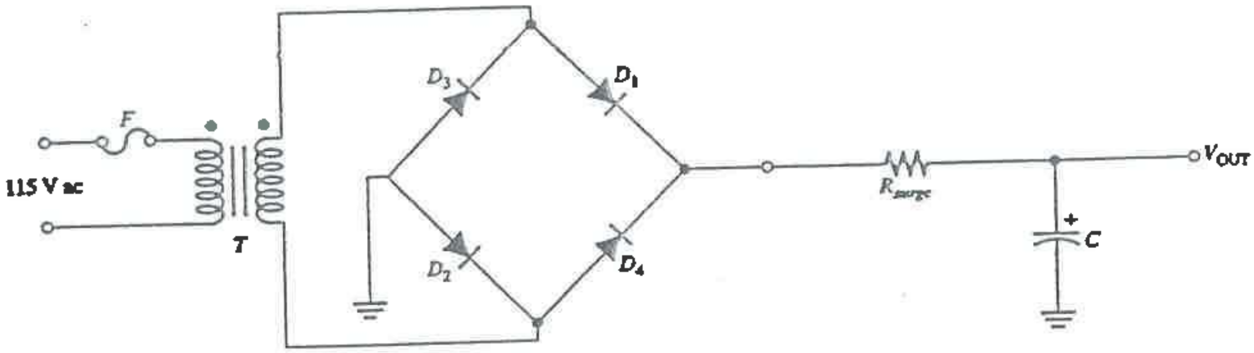
UNIT 2

DIODE APPLICATIONS



2–1 ■ HALF-WAVE RECTIFIERS

Because of their ability to conduct current in one direction and block current in the other direction, diodes are used in rectifier circuits that convert ac voltage into dc voltage. Rectifier circuits 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. In this section, you will study the most basic type of rectifier circuit, the half-wave rectifier.

After completing this section, you should be able to

- **Explain and analyze the operation of a half-wave rectifier**
  - ☐ Describe a basic dc power supply and half-wave rectification
  - ☐ Determine the average value of a half-wave rectified voltage
  - ☐ Discuss the effect of barrier potential on a half-wave rectifier output
  - ☐ Define peak inverse voltage (PIV)
  - ☐ Describe the tranformer-coupled half-wave rectifier

The Basic DC Power Supply

The dc **power supply** converts the standard 110 V, 60 Hz ac available at wall outlets into a constant dc voltage. It is one of the most common electronic circuits that you will find. The dc voltage produced by a power supply is used to power all types of electronic circuits, such as television receivers, stereo systems, VCRs, CD players, and laboratory equipment.

A basic block diagram for a power supply is shown in Figure 2–1. The rectifier can be either a half-wave rectifier or a full-wave rectifier (covered in Section 2–2). The rectifier converts the ac input voltage to a pulsating dc voltage, which is half-wave rectified as shown. The **filter** eliminates the fluctuations in the rectified voltage and produces a relatively smooth dc voltage. Power supply filters are covered in Section 2–3. The **regulator** is a circuit that maintains a constant dc voltage for variations in the input line voltage or in the load. Regulators vary from a single device to more complex circuits. You will study a single-device regulator in Chapter 3. The load block is usually a circuit for which the power supply is producing the dc voltage and load current.

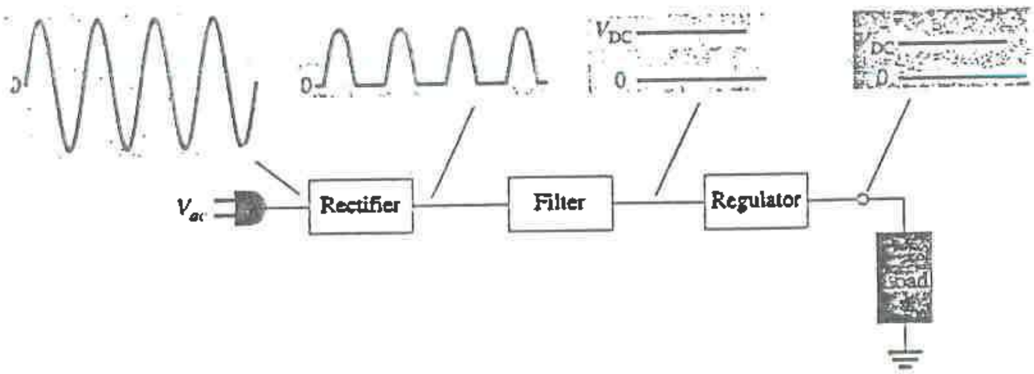


FIGURE 2–1
Block diagram of a dc power supply.

The Half-Wave Rectifier

Figure 2–2 illustrates the process called *half-wave rectification*. In part (a), a diode is connected to an ac source and a load resistor R_L, forming a **half-wave rectifier**. Let's examine what happens during one cycle of the input voltage using the ideal model for the diode. When the sinusoidal input voltage (V_{in}) goes positive, the diode is forward-biased and conducts current through the load resistor, as shown in part (b). The current produces an output voltage across the load R_L, which has the same shape as the positive half-cycle of the input voltage.

When the input voltage goes negative during the second half of its cycle, the diode is reverse-biased. There is no current, so the voltage across the load resistor is 0 V, as shown in Figure 2–2(c). The net result is that only the positive half-cycles of the ac input voltage appear across the load. Since the output does not change polarity, it is a *pulsating dc voltage* with a frequency of 60 Hz as shown in part (d).

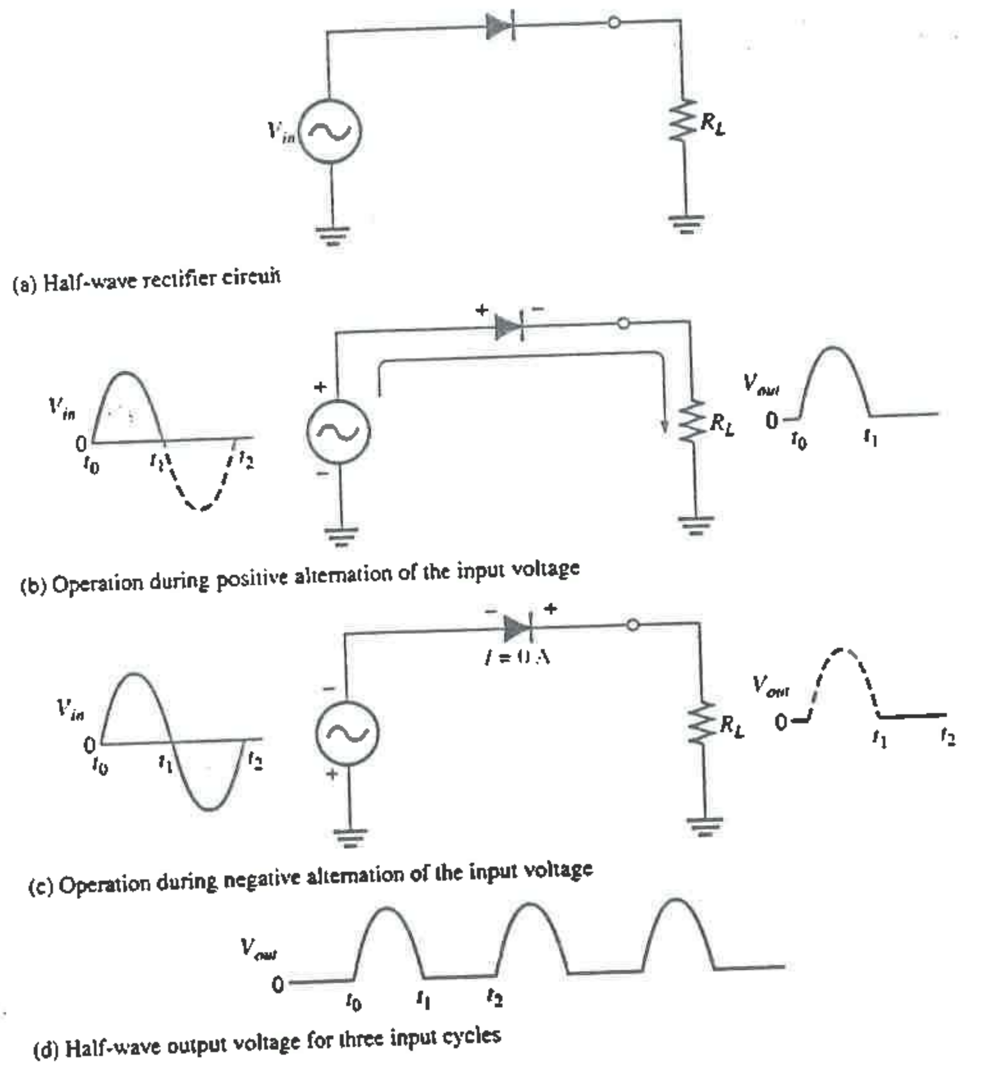


FIGURE 2–2
Half-wave rectifier operation. The diode is considered to be ideal.

Average Value of the Half-Wave Output Voltage The average value of the half-wave rectified output voltage is the value you would measure on a dc voltmeter. It is determined by finding the area under the curve over a full cycle, as illustrated in Figure 2–3, and then dividing by the period, T. See Appendix B for detailed derivation.

$$V_{AVG} = \frac{V_p}{\pi} \quad (2\text{–}1)$$

V_p is the peak value of the voltage.

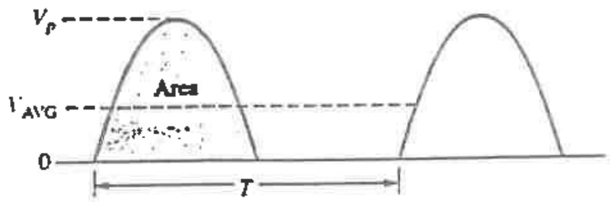


FIGURE 2–3
Average value of half-wave rectified signal.

EXAMPLE 2–1 What is the average value of the half-wave rectified voltage in Figure 2–4?

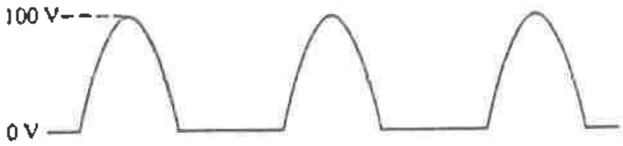


FIGURE 2–4

Solution

$$V_{AVG} = \frac{V_p}{\pi} = \frac{100\ V}{\pi} = 31.8\ V$$

Related Exercise Determine the average value of the half-wave voltage if its peak amplitude is 12 V.

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

In the previous discussion, the diode was considered ideal. When the practical diode model is used and the barrier potential is taken into account, this is what happens. During the positive half-cycle, the input voltage must overcome the barrier potential before the diode becomes forward-biased. For a silicon diode this results in a half-wave output with a peak value that is 0.7 V less than the peak value of the input, as shown in Figure 2–5. For silicon, the expression for the peak output voltage is

$$V_{p(out)} = V_{p(in)} - 0.7\ V \quad (2\text{–}2)$$

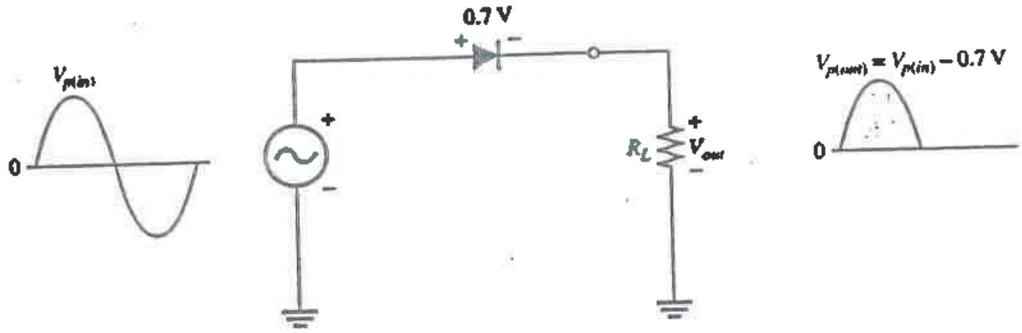


FIGURE 2–5
Effect of the barrier potential on the half-wave rectified output voltage (silicon diode shown).

It is usually acceptable to use the ideal diode model, which neglects the effect of the barrier potential, when the peak value of the applied voltage is much greater than the barrier potential (at least 10 V, as a rule of thumb). However, for consistency, we will always use the practical model of a silicon diode, taking the 0.7 V barrier potential into account unless stated otherwise.

EXAMPLE 2–2 Sketch the output voltages of each rectifier for the indicated input voltages, as shown in Figure 2–6.

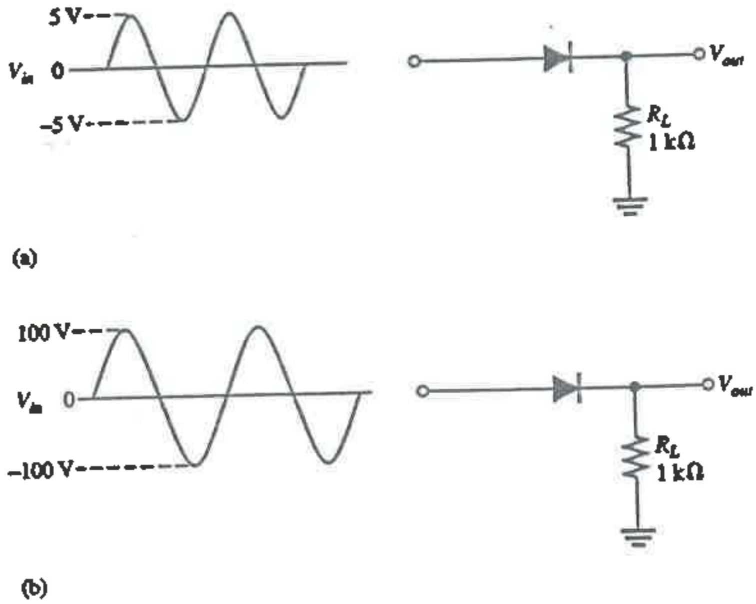


FIGURE 2–6

Solution The peak output voltage for circuit (a) is

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

The peak output voltage for circuit (b) is

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

These output voltage waveforms are shown in Figure 2–7. Note that the barrier potential could have been neglected in circuit (b) with very little error (0.7 percent); but, if it is neglected in circuit (a), a significant error results (14 percent).

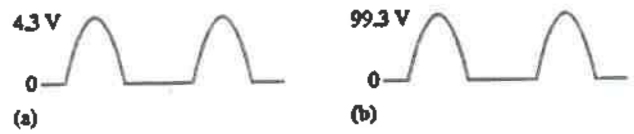


FIGURE 2–7
Output voltages for the circuits in Figure 2–6. They are not shown on the same scale.

Related Exercise Determine the peak output voltages for the rectifiers in Figure 2–6 if the peak input in part (a) is 3 V and the peak input in part (b) is 210 V.

Open file FG02-06.CA4 on your circuit disk. For the inputs specified in the example, measure the resulting output voltage waveforms. Compare your measured results with those shown in the example.

Peak Inverse Voltage (PIV)

The maximum value of reverse voltage, designated as peak inverse voltage (PIV), occurs at the peak of each negative alternation of the input voltage when the diode is reverse-biased. This condition is illustrated in Figure 2–8. The PIV equals the peak value of the input voltage, and the diode must be capable of withstanding this amount of repetitive reverse voltage.

$$PIV = V_{p(in)} \qquad (2\text{–}3)$$

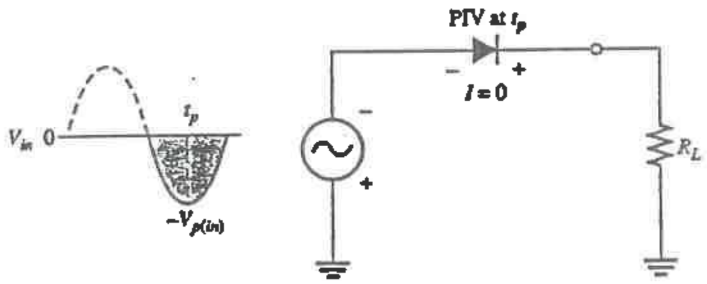


FIGURE 2–8
The PIV occurs at the peak of each half-cycle of the input voltage when the diode is reverse-biased. In this circuit, the PIV occurs at the peak of each negative half-cycle.

Half-Wave Rectifier with Transformer-Coupled Input Voltage

A transformer is often used to couple the ac input voltages from the source to the rectifier circuit, as shown in Figure 2–9. Transformer coupling provides two advantages. First, it allows the source voltage to be stepped up or stepped down as needed. Second, the ac power source is electrically isolated from the rectifier circuit, thus reducing the shock hazard.

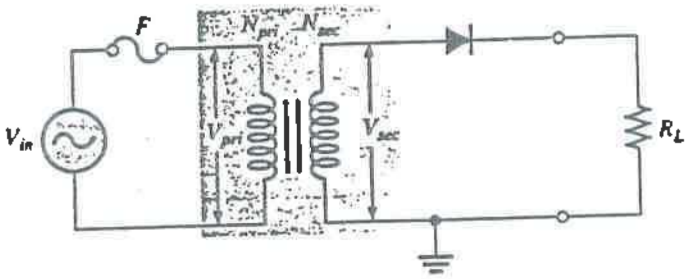


FIGURE 2–9
Half-wave rectifier with transformer-coupled input voltage.

From basic ac circuits recall that the secondary voltage of a transformer equals the turns ratio (N_{sec}/N_{pri}) times the primary voltage, as expressed in Equation (2–4).

$$V_{sec} = \left(\frac{N_{sec}}{N_{pri}}\right)V_{pri} \tag{2–4}$$

If $N_{sec} > N_{pri}$, the secondary voltage is greater than the primary voltage. If $N_{sec} < N_{pri}$, the secondary voltage is less than the primary voltage. If $N_{sec} = N_{pri}$, then $V_{sec} = V_{pri}$.

EXAMPLE 2–3 Determine the peak value of the output voltage for Figure 2–10.

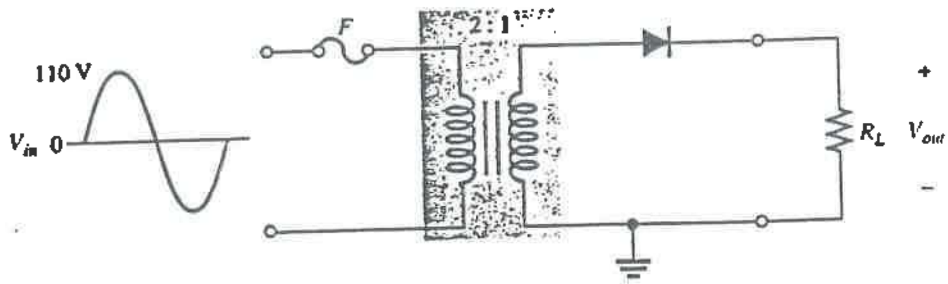


FIGURE 2–10

The difference between full-wave and half-wave rectification is that a full-wave rectifier allows unidirectional (one-way) current to the load during the entire 360° of the input cycle, and the half-wave rectifier allows this only during one half-cycle. The result of full-wave rectification is an output voltage with a frequency twice the input frequency that pulsates every half-cycle of the input, as **shown in Figure 2–11.**

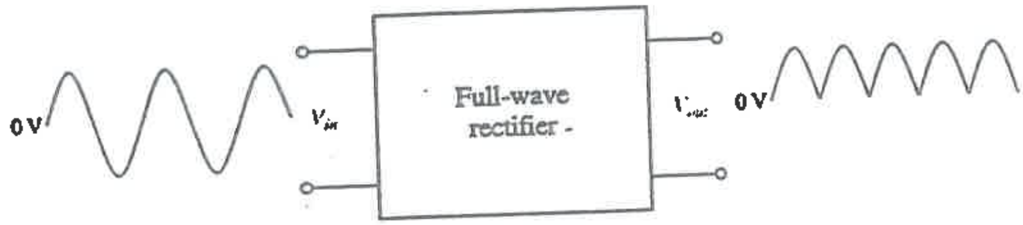


FIGURE 2–11
Full-wave rectification.

Since the number of positive alternations that make up the full-wave rectified voltage is twice that of the half-wave voltage for the same time interval, the average value for a full-wave rectified sinusoidal voltage is twice that of the half-wave, as shown in the following formula:

$$V_{AVG} = \frac{2V_p}{\pi} \quad (2\text{–}5)$$

EXAMPLE 2–4 Find the average value of the full-wave rectified voltage in Figure 2–12.

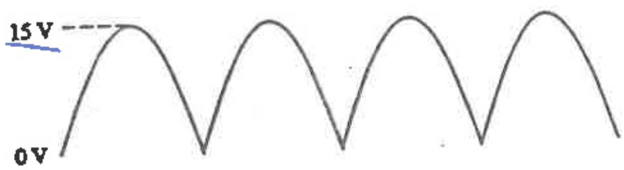


FIGURE 2–12

Solution

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

Related Exercise Find the average value of the full-wave rectified voltage if its peak is 155 V.

Solution $V_{p(pri)} = V_{p(in)} = 110 \text{ V}$

The secondary peak voltage is

$$V_{p(sec)} = \left(\frac{N_{sec}}{N_{pri}}\right)V_{p(pri)} = 0.5(110 \text{ V}) = 55 \text{ V}$$

The peak rectified output voltage is

$$V_{p(out)} = V_{p(sec)} - 0.7 \text{ V} = 55 \text{ V} - 0.7 \text{ V} = 54.3 \text{ V}$$

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

Related Exercise

(a) Determine the peak value of the output voltage for Figure 2–10 if $N_{sec}/N_{pri} = 2$ and $V_{p(in)} = 220$ V.

(b) What is the PIV across the diode?

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

Open file FG02-10.CA4 on your circuit disk. For the specified input, measure the peak output voltage. Compare your measured result with the calculated value.

SECTION 2–1 REVIEW

1. At what point on the input cycle does the PIV occur?
2. For a half-wave rectifier, there is current through the load for approximately what percentage of the input cycle?
3. What is the average of a half-wave rectified voltage with a peak value of 10 V?
4. What is the peak value of the output voltage of a half-wave rectifier with a peak sine wave input of 25 V?
5. What PIV rating must a diode have to be used in a rectifier with a peak output voltage of 50 V?

2–2 ■ FULL-WAVE RECTIFIERS

Although half-wave rectifiers have some applications, the full-wave rectifier is the most commonly used type in dc power supplies. In this section, you will use what you learned about half-wave rectification and expand it to full-wave rectifiers. You will learn about two types of full-wave rectifiers: center-tapped and bridge.

After completing this section, you should be able to

- Explain and analyze the operation of full-wave rectifiers
  - Discuss how full-wave rectification differs from half-wave rectification
  - Determine the average value of a full-wave rectified voltage
  - Describe the operation of a full-wave center-tapped rectifier
  - Explain how the transformer turns ratio affects the rectified output voltage
  - Determine the peak inverse voltage (PIV)
  - Describe the operation of a full-wave bridge rectifier
  - Compare the center-tapped rectifier and the bridge rectifier

The Full-Wave Center-Tapped Rectifier

The full-wave center-tapped rectifier uses two diodes connected to the secondary of a center-tapped transformer, as shown in Figure 2–13. The input voltage is coupled through the transformer to the center-tapped secondary. Half of the total secondary voltage appears between the center tap and each end of the secondary winding as shown.

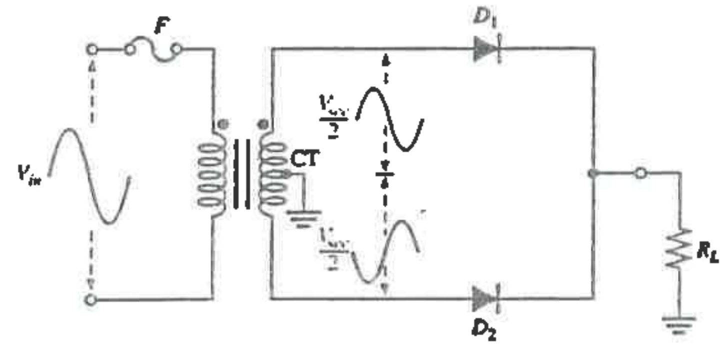


FIGURE 2–13
A full-wave center-tapped rectifier.

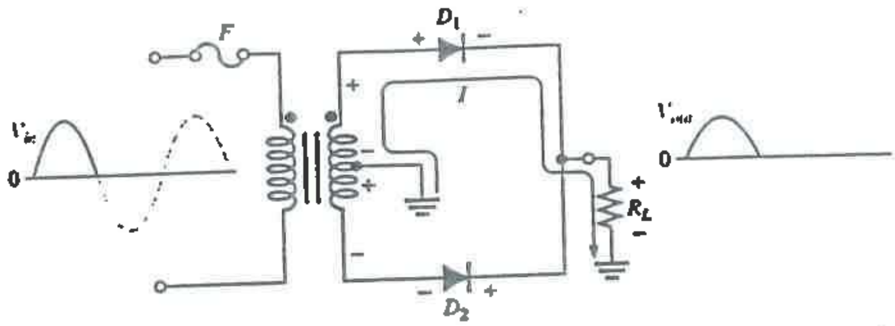
For a positive half-cycle of the input voltage, the polarities of the secondary voltages are as shown in Figure 2–14(a). This condition forward-biases the upper diode D_1 and reverse-biases the lower diode D_2. The current path is through D_1 and the load resistor R_L, as indicated. For a negative half-cycle of the input voltage, the voltage polarities on the secondary are as shown in Figure 2–14(b). This condition reverse-biases D_1 and forward-biases D_2. The current path is through D_2 and R_L, as indicated. Because the output current during both the positive and negative portions of the input cycle is in the same direction through the load, the output voltage developed across the load resistor is a full-wave rectified dc voltage, as shown.

Effect of the Turns Ratio on the Output Voltage If the transformer's turns ratio is 1, the peak value of the rectified output voltage equals half the peak value of the primary input voltage less the barrier potential as illustrated in Figure 2–15. This is because half of the primary voltage appears across each half of the secondary winding ($V_{p(sec)} = V_{p(pri)}$). Incidentally, we will begin referring to the forward voltage due to the barrier potential as the **diode drop**.

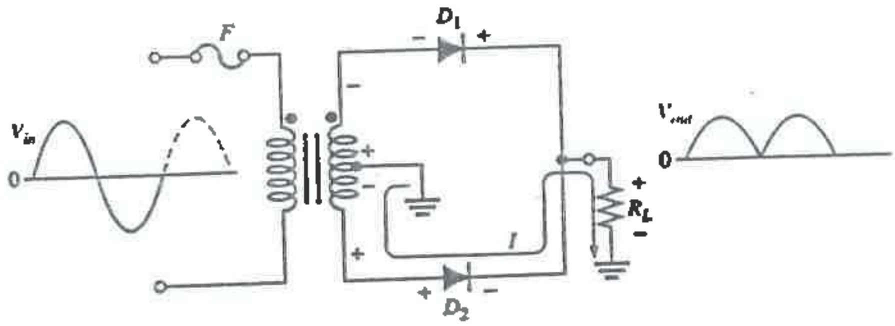
In order to obtain an output voltage with a peak equal to the input peak (less the diode drop), a step-up transformer with a turns ratio of $N_{sec}/N_{pri} = 2$ must be used, as shown in Figure 2–16. In this case, the total secondary voltage V_{sec} is twice the primary voltage ($2V_{pri}$), so the voltage across each half of the secondary is equal to V_{pri}.

In any case, the output voltage of a full-wave center-tapped rectifier is always one-half of the total secondary voltage less the diode drop, no matter what the turns ratio.

$$V_{out} = \frac{V_{sec}}{2} - 0.7\text{ V} \qquad (2\text{–}6)$$



(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.

FIGURE 2–14
Basic operation of a full-wave center-tapped rectifier. Note that the current through the load resistor is in the same direction during the entire input cycle, so the output voltage always has the same polarity.

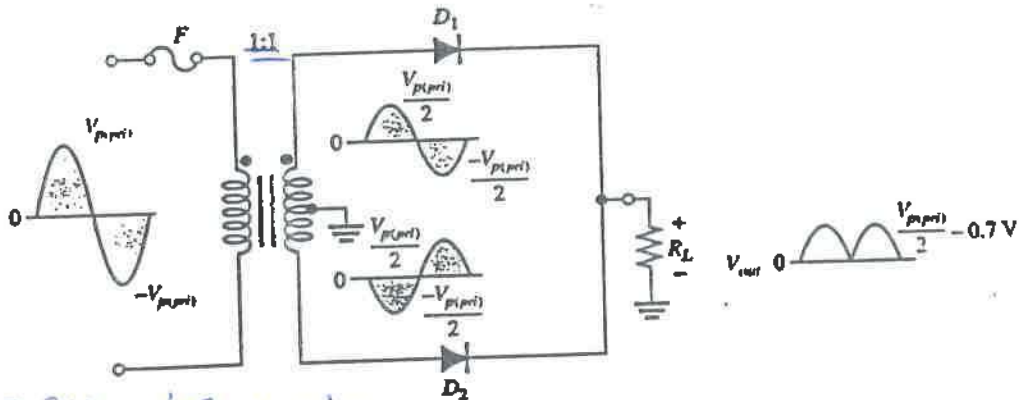


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FIGURE 2–15
Full-wave center-tapped rectifier with a transformer turns ratio of 1. $V_{p(pri)}$ is the peak value of the primary voltage.

PIV = Vp(sec) − 0.7 V

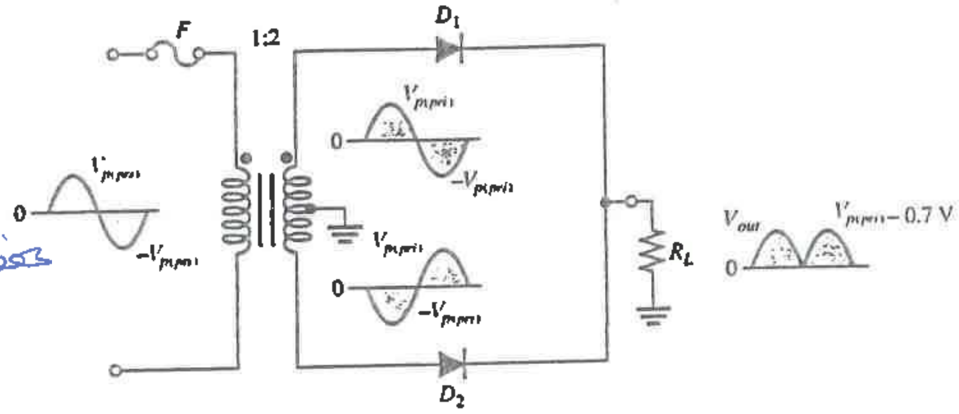


FIGURE 2–16
Full-wave center-tapped rectifier with a transformer turns ratio of 2.

Peak Inverse Voltage Each diode in the full-wave rectifier is alternately forward-biased and then reverse-biased. The maximum reverse voltage that each diode must withstand is the peak secondary voltage $V_{p(sec)}$. This is shown in Figure 2–17.

When the total secondary voltage has the polarity shown, the maximum anode voltage of D_1 is $+V_{p(sec)}/2$ and the maximum anode voltage of D_2 is $-V_{p(sec)}/2$. Since D_1 is forward-biased, its cathode is at the same voltage as its anode minus the diode drop; this is also the voltage on the cathode of D_2. Applying Kirchhoff's voltage law around the loop, the peak inverse voltage across D_2 is

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

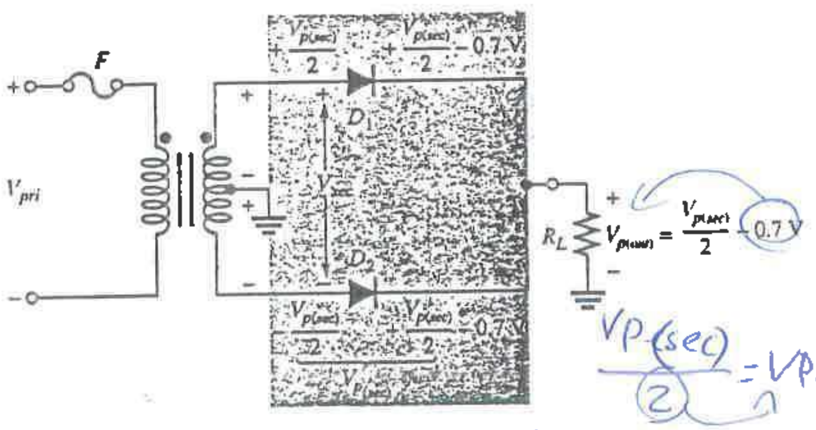
Since

$$V_{p(out)} = \frac{V_{p(sec)}}{2} - 0.7\text{ V}$$

the peak inverse voltage across either diode in the full-wave center-tapped rectifier in terms of $V_{p(out)}$ is

$$\text{PIV} = 2V_{p(out)} + 0.7\text{ V} \qquad (2\text{–}7)$$

FIGURE 2–17
Diode reverse voltage (D_2 shown reverse-biased). The PIV is twice the peak value of the output voltage plus a diode drop.



Vp(sec)/2 = Vp(out) + 0.7
Vp(sec) = 2Vp(out) + 0.7
= 2Vp(out) + 1.4 V

EXAMPLE 2–5 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 2–18. Also, what minimum PIV rating must the diodes have?

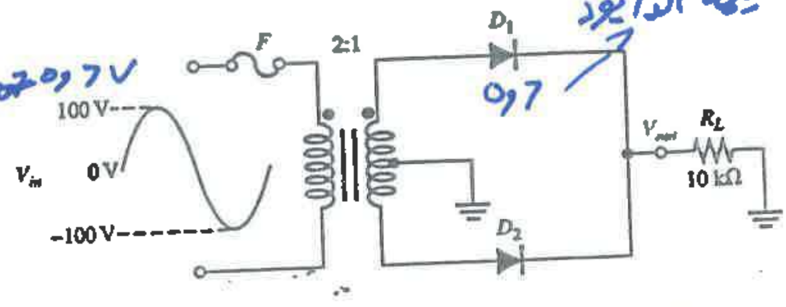


FIGURE 2–18

Solution The total peak secondary voltage is

$$V_{p(sec)} = \left(\frac{N_{sec}}{N_{pri}}\right)V_{p(pri)} = (0.5)100\text{ V} = 50\text{ V}$$

There is a 25 V peak across each half of the secondary. The output load voltage has a peak value of 25 V, less the 0.7 V drop across the diode. Neglecting the diode drop, each diode must have a minimum PIV rating of

$$\text{PIV} = 50\text{ V}$$

The waveforms are shown in Figure 2–19.

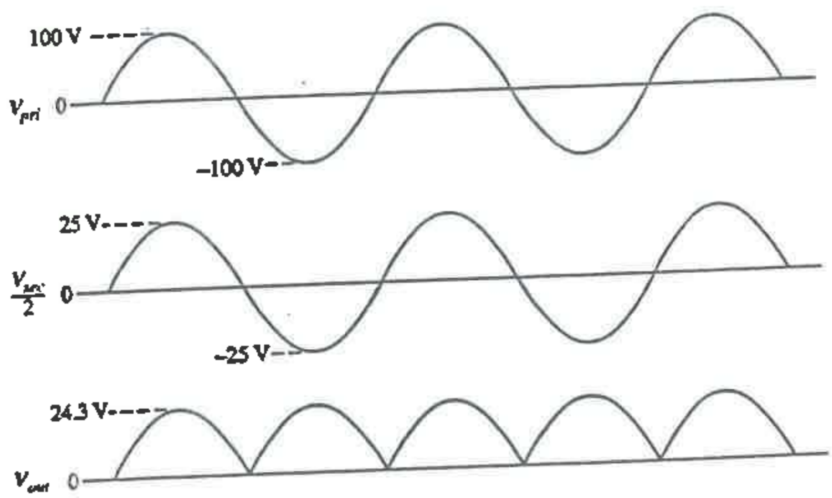


FIGURE 2–19

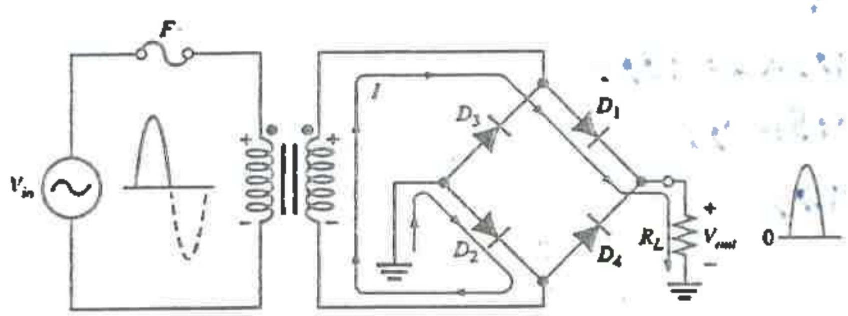
Related Exercise What diode PIV rating is required to handle a peak input of 160 V in Figure 2–18?

Open file FG02-18.CA4 on your circuit disk. For the specified input voltage, measure the voltage waveforms across each half of the secondary and across the load resistor. Compare with the results shown in the example.

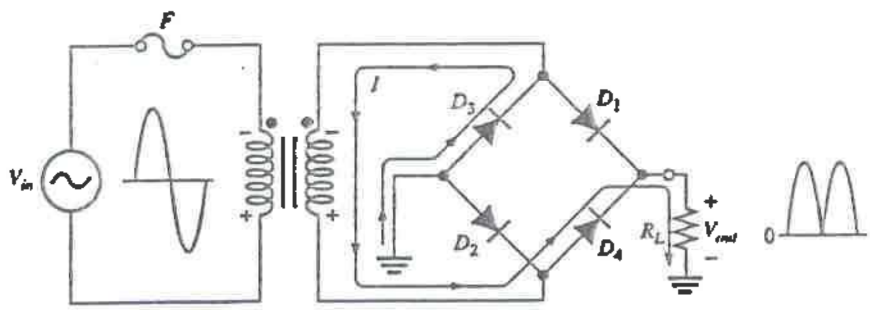
The Full-Wave Bridge Rectifier

The full-wave bridge rectifier uses four diodes, as shown in Figure 2–20. When the input cycle is positive as in part (a), diodes D_1 and D_2 are forward-biased and conduct current in the direction shown. A voltage is developed across R_L which looks like the positive half of the input cycle. During this time, diodes D_3 and D_4 are reverse-biased.

When the input cycle is negative as in Figure 2–20(b), diodes D_3 and D_4 are forward-biased and conduct current in the same direction through R_L as during the positive half-cycle. During the negative half-cycle, D_1 and D_2 are reverse-biased. A full-wave rectified output voltage appears across R_L as a result of this action.



(a) During positive half-cycle of the input, D_1 and D_2 are forward-biased and conduct current. D_3 and D_4 are reverse-biased.

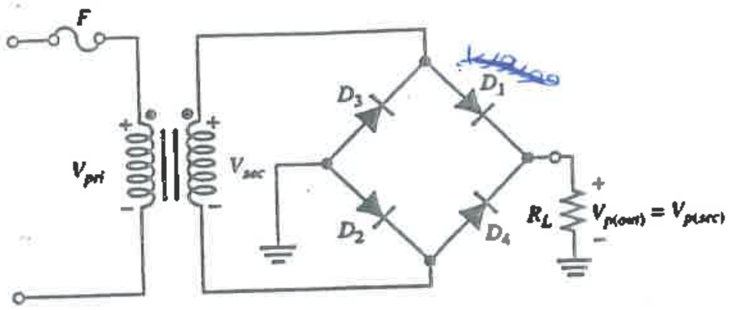


(b) During negative half-cycle of the input, D_3 and D_4 are forward-biased and conduct current. D_1 and D_2 are reverse-biased.

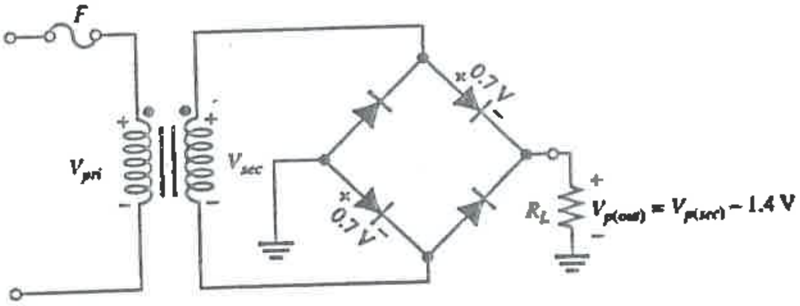
FIGURE 2–20
Operation of a full-wave bridge rectifier.

Bridge Output Voltage A bridge rectifier with a transformer-coupled input is shown in Figure 2–21(a). During the positive half-cycle of the total secondary voltage, diodes D_1 and D_2 are forward-biased. Neglecting the diode drops, the secondary voltage appears across the load resistor. The same is true when D_3 and D_4 are forward-biased during the negative half-cycle.

$$V_{p(out)} = V_{p(sec)}$$



(a) Ideal diodes



(b) Practical diodes (Diode drops included)

FIGURE 2–21
Bridge operation during a positive half-cycle of the secondary voltage.

As you can see in Figure 2–21(b), two diodes are always in series with the load resistor during both the positive and negative half-cycles. If these diode drops are taken into account, the output voltage is

$$V_{p(out)} = V_{p(sec)} - 1.4\text{ V} \qquad (2\text{–}8)$$

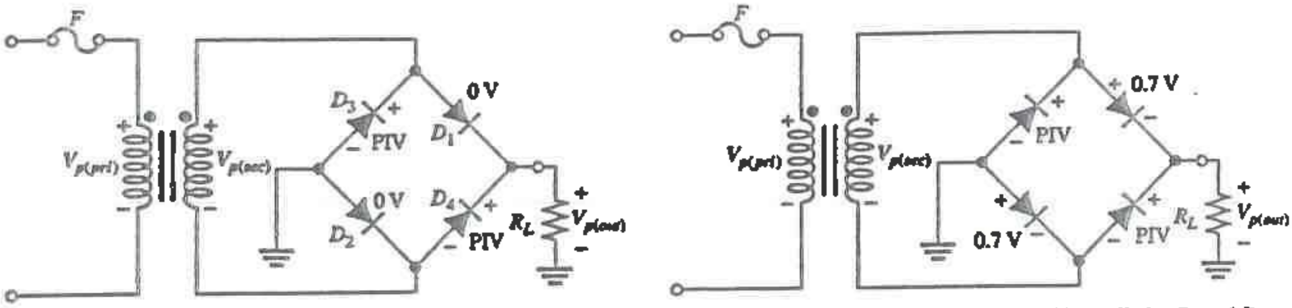
Peak Inverse Voltage Let's assume that D_1 and D_2 are forward-biased and examine the reverse voltage across D_3 and D_4. Visualizing D_1 and D_2 as shorts (ideal model), as in Figure 2–22(a), you can see that D_3 and D_4 have a peak inverse voltage equal to the peak secondary voltage. Since the output voltage is *ideally* equal to the secondary voltage,

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

If the diode drops of the forward-biased diodes are included as shown in Figure 2–22(b), the peak inverse voltage across each reverse-biased diode in terms of $V_{p(out)}$ is

$$\text{PIV} = V_{p(out)} + 0.7\text{ V} \qquad (2\text{–}9)$$

The PIV rating of the bridge diodes is less than that required for the center-tapped configuration. If the diode drop is neglected, the bridge rectifier requires diodes with half the PIV rating of those in a center-tapped rectifier for the *same* output voltage.



(a) For the ideal diode model (forward-biased diodes D_1 and D_2 are shown in blue). PIV = $V_{p(out)}$

(b) For the practical diode model (forward-biased diodes D_1 and D_2 are shown in blue). PIV = $V_{p(out)}$ + 0.7 V

FIGURE 2–22
Peak inverse voltages across diodes D_3 and D_4 in a bridge rectifier during the positive half-cycle of the secondary voltage.

EXAMPLE 2–6

Determine the peak output voltage for the bridge rectifier in Figure 2–23. What PIV rating is required for the silicon diodes? The transformer is specified to have a 12 V rms secondary voltage for the standard 110 V across the primary.

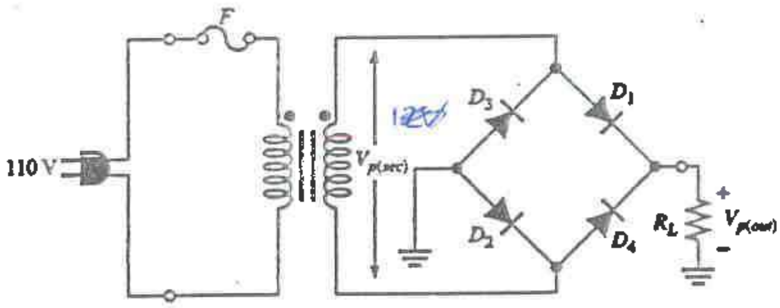


FIGURE 2–23

Solution The peak output voltage (taking into account the two diode drops) is

$$V_{p(sec)} = 1.414V_{rms} = 1.414(12\text{ V}) \cong 17\text{ V}$$

$$V_{p(out)} = V_{p(sec)} - 1.4\text{ V} = 17\text{ V} - 1.4\text{ V} = 15.6\text{ V}$$

The PIV for each diode is

$$\text{PIV} = V_{p(out)} + 0.7\text{ V} = 15.6\text{ V} + 0.7\text{ V} = 16.3\text{ V}$$

Related Exercise Determine the peak output voltage for the bridge rectifier in Figure 2–23 if the transformer produces an rms secondary voltage of 30 V. What is the PIV rating for the diodes?

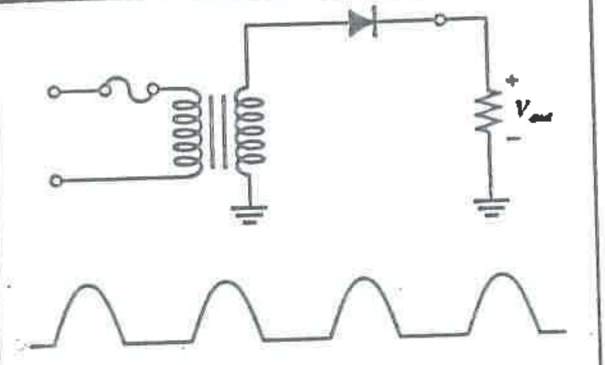
1.414(20) = 28,28 + 0,7 = 28,38 + 0,7

26,88

28,28 − 1,4 = 28,26 28

SUMMARY OF POWER SUPPLY RECTIFIERS

HALF-WAVE RECTIFIER



Output voltage waveform

- Peak value of output:

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

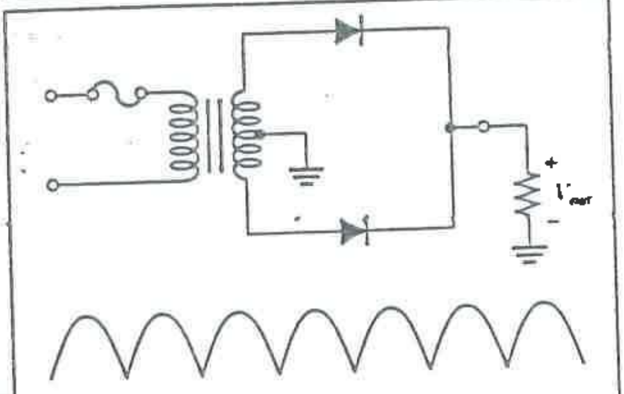
- Average value of output: القيمة المتوسطة

$$V_{AVG} = \frac{V_{p(out)}}{\pi}$$

- Diode peak inverse voltage:

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

FULL-WAVE CENTER-TAPPED RECTIFIER



Output voltage waveform

- Peak value of output:

$$V_{p(out)} = \frac{V_{p(sec)}}{2} - 0.7\text{ V}$$

- Average value of output:

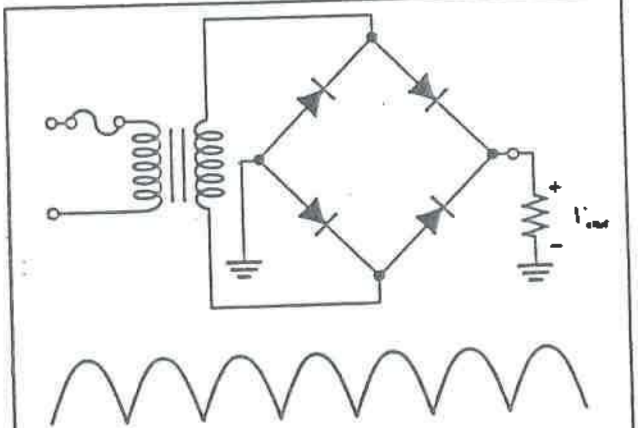
$$V_{AVG} = \frac{2V_{p(out)}}{\pi}$$

- Diode peak inverse voltage:

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

PIV=VP(sec)-0.7V

FULL-WAVE BRIDGE RECTIFIER



Output voltage waveform

- Peak value of output:

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

- Average value of output:

$$V_{AVG} = \frac{2V_{p(out)}}{\pi}$$

- Diode peak inverse voltage:

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

PIV=VP(sec)-0.7V

2–6 ■ THE DIODE DATA SHEET

A manufacturer's data sheet gives detailed information on a device so that it can be used properly in a given application. A typical data sheet provides maximum ratings, electrical characteristics, mechanical data, and graphs of various parameters. In this section, we use a specific example to illustrate a typical data sheet.

After completing this section, you should be able to

- **Interpret and use a diode data sheet**
  - ☐ Identify maximum voltage and current ratings
  - ☐ Determine the electrical characteristics of a diode
  - ☐ Analyze graphical data
  - ☐ Select an appropriate diode for a given set of specifications

Table 2–1 shows the maximum ratings for a certain series of rectifier diodes (1N4001 through 1N4007). These are the absolute maximum values under which the diode can be operated without damage to the device. For greatest reliability and longer life, the diode should always be operated well under these maximums. Generally, the maximum ratings are specified at 25°C and must be adjusted downward for higher temperatures.

TABLE 2–1
Maximum ratings.

Rating	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
Peak repetitive reverse voltage Working peak reverse voltage DC blocking voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
Nonrepetitive peak reverse voltage	V_{RSM}	60	120	240	480	720	1000	1200	V
rms reverse voltage	$V_{R(rms)}$	35	70	140	280	420	560	700	V
Average rectified forward current (single-phase, resistive load, 60 Hz, $T_A = 75°C$)	I_O	1.0							A
Nonrepetitive peak surge current (surge applied at rated load conditions)	I_{FSM}	30 (for 1 cycle)							A
Operating and storage junction temperature range	T_J, T_{stg}	−65 to +175							°C

An explanation of the parameters from Table 2–1 follows.

V_{RRM} The maximum reverse peak voltage that can be applied repetitively across the diode. Notice that in this case, it is 50 V for the 1N4001 and 1 kV for the 1N4007. This is the same as PIV rating.

V_R The maximum reverse dc voltage that can be applied across the diode.

V_{RSM} The maximum reverse peak value of nonrepetitive voltage that can be applied across the diode.

I_O The maximum average value of a 60 Hz rectified forward current.

I_{FSM} The maximum peak value of nonrepetitive (one cycle) forward surge current. The graph in Figure 2–58 expands on this parameter to show values for more than one cycle at temperatures of 25°C and 175°C. The dashed lines represent values where typical failures occur.

T_A Ambient temperature (temperature of surrounding air).

T_J The operating junction temperature.

T_{stg} The storage junction temperature.

Table 2–2 lists typical and maximum values of certain electrical characteristics. These items differ from the maximum ratings in that they are not selected by design but

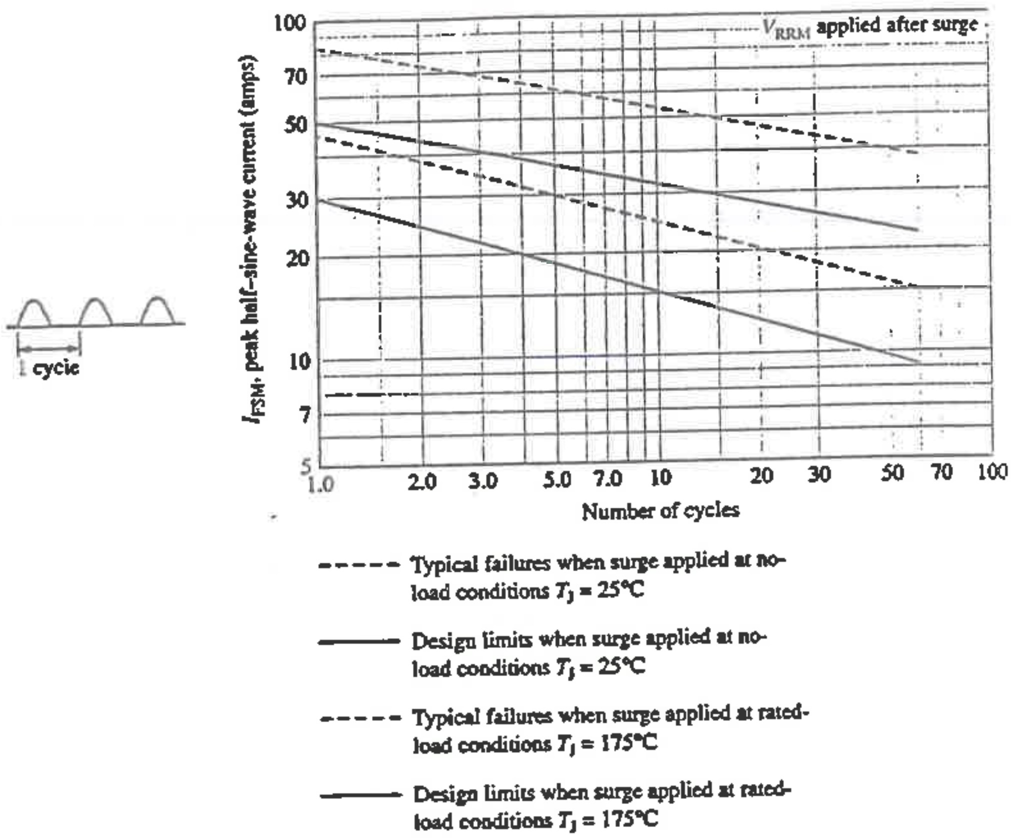


FIGURE 2–58
Nonrepetitive forward surge current capability.

TABLE 2–2
Electrical characteristics.

Characteristics and Conditions	Symbol	Typical	Maximum	Unit
Maximum instantaneous forward voltage drop ($I_F = 1$ A, $T_J = 25°C$)	v_F	0.93	1.1	V
Maximum full-cycle average forward voltage drop ($I_O = 1$ A, $T_L = 75°C$, 1 inch leads)	$V_{F(avg)}$	—	0.8	V
Maximum reverse current (rated dc voltage)	I_R			μA
$T_J = 25°C$		0.05	10.0	
$T_J = 100°C$		1.0	50.0	
Maximum full-cycle average reverse current ($I_O = 1$ A, $T_L = 75°C$, 1 inch leads)	$I_{R(avg)}$	—	30.0	μA

are the result of operating the diode under specified conditions. A brief explanation of these parameters follows.

v_F The instantaneous voltage across the forward-biased diode when the forward current is 1 A at 25°C. Figure 2–59 shows how the forward voltages vary with forward current.

$V_{F(avg)}$ The maximum forward voltage drop averaged over a full cycle.

I_R The maximum current when the diode is reverse-biased with a dc voltage.

$I_{R(avg)}$ The maximum reverse current averaged over one cycle (when reverse-biased with an ac voltage).

T_L The lead temperature.

Figure 2–60 shows a selection of rectifier diodes arranged in order of increasing I_O, I_{FSM}, and V_{RRM} ratings.

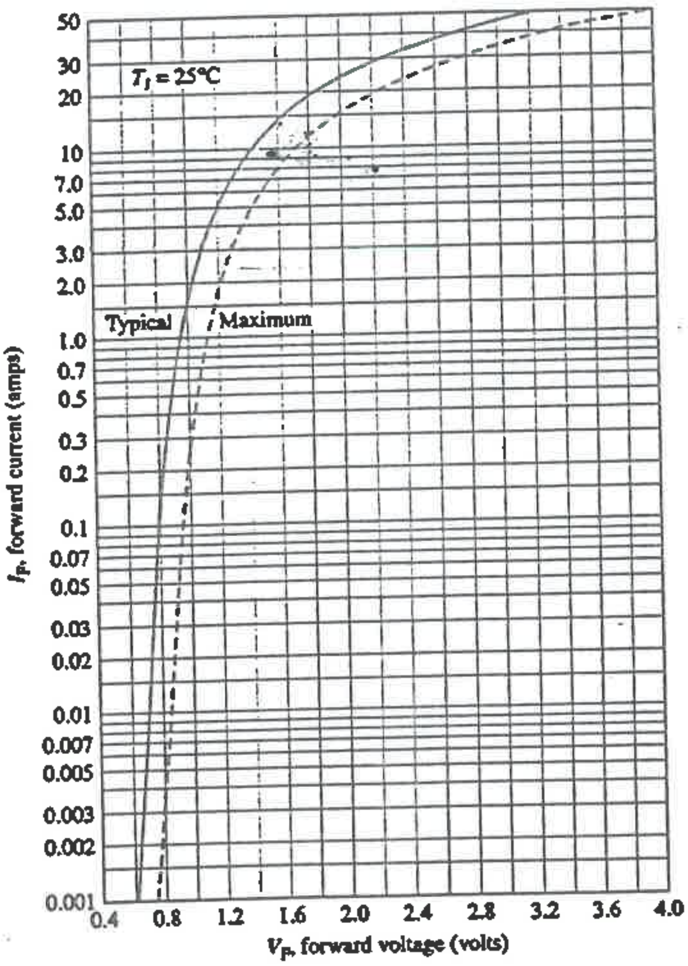


FIGURE 2–59
Forward voltage (V_F) versus forward current (I_F).

V_{RRM} (Volts)	I_O, Average Rectified Forward Current (Amperes) 1.0	1.5	3.0			6.0
	59-03 (DO-41) Plastic	59-04 Plastic	60-01 Metal	267-03 Plastic	267-02 Plastic	194-04 Plastic
						
50	1N4001	1N5391	1N4719	MR500	1N5400	MR750
100	1N4002	1N5392	1N4720	MR501	1N5401	MR751
200	1N4003	1N5393 MR5059	1N4721	MR502	1N5402	MR752
400	1N4004	1N5395 MR5060	1N4722	MR504	1N5404	MR754
600	1N4005	1N5397 MR5061	1N4723	MR506	1N5406	MR756
800	1N4006	1N5398	1N4724	MR508		MR758
1000	1N4007	1N5399	1N4725	MR510		MR760
I_{FSM} (Amps)	30	50	300	100	200	400
T_A @ Rated I_O (°C)	75	$T_L = 70$	75	95	$T_L = 105$	60
T_C @ Rated I_O (°C)						
T_J (Max) (°C)	175	175	175	175	175	175

V_{RRM} (Volts)	I_O, Average Rectified Forward Current (Amperes) 12	20	24	25	30		40	50	[illegible]	[illegible]	
	245A-02 (DO-203AA) Metal		339-02 Plastic	193-04 Plastic	43-02 (DO-21) Metal		42A-01 (DO-203AB) Metal	43-04 Metal	309A-03	309A-02	
											
50	MR1120 1N1199,A,B	MR2000	MR2400	MR2500	1N3491	1N3659	1N1183A	MR5005	MDA2500	MDA3500	
100	MR1121 1N1200,A,B	MR2001	MR2401	MR2501	1N3492	1N3660	1N1184A	MR5010	MDA2501	MDA3501	
200	MR1122 1N1202,A,B	MR2002	MR2402	MR2502	1N3493	1N3661	1N1186A	MR5020	MDA2502	MDA3502	MDA4002
400	MR1124 1N1204,A,B	MR2004	MR2404	MR2504	1N3495	1N3663	1N1188A	MR5040	MDA2504	MDA3504	MDA4004
600	MR1126 1N1206,A,B	MR2006	MR2406	MR2506			1N1190A		MDA2506	MDA3506	MDA4006
800	MR1128	MR2008		MR2508					MDA2508	MDA3508	MDA4008
1000	MR1130	MR2010		MR2510					MDA2510	MDA3510	
I_{FSM} (Amps)	300	400	400	400	300	400	800	600	[illegible]	[illegible]	[illegible]
T_A @ Rated I_O (°C)									[illegible]	[illegible]	[illegible]
T_C @ Rated I_O (°C)	150	150	125	150	130	100	150	150	[illegible]	[illegible]	[illegible]
T_J (Max) (°C)	190	175	175	175	175	175	190	195	[illegible]	[illegible]	[illegible]

FIGURE 2–60
A selection of rectifier diodes based on maximum ratings of I_O, I_{FSM}, and V_{RRM}.