Since the source voltage is 10 V rms, the first thing to do is calculate the peak value of the ac source. You know from earlier courses that the rms value of a sine wave equals:

$$V_{rms} = 0.707V_p$$

Therefore, the peak source voltage in Fig. 4-3 is:

$$V_p = \frac{V_{rms}}{0.707} = \frac{10\text{ V}}{0.707} = 14.1\text{ V}$$

With an ideal diode, the peak load voltage is:

$$V_{p(out)} = V_{p(in)} = 14.1\text{ V}$$

The dc load voltage is:

$$V_{dc} = \frac{V_p}{\pi} = \frac{14.1\text{ V}}{\pi} = 4.49\text{ V}$$

With the second approximation, we get a peak load voltage of:

$$V_{p(out)} = V_{p(in)} - 0.7\text{ V} = 14.1\text{ V} - 0.7\text{ V} = 13.4\text{ V}$$

and a dc load voltage of:

$$V_{dc} = \frac{V_p}{\pi} = \frac{13.4\text{ V}}{\pi} = 4.27\text{ V}$$

Figure 4-3 shows you the values that an oscilloscope and a multimeter will read. Channel 1 of the oscilloscope is set at 5 V per major division (5 V/Div). The half-wave signal has a peak value between 13 and 14 V, which agrees with the result from our second approximation. The multimeter also gives good agreement with theoretical values, because it reads approximately 4.22 V.

PRACTICE PROBLEM 4-1 Using Fig. 4-3, change the ac source voltage to 15 V. Calculate the second approximation dc load voltage V_{dc}.

4-2 The Transformer

Power companies in the United States supply a nominal line voltage of 120 V rms and a frequency of 60 Hz. The actual voltage coming out of a power outlet may vary from 105 to 125 V rms, depending on the time of day, the locality, and other factors. Line voltage is too high for most of the circuits used in electronics equipment. This is why a transformer is commonly used in the power-supply section of almost all electronics equipment. The transformer steps the line voltage down to safer and lower levels that are more suitable for use with diodes, transistors, and other semiconductor devices.

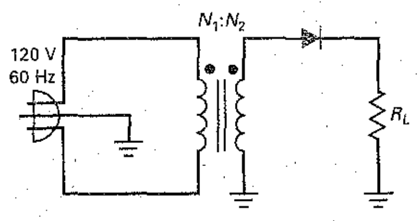
Basic Idea

Earlier courses discussed the transformer in detail. All we need in this chapter is a brief review. Figure 4-4 shows a transformer. Here you see line voltage applied to the primary winding of a transformer. Usually, the power plug has a third prong to ground the equipment. Because of the turns ratio N_1/N_2, the secondary voltage is stepped down when N_1 is greater than N_2.

Phasing Dots

Recall the meaning of the phasing dots shown at the upper ends of the windings. Dotted ends have the same instantaneous phase. In other words, when a positive half cycle appears across the primary, a positive half cycle appears across the

Figure 4-4 Half-wave rectifier with transformer.



secondary. If the secondary dot were on the ground end, the secondary voltage would be 180° out of phase with the primary voltage.

On the positive half cycle of primary voltage, the secondary winding has a positive half sine wave across it and the diode is forward biased. On the negative half cycle of primary voltage, the secondary winding has a negative half cycle and the diode is reverse-biased. Assuming an ideal diode, we will get a half-wave load voltage.

Turns Ratio

Recall from your earlier course work the following derivation:

$$V_2 = \frac{V_1}{N_1/N_2} \tag{4-5}$$

This says that the secondary voltage equals the primary voltage divided by the turns ratio. Sometimes you will see this equivalent form:

$$V_2 = \frac{N_2}{N_1} V_1$$

This says that the secondary voltage equals the inverse turns ratio times the primary voltage.

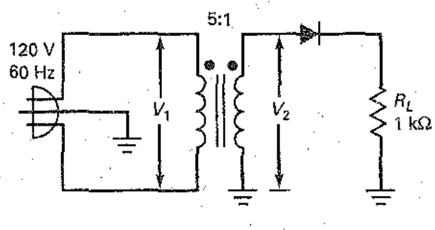
You can use either formula for rms, peak values, and instantaneous voltages. Most of the time, we will use Eq. (4-5) with rms values because ac source voltages are almost always specified as rms values.

The terms *step up* and *step down* are also encountered when dealing with transformers. These terms always relate the secondary voltage to the primary voltage. This means that a step-up transformer will produce a secondary voltage that is larger than the primary, and a step-down transformer will produce a secondary voltage that is smaller than the primary.

Example 4-2

What are the peak load voltage and dc load voltage in Fig. 4-5?

Figure 4-5



SOLUTION The transformer has a turns ratio of 5 : 1. This means that the rms secondary voltage is one-fifth of the primary voltage:

$$V_2 = \frac{120\text{ V}}{5} = 24\text{ V}$$

and the peak secondary voltage is:

$$V_p = \frac{24\text{ V}}{0.707} = 34\text{ V}$$

With an ideal diode, the peak load voltage is:

$$V_{p(\text{out})} = 34\text{ V}$$

The dc load voltage is:

$$V_{\text{dc}} = \frac{V_p}{\pi} = \frac{34\text{ V}}{\pi} = 10.8\text{ V}$$

With the second approximation, the peak load voltage is:

$$V_{p(\text{out})} = 34\text{ V} - 0.7\text{ V} = 33.3\text{ V}$$

and the dc load voltage is:

$$V_{\text{dc}} = \frac{V_p}{\pi} = \frac{33.3\text{ V}}{\pi} = 10.6\text{ V}$$

PRACTICE PROBLEM 4-2 Using Fig. 4-5, change the transformer's turns ratio to 2:1 and solve for the ideal dc load voltage.

4-3 The Full-Wave Rectifier

Figure 4-6*a* shows a **full-wave rectifier** circuit. Notice the grounded center tap on the secondary winding. The full-wave rectifier is equivalent to two half-wave rectifiers. Because of the center tap, each of these rectifiers has an input voltage equal to half the secondary voltage. Diode D_1 conducts on the positive half cycle, and diode D_2 conducts on the negative half cycle. As a result, the rectified load current flows during both half cycles. The full-wave rectifier acts the same as two back-to-back half-wave rectifiers.

Figure 4-6*b* shows the equivalent circuit for the positive half cycle. As you see, D_1 is forward biased. This produces a positive load voltage as indicated by the plus-mi[illegible]olarity across the load resistor. Figure 4-6*c* shows the equivalent circu[illegible] for the [illegible]ative half cycle. This time, D_2 is forward biased. As you can see, this [illegible] produ[illegible]s a positive load voltage.

I[illegible]n half cycles, the load voltage has the same polarity and the load current is in the same direction. The circuit is called a *full-wave rectifier* because it has changed the ac input voltage to the pulsating dc output voltage shown in Fig. 4-6*d*. This waveform has some interesting properties that we will now discuss.