① * * Wave shaping Circuits : * *

→ Linear wave shaping.

→ Non-linear wave shaping.

Differences :

Linear W.S.C :	Non-linear W.S.C :
* Elements used..	* Elements used ..
R, L, C	diodes, transistors including a cap.
Ex : R.C L.P ckt R.C H.P ckt RL L.P ckt R.L H.P ckt R.L.C ckts.	Ex : * clippers * clampers.

Wave shaping :

It is used to change the shape of the wave form to provide the req. output.

CLIPPERS :

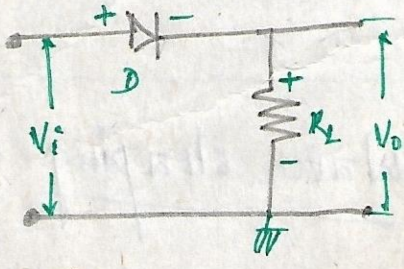
- It is used to limit (or) remove the undesired portion of the wave form.
- Due to this --- it is also called as - amplitude selector's (or) amp. limiter's.

Classification of clipper's :

- Serie's clipper's
- shunt clipper's

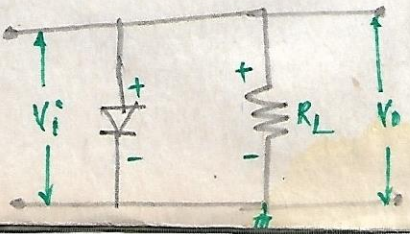
Series clipper :

Here, the diode is connected in series with the load.



shunt clipper :

Here, the diode is connected in shunt (or) parallel with the load.



* Serie's clipper's :

- ⊛ positive peak s.c
- ⊛ negative peak s.c

* Positive peak s.c : *

- → positive peak s.c with out ref voltage
- → positive peak s.c with +ve ref voltage
- → positive peak s.c with -ve ref voltage.

* Negative peak s.c : *

- → Negative peak s.c without ref voltage
- → Negative peak s.c with +ve ref voltage.
- → Negative peak s.c with -ve ref voltage.

CLIPPERS :

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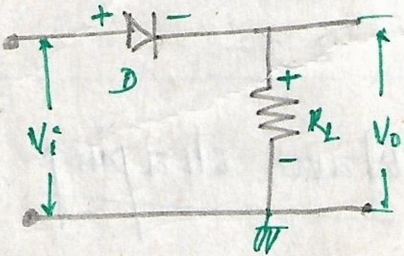

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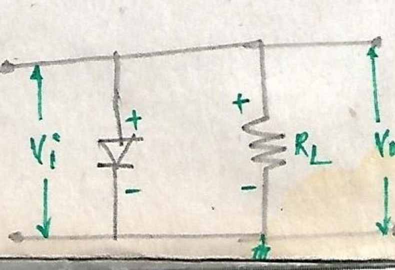
Here, the diode is connected in shunt (or) parallel with the load.



* Serie's clipper's :

- ⊛ positive peak s.c
- ⊛ negative peak s.c

* Positive peak s.c : *

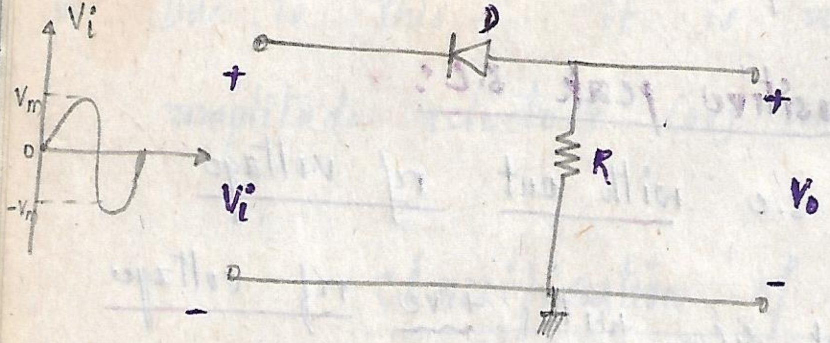
- → positive peak s.c with out ref voltage
- → positive peak s.c with +ve ref voltage
- → positive peak s.c with -ve ref voltage.

* Negative peak s.c : *

- → Negative peak s.c without ref voltage
- → Negative peak s.c with +ve ref voltage.
- → Negative peak s.c with -ve ref voltage.

positive peak s.c :

* positive peak s.c with out ref. voltage: *



where -- "R" → current limiting resistor.

It is used to limit the current through diode --

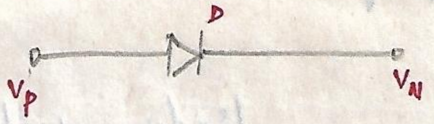
For proper clipping operation --

*** $\boxed{R = \sqrt{R_f \cdot R_r}}$ ***

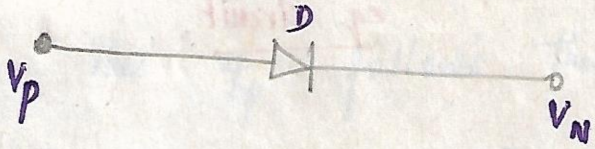
R_f → forward res of a diode

R_r → reverse res of a diode

Ideal characteristics of a diode :



- $R_f = 0$
- $R_r = \infty$
- $V_r = 0$

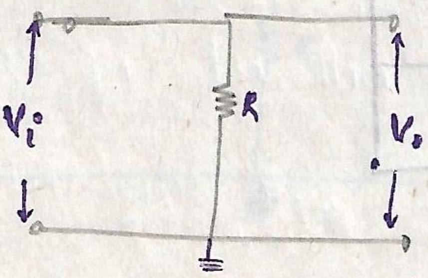


* If ... $V_p < V_N \longrightarrow$ R.B $\longrightarrow$ O.C

* If ... $V_p > V_N \longrightarrow$ F.B $\longrightarrow$ S.C

Analyzing ---

(i) If -- $V_i < 0$ --- diode will be in F.B and it act's as short circuit.

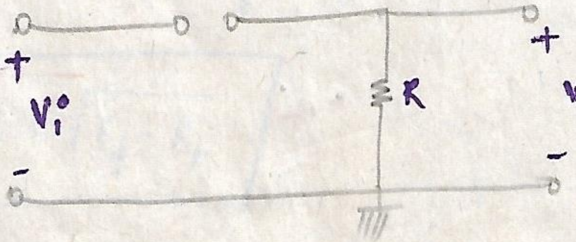


eq. circuit.

In this case ---

$$\boxed{V_o = V_i}$$

(ii) If --- $V_i > 0$ -- diode will be in R.B and it act's as an O.C

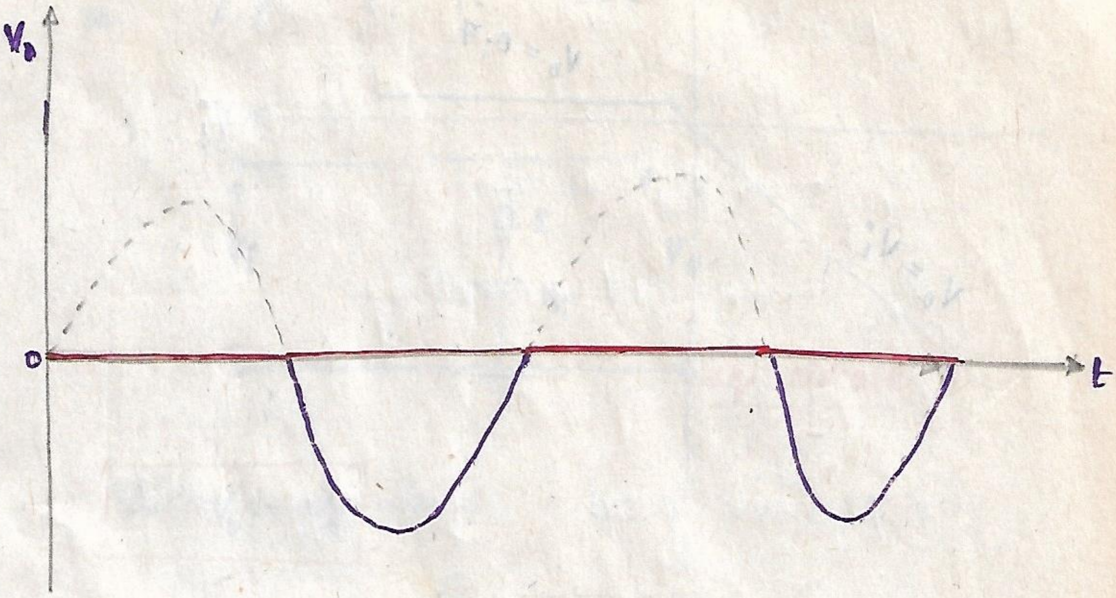


In this case ...

$$\boxed{V_o = 0}$$

since, no current flow's through the "R".

out put wave form's :



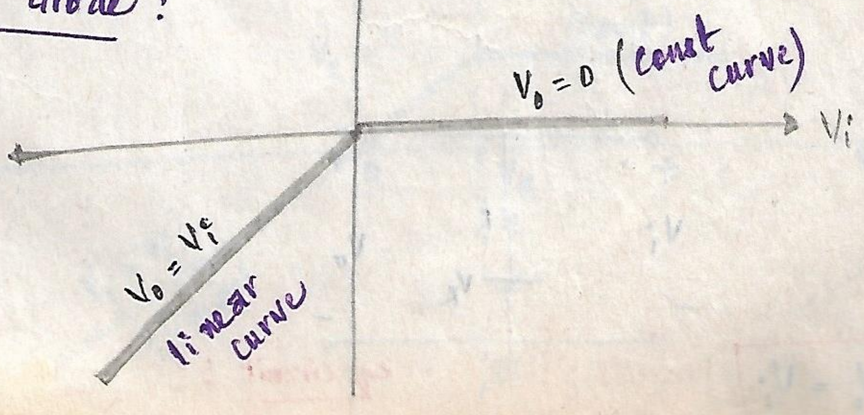
Here.. the o/p follow's the i/p.

* This clipping circuit remove's +ve peak of the wave form. Hence it is called as +ve p.c

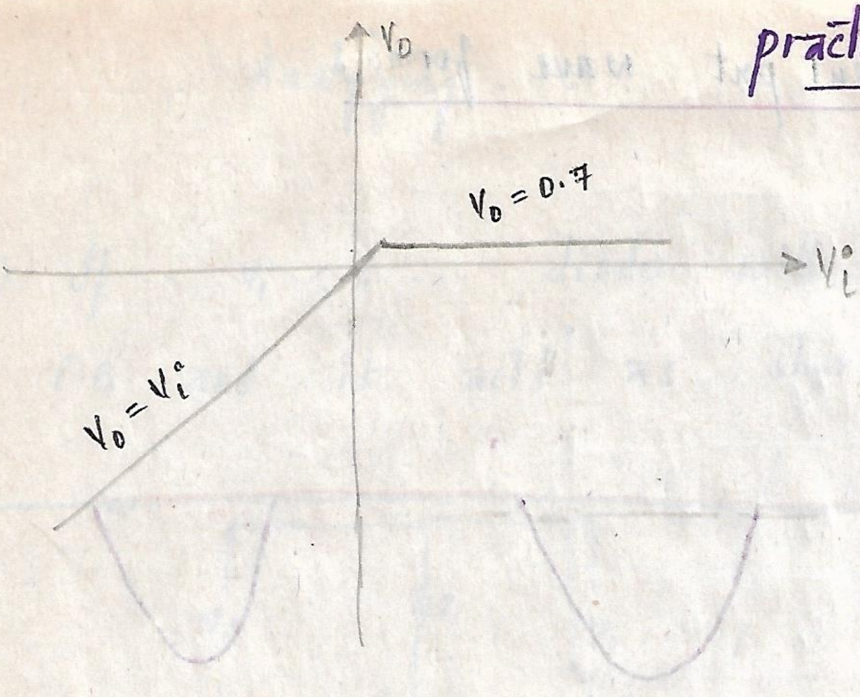
Transfer characteristic's :

It is the plot of V_0 (vs) V_i.

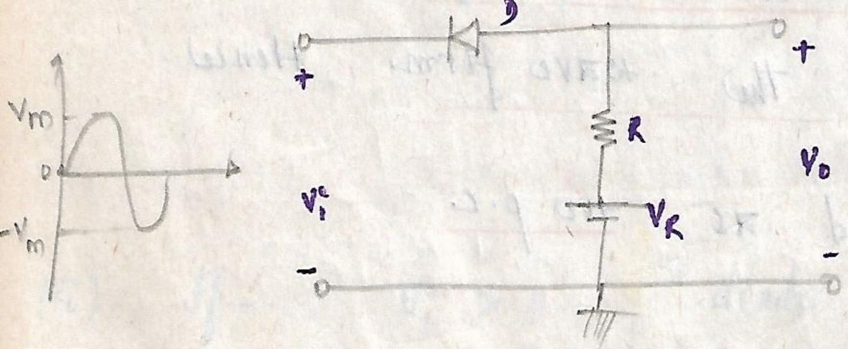
Ideal diode :



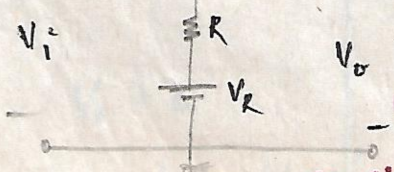
practical diode :



* positive peak s.c with +ve ref voltage: *



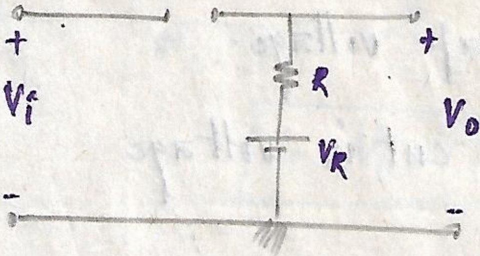
(i) If ... $V_i < V_R$ ... diode will be in F.B & it acts a S.C



$\boxed{\therefore V_o = V_i}$

eq. circuit :

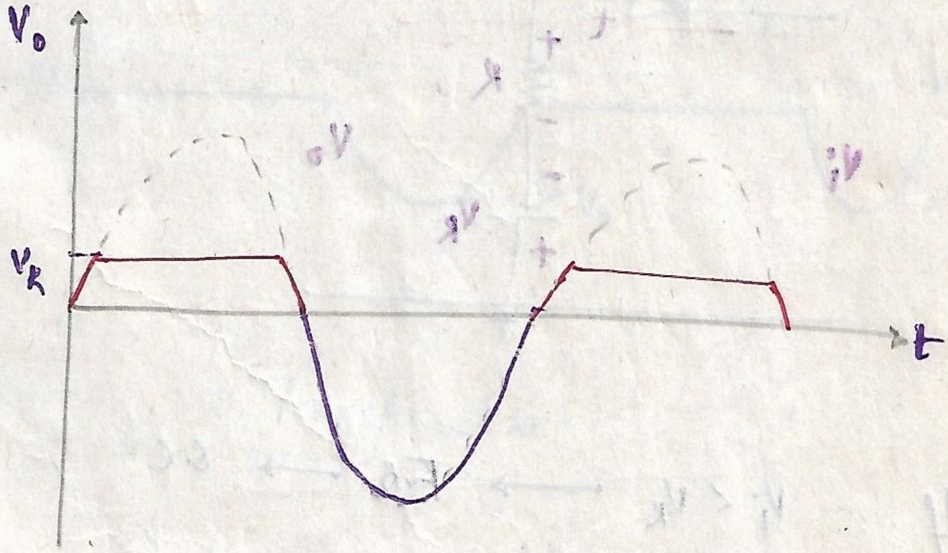
(ii) If ... $V_i > V_R$ .. diode will be in R.B & it acts as O.C



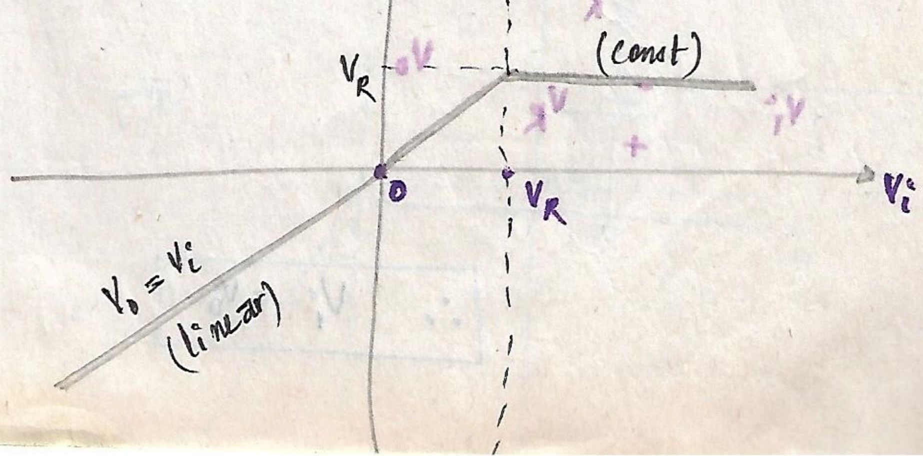
eq circuit.

$$\boxed{\therefore V_0 = V_R}$$

output wave forms:



Transfer characteristics:



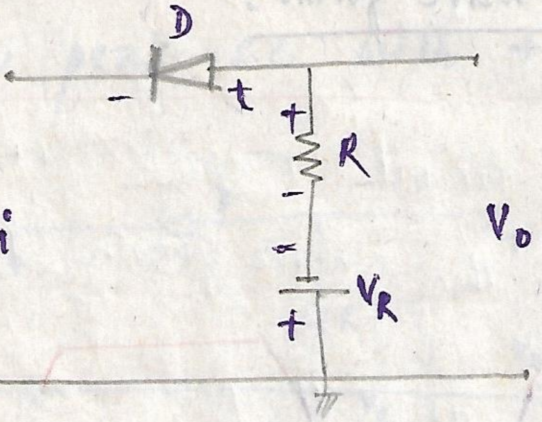
Note :

* For practical diode --- $\boxed{V_R - V_r}$

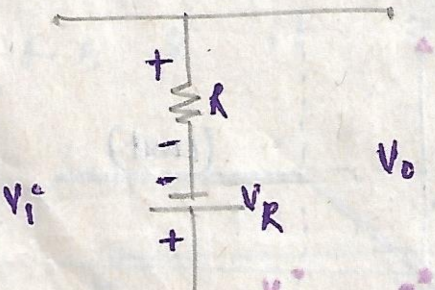
"V_R" ⟶ ref voltage.

"V_r" ⟶ cut in voltage

* positive peak series clipper with -ve ref. voltage: *



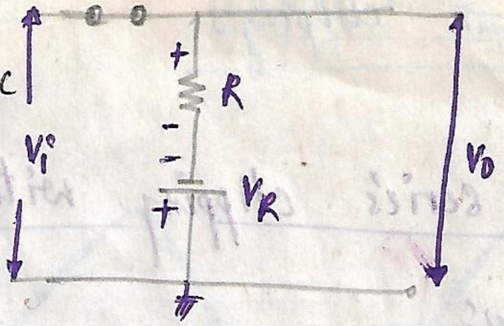
* If ... $V_i < V_R$ ⟶ F.B ⟶ S.C



$\boxed{\therefore \quad V_i = V_0.}$

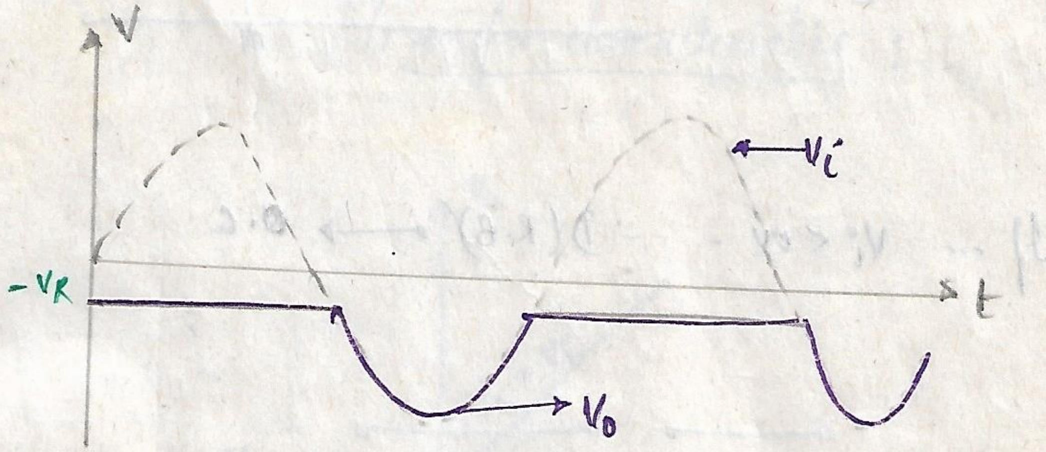
* If $V_i > V_R$

$\longrightarrow R_B \longrightarrow O.C$

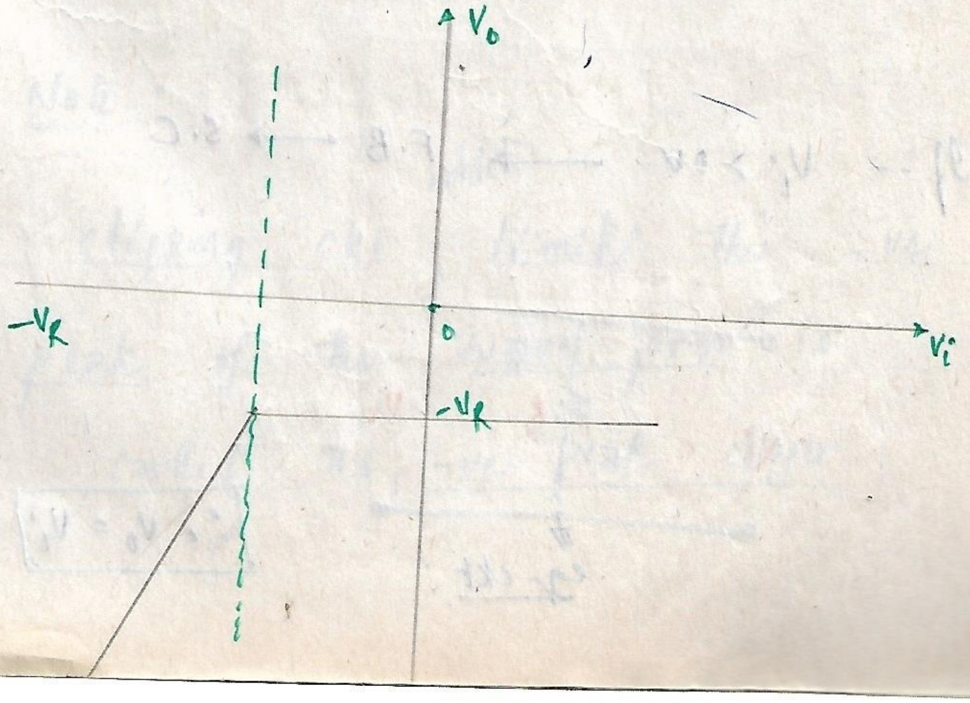


$$\boxed{\therefore\ V_0 = -V_R.}$$

Wave form's :

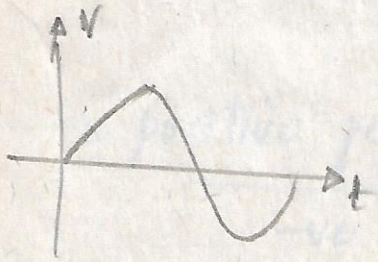


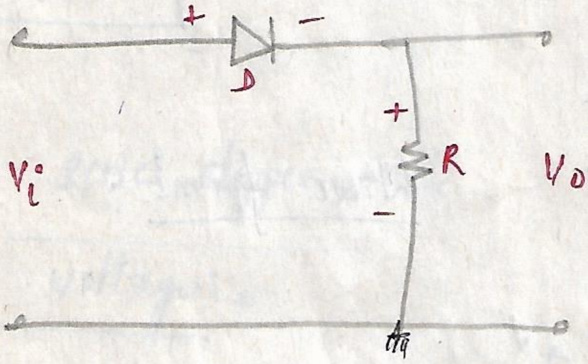
Transfer char :



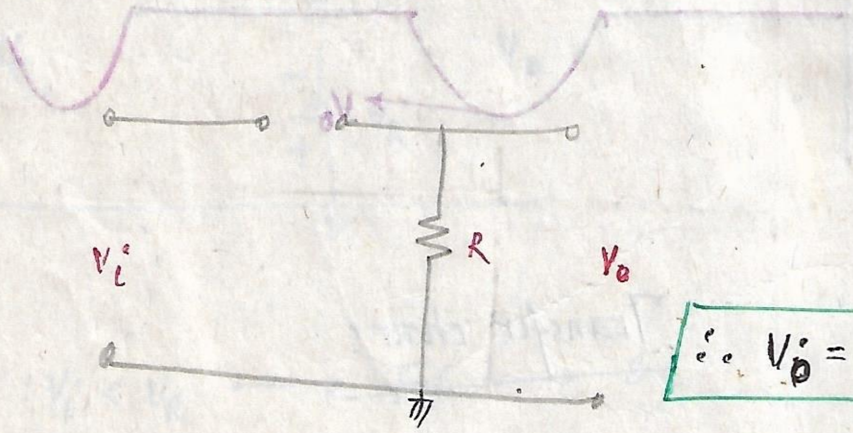
Negative peak clipping:

* -ve peak series clipping with out ref voltage:



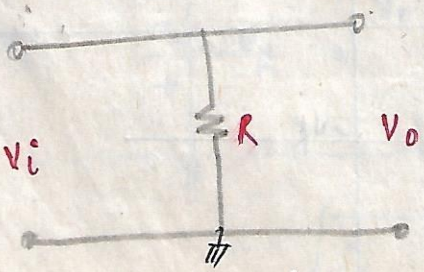


* If -- $V_i < 0V$ --- D(R.B) ⟶ O.C



$\boxed{\therefore V_0 = 0}$

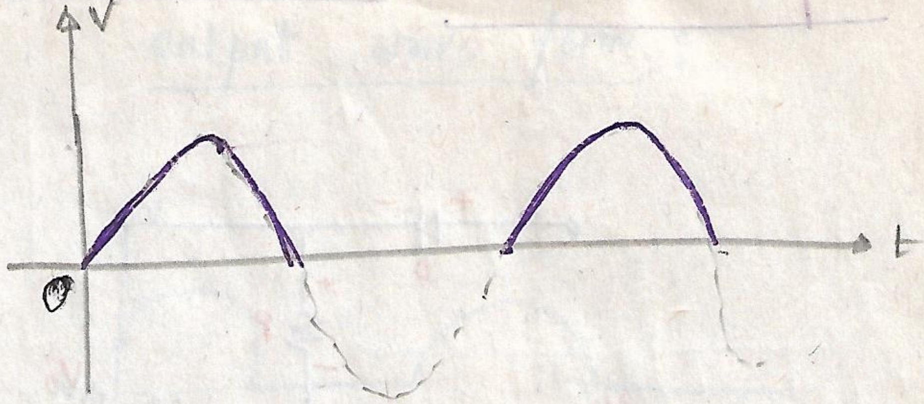
* If -- $V_i > 0V$ ⟶ F.B ⟶ S.C



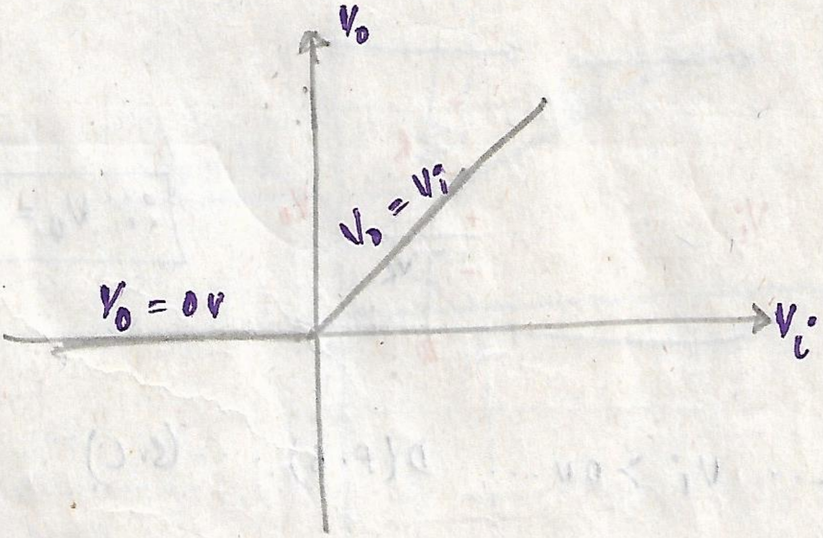
eq ckt:

$\boxed{\therefore V_0 = V_i}$

output wave form :



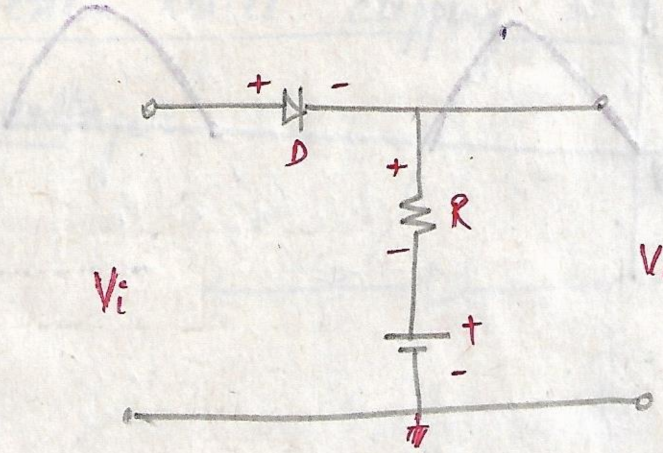
Transfer characteristics :



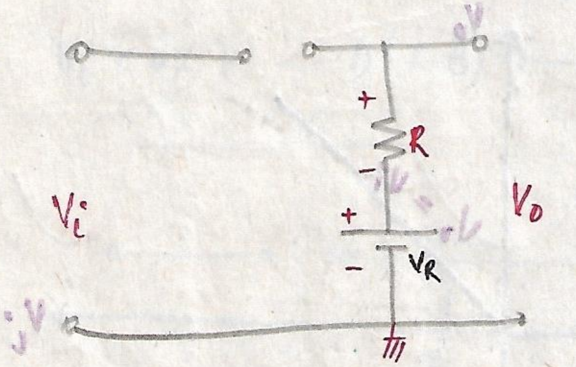
Note :

clipping ckt which limits the -ve peak of the wave form is called as -ve peak clipper.

* -ve peak S.C with +ve ref voltage:

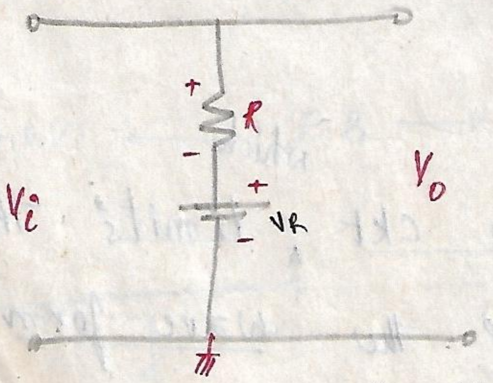


* If --- $V_i < 0V$ --- D (R.B) --- (O.C)



$\therefore V_0 = V_R$

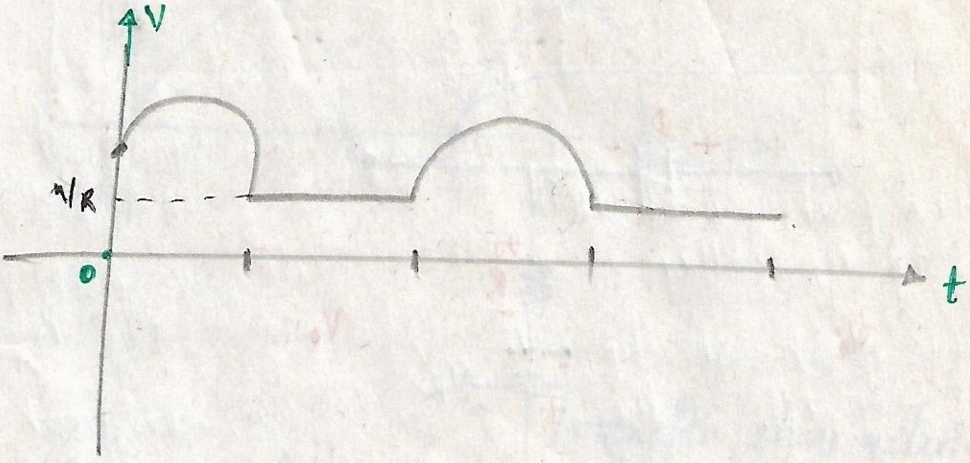
* If --- $V_i > 0V$ --- D (F.B) --- (S.C)



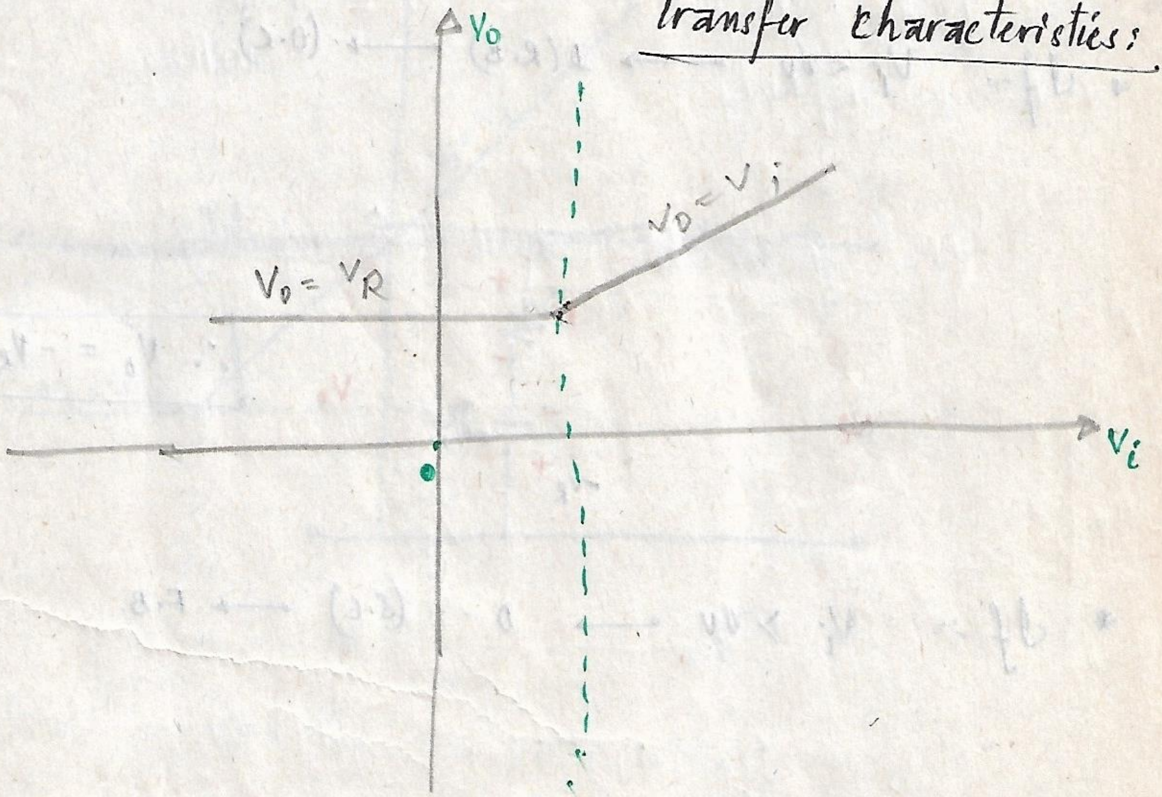
eq ckt

$V_i = V_0$.

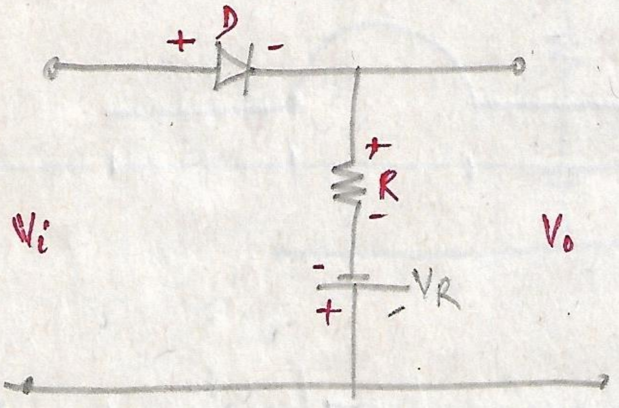
output wave form :



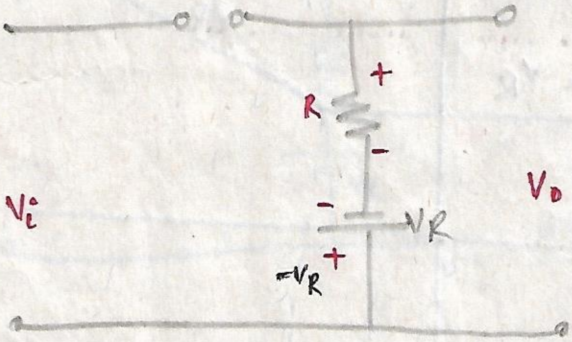
Transfer characteristics:



* -ve peak series clipper with -ve ref voltage:

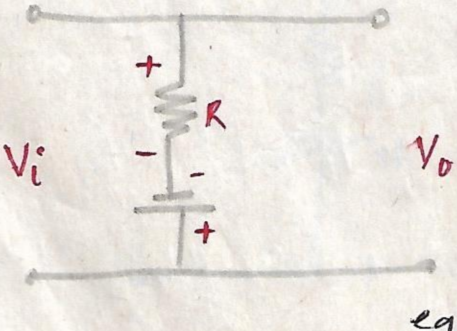


* If -- $V_i < 0V$ ⟶ D (R.B) ⟶ (O.C)



$$\boxed{\therefore V_0 = -V_R}$$

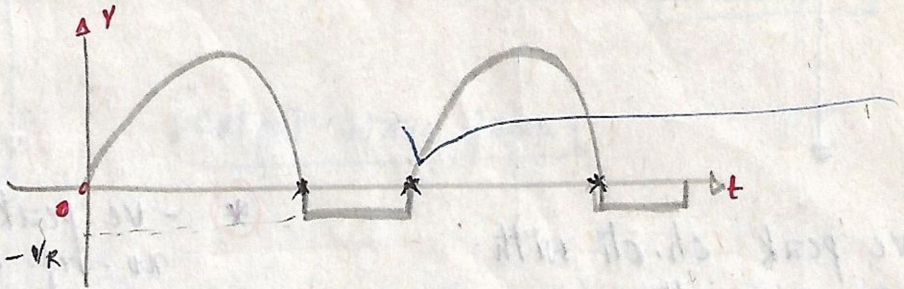
* If -- $V_i > 0V$ ⟶ D -- (S.C) ⟶ F.B.



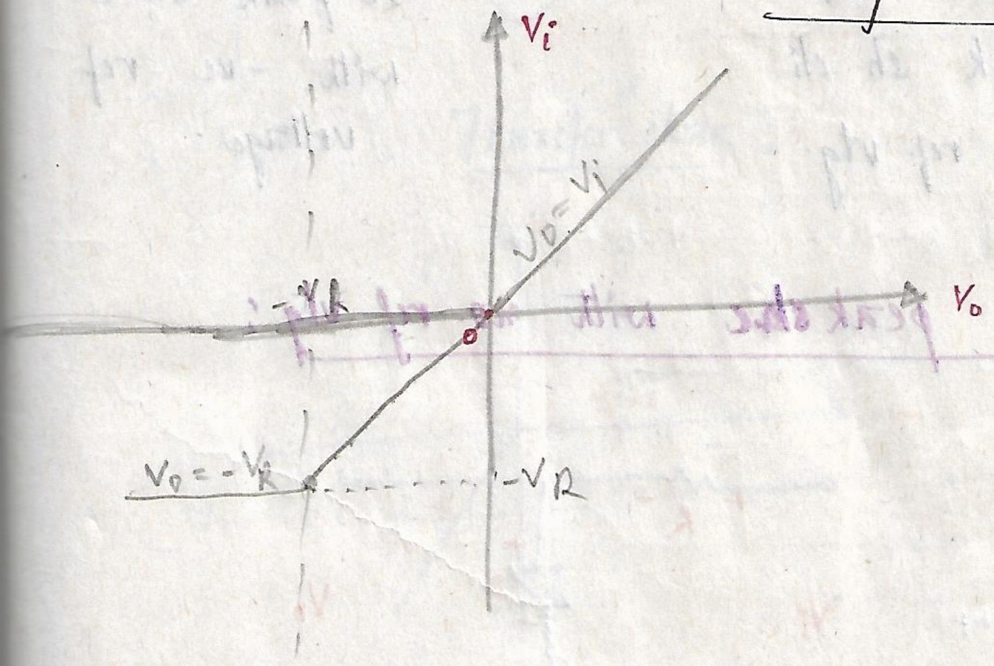
$$\boxed{\therefore V_0 = V_i}$$

eq. ckt.

output wave form :



Transfer characteristics :

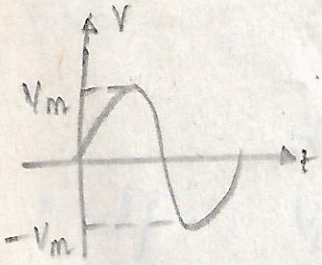


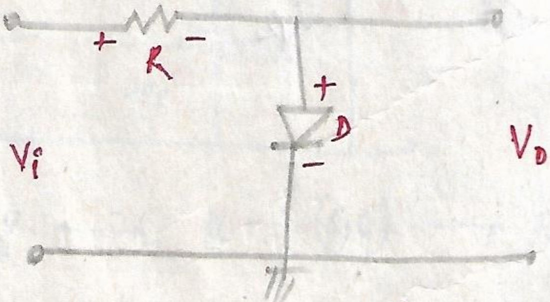
SHUNT CLIPPERS :

- ⊛ +ve peak sh. cli with no. ref. voltage
- ⊛ +ve peak sh. clip with +ve ref voltage.
- ⊛ +ve peak sh. cli with -ve ref vtg.

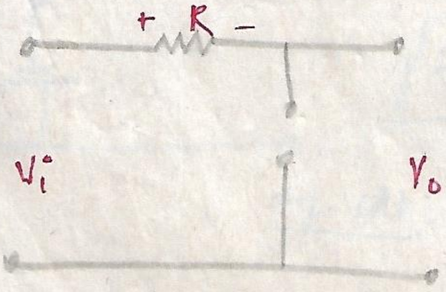
- ⊛ -ve peak sh. c with no - ref voltage
- ⊛ -ve peak sh. c with +ve ref voltage.
- ⊛ -ve peak sh. c with -ve ref voltage.

+ve peak sh.c with no. ref vtg :



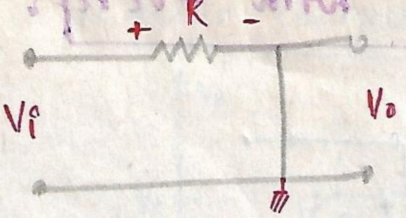


* If .. $V_i < 0V \longrightarrow D(R.B) \longrightarrow (O.C)$.



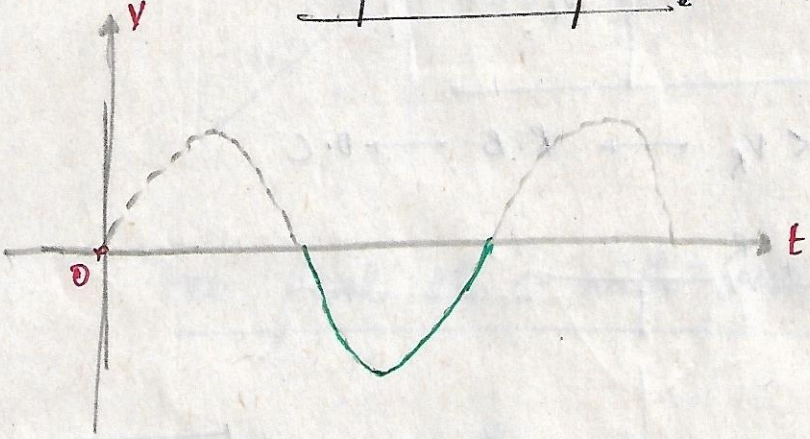
$\boxed{\therefore V_i = V_o}$

* If $V_i > 0V$ ... $D(F.B) \longrightarrow (S.C)$

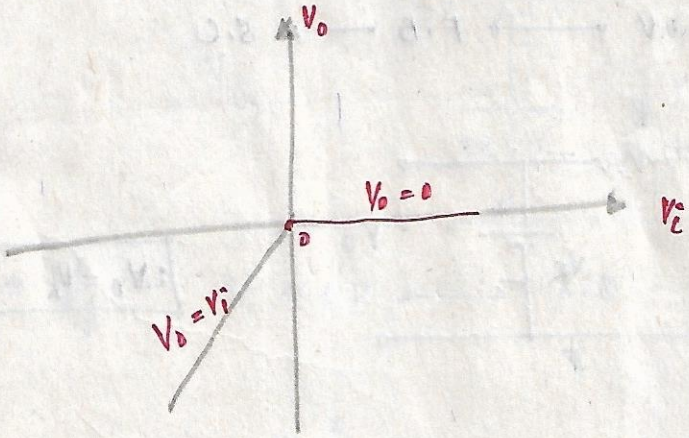


$\boxed{V_0 = 0}$

Output wave form:



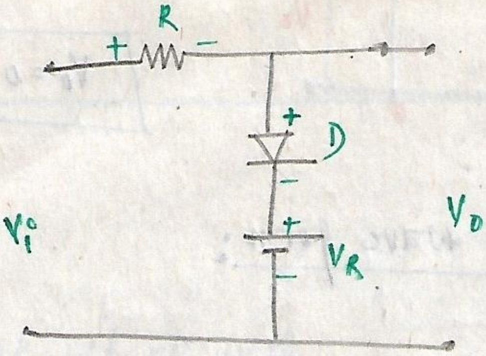
Transfer char:



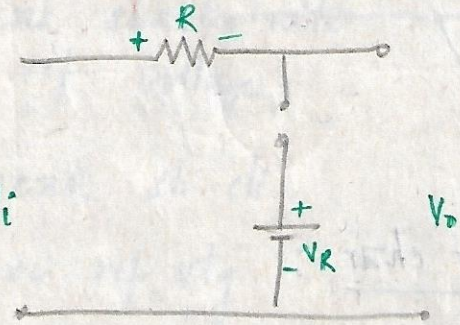
Note:

This clipping ckt limits the +ve peak of wave form. Hence, it is called as +ve peak clipper.

* +ve peak sh.c with +ve ref:

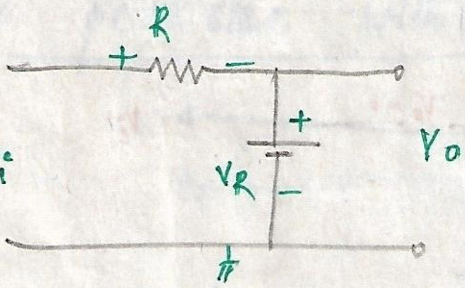


* If -- $V_i < V_R$ → R.B → O.C



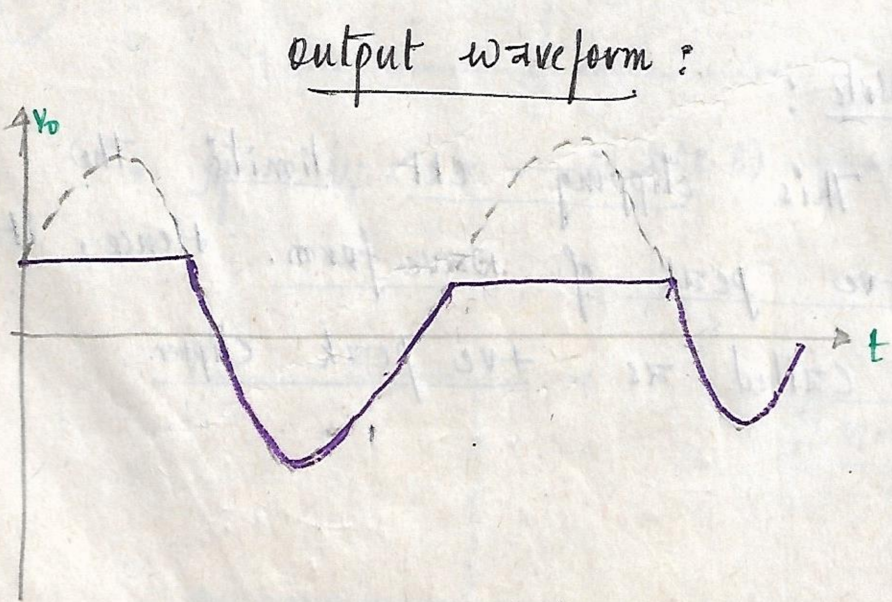
$\therefore V_i = V_o$

* If $V_i > 0V$ → F.B → S.C

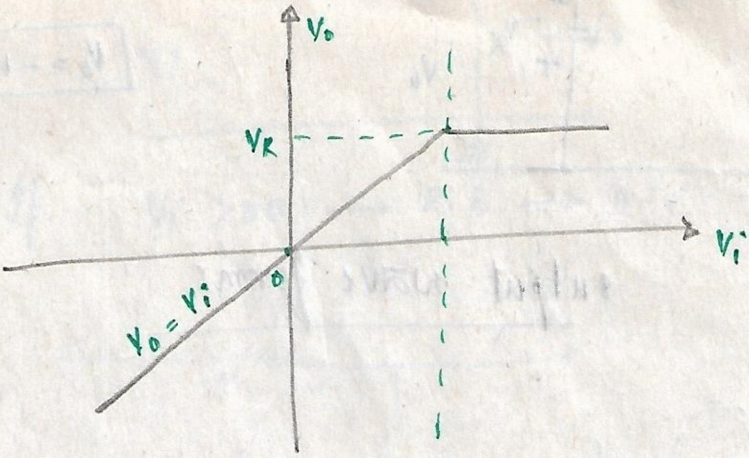


$\therefore V_o = V_R$

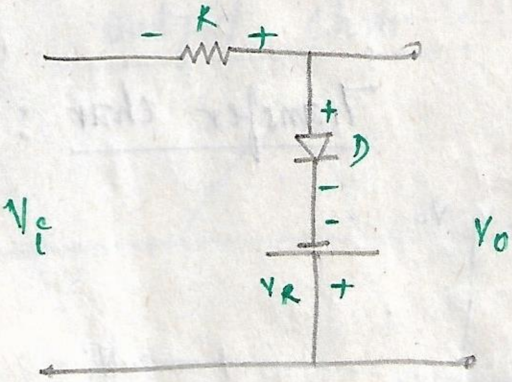
Output waveform:



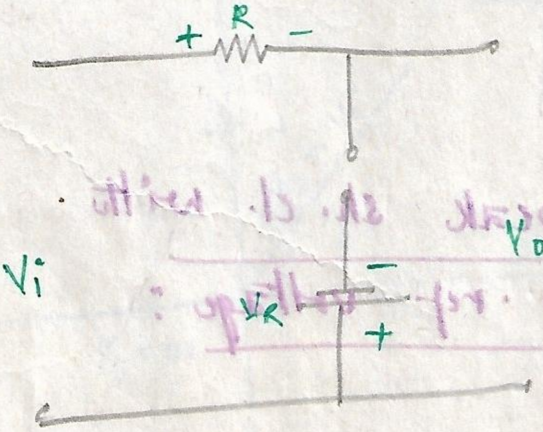
Transfer characteristics:



+ve peak sh. c with -ve ref:

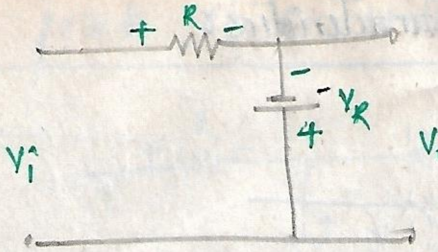


* If -- $V_i < 0V$ → R.B → O.C



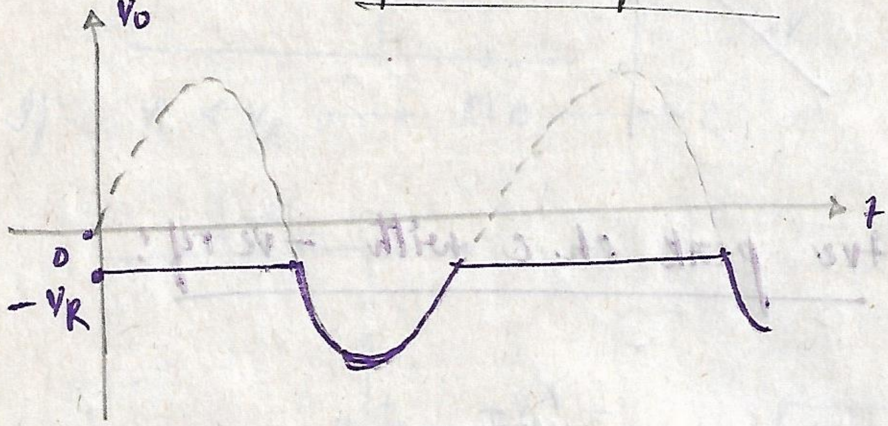
$\boxed{\text{i.e. } V_0 = V_i}$

* If $V_i > 0V$ → F.B → S.C



$\boxed{V_0 = -V_R}$

output wave form:



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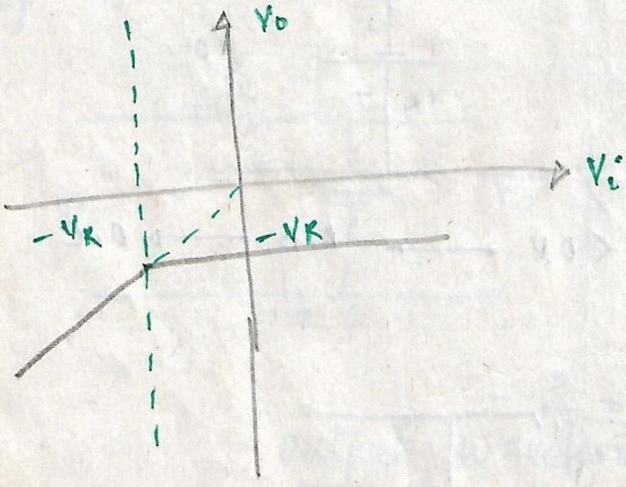
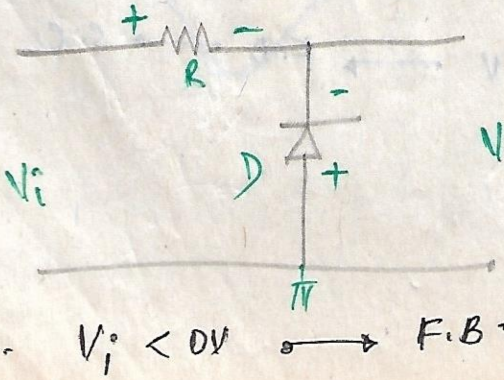
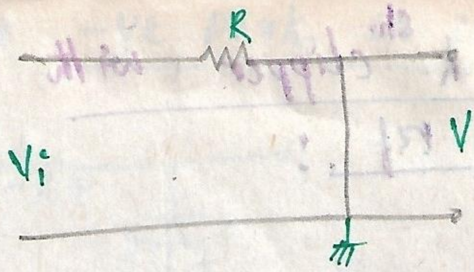


* -ve peak sh. cl. with no. ref voltage:

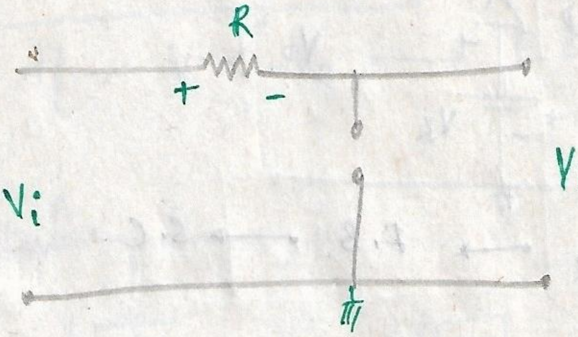


* If .. $V_i < 0V$ → F.B → S.C.



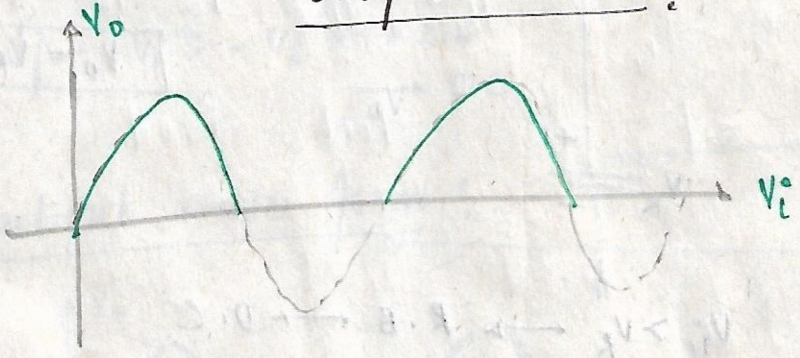
$\boxed{V_0 = 0V}$

* If -- $V_i > 0V$ ⟶ R.B ⟶ O.C

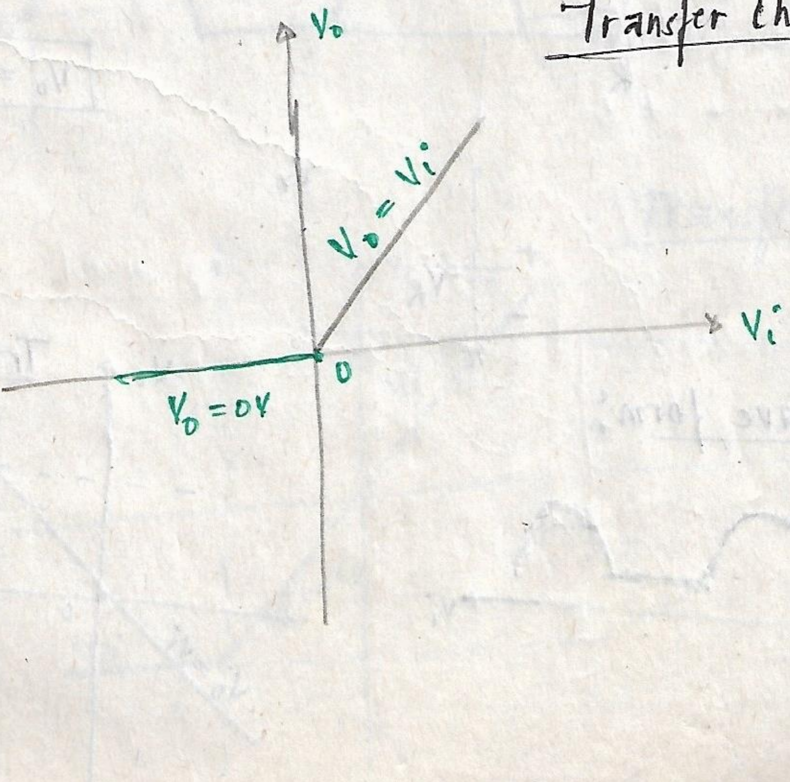


$\boxed{V_0 = V_i}$

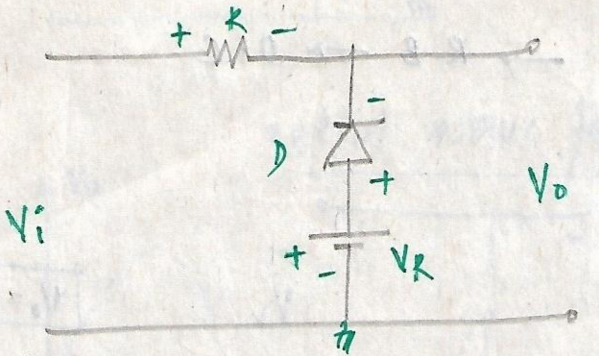
output char :



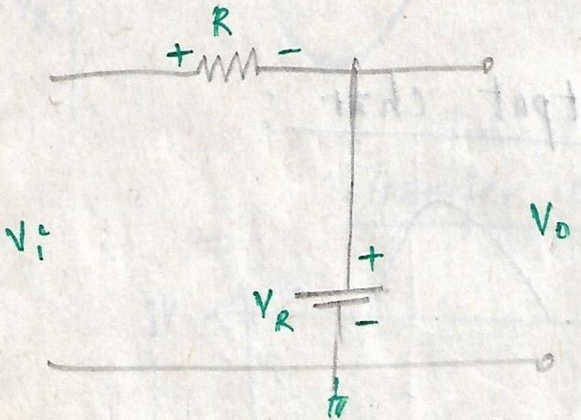
Transfer char :



* -ve peak sh. clipper with +ve ref. :

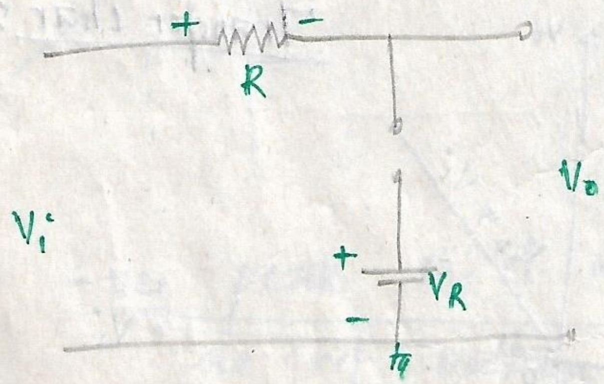


* If $V_i < V_R$ → F.B → S.C



$\boxed{V_0 = V_R}$

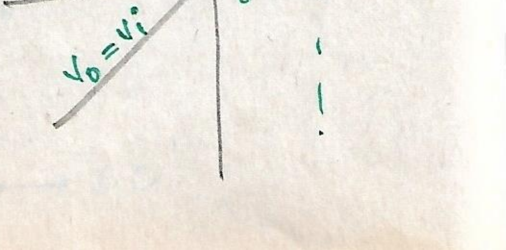
* If -- $V_i > V_R$ → R.B → O.C



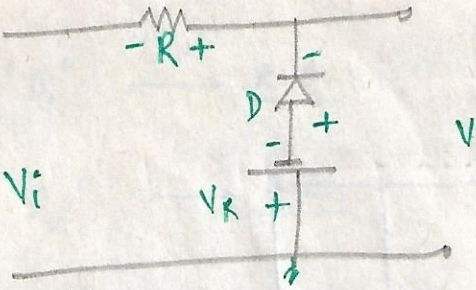
$\boxed{V_0 = V_i}$

output wave form:

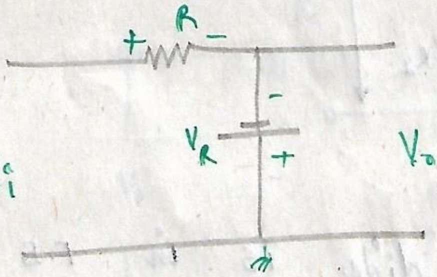
Transfer char



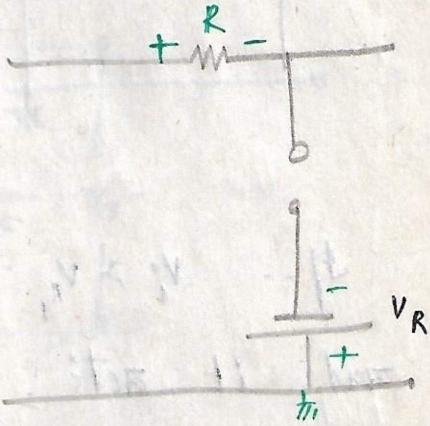
* -ve peak sh. clip with -ve ref



* If -- $V_i < -V_R$ ⟶ F.B ⟶ S.C



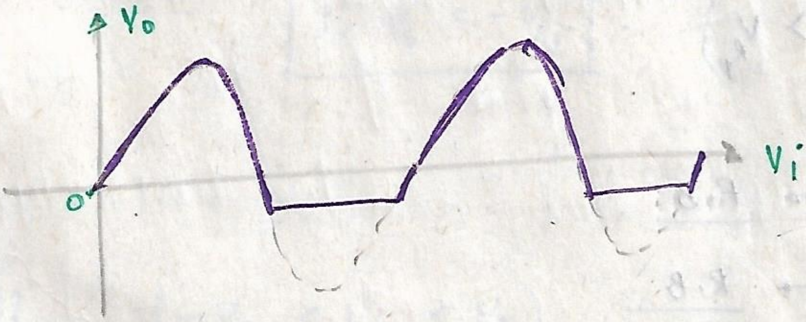
$\boxed{V_o = -V_R}$



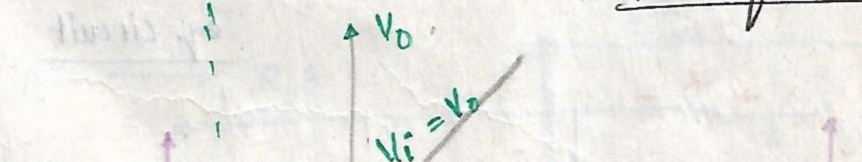
$\boxed{V_o = V_i}$

* If -- $V_i > -V_R$ ⟶ R.B
⟶ O.C

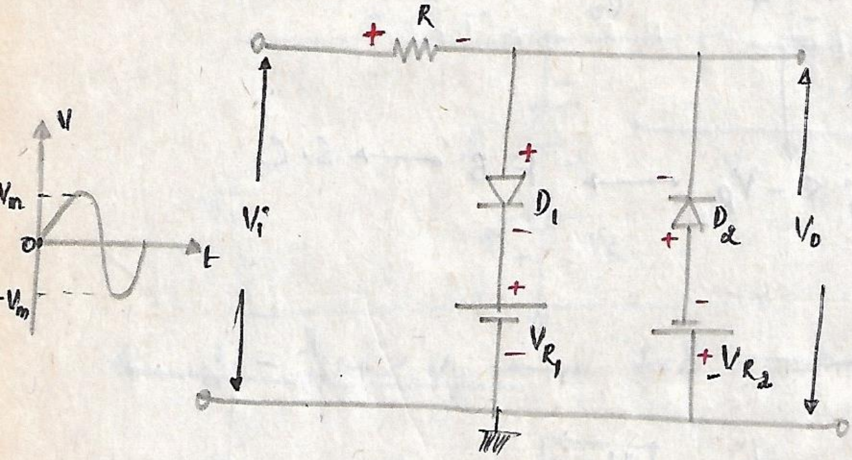
output wave form :



Transfer char :



* Two level clipper : *

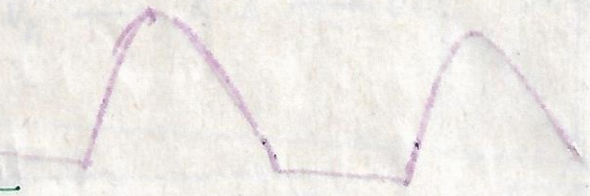


If .. $V_i > V_{R_1}$ ... the dide is in F.B and it acts as .. short circuit ..

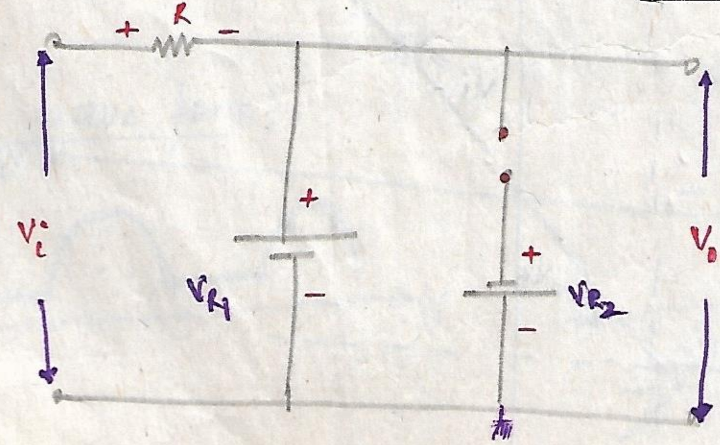
* If .. $(V_i > V_{R_1})$ ....

"D_1" ⟶ F.B

"D_2" ⟶ R.B



eq. circuit

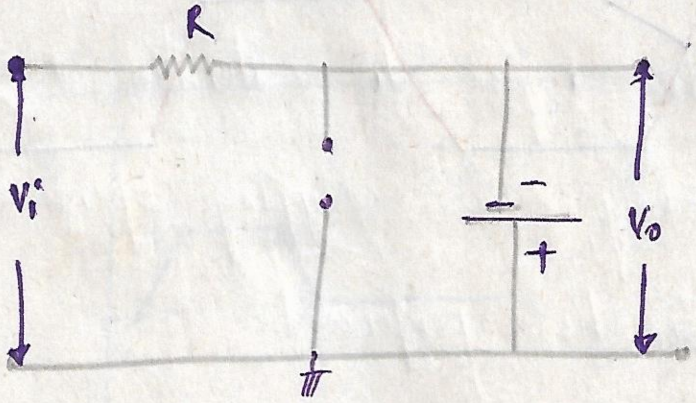


$\therefore \boxed{V_o = V_{R_1}}$

* If .. $(V_i < -V_{R_2})$

"D_1" ⟶ R.B

"D_2" ⟶ F.B.

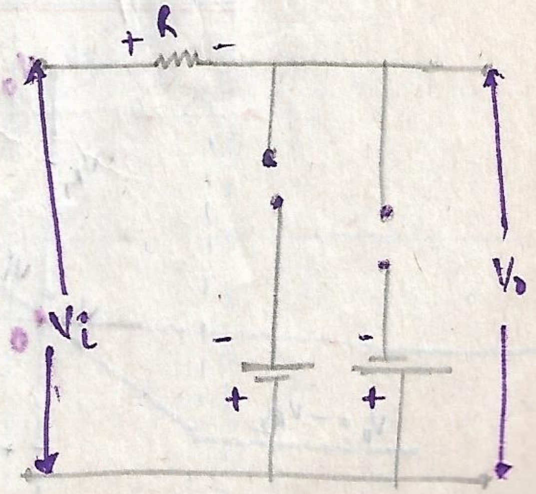


$$\boxed{\therefore \; V_o = -V_{R_2}}$$

* If ... $(-V_{R_2} < V_i < V_{R_1})$ . . .

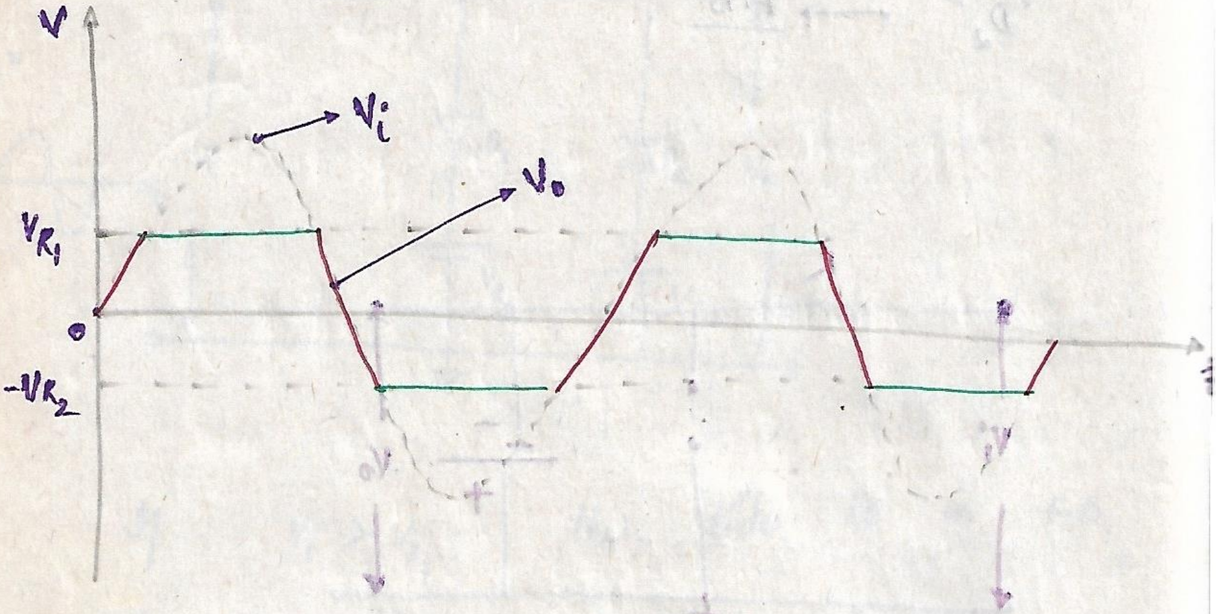
"D_1" ⟶ R.B

"D_2" ⟶ R.B.



$$\boxed{\therefore \; V_o = V_i}$$

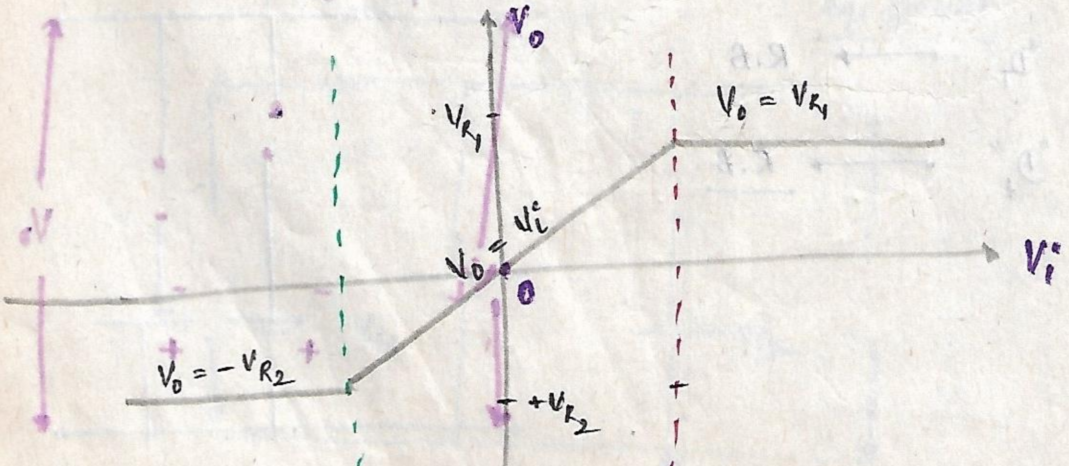
* output wave form : *



Note :

This clipping circuit limits both -- +ve and -ve peak of the wave form. Hence, it is called as "two level clipper."

⊛ Transfer char : ⊛



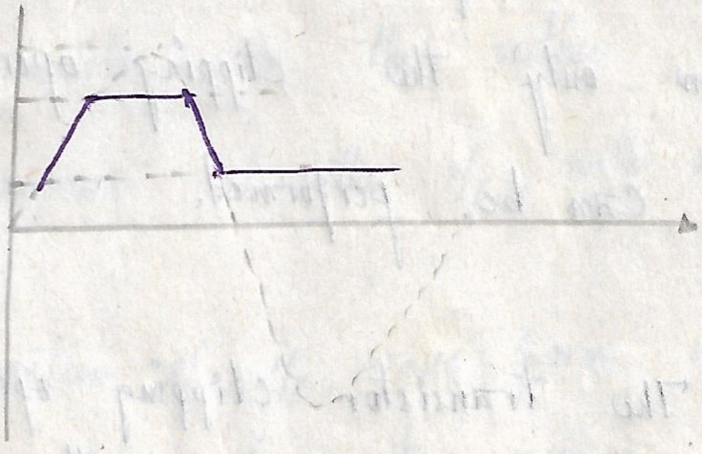
Example . . .

If .. $V_1 = 5 \sin w_0 t$

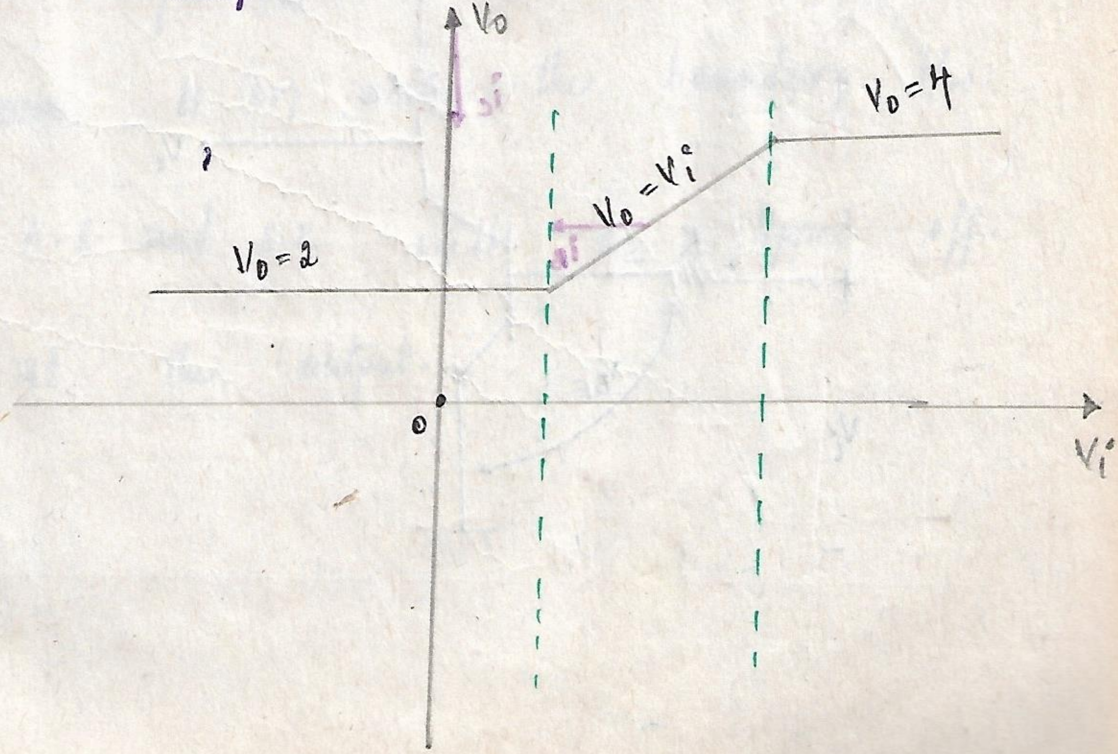
$V_{R_1} = 4V$

$V_{R_2} = 2V$..

then, the o/p wave form is...



Transfer characteristics :



Transistor clipper :

There are 2 non-linearitie's ...

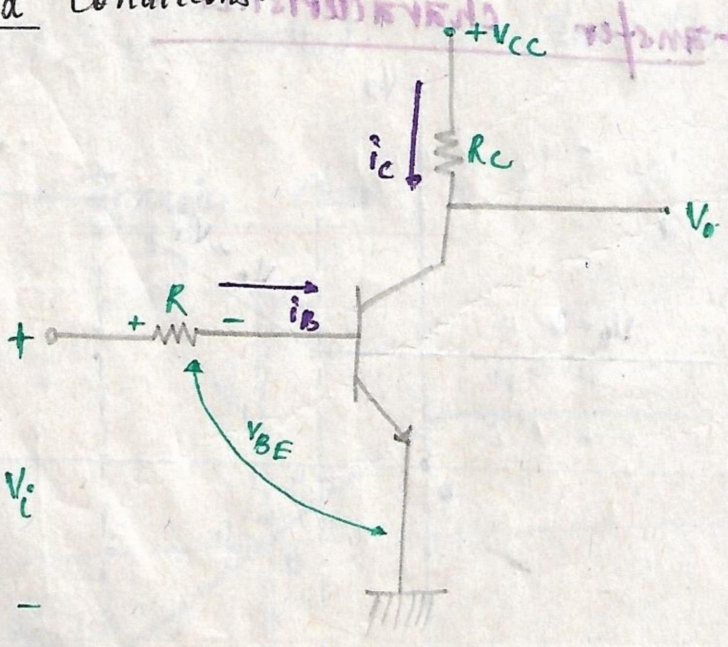
Here ... The transistor cross.. from ...

→ cut off region to active region.

→ Active region to saturation region ..

... then only the clipping operation can be performed.

<u>Note</u> : The transistor clipping operation is performed only with the above <u>2</u> conditions.



* $i_B = \frac{V_i - V_r}{R}$

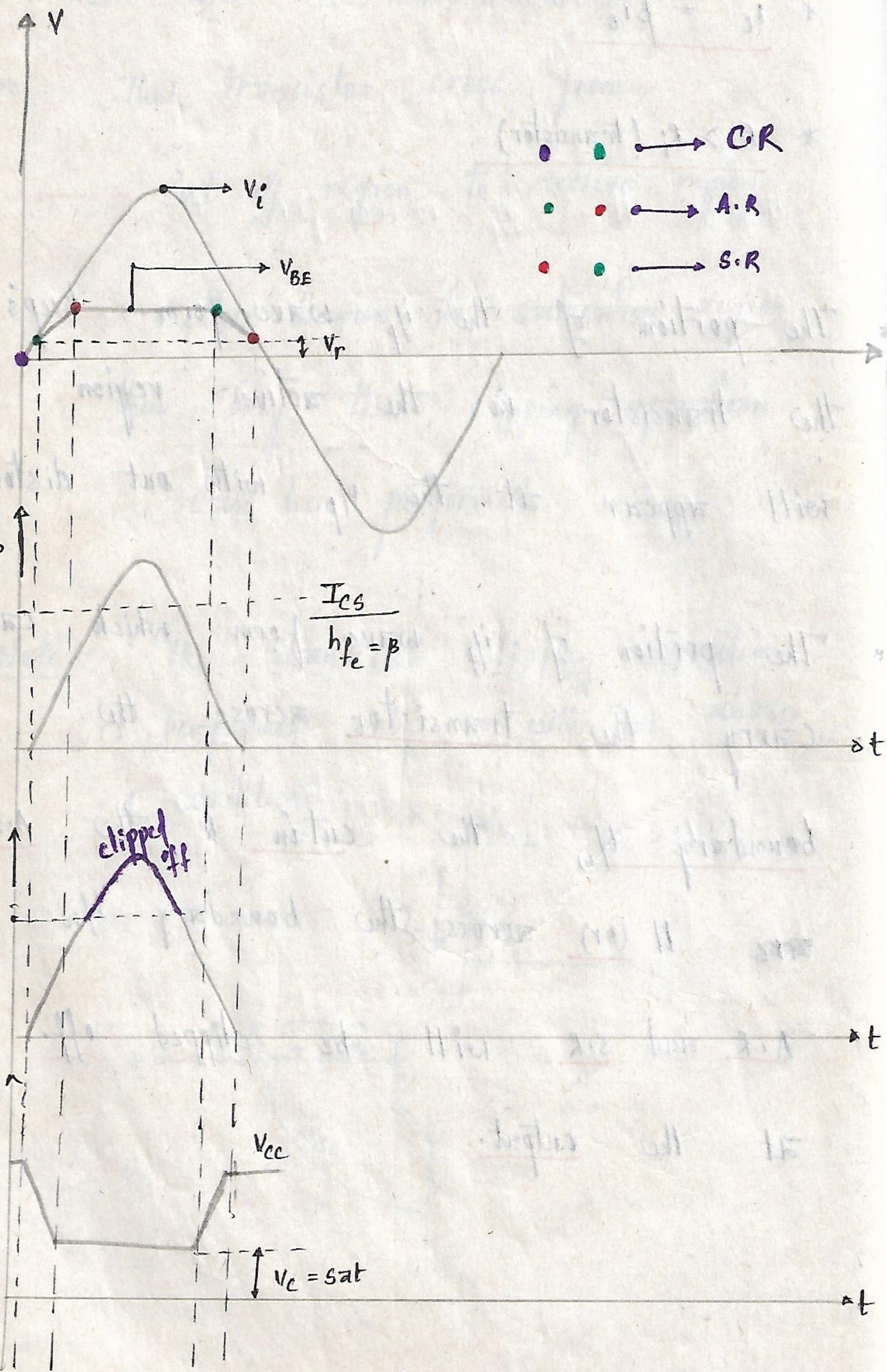
* $i_C = \beta i_B$.

* $R > R_i$ (transistor).

- The portion of the i/p wave form.. keep's the transistor in the active region will appear at the o/p with out distortion.

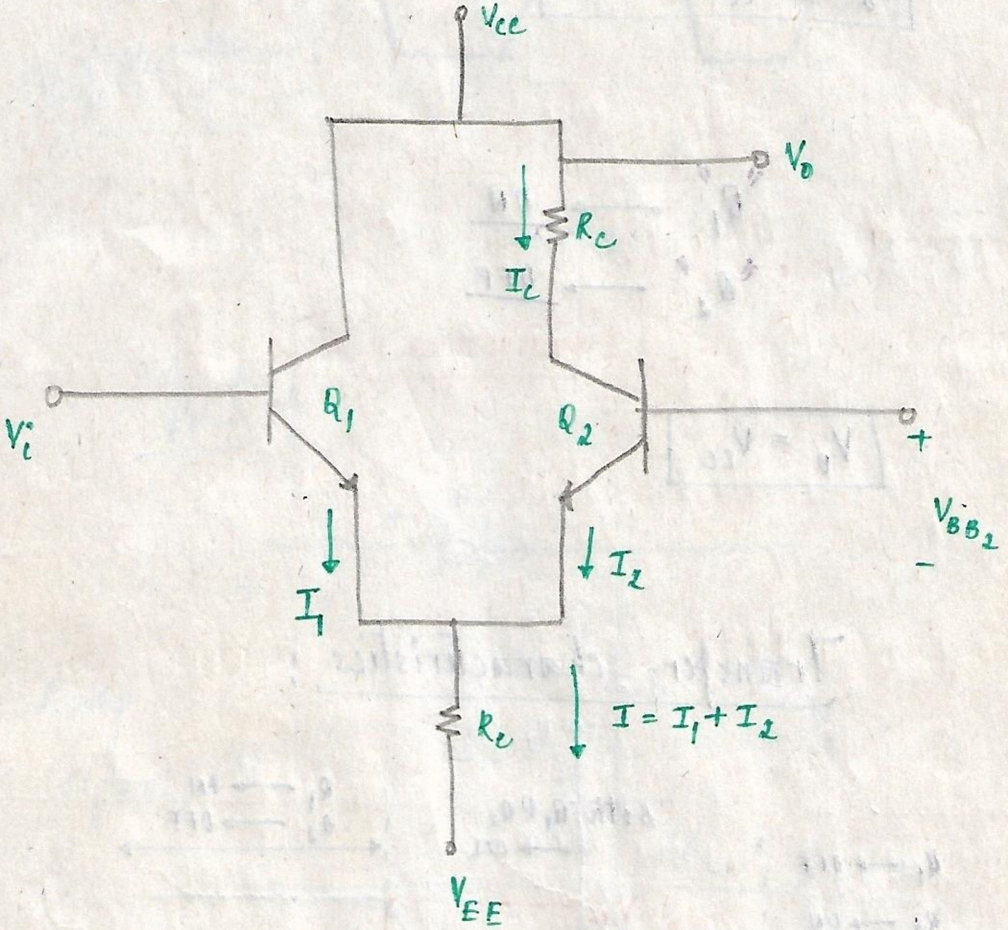
- The portion of i/p wave form which can carry the transistor across the boundary b/w the cut in & the A.R ~~are~~ ~~H~~ (or) across the boundary b/w.. A.R and S.R will be clipped off at the output..

* output wave form's: *



Emitter coupled clipper :

* It is a two-level clipper i.e, it clipp's two peak's (+ve & -ve) at a time.



* V_{BB_2} ⟶ fixed voltage which is applied ~~at~~ the base of "Q_2".

* V_i ⟶ app to the base of "Q_1"

* I ⟶ fixed.

* Initially --- "Q_1" → OFF

"Q_2" → ON.

then "I_c" flow's ---

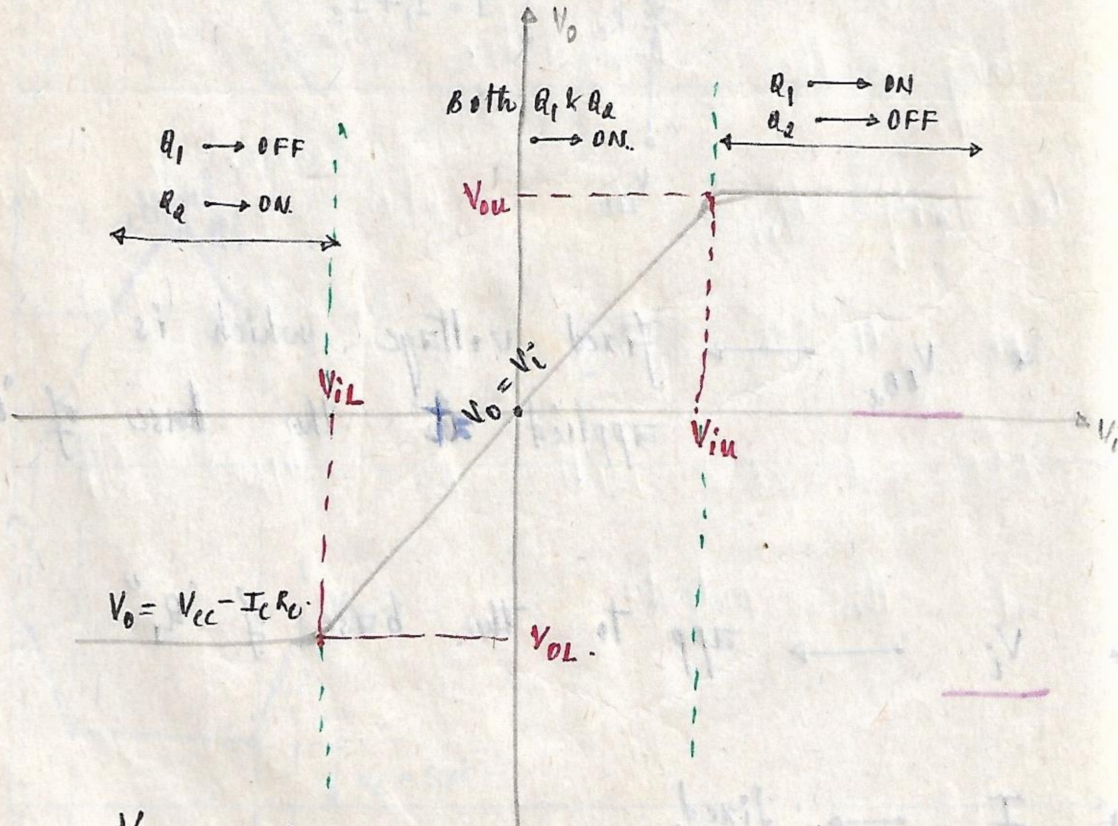
$$\boxed{V_0 = V_{cc} - I_c R_c}$$

* If --- "Q_1" → ON

"Q_2" → OFF

$$\boxed{V_0 = V_{cc}}$$

Transfer characteristics :



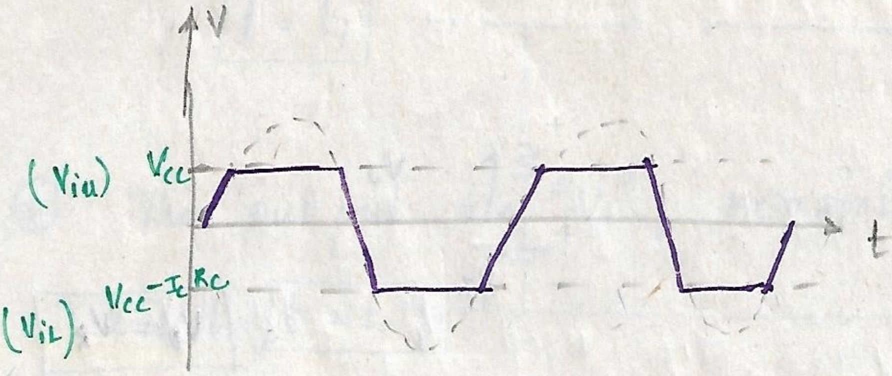
V_{ou} →

V_{oL} →

V_{iL} →

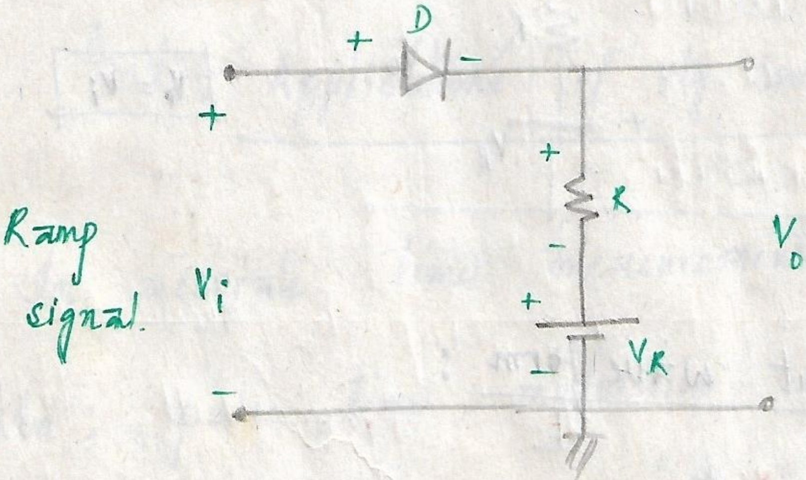
V_{iu} →

output wave form :



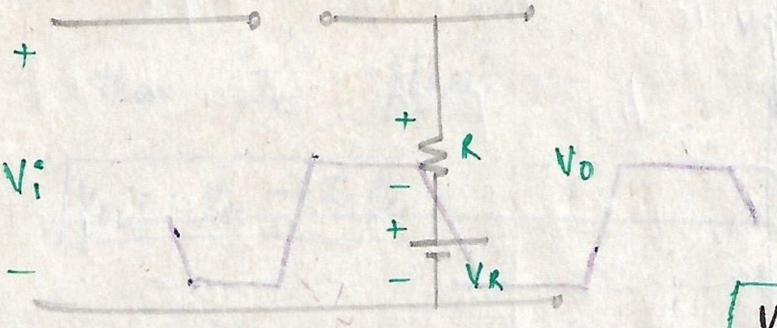
Comparator :

Int :



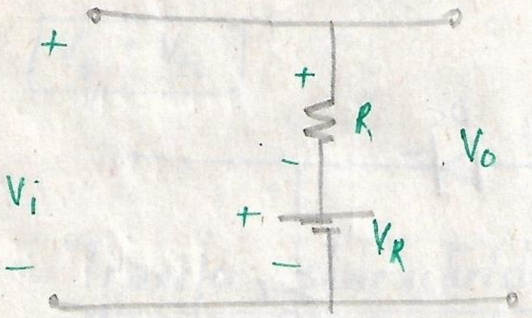
- * Here.. we are applying ramp signal as i/p
- * Comparator is a circuit.. which can be employed to mark the instant when, an arbitrary wave form attains a certain ref. level

* If .. $V_i < V_R$ .. D(R.B) $\longrightarrow$ O.C



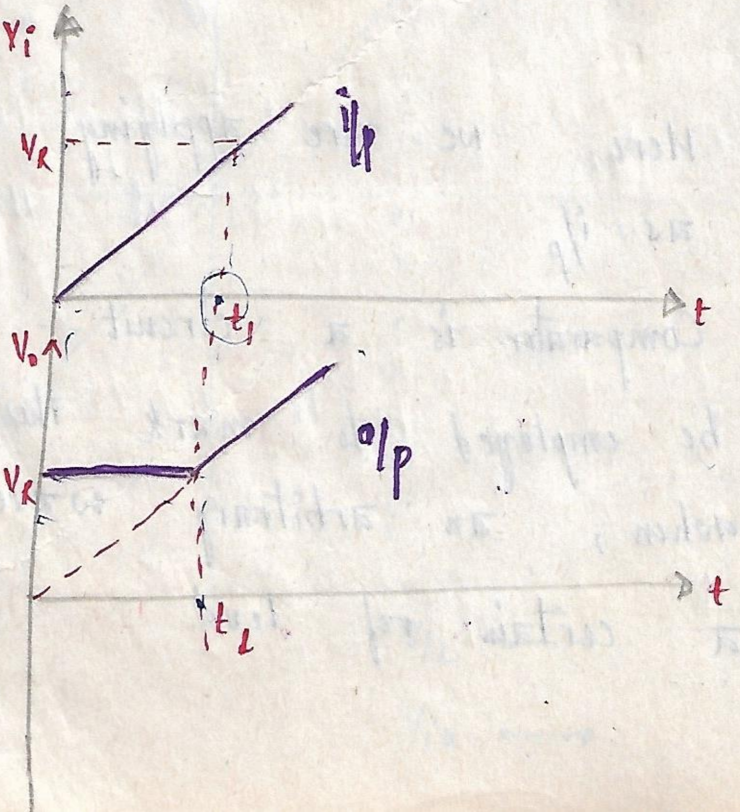
$$\boxed{V_0 = V_R}$$

* If $V_i > V_R$ .. F.B $\longrightarrow$ S.C



$$\boxed{V_0 = V_i}$$

Output wave form :



⊛ "V_i" crosse's the "V_R" level -- at..

$$\boxed{t = t_1}$$

⊛ The out put vtg "V_0", remain's at "V_R" untill $\boxed{t = t_1}$.

⊛ Beyond $(t = t_1)$ ... the o/p rise's with the i/p signal.

Int! **Application's of vtg comperator :**

- * In accurate time measurement's.
- * In, pulse time modulation.
- * As timing marker's generated from a sin wave
- * In phase metre's.
- * In amplitude distribution analysis.
- * To obtain $\square^{re}$ wave  from a sin wave. 

* In analog to digital convertor's.

* * CLAMPERS : * *

Clamper's are used to add D.C component to the A.C wave form. Hence, they are also called as --

D.C restorer

(or)

D.C reinserter.

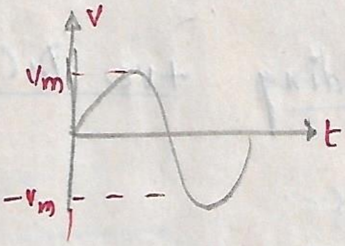
* If we add D.C comp to the A.C wave form --- the signal will shift up (or) down. But there is no change in the shape of the wave form

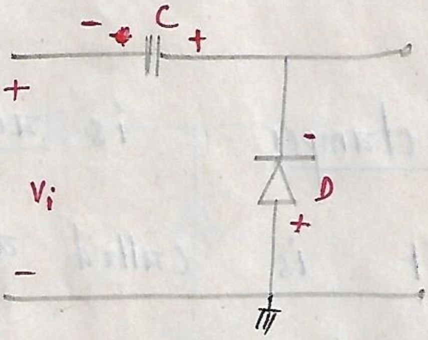
Classification :

- * +ve clamper (-ve peak clamper)
- * -ve clamper. (+ve peak clamper)

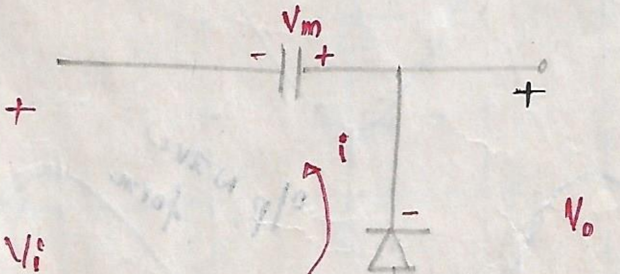
+ve clamper :

+ve clamper is used to add +ve D.C value to the i/p wave form. So, that ... the wave form will shift upward's i.e, (+ve) side.





During the (-ve) 1/2 half cycle -- Diode conduct's -- and the diode current flows -- then, the cap charge's upto peak value (Vm)



Now :

App K.V.L to the circuit ..

We get --

$$V_i - V_0 + V_m = 0$$

$$\boxed{\therefore V_0 = V_i + V_m} \longrightarrow \text{+ve D.C value}$$

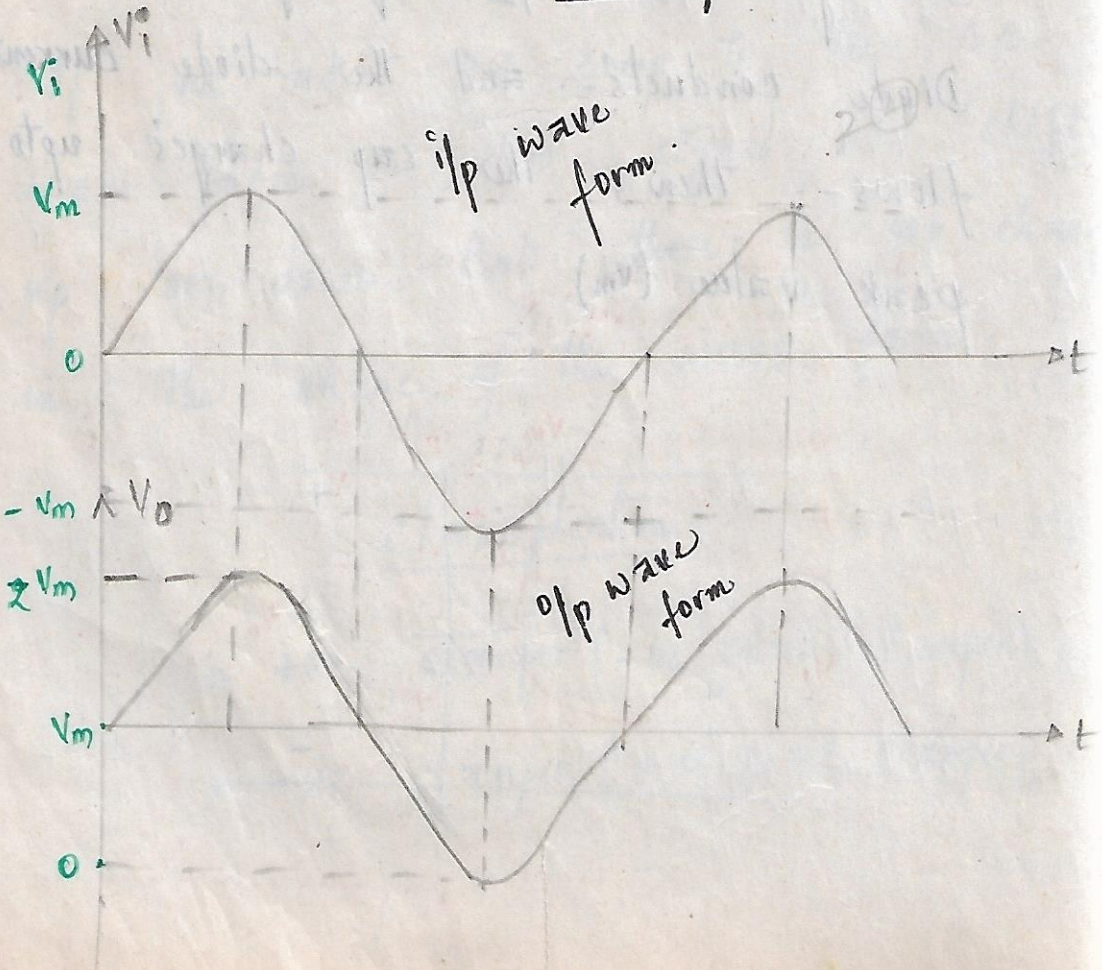
Note :

this clamper -- is adding +ve D.C valu

Hence, it is called as --

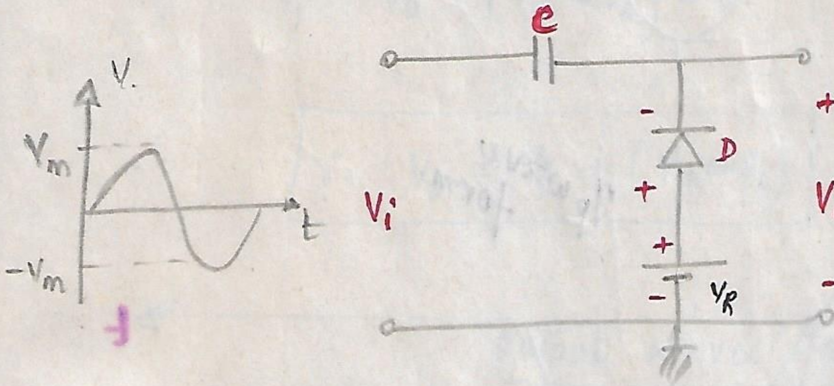
+ve clamper

* Wave forms : *

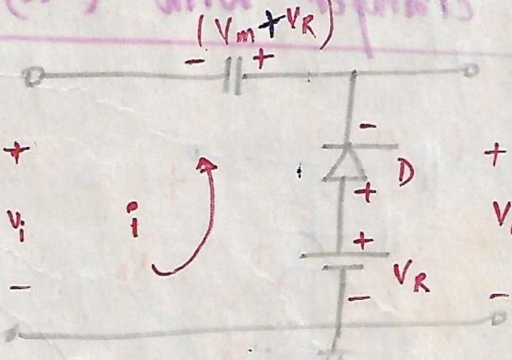


*) This clamper-- clamp's (-ve) peak of the wave form to the (0-level). Hence, it is also called as (+ve) peak clamper. -

+ve clamper with (+ve) ref:



* If ($V_i < V_R$) → Diode conduct's and cap charge's upto -- ($V_m + V_R$).

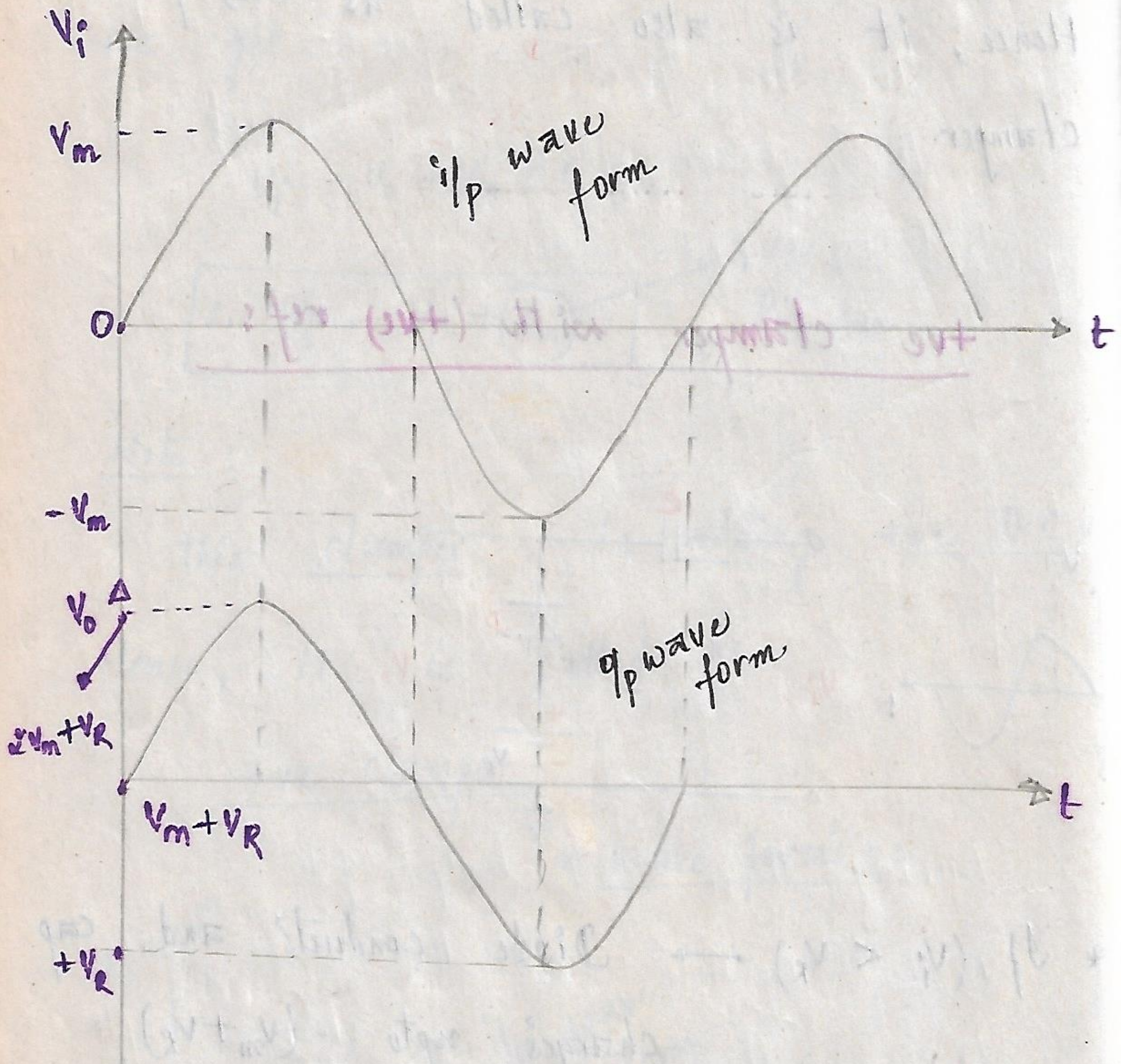


App K.V.L to the loop.. we get..

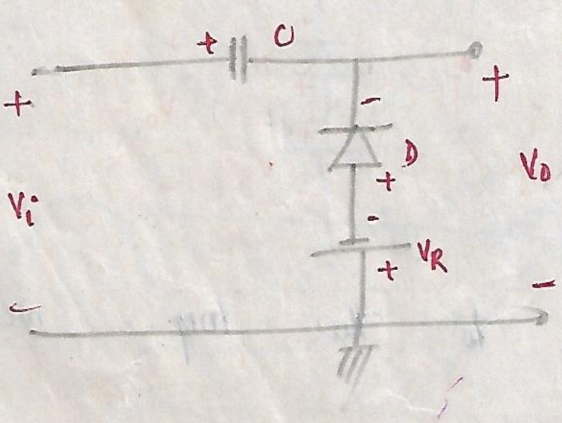
$$V_i - V_0 + (V_m + V_R) = 0$$

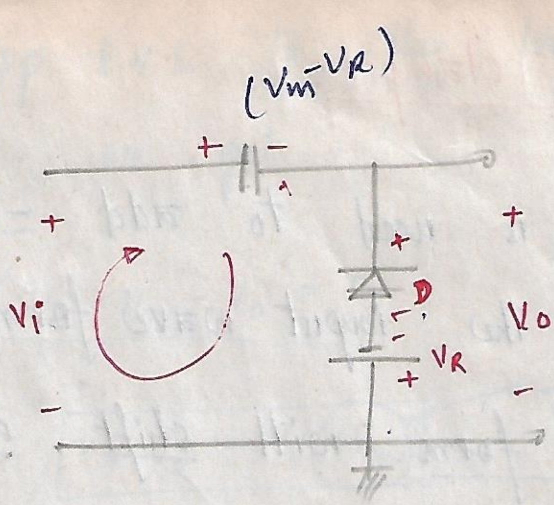
$$\boxed{\therefore V_0 = V_i + (V_m + V_R)}$$

output wave form:



* +ve clamper with (-ve) ref: *



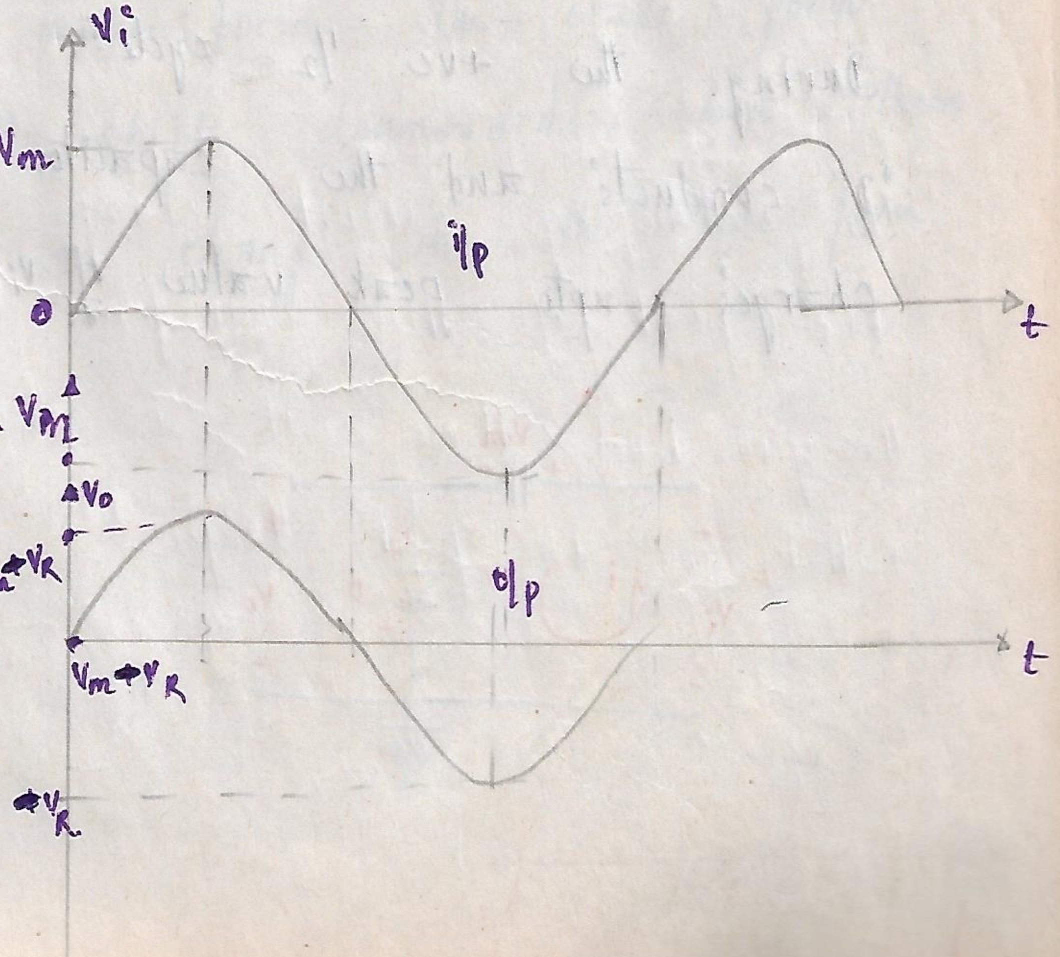


app K.V.L to the loop.. we get-

$$V_i - V_o + (V_m + V_R) = 0$$

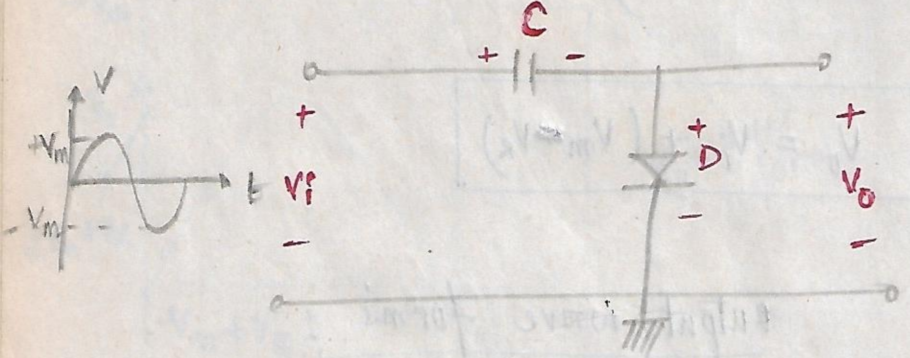
$$\boxed{\therefore\ V_o = V_i + (V_m + V_R)}$$

output wave form's :

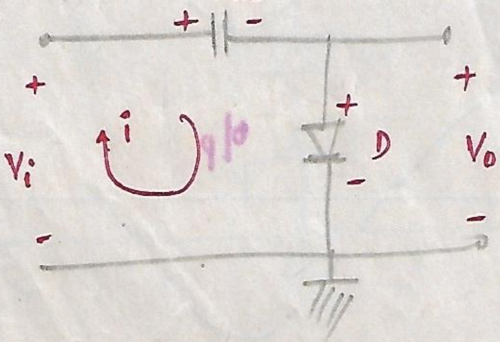


-ve clamper:

-ve clamper is used to add -ve D.C value to the input wave form so that the wave form will shift downwards i.e., (-ve) side



During the +ve ½ cycle "D" conducts and the capacitor charges upto peak value of v_i (V_m)



app K.V.L to the loop..

we get...

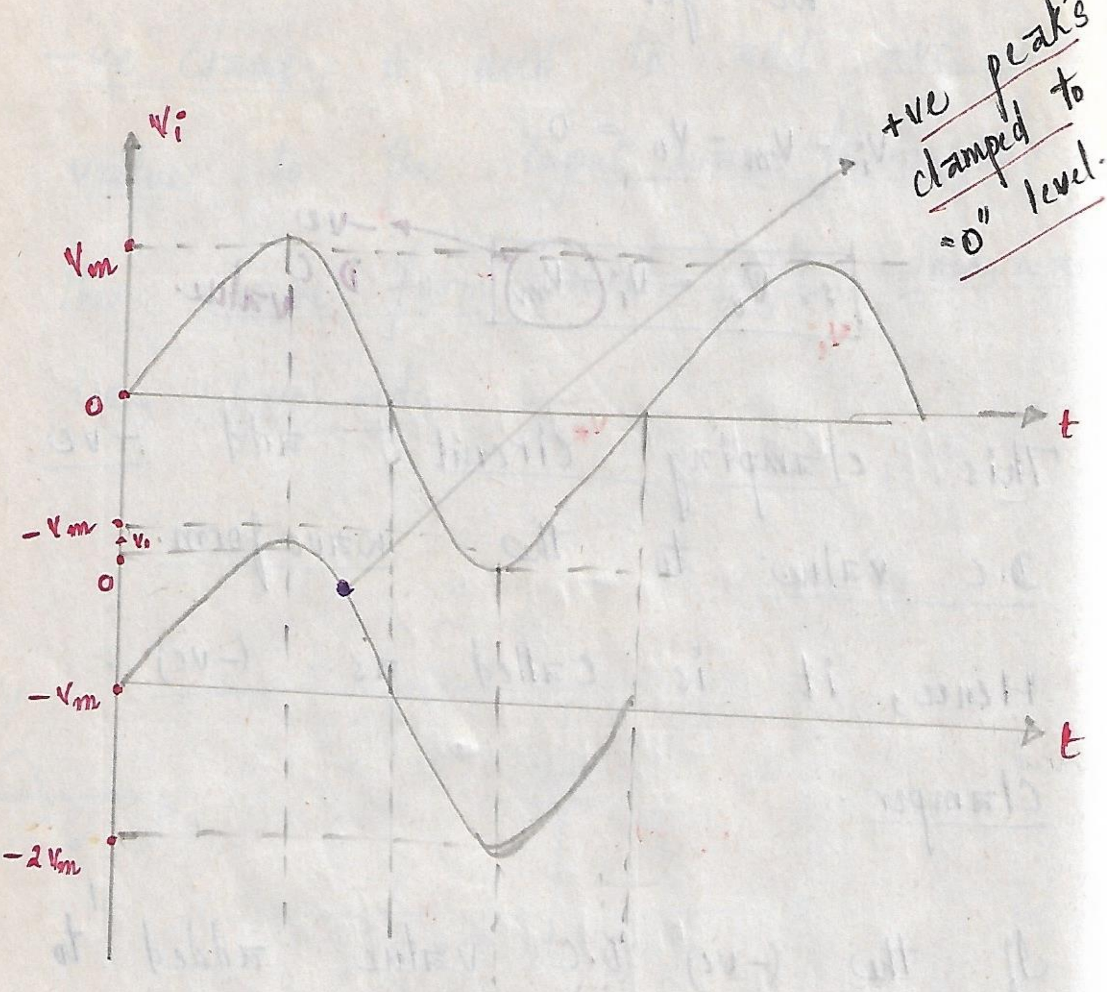
$$V_i - V_m - V_o = 0$$

$$\boxed{\therefore V_o = V_i - V_m}$$ -ve D.C value

* This clamping circuit.. add -ve D.C value to the wave form. Hence, it is called as.. (-ve) Clamper..

* If the (-ve) D.C value added to the wave form.. the wave form will shift downwards, but there is no change in the wave form.

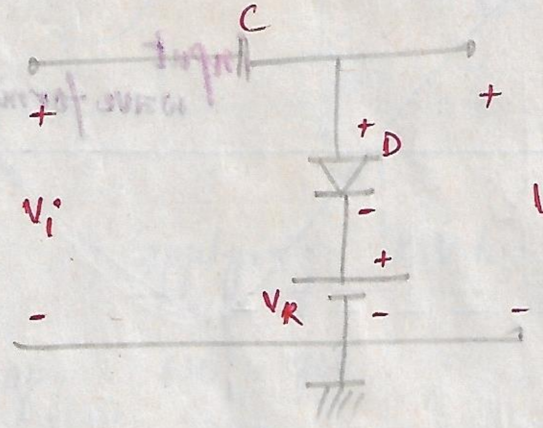
output wave form:



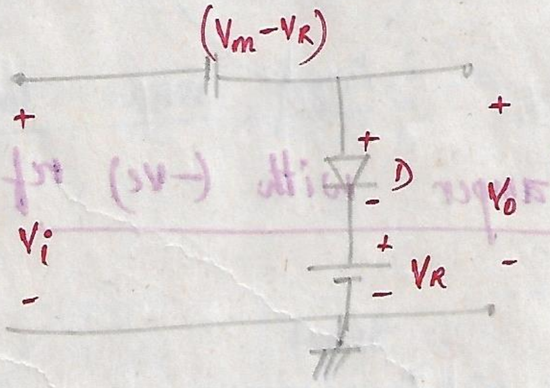
Note :

This clamping circuit clamps +ve peak of the waveform to the zero level. Hence, it is also called as +ve peak clamper.

(-ve) clamper with +ve ref voltage :



* If ... $V_i > V_R$ .. Diode conducts and the cap charges upto $(V_m - V_R)$

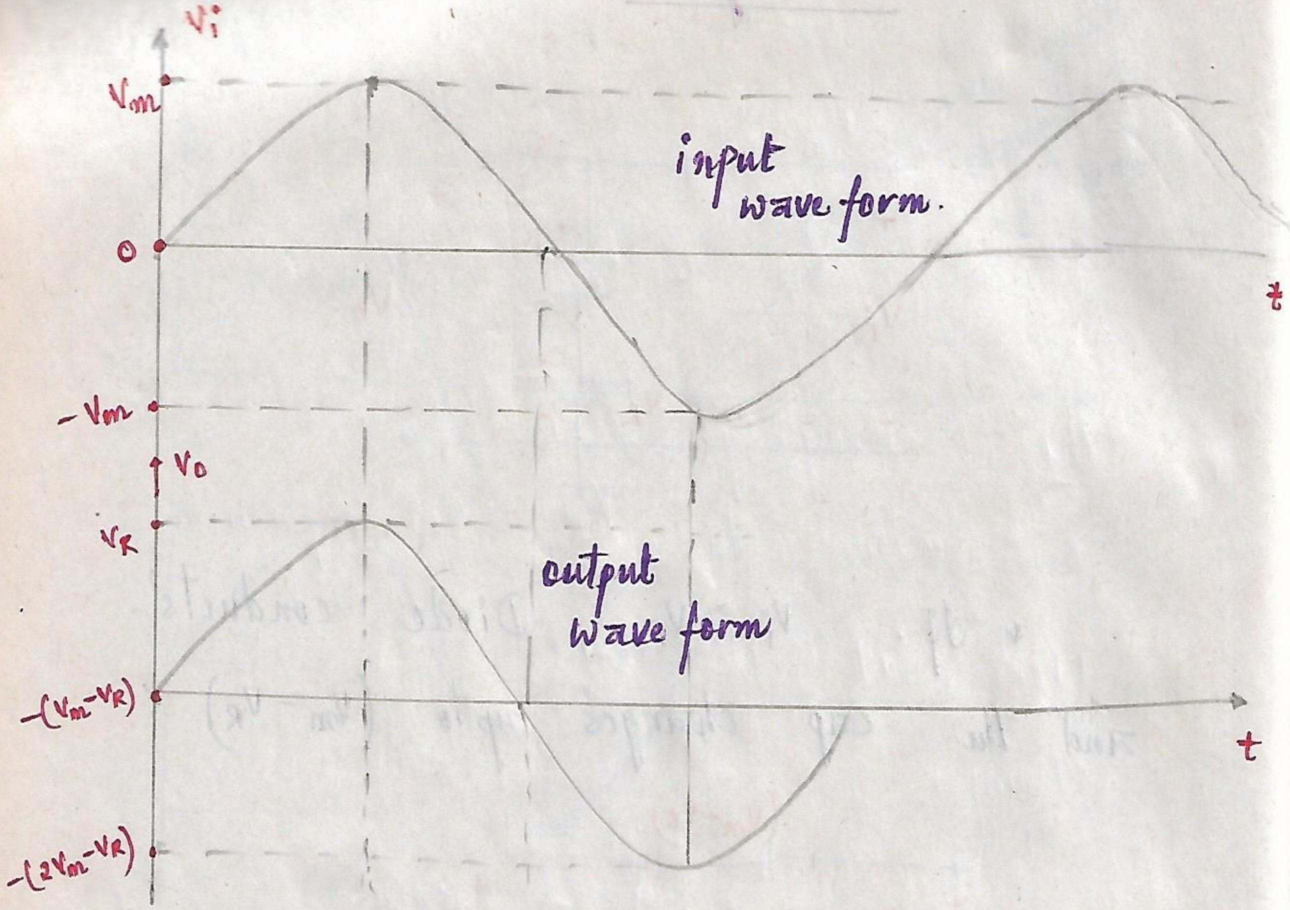


app K.V.L to the loop .. we get ..

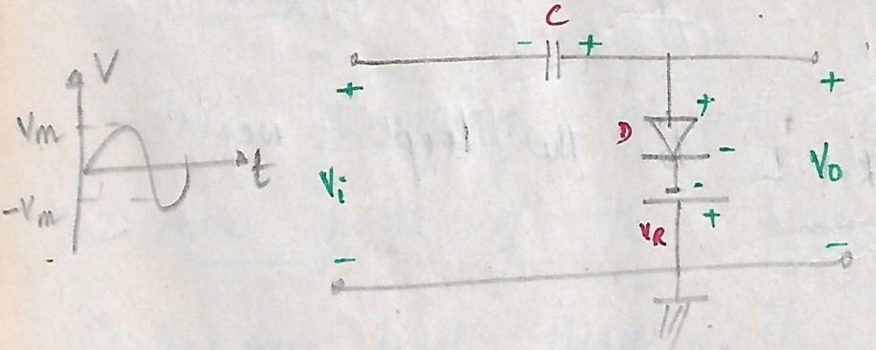
$V_i - (V_m - V_R) - V_0 = 0$

$$\boxed{\therefore V_0 = V_i - (V_m - V_R)}$$

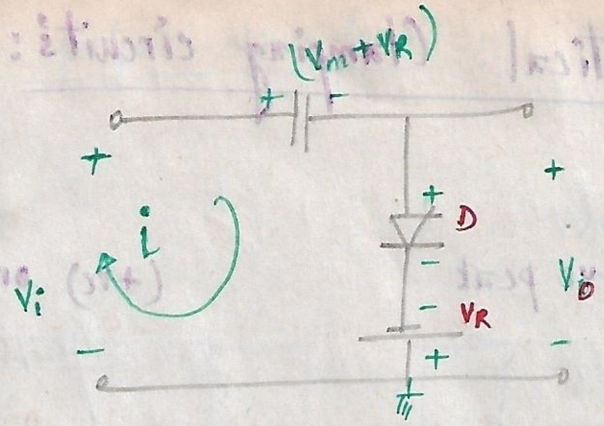
output wave form's :



-ve clamper with (-ve) ref :



* If .. $V_i > -V_R$ .. the Diode conducts and the cap charge's upto $(V_m + V_R)$.

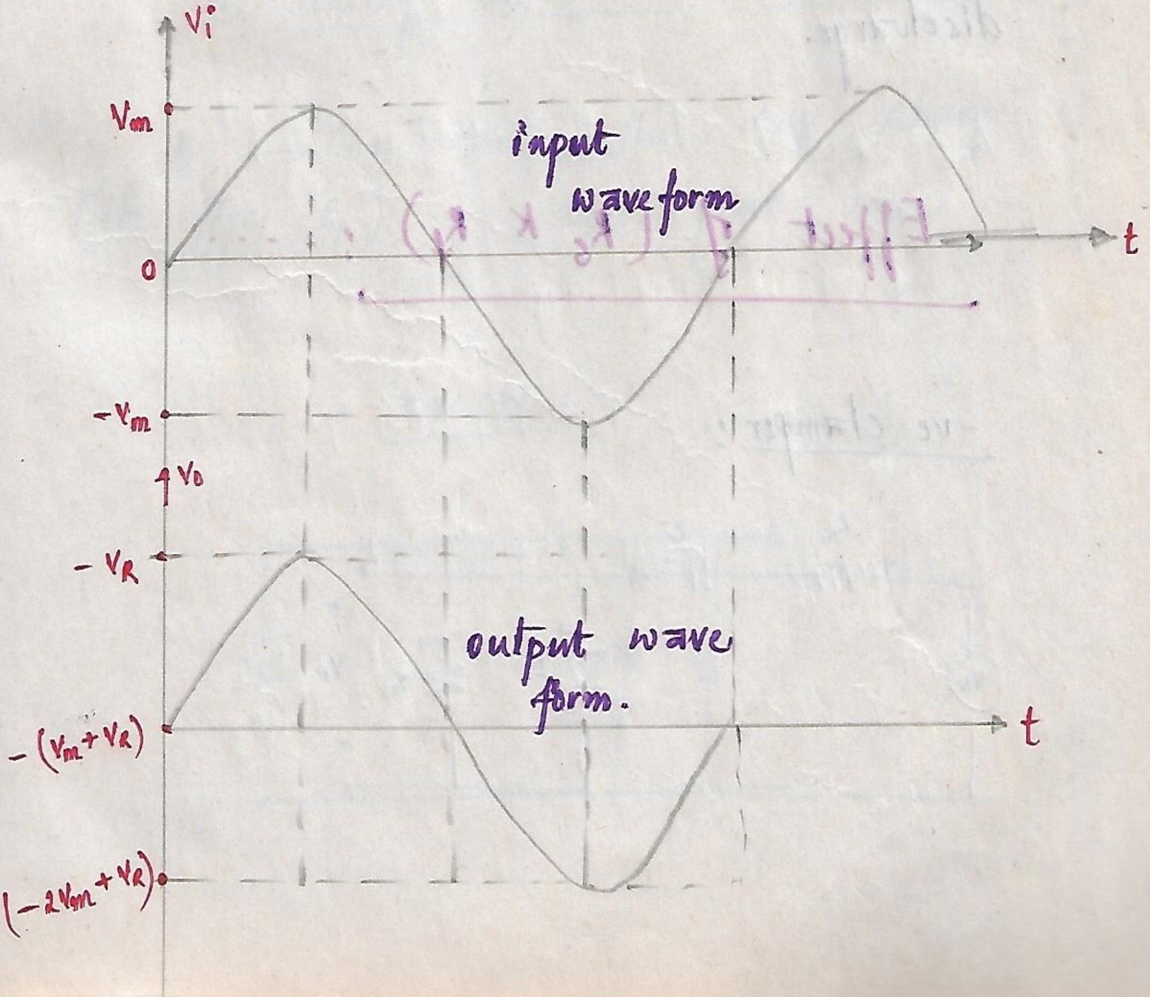


applying K.V.L... to the loop.. we get..

$$V_i - (V_m + V_R) - V_0 = 0$$

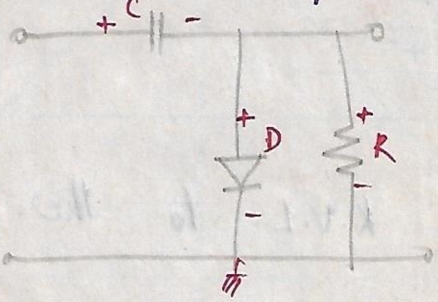
$$\boxed{\therefore\ V_0 = V_i - (V_m + V_R)}$$

output wave form's :

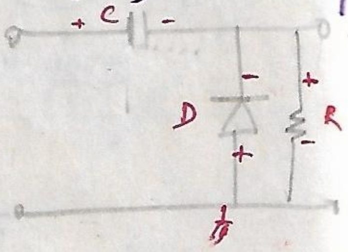


practical Clamping circuits:

(-ve) or +ve peak



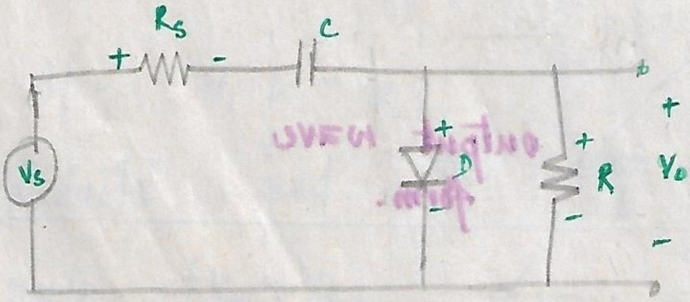
(+ve) or -ve pe



- In practical clamping circuits, we need to connect a resistor in $||^{lel}$ with the diode ...
- Due to this, the cap will discharge

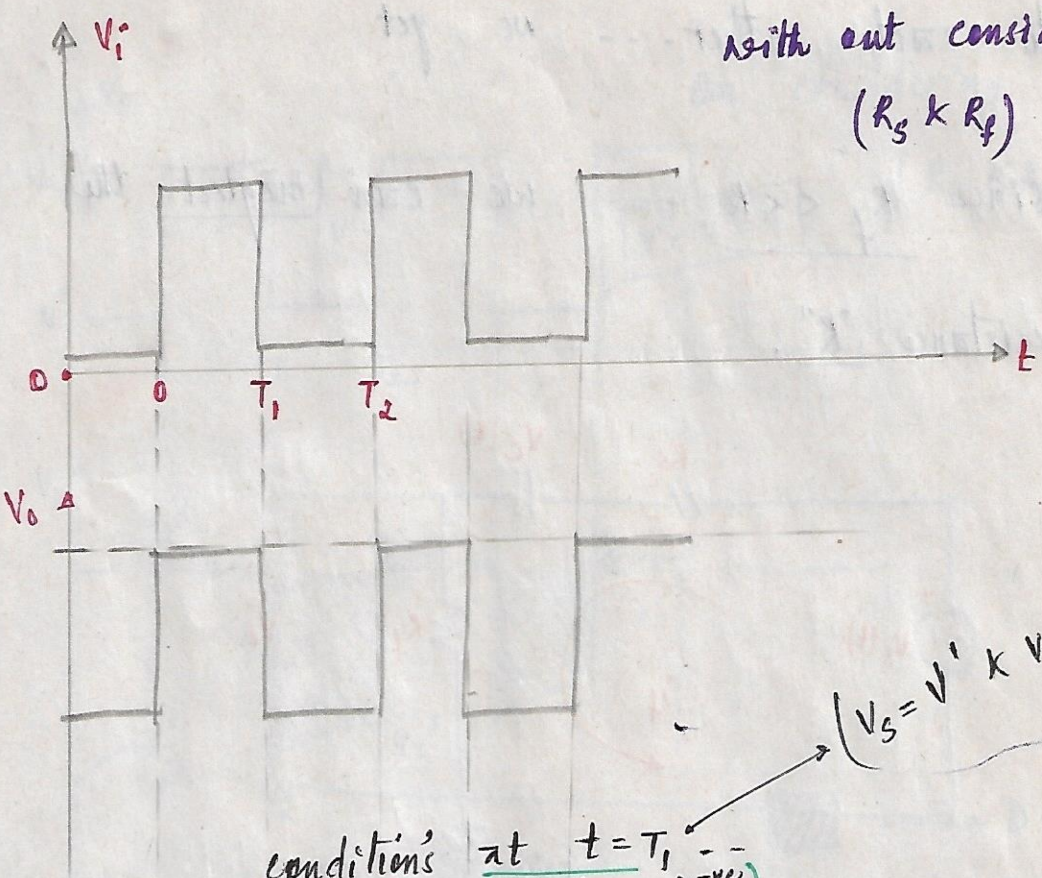
Effect of (R_s & R_f) :....

-ve clamper:



output wave form's :

with out considering
(R_S & R_f)



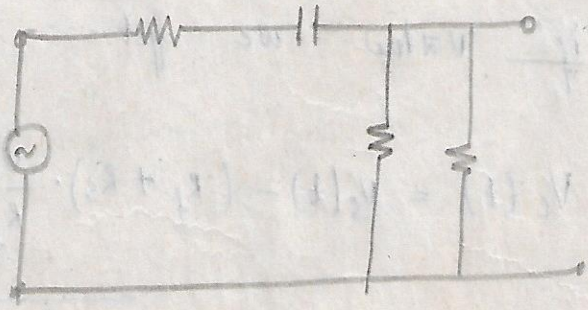
($V_S = V'$ & $V_0 = V_i'$)

condition's at $t = T_1$ - -
(at $t = T_1$ + -ve - - .)

① During the time interval .. ~~(0 to T_1)~~ ..

D ⟶ ON and the cap charge's
(it offer's "R_f") upto peak value

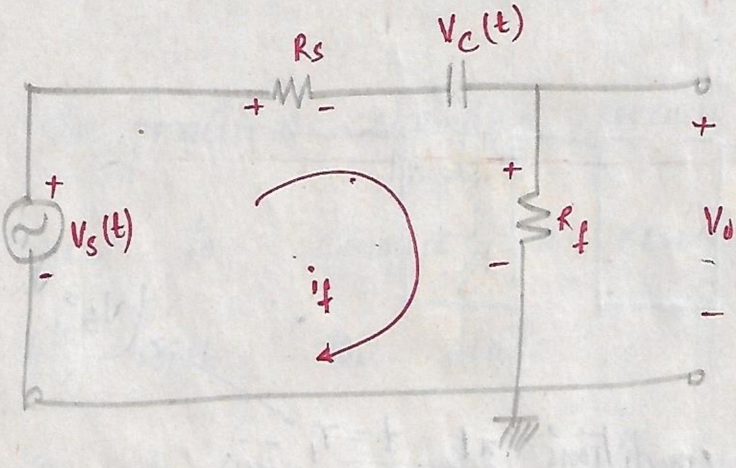
eq. ckt :



* If two resistors are connected in para

to each other--- we get

* since $R_f << R$ --- we can neglect the resistance "R".



$$V_0 = i_f R_f \longrightarrow i_f = \frac{V_0}{R_f}.$$

App K.V.L to the loop we get---

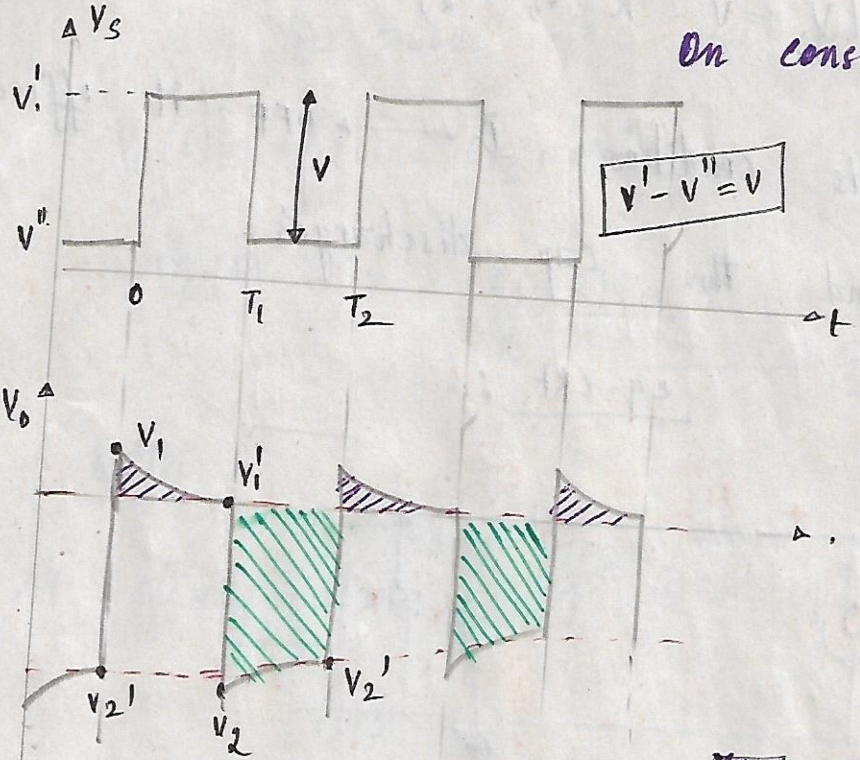
$$V_S(t) - (R_S + R_f) i_f - V_C(t) = 0$$

$$V_C(t) = V_S(t) - (R_f + R_S) \cdot i_f.$$

sub "i_f" value we get---

$$V_C(t) = V_S(t) - (R_f + R_S) \cdot \frac{V_0}{R_f} \quad \text{———} ⊛$$

output wave form's :



On considering (R_s & R_f)

Here, $V_1' = V_1 \cdot e^{-T_1/(R_f+R_s)C}$

$V_2' = V_2 \cdot e^{-T_2/(R+R_s)C}$

▨ → D → ON

🟩 → D → OFF

sub the value's of (V_s & V_0) in eqⁿ ⊛ ..

we get ...

$$V_C(t) = v' - \frac{(R_f + R_s) \cdot V_1'}{R_f} \quad \text{———} \; ①$$

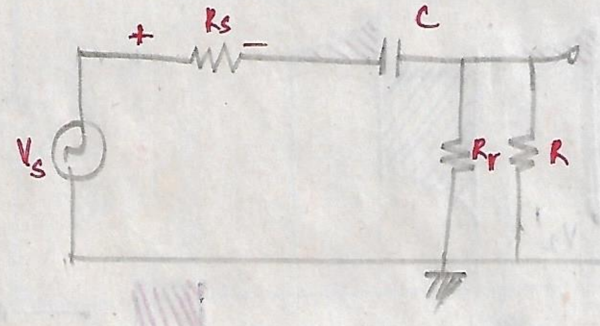
* at $t = T_1^{+}$ . .

$(V_S = V'' \;\; \& \;\; V_0 = V_2)$.

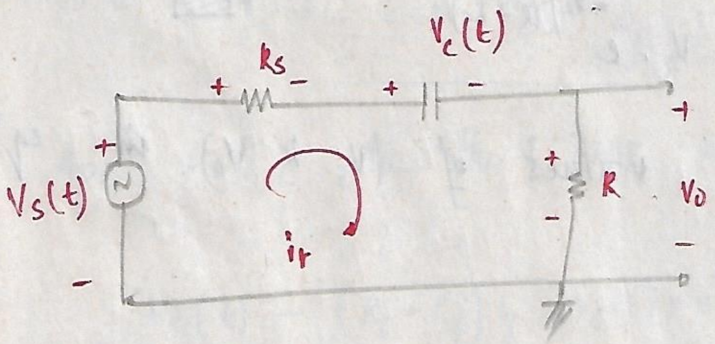
In this condition D ⟶ OFF. it offe

"R_r" and the cap discharge's.

eq. ckt :



* ∵ $R_r >> R$ . . "R_r" is neglected.



i_r ⟶ dischargi circui

$$V_0 = i_r \cdot R$$

$$i_r = \frac{V_0}{R}$$

Applying K.V.L . . we get - -

$$V_s(t) - (R_s + R)\, i_r - V_c(t) = 0$$

$$V_c(t) = V_s(t) - (R_s + R)\, i_r$$

sub the value of "i_r" in

the above eq^n .. we get ..

$$V_c(t) = V_s(t) - (R_s + R) \cdot \frac{V_0}{R}$$

$$V_c(t) = V'' - \frac{(R_s + R)}{R} \cdot V_2 \quad \text{———} \ ②$$

<u>Note</u> :

At steady state, eq^n ① = eq^n ② ..

(or)

Since, the voltage across the cap can not change instantaneously, so that we can equate ① & ② . i.e, ① = ②.

Equating ① = ②.

$$V' - \frac{(R_f + R_s)}{R_f} \cdot V_1' = V'' - \frac{(R_s + R)}{R} \cdot V_2 \quad \text{———} \ (*)$$

As we know that -- $\boxed{V' - V'' = V}$ ...

$$\boxed{V' - V'' = V = \frac{(R_f + R_s)}{R_f} \cdot V_1' - \frac{(R_s + R)}{R} \cdot V_2}$$

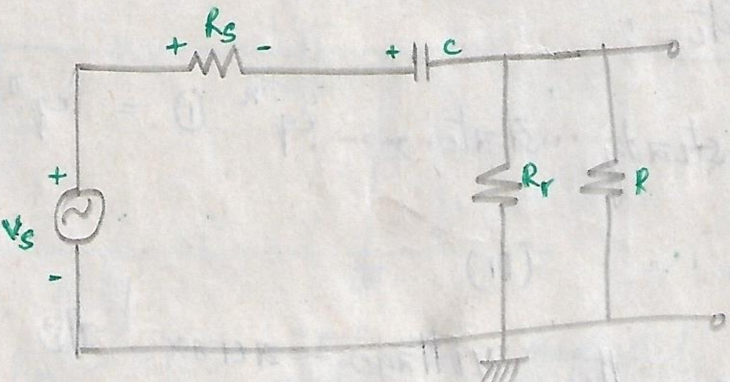
* at $t = 0^-$ - - -

($v_S = V''$ and $v_0 = V_2'$)

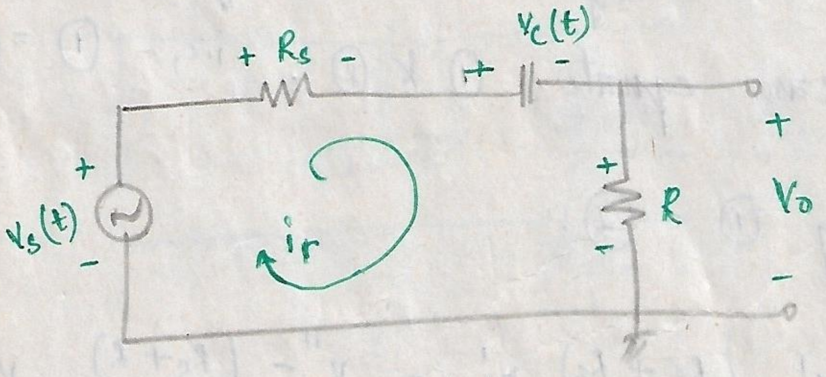
In this condition ... (or) at this condition "D" ⟶ OFF and it offer's 'R_r

The cap discharge's.

eq. ckt :



* ∵ $R_r >> R$ . . 'R_r' is neglected.



$$v_C(t) = v_S(t) - \frac{(R_S + R)}{R} v_0$$

$$\therefore v_C(t) = V'' - \frac{(R_S + R)}{R} V_2'$$

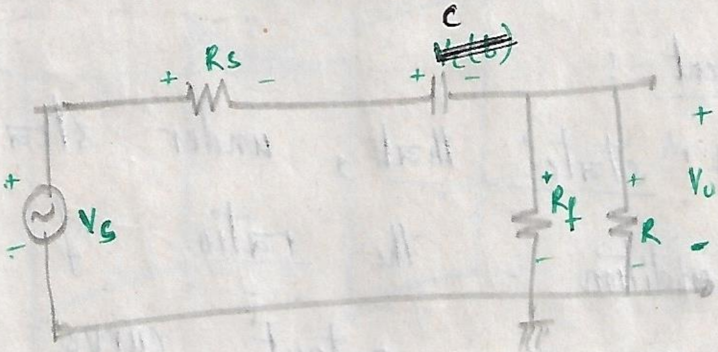
—— ①

* at $t = 0^+$ ----

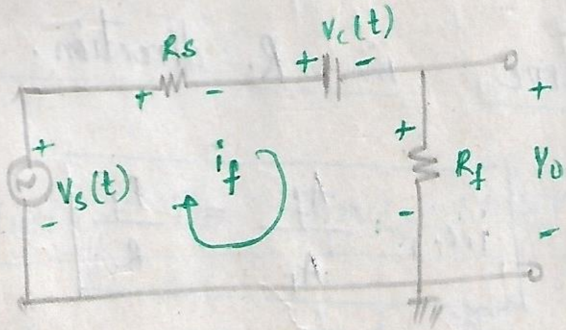
$(V_s = v'$ and $V_0 = V_1)$

At this condition ---- D → ON, it offer's "R_f" and the cap charge's upto peak value

eq. ckt :



∵ $R_f << R$ ... 'R' is neglected.



$$V_c(t) = V_s(t) - \frac{(R_f + R_s)}{R_f} V_0$$

$$V_c(t) = v' - \frac{(R_f + R_s)}{R_f} \cdot V_1 \quad \text{———} ①$$

equating ① and ② --- we get--

$$\boxed{v' - v'' = V = \left[\frac{R_f + R_s}{R_f}\right] \cdot V_1 - \left[\frac{R_s + R}{R}\right] V_2'}$$

7M!

V.V.V Imp * *

CLAMPING CIRCUIT THEOREM:

* * *

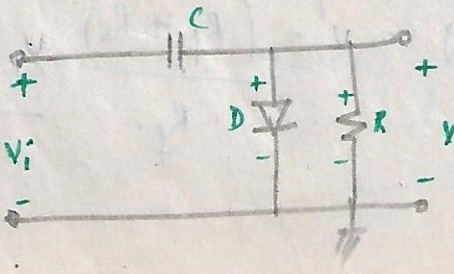
Imp!

Statement :

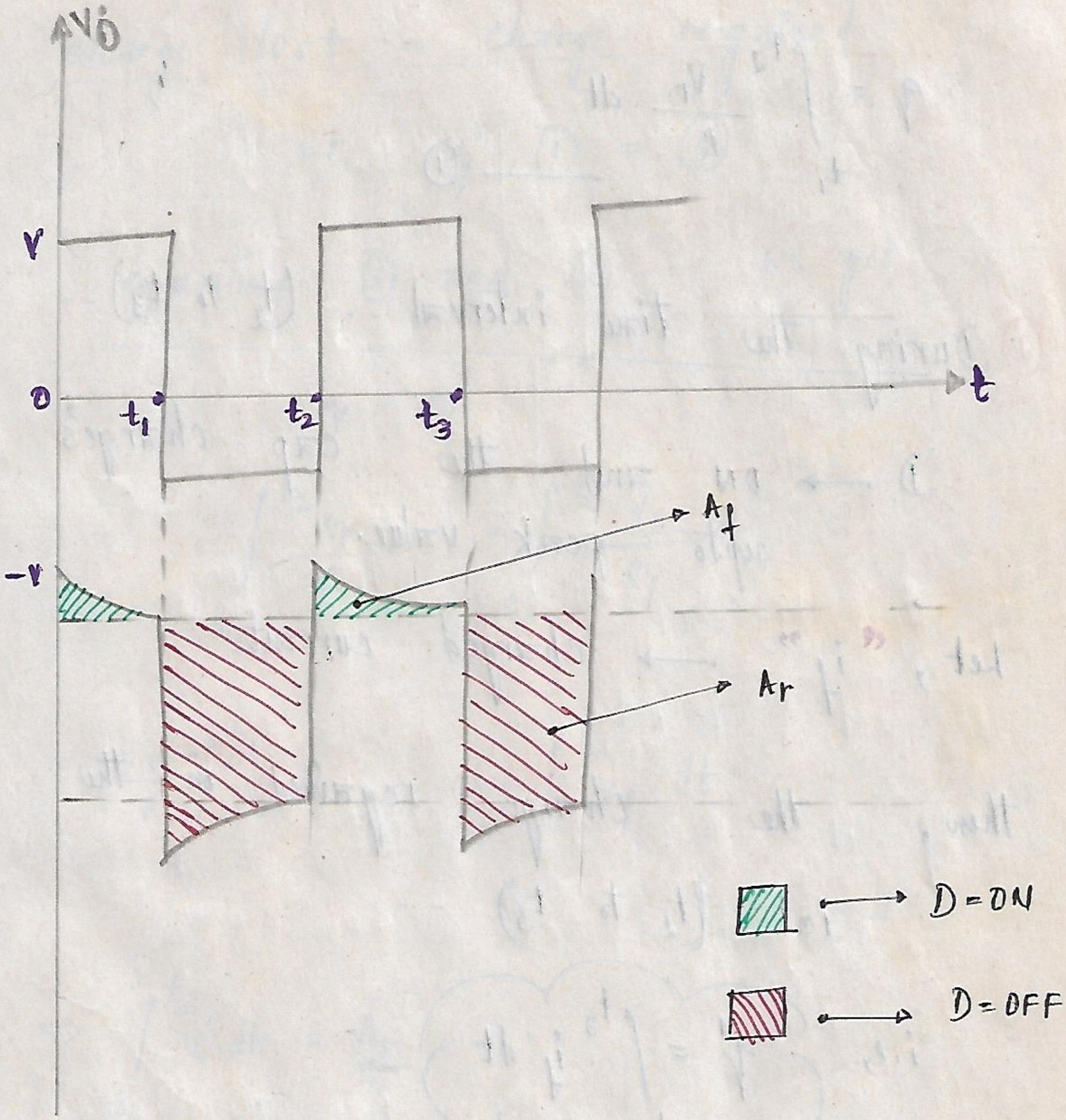
It states that, under steady state condition -- the ratio of the area under the output curve in F. direction to the area under the output curve in R. direction. = $\left(\frac{R_f}{R}\right)$.

$$\boxed{\text{i.e.,} \quad \frac{A_f}{A_r} = \frac{R_f}{R}}$$

proof : Consider -ve clamping ckt



output wave form's :



① During the time interval (t_1 to t_2) ...

D → OFF and the cap discharge's.

then, the charge lost in the time interval (t_1 to t_2) i.e.,

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

where, $i_r = \frac{V_r}{R}$

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

② During the time interval .. (t_2 to t_3) ..

D → ON and the cap charge's upto peak value

Let, "i_f" → charged current.

then, the charge regained in the int (t_2 to t_3) --

i.e, $$\boxed{q' = \int_{t_2}^{t_3} i_f \cdot dt}$$

where, $i_f = \frac{V_f}{R_f}$.

on sub -. we get --

$$q' = \int_{t_2}^{t_3} \frac{V_f}{R_f} \cdot dt \qquad \text{———} \ ②$$

At steady state ...

<u>charge lost = charge regained.</u>

i.e, eq^n ① = ②.

equating ① and ② ... we get ..

$$q = q'$$

$$\int_{t_1}^{t_2} \frac{V_r}{R} dt = \int_{t_2}^{t_3} \frac{V_f}{R_f} . dt$$

$$\frac{1}{R} \int_{t_1}^{t_2} V_r . dt = \frac{1}{R_f} \int_{t_2}^{t_3} V_f . dt .$$

$$\Rightarrow \int_{t_1}^{t_2} V_r . dt = \underline{\underline{A_r}}$$

$$\int_{t_2}^{t_3} V_f . dt = \underline{\underline{A_f}} .$$

<u>Now</u> ...

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

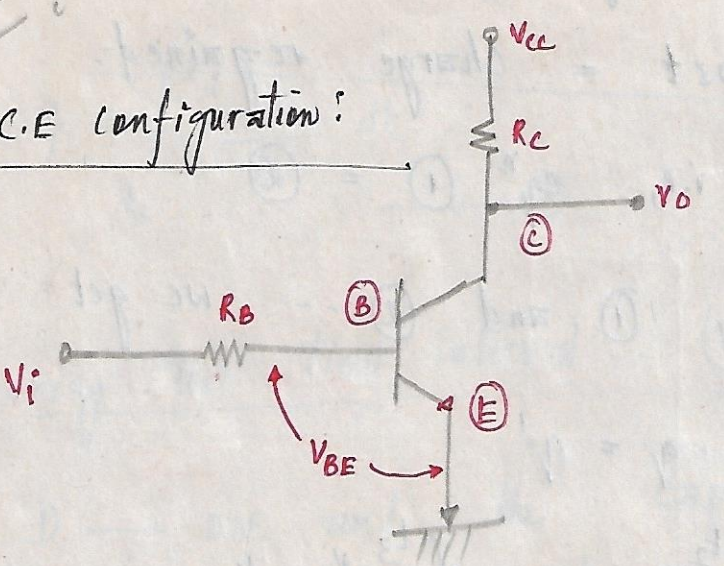
$$\boxed{\Rightarrow \frac{A_f}{A_r} = \frac{R_f}{R}}$$

Hence, proved.

Int :

Transistor as a switch:

C.E configuration:

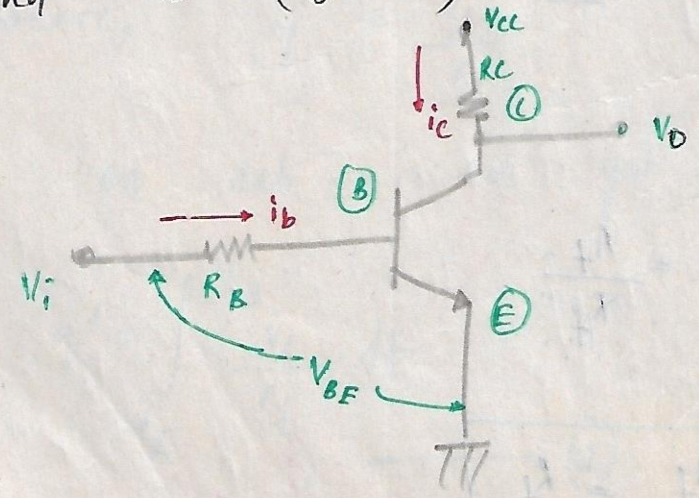


* If $\underline{V_i < V_{BE}}$ cut in, transistor does not conduct.

* If it doe's not conduct...

$\boxed{i_c = 0}$ and $\boxed{V_0 (V_{CE}) = V_{CC}}$..

* If $V_i > V_{BE}$ cut in, transistor conduct's, and the $(i_B$ & $i_c)$ start's flowing.



$i_B = \frac{V_i - V_{BE}}{R_B}$, $V_0 = V_{CC} - i_C R_C$

* In the A.R ...

$$\boxed{i_C \simeq \beta i_B}$$

* If $V_i \uparrow \longrightarrow i_B \uparrow \longrightarrow i_C \uparrow \longrightarrow V_0 (V_{CE}) \downarrow$

* when (V_{CE}) reache's to $V_{CE(sat)}$ it can not decrease further, so (i_c) can not increase further. In this region we can say that (BJT) is saturated.

i.e, $\boxed{I_C = I_{C\,sat}}$

$$\boxed{V_{CE}(V_0) = V_{CE\,sat} \simeq 0.}$$

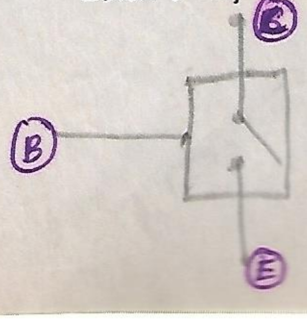
Conclusion :

In cut off region ...

$\boxed{I_C = 0}$

$\boxed{V_0 (V_{CE}) = V_{CC}}$

BJT is a controlled switch. This switch is in b/w (C and E) and the (B) is used as controlled terminal.



⊛ In the cut - off region,

BJT acts as open switch

$(\because i_c = 0)$

⊛ In Sat. region ...

$$I_C = I_{C\,sat}$$

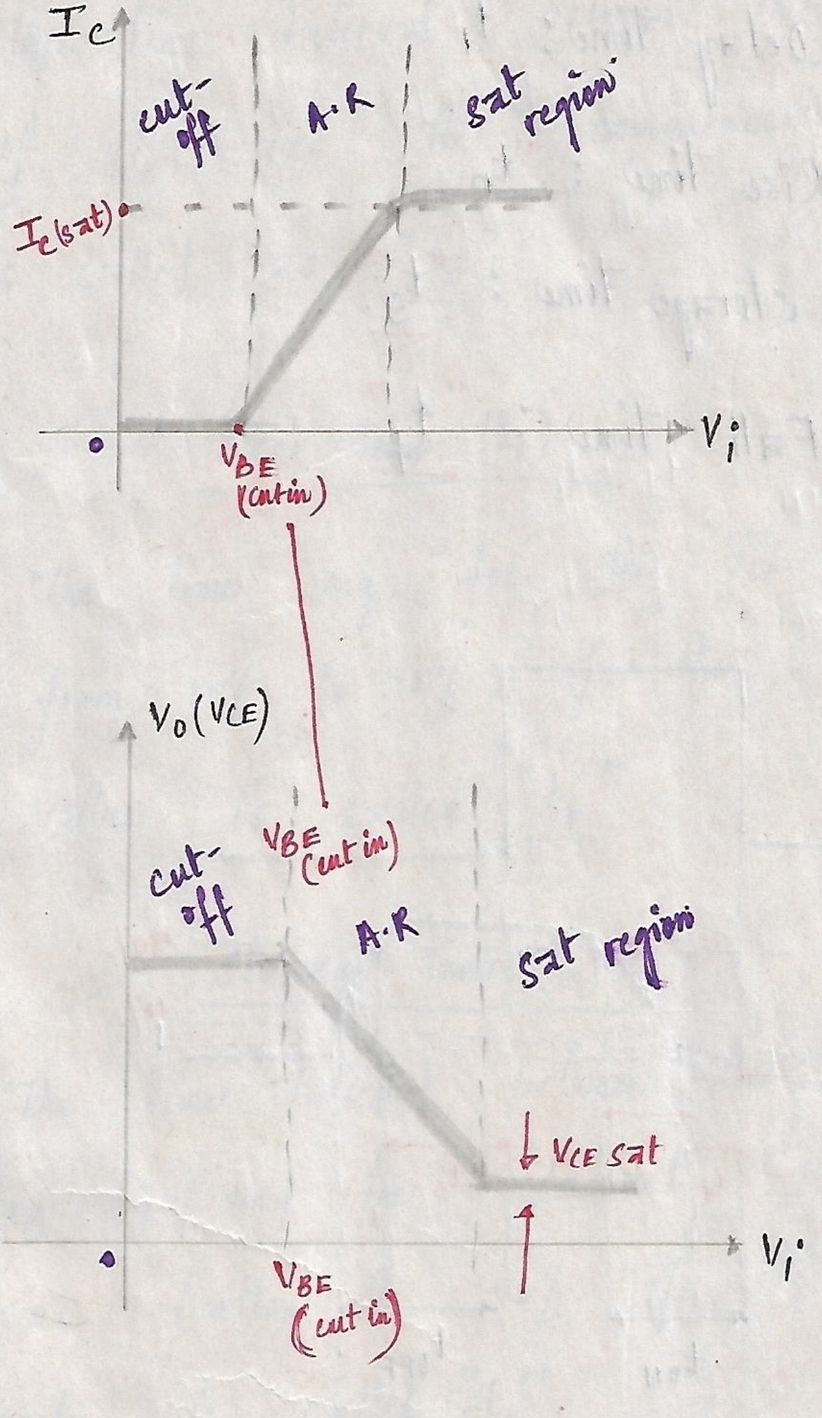
$$V_{CE}(V_0) = V_{CE\,sat} \approx 0$$

BJT acts as a closed switch.

$(\because V_0 \approx 0)$.

⊛ In A.R ...

transistor acts as an amplifier.



I_C
cut-off
A.R
sat region
$I_{C(sat)}$
V_i
V_{BE} (cut in)
$V_0 (V_{CE})$
V_{BE} (cut in)
cut-off
A.R
sat region
V_{CE} sat
V_i
V_{BE} (cut in)