

CATHODE-RAY OSCILLOSCOPE (CRO)

INTRODUCTION:

- The cathode-ray oscilloscope (CRO) is a multipurpose display instrument used for the observation, measurement, and analysis of waveforms by plotting amplitude along **y-axis and time along x-axis.**
- CRO is generally an x-y plotter; on a single screen it can display different signals applied to different channels. It can measure amplitude, frequencies and phase shift of various signals. Many physical quantities like temperature, pressure
- and strain can be converted into electrical signals by the use of transducers, and the signals can be displayed on the CRO.
- A moving luminous spot over the screen displays the signal. CROs are used to study waveforms, and other time-varying phenomena from very low to very high frequencies.
- The central unit of the oscilloscope is the cathode-ray tube (CRT), and the remaining part of the CRO consists of the circuitry required to operate the cathode-ray tube.

Block diagram of a cathode-ray oscilloscope:

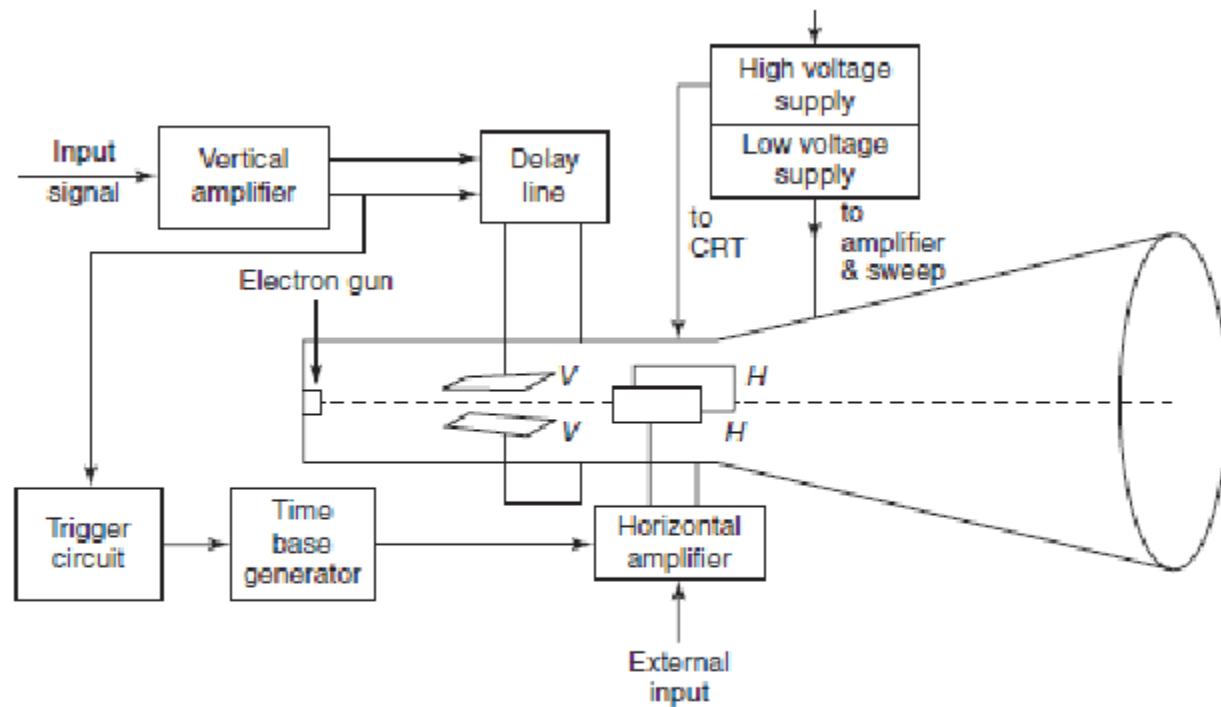


Figure 14-1 Block diagram of a cathode-ray oscilloscope

COMPONENTS OF THE CATHODE-RAY OSCILLOSCOPE:

The CRO consists of the following:

- (i) CRT
- (ii) Vertical amplifier
- (iii) Delay line
- (iv) Horizontal amplifier
- (v) Time-base generator
- (vi) Triggering circuit
- (vii) Power supply

Power supply

- It provides the voltages required by the cathode ray tube to generate and accelerate the electron beam.
- Cathode ray tube (CRT) requires high voltage for pre-accelerating and accelerating anode, low voltage required for heater, control grid, focusing anode and the other circuits of CRO.

Vertical Amplifier: The signal under the analysis is to be applied to vertical deflection plates through the vertical amplifier.

Delay line

- If both vertical and horizontal signals arrive at the same time to the corresponding deflection plates, then only we will get exact waveform.
- But vertical signal arrives much early compared to the horizontal signal. For this reason, the vertical signal at the output of the vertical amplifier should be delayed with the help of delay line. The delay time is almost equal to 200nsec.

Trigger circuit

- This is triggered by the portion of the vertical amplifier output.
- This circuit initiates then time base generator. It is the link between the vertical input and horizontal time base.
- Trigger circuit is used to synchronize horizontal deflection with vertical deflection.

Horizontal Amplifier

- The saw tooth voltage produced by the time base generator may not be of sufficient strength.
- Hence before giving it to the horizontal deflection plates, it is amplified using the horizontal amplifier.

CATHODE-RAY TUBE:

- The **electron gun or electron emitter, the deflecting system and the fluorescent screen** are the three major components of a general purpose CRT. A detailed diagram of the cathode-ray oscilloscope is given in Figure 14-2.

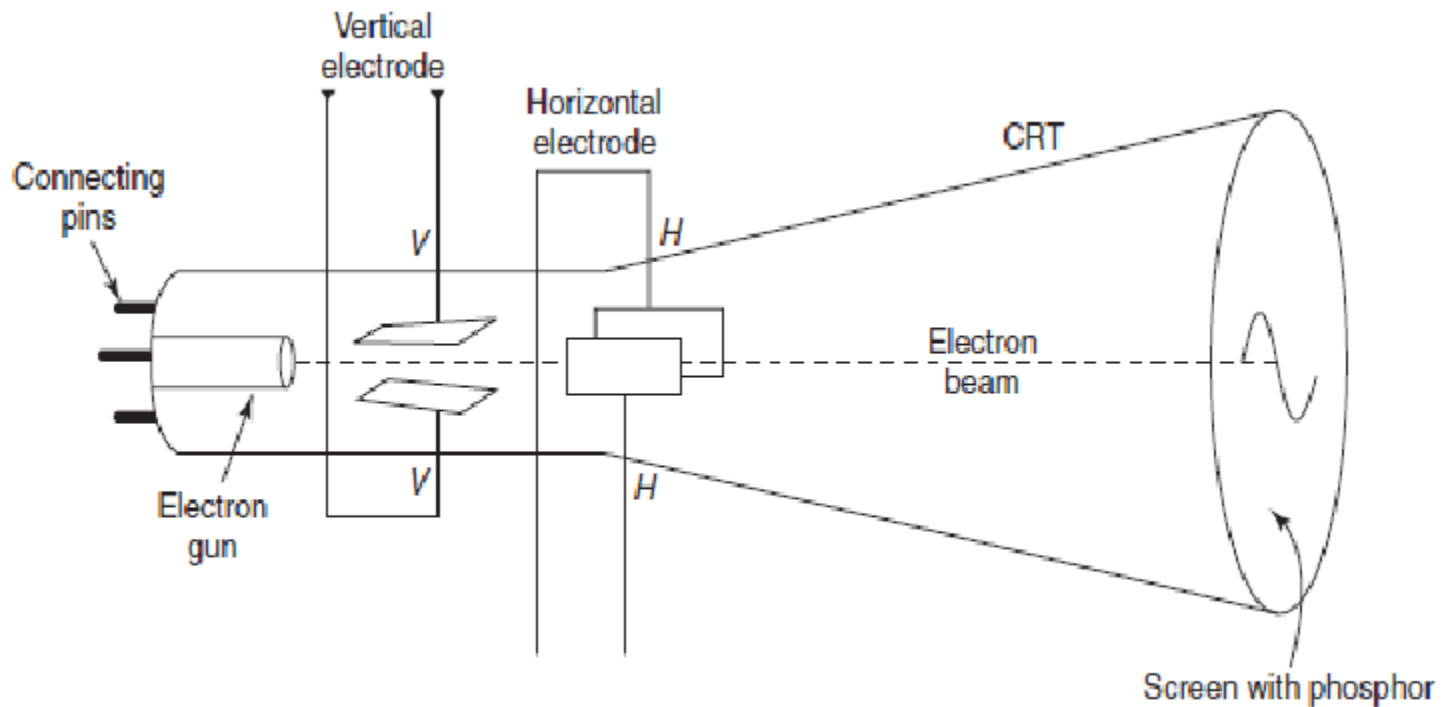


Figure 14-2 Components of a cathode-ray oscilloscope

Electron Gun:

- In the electron gun of the CRT, electrons are emitted, converted into a sharp beam and focused upon the fluorescent screen.
- The electron beam consists of an indirectly heated cathode, a control grid, an accelerating electrode and a focusing anode.
- The electrodes are connected to the base pins. The cathode emitting the electrons is surrounded by a control grid with a fine hole at its centre.
- The accelerated electron beam passes through the fine hole.
- The negative voltage at the control grid controls the flow of electrons in the electron beam, and consequently, the brightness of the spot on the CRO screen is controlled.

Deflection Systems:

- Electrostatic deflection of an electron beam is used in a general purpose oscilloscope. The deflecting system consists of a pair of horizontal and vertical deflecting plates.
- Let us consider two parallel vertical deflecting plates *P1* and *P2*. The beam is focused at point *O* on the screen in the absence of a deflecting plate voltage.
- *If a positive voltage is applied to plate P1 with respect to plate P2, the negatively charged electrons are attracted towards the positive plate P1, and these electrons will come to focus at point Y1 on the fluorescent screen.*

Deflection Systems:

The deflection is proportional to the deflecting voltage between the plates. If the polarity of the deflecting voltage is reversed, the spot appears at the point Y_2 , as shown in *Fig. 14-3(a)*.

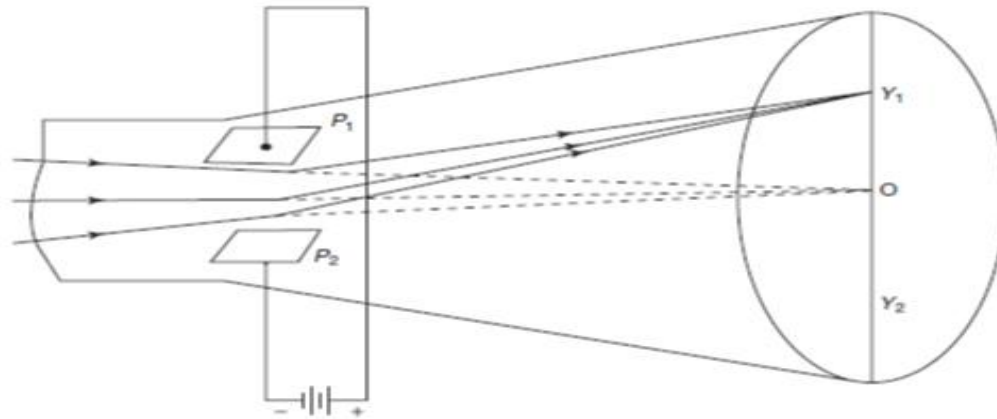


Figure 14-3(a) Deflecting system using parallel vertical plates

Deflection Systems:

- To deflect the beam horizontally, an alternating voltage is applied to the horizontal deflecting plates and the spot on the screen horizontally, as shown in Fig. 14-3(b).
- The electrons will focus at point X_2 . *By changing the polarity of voltage, the beam will focus at point X_1 . Thus, the horizontal movement is controlled along $X_1O X_2$ line.*

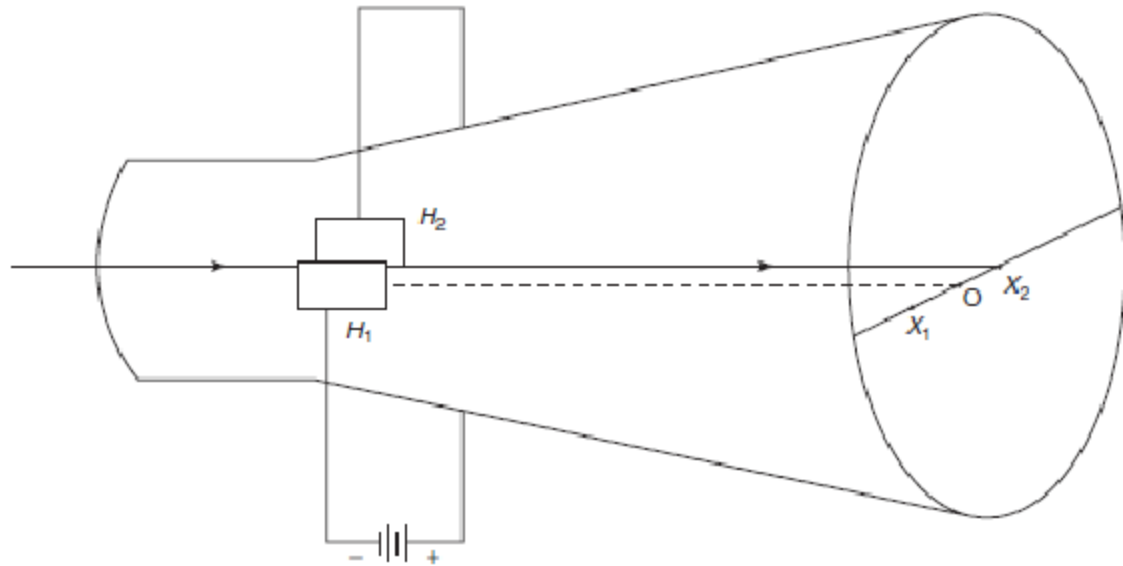


Figure 14-3(b) Deflecting system using parallel horizontal plate

Display waveform on the screen:

Figure 14-5(a) shows a sine wave applied to vertical deflecting plates and a repetitive ramp or saw-tooth applied to the horizontal plates.

- The ramp waveform at the horizontal plates causes the electron beam to be deflected horizontally across the screen.
- If the waveforms are perfectly synchronized then the exact sine wave applied to the vertical display appears on the CRO display screen.

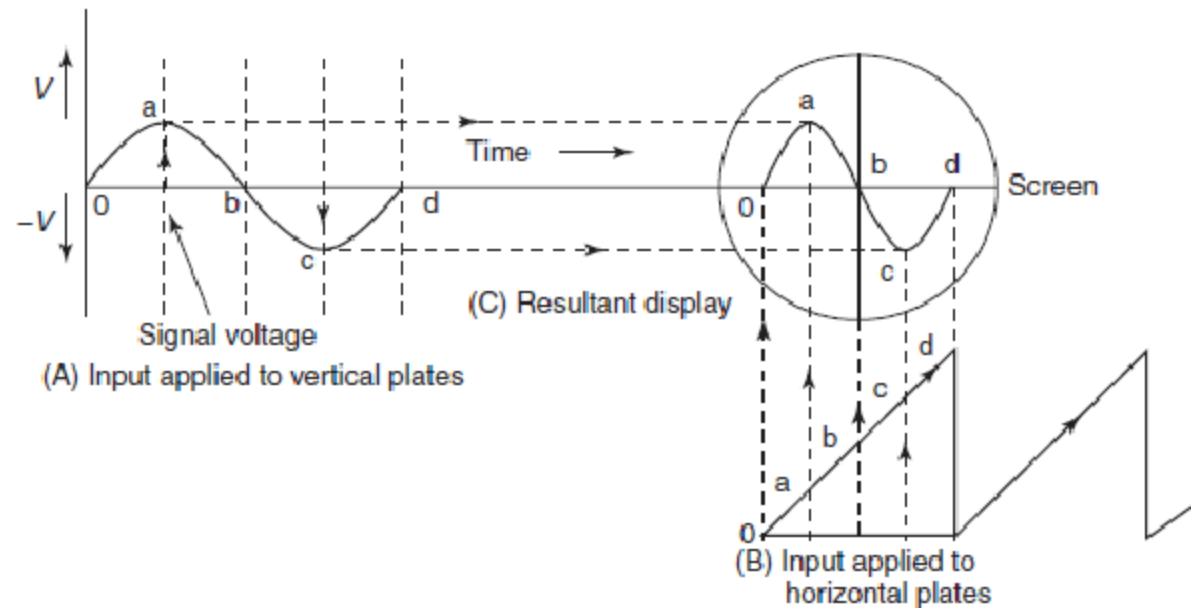


Figure 14-5(a) A typical display waveform on the screen

Fluorescent Screen:

- Phosphor is used as screen material on the inner surface of a CRT. Phosphor absorbs the energy of the incident electrons. The spot of light is produced on the screen where the electron beam hits.
- The bombarding electrons striking the screen, release secondary emission electrons. These electrons are collected or trapped by an aqueous solution of graphite called “Aquadag” which is connected to the second anode.
- Collection of the secondary electrons is necessary to keep the screen in a state of electrical equilibrium.
- The type of phosphor used, determines the color of the light spot. The brightest available phosphor isotope, P31, produces yellow–green light with relative luminance of 99.99%.

TIME-BASE GENERATORS:

- The CRO is used to display a waveform that varies as a function of time. If the wave form is to be accurately reproduced, the beam should have a constant horizontal velocity.
- As the beam velocity is a function of the deflecting voltage, the deflecting voltage must increase linearly with time.
- A voltage with such characteristics is called a ramp voltage. If the voltage decreases rapidly to zero—with the waveform repeatedly produced, as shown in Fig. 14-6—we observe a pattern which is generally called a saw-tooth waveform.
- The time taken to return to its initial value is known as flyback or return time.

Time base generator is used to generate saw tooth voltage, required to deflect the beam in horizontal section.

In saw tooth wave form, the deflecting voltage increases slowly and linearly with respect to time and reduces to zero quickly (fast) i.e. raise time is high and fall time is less.

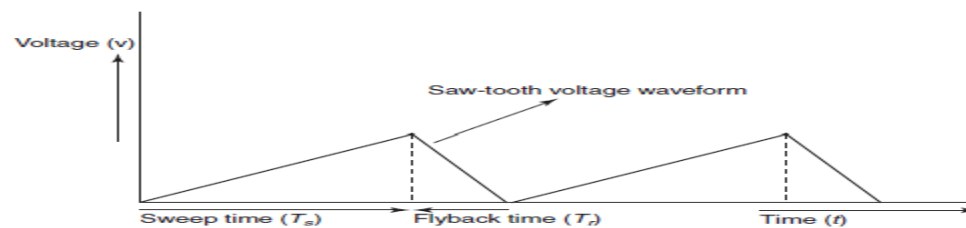


Figure 14-6 Typical saw-tooth waveform applied to the horizontal deflection plates

TYPES OF THE CATHODE - RAY OSCILLOSCOPE:

- The categorization of CROs is done on the basis of whether they are digital or analog. Digital CROs can be further classified as storage oscilloscopes.
- **1. Analog CRO:** In an analog CRO, the amplitude, phase and frequency are measured from the displayed waveform, through direct manual reading.
- **2. Digital CRO:** A digital CRO offers digital read-out of signal information, i.e., the time, voltage or frequency along with signal display. It consists of an electronic counter along with the main body of the CRO.
- **3. Storage CRO:** A storage CRO retains the display up to a substantial amount of time after the first trace has appeared on the screen. The storage CRO is also useful for the display of waveforms of low-frequency signals.
- **4. Dual-Beam CRO:** In the dual-beam CRO two electron beams fall on a single CRT. The dual-gun CRT generates two different beams.
- These two beams produce two spots of light on the CRT screen which make the simultaneous observation of two different signal waveforms possible. The comparison of input and its corresponding output becomes easier using the dual-beam CRO.

IMPORTANT FORMULAE:

1. The deflection sensitivity of the CRT is:

$$S = \frac{l_{\text{total}}}{V_d} = \frac{IL}{2sV_a} \text{ m/V}$$

2. The deflection factor of the CRT is:

$$G = \frac{1}{S} = \frac{2sV_a}{IL} \text{ V/m}$$

ELECTROSTATIC DEFLECTION AND ITS DEFLECTION SENSITIVITY

- The electro static deflection system uses a pair of deflection plates as shown in fig.
- The hot cathode K emits electrons which are accelerated towards the anode by the potential V_a .
- Those electrons which are not collected by the anode pass through the tiny anode hole and strike the end of the glass envelope.
- The glass envelope has been coated with a material that fluoresces when bom-barded by electrons. Thus the position where the electrons strike the screen are made visible to the eye.

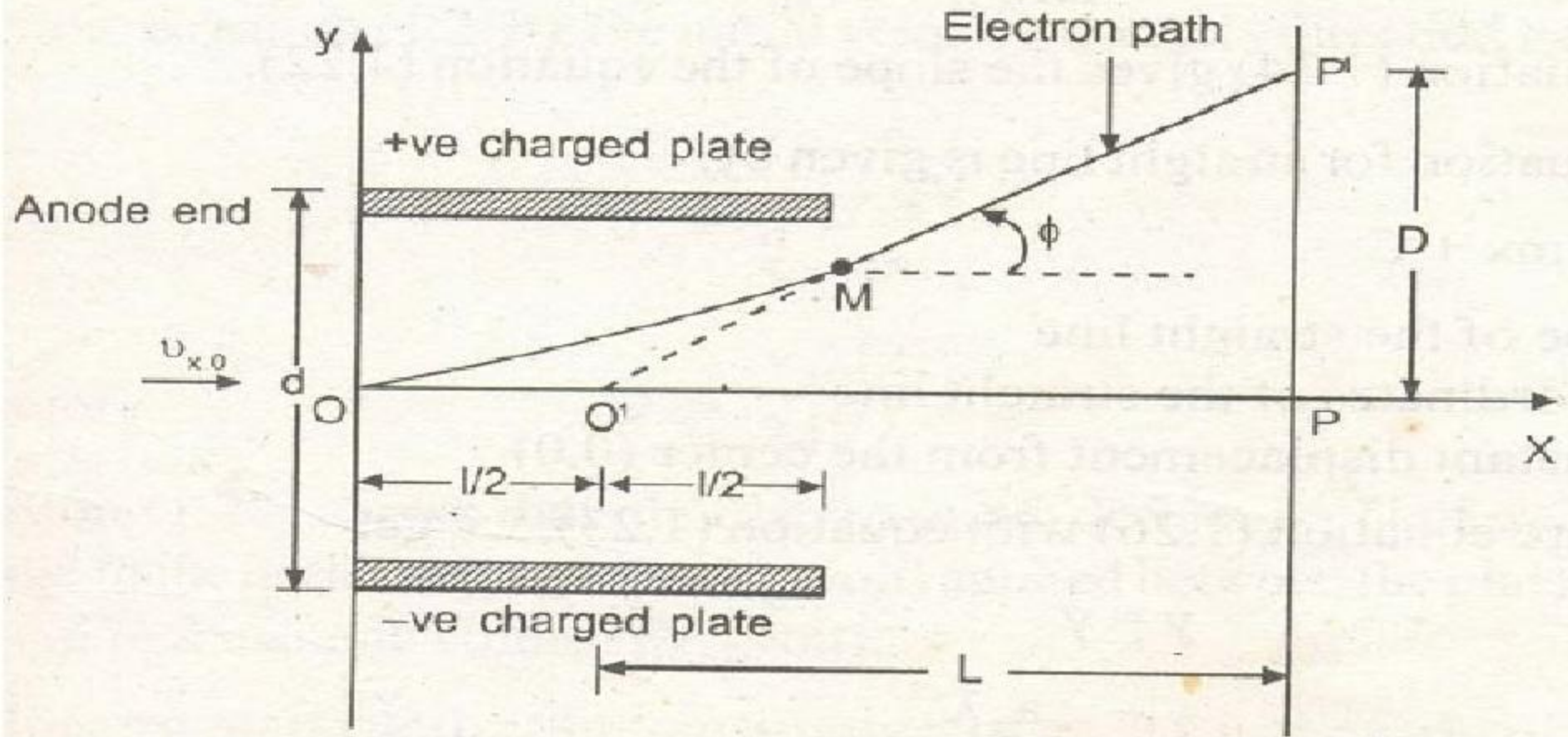


Fig: Electrostatic deflection in a cathode - ray Tube

$$D = \frac{LlV_d}{2dV_a}$$

- This result shows that the deflection on the screen of a cathode – ray tube is directly proportional to the deflecting voltage V_d applied between the plates.
- CRT may be used as a linear – voltage indicating device.
- **Deflection Sensitivity:**
- The electrostatic – deflection sensitivity of a cathode – ray tube is defined as the deflection (in meters) on the screen per volt of deflecting voltage.

Spot Beam Deflection Sensitivity:

The deflection sensitivity of a CRT is defined as the distance of the spot-beam deflection on the screen per unit voltage. If I_{total} is the total amount of deflection of the spot beam on the screen for the deflecting voltage V_d , as shown in Fig. 14-4, the sensitivity can be expressed as:

$$S = \frac{I_{\text{total}}}{V_d} \quad (14-1)$$

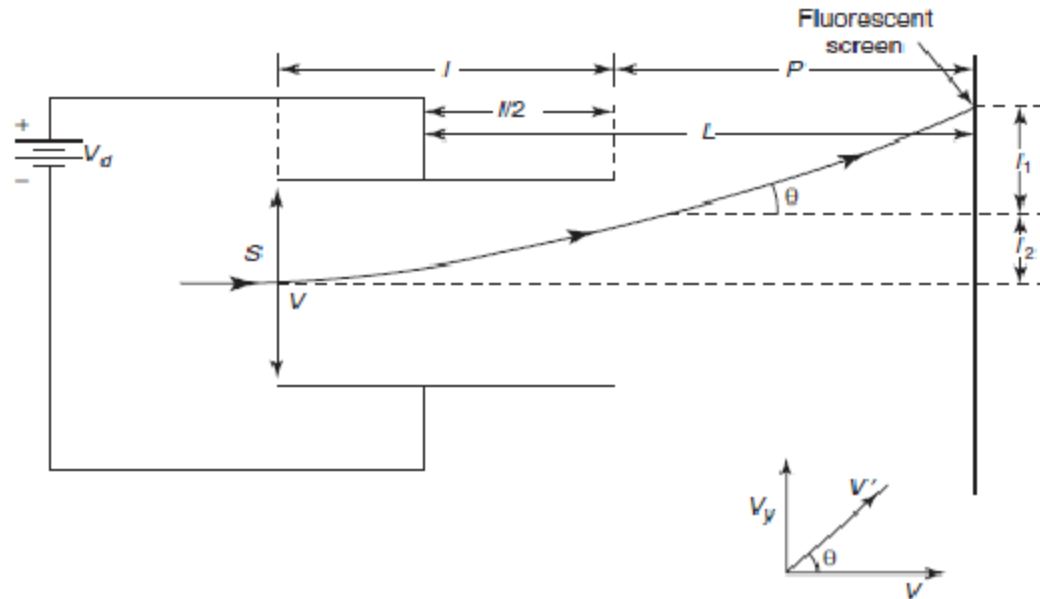
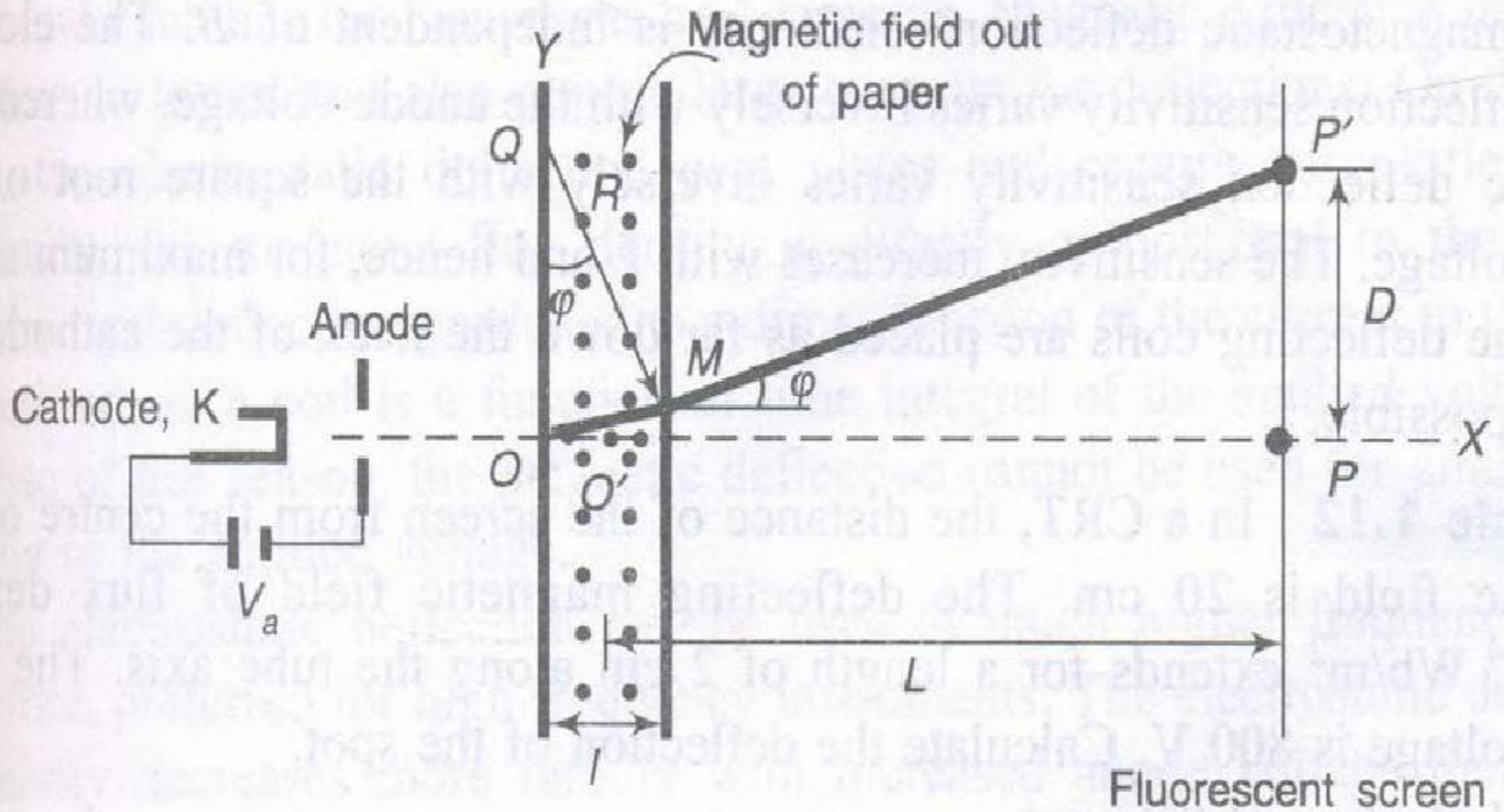


Figure 14-4 Schematic diagram of electrostatic deflection systems

MAGNETIC DEFLECTION SYSTEM

- Here the magnetic field is perpendicular to direction of electron beam i.e., it directs towards the reader.
- The electron beam is deflected upwards. The electron moves in a straight line to point 'O' from cathode with initial velocity V_0 .
- Now the force acts on the electron and the resultant direction is perpendicular to both 'B' and 'v' is so resultant path is circular one.
- Path taken by the electron with in this uniform magnetic field is an arc of circle with radius 'R'.
- The path OM is an arc of the circle whose center is at "θ"



□ Fig: Magnetostatic deflection in a cathode – ray Tube

$$D = \frac{\square LB}{\sqrt{V_a}} \cdot \sqrt{\frac{e}{2m}}$$

□ Magnetic Deflection Sensitivity:

The Deflection per unit magnetic field intensity D/B is given by
is called the magnetic – deflection Sensitivity of the tube

$$\frac{D}{B} = \frac{IL}{\sqrt{V_a}} \sqrt{\frac{e}{2m}}$$

Which is independent of magnetic flux density 'B'.

$$S = \frac{IL}{\sqrt{V_a}} \sqrt{\frac{e}{2m}}$$