# Cathode Ray Oscilloscope.

The CRO is the most versatile laboratory instrument used for studying wave-shapes of alternating currents and voltages. It is also used for measurement of voltage, current, power and frequency. It can also be used for any quantity that involves amplitude and waveform. It allows the user to see the amplitude of electrical signals as a function of time on the screen. It is an extremely useful instrument in the laboratory.

The CRO is capable of much fast operations since it is completely electronic in nature. It is a kind of voltmeter which uses beam instead of a pointer. It is also a kind of recorder & uses an electron beam instead of a pen. It is capable of displaying events that take place over periods of microseconds and nanoseconds. Meter movements can only follow instantaneous variations up to a few cycles/second (Hz) while the high speed Oscillographs are limited to displaying signals below 500Hz but b/c of the unique displaying mechanism, CRO are being made c̄ can follow signals c̄ frequencies up to 500MHz. The cheapest models can measure signals of frequencies up to 20MHz while the more expensive models can measure signals at frequencies up to 500MHz.

The CRO has a very high input impedance ($Z \simeq 1M\Omega$). This means that it has a negligible loading effect in most measurement situations. In most ~~oscou~~ oscilloscopes, the amplifier is direct-coupled meaning that it amplifies dc voltages by the same factor as low-frequency ac voltages. For this kind of instruments, the minimum frequency measurable is zero and the **Bandwidth** (BW) can be interpreted as the maximum frequency where the sensitivity (deflection/volt) is c̄in 3dB of the peak value. Thus, the Oscilloscope must be chosen such that the maximum frequency to be measured is well within the bandwidth (BW)

* **Bandwidth** (BW) is defined as the range of frequencies over which the oscilloscope amplifier gain is c̄in 3dB of its peak value.*

The $-3dB$ (the $-3dB$ point is where the gain is 0.707 times its maximum value) specification means that an oscilloscope c̄ a specified accuracy of ±2% and BW of 100MHz will have an accuracy of ±5% when measuring 30MHz signals and this accuracy will fall still further at higher frequencies. When ~~when~~ applied to signal amplitude measurement, the Oscilloscope is only usable at frequencies up to about 0.3 times its specified BW.

An oscilloscope is a relatively complicated instrument c̄ is constructed from a no. of subsystems. Thus it is necessary to consider each of them in turn in order to understand how the complete instrument functions.

When a step input is applied to the oscilloscope, a rise time exists which is the transit time b/w the 10% and 90% levels of the response.

$\therefore$ BW * Rise time = 0.35

$\therefore$ for a BW of 100MHz.

$$\text{Rise Time} = \frac{0.35}{100 \times 10^6}$$

$$= \underline{3.5ns}.$$

## Drawbacks:

1. Fragility : CR Oscilloscope is been built around a Cathode ray tube (CRT).
2. Moderately high Cost.

## Merits

1. Accuracy: The accuracy of the cheapest CRO is ±10% while that of the best other instruments is ±1%.
2. specifications aspects of CRO such as
   - Bandwidth.
   - Rise time. etc.

## Applications of CRO.

1. Colour oscilloscopes are finding application in Computers and television although most oscilloscopes are Monochromatic.
2. Most modern oscilloscopes are Capable of accepting two or more inputs displaying them simultaneously by using a split beam or using multiple beam tube.
3. Sampling Oscilloscopes are available for high speed applications.
4. Storage Oscilloscopes Can be employed for Capturing transient signal and then display them for periods varying from a few minutes to several years.

5. Analog Oscilloscope makes use of a modified form of a Conventional CRT to store the trace.

6. Digital storage Oscilloscope first Converts the analog signal to a digital form and stores it in digital memory, where the signal can then be recalled for display as and when needed.

7. Many Oscilloscopes are now available with instrumentation interface (IEEE 488) bus capabilities, so that they can be employed as a part of measurement test bed, with the instruments controls set at a remote location and the readings digitized and retrieved for the purposes of recording and analysis.

## Operation Principles of the CRO.

The CRO employs a cathode ray tube (CRT) which is the heart of the Oscilloscope. It generates the electron beam, accelerates the beam to high velocity, deflects the beam to create the image. The CRT contains a phosphor screen where the electron beam eventually becomes visible. To accomplish these tasks various electrical signals and voltages are required which are provided by the power supply cct. of the Oscilloscope.

Low voltage supply is required for the heater of the electron gun for generation of electron beam and the high voltage of the order of few thousand volts is required for cathode ray tube to accelerate the beam while normal supply i.e. few hundred volts is reqd. for other control ccts of the Oscilloscope.

The horizontal and vertical deflection plates are fitted b/w electron gun and the screen to deflect the beam according to input signal. The electron beam strikes the screen and creates a visible spot which is deflected on the ~~screen~~ screen in horizontal deflection (X-axis) with constant time dependent rate. This is accomplished by a time-base cct. provided in the Oscilloscope.

The signal to be viewed is supplied to the vertical deflection plates thro' the vertical amplifier, which raises the potential of the input signal to a level that will provide usable deflection of the electron beam. The electron beam now deflects in two directions i.e. horizontal on X-axis and vertical on Y-axis.

A triggering cct. is provided for synchronising the two types of deflections so that horizontal deflection starts at the same point of the input vertical signal each time it sweeps.

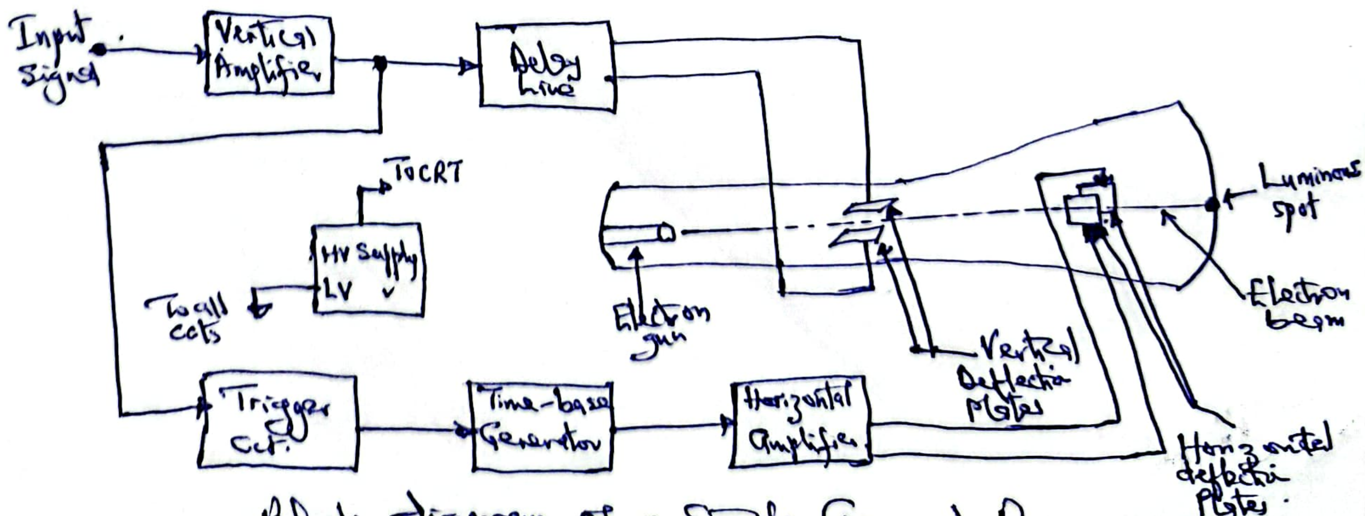



fig. Block diagram of a Simple General Purpose CRO.

# Basic Controls in CRO.



To facilitate the proper function of the CRO, a number of Controls are required to be provided on a panel of the CRO. These Controls are

- Intensity Control.
- Horizontal and Vertical position Controls.
- Position Controls.
- Focus Control.
- Astigmatism Control.
- Calibration cat Control etc.

** Intensity Control:
- This is for the adjustment of brightness of the spot on the screen.
- It is accomplished by varying the voltage b/w the first and the second anodes. The potential of the control grid wrt Cathode is controlled c the help of potentiometer in order to control the intensity of brightness of the spot. The grid potential determines the amount of electrons leaving the Cathode & thus Controls the intensity of the beam. A larger no of electrons in the beam causes a brighter spot to appear on the screen.

* Horizontal and vertical position Controls.
- These Controls are provided for moving the beam on any part of the screen.
- It is accomplished by applying a dc voltage to horizontal or vertical deflection plates.

* Position Controls:
- These are two knobs, one for controlling the horizontal position and the other for Controlling the vertical position.
- The spot can be moved to left or right i.e. horizontally with the help of a knob c regulates the dc potential applied to the horizontal deflection plates in addition to the usual saw-tooth-wave.
  Also the spot can be moved up and down i.e. vertically with the help of another knob c regulates the dc potential applied to the vertical deflection plates in addition to the signal.

** Care must be taken to prevent the electron beam from burning spots on the screen. A stationary spot should be kept on very low intensity. If the intensity is kept high, the spot must be kept moving. If a 'halo' appears around the spot, the intensity is too high. By turning the Oscilloscope on, turn down the intensity.

* Focus Control:
In the electron gun of a CRT, the middle anode is kept at a lower potential wrt the other two anodes. It acts like an electrostatic lens and

focal length of this lens can be varied by varying the potential of the middle anode wrt other two anodes. Thereby the focussing of an elect beam is done by varying the potential of middle anode $\bar{c}$ the help of a potentiometer. By increasing the +ve potential applied to the focussing anode, the electron beam can be narrowed and the spot on the screen can be made a pin point.

* Astigmatism:

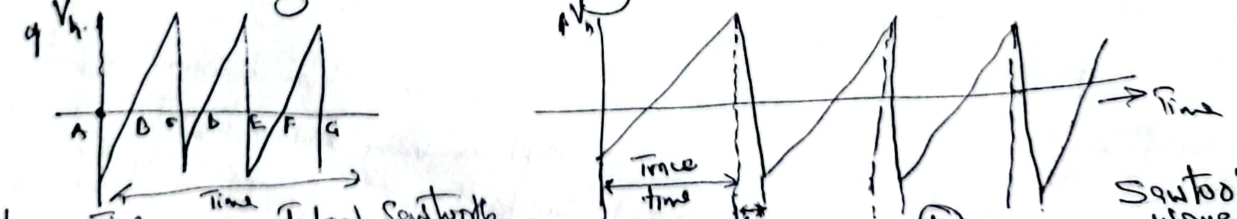
This is an additional focusing control and is analogous to astigmatism in optical lenses. A beam that is focussed at the centre of the screen would be defocussed at the edges of the screen b/c the lengths of the electron paths are different for the centre and the edges. Adjustment of this control gives a sharp focus over the entire screen. The control is affected by varying the potential of deflection plates and accelerating anodes.

* Calibration Cct:

Normally an oscillator $\bar{c}$ generates a known and fixed voltage in square waveform is fitted in the CRO for calibration purpose.

* Blanking Circuit:

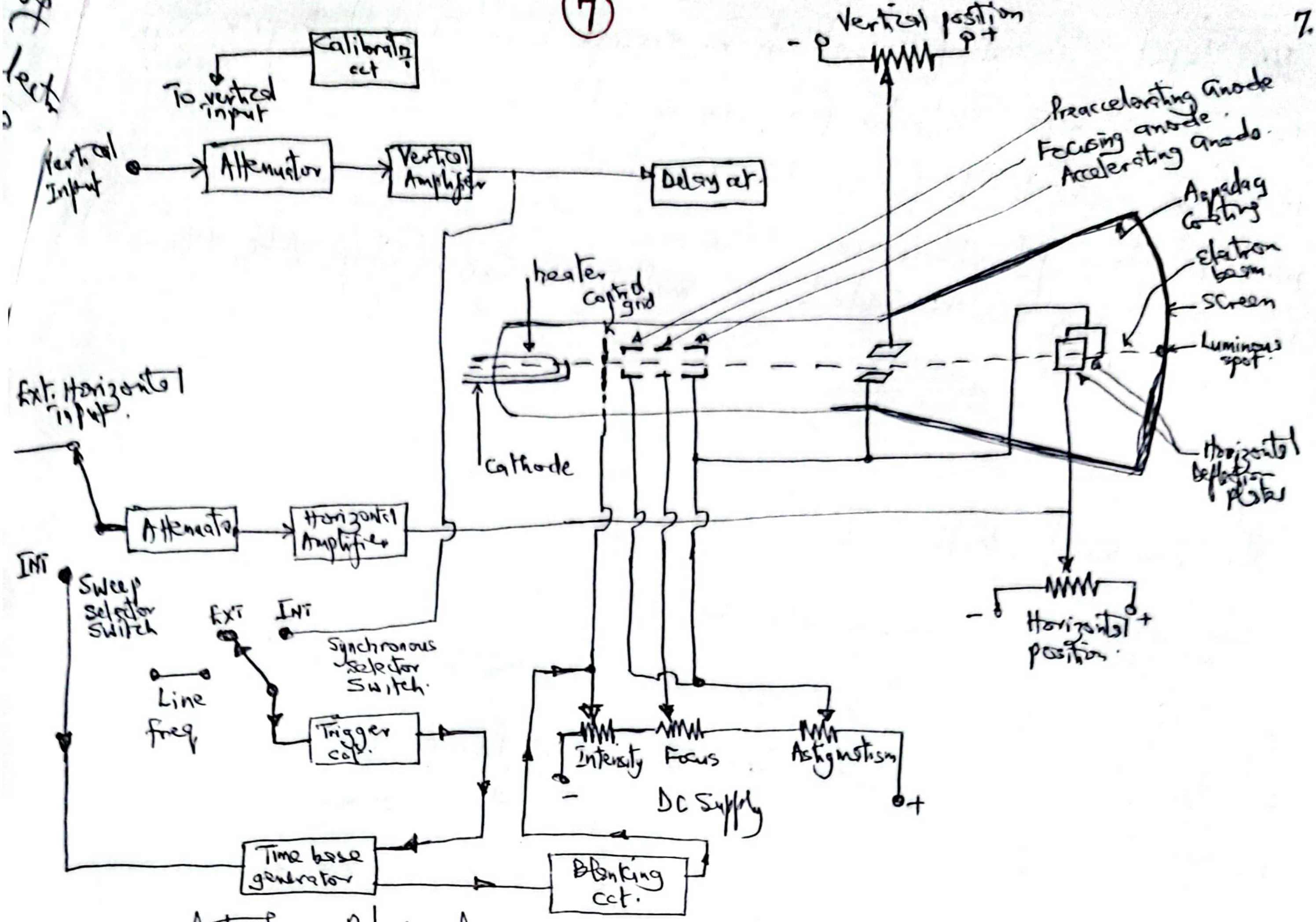
The saw-tooth sweep voltage is applied to the horizontal deflection plates of the CRT $\bar{c}$ moves the spot on the screen following a straight horizontal line from left to right during the sweep period. When the spot moves slowly so that its rate of movement exceeds the threshold of persistence vision, the spot appears as a solid line. Below the threshold limit, only spot or some portion of line after the spot appears. If the movement of the spot is fast, it appears as thin and dim horizontal line or may be invisible.




Linear Time base (a) Ideal Sawtooth Voltage Waveform

Retrace time (b) Sawtooth Voltage waveform.

Fig. (a) shows a sawtooth voltage waveform $\bar{c}$ is an ideal one. In this wave form retrace time is zero but in practice it is not possible to achieve this, so there is some retrace time of waveform as shown in (b). During this retrace time, the spot moves from right to left and leads to confusion. This trace is blanked out by supplying a high -ve voltage to the grid during the retrace time. This blanking voltage is usually triggered by the time-base generator.




Detailed Block Diagram of a CRO.

## Oscilloscope Front Panel.

In most Cases, all necessary Controls to operate an Oscilloscope are located in its front panel. Amongst the Switches and Controls are

1. channel vertical position knob(s) for setting vertical signal position.
2. Horizontal position knob for setting signal along its horizontal axis.
3. Time base selector (sec/div) or (sec/cm).
4. Voltage amplitude sensitivity selector (Volts/div) or (Volts/cm).
5. Trigger source selector.
6. Trigger Level Control.
7. Vertical display INTERNAL trigger source selector – applicable for multitrace oscilloscopes.
8. Focus knob to control sharpness and clarity of display.
9. Intensity knob to control brightness of the display
10. Beam finder required to bring beam or trace into viewing area of the CRT

11. Input Sockets (signals to be viewed and external trigger signal.
12. Signal type selector (ac, dc or gnd).
13. Power switch to put on the Oscilloscope.
14. Display phosphorescent screen.
15. Display mode selector for multitrace CRO (Chop, Add, Alternate)

## Measurement with an Oscilloscope.

The following quantities can be measured with an Oscilloscope.

1. Signal voltage (peak, peak-to-peak amplitude, instantaneous value.
2. Signal Period (frequency is inverse of period).
3. Signal Current can be measured indirectly in terms of voltage.
4. Phase difference or time delay can be measured by Oscilloscope with more than one input sockets.

Phase difference can be measured as time ~~day~~ delay by using a dual trace Oscilloscope displaying simultaneously two wave-forms one of which is the input to a system or reference, while the other is the output of the system.

Phase difference can also be measured by applying one of the signals to the horizontal axis in place of the time base signal. This method produces what are known as Lissajous figures. The method can also be used to measure the phase difference b/w different harmonic contents.

5. Pulse delay and width.

# Other features of Oscilloscope.

The CRO has followed the trends in technology by becoming more sophisticated. Amongst a number of features that are found in modern Oscilloscopes are:

1. Delayed sweep and expanded view of selected part of signal
2. Storage facility of measured signal for future viewing
3. Screen partitioning.
4. Digital read-out of measured quantities.
5. This is incorporating the functions of a Multimeter into a CRO.

Thus, the CRO is a very useful instruments & combines the measuring capabilities of multimeters with visual display. Due to its versatility, it is often made a component part of other specialised test, observation and measuring equipment such as communication receivers, radar receivers etc.