Engineering and Architecture Analog Electronics Fundamentals **EEE223** Lec 7

Diode Limiters and Clampers

Lecturer Sally Adil

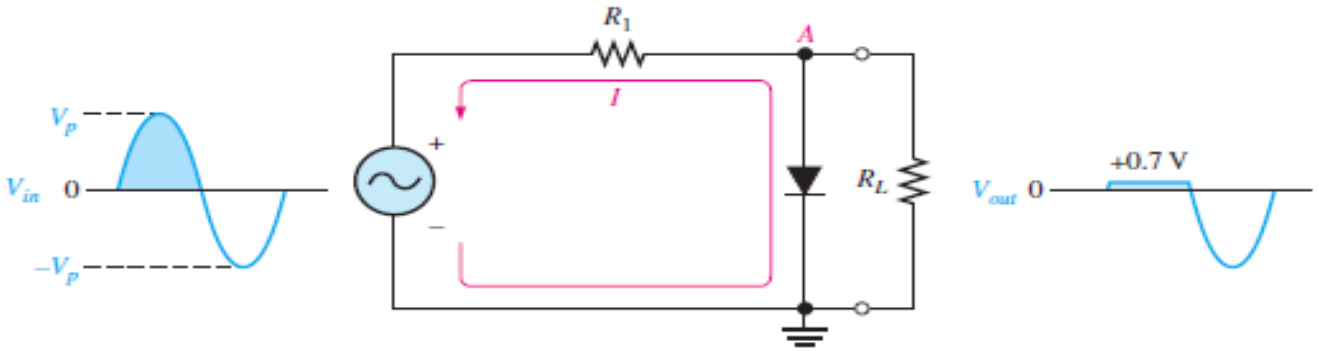
Clippers

- Diode circuits, called limiters or clippers, are sometimes used to clip off portions of signal voltages above or below certain levels.
- Figure shows a diode positive **limiter** (also called **clipper**) that limits or clips the positive part of the input voltage. As the input voltage goes positive, the diode becomes forward biased and conducts current. Point *A* is limited to +0.7 V when the input voltage exceeds this value. value.

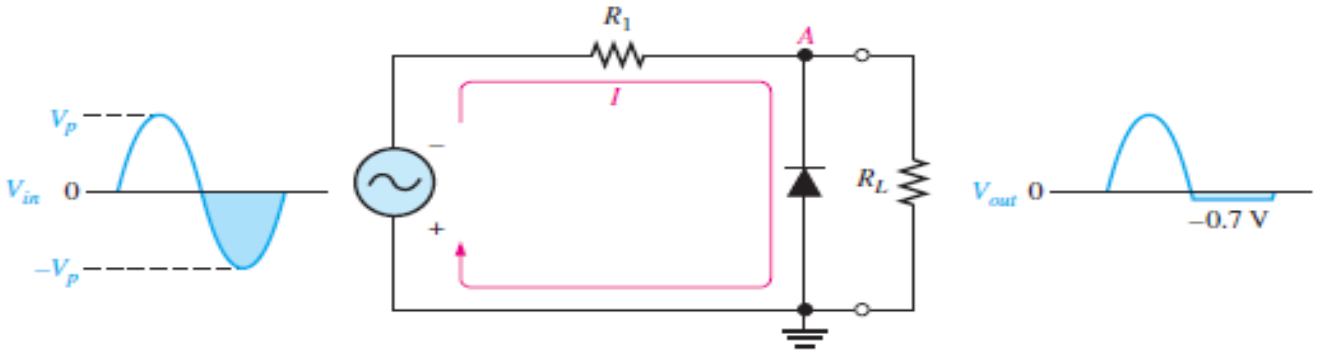
- When the input voltage goes back below 0.7 V, the diode is reverse-biased and appears as an open. The output voltage looks like the negative part of the input voltage, but with a magnitude determined by the voltage divider formed by *R*1 and the load resistor, *RL*, as follows:

$$V_{out} = \left(\frac{R_L}{R_1 + R_L}\right)V_{in}$$

- If the diode is turned around, as in Figure 2–52(b), the negative part of the input voltage is clipped off. When the diode is forward-biased during the negative part of the input voltage, point *A* is held at - 0.7 V by the diode drop. When the input voltage goes above – 0.7 V, the diode is no longer forward-biased; and a voltage appears across *RL* proportional to the input voltage.



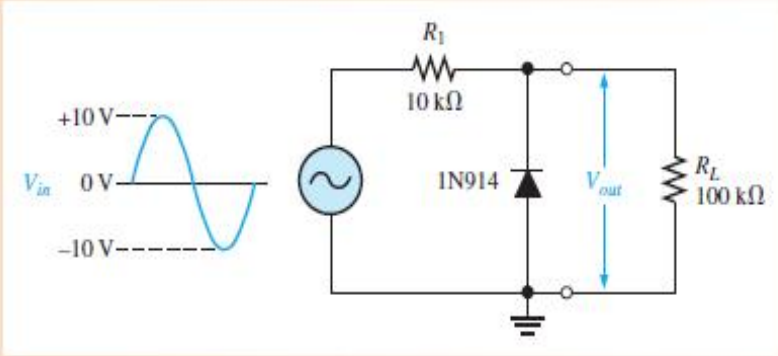
(a) Limiting of the positive alternation. The diode is forward-biased during the positive alternation (above 0.7 V) and reverse-biased during the negative alternation.



(b) Limiting of the negative alternation. The diode is forward-biased during the negative alternation (below –0.7 V) and reverse-biased during the positive alternation.

EXAMPLE 2–10

What would you expect to see displayed on an oscilloscope connected across R_L in the limiter shown in Figure 2–53?

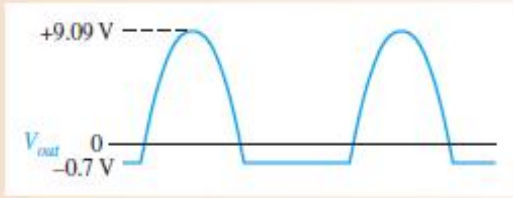


▶ FIGURE 2–53

Solution The diode is forward-biased and conducts when the input voltage goes below −0.7 V. So, for the negative limiter, determine the peak output voltage across R_L by the following equation:

$$V_{p(out)} = \left(\frac{R_L}{R_1 + R_L}\right)V_{p(in)} = \left(\frac{100\,\text{k}\Omega}{110\,\text{k}\Omega}\right)10\,\text{V} = 9.09\,\text{V}$$

The scope will display an output waveform as shown in Figure 2–54.

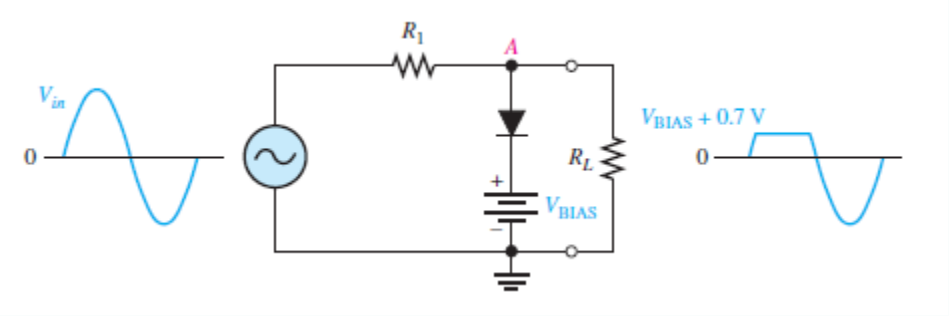


▶ FIGURE 2–54

Output voltage waveform for Figure 2–53.

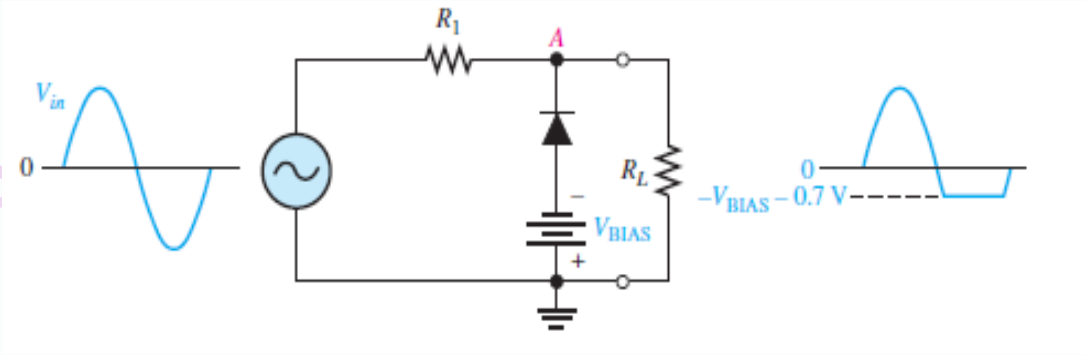
Biased Limiters

- The level to which an ac voltage is limited can be adjusted by adding a bias voltage, *V*BIAS, in series with the diode.
- The voltage at point *A* must equal *V*BIAS + 0.7 V before the diode will become forward-biased and conduct.
- Once the diode begins to conduct, the voltage at point *A* is limited to *V*BIAS + 0.7 V so that all input voltage above this level is clipped off.

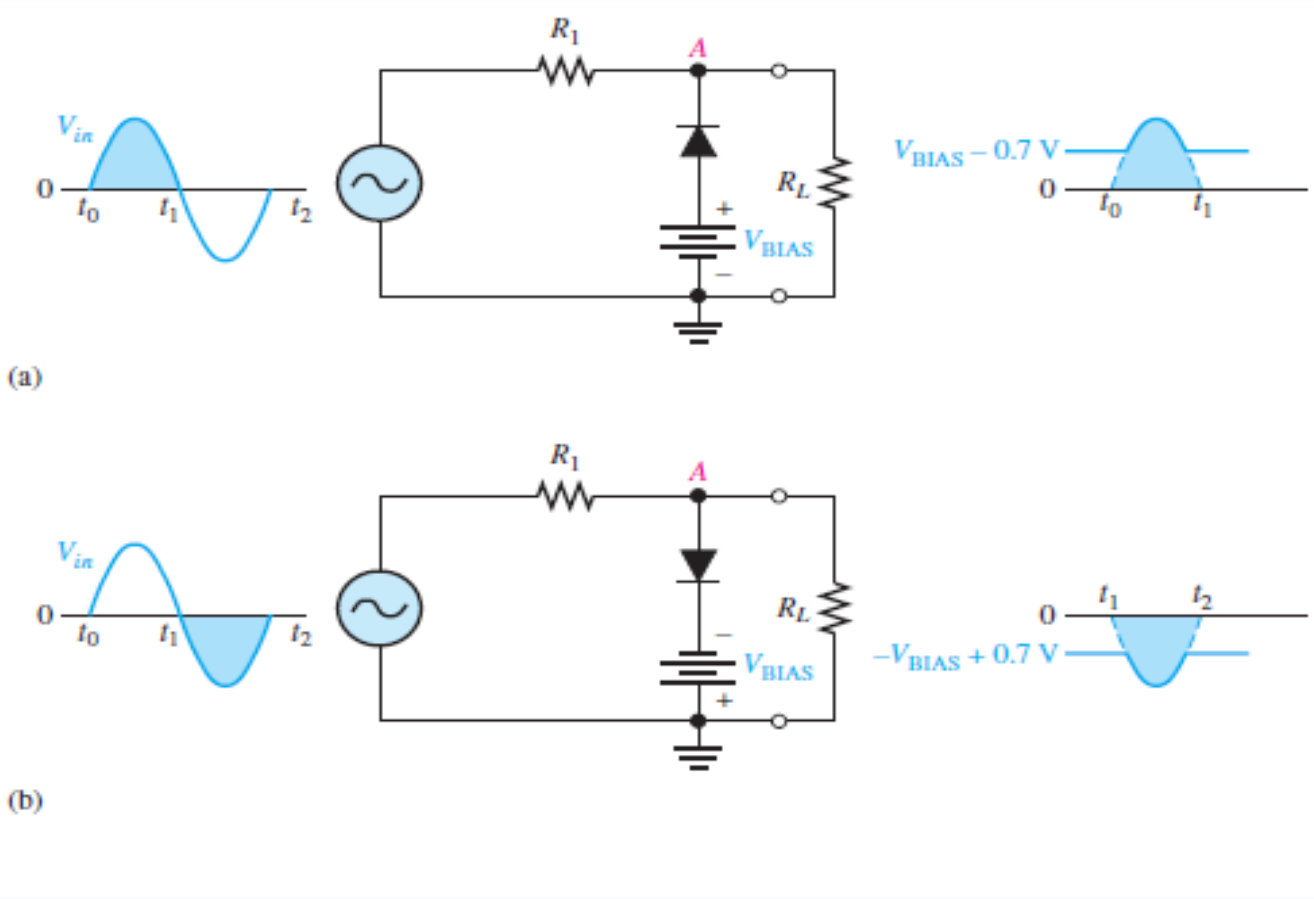


Negative Limiters:

– To limit a voltage to a specified negative level, the diode and bias voltage must be connected as in Figure. In this case, the voltage at point *A* must go below -*V*BIAS - 0.7 V to forward-bias the diode and initiate limiting action as shown.



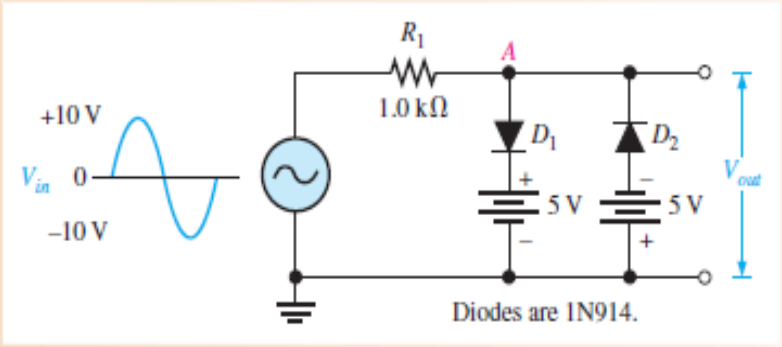
- By turning the diode around, the positive limiter can be modified to limit the output voltage to the portion of the input voltage waveform above VBIAS – 0.7 V as shown by the output waveform in Figure (a). Similarly, the negative limiter can be modified to limit the output voltage to the portion of the input voltage waveform below -*V*BIAS + 0.7 V, as shown by the output waveform in part (b).


R_1
A
V_{in}
0
t_0
t_1
t_2
R_L
+
V_{BIAS}
–
V_{BIAS} – 0.7 V
0
t_0
t_1
(a)
R_1
A
V_{in}
0
t_0
t_1
t_2
R_L
–
V_{BIAS}
+
0
t_1
t_2
$-V_{BIAS}$ + 0.7 V
(b)

EXAMPLE 2–11

Figure 2–58 shows a circuit combining a positive limiter with a negative limiter. Determine the output voltage waveform.

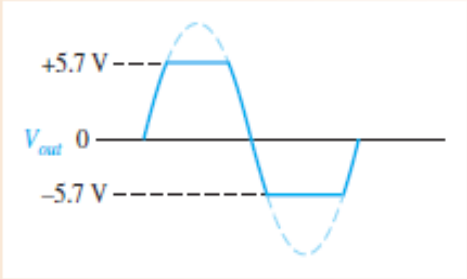
▶ FIGURE 2–58



Solution When the voltage at point *A* reaches +5.7 V, diode D_1 conducts and limits the waveform to +5.7 V. Diode D_2 does not conduct until the voltage reaches −5.7 V. Therefore, positive voltages above +5.7 V and negative voltages below −5.7 V are clipped off. The resulting output voltage waveform is shown in Figure 2–59.

▶ FIGURE 2–59

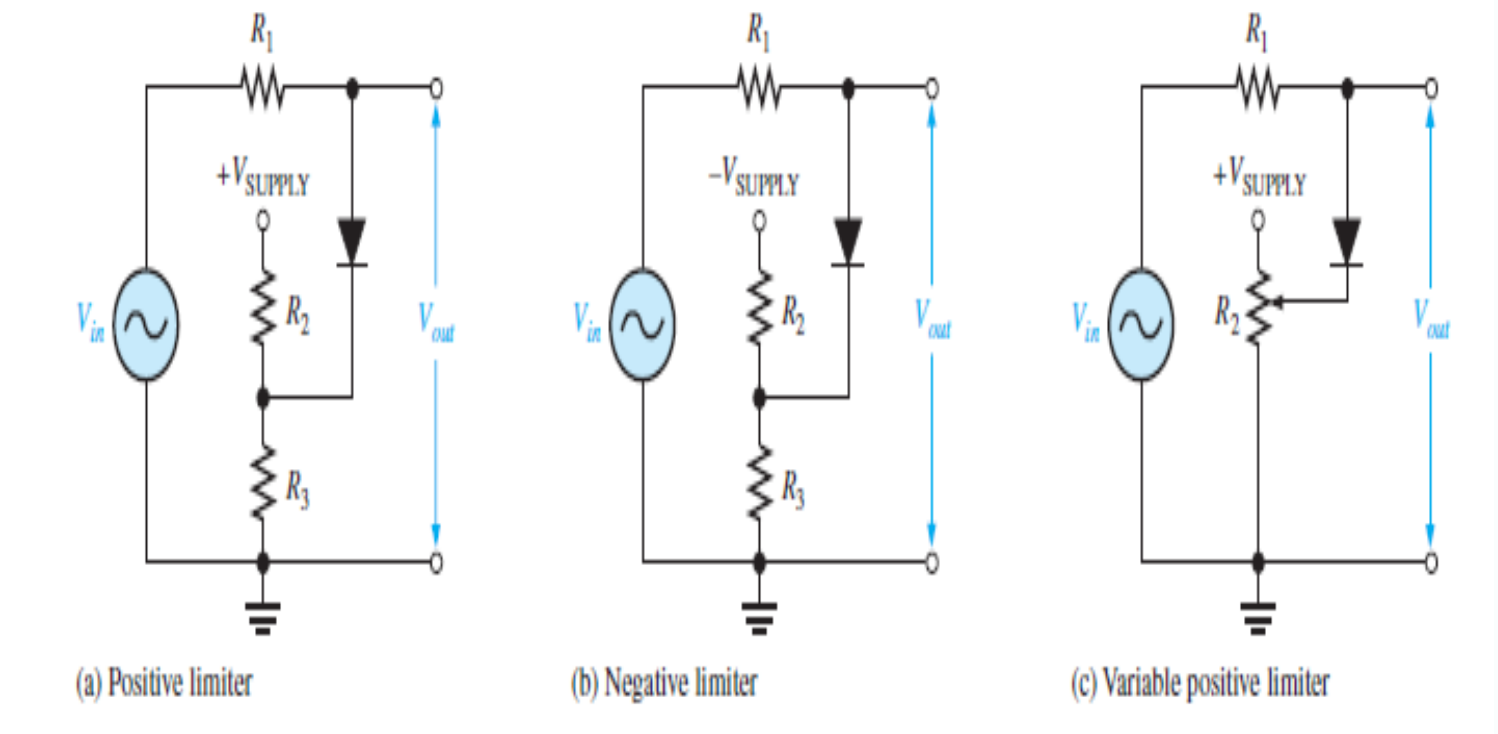
Output voltage waveform for Figure 2–58.



Related Problem Determine the output voltage waveform in Figure 2–58 if both dc sources are 10 V and the input voltage has a peak value of 20 V.

– ***Voltage-Divider Bias*** The bias voltage sources that have been used to illustrate the basic operation of diode limiters can be replaced by a resistive voltage divider that derives the desired bias voltage from the dc supply voltage.

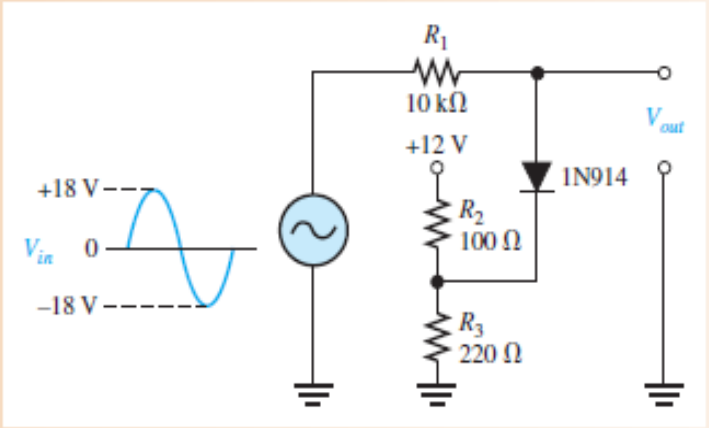
$$V_{BIAS} = \left(\frac{R_3}{R_2 + R_3}\right)V_{SUPPLY}$$


R_1
$+V_{SUPPLY}$
V_{in}
R_2
V_{out}
R_3
(a) Positive limiter
R_1
$-V_{SUPPLY}$
V_{in}
R_2
V_{out}
R_3
(b) Negative limiter
R_1
$+V_{SUPPLY}$
V_{in}
R_2
V_{out}
(c) Variable positive limiter

EXAMPLE 2–12

Describe the output voltage waveform for the diode limiter in Figure 2–61.

▶ FIGURE 2–61

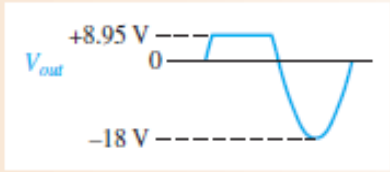


Solution The circuit is a positive limiter. Use the voltage-divider formula to determine the bias voltage.

$$V_{BIAS} = \left(\frac{R_3}{R_2 + R_3}\right)V_{SUPPLY} = \left(\frac{220\ \Omega}{100\ \Omega + 220\ \Omega}\right)12\ \text{V} = 8.25\ \text{V}$$

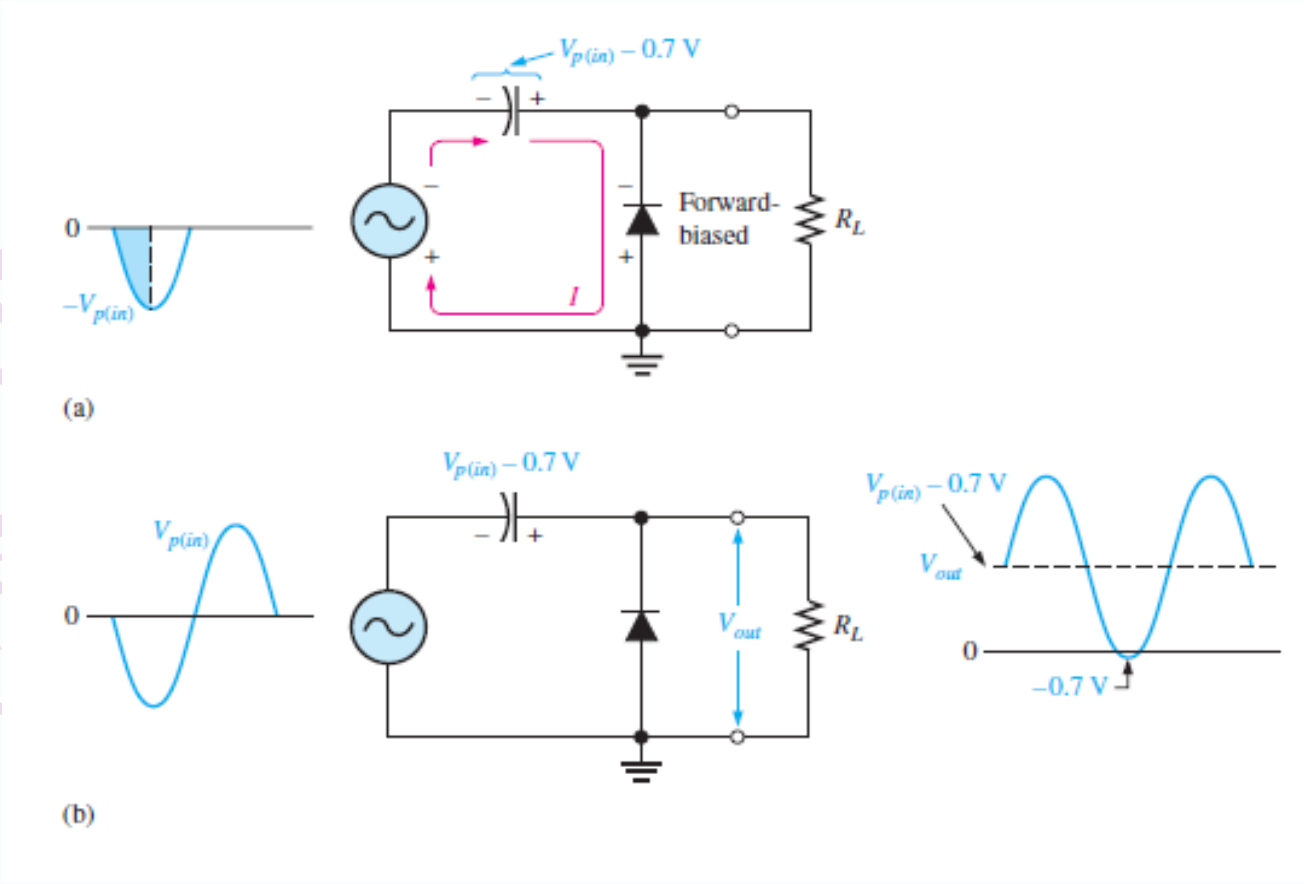
The output voltage waveform is shown in Figure 2–62. The positive part of the output voltage waveform is limited to $V_{BIAS} + 0.7$ V.

▶ FIGURE 2–62



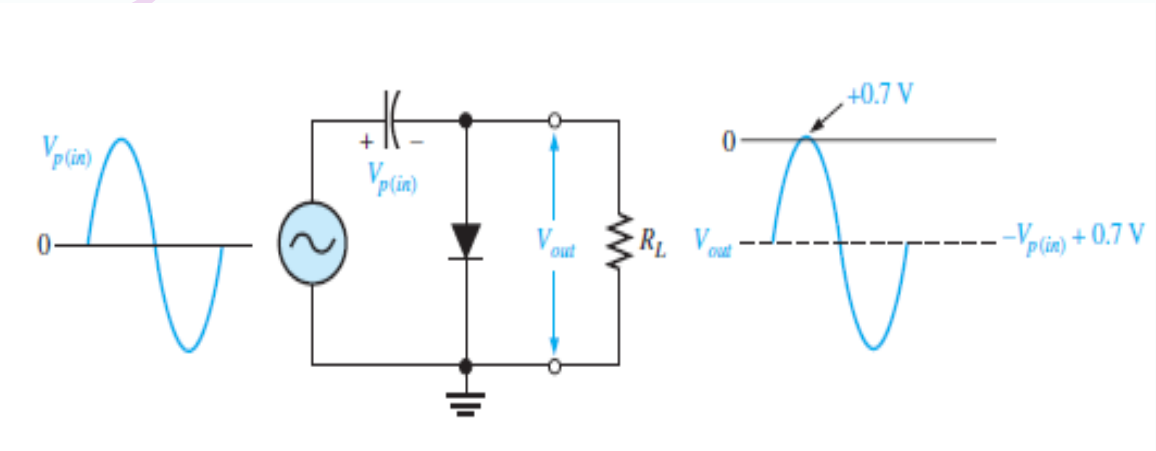
Diode Clampers

- A clamper adds a dc level to an ac voltage. **Clampers** are sometimes known as *dc restorers.*
- The operation of this circuit can be seen by considering the first negative half-cycle of the input voltage. When the input voltage initially goes negative, the diode is forward biased, allowing the capacitor to charge to near the peak of the input Vpin – 0.7 V.
- Just after the negative peak, the diode is reverse-biased. This is because the cathode is held near Vpin – 0.7 V by the charge on the capacitor. The capacitor can only discharge through the high resistance of *RL.*


$V_{p(in)} - 0.7$ V
0
$-V_{p(in)}$
Forward-biased
R_L
I
(a)
$V_{p(in)} - 0.7$ V
$V_{p(in)}$
0
V_{out}
R_L
$V_{p(in)} - 0.7$ V
V_{out}
0
-0.7 V
(b)

Negative Clampers

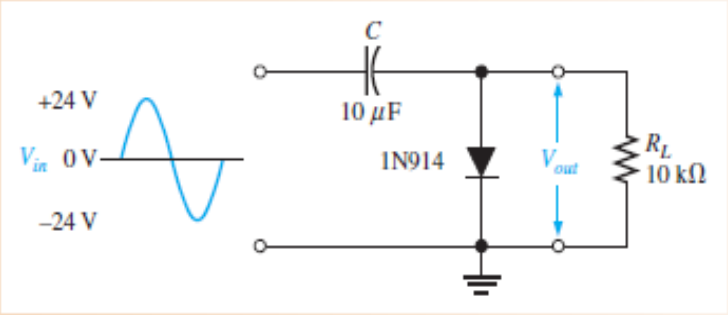
– If the diode is turned around, a negative dc voltage is added to the input voltage to produce the output voltage as shown in Figure



EXAMPLE 2–13

What is the output voltage that you would expect to observe across R_L in the clamping circuit of Figure 2–65? Assume that RC is large enough to prevent significant capacitor discharge.

▶ FIGURE 2–65



Solution

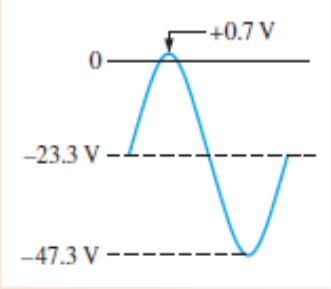
Ideally, a negative dc value equal to the input peak less the diode drop is inserted by the clamping circuit.

$$V_{DC} \cong -(V_{p(in)} - 0.7\text{ V}) = -(24\text{ V} - 0.7\text{ V}) = \mathbf{-23.3\text{ V}}$$

Actually, the capacitor will discharge slightly between peaks, and, as a result, the output voltage will have an average value of slightly less than that calculated above. The output waveform goes to approximately +0.7 V, as shown in Figure 2–66.

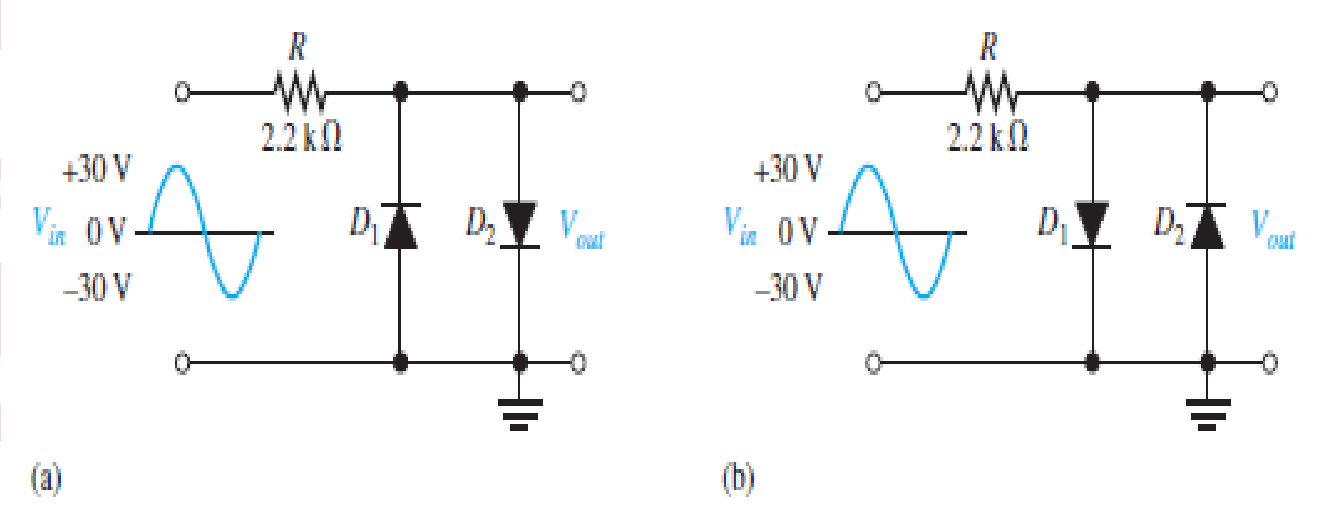
▶ FIGURE 2–66

Output waveform across R_L for Figure 2–65.



Homework:

- Determine and draw the output waveform of the following circuits



Thank you