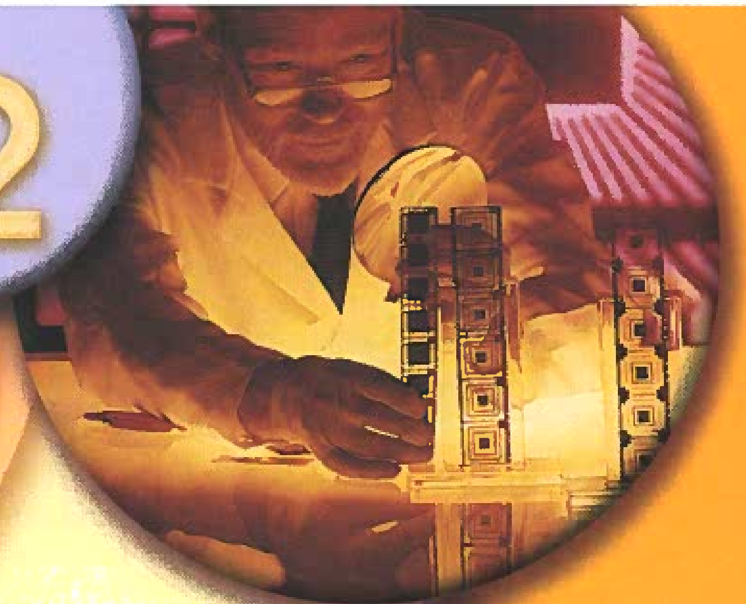
12

Electronics



Basic Concepts

- Identify the values for resistors based on the resistor color code.
- State the purpose of using capacitors in conjunction with resistors for timing functions.
- Recognize the purposes of common electronic components, including resistors, capacitors, transistors, and diodes.

Intermediate Concepts

- Explain the purpose of specific integrated circuits (ICs).
- Convert basic schematics into electronic circuits.

Advanced Concepts

- Construct electronic circuits that include ICs.
- Troubleshoot electronic circuitry in a systematic way.

Electronics is the science that deals with electron flow. The science becomes a technology when it is applied to serve a useful purpose, in devices such as microwaves, cameras, stereos, and personal organizers. Electronics helped to usher in the age of miniaturization and the age of information.

An *electronic device* is made of one or more electronic circuits. An *electronic circuit* is a group of electronic components, such as resistors, capacitors, and diodes, connected together in such a way that they work together to perform a specific function. For example, a television set may have one circuit to receive a TV transmission and another circuit to produce the transmitted images on the TV screen. Another circuit may control the audio portion of the transmission. Each circuit may consist of similar electronic components. Because of each circuit's unique characteristics and arrangement, however, they are each able to perform a specific function.

Electronic device: A device made of one or more electronic circuits.

Electronic circuit: A group of electronic components arranged on a circuit board so that they work together to perform a specific function.

Resistor: A device that resists the flow of electricity.

Common Electronic Components and Circuits

There are many types of electronic components. Some components can control the flow of current through a circuit. Others can act as a switch to turn the circuit on or can store a charge for later use. Electronic components can be combined to create a circuit, which can perform a certain function.

Resistors

A ***resistor*** simply resists the flow of electricity. Some components can only work properly and safely from lower voltages. Restricting current flow can be useful for protecting components in a circuit. A resistor can be used to reduce current flow. Resistors can also be used to modify the time it takes to charge a battery or capacitor or to divide a source voltage into smaller voltages.

Resistor values

The unit of resistance is known as the ohm (Ω). The amount of resistance offered by an individual resistor can be determined by reading the four or five color bands on the resistor and then calculating the resistance. See **Figure 12-1.** Using the chart in Figure 12-1B, you can calculate the resistance of any resistor labeled with color bands. Look at the example provided with the chart. Notice that the first two bands represent a numeric value. In the example, the first band, which is red, represents the numerical value 2. The second band, which is violet, represents the numerical value 7. These values are put together to create a single numerical value, 27. The third band is a multiplier. In this example, the third band is green and represents a multiplier value of 100,000. This value is multiplied by the value derived from the first two bands, which gives the resistor a total resistive value of 2,700,000 Ω, or 2.7 MΩ. The last band is known as the tolerance band. It indicates the tolerance or variance of the resistor. The tolerance depends on the specifications that the resistor must adhere to during manufacturing to be within acceptable limits of resistance for proper operation.

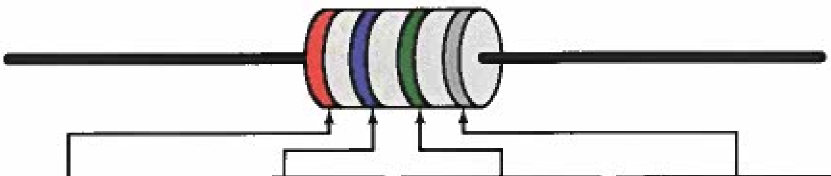
On a five-band resistor, the first three bands represent digits, the fourth band is the multiplier, and the fifth band indicates the tolerance. Any resistor that does not have a fourth or fifth band has a tolerance of +/− 20%. This level of tolerance may be acceptable for many applications. Any resistor that ends with a silver band means the resistor should measure within +/− 10% of its indicated value. If greater accuracy is required, a resistor with a gold band must be used to maintain tolerance to within +/− 5% of its indicated value. Lastly, if a resistor ends in a color band other than silver or gold, the tolerance would be equal to the number on the color code. Look again at the example in Figure 12-1. Notice that the fourth band is silver, which represents a +/− 5% tolerance. This means that the resistor's value will measure anywhere from 2.43 MΩ to 2.97 MΩ. The letter *k* (meaning "kilo-") can be used to substitute for thousands and the letter *M* can be used to substitute for millions.

Of course, resistance can also be measured with an ohmmeter. In order to accurately measure resistors in circuits, it is necessary for a technician to disconnect one lead from the circuit before measuring. When checking

Figure 12-1. A resistor and a resistor color-code chart. A—Color-code bands encircle a resistor and represent the resistive value of the resistor. B—A color-code chart for resistors with four or five bands and an example of how to interpret the color code.

A

B



First Band 1st Digit	
Color	Digit
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Second Band 2nd Digit	
Color	Digit
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Gray	8
White	9

Third Band Multiplier	
Color	Multiplier
Black	1
Brown	10
Red	100
Orange	1,000
Yellow	10,000
Green	100,000
Blue	1,000,000
Silver	0.01
Gold	0.1

Fourth Band* Resistance Tolerance	
Color	Tolerance
Silver	± 10%
Gold	± 5%
*No Band	± 20%

red 2 | violet 7 | green ¥ 100,000 | silver ± 10%

2,700,000 Ω *or* 2.7 MΩ

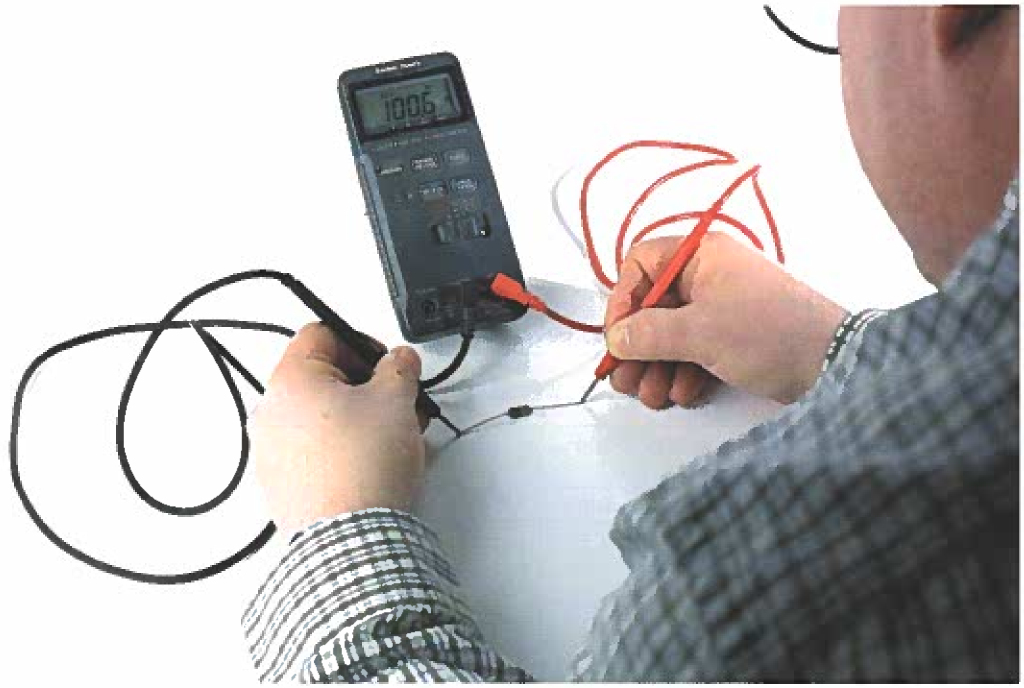
± 270,000 Ω *or* 2.43 MΩ– 2.97 MΩ

at the component level, it is common to isolate each individual resistor and check its value independently. See **Figure 12-2.** Troubleshooting resistors can also be performed with an ohmmeter. First, calculate the rated resistance from the color code on the resistor. Compare the calculated value of the resistor to the measured value, using the ohmmeter. Remember to take the tolerance of the resistor into consideration when comparing the calculated and measured values.

Safety Note

Before measuring resistance in a circuit, be sure the circuit is de-energized. Measuring resistance in an energized circuit could cause personal injury, damage to the ohmmeter, or both.

Figure 12-2. Measuring resistance with an ohmmeter. Note that the component to be tested is isolated from the circuit and tested when it is not energized. The power from the battery in the meter is enough to test the component.



Variable resistors

Variable resistors perform the same function as fixed resistors, except the resistive value can be varied. This is typically performed by rotating a knob or moving a sliding switch, such as a dimmer switch for a light. See **Figure 12-3.** The variable resistor is made of a piece of resistive material, often carbon, with an electrical connection (terminal) at each end of the resistive material, similar to a fixed resistor. A variable resistor, however, includes another electrical connection (terminal) known as a ***wiper***. The wiper can change position along the resistive material, based on the position of the knob or slider. This, in turn, changes the amount of resistive material between the wiper and each end terminal of the variable resistor. The result is a resistor that can offer a varying resistive value as the position of the variable resistor is changed.

Wiper: The electrical connection on a potentiometer that can change position along the resistive material, based on the position of the knob or slider.

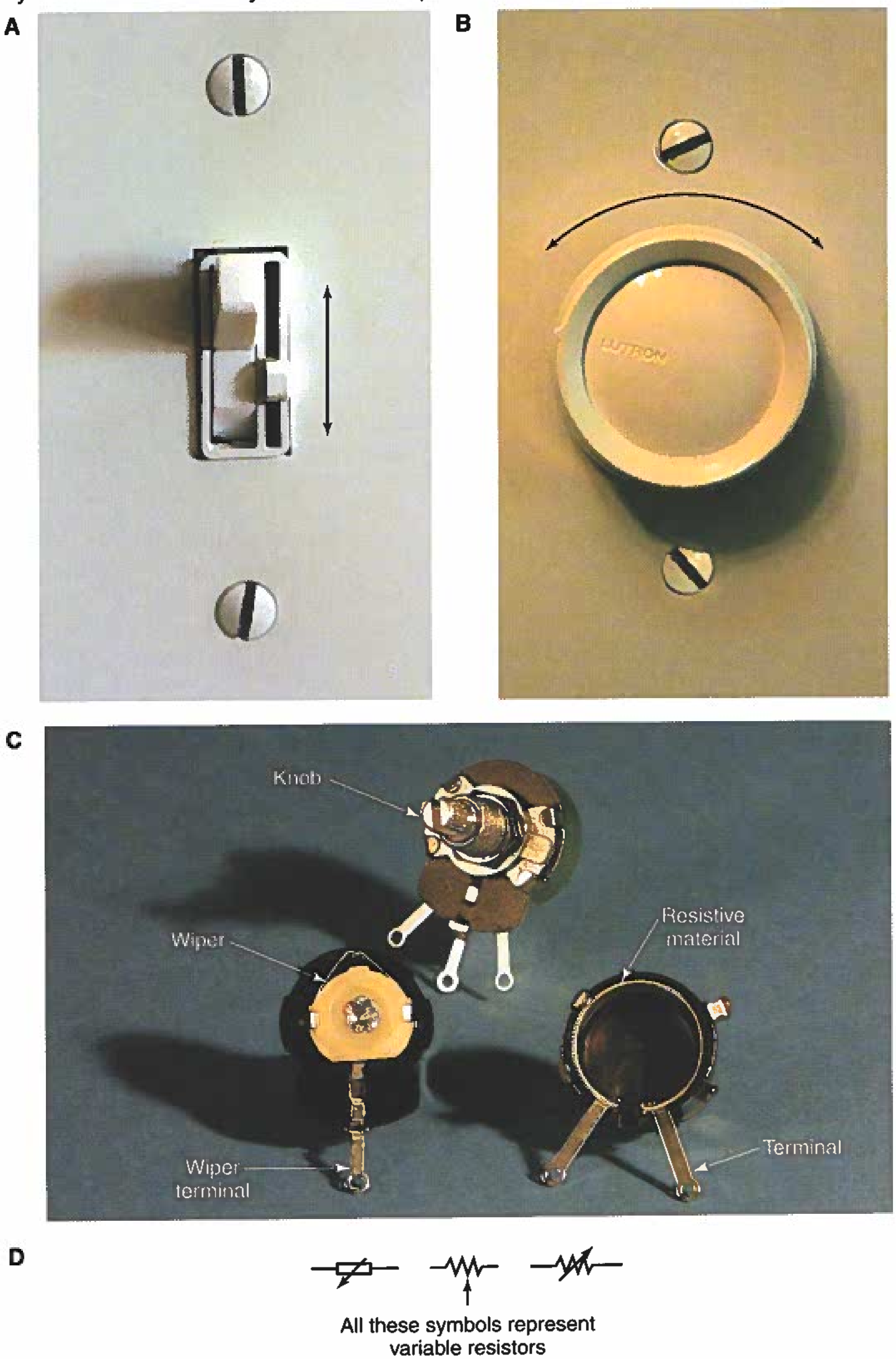
Capacitors

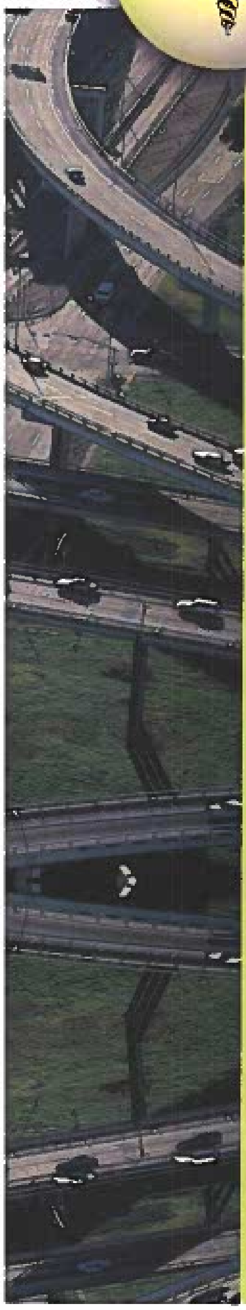
A ***capacitor*** has the ability to store an electrical charge. Unlike batteries, capacitors can store and discharge electricity very quickly. The electrical charge can last for very long periods of time. Capacitors in a circuit can also be used to smooth out variations in power pulses and to block continuous, direct current (DC) flow, while allowing for current pulses to flow.

Capacitor: A device that has the ability to store an electrical charge. Unlike batteries, capacitors can store and discharge electricity very quickly.

There are several types of capacitors, but two of the most common are ceramic disk and electrolytic. The ceramic disk capacitor is made of ceramic and silver, and the electrolytic capacitor is made of an electrolyte

Figure 12-3. Variable resistors are often used in dimmer switches. A—A dimmer switch with a slide control. B—A dimmer switch with a knob (dial) control. C—The inside of a variable resistor. D—Each of the schematic symbols identified may be used to represent a variable resistor.





Technology Link

Medicine: Electrical Shocks

Working with electronics can be dangerous. Several precautions can be taken to prevent accidents from occurring, but medical technology is very important when accidents do occur. Power technology depends on medicine and treatment for the safety and well-being of anyone working with live electricity.

Electricity can cause vital organs, such as the heart and brain, to malfunction. It can also lead to fatal burns. Electric shocks are responsible for about 1000 deaths in the United States every year. The severity of an injury from an electric shock depends on several factors: the voltage and amperage, the body's resistance to the current, the current's path through the body, and how long the body remains in contact with the current.

Various types of medical technology are important for treating victims of electric shocks. Neurological problems (injuries to the brain, spinal cord, or nerves) are the most common forms of nonlethal damage caused by electric shocks. Extensive damage can also be done to the respiratory and cardiovascular systems. Electric shocks can even cause cataracts, kidney failure, destruction of muscle tissue, and violent muscle spasms that can break and dislocate bones.

After an electrical accident has occurred, emergency medical help should be called immediately. Bystanders trained in cardiopulmonary resuscitation (CPR) may be required to perform first aid until help arrives. First, check to see if the victim is breathing and if there is a heartbeat. Feel for a pulse and watch the victim's chest to see if it is rising and falling. If the victim has no heartbeat or breath, CPR must be performed. If the heart is beating but the victim is not breathing, rescue breathing should be started immediately.

Once medical help has arrived and the victim is in stable condition, his or her cardiovascular system and kidneys must be monitored. Neurological activity also must be observed closely for changes. Medical technology, such as a computerized tomography (CT) scan or magnetic resonance imaging (MRI), may be necessary to check for brain injuries. Treatment for kidney failure may be required.

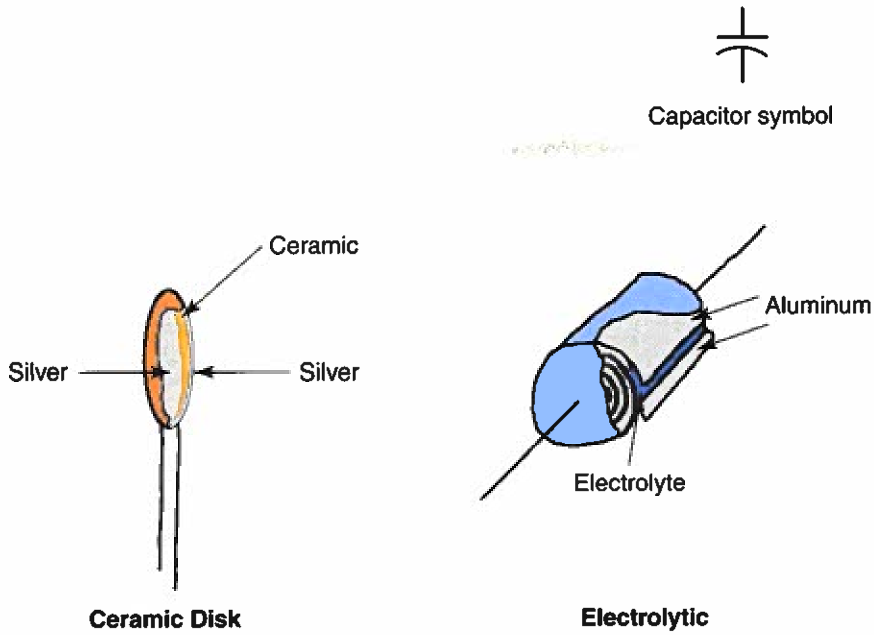
The victim also may suffer from third-degree burns from an electric shock. Burn victims typically require treatment at a burn center. To restore lost fluids and electrolytes, fluid replacement therapy is necessary. Tissue that has been severely damaged can be repaired surgically and may include skin grafting or amputation. To prevent infections, antibiotics and antibacterial creams are used.

Depending on the extent of the injuries, a victim of an electric shock may require physical therapy in order to recover. He or she may also need psychological counseling to cope with the tragedy and, in some cases, the disfigurement or other long-term effects. Prevention is the best medicine for electrical accidents, so every precaution should be taken when dealing with this dangerous form of power.

material and aluminum. See **Figure 12-4.** Both types can store electricity, but the electrolytic capacitor has more storage capacity. Other types of capacitors are made of other materials, such as Mylar® film, metalized film, and polyester film.

The unit of capacitance is known as the farad (F). The majority of capacitors have a capacitance of only a few millionths of a farad. The range of capacitance varies so widely that capacitors are typically rated in

Figure 12-4. Ceramic disk and electrolytic capacitor construction.



terms of millionths of a farad (microfarads, or µF) or trillionths of a farad (picofarads, or pF). See **Figure 12-5.**

Electrolytic capacitors are typically large enough to have their value in µF marked on their casing. Ceramic disk capacitors may be marked with a value in µF, or they may be marked with a three-digit code, indicating their value in pF. The first two digits of the code represent numerical values, and the last digit represents the number of zeros. For instance, a capacitor stamped *224* would calculate as 22 + 0000, translating to 220,000 pF, or .22 µF. Some capacitors use a color-coded system similar to resistors.

GREEN TECH
In recent years, light-emitting diodes (LEDs) have been used to replace traditional lighting, such as in traffic lights. LED have less of an impact on the environment because they are more efficient.

Diodes

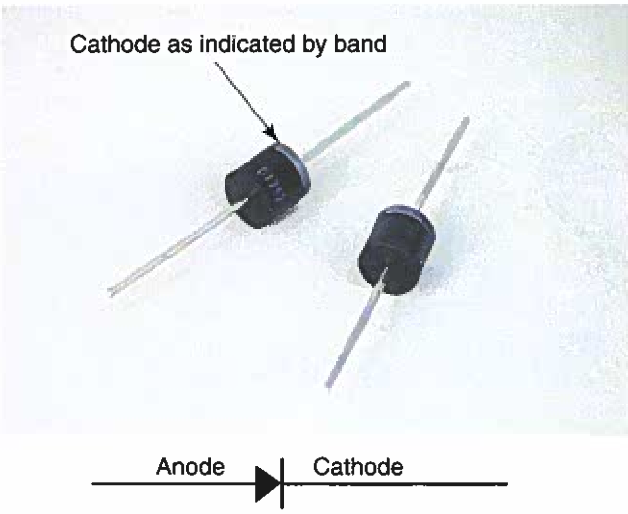
A standard ***diode*** allows for the one-way flow of electricity. It is similar to a check valve in a fluid power circuit. Diodes can also perform a switching function, in that electricity cannot flow through them until it reaches a certain voltage. For small diodes, this may be about .6 V, but larger diodes may require higher voltages before allowing electricity to

Diode: A device that allows for the one-way flow of electricity. It can also perform a switching function, in that electricity cannot flow through it until it reaches a certain voltage.

Figure 12-5. This table shows the relationship between farads (F), microfarads (µF), and picofarads (pF).

Farads (F)	Microfarads (µF)	Picofarads (pF)
.001	1000	1,000,000,000
.0001	100	100,000,000
.00001	10	10,000,000
.000001	1	1,000,000
.0000001	.1	100,000
.00000001	.01	10,000
.000000001	.001	1,000

Figure 12-6. Typical rectifier diodes. Notice that the band on the diode indicates the cathode end. In the schematic symbol of a diode, the arrow represents the anode, and the line represents the cathode.



flow. The physical size of a diode is usually indicative of its amperage rating. A band on the diode indicates the cathode of the diode. See **Figure 12-6.** The cathode is the negative terminal into which electrons will flow. The anode is the positive terminal from which electrons will flow. The line in the schematic symbol of a diode represents the cathode, while the triangle represents the anode.

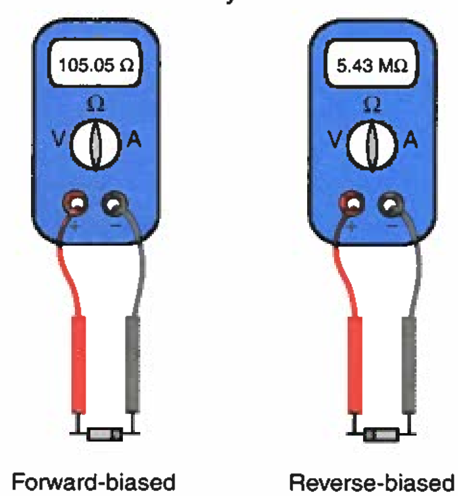
The flow of electricity occurs through a standard diode only when electricity of the proper polarity is applied. This is called a ***forward bias***. *Polarity* is defined as the condition of being electrically positive or negative, with respect to ground. DC flows through the diode in circuits in which the diode is forward-biased, but it does not flow through the diode in circuits in which the diode is reverse-biased. Alternating current (AC) has a charge that constantly changes between positive and negative. When AC flows in a direction in which the diode is forward biased, current flows through the diode. When AC flows in a direction in which the diode is reverse biased, the current cannot flow through the diode.

Forward bias: The flow of electricity occurring through a standard diode when electricity of the proper polarity is applied.

Testing diodes

Diodes can be tested in a de-energized state using an ohmmeter or continuity tester. Some continuity testers are labeled as both "continuity check" and "diode check." The diode should indicate a low level of resistance when the meter probes are placed on the diode in the forward-biased position and a high level or infinite level (overload) of resistance when the meter probes are placed on the diode in the reverse-biased position. See **Figure 12-7.**

Figure 12-7. Testing a diode. The diode should only allow for continuity in one direction.



Rectifier circuits

Many appliances use DC power instead of AC power. A diode is a useful tool for converting AC current into DC current. A half-wave rectifier is the simplest form of AC-to-DC converter. The half-wave rectifier allows only half the AC cycle to progress past the rectifier. The result produces a pulsating, DC current. See **Figure 12-8.** In Figure 12-8A, the positive alternation of an AC waveform is applied to the circuit. The diode allows current to flow because it is forward biased. In Figure 12-8B,

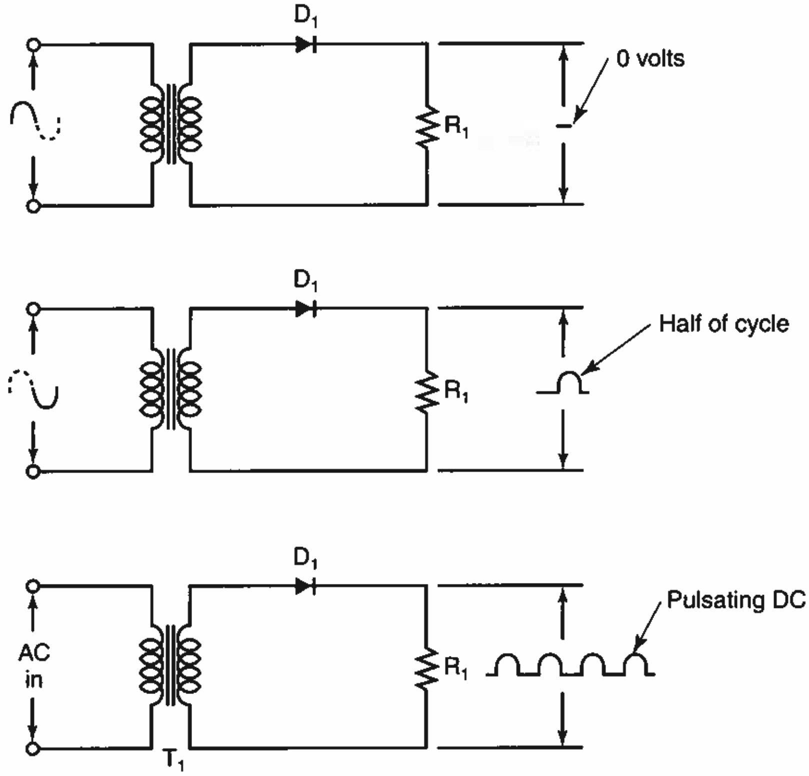


Figure 12-8. Using a diode to create a half-wave rectifier.

the negative alternation of an AC waveform is applied to the circuit. The diode prevents current flow. Figure 12-8C shows the continual output of this circuit, which is a pulsating DC.

Zener diode: A diode that conducts current in the reverse-biased direction. It blocks current until the voltage exceeds a certain level, and then it allows the current to flow. Once the zener diode allows current to flow, it is able to maintain a steady voltage.

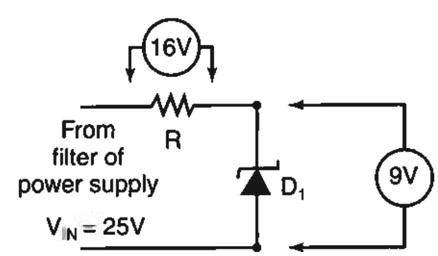
Zener diodes

Another type of diode is referred to as a zener diode. Like a standard diode, a ***zener diode*** only allows for electricity to flow in one direction. The zener diode, however, conducts current in the reverse-biased direction. Therefore, zener diodes are connected in the reverse-biased direction. They block current until the voltage exceeds a certain level, and then they allow the current to flow. Once the zener diode allows current to flow, it is able to maintain a steady voltage. Zener diodes are often used in voltage regulation circuits because of this characteristic. See **Figure 12-9.**

Light-emitting diodes (LEDs)

The third type of diode is extremely popular for visual displays. It is known as a light-emitting diode (LED). LEDs are often used as indicator lights and can be produced in a variety of colors. Some can emit more than one color. The cathode lead from an LED is often shorter than the anode lead and is typically indicated by a flat area on the base of the LED.

Figure 12-9. A zener diode is properly inserted into a circuit in the reverse-bias direction.



STEM Connection

Science: Light-Emitting Diodes (LEDs)

Light is emitted in waves of energy. Higher energy lights have higher frequencies, resulting in light beyond the visible spectrum. The frequency of a light determines its color. In the electromagnetic spectrum, the lowest visible frequency is red, while violet is the highest. Light waves with a frequency lower than those of red light are infrared. Higher frequency light waves than those of violet light are ultraviolet (UV). The wavelength, or size of a wave, is determined by measuring the distance between peaks of waves.

One of the most common methods of producing light is by an incandescent bulb. This type of bulb contains a filament of tungsten, which glows white when heated. Producing light in this way requires that a great deal of energy supplied to the filament be converted to heat rather than light.

A more efficient means of lighting is the use of light-emitting diodes (LEDs). LEDs typically produce light in a single color and are used in several practical applications, including remote controls and traffic lights. In the 1960s, LEDs were created to produce infrared light. Shortly afterward, visible red, yellow, and green light could be produced by LEDs. More recently, violet and UV lights have been achieved by using LEDs.

LEDs operate more efficiently than incandescent bulbs to provide light because they do not produce heat. The semiconductor material is placed within a casing that is typically transparent. The current that flows through the diode must be forward biased in order to produce a wavelength of a single color. The casing is usually formed so the light reflects off the sides and so it is focused outward.

One popular form of alphanumeric display is a seven-segment LED. See **Figure 12-10.** The seven segments of the visual display are each powered by an individual LED. Lighting different combinations of the seven segments can create numbers *0* through *9* on the visual display. The seven-segment LED can also be used to create many letters and symbols.

Transistors

Solid-state: A type of device that can perform a switching function without any physical moving parts.

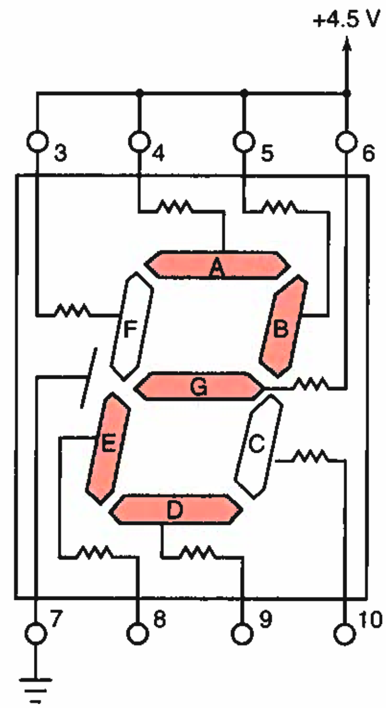
Bipolar transistor: A transistor with three junction points: an emitter, a base, and a collector.

Transistors are ***solid-state*** switching devices. This means they can perform a switching function without any physical moving parts. There are two types of transistors: bipolar and power field-effect. A ***bipolar transistor*** usually has three junction points. These points are known as the emitter, base, and collector. See **Figure 12-11.** Current typically flows between the emitter and the collector. This current flow can be switched on or off by a current delivered to the base. Bipolar transistors can sometimes be used for amplification purposes. When used for amplification, a small amount of current applied to the base of the transistor controls a larger amount of current across the collector and emitter. In other words, a gain in base current will produce a proportional gain in collector/emitter current.

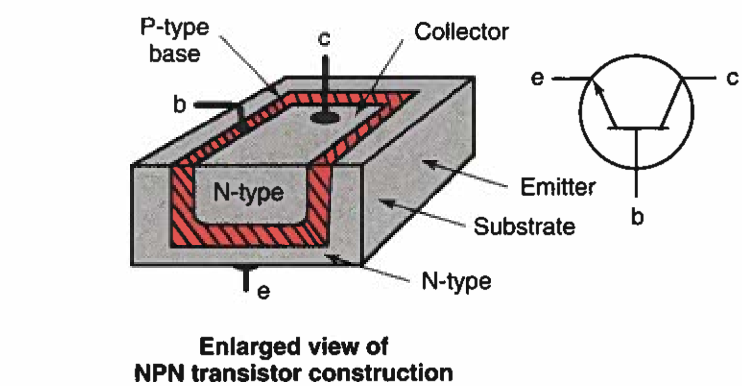
Figure 12-10. Light-emitting diodes (LEDs) are often used to display numbers, letters, and symbols. A—A device that uses several, seven-segment LEDs. B—A seven-segment LED. Notice how the seven segments can be used in any combination to portray numbers *0* through *9*.

A

B



A



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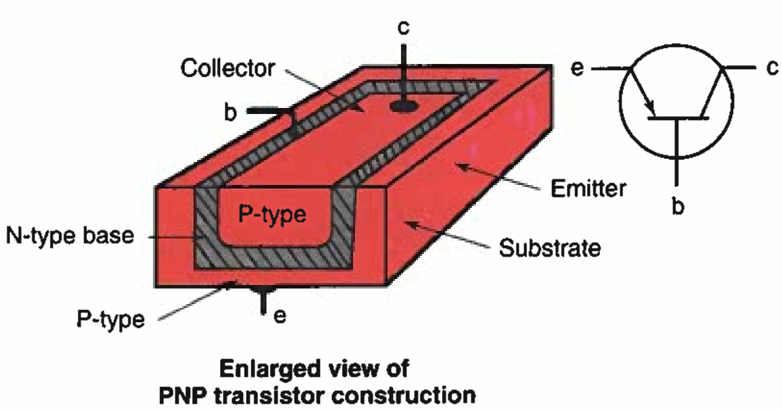


Figure 12-11. Bipolar transistor construction and schematic symbols. The three junction points are the emitter (e), base (b), and collector (c). A—An NPN transistor. B—A PNP transistor.

Field-effect transistor: A switching device often used because it can carry much more current than a bipolar transistor. It has three terminals: a gate, a drain, and a source.

Integrated circuit (IC): A collection of electronic circuits, undistinguishable to the naked eye, etched into a thin layer of silicon and installed into a plastic or ceramic housing.

A ***field-effect transistor (FET)*** is another type of transistor. The metal-oxide-semiconductor field-effect transistor (MOSFET) and junction field-effect transistor (JFET) are two common types, and they operate in similar ways. FETs are popular in today's circuits because they are easy to manufacture, cheap to make, and can be made extremely tiny. They are exceptional switching devices and are often used because they can carry much more current than bipolar transistors. FETs have three terminals. These terminals are the gate, drain, and source. The MOSFET may have an additional terminal connected to the substrate. Current typically flows between the source and the drain. It can be switched on and off by voltage at the gate. MOSFETs are often used as switches. They can also be used for amplification purposes, similar to the bipolar transistor. See **Figure 12-12.**

Integrated Circuits (ICs)

An ***integrated circuit (IC)*** is a collection of electronic circuits, undistinguishable to the naked eye, etched into a thin layer of silicon, and installed into a plastic or ceramic housing. See **Figure 12-13.** The ceramic housing contains a series of protruding leads. These leads are known as pins. The pins allow the IC to be installed into a base, called a ***socket,*** so the IC can be connected with other components in a circuit.

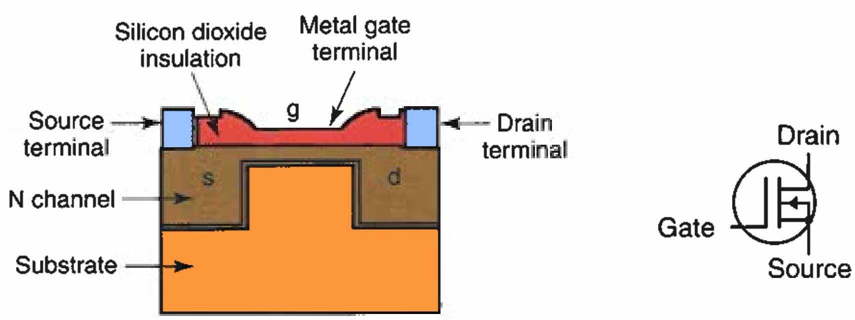


Figure 12-12. N-channel metal-oxide-semiconductor field-effect transistor (MOSFET) construction and its schematic symbol.

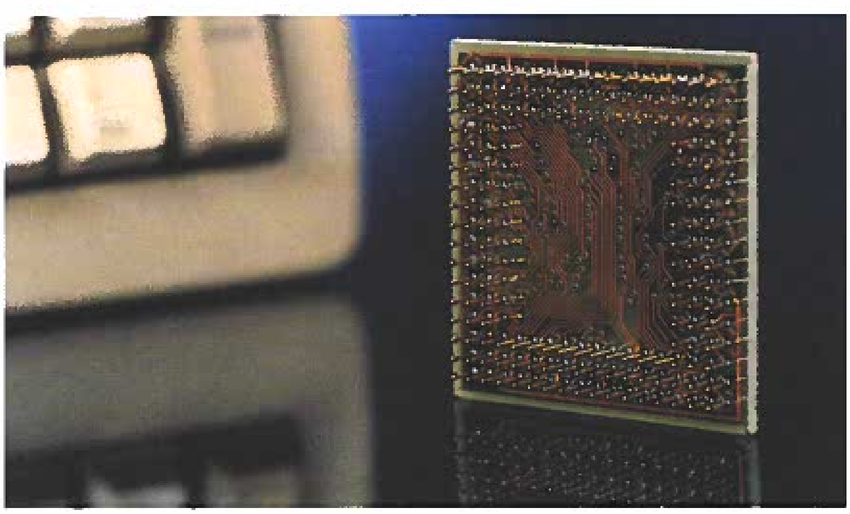


Figure 12-13. An integrated circuit (IC).

Always be careful not to bend or force the pins of an IC when installing them into a socket. IC pins can easily be damaged. A dot or notch usually identifies Pin 1 on an IC. Pin 1 is always the bottom pin on the left-hand side of the index marker. A ***pin-out*** shows all the pins on a given IC and may indicate their purpose. See **Figure 12-14.**

Common applications for ICs include counting functions, timing functions, and logic functions. Logic functions include AND, OR, and NOT logic, identical to the circuit logic studied in Chapter 11. Other ICs convert analog signals into digital signals.

ICs come in two basic types. The first type of IC is known as transistor-transistor logic (TTL), and the second type is known as complementary metal oxide semiconductor (CMOS). The ***transistor-transistor logic (TTL)*** IC works on low voltage, typically 5 V or less. An advantage of the TTL IC is it is relatively easy to work with because it is not subject to damage by static electricity. A downside to using a TTL IC is that it has a higher current draw than a CMOS IC.

Complementary metal oxide semiconductor (CMOS) ICs typically work with voltages up to 18 V and draw very little current. This provides an advantage when powering the circuit from a remote source, such as a battery. CMOS ICs are easily damaged by static electricity, however, and must be handled and stored with care. IC labels that begin with the number 4, like the 4046, are typically part of the CMOS family. TTL ICs and CMOS ICs are generally incompatible with one another. Selection of the appropriate IC family is made based on the particular application.

ICs labeled beginning with the number 74, such as the 7448, are usually part of the TTL family. The 7448 IC is a decoder-driver for a seven-segment LED. It interprets signals received and illuminates certain segments of an LED, thereby creating numbers, symbols, and letters based on the interpreted signals. A seven-segment LED would be of little use without a decoder-driver IC to sort out the signals and illuminate the correct segments on the LED.

The 741 series of ICs are operational amplifiers (op-amps). An ***operational amplifier (op-amp)*** has the ability to take in an AC or DC signal and amplify the output by as much as 100,000 times the input. This makes op-amps ideal for use in radios, TVs, and other sound-producing media devices. The 741 IC has two inputs: inverting and noninverting. A signal applied to an inverting input results in a signal of the opposite polarity at the output. One applied to a noninverting input results in a signal of the same polarity at the output.

The 555 IC chip is based on CMOS technology and is among the most popular ICs. It can be used for all sorts of timing operations, including monostable and astable applications. A ***monostable application*** turns something on or off for a specific period of time, such as the indicator light for seat belts in a car. An ***astable application*** provides continuous pulses at timed intervals. A 555 IC used to make an indicator light blink continually is an example of an astable application.

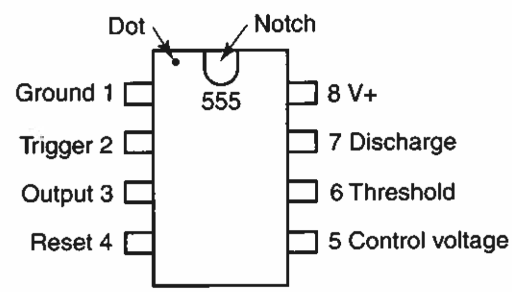
Socket: A base into which an integrated circuit (IC) is installed, allowing the IC to be connected with other components in a circuit.

Pin-out: A device that shows all the pins on an integrated circuit (IC) and may indicate their purpose.

Transistor-transistor logic (TTL): A type of integrated circuit (IC) that works on low voltage, typically 5 V or less.

Complementary metal oxide semiconductor (CMOS): A type of integrated circuit (IC) that typically works with voltages up to 18 V and draws very little current.

Figure 12-14. A pin-out for a typical integrated circuit (IC) chip.



Operational amplifier (op-amp): An integrated circuit (IC) that has the ability to take in an alternating current (AC) or direct current (DC) signal and amplify the output by as much as 100,000 times the input.

Monostable application: An integrated circuit (IC) application that turns something on or off for a specific period of time.

Astable application: An integrated circuit (IC) application that provides continuous pulses at timed intervals.

The 556 IC is actually a pair of 555 ICs combined into one 14-pin package. This IC is extremely useful when two timing functions are required. For instance, if you wanted an indicator light to blink, it would require the use of one 555 IC in astable mode. If you wanted the blink to occur for a specific duration of time, it would require a second 555 IC operating in monostable mode.

Fuses and Circuit Breakers

Fuses and circuit breakers protect electronic circuits from excessive current flow (amperage). Most often, fuses are used in electronic circuits, but occasionally restorable circuit breakers are used to protect the circuit. Regardless of which protection method is used, it is important that the protection device be properly sized to protect all components of the circuit from excessive current flow that could damage components in the circuit.

Circuit Boards and Solderless Breadboards

Circuit boards provide a platform for electronic circuitry. They serve as a base for mounting components and serve as part of the circuitry. Tiny copper paths on the circuit board make many of the connections between electronic components. See **Figure 12-15.**

A solderless breadboard is ideal for testing electronic circuits for educational purposes and for testing circuits prior to permanent installation. See **Figure 12-16.** Since components are not soldered in place, they can be easily removed and replaced. The solderless breadboard saves a lot of time and allows components to be easily installed and removed. Solderless breadboards sometimes use a coordinate system made of letters and numbers to indicate junction points. This can be helpful for creating circuits from specific plans that state, for instance, "Insert Pin 1 in Slot F-12."

Figure 12-15. A circuit board provides a platform for electronic circuitry. A—Components are mounted to the circuit board. B—Copper paths on the circuit board connect the electronic components and form a circuit.

A B

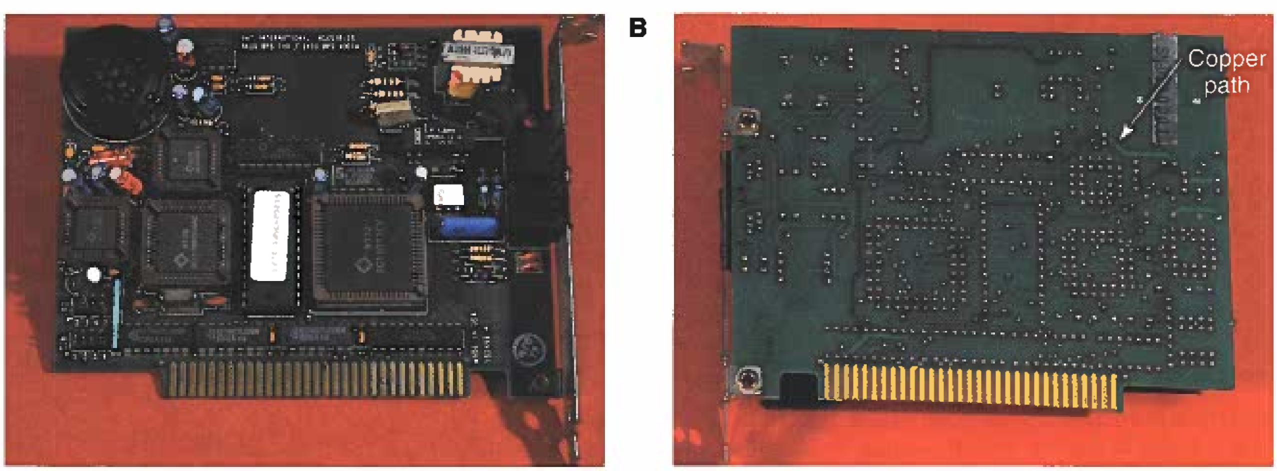
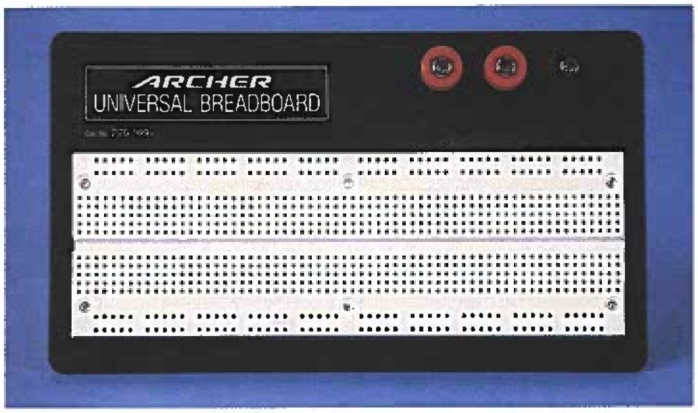


Figure 12-16. A solderless breadboard.



GREEN TECH

The manufacture of integrated circuits involves consumption of a great deal of water and silicon for each circuit, as well as energy and waste. Scientists are working on reducing this environmental impact.

Wire

Wire leads are often used to feed an electronic circuit and sometimes used to make connections within an electronic circuit. The solderless breadboard uses a series of wire leads to make connections to the various components of a circuit. Copper paths often serve this purpose on a conventional electronic breadboard, but even a conventional breadboard may require wires to power the breadboard or to power components like speakers, which are located remotely from the breadboard. Wire leads, like all electrical components, must be sized appropriately to handle the anticipated ampere flow without overheating.

Schematic Diagrams

Schematic diagrams allow for the construction of electronic circuitry. Reading and interpreting schematic diagrams—from the simplest circuits involving only a few components to more complex circuits involving dozens of components—is essential. See **Figure 12-17.** Buzzers and relays are examples of loads.

Even complex schematics that appear intimidating at first glance can be broken down into simple elements. For instance, if asked to construct the circuit in **Figure 12-18,** you might begin with the first component, or you might begin with the simple components, such as switches you are absolutely sure you know about. You may also seek some additional assistance. For instance, if the circuit includes an IC, locating the pin-out for the chip may be necessary to ensure it is installed properly. In time, your knowledge of schematic symbols and proper component installation will grow, and your confidence in constructing circuits from schematics will grow as well.

Troubleshooting Electronic Circuits

Troubleshooting electronic circuits requires more advanced skills than simply constructing electronic circuits. To effectively troubleshoot, it is important to know how to operate a multimeter properly. It is also important to have a thorough understanding of how the components are intended to work in their proper state so faults can be correctly identified.

Figure 12-17. Schematic symbols for common electronic components.

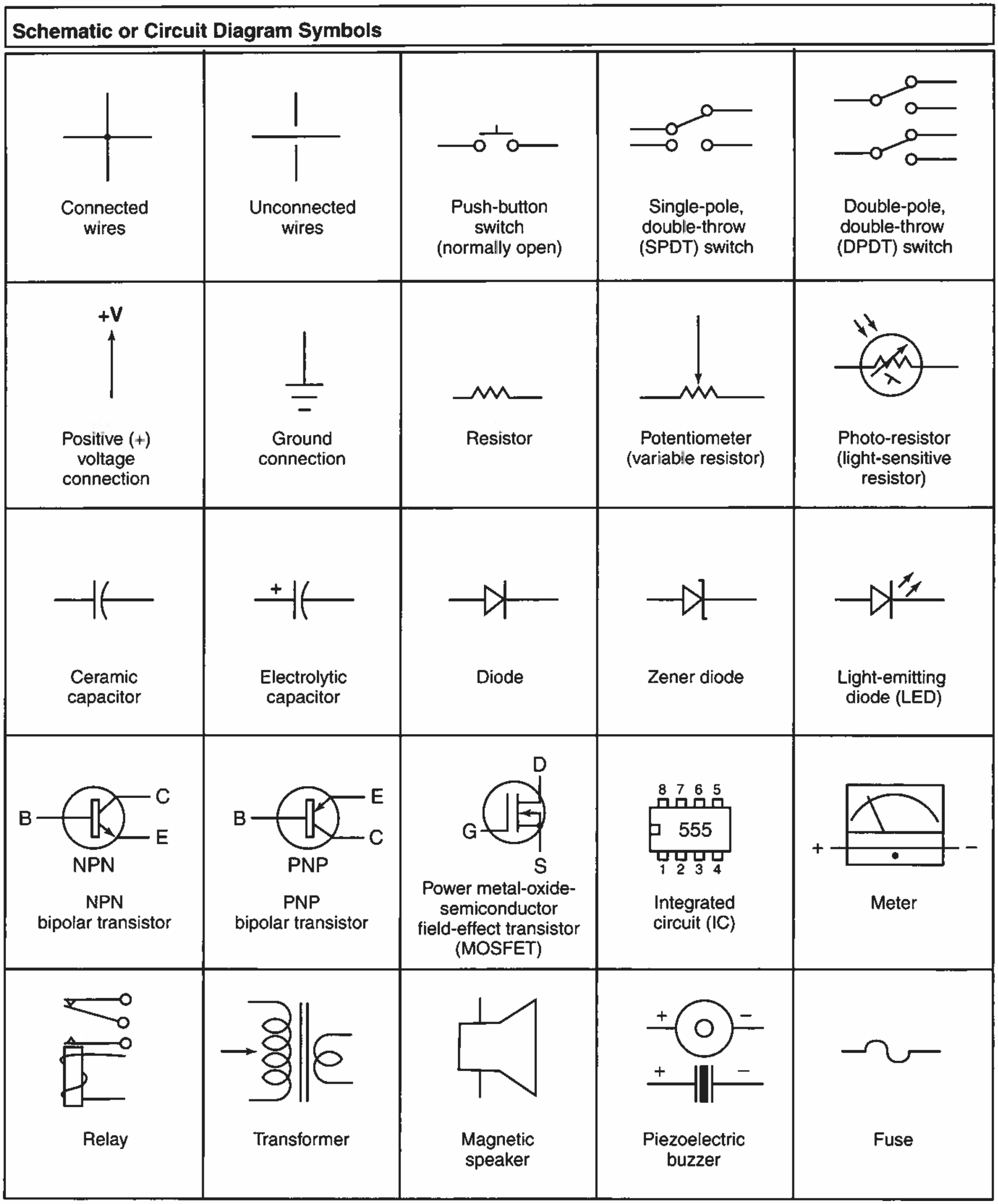
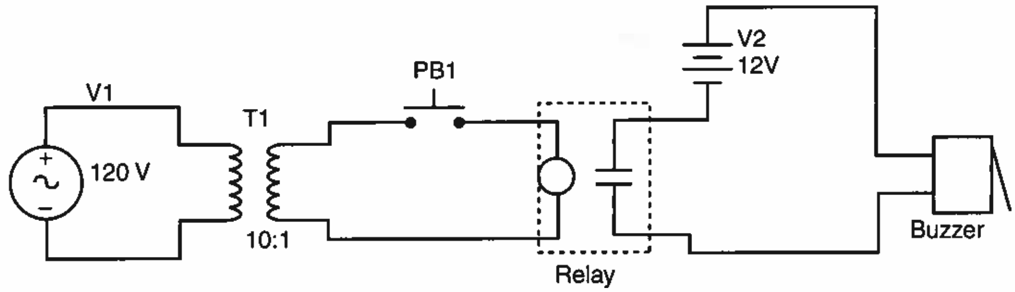
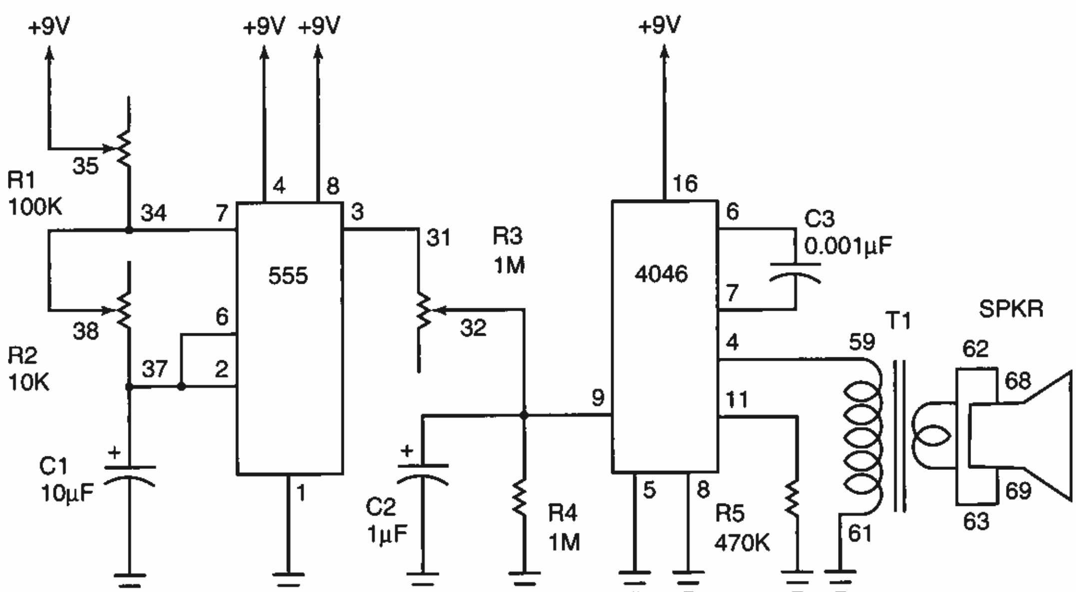


Figure 12-18. A schematic of a buzzer activated by a push button. Notice that a relay separates the alternating current (AC) control circuit from the direct current (DC) buzzer circuit. When the push button is pressed, the coil in the relay energizes, and the relay contacts close. This energizes the buzzer.



Lastly, it is important to perform troubleshooting in a systematic manner. This means checking only one component at a time, verifying it is functioning properly, and then moving on to the next component. See **Figure 12-19.**

Figure 12-19. An electronic circuit for troubleshooting.



Career Connection

Power Plant Maintenance Electricians

Manufacturing

Power plant maintenance electricians are responsible for the installation, inspection, repair, and testing of all major equipment associated with an electric power generating station. The equipment typically includes high-wattage generators and high-voltage transformers. This work also includes training and supervising coworkers and outside contractors during major power outages. Being an electrician requires a knowledge of electrical and electronic theory and practices, as well as a high degree of safety.

One of the most desirable aspects of this job is the opportunity to work with all types of equipment, both very new and very old. Electricians use their training to meet the challenges of the job. They also often work with a multitalented workforce.

This job, like any other, also has some disadvantages. One of the least desirable parts of this job is having to deal with the weather. On any given day, a maintenance electrician may be outside working in the freezing cold or blazing heat. Working inside a power plant is also very hot because of the generating equipment that gives off heat.

Entry-level technicians need to have at least an Associate Degree in Electronics or Electrical Systems. From there, a Journeyman Certification in Powerhouse Electricity would typically be pursued. This leads to a state licensure in many states. It is also beneficial to have a Bachelor of Science Degree in a field such as Industrial Technology. The estimated entry-level salary is about $46,000.

To troubleshoot this circuit, you might begin by setting your multimeter to DC volts and verifying that proper voltage is supplied to the circuit. Next, you might remove the voltage source and use the continuity function of the meter to verify that the fuse is not blown and that the switch works properly. From this point, you could use the ohms function of the meter to compare resistor readings to their calculated values. You could also check the diode with the continuity checker to ensure that it works in the proper bias and is installed correctly. It may also be most effective to check some ICs simply by switching them with another IC that is known to be functioning properly. This is an easy, but potentially expensive, method of troubleshooting.

Safety Note

Be sure to use antistatic precautions before touching or handling a CMOS IC. CMOS ICs are easily damaged by static electricity.

Summary

Electronic components drive our technological society. Some knowledge of how electronic components work is essential to technological literacy. Components such as resistors, capacitors, diodes, transistors, and integrated circuits (ICs) are used in combination to produce thousands of electronic devices. Schematic diagrams are used to visually represent how these components are connected to produce electronic circuits for practical use. Interpreting these diagrams requires knowledge of the various symbols used to represent the electronic components. Troubleshooting electronic circuitry requires knowledge of how electronic components are supposed to function, the ability to properly interpret schematics, the skill to test electronic components, and the ability to analyze a circuit in a systematic way.

Key Words

All the following words have been used in this chapter. Do you know their meanings?

astable application
bipolar transistor
capacitor
complementary metal oxide semiconductor (CMOS)
diode
electronic circuit
electronic device
field-effect transistor (FET)
forward bias
integrated circuit (IC)
monostable application
operational amplifier (op-amp)
pin-out
resistor
socket
solid-state
transistor-transistor logic (TTL)
wiper
zener diode

Test Your Knowledge

Write your answers on a separate sheet of paper. Do not write in this book.

1. On a resistor with four color bands, the third band represents:
   A. the tolerance.
   B. the multiplier.
   C. the last digit of the total resistance.
   D. the anode end of the resistor.
2. On a resistor with four color bands, the fourth band represents:
   A. the tolerance.
   B. the multiplier.
   C. the last digit of the total resistance.
   D. the anode end of the resistor.

3. If a resistor has a color code of "red-orange-brown-gold," it offers _____ ohms of resistance.
4. Devices that change resistance in relation to the position of a knob or slider are known as _____.
5. A(n) _____ can store electricity.
6. The unit of storage for capacitance is known as the:
   A. volt.
   B. ampere.
   C. farad.
   D. ohm.
7. A(n) _____ is a device that permits current to flow in only one direction.
8. The cathode end of a component is considered to be the _____ end.
9. Describe how to test a diode.
10. Describe the purpose of a rectifier circuit.
11. The cathode lead on a light-emitting diode (LED) can be identified by:
    A. a color band.
    B. a flat spot at the base of the LED.
    C. the shorter lead from the LED.
    D. Both *B* and C.
12. List the letters and numbers that can be displayed using one seven-segment LED.
13. Transistors can perform a(n) _____ function without any physical moving parts.
14. A MOSFET is a type of:
    A. integrated circuit (IC).
    B. diode.
    C. transistor.
    D. capacitor.
15. *True or False?* An IC can be used in a circuit to replace hundreds or thousands of individual components, such as resistors and transistors.
16. Summarize the two types of ICs and provide the advantages and disadvantages of each.
17. One disadvantage of complementary metal oxide semiconductor (CMOS) ICs is they can be easily damaged by _____.

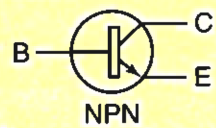
18. This IC is among the most widely used of all ICs. It is used for single timing functions:
    A. 4046.
    B. 7447.
    C. 555.
    D. 556.

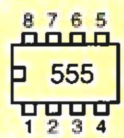
19. Devices that protect electronic circuitry from excessive amperage include _____ and _____.

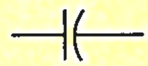
Matching questions: For Questions 20 through 27, match the schematic symbols on the right with the correct term on the left.

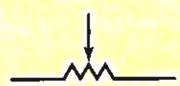
20. _____ Resistor.
21. _____ Potentiometer.
22. _____ Capacitor.
23. _____ Diode.
24. _____ LED.
25. _____ Transistor.
26. _____ IC chip.
27. _____ Fuse.

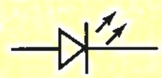
A. 

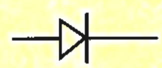
B. 

C. 

D. 

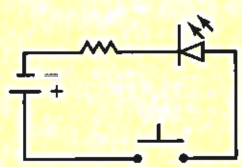
E. 

F. 

G. 

H. 

28. If you wanted to build the following circuit, what parts would you need?



29. Devices such as buzzers and relays, which actually use electricity, are known as _____.

30. Discuss the process for systematically troubleshooting electronic circuitry.

STEM Activities

1. Interpret the color codes on various resistors, and then calculate their resistive values. Next, measure their resistance, using an ohmmeter. Lastly, compare the calculated values to the measured values to determine if all the resistors are within tolerance.
2. Using the continuity function on a multimeter, test a diode to determine the forward bias and the reverse bias.
3. Design a simple electronic circuit to perform a practical use. For instance, you might design a photosensor to turn on a light when it is dark in the room. Next, construct the circuit using a solderless breadboard and various electronic components to see if it works. If it does not, the solderless breadboard will allow you to quickly change components. Each component can be tested to ensure it is in working order, and new components can be substituted to try to get the circuit to work as you had intended.