Chapter 3

Semiconductors And Junction Diodes

OUTLINE

- Semiconductors
- Covalent Bonding
- PN Junction Diodes
- Diode Characteristics and Lead Identification
- Diode Malfunctions and Fault Isolation Techniques
- Diode Types and Applications

OBJECTIVES

Given various electronic devices, symbols, and diagrams, you will be able to accomplish the following objectives:

- Describe semiconductor theory of operation.
- Describe the covalent bonding process for semiconductors.
- Describe and explain electron and hole flow in a semiconductor.
- Describe basic solid-state theory of a diode.
- Define the terms forward and reverse bias.
- Identify the name and function of various types of diodes.

Semiconductors

- An atom will always attempt to fill its valence shell with eight electrons.

- If the atom does not have eight valence electrons, it will attempt to either gain enough electrons to fill the valence shell or give up all of its valence electrons to completely empty its valence shell.

- No atom can have more than eight electrons in its valence shell. Atoms with fewer than four valence electrons will attempt to give up their valence electrons. Materials made of atoms with fewer than four valence electrons are called conductors of electricity.

- Atoms with more than four valence electrons tend to not give up their valence electrons. Materials made of atoms with more than four valence electrons are insulators.

- Semiconductors have four valence electrons. As such, they are neither good conductors nor good insulators.

- A semiconductor atom will readily give up its four valence electrons or accept four electrons to fill its outer shell.

- The most common semiconductor materials used in electronics today are silicon, germanium, and carbon.

- Semiconductor materials have a negative temperature coefficient. As temperature increases, resistance decreases.

Covalent Bonding

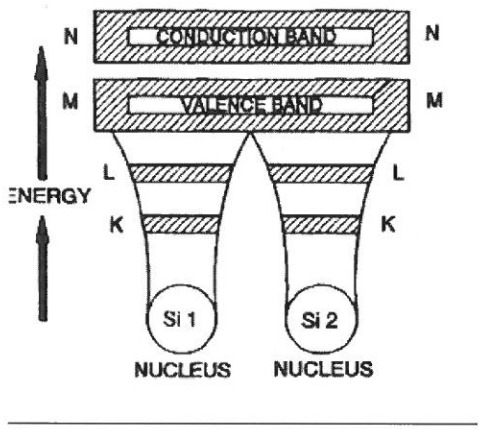


Figure 3-1

- When atoms are brought close together, there is an interaction between the orbits of the atoms.

- The valence orbits will overlap and act as a single valence band (only the outermost orbit is affected). The sharing of valence electrons is called covalent bonding.

- Figure 3-1 shows two Silicon atoms sharing valence electrons. The structure that results is called a crystal.

Valence Band

- As more and more atoms are brought together, the valence orbits continue to interact until they form a solid permissible energy level called the valence band.

Conduction Band

- The conduction band is simply the next orbit (permissible energy level) above the valence band. This band is made up of any "free" electrons present, and can provide a flow of electrons in response to an applied potential difference.

- Valence electrons are still under the influence of the nucleus. An external force such as heat or light must be used to elevate the valence electrons from the valence band into the conduction band.

Electron-Hole Pair Generation

- When a valence electron has been elevated from the valence band to the conduction band, this electron leaves behind a vacancy in the valance band. This vacancy is called a hole. The free electron and its adjacent hole form what is termed an electron-hole pair.

Crystal Structure

- Covalent bonding in a silicon structure results in the formation of a crystalline structure. Each atom shares its valence electrons with its neighboring atom. This makes each atom think that its valance orbit is full (eight valence electrons).

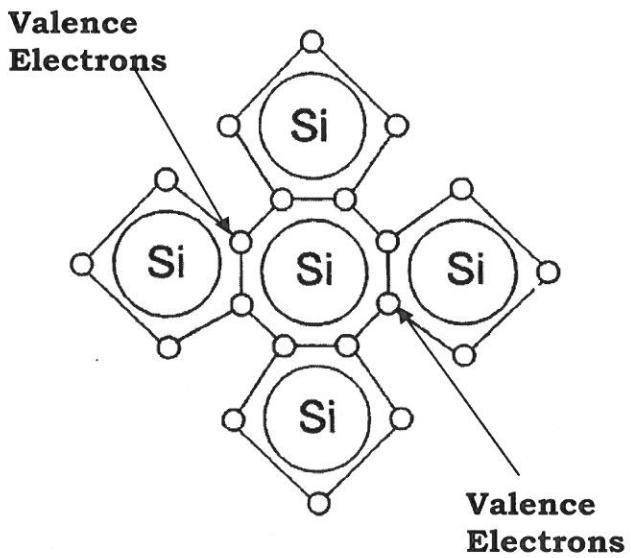


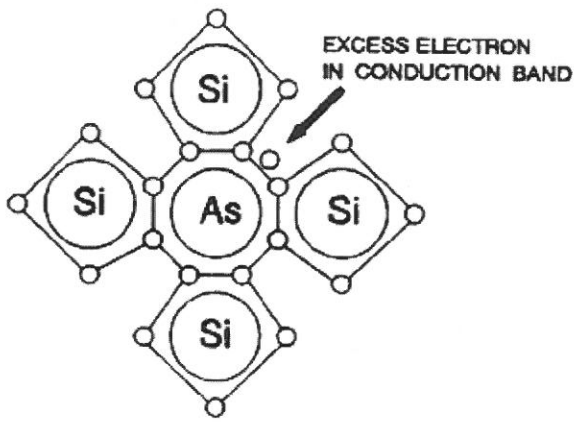
Figure 3-2

Doping

- Doping is the process of adding of impurities to pure semiconductor material.

- Pure silicon contains very few free electrons to support the flow of current. Pure silicon, without the addition of impurities, is called intrinsic. When certain impurities are added to the crystal during the manufacturing process, the number of free electrons is increased. These free electrons are available to product a current flow. Once an impurity has been added, the crystal is called extrinsic.

N-Type Material (Donor Impurity)



Covalent Bonding With
Donor Impurity

Figure 3-3

- When an impurity is added to semiconductor material to form a covalent bond, sometimes there is one electron (or excess of electrons) that is not used to form the bond.

- This electron is not under the influence of the nucleus and will go into the conduction band where it becomes a free electron. Because this type of impurity donates one electron to the conduction band without generating a hole in the valence band it is referred to as a donor impurity.

- Arsenic is a common donor impurity. It has five valence electrons, one more than needed to complete the covalent bond. Because this material has an excess of free electrons, this type of material will conduct by electron movement and have an overall negative potential. It is called N-type material.

Majority and Minority Carriers

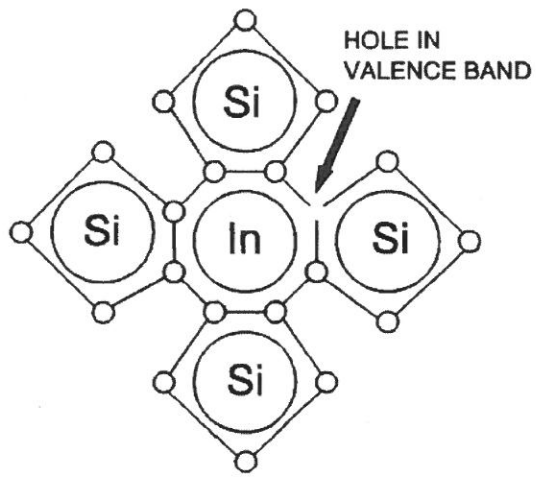
- As we have established, there is a great number of free electrons in an N-type material. These electrons are called majority carriers. The level of doping determines the number of majority carriers.

- In addition, some of the bonded electrons in the Si to Si bonds will absorb enough energy from heat to escape the bond and move into the conduction band.

- The result is the formation of an electron-hole pair. The freed electron simply joins the other free electrons simply join the other free electrons in the conduction band as a majority carrier, but the vacated hole is also a current carrier. These holes are called minority carriers.

- Also, material impurities will be present that will offer "holes". These also will be minority carriers in the N-type material.

P-Type Material (Acceptor Impurity)



Covalent Bonding with Acceptor Impurity

Figure 3-4

- To create P-Type material, intrinsic silicon is doped with an impurity that has three valence electrons. Indium and Boron are two common examples.

- Indium has one electron less than it needs to form all the covalent bonds with its four neighboring atoms. There, an incomplete covalent bond (hole) is created. Because this impurity created a hole, which will accept one electron to complete the bond, it is called an acceptor impurity.

Majority and Minority Carriers

- Since the number of holes are increased without increasing the number of electrons, conduction is by hole movement and the material has an overall positive potential.

- The hole is actually a mobile positive charge and exists in the valence band. These holes are the majority current carriers.

- When exposed to heat or light some bonded electrons will escape into the conduction band and become current carriers. These freed electrons are the minority carriers in the P-type material. As with the N-type material, the number of majority carriers is determined by the amount of doping.

Activity 1

Semiconductors

Determine whether each statement is true or false.

1. When two atoms are moved close together so that their valence shells overlap, a valence band is formed.
2. The conduction band is the next permissible energy level above the valence band.
3. Semiconductors have three or less valence electrons.
4. Intrinsic silicon acts as a conductor at room temperature.
5. A free electron in P-type material is called majority current.

Complete the following statements.

6. The sharing of valence electrons with neighboring atoms is called _____.
7. The process of adding impurities to a silicon crystal is called _____.
8. Once an impurity has been added to a silicon crystal, the crystal is called _____.
9. As temperature is increased in semiconductor material, resistance decreases. This is called a _____.
10. When heat is used to break a covalent bond, both a free electron and a free hole is produced. This process is called _____ generation.
11. Indium and Boron are _____ impurities.
12. As heat increases, the number of minority and majority current carriers _____ (increases/decreases).

PN Junction Diodes

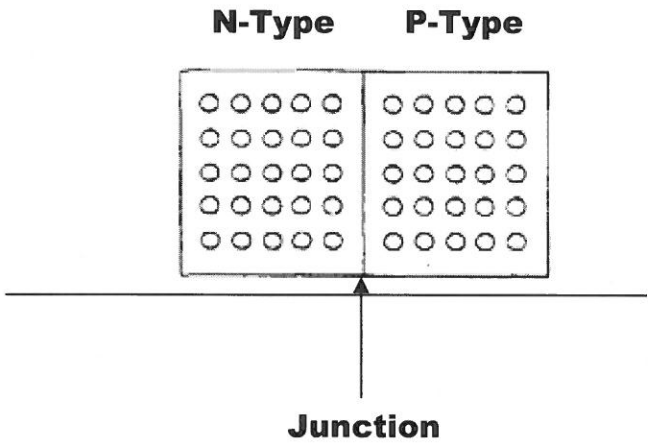


Figure 3-5

- A PN junction is one continuous structure that contains a P-type region with free holes and an N-type region with free electrons.

- When P-type and N-Type are joined together forming a PN junction, the electrons in the N-type material diffuse across the junction into the P-type material and fill the holes. This action is called junction recombination.

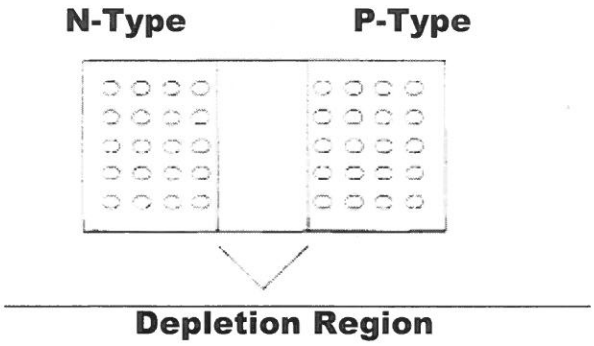


Figure 3-6

- Since the electron current carriers on the N-side of the junction moved over to the P-side of the junction and filled the holes, the area on both side of the junction is depleted of current carriers. This region is called the depletion region.

- The barrier potential is an electrical force or potential formed along with the depletion region that prevents any more electrons in the N-type material from crossing over and filling any more of the holes in the P-type material.

Forward Bias

- An external DC potential (such as a battery) applied across a PN junction is called a bias. Figure 3-7 is a diagram of a forward biased junction.

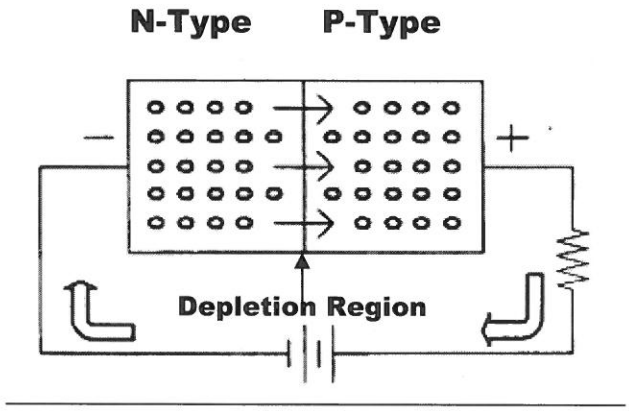


Figure 3-7

- When the DC potential is connected to the PN junction where it opposes the depletion region, the junction is forwarded biased.

- A forward-biased junction has many characteristics of a shorted component: low resistance, large majority current flow, and zero volts.

Current Flow

- Since large amounts of majority current flow, the PN junction is considered to be conducting or ON.

Reverse Bias

- Reverse bias is when an external DC potential is connected across a PN junction to aid the depletion region. Figure 3-8 is a diagram of a reverse biased junction.

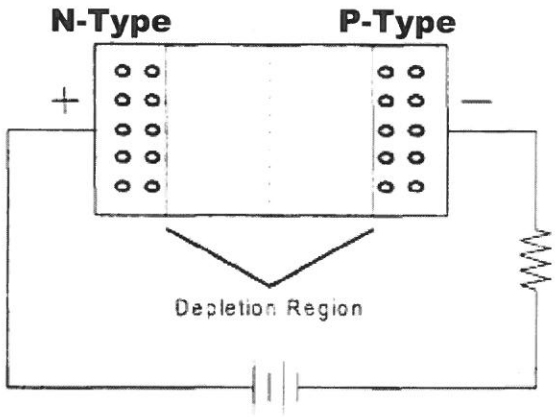


Figure 3-8

Impact on Depletion Region

- The depletion region is increased in width and in height. It acts as an insulator and will block the flow of current.

Current Flow

- A reverse biased PN junction has no majority current flow. Any trickle current that flows is due to the minority current carriers. The PN junction behaves as an open component: Maximum resistance, no current flow, and maximum voltage.

Activity 2

PN Junction Diodes

Determine whether each statement is true or false.

1. The depletion region is a good insulator.
2. Reverse bias reduces the depletion region.
3. Forward bias turns the diode on.
4. A junction diode is doped with both P and N-type impurities.
5. The depletion region permits the recombination of holes and electrons.

Complete the following statements.

6. The _____ of a diode is that part of the crystal where the N-type material ends and the P-type material begins.
7. The region of the diode where there are no free current carriers left is called the _____ region.
8. A potential connected across a PN junction that collapses the depletion region is called _____.
9. When a diode is _____, the depletion region is an insulator and blocks the flow of current.
10. N-type material has a few minority _____ while P-type material has few minority _____.

Diode Characteristics and Lead Identification

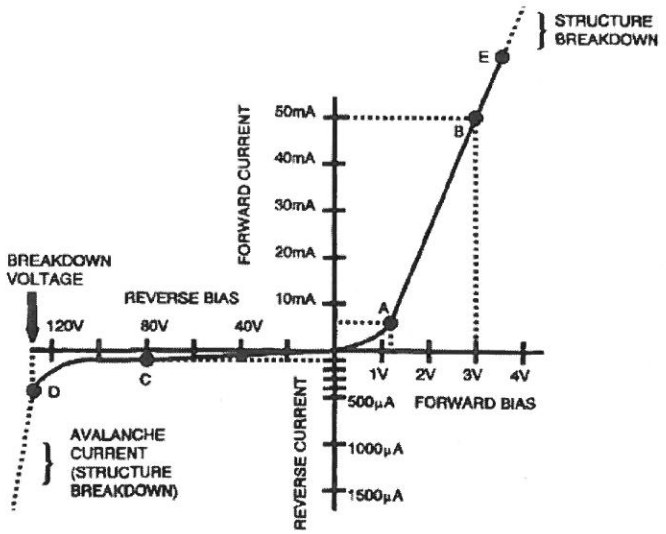


Figure 3-9

- Characteristic curves of PN junctions show the amount of current flow for different values of voltages. This is called a volt-ampere characteristic curve of a diode.

- At point A, in Figure 3-9, the forward voltage is 1V and the forward current is 5mA. This represents 200Ω of resistance. At point B, the voltage is 3V and the current is 50mA. This represents 60Ω of resistance for the diode. Forward bias is increased only three times, however the current is increased ten times. The resistance is decreased to 60 ohms when forward bias voltage is increased.

- The PN junction diode conducts very little when reverse biased. At point C, in Figure 3-9, the reverse voltage is 80V and the current is 100μA. The diode has 800kΩ of resistance, which is significantly larger than the resistance of the junction with forward bias. Both forward bias and reverse bias situations demonstrate the non-linear characteristics of a PN junction diode.

- At reverse bias voltages greater than point D or about 130 volts in figure 3-9, current flow increases rapidly. Current at this point in the curve is called avalanche current. If the reverse current is not limited, the device will break down.

Diode Diagrams

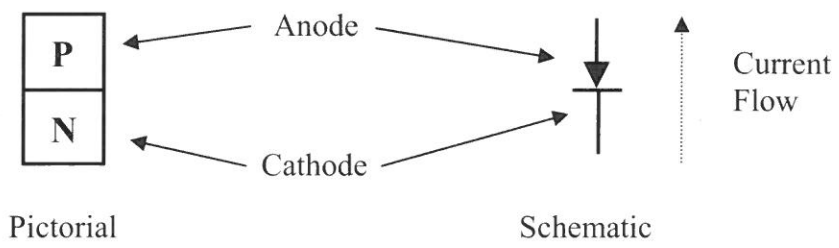


Figure 3-10

- The anode represents the P-Type material, and identifies the terminal that attracts electrons. It is always shown as an arrow in a schematic diagram. The main purpose of a diode is to allow current flow in one direction. Electron flow is always against the arrow (cathode to anode)

- The cathode represents the N-Type material. It is always shown as a bar in a schematic diagram. Any markings on a diode represent the cathode lead. In older diodes, a plus (+) sign denotes the cathode lead.

- PN junction diodes are generally rated for maximum average forward current (max average current allowable during forward bias), peak recurrent forward current (maximum peak current permitted during forward bias in the form of recurring pulses), maximum surge current (maximum current permitted during forward bias in the form of non-recurring pulses) and peak inverse voltage (maximum voltage during reverse bias).

Activity 3

Diode Characteristics and Lead Identification

Define the following terms:

1. Reverse Breakdown Voltage

2. Avalanche Current

3. Volt-Ampere Characteristic Curve

Complete the following statements.

4. The volt-ampere characteristic curve of a diode is _____.
5. The _____ lead represents N-type material and the _____ lead represents P-type material.
6. Structural breakdown is caused by excessive _____ or _____.
7. The characteristics curve of a diode is _____.
8. Manufacturers mark the cathode lead with a band, bevel, flange, or _____.

Diode Malfunctions and Fault Isolation Techniques

Malfunctions

- The most common types of diode malfunctions are caused by too much forward or reverse bias being applied to the diode. This causes the PN junction to become shorted or opened.

- Occasionally, the diode also becomes leaky and loses its characteristic of allowing current to flow in only one direction.

- An open diode will measure maximum voltage, infinite ohms, and zero current flow. An open diode will measure infinite ohms in both the forward and reverse biased directions. A good diode measures high ohms when reverse biased and low ohms when forward biased. (10:1 ratio)

- When tested, a shorted diode will measure zero volts, zero ohms, and maximum current flow. The resistance of a shorted diode will measure zero ohms when checked in both the forward and reversed biased directions.

- Leaky diodes measure a fixed resistance in both the forward and reverse bias directions condition (less than 10:1 resistance ratio).

Fault Isolation Techniques

- A voltmeter can be used to isolate a faulty diode. A good diode will measure high voltage if reverse biased, and near zero volts if forward biased. On the other hand, a shorted diode will read zero volts whether forward or reverse biased.

- An oscilloscope can also be used to isolate a faulty diode. If an AC voltage (referenced at zero volts) is ever measured across a diode, the diode is open. Remember a good diode will conduct when forward biased (measure 0 V).

- Once the diode is determined to be faulty, the best method to determine the condition of a diode is to use an ohmmeter to measure its resistance ratio. Most digital multimeters today have a diode feature, which gives a beep when the diode is forward biased

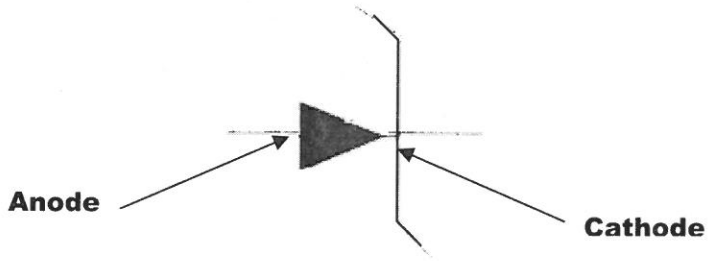
Activity 4

Diode Malfunctions and Fault Isolation Techniques

Complete the following statements.

1. The most common types of diode malfunctions are caused by too much _____ or _____ being applied to the diode.
2. The most common types of test equipment used to isolate a faulty diode are the _____, _____ and the _____.
3. An ideal diode acts like a/an _____ component when forward bias is applied and a/an _____ component when reverse bias is applied.
4. A shorted diode will measure _____ ohms when forward bias is applied and _____ ohms when reverse bias is applied.
5. If an AC voltage waveform is ever measured across a diode with an oscilloscope, this automatically indicated the diode is_____.
6. To forward bias a diode, the anode must be made _____ (positive/negative) with respect to the cathode.
7. The reverse resistance of a good diode must be at least _____ times greater than the forward resistance.
8. The best method to test the condition of a diode is to use a _____ and check the _____.

Diode Types and Applications



Zener Diode

Figure 3-11

Zener Diode

- The purpose of the zener diode is to regulate voltage. Zener diodes conduct from anode to cathode (they allow current flow with the arrow). They operate in a reverse biased condition.

- The schematic symbol for the cathode of a zener diode resembles a "z." The zener is placed in parallel with the load and is always operated with a series current-limiting resistor. Zener diodes are not usually operated with a forward bias.

- When reverse biased, the zener acts as a voltage regulator or a current surge protection device. Zener diodes are heavily doped; therefore it will take very little forward voltage to produce a large increase in forward current.

- In reverse bias condition, the zener is used as a voltage regulator. It will not conduct until it reaches the zener voltage or the reverse breakdown voltage (RBV).

- The RBV is accompanied by high reverse current, and if left unchecked, may ultimately destroy the diode.

- A series current limiting resistor is always used in conjunction with the zener diode. The amount of current that flows through a zener is determined by two factors: a series current-limiting resistor and the parallel load resistance.

- When a regulated voltage in excess of the rating of one zener is required, two or more zeners may be connected in series to provide proper regulation.

- When forward biased, the zener will act like a normal diode.

Schottky Diode

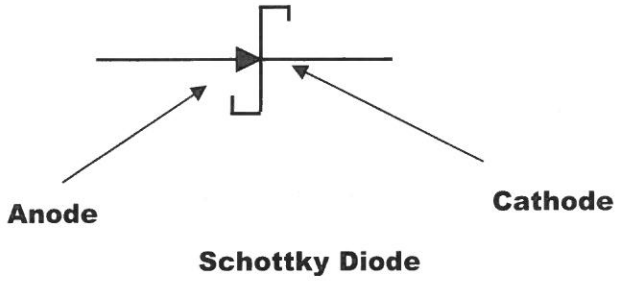


Figure 3-12

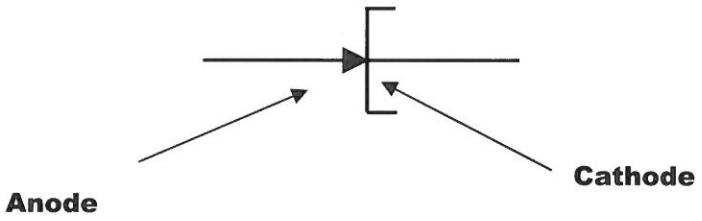
- The Schottky diode is a metal-to semiconductor. It is designed with the N-type (cathode) of the silicon bonded directly to platinum (anode). It has no depletion region. This type of construction allows the Schottky to provide faster switching than the PN junction diode.

- When forward-biased, the electrons in the N-type cathode must gain energy to cross the barrier to the metal anode. Once the electrons reach the metal, they join a large number of free electrons and quickly give up their extra energy.

- When reverse bias is applied, the diode stops conducting almost immediately, since a depletion region does not have to be established to block current flow. At this point, the electrons will be unable to cross back over the barrier because they now lack the extra energy needed to do so.

- If more than about 50V of reverse bias is applied, the electrons will gain the required energy and the barrier will break down and conduct. For this reason, the Schottky cannot be used in high-voltage applications. It is well suited for high frequency, low voltage applications.

Tunnel Diode



Tunnel Diode

Figure 3-13

- This diode is sometimes used as an electronic switch. Its key features are that it can switch at high speeds and it takes little power to operate.

- Because the tunnel diode is heavily doped, the depletion region is very thin. A unique feature of the Tunnel diode is that a continued increase in forward voltage causes a decrease in forward current. This phenomenon is called a "tunneling effect." This occurrence is also termed negative resistance.

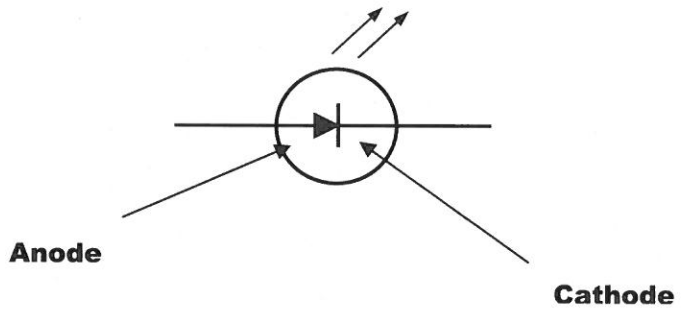
- When a small amount of forward bias is applied to the diode, a large amount of current is produced. This is due to the large numbers of current carries produced by the excessive doping. The electrons from the cathode are said to "tunnel" through the barrier almost instantaneously.

- This occurs primarily because the barrier is so thin. A further increase in forward bias causes the current flow to decrease to nearly zero amps. However, as the forward bias is increased even further, the current will increase again. At this point the Tunnel diode will perform like a conventional diode.

- Reverse bias applied to a Tunnel diode will also result in a significant amount of current flow. This is due to the heavy amount of doping applied to both elements of the diode.

- Tunnel diodes can be used as conventional diodes, switching circuits, oscillators and high frequency amplifiers.

Light Emitting Diode



Light Emitting Diode

Figure 3-14

- The LED is defined as a semiconductor diode, usually of the Gallium-Arsenide type, which emits coherent light when forward bias is applied to its terminal.

- The symbol, shown in Figure 3-14, has two arrows, which indicate emitted light. A popular arrangement is the seven-segment LED, which is used to display numbers from 0-9.

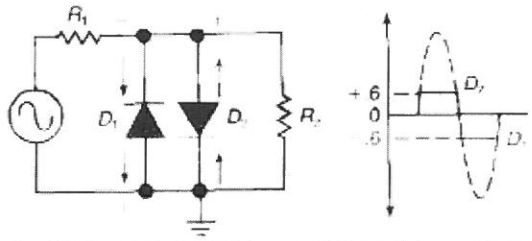
- Gallium Arsenide is one of the materials used to produce visible light. The color projected by any LED is dependent on the material used when it is manufactured.

- The seven-segment display consists of seven individual LEDs that are contained in one package. These diodes are operated by a driver circuit, which causes different combinations of the diodes to be ON, or forward biased at different times. Forward biasing selected diodes produces the numerals 0-9.

- The invention of the LED has greatly aided the field of electronics, especially in the areas of indicators, readouts, and in remote control devices. Other applications are card reading applications, electro-optical switching applications, and burglar alarms.

Applications

Limiters



Clippers (Limiters)

Figure3-15

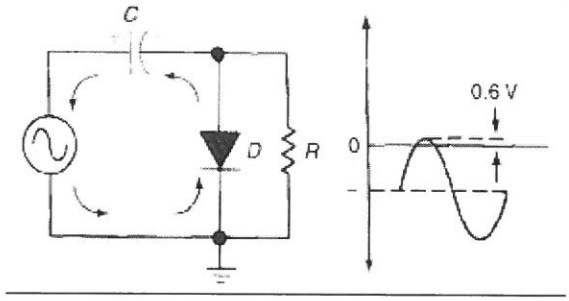
- A Clipper, also called a Limiter, is defined as a device that limits or prevents some characteristic of a waveform from exceeding a specific value.

- Clippers have three main purposes: 1) to keep signals from exceeding a certain limit, 2) to change the shape of a signal, and 3) to remove noise and distortion from a signal.

- Clippers or limiters can be positive or negative. Negative limiters remove part or all of the negative alternation of a waveform. Positive limiters remove part or all of the positive alternation of a waveform.

- As wave-shaping circuits, limiters clip or modify the wave shape of a signal. As protection circuits, limiters prevent a voltage from exceeding a specified negative or positive voltage level. The fact that a limiter puts out a signal with constant amplitude eliminates any noise that may be riding on the incoming signal.

Clamps



Negative Clamp (DC Restorer)

Figure 3-16

- Clamps or DC restoration circuits are similar to clipper circuits, but they have no effect of the waveform to be clamped. Clamps only move the entire waveform by adding or subtracting from its reference voltage level.

- Like clippers, clamps can also be negative or positive. The term negative clamp is used when the amplitude of the signal to be clamped is subtracted from the reference voltage. The term positive clamp is used when the amplitude of the signal to be clamped is added to the reference voltage level.

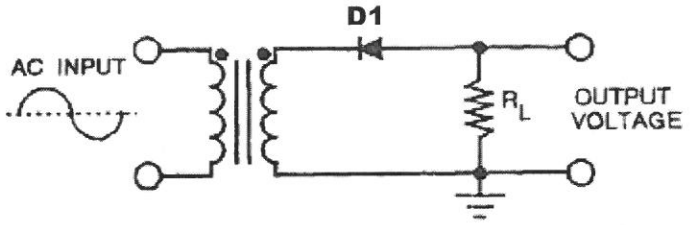
- A typical clamper circuit consists of a capacitor, a resistor and a diode.

- The resistor is used to provide a discharge path for the capacitor. This resistance value is large, so the discharge time of the capacitor will be very long.

- The diode provides a very fast charge path for the capacitor. Once the capacitor becomes charged, it will act as a source of voltage.

- Electrostatic and electromagnetic sweep voltage circuits, as well as gating and counting circuits are a few applications of clamper circuits.

Rectifiers



Rectifier Circuit

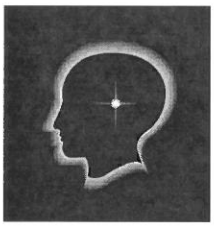
Figure 3-17

- Most electronic circuits need direct current (DC), however, power companies supply alternating current (AC). To convert AC to DC, rectification is required.

- Rectification is the process of changing AC into DC. Since a diode only allows current flow in one direction, they can serve as rectifiers.

- A typical power supply consists of a transformer, a diode, and a load resistor as shown in Figure 3-17. There are three types, half-wave, full-wave and full-wave bridge. These circuits will be discussed later in Chapter 6.

- Rectifiers are used extensively in power supply circuit operations.



Activity 5

Diode Types and Applications

Determine whether each statement is true or false.

1. Rectifier diodes are used in the same way as zener diodes.
2. Zener diodes are normally operated with the cathode negative with respect to the anode.
3. Light-emitting diodes emit light by heating a tiny filament red hot.
4. Diode clippers are also called limiters.
5. Clippers add a DC component to an AC signal.
6. As the forward bias is increased in a tunnel diode the forward current is decreased.

Complete the following statements.

7. A _____ diode is used to change alternating current to direct current.
8. _____ diodes do not have a depletion region.
9. The depletion region of the _____ diode is very thin because of heavy doping.
10. A _____ diode emits light when forward biased.

The purpose of this chapter is to provide a general understanding of the subject areas addressed. For more information on the topics covered in this unit, refer to the reference books and other study materials listed in the Study Guide for the Basic Electronics Test.

SUMMARY

1. *The outermost shell of an atom is called the valance shell.*
2. *When two atoms are brought close together so that their valence shells overlap, a valance band is formed.*
3. *The conduction band is the next permissible energy level above the valance band.*
4. *Semiconductors have four valence electrons.*
5. *Heating semiconductors reduce their resistance. This is called a negative coefficient of resistance.*
6. *The process of adding impurities to a semiconductor crystal is called doping.*
7. *Donor impurities have five valence electrons and produce free electrons in a semiconductor crystal. This process forms N-type material.*
8. *Acceptor impurities have three valence electrons and produce free holes in a semiconductor crystal. This process forms P-type material.*
9. *Majority carriers are electrons for N-type material. Holes are majority carriers for P-type material.*
10. *Minority carriers are holes for N-type material and electrons for P-type material.*
11. *Forward bias causes majority current to flow and collapses the depletion region. The diode conducts or is "turned on."*
12. *Reverse bias widens the depletion region. This forces the minority carriers (trickle current) to flow across the junction. The diode is "turned off."*
13. *The volt-ampere characteristic curve of a diode is nonlinear.*
14. *The anode lead of a diode attracts electrons while the cathode lead emits electrons. The anode represents the P-type material and the cathode represents the N-type material.*
15. *An ohmmeter test is the most reliable method for isolating the condition of a diode.*
16. *Schottky diodes do not have a depletion region.*
17. *Zener diodes are used to regulate voltage. They conduct from anode to cathode when regulating voltage.*
18. *A diode limiter can be used to stabilize the peak-to-peak amplitude of a signal.*
19. *Light-emitting diodes are used as transmitters and indicators.*
20. *Clamps or DC restorers add a DC component to an AC signal.*
21. *Tunnel diodes decrease in forward current with an increase in forward voltage. This is called the "tunneling effect."*
22. *Rectifiers change AC into DC.*

Chapter 3 Self Test

Answer the following statements.

1. Which diode is properly labeled?

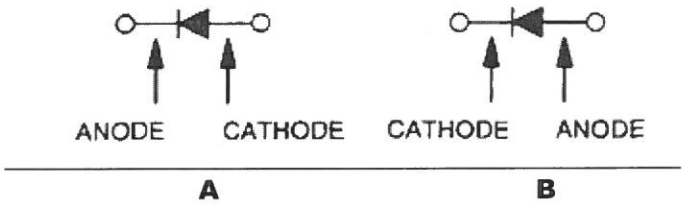


Figure 3-18

2. The process of adding impurities to a crystal structure is referred to as

   a. doping
   b. biasing
   c. conducting.

3. _____ is used as a donor impurity.

4. _____ is used as an acceptor impurity.

5. Conduction in P-type material is mainly due to the movement of
   a. electrons
   b. crystals
   c. holes

6. The _____ prevents all of the electrons on the N-type side from crossing the junction to fill the holes in the P-type side.

7. Junction recombination results in the development of a(n) _____ region.

   a. low resistance
   b. conduction
   c. depletion

8. If the temperature of a diode is increased, its resistance will _____. This is called a _____ temperature coefficient.

9. Connecting the positive side of the battery to the P-type material of a diode and the negative side to the N-type material will establish

   a. reverse bias
   b. forward bias
   c. equal bias

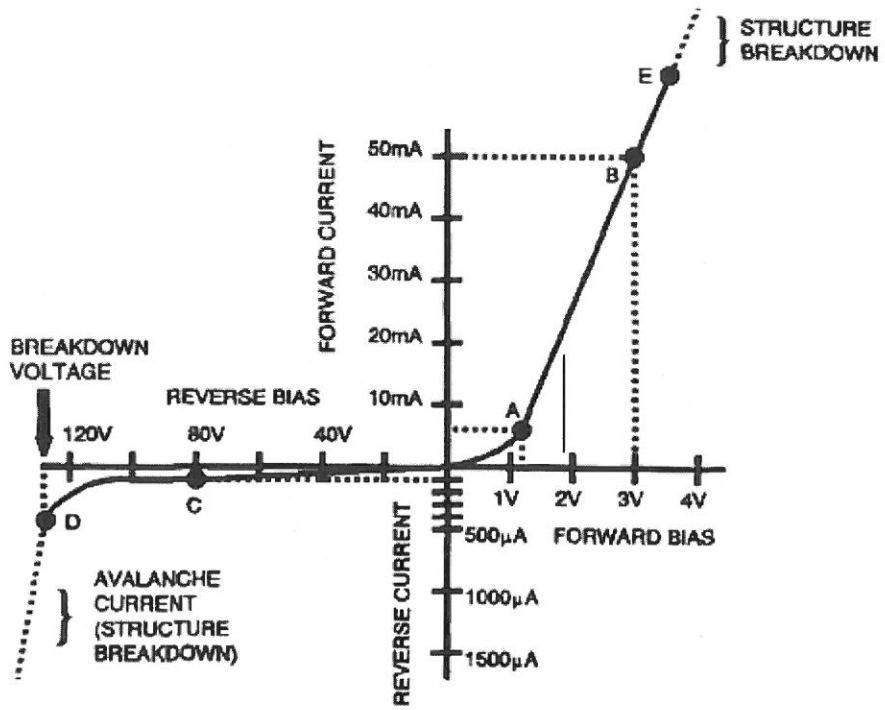


Figure 3-19

Use Figure 3-19 to answer questions 10-13.

10. With 2 volts of forward bias, the forward current is approximately

   a. 12mA
   b. 16mA
   c. 20mA
   d. 27mA

11. Would 4 volts of forward bias be an excessive amount?

    a. Yes
    b. No

12. With 80 volts of reverse bias, the reverse current is approximately

    a. 100μA
    b. 200μA
    c. 300μA
    d. 500μA

13. Would 120 volts of reverse bias be an excessive amount?

    a. Yes
    b. No

14. A plus (+) sign on an older diode denotes the _____ lead.

15. When the positive lead from an ohmmeter is applied to the anode lead of a diode, the diode is turned _____.

16. If the resistance of a diode measures infinity in both directions, the diode is

    a. good
    b. open
    c. leaky
    d. shorted

17. If an AC waveform is displayed with an ocsilloscope when probing across a diode in a circuit, the diode is

    a. good
    b. open
    c. leaky
    d. shorted

18. If zero ohms is measured across a diode in both directions, the diode is
    a. good
    b. open
    c. leaky
    d. shorted

19. If the resistance of a diode measures 10 ohms in one direction and 1k ohms in the other direction, the diode is

    a. good
    b. open
    c. leaky
    d. shorted

20. What is meant by the term "reverse breakdown voltage" as applied to the Zener diode?

21. What is the difference in the conduction path of a Zener diode as compared to an ordinary diode?

22. What gives the tunnel diode its extremely thin barrier?

23. What does the term "negative resistance" region of a tunnel diode mean?

24. Name two purposes of clipper or limiters in a circuit.

25. What is the purpose of a diode clamp in a circuit?

26. The LED is a PN junction of a crystal material that produces light when forward biased.

    a. True
    b. False

27. What determines the color of an LED?

28. A _____ is a device that changes AC into DC.

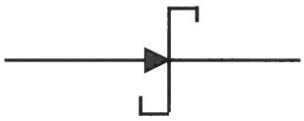


Figure 3-20

Use Figure 3-20 to answer questions 29 and 30.

29. The diode represented in Figure 3-20 is called a _____ diode.

30. What is the major difference in the construction of the diode in Figure 3-20 and the construction of an ordinary diode?

Unit 3 Answer Key

Activity 1

1. True
2. True
3. False
4. False
5. False
6. Covalent bonding
7. Doping
8. Extrinsic
9. Negative temperature coefficient
10. Electron-hole pair
11. Acceptor
12. Increases

Activity 2

1. True
2. False
3. True
4. True
5. False
6. Junction
7. Depletion
8. Forward bias
9. Reverse biased
10. Holes; Electrons

Activity 3

1. Reverse breakdown voltage is excessive reverse voltage that causes structure breakdown. Excessive reverse current is released and destroys the diode. Zener diodes operate during reverse breakdown voltage.

2. Avalanche current is excessive current flow at the point of structure breakdown. Avalanche current occurs in the reverse bias condition.

3. A volt-ampere characteristic curve shows the amount of current flow for different values of voltage for a PN junction.

4. A graph of the amount of current flow for different values of voltages for a PN junction.

5. Cathode; Anode

6. forward bias; reverse bias

7. Non-linear

8. Plus (+) sign

Activity 4

1. Forward bias, reverse bias
2. Voltmeter; oscilloscope: ohmmeter
3. Shorted, open
4. Zero, zero
5. Open
6. Positive
7. Ten
8. Ohmmeter, resistance

Activity 5

1. False
2. False
3. False
4. True
5. False
6. True
7. Rectifier
8. Schottky
9. Tunnel
10. Light emitting

Chapter 3 Self Test

Answer the following statements.

1. Which diode is properly labeled?

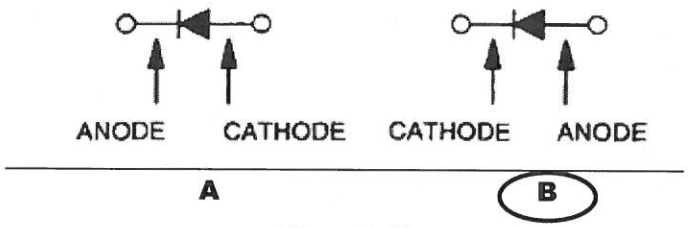


Figure 3-18

2. The process of adding impurities to a crystal structure is referred to as

   a. doping
   b. biasing
   c. conducting.

3. **Arsenic** is used as a donor impurity

4. **Indium/Boron** is used as an acceptor impurity.

5. Conduction in P-type material is mainly due to the movement of
   a. electrons
   b. crystals
   c. holes

6. The **barrier potential** prevents all of the electrons on the N-type side from crossing the junction to fill the holes in the P-type side.

7. Junction recombination results in the development of a(n) _____ region.

   a. low resistance
   b. conduction
   c. depletion

8. If the temperature of a diode is increased, its resistance will **decrease.** This is called a **negative** temperature coefficient.

9. Connecting the positive side of the battery to the P-type material of a diode and the negative side to the N-type material will establish

   a. reverse bias
   b. forward bias
   c. equal bias

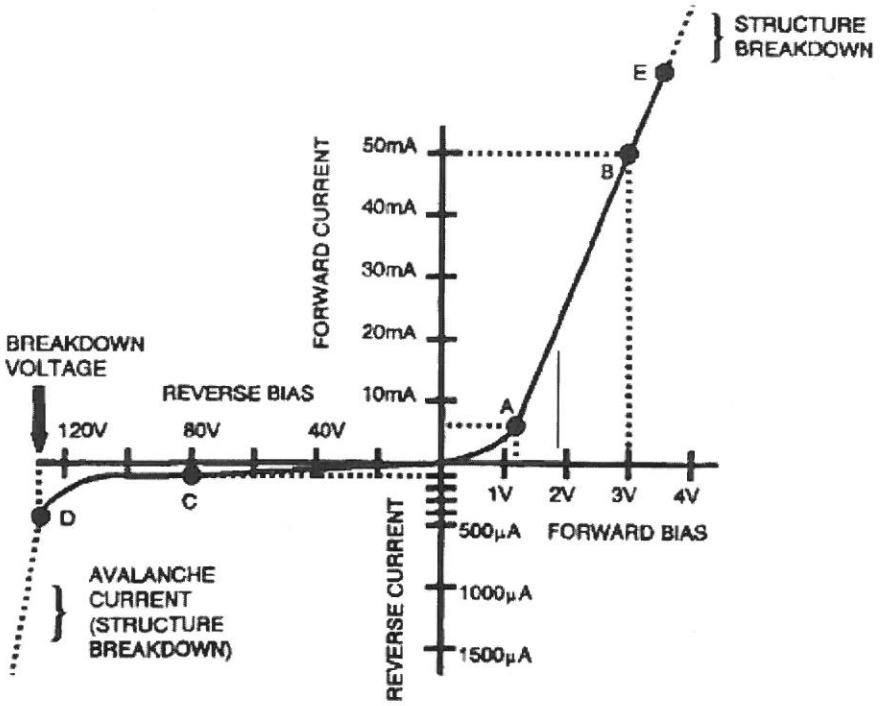


Figure 3-19

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11. Would 4 volts of forward bias be an excessive amount?

    a. Yes
    b. No

12. With 80 volts of reverse bias, the reverse current is approximately

    a. 100μA
    b. 200μA
    c. 300μA
    d. 500μA

13. Would 120 volts of reverse bias be an excessive amount?

    a. Yes
    b. No

14. A plus (+) sign on an older diode denotes the **cathode** lead.

15. When the positive lead from an ohmmeter is applied to the anode lead of a diode, the diode is turned **on**.

16. If the resistance of a diode measures infinity in both directions, the diode is

    a. good
    b. open
    c. leaky
    d. shorted

17. If an AC voltage is measured across a diode in a circuit, the diode is

    a. good
    b. open
    c. leaky
    d. shorted

18. If zero ohms is measured across a diode in both directions, the diode is
    a. good
    b. open
    c. leaky
    d. shorted

19. If the resistance of a diode measures 10 ohms in one direction and 1k ohms in the other direction, the diode is

    a. good
    b. open
    c. leaky
    d. shorted

20. What is meant by the term "reverse breakdown voltage" as applied to the Zener diode?

The reverse voltage that causes zener diodes to regulate voltage in the avalanche region of their characteristic curves.

21. What is the difference in the conduction path of a Zener diode as compared to an ordinary diode?

Current flow is with the arrow.

22. What gives the tunnel diode its extremely thin barrier?

Heavy doping.

23. What does the term "negative resistance" region of a tunnel diode mean?

An increase in forward bias voltage produces a decrease in forward current.

24. Name two purposes of clipper or limiters in a circuit.

Wave shaping, and circuit protection.

25. What is the purpose of a diode clamp in a circuit?

Re-reference waveform by adding or subtracting from its reference voltage level.

26. The LED is a PN junction of a crystal material that produces light when forward biased.

    a. True
    b. False

27. What determines the color of an LED?

The type of doping material.

28. A rectifier is a device that changes AC into DC.

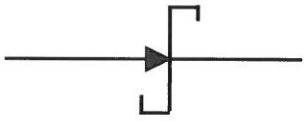

Figure 3-20

Use Figure 3-20 to answer questions 29 and 30.

29. The diode represented in Figure 3-20 is called a **Schottky** diode.

30. What is the major difference in the construction of the diode in Figure 3-20 and the construction of an ordinary diode?

This diode has no depletion region.