NEIL GOGTE INSTITUTE OF TECHNOLOGY

Subject: Basic Electronics **Unit:1**

UNIT-I Syllabus

- **PN Junction Diode: Characteristics**
- **Half wave rectifier, Full wave rectifier, filters, ripple, regulation, TUF and efficiency**
- **Zener diode and Zener diode regulators.**
- **CRT construction and CRO applications**

RECTIFIERS WITH FILTERS

The output of a rectifier contains dc component as well as ac component. Filters are used to minimize the undesirable ac i.e., ripple leaving only the dc component to appear at the output.

Some important filters are:

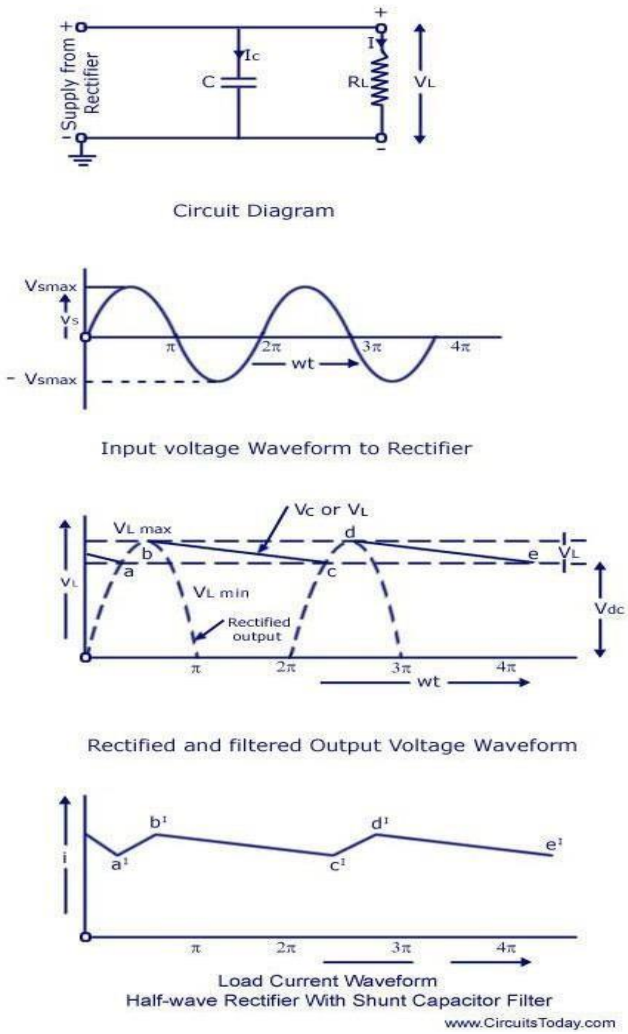
1. Inductorfilter
2. Capacitorfilter
3. LC or L sectionfilter
4. CLC or Π-typefilter

CAPACITOR FILTER

This is the most simple form of the **filter circuit**and in this arrangement a high value capacitor C is placed directly across the output terminals, as shown in figure. During the conduction period it gets charged and stores up energy to it during non-conduction period. Through this process, the time duration during which Ft is to be noted here that the capacitor C gets charged to the peak because there is no resistance (except the negligible forward resistance of diode) in the charging path. But the discharging time is quite large (roughly 100 times more than the charging time depending upon the value of RL) because it discharges through load resistanceRL.

The function of the capacitor filter may be viewed in terms of impedances. The large value capacitor C offers a low impedance shunt path to the ac components or ripples but offers high impedance to the dc component. Thus ripples get bypassed through capacitor C and only dc component flows through the load resistance RL

Capacitor filter is very popular because of its low cost, small size, light weight and good

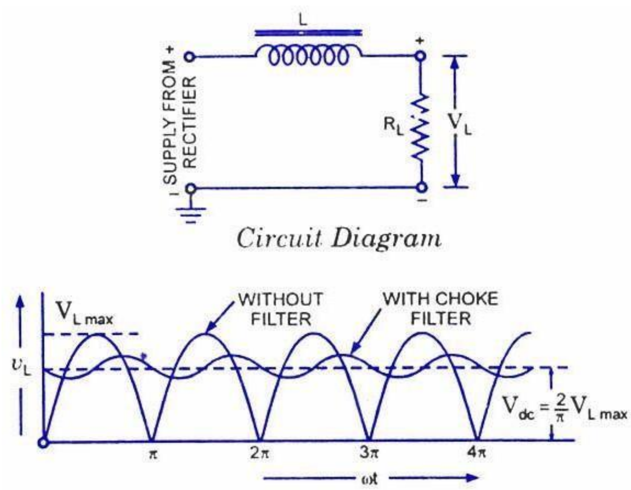


characteristics

SERIES INDUCTOR FILTER.

In this arrangement a high value inductor or choke L is connected in series with the rectifier element and the load, as illustrated in figure. The filtering action of an inductor filter depends upon its property of opposing any change in the current flowing through it. When the output current of the rectifier increases above a certain value, energy is stored in it in the form of magnetic field and this energy is given up when the output current falls below the average value. Thus by placing a choke coil in series with the rectifier output and load, any sudden change in current that might have occurred in the circuit without an inductor is smoothed out by the presence of the inductor L.

The function of the inductor filter may be viewed in terms of impedances. The choke offers high impedance to the ac components but offers almost zero resistance to the desired dc components. Thus ripples are removed to a large extent. Nature of the output voltage without filter and with



Output Voltage Waveforms
Full-Wave Rectifier With Series Inductor Filter

choke filter is shown in figure.

For dc (zero frequency), the choke resistance R_C in series with the load resistance R_L forms a voltage divider and dc voltage across the load is given as

where V_{dc} is dc voltage output from a full-wave rectifier. Usually choke coil resistance Rc, is much small than R_L and, therefore, almost entire of the dc voltage is available across the load resistance R_L.

Since the reactance of inductor increases with the increase in frequency, better filtering of the higher harmonic components takes place, so effect of third and higher harmonic voltages can be neglected.

As obvious from equation , if choke coil resistance $R_C$is negligible in comparison to load resistance R_L, then the entire dc component of rectifier output is available across 2 R_L and isequal to — V_{Lmax}. The ac voltage partly drops across X_L and partly overR_L.

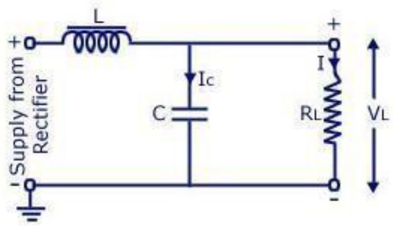
LC FILTER:

A simple series inductor reduces both the peakand effective values of the output current and output voltage. On the other hand a simple **shunt capacitor filter**reduces the ripple voltage but increases the diode current. The diode may get damaged due to large current and at the same time it causes greater heating of supply transformer resulting in reducedefficiency.

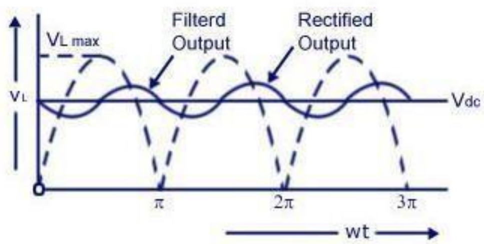
In an inductor filter, ripple factor increases with the increase in load resistance RL while in a capacitor filter it varies inversely with load resistance RL.

From economical point of view also, neither series inductor nor shunt capacitor type filters are suitable.

Practical **filter-circuits**are derived by combining the voltage stabilizing action of shunt capacitor with the current smoothing action of series choke coil. By using combination of inductor and capacitor ripple factor can be lowered, diode current can be restricted and simultaneously ripple factor can be made almost independent of load resistance (or load current). Two types of most commonly used combinations are choke-input or L-section filter-and capacitor-input or Pi-Filter.



Circuit Digram

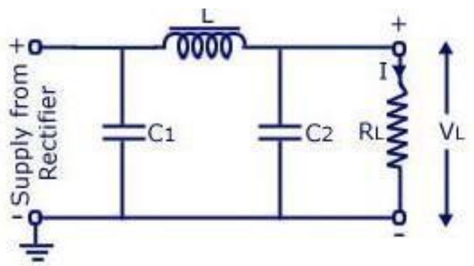


Rectified and Filtered Output Voltage Waveform
Full-wave Rectifier With Choke-Input Filter

Choke-input filter (LC filer) is explained below:

Choke-input filter consists of a choke L connected in series with the rectifier and a capacitor C connected across the load . This is also sometimes called the L-section filter because in this arrangement inductor and capacitor are connected, as an inverted L. ln figure only one filter section is shown. But several identical sections are often employed to improve the smoothing action. (The choke L on the input side of the filter readily allows dc to pass but opposes the flow of ac components because its dc resistance is negligibly small but ac impedance is large. Any fluctuation that remains in the current even after passing through the choke are largely by-passed around the load by the shunt capacitor because Xc is much smaller than RL. Ripples can be reduced effectively by making XL greater than Xc at ripple frequency. However, a small ripple still remains in the filtered output and this is considered negligible if it than l%. The rectified and filtered output voltage waveforms from a full-wave re with choke-input filter are shown in figure.

Π-SECTION FILTER:



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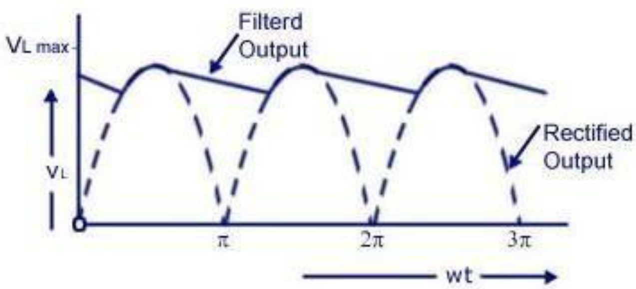


Rectified and Filtered Output Voltage Waveform
Full-wave Rectifier With capacitor Input Filter

Pi-Filter.

Such a filter consists of a shunt capacitor C1 at the input followed by an L-section filter formed by series inductor L and shunt capacitor C2. This is also called the *n-filter* because the shape of the circuit diagram for this filter appears like Greek letter *n (pi)*. Since the rectifier feeds directly into the capacitor so it is also called *capacitor input filter.*

As the rectified output is fed directly into a capacitor C1. Such a filter can be used with a half-wave rectifier (series inductor and L-section filters cannot be used with half-wave rectifiers). Usually electrolytic capacitors are used even though their capacitances are large but they occupy minimum space. Usually both capacitors C1 and C2 are enclosed in one metal container. The metal container serves as, the common ground for the two capacitors.

A capacitor-input or *pi*- filter is characterized by a high voltage output at low current drains. Such a filter is used, if, for a given transformer, higher voltage than that can be obtained from an L-section filter is required and if low ripple than that can be obtained from a shunt capacitor filter or L-section filter is desired. In this filter, the input capacitor C1 is selected to offer very low reactance to the ripple frequency. Hence major part of filtering is accomplished by theinput capacitor *C1*. Most of the remaining ripple is removed by the L-section filter consisting of a choke L and capacitor C2.)

The action of this filter can *best* be understood by considering the action of L-section filter, formed by L and C2, upon the triangular output voltage wave from the input capacitor C1 The charging and discharging action of input capacitor C1 has already been discussed. The output voltage is roughly the same as across input capacitor C1 less the dc voltage drop in inductor. The ripples contained in this output are reduced further by L-section filter. The output voltage of pi- filter falls off rapidly with the increase in load-current and, therefore, the voltage regulation with this filter is very poor.

COMPARISON OF FILTERS

1) A capacitor filter provides Vm volts at less load current. But regulation ispoor.

2) An Inductor filter gives high ripple voltage for low load currents. It is used for high loadcurrents

3) L – Section filter gives a ripple factor independent of load current.Voltage Regulation can be improved by use of bleeder resistance

4) Multiple L – Section filter or π filters give much less ripple than the single L – SectionFilter.

Zener diode

A normal p-n junction diode allows electric current only in forward biased condition. When forward biased voltage is applied to the p-n junction diode, it allows large amount of electric current and blocks only a small amount of electric current. Hence, a forward biased p-n junction diode offer only a small resistance to the electric current.

When reverse biased voltage is applied to the p-n junction diode, it blocks large amount of electric current and allows only a small amount of electric current. Hence, a reverse biased p-n junction diode offer large resistance to the electric current.

If reverse biased voltage applied to the p-n junction diode is highly increased, a sudden rise in current occurs. At this point, a small increase in voltage will rapidly increases the electric current. This sudden rise in electric current causes a junction breakdown called zener or avalanche breakdown. The voltage at which zener breakdown occurs is called zener voltage and the sudden increase in current is called zener current.

A normal p-n junction diode does not operate in breakdown region because the excess current permanently damages the diode. Normal p-n junction diodes are not designed to operate in reverse breakdown region. Therefore, a normal p-n junction diode does not operate in reverse breakdown region.

What is zener diode?

A zener diode is a special type of device designed to operate in the zener breakdown region. Zener diodes acts like normal p-n junction diodes under forward biased condition. When forward biased voltage is applied to the zener diode it allows large amount of electric current and blocks only a small amount of electric current.

Zener diode is heavily doped than the normal p-n junction diode. Hence, it has very thin depletion region. Therefore, zener diodes allow more electric current than the normal p-n junction diodes.

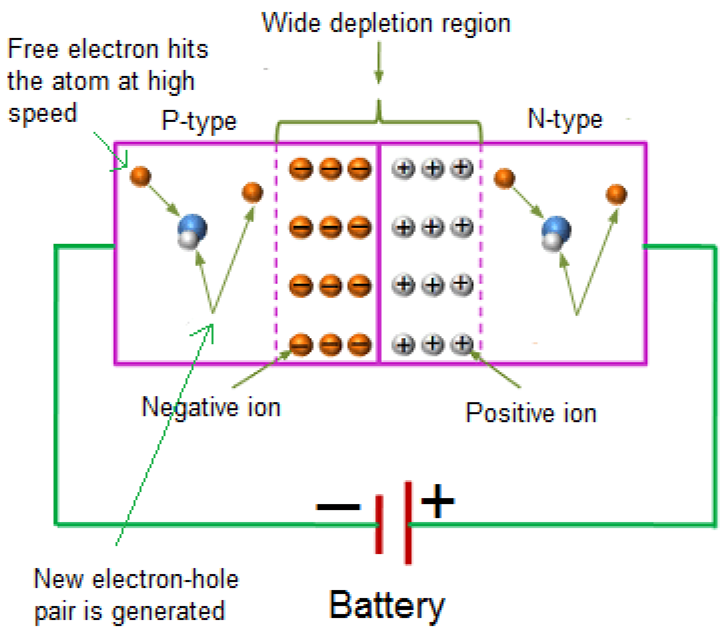
Zener diode allows electric current in forward direction like a normal diode but also allows electric current in the reverse direction if the applied reverse voltage is greater than the zener voltage. Zener diode is always connected in reverse direction because it is specifically designed to work in reverse direction.

Breakdown in zener diode

There are two types of reverse breakdown regions in a zener diode: avalanche breakdown and zener breakdown.

Avalanche breakdown

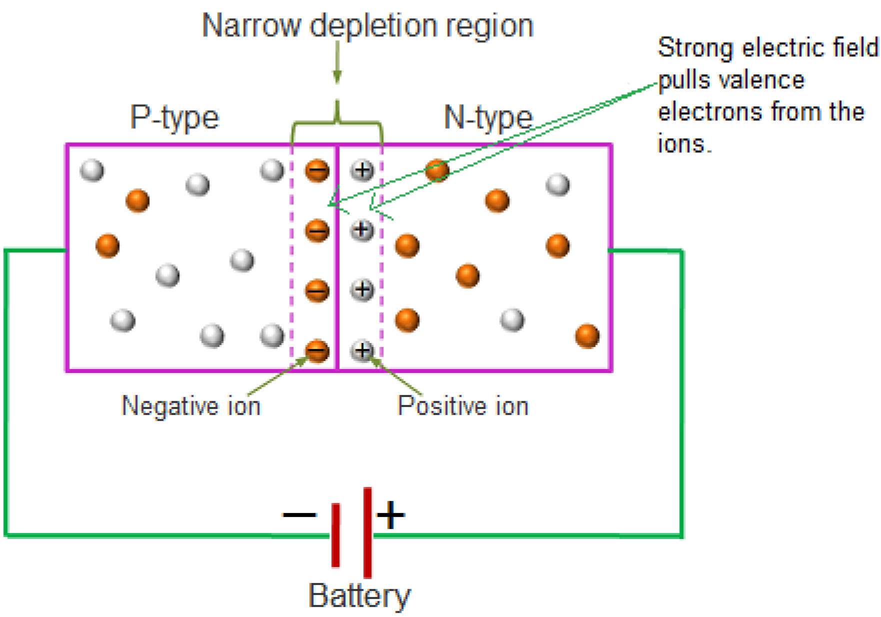
The avalanche breakdown occurs in both normal diodes and zener diodes at high reverse voltage. When high reverse voltage is applied to the p-n junction diode, the free electrons (minority carriers) gains large amount of energy and accelerated to greater velocities.



The free electrons moving at high speed will collides with the atoms and knock off more electrons. These electrons are again accelerated and collide with other atoms. Because of this continuous collision with the atoms, a large number of free electrons are generated. As a result, electric current in the diode increases rapidly. This sudden increase in electric current may permanently destroys the normal diode. However, avalanche diodes may not be destroyed because they are carefully designed to operate in avalanche breakdown region. Avalanche breakdown occurs in zener diodes with zener voltage (V_z) greater than 6V.

Zener breakdown

The zener breakdown occurs in heavily doped p-n junction diodes because of their narrow depletion region. When reverse biased voltage applied to the diode is increased, the narrow depletion region generates strong electric field.



When reverse biased voltage applied to the diode reaches close to zener

voltage, the electric field in the depletion region is strong enough to pull electrons from their valence band. The valence electrons which gains sufficient energy from the strong electric field of depletion region will breaks

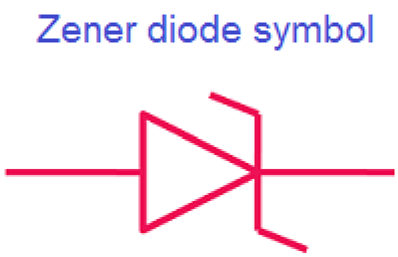
bonding with the parent atom. The valance electronswhich break bonding with parent atom will become free electrons. This free electrons carry electric current from one place to another place. At zener breakdown region, a small increase in voltage will rapidly increases the electric current.

- Zener breakdown occurs at low reverse voltage whereas avalanche breakdown occurs at high reverse voltage.
- Zener breakdown occurs in zener diodes because they have very thin depletion region.
- Breakdown region is the normal operating region for a zener diode.

- Zener breakdown occurs in zener diodes with zener voltage (V_z) less than 6V.

Symbol of zener diode

The symbol of zener diode is shown in below figure. Zener diode consists of two terminals: cathode and anode.



In zener diode, electric current flows from both anode to cathode and

cathode to anode.

The symbol of zener diode is similar to the normal p-n junction diode, but with bend edges on the vertical bar.

VI characteristics of zener diode

The VI characteristics of a zener diode is shown in the below figure. When forward biased voltage is applied to the zener diode, it works like a normal diode. However, when reverse biased voltage is applied to the zener diode, it works in different manner.

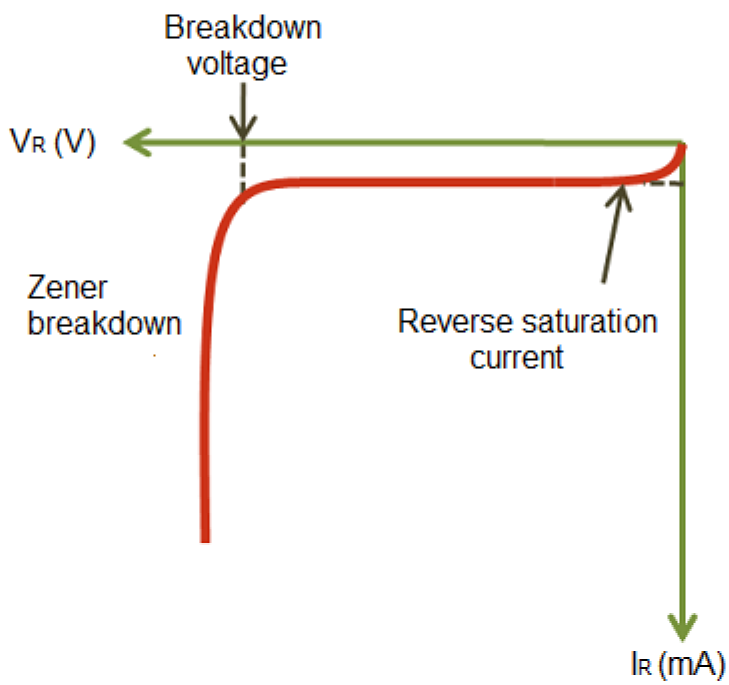


Fig: Zener breakdown

When reverse biased voltage is applied to a zener diode, it allows only a

small amount of leakage current until the voltage is less than zener voltage. When reverse biased voltage applied to the zener diode reaches zener voltage, it starts allowing large amount of electric current. At this point, a small increase in reverse voltage will rapidly increases the electric current.

Because of this sudden rise in electric current, breakdown occurs called

zener breakdown. However, zener diode exhibits a controlled breakdown that does damage the device.

The zener breakdown voltage of the zener diode is depends on the amount of doping applied. If the diode is heavily doped, zener breakdown occurs at low reverse voltages. On the other hand, if the diode is lightly doped, the zener breakdown occurs at high reverse voltages. Zener diodes are available with zener voltages in the range of 1.8V to 400V.

Advantages of zener diode

- Power dissipation capacity is very high
- High accuracy
- Small size
- Low cost

Applications of zener diode

- It is normally used as voltage reference
- Zener diodes are used in voltage stabilizers or shunt regulators.
- Zener diodes are used in switching operations
- Zener diodes are used in clipping and clamping circuits.
- Zener diodes are used in various protection circuits

Zener Diode as Voltage Regulators

The function of a regulator is to provide a constant output voltage to a load connected in parallel with it in spite of the ripples in the supply voltage or the variation in the load current and the zener diode will continue to regulate the voltage until the diodes current falls below the minimum $I_{Z(min)}$ value in the reverse breakdown region. It permits current to flow in the forward direction as normal, but will also allow it to flow in the reverse direction when the voltage is above a certain value - the breakdown voltage known as the Zener voltage. The Zener diode specially made to have a reverse voltage breakdown at a specific voltage. Its characteristics are otherwise very similar to common diodes. In breakdown the voltage across the Zener diode is close to constant over a wide range of currents thus making it useful as a shunt voltage regulator.

The purpose of a voltage regulator is to maintain a constant voltage across a load regardless of variations in the applied input voltage and variations in the load current. A typical Zener diode shunt regulator is shown in Figure . The resistor is selected so that when the input voltage is at $V_{IN(min)}$ and the load current is at $I_{L(max)}$ that the current through the Zener diode is at least $I_{z(min)}$. Then for all other combinations of input voltage and load current the Zener diode conducts the excess current thus maintaining a constant voltage across the load. The Zener conducts the least current when the load current is the highest and it conducts the most current when the load current is the lowest.

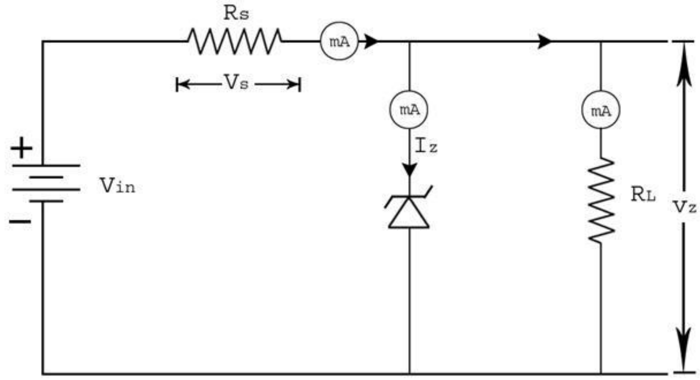


Fig : Zener diode shunt regulator

If there is no load resistance, shunt regulators can be used to dissipate total power through the series resistance and the Zener diode. Shunt regulators have an inherent current limiting advantage under load fault conditions because the series resistor limits excess current.

A zener diode of break down voltage V_z is reverse connected to an input voltage source V_i across a load resistance R_L and a series resistor R_S. The voltage across the zener will remain steady at its break down voltage V_Z for all the values of zener current I_Z as long as the current remains in the break down region. Hence a regulated DC output voltage $V_0 = V_Z$ is obtained across RL, whenever the input voltage remains within a minimum and maximum voltage.

Basically there are two type of regulations such as:

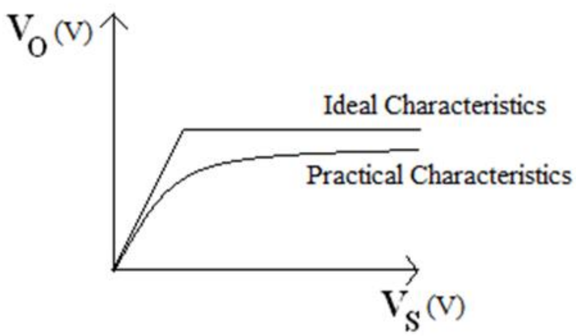
a) Line Regulation

In this type of regulation, series resistance and load resistance are fixed, only input voltage is changing. Output voltage remains the same as long as the input voltage is maintained above a minimum value.

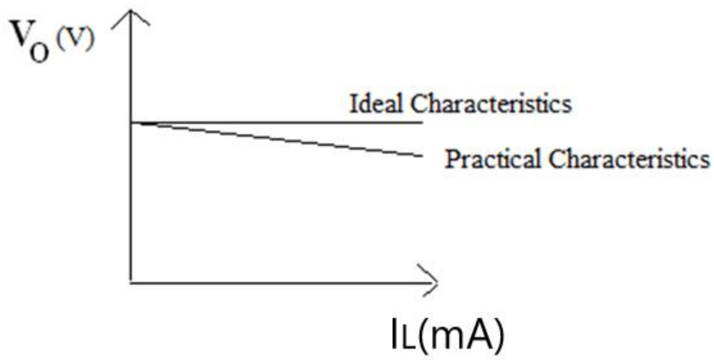
b) Load Regulation

In this type of regulation, input voltage is fixed and the load resistance is varying. Output volt remains same, as long as the load resistance is maintained above a minimum value.

Line Regulation

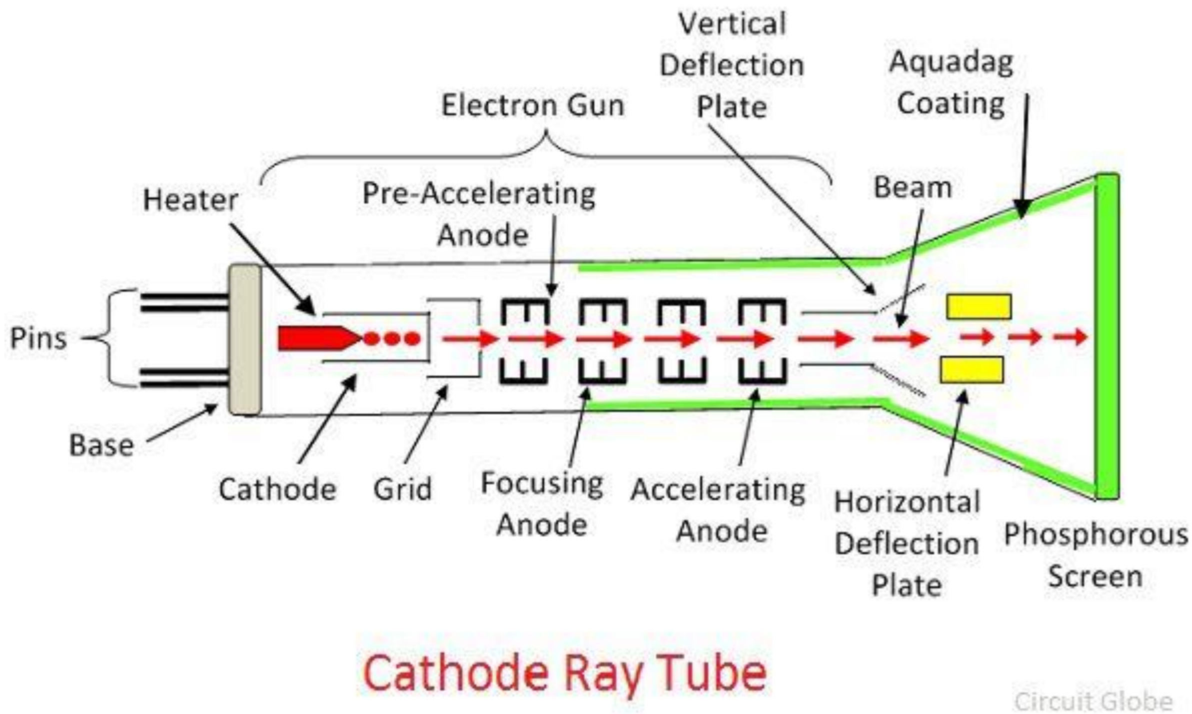


Load Regulation:



Cathose Ray Oscilloscope:

Cathode Ray Tube Construction and working:



1. Electron gun

The electron gun is used for generating, controlling and focusing the beam of electrons enclosed in a vacuum tube.

The electron gun again internally consists of five components. They are:

A. Heater
B. Cathode
C. Control grid
D. Accelerating anode.
E. Focusing anode

2. Horizontal deflection plates

The horizontal deflection plates deflects the electrons horizontally.

3. Vertical deflection plates

The vertical deflection plates deflects the electrons vertically.

Both the horizontal and vertical deflection plates controls the path of electrons beam so that it can be directed towards a specified positions on the phosphor-coated screen.

4. Fluorescent screen

Fluorescent screen is a transparent screen coated on one side with a phosphor that glows brightly when exposed to cathode rays.

How cathode ray tube works

The electron gun is used for generating, controlling and focusing the beam of electrons enclosed in a vacuum tube.
The electron gun again internally consists of five components. They are: heater, cathode, control grid, accelerating anode, and focusing anode.
The heater at the left side in the figure heats the cathode to a high temperature. Cathode is a conductor that emits electrons from its surface when heated to a high temperature.

A high positive voltage is applied to the accelerating anode of the order of 1 to 20,000 volts, relative to the cathode. This potential difference generates an electric field between the accelerating anode and the cathode which accelerates electrons from cathode to accelerating anode. Electrons passing through the hole in the anode form a narrow beam and travel with constant horizontal velocity from the anode to the florescent screen. The area where the electrons beam strikes the screen glows brightly.
The control grid controls the flow of electrons between the cathode and the accelerating anode. Hence, it controls the brightness of the spot on the screen.
The focusing anode ensures that the electrons emitted from the cathode in slightly different directions are focused down to a narrow beam and all arrive at the same spot on the screen.
The assembly of heater, cathode, control grid, accelerating anode and focusing anode is called the electron gun.
The beam of electrons passes between two pairs of deflection plates: horizontal deflection plates and vertical deflection plates. The electric field between the horizontal deflection plates change the direction of electrons horizontally, while the electric field between the vertical deflection plates change the direction of electrons vertically.
The screen consists of a glass which is coated by some florescent material like zinc silicate which is semitransparent phosphor substance. The phosphor substance converts the electrical energy into light energy. When the high velocity electrons strike the phosphorescent screen, the light is emitted from it. The property of phosphor to emit light when its atoms are excited is called fluorescence. The intensity of the glow produced at the screen is determined by the number of electrons striking the screen.

Block Diagram of CRO:

CRO is made up of different blocks such as

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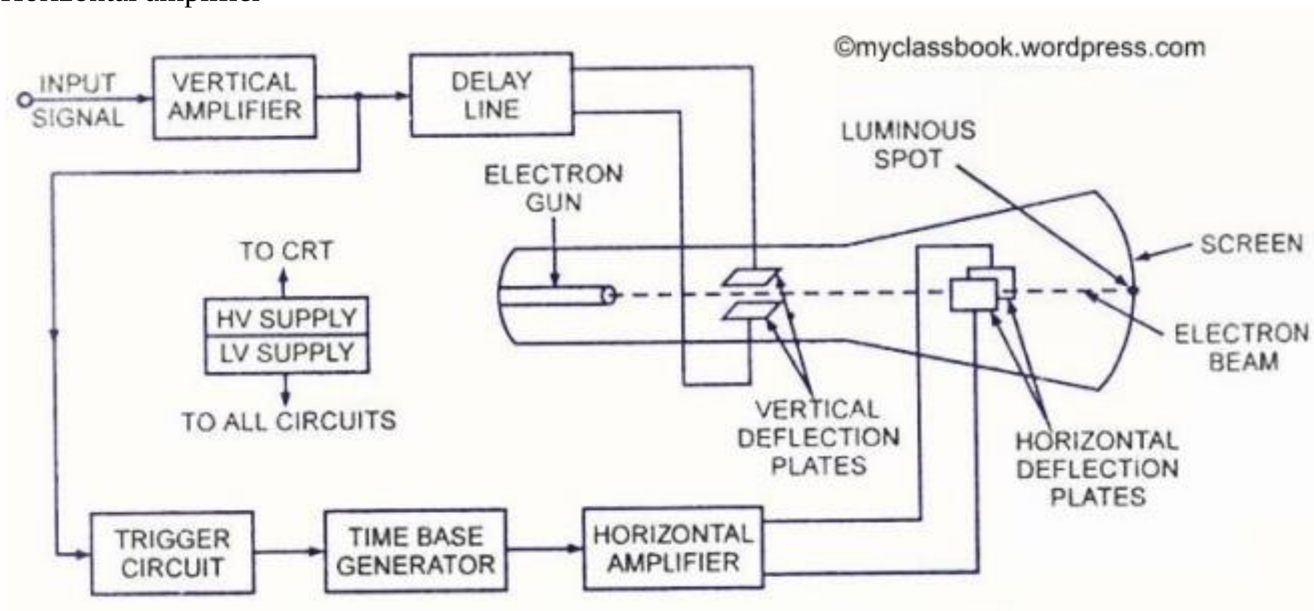
Subject: Basic Electronics **Unit:1**

1. Cathode Ray Tube (CRT)
2. Vertical amplifier
3. Delay Line
4. Trigger circuit
5. Timebase generator
6. Horizontal amplifier



CRO Block Diagram

CRO Working:

Cathode Ray Tube (CRT):

CRT Produces a sharply focused beam of electrons, accelerated to a very high velocity. This electron beam travels from the electron gun to the screen. The electron gun consists of filament, cathode, control grid, accelerating anodes and focusing anode. While travelling to the screen, electron beams passes between a set of vertical deflecting plates and a set of horizontal deflection plates. Voltages applied to these plates can move the beam in vertical and horizontal plane respectively. The electron beam then strikes the fluorescent material (phosphor) deposited on the screen with sufficient energy to cause the screen to light up in a small spot.

Vertical Amplifier - The input signals are amplified by the vertical amplifier. Usually, the vertical amplifier is a wide band amplifier which passes the entire band of frequencies.

Delay Line - As the name suggests, this circuit is used to delay the signal for a period of time in the vertical section of CRT. The input signal is not applied directly to the vertical plates because the part of the signal gets lost, when the delay time is not used. Therefore, the input signal is delayed by a period of time.

Trigger Circuit - The signals which are used to activate the trigger circuit are converted to trigger pulses for the precision sweep operation whose amplitude is uniform. Hence input signal and the sweep frequency can be synchronized.

Time Base (Sweep) Generator - Time base circuit uses a uni-junction transistor, which is used to produce the sweep. The saw tooth voltage produced by the time base circuit is required to deflect the beam in the horizontal section. The spot is deflected by the saw tooth voltage at a constant time dependent rate.

Horizontal Amplifier - The saw tooth voltage produced by the time base circuit is amplified by the horizontal amplifier before it is applied to horizontal deflection plates.

Power supply - The voltages required by CRT, horizontal amplifier, and vertical amplifier are provided by the power supply block. It is classified into two types -

(1) Negative high voltage supply

(2) Positive low voltage supply

The voltage of negative high voltage supply is from -1000V to -1500V. The range of positive voltage supply is from 300V to 400V.

Oscilloscope Application:

1. Voltage Measurement
2. Time Period measurement
3. Frequency measurement
4. Phase difference measurement
5. Component test
6. To find Modulation Index