UNIT II

OSCILLOSCOPES

Introduction:

In studying the various electronic, electrical networks and systems, signals which are functions of time, are often encountered. Such signals may be periodic or non periodic in nature. The device which allows, the amplitude of such signals, to be displayed primarily as " function of time, is called **cathode ray** oscilloscope, commonly known as C.R.O. The CR.O gives the visual representation of the time varying signals. The oscilloscope has become an universal instrument and is probably most versatile tool for the development of electronic circuits and systems. It is an integral part of electronic laboratories.

The oscilloscope is, in fact, a voltmeter. Instead of the mechanical deflection of a metallic pointer as used in the normal voltmeters, the oscilloscope uses the movement of an electron beam against a fluorescent screen, which produces the movement of a visible spot. The movement of such spot on the screen is proportional to the varying magnitude of the signal, which is under measurement.

Basic Principle:

As shown in the Fig. , the electron beam passes through these plates. A positive voltage applied to the Y input terminal (Vy) Causes the beam to deflect vertically upward due to the attraction forces, while a negative voltage applied to. the Y input terminal will cause the electron beam to deflect vertically downward, due to the repulsion forces. When the voltages are applied simultaneously to vertical and horizontcl1 deflecting plates, the electron beam is deflected due to The momentum of the electrons (their number x their speed) determines the intensity, or brightness, of the light emitted from the fluorescent screen due to the electron bombclrdl1lent. The light emitted is usually of the green colour. Because the electrons are negatively charged, a repulsive force is created by applying a negative voltage to the control grid (in CRT, voltages applied to various grids are stated with respect to cathode, which is taken as common point). This negative control voltage can be made variable.
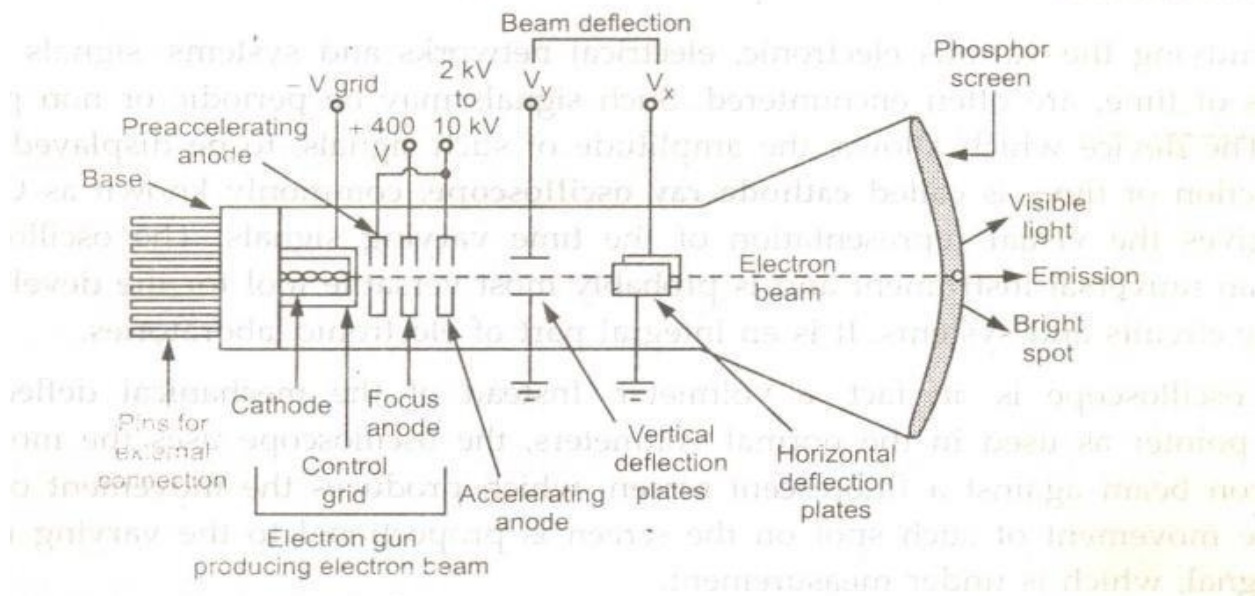
Electron Gun:

      The electron gun section of the cathode ray tube provides a sharply focused electron beam directed :towards the fluorescent-coated screen. This section starts from theql1ally heated cathode, limiting the electrons. The control grid is give!! negative potential with respect to cathode dc. This grid controls the number of electrons in the beam, going to the screen.

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Deflection System:

      When the electron beam is accelerated it passes through the deflection system, with which beam can be positioned anywhere on the screen. The deflection system of the cathode-ray-tube consists of two pairs of parallel plates, referred to as the vertical and horizontal deflection plates. One of the plates' in each set is connected to ground (0 V), To the other plate of each set, the

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external deflection voltage is applied through an internal adjustable gain amplifier stage, To apply the deflection voltage externally, an external terminal, called the Y input or the X input, is available.

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Fluorescent Screen:

The light produced by the screen does not disappear immediately when bombardment by electrons ceases, i.e., when the signal becomes zero. The time period for which the trace remains on the screen after the signal becomes zero is known as "persistence". The persistence may be *jS*short as a few microsecond, or as long as tens of seconds ~enminutes.

Long persistence traces are used in the study..of transients. Long persistence helps in the study of transients since the trace is still seen on the screen after the transient has disappeared.

Phosphor screen characteristics:

Many phosphor materials having different excitation times and colours as well as different phosphorescence times are available. The type PI, P2, PI1 or P3I are the short persistence phosphors and are used for the general purpose oscilloscope

Medical oscilloscopes require a longer phosphor decay and hence phosphors like P7 and P39 are preferred for such applications. Very slow displays like radar require long persistence phosphors to maintain sufficient flicker free picture. Such phosphors are P19, P26 and, P33.

The phosphors P19, P26, P33 have low burn resistance. The phosphors PI, P2, P4, P7, Pll have medium burn resistance while PIS, P3I have high burn resistance.

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Block diagram of simple oscilloscope:
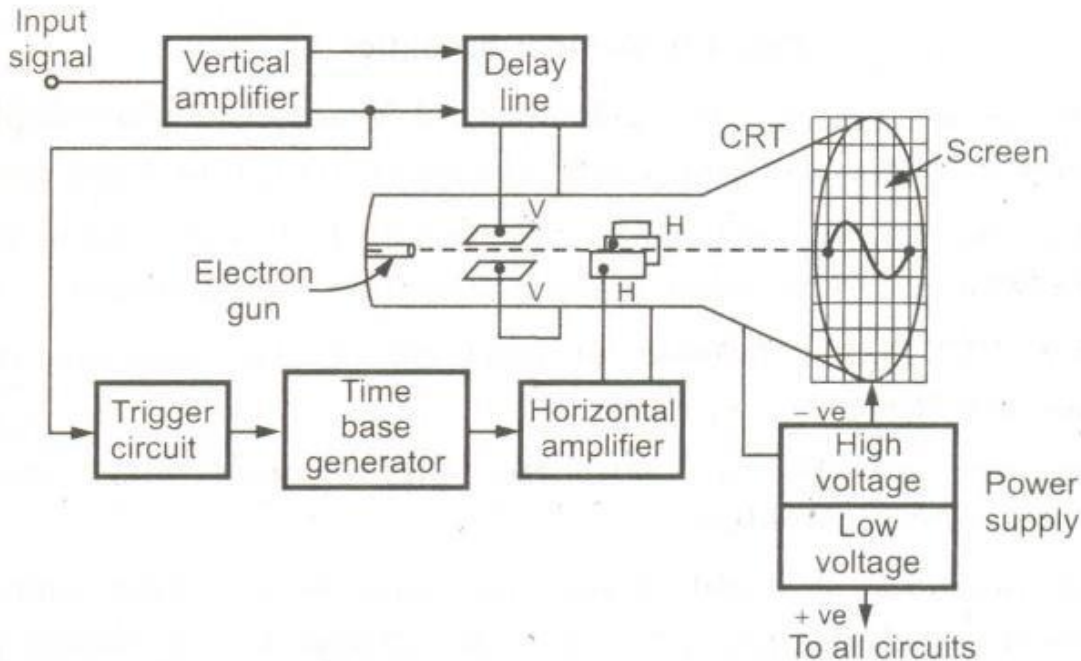

CRT:

      This is the cathode ray tube which is the heart of CR.O. It is' used to emit the rlectrons required to strike the phosphor screen to produce the spot for the visual display of the signals.

Vertical Amplifier:

      The input signals are generally not strong to provide the measurable deflection on the screen. Hence the vertical amplifier.stage is used Jo amplify the input signals. The amplifier stages used are generally wide band amplifiers so as to pass faithfully the entire band of frequencies to be measured. Similarly it contains the attenuator stages as well. The attenuators are used when very high voltage signals are to be examined, to bring the signals within the proper range of operation.

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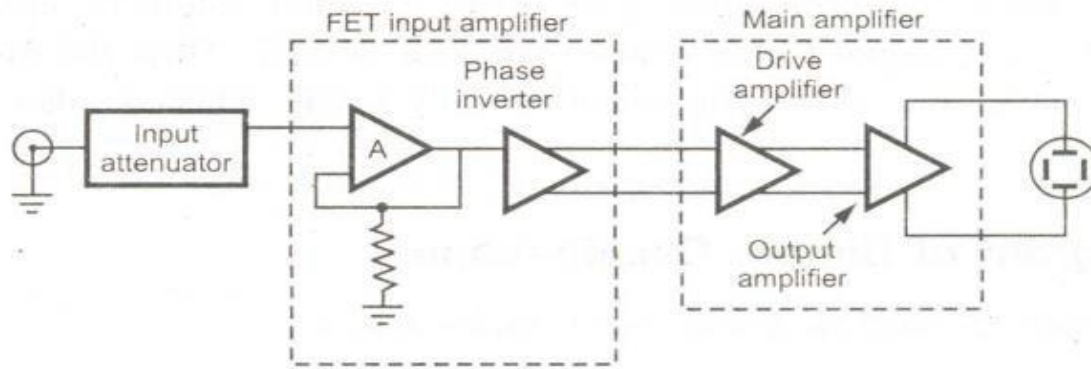
It consists of several stages with overall fixed sensltivity. The amplifier can be designed for stability and required bandwidth very easily due to the fixed gain. The input stage colrtsists of an attenuator followed by FET source follower. It has vel' high input impedance required to isolate the amplifier from the attenuator. It is followed by BJT emitter follower to match the output impedance of FET output With input of phase inverter. The phase inverter provides two antiphase output signals which are required to operate the push pull output amplifier. The push pull operation has advantages like better hum voltage cancellation, even harmonic suppression especially large 2nd harmonic, greater power output per tube and reduced number of defocusing and nonlinear effects.

Delay line:

The delay line is used to delay the signal for some time in the verticClI sections. When the delay line is not used, the part of the signal gets lost. Thus the input signal is not applied directly to the vertical plates but is delClyedbv some time using a delay line cu-cuit as shown in the Fig.
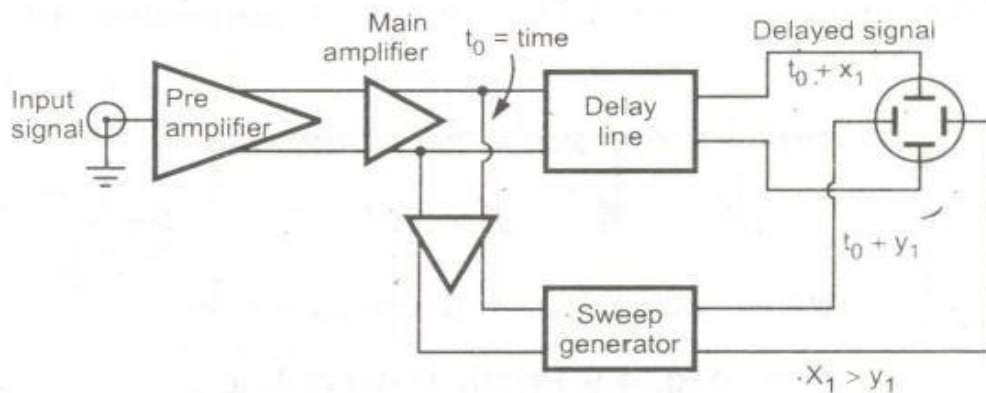
If the trigger pulse is picked off at a time t = to after the signal has passed through the main amplifier then signal is delayed by XI nanoseconds while sweep takes YI nanoseconds to reach. The design of delay line is such that the delay time XI is higher than the time YI' Generally XI is

200. nsec while tl;1.eYI is 80 ns, thus the sweep starts well in time and no part of the signal is lost. There are two types of delay lines used in CR.O. which are:

i) Lumped parameter delayline

ii) Distributed parameter delayline

Trigger circuit:

It is necessary that horizontal deflection starts at the same point of the input vertical signal, each time it sweeps. Hence to synchronize horizontal deflection with vertical deflection a synchronizing or triggering circuit is used. It converts the incoming signal into the triggering pulses, which are used for the synchronization.

Time base generator:

The time base generator is used to generate the sawtooth voltage, required to deflect the beam in the horizontal section. This voltage deflects the spot at a constant time dependent rate. Thus the x- axis' on the screen can be represented as time, which, helps to display and analyse the time varying signals.

Dual Beam Oscilloscope:

Another method of studying two voltages simultaneously on the screen is to u special cathode ray tube having two separate electron guns generating two separate beamiEach electron beam has its own vertical deflection plates.

But the two beams are deflected horizontally by the common set of horizontal plate\ The time base circuiIt is necessary that horizontal deflection starts at the same point of the input vertical signal, each time it sweeps. Hence to synchronize horizontal deflection with vertical deflection a synchronizing or triggering circuit is used. It converts the incoming signal into the triggering pulses, which are used for the synchronizationt may be same or different. Such an oscilloscope is called **Dual** Beam Oscilloscope.

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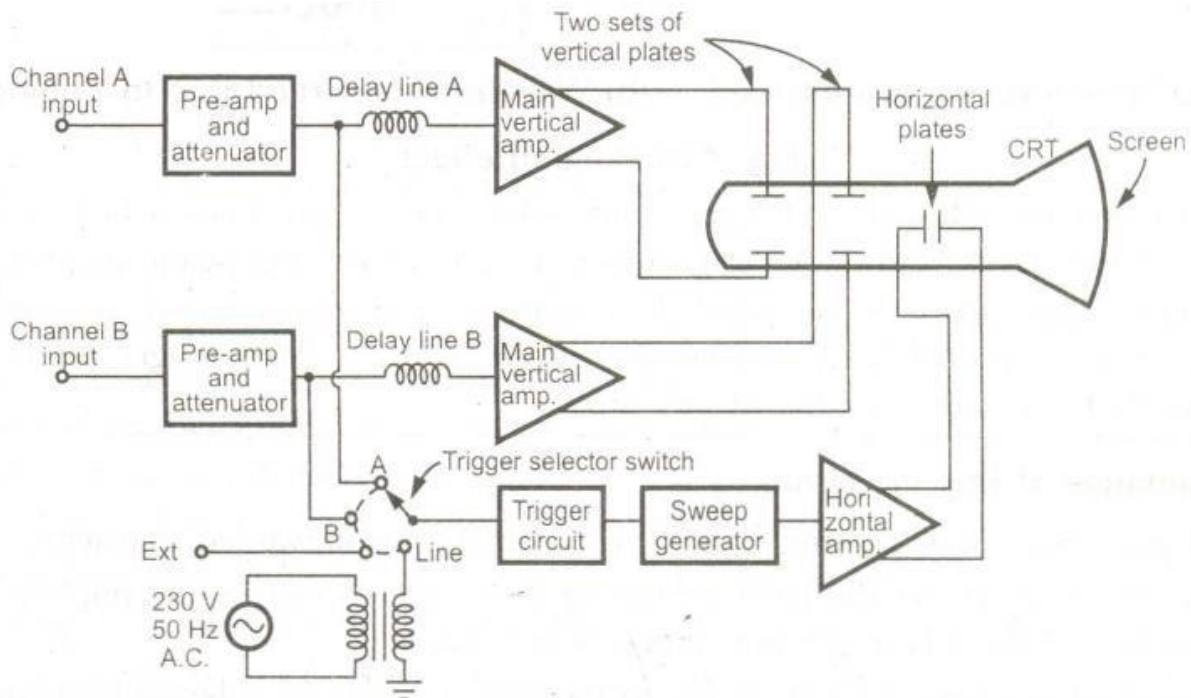
The oscilloscope has two vertical deflection plates and two separate channels A and B for the two separate input signals. Each channel consists of a preamplifier and an attenuator. A delay line, main vertical amplifier and a set of vertical deflection plates together forms a single channel. There is a single set of horizontal plates and single time base circuit. The sweep generator drives the horizontal amplifier which inturn drives the plates. The' horizontal plates sweep both the beams across the screen at the same rate. The sweep generator can be triggered internally by the channel A signal or .channel B signal. Similarly it' can also be triggered from an external signal or line frequency signal. This is possible with the help of trigger selector switch, a front panel control. Such an oscilloscope may have separate timebase circuit for separate channel. This allows different sweep rates for the two channels but increases the size and weight of the oscilloscope.

There are two separate vertical input channels A and B. A separate preamplifier and - attenuator stage exists for each channel. Hence amplitude of each input can be individually controlled. After preamplifier stage, both the signals are fed to an electronic switch. The switch
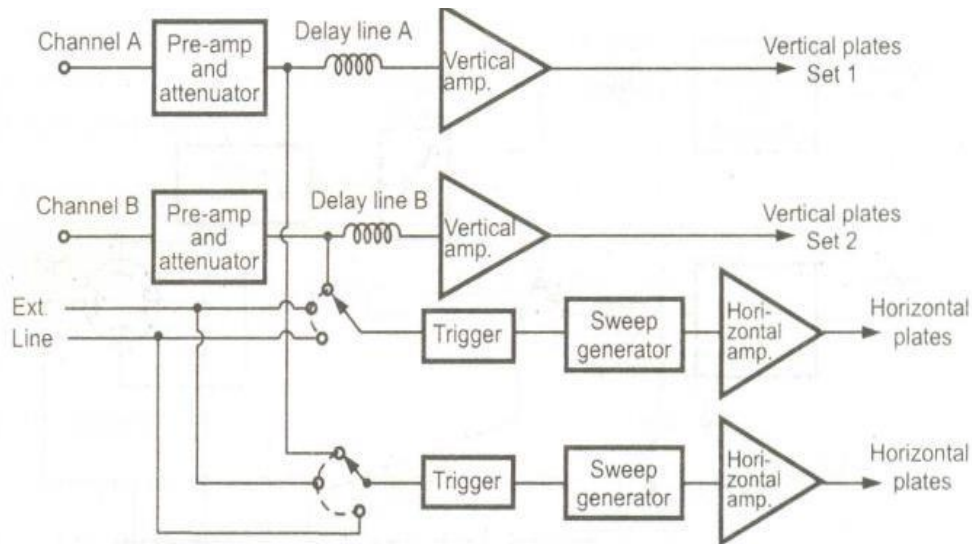
Dual beam CRO with separate time bases

Multiple beam oscilloscopes:

Multiple beam oscilloscope has a single tube but several beam producing systems inside. Each system has separate vertical deflecting pair of plates and generally (l common time base system. The triggering can be done internally using eith.er of the multiple inputs or externally by an external signal or line voltages.

Dual trace oscilloscope:

The comparison of two or more voltages is very much ,necessary in the analysis and study of many electronic circuits and systems. This is possible by using more than one oscilloscope but in such a case it is difficult to trigger the sweep of each oscilloscope precisely at the same time. A common and less costly method to solve this problem is to use dual trace or multitrace oscilloscopes. In this method, the same electron beam is used to generate two traces which can be deflected from two independent vertical sources. The methods are used to generate two independent traces which the alternate sweep method and other is chop method.

The block diagram of dual trace oscilloscope is shown in the Fig

There are two separate vertical input channels A and B. A separate preamplifier and - attenuator stage exists for each channel. Hence amplitude of each input can be individually controlled. After preamplifier stage, both the signals are fed to an electronic switch. The switch

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has an ability to pass one channel at a time via delay line to the vertical amplifier. The time base circuit uses a trigger selector switch 52 which allows the circuit to be triggered on either A or B channel, on line frequency or on an external signal. The

horizontal amplifier is fed from the sweep generator or the B channel via switch 5! and 51. The X- Y mode means, the oscilloscope operates from channel A as the vertical signal and the channel B as the horizontal signal. Thus in this mode very accurate X-Y measurements can bedone.
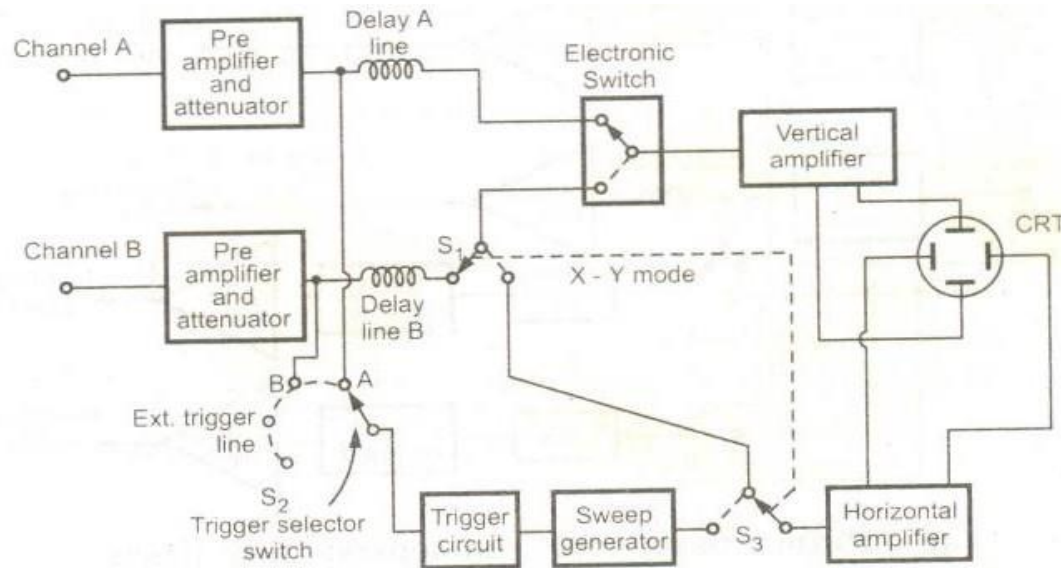

Recommended questions:

1. State the various characteristics of P31 phosphor.

   .J. Draw the block diagram of general purpose CRO. Explain the functions of various blocks..

2. Draw alld Explain the block diagram of the vertical amplifier used IIIoscilloscopes.

3. Explain the functions of delay lille ill oscilloscopes. WllIch are the two types of delay lilies7

4. State and Explain vorlous front panel controls of a Simple CRO. **[all years asked tillnow]**

5. Explaill the followll1g modes of operatioll of time base generator **[jan 06, 05, jul07]**

 i) Free runmode

 ii) Automode

 iii) single sweepmode

6. Draw the block diagram of a trigger generator. Explain the various controls associated WithIt.

7. What is the use of ACs and ACFcontrols?

SpecialOscilloscopes:

Delayed time baseoscilloscope:

In a conventional oscilloscope, the signal to the vertical plates is delayed by sOllle time, using ,1 delay line circuit. The waveform before the delay circuit is used to trigger the time base. This allows the study of all the leading or lagging edges of a pulse type waveform. This i~ shown in the Fig
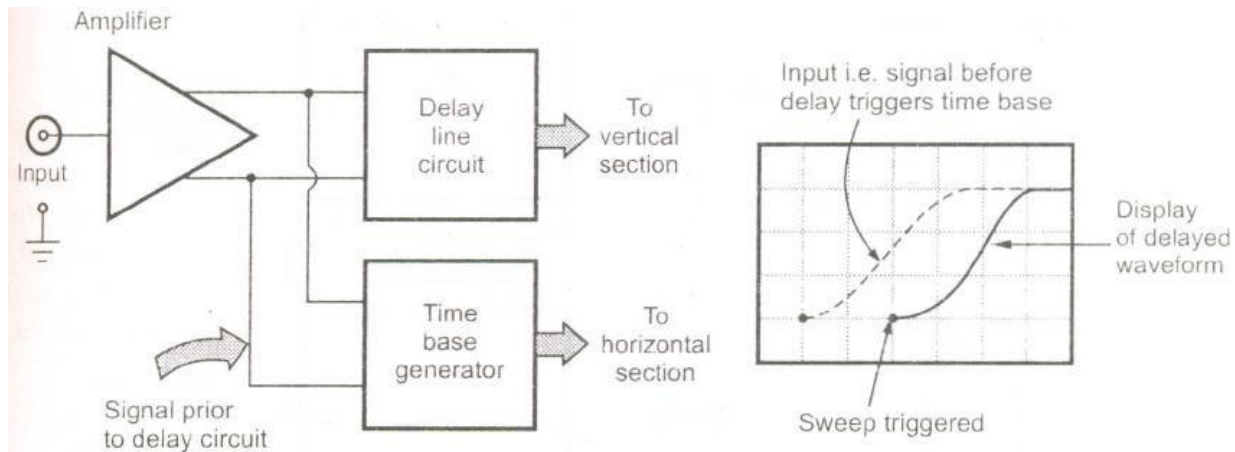

Due to triggering of time base by input signal, sweep starts well in time and when input appears at vertical sections, the sweep is triggered and delayed W(l\ dorm is displayed. The delay ensures that no part of the waveform gets lost.

If inpu,t is pulse waveform and leading edge is used to trigger the delay time, then bgging edge can be displayed to fill the entire oscilloscope screen. This is shown in the Fig (a). Similarly jf the lagging edge is used to trigger the delay time then leading edge Gln be displayed on the entire screen for the time tx. This is shown in the Fig.(b). If the time delay is perfectly adjusted, then any portion of the waveform can be extended to fill the entire screen. This is shown in the Fig. (c).

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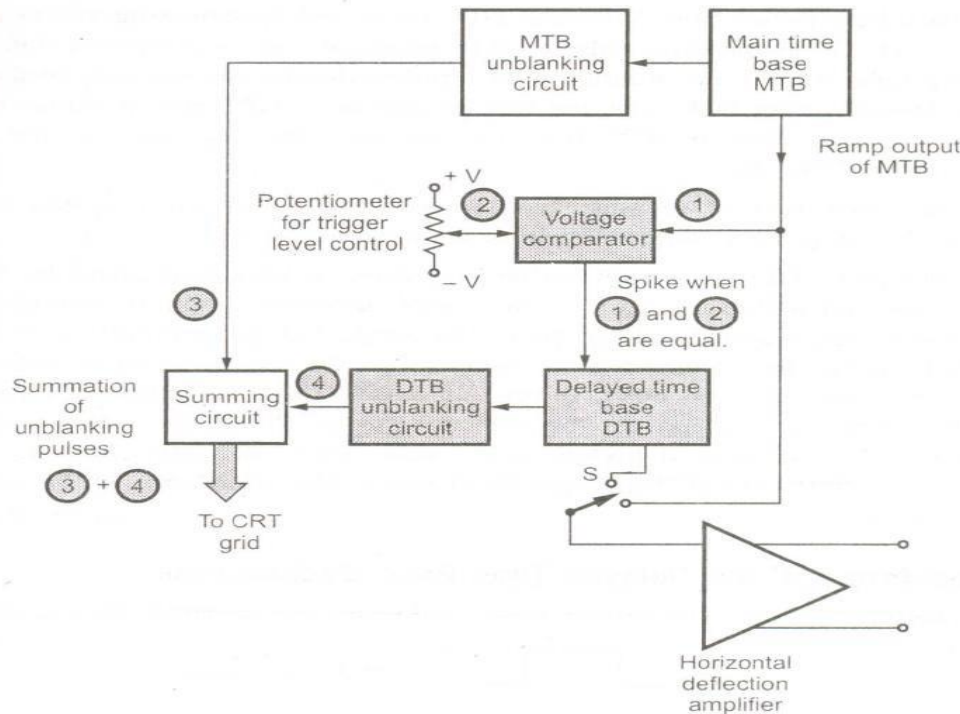
In c1 delayed time base oscilloscope, a variable time delay circuit is used in the basic time base circuit. This allows the triggering of sweep time after the delay time. Thus the delay time is variable. This time is denoted as td. After this, the sweep is triggered for the time t,. Then the portion of the waveform for the time t x gets expanded on the complete ()scillo~cope screen, for the detailstudy.

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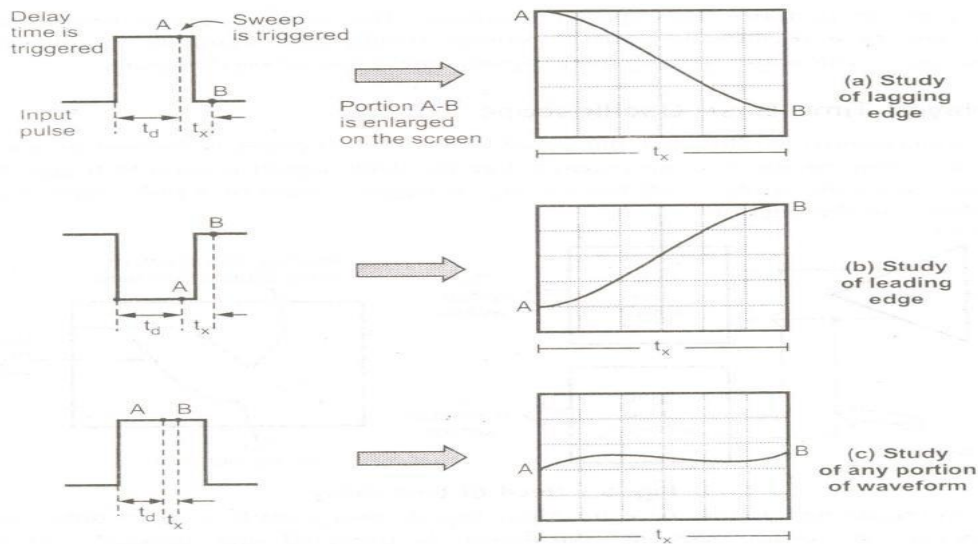
Use of additional time delay

Delayed time base oscilloscope

The normal time base circuit is main time base (MTB) circuit which functions same as c1 conventional oscilloscope. The function of MTB blanking circuit is to produce an unblanking pulse which is applied to CRT grid to turn on an electron beam in the CRT, during the display sweep time. The ramp output of MTB is given to the horizontal deflection amplifier via switch S. It is also given as one input to the voltage comparator. The other input to the voltage comparator is derived from the potentiometer whose level isadjustable.

The unblanking pulses from MTB and DTB are added by **summing circuit** and given to the CRT grid. The unblanking pulse of MTB produces a trace of uniform intensity. But during ramp time of DTB, the addition of two pulses decides the intensity of the trace on the screen. Hence during DTB time, the voltage applied to CRT grid is almost twice than the voltage corresponding to MTB time. This increases the brightness of the displayed waveform for the DTB time.

When the part of the waveform to be brightened is identified, then the DTB ramp output is connected to the input of the horizontal deflection amplifier through switch S. The DTB ramp time is much smaller than MTB period but its amplitude (- V to + V) is same as MTB ramp. 1Ience it

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causes the oscilloscope electron beam to be deflected from one side of the screen to the other, during short DTB time. By adjusting DTB time/ div control, the brightened portion can be extended, so as to fill the entire screen of the oscilloscope. The horizontal deflection starts only after the delay time t d from the beginning of the MTB sweep. Thus very small part of the waveform can be extended on the entire screen.

Waveforms of the Delayed Time Base Oscilloscope

The waveforms of the delayed time base oscilloscope are shown **in** the Fig
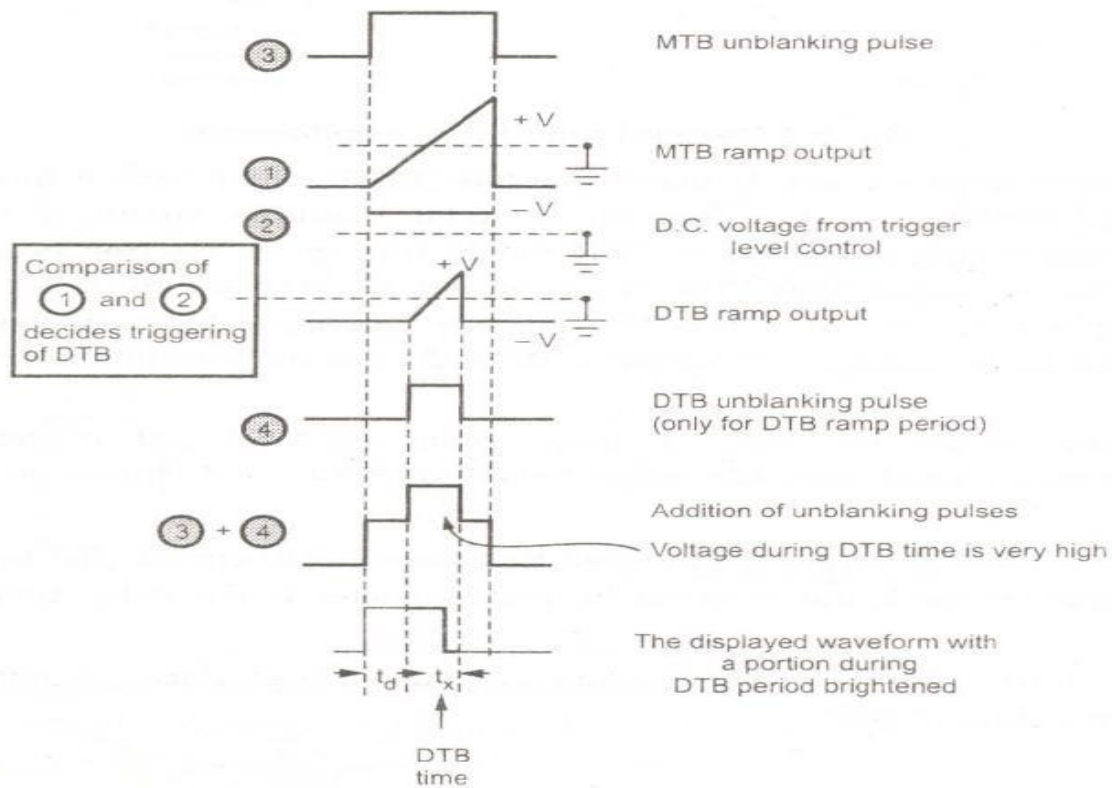
Analog storage oscilloscope:

The conventional cathode ray tube has the persistence of the phosphor ranging from a Few millisecond to several seconds. But sometimes it is necessary to retain the image for much 'longer periods, upto several hours. It requires storing of a waveform for a certain duration,' independent of phosphor persistence. Such a retention property helps to display the waveforms of very low frequency.

Mainly two types of storage techniques are used in cathode ray tubes which are:

i) Mesh storage and ii) Phosphorstorage

Sampling Time Base:

The time base circuit of the sampling oscilloscope is different than the conventional oscilloscope.

The time base of sampling oscilloscope has two functions:

i) To move the dots across thescreen

ii) To generate the sampling command pulses for the samplingcircuit.

It consists of synchronous circuit, which determines the sampling rate and establishes a reference point in time with respect to the input signal. The time base generates a triggering pulse which activates the oscillator to generate a ramp voltage. Similarly it generates a stair case waveform. The ramp generation is based on the output of the synchronizing circuit.

Both the ramp as well as staircase waveforms are applied to a voltage comparator. This comparator compares the two voltages and whenever these two voltages are equal, it generates a samppng pulse. This pulse then momentarily bias the diodes of the sampling gate in the forward direction and thus diode switch gets closed for short duration of time.

The capacitor charges but for short time hence, it can charge to only a small percentage of the input signal value at that instant. This voltage is amplified by the vertical amplifier and then applied to the vertical deflecting plates. This is nothing but a sample. At the same time, the comparator gives a signal to the staircase generator to advance through one step. This is applied to horizontal deflecting plates, thus during each step of the stair case waveform, the spot moves across the screen. Thus the sampling time base is called a staircase-ramp generator in case of a samplingoscillosope.

Block diagram of Sampling Oscilloscope:

The block diagram of sampling oscilloscope is shown in the Fig.

The staircase generator produces a staircase waveform which is applied to an attenuator. The attenuator controls the magnitude of the staircase signal and then it is applied to a voltage comparator. Another input to the voltage comparator is the output of the ramp generator. The voltage comparator compares the two signals and produces the output pulse when the two voltages are equal. This is nothing but a sampling pulse which is applied to sampling gate through the gate control circuitry.
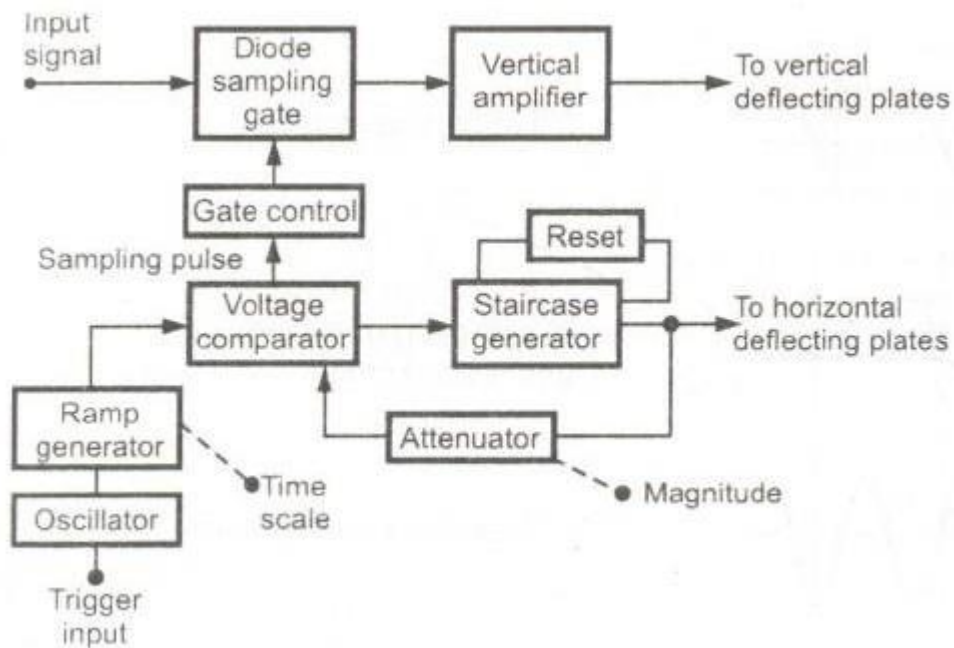
The input signal is applied to the diode sampling gate. At the start of each sampling cycle a trigger inpu t pulse is generated which activates the blocking oscillator. The oscillator output is given to the ramp generator which generates the linear ramp signal. Since the sampling must be synchronized with the input signal freq\,lency, the signal is delayed in the vertical amplifier.

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This pulse opens the diode gate and sample is taken in. This sampled signal is then applied to the vertical amplifier and the vertical deflecting plates. The output of the staircase generator is also applied to the horizontal deflecting plates.

During each step of staircase the spot moves on the screen. The comparator output advances the staircase output through one step. After certain number of p\llses about thousand or so, the staircase generator resets. The sm,lIler the size of the steps of the staircase generator, larger is the number of samples and higher *is* the resolution of theimage.

Digital Storage Oscilloscope:

In this digital storage oscilloscope, the waveform to be stored is digitised ,md then stored in a digital memory. The conventional cathode ray tube is used in this oscilloscope hencethe cost is less. The power to be applied to memory is small and can be supplied by small battery. Due to this the stored image can be displayed indefinitely as long ,15 power is supplied to memory. Once the waveform is digitised then it can be further loaded into thecomputer and can be ana lysed in detail.

Block Diagram:

The block diagram of digital storage oscilloscope is shown in the Fig.
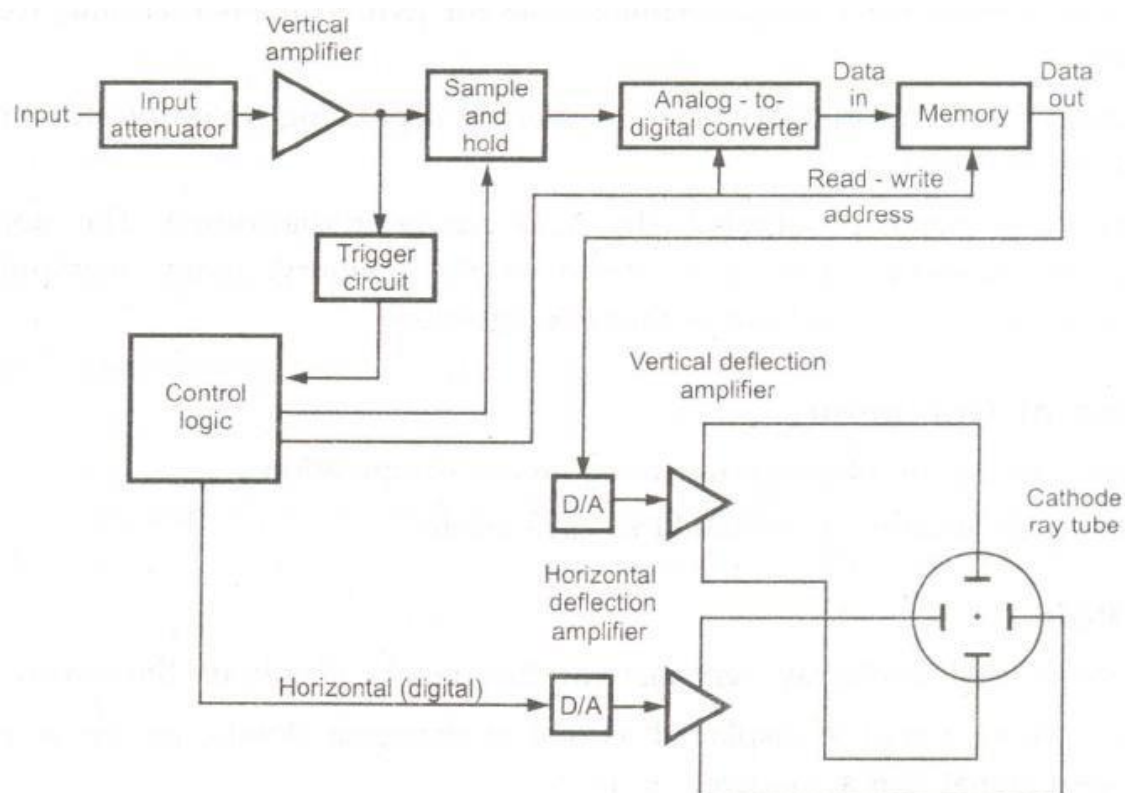
As done in all the oscilloscopes, the input signal is applied to the amplifier and attenuator section. The oscilloscope uses same type of amplifier and attenuator circuitry as used in the conventional oscilloscopes. The attenuated signal is then applied to the vertical amplifier.

The vertical input, after passing through the vertical amplifier, is digitised by an analog to digital converter to create a data set that is stored in the memory. The data set is processed by the microprocessor and then sent to the display.

To digitise the analog signal, analog to digital *(AID)* converter is used.

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