UNIT-2

NON-LINEAR WAVE SHAPING

Non-Linear Wave Shaping

Definition: The process where by the form of a signal is changed by transmission through a non-linear network is called Non-linear Wave Shaping.

Types:

i. Clippers.

ii. Clampers.

Clipper Classifications

According to biasing, the clippers may be classified as

- Unbiased clippers and
- Biased clippers.

According to configuration used the clippers may be

- Series diode clippers
- Parallel or shunt diode clippers
- A series combination of diode, resistor and reference supply
- Multi-diode clippers consisting of several diodes, resistors and reference voltages
- Two emitter-coupled transistors operating as an over-driven

Contd…

According to level of clipping the clippers may be

- Positive clippers
- Negative clippers
- Biased clippers and
- Combination clippers

Clipper

- Clipping circuits are used to remove the part of a signal that is above or below some defined reference level.

•Clippers also known as

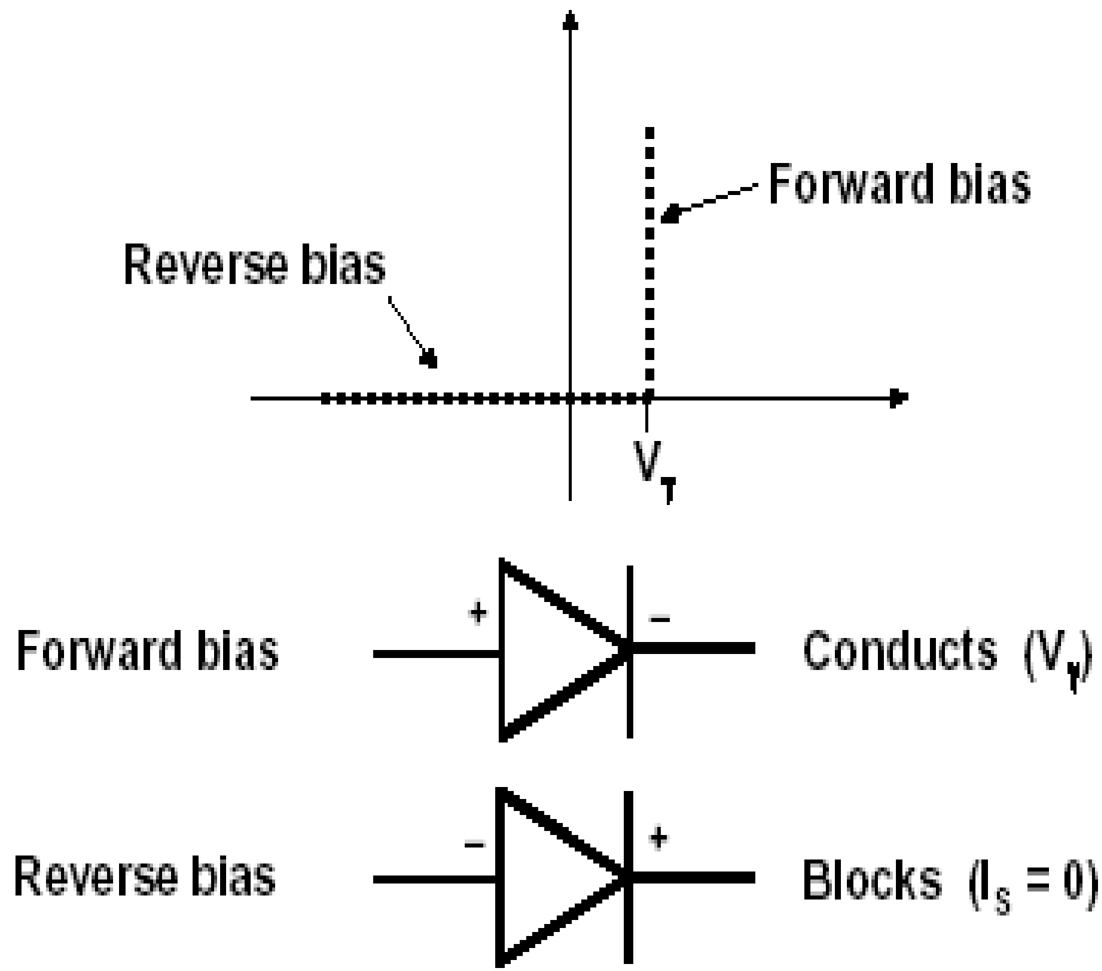
Voltage limiters

Current limiters

Amplitude selectors

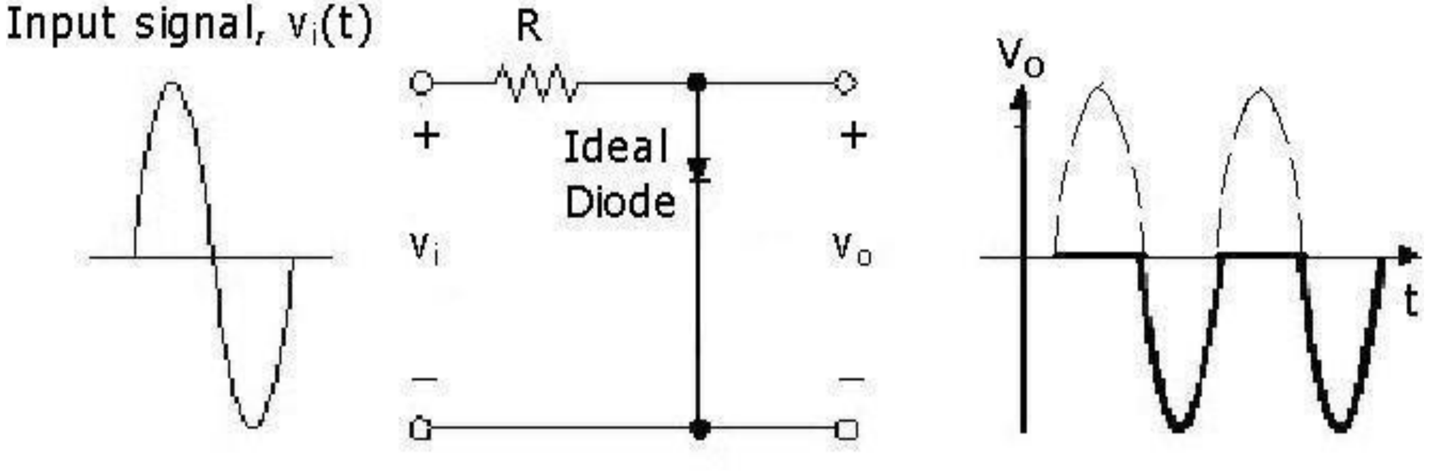
Slicers

Let's again consider piecewise linear diode model



Unbiased clippers(Parallel PositiveClippers)

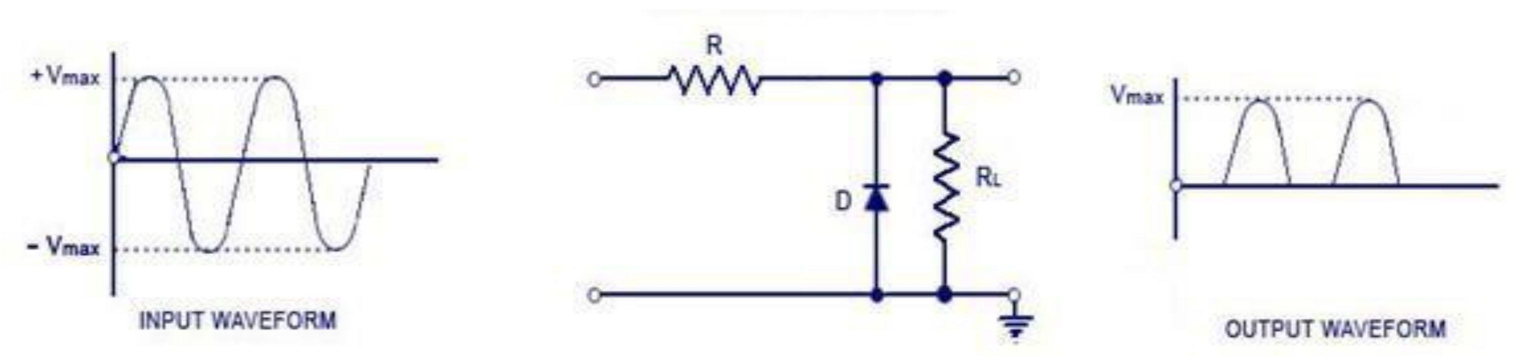
- **Without** the battery, the output of the circuit below would be the negative portion of the input wave (assuming the bottom node is grounded). When *vi* > 0, the diode is on (short-circuited), *vi* is dropped across R and *vo*=0. When *vi* <0, the diode is off (open-circuited), the voltage across R is zero and *vo*=*vi*.



Unbiased clippers(Parallel Negative Clippers)

+ive cycle :- anode is at ground potential and cathode sees variable +ive voltage from 0 to +Vm So complete cycle, the diode is reverse biased and Vo =Vin.At positive peak Vo=+5V

-ive cycle :- anode is at ground potential and cathode sees variable -ive vols from 0 to –Vm. When magnitude of in put volatge i.e / Vin/ >Vd, the diode become forward biased and hence Vo =-Vd =0.7V

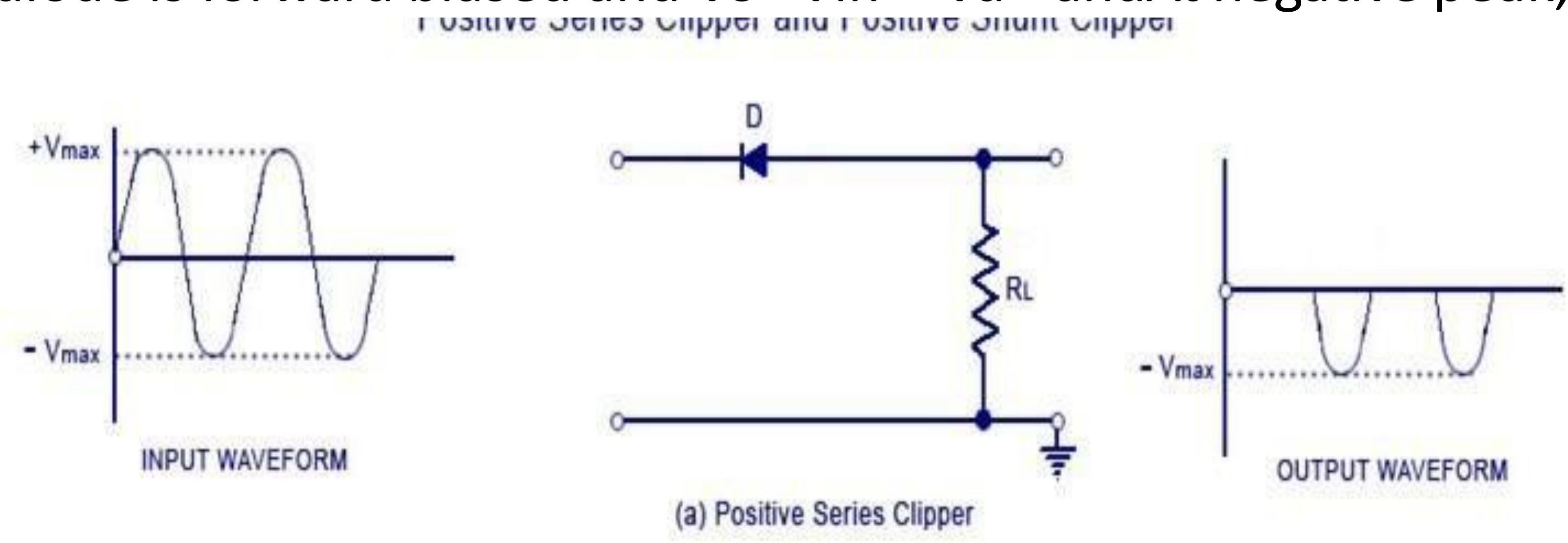


(b) Negative Shunt Clipper

Series positive clipper

+ive cycle :- anode is at ground potential and cathode sees variable +ive voltage from 0 to +Vm.For comlpete, cycle, diode become reverse biased and hence Vo =0V

-ive cycle :- anode is at ground potential and cathode sees variable -ive voltage from 0 to –Vm. So in complete cycle, the diode is forward biased and Vo= Vin + Vd andAt negative peak,

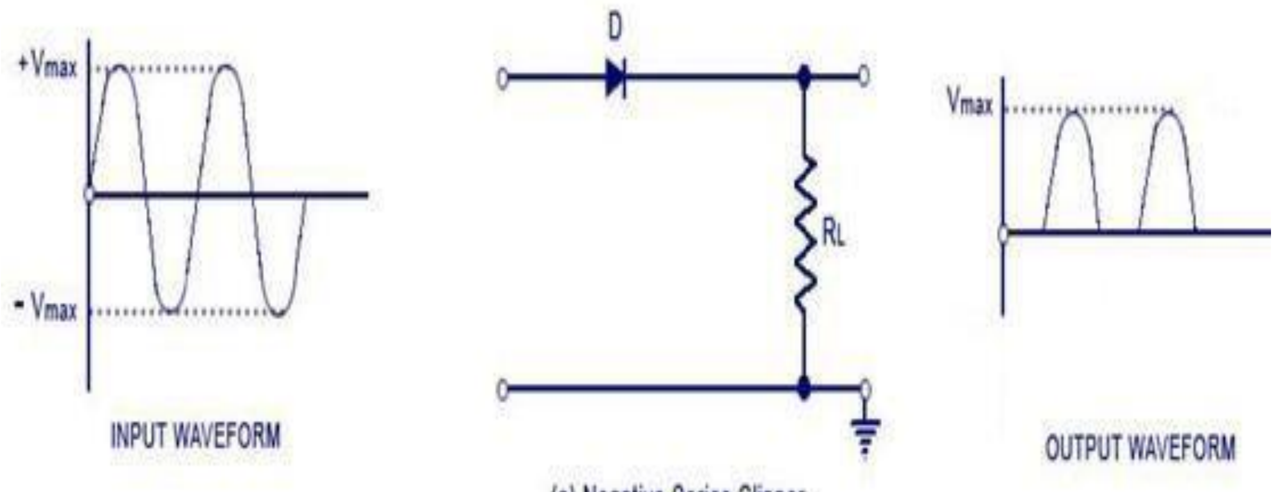


(a) Positive Series Clipper

Series Negative clipper

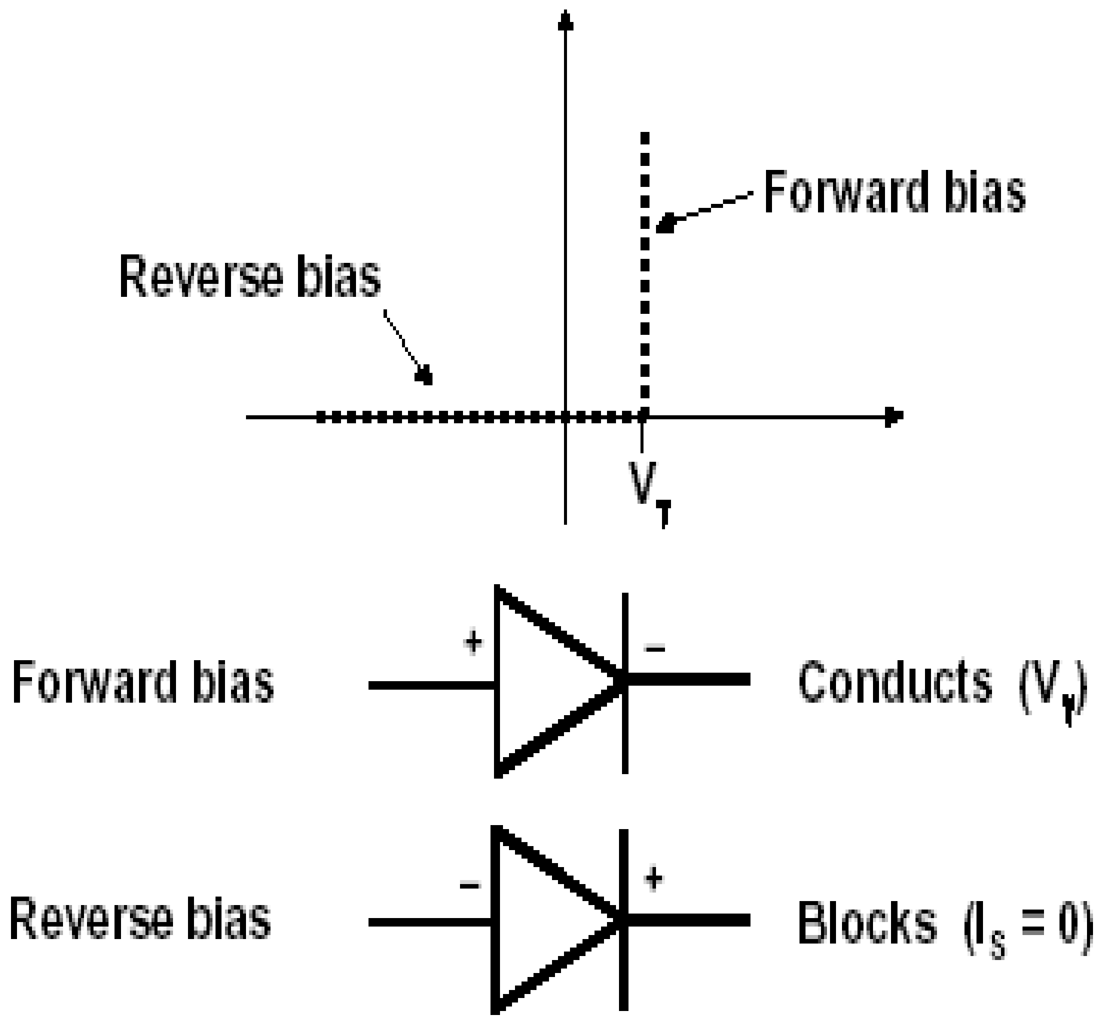
+ive cycle :- anode is at positive potential from 0 to +Vm.For comlpete, cycle, diode become forward biased and hence vo= 5v

-ive cycle :- Cathode is at ground potential and cathode sees variable -ive voltage from 0 to –Vm. So in complete cycle, the diode is Reverse biased and negative peak, Vo= 0

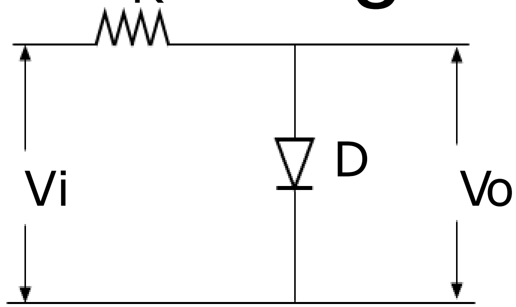


(a) Negative Series Clipper

Let's again consider piecewise linear diode model



Positive Shunt clipping with zero reference voltage

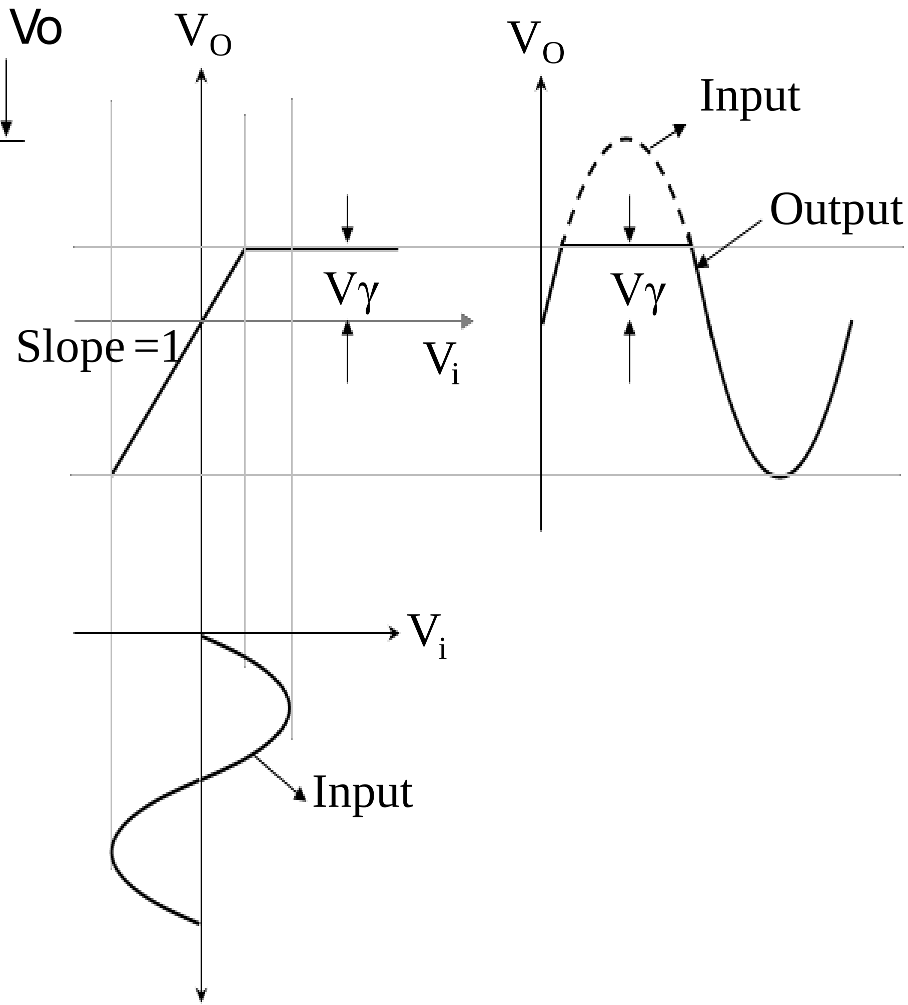


Transfer characteristics equations:

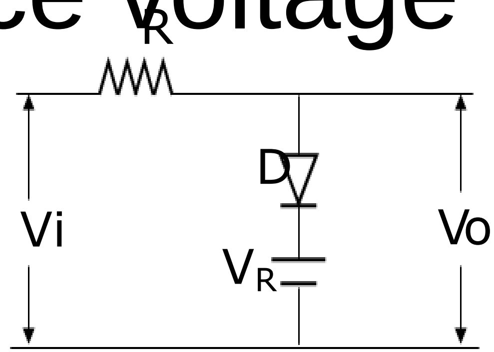
$V_O = 0$ for $V_i > 0$
$V_O = V_i$ for $V_i < 0$
[Ideal]

$V_O = V_\gamma$ for $V_i > V_\gamma$ D – ON

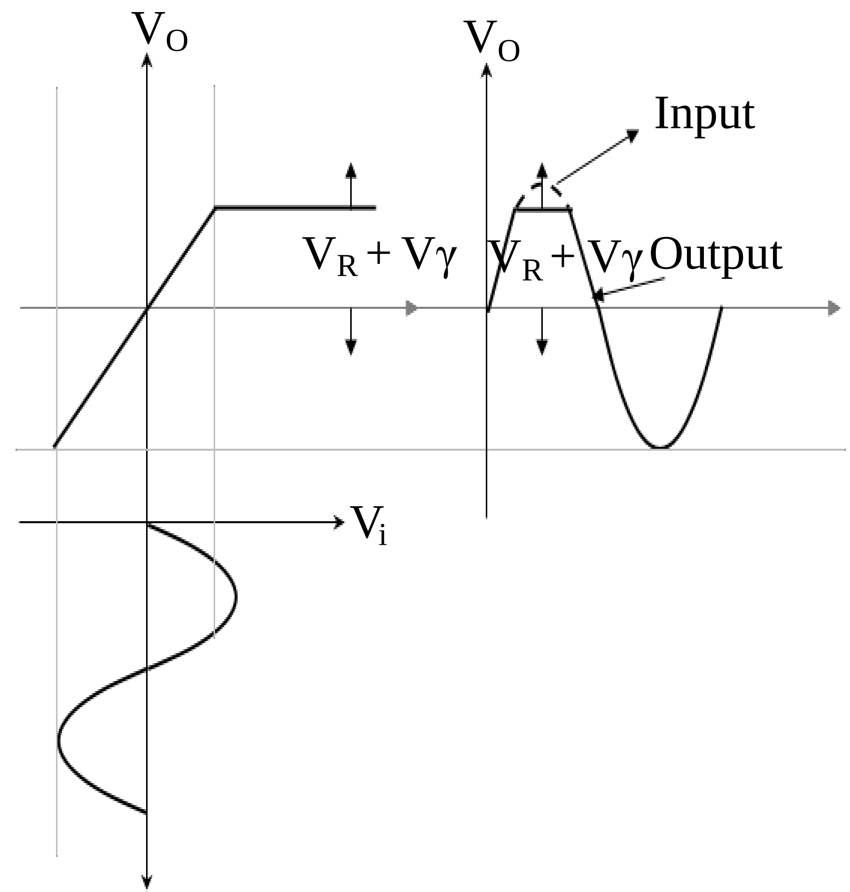
$V_O = V_i$ for $V_i < V_\gamma$ D – OFF



Positive Shunt clipping with positive reference voltage



Transfer characteristics equations:



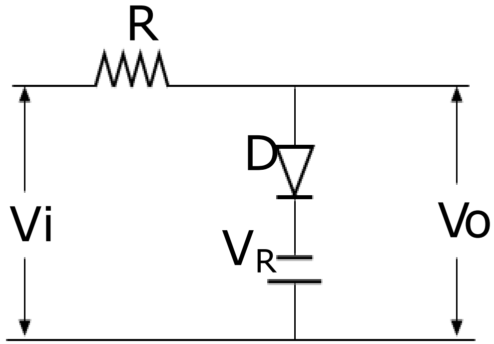
$V_i < V_R + V\gamma$ D – OFF

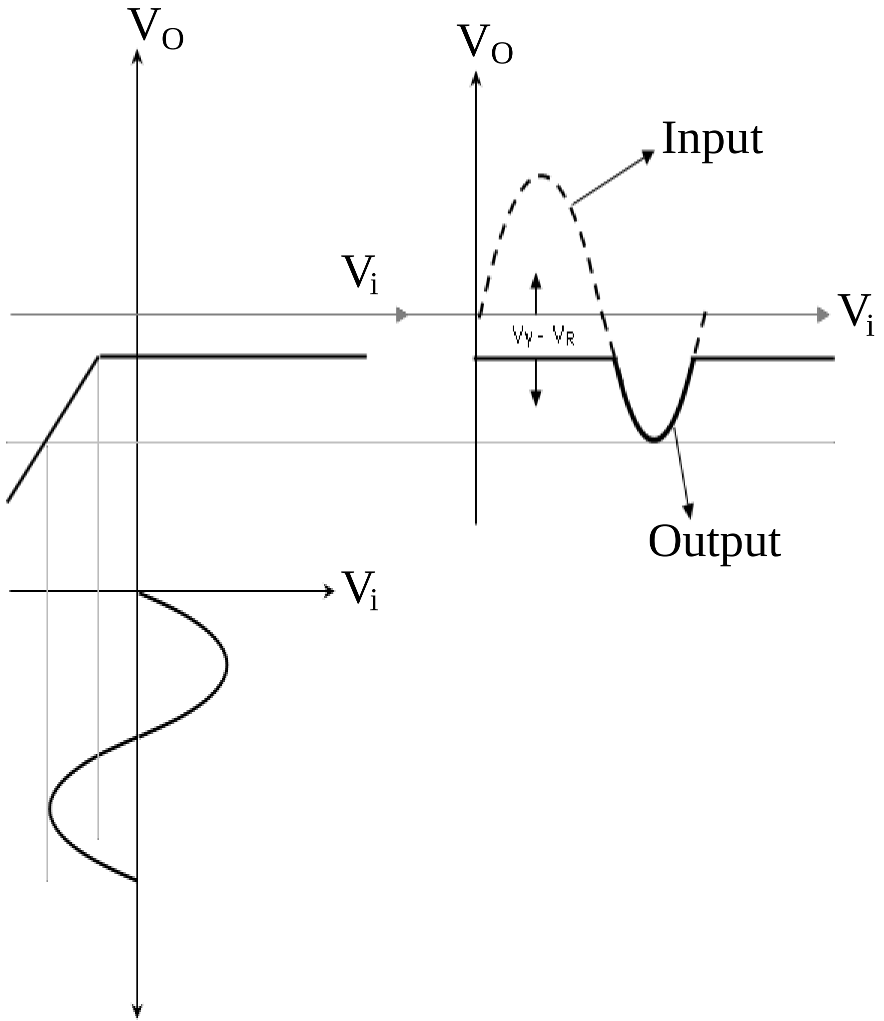
$V_O = V_i$

$V_i > V_R + V\gamma$ D – ON

$V_O = V_R + V\gamma$

Positive Shunt clipping with negative reference voltage





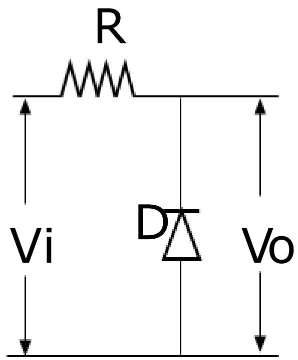
<u>Transfer characteristics equation:</u>

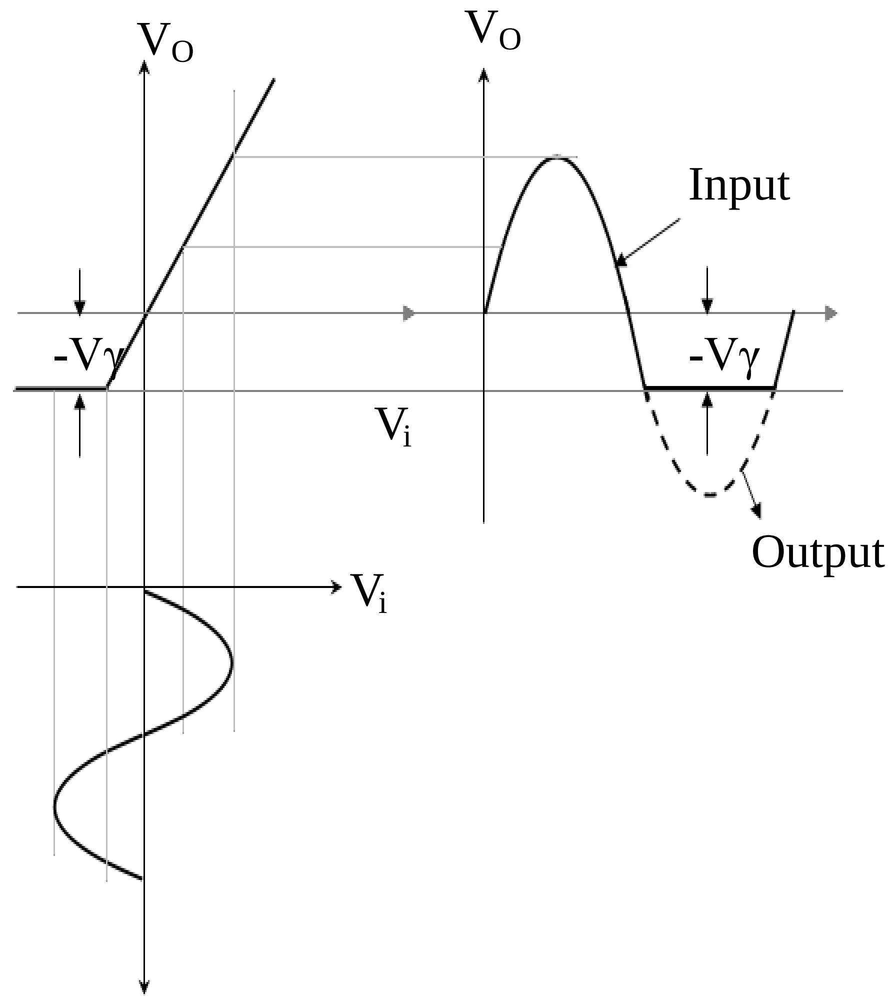
$V_i > V\gamma - V_R$ D – ON $V_O = V\gamma - V_R$

$V_i < V\gamma - V_R$ D – OFF

$V_O = V_i$

Negative Shunt clipping with zero reference voltage



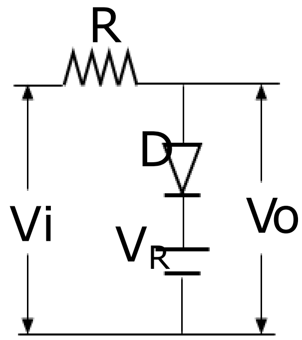


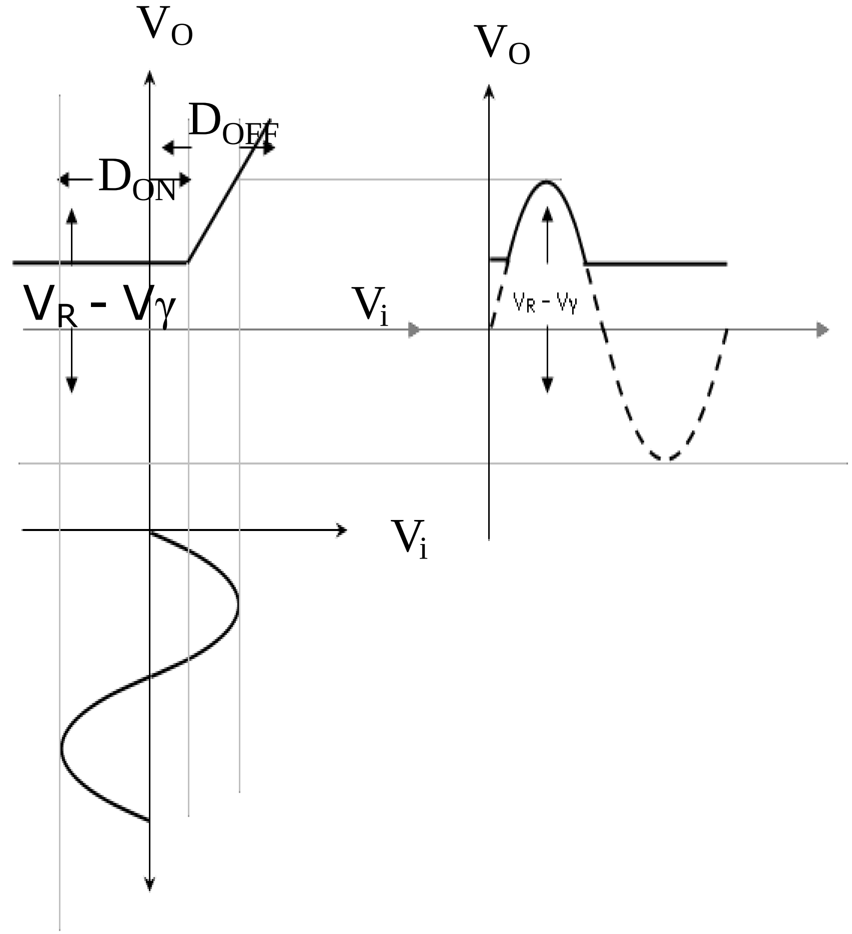
Transfer characteristic equations:

$V_i > -V\gamma$ D – OFF $\quad V_O = V\gamma$

$V_i < -V\gamma$ D – ON $\quad V_O = -V\gamma$

Negative Shunt clipping with positive reference voltage





Transfer characteristics equations:

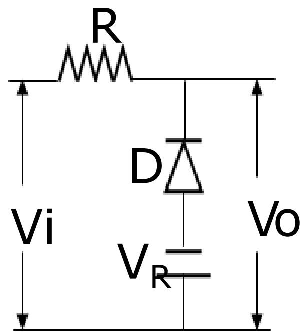
$V_i < V_R - V\gamma$ D – ON

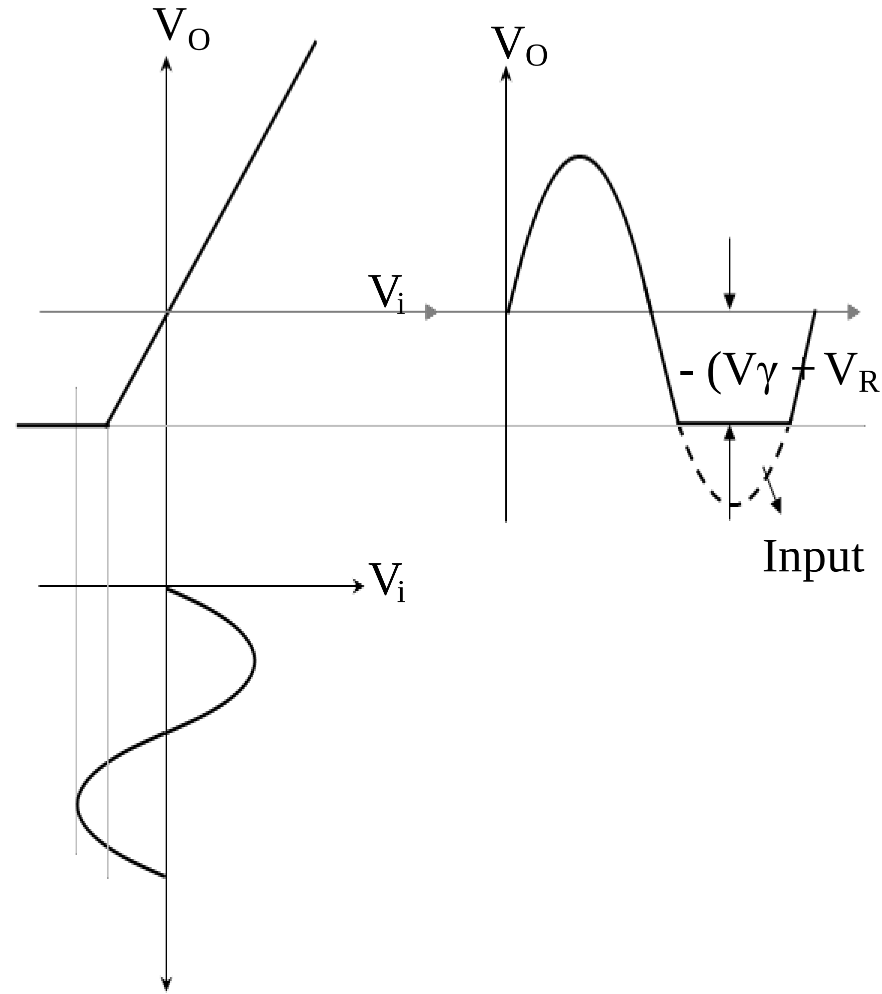
$V_O = V_R - V\gamma$

$V_i > V_R - V\gamma$ D – OFF

$V_O = V_i$

Negative Shunt clipping with negative reference voltage



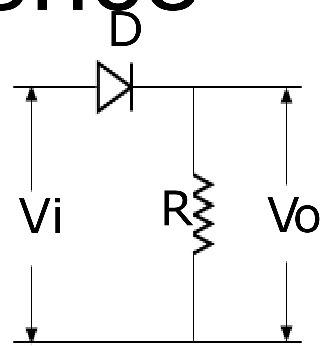


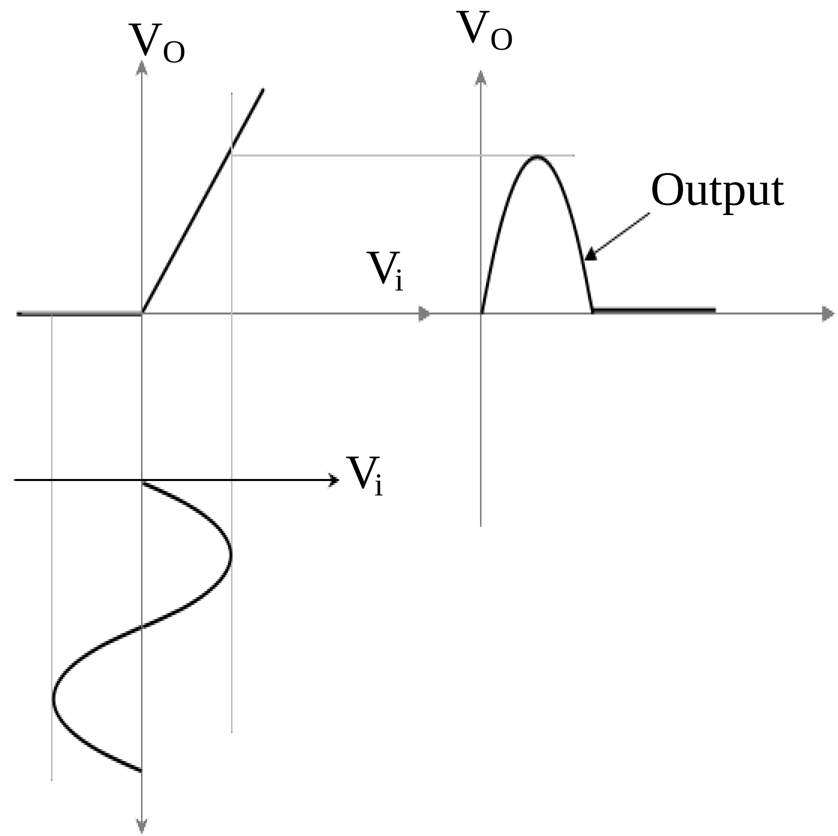
Transfer characteristic equations:

$V_i < -(V\gamma + V_R)$ D – ON $V_O = -(V\gamma + V_R)$

$V_i < -(V\gamma + V_R)$ D – OFF $V_O = V_i$

Negative Series clipper with zero reference

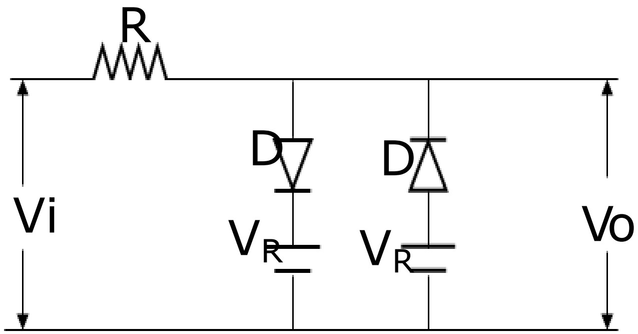


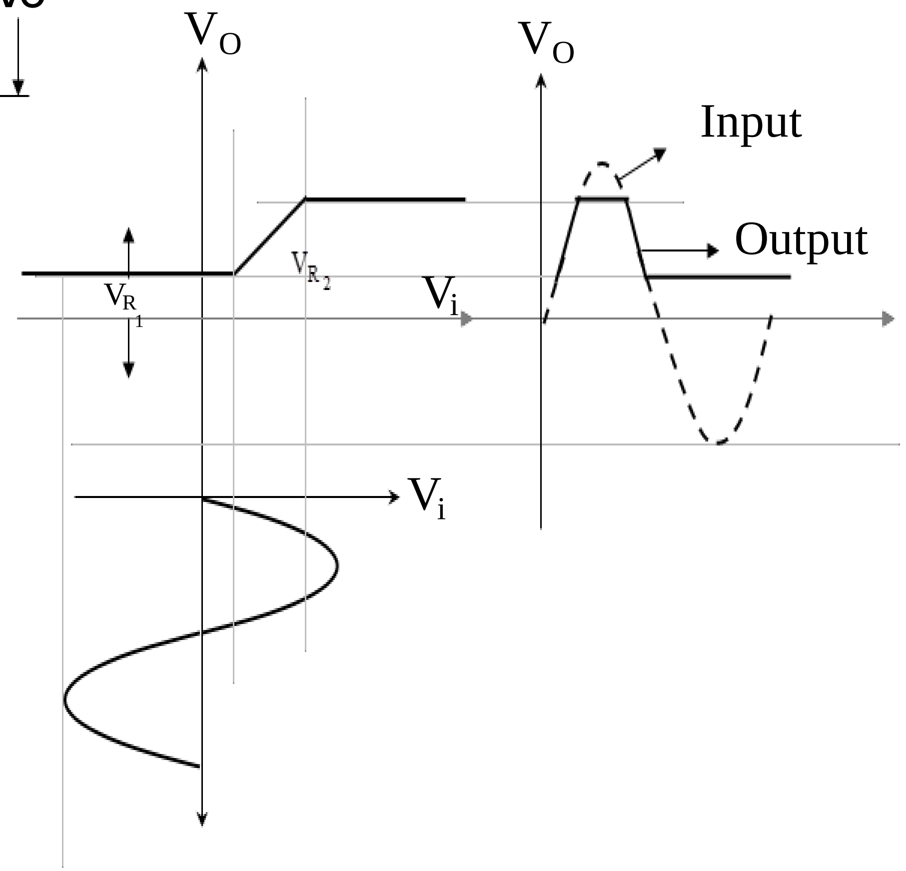


Transfer characteristic equations:

$V_i<0$	D–OFF	$V_O=0$	Ideal Diode
$V_i>0$	D–ON	$V_O=V_i$	
$V_i<V_\gamma$	D–OFF	$V_O=0$	Practical Diode
$V_i>V_\gamma$	D–ON	$V_O=V_i-V_\gamma$	

CLIPPING AT TWO INDEPENDENT LEVELS

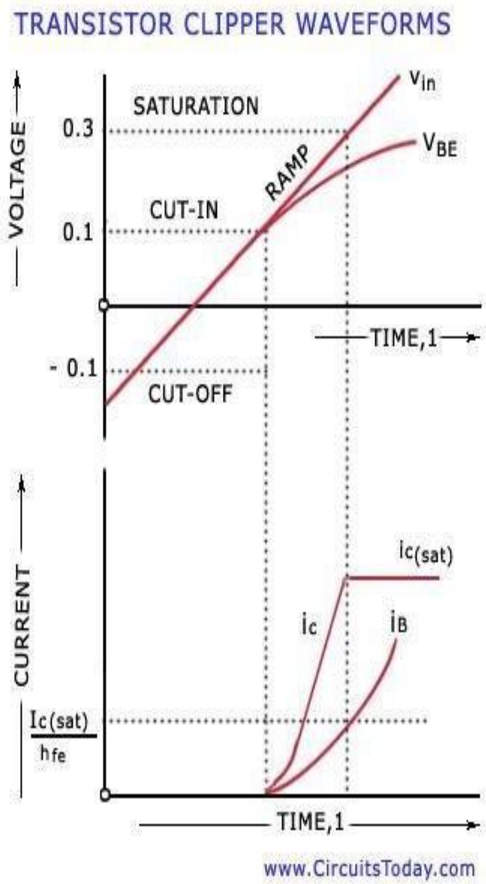


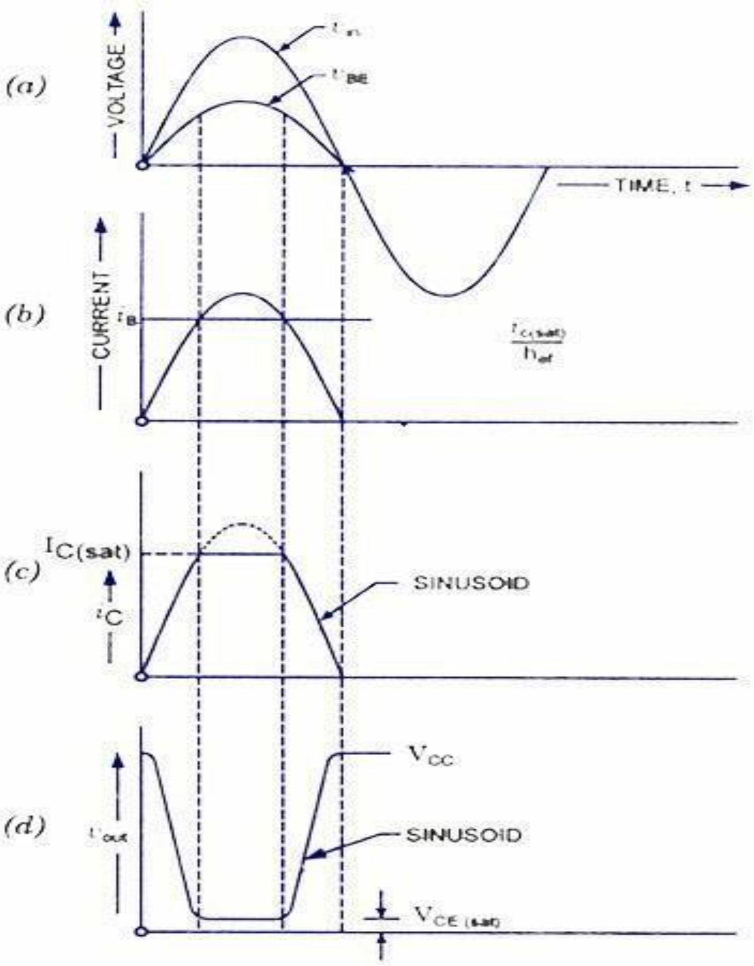


Transfer characteristic equations:

Input (V_i)	Diode State	Output (V_O)
$V_i \le V_{R_1}$	D_1 – ON, D_2 – OFF	$V_O = V_{R_1}$
$V_{R_1} < V_i < V_{R_2}$	D_1 – OFF, D_2 – OFF	$V_O = V_i$
$V_i \ge V_{R_2}$	D_1 – OFF, D_2 – ON	$V_O = V_{R_2}$

Contd..



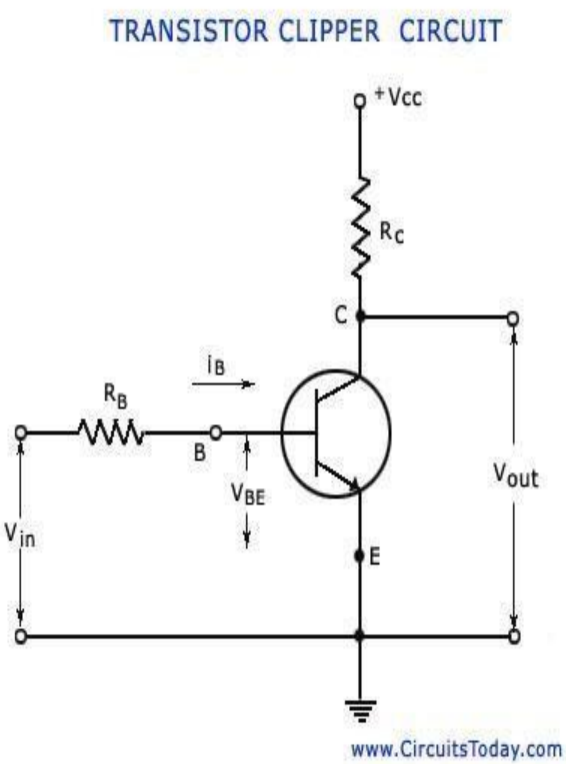


Transistor Clipper Waveforms For Sinusoidal Input

Transistor Clipper circuit

- The transistor has two types of linearities

—One linearity happens when the transistor passes from cut-in region to the active region. The other linearity occurs when the transistor passes from the active region to the saturation region. When any input signal passes through the transistor, across the boundary between cut-in region and active region, or across the boundary between the active region and saturation region, a portion of the input signal f.



CLAMPING CIRCUIT

- The need to establish the extremity of the positive (or) negative signal excursion at some reference level. When the signal is passed through a capacitive coupling network such a signal has lost its d.c. component. The clamping circuit introduces the d.c. components at the outside, for this reason the coupling circuits are referred to as d.c. restore (or) d.c. reinserter.

- Def : “ A clamping circuit is one that takes an input waveform and provides an output i.e., a faithful replica of its shape, but has one edge clamped to the zero voltage reference point.

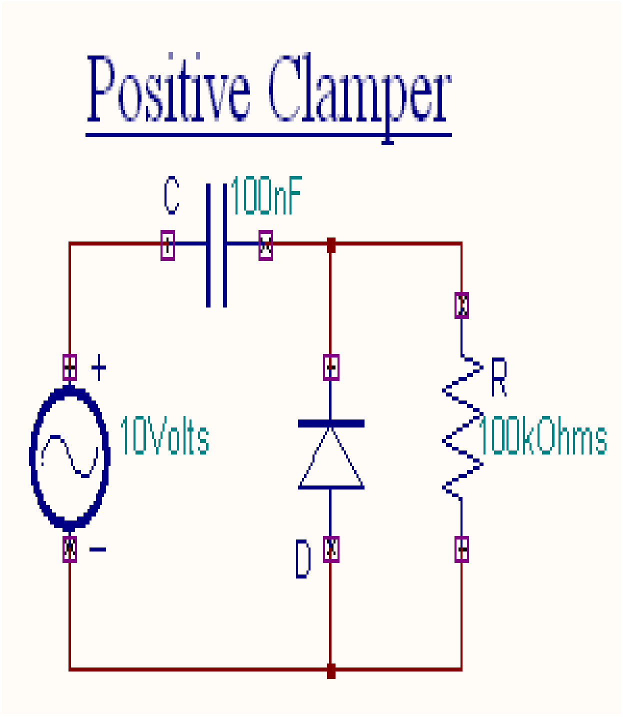
There are two types of clamping circuits.

- 1) Negative clamping circuit.
- 2) Positive clamping circuit.

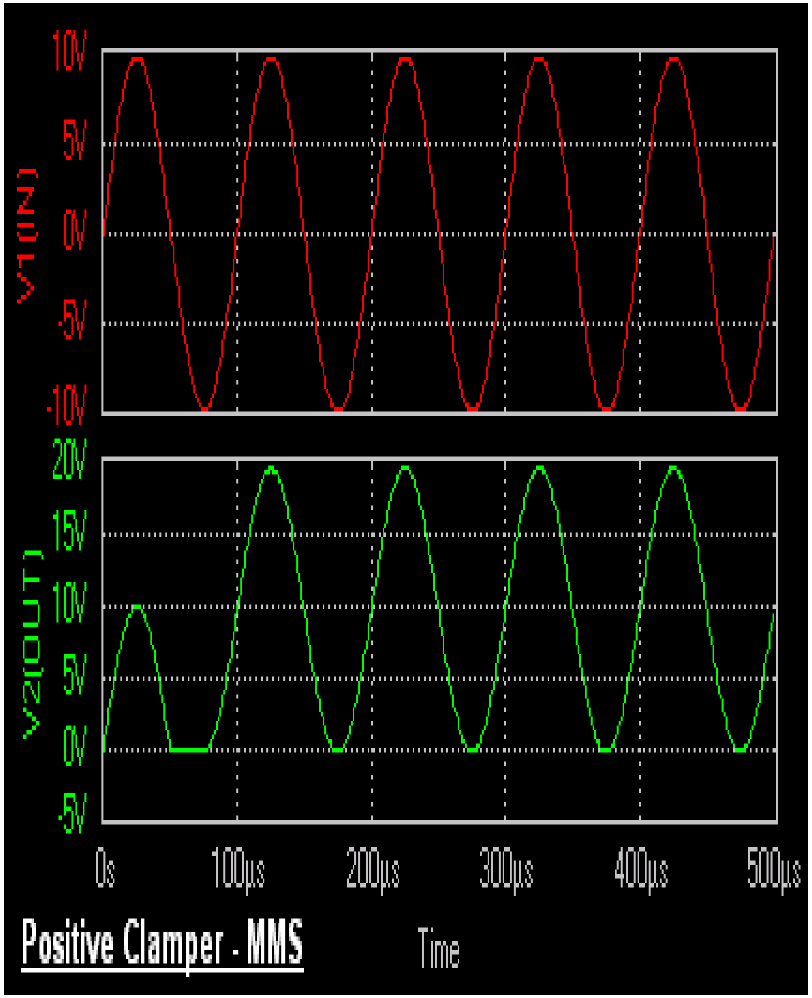
Diode :- Clamper

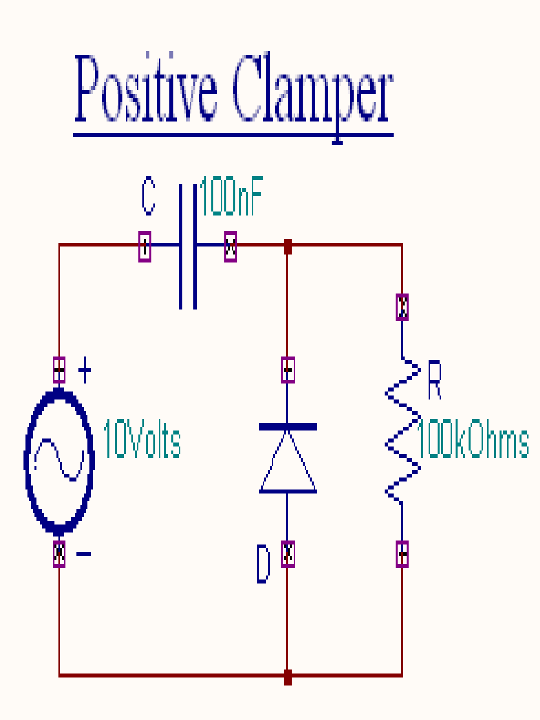
Positive Clamper

The circuit for a positive clamper is shown in the figure. During the negative half cycle of the input signal, the diode conducts and acts like a short circuit. The output voltage $V_o \Rightarrow 0$ volts . The capacitor is charged to the peak value of input voltage V_m. and it behaves like a battery. During the positive half of the input signal, the diode does not conduct and acts as an open circuit. Hence the output voltage $V_o \Rightarrow V_m + V_m$ This gives a positively clamped voltage.



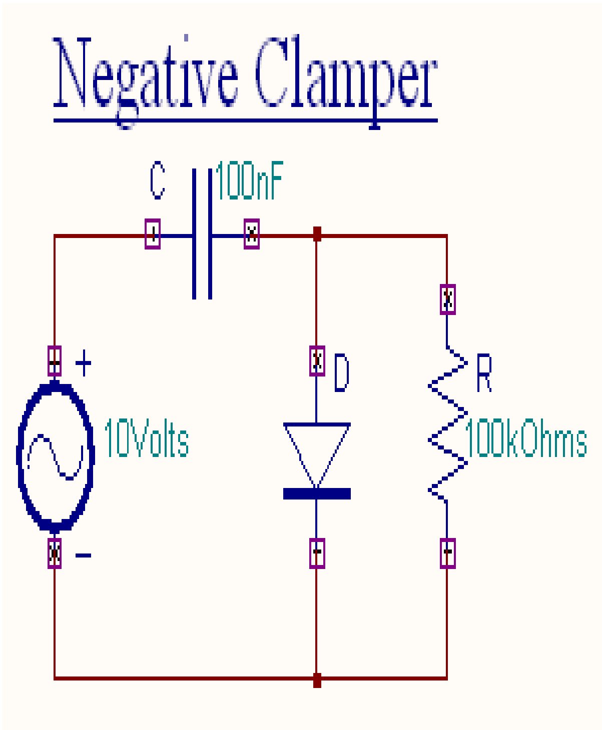
$$V_o \Rightarrow V_m + V_m = 2\ V_m$$


10V
5V
0V
-5V
-10V
V1(IN)
20V
15V
10V
5V
0V
-5V
V2(OUT)
0s
100µs
200µs
300µs
400µs
500µs
Positive Clamper - MMS
Time

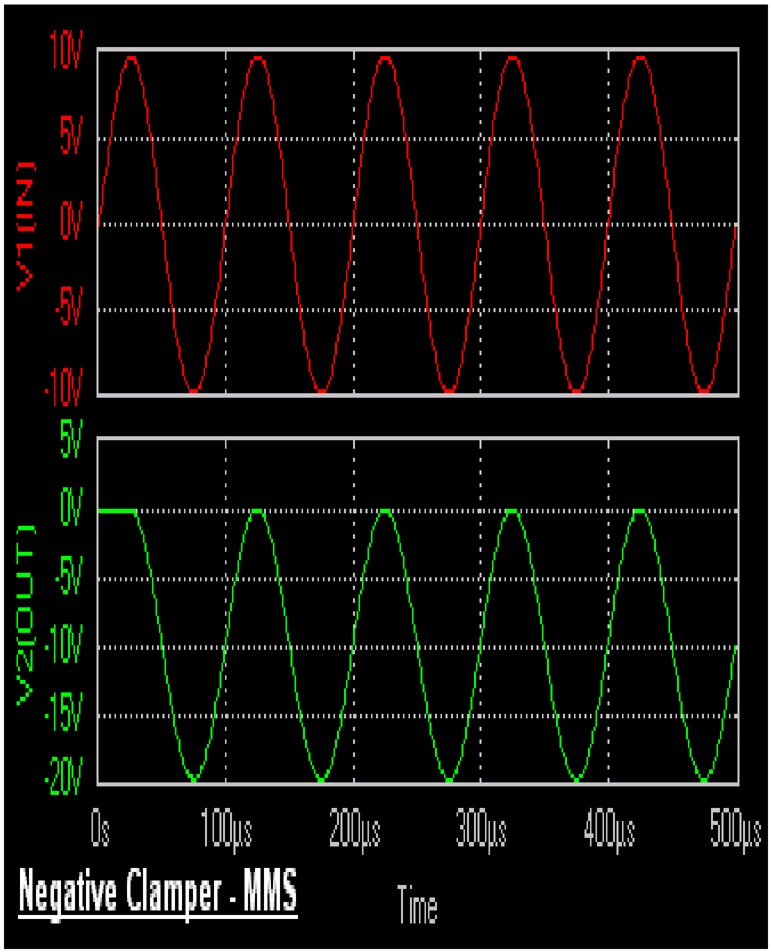

Positive Clamper
C
100nF
+
10Volts
−
D
R
100kOhms

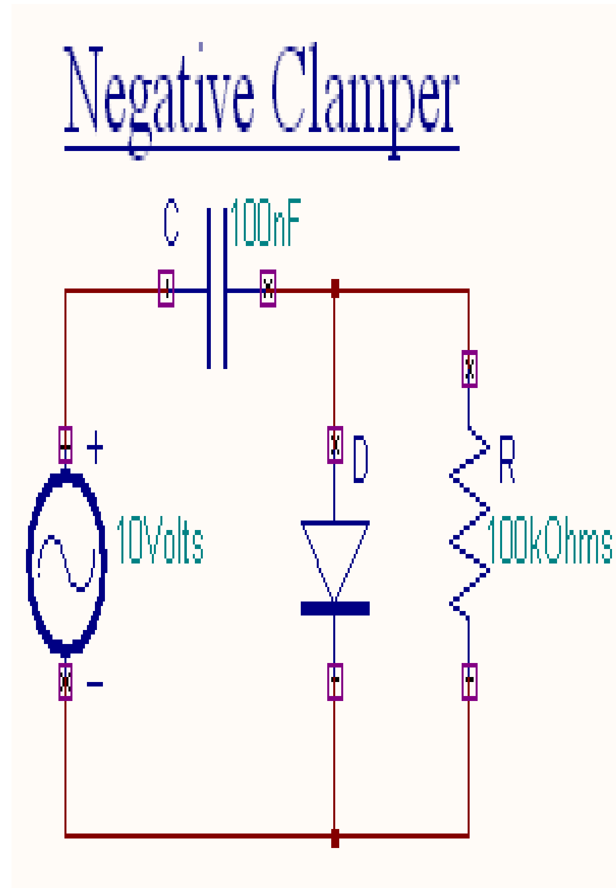
Negative Clamper

During the positive half cycle the diode conducts and acts like a short circuit. The capacitor charges to peak value of input voltage V_m. During this interval the output V_o which is taken across the short circuit will be zero During the negative half cycle, the diode is open. The output voltage can be found by applying KVL.

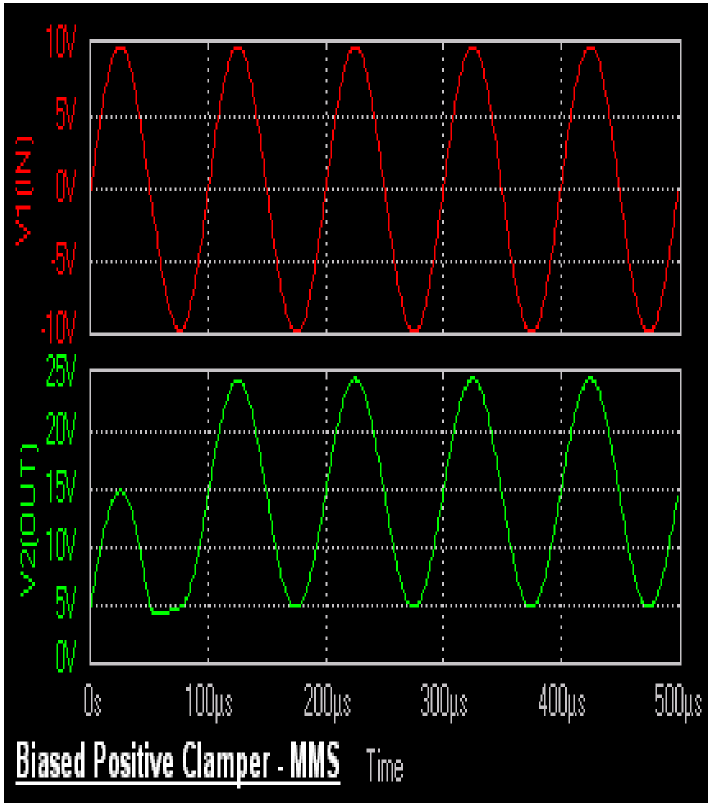


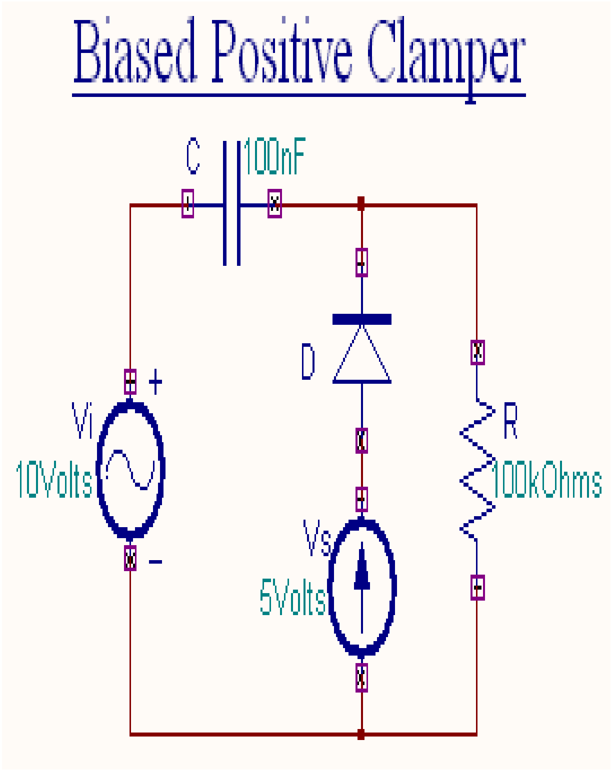
$$-V_m - V_m - V_o = 0 \qquad V_o = -2V_m$$


10V
5V
0V
-5V
-10V
V1(IN)
5V
0V
-5V
-10V
-15V
-20V
V2(OUT)
0s
100µs
200µs
300µs
400µs
500µs
Negative Clamper - MMS
Time


Negative Clamper
C
100nF
+
-
10Volts
D
R
100kOhms

Biased Clamper





CLAMPING CIRCUIT THEOREM

- Therefore the charge acquired by the capacitor during the forward interval

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

Consider a square wave input is applied to a clamping circuit under steady state condition

If V_f (t) is the output waveform in the forward direction, then from below figure the capacitor charging current is

$$i_f = \frac{V_f}{R_f}$$

Therefore the charge acquired by the capacitor during the forward interval

$$\int_0^{T_1} i_f \, dt = \frac{1}{R_f} \int_0^{T_1} V_f \, dt = \frac{A_f}{R_f} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

•Similarly if $V_f(t)$ is the output voltage in the reverse direction, then the current which discharges by the capacitor is

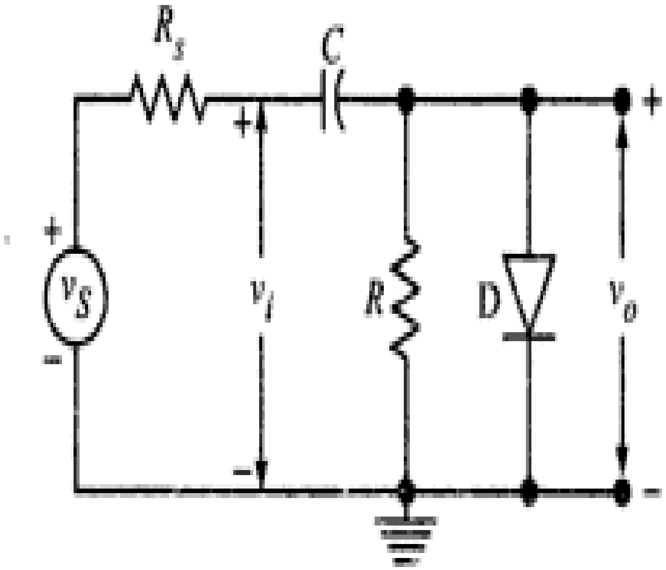
$$i_r = \frac{V_r}{R}$$

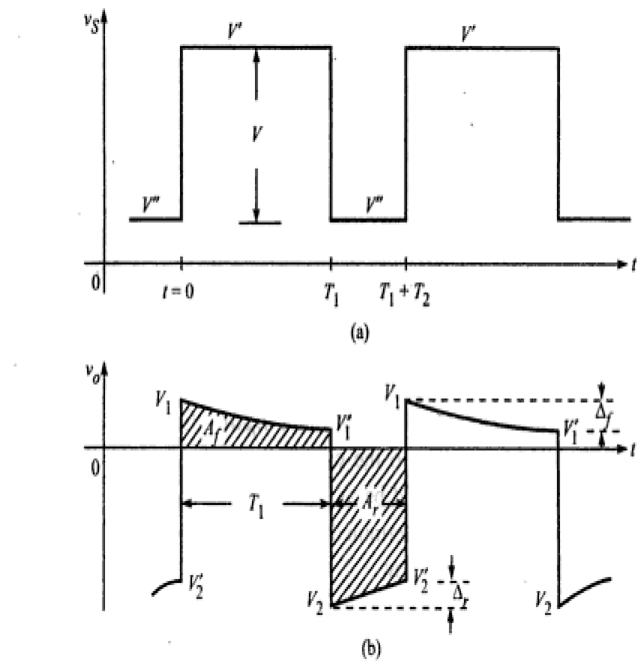
$$\int_{T_1}^{T_2} i_r \, dt = \frac{1}{R}\int_{T_2}^{T_2} V_r \, dt = \frac{A_r}{R} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

In the steady-state the net charge acquired by the capacitor must be zero.

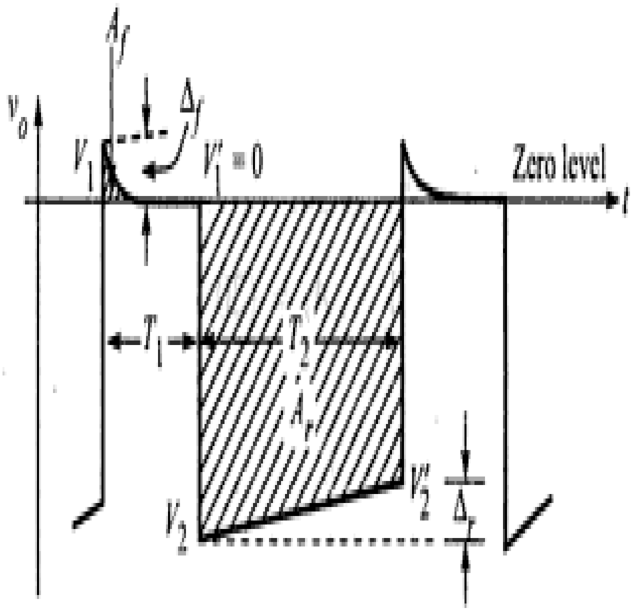
Therefore from equation (1) & (2) $\frac{A_f}{R_f} = \frac{A_r}{R}$ this equation says that for any input waveform the ratio of the area under the output voltage curve in the forward direction to the reverse direction is equal to the ratio $\frac{R_f}{R}$.

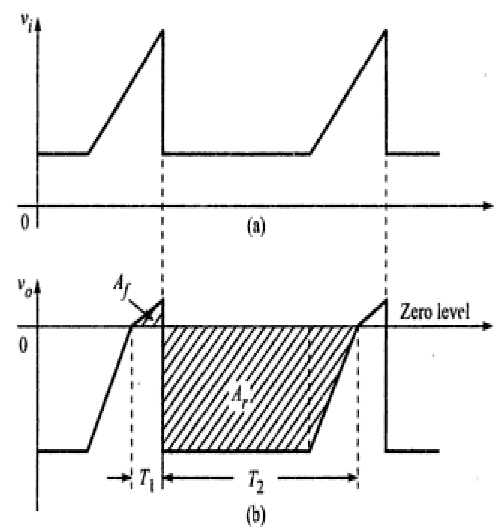
Clamping Circuit taking Source and Diode Resistances into account



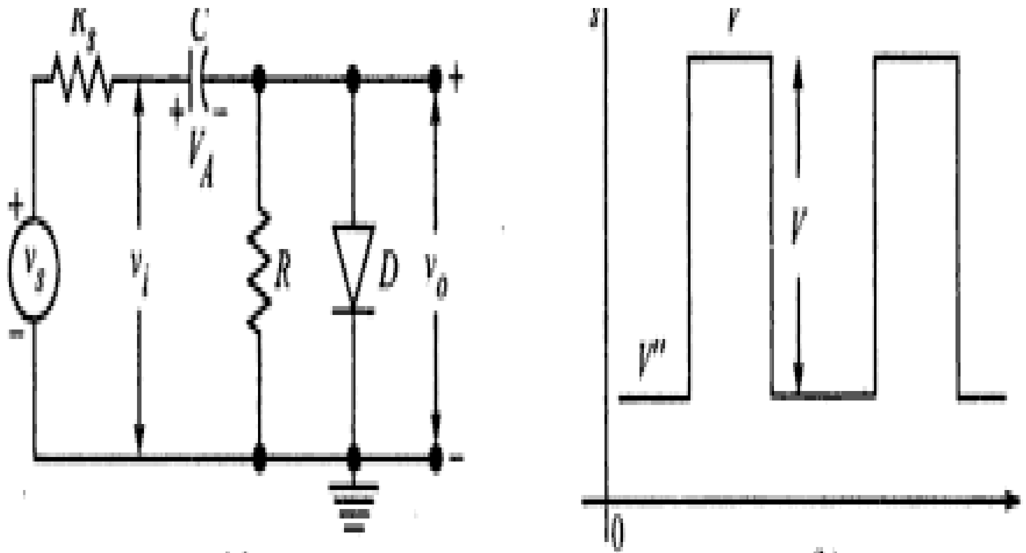


Practical Clamping circuit





Effect of diode characteristics on clamping voltage



(a) (b)

$$dV_{cl} = \eta V_T \frac{dV}{V}$$

Synchronized Clamping