EXERCISES

4.22 Derive the expressions in Eqs. (4.33), (4.34), and (4.35).

4.23 Consider a bridge-rectifier circuit with a filter capacitor C placed across the load resistor R for the case in which the transformer secondary delivers a sinusoid of 12 V (rms) having a 60-Hz frequency and assuming $V_D = 0.8$ V and a load resistance $R = 100\ \Omega$. Find the value of C that results in a ripple voltage no larger than 1 V peak-to-peak. What is the dc voltage at the output? Find the load current. Find the diodes' conduction angle. Provide the average and peak diode currents. What is the peak reverse voltage across each diode? Specify the diode in terms of its peak current and its PIV.
Ans. 1281 μF; 15.4 V or (a better estimate) 14.9 V; 0.15 A; 0.36 rad (20.7°); 1.45 A; 2.74 A; 16.2 V. Thus select a diode with 3.5-A to 4-A peak current and a 20-V PIV rating.

THE EARLIEST SEMICONDUCTOR DIODE:

The cat's whisker or crystal detector was the first electronic diode to be commercialized as an envelope detector for the radio-frequency signals used in radio telephony. The earliest diode, invented in Germany by Karl Ferdinand Braun, consisted of a small slab of galena (lead sulfide) to which contact was made by sharpened spring wire, which could be adjusted. For this and other contributions to early radios, Braun received the Nobel Prize in Physics in 1909. The silicon-based point-contact diode, later refined and packaged, was an important solid-state component of radar equipment during World War II.

4.5.5 Precision Half-Wave Rectifier—The Superdiode[4]

The rectifier circuits studied thus far suffer from having one or two diode drops in the signal paths. Thus these circuits work well only when the signal to be rectified is much larger than the voltage drop of a conducting diode (0.7 V or so). In such a case, the details of the diode forward characteristics or the exact value of the diode voltage do not play a prominent role in determining circuit performance. This is indeed the case in the application of rectifier circuits in power-supply design. There are other applications, however, where the signal to be rectified is small (e.g., on the order of 100 mV or so) and thus clearly insufficient to turn on a diode. Also, in instrumentation applications, the need arises for rectifier circuits with very precise and predictable transfer characteristics. For these applications, a class of circuits has been developed utilizing op amps (Chapter 2) together with diodes to provide precision rectification. In the following discussion, we study one such circuit. A comprehensive study of op amp–diode circuits is available on the website.

[4]This section requires knowledge of operational amplifiers (Chapter 2).

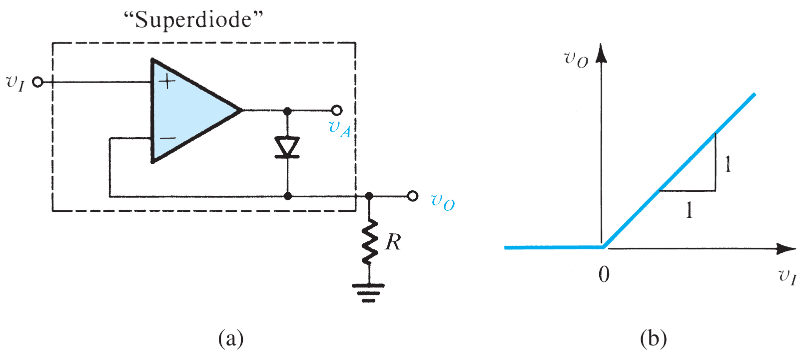

Figure 4.29 **(a)** The "superdiode" precision half-wave rectifier and **(b)** its almost-ideal transfer characteristic. Note that when $v_I > 0$ and the diode conducts, the op amp supplies the load current, and the source is conveniently buffered, an added advantage. Not shown are the op-amp power supplies.

Figure 4.29(a) shows a precision half-wave rectifier circuit consisting of a diode placed in the negative-feedback path of an op amp, with R being the rectifier load resistance. The op amp, of course, needs power supplies for its operation. For simplicity, these are not shown in the circuit diagram. The circuit works as follows: If v_I goes positive, the output voltage v_A of the op amp will go positive and the diode will conduct, thus establishing a closed feedback path between the op amp's output terminal and the negative input terminal. This negative-feedback path will cause a virtual short circuit to appear between the two input terminals of the op amp. Thus the voltage at the negative input terminal, which is also the output voltage v_O, will equal (to within a few millivolts) that at the positive input terminal, which is the input voltage v_I,

$$v_O = v_I \qquad v_I \geq 0$$

Note that the offset voltage ($\simeq 0.7$ V) exhibited in the simple half-wave rectifier circuit of Fig. 4.23 is no longer present. For the op-amp circuit to start operation, v_I has to exceed only a negligibly small voltage equal to the diode drop divided by the op amp's open-loop gain. In other words, the straight-line transfer characteristic v_O–v_I almost passes through the origin. This makes this circuit suitable for applications involving very small signals.

Consider now the case when v_I goes negative. The op amp's output voltage v_A will tend to follow and go negative. This will reverse-bias the diode, and no current will flow through resistance R, causing v_O to remain equal to 0 V. Thus, for $v_I < 0$, $v_O = 0$. Since in this case the diode is off, the op amp will be operating in an open-loop fashion, and its output will be at its negative saturation level.

The transfer characteristic of this circuit will be that shown in Fig. 4.29(b), which is almost identical to the ideal characteristic of a half-wave rectifier. The nonideal diode characteristics have been almost completely masked by placing the diode in the negative-feedback path of an op amp. This is another dramatic application of negative feedback, a subject we will study formally in Chapter 11. The combination of diode and op amp, shown in the dashed box in Fig. 4.29(a), is appropriately referred to as a "superdiode."