Diode Circuit Applications

Sinusoidal inputs:

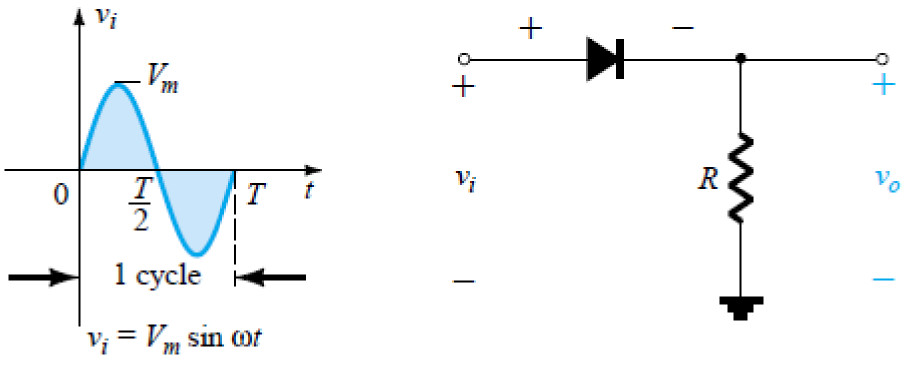


Fig.10.1 Half-wave rectifier.

Half wave rectifier

With an ideal diode and sinusoidal input voltage V_{in} *as* shown. During the time when $Vin>0$ the diode is forward biased and so the voltage across this "ideal" diode is zero. This observation is also represented by the equivalent circuit shown on Figure, which clearly indicates that the output voltage V_o is equal to the input voltage V_{in}.

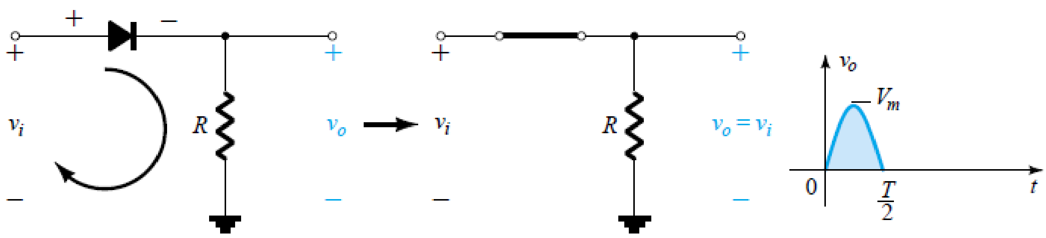


Fig 10.2. Conduction region (0 → T/2).

Similarly, during the time when $V_{in}<0$, the diode is reverse biased and so the current flowing through the diode is zero, see equivalent circuit on Figure and the output voltage is zero.

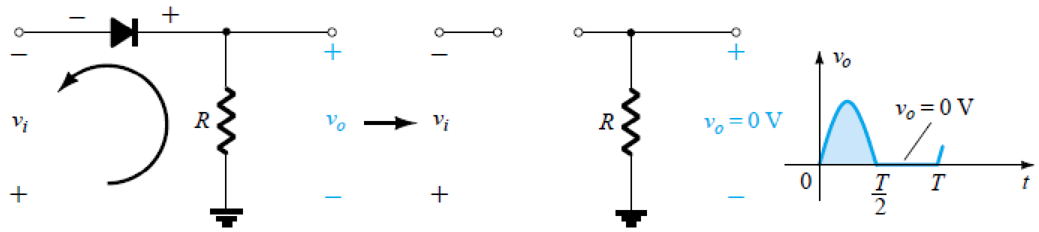


Fig 10.3. Conduction region (T/2→T).

The total response of the circuit to the input signal *Vin* is shown on Fig. 10.4. Note that the presence of the diode alters the output signal in a profound way: it converts an AC (alternating current) input voltage, whose average value over time is zero, into an output voltage whose polarity does not change over time, and which has a non-zero average value. This type of voltage signal is called DC (direct current) since the direction of the current does not change over time. We have just taken the first step in the design of an AC to DC converter.

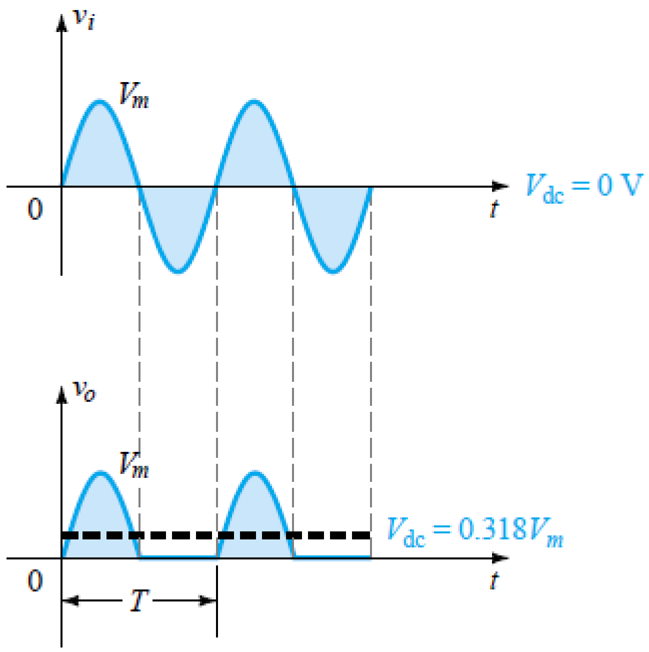


Fig.10.4 Half-wave rectifier signal.

The output signal V_o is a ***rectified*** signal of the input *Vin* and the circuit that generated this signal, the circuit, is called *Rectifier* circuit. Furthermore, since it passes only half of the input signal it is called a *Half Wave Rectifier Circuit*.

A dc voltmeter is constructed to read the average values

$$V_{DC} = \frac{1}{2\pi}\int_0^{2\pi} v_o \, d\alpha$$

$$V_{DC} = \frac{1}{2\pi}\int_0^{\pi} V_m \sin\alpha \, d\alpha$$

$$V_{DC} = \frac{V_m}{2\pi}\left(-\cos\alpha\right)_0^{\pi}$$

$$V_{DC} = \frac{V_m}{2\pi}\left(-\cos\pi + \cos 0\right) = \frac{V_m}{2\pi}\left(-(-1)+1\right) = \frac{V_m}{\pi}$$

$$V_{DC} = 0.318V_m$$

The effect of using silicon diode (V_T=0.7V). The applied signal must now be at least 0.7V before the diode can turn **on**. For levels of vi

- $v_o = v_{in} - V_T$ for $V_{in} > V_T$, $i_D = i_L = (v_{in} - V_T)/R_L$
- $v_o = 0$ for $V_{in} < V_T$ (Open circuit) Diode in **off** state: $i_D = i_L = 0$ and $v_o = 0$

$$V_{DC} = 0.318(V_m - V_T)$$

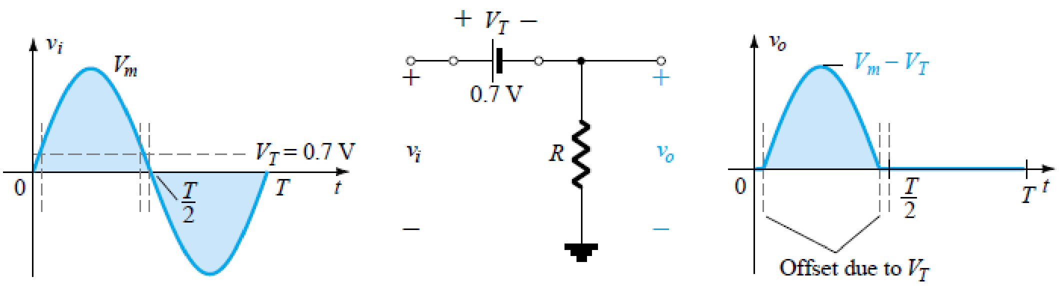


Fig.10.5. Effect of V_T on half wave rectified signal.

Example 10.1

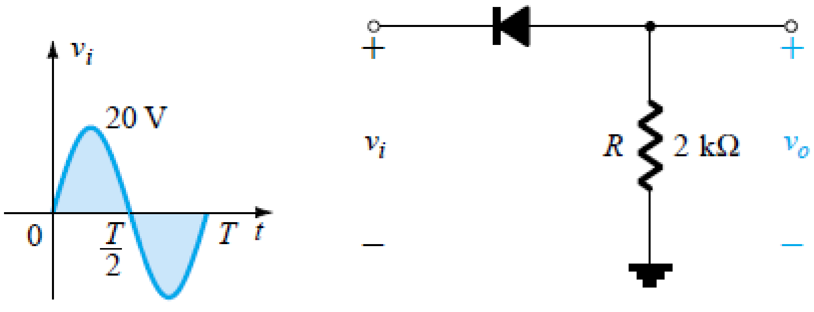


Fig.10.6. Example10.1

a- Sketch v_o and determine V_{dc}.

b- Repeat (a) if the ideal diode is replaced by silicon diode.

c- Repeat (a)and (b) if V_{mi}=200V.

Solution

a- The diode will contact during the negative half of input.

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

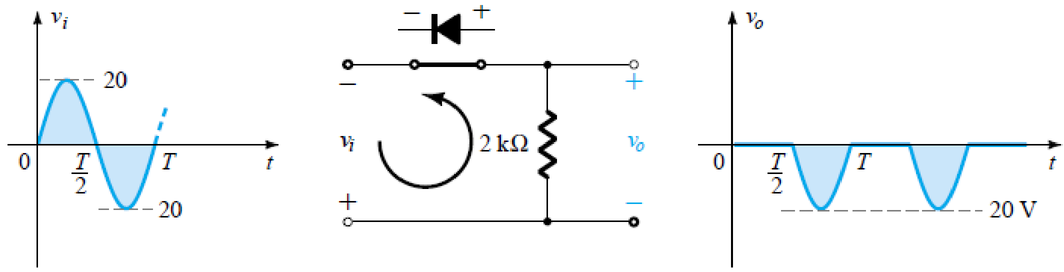


Fig.10.6. Resulting vo for the circuit of Example10.1

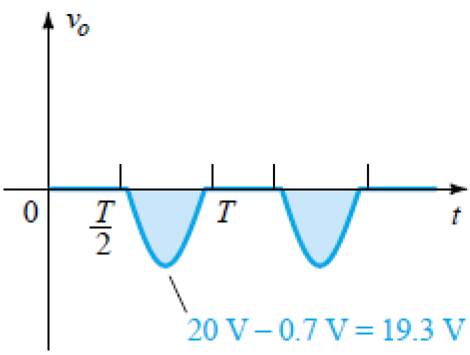


Fig.10.7 Effect of VT on output of Fig. 10.6

b- Using a silicon diode

V_{mo}=20-0.7=19.3V

$$V_{DC} = -0.318(20-0.7) = -6.14V$$

c-

$$V_{DC} = -0.318(200) = -63.6V$$

$$V_{DC} = -0.318(200-0.7) = -63.38V$$

PIV

The peak inverse voltage (PIV) or peak reverse voltage (PRV). The voltage rating must not be exceeded in the reverse–bias and diode enter the zener avalanche region therefore PIV>V_m .

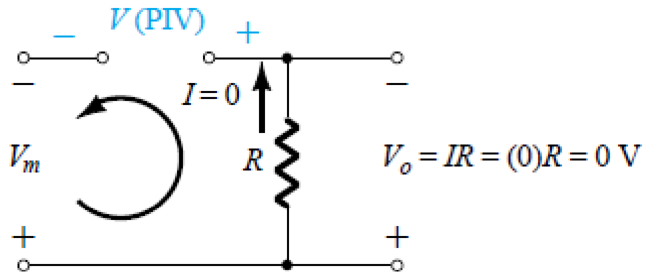


Fig. 10.8 Determining the required PIV rating for the halfwave rectifier.

Full-wave rectifier

Bridge rectifier

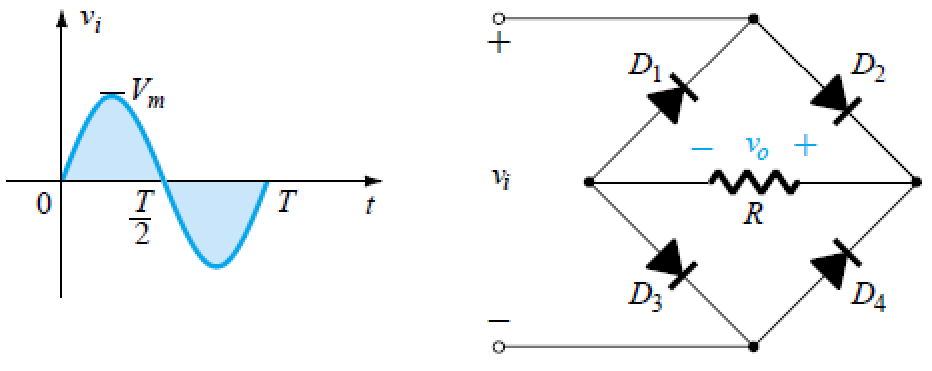


Fig. 10.9 Full-wave bridge rectifier.

The dc level obtained from sinusoidal input can be improved 100% using full-wave rectifier, this circuit called bridge circuit.

During the positive half cycle $D_2$and D_3 are conducting while D_1 and D_4 are in the off state the current pass through R_L, since the diodes are ideal $v_i = v_o$.

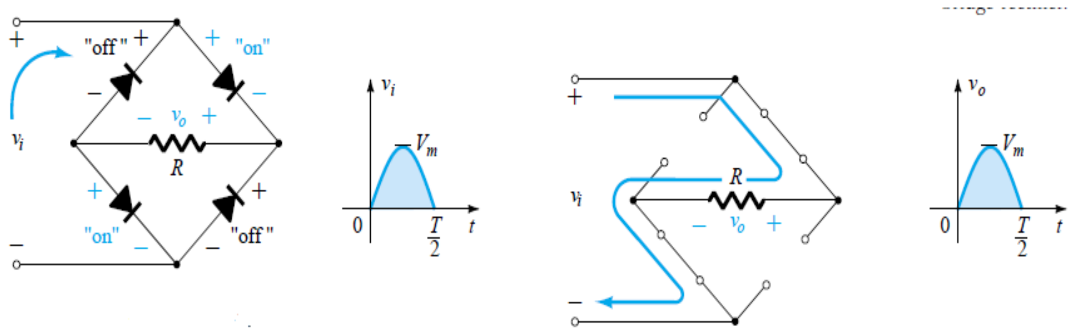


Fig. 10.10 Conduction path for the positive region of vi.

During the negative half cycle D_4 and D_1 are conducting, the important result that the current pass through R_L is in the same direction, establishing the second positive pulse.

$$V_{DC} = 2(0.318V_m) = 0.636V_m$$

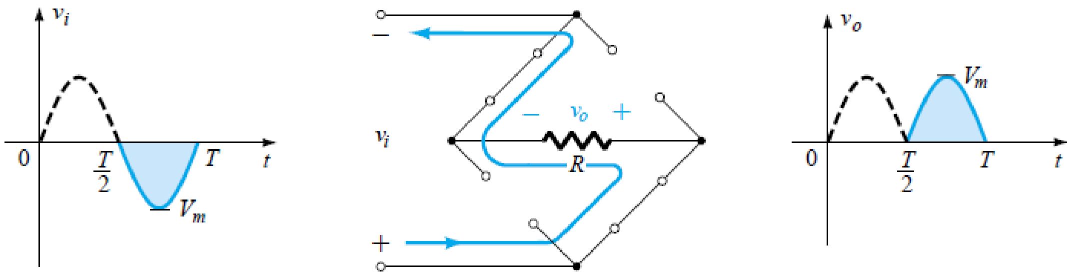


Fig. 10.11 Conduction path for the negative region of vi.

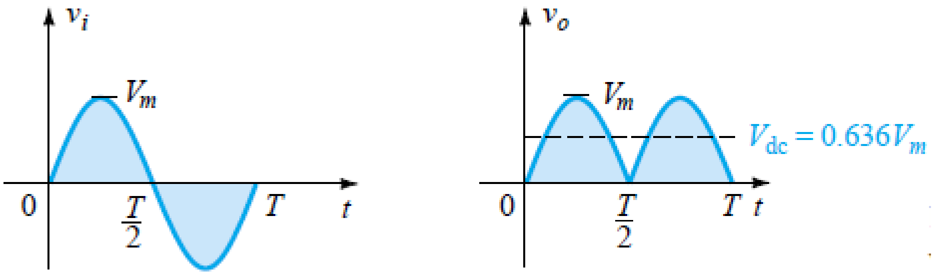


Fig.10.12 Input and output waveforms for a full-wave rectifier.

If silicon rather than ideal diodes, an application of Kirchhoff's voltage law

$v_o = v_i - 2V_T$

$$V_{DC} = 0.636(V_m - 2V_T)$$

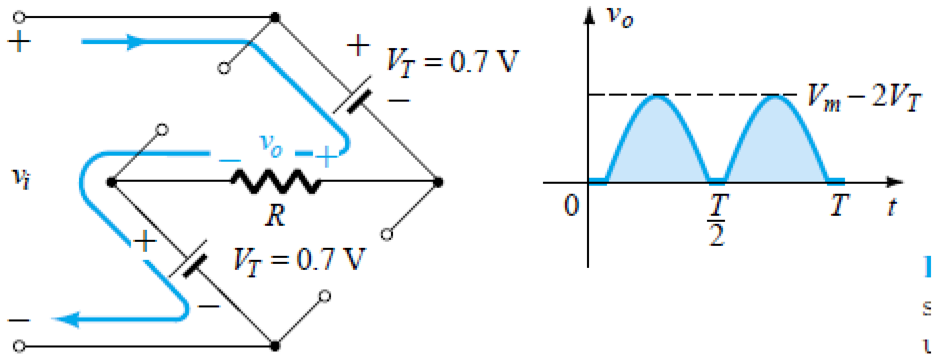


Fig.10.13 Determining $V_o$max for silicon diodes in the bridge configuration.

PIV

The required peak inverse voltage (PIV)

of each ideal diode for the indicated

Loop the maximum voltage a cross R is

V_m and the (PIV) rating is defined by

PIV>V_m

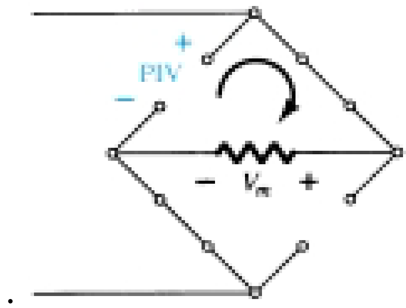


Fig.10.13 Determining the required PIV for the bridge configuration.

Center tapped transformer (CT)

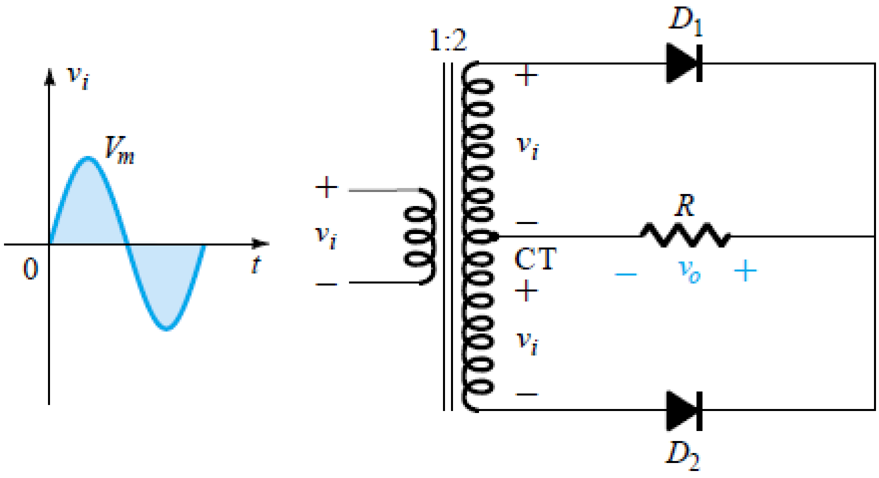


Fig.10.14 Center-tapped transformer full-wave rectifier

Full wave rectifier with only two diodes but required CT transformer. During a positive half cycle D_1 assume short circuit equivalent and D_2 open circuit equivalent. The output voltage appears as shown.

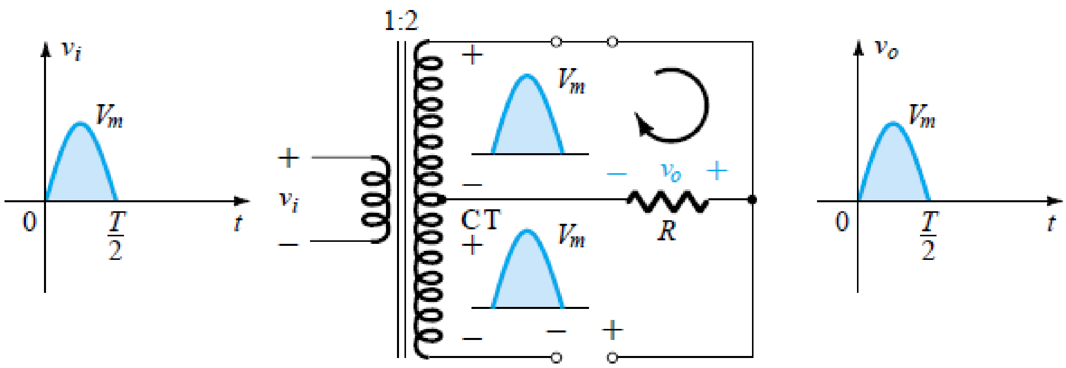


Fig.10.15 Network conditions for the positive region of vi.

During a negative half cycle reversing the roles of diodes but maintaining the same direction of current through *R*, the output voltage as shown with the same V_{dc}

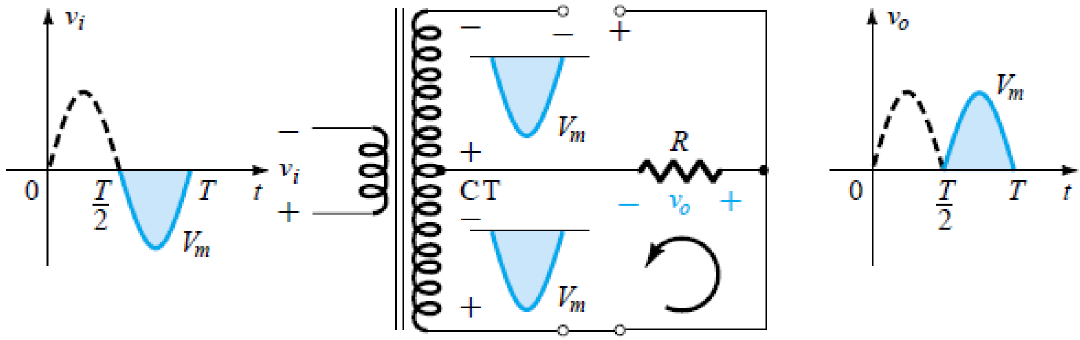


Fig.10.16 Network conditions for the negative region of vi.

PIV

The required peak inverse voltage (PIV) of each ideal diode for the indicated Loop the maximum voltage a cross R is v_m and the (PIV) rating is defined by

PIV-V_m- v_R=0

PIV=V_m+ V_m=2 V_m.

PIV>2V_m.

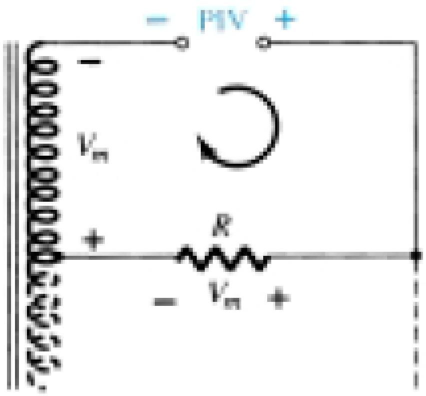


Fig.10.17 Determining the PIV level for the diodes of the CT transformer full-wave rectifier.

<u>Example 10.2</u>

Determine V_o, V_{dc}, and PIV.

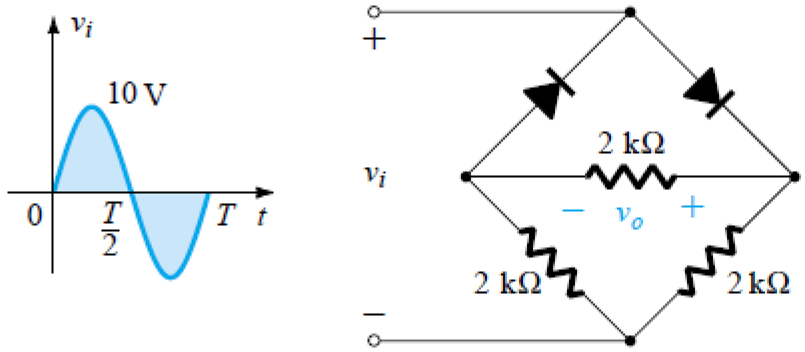


Figure 10.18 Example 10.2

Solution

During the positive half cycle

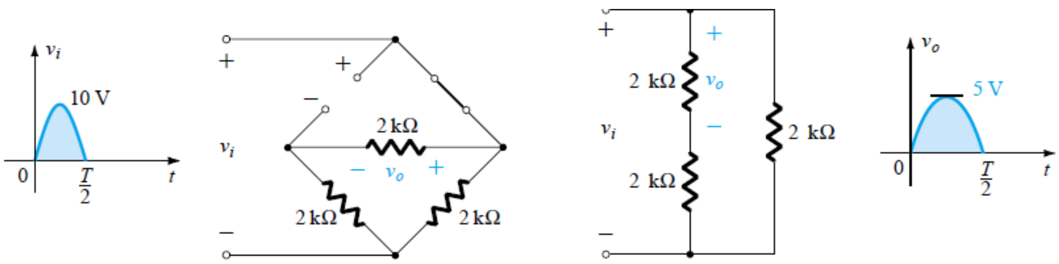


Figure 10.19 Network of Fig. 10.18 for the positive region of vi. region of vi.

$$V_o = Vi\frac{R1}{R1+R2} = 10\frac{2}{2+2} = 5V$$

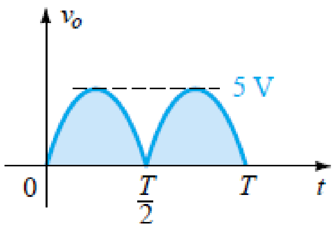


Figure 10.20 Resulting output for the Example

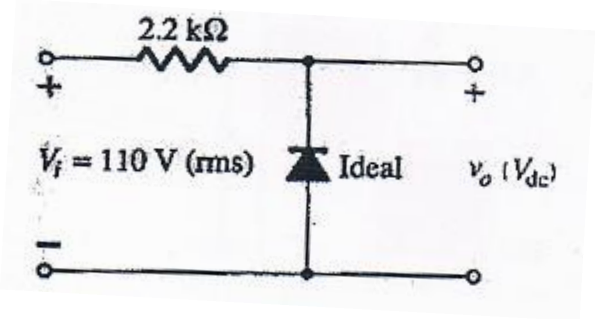
During the negative half cycle the roles of the diodes will be interchanged and *Vo* appear as

$$V_{DC} = 0.636(V_m) = 0.636(5) = 3.18V$$

PIV=5V

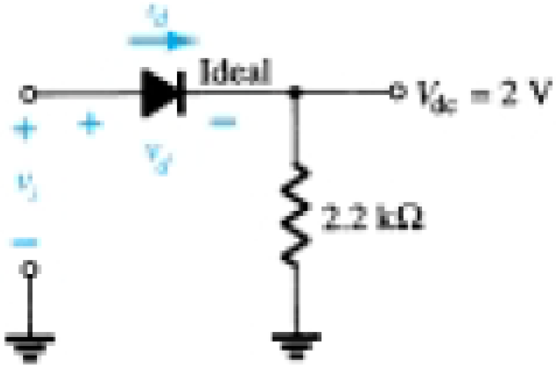
Problems

Q1: Sketch v_o and determine V_{dc}.

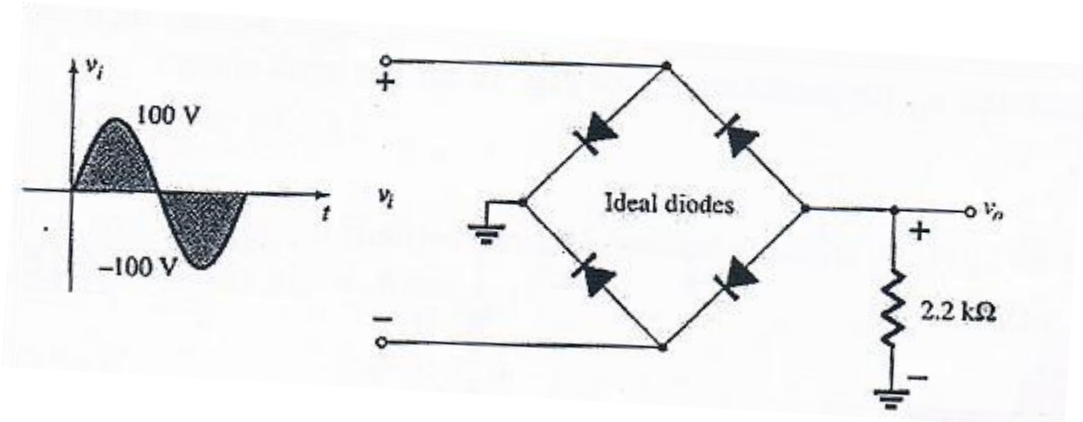


(Ans: V_{peak} =155.56V, V_{dc} =49.47V)

Q2: Assuming an ideal diode, sketch *vi*, *vd*, and *id* for the half-wave rectifier 7. The input is a sinusoidal waveform



Q3: Determine v_o and the required PIV rating for each for each diode.



(Ans: V_{peak} =-100V, *PIV* =100V)

Q4: Sketch v_o and determine V_{dc}.

(Ans: V_{peak} =56. 67V, V_{dc} =36.04V)