Electronic Devices and Circuits Lab : Report-6

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Contents

1 Aim :

The aim of the experiment was to understand the wave shaping circuits - clippers and clampers, their behaviour and applications.

2 Procedure :

2.1 Clippers

Clippers are wave shaping circuits that limit the input voltage to prevent it from attaining a value larger or smaller or both, than a predefined ones respectively. The main application is to protect the circuit from high voltage spikes . There are mainly two types of clipper circuits

1. Series Clipper : Here a diode is in series with the load.
2. Parallel or Shunt Clipper : Here the diode is in a branch parallel to the load.

Again in these clipper circuits they can be further classified basing on the voltage they clip.

1. Positive Clipper : The positive half cycles of the input voltage will be removed or be limited.

2. Negative Clipper : The negative half cycles of the input voltage will be removed or be limited.

The series clipper circuits are nothing but the half-wave and the full-wave rectifiers as studied earlier. Here we analyse the parallel or the shunt clipper circuits.

Shunt or Parallel Positive Clipper

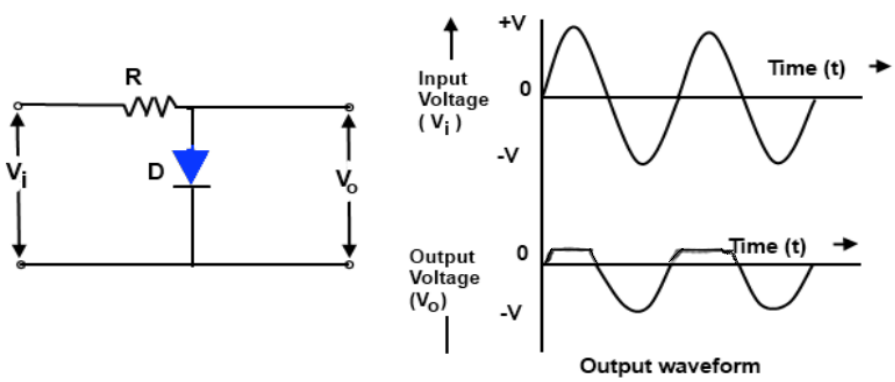


Figure 1: Parallel positive clipper

It can be seen that when the bias across the diode is greater than its cut-in voltage(0.7 for Si), the diode is in forward bias, and the output voltage is same as the knee voltage. And when the input voltage is in opposite direction, the diode will be in reverse bias allowing no current through it behaving like open switch. Hence the voltage across the output would resemble the input.

Shunt or Parallel Positive Clipper with Applied Bias

When we attach a battery in series with the diode as as shown, the effective bias would be the resultant of both V_{in} and V. If the V is connected such that the positive terminal of the battery is connected to the n-type of the diode, i.e., positive bias is applied, then to make the diode effectively forward bias, V_{in} should be greater than the sum of knee voltage and V, so comparatively the clipping happens after $V + V_{cut-in}$ (if V is much greater than cut-in voltage in the output as shown). If the battery is connected in negative bias(V is negative), then for input voltage greater than $-V$, the diode would be in forward bias, else it would be in reverse bias. Here, whenever the diode is in forward bias, it can be treated as shorted and the output voltage would be same the applied bias voltage and whenever it is in reverse bias, it can be treated as open circuit, and the output voltage resembles the input voltage.

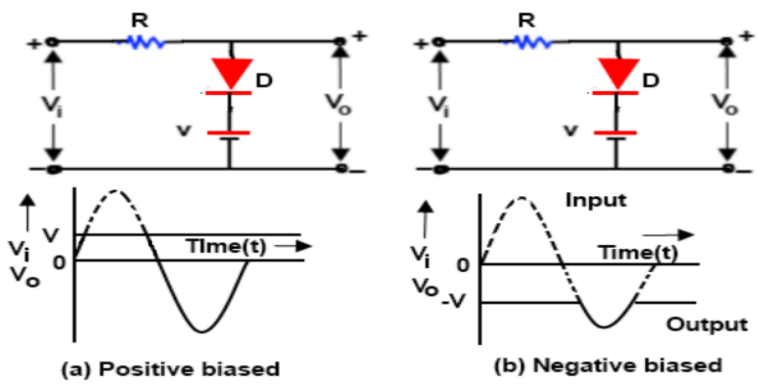


Figure 2: Parallel positive clipper with applied bias

Shunt or Parallel Negative Clipper

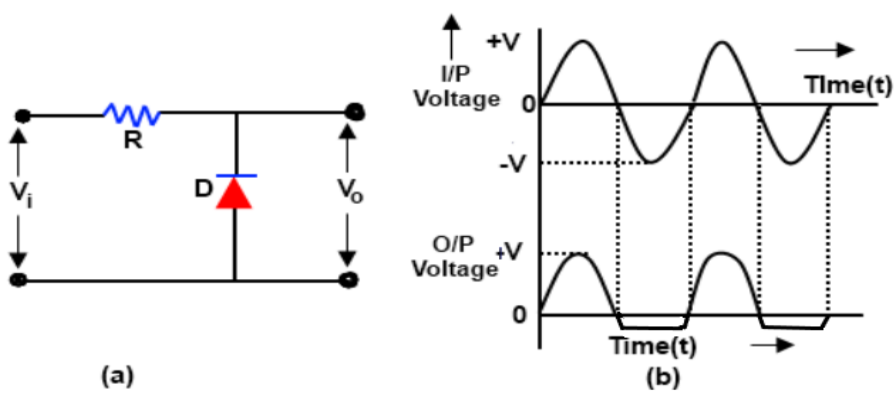


Figure 3: Parallel negative clipper

Similar to that observed in the positive parallel clipper with diode being reversed, when the input voltage is greater than cut-in voltage, the output voltage would be same as the input as diode would be in reverse bias and acts as open circuit, and when input voltage is less than cut-in voltage, the diode will be in forward bias, hence the output across load is same as knee voltage.

Shunt or Parallel Negative Clipper with applied bias

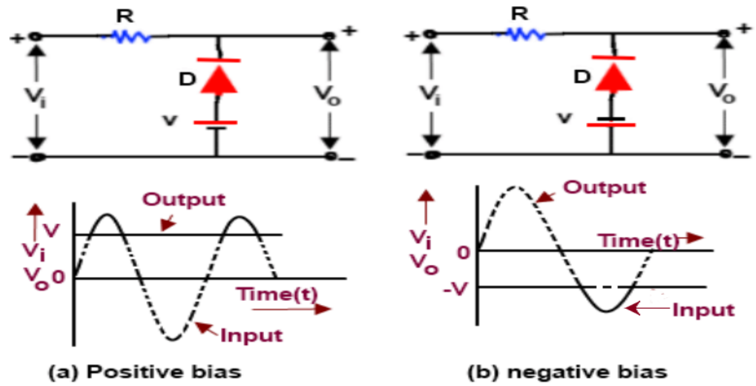


Figure 4: Parallel negative clipper with applied bias

The behaviour of this circuit can seen with the similar analysis done for positive clipper with applied bias. When the positive bias is applied, unless the input voltage is greater than $V + V_{cut-in}$, the diode effectively would be in forward bias, hence can be treated shorted. Neglecting the cut-in voltage, the output voltage would be same as the applied bias V. Else would be in reverse bias and the output voltage would resemble input voltage. Similarly when negative bias is applied, unless the input voltage is lesser than $-V$, diode would be in reverse bias and the voltage in output resembles input and when greater than $-V$, diode will be in forward bias and hence, voltage across the output is the same as applied bias.

Dual diode clipper

By cascading the positive and negative clipper as shown, the input voltage can be clipped in both half cycles.

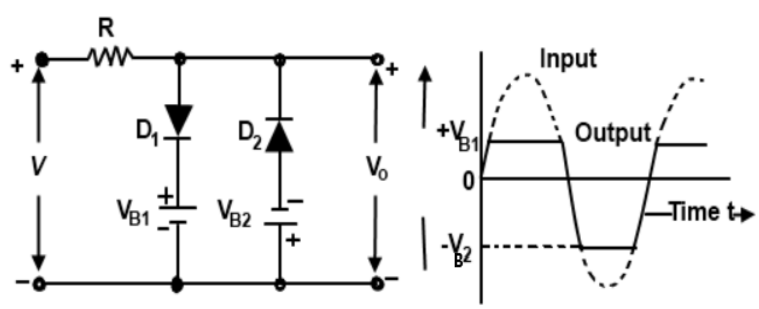


Figure 5: Dual Diode clipper

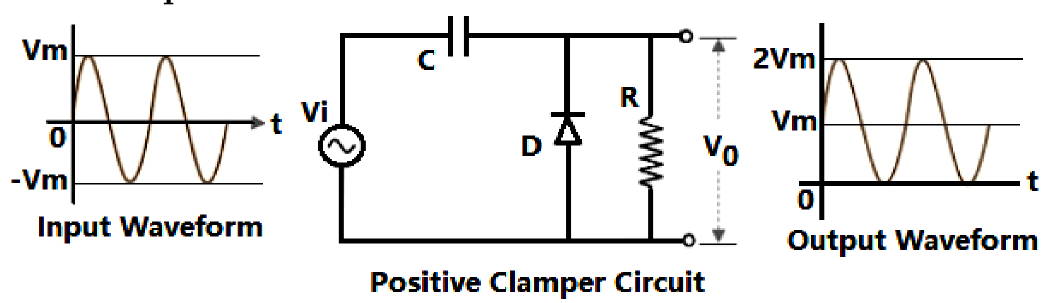
By applying the respective bias V_{B1} and V_{B_2}, the voltage could be clipped between them as shown, with similar working principle. In our design, we need to have The maximum voltage in the positive half cycle is $+2V_\gamma$ and the minimum voltage in negative half is $-3V_\gamma$ where V_γ is the cut-in voltage. As cut-in voltage is diode specific, for design purpose, we can place 2 diodes for the positive clipping in series in one parallel branch and 3 diodes in reverse direction for the negative clipping in series for the other branch and get the required output. In simulation the input signal is a sinusoidal wave with 5V as its peak with 1kHz frequency. The series resistance is taken to be 100Ω to limit the current through the diode.

2.2 Clampers

Clampers are used to set a DC offset to the input signal i.e., change DC level of the signal to a desired level without changing the shape of the signal. Generally these circuits are used in voltage multipliers. There three types of clamper circuits :

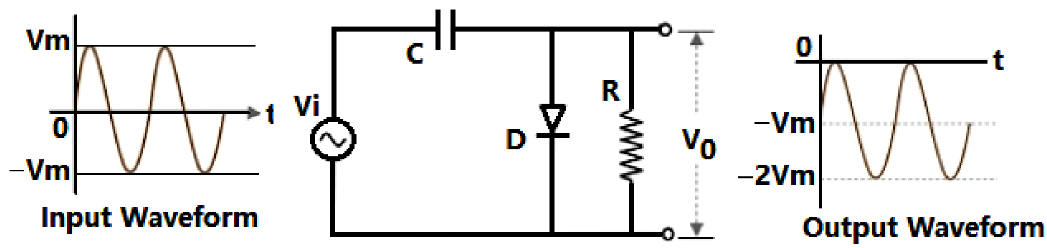
1. Positive Clamper : Pushes signal upwards.
2. Negative Clamper : Pushes signal downwards.
3. Biased Clampers : Pushes signal according to bias applied.

Positive Clamper :



In positive clamper circuit, the wave form shifts above the zero voltage level as shown. Analysing the circuit, assuming a sinusoid is applied, initially, in the first positive half-cycle, the potential across the diode is in reverse bias and hence, acts as an open circuit. By setting the product RC to be much greater than the time period of the input signal (at least $RC >> 10T_s$), we can make the charge/discharge rate to be slow. Hence, output voltage would resemble the input. After the end of positive half-cycle, when the input signal is negative, the diode would be in forward bias and acts as a short circuit. Hence output voltage would remain zero . During this time, the capacitor gets charged along with the applied input voltage till its peak(-V_m) is attained. Now the voltage across capacitor would be -V_m and the voltage across diode would be V_m+V_{in}, which is positive, hence again the diode gets reverse bias, and acts as open circuit. During this time, the output voltage would be V_{in}+V_m, hence the voltage has clamped up by V_m. Again when the input voltage reaches the next positive half-cycle, diode remains in reversed bias and as the discharge rate of the capacitor is very slow, the output voltage would be V_{in}+V_m, remains the same thereafter. Hence we get a positively-clamped input sinusoidal at the output as shown in the steady state.

Negative Clamper : In negative clamper circuits, the wave form shifts



Negative Clamper Circuit

below the zero voltage level as shown. The analysis remains similar to that of positive clamper except that the diode is reversed. So, in the first positive half-cycle, the diode would be forward bias and acts as short circuited. During this time the capacitor gets charged along with the input voltage until it peak(+V_m) is attained. Now the voltage across the diode would be V_{in}-V_m. So the voltage across the diode becomes negative as V_{in} decreases, and hence becomes reversed bias, thus open-circuited. The output voltage is hence V_{in}-V_m(assuming discharge rate is very slow), where we can see that the signal has clamped down. And when next positive half cycle starts, capacitor will be maintaining constant voltage across it, making output voltage V_{in}-V_m. So at steady state, the output voltage is negatively clamped input sinusoidal.
Note that in both the analysis, we have neglected the contribution of cut-in. In general considering it, we get clamping as V_m-V_{cut-in} instead of V_m.

Biased Clampers are same as the positive(or)negative clampers with a battery in series to the diode in the same branch. By changing the bias, say V, the voltage across the capacitor can be altered as $V_m \pm V$, affecting the clamping similarly.

3 Results and discussion

3.1 Clippers

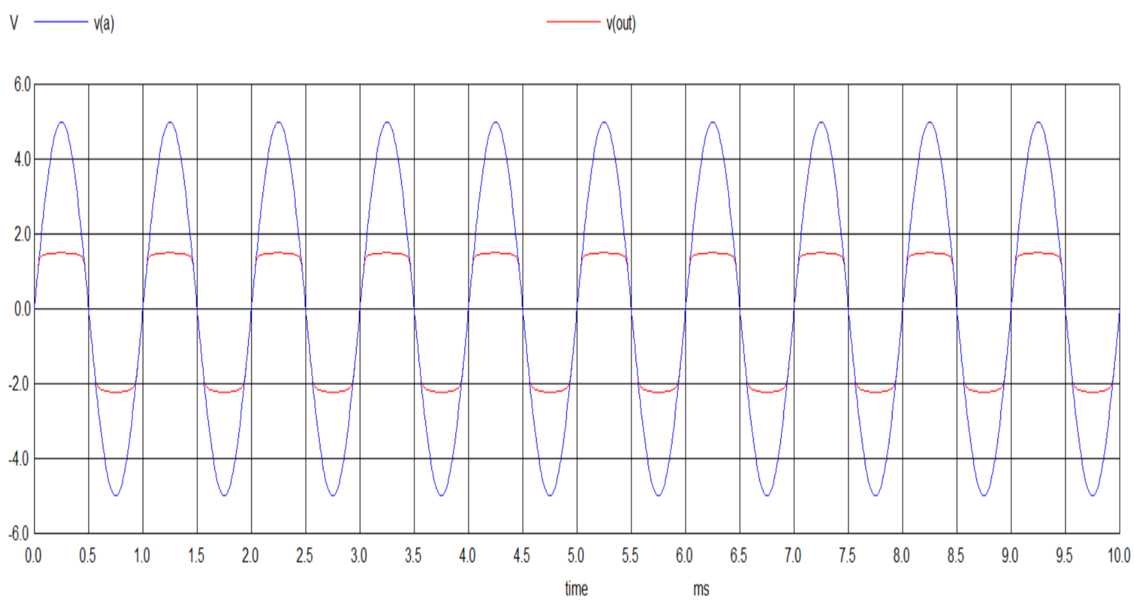


Figure 6: Clipper circuit Simulation Output with Upper limit of Voltage = $2V_\gamma$ and Lower limit of voltage =-$3V_\gamma$ where V_γ is the cut-in voltage of diode

Observations

- The input 5V sinusoidal is effectively clipped between 1.4V (i.e, $2V_\gamma$) and -2.1V (i.e, -$3V_\gamma$).
- The clipped voltages are not very straight, as the voltage across the diode changes slightly with varying input signal in the clipped regions which can be seen in the diode's characteristics. After the knee voltage, for high change in current the change in voltage is very small but finite, hence we get those curvilinear boundaries.
- The similar output with much precise clipping boundaries could be obtained if the cut-in voltage of the diode is accurately known, done by applying the equivalent bias instead of using more number of diodes.
- The series resistance used in the circuit helps to keep amount of current within the limits of maximum current for the diode and has very small voltage drop comparatively making the output overlap with input in unclipped areas.

3.2 Clampers - (Negative)

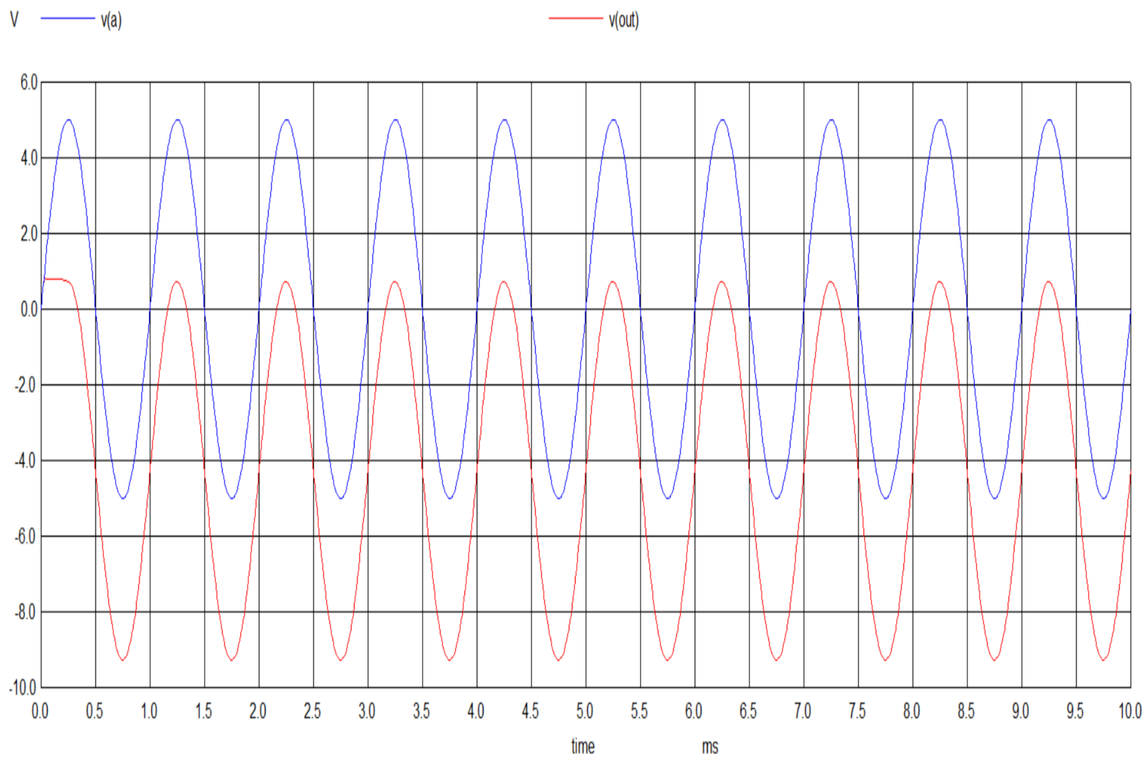


Figure 7: Negative Clamper circuit simulation output with RC = $100T_s$, for input as sinusoidal with peak 5V and 1kHz frequency

Observations

- The output voltage is negatively d.c. shifted by nearly by -4.3 V $\approx$ V_m-V_{cut-in}. And the output is not completely below the 0-level line, because of the cut-in voltage of the diode, which can be taken care by applying equivalent bias to it.

- The transient output is as expected. In the first half cycle, when the voltage increases, the output voltage rises quickly to a constant value (knee voltage) until input voltage starts decreasing. There onwards the clamping of input starts and at from the next cycle we have the negatively clamped in output.

- As the output is as expected, the discharge rate is slow enough preventing the discharge of the capacitor.

4 Conclusions

1. The voltage signals can be shaped accordingly using wave-shaping circuits such as Clampers and Clippers .

2. We can clip the signal between the defined limits using clippers. Arranging diodes in correct manner, applying proper bias we limit the signal with in the boundaries.

3. We can clip the positive part or negative part or both by using positive clipper or negative clipper or by cascading both respectively.

4. Even in forward bias, there would be small finite voltage drop across diode affecting in the non linearity of the boundary.

5. There must some series resistance to limit the amount of current flow into the diode.

6. Clampers are the circuits which help to create a dc offset to the signal by just using a capacitor and diodes arranged in specific manner along with applying required bias.

7. In the circuit, clamping is less than expected clamping because of the cut-in voltage of the diode. Hence additional bias is required to overcome this factor

8. The resistance and capacitance have to be chosen such that the discharge rate has to be very slow compared to the frequency of the signal at the same ensure that the current passing through the diode does not exceed its limit.

9. The clippers are very helpful in the applications of protection of circuits from spikes, voltage limiters, FM transmitters etc.

10. The clampers are very helpful in the applications of direct current restorers, removing distortions,voltage multipliers,protection of amplifiers,baseline stabilizers etc.