Al-Mustaqbal University
College of Engineering and Technologies
Medical Instrumentation Technique Engineering Department
Class: 2nd
Subject: Electronic Circuits
Lecturer: Dr. Rami Qays Malik
Lecture: 5- Diode Applications (clipper & clamper)

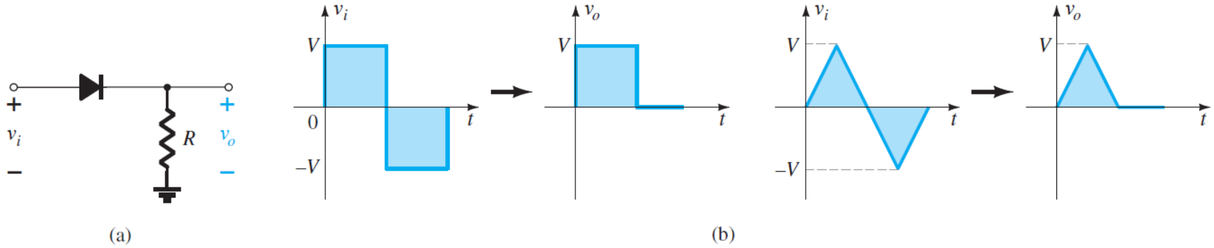
Diode Applications-2-

Clippers

Clippers are networks that employ diodes to “clip” away a portion of an input signal without distorting the remaining part of the applied waveform. The half-wave rectifier is an example of the simplest form of diode clipper

1. **Series:**

   The series configuration is defined as one where the diode is in series with the load



(a) (b)

FIG. 2.68
Series clipper.

there are some things one can do to give the analysis some direction. First and most important:

1. Take careful note of where the output voltage is defined.

2. Try to develop an overall sense of the response by simply noting the “pressure” established by each supply and the effect it will have on the conventional current direction through the diode.

Keep in mind that we are dealing with an ideal diode for the moment, so the turn-on voltage is simply 0 V.

3. Determine the applied voltage (transition voltage) that will result in a change of state for the diode from the "off" to the "on" state.

EXAMPLE 2.18: Determine the output waveform for the sinusoidal input of Fig. 2.74 .

Solution:

Step 1: The output is again directly across the resistor R.

Step 2: The positive region of v i and the dc supply are both applying "pressure" to turn the diode on. The result is that we can safely assume the diode is in the "on" state for the entire range of positive voltages for v i . Once the supply goes negative, it would have to exceed the dc supply voltage of 5 V before it could turn the diode off.

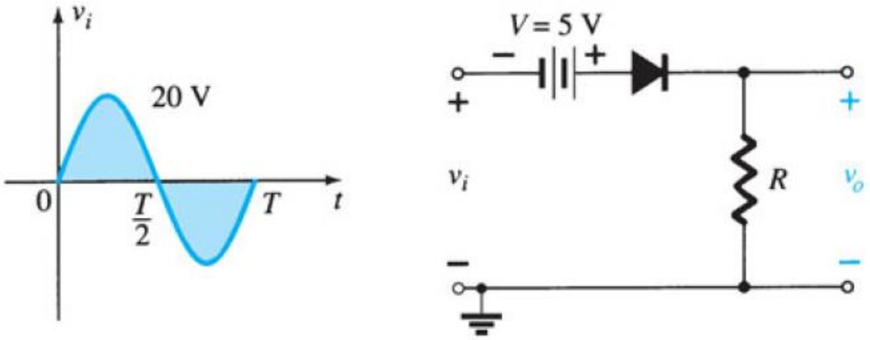


FIG. 2.74

Series clipper for Example 2.18.

Step 3: The transition model is substituted in Fig. 2.75, and we find that the transition from one state to the other will occur when

$$v_i + 5\text{ V} = 0\text{ V}$$

or

$$v_i = -5\text{ V}$$

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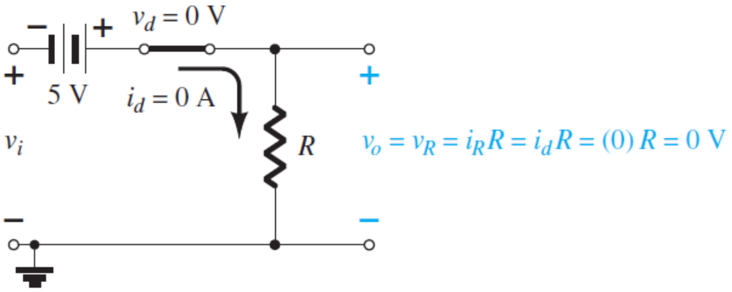

FIG. 2.75
Determining the transition level for the clipper of Fig. 2.74.

Step 4: In Fig. 2.76 a horizontal line is drawn through the applied voltage at the transition level. For voltages less than −5 V the diode is in the open-circuit state and the output is 0 V, as shown in the sketch of v_o. Using Fig. 2.76, we find that for conditions when the diode is on and the diode current is established the output voltage will be the following, as determined using Kirchhoff's voltage law:

$$v_o = v_i + 5\text{ V}$$

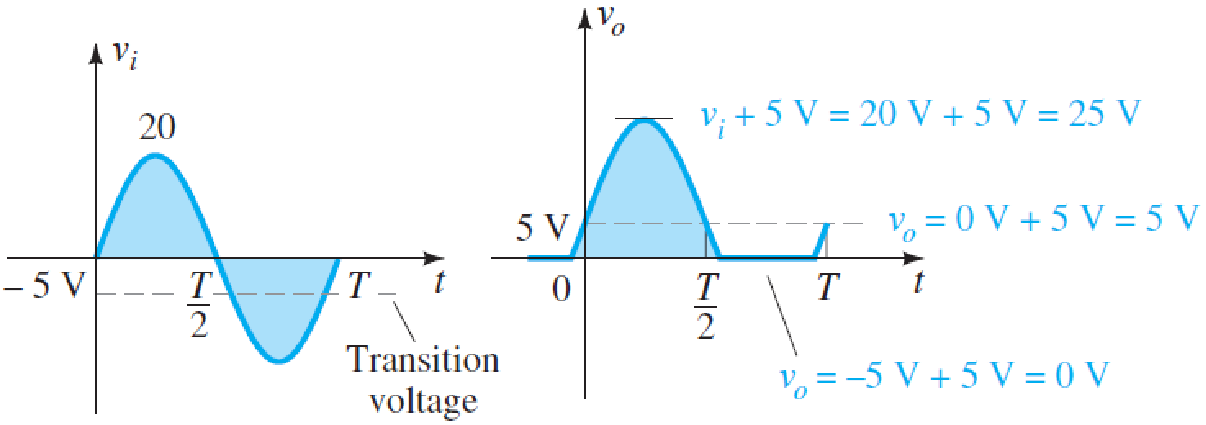

FIG. 2.76
Sketching v_o for Example 2.18.

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EXAMPLE 2.19 Find the output voltage for the network examined in Example 2.18 if the applied signal is the square wave of Fig. 2.77.

Solution: For vi = 20 V (0 T/2) the network of Fig. 2.78 results. The diode is in the short-circuit state, and vo = 20 V + 5 V = 25 V. For vi = -10 V the network of Fig. 2.79results, placing the diode in the off state, and vo = (IR R) = (0)R = 0 V. The resulting output voltage appears in Fig. 2.80.

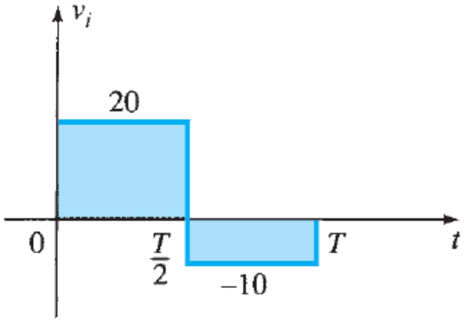

FIG. 2.77
Applied signal for Example 2.19.

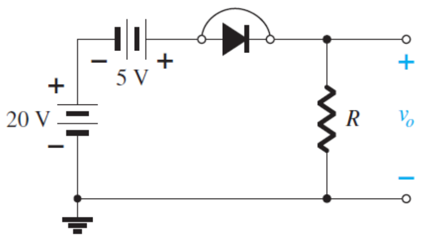

FIG. 2.78
v_o at $v_i = +20$ V.

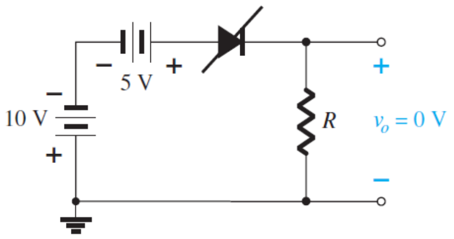

FIG. 2.79
v_o at $v_i = -10$ V.

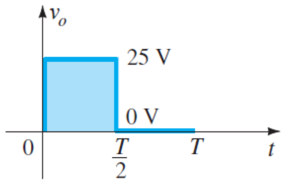

FIG. 2.80
Sketching v_o for Example 2.19.

Note in Example 2.19 that the clipper not only clipped off 5 V from the total swing, but also raised the dc level of the signal by 5 V.

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2. Parallel

The network of Fig. 2.81 is the simplest of parallel diode configurations with the output for the same inputs of Fig. 2.68. The analysis of parallel configurations is very similar to that applied to series configurations, as demonstrated in the next example.

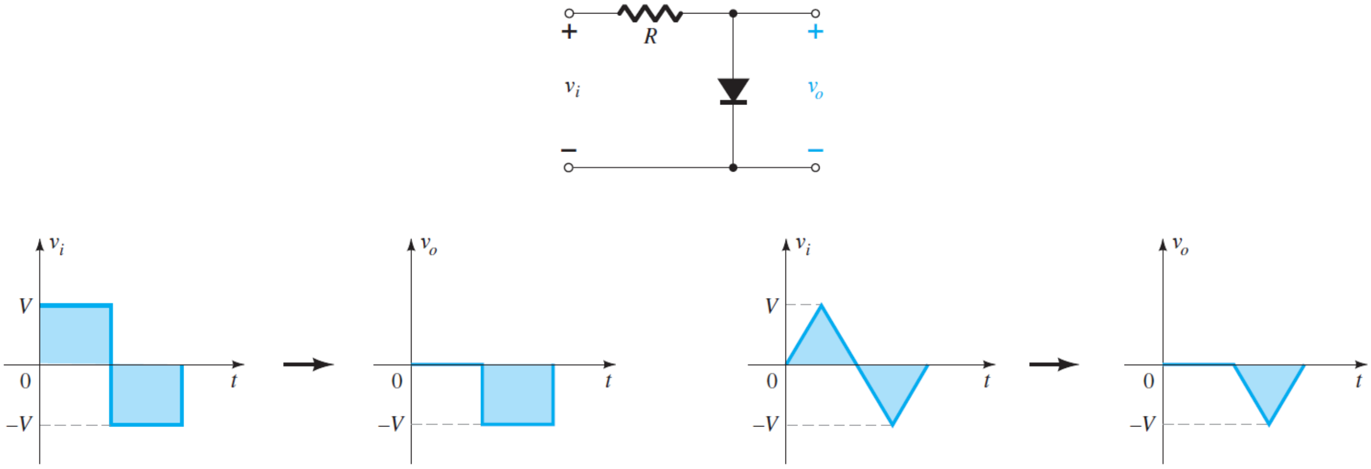

FIG. 2.81
Response to a parallel clipper.

EXAMPLE 2.20 Determine v o for the network of Fig. 2.82 .

Solution:

Step 1: In this example the output is defined across the series combination of the 4-V supply and the diode, not across the resistor R.

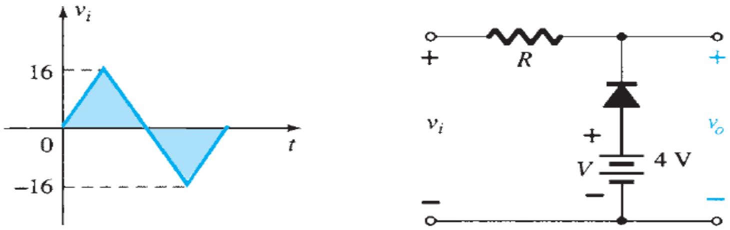

FIG. 2.82
Example 2.20.

Step 2: The polarity of the dc supply and the direction of the diode strongly suggest that the diode will be in the “on” state for a good portion of the negative region of the input signal. In fact, it is interesting to note that since the output is directly across the series combination, when the diode is in its short-circuit state the output voltage will be directly across the 4-V dc supply, requiring that the output be fixed at 4 V. In other words, when the diode is on the output will be 4 V. Other than that, when the diode is an open circuit, the current through the series network will be 0 mA and the voltage drop across the resistor will be 0 V. That will result in $v_o = v_i$ whenever the diode is off.

Step 3: The transition level of the input voltage can be found from Fig. 2.83 by substituting the short-circuit equivalent and remembering the diode current is 0 mA at the instant of transition. The result is a change in state when

$$v_i = 4\text{ V}$$

Step 4: In Fig. 2.84 the transition level is drawn along with $v_o = 4$ V when the diode is on. For $v_i \geq 4$ V, $v_o = 4$ V, and the waveform is simply repeated on the output plot.

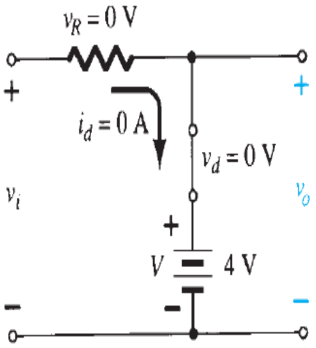

FIG. 2.83
Determining the transition level for Example 2.20.

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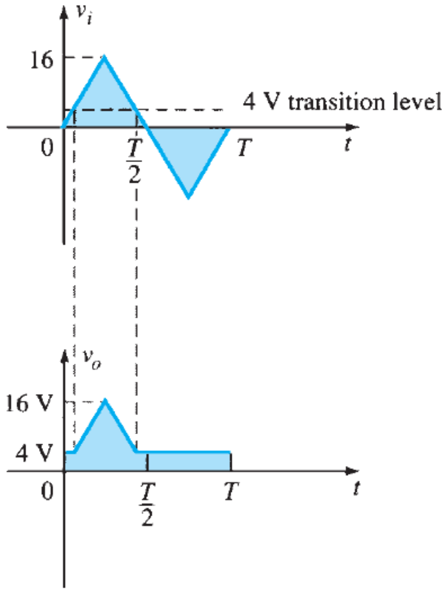


FIG. 2.84
Sketching v_o for Example 2.20.

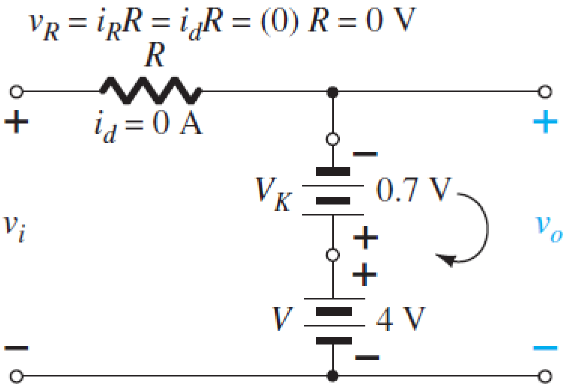


FIG. 2.85
Determining the transition level for the network of Fig. 2.82.

EXAMPLE 2.21 Repeat Example 2.20 using a silicon diode with $V_K = 0.7$ V.

Solution: The transition voltage can first be determined by applying the condition $i_d = 0$ A at $v_d = V_D = 0.7$ V and obtaining the network of Fig. 2.85. Applying Kirchhoff's voltage law around the output loop in the clockwise direction, we find that

$$v_i + V_K - V = 0$$

and $$v_i = V - V_K = 4\text{ V} - 0.7\text{ V} = \mathbf{3.3\ V}$$

For input voltages greater than 3.3 V, the diode will be an open circuit and $v_o = v_i$. For input voltages less than 3.3 V, the diode will be in the "on" state and the network of Fig. 2.86 results, where

$$v_o = 4\text{ V} - 0.7\text{ V} = \mathbf{3.3\ V}$$

The resulting output waveform appears in Fig. 2.87. Note that the only effect of V_K was to drop the transition level to 3.3 from 4 V.

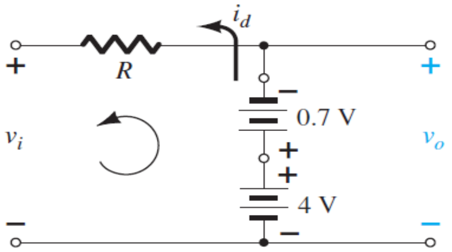


FIG. 2.86
Determining v_o for the diode of Fig. 2.82 in the "on" state.

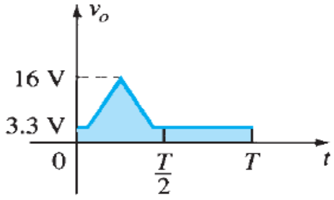
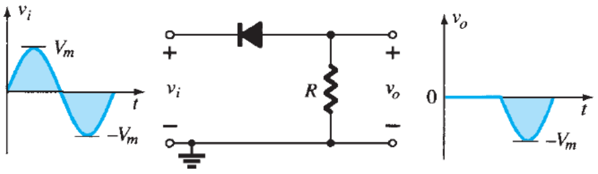


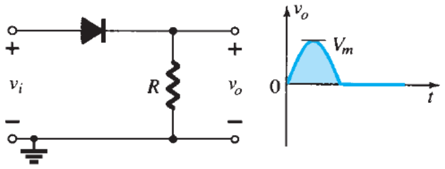
FIG. 2.87
Sketching v_o for Example 2.21.

Simple Series Clippers (Ideal Diodes)

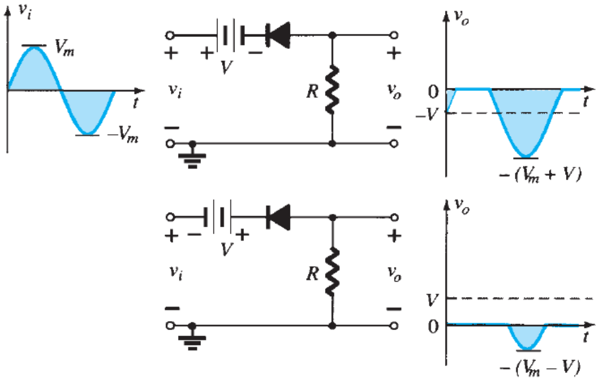
POSITIVE

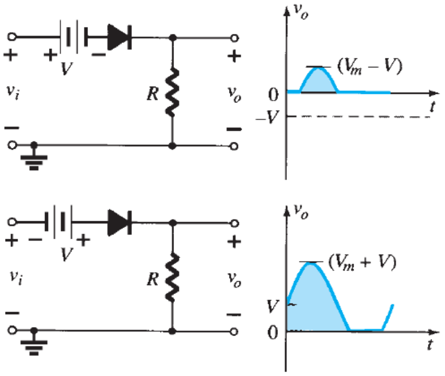


NEGATIVE



Biased Series Clippers (Ideal Diodes)





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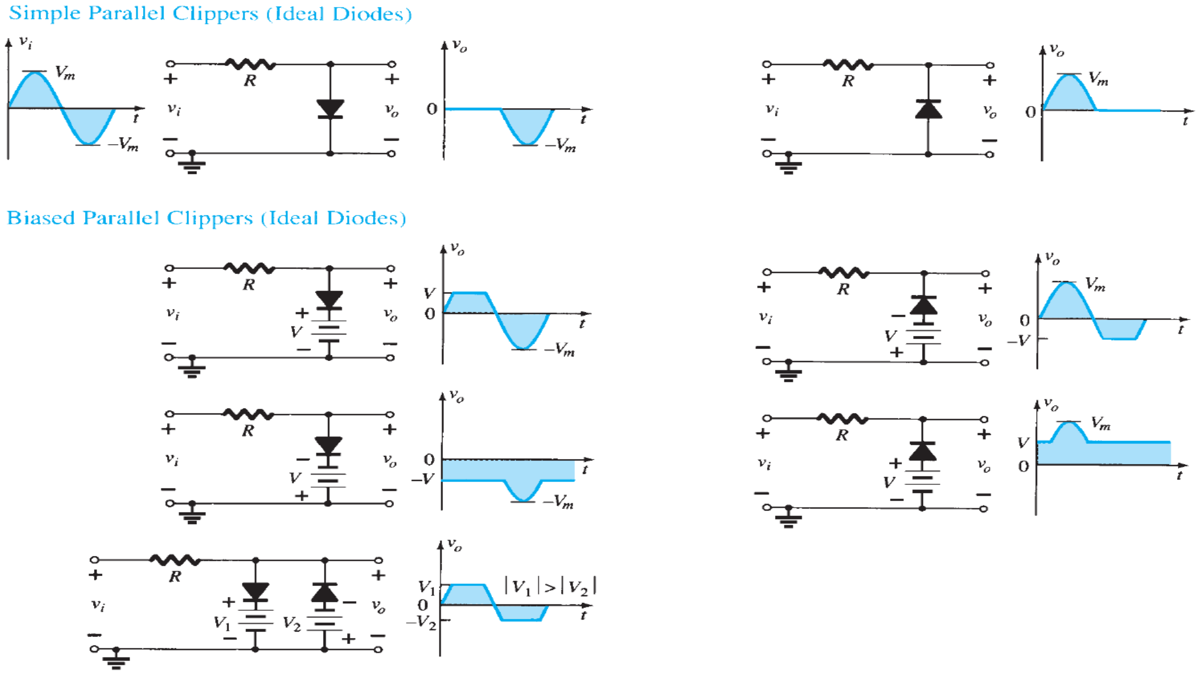
Simple Parallel Clippers (Ideal Diodes)

Biased Parallel Clippers (Ideal Diodes)

FIG. 2.88
Clipping circuits.

clamper

A clamper is a network constructed of a diode, a resistor, and a capacitor that shifts a waveform to a different dc level without changing the appearance of the applied signal. Clamping networks have a capacitor connected directly from input to output with a resistive element in parallel with the output signal. The diode is also in parallel with the output signal but may or may not have a series dc supply as an added element.

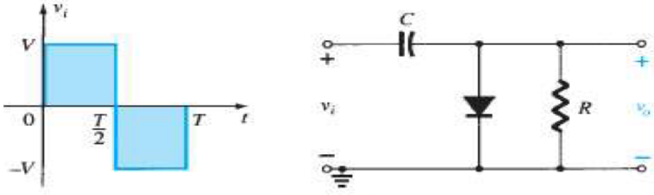

FIG. 2.89
Clamper.

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There is a sequence of steps that can be applied to help make the analysis straightforward.

Step 1: Start the analysis by examining the response of the portion of the input signal that will forward bias the diode.

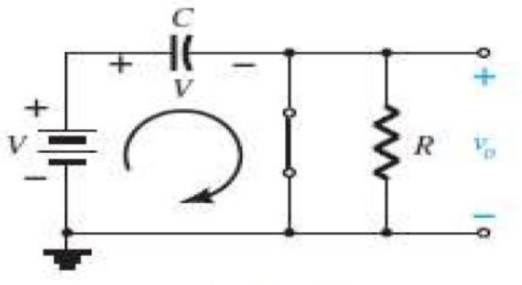

FIG. 2.90
Diode "on" and the capacitor charging to V volts.

Step 2: During the period that the diode is in the "on" state, assume that the capacitor will charge up instantaneously to a voltage level determined by the surrounding network.

Step 3: Assume that during the period when the diode is in the "off" state the capacitor holds on to its established voltage level.

Step 4: Throughout the analysis, maintain a continual awareness of the location and defined polarity for v o to ensure that the proper levels are obtained.

EXAMPLE 2.22: Determine v o for the network of Fig. 2.93 for the input indicated.

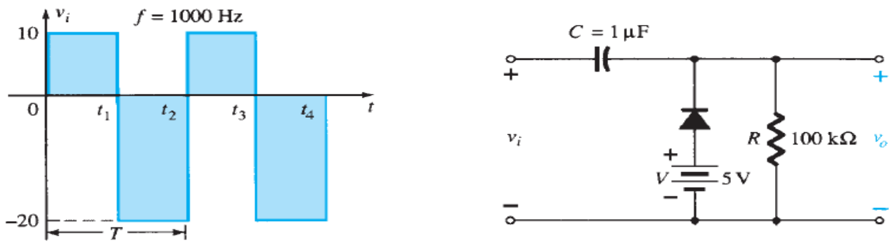

FIG. 2.93
Applied signal and network for Example 2.22.

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Solution: Note that the frequency is 1000 Hz, resulting in a period of 1 ms and an interval of 0.5 ms between levels. The analysis will begin with the period t1 St2 of the input signal since the diode is in its short-circuit state. For this interval the network will appear as shown in Fig. 2.94 . The output is across R , but it is also directly across the 5-V battery if one follows the direct connection between the defined terminals for vo and the battery terminals. The result is v o =5 V for this interval. Applying voltage law around the input loop results in.

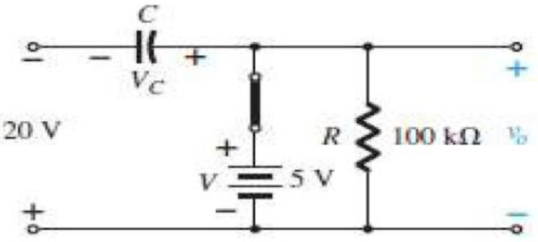

FIG. 2.94
Determining v_o and V_C with the diode in the "on" state.

$$-20\text{ V} + V_C - 5\text{ V} = 0$$
$$V_C = 25\text{ V}$$

The capacitor will therefore charge up to 25 V. In this case the resistor R is not shorted out by the diode, but a Thévenin equivalent circuit of that portion of the network that includes the battery and the resistor will result in RTh = 0 with Eth = V = 5 V. For the period t2 t3 the network will appear as shown in Fig. 2.95 . The open-circuit equivalent for the diode removes the 5-V battery from having any effect on v o , and applying voltage law around the outside loop of the network

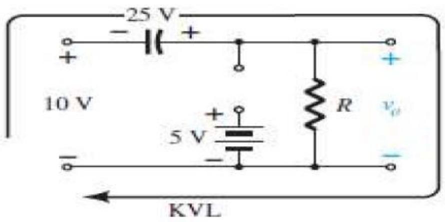

FIG. 2.95
Determining v_o with the diode in the "off" state.

$$+10\text{ V} + 25\text{ V} - v_o = 0$$
$$v_o = 35\text{ V}$$

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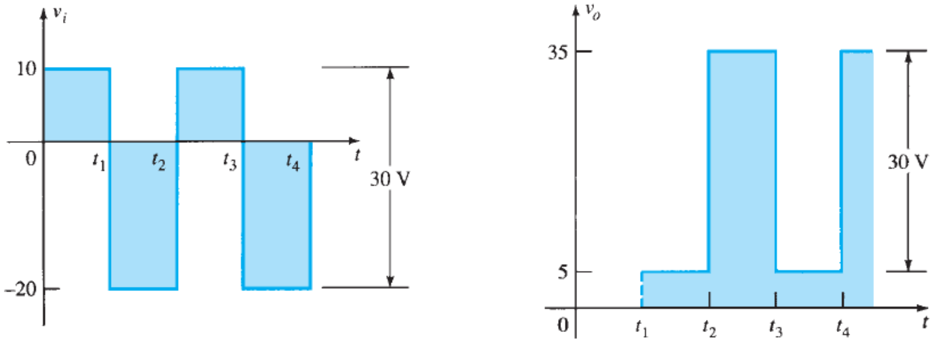

FIG. 2.96
v_i and v_o for the clamper of Fig. 2.93.

Clamping Networks

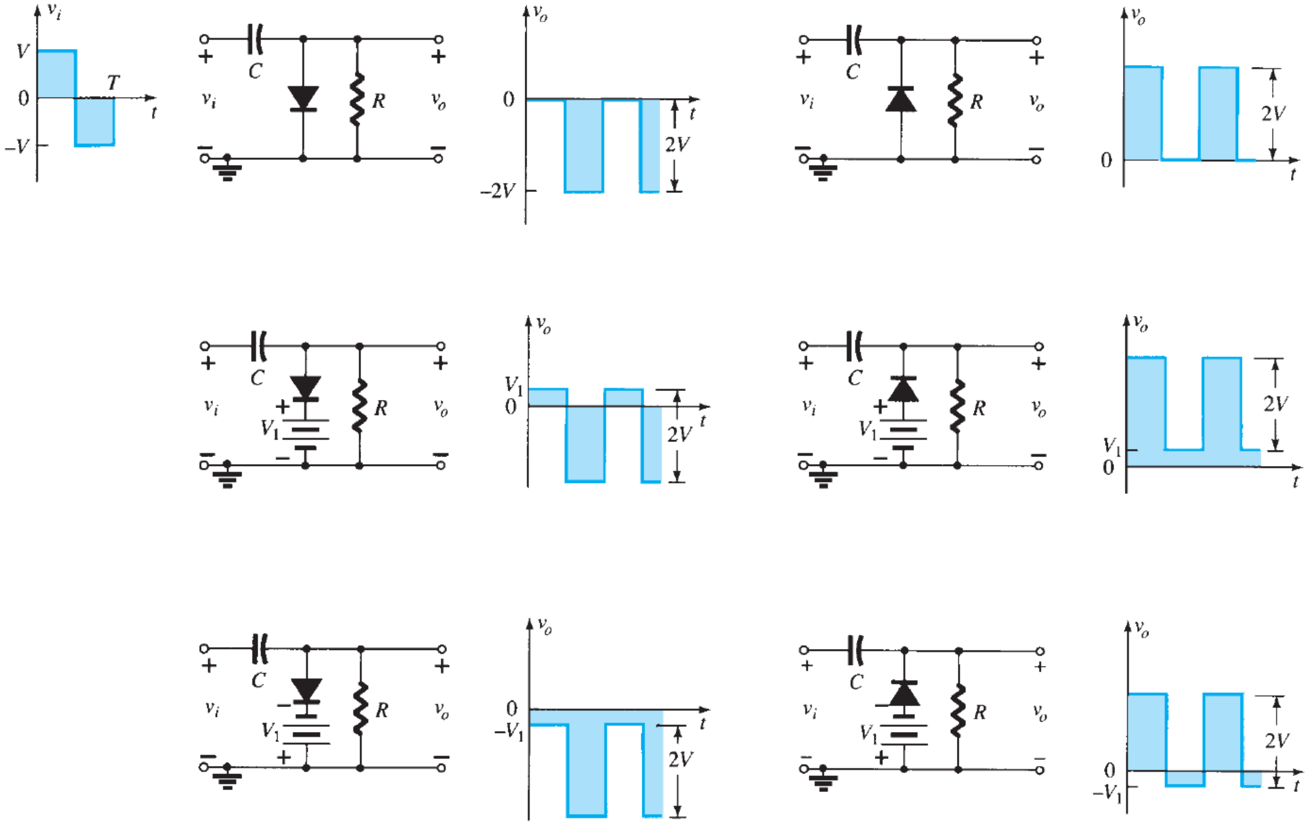

FIG. 2.100
Clamping circuits with ideal diodes ($5\tau = 5RC \gg T/2$).

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