UNIT- I
ELECTRON OPTICS

ELECTRON OPTICS

- ***Electron Refraction (Bethe's Law):***

The motion of electron beam in non-uniform electric field can be understood by studying Bethe'slaw. The non uniform electric field is a field in which electric intensity varies from point to pointand field lines are not straight and evenly spaced. Electron motion in non-uniform electric field isbetter understood with the help of equipotential surfaces. Equipotential surfaces are those surfaceswhere electric potential remains constant and electric lines are perpendicular to the surface at anypoint. Therefore the normal to the equipotential surface shows the line of action of electric force ontheelectron.

Let us consider a uniform electric field produced in an infinitesimally thin region. Thisuniform electric field being set up by two metal plates charged to appropriate potentials. Theelectrons are allowed to pass through the electric field being set up by two closely spaced metalgridsas shown infig.

Consider an equipotential surface AB. It is considered as the boundary across which thepotential V_1 abruptly changes to V_2. Let an electron travel through the region-I with a uniformvelocity$v_1$and entertheregion-IIandmoves with avelocityv_2.

As the electrons passes through equipotential surface AB it experiences a force which altersits velocity. Because the electric field exists only in the vertical direction (Y-direction). Hence thenormal component of electron velocity v_y undergoes a change whereas the tangential component $v_x$remainsconstant.

If $V_2>V_1$, $v_y$increasesand if $V_2<V_1$, $v_y$decreases.

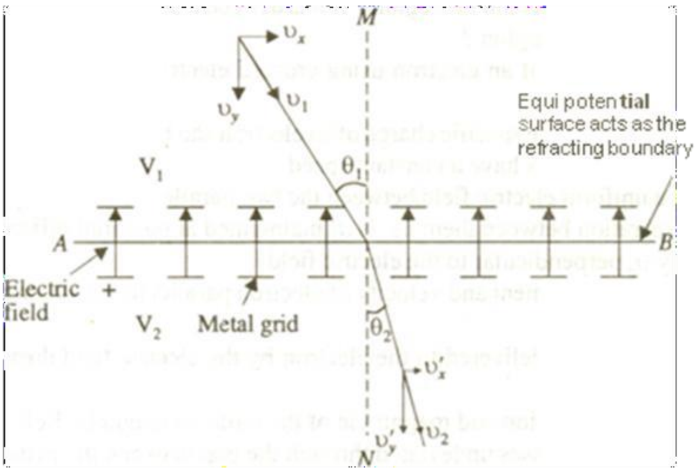


Fig:ElectronRefraction

Intheabovefig.,$V_2>V_1$i.e.V_2istakentobegreaterthanV_1andhence$v_y$increases.Theelectronpathis thereforebent nearer to thesurfacenormal.

As the tangential componentof the velocityremainsconstant inregion-Iandregion-IIwecanwrite,

$v_x = v'_x$

$$v_1 \sin\theta_1 = v_2 \sin\theta_2$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_2}{v_1} \text{-----}(1)$$

Thevelocityofelectron in termsof potential isgiven by

$$v = \sqrt{\frac{2eV}{m}}$$

$$\text{So,}\quad \frac{\sin\theta_1}{\sin\theta_2} = \frac{\sqrt{2eV_2/m}}{\sqrt{2eV_1/m}}$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \sqrt{\frac{V_2}{V_1}}$$

$$\frac{\sin\theta_1}{\sin\theta_2} = \left[\frac{V_2}{V_1}\right]^{1/2} \quad \text{-----(2)}$$

The**Eqn.(2)**issimilartoSnell’slawofrefractioninopticsandisknownasBethe’slawforelectron refraction. When light enters from rarer to denser medium it gets slowed down and bendstowards the normal.However when electrons are moving fromregion of lower potential to regionofhigher potentialgets accelerated and bends toward thenormal.

ComparisonBetweenSnell’sLawandBethe’sLaw:

Snell’sLaw	Bethe’sLaw
1. $\frac{\sin i}{\sin r} = \frac{v_1}{v_2} = \frac{\mu_2}{\mu_1}$	1. $\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_2}{v_1} = \sqrt{\frac{V_2}{V_1}}$
2.Itdealswithrefractionof light.	2.Itdealswithrefractionof electrons.
3.Alightenteringfromararermedium to denser medium bendstowardsthenormal.	3.An electron entering from a region oflow potential to high potential bendstowardthenormal(i.e.bendstoward thedirectionofelectricfield).
4.Alightenteringfromararermedium to denser medium decreasesinvelocity.	4.Anelectronenteringfromaregionoflowpotentialtoaregionofhigh potentialincreasesinvelocity.

Eqn.(2)canbeextendedto anyarbitraryelectrostaticfieldwhich isnonuniform.
Fig. demonstrates the motion of an electron ina nonuniform electric field represented byequipotentialsurfacesseparatingequipotential regions of potentials **V_1 ,V_2 ,V_3 ,V_4**etc.At eachsurfaceelectronpath bendstowards orawayfrom thehigher or lower potential region. It is seen that theelectron motion occurs along a curved path in anonuniformelectricfield.

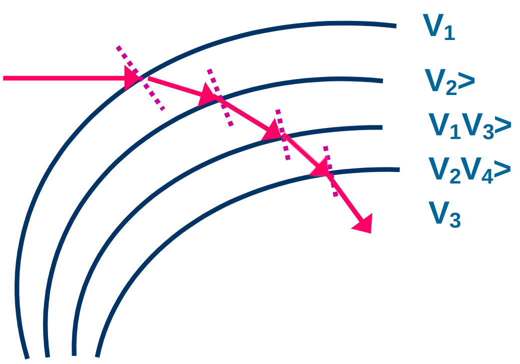


Fig : Electron Refraction in aNonuniformElectric

• *Electron Lens or Electrostatic Lens:*

An electron lens is an electrical component that focuses an electron beam to a point.

Principle: A stream of electrons bends at each equi-potential surface when it travels through a non-uniformelectric field. Thus non-uniform electric field can be used to focus or defocus electron rays. C.J. Davisson and C.J. Calbick demonstrated in 1931 such optical properties of electrostatic fields.

Construction/Description:

An electrostatic lens consists of two coaxial short cylindrical metal tubes $\mathbf{T_1}$and $\mathbf{T_2}$of same size and separated by small distance. They are held at different potentials $\mathbf{V_1}$and $\mathbf{V_2}$respectivelysuch that $\mathbf{V_2 > V_1}$. Electric field does not exist inside the cylindrical metal tubes; however a non-uniform electric field is produced in the gap between the tubes as a result of different potentials applied to the tubes. **Fig.** shows a schematic of a simple electrostatic lens wherein electric field lines and equipotential surfaces are demonstrated. The equipotential surfaces are perpendicular to theelectric field lines everywhere.

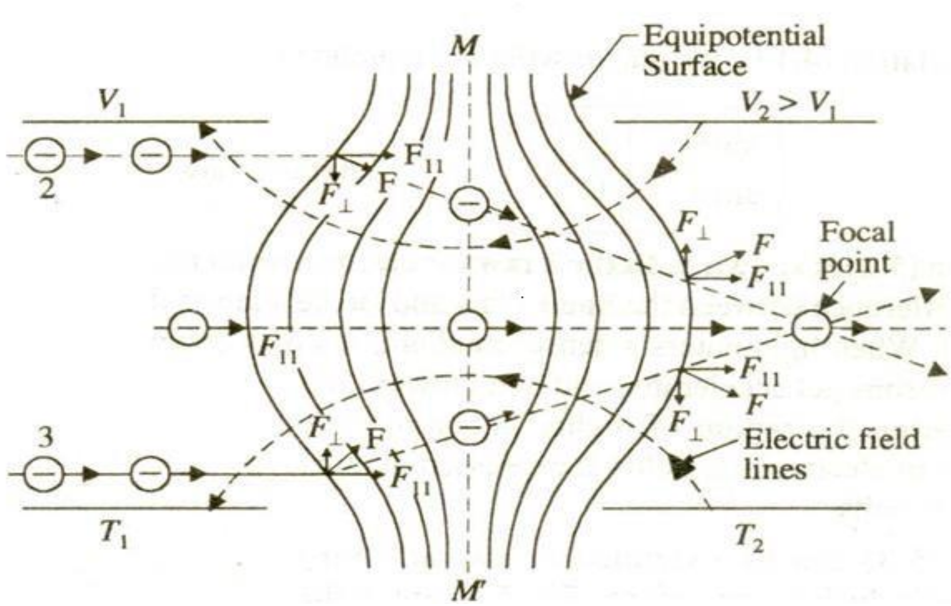


Fig: Schematic of Electron Lens

Working:

Let us consider a thin bundle of electron rays parallel to the axis and entering the system from the side of the cylindrical metal tube which is at a lower potential V_1.

Electron moving along the axis of the two tubes (shown by position 1) on reaching the equi-potential surface, experience an electric force acting along the axis in forward direction so the electrons would be accelerated in forward direction towards tube T2 along the axis and would not deviate from their initial direction of travel.

The electrons traveling at a distance above the axis (shown by position 2) on reaching the convex equi-potential surface in the gap experience electrostatic force F acting at an angle to the direction of their motion. This force **F** experienced by the electrons at the convex equipotential surface can be resolved into two rectangular components; $F_{\parallel}$ parallel to the axis and $\mathbf{F_\perp}$ perpendicular to the axis of the tube.

The action of the $F_{\parallel}$ component is to accelerate the electrons along the axial direction. These electrons would be acted upon by $\mathbf{F_\perp}$ component and get deflected towards the axis and are also simultaneously accelerated toward tube $\mathbf{T_2}$ due to the force component $F_{\parallel}$. Similarly electrons moving below the axis (shown by position3) are deflected upward towards the axis and areaccelerated in forward direction. Thus all the off axis electron paths around the axis tend to converge toward the axis.

However on crossing the mid plane **MM'** of the gap, the converging electron rays encounter equi-potential surface of concave shape. In this region the normal component **$F_\perp$** is directed away from the axis and hence the electrons tend to diverge. However the parallel component $F_{\parallel}$ acts to accelerate the electrons further in the direction parallel to the axis. Similarly electrons traveling at a distance below the axis of the tube would be deflected towards the axis in the first half of the gap and deflected away from the axis in the second half of the gap and the net result is that the field between **T_1**and the midplane **MM'** converges the electron beam like a convex lens while the field between the midplane **MM'** and **T_2**diverges the electron beam like a concave lens.

The electrons spends a greater time in the first half of the gap as it travels slower and the impulse '$F_{\parallel}$ t' is greater for the convergence interval. In the second half the electrons move faster and spends less time and the impulse '$F_{\parallel}$ t' is smaller for the divergence interval. Consequently, the electrons rays are less diverged by the second half than converged by the first half of the gap. Therefore the converging action of the first half of the gap will be stronger than diverging action of the second half of the gap and the electron ray emerge from T2 will be sufficiently convergent as shown in fig.

Comparison of electrostatic lens with glass lens

- Light rays are bent only at the two boundaries of a lens but electron beam is refracted continuously through successive equi-potential surfaces.
- Secondly focal length of glass lens is fixed while focal length of electron lens may be varied by adjusting the potentials $V_1$and **V_2** of the tubes.

Applications: Electron lens forms the most important component of an electron gun used for producing narrow intense electron beam. Electron lens action is utilized in particle accelerators to focus charged particles into a narrow beam.

Electron Gun:

An electron gun is a device which produces (focuses and accelerates) an arrow electron beam of high intensity. It was designed by V. K. Zworyk in in1933.

Principle: The electron gun makes use of the fact that non-uniform electric field causes bending of electron paths and an appropriate configuration of non-uniform electric field leads to focusing of electrons.

Construction: The schematic diagram of an electron gun is shown in fig.

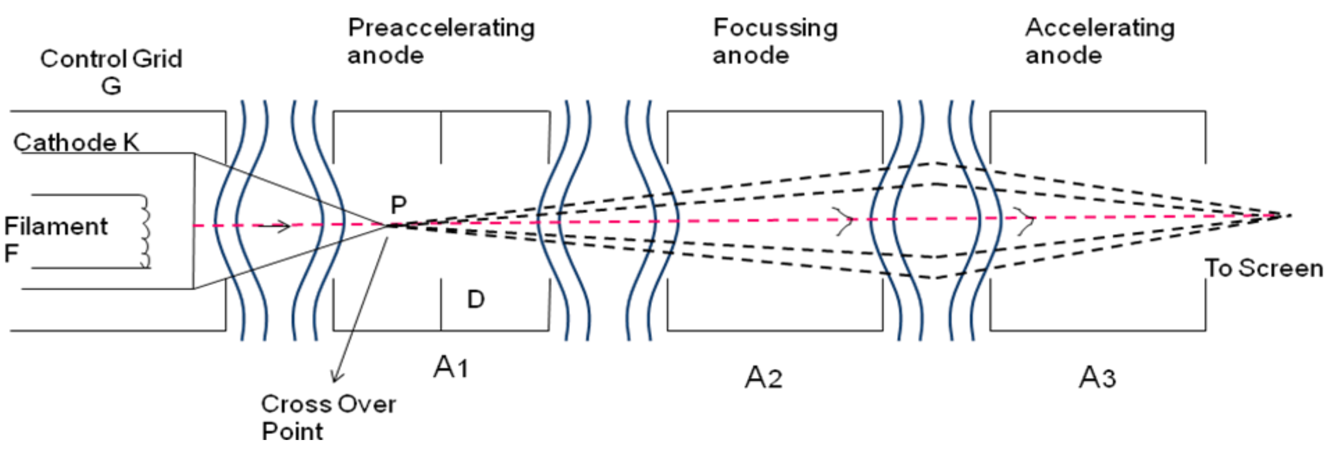


Fig: Electron Gun

The electron gun consists of a cathode K, a filament F, a control grid G and three anodes A_1-Preaccelerating Anode, A_2-Focussing Anode and A_3-Accelerating Anode. The cathode is a short hollow Nickel cylinder and encloses the filament heater F. The front face of the cathode is coated with thoriated tungsten or Barium and Strontium oxides. The coating helps thermionic emission of electrons to occur at moderate temperatures of about 700°C to 900°C. The cathode is surrounded bythecontrolgridGwhichalsoisahollowmetalcylinderwithasmallcentralapertureinitsfrontface to allow electrons to pass through. Three short metal cylinders with central apertures are placed co-axial beyond the control grid. The entire assembly is kept in an evacuated glass tube. A power supply provides the necessary voltage to the electrodes.

Working:

When the power is turned on, the filament heater heats up the cathode. At a temperaturecharacteristic of the cathode material, electrons are emitted from its front surface and they passthrough the control grid. The grid is held at a negative potential with respect to cathode and controlsthenumberofelectronspassingthroughit.Ifthegridisheldatlessernegativepotential,a large number of electrons pass through it. On the other hand, If the grid is held at higher negativepotential, smaller number of electrons passthrough it. Thusgrid withanegative potential (0 to50V)on it acts as a gateand regulates thepassage of electrons through it.

The anodes of the electron gun provide an electron lens system for focusing the electronbeam on the screen. The preaccelerating anode A_1 and accelerating anode A_3 are connected to highpositive potential and are held at same voltage and focusing anode A_2 is connected to lower positivepotential. The grid and anode A_1constitutes the first electron lens of the system. The convexequipotentialsurfacesbendtheelectronpathstowardsthecentralaxis.Consequentlyalltheelectrons passing through the aperture in the control grid converges toward a point P just inside thefirst anode.The point Pis located ontheaxis of thegunand knownas the cross over point. Thearea of the point P would be very small compared tothe relatively large cathode surface emittingthe electrons. Therefore electrons emerging from point P can be easily focused to a fine point betterthan the electrons emerging than the cathode. Thus the role of first lens is to converge the beam tothecross overpoint which thenacts as apoint sourceoftheelectrons forthesecondlens.

The anodes, A_2 and A_3 constitute the second lens system which focuses and accelerates theelectron beam to a fine point on the fluorescent screen. The diaphragm D in anode A_1 cuts off wideangle electrons emerging from P. The anode A_3 imparts further acceleration to the electrons as theyemerge out of the electron gun. **The focus of the beam is adjusted by varying the positivepotential on A_2.**

Applications:

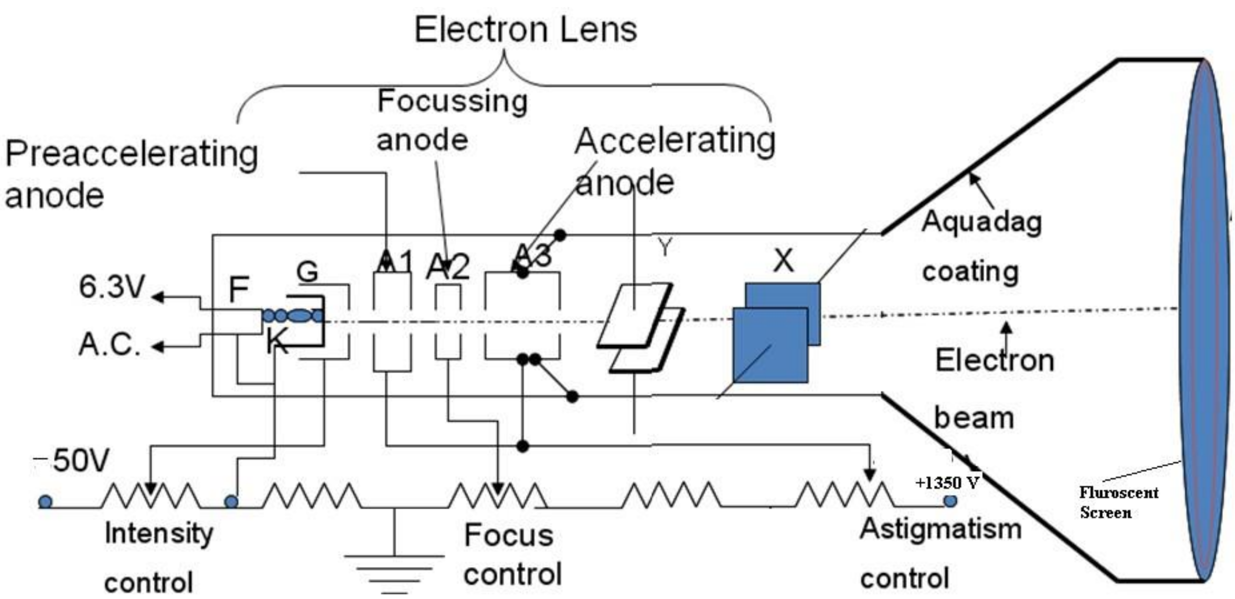
Electron gun is used in a CRO to display wave shapes, in a TV to display pictures, in anelectron microscope to obtain a magnified image and in EBM and EWM for machine and weldingjobs.

CRT (Cathode Ray Tube):

A Cathode Ray Tube (CRT) is a specially constructed vacuum tube in which an electron beam controlled by electric or magnetic fields generates a visual display of input electrical signals on a fluorescent screen. It consists of three important parts,

i) Electron Gun
ii) Deflection System
iii) Fluorescent Screen

Construction/Description:



The CRT resembles a horizontally placed conical flask sealed at its open end. The electron gun consisting of several electrodes is mounted at one end of the tube as a single unit and electrical connections are given to them through base pins. The deflection system consists of two pairs of parallel metal plates mounted in the neck of the tube. They are oriented in such a way that they are in mutually perpendicular directions to the axis of the CRT. The screen consists of a thin coating of phosphors deposited on the inner face of the wide end of the glass envelope. The inner surface of the flare of the envelope is coated with conductive graphite called acquadag. A power supply provides the required potentials to the various elements of CRT.

Working:

In the CRT, the electron gun generates an electron beam, focuses it and accelerates it towards a fluorescent screen located at the further end of the tube. The electron beam may be moved to any spot on the screen with the help of deflection system.

I) Electron Gun:

The indirectly heated cathode K emits a stream of electrons from its coated front face. The electrons pass through the control grid G held at a negative potential. The effective size of the aperture in the grid varies depending upon the potential difference between grid and cathode. The intensity of the glow produced at the screen is determined by the number of electrons striking the screen. Therefore by varying the negative dc voltage on the grid, the intensity of the luminous spot on the screen is controlled. The grid bias is usually varied between 0 to -50V. The anodes A1 andA3 are internally connected and held at a higher positive potential of a few kilovolts and A2 is maintained at a relatively low positive potential. The anode A1 accelerates the incoming electrons. The Grid G and anode A1 forms the first lens system which pre-focuses the electron beam. The anode A2 and A3 constitutes the second lens system which focuses the electron beam to a fine point on the fluorescent screen. The focus of the beam is adjusted by varying the positive potential on A2.TheanodeA3impartsfurther acceleration to the electrons as they emerge out of the electron gun.

II) Deflection System:

There are two types of deflection system namely electrostatic type and electromagnetic type. In the electrostatic deflection system, two pairs of metal plates are employed for deflecting the electron beam. The two plates in each pair are aligned strictly parallel to each other as shown in fig and the two pairs of plates are mounted at right angles to each other and also at right angles to the path of electrons. One pair of plates is arranged horizontally. When a potential difference is applied to the plates then the uniform electric field is produced in vertical direction. The fields acts perpendicular to the beam and deflects the beam vertically, so these are called as vertical deflecting plates or Y-plates.The second set of plates is oriented vertically and produces the uniform horizontal field, when a potential difference is applied between them. The field acts normal to the beam and deflects the beam horizontally so this set of plates is called horizontal deflection plates or X-plates.

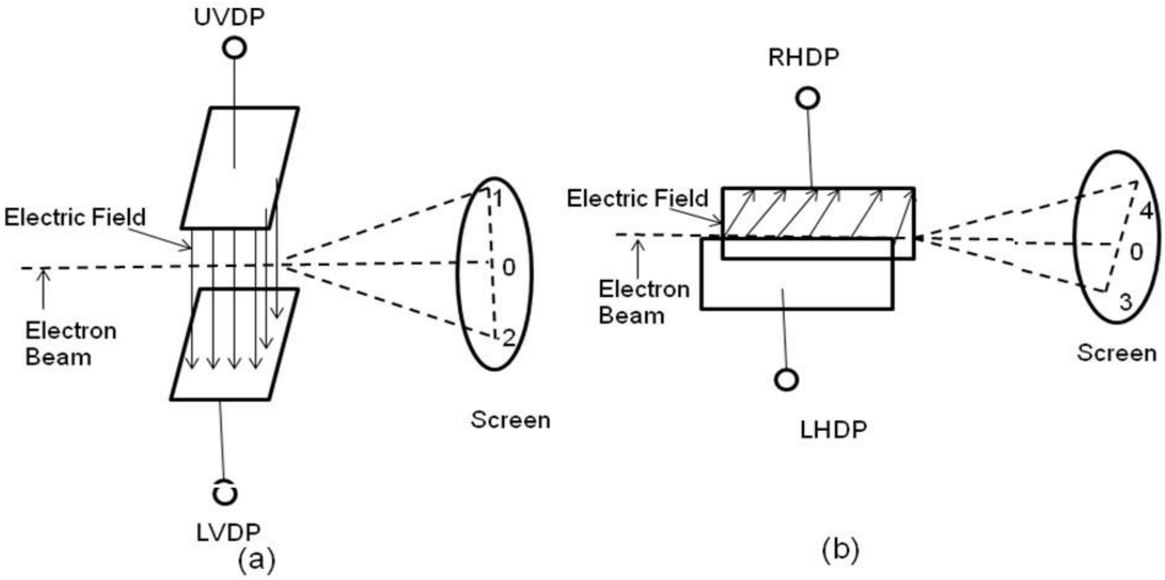


Fig: Electron Beam Deflection a) Vertical Deflection b) Horizontal Deflection

When voltages are not applied to X-plates and Y-plates, the electron beam travels along the CRT axis and strikes the geometrical centre of the viewing screen. When a dc voltage is applied to Y-plates, the electron beam gets deflected vertically and when a dc voltage is applied to the X-plates, the electron beam is deflected horizontally as shown in figures. The amount of deflection depends on the magnitude of the applied voltage. When dc voltages are applied to both the X and Y plates, the electron beam will be acted upon simultaneously by two forces due to vertical and horizontal electric fields and gets deflected along the direction of their resultant as shown in fig. Thus by varying the dc voltages the vertical and horizontal plates, the luminous spot may be moved to any position in the plane of the screen.

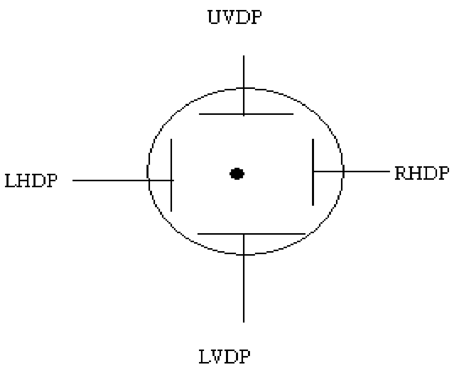


Fig : Voltage not applied to deflection plates

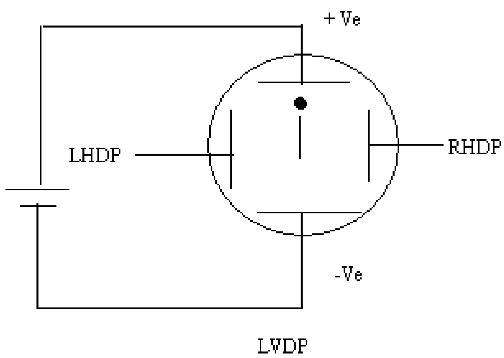


Fig : Positive Voltage applied to UVDP

III) Fluorescent Screen:

The interior surface of circular front face of the CRT is coated with a thin translucent layer of phosphors. The phosphor coating glows at the point where it is struck by high energy electron beam. At that spot the coating continues to glow for a short period of time even after the electron beam moves away. So electron beam position can be located with the help of a fluorescent screen.

Aquadag Coating:

Electrons impinging on the screen tend to charge it negatively and repel the electrons arriving afterwards it will reduce the number of electrons reaching the screen leading to a decrease in the brightness of the glow. Therefore the electrons are to be conducted away. Similarly the cathode assumes gradually a positive charge as electrons are emitted from it in large numbers. It again leads to a reduction in the intensity of the glow on the screen. Therefore the cathode is to be replenished with electrons. This is accomplished by the Aquadag coating. The inner surface of the flare of the glass envelope of CRT is coated with conductive graphite coating called Aquadag. It is used to complete the circuit from screen to cathode. The electrons striking the fluorescent screen not only causes emission of light, but also produce secondary emission of electrons. The secondary electrons are attracted by the Aquadag coating which is electrically connected to anode A3. The electrons are restricted to cathode through the ground.

Application: The electrostatic CRT is used in CRO as a display device and study of waveforms.

• Cathode Ray Oscilloscope (CRO):

Cathode Ray Oscilloscope is a very important electronic measuring instrument which is used to display and measure electrical signals, time intervals and phase shift between two electrical signals.

Non electrical quantities such as pressure, strain and temperature can be measured by first converting them into an equivalent voltage using an appropriate transducer. Any CRO basically consists of the following **seven major sections**

i) Cathode Ray Tube (CRT)

ii) Time base circuits

iii) Trigger circuits

iv) Vertical Circuits

v) Horizontal Circuits

vi) High Voltage Power Supply

vii) Low Voltage Power Supply

Thearrangement ofthese sections inaCROis shownin figin theform of Block diagram.

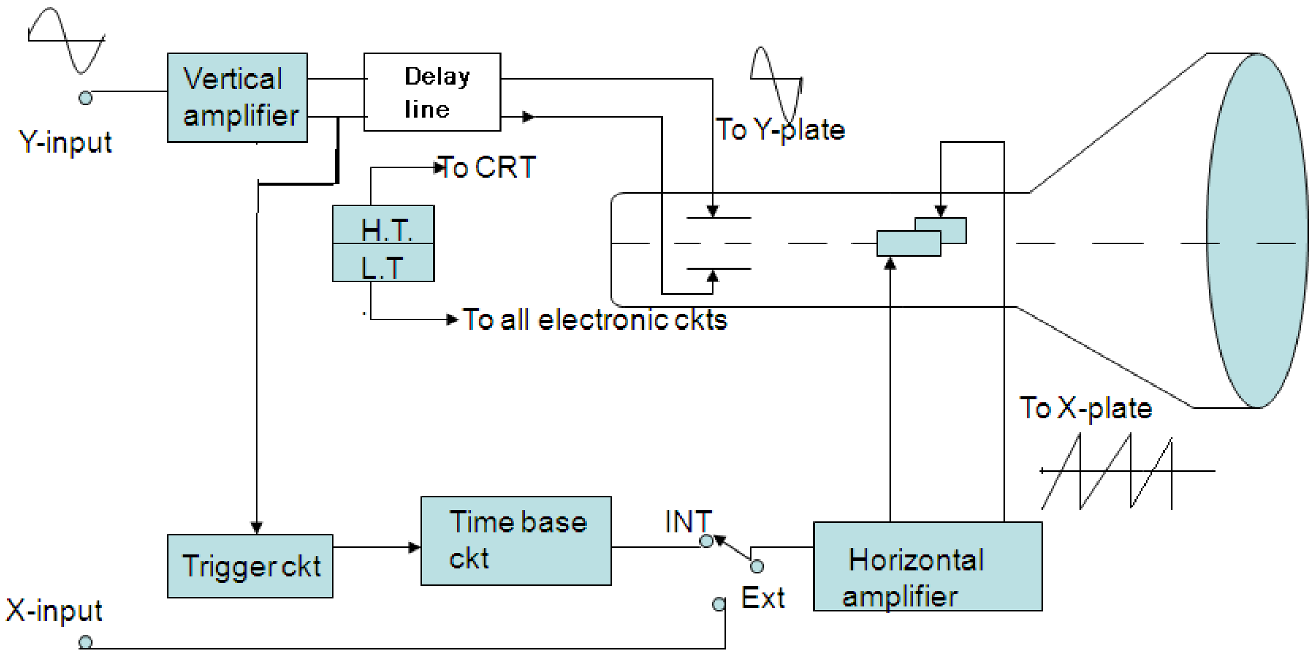
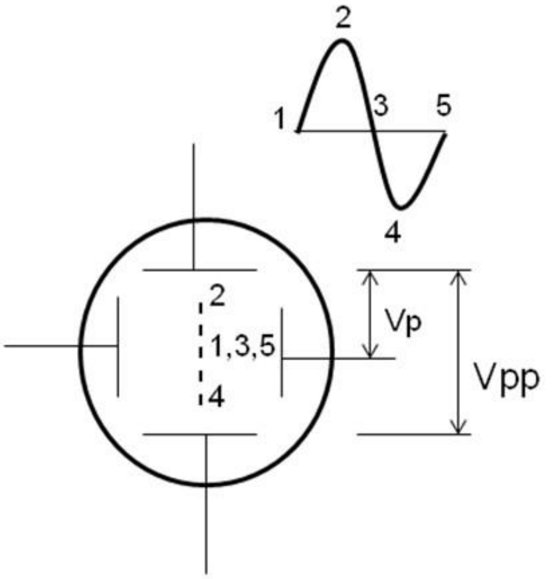


Fig: Block diagram of CRO

I) CATHODE RAY TUBE (CRT):

A cathode ray tube with electrostatic deflection forms the central part of a CRO. The CRTgenerates the electron beam, focuses it and accelerates it towards the fluorescent screen. The rest ofthe sections are electronic circuits which cause the desired movement of luminous spot on thescreen. In its action the electron beam is similar to pen. It writes on the fluorescent screen in theform of bright trace. Writing on paper involves two motions i.e. horizontal motion of the pensweeping across the page and other is vertical motion of the pen indicating the message.It isobviousthattheelectronbeamshouldbemadetomovebothhorizontallyandvertically.Atransparentgraphcalled**graticule**markedincentimeterlines(divisions)bothverticallyandhorizontally,is attached to the faceof theCRT formakingmeasurements.

When a signal is to be displayed, it is applied to the Y-plates of CRO by connecting it to theY input of CRO. For example, let the signal be a simple harmonic wave. Because of the applicationof the signal to the Y plates, the luminous spot moves up and down on the screen at the samefrequency as that of applied voltage. The successive positions of the spot can be seen as shown infig.(a).,when the frequency of the signal is less than about 20 Hz. At higher frequencies the path ofthebeamisseenasaverticalline(figb).Thisisduetothepersistenceofvisionandthefluorescence of the coating. The luminous line is called trace. The length of the vertical tracecorrespondsto the peak to peak value ofapplied voltage.



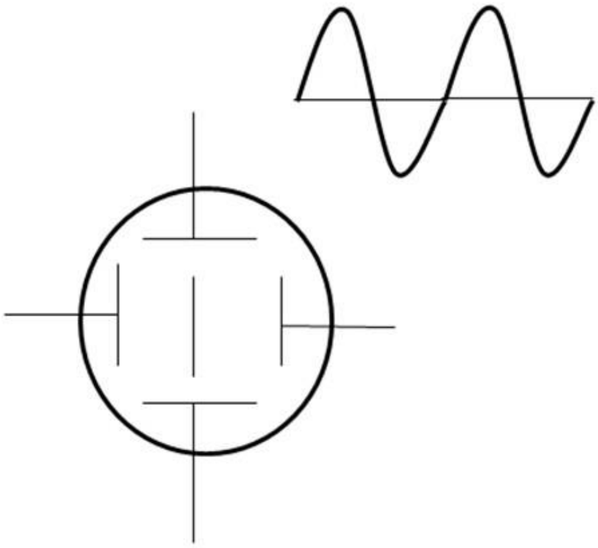


Fig (a): Trace with low freq signal Fig (b): Trace with high freq signal

II) TIMEBASECIRCUIT:

The faithful display of the signal variation by the electron beam requires the beam to movehorizontally at a uniform rate across the screen, covering equal distances in equal intervals oftime.This condition issatisfied by ramp voltageor sawtooth voltage. The ramp voltage isgenerated byTimeBaseCircuit

The time base circuitconsists oftime basegenerator.The timebase generator isavariablefrequencyoscillatorwhichproducesan outputvoltageofsawtoothshape.

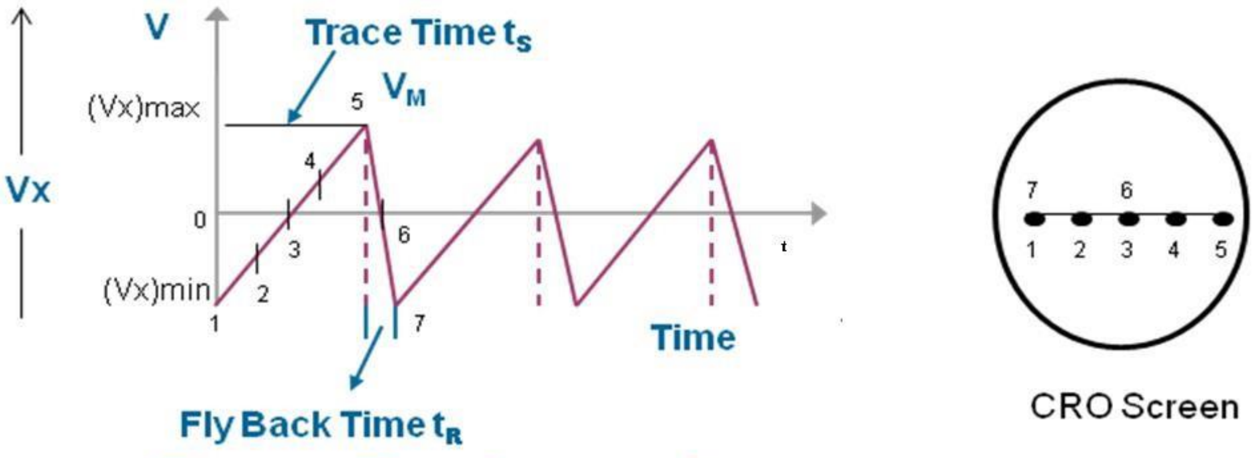


Fig. : Time base voltage

Toobtainavisualdisplayofthewaveformofappliedvoltage,itisnecessarytoapplythis A.C. voltage to one set of the deflection plates say **Y-**plates and the other time base voltage or rampvoltage, generated by time base generator, to **X-**plates. This time base voltage is periodic in natureand its frequency can be varied. This voltage increases linearly with time and after reaching amaximum value **$(V_x)_{max}$**,it suddenly drops to minimum value **$(V_x)_{min}$**. When this voltage is appliedto the horizontal deflection plates, the luminous spot sweeps the face of the screen at a uniformvelocity from left edge to right edge depending on the polarity of the voltage. Because of this reasonrampvoltageisalsocalledas**sweepvoltage**.Thedeflectionofspotbecomesmaximumwhen voltagereachesthevalue$(V_x)_{max}$afterwhichthespotsuddenlyreturnstoitsoriginalposition.Ifthefrequencyof thetime basevoltageis sufficientlyhighthe traceof thespot appears asastraight line.

Duetoresemblanceofsweepvoltagetoteeth ofsaw,itisalsocalled**saw-toothvoltage.**

Sweep Time or Trace Time (t_s): The time taken by the sweep voltage to rise from itsmaximumnegativevoltageto itsmaximumpositivevoltageiscalledsweep timeoratracetime**t_S.**

Retrace Time or Flyback Time (t_r): The time taken by the sweep voltage to dip from itsmaximum positive voltage to its maximum negative voltage is called retrace time or fly back time**t_R.**

SweepPeriod(T_{sweep}): Thesumofsweeptimeandretracetimeconstitutesthesweepperiod**T_{sweep}.**

$$T_{sweep} = t_s + t_r \approx t_s$$

Blanking :

The retrace path , if seen on the screen , gives a bad visual effect. By making the retracetime equal to zero , the retrace path can be eliminated.The trace during the flyback time or retracetime can be made invisible by applying a high negative voltage pulse to control grid in the electrongun which turns off the electron beam momentarily. **The process of making retrace pathinvisibleis known as Blanking ofthetrace.**

Displayofthesignalshape:

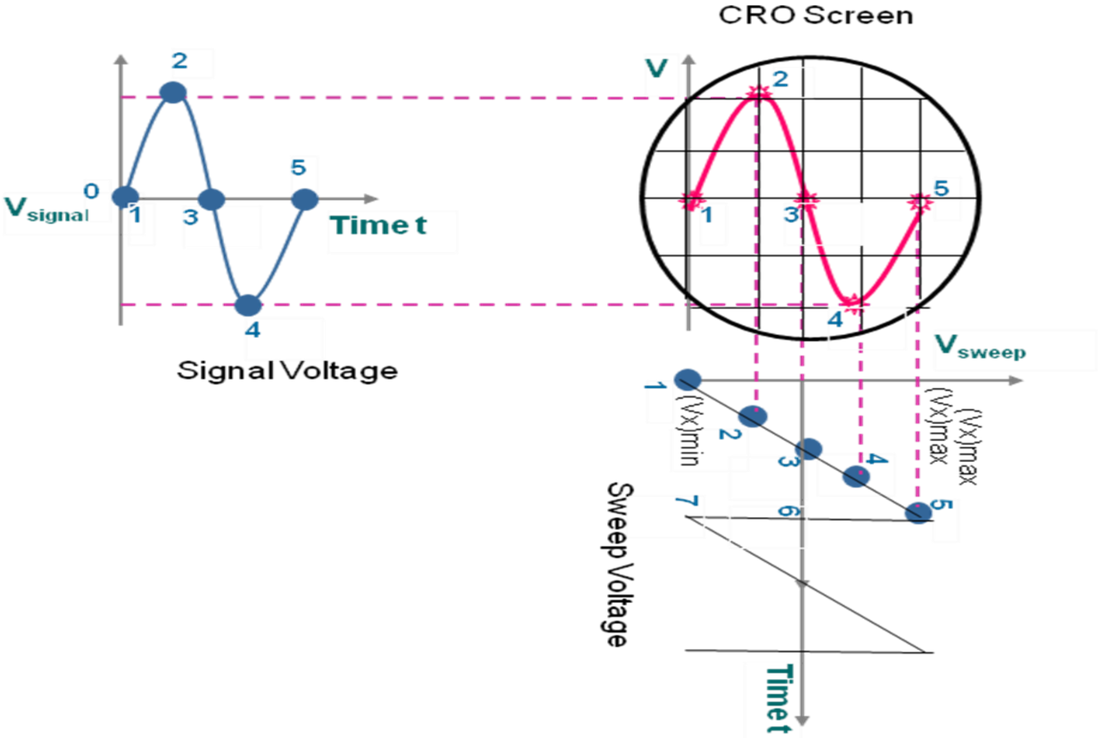


Fig. 24: Display of Signal Shape

As the signal is applied to the Y-plates and time base voltage (sweep voltage)to the X-plates,theelectronbeamissimultaneouslysubjectedtotwoforcesactinginperpendiculardirection.Thedeflectionofthe beamatanyinstant is determinedbyresultantof thesetwoforces.

Referring to above fig it is seen that at any instant 1, the input signal (signal voltage) is zeroandsweepvoltageis$(V_x)_{min}$,theresultantoftheforcesduetothemactsalongtheleftdirectionand the beam is deflected to the left extreme. At the instant 2, the signal amplitude is positive and sweepvoltage is at a lesser negative value. The beam is deflected left upward in the second quadrant of thescreen. At the instant 3, both the input and sweep voltages are zero. The resultant force is zero andthe beam stays at the centre of the screen. At the instant 4, the signal amplitude is negative and thesweep voltage is positive. The beam is deflected to right down in the fourth quadrant of the screen.At the instant 5, the signal voltage is zero and sweep voltage is (vx)max, the electron beam isdeflected toward the right extreme along the horizontal direction. Then the beam returns to position1 and the process repeats. By joining the resultant positions of the spot, it is seen that waveform oftheinput voltageis faithfullydisplayed.

III) TRIGGERCIRCUIT:

To display a stationary wave pattern on the CRO screen, the horizontal deflection shouldstart at the same point of the input signal in each sweep cycle. When it occurs it is said that thehorizontal sweep voltage is synchronized with input signal. If the sweep and signal voltages are notsynchronizedastandstillpatternisnotdisplayedonthescreen;thewavepatternmovescontinuouslyto therightorleft of thescreen.

Thus<u>synchronization</u>isthemethodoflockingthefrequencyofthetimebasegenerator tothe frequency of input signal so that a stationary display of wave pattern is seenontheCRO screen.

Thesignalwillbeproperlysynchronizedonlywhenitsfrequencyequalsthesweepfrequencyor sub multipleof sweep frequency.That is

$$f_{signal}=nf_{sweep}$$

$$\frac{1}{T_{signal}}=n\frac{1}{T_{sweep}}$$

$$\therefore T_{sweep}=nT_{signal}$$

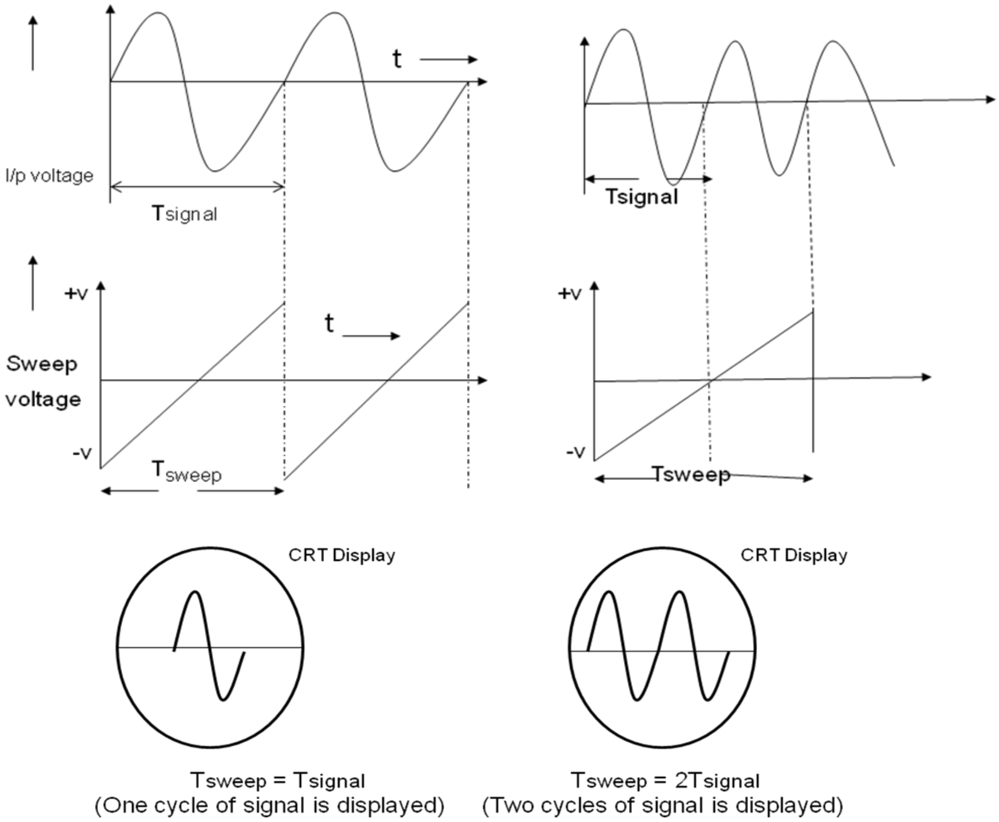


Fig 25: Synchronization of Sweep and Signal Voltages

As an example, if the sweep frequency is 50Hz and signal frequency is 50Hz, one wave isdisplayed on the screen. On the other hand if the sweep frequency is 50Hz and the signal frequencyis 100Hz, the time period of sweep voltage is 20ms and time period of signal is 10ms. In the sweeptime which actually is horizontal trace length, the signal goes through two complete cycles. As aresult the two cycles of thesignal voltagearedisplayed onthe screen.

Oneof themethods of**achievingsynchronization**is theuse of triggercircuit.

Thetriggercircuitinitiatesthetimebasesothatthehorizontaldeflectionsweepsinsynchronization with vertical signal. For this a delay line circuit is used which delays the signalbefore it reaches to y-deflecting plates. A part of the output obtained from the vertical amplifier isfed to the trigger generator. Trigger generator is sensitive to the level of the voltage applied at itsinput.Thecircuitmonitorstheinputsignalanddetectsthepointwhenitreachesselectedlevelwhilemovingtowardstheselectedpolarity.Whenpredeterminedlevelisreachedthecircuitproduces a trigger pulse. This trigger pulse is fed to the time base generator and it acts as commandsignal to the time base generator and start one sweep cycle of the time base. The sweep voltage isnot developed in the trigger mode if the input signal is not given. A portion of the triggerpulse isfed to a second circuit, which produces an unblanking bias voltage to bring the grid of CRT to apotential, which allows electron beam to appear. Thus a stationary display of the wave is seen onlyabove a predetermined level of the input voltage. It happens in each cycle. Because the signalvoltage is initiating the sweep cycle, both voltages will be synchronized. By proper adjustment ofcontrols, the trigger pulse may be made to originate when the input signal is going positive ornegative or at any particular voltage level. However in AUTO trigger mode the trigger circuit willautomatically provide a trigger pulse to the sweep generator even when the input signal is notappliedto it and thehorizontal traceis seenevenwithout signal at Y-input.

IV) VERTICALCIRCUITS:

The vertical circuits mainly consist of an attenuator and a voltage amplifier. The signal is applied atthe Y-input. It goes to the input of the attenuator. The signal amplitude is increased or decreased bychanging the amount of attenuation and then fed to the input of the voltage amplifier so thatadequatedeflection is obtained on the screen.

V) HORIZONTALCIRCUITS:

The sweep generator output cannot directly drive the horizontal plates. Therefore it must be initiallyamplified. The horizontal circuits mainly consist of a voltage amplifier. When the sweep selectorswitch is in ‘INT’ position, the sweep voltage is applied to the horizontal amplifier. The output ofthe amplifier is fed to the X-plates and a linear trace is produced on the CRO screen. When thesweep selector switch is held in ’EXT’ position the horizontal amplifier input is disconnected fromthe internal sweep generator and is instead connected to the horizontal input jack. In this position,theelectron beamremains stationaryand producesaluminous spoton theCRO screen.

VI) LOW VOLTAGE POWER SUPPLY:

The low voltage power supply powers the electronic circuits such as amplifiers, time base generator, trigger circuit. It gives an output of the order of few tens to a few hundreds of volts.

VII) HIGH VOLTAGE POWERSUPPLY:

The high voltage power supply provides voltages to anodes in the electron gun assembly. It supplies voltages of the order of 1600 V to 2200 V.

DELAY LINE:

All electronic circuitry in the CRO causes a certain amount of time delay in the transmissionof signal voltages to the deflection plates. Comparing the vertical and horizontal circuits in the CROblock diagram, we obtain that a portion of the output signal applied to the vertical CRT platestriggers the horizontal signal. Signal processing in the horizontal circuit consists of generatingtrigger pulse that starts the time base generator (sweep generator) then output of this is given to thehorizontal amplifier and then to the horizontal plates. This whole process takes time. The signal ofthe vertical CRT plates must therefore be delayed by the same amount of time so as to reach thesignalat the same instant as thatofhorizontal one. This is thefunction ofthe delayline.

APPLICATIONSofCRO:

TheCROisaversatileelectronicinstrumentanditisusedinmeasuringaverityofelectricalparameters.

a) Study of the Wave Forms: CRO is widely used in maintenance and trouble shooting where thewaveshapesofvoltagesindifferentelectroniccircuitsaretobeexamined.Thesignalunderstudyis applied at the Y-input terminal and the sweep voltage is internally applied to X-plates. The size ofthefiguredisplayed on thescreen maybeadjustedsuitablybyadjustingthegaincontrol.

b) Measurement of D.C. Voltages: The D.C. voltage under study is applied at Y-input. The tracegetsdeflectedupwardordownwarddependinguponthepolarity oftheappliedvoltage.Thedeflection of the spot produce on the screen can be measured and by multiplyingit with thedeflectionsensitivity(volts/div), the magnitudeofunknown voltagecanbeobtained.

c) Measurement of A.C. Voltages: For this measurement the trace is to be adjusted at the center ofthe screen and the A.C. voltage under study is applied at Y-input. The peak to peak distance ismeasuredandonmultiplyingitwithdeflectionsensitivity(volts/div),peaktopeakvalueofapplied A.C.voltage canbe calculated.Thermsvalue andaveragevalueofthevoltage are calculatedusing theformulae, $V_P = \frac{V_{P-P}}{2}$, $V_{rms} = \frac{V_P}{\sqrt{2}}$, $V_{aver} = 0.636 V_P$

d) Measurement of Current: For this measurement current has to be passed through suitableknown resistor and the potential developed across it can bemeasured as has been explained above.The current may then be calculated. However if the cathode ray oscilloscope having magneticdeflectionsystem, thecurrents maybemeasuredbypassingit throughoneof thedeflection coil.

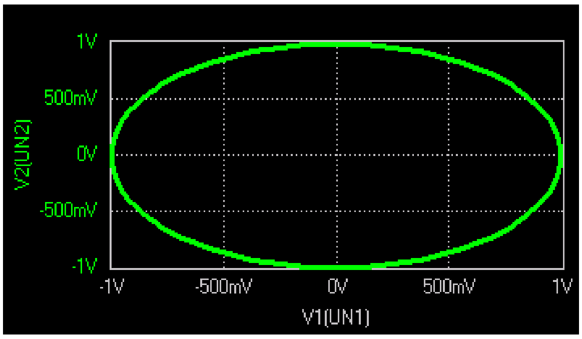
e) MeasurementofFrequency:

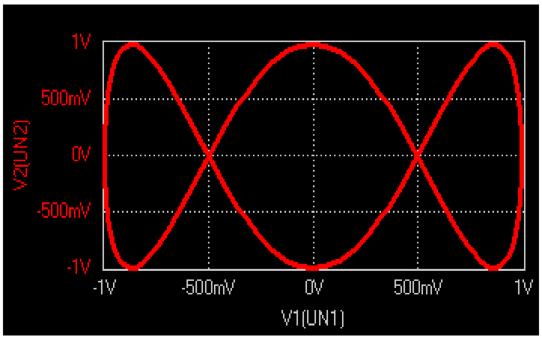
1) **Calibration Method:** A sinusoidal signal whose frequency is to be determined is applied toY-input. The time base control is adjusted to obtain 2 or 3 cycles of the signal on the screen. Thehorizontal spread of one cycle is noted. By multiplying it with the time base sensitivity (time/div),the time period of the signal is obtained. The reciprocal of the time period gives the frequency ofthesignal.
2) **Lissajous Method:**Alternatively, the frequency of a test signal can be determined usingLissajous patterns. **When two sine waves oscillating in mutually perpendicular planes arecombined, different types of closed loop patterns are obtained. They are called LissajouspatternsinhonouroftheFrenchphysicist Lissajous.**

The signal of unknown frequency is applied to vertical input (Y) and a voltage of known frequencyobtainedfromstandardvariablefrequencygeneratorisgiventohorizontalinput(X).The frequency of this frequency generator can be varied until a suitable stationary Lissajous figure isobtained. Knowing the frequency from frequency generator and counting the number of tangencypoints along horizontal and vertical axes, the unknown frequency can be determined. If f_Y and $f_X$are the unknown and known frequencies of the sinusoidal voltage fed to the vertical and horizontalplates of CRO respectivelyand $n_x$and $n_y$arenumber oftangencypoints alongX andY-axis respectivelythen the unknown frequencyiscalculatedfrom ,

$$f_y = f_x \frac{n_X}{n_Y} \quad \text{—(1)}$$

Where$\boldsymbol{f_x}$is theknown frequency. Examples of measurements are:





a)1:1 **b) 3:1**

f) Measurementofphasedifference:

(i) ***Dual Sweep Method:*** It requires a dual trace CRO. The phase relationship between twosinusoidalsignalsofsamefrequencymaybedirectlymeasuredbydisplayingbothwaveforms on the CRO screen and determining the delay time between the two waveforms.Thesensitivityandtriggercontrolsofeachchannelareadjustedfortwostationary sinusoidalsignals.The sweep speed isinitiallyadjusted suchthat the timeperiodT ofthe sine waveis measured. Then the sweep speed is increased and the delay timeT_d betweenthe two sine waves is accuratelydetermined.

Thedifferenceis calculatedusingthe relation

$$\phi = \frac{\Delta t}{T} \times 360$$

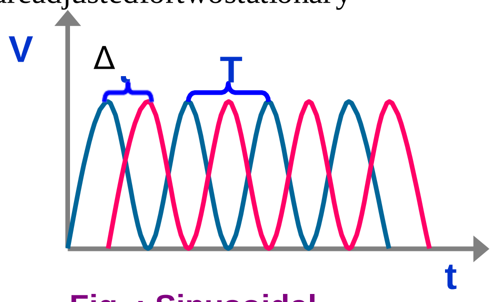


Fig. : Sinusoidal voltages$V_A$and V_c

(ii) ***Lissajous Pattern Method:*** A second method for determining phase difference oftwo sinewaves of same frequency is to feed one sine wave to vertical input and other sine wave tohorizontalinput. Thesweep selector switch is kept in EXT position.

A Lissajous pattern namely ellipse is obtained on the screen.BymeasuringthelengthsA=$2Y_1$andB=$2Y_2$ofthe elliptical

$$\phi = \sin^{-1}\left(\frac{A}{B}\right)$$

patternthephase shift$\phi$is calculated.$\phi = \sin^{-1}\left(\frac{2Y_1}{2Y_2}\right)$