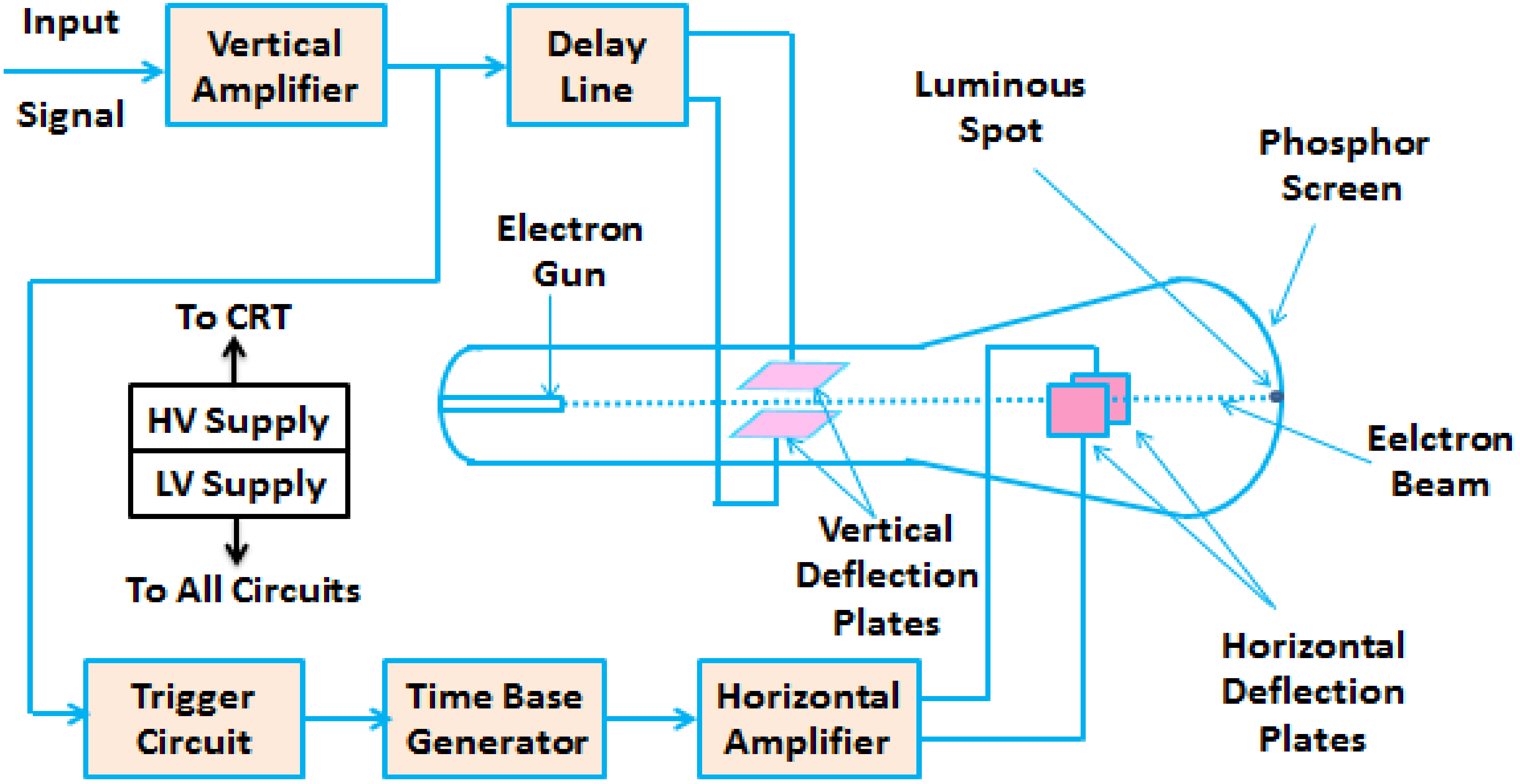
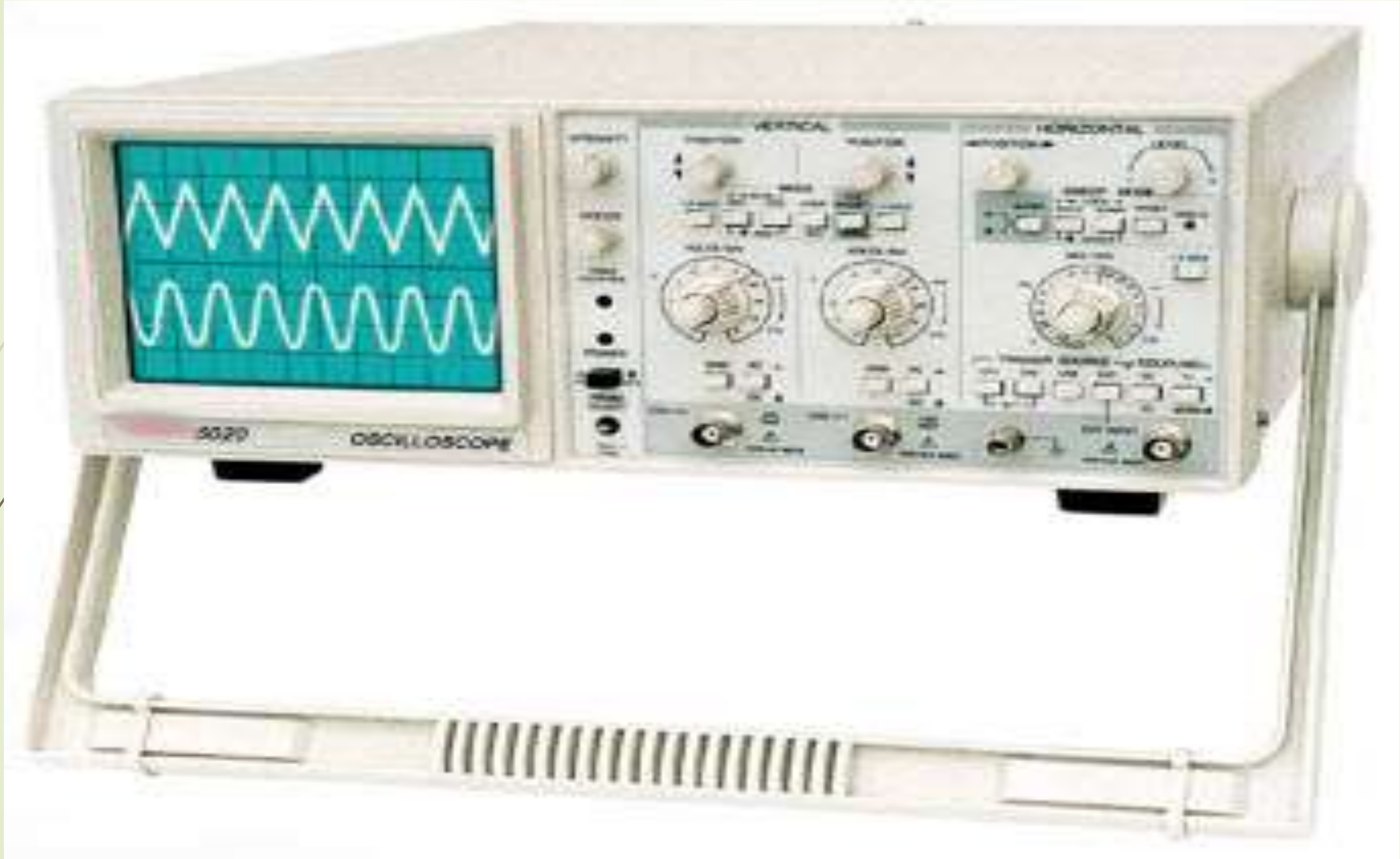
UNIT-3

OSCILLOSCOPES



Block Diagram of Cathode Ray Oscilloscope (CRO)


VERTICAL
HORIZONTAL
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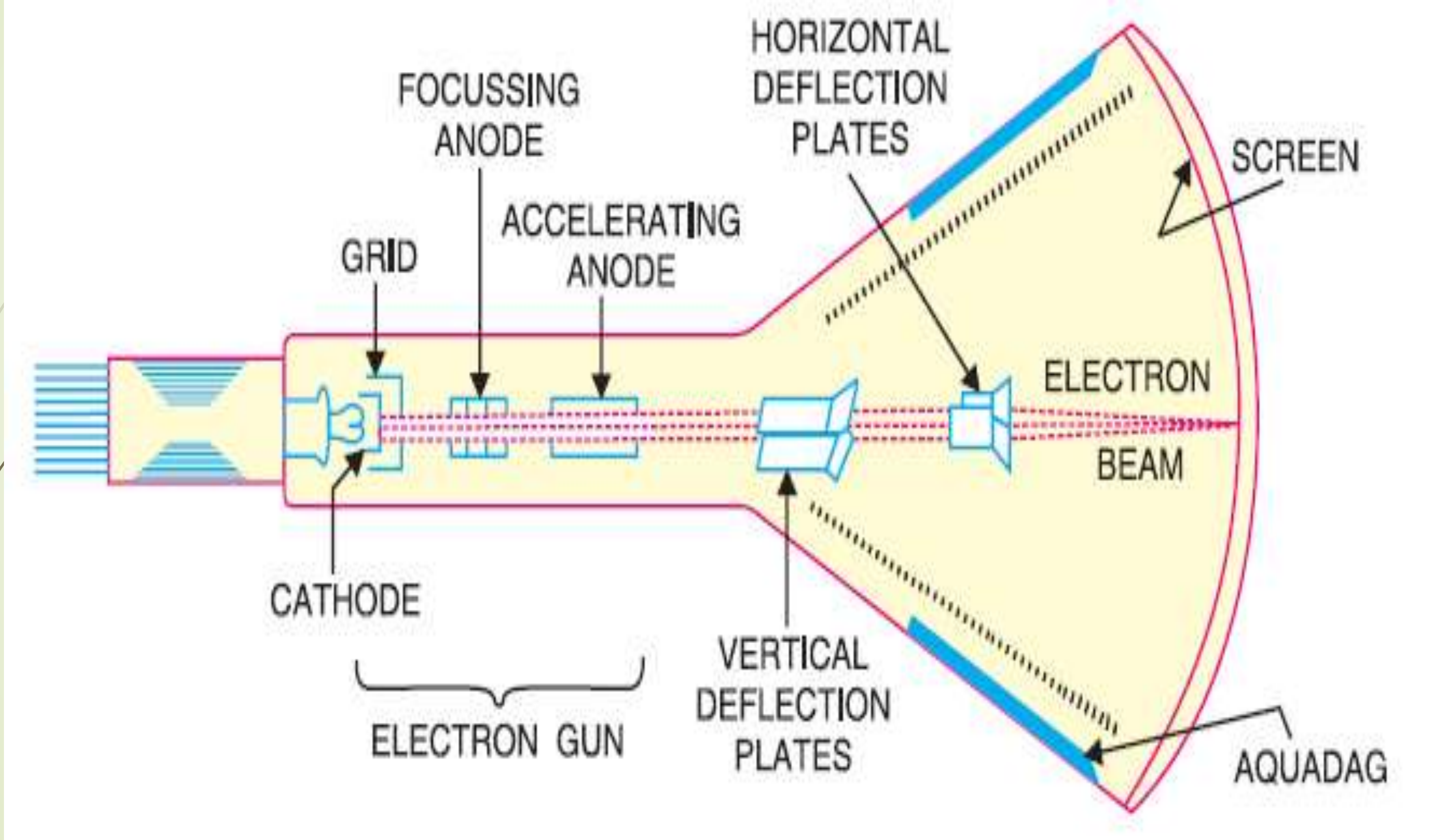
Cathode Ray Tube:-



- **Cathode Ray Oscilloscope**
- The cathode Ray Oscilloscope or mostly called as CRO is an electronic device used for giving the visual indication of a signal waveform.
- It is an extremely useful and the most versatile instrument in the electronic industry.
- CRO is widely used for trouble shooting radio and television receivers as well as for laboratory research and design.
- Using a CRO , the wave shapes of alternating currents and voltages can be studied. It can also be used for measuring voltage, current, power, frequency and phase shift. Different types of oscilloscopes are available in the market for various purposes.
- As we can see from the above figure above, a CRO employs a cathode ray tube (CRT) ,which acts as the heart of the oscilloscope.
- In an oscilloscope, the CRT generates the electron beam which are accelerated to a high velocity and brought to focus on a fluorescent screen. This screen produces a visible spot where the electron beam strikes it. By deflecting the beam over the screen in response to the electrical signal, the electrons can be made to act as an electrical pencil of light which produces a spot of light wherever it strikes.
- For accomplishing these tasks various electrical signals and voltages are needed, which are provided by the power supply circuit of the oscilloscope.

- Low voltage supply is required for the heater of the electron gun to generate the electron beam and high voltage is required for the cathode ray tube to accelerate the beam. Normal voltage supply is required for other control units of the oscilloscope.

- Horizontal and vertical deflection plates are fitted between the electron gun and the screen so that these can deflect the beam according to the input signal.

- To deflect the electron beam on the screen in horizontal direction i.e. X-axis with constant time dependent rate, a time base generator is provided in the oscilloscope.

- The signal to be viewed is supplied to the vertical deflection plate through the vertical amplifier, so that it can amplify the signal to a level that will provide usable deflection of the electron beam.

- As the electron beam is deflected in X-axis as well as Y-axis, a triggering circuit is provided for synchronizing these two types of deflections so that horizontal deflection starts at the same point of the input vertical signal each time it sweeps.

- Since CRT is the heart of the oscilloscope, we are going to discuss its various components in detail.

- The cathode ray tube or CRT is a vacuum tube of special geometrical shape which converts an electrical signal into a visual one.

- A CRT makes available a large number of electrons which are accelerated to high velocity and are brought to focus on a fluorescent screen where it produces a spot when strikes it. The electron beam is deflected during its journey in response to the applied electrical signal. As a result, the electrical signal waveform is displayed visually.

- **(i) Glass Envelope**
- It is a conical highly evacuated glass housing which maintains vacuum inside it and supports various electrodes.
- The inner wall of CRT between the neck and screen are usually coated with a conducting material known as aquadog.

- This coating is electrically connected to the accelerating anode so that the electrons which accidentally strike the walls are returned to the anode. This prevents the walls from charging to a high negative potential.

- **(ii) Electron Gun Assembly**
- The electron gun assembly consists of an indirectly heated cathode, a control grid, a focussing anode and an accelerating anode and it is used to produce a focused beam of electrons.
- The control grid is held at negative potential w.r.t. cathode. However, the two anodes are held at high positive potential w.r.t. cathode.
- The cathode consists of a nickel cylinder coated with oxide coating and provides a large number of electrons.
- The control grid encloses the cathode and consists of a metal cylinder with a tiny circular opening to keep the electron beam small.
- By controlling the positive potential on it,the focusing anode focuses the electron beam into a sharp pin point.
- Due to the positive potential of about 10,000 V on the accelerating anode which is much larger than on the focusing diode, the electron beam is accelerated to a high velocity.
- In this way, the electron gun assembly forms a narrow, accelerated electron beam which produces a spot of light when it strikes the screen.

- **(iii) Deflection Plate Assembly**
- It consists of two sets of deflecting plates within the tube beyond the accelerating anode and is used for the deflection of the beam.
- One set is called as vertical deflection plates and the other set is called horizontal deflection plates.
- The vertical deflection plates are mounted horizontally in the tube. On application of proper potential to these plates, the electron beam can be made to move up and down vertically on the screen.
- The horizontal deflection plates are mounted vertically in the tube. On application of proper potential to these plates, the electron beam can be made to move right and left horizontally on the screen.
- **(iv) Screen**
- The screen is coated with some fluorescent materials such as zinc orthosilicate, zinc oxide etc and is the inside face of the tube.

- When high velocity electron beam strikes the screen, a spot of light appears at the point of impact. The colour of the spot depends upon the nature of fluorescent material.

- **Working of Cathode Ray Tube**
- As the cathode is heated, it produces a large number of electrons.

- These electrons pass through the control grid on their way to the screen.

- The control grid controls the amount of current flow as in standard vacuum tubes. If negative potential on the control grid is high, fewer electrons will pass through it. Hence the electron beam will produce a dim spot of light on striking the screen. Reverse will happen when the negative potential on the control grid is reduced.

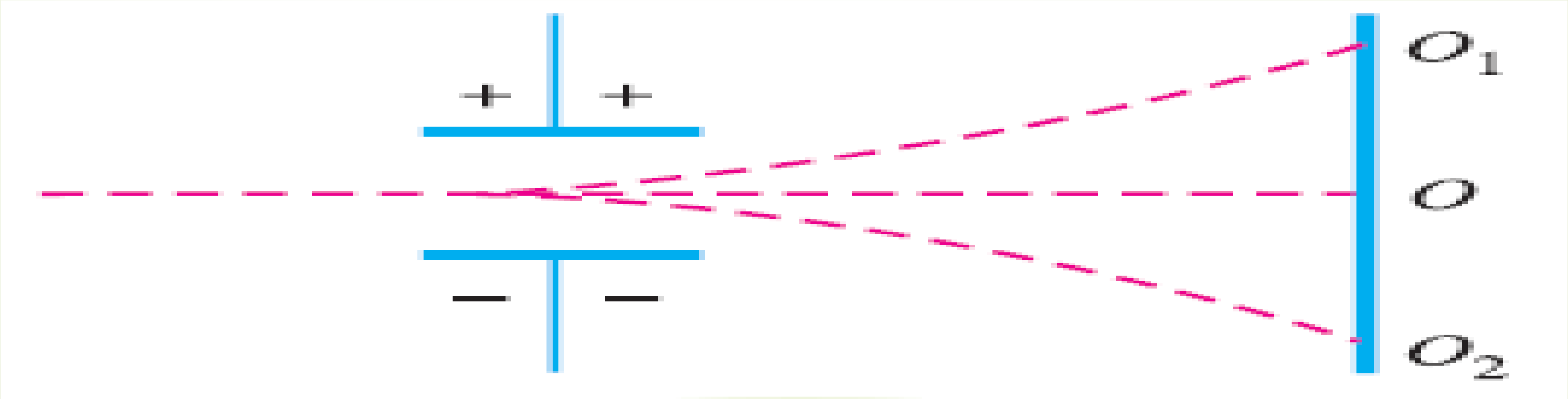
- Therefore, the intensity of the light spot on the screen can be controlled by changing the negative potential on the control grid.

- After leaving the control grid, the electron beam comes under the influence of focusing and accelerating anodes.

- Since, the two anodes are at high positive potential, therefore, they produce a field which acts as electrostatic lens to converge the electron beam at a point on the screen.

- After leaving the accelerating anode, the electron beam comes under the influence of vertical and horizontal deflection plates.

- When no voltage is applied to these deflection plates, the electron beam produces a spot of light at the centre as shown by point O in fig below on the screen.



- If the voltage is applied to the vertical deflection plates only, the electron beam and so as the spot of light will be deflected upwards i.e. point O1. Ans if the potential on the plates is reversed, the spot of light will be deflected downwards i.e. point O2.
- Similarly, the spot of light can be deflected horizontally by applying voltage across the horizontal deflection plates.

Block Diagram of Oscilloscope:

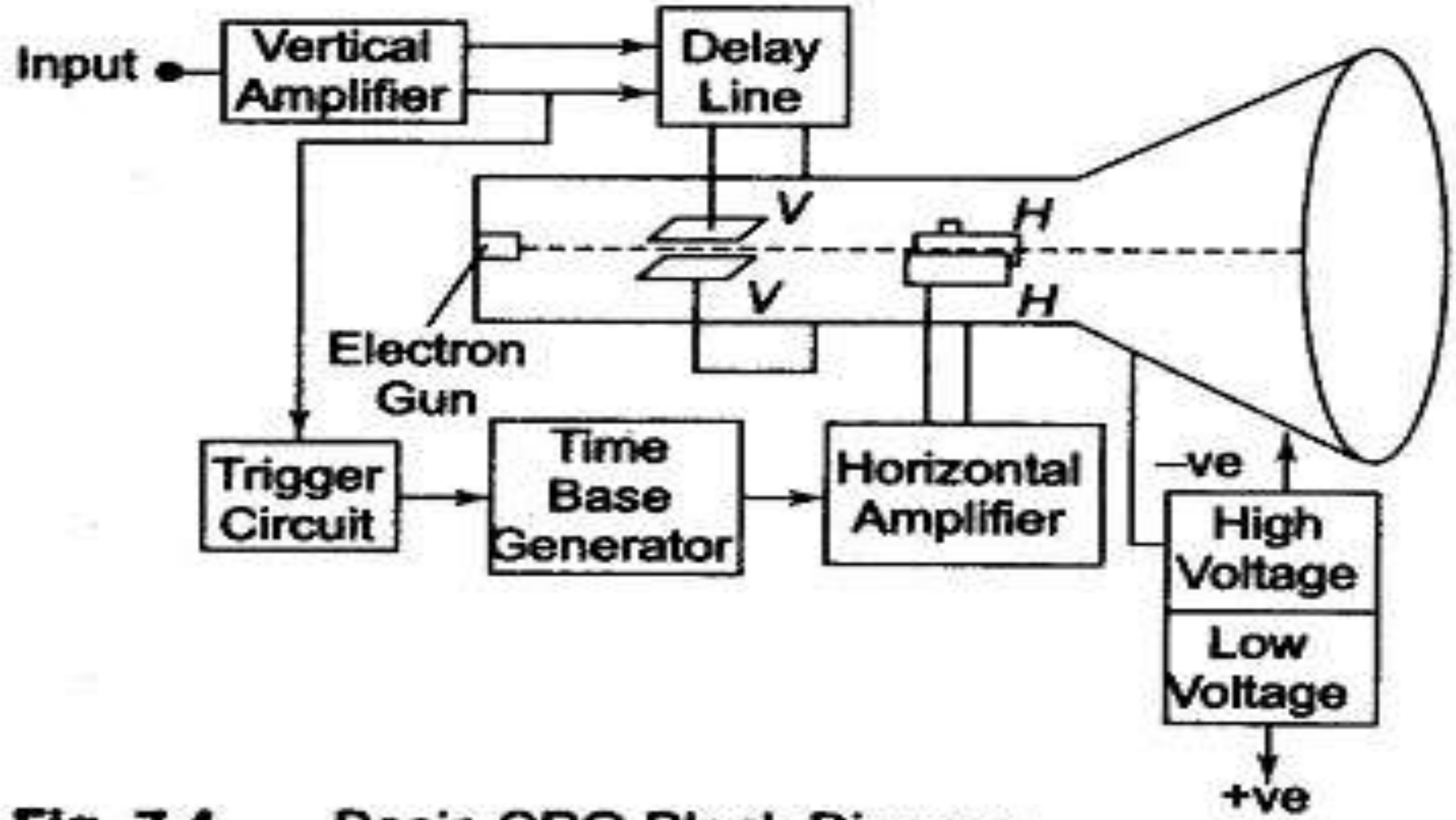


Fig. 7.4 Basic CRO Block Diagram

1.CRT

2.Vertical amplifier

3.Delay line

4.Time base

5.Horizontal amplifier

6.Trigger circuit

7.Power Supply

1.CRT:-

- This is the cathode ray tube which emits electrons that strikes the phosphor screen internally to provide a visual display of signal.

2.Vertical Amplifier:-

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

3.Delay Line:-

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

4.Time Base:-

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

5.Horizontal Amplifier:-

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

6.Trigger Circuit:-

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

7.Power Supply:-

- There are two power supplies, a —ve High Voltage (HV) supply and a +ve Low Voltage (LV) supply. Two voltages are generated in the CRO. The +ve volt supply is from + 300 to 400 V. The —ye high voltage supply is from — 1000 to — 1500 V. This voltage is passed through a bleeder resistor at a few mA. The intermediate voltages are obtained from the bleeder resistor for intensity, focus and positioning controls.

Advantages of using —ve HV Supply:

- The accelerating anodes and the deflection plates are close to ground The ground potential protects the operator from HV shocks when making connections to the plates.

- The deflection voltages are measured wrt ground, therefore HV blocking or coupling capacitor are not needed, but low voltage rating capacitors can be used for connecting the HV supply to the vertical and horizontal

Simple CRO:-

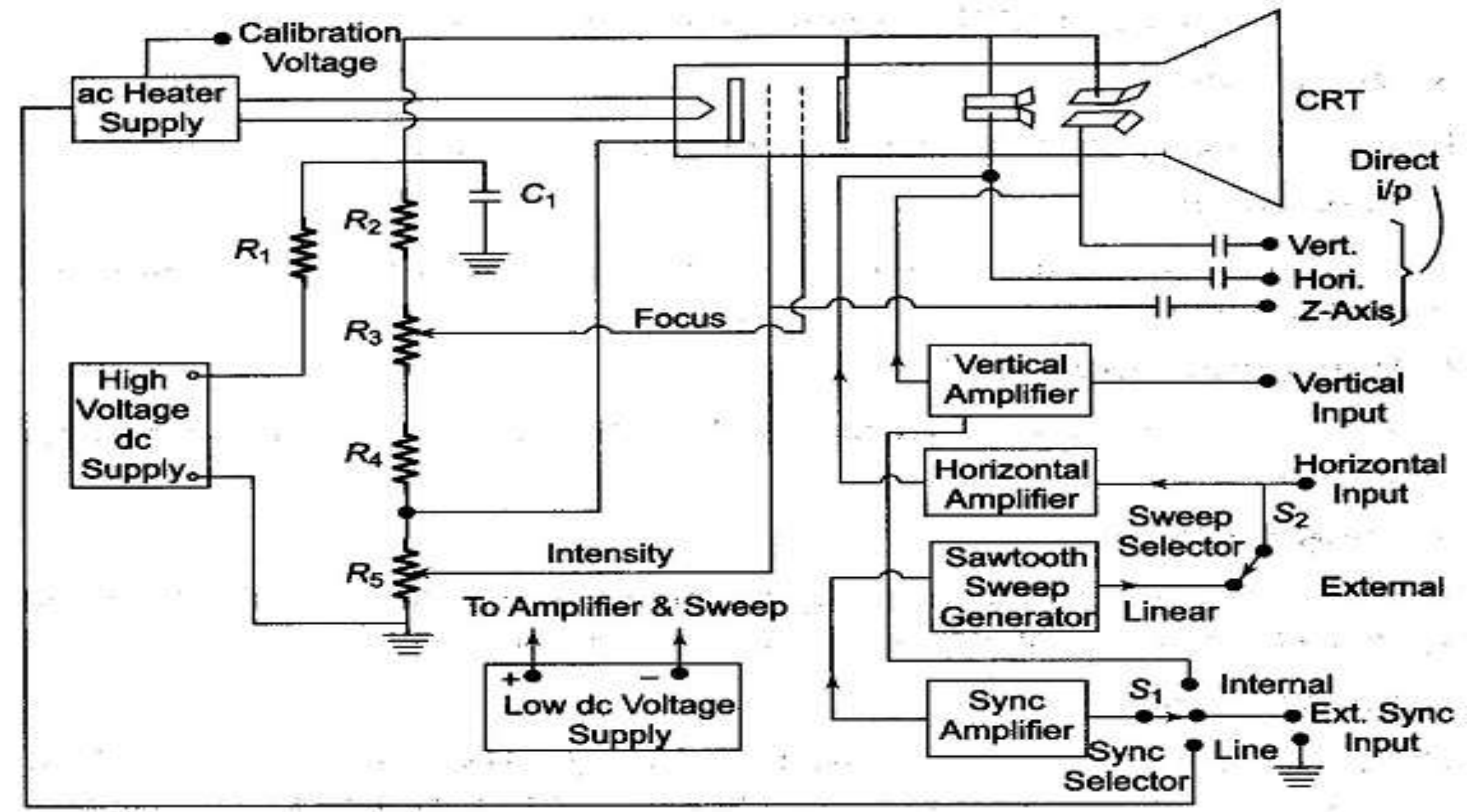


Fig. 7.5 Simple CRO

- The Basic block diagram of a simple CRO is shown in Fig.7.5. The ac filament supplies power to the CRT heaters. This also provides as accurate ac calibrating voltage.
- CRT dc voltage is obtained from the HV dc supply through voltage dividers. R_1 — R_5. Included along with this voltage divider is a potentiometer (R_3) which varies the potential at the focusing electrode, known as focus control, and one which varies the control grid voltage, called the intensity control (R_5).
- Capacitor C_1 is used to ground the deflection plates and the second anode for the signal voltage, but dc isolates these electrodes from the ground.
- Normally S_2 is set to its linear position. This connects the sweep generator output to the horizontal input. The sweep voltage is amplified before being applied to the horizontal deflecting plates.
- When an externally generated sweep is desired, S_2 is connected to its external position and the external generator is connected to the input.
- The sweep synchronizing voltage is applied to the internal sweep generator through switch S_1, which selects the type of synchronization.

CRT Showing Power Supply

Figure 7.6 shows the various voltages applied to CRT electrodes. The intensity control controls the number of electrons by varying the control grid voltage. Focusing can be done either electrostatically or electromagnetically. Electrostatic focusing is obtained by using a cylindrical anode, which changes the electrostatic lines of force which controls the beam.

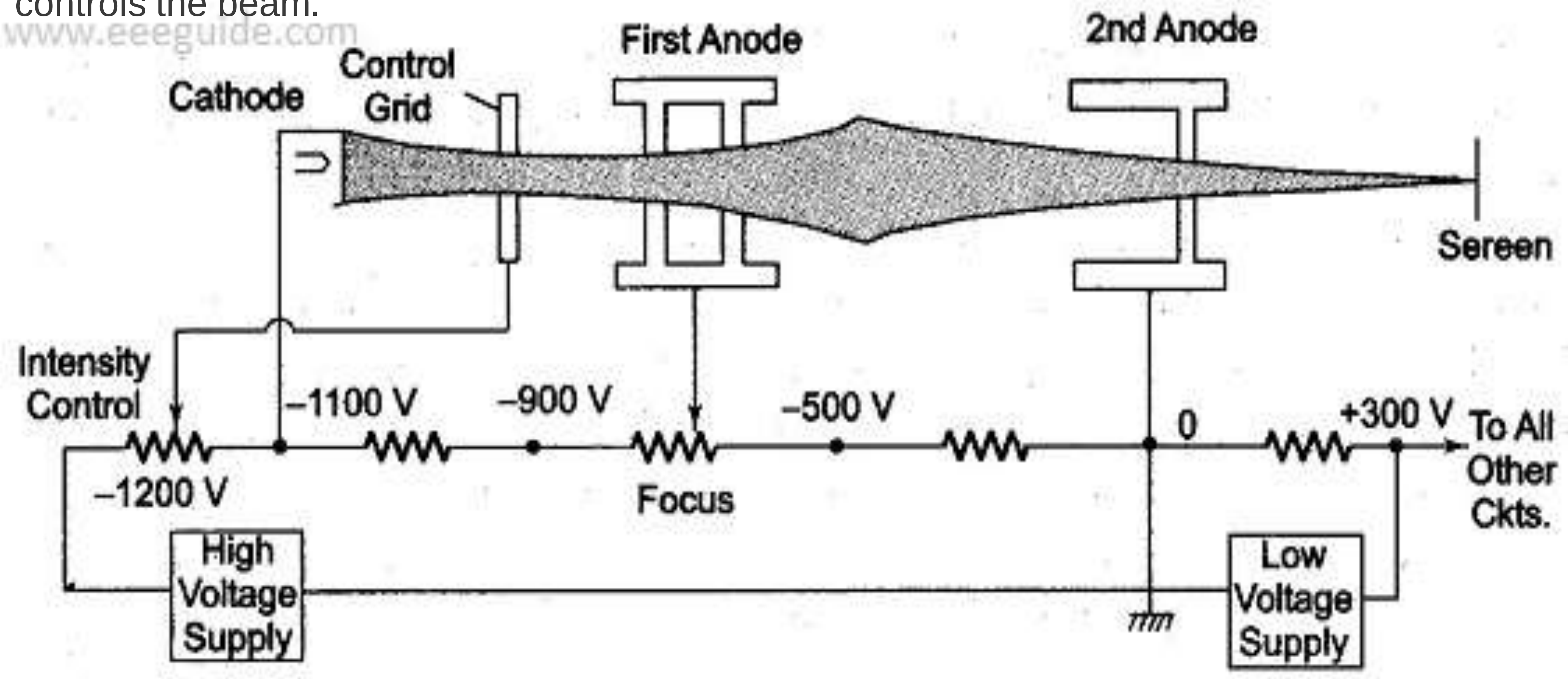
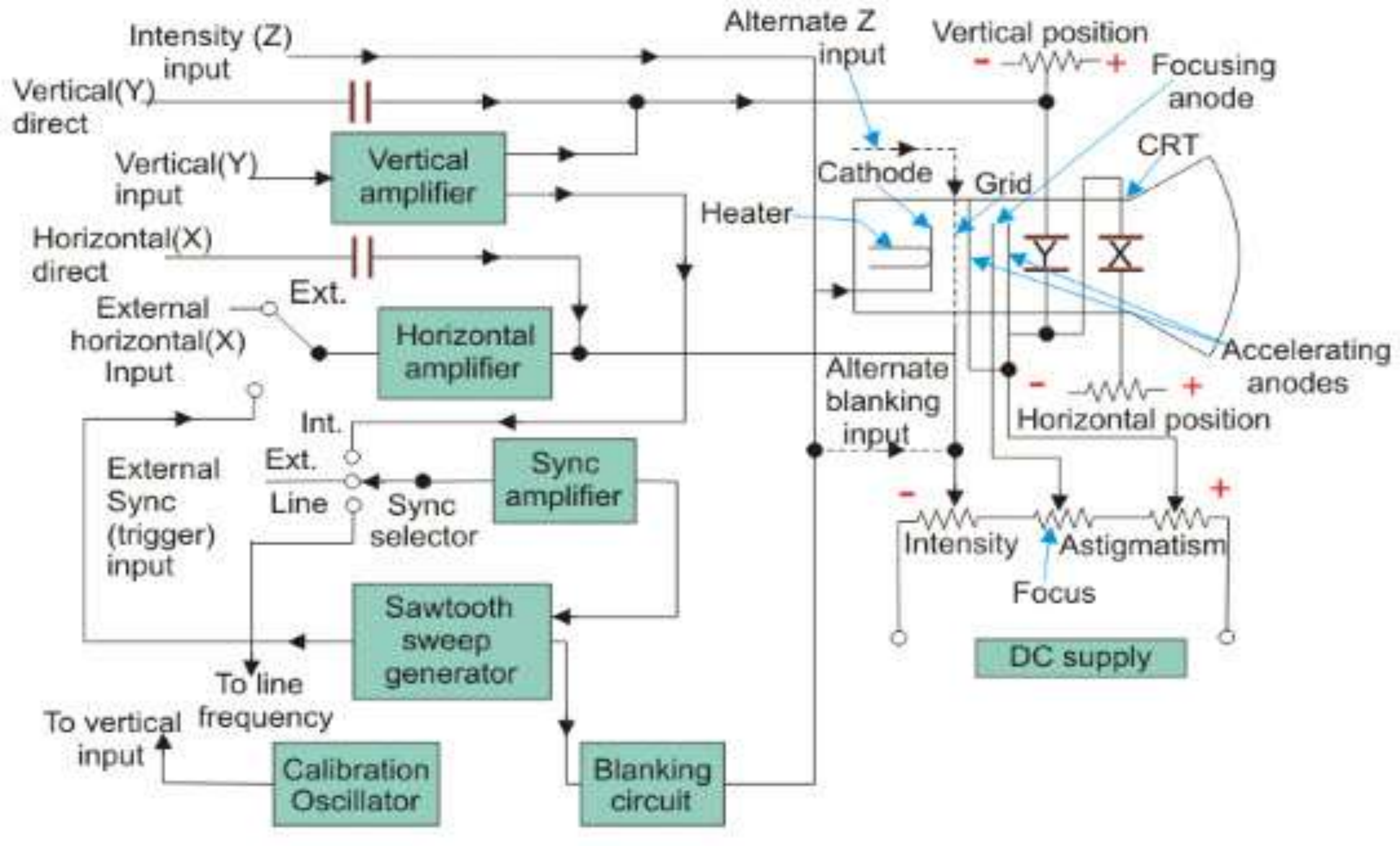


Fig. 7.6 CRT Showing Power Supplies



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

Working of CRO

The following circuit diagram shows the ***basic circuit of a cathode ray oscilloscope***. In this, we will discuss important parts of the oscilloscope.

Vertical Deflection System

The main function of this amplifier is to amplify the weak signal so that the amplified signal can produce the desired signal. To examine the input signals are penetrated to the vertical deflection plates through the input attenuator and number of amplifier stages.

Horizontal Deflection System

The vertical and horizontal system consists of horizontal amplifiers to amplify the weak input signals, but it is different to the vertical deflection system. The horizontal deflection plates are penetrated by a sweep voltage that gives a time base. By seeing the circuit diagram the sawtooth sweep generator is triggered by the synchronizing amplifier while the sweep selector switches in the internal position. So the trigger saw tooth generator gives the input to the horizontal amplifier by following the mechanism. Here we will discuss the four types of sweeps.

Recurrent Sweep

As the name, itself says that the saw tooth is respective that is a new sweep is started immodestly at the end of the previous sweep.

Triggered Sweep

Sometimes the waveform should be observed that it may not be predicted, thus the desired that the sweep circuit remains inoperative and the sweep should be initiated by the waveform under the examination. In these cases, we will use the triggered sweep.

Driven Sweep

In general, the drive sweep is used when the sweep is a free running but it is a triggered by the signal under the test.

Non-Saw Tooth Sweep

This sweep is used to find the difference between the two voltages. By using the non-sawtooth sweep we can compare the frequency of the input voltages.

Synchronization

The synchronization is done to produce the stationary pattern. The synchronization is between the sweep and the signal should measure. There are some sources of synchronization which can be selected by the synchronization selector. Which are discussed below.

Internal

In this the signal is measured by the vertical amplifier and the trigger is abstained by the signal.

External

In the external trigger, the external trigger should be present.

Line

The line trigger is produced by the power supply.

Intensity Modulation

This modulation is produced by inserting the signal between the ground and cathode. This modulation causes by brightening the display.

Positioning Control

By applying the small independent internal direct voltage source to the detecting plates through the potentiometer the position can be controlled and also we can control the position of the signal.

Intensity Control

The intensity has a difference by changing the grid potential with respect to the cathode.

Applications of CRO

- Voltage measurement
- Current measurement
- Examination of waveform
- Measurement of phase and frequency

Uses of CRO

In laboratory, the CRO can be used as

- It can display different types of waveforms
- It can measure short time interval
- In voltmeter, it can measure potential difference

Oscillosopes CRT features:-

- CRT Features – Electrostatic CRTs are available in a number of types and sizes to suit individual requirements. The important features of these tubes are as follows.

1.Size

2.Phosphor

3.Operating Voltages

4.Deflection Voltages

5.Viewing Screen

1. ***Size***:-

- Size refers to the screen diameter. CRTs for oscilloscopes are available in sizes of 1, 2, 3, 5, and 7 inches. 3 inches is most common for portable instruments.
- For example a CRT having a number 5GP1. The first number 5 indicates that it is a 5 inch tube.
- Both round and rectangular CRTs are found in scopes today. The vertical viewing size is 8 cm and horizontal is 10 cm.

2. ***Phosphor***:-

- The screen is coated with a fluorescent material called phosphor. This material determines the colour and persistence of the trace, both of which are indicated by the phosphor.

- The trace colours in electrostatic CRTs for oscilloscopes are blue, green and blue green. White is used in TVs, and blue-white, orange, and yellow are used for radar.

- Persistence is expressed as short, medium and long. This refers to the length of time the trace remains on the screen after the signal has ended.

- The phosphor of the oscilloscope is designated as follows.

  P1 – Green medium

  P2 – Blue green medium

  P5 – Blue very short

  P11 – Blue short

- These designations are combined in the tube type number. Hence 5GP1 is a 5 inch tube with a medium persistence green trace.

- Long persistence traces are used for transients, since they keep the fast transient on the screen for observation after the transient has disappeared.

- Short persistence is needed for extremely high speed phenomena, to prevent smearing and interference caused when one image persists and overlaps with the next one.

- P11 phosphor is considered the best for photographing from the CRT screen.

3.***Operating Voltages***:-

- The CRT requires a heater voltage of 6.3 volts ac or dc at 600 mA.

- Several dc voltages are listed below. The voltages vary with the type of tube used.

Negative grid (control) voltage – 14 V to – 200 V.

Positive anode no. 1 (focusing anode) – 100 V to – 1100 V

Positive anode no. 2 (accelerating anode) 600 V to 6000 V

Positive anode no. 3 (accelerating anode) 200 V to 20000 V in some cases

4.**_Deflection Voltages_**:-

- Either ac or dc voltage will deflect the beam.

- The distance through which the spot moves on the screen is proportional to the dc, or peak ac amplitude.

- The deflection sensitivity of the tube is usually stated as the dc voltage (or peak ac voltage) required for each cm of deflection of the spot on the screen.

5.**_Viewing Screen_**:-

- The viewing screen is the glass face plate, the inside wall of which is coated with phosphor.

- The viewing screen is a rectangular screen having graticules marked on it.

- The standard size used nowadays is 8 cm x 10 cm (8 cm on the vertical and 10 cm on horizontal). Each centimeter on the graticule corresponds to one division (div).

- The standard phosphor colour used nowadays is blue.

Vertical Amplifier:-

- Vertical Amplifier – The sensitivity (gain) and frequency bandwidth (B.W.) response characteristics of the oscilloscope are mainly determined by the vertical amplifier.

- Since the gain B.W. product is constant, to obtain a greater sensitivity the B.W. is narrowed, or vice-versa.

- Some oscilloscopes give two alternatives, switching to a wide bandwidth position, and switching to a high sensitivity position.

- The vertical amplifier consists of several stages, with fixed overall sensitivity or gain expressed in V/divs. The advantage of fixed gain is that the amplifier can be more easily designed to meet the requirements of stability and B.W.

- The vertical amplifier is kept within its signal handling capability by proper selection of the input attenuator switch.

- The first element of the pre-amplifier is the input stage, often consisting of a FET source follower whose high input impedance isolates the amplifier from the attenuator.

Block Diagram of a Vertical Amplifier:-

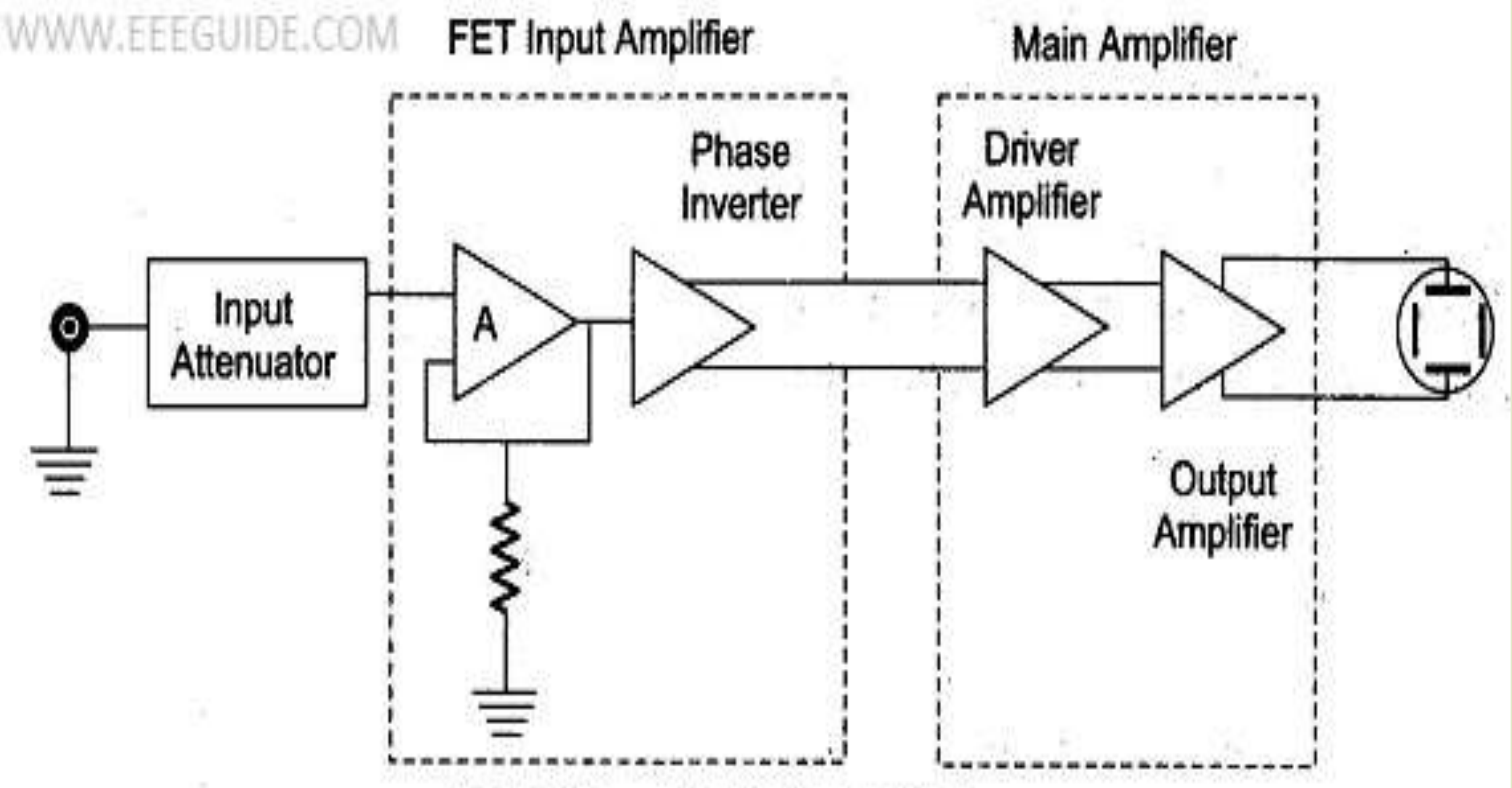


Fig. 7.7 Vertical Amplifier

- This FET input stage is followed by a BIT emitter follower, to match the medium impedance of FET output with the low impedance input of the phase inverter.
- This phase inverter provides two antiphase output signals which are required to operate the push-pull output amplifier.
- The push-pull output stage delivers equal signal voltages of opposite polarity to the vertical plates of the CRT.
- The advantages of push-pull operation in CRO are similar to those obtained from push-pull operation in other applications; better hum voltage cancellation from the source or power supply (i.e. dc), even harmonic suppression, especially the large 2nd harmonic is cancelled out, and greater power output per tube as a result of even harmonic cancellation.
- In addition, a number of defocusing and non-linear effects are reduced, because neither plate is at ground potential.

Horizontal Deflecting System:-

- The Horizontal Deflecting System consist of a Time Base Generator and an output amplifier.

- **Sweep or Time Base Generator**

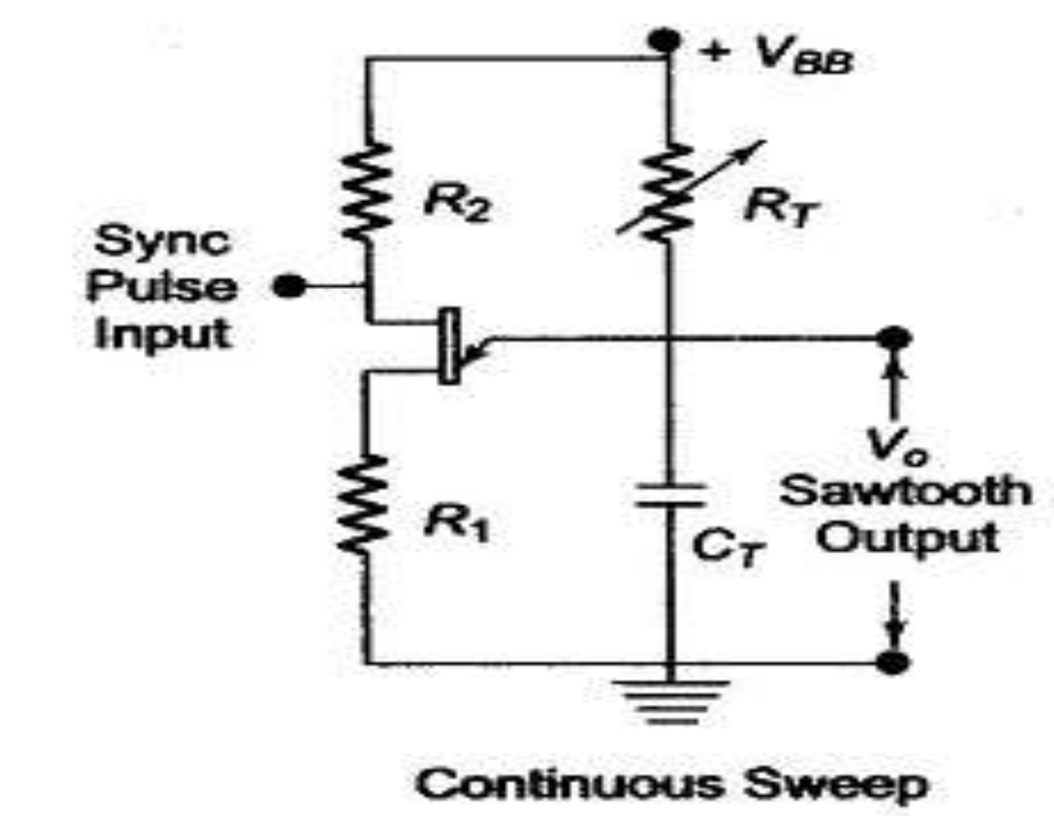


Fig. 7.8 Continuous Sweep

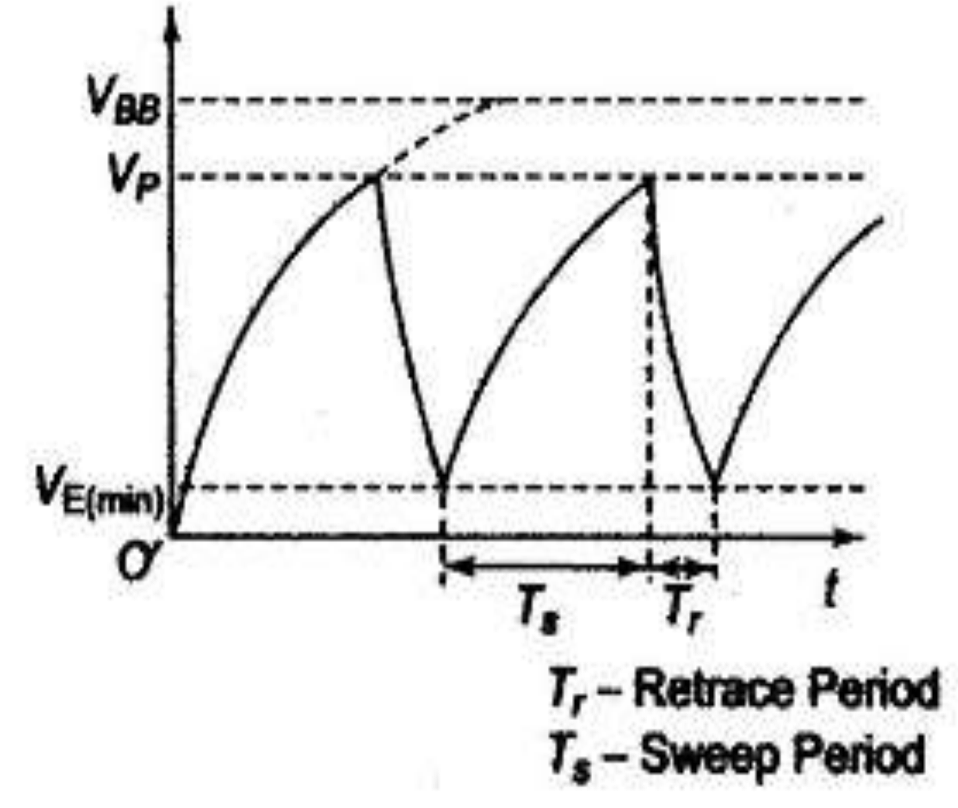


Fig. 7.9 Sawtooth Output Waveform

- A continuous sweep CRO using a UJT as a time base generator is shown in Fig. 7.8.

- The UJT is used to produce the sweep. When the power is first applied, the UJT is off and the C_T changes exponentially through R_T The UJT emitter voltage V_E rises towards V_{BB} and when V_E reaches the peak voltage V_P, as shown in Fig. 7.9,

- the emitter to base '1' (B_1) diode becomes forward biased and the UJT triggers ON. This provides a low resistance discharge path and the capacitor discharges rapidly.

- The emitter voltage V_E reaches the minimum value rapidly and the UJT goes OFF. The capacitor recharges and the cycle repeats.

- To improve sweep linearity, two separate voltage supplies are used, a low voltage supply for UJT and a high voltage supply for the R_TC_T circuit.

- R_T is used for continuous control of frequency within a range and C_T is varied or changed in steps for range changing. They are sometimes called as timing resistor and timing capacitor respectively.

- The sync pulse enables the sweep frequency to be exactly equal to the input signal frequency, so that the signal is locked on the screen and does not drift.

Triggered Sweep CRO:-

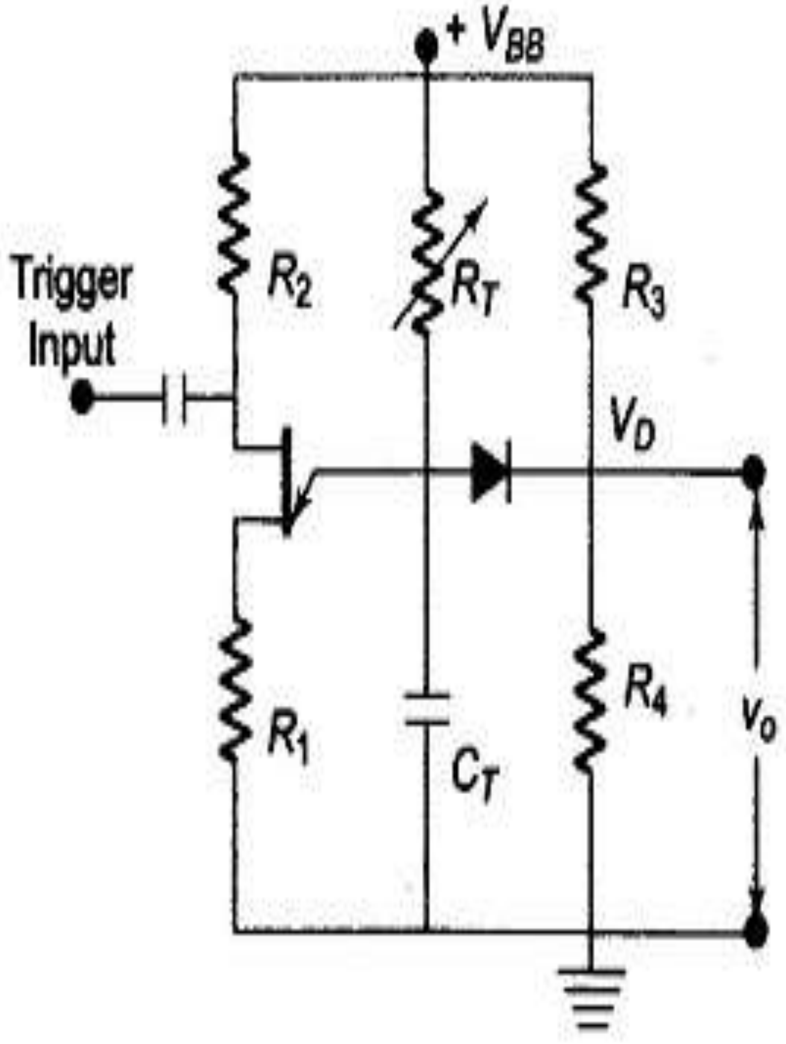


Fig. 7.10 Triggered Sweep

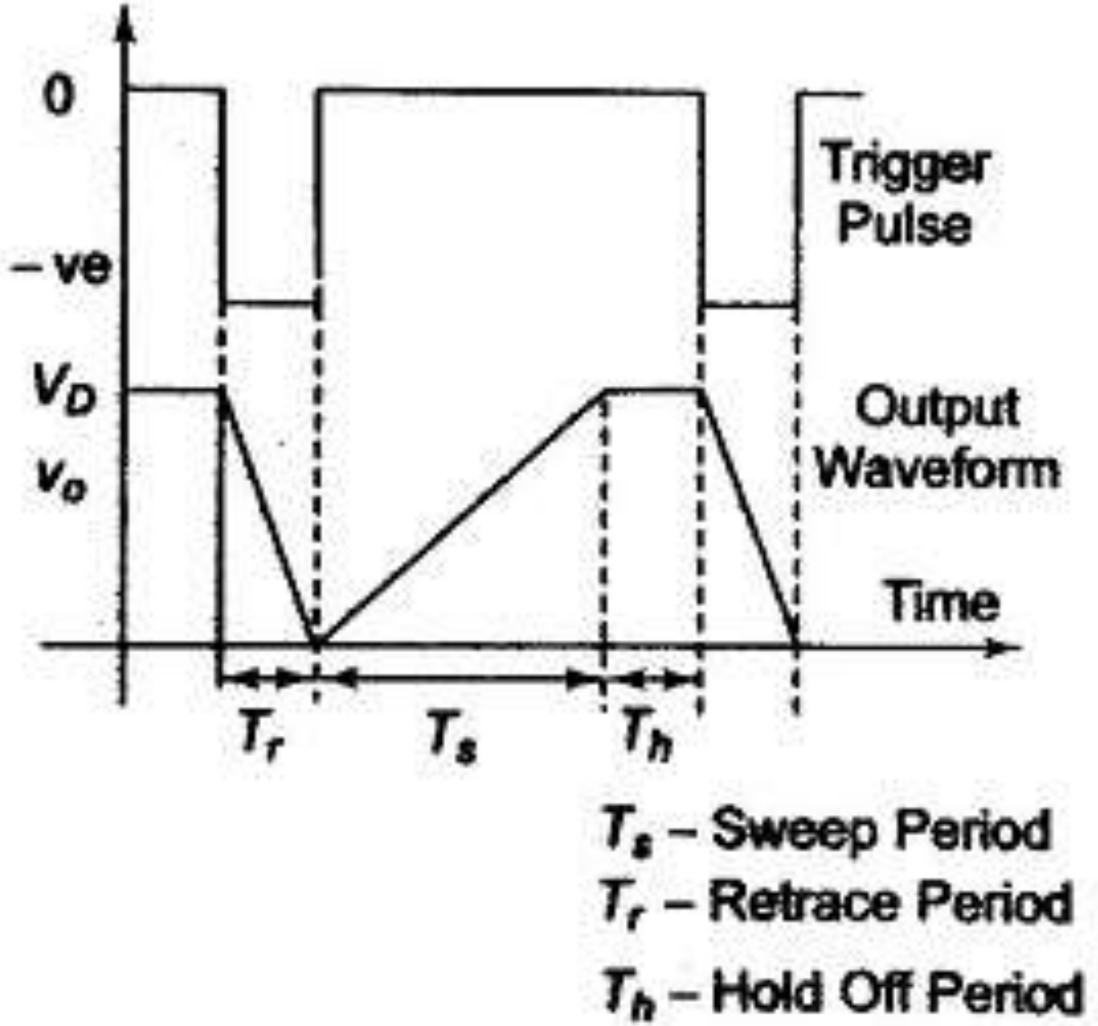


Fig. 7.11 Output Waveform

- Triggered Sweep CRO – The continuous sweep is of limited use in displaying periodic signals of constant frequency and amplitude.

- When attempting to display voice or music signals, the pattern falls in and out of sync as the frequency and amplitude of the music varies resulting in an unstable display.

- A triggered sweep can display such signals, and those of short duration, e.g. narrow pulses. In triggered mode, the input signal is used to generate substantial pulses that trigger the sweep. Thus ensuring that the sweep is always in step with the signal that drives it.

- As shown in Fig. 7.10, resistance R_3 and R_4 form a voltage divider such that the voltage V_D at the cathode of the diode is below the peak voltage V_P for UJT conduction.

- When the circuit is switched on, the UJT is in the nonconducting stage, and C_T charges exponentially through R_T towards V_{BB} until the diode becomes forward biased and conducts; the capacitor voltage never reaches the peak voltage required for UJT conduction but is clamped at V_D. I

- f now a –ve pulse of sufficient amplitude is applied to the base and the peak voltage $V/_P$ is momentarily lowered, the UJT fires.

- As a result, the C_T discharges rapidly through the UJT until the maintaining voltage of the UJT is reached; at this point the UJT switches off and the C_T charges towards V_{BB}, until it is clamped again at V_D. Figure 7.11 shows the output waveform.

Trigger Pulse Generator Circuit:-

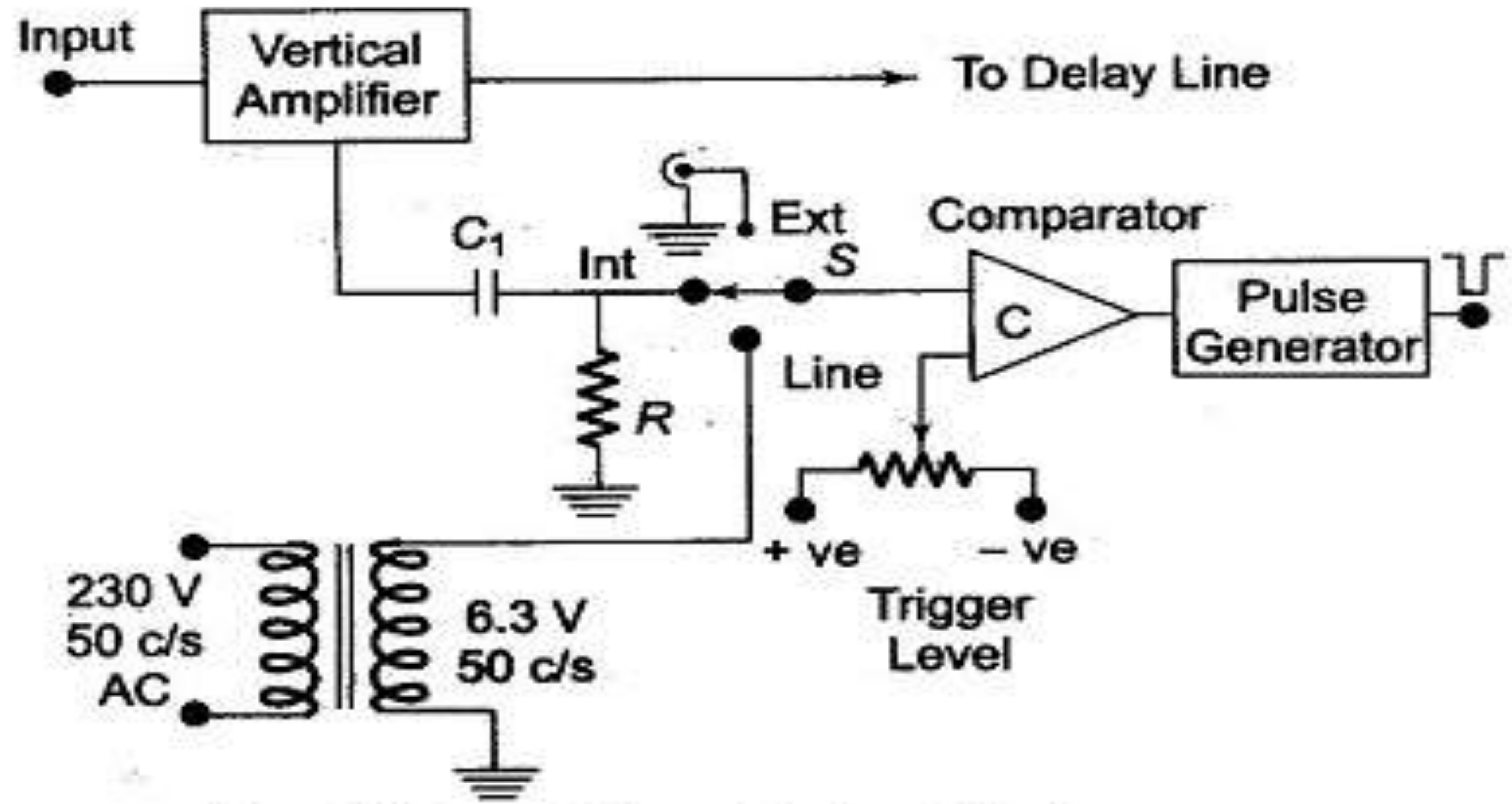


Fig. 7.12 Trigger Pulse Circuit

- The Trigger Pulse Generator Circuit is activated by signals of a variety of shapes and amplitudes, which are converted to trigger pulses of uniform amplitude for the precision sweep operation.

- If the trigger level is set too low, the trigger generator will not operate. On the other hand, if the level is too high, the UJT may conduct for too long and part of the leading edge of the input signal may be lost.

- The trigger selection is a 3-position switch, Internal-External-Line, as shown in Fig. 7.12. The trigger input signal is applied to a voltage comparator whose reference level is set by the Trigger Level control on the CRO front panel.

- The comparator circuit C produces a change in the output whenever the trigger input exceeds the present trigger levels. The pulse generator that follows the comparator produces —ve trigger pulses each time the comparator output crosses its quiescent level, which in turn triggers the sweep generator to start the next sweep.

- The trigger sweep generator contains the stability or sync control, which prevents the display from uttering or running on the screen. Stability is secured by proper adjustments of the sweep speed.

- Sweep speed is adjustable by means of a sweep rate control and its multiplier, i.e. range control. The timing resistance R_T is used for sweep rate control and timing capacitor C_T is changed in steps for sweep rate control.

Delay Line in Triggered Sweep Circuit:-

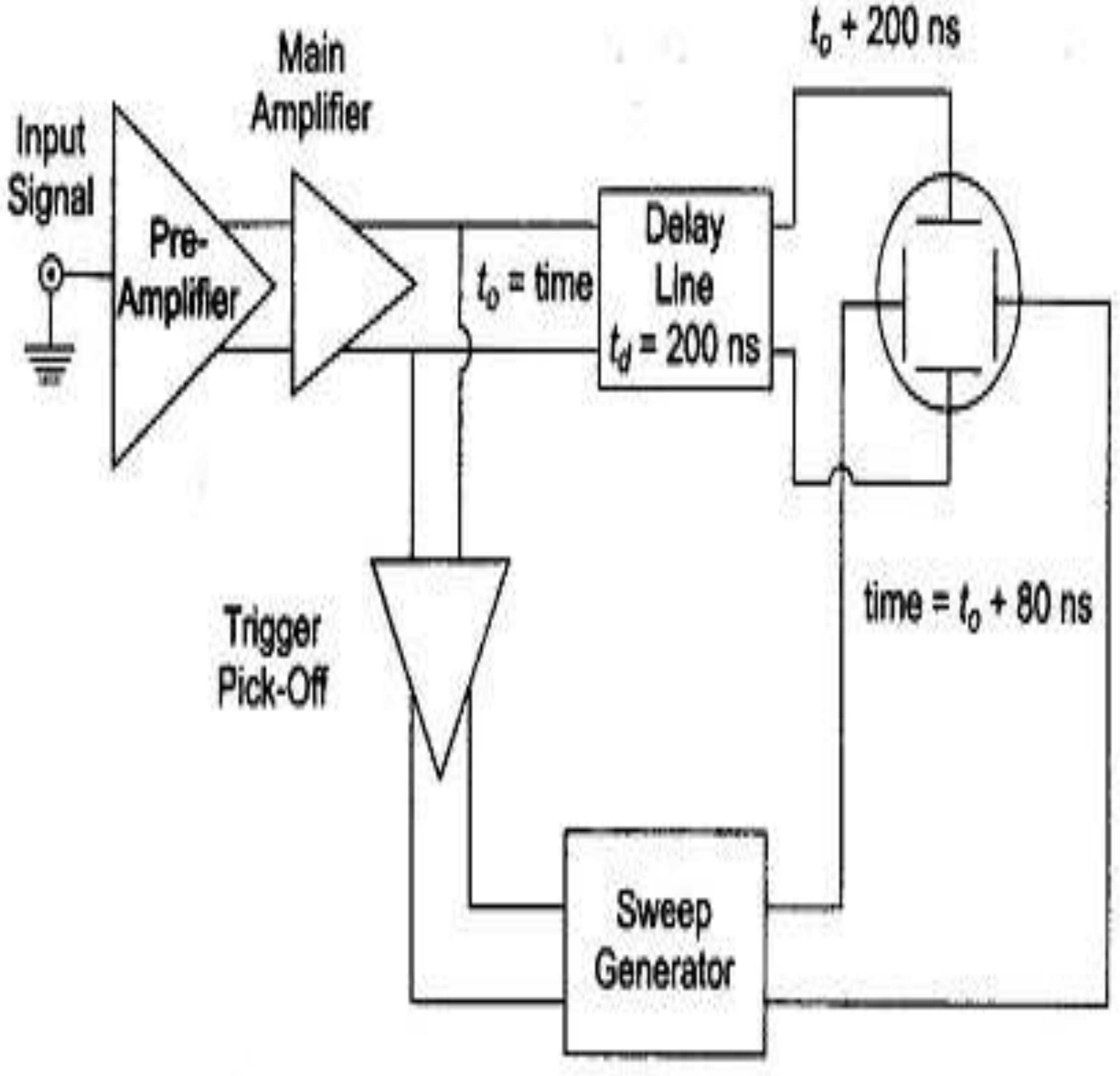


Fig. 7.13 Delay Line Circuit

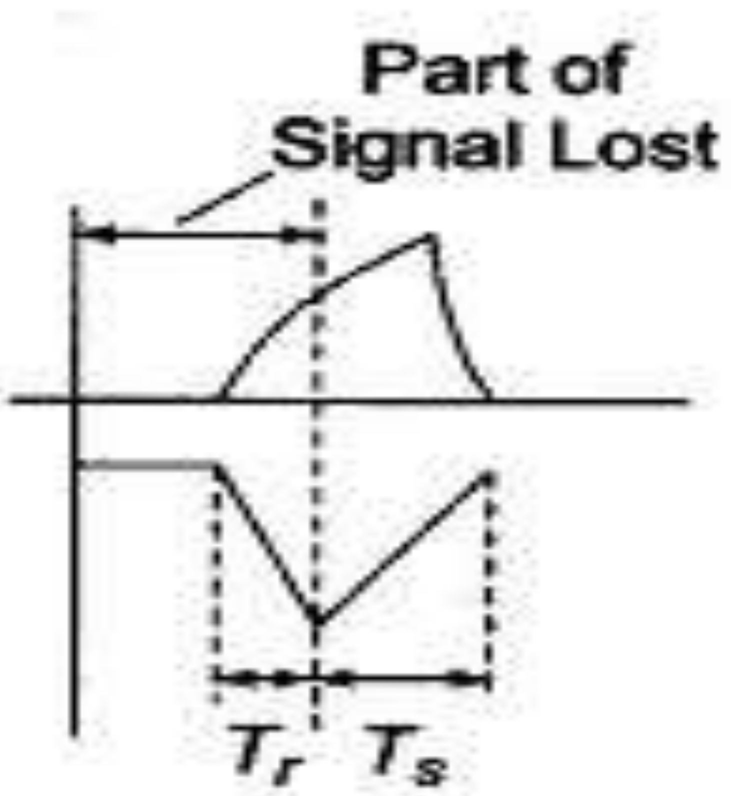


Fig. 7.14 Delay Line Wave-form

- Figure 7.13 shows a Delay Line in Triggered Sweep Circuit. Figure 7.14 indicates the amplitude of the signal wrt time and 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 and only part of the signal is displayed.

- To counteract this disadvantage the signal is not applied directly to the vertical plates but is passed through a delay line circuit, as shown in Fig. 7.13. This gives time for the sweep to start at the horizontal plates before the signal has reached the vertical plates.

- The trigger pulse is Picked off at a tune t_0 after the signal has passed through the main amplifier.

- The sweep generator delivers the sweep ti; the horizontal amplifier and the sweep starts at the HDP at time t_0 + 80 ns. Hence the sweep starts well in time, since the signal arrives at the VDP at time t_0 + 200 ns.

Dual Beam CRO:-

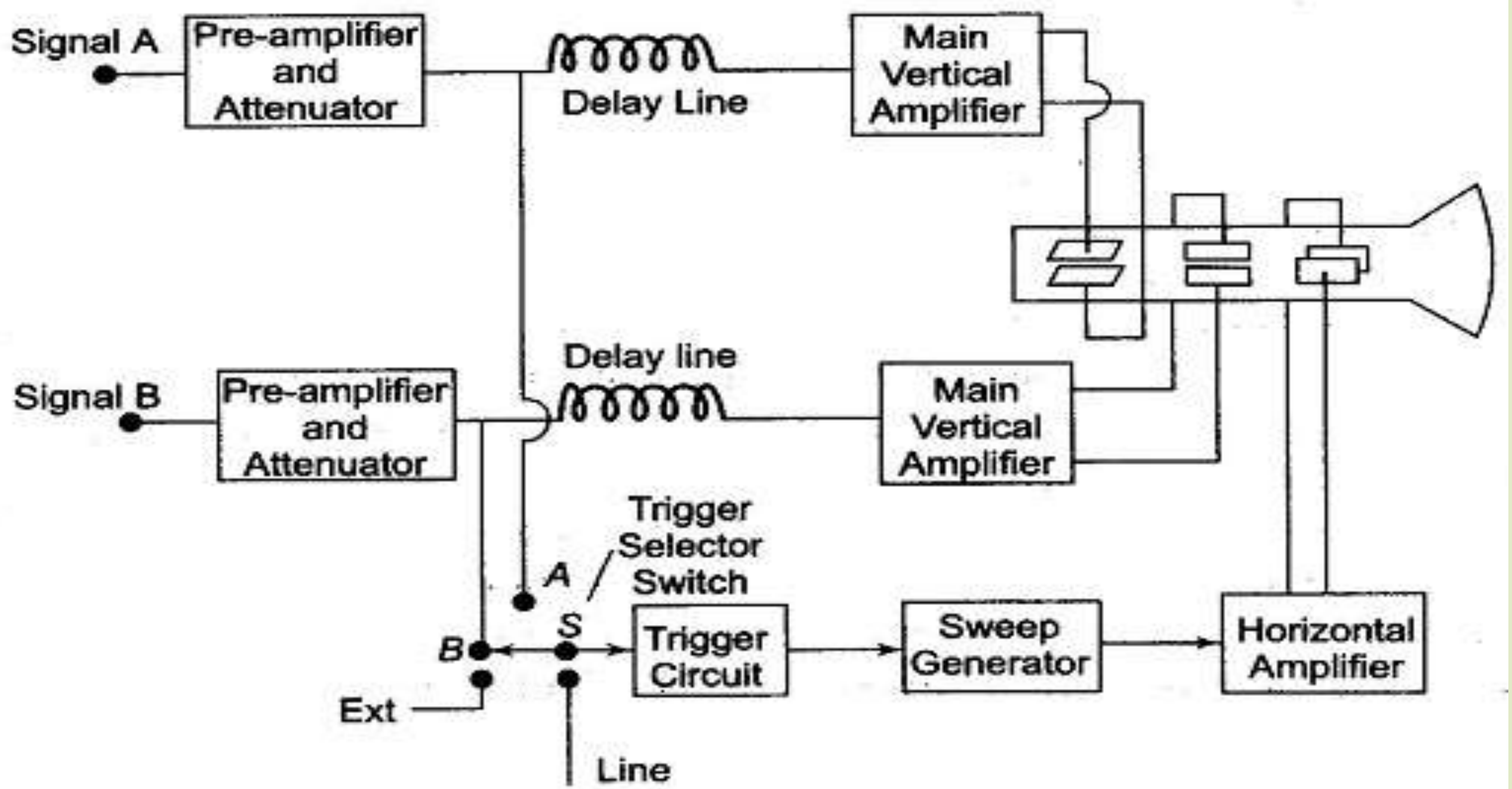


Fig. 7.18 Dual Beam CRO

- The dual trace oscilloscope has one cathode ray gun, and 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 VDPs and a single set of HDPs.
- Only one beam can be synchronised at one time, since the sweep is the same for both signals, i.e. a common time base is used for both beams.
- Therefore, the signals must have the same frequency or must be related harmonically, in order to obtain both beams locked on the CRT screen, e.g. the input signal of an amplifier can be used as signal A and its output signal as signal B.

Dual Trace Oscilloscope:-

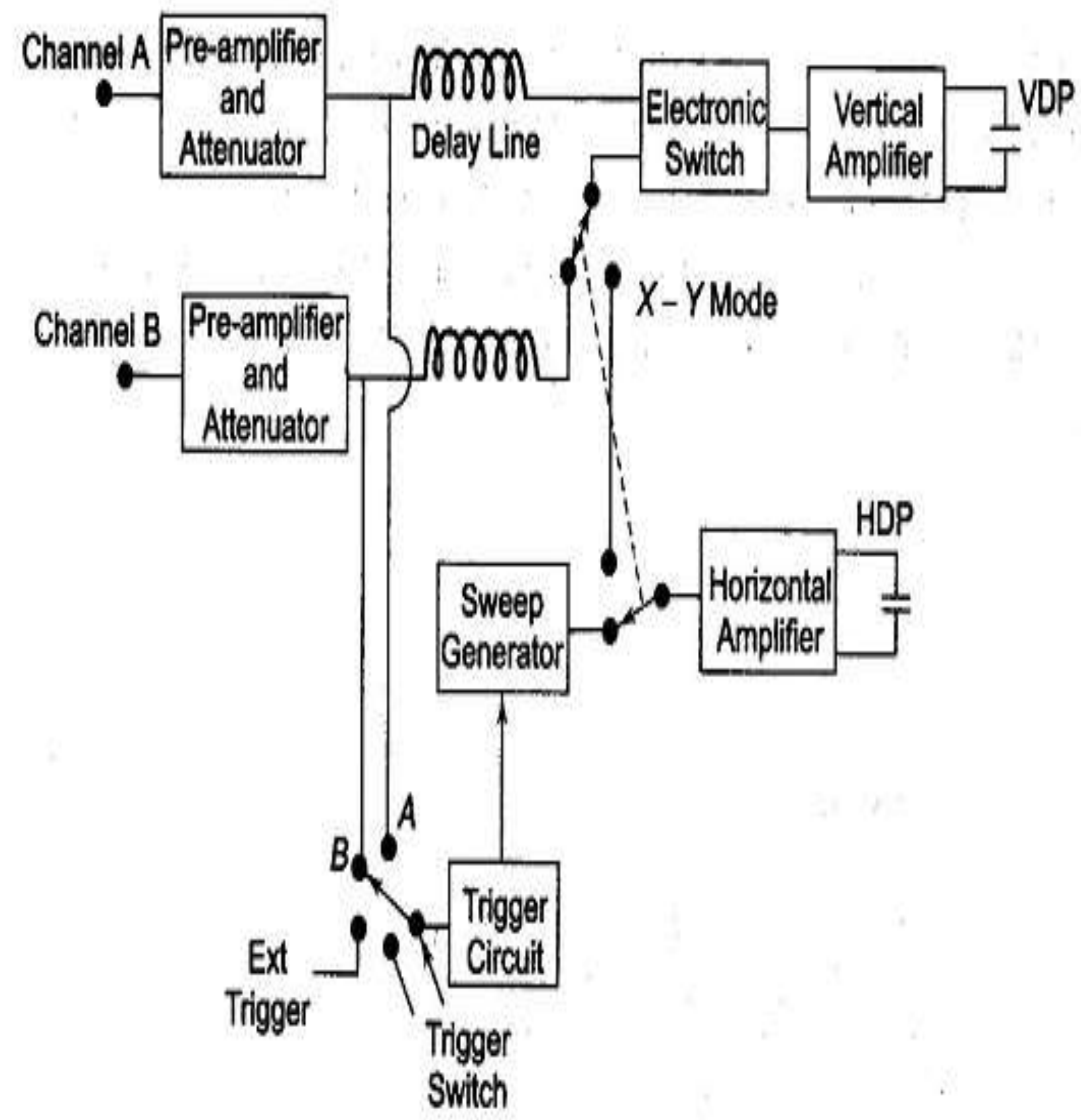


Fig. 7.19 (a) Dual Trace Oscilloscope

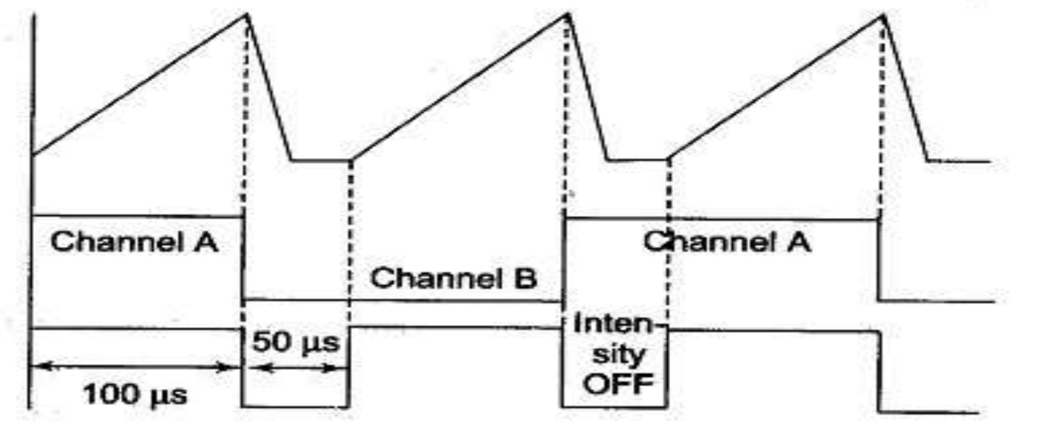


Fig. 7.19 (b) Time Relation of a Dual-Channel Vertical Amplifier in Alternate Mode

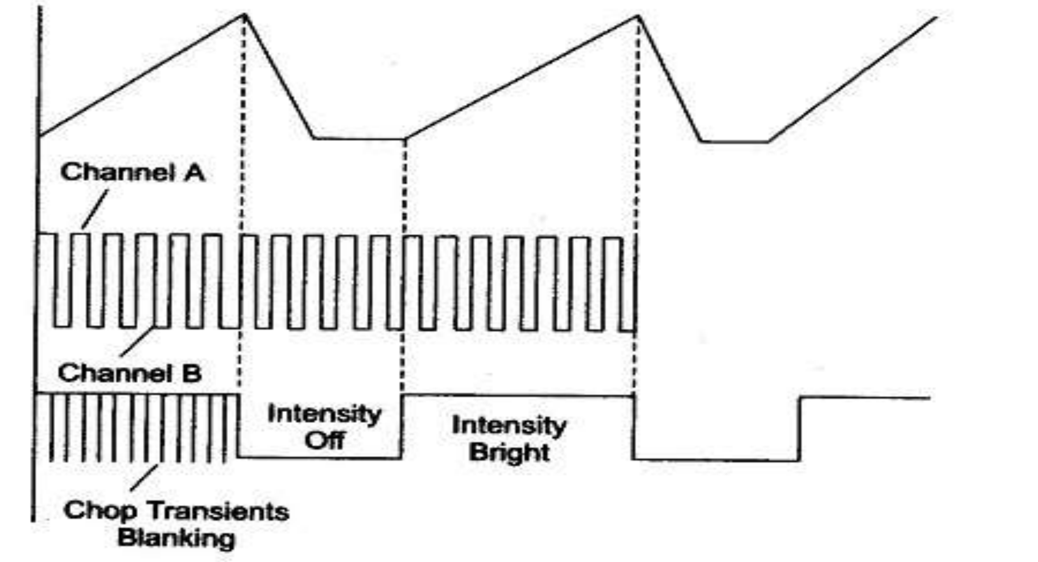


Fig. 7.19 (c) Time Relation of a Dual-Channel Vertical Amplifier in Chop Mode

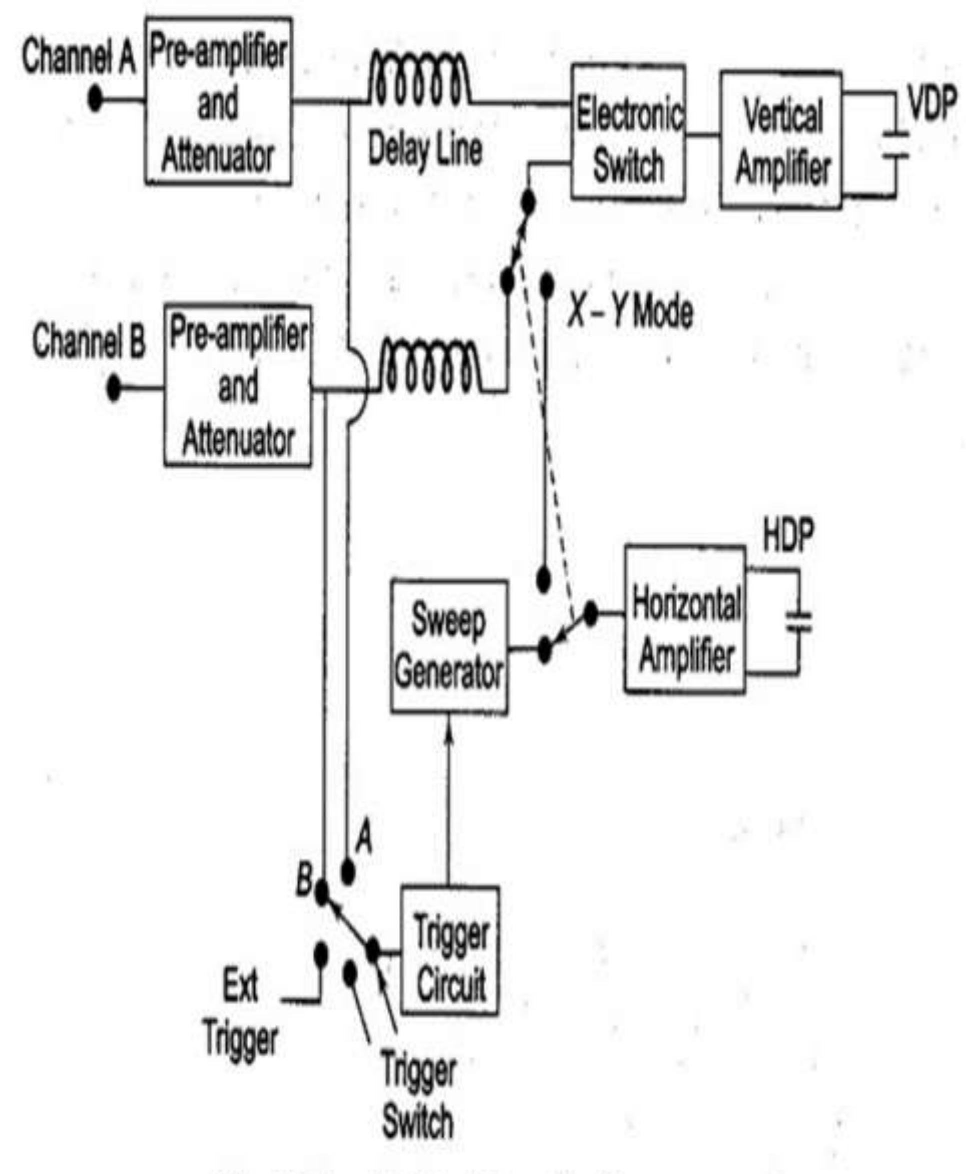
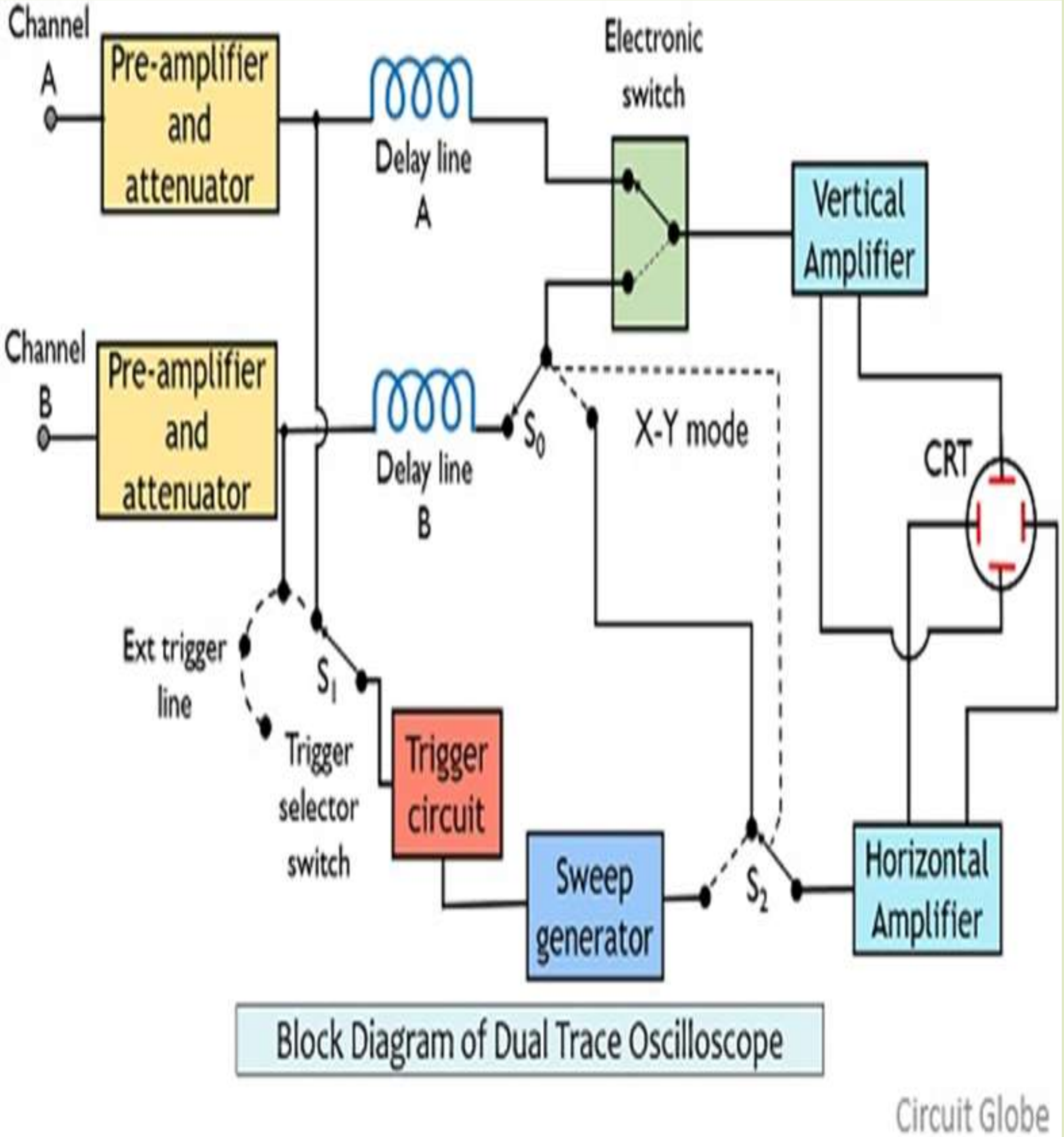
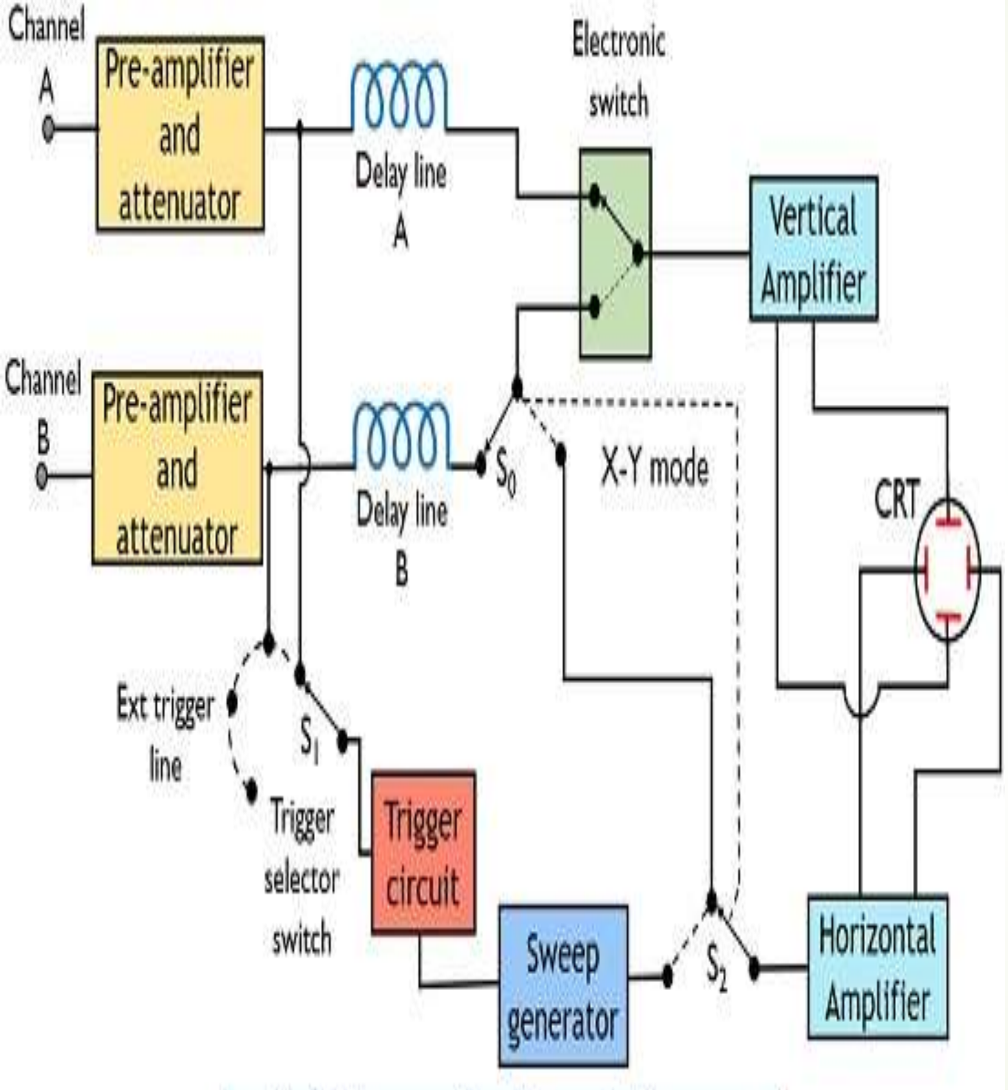


Fig. 7.19 (a) Dual Trace Oscilloscope

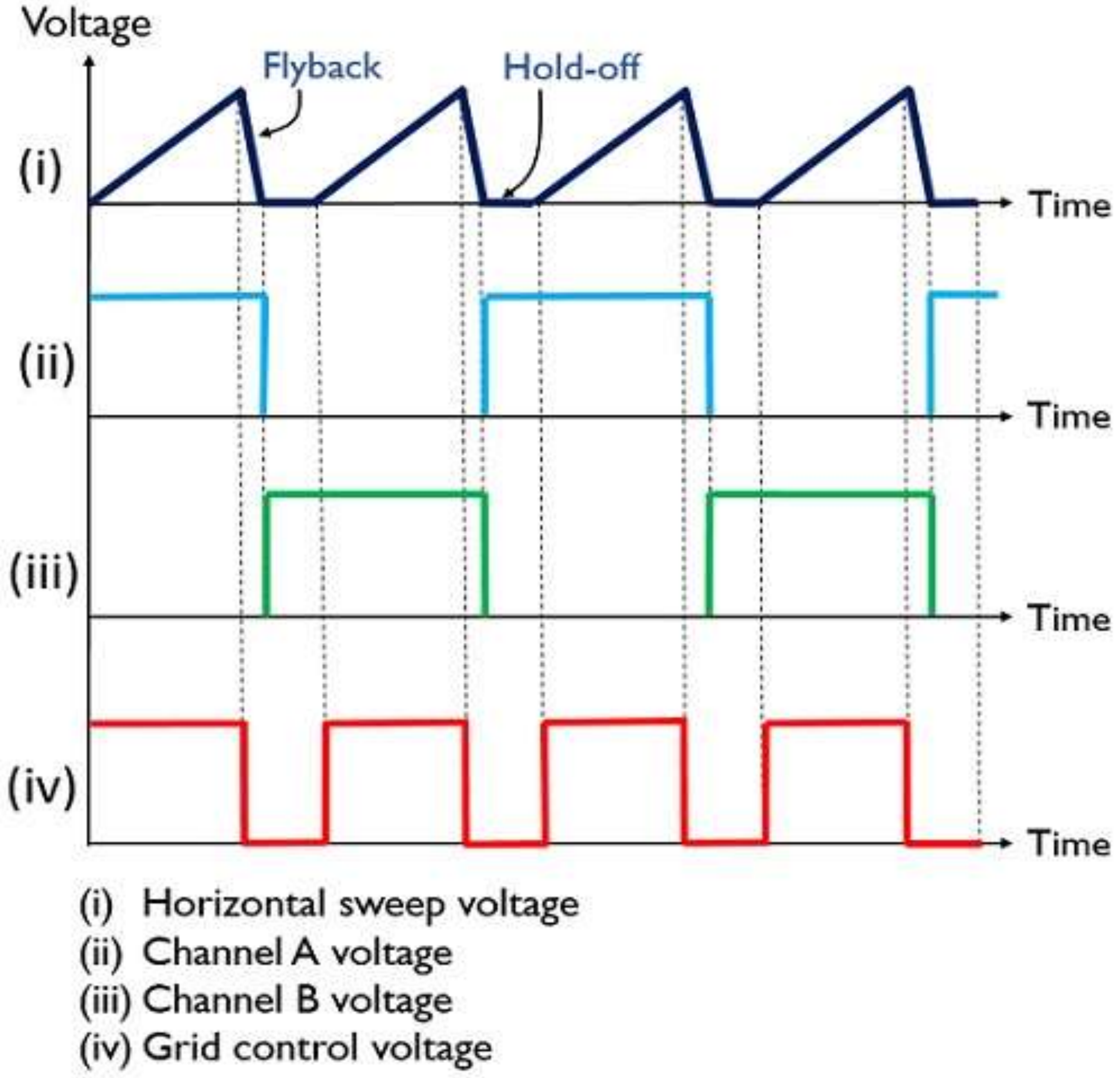


Block Diagram of Dual Trace Oscilloscope

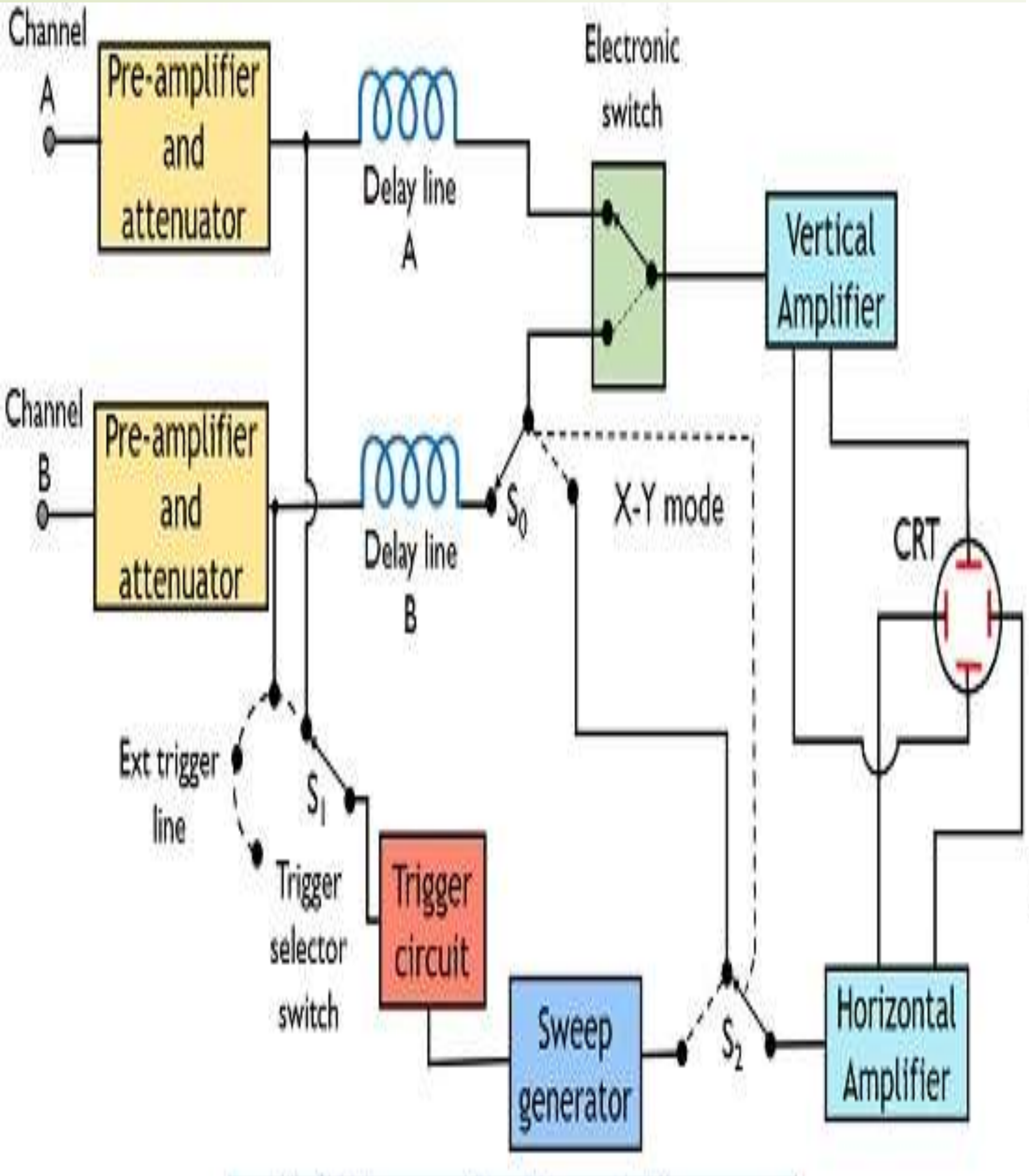
Dual Trace Oscilloscope:-



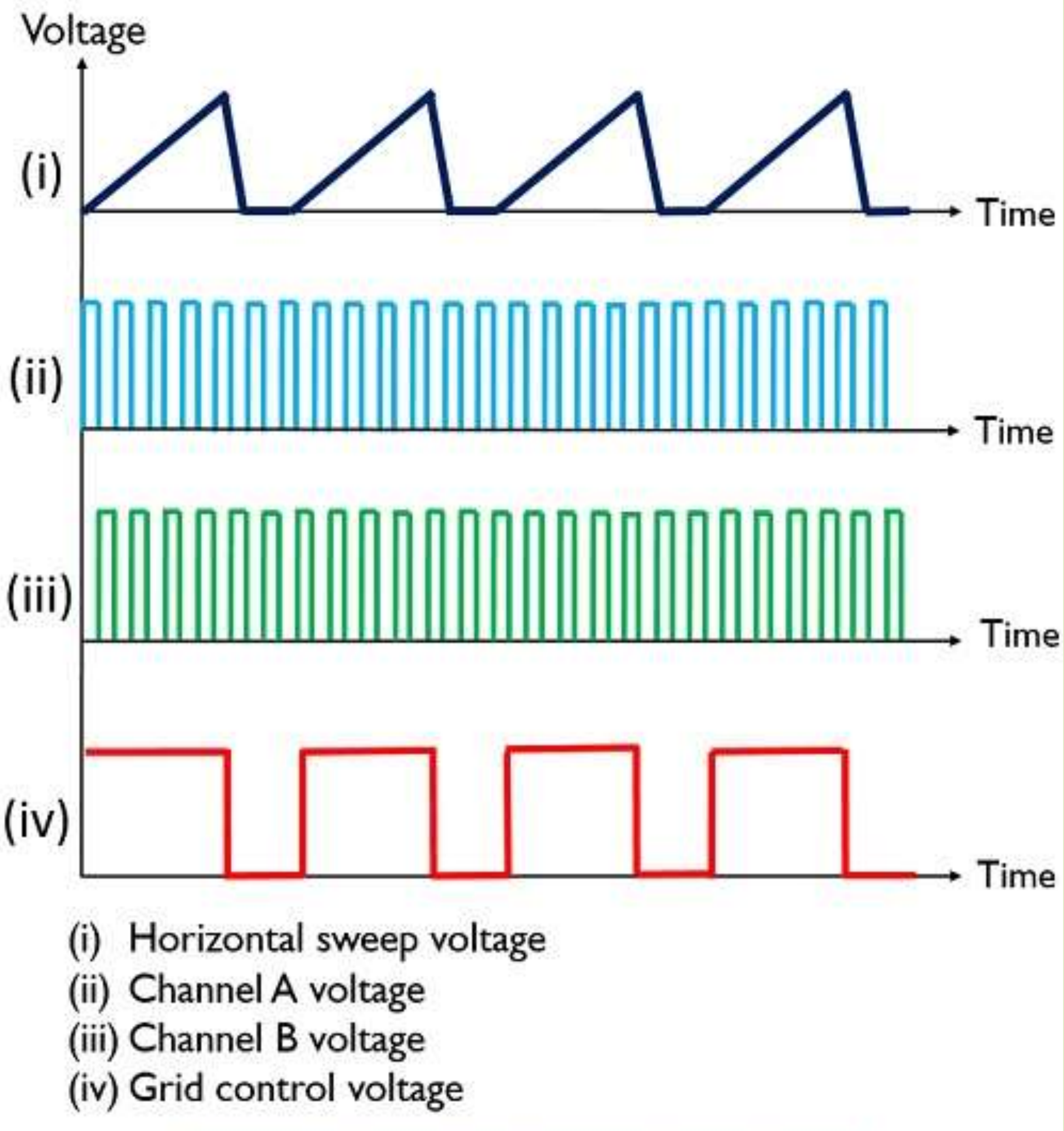
Block Diagram of Dual Trace Oscilloscope



Waveform for Alternate Mode



Block Diagram of Dual Trace Oscilloscope



Waveform for Chopped Mode

- This CRO has a single electron gun whose electron beam is split into two by an electronic switch.

- There is one control for focus and another for intensity. Two signals are displayed simultaneously. The signals pass through identical vertical channels or vertical amplifiers.

- Each channel has its own calibrated input attenuator and i positioning control, so that the amplitude of each signal can be independently adjusted.

- A mode control switch enables the electronic switch to operate in two modes. When the switch is in ALTERNATE position, the electronic switch feeds each signal alternately to the vertical amplifier.

- The electronic switch alternately connects the main vertical amplifier to channels A and **B** and adds a different dc component to each signal; this dc component directs the beam alternately to the upper or lower half of the screen.

- The switching takes place at the start of each new sweep of the sweep generator. The switching rate of the electronic switch is synchronized to the sweep rate, so that the CRT spot traces the channel A signal on one sweep and the channel B signal on the succeeding sweep [Fig. 7.19 (b)]

- The sweep trigger signal is available from channels A or B and the trigger pick-off takes place before the electronic switch. This arrangement maintains the correct phase relationship between signals A and B.
- When the switch is in the CHOP mode position, the electronic switch is free running at the rate of 100-500 kHz, entirely independent of the frequency of the sweep generator.
- The switch successively connects small segments of A and B waveforms to the main vertical amplifier at a relatively fast chopping rate of 500 kHz e.g. $1\mu s$ its segments of each waveform are fed to the CRT display (Fig. 7.19 (c)).
- If the chopping rate is slow, the continuity of the display is lost and it is better to use the alternate mode of operation.
- In the added mode of operation a single image can be displayed by the addition of signal from channels A and B, i.e. (A + B), etc. In the X — Y mode of operation, the sweep generator is disconnected and channel B is connected to the horizontal amplifier.
- Since both preamplifiers are identical and have the same delay time, accurate X — Y measurements can be made.

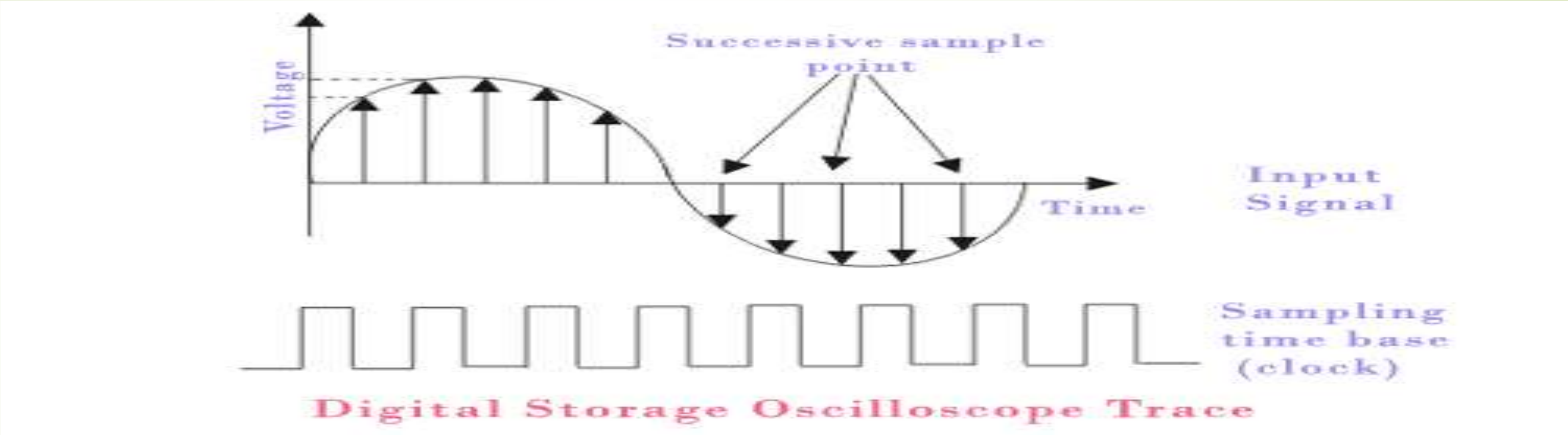
Digital Oscilloscope Technology

First the waveforms are conditioned by some analogue circuits then enter in the second stage which involves receiving the digital signals.

To do so, samples have to pass through analogue to digital converter and output signals get recorded in digital memory at different interval of time. These recorded points together make a waveform.

The set of points in a waveform show its length. The rate of samples defines the design of the oscilloscope.

The recorded traces are then processed by the processing circuit and obtained traces are ready to display for visual assessment.



Uses of Digital Storage Oscilloscope

- used for testing signal voltage in circuit debugging.
- Testing in manufacturing.
- Designing.
- Testing of signals voltage in radio broadcasting equipment.
- In the field of research.
- Audio and video recording equipment.

Dual Trace Oscilloscope Specifications:-

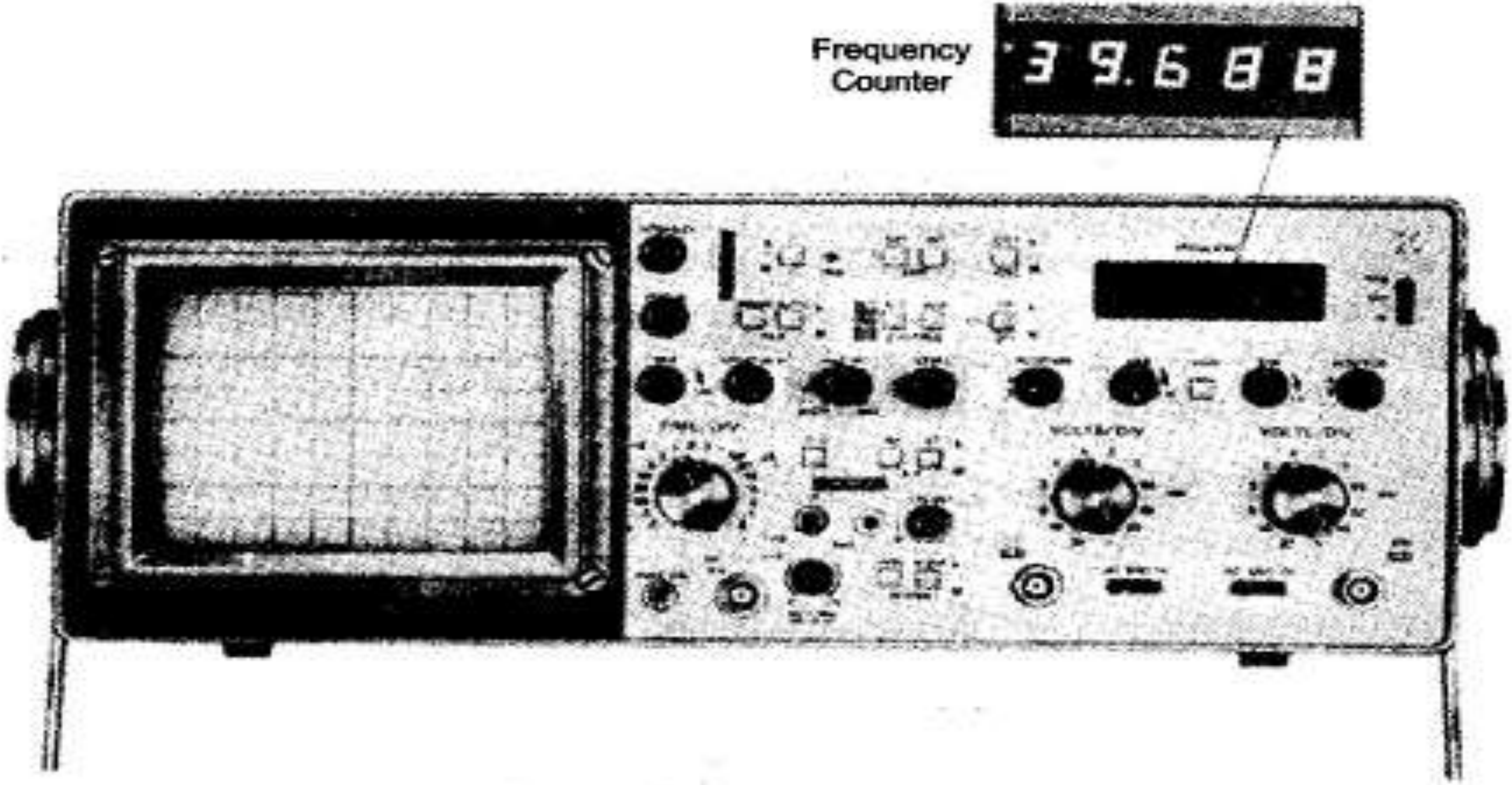


Fig. 7.21 30 MHz Dual Trace Oscilloscope with Delayed Sweep and Frequency Counter (Courtesy: International Electronics Ltd., Bombay; Marketed by: Signetics Electronics Ltd.)

Maximum sensitivity	:	5 mV/div and B.W. 15 MHz
Operating temperature	:	+ 5° to 40°C
CRT	:	
Measuring area	:	8 × 10 Div (1 cm = 1 Div)
Screen type	:	B31 or 3B1
Total acceleration voltage	:	2kV
Vertical Amplifier	:	
Display modes	:	A, A and B, B (chopped in ms) (alternated in μs)
Input coupling	:	AC/DC
		Bandwidth DC – 0 – 15 MHz (– 3db)
		AC – 10 Hz – 15 MHz (– 3db)
Deflection accuracy	:	± 5%
Input impedance	:	1 MΩ/35 pF
Maximum rated input voltage	:	400 V (dc + ac peak) (no damage)
Chopper frequency	:	120 kHz approximately
Time Base		
Time coefficients	:	0.2 s/Div to 0.5 s/Div in 2 × 9
	:	calibrated steps (1-2-5 sequence) with
	:	5 × magnifier, max. 0.1 μs/Div
	:	Uncalibrated continuous control
		1 : ≥ 2, 5
Coefficient error	:	± 5%
Additional error for × 5 magnifier	:	± 2%
Trigger		
Source	:	CH A, B or Ext
Mode	:	AC/TV
Sensitivity Int	:	0.75 Div/0.75 V – Trigger freq. at 100 kHz.
Ext	:	1 Div/1.0 V – Trigger freq. at 15 MHz.
Trigger frequency	:	10 Hz – 15 MHz
Input impedance	:	1 MΩ/35 pF
Z-Modulation input trace blanking	:	TTL high blanks trace
Power Supply		
Voltage range	:	220 V ± 10%
Frequency	:	50 Hz
Power	:	30 VA
Size	:	378 (L) × 348 (W) × 142 (H)
Weight	:	5 kg Approx.
X-Deflection		
Phase shift	:	3 at 10 kHz
Accuracy	:	± 5%
μs/ms	:	Slide switch in combination with time base
	:	The display is chopped in ms and Alternated in μs

Sampling Oscilloscope Block Diagram:-

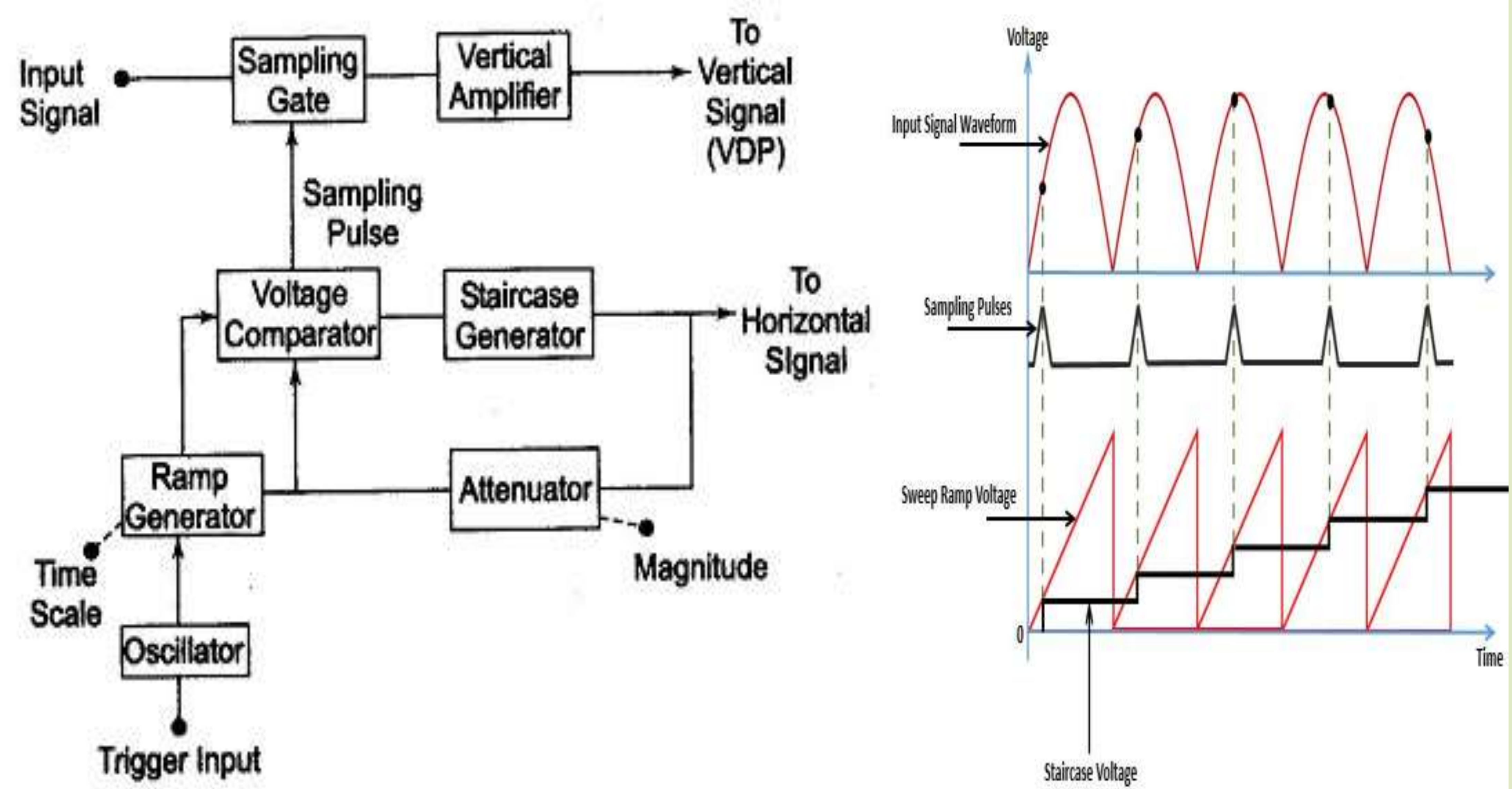
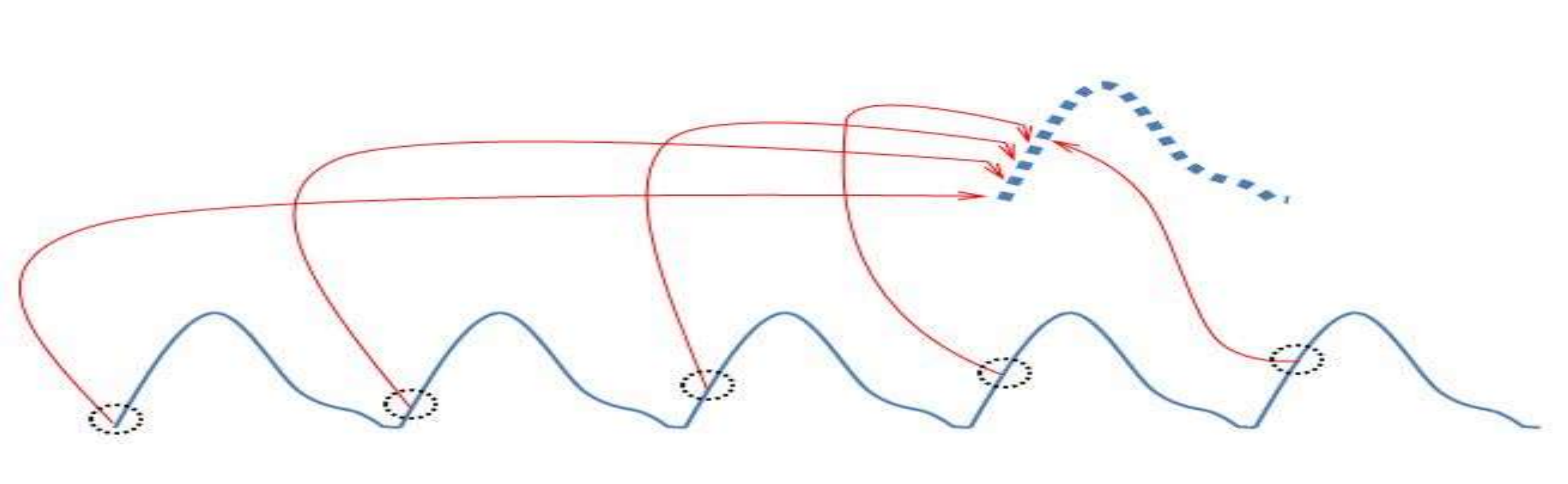


Fig. 7.24 Sampling Oscilloscope

The general cathode ray oscilloscope generally does not have a very wide bandwidth of operation. Hence, the direct tracing of waveforms for a very high-frequency signal may not be possible. Since the brightness and sharpness of the output image on the screen decrease at a very high frequency of operation. So, we require some different technique for the proper tracing of an ultra high-frequency signal. Hence, the sampling technique comes into the picture. And, the **sampling oscilloscope** is a device which applies the sampling technique to trace the waveform.

Sampling Technique of Tracing

In the sampling technique, a large number of dots assemble a complete waveform. Each of the dots comes from one successive cycle of the wave one by one. In other words, one drop comes from one small portion of a cycle of the wave. Then the next successive dot comes from next small portion of the next successive cycle of the wave.



- An ordinary Sampling Oscilloscope has a B.W. of 10 MHz. The HF performance can be improved by means of sampling the input waveform and reconstructing its shape from the sample, i.e. the signal to be observed is sampled and after a few cycles the sampling point is advanced and another sample is taken.

- The shape of the waveform is reconstructed by joining the sample levels together. The sampling frequency may be as low as 1/10th of the input signal frequency (if the input signal frequency is 100 MHz, the bandwidth of the CRO vertical amplifier can be as low as 10 MHz). As many as 1000 samples are used to reconstruct the original waveform. Figure 7.24 shows a Sampling Oscilloscope Block Diagram.

- The input waveform is applied to the sampling gate of the Sampling Oscilloscope Block Diagram. The input 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 amplifier, allowing the horizontal sweep to be initiated by the input signal. The waveforms are shown in Fig. 7.25.

- At the beginning of each sampling cycle, the trigger pulse activates an oscillator and a linear ramp voltage is generated. This ramp voltage is applied to a voltage comparator which compares the ramp voltage to a staircase generator.

- When the two voltages are equal in amplitude, the staircase advances one step and a sampling pulse is generated, which opens the sampling gate for a sample of input voltage.

- The resolution of the final image depends upon the size of the steps of the staircase generator. The smaller the size of the steps the larger the number of samples and higher the resolution of the image.

Storage Oscilloscope(For VLF Signal):

- Storage Oscilloscope – 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.

- Two storage techniques are used in oscilloscope CRTs, mesh storage and phosphor storage.

- A mesh-Storage Oscilloscope uses a dielectric material deposited on a storage mesh as the storage target. This mesh is placed between the deflection plates and the standard phosphor target in the CRT.

- The writing beam, which is the focussed electron beam of the standard CRT, charges the dieletric material positively where hit.

- The storage target is then bombarded with low velocity electrons from a flood gun and the positively charged areas of the storage target allow these electrons to pass through to the standard phosphor target and thereby reproduce the stored image on the screen.

- Thus the mesh storage has both a storage target and a phosphor display target. The phosphor Storage Oscilloscope uses a thin layer of phosphor to serve both as the storage and the display element.

Mesh Storage

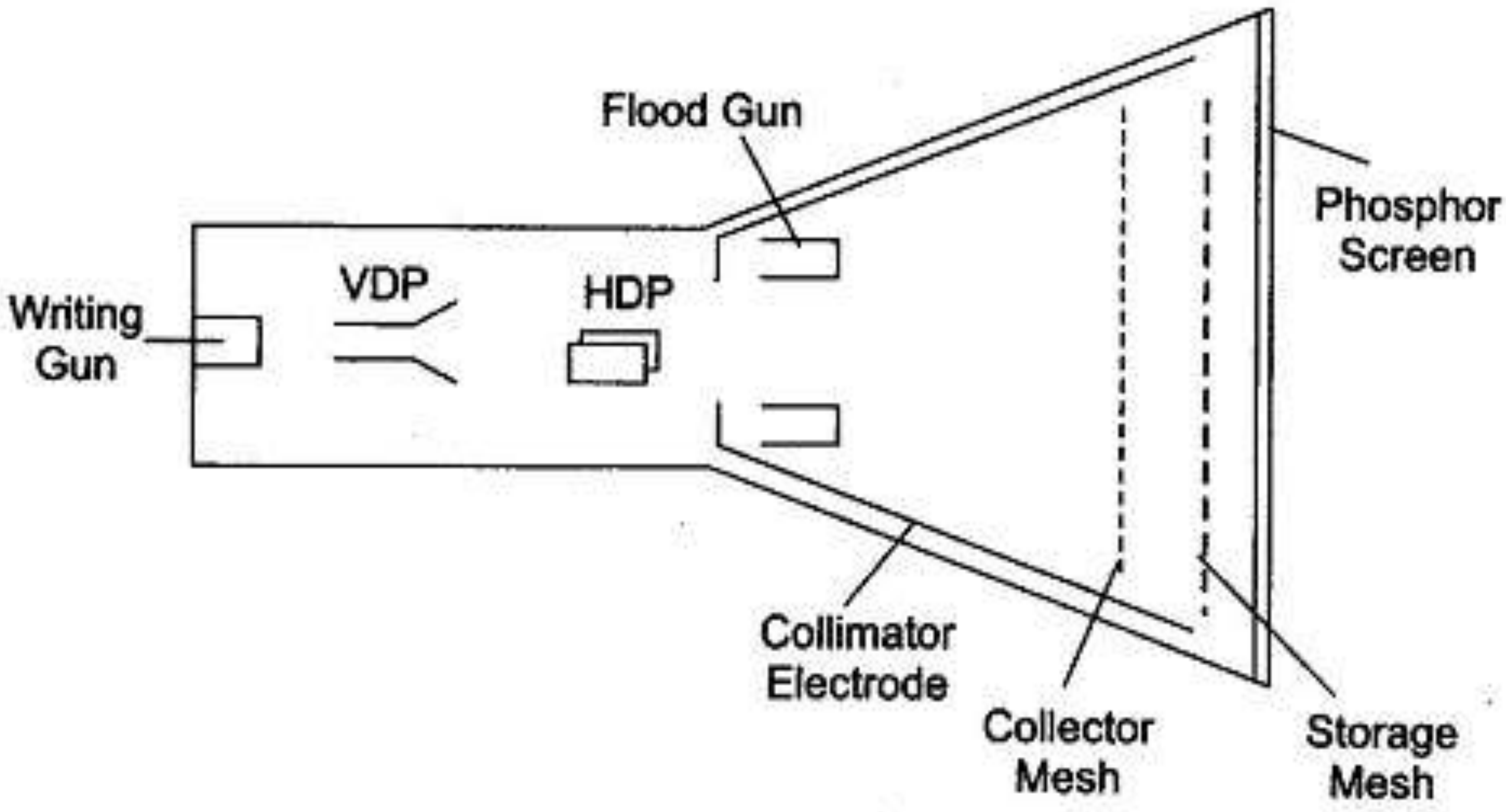


Fig. 7.26 Basic Elements of Storage Mesh CRT

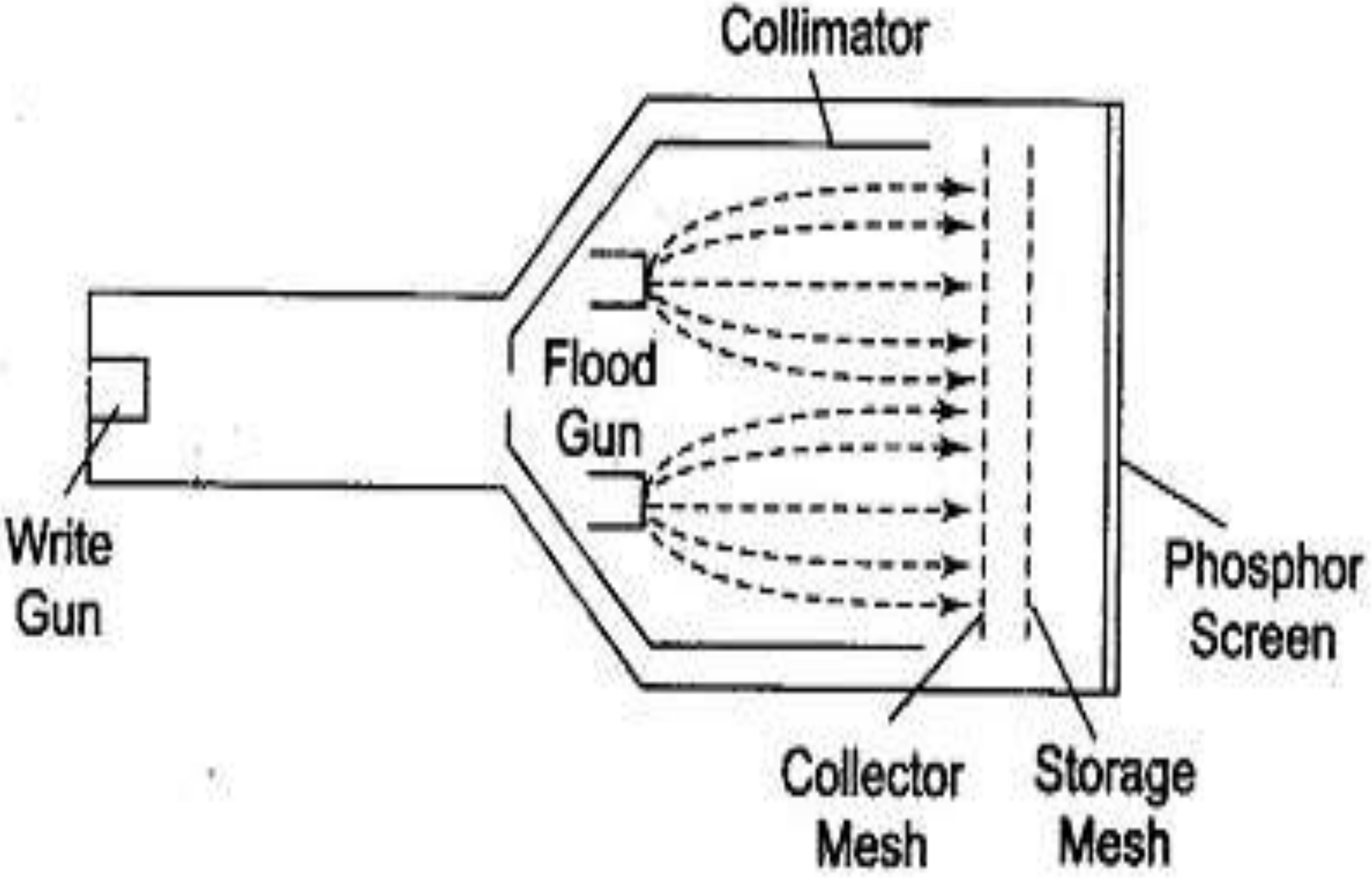


Fig. 7.27 Storage Mesh CRT

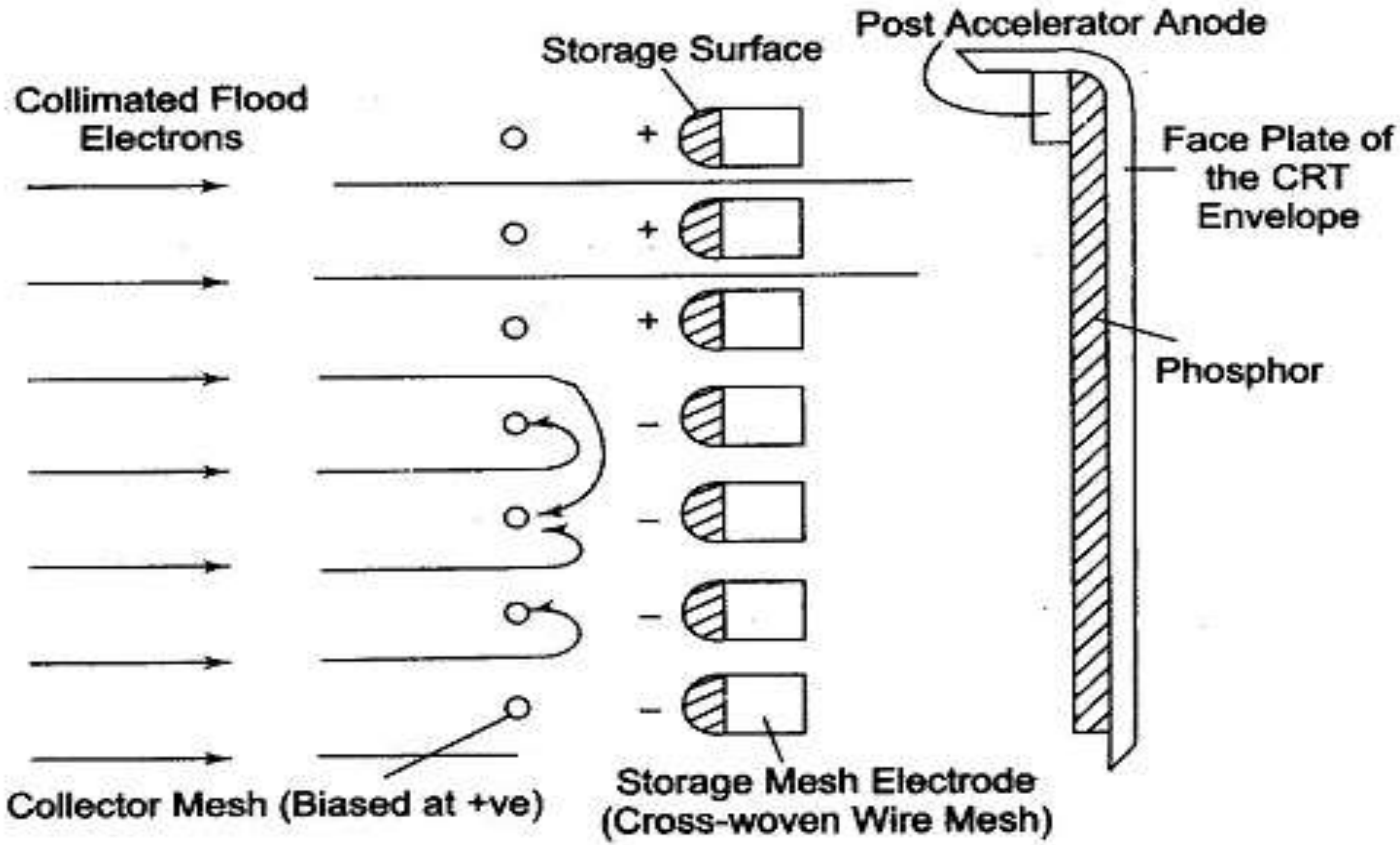


Fig. 7.28 Display of Stored Charged Pattern on a Mesh-storage

- It is used to display Very Low Frequencies (VLF) signals and finds many applications in mechanical and biomedical fields.

- The conventional scope has a display with a phosphor peristence ranging from a few micro seconds to a few seconds. The persistence can be increased to a few hours from a few seconds.
- A mesh Storage Oscilloscope, shown in Fig. 7.26, 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.

- The storage target, a thin deposition of a dielectric material such as Magnesium Fluoride on the storage mesh, makes use of a property known as secondary emission.

- The writing gun etches a positively charged pattern on the storage mesh or target by knocking off secondary emission electrons.

- Because of the excellent insulating property of the Magnesium Fluoride coating, this positively charged pattern remains exactly in the position where it is deposited.

- In order to make a pattern visible, a special electron gun, called the flood gun, is switched on (even after many hours).

- The electron paths are adjusted by the collimator electrode, which constitutes a low voltage electrostatic lens system (to focus the electron beam), as shown in Fig. 7.27.
- Most of the electrons are stopped and collected by the collector mesh. Only electrons near the stored positive charge are pulled to the storage target with sufficient force to hit the phosphor screen.
- The CRT will now display the signal and it will remain visible as long as the flood guns operate. To erase the pattern on the storage mesh, a negative voltage is applied to neutralise the stored positive charge.
- Since the storage mesh makes use of secondary emission, between the first and second crossover more electrons are emitted than are absorbed by the material, and hence a net positive charge results.
- Below the first crossover a net negative charge results, since the impinging electrons do not have sufficient energy to force an equal number to be emitted.
- In order to store a trace, assume that the storage surface is uniformly charged and write gun (beam emission gun) will hit the storage target. Those areas of the storage surface hit by the deflecting beam lose electrons, which are collected by the collector mesh.
- Hence, the write beam deflection pattern is traced on the storage surface as a positive charge pattern. Since the insulation of the dielectric material is high enough to prevent any loss of charge for a considerable length of time, the pattern is stored. To view, the stored trace, a flood gun is used when the write gun is turned off.

- The flood gun, biased very near the storage mesh potential, emits a flood of electrons which move towards the collector mesh, since it is biased slightly more positive than the deflection region.
- The collimator, a conductive coating on the CRT envelope with an applied potential, helps to align the flood electrons so that they approach the storage target perpendicularly.
- When the electrons penetrate beyond the collector mesh, they encounter either a positively charged region on the storage surface or a negatively charged region where no trace has been stored.
- The positively charged areas allow the electrons to pass through to the post accelerator region and the display target phosphor.
- The negatively charged region repels the flood electrons back to the collector mesh.
- Thus the charge pattern on the storage surface appears reproduced on the CRT display phosphor just as though it were being traced with a deflected beam.

Advantages of sampling oscilloscope:-

•It is advantageous using a sampling oscilloscope, as it can measure high-speed electrical signals.

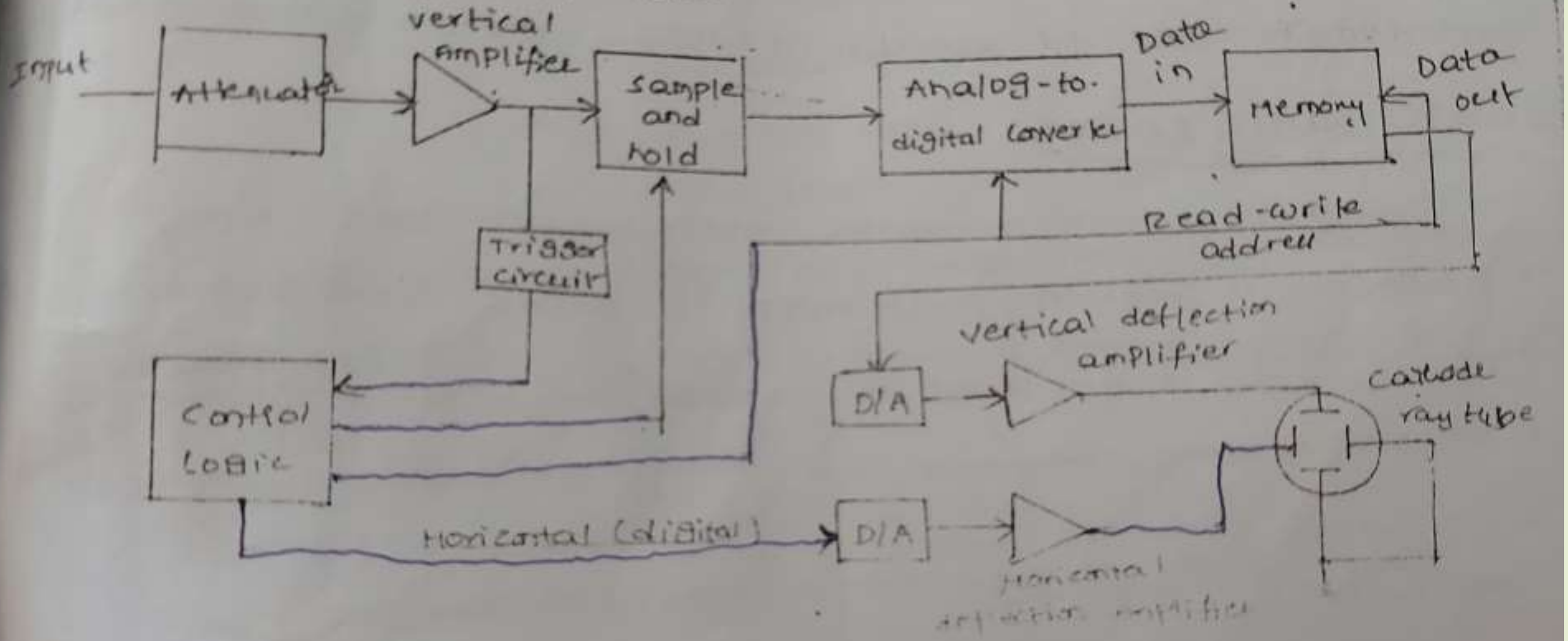
•By using sampling techniques, the input signal can be instantly transformed into a signal in a low-frequency domain. Further circuitry produces a highly efficient display.

•It has the ability to react and store information in the form of rapid bits.

Disadvantage of sampling oscilloscope:-

•Sampling oscilloscope allows the measurement to be done on signals having repetitive waveforms.

indefinitely as long as power is supplied to memory. once the waveform is digitised then it can be further loaded into the computer and can be analysed in detail.



8

Frequency Measurement by Lissajous Method:-

- The oscilloscope is a sensitive indicator for frequency and phase measurements.
- This Frequency Measurement by Lissajous Method techniques used are simple and dependable, and measurement may be made at any frequency in the response range of the oscilloscope.
- One of the quickest methods of determining frequency is by using Lissajous patterns produced on a screen. This particular pattern results when sine waves are applied simultaneously to both pairs of the deflection plates.
- If one frequency is an integral multiple (harmonic) of the other, the pattern will be stationary, and is called a Lissajous figure.
- In this Frequency Measurement by Lissajous Method a standard frequency is applied to one set of deflection plates of the CRT tube while the unknown frequency (of approximately the same amplitude) is simultaneously applied to the other set of plates.
- However, the unknown frequency is presented to the vertical plates and the known frequency (standard) to the horizontal plates.
- The resulting patterns depend on the integral and phase relationship between the two frequencies. (The horizontal signal is designated as f_h and the vertical signal as f_v)

Measurement Procedure

:

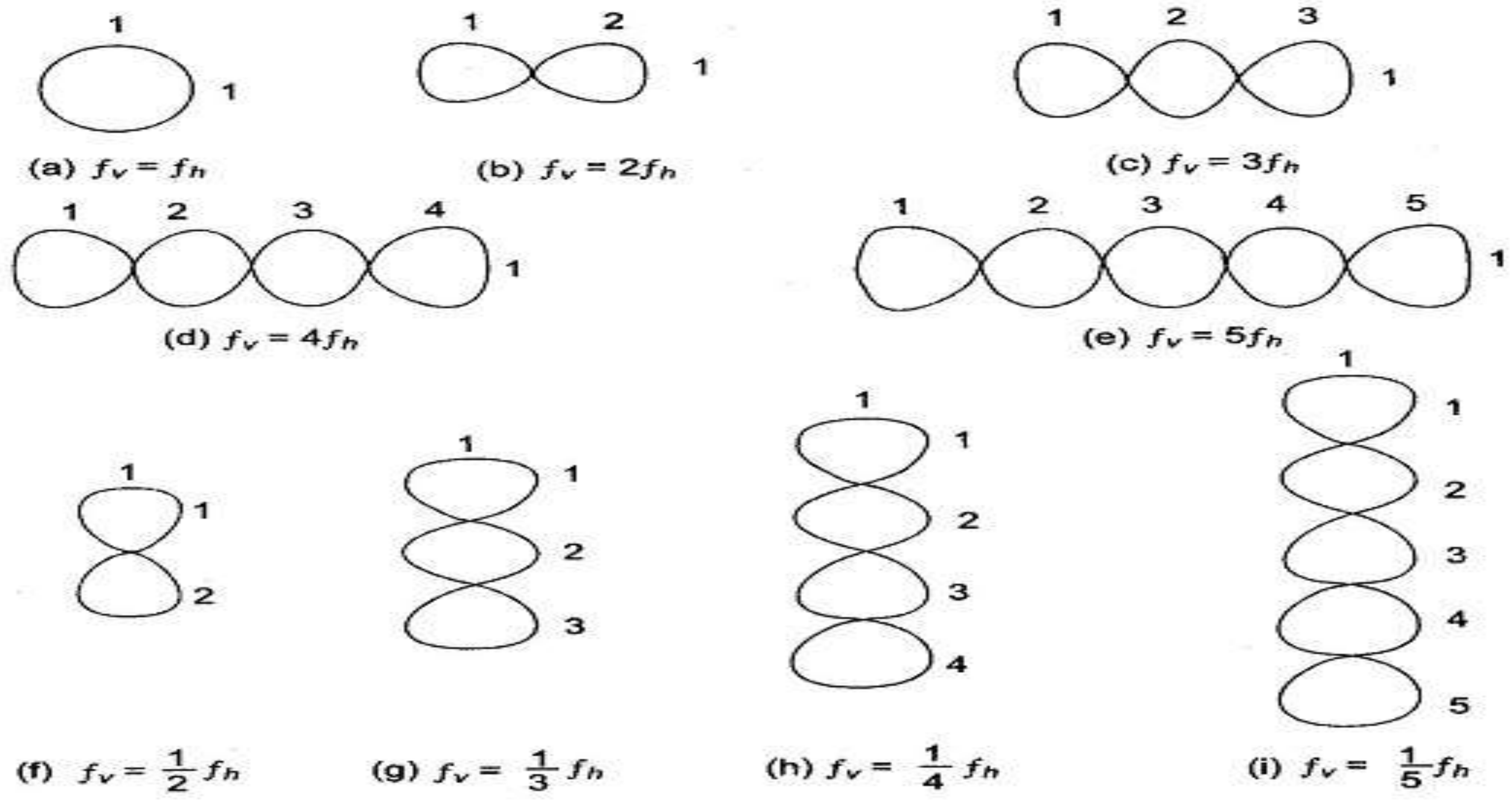


Fig. 7.31 Lissajous Patterns for Integral Frequencies

- Set up the oscilloscope and switch off the internal sweep (change to Ext). Switch off sync control. Connect the signal source as given in Fig. 7.33.

- Set the horizontal and vertical gain control for the desired width and height of the pattern.

- Keep frequency f_v constant and vary frequency f_h, noting that the pattern spins in alternate directions and changes shape.

- The pattern stands still whenever f_v and f_h are in an integral ratio (either even or odd). The $f_v = f_h$ pattern stands still and is a single circle or ellipse. When $f_v = 2\ f_h$, a two loop horizontal pattern is obtained as shown in Fig. 7.31.

- To determine the frequency from any Lissajous figure, count the number of horizontal loops in the pattern, divide it by the number of vertical loops and multiply this quantity by f_h (known or standard frequency).in Fig. 7.31 (g), there is one .

- An accurately calibrated, variable frequency oscillator will supply the horizontal search frequency for Frequency Measurement.

- For the case where the two frequencies are equal and in phase, the pattern appears as a straight line at an angle of 45° with the horizontal.

- As the phase between the two alternating signals changes, the pattern changes cyclically, i.e. an ellipse (at 45° with the horizontal) when the phase difference is π/4, a circle when the phase difference is π/2 and an ellipse (at 135° with horizontal) when the phase difference is 3π/4, and a straight line pattern (at 135° with the horizontal) when the phase difference is π radians.

- As the phase angle between the two signals changes from π to 2π radians, the pattern changes correspondingly through the ellipse-circle-ellipse cycle to a straight line.

- Hence the two frequencies, as well as the phase displacement can be compared using Lissajous figures techniques.

- When the two frequencies being compared are not equal, but are fractionally related, a more complex stationary pattern results, whose form is dependent on the frequency ratio and the relative phase between the two signals, as in Fig. 7.32.

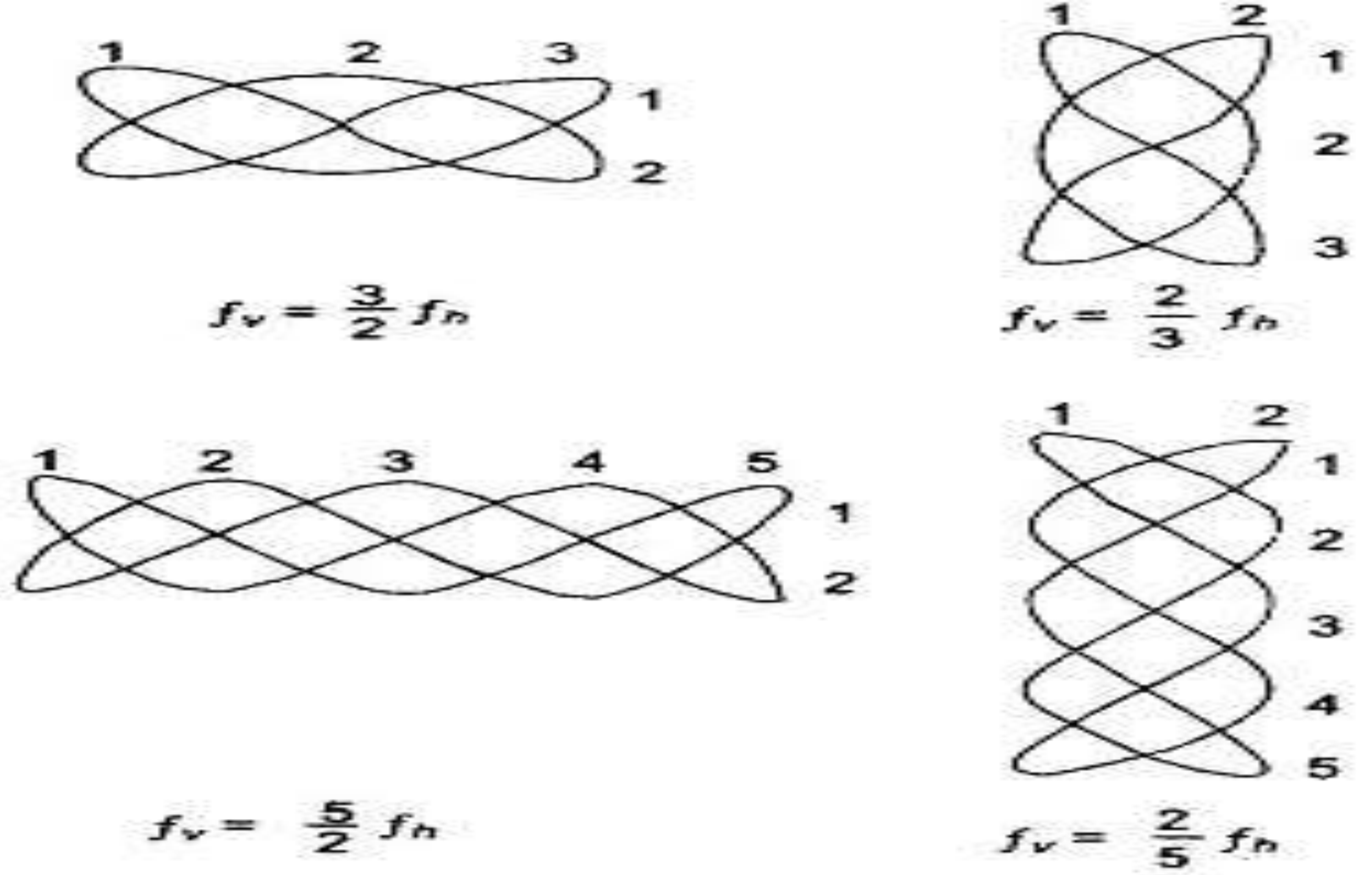


Fig. 7.32 Lissajous Patterns for Non-Integral Frequencies

- The fractional relationship between the two frequencies is determined by counting the number of cycles in the vertical and horizontal.
-

$$f_v = (\text{fraction}) \times f_h$$

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

Figure 7.33 illustrates the basic circuit for comparing two frequencies by the Lissajous method.

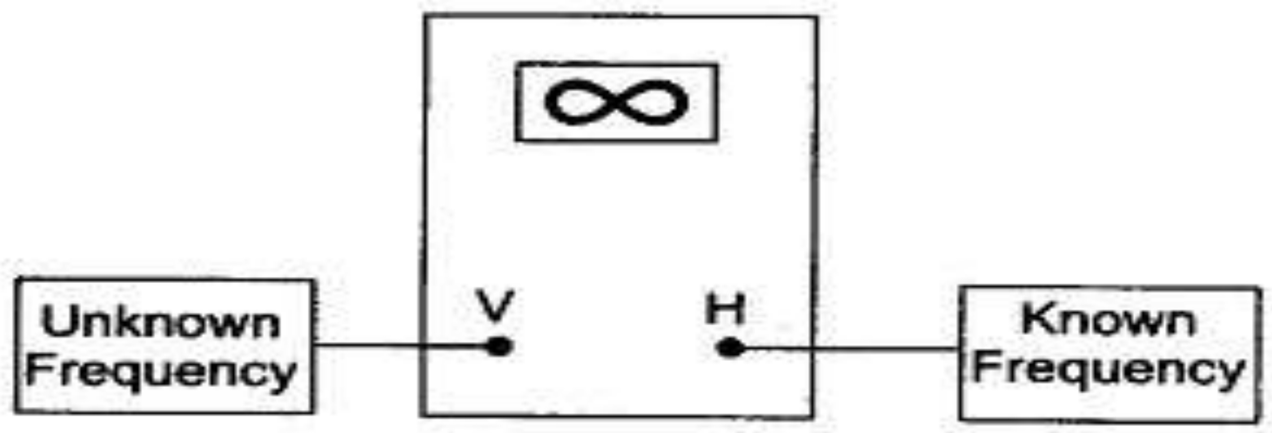


Fig. 7.33 Basic Circuit for Frequency Measurements with Lissajous Figures