

UNIT-3- OSCILLOSCOPES & SPECIAL PURPOSE OSCILLOSCOPES

OSCILLOSCOPES

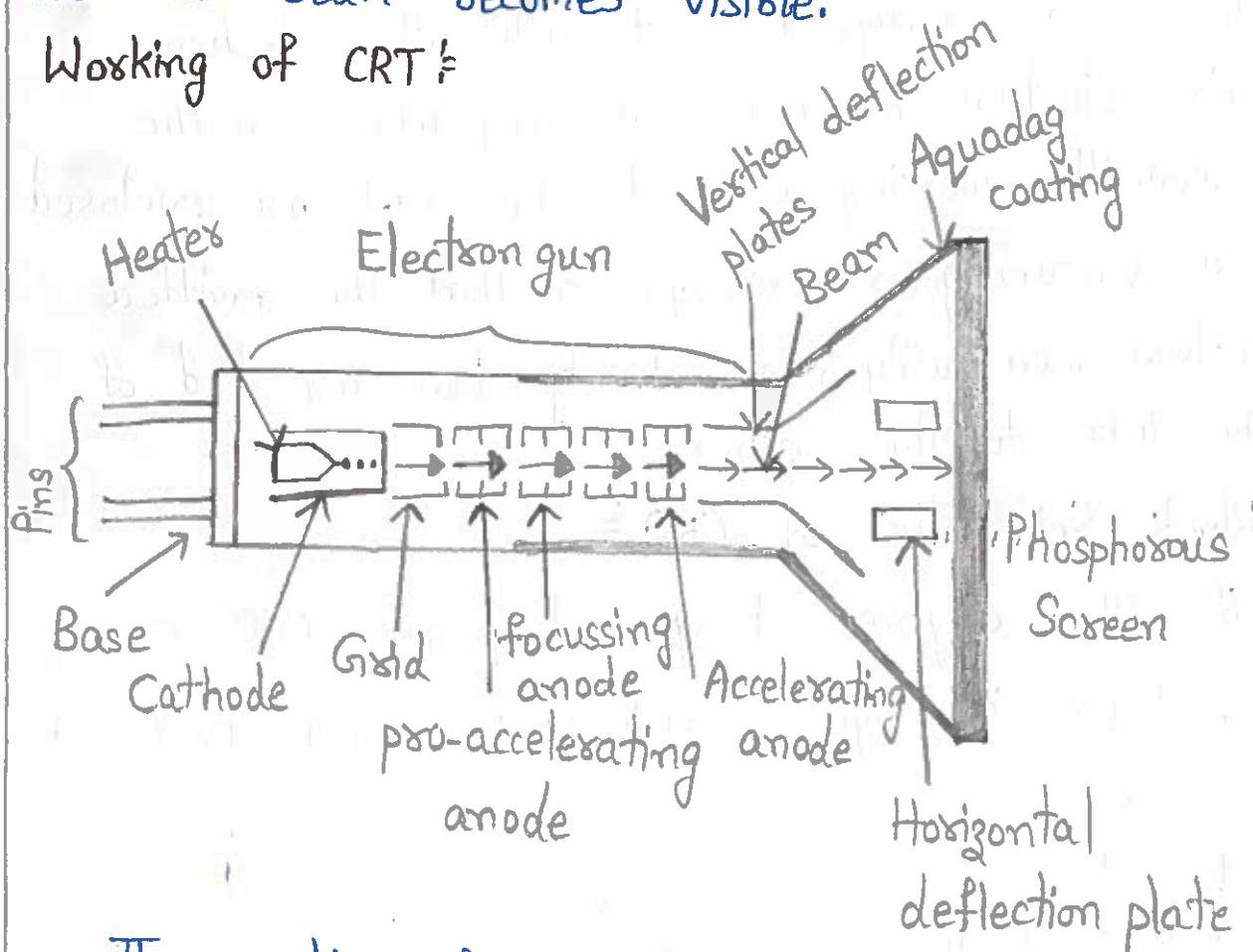
(1)

Cathode Ray Tube [CRT]:

The CRT is the displays screen which produces the image in the form of video signal. It is a type of vacuum tube which displays images when the electron beam through electron gun strikes on the phosphorescent surface.

In other words, the CRT generates beams, accelerates it at high velocity & deflects it for creating the images on the phosphorous screen so that the beam becomes visible.

Working of CRT:



The working of CRT depends on the movement of electron beams. The electron gun generates sharply

focussed electrons which are accelerated at high voltage. The high velocity electron beam be when it strikes on the phosphorescent screen create luminous spot.

After existing from the electron gun the beam passes through the pairs of electrostatic deflection plate. These plates deflects the beams when the voltage applied across it. The 1 pair of plate moves the beam upward & second pair of plate moves the beam from one side to another.

The horizontal & vertical movement of the electron are independent of each other & hence their electron beam position anywhere on the screen. The working parts of the CRT are enclosed in a vacuum glass envelope so that the emitted electron can easily move freely from one end of the tube to the other.

Block Schematic of CRO :-

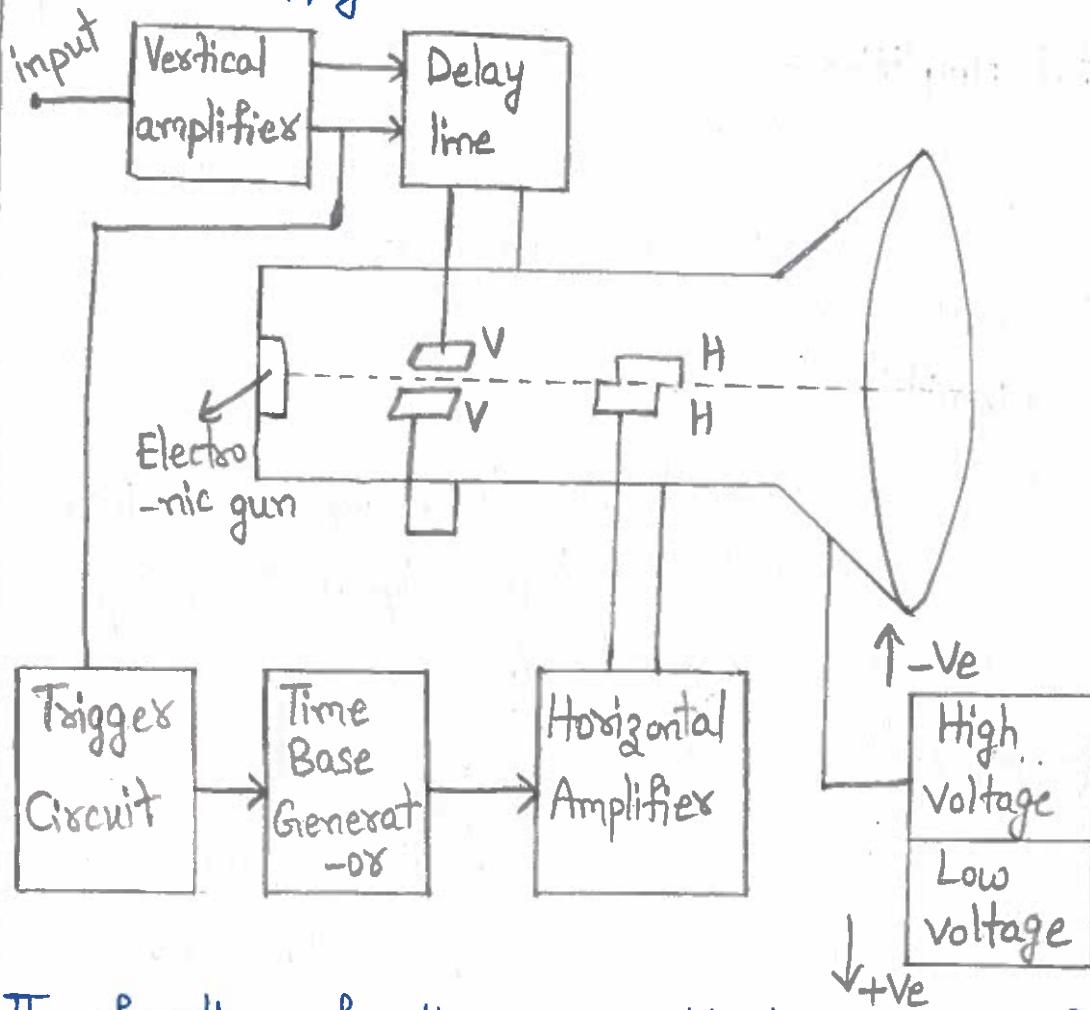
The Block diagram of general purpose CRO is as shown in figure which contain major parts as follows:

1. CRT
2. Vertical Amplifiers
3. Delay line
4. Time Base Generator

5. Horizontal Amplifiers

6. Trigger circuit

7. Power Supply.



The function of the various blocks are as follows:

CRT- Cathode Ray Tube :

This is the CRT which emits the electrons that strikes the phosphor screen internally to provide a visual display of a signal.

Vertical Amplifiers :

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

Delay Line :

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

Time Base Generator :

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

Horizontal Amplifier :

This is used to amplify the sawtooth voltage before it is being applied to the horizontal deflection plates.

Trigger Circuit :

This is used to convert the incoming signal into trigger pulses so that the input signal & sweep frequency can be synchronized.

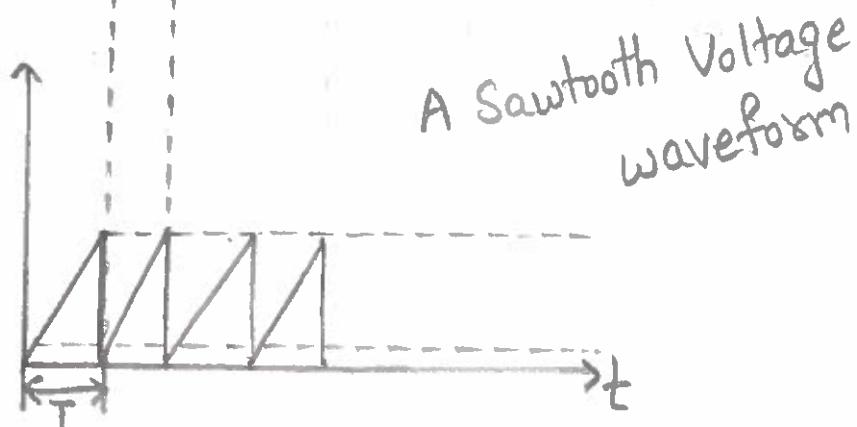
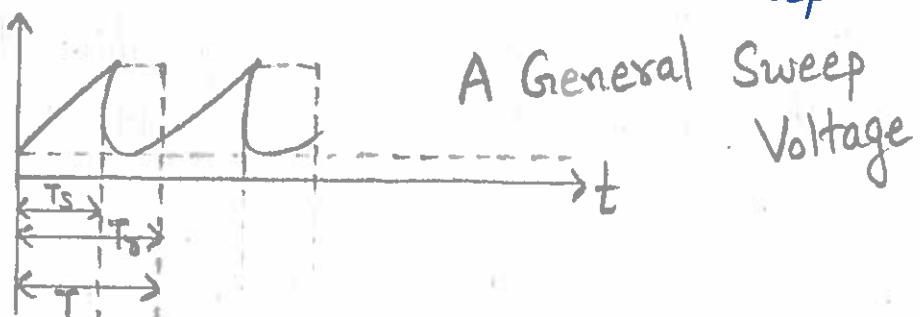
Power Supply :

There are two power supplies, a -ve high voltage (HV) supply & a +ve low voltage (LV) supply. These two voltages are generated in the CRO. The +ve volt supply is from 300 to 400 V & -ve volt supply is from -1000 to -1500 V. This voltage is passed through a bleeder resistor at a few milli amperes. The intermediate voltages are obtained from the bleeder resistor for intensity, focus & positioning controls.

Time Base Circuits (or) Time Base Generator:

An Electronic Generator that generates a high frequency sawtooth waves is termed as Time-Base Generator. It also generates an output voltage or current waveform, a portion of which where is linearly with time but horizontal velocity of a time base generator, must be constant.

To display the variations of the signal with respect to time on an oscilloscope, a voltage that vary linearly with time as to be applied the deflection plates. This makes the signal to sweep the beam horizontally across the screen hence, the voltage is called Sweep voltage & time base generators are called as Sweep Circuits.

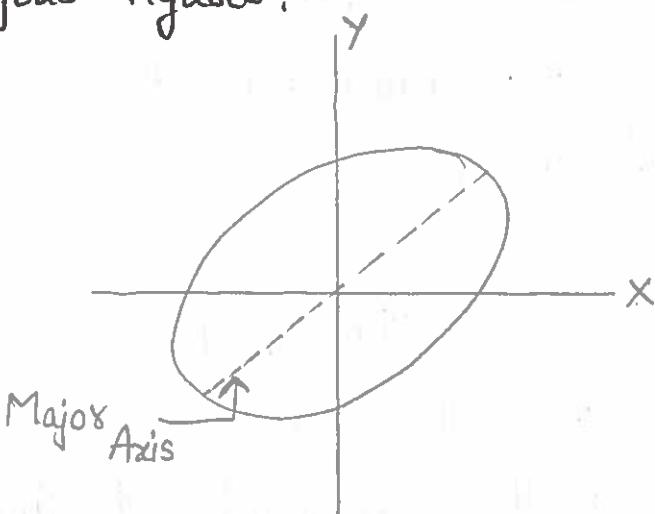


Features of Time Base Signal :-

- To generate a time base waveform in a CRO or a picture-tube the deflecting voltage increases linearly with time.
- Generally, a time base generator is used where the beam deflects over the screen linearly & returns to its starting point. This occurs during the process of scanning.
- A Cathode Ray Tube & also a picture-tube works on the same principle. The beam deflects over the screen from one side to the other & gets back to the same point. This phenomenon is called as Trace & Retrace.
- The deflection of beam over the screen from left to right which called as trace. While, the return of the beam from right to left is called as Fly back.

Usually, this retrace is not visible, this process is done with the help of a sawtooth generator, which sets the time period of the deflection with the help of RC components used.

Lissajous figures:



Lissajous figure is the pattern which is displayed on the screen when sinusoidal signals are applied to both horizontal & vertical deflection plates of the CRO. These patterns will vary based on the amplitudes, frequencies & phase differences of the sinusoidal signals which are applied to both horizontal & vertical deflection plates of the CRO. The above Lissajous figure is in Elliptical shape & its major axis has some inclination angle w.r.t the X-axis. The following two measurements from a Lissajous figure is shown below.

- 1) Frequency of the sinusoidal signal
- 2) Phase difference b/w two sinusoidal signals.

Measurement of Frequency:

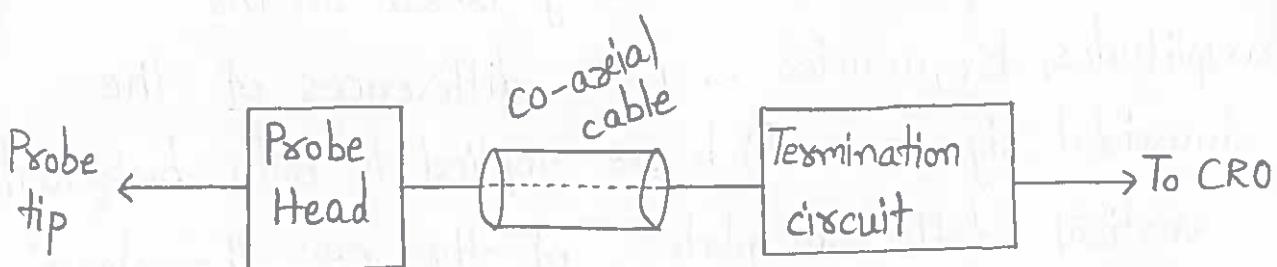
Lissajous figures will be displayed on the screen when the sinusoidal signals are applied to both

horizontal & vertical deflection plates of CRO. Hence, apply the sinusoidal signal which has the standard known frequency to the horizontal deflection plates of CRO.

Similarly, apply sinusoidal signal, whose frequency is unknown to the vertical deflection plates of CRO.

Let f_H & f_V are the frequencies of sinusoidal signals which are applied to the horizontal & vertical deflection plates of CRO respectively.

CRO Probes :



We can connect any test circuit to an oscilloscope through a probe. As CRO is the basic oscilloscope, the probe is connected to it is also called as a CRO probe.

We should select the probe in such a way that it should not create any loading issues with the test circuit.

CRO probe should have the following characteristics

- 1) High Impedance
- 2) High Bandwidth

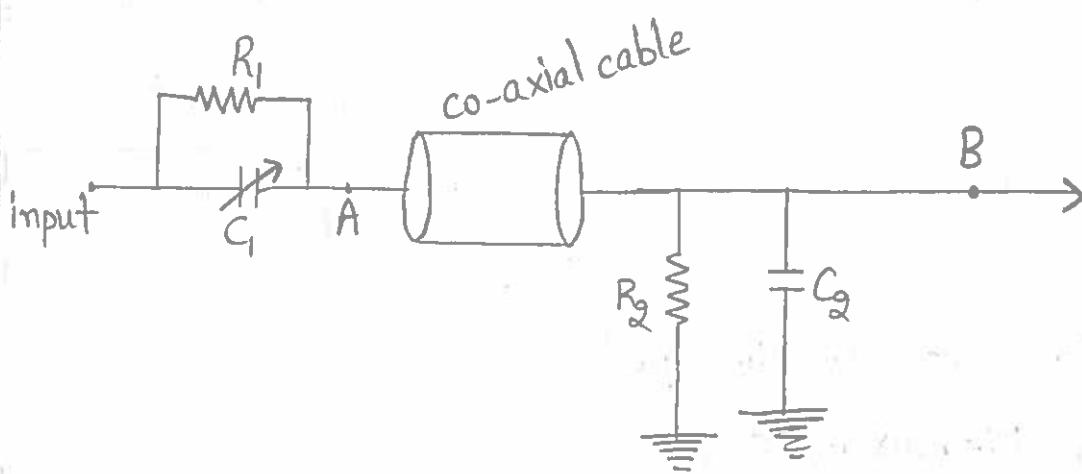
As shown in the figure, the CRO probe mainly consists of 3 blocks.

- Probe Head
- Co-axial cable
- Termination Circuit

Types of CRO probes :

- 1) Passive Probes
- 2) Active Probes

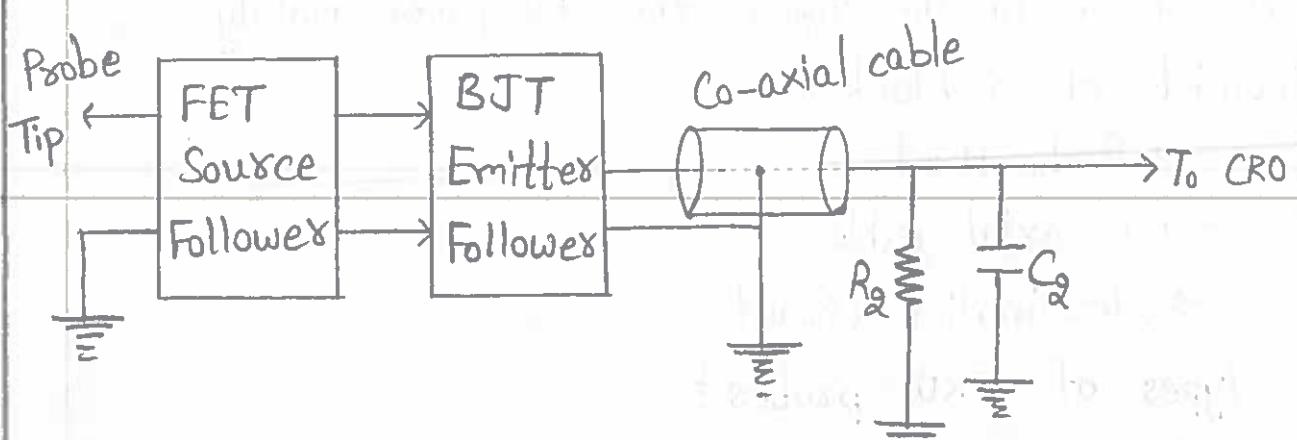
Passive Probes :



If the probe head consisting of passive elements then it is called Passive Probe. As shown in the figure, the probe head consists of a parallel combination of Resistor R_1 & variable capacitor C_1 . Similarly, the termination circuit consists of a parallel combination of Resistor R_2 & Capacitor C_2 .

Active Probes :

If the probe head consists of Active component then it is called Active probe.



As shown in the figure, the probe head consists of a FET Source follower in cascade with BJT Emitter follower. The FET Source follower provides High input impedance & Low output impedance whereas, the purpose of BJT emitter follower is that it avoids (or) eliminates impedance matching.

Applications of Oscilloscope:

1) Voltage Measurements:

The range of applications of an oscilloscope varies from basic voltage measurements & waveform observation to highly specialized applications in all areas of science Engineering & Technology.

The Most direct voltage measurements made with the help of an oscilloscope is the peak-to-peak value. The RMS value of the voltage can then be easily calculated from the p-p value.

To measure the voltage from the CRT display one must observe the setting of the vertical

attenuator in V/div and the p-p deflection of the beam. (i.e., no. of vertical divisions). The p-p value of voltage is then ~~computed~~ computed as follows.

$$\text{i.e., } V_{\text{p-p}} = \left(\frac{\text{Volts}}{\text{division}} \right) \times \left(\frac{\text{No. of divisions}}{1} \right)$$

2) Period & Frequency Measurements:

The period & frequency of periodic signals are easily measured with an oscilloscope. The waveform must be displayed such that a complete cycle is displayed on the CRT screen. Accuracy is generally include, if a single cycle display fills as much of the horizontal distance across the screen has possible.

The period is calculated as follows:

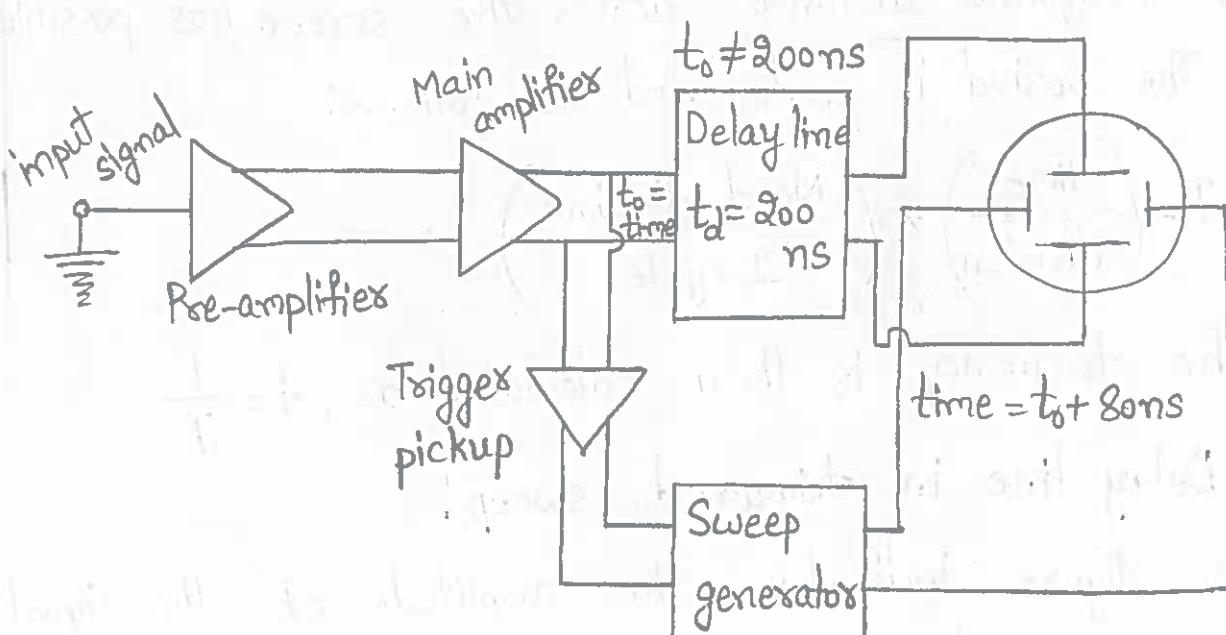
$$T = \left(\frac{\text{Time}}{\text{division}} \right) \times \left(\frac{\text{No. of divisions}}{1 \text{ cycle}} \right)$$

The frequency is then calculated as, $f = \frac{1}{T}$

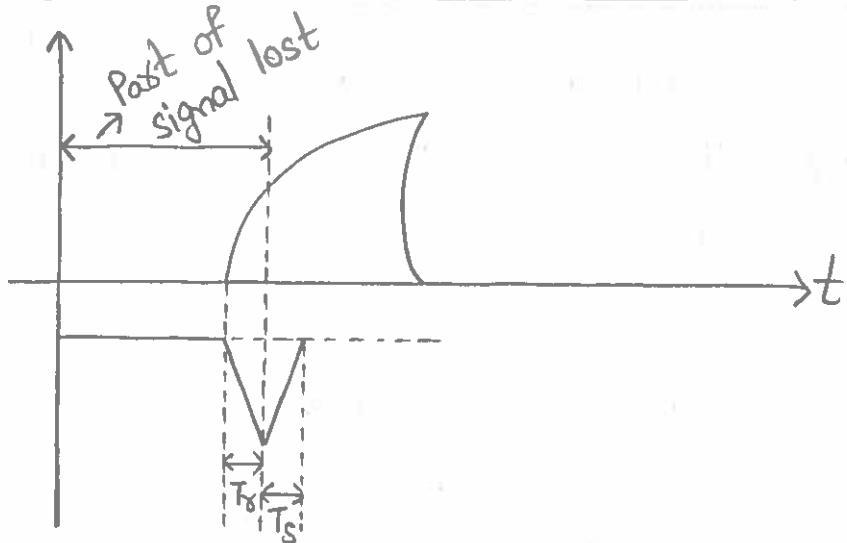
3) Delay line in triggered sweep:

The figure indicates the amplitude of the signal with respect to time & the relative position of the sweep generator output signal. The diagram shows that when the delay line is not used, the initial part of the signal is lost & only part of the signal is display.

To overcome this disadvantage the signal is not applied directly to the vertical plates. But, it is pass through a delay line circuit. as shown in figure, this used time for the sweep to start at the horizontal plates before the signal has reached vertical plates. The trigger pulse is picked off at a time t_0 after the signal has pass through the main amplifiers. The Sweep Generator delivers to sweep to the ~~frequency~~ horizontal amplifiers & sweep starts HDP at time $t_0 + 80\text{ns}$ hence, sweep starts well in time, since the signal arrives at the VDP at time $t_0 + 90\text{ns}$.



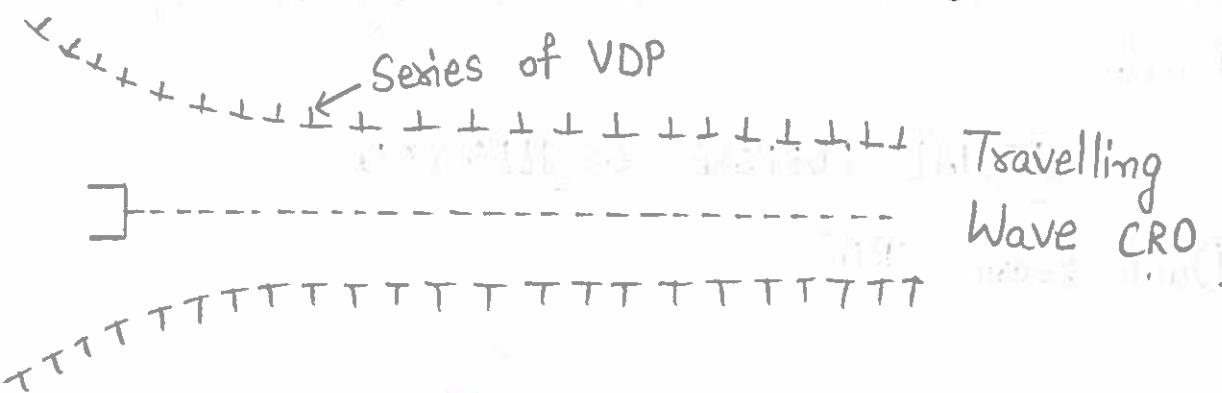
Delay Line Circuit



Delay line waveform

High Frequency CRO Considerations :-
(or)

High Frequency CRT or travelling wavetype CRT :-



Above figure shows the High frequency CRT. In an ordinary CRO there is only 1 pair of VDP's. When the signal to be displayed is of a very high frequency, the electron beam does not get sufficient time to pickup the instantaneous level of the signal. Also at high frequency the no.of electrons striking the screen in a given time & the intensity of beam is reduced. Hence, instead of 1 set of Vertical deflection plates a series of VDP's are used.

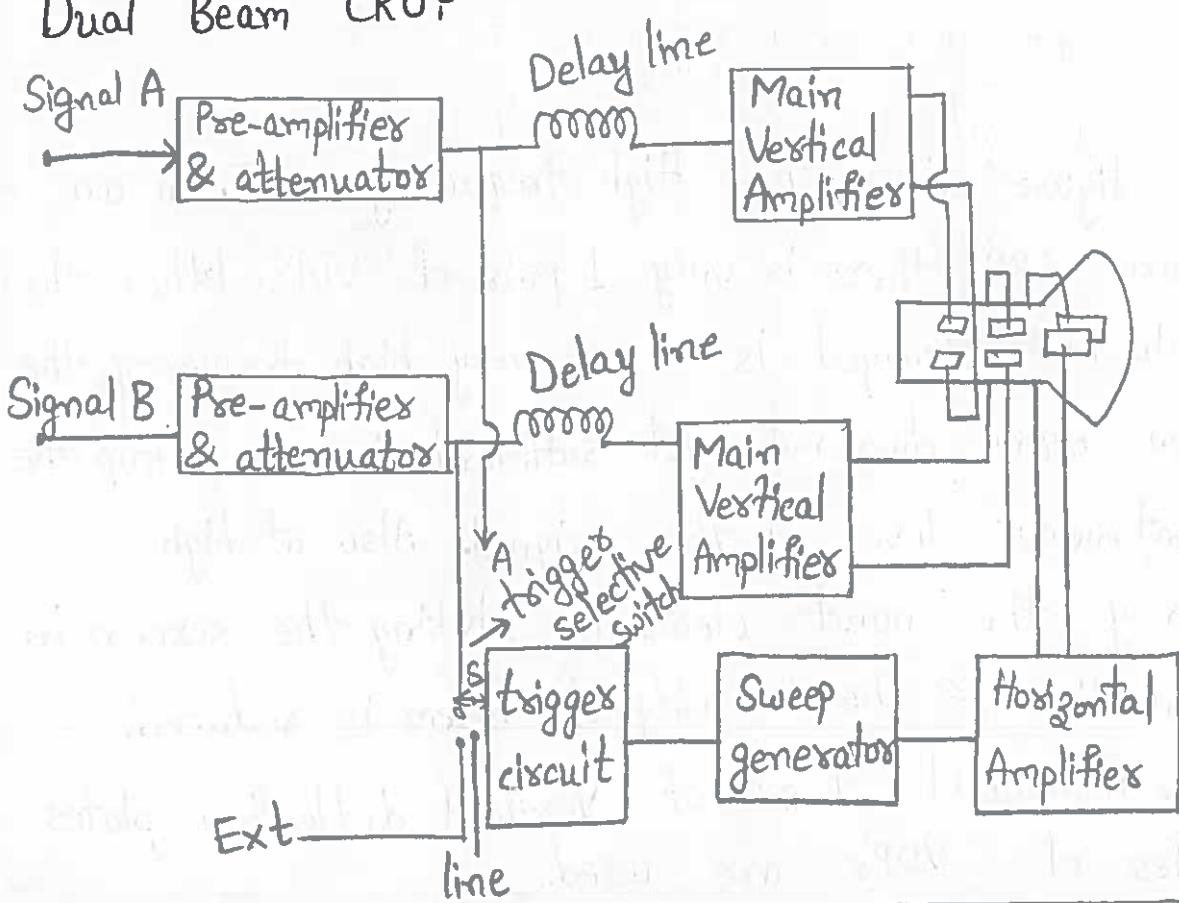
The plates are so shaped & spaced that an electron travelling along the CRT receives from each set of place an additional deflecting force in proper time sequence.

This synchronization is achieved by making the signal to travel from one plate to the next at the same speed as the transit time of the electron.

The signal is applied to each pair of plates & as electron beam travels the signal also travels to the delay line. The time delays are so arranged that the electrons are deflected by the input signal.

SPECIAL PURPOSE OSCILLOSCOPES.

Dual Beam CRO:

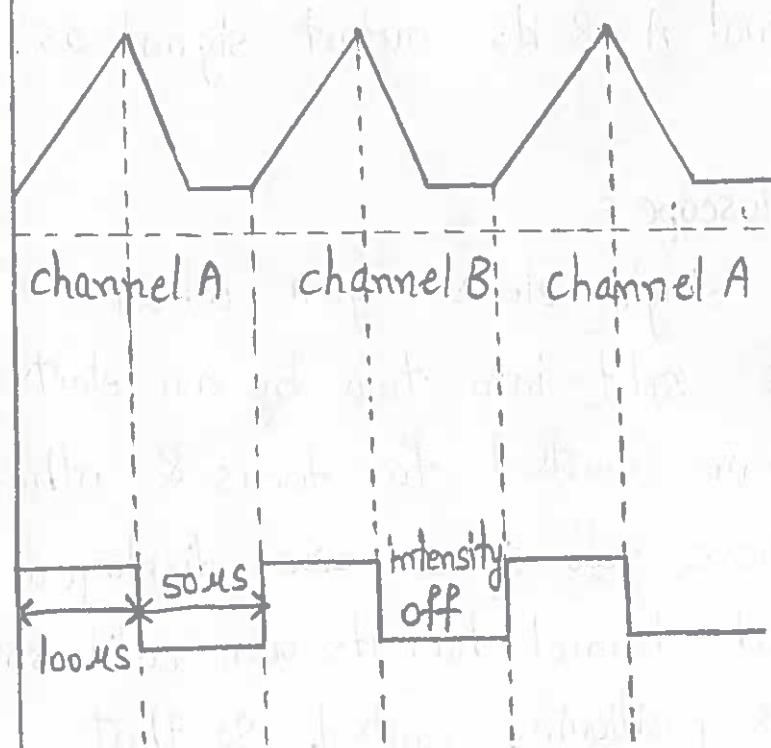
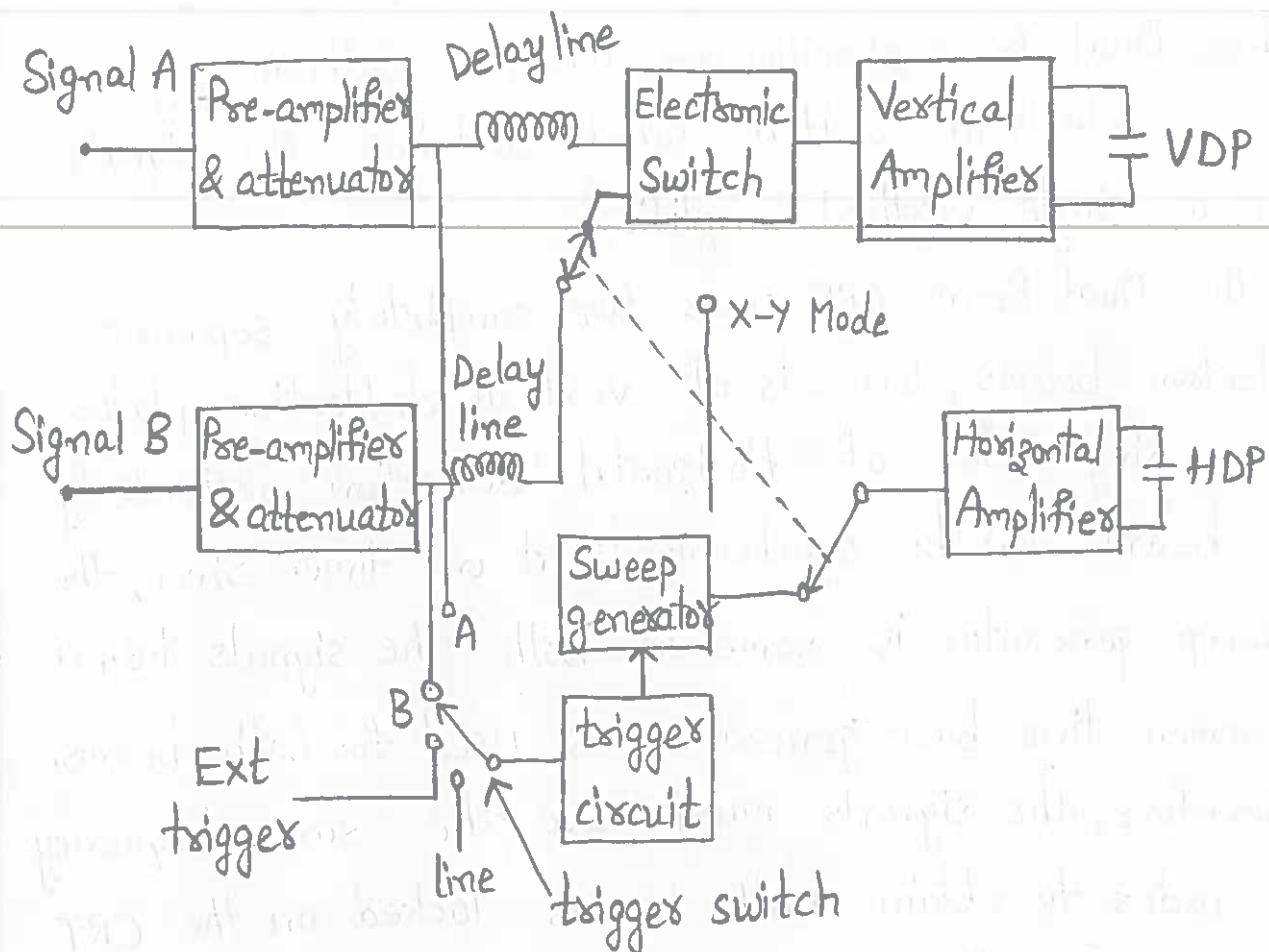


The Dual Trace Oscilloscope has one cathode ray gun & an electronic switch which switches two signals to a single vertical amplifier.

The Dual Beam CRO uses two completely separate electron beams, two sets of vertical deflection plates & a single set of Horizontal deflection plate. Only 1 beam can be synchronized at one time. Since, the sweep generator is same for both the signals i.e., a common time base generator is used for both beams. Therefore, the signals must have the same frequency in order to obtain both beams locked on the CRT screen i.e., the input signal of an amplifier can be used as signal A & its output signal as signal B.

Dual Trace Oscilloscope:

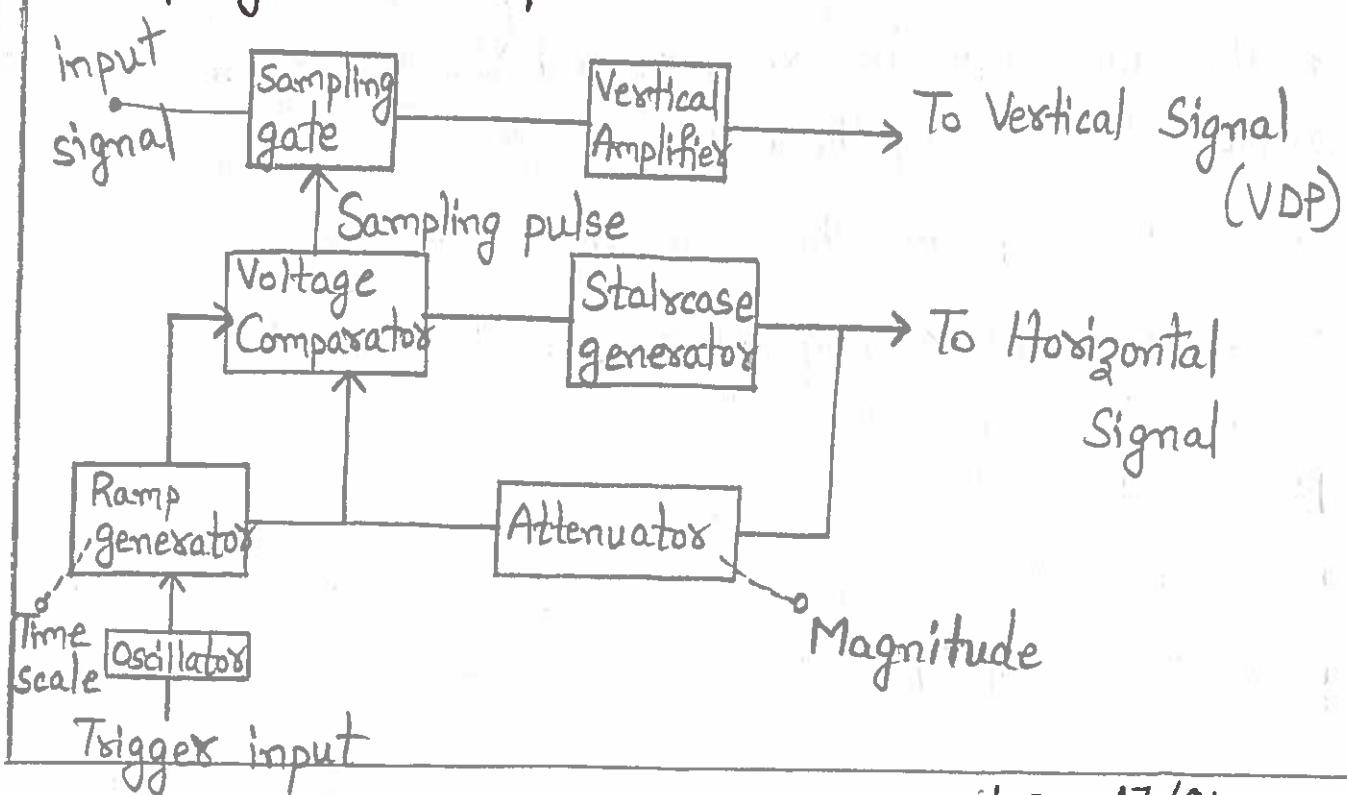
→ This CRO has a single electron gun whose electron beam is split into two by an electronic switch. There is one control for focus & others for Intensity, these two signals are displayed simultaneously. Each channel has its own calibrated input attenuator & positioning control. So, that amplitude of each signal can be independently adjusted.

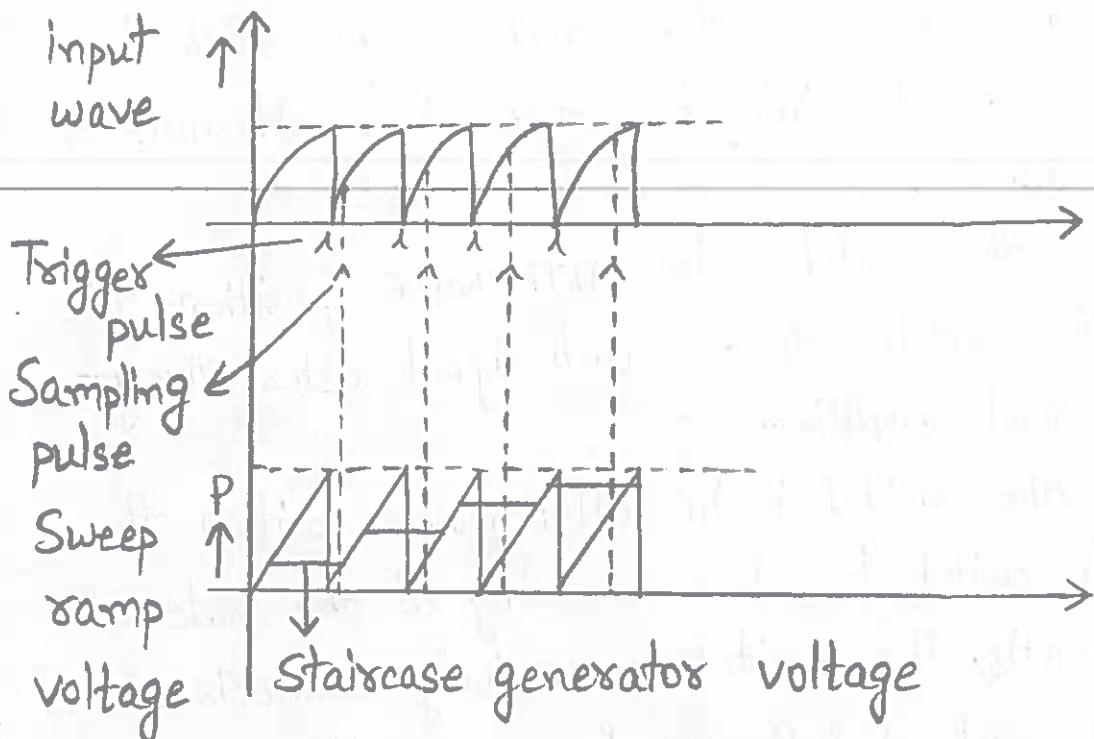


Time relation of a dual channel vertical amplifier in alternate mode.

- A mode control switch enables the electronic switch to operate into two modes i.e., alternate & chop mode.
- When the switch is in ALTERNATE position the electronic switch feeds each signal alternatively to vertical amplifiers.
- When the switch is in CHOP mode position the electronic switch is free running at the rate of 100-500 kHz. The switch successively connects small segments of A & B waveforms to the main vertical amplifiers at a chopping rate of 500 kHz if the chopping rate is slow, the conductivity of the display is lost & it is better to use the alternate mode of operation.

Sampling Oscilloscope : (VHF)





Various waveforms at each block of a sampling oscilloscope.

An ordinary oscilloscope has a bandwidth of 10MHz . A High frequency ~~response~~ performance can be improved by means of Sampling the input waveform & reconstructing its shape from the sample. The shape of the waveform is reconstructed by joining the samples levels together. The sampling frequency may be as low as $\frac{1}{10^{\text{th}}}$ of the i/p signal frequency. Figure shows the block diagram of sampling oscilloscope.

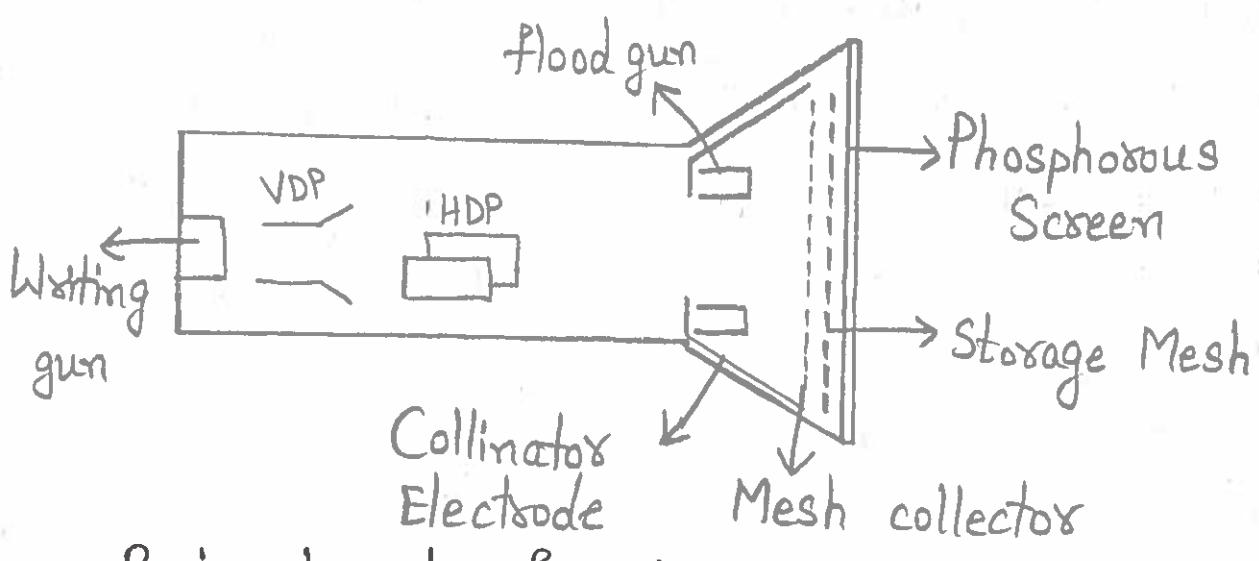
The Input waveform is applied to the sampling gate, this waveform is sampled whenever a sampling pulse opens the sampling gate. The sampling must be synchronized with the input signal frequency.

The signal is delayed in the vertical amplifiers allowing the horizontal sweep to be initiated by the input signal.

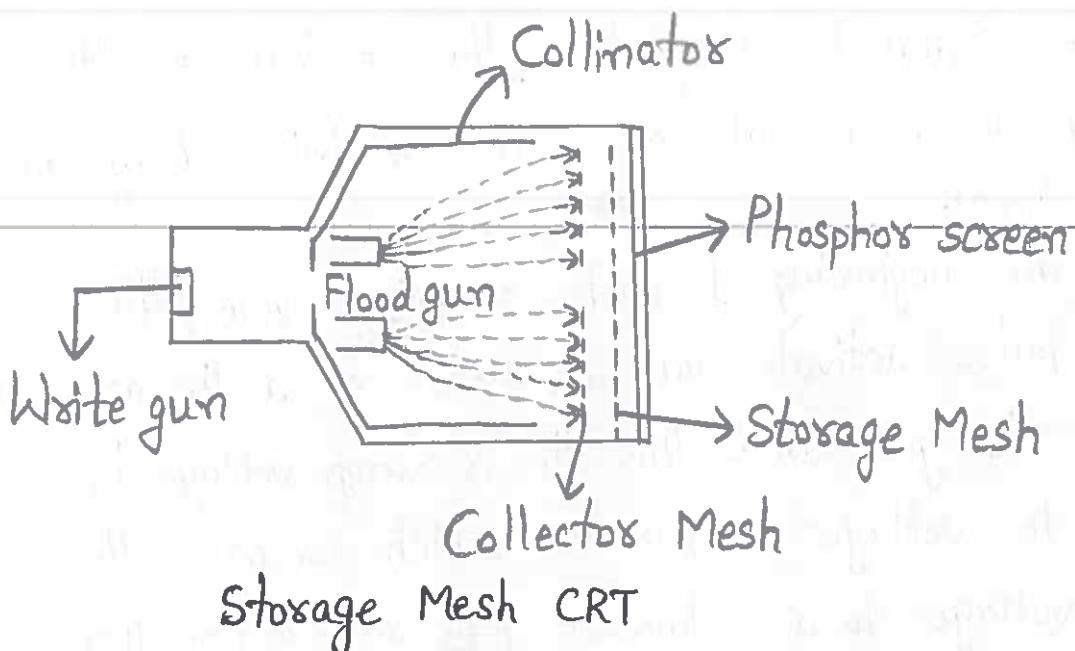
At the beginning of each sampling cycle, the trigger pulse activates an oscillator & a linear ramp voltage is generated. This linear ramp voltage is applied to voltage comparators which compares the ramp voltage to a staircase generator. When two voltages are equal in amplitude, the staircase advances one step & sampling pulse is generated which opens the sampling gate, for a sample of input voltage.

The resolution of the final image depends on the size of the steps of the staircase generator. The smaller the size of the steps, the larger the no. of samples & higher the resolution of the image.

Storage Oscilloscope (for VLF Signal):



Basic elements of Storage Mesh CRT



Storage Targets can be distinguished from standard phosphor targets by their ability to retain a waveform pattern for a long time independent of phosphor persistence.

To storage techniques are used in oscilloscope CRTs

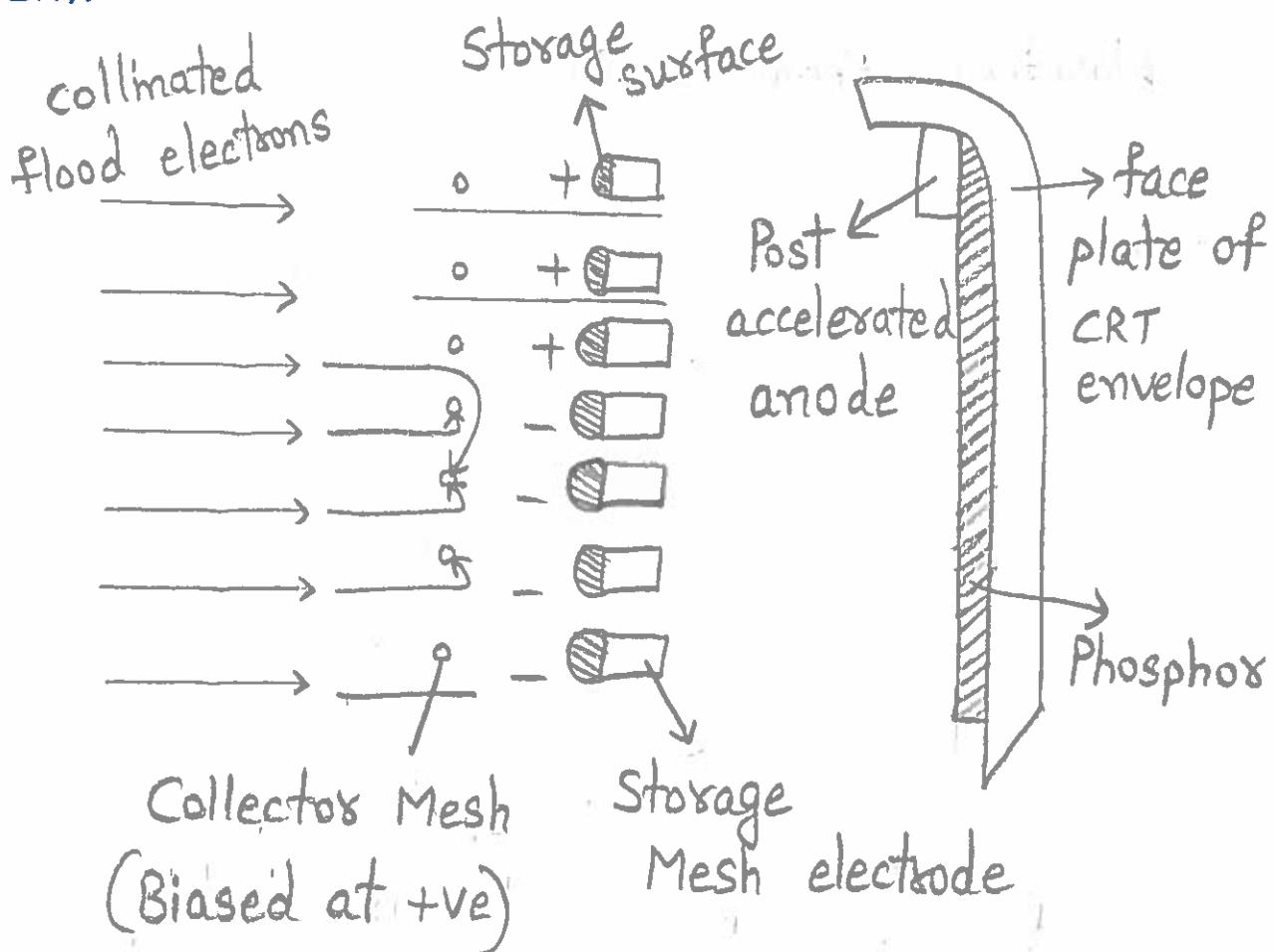
- i) Mesh storage
- ii) Phosphor storage

A Mesh Storage Oscilloscope uses a dielectric material deposited on storage mesh as the storage target. This mesh is placed b/w the deflection plates & the standard phosphor target in the CRT. The writing beam which is focussed electron beam of the standard CRT charges the dielectric material +vely every hits.

The storage target is then bombarded with low velocity electrons from a flood gun and the +vely

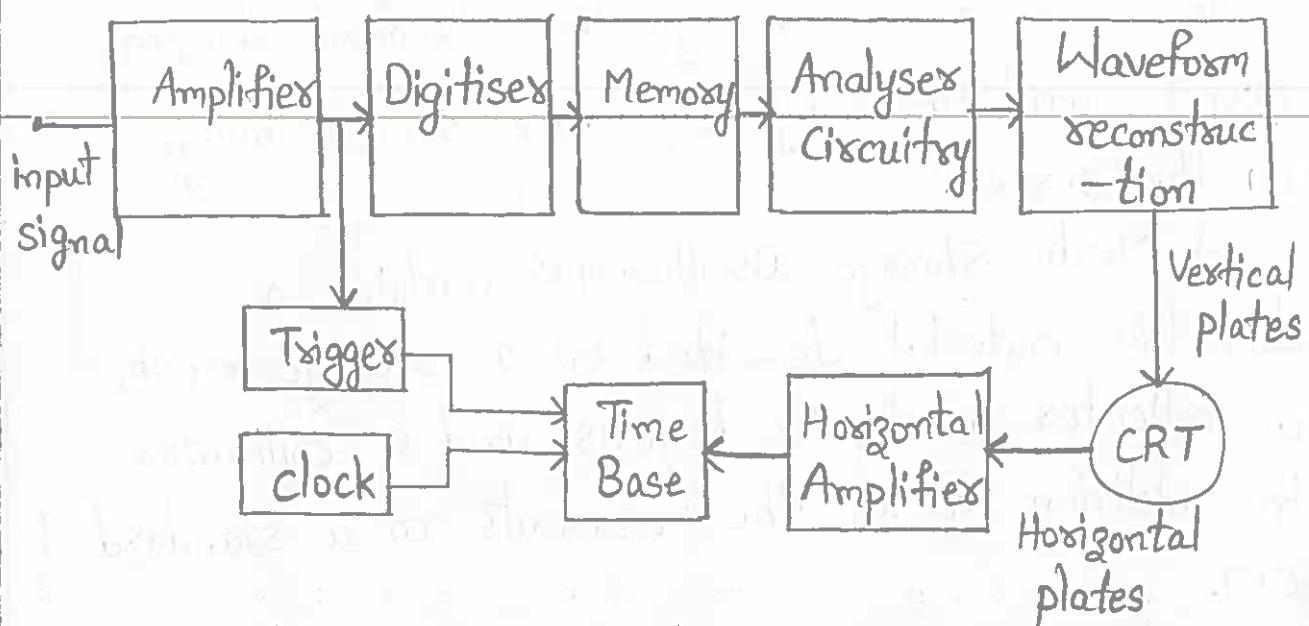
charge areas of the storage target allows these electrons to pass through the standard phosphor target and thereby reproduce stored image on the screen.

A Mesh Storage Oscilloscope contains a dielectric material deposited on a storage mesh, a collector mesh, flood guns and a collimator in addition to all the elements of a standard CRT.



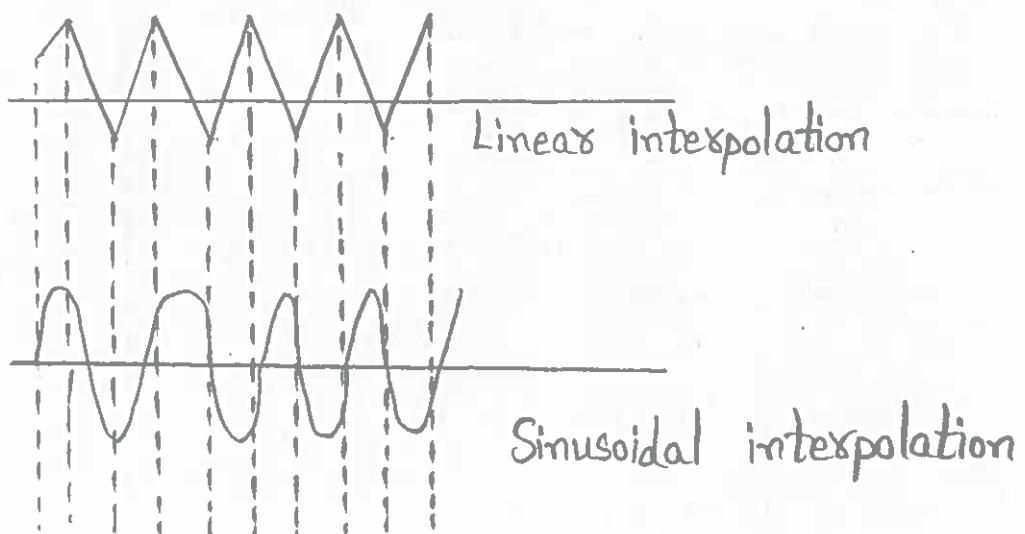
Display of stored charged pattern on a mesh storage.

Digital Storage CRO's :



Waveform Reconstruction

• Without interpolation



Digital Storage Oscilloscope is an instrument which gives the storage of digital waveform or the digital copy of the waveform. It allows us to store the signal or the waveform in digital format & in the

digital memory also it allows us to do the digital signal processing techniques over that signal. The maxm frequency measured on the digital signal oscilloscope depends upon two things, they are

- 1) Sampling rate of the oscilloscope
- 2) Nature of the converter.

As shown in the block diagram the input signal is amplified & digitised the analog input signal. And this digitised signal stores in the memory.

The Analysers circuit process the digital signal & waveform is reconstructed (again the digital signal is converted back to analog form) this analog signal is applied to vertical plates of CRT.

The CRT has two inputs these are vertical input & horizontal input. The vertical i/p signal is Y-axis & the horizontal i/p signal is X-axis. The time base circuit is triggered by the trigger & the clock input signal so it is going to generate a time base signal which is ramp signal & this ramp signal is amplified by the Horizontal amplifier & we provide input to the horizontal plate. So, on the CRT screen we will get the waveform of the input signal versus time.

The Digital Storage Oscilloscope works in 3 modes, they are.

- 1) Roll-Mode - In Roll-Mode very fast varying signals are displayed on the display screen.
- 2) Store Mode - In Store Mode the signals are stored in the memory.
- 3) Hold or Save Mode - Here some part of the signal will be held for sometime & then they will be stored in memory.