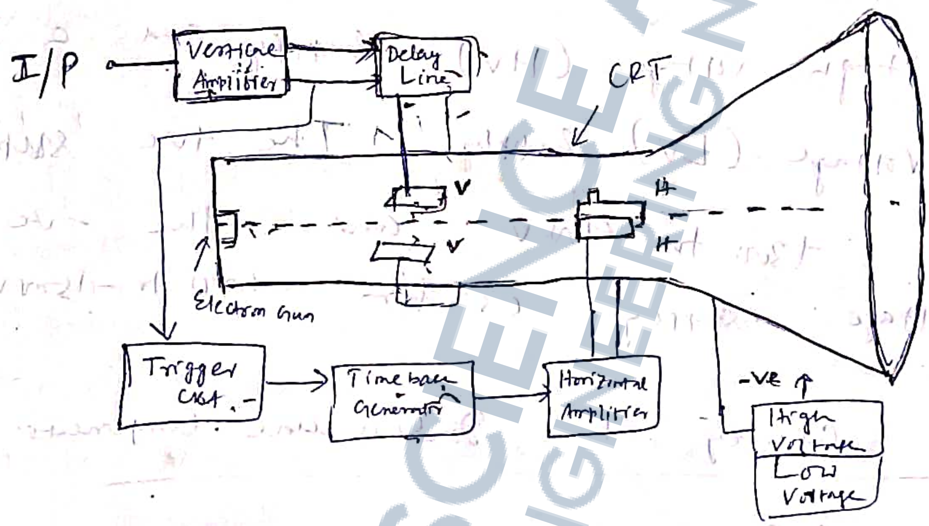
# Electronic Instruments :-

## CRO (Cathode Ray Oscilloscope)

The Cathode ray Oscilloscope (CRO) is very useful & versatile laboratory instrument used for display, measurement and analysis of waveforms in electrical & electronic ckt.

## Block Diagram of Oscilloscope




### CRT

This is the Cathode Ray Tube which emits electrons that strikes the phosphor screen internally to give a visual display of signal.

### Vertical Amplifier :-

This is a wide band amplifier used to amplify signals in the vertical section.

### Delay line :-

It is used to delay the signal for some time in the vertical section.

### Time Base :-

It is used generate Sawtooth Voltage needed to deflect the beam in horizontal section.

## Horizontal Amplifier:-

This is used to amplify the sawtooth voltage before it is applied to horizontal deflection plate.

## Trigger Ckt:-

This is used to convert the incoming signal into trigger pulses so that input signal and sweep frequency can be synchronised.

## Power Supply:-

~~There~~ There are 2 power supplies, a -ve High voltage (HV) supply and a +ve low voltage (LV) supply. The +ve supply is from +300 to 400 V and the -ve high voltage supply is from -1000 to -1500 V.

## Detail Study of Individual Components:

### CRT:- (Cathode Ray Tube)

A Cathode ray oscilloscope consists of a cathode ray tube (CRT) which is the heart of the tube and some additional circuitry to operate the CRT.

The main part of CRT are

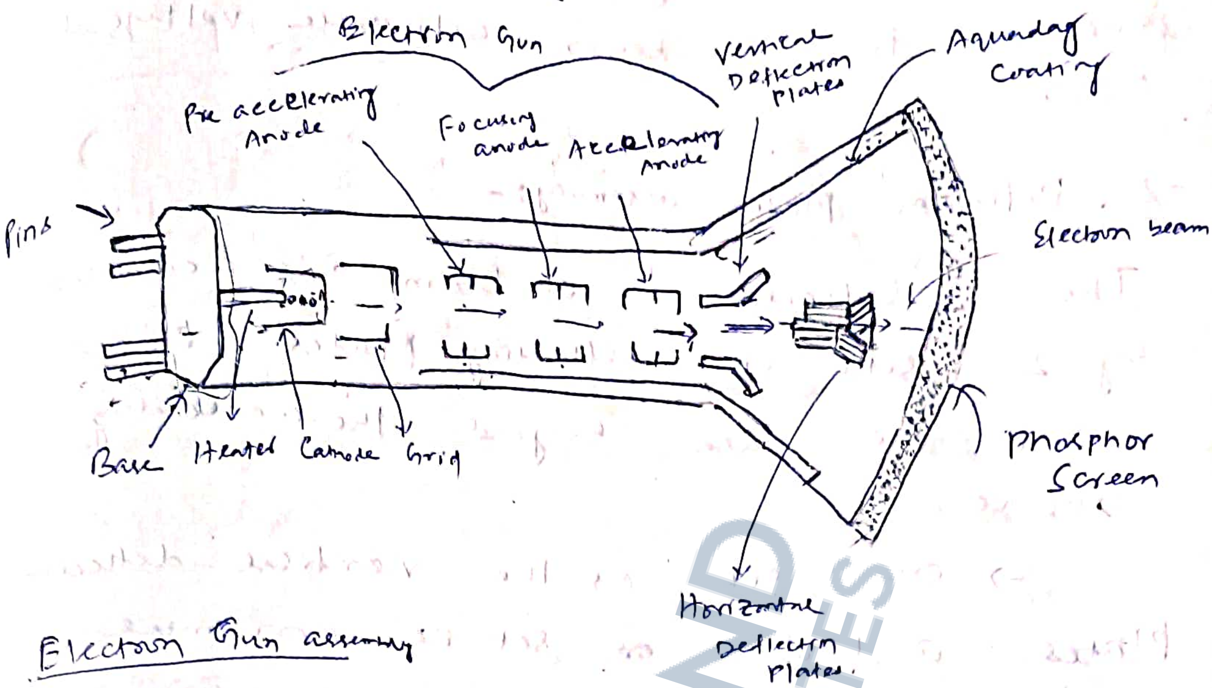
(i) Electron gun assembly

(ii) Deflection plate assembly

(iii) Fluorescent screen

(iv) Glass envelope

(v) Base, through which connections are made to various parts.




Electron Gun assembly:

→ The Source of focused & accelerated electron beam is the electron gun. The electron gun consists of a heater, a grid, a pre-accelerating anode, a focusing anode & an accelerating anode.

→ Electrons are emitted from the indirectly heated Cathode. These electrons pass through a small hole in the "Control grid". The intensity of electron beam depends on the number of electrons emitted from the Cathode. The grid with its -ve bias controls the number of electrons emitted from the Cathode and hence the intensity is controlled by the grid.

→ Then the electrons are accelerated by the high +ve potential which is applied to the "pre-accelerating" and "accelerating anodes".

→ The Pre-accelerating anode and accelerating anode are connected to a common +ve high voltage of about 1500V.

→ The electron beam is focused by the "focusing Anode". The focusing anode is connected to a lower adjustable voltage of 500V.

→ **Deflection Plate assembly:-**

The deflection of beam is accomplished by 2 sets of deflecting plates placed within the tube beyond the accelerating anode.

→ one set is the vertical deflection plates and other set is horizontal deflection plates.

The vertical deflection plates are mounted horizontally in the tube. By applying proper potential to these plates, the electron beam can be move up & down vertically on the fluorescent screen.

The horizontal deflection plates are mounted ~~horizontally~~ vertically in the tube. By applying appropriate potential on these plates. can cause the electron beam to move right and left horizontally on the screen.

**Viewing Screen:-**

The viewing screen is the glass face plate; the inside wall of which is coated with phosphor. The viewing screen is a rectangular screen with graticules (Grid of lines) marked on it. The standard size used now-a-days is 8cm × 10cm. The standard phosphor color used now-a-days is blue.

↓

( 8 cm ~~~~ height, 10 cm ~~~~ wide )

## Glass envelope:-

It is conical highly evacuated glass housing & maintains ~~vacuum~~ vacuum inside and supports the various electrodes. The inner walls of CRT between neck & screen are usually coated with a conducting material called ~~'aquadag'~~ aquadag. This coating is electrically connected to the accelerating anode so that electrons which accidentally strike the walls are returned to the anode. This prevents the walls of the tube from charging to a high -ve potential.

## Deflection sensitivity of CRT:-

The shift of the spot of light on the screen per unit change in voltage across the deflection plate is known as deflection sensitivity of CRT.

e.g if a voltage of 100 V applied to the vertical plates produces a vertical shift of 3 mm in the spot, then deflection sensitivity is $0.03 \frac{mm}{V}$.

In general,

Spot deflection = Deflection sensitivity × Applied voltage.

Ex:- The deflection sensitivity of a CRT is 0.01 mm/V. Find the shift produced in the spot when 400 V are applied to the vertical plates.

Ans →

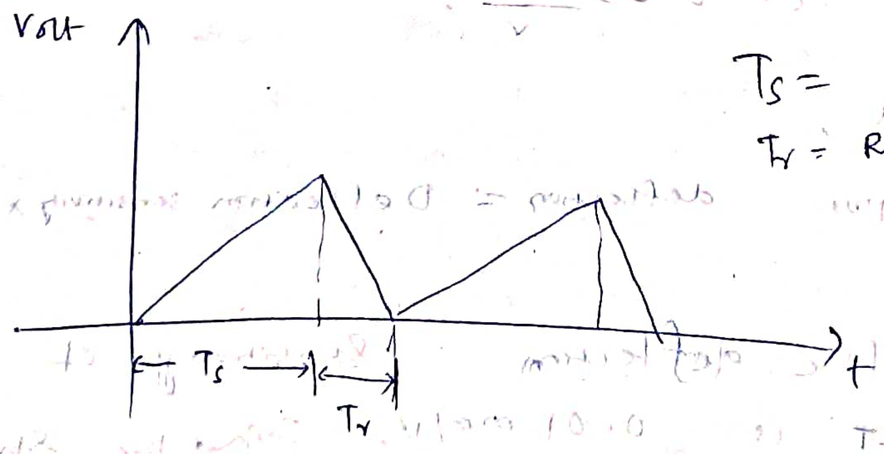
$$\text{Spot shift} = \text{Deflection Sensitivity} \times \text{Applied Voltage}$$

$$\Rightarrow \text{Spot shift} = 0.01 \tfrac{mm}{volt} \times 400 \text{ volt}$$

$$\Rightarrow \text{Spot shift} = 4 \text{ mm} \quad \text{(Ans)}$$

## Time Base Generators. (Sweep Generators)

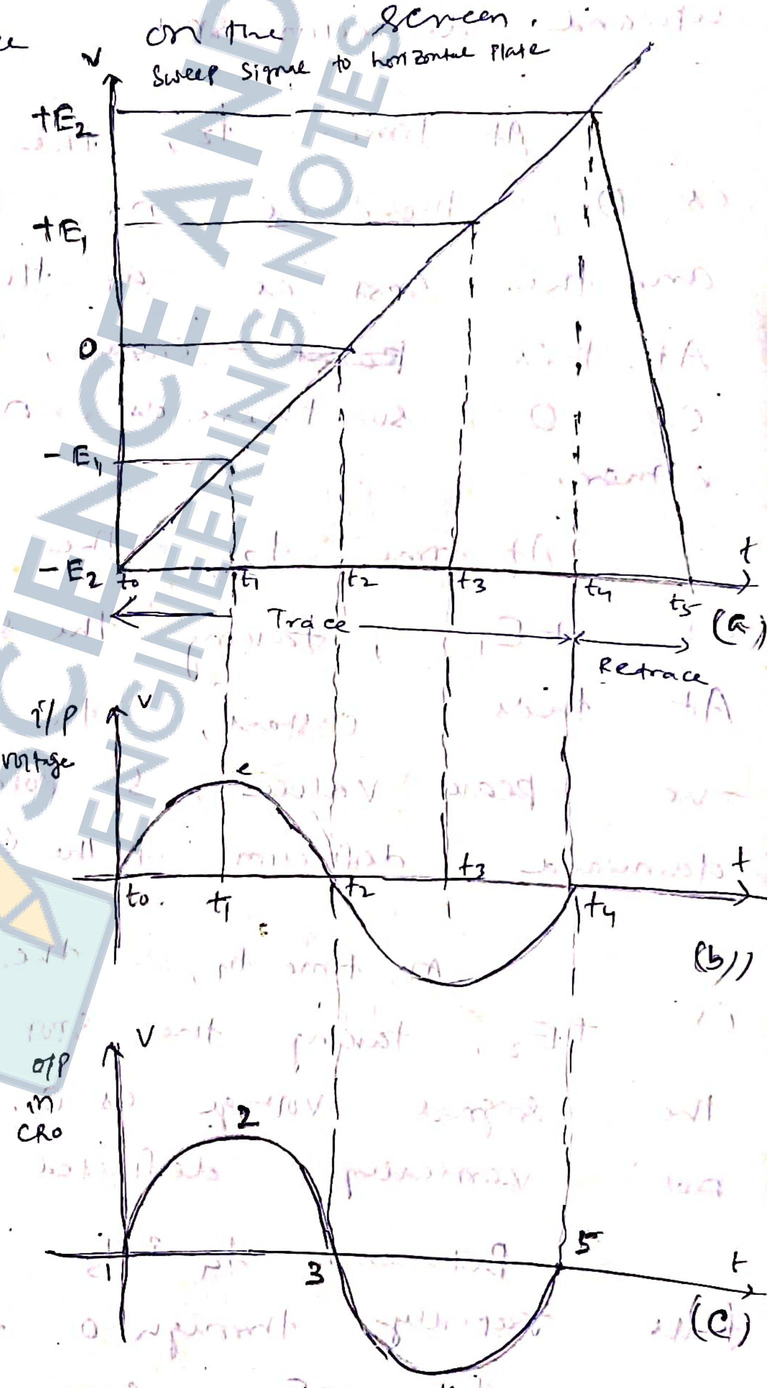
Oscilloscopes are generally used to display a waveform that varies as a function of time. If the waveform is to be accurately reproduced, the beam must have a constant horizontal velocity. Since the beam ~~voltage~~ velocity is a function of deflecting voltage, the deflecting voltage must increase linearly with time. A voltage with this characteristic is called ramp voltage. If the voltage decreases rapidly to zero with the waveform repeatedly reproduced. This pattern is called a sawtooth waveform.




$T_s$ = Sweep time

$T_r$ = Retrace time

So the signal to be displayed is applied to the vertical plates and it moves the spot vertically to positions, corresponding to instantaneous values of the signal.
Simultaneously, the spot is moved horizontally by a sweep voltage applied to the horizontal plates. The resultant action of these 2 voltages causes the spot to generate a trace on the screen.




-> There are 2 important sweep generator requirements

(i) The sweep must be linear

(ii) The spot must move in one direction only e.g from left to right only. So the sweep voltage must drop suddenly after getting maxm value.

Analysis :-

At time 't0' the sweep voltage $-E_2$, and the -ve horizontal voltage moves the spot to point 1 on the screen. At this instant the signal voltage is 0, so the spot rests at the left end zero line on the screen.

At time $t_1$, the linearly increasing sawtooth reaches at $+E_1$, which being more +ve than $-E_2$, moves the spot to the screen, point 2. At this instant, the signal voltage is e, the +ve peak value, so the point indicates its maxm upward deflection spot.

At time $t_2$, the sawtooth voltage is 0, there is no horizontal deflection and the spot is at the center, point 3. At this ~~instant~~ instant, the signal voltage is 0, so there is no vertical deflection either.

At time $t_3$, the sawtooth voltage is $+E_1$, taking the spot to point 4. At this instant, the signal is $-e'$, the -ve peak value, so point 4 is the maxm downward deflection of the spot.

At time $t_4$, the saw tooth voltage is $+E_2$, taking the spot to point 5. Now the signal voltage is 0, so the spot is not vertically deflected.

Between $t_4$ & $t_5$ the sawtooth voltage falls rapidly through 0 to its initial value of $-E_2$, snapping the spot back to point 1, in time to sweep forward on next cycle of signal voltage.

## The various types of sweeps produced

(a) Recurrent sweep / Free running sweep.

(b) Single sweep

(c) Driven sweep

(d) Triggered sweep.

## Measurement of Phase and frequency (By Lissajous Patterns)

When sinusoidal voltages are simultaneously applied to horizontal & vertical plates, a characteristic pattern is obtained on the screen. These patterns are called 'Lissajous Pattern'.

→ No need of sweep generator at the time of 'Lissajous Pattern'.

### Measurement of phase

When 2 sinusoidal voltage of equal frequency which are in phase with each other are applied to the horizontal & vertical plates the pattern appearing on the screen is a straight line.

Proof :- Let us consider two alternating voltages

ie. $e_x$ applied to X plate.

$e_y$ applied to Y-plate.

Let $e_x = E_x \sin \omega_x t$.

$e_y = E_y (\sin \omega_y t + \alpha)$.

→ Where $E_x$ & $E_y$ are the max$^m$ amplitude of the voltages.

→ $W_x$ & $W_y$ are the angular frequencies of the voltages.

→ $\alpha$ is the phase angle of $e_y$.

<u>Case - I</u> < when $W_x = W_y$, $\alpha = 0$ >

$$e_x = E_x \sin w_x t$$

$$e_y = E_y \sin w_x t$$

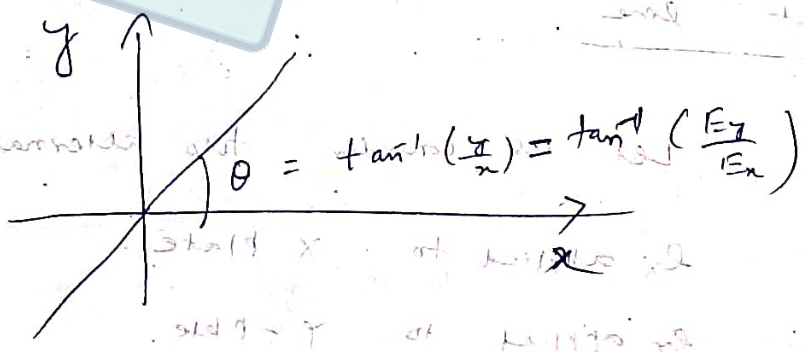
$$\Rightarrow \frac{e_x}{e_y} = \frac{E_x}{E_y}$$

$$\Rightarrow \frac{e_y}{e_x} = \frac{E_y}{E_x}$$

$$\Rightarrow e_y = \left(\frac{E_y}{E_x}\right) e_x$$

$$\Rightarrow y = m x$$

It is a eq$^n$ of straight line passing through origin




∴ If 2 voltages have same freq and phase the pattern shown on the CRO screen is a <u>straight line</u>

Case - II If $\omega_x = \omega_y$, $\alpha = \frac{\pi}{2}$

$e_x = E_x \sin \omega_x t$ ——— ①

$e_y = E_y \sin(\omega_y t + \frac{\pi}{2})$

$\therefore e_y = E_y \cos \omega_y t$

$e_y = E_y \cos \omega_x t$ — ② $\quad \because \omega_x = \omega_y$

~~$e_x^2 + e_y^2$~~ $e_x^2 = E_x^2 \sin^2 \omega_x t$

$e_y^2 = E_y^2 \cos^2 \omega_x t$

$\sin^2 \omega_x t = \frac{e_x^2}{E_x^2}$ ——— ③

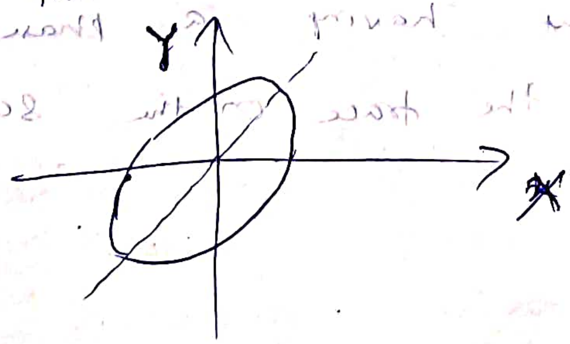
$\cos^2 \omega_x t = \frac{e_y^2}{E_y^2}$ ——— ④

Adding eqn ③ & ④,

$\sin^2 \omega_x t + \cos^2 \omega_x t = \frac{e_x^2}{E_x^2} + \frac{e_y^2}{E_y^2}$

$$\Rightarrow \boxed{\frac{e_x^2}{E_x^2} + \frac{e_y^2}{E_y^2} = 1}$$

This is the equation of an ellipse.



~~Lo ff unequal equ~~

If 2 signals of same freq, but different amplitude with phase difference of $\frac{\pi}{2}$ applied, a ellipse is shown on the CRO.

Case III (If $\omega_x = \omega_y$, $E_x = E_y$, $\alpha = \frac{\pi}{2}$)

$$e_x = E_x \sin \omega_x t$$

$$e_y = E_y \sin(\omega_y t + \alpha)$$

$$= E_x \sin(\omega_x t + \frac{\pi}{2})$$

$$e_y = E_x \cos \omega_x t$$

$$e_x^2 + e_y^2$$

$$= E_x^2 \sin^2 \omega_x t + E_x^2 \cos^2 \omega_x t$$

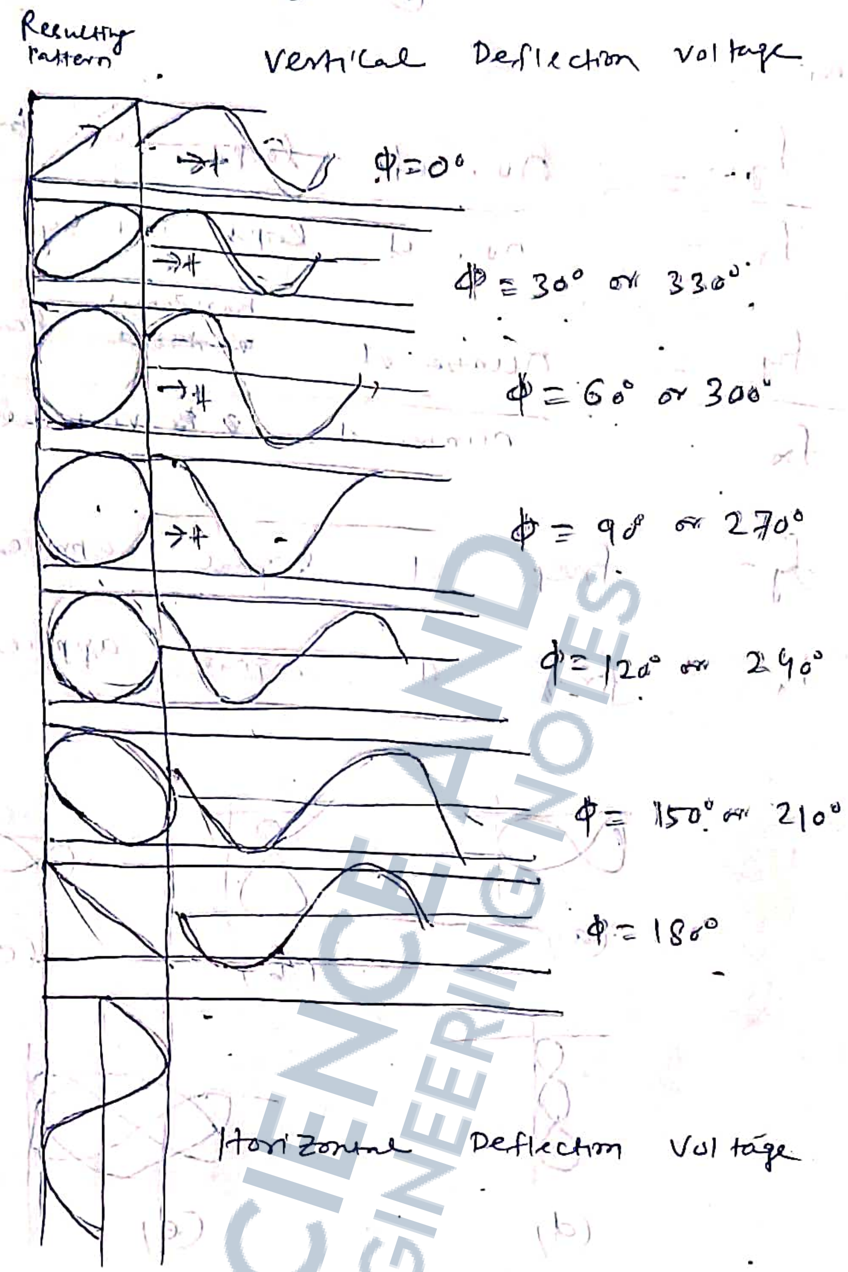
$$= E_x^2 \left[\sin^2 \omega_x t + \cos^2 \omega_x t\right]$$

$$e_x^2 + e_y^2 = E_x^2 = E^2 \quad \mid \text{Let } E_x = E_y = E$$

$$\boxed{e_x^2 + e_y^2 = E^2}$$

This is the eqn of circle.

∴ If 2 signals of equal amplitude, freq but having phase difference of 90°, the trace on the screen is a circle.




## Frequency Measurement:-

→ The signal, whose frequency is to be measured, is applied to the Y-plates.

→ An accurately calibrated standard variable frequency source is used to supply voltage to the X-plate, with internal sweep generator switched off.

→ The standard freq. is adjusted so that we got a pattern of circle, ellipse or loop of circles or ellipse, or mixture of both.

Then

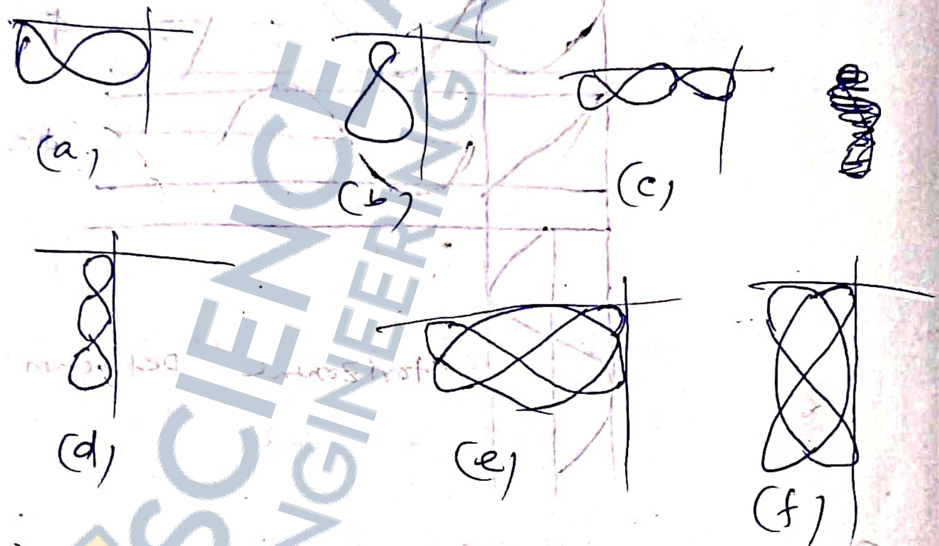
$$\frac{f_y}{f_x} = \frac{\text{no. of loops cut by horizontal line}}{\text{no. of loops cut by vertical line}}$$

$$\frac{f_y}{f_x} = \frac{\text{number of ~~vertical~~ horizontal tangencies}}{\text{number of vertical tangencies}}$$

$f_y$ = freq of signal applied to Y plate

$f_x$ = freq of signal applied to X plate.

ex




For (fig a) $\frac{f_y}{f_x} = \frac{2}{1} \Rightarrow \boxed{f_y = 2 f_x}$

fig (b) $\frac{f_y}{f_x} = \frac{1}{2} \Rightarrow \boxed{f_y = \frac{f_x}{2}}$

fig c $\frac{f_y}{f_x} = \frac{3}{1} \Rightarrow \boxed{f_y = 3 f_x}$

fig (d) $\frac{f_y}{f_x} = \frac{1}{3} \Rightarrow \boxed{f_y = \frac{f_x}{3}}$

fig (e) $\frac{f_y}{f_x} = \frac{3}{2} \Rightarrow f_y = \frac{3}{2} f_x$

fig (f) $\frac{f_y}{f_x} = \frac{2}{3} \Rightarrow f_y = \frac{2}{3} f_x$

✓ Done in practical

## Voltage Measurement:-

$V_{p-p} = \left(\frac{\text{volts}}{\text{div}}\right) \times (\text{No of divisions in Y-axis})$

$\text{Amplitude} = \frac{V_{p-p}}{2}$

## Freq Measurement

$T = \left(\frac{\text{time}}{\text{div}}\right) \times (\text{No of div in X-axis})$

$\therefore \text{Freq} = \frac{1}{T}$

## Signal Generators :-

Signal generators are applied on various fields such as checking the stage gain, freq. response and alignment in receiver and in a wide range of other electronic equipments.

### Common requirement in a signal generator

→ The freq. of signal should be known & stable

→ The amplitude should be controllable from very small to relatively large values.

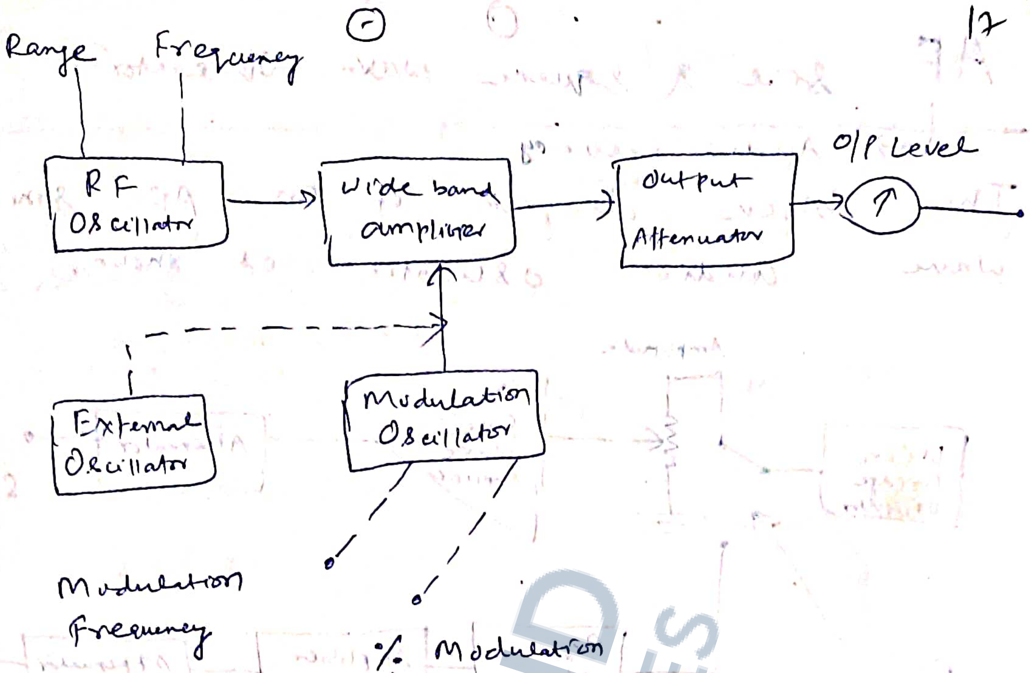
→ Finally, the signal should distortion free

## Standard Signal Generator :-

→ A standard signal generator generates known and controllable voltages. It is used as power source for measurement of gain, signal to noise ratio (S/N), Bandwidth, Standing wave ratio and other properties.

→ It is extensively used in testing of radio receivers & transmitters.

→ The instrument is used to modulate the carrier frequency, which is represented by the dial setting on the front panel. The modulation is represented by a ~~[illegible]~~ meter. The o/p signal can be Amplitude modulated (AM) or frequency modulated (FM). Modulation may be done by a sinewave, square wave, triangular wave or a pulse.




→ The carrier frequency is generated by a very stable RF ~~oscillating~~ oscillator using LC tank circuit, having a constant O/P over any frequency range. The frequency of oscillation is represented by the frequency range control. ~~and the~~ AM is provided by an internal sine wave generator or from external source.

→ Frequency stability is limited by the LC design of master oscillator. Since tank circuit is usually obtained by selecting range switching appropriate capacitors, any change in frequency range perturbs (disturb) the ckt design slightly and the instrument must be given time to stabilize at new resonant frequency.

→ For high freq oscillators, the oscillator circuit must be isolated from the O/P ckt. Because of this isolation, changes occuring in the O/P ckt. don't affect the oscillator frequency, amplitude and distortion characteristics. Buffer amplifier are used for this purpose.

# AF Sine & Square wave Generator

AF → Audio Frequency

The block diagram of an AF sine-square wave audio oscillator is shown.

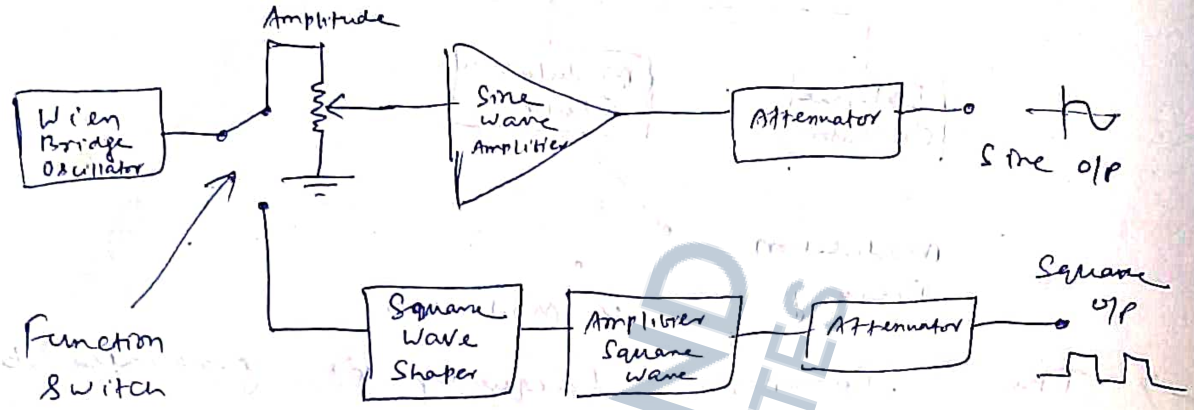



fig:- AF Sine and Square wave generator.

→ The signal generator is called an oscillator. A Wien bridge oscillator is used in this generator. The Wien bridge oscillator is the best suitable for audio frequency range. The frequency of oscillations can be changed by varying capacitance in the oscillator. The frequency can also be changed in steps by switching in resistors of different values.

→ The o/p of the Wien bridge oscillator goes to the function switch. The function switch directs the oscillator o/p either to the sine wave amplifier or to the square wave shaper. At the o/p, we obtain either a square or sine wave. The o/p is varied by means of an attenuator.

→ The instrument produces a frequency ranging from 10 HZ to 1 MHZ. The o/p sine wave amplitude can be varied from 5mV to

5 V (rms). The o/p is taken through a Push-pull amplifier.

→ For low op, the impedance is 600Ω.

The Square wave amplitude can be varied from (0-20 V) peak.

→ The instrument needs only 7 watt power at 220V - 50 Hz.

The Signal generator compromises of the following

• **Frequency Selector:-**

It chooses the frequency in different ranges & varies it continuously in a ratio 1:11. The scale is non-linear.

• **Frequency multiplier:-**

It chooses the frequency range over 5 decades from 10 Hz to 1 MHz. ( 10 to $10^6$ )

• **Amplitude multiplier:-**

It attenuates the sine wave in 3 decades

x 1, x .1, x .01.

• **Variable Amplitude:-**

We can achieve variable ~~amp~~ amplitude continuously.

**Symmetry Control:-**

It varies the symmetry of square wave from 30% to 70%.

**Function Switch:-**

It chooses either sine wave or square wave output.

Output :- This gives sine wave or square wave output.

Sync : This terminal is used to provide synchronisation of the ~~external~~ internal signal with an external signal

On-off Switch.

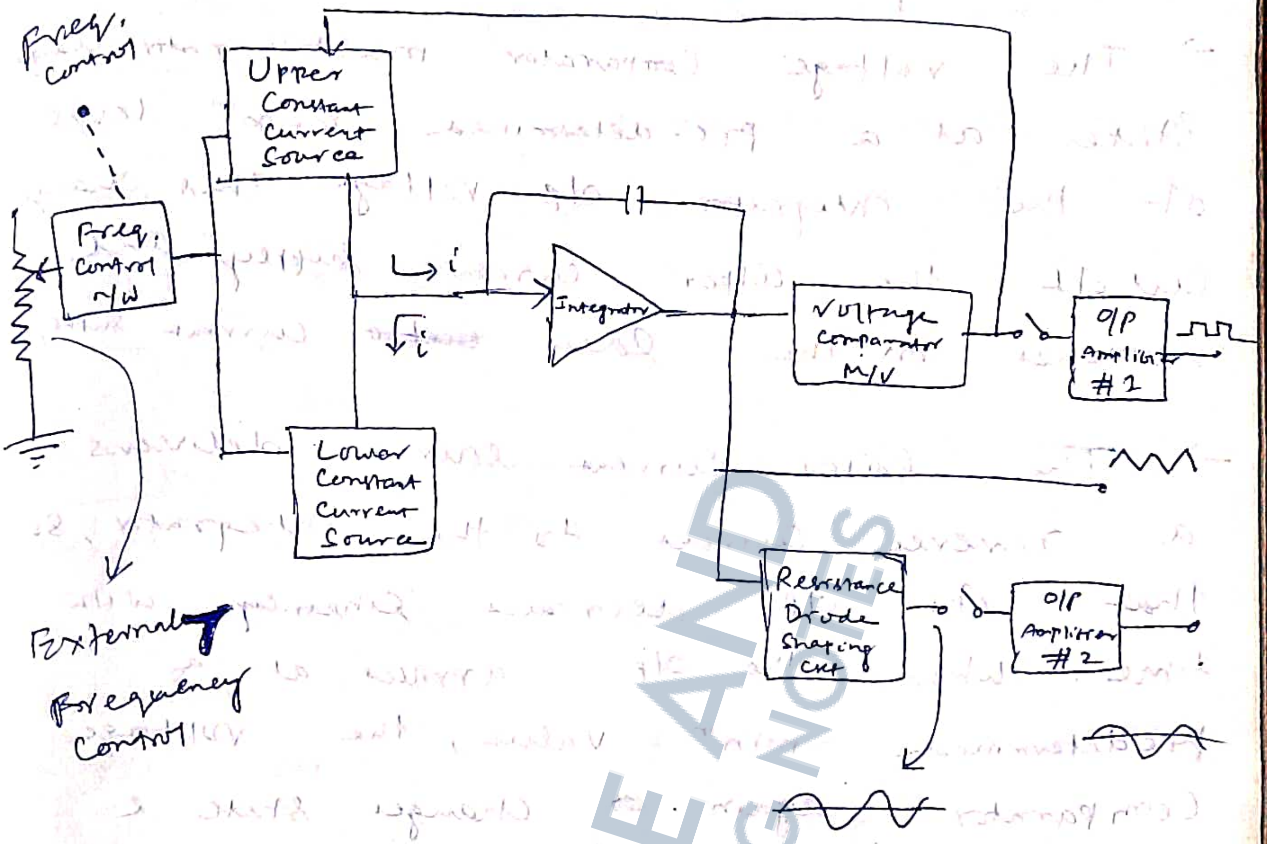
# Function Generator:-

→ It is a generator which generates different waveforms of adjustable frequency. The common output waveforms are sine, square, triangular, saw tooth waves.

→ The various o/p. of generator can be accomplished at the same time. e.g the generator can provide a square wave to test the linearity of an amplifier and simultaneously provide a saw tooth to drive the horizontal deflection amplifier of CRO to provide a visual display.

→ The function generator can be phase locked to an external source. One function generator can be used to lock a second function generator and the 2 o/p signals can be displayed in phase by adjustable amount.

Also the fundamental frequency of one generator can be phase locked to a harmonic of another generator by adjusting




Block diagram of
(Function Generator)

the amplitude & phase of the harmonic, almost any waveform can be produced on addition.

→ Usually the frequency is regulated by varying the Capacitor in the LC or RC ckt. But in this instrument, the freq is controlled by varying the magnitude of current which drives the integrator.

→ The freq controlled voltage regulates 2 current sources. The upper current source delivers const. current to the integrator whose o/p voltage increases linearly with time,

$$e_{out} = -\frac{1}{C}\int_0^t i\,dt$$

→ An increase or decrease in the current increases or decreases the slope of the

O/P voltage and hence regulates the freq.

→ The voltage comparator multivibrator changes state at a pre-determined maxm level of the integrator O/P voltage. This change cut off the upper current supply and switches on the lower ~~curr~~ current supply.

→ The lower current source delivers a reverse current to the integrator, so that its O/P decreases linearly with time. When the O/P arrives at a predetermined minm value, the voltage comparator again ~~ch~~ changes state & switches on the upper current source.

→ The O/P of the integrator is a triangular waveform whose frequency is obtained by the magnitude of the current supplied to the constant current source.

→ The comparator O/P supplies a square wave voltage of same freq. The resistance divide N/W changes the slope of the triangular wave as its amplitude changes and generates a sine wave with less than 1% distortion.

—T—