ज्ञानेन प्रकाशते जगत्
INDUS UNIVERSITY

ELECTRONICS & COMMUNICATION ENGINEERING
IITE Ahmedabad

Electronics Instrumentation (EC0216)

Unit-3

B.Tech (Electronics and Communication)

Semester-II

Zalak Patel

Academic Year 2020

UNIT-3 Topics

1. Signal generators/sources- Oscillators & Wein Bridge oscillator

2. Function Generator- Square wave generator, triangular wave generator, triangular to sinusoidal wave converter

3. Pulse Generator- Astable Multivibrator, Monostable Multivibrator & Attenuator

4. Measuring Instrument/ Signal displaying device: CRO, DSO, DVM, Spectrum Analyzer, Logic Analyzer, Network Analyzer, Distortion meter, RF power meter

Signal Generators/Signal Sources

- Signal generators provide a variety of waveforms for testing of electronic circuits at low power levels.

- There are various types of signal generators, but the following characteristics are common to all types:

1. Always a stable generator with desired frequency signals should be generated.

2. Generated signal amplitude should be regulated over a wide range from very small to relatively large level.

3. Generated signal should be free from any distortions.

Signal Generator/Signal Sources

They are classified as

- Low frequency sine wave generator
- Function Generators
- Pulse Generators
- RF frequency sine wave generator

Oscillators

- Oscillator is the basic element of ac signal sources and generates sinusoidal signals of known frequency and amplitude.

- The main applications of oscillators are as sinusoidal waveform sources in electronic measurement work.

- Oscillators can generate a wide range of frequencies (few Hz to many GHz) as per the requirement of the application.

- It converts a dc source of supply to alternating current of desired frequency.

LF Signal Generators

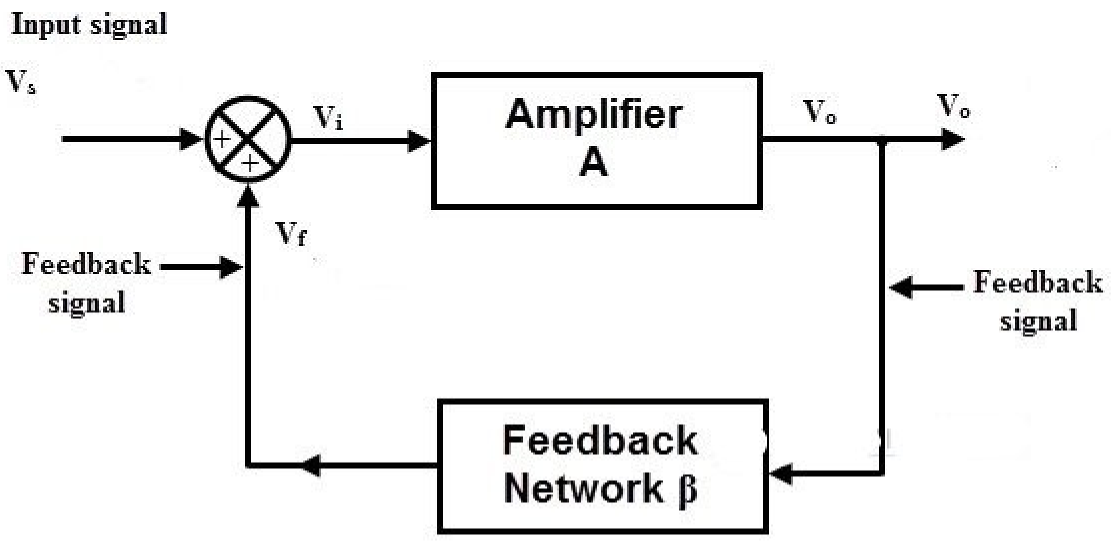
- It have a maximum output frequency of 100 KHz and output voltage adjustable from 0 to 10V.

RF Signal Generators

- RF signal generators typically range from a few kHz to 6 GHz, while microwave signal generators cover a much wider frequency range, from 1 MHz up to 20 GHz.

Feedback oscillatros

They use an active device such as an amplifier whose output is feedback in phase to its input (**positive feedback**) to cause regerative action hence oscillations.



Feedback oscillatros

Voltage Gain $$A = \frac{V_o}{V_i}$$

Feedback Factor *B*=

Amplifer input

Amplifer output A= A(+B)

Hence =A/ (1-AB)

Gain with feedback G_f = Vo/Vs = A / (1-AB)

Feedback oscillatros

- Equation shows if loop gain AB is positive, as it approaches unity, gain increases without limit.

- If AB= 1 then overall gain is infinite. i.e. input signal voltage can be reduced to zero without affecting output volatge.

- Hence amplifIer with positive feedback provide an output without an input and such self excited source is called feedback oscillator.

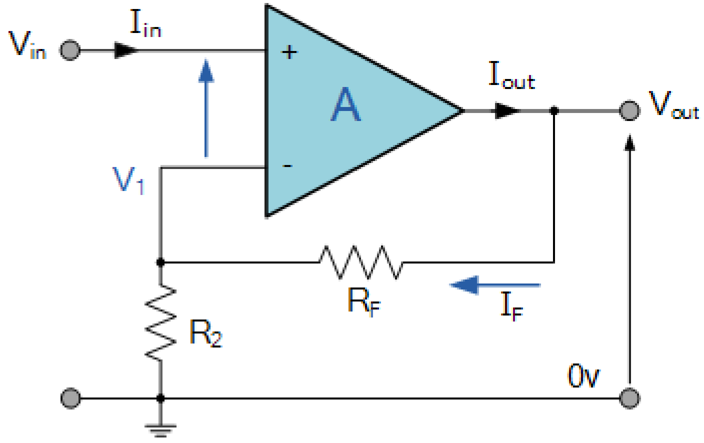
Barkhausen conditions:

1.Magnitude of the loop gain (AB) = 1, where, A= Amplifier gain and β= Feedback gain.
2.Phase shift around the loop must be 360° or 0°.

- The input noise is sufficient to start oscillations.

Non-Inverting Operational Amplifier

- In this configuration, the input voltage signal, (VIN) is applied directly to the non-inverting (+) input terminal which means that the output gain of the amplifier becomes “Positive” in value.



- Feedback control of the non-inverting operational amplifier is achieved by applying a small part of the output voltage signal back to the inverting (–) input terminal via a $Rƒ – R2$ voltage divider network, again producing negative feedback.

- This closed-loop configuration produces a non-inverting amplifier circuit with very good stability.

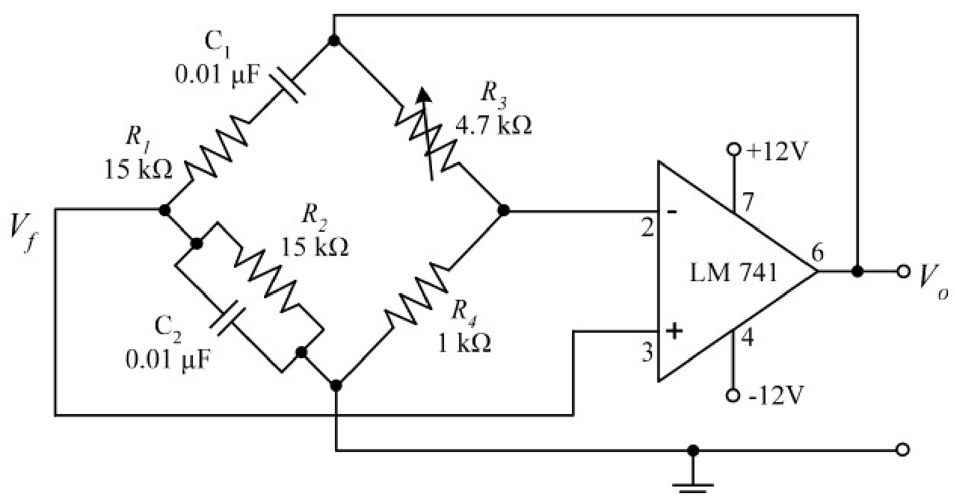
Wein Bridge Oscillator

- An oscillator is a circuit that produces periodic electric signals such as sine wave.
- It generates an oscillatory output signal without having any input source.
- It is a low frequency oscillator. Also called audio frequency oscillator.
- The Wien bridge oscillator is essentially a feedback amplifier in which the Wien bridge serves as the phase-shift network.
- The Wien bridge is an ac bridge, the balance of which is achieved at one particular frequency.
- The Wien-bridge oscillator is a unique circuit because it generates an oscillatory output signal without having a sinusoidal input source.

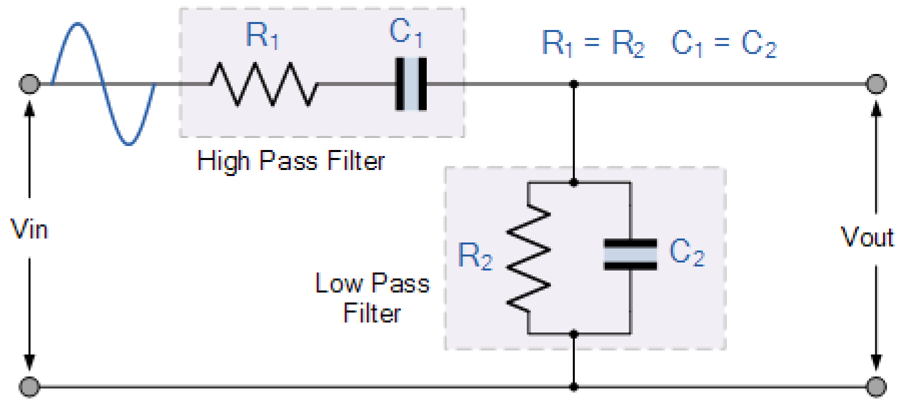
Wein Bridge Oscillator

- Wien bridge oscillator is an audio frequency sine wave oscillator of high stability and simplicity. The feedback signal in this circuit is connected to the non-inverting input terminal so that the op-amp is working as a non-inverting amplifier.

- Therefore, the feedback network need not provide any phase shift. The circuit can be viewed as a Wien bridge with a series combination of R1 and C1 in one arm and parallel combination of R2 and C2 in the adjoining arm. Resistors R3 and R4 are connected in the r … und the circuit is achieved



RC Phase Shift Network



The Wien Bridge Oscillator uses a feedback circuit consisting of a series RC circuit connected with a parallel RC of the same component values producing a phase delay or phase advance circuit depending upon the frequency. At the resonant frequency fr the phase shift is 0 degree.

RC Phase Shift Network

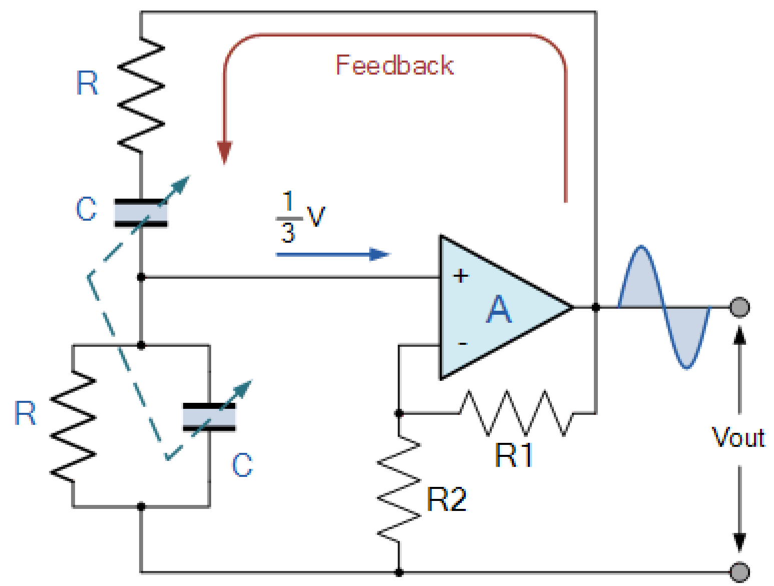
- The above RC network consists of a series RC circuit connected to a parallel RC forming basically a High Pass Filter connected to a Low Pass Filter producing a very selective second-order frequency dependant Band Pass Filter with a high Q factor at the selected frequency, ƒr.

- At low frequencies the reactance of the series capacitor (C1) is very high so acts a bit like an open circuit, blocking any input signal at Vin resulting in virtually no output signal, Vout.

- Likewise, at high frequencies, the reactance of the parallel capacitor, (C2) becomes very low, so this parallel connected capacitor acts a bit like a short circuit across the output, so again there is no output signal.

- So there must be a frequency point between these two extremes of C1 being open-circuited and C2 being short-circuited where the output voltage, VOUT reaches its maximum value. The frequency value of the input waveform at which this happens is called the oscillators Resonant Frequency, (ƒr).

Wein Bridge Oscillator



- The output of the operational amplifier is fed back to both the inputs of the amplifier.

- One part of the feedback signal is connected to the inverting input terminal (negative or degenerative feedback) via the resistor divider network of R1 and R2 which allows the amplifiers voltage gain to be adjusted within narrow limits.

Wein Bridge Oscillator

- The other part, which forms the series and parallel combinations of R and C forms the feedback network and are fed back to the non-inverting input terminal (positive or regenerative feedback) via the RC Wien Bridge network and it is this positive feedback combination that gives rise to the oscillation.

- The RC network is connected in the positive feedback path of the amplifier and has zero phase shift at just one frequency. Then at the selected resonant frequency, (fr) the signal fedback will be "in-phase" with output signal. And hence barkshauen criteria of o degree phase shift is satisfied and at resonat frequency circuit oscillates.

- And loop gain AB can be made unity by properly selecting the values of R1,C1, R2 and C2 componets of feedback network.

Frequency of Oscillation

Under balanced bridge condition, $f_r = \frac{1}{2\pi RC}$

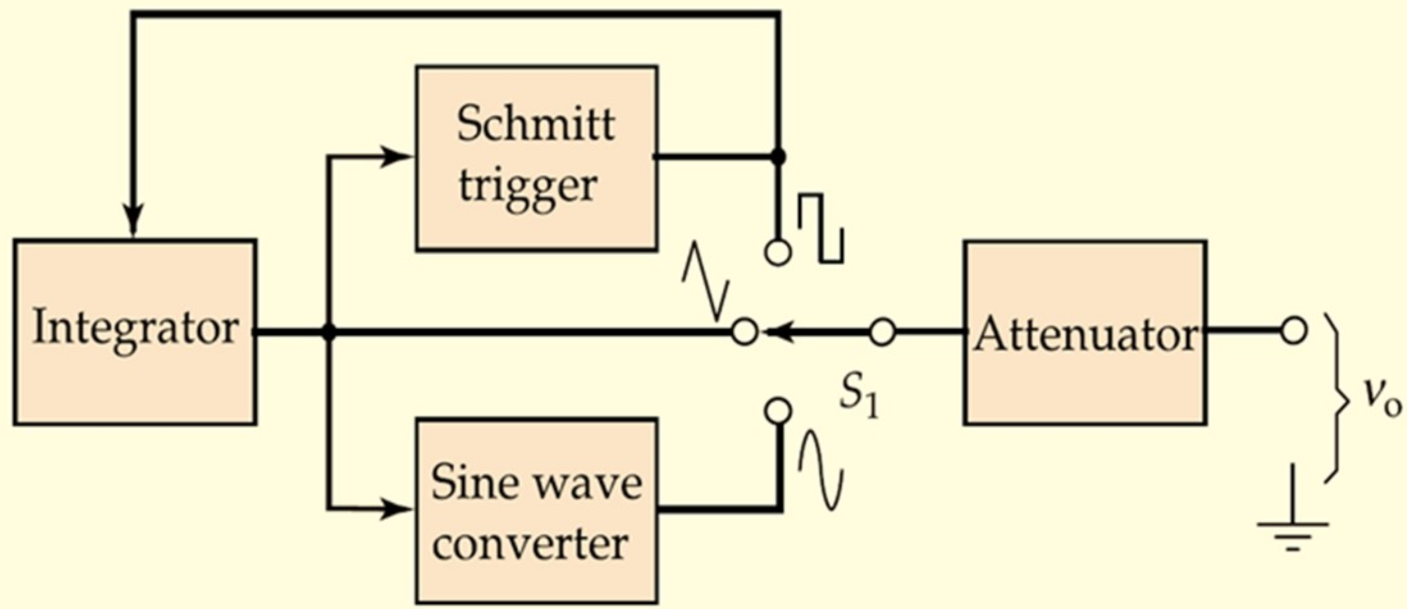
when R1=R2=R

and Ca=C2=C

Function Generator

- Used to produce sine ,square, and triangular waveform with variable frequency and amplitude.
- Sine wave is generated using oscillator or sine wave can be approximated from Triangular wave.
- Square and Triangular waveform is generated using Schmitt trigger and integrator.

Block diagram of function Generator

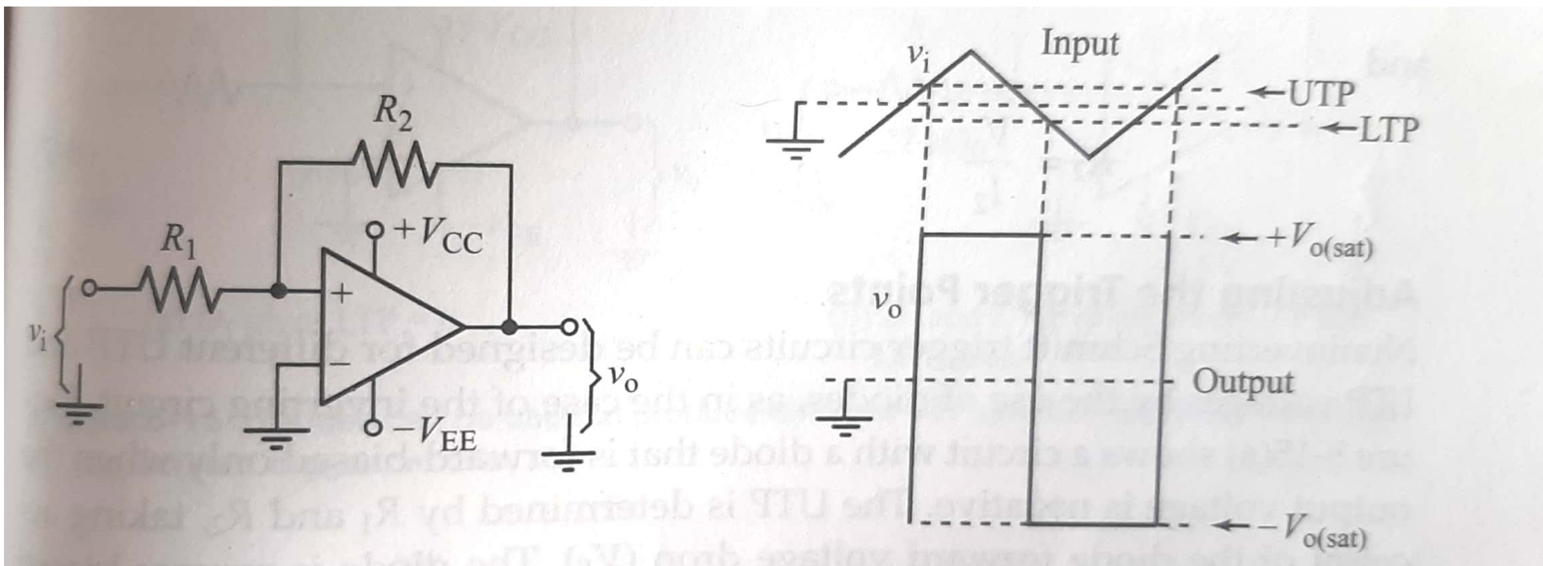


Basic function generator block diagram.

Non Inverting Schmitt Trigger as SQUARE Wave Generator

- The inverting (-) input is gounded and noninverting (+) input is connected to the junction of R1 and R2.

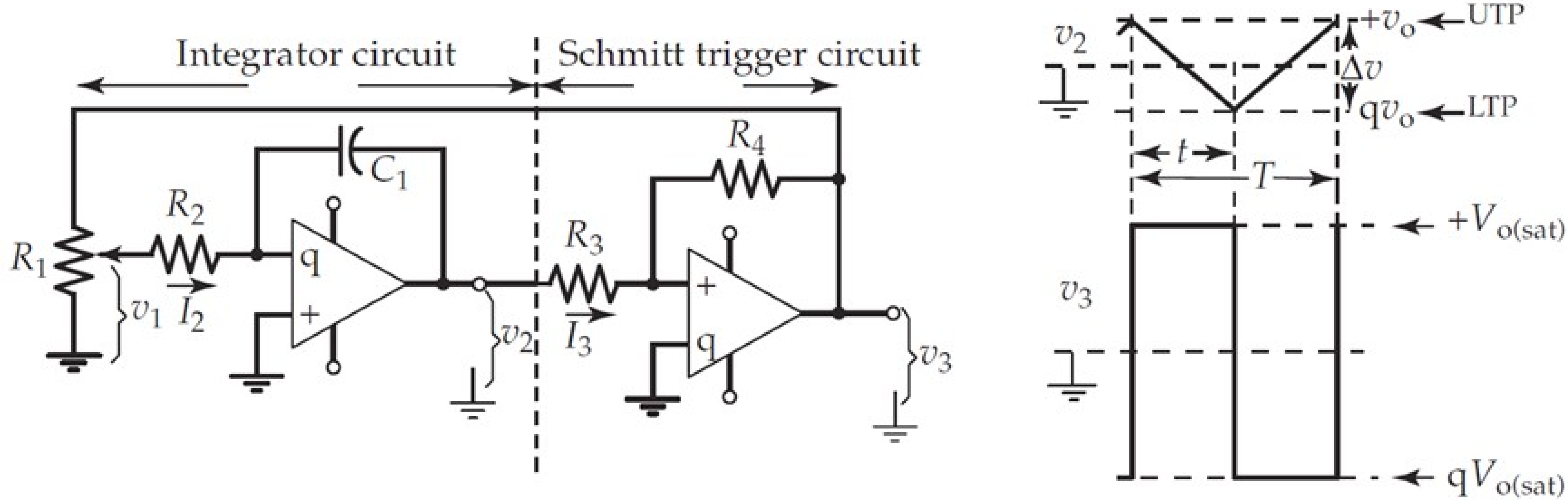
- The input and output waveform shows that output Vo switches rapidly from -Vo(sat) to +Vo(sat) when Vi arrives at the Upper trigger point and that Vo switches back to -Vo(sat) when Vi falls to Lower trigger point.



(a) Noninverting Schmitt trigger circuit

(b) Input and output waveforms

Trinagular Wave generator

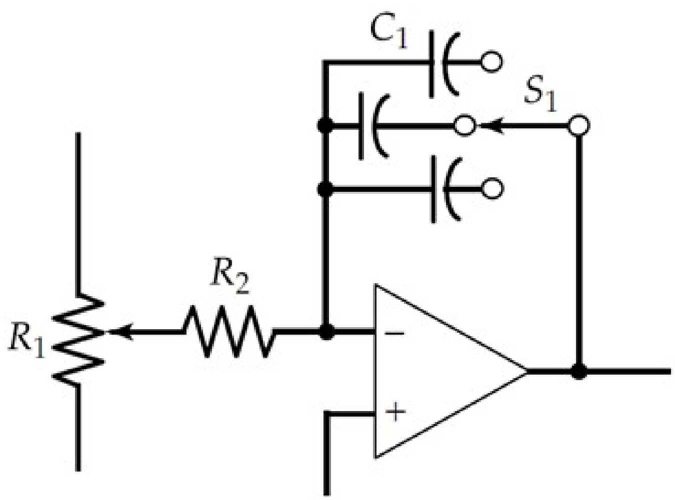


(a) Triangular/rectangular waveform generator (b) Circuit waveforms

A basic function generator circuit consists of an integrator and a Schmitt trigger circuit. The integrator output is a negative-going ramp voltage when the Schmitt output is positive, and vice versa. The Schmitt output changes state when the integrator output ramp reaches the Schmitt upper or lower trigger point.

Triangular Wave Generator

- Schmitt trigger is non inverting type whose output is square waveform.
    - UTP-Upper Trigger Point
    - LTP-Lower Trigger Point
- The integrator output is applied to Schmitt circuit input and schmitt output is applied to the integrator input.
- The integrator ckt produces a triangular output waveform when it has a square wave input.
- The schmitt output cahnges from one saturation level to other at each time the integrator output arrives at schmitt UTP or LTP.
- Frequency of output waveform is depend charging and discharging of the capacitor.

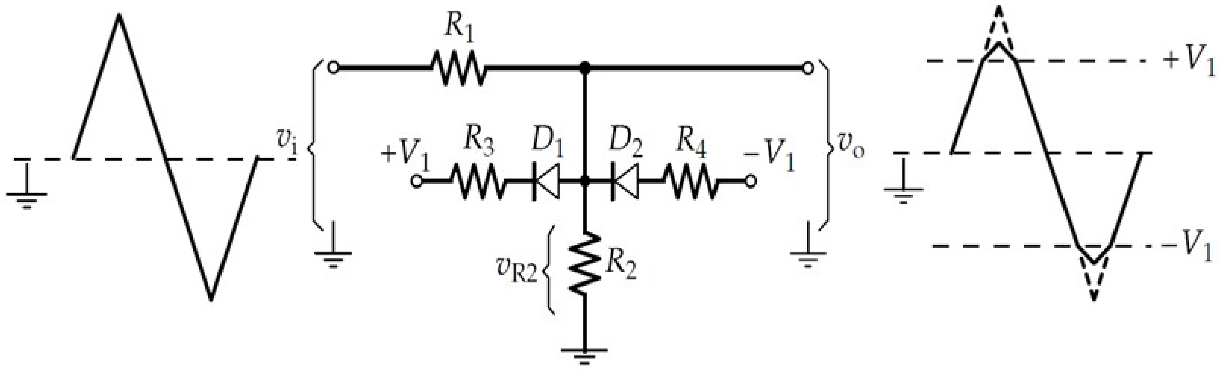


The output frequency of the basic function generator in Fig. 13-7 is adjusted continuously by means of a potentiometer (R_1), and the frequency range is changed by capacitor selection.

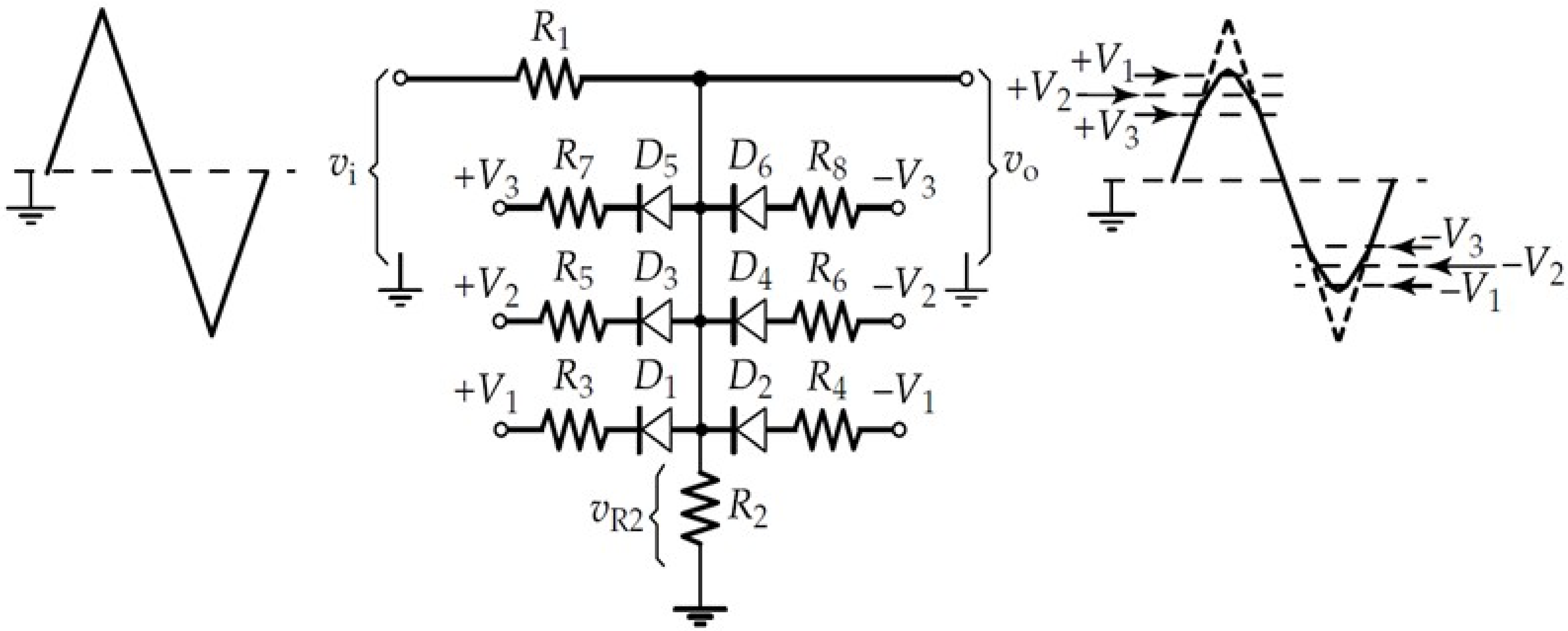
Sine Wave Conversion

- Used to convert approximate sinusoidal waveform.
- When six or more diodes are used a good approximation

can be achieved.

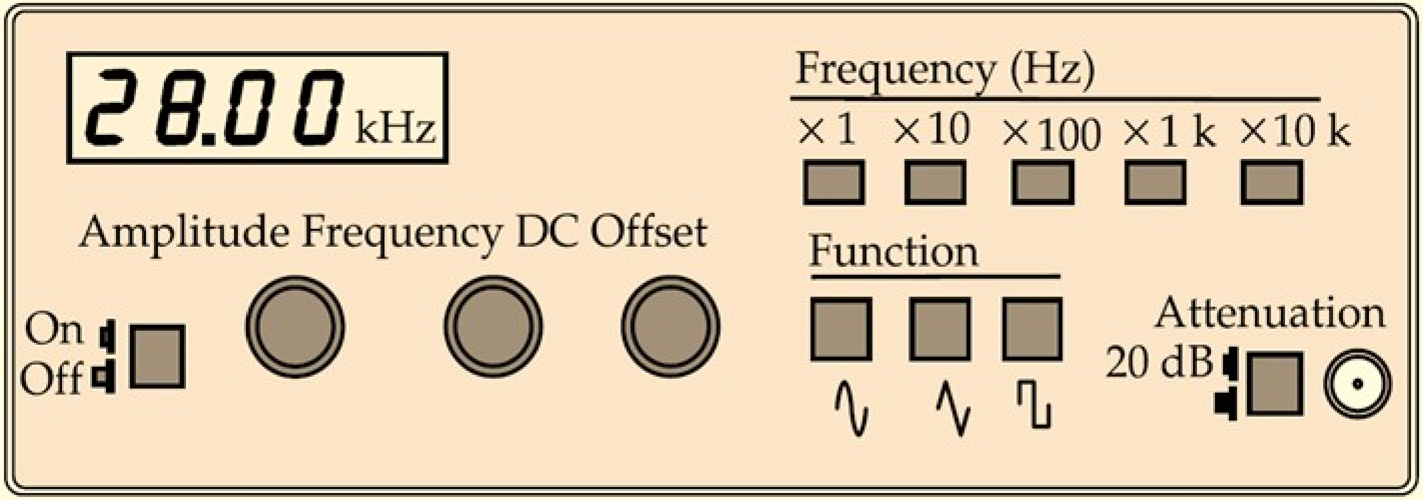


A triangular waveform can be shaped into an approximation of a sine wave by diode/resistor loading. Low-amplitude input voltages are divided across resistors R_1 and R_2. At higher amplitudes, diodes D_1 and D_2 become forward biased, causing either R_3 or R_4 to parallel R_2 and produce further attenuation.



The addition of more diodes and resistors with different bias levels in a Traingular to sine wave convertor gives a good sine wave approximation.

Front panel of Function Generator

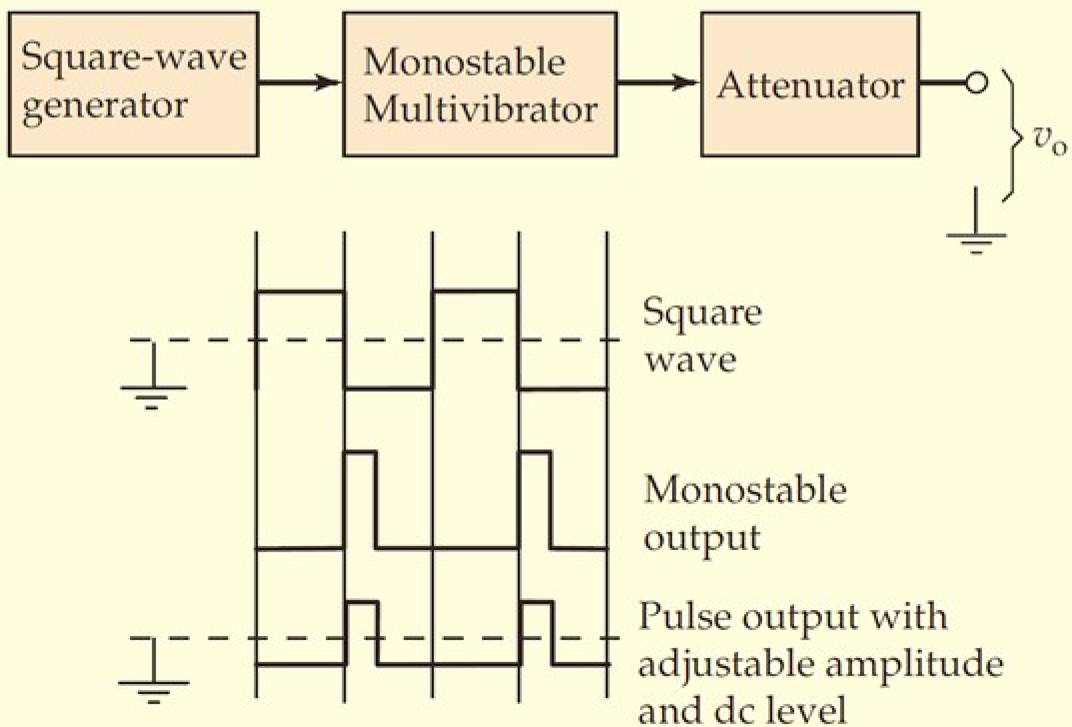


Typical function generator controls. Frequency range and function are selected by pushbutton switches, and the frequency is controlled continuously by the rotatable knob. The frequency is displayed digitally.

- **Attednuator stage is used to control the amplitude of the waveform & aslo used to shift DC level of the waveform.**

Pulse Generator

- It is made up of a square wave generator/astable multivibrator , monostable multivibrator and an attenuator output stage.



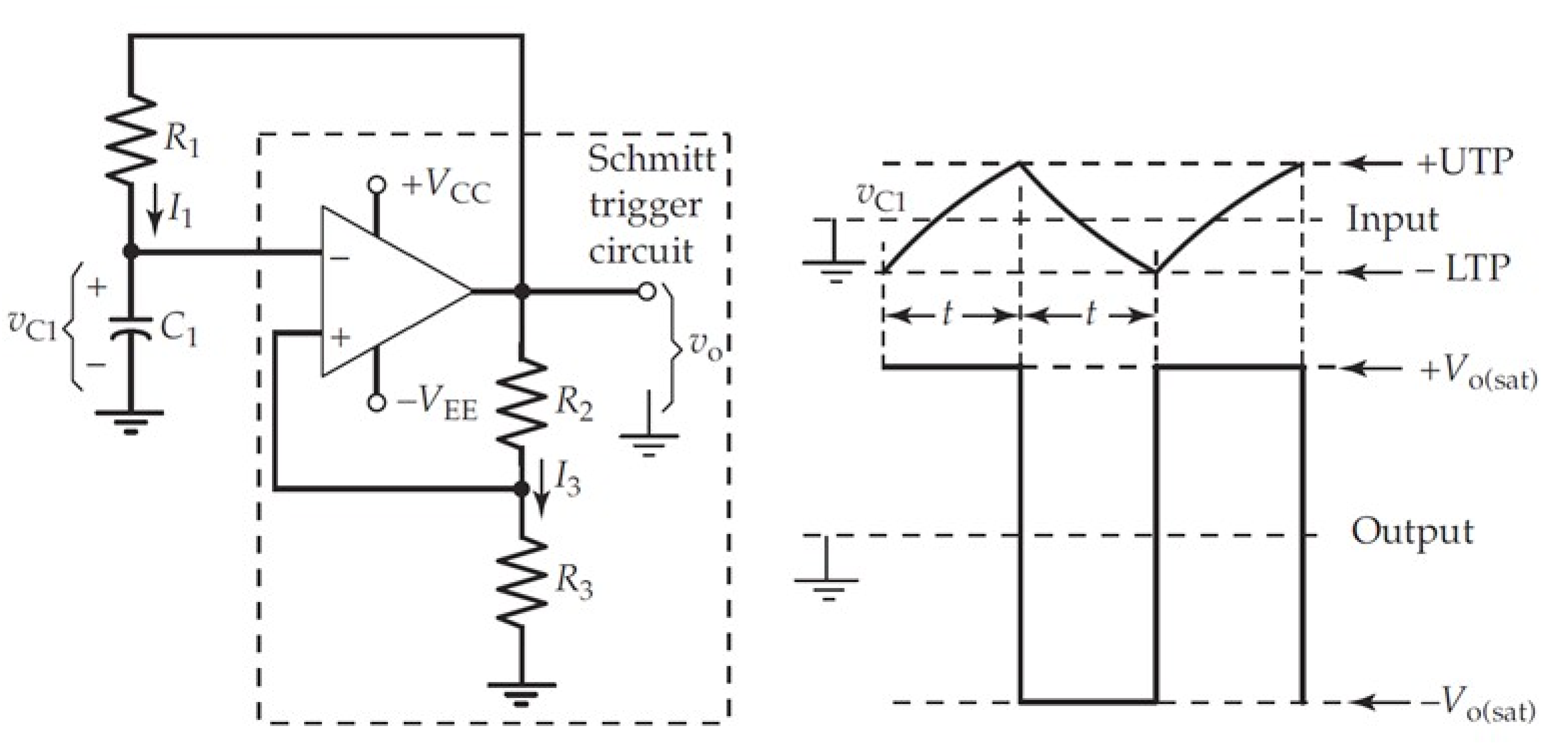
Basic pulse generator block diagram. A square-wave generator triggers the monostable multivibrator to produce the pulse waveform. The pulse frequency is determined by the frequency of the square wave, the pulse width can be set by adjusting the monostable, and the pulse amplitude is controlled by the output attenuator.

Square wave generator

- Also known as **astable multivibrator.**
- It consists of an RC circuit and an inverting Schmitt trigger circuit.
- The capacitor voltage Vc1 is the input to the Schmitt ckt and capacitor is cahrged

from the Schmitt ckt via resistor R1.

- The ckt output scillates continuously between high and low level.
- Frequency range is changed by selecting various capacitor.



(a) Astable multivibrator circuit (b) Capacitor and output waveforms

An op-amp astable multivibrator is the simplest form of square-wave generator. The op-amp together with resistors R_2 and R_3 constitute a Schmitt trigger circuit. C_1 is charged via R_1 from the Schmitt output.

Monostable multivibrator

- It has one stable state.

- Its normal output voltage may be high or low and it stays in the normal state until triggered by an input signal.

- When triggered, the output switches to the opposite state for a time that is dependant upon the circuit component values and then switches back again.

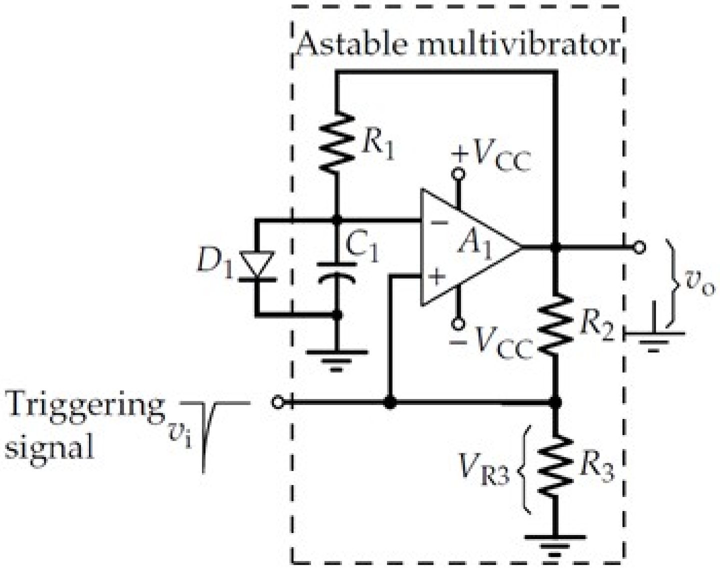
- This produces an output pulse with a fixed time duration.

- It is exactly an astable mutivirator with the addition of a diode and the triggering signal.

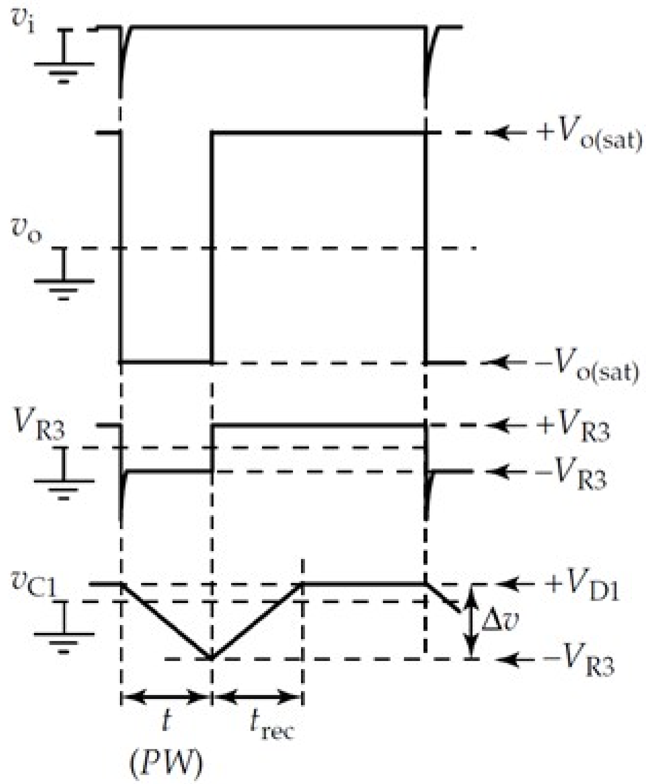
- When the op-amp output is at its positive meximum level +Vo(sat), the presance of diode D1 prevents capacitor C1 from charging to a higher voltage than the diode voltage drop (VD1).

- The volatge across R3 is the Scmitt UTP and if it is greater than VD1, the op-amp output remains at max positive level.

- So normal state of ckt is V-=VD1, V+= VR3> VD1 and Vo=+Vo(sat).



(a) Monostable multivibrator circuit



(b) Circuit waveforms

Op-amp monostable multivibrator circuit. This is exactly the same as the astable circuit with the addition of D_1. The diode prevents the circuit output from switching to $-v_o$ until a triggering signal is applied to the op-amp noninverting input.

- Now when a negative input spike signal Vi is applied to the op-amp noninverting input terminal as shown in figure.

- The negative input spike temorarily derives the noninverting termianl below diode voltage drop at the inverting terminal causing op-amp output to rapidly switch from +Vo(sat) to -Vo(sat).

- When the output goes -ve, VR3 switches from + to - value, thus providing the biasing voltage at noninverting input to hold the output at -Vo(sat).

- As output goes -ve, capacitor C1 starts to discharge and to recharge with opposite polarity.

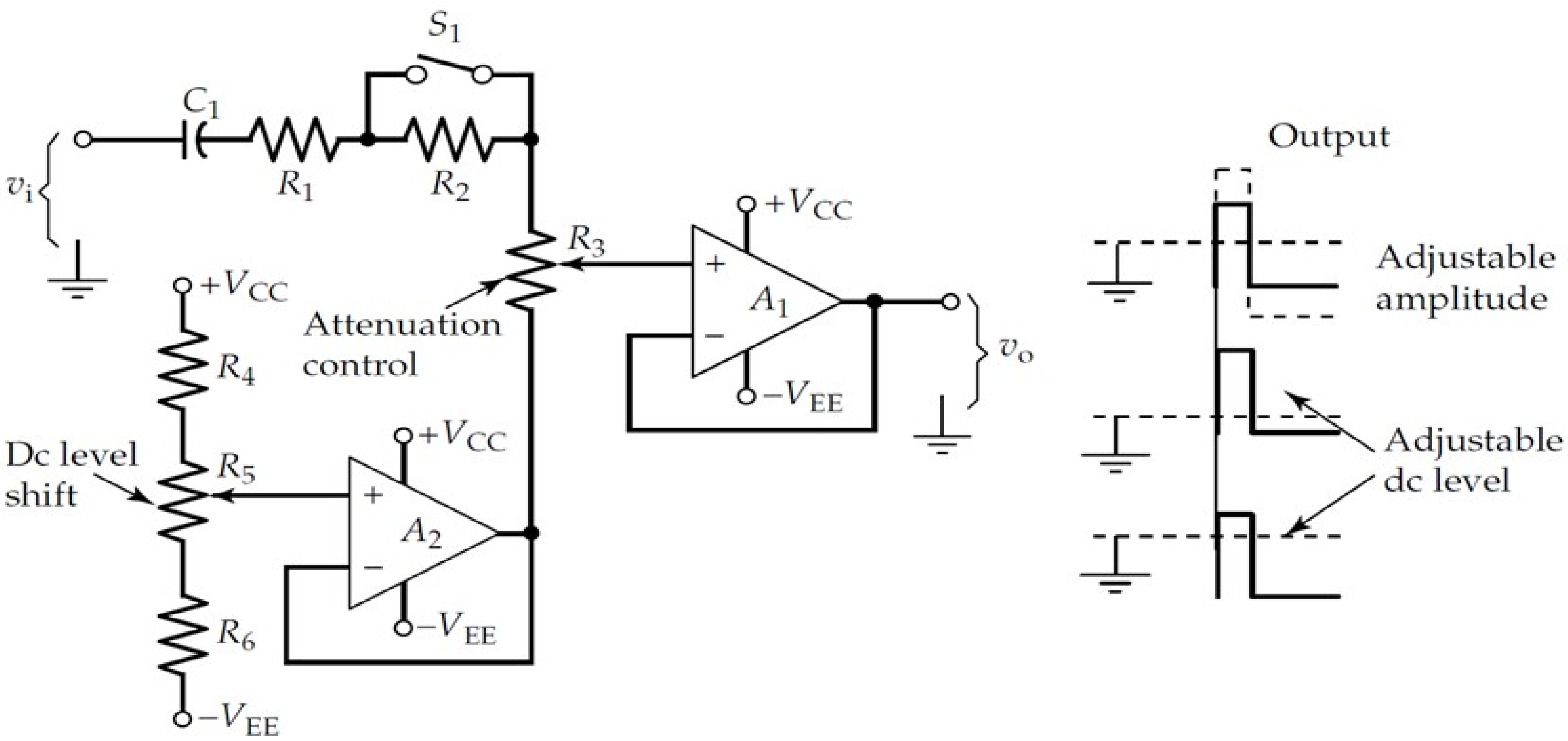
- thus the op-amp inverting input terminal voltage becomes increasingly negative and when -vc1 becomes more than -VR3, voltage at (-) termianl is more than voltage at (+) terminal and output switches to +Vo(sat) once again.

- From fig, it is observed that monostable ckt produces a negative going output pulse each time the ckt is triggered.

- The pulse width of output depens on capacitance C1, voltage VR3 and resistance R1.

Output Attenuator

- R1,R2,R3 together with operational amplifier controls the output amplitude of pulse generator.
- R4,R5,R6 provide DC shifting.



Attenuator and dc offset control for use with a pulse generator. Potentiometer R_3 provides continuous output amplitude control, and S_1 changes the attenuation range. Potentiometer R_5 is the dc offset control.

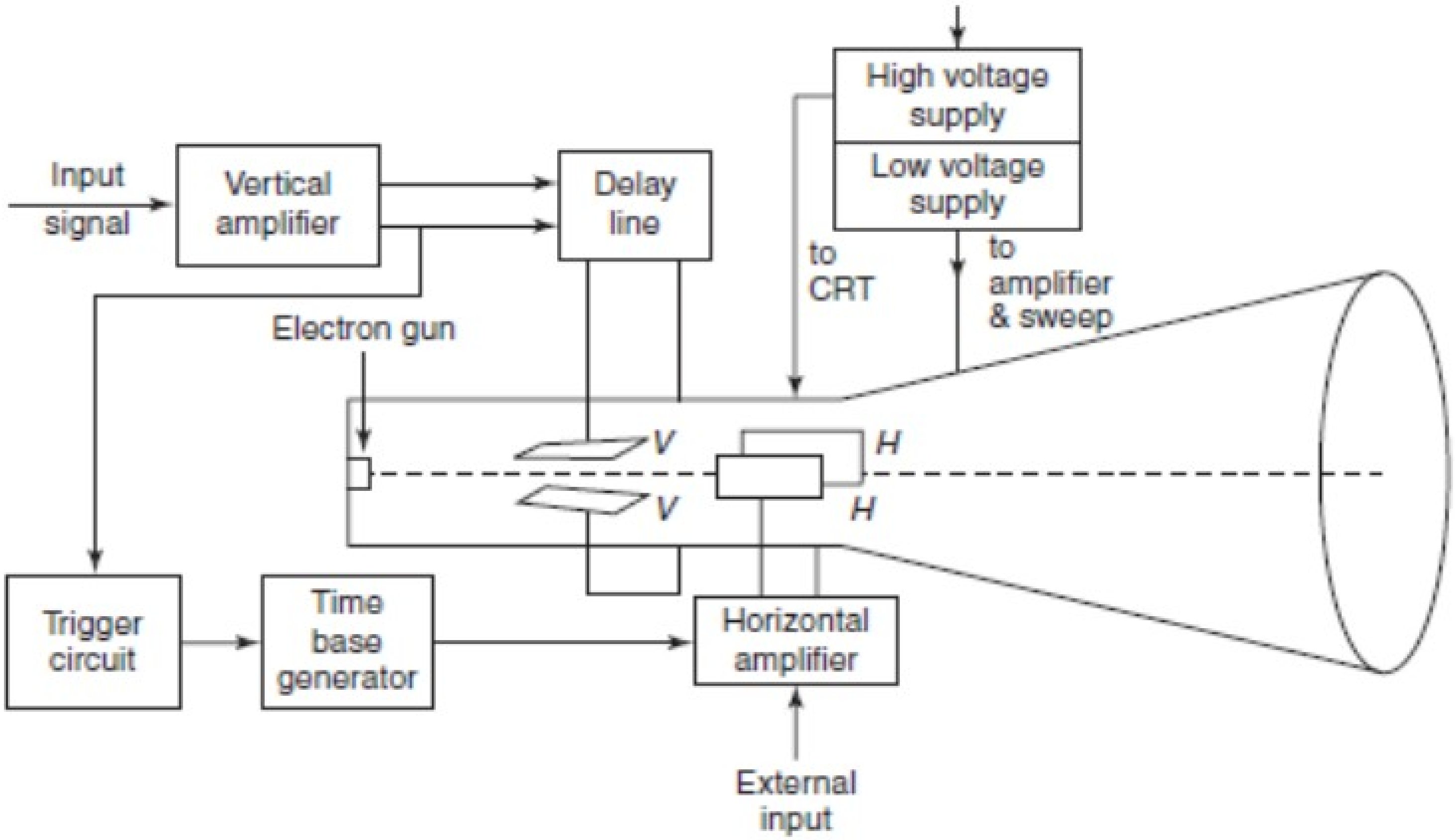
Measuring Instruments

1. Cathode Ray Oscilloscope (C.R.O)
2. Specfic type of CRO- Digital Storage Oscilloscope (D.S.O.)
3. Spectrum Analyzer
4. Network Analyzer
5. Logic Analyzer
6. Distortion meter
7. RF Power meter

Cathode Ray Oscilloscope

- 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:



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

Functions of Components of CRO

Power Supply:

- It provides the voltages required by the Cathode Ray Tube to generate and accelerate the electron beam.

- Cathode ray tube (CRT) requires high voltage for pre-accelerating and accelerating anode, low voltage required for heater, control grid, focusing anode and the other circuits of CRO.

Vertical Amplifier: The signal under the analysis is to be applied to vertical deflection plates through the vertical amplifier.

Delay line

- If both vertical and horizontal signals arrives at the same time to the corresponding deflection plates, then only we will get exact waveform.

- But vertical signal arrives much early compared to the horizontal signal.

- For this reason, the vertical signal at the output of the vertical amplifier should be delayed with the help of delay line. The delay time is equal to 200 nsec.

Trigger circuit

- This is triggered by the portion of the vertical amplifier output.

- This circuit initiates then time base generator. It is the link between the vertical input and horizontal time base.

- Trigger circuit is used to synchronize horizontal deflection with vertical deflection.

Horizontal Amplifier

- The saw tooth voltage produced by the time base generator may not be of sufficient strength.
- Hence before giving it to the horizontal deflection plates, it is amplified using the horizontal amplifier.

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.

- Time base generator is used to generate saw tooth voltage, required to deflect the beam in horizontal section.

- In saw tooth wave form, the deflecting voltage increases slowly and linearly with respect to time and reduces to zero quickly (fast) i.e. raise time is high and fall time is less.

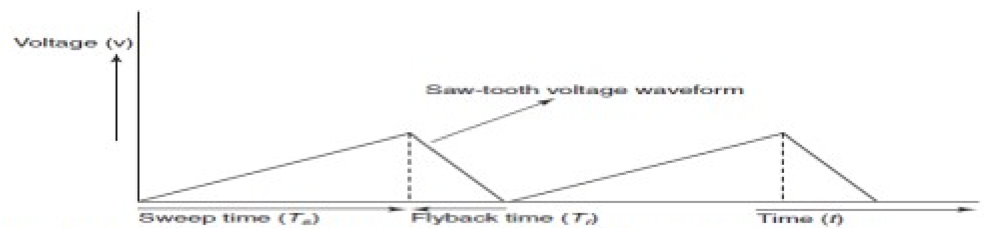
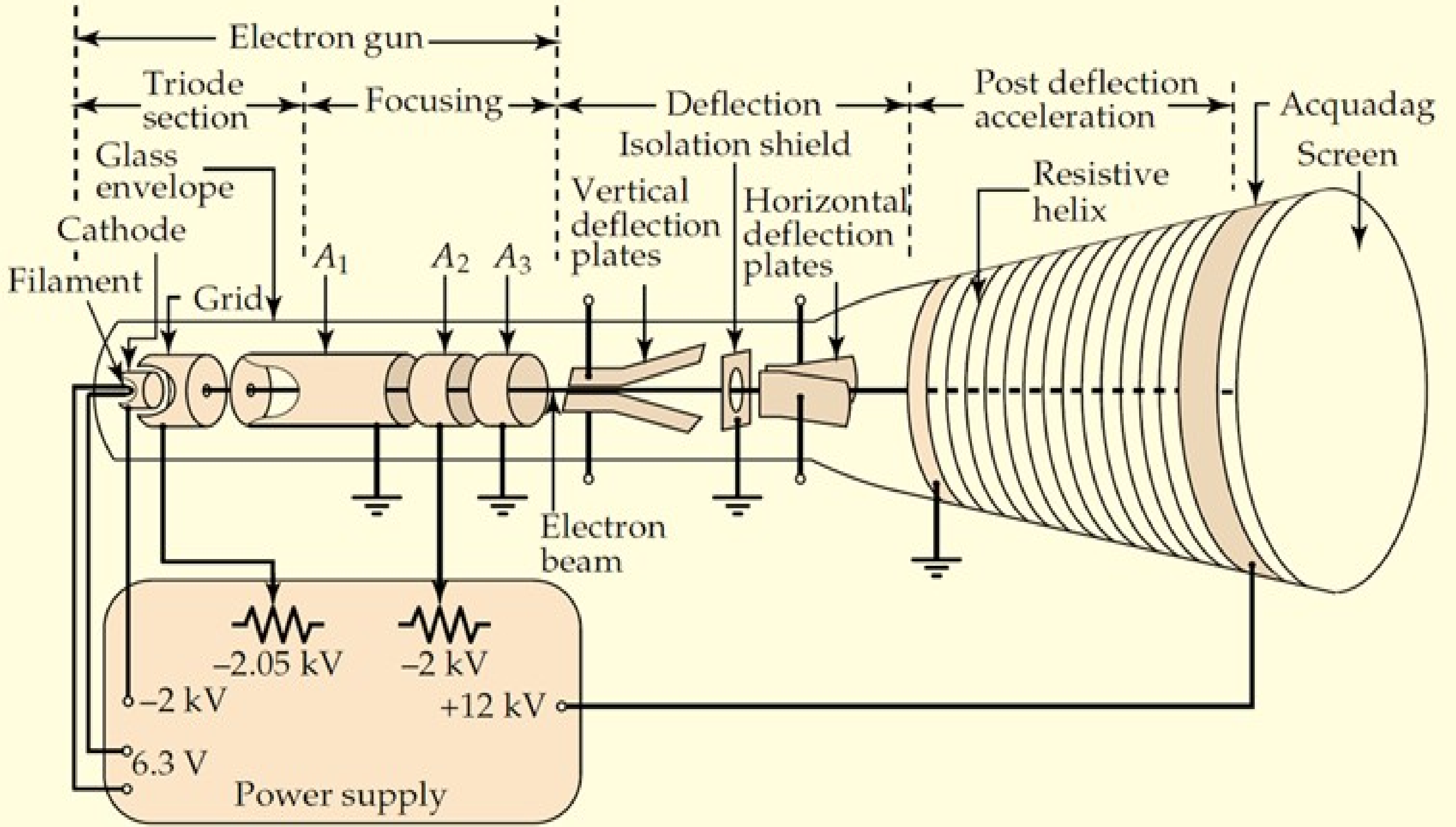


Figure 14-6 Typical saw-tooth waveform applied to the horizontal deflection plates

Cathode Ray Tube-- The electron gun & the deflecting system & the fluorescent screen



Basic cathode-ray tube construction. The filament heats the cathode which emits electrons, and the grid voltage controls the flow of electrons toward anodes A_1, A_2, and A_3. The anodes focus the beam to a fine point at the screen. Voltages applied to the vertical and horizontal deflecting plates move the electron beam around the screen.

Components of CRT

Triode Section

- It consist of cathode ,grid (made up of nickel) and anode
- A filament is present in cathode.

Focusing Section

- A1,A2,A3 are term as focusing electrodes.

- Triode & Focusing sections together is called electron gun or electron emmiter.

Deflection Section

- Consists of vertical and horizontal section.

Screen

- It is formed by depositing a coating of phosphor material on the inside of tube face.

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

- The deflection is propc ɔlarity of the deflecting voltage is

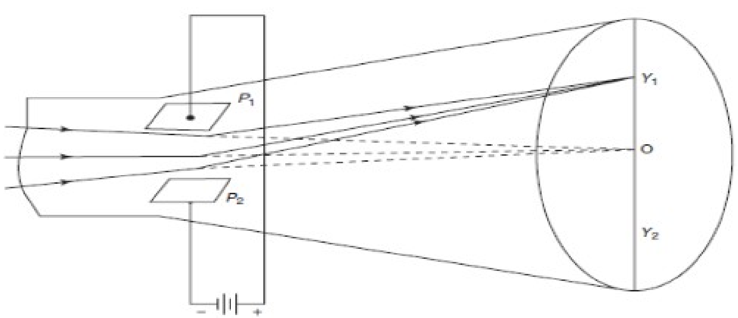
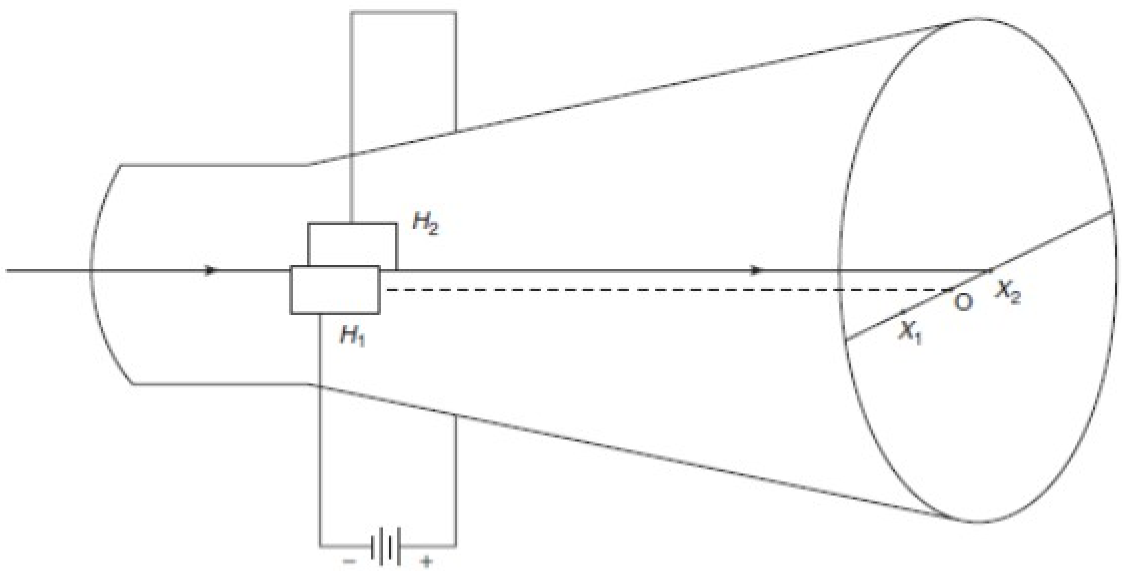


Figure 14-3(a) Deflecting system using parallel vertical plates

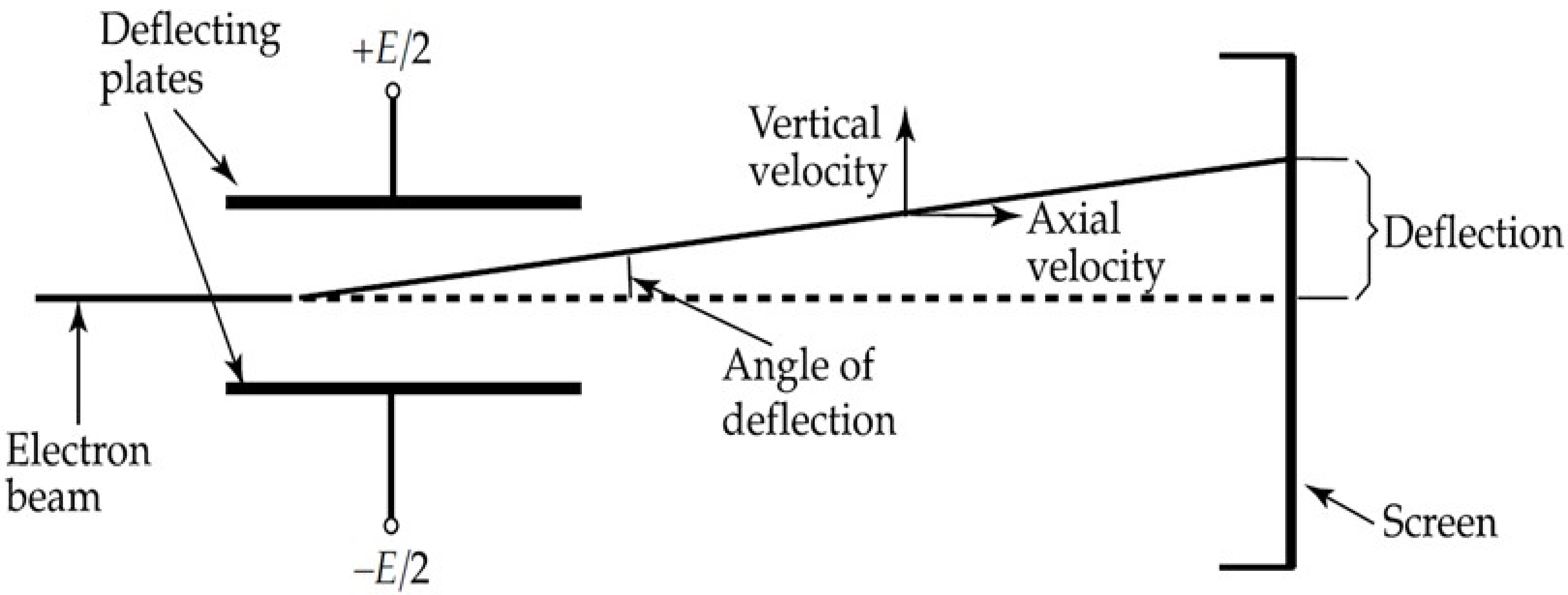
Deflection Systems:

- To deflect
deflecting plat

- The electr ɔcus
at point X1. Tl



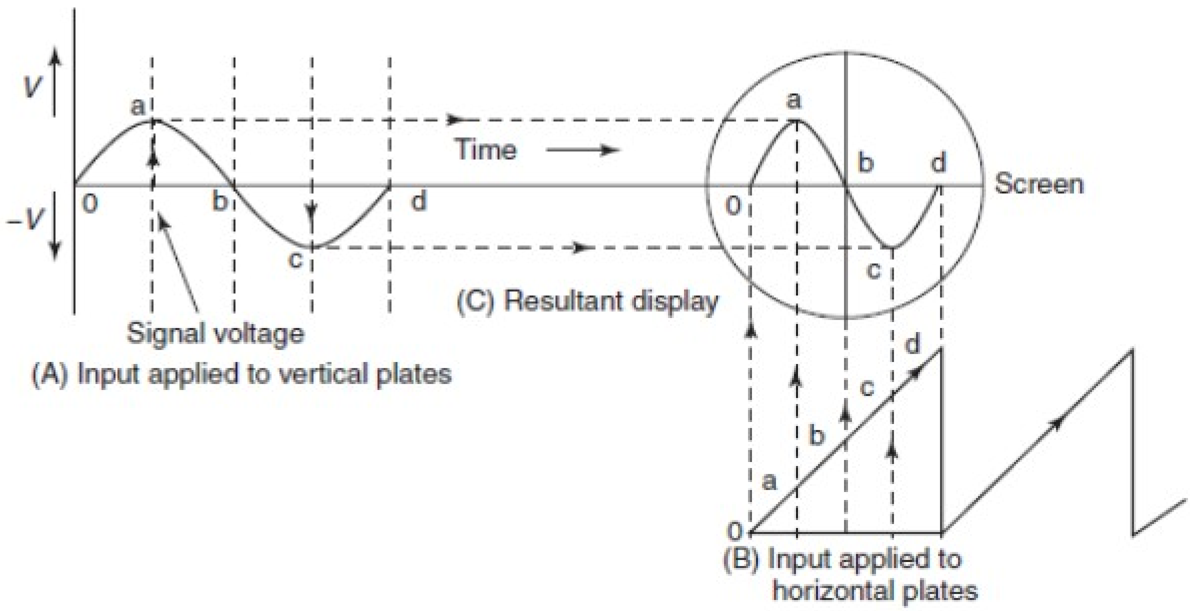
Deflecting system using parallel horizontal plate

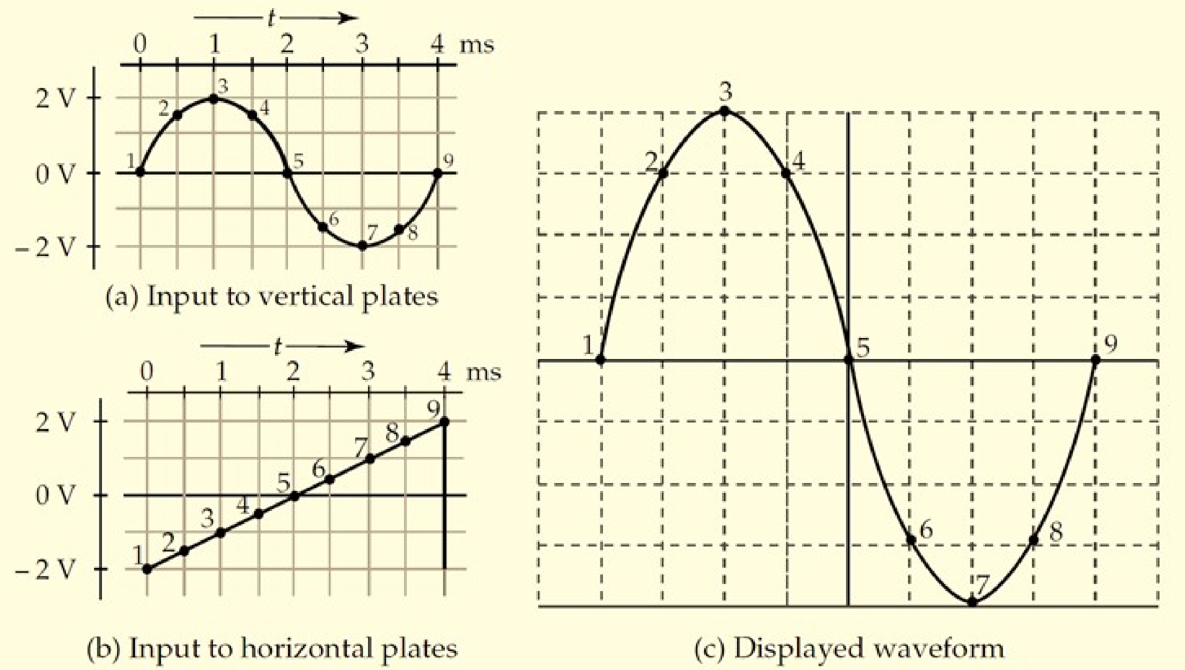


Electrostatic deflection. Electrons traveling from the electron gun to the screen of the cathode-ray tube are attracted toward the positive deflecting plate and repelled from the negative plate. The electrons do not strike the plate, but the electron beam is deflected.

Display waveform on the screen:

- Figure s
saw-tooth ap
- The ram
horizontally a
- If the wa rtical
display appe





A ramp waveform applied to the horizontal deflecting plates of an oscilloscope causes the electron beam to be deflected horizontally across the screen. Another waveform, synchronized with the ramp and applied to the vertical deflecting plates, is displayed on the screen.

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%.

TYPES OF THE CATHODE-RAY OSCILLOSCOPES:

INDUS UNIVERSITY
Where Practice Meets Theory

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.

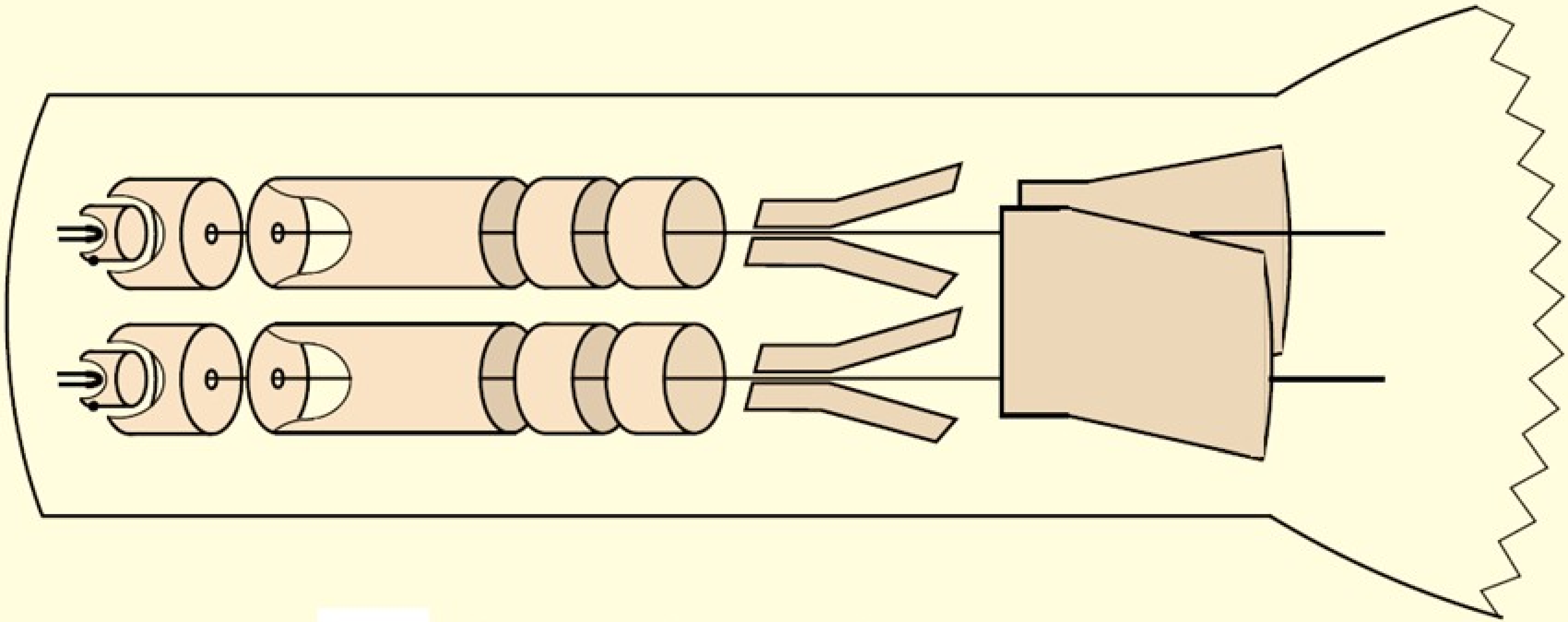
2. Digital CRO: A digital CRO offers digital read-out of signal information, i.e., the time, voltage or frequency along with signal display. It consists of an electronic counter along with the main body of the CRO.

3. Storage CRO: It is used to measure fast nonrepetitive signals.
It does this by capturing the signal on demand and continuing to display it until reset.
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.

Dual Trace Oscilloscopes



CRT with two electron guns

Measurement of voltage , Frequency and Phase using CRO

- Peak to Peak Voltage Measurement

$$V_{p-p} = \text{Vertical P to P Division} * (\text{Volt /division})$$

- T= (Horizontal divisions/ Cycle)* Time/DIV
- f=1/T
- The Phase difference between two sine waves may be determined by first calculating the horizontal degrees/divisions for one cycle.
- This factor is multiplied by horizontal division between the commencement of cycles.

Spectrum Analyzer

- A spectrum analyzer measures the magnitude of an **input signal versus frequency** within the full frequency range of the instrument.

- It is used to measure the power of the spectrum of known and unknown signals.

- By analyzing the spectra of electrical signals, dominant frequency, power, distortion, harmonics, bandwidth, and other spectral components of a signal can be observed that are not easily detectable in time domain waveforms.

- The display of a spectrum analyzer has frequency on the horizontal axis and the amplitude displayed on the vertical axis.

- To the casual observer, a spectrum analyzer looks like an oscilloscope and, in fact, some lab instruments can function either as an oscilloscope or a spectrum analyzer.

Network Analyzer

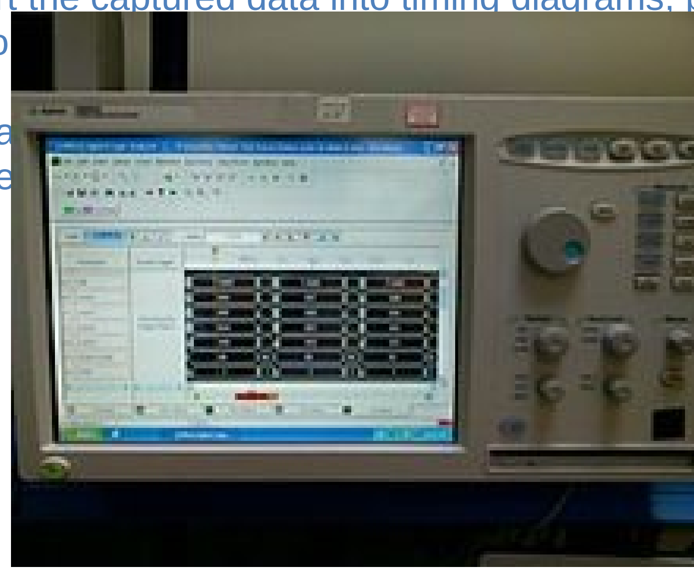
- Network analyzer is an instrument that **measures the network parameters of electrical networks.**
- Network analyzers commonly measure s–parameters because reflection and transmission of electrical networks are easy to measure at high frequencies, but there are other network parameter sets such as y-parameters, z-parameters, and h-parameters.
- Network analyzers are ofte amplifiers and filters, but they can be used on

Logic Analyzer

- Logic analyzer is an electronic instrument that **captures and displays multiple signals from a digital system** or digital circuit.

- Logic analyzer may convert the captured data into timing diagrams, protocol decodes, assembly language, or may co e.

- Logic analyzers have adva l when a user needs to see the timing relationships betwee



Distortion Meter

INDUS UNIVERSITY
Where Practice Meets Theory

Harmonic distortion

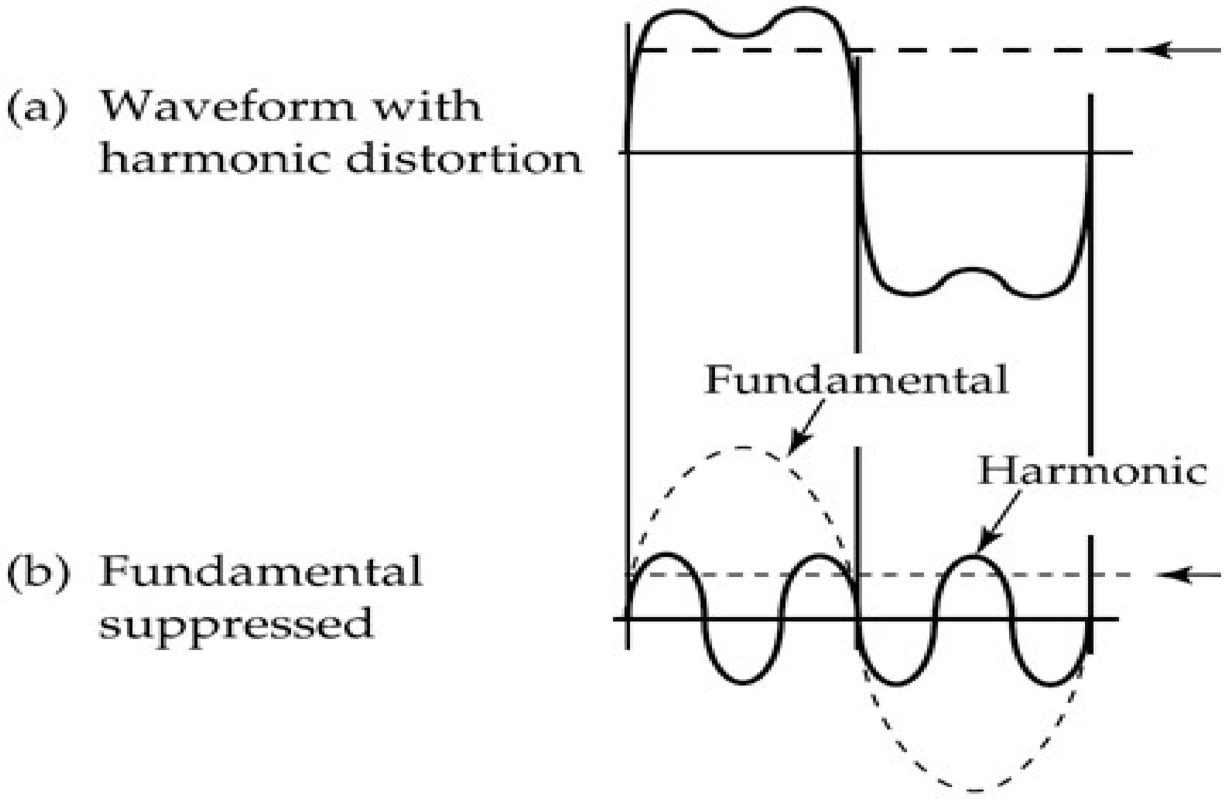
- Harmonic distortion is the distortion in our signal that is produced by the additional frequencies generated in the signal. These frequencies are nothing but multiples of the original frequency of our signal. Harmonic distortion occurs in sound waves, electrical signals etc..

- when a current is passing through a circuit, it can induce vibrations in the circuit and the vibrations produced would obviously be some multiple of the current signal frequency. Hence these vibrations can cause distortion in our original signal. This distortion in current can lead to many problems like voltage fluctuation etc.

- Distortion meter is used for the **detection and measurement of harmonic frequencies of original signal.**

- Distortion meter not only detects and measures the distortion in our signal frequencies but also works to overcome or eliminate them

Distrortion in Electrical Signal



RF Power Meter

- RF power meters or wattmeters are used **for measuring power in RF circuits**.
- In many areas of RF development, design, test, service repair and field service, RF and microwave power meters or wattmeters are needed.
- In-line RF power meters take a sample of the power flowing along a feed-line and use this to indicate the power level. These inline RF power meters are used on live systems, such as radio transmitters as a check of the outgoing power.
- They are normally directional and can be used to check the power travelling in either direction.