Diode Clipper and Clamper Circuits

These are diode waveshaping circuits *i.e.* circuits meant to control the **shape** of the voltage and current waveforms to suit various purposes. Each performs the waveshaping function indicated by its name. The output of the clipping circuit appears as if a portion of the input signal were ***clipped off***. But clamper circuits simply clams (*i.e.* lift up or down) the input signal to a different dc level.

Clippers

A clipping circuit requires a minimum of two components *i.e.* a diode and a resistor. Often, dc battery is also used to fix the clipping level. The input waveform can be clipped at different levels by simply changing the battery voltage and by interchanging the position of various elements. We will use an ideal diode which acts like a closed switch when forward-biased and as an open switch when reverse-biased.

Such circuit are used in radars and digital computers etc. when it is desired to remove signal voltages above or below a specified voltage level. Another application is in radio receivers for communication circuits where noise pulses that rise well above the signal amplitude are clipped down to the desired level.

Example. *For the simple parallel clipper of Fig. 1, find the shape of the output voltage V_O across the diode if the input sine wave signal is as shown in Fig. 1 (a). What will happen when diode and resistor are inter-changed ?*

Solution. When positive half-cycle of the signal voltage is applied to the clipper *i.e.* when *A* is positive with respect to *B*, the diode *D* is reverse-biased. Hence, it acts as an open switch. Consequently, the entire input voltage appears across it.

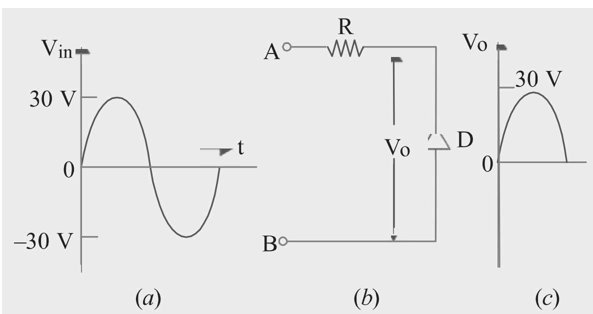

Fig. 1

During the negative half-cycle of the signal voltage when circuit terminal *B* becomes positive with respect to *A*, the diode is forward-biased. Hence, it acts like a closed switch (or short) across which no voltage is dropped. Hence, the waveshape of V_0 is as shown in Fig. 1 (*c*). It is seen thatthe negative portion of the signal voltage has been removed. Hence, such a circuit is called a **negative clipper**.

When Diode and Resistor are Interchanged

In this case, the circuit becomes as shown in Fig. 2(*b*). Now, the output voltage V_0 is that which is dropped across *R*. During the positive half-cycle of the signal voltage, *D* acts as an open switch. Hence, all applied voltage drops across *D* and none across *R*. So, there is no output signal voltage.

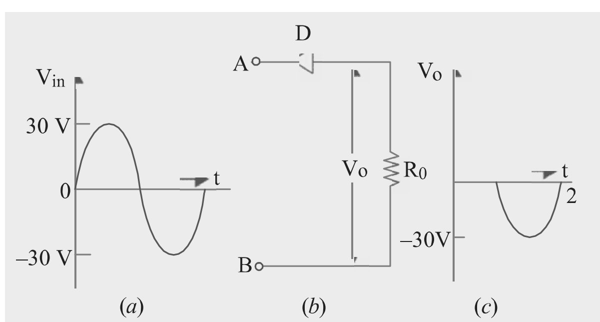

Fig.2

During the negative input half-cycle, terminal *B* is positive and so it is forward-biases *B* which acts as a short. Hence, there is no voltage drop across *D*. Consequently, all the applied signal voltage drops across *R* and none across *D*. As a result, the negative half-cycle of the input signal is allowed to pass through the clipper circuit. Obviously, now the circuit acts as a **positive** clipper.

Example 2. *What would be the output waveform displayed by the oscilloscope in Fig.3? The silicon diode has a barrier voltage of 0.7 V.*

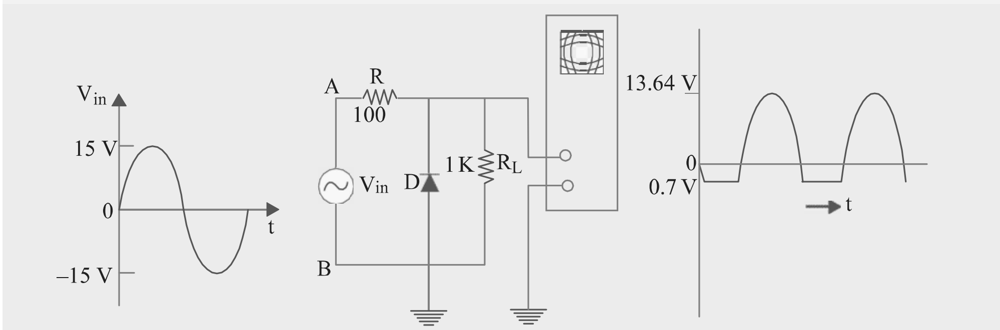

Fig. 3

Solution. Consider the negative input half-cycle first *i.e.* when point B is positive with respect to point A. The diode starts conducting when applied voltage exceeds 0.7 V. Since D and R_L are in parallel, voltage across them cannot exceed 0.7 V. Obviously, negative half-cycle beyond 0.7 V gets clipped. Hence, circuit behaves like a negative clipper.

During the positive input half-cycle when point A is positive, diode becomes reverse-biased and hence, becomes open-circuited. The applied voltage drops across the resistors R and R_L connected in series. The peak value of the output voltage is

$$= 15 \times \left(\frac{R_L}{R + R_L} \right) = 15 \times \frac{1}{1.1} = 13.64 \text{ V}$$

Hence, the output voltage as displayed by the oscilloscope would be as shown in Fig. 3.

Example. 3. *With the sine wave signal input of Fig. 4 (a), find the shape of the output signal V_0 in the biased series clipper of Fig. 4 (b). What would happen if battery connections are reversed ?*

Solution. Let us consider the positive half-cycle of the singal *i.e.* when terminal A of the circuit becomes positive with respect to B. The diode appears as a short since it is forward-biased.

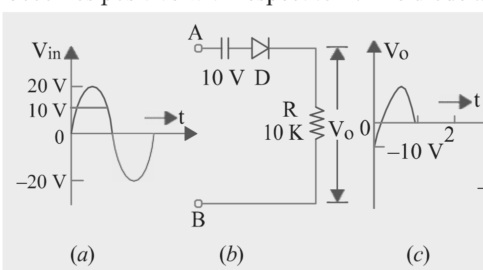

Fig.4

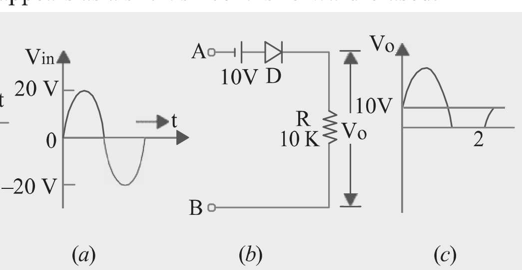

Fig. 5

But no current flows till V_{in} exceeds the opposing battery voltage of 10 V. Hence, only upper part of the positive signal voltage passes through the clipper circuit and appears as V_0 across R. Its shape is shown in Fig. 4 (*c*). The negative half-cycle of the signal voltage is clipped off.

In fact, in this circuit, the entire input is clipped off except positive peak portions.

Reversed Battery Connections

The battery connections have been reversed in Fig. 5. In this case, during the positive half-cycle of the signal, the voltage across R would be the sum of the signal voltage and the battery voltage *i.e.* signal voltage would be lifted up by 10 V as shown in Fig.5 (*c*).

During the negative input half-cycle, the lower peak portions of the signals would be clipped off because of the 10 V battery.

Example. 4. *The triangular voltage of Fig. 6 (a) is applied to the biased parallel clipper circuit of Fig 52.36 (b). Find the wave-shape of the output voltage.*

Solution. During the positive half-cycle, D_1 would conduct but D_2 will act as an open-circuit. However, value of V_0 cannot exceed 10V because points C and D are electrically connected across the 10 V battery since D_1 is shorted. Hence, signal voltage above 10 V level would be clipped off as shown in Fig. 6 (*c*).

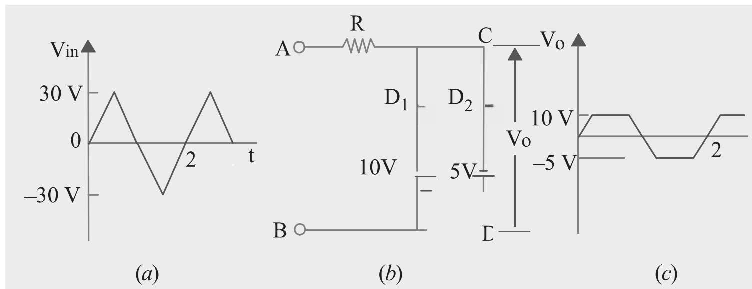

Fig. 6

During the negative half-cycle, D_1 is open but D_2 conducts. Again, V_0 cannot exceed 5 V since it is the voltage across points C and D whose value is fixed by the battery connected in that branch. Hence, signal voltage beyond 5 V is clipped off. The wave-shape of V_0 is as shown in Fig. 6 (*c*).

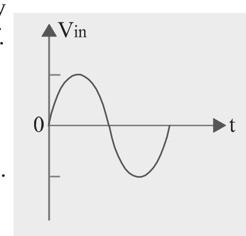

Fig. 7

Some Clipping Circuits

For the following circuits, a sinusoidal input signal as shown in Fig. 7 would be assumed.

(a) Biased Series Clippers

The output voltage has the waveform as shown in Fig. 8.

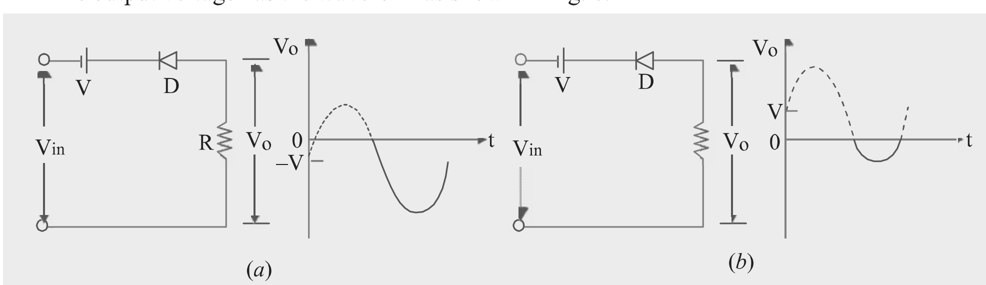

Fig. 8

(b) Biased Parallel Clippers

The waveforms of the output voltage are as shown in Fig. 9.

Clipping has been changed by changing the battery and diode connections.

Clampers

To put it simply, clamping is the process of introducing a dc level into an ac signal. Clampers are also sometimes known as dc restorers.

By way of illustration, consider the signal shown in Fig. 10 (*a*). It is a sine wave with equal positive and negative swings of ± 5 V about 0 V. Hence, its average value over one cycle is zero (it has no dc level).

In Fig. 52.40 (*b*), the signal waveform has been lifted up so as to just touch the horizontal axis. It is now said to have acquired a dc level of 5 V. This output wave-form is said to be ***positively*** clamped at 0 V. Fig. 52.40 (*c*) shows an output waveform which is negatively clamped at 0 V.

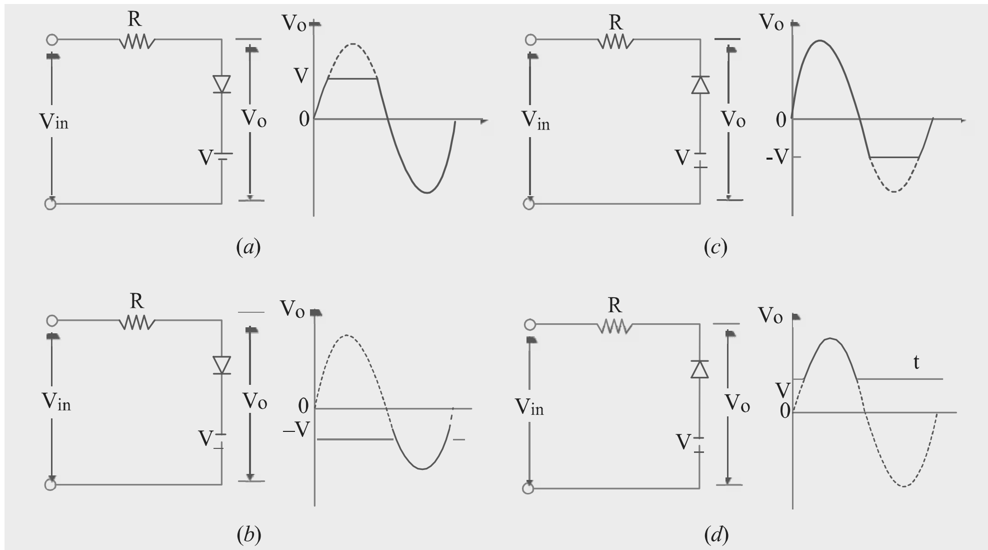

Fig. 9

A circuit capable of accepting the input signal shown in Fig. 52.40 (*a*) and delivering the output shown in Fig. 52.40 (*b*) or (*c*) is called a ***clamper***. Such a circuit has a minimum requirement of ***three*** elements.

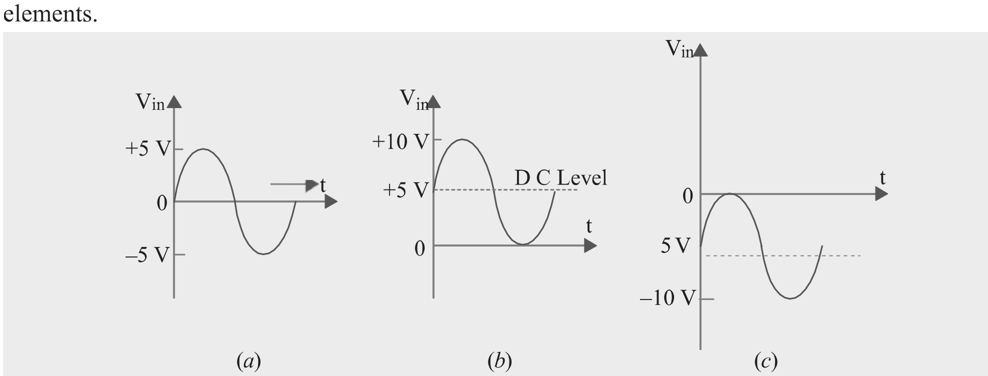

Fig. 10

1. a diode **2.** a capacitor and **3.** a resistor.

It will generally need a dc battery also. Following additional points regarding clamper circuits are worth keeping in mind.

1. both *R* and *C* affect the waveform.
2. values of *R* and *C* should produce a time constant ($\lambda = CR$) which is large enough to ensure that capacitor remains almost fully charged during the time-period of the signal. In other words, time constant $\lambda \gg T/2$ where *T* is the time-period of the input signal. For good clamping action, the *RC* time constant should be at least ten times the time-period of the input signal voltage.

3. it is advantageous to first consider the condition under which the diode becomes forward biased.
4. for all clamping circuits, voltage swing of the input and output waveforms is the same.
5. such circuits are often used in TV receivers as dc restorers. The incoming composite video signal is normally processed through capacitively-coupled amplifiers which eliminate the dc component thereby losing the black and white reference levels and the blanking level. These reference levels have to be restored before applying the video signal to the picture tube.

Example 5. *The input signal of Fig. 11 (a) is applied to the clamper circuit shown in Fig.11 (b). Draw the waveform of the output voltage V_0. How will it change if R is made 100 Ω ?*

Solution. As seen, time-period of the input signal is $T = 1/1000$ second = 1 ms

∴ $0 \rightarrow t_1 = t_1 \rightarrow t_2 = t_2 \rightarrow t_2 = T/2$ .... = 0.5 ms.

$\lambda = C_R = 1 \times 10^{-6} \times 10 \times 10^{3} = 10$ ms

As seen, λ » $T/2$. Hence, once charged, the capacitor will have hardly any time to discharge by the time signal polarity reverses.

(a) Positive Input Half-cycle

When positive half-cycle of the input signal voltage is applied to the clamper circuit, its terminal *A* becomes positive with respect to terminal *B*. Hence, *D* acts like a short as shown in Fig. 11 (*c*).A steady positive voltage of 5 V remains applied to *A* for 0.5 ms. At the same time, *R* is also shorted out [Fig. 11 (*c*)] because it is in parallel with *D*. Hence, C will rapidly charge to 5 V. Being acrossa short, $V_0 = 0$ during positive half-cycle as shown in Fig. 11 (*d*).

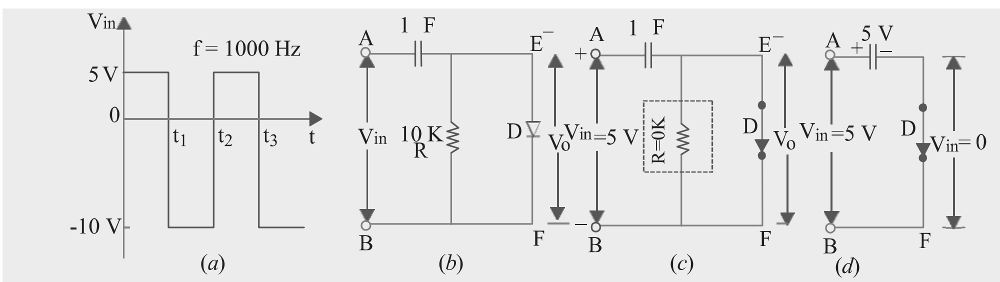

Fig. 11

(b) Negative Input Half-cycle

In this case, terminal *B* becomes positive and so reverse-biases *D* by 10 V. Hence, *D* acts like an open switch as shown in Fig. 12 (*a*). Now, *R* and *C* get connected in series so that their $\lambda = RC = 10$ ms. As stated earlier, capacitor will take a time of 5λ = 50 ms to get fully discharged. But the input signal will allow it just 0.5 ms during which to discharge. Obviously, *C* would hardly get discharged in this extremely short time interval of 0.5 ms. Hence, it can be assumed to be still fully charged with the original polarity during this negative half-cycle.

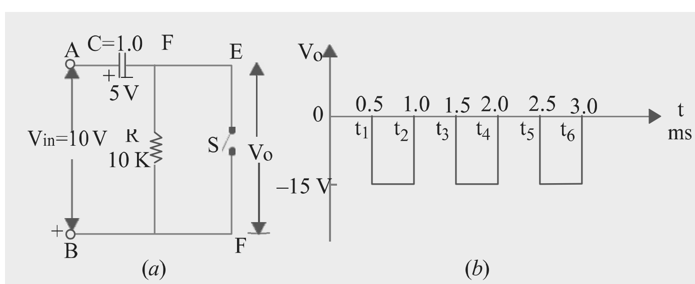

Fig. 12

The output voltage V_0 across the 'open' will be

= voltage from $E \rightarrow A \rightarrow B \rightarrow F$

= 5 + 10 = 15 V – with E negative

The waveform of the output voltage is shown in Fig. 12 (*b*). It has same frequency as that of the input signal. However, it has been clamped down in the negative region. It is seen that voltage swing of both input and output circuits is the same *i.e.* 15 V. It is never the case in clipping circuits.

When R = 100

Now, $\lambda = 100 \times 1 \times 10^{-6}$ ms = 0.1 ms. Hence, the capacitor which is almost instantaneously charged to +5 V during the positive input half-cycle, will be almost completely discharged during the negative half-cycle because, now, 5 λ (full discharge time) equals the half time-period (0.5 s) of the signal.

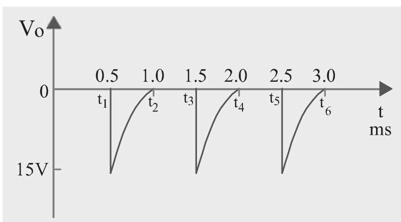

Fig. 1 3

Hence, in this case, V_0 would be momentarily equal to – 15 V at the beginning of the negative half-cycle but will fall off to almost 0 V before the signal reverses its polarity (Fig. 52.43). As seen, υ_0 consists of voltage spikes of amplitude – 15 V.

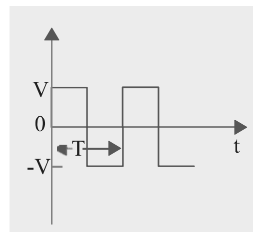

Fig. 14

Summary of Clamping Circuits

In the following clamping circuits, it would be assumed that the amount of the time $5\lambda = 5\,RC \gg T/2$ where T is the time-period of the input signal. For all circuits, we will take the same input signal shown in Fig. 52.44 with a peak value of V . We will also take note of the change in the output waveform when diode connections are reversed.

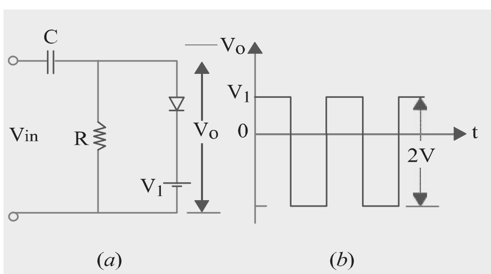

Fig. 15

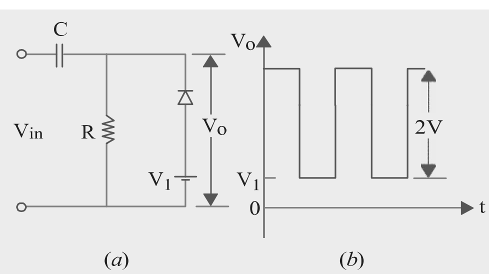

Fig. 16

It is seen from Fig. 52.44 and 52.45 that negative clamping has changed to positive clamping when the diode connections are reversed.

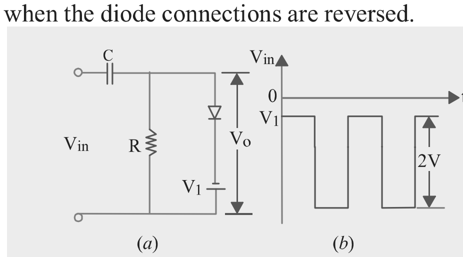

Fig. 17

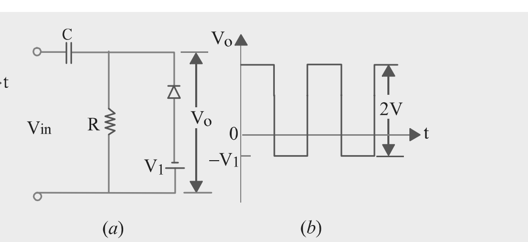

Fig. 18

The same thing happens in the case of clamping circuits shown in Fig. 17 and 18.

Tutorial Problems No. 1

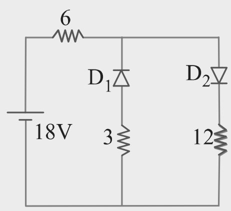

Fig. 19

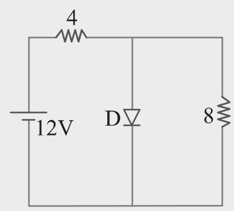

Fig. 20

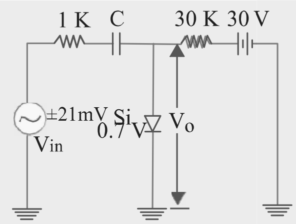

Fig. 21

1. Find the current supplied, if any, by the battery in the circuit of Fig. 19 which uses two oppositely-connected ideal diodes in parallel. **[1 A]**
2. What is the current supplied by the battery in Fig. 20 if *D* is an ideal diode. **[3 A]**
3. In Fig. 21, signal voltage has a peak value of ≠ 21 mV and its frequency is so high that reactanceof the coupling capacitor can be neglected. If bulk resistance of the silicon diode is neglected, what

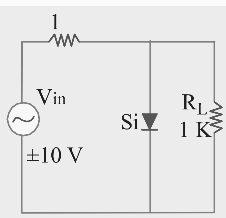

Fig. 22

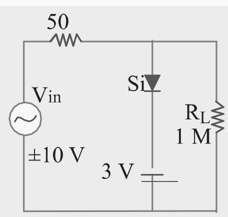

Fig. 23

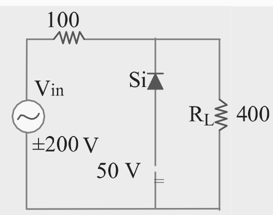

Fig. 24

would be the approximate waveform of the total voltage 'V_0' across the diode. **[0.7 V dc on which rides an ac voltage of peak value = 1 mV]**

4. Sketch the voltage across R_L in the clipper circuit of Fig. 22.
5. Sketch the voltage across R_L in the clipper circuit of Fig. 23.
6. What is the waveform of the voltage across R_L in Fig. 24 ?
7. What is the approximate dc component in the output of a positive diode clamper with a peak input of 20 V ? **[20 V]**