Chapter 18

Transformers

Objectives

- After completing this chapter, you will be able to:
  - Describe how a transformer operates
  - Explain how transformers are rated
  - Explain how transformers operate in a circuit
  - Describe the differences between step-up, step-down, and isolation transformers

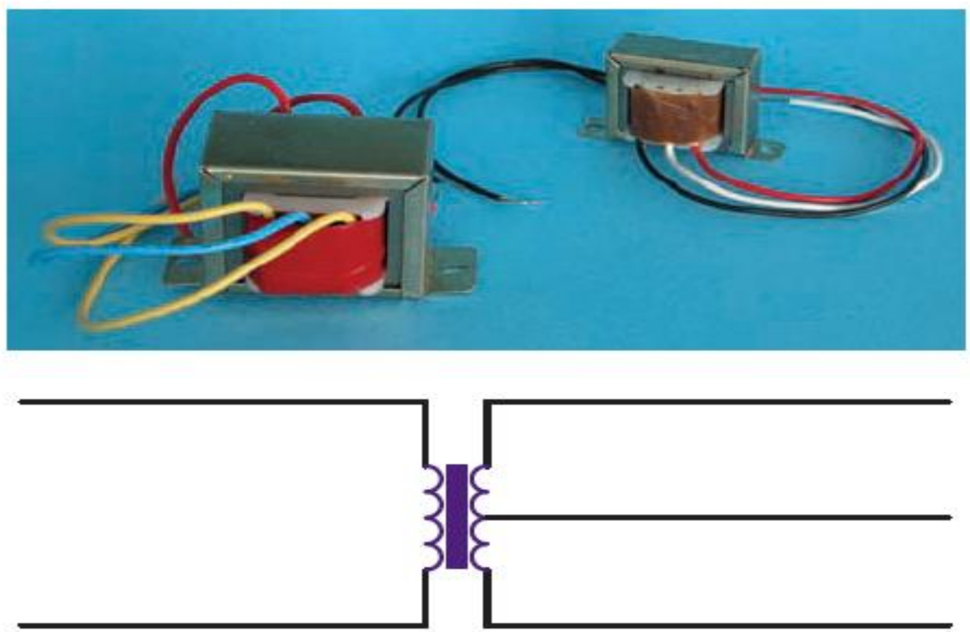
Objectives (cont'd.)

- Describe how the ratio of the voltage, current, and number of turns are related with a transformer
- Describe applications of a transformer
- Identify different types of transformers

Electromagnetic Induction

- Transfor
  - Consis ng and a second
  - Rated
- Primary
  - Coil co
- Seconda
  - Coil in which the voltage is induced

FIGURE 18–2
(A) Transformers with a center-tapped secondary.
(B) Schematic symbol showing transformer with a center-tapped secondary.



he amount of ge induced ends on the unt of mutual ction between wo coils.

Mutual Inductance

- Expanding magnetic field in loaded secondary causes current increase in primary

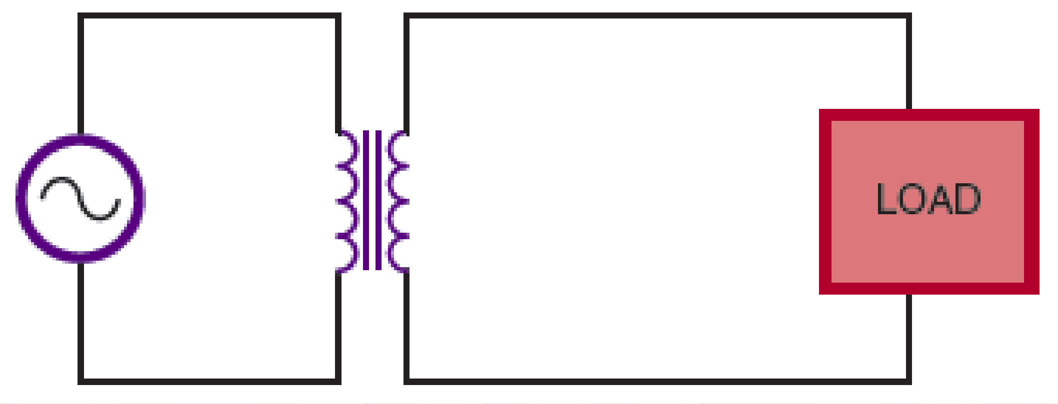


Figure 18-4.Transformer with a loaded secondary.

Turns Ratio

- Turns ratio
  - Determines whether the transformer is used to step up, step down, or pass voltage unchanged
  - Can be expressed as:

$$\text{turns ratio} = N_S/N_P$$

where: N = number of turns (primary and secondary)

Turns Ratio (cont'd.)

- Step-up transformer
  - Produces a secondary voltage greater than its primary voltage
  - Turns ratio is always greater than one

Turns Ratio (cont'd.)

- Step-down transformer
  - Produces secondary voltage less than its primary voltage
  - Turns ratio is always less than one

EXAMPLE: A transformer has 400 turns on the primary and 1200 turns on the secondary. If 120 volts of AC current are applied across the primary, what voltage is induced into the secondary?

Given:

$E_S = ?$

$E_P = 120\ V$

$N_S = 1200$ turns

$N_P = 400$ turns

Solution:

$$\frac{E_S}{E_P} = \frac{N_S}{N_P}$$

$$\frac{E_S}{120} = \frac{1200}{400}$$

$$E_S = 360\ V$$

EXAMPLE: A transformer has 500 turns on the primary and 100 turns on the secondary. If 120 volts AC are applied across the primary, what is the voltage induced in the secondary?

Given:

$E_S = ?$

$N_P = 500$ turns

$N_S = 100$ turns

$E_P = 120\ V$

Solution:

$$\frac{E_S}{E_P} = \frac{N_S}{N_P}$$

$$\frac{E_S}{120} = \frac{100}{500}$$

$$E_S = 24\ V$$

- Assuming no transformer losses, the power in the secondary must equal the power in the primary.

$$P_P = P_S$$

$$(I_P)(E_P) = (I_S)(E_S)$$

The current is inversely proportional to the turns ratio. This can be expressed as:

$$\frac{I_P}{I_S} = \frac{N_S}{N_P}$$

EXAMPLE: A transformer has a 10:1 turns ratio. If the primary has a current of 100 milliamperes, how much current flows in the secondary?

NOTE: THE FIRST NUMBER IN THE RATIO REFERS TO THE PRIMARY, THE SECOND NUMBER TO THE SECONDARY.

Given:

$I_S = ?$

$N_P = 10$

$N_S = 1$

$I_P = 100\text{ mA} = 0.1\text{ A}$

Solution:

$$\frac{I_P}{I_S} = \frac{N_S}{N_P}$$

$$\frac{0.1}{I_S} = \frac{1}{10}$$

$$I_S = 1\text{ A}$$

EXAMPLE: What must the turns ratio of a transformer be to match a 4-ohm speaker to a 100-ohm source?

Given:

$N_P = ?$

$N_S = ?$

$Z_P = 100$

$Z_S = 4$

Solution:

$$\frac{Z_P}{Z_S} = \left(\frac{N_P}{N_S}\right)^2$$

$$\frac{100}{4} = \left(\frac{N_P}{N_S}\right)^2$$

$$\sqrt{25} = \frac{N_P}{N_S}$$

$$\frac{5}{1} = \frac{N_P}{N_S}$$

Applications

- Transformer applications include:
  - Stepping up/down voltage and current
  - Impedance matching
  - Phase shifting
  - Isolation
  - Blocking DC while passing AC
  - Producing several signals at various voltage levels

Applications (cont'd.)

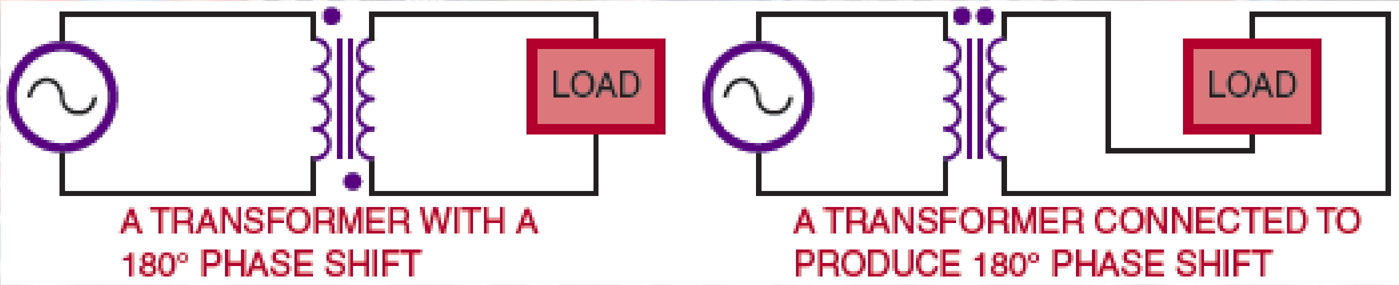


Figure 18-5. A transformer can be used to generate a phase shift.

Applications (cont'd.)

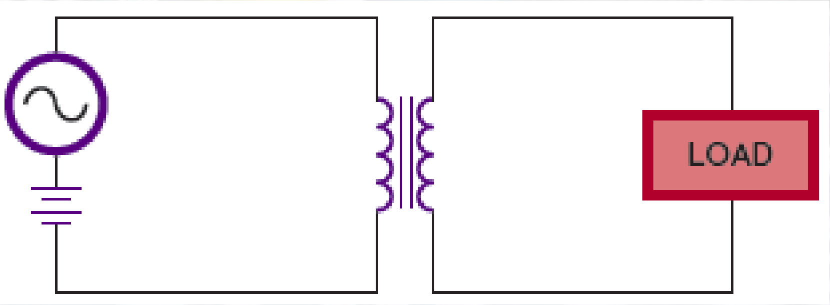


Figure 18-6. A transformer can be used to block DC voltage.

Applications (cont'd.)

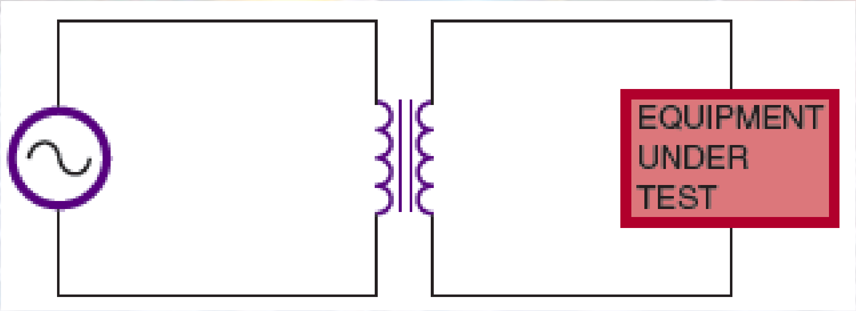


Figure 18-7. An isolation transformer prevents electrical shock by isolating the equipment from ground.

Applications (cont'd.)

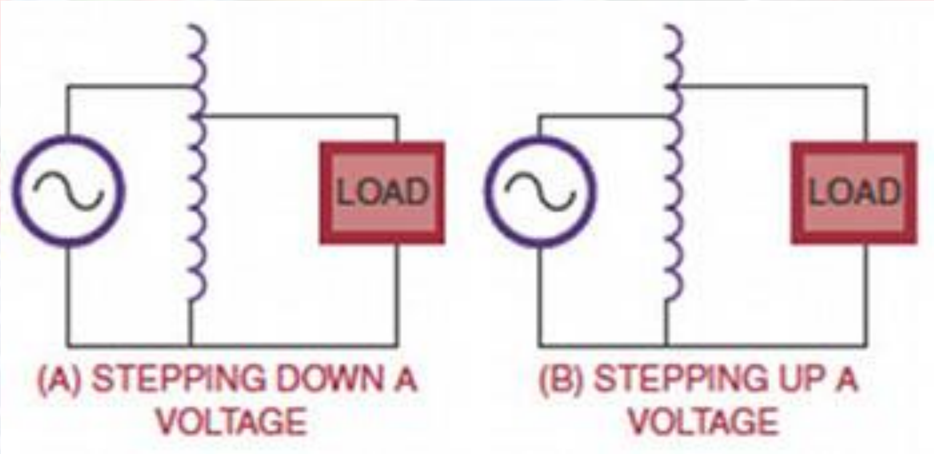


Figure 18-8. An autotransformer is a special type of transformer used to step up or step down the voltage.

Applications (cont'd.)

Figure 18-9. A variable autotransformer.

Summary

- A transformer consists of two coils, a primary winding and a secondary winding
- An AC voltage is put across the primary winding, inducing a voltage in the secondary winding
- Transformers allow an AC signal to be transferred from one circuit to another

Summary (cont'd.)

- Transformers are rated in volt-amperes(VA)
- The turns ratio determines whether a transformer is used to step up, step down, or pass voltage unchanged
- Transformer applications: impedance matching, phase shifting, isolation, blocking DC while passing AC, etc.

Chapter 19

Semiconductor Fundamentals

Objectives

- After completing this chapter, you will be able to:
  - Identify materials that act as semiconductors
  - Define *covalent bonding*
  - Describe the doping process for creating N- and P-type semiconductor materials
  - Explain how doping supports current flow in a semi-conductor material

Semiconduction in Germanium and Silicon

- Semiconductor materials
  - Possess characteristics that fall between those of insulators and conductors
- Pure semiconductor elements
  - Carbon (C)
  - Germanium (Ge)
  - Silicon (Si)
    - Used for most semiconductor devices

Semiconduction in Germanium and Silicon (cont’d.)

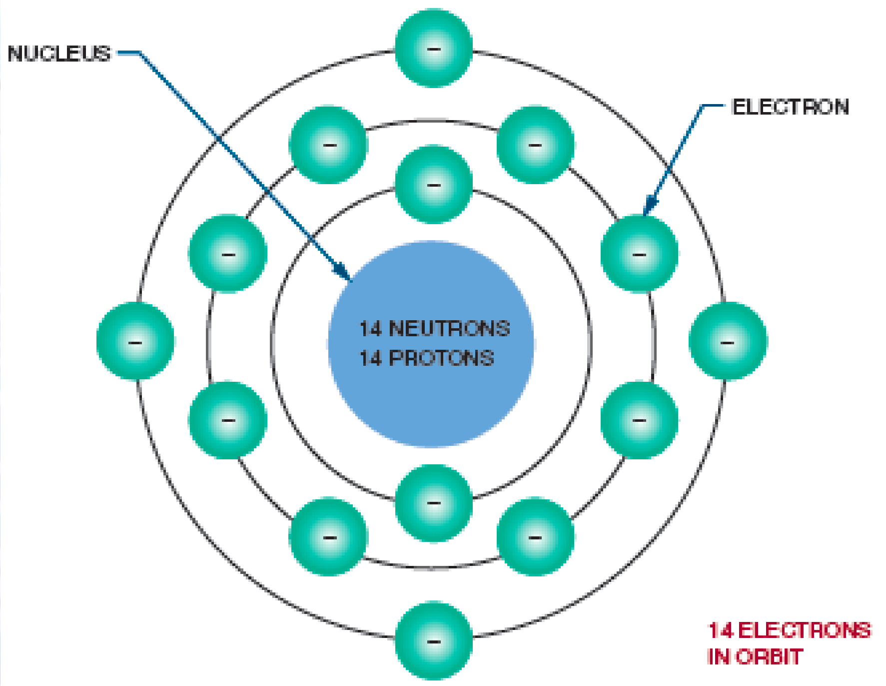


Figure 19-1. Atomic structure of silicon.

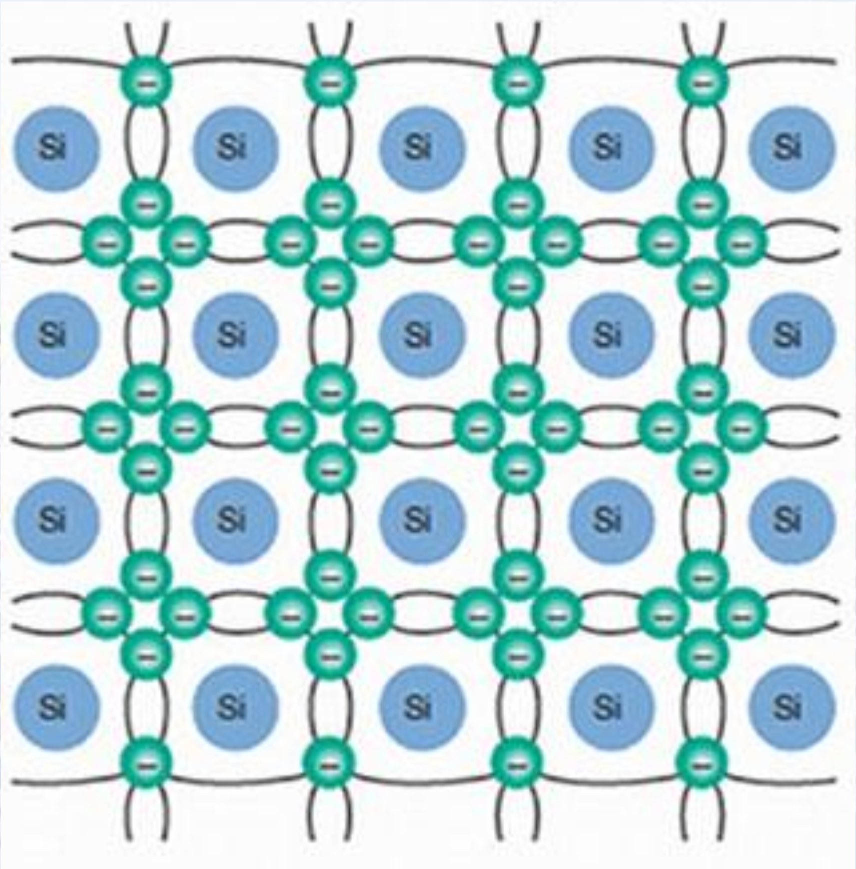


Figure 19-3. Crystalline structure of silicon with covalent bonding.

Semiconduction in Germanium and Silicon (cont'd.)

- Negative temperature coefficient
  - As temperature increases, resistance decreases
- Heat
  - Potential source of trouble for semiconductors
  - Electrons break their covalent bonds

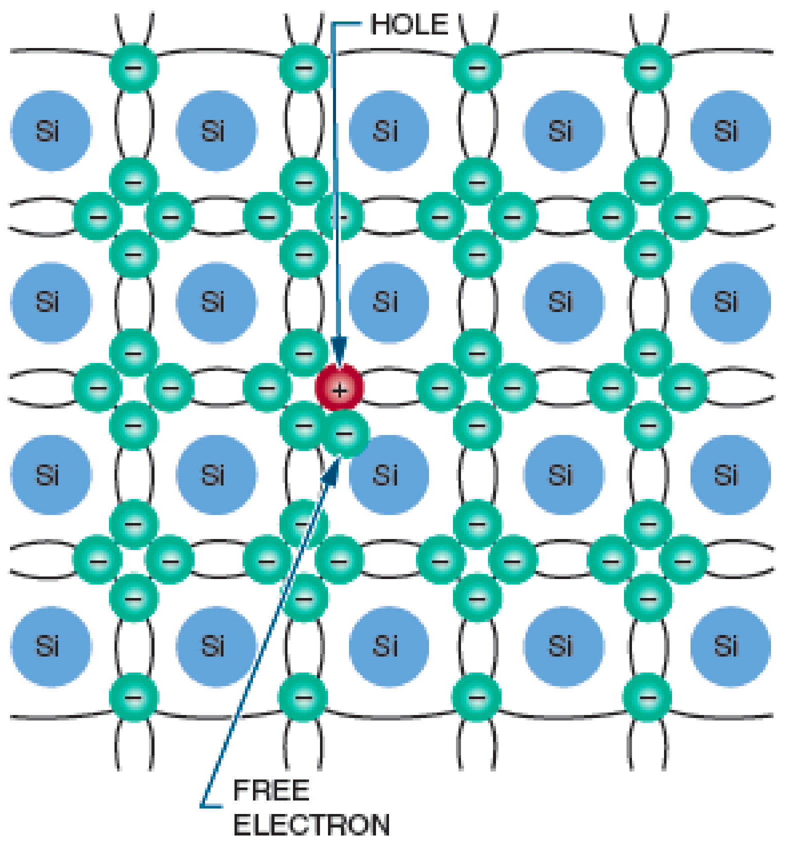


Figure 19-4. A hole is created when an electron breaks its covalent bond.

Conduction in Pure Germanium and Silicon (cont'd.)

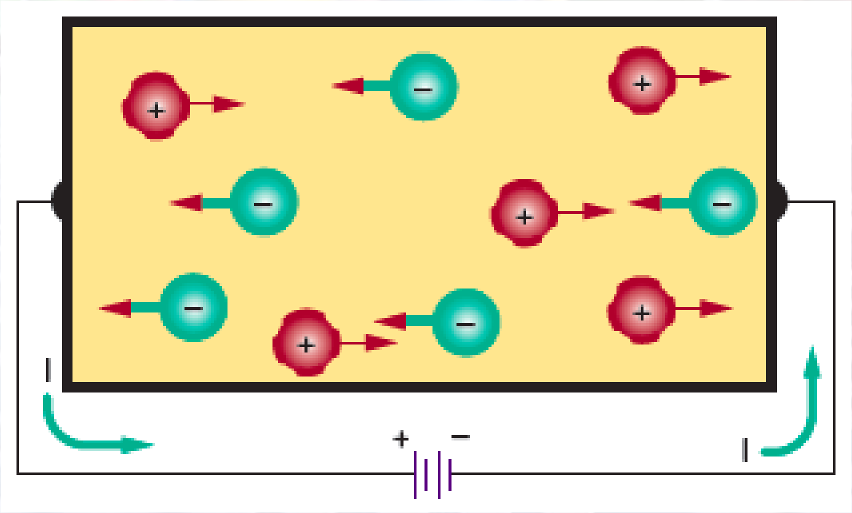


Figure 19-5. Current flow in pure semiconductor material.

Conduction in Doped Germanium and Silicon

- Doping
  - Adding impurities to a semiconductor material
- Pentavalent
  - Made of atoms with five valence electrons
- Trivalent
  - Made of atoms with three valence electrons

Conduction in Doped Germanium and Silicon (cont'd.)

- N-type material
  - Pentavalent materials
  - Electrons are the majority carrier
  - Holes are the minority carrier

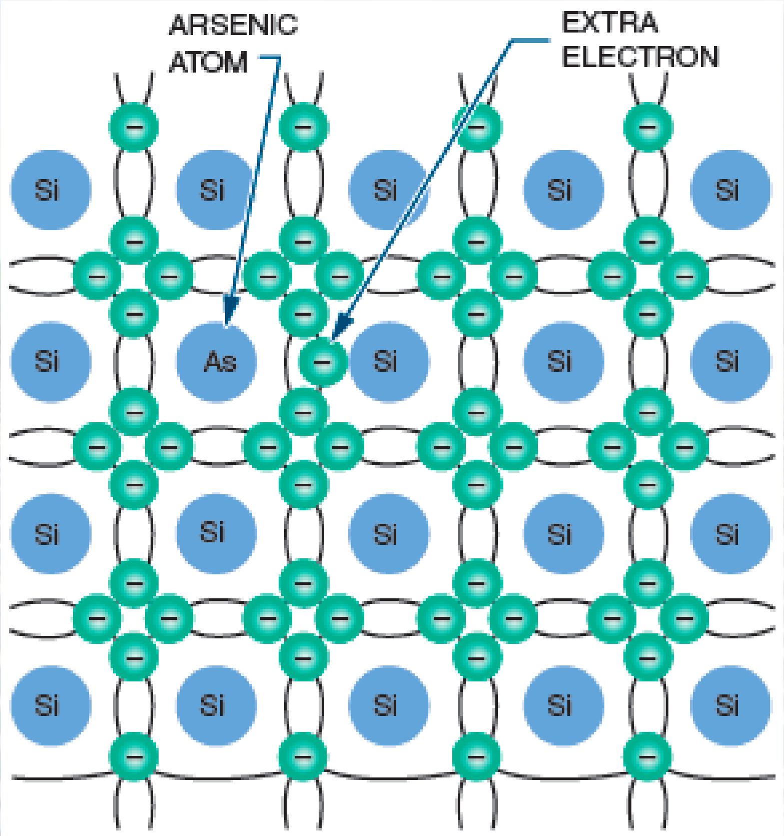


Figure 19-6. Silicon semiconductor material doped with an arsenic atom.

Conduction in Doped Germanium and Silicon (cont'd.)

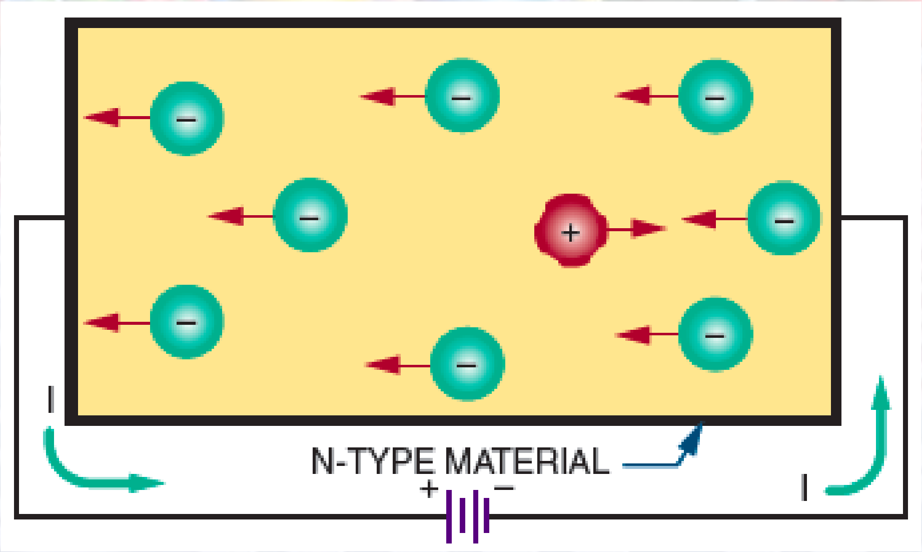


Figure 19-7. Current flow in N-type material.

Conduction in Doped Germanium and Silicon (cont'd.)

- P-type material
  - Trivalent materials
  - Holes are the majority carrier
  - Electrons are the minority carrier

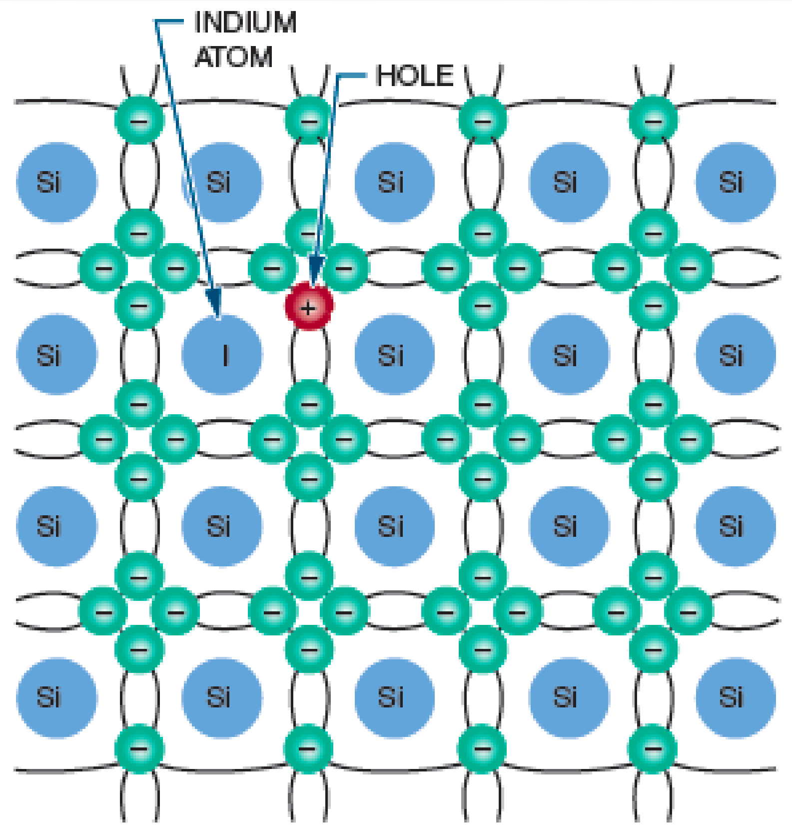


Figure 19-8. Silicon semiconductor material doped with an indium atom.

Conduction in Doped Germanium and Silicon (cont'd.)

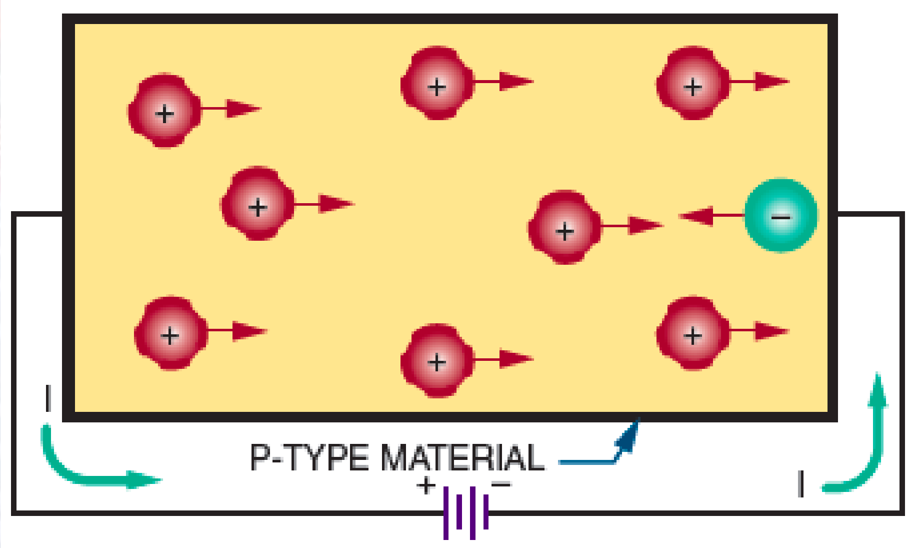


Figure 19-9. Current flow in P-type material.

Summary

- Pure semiconductor materials are germanium, silicon, and carbon
- As the temperature increases in a semiconductor material, electrons drift from one atom to another
- Current flow in semiconductor materials consists of both electron flow and hole movement

Summary (cont'd.)

- Doping is the process of adding impurities to a semiconductor material
- In N-type material, electrons are the majority carrier and holes are the minority carrier
- In P-type material, holes are the majority carrier and electrons are the minority carrier

Chapter 20

PN Junction Diodes

Objectives

- After completing this chapter, you will be able to:
  - Describe what a junction diode is and how it is made
  - Define *depletion region* and *barrier voltage*
  - Explain the difference between forward bias and reverse bias of a diode

Objectives (cont'd.)

- Draw and label the schematic symbol for a diode
- Describe three diode construction techniques
- Identify the most common diode packages
- Test diodes using an ohmmeter

PN Junctions

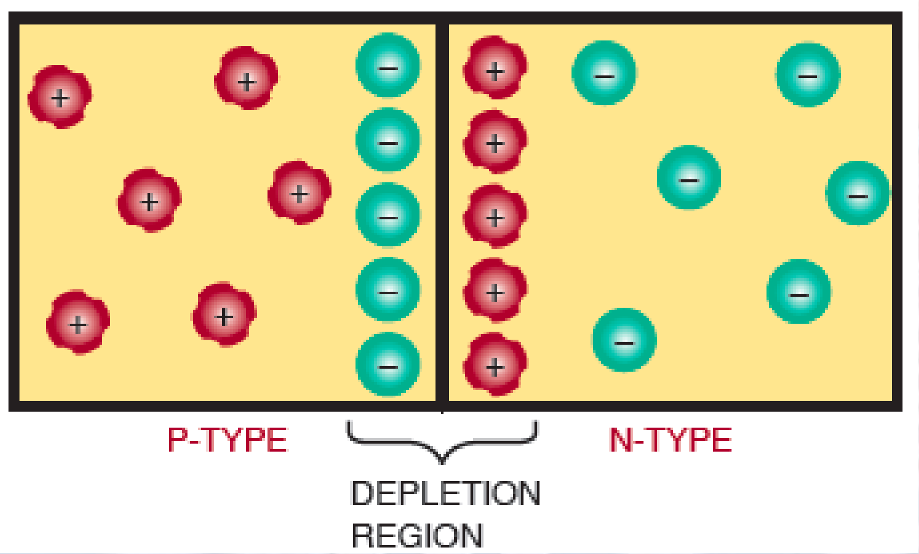


Figure 20-1. Diode formed by joining P- and N-type material to form a PN junction.

PN Junctions (cont'd.)

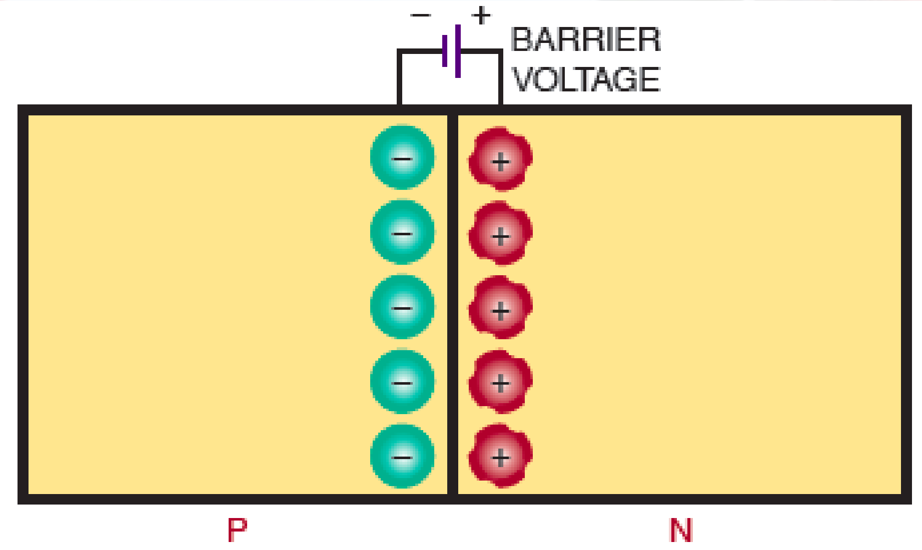


Figure 20-2. Barrier voltage as it exists across a PN junction.

The amount of forward current (I_F) is a function of the external voltage (E), the forward voltage drop (E_F), and the external resistance (R).

$$I = \frac{E}{R}$$

$$I_F = \frac{E - E_F}{R}$$

EXAMPLE: A silicon diode has an external bias voltage of 12 V with an external resistor of 150 Ω. What is the total forward current?

Given:

$I_F = ?$

$E = 12\ V$

$R = 150\ \Omega$

$E_F = 0.7\ V$

Solution:

$$I_F = \frac{E - E_F}{R}$$

$$I_F = \frac{12 - 0.7}{150}$$

$$I_F = 0.075\ A$$

or 75 mA

Diode Biasing

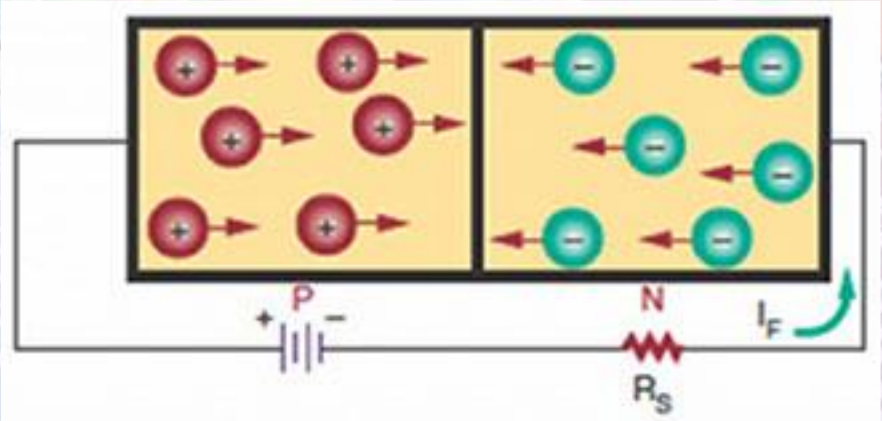


Figure 20-3. PN junction diode with forward bias.

Diode Biasing (cont'd.)

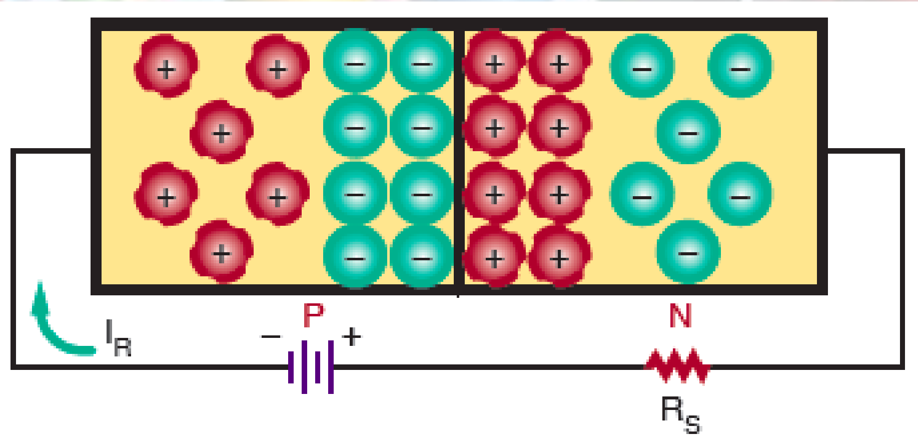


Figure 20-4. PN junction diode with reverse bias.

Diode Characteristics

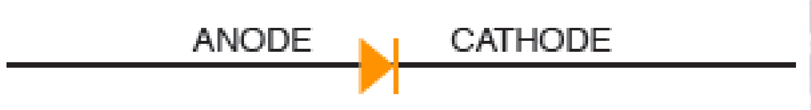


Figure 20-5. Diode schematic symbol.

Diode Characteristics (cont'd.)

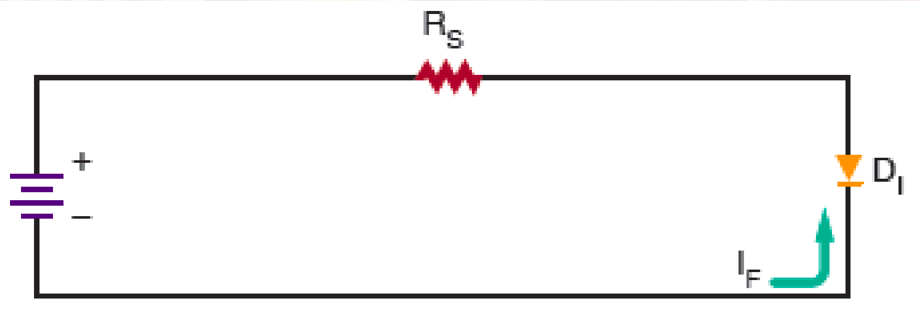


Figure 20-6. Diode connected with forward bias.

Diode Characteristics (cont'd.)

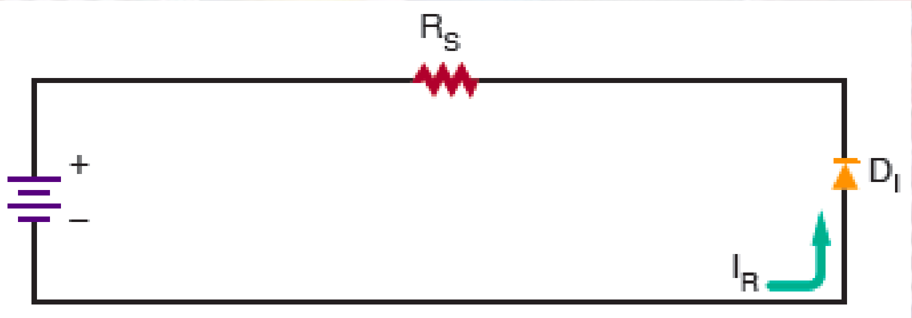


Figure 20-7. Diode connected with reverse bias.

Diode Construction Techniques

- Types of PN junctions
  - Grown junction
  - Alloyed junction
  - Diffused junction

Diode Construction Techniques (cont'd.)

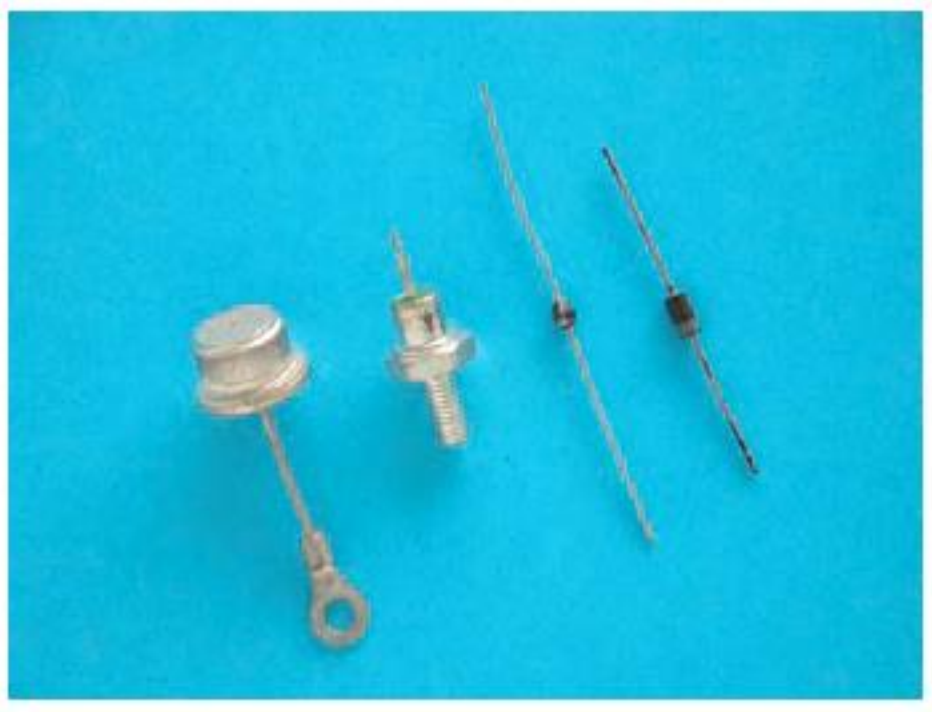


Figure 20-8. Common diode packages.

Diode Construction Techniques (cont'd.)

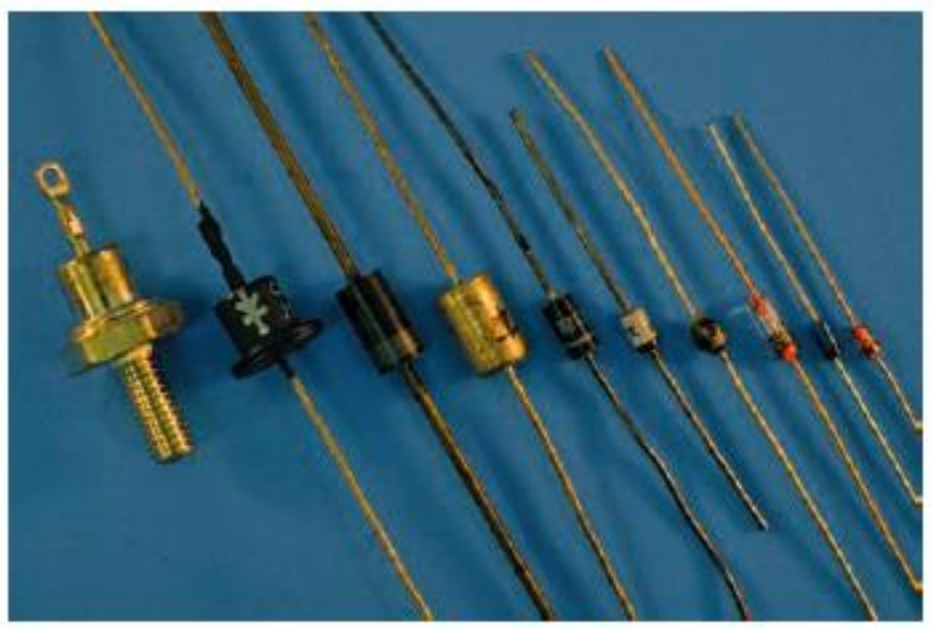


Figure 20-9. Packages for diodes.

Testing PN Junction Diodes

- Ohmmeter
  - Checks the forward-to-reverse-resistance ratio of a diode
- Forward-biased diode
  - Low resistance
- Reverse-biased diode
  - High resistance

Summary

- A junction diode is created by joining N-type and P-type materials together
- The region near the junction is referred to as the depletion region
- The charge at the junction creates a voltage called the barrier voltage
- A diode that is forward biased conducts current

Summary (cont'd.)

- A diode that is reverse biased conducts only a small leakage current
- Diodes can be constructed by the grown junction, alloyed junction, or diffused junction method
- A diode is tested by comparing the forward to the reverse resistance with an ohmmeter

Chapter 21

Zener Diodes

Objectives

- After completing this chapter, you will be able to:
  - Describe the function and characteristics of a zener diode
  - Draw and label the schematic symbol for a zener diode
  - Explain how a zener diode operates as a voltage regulator

Objectives (cont'd.)

– Describe the procedure for testing zener diodes

Zener Diode Characteristics

- Zener diode
  - Operates at voltages that exceed breakdown voltage
  - Manufactured with a specific breakdown voltage (E_Z)
  - Packaged like PN junction diodes
- Power dissipation
  - Based on temperature and lead lengths

Zener Diode Characteristics (cont'd.)

Figure 21-1. Zener diode packages.

Zener Diode Characteristics (cont'd.)

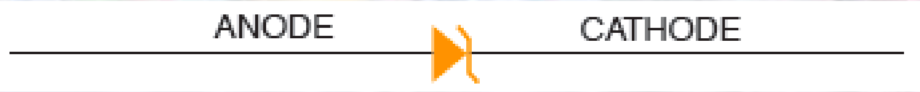


Figure 21-2. Schematic symbol for a zener diode.

Zener Diode Ratings

- Positive zener voltage-temperature coefficient
  - Breakdown voltage increases as temperature increases
- Negative zener voltage-temperature coefficient
  - Breakdown voltage decreases as temperature increases

Voltage Regulation with Zener Diodes

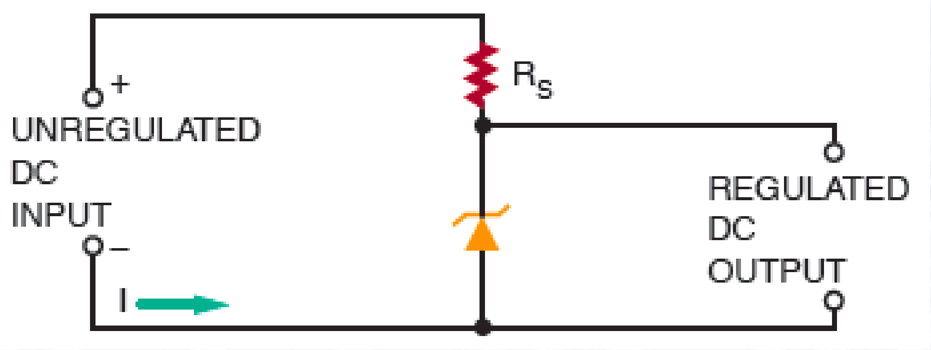


Figure 21-3. Typical zener diode regulator circuit.

- Zener diodes are manufactured to have a specific breakdown voltage rating that is often referred to as the diode's *zener voltage rating* (E_z).
- The voltage drop across the resistor is equal to the difference between the zener (breakdown) voltage and the input voltage.

Voltage Regulation with Zener Diodes (cont'd.)

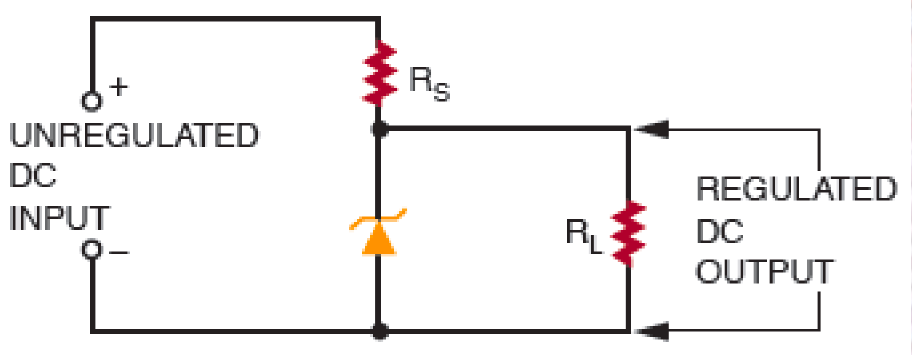


Figure 21-4. Zener diode voltage regulator with load.

Testing Zener Diodes

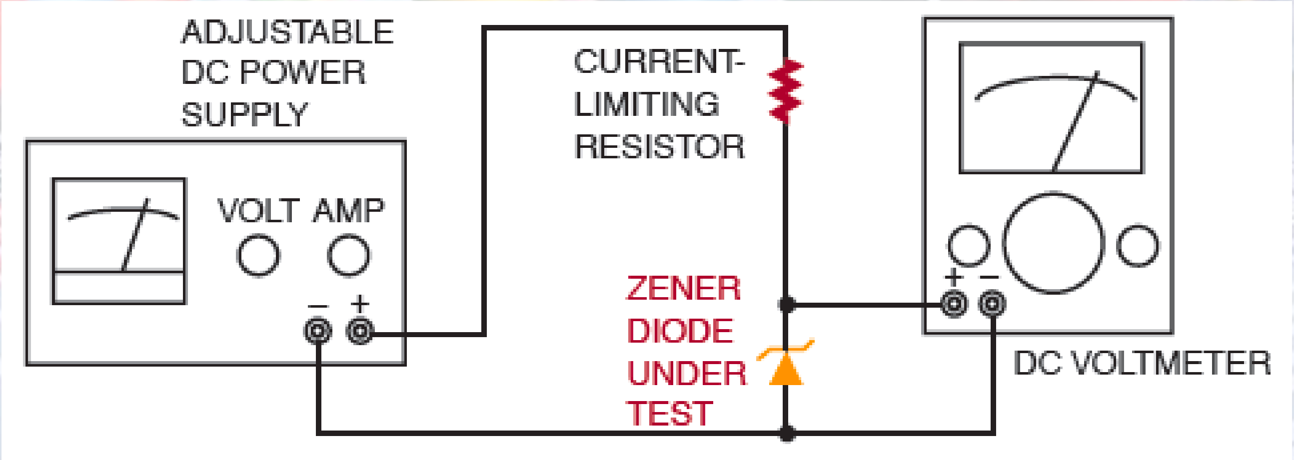


Figure 21-5. Setup for testing zener diode regulation.

Summary

- Zener diodes are designed to operate at voltages greater than the breakdown voltage (peak reverse voltage)
- The breakdown voltage of a zener diode is determined by the resistivity of the diode
- Zener diodes are used to stabilize or regulate voltage

Summary (cont'd.)

- Zener diode regulators provide a constant output voltage despite changes in the input voltage or output current
- To determine whether a zener diode is regulating at the proper voltage, a regulation test must be performed