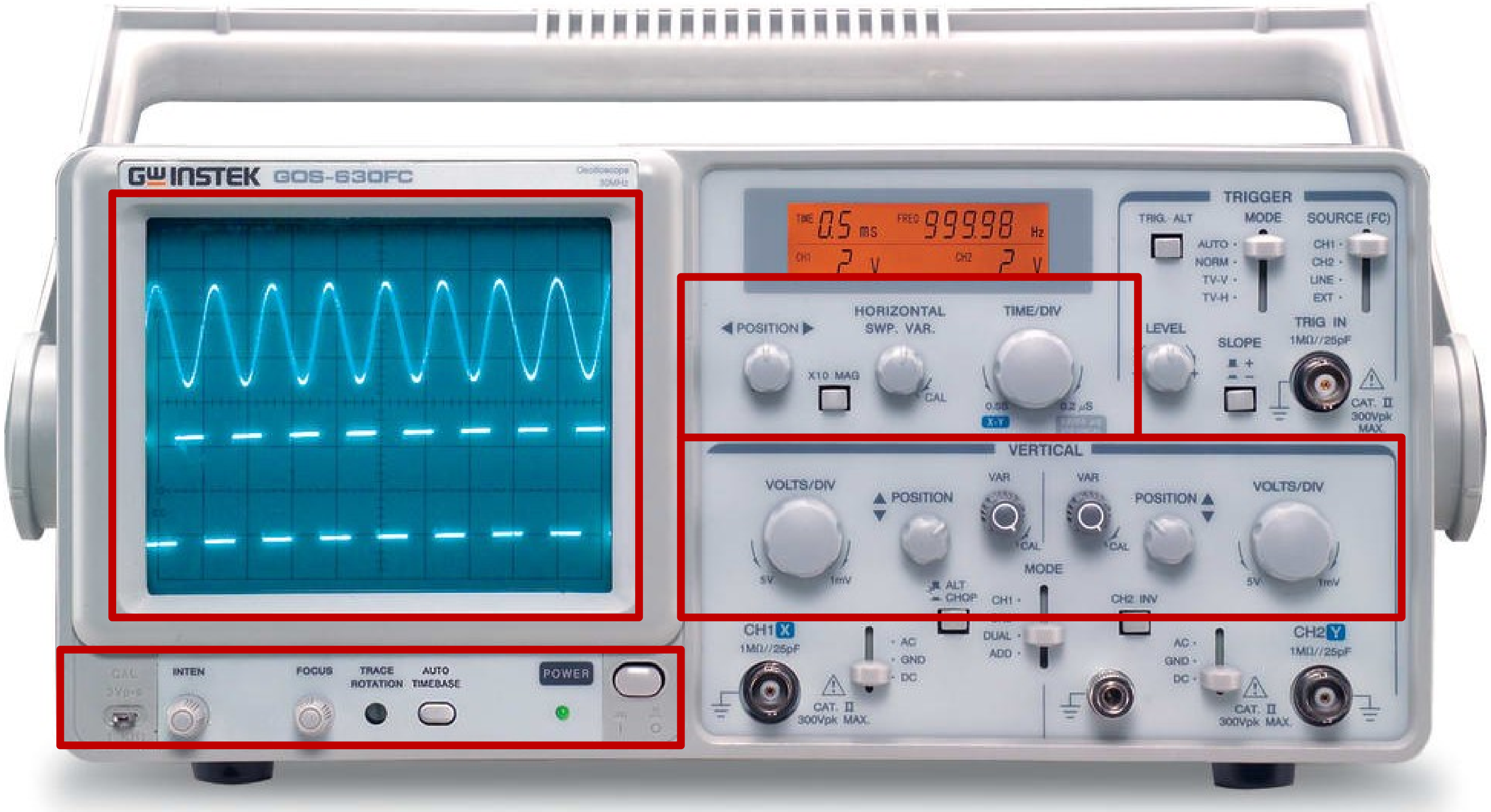
CATHODE
RAY
OSSCILOSCOPE

Cathode ray oscilloscope



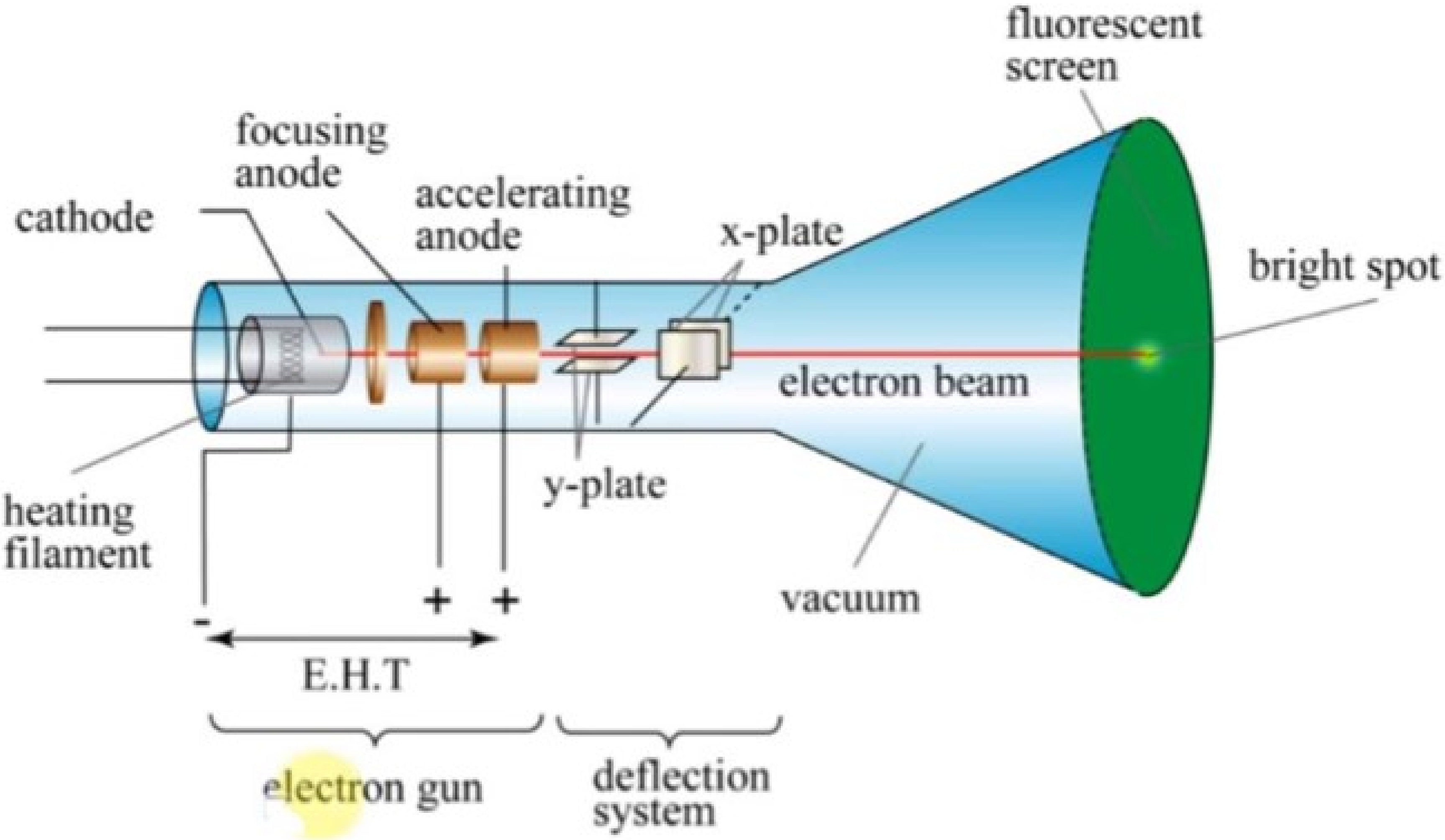
Introduction

- Heart of the oscilloscope is CRT, which
  - generates electron beam,
  - accelerates beam to a high velocity,
  - deflects the beam to create image, and
  - contains the phosphor screen where the electron beam eventually becomes visible.

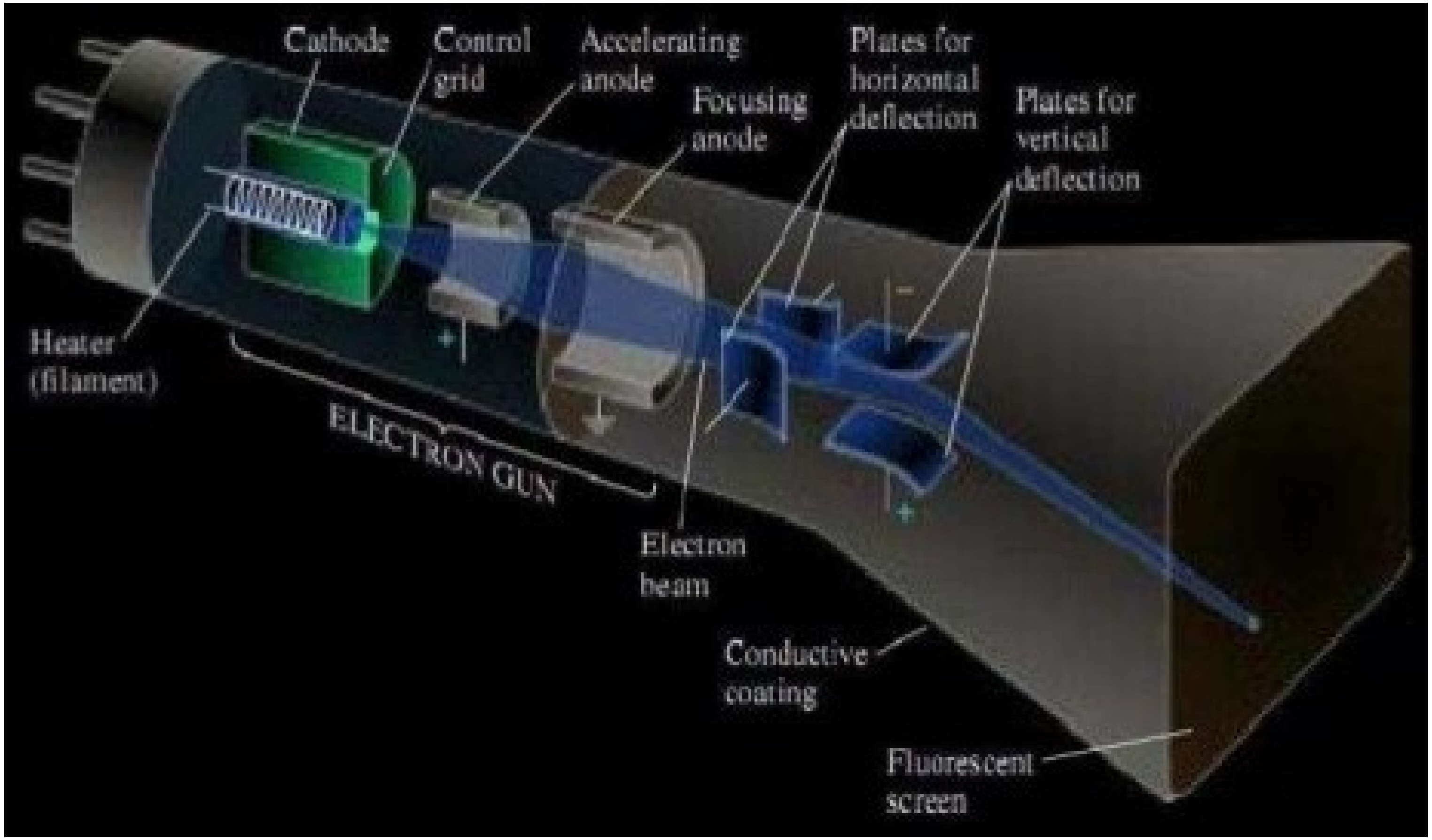
- Electrons are called **cathode rays** because they are emitted by the cathode and this gives oscilloscope its full name of cathode ray oscilloscope.

- CRO can measure
  - amplitude, frequencies and phase shift of various signals.

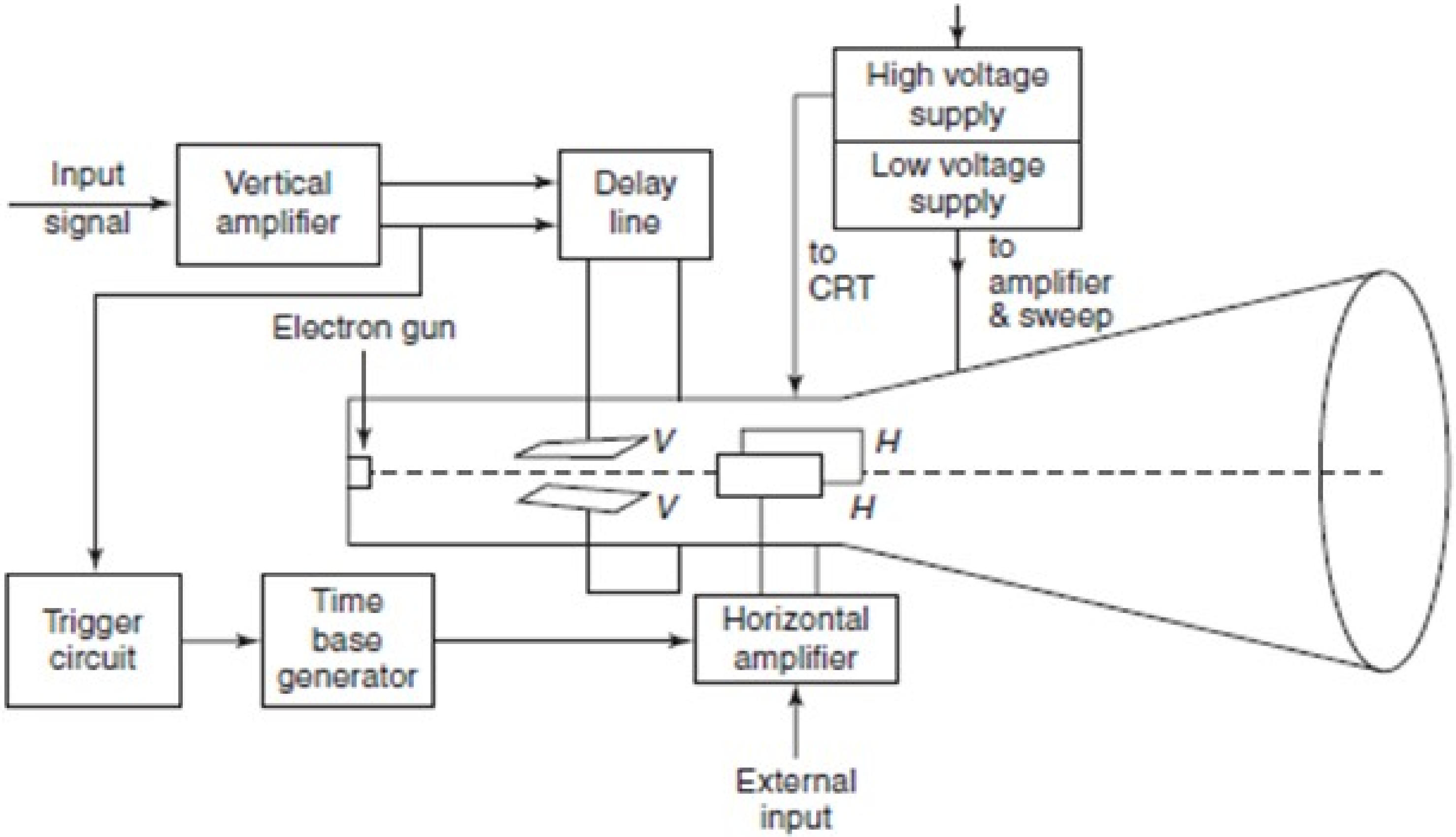
- Many physical quantities like temperature, pressure and strain can be converted into electrical signals by use of transducers, and the signals can be displayed on the CRO.


fluorescent screen
focusing anode
accelerating anode
cathode
x-plate
bright spot
electron beam
heating filament
y-plate
vacuum
+
+
-
E.H.T
electron gun
deflection system

CATHODE-RAY TUBE

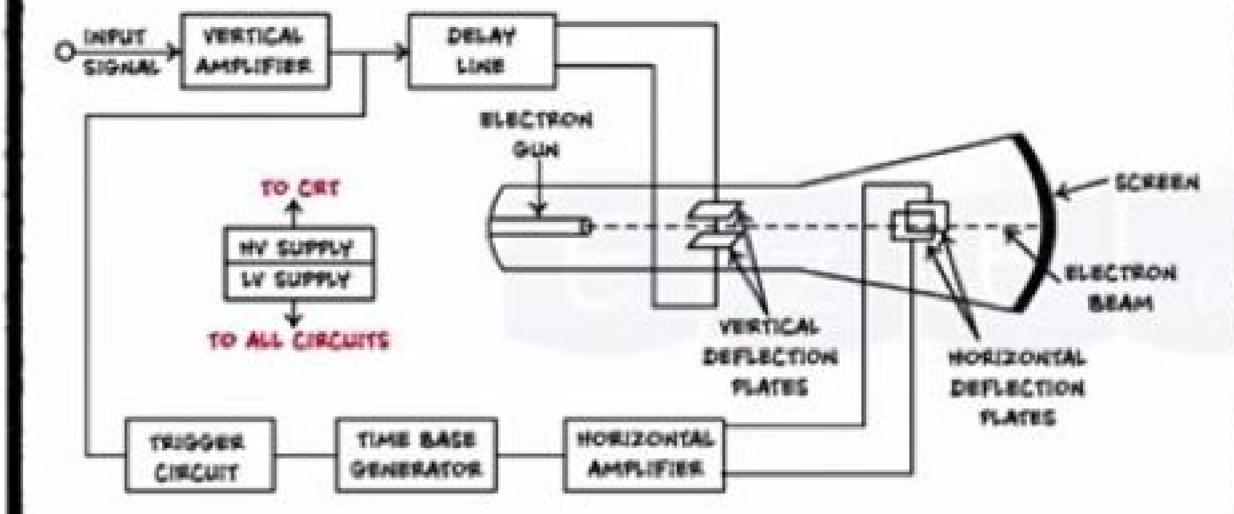


Block diagram of a cathode-ray oscilloscope



Block diagram of a cathode-ray oscilloscope

Power Supply



Block Diagram of General Purpose CRO

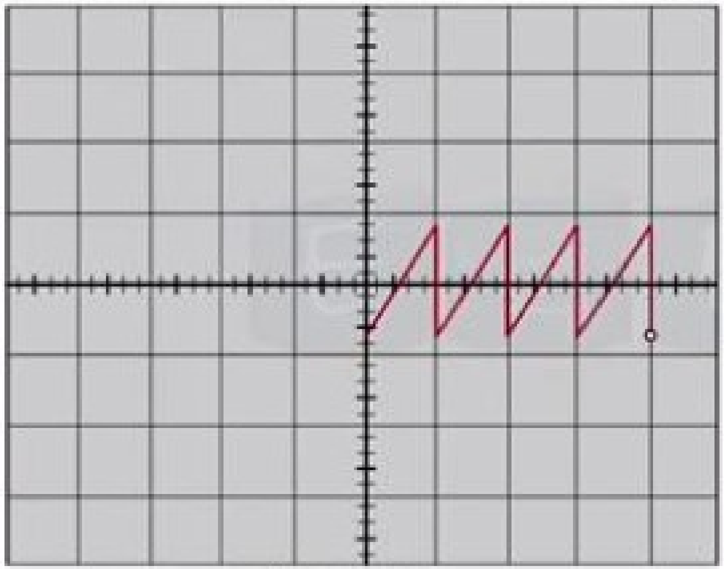
Low Voltage :

- Used for working of Electronic Circuits

High Voltage :

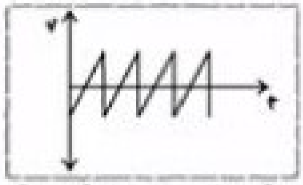
- Generates voltage of 1000 Volts to 1500 Volts

Time Base Generator



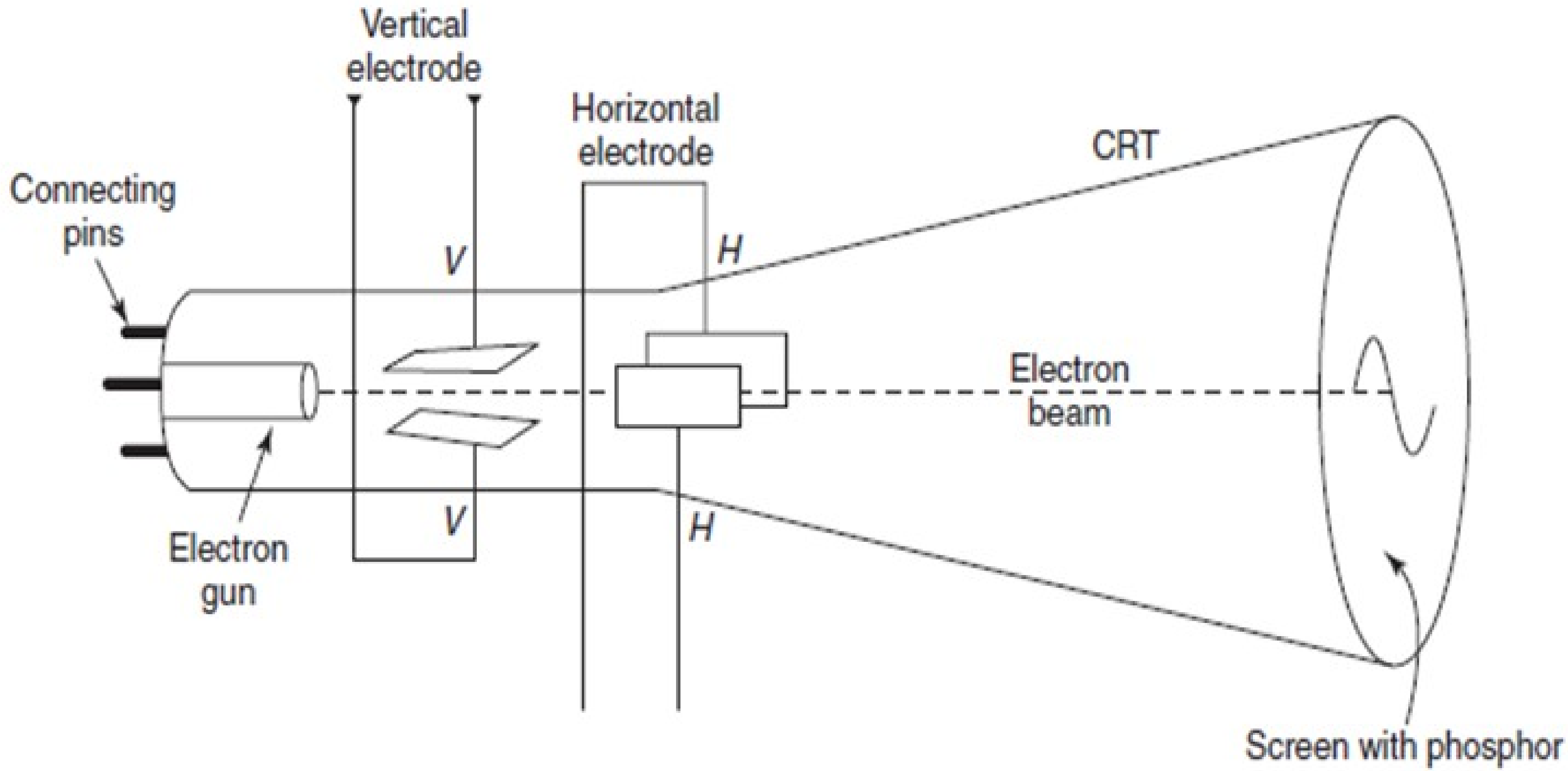
CRO Screen

- Generates Sawtooth Waveforms



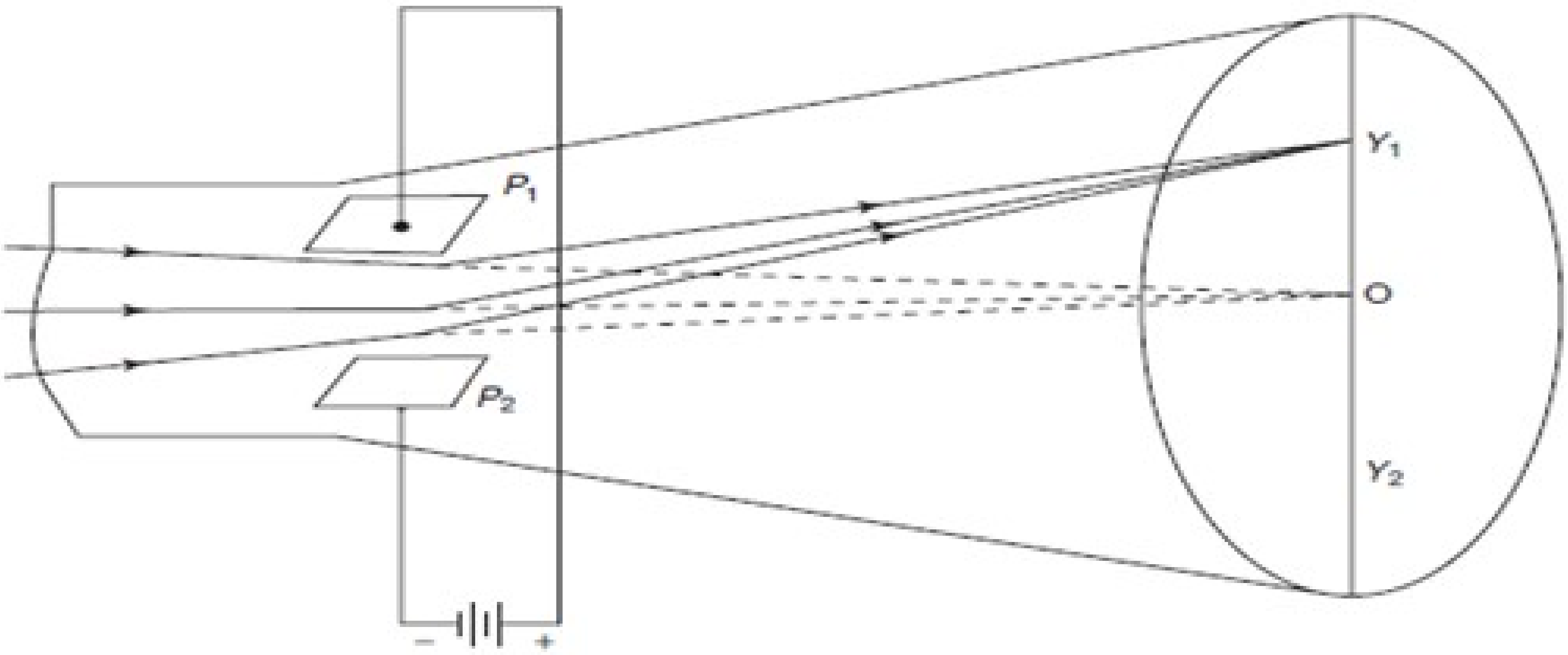
- Applied to Horizontal Deflection Plates
- Electron beam varies at constant velocity

CATHODE-RAY TUBE



Components of a cathode-ray oscilloscope

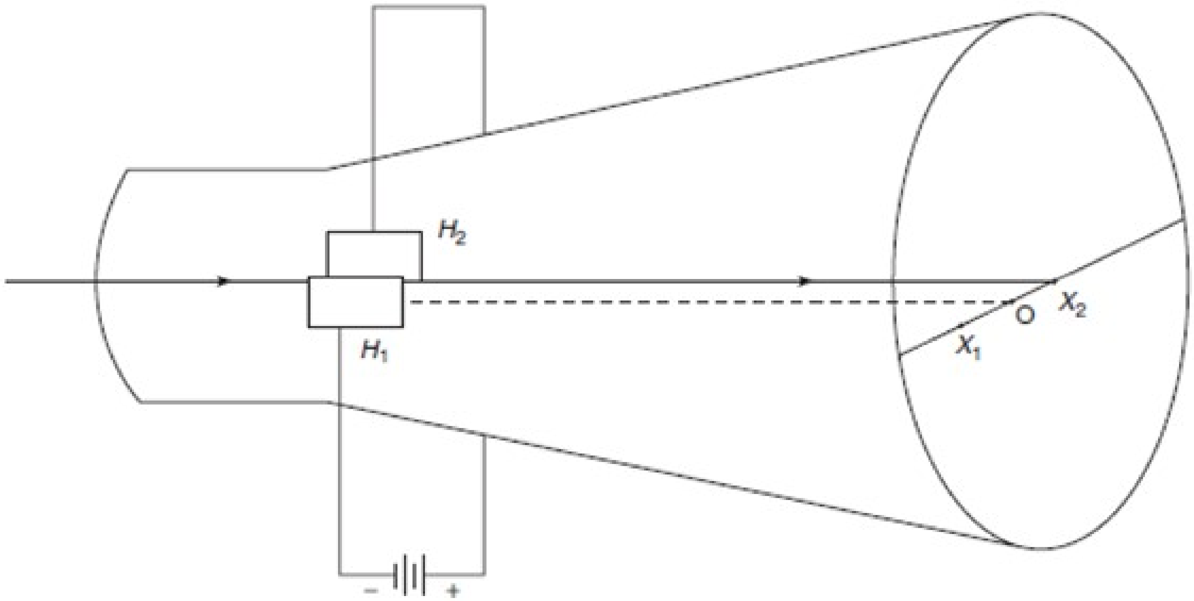
Deflection Systems



Deflecting system using parallel vertical plates

Deflection Systems:

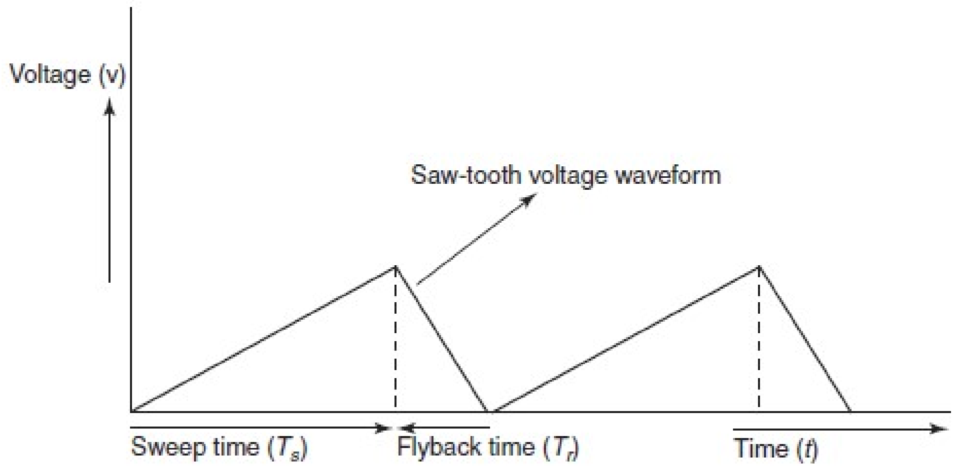
To deflect the beam horizontally, an alternating voltage is applied to the horizontal deflecting plates and the spot on the screen moves horizontally.

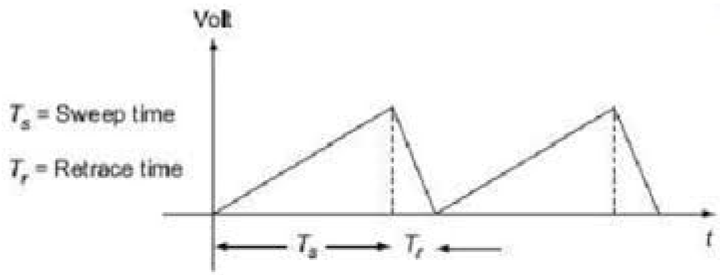


Deflecting system using parallel horizontal plate

TIME-BASE GENERATORS

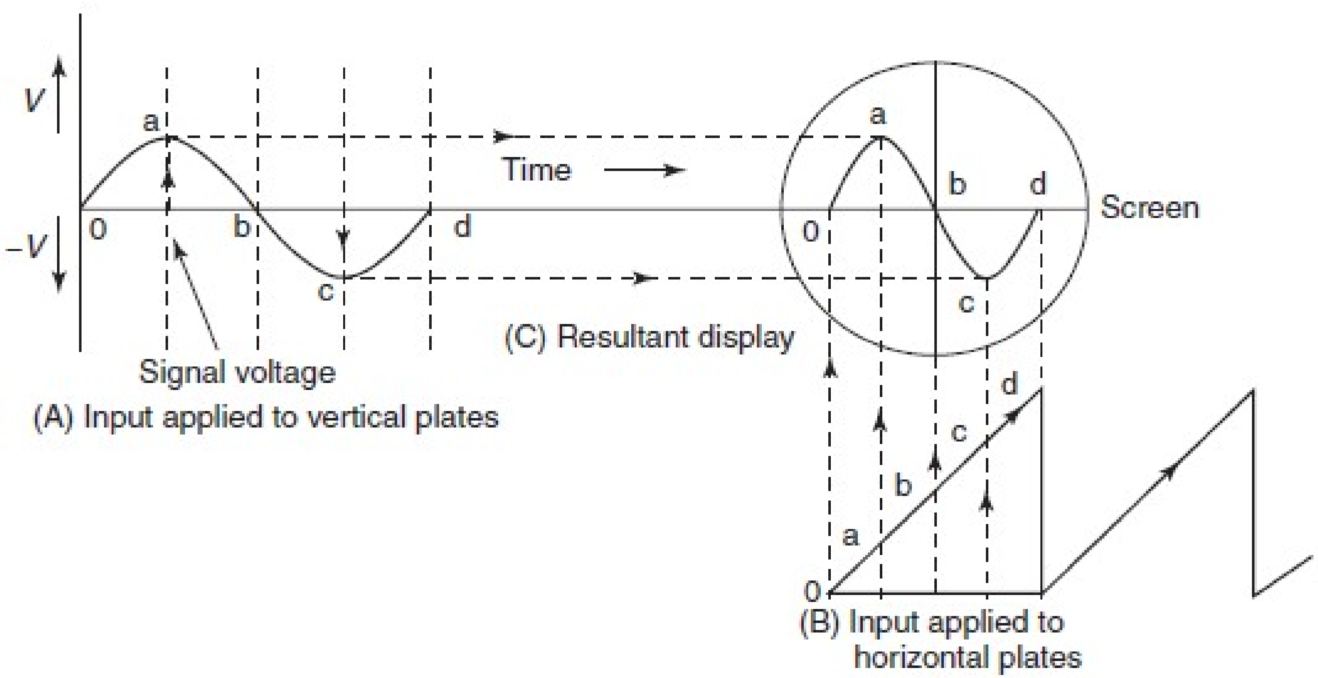
- CRO is used to display a waveform that varies as a function of time. If the wave form is to be accurately reproduced, the beam should have a constant horizontal velocity..
- Beam velocity is a function of deflecting voltage, the deflecting voltage must increase linearly with time.
- A voltage with such characteristics is called a ramp voltage.



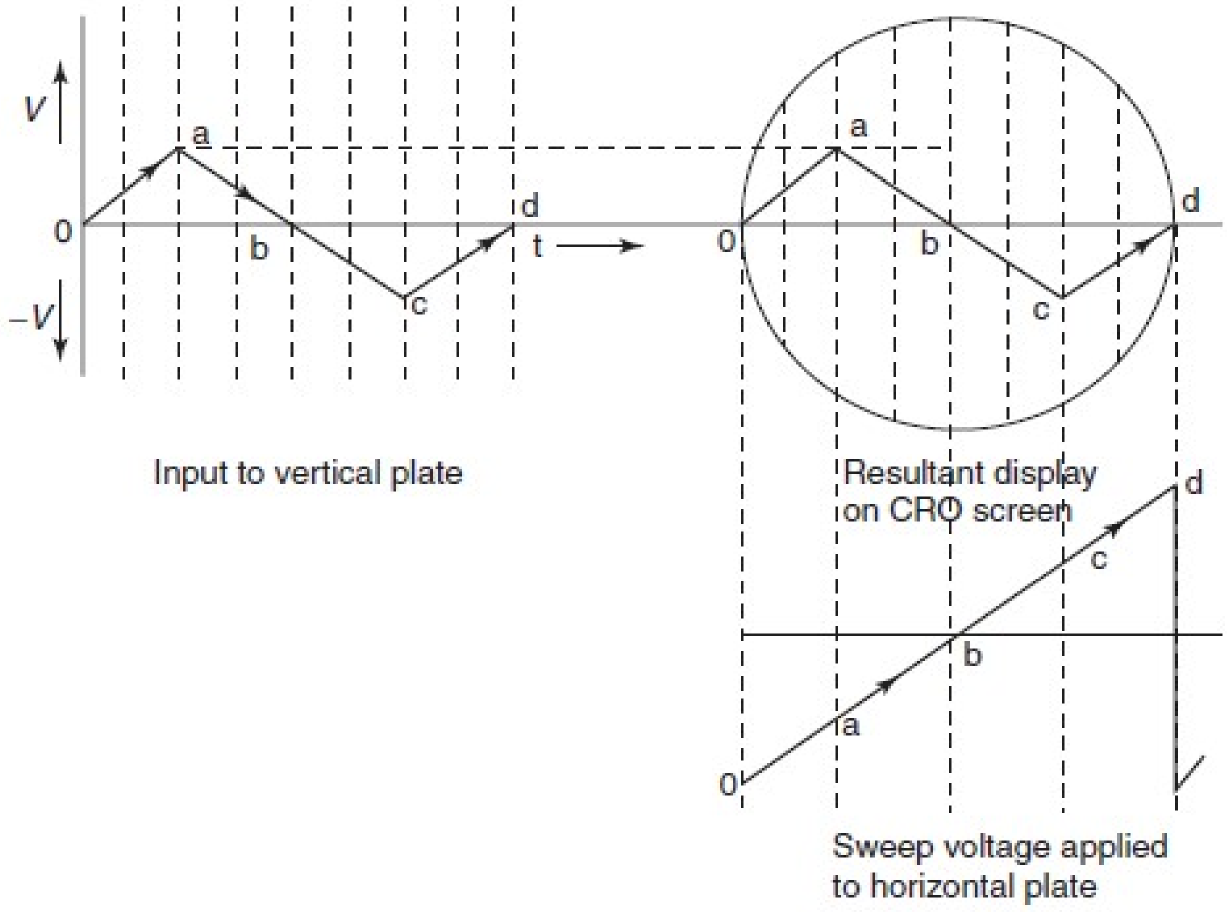


Display waveform on the screen

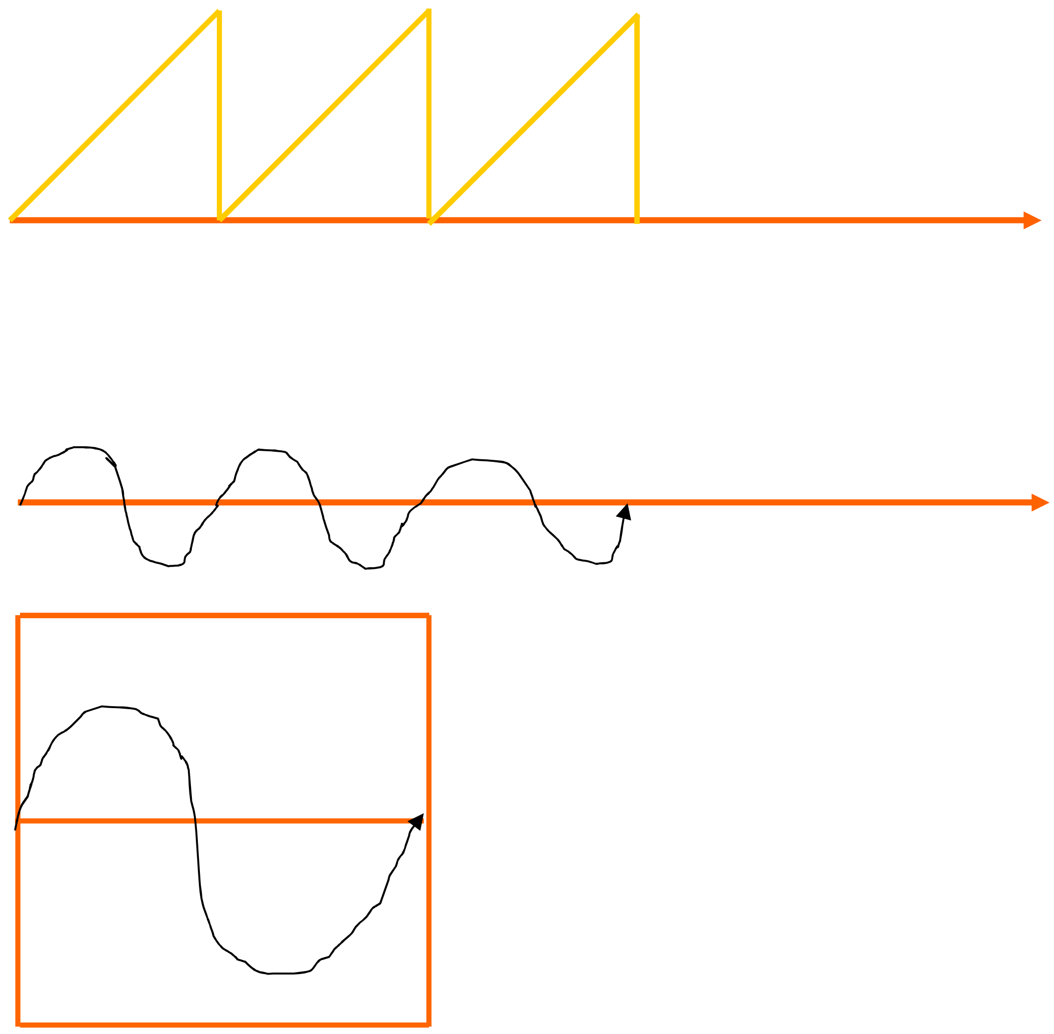
- Sine wave applied to vertical deflecting plates and a saw-tooth applied to the horizontal plates.
- The ramp at horizontal plates causes the electron beam to be deflected horizontally across the screen.



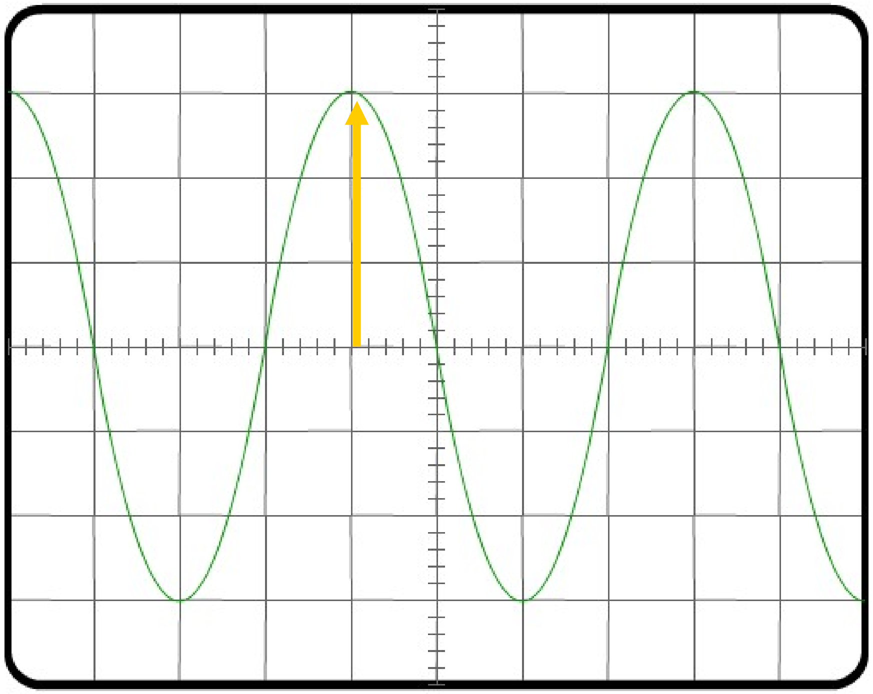
Triangular waveform



A sawtooth waveform applied on X-plate is having a frequency of 1kHz. Suppose a sine wave of frequency 1kHz is applied on Y plate then show the output on the CRT screen. What would be the output when the frequency of sine wave is doubled

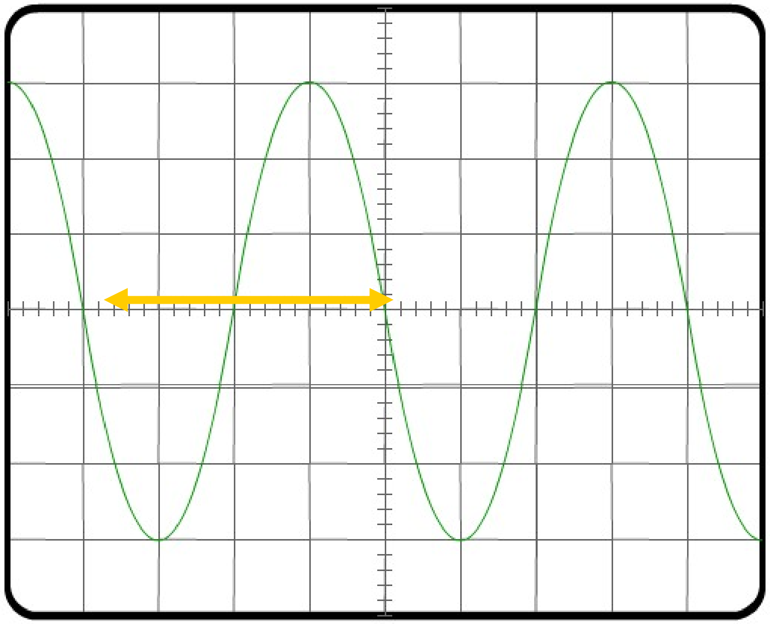


Peak voltage



Peak PD = 3 Divisions x 2.0 V/div = 6.0 V

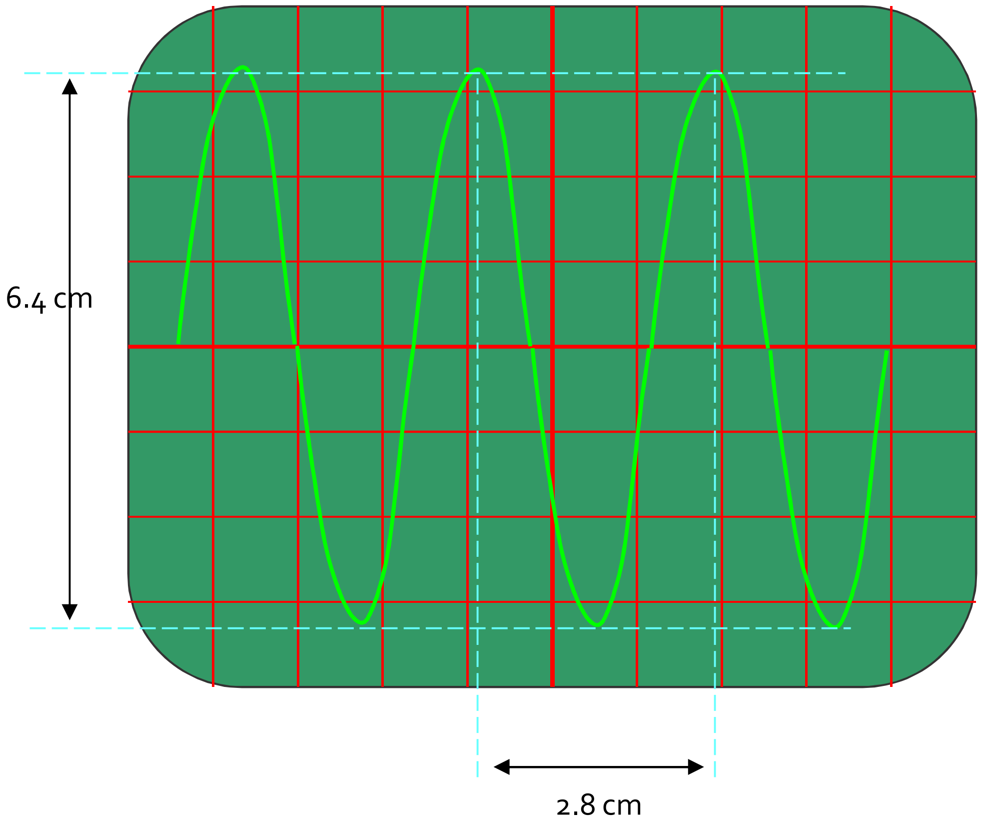
Period & frequency



period = 4.0 divisions x 0.5 ms/div = 2.0 ms

frequency = 1 / period
frequency = 1 / 0.002 s
frequency = 500 Hz

Reading the CRO



- The total height of the wave from peak to trough is 6.4 cm
  $\Rightarrow V_{pk\ to\ pk} = 12.8\ \mathrm{V}$
  $\Rightarrow V_o = \mathbf{6.4\ V}$

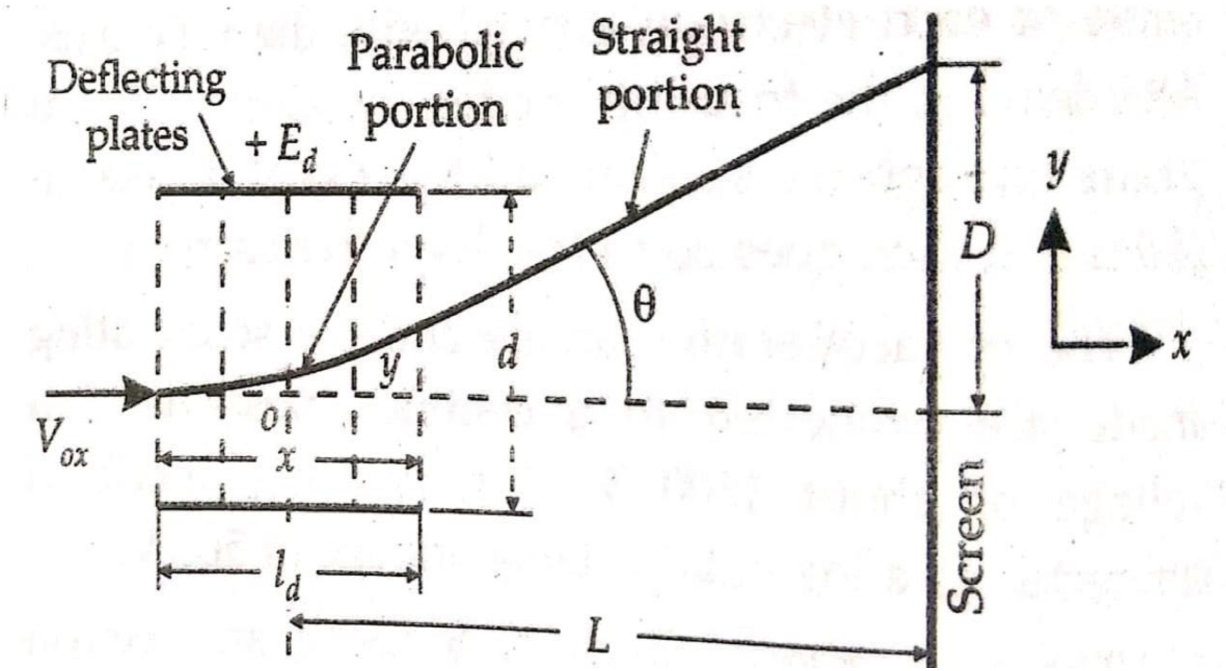
- 1 cycle occupies 2.8 cm
  $\Rightarrow T = 1.40\ \mathrm{ms} = \mathbf{1.40} \times \mathbf{10^{-3}}\ \mathrm{s}$

$\Rightarrow$ Frequency $= 1 \div 1.40 \times 10^{-3}\ \mathrm{s}$ $= \mathbf{714\ Hz}$

The time base controls are set at 5 ms/cm
The voltage gain is set at 2 V/cm

Spot Beam Deflection Sensitivity

- Two parallel plates with a potential applied between them.
- These plates produces a uniform electrostatic field in the Y direction. So, an electron entering the field will experience a force in the Y direction.
- There is no force either in X- direction Z-direction.



Spot Beam Deflection Sensitivity

$$D = L\frac{e\epsilon_y l_d}{m{v_{0x}}^2} = \frac{Ll_dE_d}{2dE_a}$$

D = deflection on the fluorescent screen
L=distance from center of deflection plates to screen
Ld = effective length of the deflecton plates
d=distance between the deflection plates
Ed = deflection voltage
Ea = accelerating Voltage

Deflection Sensitivity: It is defined as the deflection on the screen per volt of deflection voltage .

$$\text{deflection } sensitivity = \frac{D}{E_d} = \frac{Ll_d}{2dE_a}$$

Deflection Factor: It is the reciprocal of deflection factor G

$$\text{deflection } factor = \frac{1}{S} = \frac{2dE_a}{Ll_d}$$

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 type of phosphor used, determines the color of the light spot.

- The phosphor isotope, P31, produces yellow–green light with relative luminance of 99.99%.

Fluorescent Screen

- The property of some crystalline materials, such as phosphor or zinc oxide, to emit light when stimulated by radiation is called **fluorescence.**

- Fluorescent materials have a second characteristic, called **phosphorescence**, which refers to the property of the material to continue light emission even after the source of excitation (in this case the electron beam) is cut off.

- The length of time during which phosphorescence, or afterglow, occurs is called the **persistence** of the phosphor.

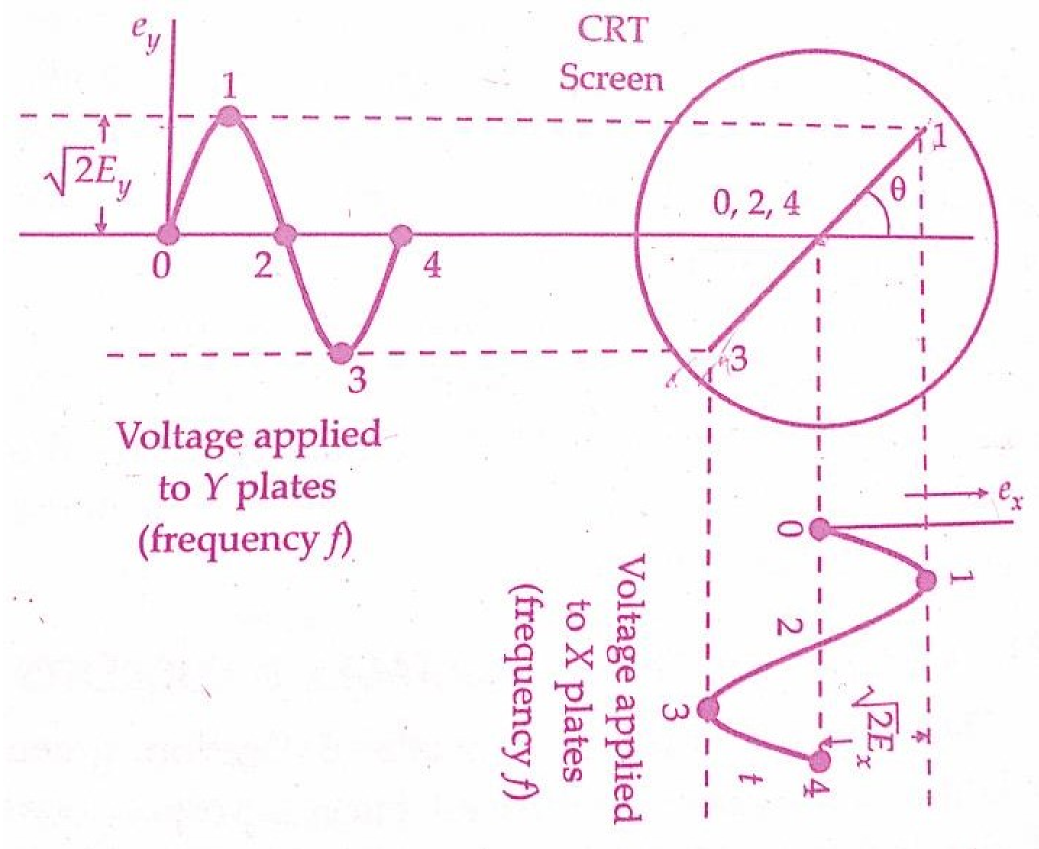
- The intensity of the light emitted from the CRT screen, called **luminance**

Fluorescent Screen

Phosphor Type	Flourescence	Phosphorescence
P1	Yellow green	Yellow green
P2	Blue green	Yellow green
P4	White	White
P7	Blue	Yellow green
P11	Purple blue	Purple blue
P31	Yellow green	Yellow green

Lissajous patterns (for frequency and phase calculations)

- Two Channel CRO using Multiplexer
- When the two sinusoidal voltages of equal frequencies which are in phase with each other are applied to the horizontal as well as to the vertical deflection plates, the pattern appearing on the screen is a straight line.
- X-signal on X-axis and Y-signal on Y-axis

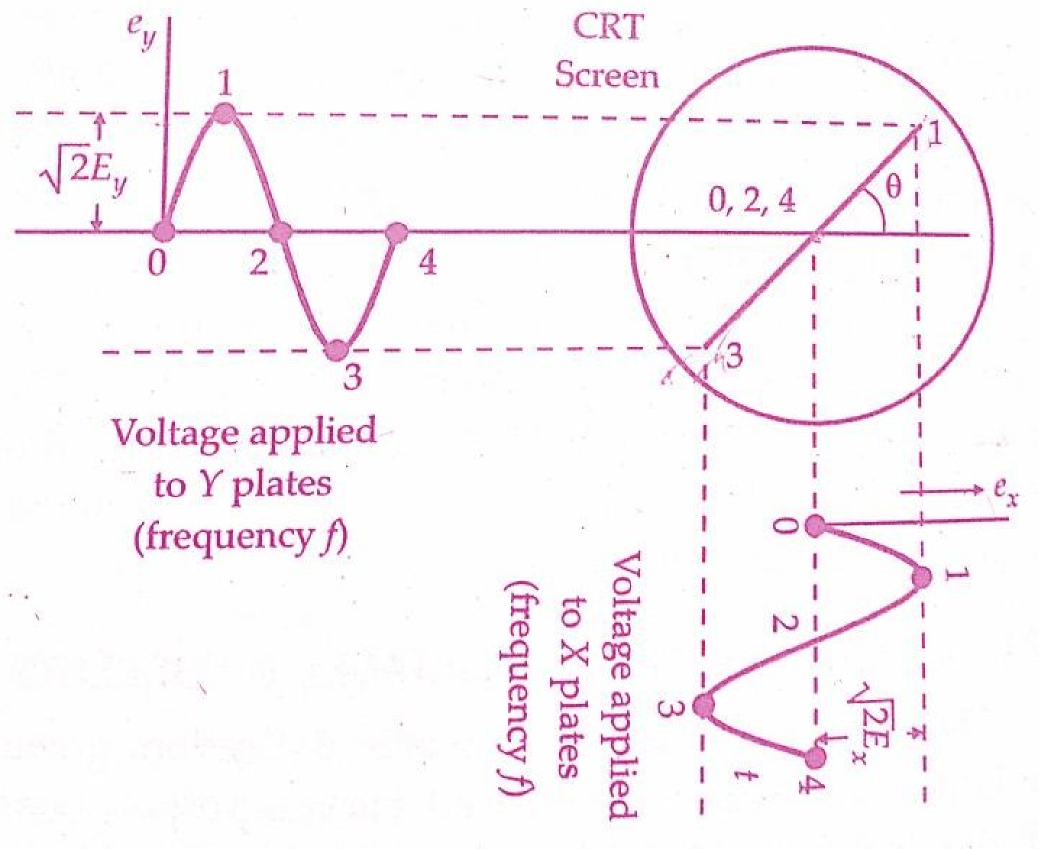


Lissajous patterns (for frequency and phase calculations)

$$v_x = v_m sin\omega t$$
$$v_y = v_m \sin(\omega t + \emptyset)$$

Case-I, $\emptyset=0$

$$v_x = v_m sin\omega t$$
$$v_y = v_m \sin(\omega t)$$

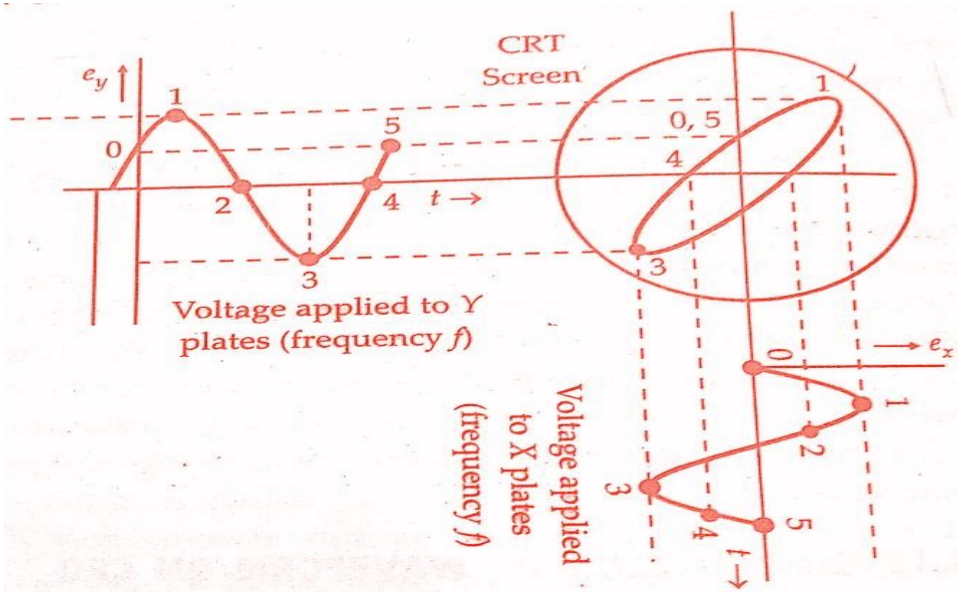


Lissajous patterns (for frequency and phase calculations)

Case-II,0<ø<90

$$v_x = v_m sin\omega t$$
$$v_y = v_m \sin(\omega t + 60)$$

At t=0 , vx = 0 , vy = 0.86 vm
At wt = 30 , vx = vm/2. , vy = vm
At wt =60 , vx = 0.86 vm , 0.86 vm



2. When two equal voltages of equal frequency but with a phase shift (not equal to 0 or 90) are applied to the CRO then we will obtain an ellipse shape. An ellipse is also obtained when unequal voltages of same frequency are applied to the CRO.

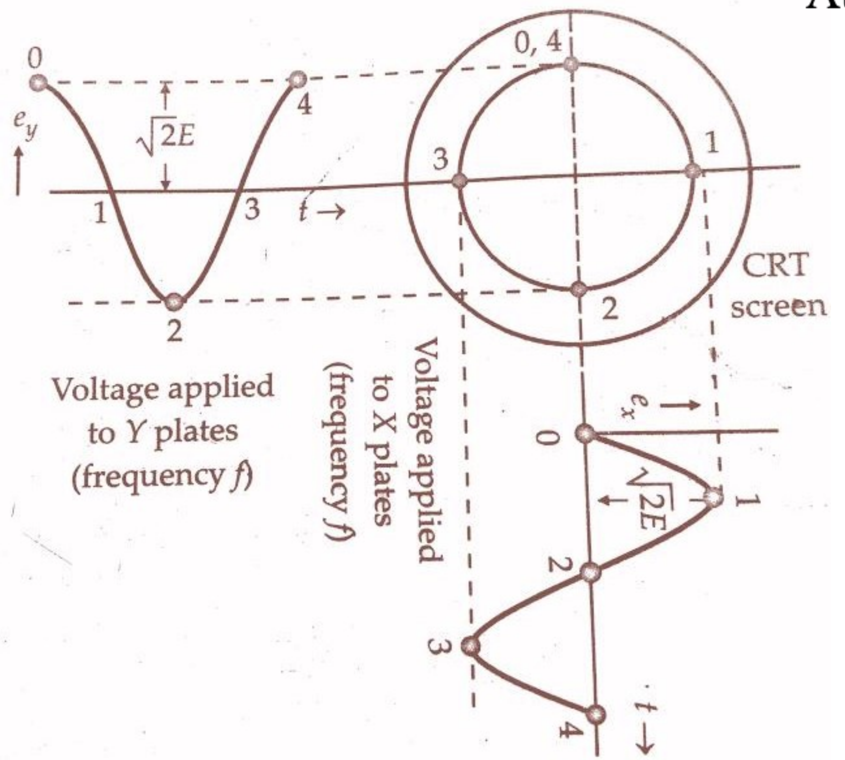
Lissajous patterns (for frequency and phase calculations)

Case-III, $\emptyset=90$

3. When two equal voltages of equal frequency but with 90*o* phase shift are applied to the CRO the trace on the screen is a circle.

$$v_x = v_m sin\omega t$$
$$v_y = v_m \sin(\omega t + 90) = v_x = v_m cos\omega t$$
$$v_x\text{^}2 + v_y\text{^}2 = v_m\text{^}2$$

At t=0 , vx = 0 , vy = 0.86 vm
At wt = 30 , vx = vm/2. , vy = vm
At wt =60 , vx = 0.86 vm , 0.86 vm

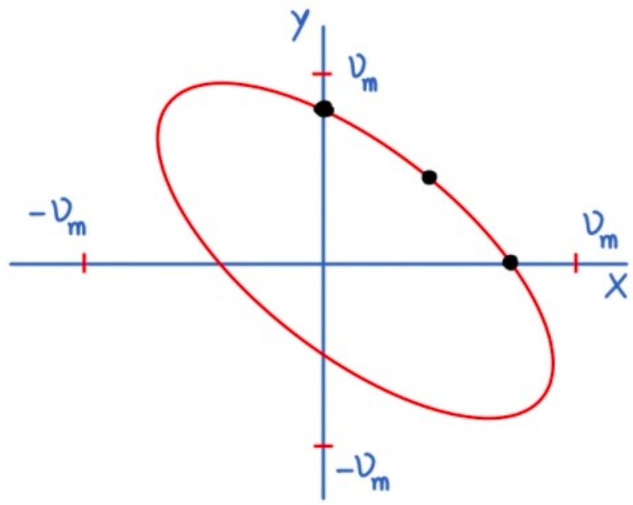


Lissajous patterns (for frequency and phase calculations)

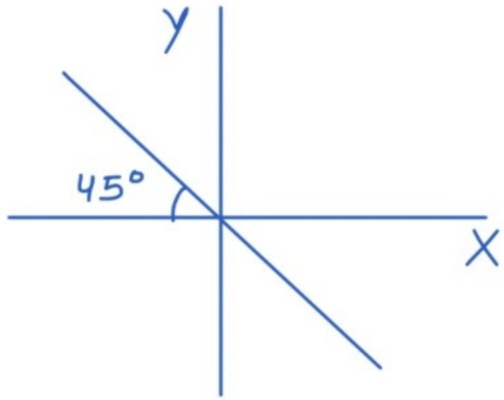
Case-IV,90<ø<180

$$v_x = v_m sin\omega t$$
$$v_y = v_m \sin(\omega t + 60)$$

At t=0 , vx = 0 , vy = 0.86 vm
At wt = 30 , vx = vm/2. , vy = vm
At wt =60 , vx = 0.86 vm , 0.86 vm

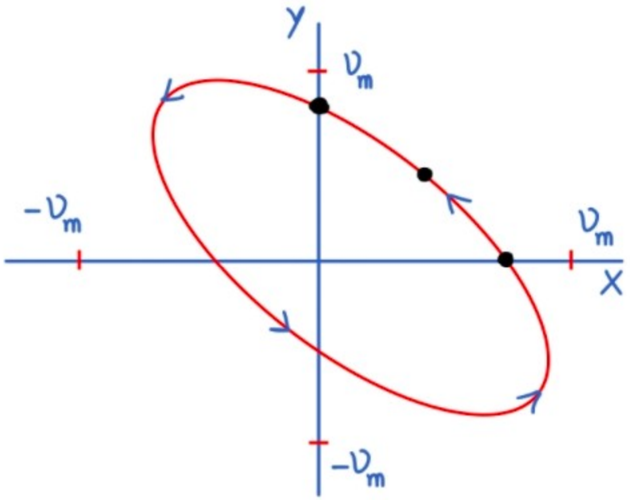


Case-V, ø=180



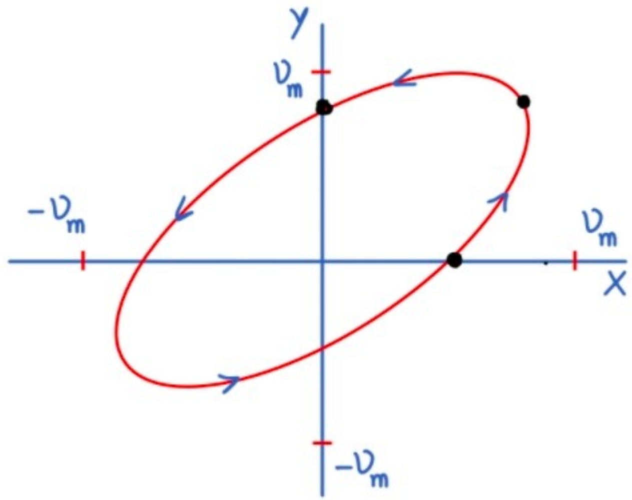
Lissajous patterns (for frequency and phase calculations)

Case ⑥ $180° < \phi < 270°$



Lies in – II & IV

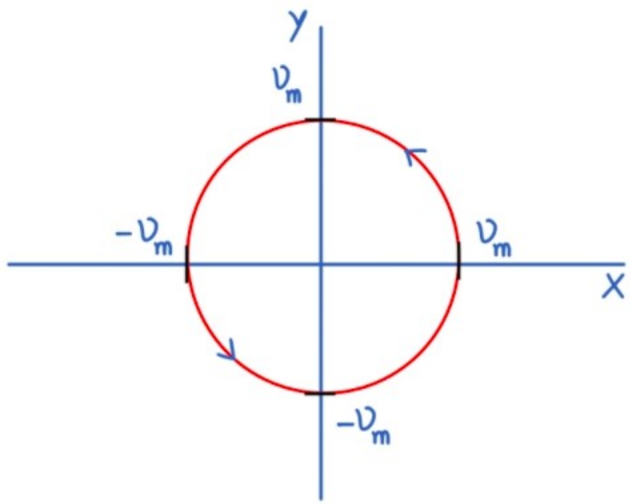
Case ⑦ $270° < \phi < 360°$



Lies in – I & III

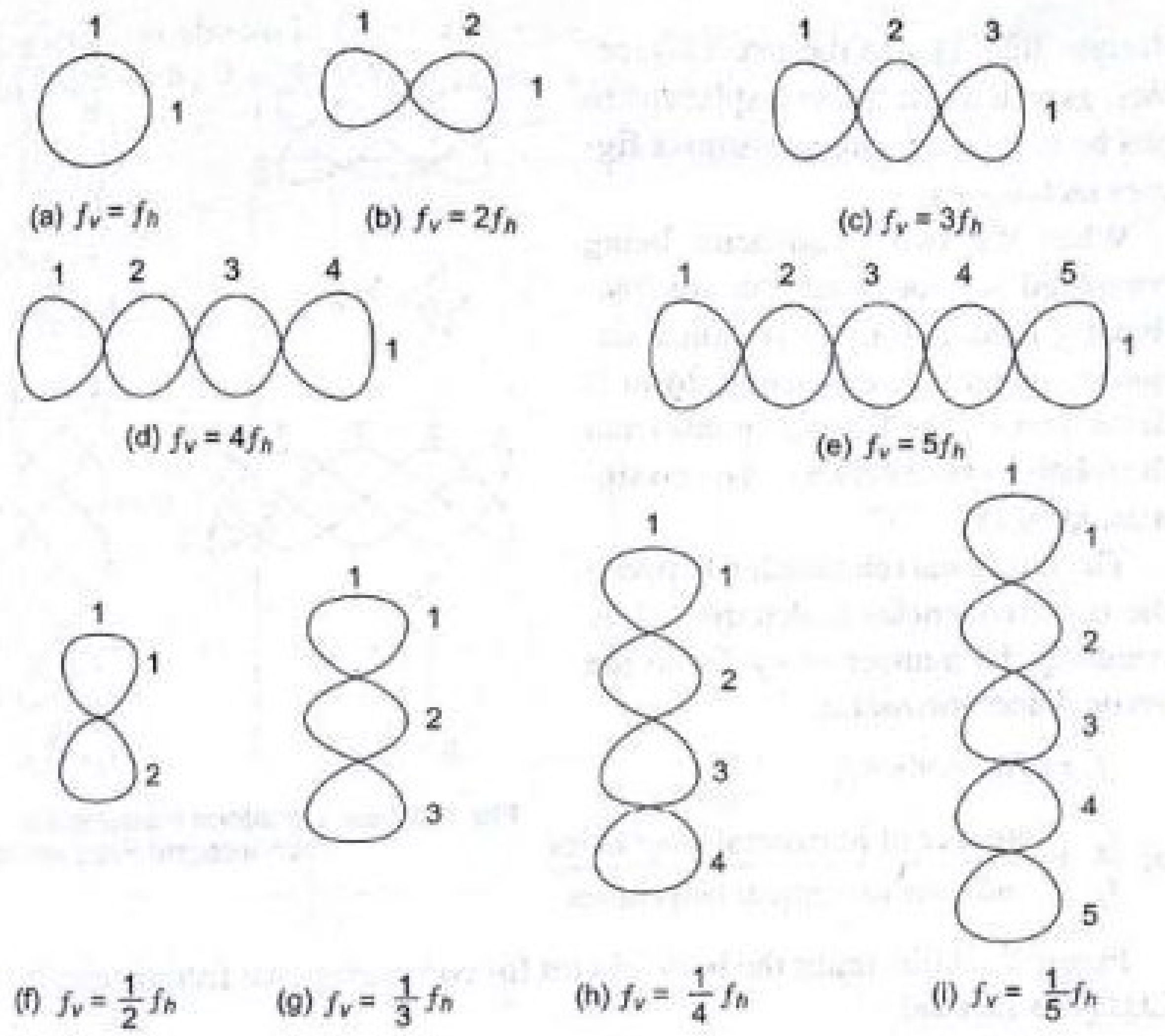
Lissajous patterns (for frequency and phase calculations)

Case 8 $\phi = 270^\circ$



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

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



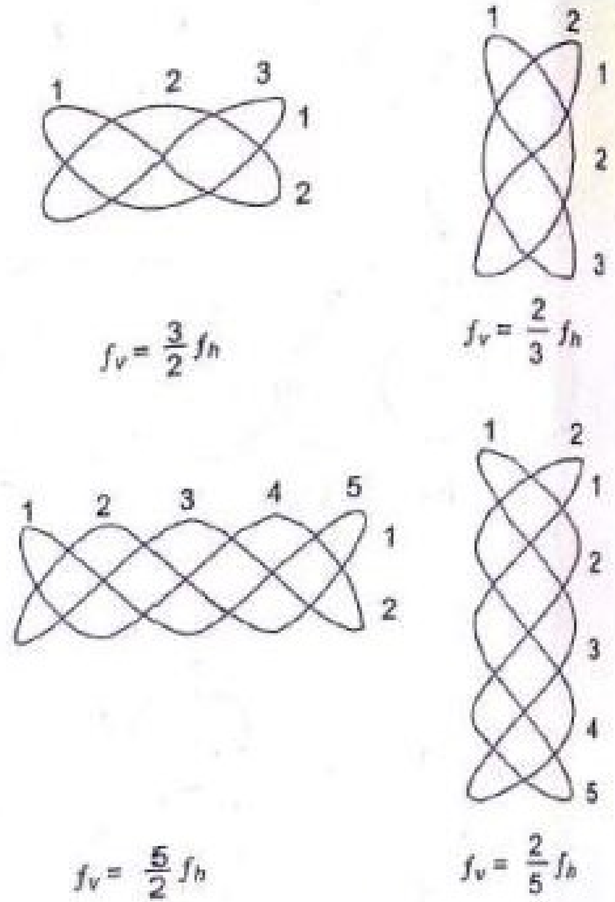
(a) $f_v = f_h$ (b) $f_v = 2f_h$ (c) $f_v = 3f_h$

(d) $f_v = 4f_h$ (e) $f_v = 5f_h$

(f) $f_v = \frac{1}{2} f_h$ (g) $f_v = \frac{1}{3} f_h$ (h) $f_v = \frac{1}{4} f_h$ (i) $f_v = \frac{1}{5} f_h$

Measurement of Frequency by Lissajous method

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.



Lissajous Patterns for Non-Integral Frequencies