(UNIT-4)

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Contents:

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- Components of the Cathode-Ray Oscilloscope
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- AF Signal Generator

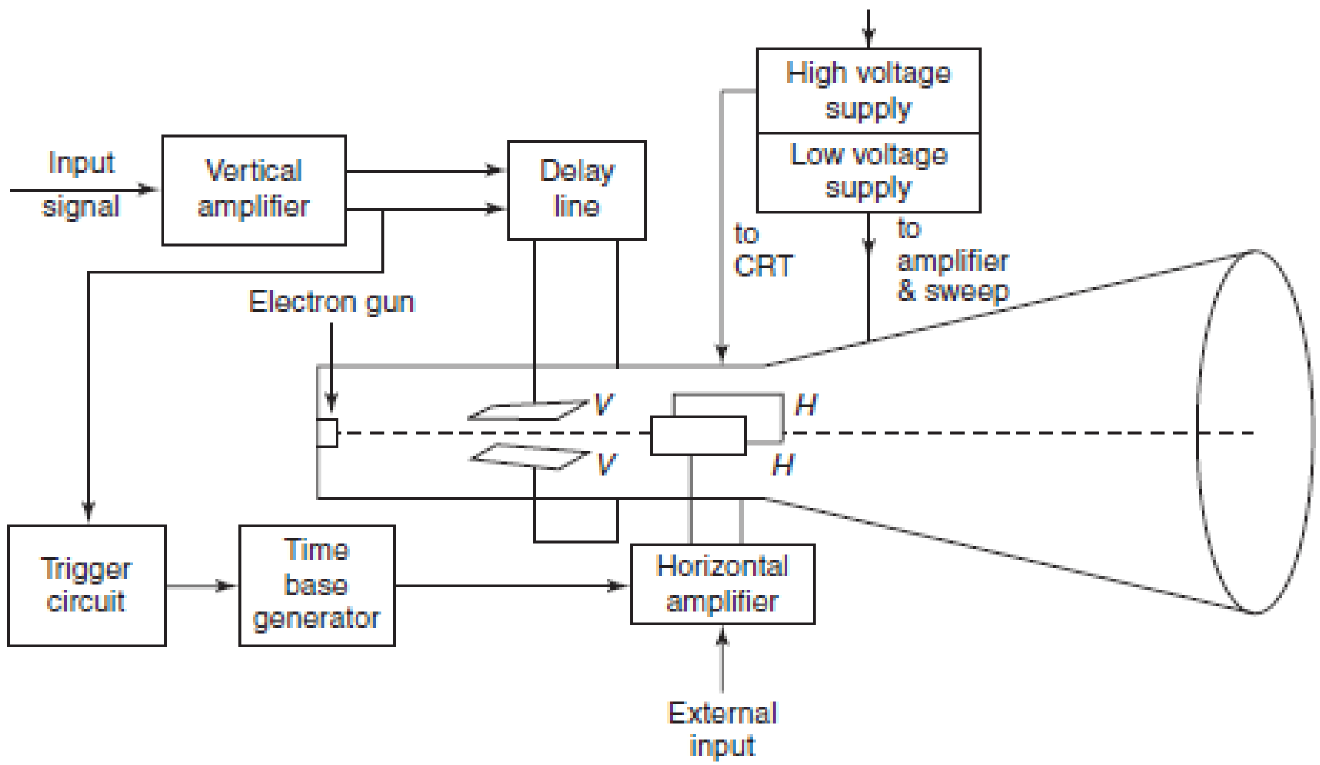
Objectives:

- This final chapter discusses the key instruments of electronic measurement with special emphasis on the most versatile instrument of electronic measurement—the cathode-ray oscilloscope (CRO).
- The objective of this book will remain unrealized without a discussion on the CRO.
- The chapter begins with the details of construction of the CRO, and proceeds to examine the active and passive mode input–output waveforms for filter circuits and lead-lag network delay.
- This will be followed by a detailed study of the dual beam CRO and its uses in op-amp circuit integrator, differentiator, inverting and non-inverting circuits, comparative waveform study, and accurate measurement with impeccable visual display.
- In addition to the CRO, the chapter also examines the sweep frequency generator, the function generator, the sine wave generator, the square wave generator and the AF signal generator.

INTRODUCTION:

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

Block diagram of a cathode-ray oscilloscope:



Block diagram of a cathode-ray oscilloscope

COMPONENTS OF THE CATHODE-RAY OSCILLOSCOPE:

The CRO consists of the following:

(i) CRT

(ii) Vertical amplifier

(iii) Delay line

(iv) Horizontal amplifier

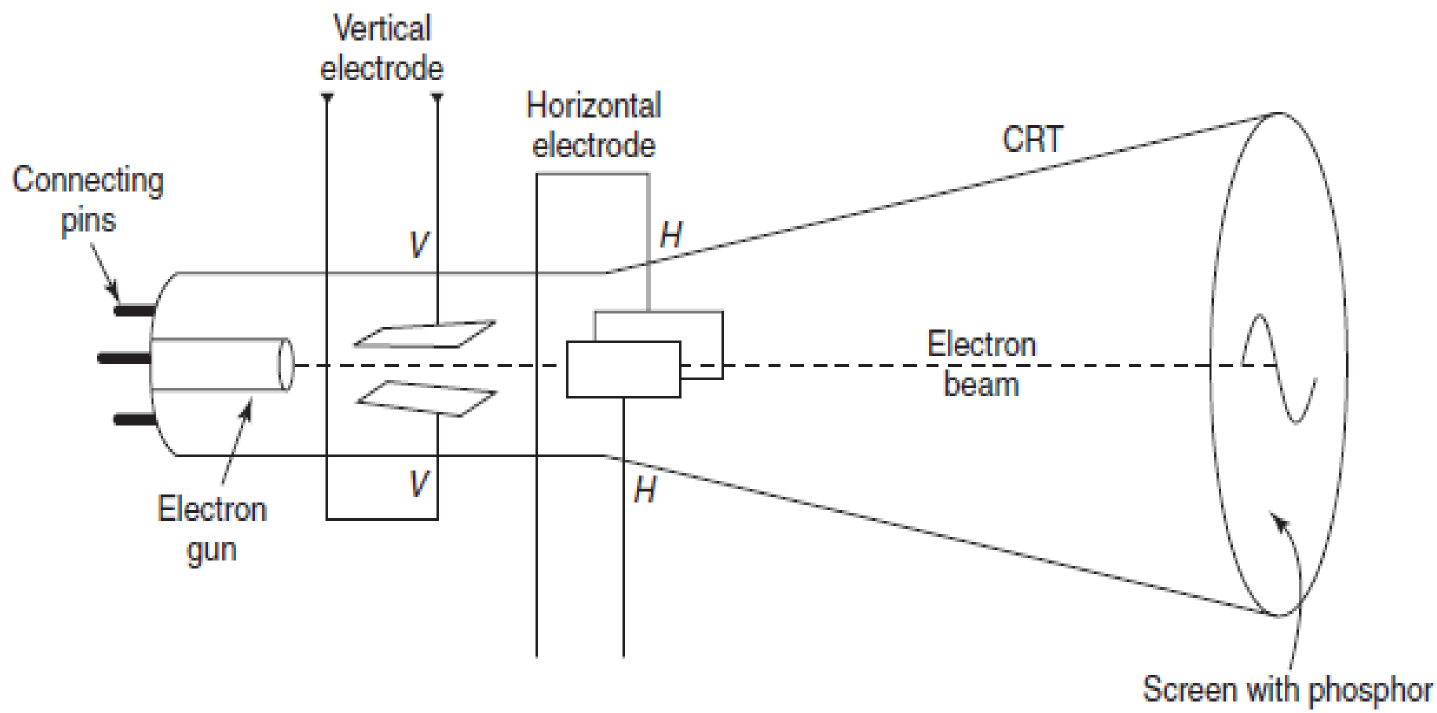
(v) Time-base generator

(vi) Triggering circuit

(vii) Power supply

CATHODE-RAY TUBE:

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



Components of a cathode-ray oscilloscope

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Electron Gun:

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

Deflection Systems:

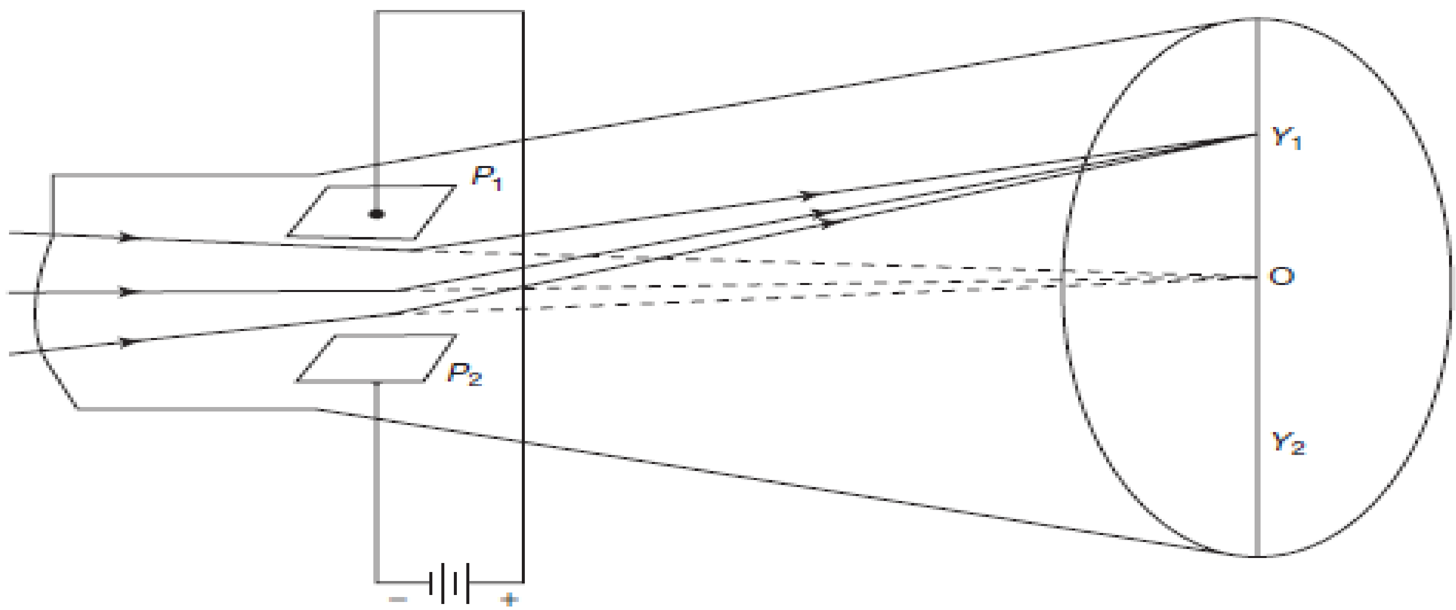
- Electrostatic deflection of an electron beam is used in a general purpose oscilloscope. The deflecting system consists of a pair of horizontal and vertical deflecting plates.

- Let us consider two parallel vertical deflecting plates *P1 and P2. The beam is focused at point O on the screen in the absence of a deflecting plate voltage.*

- *If a* positive voltage is applied to plate *P1 with respect to plate P2, the negatively charged electrons are attracted towards* the positive plate *P1, and these electrons will come to focus at point Y1 on the fluorescent screen.*

Deflection Systems:

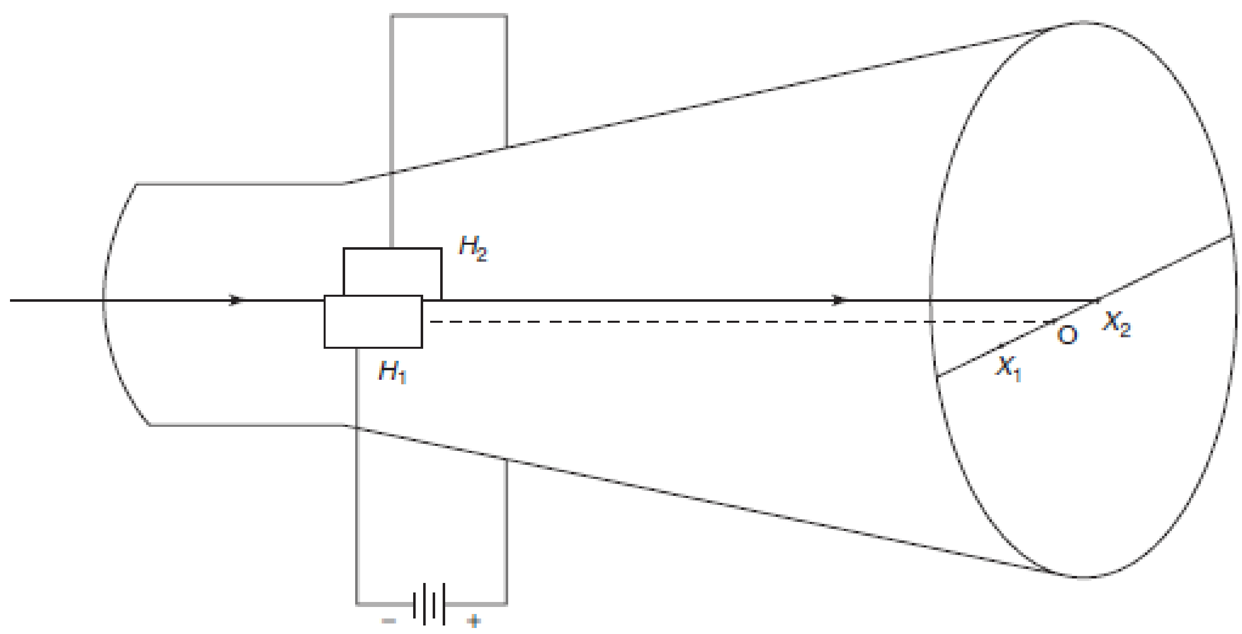
The deflection is proportional to the deflecting voltage between the plates. If the polarity of the deflecting voltage is reversed, the spot appears at the point *Y2, as shown in Fig.*



Deflecting system using parallel vertical plates

Deflection Systems:

- To deflect the beam horizontally, an alternating voltage is applied to the horizontal deflecting plates and the spot on the screen horizontally, as shown in Fig.
- The electrons will focus at point X_2*. By changing the polarity of voltage, the beam will focus at point* X_1*. Thus, the* horizontal movement is controlled along X_1OX_2 *line.*

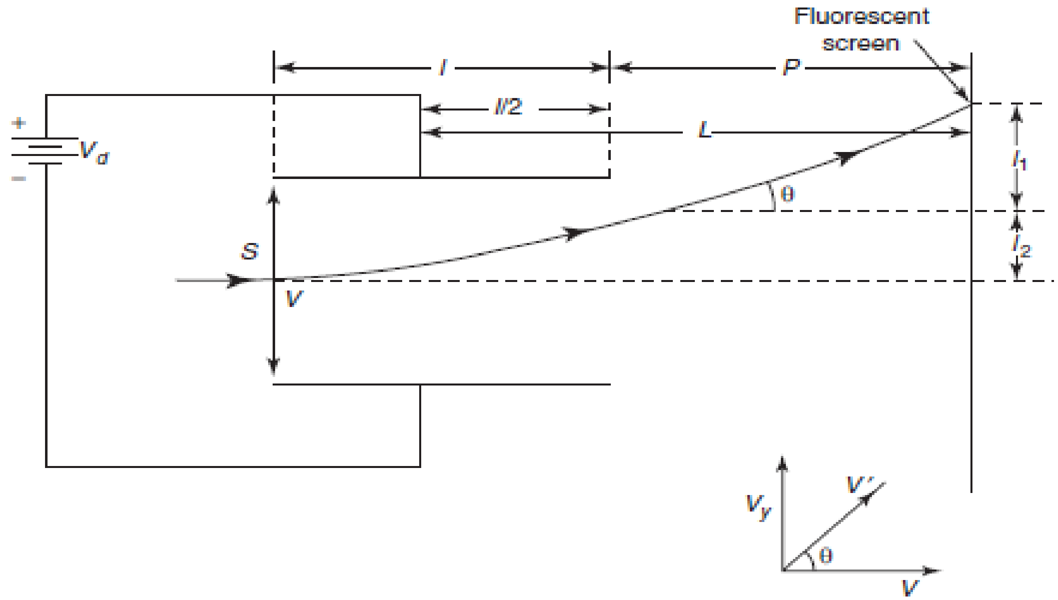


Deflecting system using parallel horizontal plate

Spot Beam Deflection Sensitivity:

The deflection sensitivity of a CRT is defined as the distance of the spot-beam deflection on the screen per unit voltage. If l_{total} is the total amount of deflection of the spot beam on the screen for the deflecting voltage V_d, as shown in Fig.1 the sensitivity can be expressed as:

$$S = \frac{l_{total}}{V_d}$$



Schematic diagram of electrostatic deflection systems

Electrostatic Deflection:

Electrostatic Deflection

s = separation between deflecting plates

P = distance between the plate and screen S

l = length of each deflecting plate

V_d = deflecting voltage applied across the plates

m = mass of the electron

e = charge of the electron

v = velocity of the entering electron

V_a = accelerating anode voltage

Thus:

$$\frac{1}{2} mv^2 = eV_a$$

$$v^2 = \frac{2eV_a}{m}$$

Force exerted on the electron towards the positive deflecting plate is:

$$F.s = eV_d$$

$$F = \frac{eV_d}{s}$$

Electrostatic Deflection:

$$mf = \frac{eV_d}{s}$$

Hence, acceleration is:

$$f = \frac{eV_d}{ms}$$

Time taken by the electron to move through the deflecting plates is:

$$t = \frac{l}{v}$$

Therefore, the upward velocity acquired by the emerging electron is:

$$v_y = ft$$

$$v_y = \frac{fl}{v}$$

$$v_y = \frac{fl}{v} = \frac{eV_d}{sm}\frac{l}{v}$$

Electrostatic Deflection:

where, D is the distance traversed by an electron, u is the initial velocity, f is the acceleration of an electron, and t is the time taken.

As the electron is starting from rest, the initial velocity is zero, i.e., $u = 0$ and the distance travelled by the electron $D = l_2$.

Substituting this value of D in the expression for D, from the formula of mechanics, we get:

$$l_2 = \frac{1}{2} ft^2$$

Substituting the value of t in Eq. . we get:

$$l_2 = \frac{1}{2} f(\frac{l}{v})^2 = \frac{eV_d}{2\,sm}(\frac{l}{v})^2$$

$$\tan\theta = \frac{v_y}{v} = \frac{l_1}{P}$$

$$l_{total} = l_1 + l_2 = \frac{eV_d l}{smv^2}(\frac{l}{2} + P)$$

Here: $$L = \left(\frac{l}{2} + P\right)$$

Electrostatic Deflection:

$$l_{\text{total}} = \frac{lLV_d}{2sV_a}$$

The deflection sensitivity of the CRT is, by definition:

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

The deflection factor of the CRT is:

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

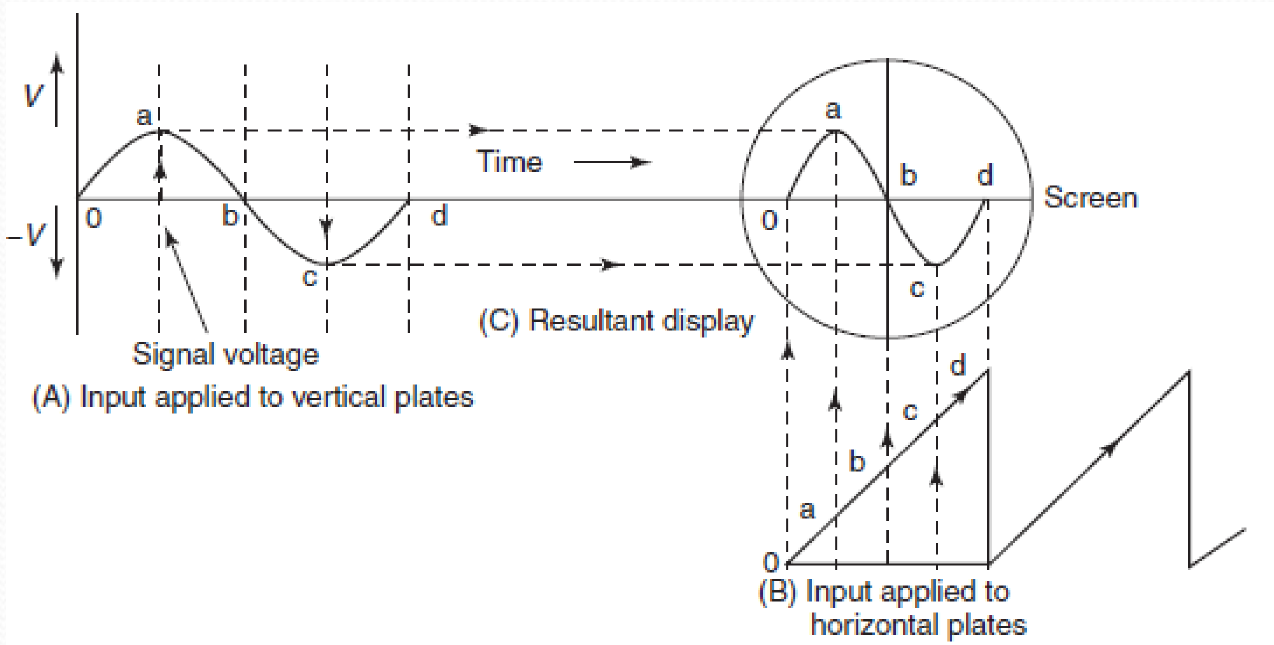
Fluorescent Screen:

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

Display waveform on the screen:

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

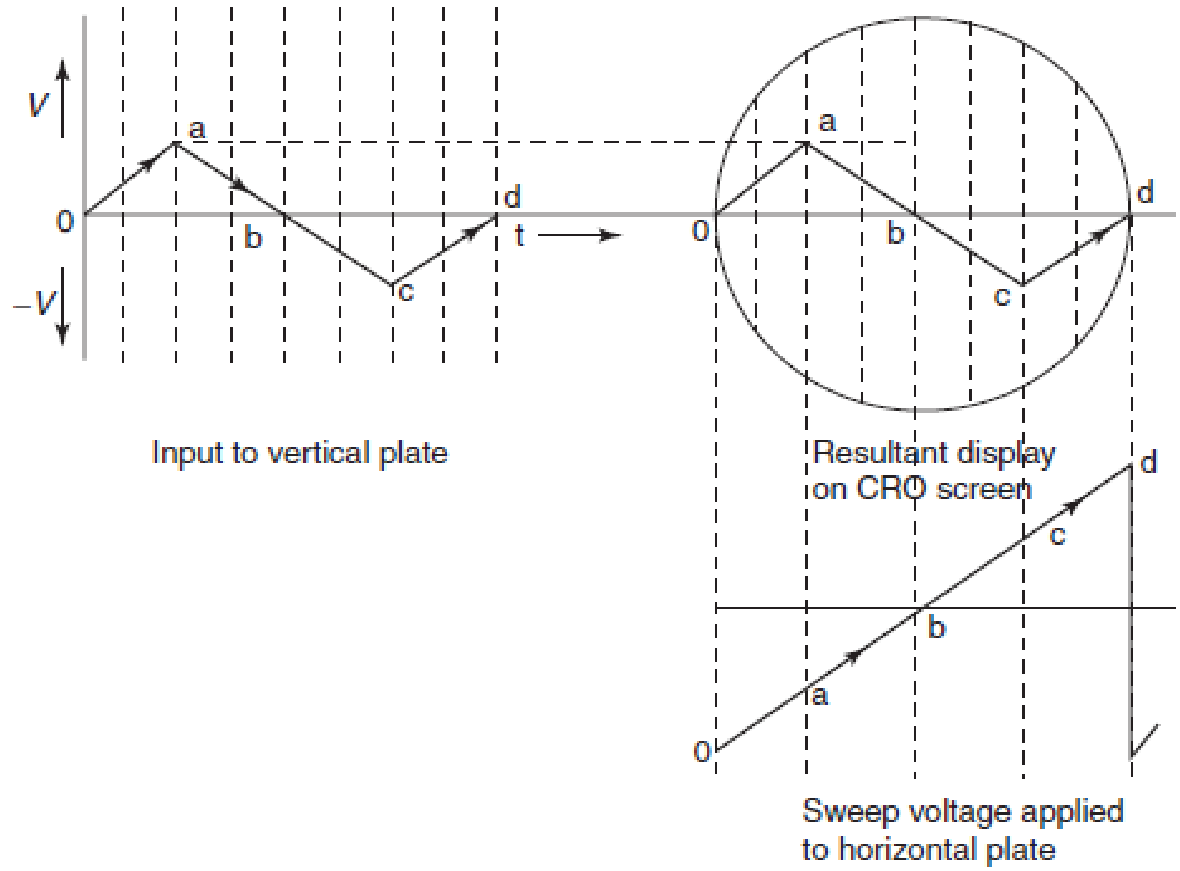
- The ramp waveform at the horizontal plates causes the electron beam to be deflected horizontally across the screen.
- If the waveforms are perfectly synchronized then the exact sine wave applied to the vertical display appears on the CRO display screen.



(a) A typical display waveform on the screen

Triangular waveform:

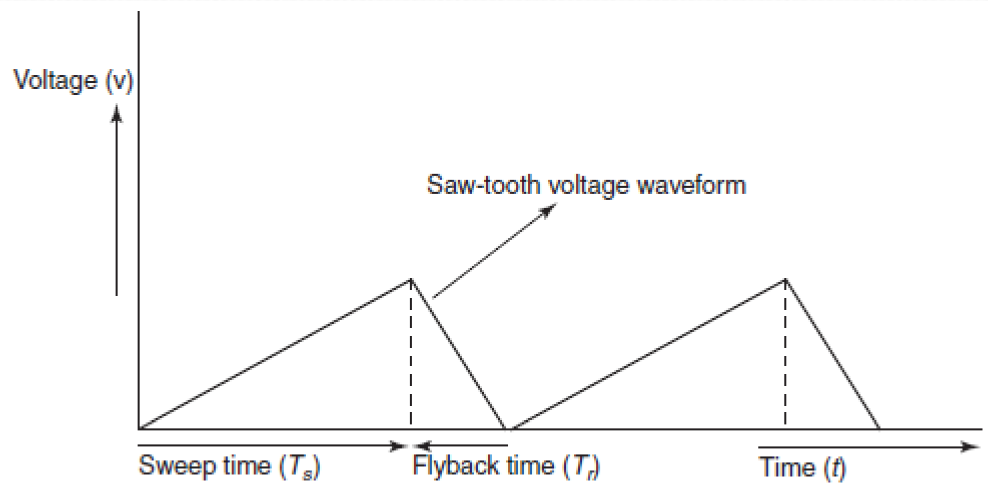
- Similarly the display of the triangular waveform is as shown in Fig.



Triangular waveform input applied to the vertical deflecting plates of CRO

TIME-BASE GENERATORS:

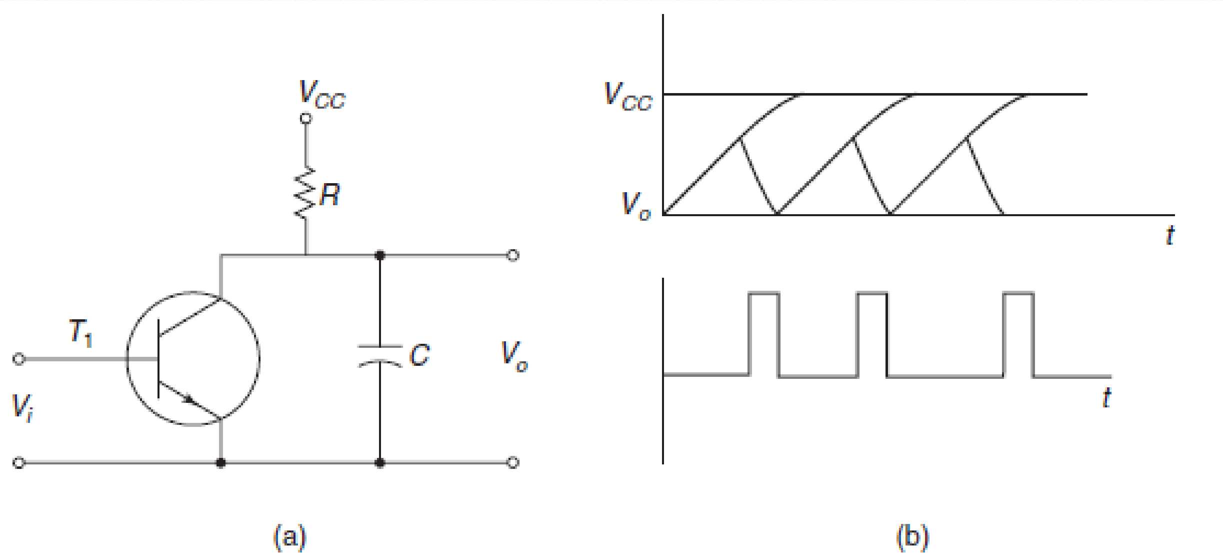
- The CRO is used to display a waveform that varies as a function of time. If the wave form is to be accurately reproduced, the beam should have a constant horizontal velocity.
- As the beam velocity is a function of the deflecting voltage, the deflecting voltage must increase linearly with time.
- A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



Typical saw-tooth waveform applied to the horizontal deflection plates

Simple saw-tooth generator & associated waveforms:

- The circuit shown in Fig. (a) is a simple sweep circuit, in which the capacitor *C charges through the* resistor *R.*
- *The capacitor discharges periodically through the transistor T1, which causes the waveform shown* in Fig. (b) to appear across the capacitor.
- The signal voltage, *Vi which must be applied to the base of the* transistor to turn it ON for short time intervals is also shown in Fig. (b).



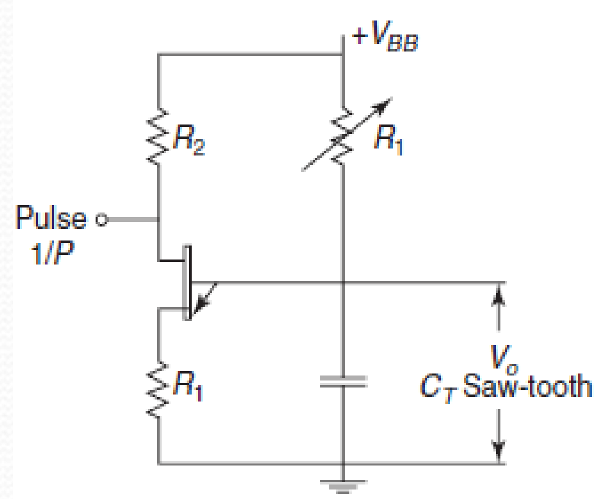
': (a) simple saw-tooth generator (b) associated waveforms.

Time-base generator using UJT:

- The continuous sweep CRO uses the UJT as a time-base generator. When power is first applied to the UJT, it is in the OFF state and *CT changes exponentially through RT* .
- *The UJT emitter* voltage *VE rises towards VBB and VE reaches the plate voltage VP.*
- The emitter-to-base diode becomes forward biased and the UJT triggers ON. This provides a low resistance discharge path and the capacitor discharges rapidly.
- When the emitter voltage *VE reaches* the minimum value rapidly, the UJT goes OFF. The capacitor recharges and the cycles repeat.

To improve the sweep linearity, two separate voltage supplies are used; a low voltage supply for the UJT and a high voltage supply for the *RTCT circuit. This circuit is as shown in Fig. (c).*

RT is used for continuous control of frequency within a range and CT is varied or changed in steps. They are sometimes known as timing resistor and timing capacitor.



(c) Time-base generator using UJT

Oscilloscope Amplifiers:

- The purpose of an oscilloscope is to produce a faithful representation of the signals applied to its input terminals.
- Considerable attention has to be paid to the design of these amplifiers for this purpose. The oscillographic amplifiers can be classified into two major categories.

  (i) AC-coupled amplifiers

  (ii) DC-coupled amplifiers
- The low-cost oscilloscopes generally use ac-coupled amplifiers. The ac amplifiers, used in oscilloscopes, are required for laboratory purposes. The dc-coupled amplifiers are quite expensive. They

  offer the advantage of responding to dc voltages, so it is possible to measure dc voltages as pure signals

  and ac signals superimposed upon the dc signals.
- DC-coupled amplifiers have another advantage. They eliminate the problems of low-frequency phase shift and waveform distortion while observing low-frequency pulse train.
- The amplifiers can be classified according to bandwidth use also:

  (i) Narrow-bandwidth amplifiers

  (ii) Broad-bandwidth amplifiers

Vertical Amplifiers:

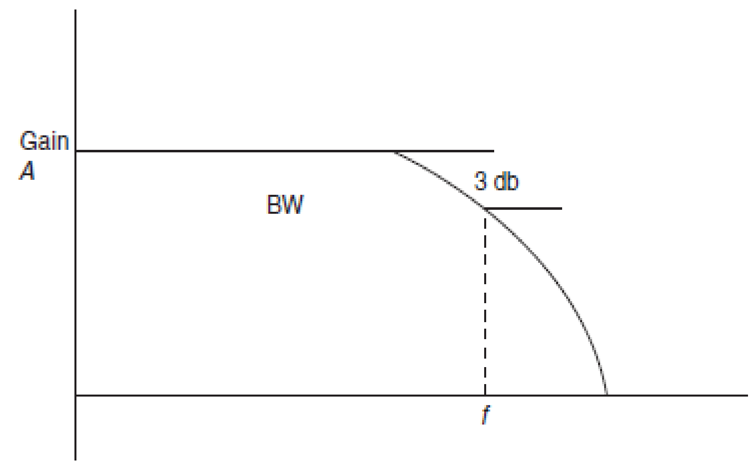
- Vertical amplifiers determines the sensitivity and bandwidth of an oscilloscope. Sensitivity, which is expressed in terms of V/cm of vertical deflection at the mid-band frequency.
- The gain of the vertical amplifier determines the smallest signal that the oscilloscope can satisfactorily measure by reproducing it on the CRT screen.
- The sensitivity of an oscilloscope is directly proportional to the gain of the vertical amplifier. So, as the gain increases the sensitivity also increases.
- The vertical sensitivity measures how much the electron beam will be deflected for a specified input signal. The CRT screen is covered with a plastic grid pattern called a graticule.
- The spacing between the grids lines is typically 10 mm. Vertical sensitivity is generally expressed in volts per division.
- The vertical sensitivity of an oscilloscope measures the smallest deflection factor that can be selected with the rotary switch.

Frequency response:

- The bandwidth of an oscilloscope detects the range of frequencies that can be accurately reproduced on the CRT screen. The greater the bandwidth, the wider is the range of observed frequencies.
- The bandwidth of an oscilloscope is the range of frequencies over which the gain of the vertical amplifier stays within 3 db of the mid-band frequency gain, as shown in Fig.
- Rise time is defined as the time required for the edge to rise from 10–90% of its maximum amplitude. An approximate relation is given as follows:

$$t_r \times BW = 0.35$$

where, t_r is the rise time in seconds and BW is the band width in Hertz.



Frequency response graphs

MEASUREMENTS USING THE CATHODE-RAY OSCILLOSCOPE:

1) Measurement of Frequency:

Time-base Measurement

Time-base measurement helps to determine the frequency of a time-varying signal displayed on the CRT screen. If a time interval t has x complete cycles, then the time period of the signal is:

$$T = \frac{t}{x}$$

or,

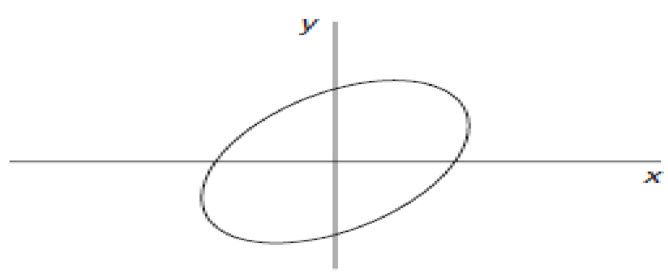
$$f = \frac{1}{T} = \frac{x}{t}$$

Hence, the frequency is determind.

Measurement Using Lissajous Figures

The application of sinusoidal waves at the same time to the deflection plates produces various patterns. These patterns, are generated on the basis of the relative amplitudes, frequencies and phases of the different waveforms and are known as Lissajous figures.

Figure 14-9 shows the Lissajous figure as a form of ellipse.



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Lissajous figure as a form of ellipse

Frequency can be determined from:

$$\frac{fv}{fh} = \frac{\text{Number of horizontal tangencies}}{\text{Number of vertical tangencies}}$$

where, fv and fh are the frequencies of the vertical and the horizontal signals, respectively.

MEASUREMENTS USING THE CATHODE-RAY OSCILLOSCOPE:

- ## 2) Measurement of Phase:

The phase difference of two different waveforms displayed on the CRT screen can be found from the time axis. Two sinusoidal signals of time period T are in the same phase at time t_1 and t_2 respectively, and the phase difference between them is expressed as:

$$\varphi = \frac{2\pi}{T}(t_1 - t_2)$$

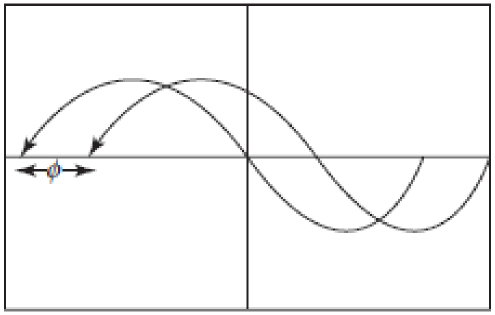
. shows the phase difference of two different waveforms.

- ## 3 Measurement of Phase Using Lissajous Figures:

Lissajous figures are used to measure the phase difference between two sinusoidal voltages of the same amplitude and frequency. The signals are applied simultaneously to the horizontal and vertical deflection plates. The values of the deflection voltages are given by:

$$v_y = A \sin(\omega t + \varphi)$$

and $$v_x = A \sin \omega t$$



Measurement of phase difference

Measurement of Phase Using Lissajous Figures:

The values of the deflection voltages are given by:

$$v_y = A \sin(\omega t + \varphi)$$

$$v_x = A \sin \omega t$$

Here A is the amplitude, ω is the angular frequency and φ is the phase angle by which v_y leads v_x. I .
can be expanded as:

$$v_y = A \sin \omega t \cos \varphi + A \cos \omega t \sin \varphi$$

I .

$$A \cos \omega t = \sqrt{A^2 - v_x^2}$$

Substituting the sine and cosine terms .

$$v_y = A \sin \omega t \cos \varphi + \sqrt{A^2 - v_x^2} \sin \varphi$$

$$v_y = v_x \cos \varphi + \sqrt{A^2 - v_x^2} \sin \varphi$$

$$v_y - v_x \cos \varphi = \sqrt{A^2 - v_x^2} \sin \varphi$$

$$(v_y - v_x \cos \varphi)^2 = (A^2 - v_x^2)\sin^2 \varphi$$

$$v_y^2 - 2v_x \cos \varphi\, v_y + v_x^2 \cos^2 \varphi = A^2 \sin^2 \varphi - v_x^2 \sin^2 \varphi$$

$$v_y^2 - 2v_x \cos \varphi\, v_y + v_x^2 \cos^2 \varphi\, v_x^2 \sin^2 \varphi = A^2 \sin^2 \varphi$$

$$v_y^2 - 2v_x \cos \varphi\, v_y + v_x^2 (\cos^2 \varphi + \sin^2 \varphi) = A^2 \sin^2 \varphi$$

$$v_y^2 - 2v_x \cos \varphi\, v_y + v_x^2 = A^2 \sin^2 \varphi$$

$$v_x^2 + v_y^2 - 2v_x v_y \cos\varphi = A^2 \sin^2 \varphi.$$

Measurement of Phase Using Lissajous Figures:

Case I: When $\varphi = 0°$, cos $\varphi = 1$, sin$\varphi = 0$

Then, Eq. . reduces to:

$$v_x^2 + v_y^2 - 2v_x v_y = 0$$

$$(v_x - v_y)^2 = 0$$

$$v_x = v_y$$.

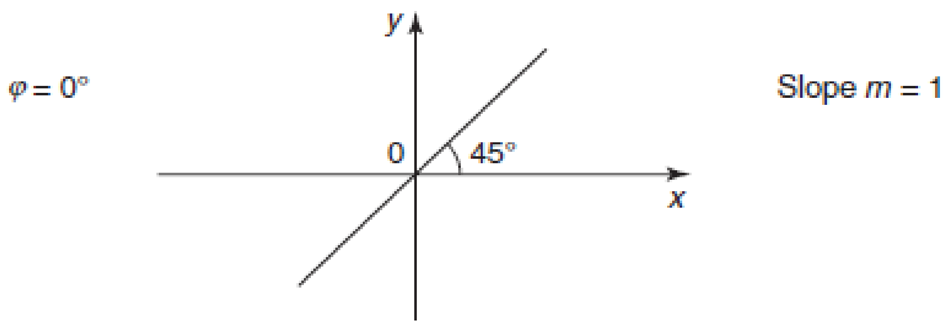
Equation . represents a straight line with slope 45°, i.e., $m = 1$. The straight line diagram is shown in

.

Case II: When $0 < \varphi < 90$, $\varphi = 45°$, cos $\varphi = \frac{1}{\sqrt{2}}$, sin $\varphi = \frac{1}{\sqrt{2}}$

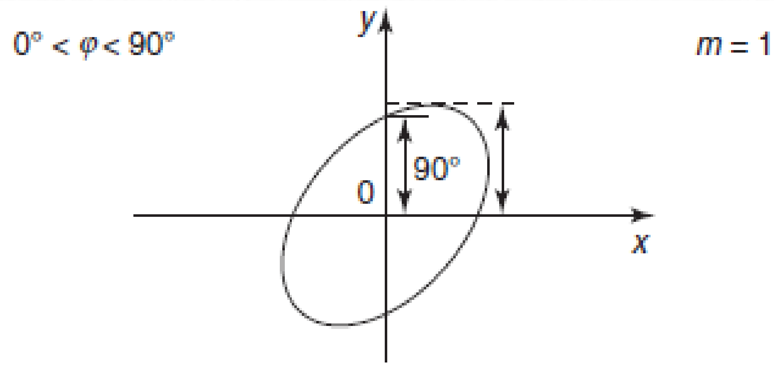
Then Eq. . reduces to:

$$v_x^2 + v_y^2 - \sqrt{2}v_x v_y = \frac{A^2}{2}$$.



. Lissajous figure at $\varphi = 0°$ is a straight line with slope $m = 1$

Measurement of Phase Using Lissajous Figures:



Lissajous figure at $0^\circ < \varphi < 90$ takes the shape of an ellipse

Equation represents an ellipse, as shown in Fig.

Case III: When $\varphi = 90^\circ$, $\cos\varphi = 0$, $\sin\varphi = 1$

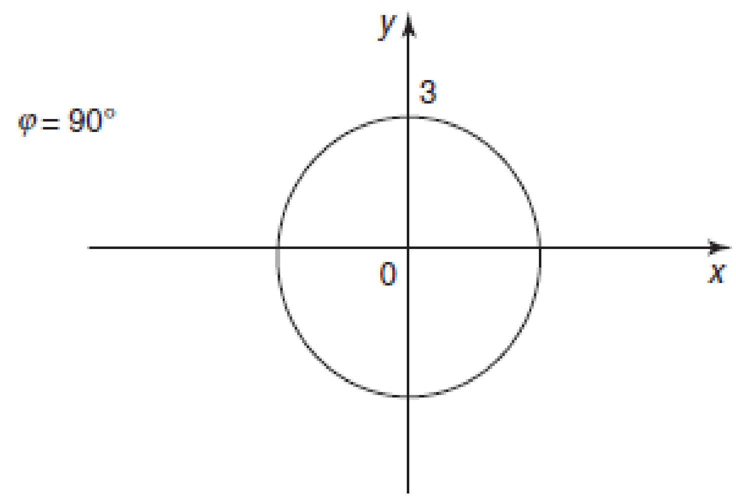
Then Eq. reduces to:

$$v_x^2 + v_y^2 = A^2$$

Equation represents a circle shown in Fig.

Case IV: When $90 < \varphi < 180$; say $\varphi = 135^\circ$,

$$\cos\varphi = -\frac{1}{\sqrt{2}}, \quad \sin\varphi = \frac{1}{\sqrt{2}}$$



Lissajous figure at $\varphi = 90^\circ$: it forms a circle

Measurement of Phase Using Lissajous Figures:

Then Eq. .   reduces to:

$$v_x^2 + v_y^2 + \sqrt{2}v_x y_y = \frac{A^2}{2} \quad .$$

Equation .   ) represents an ellipse shown in Fig. .

Case V: $\varphi = 180°$, $\cos\varphi = -1$, $\sin\varphi = 0$

Then Eq. .   reduces to:

$$v_x^2 + v_y^2 + 2v_x v_y = 0$$

$$(v_x + v_y)^2 = 0$$

$$v_x = -v_y \quad .$$

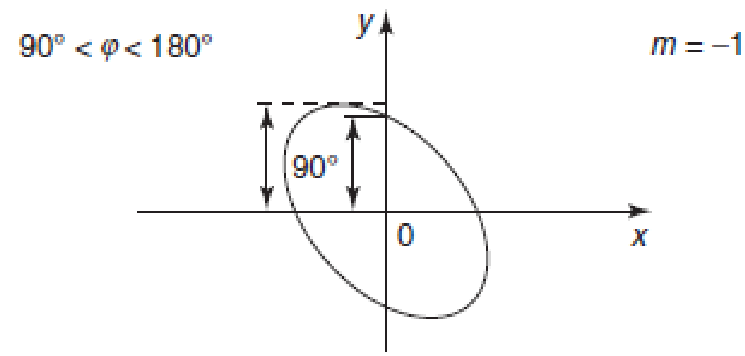
Equation (.   represents a straight line with slope $m = -1$; a slope of 45° in the negative direction of the x-axis, as shown in Fig. .

The maximum y-displacement, A, and the vertical displacement, V_y, at time $t = 0$ can be measured from the vertical scale of the CRO. Putting $t = 0$ in Eq. .   we get:

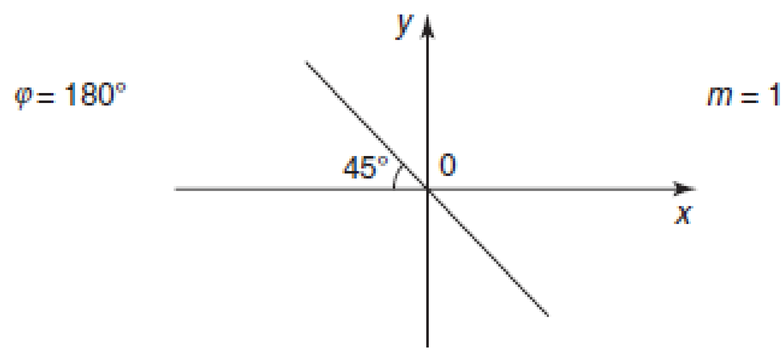
$$v_{y0} = A \sin\varphi \quad .$$

$$\sin\varphi = \frac{v_{y0}}{A} \quad .$$

Thus, the phase angle can be found from Eq. . using any form of the Lissajous figure.



Lissajous figure when $90 < \varphi < 180$



Lissajous figure at $\varphi = 180°$ with negative slope $m = -1$

TYPES OF THE CATHODE-RAY OSCILLOSCOPES:

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

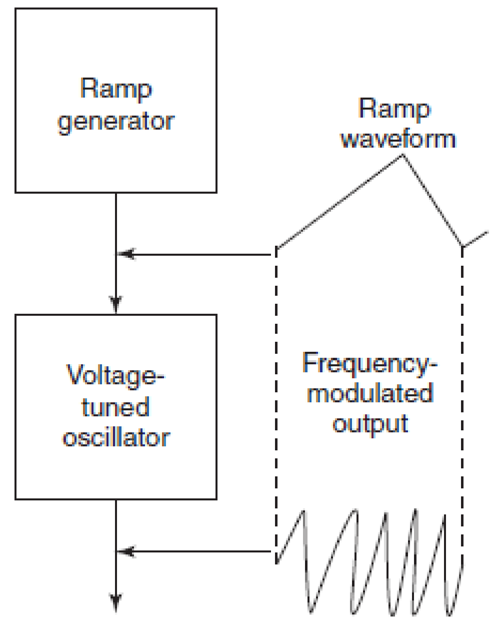
SWEEP FREQUENCY GENERATOR:

- A sweep frequency generator is a signal generator which can automatically vary its frequency smoothly and continuously over an entire frequency range. Figure 14-15 shows the basic block diagram of a sweep frequency generator.
- The sweep frequency generator has the ramp generator and the voltage-tuned oscillator as its basic components.

The output of the ramp generator is a linear ramp voltage which serves as the input to the voltage-tuned oscillator. The basic circuit of a voltage-tuned oscillator is similar to that of a frequency modulator circuit.

The resonant frequency of the tank circuit is given by:

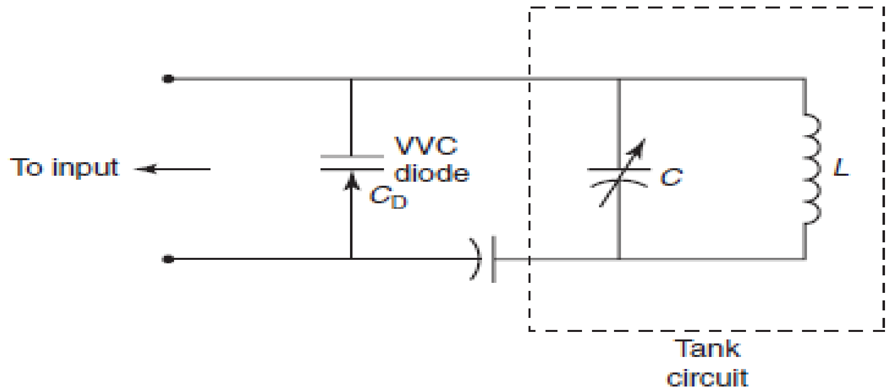
$$f = \frac{1}{2\pi\sqrt{LC}}$$



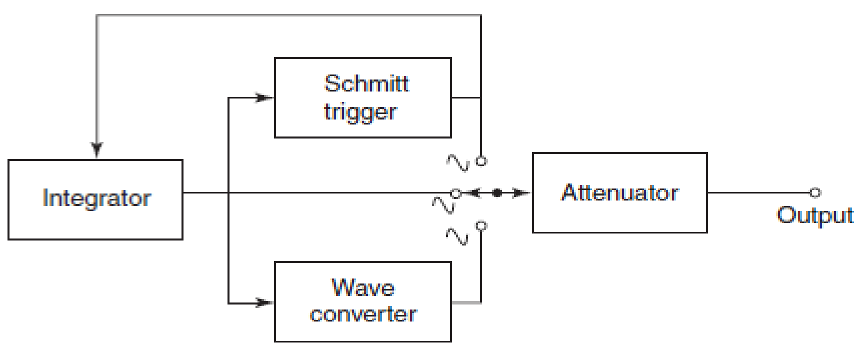
Block diagram of a sweep frequency generator

Applications of the Sweep Frequency Generator:

1. Sweep frequency generators are used to display the response curve of the various stages of frequency of television or radio receivers.
2. Sweep frequency generators can be used to determine the characteristics of a device over a wide continuous range of frequencies.



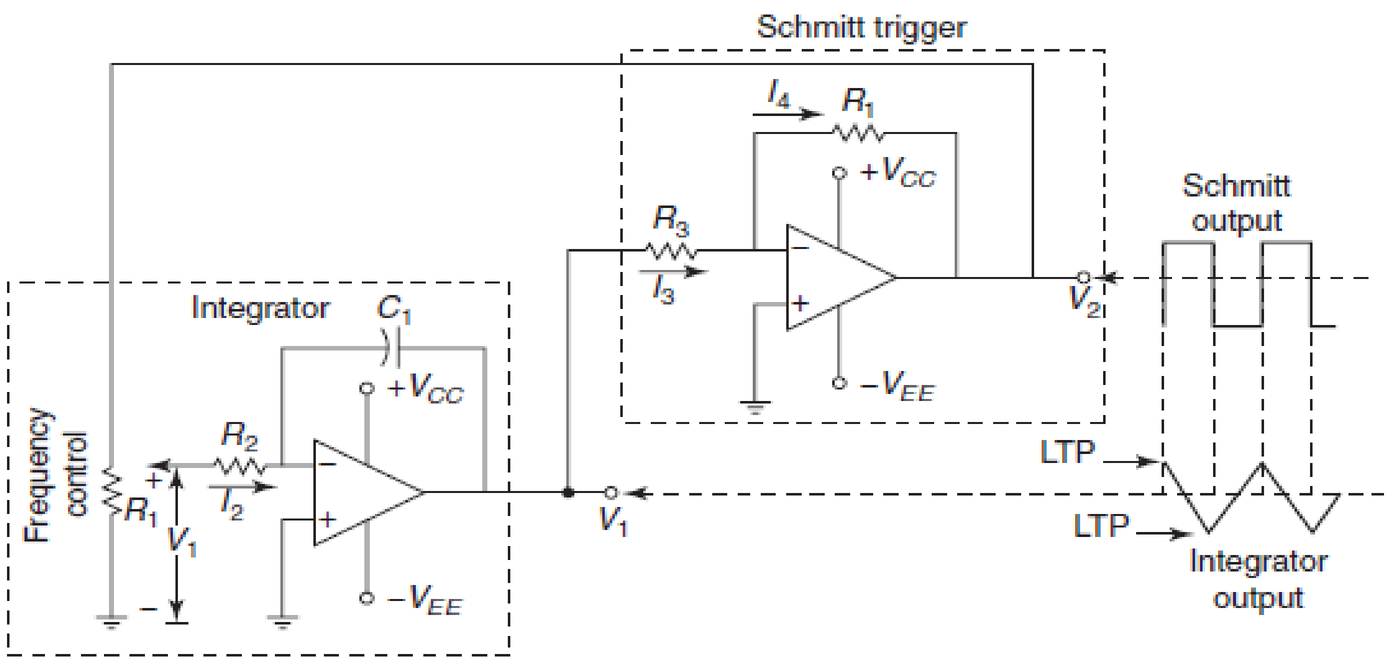
Oscillator tank circuit



Block diagram of a function generator

FUNCTION GENERATOR:

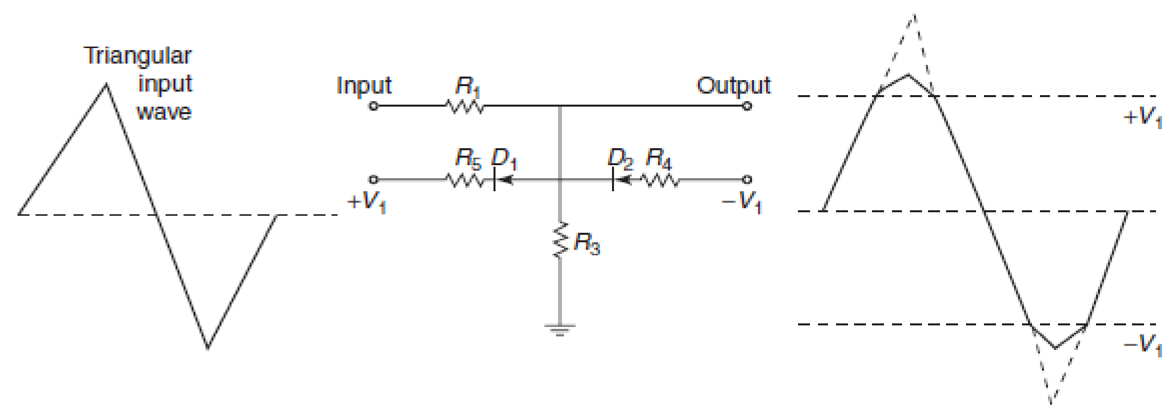
- The basic components of a function generator are:
- (i) Integrator
- (ii) Schmitt trigger circuit
- (iii) Sine wave converter
- (iv) Attenuator



Circuit diagram of a function generator

SINE WAVE GENERATOR:

- A sine wave is produced by converting a triangular wave, applying proper circuits. The triangular wave is produced by employing an integrator and a Schmitt trigger circuit.
- This triangular wave is then converted to a sine wave using the diode loading circuit ,as shown in Fig. Resistors *R_1 and R_2 behave as the voltage divider. When V_{R2} exceeds V_1, the diode D_1 becomes forward*-biased.
- There is more attenuation of the output voltage levels above *V_1 than levels below V_1. With* the presence of the diode *D_1 and resistor R_3 in the circuit, the output voltage rises less steeply.*
- *The output voltage* falls below *V_1 and the diode stops conducting, as it is in reverse-bias. The circuit behaves as a simple* voltage-divider circuit. This is also true for the negative half-cycle of the input *V_i . If R_3 is carefully chosen to* be the same as *R_4 , the negative and the positive cycles of the output voltage will be the same. The output is* an approximate sine wave.



Two-level diode loading circuit

SINE WAVE GENERATOR:

- The approximation may be further improved by employing a six-level diode loading circuit, as shown in Fig.

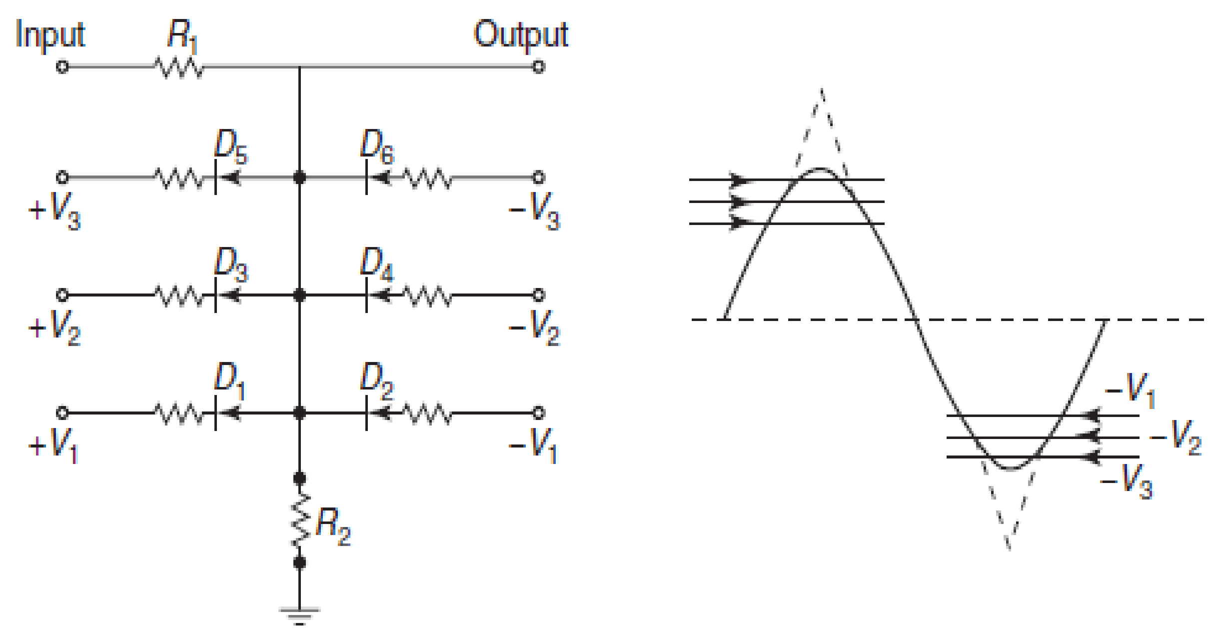


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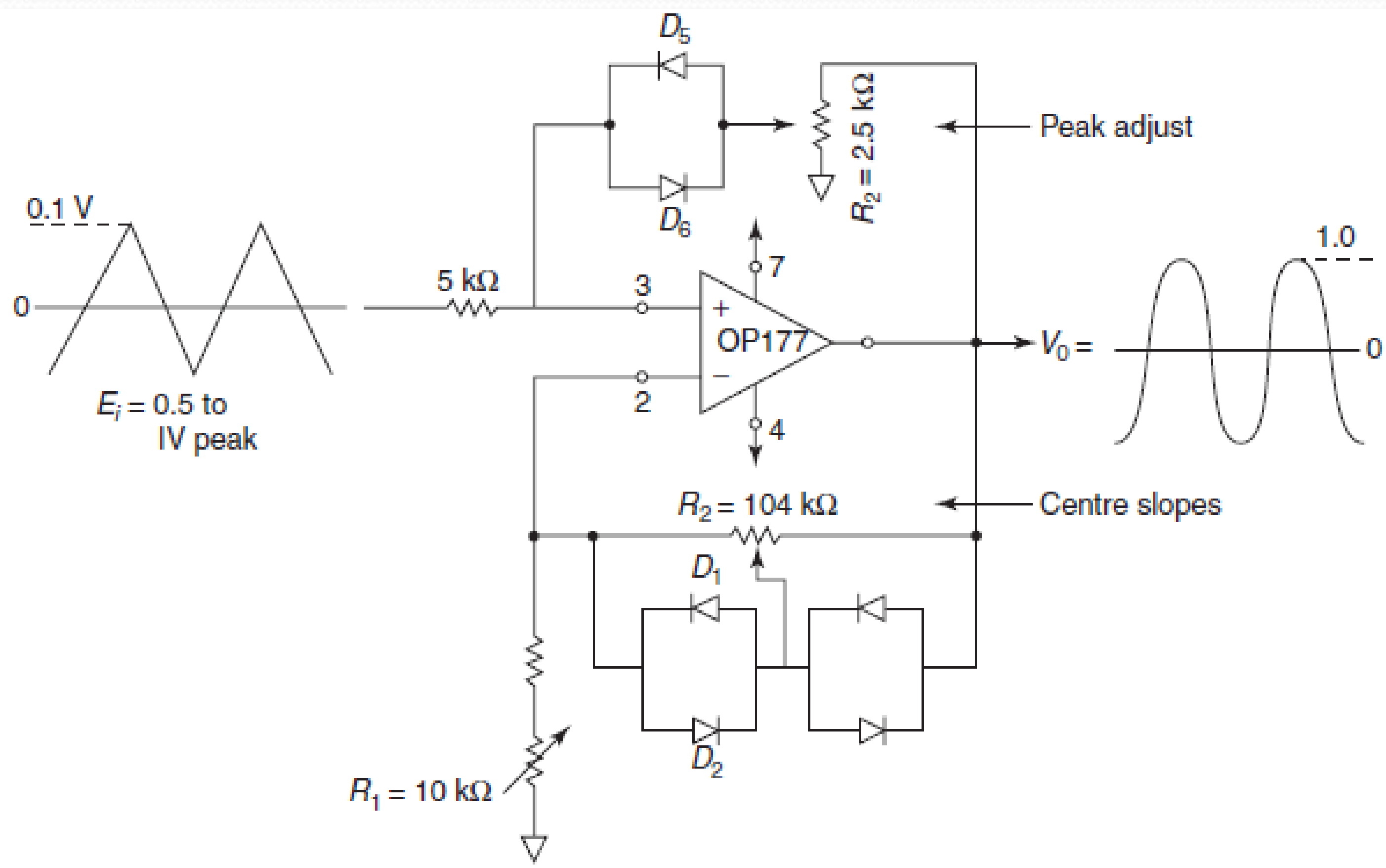
Diagram for the six-level diode loading circuit

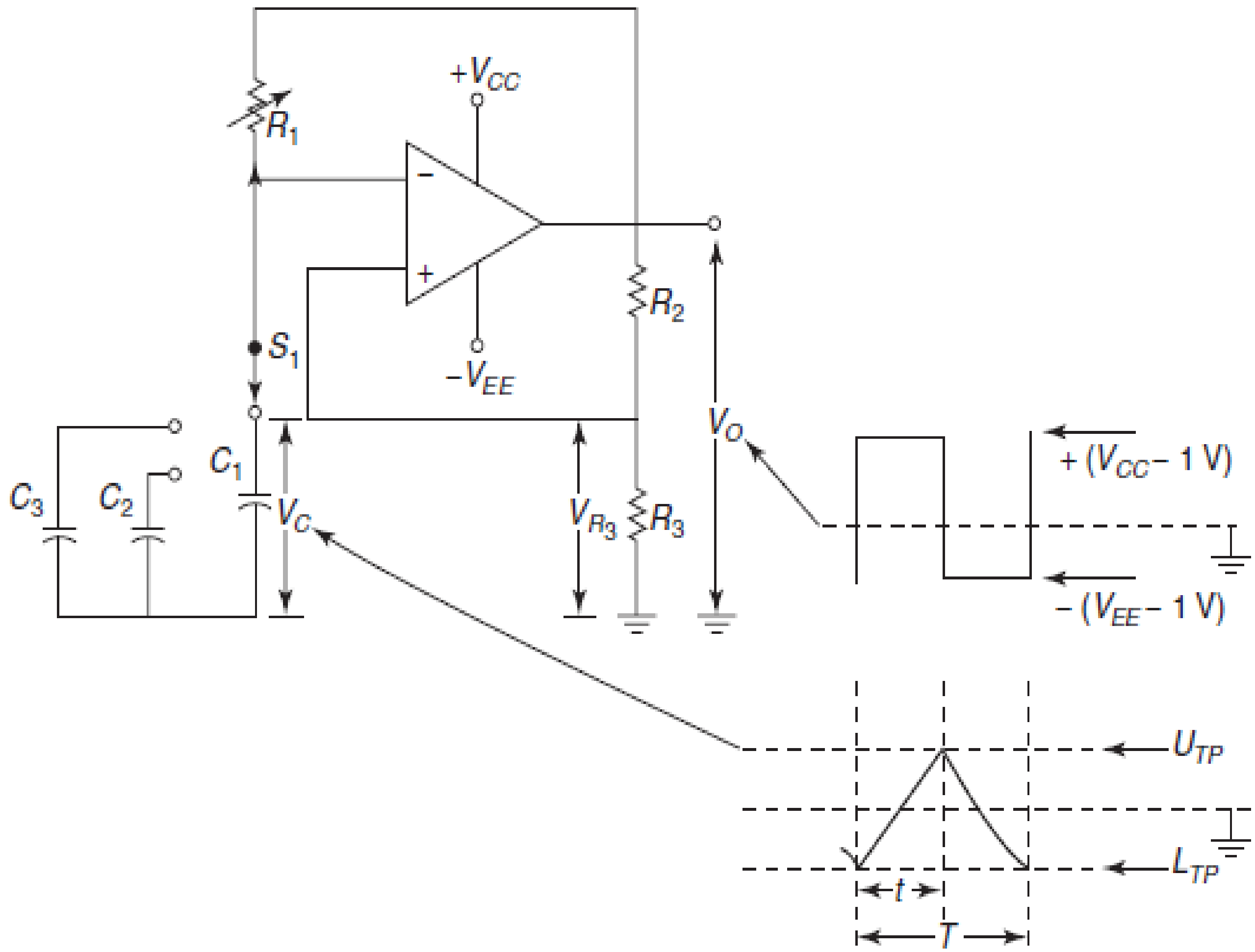
SINE WAVE GENERATOR:

- The circuit is adjusted by comparing a 1 kHz sine wave and the output of the triangular/sine wave converter on a dual-track CRO. *R1, R2, R3 and the peak amplitude of Ei are adjusted in sequence for the best sinusoidal shape.*



Triangular to sinewave generator using op-amp

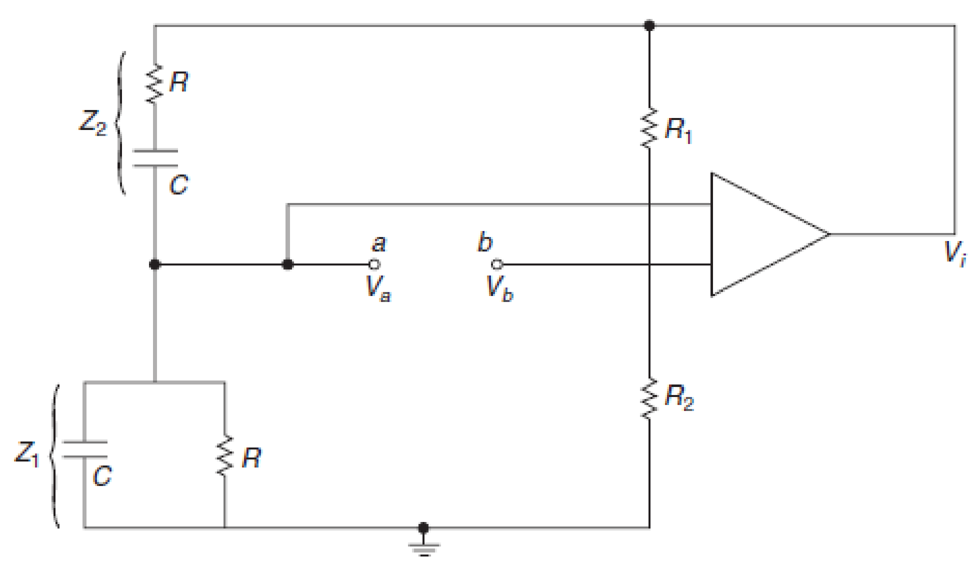
CIRCUIT DIAGRAM OF SINE WAVE GENERATOR:



Sine wave generator

SQUARE WAVE GENERATOR

- A square wave can be most easily obtained from an operational amplifier astable multi-vibrator. An astable multi-vibrator has no stable state—the output oscillates continuously between high and low states.
- In Fig., the block comprising the op-amp, resistors *R2 and R3 constitutes a Schmitt trigger circuit. The* capacitor *C1 gets charged through the resistor R1. When the voltage of the capacitor reaches the upper trigger* point of the Schmitt trigger circuit, the output of the op-amp switches to output low. This is because the Schmitt trigger is a non-inverting type. Now, when the op-amp output is low, the capacitor *C1 starts getting discharged.*



Wien-bridge feedback network with an amplifier

SQUARE WAVE GENERATOR:

- As the capacitor discharges and the capacitor voltage reaches the lower trigger point of the Schmitt trigger, the output of the op-amp switches back to the output high state.
- The capacitor charges through the resistor again and the next cycle begins. The process is repetitive and produces a square wave at the output.
- The frequency of the output square wave depends on the time taken by the capacitor to get charged and discharged when the capacitor voltage varies from UTP (upper trigger point) and LTP (lower trigger point).

The frequency of the output square wave is given by:

$$f = \frac{1}{T} = \frac{1}{2t}$$

where, t is the time taken by the capacitor to get charged or discharged. The UTP and LTP values for the Schmitt trigger can be fixed by choosing appropriate values of R_2 and R_3.

$$|\mathrm{UTP}| = |\mathrm{LTP}| = V_0 \frac{R_3}{R_2 + R_3}$$

AF SIGNAL GENERATOR:

An AF signal generator generally uses an oscillator which is regulated by a controlled phase shift through a resistor and capacitor network. The Wien-bridge oscillator produces sine waves using an RC network as a feedback.

The amplifier is connected as an oscillator in order to determine at what frequency the Wien-bridge provides the required criterion for oscillation. With respect to ground, the voltage at A is given by:

$$V_a = \frac{Z_1}{Z_1 + Z_2} V_i$$

and

$$V_b = \frac{R_1}{R_1 + R_2} V_i$$

Since V_a and V_b are the same, from Eqs. (14-32) and (14-33) we can write:

$$\frac{R_1}{R_1 + R_2} = \frac{Z_1}{Z_1 + Z_2}$$

At a frequency $f_0 = 1/2\pi RC$, the phase angle between V_a and the output is zero. The Wien-bridge oscillator is tuned with a variable capacitance and the oscillator is band-switched using the resistance. The Wien-bridge oscillator is usually the heart of a general purpose AF signal generator. Harmonic distortion is then less than a few tenths of a percent.

POINTS TO REMEMBER:

- 1. CRO is used to study waveforms.
- 2. CRT is the main component of a CRO.
- 3. Prosperous P31 is used for the fluorescent screen of a CRO.
- 4. A CRO has the following components:
- (a) Electron gun
- (b) Deflecting system
- (c) Florescent screen
- 5. Lissajous figures are used to measure frequency and phase of the waves under study.
- 6. A time-base generator produces saw-tooth voltage.
- 7. An oscilloscope amplifier is used to provide a faithful representation of input signal applied to its input terminals.

IMPORTANT FORMULAE:

1. The deflection sensitivity of the CRT is:

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

2. The deflection factor of the CRT is:

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

3. Phase angle is given by:

$$\varphi = \frac{2\pi}{T}(t_1 - t_2)$$

4. Lissajous equation is given by:

$$v_x^2 + v_y^2 - 2v_x v_y \cos\varphi = A^2 \sin^2\varphi$$