Electrical Systems

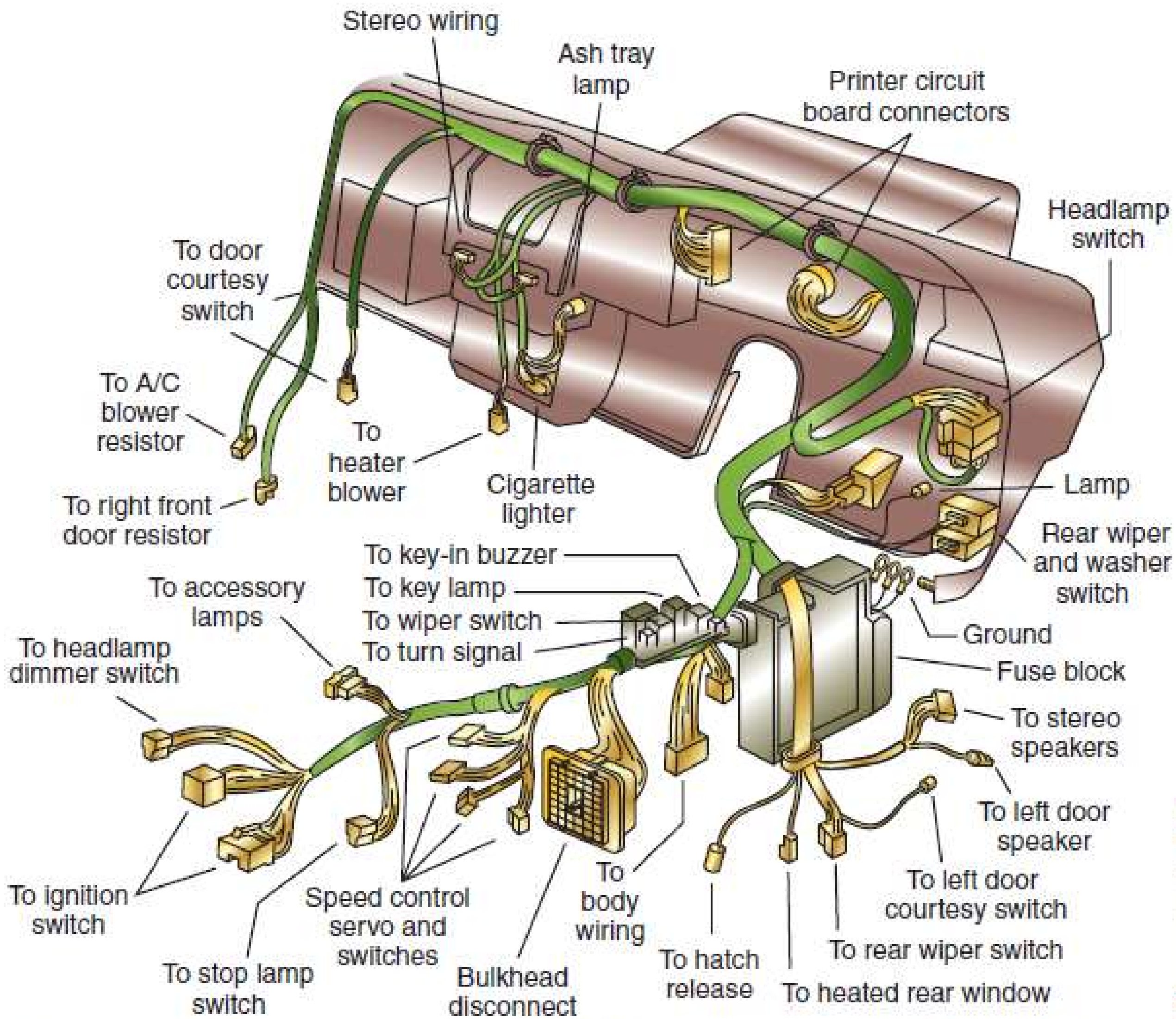


Figure 15-1 An example of common electrical components of their associated wiring.

Grounding the Load

Most automotive electrical circuits use the chassis as a conductor for the negative side of the battery, as shown in **Figure 15–13** .

Current passes from the battery, through the load, through the metal frame, and back to the battery. Using the frame as a return path or

ground eliminates the need for a separate ground wire at each component.

Without grounding parts to the frame, hundreds of additional wires would be needed to complete the individual circuits.

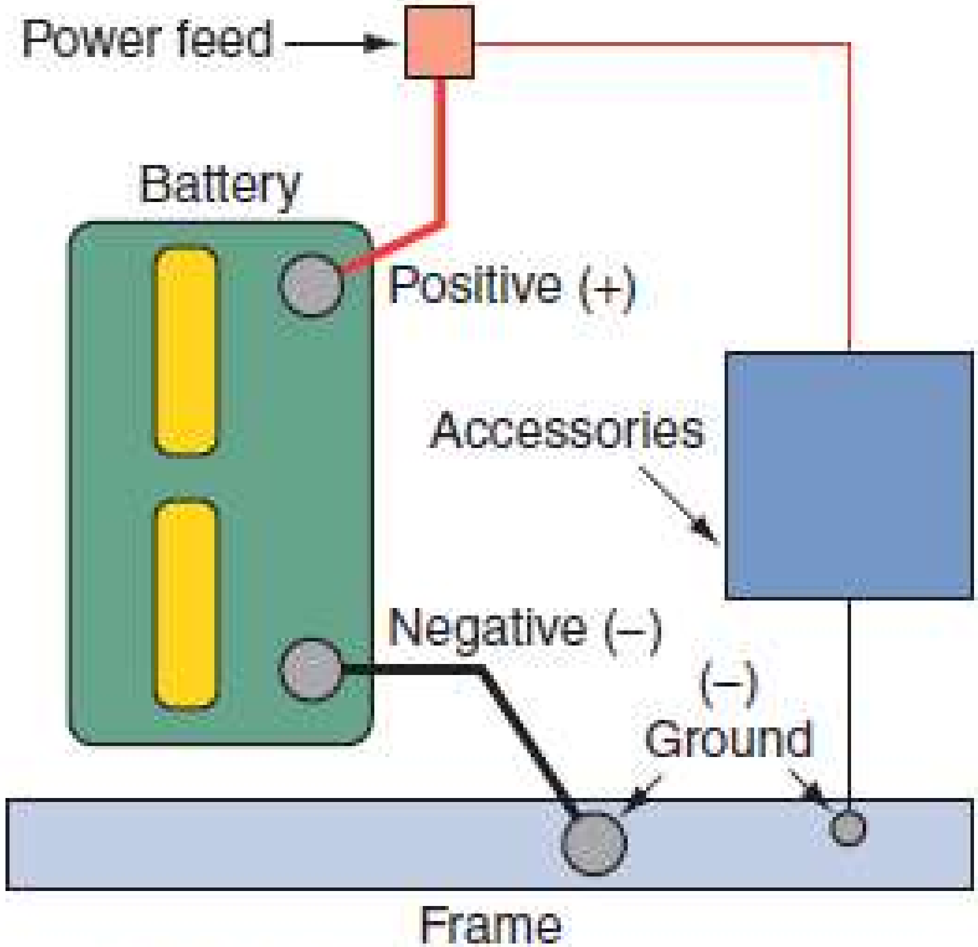


Figure 15-13 Most automotive electrical circuits use the chassis as the conductor for the negative side of the battery.

Major components, such as the engine block and transmission case, also have a grounding wire connected to the frame. This provides a ground circuit for parts that are mounted directly to the block **(Figure 15–14)** or transmission.

Other parts have a separate ground wire that connects them to the frame, engine, or transmission. These connections are called **chassis ground** connections.

The wire that serves as the contact to the chassis is commonly called the **ground wire** or lead **(Figure 15–15)** .

Figure 15-14 Many electrical parts are grounded through their mounting to the engine, transmission, or frame.

Figure 15-15 Chassis ground connections for a very dirty battery.

In wiring diagrams, chassis ground connections are drawn to show the type of ground connection for that part.

When the ground is made through the mounting of the component, the connection is represented in the drawing A **(Figure 15–16A)** .

When the ground is made by a wire that connects to the chassis, the connection is shown as B **(Figure 15–16B)** .

Some circuits, particularly computer sensor circuits, often use floating or isolated grounds **(Figure 15–16C)** .

These ground circuits are typically shown as reference low in wiring diagrams. In these circuits, the ground is not directly attached to chassis ground. Instead, inside

of the computer, the reference low circuit floats above chassis ground by passing through a fixed resistance.

This allows the computer to use a fixed ground reference voltage that is not affected by noise generated by other, often high-current circuits. For example, inside of the computer, the reference low circuit “ground” voltage

may be 0.75 V (75 mV) above chassis ground voltage.

The computer can then compare the sensor signal high, which may be a 5 to 12 V signal, to the 0.75 V low reference.

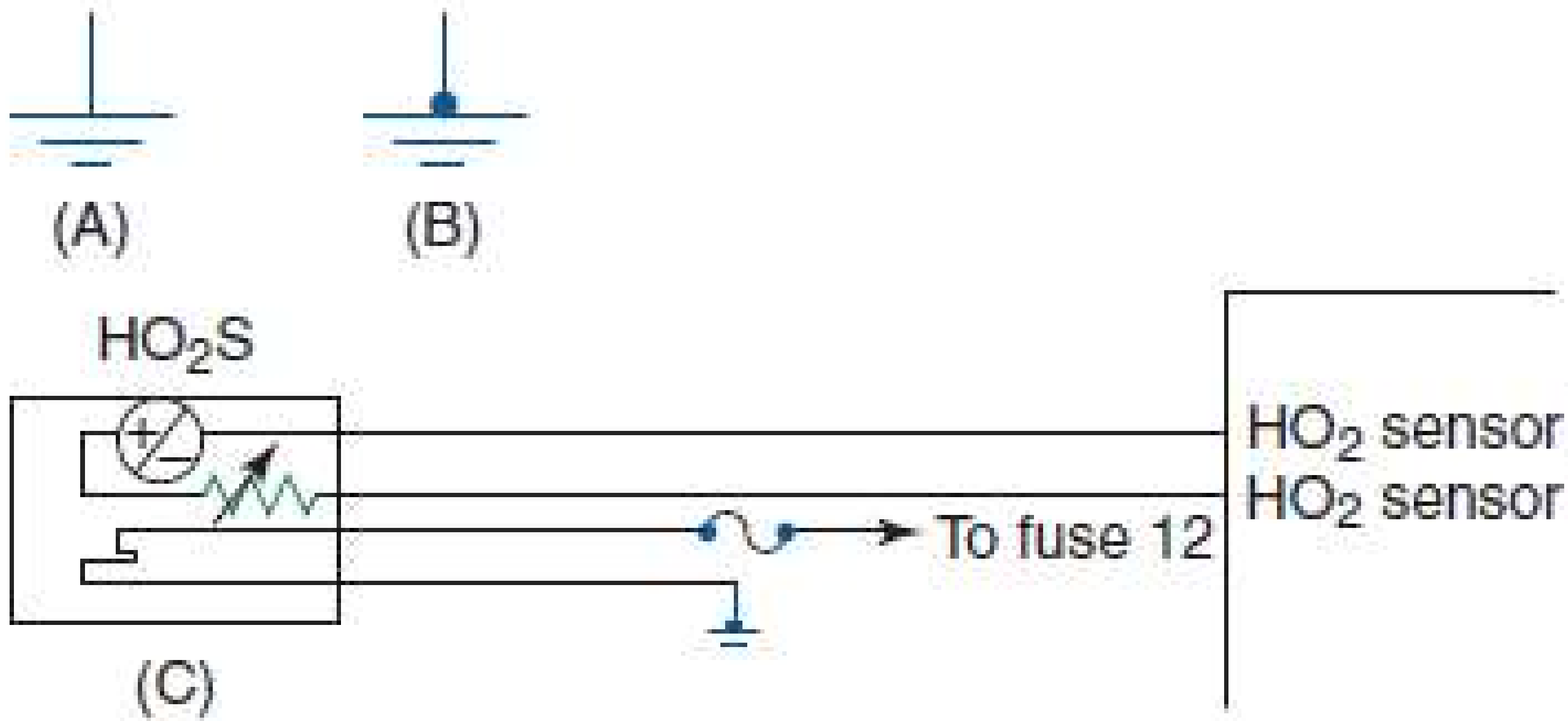


Figure 15-16 Symbols for grounds: (A) made through the component's mounting, (B) made by a remote wire, and (C) is an example of a component's circuit with a remote ground.

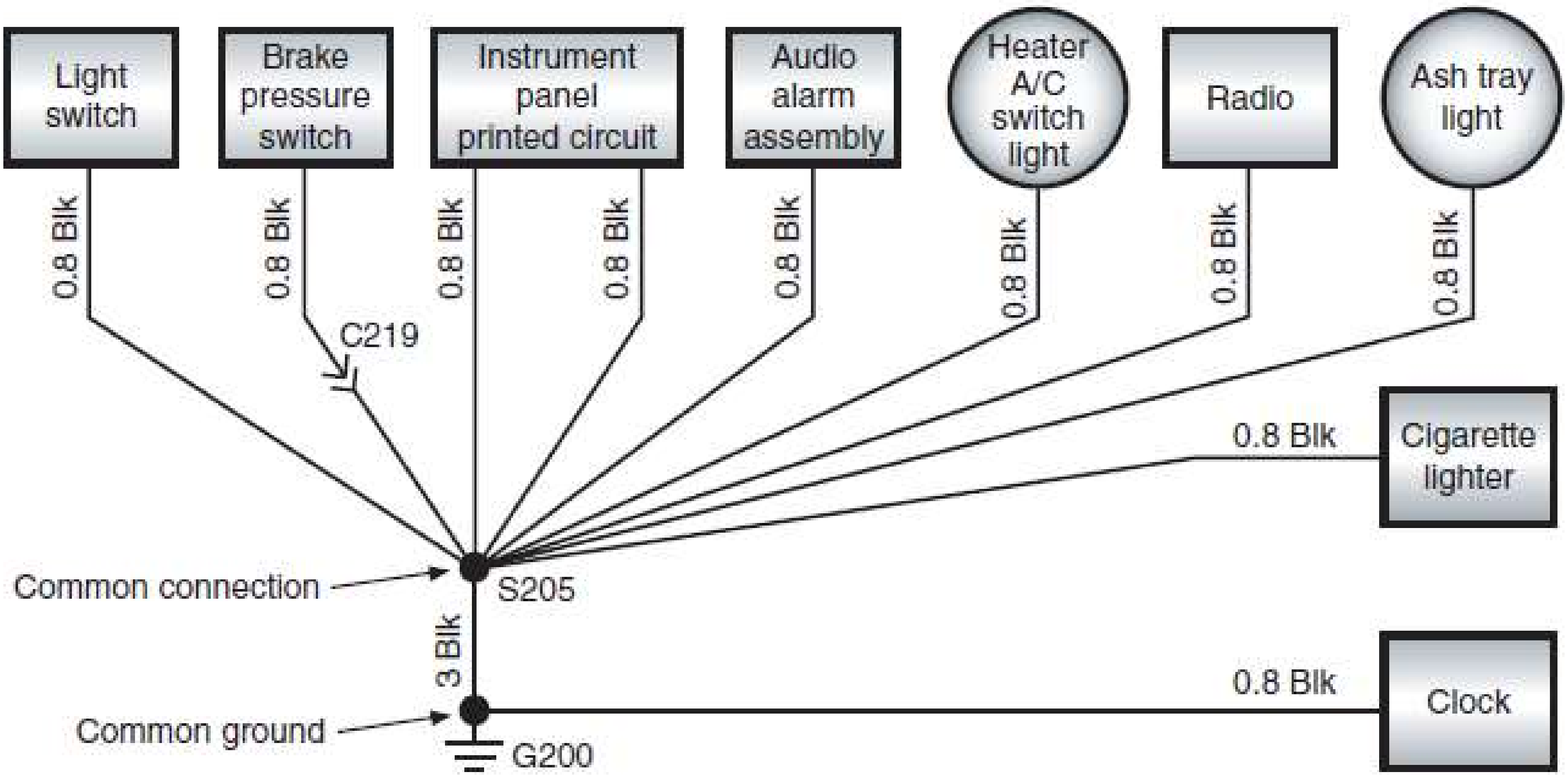


Figure 15-17 Common connections and splices are used to reduce the number of wires and connectors.

Circuit Protective Devices

When overloads or shorts in a circuit cause too much current to flow, the wiring in the circuit heats up, the insulation melts, and a fire can result, unless the circuit has some kind of protective device. Fuses, fuse links, maxi-fuses, and circuit breakers are designed to provide protection from high current. They may be used singly or in combination. Typical symbols for protection devices are shown in **Figure 15–41** .

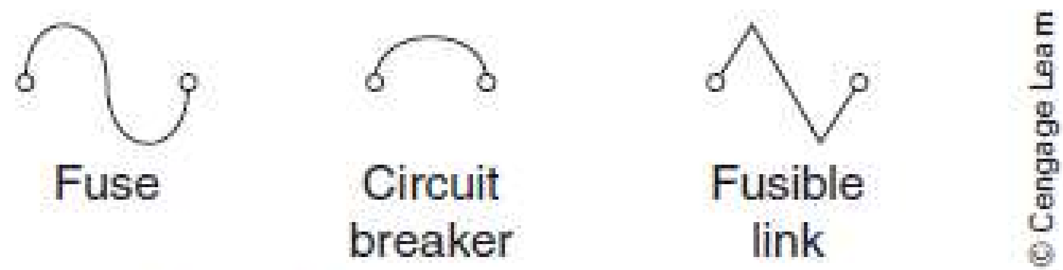


Figure 15-41 Electrical symbols for common circuit protection devices.

W A R N I N G !

Fuses and other protection devices normally do not wear out. They go bad because something went wrong. Never replace a fuse or fusible link, or reset a circuit breaker, without finding out why it went bad.

Fuses

Automotive fuses are normally rated for circuits no higher than 24 volts DC, but some may be rated for 42 -volt systems. There are three basic types of fuses used in automobiles: cartridge, ceramic, and blade **(Figure 15–42)** .

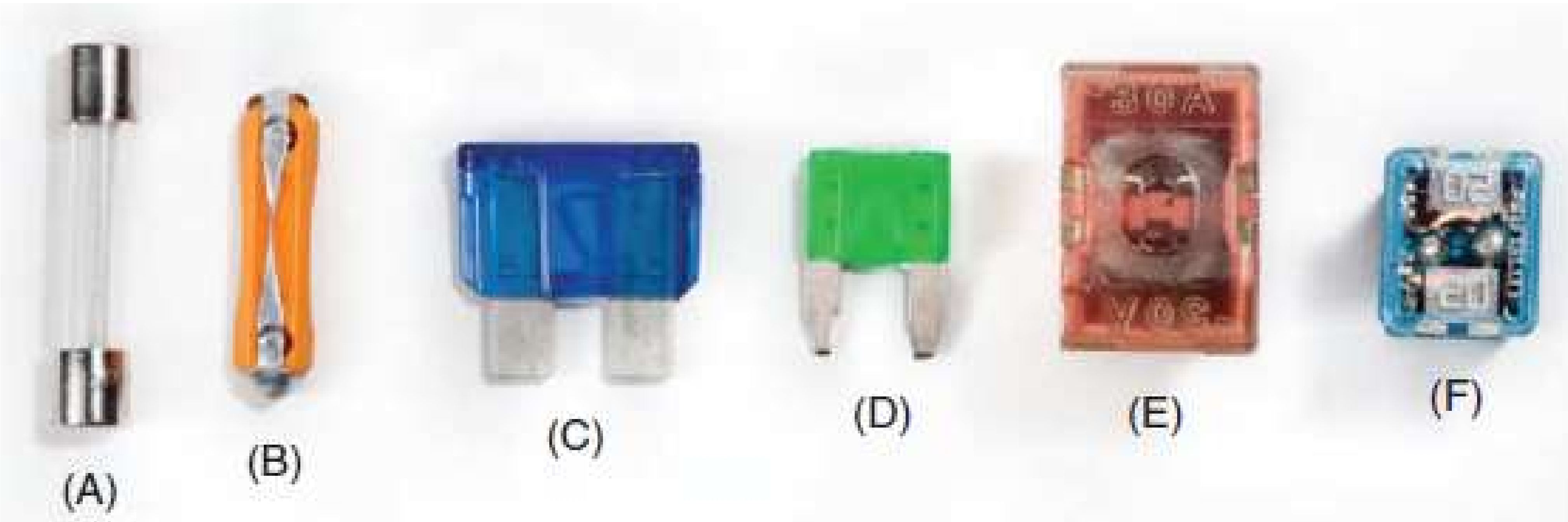


Figure 15-42 Common fuses (A) glass cartridge, (B) ceramic, (C) blade, (D) mini, (E) maxi, and (F) mega.

BLADE TYPE	BLADE SERIES	DIMENSIONS L x W x H
Low-profile Mini	APS, ATT	0.43 x 0.15 x 0.34 in. (*10.9 x 3.81 x 8.73 mm*)
Mini	APM, ATM	0.43 x 0.014 x 0.64 in. (*10.9 x 3.6 x 16.3 mm*)
Standard	APR, ATC, ATO	0.75 x 0.2 x 0.73 in. (*19.1 x 5.1 x 18.5 mm*)
Maxi	APX	0.15 x 0.33 x 1.35 in. (*29.2 x 8.5 x 34.3 mm*)

Figure 15-44 Description of the commonly used blade fuses.

Figure 15-43 Typical fuse box or panel.

Fuse Links

Fuse or **fusible links** were used in circuits where limiting the maximum current is critical. They were normally found in the engine compartment near the battery or on the battery connection at the starter solenoid.

Fusible links were also used when it would be awkward to run wiring from the battery to the fuse panel and back to the load.

A fuse link **(Figure 15–45)** is a short length of small gauge wire installed in a conductor. Because the fuse link is a lighter gauge of wire than the main conductor, it melts and opens the circuit before damage can occur in the rest of the circuit **(Table 15–2)** . Fuse link wire is covered with a

special insulation that bubbles when it overheats, indicating that the link has melted.

C A U T I O N ! ***Always disconnect the battery ground cable prior to servicing any fuse link.***

Figure 15-45 A typical fuse link.

Mega Fuses

Rather than use a fusible link to protect high amperage

circuits, many new vehicles have mega fuses.

These fuses may be rated for 100 , 125 , 150 , 175 , 200 , 225 , or 250 amps .

Circuit Breakers

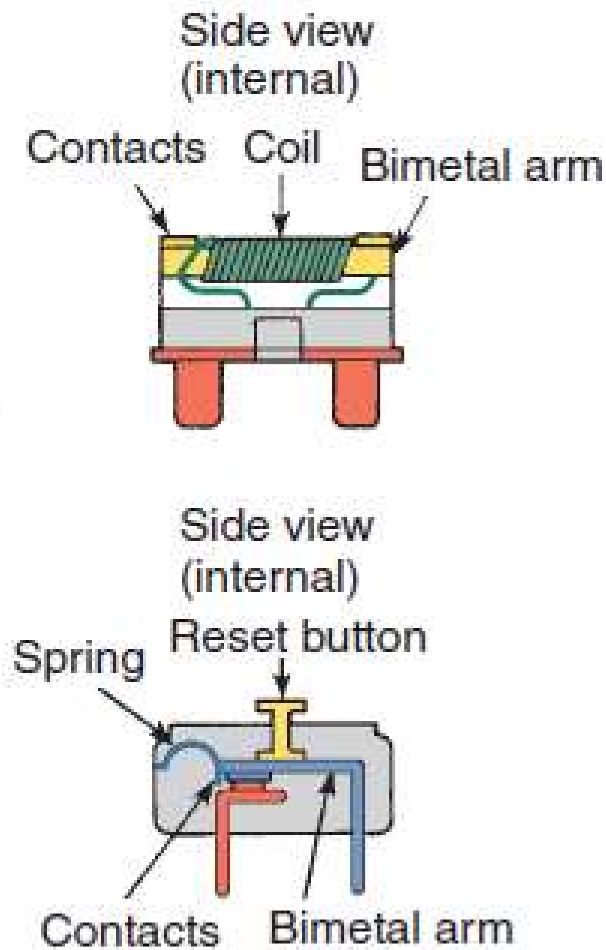
Some circuits are protected by **circuit breakers** (abbreviated c.b. in most fuse charts and wiring diagrams). They can be fuse panel mounted or inline. Like fuses, they are rated in amperes.

In a circuit breaker, current flows through an arm made of two different metals bonded together. If the arm starts to carry too much current, it heats up.

As one metal expands faster than the other, the arm bends, opening

the contacts. This opens the circuit and the path for current flow is broken. A circuit breaker can be cycling **(Figure 15–46)** or must be manually reset.

In the cycling type, the bimetal arm begins to cool once the current stops. Once it returns to its original shape, the contacts are closed and power is restored. If the current is still too high, the cycle of breaking the circuit is repeated.



(A)

(B)

Figure 15-47 Resetting noncycling circuit breakers by (A) removing power from the circuit and (B) depressing a reset button.

Switches

Electrical circuits are usually controlled by some type of switch **(Figure 15–48)** . Switches do two things: turn the circuit on or off, or direct the flow of current in a circuit.

Switches can be controlled by the driver or can be self operating through the condition of the circuit, the vehicle, or the environment.

Figure 15-48 Examples of the various switches used in automobiles.

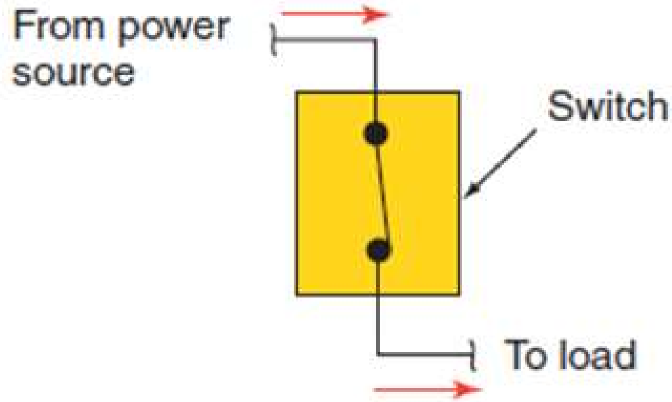


Figure 15-49 SPST hinged-pawl switch diagram.

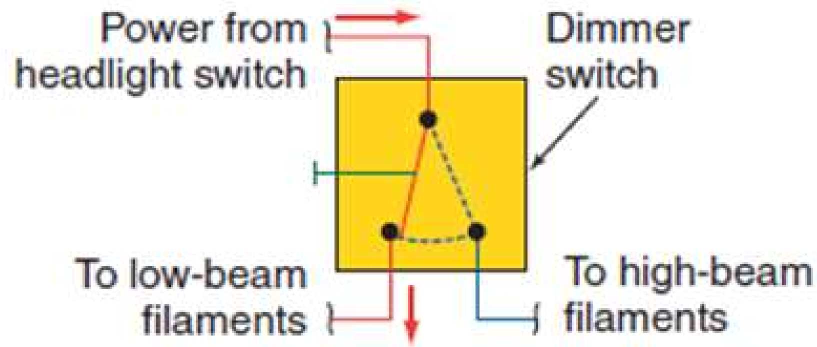


Figure 15-51 SPDT headlight dimmer switch.

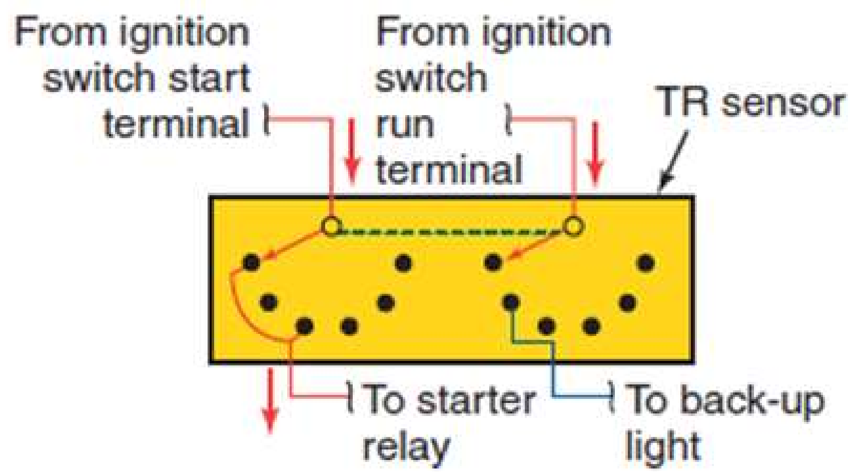


Figure 15-52 MPMT neutral start safety switch.

Relays

A **relay** is an electric switch that allows a small amount of current to control a high-current circuit **(Figure 15–54)** .

When the control circuit switch is open, no current flows to the coil of the relay, so the windings are deenergized.

When the switch is closed, the coil is energized, turning the iron core into an electromagnet and drawing the armature down. This closes the power circuit contacts, connecting power to the load circuit **(Figure 15–55)** . When the control switch is opened, current stops flowing and the electromagnet disappears. This releases the armature, which breaks the power circuit contacts.

The terminals of nearly all ISO relays have the same identification number and the general purpose of each terminal is also the same **(Figure 15–56)**.

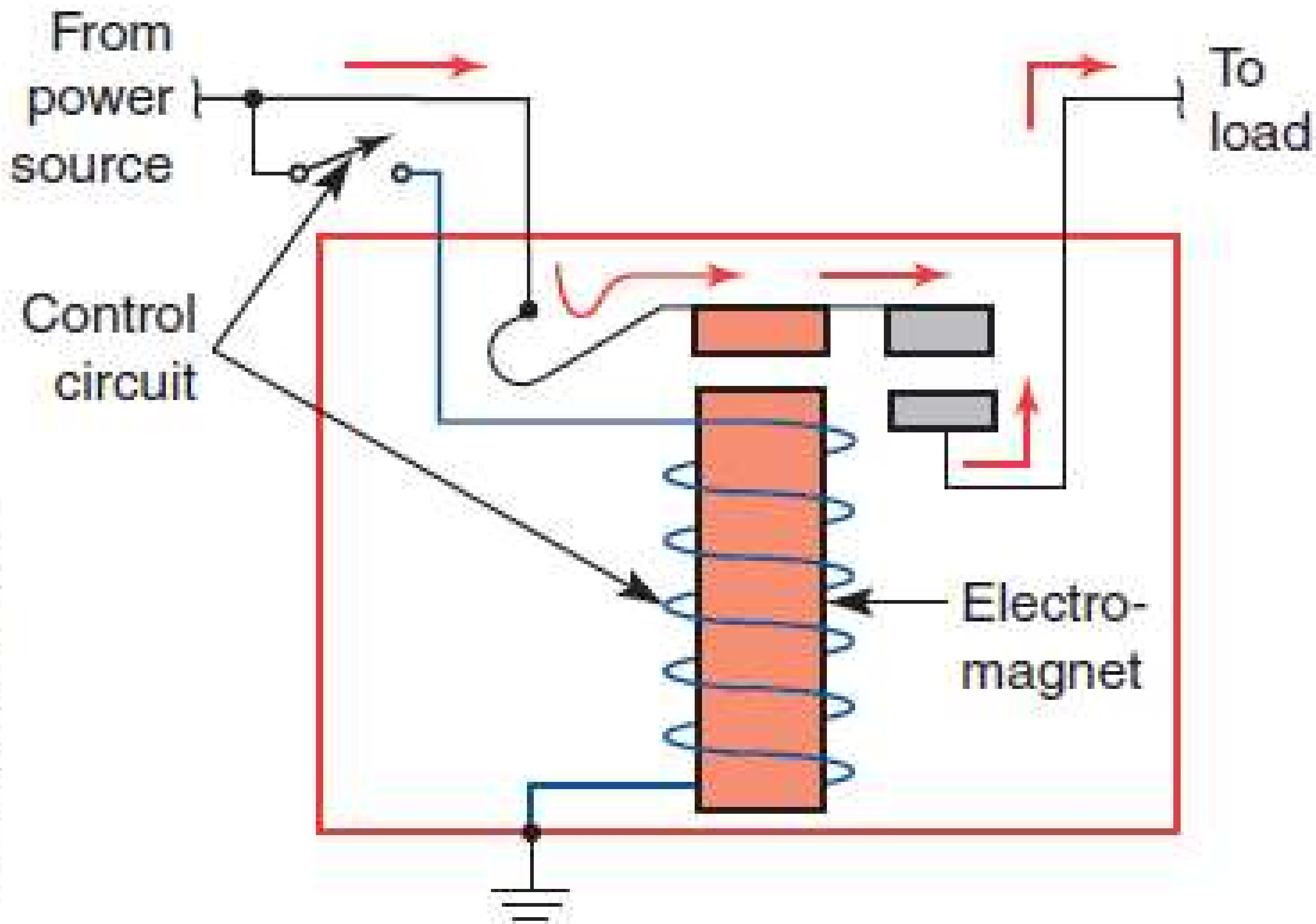


Figure 15-54 The basic way a relay works.

TERMINAL	GENERAL PURPOSE
30	Normally connected to battery voltage
85	Ground for the electromagnet (coil)
86	Voltage supply for the electromagnet (coil)
87	Connects with terminal 30 when the relay is energized
87A	Connects with terminal 30 when the relay is energized

Figure 15-56 ISO relay terminal identificatior and their purpose.

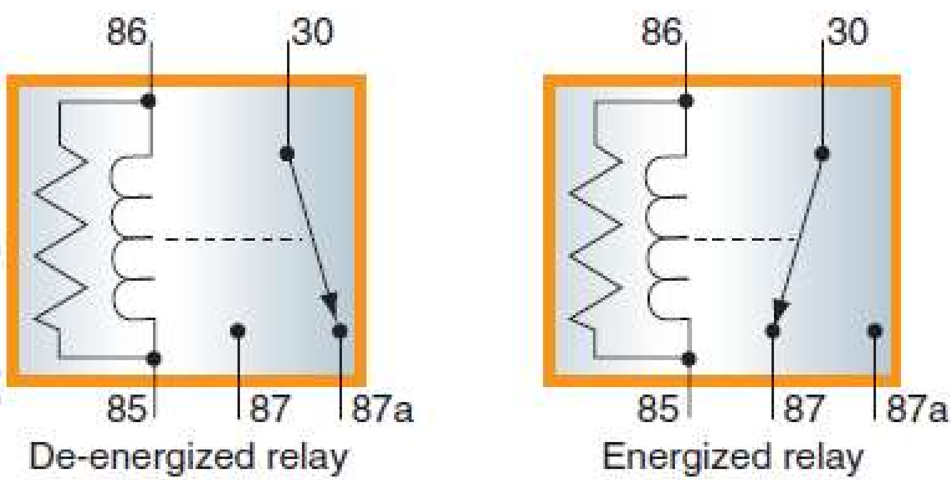


Figure 15-55 Action of an ISO relay.

Solenoids

Solenoids are also electromagnets with movable cores used to change electrical current flow into mechanical movement **(Figure 15–57)** . They are used in a wide variety of systems and can also close contacts, acting as a relay at the same time they mechanically cause something to happen.

Example: Starter solenoid

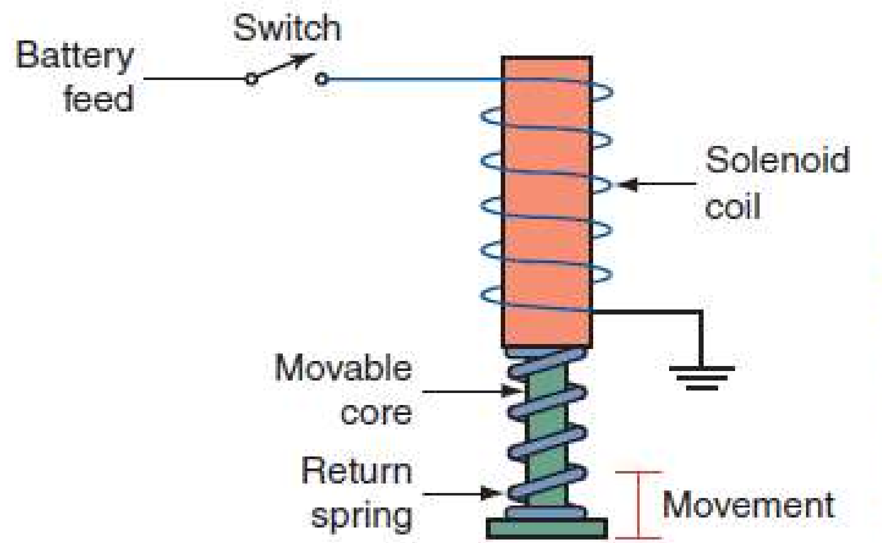


Figure 15-57 A solenoid is a device that has a movable electromagnetic core.

Printed Circuits

Many vehicles use flexible printed circuits **(Figure 15–61)** and printed circuit boards. Both types of printed circuits allow for complete circuits without the need to run dozens of wires.

Printed circuit boards are typically contained in a housing, such as the engine control module.

These boards are not serviceable and in some cases not visible.

When these boards fail, the entire unit is replaced.

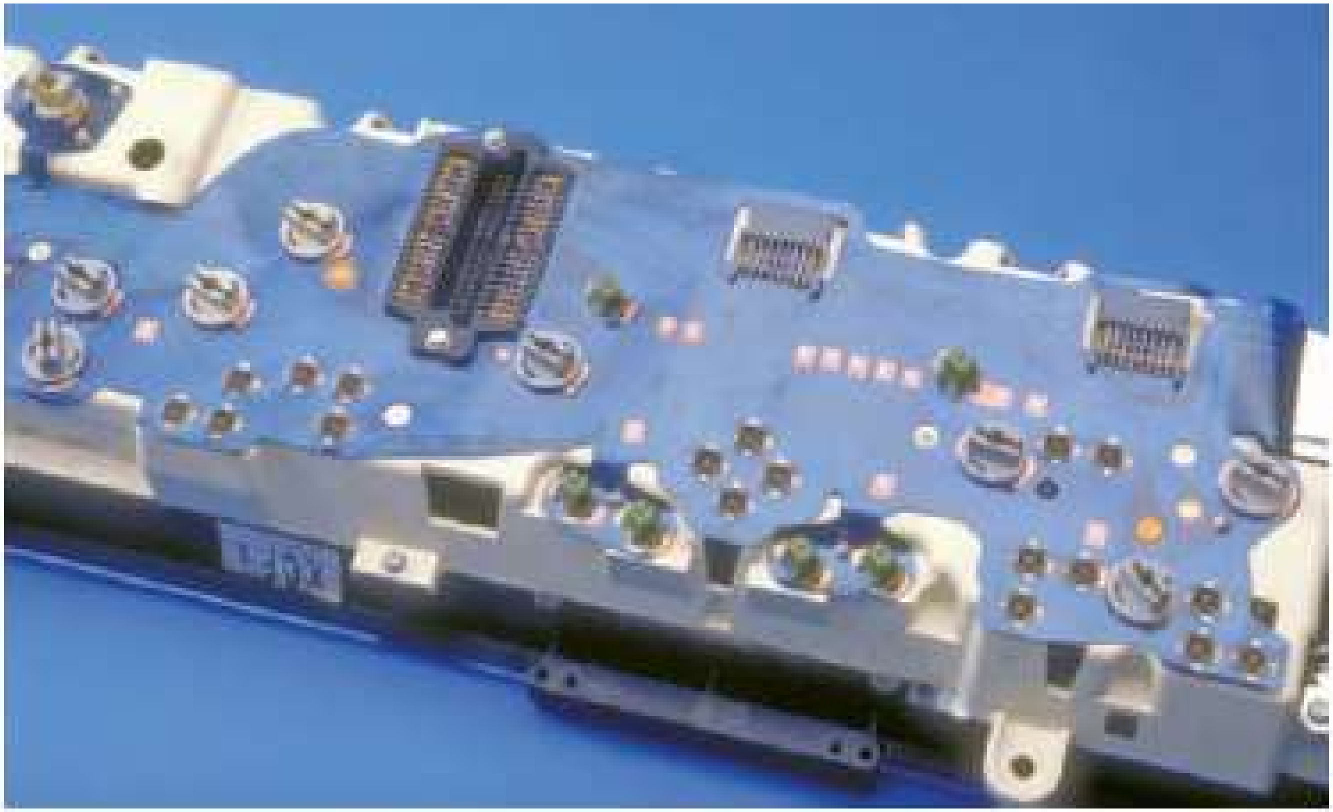


Figure 15-61 A typical printed circuit board.

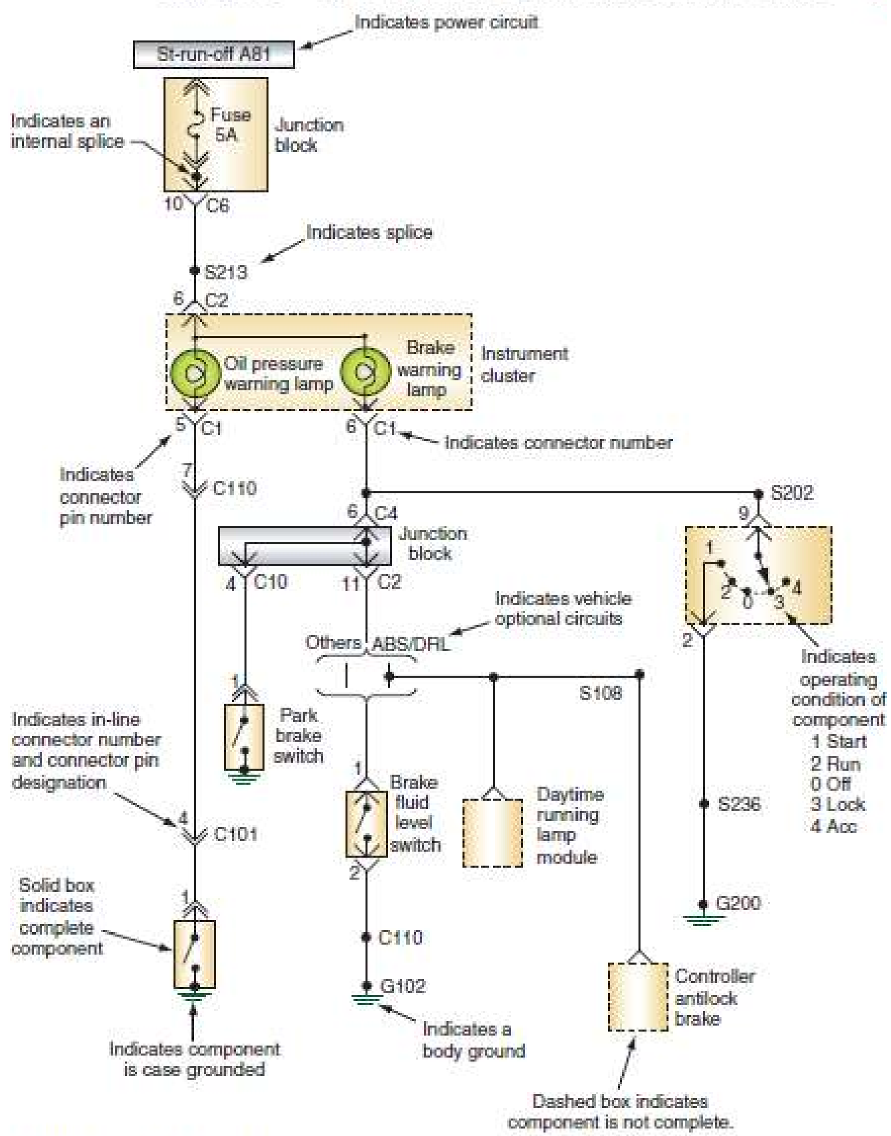


Figure 16-1 A wiring diagram for part of an instrument panel.

SYMBOLS USED IN WIRING DIAGRAMS			
+	Positive		Temperature switch
—	Negative		Diode
	Ground		Zener diode
	Fuse		Motor
	Circuit breaker	C101	Connector 101
	Condenser		Male connector
	Ohms		Female connector
	Fixed value resistor		Splice
	Variable resistor	S101	Splice number
	Rheostat		Thermal element
	Coil		Multiple connectors
	Open contacts		Digital readout
	Closed contacts		Single filament bulb
	Closed switch		Dual filament bulb
	Open switch		Light-emitting diode
	Ganged switch (N.O.)		Thermistor
	Single pole double throw switch		PNP bipolar transistor
	Momentary contact switch		NPN bipolar transistor
	Pressure switch		Gauge

Figure 16-10 Common electrical symbols used on wiring diagrams.

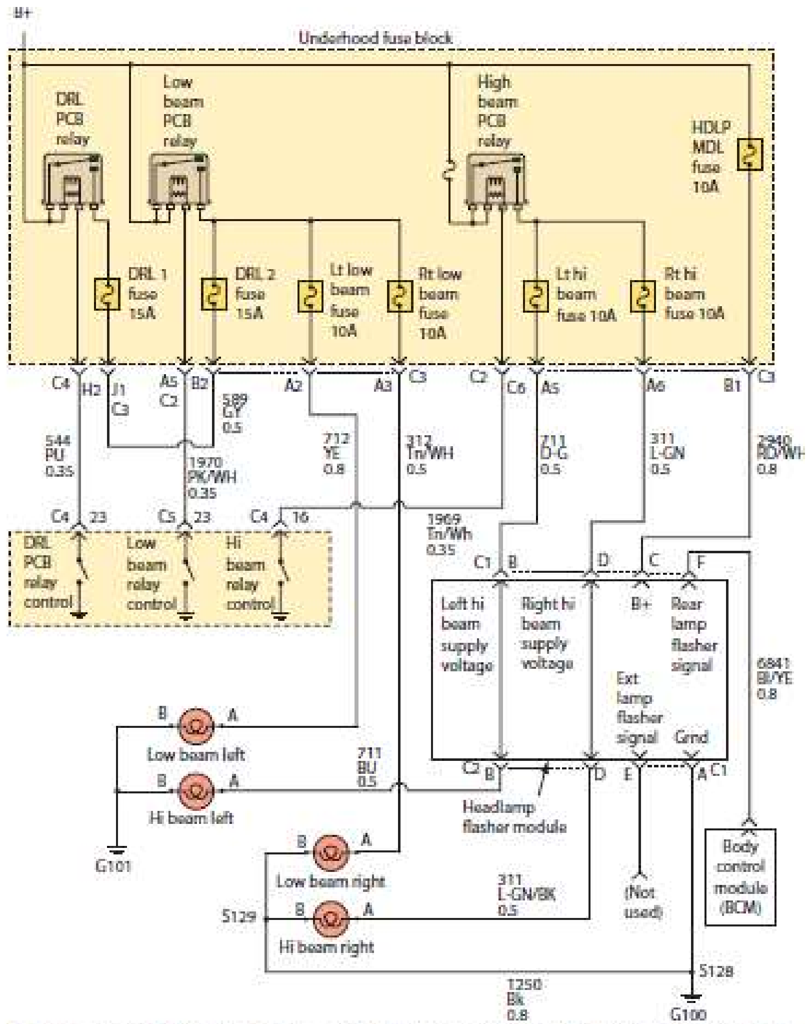


Figure 16-64 A wiring diagram of a headlight system with the right low beam circuit traced.

BATTERY

The primary source for electrical power in all automobiles is the battery. The battery has undergone many changes through the years.

However, lead-acid batteries have been, and continue to be, the most common power source for conventional vehicles.

The introduction of hybrid vehicles and the promise of fuel cell vehicles have drastically changed the basic design of an automotive battery. Many different types of batteries are available or under development to exceed the needs of hybrid or fuel cell vehicles. Each of these energy-storing devices is discussed in this chapter.

Figure 17-1 A typical 12-volt battery.

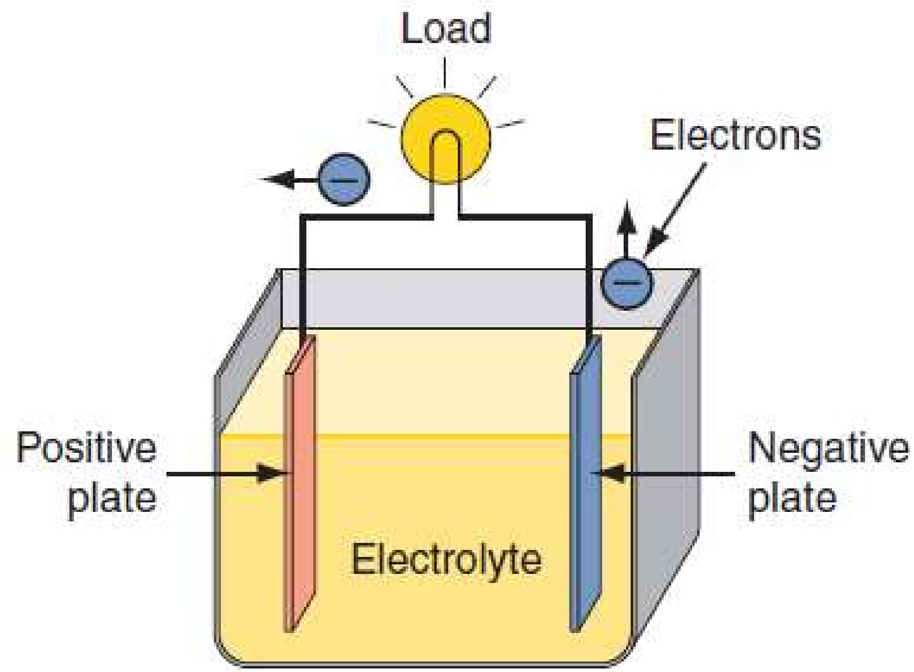


Figure 17-2 A simple electrochemical cell.

Batteries convert chemical energy into electrical energy. Chemical reactions that produce electrons are called **electrochemical reaction** . A battery stores DC voltage.

Charging

Charging a battery restores the chemical nature of the cells. To do this, a chemical reaction takes place, causing current flow within the cells. Discharging allows for current flow outside the cell. To understand the charging process, remember that current flows from a higher potential (voltage) to a lower potential. If the voltage applied by an outside source to the battery is higher than the voltage of the battery, current will flow into the battery. This means the charging voltage must be higher than the battery's voltage in order to charge it.

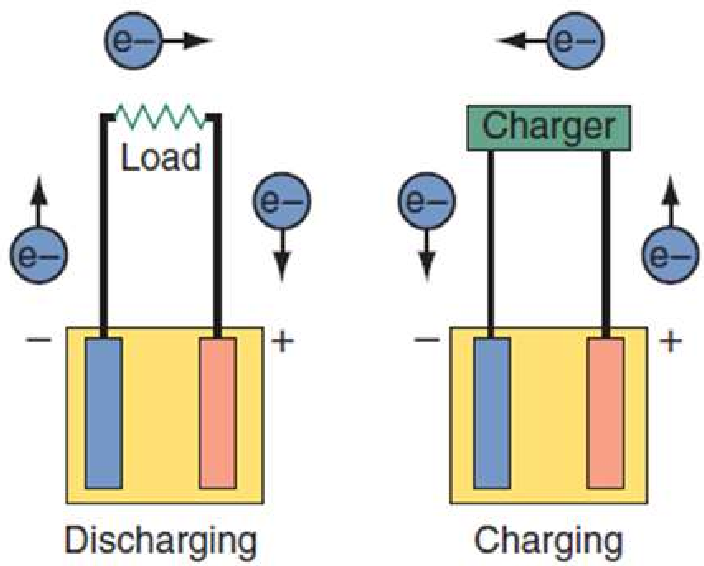


Figure 17-3 The flow of electrons in a battery while discharging and charging.

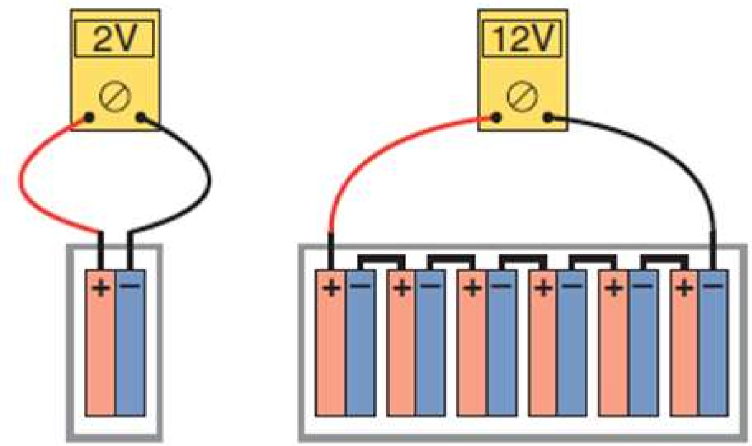


Figure 17-4 When individual cells are connected in series, the total voltage is equal to the sum of the cells.

BATTERY RATINGS

The voltage rating of a battery may be expressed as open circuit or operating voltage.

Open circuit voltage is the voltage measured across the battery when there is no load on the battery. Operating voltage is the voltage measured across the battery when it is under a load.

The available current from a battery is expressed as the battery's capacity to provide a certain amount of current for a certain amount of time and at a certain temperature.

Basically, a capacity rating expresses how much electrical energy a battery can store. Battery ratings are found on the battery sticker, as shown in **Figure 17–10** . The sticker on some batteries will not reference all possible ratings. However, most will give the BCI group number, CCA, and CA.

Figure 17-10 The sticker on this battery shows its CA and CCA ratings.

BCI Groups

The BCI or Battery Council International group number defines the physical qualities of a battery, such as terminal location and the height, width, and depth of the battery.

This is a standardized system that ensures that a battery in a specific group will have similar physical characteristics no matter who manufactures the battery or where it is purchased.

Cold Cranking Amps

The **cold cranking amps (CCA)** rating is the common method of rating starting batteries. It expresses the amount of amperage a battery can deliver for 30 seconds

at 0 °F (− 17.7 ° C) without its voltage dropping below a predetermined level. That voltage level for a 12 –volt battery is 7.2 volts.

The normal CCA range for automotive

batteries is between 300 and 600 CCA; some batteries have a rating as high as 1,100 CCA.

Cranking Amps

The **cranking amps (CA) rating** is similar to CCA and expresses the amount of the current a battery can deliver at 32 °F (0 ° C) for 30 seconds and maintain voltage at a predetermined level. Normally, the CCA rating of a battery is about 20 percent less than its CA rating.

Reserve Capacity

The **reserve capacity (RC) rating** represents the number of minutes that a fully charged battery can be discharged at 25 amperes before battery voltage drops below 10 . 5 volts. A battery with a reserve capacity of 120 would be able to deliver 25 amps for 120 minutes before its voltage drops below 10.5 volts.

Ampere-Hour

In the past, the ampere-hour rating was the common rating method for lead-acid batteries. The **ampere-hour(AH) rating** represents the amount of steady current a fully charged battery can supply for 20 hours at 80 °F

(26.7 ° C) without the cell's voltage dropping below a predetermined level. For example, if a 12 -volt battery can be discharged for 20 hours at a rate of 4.0 amperes before its voltage drops to 10.5 volts, it would be rated at 80 AH(20 hours × 4 amps = 80 AH).

Watt-Hour Rating

Some battery manufacturers rate their batteries in watt hours. The watt-hour rating is determined at 0 ° F(− 17.7 ° C) because the battery's capacity changes with temperature. The rating is calculated by multiplying a battery's AH rating by the battery's voltage. The watt-hour rating of a battery may be listed in units of kilowatts. If a battery can deliver 5 AH at 200 volts, it would be rated at1 kilowatt-hour (5 AH × 200 volts = 1 , 000 watt - hour or1 kilowatt - hour).

STARTING MOTORS

The starting motor **(Figure 18–9)** is a special type of electric motor designed to operate under great electrical loads and to produce great amounts of torque for short periods.

All starting motors are generally the same in design and operation. Basically the starter motor consists of a housing, field coils (windings), an armature, a commutator

with brushes, and end frames **(Figure 18–10)** .

The starter housing or **starter frame** encloses the internal parts and protects them from damage, moisture, and foreign materials. The housing also supports the field coils.

The **field coils** and their pole shoes **(Figure 18–11)** are securely attached to the inside of the housing. The field coils are insulated from the housing but are connected to a terminal that protrudes through the outer surface of the housing. This terminal connects to the solenoid.

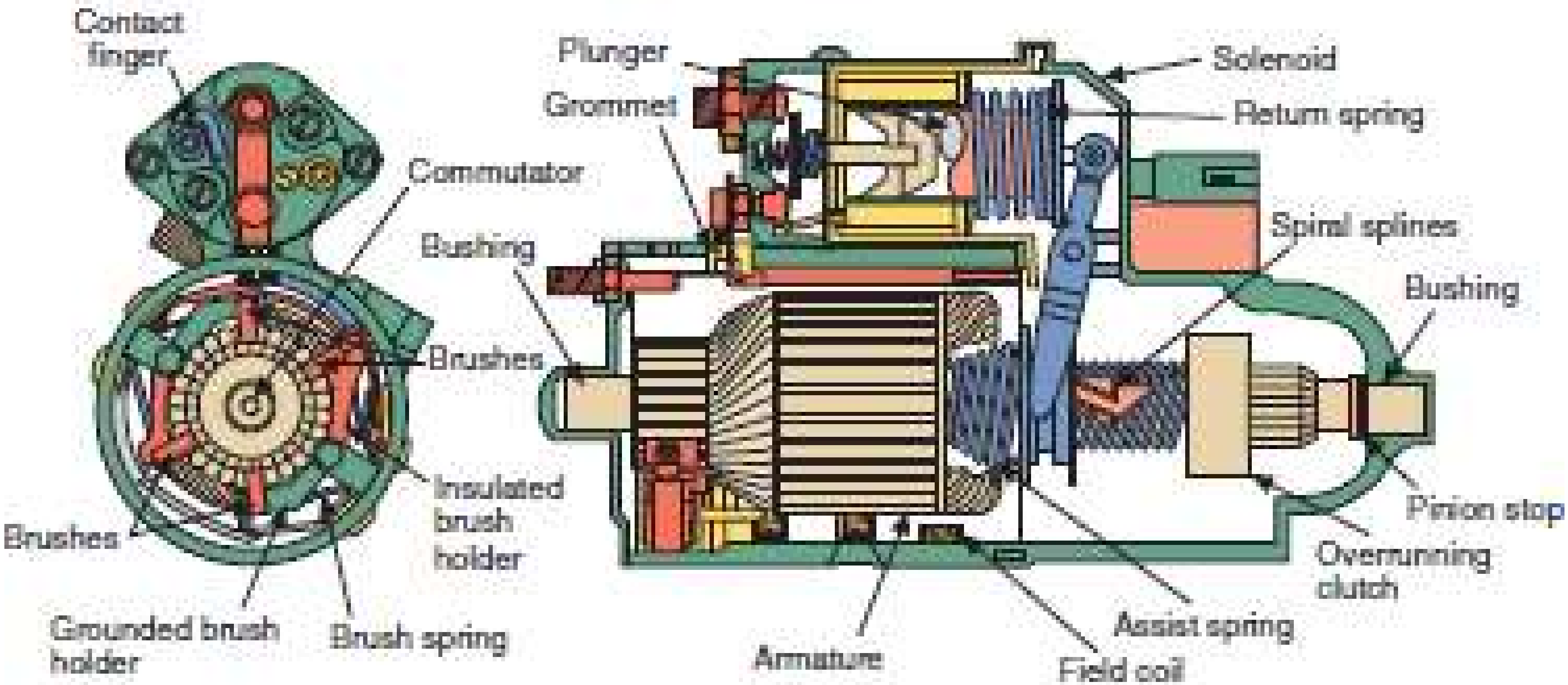


Figure 18-10 A typical starter motor assembly.

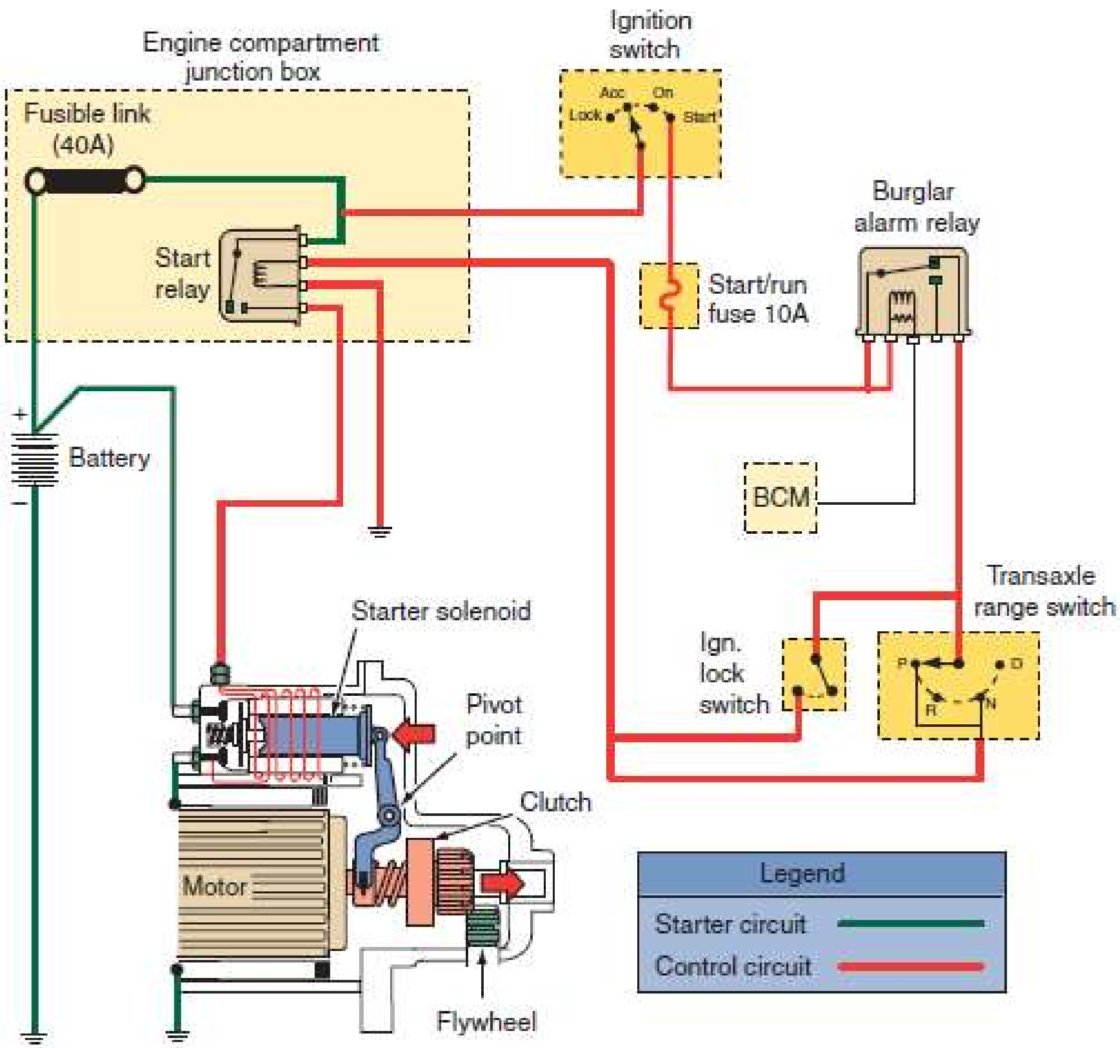


Figure 18-18 The starting system is made up of two separate systems: the starter and control systems.

Charging system

The primary purpose of a charging system is to recharge the battery. After the battery has supplied the high current needed to start the engine, the battery, even a good battery, has a low charge.

The charging system recharges the battery by supplying a constant and relatively low charge to the battery. Charging systems work on the principles of magnetism and change mechanical energy into electrical energy. This

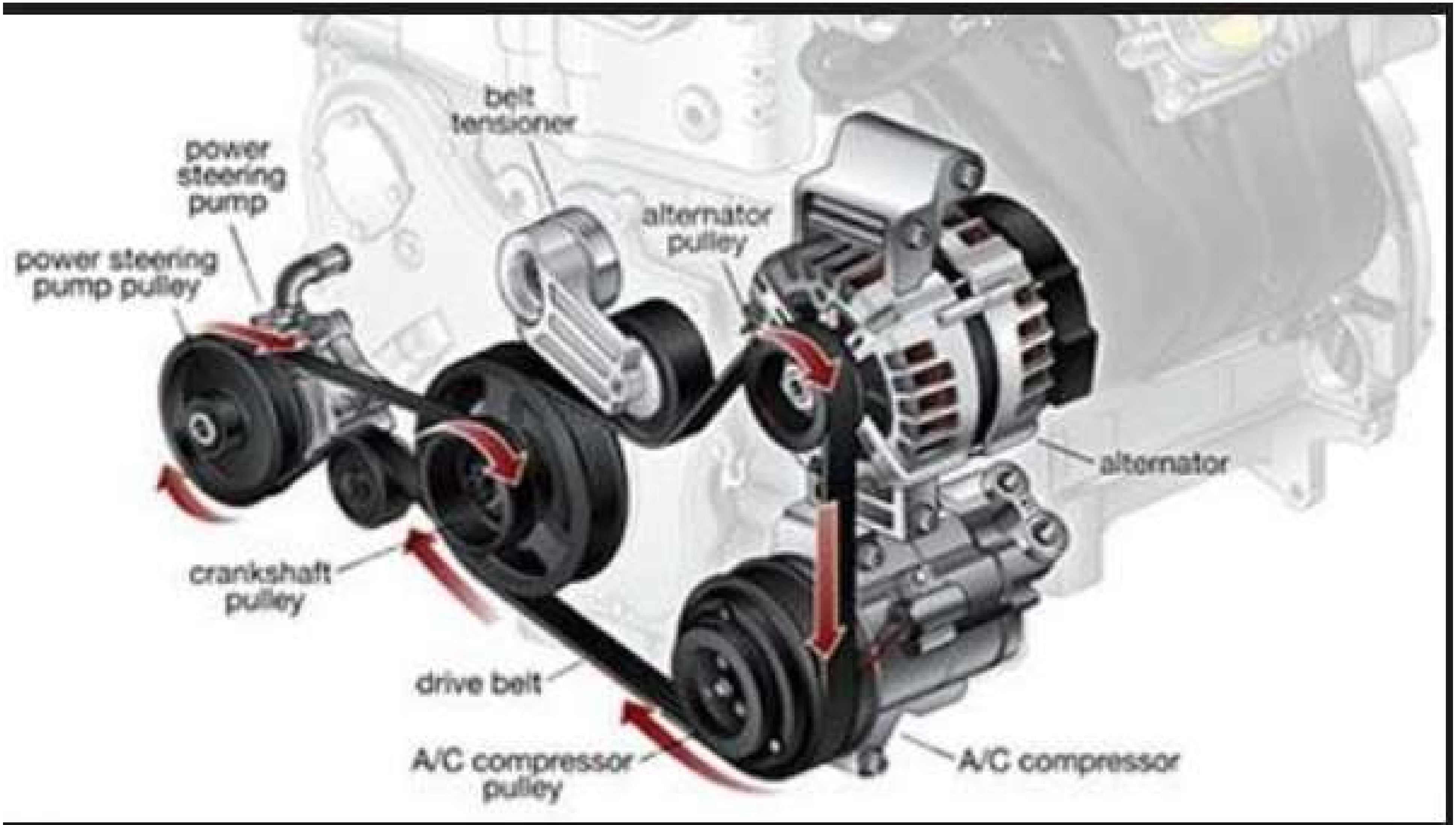
During cranking, the battery supplies all of the vehicle's electrical power. However, once the engine is running, the charging system is responsible for producing enough is done by inducing voltage. energy to meet the demands of the loads in the electrical system while also recharging the battery.

Alternators

are used in modern automobiles to charge the battery and to power the electrical system when its engine is running.

Until the 1960s, automobiles used DC dynamo generators with commutators.

With the availability of affordable silicon diode rectifiers, alternators were used instead. This was encouraged by the increasing electrical power required for cars in this period, with increasing loads from larger headlamps, electric wipers, heated rear windows and other accessories.


belt tensioner
power steering pump
power steering pump pulley
alternator pulley
alternator
crankshaft pulley
drive belt
A/C compressor pulley
A/C compressor

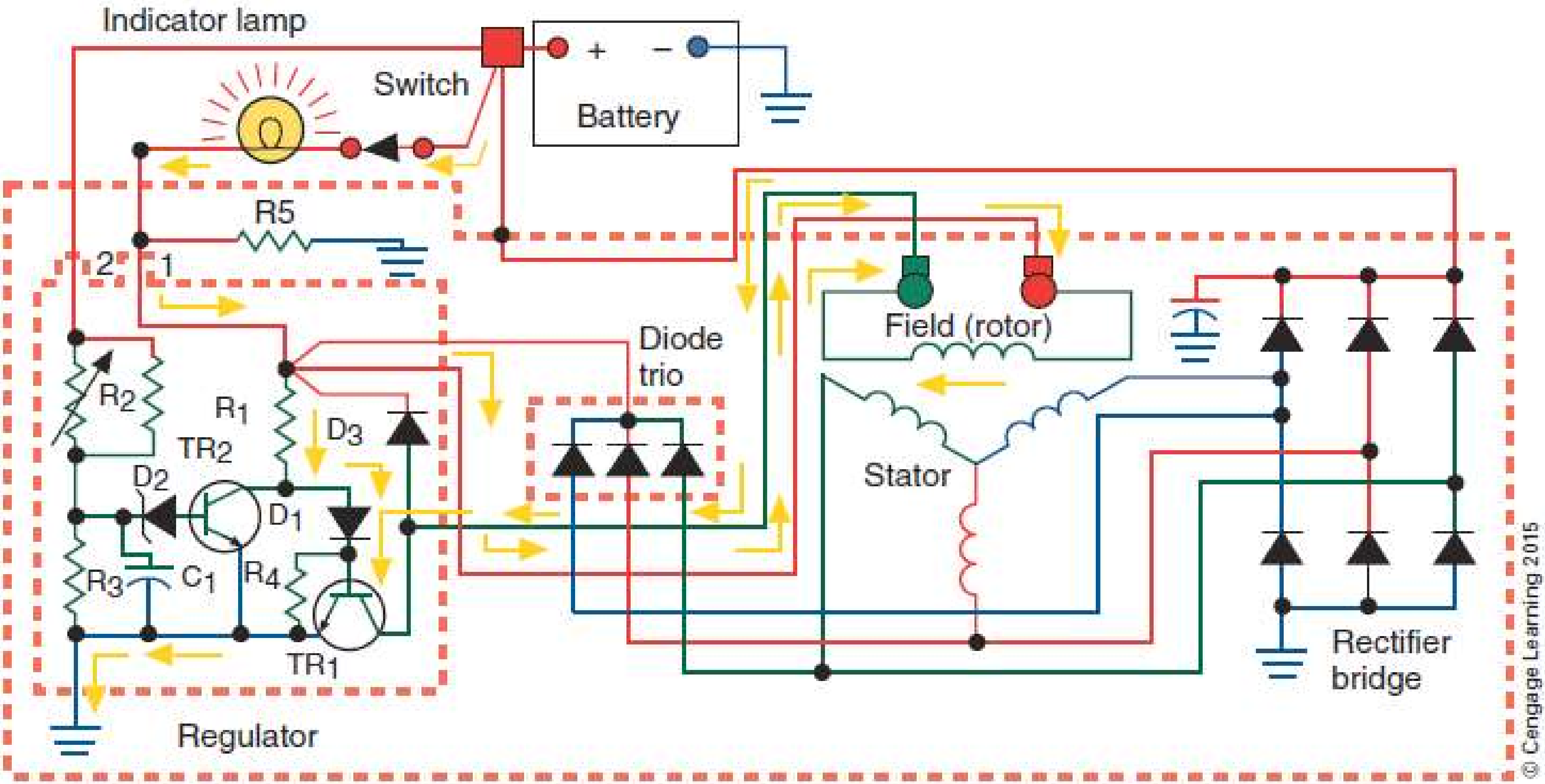


Figure 19-33 An electronic regulator with an indicator light "ON" due to no AC generator output.

The lighting system

The lighting system provides power to both exterior and interior lights. It consists of the headlights, parking lights, marker lights (like the ones attached to a front bumper), taillights, turn signals, hazard warning lights, back-up lights, stoplights, courtesy lights (like the LEDs installed inside doors),

dome/map lights (An interior cabin light with a dome-shaped cover attached to the ceiling of a car), instrument illumination or dash lights, coach lights (if so equipped), headlight switch, and various other control switches.

Other lights,

such as vanity mirror lights, the underhood light, the glove box light, and the trunk compartment light, are used on some vehicles and are also part of the lighting system.

The most commonly used lights are:

Incandescent Lamps

Perhaps the most commonly used type of lamp today is the incandescent lamp. These lamps produce light when current passes through a filament made of tungsten. The filament wire is heated to a high temperature, causing it to glow and give off light. Basically electrical energy is changed to heat energy in the wire filament.

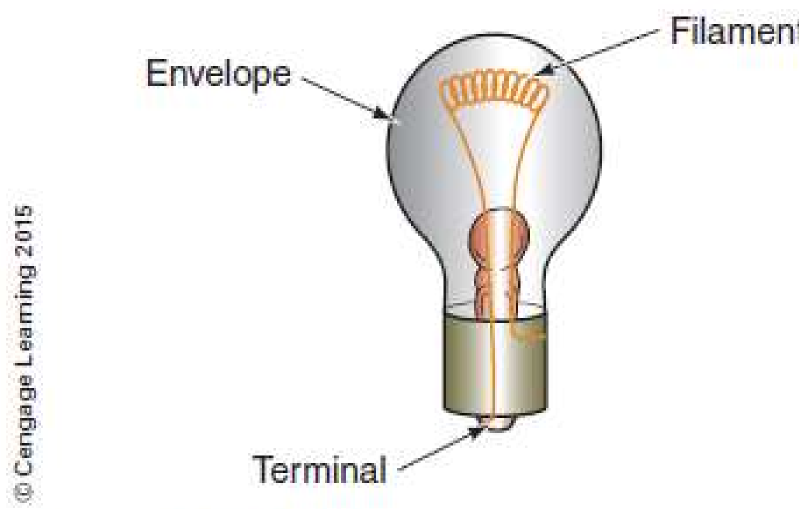


Figure 20-2 An incandescent lamp.

The filament is enclosed in a glass bulb that has been purged of air, therefore the filament “burns” in a vacuum.

If air enters the bulb, the oxygen will allow the filament to oxidize and burn up.

As the filament burns, blackish deposits are left on the glass bulb. The presence of this coating is an indication that the bulb is bad or has little life

remaining in it. Incandescent lamps use more energy to provide light

than other types of lamps.

In an incandescent lamp, about 95 percent of the energy it consumes is lost through heat.

Today, these lamps are being replaced by a variety of fluorescent lamps (including cold cathode fluorescent lamps [CCFL] and compact fluorescent lamps [CFL]), light emitting diodes (LEDs), and high-intensity discharge lamps.

Halogen Lamps

Halogen lamps are actually incandescent lamps. This lamp is comprised of a tungsten filament enclosed in a halogen filled bulb made of high-temperature resistant glass.

The name **halogen** is used to identify a group of chemically related nonmetallic elements, such as iodine, chlorine, and fluorine. Most halogen lamps use iodine vapor.

These lamps provide brighter light because the filament is able to burn at higher temperatures, due to the presence of halogen in the bulb.

Another positive about a halogen lamp is the filament does not break down, as it does in an incandescent bulb, due to the reaction of the burning tungsten and the halogen. As a result, the metal vapor from burning is redeposited on the filament.

Neon Lamps

A neon lamp contains neon or similar gas (such as argon or mercury vapor) at a low pressure in a glass tube or capsule

A small amount of AC or DC current flows through the tube, causing it to glow. The applied voltage must reach the striking voltage before the lamp actually lights up.

At this voltage, the lamp will begin to glow. The required voltage to maintain the glow is about 30 percent less than the voltage required to start the lamp. Neon lamps have been used as the “third” brake light, because of their relatively short response time and their cost.

Fluorescent Lamps

Like a neon lamp, a fluorescent lamp is a gas-discharge lamp. The excited gas in the lamp is typically mercury vapor.

The enclosure of the lamp is coated with phosphor. When current flows through the mercury vapor, the mercury atoms produce short-wave ultraviolet light causing the phosphor to fluoresce, providing visible light.

The advantage of using fluorescent lamps is they use less energy than a conventional incandescent lamp. However, their initial cost is higher because they need an electric ballast assembly to regulate the current through the tube.

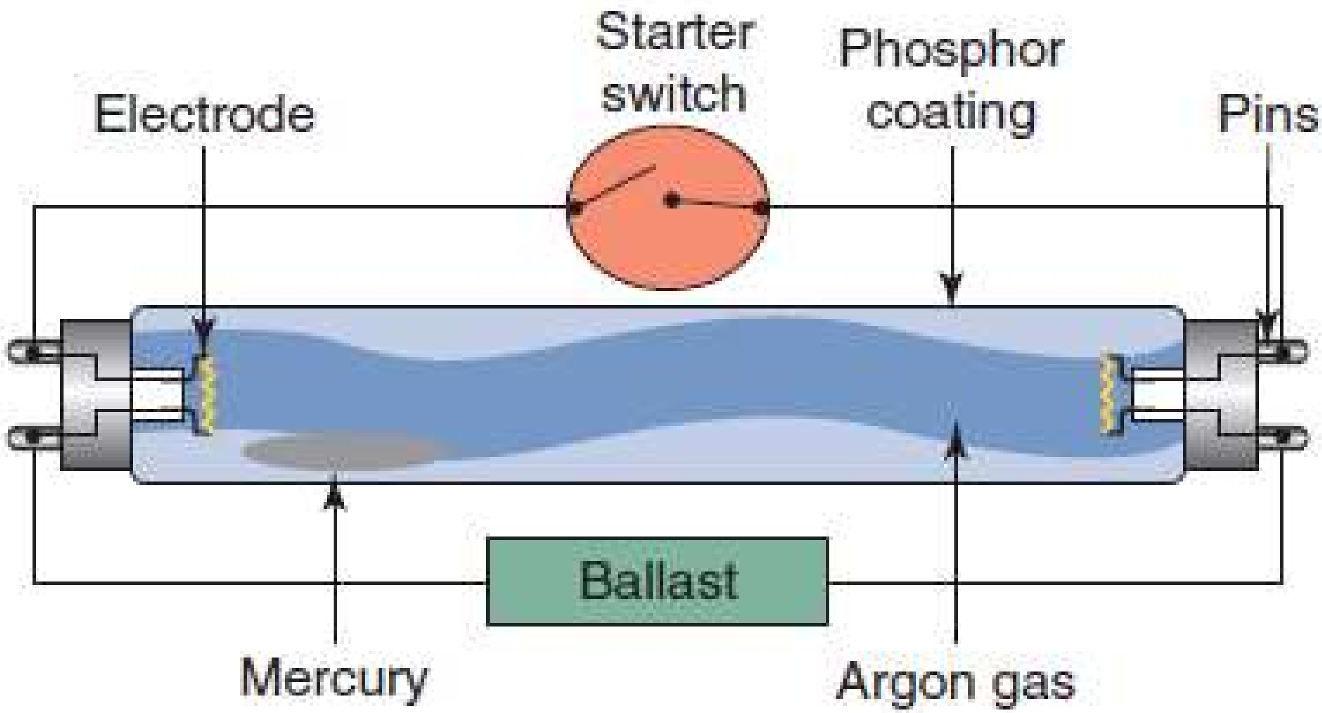


Figure 20-4 The construction of a fluorescent bulb.

High-Intensity Discharge Lamps

High-intensity discharge (HID) lamps provide more visible light, for the amount of consumed electrical power, compared to fluorescent and incandescent lamps. This is

because less heat is lost while the lamp is lit.

Light is emitted when an electric arc jumps across the tungsten electrodes

inside a clear or opaque tube filled with a gas and metal salts.

The gas helps the voltage jump the gap between the electrodes. Once the gap is jumped, the heat of the electrical arc reacts with the metal salts and forms a highly ionized gas that provides a great amount of light.

The presence of the gas also reduces the amount of energy required to provide the light. A ballast unit is required to start and maintain the arcing in a HID lamp.

There are many types of HID lamps including:

■ **Mercury-vapor lamps** are commonly found in large parking lots or assembly halls. Like fluorescent lamps, they require a ballast to start. Older designs produced a bluish-green light, but the light from current versions has little color. Due to inadequate lighting, energy costs, and the noise of the ballast, mercury vapor lamps are being replaced by other designs.

■ **Sodium-vapor lamps** have two types: low pressure and high pressure. Both are rather energy efficient and the high-pressure lamps provide a much whiter light.

■ **Metal-halide and ceramic-metal halide lamps** can emit white light with lower cost and reduced noise than a mercury-vapor lamp.

■ **Xenon lamps** are metal-halide lamps filled with xenon gas. Xenon gas gives off light almost immediately after arcing begins across the electrodes of the lamp. Xenon bulbs provide a bright light that increases in intensity shortly after the arc has been established.

Light-Emitting Diodes (LED)

A light-emitting diode (LED) is a semiconductor that emits light when current passes through it (Figure 20–5) .

LEDs also produce more light than heat and are much smaller than other types of lamps. The brightness of an LED depends on its temperature.

More light is produced when the LED is operating with low current and is at a low temperature. Also, in order for an LED to provide a constant

light output, it needs to be powered by a constant current power supply. The power supply helps keep the LED within the desirable temperature range.

Figure 20-5 A LED lamp.

Unlike other lamps, the bulb of an LED lamp does not put off much heat. However, a great amount of heat is produced at the mounting base of the lamp assembly.

That heat must be controlled to provide constant light and to protect the lamp. The need to keep LED temperatures low requires the use of heat sinks, ventilation systems, or cooling fans, which are normally quite expensive.

LED lamps are normally used in clusters because a single lamp does not provide the brightness of conventional lamps. For late-model vehicles, LEDs are commonly the bulb of choice for brake, parking, turn signals, and daytime running lamps.

HEADLIGHTS

Headlights are mounted on the front of a vehicle to light the road ahead during periods of low visibility, such as

darkness or precipitation.

Headlight designs and construction have been influenced by the changes in technology and safety regulations. In the past, all cars had two or four round or rectangular headlamps.

Now headlights are an integral part of a vehicle’s overall design . A headlamp system must offer a low and a high beam.

The two beams on each side of the vehicle may have two separate lamps or a single lamp that can deliver both beams.

Low beams are intended to be used whenever other vehicles are in front of a vehicle or approaching it from the opposite direction. Low beams are designed to provide

adequate lighting in front of the vehicle with some light spread to the sides of that forward beam.

But they are also set to minimize the amount of light that can shine in the

eyes of other drivers, which can temporarily blind them.

Sealed-Beam Headlights

Until recently, all vehicles had sealed-beam headlights. A sealed-beam headlamp is an air-tight assembly with a filament, reflector, and lens.

The curved reflector is sprayed with vaporized aluminum and the inside of the lamp is normally filled with argon gas.

The reflector intensifies the light produced by the filament, and the lens directs the light to form a broad flat beam (Figure 20–7) .

To direct the light, the surface of the glass lens has concave prisms. Low- and high-beam filaments are placed at slightly different locations within a sealed-beam bulb (Figure 20–8) .

The filaments' location determines how light passes through the bulb's lens. This, in turn, determines the direction

of the light beam. In a dual-filament lamp, the lower filament is used for the high beam and the upper filament is used for the low beam.

Halogen Headlamps

A halogen headlamp (Figure 20–9) is a glass lamp filled with halogen that encloses a tungsten filament.

Figure 20-9 A sealed-beam halogen headlamp.

tungsten-halogen combination, also called quartz-halogen, increases the light emitted by the tungsten filament.

In other words, a tungsten-halogen lamp emits more lumens than other lamps when the watts used to produce the light are considered.

As you may recall, a lumen is a simple measurement

of the total amount of visible light a source emits.

A halogen sealed beam provides about 25 percent more

lighting than conventional bulbs.

Composite Headlights

Most of today's vehicles have halogen headlight systems that use a replaceable bulb (Figure 20–10) . Replaceable halogen bulbs were permitted in the United States in 1983 and their popularity grew quickly. Composite headlights allow manufacturers to produce any style of headlight lens they desire. This improves the aerodynamics, fuel economy, and styling of the vehicle.

The bulb is inserted into the composite headlight housing. The filament is capable of withstanding high temperatures because of the presence of the halogen. Therefore, the filament can operate at higher temperatures and can burn brighter.

Composite headlight housings are often vented to release some of the heat developed by the bulbs. The vents allow condensation to collect on the inside of the lens assembly. The condensation is not a problem and does not affect headlight operation.

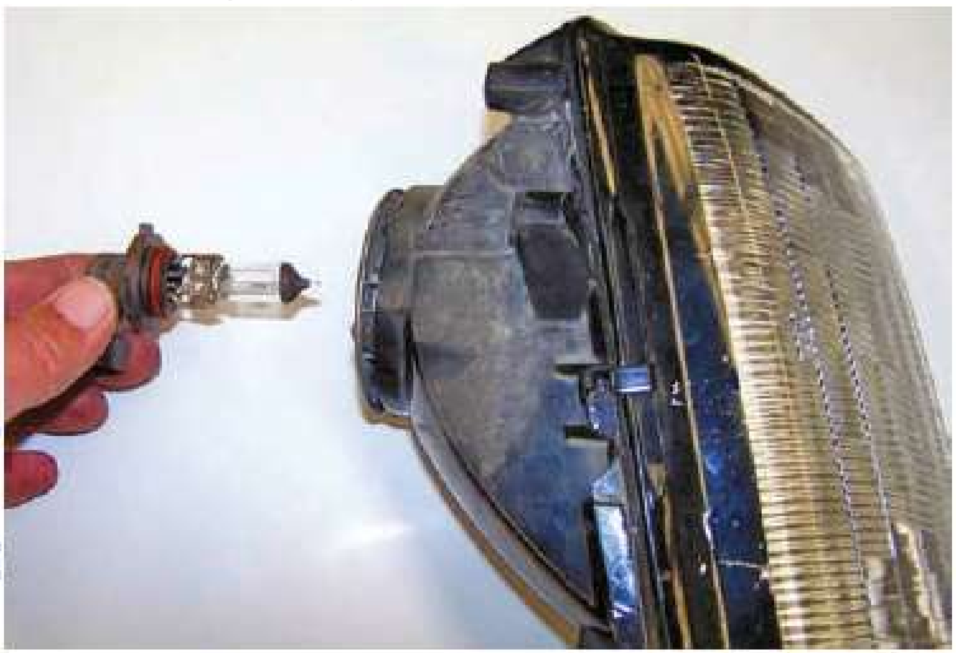


Figure 20-10 A composite headlamp with a replaceable halogen bulb.

High-Intensity Discharge (HID) Headlamps

High-intensity discharge (HID) or **xenon headlamps**

create light by creating and maintaining an electrical arc across two electrodes inside a bulb. The arc excites the gasand salts inside the bulb **(Figure 20–11)**.

This allows the arcing to continue to emit light. These lights are recognizable by their slightly bluish light beams **(Figure 20–12)** . They emit this colored light because the inside of the bulb is filled with xenon gas mixed with mercury or bismuth. The result is a light that is much closer to natural daylight than that of other bulbs.

Figure 20-11 A xenon light bulb.

Figure 20-12 HID (xenon) headlights are readily identifiable by their bluish light.

The lamps use AC voltage and at least volts are needed to jump the gap betwee the electrodes. Once the voltage bridges gap, only about 80 volts are needed to keep current flowing across the gap. Each HID assembly includes a lamp, ballast unit (to limit the current), and start (igniter) **(Figure 20–13)** . The igniter m be part of the bulb assembly or mounted externally **(Figure 20–14)** .

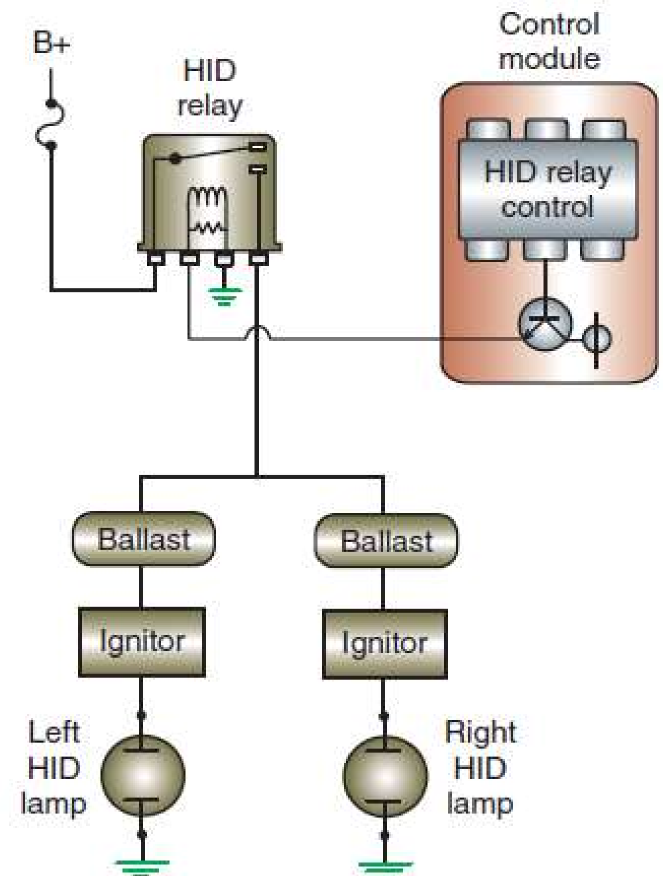


Figure 20-13 An HID headlamp schematic showing the lamps, ballasts, and igniters.

LED Headlights

Currently available on son
vehicles are LED headlam
An individual LED does no
produce enough light to
serve as a headlamp. Ten to
twenty LEDs are needed for
ample forward lighting
(Figure 20–19).

Figure 20-19 A headlight assembly of HID bulbs and LEDs.

There are many reasons for using LEDs in headlights:

■ L EDs do not require a vacuum bulb or high voltage to work.

■ LED-based lighting sources require up to 40 percent less power than traditional lighting sources. This improves a vehicle's fuel economy.

■ LEDs provide a whiter light than xenon.

■ Prototype LED headlights have achieved a 1,000 - lumen output in the low-beam mode; this is the same as a xenon headlamp.

■ L EDs are mercury-free, making them environmentally friendly unlike some HID/xenon systems.

■ The average operating life of an LED is twice that of the vehicle itself. This means the headlamp may never

need to be replaced.

■ LEDs are resistant to shock and vibration.

■ L ED headlamps reduce oncoming driver perception of glare.

■ LED-based headlamps are up to 55 percent thinner than other designs, which give designers more flexibility and freedom