Basics of Electronics.

Some General Terms:

Conductors: Materials that are good conductors (allow the passage) of electricity and offer low resistivity are called conductors.

Insulators: Materials that are bad conductors (don't allow the passage) of electricity and offer very high resistivity are insulators.

Semi-conductors: Materials that are poor conductors (allow the passage but very less as compared to conductor) of electricity and have a slight high resistivity are called semi-conductors.

Properties of semi-conductors:

1) Their conductivity (as well as resistivity) lies between that of conductor and insulators.
2) The conductivity of semi-conductors increases with the rise of temperature.
3) At very low temperature, they behave as insulators.
4) They have four valence electrons.
5) Free electrons and holes are the charge carriers in case of semiconductor.
6) They can interact with light and their optical properties play crucial role in technologies.

Examples:- silicon, germanium, graphite, etc.

Bands (Energy bands)

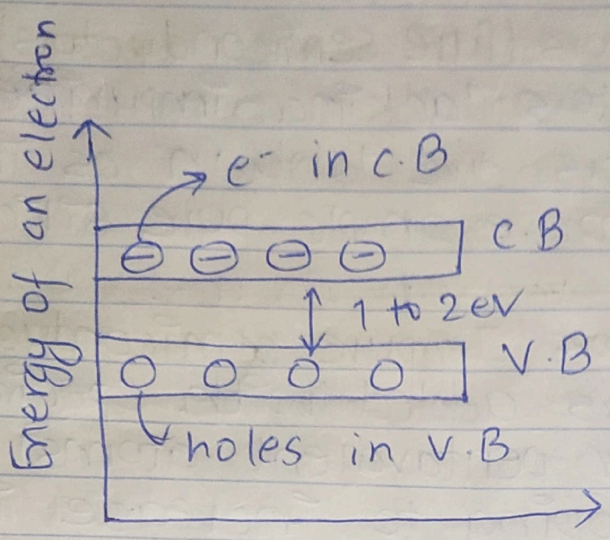
1) Valence Band (V.B.)
The energy band (i.e. range of energies) formed by the valence electrons of an atom is called valence band (V.B.).

2) Conduction Band (C.B.)
The energy band formed by the electrons taking part in the conduction i.e. free electrons is called conduction band. (C.B.)

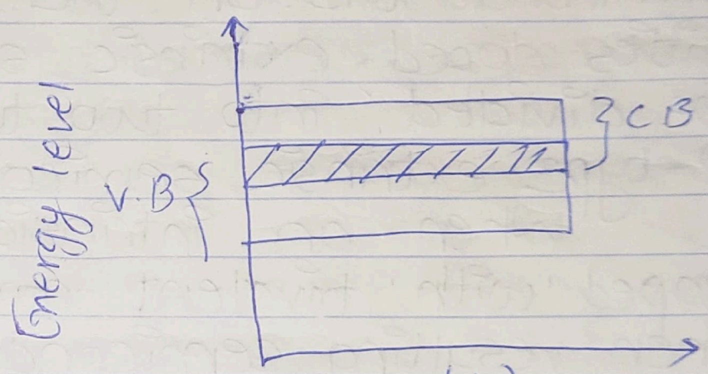
3) Forbidden band:
The separation between valence band and conduction band in an atom is called forbidden gap or forbidden band or forbidden energy gap (E_g)

Band-Energy Diagram of conductors, Insulators
a) ~~Cond~~ and Semi-conductors.
The plot illustrating V.B, C.B and E_g is known as band-energy diagram. It is to be noted that free electrons in ~~valer~~ conduction band and holes in valence band are only the charge carriers.

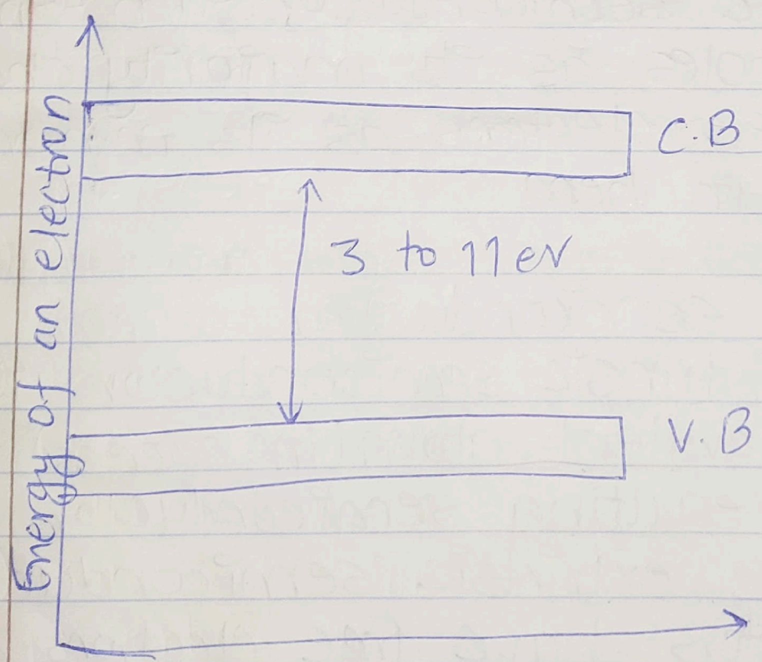
Charge carrier(s) for
1) Conductor → free electrons in C.B.
2) Insulators → no charge carriers
3) Semi-conductor → free electrons in C.B and holes in V.B.



(a)



(b)



(c)

Fig: Energy band diagram for (a) semi-conductor (b) conductor and (c) insulator.

Types of semi-conductors.

1) Intrinsic semiconductors (Pure semiconductors):

The semiconductors lacking impurities i.e. pure semiconductors are known as intrinsic semiconductors. For example: pure silicon.

2) Extrinsic semiconductors (Impure semiconductors):

The semiconductors added with special impurities (trivalent or pentavalent atoms) by the process called doping to increase its conductivity is known as extrinsic (impure) semiconductors. On the basis of the impurities doped, extrinsic semiconductors can be divided into two types:

a) P-type extrinsic semiconductor:

When an intrinsic semiconductor is doped with trivalent atom (in excess) impurity, then resulting semiconductor is called p-type extrinsic semiconductor. Such semiconductors has holes as its majority charge carriers and free electrons as its minority charge carriers in them.

b) N-type extrinsic semiconductor:

When an intrinsic semiconductor is doped with pentavalent atom (in excess) as impurity, then resulting semiconductor is known as n-type extrinsic semiconductor. Such semiconductors have free electrons as its majority charge carriers and ~~free elec~~

holes ~~trons~~ as its minority charge carriers.

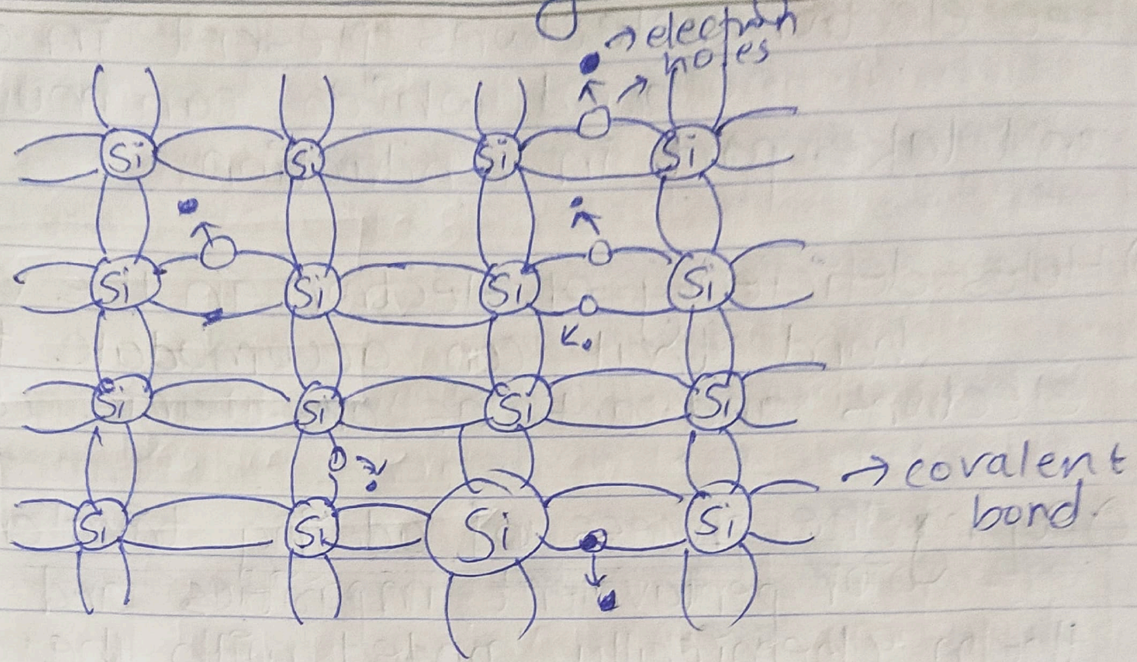
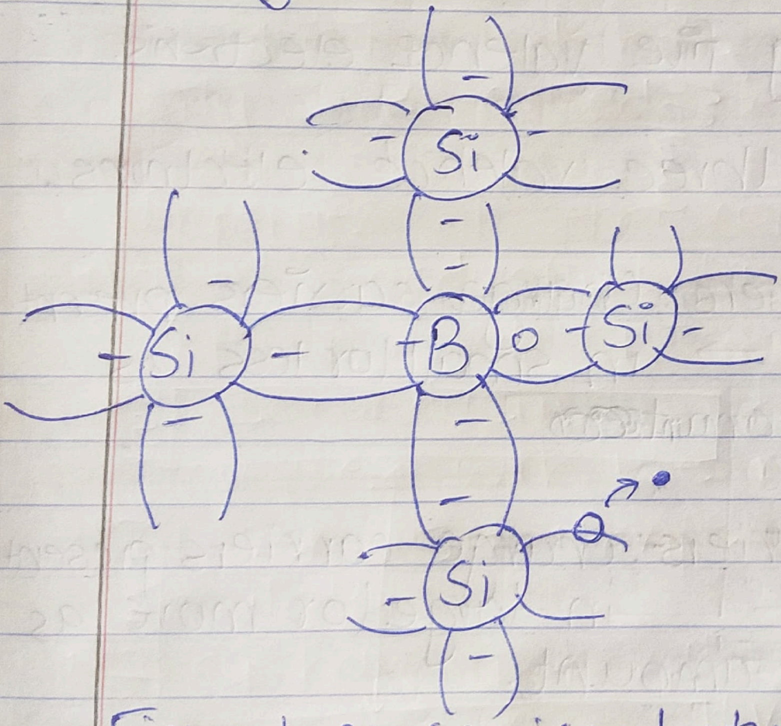


Fig: Intrinsic silicon semiconductor



o → hole
• → ~~electrons~~ free electrons
– → electrons

Fig: p-type semiconductor
no. of holes > no. of free electrons

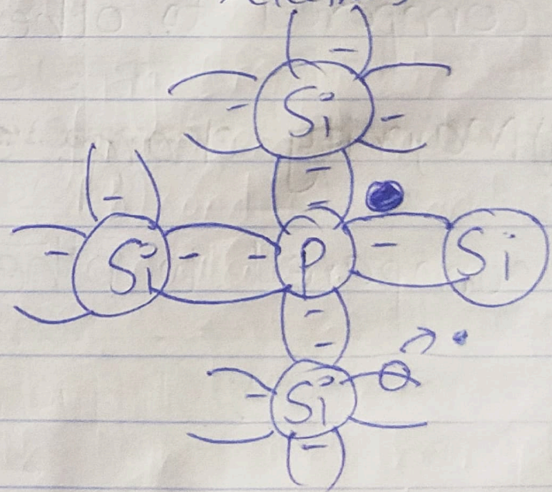


Fig: n-type semiconductor
no. of electrons > no. of holes

Some Terms to be understood

a) Free electrons: electrons present in conduction band which can move freely and take part in conduction.

b) Holes: deficiency of electron in the valence band that can accomodate ~~free~~ electrons and act as a charge carrier.

c) Doping: The process of adding trivalent ~~of~~ or pentavalent impurities and making them chemically bonded with the atoms of intrinsic semiconductor.

d) Pentavalent: having five valence electrons.

e) Trivalent: having three valence electrons.

f) Minority charge carriers: Charge carriers present in small (or less as compared to other) amount

g) Majority charge carriers: Charge carriers present in large (or more as compared to other) amount.

Special points to be Understood.

1) Both p-type and n-type extrinsic semiconductors are electrically neutral as the no. of protons and no. of electrons in them are always equal.
2) Holes are not positive mobile charge carriers. They are the deficiency (or lack) of electrons in covalent bond and can accomodate electrons within them.
3) Doping not only means mixing of impurities, but it is the process of forming chemical bonds (i.e. covalent bonds) between atoms of intrinsic (pure) semiconductors and impurity atoms.
4) The mobility of holes is small as compared to that of free electrons due to restricted path and nuclear attraction to some extent.

Semi-Conductor Diode

Diode, also called P-N Junction is a two terminal non-linear diode (doesn't obey Ohm's law) made up two types of extrinsic ~~cond~~ semiconductor with P-N junction betn them.

Formation of P-N Junction Diode

(How is P-N Junction is formed?)

When p-type and n-type semiconductor are joined together, then the process of diffusion occurs. As we know that p-type semiconductor has holes as majority charge carriers and n-type ~~of~~ semiconductor has electron as majority charge carriers with their respective immobile negative and positive ions associated with them respectively.

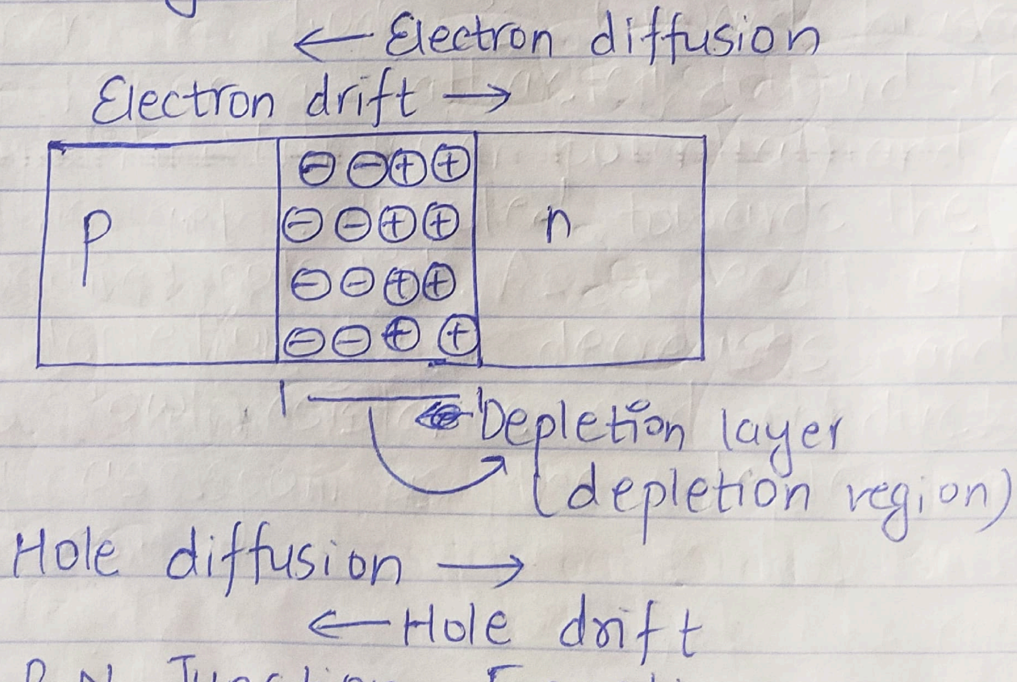
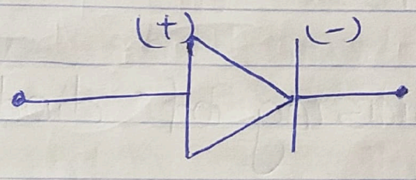


Fig: P-N Junction Formation process

When they are brought together, the process of diffusion occurs, i.e. holes move toward n-type and free electron move towards p-type After sometime, an electric field is set up at the junction that stops the further process of diffusion. As a result of this depletion layer (where immobile atoms after diffusion at junction) is formed with a barrier potential (potential set up due to electric field in the depletion layer). In this way, P-N junction is formed in the diode

Circuit Diagram of Diode



+ → Anode
- → Cathode

Fig: Circuit Diagram of Diode

Structural Diagram of Diode

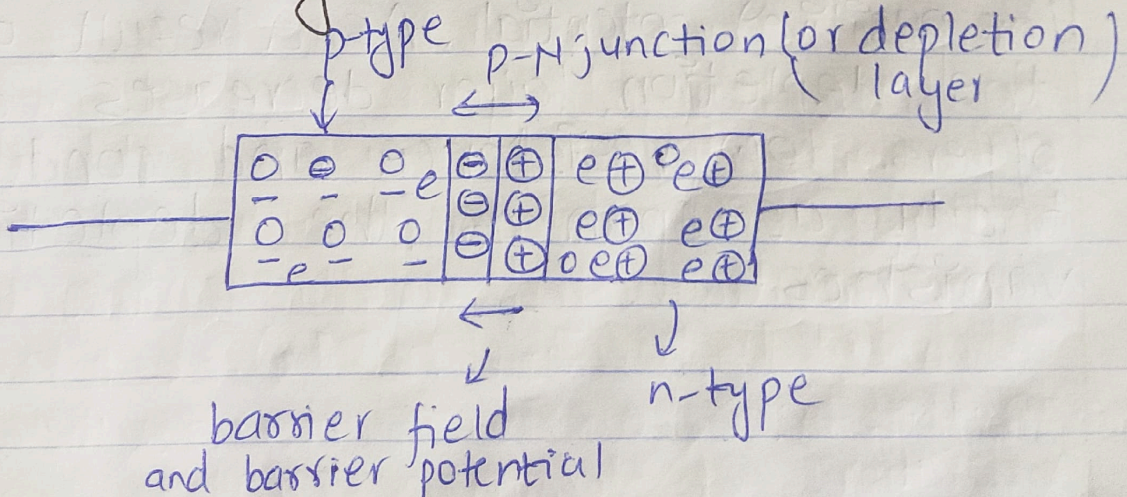


Fig: Structural diagram of diode

Biasing of a Diode

The process of setting up an external electric field by the application of DC supply across a diode is called biasing of a diode. There are two types of biasing of diode.

a) Forward biasing.

In this type of biasing of diode, anode is connected to higher potential and cathode (n-type) is connected to lower potential.

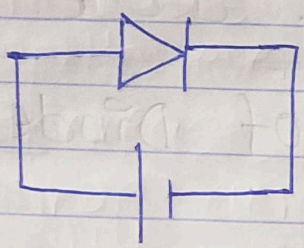


Fig: Forward biasing of diode

When a diode is forward biased, holes of p-region get attracted toward the negative potential (or lower potential) and free electrons get attracted towards the higher (or positive) potential. As a result of which the depletion layer decreases and diode offers low resistance and conducts electricity as soon as the depletion layer vanishes.

2) Reverse biasing.

In this type of biasing of diode, anode is connected to ~~hi~~ lower potential and cathode (n-type) is connected ~~wi~~ to higher potential

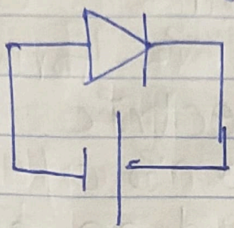


Fig: Reverse biasing of diode

When a diode is reverse biased, holes of p-region get attracted towards the negative potential (or lower potential) and free electrons get attracted towards the positive (or higher) potential. As a result of which the depletion layer increases and diode offers high resistance. However, a small passage of current is present due to the conduction by minority charge carriers.

Forward and Reverse characteristics of a semi-conductor Diode.
(Explain diode characteristics OR Describe the forward and reverse biasing of diode)

Forward characteristics
When a diode is forward biased, i.e an ~~pote~~ external electric field is set up, there is no flow ~~o~~ of current until a certain voltage drop across a diode known as ~~threshold~~ cut-in voltage. Then, current increases with the increase of voltage drop. However, a stage comes when current increases sharply at a particular voltage drop across the diode known as threshold voltage (knee voltage). It is to be noted that the current is due to the movement of both majority and minority charge carriers however significant part of it is due to the majority charge carriers.

Reverse characteristics.
When a diode is reversed biased, the depletion layer increases and the diode offers very high resistance. However, with the increase of voltage drop across the diode, the current almost remains same (~~but~~ however increases slightly) due to the conduction by the minority

charge carriers. At a stage, when diodes internal field cannot withstand the effect of external field, breakdown of diode occurs and current increases drastically.

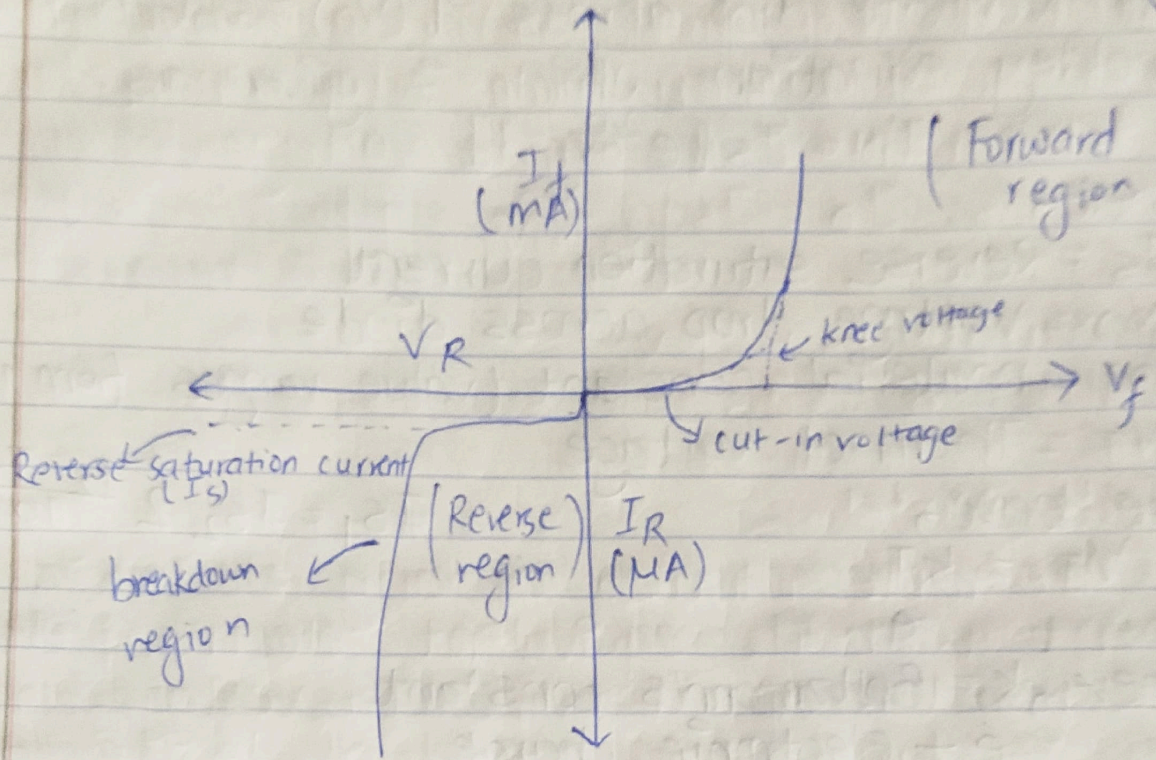


Fig: Characteristics of a Semi-Conductor Diode

Some Important Terms to be Understood.

→ Diffusion is the process of flow of a particle from a higher concentration region to lower concentration region.

→ The immobile atom formed after process of diffusion throughout where an internal field is set-up that prevents further diffusion process ~~ex~~ is known as depletion region and potential across such region is called its barrier potential.

Schokley Equation

Schokley experimentally found the relation between diode current and voltage drop across it. The relation between diode current (I_D) and voltage drop across it (V_D) is known as Schokley equation which is given as:

$$I_D = I_S[e^{\frac{V_D}{\eta V_T}} - 1]$$

where,

I_S = Reverse saturation current

V_D = Voltage drop across diode

η = material constant (value ranges from 1 to 2)

V_T = Thermal voltage

We have,

$$I_{S_1} = I_{S_2} 2^{\frac{T_2 - T_1}{10}}$$

$$V_T = \frac{kT}{e}$$

where, k = Boltzmann's constant

e = electronic charge

T = Temperature

At room temperature (25°c), $V_T = 25mV$

Explain the effect of temperature on diode characteristics.

The characteristics of diode is affected by the change in temperature. Suppose a diode is forward biased ~~and the ter~~ initially the room temperature is T_1. Let us suppose that the room temperature is increased to T_2 ($T_2 > T_1$). As we know due to the increase ~~is~~ in temperature the thermal vibration of ~~electron~~ atom increases as well as the number of charge carriers increases within the diode which in turn reduces the width of the depletion layer. Hence, on increasing temperature the cut-in voltage as well as the threshold voltage of the diode decreases and vice-versa.

It is to be noted that with the increase in temperature, the no. of minority charge carriers increases as well due to which the reverse saturation current in the diode at higher temperature is ~~d~~ greater than that at lower temperature (with 10°C rise in temperature, current through diode becomes double)

The figure given below shows the variation of diode characteristics with temperature.

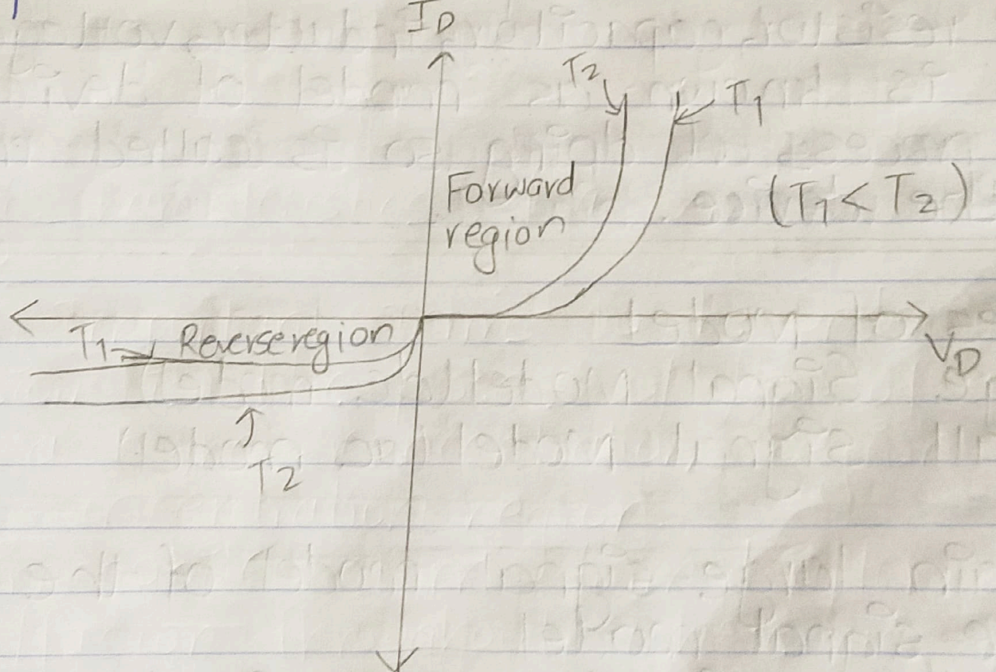


Fig: Variation of diode characteristics with temperature of the diode

→ It is to be noted that with the rise of temperature ~~(a)~~, thermal voltage (V_T) increases as well but the increase of reverse saturation current (I_S) is predominant and hence current in the diode (V_D) is always greater in case of higher temperature than lower ~~ve~~ temperature at same voltage.

as $$I_D = I_S \left[e^{\frac{V_D}{\eta V_T}} - 1 \right]$$

Approximately,
$$I_D = I_S e^{\frac{V_D}{\eta V_T}}$$

Diode Model

The representation of any electronic component with its equivalent electrical element like resistor, capacitor, inductor, voltage, current, etc is known as model of device and the process of doing so is called modelling of the device.

Types of Model
1) Large Signal Model (dc model)
2) Small signal Model (ac model)

Explain large-signal model of the diode.

Large-signal model

Large-signal model is the equivalent electrical device ~~in which of when dc is~~ and the behaviour shown by the ~~dc compo-nen~~ electronic component when an external dc-signal is applied across it. Diode has different ~~three~~ dc-signal model depending on its nature which are described below:

1) Ideal Diode Model.

An ideal diode is the diode which has zero resistance when forward biased and infinite resistance when reversed biased.

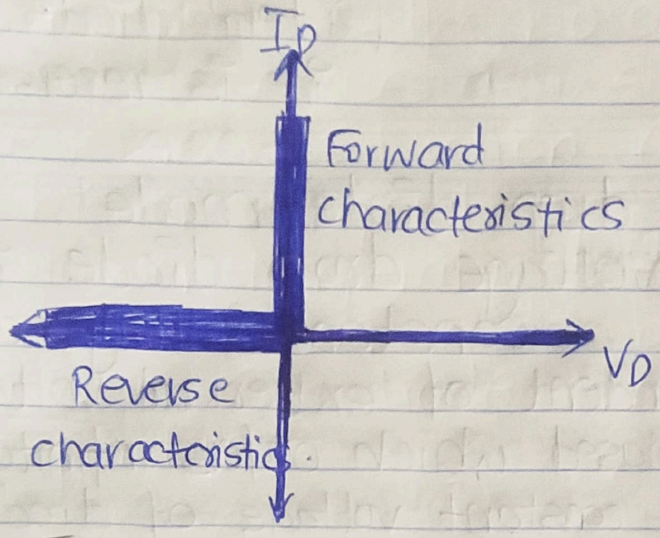
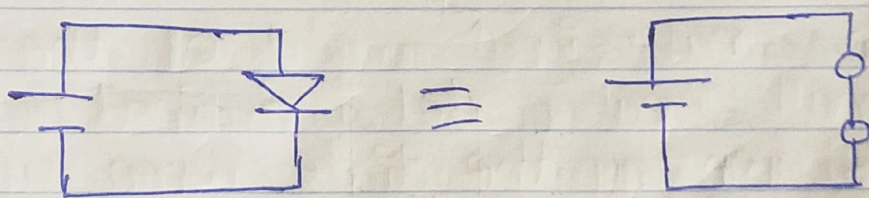


Fig: Characteristics of an ideal diode

Model of an ideal ~~A~~ diode.

1) During forward biasing

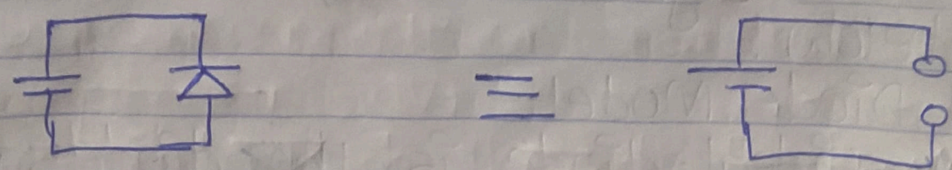


Ideal diode forward biasing

~~open circuit~~ closed circuit

(As model of an ideal diode when it is forward biased.)

2) During reverse biased.



(Ideal diode in reverse biased condⁿ)

& open circuit
(As a model of an ideal diode when it is reverse biased)

2) Constant voltage drop diode model!
A constant voltage drop diode is the diode that has a constant voltage drop across it independent of external voltage during forward biased which offers infinite resistance until ext. voltage = constant voltage of diode and then offers zero resistance and ~~offers~~ always offers infinite resistance when it is reverse biased.

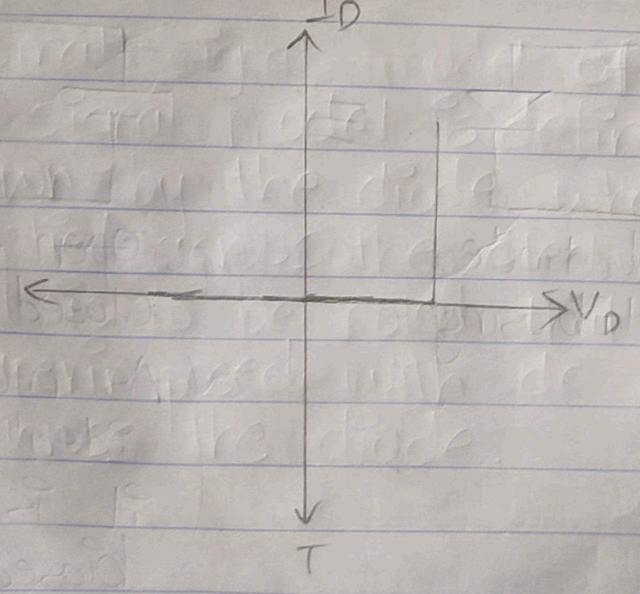
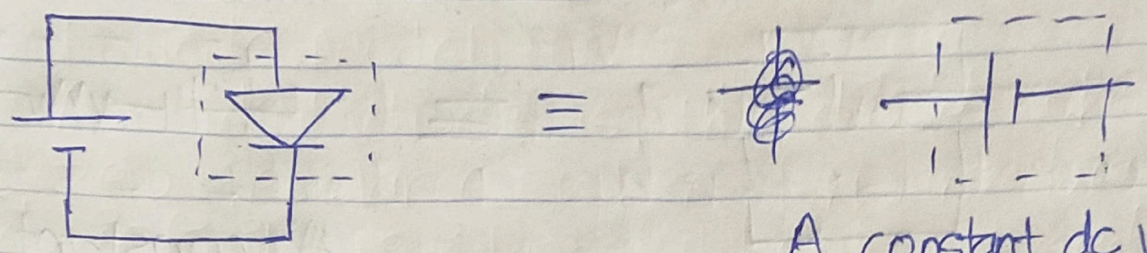


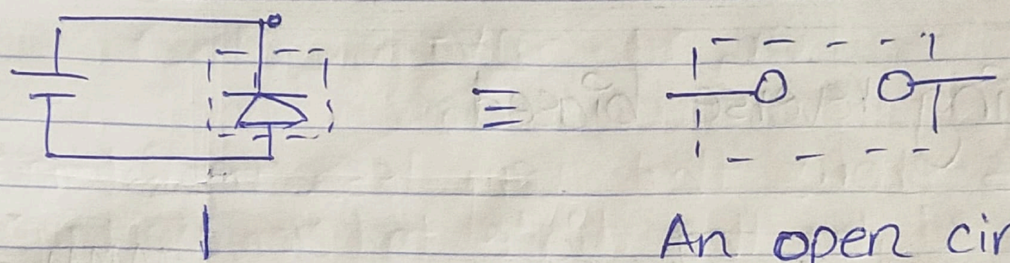
Fig: Characteristics of a constant voltage drop diode model

Model of a constant voltage drop diode
During forward biasing.



A constant dc voltage

During reverse biasing



An open circuit

Piecewise linear diode model

A piecewise linear diode is the diode that has a constant voltage drop for some extent of external field but its voltage drop increases after that extent and current in the diode increases linearly when forward biased and offers very high but constant resistance when ~~in~~ it is in reversed biased condition.

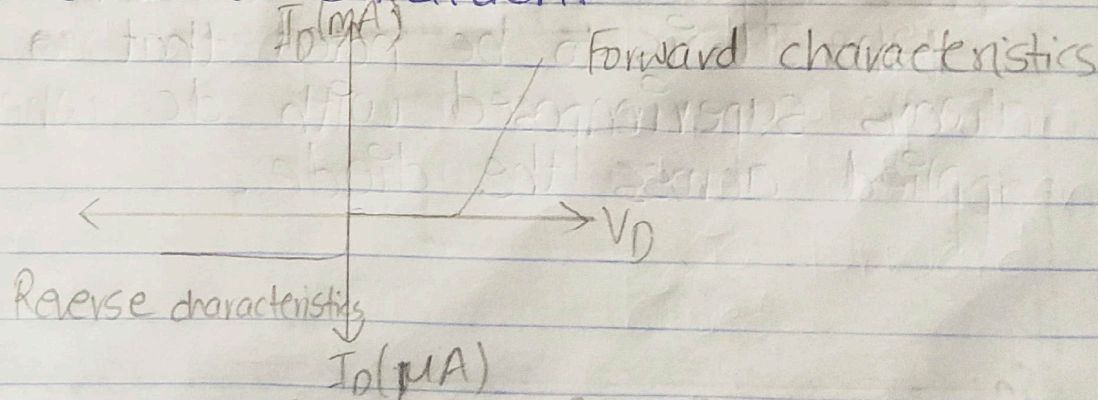
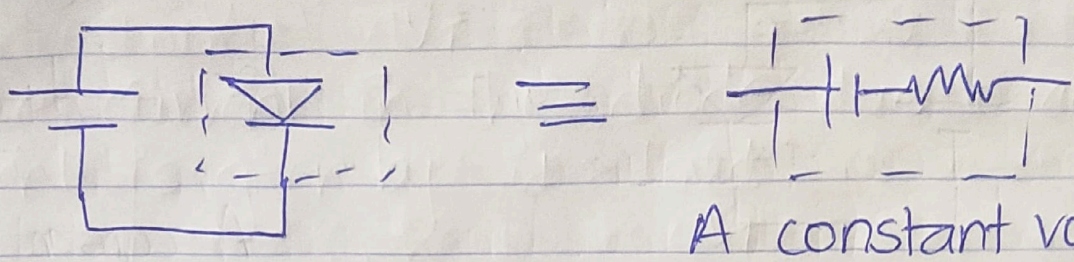


Fig: characteristics of a piecewise linear diode.

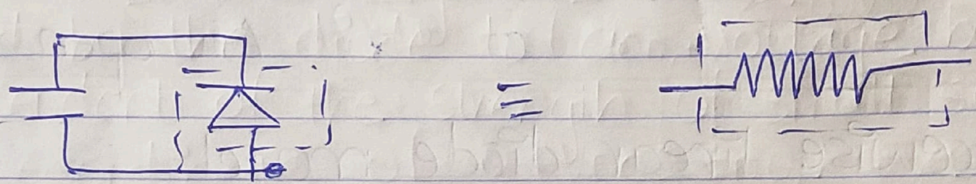
Model of a piecewise linear diode.

1) During forward biased.



A constant voltage supply with resistance in series

2) During reverse biased



A very high resistance in order of megaohms (M-Ω)

Explain small signal model of the diode

Small-signal model is defined as the equivalent electrical behaviour shown by the diode when an external ac is applied across the electronic component.

~~Whe~~ It is to be noted that ac is always superimposed with dc when it is applied across the diode.

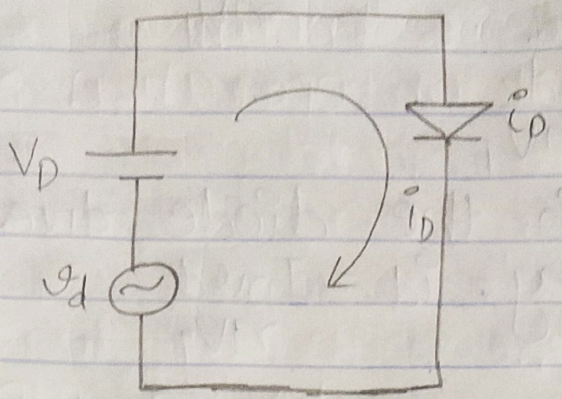


Fig: Conceptual circuit of small scale modeling of a diode

Let us consider initially, no ~~as~~ ac source is present. Then current flowing through the diode is given by

$$I_D = I_S e^{\frac{V_D}{nV_T}} \quad --- (i)$$

Now considering ac as well. Then,

$$i_D = I_D + i_d$$
$$v_D = V_D + v_d$$

Then current flowing through the diode analogous to (i) becomes,

$$i_D = I_S e^{\frac{v_D}{nV_T}}$$

$$\text{or, } i_D = I_S e^{\frac{V_D + v_d}{nV_T}}$$

$$\text{or, } i_D = I_S e^{\frac{V_D}{nV_T}} \cdot e^{\frac{v_d}{nV_T}}$$

$$\text{or, } i_D = I_D \left(e^{\frac{v_d}{nV_T}} \right)$$

$$\text{or, } I_D + i_d = I_D \left(1 + \frac{v_d}{nV_T} + \frac{\left(\frac{v_d}{nV_T}\right)^2}{2!} + \cdots \right)$$

or, $I_D + i_d = I_D + I_D \frac{v_d}{nV_T}$

or, $i_d = I_D \frac{v_d}{nV_T}$

Hence, current in the diode due to ac current is given by $i_d = \frac{I_D v_d}{nV_T}$

Also,

$$\frac{v_d}{i_d} = \frac{nV_T}{I_D}$$

or, $r_d = \frac{nV_T}{I_D}$

This shows that very less resistance is offered by the diode to ac voltage but it is independent of the strength of small signal.

Concept of Load-Line

Load-line is a straight line drawn on the graph containing characteristics curve of the diode which joins the maximum current flowing and voltage drop across the diode. The point of intersection of load-line and the characteristic curve gives the current current flowing and voltage drop across the diode.

According to KVL,

$$V_{DD} = I_D R + V_D$$

$$\Rightarrow I_D = \frac{V_{DD}}{R} - \frac{V_D}{R}$$

$$\Rightarrow I_D = \frac{-V_D}{R} + \frac{V_{DD}}{R}$$

which ~~it~~ is in the form $y = mx + c$.

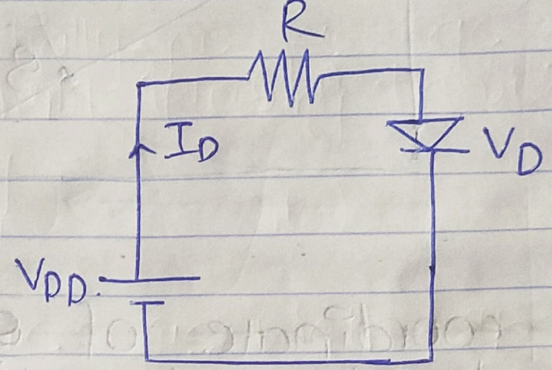


Fig: conceptual figure of diode-circuit to show load-line.

~~For~~

When $I_D = 0$, $V_D = V_{DD}$ and when $V_D = 0$, then $I_D = \frac{V_{DD}}{R}$

Hence, the maximum voltage drop and maximum current ~~flowing through the diode~~ that can flow through the diode are V_{DD} and $\frac{V_{DD}}{R}$ respectively.

- The point of intersection of load-line and characteristic curve is known as Q-point or working point or operation point. The

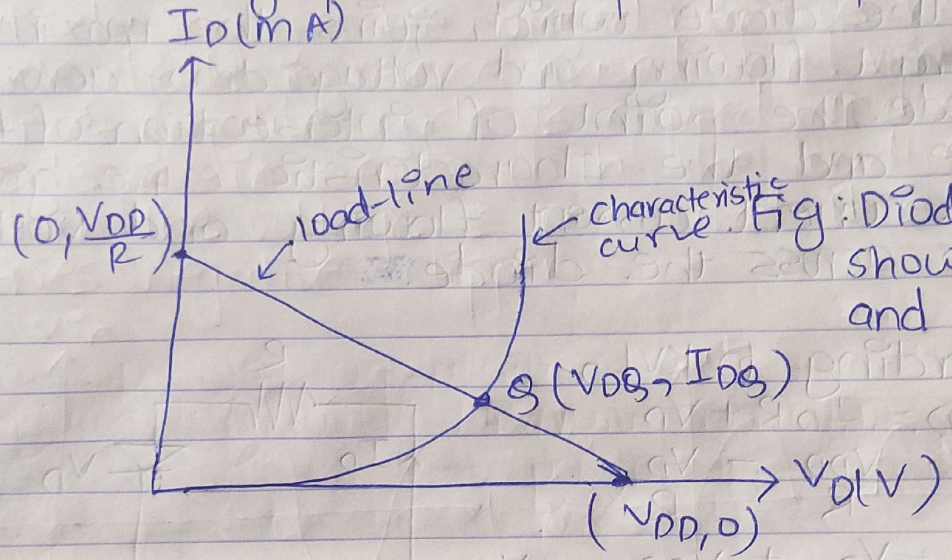


Fig: Diode characteristics showing load-line and Q-point.

- The coordinate of $Q(V_{DQ}, I_{DQ})$ gives the actual value of voltage drop and current flowing through the diode.

Diode Circuits.

Diodes have many applications. They are used as rectifiers and are used in making simple to complex logic gates. Besides these, diodes have following two applications as well.

(i) diode as a clipper
(ii) diode as a clamper.

Clipping circuits.

The circuit with which the waveform is shaped by removing (or clipping) a portion of the applied wave is known as a clipping circuit. Clippers find extensive use in radar, digital and other electronic systems.

Depending upon the nature of the connection between the load across which the output voltage is taken and the diode used, clipping circuits are classified as:

(a) Series clipper (b) Parallel clipper.

Depending upon the nature of the clipped waveform of the input, clippers are classified as:

(i) Positive clipper
(ii) Negative clipper
(iii) Biased clipper.

* Series ~~positive~~ negative clipper.

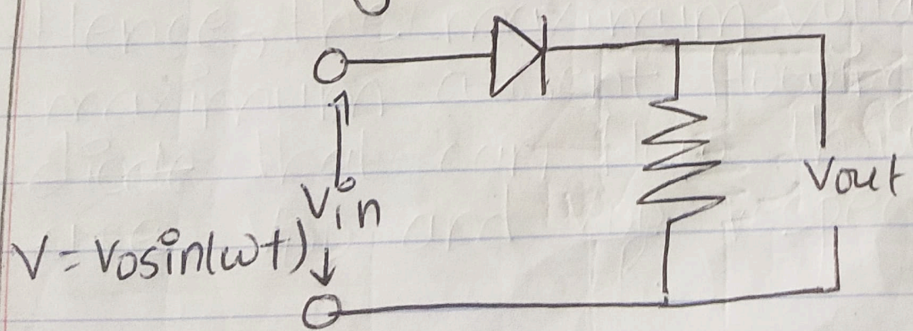


Fig: Circuit diagram of series negative clipper.

Let us assume that the diode is ideal. During positive cycle, diode is forward biased and the diode is short circuit. So, Vout = Vin. But during ~~reverse biased~~ negative half cycle, diode is reverse biased and ~~Vin~~ Vout = 0. Hence, negative cycle is clipped and since diode is in series with the load across which the voltage is measured, it is called series negative clipper.

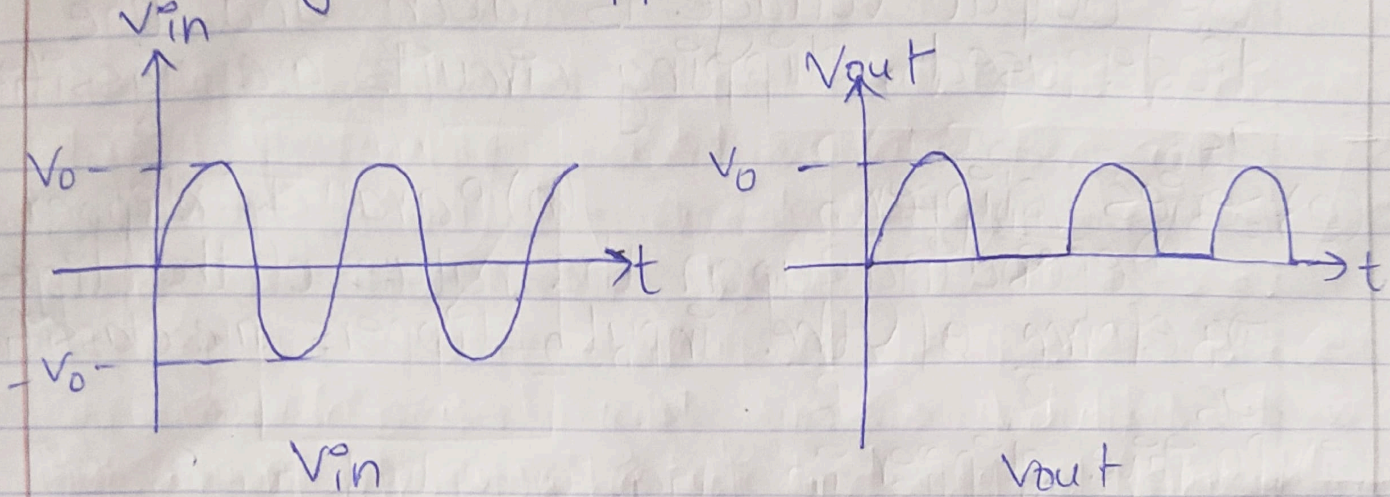


Fig: Waveforms for input and output signal for series negative clipper.

* Series positive clipper

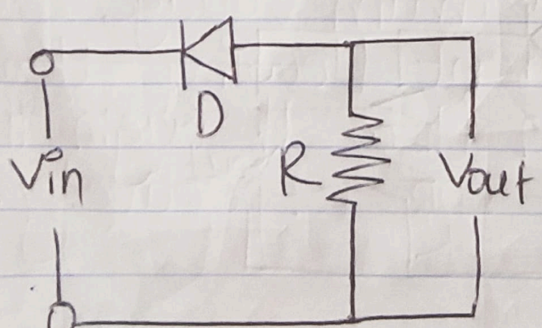


Fig: Circuit diagram of series positive clipper.

During positive half-cycle, diode 'D' is reversed biased. So, in this condition Vout = 0 and during negative half-cycle, diode 'D' is forward biased. So, in this condition Vout = Vin

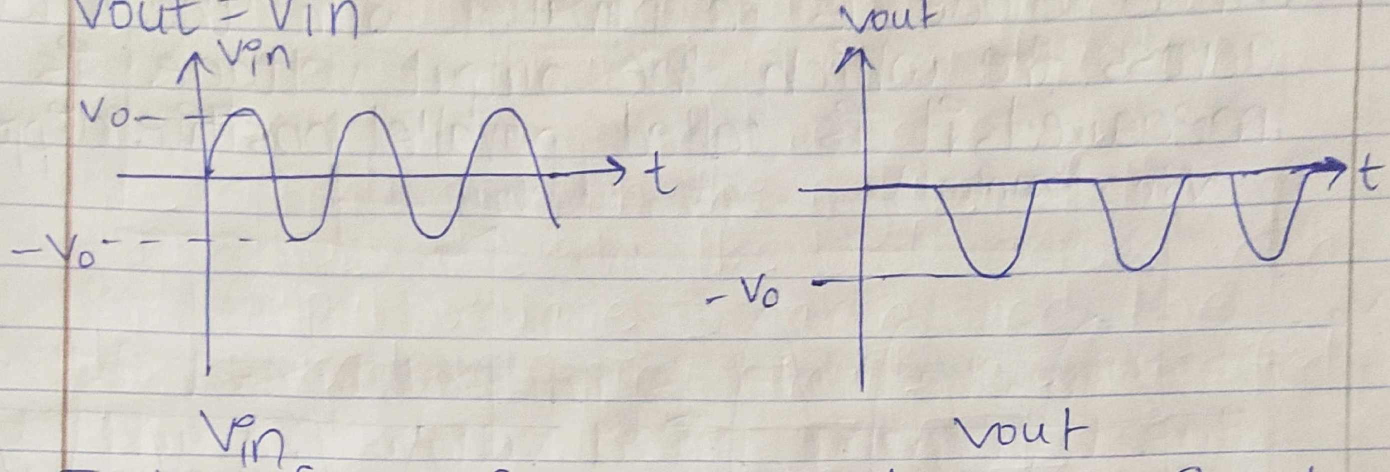


Fig: Waveforms for input and output signal for series positive clipper.

* Parallel positive clipper.

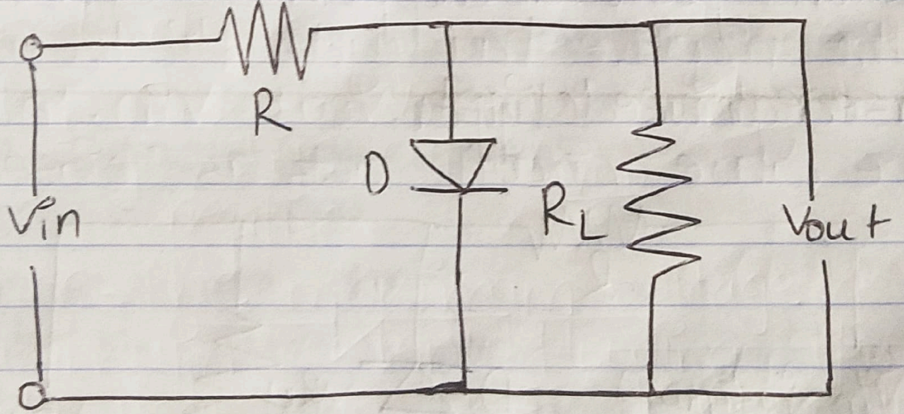


Fig: Circuit diagram of parallel positive clipper.

let us assume that the diode 'D' is ideal. During positive cycle, diode is forward biased and the diode is short circuit. So, vout = 0

But during negative half-cycle diode 'D' is reverse biased and it is open circuit. So, $V_{out} \approx V_{in}$ if R is very small in comparison to R_L. Hence, positive cycle is clipped and since diode is in parallel with the load across ~~the~~ which the output voltage is measured, it is called parallel positive clipper.

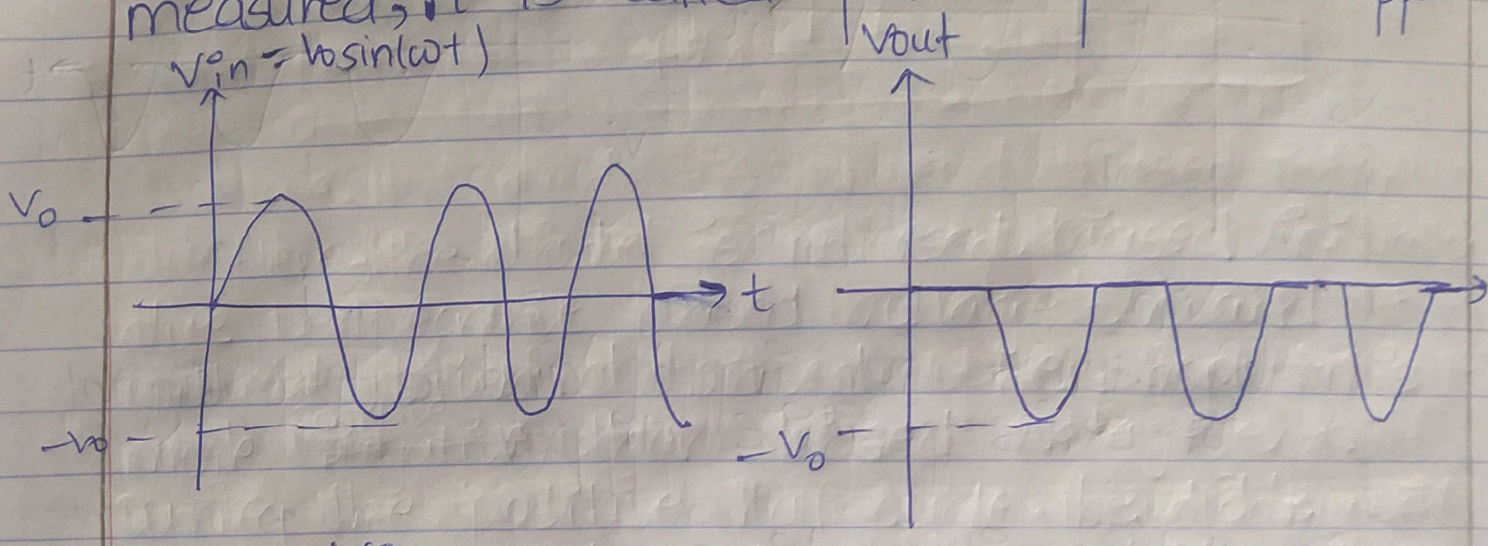


Fig: Waveforms for input and output signal for parallel positive clipper.

* Parallel negative clipper.

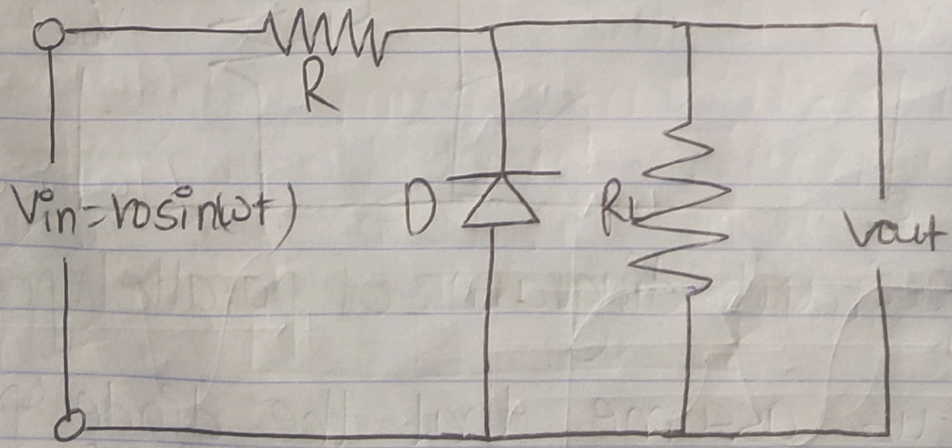


Fig: Circuit diagram for parallel negative clipper.

During the positive half cycle, diode D is open circuit as it is in ~~forward~~ reversed biased condition. So, $V_{out} = V_{in}$. But during negative half cycle, diode D is short circuit as it is in forward biased condition. So, $V_{out} = 0$.

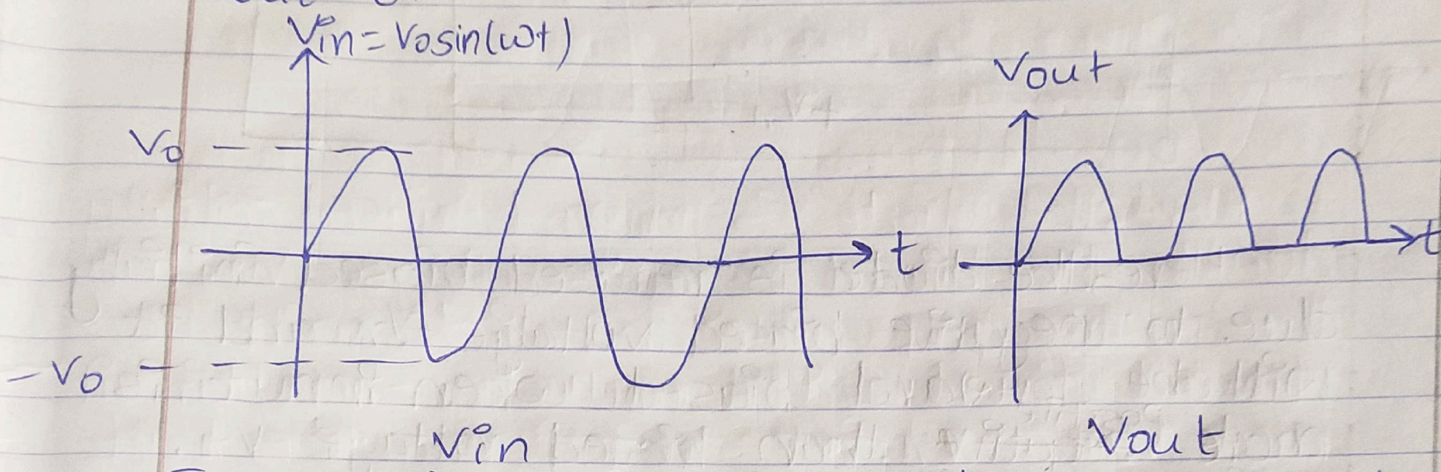
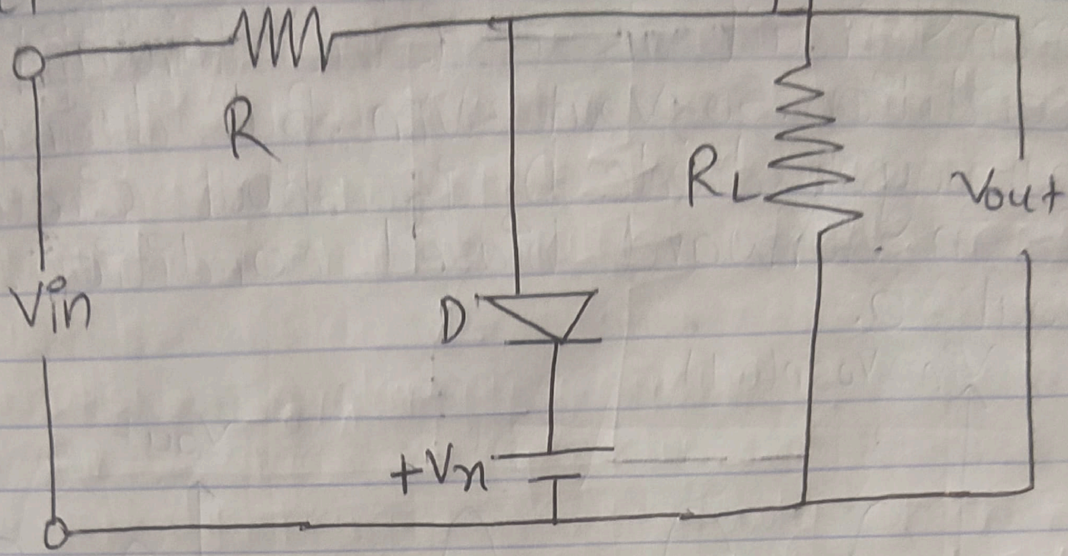


Fig: Waveforms for input and output signals for parallel negative clipper.

Biased clipper

Sometimes it is desired to remove a small portion of positive or negative half-cycle of the signal voltage. For this purpose, biased clipper is used. The diode may be biased either with positive voltage or either with negative voltage. Biased clipper removes a small portion of the ~~waveform~~. one cycle of ~~the~~ waveform ~~and~~ or large portion of the waveform of the one of the cycles depending upon the arrangement of the diode and the voltage that biases the waveform.

Parallel Positive biased Positive clipper.



Here, the diode is reversed biased initially due to negative biased voltage -Vx and it will be forward biased when input is more ~~negative~~ Positive than biased voltage Vx.
During the positive half cycle, the diode will be reversed biased until Vin=Vx and ~~+~~ Vout=Vin
But when Vin>Vx, the diode will be forward biased and it is short circuit and Vout=0.
Again in negative half cycle diode will still be reversed biased and Vout=Vin. In this way, the above circuit acts as biased

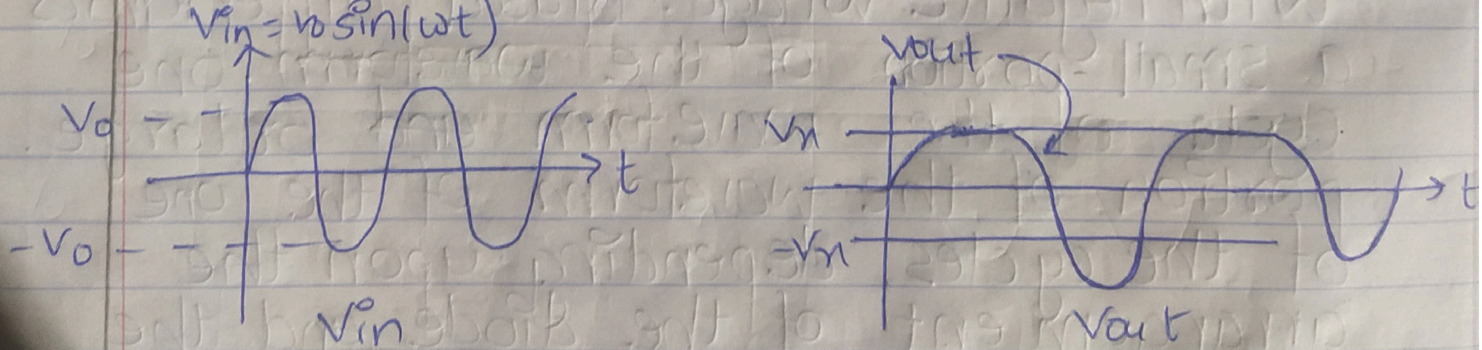
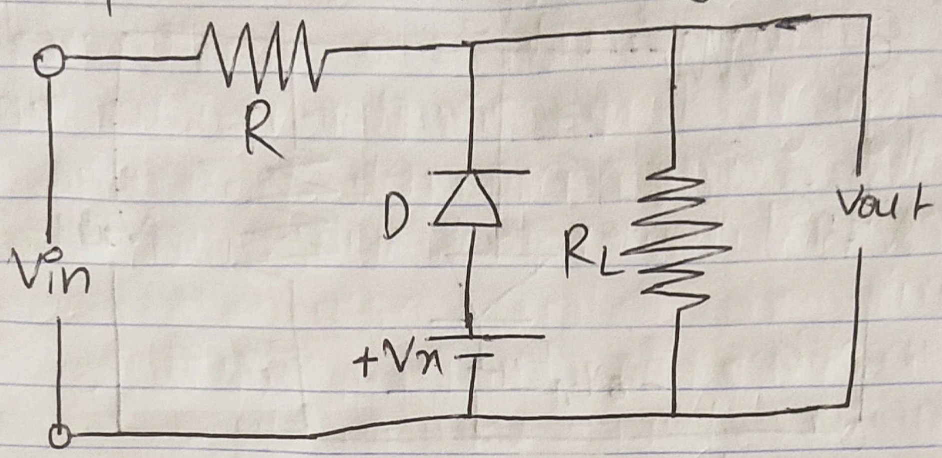


Fig: Waveforms of input and output signals for above circuit.

Parallel positive biased negetive clipper.



Here, the diode is forward biased initially due to positive biased voltage V_r and it will be reversed biased if input will become more positive than V_r. During positive half cycle, the diode will be ~~ve~~ forward biased until $V_{in} < V_r$. During this period diode will become short circuit and $V_{out} = V_r$. But when $V_{in} > V_r$. The diode becomes reversed biased and become open circuit and $V_{out} = V_{in}$. During negative half cycle diode will be forward biased and it will be short circuit and $V_{out} = V_r$.

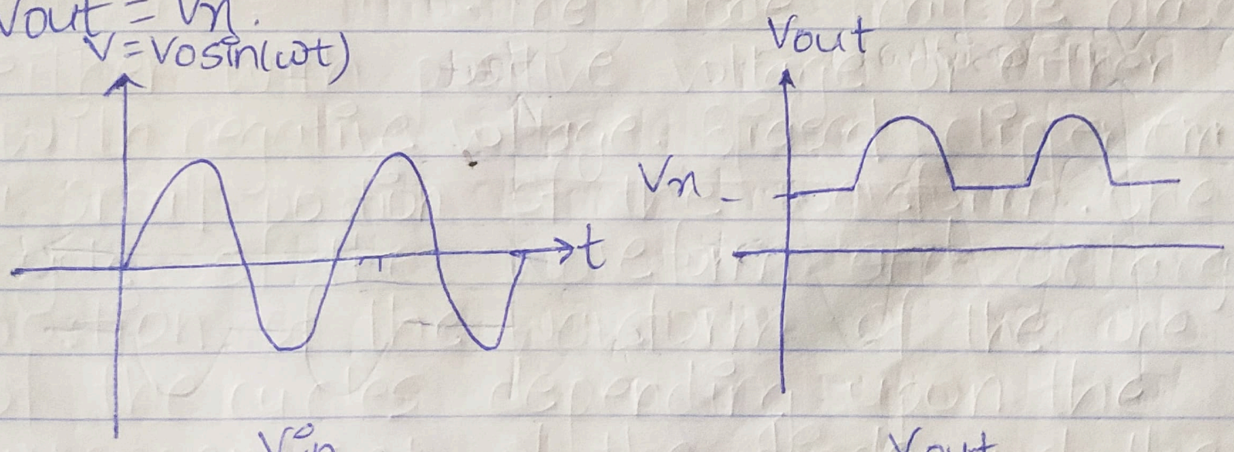
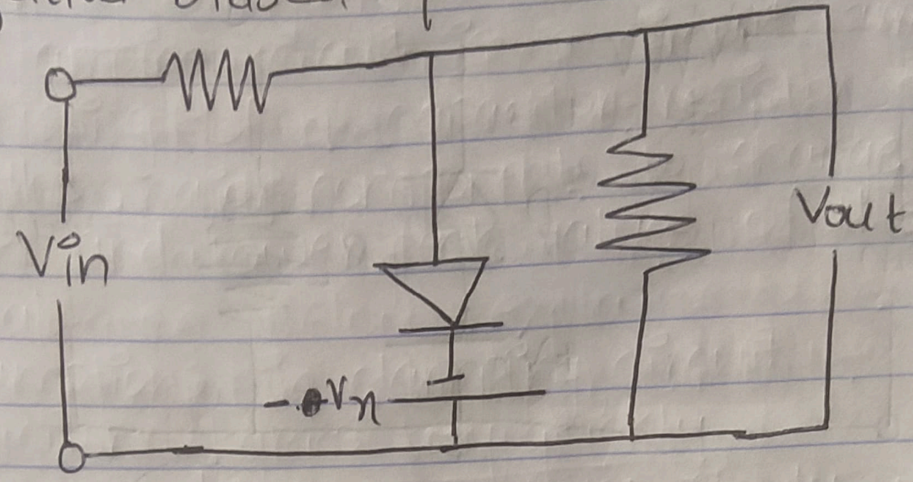


Fig: Waveforms of input and output signals for the above circuit.

Negative biased positive ~~series~~ parallel clipper.



Here, the diode is forward biased initially due to the biased negative voltage $-V_\gamma$. During the positive half cycle the diode will be forward biased and it will be short circuit and $V_{out} = -V_\gamma$. But during negative half cycle the diode will be in forward biased condition as long as $V_{in} > -V_\gamma$. But when $V_{in} < -V_\gamma$, then diode will be in reversed biased condition and $V_{out} = V_{in}$. In this way, the above circuit will act as

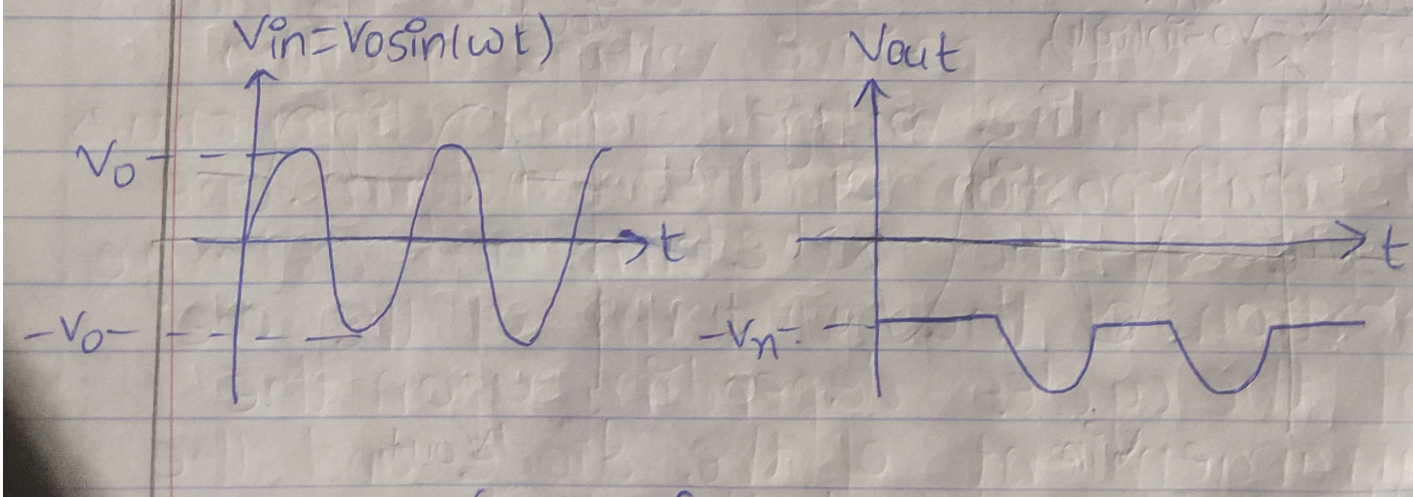
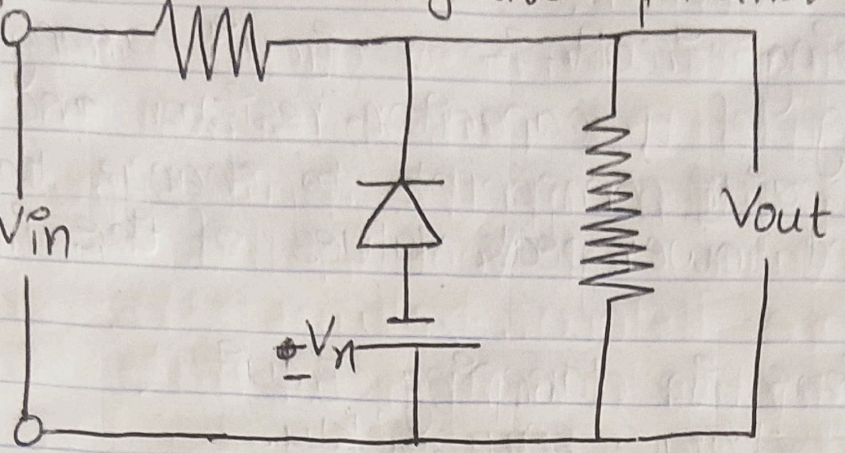


Fig: Waveforms of input and output signals for the above circuits.

Negative biased negative parallel clipper



Here, the diode is reverse biased initially due to biased negative voltage $-V_n$. During the positive half cycle, the diode will be reversed biased and it will be short circuit and ~~Vout = Vn~~ Vout = Vin. And during negative biased condition until Vin > $-V_n$, the diode will be in reversed biased condition and Vout = Vin But when Vin < $-V_n$, then diode will be in forward biased condition and it will be short circuit and Vout = $-V_n$.

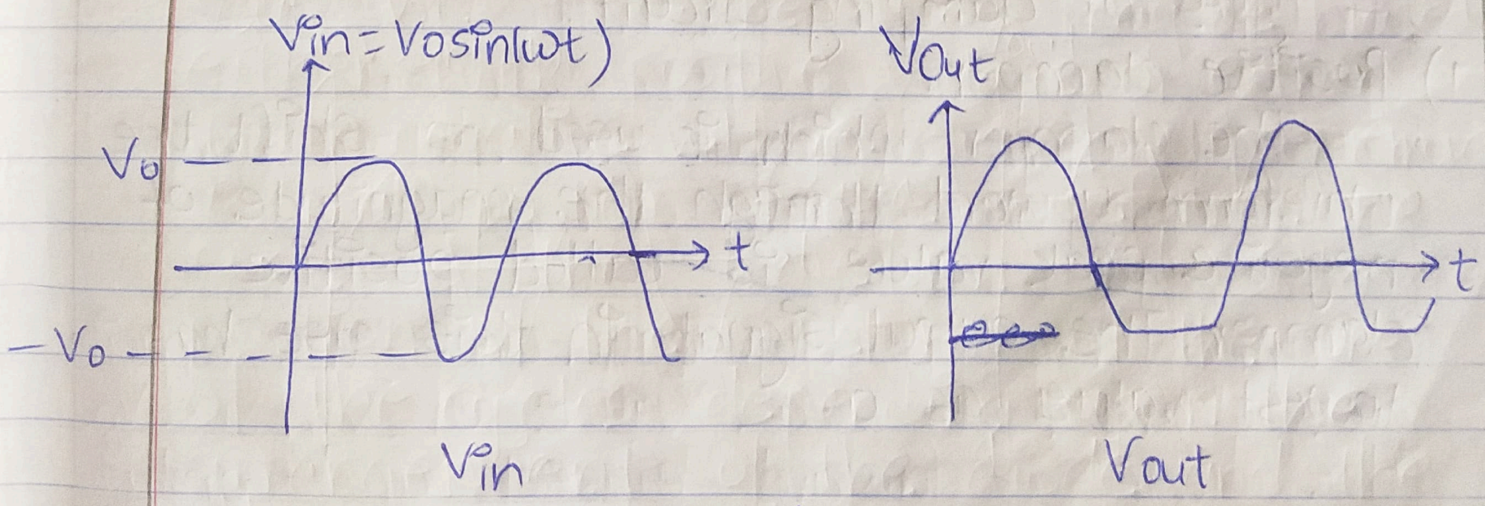


Fig: ~~When~~ Waveforms of input and output signals for the above circuit.

Clamping circuit.

clamping circuit is a circuit arrangement consisting of a capacitor, resistor and diode as the major components to change the upper and lower peak values of the input signals.

Assumptions in clamping circuit

1) Capacitor charges very quickly.
2) Capacitor discharges very slowly which means that it retains its charge over long period of time.

A clamper circuit can be defined as the circuit that shifts the waveform to a desired DC level without changing the actual appearance of the applied signal.

In order to maintain the time period of the wave form, the tau (i.e. relaxation time) must be greater than, half the time period of ~~ac~~ input signal.

i.e. $\cancel{t =} \tau = RC > \frac{T}{2}$

Types of clamping circuit.

1) Positive clamper.

The clamper which is used to shift the waveform upward through the magnitude of negative peak value is called positive clamper. The output signal in this case has lowest value as 0.

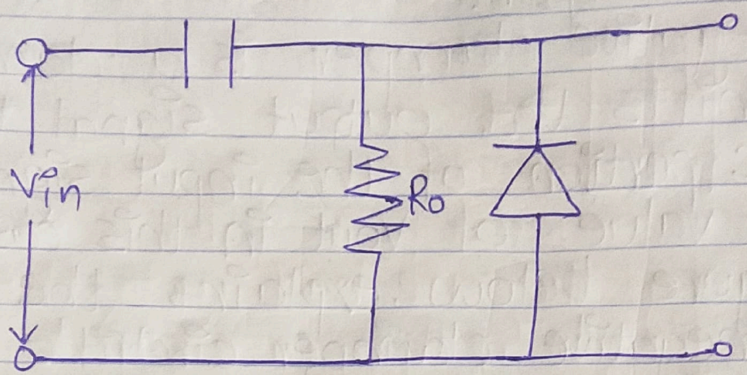


Fig: Positive clamper.

When input is -ve peak value, diode D is forward biased and it is short and Vout = 0. But during positive half-cycle the diode was reversed biased and the capacitor was charged with positive potential and it charges to ~~Vc = Vin~~. $V_C = V_{in}$. In next positive ~~cycle negative~~ cycle, diode is again reversed biased but in this case capacitor begins to discharge and $V_{out} = V_C + V_{in}$.

As; $V_C = |-V_0|$

$V_{out} = V_0 + V_0 = 2V_0$

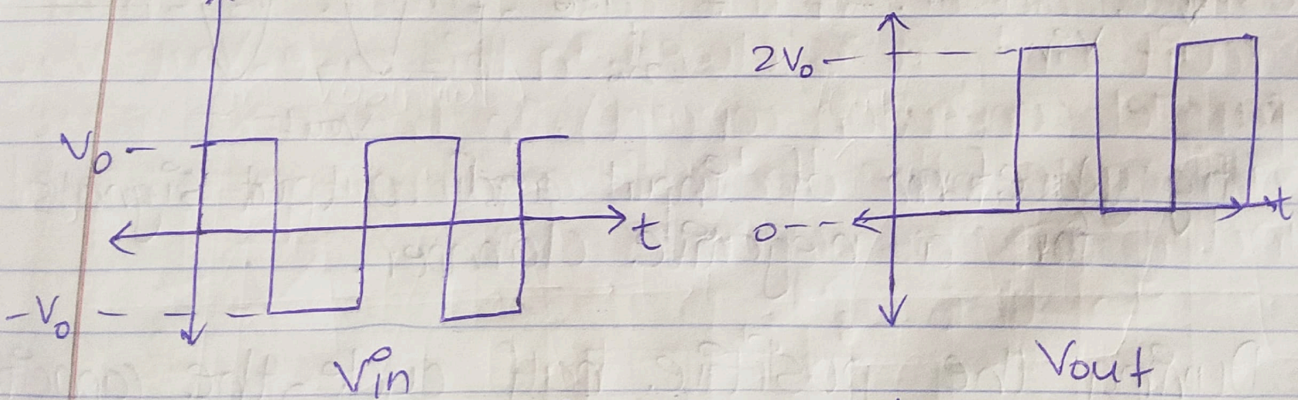
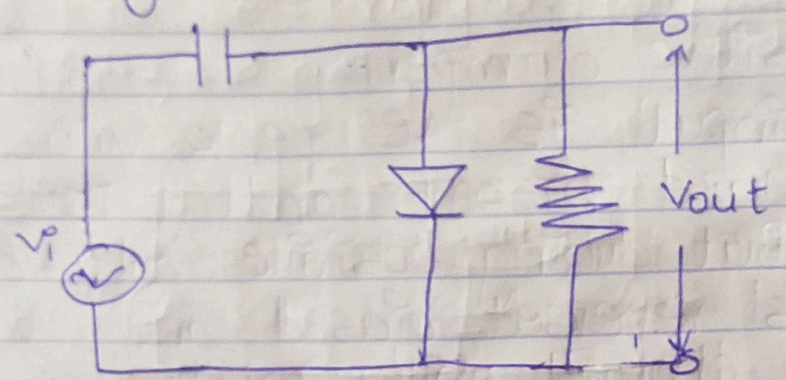


Fig: Waveform of input and output signal for positive clamper.

2) Negative clamper.

A negative clamper is a 'clamping circuit that shifts the output signal to the negative portion of the input signal. The highest value of Vout in this case is zero. The figure below explains the construction of a negative clamper circuit.



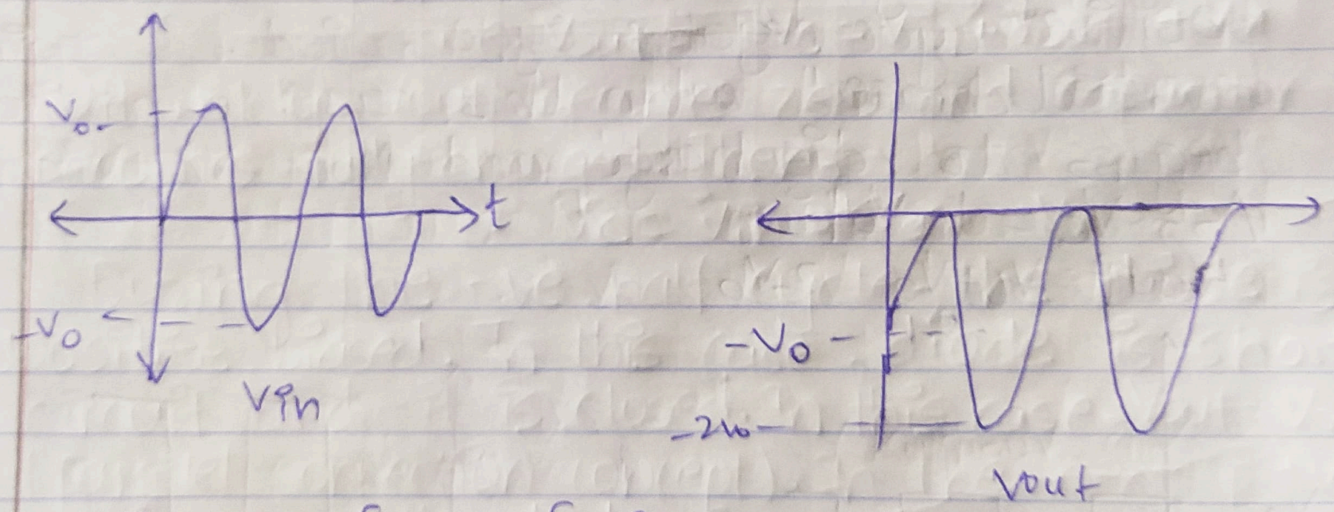


Fig: Waveform of input and output signals for a negative clamper.

During the positive half cycle, the capacitor gets charged to peak value of Vin i.e. Vo. The diode is forward biased and conducts. During the negative half cycle, the diode gets reverse biased and gets open circuited. The output of the circuit at this moment will be

$$v_o = V_i + V_m \text{ (but in opposite magnitude)}$$

Hence, the signal is negatively clamped as shown in the above figure. The output signal changes according to the changes in the input, but shifts the level according to the charge on the capacitor, as it adds the input voltage.

3) Positive clamper with positive voltage V_r.

~~The~~ It is the clamper that shifts the waveform of the output resulted by positive clamper upward with the magnitude of V_r.

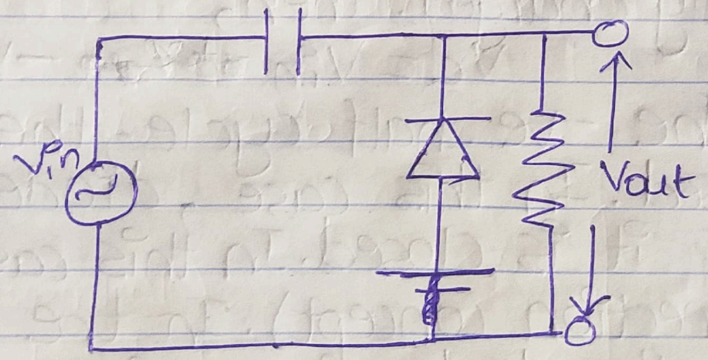
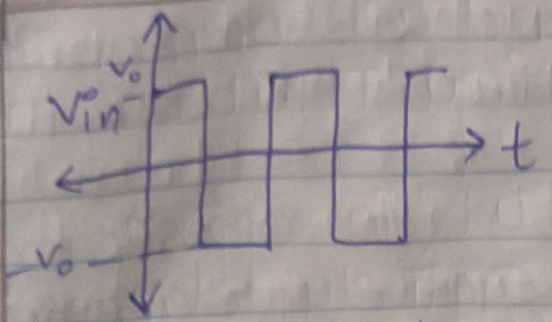
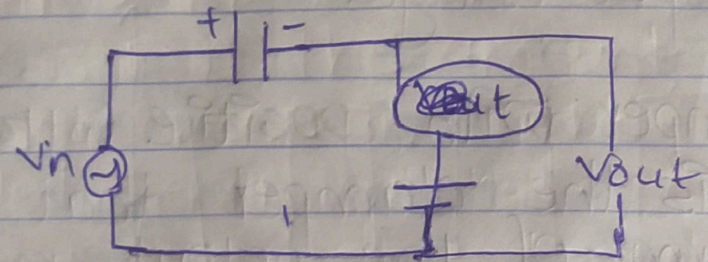


Fig: Circuit diagram of positive clamper with positive voltage V_r.



During the +ve half cycle, the diode is reverse biased. ~~In this case, diode capacitor begins to be charged. Applying KVL in this condition, we get,~~



Here, Vout = 0

$$-V_\gamma + V_{in} - V_c = 0$$

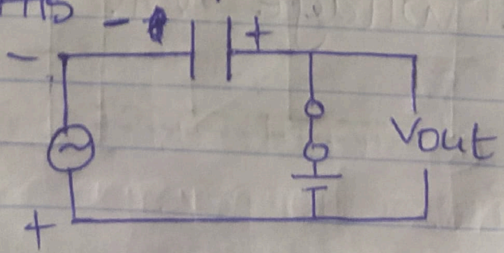
~~i.e. Vout =~~ $V_C = V_{in} + V_\gamma$

Ultimately, Vout becomes zero and capacitor becomes fully charged. Then,

$$V_C = V_{in} - V_\gamma$$

During the −ve half cycle, the diode is forward ~~positive~~ biased. In this case, diode is short circuit and it is closed. In this case, $V_{out} = V_\gamma$. (parallel connection concept). In the next +ve half cycle, the diode is again reverse biased and it acts as open.

~~In this~~



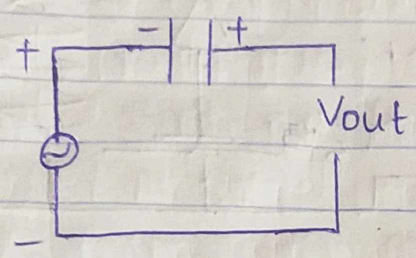
Applying KVL, we get,

$V_{in} - V_C - V_{out} = 0$

$\Rightarrow V_{out} = V_{in} - V_C = V_{in} - ($

$-V_{in} + V_C - V_x = 0$

$V_C = +V_{in} + V_x$



Applying KVL, we get,

$V_{out} = V_{in} + V_C$

$= V_{in} + V_{in} + V_x$

$= 2V_{in} + V_x$

Which means that during ~~forward~~ +ve half cycle, $V_{out} = 2V_{in} + V_x$ and during -ve half cycle $V_{out} = V_x$.

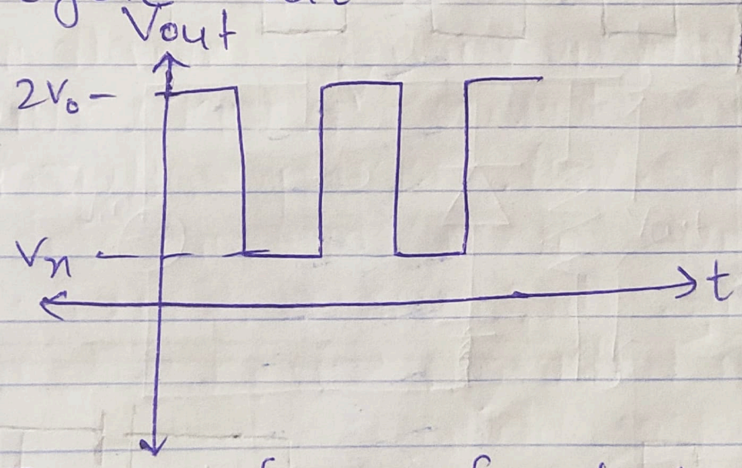
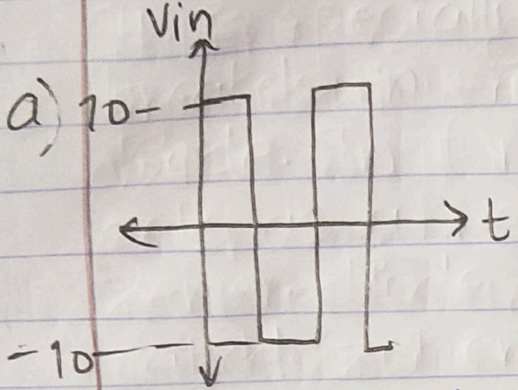
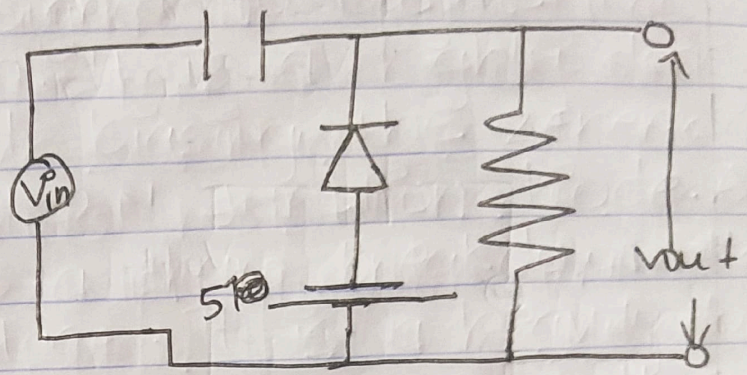


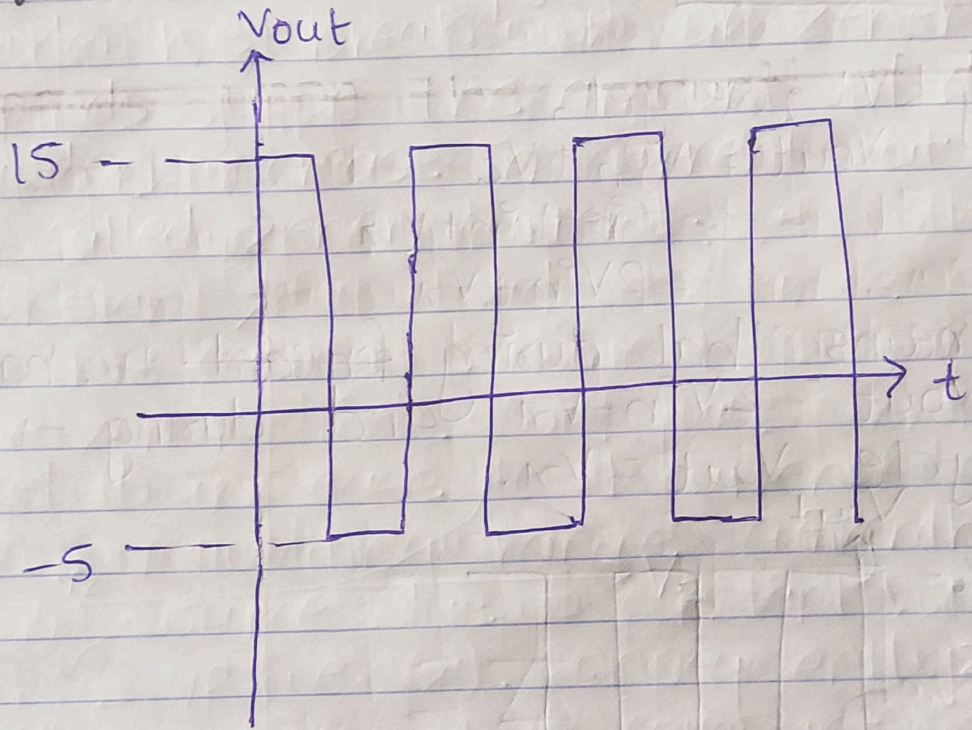
Fig: Waveform of output signal in case of positive clamper with positive voltage V_x.

Draw the output waveform of the given input signal with respect to given clamping circuit.

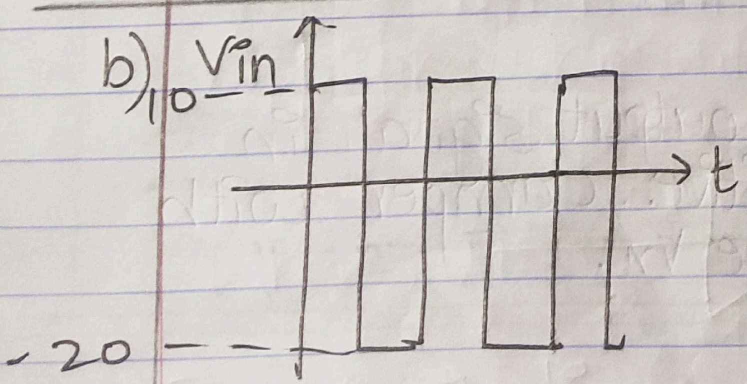
a)

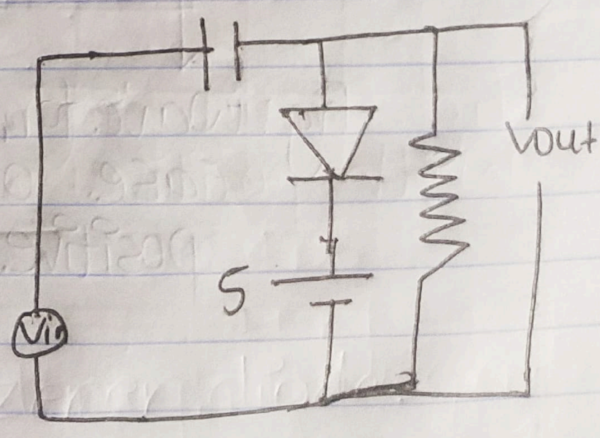


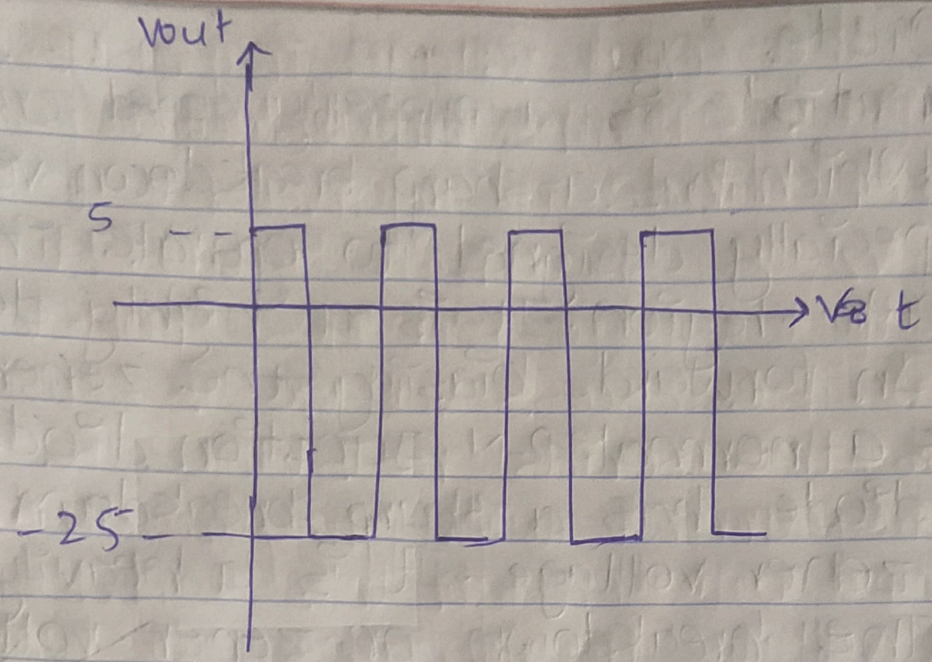




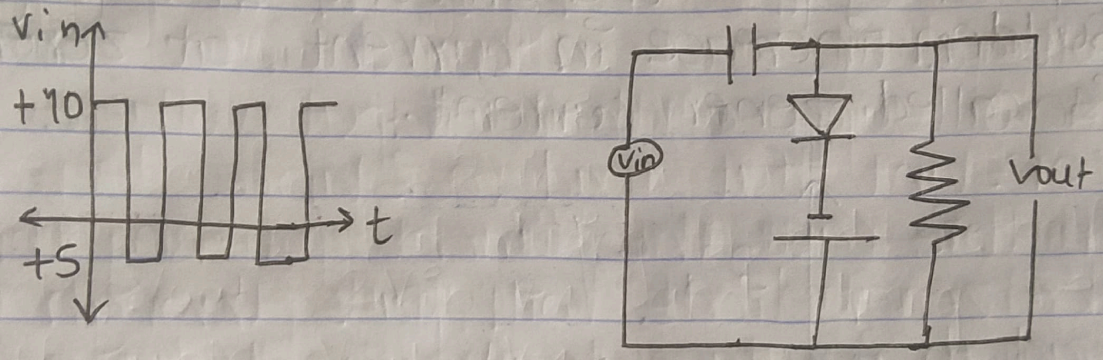
b)

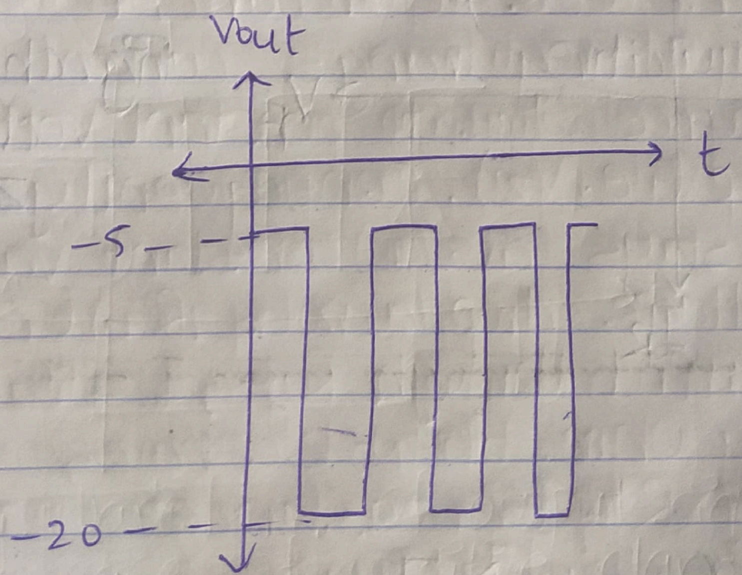






c)





Zener Diode.

Zener diode is a properly doped crystal diode which has a sharp breakdown voltage. It is specially designed to operate in breakdown region. It is a highly doped diode. In forward biasing, the zener diode acts as a normal P-N Junction diode. A zener diode has a sharp breakdown voltage called zener voltage. It is a heavily doped diode. The breakdown or zener voltage depends upon the amount of doping. The sudden increase in current at zener voltage is called zener current.

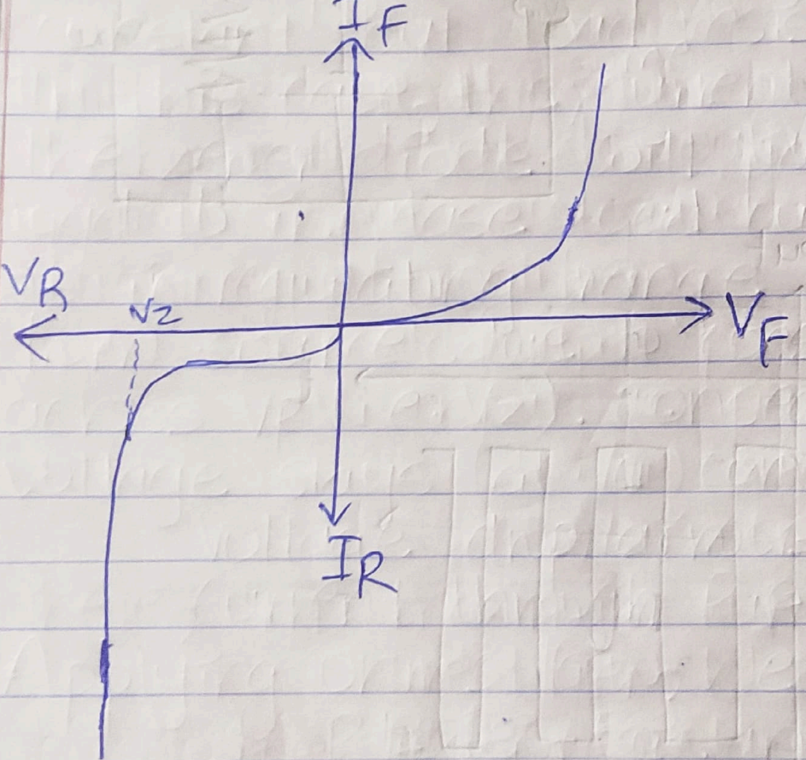


Fig: characteric curve of zener diode.

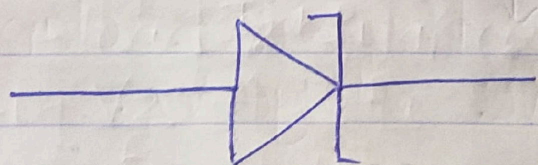
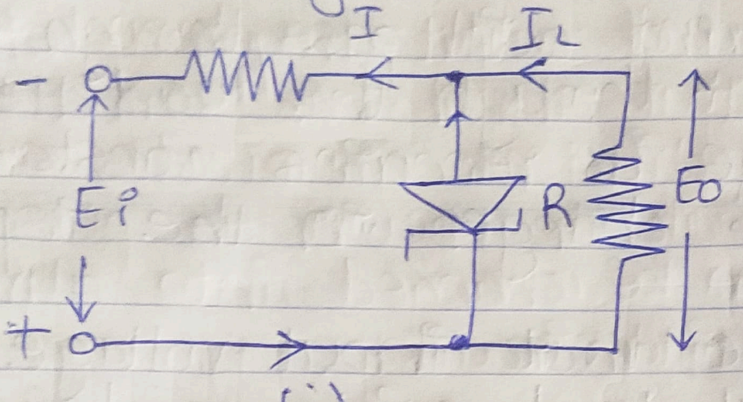


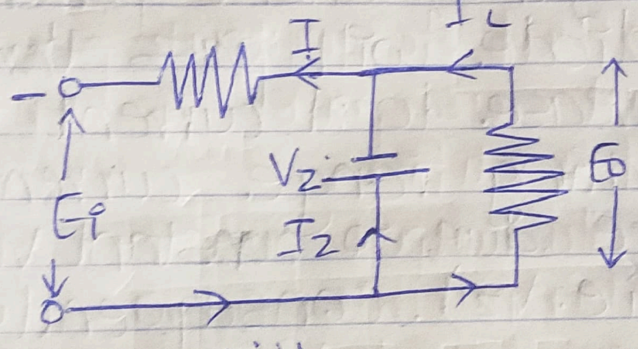
Fig: circuit diagram of zener diode.

Zener Diode as a Voltage Stabilizer.

A zener diode can be used as a voltage regulator to provide a constant voltage from a source whose voltage may vary over sufficient range. The circuit arrangement of zener diode as voltage stabiliser is shown in figure:



(i)



(ii)

It may be noted that the zener diode will maintain a constant voltage $V_z (= E_0)$ across the load so long as the input voltage does not fall below V_z.

When the circuit is properly designed, the load voltage E_0 remains essentially constant (equal to V_z) even though the input voltage E_i and load resistance R_L may vary over a wide range.

(i) Suppose the input voltage increases. Since, the zener is in the breakdown region, the zener diode is equivalent to a battery V_Z as shown in Fig(ii). It is clear that output voltage remains constant at $V_Z (= E_0)$. The excess voltage is dropped accross the series resistance R. The increased current will pass through the diode and not through the load. Hence, output voltage E_0 remains constant irrespective of the changes in the input voltage E_i.

(ii) Now suppose that input voltage is constant but load resistance decreases. In this case, the some current passing through the zener diode will pass through the load to increase load current ~~ta~~ as zener is in regulating range current can't come from source due to constant voltage drop across V_R (i.e. V_Z). Consequently, the output voltage stays at a constant value.

Voltage drop across $R = E_i - E_0$

Current through R, $I = I_Z + I_L$.

Applying ohm's law, we have,

$$R = \frac{E_i - E_0}{I_Z + I_L}.$$

Where, $I_L = \frac{V_Z}{R}$

(that means current through load depends upon ~~V_Z only~~ V_Z)

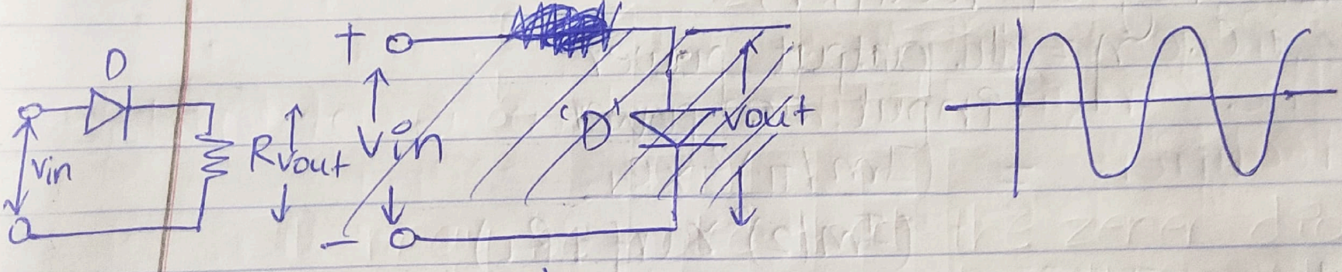
Rectification.

The process of conversion of ac to dc is known as rectification. The appliance used in our household generally requires dc signal eventually to perform their functions. When such d.c supply is required, the mains a.c. supply is rectified by using crystal diodes. The types of rectifiers are:

(1) Half-wave rectifier
(2) Full-wave rectifier
(a) centre tapped full wave rectifier
(b) ~~centre tap~~ Bridge full wave rectifier.

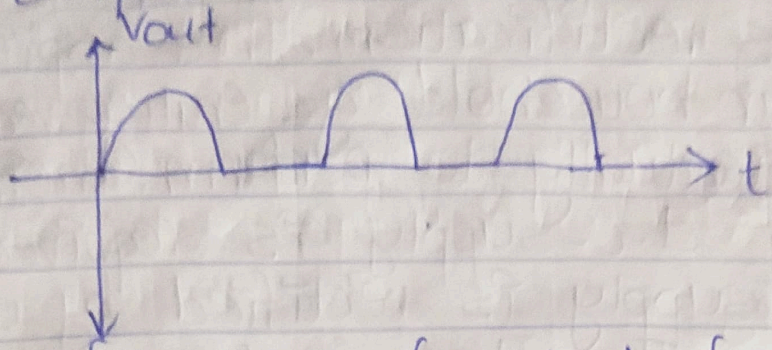
Half-wave rectifier.

The rectifier that only converts one half cycle to ac to dc and other as zero output voltage is known as half-wave rectifier.



(i)

Consider figure (i), during positive half cycle diode 'D' will be in forward biased condition and is equivalent to a closed circuit. In this case Vout = Vin. But in the next half-cycle (i.e. in negative half cycle), diode ~~to~~ D will be in reverse biased condition and it will act as open circuit. In this case, Vout = 0. This process gets repeated in each complete cycle. The output waveform will look like:



Here, frequency of output = frequency of input. The above output signal has same direction of p.d. but of different magnitudes. such type of electric signal is known as pulsating dc and it can be changed into almost pure dc by using filter circuit.

Efficiency of Half-Wave Rectifier.

The ratio of dc output power to the applied input ac power is known as efficiency of rectifier,

i.e. $\eta = \dfrac{\text{dc output power}}{\text{input ac power}}$

$= \dfrac{(I_m/\pi)^2 \times R_L}{(I_m/2)^2 \times (r_f + R_L)}$

where, I_m = maximum current flowing through rectifier

r_f = diode resistance

R_L = load resistance

so, $\eta = \dfrac{0.406 R_L}{r_f + R_L} = \dfrac{0.406}{1 + \frac{r_f}{R_L}}$

∴ max. rectifier efficiency = 40.6%.

Ripple Factor

The output of rectifier consists of dc component and ac component(also known as ripple). The ac component is undesirable and accounts for the pulsation in output. The ratio of rms value of ac component to the dc component in the rectifier output is known as ripple factor.

$$\text{Ripple Factor} = \frac{\text{Rms ac}}{\text{Rms dc}} = \frac{I_{ac}}{I_{dc}}$$

Centre-Tapped Full Wave Rectifier.

The circuit diagram below shows centre-tapped full-wave rectifier.

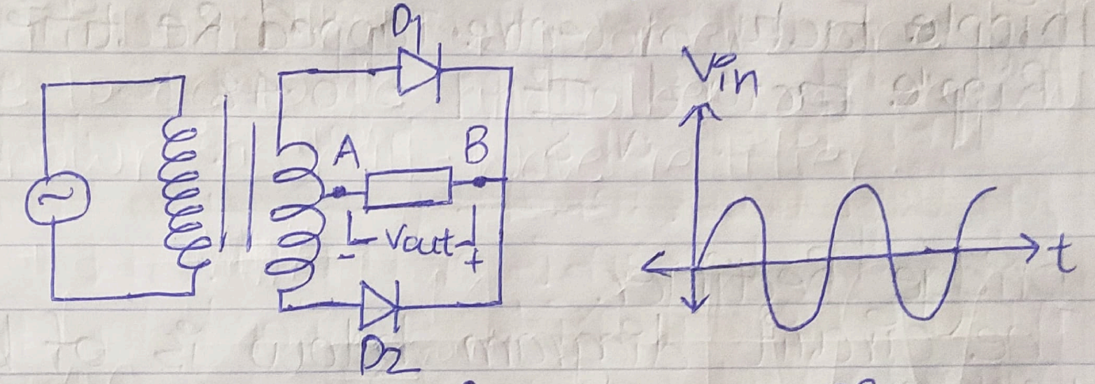
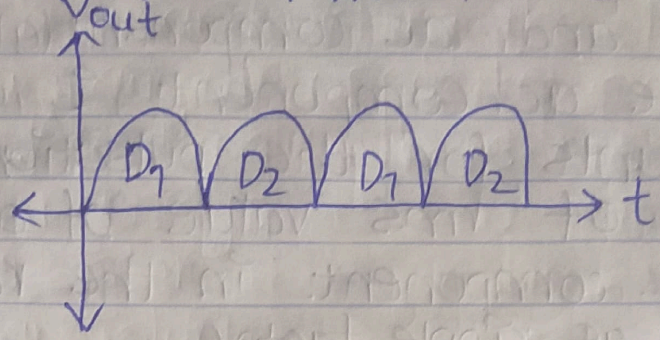


Fig: centre tapped full wave rectifier.

In the ~~full wave rect~~ positive half cycle, diode D_1 is forward biased whereas diode D_2 is reverse biased. In this cycle, current flows from B to A and vout = |Vin|.

In the negative half cycle, diode D_2 is forward biased whereas diode D_1 is reverse biased. In this cycle, current

again flows from B to A and $V_{out} = |V_{in}|$.
The output waveform is as shown



Efficiency of centre Tapped Rectifier

$$\eta = \frac{8}{\pi^2} \cdot \frac{1}{1+\frac{r_f}{R_L}}$$

and $\eta_{max} = 0.812$ $(r_f << R_L)$

Ripple Factor of Centre Tapped Rectifier.

$$\text{Ripple Factor} = \sqrt{\frac{\pi^2}{8} - 1} = 0.48$$

Bridge Rectifier.

The circuit diagram below is of bridge rectifier.

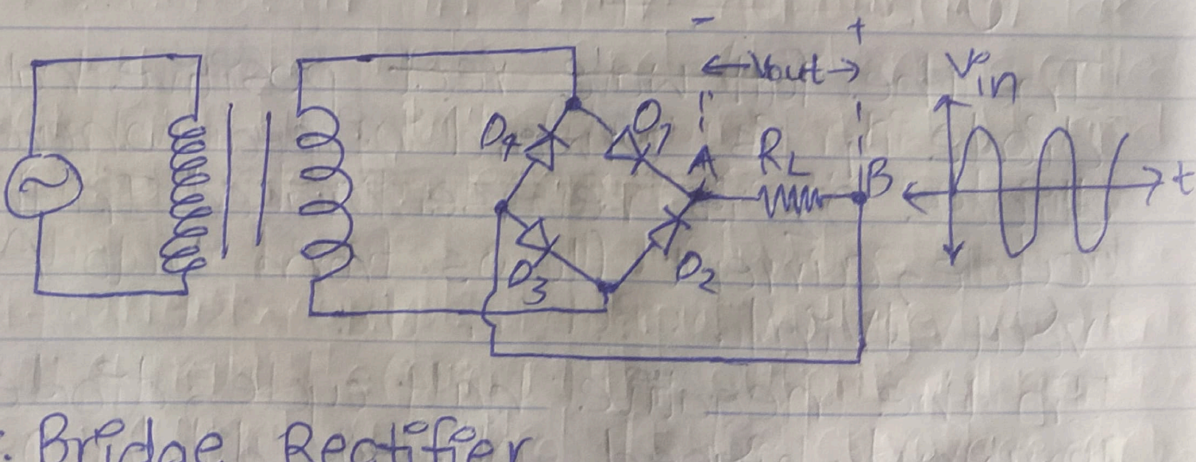
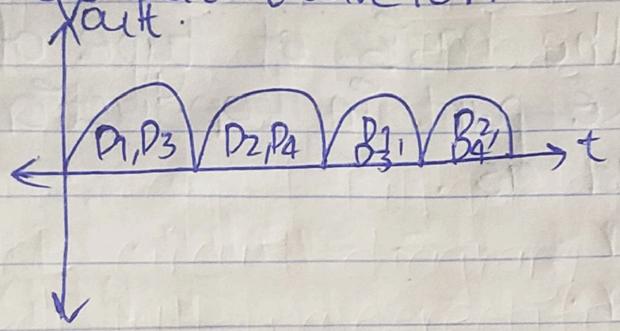


Fig: Bridge Rectifier.

In the positive half cycle, diodes D_1 and D_3 are forward biased whereas diodes D_2 and D_4 are reverse biased. In this condition, current flows from B to A and $V_{out} = |V_{in}|$

In the negative half cycle, diodes D_2 and D_4 are forward biased whereas diodes D_1 and D_3 are reverse biased. In this condition, current again flows from B to A and $V_{out} = |V_{in}|$.

The output waveform is as shown.



Efficiency of Bridge Rectifier

$$\eta = \frac{8}{\pi^2} \frac{1}{1 + \frac{r_f}{R_L}}$$

$$\eta_{max} = 81.2\% \;(r_f << R_L)$$

Ripple Factor of Bridge Full Wave Rectifier.

$$\text{Ripple Factor} = \sqrt{\frac{\pi^2}{8} - 1} = 0.48.$$