Chapter 22

Bipolar Transistors

In 1948, Bell Laboratories developed the first working junction transistor. A transistor is a three-element, two-junction device used to control electron flow

Objectives

- After completing this chapter, you will be able to:
  - Describe how a transistor is constructed and its two different configurations
  - Draw and label the schematic symbol for an NPN and a PNP transistor
  - Identify the ways of classifying transistors

Objectives (cont'd.)

– Identify the function of a transistor using a reference manual and the identification number (2NXXXX)
– Identify commonly used transistor packages
– Describe how to bias a transistor for operation
– Explain how to test a transistor with both a transistor tester and an ohmmeter
– Describe the process used for substituting a transistor

Transistor Construction

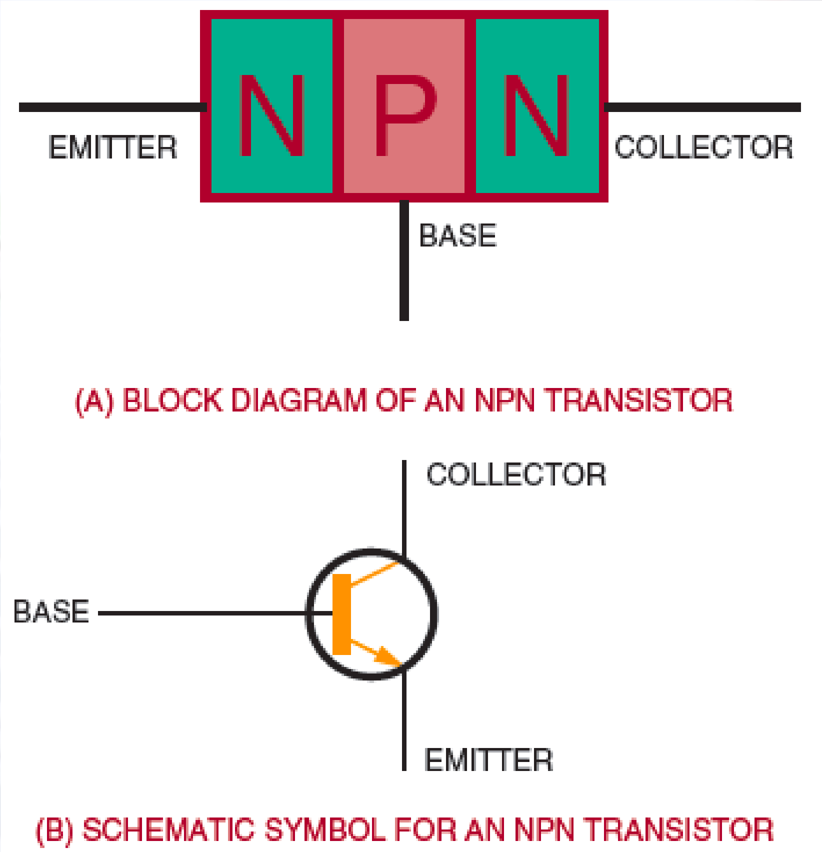


Figure 22-1. NPN transistor.

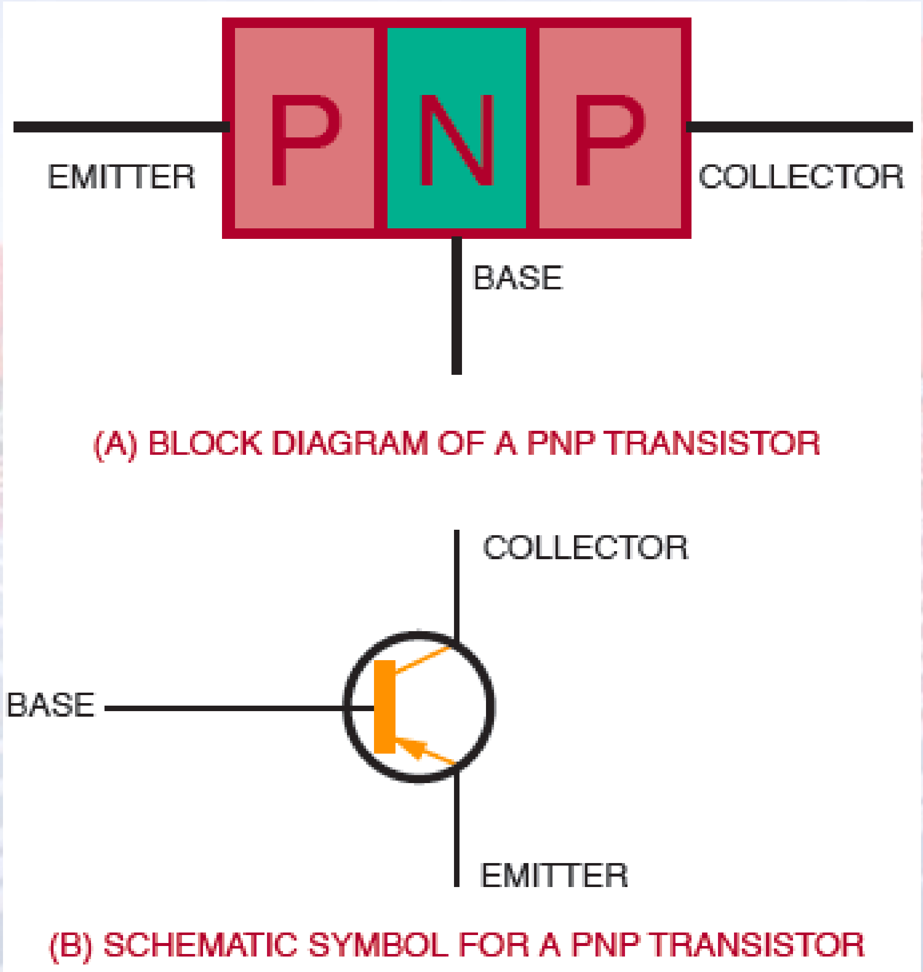


Figure 22-2. PNP transistor.

Transistor Types and Packaging

- Transistor classifications
  - According to type
    - NPN or PNP
  - According to material used
    - Germanium or silicon
  - According to major use
    - High or low power, switching, or high frequency

Transistor Types and Packaging (cont'd.)

- Transistor identification
  - Prefix of 2N followed by up to four digits
- Transistor package
  - Protects transistor
  - Provides means of electrical connection
  - Serves as a heat sink
  - Identified with letter TO (***t***ransistor ***o***utline)

Transistor Types and Packaging (cont'd.)

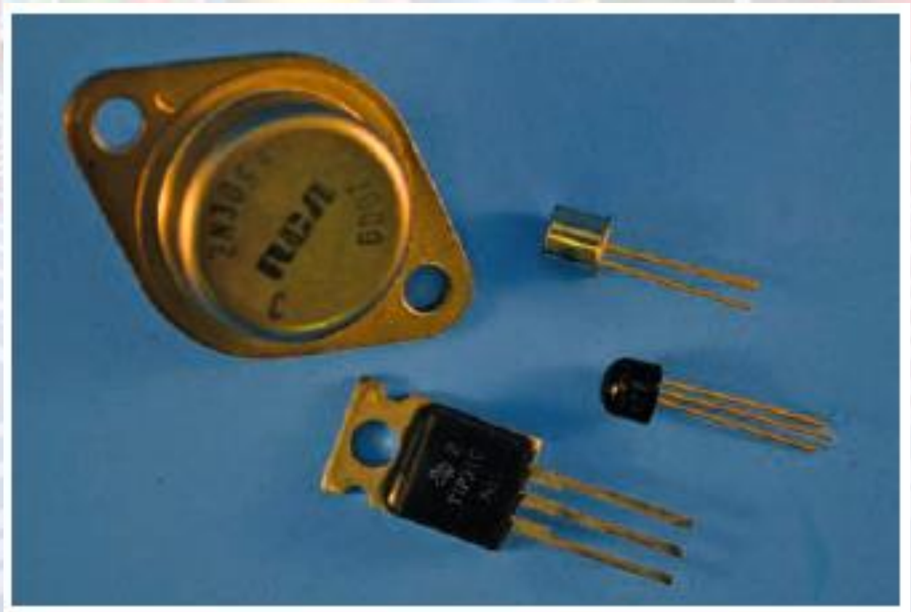


Figure 22-3. Various transistor packages.

Transistor Types and Packaging (cont'd.)

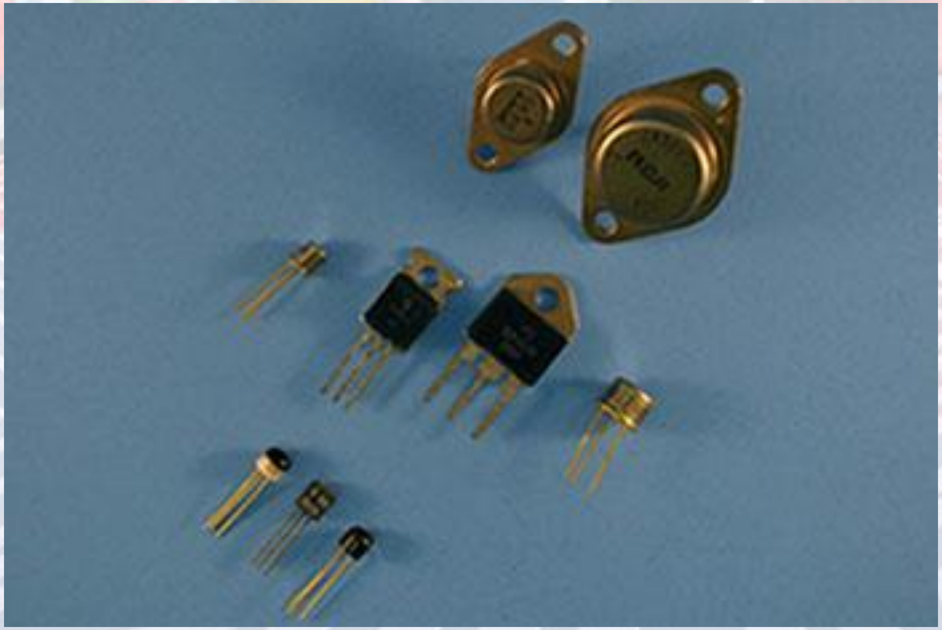


Figure 22-4. Typical transistor packages.

Basic Transistor Operation

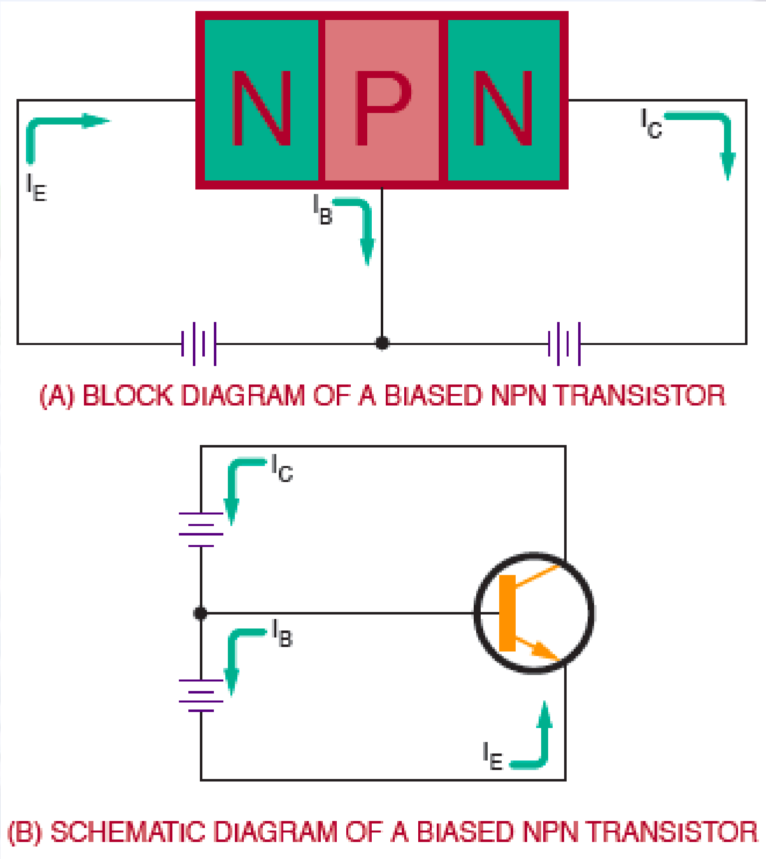


Figure 22-5. Properly biased NPN transistor.

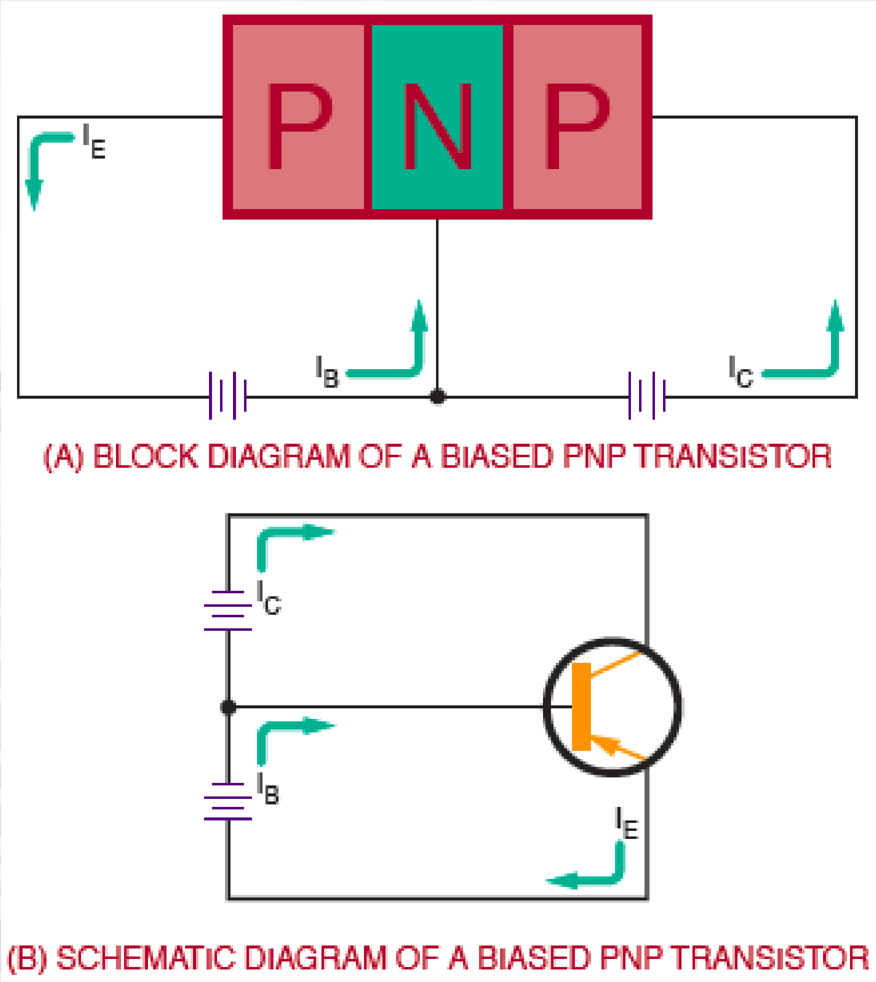


Figure 22-6. Properly biased PNP transistor.

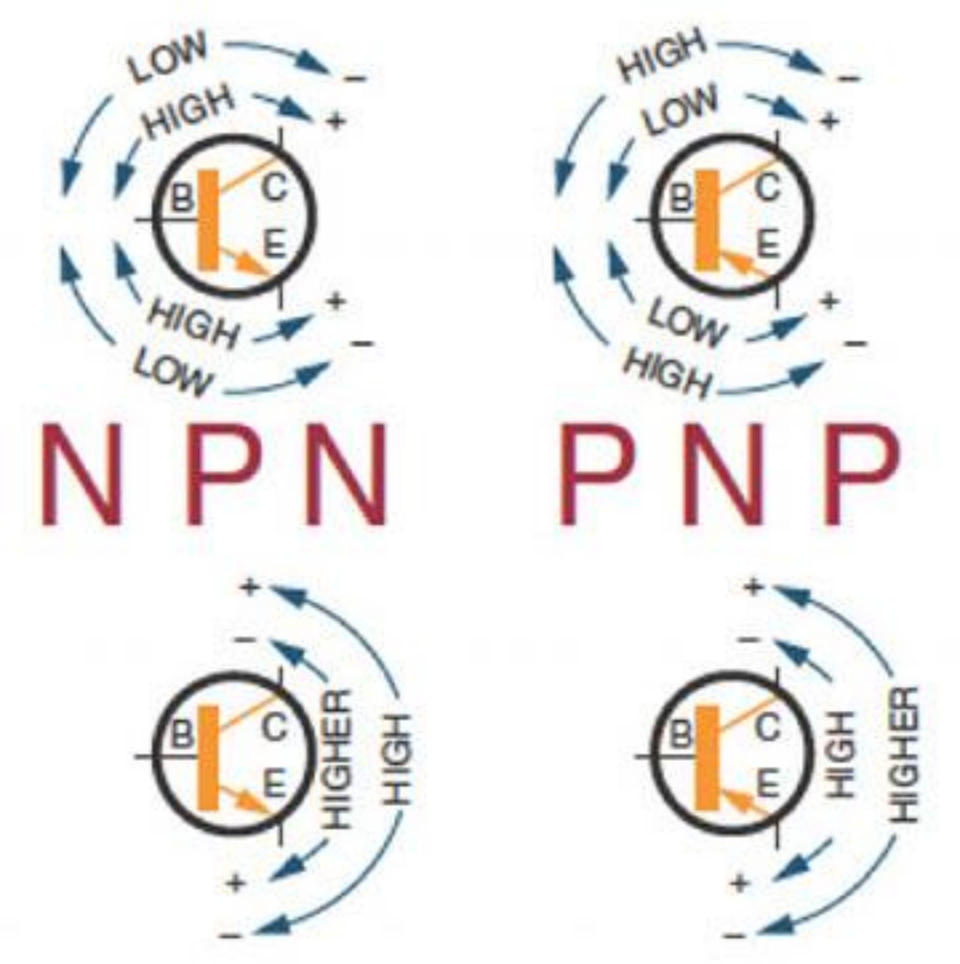


Figure 22-7. Resistance measurements of transistor junctions.

Figure 22-8. Transistor tester.

Transistor Substitution

Figure 22-9. How to remember the polarity of the collector voltage.

Summary

- A transistor is a three-layer device used to amplify and switch power and voltage
- A transistor is classified according to type, material used, and major use
- In a properly biased transistor, the emitter-base junction is forward biased and the collector-base junction is reverse biased

Summary (cont'd.)

- PNP transistor bias sources are the reverse of NPN bias sources
- When a transistor is tested with an ohmmeter, each junction exhibits a low resistance when it is forward biased and a high resistance when it is reverse biased
- Transistor testers are available for testing transistors in and out of circuit

Chapter 23

Field Effect Transistors (FETs)

Objectives

- After completing this chapter, you will be able to:
  - Describe the difference between transistors, JFETs, and MOSFETs
  - Draw schematic symbols for both P-channel and N-channel JFETs, depletion MOSFETs, and enhancement MOSFETs

Objectives (cont'd.)

- Describe how a JFET, depletion MOSFET, and enhancement MOSFET operate
- Identify the parts of JFETs and MOSFETs
- Describe the safety precautions that must be observed when handling MOSFETs
- Describe the procedure for testing JFETs and MOSFETs with an ohmmeter

Junction FETs

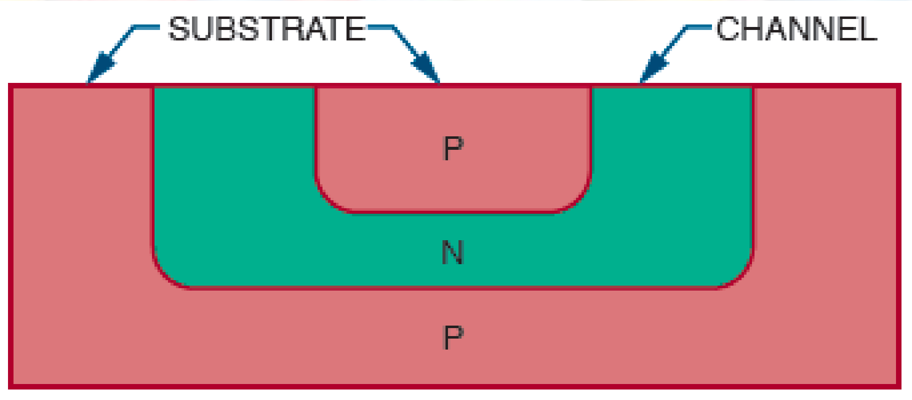


Figure 23-1. Cross section of an N-channel JFET.

- **Junction field effect transistor (JFET)** is a unipolar transistor that functions using only majority carriers.
- JFET is a voltage-operated device.

Junction FETs (cont'd.)

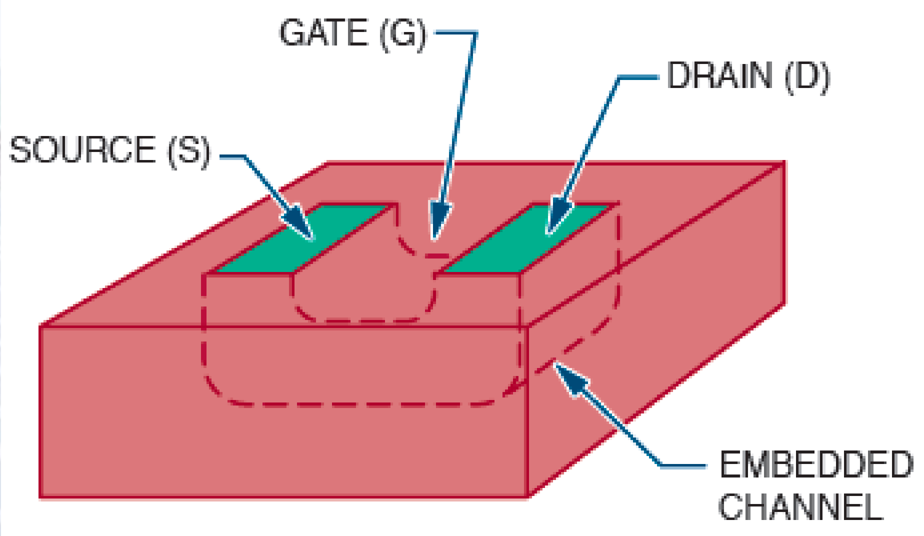


Figure 23-2. Lead connections for an N-channel JFET.

Junction FETs (cont'd.)

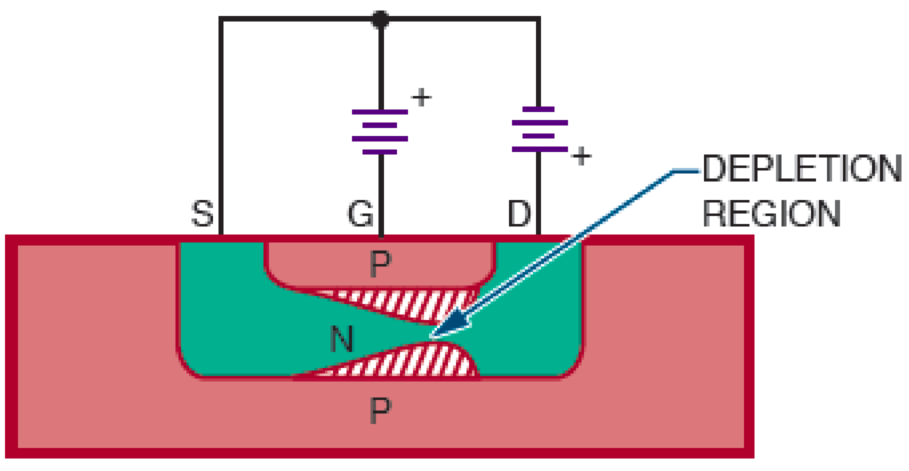


Figure 23-3. Properly biased N-channel JFET.

- JFET requires two external bias voltages
- Voltage sources between the source and the drain denoted as E_{DS}.
- Other voltage source between
- the gate and the source denoted as E_{GS}.
- It controls the amount of current flowing through the channel

Junction FETs (cont'd.)

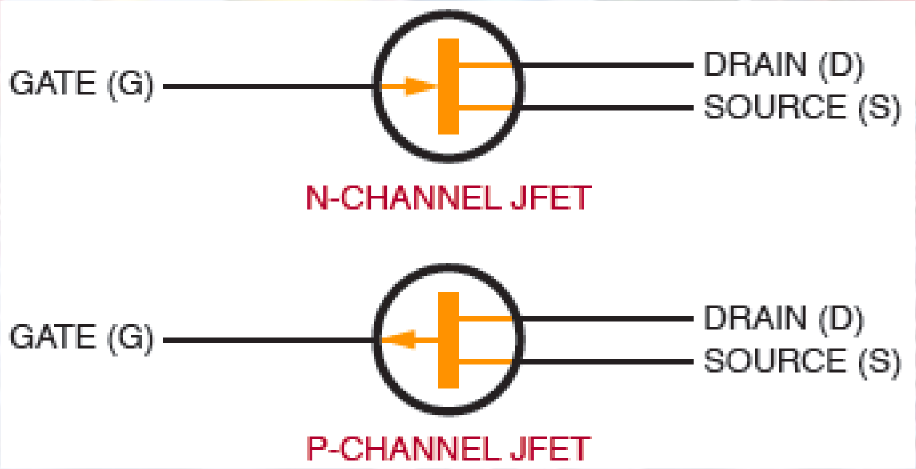
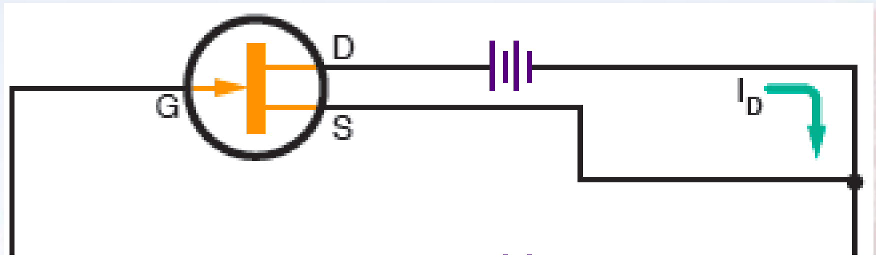


Figure 23-4. Schematic symbols for JFETs.



I_D levels off because the depletion region expands and reduces the channel's width. When this occurs, I_D is said to *pinch off.* The value of E_{DS} required to pinch off or limit I_D is called the *pinch-off voltage* (E_P). E_P is usually given by the manufacturer for an E_{GS} of zero.

Figure 23-6. The polarities required to bias a P-channel JFET.

- In a P-channel JFET, the polarity of the bias voltages (E_{GS}, E_{DS}) is opposite to that in an N-channel JFET

Depletion Insulated Gate FETs (MOSFETs)

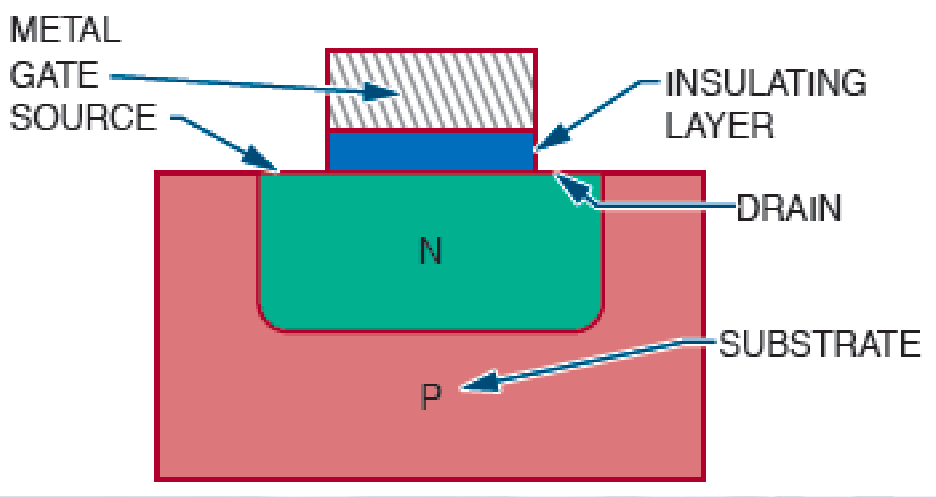


Figure 23-7. N-channel depletion MOSFET.

- There are two important types of MOSFETs: i) N-type units with N channels and ii) P-type units with P channels.
- N-type units with N channels are called **depletion mode** devices at zero bias to the gate.

Depletion Insulated Gate FETs (MOSFETs) (cont'd.)

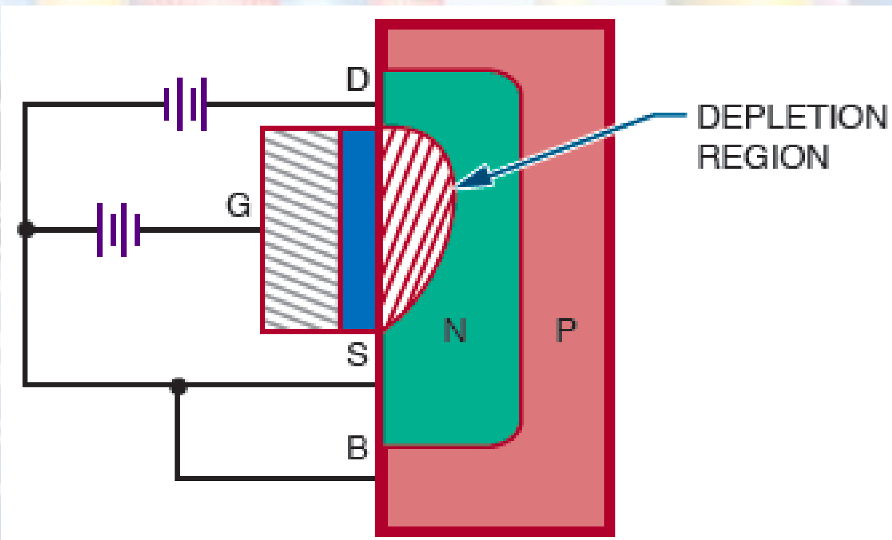


Figure 23-8. N-channel depletion MOSFET with bias supply.

- P-type units with P channels are **enhancement mode** devices.
- In the enhancement mode, the electron flow is normally cut off until it is aided or enhanced by the bias voltage on the gate

Depletion Insulated Gate FETs (MOSFETs) (cont'd.)

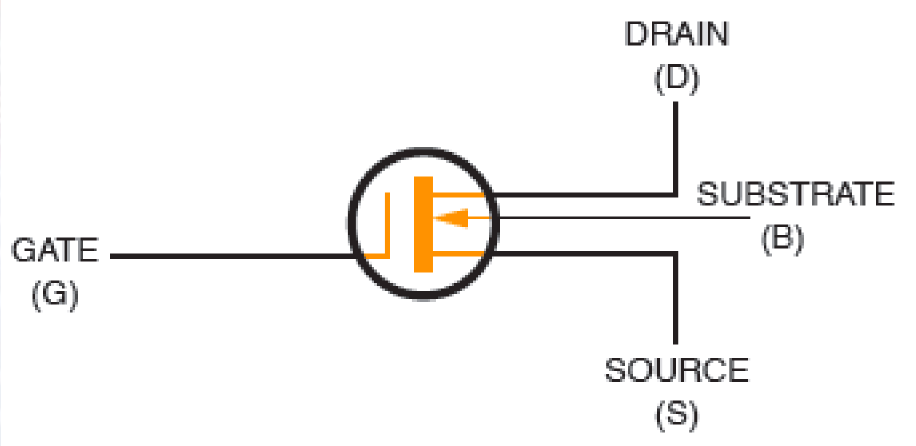


Figure 23-9. Schematic symbol for an N-channel depletion MOSFET.

Depletion Insulated Gate FETs (MOSFETs) (cont'd.)

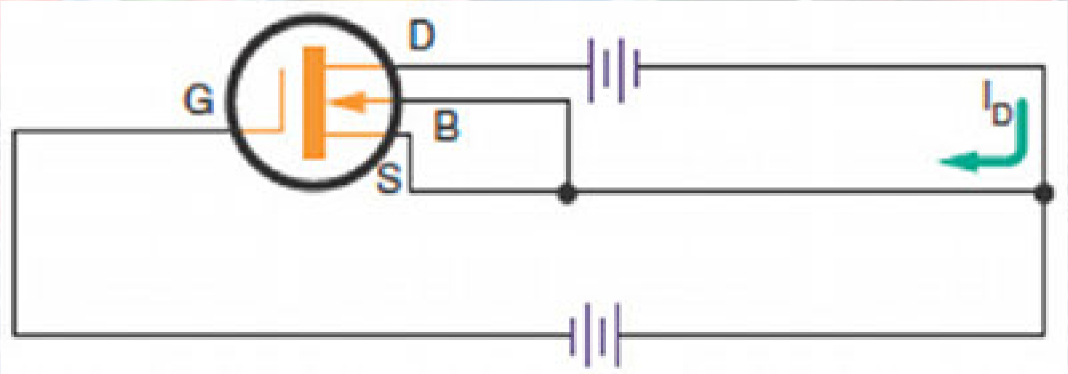


Figure 23-10. Properly biased N-channel depletion MOSFET.

Depletion Insulated Gate FETs (MOSFETs) (cont'd.)

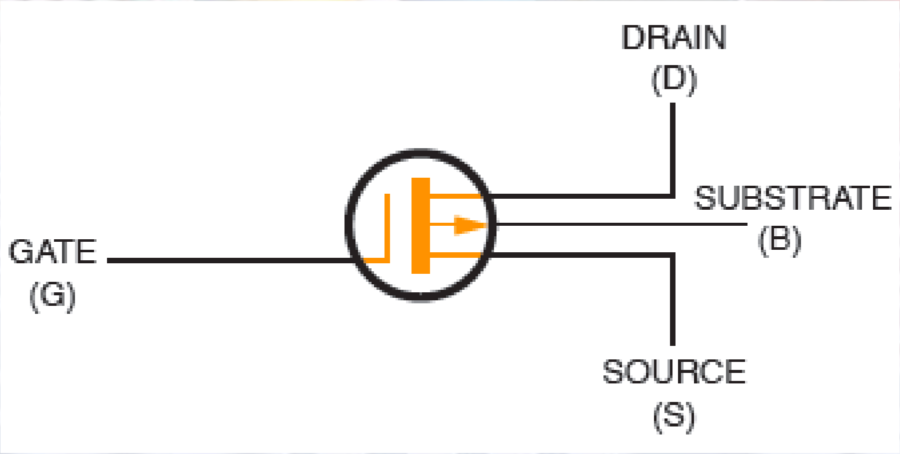


Figure 23-11. Schematic symbol for a P-channel depletion MOSFET.

Enhancement Insulated Gate FETs (MOSFETs)

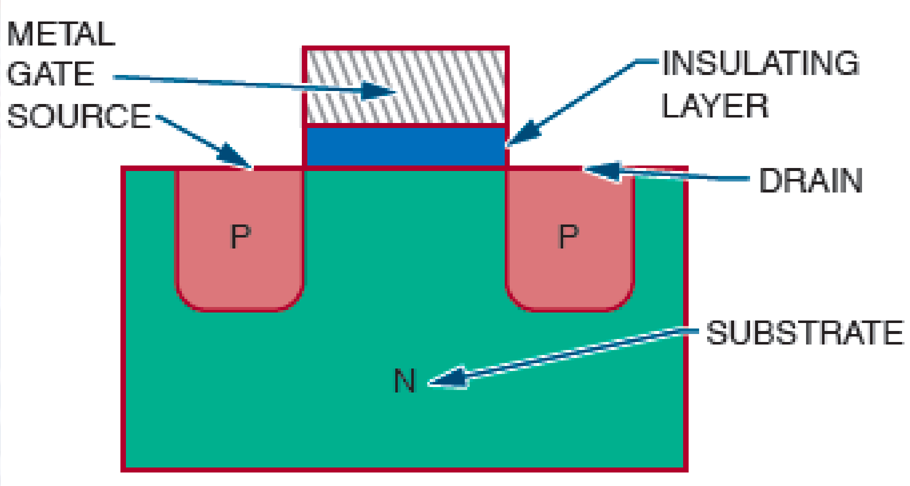


Figure 23-12. P-channel enhancement MOSFET.

Enhancement Insulated Gate FETs (MOSFETs)

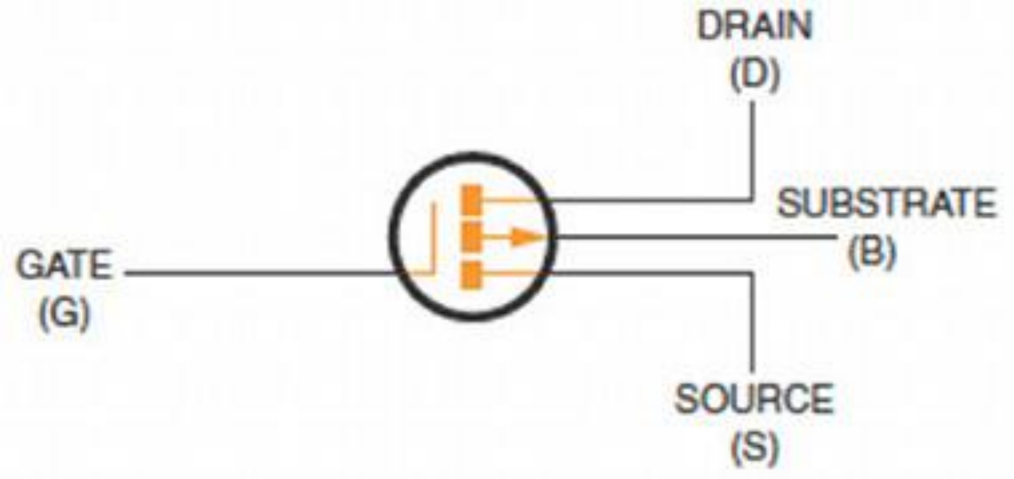


Figure 23-13. Schematic symbol for a P-channel enhancement MOSFET.

Enhancement Insulated Gate FETs (MOSFETs)

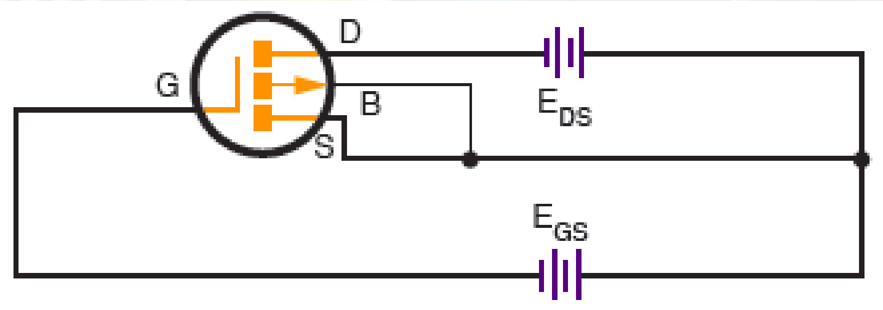


Figure 23-14. Properly biased P-channel enhancement MOSFET.

Enhancement Insulated Gate FETs (MOSFETs)

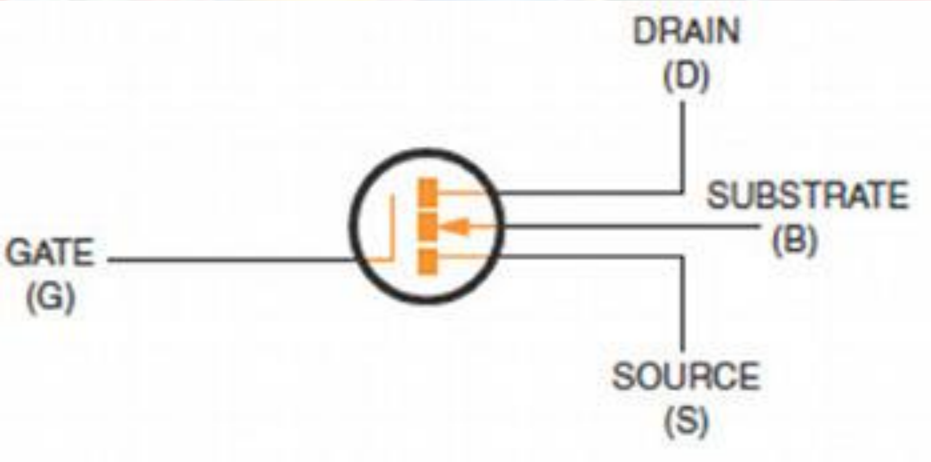


Figure 23-15. Schematic symbol for an N-channel enhancement MOSFET.

Enhancement Insulated Gate FETs (MOSFETs)

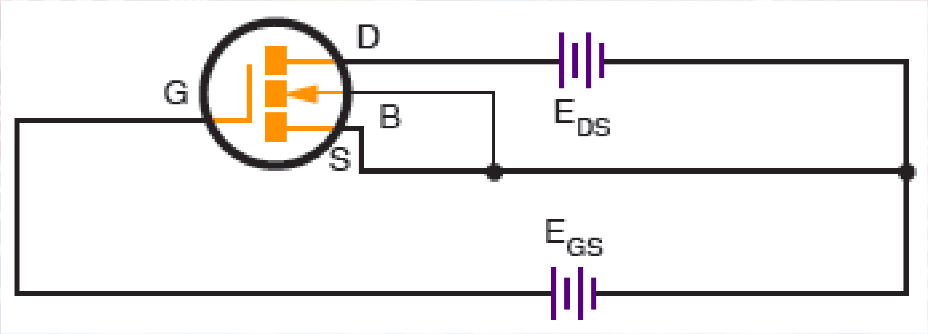


Figure 23-16. Properly biased N-channel enhancement MOSFET.

MOSFET Safety Precautions

- Keep the leads shorted together
- Wear a grounded metallic wristband
- Use a grounded soldering iron tip
- Make sure power is off

Testing FETs

- Commercial transistor test equipment
- Ohmmeter

Summary

- The three leads of a JFET are attached to the gate, source, and drain
- MOSFETs (insulated gate FETs) isolate the metal gate from the channel with a thin oxide layer
- Depletion mode MOSFETs are usually N-channel devices and are classified as normally on

Summary (cont'd.)

- Enhancement mode MOSFETs are usually P-channel devices and are normally off
- Electrostatic charges from fingers can damage a MOSFET
- JFETs and MOSFETs can be tested using a commercial transistor tester or an ohmmeter

Chapter 24

Thyristors

Objectives

- After completing this chapter, you will be able to:
  - Identify common types of thyristors
  - Describe how an SCR, TRIAC, or DIAC operates in a circuit
  - Draw and label schematic symbols for an SCR, TRIAC, and DIAC

Objectives (cont'd.)

- – Identify circuit applications of the different types of thyristors
- – Identify the packaging used with the different types of thyristors
- – Test thyristors using an ohmmeter

Silicon-Controlled Rectifiers

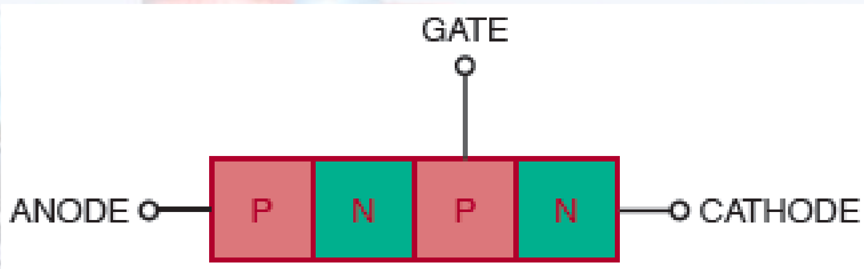


Figure 24-1. Simplified SCR.

- Thyristors are semiconductor devices with a bistable action that depends on a PNPN regenerative feedback **Bistable action** refers to locking onto one of two stable states.
- **Regenerative feedback** is a method of obtaining an increased output by feeding part of the output back to the input.
- Thyristors are widely used for applications where DC and AC power must be controlled.

Silicon-Controlled Rectifiers (cont'd.)

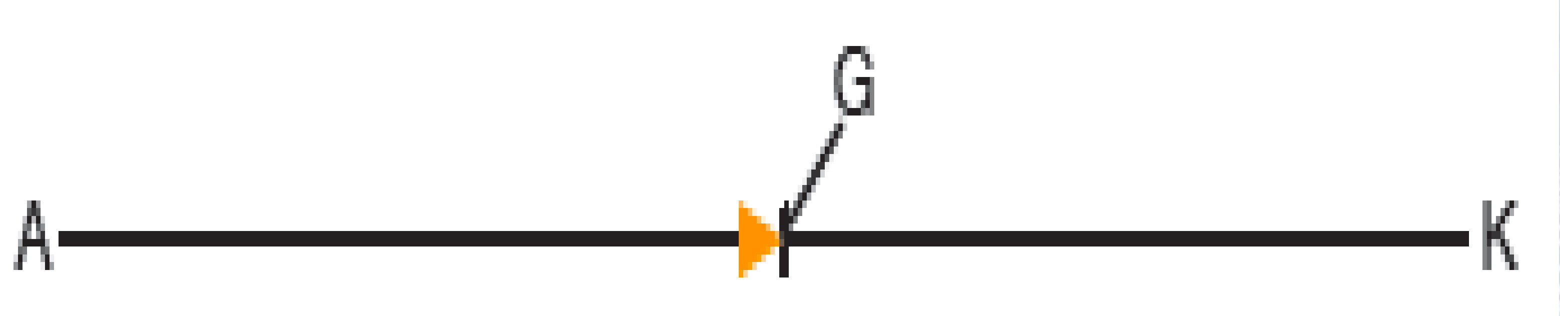


Figure 24-4. Schematic symbol for an SCR.

Silicon-Controlled Rectifiers (cont'd.)

Figure 24-5. Common SCR packages.

Silicon-Controlled Rectifiers (cont'd.)

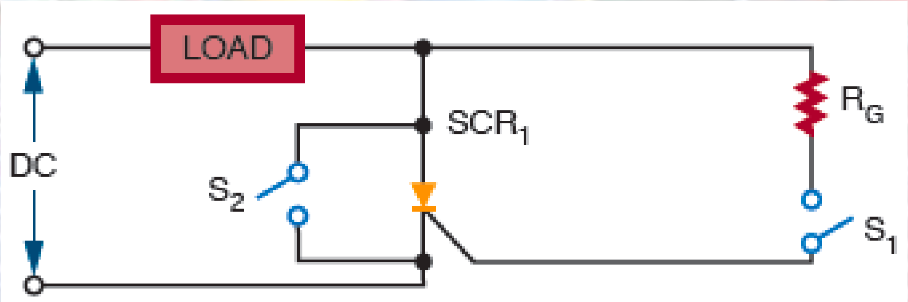


Figure 24-7. Removing power in a DC circuit.

TRIACs

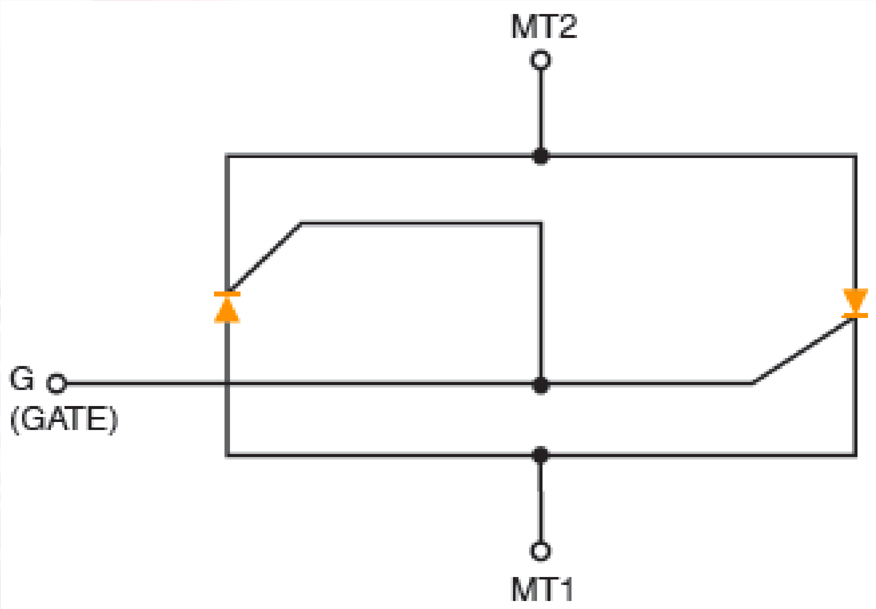


Figure 24-9. Equivalent TRIAC.

- A TRIAC is equivalent to two SCRs connected in parallel, back to back
- Input and output terminals are identified as main terminal 1 (MT1) and main terminal 2 (MT2).

TRIACs (cont'd.)

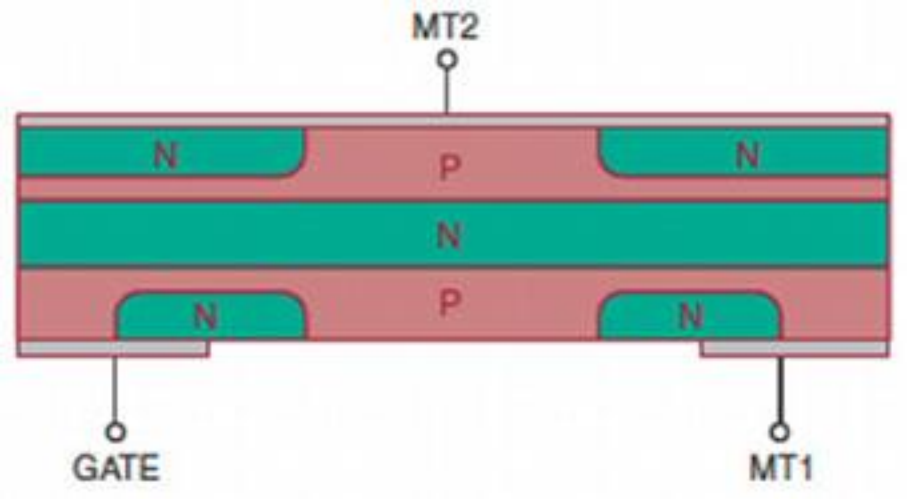


Figure 24-10. Simplified TRIAC.

TRIACs (cont'd.)

Figure 24-11. Schematic symbol for a TRIAC.

TRIACs (cont'd.)

Figure 24-12. Common TRIAC packages.

TRIACs (cont'd.)

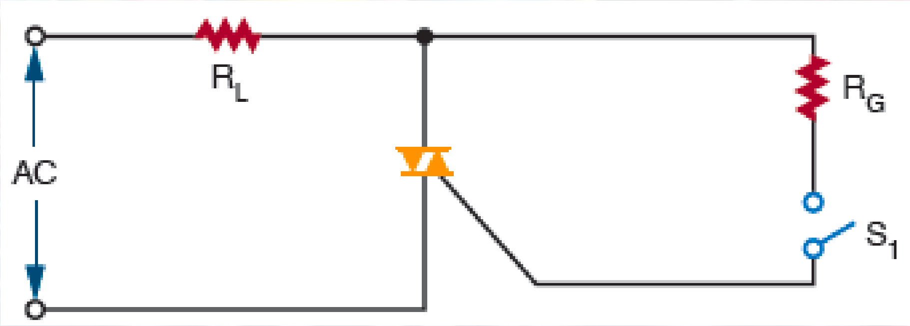


Figure 24-13. TRIAC AC switch circuit.

TRIACs (cont'd.)

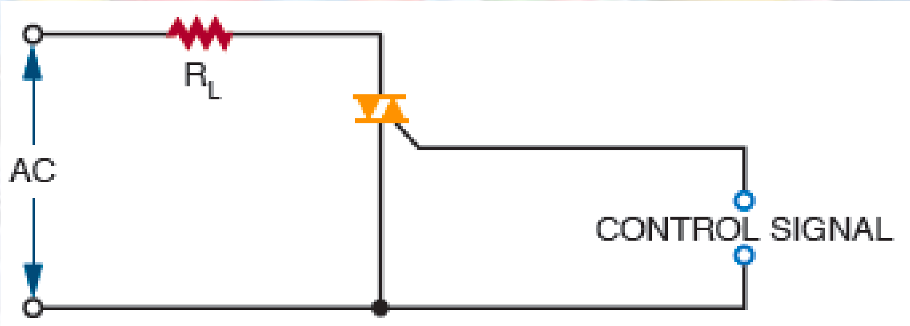


Figure 24-14. TRIAC AC control circuit.

TRIACs have disadvantages when compared to SCRs. TRIACs have current ratings as high as 25 amperes, but SCRs are available with current ratings as high as 1400 amperes

Bidirectional Trigger Diodes

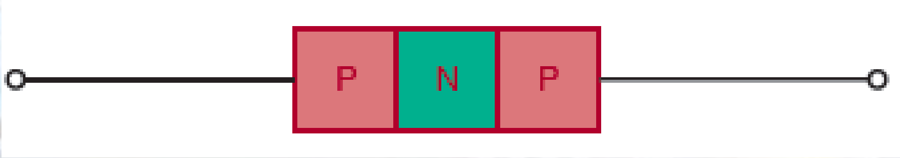


Figure 24-15. Simplified DIAC.

- The DIAC is constructed in the same manner as the transistor. It has three alternately doped layers (Figure 24–15).
- The only difference in the construction is that the doping concentration around both junctions in the DIAC is equal.

Bidirectional Trigger Diodes (cont'd.)

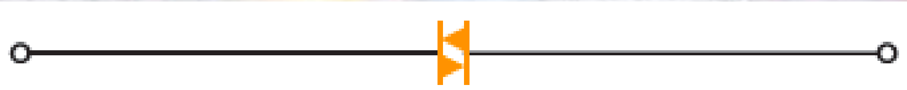


Figure 24-17. Schematic symbol for a DIAC.

Bidirectional Trigger Diodes (cont'd.)

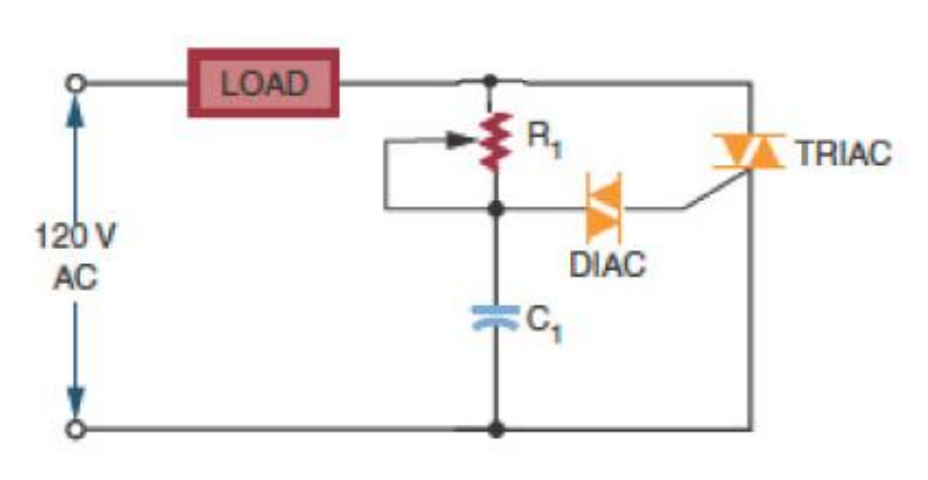


Figure 24-18. Variable full-wave phase-control circuit.

- When the voltage across C1 reaches the breakover voltage of the DIAC, C1 partially discharges through the DIAC into the gate of the TRIAC.
- This discharge creates a pulse that triggers the TRIAC into conduction.

Testing Thyristors

- Commercial test equipment
- Ohmmeter

Summary

- Thyristors include SCRs, TRIACs, and DIACs
- An SCR controls current in one direction by a positive gate signal
- SCRs can be used to control current in both AC and DC circuits
- TRIACs are bidirectional triode thyristors

Summary (cont'd.)

- TRIACs control current in either direction by either a positive or negative gate signal
- Because TRIACs have nonsymmetrical triggering characteristics, they require the use of a DIAC
- DIACs are bidirectional trigger diodes
- Thyristors can be tested using commercial transistor testers or ohmmeters

Chapter 25

Integrated Circuits

Objectives

- After completing this chapter, you will be able to:
  - Explain the importance of integrated circuits
  - Identify advantages and disadvantages of integrated circuits
  - Identify the major components of an integrated circuit

Objectives (cont'd.)

- Describe the four processes used to construct integrated circuits
- Identify the major integrated circuit packages
- List the families of integrated circuits

Introduction to Integrated Circuits

- Advantages of the integrated circuit
  - Reliable with complex circuits
  - Low power consumption
  - Small size and weight
  - Economical to produce
  - New and better solutions to system problems

Introduction to Integrated Circuits (cont'd.)

- Disadvantages of the integrated circuit
  - Cannot handle large amounts of current or voltage
  - Cannot be repaired

Introduction to Integrated Circuits (cont'd.)

- Components of integrated circuits
  - Diodes
  - Transistors
  - Resistors
  - Capacitors

Integrated Circuit Construction Techniques

- Monolithic integrated circuits
  - Formed on a circular silicon wafer substrate
- Thin-film integrated circuits
  - Formed on surface of an insulating substrate
    - Glass
    - Ceramic

Integrated Circuit Construction Techniques (cont'd.)

Figure 25-1. Integrated circuits on wafer.

Integrated Circuit Construction Techniques (cont'd.)

- Thick-film construction
  - Components are formed using a screen printing process
- Hybrid integrated circuits
  - Formed using monolithic, thin-film, thick-film, and discrete components

Integrated Circuit Packaging

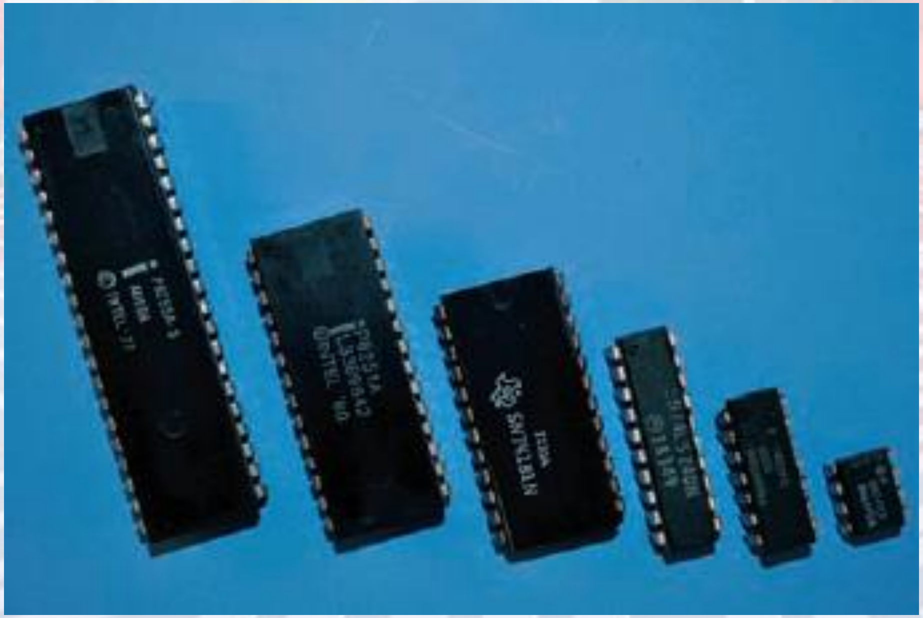


Figure 25-2. Integrated circuit dual-inline packages.

Integrated Circuit Packaging (cont'd.)

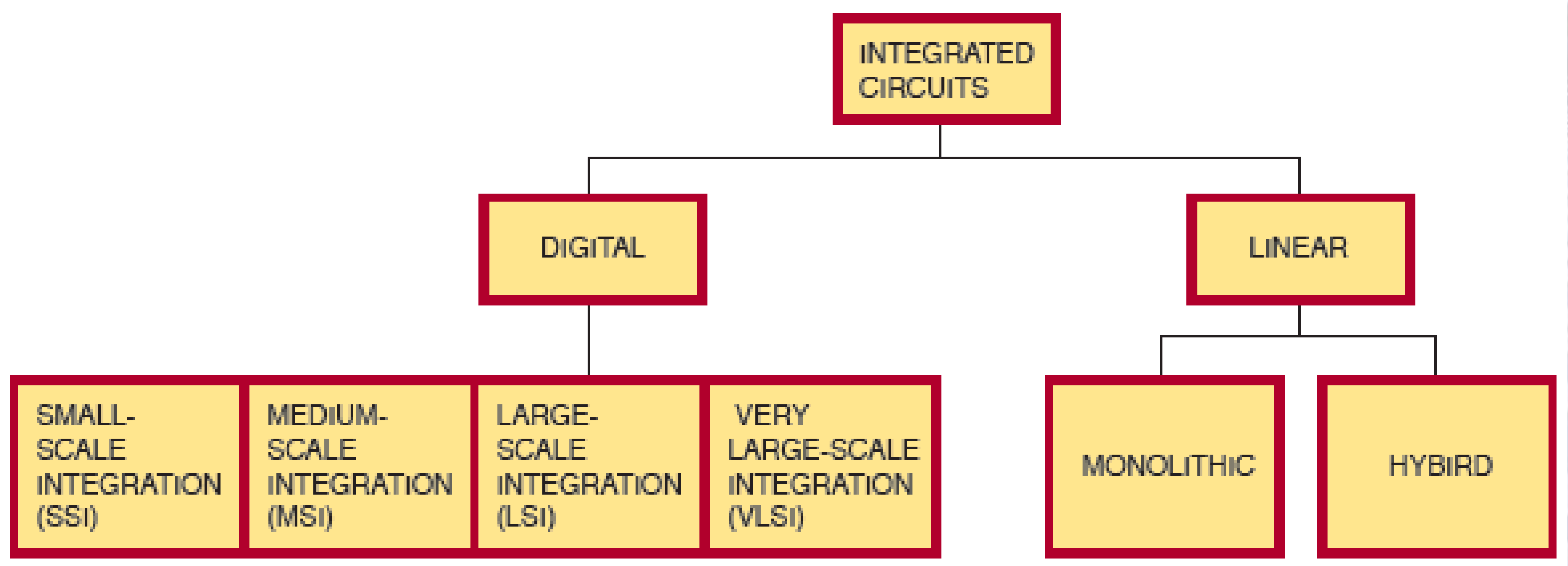


Figure 25-3. Families of integrated circuits.

Handling of Integrated Circuits

Figure 25-4. Warning labels printed on packaging for devices that can be easily damaged by ESD.

Summary

- Integrated circuits are popular because they: are reliable with complex circuits; consume little power; are small and light; are economical to produce; etc.
- Integrated circuits cannot handle large amounts of current or voltage
- Only diodes, transistors, resistors, and capacitors are available as ICs

Summary (cont'd.)

- Integrated circuits are constructed by monolithic, thin-film, thick-film, or hybrid techniques
- The most popular integrated circuit package is the DIP (dual-inline package)
- Electrostatic discharge (ESD) can damage integrated circuits

Homework

1. Describe how a JFET differs in construction from a bipolar transistor.
2. Describe how a MOSFET conducts a current.