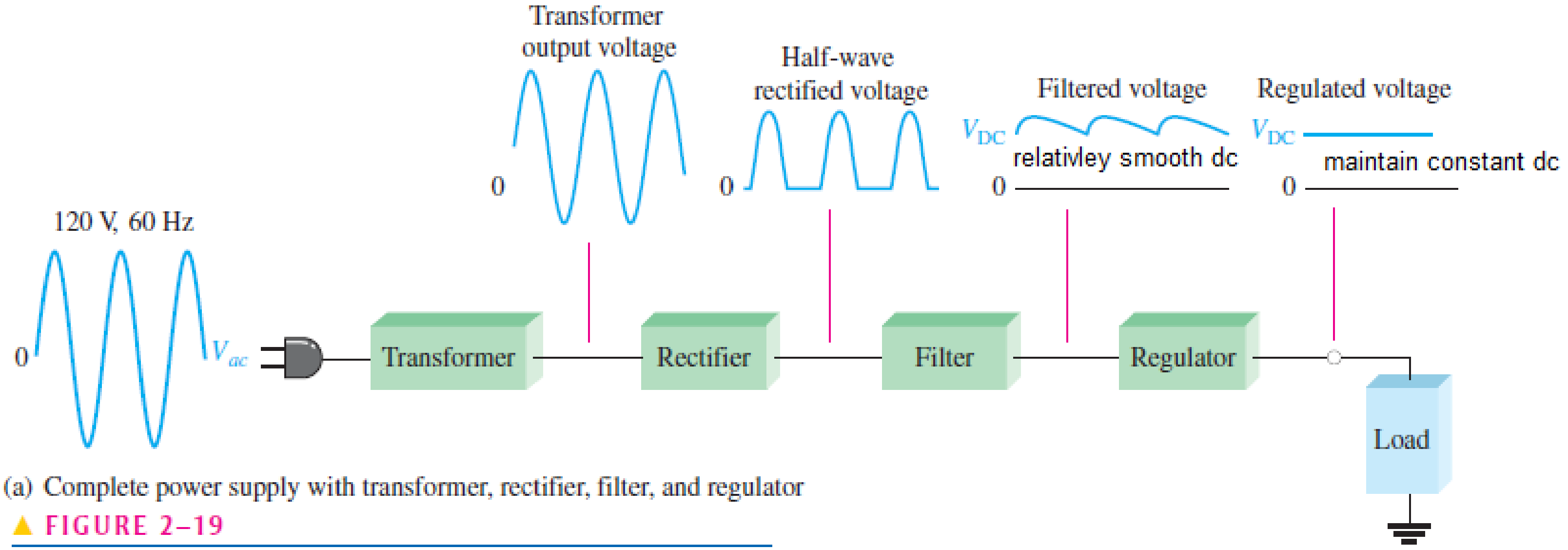
2–4 **Half-Wave Rectifiers**

► Because of their ability to conduct current in one direction and block current in the other direction, diodes are used in circuits called **rectifiers** that **convert ac voltage into dc voltage**.

►Rectifiers are found in all **dc power supplies** that operate from an ac voltage source. A power supply is an essential part of each electronic system from the simplest to the most complex.

The Basic DC Power Supply



(a) Complete power supply with transformer, rectifier, filter, and regulator

▲ FIGURE 2–19

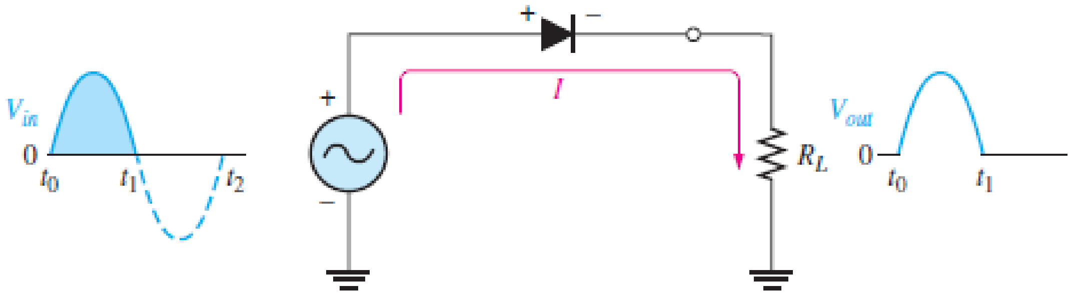
Block diagram of a dc power supply with a load and a rectifier.

2–4 **Half-Wave Rectifiers**

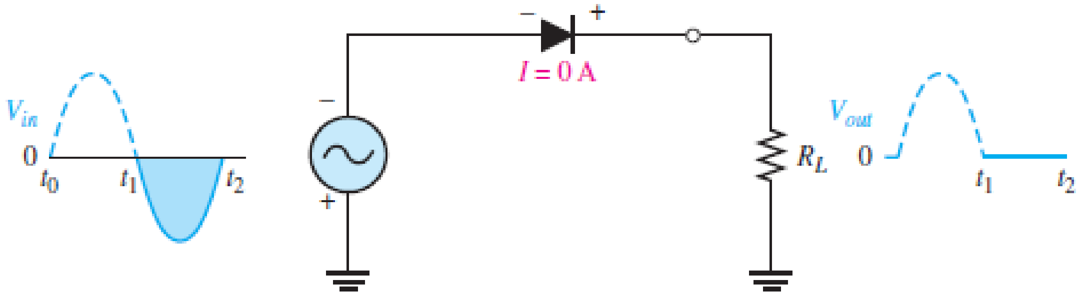
Operation:

▶ Assume ideal diode (neglect barrier potential 0.7)

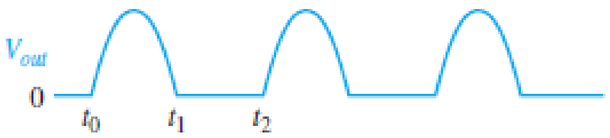
❑ During the positive half-cycle of the input voltage, the output voltage looks like the positive half of the input voltage. The current path is through ground back to the source.



❑ During the negative half-cycle of the input voltage, the current is 0, so the output voltage is also 0.



❑ The half-wave output voltage for three input cycles ▶



2–4 Half-Wave Rectifiers

Average Value of the Half-Wave Output Voltage

(measured on a dc voltmeter).

- assume ideal diode, neglect barrier potential 0.7
- **Mathematically**: the area under a full cycle divided by 2π (the number of radians in a full cycle)

Vp: peak value of the rectified voltage

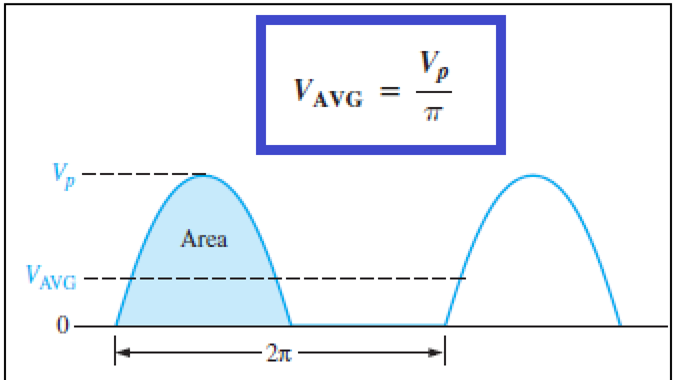
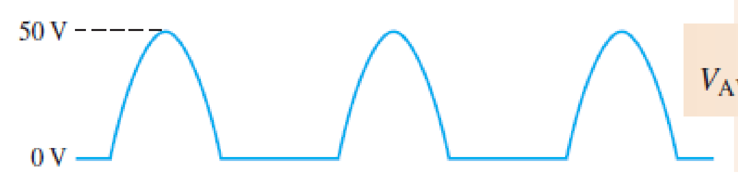


FIGURE 2–21

Average value of the half-wave rectified signal.

EXAMPLE 2–2 What is the average value of the half-wave rectified voltage in Figure 2–22?

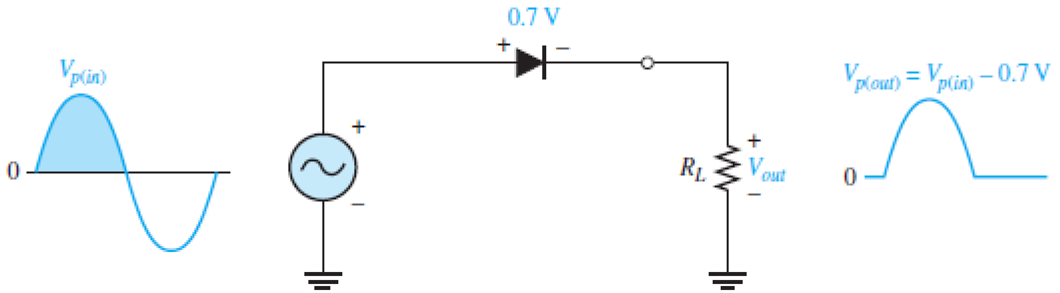
FIGURE 2–22



$$V_{AVG} = \frac{V_p}{\pi} = \frac{50\ V}{\pi} = 15.9\ V$$

2–4 **Half-Wave Rectifiers**

► Effect of the Barrier Potential on the Half-Wave Rectifier Output

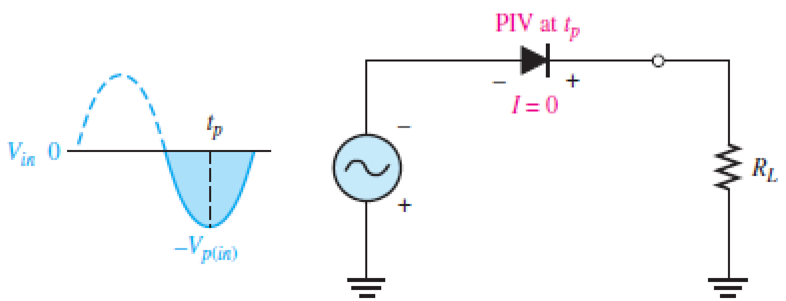


▲ FIGURE 2–23

The effect of the barrier potential on the half-wave rectified output voltage is to reduce the peak value of the input by about 0.7 V.

► Peak Inverse Voltage (PIV)

$$\text{PIV} = V_{p(in)}$$

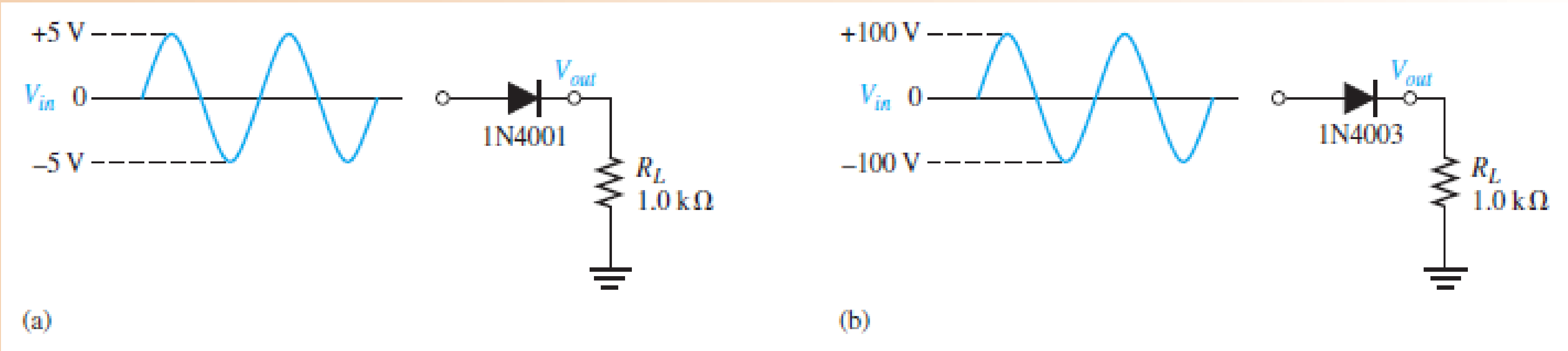


The PIV occurs at the peak of each half-cycle of the input voltage when the diode is reverse-biased. In this circuit, the PIV occurs at the peak of each negative half-cycle.

2–4 Half-Wave Rectifiers

Example

EXAMPLE 2–3 Draw the output voltages of each rectifier for the indicated input voltages, as shown in Figure 2–24. The 1N4001 and 1N4003 are specific rectifier diodes.

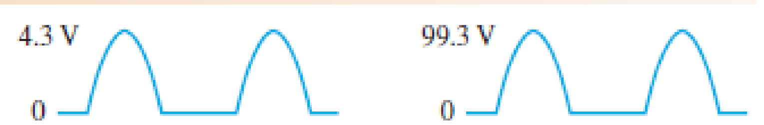


▲ FIGURE 2–24

Solution

(a) $V_{p(out)} = V_{p(in)} - 0.7\text{ V} = 5\text{ V} - 0.7\text{ V} = \mathbf{4.30\text{ V}}$

(b) $V_{p(out)} = V_{p(in)} - 0.7\text{ V} = 100\text{ V} - 0.7\text{ V} = \mathbf{99.3\text{ V}}$



$= \mathbf{4.30\text{ V}}$

2–4 Half-Wave Rectifiers

Transformer Coupling

Transformer coupling provides two advantages:

- It allows the source voltage to be stepped down as needed.
- The ac source is electrically isolated, thus preventing a shock hazard in the secondary Circuit.

turns ratio = n = N sec / N pri

$$V_{sec} = nV_{pri}$$

n > 1 : $V_{sec} > V_{pri}$

n< 1 : $V_{sec} < V_{pri}$

n =1 : $V_{sec} = V_{pri}$

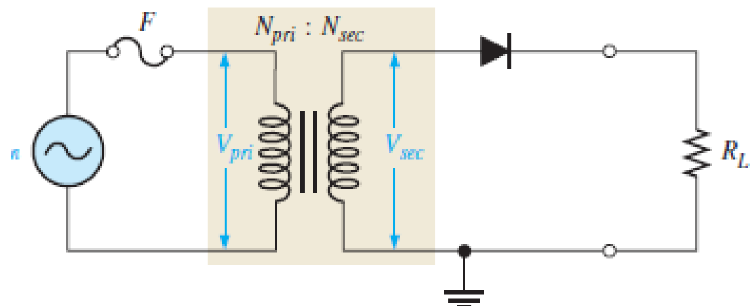


FIGURE 2–27

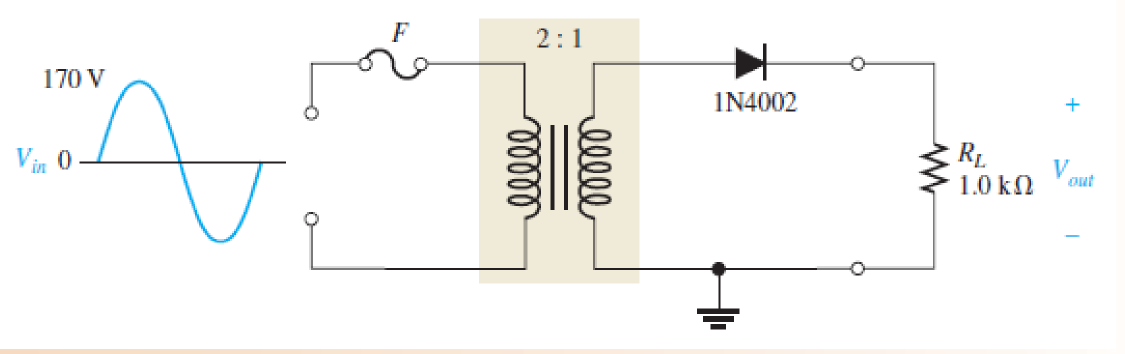
Half-wave rectifier with transformer-coupled input voltage.

$$V_{p(out)} = V_{p(sec)} - 0.7\text{ V}$$

$$\text{PIV} = V_{p(sec)}$$

EXAMPLE 2–4 Determine the peak value of the output voltage for Figure 2–28 if the turns ratio is 0.5.

▶ FIGURE 2–28



Solution

$$V_{p(pri)} = V_{p(in)} = 170\text{ V}$$

The peak secondary voltage is

$$V_{p(sec)} = nV_{p(pri)} = 0.5(170\text{ V}) = 85\text{ V}$$

The rectified peak output voltage is

$$V_{p(out)} = V_{p(sec)} - 0.7\text{ V} = 85\text{ V} - 0.7\text{ V} = \mathbf{84.3\text{ V}}$$

where $V_{p(sec)}$ is the input to the rectifier.

Related Problem

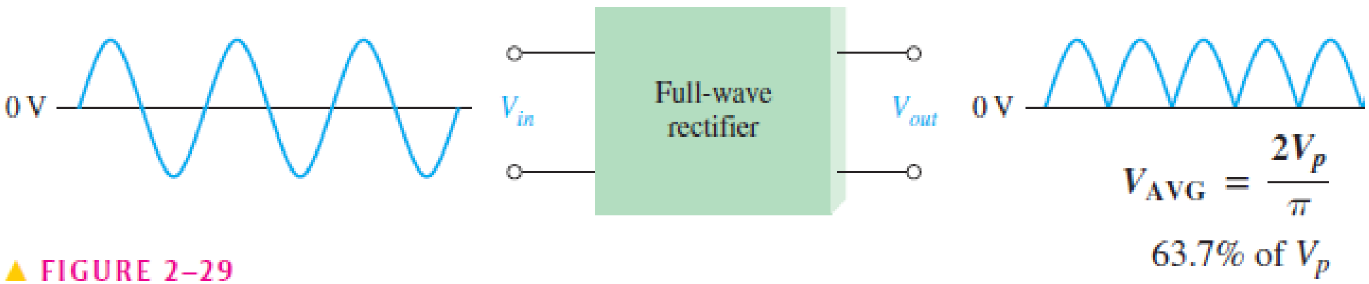
(a) Determine the peak value of the output voltage for Figure 2–28 if $n = 2$ and $V_{p(in)} = 312$ V.

(b) What is the PIV across the diode?

(c) Describe the output voltage if the diode is turned around.

2–5 **Full-Wave Rectifiers**

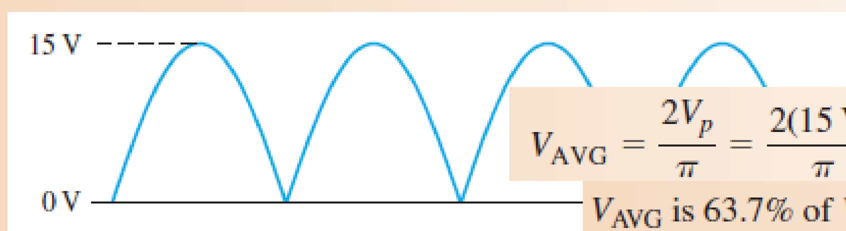
► Allows unidirectional (one-way) **current through the load** during the entire 360° of the input cycle



▲ FIGURE 2–29

Full-wave rectification.

Find the average value of the full-wave rectified voltage in Figure 2–30.

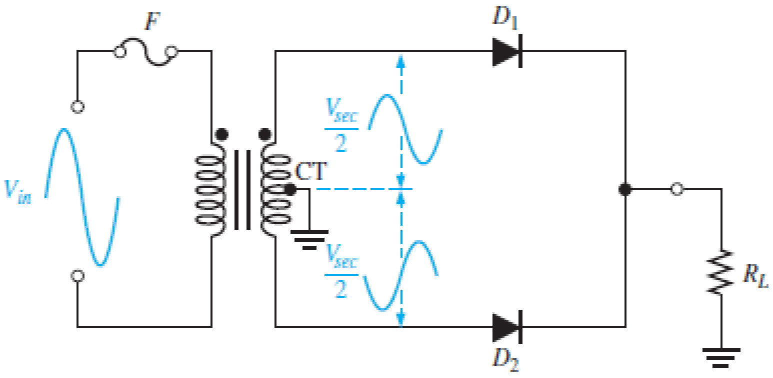


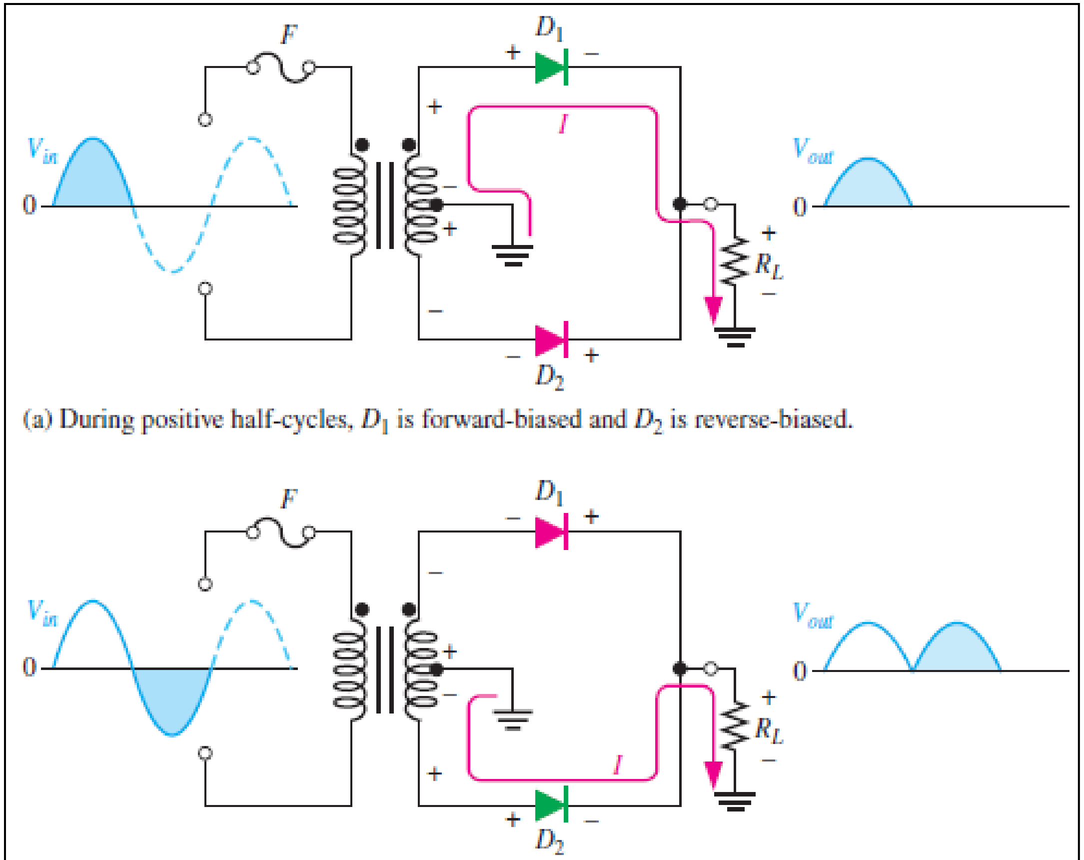
$$V_{AVG} = \frac{2V_p}{\pi} = \frac{2(15\text{ V})}{\pi} = \mathbf{9.55\ V}$$

V_{AVG} is 63.7% of V_p.

2–5 Full-Wave Rectifiers

a) Center-Tapped Full-Wave Rectifier Operation:





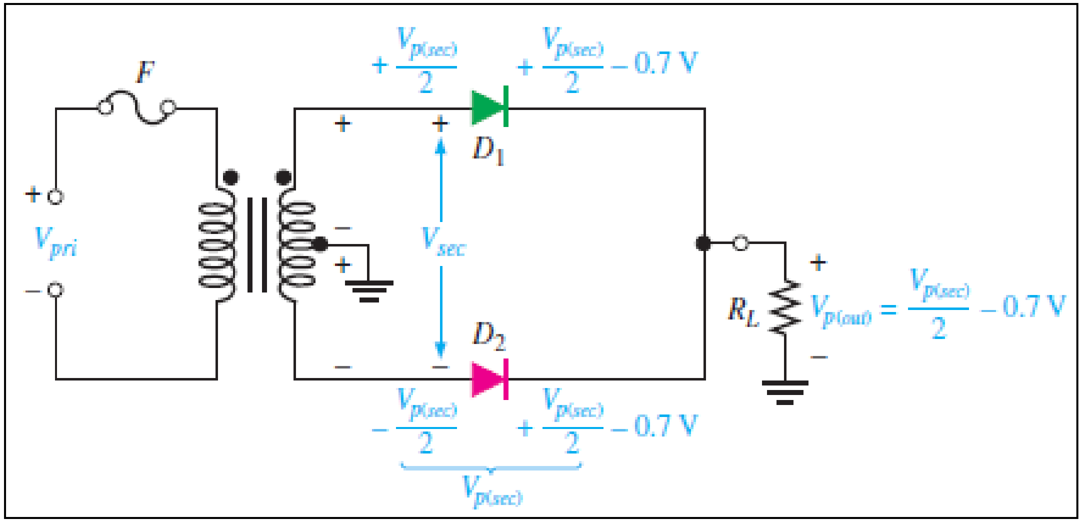
(a) During positive half-cycles, D_1 is forward-biased and D_2 is reverse-biased.

(b) During negative half-cycles, D_2 is forward-biased and D_1 is reverse-biased.

2–5 Full-Wave Rectifiers (Center-Tapped)

Peak Inverse Voltage (PIV)

- if this voltage is exceeded the diode may be destroyed



The peak inverse voltage across D_2 is

$$\text{PIV} = \left(\frac{V_{p(sec)}}{2} - 0.7\text{ V}\right) - \left(-\frac{V_{p(sec)}}{2}\right) = \frac{V_{p(sec)}}{2} + \frac{V_{p(sec)}}{2} - 0.7\text{ V}$$
$$= V_{p(sec)} - 0.7\text{ V}$$

Since $V_{p(out)} = V_{p(sec)}/2 - 0.7\text{ V}$, then by multiplying each term by 2 and transposing,

$$V_{p(sec)} = 2V_{p(out)} + 1.4\text{ V}$$

Therefore, by substitution, the peak inverse voltage across either diode in a full-wave center-tapped rectifier is

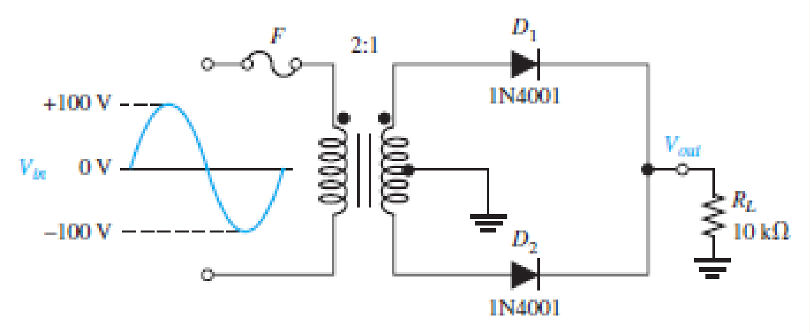
$$\mathbf{PIV = 2V_{p(out)} + 0.7\text{ V}}$$

EXAMPLE 2–6

(a) Show the voltage waveforms across each half of the secondary winding and across R_L when a 100 V peak sine wave is applied to the primary winding in Figure 2–36.

(b) What minimum PIV rating must the diodes have?

▶ FIGURE 2–36



Solution (a) The transformer turns ratio $n = 0.5$. The total peak secondary voltage is

$$V_{p(sec)} = nV_{p(pri)} = 0.5(100\text{ V}) = 50\text{ V}$$

There is a 25 V peak across each half of the secondary with respect to ground. The output load voltage has a peak value of 25 V, less the 0.7 V drop across the diode. The waveforms are shown in Figure 2–37.

(b) Each diode must have a minimum PIV rating of

$$\text{PIV} = 2V_{p(out)} + 0.7\text{ V} = 2(24.3\text{ V}) + 0.7\text{ V} = \mathbf{49.3\text{ V}}$$

▶ FIGURE 2–37