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Basic Electronics (EC-201)

B.Tech - II<sup>nd</sup> Sem

## Unit (V) Electronic Instrumentation & Measurements

The measurement of a given quantity is the result of Comparison between the quantity to be measured and definite standard. The instruments which are used for such measurements are called measuring instruments. Three basic quantities in the Electronic measurement are Current, Voltage & power.

The necessary requirements for any measuring instruments are:-

- 1) With the introduction of the instrument in the circuit, the circuit conditions should not be altered.
- 2) The power consumed by the instrument for their operation should be as small as possible.

The instrument which measures the Current flowing in the circuit is called ammeter while instrument which measures the Voltage across any two points of a circuit is called Voltmeter. The instruments which are used to measure the power are called power meters or wattmeters.

Digital Voltmeters - The digital Voltmeters generally referred as DVM, convert the analog signal into digital & display the Voltages to be measured as discrete numericals instead of pointer deflection on the digital displays. Such Voltmeters can be used to measure a.c. & d.c. Voltages & also to measure the quantities like pressure, temperature, stress etc. using proper transducer and signal conditioning system.

→ Transducer converts the quantity into proportional Voltage Signal and Signal Conditioning circuit brings the signal into the proper limit which can be easily measured by Voltmeter. The output Voltage is displayed on the digital display on the front panel. Such a digital output reduces the human error reading, interpolation & parallax errors.

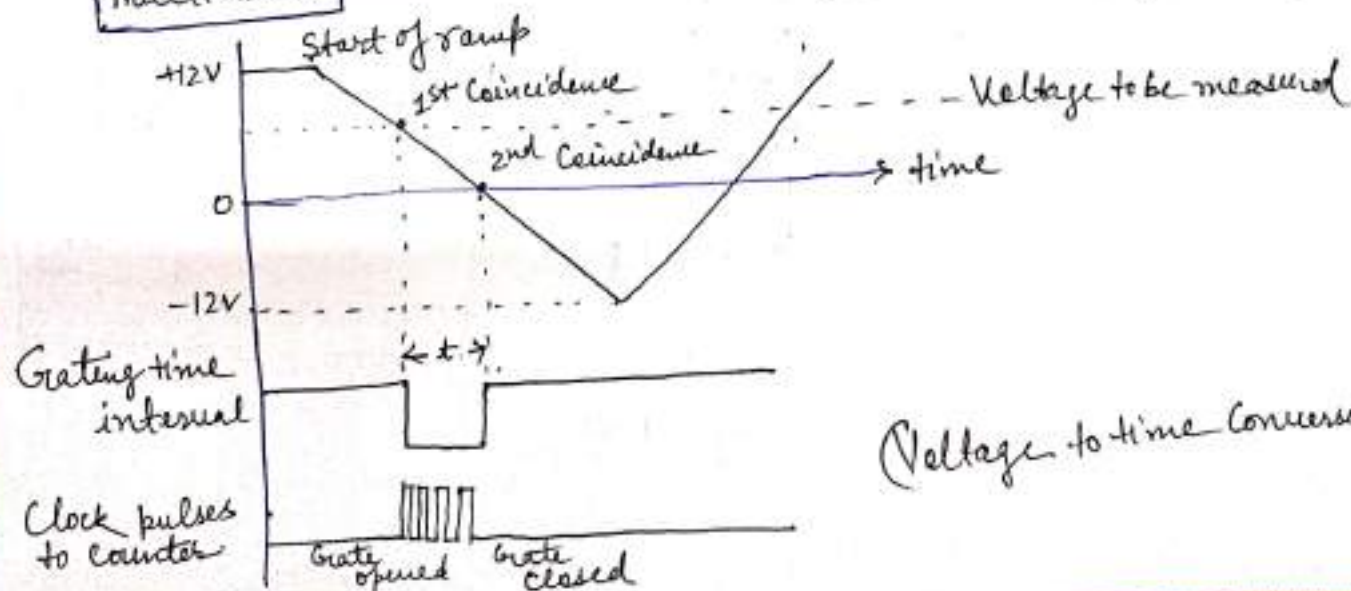
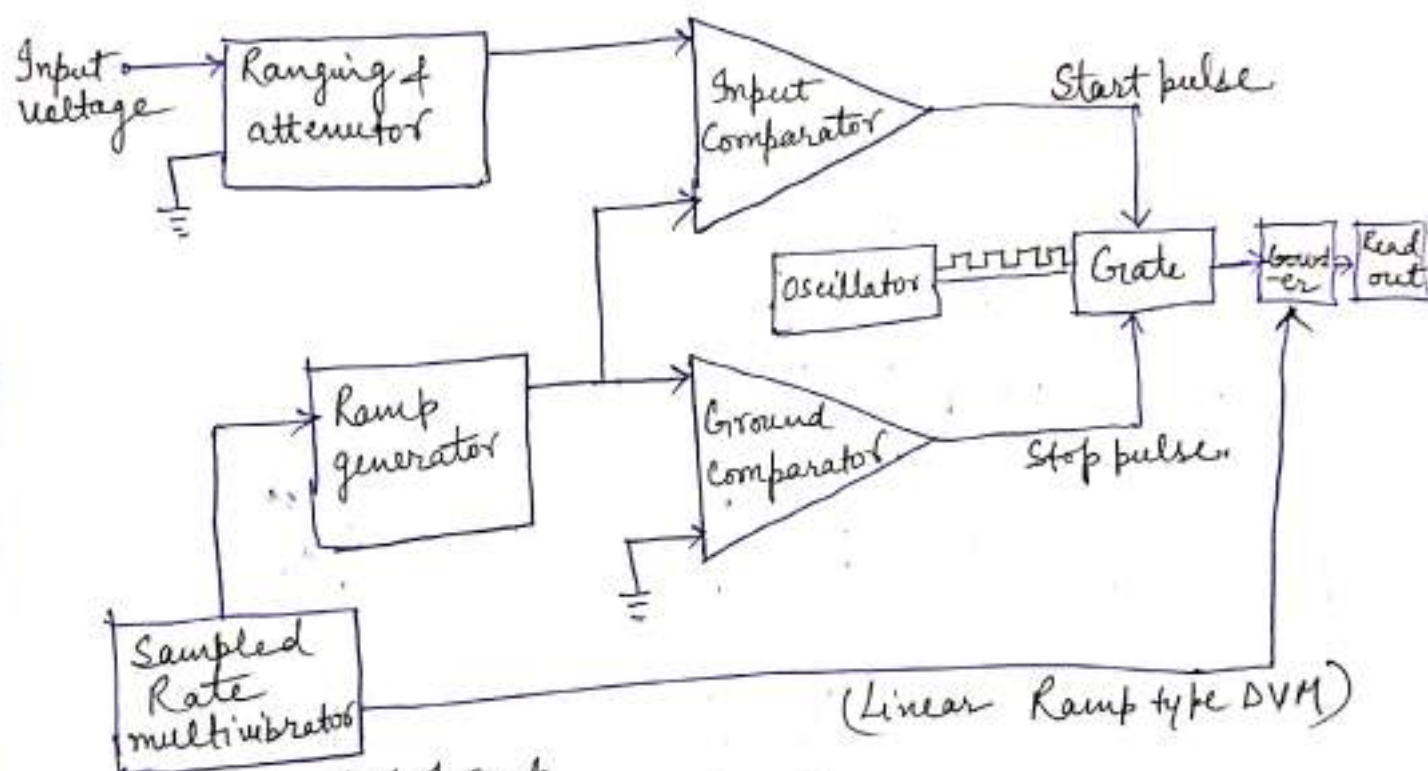
DVM have number of advantages over conventional analog Voltmeters.

- 1) Due to digital display, the human reading error, interpolation errors & parallax errors are reduced.
- 2) They have input range from  $+1.000V$  to  $1000V$  with automatic range selection & overload indication.
- 3) The accuracy is high upto  $\pm 0.005\%$  of the reading.
- 4) The resolution is better as  $1\mu V$  reading can be measured on  $1V$  range.
- 5) The input impedance is as high as  $10M\Omega$ .
- 6) The reading speed is very high due to digital display.
- 7) They can be programmed & well <sup>Suited</sup> ~~suited~~ for computerised control.
- 8) The o/p in digital form can be directly recorded & it is suitable for further processing.
- 9) With the development of IC chips, the cost of DVMs, size & power requirements of DVMs are drastically reduced.
- 10) Due to small size are portable.
- 11) The internal calibration does not depend on the measuring ckt.

# Ramp type digital voltmeter (DVM)

It uses a linear ramp technique or staircase ramp technique.

1) Linear Ramp Technique - The basic principle of such measurement is based on the measurement of time taken by a linear ramp to rise from 0V to the level of input voltage or to decrease from the level of the input voltage to zero. This time is measured with the help of electronic time interval counter & the counter is displayed in the numeric form with the help of a digital display.



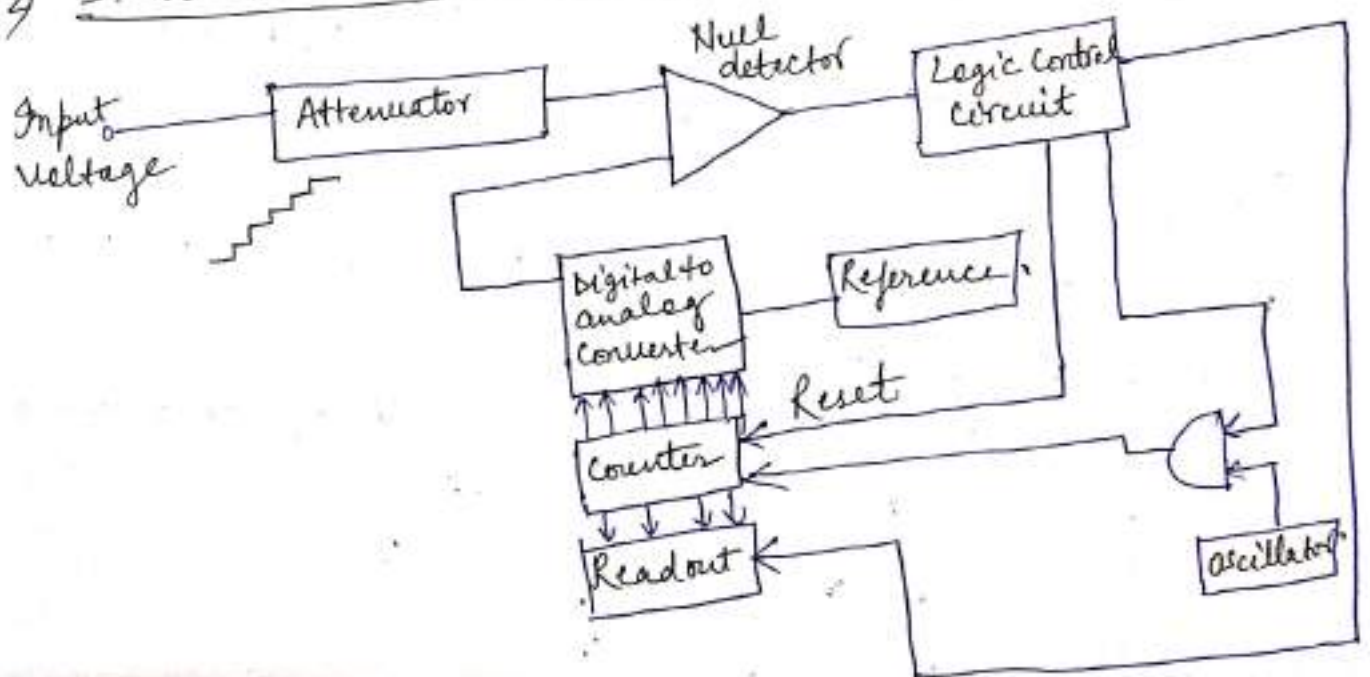
(Voltage to time conversion)

From the above figure it is clear that at the start of measurement, a ramp voltage is initiated which is simultaneously compared with the input voltage. When these voltages are same, the comparator generates a pulse which opens a gate i.e. the input comparator generates a start pulse. The ramp continues to decrease and finally reaches to 0V or ground potential.

This is sensed by the second comparator or ground comparator. At exactly 0V, this comparator produces a stop pulse which closes the gate. The number of clock pulses are measured by the counter. Thus, the time duration for which gate is opened, is proportional to the input voltage.

In the time interval between start & stop pulses, the gate remains open & the oscillator circuit drives the counter. The magnitude of the count indicates the magnitude of the input voltage, which is displayed by the display.

## 2) Stair Case Ramp Technique



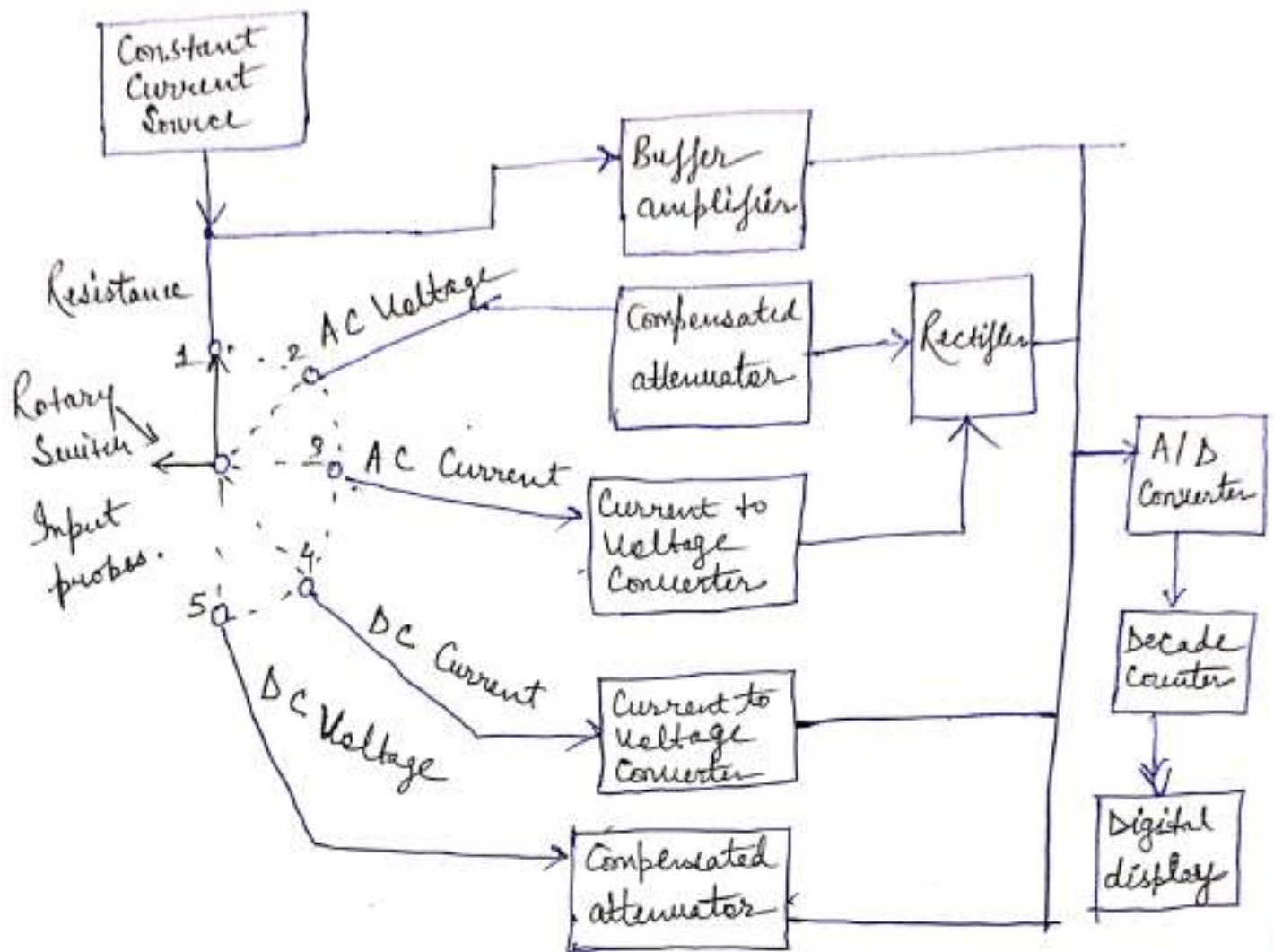
(Stair Case ramp type DVM)

In this type of DVM, instead of linear ramp, stair case ramp is used. This technique of using stair case ramp is called null balance technique. The input voltage is properly attenuated & is applied to a null detector. and another input to null detector is the staircase ramp generated by digital to analog converter. The ramp is continuously compared with the input signal.

- 1) Initially, logic control circuit sends a reset signal. This signal resets the counter. The digital to analog converter is also reset by same signal.
- 2) At the start of the measurement, the logic control circuit sends a starting pulse which opens the gate. The counter starts counting the pulses generated by the local oscillator.
- 3) The output of counter is given to the digital to analog converter which generates the ramp signal. At every count, there is incremental change in the ramp generated. Thus, the staircase ramp is generated at the output of the digital to analog converter. This is given as the second input of the null detector. The increase in ramp continues till it achieves the voltage equal to input voltage.
- 4) When the two voltages are equal, the null detector generates a signal which in turn initiates to the logic control circuit. The increase in ramp continues till it achieves the voltage equal to input voltage. Thus, logic control circuit sends a stop pulse, which closes the gate & the counter stops counting.
- 5) At the same time, logic control circuit generates a transfer signal due to which, the counter information is transferred to the readout. The readout shows a digital result of the counter.

Digital Multimeter (DMM) → A multimeter is an electronic instrument which can measure voltage, current & resistance. The voltage & current may be a.c. or d.c.

# DMM



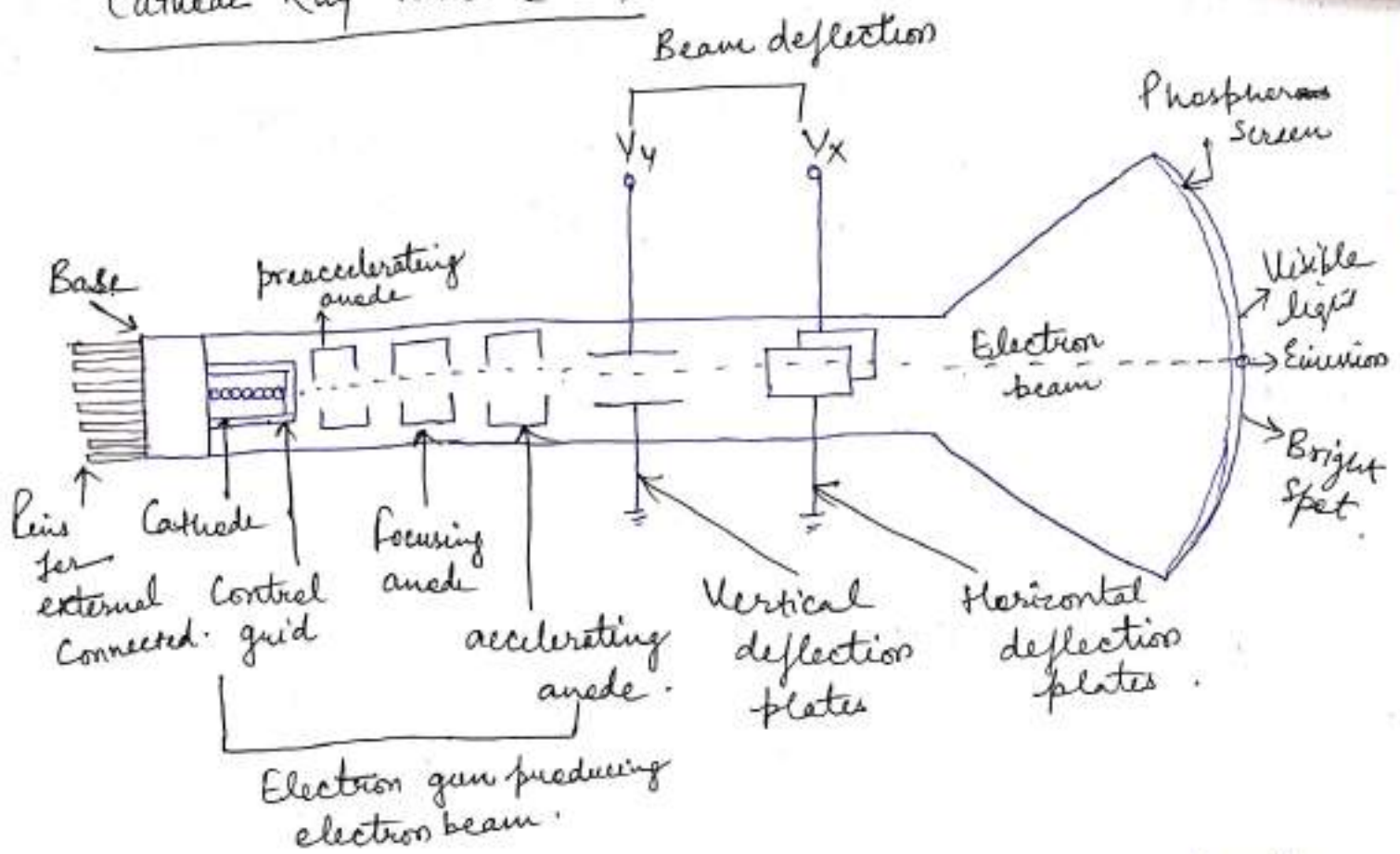
- This instrument is Capable of measuring ac Voltages, dc Voltages & dc current, ac currents & resistances over several ranges & display the reading in digital form.

→ It works on principle of constant dc Voltage

The selection of the parameter is possible with the help of rotary switch ~~is~~ connected to input probes of DMM.

- 1) Resistance measurement:- the rotary switch is in position 1 & resistance is connected to i/p probes. the Constant Current Source drives a current through unknown resistance. this produces voltage across resistance which is directly proportional to the resistance, it is given to buffer amplifier & then to A/D converter. the ADC converts it to equivalent digital signal & is displayed with the help of digital display.
- 2) AC Voltage measurement:- the rotary switch is in position 2 and input ac voltage is applied to probes. if it is above the selected range, it is attenuated with the help of compensated attenuator. it is rectified to produce proportional d.c. voltage. then it is given to ADC which display it in volts.
- 3) AC Current measurement:- the rotary switch is in position 3 & unknown current is applied across input probes. it is converted to proportional voltage using current to voltage converter & displays.
- 4) DC Current measurement:- Similarly current is also measured at rotary switch position 4.
- 5) DC Voltage measurement:- the rotary switch is out in position 5 & unknown voltage is applied across input probes. it is attenuated & directly given to ADC without rectification. the ADC displays it in volts.

# Cathode Ray Tube (CRT)



The heart of CRO is Cathode ray tube CRT which makes the applied signal visible by the deflection of a thin beam of electrons.

## Constructional features of CRT

- 1) Glass envelope - it is conical highly evacuated glass covering & maintains vacuum inside & support the various electrodes. The inner walls of CRT between neck & screen are coated with conducting materials called aquadag. This coating is electrically connected to the ~~accelerating~~ accelerating anode so that electrons which accidentally strikes.
- 2) Electron gun assembly. - Electron gun in CRT is combined name for indirectly heated cathode, a control grid, a focusing anode and an accelerating anode. The control grid is held at negative potential w.r.t. Cathode where as two anodes are maintained at high positive potential w.r.t. Cathode.

3) Control grid - Control grid in the CRT is cylindrical with a small aperture in line with the Cathode. The electrons emitted from the Cathode emerge from this. The negative bias Voltage applied to the grid, controls the beam current. The intensity (or brightness) of spot depends on the beam current.

4) Focusing anode: - The beam of electron is converged & focused on the screen by two anodes which form an electronic lens. The first anode (focusing anode) is kept at higher potential w.r.t to the Cathode.

5) Accelerating anode: - The second plate is still operated at higher positive potential (about 10,000V) and does most of the acceleration of the beam and increases the velocity.

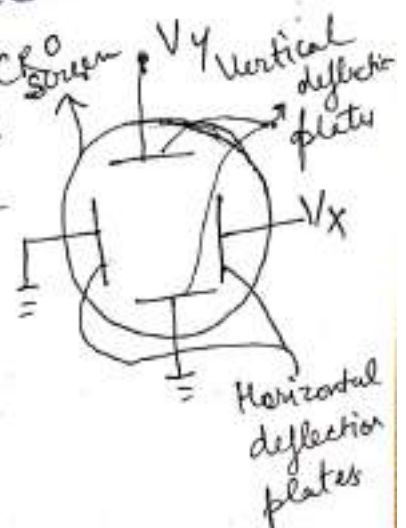
6) Deflection plate assembly: - Electrostatic deflection of an electron beam is used in general purpose oscilloscope. The deflecting system consists of a pair of horizontal ( $H_1$  &  $H_2$ ) & vertical deflecting plates ( $V_1$  &  $V_2$ ).

→ When the plates are at zero voltage, the beam is midway between them & spot is in the Centre of the Screen.

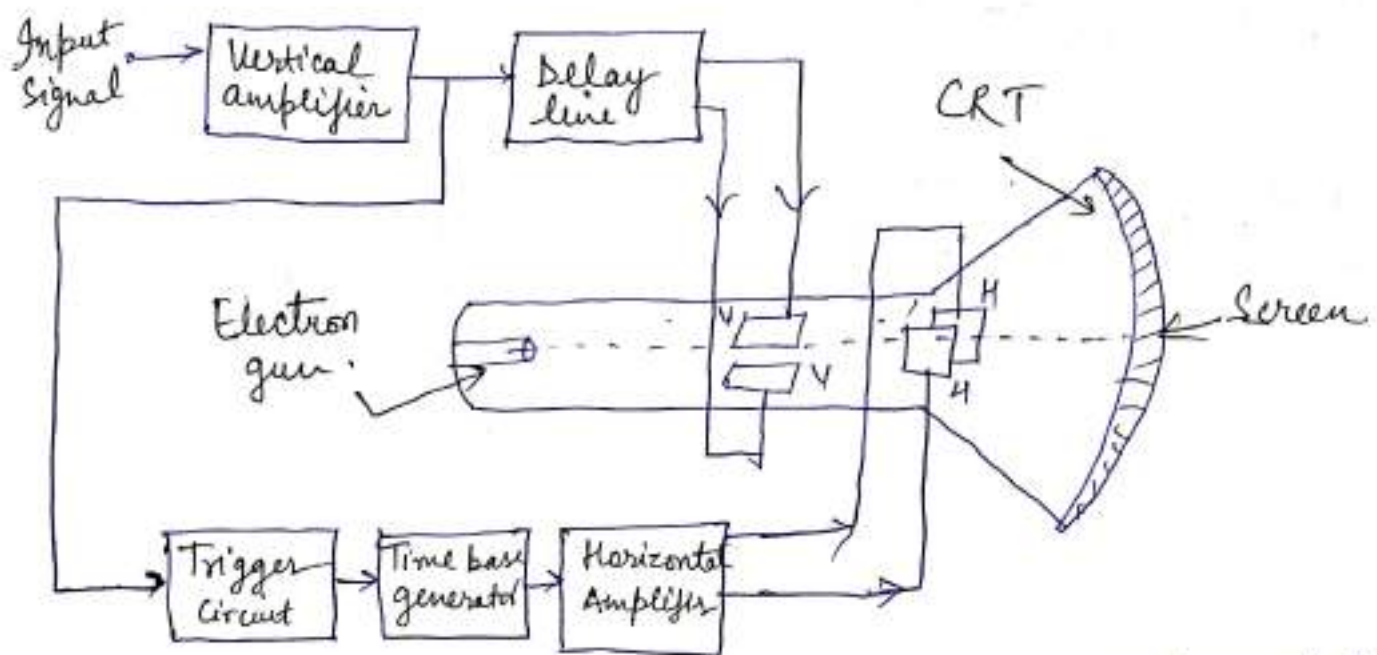
→ When  $H_1$  is made positive w.r.t. Cathode & all other plates are at zero voltage. It attracts the beam & the spot moves horizontally to the right.

→ Similarly when  $V_1$  is made positive, the spot moves vertically & where  $V_2$  is made positive. It moves vertically downwards.

7) Screen: - Screen is coated with fluorescent material.



# Cathode Ray Oscilloscope (CRO)



- 1) **CRT** — This is a Cathode ray tube which emits electrons that strikes the phosphor screen internally to provide a visible display of signals.
- 2) **Vertical Amplifier** — Vertical amplifier determines the sensitivity & bandwidth of oscilloscope. Sensitivity, which is expressed in terms of  $V/cm$  of vertical deflection at the mid band frequency.
- 3) **Delay line** — It is used to delay the signal for some time in the vertical sections till the time horizontal amplifier also receives signal.
- 4) **Time Base generators** — The CRO is used to display a waveform that varies as a function of time. If the waveform is to be accurately reproduced, the beam should have a constant horizontal velocity. It is used to generate sawtooth voltage required to deflect the beam in the horizontal section.
- 5) **Horizontal Amplifier** — This is used to amplify the sawtooth voltage before it is applied to horizontal deflection plates.

6) Trigger circuit :- This is used to convert the incoming signal into trigger pulses so that the input signal and the Sweep frequency can be Synchronized.

7) Power supply :- There are two power supplies, a -ve high Voltage (HV) Supply and a +ve low Voltage (LV) Supply.

Working of CRO :- The electron beam generated from an electron gun will be accelerated toward a phosphorous screen by a potential difference between the electron gun and the screen. As the beam emerges from the gun, it passes through a set of parallel plates (the vertical deflection plates) oriented horizontally. The voltage to be displayed is amplified by vertical amplifier & applied across the plates producing an electric field which deflects the path of electron vertically. The polarity of signal determines whether the deflections will be up or down & the magnitude of the signal determines the amount of vertical displacement of the electrons. After the beam has passed through vertical deflection plates, it passes through a second set of similar plates that are oriented horizontally. A potential difference applied to these plates produces an electric field which deflects left or right. Under normal configuration, these horizontal deflection plates are connected to a time base circuitry. This circuit can control how fast the electron beam sweeps from the left to the right (use Sweep knob). Adjusting the Sweep speed, the resulting trace on the screen can be spread out or compressed.

### Application of CRO

- 1) Examination of waveforms
- 2) Voltage measurement
- 3) Current measurement
- 4) Frequency measurement
- 5) Phase measurement

## Voltage Measurement (Amplitude Measurement)

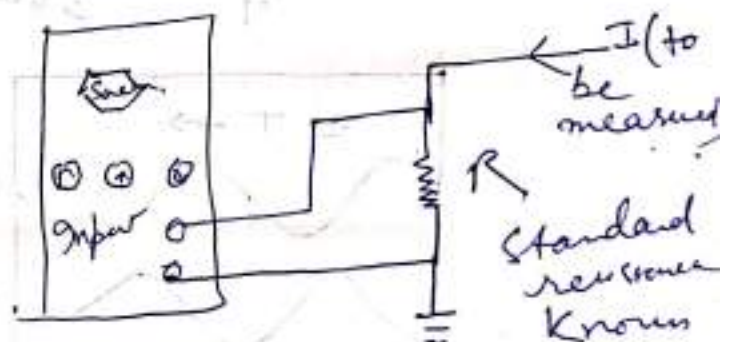
- 1) Note down the selection in volt/division from the front panel, selected for measurement.
- 2) Adjust shift control to adjust on screen so that it becomes easy to count number of divisions corresponding to peak to peak value of the signal.
- 3) Note down peak to peak value in terms of number of division on screen.

$$V_{PP} = (\text{Number of divisions or units needed}) \times \left( \frac{\text{Volts}}{\text{division}} \right)$$

amplitude  $V_m = \frac{V_{PP}}{2}$

## Current Measurement

$$I = \frac{V_{\text{measured on CRO}}}{R}$$



The CRO is basically voltage indicating device. Hence to measure the current.

## Period or frequency measurement

$T = (\text{Number of divisions occupied by 1 cycle}) \times \text{time division}$   
frequency is the reciprocal of period

$$f = \frac{1}{T}$$

# Phase measurement Using CRO

- ~~the~~ a) phase measurement by means of time measurement  
 b) phase measurement using Lissajous figures.

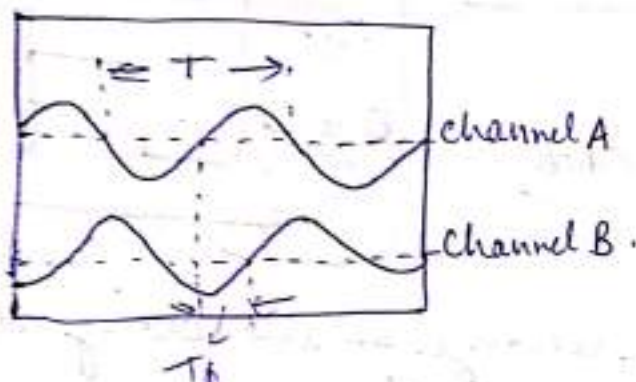
→ Measure the time difference  $T_p$  between the points of identical phase on the two signals as.

\* Measure the time of one complete cycle of the waveforms. it may be noted that for both the waveforms have same frequency.

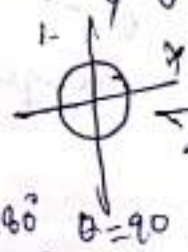
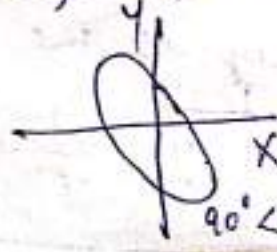
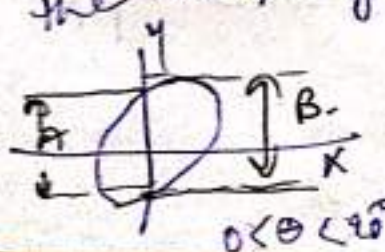
1 cycle period  $T = \text{phase shift of } 360^\circ$

Period  $T_\phi = \text{How much phase shift } (\phi = ?)$

$$\frac{T_\phi}{T} = \frac{\phi}{360^\circ} \quad \text{or} \quad \phi = \left[ 360^\circ \times \frac{T_\phi}{T} \right]$$



→ In this method, two Sinewaves of same frequency are applied to CRO (one to the vertical plates and other to horizontal plates.) the CRO is set to operate in X-Y mode. then display obtained on the CRO screen is called Lissajous pattern. depending on phase shift between two signals the shape of Lissajous pattern will go on changing.



# Applications

phase shifts  $0^\circ$  &  $90^\circ$

$$n = \frac{1}{\sqrt{1 + \frac{1}{4}}}$$

$$\theta = \sin^{-1}(A/B)$$

for phase difference between above  $90^\circ$  & less than  $180^\circ$

$$\theta = 180^\circ - \sin^{-1}(A/B)$$

## Applications of CRO

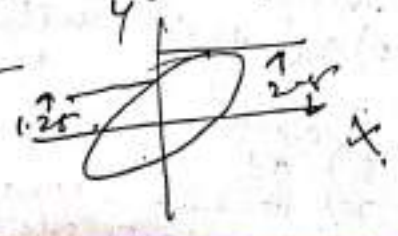
- 1) for analysis of ckt, by observing waveforms at various points of the circuit.
- 2) to measure voltage, time frequency duty cycle & phase shift.
- 3) to measure modulation index of an A.M wave
- 4) for testing the components such as diodes & transistors.
- 5) In an instrument called curve tracer which directly displays the V.I. characteristics of device such as transistor
- 6) In the Radar, CRO is used to display transmitted & received pulses to measure distance.

B. Voltage  $E_1$  is applied to the horizontal input & Voltage  $E_2$  is applied to the vertical input of a CRO.  $E_1$  &  $E_2$  have the same frequency. the trace is an ellipse - the slope of the major axis is positive. the maximum vertical value is 2.5 division & the point where the ellipse crosses the vertical axis is 1.25 divisions. the ellipse is symmetrical about the horizontal & vertical axis. determine the possible phase angles of  $E_2$  w.r.t. to  $E_1$ .

$$\sin \phi = \frac{1.25}{2.5} = 0.5$$

$$\phi = 30^\circ$$

$$\text{possible phase diff} = 30^\circ = 330^\circ$$



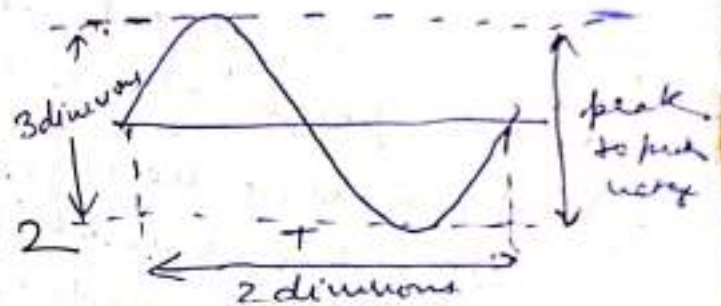
In an experiment, the voltage across a  $10\text{K}\Omega$  resistor is applied to CRO. The screen shows a sinusoidal signal of total vertical occupancy  $3\text{cm}$  & total horizontal occupancy of  $2\text{cm}$ . The front panel controls of  $V/\text{div}$  and time/div are on  $2\text{V}/\text{div}$  &  $2\text{ms}/\text{div}$  respectively. Calculate the rms value of the voltage across the resistor & its frequency.

given,

$$R = 10\text{K}\Omega$$

Number of vertical divisions = 3

Number of horizontal divisions = 2



i) Peak to peak voltage =  $3\text{ div} \times 2\text{V} = 6\text{ volts}$

$$\text{RMS Voltage} = \frac{V_{PP}}{2\sqrt{2}} = \frac{6}{2\sqrt{2}} = 2.121\text{ volts}$$

iii) Time corresponding to 1 cycle

$$T = 2 \times 2\text{ms/div} = 4\text{ms}$$

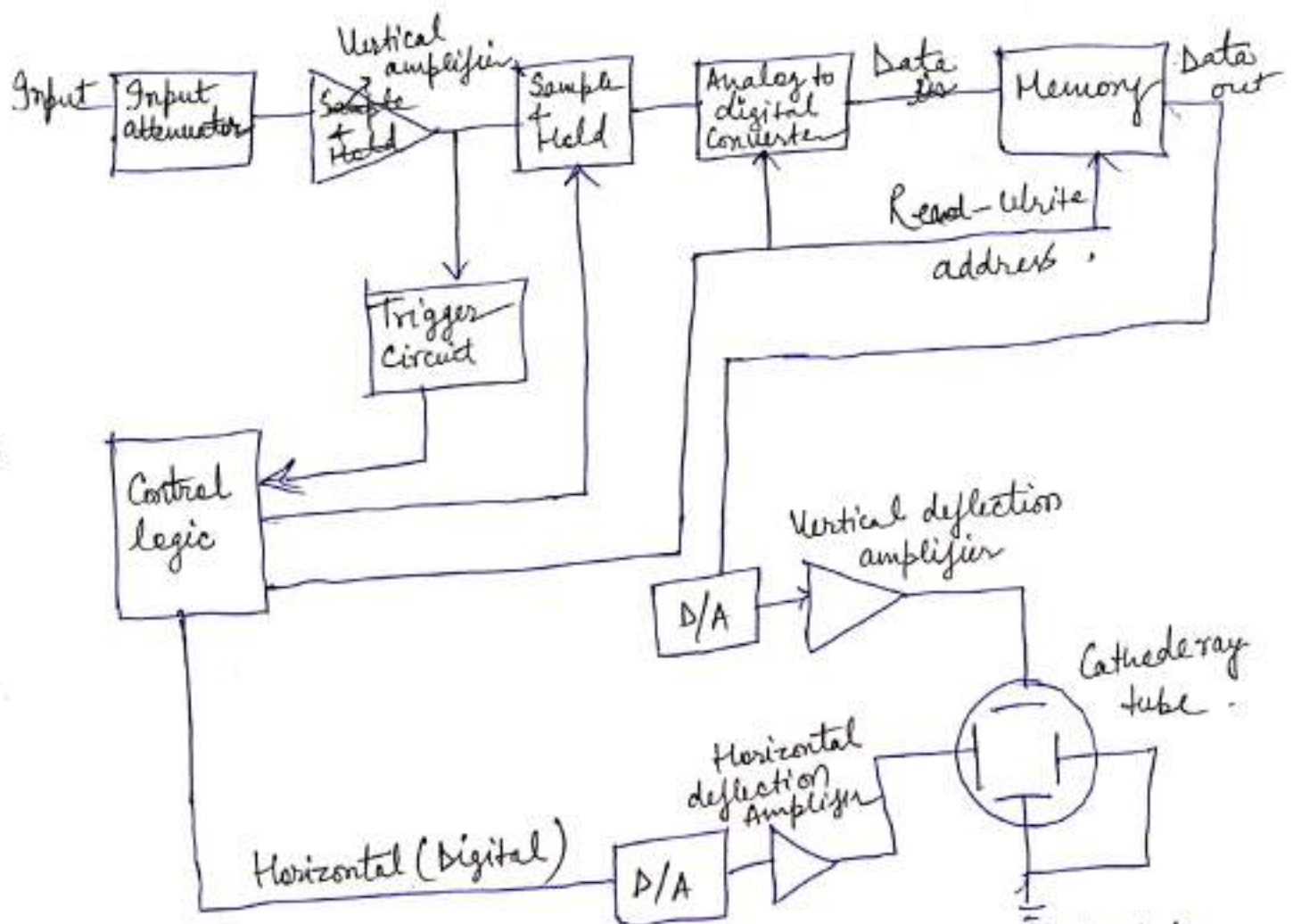
$$\text{Frequency } f = \frac{1}{T} = \frac{1}{4 \times 10^{-3}} = 250\text{Hz}$$

DSO

ASO

- |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ol style="list-style-type: none"> <li>1) It can store the given signal indefinitely as long as the small amount of power is supplied to the memory.</li> <li>2) It always collects the data &amp; stops when triggered.</li> <li>3) It employs normal CRT tube.</li> <li>4) Cost of tube is much cheaper than store tube used in ASO.</li> <li>5) It can produce very bright image even for high frequency signal.</li> <li>6) In this oscilloscope, time base is generated by a crystal clock.</li> <li>7) It has higher resolution than ASO.</li> <li>8) It has less operating speed than ASO.</li> <li>9) It does not have aliasing effect.</li> </ol> | <ol style="list-style-type: none"> <li>1) On this oscilloscope, heavy amount of power is to be supplied to storage CRT.</li> <li>2) It collects the data only after triggering.</li> <li>3) The cost of tube is costlier than storage tube used in DSO.</li> <li>4) It cannot produce bright image for high frequency signal.</li> <li>5) In this oscilloscope, time base is generated by ramp generator.</li> <li>6) It has lower resolution than DSO.</li> <li>7) It has high operating speed than DSO.</li> <li>8) It does not have aliasing effect.</li> </ol> |
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# Digital Storage Oscilloscope (DSO)



- The digital Storage Oscilloscope replaces the unreliable storage method used in analog storage oscilloscopes with digital storage with the help of memory.
- The memory can store data as long as required without degradation.
- In DSO, waveforms to be stored are digitized and stored in digital memory.
- The conventional Cathode ray tube is used, so cost is less.
- Power to be applied to memory is small and can be supplied by a small battery.
- Once the waveform is digitized, it can be

- further loaded into Computer & Can be analysed in detail.

### Advantages of DSO

- 1) it is easier to operate & has more Capability.
- 2) Storage time is infinite
- 3) display flexibility is available. the number of traces Can be stored & recalled depend on the size of memory.
- 4) Brighter & bigger display with colour to distinguish multiple traces.
- 5) Keeping records is possible by transmitting the data to the Computer Systems.