communication cable.

# Cathode Ray Tube

- The Analog oscilloscope uses a modified form of conventional Cathode Ray Tube (CRT) to display the waveform.
- The main parts of CRT are:
  a) Electron Gun assembly
  b) Deflection plate assembly
  c) Fluorescent Screen
  d) Glass Envelope
  e) Base, through which connections are made to various parts.

# Cathode Ray Tube

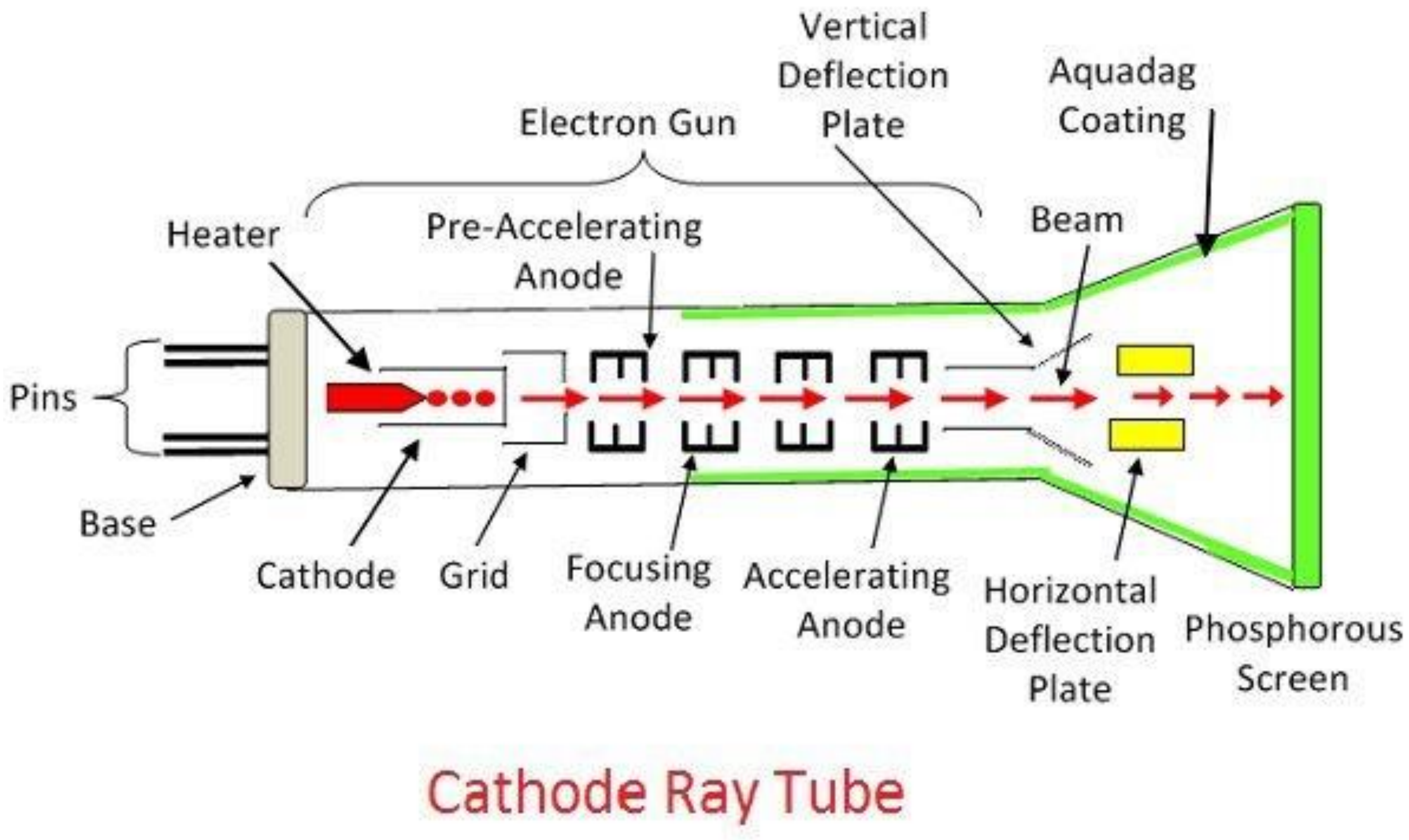



**Figure 4**

# Cathode Ray Tube

- The Electron gun assembly produces a beam of electrons, which is focused and accelerated to high velocity. This beam of electrons strike the fluorescent screen with sufficient energy, which produces a luminous spot on the screen.
- After leaving the electron gun, the beam passes through two pairs of Electrostatic deflection plates. Voltage applied to these plates deflects the beam. One of the plate is responsible for vertical deflection / movement of beam and the other for horizontal movement.

# Cathode Ray Tube

- **Electron Gun**: The source of focused and accelerated electron beam is the electron gun.
- This consists of a heater, a cathode, a grid, a pre-accelerating anode, a focusing anode and an accelerating anode.
- The connections to the various electrodes are brought out through pins in the base of the tube as shown in Fig.

# Cathode Ray Tube

- Electrons are emitted from the indirectly heated cathode. A layer of Barium and Strontium Oxide is deposited on the end of the cathode to obtain high emission of electrons.
- The typical values of current and voltage required by an indirectly heated cathode are 600 mA at 6.3 V. High efficiency systems uses 300 mA at 6.3 V. Special low power design uses 140 mA at 1.5 V.
- These electrons pass through a small hole in the control grid. The control grid is usually a Nickel cylinder, with a centrally located hole, co-axial with the CRT axis.

# Cathode Ray Tube

- The intensity 0f 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 of the beam.
- Then the beam is accelerated by the high positive potential applied to the pre-accelerating and accelerating anodes.
- The electron beam is focused by the focusing beam.
- The accelerating and focusing anodes are cylindrical in shape, with small opening in the center and coaxial with the tube axis.

# Cathode Ray Tube

- There are two methods of focusing an electron beam:

1. Electrostatic focusing and
2. Electromagnetic focusing

- The CRO uses electrostatic method of focusing as compared to the TV picture tube which uses electromagnetic focusing.

# Cathode Ray Tube

- **Electrostatic Focusing:** The force acting on an electron is given by

$$\boldsymbol{F = -eE} \text{ (Newton)}$$

Where: $e$ = charge of electron = $-1.6 \times 10^{-19}$ (C)

& $E$ = Electric field intensity (V/m)

- In above equation, the –ve sign indicates that the force F is acting in the opposite direction to that of the electric field E.
- The above discussion is valid only when the electron is placed in uniform field, as shown in figure 5.

# Cathode Ray Tube

- In practice however, the field is not uniform, but are curved at the ends due to lateral repulsion.

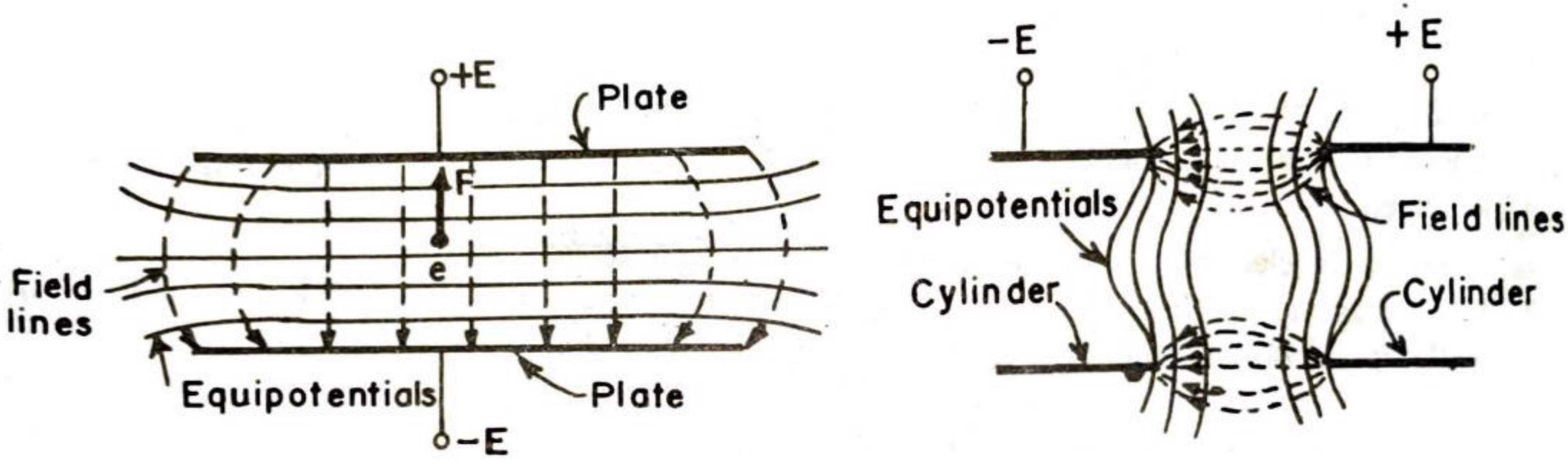



**Figure 5**

# Cathode Ray Tube

- **Refraction of Electron Beam**: Consider the region on two sides of an equipotential surface S, as shown in figure 6.

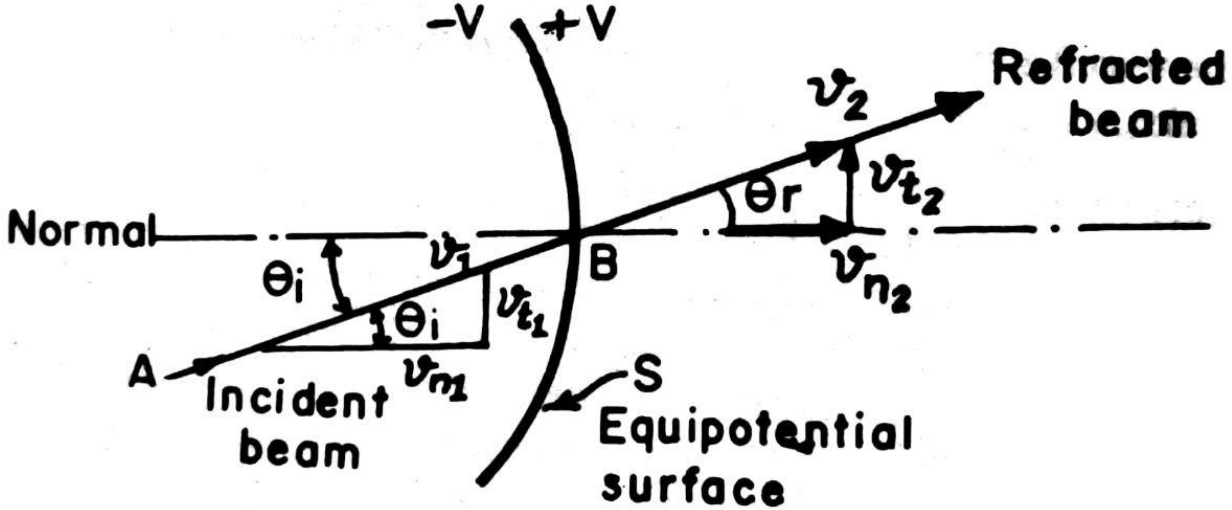



**Figure 6**

# Cathode Ray Tube

- The potential on left side of S is –V and on right side is +V.
- Let an electron is moving from left to right in AB direction.
- This electron will experience a force which is normal to the surface S, and will be accelerated.
- Since the force is in normal direction, the normal component of velocity is increased while the tangential component remains same.
- Let the velocity before surface S is v1 and after surface is v2.
- Since tangential components are same

$$v_{t1} = v_{t2}$$

# Cathode Ray Tube

$$v_{t1} = v_{t2}$$
$$\Rightarrow v_1 \sin\theta_i = v_2 \sin\theta_r$$
$$\Rightarrow \frac{\sin\theta_i}{\sin\theta_r} = \frac{v_2}{v_1}$$

Where

$v_1$ = initial velocity of electron

$v_2$ = velocity of electron after leaving surface S

$\theta_i$ = angle of incidence

$\theta_r$ = angle of refraction

# Cathode Ray Tube

- The above equation is identical to the expression of refraction of light.
- The refraction of electron beam occurs similar to the refraction of light beam. And so, the focusing system in CRT is known as "electron lens".
- Figure 7 shows the functional diagram of electrostatic focusing in a CRT.
- Here, the pre-accelerating and accelerating anodes are connected to the same potential while the focusing anode is connected to a lower potential.

# Cathode Ray Tube

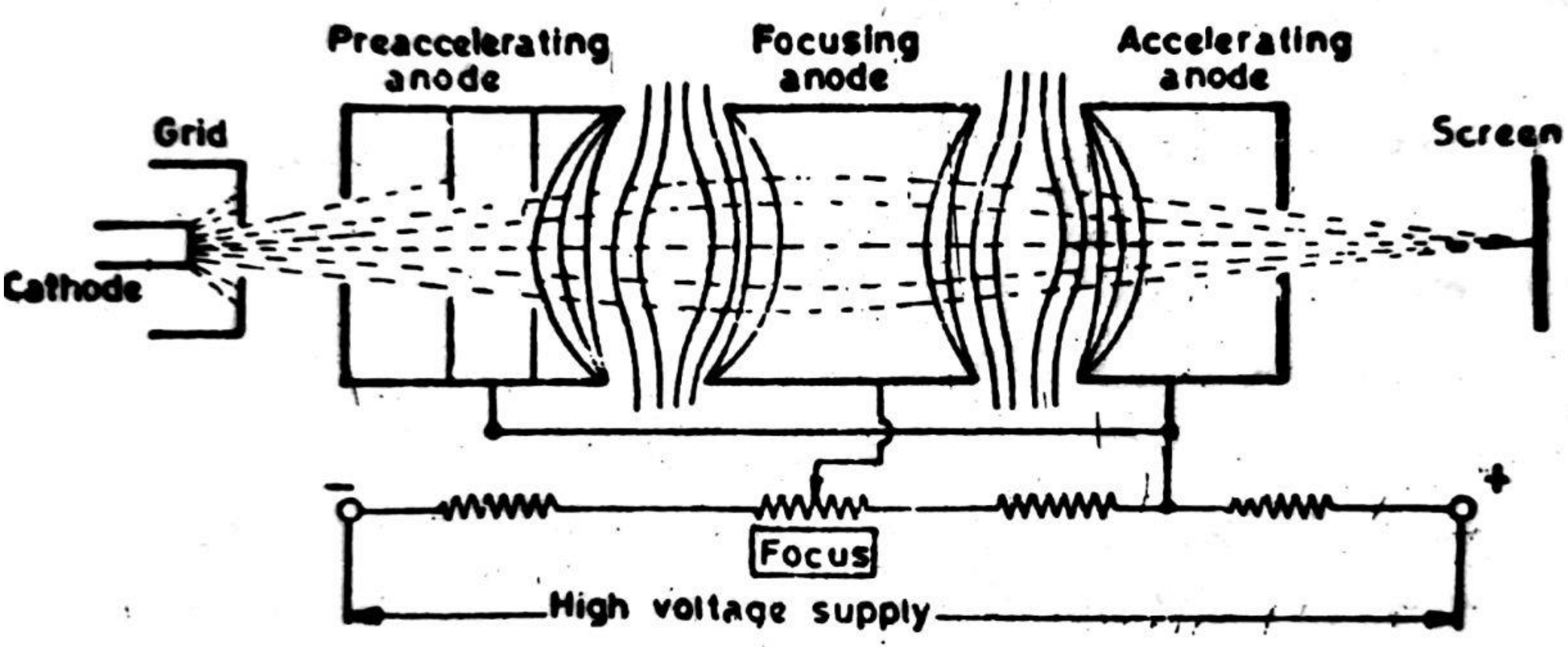



Figure 7

# Cathode Ray Tube

- On account of difference of potential between focusing anode and the two accelerating anodes a non-uniform field exists on each of the two ends of the focusing anode.
- The equipotential surfaces, thus, form a “double concave lens”.
- By changing the voltage of the focusing anode, the refractive index of the electron lens is changed and therefore the focal point of the beam can be changed.
- The change in voltage is brought about by changing the setting of a potentiometer. This control is located at the front panel of CRO and is marked as **Focus.**

# Cathode Ray Tube

- **Deflection Plates:** After leaving the electron gun the beam passes through two pairs of deflection plates.
- One pair is mounted horizontally and produces an electric field in the vertical plane. This pair produces a vertical deflection and is thus called **Vertical Deflection Plates** or **Y Plates.**
- The other pair of plates is mounted vertically and produces a horizontal deflection. This pair of plates is called **Horizontal Deflection Plates** or **X Plates**.

# Cathode Ray Tube

- **Screen:** The front of the CRT is called the face plate.
- It is flat for screen sizes up to about 100 mm x 100 mm, and is slightly curved for larger displays.
- The face plate is formed by pressing molten glass in a mould. Some CRTs have a face plate made entirely from fiber optics.
- The inside surface of the face plate is coated with **phosphor**.
- This consists of very pure inorganic crystalline phosphor crystals, about 2-3 micron in diameter, to which traces of other elements, called activators, have been added.

# Cathode Ray Tube

- The **Activators** are usually metals such as silver, manganese, copper and chromium and they affect certain characteristics of the phosphor, such as its luminous efficiency, spectral emission and persistence.
- A **phosphor** converts electrical energy to light energy.
- When an electron beam strikes phosphor crystals it raises their energy level. This is known as ***cathodoluminescence.***
- Light is emitted during phosphor excitation and this is called **fluorescence**.

# Cathode Ray Tube

- When the electron beam is switched off the phosphor crystals return to their initial state, and releases a quantum of light energy. This is called ***phosphorescence*** or ***Persistence.***

# Cathode Ray Tube

- **Graticule:** It is a grid of lines that serves as a scale when making time and amplitude measurements.
- There are three types of graticules:

1. **External Graticule:** This is scribed on a Plexiglas acrylic plastic and fitted to screen. This graticule can be easily changed to make different types of measurements. External graticules suffer from parallax errors as they are not in the plane of the phosphor.

# Cathode Ray Tube

2. **Internal Graticule:** This is deposited on the internal surface of the CRT face plate, and is therefore on the same surface as the phosphor. Although there is no parallax error, an internal graticule cannot be changed for different measurements, and it also needs some method of electrical trace alignment.

3. **Projected Graticule:** It is available with some cameras. It provides flexibility which can include additional features such as legends on the graticule etc.

# Cathode Ray Tube

- **Aquadag:** The bombarding electrons, striking the screen, release secondary emission electrons.
- These secondary electrons are collected by an aqueous solution of graphite called *Aquadag* which is connected to the second anode.
- Collection of secondary electrons is necessary to keep the CRT screen in a state of electrical equilibrium.

# Block Diagram of generalised CRO

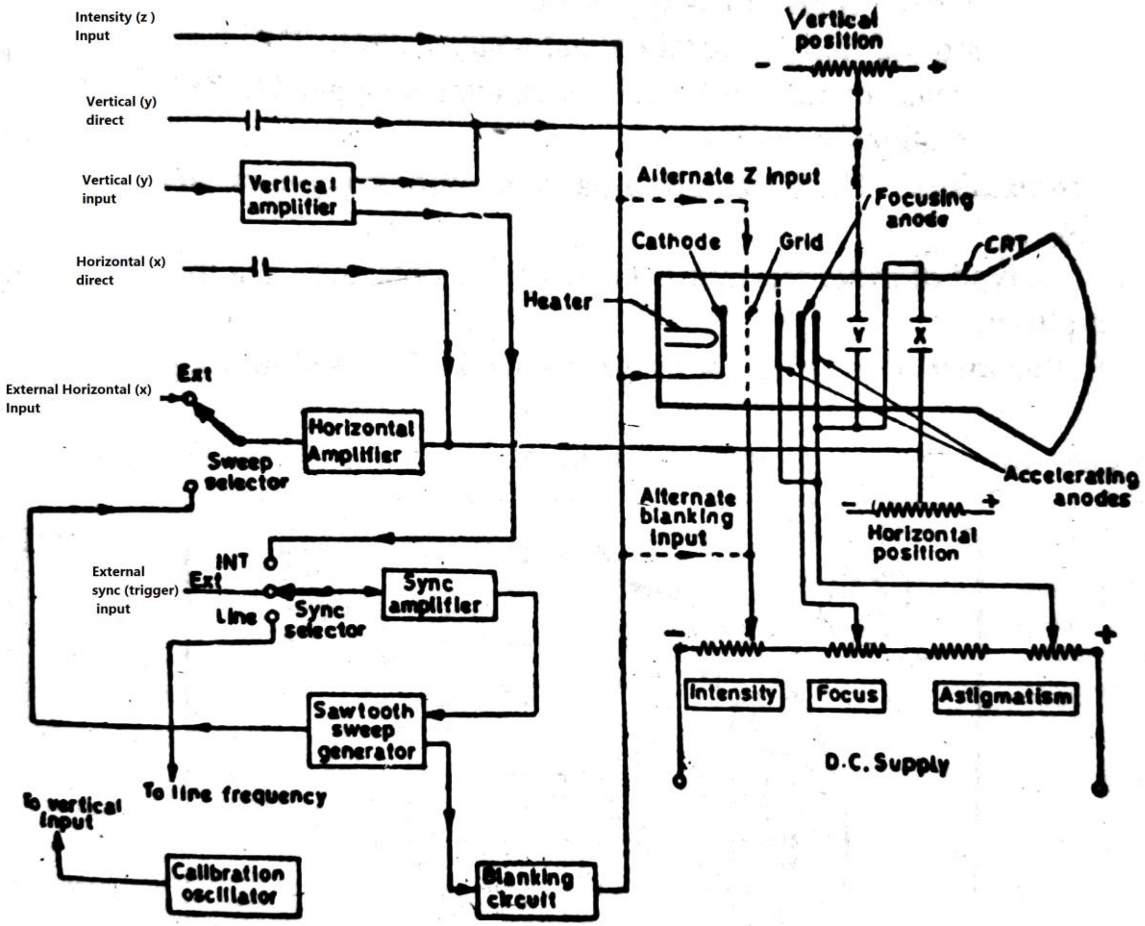



**Figure 8**

# Measurement of Voltages & Current

- The expression for electrostatic deflection is given by

$$D = \frac{LE_d I_d}{2dE_a}$$

Where:

$E_d$ = potential between deflecting plates (Volts)

$E_a$ = accelerating voltage (Volts)

$l_d$ = length of deflecting plates (m)

d = distance between deflecting plates (m)

L = distance between screen and center of deflection plate (m)

# Measurement of Voltages & Current

- From above expression, we can say that the deflection is proportional to the deflection plate voltage $E_d$.
- Thus we can measure voltage with the CRO.
- We can calibrate the reading with a known voltage and then measure the unknown voltage.
- Direct measurement can also be done from the length of the line produced on display by applying voltage to Y plates and no voltage to X plates.
- The length of this line corresponds to the peak-to-peak voltage.

# Measurement of Voltages & Current

- When dealing with sinusoidal voltages, the RMS value will be given by dividing peak-to-peak voltage with $2\sqrt{2}$.
- The current can be measured by measuring the voltage drop across a known resistance.

# Measurement of Phase & Frequency

- **Lissajous Patterns:** The patterns that appear on the CRO screen, when sinusoidal signals are applied to horizontal and vertical planes, are called as Lissajous Patterns.
- When two sinusoidal signals of same frequency and magnitude are applied to both pairs of deflecting plates of **CRO**, the Lissajous pattern changes with change of phase difference between the two signals.
- For different value of phase differences, the shape of Lissajous patterns is shown in figure below:

# Measurement of Phase & Frequency

1. Phase Difference $\Phi$ = 0° or 360°

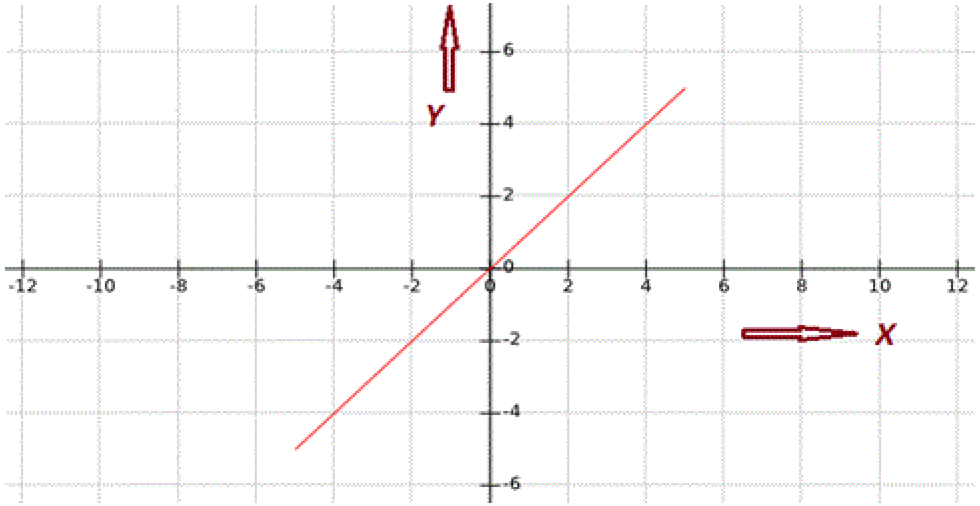



**Figure 9**

# Measurement of Phase & Frequency

2. Phase Difference $\Phi$ = 30° or 330°

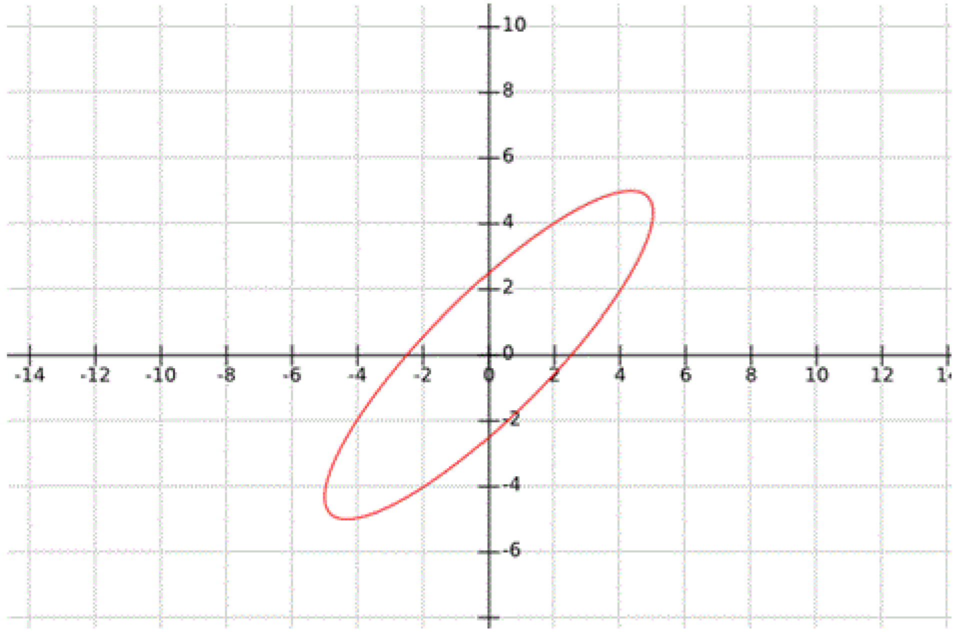



**Figure 10**

# Measurement of Phase & Frequency

3. Phase Difference $\Phi = 45°$ or $315°$

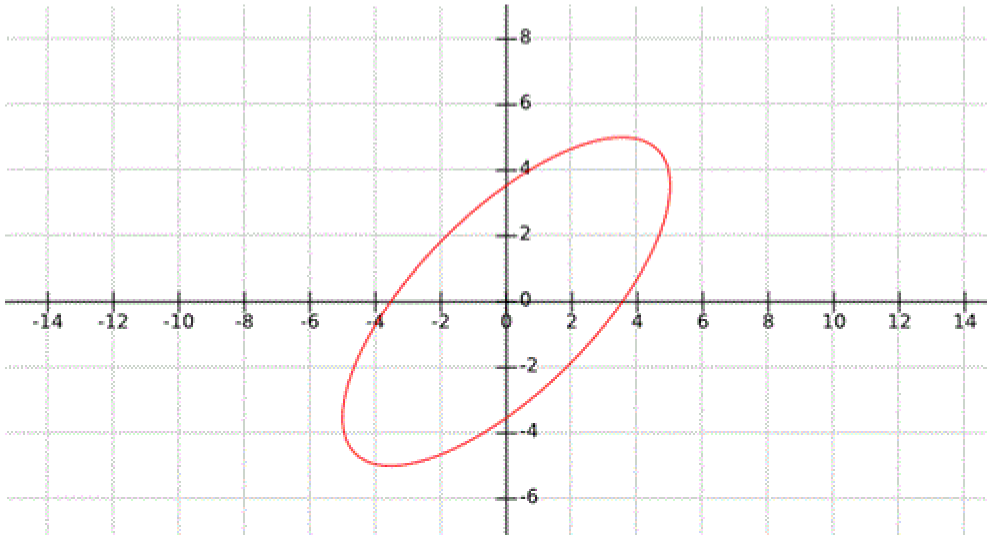



**Figure 11**

# Measurement of Phase & Frequency

4. Phase Difference $\Phi = 60^\circ$ or $300^\circ$

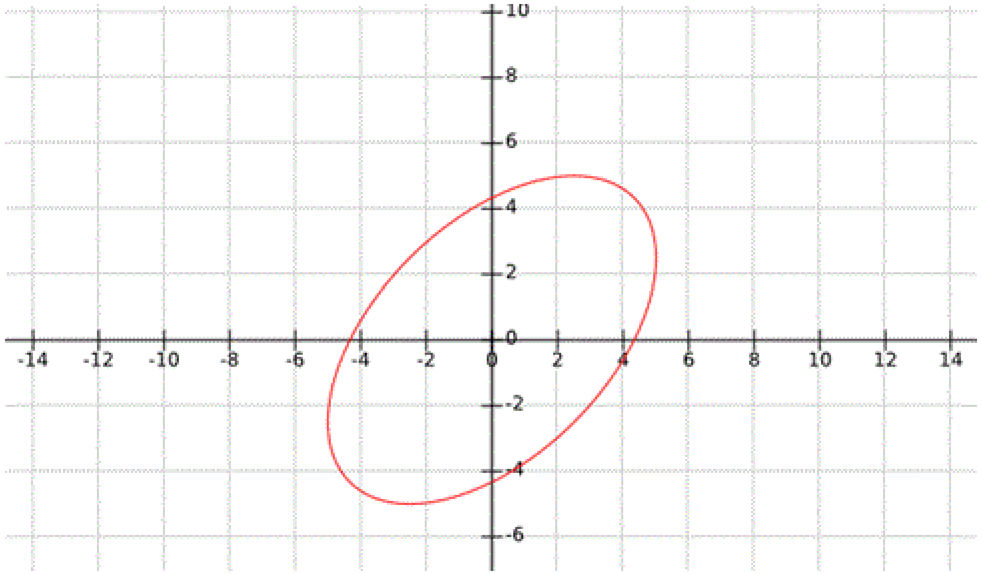



**Figure 12**

# Measurement of Phase & Frequency

5. Phase Difference $\Phi$ = 90° or 270°

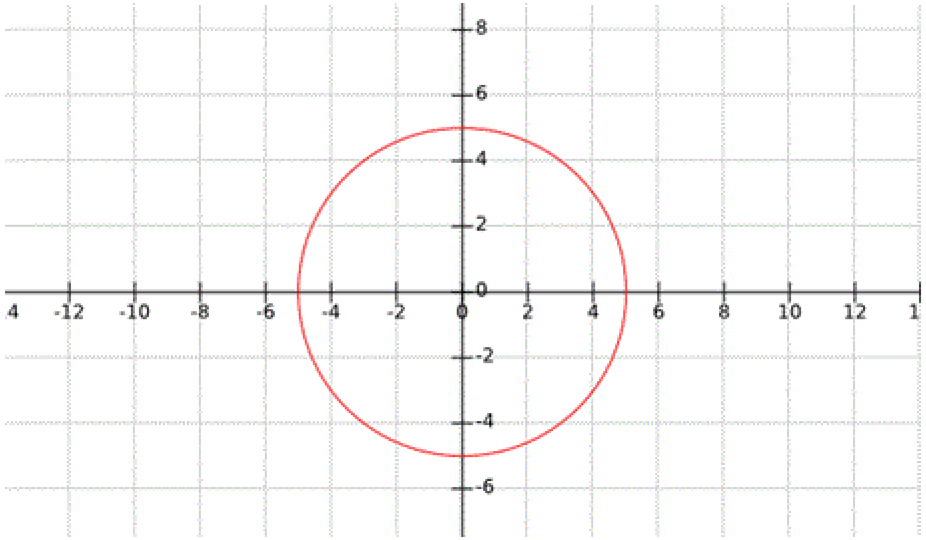



**Figure 13**

# Measurement of Phase & Frequency

6. Phase Difference $\Phi$ = 120° or 240°

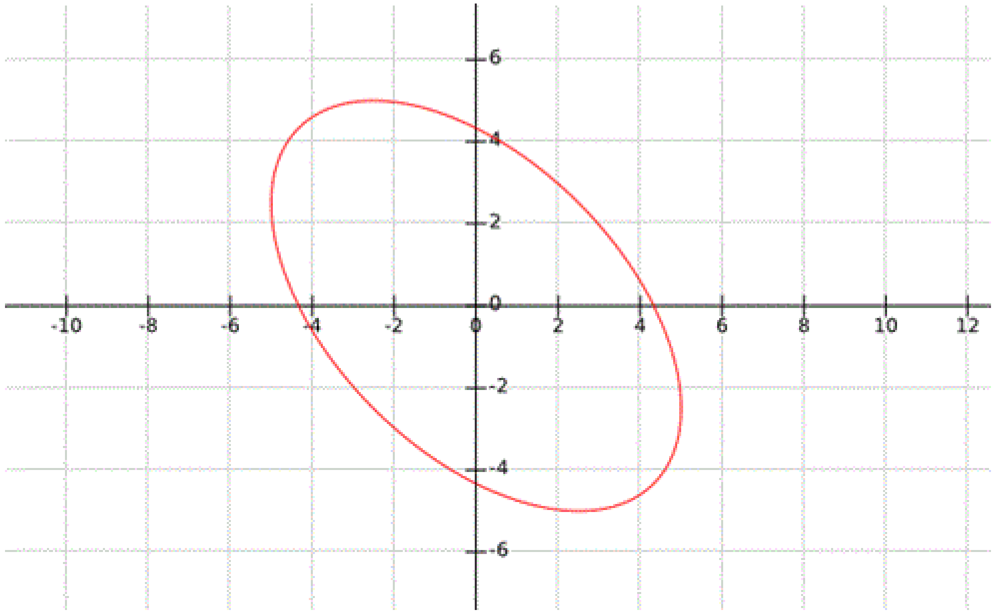



**Figure 14**

# Measurement of Phase & Frequency

7. Phase Difference $\Phi$ = 150° or 270°

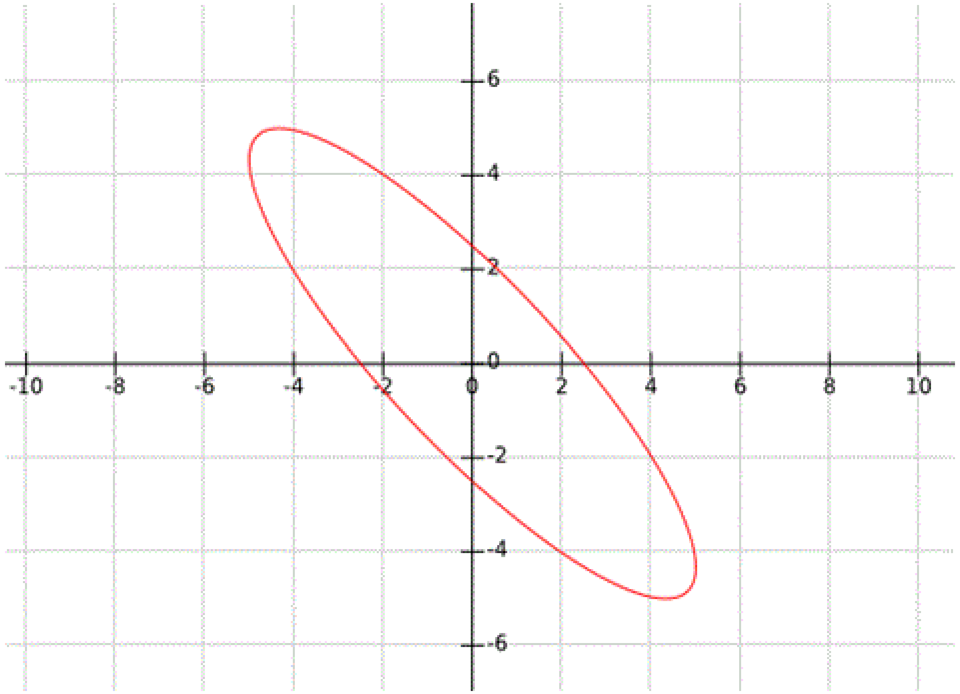



**Figure 15**

# Measurement of Phase & Frequency

8. Phase Difference $\Phi = 180°$

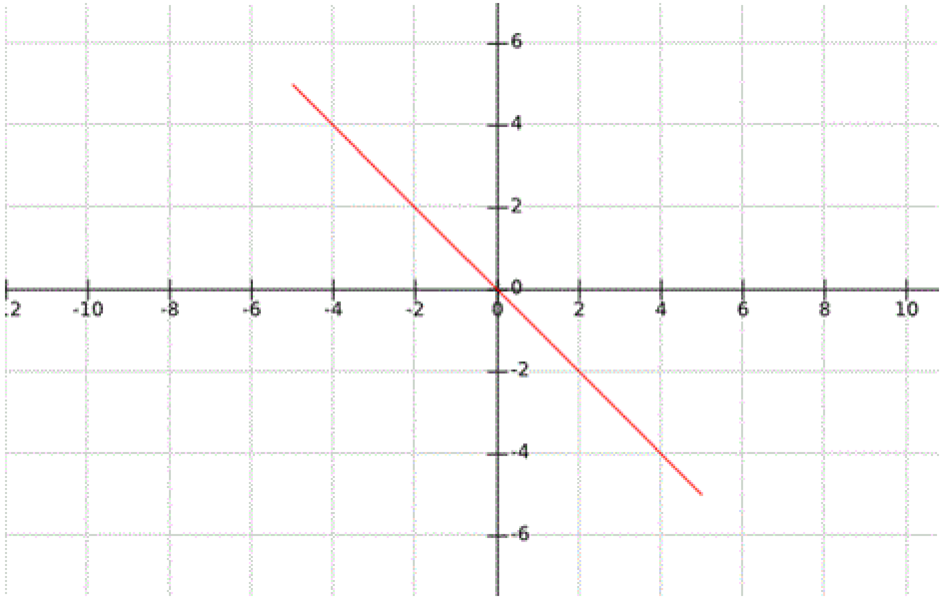



**Figure 16**

# Measurement of Phase & Frequency

- Observations: When we apply two signals with equal amplitude / voltage and equal frequency, shifted by some phase, we will get an ellipse.
- An ellipse is also obtained when the two voltages are different, with equal frequency and some phase shift.

- Some conclusions are made about these patterns, which are:

# Measurement of Phase & Frequency

Conclusion-1

- An straight line results, when the two voltages are equal and are either in-phase with each other or 180° out of phase.
- The angle formed with horizontal axis is 45° when the voltages are equal.
- When vertical deflection voltage > horizontal deflection voltage, angle with horizontal axis will be more than 45°.
- When vertical deflection voltage < horizontal deflection voltage, angle with horizontal axis will be less than 45°.

# Measurement of Phase & Frequency

Conclusion-2

- Two sinusoidal waveforms of same frequency produces a Lissajous pattern, which may be a straight line, a circle or an ellipse, depending upon the phase and magnitude of the voltage.
- A circle can be formed only when the two voltages are equal and phase is either 90° or 270°.
- If Y voltage > X voltage, an ellipse with major axis along the vertical is formed.
- If Y voltage < X voltage, an ellipse with major axis along the horizontal is formed.

# Measurement of Phase & Frequency

Conclusion-3

- For signals with equal voltages and equal frequency, with progressively increasing phase the pattern vary from a straight diagonal line to ellipses of different eccentricities and then to a circle, after that, another series of ellipses and finally to a diagonal straight line again.

# Measurement of Phase & Frequency

- **Phase Measurement:** Regardless of the two voltages applied, the ellipse provides a simple means of finding phase difference between the two signals.

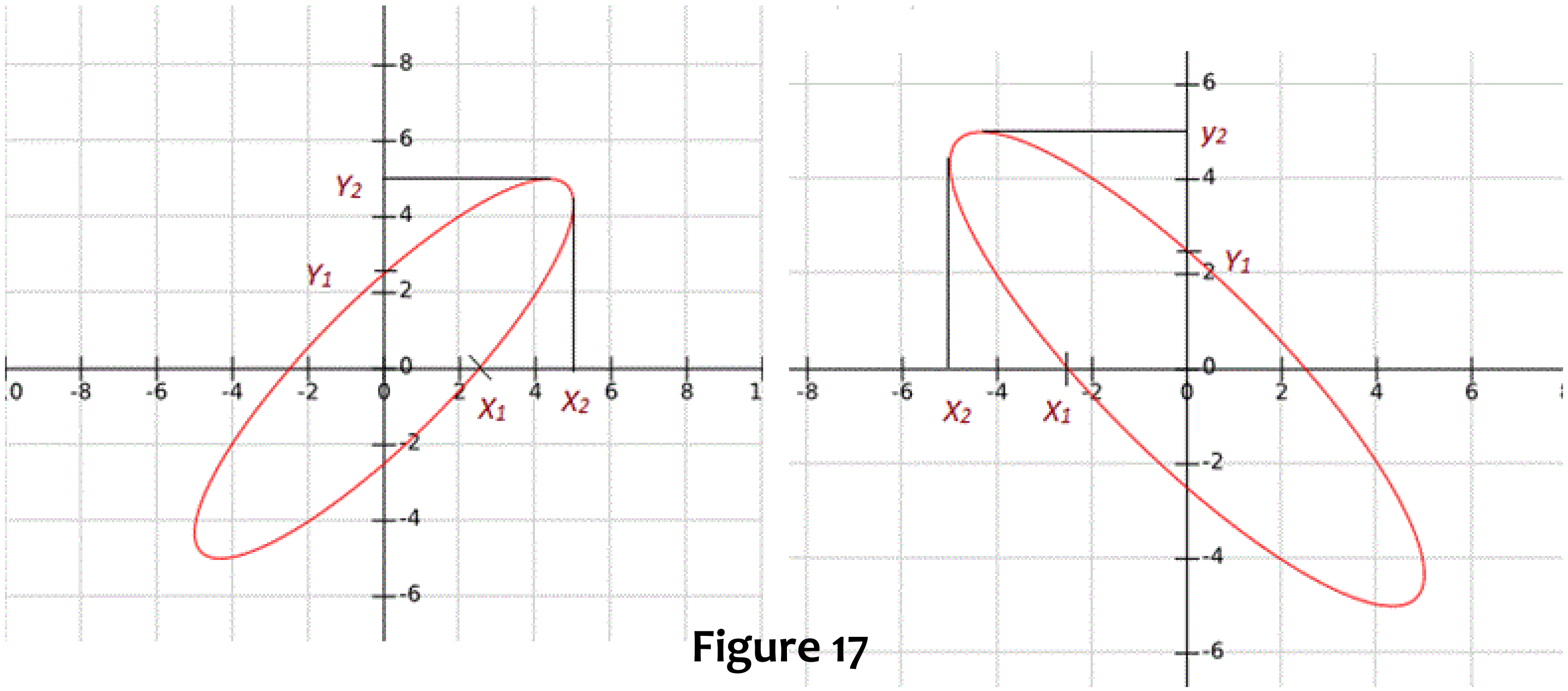



Figure 17

# Measurement of Phase & Frequency

- With reference to above figure, the sine of phase angle is given by:

$$\sin\phi = \frac{Y_1}{Y_2} = \frac{X_1}{X_2}$$

# Measurement of Phase & Frequency

- **Frequency Measurement:** Lissajous patterns may be used for accurate measurement of frequency.
- The signal whose frequency is to be measured, is applied to the Y plates, and an accurately calibrated standard variable frequency source is used to apply signal to X plates.
- Then the standard frequency is adjusted until the pattern appears as a circle or ellipse (indicating both signals are of same frequency).
- When it is not possible to adjust the standard freq. to the exact freq. of unknown signal, it is adjusted to multiple or sub-multiple of the freq. of the unknown signal so that pattern appears stationary.

# Measurement of Phase & Frequency

- **Example:** Let two sine waves are applied to X & Y plates, and the freq of Y plate wave is twice that of X plate wave.
- It means the spot travels 2 complete cycles in vertical direction against one cycle in horizontal direction.

- Then the Lissajous pattern will appear as shown →

# Measurement of Phase & Frequency

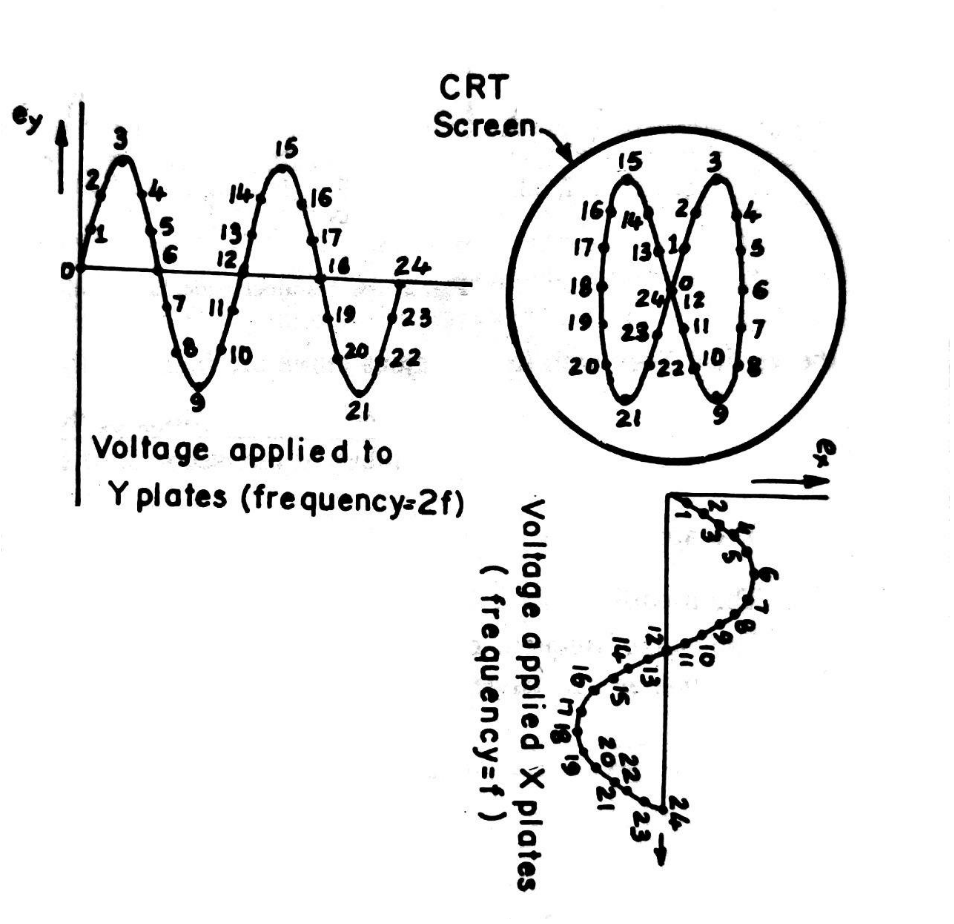



**Figure 18**

# Measurement of Phase & Frequency

- To determine the ratio of frequencies of signal applied to the vertical and horizontal deflecting plates by using the Lissajous pattern, simply draw horizontal and vertical tangent lines on Lissajous pattern.
- Now count the number of times horizontal and vertical tangents touches / intersects the Lissajous pattern.
- Then

$$\frac{f_Y}{f_X} = \frac{\textit{No. of times tangent touches top or bottom}}{\textit{No. of times tangent touches either side}}$$

$$= \frac{\textit{No. of horizontal tangencies}}{\textit{No. of vertical tangencies}}$$

# Measurement of Phase & Frequency

- Where $f_X$ = freq of signal applied to X plate

  $f_Y$ = freq of signal applied to Y plate
- Ex. -

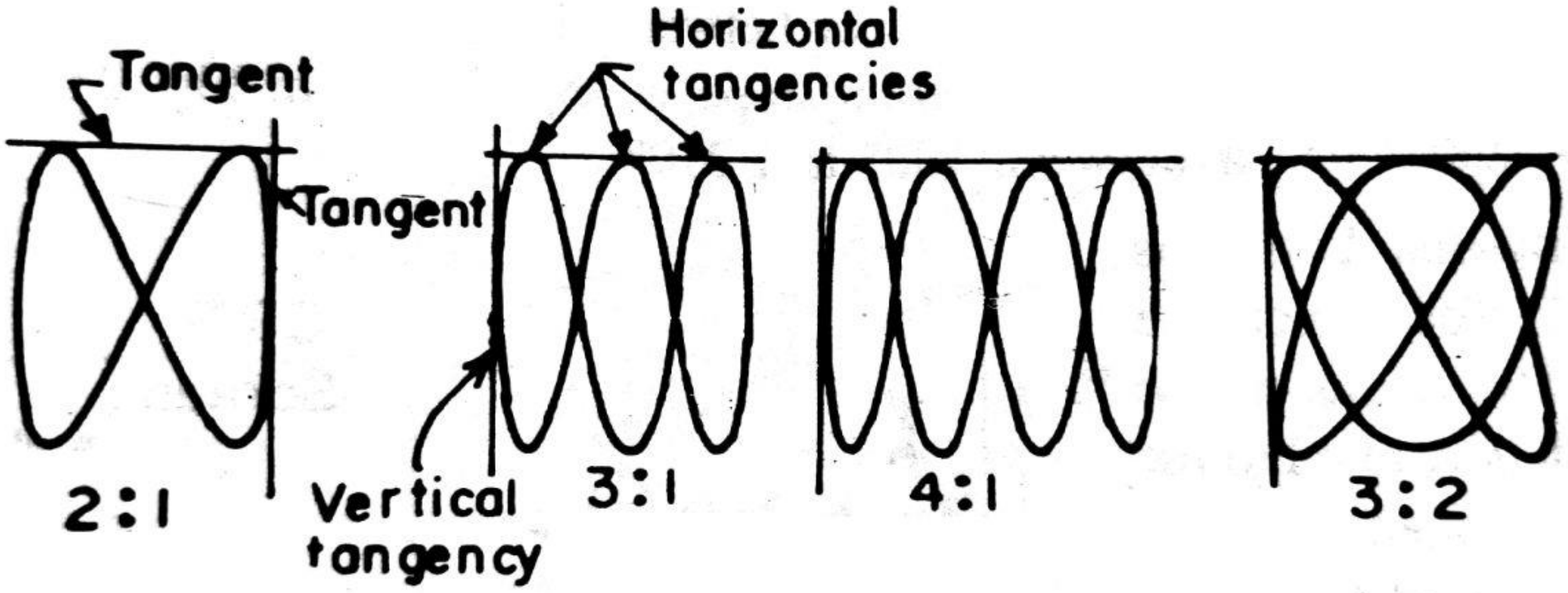
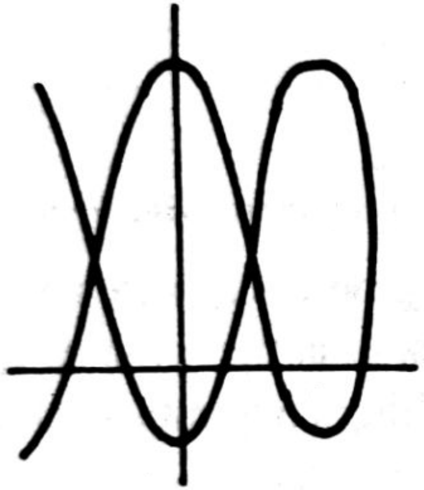



**Figure 19**

# Measurement of Phase & Frequency

- The above rule does not apply when the Lissajous pattern has free ends.



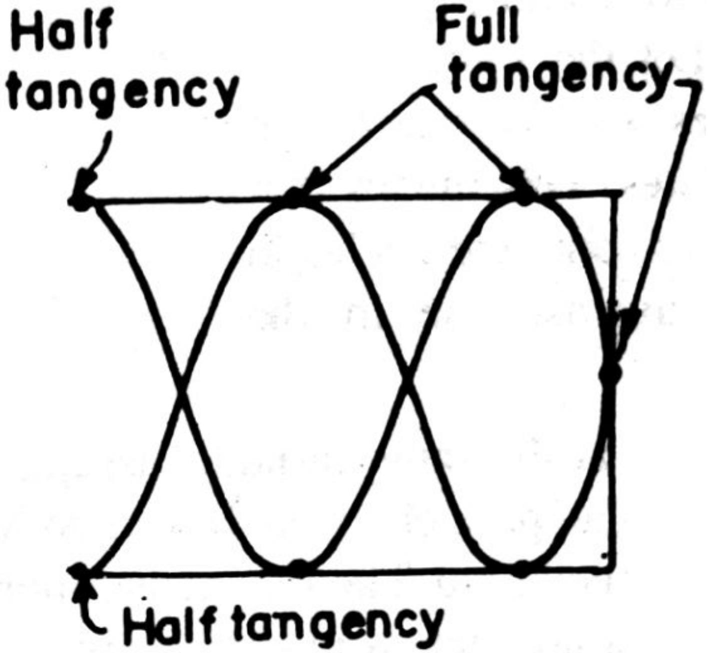



**Figure 20**

# Measurement of Phase & Frequency

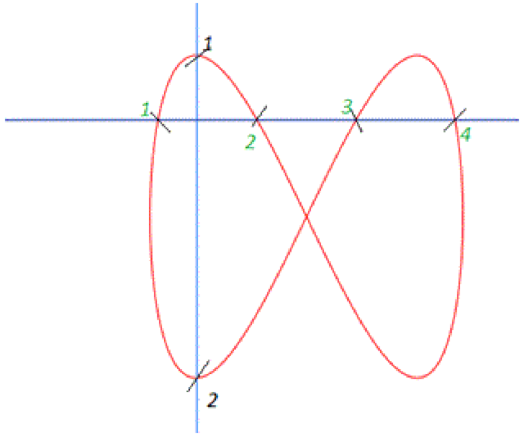
- Then the rule has to be modified as follows:
- The two lines, horizontal & vertical are drawn such that they do not pass through any intersections of different parts of the Lissajous curve.
- The no. of intersections with the two lines are counted, then

$$\frac{f_Y}{f_X} = \frac{\textit{No. of intersections of horizontal line with the curve}}{\textit{No. of intersections of vertical line with the curve}}$$

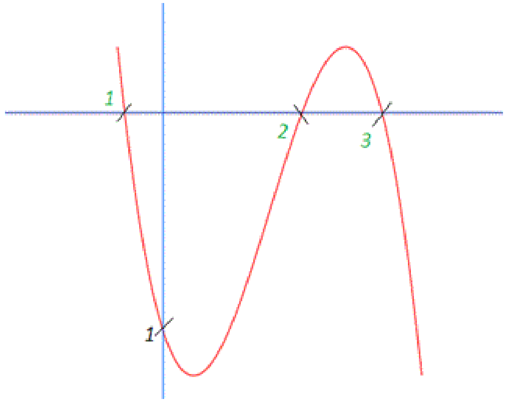
- In above figure $f_Y/f_X = (2+1/2)/1 = 5/2$

# Measurement of Phase & Frequency

- Some more examples:



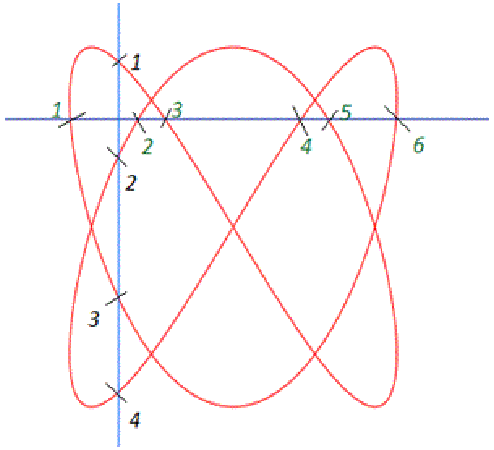

$f_y/f_x = 4/2 = 2$



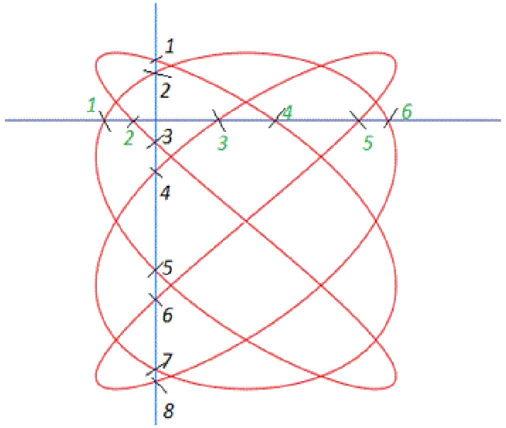

$f_y/f_x = 3/1 = 3$

**Figure 21**

# Measurement of Phase & Frequency



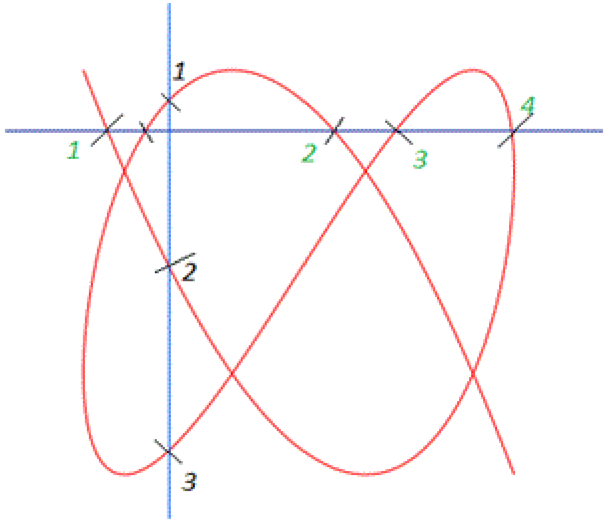

$f_y/f_x = 6/4 = 3/2$




$f_y/f_x = 6/8 = 3/4$

**Figure 22**

# Measurement of Phase & Frequency




$f_y/f_x = 4/3$

**Figure 23**

# Measurement of Phase & Frequency

- In above measurement, the two frequencies must be chosen such that the pattern do not become too complicated.
- Here ratios as high as 10:1 and as low as 10:9 can be determined comfortably.

# Multi-input Oscilloscope

- Oscilloscopes can have multiple inputs and display facility.
- 2 input is the most common, 4 & 8 inputs scopes are also available.

- There are two primary types of multi-input scopes:

1. Single Beam : which can be converted into several traces
2. Dual Beam : which can also be converted into further more traces.

# Dual Trace Oscilloscope

- Fig. 24 below shows block diagram of dual trace oscilloscope:

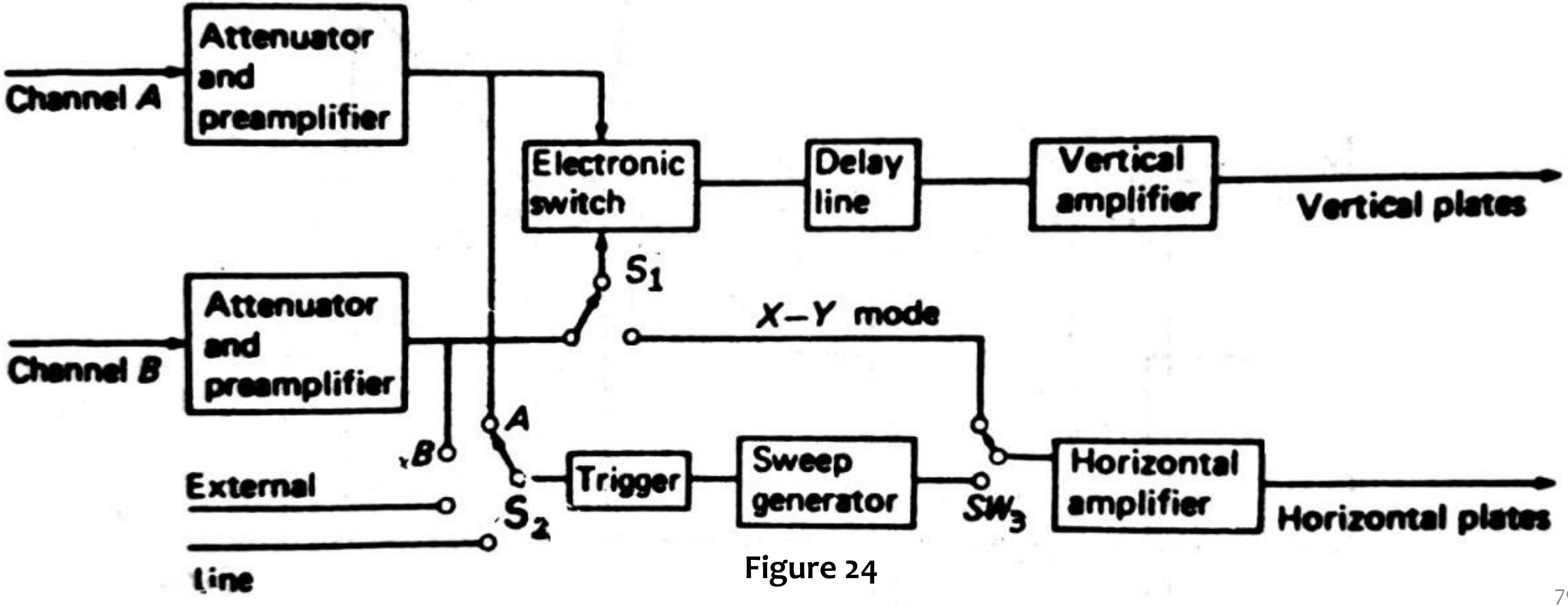



Figure 24

# Dual Trace Oscilloscope

- Various blocks of dual trace oscilloscope are as follows:

- **Channels** – As shown in figure 24, the dual trace oscilloscope has two separate vertical input channels A & B, through which the two signals will be fed to the CRO.

- **Pre-Amplifier** – For the two channels, two separate attenuator and pre-amplifier stages are used, and so the amplitude of each input can be adjusted separately.

# Dual Trace Oscilloscope

- **Electronic Switch** – After pre-amplification the two channels meet at an Electronic Switch S1, which sends one signal at a time towards the vertical amplifier through delay.
- There are two operating modes of electronic switch, which can be selected from the CRO's front panel –

1. Alternate Mode
2. Chop Mode

# Dual Trace Oscilloscope

1. **Alternate Mode:** In this mode, the electronic switch alternates between the two channels A & B, passing each one for one cycle of the horizontal sweep, i.e. for one cycle channel A will pass the for 2nd cycle channel B will pass, then again for 3rd cycle channel A will pass, and so on.

- The display is blanked during fly-back and hold-off periods.
- Since the sweep speed is very high the waveforms of the two signals appear stable.
- The alternate mode can not be used for displaying very low frequency signals.

# Dual Trace Oscilloscope

- Waveform for Alternate mode:

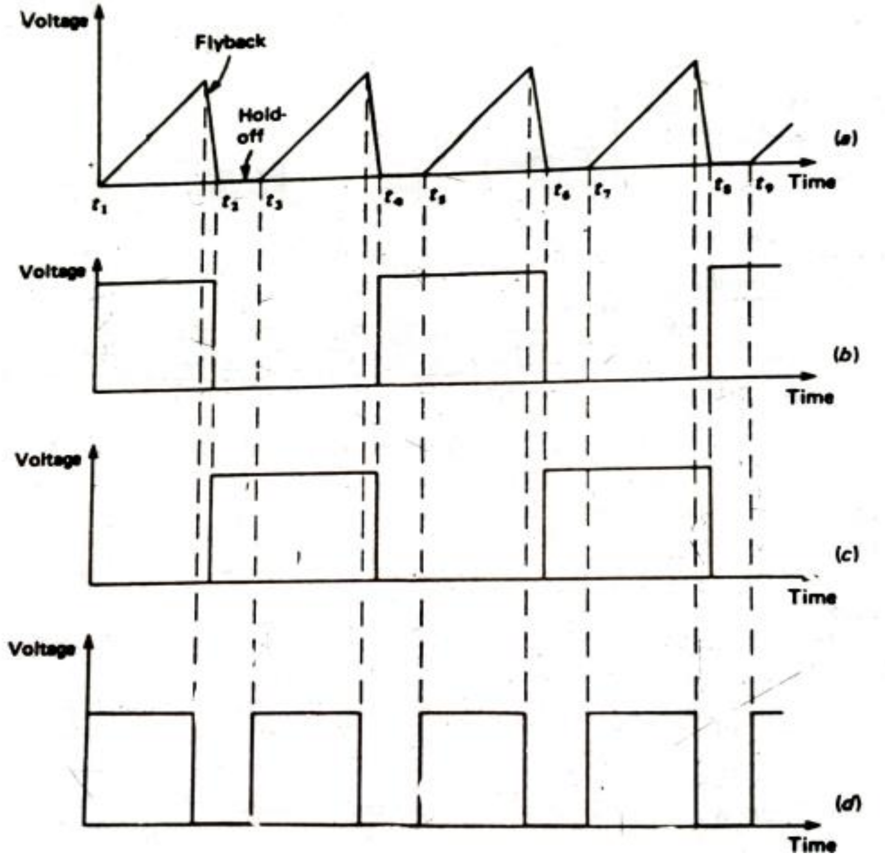



**Figure 25**

# Dual Trace Oscilloscope

**2.Chopped Mode:** In this mode the electronic switch free runs at a high frequency of the order of 100 kHz – 500 kHz.

- As a result very small segments of signals from channels A & B are sent to vertical amplifier, which is then displayed on the screen.
- When the chopping rate is much faster than the horizontal sweep rate, the display will show a continuous line for the both channels.
- When chopping rate is low, similar to horizontal sweep rate, the individual segments will not be visible and in that case we will have to use alternate mode.

# Dual Trace Oscilloscope

- Waveform for Chop mode:

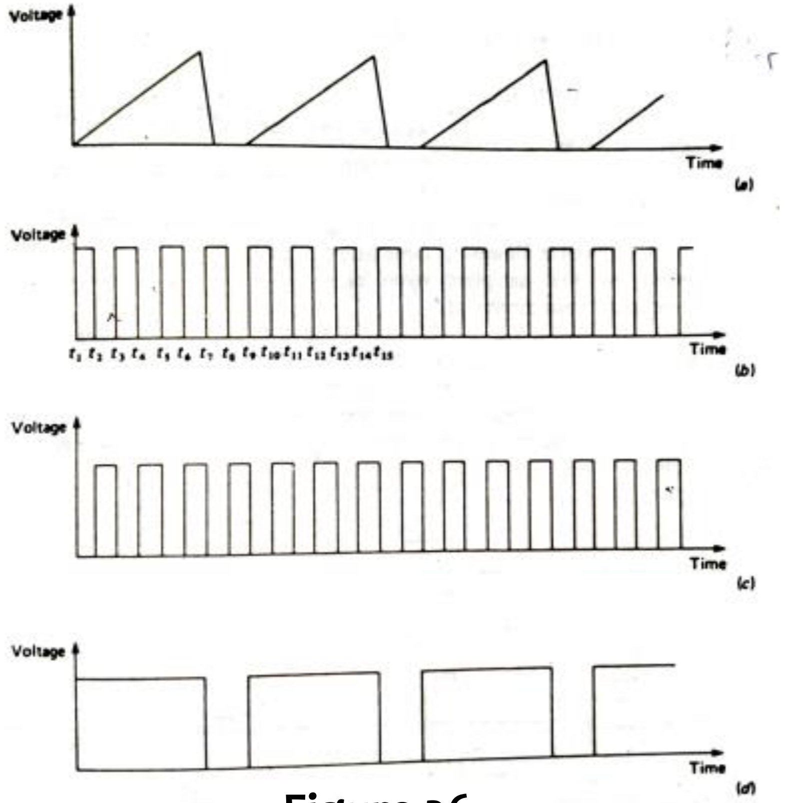



**Figure 26**

# Dual Trace Oscilloscope

- **Time Base Circuit:** Switch S2 allows the time base circuit to be triggered by signals from channels A or B or from external source or from line frequency.
- The input to the horizontal amplifier can be selected via switch SW3, to be either the time base signal or the signal from channel B via switch S1.
- When signal from channel B is fed to the horizontal amplifier, the mode is called as X-Y mode useful for X-Y measurement.

# Dual Trace Oscilloscope

- Various modes of display are: channel A only, channel B only, both A & B as two traces, channel A w.r.t. channel B in X-Y mode, or signals A+B, A-B, B-A, -(A+B) as single trace.

# Dual Beam Oscilloscope

- The dual trace oscilloscope can not capture two fast transient events, as it cannot switch quick enough between the two channels.
- The dual beam oscilloscope has two separate electron beams and two separate vertical amplifiers.
- The two channels may have a common time base circuit or two separate time base circuits.
- A separate time base circuit allows different sweep rate but it also increases weight and size of the CRO.

# Dual Beam Oscilloscope

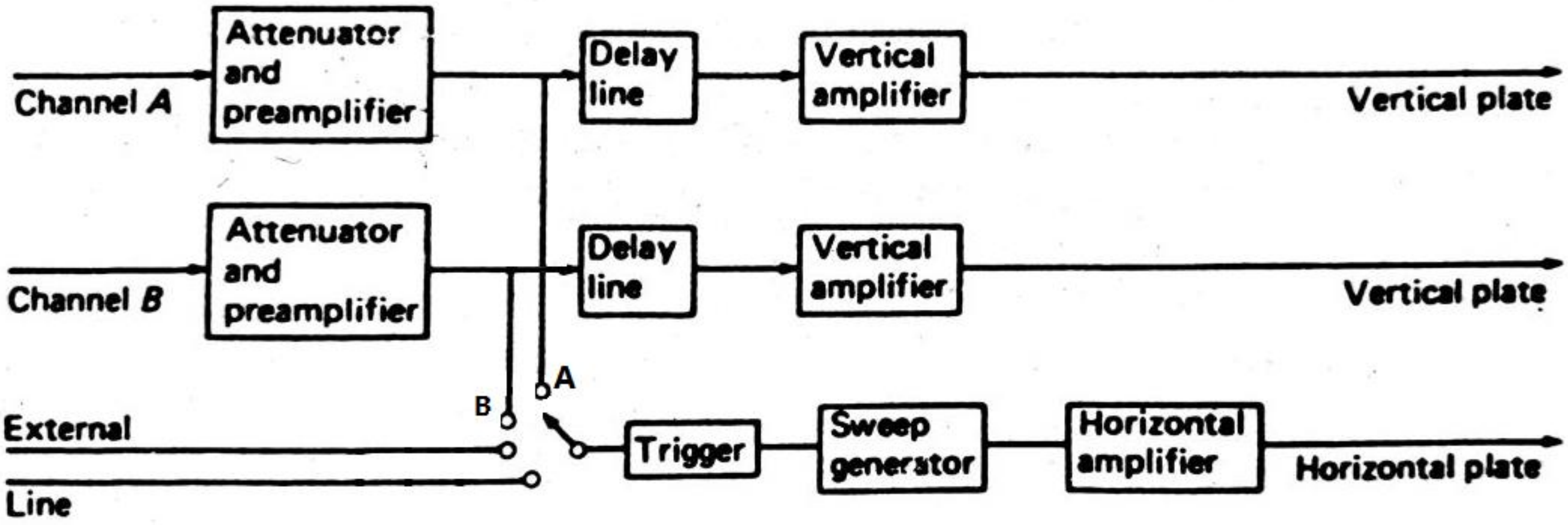



**Figure 27**

# Dual Beam Oscilloscope

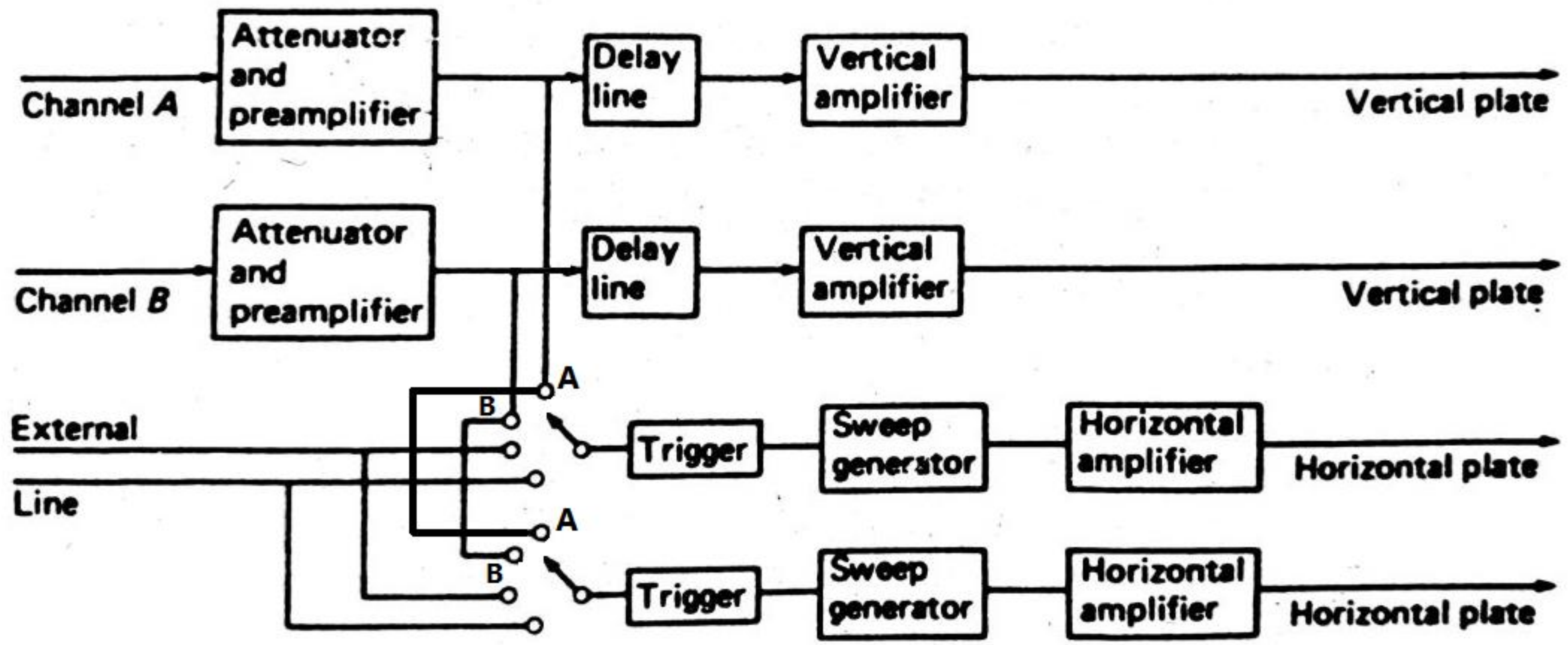



**Figure 28**

# Dual Beam Oscilloscope

- There are two methods of generating two electron beams.

1. Double electron gun
2. Split Beam

- In double electron gun method, there are two complete separate electron gun assembly, and so the brightness and focus of two beams can be adjusted separately. But it also increases weight and size of the CRO.

# Dual Beam Oscilloscope

- In split beam method, a horizontal splitter plate is placed between the last anode and the Y (or vertical) deflection plates.
- This plate is kept at same potential as the last anode and it goes between the two vertical deflection plates, isolating the two channels.
- This method results in reduced (half) brightness of single beam.
- An alternate method of splitting the beam, which improves the brightness, is to have two apertures in the last anode, so that two beams emerge from it.

# Dual Beam Oscilloscope

- In split beam method the brightness and focus of two beams will have common control, i.e. the brightness and focus of two beams can not be changed separately.
- The disadvantage of this method is that the two signals may have different brightness if the two signals have widely different sweep speeds.

# Sampling Oscilloscope

- The sampling oscilloscope is used to examine very fast signals.
- Samples are taken at different portions of waveform, which are then amplified and then displayed on screen as a continuous wave.
- The disadvantage of sampling oscilloscope is that it can only make measurements on repetitive waveforms.
- The range of frequency which can be displayed properly is 50-300 MHz.
- The display may be made up of up-to 1000 dots of luminescence.

# Sampling Oscilloscope

- The vertical deflection for each dot is obtained from samples taken at each successive cycle of the input waveform.
- Horizontal deflection is obtained by application of staircase waveform to the X plates.

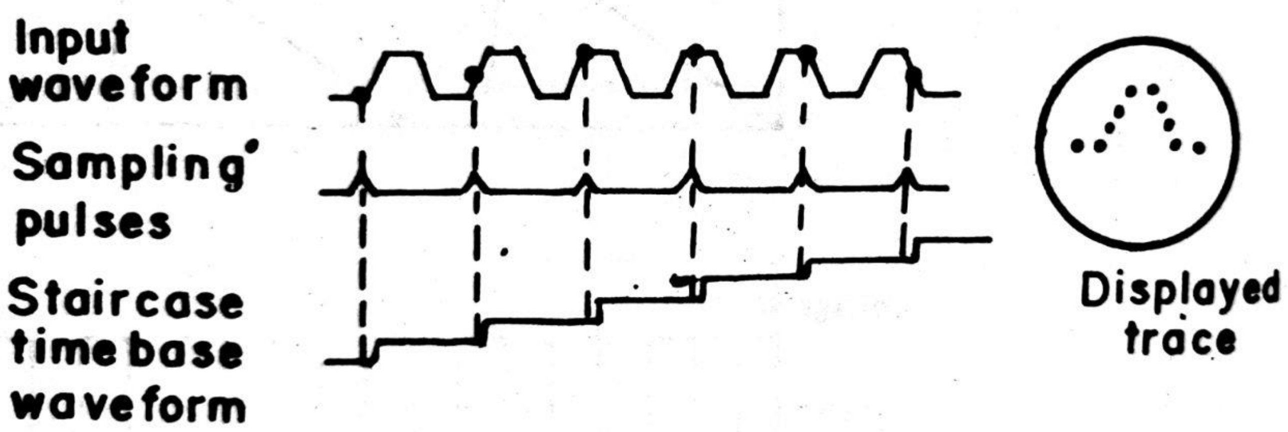



**Figure 29**

# Sampling Oscilloscope

- Block Diagram:

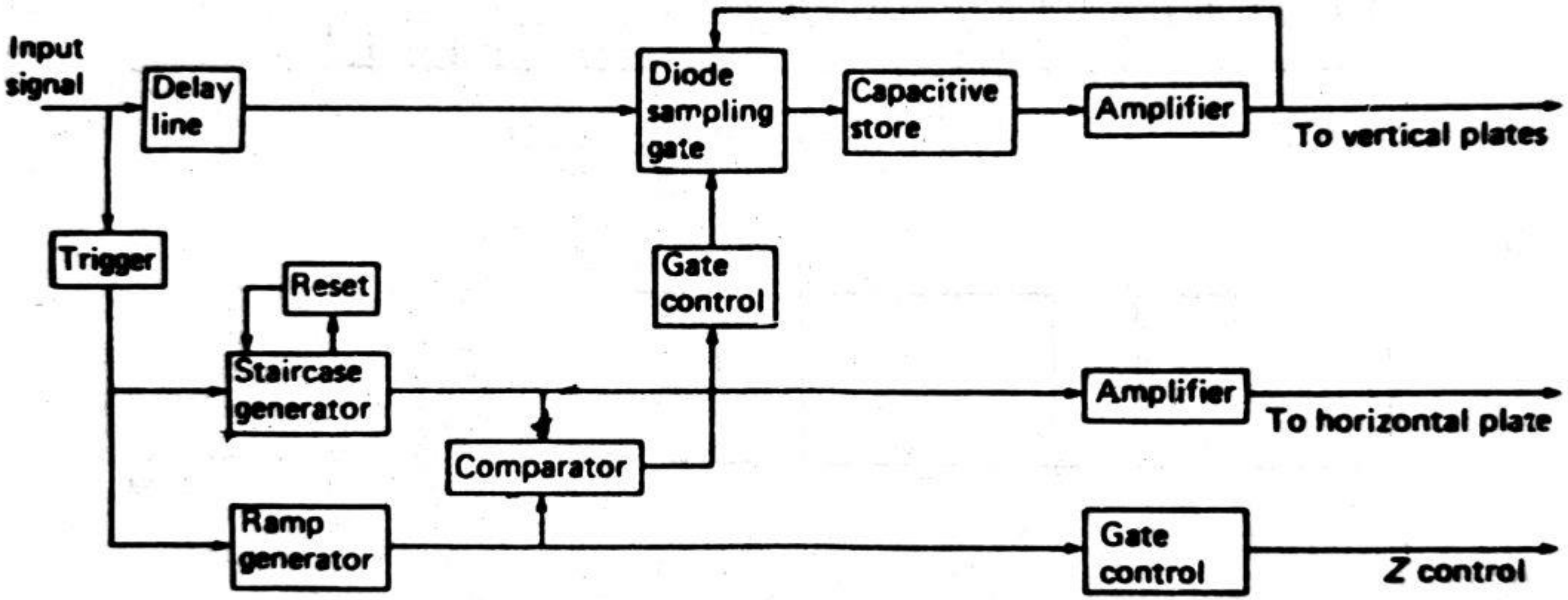



**Figure 30**

# Sampling Oscilloscope

- As shown in block diagram, the input signal is delayed and then sampled by Diode Sampling Gate.
- The sampled signal is then stored in Capacitive Store, which is then amplified and fed to the vertical plates.
- A unity feedback is used from amplifier output to the Diode Sampling Gate. This ensures that the voltage on the capacitor store is only increased by incremental value of the input voltage change between each sample.

# Sampling Oscilloscope

- The staircase signal being fed to the horizontal plates is reset after every 100 to 1000 samples, and then it is started again.
- Therefore the signal being displayed is made up from 100-1000 dots.

# Storage Oscilloscope

- Storage oscilloscope are capable of retaining the image on the screen for longer period as compared to the conventional CROs.
- Some storage scopes can also store the image being displayed on screen to the internal memory or to external memory or to a computer system connected via serial communication cable.
- Other than storage, the Storage scopes have more advantages over conventional scopes such as, capture the transient part of signal, steady state display of very low frequency signals, etc.

# Storage Oscilloscope

- There are two basic types of storage scopes:

1. Analog Storage Oscilloscope
2. Digital Storage Oscilloscope

# Analog Storage Oscilloscope

- These are capable of display of higher speed data/signals.
- The two most frequently used methods are:

1. Variable Persistence
2. Bi-stable Storage

Note: Analog Storage Oscilloscope is not in Syllabus.

# Digital Storage Oscilloscope (DSO)

- Availability of low cost digital circuitry has enabled us to add many digital features such as:

1. Digital display of various parameters
2. Integrated Voltmeter and Counter
3. Generation of trigger after a particular delay or after count of pulses.
4. Remote Control
5. Digital Storage etc.

# DSO

- A DSO digitises the input signal, so that all subsequent signals are digital.
- A conventional CRT is used, and for storage digital electronic memory is used.

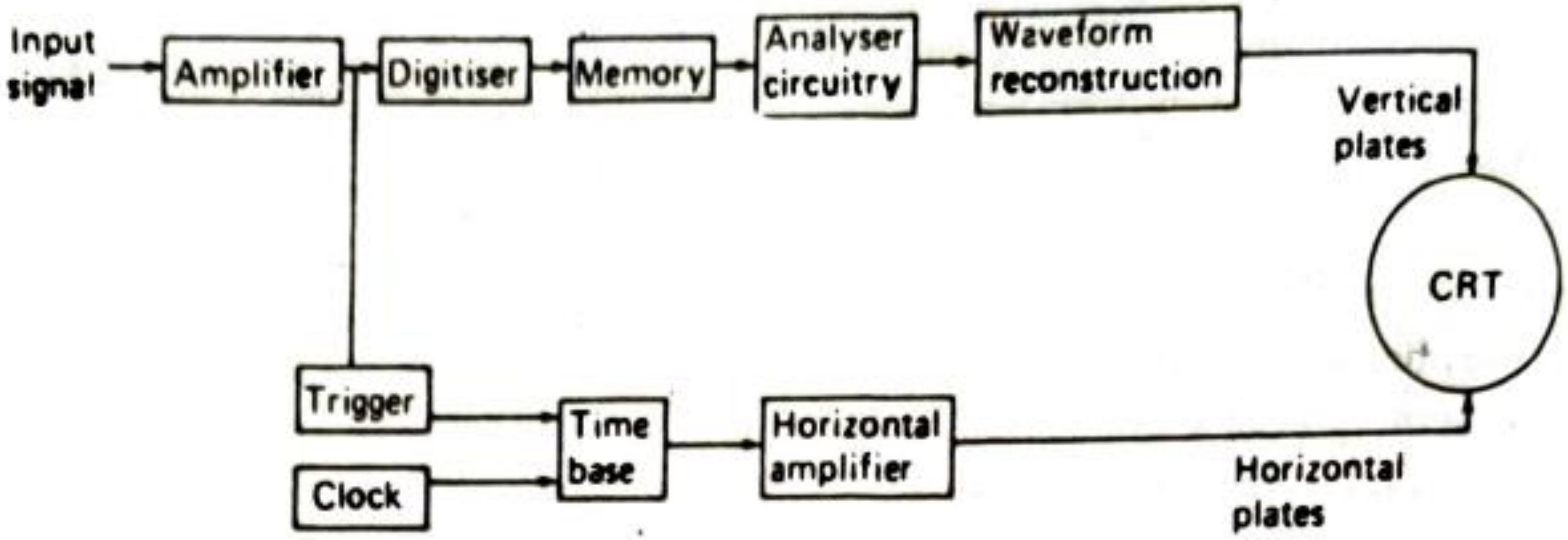



**Figure 31**

# DSO

- Fig. 31 shows the block diagram of DSO.
- The input signal is amplified and then digitised using a digitiser.
- The digital signal is then stored in memory, after which it can be analysed to produce a variety of information.
- Now to display the signal, it is reconstructed in Analog form, and fed to the vertical plates.
- Digitizing is done by sampling the signal at a periodic interval.

# DSO

- **Sampling Theorem:** In order to ensure that no information from signal is lost, the sampling theory states that the sampling rate must be at least twice of the highest frequency of the signal.
- This rate is called as **Nyquist Rate**.
- If this is not done **aliasing** will result, which is shown in fig. 32.

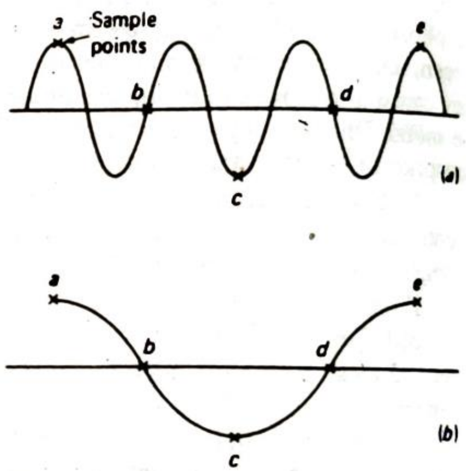



**Figure 32**

# DSO

- **Digitizer:** The requirement of high sampling rate means that the digitizer, which is an Analog to Digital converter, must have a fast conversion rate.
- This usually requires expensive flash analog to digital converters, whose resolution decreases as the sampling rate is increased.
- For this reason the bandwidth and resolution od DSO depends upon the Digitizer.

# DSO

- One method of avoiding the need of fast & expensive digitizer is to use analog storage as shown in fig. 33 below. The signal stored in analog storage can be sampled at a slower rate.

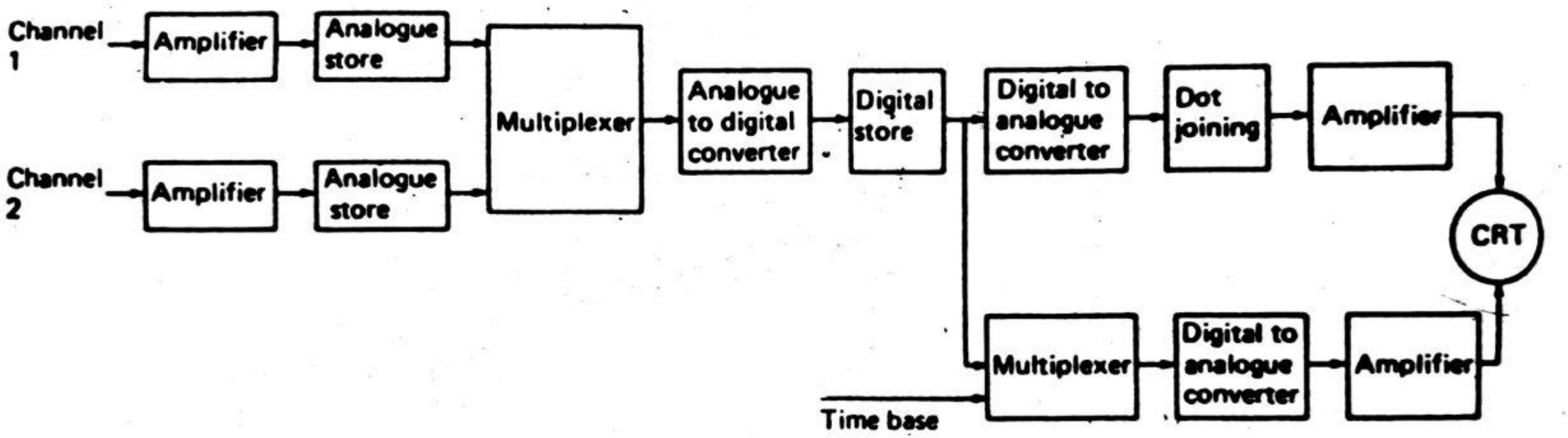



**Figure 33**

# DSO

- Block Diagram of DSO

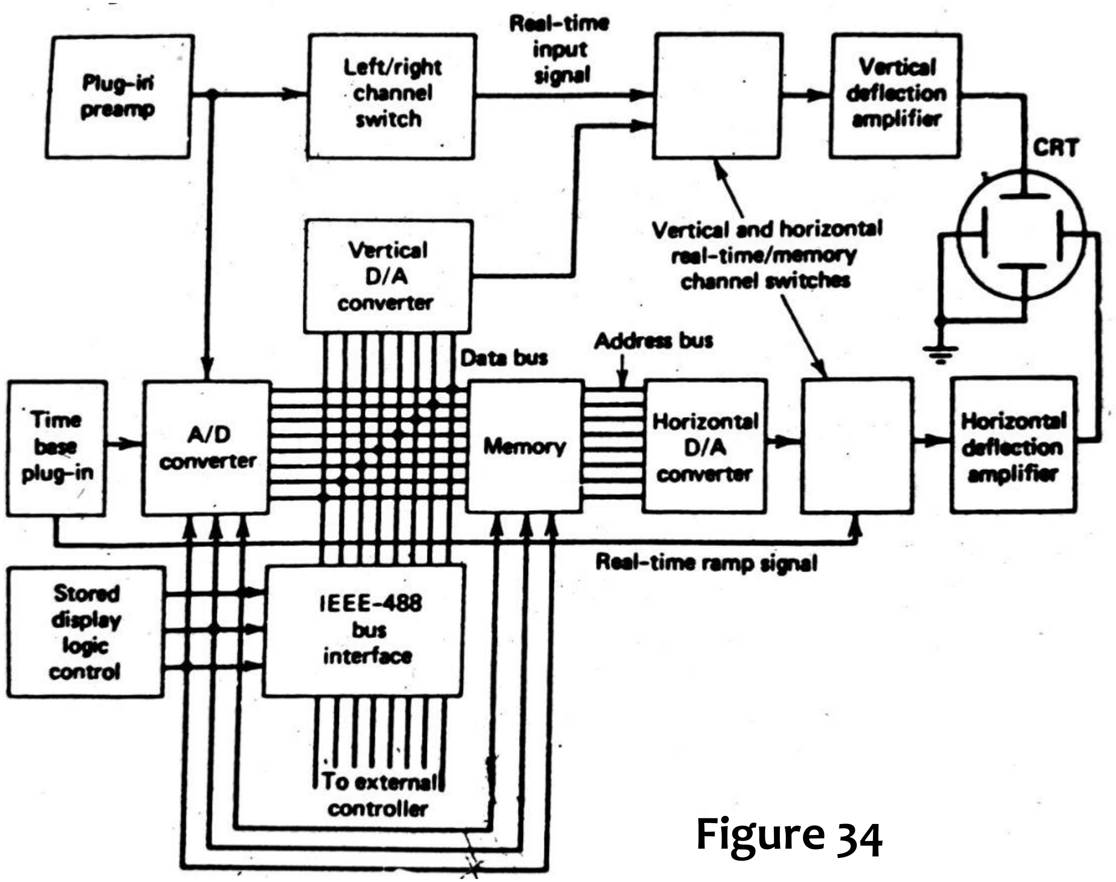



**Figure 34**

# Waveform Reconstruction

- Even though we sample the input at more that twice of the highest frequency, the output signal visible on the screen may still have aliasing effects.
- To overcome this **Interpolation** methods are used.
- Two basic interpolation methods are:

1. Linear Interpolation – connecting the dots with straight lines.
2. Sinusoidal Interpolation – connecting the dots with sinusoidal curved lines.

# Waveform Reconstruction

a) Without Interpolation

b) Linear Interpolation

c) Sinusoidal Interpolation

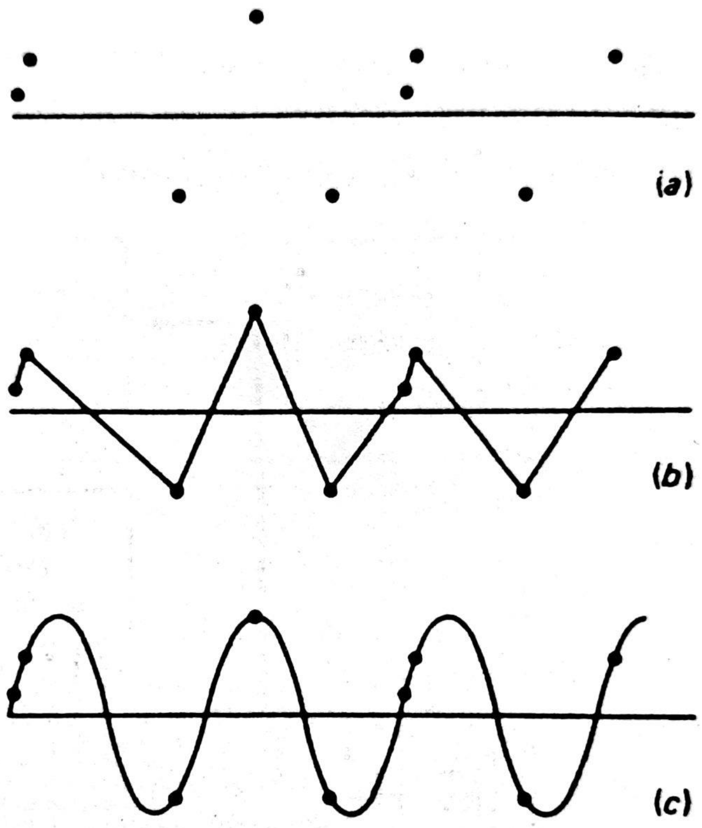



**Figure 35**

# Display Devices

- There are various types of display devices:
  1. CRT
  2. Segment Display (7, 14, 16 etc.)
  3. Dot Matrix
  4. Nixie Tube
  5. LED, OLED, AMOLED, PMOLED
  6. LCD
  7. Plasma Display Panel (PDP)
  8. Gas Discharge Displays

  etc.

Note: Refer Wikipedia on Display devices for more information.

# LED

- LED stands for Light Emitting Diode (D stands for Diode not display)
- A LED display is a flat panel display that uses an array of light-emitting diodes as pixels for a video display.

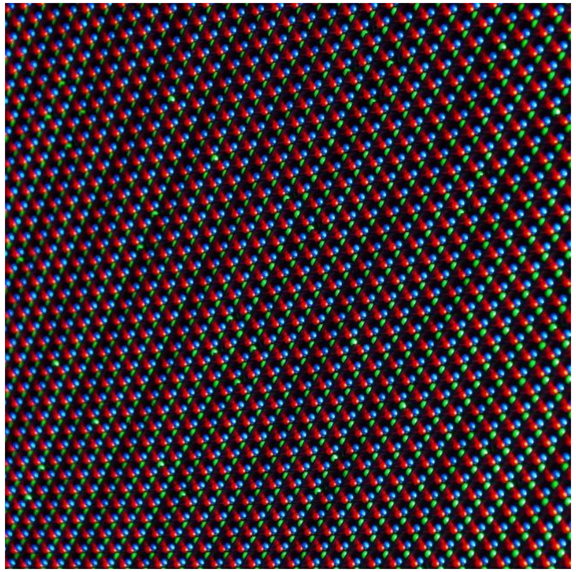


**Figure 36**

# LED

- The LED is a PN junction device which emits light when a current passes through it in the forward direction
- Charge carrier  recombination occurs at a PN junction as electrons cross from N side and recombines with holes on P side.
- When recombination takes place, the charge carriers give up energy in the form of heat and light.
- If the semiconducting material is translucent the light is emitted, and here the junction is source of light.

# LED

- Fig. 37 shows a cross-sectional view of a typical LED.
- The charge carrier recombination takes place in the P type material. Therefore, the P region becomes the surface of the device.

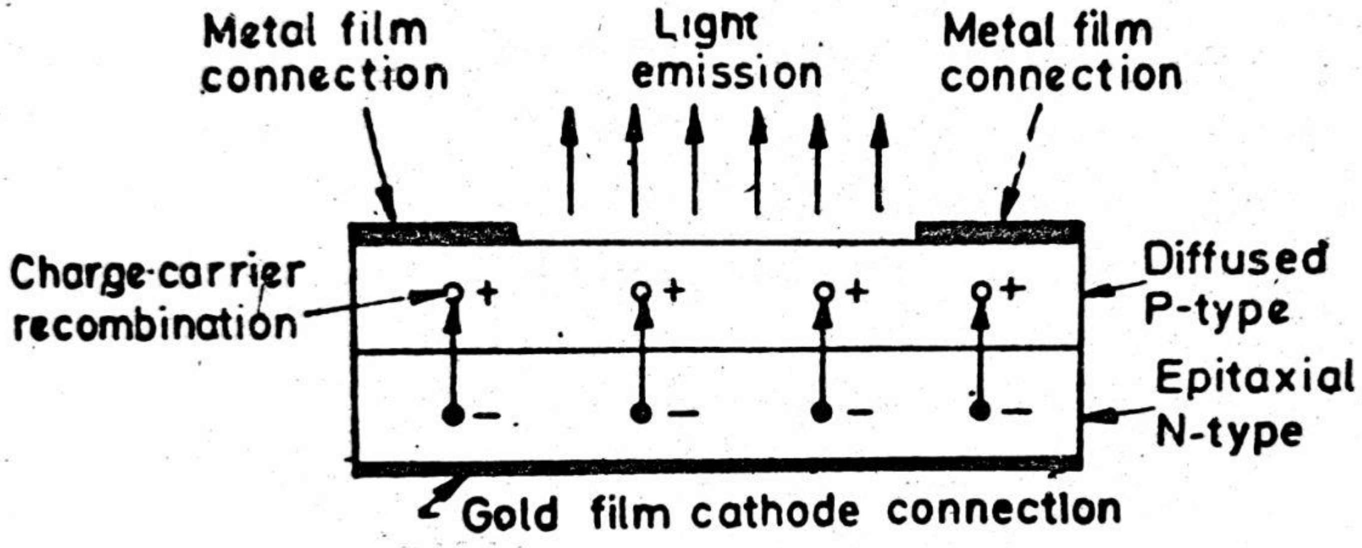



**Figure 37**

# LED

- For maximum light emission, a metal film anode is deposited around the edge of the P type material.
- The cathode connection for the device is usually a gold film at the bottom of the N type region.
- This helps in reflecting the light to the surface.
- Semiconductor materials used for manufacture of LED are gallium arsenide phosphide (GaAsP) which emits red or yellow light or gallium arsenide (GaAs) which- gives green or red light emission.

# LED

- LEDs are used extensively in segmental and dot matrix displays of numeric and alphanumeric characters.
- Several LEDs in series form one segment while a single LED may be used to form a decimal point.
- A simple transistor can be used for ON/OFF of an LED as shown in Fig. 36.

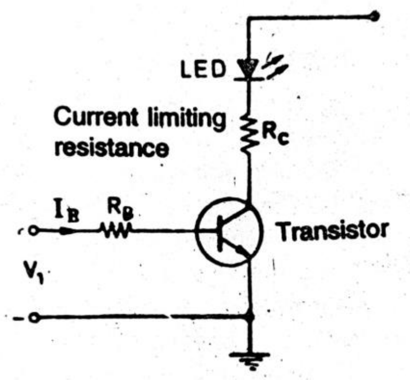



**Figure 38**

# LED

- The major advantages of LEDs in electronic displays are:

1. LEDs are miniature in size and they can be stacked together to form numeric and alphanumeric displays in high density matrix.
2. The light output from an LED is a function of the current flowing through it. Therefore intensity of light emitted from LEDs can be smoothly controlled.
3. LEDs have a high efficiency as emitters of electromagnetic radiation. They require moderate power for their operation. A typical voltage drop of 1.2 V and a current of 20 mA is required for full brightness.

# LED

4. Therefore, LEDs are useful where miniaturization with low D.C. power are important.
5. LEDs are available in different colors like red, green, yellow and amber.
6. The switching time (both on and off) is less than 1 ns and therefore they very useful where dynamic operation 0f large number of arrays is involved.
7. LEDs are manufactured with the same type of technology as is used for transistors and ICs and therefore they are economical and have a high degree of reliability.

# LED

8. LEDs are rugged and can therefore withstand shocks and vibrations. They can be operated over a wide range of temperature say 0-70 °C.

**Disadvantages:**

- High power requirement.
- LEDs are not suited for large area displays, primarily because of their high cost.

# LCD

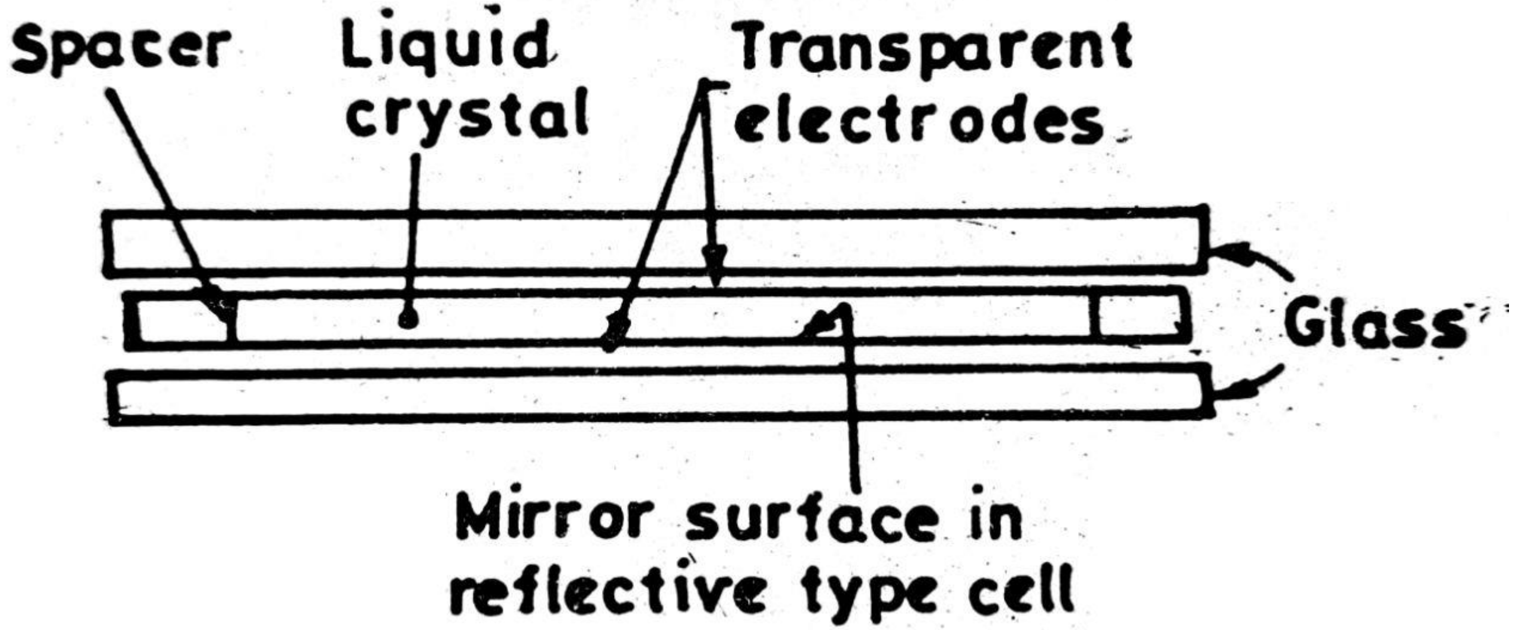
- LCD stands for Liquid Crystal Display (not Diode)
- LCDs are used in similar applications where LED displays are used.
- These applications include display of numeric and alphanumeric characters in segmental and do-matrix forms.

- The LCDs are of 2 type:

1. Dynamic Scattering type
2. Field Effect type

# LCD

- The construction of dynamic scattering type LCD is shown below.



# LCD

- There are several organic compounds which exhibits optical properties and the liquid crystal is one of them and also it remain in liquid form.
- The liquid crystal is layered between glass sheets with transparent electrodes deposited on the inside faces.
- When a potential is applied across the cell, charge carriers flowing through the liquid disrupt its molecular alignment and produce turbulence.
- When the liquid crystal is not activated, it is transparent.

# LCD

- But when the liquid is activated the molecular turbulence causes light to be scattered in all directions and the cell appears to be bright.
- The phenomenon is called **Dynamic Scattering**.

# LCD

- The construction of a **field effect** liquid crystal display is similar to that of the dynamic scattering type, with the exception that two thin polarizing optical filters are placed at the inside of each glass sheet.
- The liquid crystal material in the field effect cell is also of different type.
- The material used is twisted Nematic type crystal.

# LCD

- This crystal twists the light passing through the cell, when the cell is not energized.
- This allows the light to pass through the optical filters and the cell appears bright.
- When the cell is energized, no twisting of light takes place and the cell appears dull.

# LCD

- Liquid crystal cells are of two types:

1. **Transmittive type** - In the transmittive type cell, both glass sheets are transparent, so that light from a rear source is scattered in the forward direction when the cell is activated.
2. **Reflective type** - The reflective type cell has a reflecting surface on one side of glass sheets. The incident light on the front surface of the cell is dynamically scattered by activated cell.

# LCD

- Both types of cells appear quite bright when activated even under ambient light conditions.
- The liquid crystals are light reflectors or transmitters and therefore they consume small amounts of energy (unlike light generators).
- Considering the case of seven segmental display, the current is about 25 μA for dynamic scattering cells and 300 μA for field effect cells.
- Unlike LEDs which can work on d.c. the LCDs require a.c. voltage supply. A typical voltage supply to dynamic scattering LCD is 30 V peak to peak with 50 Hz frequency.

# LCD

- The **advantages** of LCDs are:

1. They have a low power consumption. A seven segmental display requires about 140 μW (20 μW/segment). This is great advantage over LEDs which require about 40 mW per numeral.
2. They have a low cost.

# LCD

- The **disadvantages** of LCDs are:

1. LCDs are very slow devices. The tum on and the tum off times are quite large. The turn on time is typically of the order a few milliseconds while the turn-off is ten milliseconds.
2. When used on d.c. their life span is quite small. Therefore they are used with a.c. supplies having a frequency less than 500 Hz.
3. They occupy a large area.

# Assignment - 1

Date of Submission:

Qu.1 – Write advantages and disadvantages of following displays:

(1) CRT

(2) LED

(3) LCD

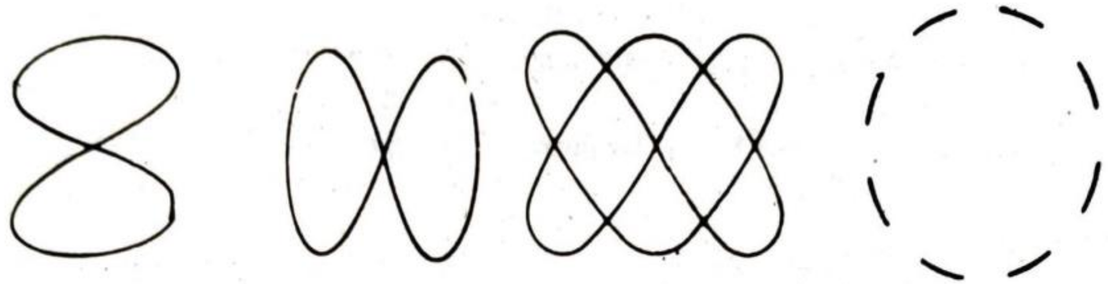
Note: Take help of Internet.

Qu.2 – Draw block diagram of CRO and explain each block.

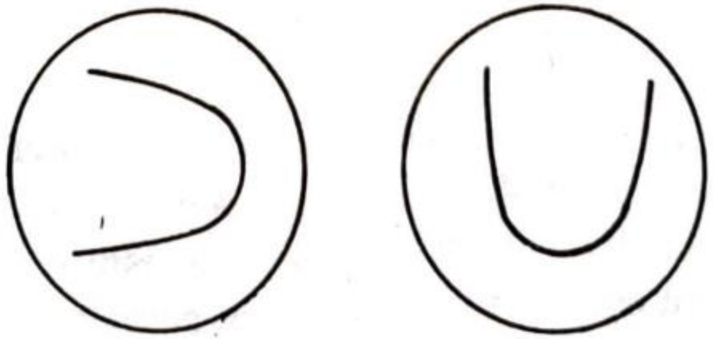
Qu.3 – Draw block diagram of DSO and explain each block.

# Assignment - 1

Qu.4 – Find fx/fy for following Lissajous patterns:



Qu.5 – Find freq. of vertical plates, if freq. of horizontal plates is 50 Hz.



# Suggestions

- Read solved examples given in the book.
- Solve previous year question papers.

# End of Unit-1