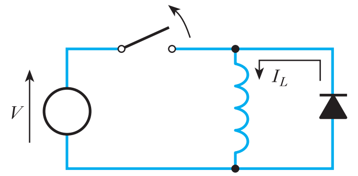


Figure 16.24 Use of a catch diode.

the diode, which then conducts and dissipates the stored energy. The diode must be able to handle a current equal to the forward current flowing before the supply is removed.

Key points

- Semiconductor materials are used at the heart of a multitude of electronic devices.
- The electrical properties of materials are brought about by their atomic structure.
- At very low temperatures semiconductors have the properties of an insulator. At higher temperatures thermal vibration of the atomic lattice leads to the generation of mobile charge carriers.
- Pure semiconductors are poor conductors, even at high temperatures. However, the introduction of small amounts of impurities dramatically changes their properties.
- Doping of semiconductors with appropriate materials can lead to the production of *n*-type or *p*-type materials.
- A junction between *n*-type and *p*-type semiconductors (a *pn* junction) has the properties of a diode.
- Semiconductor diodes approximate ideal diodes, but have a conduction voltage. Silicon diodes have a conduction voltage of about 0.7 V.
- In addition to conventional *pn* junction diodes, there are a wide variety of more specialised diodes, such as Zener, Schottky, tunnel and varactor diodes.
- Diodes are used in a range of applications, in both analogue and digital systems, including rectification, demodulation and signal clamping.

Exercises

16.1 Describe briefly the electrical properties of conductors, insulators and semiconductors.

16.2 Name three materials commonly used for semiconductor devices. Which material is most widely used for this purpose?

16.3 Outline the effect of an applied electric field on free electrons and holes.

16.4 Explain, with the aid of suitable diagrams where appropriate, what is meant by the terms ‘tetravalent material’, ‘covalent bonding’ and ‘doping’.

16.5 What are meant by the terms ‘intrinsic conduction’ and ‘extrinsic conduction’? What form of charge carriers is primarily responsible for conduction in doped semiconductors?

Exercises continued

16.6 Explain what is meant by a depletion layer and why this results in a potential barrier.

16.7 Explain the diode action of a *pn* junction in terms of the effects of an external voltage on the drift and diffusion currents.

16.8 Sketch the current–voltage characteristic of a silicon diode for both forward- and reverse-bias conditions.

16.9 Sketch the current–voltage characteristic of an ideal diode.

16.10 What is the difference between a diode and a rectifier?

16.11 What is meant by the reverse saturation current of a diode?

16.12 Explain what is meant by the turn-on voltage and the conduction voltage of a diode. What are typical values of these quantities for a silicon diode?

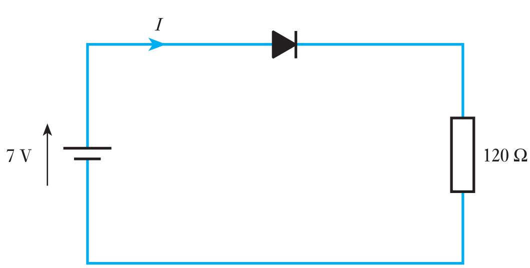
16.13 What are typical values for the turn-on voltage and conduction voltage of diodes formed from germanium and gallium arsenide?

16.14 Explain the use of equivalent circuits of diodes and give examples of diode equivalent circuits of different levels of sophistication.

16.15 Use computer simulation to plot the characteristic of a typical silicon diode, such as a 1N4002, and use this to determine appropriate values for V_{ON} and r_{ON}. Assume that the diode is to be used in a circuit where the quiescent current through the diode will be approximately 20 mA, then construct an equivalent circuit of the diode when used in such a circuit.

16.16 Repeat the previous exercise using a different diode, such as a 1N914, and compare your results.

16.17 Explain, with the aid of a suitable sketch, how you would use load line analysis to determine the current I in the following circuit.



16.18 Estimate the current in the circuit of the previous exercise, assuming that the diode can be adequately represented by an equivalent circuit consisting of an ideal diode and a fixed voltage source.

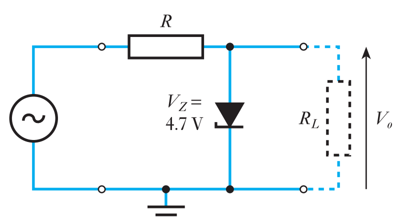
16.19 Explain the terms 'Zener breakdown' and 'avalanche breakdown'.

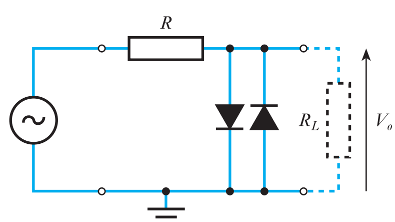
16.20 Sketch a simple circuit that uses a Zener diode to produce a constant output voltage of 5.6 V from an input voltage that may vary from 10 to 12 V. Select appropriate component values, such that the circuit will deliver a current of at least 100 mA to an external load, and estimate the maximum power dissipation in the diode.

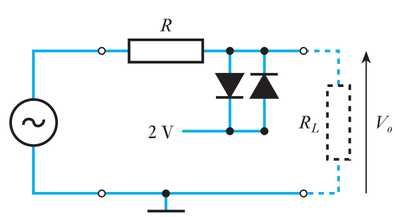
16.21 A half-wave rectifier is connected to a 50 Hz supply and generates a peak output voltage of 100 V across a 220 μF reservoir capacitor. Estimate the peak ripple voltage produced if this arrangement is connected to a load that takes a constant current of 100 mA.

16.22 What would be the effect on the ripple voltage calculated in the last exercise of replacing the half-wave rectifier with a full-wave rectifier of similar peak output voltage?

16.23 Sketch the output waveforms of the following circuits. In each case, the input signal is a sine wave of ±5 V peak.







Exercises continued

16.24 Use circuit simulation to verify your answers to the last exercise. How does the value of R_L affect the operation of the circuits?

16.25 Design a circuit that will pass a signal unaffected, except that it limits its excursion to the range $+10.4\ \text{V} > V > -0.4\ \text{V}$.

16.26 Use circuit simulation to verify your solution to the last exercise.