INTRODUCTION

The vehicle has many different lighting and signaling systems, each with its own specific components and operating characteristics. The major light-related circuits and systems covered include:

- Exterior lighting
- Headlights (halogen, HID, and LED)
- Bulb trade numbers
- Brake lights
- Turn signals and flasher units
- Courtesy lights
- Light-dimming rearview mirrors

EXTERIOR LIGHTING

HEADLIGHT SWITCH CONTROL Exterior lighting is controlled by the headlight switch, which is connected directly to the battery on most vehicles. Therefore, if the light switch is left on manually, the lights could drain the battery. Older headlight switches contained a built-in circuit breaker. If excessive current flows through the headlight circuit, the circuit breaker will momentarily open the circuit, then close it again. The result is headlights that flicker on and off rapidly. This feature allows the headlights to function, as a safety measure, in spite of current overload.

The headlight switch controls the following lights on most vehicles, usually through a module.

1. Headlights
2. Taillights
3. Side-marker lights
4. Front parking lights
5. Dash lights
6. Interior (dome) light(s)

COMPUTER-CONTROLLED LIGHTS Because these lights can easily drain the battery if accidentally left on, many newer vehicles control these lights through computer modules. The computer module keeps track of the time the lights are on and can turn them off if the time is excessive. The computer can control either the power side or the ground side of the circuit.

For example, a typical computer-controlled lighting system usually includes the following steps.

STEP 1 The driver depresses or rotates the headlight switch.

STEP 2 The signal from the headlight switch is sent to the nearest control module.

STEP 3 The control module then sends a request to the headlight control module to turn on the headlights as well as the front park and side-marker lights.
Through the data BUS, the rear control module receives the lights on signal and turns on the lights at the rear of the vehicle.

STEP 4 All modules monitor current flow through the circuit and will turn on a bulb failure warning light if it detects an open bulb or a fault in the circuit.

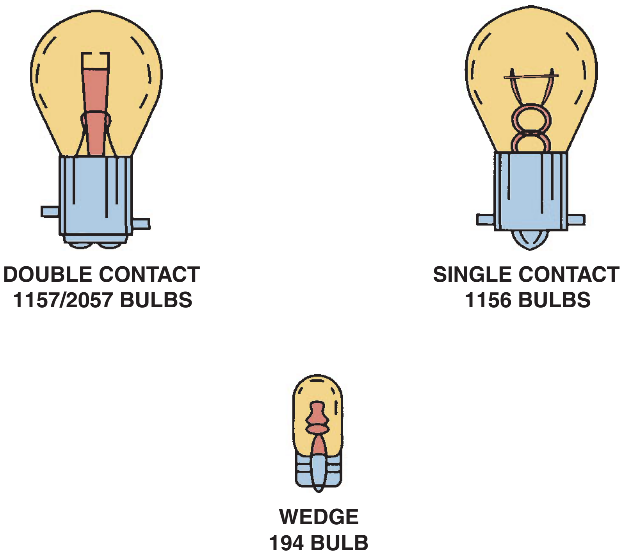

FIGURE 56–1 Dual-filament (double-contact) bulbs contain both a low-intensity filament for taillights or parking lights and a high-intensity filament for brake lights and turn signals. Bulbs come in a variety of shapes and sizes. The numbers shown are the trade numbers.

STEP 5 After the ignition has been turned off, the modules will turn off the lights after a time delay to prevent the battery from being drained.

BULB NUMBERS

TRADE NUMBER The number used on automotive bulbs is called the bulb **trade number,** as recorded with the American National Standards Institute (ANSI). The number is the same regardless of the manufacturer. ● **SEE FIGURE 56–1**.

CANDLEPOWER The trade number also identifies the size, shape, number of filaments, and amount of light produced, measured in **candlepower.** For example, the 1156 bulb, commonly used for backup lights, is 32 candlepower. A 194 bulb, commonly used for dash or side-marker lights, is rated at only 2 candlepower. The amount of light produced by a bulb is determined by the resistance of the filament wire, which also affects the amount of current (in amperes) required by the bulb.

It is important that the correct trade number of bulb always be used for replacement to prevent circuit or component damage. The correct replacement bulb for a vehicle is usually listed in the owner or service manual. ● **REFER TO CHART 56–1** for a listing of common bulbs and their specifications used in most vehicles.

BULB NUMBER SUFFIXES Many bulbs have suffixes that indicate some feature of the bulb, while keeping the same size and light output specifications.

Typical bulb suffixes include:

- NA: natural amber (amber glass)
- A: amber (painted glass)
- HD: heavy duty
- LL: long life
- IF: inside frosted

FIGURE 56–2 Bulbs that have the same trade number have the same operating voltage and wattage. The NA means that the bulb uses a natural amber glass ampoule with clear turn signal lenses.

- R: red
- B: blue
- G: green

SEE FIGURE 56–2.

BULB NUMBER	FILAMENTS	AMPERAGE LOW/HIGH	WATTAGE LOW/HIGH	CANDLEPOWER LOW/HIGH
Headlights				
1255/H1	1	4.58	55.00	129.00
1255/H3	1	4.58	55.00	121.00
6024	2	2.73/4.69	35.00/60.00	27,000/35,000
6054	2	2.73/5.08	35.00/65.00	35,000/40,000
9003	2	4.58/5.00	55.00/60.00	72.00/120.00
9004	2	3.52/5.08	45.00/65.00	56.00/95.00
9005	1	5.08	65.00	136.00
9006	1	4.30	55.00	80.00
9007	2	4.30/5.08	55.00/65.00	80.00/107.00
9008	2	4.30/5.08	55.00/65.00	80.00/107.00
9011	1	5.08	65.00	163.50
Headlights (HID—Xenon)				
D2R	Air Gap	0.41	35.00	222.75
D2S	Air Gap	0.41	35.00	254.57
Taillights, Stop, and Turn Lamps				
1156	1	2.10	26.88	32.00
1157	2	0.59/2.10	8.26/26.88	3.00/32.00
2057	2	0.49/2.10	6.86/26.88	2.00/32.00
3057	2	6.72/26.88	0.48/2.10	1.50/24.00
3155	1	1.60	20.48	21.00
3157	2	0.59/2.10	8.26/26.88	2.20/24.00
4157	2	0.59/2.10	8.26/26.88	3.00/32.00
7440	1	1.75	21.00	36.60
7443	2	0.42/1.75	5.00/21.00	2.80/36.60
17131	1	0.33	4.00	2.80
17635	1	1.75	21.00	37.00
17916	2	0.42/1.75	5.00/21.00	1.20/35.00
Parking, Daytime Running Lamps				
24	1	0.24	3.36	2.00
67	1	0.59	7.97	4.00
168	1	0.35	4.90	3.00
194	1	0.27	3.78	2.00
889	1	3.90	49.92	43.00
912	1	1.00	12.80	12.00
916	1	0.54	7.29	2.00
1034	2	0.59/1.80	8.26/23.04	3.00/32.00
1156	1	2.10	26.88	32.00
1157	2	0.59/2.10	8.26/26.88	3.00/32.00
2040	1	0.63	8.00	10.50
2057	2	0.49/2.10	6.86/26.88	1.50/24.00
2357	2	0.59/2.23	8.26/28.54	3.00/40.00
3157	2	0.59/2.10	8.26/26.88	3.00/32.00
3357	2	0.59/2.23	8.26/28.54	3.00/40.00
3457	2	0.59/2.23	8.26/28.51	3.00/40.00
3496	2	0.66/2.24	8.00/27.00	3.00/45.00
3652	1	0.42	5.00	6.00
4114	2	0.59/2/23	8.26/31.20	3.00/32.00
4157	2	0.59/2.10	8.26/26/88	3.00/32.00
7443	2	0.42/1.75	5.00/21.00	2.80/36.60
17131	1	0.33	4.00	2.80
17171	1	0.42	5.00	4.00
17177	1	0.42	5.00	4.00
17311	1	0.83	10.00	10.00
17916	2	0.42/1.75	5.00/21.00	1.20/35.00
68161	1	0.50	6.00	10.00
Center High-Mounted Stop Lamp (CHMSL)				
70	1	0.15	2.10	1.50
168	1	0.35	4.90	3.00
175	1	0.58	8.12	5.00
211-2	1	0.97	12.42	12.00
577	1	1.40	17.92	21.00
579	1	0.80	10.20	9.00
889	1	3.90	49.92	43.00
891	1	0.63	8.00	11.00
906	1	0.69	8.97	6.00
912	1	1.00	12.80	12.00
921	1	1.40	17.92	21.00
922	1	0.98	12.54	15.00
1141	1	1.44	18.43	21.00

CONTINUED

CHART 56–1

Bulbs that have the same trade number have the same operating voltage and wattage. The NA means that the bulb uses a natural amber glass ampoule with clear turn signal lenses.

BULB NUMBER	FILAMENTS	AMPERAGE LOW/HIGH	WATTAGE LOW/HIGH	CANDLEPOWER LOW/HIGH
1156	1	2.10	26.88	32.00
2723	1	0.20	2.40	1.50
3155	1	1.60	20.48	21.00
3156	1	2.10	26.88	32.00
3497	1	2.24	27.00	45.00
7440	1	1.75	21.00	36.60
17177	1	0.42	5.00	4.00
17635	1	1.75	21.00	37.00
License Plate, Glove Box, Dome, Side Marker, Trunk, Map, Ashtray, Step/Courtesy, Underhood				
37	1	0.09	1.26	0.50
67	1	0.59	7.97	4.00
74	1	0.10	1.40	.070
98	1	0.62	8.06	6.00
105	1	1.00	12.80	12.00
124	1	0.27	3.78	1.50
161	1	0.19	2.66	1.00
168	1	0.35	4.90	3.00
192	1	0.33	4.29	3.00
194	1	0.27	3.78	2.00
211-1	1	0.968	12.40	12.00
212-2	1	0.74	9.99	6.00
214-2	1	0.52	7.02	4.00
293	1	0.33	4.62	2.00
561	1	0.97	12.42	12.00
562	1	0.74	9.99	6.00
578	1	0.78	9.98	9.00
579	1	0.80	10.20	9.00
PC579	1	0.80	10.20	9.00
906	1	0.69	8.97	6.00
912	1	1.00	12.80	12.00
917	1	1.20	14.40	10.00
921	1	1.40	17.92	21.00
1003	1	0.94	12.03	15.00
1155	1	0.59	7.97	4.00
1210/H2	1	8.33	100.00	239.00
1210/H3	1	8.33	100.00	192.00
1445	1	0.14	2.02	0.70
1891	1	0.24	3.36	2.00
1895	1	0.27	3.78	2.00
3652	1	0.42	5.00	6.00
11005	1	0.39	5.07	4.00
11006	1	0.24	3.36	2.00
12100	1	0.77	10.01	9.55
13050	1	0.38	4.94	3.00
17036	1	0.10	1.20	0.48
17097	1	0.25	3.00	1.76
17131	1	0.33	4.00	2.80

CONTINUED

BULB NUMBER	FILAMENTS	AMPERAGE LOW/HIGH	WATTAGE LOW/HIGH	CANDLEPOWER LOW/HIGH
17177	1	0.42	5.00	4.00
17314	1	0.83	10.00	8.00
17916	2	0.42/1.75	5.00/21.00	1.20/35.00
47830	1	0.39	5.00	6.70
Instrument Panel				
37	1	0.09	1.26	0.50
73	1	0.08	1.12	0.30
74	1	0.10	1.40	0.70
PC74	1	0.10	1.40	0.70
PC118	1	0.12	1.68	0.70
124	1	0.27	3.78	1.50
158	1	0.24	3.36	2.00
161	1	0.19	2.66	1.00
192	1	0.33	4.29	3.00
194	1	0.27	3.78	2.00
PC194	1	0.27	3.78	2.00
PC195	1	0.27	3.78	1.80
1210/H1	1	8.33	100.00	217.00
1210/H3	1	8.33	100.00	192.00
17037	1	0.10	1.20	0.48
17097	1	0.25	3.00	1.76
17314	1	0.83	10.00	8.00
Backup, Cornering, Fog/Driving Lamps				
67	1	0.59	7.97	4.00
579	1	0.80	10.20	9.00
880	1	2.10	26.88	43.00
881	1	2.10	26.88	43.00
885	1	3.90	49.92	100.00
886	1	3.90	49.92	100.00
893	1	2.93	37.50	75.00
896	1	2.93	37.50	75.00
898	1	2.93	37.50	60.00
899	1	2.93	37.50	60.00
921	1	1.40	17.92	21.00
1073	1	1.80	23.04	32.00
1156	1	2.10	26.88	32.00
1157	2	0.59/2.10	8.26/26.88	3.00/32.00
1210/H1	1	8.33	100.00	217.00
1255/H1	1	4.58	55.00	129.00
1255/H3	1	4.58	55.00	121.00
1255/H11	1	4.17	55.00	107.00
2057	2	0.49/2.10	6.86/26.88	1.50/24.00
3057	2	0.48/2.10	6.72/26.88	2.00/32.00
3155	1	1.60	20.48	21.00
3156	1	2.10	26.88	32.00
3157	2	0.59/2.10	8.26/26.88	3.00/32.00
4157	2	0.59/2.10	8.26/26/88	3.00/32.00
7440	1	1.75	21.00	36.00
9003	2	4.58/5.00	55.00/60.00	72.00/120.00
9006	1	4.30	55.00	80.00
9145	1	3.52	45.00	65.00
17635	1	1.75	21.00	37.00

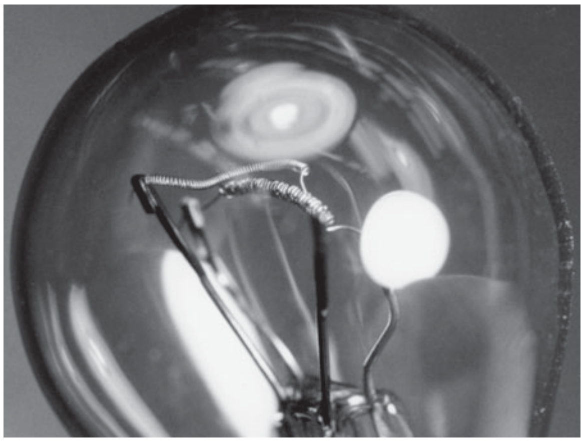

FIGURE 56–3 Close-up a 2057 dual-filament (double-contact) bulb that failed. Notice that the top filament broke from its mounting and melted onto the lower filament. This bulb caused the dash lights to come on whenever the brakes were applied.

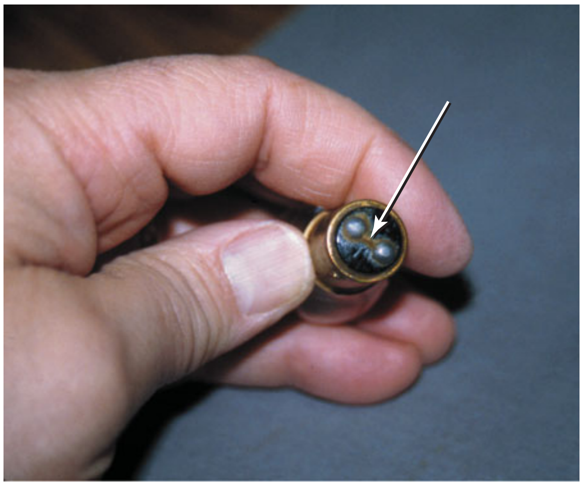

FIGURE 56–4 Corrosion caused the two terminals of this dual-filament bulb to be electrically connected.

REAL WORLD FIX

Weird Problem—Easy Solution

A General Motors minivan had the following electrical problems.

- The turn signals flashed rapidly on the left side.
- With the ignition key off, the lights-on warning chime sounded if the brake pedal was depressed.
- When the brake pedal was depressed, the dome light came on.

All of these problems were caused by *one* defective 2057 dual-filament bulb, as shown in ● **FIGURE 56–3.**

Apparently, the two filaments were electrically connected when one filament broke and then welded to the other filament. This caused the electrical current to feed back from the brake light filament into the taillight circuit, causing all the problems.

TESTING BULBS

Bulbs can be tested using two basic tests.

1. Perform a visual inspection of any bulb. Many faults, such as a shorted filament, corroded connector, or water, can cause weird problems that are often thought to be wiring issues.

   ● **SEE FIGURES 56–4 AND 56–5.**

FIGURE 56–5 Often the best diagnosis is a thorough visual inspection. This bulb was found to be filled with water, which caused weird problems.

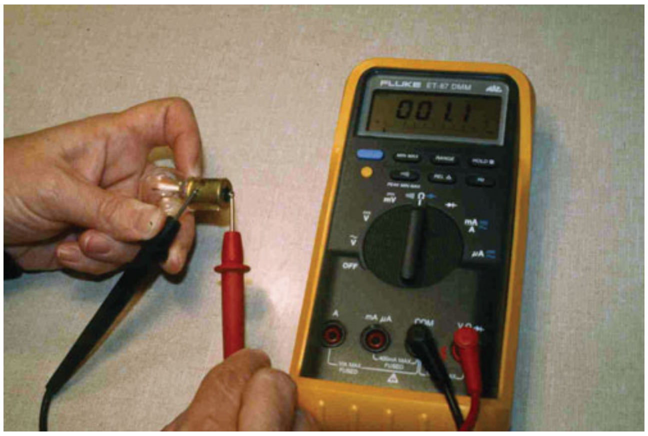

FIGURE 56–6 This single-filament bulb is being tested with a digital multimeter set to read resistance in ohms. The reading of 1.1 ohms is the resistance of the bulb when cold. As soon as current flows through the filament, the resistance increases about 10 times. It is the initial surge of current flowing through the filament when the bulb is cool that causes many bulbs to fail in cold weather as a result of the reduced resistance. As the temperature increases, the resistance increases.

2. Bulbs can be tested using an ohmmeter and checking the resistance of the filaments(s). Most bulbs will read low resistance at room temperature between 0.5 and 20 ohms depending on the bulb. Test results include:
   - **Normal resistance.** The bulb is good. Check both filaments if it is a two-filament bulb. ● **SEE FIGURE 56–6.**
   - **Zero ohms.** It is unlikely but possible for the bulb filament to be shorted.
   - **OL (electrically open).** The reading indicates that the bulb filament is broken.

BRAKE LIGHTS

OPERATION

Brake lights, also called stop lights, use the high-intensity filament of a double-filament bulb. (The low-intensity filament is for the taillights.) When the brakes are applied, the brake switch is closed and the brake lamps light. The brake switch receives current from a fuse that is hot all the time. The brake light switch is a normally open (N.O.) switch, but is closed when the driver depresses the brake

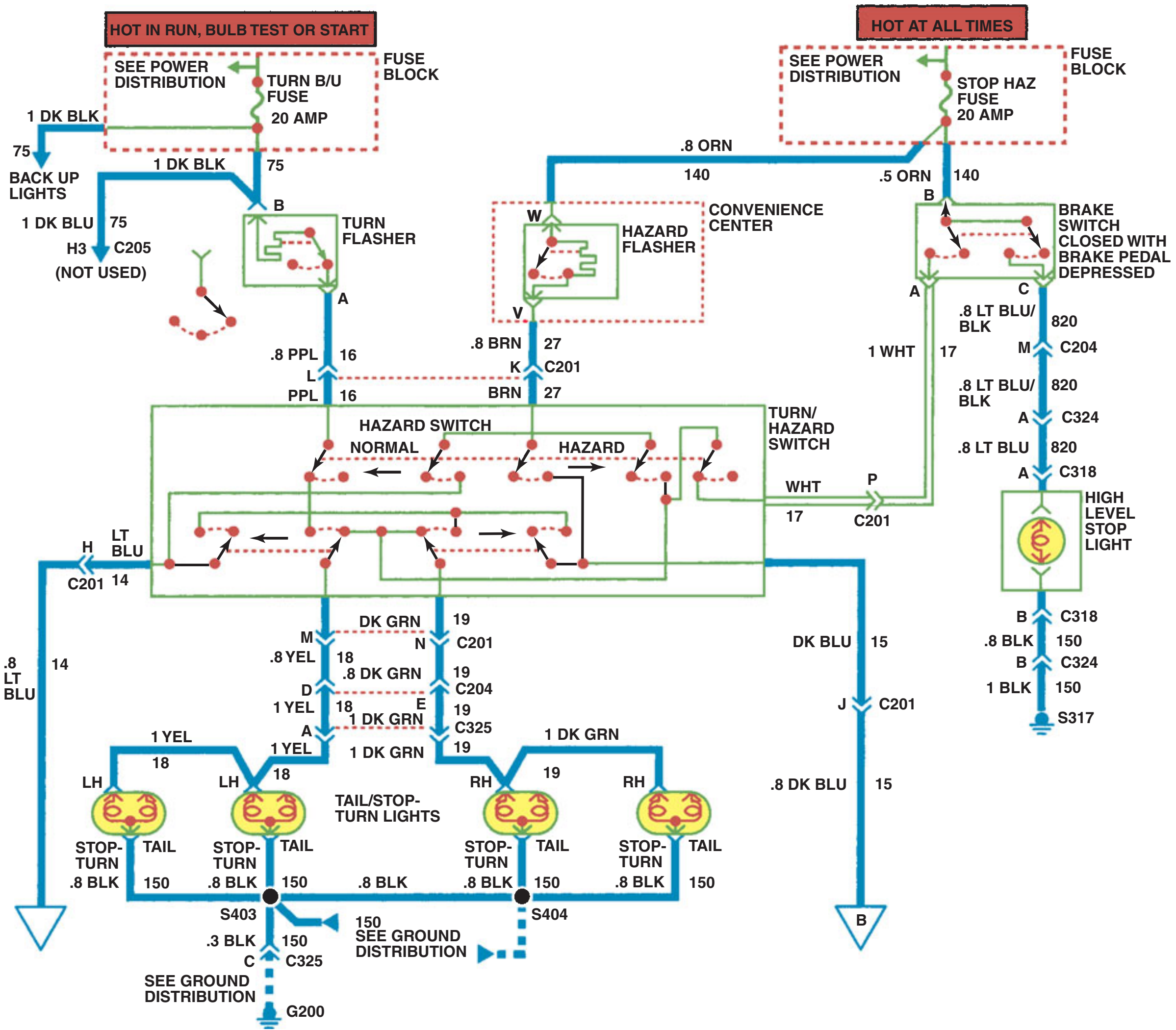

FIGURE 56–7 Typical brake light and taillight circuit showing the brake switch and all of the related circuit components.

pedal. Since 1986, all vehicles sold in the United States have a third brake light commonly referred to as the **center high-mounted stop light (CHMSL).** ● **SEE FIGURE 56–7.**

? FREQUENTLY ASKED QUESTION

Why Are LEDs Used for Brake Lights?

Light-emitting diode (LED) brake lights are frequently used for high-mounted stop lamps (CHMSLs) for the following reasons.

1. **Faster illumination.** An LED will light up to 200 milliseconds faster than an incandescent bulb, which requires some time to heat the filament before it is hot enough to create light. This faster illumination can mean the difference in stopping distances at 60 mph (100 km/h) by about 18 ft (6 m) due to the reduced reaction time for the driver of the vehicle behind.
2. **Longer service life.** LEDs are solid-state devices that do not use a filament to create light. As a result, they are less susceptible to vibration and will often last the life of the vehicle.

   NOTE: Aftermarket replacement LED bulbs that are used to replace conventional bulbs may require the use of a different type of flasher unit due to the reduced current draw of the LED bulbs. ● **SEE FIGURE 56–8.**

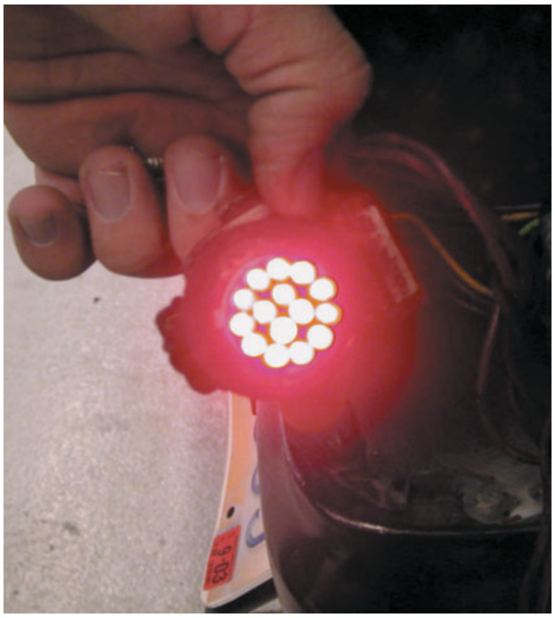

FIGURE 56–8 A replacement LED taillight bulb is constructed of many small, individual light-emitting diodes.

The brake switch is also used as an input switch (signal) for the following:

1. Cruise control (deactivates when the brake pedal is depressed)
2. Antilock brakes (ABS)
3. Brake shift interlock (prevents shifting from park position unless the brake pedal is depressed)

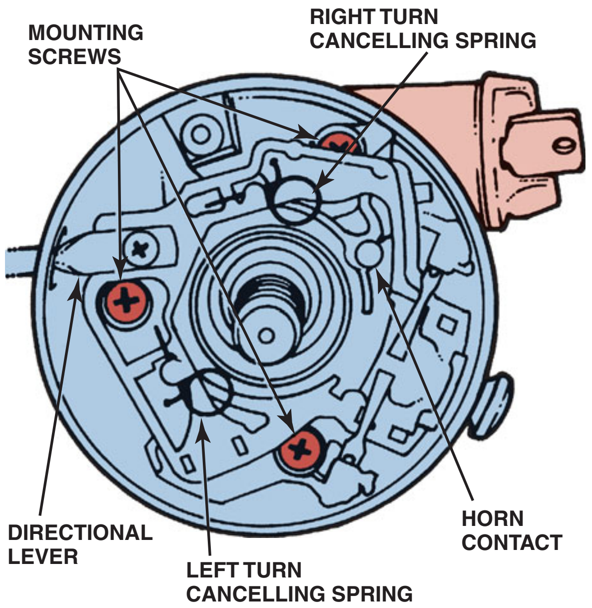

FIGURE 56–9 The typical turn signal switch includes various springs and cams to control the switch and to cause the switch to cancel after a turn has been completed.

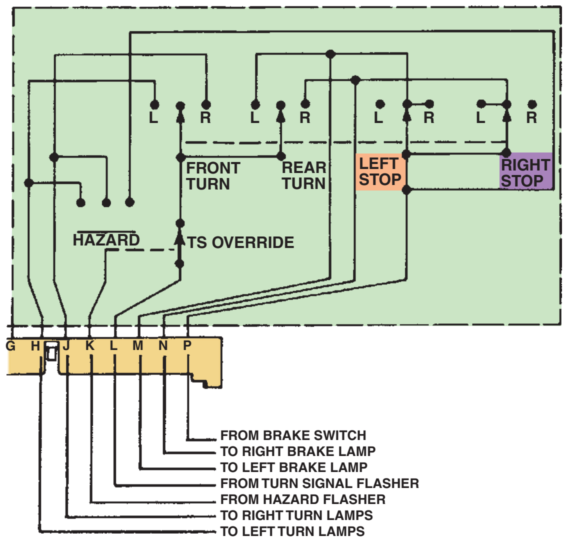

FIGURE 56–10 When the stop lamps and turn signals share a common bulb filament, stop light current flows through the turn signal switch.

TURN SIGNALS

OPERATION The turn signal circuit is supplied power from the ignition switch and operated by a lever and switch. ● **SEE FIGURE 56–9.**

When the turn signal switch is moved in either direction, the corresponding turn signal lamps receive current through the flasher unit. The flasher unit causes the current to start and stop as the turn signal lamp flashes on and off with the interrupted current.

ONE-FILAMENT STOP/TURN BULBS In many vehicles, the stop and turn signals are both provided by one filament. When the turn signal switch is turned on (closed), the filament receives interrupted current through the flasher unit. When the brakes are applied, the current first flows to the turn signal switch, except for the high-mounted stop, which is fed directly from the brake switch. If neither turn signal is on, then current through the turn signal switch flows to both rear brake lights. If the turn signal switch is operated (turned to either left or right), current flows through the flasher unit on the side that was selected and directly to the brake lamp on the opposite side. If the brake pedal is not depressed, then current flows through the flasher and only to one side. ● **SEE FIGURE 56–10.**

Moving the lever up or down completes the circuit through the flasher unit and to the appropriate turn signal lamps. A turn signal switch includes cams and springs that cancel the signal after the turn has been completed. As the steering wheel is turned in the signaled direction and then returns to its normal position, the cams and springs cause the turn signal switch contacts to open and break the circuit.

TWO-FILAMENT STOP/TURN BULBS In systems using separate filaments for the stop and turn lamps, the brake and turn signal switches are not connected. If the vehicle uses the same filament for both purposes, then brake switch current is routed through contacts within the turn signal switch. By linking certain contacts, the bulbs can receive either brake switch current or flasher current, depending upon which direction is being signaled. For

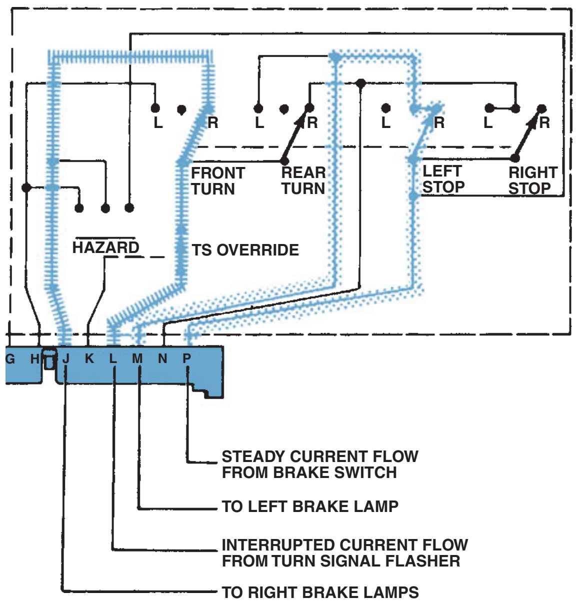

FIGURE 56–11 When a right turn in signaled, the turn signal switch contacts send flasher current to the right-hand filament and brake switch current to the left-hand filament.

example, ● **FIGURE 56–11** shows current flow through the switch when the brake switch is closed and a right turn is signaled.

Steady current through the brake switch is sent to the left brake lamp. Interrupted current from the turn signal is sent to the right turn lamps.

FLASHER UNITS A turn signal flasher unit is a metal or plastic can containing a switch that opens and closes the turn signal circuit. Vehicles can be equipped with many different types of flasher units. ● **SEE FIGURE 56–12.**

- **DOT flashers.** This turn signal flasher unit is often installed in a metal clip attached to the dash panel to allow the “clicking” noise of the flasher to be heard by the driver. The turn signal flasher is designed to transmit the current to light the front and rear bulbs on only one side at a time. The U.S. **Department of Transportation (DOT)** regulation requires that the driver be

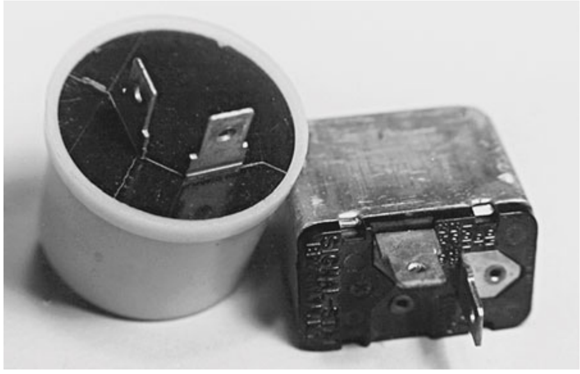

FIGURE 56–12 Two styles of two-prong flasher units.

alerted when a turn signal bulb is not working. This is achieved by using a series-type flasher unit. The flasher unit requires current flow through two bulbs (one in the front and one in the rear) in order to flash. If one bulb burns out, the current flow through only one bulb is not sufficient to make the unit flash; it will be a steady light. These turn signal units are often called DOT flashers.

- **Bimetal flashers.** The bimetal flashers have a lower cost and shorter life expectancy than hybrid or solid-state flashers. The operation of this flasher is current sensitive, which means that the flasher will stop flashing when one of the light bulbs is out and that it will flash at a faster rate when adding additional load, such as a trailer. The bimetal element is a sandwich of two different metals that distorts with temperature changes similar to a circuit breaker. The turn signal lamp current is passed through the bimetal element and causes heating. When the element is hot enough, the bimetal distorts, opening the contacts and turning off the lamps. After the bimetal cools, it returns to the original shape, closing the contacts and turning on the lamps again. This sequence is repeated until the load is removed. If one bulb burns out, the turn signal indicator lamp on the dash will remain lighted. The flasher will not flash because there is not enough current flow through the one remaining bulb to cause the flasher to become heated enough to open.
- **Hybrid flashers.** The **hybrid flashers** have an electronic flasher control circuit to operate the internal electromechanical relay and are commonly called a **flasher relay.** This type of flasher has a stable electronic timing circuitry that enables a wide operating voltage and temperature range with a reasonable cost. The life expectancy is considerably longer compared to bimetal units and is dependent on the load and relay used internally for switching the load. The hybrid flasher has a lamp current-sensing circuit which will cause the flash rate to double when a bulb is burned out.
- **Solid-state flashers.** The solid-state flashers have an internal electronic circuit for timing and solid-state power output devices for load switching. Life expectancy is longer than other flashers because there are no moving parts for mechanical breakdown. The biggest disadvantage of solid state is the higher cost. Solid-state units cause the turn indicator to flash rapidly if a bulb is burned out.

ELECTRONIC FLASHER REPLACEMENT UNITS Older vehicles (and a few newer ones) use thermal (bimetal) flashers that use heat to switch on and off. Most turn signal flasher units are mounted in a metal clip that is attached to the dash. The dash panel acts as a sounding board, increasing the sound of the flasher unit.

FIGURE 56–13 A hazard warning flasher uses a parallel resistor across the contacts to provide a constant flashing rate regardless of the number of bulbs used in the circuit.

Most four-way hazard flasher units are plugged into the fuse panel. Some turn signal flasher units are plugged into the fuse panel. How do you know for sure where the flasher unit is located? With both the turn signal and the ignition on, listen and/or feel for the clicking of the flasher unit. Some service manuals also give general locations for the placement of flasher units.

Newer vehicles have electronic flashers that use microchips to control the on/off function. Electronic flashers are compatible with older systems and are wise to use for the following reasons.

1. Electronic flashers do not burn out, and they provide a faster "flash" of the turn signals.
2. If upgrading to LED tail lamps, or lights, the LED bulbs only work with electronic flashers unless a resistor is added in the circuit.

HAZARD WARNING FLASHER The **hazard warning** flasher is a device installed in a vehicle lighting system with the primary function of causing both the left and right turn signal lamps to flash when the hazard warning switch is activated. Secondary functions may include visible dash indicators for the hazard system and an audible signal to indicate when the flasher is operating. A typical hazard warning flasher is also called a *parallel* or *variable-load* flasher because there is a resistor in parallel with the contacts to provide a control load and, therefore, a constant flash rate, regardless of the number of bulbs being flashed. ● **SEE FIGURE 56–13.**

COMBINATION TURN SIGNAL AND HAZARD WARNING FLASHER The combination flasher is a device that combines the functions of a turn signal flasher and a hazard warning flasher into one package, which often uses three electrical terminals.

HEADLIGHTS

HEADLIGHT SWITCHES The headlight switch operates the exterior and interior lights of most vehicles. On noncomputer-controlled lighting systems, the headlight switch is connected directly to the

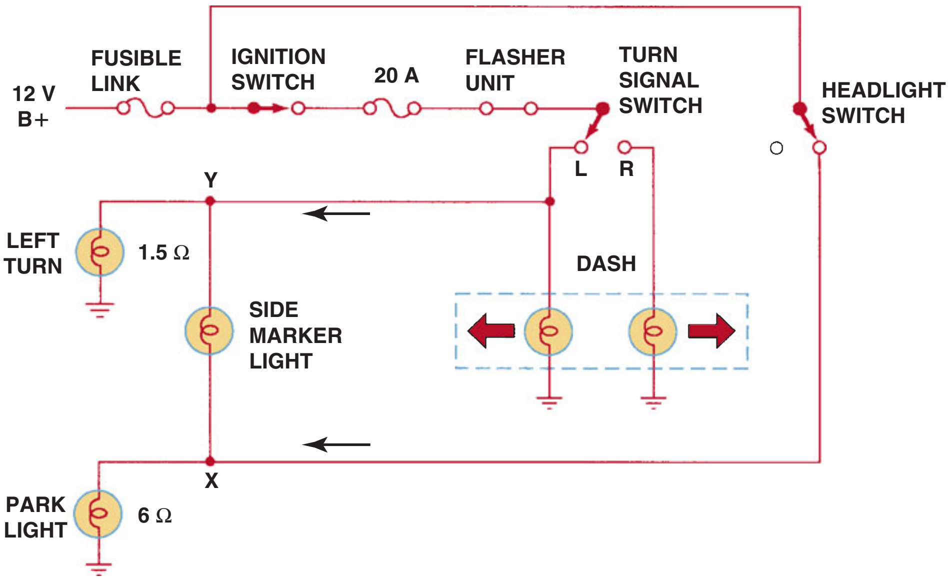

FIGURE 56–14 The side-marker light goes out whenever there is voltage at both points X and Y. These opposing voltages stop current flow through the side-marker light. The left turn light and left park light are actually the same bulb (usually 2057) and are shown separately to help explain how the side-marker light works on many vehicles.

FREQUENTLY ASKED QUESTION

How Do You Tell What Type of Flasher Is Being Used?

The easiest way to know which type of flasher can be used is to look at the type of bulb used in the tail lamps and turn signals. If it is a "wedge" style (plastic base, flat and rectangular), the vehicle has an electronic flasher. If it is a "twist and turn" bayonet-style (brass base) bulb, then either type of flasher can be used.

FREQUENTLY ASKED QUESTION

Why Does the Side-Marker Light Alternately Flash?

A question that service technicians are asked frequently is why the side-marker light alternately goes out when the turn signal is on, and is on when the turn signal is off. Some vehicle owners think that there is a fault with the vehicle, but this is normal operation. The side-marker light goes out when the lights are on and the turn signal is flashing because there are 12 volts on both sides of the bulb (see points X and Y in ● **FIGURE 56–14**).

Normally, the side-marker light gets its ground through the turn signal bulb.

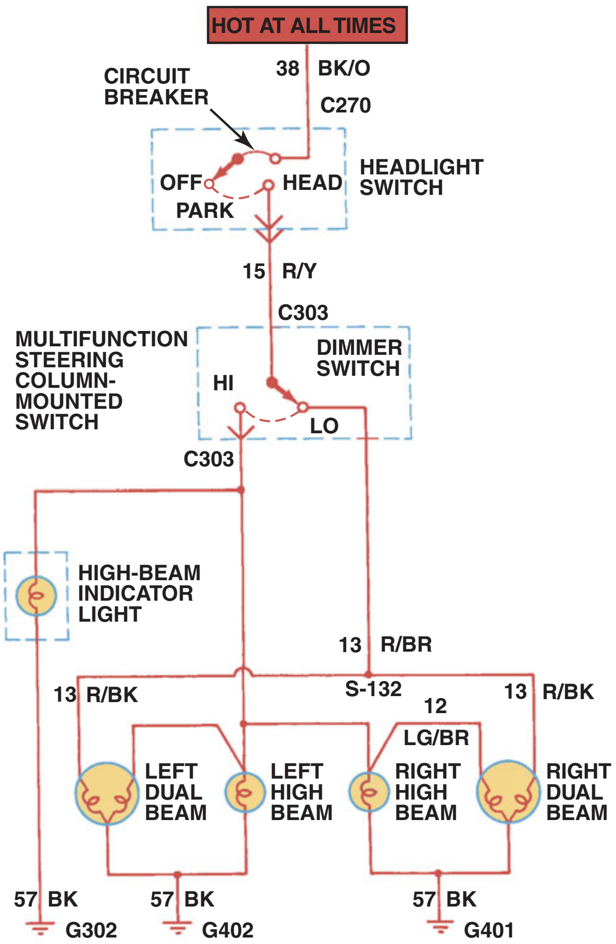

FIGURE 56–15 Typical headlight circuit diagram. Note that the headlight switch is represented by a dotted outline indicating that other circuits (such as dash lights) also operate from the switch.

battery through a fusible link, and has continuous power or is "hot" all the time. A circuit breaker is built into most older model headlight switches to protect the headlight circuit. ● **SEE FIGURE 56–15.**

The headlight switch may include the following:

- The interior dash lights can often be dimmed manually by rotating the headlight switch knob or by another rotary knob that controls a variable resistor (called a **rheostat**). The rheostat drops the voltage sent to the dash lights. Whenever there is a voltage drop (increased resistance), there is heat. A coiled resistance wire is built into a ceramic housing that is designed to insulate the rest of the switch from the heat and allow heat to escape.
- The headlight switch also contains a built-in circuit breaker that will rapidly turn the headlights on and off in the event of a short circuit. This prevents a total loss of headlights. If the headlights are rapidly flashing on and off, check the entire headlight circuit for possible shorts. The circuit breaker controls only the headlights. The other lights controlled by the headlight switch (taillights, dash lights, and parking lights) are fused separately. Flashing headlights also may be caused by a failure in the built-in circuit breaker, requiring replacement of the switch assembly.

FIGURE 56–16 A typical four-headlight system using sealed beam headlights.

AUTOMATIC HEADLIGHTS

Computer-controlled lights use a light sensor that signals when to have the computer turn on the headlights. The sensor is mounted on the dashboard or mirror. Often these systems have a driver-adjusted sensitivity control that allows for the lights to be turned on at various levels of light. Most systems also have a computer module control over the time that the lights remain on after the ignition has been turned off and the last door has been closed. A scan tool is often needed to change this time delay.

SEALED BEAM HEADLIGHTS

A sealed beam headlight consists of a sealed glass or plastic assembly containing the bulb, reflective surface, and prism lenses to properly focus the light beam. Low-beam headlights contain two filaments and three electrical terminals.

- One for low beam
- One for high beam
- Common ground

High-beam headlights contain only one filament and two terminals. Because low-beam headlights also contain a high-beam filament, the entire headlight assembly must be replaced if either filament is defective. ● **SEE FIGURE 56–16.**

A sealed beam headlight can be tested with an ohmmeter. A good bulb should indicate low ohms between the ground terminal and both power-side (hot) terminals. If either the high-beam or the low-beam filament is burned out, the ohmmeter will indicate infinity (OL).

HALOGEN SEALED BEAM HEADLIGHTS

Halogen sealed beam headlights are brighter and more expensive than normal headlights. Because of their extra brightness, it is common practice to have only two headlights on at any one time, because the candlepower output would exceed the maximum U.S. federal standards if all four halogen headlights were on. Therefore, before trying to repair the problem that only two of the four lamps are on, check the owner or shop manual for proper operation.

CAUTION: Do not attempt to wire all headlights together. The extra current flow could overheat the wiring from the headlight switch through the dimmer switch and to the headlights. The overloaded circuit could cause a fire.

COMPOSITE HEADLIGHTS

Composite headlights are constructed using a replaceable bulb and a fixed lens cover that is part of the vehicle. Composite headlights are the result of changes in the aerodynamic styling of vehicles where sealed beam lamps could no longer be used. ● **SEE FIGURE 56–17.**

FIGURE 56–17 A typical composite headlamp assembly. The lens, housing, and bulb sockets are usually included as a complete assembly.

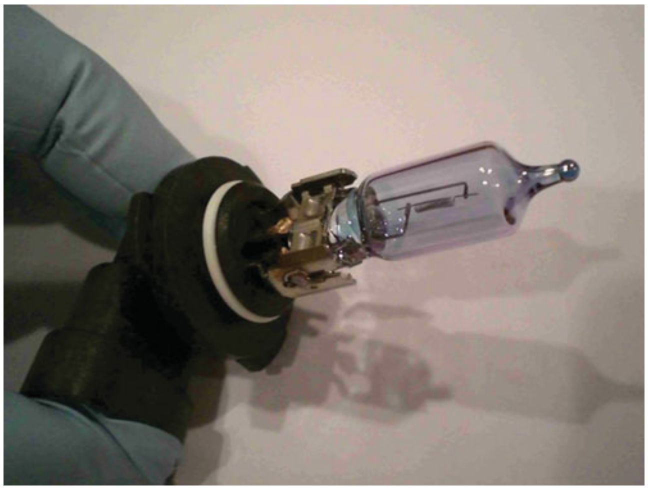

FIGURE 56–18 Handle a halogen bulb by the base to prevent the skin's oil from getting on the glass.

TECH TIP

Diagnose Bulb Failure

Halogen bulbs can fail for various reasons. Some causes for halogen bulb failure and their indications are as follows:

- **Gray color.** Low voltage to bulb (check for corroded socket or connector)
- **White (cloudy) color.** Indication of an air leak
- **Broken filament.** Usually caused by excessive vibration
- **Blistered glass.** Indication that someone has touched the glass

NOTE: *Never touch the glass (called the ampoule) of any halogen bulb.* The oils from your fingers can cause unequal heating of the glass during operation, leading to a shorter-than-normal service life. ● **SEE FIGURE 56–18.**

The replaceable bulbs are usually bright halogen bulbs. Halogen bulbs get very hot during operation, between 500°F and 1,300°F (260°C and 700°C). It is important never to touch the glass of any halogen bulb with bare fingers because the natural oils of the skin on the glass bulb can cause the bulb to break when it heats during normal operation.

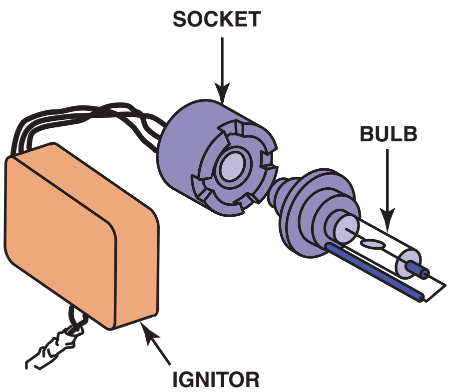

FIGURE 56–19 The igniter contains the ballast and transformer needed to provide high-voltage pulses to the arc tube bulb.

FIGURE 56–20 HID (xenon) headlights emit a whiter light than halogen headlights and usually look blue compared to halogen bulbs.

? FREQUENTLY ASKED QUESTION

What Is the Difference Between the Temperature of the Light and the Brightness of the Light?

The temperature of the light indicates the color of the light. The brightness of the light is measured in lumens. A standard 100 watt incandescent light bulb emits about 1,700 lumens. A typical halogen headlight bulb produces about 2,000 lumens, and a typical HID bulb produces about 2,800 lumens.

HIGH-INTENSITY DISCHARGE HEADLIGHTS

PARTS AND OPERATION **High-intensity discharge (HID)** headlights produce a distinctive blue-white light that is crisper, clearer, and brighter than light produced by a halogen headlight.

High-intensity discharge lamps do not use a filament like conventional electrical bulbs, but contain two electrodes about 0.2 in. (5 mm) apart. A high-voltage pulse is sent to the bulb which arcs across the tips of electrodes producing light.

It creates light from an electrical discharge between two electrodes in a gas-filled arc tube. It produces twice the light with less electrical input than conventional halogen bulbs.

The HID lighting system consists of the discharge arc source, igniter, ballast, and headlight assembly. ● **SEE FIGURE 56–19.**

The two electrodes are contained in a tiny quartz capsule filled with xenon gas, mercury, and metal halide salts. HID headlights are also called **xenon headlights.** The lights and support electronics are expensive, but they should last the life of the vehicle unless physically damaged.

HID headlights produce a white light giving the lamp a blue-white color. The color of light is expressed in temperature using the Kelvin scale. **Kelvin (K)** temperature is the Celsius temperature plus 273 degrees. Typical color temperatures include:

- Daylight: 5,400°K
- HID: 4,100°K
- Halogen: 3,200°K
- Incandescent (tungsten): 2,800°K

● **SEE FIGURE 56–20.**

The HID ballast is powered by 12 volts from the headlight switch on the body control module. The HID headlights operate in three stages or states.

1. Start-up or stroke state
2. Run-up state
3. Steady state

START-UP OR STROKE STATE When the headlight switch is turned to the on position, the ballast may draw up to 20 amperes at 12 volts. The ballast sends multiple high-voltage pulses to the arc tube to start the arc inside the bulb. The voltage provided by the ballast during the start-up state ranges from −600 volts to +600 volts, which is increased by a transformer to about 25,000 volts. The increased voltage is used to create an arc between the electrodes in the bulb.

RUN-UP STATE After the arc is established, the ballast provides a higher than steady state voltage to the arc tube to keep the bulb illuminated. On a cold bulb, this state could last as long as 40 seconds. On a hot bulb, the run-up state may last only 15 seconds. The current requirements during the run-up state are about 360 volts from the ballast and a power level of about 75 watts.

STEADY STATE The steady state phase begins when the power requirement of the bulb drops to 35 watts. The ballast provides a minimum of 55 volts to the bulb during steady state operation.

BI-XENON HEADLIGHTS Some vehicles are equipped with bi-xenon headlights, which use a shutter to block some of the light during low-beam operation and then mechanically move to expose more of the light from the bulb for high-beam operation. Because xenon lights are relatively slow to start working, vehicles equipped with bi-xenon headlights use two halogen lights for the "flash-to-pass" feature.

FAILURE SYMPTOMS The following symptoms indicate bulb failure.

- A light flickers
- Lights go out (caused when the ballast assembly detects repeated bulb restrikes)
- Color changes to a dim pink glow

Bulb failures are often intermittent and difficult to repeat. However, bulb failure is likely if the symptoms get worse over time. Always follow the vehicle manufacturer's recommended testing and service procedures.

DIAGNOSIS AND SERVICE High-intensity discharge headlights will change slightly in color with age. This **color shift** is usually not noticeable unless one headlight arc tube assembly has been replaced due to a collision repair, and then the difference in color may be noticeable. The difference in color will gradually change as the arc tube ages and should not be too noticeable by most customers. If the arc tube assembly is near the end of its life, it may not light immediately if it is turned off and then back on immediately. This test is called a "hot restrike" and if it fails, a replacement arc tube assembly may be needed or there is another fault, such as a poor electrical connection, that should be checked.

WARNING

Always adhere to all warnings because the high-voltage output of the ballast assembly can cause personal injury or death.

LED HEADLIGHTS

Some vehicles, including several Lexus models, use LED headlights either as standard equipment (Lexus LS600h) or optional. ● **SEE FIGURE 56–21.**

Advantages include:

- Long service life
- Reduced electrical power required

Disadvantages include:

- High cost
- Many small LEDs required to create the necessary light output

HEADLIGHT AIMING

According to U.S. federal law, all headlights, regardless of shape, must be able to be aimed using headlight aiming equipment. Older vehicles equipped with sealed beam headlights used a headlight aiming system that attached to the headlight itself. ● **SEE FIGURES 56–22 AND 56–23.** Also see the photo sequence on headlight aiming at the end of the chapter.

FIGURE 56–21 LED headlights usually require multiple units to provide the needed light as seen on this Lexus LS600h.

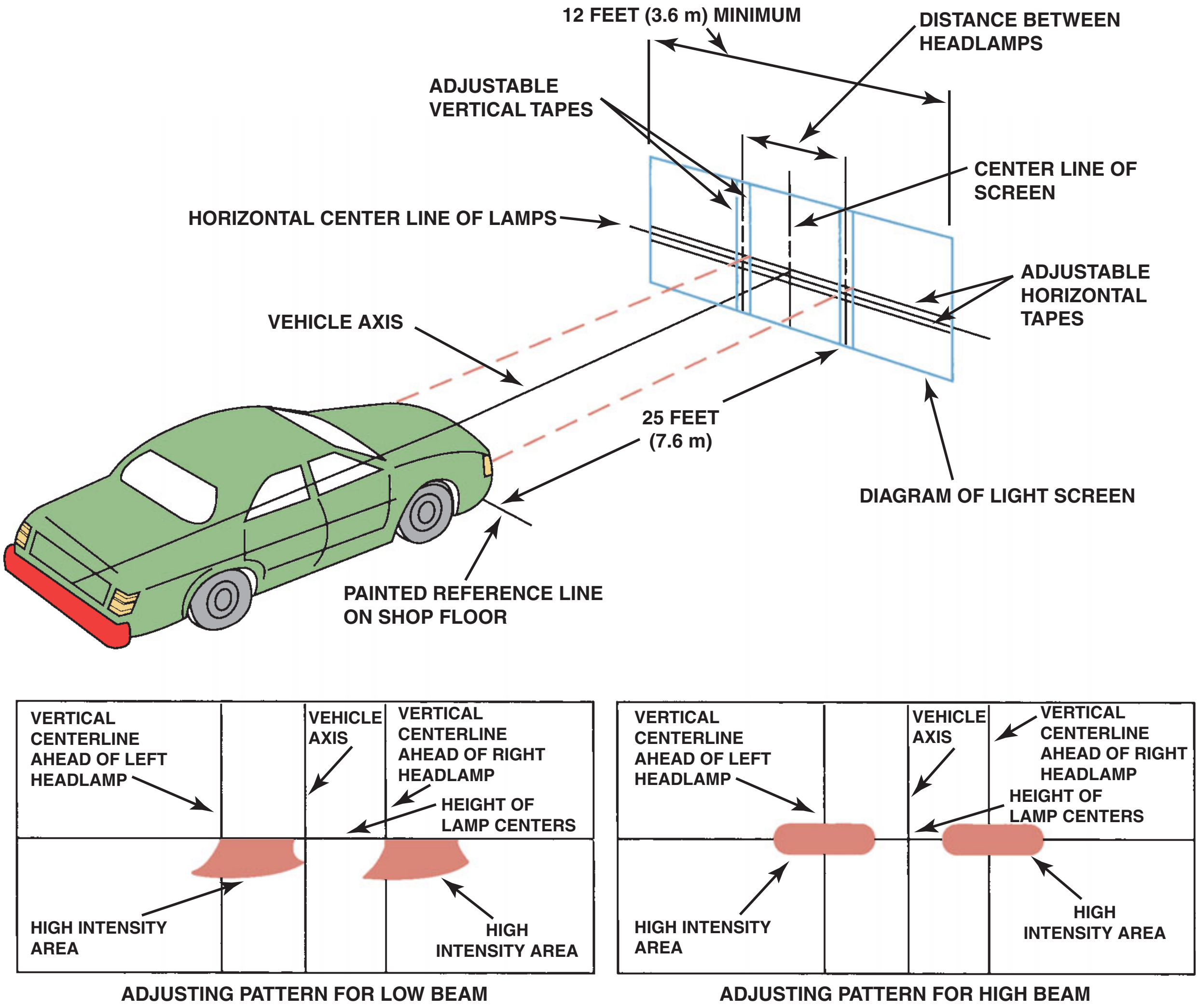

FIGURE 56–22 Typical headlight aiming diagram as found in service information.

FIGURE 56–23 Many composite headlights have a built-in bubble level to make aiming easy and accurate.

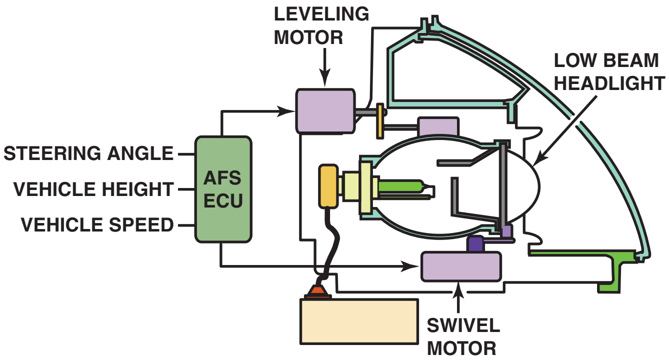

FIGURE 56–25 A typical adaptive front lighting system uses two motors: one for the up and down movement and the other for rotating the low-beam headlight to the left and right.

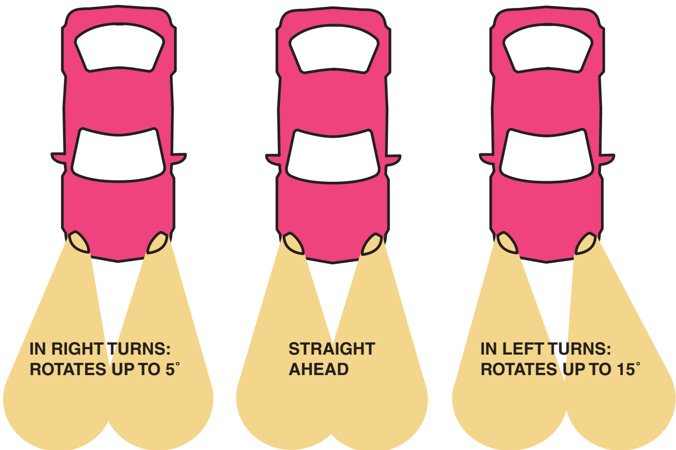

FIGURE 56–24 Adaptive front lighting systems rotate the low-beam headlight in the direction of travel.

FIGURE 56–26 Typical dash-mounted switch that allows the driver to disable the front lighting system.

ADAPTIVE FRONT LIGHTING SYSTEM

PARTS AND OPERATION A system that mechanically moves the headlights to follow the direction of the front wheels is called **adaptive** (or **advanced**) **front light system,** or **AFS.** The AFS provides a wide range of visibility during cornering. The headlights are usually capable of rotating 15 degrees to the left and 5 degrees to the right (some systems rotate 14 degrees and 9 degrees, respectively). Vehicles that use AFS include Lexus, Mercedes, and certain domestic models, usually as an extra cost option. ● **SEE FIGURE 56–24.**

NOTE: These angles are reversed on vehicles sold in countries that drive on the left side of the road, such as Great Britain, Japan, Australia, and New Zealand.

The vehicle has to be moving above a predetermined speed, usually above 20 mph (30 km/h) and the lights stop moving when the speed drops below about 3 mph (5 km/h).

AFS is often used in addition to self-leveling motors so that the headlights remain properly aimed regardless of how the vehicle is loaded. Without self-leveling, headlights would shine higher than normal if the rear of the vehicle is heavily loaded. ● **SEE FIGURE 56–25.**

When a vehicle is equipped with an adaptive front lighting system, the lights are moved by the headlight controller outward, and then inward as well as up and down as a test of the system. This action is quite noticeable to the driver, and is normal operation of the system.

DIAGNOSIS AND SERVICE The first step when diagnosing an AFS fault is to perform the following visual inspection.

- Start by checking that the AFS is switched on. Most AFS headlights are equipped with a switch that allows the driver to turn the system on and off. ● **SEE FIGURE 56–26.**
- Check that the system performs a self-test during start-up.
- Verify that both low-beam and high-beam lights function correctly. The system may be disabled if a fault with one of the headlights is detected.
- Use a scan tool to test for any AFS-related diagnostic trouble codes. Some systems allow the AFS to be checked and operated using a scan tool.

Always follow the recommended testing and service procedures as specified by the vehicle manufacturer in service information.

TECH TIP

Checking a Dome Light Can Be Confusing

If a technician checks a dome light with a test light, both sides of the bulb will "turn on the light" if the bulb is good. This will be true if the system's "ground switched" doors are closed and the bulb is good. This confuses many technicians because they do not realize that the ground will not be sensed unless the door is open.

DAYTIME RUNNING LIGHTS

PURPOSE AND FUNCTION **Daytime running lights (DRLs)** involve operation of the following:

- Front parking lights
- Separate DRL lamps
- Headlights (usually at reduced current and voltage) when the vehicle is running

Canada has required daytime running lights on all new vehicles since 1990. Studies have shown that DRLs have reduced accidents where used.

Daytime running lights primarily use a control module that turns on either the low or high-beam headlights or separate daytime running lights. The lights on some vehicles come on when the engine starts. Other vehicles will turn on the lamps when the engine is running but delay their operation until a signal from the vehicle speed sensor indicates that the vehicle is moving.

To avoid having the lights on during servicing, some systems will turn off the headlights when the parking brake is applied and the ignition switch is cycled off then back on. Others will only light the headlights when the vehicle is in a drive gear. ● **SEE FIGURE 56–27.**

CAUTION: Most factory daytime running lights operate the headlights at reduced intensity. These are *not* designed to be used at night. Normal intensity of the headlights (and operation of the other external lamps) is actuated by turning on the headlights as usual.

DIMMER SWITCHES

The headlight switch controls the power or hot side of the headlight circuit. The current is then sent to the dimmer switch, which allows current to flow to either the high-beam or the low-beam filament of the headlight bulb, as shown in ● **FIGURE 56–28.**

An indicator light illuminates on the dash when the high beams are selected.

The dimmer switch is usually hand operated by a lever on the steering column. Some steering column switches are actually attached to the *outside* of the steering column and are spring loaded. To replace these types of dimmer switches, the steering column needs to be lowered slightly to gain access to the switch itself.

COURTESY LIGHTS

Courtesy light is a generic term primarily used for interior lights, including overhead (dome) and under-the-dash (courtesy) lights. These interior lights are controlled by operating switches located in the doorjambs of the vehicle doors or by a switch on the dash. ● **SEE FIGURE 56–29.**

Many Ford vehicles use the door switches to open and close the power side of the circuit. Many newer vehicles operate the interior lights through the vehicle computer or through an electronic module. Because the exact wiring and operation of these units differ, consult the service information for the exact model of the vehicle being serviced.

ILLUMINATED ENTRY

Some vehicles are equipped with illuminated entry, meaning the interior lights are turned on for a given amount of time when the outside door handle is operated while the doors are locked. Most vehicles equipped with illuminated entry also light the exterior door keyhole. Vehicles equipped with body computers use the input from the key fob remote to "wake up" the power supply for the body computer.

FIBER OPTICS

Fiber optics is the transmission of light through special plastic (polymethyl methacrylate) that keeps the light rays parallel even if the plastic is tied in a knot. These strands of plastic are commonly used in automotive applications as indicators for the driver that certain lights are functioning. For example, some vehicles are equipped with fender-mounted units that light when the lights or turn signals are operating. Plastic fiber-optic strands, which often look like standard electrical wire, transmit the light at the bulb to the indicator on top of the fender so that the driver can determine if a certain light is operating. Fiber-optic strands also can be run like wires to indicate the operation of all lights on the dash or console. Fiber-optic strands are also commonly used to light ashtrays, outside door locks, and other areas where a small amount of light is required. The source of the light can be any normally operating light bulb, which means that one bulb can be used to illuminate many areas. A special bulb clip is normally used to retain the fiber-optic plastic tube near the bulb.

AUTOMATIC DIMMING MIRRORS

PARTS AND OPERATION Automatic dimming mirrors use electrochromic technology to dim the mirror in proportion to the amount of headlight glare from other vehicles at the rear. The electrochromic technology developed by Gentex Corporation uses a gel that changes with light between two pieces of glass. One piece of glass acts as a reflector and the other has a transparent (clear) electrically conductive coating. The inside rearview mirror also has