1

Non-linear Wave Shaping

The circuit for which the outputs are non-sinusoidal for sinusoidal inputs are called non-linear wave shaping circuits, for example clipping circuits and clamping circuits

→ Non-linear wave shaping circuits may be classified as clipping circuits and clamping circuits. clipping circuits may be single level clippers or two level clippers.

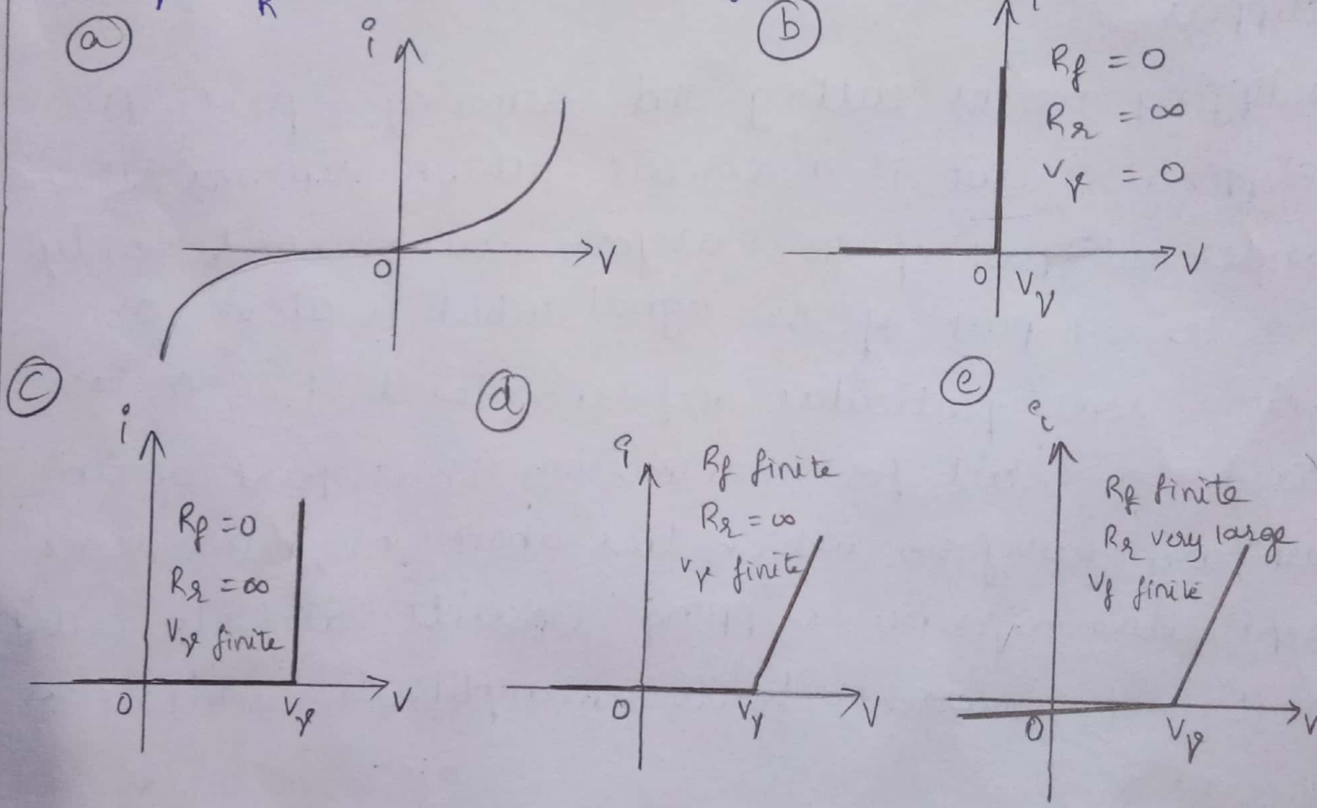
→ clipping means cutting and removing a part. A clipping circuit is a circuit which removes the undesired part of the waveform and transmits only the desired part of the signal which is above or below some particular reference level, i.e., it is used to select for transmission that part of an arbitary waveform which lies above or below some particular reference. clipping circuits are also called voltage (or current) limiters, amplitude selectors or slicers

→ Single level clippers may be series diode clippers with and without reference or shunt diode clippers with and without reference. clipping circuits may use diodes or transistors.

→ clamping circuits may be negative clampers (positive peak clampers) with and without reference or positive clampers (negative peak clampers) with and without reference.

** Diode clippers

The figure (a) shows the v-i characteristics of a practical diode & figures (b), (c), (d), (e) show the v-i characteristics of an idealized diode approximated by a curve which is piece-wise linear and continuous. The break point occurs at V_γ, where $V_\gamma \approx 0.2V$ for Ge and $V_\gamma \approx 0.6$ for Si. Usually V_γ is very small compared to the reference voltage V_R and can be neglected



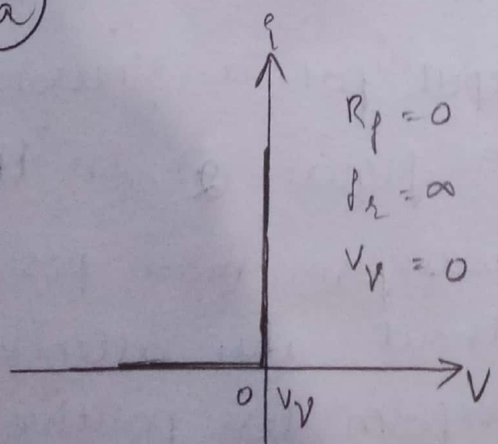
* Shunt clippers

- clipping above reference level

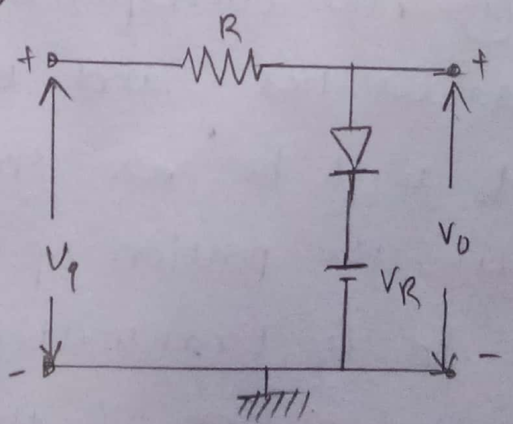
Using the ideal diode characteristics of figure (a), the clipping circuit shown in figure (b), has the transmission characteristics shown in figure (c). The transmission characteristics which is a plot of the output voltage V_o as a function of the input voltage V_i also exhibits piece-wise linear discontinuity. The break point occurs at the reference voltage V_R. To the left of the break point i.e., for $V_i < V_R$ the diode is reverse biased (OFF) and the equivalent circuit shown in figure (d) results. In this region the signal V_i may be transmitted directly to the output, since there is no load across the output to cause a drop across the series resistor R. To the right of the break point i.e., for $V_i > V_R$ the diode is forward biased (ON) and the equivalent circuit shown in figure (e) results and increments in the inputs are totally attenuated and the output is fixed at V_R.

Figure (c) shows a sinusoidal input signal of amplitude large enough so that the signal makes excursions past the break point. The corresponding output exhibits a suppression of the +ve peak of the signal. The output will appear as if the +ve peak had been clipped off or sliced off.

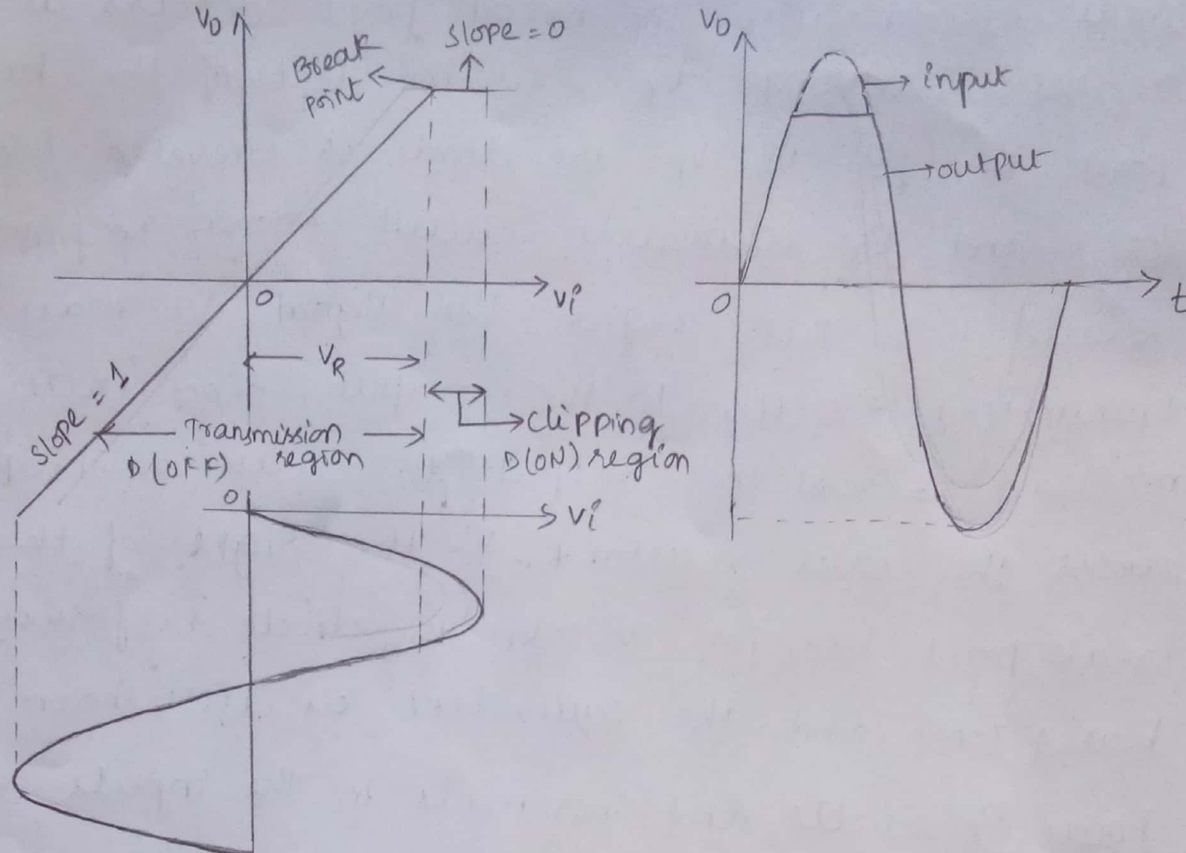
(a)



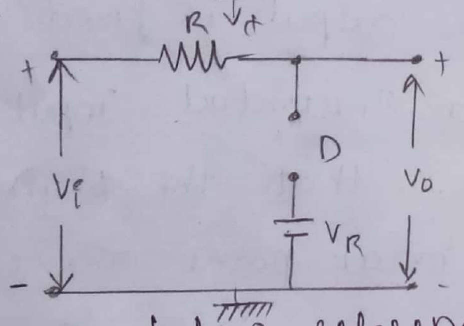
(b)



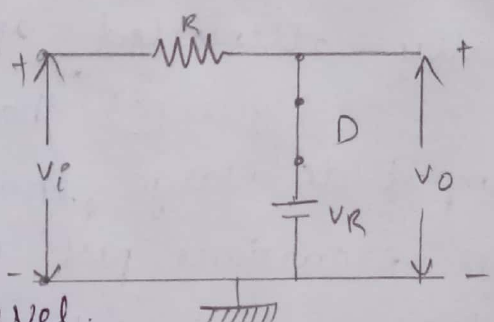
(c)



(d)



(e)

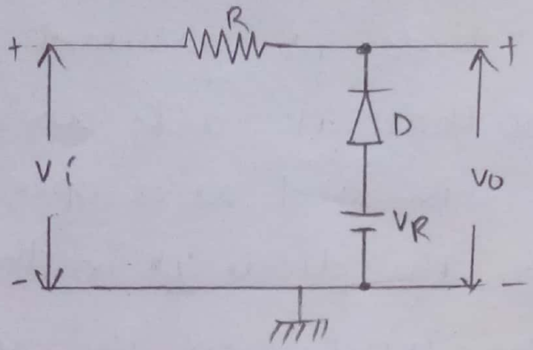


- clipping below reference level.

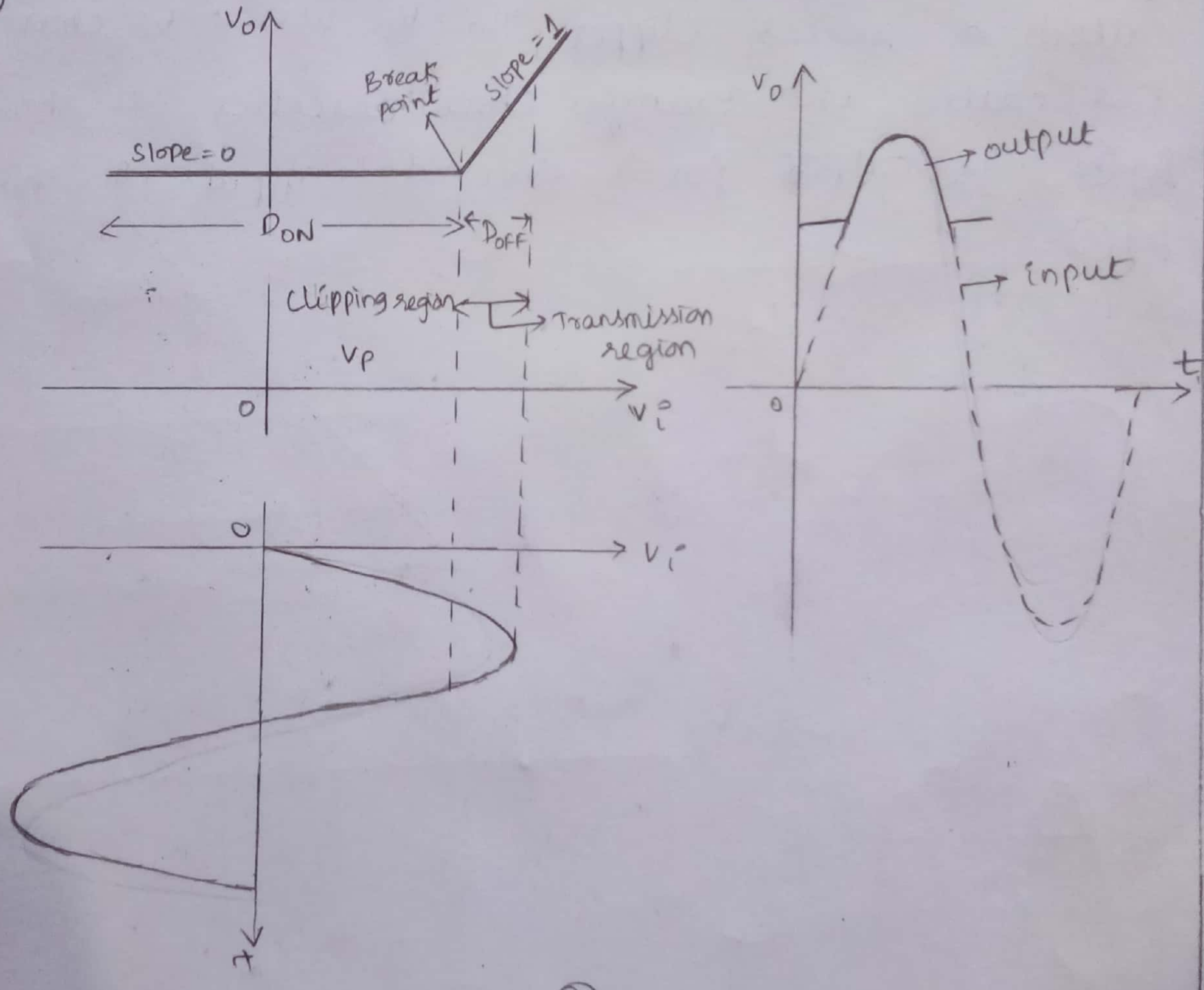
If this clipping circuit of fig (b) (above reference), is modified by reversing the diode as shown in fig (1), the corresponding piece-wise linear transfer characteristics and the output for a sinusoidal input will be as shown in figure (2). In this circuit, the portion of the waveform more positive than V_R is transmitted without any attenuation but the portion of the waveform less positive than V_R is totally suppressed. For $V_i < V_R$, the diode conducts and acts as a short circuit and the equivalent circuit shown in fig (3) results and the

3 output is fixed at V_R. For $V_i > V_R$, the diode is reverse biased and acts as an open circuit & the equivalent circuit shown in fig ④ results and the o/p is the same as the input.

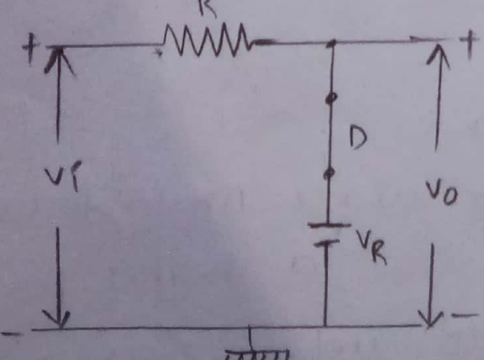
①



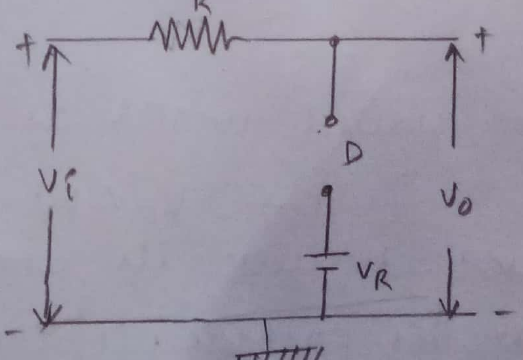
②



③



④

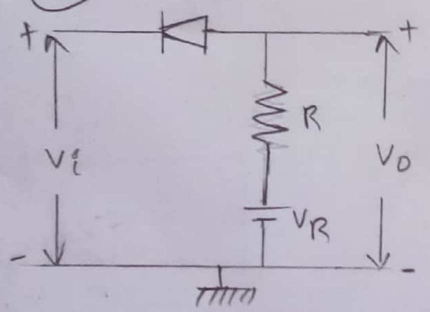


* Series Clippers

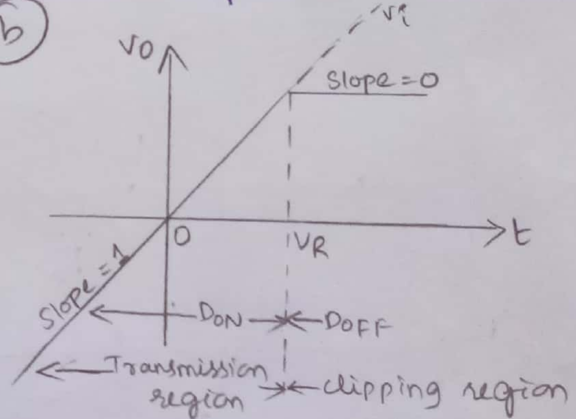
- Clipping above the reference voltage V_R.

Figure ⓐ shows a series clippers circuit using a p-n junction diode. V_R is the reference voltage source. the diode is assumed to be ideal ($R_f = 0, R_r = \infty, V_\gamma = 0$) so that it acts as a short circuit when it is ON and as a open circuit when it is OFF. since the diode is in the series path connecting the input and the output it is called a series clipper. the V_o versus V_i characteristics called the transfer characteristics is shown in fig ⓑ. The output for a sinusoidal input is shown in fig ⓒ.

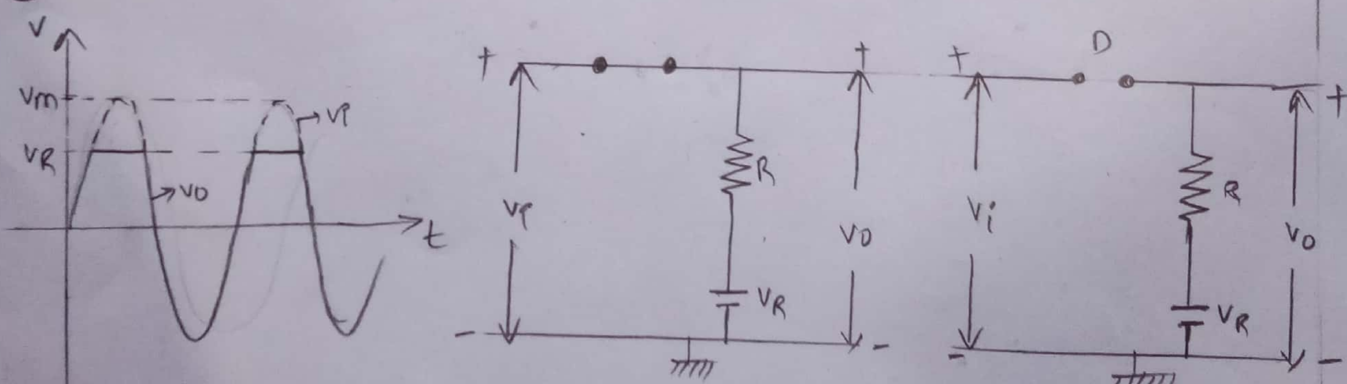
(a)



(b)



(c)



The circuit works as follows:

For $V_i < V_R$, the diode D_1 is forward biased because its anode is at a higher potential than its cathode. It conducts and acts as a a short circuit and the equivalent circuit shown in ~~the circuit~~ fig ⓓ results. The difference voltage between the input V_i and the reference voltage V_R i.e., $(V_R - V_i)$ is dropped across R. Therefore $V_o = V_i$ and the slope of the transfer characteristic for $V_i < V_R$ is 1. Since the input signal is transmitted to the output without any change, this region is called the transmission region.

For $V_i > V_R$, the diode is reverse biased because its cathode is at a higher potential than its anode, it does not conduct and acts as an open circuit and the equivalent circuit shown in figure ⓔ results. No current flows through R and so no voltage drop across it. so the o/p voltage $V_o = V_R$ and slope of the transfer characteristics is zero. Since the input signal above V_R is clipped off for $V_i > V_R$, this region is called the clipping region. The equations i.e.,

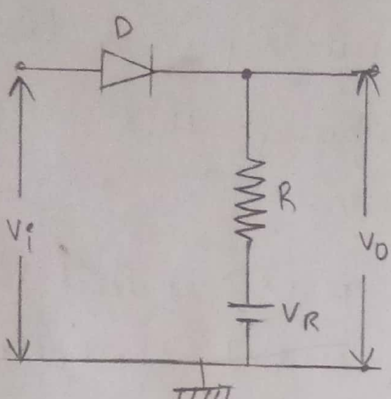
$V_o = V_i$ for $V_i < V_R$ and

$V_o = V_R$ for $V_i > V_R$ are called the transfer characteristics equations.

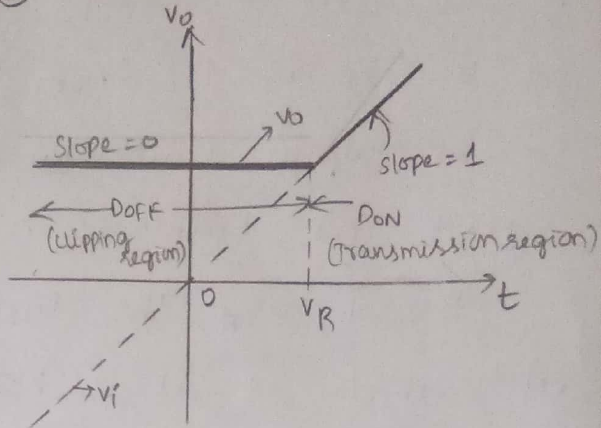
- Clipping below the reference voltage V_R

Figure ⓐ shows a series clipper circuit using a p-n junction diode and a reference voltage source V_R. The diode is assumed to be ideal ($R_f = 0$, $R_r = \infty$, $V_\gamma = 0$) so that it acts as a short circuit when it is ON and as a open ckt when it is OFF. Since the diode is in the series path connecting the input and the output it is called a series clipper. The transfer characteristic is shown in fig (b). The output for a sinusoidal input is shown in figure (c).

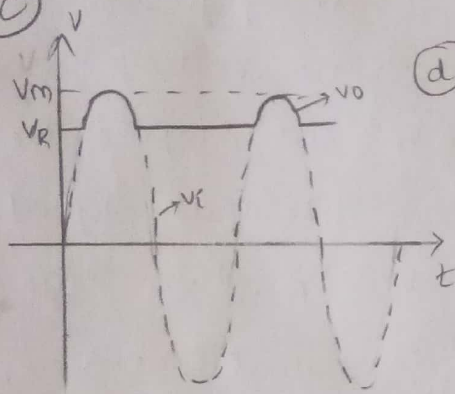
(a)



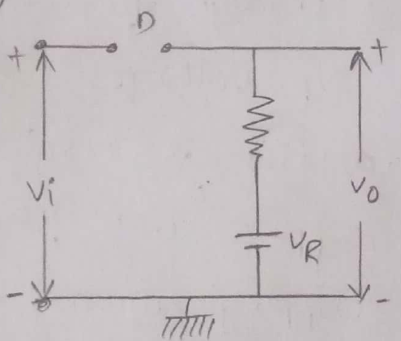
(b)



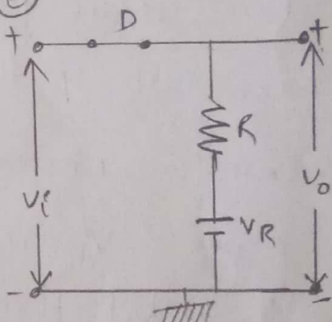
(c)



(d)



(e)



The circuit works as follows:

For $V_i < V_R$, D is reversed biased because its anode is at a lower potential than its cathode. The diode does not conduct and acts as an open circuit and the equivalent circuit shown in fig (d) results. No current flows through R and hence no voltage drop across R and hence $V_o = V_R$, so the slope of the transfer characteristic is zero for $V_i < V_R$. Since the i/p is clipped off for $V_i < V_R$, this region is called the clipping region.

5

For $v_i > V_R$, the diode is forward biased because its anode is at a higher potential than its cathode. The diode conducts and acts as a short circuit and the equivalent ckt shown in fig (e) results, current flows through R and the difference voltage between the input and the output voltage $v_i - V_R$ drops across R and the output $v_o = v_i$. The slope of the transfer characteristics for $v_i > V_R$ is unity. Since the input is transmitted to the o/p for $v_i > V_R$, This region is ~~shown~~ called the transmission region.

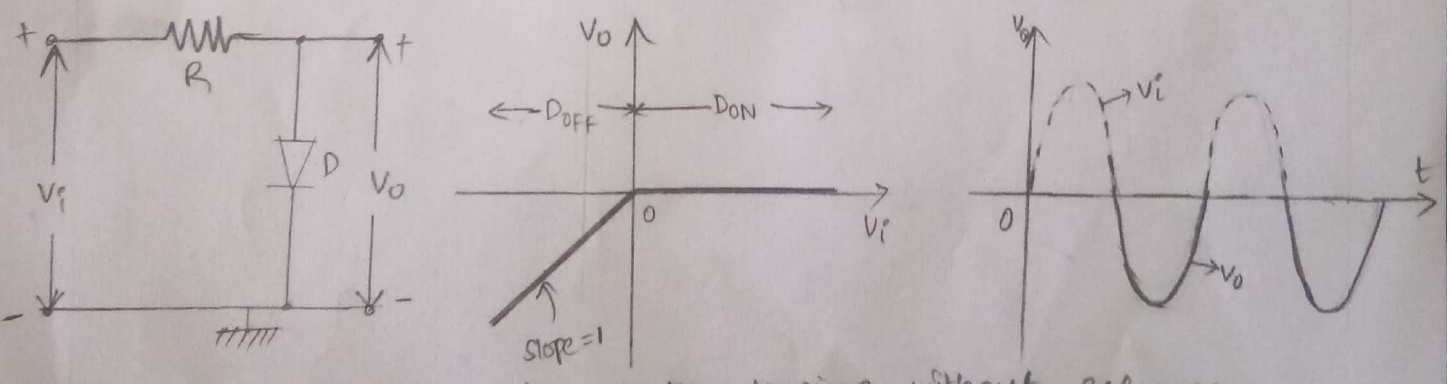
The equations

$$v_o = V_R \text{ for } v_i < V_R$$
$$v_o = v_i \text{ for } v_i > V_R$$

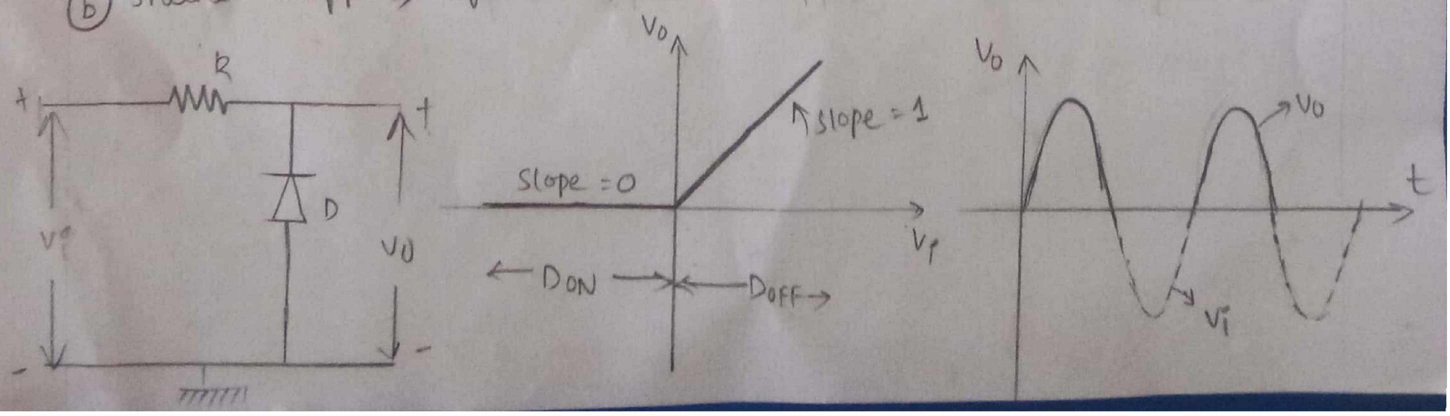
are called the transmission characteristic eq^n's.

* Some single-ended clipping circuits

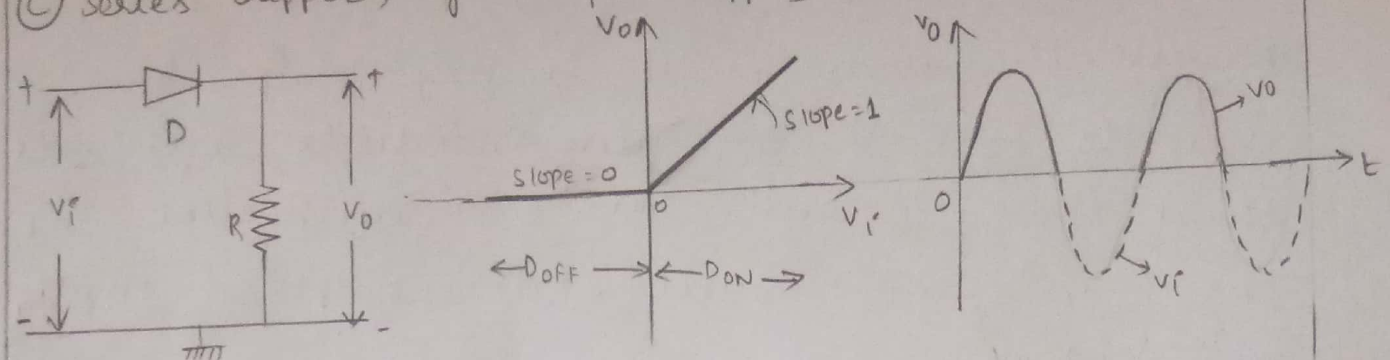
(a) shunt clipper, positive peak clipping without reference



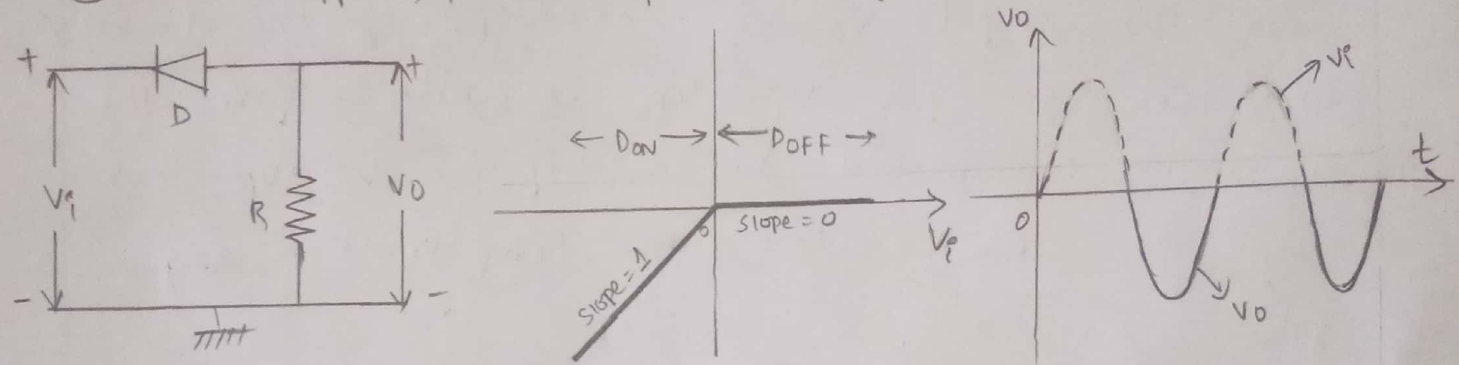
(b) shunt clipper, negative peak clipping without reference.



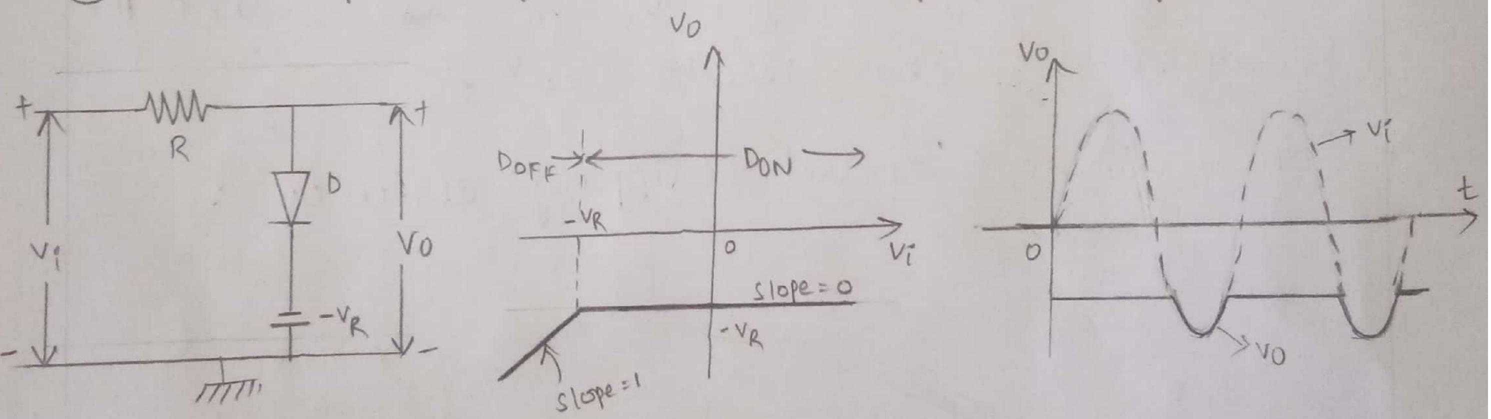
(c) series clipper, negative peak clipping without reference.



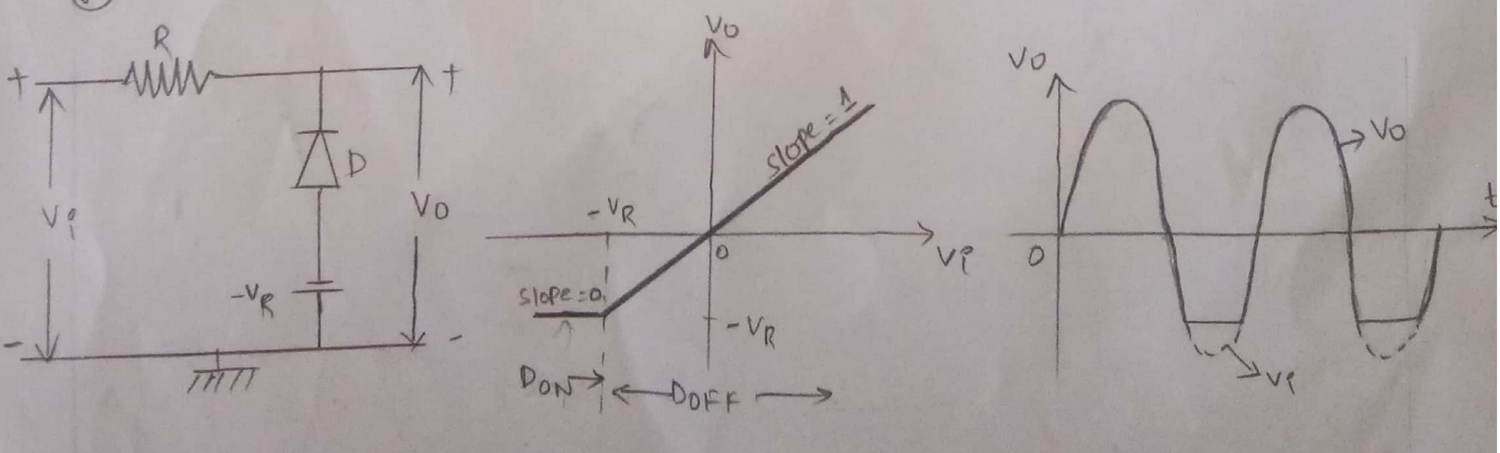
(d) series clipper, positive peak clipping without reference.



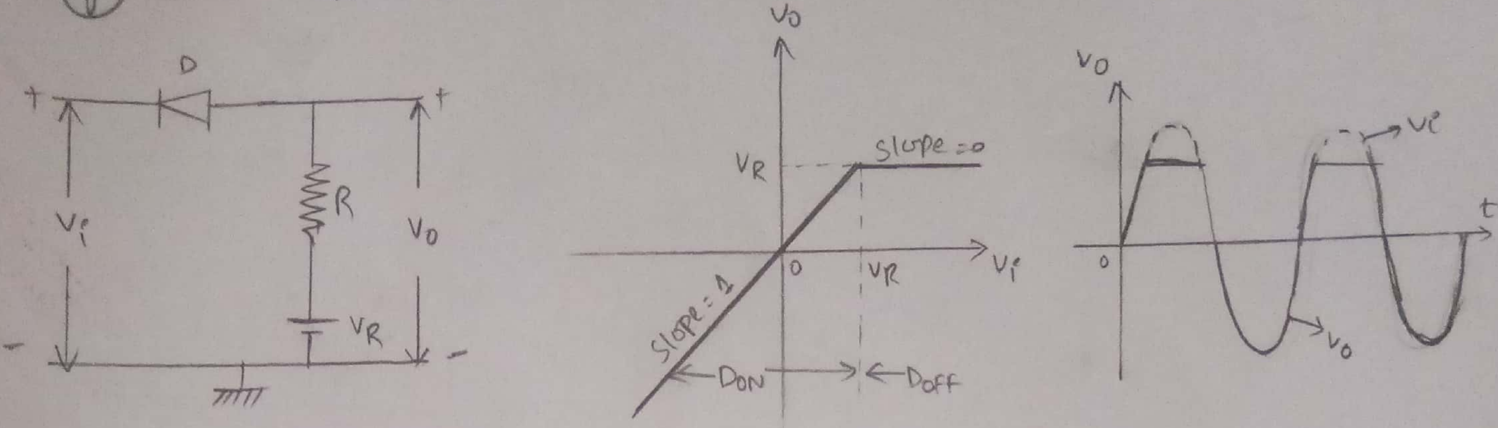
(e) shunt clipper, negative base clipping above reference level



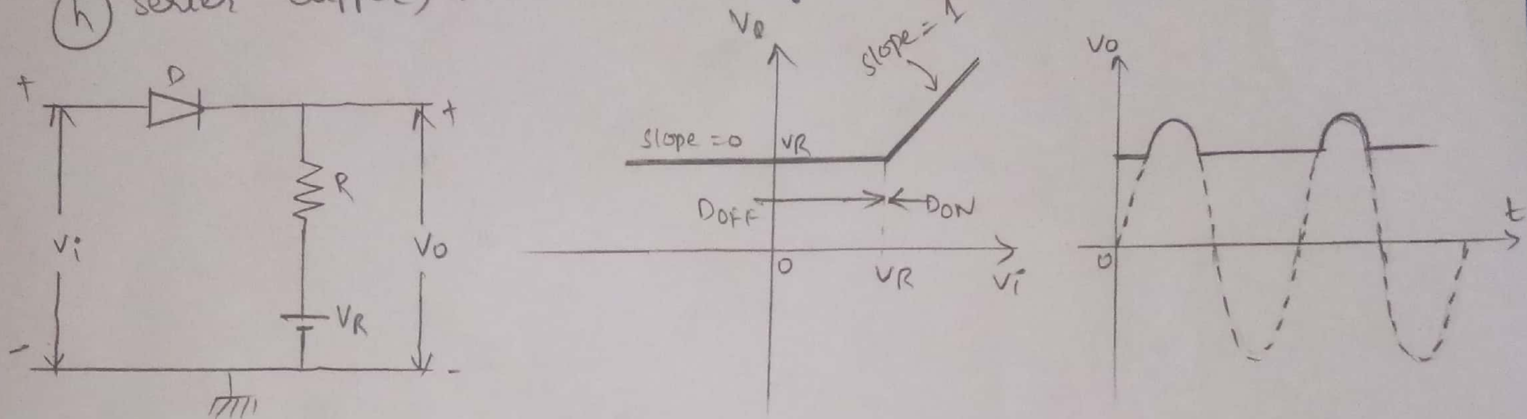
(f) shunt clipper, negative base clipping below reference level



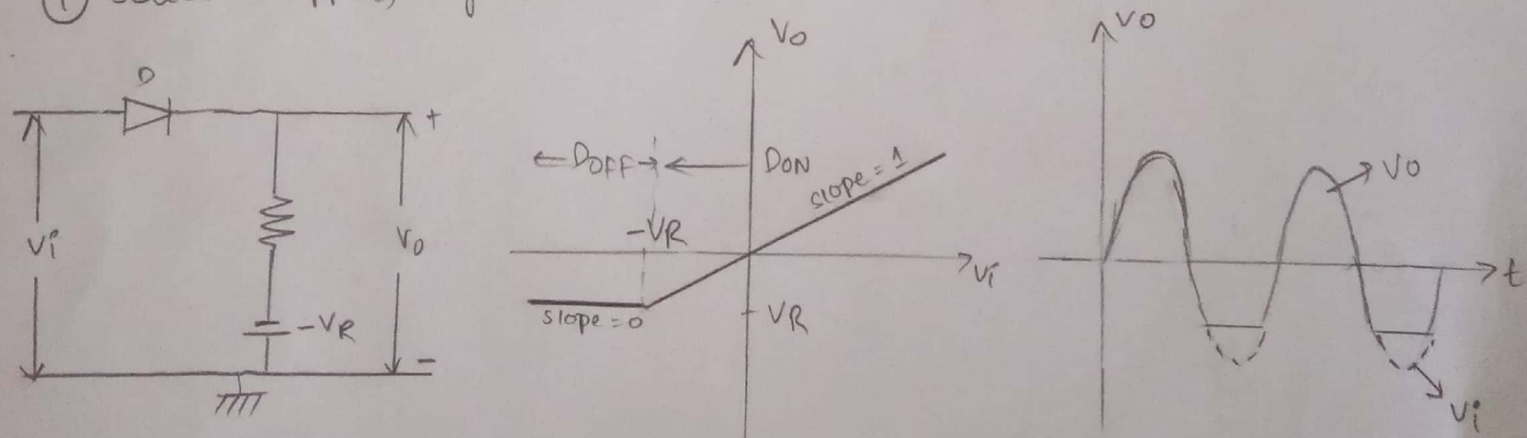
(g) series clipper, positive base clipping above reference level



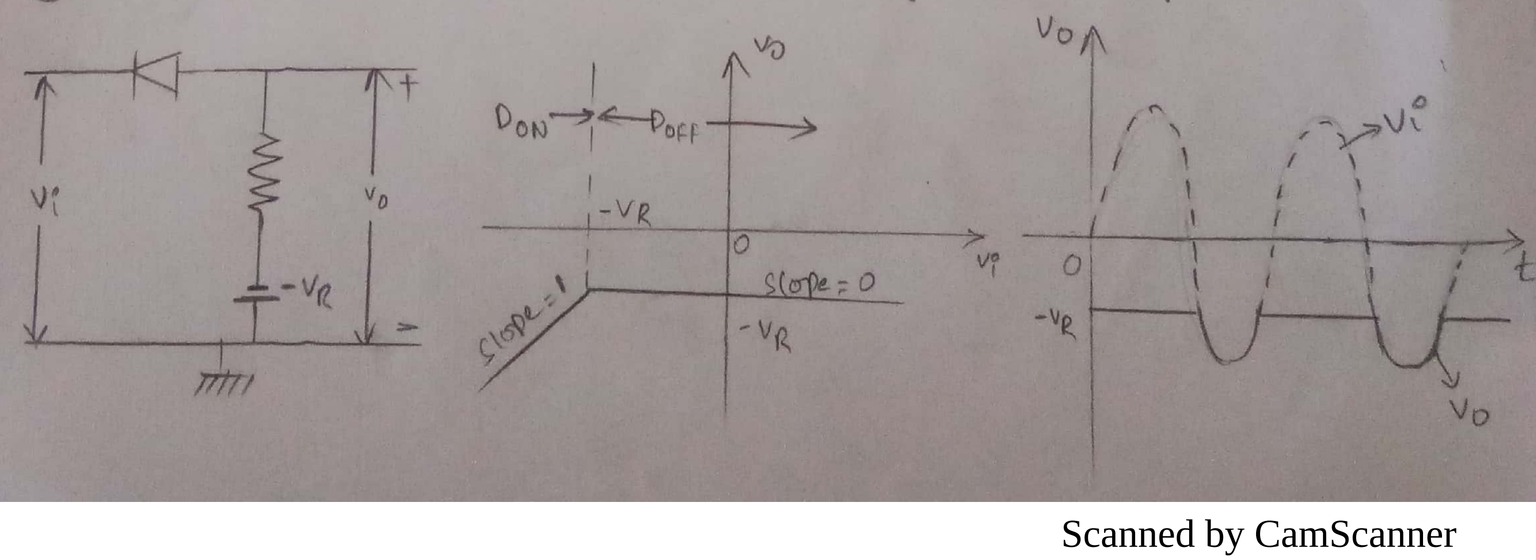
(h) series clipper, +ve base clipping before reference level



(i) Series clipper, negative base clipping below/before reference level



(j) series clipper, negative base clipping above reference level



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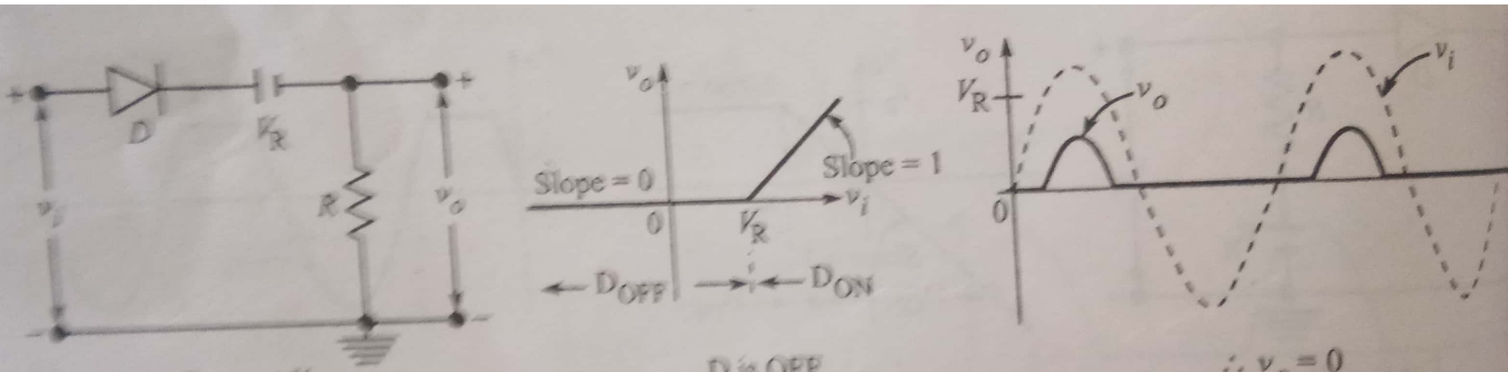
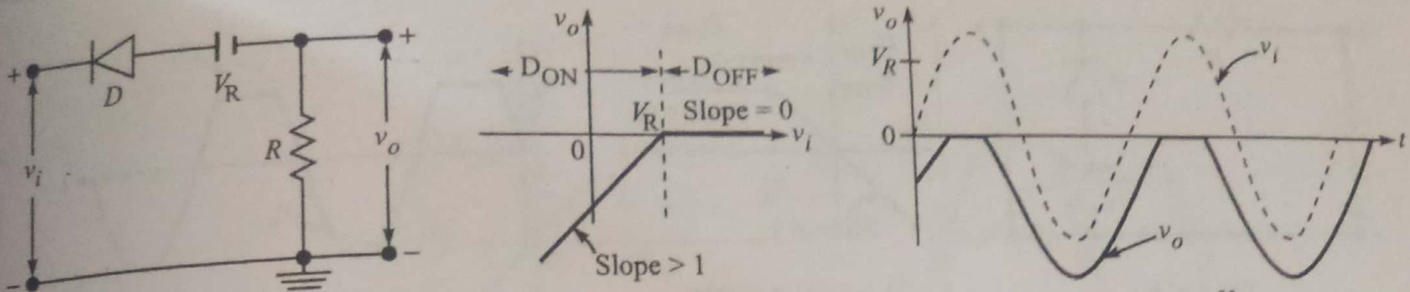


For $v_i < V_R$, D is OFF $\therefore v_o = 0$

For $v_i > V_R$, D is ON $\therefore v_o = v_i - V_R$

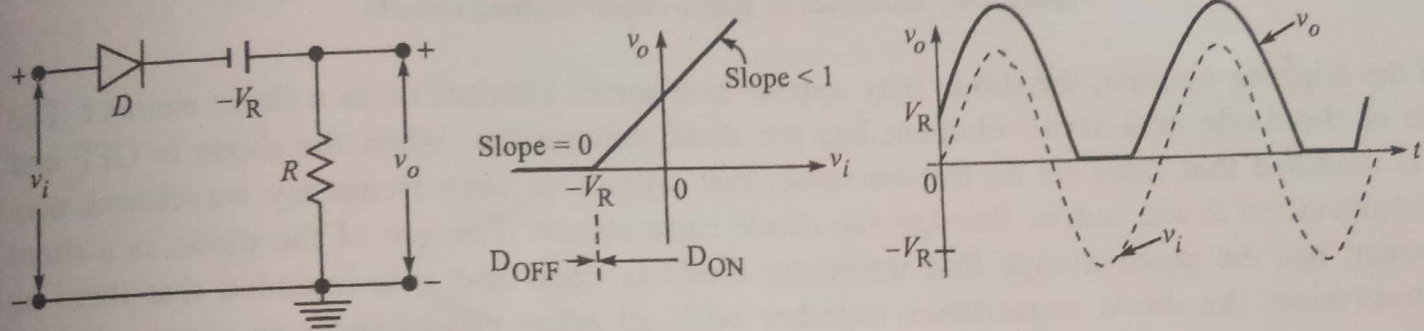
(k) Series clipper (Biased)



For $v_i < V_R$, D is ON $\therefore v_o = v_i - V_R$

For $v_i > V_R$, D is OFF $\therefore v_o = 0$

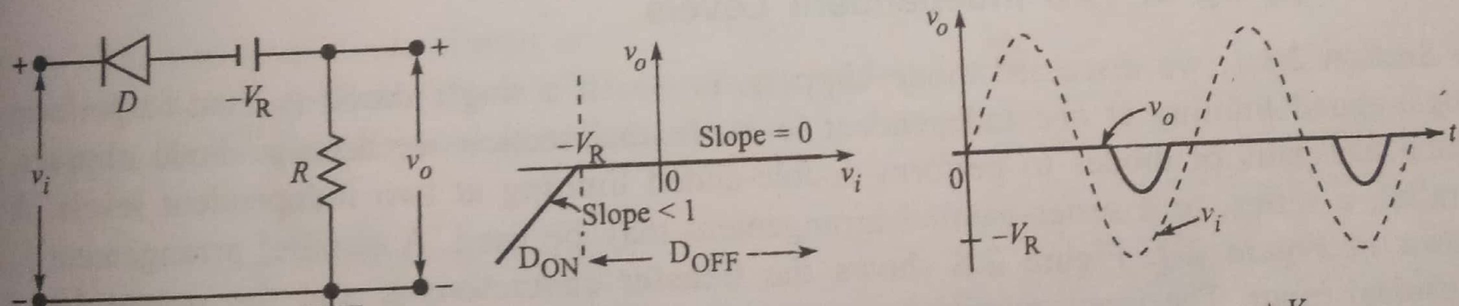
(l) Series clipper (Biased)



For $v_i < -V_R$, D is OFF $\therefore v_o = 0$

For $v_i > -V_R$, D is ON $\therefore v_o = v_i + V_R$

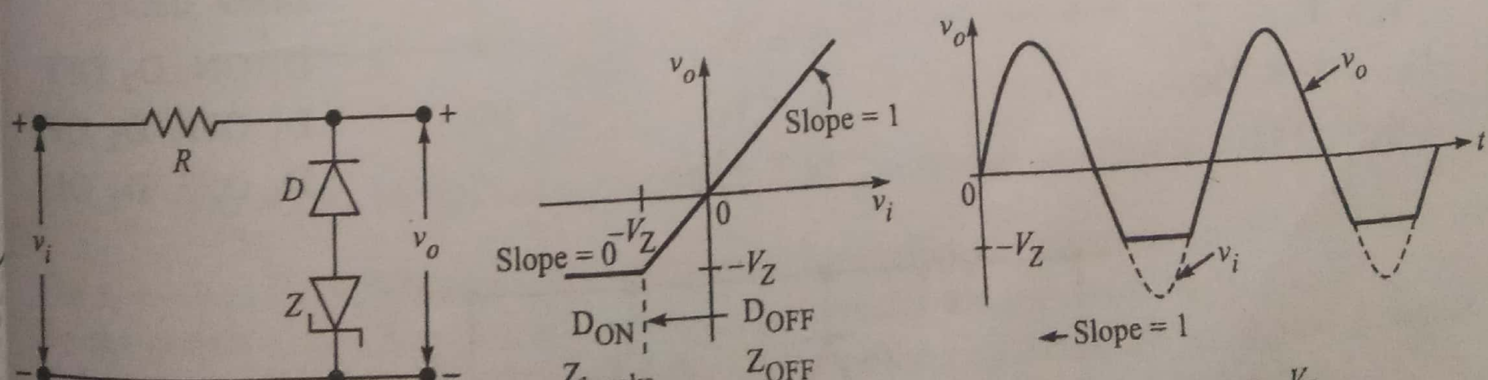
(m) Series clipper (Biased)



For $v_i < -V_R$, D is ON $\therefore v_o = v_i + V_R$

For $v_i > -V_R$, D is OFF $\therefore v_o = 0$

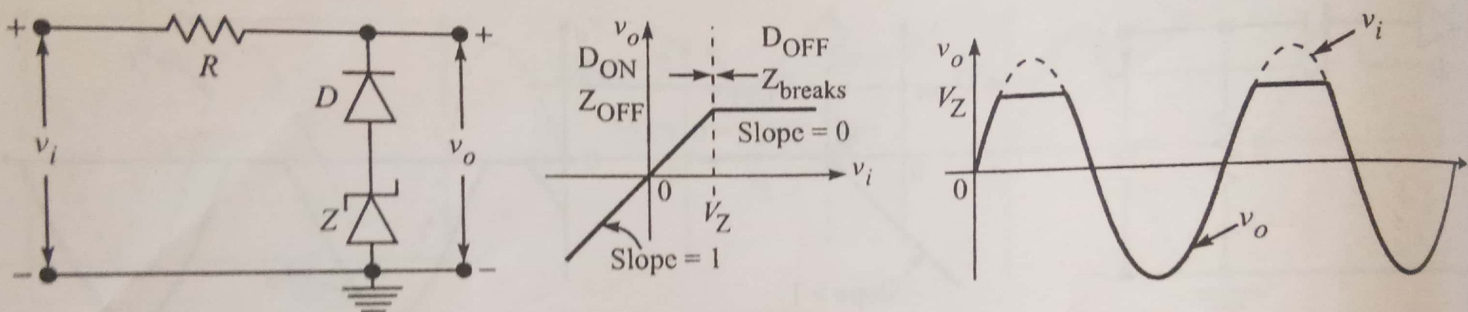
(n) Series clipper (Biased)



For $v_i < -V_Z$, D is ON, Z breaks $\therefore v_o = -V_Z$

For $v_i > -V_Z$, D is OFF, Z is OFF $\therefore v_o = v_i$

(o) Shunt clipper using zener diode, negative clipping



For $v_i < V_Z$, D is OFF, Z is OFF $\therefore v_o = v_i$

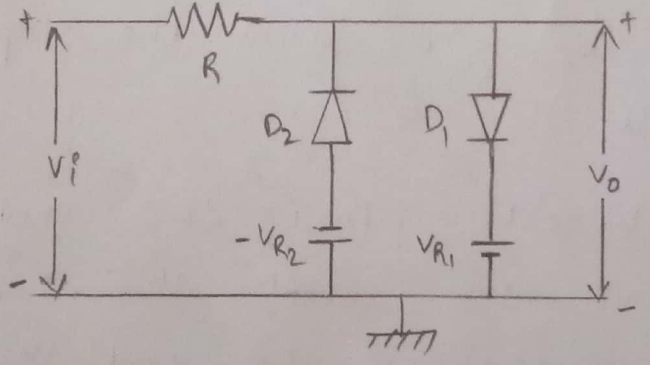
For $v_i > V_Z$, D is ON, Z breaks $\therefore v_o = V_Z$

(p) Shunt clipper using zener diode, positive clipping

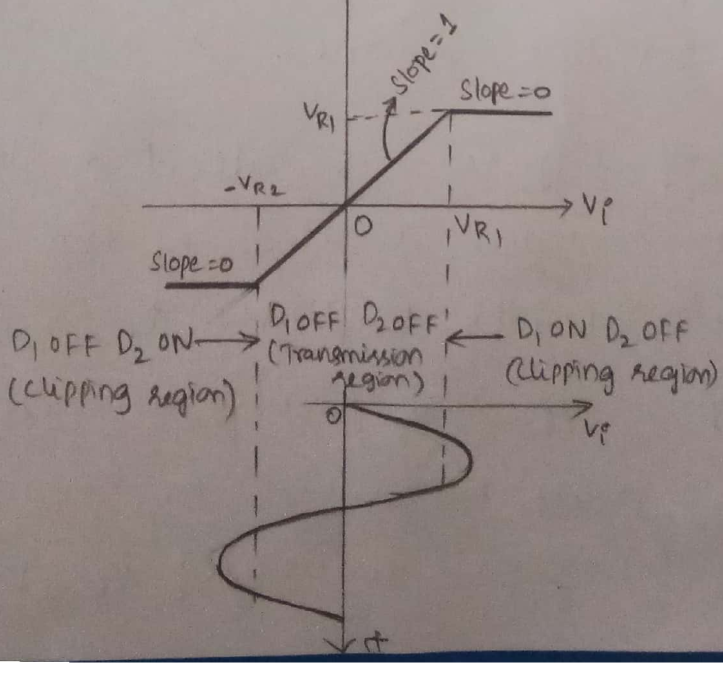
6. * Clipping at Two Independent Levels

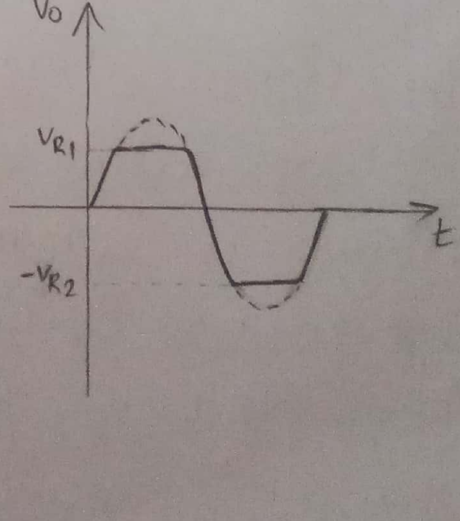
As we discussed about diode clippers, in which a single diode is used to perform single-ended limiting at one independent level. The diode clippers which use pairs of diodes to perform double-ended limiting at two independent levels. A parallel, a series, or a series-parallel arrangement may be used. A parallel arrangement is shown in fig ⓐ.

Fig ⓑ shows the transfer characteristic and the output for a sinusoidal input. The i/p-o/p characteristic has two break points, one at $v_o = v_i = V_{R1}$ and the second at $v_o = v_i = -V_{R2}$ and has the following characteristics.



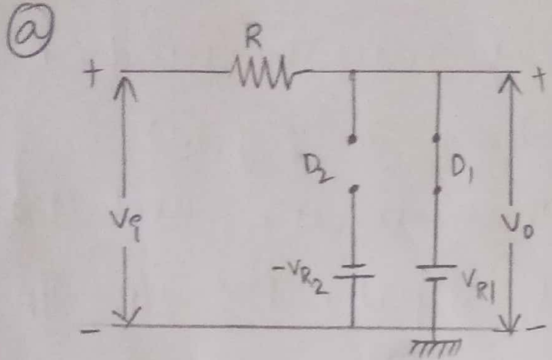
[A diode clipper which limits at two independent levels].



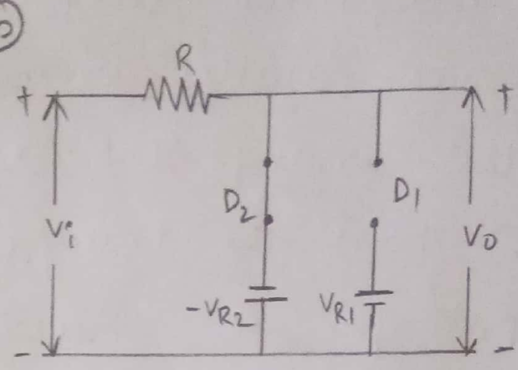


The two level diode clipper shown in the above figure works as follows:

→ For $v_i > V_{R_1}$, D_1 is ON and D_2 is OFF and the equivalent circuit shown in figure (a) results. So the o/p $V_o = V_{R_1}$ and the slope of the transfer characteristic is zero.



Equivalent circuit for $v_i > V_{R_1}$



Equivalent circuit for $v_i < -V_{R_2}$

→ For $v_i < -V_{R_2}$; D_1 is OFF and D_2 is ON and the equivalent circuit shown in fig (b) results. So the output $V_o = -V_{R_2}$ and the slope of the transfer characteristic is zero.

→ For $-V_{R_2} < v_i < V_{R_1}$; D_1 is OFF and D_2 is OFF and the equivalent circuit shown in fig (c) results. So the output $V_o = V_i$ and the slope of the transfer characteristics is one.

The circuit of figure is called a slicer because the output contains a slice of the i/p between two reference levels V_{R_1} and V_{R_2}. Looking at the i/p & o/p waveforms, we observe that this circuit may be used to convert a sine wave into a square wave, if $V_{R_1} = V_{R_2}$,

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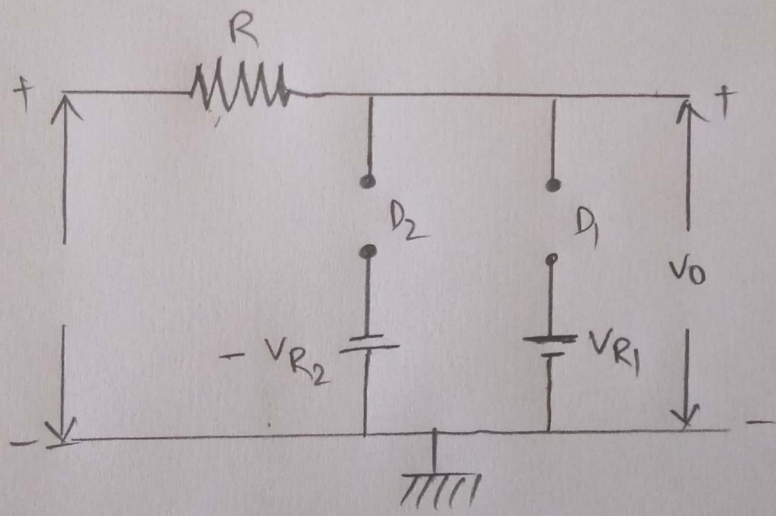
, and if the amplitude of the input signal is very large compared with the difference in the reference levels, the output will be a symmetrical square wave.



Equivalent circuit for $-V_{R_2} < V_i < V_{R_1}$