Basic Electronics(EEE-1221)

Segment-3

Wave shaping & Op-amp circuit applications: Shaping

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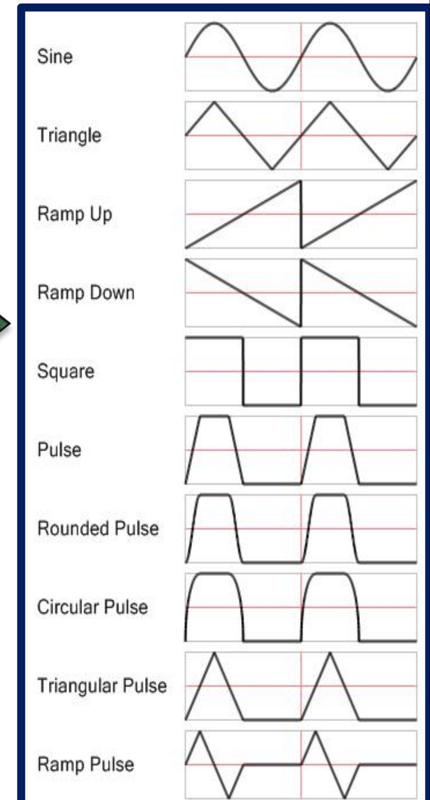
Lecture Outline

- Linear & non- linear wave shaping
- Definitions & characteristics of Different wave forms
  - ❖ Sinusoidal waveform
  - ❖ Step waveform
  - ❖ Pulse waveform
  - ❖ Square waveform
  - ❖ Ramp waveform
  - ❖ Impulse waveform
  - ❖ Exponential waveform



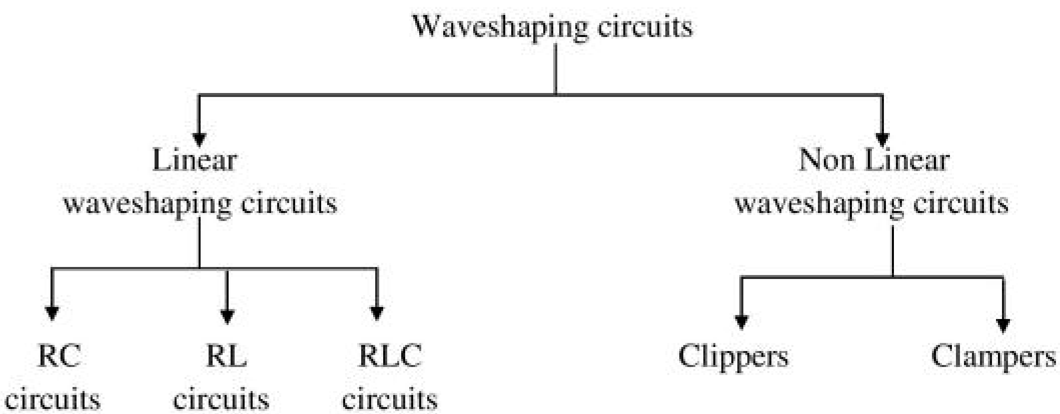
- High pass and low pass RC circuits
- Distinguish between high pass & Low pass RC circuit.
- Show the response of a Step, Square & Pulse waveforms through high pass circuit.(Only Input & output response-circuit)
- Show the response of a Step, Square & Pulse waveforms through low pass circuit.(Only Input & output response-circuit)
- Clipping and clamping circuits (**sample question: Explanation of diode Clipping & Clamping with circuit diagrams-for 8 marks).**

Linear & Non linear wave shaping

- Wave-shaping circuits modify or filter electrical signals to remove unwanted components and shape the signal according to specific requirements. Common types of wave-shaping circuits include filters, clipper & clamper circuit.

- A wave shaping circuit is the one that used to convert from an input waveform to a desired output waveform. Many wave shaping circuits (clipper, clamper, differentiator and integrator) are useful in variety of applications such as radios, television, radar circuits and communications system.

Classification of Waveshaping Circuits:



Linear & Non linear wave shaping

<u>Linear waveshaping circuits:</u>

- The circuits, which make use of only linear circuit elements such as the inductors, capacitors and resistors are known as linear waveshaping circuits.
- Such circuits are used to perform functions of differentiation and integration "or" filter circuit.

The linear waveshaping circuits contain only linear components like R, L and C.

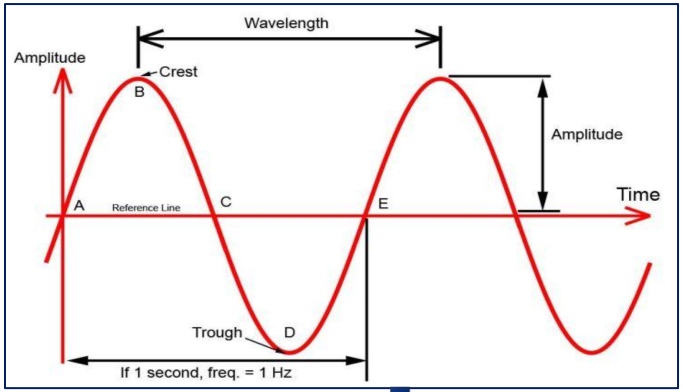
<u>Non-Linear waveshaping circuits:</u>

- The circuits, which (in addition to linear circuit elements) make use of nonlinear circuit elements such as diodes and transistors are known as nonlinear waveshaping circuits.
- Such circuits are used to perform functions of amplitude limiting, clipping and clamping.

Different Wave Form

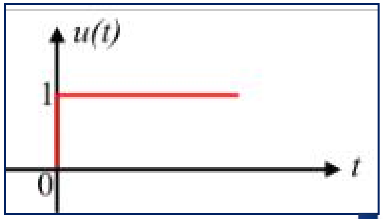
- ***Sinusoidal*** waveforms are periodic waveforms whose shape can be plotted using the sine or cosine function from trigonometry. Electrical circuits supplied by sinusoidal waveforms whose polarity changes every cycle and are commonly known as “AC” voltages and current sources.

- ***Characteristics of sinusoidal waveform*:** All sinusoidal signals have the same general shape, but they are not identical. The three characteristics that separate one sinusoid from another are amplitude, frequency, and phase.



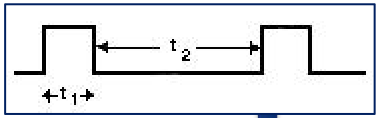
- ***Step signal or step function*** is that type of standard signal which exists only for positive time and it is zero for negative time. In other words, a signal x(t) is said to be step signal if and only if it exists for t > 0 and zero for t < 0. The step signal is an important signal used for analysis of many systems.

- If a step signal has unity magnitude, then it is known as unit step signal or unit step function. It is denoted by u(t).

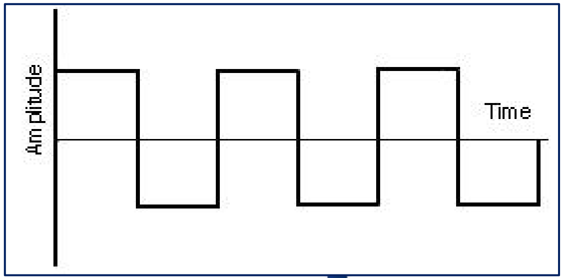


Different Wave Form

- A ***pulse wave*** is an AC signal, whose WAVEFORM contains both positive and negative sections. The ratio of the 'on' to 'off' times of the waveform is called the *duty cycle*. The pulse wave may be distinguished from the SQUARE WAVE in that the latter has a duty cycle of 1:1.



- A ***square wave*** is a non-sinusoidal periodic waveform in which the amplitude alternates at a steady frequency between fixed minimum and maximum values, with the same duration at minimum and maximum. In an ideal square wave, the transitions between minimum and maximum are instantaneous.

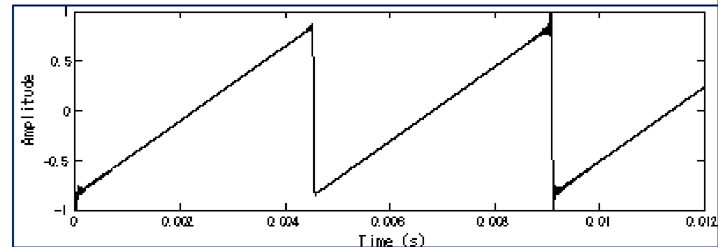


Difference Between square wave and pulse wave

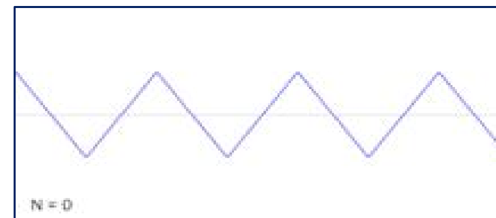
A **square wave** is a certain kind **of pulse wave -** one where the positive portion **of** its cycle equals the negative portion. Also called a “50% duty cycle”. If the two halves are not equal, it's generically a **pulse wave**

Different Wave Form

- The ***sawtooth wave (or saw wave)*** is a kind of non-sinusoidal waveform. It is so named based on its resemblance to the teeth of a plain-toothed saw with a zero rake angle.

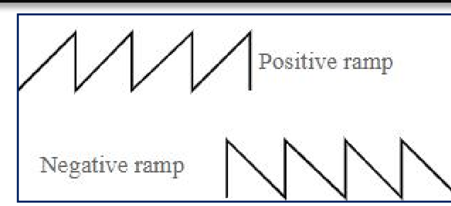


- A ***triangular wave or triangle wave*** is a non-sinusoidal waveform named for its triangular shape. It is a periodic, piecewise linear, continuous real function. A bandlimited triangle wave pictured in the time domain (top) and frequency domain (bottom).



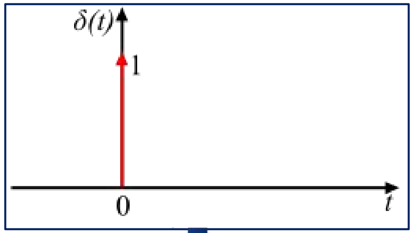
The difference between the triangular wave and sawtooth waveform is that the rise time of triangular wave is always equal to its fall of time while in saw tooth generator, rise time may be much higher than its fall of time

- A ***ramp waveform*** that is similar to a sawtooth waveform but different in that it starts at zero level and gradually rises to its peak level and then instantly drops back to zero level to form one cycle.



Different Wave Form

An ideal ***impulse signal*** is a signal that is zero everywhere but at the origin (t = 0), it is infinitely high. Although, the area of the impulse is finite. The unit impulse signal is the most widely used standard signal used in the analysis of signals and systems

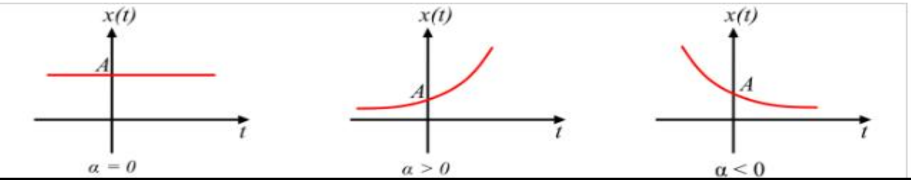


Exponential waveform: A nonrepetitive waveform that rises or falls exponentially from some initial value at some initial time, according to the law y(t) = e at For a>0 the waveform rises without bound with increasing time t; for a<0 the waveform decays to zero.

Depending upon the value of α, we obtain different exponential signals as –

- When $\alpha = 0$, the exponential signal x(t) is a signal of constant magnitude for all times.
- When $\alpha > 0$, i.e., α is positive, then the exponential signal x(t) is a growing exponential signal.
- When $\alpha < 0$, i.e., α is negative, then the signal x(t) is a decaying exponential signal.

The waveforms of these three signals are shown in Figure-1.



RC Filter

High Pass Filter

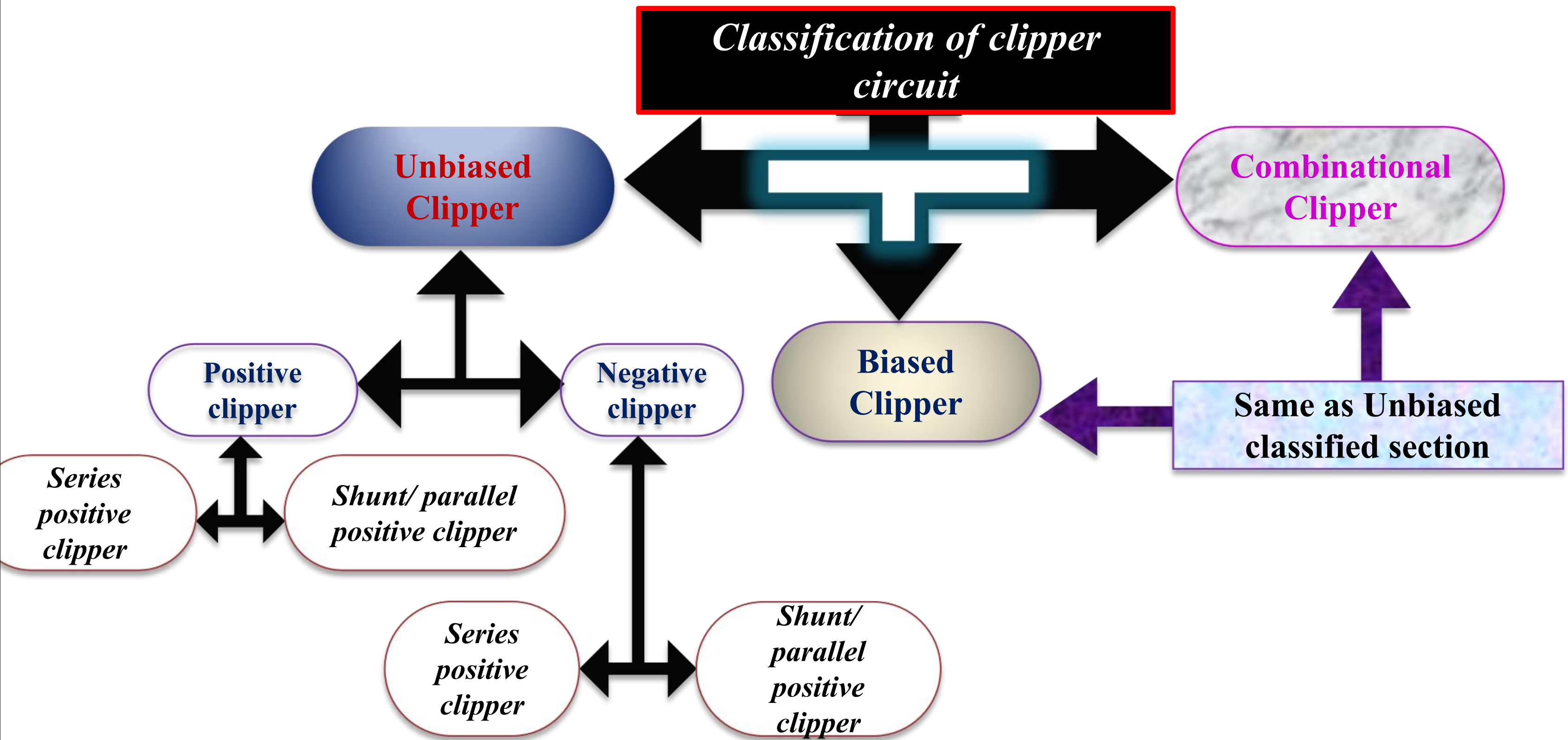
https://www.electronics-tutorials.ws/filter/filter_3.html

Low Pass Filter

https://www.electronics-tutorials.ws/filter/filter_2.html

Clipper

Definition	The circuit, with which the waveform is shaped by removing (or clipping) a certain portion of the input signal voltage above or below a certain level, is called clipping circuit or simply clipper.



Clipper

Unbiased Clipper

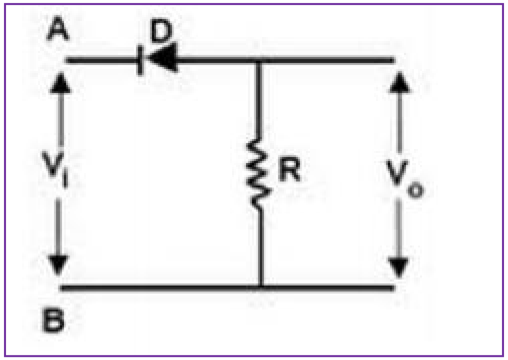
Series Clipper: In this configuration the diode is connected in series with the load.

Parallel Clipper: in this configuration the diode is connected in parallel with the load.

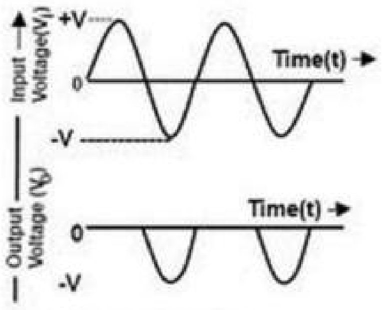
A Series Clipper Circuit:

Series Positive Clipper:

- The figure below shows the circuit of positive clipper. It consists of a diode (D) and a resistor (R) with output taken across the resistor.
- The diode acts as an ideal switch between the source and the load.
- The below circuit is called as a "Positive Series clipper" as it "clips off" the positive half cycle of the applied voltage.



Operation and Waveform:



- During the positive half cycle of the input voltage, the terminal A is positive with respect to B. This reverse biases the diode and it acts as an open switch.
- Therefore, the entire voltage drop is across the diode and none across the resistor.
- As, a result there is no output voltage during the positive half cycle of the input voltage as shown in the fig above.

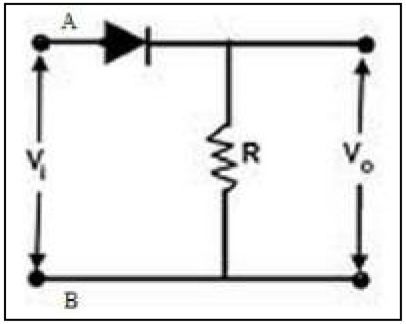
- During the negative half cycle of the input voltage, the terminal B is positive with respect to B. Therefore it forward biases the diode and it acts as a closed switch.
- Thus there is no voltage drop across the diode during the negative half cycle of the input voltage.
- All the input voltage is dropped across the resistor as shown in the output waveform.

Clipper

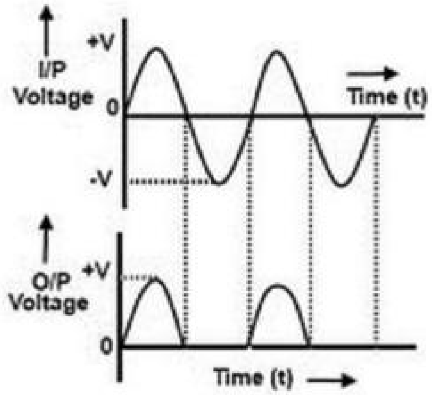
Unbiased Clipper

Series Negative Clipper:

- The figure below shows the circuit of negative clipper. It consists of a diode (D) and a resistor (R) with output taken across the resistor.
- The diode acts as an ideal switch between the source and the load.
- The below circuit is called as a "Negative Series clipper" as it "clips off" the negative half cycle of the applied voltage.



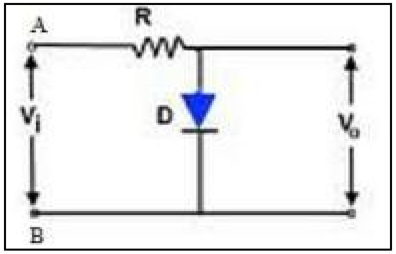
Operation and Waveform:



- During the positive half cycle of the input voltage, the terminal A is positive with respect to B. This forward biases the diode and it acts as a closed switch.
- Thus there is no voltage drop across the diode during the positive half cycle of the input voltage.
- All the input voltage is dropped across the resistor as shown in the output waveform.
- During the negative half cycle of the input voltage, the terminal B is positive with respect to B. Therefore it reverse biases the diode and it acts as an open switch.
- As, a result there is no output voltage during the negative half cycle of the input voltage as shown in the fig above.

Clipper

Unbiased Clipper

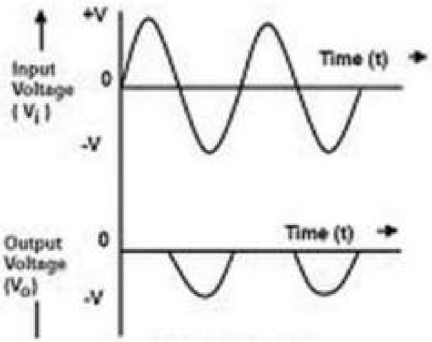


A Shunt Clipper Circuit:

Shunt Positive Clipper:

- The figure below shows the circuit of positive clipper. It consists of a diode (D) and a resistor (R) with output taken across the resistor.
- The diode acts as an ideal switch between the source and the load.
- The below circuit is called as a "Positive Series clipper" as it "clips off" the positive half cycle of the applied voltage.

Operation and Waveform:

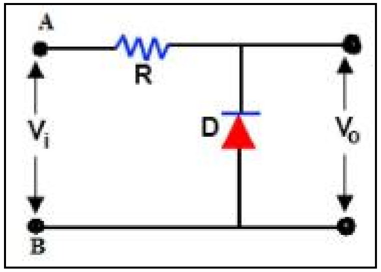


- During the positive half cycle of the input voltage, the terminal A is positive with respect to B. This forward biases the diode and it acts as a closed switch.
- Thus there is no voltage drop across the diode during the positive half cycle of the input voltage.
- All the input voltage is dropped across the resistor as shown in the output waveform.

- During the negative half cycle of the input voltage, the terminal B is positive with respect to B. Therefore it reverse biases the diode and it acts as an open switch.
- As, a result there is no output voltage during the negative half cycle of the input voltage as shown in the fig above.

Clipper

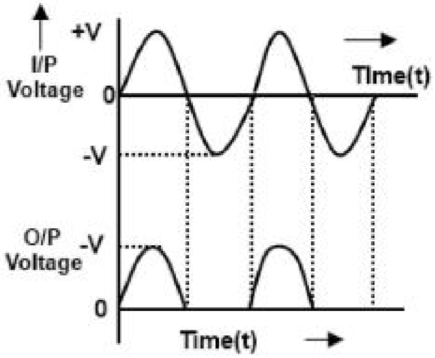
Unbiased Clipper



Shunt Negative Clipper:

- The figure below shows the circuit of negative clipper. It consists of a diode (D) and a resistor (R) with output taken across the resistor.
- The diode acts as an ideal switch between the source and the load.
- The below circuit is called as a "Negative Series clipper" as it "clips off" the negative half cycle of the applied voltage.

Operation and Waveform:



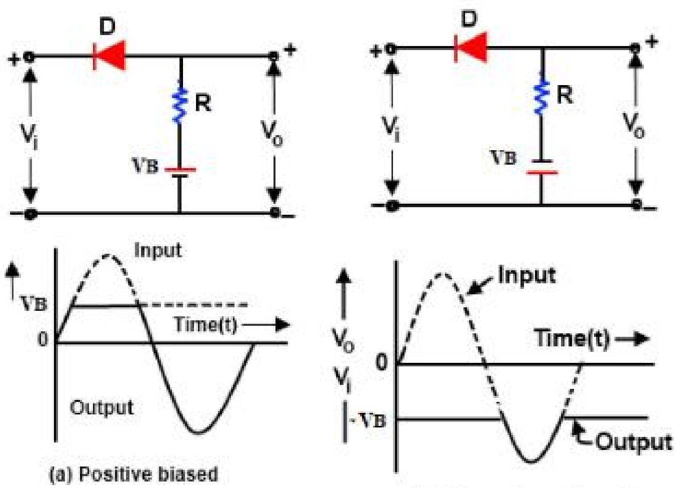
- During the positive half cycle of the input voltage, the terminal A is positive with respect to B. This reverse biases the diode and it acts as an open switch.
- Thus there is no voltage drop across the diode during the positive half cycle of the input voltage.
- All the input voltage is dropped across the resistor as shown in the output waveform.
- During the negative half cycle of the input voltage, the terminal B is positive with respect to B. Therefore it forward biases the diode and it acts as an closed switch.
- As, a result there is no output voltage during the negative half cycle of the input voltage as shown in the fig above.

Clipper

Biased Clipper

Biased Series Positive Clipper:

- A clipping circuit which has the provision for the adjustment of a clipping level is called a biased clipper.
- The name bias is designated because the adjustment of the clipping level is achieved by adding a bias voltage in series with the resistor.



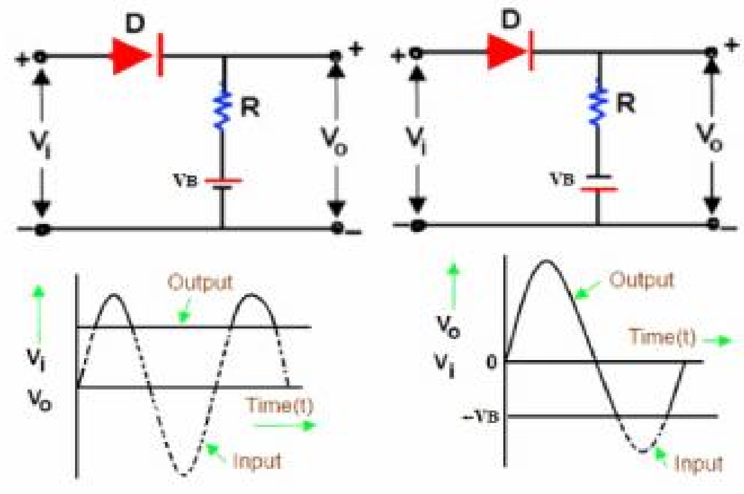
(a) Positive biased

(b) Negative Biased

- In a biased series positive clipper. It may be noted that the clipping takes place during the positive cycle when the input voltage is greater than the battery voltage (i.e., $V_i >= V_B$).
- The clipping level can be shifted up and down by varying the bias voltage (V_B)

Biased Series Negative Clipper:

- A clipping circuit which has the provision for the adjustment of a clipping level is called a biased clipper.
- The name bias is designated because the adjustment of the clipping level is achieved by adding a bias voltage in series with the resistor.



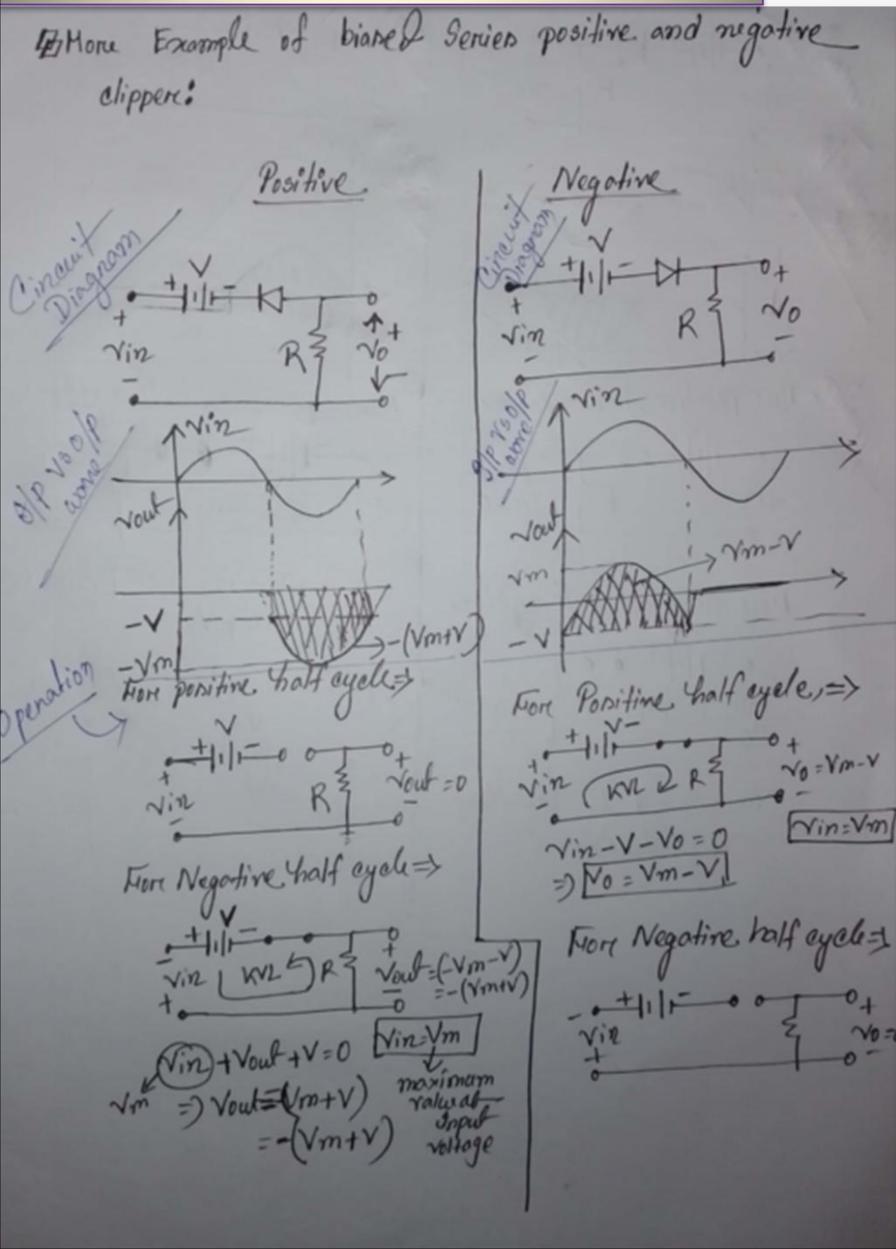
(a) Positive biased

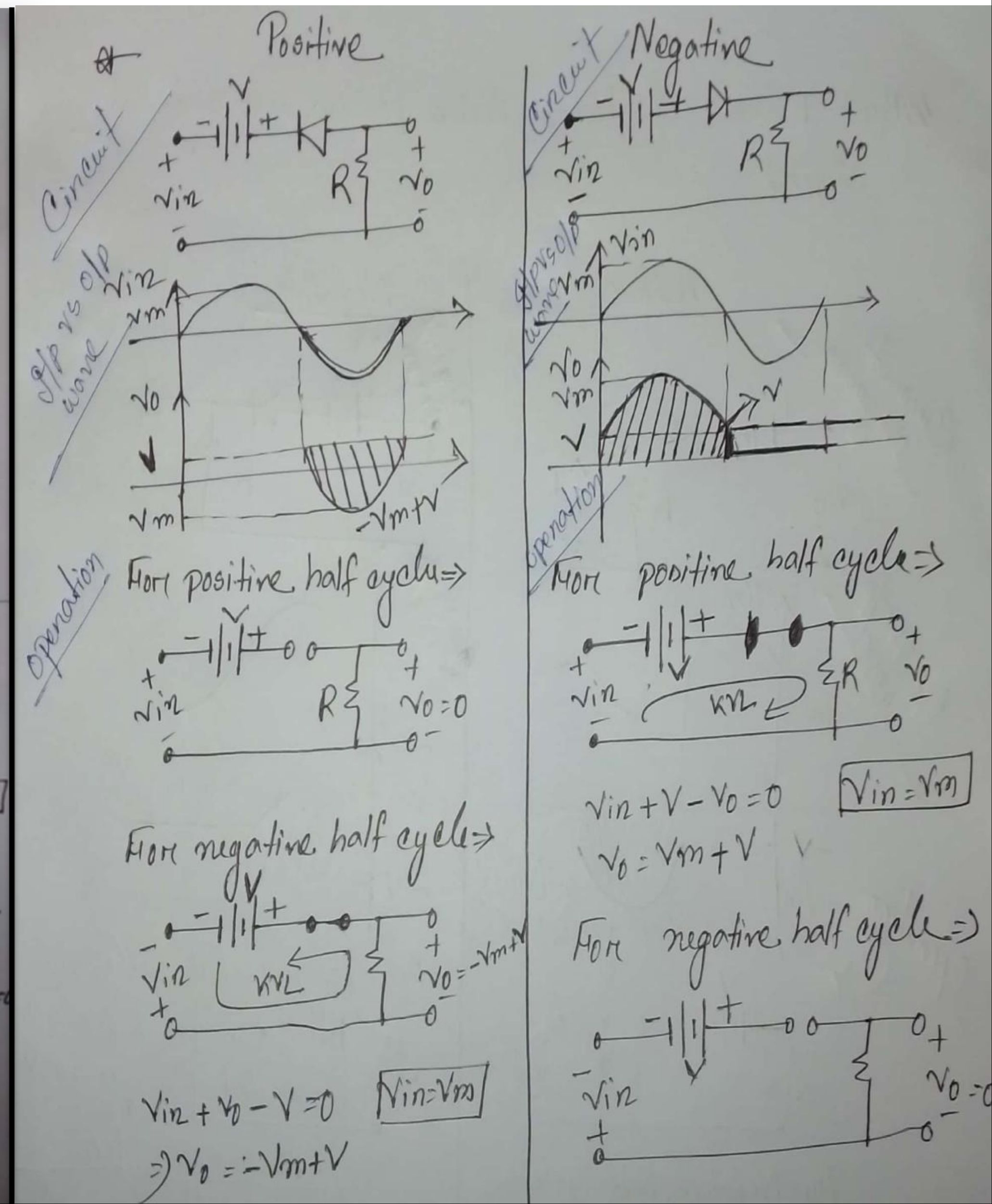
(b) Negative biased

- In a biased series negative clipper. It may be noted that the clipping takes place during the negative cycle when the input voltage is greater than the battery voltage (i.e., $V_i >= V_B$).
- The clipping level can be shifted up and down by varying the bias voltage (V_B).
- Here the input voltage level $-V_B$ is clipped.

Clipper

Biased Clipper



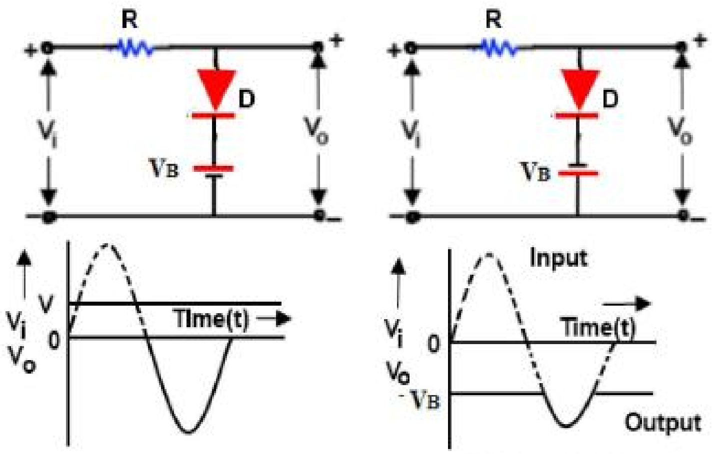


Clipper

Biased Clipper

Biased Shunt Positive Clipper:

- A clipping circuit which has the provision for the adjustment of a clipping level is called a biased clipper.
- The name bias is designated because the adjustment of the clipping level is achieved by adding a bias voltage in shunt with the resistor.

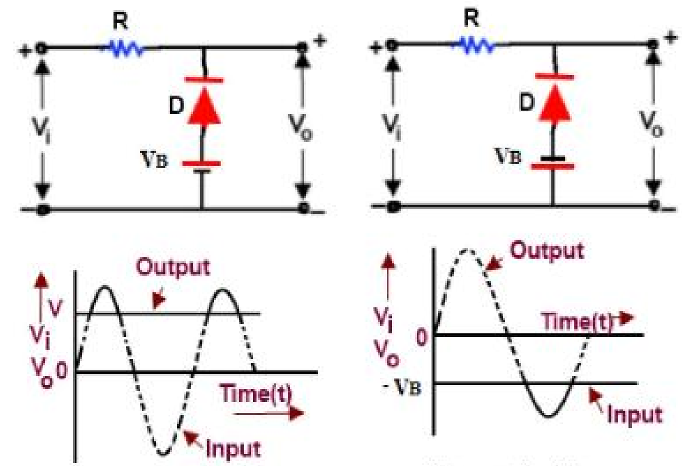


(a) Positive biased (b) Negative biased

- In a biased shunt positive clipper. It may be noted that the clipping takes place during the positive cycle when the input voltage is greater than the battery voltage (i.e., $V_i >= V_B$).
- The clipping level can be shifted up and down by varying the bias voltage (V_B)

Biased Shunt Negative Clipper:

- A clipping circuit which has the provision for the adjustment of a clipping level is called a biased clipper.
- The name bias is designated because the adjustment of the clipping level is achieved by adding a bias voltage in shunt with the resistor.



(a) Positive bias (b) negative bias

- In a biased shunt positive clipper. It may be noted that the clipping takes place during the positive cycle when the input voltage is greater than the battery voltage (i.e., $V_i >= V_B$).
- The clipping level can be shifted up and down by varying the bias voltage (V_B)

Clipper

Combination Clipper

Combination clipper. It is a combination of biased positive and negative clippers. With a combination clipper, a portion of both positive and negative half-cycles of input voltage can be removed or clipped as shown in Fig. 18.27.

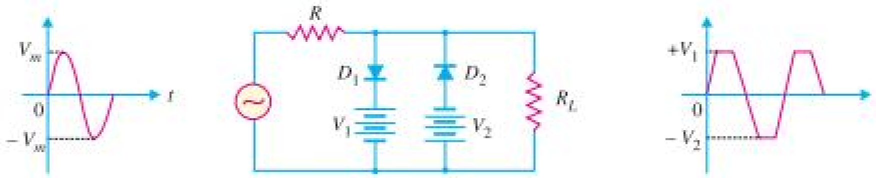


Fig. 18.27

* It may be noted that all the input voltage during this half-cycle is dropped across R.

The circuit action is as follows. When positive input voltage is greater than $+V_1$, diode D_1 conducts heavily while diode D_2 remains reverse biased. Therefore, a voltage $+V_1$ appears across the load. This output stays at $+V_1$ so long as the input voltage exceeds $+V_1$. On the other hand, during the negative half-cycle, the diode D_2 will conduct heavily and the output stays at $-V_2$ so long as the input voltage is greater than $-V_2$. Note that $+V_1$ and $-V_2$ are less than $+V_m$ and $-V_m$ respectively.

Between $+V_1$ and $-V_2$ neither diode is on. Therefore, in this condition, most of the input voltage appears across the load. It is interesting to note that this clipping circuit can give square wave output if V_m is much greater than the clipping levels.

Clipper

Mathematics of Clipper circuit

Example 18.7. *For the negative series clipper shown in Fig.18.28, what is the peak output voltage from the circuit ?*

Solution. When the diode is connected in series with the load, it is called a series clipper. Since it is a negative clipper, it will remove negative portion of input a.c. signal.

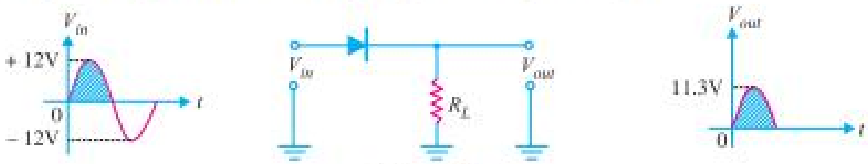


Fig. 18.28

During the positive half-cycle of input signal, the diode is forward biased. As a result, the diode will conduct. The output voltage is

$$V_{out\,(peak)} = V_{in\,(peak)} - 0.7 = 12 - 0.7 = \mathbf{11.3\ V}$$

During the negative half-cycle of input signal, the diode is reverse biased and consequently it will not conduct. Therefore, $V_{out} = 0$. Note that under this condition, the entire input voltage will appear across the diode.

Example 18.8. *The negative shunt clipper shown in Fig. 18.29 (i) has a peak input voltage of + 10 V. What is the peak output voltage from this circuit ?*

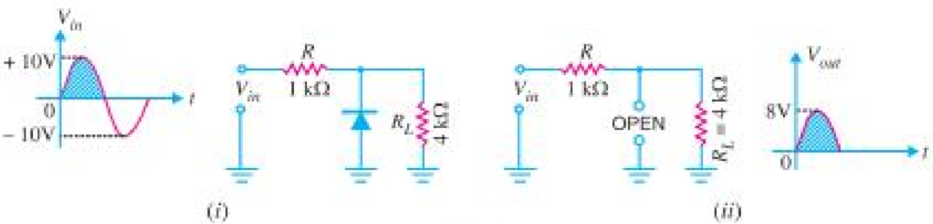


Fig. 18.29

Solution. When the diode is connected in parallel with the load, it is called a shunt clipper. During the positive half-cycle of input ac signal, the diode is reverse biased and it will behave as an open. This is shown in Fig. 18.29 (*ii*). With diode as an open,

$$V_{out\,(peak)} = \text{Peak voltage across } R_L$$

$$= \frac{R_L}{R + R_L} V_{in\,(peak)} = \frac{4}{1 + 4} \times 10 = \mathbf{8V}$$

Note that peak output voltage is somewhat less than the peak input voltage.

Example 18.9. *In example 18.8, what will be the output voltage and voltage across R when the input voltage is –10 V ?*

Solution. During the negative half-cycle of input signal, the diode is forward biased. Therefore, diode can be replaced by its simplified equivalent circuit as shown in Fig. 18.30. Since load is connected in parallel with the diode,

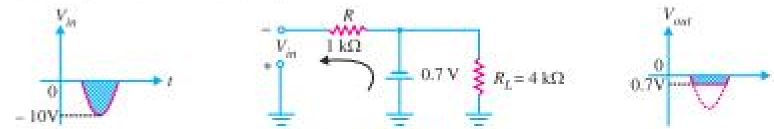


Fig. 18.30

$$\therefore \quad V_{out} = \mathbf{-0.7\ V}$$

$$\text{Voltage across } R,\ V_R = (-10) - (-0.7) = -10 + 0.7 = \mathbf{-9.3\ V}$$

Clipper

Mathematics of Clipper circuit

Example 18.10. *The positive shunt clipper shown in Fig. 18.31 has the input waveform as indicated. Determine the value of V_{out} for each of the input alternations.*

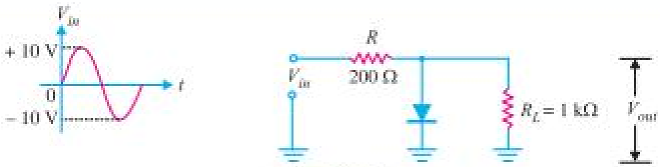


Fig. 18.31

Solution.

Positive half-cycle. During the positive half-cycle of the input ac signal, the diode is forward biased. Therefore, diode can be replaced by its simplified equivalent circuit as shown in Fig. 18.32. Since the load is connected in parallel with the diode,

$$\therefore \quad V_{out} = \mathbf{0.7\ V}$$

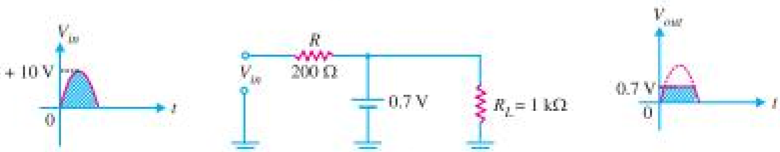


Fig. 18.32

Negative half-cycle. During the negative half-cycle of the input a.c. signal, the diode is reverse biased and it conducts no current. Therefore, the diode will behave as an open as shown in Fig. 18.33.

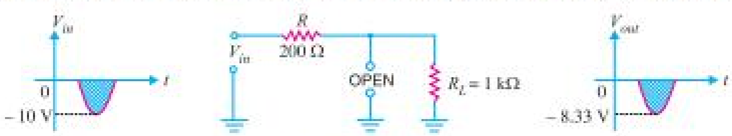


Fig. 18.33

$$\therefore \quad V_{out\,(peak)} = \frac{R_L}{R + R_L} V_{in\,(peak)}$$

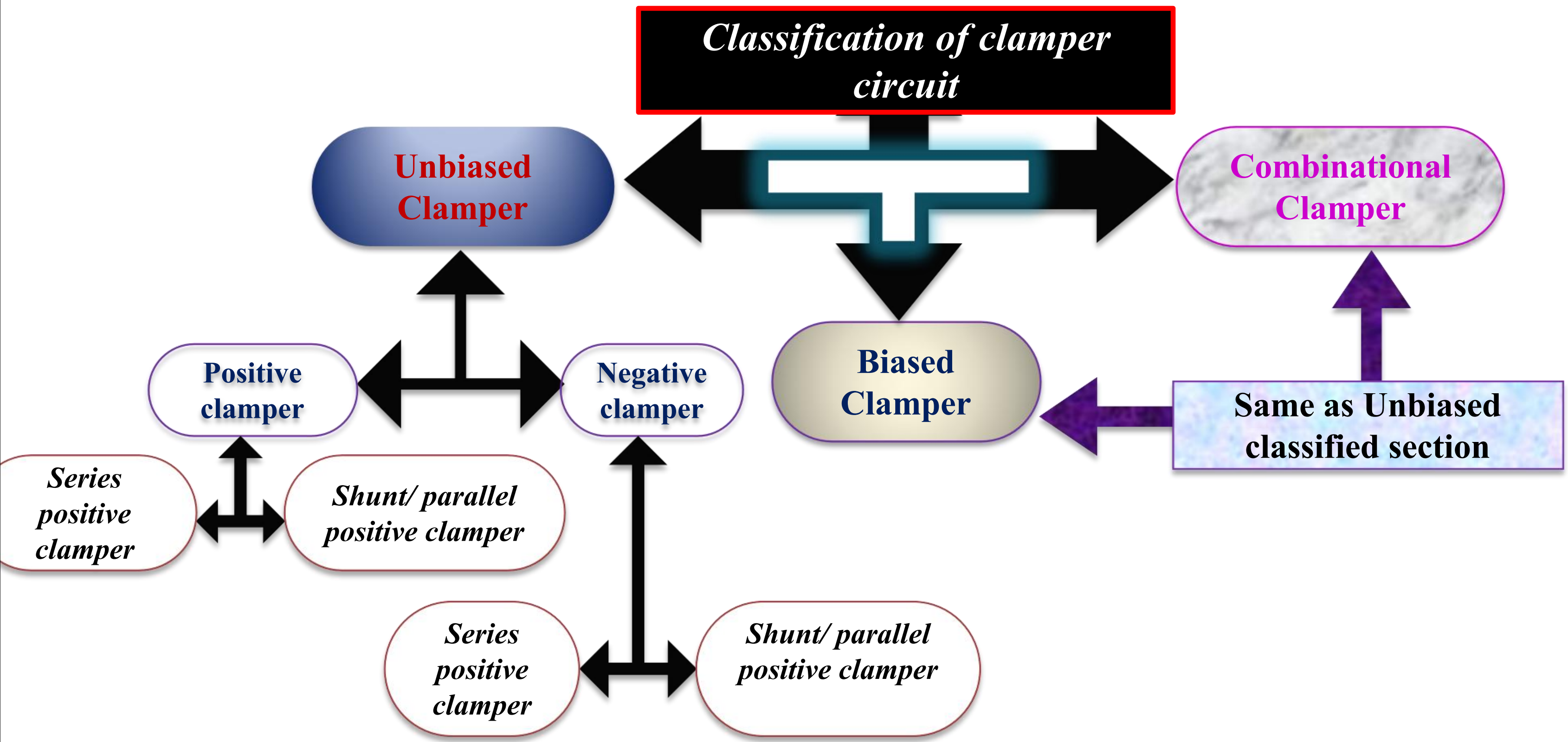
$$= \left(\frac{1000}{200 + 1000}\right)(-10\ \text{V}) = \mathbf{-8.33\ V}$$

Again the peak output voltage is somewhat less than the peak input voltage.

More math
8.11 – 8.14

Clamper

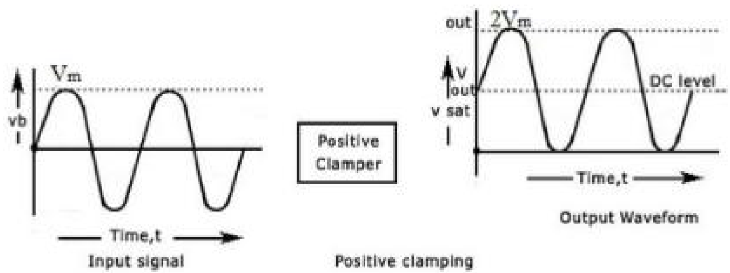
Definition	The circuits, with which the waveform can be shifted in such a way so that a particular part of it (say positive or negative peak) is maintained at a specified voltage level, is called camping circuit.



Clamper

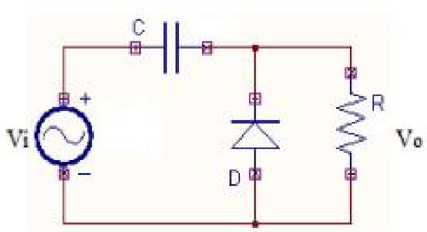
Biased Clamper

1. **Positive clamper**



- The fig above explains the basic concept of positive clamper. As shown the fig it adds a positive DC voltage to the AC input voltage.
- In other words the AC input is shifted upwards.

Circuit Diagram:



- Fig above shows the circuit diagram of positive clamper.
- The clamping network will always consist of three elements viz. a capacitor, a diode and a resistor.
- Sometimes an additional DC source is connected in the clamper circuit to introduce an additional shift.

Operation:

- In the first negative half cycle after turning on the circuit, the diode acts as a closed switch and charges the capacitor to peak input voltage V_m.
- In all the subsequent positive and negative half cycles, due to large RC time constant, the capacitor does not loose much charge. So V_o almost remains constant.
- So for rest of operation, the diode is reverse biased in both the half cycles, so it remains off.
- So we can write the expression for Vo as,

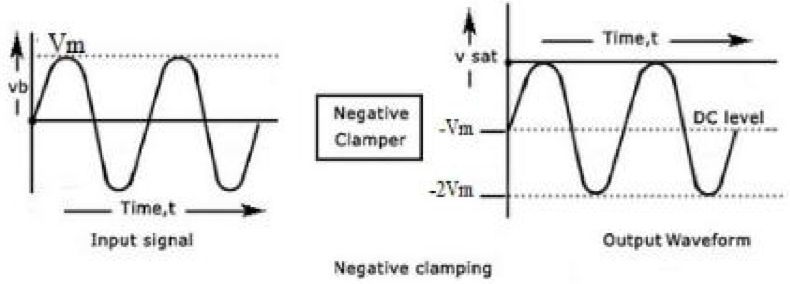
  $$Vo = Vi + Vm$$

- This shows that the clamper adds a positive DC shift.

Clamper

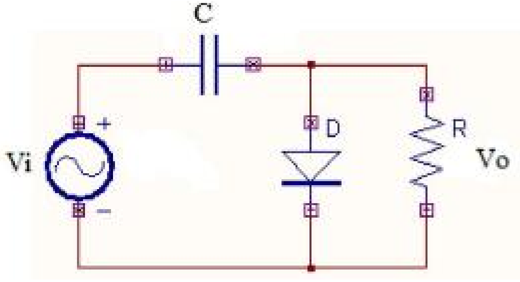
Biased Clamper

2. <u>Negative Clamper:</u>



- A negative clamper will add a negative DC level to the input signal.
- The fig above shows a simple negative clamper circuit which adds a negative level to the AC input. R is the load resistance.

<u>Operation:</u>



- In the first positive half cycle the capacitor will charge through the forward biased diode to peak voltage Vm.
- The charging takes place very quickly as the diode resistance is negligibly small.
- Once the capacitor charges to "Vm", the diode is reverse biased and stops conducting.
- The diode is reversed biased. So remains off.
- The expression for output voltage is given by,

  Vo = Vi + Vm
- This shows that the negative clamper adds a negative DC shift.

Clamper

Mathematics of Clamper circuit

More math
8.18 – 8.19