sensitivity of 5 V/Div. Since the full-wave output reads approximately 1.4 Div, its peak value is approximately 7 V. Both input and output readings are in reasonable agreement with theoretical values.

Once again, notice that the second approximation improves the answer only slightly. If you were troubleshooting, the improvement would not be of much value. If something was wrong with the circuit, the chances are that the full-wave output would be drastically different from the ideal value of 8.5 V.

PRACTICE PROBLEM 4-3 Using Fig. 4-7, change the transformer's turns ratio to 5:1 and calculate the V_p (in) and V_p (out) second approximation values.

Example 4-4

MultiSim

If one of the diodes in Fig. 4-7 were open, what would happen to the different voltages?

SOLUTION If one of the diodes is open, the circuit reverts to a half-wave rectifier. In this case, half the secondary voltage is still 8.5 V, but the load voltage will be a half-wave signal rather than a full-wave signal. This half-wave voltage will still have a peak of 8.5 V (ideally) or 7.8 V (second approximation).

4-4 The Bridge Rectifier

Figure 4-8*a* shows a **bridge rectifier** circuit. The bridge rectifier is similar to a full-wave rectifier because it produces a full-wave output voltage. Diodes D_1 and D_2 conduct on the positive half cycle, and D_3 and D_4 conduct on the negative half cycle. As a result, the rectified load current flows during both half cycles.

Figure 4-8*b* shows the equivalent circuit for the positive half cycle. As you can see, D_1 and D_2 are forward biased. This produces a positive load voltage as indicated by the plus-minus polarity across the load resistor. As a memory aid, visualize D_2 shorted. Then, the circuit that remains is a half-wave rectifier, which we are already familiar with.

Figure 4-8*c* shows the equivalent circuit for the negative half cycle. This time, D_3 and D_4 are forward biased. This also produces a positive load voltage. If you visualize D_3 shorted, the circuit looks like a half-wave rectifier. So the bridge rectifier acts like two back-to-back half-wave rectifiers.

During both half cycles, the load voltage has the same polarity and the load current is in the same direction. The circuit has changed the ac input voltage to the pulsating dc output voltage shown in Fig. 4-8*d*. Note the advantage of this type of full-wave rectification over the center-tapped version in the previous section: *The entire secondary voltage can be used.*

Fig. 4-8*e* shows bridge rectifier packages that contain all four diodes.

Average Value and Output Frequency

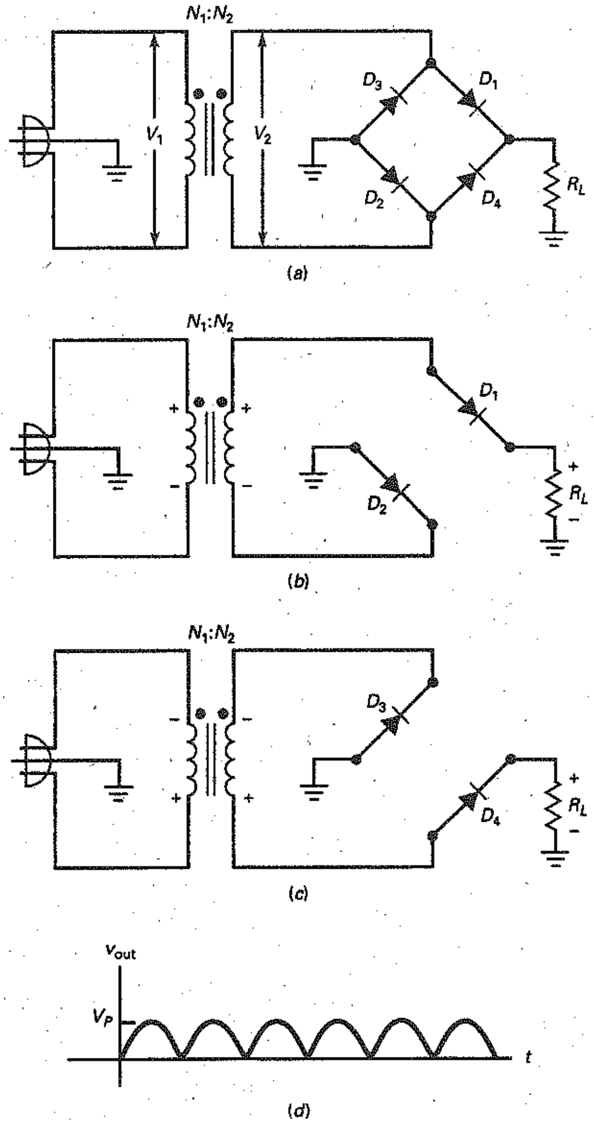
Because a bridge rectifier produces a full-wave output, the equations for average value and output frequency are the same as given for a full-wave rectifier:

$$V_{dc} = \frac{2V_p}{\pi}$$

GOOD TO KNOW

When a bridge rectifier, as opposed to a two-diode full-wave rectifier, is used, the same dc output voltage can be obtained with a transformer having a higher turns ratio N_1/N_2. This means that with a bridge rectifier, fewer turns of wire are needed in the transformer. Therefore, the transformer used with a bridge rectifier versus a two-diode full-wave rectifier will be small and lighter and will cost less. This benefit alone outweighs using four diodes instead of two in a conventional two-diode full-wave rectifier.

Figure 4-8 (*a*) Bridge rectifier; (*b*) equivalent circuit for positive half cycle; (*c*) equivalent circuit for negative half cycle; (*d*) full-wave output; (*e*) bridge rectifier packages.



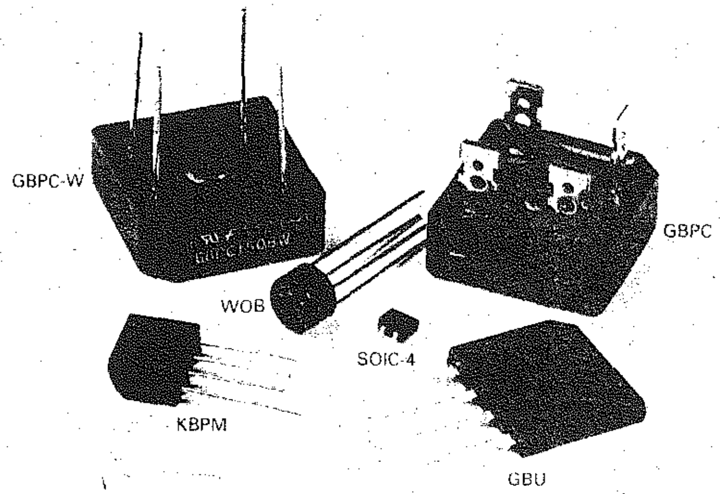
and

$$f_{out} = 2f_{in}$$

The average value is 63.6 percent of the peak value, and the output frequency is 120 Hz, given a line frequency of 60 Hz.

One advantage of a bridge rectifier is that all the secondary voltage is used as the input to the rectifier. Given the same transformer, we get twice as much peak voltage and twice as much dc voltage with a bridge rectifier as with a full-wave rectifier. Doubling the dc output voltage compensates for having to use two extra diodes. As a rule, you will see *the bridge rectifier used a lot more than the full-wave rectifier.*

Figure 4-8 (continued)



(e)

Incidentally, the full-wave rectifier was in use for many years before the bridge rectifier was used. For this reason, it has retained the name *full-wave rectifier* even though a bridge rectifier also has a full-wave output. To distinguish the full-wave rectifier from the bridge rectifier, some literature may refer to a full-wave rectifier as a *conventional full-wave rectifier,* a *two-diode full-wave rectifier,* or a *center-tapped full-wave rectifier.*

Second Approximation and Other Losses

Since the bridge rectifier has two diodes in the conducting path, the peak output voltage is given by:

$$\textbf{2d bridge: } V_{p(out)} = V_{p(in)} - 1.4\text{ V} \tag{4-8}$$

As you can see, we have to subtract two diode drops from the peak to get a more accurate value of peak load voltage. Summary Table 4-1 compares the three rectifiers and their properties.

Summary Table 4-1 | Unfiltered Rectifiers*

	Half-wave	Full-wave	Bridge
Number of diodes	1	2	4
Rectifier input	$V_{p(2)}$	$0.5V_{p(2)}$	$V_{p(2)}$
Peak output (ideal)	$V_{p(2)}$	$0.5V_{p(2)}$	$V_{p(2)}$
Peak output (2d)	$V_{p(2)} - 0.7\text{ V}$	$0.5V_{p(2)} - 0.7\text{ V}$	$V_{p(2)} - 1.4\text{ V}$
DC output	$V_{p(out)}/\pi$	$2V_{p(out)}/\pi$	$2V_{p(out)}/\pi$
Ripple frequency	f_{in}	$2f_{in}$	$2f_{in}$

*$V_{p(2)}$ = peak secondary voltage; $V_{p(out)}$ = peak output voltage.

Example 4-5

MultiSim

Calculate the peak input and output voltages in Fig. 4-9. Then, compare the theoretical values to the measured values.

Notice the circuit uses a bridge rectifier package.

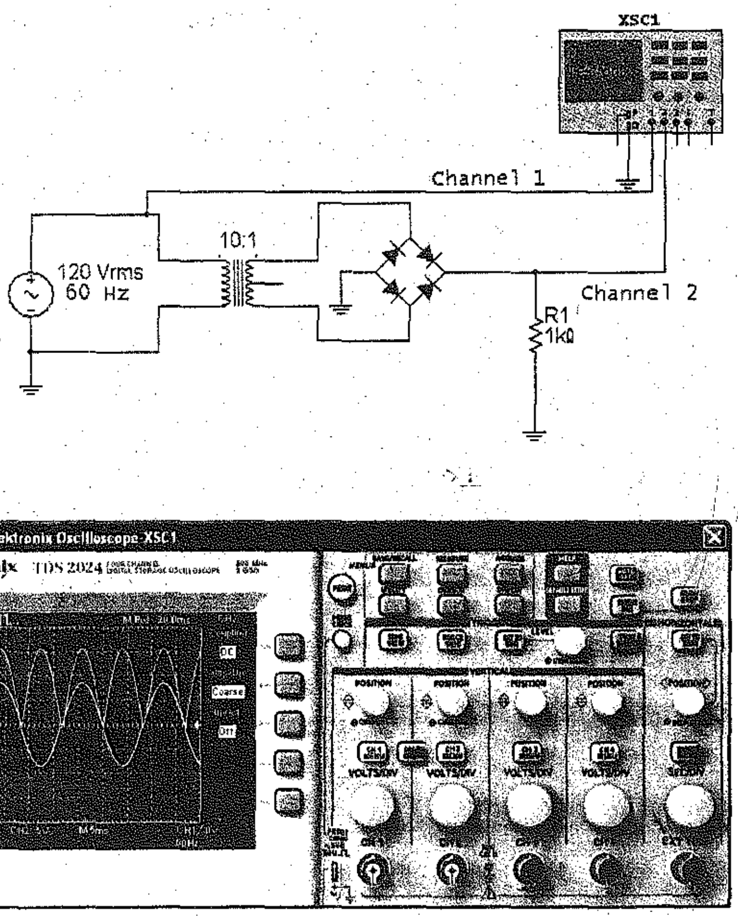
SOLUTION The peak primary and secondary voltages are the same as in Example 4-3:

$$V_{p(1)} = 170\ \text{V}$$
$$V_{p(2)} = 17\ \text{V}$$

With a bridge rectifier, all of the secondary voltage is used as the input to the rectifier. Ideally, the peak output voltage is:

$$V_{p(\text{out})} = 17\ \text{V}$$

Figure 4-9 Lab example of bridge rectifier.



To a second approximation:

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

Now, let's compare the theoretical values with the measured values. The sensitivity of channel 1 is 100 V/Div. Since the sine-wave input reads approximately 1.7 Div, its peak value is approximately 170 V. Channel 2 has a sensitivity of 5 V/Div. Since the half-wave output reads approximately 3.2 Div, its peak value is approximately 16 V. Both input and output readings are approximately the same as the theoretical values.

PRACTICE PROBLEM 4-5 As in Example 4-5, calculate the ideal and second approximation V_p(out) values using a 5:1 transformer turns ratio.

4-5 The Choke-Input Filter

At one time, the choke-input filter was widely used to filter the output of a rectifier. Although not used much anymore because of its cost, bulk, and weight, this type of filter has instructional value and helps make it easier to understand other filters.

Basic Idea

Look at Fig. 4-10*a*. This type of filter is called a **choke-input filter.** The ac source produces a current in the inductor, capacitor, and resistor. The ac current in each component depends on the inductive reactance, capacitive reactance, and the resistance. The inductor has a reactance given by:

$$X_L = 2\pi fL$$

The capacitor has a reactance given by:

$$X_C = \frac{1}{2\pi fC}$$

As you learned in previous courses, the choke (or inductor) has the primary characteristic of opposing a change in current. Because of this, a choke-input filter ideally reduces the ac current in the load resistor to zero. To a second approximation, it reduces the ac load current to a very small value. Let us find out why.

The first requirement of a well-designed choke-input filter is to have X_C at the input frequency be much smaller than R_L. When this condition is satisfied, we can ignore the load resistance and use the equivalent circuit of Fig. 4-10*b*. The second requirement of a well-designed choke-input filter is to have X_L be much greater than X_C at the input frequency. When this condition is satisfied, the ac

Figure 4-10 (*a*) Choke-input filter; (*b*) ac equivalent circuit.