كلية الرشيد الجامعة

هندسة تقنيات الاجهزة الطبية

ELECTRONIC CIRCUITS AND DEVICES

Chapter tow

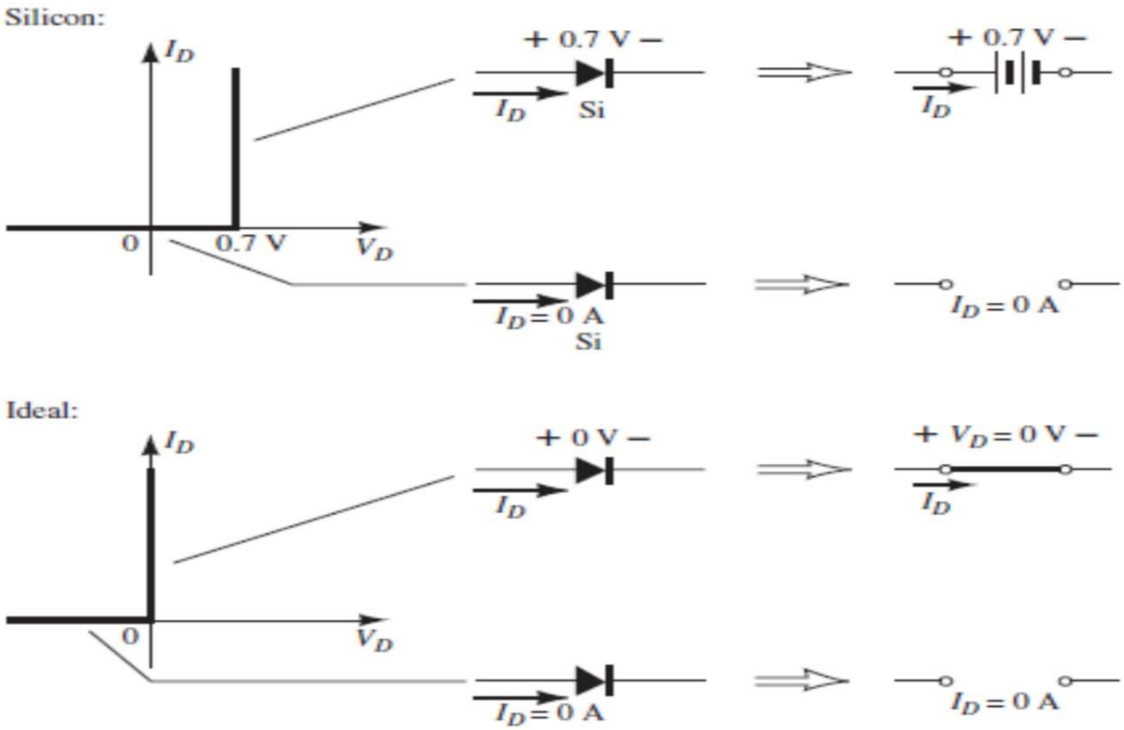
(Diode Applications)

(3)

م.م. دينا جمال

مرحلة ثانية

SERIES DIODE CONFIGURATIONS



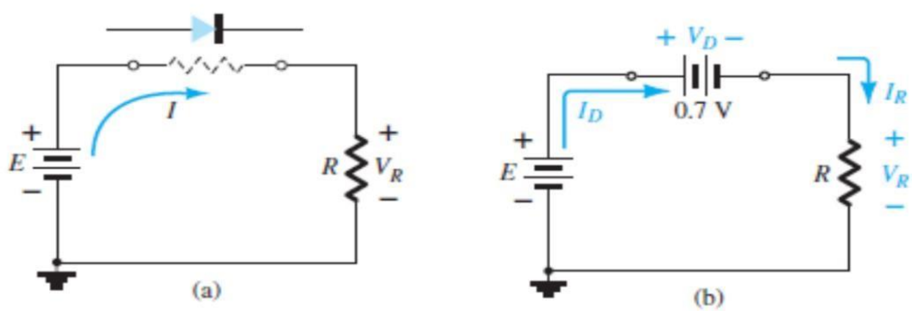


FIG. 2.9
(a) Determining the state of the diode of Fig. 2.8: (b) substituting the equivalent model for the "on" diode of Fig. 2.9a.

In Fig. 2.10 the diode of Fig. 2.7 has been reversed. Mentally replacing the diode with a resistive element as shown in Fig. 2.11 will reveal that the resulting current direction does not match the arrow in the diode symbol. The diode is in the "off" state, resulting in the equivalent circuit of Fig. 2.12 . Due to the open circuit, the diode current is 0 A and the

voltage across the resistor R is the following:

$$V_R = I_R R = I_D R = (0\ \text{A})R = 0\ \text{V}$$

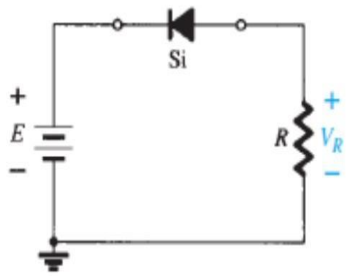


FIG. 2.10
Reversing the diode of Fig. 2.8.

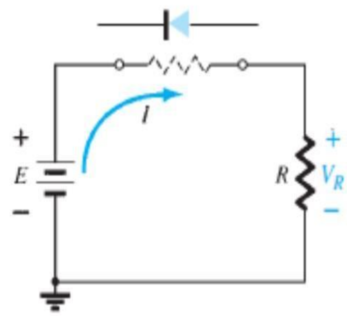


FIG. 2.11
Determining the state of the diode of Fig. 2.10.

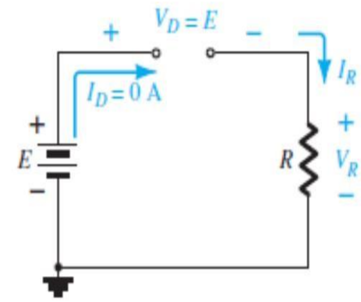


FIG. 2.12
Substituting the equivalent model for the "off" diode of Fig. 2.10.

EXAMPLE 2.4 For the series diode configuration of Fig. 2.13 , determine V_D , V_R , and I_D

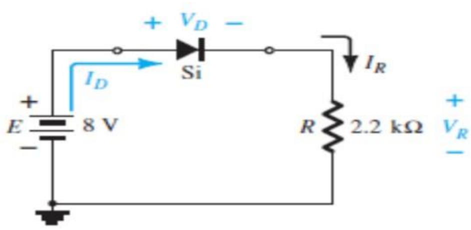


FIG. 2.13
Circuit for Example 2.4.

Solution: Since the applied voltage establishes a current in the clockwise direction to match the arrow of the symbol and the diode is in the "on" state,

$$V_D = \mathbf{0.7\ V}$$

$$V_R = E - V_D = 8\ \text{V} - 0.7\ \text{V} = \mathbf{7.3\ V}$$

$$I_D = I_R = \frac{V_R}{R} = \frac{7.3\ \text{V}}{2.2\ \text{k}\Omega} \cong \mathbf{3.32\ mA}$$

EXAMPLE 2.6 For the series diode configuration of Fig. 2.16 , determine V_D , V_R , and I_D

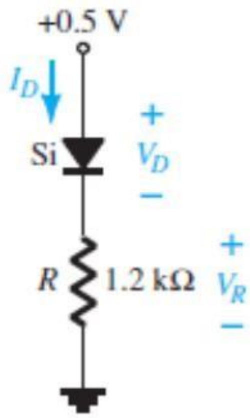


FIG. 2.16
Series diode circuit for Example 2.6.

Solution: Although the "pressure" establishes a current with the same direction as the arrow symbol, the level of applied voltage is insufficient to turn the silicon diode "on." The point of operation on the characteristics is shown in Fig. 2.17, establishing the open-circuit equivalent as the appropriate approximation, as shown in Fig. 2.18. The resulting voltage and current levels are therefore the following:

$$I_D = \mathbf{0\ A}$$

$$V_R = I_R R = I_D R = (0\ \text{A})\,1.2\ \text{k}\Omega = \mathbf{0\ V}$$

and

$$V_D = E = \mathbf{0.5\ V}$$

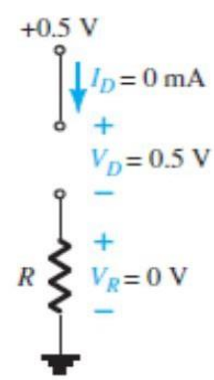


FIG. 2.18
Determining I_D, V_R, and V_D for the circuit of Fig. 2.16.

a **EXAMPLE 2.8** Determine I_D , V_{D2}, and Vo for the circuit of Fig. 2.21 ..

Solution: Removing the diodes and determining the direction of the resulting current I result in the circuit of Fig. 2.22 . There is a match in current direction for one silicon diode but not for the other silicon diode. The combination of a short circuit in series with an open circuit always results in an open circuit nd I D 0 A, as shown in Fig. 2.23 .

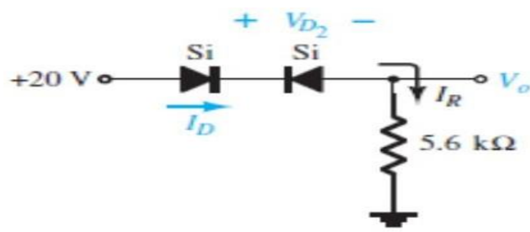


FIG. 2.21
Circuit for Example 2.8.

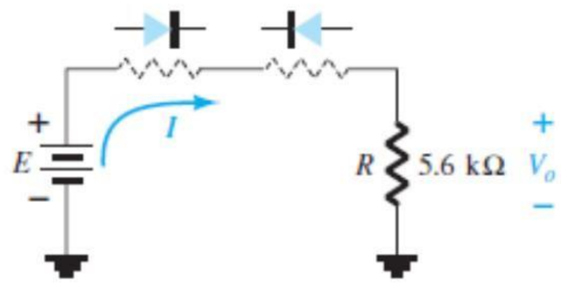


FIG. 2.22
Determining the state of the diodes of Fig. 2.21.

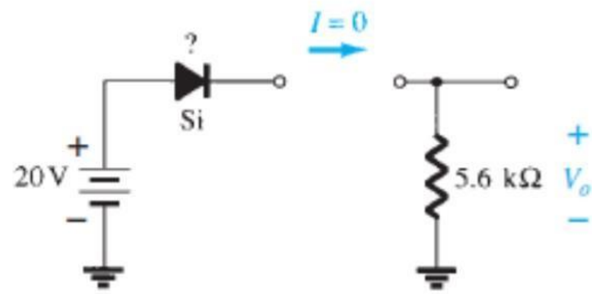


FIG. 2.23
Substituting the equivalent state for the open diode.

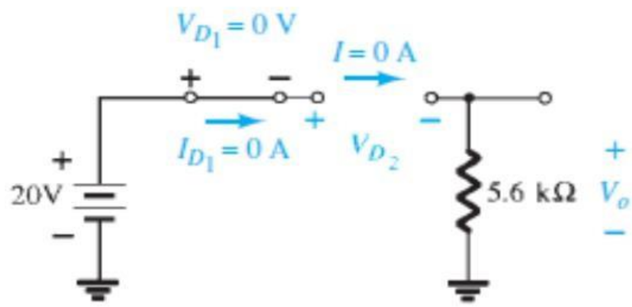


FIG. 2.24
Determining the unknown quantities for the circuit of Example 2.8.

The question remains as to what to substitute for the silicon diode. For the analysis to follow in this and succeeding chapters, simply recall for the actual practical diode that when $I_D = 0$ A, $V_D = 0$ V (and vice versa), as described for the no-bias situation in Chapter 1. The conditions described by $I_D = 0$ A and $V_{D_1} = 0$ V are indicated in Fig. 2.24. We have

$$V_o = I_R R = I_D R = (0\text{ A})R = \mathbf{0\ V}$$

and
$$V_{D_2} = V_{\text{open circuit}} = E = \mathbf{20\ V}$$

Applying Kirchhoff's voltage law in a clockwise direction gives

$$E - V_{D_1} - V_{D_2} - V_o = 0$$

and
$$V_{D_2} = E - V_{D_1} - V_o = 20\text{ V} - 0 - 0 = \mathbf{20\ V}$$

with
$$V_o = \mathbf{0\ V}$$

PARALLEL AND SERIES–PARALLEL CONFIGURATION

The methods applied in Section 2.3 can be extended to the analysis of parallel and series– parallel configurations. For each area of application, simply match the sequential series of steps applied to series diode configurations.

EXAMPLE 2.10 Determine Vo , I1 , I_D1, and I_D2 for the parallel diode configuration of Fig. 2.28

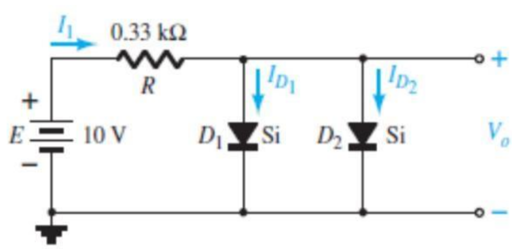


FIG. 2.28
Network for Example 2.10.

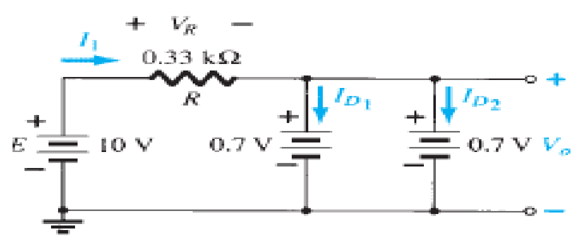


FIG. 2.29
Determining the unknown quantities for the network of Example 2.10.

Solution: For the applied voltage the "pressure" of the source acts to establish a current through each diode in the same direction as shown in Fig. 2.29 . Since the resulting current direction matches that of the arrow in each diode symbol and the applied voltage is greater than 0.7 V, both diodes are in the "on" state. The voltage across parallel elements is always the same and the same and

$$V_o = 0.7\ \mathrm{V}$$

The current is

$$I_1 = \frac{V_R}{R} = \frac{E - V_D}{R} = \frac{10\ \mathrm{V} - 0.7\ \mathrm{V}}{0.33\ \mathrm{k\Omega}} = 28.18\ \mathrm{mA}$$

Assuming diodes of similar characteristics, we have

$$I_{D_1} = I_{D_2} = \frac{I_1}{2} = \frac{28.18\ \mathrm{mA}}{2} = 14.09\ \mathrm{mA}$$

EXAMPLE 2.13 Determine the currents I1 , I2 , and ID2 for the network of Fig. 2.37

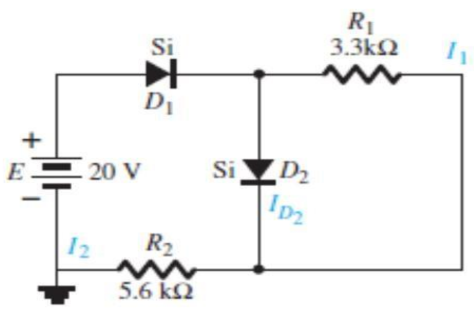


FIG. 2.37
Network for Example 2.13.

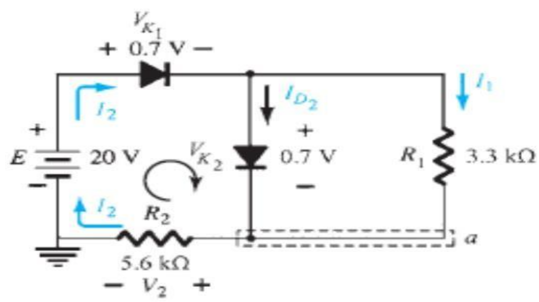


FIG. 2.38
Determining the unknown quantities for Example 2.13.

Solution: The applied voltage (pressure) is such as to turn both diodes on, as indicated by the resulting current directions in the network of Fig. 2.38 . Note the use of the abbreviated notation for “on” diodes and that the solution is obtained through an application of techniques applied to dc series–parallel networks. We have

$$I_1 = \frac{V_{K_2}}{R_1} = \frac{0.7\text{ V}}{3.3\text{ k}\Omega} = \mathbf{0.212\text{ mA}}$$

Applying Kirchhoff's voltage law around the indicated loop in the clockwise direction yields

$$-V_2 + E - V_{K_1} - V_{K_2} = 0$$

and $$V_2 = E - V_{K_1} - V_{K_2} = 20\text{ V} - 0.7\text{ V} - 0.7\text{ V} = \mathbf{18.6\text{ V}}$$

with $$I_2 = \frac{V_2}{R_2} = \frac{18.6\text{ V}}{5.6\text{ k}\Omega} = \mathbf{3.32\text{ mA}}$$

At the bottom node *a*,

$$I_{D_2} + I_1 = I_2$$

and $$I_{D_2} = I_2 - I_1 = 3.32\text{ mA} - 0.212\text{ mA} \cong \mathbf{3.11\text{ mA}}$$

SINUSOIDAL INPUTS; HALF-WAVE RECTIFICATION

The diode analysis will now be expanded to include time-varying functions such as the

sinusoidal waveform and the square wave. There is no question that the degree of difficulty

will increase, but once a few fundamental maneuvers are understood, the analysis will be fairly direct and follow a common thread.

The simplest of networks to examine with a time-varying signal appears in Fig. 2.44 . For

the moment we will use the ideal model (note the absence of the Si, Ge, or GaAs label) to

ensure that the approach is not clouded by additional mathematical complexity.

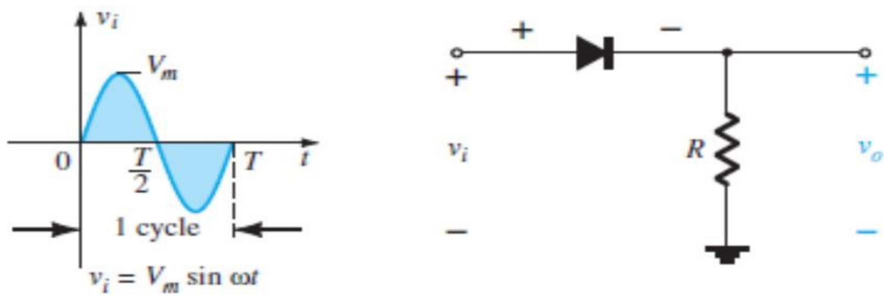


FIG. 2.44
Half-wave rectifier.

During the interval t = 0ST>2 in Fig. 2.44 the polarity of the applied voltage v i is such as to establish "pressure" in the direction indicated and turn on the diode with the polarity appearing above the diode. Substituting the short-circuit equivalence for the ideal diode will result in the equivalent circuit of Fig. 2.45 , where it is fairly obvious that the output signal is an exact replica of the applied signal. The two terminals defining the output voltage are connected directly to the applied signal via the short-circuit equivalence of the diode. For the period T>2ST, the polarity of the input v i is as shown in Fig. 2.46 , and the resulting polarity across the ideal diode produces an "off" state with an open-circuit equivalent. The result is the absence of a path for charge to flow, and vo = iR = (0)R = 0 V for the period T>2ST. The input v i and the output v o are sketched together in Fig. 2.47 for comparison purposes. The output signal v o now has a net positive area above the axis over

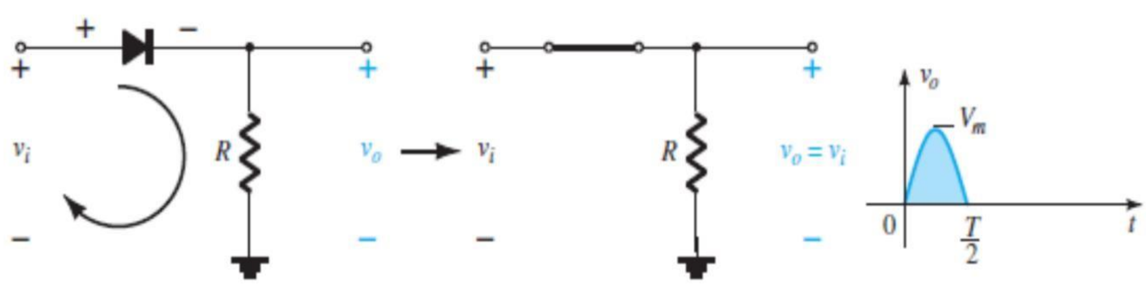


FIG. 2.45
Conduction region (0 → T/2).

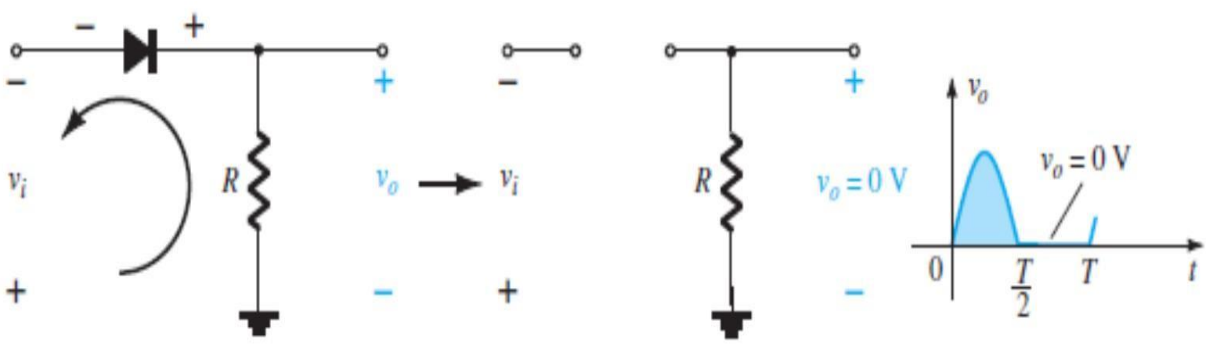
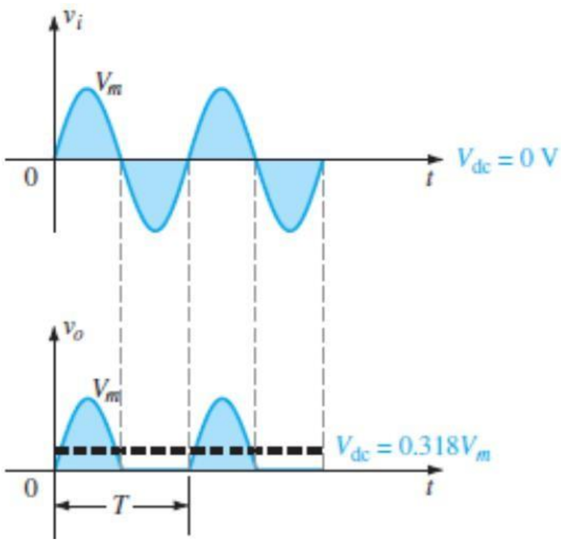


FIG. 2.46
Nonconduction region ($T/2 \rightarrow T$).



a full period and an average value determined by

$$V_{dc} = 0.318\, V_m \quad \text{half-wave}$$

The process of removing one-half the input signal to establish a dc level is called **half wave rectification**

The effect of using a silicon diode with V K 0.7 V is demonstrated in Fig. 2.48 for the forward-bias region. The applied signal must now be at least 0.7 V before the diode can turn "on." For levels of v i less than 0.7 V, the diode is still in an open-circuit state and v o 0 V, as shown in the same figure. When conducting, the difference between v o and v i is a fixed

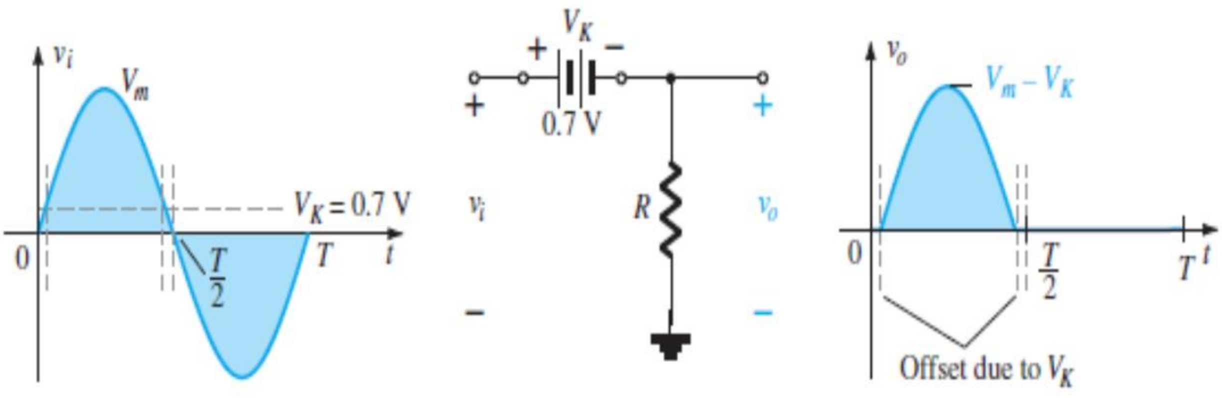


FIG. 2.48
Effect of V_K on half-wave rectified signal.

level of V K = 0.7 V and vo = vi - VK, as shown in the figure. The net effect is a reduction in area above the axis, which reduces the resulting dc voltage level. For situations where Vm << VK, the following equation can be applied to determine the average value with a
relatively high level of accuracy

$$V_{dc} \cong 0.318(V_m - V_K)$$

.

EXAMPLE 2.16

a. Sketch the output v o and determine the dc level of the output for the network of Fig. 2.49

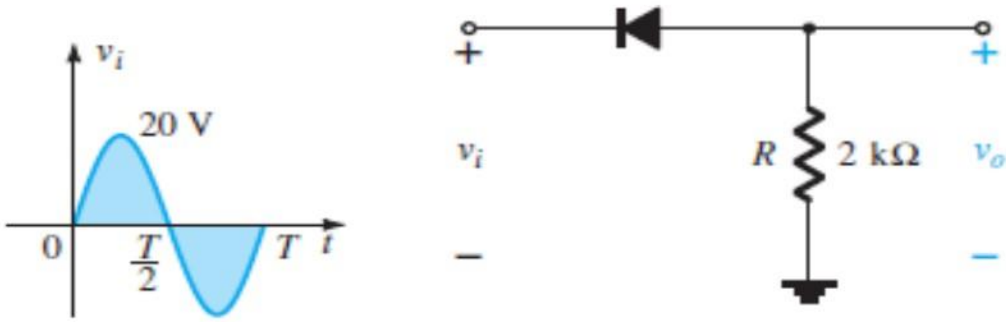


FIG. 2.49
Network for Example 2.16.

Solution:

a. In this situation the diode will conduct during the negative part of the input as shown in Fig. 2.50 , and v o will appear as shown in the same figure. For the full period, the dc level is

$V_{dc} = - 0.318\ V_m = -0.318(20\ V) = - 6.36\ V$

The negative sign indicates that the polarity of the output is opposite to the defined polarity of Fig. 2.49 .

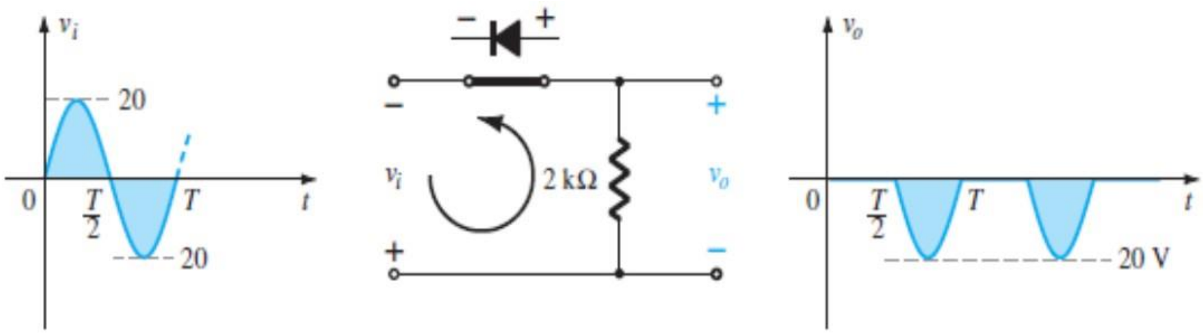


FIG. 2.50
Resulting v_o for the circuit of Example 2.16.