Non-Linear wave shaping

Clippers: Clipping means cutting and removing a part.

A clipping circuit which removes the undesired part of the waveform and transmitts only the desired part of the signal which is above or below some particular reference level. Clipping circuits are also called voltage (or current) limiters, amplitude selectors or slicers. It is used in over voltage ckts to prevent the ckts from high voltage spikes.

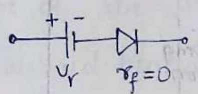
Clippers are classified into two types

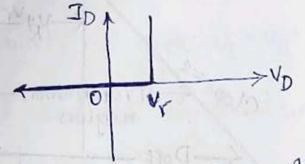
(1) shunt clippers

(2) series clippers.

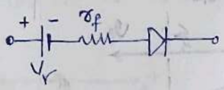
Piecewise Linear model of diode:

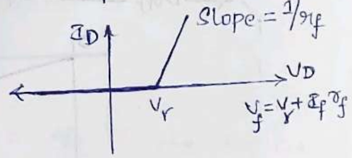
with $r_f = 0\Omega$
$r_r = \infty$



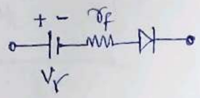


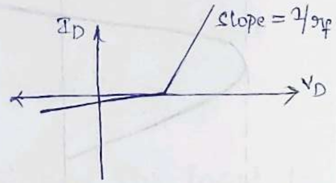
with r_f = finite value
$r_r = \infty$



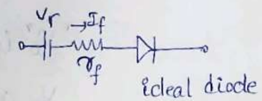


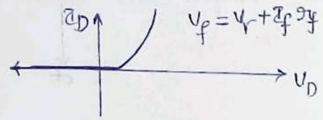
with r_f = finite
r_r = very large



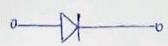


practical diode

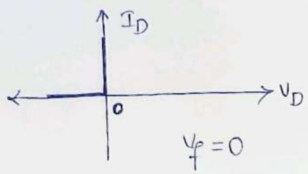




Ideal diode



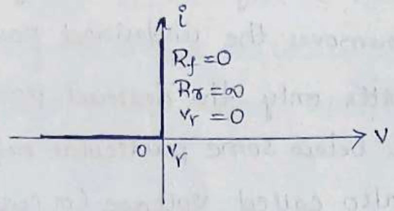
$r_f = 0$, $V_r = 0$

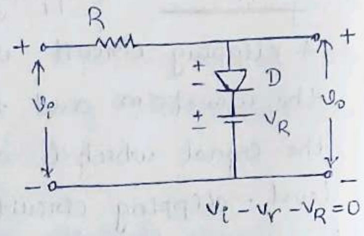


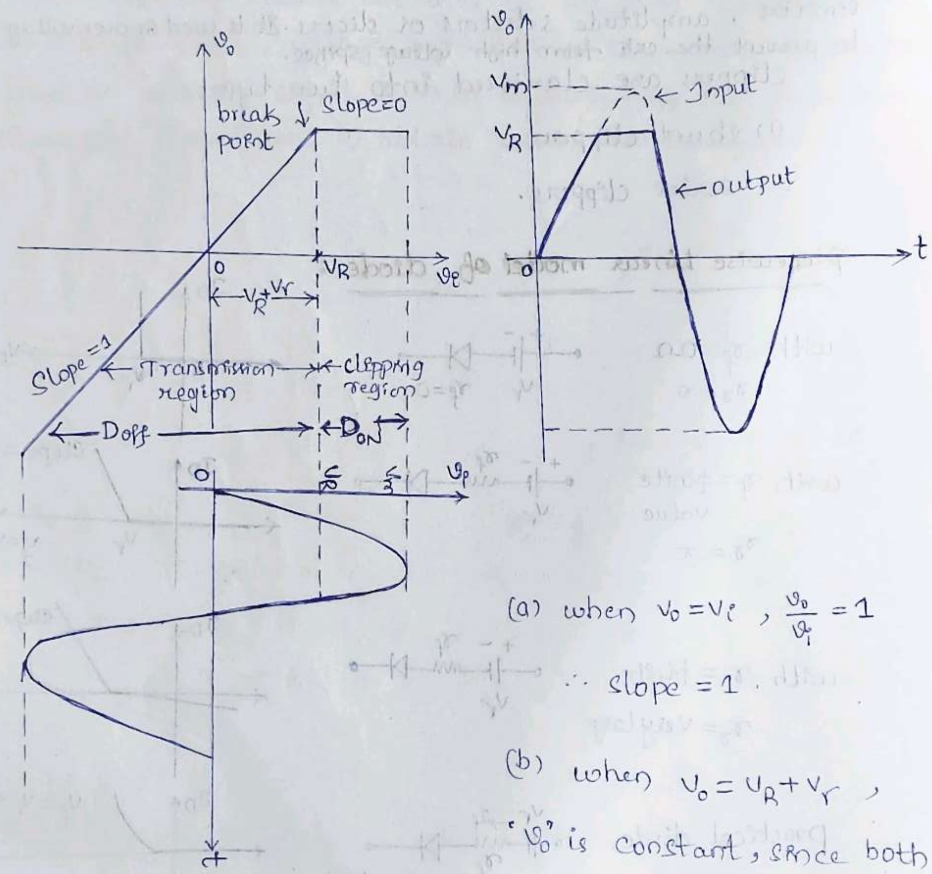
$V_f = 0$

Shunt clippers :

Clipping above reference level :







(a) when $v_o = v_i$, $\frac{v_o}{v_i} = 1$

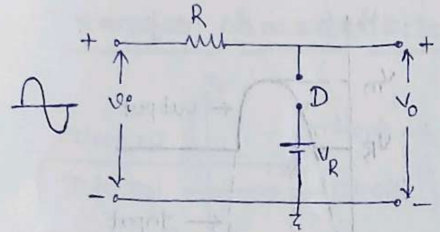
$\therefore$ slope = 1 .

(b) when $v_o = V_R + V_r$,

'v_o' is constant, since both V_R and V_r are of fixed magnitude.

$\therefore$ slope = 0 .

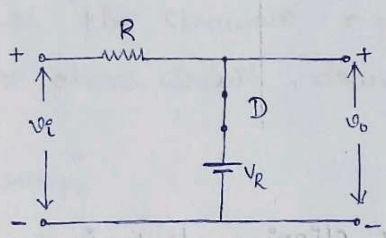
In the above shown clipping circuit the transmission characteristic which is a plot of the output voltage 'v_o' as a function of the input voltage 'v_i', also exhibits piece-wise linear discontinuity. The break point occurs at the reference voltage V_R. To the left of the break point i.e $v_i < V_R + V_r$ the diode is reverse biased (OFF) and the equivalent circuit when the diode is reverse biased is



$V_o = V_i$ for -ve half cycle

Diode is 'OFF'

To the right of the break point i.e for $v_i > V_R + V_r$ the diode is forward biased (ON) and the equivalent circuit when the diode is forward biased is

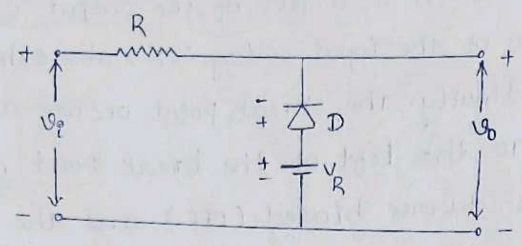


$V_o = V_R$ for +ve half cycle.

Diode is 'ON'

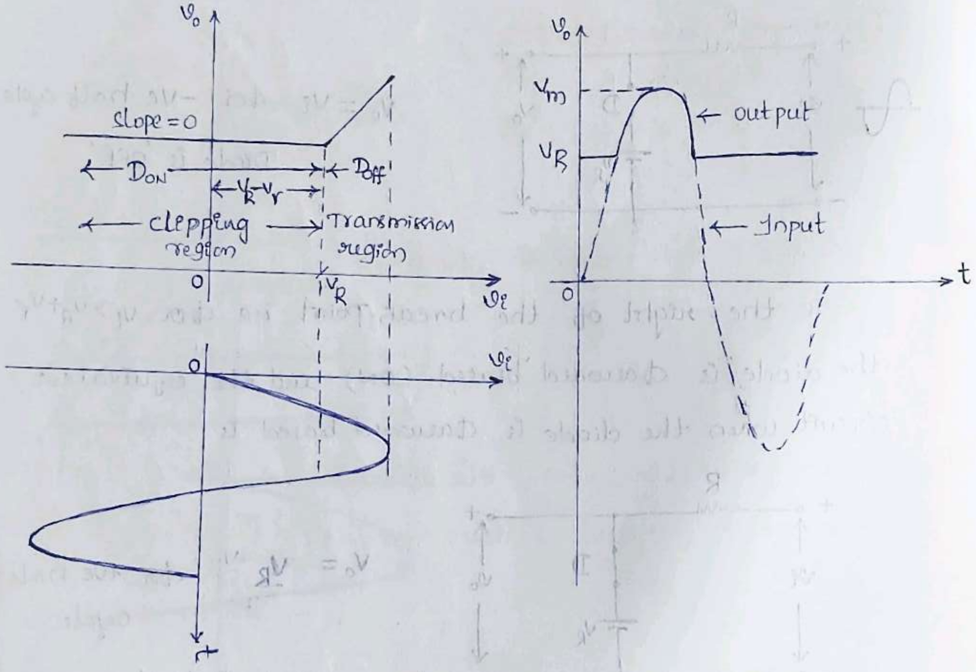
for $v_i > V_R + V_r$ the diode is 'ON' and the input is clipped off by 'V_R' part.

Clipping below reference level :

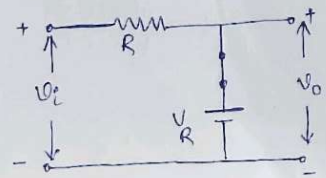


$$v_i + V_r - V_R = 0$$

$$v_i = V_R - V_r$$

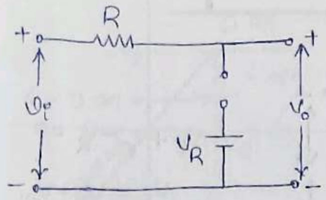


This clipping diode is modified by reversing the diode. In this circuit if $v_i < V_R - V_r$ the diode will be forward biased (ON).



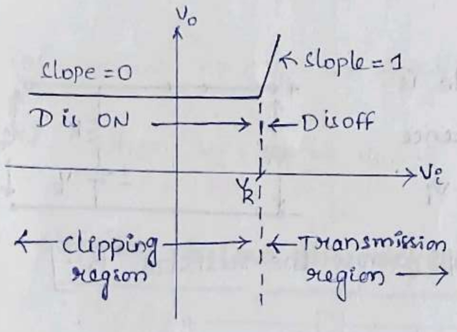
$v_o = V_R$ for -ve half cycle

For $V_i > V_R - V_r$ the diode will be reverse biased and it is in 'off' state.



$V_o = V_{in}$ for +ve half cycle

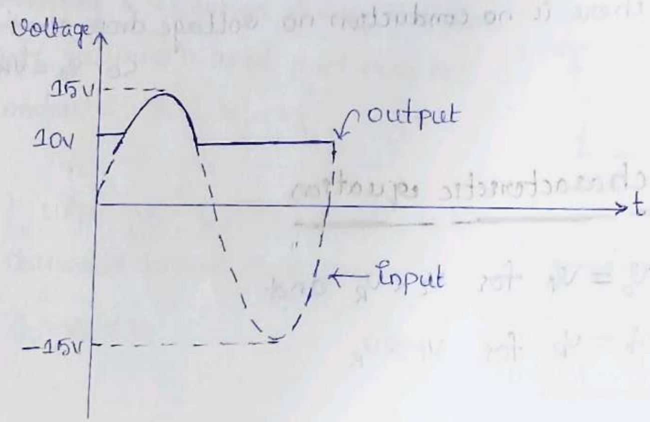
Transfer characteristic :



(i) when $V_o = V_R$ i.e V_o is constant $V_o = 0$

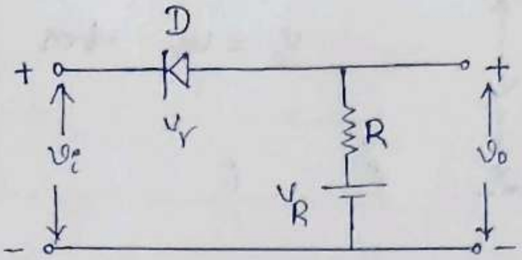
(ii) when $V_o = V_i$ i.e $\frac{V_o}{V_i} = 1$, slope = 1

Q8 Let the sinewave $e = 15 \sin\omega t$ be passed through the above circuit, draw the output waveform if $V_R = 10V$



Series clippers :

(a) clipping above the reference voltage :

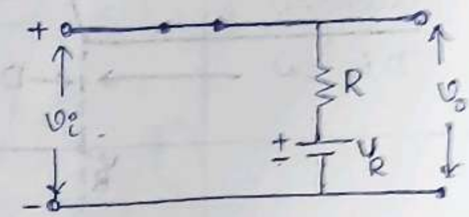


$v_i + V_r - V_R = 0$

$V_i = V_R - V_r$

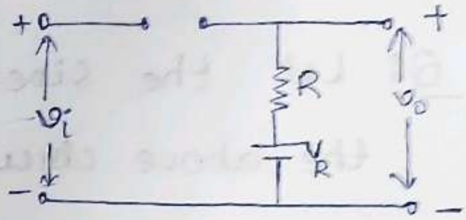
working :

(a) when $v_i < V_R - V_r$, the diode is forward biased and hence it conducts. so $v_o = v_i$



[∵ the total voltage drops across the resistor 'R'.]

(b) when $v_i > V_R - V_r$ the diode is reverse biased and hence it does not conducts. so $v_o = V_R$



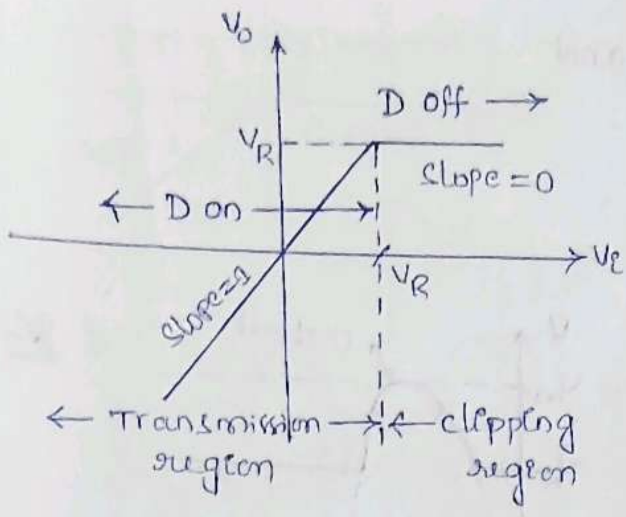
[∵ Since there is no conduction no voltage drop across 'R', So $v_o = V_R$]

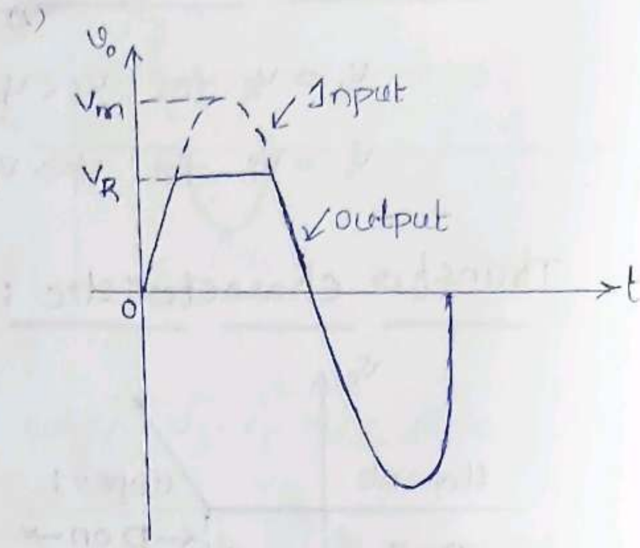
Transfer characteristic equation

$v_o = v_i$ for $v_i < V_R$ and

$v_o = V_R$ for $v_i > V_R$

Transfer characteristic :

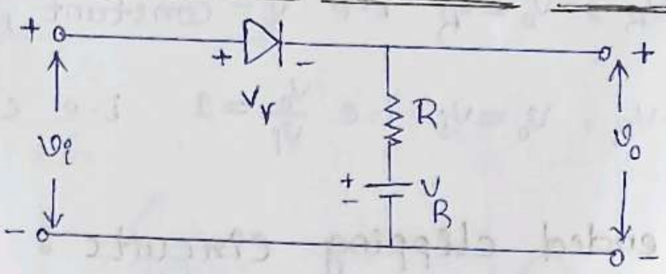




(a) when $v_i < V_R \Rightarrow V_o = V_i$ i.e $\frac{v_o}{v_i} = 1$, slope = 1

(b) when $v_i > V_R \Rightarrow V_o = V_R$ i.e v_o = constant , slope = 0

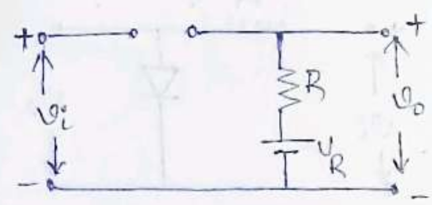
(b) clipping below the reference voltage :



$v_i - V_r - V_R = 0$

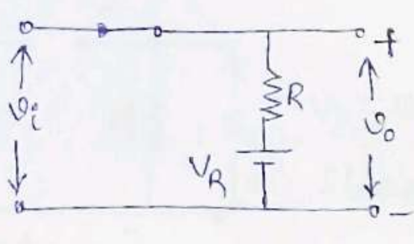
$v_i = V_R + V_r$

Working : (a) when $v_i < v_R$ the diode gets reverse biased and does not conducts. So $v_o = V_R$. (OFF)



(b) when $v_i > V_R$ the diode is forward biased and conducts.

So $v_o = v_i$ (ON)

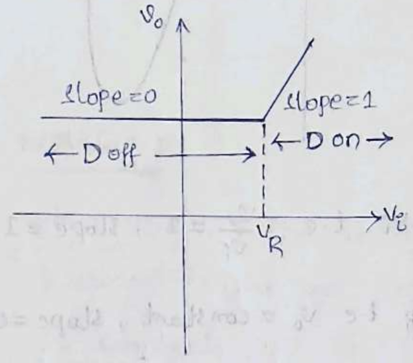


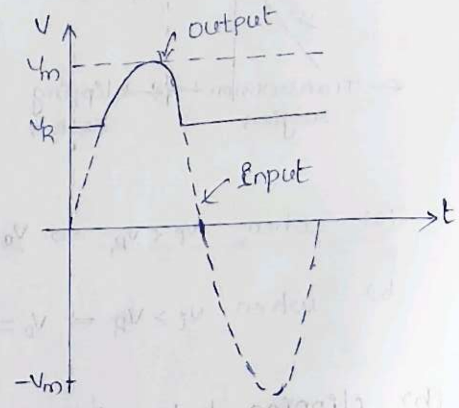
Transfer characteristic equation :

$v_o = v_R$ for $v_i < v_R$ and

$v_o = v_i$ for $v_i > v_R$

Transfer Characteristic :



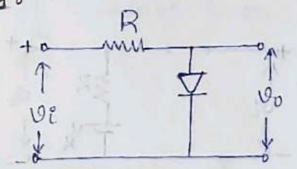


(a) when $v_i < v_R$, $v_o = v_R$ i.e v_o = constant , slope = 0

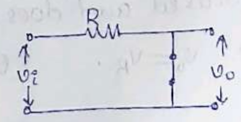
(b) when $v_i > v_R$, $v_o = v_i$ i.e $\frac{v_o}{v_i} = 1$ i.e slope = 1

Some single ended clipping circuits :

1a :



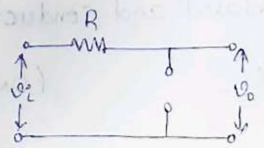
(a) when $v_i > v_r$ diode is 'ON'



$v_o = 0V$

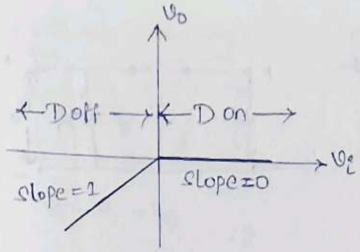
slope = constant

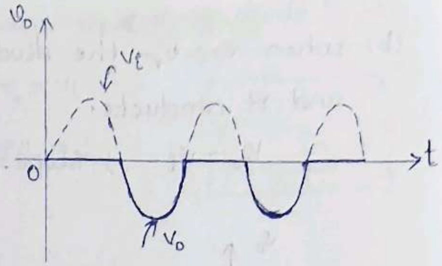
(b) when $v_i < v_r$ diode is 'Off'



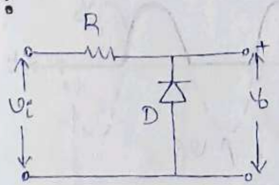
$v_o = v_i$

slope = 1

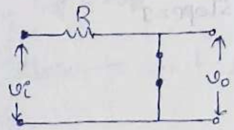




2Q :



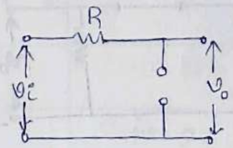
(a) when $v_i < V_r$ the diode is 'ON'



$v_o = 0V$

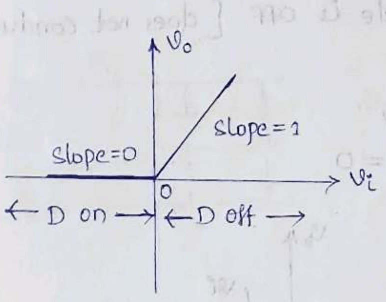
slope = 0

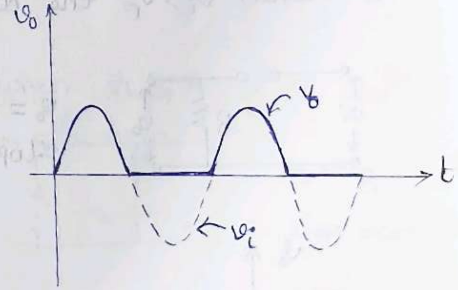
(b) when $v_i > V_r$ the diode is 'off'



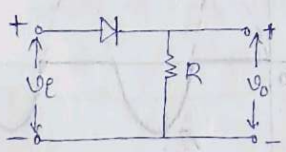
$v_o = v_i$

slope = 1

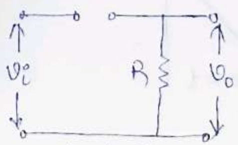




3Q



(a) when $v_i < V_r$ the diode is OFF



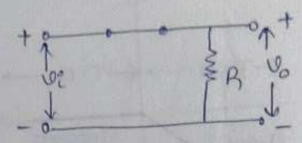
$v_o = 0V$

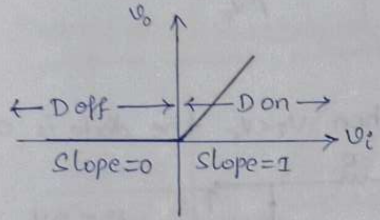
slope = 0

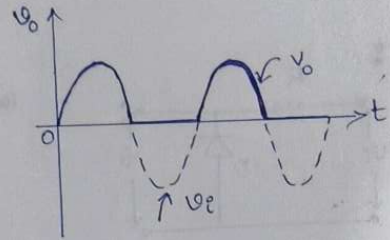
[∵ diode does not conducts]

(b) when $v_i > V_r$ the diode is 'ON' and it conducts.

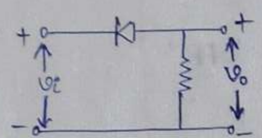
$v_o = v_i$; slope = 1



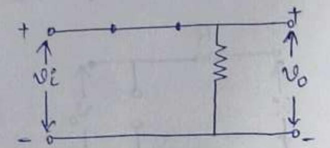




4Q :



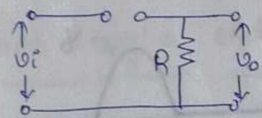
(a) when $v_i < V_r$ the diode is ON



$v_o = v_i$

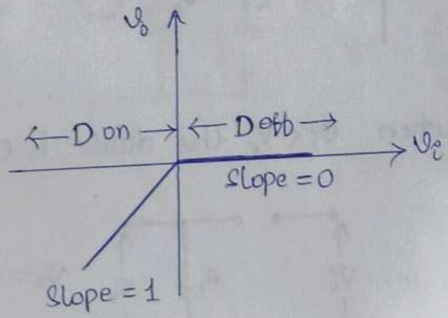
slope = 1

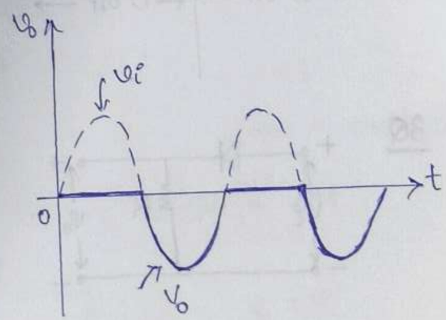
(b) when $v_i > V_r$ the diode is off [does not conducts]



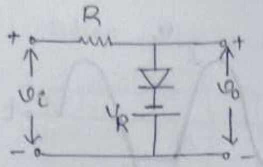
$v_o = 0V$

slope = 0





5Q6

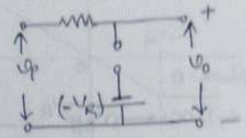


$v_i - V_r + V_R$

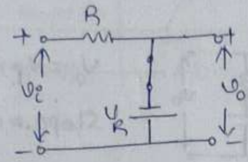
(a) when $v_i < V_r - V_R$ diode is off

so $v_o = v_i$

slope = 1

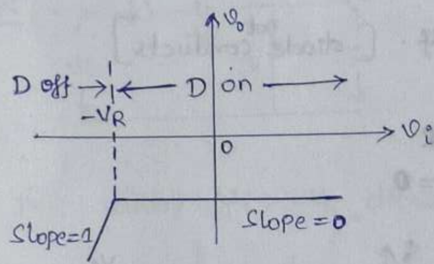


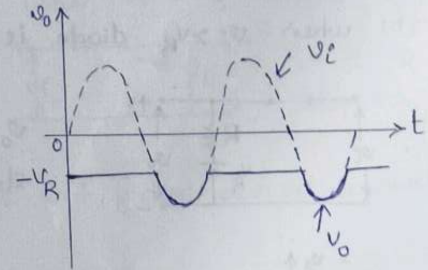
(b) when $v_i > V_r - V_R$ diode is ON, conducts.



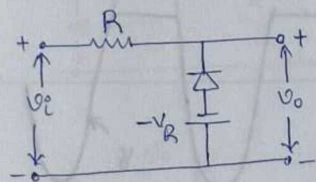
so $v_o = -V_R$

slope = constant = 0

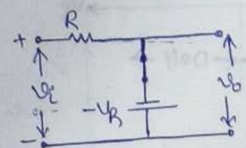




6Q:



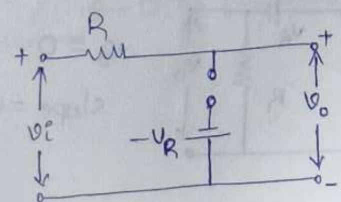
(a) when $v_i < -V_R$ diode is ON



$v_o = -V_R$

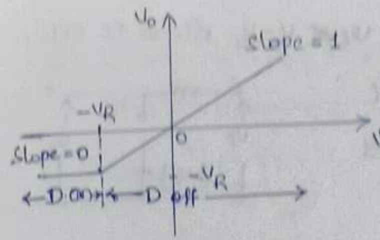
slope = constant = 0

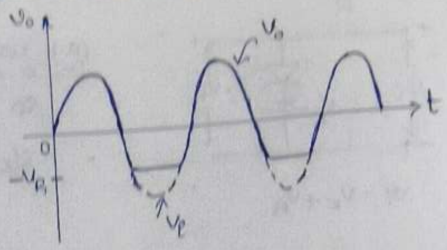
(b) when $v_i > -V_R$ diode is off [does not conducts].



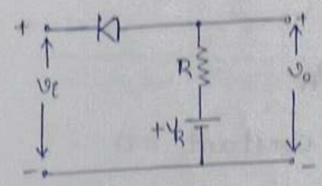
$v_o = v_i$

slope = 1

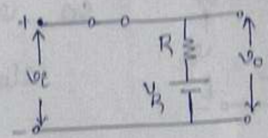




7Q



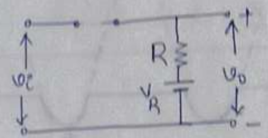
(a) when $v_i < +V_R$ diode is ON.



$V_o = V_R$

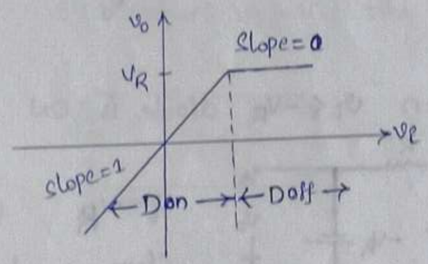
Slope = constant = 1

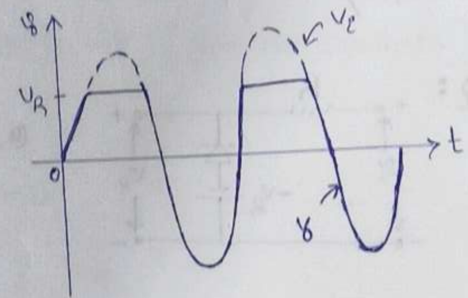
(b) when $v_i > V_R$ diode is off. [diode not conducts]



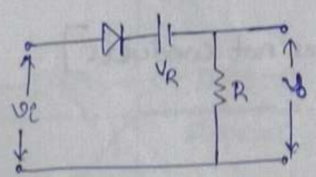
$v_o = V_R$

slope = 0

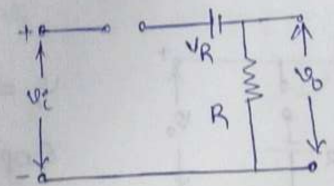




8Q



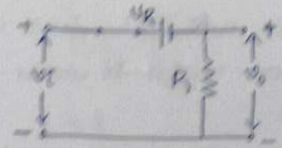
(a) when $v_i < V_R$ diode is off.



$v_o = 0$

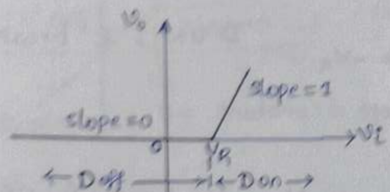
slope = 0

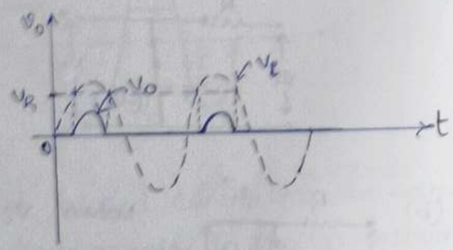
(b) when $v_i > V_R$ diode is ON.



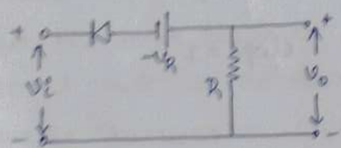
$v_o = v_i - V_R$

slope = 1

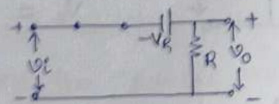




9Q:



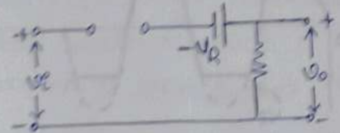
(a) when $v_i < -V_R$ diode is ON



$v_o = v_i - V_R$

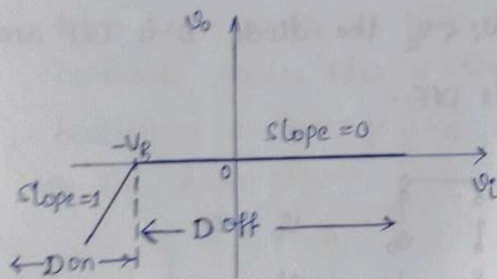
slope = 1

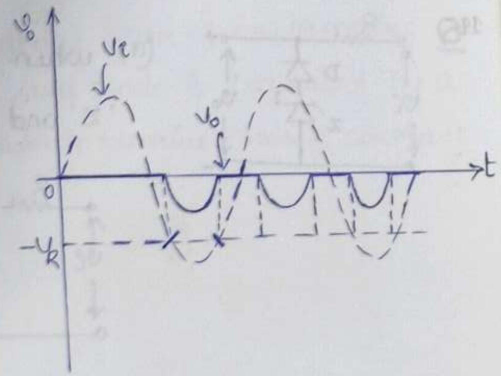
(b) when $v_i > -V_R$ diode is off [diode does not conducts]



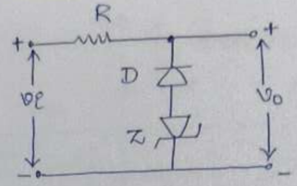
$v_o = 0$

slope = 0

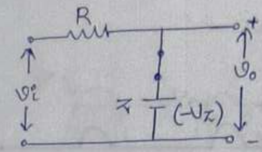




10Q



(a) when $v_i < -V_z$ the diode 'D' conducts and 'Z' breaks. when the zener diode is in breakdown region it works as a voltage source.

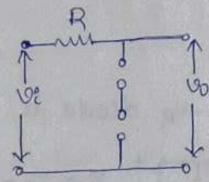


'D' ON , 'Z' breaks

$v_o = -V_z$

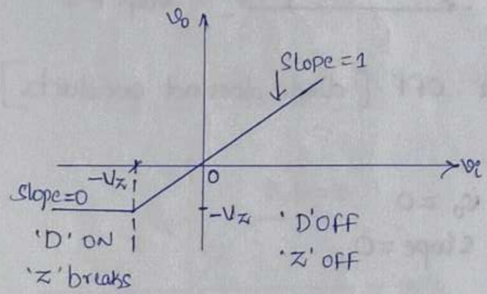
slope = constant = 0

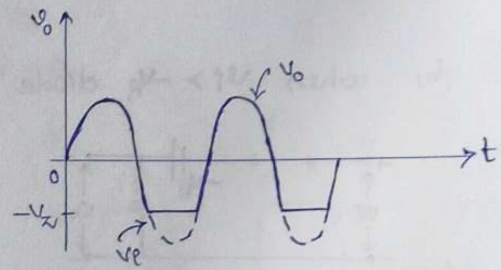
(b)



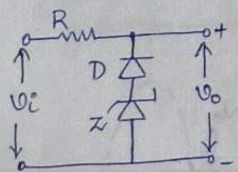
when $v_i > -V_z$ the diode 'D' is off and 'Z' is off. so the output follows the input.

$v_o = v_i$; slope = 1

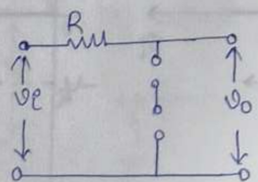




11Q



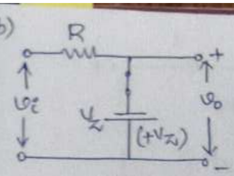
(a) when $v_i < V_z$ the diode 'D' is off and 'Z' and is off.



$v_o = v_i$

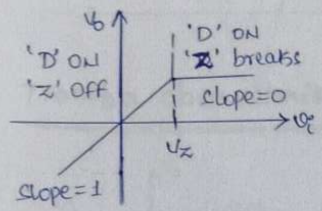
slope = 1

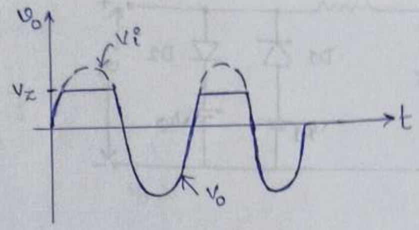
(b)



when $v_i > V_z$, 'D' is ON and 'Z' breaks

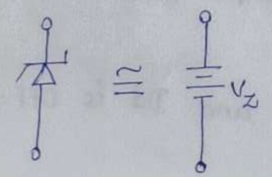
$v_o = V_z$; slope = constant = 0





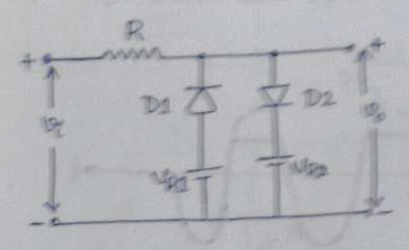
Zener diode : In the forward biased condition, the normal rectifier diode and the zener diode operates in similar fashion. But the zener diode is designed to be operated in the reverse biased condition. In reverse biased condition, the diode carries reverse saturation current till the reverse voltage is applied is less than the reverse breakdown voltage. When the reverse voltage exceeds reverse breakdown voltage, the current through it changes drastically but the voltage across it remains almost constant. Such a breakdown region is a normal operating region for a zener diode.

When the breakdown occurs then I_z may increase from I_{zmin} to I_{zmax} but voltage across zener remains constant. Hence ideally the zener diode is indicated by a battery of a voltage 'V_z', which remains fairly constant in the zener region.



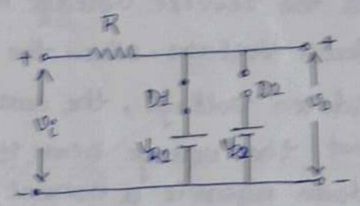
Clipping at two independent levels :

Q :



Working : The diode D1 conducts only when $v_i < V_{R1}$ and the diode D2 conducts only when $v_i > V_{R2}$.

(a) for $v_i < V_{R1}$, D1 conducts and D2 is OFF.

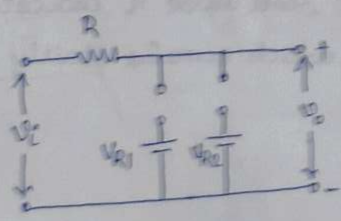


$v_o = V_{R1}$

Slope = constant = 0

(b) for $V_{R1} < v_i < V_{R2}$, both diodes gets reverse biased.

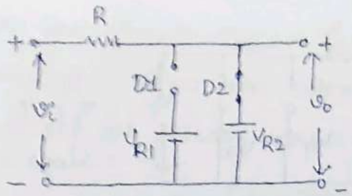
hence D1 is off and D2 is off.



$v_o = v_i$

Slope = 1

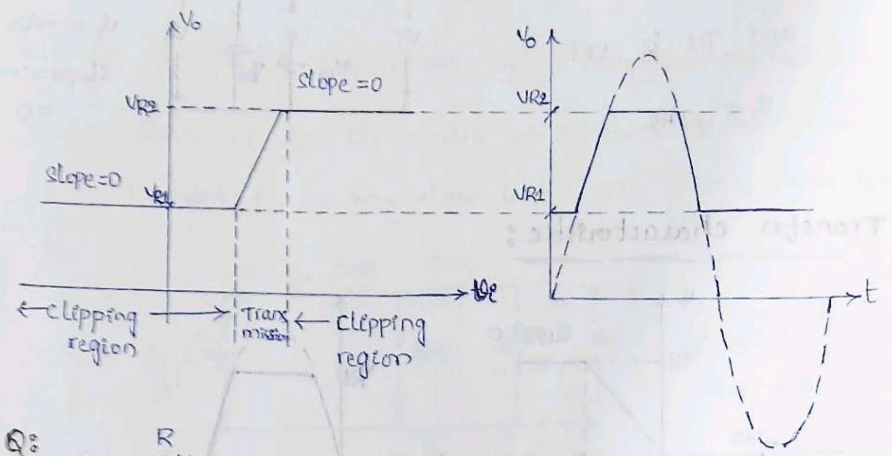
(c) for $v_i > V_{R2}$, D2 conducts and D1 is OFF.



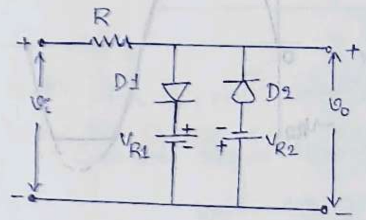
$v_o = V_{R2}$

slope = constant = 0

Transfer characteristic :



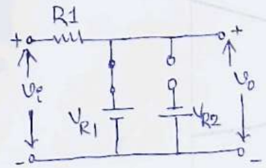
Q:



Working: The diode D1 conducts when $v_i > V_{R1}$ and D2 Conducts $v_i < -V_{R2}$.

(a) when $v_i > V_{R1}$ D1 is ON, and D2 is Off.

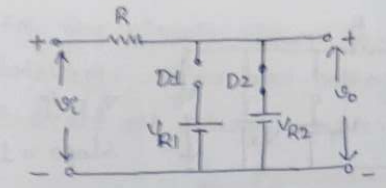
$v_o = V_{R1}$



$v_o = V_{R1}$

Slope = constant

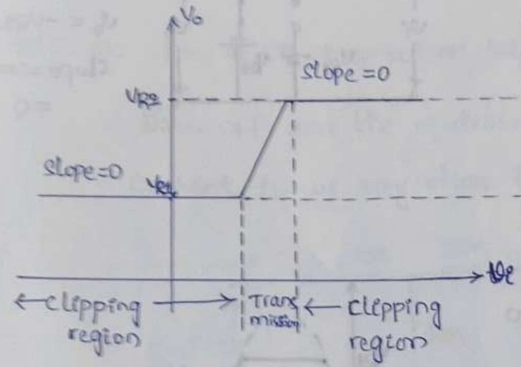
slope = 0

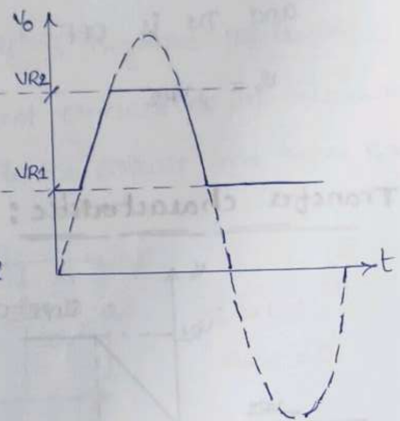


$v_o = V_{R2}$

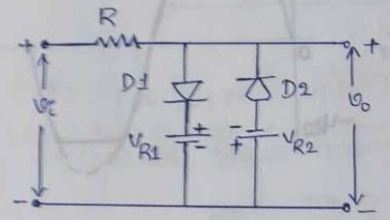
slope = constant = 0

Transfer characteristic :





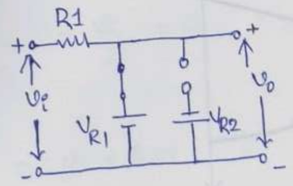
Q:



Working: The diode D1 conducts when $v_i > V_{R1}$ and D2 Conducts $v_i < -V_{R2}$.

(a) when $v_i > V_{R1}$ D1 is ON, and D2 is off.

$v_o = V_{R1}$



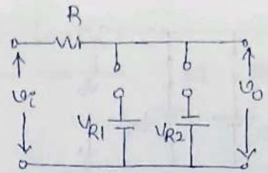
$v_o = V_{R1}$

slope = constant

slope = 0

(b) when $-V_{R2} < v_i < V_{R1}$ both the diodes are off.

$v_o = v_i$

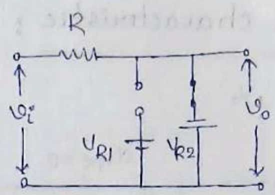


$v_o = v_i$

slope = 1

(C) when $v_i < -V_{R2}$, D_2 is ON and D1 is off.

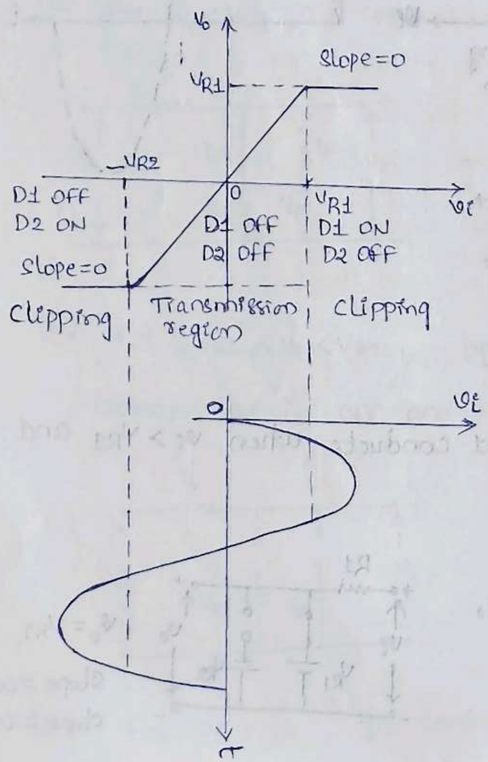
$v_o = -V_{R2}$

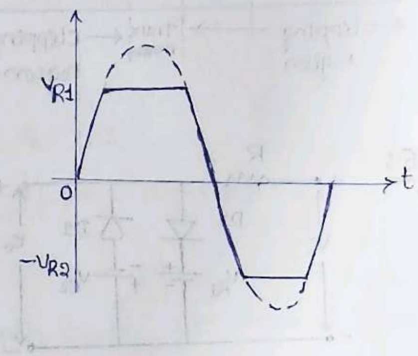


$v_o = -V_{R2}$

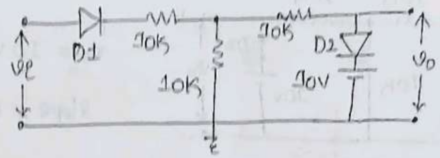
slope = constant = 0

Transfer characteristic :

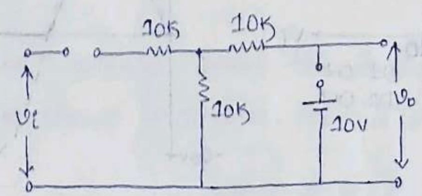




Q For the circuit shown in figure plot v_o vs v_i indicating all intercepts, slopes and voltage levels. Also sketch v_o, if $v_i = 20\sin\omega t$ indicate all voltage levels.



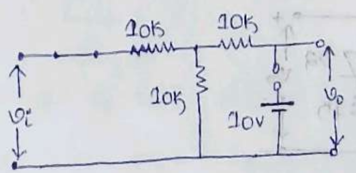
Sol: (a) For $v_i < 0$ i.e when 'v_i' is negative D1 is OFF, D2 is OFF and the equivalent circuit is shown below. No current flows anywhere in the circuit and hence $v_o = 0V$



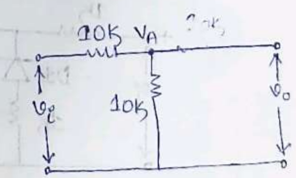
$v_o = 0V$

slope $= 0$

(b) For $v_i > 0$, upto 10V D1 is ON and D2 is OFF. Current flows through D1.



$\approx$



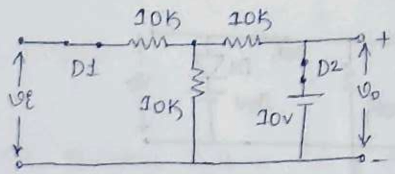
$$v_A = v_i \times \frac{10K}{10K + 10K} = \frac{v_i}{2} = v_o$$

$$V_A = v_o = \frac{v_i}{2} \text{ for } 0 < v_i < 10V \quad ; \quad \frac{v_o}{v_i} = \frac{1}{2}$$

slope $= 0.5$

If $V_A = 10V$; $v_i = 2V_A = 2 \times 10 = 20V$

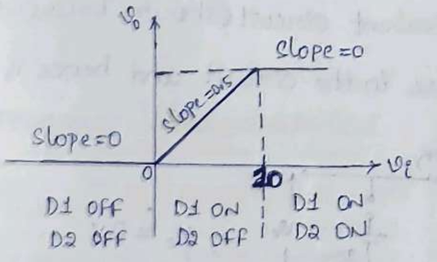
(c) When $v_i > 10V$, v_o rises above 10V D2 starts conducting and v_o is fixed at 10V.

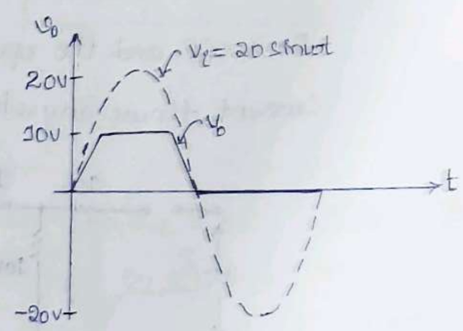


$v_o = 10V$

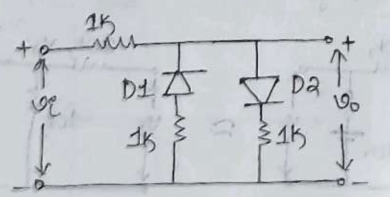
slope = constant = 0

Transfer characteristic and output waveform:



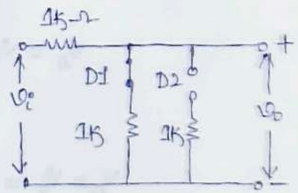


Q draw the transfer characteristic for the circuit shown below. Also draw the output waveform for a sinusoidal input of 20V?



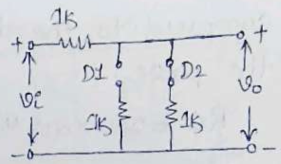
Sol: Case (a): for $v_i < 0$, D1 is ON, D2 is OFF and the output is given by

$$v_o = \frac{v_i (1K)}{1K+1K} = \frac{v_i}{2}$$

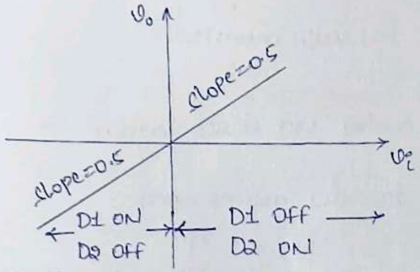


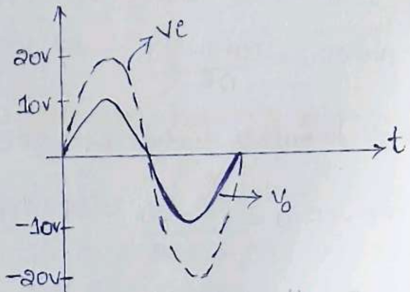
$$slope = \frac{v_o}{v_i} = 1/2$$

Case b) : For $v_i > 0$, D1 is OFF and D2 is ON and the output is given by

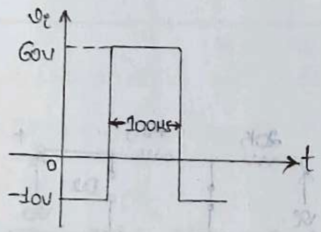


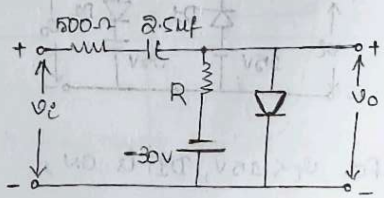
$$v_o = \frac{v_i(1k)}{1k + 1k} = \frac{v_i}{2} = \frac{v_i}{2} \; ; \; \text{Slope} = \frac{v_o}{v_i} = 1/2$$





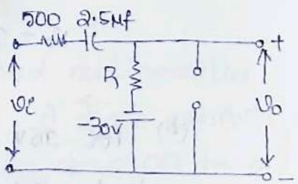
Q. Sketch the voltage across the diode of figure shown below for the input shown in figure. for the diode used $V_r = 0.6$ V and $R_f = 100\Omega$?





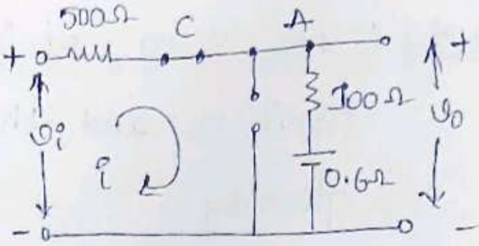
Sol : (a) For the circuit shown in figure

when the input level is -10V, the diode 'D' is reverse biased.



So the output voltage is given by $v_o = -30$ V

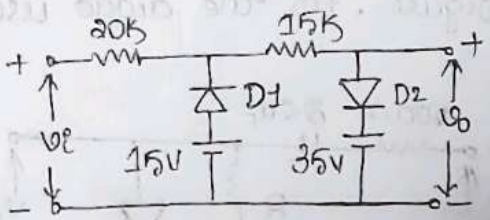
(b) when the input v_i goes to +60V, the capacitor cannot charge as its time constant is very large compared to the duration of the pulse.



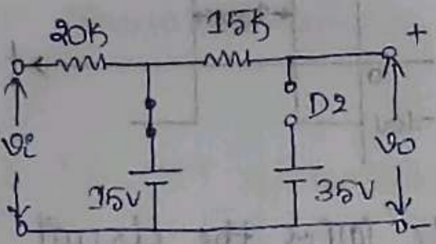
$RC = 500 \times 2.5\mu f = 1250\mu s$

Since $R >> R_f$, the entire current 'I' flows through 'R_f' only.

Q For the circuit shown in figure, 'v_i' is a sinusoidal voltage of 60V. Assuming ideal diodes, sketch one cycle of output voltage. determine the maximum diode currents?

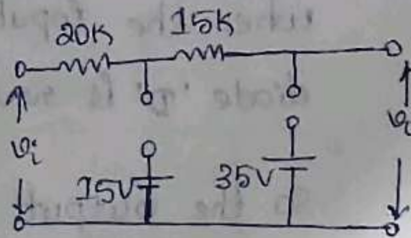


Sol: (a) for $v_i < 15V$, D1 is ON, D2 is off and $v_0 = 15V$



$v_0 = 15V$; slope = constant $= 0$

(b) for $15V < v_i < 35V$ both the diodes D1 and D2 are off.

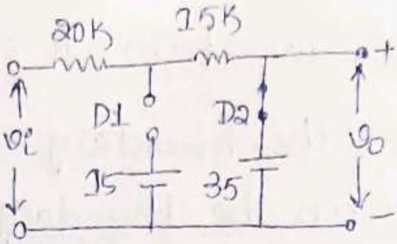


$v_0 = v_i$

Slope $= 1$

(C) For $v_i > 35V$, D1 is OFF, D2 is ON and $v_o = 35V$

Slope = constant = 0

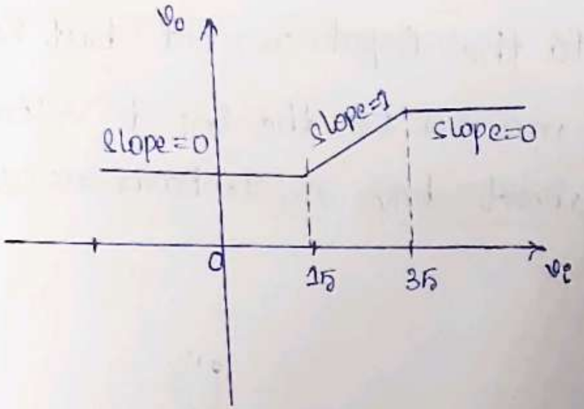


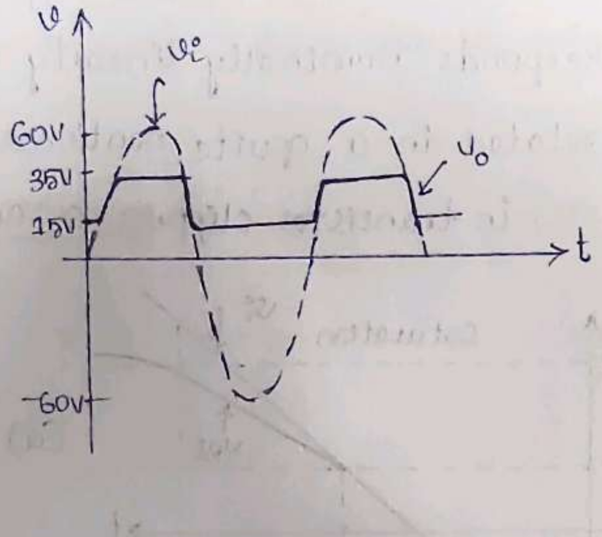
⇒ when D1 is ON when $v_i < 15V$. The lowest value of v_i is -60V

maximum current through D1 = $\frac{15-(-60)}{20} = 3.75mA$

⇒ when D2 is ON when $v_i > 35V$. The highest value of v_i is 60V

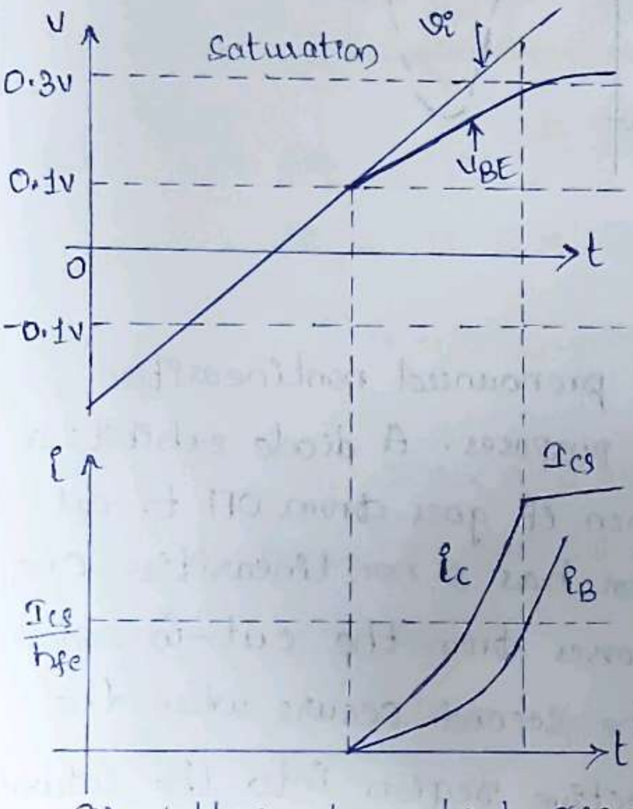
maximum current through D2 = $\frac{60-35}{20+15} = 0.714 mA$

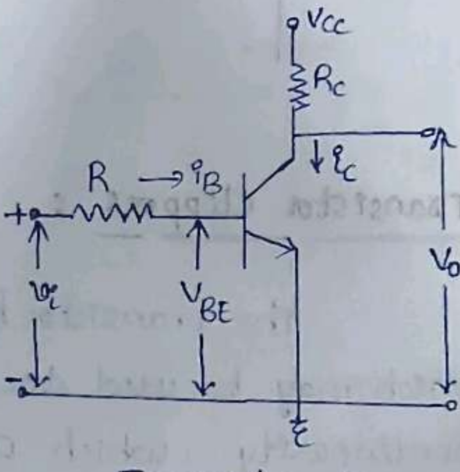




Transistor clippers :

The transistor has two pronounced nonlinearities which may be used for clipping purposes. A diode exhibits a nonlinearity, which occurs when it goes from OFF to ON. On the otherhand, the transistor has 2 non linearities. One occurs when the transistor crosses from the cut-in region into the active region and the second occurs when the transistor crosses from the active region into the saturatio-n region. Therefore, if the peak-to-peak value of the input waveform is such that it can carry the transistor across the boundary between the cut-in and active regions or across the boundary between the active and saturation regions, a portion of the input waveform will be clipped. Normally it is required that the portion of the input waveform, which keeps the transistor in the active region shall appear at the output without distortion. In that case it is required that the input current rather than the input voltage be the waveform of the signal of interest. The reason for this requirement is that over a large signal excursion in the active region, the transistor o/p current responds nominally linearly to the input current but is related in a quite nonlinear manner to the input voltage. So, in transistor clippers a current drive needs to be used.





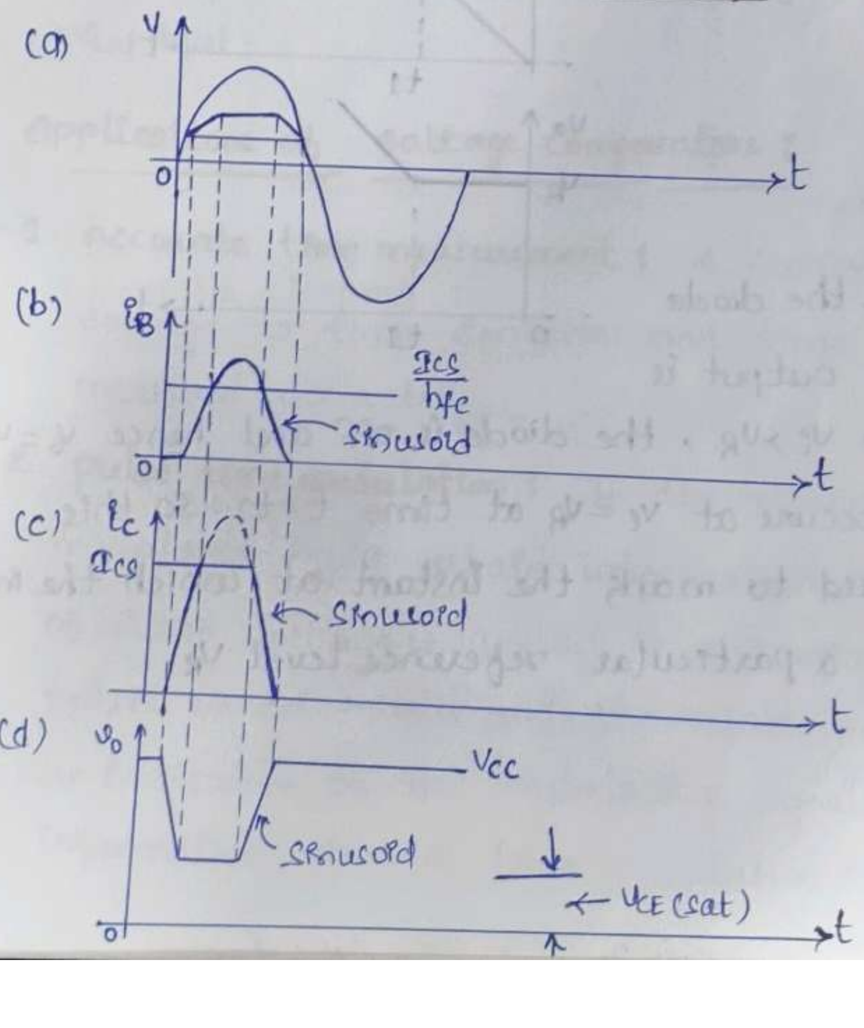
Transistor clipper

(a) voltage V_{BE} which results when a ramp input drives the transistor from cut off to saturation (b) The base and collector currents

A transistor clipper is shown below the figure, 'R' represents either the signal source impedance or a resistor deliberately introduced must be large compared with the input resistance of the transistor in the active region. under these circumstances, the input base current will very nearly have the waveform of input voltage, because the base current is given by $i_B = (v_i - V_r)/R$

If a ramp signal v_i which starts at a voltage below cutoff and carries the transistor into saturation is applied, the base voltage, base current and collector current waveforms of the transistor clipper are shown in figures (a) & (b)

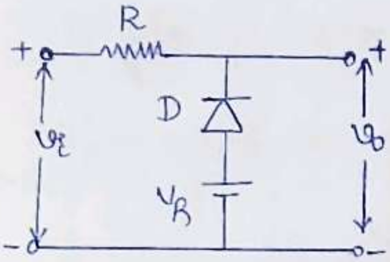
Waveforms of sinusoidal voltage:

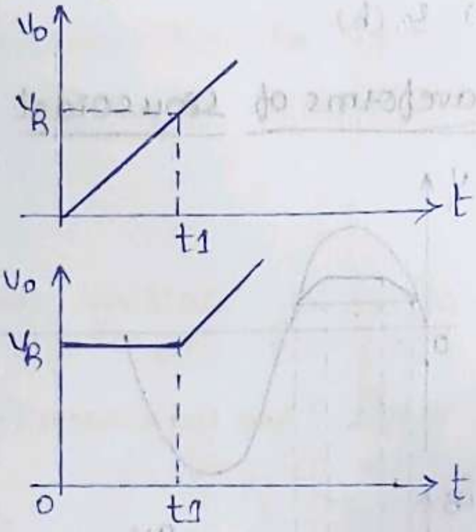


(a) input voltage v_i and the base to emitter voltage V_{BE} (b) the base current i_B (c) the collector current i_C and (d) the output voltage v_o.

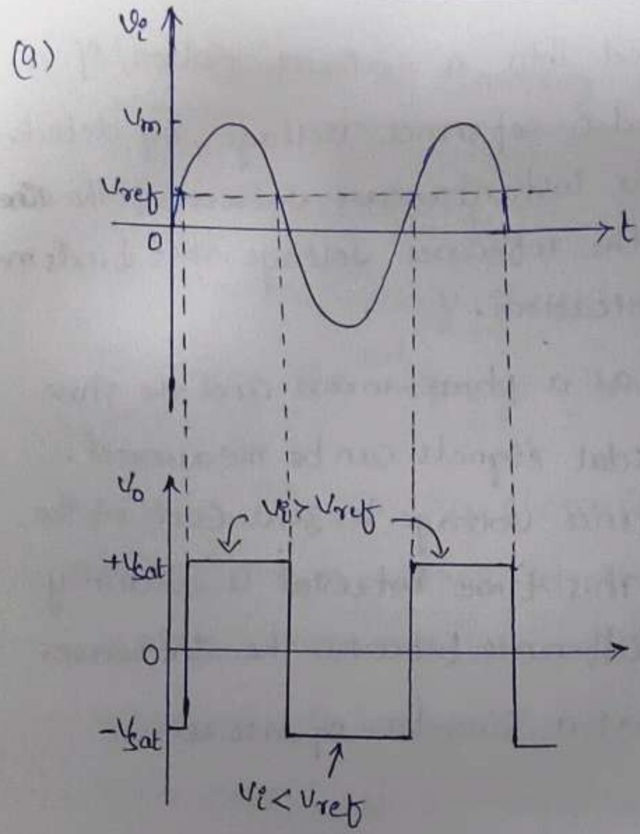
Comparator: A clipper may also be used as a comparator. Basically a comparator is a circuit which can be employed to mark the instant when an arbitrary waveform attains a certain reference level.

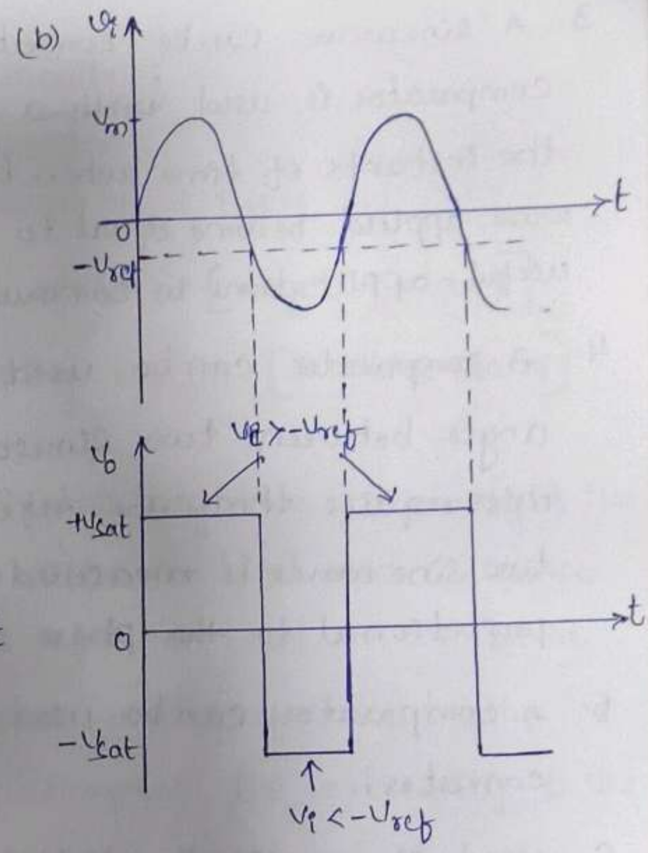
The basic difference between clipper and a comparator is that whereas in clipper circuit, a signal is clipped at the desired level, in comparator there is no such interest involved in reproducing any desired portion of the signal.





As long as $v_i < V_R$, the diode 'D' is ON and the output is fixed at V_R. When $v_i > V_R$, the diode is off and hence $v_o = v_i$. The breakdown occurs at $v_i = V_R$ at time $t = t_1$. So this circuit can be used to mark the instant at which the input voltage reaches a particular reference level V_R.





from the above two circuits as long as $v_i < v_{ref}$ the output is at $-V_{sat}$ level and $v_i > v_{ref}$ the output is at $+V_{sat}$ level.

Applications of voltage comparators:

1. **Accurate time measurement:** A comparator can be used as voltage to time converter and time intervals can be measured accurately.
2. **Pulse time modulation:** If the reference voltage is modulated by a certain information and a periodic waveform of sweep voltage is applied to a comparator, a train of pulses would result and the relative spacing of the pulses is an indication of the modulating signals containing the information. Thus a time modulation system can be obtained.

3. A sinewave can be converted into a series of pulses, if a comparator is used with a d.c reference voltage, by detecting the instants of time when the instantaneous values of the sine wave applied become equal to the reference voltage. This finds many useful applications in communications.

4. A comparator can be used as a phase-meter and the phase angle between two sinusoidal signals can be measured. Each of the this requires that the reference voltage be zero. two sine waves is measured. This time interval is evidently proportional to the phase difference between the sine waves.

5. A comparator can be used as a sine-to-square wave converter.

6. used as amplitude distribution analyser.

7. Comparator finds use as an analog to digital converter.

Clamping circuits :

We know that a capacitor blocks the passage of direct current. Hence when a non sinusoidal, periodic signal is transmitted through a capacitive coupling circuit, it loses it's d.c component. If it is neccessary to restore to the signal it's d.c component at a later stage, the signal needs to be passed through a clamping circuit. Since the clamping circuit restores or reinserts the lost d.c component, it is also termed as d.c restorer or d.c inserter

Classification of clamping circuits :

Basically clamping circuits are of 2 types

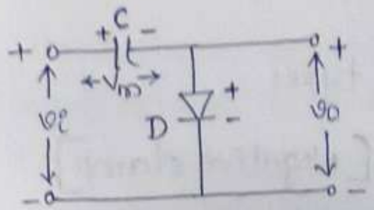
(1) Positive peak voltage clamping circuits [Negative clamp]

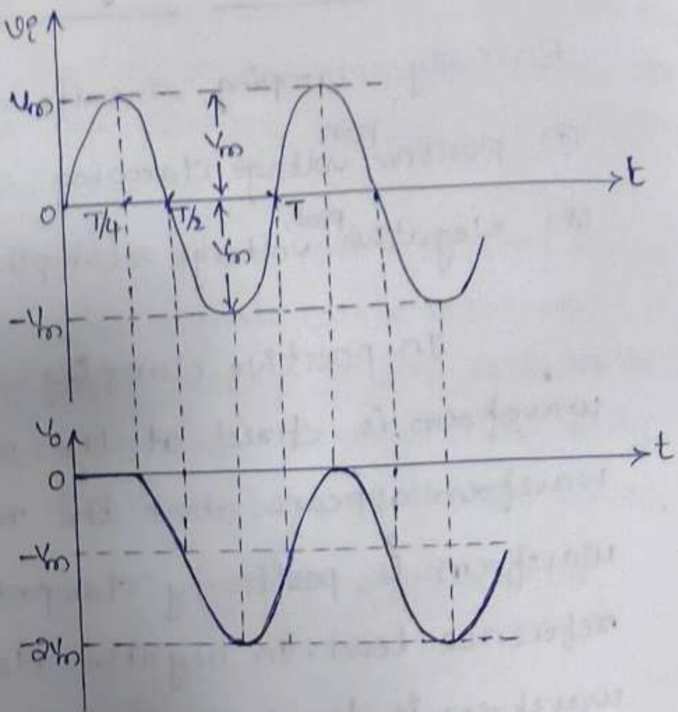
(2) Negative peak voltage clamping circuits [positive clamp]

In positive clamping the negative extremity of the waveform is fixed at the reference level and the entire waveform appears above the reference level i.e the output waveform is positively clamped with reference to the reference level. In negative clamping the extremity of the waveform is fixed at the reference level and the entire waveform appears below the reference i.e the output waveform is negatively clamped with respect to the reference level. The capacitors are essential in clamping circuits. "The difference between the clipping and clamping circuits is that while the clipper clipps off an unwanted portion of the input waveform, the clamper simply clamps the maximum positive or negative peak of the waveform to a desired level". There will be no distortion of waveform.

Negative Clamp [positive peak clamper]:

This is also termed as positive peak clamper, since the circuit clamps the positive peak of a signal to zero level. This type of clamper introduces a negative d.c value. Hence the name "negative clamp".





$v_i - V_c - V_D = 0$ $[V_D = V_o]$

$v_o = v_i - V_c$ $[V_c = V_m]$

for $v_i = 0 \Rightarrow V_o = 0 - V_m = -V_m$

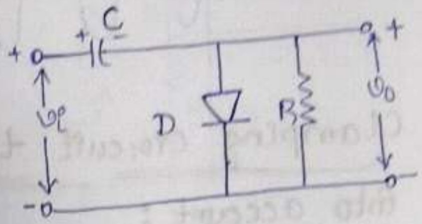
for $v_i = V_m \Rightarrow V_o = V_m - V_m = 0$

for $v_i = -V_m \Rightarrow V_o = -V_m - V_m = -2V_m$

During the first quarter cycle, the input signal rises from zero to maximum value. The diode conducts during this time and since the diode is ideal diode [$R_f = 0$ and $V_f = 0$] the voltage across it is zero. The capacitor 'C' is charged through the series combination of the signal source and the diode voltage across 'C' rises sinusoidally. At the end of the first quarter cycle, the voltage across the capacitor $V_c = V_m$.

After the first quarter cycle, the peak has been passed and the input signal begins to fall, the voltage 'V_c' across the capacitor is no longer able to follow the input, because there is no path for the capacitor to discharge. Hence the voltage across the capacitor remains constant at $V_c = V_m$ and the charged capacitor acts as a voltage source of 'V' volts and after the first quarter cycle, the output is given by $V_0 = V_i - V_m$. During the succeding cycles, the positive extremity of the signal will be clamped or restored to zero and the output waveform shown in figure results.

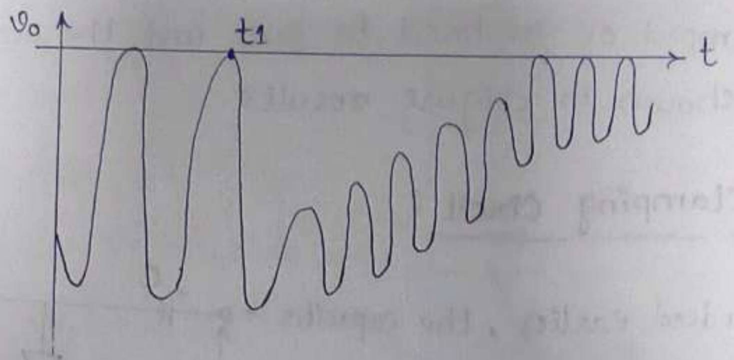
Modified clamping circuit :



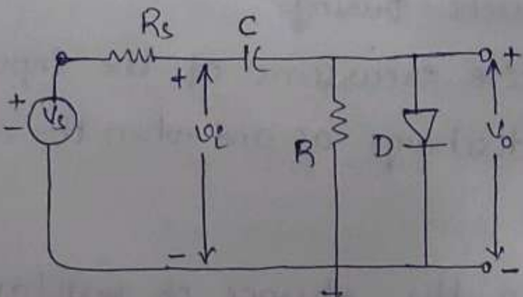
As studied earlier, the capacitor charges to voltage V_m at the end of the first quarter cycle, during which the diode conducts. During the subsequent positive excursions of the input signal, the capacitor cannot discharge as and when the amplitude goes below V_m.

This is due to the absence of resistance through which the capacitor can discharge. Inorder to enable the capacitor to descharge, either the capacitor or the diode must be shunted by a suitable resistance. The more usual practice is to have a resistance across the diode as shown in figure.

If after attaining steady state, the amplitude of the input signal is abruptly decreased as $t = t_1$ in the figure, it is found that a transient state results and the positive peaks which were their to clamped at zero level, no longer attain zero. However, as the capacitor discharges due to the diminition of the signal amplitude the voltage across 'C' decreases exponentially. The positive peaks approach zero progressively.

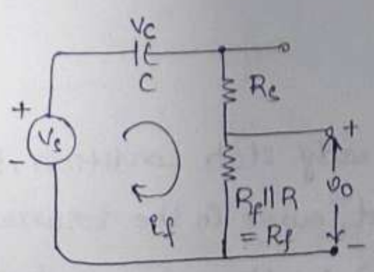


Clamping circuit taking source and diode resistance into account :

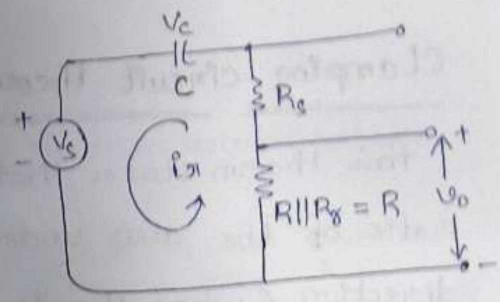


In the discussion of clamping circuit, we neglected the output resistance of the source as well as the diode farward resistance. Many times these forward resistances cannot be neglected. figure above shows a more realistic clamping circuit taking into consideration the output resistance resistance of the source R_s, which may be negligible or may range upto many thousands of ohms depending on the source, and the diode forward resistance

'R_f' which may range from tens to hundreds of ohms. Assume that the diode break point 'V_γ' occurs at zero voltage. The precision of operation of the circuit depends on the condition that $R >> R_f$ and $R_r >> R$. When the input is +ve, the diode is ON and when the input is -ve, the diode is OFF.

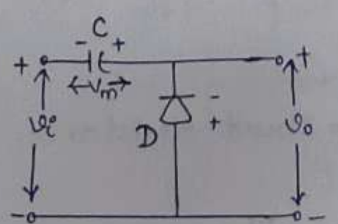


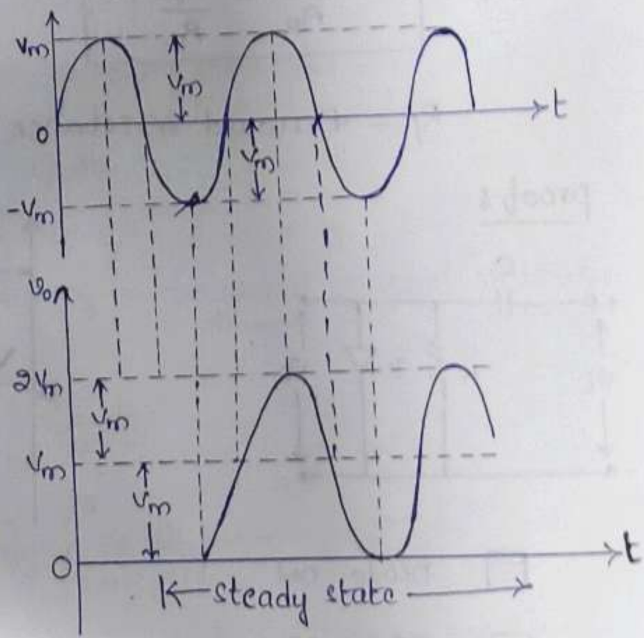
(a) when diode is conducting



(b) when diode is not conducting

positive clamper [Negative peak clamper]:





$v_i + v_m - v_0 = 0 \quad (v_D = v_0)$

$v_0 = v_i + v_m$

for $v_i = 0$; $v_0 = v_m$

for $v_i = -V_m$ the diode conducts and $v_0 = 0$

for $v_i = V_m \Rightarrow v_0 = 2v_m$

Always start the analysis from the conducting point of the diode. here the diode conducts only when $v_i = -V_m$ i.e peak value of the input and the capacitor charged to $-V_m$. Under steady state conditions, the capacitor acts as a constant voltage source and the output is given by

$$v_0 = v_i + V_m$$

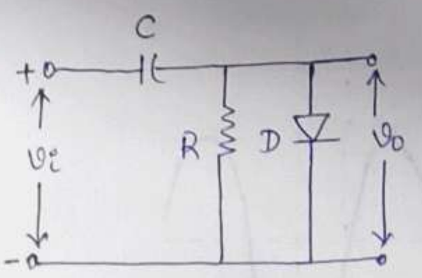
Clamping circuit theorm:

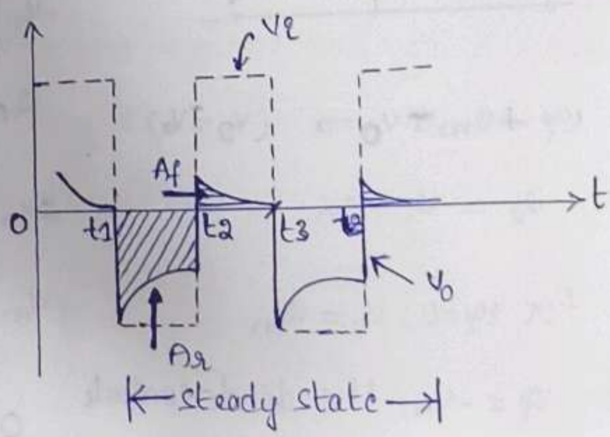
This theorm states that under steady state condition, the ratio of the area under the output curve in the forward direction (when the diode conducts) to the area under the output curve in the Reverse direction (when the diode does not conduct) is given as

$$\frac{A_f}{A_R} = \frac{R_f}{R}$$

R_f = forward resistance ; R = shunt resistance.

proof:





Diode ON

Diode Off

Referring to the above shown figure, we see that the diode 'D' is 'OFF' during the interval from t_1 to t_2. Hence the capacitor 'C' discharges.

Let 'i_r' denotes the discharge current. The charge Lost in the time interval t_1 to t_2 is given as

$$q = \int_{t_1}^{t_2} i_r \, dt$$

But $i_r = \frac{V_r}{R}$; where V_R = reverse output voltage

$$q = \int_{t_1}^{t_2} \frac{V_r}{R} \, dt$$

$$q = \frac{1}{R} \int_{t_1}^{t_2} V_r \, dt \quad \text{——— (1)}$$

In the interval t_2 to t_3 the diode is 'ON'. Hence the capacitor charges and regains the lost charge.

Let i_f denote the charging current

$$q' = \int_{t_2}^{t_3} i_f \, dt$$

But $i_f = \frac{V_f}{R_f}$; where V_f = forward output voltage

$$q' = \int_{t_2}^{t_3} \frac{V_f}{R_f} \, dt$$

$$= \frac{1}{R_f} \int_{t_2}^{t_3} V_f \, dt \quad \text{——— (2)}$$

At steady state charge lost = charge regained

i.e $q = q'$

$$\therefore \frac{1}{R}\int_{t_1}^{t_2} v_r \, dt = \frac{1}{R_f}\int_{t_2}^{t_3} v_f \, dt \quad \text{from (1) \& (2)}$$

But $\int_{t_1}^{t_2} v_r \, dt = A_R$ and $\int_{t_2}^{t_3} v_f \, dt = A_f$

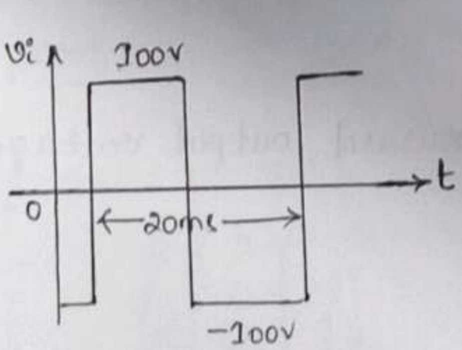
A_f = Area under the output curve in the forward direction with diode ON

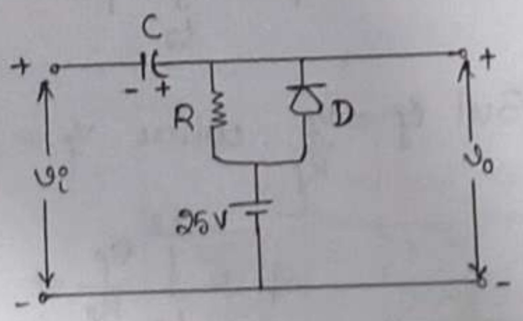
A_r = Area under the output curve in the reverse direction with diode OFF

$$\frac{1}{R} \cdot A_R = \frac{1}{R_f} \cdot A_f$$

(or) $$\boxed{\frac{A_f}{A_R} = \frac{R_f}{R}}$$

Q6 A 100 V peak square wave with a period of 20 ms shown in fig is to be positively clamped at 25 V. draw the circuit diagram neccessary for this purpose. draw the output waveform.

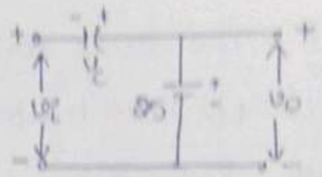




Sol: here 25 V reference voltage connected to the circuit.

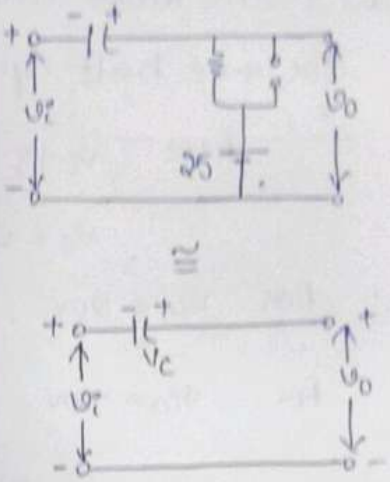
The diode conducts when the input swing goes to -100 V and the capacitor 'C' charges to +125 V in a few cycles.

Step 1: The diode conducts for -ve half-cycle of the input and the equivalent circuit is $v_i = -100V$



here $+(-100) + v_c - 25 = 0 \Rightarrow v_c = 125$ V [when diode FB]

Step 2: The diode will be in OFF state for the +ve half cycle of the input and equivalent circuit is

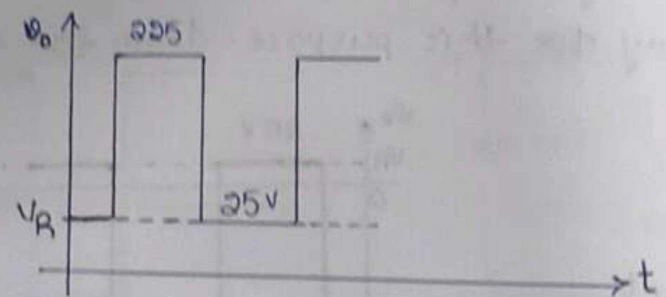


here $v_i + V_c - V_o = 0 \Rightarrow v_o = v_i + v_c$

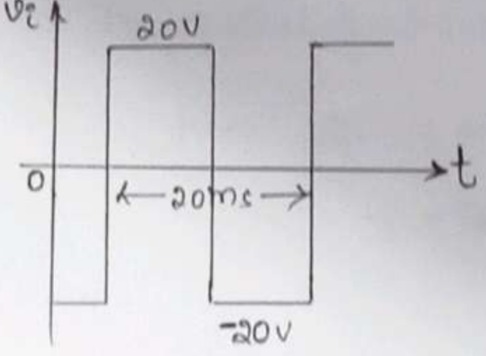
for $v_i = 100V$, $v_o = 100 + 125 = 225$ V

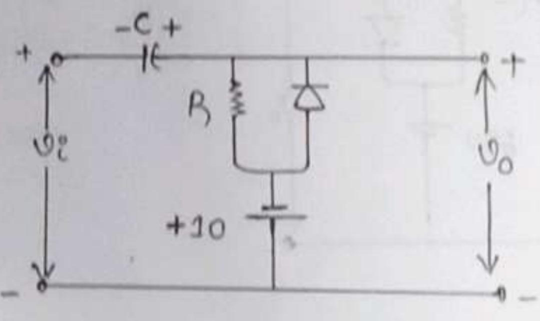
for $v_i = -100V$, $v_o = -100 + 125 = 25$ V

Note: Always start the analysis when diodes gets forward biased.

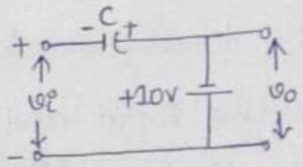


Q8 Sketch the output waveform that would expected from the circuit shown in fig below. when the input is ±20V square.



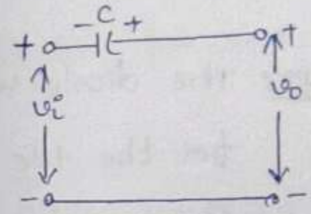


step1: The diode will be forward biased for −ve half cycle of the input. $v_i = -20\,V$



here $+(-20) + v_c + (+10) = 0 \Rightarrow v_c = 10\,V$

step2: The diode will be reverse biased for +ve half cycle of the input.

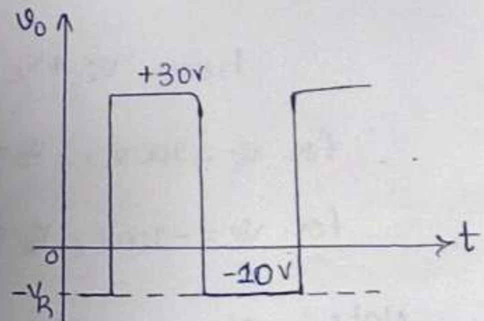


here $v_i + v_c - v_o = 0$

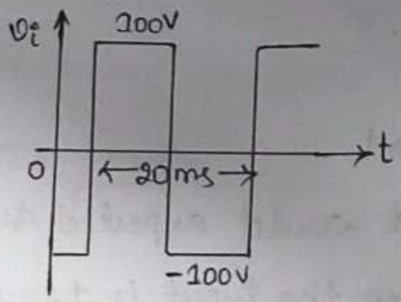
$v_o = v_i + v_c$

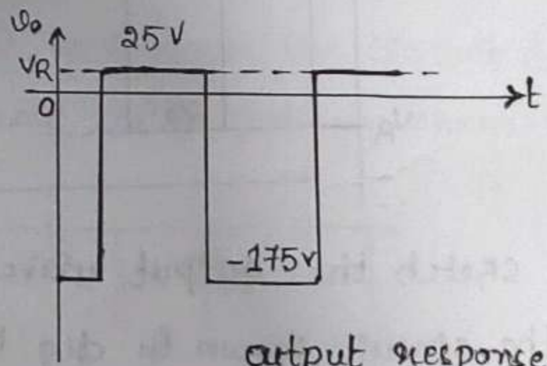
for $v_{in} = 20V$; $v_o = 20 + 10 = 30V$

for $v_{in} = -20V$; $v_o = -20 + 10 = -10V$

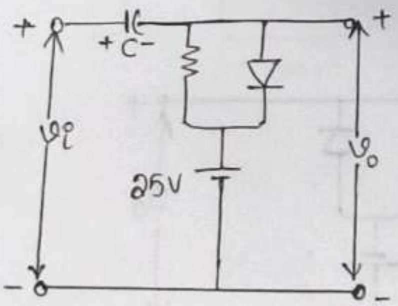


Q: A 100V peak square wave with a period of 20ms shown in figure is to be negatively clamped at 25V. draw the circuit diagram neccessary for this purpose. draw the output waveform?

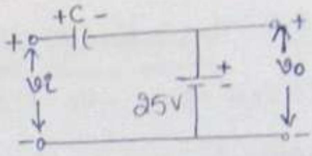




output response

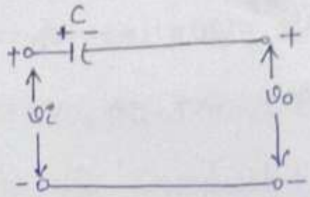


Step1: The diode will be forward biased for +ve half cycle of the input and the equivalent circuit is $v_i = 100\,V$



here $100 - V_c - 25 = 0 \Rightarrow V_c = +75\,V$

Step2: The diode will be reverse biased for -ve half cycle of the input and the equivalent circuit is

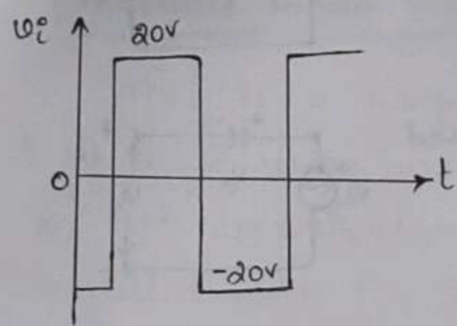


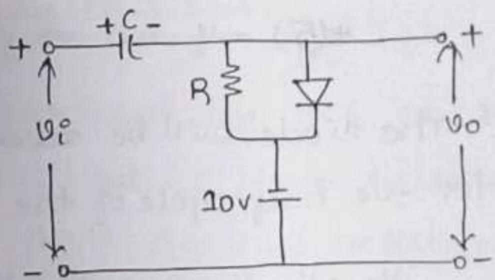
here $v_i - V_c - v_o = 0 \Rightarrow v_o = v_i - V_c$

$v_i = 100V$; $v_o = 100 - 75 = 25V$

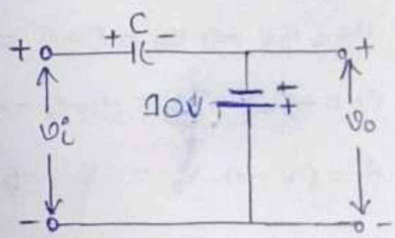
$v_i = -100V$; $v_o = -100 - 75 = -175V$

Q: Sketch the output waveform that would be expected from the circuit shown in figure when the input is a ±20V square wave.





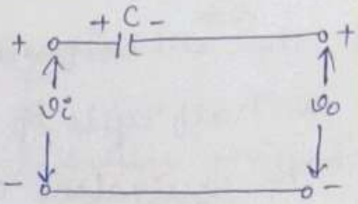
Step1: The diode will be forward biased for +ve half cycle of the input and the equivalent circuit is; $v_i = 20V$



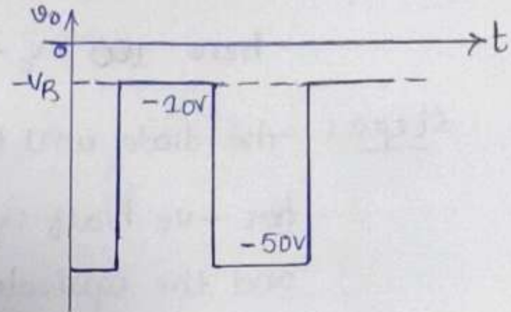
here $20 - V_c + 10 = 0$

$V_c = 30V$

Step 2: The diode will be reverse biased for −ve half cycle of the input.



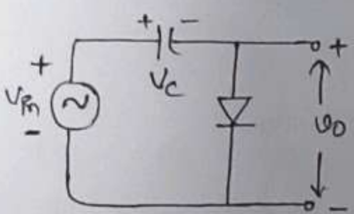
$$v_i - V_C - v_o = 0 \Rightarrow V_o = v_i - V_C$$

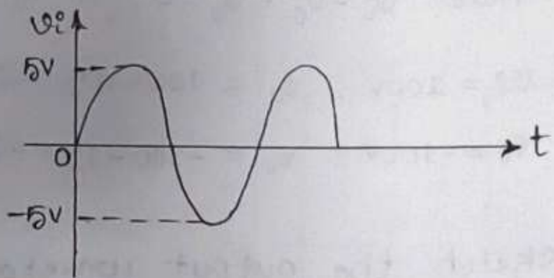


$v_i = 20V \Rightarrow v_o = 20 - 30 = -10V$

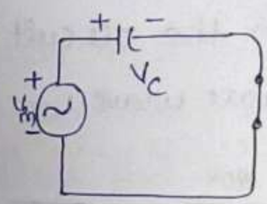
$v_i = -20V \Rightarrow v_o = -20 - 30 = -50V$

Q: Sketch the clamped output across the diode?



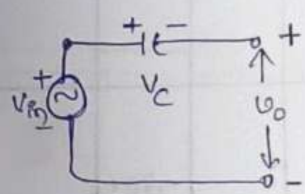


Step 1: The diode will be forward biased for +ve half cycle of the input.



$$+(5) - V_C = 0 \Rightarrow V_C = 5V$$

Step 2: The diode will be reverse biased for −ve half cycle of the input.



$$V_{in} - V_C - V_o = 0 \Rightarrow V_o = V_{in} - V_C$$

$v_i = 5V \Rightarrow v_o = 5 - 5 = 0V$

$v_i = -5V \Rightarrow v_o = -5 - 5 = -10V$

$v_i = 0V \Rightarrow v_o = -V_C = -5$