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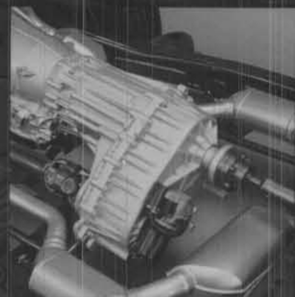
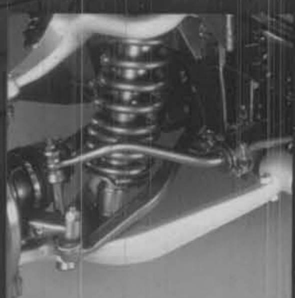
CAR & LIGHT TRUCK SERIES

A6 Electrical/Electronic Systems





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Taking An ASE Certification Test

This study guide will help prepare you to take and pass the ASE test. It contains descriptions of the types of questions used on the test, the task list from which the test questions are derived, a review of the task list subject information, and a practice test containing ASE style questions.

ABOUT ASE

The National Institute for Automotive Service Excellence (ASE) is a non-profit organization founded in 1972 for the purpose of improving the quality of automotive service and repair through the voluntary testing and certification of automotive technicians. Currently, there are over 400,000 professional technicians certified by ASE in over 40 different specialist areas.

ASE certification recognizes your knowledge and experience, and since it is voluntary, taking and passing an ASE certification test also demonstrates to employers and customers your commitment to your profession. It can mean better compensation and increased employment opportunities as well.

ASE not only certifies technician competency, it also promotes the benefits of technician certification to the motoring public. Repair shops that employ at least one ASE technician can display the ASE sign. Establishments where 75 percent of technicians are certified, with at least one technician certified in each area of service offered by the business, are eligible for the ASE Blue Seal of Excellence program. ASE encourages consumers to patronize these shops through media campaigns and car care clinics.

To become ASE certified, you must pass at least one ASE exam and have at least two years of related work experience. Technicians that pass specified tests in a series earn Master Technician status. Your certification is valid for five years, after which time you must retest to retain certification, demonstrating that you have kept up with the changing technology in the field.

THE ASE TEST

An ASE test consists of forty to eighty multiple-choice questions. Test questions are written by a panel of technical experts from vehicle, parts and equipment manufacturers, as well as working technicians and technical education instructors. All questions have been pre-tested and quality checked on a national sample of technicians. The questions are derived from information presented in the task list, which details the knowledge that a technician must have to pass an ASE test and be recognized as competent in that category. The task list is periodically updated by ASE in response to changes in vehicle technology and repair techniques.

There are five types of questions on an ASE test:

- **Direct, or Completion**
- **MOST Likely**
- **Technician A and Technician B**
- **EXCEPT**
- **LEAST Likely**

Direct, or Completion

This type of question is the kind that is most familiar to anyone who has taken a multiple-choice test: you must answer a direct question or complete a statement with the correct answer. There are four choices given as potential answers, but only one is correct. Sometimes the correct answer to one of these questions is clear, however in other cases more than one answer may seem to be correct. In that case, read the question carefully and choose the answer that is most correct. Here is an example of this type of test question:

A compression test shows that one cylinder is too low. A leakage test on that cylinder shows that there is excessive leakage. During the test, air could be heard coming from the tailpipe. Which of the following could be the cause?

A. broken piston rings
B. bad head gasket
C. bad exhaust gasket
D. an exhaust valve not seating

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A6 - ELECTRICAL/ELECTRONIC SYSTEMS

There is only one correct answer to this question, answer D. If an exhaust valve is not seated, air will leak from the combustion chamber by way of the valve out to the tailpipe and make an audible sound. Answer C is wrong because an exhaust gasket has nothing to do with combustion chamber sealing. Answers A and B are wrong because broken rings or a bad head gasket would have air leaking through the oil filler or coolant system.

MOST Likely

This type of question is similar to a direct question but it can be more challenging because all or some of the answers may be nearly correct. However, only one answer is the most correct. For example:

When a cylinder head with an overhead camshaft is discovered to be warped, which of the following is the most correct repair option?
A. replace the head
B. check for cracks, straighten the head, surface the head
C. surface the head, then straighten it
D. straighten the head, surface the head, check for cracks

The most correct answer is B. It makes no sense to perform repairs on a cylinder head that might not be usable. The head should first be checked for warpage and cracks. Therefore, answer B is more correct than answer D. The head could certainly be replaced, but the cost factor may be prohibitive and availability may be limited, so answer B is more correct than answer A. If the top of the head is warped enough to interfere with cam bore alignment and/or restrict free movement of the camshaft, the head must be straightened before it is resurfaced, so answer C is wrong.

Technician A and Technician B

These questions are the kind most commonly associated with the ASE test. With these questions you are asked to choose which technician statement is correct, or whether they both are correct or incorrect. This type of question can be difficult because very often you may find one technician's statement to be clearly correct or incorrect while the other may not be so obvious. Do you choose one technician or both? The key to answering these questions is to carefully examine each technician's statement independently and judge it on its own merit. Here is an example of this type of question:

A vehicle equipped with rack-and-pinion steering is having the front end inspected. Technician A says that the inner tie rod ends should be inspected while in their normal running position. Technician B says that if movement is felt between the tie rod stud and the socket while the tire is moved in and out, the inner tie rod should be replaced. Who is correct?
A. Technician A
B. Technician B
C. Both A and B
D. Neither A or B

The correct answer is C; both technicians' statements are correct. Technician B is clearly correct because any play felt between the tie-rod stud and the socket while the tire is moved in and out indicates that the assembly is worn and requires replacement. However, Technician A is also correct because inner tie- rods should be inspected while in their normal running position, to prevent binding that may occur when the suspension is allowed to hang free.

EXCEPT

This kind of question is sometimes called a negative question because you are asked to give the incorrect answer. All of the possible answers given are correct EXCEPT one. In effect, the correct answer to the question is the one that is wrong. The word EXCEPT is always capitalized in these questions. For example:

All of the following are true of torsion bars **EXCEPT**:
A. They can be mounted longitudinally or transversely.
B. They serve the same function as coil springs.
C. They are interchangeable from side-to-side
D. They can be used to adjust vehicle ride height.

The correct answer is C. Torsion bars are not normally interchangeable from side-to-side. This is because the direction of the twisting or torsion is not the same on the left and right sides. All of the other answers contain true statements regarding torsion bars.

LEAST Likely

This type of question is similar to EXCEPT in that once again you are asked to give the answer that is wrong. For example:

Blue-gray smoke comes from the exhaust of a vehicle during deceleration. Of the following, which cause is **LEAST** likely?
A. worn valve guides
B. broken valve seals
C. worn piston rings
D. clogged oil return passages

The correct answer is C. Worn piston rings will usually make an engine smoke worse under acceleration. All of the other causes can allow oil to be drawn through the valve guides under the high intake vacuum that occurs during deceleration.

PREPARING FOR THE ASE TEST

Begin preparing for the test by reading the task list. The task list describes the actual work performed by a technician in a particular specialty area. Each question on an ASE test is derived from a task or set of tasks in the list. Familiarizing yourself with the task list will help you to concentrate on the areas where you need to study.

The text section of this study guide contains information pertaining to each of the tasks in the task list. Reviewing this information will prepare you to take the practice test.

Take the practice test and compare your answers with the correct answer explanations. If you get an answer wrong and don't understand why, go back and read the information pertaining to that question in the text.

After reviewing the tasks and the subject information and taking the practice test, you should be prepared to take the ASE test or be aware of areas where further study is needed. When studying with this study guide or any other source of information, use the following guidelines to make sure the time spent is as productive as possible:

- Concentrate on the subject areas where you are weakest.
- Arrange your schedule to allow specific times for studying.
- Study in an area where you will not be distracted.
- Don't try to study after a full meal or when you are tired.
- Don't wait until the last minute and try to 'cram' for the test.

REGISTERING FOR ASE COMPUTER-BASED TESTING

Registration for the ASE CBT tests can be done online in myASE or over the phone. While not mandatory, it is recommended that you establish a myASE account on the ASE website (www.ase.com). This can be a big help in managing the ASE certification process, as your test scores and certification expiry dates are all listed there.

Test times are available during two-month windows with a one-month break in between. This means that there is a total of eight months over the period of the calendar year that ASE testing is available.

Testing can be scheduled during the daytime, night, and weekends for maximum flexibility. Also, results are available immediately after test completion. Printed certificates are mailed at the end of the two-month test window. If you fail a test, you will not be allowed to register for the same test until the next two-month test window.

TAKING THE ASE TEST – COMPUTER-BASED TESTING (CBT)

On test day, bring some form of photo identification with you and be sure to arrive at the test center 30 minutes early to give sufficient time to check in. Once you have checked in, the test supervisor will issue you some scratch paper and pencils, as well as a composite vehicle test booklet if you are taking advanced tests. You will then be seated at a computer station and given a short online tutorial on how to complete the ASE CBT tests. You may skip the tutorial if you are already familiar with the CBT process.

The test question format is similar to those found in written ASE tests. Regular certification tests have a time limit of 1 to 2 hours, depending on the test. Recertification tests are 30 to 45 minutes, and the L1 and L2 advanced level tests are capped at 2 hours. The time remaining for your test is displayed on the top left of the test window. You are given a warning when you have 5 minutes left to complete the test.

Read through each question carefully. If you don't know the answer to a question and need to think about it, click on the "Flag" button and move on to the next question. You may also go back to previous questions by pressing the "Previous Question" button. Don't spend too much time on any one question. After you have worked through to the end of the test, check your remaining time and go back and answer the questions you flagged. Very often, information found in questions later in the test can help answer some of the ones with which you had difficulty.

Some questions may have more content than what can fit on one screen. If this is the case, there will be a "More" button displayed where the "Next Question" button would ordinarily appear. A scrolling bar will also appear, showing what part of the question you are currently viewing. Once you have viewed all of the related content for the question, the "Next Question" button will reappear.

You can change answers on any of the questions before submitting the test for scoring. At the end of the examination, you will be shown a table with all of the question numbers. This table will show which questions are answered, which are unanswered, and which have been flagged for review. You will be given the option to review all the questions, review the flagged questions, or review the unanswered questions from this page. This table can be reviewed at any time during the exam by clicking the "Review" button.

If you are running out of time and still have unanswered test questions, guess the answers if necessary to make sure every question is answered. Do not leave any answers blank. It is to your advantage to answer every question, because your test score is based on the number of correct answers. A guessed answer could be correct, but a blank answer can never be.

Once you are satisfied that all of the questions are complete and ready for scoring, click the "Submit for Scoring" button. If you are scheduled for more than one test, the next test will begin immediately. If you are done with testing, you will be asked to complete a short survey regarding the CBT test experience. As you are leaving the test center, your supervisor will give you a copy of your test results. Your scores will also be available on myASE within two business days.

To learn exactly where and when the ASE Certification Tests are available in your area, as well as the costs involved in becoming ASE certified, please contact ASE directly for registration information.

The National Institute for Automotive Service Excellence
101 Blue Seal Drive, S.E. Suite 101
Leesburg, VA 20175
1-800-390-6789
http://www.ase.com

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A6 — Electrical/Electronic Systems

Electrical/Electronic Systems

TEST SPECIFICATIONS FOR ELECTRICAL/ELECTRONIC SYSTEMS (TEST A6)

	NUMBER OF QUESTIONS CONTENT AREA IN ASE TEST	PERCENTAGE OF COVERAGE IN ASE TEST
A. General Electrical/Electronic System Diagnosis	13	26%
B. Battery and Starting System Diagnosis and Repair	9	18%
C. Charging System Diagnosis and Repair	5	10%
D. Lighting Systems Diagnosis and Repair	6	12%
E. Instrument Cluster and Driver Information Systems Diagnosis and Repair	6	12%
F. Body Electrical Systems Diagnosis and Repair	11	22%
Total	**50**	**100%**

There could be up to ten additional questions that are included for statistical research purposes only. Your answers to these questions will not affect your test score, but since you do not know which ones they are, you should answer all questions in the test. The 5-year Recertification Test will cover the same content areas as those listed above. However, the number of questions in each content area of the Recertification Test will be reduced by about one-half.

The following pages list the tasks covered in each content area. These task descriptions offer detailed information to technicians preparing for the test, and to persons who may be instructing Electrical/Electronic Systems technicians. The task list may also serve as a guideline for question writers, reviewers and test assemblers. It should be noted that the number of questions in each content area may not equal the number of tasks listed. Some of the tasks are complex and broad in scope, and may be covered by several questions. Other tasks are simple and narrow in scope; one question may cover several tasks. The main purpose for listing the tasks is to describe accurately what is done on the job, not to make each task correspond to a particular test question.

ELECTRICAL/ELECTRONIC SYSTEMS TEST TASK LIST

A. GENERAL ELECTRICAL/ ELECTRONIC SYSTEM DIAGNOSIS

(13 questions)

Task 1 – Check voltages and voltage drops in electrical/electronic circuits; interpret readings and determine needed repairs.

Task 2 – Check current flow in electrical/electronic circuits and components; interpret readings and determine needed repairs.

Task 3 – Check continuity and resistances in electrical/electronic circuits and components; interpret readings and determine needed repairs.

Task 4 – Check electronic circuit waveforms; interpret readings and determine needed repairs.

Task 5 – Use scan-tool data and/or diagnostic trouble codes (DTCs) to diagnose electronic systems; interpret readings and determine necessary action.

Task 6 – Find shorts, grounds, opens, and resistance problems in electrical/ electronic circuits; determine needed repairs.

Task 7 – Measure and diagnose the cause(s) of abnormal key off battery drain (parasitic draw); determine needed repairs.

Task 8 – Inspect, test, and replace fusible links, circuit breakers, fuses, diodes, and current limiting devices.

Task 9 – Read and interpret electrical schematic diagrams and symbols.

Task 10 – Diagnose failures in the data bus communications network; determine needed repairs.

Task 11 – Remove and replace control modules; program as needed.

B. Battery and Starting System Diagnosis and Repair

(9 questions)

Task 1 – Perform battery state of charge test; determine needed service.

Task 2 – Perform battery tests (load and capacitance) determine needed service.

Task 3 – Maintain or restore electronic memory functions.

Task 4 – Perform slow/fast battery charge in accordance with manu-

facturer's recommendations.
Task 5 – Inspect, clean, and repair or replace battery(s), battery cables, connectors, clamps hold downs, and vent tubes.
Task 6 – Jump start a vehicle using jumper cables, and a booster battery or auxiliary power supply.
Task 7 – Perform starter current draw test; determine needed repairs.
Task 8 – Perform starter circuit voltage drop tests; determine needed repairs.
Task 9 – Inspect, test, and repair or replace starter, relays, solenoids, modules, switches, connectors, and wires of starter circuits.
Task 10 – Differentiate between electrical and engine mechanical problems that cause a slow crank, no crank, extended cranking, or a cranking noise condition.

C. Charging System Diagnosis and Repair
(5 questions)
Task 1 – Diagnose charging system problems that cause, a no charge, a low charge, or an overcharge condition; determine needed repairs.
Task 2 – Inspect and reinstall/ replace pulleys, tensioners and drive belts; adjust belts and check alignment.
Task 3 – Perform charging system voltage output test; determine needed repairs.
Task 4 – Perform charging system current output test; determine needed repairs.
Task 5 – Inspect and test generator (alternator) control components including computers/regulators; determine needed repairs.
Task 6 – Perform charging circuit voltage drop tests; determine needed repairs.
Task 7 – Inspect and repair, or replace connectors and wires of charging system circuits.
Task 8 – Remove, inspect, and replace generator (alternator).

D. Lighting System Diagnosis and Repair
(6 questions)
Task 1 – Diagnose the cause of brighter than normal, intermittent, dim, continuous or no operation of exterior lighting; determine needed repairs.
Task 2 – Inspect, replace, and aim/ level headlights/bulbs including high-intensity discharge systems (HID), and auxiliary lights (fog lights/driving lights).
Task 3 – Inspect, test, and repair or replace switches, relays, bulbs, LEDs, sockets, connectors, wires, and controllers of exterior lighting.
Task 4 – Diagnose the cause of turn signal and/or hazard light, system malfunctions; determine needed repairs.
Task 5 – Inspect, test, and repair or replace switches, flasher units, bulbs, sockets, connectors, wires, and controllers of turn signal and hazard light circuits.
Task 6 – Diagnose the cause of intermittent, dim, continuous or no operation of interior lighting (courtesy, dome, map, vanity, cargo, trunk, and hood); determine needed repairs.
Task 7 – Inspect, test, and repair or replace switches, relays, bulbs, sockets, connectors, wires, and controllers of interior lighting circuits (courtesy, dome, map, vanity, cargo, trunk, and hood).
Task 8 – Inspect, test and repair or replace trailer wiring harness, relays, connectors, and controllers.

E. Instrument Cluster and Driver Information Systems Diagnosis and Repair
(6 questions)
Task 1 – Diagnose the cause of intermittent, dim, no lights, continuous operation, or no brightness control of instrument lighting circuits; determine needed repairs.
Task 2 – Inspect, test, and repair or replace switches, relays, bulbs, LEDs, sockets, connectors, wires, and controllers of instrument lighting circuits.
Task 3 – Diagnose the cause of high, low, intermittent, or no readings on electronic instrument cluster gauges; determine needed repairs.
Task 4 – Diagnose the cause of constant, intermittent, or no operation of warning lights, indicator lights, audible warning devices, and other driver information systems; determine needed repairs.
Task 5 – Inspect, test, and repair or replace bulbs, sockets, connectors, switches, relays, sensors, timers, wires, gauges, sending units, sensors, electronic components, and controllers of electronic instrument clusters and driver information system circuits.

F. Body Electrical Systems Diagnosis and Repair
(11 questions)
Task 1 – Diagnose operation of comfort and convenience accessories and related circuits (such as: power window, power seats, pedal height, power locks, truck locks, remote start, moon roof, sun roof, sun shade, remote keyless entry, voice activation, steering wheel controls, backup camera, park assist, and auto dimming headlamps); determine needed repairs.
Task 2 – Inspect, test, and repair or replace components, connectors and wiring of comfort and convenience accessories.
Task 3 – Diagnose operation of heated and cooled accessories and related circuits (such as: heated/cooled seats, heated steering wheel, heated mirror, heated glass, and heated/cooled cup holders); determine needed repairs.
Task 4 – Inspect, test, and repair or replace components, connectors and wiring of heated and cooled accessories.
Task 5 – Diagnose operation of security/anti-theft systems and related circuits (such as: theft deterrent, door locks, remote keyless entry, remote start, and starter/fuel disable); determine needed

repairs.

Task 6 – Inspect, test, and repair or replace components, connectors and wiring of security/anti-theft systems.

Task 7 – Diagnose operation of entertainment and related circuits (such as: radio, DVD, remote CD changer, navigation, amplifiers, speakers, antennas, and voice activated accessories); determine needed repairs.

Task 8 – Inspect, test, repair and/or replace components, connectors and wiring of entertainment systems.

Task 9 – Diagnose operation of safety systems and related circuits (such as: airbags, seat belt pretensioners, occupancy classification, wipers, washers, collision avoidance, passive speed control, heads-up display, park assist, and back up camera); determine needed repairs.

Task 10 – Inspect, test, and repair or replace components, connectors and wiring of safety systems.

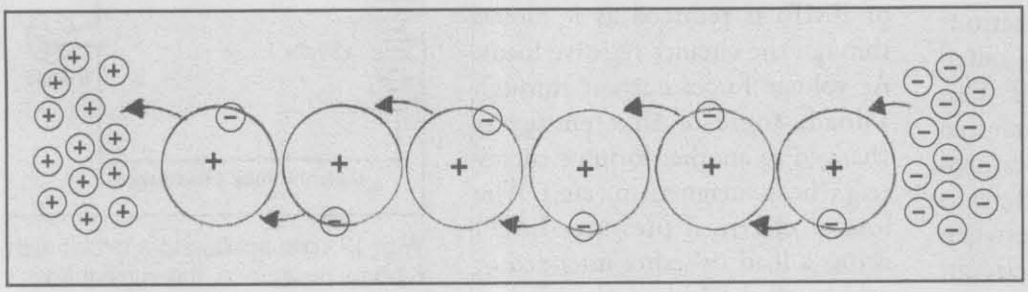
This Task List details all of the related subject matter you are expected to know in order to sit for this ASE Certification Test. Your own years of experience as a technician in the professional automotive service repair trade also should provide you with added background.

Finally, a conscientious review of the self-study material provided in this Training for ASE Certification unit also should help you to be adequately prepared to take this test.

General Electrical/Electronic System Diagnosis

ELECTRICITY BASICS

Before we look at each of the tasks ASE's panel of A6 automotive electrical and electronics subject matter experts have determined you need to know, let's review the properties of voltage, amperage and resistance in automobile circuits. Only then will you be able to troubleshoot and diagnose electrical circuit and component problems.



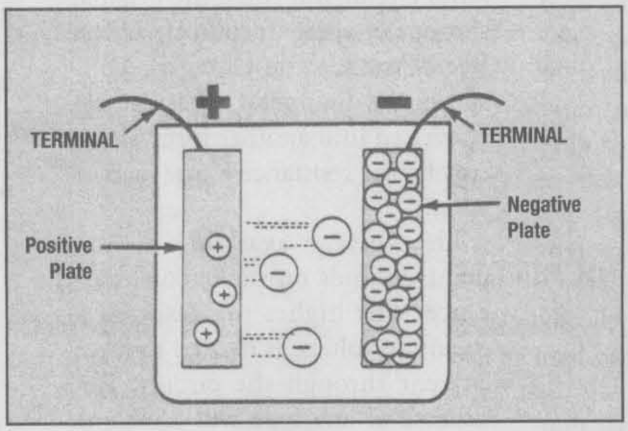
Electron flow in a conductor.

REVIEW OF ELECTRICITY BASICS

You may recall that everything is made of atoms, which in turn are composed of an equal number of protons, neutrons and electrons. The protons, which have a positive charge, and the neutrons, which have no charge, are contained in the atom's nucleus. The electrons, which have a negative charge, orbit around the nucleus.

The outermost electron orbit of an atom is called the valence ring. When discussing electricity, we are only concerned with the electrons in the valence ring.

Atoms will always try to be balanced, which means that they will attempt to have the same number of electrons as there are protons in the nucleus. If an atom is missing electrons from its valance ring, it will try to gain them from nearby atoms. Conversely, if an atom has an excess of electrons in its valance ring, it will try to pass them on to nearby atoms. Electricity is the movement of electrons from atom to atom in a substance called a conductor.

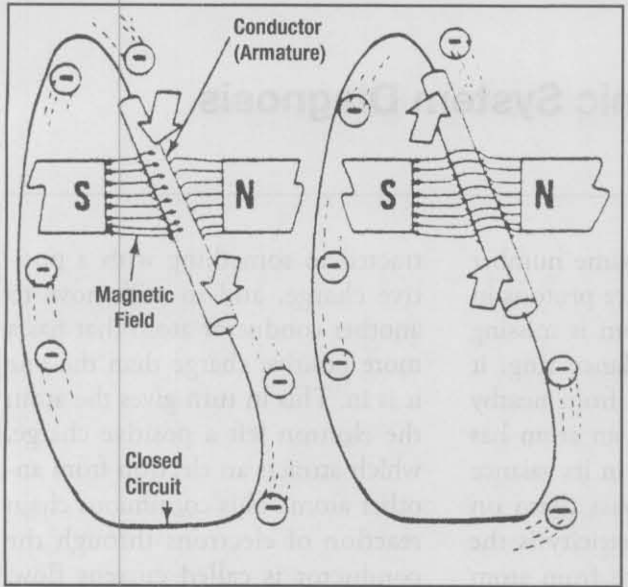


A basic battery. *(Courtesy: Ford Motor Co.)*

Substances that are good conductors shed or attract electrons easily, while substances that are good insulators do not. Copper is an example of a good conductor. The negatively charged electron in a conductor atom is attracted to something with a positive charge, and so will move to another conductor atom that has a more positive charge than the one it is in. This in turn gives the atom the electron left a positive charge, which attracts an electron from another atom. This continuous chain reaction of electrons through the conductor is called current flow. One amp is the measurement of roughly 6.3 X 1018 (billion x billion) electrons passing one point in one second.

For current to flow, there must be a power source that provides a positive charge to attract electrons and a supply of free electrons. The two major power sources in an automobile are the battery and the alternator. The battery has positive and negative terminals. The chemical reaction that takes place in the battery causes a lack of electrons at the positive terminal and an excess of electrons at the negative terminal. This imbalance causes electrons to flow through a conductor when connected to the battery terminals.

The alternator produces electricity to recharge the battery and to provide power to the vehicle's electrical system once the vehicle is running. The alternator generates current by moving a conductor through a magnetic field. This is the principle of electromag-



Induction. *(Courtesy: Ford Motor Co.)*

netic induction.

The force that causes electrons to flow in a conductor is called electro-motive force, or EMF. This force Is more commonly referred to as "voltage", which is measured in Volts. Voltage is the difference in electrical pressure between two different points in a circuit; in a 12-volt electrical system, the forceor pressure measured between the two battery posts is considered as being "12 volts". Voltage potential is the amount of voltage or electrical pressure at a given point in a circuit with respect to another point. For example, if the voltage potential at one post (ground) of a 12-volt battery is zero, the potential at the other post (positive) of a fully charged battery is typically 12.6 volts as compared to the battery ground post.

Where voltage is the force that causes electrons (amperage, or current)) to flow, resistance to the flow of electrons is measured in ohms. Thus, resistance opposes current flow. The amount of resistance varies according to the materials, the temperature, and other factors. A certain amount of resistance is designed into an electrical circuit in the form of a load (such as a motor, lamp, etc.) to safely limit the amount of current flow In a circuit. There is also some resistance from wiring and switches. However, unwanted resistance can also occur in the form of damaged wiring and corroded connectors.

Each component in a circuit has some resistance value, and the voltage potential (electrical pressure, or EMF) is reduced as it moves through the circuit's resistive loads. As voltage forces current through a load, some of that energy is changed to another form of energy (e.g., heat, magnetism, etc.). The loss of electrical pressure (EMF) across a load (whether intended or not) is called a "voltage drop."

The sum of all voltage drops in a series circuit will equal the original amount of applied (source) voltage (see below Electric Circuits). Voltage never disappears. It is merely converted into another form of energy by the resistance of the load or wires.

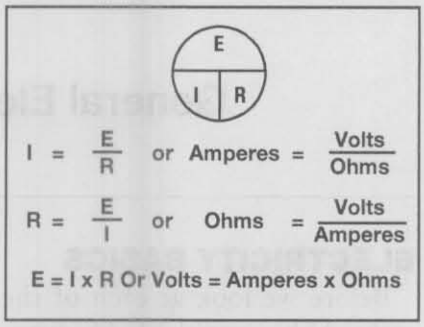
The voltage available at any point depends on the circuit resistance. The higher the resistance, the more voltage is needed to force current through the circuit. Resistance of any type will use some voltage potential (drop voltage), so voltage (electrical pressure) is lost (dropped) across any type of resistance.

Ohm's Law

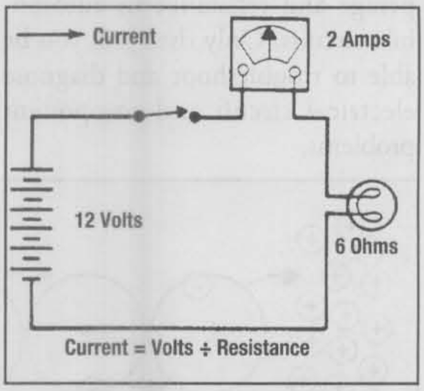
In the early 19th century, a German physicist named George Ohm first described the relationship between voltage, current and resistance, which would become known as Ohm's law. Ohm's law states that the current in a circuit is directly proportional to the applied voltage and inversely proportional to the resistance in a circuit. In other words:

- When voltage in a circuit goes up, current flow goes up; when voltage goes down, current flow goes down, providing the resistance stays the same.
- When the resistance in a circuit goes up, current goes down, providing the voltage stays the same.
- When resistance in a circuit goes down, the current will go up, providing the voltage stays the same.

The mathematical formula for Ohm's law is E = I x R, where E



In electrical measurements, use Ohm's law as a foundation. If two known values exist, use the formula to calculate the third.



With 12 volts applied to a circuit with 6 ohms resistance, the current flow is 2 amps. *(Courtesy: Ford Motor Co.)*

refers to voltage (think EMF), I to current (think Intensity of electrons), and R to resistance. Ohm's formula (Law) provides the unknown voltage if you know current and resistance. For example, it says that if 12 volts are applied to a circuit with a resistance of 1 ohm, the current flow will be 12 amps. That is 12 (volts) = 12 (amps) x 1 (ohm).

A circuit with 2 ohms resistance would have a flow of 6 amps at 12 volts, because 12 (volts) = 6 (amps) x 2 ohms.

To find current flow when you know voltage and resistance, use the formula this way: I = E/R. To find the resistance of the circuit when volts and amps are known, use R = E/I.

Be sure you practice working with Ohm's Law as shown in the circular chart provided. Cover the unknown property (E, I or R) with your finger to see the required formula needed to solve for it.

Direct Current vs Alternating Current

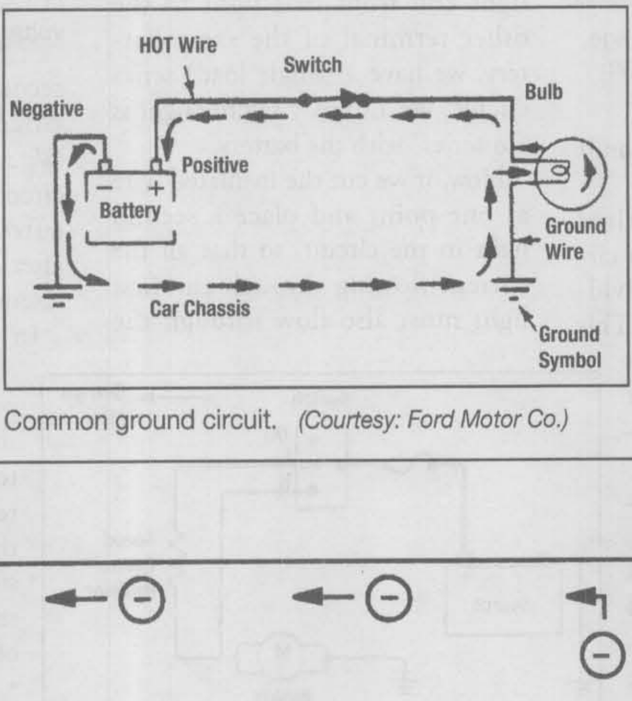
Direct current (DC) travels in one direction only; in our automotive examples, from positive to negative. Alternating current (AC) reverses direction at specified time intervals, measured in cycles per second, or more commonly Hertz. AC voltage can be stepped up or down, such as for ignition purposes; DC cannot be stepped up or down.

The A6 exam does not get into AC, but learning more about AC would be helpful if you want to understand inductors, transformers, inverters, etc., or the basics of hybrid-electric vehicle power trains.

Electric Circuits

An electric circuit must be complete before current will flow. For a circuit to be considered complete, or to provide a clear path for current flow, it must have the following four components:

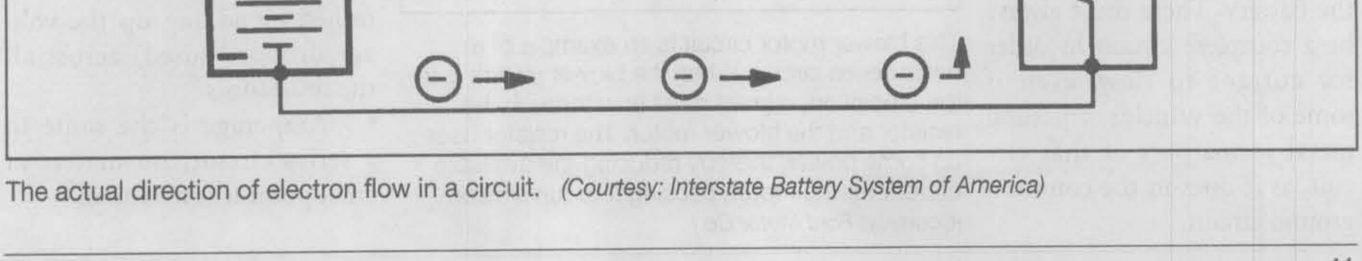
- power source
- wiring
- load(s)
- control device(s).



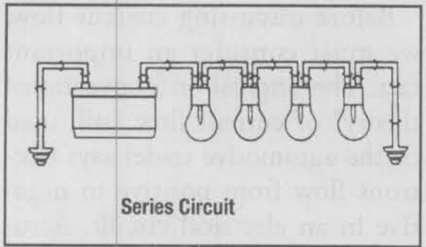
Common ground circuit. *(Courtesy: Ford Motor Co.)*

Before discussing current flow, we must consider an important fact. The original or "conventional theory" of current flow (still used In the automotive trade) says electrons flow from positive to negative in an electrical circuit. Actually, however, we now know that electrons flow from negative to positive. Remember, electrons have a negative charge, and these negative charges seek the opposite charge—the positive terminal of the battery—since positive charges have too few electrons. As an automotive technician, it usually doesn't matter which way you think of it, as long as you understand the concept of current voltage causing flow, and how resistance blocks the flow of electrons.

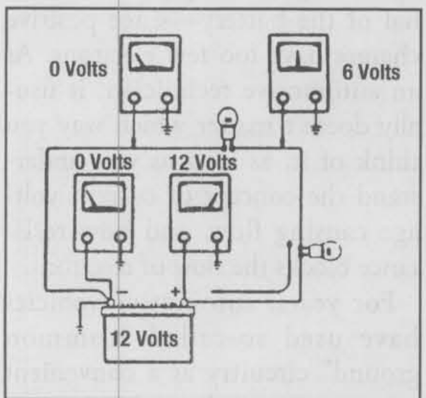
For years, automotive vehicles have used so-called "common ground" circuitry as a convenient way to reduce the amount of wiring needed in the automobile, although the amount of wiring in today's vehicles has grown considerably over time (more on this later). Since the 50's, most vehicles have the negative battery post connected to (a common) "ground". The electrical ground path is normally routed via the engine



The actual direction of electron flow in a circuit. *(Courtesy: Interstate Battery System of America)*



Series circuits provide only one path for current to flow. If the circuit breaks—for example, if one bulb burns out—current ceases to flow through the entire circuit. All the remaining bulbs go out as well.



In 12-volt series circuits, the voltage drop in the circuit must be the sum of the voltage drop at each light.

block, the metal vehicle body, and/ or the metal vehicle frame.

The other (positive) terminal of the battery is connected to circuits with loads such as individual lights, motors, relays, etc. This situation requires two ingredients: first, that we have current carried in insulated wires running from the battery to the positive side of various electrical components of the vehicle; and second, metal (which does not have to be insulated) and wires running from the negative side of components back through the ground path to the battery. There must always be a complete circuit in order for current to flow, even if some of the vehicle's structural metal forms part of that circuit, as it does in the common ground circuit.

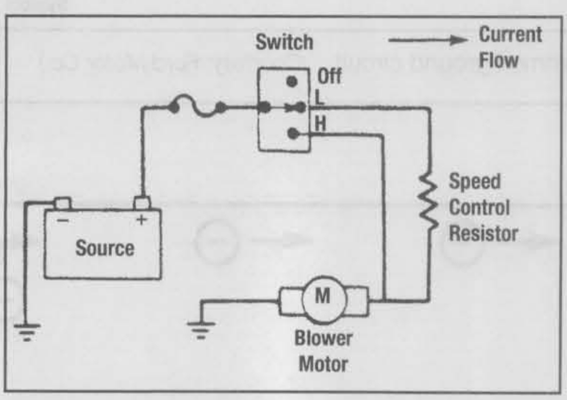
Often you may find a ground wire on various components. These components are usually remotely located from a metal portion of the vehicle. This is especially true if the body or body parts to which they are mounted are made of plastic.

The Series Circuit

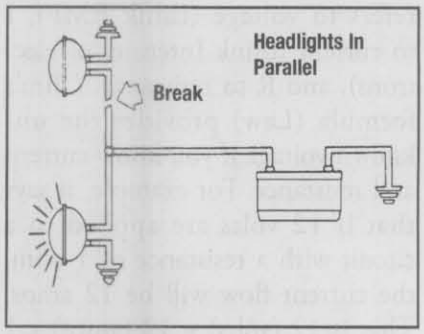
Electrical circuits are wired in series, in parallel or as series-parallel.

To picture a series circuit, think of anything that is lined up one after the other, like a line of people holding hands. The components of a series circuit are connected in this manner. Series circuits provide only one path for current flow. If the circuit breaks, for instance, if one bulb burns out, current ceases to flow through the entire circuit. All the remaining bulbs go out as well. If we run an insulated wire from a battery terminal to a single light and from that light to the other terminal of the same battery, we have a (single load) series circuit. We also may say the light is "in series" with the battery.

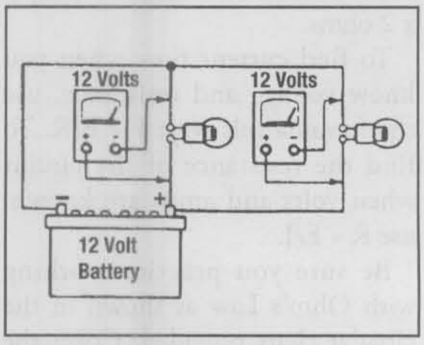
Now, if we cut the insulated wire at one point and place a second light in the circuit, so that all the current flowing through the first light must also flow through the



This blower motor circuit is an example of a basic series circuit. When the blower switch is in the L position, current must flow through the resistor and the blower motor. The resistor uses up some power, thereby reducing the available current for the motor, causing it to run slower. *(Courtesy: Ford Motor Co.)*



Parallel circuits allow several paths for current flow. If a break occurs in one circuit, flow continues in the intact circuit.

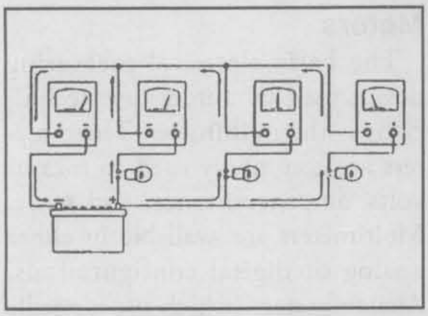


In 12-volt parallel circuits, the voltage drop at each light is 12 volts.

second light, we have two lights wired in series with the battery. We may add as many lights as the circuit will operate. As long as the current flows through one load after another, we continue to have a series circuit.

In a series circuit, the value of the current is the same at all points of the circuit; the resistance of the circuit is equal to the sum of the individual resistances; and voltage across the total circuit is equal to the sum of the voltages across the separate resistances. The laws of series circuits state that:

- Voltage across the entire series circuit can be determined by adding up the voltage dropped (used) across all the resistances.
- Amperage is the same in a series circuit, no matter at what point it is measured.



Typical amp draw in a 12-volt parallel circuit. The sum of all the lights' amp draws will add up to the total circuit amp draw.

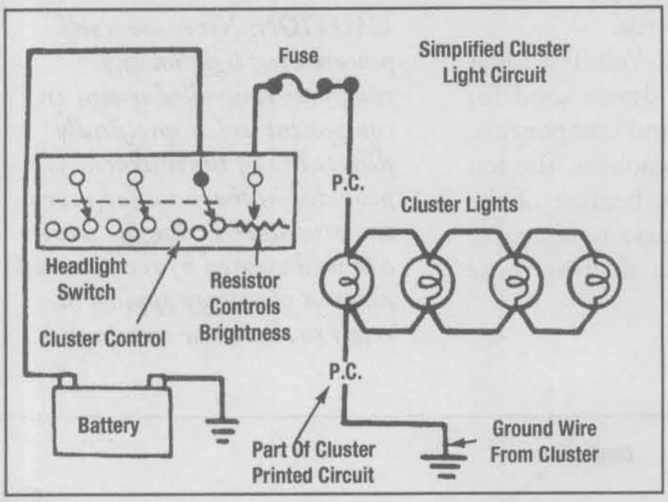
- If you want to know the total resistance in a series circuit, add up the individual resistances.

Parallel Circuit

Now, if we take the same series circuit and remove all lights but one from it, and reconnect the wires, we have a single bulb in series with the battery. Next, wire in a second light, connecting the first wire to the battery's positive terminal and the other wire to its negative terminal. You now have two lights, but they are connected in parallel. Both lights should be fully illuminated. But unlike a series-wired circuit, if one light burns out and opens its circuit, the other will remain lit. Most all circuits in the automobile are wired in parallel.

The laws of parallel circuits state:

- Voltage (dropped) across each parallel circuit is the same as the source voltage supplied to each of the individual branches.
- Total current in a parallel circuit is the sum of the branch currents.
- The reciprocal of the total resistance of the circuit is equal to the sum of the reciprocal of the branch resistances. In a parallel circuit, the resistance of the entire circuit is less than the resistance of the smallest branch of the circuit.



This instrument cluster light circuit is an example of a series-parallel circuit. The four cluster lights are connected in parallel, within the cluster printed circuit. The variable resistor, which is part of the headlight switch, is in series with the system of lights. *(Courtesy: Ford Motor Co.)*

For example: Consider a two-branch parallel circuit attached to a 12-volt battery. The resistance in one branch is 2 ohms, while the resistance in the other branch is 4 ohms. Where the sum of the two parallel resistances is 6 (because 2 + 4 = 6), the product of the resistance is 8 (because 2 x 4 = 8). Now, by dividing the product (8) by the sum (6), we get an answer of 1.33 ohms of total circuit resistance (8 over 6 = 1.33). Note that this is less than the lowest resistance of any single branch.

Series-Parallel Circuit

A third circuit has part of its loads wired in series, and part of them in parallel. This is called a series-parallel circuit. A series-parallel circuit is composed of the following basic elements:

- a power source and its connecting wiring
- two or more loads joined in series and in parallel
- at least one control device (switch, etc.).

An example of a series-parallel circuit in the automobile is the dash-light dimming circuit used in older automobiles (before the use of electronic dimmers).

To find the total effective resistance of a series-parallel circuit, solve for total resistance in the series section, then solve for total resistance in the parallel section. Add the two together for the total effective circuit resistance. Once we know the total effective resistance (R) and the system voltage (E), apply Ohm's Law to find total current flow through the entire series-parallel circuit.

At this point, relax. The A6 exam will not go deep into Ohm's Law, or beyond 12 DC circuits. But, at this point, you should at least understand the properties of series and parallel DC circuits.

ELECTRICAL SYSTEM TESTING AND DIAGNOSIS

Task A1: Check voltages and voltage drops in electrical/electronic circuits; interpret readings and determine needed repairs.

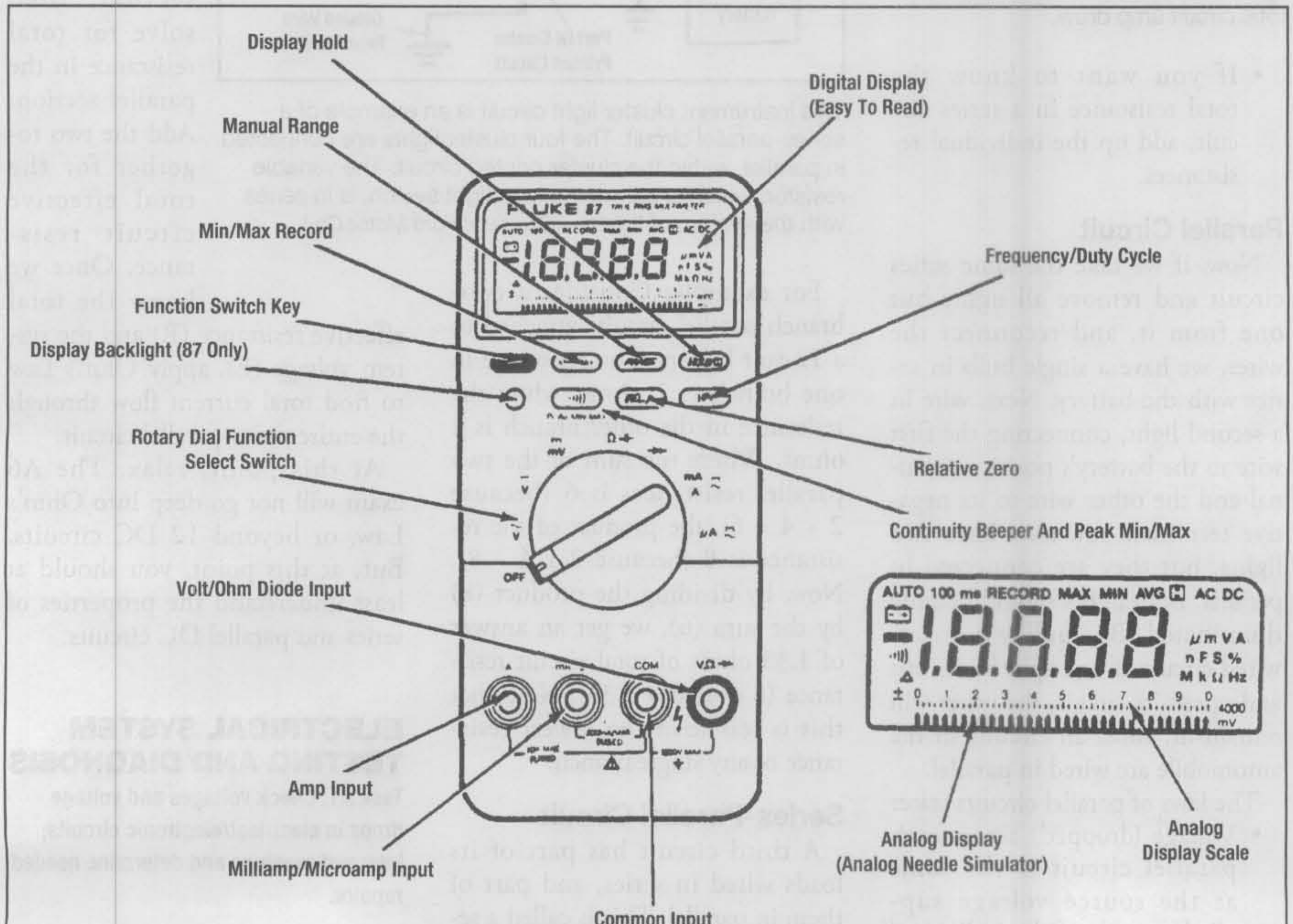
Today's cars contain a network of 20 or more computers which monitor and control everything from lighting to the engine and powertrain. So-called info-tainment systems are now commonplace, as are anti-roll and accident avoidance systems which adjust steering and brake the car with the use of front and rear vehicle radar. Electronic systems monitor tire pressures, and braking and anti-slip system help control vehicle intertia.

For years, the 12-Volt Test Light was the standard device used for checking circuits and components. With today's automobiles, the test light is rarely used because of the damage it can cause to sensitive electronic circuits such as those mentioned above.

CAUTION: Never use a self-powered test light on any computer-controlled system or component unless specifically directed to by the instructions provided in the manufacturer's test procedure(s). Engine sensors can be destroyed by even a small amount of voltage applied directly to the sensor terminals.

Meters

The basic electrical measuring device used by automotive technicians is the multimeter. These meters are commonly used to measur volts, amps, resistance, and more. Multimeters are available in either analog or digital configurations. Analog meters (which use a needle to read measurements on an analog scale) are sensitive to polarity,



ROTARY DIAL SELECT SWITCH FUNCTION SYMBOLS

Ṽ = Volts AC	⊣⊢ = Capacitance In Microfarads
V̄ = Volts DC	mA = Milliamps DC
mV = Millivolts DC	A = Amps DC
·))) = Beeper	μA = Microamps
Ω = Ohms (Resistance)	~ = Same As Above 3, But AC

Typical Digital Multimeter. *(Courtesy: GM Corp.)*

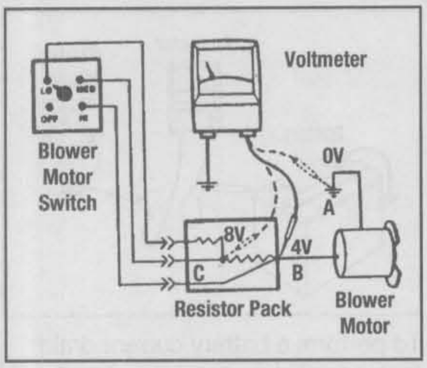
which means that care has to be taken to connect the red or positive lead to a part of the circuit that carries voltage from the battery and alternator to the accessory or load, and the ground or black lead to the ground side of the component. Also, because of their low internal resistance, analog meters cannot be used to test solid-state circuits, such as computers and electronic ignition control modules. Thus, like the test light, analog multimeters are rarely used anymore by automotive technicians.

Digital Multimeters (DMMs) read out via a display of numbers in digital form. They are superior for testing electronic circuits because of their higher accuracy. A DMM will read the voltage no matter which way it is connected. If connected backwards, a (-) sign will precede the voltage readout, but the meter will not be damaged. Also, since some circuits are designed to carry very small amounts of current, a high-impedance (over 10 megohms across the leads) digital meter must always be used when troubleshooting today's solid-state (transistorized/microchip) circuits.

Voltmeter

A voltmeter is used to measure voltage potential at any point in a circuit, or to measure the voltage drop across any part of a circuit. Think of It as a scale comparing two electrical pressures (potential) in a circuit.

A voltmeter should only be connected in parallel with a circuit. The DMM has a very high resistance to current flow, so when the digital meter is connected in parallel across a load, only a very small amount of current will flow through the voltmeter; virtually all



A voltmeter will detect voltage drops across components and wiring.

of the current will flow through the normal circuit current path, and the circuit will work normally.

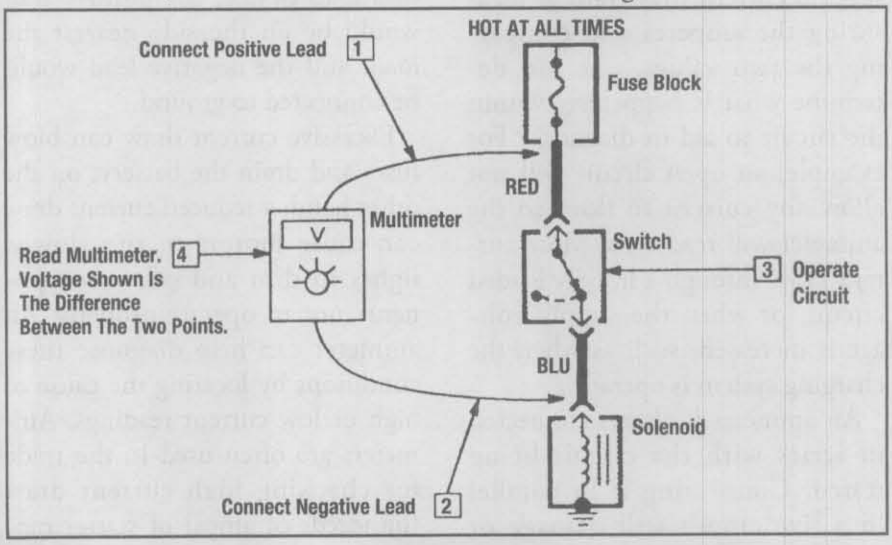
Measuring Available Voltage

Many electrical problems, especially on computer-controlled automotive systems, can be caused by a low state-of-charge (SOC) in the vehicle battery. To measure system voltage, move the voltmeter selector switch to the 20V position and connect the meter negative lead to the negative (–) post of the battery. Then, connect the positive meter lead to the positive (+) post of the battery. A well-charged battery should register 12.6 volts or more on your meter. If the meter reads below 11.5 volts, battery power may not be sufficient to properly operate the electrical system. This test determines voltage available from the battery and should be the first step in any electrical trouble diagnostic procedure. With the engine running at a fast idle, voltage measured across the battery should be higher than 12.6 volts thanks to the charging system. More on this later.

Measuring Voltage Drop

Voltage is used to overcome resistance in an electrical circuit. Normally, the only source or significant resistance is the circuit load, or the component that is doing the "work". Once source voltage has overcome the load's resistance, it "drops" to nearly zero on the opposite side. But there are sources of unwanted resistance caused by corrosion, loose terminal connections, or other similar conditions. These "thieves" can rob the load's current flow by demanding some of the available source voltage be used to overcome them as well. That leaves less at the load, and reduces current flow in the circuit. Have you ever seen a light bulb that wasn't as bright as it should be?

It is this very fact that makes the measurement of voltage drop in a circuit such a valuable testing tool. By measuring voltage drop on both sides of an electrical load, the knowledgeable technician can



Using a voltmeter to perform a voltage drop test.

quickly identify circuit faults and narrow them down to the "thief". And since this is a dynamic test of the circuit (the circuit must be on and operating to perform this test), it is much more precise than measuring circuit voltage and resistance alone.

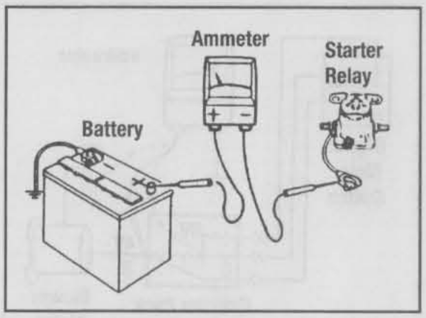
Task A2: Check current flow in electrical/ electronic circuits and components; interpret readings and determine needed repairs.

Ammeter

An ammeter measures the amount of current that is flowing through a circuit in units called amperes or 'amps.' Amps are units of electron flow that indicate how many electrons are flowing through the circuit. Since Ohm's Law states that current flow in a circuit is equal to the circuit voltage divided by the total circuit resistance, increasing voltage also increases the current level (amps). Likewise, any decrease in resistance will increase the amount of amps in a circuit.

At normal operating voltage, most circuits have a characteristic amount of amperage, called 'current draw', which can be measured using an ammeter. By referring to a specific current draw rating, measuring the amperes and comparing the two values, one can determine what is happening within the circuit to aid in diagnosis. For example, an open circuit will not allow any current to flow, so the ammeter will read zero. More current flows through a heavily loaded circuit, or when the supply voltage is increased, such as when the charging system is operating.

An ammeter is always connected in series with the circuit being tested. Connecting it in parallel in a live circuit will damage or even destroy the ammeter if it isn't properly fused. All of the current that normally flows through the circuit must pass through the ammeter. If there is any other path for the current to follow, the ammeter reading will not be accurate. The ammeter itself has very little resistance to current flow and therefore will not affect the circuit, but it will measure current draw only when the circuit is closed and electricity is flowing.



To perform a battery current drain test, connect an ammeter directly into the circuit.

Connect the ammeter's lead polarity as you would with a voltmeter; that Is, with the positive lead connected on the positive side of the circuit, and the negative lead toward the ground side of the circuit. When working on the power side of a load, the positive ammeter lead would be on the supply side. If working on the ground side of a load device, the positive lead would be on the side nearest the load, and the negative lead would be connected to ground.

Excessive current draw can blow fuses and drain the battery; on the other hand, a reduced current draw can cause motors to run slowly, lights to dim and other components not to operate properly. An ammeter can help diagnose these conditions by locating the cause of high or low current readings. Ammeters are often used in the trade for checking high current draw (hundreds of amps) of starter motors, or very small current drain (in milliamperes) for keep alive memory (KAM) circuits.

Measuring Current

Current tests can be performed anywhere in the circuit using an ammeter inserted into the circuit. Make sure the meter is capable of handling the current being measured. Likewise, both low and high current amp testing can be done using an appropriate inductive "amp clamp." The non-intrusive clamp, placed around a live conductor, will sense the magnetism surrounding the live wire and feed the signal to a meter for reading current flow. The clamp is polarity sensitive, so be sure to observe which way current is flowing and place the clamp properly on what is being read or the meter will read backwards. When diagnosing current faults, remember Ohm's Law. Higher than normal current flow indicates a circuit with a lower than normal resistance and one with lower than normal current flow indicates a circuit with higher than normal resistance.

Measuring for parasitic drain and starter motor current draw are covered in more detail in a later section of this study guide.

Caution: The lion's share of readings you take with your multimeter will be for reading voltage. Keep a watchful eye when connecting leads to your meter for taking amperage readings. The cavities (holes) where leads are inserted into the meter for taking amps readings are not the same as those used for taking voltage readings. Failure to switch the leads back to the voltage cavities after taking amperage readings has caused many inexperienced technicians to ruin their multimeters!

Task A3: Check continuity and resistances in electrical/electronic circuits and components; interpret readings and determine needed repairs.

Ohmmeter

The ohmmeter is designed to read resistance—measured in ohms—in a circuit or component. Although there are several different styles of ohmmeters, most have a selector switch that permits the measurement of different ranges of resistance. Usually the selector switch allows the multiplication of the meter reading by either 10, 100, 1000, etc. or 2, 20, 200, 2000, etc. Since all ohmmeters are powered by an internal battery (usually a 9 volt), the ohmmeter can be used as a continuity test in non-live circuits. When the ohmmeter is connected, current from the ohmmeter flows through the circuit or component being tested. Since the ohmmeter's internal resistance and voltage are known values, the amount of current flowing through the meter depends on the resistance of the circuit or component being tested.

Ohmmeter Testing

Self-calibrating digital ohmmeters do not have an adjusting knob, but it's a good idea to check for a zero readout before use by touching the two leads together. An ohmmeter can be used to perform continuity tests for opens or shorts and to read actual resistance in a non-live (dead) circuit. That is, the ohmmeter is used to check the resistance of a component or wire while there is no voltage applied to the circuit.

Current flow from an outside voltage source, such as a vehicle battery, can damage the ohmmeter, so the circuit or component should be isolated from the electrical system before any testing is done.

Since the ohmmeter uses its own voltage source, either lead can be connected to any test point. In using the meter for making continuity checks, do not be concerned with the actual resistance readings. Zero resistance, or any resistance readings, indicates continuity in the circuit. Infinite resistance indicates an open in the circuit. A high resistance reading where there should be none indicates a problem in the circuit.

***Note:** An ohmmeter measures the resistance of a circuit when it is not operating, also known as a "static" test. As long as there is at least one strand of wire present, the ohmmeter will report a complete, or continuous, path. But when the circuit has current running through it, that same path may not be strong enough to handle the load and will fail. That's why voltage drop testing is preferred over static resistance testing.*

Checks for short circuits are made in the same manner as checks for open circuits, but when checking for shorts, the circuit must be isolated from both power and normal ground. Infinite resistance normally indicates no continuity to ground; zero resistance indicates a dead short to ground.

When checking for proper resistance of a component, such as an injector winding to determine if it is open or shorted, compare your reading to the OEM's specifications.

All computer-controlled systems require the use of a digital ohmmeter with at least 10 megohms of impedance (internal meter resistance) when used for testing. Before any test procedures are attempted, be sure the ohmmeter used is compatible with the electrical system, or damage to the onboard electronics could result.

To measure resistance, first isolate the circuit from the vehicle power source by disconnecting the battery cables or the harness connector. Where necessary, also isolate at least one side of the circuit to be checked to avoid reading parallel resistance.

Parallel circuit resistances will always be lower than the resistance of any one branch circuit. Connect the meter leads to both sides of the circuit, wire or component, and read the actual measured ohms on the meter scale. Make sure the selector switch is set to the proper ohm scale for the circuit being tested to avoid misreading the ohmmeter test value.

When checking for proper resistance of a component, such as an injector winding to determine if it is open or shorted, compare your reading to the OEM's specifications.

Backprobing/Piercing

Often, a connecter will need to be "backprobed" (or a wire pierced) in order to check for power or take a reading in a circuit. Backprobing involves carefully sliding a thin stiff wire or long pin into the back side of the connector to make electrical contact. Use caution when inserting pins into the back side of connectors to avoid damaging them or the wire insulation. Be sure to seal any piercing with liquid electrical tape or even clear finger nail polish to prevent moisture from entering the wiring, and causing corrosion to form. NEVER USE SILICONE AS A SEALING AGENT.

***WARNING:** When working in cramped, hard-to-reach areas, it is advisable to have insulated boots over jumper wire terminals and backprobe pins in order to prevent accidental grounding, sparks and possibly fires, especially when testing fuel system components.*

Jumper Wires

Jumper wires are used to bypass sections of a circuit. The simplest jumper wire is a length of multi-strand wire with alligator clips or appropriate spade or pin connectors at each end, depending on what is required for the particular circuit being tested. Always use a fuse protected jumper wire to prevent accidental damage to the vehicle's wiring harness.

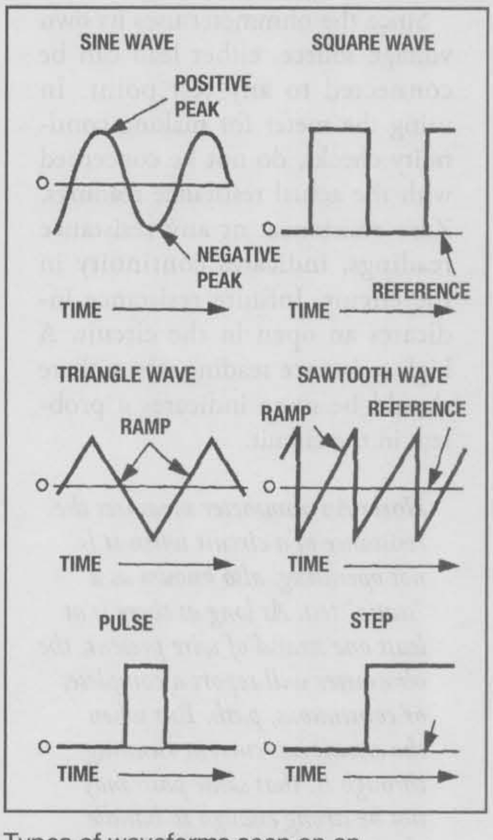
Jumper wires are used primarily to locate open electrical circuits on either the ground (–) side of the circuit or on the power (+) side. If an electrical component fails to operate, connect the jumper wire between the component and a good ground. If the component operates only with the jumper installed, the ground circuit is open. If the ground circuit is good, but the component does not operate, the circuit between the power feed and component is open.

Task A4: Check electronic circuit waveforms; interpret readings and determine needed repairs.

Oscilloscope

An oscilloscope is a valuable tool for electrical system diagnosis. It displays a graph (or waveform) of an electrical signal (normally as voltage), and shows how that electrical signal changes in value over a period of specified time. The time constant on automotive lab-type oscilloscopes can range from microseconds to greater than 1 second. Variations in voltage are shown as a waveform. By comparing a given scope pattern to a known good pattern, the technician can determine whether something is wrong in an electrical circuit or with a component.

An oscilloscope is especially useful for diagnosing intermittent problems that might not be detected with a voltmeter, such as a faulty TPS, MAP or MAF sensor and so forth. An analog voltmeter only displays average values, and a digital voltmeter only samples voltage levels several times each second. But because an oscilloscope displays voltage in real time, it will show any momentary changes in the signal. These momentary changes can be caused by an intermittent open in the circuit or an intermittent short to power or ground.



Types of waveforms seen on an oscilloscope. *(Courtesy: GM Corp.)*

There are two basic types of oscilloscopes: live analog scopes and Digital Storage Oscilloscopes, or DSOs. On live analog scopes, the signal has to be repetitive or occurring at the moment of observation. A DSO takes momentary samples of signals and stores them in memory. The waveform that appears on the screen is a reconstruction of samples from memory put back in order.

Scope Display

The scope display represents values of voltage (or current) on a vertical (Y axis) scale, and values of time on a horizontal (X axis) scale. Lines (graticule) on the screen indicate divisions of values, as determined by the selected scope settings. The lower left hand corner may represent a zero value, or a negative value, depending on the setup or configuration. The values of the vertical divisions are selectable using switches or software, and are sometimes expressed as the value of the entire scale, such as a total value of 25 volts from the zero line up to the top of the scale. Other choices might include .1, .5, 1.0, 5, 10, 15 volts, etc. per "graticule" or division, with a number of horizontal and vertical divisions shown on the screen.

Much like setting up a multimeter, begin with a value higher than expected, and work your way lower until the waveform occupies an area of the screen that lets you see the desired portion. The horizontal line values of time are also manually selected. The easiest scopes to use have "auto set" feature for quick setup using preprogrammed settings determined by the manufacturer. Such settings are set automatically by the software according to the type of circuit or component to be tested, such as ABS sensors, fuel injectors, hall-effect pickups, and many more.

The preprogrammed settings also control the manner of sweep "triggering" required for the function selected. Some lab scopes allow you to program and save your favorite settings and reference waveforms for future recall. You can devise your own trigger points and polarities as you see fit using a manual override.

Many units allow you to view multiple traces at the same time, allowing you to compare events in real time. This was commonly done when diagnosing ignition problems on older ignition analyzers, and today when comparing the timing of CKP and CMP traces.

Determining and Interpreting Readings

The DSO is nothing more than a voltmeter that plots the voltage over time, providing a graphical display or picture of what is happening in the circuit being tested. For example, a common cause of tip-in hesitation is an intermittent loss of signal from the Throttle Position Sensor (TPS). You can't see it on the DMM because the problem occurs too fast for the tool to catch. But on a scope, the loss will be immediately seen as you trace the sensor signal on your screen while opening and closing the throttle.

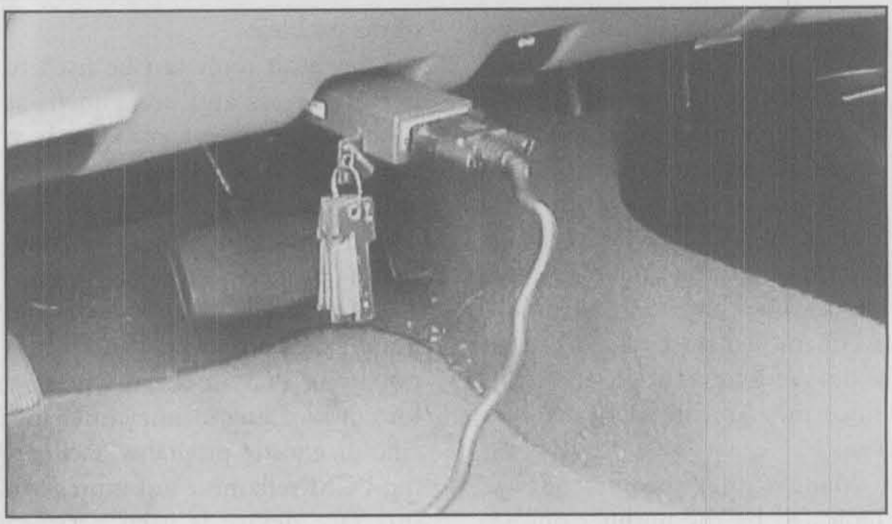
Often you may need to compare the pattern on your scope with a "known good" pattern from another vehicle. You can find several sources for these patterns online.

In all cases, think of the pattern on the scope screen the same as you would the numbers on your multimeter and consider what is happening in the circuit you are testing. Is the full range of voltage present? Are there anomalies in the pattern? Is the signal ground showing signs of improper voltage drop?

Task 5: Use scan-tool data and/or diagnostic trouble codes (DTCs) to diagnose electronic systems; interpret readings and determine necessary action.

Scan Tools

A scan tool is a diagnostic tool that connects to the DLC (Data Link Connector) to communicate with the vehicle's computers. Scan tools can be used to read DTCs (Diagnostic Trouble Codes), perform tests and monitor specific system data.



A scan tool connected to the DLC on an OBD II vehicle.

Scan tools show a text display of labeled values determined by the manufacturer's control systems and the programming module used in the scan tool. The display can be reorganized, frozen, recorded and interpreted, depending on the unit and its cartridge, and can often present its data on a separate monitor, which is usually easier to view. More modern scan tools also graph values of processed data Including electrical, pressure, vacuum, temperatures, etc. much as does the oscilloscope.

The technician can quickly determine failed or out of range components, and also whether or not the failure is module related or is the result of a peripheral component or wiring.

OE scan tools are available direct from the manufacturer providing all technicians with the same data access. Many aftermarket scan tools offer similar accessibility at a lower cost. Both sources offer tooling that can be either handheld units or PC-based, with software updates typically available as internet downloads. Before using any scan tool, read the manufacturers instructions to become familiar with its operation.

Make sure the ignition key is in the OFF position when connecting a scan tool cable connector to the DLC. On pre-OBD II vehicles (1995 and earlier), an adapter may have to be used. If the scan tool is not powered through the DLC, connect the power lead(s) to the cigarette lighter or battery.

The scan tool may ask you certain questions to identify the vehicle being serviced. Most scan tools have buttons or knobs with which to input information. Once the vehicle is identified, you can then select the desired diagnostic information.

DTCs are the most common requested information. Prior to OBD II, vehicle manufacturers used two and three digit codes that were proprietary to specific vehicles and systems and each manufacturer also had their own code definitions. With OBD II, common codes and definitions were developed to identify all basic emissions-related failures ((Refer to the Society of Automotive Engineers (SAE) Recommended Practice document J2012)) OBD II trouble codes consist of one alpha character followed by four digits. The alpha character indicates the area of the vehicle where the failure occurred. This includes (B) Body, (C) Chassis, (P) Powertrain, and (U) Network. The first digit of the DTC denotes the origin of the code. Codes authored by the SAE are identified by a zero (0). These codes are known as generic DTCs since they are the same for every vehicle.

Manufacturer specific codes are indicated by the number one (1). These DTCs are part of the manufacturer's enhanced diagnostic software, and vary between vehicle brands. The second digit in the DTC identifies the system experiencing the problem, while the last two digits correspond to a specific code definition.

In addition to accessing DTCs, modern scan tools can also display datastream values known as PIDs, (short for Parameter IDentification). OBD-II PIDs are codes used to request data from a vehicle. SAE standard J1979 defines many PIDs, but manufacturers also have their own specific to their vehicles. These data-stream values include the electrical operating values of the sensors, actuators and circuits in the engine control *system*. The displayed values can then be com*pared* with specifications in the service manual.

Some scan tools can also provide "snapshot" data. This allows the technician to check for problems when driving the vehicle. If there is an intermittent or condition–specific problem, the technician can then take a snapshot of the engine control system, capturing the various sensor readings when the malfunction occurs. The technician can then review the information back at the shop to find the cause of the problem.

Some scan tools can be used to perform tests and are known as bi-directional scan tools. The scan tool can activate various switches and actuators and then tell you whether the component is functioning properly.

Today, technicians are more and more using dedicated laptops and notebook PCs in the service bay for downloading manufacturer specific diagnostic programs, facilitating PCM reflashes, and more. An interface device is used between the PC and the vehicle's data link connector. This topic is covered in more detail later in this guide. The software programs used today offer just-in-time repair instructions for the technician to follow. They lead the technician from finding fault code data to the most likely causes, and then indicate for the specific vehicle and model where to diagnose the respective fault(s) and how to perform the needed repairs.

Task 6: Find shorts, grounds, opens, and resistance problems in electrical/electronic circuits; determine needed repairs.

Short Circuits

There are two kinds of short circuits, a short to power and a short to ground. A short to power can occur within a component or between circuits. If the short is within a component, the component will not operate properly or may not operate at all. Check the resistance of the component with an ohmmeter; if there is a short the resistance will be less than specified.

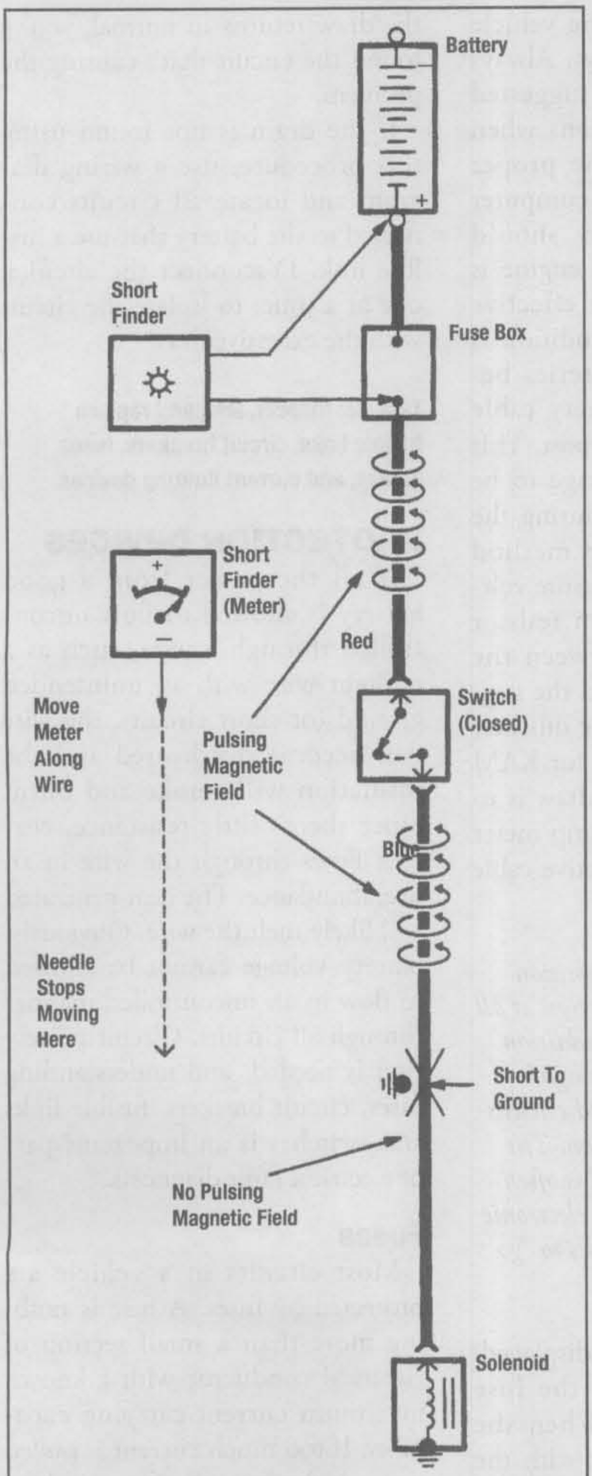
A short to power between circuits usually results in components operating unintentionally. This can be due to worn, abused or burned wiring insulation. A short to ground will usually cause a fuse to blow as soon as it is installed. However, if the short is on the ground side of the load but before a ground-side switch, the fuse will not blow but the component will not turn off. A voltmeter or a circuit probe will be useful for diagnosing such electrical faults.

A short to ground can also be detected using a tool called a "short finder". The short finder is connected between the fuse terminals (in place of the blown fuse) and will create a pulsing magnetic field in the circuit. After installing the short finder, turn on the load device. Move the short finder meter along the circuit, beginning at the fuse box. The meter needle will deflect with each current pulse. When the meter goes past the short, the needle will stop deflecting. This area should be checked for the cause of the short. A simple lamp and flasher may also be used along with a compass to detect the magnetic field in the wires before, but not after, the inadvertent ground.

Finding Short Circuits

Occasionally you will come across a burned fuse with no evidence of a short. If you plug in a new fuse, the fuse holds, and all seems to work well. This may be due to a transient short. The current flow may be high enough to pop the fuse or breaker, but only during a transient period. This condition could be due to faulty insulation where the wiring harness rubs the body or some other object, or where moisture may enter the wire through the worn spot. The circuit will temporarily ground and the fuse will blow, but not until the next time it rains, or slush is thrown up by the wheel to wet the circuit. This condition occurs often in bumper-integral light circuits.

A mysterious short may be caused by a momentary overload.



Testing for a short to ground with a short finder. *(Courtesy: Hyundai Motor America)*

This may be due to the high load of a defective motor unit as it starts up. Usually it takes a lot more current to get an electric motor moving than to keep it moving.

A jammed unit may cause a fuse to blow. If a motor or its mechanism is jammed, the protection device will perform its job - motor protection! A conversation with the driver may tip you off to the real cause of this kind of transient condition. More than one wiper motor or door window motor frozen in place with ice has popped its protective device when the customer turns the switch on. In the case of wiper blades, the circuit breaker will likely automatically reset.

In the vent a normal blade fuse blows, or a fusible link burns out, something is faulty and needs to be corrected. Use the technique described above to locate the fault.

Lastly, you may have a transient condition that occurs in a circuit which has more than one load; one in parallel with another. For example, many cars have the dome lights and the cigarette lighter on the same fuse. Replace the fuse, and the interior lights work great. Try as you might, you can't reproduce the short until you check the diagram and realize the dual nature of the circuit. Check the schematic for such possibilities when troubleshooting for short circuits.

Open Circuits

The current flow through a circuit is interrupted when the circuit is opened by a break in the conductor. The open may be created by a defective switch, relay or wire. In order to restore the circuit, find and repair the open. Check the wiring diagrams carefully and trace the normal current flow. Then trace the circuit using a voltmeter.

Circuit Loads

The load device in a circuit is the unit that does the work, such as the lights, horn, wiper motor, etc. Once adequate voltage gets to the load, it should operate - that is, if the circuit isn't shorted, open internally, or improperly grounded.

You can use a voltmeter to check for power and proper voltage drops across load devices. Source voltage should be dropped across any load in a simple or parallel circuit (not in a series circuit).

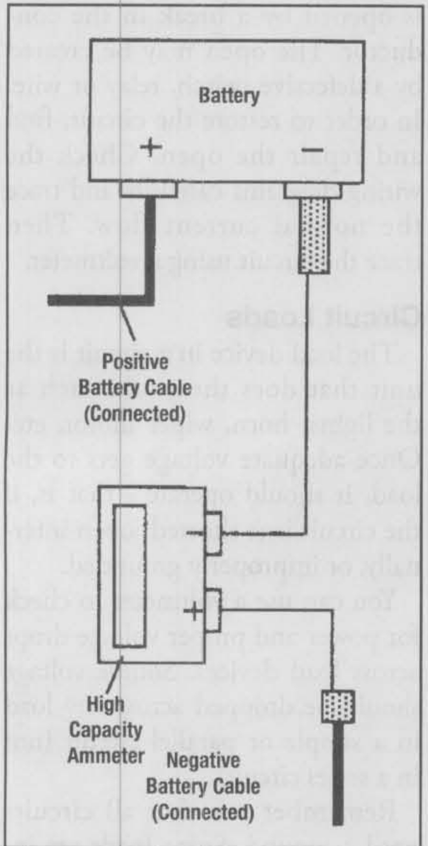
Remember too that all circuits need a ground. Some loads are internally grounded to the frame of the unit; others are externally wired to ground. With the move to the greater use of plastic and fiberglass panels in vehicles, you may find a larger number of units using external grounding methods. When replacing a part, especially where wiper motors are concerned, be sure to reconnect the ground wire before you apply energy.

Task A7: Measure and diagnose the cause(s) of abnormal key off battery drain (parasitic draw); determine needed repairs.

Key-Off Battery Drain

Excessive circuit drain when the vehicle is not running can lead to a run down battery, even if the battery is in good condition and the charging system is in proper working order.

The main reason for a very slight draw on the battery is because some systems in the vehicle need



Battery electrical drain check.
(Courtesy: GM Corp.)

voltage at all times in order to keep information stored - think of radio presets for example. Memories and stored diagnostic data must be kept alive in the PCM and other electronic modules whether the vehicle is running or not. The digital clock and other such items also draw a very small current while the vehicle is off. This is not a problem for today's vehicles as long as the drain is not excessive, say under 30 to 50 milliamps. These circuits can sometimes stay operative (commonly called "awake") after the ignition is shut off and the doors are locked for as long as eight hours before shutting down (called "going to sleep"). Remember this when checking for excessive key-off battery draw.

On the other hand, a defective glove box or trunk light switch would draw more current than this, and easily drain the vehicle battery in just a few days. Always use the manufacturer's suggested key-off drain specifications when trying to determine the proper amount of current that computer systems and accessories should draw when the vehicle's engine is not running. The most effective way of checking this condition is to use an ammeter in series between the negative battery cable and the negative battery post. This enables full battery voltage to be supplied to the vehicle during the measurement. Another method that can be used is to measure voltage drop across a 1-ohm resistor connected in series between the negative battery cable and the negative battery post. But the quickest and easiest way to check for KAM and/or excessive current draw is to place a low-amperage clamp meter around the battery's negative cable and take the reading.

NOTE: *Make sure the ignition switch is in the OFF position at all times during testing. In addition, all courtesy and accessory lights must be off and any KAM circuits should have powered down. The use of a capable scan tool is often helpful in identifying an electronic control module that refuses to "go to sleep."*

If an excessive drain is displayed, remove the fuses from the fuse block one at a time. When the fuse powering the circuit with the drain is removed, the high amperage reading will return to a normal reading.

Using a wiring diagram, note the specific circuits that run to the particular fuse that was pulled. Reinstall the fuse and allow the DMM to read the excessive draw. Now, disconnect each circuit to further isolate the current draw. When the draw returns to normal, you've found the circuit that's causing the problem.

If the drain is not found using this procedure, use a wiring diagram and locate all circuits connected to the battery that use a fusible link. Disconnect the circuits, one at a time, to isolate the circuit with the excessive draw

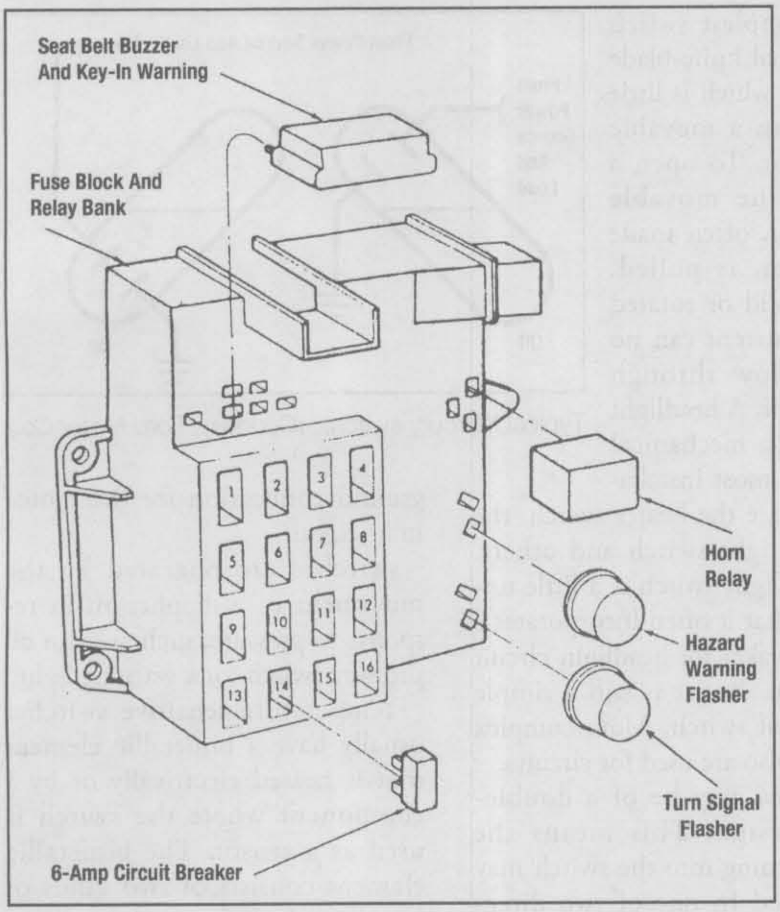
Task A8: Inspect, test, and replace fusible links, circuit breakers, fuses, diodes, and current limiting devices.

PROTECTION DEVICES

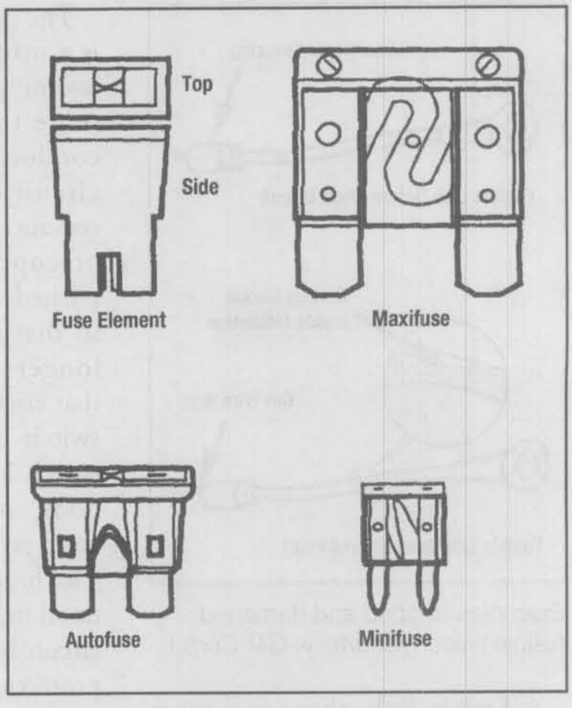
If all the power from a good battery is allowed to flow uncontrolled through a wire, such as a taillight wire with an unintended ground (or short circuit), the wire will become overheated and the insulation will smoke and burn. Since there's little resistance, current flows through the wire in an overabundance. The heat generated will likely melt the wire. Obviously, battery voltage cannot be allowed to flow in an uncontrolled manner through all circuits. Circuit protection is needed, and understanding fuses, circuit breakers, fusible links and switches is an important part of electrical fault diagnosis.

Fuses

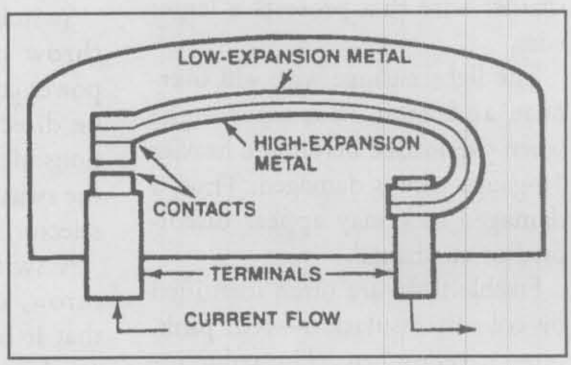
Most circuits in a vehicle are protected by fuses. A fuse is nothing more than a small section of electrical conductor with a known maximum current-carrying capability. If too much current is pulled through the fuse, the fuse will heat up, melt, and thus open the circuit to stop the excessive current flow. The fuse is designed to be the sacrificial part, giving its electrical life for the good of the circuit it protects. After the excessive electrical flow problem is corrected, a new fuse must be installed. Modern fuses are rated in amps by num-



Details of a typical fuse panel.



Typical automotive fuses. *(Courtesy: GM Corp.)*



Functional view of a typical circuit breaker. *(Courtesy: Ford Motor Co.)*

bers - 15, 20, 30, etc. Higher-draw circuits require an increased level of circuit protection.

Circuit Breakers

A popular circuit breaker in use today, known as a thermal unit, features coil windings wrapped around an iron core. The winding is connected in series with a current-carrying, bimetal blade. The bimetal blade terminates in a contact point that matches a stationary contact point. Normal current flow magnetizes the iron core to attract the bimetal arm. This helps hold the points closed.

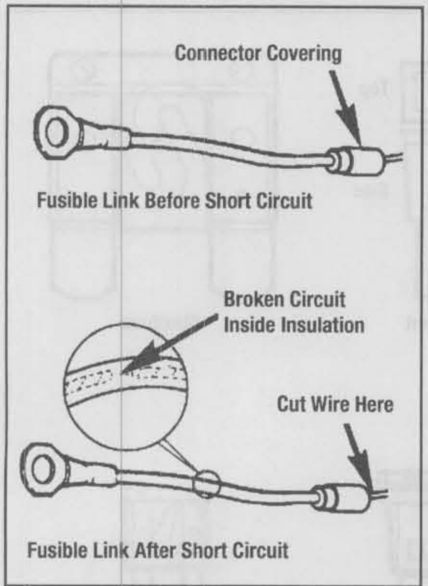
Excessive current flow can be stopped when the bimetal arm overheats and curls up against magnetic pull, thus opening the breaker points to open the circuit. When current stops flowing in the circuit, the bimetal arm uncurls to close the points and close the circuit, allowing current to resume its flow.

The bimetal arm is actually two separate sections of metal welded together. One section of metal has more of an ability to expand with heat—that is, a higher coefficient of expansion—than the section to which it is welded. Since one section expands faster and farther than the metal to which it is attached, the overall effect is a curling-up action, which opens the breaker points. When the parts cool, the contacts touch once more, and current flow is restored. If too much current still flows, the breaker opens again.

Fusible Links

A fusible link is a fused wire that protects a particular circuit from high currents, and may be either in a harness, or mounted separately, and performs the same function as the fuses in a fuse block.

Main circuits from the battery often include fusible links. If we want to protect a circuit made of 14-gauge (2.0mm) wire from possible current overload and damage, we would Insert a small length of thinner (18 or 16 gauge wire) in series in the feed circuit. The fusible link size is typically two gauge sizes smaller than the wiring it protects.



Examples of good and damaged fusible links. *(Courtesy: GM Corp.)*

A fusible link, then, is a short section (several inches or so) of smaller wire that protects a larger wire.

The lighter-gauge wire will overheat and melt (burn through) when overloaded before the heavier 14-gauge wire is damaged. Thus, a damaged link may appear discolored or misshaped.

Fusible links are often identified by colored insulation—red, pink, brown, yellow, etc. The color indicates the amount of maximum circuit protection available. Several fusible links may be found inside a vehicle. For example, a fusible link at the battery terminal of the starting motor protects the complete vehicle wiring; a fusible link at the ignition terminal of the ignition switch protects the alternator field, and so on.

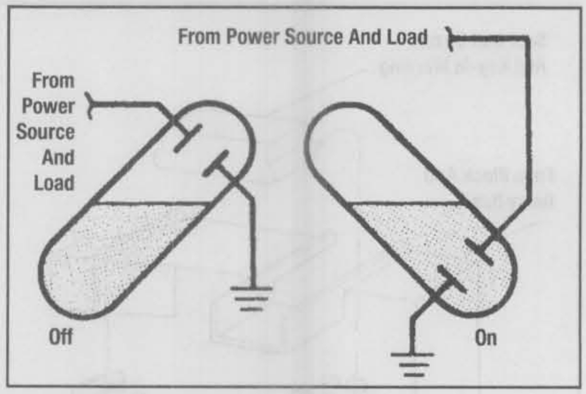
Switches

Electrical circuits must be opened or closed on demand from the system or by the vehicle driver. Current will flow only in a closed circuit. Opening and closing a circuit is accomplished via the use of a switch.

The simplest switch is a manual knife-blade assembly, which is little more than a movable conductor. To open a circuit, the movable conductor, often made of copper, is pulled, pushed, slid or rotated so that current can no longer flow through that circuit. A headlight switch is a mechanical switch in most installations; so are the heater switch, the courtesy light switch and others. The headlight switch is a little unusual in that it often incorporates a circuit breaker for headlight circuit protection. But it is still a simple mechanical switch. More complex switches also are used for circuits.

Switches may be of a double-throw design. This means the power coming into the switch may be directed In one of two directions, depending on the position of the switch's two-way (or three-way) selector if of the "center off" type.

A switch also may be double-throw, double-pole. This means that it has two or three positions, much like the single-pole, double-throw unit just discussed. But the double-pole version may complete or disconnect two separate circuits with one switching motion; it also may do the same when flipped in the opposite direction. This type of switch is used extensively in power windows and seats t reverse DC polarity to reverse motor direction. The switch puts the window up, down, or stops it (center off). When the switch is tripped, it makes both a power connection and a ground connection for the motor in its circuit.

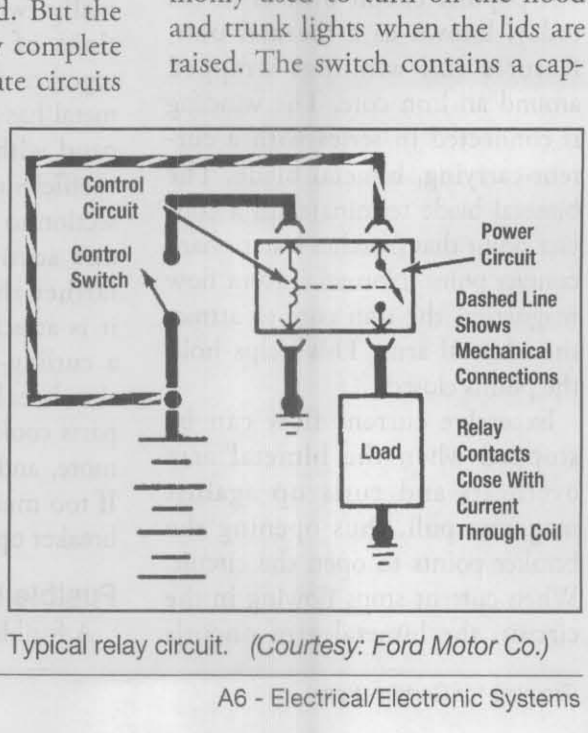


Typical Mercury switch. *(Courtesy: Ford Motor Co.)*

switches are operated by the movement of a diaphragm in response to pressure, such as in an oil pressure switch for a warning light.

Temperature sensitive switches usually have a bimetallic element that is heated electrically or by a component where the switch is used as a sensor. The bimetallic element consists of two kinds of metal, with different thermal expansion rates, that when attached to one another, the resulting assembly will bend in the direction of the metal that expands the least.

Mercury switches are used to detect motion. They are commonly used to turn on the hood and trunk lights when the lids are raised. The switch contains a cap-



Typical relay circuit. *(Courtesy: Ford Motor Co.)*

sule partially filled with mercury, with two electrical contacts at one end. The capsule is situated such that, when the lid is raised, the mercury flows to the end with the contacts, completing the circuit for the light.

Some switches are not hard wired to the circuit they control, but are input sensors to an electronic module. These switches are fed a reference voltage that is usually less than system voltage and return a varying voltage to the control module based on the switch's position. For example, a headlight switch may send 5 volts to the body module when the lights are off, 3.5 volts when the running lights alone are on, and 1.7 volts when the headlights are added. The body module uses this signal to turn on the appropriate lights using drivers (internal switches) of its own. Control module drivers can complete the ground path of a circuit or provide power side voltage that may or may not be the same as system voltage at the battery. When diagnosing any circuit, be sure to read up on its proper operation and have a wiring schematic printed out and on hand.

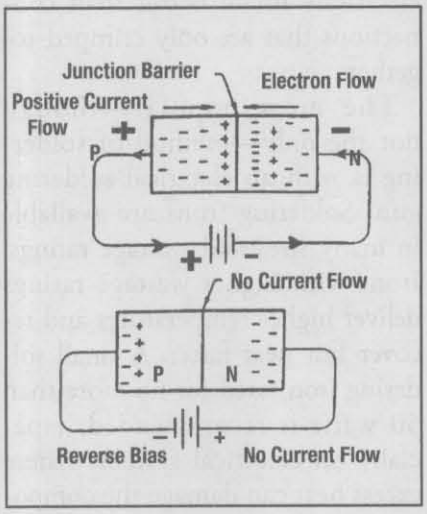
Relays

A relay is basically a remotely operated magnetic mechanical switch. Relays allow a low control current to switch on or off higher amperage circuits. Relays may be normally off, or normally on. Some are double pole, double throw, or both. Relays may have many terminals, but in general, look for the three basic items: the hot power supply, the control ground and the power-out terminals. Most relays operate on these basic wiring terminal elements. The control voltage goes into the relay to energize the relay coil. This may be a separate feed or a common one with the main power feed.

The control circuit in one of the modules (ECM, PCM, TCM, etc) sometimes provides a ground for the relay coil. So-called driver circuits in a module often provide a negative, or ground side, connection for the relay circuits they control. When the relay magnet energizes, the relay points close and power is allowed to go through the relay.

The relay coil is the control part of the relay, and has sufficient resistance to allow a safe current flow from the power source, through its windings, and back to ground through the ECM driver (in this example) for a complete circuit. All circuits make this circle. If the coil develops a short, it can allow too much current to flow through the driver, which can sometimes lead to replacement of the module.

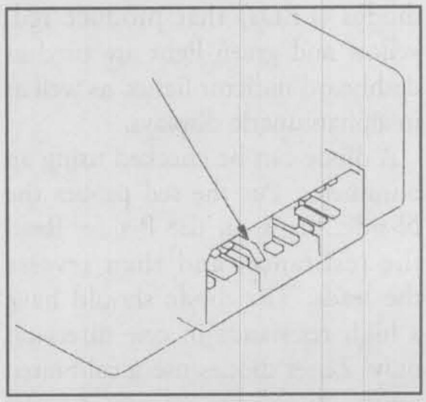
A tip-off when examining a relay is sometimes found in the wire sizes. The hot power wires that drive lights, wipers and motors will usually be thicker than the control circuit wires. The smaller control circuit amperage controls the high-powered circuit and usually uses a lighter-gauge wire.

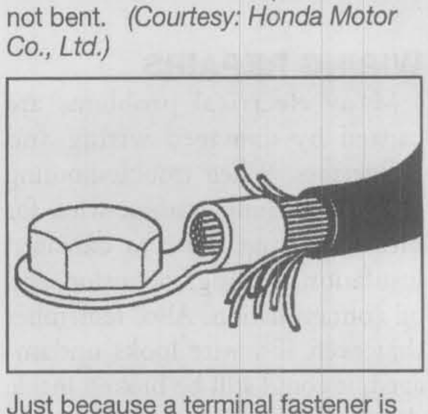


A diode is akin to an electrical switch. When voltage is connected in a forward mode, electrons will cross the junction barrier and current will start to flow. When voltage is connected in a reverse mode, no electrons flow across the junction barrier.

Whenever a relay is being replaced, make certain the correct part number for the application is used. Relays may often look alike but be wired for different functions or purposes. Many relays include diodes to prevent unwanted voltage spikes from reaching the parent control module. Failure to use the same relay can cause permanent damage to the module's circuit board.

For fast and reliable switching or remote control of electrical devices, solid-state (no moving parts) transistors are often used instead of mechanical relays. On many later


Before attaching a connector, make sure all terminals are in place and not bent. *(Courtesy: Honda Motor Co., Ltd.)*


Just because a terminal fastener is tight does not mean there is a good connection. There could be broken wire strands or a buildup of corrosion between the terminal and component, either of which could create additional resistance in the circuit. *(Courtesy: Interstate Battery System of America)*

model vehicles, these relays are incorporated into a control module and are not serviceable separately. When troubleshooting these circuits, transistors do not tolerate test lights or low-Impedance analog meters which can overload and destroy sensitive solid-state components.

Diodes

A diode is like an electrical check valve; a semiconductor that permits the flow of electricity in only one direction. Diodes are used to rectify the alternating current of an AC alternator and transform it into pulsating Direct Current (DC).

Diodes that have optical abilities also are important. Light-emitting diodes (LEDs) that produce red, yellow and green light are used as dashboard indictor lights, as well as in alphanumeric displays.

A diode can be checked using an ohmmeter. Put the red probes the N-side; black on the P-side. Read the resistance, and then reverse the leads. The diode should have a high resistance in one direction only. Zener diodes use a calibrated reverse current to 'clamp' circuits once they go past specified voltages.

WIRING REPAIRS

Many electrical problems are caused by damaged wiring and connectors. When troubleshooting circuits, carefully examine wires for breaks, melting, worn or damaged insulation, fraying, corrosion and oil contamination. Also, remember that even if a wire looks undamaged, it could still be broken inside the insulation. Checking for voltage drop while current is applied is a good method for testing for such faults.

Check connectors for damaged terminal housings, bent, broken or loose terminals, and corrosion. Check ring terminals for loose fasteners, corrosion or overheating.

If repairs are required, always follow the manufacturer's recommendations listed in the service manual. Some manufacturers recommend replacing wiring harnesses for systems like the SRS (Supplemental Restraint System), rather than repairing them.

Although soldering is the preferred way to connect wires, solderless connectors can be used if properly crimped. When stripping the insulation from a wire, be careful not to cut any wire strands and only remove enough insulation to allow the wire to properly fit inside the connector. After crimping, use electrical tape or heat shrink tubing to seal the connection.

Soldering

Soldering is a quick, efficient method of joining metals permanently. Everyone who has to make wiring repairs should know how to solder. Electrical connections that are soldered are far less likely to come apart and will conduct electricity much better than connections that are only crimped together.

The most popular—though not the only—method of soldering is with an electrical soldering gun. Soldering irons are available in many sizes and wattage ratings. Irons with higher wattage ratings deliver higher temperatures and recover lost heat faster. A small soldering iron rated for no more than 50 watts is recommended, especially on electrical systems where excess heat can damage the components being soldered. Replacement of alternator pigtails requires a gun that is intended for heavy use, due to the high heat loss through the large diameter wires.

Three ingredients are necessary for successful soldering:

- proper flux
- good solder
- sufficient heat.

A soldering flux is necessary to clean the metal of tarnish, prepare it for soldering and enable the solder to spread into tiny crevices. When soldering, always use a rosin flux or rosin core solder which is non-corrosive and will not attract moisture once the job is finished. Other types of flux (acid core) will leave a residue that will attract moisture and cause wires to corrode.

Tin is a unique metal with a low melting point. In a molten state, it dissolves and easily forms alloys with many metals. Solder was formerly created by mixing tin with lead. The most common proportions were 40/60, 50/50 and 60/40, with the percentage of tin listed first. Today's solders contain only tin, making them very difficult for a beginner to use because more heat is required to melt the solder. Always use solder that says "rosin core" on the package.

Successful soldering requires that the metals to be joined be heated to a temperature that will melt the solder, usually between 360 and 460°F. Contrary to popular belief, the purpose of the soldering iron is not to melt the solder itself, but to heat the parts being soldered to a temperature high enough to melt the solder when it touches the work. Melting flux-cored solder on the soldering iron will usually destroy the effectiveness of the flux. Be sure to read up and practice your soldering techniques before attempting automotive wiring or circuit board repairs. Use an alligator clip or needle-nose pliers when soldering leads on heat-sensitive components. Doing so acts provides a "heat-sink" to draw away heat from the component itself and prevent its possible destruction.

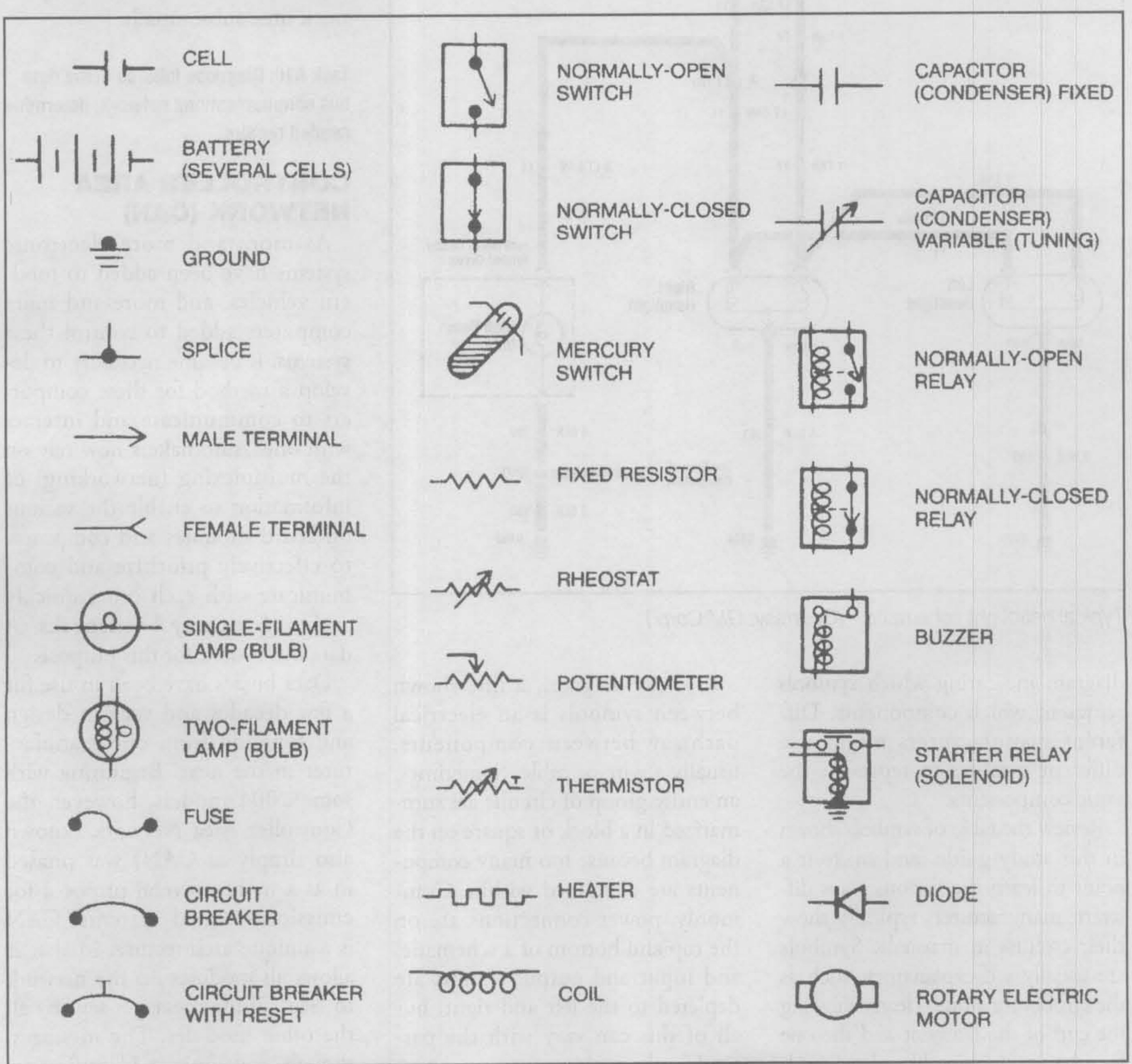
Always use the lowest heat possible when replacing LEDs or other components on circuit boards, or repairing cracks on them with a solder bridge. Excessive heat will lift the printed circuit from the board and render it useless.

Task A9: Read and interpret electrical schematic diagrams and symbols.

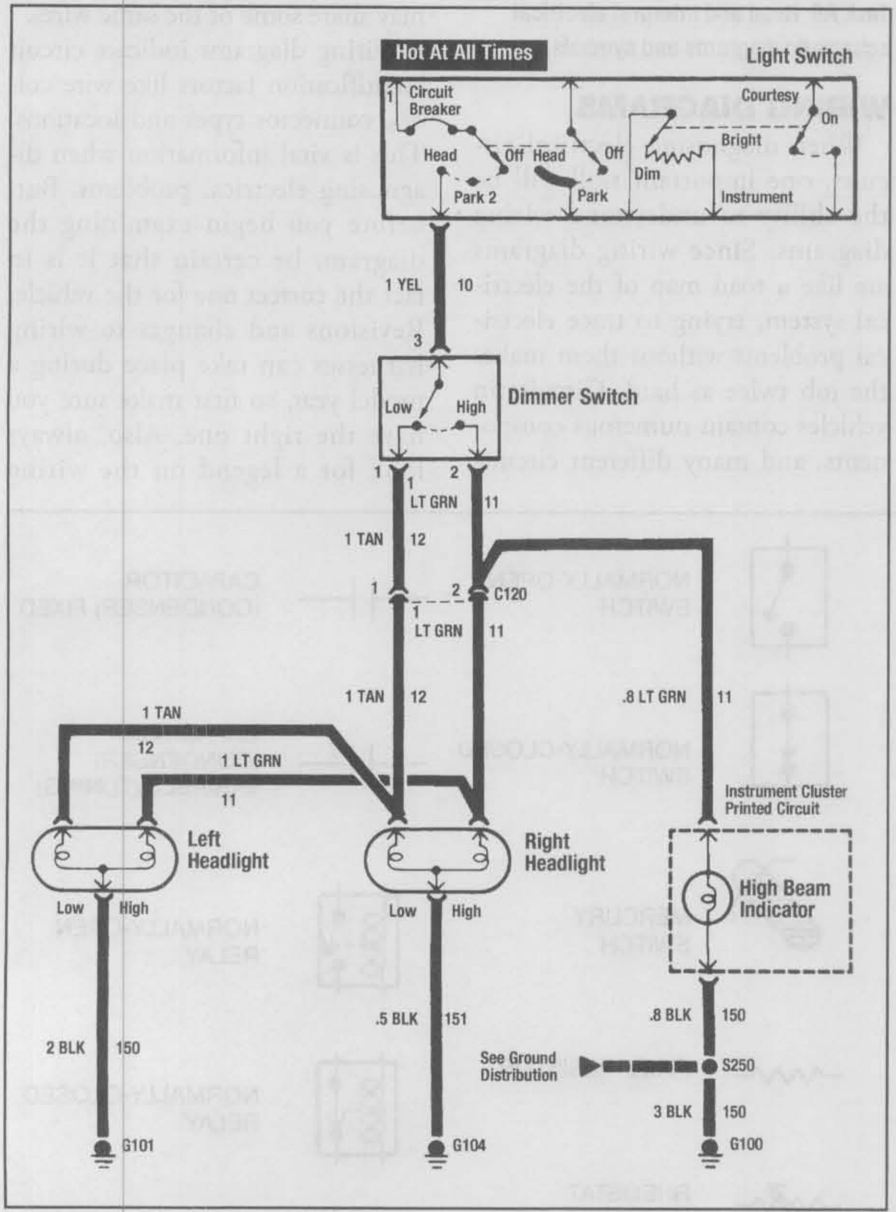
WIRING DIAGRAMS

When diagnosing electrical circuits, one important skill will be the ability to understand wiring diagrams. Since wiring diagrams are like a road map of the electrical system, trying to trace electrical problems without them makes the job twice as hard. Circuits in vehicles contain numerous components, and many different circuits may share some of the same wires.

Wiring diagrams indicate circuit identification factors like wire colors, connector types and locations. This is vital information when diagnosing electrical problems. But, before you begin examining the diagram, be certain that it is in fact the correct one for the vehicle. Revisions and changes to wiring harnesses can take place during a model year, so first make sure you have the right one. Also, always look for a legend on the wiring



Typical electrical symbols used in automotive wiring diagrams and schematics.



Typical headlight schematic. *(Courtesy: GM Corp.)*

diagram indicating which symbols represent which components. Different manufacturers might use different symbols to represent the same components.

Review the table of symbols shown in this study guide, and make it a point to learn the various ways different manufacturers typically show their circuits in manuals. Symbols are usually self-explanatory, such as the symbol for a bulb clearly showing the curl of the filament and the one for a battery looking like plates sandwiched together.

In every diagram, a line shown between symbols is an electrical pathway between components, usually a wire or cable. Sometimes, an entire group of circuits are summarized in a block or square on the diagram because too many components are contained within. Commonly, power connections are on the top and bottom of a schematic, and input and output circuits are depicted to the left and right, but all of this can vary with the particular schematic.

If simplified schematics aren't available for a given vehicle, don't be intimidated by the more complex type that shows several circuits lumped together. Just make a photocopy of the schematic and highlight the circuit you are interested in. It's often helpful to redraw it on a separate piece of paper in simplified fashion. Straighten out the wires and arrange the components so you can understand the intended current path. This may seem like a lot of trouble, but a clear schematic can shorten your work time substantially.

Task A10: Diagnose failures in the data bus communications network; determine needed repairs.

CONTROLLER AREA NETWORK (CAN)

As more and more electronic systems have been added to modern vehicles, and more and more computers added to control these systems, it became necessary to develop a method for these computers to communicate and interact with one. Automakers now rely on the multiplexing (networking) of information to enable the various on-board modules and computers to effectively prioritize and communicate with each other quickly and without any bottlenecks. A data bus is used for this purpose.

Data busses have been in use for a few decades and vary in design and function from one manufacturer to the next. Beginning with some 2004 models, however, the Controller Area Network (known also simply as CAN) was phased in as a more univeral protocol for emissions-related systems. CAN is a unique architecture, in that it allows all modules on the network to "see" all the mesaages sent by all the other modules. The messages, though, have unique identifiers attached so that only the modules that need to listen will act on the data sent. CAN modules are also wired in parallel to the bus, allowing any number of modules to exist on one network. This, merged with the high data transmission speeds CAN is capable of, has led to the growth in electronic system controls of all types.

Even on those vehicles using CAN, many automakers still utilize their older designs for many vehicle functions. On these, one module is often earmarked as a "gateway" module. All the different networks meet in this central location, and the gateway acts as a translator so that information on one network can be used by modules on another.

Diagnosis

Serial data on the various vehicle networks can be monitored by a scan tool and interpreted for diagnostic purposes. To diagnose a malfunction in a network, a scan tool (typically an OE level tool or aftermarket unit with "enhanced" OE data) that can read 'U' (network) codes is required.

If one module loses communication with other modules in the network, the onboard diagnostics system will set a DTC and the MIL (Malfunction Indicator Light) may come on. The DTC will begin with "U1" followed by the number assigned to the module in question by the manufacturer. It is important to note here that this code does not necessarily mean that the module has failed, but rather that there is a problem which is preventing communication.

A communications DTC can be caused by a faulty connector or wiring, an open or short circuit, a voltage problem on the network, another module in the network, or the module itself. Bad ground connections are often at fault for such DTCs.

To isolate the problem, check the circuit for shorts and opens and check the ground and base voltage using a DMM. If another module in the network is disconnected and the module that set the DTC begins communicating, the problem is with the other module.

If all wiring connections are good and there is no change after unplugging each of the other modules in the network, one at a time, the module in question is most likely at fault.

Task A11: Remove and replace control modules; program as needed.

Because modules can be very expensive, always follow the manufacturer's diagnostic instructions completely before deciding on module replacement. Some shops will replace a suspected faulty module with a "known good one" from another like vehicle before investing In a replacement module.

Always remove the ground (negative) battery cable connector from the battery before attempting to replace a module. Avoid touching the terminals of any module to avoid destroying the module from static electricity in your body. Keeping contact with the vehicle ground may help to help avoid electrostatic discharge into a module's circuitry.

If swapping computers or modules for use in a vehicle, sometimes vehicle identification data or other important information must be transferred (downloaded and uploaded) from the old/used module to the newer one or else the vehicle may not operate correctly, or even start. Make sure all relevant data is provided/uploaded to the new module as required.

Also, be extremely careful is deciding to swap modules or even components, as they may look the same but be different in their design characteristics. On many vehicles, swapping can cause module failures or the installed module may not meet the security protocol for the new vehicle installation, providing a false conclusion to the technician attempting to use this type of test. Also, delicate electronic circuits do not give an indication of being destroyed (no smoke emitted), but can be demand expensive tuition payments of the unwary technician who carelessly thinks to himself, "Let's see if this one works!"

Reflashing of PCMs

Most domestic vehicles built since 1996 have computers that can be reprogrammed (reflashed). Car companies are relying more and more on flash reprogramming to correct driveability and emissions related problems in newer vehicles. This procedure may be done at a new car dealership, but independent repair shops, or even individuals, can now reprogram vehicle PCMs and other onboard electronic devices.

The EPA requires original equipment manufacturers to make emissions-related onboard diagnostic service information available to the aftermarket via their technical websites. Always check for updates before reprogramming vehicle modules. So-called "flash" reprogramming procedures must conform to SAE J-2534-1 standards which allow the use of aftermarket scan tools or similar "pass-through" devices, in addition to factory scan tools.

Reprogramming may be required for a variety of reasons, such as when a vehicle sets false trouble codes, or the original factory programming is overly sensitive, and not take into account wear or other factors that affect the operation of sensors or OBD II monitors.

Be sure to connect a reliable and recommended external battery charger to the vehicle before attempting to reflash a module in a vehicle. Follow the OEM's instructions carefully, as a power Interruption during the programming procedure could damage or destroy the module.

Battery and Starting System Diagnosis And Repair

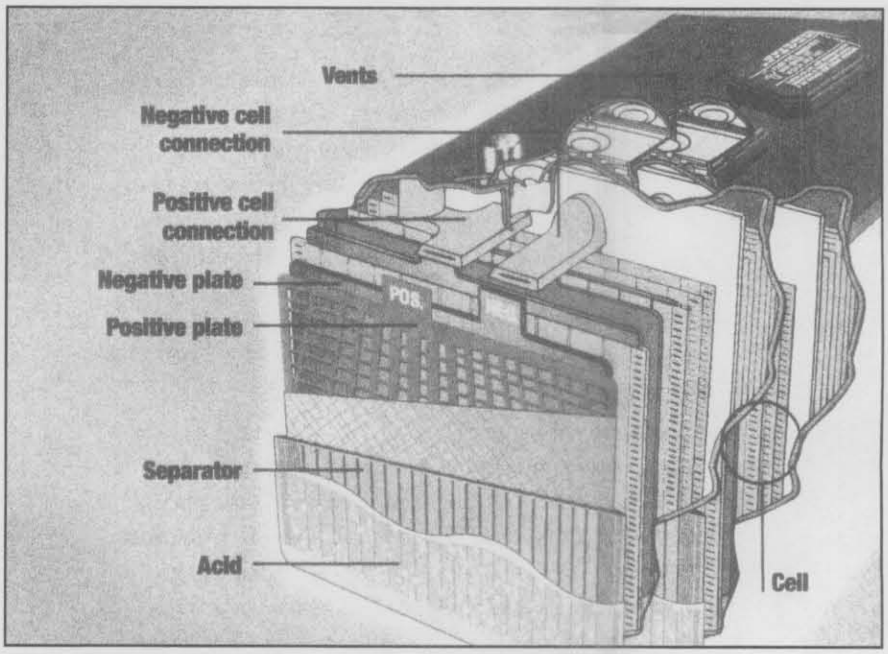
DESCRIPTION AND OPERATION

The battery and charging device are the primary sources for the electrical current required by the vehicle. The battery is often called a storage battery even though it does not technically 'store' electrical energy. Until the mid 50's, the on-board charging device was a direct current (DC) generator; since then, power is provided by a more efficient alternating current (AC) generator, more commonly called simply the alternator. AC current is rectified to DC for output to the automobile's electrical system and the 12 volt DC battery. The battery must supply current to the starter and ignition system during engine cranking. The battery must also supply current during times of low charging system output and times of high current drain.

The standard battery design in use today is the 'flooded' lead-acid battery, so called because the electrolyte in the battery is in liquid form. A typical standard flooded lead-acid battery is comprised of a large number of positive and negative electrodes in the form of plates, an electrolyte consisting of 64% water and 36% sulfuric acid (H_2SO_4), in which the plates are immersed. Polyethylene separators between the plates and lead-alloy electrical connections are all encased in a polypropylene box.

There are 6 cells in the DC automotive battery, each rated at 2.1 volts for a fully charged 12.6 volt battery. When a load is connected between the positive and negative terminals of the battery, a chemical reaction takes place in the battery and the electrolyte provides potential (electrical energy). As current flows through the completed starting circuit, the mass on both plates is converted to lead sulfate ($PbSO_4$) and water. The plates gradually become similar in charge and the electrolyte becomes weaker (greater H_2O content) as the battery becomes discharged.

Once the engine starts, the charging system forces current to move in the opposite direction through the battery cables and the battery's chemical reaction reverses as the battery is recharged. The lead sulfate on the plates separates into lead (Pb) and sulfate (SO_4). The sulfate combines with hydrogen in the electrolyte to form sulfuric acid (H_2SO_4) and the oxygen in the electrolyte combines with the lead (Pb) at the positive plate to form lead dioxide (PbO_2).



Cutaway view of a typical flooded lead-acid battery.

The continuous discharging and charging of a battery is called battery cycling.

WARNING: *The sulfuric acid in battery electrolyte can cause serious injury if it contacts the eyes or skin. To prevent injury, always wear skin and eye protection when servicing the battery. Batteries give off hydrogen gas, which is highly explosive. Never smoke or allow flames near a battery.*

Low-Maintenance and Maintenance-Free Batteries

Standard flooded lead-acid batteries lose water as a result of electrolysis and evaporation. During charging, the passage of electrical current through the electrolyte breaks down the water into hydrogen and oxygen, which escape into the atmosphere through the battery's vent caps. This process is commonly known as "gassing" A note of caution: The hydrogen gas released during the battery charging process is highly explosive. A certain amount of gassing is a normal product of charging, but overcharging can increase gassing and water loss. Evaporation of water is normally not a problem except in very hot, dry climates. If the electrolyte level is not periodically checked and the electrolyte is allowed to fall below the top of the plates, the plate material exposed to air will harden and become chemically inactive, which will reduce the battery's capacity and shorten its lifespan.

Low-maintenance batteries usually have the same appearance as conventional batteries; both have cell openings to allow water to be added. Where these batteries differ is in the alloy used in the grids. The grids in conventional wet-cell batteries are made of lead alloyed with about 5% antimony, whereas the amount of antimony in the grids of low-maintenance batteries is usually held to 3% or less. Antimony was originally used in conventional batteries to add strength, but it was found to increase gassing. Reducing the amount of antimony in low-maintenance batteries reduces gassing up to 97% and helps resist overcharging. Thus, water must be added less often than with conventional lead-acid batteries.

Maintenance-free batteries usually have a larger amount of electrolyte above the plates and there is usually no provision for adding water to a maintenance-free battery. Instead, a baffled chamber or separator is attached to the top of the battery case to collect electrolyte lost during gassing, and allows It to return to the battery cells.

VRLA Batteries

Another type of maintenance-free battery in use today is the Valve Regulated Lead-Acid (VRLA) battery. In a VRLA battery, the hydrogen and oxygen recombine during charging to form water. Thus, they are also known as 'recombinant' batteries. There are two types of VRLA batteries, the gel-type and Absorbent Glass Mat (AGM).

Gel-type batteries use the same plates and separators as flooded lead-acid batteries, but a pure form of silica is added to the electrolyte to form an acidic gel. As the gel hardens, cracks are formed, which are essential to the recombination process.

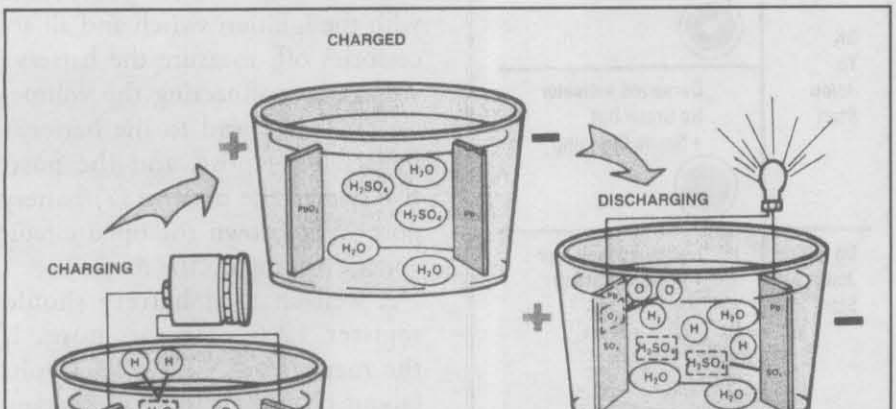
In an AGM battery, the electrolyte is immobilized in an absorbent Boron-Silicate glass mat separator between the battery plates. This separator can be compared to a sponge in that it holds the liquid electrolyte but at the same time has voids to allow the passage of oxygen during the recombination process.

VRLA batteries are designed with a specific material balance (between positive and negative active materials) to minimize gassing to ensure that there will always be an excess of lead sulfate (PbSO4) and lead (Pb) at the negative plate that is available to react with the oxygen generated at the positive plate. Under normal charging conditions and with minimal overcharge, the negative plate will not produce hydrogen gas, thus minimizing the chances of loss of hydrogen (and oxygen) due to system venting.

If there is considerable overcharge, to the point where the cell cannot recombine all of the oxygen generated, hydrogen evolution can take place. If enough oxygen and hydrogen are generated, the resealable safety valve will open up and gas will be lost to the atmosphere. This resealable safety valve is the 'valve' in VRLA. It not only acts as a safety release vent, but also maintains pressure (1-8 psi) within the cell for recombination to occur.

Battery Ratings

Batteries are classified according to physical size, Cold Cranking



Battery charge and discharge cycles. *(Courtesy: Ford Motor Co.)*

Amps (CCA) and Reserve Capacity (RC). Cold Cranking Amps are the number of amps a fully charged battery can deliver for 30 seconds at 0°F, while maintaining a minimum voltage of 7.2 volts or more. Reserve Capacity is the number of minutes the battery can deliver 25 amps at 80°F while maintaining a minimum voltage of 10.5 volts.

Battery Testing

Before testing the battery, perform a visual inspection, looking for damage to the battery case and damage or corrosion on the battery terminals and cables. If the battery case is damaged and there is any evidence of leakage, the battery must be replaced. Check the battery's date of manufacture. Just because the battery is near the end of its service life does not mean that it will necessarily test bad, however the age of the battery must be considered when deciding whether replacement is necessary.

If the battery has removable vent caps, check the electrolyte condition and level in each battery cell. Look for cloudy or muddy discoloration of the fluid. Discolored fluid is a sign of recent deep cycle discharge action. Add distilled water to the proper level, if necessary. In general, the electrolyte should be 1/4 - 1/2-in. above the plates.

Excessive corrosion at the battery cable terminals can cause a poor contact that will prevent proper charging and full battery current flow. However, don't use this as a comprehensive battery test.

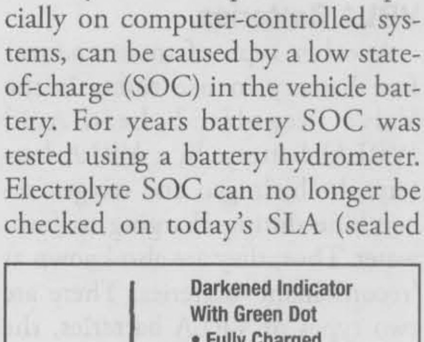
Normal voltage for a fully-charged battery is at least 12.6 volts. When the battery is supplying current to one or more circuits, it is said to be under load. When everything is off, the electrical system is under a no-load condition. A fully-charged battery showing about 12.6 volts at no-load may drop to 12 volts under medium load, and will drop even lower under heavy load.

If the battery is partially discharged, the voltage decrease under heavy load may be excessive, even though the battery shows 12 volts or more at no-load. When allowed to discharge further, the battery's available voltage under load will decrease more severely. For this reason, it is important that the battery be fully charged during all testing procedures to avoid errors in diagnosis and incorrect test results.

Task B1: Perform battery state of charge test; determine needed service.

SOC - Hydrometer Testing

Many electrical problems, especially on computer-controlled systems, can be caused by a low state-of-charge (SOC) in the vehicle battery. For years battery SOC was tested using a battery hydrometer. Electrolyte SOC can no longer be checked on today's SLA (sealed lead acid) maintenance-free batteries. However, some of these batteries have a built-in charge indicator "green eye" (a single-cell hydrometer). Usually a good battery is indicated by a green or light-colored dot (visible float) in the center of a round window; a dark indicator means the battery is undercharged and may be jumped or recharged, and a clear or light yellow indicator means the electrolyte fluid level is too low. In such cases, the battery should not be charged; it should be replaced. Always refer to the instructions on the battery label and be aware that the charge indicator only represents the condition of one cell.



Charge indicator in a sealed maintenance-free battery.

With today's sealed batteries, plus the time required and the risk involved (exposing body paint to battery acid), the standard hydrometer test is seldom performed. Thus it is no longer covered on the A6 exam.

SOC - Open Circuit Voltage Test

A simple SOC test can be done using a voltmeter to measure open circuit voltage. At 70°F (21°C) and with the ignition switch and all accessories off, measure the battery's voltage by connecting the voltmeter's negative lead to the battery's negative (–) post, and the positive lead to the positive (+) battery post. Write down the open circuit voltage reading on the meter.

A well-charged battery should register 12.6 volts or more. If the meter reads below 12.2 volts (about 60 percent state of charge), battery power may not be sufficient to properly further test the battery or vehicle systems. If this is the case, fully recharge the battery using an external battery charger. Do not expect the vehicle charging system to recharge a battery from a deeply discharged state-of-charge. Once the battery has been fully charged, remove any surface charge by turning on the headlights for 15 seconds. Then wait several minutes, and then read the open-circuit voltage once more. It should be 12.6 volts or more.

Task B2: Perform battery tests (load and capacitance) determine needed service.

Battery Capacity/ Load Testing

Of the many ways to rate the condition of a battery, perhaps the most revealing is to measure its ability to hold up under a high-rate discharge test. A load test should be considered as the first step in any electrical trouble diagnostic procedure.

A simple way to load test a charged battery in the field is to disable the fuel system (remove the fuel pump relay) and crank the engine for 15 seconds. Use a digital multimeter set to MIN/MAX mode to capture the lowest reading while cranking the engine. The minimum voltage reading should be 9.6 volts or higher and bounce back up to near 12 volts. This will show if the battery will do the job expected, and also if other conditions are within general allowable tolerances.

For many years load testing of a battery was performed in the shop using a Volt-Amp tester. This test involved applying a factory specified load (in amps) to the battery. The load tester was first connected to the battery terminals, and then a load control knob was rotated to draw current equal to three times the ampere-hour (amp/hr) battery rating, or one-half the CCA rating of the battery, for 15 seconds. Then the battery voltage was checked. A good battery would be 9.6 volts or higher; however, the voltage would be slightly lower if the ambient temperature were less than 70°F (21°C).

Today, however, the venerable load test is frowned upon because it can lead to overheating and damage to modern alternators; thus load testing, in the vehicle at least, is no longer a method of choice for battery testing.

OEMs, repair shops, and even parts stores are now using a conductive-capacitance type SLA battery tester for quicker and less cumbersome testing in the field. The capacitance test is reportedly 95 percent accurate, and the reduced time and labor required is noteworthy. This form of testing can also be done when the battery is less than fully charged, unlike conventional load testing. Conductive testing can indicate if a battery is fully or partly charged, or it has one or more bad cells and should be replaced. Tester operating instructions may vary, so be sure to refer to the correct procedure for the tester you have.

Task B3: Maintain or restore electronic memory functions.

When servicing the battery terminals, replacing cables, or performing other work which requires removal of the battery, keep in mind that computers, programmable radios, and other solid-state memory units may have their memories erased from a disconnected battery. To prevent this, a 12-volt power supply could be connected to the constantly-powered cigarette lighter or power point connector to maintain voltage in the system to maintain module memories (including the ECM's "Keep Alive Memory") while the battery is disconnected. Keep in mind however that the use of the cigarette lighter as a means to maintain module memory only works if power is fed to it with the ignition off - and in most cases today it is not, meaning radio presets and other KAM data could be erased.

A better method is to connect a 12 volt DC power source directly to the DLC using an adaptor specifically designed for this purpose. This will maintain power to ALL modules, and prevent the need to re-enter anti-theft codes, radio presets or any other driver preferences that would otherwise be lost. When using external power in this method, remember that there will be power at the positive battery cable and precautions need to be taken to prevent arcing the cable to ground while performing battery related service.

Vehicle Relearn

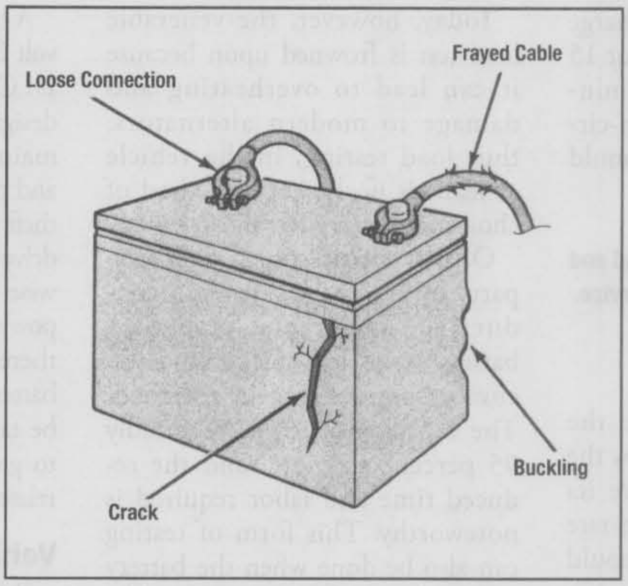
If you forget to use some type of memory maintainer when disconnecting the battery, keep in mind that the engine and transmission on some vehicles may perform erratically when first started after battery power has been disrupted (KAM lost). These modules adapt to the aging of the vehicle and must undergo a relearning process after the battery has been disconnected. Some vehicles using electronic throttles may also require some form of relearn if battery power is disconnected before they will respond to any attempt to accelerate. As a theft deterrent, some radios and navigation systems require the entering of a designated code, which is entered on the keypad and read on the display; the correctly entered code will re-enable the system to operate. Some models even require specific relearn procedures just to let the car know you installed a new one! Refer to the vehicle owner's manual or service manual for specific instructions on how to perform a reset procedure.

Task B4: Perform slow/fast battery charge in accordance with manufacturer's recommendations.

When a vehicle battery becomes discharged, a battery charger is used to force current back into the battery and restore the charge on the plates and electrolyte. A battery can be slow charged, fast charged or charged with a constant voltage charger. Slow charging applies low current over a long period of time while fast charging applies high current over a relatively short period of time. In general, it is best to use a constant voltage charger. This type of charger reduces the charge rate as the battery approaches full charge, which helps prevent overcharging the battery.

Regardless of the charging method used, to protect sensitive electronics on-board, disconnect the battery cables - negative cable first - from the battery terminals before charging a battery. Charge the battery in a well ventilated area. Be sure the battery charger is turned off before connecting or disconnecting the charger's cables at the battery terminals.

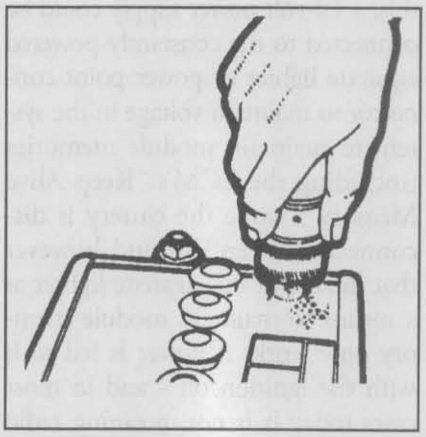
Set the battery charger to the recommended charging rate and turn on the battery charger. Check the battery voltage while the battery is charging. If the voltage reaches 15.5 volts, reduce the charging rate. The charging rate should also be reduced if the temperature of the electrolyte exceeds 125°F (52°C). In general, a battery is considered to be fully charged when the specific gravity of the electrolyte in each cell is between 1.260 and 1.280 at 80°F (27°C), if the "green eye" appears, or if open circuit voltage (after removing a surface charge) is at 12.6 volts. Correct for temperature variation as explained earlier in this section.



Inspect the battery and cables for physical damage before doing any testing. Cracks or buckling on the battery case can be caused by an over tightened hold-down, excessive temperature from overcharging or freezing of the electrolyte. *(Courtesy: Ford Motor Co.)*

Task B5: Inspect, clean, and repair or replace battery(s), battery cables, connectors, clamps hold downs, and vent tubes.

Make sure the battery tray is clean and in good condition, and that the battery is mounted securely to the vehicle - without over-tightening of the hold-down device. Corrosion on the battery and connections can be cleaned with a solution of baking soda and water. The battery terminals may be located either as posts on top of the battery, or as side terminals on some batteries. If the battery terminals and cables are corroded, remove the cables, negative cable first, and clean the terminals and cables with special battery brushes designed for battery posts or for side terminals. A special low-profile ratchet wrench is available to make removal and installation of battery side bolts easier.



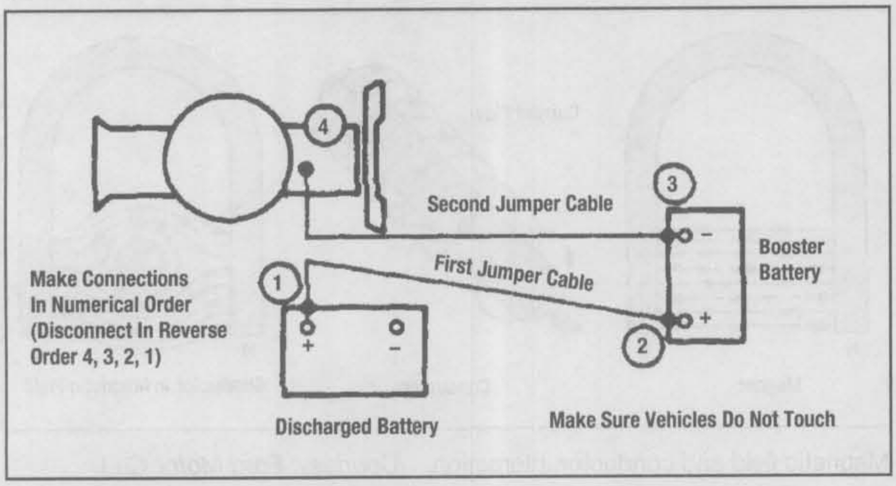
Cleaning battery terminals with a battery terminal cleaner.

Clean the battery tray and hold-downs if they are dirty or have corrosion after removing the battery from the vehicle. Clean the battery tray with baking soda and water, and clear vent tubes with low-pressure shop air. If a battery temperature sensor is located nearby, inspect it for damage and frayed wiring.

Inspect the entire length of the battery cables for heavy corrosion, frayed wires or damaged insulation, and replace as necessary. Look especially closely for corrosion under the insulation at the battery connector end of the cable. Check for battery acid which may have gotten onto wiring harnesses, fusible links and so forth. After cleaning and rinsing the battery, battery tray, hold down, cables etc. with fresh water, re-install the battery, secure the hold down, and connect the cables to the battery terminals. Apply special spray or a coating of petroleum jelly to the terminals to minimize further corrosion.

Task B6: Jump start a vehicle using jumper cables, and a booster battery or auxiliary power supply.

When using an auxiliary or portable power supply, or another vehicle, to jump start a battery, make sure the distance between the jumper battery and the dead battery is as short as possible without



Proper jumper cable connection sequence for jump starting a vehicle. *(Courtesy: Ford Motor Co.)*

letting the vehicles contact each other. Make sure the ignition is in the OFF position on both vehicles, all lights and accessories are off, and both transmissions are in Park or Neutral with the parking brake applied.

Connect the positive (red) jumper cable to the positive terminal of the dead battery and then to the positive terminal of the source battery. Next connect the negative (black) jumper cable to the negative terminal of the source battery, and to a good known chassis ground on the vehicle with the dead battery. Make sure this connection is made away from the battery, as sparks could be emitted.

After verifying that the connections are properly made, turn on the power supply, or start the source vehicle and hold engine speed at around 2000 rpm while the dead battery begins to charge. Cold temperatures and battery time of discharge will govern how long it will take to charge. After a few minutes of charging the dead battery from the power supply or host vehicle, try to start the vehicle. As soon as the engine is running, turn off the power supply or "sharply" disconnect the negative jumper cable from the chassis. Do NOT let the cable ends touch each other, or the vehicle. Disconnect both the negative and positive jumper cables from the source battery. Finally, disconnect the positive jumper cable from the battery that has been jumped.

STARTER MOTOR OPERATION

Electric motors are used to convert electrical energy to mechanical motion to perform work. If a bar magnet is placed within the magnetic field that exists between the poles of a horseshoe magnet, the bar will respond to the laws of magnetism. If mounted on a suitable shaft and bearings, it will rotate, since like-poles repel and unlike poles attract.

The shaft of the electric motor is called the armature and is wound with electro-magnets. The armature rotates within a magnetic field of so-called field coils which may be either electro-magnets, or permanent magnets.

The armature's polarity changes as it rotates, never quite allowing the armature windings to catch up to the fields; this enables the armature to continue to rotate, rather than stall. Actually, there are many segments and armature windings on the armature which provides a steady and powerful rotary motion. Power is fed into and from the armature through a set of commutator bars and carbon brushes.

A basic series-wound motor is one that incorporates a design in which the same current flowing through the armature also flows through the field windings (series wound). This makes for a very powerful motor and is most often used for starter motors.

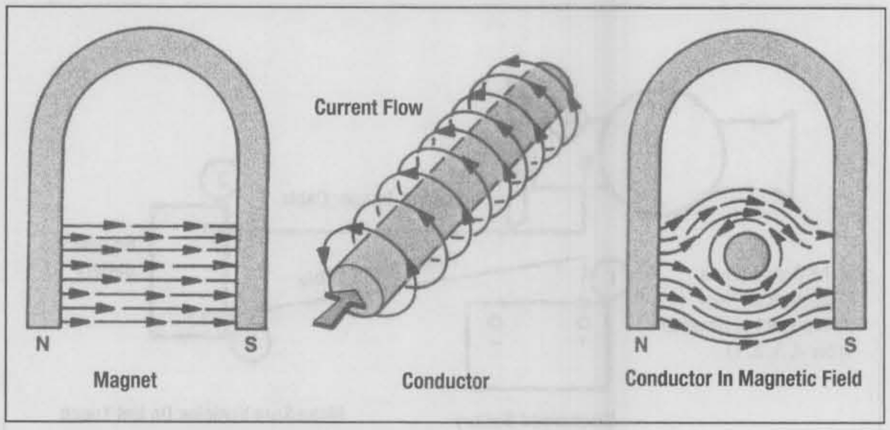
Starter Electrical Circuit

The vehicle starting system is a series circuit consisting of the battery, high amperage battery and ground cables, a starter relay (sometimes mistakenly called a starter solenoid) and the starter itself. The starter control circuit consists of the ignition switch, the starter relay (solenoid), relatively low amperage wiring and a neutral/clutch safety switch. The neutral safety switch on automatic transmission vehicles or clutch switch on manual transmission vehicles prevents the vehicle from cranking while in gear.

When the ignition switch is turned to start, the control circuit is completed for battery voltage to reach the starter relay. The relay is equipped with its own ground or is controlled by the PCM/ECM. When the key is turned to the crank position, the relay is energized (pull-in) and uses voltage in the circuit to pull the high amperage relay contacts closed to complete the cranking circuit to the starter. An additional winding in the circuit holds (hold-in) the relay contacts for the starter circuit closed and allows power to continue to flow to the starter motor.

On some starters, the armature has a pinion gear which slides endwise on splined-spiral grooves on the end of the armature shaft. As the armature starts to turn, a sliding drive gear engages with the engine flywheel. Some starter drive gears engage with the flywheel by a solenoid and shift fork. Once the solenoid and shift fork engage the drive gear endwise into the flywheel, the starter circuit is completed in the relay and the armature starts to turn the flywheel. The ratio of starter speed to flywheel speed is roughly 100:1.

Some manufacturers use gear reduction type starters. On these starters, the armature pinion gear torque is applied through a reduction gear set with an intermediate pinion gear mounted to it, or a planetary-style gear set is used.



Magnetic field and conductor interaction. *(Courtesy: Ford Motor Co.)*

BASIC STARTER TESTING

The most common starter complaints are that: 1) the starter does not crank, or 2) the starter cranks too slowly to start the engine, or 3) the starter operates but does not turn over the engine. Sometimes the starter drive gear stays engaged with the engine flywheel once the engine has started.

Engine Does Not Crank

If nothing happens when the key is turned to the Start position, turn the headlights on and turn the key to Start again. If the headlights do not dim, check for an open circuit in the starting control system. If the lights go dim, test the battery as described in the previous section of this study guide. If the lights go out, perform voltage drop tests on the starter high current circuit. Inspect the condition of the cables and wiring to the starter and solenoid, making sure all connections is clean and tight. If the wiring connections are OK, next check the starter solenoid function. If the solenoid tests OK, perform the starter current draw test.

Sometimes worn brushes can prevent a starter from cranking. Try tapping the starter with a breaker bar to seat the brushes to get the vehicle started. A bad commutator bar can also cause the starter to not crank one time, while otherwise working properly.

Task B7: Perform starter current draw test; determine needed repairs.

If the engine rotates, disable the fuel system (pull the fuel pump relay) and crank the engine. Use a high amperage clamp and a multimeter, or a Volt-Amp tester, to measure cranking amperage in the battery negative cable. If current draw is excessive and voltage drop is within specification, the starter is defective or there is a mechanical problem such as defective engine bearings.

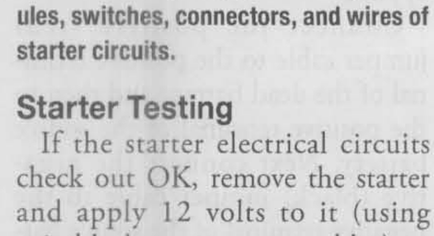
Task B8: Perform starter circuit voltage drop tests; determine needed repairs.

To determine if the battery (high current) cables or starter relay are defective, disable the fuel system and perform battery-to-starter voltage drop tests. Connect the voltmeter positive lead to the B+ terminal post and the negative lead to the starter's large battery cable terminal. Read voltage drop while cranking the engine. Generally, no more than 0.2 - 0.6 volts should be dropped in the positive circuit. If more, test each leg of the circuit (across the relay, etc.) to find the location of excessive resistance. Do the same on the ground side with the voltmeter's positive lead on the starter and the negative lead on the B- battery terminal post. On the ground side, expect even less voltage drop. Refer to OEM service specification.

Task B9: Inspect, test, and repair or replace starter, relays, solenoids, modules, switches, connectors, and wires of starter circuits.

Starter Testing

If the starter electrical circuits check out OK, remove the starter and apply 12 volts to it (using suitable heavy-current cables) to see if it free-wheels with no load at the specified rpm; refer to the OEM specs. With the starter held



Typical starter mounting. Note the shim between the starter and engine block. *(Courtesy: GM Corp.)*

in a vise, apply 12 volts to both the starter and the attached solenoid to see if the starter spins and the pinion works as it should. Oil soaked or physically damaged starters should be cleaned and tested, or replaced.

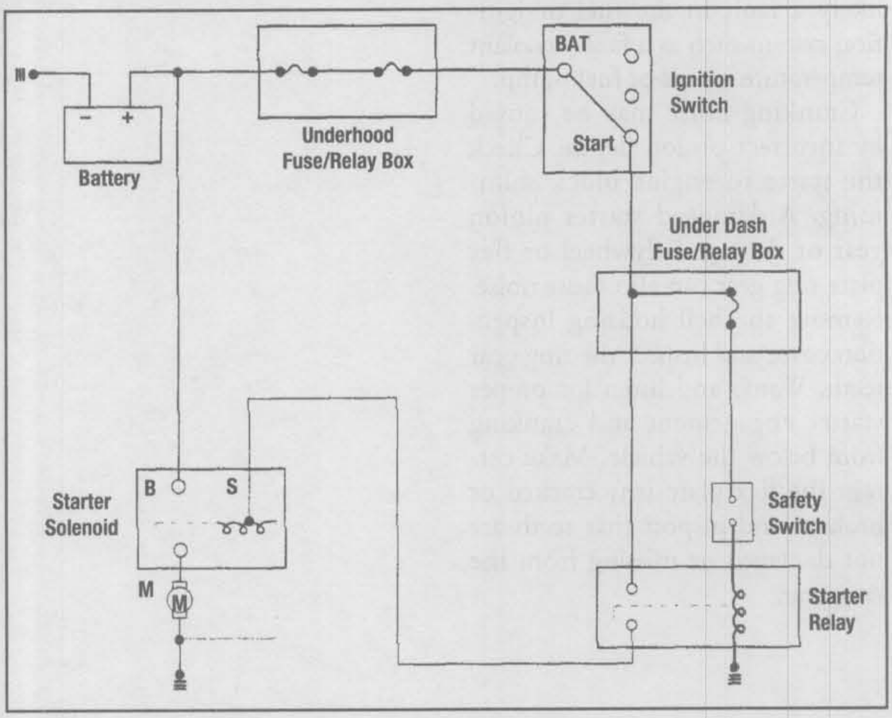
Starter Accessories, Controls and Wiring

Perform tests on all high-current starter solenoids and relays by applying power to make certain they function. If they don't, use an ohmmeter to check for continuity of relay coils and for contact resistance. Replace any components that are out of spec.

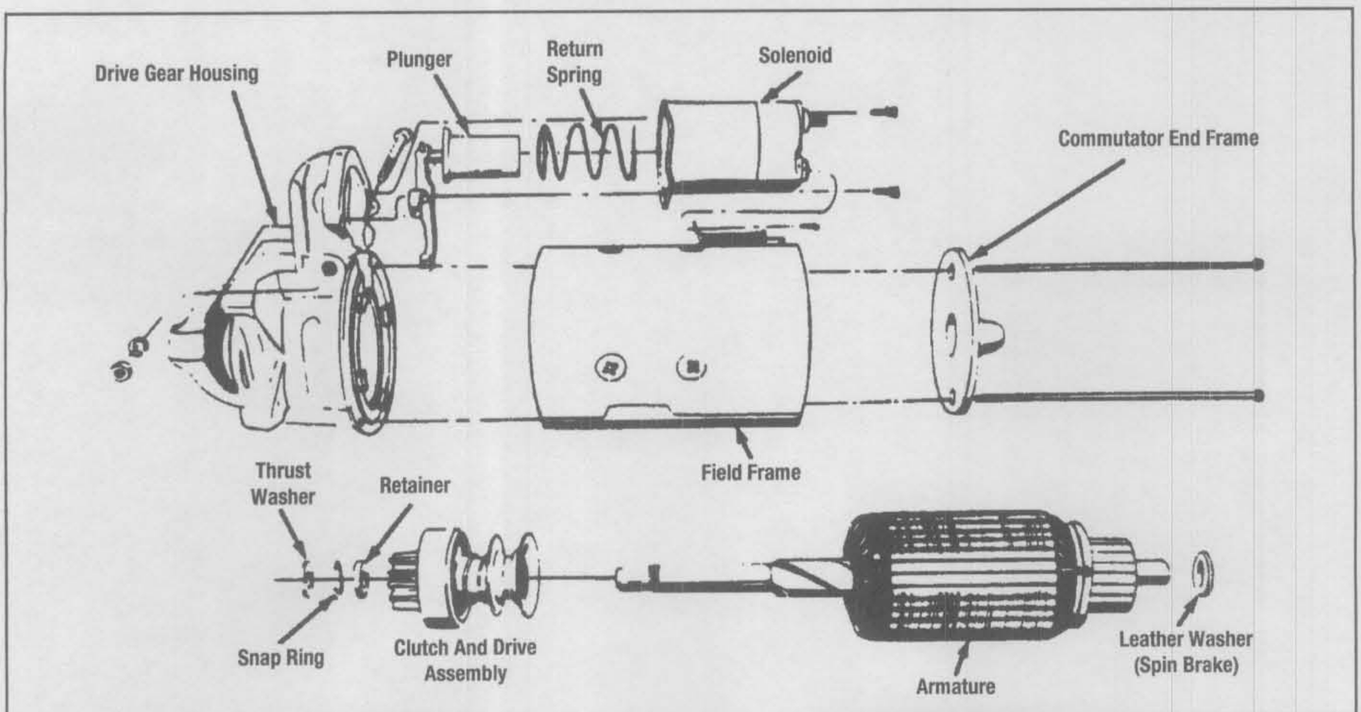
Check for proper operation of the control circuit by bypassing the starter relay at the relay box and hot-wiring the relay socket. If controlled by a module, see if the starter cranks the engine by providing a suitable ground for the high current relay. For vehicles with a theft deterrent system, be sure to check for faulty wiring in the steering column key circuit and the key itself, if the starter fails to operate.

Task B10: Differentiate between electrical and engine mechanical problems that cause a slow crank, no crank, extended cranking, or a cranking noise condition.

Slow cranking may be due to a discharged battery, or because of engine drag on the starter. A newly rebuilt engine may be somewhat more difficult to turn over if high compression pistons have been installed. Make sure that the starter is mounted securely and that the starter drive and flywheel or flexplate ring gear is not binding. If the starter pinion engages the



Typical starter system and control system circuits.



Exploded view of a typical starter and starter-mounted solenoid. *(Courtesy: GM Corp.)*

flywheel but the engine will not rotate, perhaps a thrown rod or a coolant or water hydraulic lock condition (due to a leaking head gasket or flood) is preventing the engine from turning over.

Extended cranking does not indicate a faulty starter but more likely a fault in the fuel or ignition system such as a faulty coolant temperature sensor or fuel pump.

Cranking noise may be caused by incorrect pinion depth. Check the starte to engine block shimming. A damaged starter pinion gear or damaged flywheel or flex plate ring gear can also cause noise. Remove the bell housing inspection cover and inspect the ring gear teeth. Watch and listen for proper starter engagement and cranking from below the vehicle. Make certain the flex plate isn't cracked or broken, and inspect that teeth are not damaged or missing from the ring gear.

Charging System Diagnosis And Repair

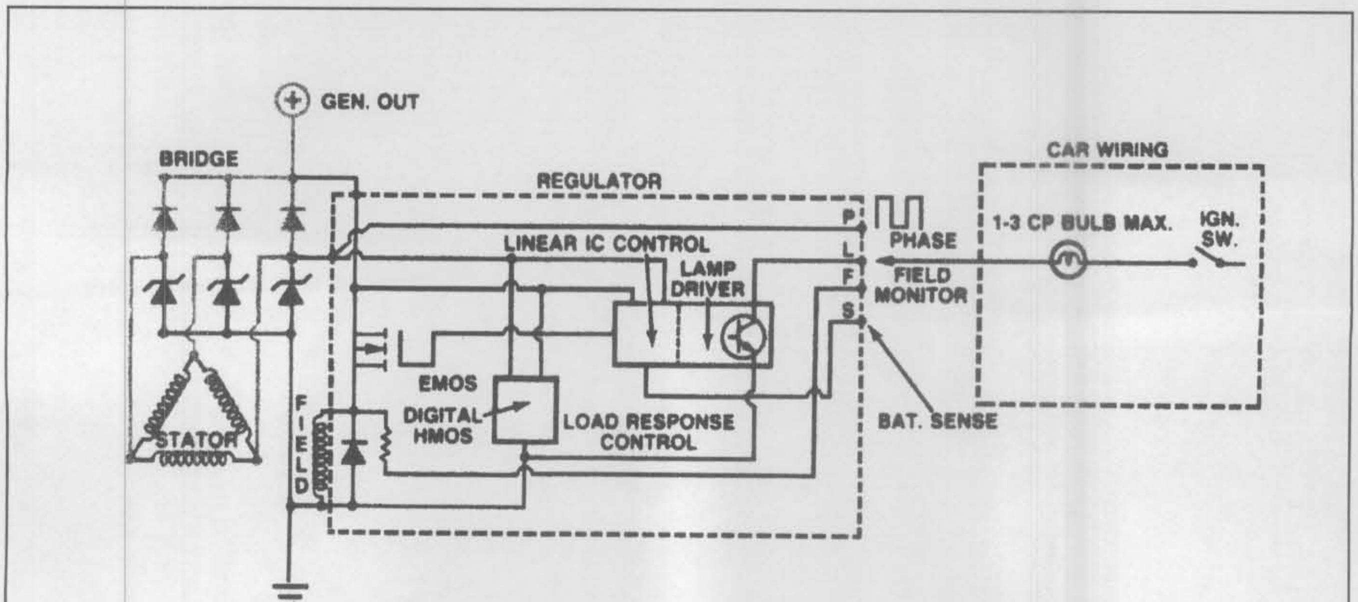
CHARGING SYSTEM OPERATION

When a conductor cuts across mag When an electrical conductor cuts across magnetic lines of force, voltage is induced in the conductor. This phenomenon is called electromagnetic induction, and is the basis of operation for both the automotive DC and the AC generator (better known as an alternator). To get current to flow, either the wire may be moved in the stationary magnetic field, or the field may move while the wire remains stationary. It makes no difference if the magnetic field is stationary and the conductor is moved, or if the conductor is stationary and the field is moved.

In a DC generator, loops of wire terminate at copper commutator bars located at one end of the rotating armature. Carbon brushes feed current into and from the armature. The DC generator's fields are wound around metal pole shoes which are stationary, similar to the way a starter motor is wired, and which surround the rotating armature. The use of large and heavy DC generators in passenger cars and light-duty trucks was discontinued in the 50's in favor of the AC generator (alternator).

Virtually all automotive vehicles now use AC generators (sometimes erroneously called alternators) which generate alternating current rather than the direct current needed by the vehicle's electrical system. AC generators are able to produce more output at lower RPMs, can spin faster without self-destruction, and are smaller and lighter in weight than DC generators. In the AC generator, stator windings are held stationary and generate the alternating current, whereas the field rotates. Hence, it's called a rotor, rather than an armature. The rotor is magnetized so it excites the stator windings as it rotates within the stator. The rotor has two slip rings by which carbon brushes pass current into and from the rotor's three individual sets of windings, each of which is 120 degrees apart. Applying relatively low current to the rotor creates a 3 phase magnetic field. Varying the rotor's field current, and therefore its magnetic strength, is what determines the alternator's output. The voltage regulator controls and limits the rotor's field strength by limiting field current.

The alternator characteristically is self-limiting in its amperage output. It also incorporates solid-state voltage control components and



Typical AC generator circuit. *(Courtesy: GM Corp.)*

employs multi-phase wiring for increased output. Carbon brushes carry limited amperage field current in and out of the rotor.

Because DC current is required to recharge the battery and to power the starting motor - and ultimately the vehicle - junction diodes are used In a "rectifier bridge" change 3-phase alternating current from the stator windings to direct current. Alternator output is relatively smooth but does have a slight ripple which may be observed on an oscilloscope.

The battery and the electrical system must be protected from excessive voltage. Voltage is regulated by a voltage regulator which varies the amount of field current flowing through the rotor. More field current results in higher voltage. Sensing voltage (sampling) to the regulator is fed from the vehicle to help with regulation of alternator output voltage. If sensing voltage is below the regulator setting, field current is increased to raise the charging voltage output (remember that it takes volts to push amps). Sensing voltage that is higher results in less field current fed to the rotor and reduced current output. As electrical loads are turned on or off, the sensing voltage drops or *rises*, and the regulator reacts accordingly to change field strength. Tjhus, alternator output (current, or amps) Immediately rises or falls according to demand.

Historically, voltage regulators on older vehicles were electromechanical (contact point) devices located externally from the alternator. Later on, alternators started using built-in solid-state voltage regulators. Regulators may also be located inside the alternator, but if an internal regulator malfunctions, the entire alternator unit is usually replaced., On many newer vehicles, the voltage regulating function is performed within the PCM/ECM to regulate the pulse width of the alternator's field (rotor winding) strength.

CHARGING SYSTEM MONITORING

An alternator with field current applied is harder to spin than one that has no field current applied. That means that energy that could be used to turn the drive wheels has to be diverted to the alternator, and that means reduced fuel economy. To improve fuel economy and reduce the strain on the alternator, many models use a current clamp mounted around one of the battery cables to constantly monitor the charge rate returning to the battery. This constant monitoring allows the ECM to continually adjust the field strength and maintain the most efficient charge rate for both the vehicle's electrical needs and the engine's fuel efficiency needs.

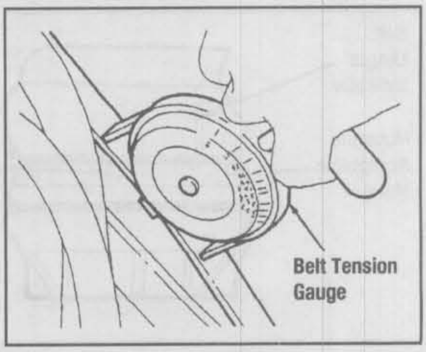
Task C1: Diagnose charging system problems that cause, a no charge, a low charge, or an overcharge condition; determine needed repairs.

CHARGING SYSTEM TESTING

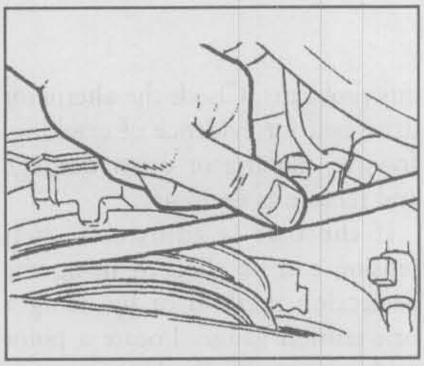
A charging system can malfunction in several ways: there can be no charging, low charging or overcharging conditions. A no charging or low charging condition can be caused by a broken or slipping alternator drive belt, defective voltage regulator, defective diodes or stator windings, an open alternator field circuit, excessive resistance or an open in the wiring between the alternator and battery, and sulfated battery plates.

Overcharging can be caused by a defective voltage regulator, a shorted-to-ground field wire, a faulty sensing circuit wire, or a battery that is internally shorted.

A system that is not charging or undercharging is usually indicated by a discharged battery that does not have enough power to operate the starter or causes the starter to crank slowly, dim headlights, a dash warning light that illuminates or flickers or an ammeter that indicates low charging. Overcharging is indicated by short light bulb life, and a battery that continually needs water.



Checking alternator belt tension with a belt tension gauge. *(Courtesy: Ford Motor Co.)*

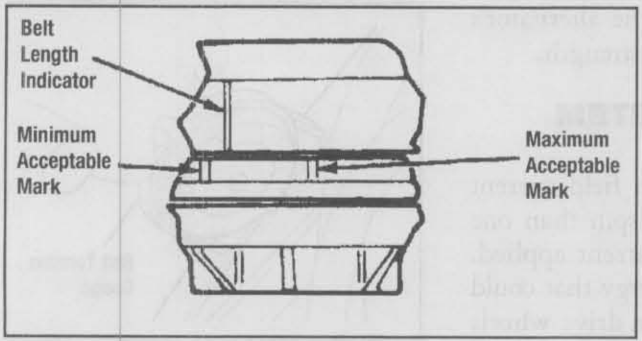


Checking alternator belt tension using the deflection method.

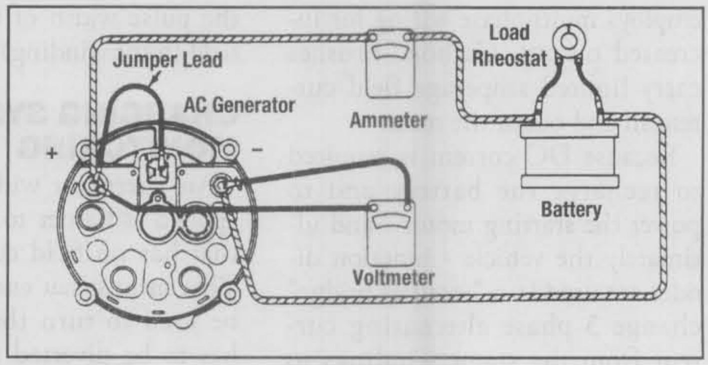
Undercharging can cause the battery plates to sulfate and can cause a high water content in the electrolyte, allowing the battery to freeze in cold weather. Over-charging can cause severe corrosion and warpage to the battery positive plates, excessive heat in the battery that can also damage plates, and electrolyte depletion, which can also cause premature deterioration of the active material in the battery plates.

Preliminary Inspection

Perform a visual inspection of the alternator to check for obvi-



Belt length indicator on an automatic belt tensioner.
(Courtesy: Ford Motor Co.)



To test maximum charging system output, connect a load rheostat to the battery. Then, connect a jumper wire to the 'FIELD' terminal and the battery terminal to provide a full field. Connect a voltmeter and ammeter to measure total output.

ous problems. Check the alternator drive belt for evidence of cracking, fraying, glazing or other damage and replace as necessary.

If the belt is adjustable, belt tension can be checked using the deflection method or by using a belt tension gauge. Locate a point midway between the longest accessible belt span. If using the deflection method, push on the belt with your finger using moderate pressure and measure the belt deflection. If you are using a belt tension gauge, position the gauge and measure the amount of force necessary to deflect the belt. Compare your reading with specification.

Belt tension should also be checked on vehicles with automatic belt tensioners to make sure the tensioner is functioning properly. Some automatic tensioners are equipped with belt length indicator and minimum and maximum acceptable marks, the theory being that if the correct length belt is installed on the engine and the mark is within range, belt tension is correct.

To adjust V-belt tension, loosen the adjuster pulley, or the alternator pivot and adjuster bolts, then use a suitable pry bar or breaker bar to carefully apply force to the pulley or alternator until the belt tension is correct. Do not damage the alternator mounting ears when using a pry bar. Tighten all fasteners and recheck belt tension. Make sure the alternator is mounted securely in its mounting brackets. Be sure to inspect and test the battery as outlined under battery service tasks B1 and B2, and perform a dynamic charging system test according to tasks C3 and C4 in this study guide. Check the condition of the battery cables and system wiring, making sure all connections are clean and tight.

Task C2: Inspect and reinstall/replace pulleys, tensioners and drive belts; adjust belts and check alignment.

A squealing noise from the engine compartment that increases in frequency as the engine rpm is raised can usually be attributed to a loose belt or a worn pulley or tensioner. In addition, pulley misalignment can cause the belt to enter the alternator pulley on an angle, also causing noise.

Check the alternator belt for wear and proper adjustment as described above. If replacement is necessary, loosen the adjuster pulley or alternator pivot and adjuster bolts, moving the pulley or alternator to eliminate belt tension, and remove the belt. It may be necessary to remove other accessory drive belts to gain access to the alternator belt.

Before removing a serpentine V-ribbed belt, make sure there is a belt routing diagram handy or draw one prior to belt removal to prevent installation problems. Use a socket or wrench to tilt the automatic tensioner away from the belt, and then remove the belt from the pulleys.

After the belt is removed, spin the pulley to determine if it wobbles or has any noticeable bearing wear. Inspect the pulleys for cracks, bent sidewalls, severe corrosion or other damage. Also check the alternator and its corresponding pulley(s) for improper alignment. Aligned pulleys reduce both pulley and belt wear, and vibration of engine components. If the belt pulleys are severely misaligned, look for improper positioning of the alternator or its corresponding pulley, improper fit of the pulley or shaft, or incorrect components installed.

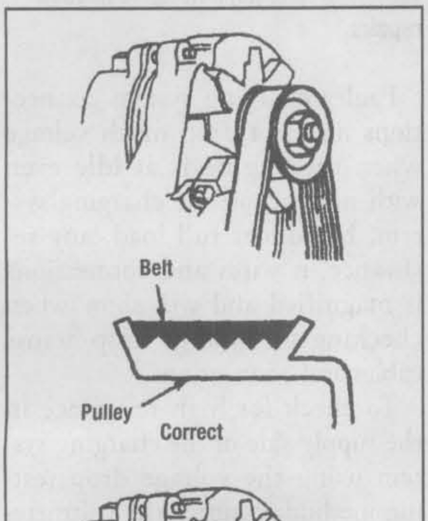
Newer style serpentine belts can be difficult to assess for wear because they hold up well even after extended mileage. Cracks and chafing may not show up on the belt. To check these belts, use a special serpentine belt wear gauge provided by belt manufacturers to check for wear of the ribs.

When installing a new belt, make sure it is correctly positioned in its pulley grooves and is properly routed.

Adjust the belt tension as required. Replacing the tensioner and pulley(s) may be a good idea if the vehicle has seen many miles (100,000 miles or more). Check the OE specs for the recommended replacement interval of belts and tensioners.

Task C3: Perform charging system voltage output test; determine needed repairs.

To perform a 3-point charging system test, place the voltmeter on the proper scale for battery voltage. Connect the red lead to the positive battery terminal and the black lead to the negative battery terminal. With the ignition off, note the battery open-circuit voltage. Start the engine and raise the rpm to about 1500-2000 rpm. With no extra loads applied to the electrical system, observe the voltage at the battery terminals. The reading should be approximately 2 volts higher than open-circuit voltage if the charging system is working properly. Be sure to consult the appropriate service specification. Generally speaking, charging system voltage should read between 13.8V and 14.5 volts.



Make sure V-ribbed belts are properly seated in the pulley grooves. One revolution of the engine with the belt incorrectly seated can damage the belt. *(Courtesy: Ford Motor Co.)*

Task C4: Perform charging system current output test; determine needed repairs.

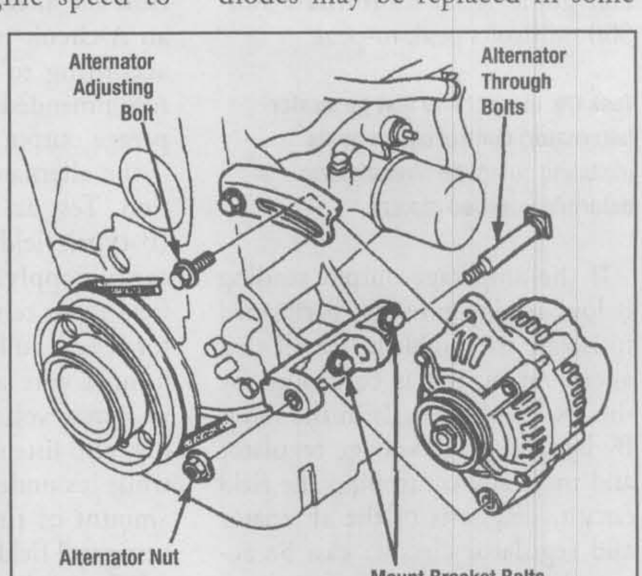
Connect an inductive amperage pickup clamp to the alternator output lead to check the alternator's output. Connect the pickup to a charging system analyzer or to a multimeter. A charging system analyzer is recommended because it will place a calibrated load on the charging system to test for full output without overloading the alternator.

If no analyzer is available, use a Volt-Amp load tester with a carbon pile load device, but do not overstress the alternator by placing a maximum load on it any longer than necessary.

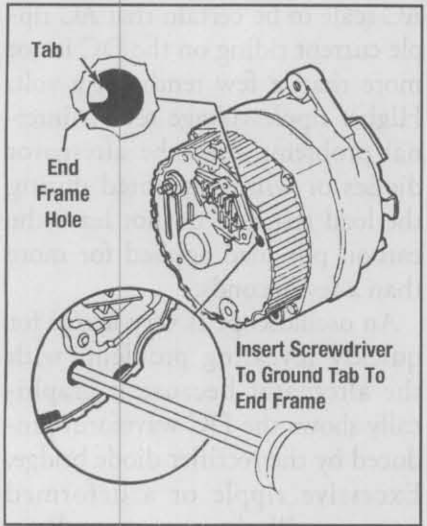
Increase the engine speed to about 2000-2500 rpm and use the carbon pile to place a load across the battery terminals. Increase the load until maximum rated output amperage is produced by the alternator and make certain output voltage is within specs. If voltage drops off early, check for wiring and other problems. Switch your voltmeter to the AC scale to be certain that AC ripple current riding on the DC is not more than a few tenths of a volt. Higher ripple voltage reveals internal problems with the alternator diodes or windings noted during the load test, but do not leave the carbon pile load applied for more than a few seconds.

An oscilloscope is very useful for quickly revealing problems with the alternator because it graphically shows the DC waveform produced by the rectifier diode bridge. Excessive ripple or a deformed pattern will show up as voltage spikes or dropouts caused by weak, shorted or open diodes. Dropouts or spikes in the DC waveform (see image) would also likely indicate one or more failed diodes.

This alternator condition can affect other electrical devices on board, especially sensitive electronics, or even cause component failures. Excessive amounts of AC ripple can also cause drivability issues and interfere with a control module's ability to understand a sensor input. Audible alternator noise or electrical noise on the vehicle radio may or may not be apparent if the alternator has faulty diodes. Faulty diodes may be replaced in some



Typical alternator mounting. *(Courtesy: Honda Motor Co.)*



This alternator may be tested for full field strength by grounding a tab showing through the rear window of the housing. Many other vehicles, however, require jumping techniques. The hook-up varies, so always consult the service manual for proper service procedures.

alternators, but from a time and labor perspective, replacing the entire alternator may be the best all around choice.

Whenever testing alternators, be sure to refer to the voltage and current specifications for the vehicle you are testing. If no specification for AC ripple is listed, a good general guide is no more than 300-500 millivolts peak-to-peak.

Task C5: Inspect and test generator (alternator) control components including computers/regulators; determine needed repairs.

If the amperage output reading is low, testing must be performed to isolate the problem. Recall that alternator output is controlled by the DC field strength in the rotor. By bypassing the voltage regulator and manually controlling the field circuit, diagnosis of the alternator and regulator circuits can be accomplished.

Full-Fielding the Alternator

Full-fielding involves by-passing the voltage regulator to test the alternator for it's ability to provide full output. How to check the alternator's maximum output depends on the type of field circuit wiring employed in the unit.

If the charging circuit is of the "A-type", the field (rotor) circuit is externally grounded AFTER the alternator by external regulation, possibly within the PCM. In such cases, with the key on, engine off (KOEO), you will find voltage on both of the field terminals (input and output) of the alternator.

If the charging system uses a "B-type" charging circuit, field current is controlled BEFORE the alternator (the positive side of the field circuit) by controlling it on the feed side of the rotor; the ground side of the field is grounded (internally) in the alternator.

Before full-fielding a charging circuit to test the alternator, refer to the service manual to determine the type of alternator circuit used, and how regulation is accomplished. In late model vehicles, a scan tool with bi-directional control features may be used to full field the alternator. Otherwise, for an A-circuit test, ground the field according to the manufacturer's recommended procedure. Full amperage output should be indicated if the alternator is in good condition. Test an internally-grounded (B-type) field circuit by momentarily supplying 12 volts to the field input terminal of the alternator. Use a full fielding device or a jumper wire and watch for a rise in system voltage. While full fielding, also listen for alternator noises while it's under full load. Keep the amount of time the alternator is being full fielded to a minimum.

When full-fielding the alternator, make sure all lights and accessories are turned off. Set engine rpm to no more than 1500-2000 rpm as needed to get system voltage; do not allow engine RPM to rise to the point that output voltage exceeds 15 volts. If the alternator voltage rises with engine RPM and produces rated amperage only when full-fielded, then the internal or external regulator circuit or component is out of adjustment, or (if PCM field regulated) the PCM is defective. If the alternator cannot produce full voltage and amperage to specs when full fielded, the rotor or stator windings, brushes, slip rings or the diode bridge may be defective. An oscilloscope can help to pinpoint internal problems.

Task C6: Perform charging circuit voltage drop tests; determine needed repairs.

Faulty charging system connections may not drop much voltage when the engine is at idle even with no load on the charging system, but under full load, any resistance in wires and connections is magnified and will show when checking for voltage drop across cables and connections.

To check for high resistance in the supply side of the charging system using the voltage drop testing method, connect the voltmeter negative lead to the positive battery post. Connect the positive lead to the alternator B+ (output) terminal. Run the engine at 2000 rpm with all electrical loads applied and read for voltage drop in the cable and connections. Compare this with manufacturer specifications. Normally, positive side voltage drop should not exceed 0.2 volts.

To check for high resistance in the ground side of the system using this method, connect the voltmeter negative lead to the negative battery cable post. Connect the positive lead to the alternator ground point (usually the alternator bracket). Run the engine under electrical load as above, and read the voltage drop in the negative cables and mechanical connections. Compare with manufacturer's specifications. Normally, ground side voltage drop should not exceed 0.1 volt.

Task C7: Inspect and repair, or replace connectors and wires of charging system circuits.

Visually inspect wires and cables for chafing, wear or corrosion. Check connectors for corrosion or overheating (burnt condition). Perform voltage and continuity checks at the regulator harness plug. Make sure the regulator has the proper sensor voltage supply from the vehicle harness and that the wires connecting the regulator and the alternator are in good condition. A faulty sensor connection at the alternator can cause erratic charging voltage and over stress the alternator. Because the alternator cannot "self-induce" (kick-start) the field circuit without initial input voltage from the battery, in some vehicles a burned out charge indicator lamp on the dash may cause a failure of the alternator to "self excite", thus preventing the alternator from being fielded. A parallel resistor across the lamp is used in some "idiot light" circuits to avoid this simple yet elusive charging system fault. A loose sensor wire connection at the alternator may overheat and burn causing the charging system to fluctuate and wreak havoc with the vehicle's electrical system. Look for such problems if the vehicle owner complains that the dash lights get intermittently brighter and dimmer at night. A loose battery connection can cause the same symptoms and even cause other components to fail from overvoltage.

Added loads such as high wattage sub-woofer systems may cause premature alternator failure (brushes) or even burnt wiring, if not properly matched to the vehicle's electrical system. A high-power-handling capacitor may be used to smooth out power supply drops and spikes caused by strong bass demands of high power audio systems, and help to save the alternator from premature destruction (if it is not overtaxed for wattage to begin with).

If found, repair or replace any faulty connections or wires at the alternator or battery. Be sure to solder and use heat shrink tubing whenever repairing or splicing wires to keep weather out. The use of "emergency" replacement bolt-on battery post clamps is not recommended. The better option is to replace the entire battery cable for a lasting repair.

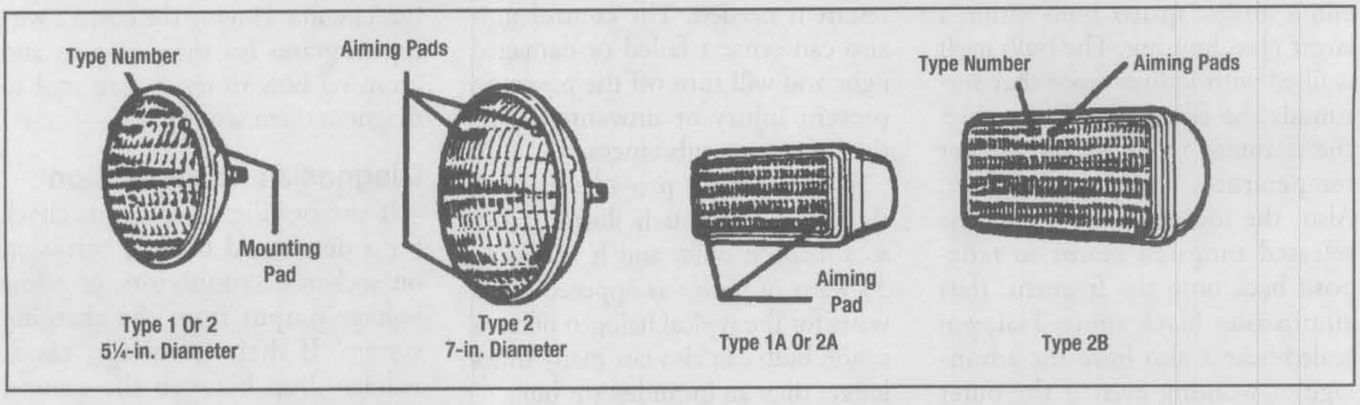
Task 8: Remove, inspect, and replace generator (alternator).

Disconnect the negative battery cable. Label and disconnect the wires from the alternator. Remove the alternator drive belt. Loosen the alternator mounting bolts. Support the alternator and remove the mounting bolts and alternator from the vehicle.

Place the replacement alternator in position and install the mounting bolts. Tighten the bolts or leave them loose at this time if they are also used to set belt tension. Install the alternator drive belt according to the underhood diagram and adjust the belt tension as required. Connect the alternator wiring and reconnect the negative battery cable. Check the charging system for correct operation.

Notes

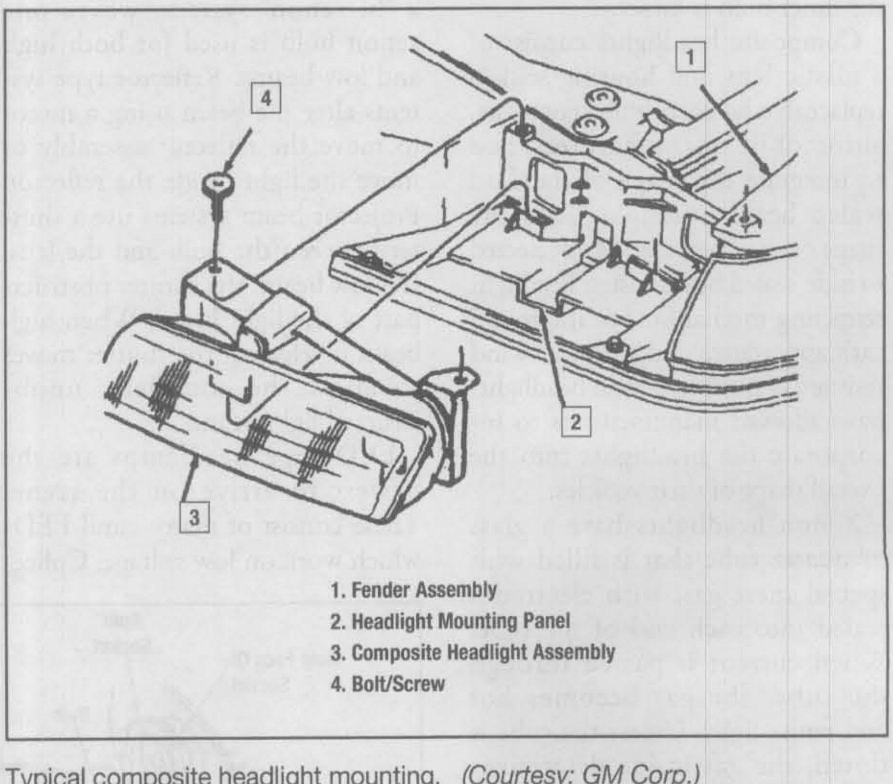
Lighting Systems Diagnosis And Repair



Types of sealed beam headlights.

Today's vehicles rely heavily on multiplexing their lighting systems under control of the body control module (BCM). Before performing any lighting system service, be sure to check for vehicle service bulletins. Also study the service information and wiring diagrams in the respective service manual to determine how the lighting systems are activated. If they are MUX controlled learn to use and rely on a quality scan tool to assist you in finding electrical problems in lighting systems. Be aware that certain lighting systems may be controlled by other vehicle circuits, and know how they inter-relate.

Task D1: Diagnose the cause of brighter than normal, intermittent, dim, continuous or no operation of exterior lighting; determine needed repairs.



Typical composite headlight mounting. *(Courtesy: GM Corp.)*

Headlights

There are four types of headlights in use on vehicles today: replacing the familiar sealed beam filament type lamps are halogen sealed beams, the composite halogen sealed beam headlights, High Intensity Discharge (HID) headlights (also known as xenon headlights, and LED headlamps).

The older style sealed-beam light comes in different sizes, shapes and intended purposes. They consisted of a low and/or high beam electrical filament, two or three spade-type electrical terminals, a glass housing/reflector and glass front lens. All of the oxygen is removed from the inside of a conventional sealed-beam and replaced with argon gas to prevent the tungsten filament from oxidizing and burning out. Even so, the heating of the filament in a conventional sealed-beam causes atoms of the tungsten to be released from the filament and deposited on the glass, creating black spots that reduce the light output.

An improvement over this type of lamp was realized with the introduction of halogen sealed-beam lamps. Halogen sealed-beams contain a smaller quartz bulb within a larger glass housing. The bulb itself is filled with iodine vapor that surrounds the filament. This enables the filament to withstand higher temperatures and burn brighter. Also, the iodine vapor causes the released tungsten atoms to redeposit back onto the filament, thus eliminating black spots. Halogen sealed-beams also have the advantage of working even if the outer lens is cracked or broken, as long as the inner bulb is intact.

Composite headlights consist of a plastic lens and housing with a replaceable halogen bulb. For years, automobile manufacturers had to integrate the shape of standard sealed beam headlights into the shape of their vehicles. Many elected to hide sealed beams using headlight retracting mechanisms to improve a car's appearance and to lower wind resistance, but composite headlights have allowed manufacturers to incorporate the headlights into the overall shape of their vehicles.

Xenon headlights have a glass or quartz tube that is filled with special inert gas, with electrodes sealed into each end of the tube. When current is passed through the tube, the gas becomes hot and emits light. Unless the tube is tinted, the gas inside determines the color of the light. Neon emits red light; mercury emits blue light. The xenon gas in HID headlights emits virtually full spectrum white light, so objects illuminated by it appear almost the same color as they do in daylight.

Xenon headlights operate on high voltage alternating current. Each light assembly includes the light, a ballast unit and a starter, sometimes called the ignition unit. The ballast contains the DC/AC power converter and a control unit that regulates AC voltage output, provides gradual warm-up of the light after cold-start, and an instant restart if needed. The control unit also can sense a failed or damaged light and will turn off the power to prevent injury or unwanted ignition of foreign substances.

A xenon bulb provides two to three times as much illumination as a halogen bulb, and it uses only 35 watts of power as opposed to 55 watts for the typical halogen bulb. A xenon bulb can also last many times longer than an incandescent bulb.

Some vehicles are equipped with a 'bi-xenon' system, where one xenon bulb is used for both high and low beams. Reflector type systems alter the beam using a motor to move the reflector assembly or move the light inside the reflector. Projector beam systems use a shutter between the bulb and the lens. On low beam, the shutter obstructs part of the light beam. When high beam is selected, the shutter moves to allow the complete, unobstructed light beam.

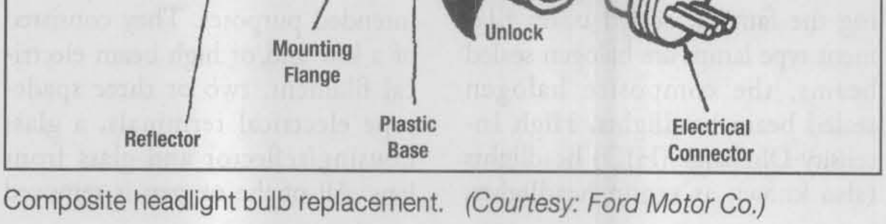
LED type headlamps are the newest to arrive on the scene. These consist of many samll LEDs which work on low voltage. Collectively they emit a greater amount of light for little comparative energy, and they last thousands of hours.

On today's vehicles much of the lighting systems used are controlled by the BCM over multiplexed CAN bus circuits. Having the correct wiring diagrams for these circuits and knowing how to use a scan tool to diagnose them is a must.

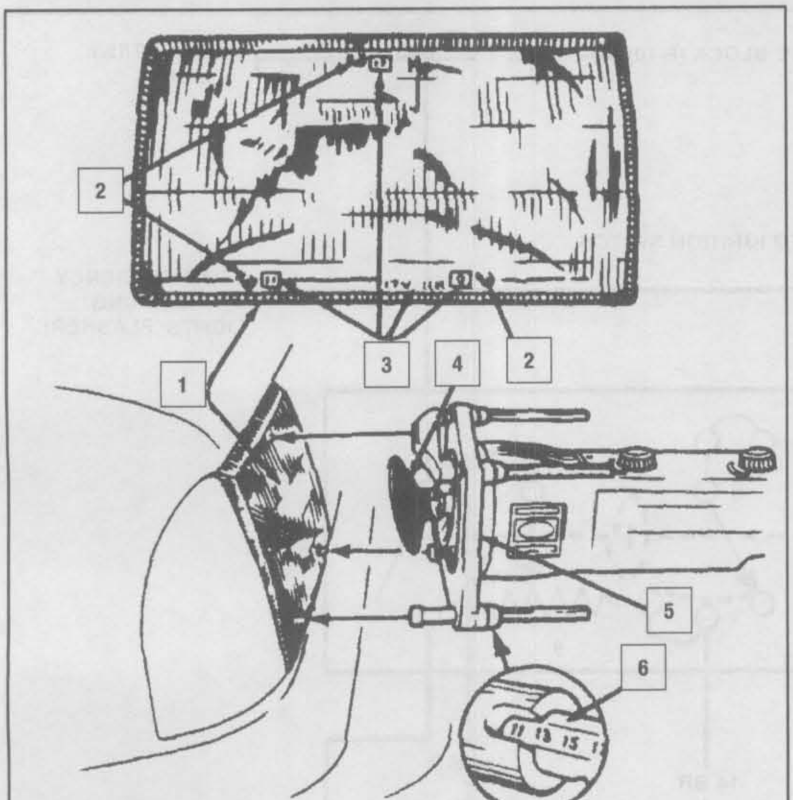
Diagnosis and inspection

If the headlights are dim, check for a discharged battery, corrosion on sockets or connectors, or a low voltage output from the charging system. If there is voltage, check voltage drop between the ground terminal and a good ground. If the voltage drop is less than 0.1 volt, replace the bulb. If voltage drop is greater than 0.1 volt, repair the cause of the high resistance and check voltage drop again. If the headlights operate intermittently, check for loose connection(s) or wiring, poor ground(s), intermittent short circuit and a defective headlight switch. If the headlights are inoperative but the parking lights work, check for open or shorted wiring, loose connections, or a defective dimmer switch or headlight switch.

If the headlights are brighter than normal, inspect the charging

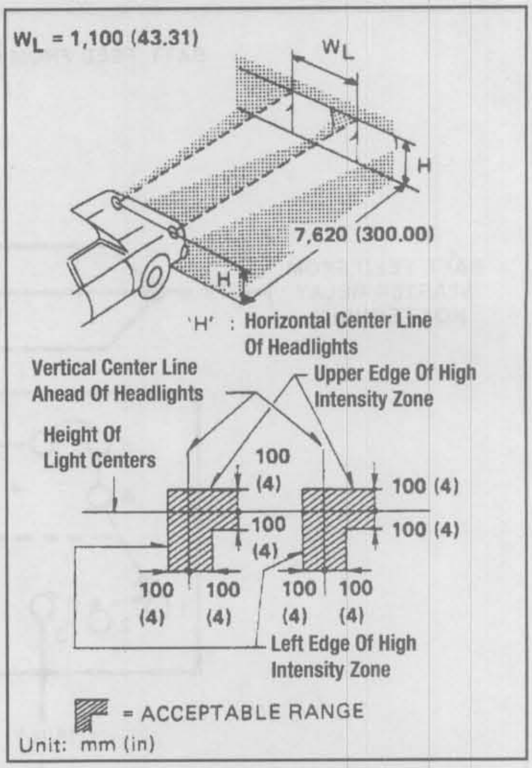


Composite headlight bulb replacement. *(Courtesy: Ford Motor Co.)*



1. COMPOSITE HEADLIGHT
2. HEADLIGHT AIMING PADS
3. ADJUSTMENT (ADAPTOR) SETTINGS FOUND NEAR PAD OR ON AN OUTSIDE EDGE
4. UNIVERSAL HEADLIGHT AIMER WITH ARTICULATING SUCTION CUP INSTALLED
5. UNIVERSAL ADAPTER ASSEMBLY
6. ADJUSTMENT ROD SETTINGS

Aiming a composite headlight with a mechanical headlight aimer. *(Courtesy: GM Corp.)*



An example of headlight adjustment range specifications. *(Courtesy: Nissan Motor Co., Ltd.)*

system for an overcharging condition and repair as necessary. This problem can lead to premature headlight failure.

If all headlights are not working, check the fuse or circuit breaker, headlight relay and the headlight switch. If only one headlight is not working, check for voltage at the light connector. If there is voltage, check voltage drop between the ground terminal and a good ground. If the voltage drop is less than 0.1 volt, replace the bulb. If voltage drop is greater than 0.1 volt, repair the cause of the high resistance and check voltage drop again.

Checking High Intensity Discharge (HID) Headlights

WARNING: HID headlights operate at high voltage and the ballast gets very hot during operation. Use caution to avoid electrical shock and burns.

When HID headlights are switched on you should be able to hear the ballast attempting to ignite the bulb. Have an assistant turn on the headlights while you listen for ignition near the headlight in question. If an ignition attempt can be heard but the bulb does not light, try exchanging the bulb with a known good unit.

If the ballast does not ignite the bulb, check the fuse. If the fuse is OK, check the voltage supply to the ballast through the relay and wiring back through the headlight switch. If there is adequate voltage and ground supplied to the ballast and a known-good bulb is in place but the light does not illuminate, replace the ballast.

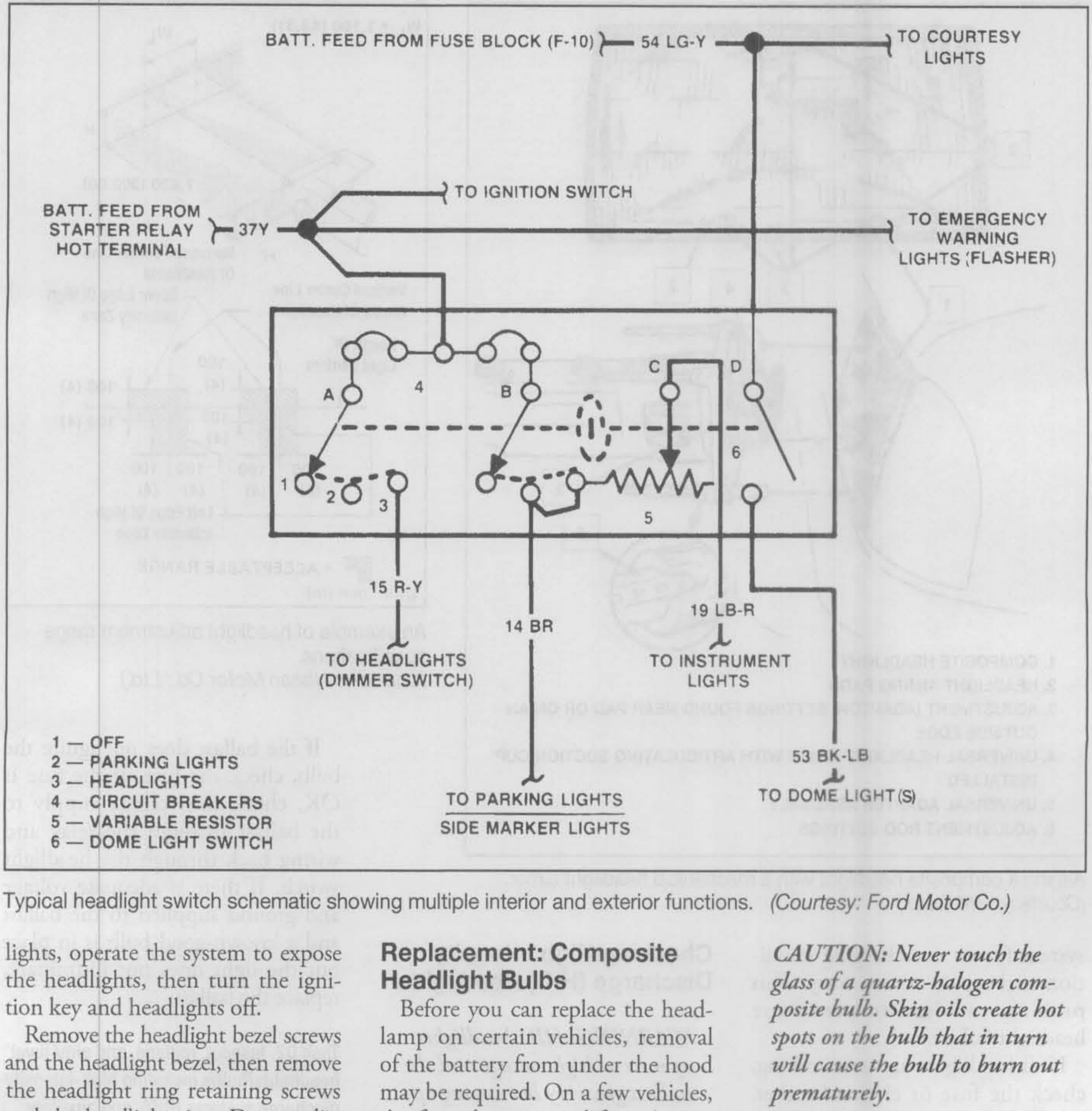
Task D2: Inspect, replace, and aim/ level headlights/bulbs including high-intensity discharge systems (HID), and auxiliary lights (fog lights/driving lights).

Inspection

Check headlights for holes or cracking from stone damage, discoloration of plastic covers due to weather and aging, and for proper headlamp aiming.

Replacement: Sealed Beam Headlights

Turn the headlights off. If equipped with retractable head-



Typical headlight switch schematic showing multiple interior and exterior functions. *(Courtesy: Ford Motor Co.)*

lights, operate the system to expose the headlights, then turn the ignition key and headlights off.

Remove the headlight bezel screws and the headlight bezel, then remove the headlight ring retaining screws and the headlight ring. Do not disturb the headlight adjusting screws.

Pull out the sealed beam and disconnect the electrical connector. Examine the connector for corrosion or other damage and repair as necessary. Plug the connector onto the new sealed beam and install the headlight into its housing, aligning the tabs and notches.

Install the headlight retaining ring and headlight bezel. Check headlight operation and headlight aim.

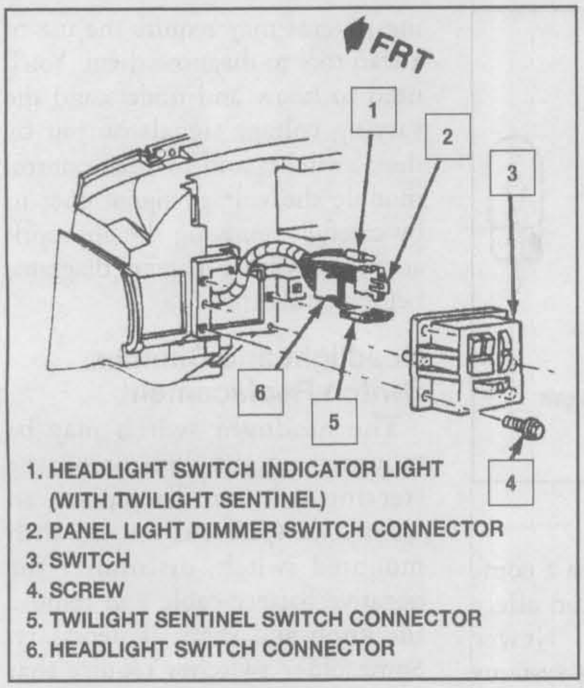
Replacement: Composite Headlight Bulbs

Before you can replace the headlamp on certain vehicles, removal of the battery from under the hood may be required. On a few vehicles, the front bumper and facia (example: Chevy Malibu) assembly must first be removed to gain access to the headlamp for replacement.

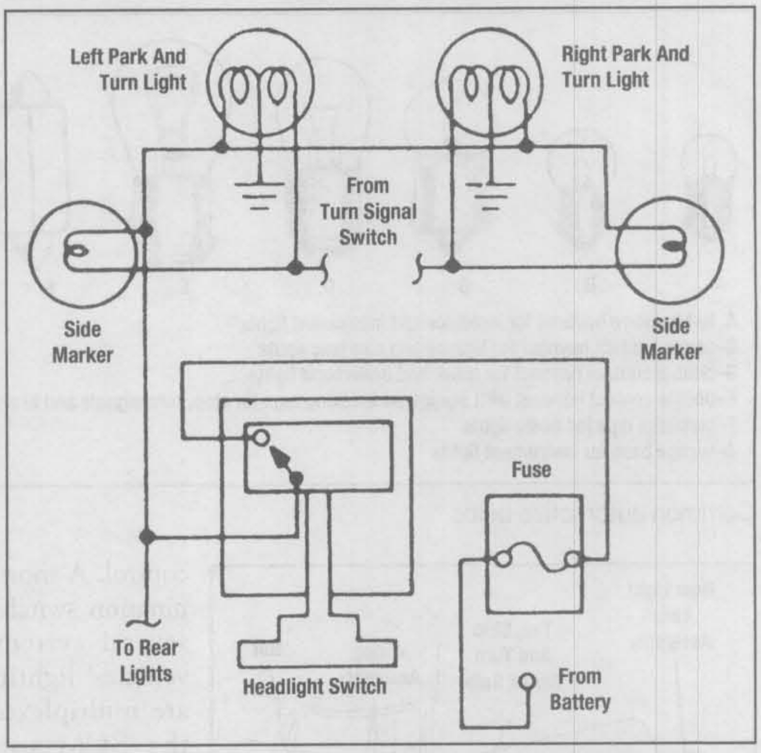
Turn off the headlights, disconnect the electrical connector from the bulb, and rotate the retaining ring to remove it from the bulb base. Pull the bulb straight back and out of the composite headlight assembly and disconnect the wiring harness from the bulb.

CAUTION: Never touch the glass of a quartz-halogen composite bulb. Skin oils create hot spots on the bulb that in turn will cause the bulb to burn out prematurely.

Inspect the sealing "O" ring on the new bulb for damage. Hold the bulb by its plastic base and firmly insert it into the composite headlight housing socket. Install the retaining ring onto the bulb base and rotate the ring to secure the bulb in position. Connect the electrical connector. Check headlight operation. If removed, reinstall the vehicle battery or front clip.



Instrument panel mounted headlight switch installation. *(Courtesy: GM Corp.)*



The side marker lights, taillights, parking lights and the license plate lights are usually located on the same circuit.

HID Headlight Bulbs

The procedure for bulb replacement varies according to manufacturer; always consult the vehicle service manual. Observe the same precautions when handling HID xenon bulbs as you would for halogen bulbs. Wear clean latex gloves, or only handle the bulb by the base.

Headlight Aiming

The headlights should be properly aimed to obtain maximum road illumination and to avoid blinding the drivers of oncoming vehicles. Headlight aim should be checked on vehicles with sealed beam headlights every time a headlight is replaced.

The aiming process consists of horizontally and vertically adjusting each headlight unit via adjusting screws, which move the retaining screws or headlight housing in the appropriate direction. Some headlight housings contain a bubble level to facilitate the alignment process.

Headlight aim can be checked using an aiming screen, a mechanical aimer or a photo-electric aimer. Follow the aiming equipment manufacturer's instructions.

Some vehicles, most often those with HID headlights, have an automatic headlight leveling system. This system automatically keeps the headlights adjusted for optimal road illumination and to prevent glare that could blind the drivers of oncoming vehicles.

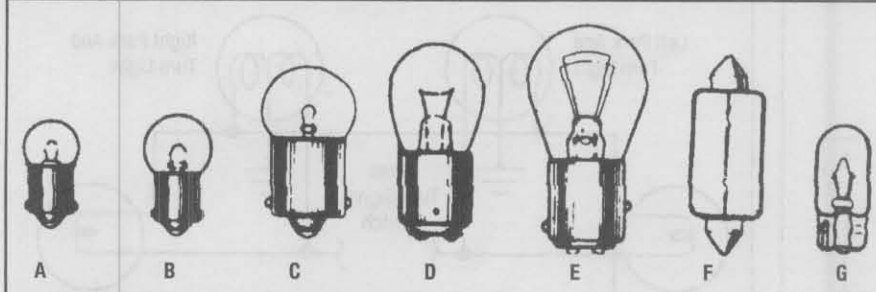
Sensors detect changes in vehicle attitude caused by passenger or cargo weight and vehicle acceleration or braking. These signals are sent to an electronic control unit that in turn commands electric motors to adjust the headlight angle. It may be necessary to check for trouble codes or perform scan tool diagnostic tests to verify the automatic adjustment function is working. Any manual adjustment must be done in accordance with the OEM service procedures.

Task D3: Inspect, test, and repair or replace switches, relays, bulbs, LEDs, sockets, connectors, wires, and controllers of exterior lighting.

Headlights and Dimmer Switches

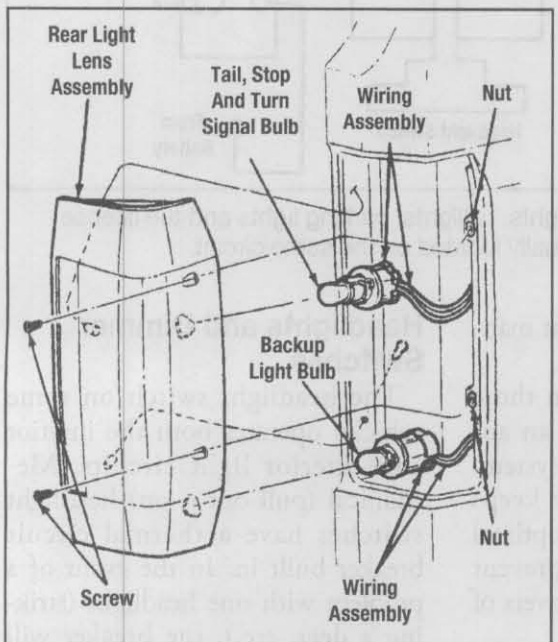
The headlight switch on some vehicles operates both the interior and exterior light circuits. Mechanical (pull out = on) headlight switches have a thermal circuit breaker built in. In the event of a problem with one headlight (striking a deer, etc.), the breaker will cause the headlights to flash on and off as the breaker overheats, which the automakers have deemed safer than having a fuse blow and losing all lights on a dark night. Some models that do not use this thermal breaker design deploy separate fuses for right and left sides, or for both high and low beams to avoid losing all lights.

Vehicles with electronic clusters usually have a dual switch function. The first detent overrides the cluster intensity reduction with the lights on. Cluster brightening for twilight operation is done at the first detent, while the second detent would dim the cluster for normal



A, B–Miniature bayonet for indicator and instrument lights
C–single contact bayonet for license and courtesy lights
D–double contact bayonet for trunk and underhood lights
E–double contact bayonet with staggered indexing lugs for stop, turn signals and brake lights
F–cartridge type for dome lights
G–wedge base for instrument lights

Common automotive bulbs.



These bulbs are accessed by removing the taillight lens. *(Courtesy: Ford Motor Co.)*

night-time operation.

Newer vehicles have enhanced headlight control abilities, such as daytime running lights, twilight sentinels, delayed off, integrated fog and driving lights.

The dimmer switch is a dual-position (double throw) switch used to choose between high and low beams. This is usually combined with the turn signal switch and is called a combination switch. The combination switch stalk may include other auxiliary system functions such as wipers and cruise control. A short in a combination switch can affect several systems. Newer vehicles' lighting systems are multiplexed through the BCM using MUX switches to control lighting functions.

Headlight and Dimmer Switch Testing

Check for voltage at the voltage input side of the headlight switch. If there is no voltage, check the power circuit to the switch. If there is voltage going into the switch, turn on the switch and check for voltage at the output terminal. If there is no power coming from the switch, it should be replaced.

Turn the headlights on and check for power at the dimmer switch terminals. There should be power at the switch when the headlights are on high or low beam. If there is only power at one terminal, the switch should be replaced. If activating the momentary-on high beams works but normal high beam operation does not work, the combination switch is defective and must be replaced.

Testing of MUX controlled lighting systems may require the use of a scan tool to diagnose them. You'll need to know and understand the varying voltage signals output by these switches and to what control module the voltage signal goes to by carefully studying the appropriate vehicle wiring diagram diagrams before testing them.

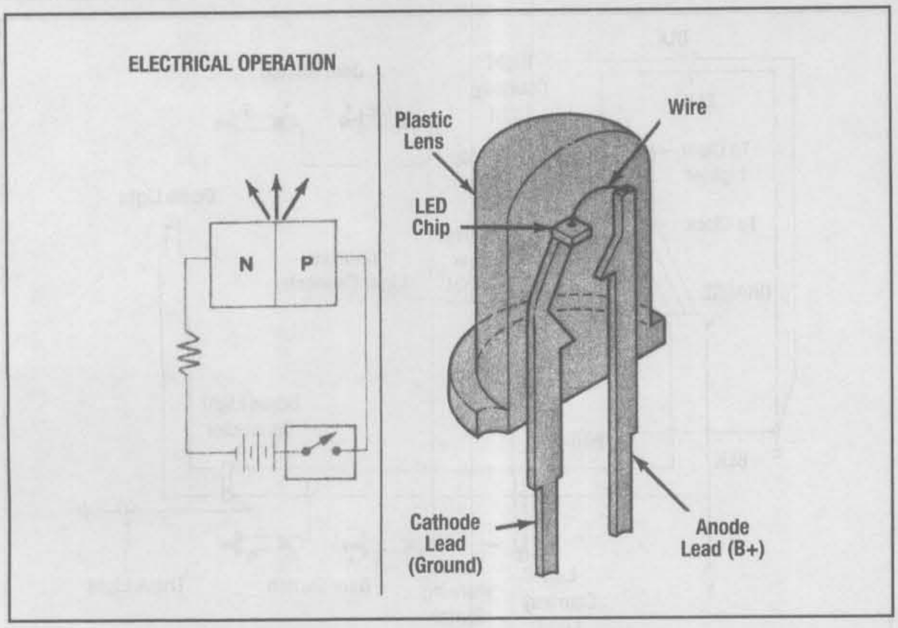
Headlight and Dimmer Switch Replacement

The headlight switch may be mounted on the dash or on the steering column. To replace an older style (pull out for on) dash mounted switch, disconnect the negative battery cable and remove the knob and shaft, if necessary. Some older switches require that a punch or similar tool be inserted into a hole, or that a spring loaded button be pushed to release the knob and shaft. Remove the necessary instrument panel trim as required. Remove the retaining screws or collar from the switch and remove the switch from the instrument panel from the rear. Disconnect the wires or wiring harness from the switch. To install, reverse the removal procedure. After installation, check for proper operation.

To remove column mounted headlight switches and dimmer switches, disconnect the negative battery cable and remove the necessary steering column shrouding. Consult the vehicle service manual for specific instructions, as steering wheel removal may be required.

> ***WARNING:** If the vehicle is equipped with an inflatable supplemental restraint system (air bag), disarm the system according to the factory procedure before removing the steering wheel. Failure to do so may result in personal injury.*

Remove the switch fasteners which hold the combination switch in



Functional view of an LED light. *(Courtesy: Ford Motor Co.)*

place. Disconnect the electrical multi-pin connector(s) from the switch, and remove it. To install, reverse the removal procedure. After installation, check for proper operation.

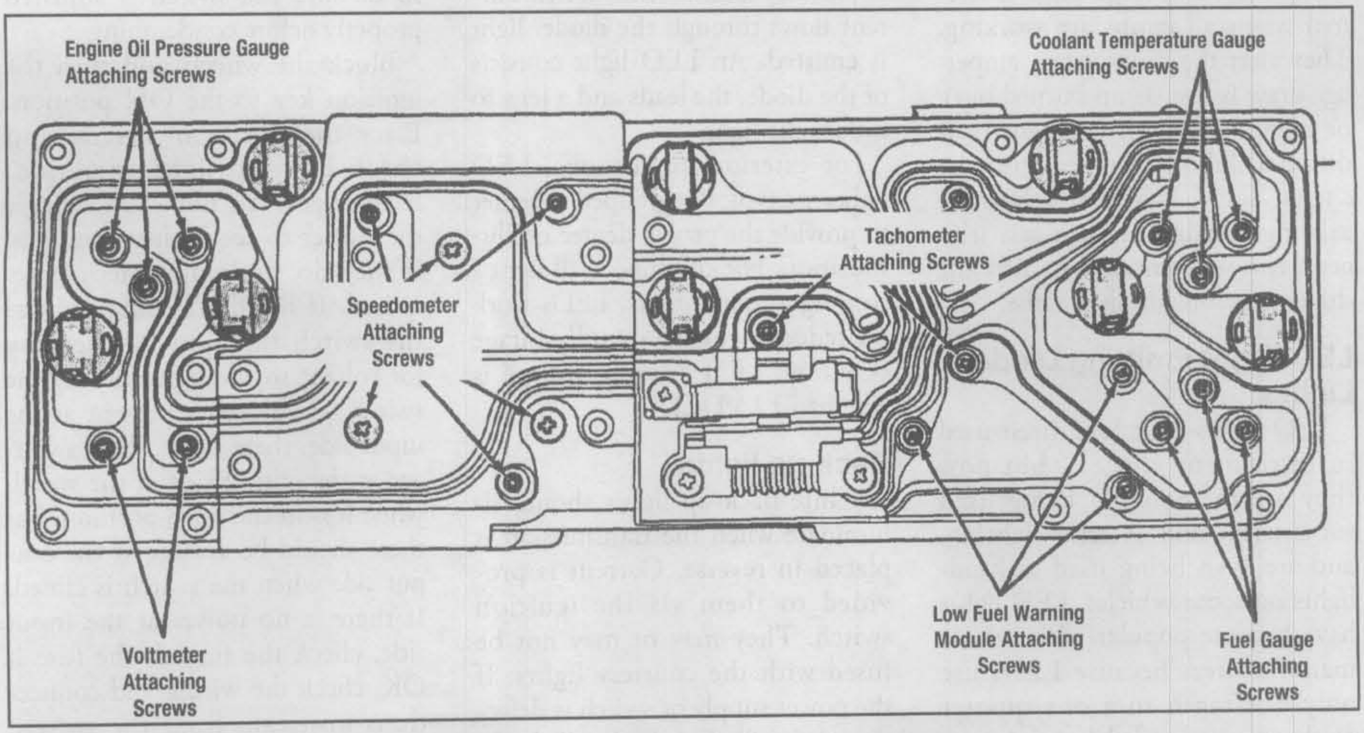
Lamp replacement

If marker lights, tail lights or stop/turn lights need replacement, remove the lens from the light or remove the bulb socket from the rear of the housing. You may have to remove plastic shrouding to gain access to these lamps. Some smaller lamps pull straight out of the their sockets. Inspect the socket and wiring for damage and corrosion.

The taillights, side markers, license plate light, and front parking lights are likely on the same circuit. Their function is controlled by the headlight switch. When the headlight switch is pulled out to the first detent, or turned to the Parking Light position, the above mentioned lights illuminate but the headlights stay off. When the switch is moved to the Headlights position, the taillights, side markers, license plate light, and front parking lights illuminate along with the headlights. Some exterior lamps are amber in color rather than clear, or have tinted lenses.

Exterior Lamp Diagnosis

If only one light on a circuit is not working, for instance if one taillight is not working, visually check the bulb to see if the filament is broken or burned out. Single contact bulbs have only one filament and are found on lights that have only one function. Double contact bulbs have two filaments (wired in parallel) and are found on lights that have a dual function such as used for turn signals, brake lights, hazard lights along with the usual parking/marker lights. If filament damage is not obvious, check

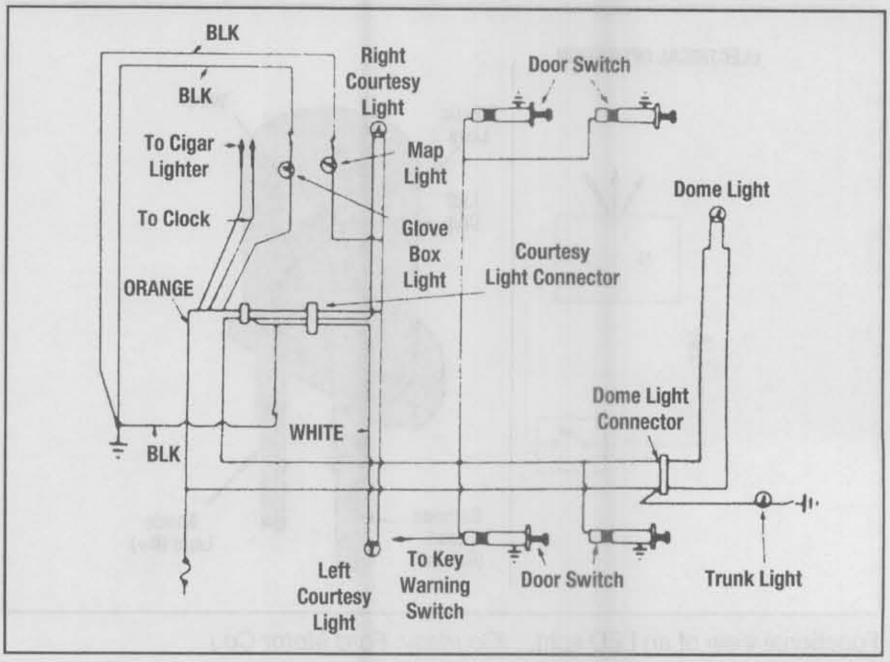


Typical printed circuit.

the bulb's continuity using an ohmmeter; if there is continuity, the bulb is good. If an open circuit is indicated, the bulb should be replaced. If the bulb and socket are good, perform voltage drop tests on the circuit to determine if there's an open in the wiring upstream from the light, and if there is good ground contact being made.

If more than one light in a circuit is not working, for example if both taillights and the license plate lights are not working, chances are that all bulbs did not blow at the same time. Rather, there is most likely a problem in the part of the circuit that is common to all the parallel-wired lights. Check the fuse and power supply and if these are good, check for an open in the circuit between the switch and the connector in the circuit that divides power to the individual lights. Check for a good ground as well.

Modern vehicles have so-called "lamp-out" modules on board which monitor exterior lamp functions in various lighting circuits. These modules are programmed to know what amperage draw is normal when all lamps are working. They alert the driver when amperage draw is less (lamp burned out), or more than normal, as when additional lights are wired into the circuit. Trailer lights wired into the existing lighting harness can trigger a lamp-out module to alert the driver that something is amiss.



The interior light circuit usually includes the courtesy lights, engine compartment and trunk lights.

LED (Light Emitting Diode) Lights

LED lights have long been used in instrument clusters, but now they are increasingly being used for interior and exterior lighting, and are even being used as headlights on some vehicles. LED lights have become popular with vehicle manufacturers because LEDs use only one-tenth to a one quarter of the power needed by an incandescent bulb; plus, they last up to 10,000 hours compared to as little as 300 hours of life for a conventional bulb. Because LEDs have no filament, they are not affected by shock or vibration.

A light emitting diode is made of special semiconductor material that is partially translucent. When current flows through the diode, light is emitted. An LED light consists of the diode, the leads and a lens to diffuse the light.

For exterior applications, LED lights are typically grouped together to provide the proper degree of illumination. For combined tail light / stop light applications, LEDs work on reduced voltage or full voltage (Caution: LED working voltage is less than 12 VDC).

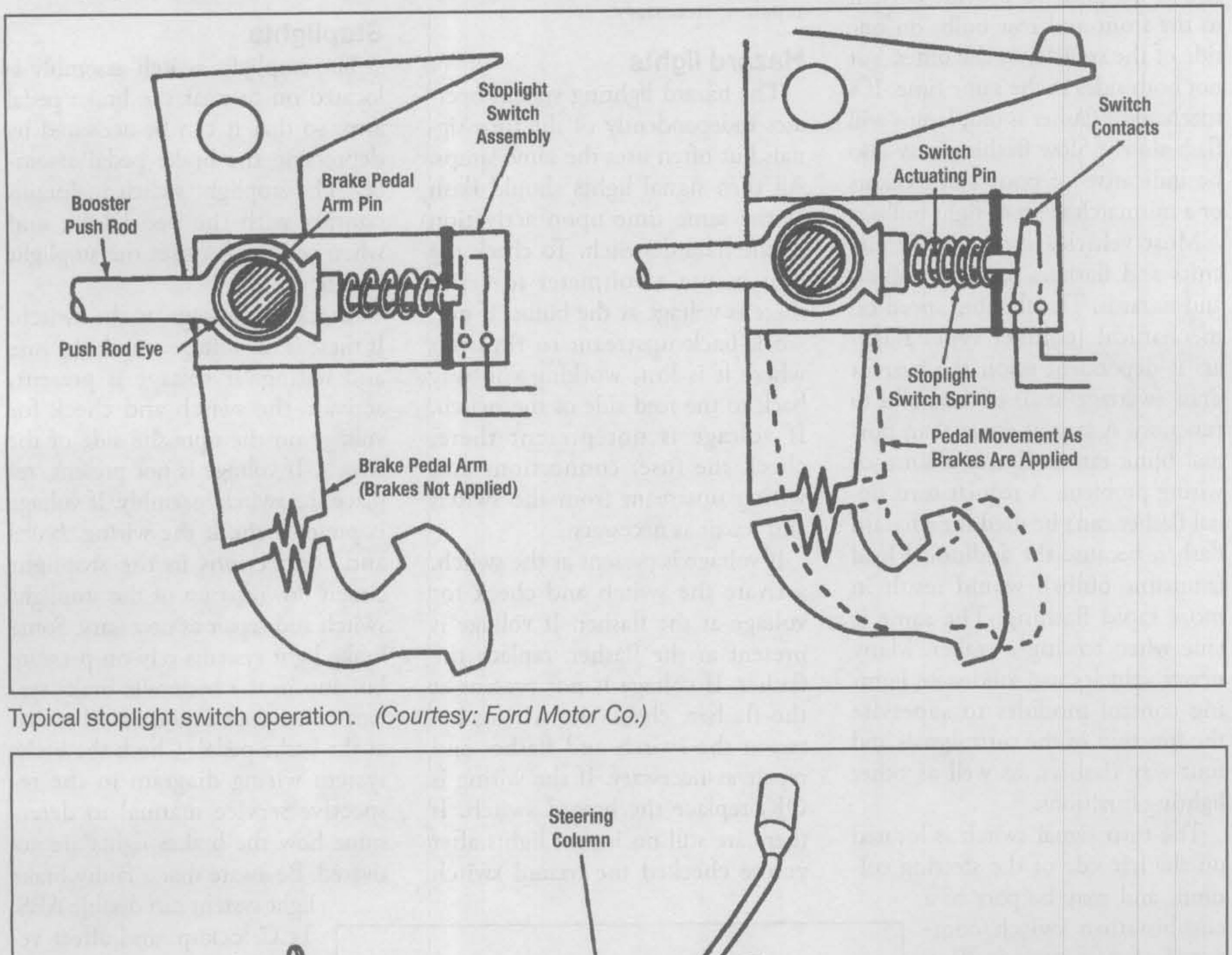
Back-up lights

White back-up lights should illuminate when the transmission is placed in reverse. Current is provided to them via the ignition switch. They may or may not be fused with the courtesy lights. If the power supply or switch is defective, that will affect both (all) back-up lights.

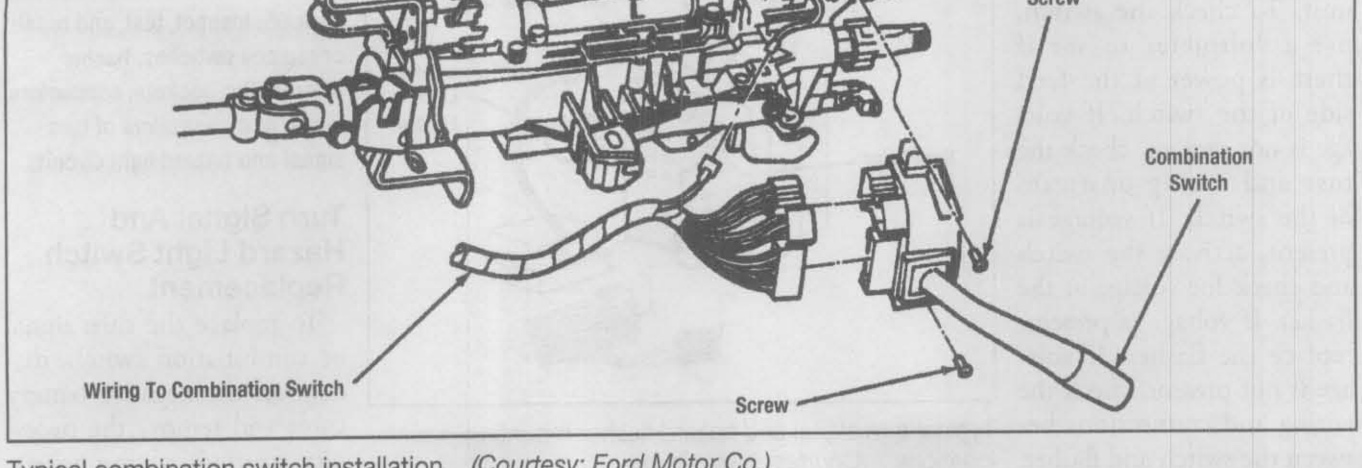
The back-up light switch can be located either on the transmission, in which case a shift fork closes the switch, or on the transmission shift linkage where the linkage closes the switch. An adjustment may be possible on linkage mounted switches, so be sure the switch is adjusted properly before condemning it.

Block the wheels and turn the ignition key to the ON position. Place the shifter in reverse and check back-up light operation. If the lights do not work, wiggle the shifter to see If they come on. if they do, and adjustment is required. If the don't come on, test the switch function by checking for voltage to the input side of the switch. If voltage is present at the input side, there should be no voltage at the output side of the switch when it is in the open position, but there should be voltage at the output side when the switch is closed. If there is no power at the input side, check the fuse. If the fuse is OK, check the wiring and connections upstream from the switch. If there is power at the input side, but there is no voltage at the output side when the switch is closed, jump the switch to activate the back up lights. If they come on, replace the switch. If there are still no back-up lights after you've checked the switch, check the wiring, bulbs and connections in the circuit downstream from the switch and repair as necessary.

On modern vehicles, backup light function may be MUX controlled, and using a scan tool will be required to trace whether a backup light command is being issued by the BCM, and if so, where the signal is being lost.



Typical stoplight switch operation. *(Courtesy: Ford Motor Co.)*



Typical combination switch installation. *(Courtesy: Ford Motor Co.)*

Task D4: Diagnose the cause of turn signal and/or hazard light, system malfunctions; determine needed repairs.

Directional signals

The directional (turn) signal system is designed to provide current to the front and rear bulbs on one side of the vehicle, or the other, but not both sides at the same time. If a mechanical flasher is old, lamps will flash slowly. Slow flashing may also be indicative of poor connections or a mismatched set of light bulbs.

Most vehicles use separate circuits and flashers for turn signals and hazards. The flashing speed on mechanical (contact type) flashers is dependent upon the current draw (wattage/load) of the bulbs to function. A lazy or faster than normal blink rate indicates a lamp or wiring problem. A regular turn signal flasher can't be used for a hazard flasher, because the additional load (multiple bulbs), would result in more rapid flashing. The same is true when towing a trailer. Many newer vehicles use solid-state lighting control modules to supervise the function of the turn signals and four-way flashers, as well as other lighting functions.

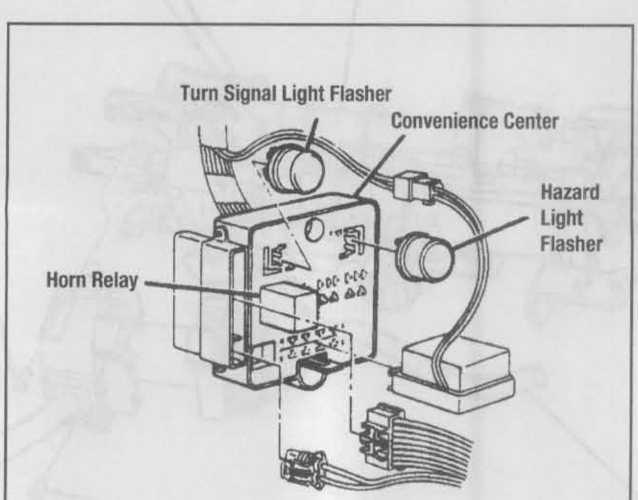
The turn signal switch is located on the left side of the steering column, and may be part of a combination switch composed of a variety of off/on switches packaged as a single unit. To check the switch, use a voltmeter to see if there is power at the feed side of the switch. If voltage is not present, check the fuse and wiring upstream of the switch. If voltage is present, activate the switch and check for voltage at the flasher. If voltage is present, replace the flasher. If voltage is not present, check the wiring and connections between the switch and flasher. If the wiring is OK, replace the turn signal switch.

If there still is no turn signal operation, check the wiring, bulbs and connections in the circuit downstream from the flasher and repair as necessary.

Hazard lights

The hazard lighting system operates independently of the turn signals but often uses the same lamps. All turn signal lights should flash at the same time upon activation of the hazard switch. To check the switch, use a voltmeter to verify there is voltage at the bulbs. If not, work back upstream to find out where it is lost, working you way back to the feed side of the switch. If voltage is not present there, check the fuse, connections and wiring upstream from the switch and repair as necessary.

If voltage is present at the switch, activate the switch and check for voltage at the flasher. If voltage is present at the flasher, replace the flasher. If voltage is not present at the flasher, check the wiring between the switch and flasher and repair as necessary. If the wiring is OK, replace the hazard switch. If there are still no hazard lights after you've checked the hazard switch and flasher operation, check the wiring, bulbs and connections in the circuit downstream from the flasher and repair as necessary. For multiplexed systems, use your scan tool to locate the problem.



Typical turn signal and hazard flasher mounting locations. *(Courtesy: GM Corp.)*

Stoplights

The stoplight switch assembly is located on or near the brake pedal arm, so that it can be activated by depressing the brake pedal assembly. The stoplight switch maintains contact with the pedal arm, and when activated, closes the stoplight circuit.

Check for voltage at the switch. If there is no voltage, check the fuse and wiring. If voltage is present, activate the switch and check for voltage on the opposite side of the switch. If voltage is not present, replace the switch assembly. If voltage is present, check the wiring, bulbs and connections in the stoplight circuit downstream of the stoplight switch and repair as necessary. Some brake light systems rely on pressure buildup in the hydraulic brake system rather than a mechanical switch at the barke pedal. Check the brake system wiring diagram in the respective service manual to determine how the brakes lights are activated. Be aware that a faulty brake light system can disable ABS, TCC lockup, and affect vehicle MPG.

Task D5: Inspect, test, and repair or replace switches, flasher units, bulbs, sockets, connectors, wires, and controllers of turn signal and hazard light circuits.

Turn Signal And Hazard Light Switch Replacement

To replace the turn signal or combination switch, disconnect the negative battery cable and remove the necessary steering column covers.

Consult the vehicle service manual for specific instructions because removal of the steering wheel may be required.

WARNING: If the vehicle is equipped with an inflatable supplemental restraint system (air bag), disarm the system according to the factory procedure before removing the steering wheel. Failure to do so may result in personal injury.

Disconnect the steering column wiring connector from the switch. Remove the switch fasteners and switch assembly from the column. Installation is the reverse of removal. Check for proper switch operation.

Hazard switches can be located on the steering column or dash, depending on the application, and can be removed by disconnecting the wiring connector and removing the switch from its mounting. On some vehicles, certain dash or steering column components must be removed to gain access to the hazard switch and/or its connection.

Flasher locations vary from vehicle to vehicle. Usually, they're located behind the dash, however, some flasher units for the turn signal and hazard flasher systems are located on the fuse panel itself. They can be removed by simply pulling them straight out from the plug or panel. When installing a new flasher, line up the metal contacts with the slots in the plug, and then press the flasher firmly into place.

When replacing older style (example #57) lamps used for park or stop/turn signaling, be aware that these bulbs have index (bayonet) pins on each side in order to locate and secure the bulb properly into the socket. Twist the bulb counterclockwise while pushing down slightly to unlock the pins, and remove the bulb from the socket. Single contact bulbs have pins opposite to each other, while dual filament/two contact bulbs have staggered bayonet pins. Be careful not to force a double bayonet pin bulb into a socket incorrectly.

Since LEDs have no filament, the most significant difference between inspecting or testing LED lighting systems and conventional systems is that a visual inspection will not determine whether the light is good. If an LED light assembly does not illuminate, check the light for an open circuit, inspect the wiring and make sure there is power to the light, just as you would for a conventional incandescent light. Again, however, LEDs do not work at normal vehicle system voltage, so jumping 12 volts to them will destroy them.

Replacing a single LED is not normally done. In the event of a single LED failure within an assembly, the entire lamp assembly will likely need to be replaced.

Task D6: Diagnose the cause of intermittent, dim, continuous or no operation of interior lighting (courtesy, dome, map, vanity, cargo, trunk, and hood); determine needed repairs.

Interior lights

The interior lights are also operated by the headlight switch or a separate interior light switch. Switches placed at the door control the current flow, and often operate a multi-function module that turns on the lights when any door is opened.

The interior light circuit may also include courtesy lights. The courtesy light circuits may in turn contain the glove box, map, trunk and engine compartment light circuits, among others. Separate switches are used to control each of the lights.

Open and close the vehicle doors separately, noting light operation. If the interior lights don't illuminate when one of the doors is opened, suspect a defective or damaged door switch. If all interior lights are inoperative, check for a blown fuse. If the fuse is OK, suspect a defective master switch.

Task D7: Inspect, test, and repair or replace switches, relays, bulbs, sockets, connectors, wires, and controllers of interior lighting circuits (courtesy, dome, map, vanity, cargo, trunk, and hood).

If one or more interior lights are inoperative, remove the lens or socket assembly and check for power to the light. If there is power, replace the bulb assembly. If there is no power, check for a problem in the circuit such as a corroded light socket, damaged wire, poor connections, or ineffective ground and repair as necessary.

Task D8: Inspect, test and repair or replace trailer wiring harness, relays, connectors, and controllers.

Trailer lighting is not complex, yet can overdraw current in the host vehicle's electrical system if not properly wired. Lighting fuses or wiring may be overloaded unless relays or solid-state lighting modules are used to power trailer or RV lighting. Vehicle lamp-out modules will sense a problem and alert the driver if trailer wiring is improperly wired to a vehicle. Special modules can be installed which allow the vehicle lamp-out module to overlook the added load of trailer lighting.

Trailer wiring and connectors are exposed to the elements and can cause problems if not properly weather protected. Inspect for physical deterioration and chafing of wiring, and for corrosion of harness connections. LED equipped testers can be used to test for power at the vehicle's trailer connector for feeding trailer marker lights, brake lights and back-up lights.

Larger trailers or RVs will require that electric brakes be wired up and working properly, so check these circuits as well.

Pendulum-type electric brake controllers are typically located under the driver's side dash, and must be adjusted properly for safe electric brake application; be sure to read and follow the brake controller manufacturer's instructions when installing or adjusting controllers in the host vehicle.

Notes

Instrument Cluster And Driver Information Systems Diagnosis And Repair

Task E1: Diagnose the cause of intermittent, dim, no lights, continuous operation, or no brightness control of instrument lighting circuits; determine needed repairs.

Instrumentation

Instrument lighting enables the driver to see all functions on the dash, such as the speedometer, tachometer, gauges etc., when there is not enough natural light to do so.

Dash lights are often wedge-type push-in bulbs, which can be accessed from behind the dash. Special sockets that make contact with the printed circuit board are mounted into the board in back of the dash. The socket is removed by twisting it and releasing it from the board. The bulb comes out with the socket and can be replaced by pulling it straight out from the socket.

Besides instruments, other areas of the dash are illuminated when the park light switch is activated. These include heater and defroster controls, entertainment system controls, the hazard switch, heated seat controls, the rear window de-fog control switch, and so on. Additionally, door window and lock-unlock switches are Illuminated. Individual light failures can usually be attributed to a defective bulb. However, if the dash lighting is experiencing multiple failures on a consistent basis, the related circuit board should be checked for cracks, corrosion or loose connections causing an open to the particular lighting components (lamps or LEDs).

Task E2: Inspect, test, and repair or replace switches, relays, bulbs, LEDs, sockets, connectors, wires, and controllers of instrument lighting circuits.

If instrument lighting operates intermittently, inspect the instrument cluster circuit board. Disconnect the negative battery cable. Remove the screws securing the instrument cluster and rock it towards you, or remove it entirely. Inspect the printed circuit for cracks, corrosion or broken solder joints. Remove all bulb and socket assemblies from the board and check resistance of printed circuits according to the manufacturer's recommended procedures and specifications.

Sometimes a faulty circuit board or film with cracked solder joints can be repaired using a low wattage soldering iron and extreme care to avoid melting or lifting the wire trace from the circuit board or melting the film. Always be on the lookout for damaged wiring and poor connections. To install, reverse the removal procedure.

Instrument clusters and panels now use LEDs in place of conventional lamps. While LEDs tend to last the lifetime of the vehicle, sometimes one or more will work intermittently or quit working entirely. In such cases, the circuit board should be removed and inspected. The LED mounting position or socket should be checked for cracks or loose solder joints. Sometimes they can be repaired, as described above.

Task E3: Diagnose the cause of high, low, intermittent, or no readings on electronic instrument cluster gauges; determine needed repairs.

Digital Gauges

Automobile manufacturers today are making use of electronic instrument clusters with either digital readout instruments or analog instruments to provide drivers with all kinds of information - from fuel level, to the time of day. Digital readouts are easier for drivers to read and are less expensive than traditional mechanical gauges. Some vehicles continue to use electronically controlled analog instruments.

Several types of digital displays are being used with electronic instrumentation. These include LED (Light-Emitting Diode), LCD (Liquid-Crystal Display), VTF (Vacuum-Tube Fluorescent), and more.

LED displays, when used in automobiles, are usually yellow, but can be green. A typical LED requires about 35mA for each segment to light.

LCD displays are used to form numbers, letters or symbols. They consist of liquid sandwiched between two polarized sheets of glass. The liquid will permit light to pass through if a small voltage is applied.

VTF displays are very bright and are usually green. The electronics necessary for this type of instrument are very involved, and similar to those of a radio or TV.

Electronic instrument panels often operate using the same sending units (or sensors) as those used by the Powertrain Control Module to control fuel, air and engine emissions. A sending unit from a fuel tank may vary from 0 (zero) ohms (empty) to

100 ohms (full). Thus a digital dash using a 20-segment fuel level bar graph display would decrease one segment for every 5-ohm change. On the other hand, many sensors are essentially potentiometers supplied with a 5 volt reference signal and a ground path. Depending on the fuel level, coolant temperature (or whatever is being measured), the sensor will provide a return signal of somewhere between 0.5 and 4.5 volts to the Body Control Module (BCM).

The BCM or in some cases the instrument panel cluster (IPC) serves as a control module, getting its information from other sources on the buss network. Input Is received from many sources to help the driver be alerted if something is amiss. Inputs include such things as Door Ajar, Low Fuel, Alternator Failure, Low Oil Pressure, High Coolant Temperature, and so on. The BCM (or IPC) determines which of these conditions take priority and alerts the driver. For example a loss of oil pressure takes priority over a door ajar situation. The OEMs provide diagnostic trouble trees and scan tool Instructions for accessing and diagnosing BCM input data. Where applicable, the scan tool is used to test actuators as well, such as when diagnosing HVAC components (blower speed, blend door position, etc.) for proper operation. BCM inputs and outputs are networked over the vehicle's CAN and require a scan tool to monitor and diagnose them.

Follow the OEM trouble trees to check for proper operation from sending units to determine if the problem is located in the sender or wiring, or if the problem is in the instrument display. For example, if engine temperature is indicated as overheating, yet the coolant temperature sensor is outputting a signal of 2.5 volts (midrange), something is amiss and a code will set. The scan tool can help uncover the problem. Two or more sensors often share the same 5 volt reference signal and the same ground connection. If several instruments are faulty at once, this may be a clue as to where to inspect for faults. Diagnostic procedures vary according to vehicle make and model, so a vehicle service manual trouble trees should always be followed religiously.

The electronic instrument clusters on some vehicles have self-diagnostic capabilities. Some clusters include a diagnostic mode that displays information when there is a defect in the system, such as a short or open in a sending unit circuit. The cluster may have a self-test procedure that is enabled by pressing certain buttons simultaneously.

The Body Control Module (BCM) used in many systems today can perform diagnostic checks of the electronic instrument cluster. The BCM monitors specific functions and will store a DTC if any are found to be outside of preprogrammed parameters. DTCs can be retrieved using a scan tool connected to the DLC or on some vehicles may be read on a digital display on the instrument panel.

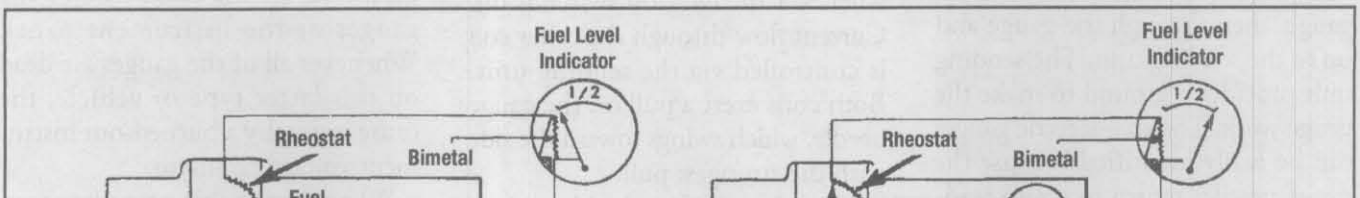
Once you have the DTCs that require diagnosis, refer to the appropriate service information to identify the systems and circuits that the DTCs represent. The diagnostic charts will describe the circuit and the fault that the code represents. follow the troubleshooting procedures and tests that must be performed to determine the cause of the malfunction.

Non-Electronic instruments

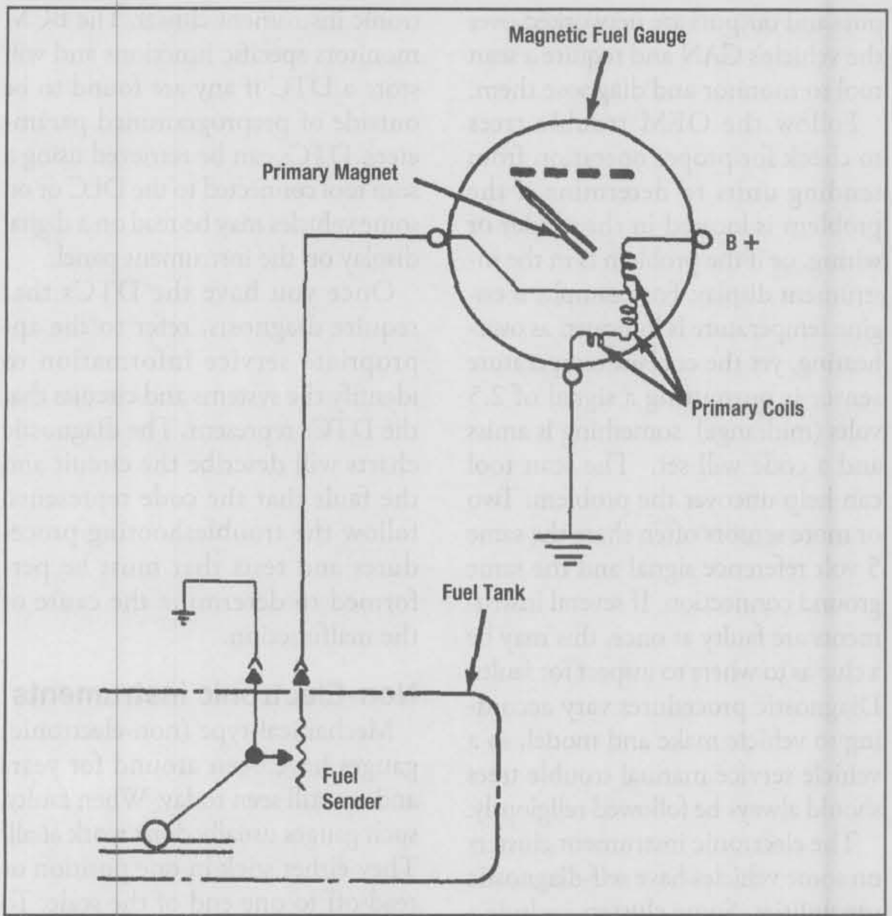
Mechanical-type (non-electronic) gauges have been around for years and are still seen today. When faulty, such gauges usually don't work at all. They either stick in one position or read off to one end of the scale. To diagnose gauge failures, we must first be able to recognize the different kinds of gauges used and understand how they work.

Bimetal Gauges

In all bimetal gauges, a fully-grounded sending unit will send the most current through the coil, and the bimetal strip will push the gauge needle to the high side of the gauge.



Electric fuel gauge operation. *(Courtesy: Ford Motor Co.)*



Magnetic fuel gauge schematic. *(Courtesy: Ford Motor Co.)*

If the sending unit is disconnected, there will be no current flow, and the gauge spring will move the needle to the low side of the scale.

Thermal-Electric Gauges

In thermal-electric gauge installations, electricity comes from the ignition switch to one side of the gauge, then through the gauge and on to the sending unit. The sending unit provides a ground to make the gauge work. Thermal-electric gauges can be easily identified because the gauge needles return to a zero reading when the ignition switch is off.

If the gauge drops completely to empty with the ignition off, it is most likely a thermal-electric gauge. Thermal-electric gauges pass current through a bimetal strip. One side of the strip heats faster than the other side, causing the strip to bend and move the pointer of the gauge.

Magnetic (Balanced Coil) Gauges

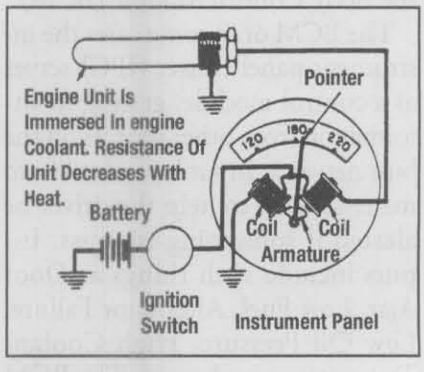
With magnetic gauges, tiny electromagnets are used to move the gauge needle. The electromagnets are made of two small coils of wire, one on each side of the gauge needle. One of the coils receives current whenever the ignition switch is on. Current flow through the other coil is controlled via the sending unit. Both coils exert a pull on the gauge needle, which swings toward the side with the strongest pull.

There is no spring inside a magnetic gauge. When the ignition switch is turned off, the gauge needle will stay in the same position, and not return to zero.

Some magnetic gauges are wired so that the gauge needle will move to the high end of the gauge when the sending unit is disconnected with the ignition switch on. These are usually fuel gauges. Other gauges, for temperature and oil, usually will go to the low side if the sending unit is disconnected.

In electromagnetic gauges, pointer movement is achieved by way of an electromagnet.

The resistance of the sensor varies with what it is measuring. This resistance determines the current flow through the empty or low side of the gauge to control pointer movement.



A thermistor controls the engine temperature gauge current. The sending unit must be immersed in coolant for proper operation.

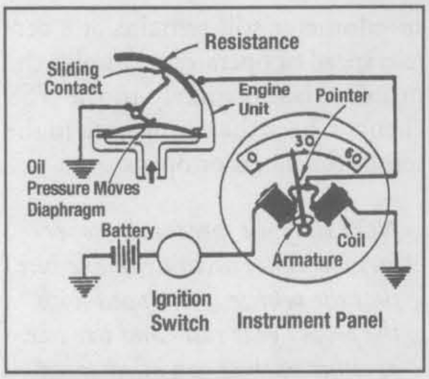
General Gauge Diagnosis

There exists a great amount of variability in each automaker's methods for testing and troubleshooting gauge systems.

For example, some automakers supply full battery current to the gauges. Others use a small instrument voltage regulator, usually mounted on the back side of the gauges or the instrument panel. Whenever all of the gauges are dead on this latter type of vehicle, the cause is usually a burned-out instrument voltage regulator.

When testing this type of system, extreme care must be used to avoid grounding any wires with the ignition switch on. If a hot gauge terminal is accidentally grounded, the instrument voltage regulator will burn out.

When testing gauges, it is a common practice to turn on the ignition switch and ground the wire at the sending unit to see if the gauge will



The oil pressure gauge operates in an analog manner, which means that it works continuously, but varies in the amount of current flow. The current flow is modulated by the sensor's variable resistance. Flow variations affect the coil's magnetic fields, and thus needle position is changed.

move. This is a dangerous practice. If the gauge is shorted, grounding the wire could burn out the instrument voltage regulator. It is much better to ground the wire through a small variable resistance unit. With a variable resistance, it is easy to keep at least a few ohms of resistance between the end of the wire and ground to avoid burning out the gauge.

Fuel Gauges

The magnetic and thermal sending units of a fuel sender appear similar. They use a sliding contact to change resistance, but these senders are not interchangeable.

A fuel gauge should move toward full (high resistance) if the wire to the sender is disconnected. Lowering the resistance should cause the gauge to move smoothly toward empty. This is typical of most instrument gauge operation.

Any fuel gauge may be tested with a spare tank unit. Disconnect the wire from the tank and connect it to the spare tank unit. Use a ground clip to connect the tank unit to the frame of the vehicle. Now turn the ignition switch on and move the tank unit through its full range. If the dash gauge operates with the spare unit, then the trouble must be in the tank unit. The ground wire may be disconnected.

When using a spare tank unit, make sure that it is compatible with the dash unit. If the gauge will not work when connected to a spare tank unit, the trouble is in the gauge itself or in the wiring.

A simple check of the wiring can be made with a voltmeter connected between the end of the wire and a good ground. With the ignition switch on, you should get a reading of a few volts, but always remember to consult the manufacturer's recommended service specification. If there is no reading at all, the gauge is not receiving current, and you will have to find the break in the circuit.

Temperature Gauges

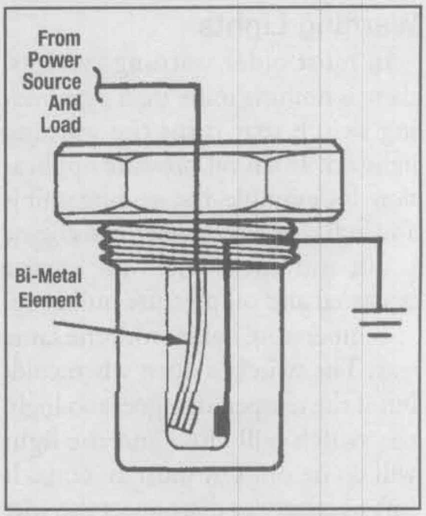
Remove the wire from the sending unit on the engine and connect a variable resistance between the end of the wire and a good ground. With the ignition switch on, rotating the resistance should make the gauge read through the full range.

If you get no movement of the gauge, it is either defective or not receiving current. If the gauge moves, the problem is in the sending unit.

Oil Pressure Gauges

A few vehicles use full-pressure gauges with an oil line connecting the engine to the gauge. Most, however, have the usual electric gauge with a sending unit on the engine. A common problem with oil pressure gauges is installation of an incorrect sending unit. An engine unit which is intended for a red warning light may fit, but will not operate the gauge, or may even damage it.

To test an oil pressure gauge, disconnect the wire from the sending unit and connect a variable resistance between the end of the wire and good ground. Turning the resistance should make the gauge move, if the ignition switch is on. If the gauge does not move, the trouble is in the wiring or the gauge itself. If the gauge passes muster, then the problem must be in the sending unit.



Cut-away view of a coolant temperature switch. If the coolant exceeds the temperature limit, the bimetallic element bends the two contacts together and the switch is closed to the indicator on the instrument panel. *(Courtesy: Ford Motor Co.)*

In some cases, it may be necessary to actually check the oil pressure with a full-pressure gauge. Remove the sending unit and connect the gauge, using the necessary fitting and hoses.

Clock

Separately installed clocks may be analog or digital. If the clock doesn't work, first check the fuse and check for power at the unit. If the fuse is good and there is no power to the clock, check for an open circuit between the fuse and the clock. If there is power to the unit and the clock doesn't work or keep proper time, the clock is faulty and must be repaired or replaced. If the clock is built into the radio or entertainment system display, the radio will likely need to be sent out for repair, or replaced. Refer to the OEM procedures.

Task E4: Diagnose the cause of constant, intermittent, or no operation of warning lights, indicator lights, audible warning devices, and other driver information systems; determine needed repairs.

Warning Lights

In most older warning systems, there is nothing more than a grounding switch that turns the warning light on. In an oil pressure application, for example, the sending unit is a switch that closes when the engine is off, and opens when the engine is started and oil pressure builds up.

Temperature lights work the same way. The switch is open when cold; but if the temperature goes too high, the switch will close and the light will come on. On most systems, it isn't necessary to disconnect the wire from the sending unit and ground it with the ignition switch in the on position. You can turn the lights on that way, but it may be done more easily by watching the lights as the engine is cranked. Most ignition switches have a built-in checking circuit that illuminates the bulb during cranking. If the bulb doesn't light up, either it is faulty or the fuse to that circuit is burned out.

Checking most warning lights is simple, because you can easily put the vehicle through the operating range to make the light come on. This becomes a little difficult on a low-fuel warning system, though, because the tank may have to be drained.

The temperature warning light system is harder to check. Many will not turn the light on until the temperature is considerably over water's normal atmospheric boiling point of 212°F (100°C). Instead of attempting to test the temperature unit, it's better to replace it if you suspect it may be bad.

Alternator warning lights are different. The light bulb is not grounded at the instrument panel. Instead, current flows through the bulb and eventually grounds at the ground brush inside the alternator.

When the alternator is charging, current flows through a wire to the opposite side of the bulb from the ignition switch. Because both sides of the bulb receive similar voltages, no current flows through the bulb and it doesn't light.

Sometimes the alternator light will glow slightly. This can be caused by a bad fuse in the light circuit, or a poor connection somewhere in the circuit. Usually, the fuse serves other units besides the alternator light. If the fuse or fuse holder develops high resistance, other units in the circuit will draw current (backfeed) through the light bulb, causing it to glow.

The beauty of newer vehicles is the buss network which enables you to use the bi-directional control feature of your scan tool you to test various components. The scan tool can command them to be activated for test purposes. On many models, the IPC can be commanded to perform a self-test of the various IPC instruments or warning lights. Use your scan tool to help you troubleshoot where IPC problems may be.

Task E5: Inspect, test, and repair or replace bulbs, sockets, connectors, switches, relays, sensors, timers, wires, gauges, sending units, sensors, electronic components, and controllers of electronic instrument clusters and driver information system circuits.

At one time, the speedometer in most vehicles was driven by a cable connected to a gear on the transmission output shaft. Today, most speedometers are electric and receive information from the Vehicle Speed Sensor (VSS).

The VSS also provides input to other systems, so if the VSS is malfunctioning, other systems beside the speedometer may also be affected. For example, if the cruise control also doesn't work, the problem could be with the VSS, VSS circuit or the PCM/ ECM.

Generally if the speedometer works and the odometer does not, or vice versa, the problem is with the cluster. If the instrument cluster passes a self-diagnostic test but the speedometer still remains at a certain speed or operates erratically, the problem is most likely in the VSS circuit. Check the wiring back to the sensor for shorts or opens.

***NOTE:** If the speedometer operates but is not accurate, make sure that the vehicle is equipped with the proper gear ratio and tire size, as either of these can affect speedometer operation.*

To test a magnetic (inductive) pickup sensor, remove the sensor from the transmission and check the sensor windings with an ohmmeter. Compare sensor resistance with specifications. A voltmeter should detect pulses when the sensor is rotated quickly by hand or rotated slowly using an electric drill. Compare the number of pulses per revolution with specifications. A digital storage oscilloscope can also be used to test this, and most other, input devices. The advantage is a graphical representation of the voltage signal you can compare to known good ones, and you can test the input sensor under its actual operating conditions.

Often the signal from a sensor (like the VSS) is sent directly to one module, and then shared by others via the bus network. In some vehicles, for example, the VSS is first read by the Transmission Contol Module (TCM), and the TCM then passes along that information to the Powertrain Control Module, the Antilock Brake Module, and the Instrument Cluster Module. Using a scan tool to see if all the modules are receiving the same information can help you isolate the location of VSS-related code faults.

Notes

Body Electrical Systems Diagnosis and Repair

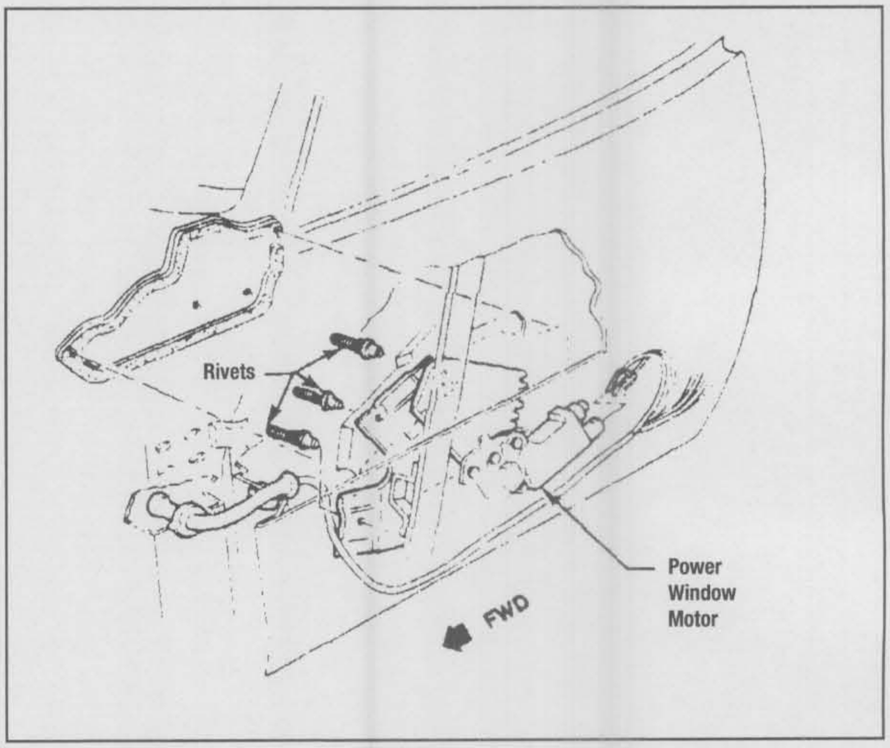
Today's vehicles rely heavily on electronics to manage the vehicle's many inter-related systems. The Body Control Module (BCM) is the primary gateway through which much of the vehicle's comfort and convenience systems (and more) are managed. Sensors monitor and provide feedback to the BCM. Actuators carry out marching orders from the BCM. To-and-from data is carried throughout the vehicle via the Controlled Area Network (CAN). The CAN carries digital information over a twisted pair (+ and -) of shielded wires. Every comfort and convenience system sensor and actuator is tied into the CAN. The BCM receives data, makes decisions and issues commands, all without the driver being aware. If something does not "compute," the BCM will perform self-tests and alert the driver by indicating such on the Driver Information Center.

If a problem is indicated in the information center or on the MIL, the technician can access data anytime on the BCM's network via the DLC, and read any stored codes. Using the appropriate scan tool, the tech can command the BCM to perform tests and carry out certain mechanical functions.

There is no end to the possibilities of how far vehicle technology will go, or the differences between OEM applications, yet despite the many onboard possibilities, the A6 exam covers the basics of various BCM systems' diagnostics, inspection, and repair.

A word to technicians

A key element in the technicians' skill set should be that of reading electrical schematics.



Typical power window regulator and motor.

Be sure to spend plenty of time studying a variety of electrical system schematics until you are totally comfortable with reading them and tracing circuits. Know the meaning of wire size and color designations, connector and ground numbering, and the meaning of dashed versus solid lines around components. Pay special attention to learning how to follow complex schematics showing wiring of power window circuits, turn signal circuits, and so forth. Ask any technician, and they will tell you: You don't want to face these kinds of wiring diagrams for the first time on exam day!

Task F1 – Diagnose operation of comfort and convenience accessories and related circuits (such as: power window, power seats, pedal height, power locks, truck locks, remote start, moon roof, sun roof, sun shade, remote keyless entry, voice activation, steering wheel controls, backup camera, park assist, and auto dimming headlamps); determine needed repairs.

Power Window Operation

Power window motors are usually of the permanent-magnet type. Each motor has a battery connection (both positive and negative) with either terminal of the motor. Reversing the direction of the current through the terminals of the motor reverses its direction.

A power window circuit generally consists of window regulator motors and individual control switches at each door. The circuit also has a master switch by which all windows can be operated. Most systems are protected by a circuit breaker and receive power only when the ignition is on.

Typically, each motor is grounded through the switch. Both terminals of each window motor are connected to opposite and adjacent sides of the switch. Pushing the switch up will cause the motor to close the window. Pushing the switch down will cause it to open the window. The switch reverses current through the motor's terminals.

Power Window Diagnosis

If all windows fail to operate, the most obvious place to start is the circuit breaker, then the fuse, fusible link and master switch. Besides the wiring and its connectors, these components are the only ones that could affect the complete circuit. To check the circuit breaker, check for voltage on both sides of the circuit breaker with the ignition on. If voltage is present on one side only, the circuit is faulty. Determine the cause and replace the circuit breaker.

If a window is binding in its track as it moves up and down, the motor will tend to draw excessive amounts of current. This high current draw may cause the circuit breaker to trip. Some circuit breakers can be manually reset.

To test the master switch, remove the switch assembly from the door. Check for voltage at the switch's battery feed. If no voltage is present, the wire connecting the switch to the circuit breaker should be checked. If voltage is present, check for voltage across the switch from the battery feed wire to the switch's ground terminal. If voltage is present, the switch is good. If no voltage is present, connect a voltmeter to the ground terminal and a good chassis ground. If voltage is present, repair the ground circuit. Often loose wires or connectors will cause the windows to work intermittently.

Check each individual switch as follows: Test the down position of the switch by jumping from the hot lead to the down terminal of the switch. Connect another jumper from the ground terminal of the switch to the up terminal. If the motor works, power is getting through. Put the switch back on the connector, and push the switch down. If the motor will not work, replace the switch.

If the switch is OK but the motor doesn't run, remove the door panel and thoroughly check for any flaws that would prevent the motor and regulator assembly from moving or operating properly. Test the motor by hooking it up to a battery. Make the positive connection at either end of the two motor terminals and the negative connection to the remaining terminal. The motor should run in one direction. If the window doesn't move, reverse the battery connections. The window should now move. If it does, reverse the lead again. If the window won't move, replace the motor.

Tailgate window motors are usually wired in the same way as side windows, except a lock switch is included in the circuit to prevent the window from being raised or lowered when the tailgate is down.

Power Seats

Power seats generally operate in much the same way as power windows: a switch activates a motor, which moves the seat.

Electrically adjustable power seats can be designed for several modes of operation, including two-way, four-way and six-way options. The most common designs used for this function are:

- The seat motor for a two-way seat system has two electromagnetic field windings
- Four-way seats usually have two reversible motor armatures inside a single housing
- The six-way power seat systems use three reversible motor assemblies.

Most power-seat diagnostics should be done by referring to the wiring diagram for the circuit. Power seat motors can be checked in the same fashion as power window motors. Some power seat circuits are equipped with a memory function that allows certain seating positions to be recalled with a touch of a button. These positions are programmed into the memory module of the system. Accurate diagnosis of these systems is possible only by following the specific procedures outlined in the service manual.

Rear Window Defogger

A rear window defogger system consists of a number of horizontal ceramic silver compound element lines and two vertical bus bars baked into the inside surface of the vehicle's rear window. The defogger power wire is soldered to one side of the bus bar and the ground wire is soldered to the other.

The system uses an on-off switch mounted on the instrument panel. When the switch is turned on, an indicator light illuminates. Very often, this light is incorporated in the switch. Once the switch is turned on, the defogger will operate for a preset time period and then automatically turn off through the use of an automatic timer.

Rear Window Defogger Testing

Before proceeding with testing, check the relevant circuit breakers and/or fuses. Turn the ignition and defogger switches on. The indicator light should come on. If not, check the rear defogger control.

If the indicator light came on, check the defogger grid to see of it becomes warm. If not, check the defogger grid.

If the grid becomes warm, consult the vehicle service manual to see when the defogger indicator light should go off. If the indicator does not go off on schedule, replace the rear defogger control.

Rear Defogger Control

Turn the ignition switch on. Using a voltmeter, measure the voltage between the supply lead and a good ground (connector disconnected). Battery voltage should be indicated. If not, repair the open circuit to the supply lead.

Measure the voltage between the supply lead and the ground lead. Battery voltage should be indicated. If not, repair the open circuit to the ground lead. Make sure the ground lead is clean and tight.

If all readings are as specified, replace the rear defogger control.

Defogger Grid

Start the engine and turn on the defogger. Using a test light, ground the end and touch the probe to each grid line, moving the probe from the power to the ground side of the grid. The test light brilliance should decrease as the probe gets closer to the ground bus bar.

If the test light remains bright at both ends of the grid lines, check for a loose ground. If there is an open in a grid line, the test light will not get dimmer and will stay the same brilliance until it reaches the other side of the open, at which point it will go out.

Broken grid lines can be repaired using special conductive repair material.

Power Door Locks

Power to the door lock circuit is usually provided via a large circuit breaker, usually in the 30-amp range, which is in turn powered directly by the battery. The door lock function doesn't rely on the ignition switch for its power.

When the switch is pressed to the lock position, current flows to the door lock motor. This energizes the motor causing a plunger to move inward. The plunger is connected to the standard lock linkage. So, when the plunger travels inward the door locks, and when it moves outward, the door unlocks.

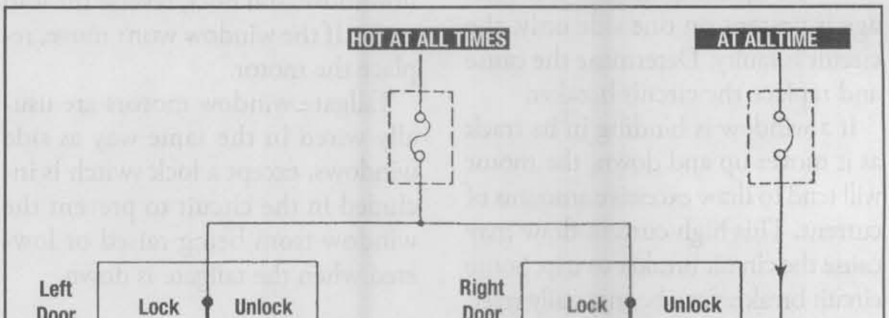
When the door lock switch is moved to the unlock position, current flows to the door lock motor in the opposite direction. Many newer cars use relays to control the locks so the switches do not bear the load-carrying burden, but only provide a signal to the relay.

Power Door Lock Testing

***NOTE:** Always make sure the door lock motor is mounted properly and the linkage is not bent or binding before condemning the door lock motor or switch. This can cause poor or intermittent operation of the door locks.*

Test the switch by checking for power at the feed circuit of the switch. If there is no power, check the fuse, circuit breaker, wiring and connectors upstream from the switch. If there is power, install a jumper wire from the positive lead to the lock terminal of the switch. Connect another jumper from the ground terminal of the switch to the unlock terminal. If the door lock motor works, power is getting through. Put the switch back on the connector, and operate the switch. If the door lock motor will not work, replace the switch.

To check the door lock motor, remove the door panel and check for 12 volts at the feed circuit when the switch is activated. If there is no power, check the wiring and connec-



Common door lock system.

tions from the switch to the motor. If there is power, the door lock motor should operate. If the motor doesn't operate, it should be replaced.

Keyless Entry

The keyless entry system allows the driver to lock and unlock the doors or the trunk without using a key. The system consists of a keypad located on the driver's door and a control module that is connected to the door lock motors. The numbers on the keypad are connected to switches that provide input to the control module. An unlock code is used to unlock the doors and certain number combinations are used to lock the doors and on some vehicles, activate an illuminated entry system.

Make sure that the battery is fully charged and all power door locks are working before testing the keyless entry system. If any individual doors do not operate properly, the problem is most likely with that door lock and not the keyless entry system. Follow the specific manufacturer's diagnostic procedure. These instructions usually include looking for particular responses from the system after entering certain number combinations on the keypad.

Remote keyless entry systems allow the driver to lock and unlock the doors and release the trunk lid with a remote hand-held transmitter. If the vehicle is equipped with a security system, that also can be enabled and disabled with the transmitter. The transmitter communicates with a small receiver installed in the vehicle.

These systems operate at fixed radio frequencies. If the vehicle does not respond when the transmitter is activated from a normal distance, check for a weak battery in the transmitter or the presence of a stronger radio transmitter nearby, such as a radio station. If neither of these is the cause of the problem, make sure that the there are no problems with the door locks or trunk latch before proceeding with the manufacturer's diagnostic procedure.

Power Sunroof, Sliding Doors and Liftgates

These panels are opened and closed with electric motors, usually by way of cables or a gear mechanism.

If the panel will not move at all, first check the fuse or circuit breaker. A gear mechanism or cables that bind can cause a fuse or circuit breaker to blow.

Check for voltage at the switch's battery feed. If no voltage is present, the wire connecting the switch to the circuit breaker should be checked. If voltage is present, check for voltage across the switch from the battery feed wire to the switch's ground terminal. If voltage is present, the switch is good. If no voltage is present, connect a voltmeter to the ground terminal and a good chassis ground. If voltage is present, repair the ground circuit.

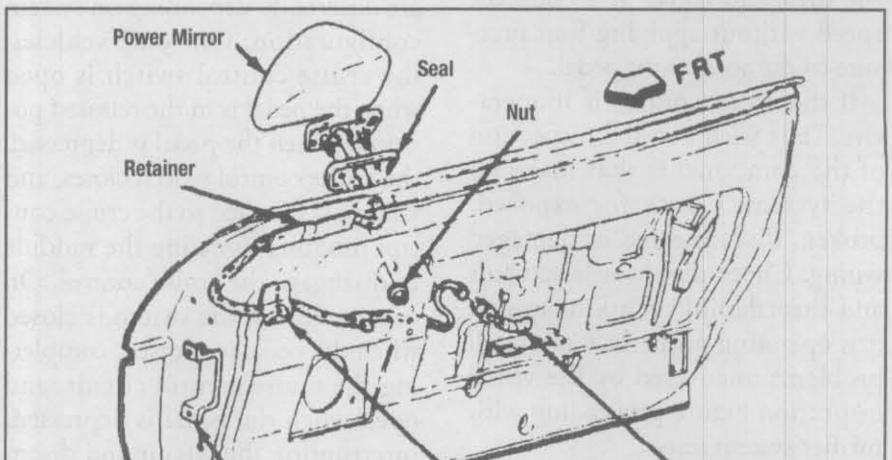
Often loose wires or connectors will cause the panel to open and close intermittently. To locate the problem, operate the system while wiggling the wires.

If the panel opens and closes slowly, there may be excessive resistance in the circuit or motor. Using the correct wiring diagram for the vehicle, perform a voltage drop test. Wear inside the motor can also cause excessive resistance. Use an ammeter to test current draw and compare the reading with the manufacturer's specifications. If the sliding door does not open or close fully, check for obstructions or for misadjusted limit switches.

Power Mirrors

Power mirrors allow the driver to adjust the outside mirrors from inside the vehicle. The electrically-powered mirror is powered by a servomotor inside the mirror head, and can be serviced separately. The control switch(s) are located inside the vehicle within reach of the driver. Usually, one part of the control switch allows for selection of either the right-hand or left-hand mirror, and another part allows for the adjustment of the mirror position.

If both mirrors are inoperative, first check the fuse. If the fuse is OK, remove the door or dash panel trim to gain access to the back of the switch, and check for power at the feed side of the switch using a 12-volt test light. If there is no power at the switch, check the wiring and



Typical power mirror installation.

connections between the fuse panel and the switch and repair as necessary. If there is power to the switch, use a jumper wire across the appropriate switch circuits as described by the manufacturer. If the mirrors can be operated, replace the switch.

If a single mirror is inoperative, verify that the harness is connected to the servomotor. Using a 12-volt test light, check for power in the harness connector at the servomotor by operating the switch. If there is power and the mirror is inoperative, replace the servomotor. If there is no power, check the wiring and connections back to the switch and repair as necessary.

Heated mirrors are part of the rear window defogger system. When the rear window defogger is turned on, current is also sent to the mirror heating elements. If the rear window defogger and mirrors do not heat up, check the defogger control. If the defogger grid works but the mirrors do not, check the fuse and make sure power is reaching the heating elements. If an element is suspected of being faulty, test it according to the manufacturer's procedure.

Cruise Control

The cruise control system allows the driver to travel at a constant speed without applying foot pressure to the accelerator pedal.

If the speed control is inoperative, start with a visual inspection of the components that make up the system. Check for exposed, broken, disconnected or damaged wiring. Check the throttle actuator and throttle linkage to make sure it is operating properly. Correct all problems uncovered by the visual inspection before proceeding with further system tests.

To check the control switches, on/off circuits, and set/accelerate/coast/resume circuits, first check the fuse. If the fuse is OK, disconnect the wire connector at the amplifier assembly. The amplifier's function is to keep a steady throttle speed as desired by the driver. Check for battery voltage and resistance at the connector pins specified by the particular manufacturer. If resistance values are above specifications, suspect the switch assemblies or a problem with the wiring or connectors in the circuit.

To test the speed sensor, raise and safely support the drive wheels and disconnect the wire connector located on the transmission housing. Connect an ohmmeter between the terminals of the speed sensor and compare readings with the manufacturer's specifications.

Next, place the vehicle in gear and allow the wheels to rotate. Use a voltmeter to test for output The voltmeter should fluctuate. If it does not, or the reading is not within specifications, replace the sensor. Apply the brakes, take the vehicle out of gear, reconnect the wire connector and lower the vehicle.

The amplifier senses stoplight voltage when the driver depresses the brake pedal. This in turn disengages the cruise control.

Switches at the brake pedal and clutch pedal provide input to the cruise control module assembly. However, these switches can operate differently depending on system configuration. On some vehicles, the cruise control switch is open when the pedal is in the released position. When the pedal is depressed, the cruise control switch closes, and voltage is supplied to the cruise control module, signaling the module to disengage the cruise control. On other vehicles, the switch is closed when the pedal is released, completing the cruise control circuit, and open when the pedal is depressed, interrupting the circuit and disengaging the cruise control. Refer to the vehicle service manual for specific voltage/switch position specifications.

Task F2 – Inspect, test, and repair or replace components, connectors and wiring of comfort and convenience accessories.

Check these systems, always first check at the fuse box to make certain the fuse has not blown. Inspect all components and wiring for damage or corrosion. Use a voltmerter or test light to pinpoint test for power on these circuits. You may also use an OEM scan tool or equivalent to test and diagnose comfort and convenience items; follow the manufacturer's test procedures.

Power Seats

For non-operational power seats, first check the fuse. Inspect for pinched or damaged seat wiring which may have been damaged by the seat mechanism or caught in the seat track. Replace any defective components, wiring or connectors.

Power Windows

If only the driver's side window operates, check that the window (child) lock is not engaged. If none work, check the fuse. If only an up or down fuction is not working,. Study the vehicle schematic carefully and check the switches and wiring for continuity.

Carefully inspect the wiring between the A pillar and the door for excessive wear or damage from flexing of the harness. With the window switch held in the ON position, wiggle the door harness to check for an intermittent connection. If only one window does *not* operate, try tapping on the window motor. It may intermittently operate if the brushes are worn. Study the window schematic diagram and pinpoint test the window circuits. If all else fails, the vehicle probably needs a new window motor or if the nmotor can be heard but the window does not operate, a window regulator (lift mechanism) is likely needed.

Task F3: Diagnose operation of heated and cooled accessories and related circuits (such as: heated/cooled seats, heated steering wheel, heated mirror, heated glass, and heated/cooled cup holders); determine needed repairs.

Cigarette Lighter

Push the lighter element into the socket and allow time for it to get hot. If the element does not get hot, check the circuit fuse. If the fuse is good, test the lighter socket by grounding a test light or voltmeter to the outer part of the socket and touching the probe to the center terminal of the socket. If the test light comes on or the voltmeter reads system voltage, check for faulty wiring.

If the test light does not come on, ground the test light to a known good ground and again touch the probe to the center terminal. If the test light comes on, repair the lighter socket ground. If the light does not come on, check the wiring between the lighter socket and the fuse panel.

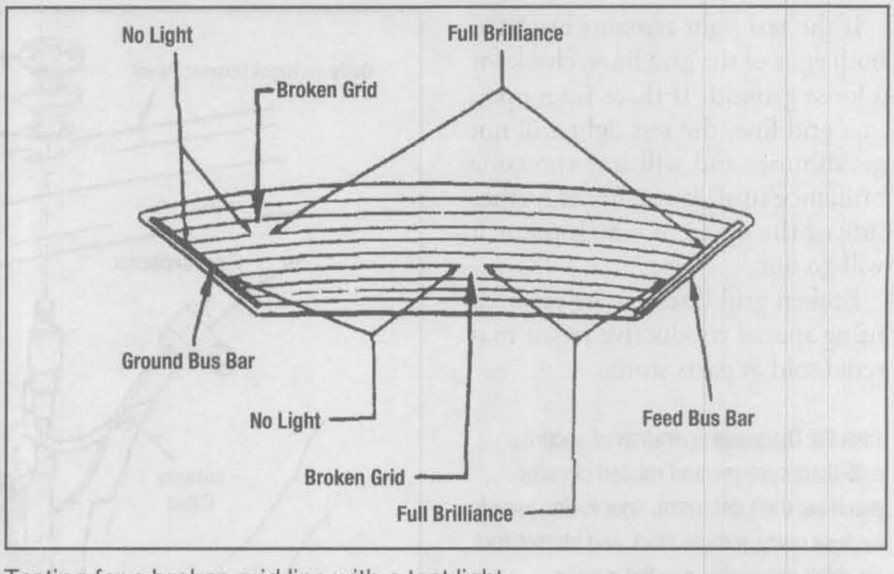
Heated Mirrors, Rear Window, Steering Wheel, Cup Holders

If heated mirrors or heated rear defroster glass grids are not functioning properly, always check the fuse first. Heated windows and mirrors are controlled by a module with a time-out feature.

Rear Window Defogger

A rear window defogger system consists of a number of horizontal ceramic silver compound element lines and two vertical bus bars baked into the inside surface of the vehicle's rear window. The defogger power wire is soldered to one side of the bus bar and the ground wire is soldered to the other.

The system uses an on-off switch mounted on the instrument panel. When the switch is turned on, an indicator light illuminates. Very often, this light is incorporated in the switch. Once the switch is turned on, the defogger will operate for a preset time period and then automatically turn off through the use of an automatic timer.



Testing for a broken grid line with a test light.

Task F4: Inspect, test, and repair or replace components, connectors and wiring of heated and cooled accessories.

Rear Window Defogger Testing

Before proceeding with testing, check the relevant circuit breakers and/or fuses. Turn the ignition and defogger switches on. The indicator light should come on. If not, check the rear defogger control.

If the indicator light came on, check the defogger grid to see of it becomes warm. If not, check the defogger grid.

If the grid becomes warm, consult the vehicle service manual to see when the defogger indicator light should go off. If the indicator does not go off on schedule, replace the rear defogger control.

Pinpoint test heated component circuits and controls according to OE test procedures and/or a scan tool. Check for power at heated rear window glass grids and inspect individual grids for physical damage from abrasion. Check grid continuity using an ohmmeter with power off .The grids are wired in parallel so if one segment is open, total resistance will go up and be out of specification. Rear window heater grids can be repaired using special electrically conductive paste intended for the purpose.

Rear Defogger Control

To test the rear defogger with power on, turn the ignition switch on. Use a voltmeter to measure the voltage between the supply lead and a good ground (connector disconnected). Battery voltage should be indicated. If not, repair the open circuit to the supply lead.

Measure the voltage between the supply lead and the ground lead. Battery voltage should be indicated. If not, repair the open circuit to the ground lead. Make sure the ground lead is clean and tight. If all readings are as specified, replace the rear defogger control.

Defogger Grid

Start the engine and turn on the defogger. Using a test light, ground the end and touch the probe to each grid line, moving the probe from the power to the ground side of the grid. The test light brilliance should decrease as the probe gets closer to the common ground side bus bar.

If the test light remains bright at both ends of the grid lines, check for a loose ground. If there is an open in a grid line, the test light will not get dimmer and will stay the same brilliance until it reaches the other side of the open, at which point it will go out.

Broken grid lines can be repaired using special conductive repair material sold at parts stores.

Task F5: Diagnose operation of security/anti-theft systems and related circuits (such as: theft deterrent, door locks, remote keyless entry, remote start, and starter/fuel disable); determine needed repairs.

Vehicle Security Systems

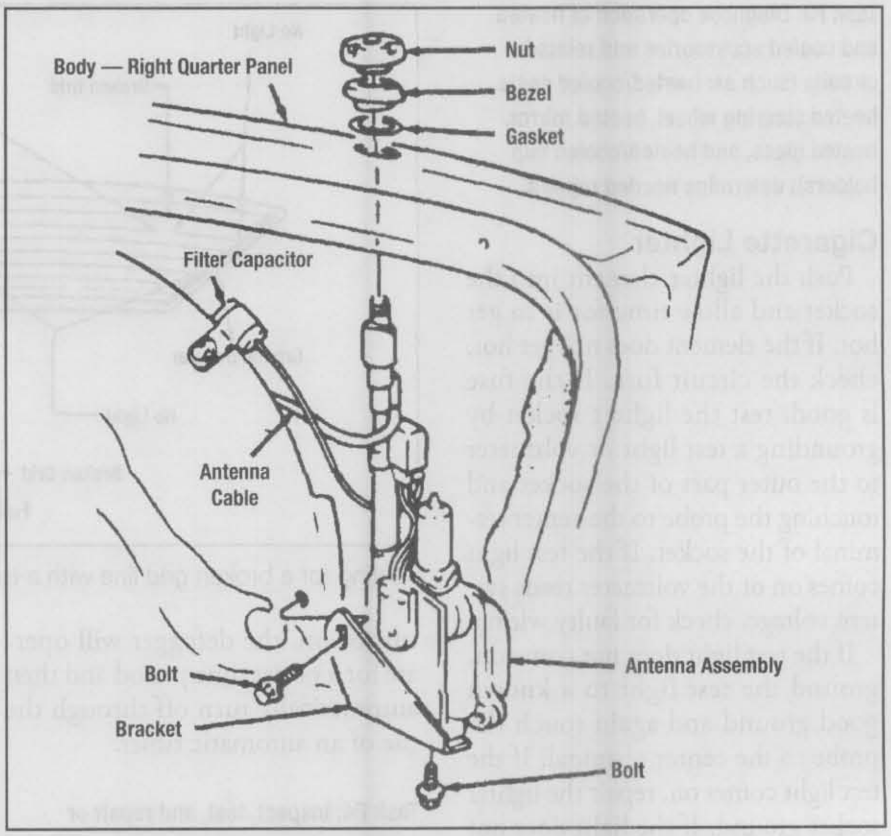
Anti-theft systems are designed to deter thieves by sounding an alarm and/or disabling the ignition system. Most systems include a control module, switches at the doors, trunk and hood, a starter inhibitor relay, a horn relay and an alarm. Some manufacturers also include the exterior lights in the system.

The system is armed when the doors are locked by the door switches or the remote keyless entry transmitter. The switches are monitored by the Body Control Module (BCM). If the doors, trunk lid or hood are opened, or if any lock cylinders are turned, the control module will turn on the alarm, and/or sound the horns and flash the lights. After a certain period of time, the module will turn off the alarm/horn/lights and rearm the system.

Follow the manufacturer's specific diagnostic procedures when troubleshooting an anti-theft system. Some systems have self-diagnostic capabilities, which may require a scan tool.

Task F6: Inspect, test, and repair or replace components, connectors and wiring of security/anti-theft systems.

Common system problems are faulty switches and relays. Switches



Typical power antenna installation.

that are damaged, corroded or out of adjustment can cause the system to activate for no apparent reason. Check lock cylinder tamper switches for looseness and make sure that jamb switches are adjusted so they are in the OFF position when the doors are closed. Relays can be bypassed with a jumper wire to test their operation. Systems use wiring to and from the key operated start switch. Check for continuity of the steering column harness to ensure that an open has not disabled the vehicle's engine cranking system and more. Refer to the manufacturer's service manual for pinpoint testing and scan tool instructions.

Task F7: Diagnose operation of entertainment and related circuits (such as: radio, DVD, remote CD changer, navigation, amplifiers, speakers, antennas, and voice activated accessories); determine needed repairs.

Audio Systems

The most common problems associated with sound systems are that the unit doesn't work, or that the sound or reception is poor.

If the radio and/or cassette or CD player doesn't work, first check the fuse and check for power at the unit. If the fuse is good and there is no power to the radio, check for an open circuit between the fuse and the radio. If there is power to the unit, remove it and send it out to a service facility that specializes in radio repair.

Poor sound quality, static and poor reception can be caused by a defective antenna, an antenna that is not grounded or connected properly or one that is not trimmed properly. An antenna can be trimmed by turning the trimmer screw until the best reception of a weak AM station is obtained.

Static can also be caused by faulty ignition components, loose or missing ground wires and defective noise suppression devices.

Task F8: Inspect, test, repair and/or replace components, connectors and wiring of entertainment systems.

Poor sound quality can be caused by damaged speakers, damaged or incorrect recorded media, or a host of other causes. Check for proper speaker mounting and for damaged speaker cones and wiring. If radio reception is poor despite a strong radio signal, move the vehicle a fews feet to see if FM reception improves. To ensure a strong incoming signal, use an ohmmeter to check for continuity between the antenna and the center lead of the antenna coaxial cable. Make sure there is no continuity between the outer ground shell and center antenna lead. For diagnosing other audio or operational problems, consult the vehicle service manual for specific pinpoint testing Instructions.

Power Antenna

If a power antenna will not raise or lower, check for voltage at the antenna motor electrical connectors. When the radio is turned on or the antenna switch is placed in the UP position, and the antenna should extend, there should be voltage at one of the connectors. When the radio is turned off or the antenna switch is placed in the DOWN position, and the antenna should retract, there should be voltage at the other connector.

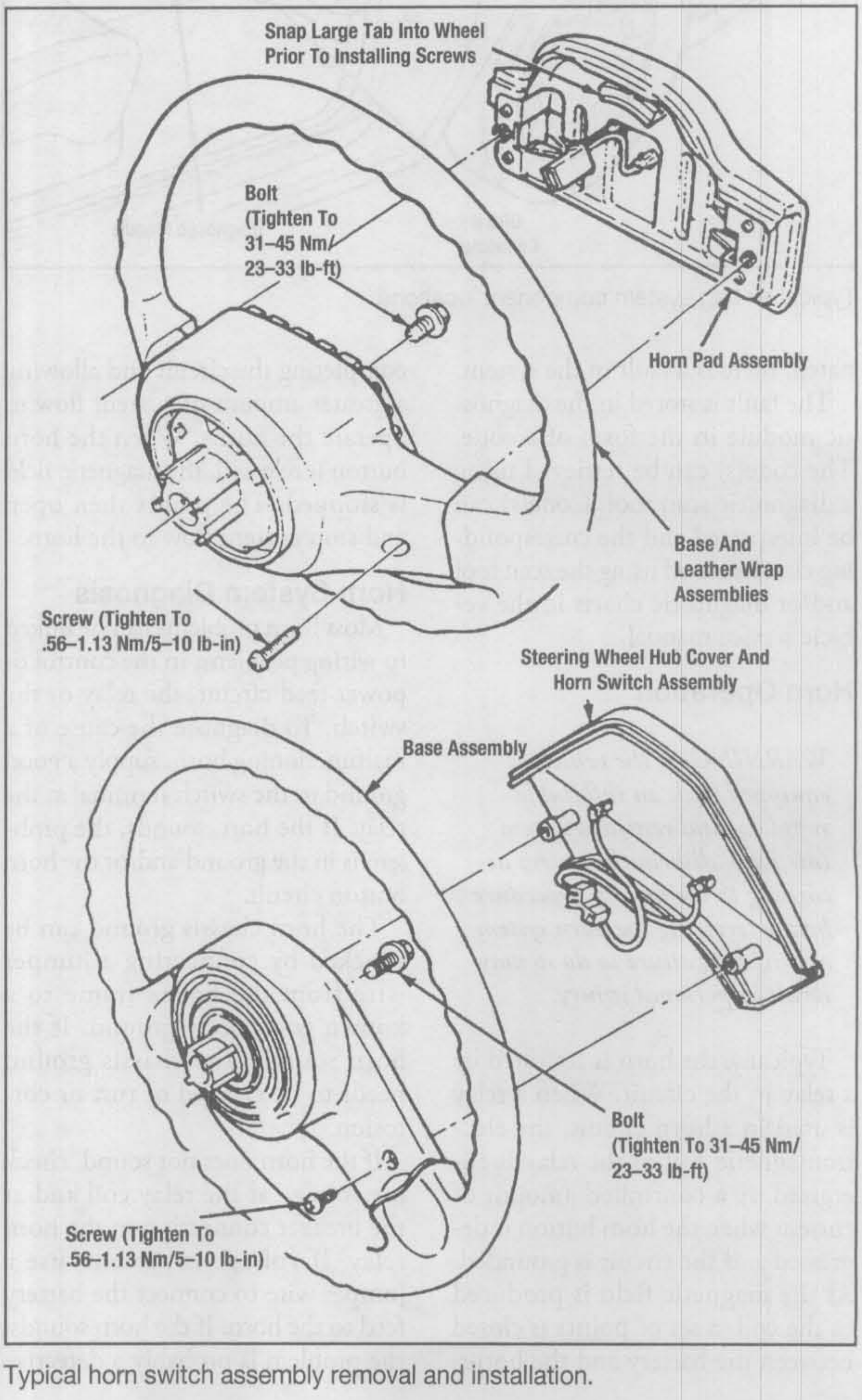
If voltage is not present in one or both connectors, check the fuse and antenna wiring. If voltage is present at both connectors, replace the antenna motor assembly.

Today's high end on-board audio systems are rather complex and aftermarket systems whichh have been installed (sub-woofers, etc), may require the assistance of an audio repair shop specialist to diagnose.

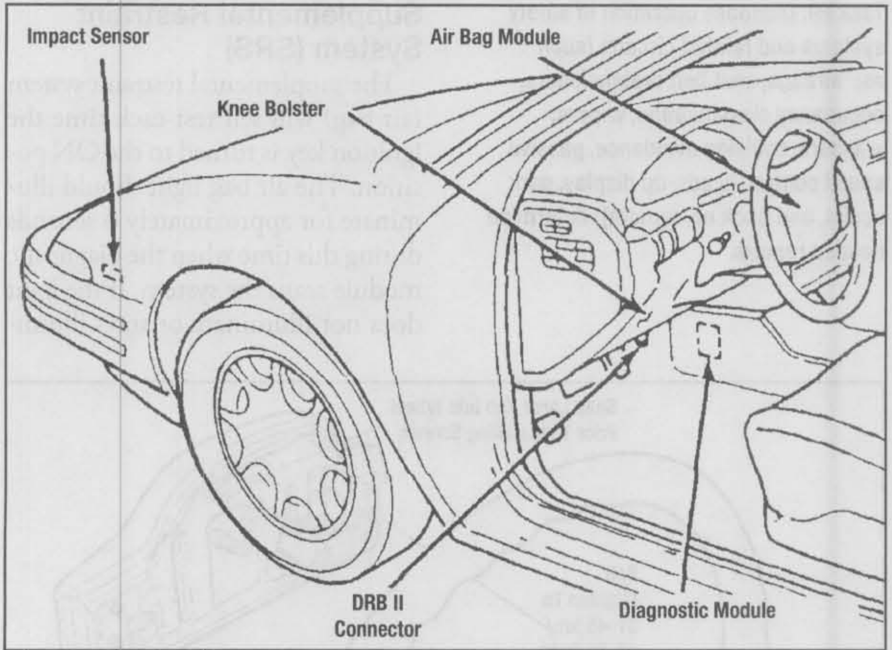
Task F9: Diagnose operation of safety systems and related circuits (such as: airbags, seat belt pretensioners, occupancy classification, wipers, washers, collision avoidance, passive speed control, heads-up display, park assist, and back up camera); determine needed repairs.

Supplemental Restraint System (SRS)

The supplemental restraint system (air bag) will self test each time the ignition key is turned to the ON position. The air bag light should illuminate for approximately 6 seconds during this time when the diagnostic module scans the system. If the light does not illuminate or stays illumi-



Typical horn switch assembly removal and installation.



Typical air bag system component locations.

nated, there is a fault in the system.

The fault is stored in the diagnostic module in the form of a code. The code(s) can be retrieved using a diagnostic scan tool. Code(s) can be interpreted and the corresponding circuits tested using the scan tool and/or diagnostic charts in the vehicle service manual.

Horn Operation

WARNING: If the vehicle is equipped with an inflatable supplemental restraint system (air bag), disarm the system according to the factory procedure before servicing the horn system or wiring. Failure to do so may result in personal injury.

Typically, the horn is activated by a relay in the circuit. When a relay is used in a horn circuit, the electromagnetic coil of the relay is energized by a controlled amount of current when the horn button is depressed and the circuit is grounded. As the magnetic field is produced in the coil, a set of points is closed between the battery and the horns, completing the circuit and allowing a greater amount of current flow to operate the horns. When the horn button is released, the magnetic field is stopped. The points then open and stop current flow to the horn.

Horn System Diagnosis

Most horn problems can be linked to wiring problems in the control or power feed circuit, the relay or the switch. To diagnose the cause of a malfunctioning horn, supply a good ground to the switch terminal at the relay. If the horn sounds, the problem is in the ground and/or the horn button circuit.

The horn chassis ground can be checked by connecting a jumper wire from the horn's frame to a known good body ground. If the horn sounds, the chassis ground needs to be cleaned of rust or corrosion.

If the horn does not sound, check for voltage at the relay coil and at the breaker connection in the horn relay. If voltage is present, use a jumper wire to connect the battery feed to the horn. If the horn sounds, the problem is probably a defective relay. If no voltage is present at the relay, check the fuse and connecting wires and/or harness.

If the horn sound is weak, current is too low; suspect poor electrical connections as the culprit. If horn tone is harsh, bend the mounting bracket assembly so the horn is not contacting sheet metal. If the horn sounds continuously, the most likely causes are a stuck horn switch or relay contacts.

To determine the cause, disconnect the relay and check for continuity across the horn relay contacts. If there is continuity, the relay contacts are stuck and the relay should be replaced. If there is no continuity between the contacts, check the horn button assembly for a short.

Wiper And Washer Systems Operation

The windshield wipers on most vehicles are powered by a multi-speed motor, the speeds of which are typically controlled by using different windings in the wiper motor. To effect different wiper speeds, the motor is equipped with brushes located at several positions on the armature. Switching to different sets of brushes changes the speed of the motor. In the event the wiper switch is turned off with the wipers in mid-position of the windshield, an internal cam operated switch feeds power to the motor until the wiper linkage reaches the park (down) position. This type of motor is also fitted with a permanent magnet-type field. A set of gears, crank arm and the necessary linkage are used to connect the windshield wiper motor to the wiper arms.

Intermittent wipers use a variable resistor normally located in the steering wheel stalk to control a pause-control module. The wiper motor is connected to the pause module and when current is interrupted, the wipers move to the parked position. The variable resistor controls how long the wipers will remain off between cycles. The greater the current flow to the module, the less time the wipers will be off.

On some vehicles, the windshield washer pump is located on the wiper motor gearbox and is driven by the wiper motor. When the washer switch is activated, a relay coil provides for the connection between the motor and the pump. Other systems are equipped with a separate motorized washer pump located in the bottom of the washer fluid reservoir or near the wiper motor assembly.

Wiper And Washer Systems Diagnosis

Identifying the cause of malfunctioning wiper systems may be difficult because the problem may be either electrical or mechanical. A self-resetting circuit breaker may be tripped if the linkage is bound by ice, a lack of lubricant, or rust.

If the wipers do not operate, try disconnecting the linkage from the motor. If after disconnecting the linkage, the motor turns when the switch is turned on, the linkage was binding. Check the linkage and bushings and replace parts as necessary. If the motor does not run, suspect the motor or an electrical problem in the wiper circuit. Linkage malfunctions can also cause the motor's circuit breaker to trip.

To diagnose electrical problems in the wiper circuit, begin by checking for power. Check and clean the motor's mounting and ground connections. Visually inspect all electrical connections to the motor. Since each manufacturer and model uses different approaches to wiper circuit design, use a schematic of the circuit and a diagnostic flow chart.

With the ignition and wiper control switch on, test for voltage at the motor. If voltage is present, replace the motor. If no voltage is present, check the motor power feed on the control switch. If voltage is present there, inspect the wire that connects the switch to the motor. If no voltage is present, check for voltage at the battery side of the switch. If voltage is present there, replace the switch. If no voltage is present, check the circuit from the circuit breaker to the switch.

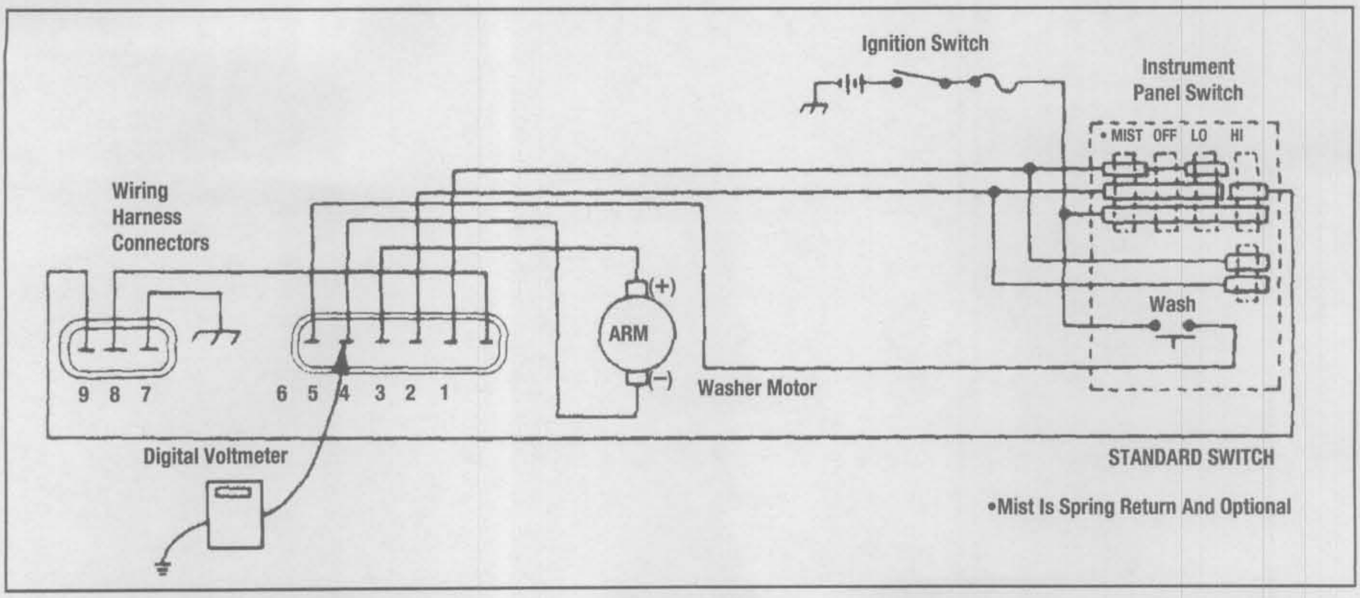
When a washer system is inoperative, check the fluid level and refill if necessary. If there is an ample amount of fluid, disconnect the hose from the pump to the nozzles, and operate the washer switch. If fluid comes out of the pump, the hose is kinked or blocked or the nozzles are plugged. Use low pressure air to clear blockage in the rubber feed lines. use a small pin to probe or aim the nozzle Itself. If the fluid does not come out of the pump, the problem is the pump or its power feed circuit. Check for voltage to the pump when the switch is activated. If voltage is present, the pump may be defective and should be replaced. If no voltage is found, check the power feed circuit to and from the pump.

Task F10: Inspect, test, and repair or replace components, connectors and wiring of safety systems.

SRS

Before performing any service to the air bag system, the air bag must be properly disarmed. In general, this usually involves disconnecting the negative battery cable from the battery terminal and taping the cable end to prevent it from accidentally contacting the battery terminal. Then, wait at least 10 minutes for the system capacitor(s) to discharge. Always consult the vehicle service manual for the exact disarming procedure.

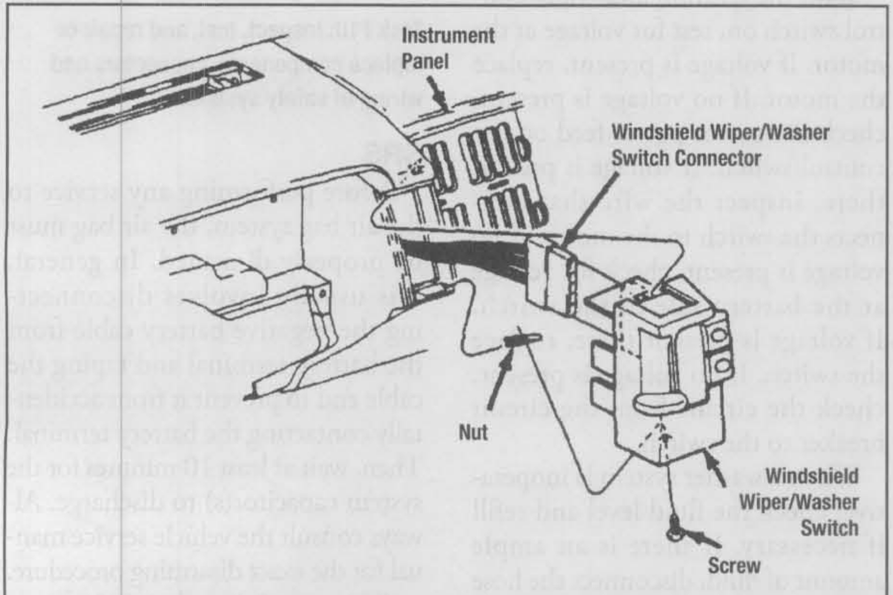
When servicing the air bag system, wear eye protection and follow all safety precautions. Follow the



Testing a typical wiper/washer switch. *(Courtesy: GM Corp.)*

recommended factory diagnostic procedures and use only the specified test equipment. Performing tests improperly or using the wrong equipment can result in accidental air bag deployment.

After an air bag module has been removed, carry the module with the cover pad facing away from the body. Store the module with the cover pad facing up, so that accidental deployment does not launch it into the air.



A dash mounted wiper/washer switch.

Consult the manufacturer's service information before attempting to repair an air bag system wiring harness. Many manufacturers recommend that these harnesses be replaced rather than repaired.

Wiper/Washer Switch Replacement

The wiper/washer switch can be mounted on the dash or on the steering column, where it is usually part of a combination switch. To replace a dash mounted switch, remove the necessary instrument panel trim, as required. Remove the retaining screws from the switch and remove the switch from the instrument panel. Disconnect the wiring harness from the switch. To install, reverse the removal procedure. After installation, check for proper operation.

To replace a steering column switch, disconnect the negative battery cable and remove the necessary steering column covers. Consult the vehicle service manual for specific instructions, as steering wheel removal may be required.

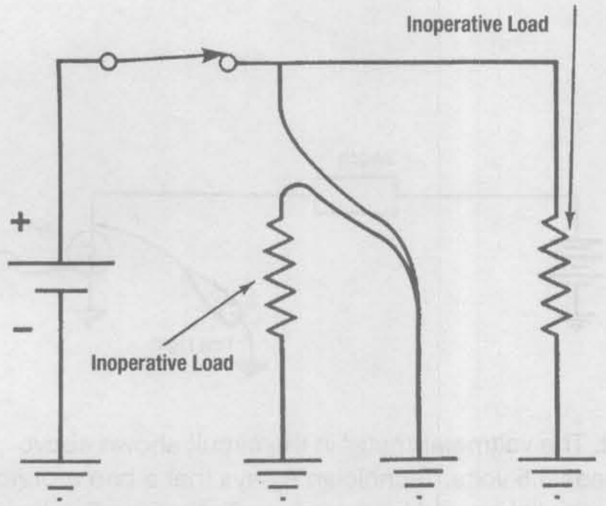
> ***WARNING: If the vehicle is equipped with an inflatable supplemental restraint system (air bag), disarm the system according to the factory procedure before removing the steering wheel. Failure to do so may result in personal injury.***

Disconnect the steering column wiring connector from the switch. Remove the switch fasteners and switch assembly from the column. Installation is the reverse of removal.

Notes

Prepare yourself for ASE testing with these questions on ELECTRICAL/ELECTRONIC SYSTEMS

NOTE: The following questions are written in the ASE style. They are similar to the kinds of questions that you will see on the ASE test. However, none of these questions will actually appear on the test.



1. The fault shown in the above circuit is:
   A. an open
   B. a short to ground
   C. too much capacitance
   D. too much resistance

2. An air bag system is being serviced., Technician A says to disconnect the yellow SRS connectors at the front of the vehicle.. Technician B says to disconnect and isolate the negative battery cable. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

3. Which of these should be used when soldering electrical wiring connections?
   A. rosin core flux
   B. acid core flux
   C. sulfur core flux
   D. none of the above

4. When testing computer-controlled systems, a digital multimeter should be used with an input impedance of at least:
   A. 10k ohms
   B. 100k ohms
   C. 1 megohm
   D. 10 megohms

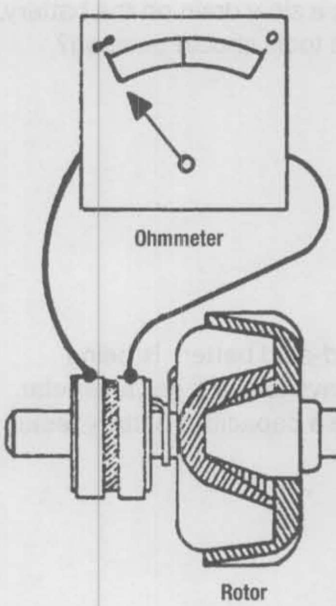
5. When troubleshooting a slow drain on the battery, which if these diagnostic tools should be used?
   A. Ohmmeter
   B. Ammeter
   C. Voltmeter
   D. Test light

6. The condition of a lead-acid battery is being checked. Technician A says to use a galvanometer.. Technician B says to use a capacitive battery tester. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

7. While testing a starting circuit on a 5.7L V8 engine, the technician finds that the engine cranks slowly. The starter current draw is 90 amps, and the battery voltage while cranking is 11 volts. What should the technician do next?
   A. Check for voltage drop of the starter motor circuit.
   B. Test the battery capacity.
   C. Replace the starter motor, as a short is indicated.
   D. Determine the condition of the engine.

Prepare yourself for ASE testing with these questions on ELECTRICAL/ELECTRONIC SYSTEMS

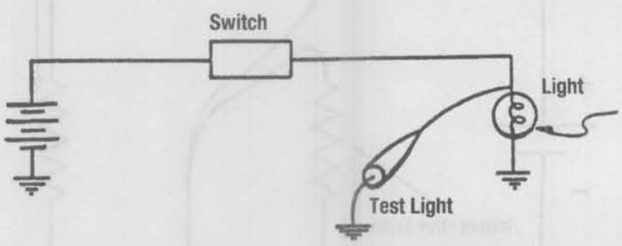
8. Technician A says that a noisy alternator could be caused by a bad diode. Technician B says that a noisy alternator could be caused by a worn bearing. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B



9. The analog ohmmeter needle does not move when connected as shown above. This indicates that the rotor winding is:
   A. shorted
   B. grounded
   C. complete
   D. open

10. A vehicle's turn signals flash too slowly. Technician A claims that the condition could be caused by a faulty flasher. Technician B says that a bulb may be the wrong type.. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

11. Technician A says a short circuit to ground in a circuit will decrease resistance. Technician B says a short circuit will increase current flow. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B



12. The voltmeter meter in the circuit shown above reads 3.5 volts. Technician A says that a bad ground for the light could be the cause. Technician B says that high resistance in the circuit from the battery to the light could be the cause. Who is right??
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

13. When using a voltmeter to check for voltage in a circuit, the voltmeter should first be connected to check for:
   A. source voltage.
   B. excessive resistance
   C. excessive amperage.
   D. a good ground.

14. When checking the green eye of a sealed maintenance-free battery, no color seen indicates that the battery is:
   A. undercharged.
   B. charged properly.
   C. overcharged.
   D. damaged.

Prepare yourself for ASE testing with these questions on ELECTRICAL/ELECTRONIC SYSTEMS

15. Both headlights on a vehicle are dim on high beam but are normal on low beam. Technician A says that a poor headlight ground could be the cause. Technician B says that a shorted headlight switch could be the cause. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

16. The oil pressure light on a vehicle dashboard stays on whenever the engine is running. The oil pressure has been checked with a mechanical gauge and it is within specifications. Technician A says that the circuit between the indicator light and the pressure switch could be grounded. Technician B says that an open in the pressure switch itself could be the cause. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

17. Nothing happens when the ignition key is turned to the START position in a vehicle with a good battery. Technician A says that if a clicking sound is heard when a jumper wire is connected between the battery and the solenoid 'S' terminal, a problem exists in the starter control circuit. Technician B says that if a jumper wire is connected between the battery and the solenoid 'S' terminal and there is no sound, the starter is defective. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

18. A vehicle continues to trip the windshield wiper circuit circuit breaker. Technician A says the cause could be a short circuit. Technician B says that the cause could be binding wiper linkage. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

19. Technician A says that a battery with an open circuit voltage of 12.1 volts is fully charged. Technician B says that if the indicator on a sealed maintenance-free battery is yellow, the battery should be charged. Who is right?

A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

20. When performing a current draw test using an ammeter, a reading greater than that which was specified would indicate:

A. excessive circuit resistance
B. a decrease in circuit resistance
C. an open circuit
D. a decrease in circuit voltage

21. Technician A says that using a 20,000 ohm/volt analog meter is a good choice for ECM circuit testing. Technician B says that careful use of a test light can determine the condition of a Throttle Position (TP) sensor. Who is right?

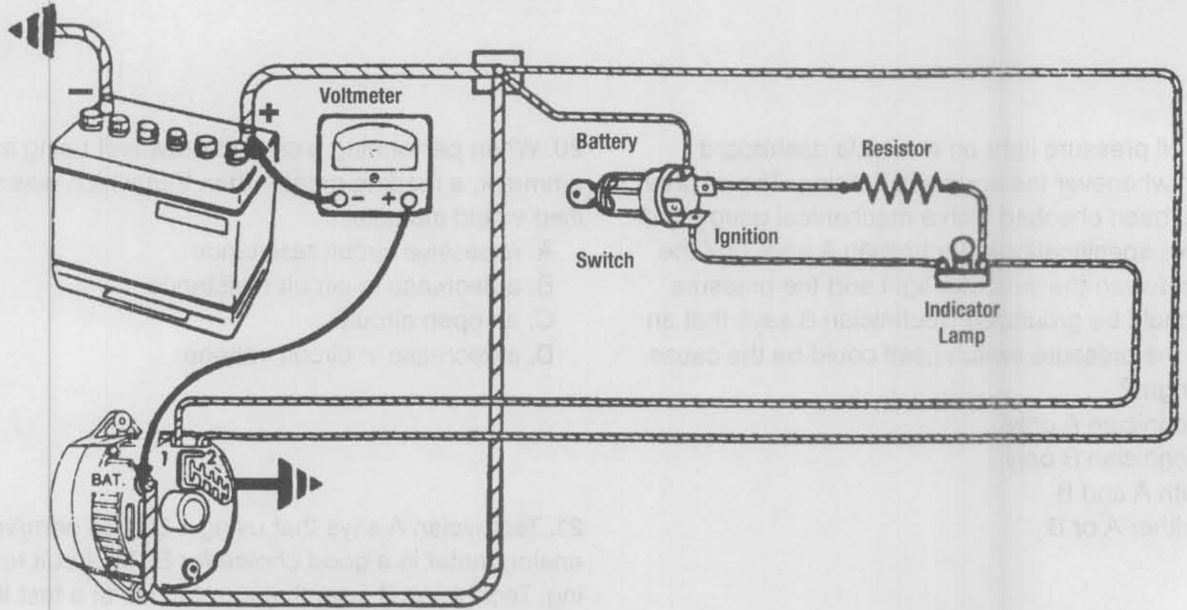
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

22. Technician A says that an in-vehicle high-rate discharge battery load test should always be performed if a 12-volt battery if its condition is in question. Technician B says that the battery should be discharged (loaded) at twice its ampere hour rating. Who is right?

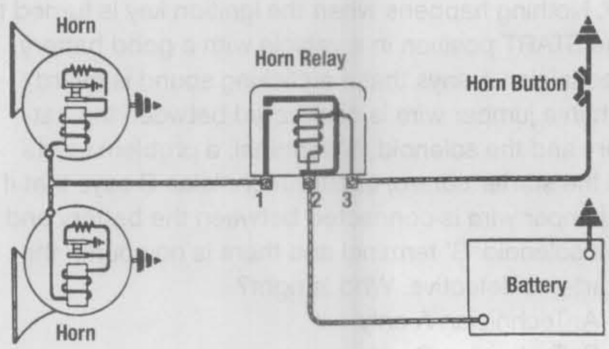
A. Technician A only
B. Technician B only
C. Both A and B
D. Neither A or B

Prepare yourself for ASE testing with these questions on ELECTRICAL/ELECTRONIC SYSTEMS

23. All of the following are indications of an undercharged battery condition **EXCEPT:**
   A. slow cranking
   B. dim headlights
   C. short light bulb life
   D. low ammeter indication



24. In the charging system shown above, the meter reading will show:
   A. charging output voltage
   B. indicator lamp operating voltage
   C. charging circuit voltage drop
   D. ignition switch voltage



25. The horns in the circuit shown above only blow when a jumper wire is connected between terminals 1 and 2 of the horn relay. Technician A says that a bad horn relay could be the cause. Technician B says that a ground in the circuit between the horn relay and the horn button could be the cause. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

Prepare yourself for ASE testing with these questions on ELECTRICAL/ELECTRONIC SYSTEMS

26. A rear defogger grid is being tested. Technician A says that when probing a grid line, the voltmeter should decrease Its reading as the probe gets closer to the ground bus bar. Technician B says that if voltmeter read 12 volts at both ends of the grid line, there is an open in the grid line. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

27. All of the following warning system lights use a grounding switch **EXCEPT:**
   A. oil pressure
   B. coolant temperature
   C. brake warning
   D. charging system

28. Technician A says that all power should be removed from a circuit before testing the circuit with an ammeter. Technician B says that all power should be removed from a circuit before testing the circuit with an ohmmeter. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

29. Technician A says that checked with an ohmmeter, a diode should have a high resistance in one direction only. Technician B says a diode permits the flow of electricity in both directions. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

30. All of the following could cause an inoperative starter **EXCEPT:**
   A. an improperly adjusted neutral safety switch
   B. worn or missing flywheel ring gear teeth
   C. an open circuit between the solenoid and the ignition switch
   D. an open in the solenoid ground circuit

31. A power seat system is extremely noisy when operated. All of the following could be the cause **EXCEPT** a:
   A. faulty motor
   B. faulty transmission
   C. bad ground
   D. lack of lubricant

32. All of these are true statements regarding air bag supplemental restraint systems (SRS) **EXCEPT:**
   A. While removed from the vehicle, the airbag module should be stored with the cover pad facing up.
   B. Safety glasses should be worn when servicing the air bag system.
   C. Only rosin core solder and heat shrink tubing should be used to repair air bag system wiring.
   D. Performing tests improperly or using the wrong equipment can result in accidental air bag deployment.

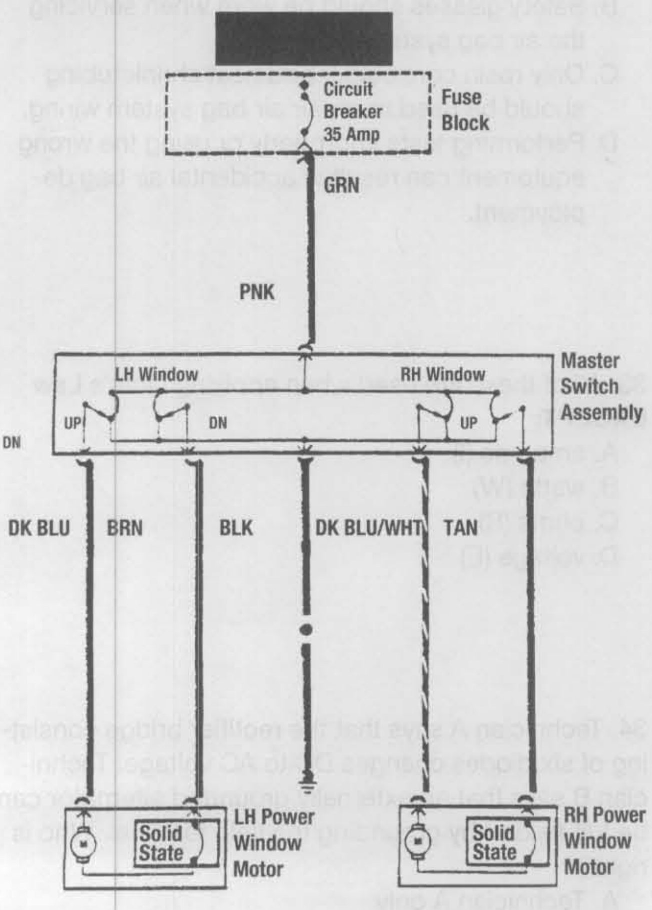
33. All of these are used when applying Ohm's Law **EXCEPT:**
   A. amperes (I)
   B. watts (W)
   C. ohms (R)
   D. voltage (E)

34. Technician A says that the rectifier bridge consisting of six diodes changes DC to AC voltage. Technician B says that an externally grounded alternator can be full-fielded by grounding the field terminal. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

Prepare yourself for ASE testing with these questions on ELECTRICAL/ELECTRONIC SYSTEMS

35. Technician A says that voltage in a series circuit should be the same at all loads of the circuit. Technician B says that current in a series circuit is the sum of all the components' current draw in a circuit. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

36. Another way of saying 75 millivolts is:
   A. 0.075 volts
   B. 0.75 volts
   C. 7.5 volts
   D. 7.05 volts



37. The left power window in the illustration above operates in the UP position, but not in the DOWN position. The right power window operates in both UP and DOWN positions. Technician A says that the BRN wire is open. Technician B says that the DK BLU wire is open. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

38. The fuse for a power window system is blown. Any of these could be the cause EXCEPT:
   A. wire is shorted to ground somewhere in the circuit.
   B. the window track is binding.
   C. an open lexists in the motor's circuit.
   D. there is a short in the motor.

39. A horn makes a very weak sound. Technician A says a faulty power connection could be the cause. Technician B says a faulty fuse could be the cause. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

40. Two lights are connected in parallel. An additional light is added, also wired in parallel. Technician A says the total resistance will decrease. Technician B says the total voltage will drop. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

41. Oh ohmmeter is being used to check a circuit for continuity. Technician A says an infinity or full scale reading on an ohmmeter indicates no continuity. Technician B says a zero reading on an ohmmeter indicates continuity. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

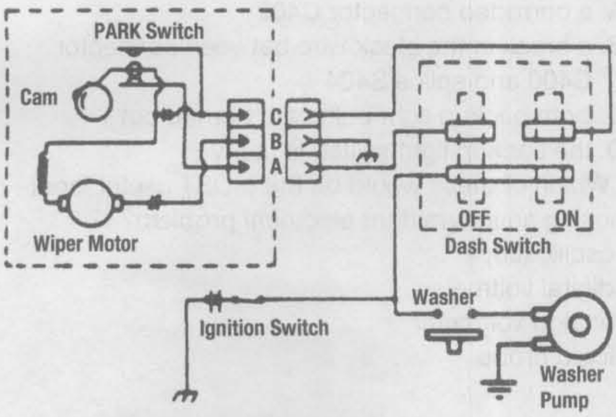
42. Neither of the low beam headlights on a vehicle will light but the high beams work normally. Technician A says the headlight thermal breaker could be faulty.. Technician B says the dimmer switch may be faulty. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

Prepare yourself for ASE testing with these questions on ELECTRICAL/ELECTRONIC SYSTEMS

43. The front and rear turn signals on the left side of a vehicle are non-functional. Technician A says the turn signal flasher could be shorted to ground. Technician B says the hazard flasher could be shorted to ground. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

44. A circuit is wired in series. Technician A says the total of all voltage drops will equal the battery voltage. Technician B says the current flow through each part of the circuit is the same. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

45. A circuit is wired in parallel. Technician A says that total circuit current is divided across each load. Technician B says the voltage is the same at each load. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B



46. Technician A says that if the washer pump ground circuit (as shown above) is faulty, the wiper motor will not run. Technician B says that the wiper motor shown will continue to run after the switch is opened until the park switch also opens. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

47. Technician A says that a self-resetting circuit breaker is sometimes used in a taillight circuit. Technician B says that the colored insulation of a fusible link indicates the amount of circuit protection available. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

48. Technician A says that a test light is a good diagnostic tool for testing solid-state electronic circuits. Technician B says that a ohmmeter is a good diagnostic tool for testing voltage sources. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

49. When performing soldering, the purpose of a soldering iron is to heat the:
   A. flux.
   B. solder.
   C. conductors.
   D. heat shrink tubing.

50. Technician A says that a digital ohmmeter should be manually set to "zero" after the switch is turned on. Technician B says that the resistance of a component should be checked while voltage is applied to the circuit. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

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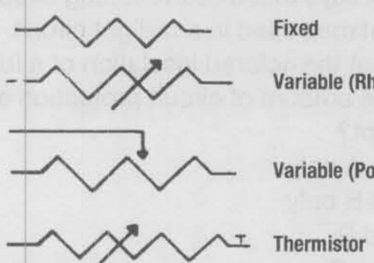


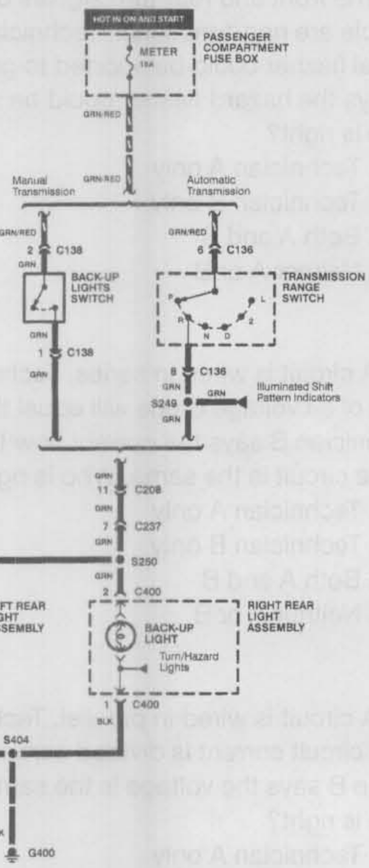
(Courtesy: Ford Motor Co.)

51. Which of the parts schematically shown above is sometimes used in a headlight switch?
   A. fixed type
   B. variable rheostat type
   C. variable potentiometer type
   D. thermistor

52. The interior lights in a vehicle stay on all the time. Technician A says that a door switch could be stuck. Technician B says there could be a short to ground in the circuit before one of the switches. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

53. A customer complains of static on the radio. Technician A says that loose or missing ground wires could be the cause. Technician B says that a defective antenna cable could be the cause. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

54. A start/clutch interlock switch is being tested. Technician A says that, with the clutch pedal in the released position, the switch should have continuity when checked with an ohmmeter. Technician B says that, with the pedal depressed, there should be voltage on both sides of the switch when checked with a voltmeter. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B



(Courtesy: Hyundai Motor America)

55. The backup lights in the circuit shown above right do not work. Which of these is the **MOST LIKELY** cause?
   A. a corroded connector C402
   B. a break in the black wire between connector C400 and splice S404
   C. both backup light bulbs are burned out
   D. the backup light switch is faulty

56. Which of these would be the MOST useful for diagnosing an intermittent electrical problem?
   A. oscilloscope
   B. digital voltmeter
   C. analog voltmeter
   D. logic probe

57. The doors will not unlock on a vehicle using the remote keyless entry. Any of these could be the cause **EXCEPT:**
   A. a weak transmitter battery
   B. interference from a stronger radio transmitter
   C. a bad passenger's door lock motor
   D. a blown circuit breaker

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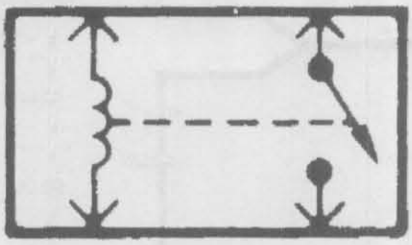
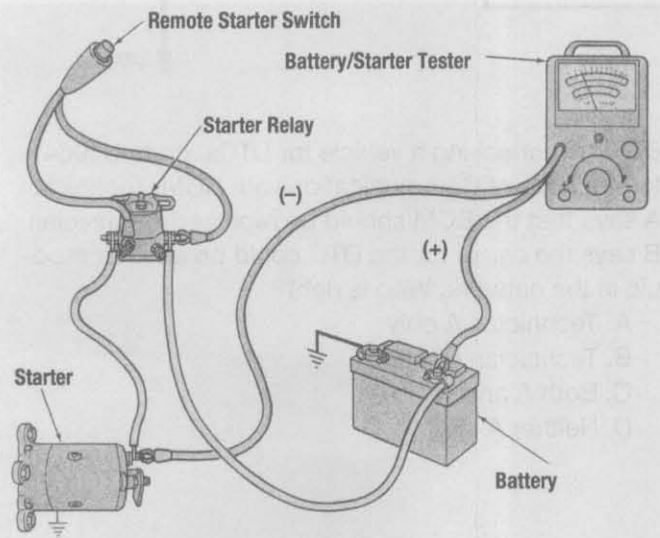
58. An electronic digital speedometer is stuck at zero. Technician A says that this could set a DTC. Technician B says that the Vehicle Speed Sensor (VSS) could be the problem. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

59. The wiring diagram symbol shown represents a:



(Courtesy: Ford Motor Co.)

   A. fuse
   B. circuit breaker
   C. relay
   D. switch



60. In the test shown above, the voltmeter reads 0.3 volts. Technician A says this indicates there is excessive resistance in the starter power circuit. Technician B says this indicates there is excessive resistance in the starter ground circuit. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

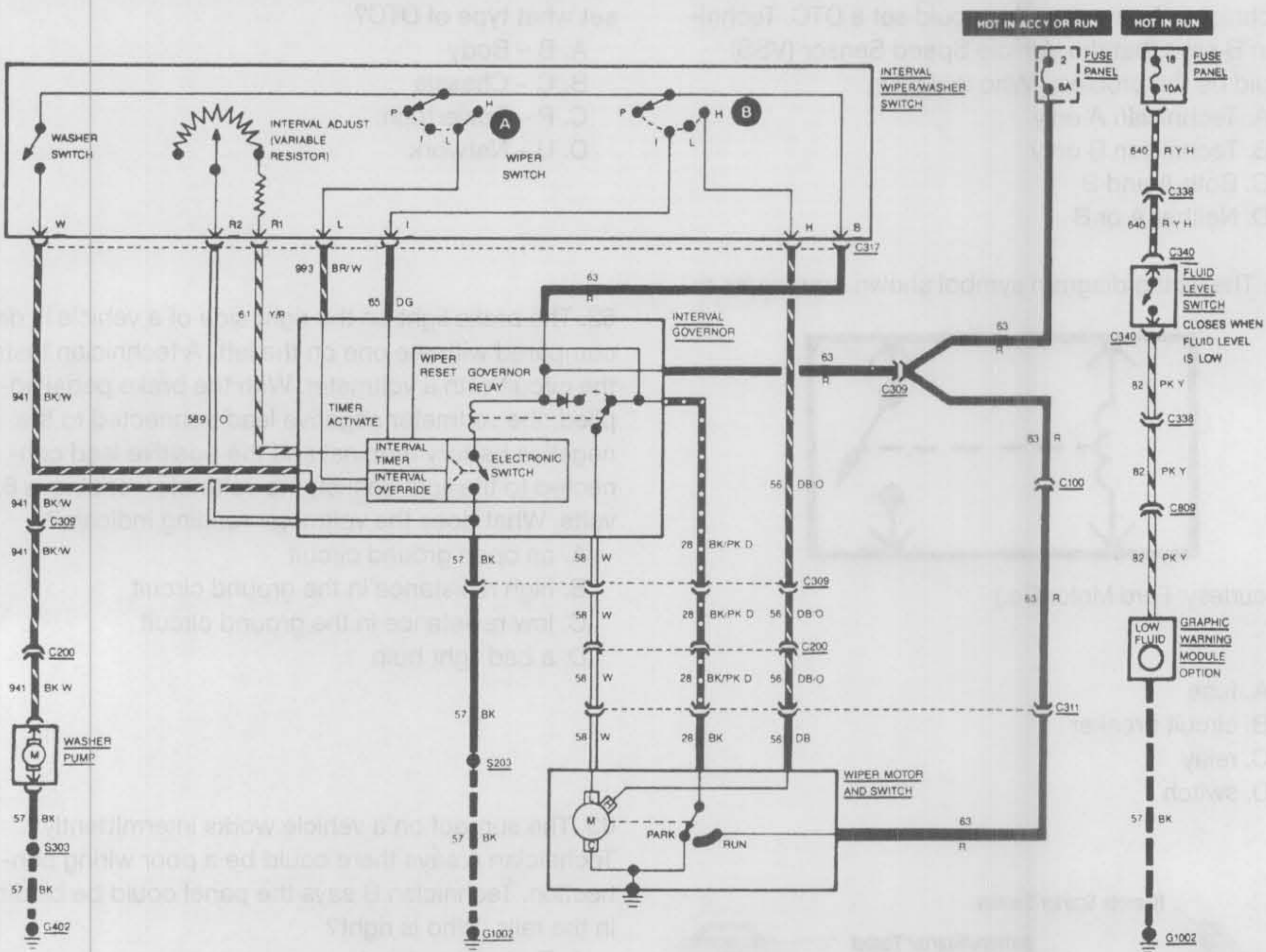
61. A communications failure in the CAN system will set what type of DTC?
   A. B – Body
   B. C – Chassis
   C. P – Powertrain
   D. U – Network

62. The brake light on the right side of a vehicle is dim compared with the one on the left. A technician tests the circuit with a voltmeter. With the brake pedal applied, the voltmeter negative lead connected to the negative battery terminal and the positive lead connected to the light socket, the voltmeter reading is 6.2 volts. What does the voltmeter reading indicate?
   A. an open ground circuit
   B. high resistance in the ground circuit
   C. low resistance in the ground circuit
   D. a bad light bulb

63. The sunroof on a vehicle works intermittently. Technician A says there could be a poor wiring connection. Technician B says the panel could be binding in the rails. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

64. The charging system on a vehicle undercharges. Technician A says the cause could be a loose alternator drive belt. Technician B says the cause could be a defective ECM. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

Prepare yourself for ASE testing with these questions on ELECTRICAL/ELECTRONIC SYSTEMS



(Courtesy: Ford Motor Co.)

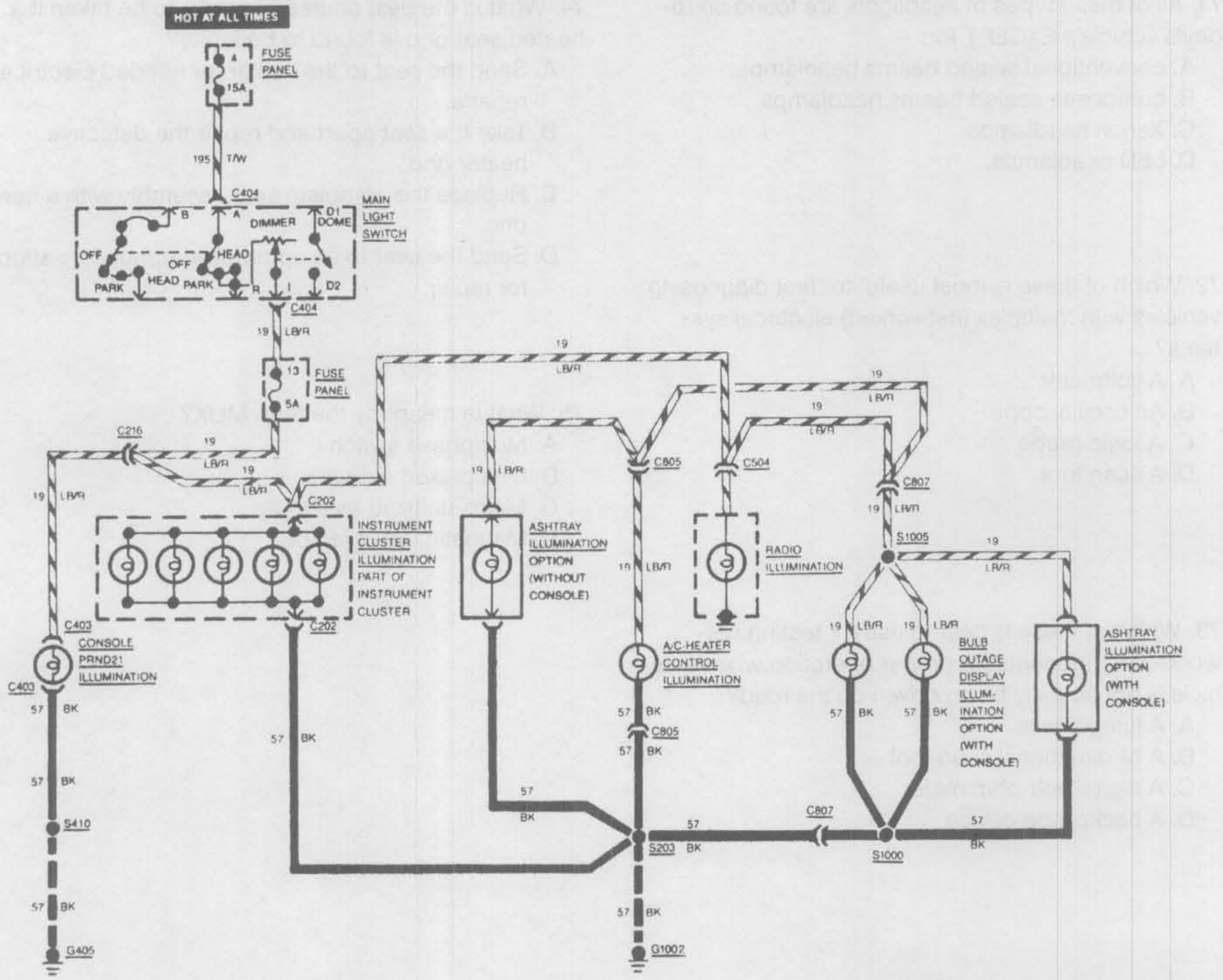
The next two questions refer to the interval windshield wiper/washer wiring schematic shown above.

65. The wipers do not work in the interval position. Which of the following should the technician do first?
   A. Measure resistance at terminals R1 and R2.
   B. Replace the interval governor.
   C. Check the fuse.
   D. Check for an open circuit at S303.

66. The wipers only work on high speed. All of the following could be the cause **EXCEPT**:
   A. a defective wiper switch
   B. a loose connection at G1002
   C. a defective interval governor
   D. an open in the DB/O wire

67. When checking a vehicle for DTCs, code U1064 is found: Loss of Communication with BCM. Technician A says that the BCM should be replaced. Technician B says the cause for the DTC could be another module in the network. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

Prepare yourself for ASE testing with these questions on ELECTRICAL/ELECTRONIC SYSTEMS



(Courtesy: Ford Motor Co.)

68. In the schematic shown above, only the console and the radio are illuminated when the lights are turned on. Which of these could be the cause?
   A. A blown five amp fuse
   B. A faulty connection at C216
   C. A loose connection at G1002
   D. A faulty connection at C504

69. When checking exterior LED lights on a vehicle, all of these can be checked EXCEPT:
   A. condition of filament.
   B. continuity.
   C. power circuit.
   D. ground circuit.

70. All of the gauges on a vehicle work except the coolant temperature gauge. A variable resistor is connected between the sending unit wire and ground. With the ignition switch ON the resistance is varied, making the gauge needle move. Technician A says the instrument voltage regulator could be the cause. Technician B says the sending unit could be faulty. Who is right?
   A. Technician A only
   B. Technician B only
   C. Both A and B
   D. Neither A or B

Prepare yourself for ASE testing with these questions on ELECTRICAL/ELECTRONIC SYSTEMS

71. All of these types of headlights are found on today's vehicle's EXCEPT for:
    A. conventional sealed beams headlamps.
    B. composite sealed beams headlamps.
    C. Xenon headlamps.
    D. LED headlamps.

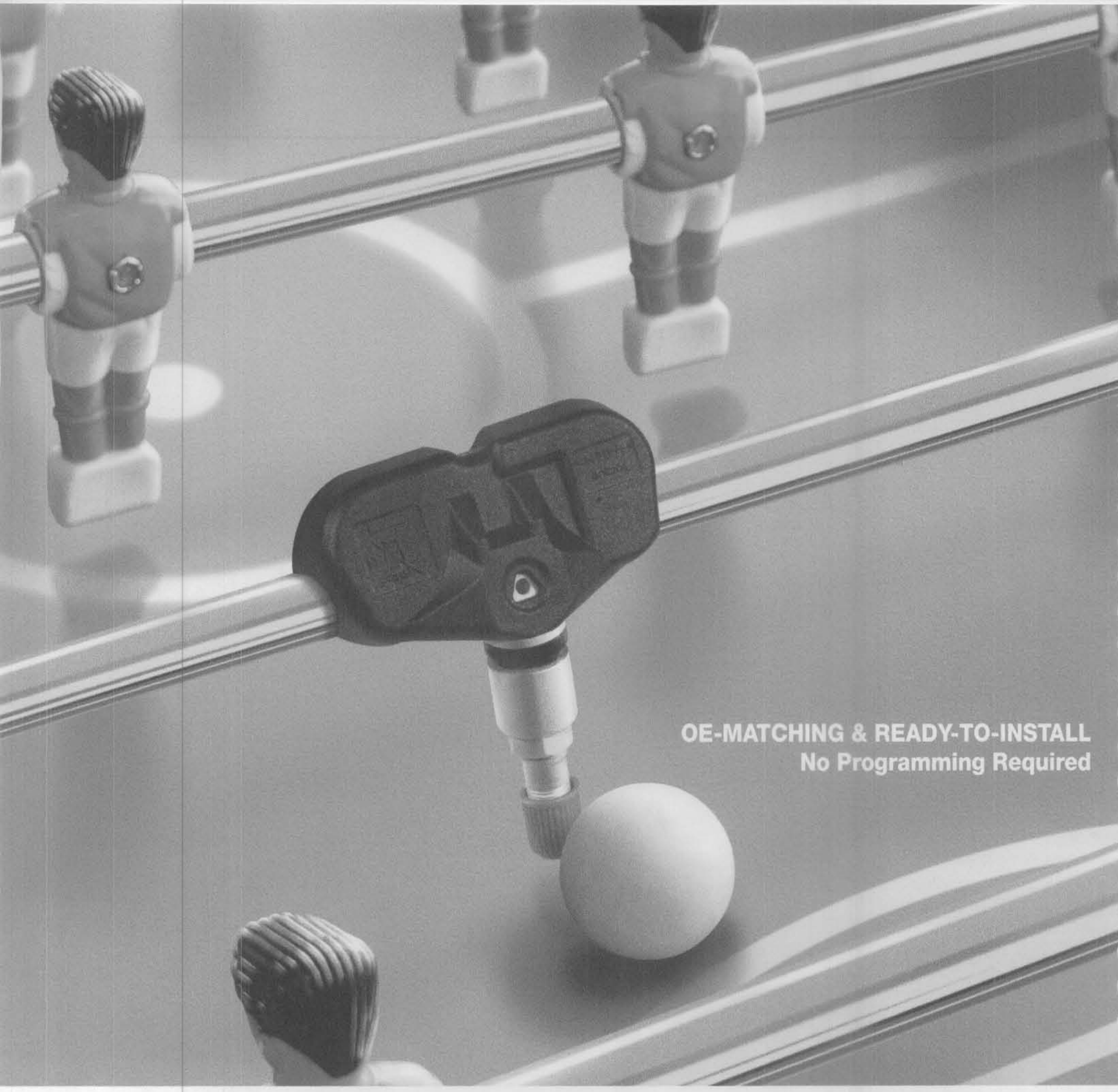
72. Which of these is most useful for first diagnosing vehicles with multiplex (networked) electrical systems?
    A. A voltmeter
    B. An oscilloscope
    C. A logic probe
    D. A scan tool

73. Which of these is best to use for testing networked components for proper operation when a vehicle is not actually being driven on the road?
    A. A jumper wire
    B. A bi-directional scan tool
    C. A digital volt-ohm meter
    D. A backprobe device

74. What is the best course of action to be taken if a heated seat grid is found to be faulty?
    A. Send the seat to the dealer for needed electrical repairs.
    B. Take the seat apart and repair the defective heater grid.
    C. Replace the complete seat assembly with a new one.
    D. Send the seat to an automotive upholstery shop for repair.

75. What is meant by the term MUX?
    A. Multiphase switch
    B. Multiplexed network
    C. Micro-unitized assembly
    D. Magnetic unit-injector

Notes


OE-MATCHING & READY-TO-INSTALL
No Programming Required

Answers to Study-Guide Test Questions

1. The correct answer is B. An "open" describes a complete breach in the current path at some junction in the circuit, whereas, a 'short' happens when a circuit load is bypassed allowing electricity to follow the path of least resistance. The grounded circuit in the illustration is a short, in that the bypass connects directly to the negative side of the power source via a chassis ground.

2. The correct answer is B. Always disconnect the negative battery cable and wrap with tape so contact cannot be made. Follow the specific vehicle's disarming instructions, as some SRS system can retain back-up power for an additional period of time.

3. The correct answer is A. For best results and less corrosion at the solder point, a rosin core flux should be used.

4. The correct answer is D. For maximum protection to the computer-controlled system or any electronic circuit, it is best to use at least a 10-megohm impedance digital multimeter.

5. The correct answer is B. Always use an ammeter or a low amperage amp clamp with your DMM to troubleshoot a slow drain in an electrical circuit.

6. The correct answer is B. A galvanometer is an analog type voltmeter. OEMs almost universally recommend the use of a non-intrusive conductive-capacitive type battery tester.

7. The correct answer is A. If an engine cranks slowly and the starter current draw is only 90 amps and the voltage is as high as 11 volts, the technician should next check for excessive voltage drop in the starter motor circuit.

8. The correct answer is C, both technicians are right. Worn alternator bearings and/or a bad alternator diode will cause the alternator to be noisy.

9. The correct answer is D. If the circuit is open, as in the rotor windings shown, the ohmmeter will show infinite resistance or infinity, and the needle will not move.

10. The correct answer is C, both technicians are right. Both an improperly rated flasher and an incorrect wattage bulb can cause the turn signals to flash at incorrect intervals.

11. The correct answer is C, both technicians are right. A short to ground has little or no resistance. Current flow increases as resistance decreases.

12. The correct answer is B. If the ground circuit past the light were faulty, added resistance would be present but the voltmeter would not indicate it from where it is placed in the circuit. Resistance before the meter would drop the 12 volts source voltage, resulting in a lower amount of voltage available at the light as shown.

13. The correct answer is A. A voltmeter should first be used to see if the circuit is getting power before doing further tests.

14. The correct answer is A. If the so-called "green eye" is not visible, the green tip of the built-in hydrometer is not floating high enough in the electrolyte to be visible. A fully charged battery will cause the built-in hydrometer to float to the top of the electrolyte and allow the green tip of it to be seen.

15. The correct answer is D, neither technician is right. A poor headlight ground would cause both the high and low beam lights to be dim. A shorted headlight switch would only cause the headlights to operate incorrectly or not at all.

16. The correct answer is A. Since voltage is supplied to the indicator light when the ignition switch is on, the indicator light will normally light when the oil pressure switch supplies a ground to complete the circuit. If a short to ground occurs between the indicator light and the oil pressure switch, the light will be on whenever the ignition switch is in the ON position. An open switch prevent the light from coming on.

Answers to Study-Guide Test Questions

17. The correct answer is D, neither technician is right. If a jumper wire is connected between the battery and the solenoid 'S' terminal and the engine cranks, there is a problem in the starter control circuit. If the solenoid makes a clicking sound, it is operating properly and the problem may be with the starter. If no sound is heard, the solenoid is defective and should be replaced.

18. The correct answer is C, both technicians are right. A circuit breaker will disconnect the circuit if the circuit has higher than normal current flow, which can be caused by a short in the circuit or a binding of the wiper linkage.

19. The correct answer is D. A battery with a 12.1 volt reading is undercharged. Technician B is wrong because if the indicator is yellow on a sealed maintenance-free battery, it means that the fluid level is below the level of the hydrometer. The battery should not be charged and should be replaced.

20. The correct answer is B. When performing a current draw test using an ammeter, a decrease in circuit resistance will cause a reading greater than what was specified.

21. The correct answer is D, neither technician is right. An analog meter with a low input resistance should only be usedfor non-computer type circuits; a test light should never be used to diagnose sensor circuitry.

22. The correct answer is D, neither technician is right. The high-rate discharge (load) test of a battery.is frowned upon by OEMs because of the likely hood of overstressing the alternator. If done with the battery removed (or disconnected) from the vehicle, the load applied should be three times the battery's ampere-hour rating or half of its CCA rating.

23. The correct answer is C. Short light bulb life and a battery that continually needs water ar indications of overcharging.

24. The correct answer is C. In the circuit shown in the illustration, the meter will show the charging circuit voltage drop from the alternator BAT terminal to the wire terminal or bus, to the positive battery post.

25. The correct answer is A. Connecting a jumper wire between terminals 1 and 2 would bypass the relay and supply direct voltage from the battery to the horns, indicating a possible bad horn relay. If the circuit between the horn button and the horn relay were grounded, the horn relay would be energized and the horns would blow all the time.

26. The correct answer is A. If the test light remains bright at both ends of the grid lines, check for a loose ground. If there is an open in a grid line, the test light will not get dimmer and will stay the same brilliance until it reaches the other side of the open, at which point it will go out.

27. The correct answer is D. Charging system warning lights are controlled by charging voltage. The light bulb is not grounded at the instrument panel. Instead, current flows through the bulb and eventually grounds at the ground brush inside the alternator. When the alternator is charging, current flows through a wire to the opposite side of the bulb from the ignition switch. Because both sides of the bulb receive similar voltages, no current flows through the bulb and it doesn't light.

28. The correct answer is B. When using an ohmmeter, all power should be removed from the circuit to be tested. Power to the circuit is necessary when testing a circuit with an ammeter.

29. The correct answer is A. A diode is a semiconductor that permits the flow of electricity in only one direction. When checking a diode with an ohmmeter, put the probes with red on the N-side; black goes on the P-side. Read the resistance, then reverse the leads. The diode should have a high resistance in one direction only.

Answers to Study-Guide Test Questions

30. The correct answer is B. Worn or missing flywheel ring gear teeth may not enable the starter to crank the engine, but would not cause the starter itself to be inoperative. All of the other choices could prevent the starter from operating.

31. The correct answer is C. While a bad ground would disable the system or make the power seat operate slowly, it would not be the cause of noisy operation.

32. The correct answer is C. Air bag system wiring harnesses should not be repaired and only replaced. All of the other answers are true statements regarding air bag systems.

33. The correct answer is B. The components of Ohm's Law include voltage (E), amperes (I) and ohms (R).

34. The correct answer is B. The rectifier bridge changes AC voltage to DC voltage. To test an externally grounded alternator, make sure all lights and accessories are off. Set the engine rpm to 1500-2000 rpm. Now ground the field according to the manufacturer's recommended procedure. Full amperage output should be indicated if the alternator is in good condition and being driven properly.

35. The correct answer is D, neither technician is right. Total voltage in a series circuit is equal to the sum of the voltages across the separate resistances. Total current in a series circuit is the same throughout the circuit.

36. The correct answer is A. 75 millivolts = 0.075 volts.

37. The correct answer is D, neither technician is right. If the BRN wire is open, the left window would not have a return or ground wire in the UP position and would not have a supply or voltage wire in the DOWN position. If the DRK BLU wire is open, the left window would not have a return or ground wire in the DOWN position and would not have a supply or voltage wire in the UP position. A possible bad switch LH WINDOW UP contact in the Master Switch Assembly would cause the problem.

38. The correct answer is C. A fuse normally blows because of high current draw. A typical cause for a blown fuse is a short circuit. A short may occur in the wiring or motor itself. If a window is binding in its track, the motor will tend to draw an excessive amount of current. This high current draw may cause the circuit breaker to trip or a fuse to blow. The problem may also cause motor damage. An open circuit will draw zero current and therefore, would not be a cause for the blown fuse.

39. The correct answer is A. If horn sound is a weak tone, current is too low, and poor electrical connections may be the culprit. If a fuse is blown, the horn will not sound at all.

40. The correct answer is A. Adding an additional path through which the current can flow has decreased the total resistance of the circuit. Each light drops 12 volts.

41. The correct answer is C, both technicians are right. An infinity reading indicates an open wire; a zero or low reading indicates a good connection.

42. The correct answer is B. The headlight switch and breaker would also affect the high beams. The dimmer switch would affect both low beam headlights.

43. The correct answer is D, neither technician is right. The flasher or fuses would affect both right and left sides. The most likely cause is two bad bulbs, a defective turn signal switch or a problem in the wiring that is common to the front and rear on the left side of the vehicle.

44. The correct answer is C, both technicians are right. Current remains constant throughout a circuit, and the total of all voltage drops always equals the source voltage provided.

45. The correct answer is C, both technicians are right. Current will be divided across the loads and the voltage is the same at each load.

Answers to Study-Guide Test Questions

46. The correct answer is B. Technician A states that a bad washer motor ground will prevent the wiper motor from working. This is wrong. The washer motor ground serves as a ground for the washer motor and would not affect the action of the wiper motor. Technician B explains the wiper motor park circuit shown in the illustration. The wiper motor will continue to run after the switch is opened until the cam opens the park switch.

47. The correct answer is B. Resetting circuit breakers are not used in taillight circuits. Fusible links are often identified by colored insulation—red, pink, brown, yellow, etc. The color indicates the amount of maximum circuit protection available.

48. The correct answer is D, neither technician is right. A test light may overload electrical circuits that contain solid-state components. Because an ohmmeter has its own battery, any circuit being tested should be disconnected from its voltage source.

49. The correct answer is C. Contrary to popular belief, the purpose of the soldering iron is not to melt the solder itself, but rather to heat the parts being soldered.

50. The correct answer is D, neither technician is right. Technician A is wrong because digital ohmmeters do not need to be zeroed before use. Test lead continuity should be checked however, by touching the two ohmmeter leads together and watching for a sero reading on the meter. Technician B is wrong because an ohmmeter is used to check the resistance of a component or wire while there is no voltage applied to the circuit. Current flow from an outside voltage source, such as the vehicle battery, can damage the ohmmeter, so the circuit or component should be isolated from the vehicle electrical system before any testing is done.

51. The correct answer is B. A rheostat is a type of variable resistor that has two terminals. One terminal is connected to the fixed end of the resistor and the other is connected to a movable contact called a wiper. The resistance is varied by moving the position of the wiper on the resistor, thereby increasing or decreasing the electrical current. In a headlight switch, the knob is connected to the wiper and as the knob is turned, the instrument panel lights dim or brighten. The other type of variable resistor, the potentiometer, is a three-terminal resistor. Potentiometers are commonly used in electronic engine control ystem sensors, such as the Throttle Position (TP) sensor.

52. The correct answer is B. A door switch is a grounding switch that completes the courtesy light circuit when a door is opened. When the door is closed, the switch opens and the interior lights go out. It is more likely that a door switch would stick in the open position, so Technician A is wrong. Technician B is right because a short to ground in the circuit before the door switch would complete the circuit, making the lights stay on regardless of switch position.

53. The correct answer is C, both technicians are right. Poor sound quality, static and poor reception can be caused by a defective antenna, an antenna that is not grounded or connected properly or one that is not trimmed properly. Static can also be caused by faulty ignition components, loose or missing ground wires and defective noise suppression devices.

54. The correct answer is B. The start/clutch interlock switch is open when the clutch pedal is in the released position, interrupting current flow in the starter circuit. Technician A is wrong because an open switch should have no continuity. When the clutch pedal is depressed, the switch closes, allowing current flow in the circuit.

55. The correct answer is D. Answers A and B are wrong because either problem would only affect one light and the question states that both lights do not work. Answer C is possible but it is not probable that both bulbs burned out at the same time. A faulty switch would affect both backup lights and is the most likely cause for failure of the choices given.

56. The correct answer is A. An oscilloscope is especially useful for diagnosing intermittent problems that might not be detected with a voltmeter. An analog voltmeter only displays average values and a digital voltmeter samples voltage several times each second, but because an oscilloscope displays actual voltage it will show any momentary changes in the signal. These momentary changes can be caused by an intermittent open in the circuit or an intermittent short to power or ground. A test light does not indicate that 12 volts (or any particular amount of voltage) are present; it only Indicates that some voltage is present.

57. The correct answer is C. A faulty passenger's door lock motor would only affect that door and would not prevent other doors from opening with the remote keyless entry. All of the other choices could prevent all the doors from opening using keyless entry.

58. The correct answer is C, both technicians are right. The Body Control Module (BCM) in some systems can make diagnostic checks of the electronic instrument cluster. The BCM monitors certain functions and will store a DTC if any are found to be outside of preprogrammed parameters. If the instrument cluster passes a self-diagnostic test but the speedometer still remains at a certain speed or operates erratically, the problem is most likely in the VSS circuit.

59. The correct answer is C. The symbol shown represents a relay.

60. The correct answer is D, neither technician is right. Technician A is wrong because 0.3 volts is within specification for voltage drop in a starter power circuit. Technician B is wrong because the starter ground circuit is not being tested in the illustration.

61. The correct answer is D. The onboard diagnostic system will set a code beginning with the letter U.

62. The correct answer is B. If there were an open ground circuit or the bulb was bad, the light would not work at all. Since the bulb is working, but not optimally, the technician is voltage drop testing. If the circuit was operating properly, the voltmeter reading would be 0.0 volts and no higher than 0.5 volts. This would mean that all the system voltage was being used by the light. The reading of 6.2 volts means that there is excessive resistance in the circuit, robbing the light of the necessary voltage needed for optimal illumination. The technician should continue checking the ground path until the voltmeter reading returns to normal and repair the problem connection.

63. The correct answer is C, both technicians are right. Loose or corroded connections could cause an intermittent problem. The glass binding in the rails could cause the electric motor to overheat and trip the circuit breaker. After the breaker cools and resets, the panel may work again until the binding again trips the breaker.

64. The correct answer is C, both technicians are right. A loose alternator drive belt could cause reduced charging system output voltage, but on some vehicles, so could a defective ECM. The PCM/ECM regulates alternator output voltage on many newer vehicles. The PCM/ECM either supplies power or ground to the alternator field, depending on the system. The power or ground is pulse-width modulated in response to the amount of sensing voltage.

65. The correct answer is A. If the fuse were bad, the wipers would not work at all, and the question states that they only don't work in the interval position. An open at S303 would affect the washer pump but not the wipers. The interval governor should not be condemned until the resistance is checked at terminals R1 and R2 of the wiper switch. If the resistance doesn't vary when the interval adjustment is turned, the wiper switch should be replaced. If the interval adjustment varies the resistance, the interval governor should be replaced.

66. The correct answer is D. An open in the DB/O wire would prevent high-speed operation and the question states that the wipers only work on high. A bad governor ground could prevent low and interval operation so a loose connection at G1002 could be the cause. No voltage at terminals L and I of the main switch could mean that the switch is faulty. However, if there is voltage at terminals L and I and wires 65 and 993 are OK, the governor should be replaced.

67. The correct answer is B. This code does not necessarily mean that the module has failed, but rather that there is a problem preventing communication. A communications DTC can be caused by a faulty connector or wiring, an open or short circuit, a voltage problem on the network, another module in the network, or the module itself.

Answers to Study-Guide Test Questions

68. The correct answer is C. A blown fuse or a faulty connection at C216 would prevent all the lights from working. A poor connection at C504 would prevent the radio light from working and we know from the question that it works. The radio is case grounded and the console light also has a separate ground. However, all the other lights share the G1002 ground and a poor connection there could cause an open circuit and keep those lights from working.

69. The correct answer is A. LED lights have no filament, so a visual inspection will not determine whether the light is good. If an LED light assembly does not illuminate, check the light for an open circuit, inspect the wiring and make sure there is power to the light, just as you would for a conventional incandescent light.

70. The correct answer is B. If all the gauges were dead, then the cause would probably be the instrument voltage regulator. However, only the temperature gauge is inoperative. The gauge was tested properly in the question so a faulty sending unit is indicated. The resistance of the sending unit can be checked by connecting an ohmmeter between the terminal lead and ground. The resistance value should change in proportion to the coolant temperature. Compare results with the manufacturer's specifications.

71. The correct answer is A. Conventional sealed beams have all but been replaced by the other types of headlamps listed In this question

72. The correct answer is D. Multiplexed networks can be monitored and tested using an OEM or equivalent scan tool.

73. The correct answer is B. A bi-directional scan tool can be used to command on-board actuators to perform their duty when the vehicle is either in for service, or when it can be safely done while the vehicle is on the road.

74. The correct answer is D. The best course of action, unless a qualified upholstery technician is on staff, is to send the seat out for repair at an automotive upholstery shop. The special tools needed and the labor time involved would otherwise be prohibitive.

75. The correct answer is B. MUX stands for "multiplex", which is the basis of operation for the type of communication system used in network equipped vehicles.

Notes

Glossary

--a--

absorbed glass mat (AGM) battery - a type of storage battery where the electrolyte is held in moistened fiberglass matting instead of existing as a liquid or gell.

actuator - a control device that delivers mechanical action in response to an electrical signal.

air gap - space or gap between spark plug electrodes, motor and generator armatures and field shoes.

alignment - an adjustment to bring into a line.

alloy - a mixture of different metals (e.g., solder, an alloy consisting of lead and tin).

alternating current (AC) - electrical current that flows in one direction, from positive to negative, and then reverses direction, from negative to positive.

alternator - a belt driven device that provides electrical current for the vehicle's charging system.

ambient temperature - the temperature of the air surrounding an object.

ammeter - instrument used to measure electrical current flow in a circuit.

amperage - the amount of electrical current flowing in a circuit.

ampere(amp) - unit for measuring electrical current.

amplifier - a circuit or device used to increase the voltage or current of a signal.

amplify - to enlarge or strengthen original characteristics; usually used in reference to electronics.

amplitude - the maximum value that can be reached by the periodically varying quantity of an oscillation.

analog - in automotive terms, a device, such as a gauge, that uses a needle and printed references, rather than an electronic readout.

arcing - electrical energy jumping across a gap.

armature - a laminated, soft iron core wrapped by wire that converts electrical energy to mechanical energy.

--b--

backlash - the clearance or play between two parts, as in gear mesh.

ball bearing - an anti-friction bearing that uses a series of steel balls held between inner and outer bearing races.

battery - a device that produces electricity through electrochemical action.

battery acid - the sulfuric acid solution used as the electrolyte in a battery.

battery cell - the part of a storage battery made from two dissimilar metals and an acid solution. A cell stores chemical energy to be used later as electrical energy.

bearing race - machined circular surface of a bearing against which the roller or ball bearings ride.

bendix drive - the starter drive gear that is attached to the starter motor armature and engages the gear teeth on the flywheel.

bimetallic - two kinds of metal, with different thermal expansion rates, that when attached to one another, the resulting assembly will bend in the direction of the metal that expands the least.

bi-xenon - a type of HID headlight that changes the beam by varying the position of the reflector or bulb, or using a shutter to obstruct a portion of the beam.

bushing - a liner, usually removable, for a bearing; an anti-friction liner used in place of a bearing; a type of bearing that is used to support rotating shafts.

--c--

capacitor - device for holding/storing a surge of current.

charge - the electrical current that passes through the battery to restore it to full power; to fill, or bring up to the specific level, an A/C system with refrigerant; the required amount of refrigerant for an A/C system.

charging system - the system that supplies electrical power for vehicle operation and recharges the battery.

check valve - a gate or valve that allows passage of gas or fluid in one direction only.

circuit - a path through which electricity flows before returning to its source.

circuit breaker - a device used in an electrical circuit to interrupt current flow in the event of an overload or short.

cold cranking amps (CCA) - the amount of cranking amperes that a battery can deliver in 30 seconds at 0°F (–18°C).

commutator - a slotted ring located at the end of the armature of a generator or motor. The commutator provides the electrical connection between the armature and brushes.

compound - a mixture of two or more ingredients.

conductor - a material that provides a path for the flow of electrical current or heat.

continuity - the condition that exists in a working electrical circuit. A circuit that is unbroken, not open.

controller area network (CAN) - a communications protocol used by vehicle on-board computers (modules) to communicate with one another and share data.

current - the flow or rate of flow of an electric charge through a conductor or medium between two points having a different potential, expressed in amperes.

--d--

deflection - bending or movement away from the normal position due to loading.

diaphragm - flexible, impermeable membrane on which pressure acts to produce mechanical movement.

diode - a simple semiconductor device that permits flow of electricity in one direction but not the other.

discharge - the flow of current from a battery; to remove the refrigerant from an air conditioning system.

dropping resistor - battery voltage reduction device.

duty cycle - a signal that varies the ratio of on time to off time, resulting in a square wave that can range between zero and 100 percent or may be high or low, and off may be high or low; in a process, the ratio of on time to total cycle time; in fuel injectors, the percentage of on-time to total cycle time; in solenoids, the percentage of on-time to total cycle time.

--e--

electrode - a terminal that conducts an electric current into or away from the conducting part of a circuit, such as the terminal of a battery; firing terminals found in a spark plug.

electrolysis - chemical and electrical decomposition process that can damage metals such as brass, copper and aluminum in the cooling system; the decomposition of an electrolyte by the action of an electric current passing through it.

electrolyte - a material whose atoms become ionized (electrically charged) in solution. In automobiles, the battery electrolyte is a mixture of sulfuric acid and water.

electromagnet - a magnet formed by electrical flow through a conductor.

electromagnetic induction - moving a wire through a magnetic field to create current flow in the wire.

electromechanical - refers to a device that incorporates both electrical and mechanical principles together in its operation.

electronic - pertaining to the control of systems or devices by the use of small electrical signals and various semiconductor devices and circuits.

emitter - in a transistor, the region or layer of semiconductor material from which electrons are injected into the base region.

--f--

field coil - a wire coil on an alternator rotor or starter motor frame; a field coil produces a magnetic field when energized.

frequency - the number of cycles of a periodic waveform typically measured in one second intervals or hertz (cycles per second).

fuse - a metal circuit protection device that melts when there is a circuit overload or short.

fusible link - a smaller gauge wire that is included in an electrical circuit to provide circuit protection. The smaller gauge wire will melt when the circuit is overloaded.

--g--

gassing - hydrogen gas bubbles that rise from the battery electrolyte during charging.

gell cell battery - a type of storage battery that contains the electrolyte in a gell form.

generator - a device that converts mechanical energy into electrical energy; SAE J1930 nomenclature for an alternator; a generating device that uses diode rectifiers to convert AC to DC.

ground - a connecting body whose electrical potential is zero to which an electrical circuit can be connected.

ground circuit - that part of the circuit that is connected electrically to the negative terminal of the battery. Every electric circuit has a power and ground side. Most computer actuations consist of completing the ground side of an actuator's circuit; this protects the computer from short circuits. Resistance in a ground circuit will reduce the current through it and cause deterioration in the function of the circuit.

--h--

high intensity discharge (HID) headlight - a type of headlight that does not use a filament, but instead uses a glass or quartz tube filled with a special inert gas and electrodes sealed into each end of the tube. When current is passed through the tube, the gas becomes hot and emits light.

hydrometer - an instrument used to measure the specific gravity of a solution.

--i--

impedance - the total resistance of an electrical device measured in ohms.

induction - the process by which an electric or magnetic effect is produced in an electrical conductor or magnetic body, when it is exposed to variation of a field of force. Induction is the principle used in an ignition coil to increase voltage.

insulated circuit - a circuit that includes all of the high-current cables and connections from the battery to the starter motor.

insulator - a non-conductive material used to insulate wires in an electrical circuit.

integral - made of one piece.

integrated circuit - diodes, transistors and other electronic components mounted on semiconductor material and able to perform numerous functions.

--l--

lamination - thin layers of soft metal used as the core for a magnetic circuit.

light-emitting diode (LED) - a type of light made of special semiconductor material that is partially translucent. When current flows through the diode, light is emitted.

liquid crystal display (LCD) - a type of digital electronic display made of special glass and liquid; requires a separate light source.

load - in mechanics, the amount of work performed by an engine; specifically, the external resistance applied to the engine by the machine it is operating. In electrical terms, the amount of power delivered by a generator, motor, etc., or carried by a circuit. The work an engine must do, under which it operates more slowly and less efficiently (e.g., driving up a hill, pulling extra weight).

--m--

magnet - any body that attracts iron or steel.

magnetic field - the areas surrounding the poles of a magnet that are affected by its forces of attraction or repulsion.

magnetic gauges - electrical analog gauges that use magnetic forces to move the needle left or right.

memory - part of a computer that stores or holds programs and other data.

mercury switch - a type of switch that uses the flow of liquid metal mercury to complete the electrical circuit. Mercury switches are frequently used to control trunk and underhood lights.

meter - an instrument used for measuring, especially the flow of a gas, liquid or electrical charge; to regulate the flow of a gas, liquid or electrical charge; to control the amount of fuel passing into an injector or carburetor.

microprocessor - the portion of a microcomputer that receives sensor input and handles calculations.

multimeter - a tool that combines the functions of a voltmeter, ohmmeter and ammeter into one diagnostic instrument.

--o--

ohm - a unit of electrical resistance of a circuit in which an electromotive force of one volt maintains a current of one ampere, named after German physicist Georg Ohm.

ohmmeter - an instrument that measures electrical resistance in ohms.

Ohm's Law - expresses the relationship between current, resistance and voltage in any electrical circuit. Ohm's law states that the voltage in a circuit is equal to the current multiplied by the resistance.

open circuit - an electrical circuit that has a break, an intentional (switch) or unintentional (bad connection) break in the wire, preventing the flow of electrons.

optical sensor - a light sensitive device that produces a voltage signal when exposed to a light source.

oscilloscope - an instrument that displays electrical activity in the form of line patterns on a screen.

--p--

parallel circuit - a circuit with more than one path for the current to follow.

period - in an electrical signal the period is the amount of time it takes for one cycle of an electrical signal to repeat itself; the number of periods that occur in one second is the frequency of the signal.

polarity - the condition of being positive or negative relative to a reference point or object; the particular state (positive or negative) with reference to the two magnetic poles.

potentiometer - a device that changes voltage by varying its internal resistance.

power circuit - the part of the circuit that is connected electrically to the positive terminal of the battery. Every electric circuit has a power and a ground side. On computer controlled systems, ordinarily power is routed to actuators directly through the ignition switch; the circuit is completed when the computer grounds it. Most manual switches directly connect the power side of the circuit to the load. Fuses are ordinarily positioned as close as possible to the battery on the power side of a circuit.

printed circuit - an electrical circuit formed by electrically conductive paths printed on a board.

program - a set of instructions or procedures that a computer must follow when controlling a system.

pulse width modulated - electronic control of a solenoid that rapidly cycles it on and off many times per second in order to achieve a specific output.

--r--

recombination battery - a type of storage battery where the oxygen and hydrogen created during charging recombine to form the water inside the battery.

rectifier - a device that changes alternating current (AC) into direct current (DC).

rectify - to change one type of voltage to another.

relay - an electromagnetic switch that uses low amperage current to control a circuit with high amperage.

reserve capacity (RC) - the number of minutes the battery can deliver 25 amps at 80°F while maintaining a voltage of 10.5 volts.

resistance - the opposition offered by a substance or body to the passage of electric current through it.

resistor - an electrical device installed in a circuit to lower voltage and current flow.

rheostat - a variable resistor used to control current flow in a circuit.

Glossary

--s--

saturation - point at which current flowing through a coil or wire has built up the maximum magnetic field.

scan tool - microprocessor designed to communicate with a vehicle's on-board computer system to perform diagnostic and troubleshooting functions.

scan tool data - Information from the ECM, PCM, or VCM that is displayed on the scan tool. This data includes component and system values on the data stream, DTCs, and on some systems, freeze frame data, system monitors and readiness monitors.

semiconductor - a material that is neither a good conductor of electricity nor a good insulator.

series circuit - a circuit that has only one path for current to follow.

series-parallel circuit - a circuit that combines series and parallel circuits.

serpentine belt - a multiple-ribbed belt.

servo - a device, such as an electric motor or hydraulic piston, which is controlled by an amplified signal from a low power command device.

servomotor - see servo.

short circuit - a condition that occurs in an electrical circuit when the current bypasses the intended load and takes a path with little or no resistance, such as another circuit or ground.

shunt - an alternate path through which electrical current or fluids may flow.

solenoid - a coil of wire that becomes an electromagnet when current flows through it. It then loses its magnetism when the current flow is turned off. The solenoid contains an iron plunger inside the wire coil that is spring loaded to one position. When the solenoid is energized, the plunger moves to the other position.

solid state - an electrical device with no moving parts.

splice - to join. Electrical wires can be joined by soldering or by using crimped connectors.

square wave/sine wave - voltage fluctuations of different shapes in an electric circuit. The square wave goes immediately from one voltage to the other; the sine wave gradually changes, going through the intervening values. An electromagnetic pulse generator like a wheel speed sensor or a reluctor-type distributor pickup produces a sine wave. Hall Effect sensors, photoelectric switches, and other on-off signal generators produce square waves. For many purposes, square waves are easier for computers to work with, so on many vehicles there are electronic devices to modify sine waves into square waves.

starter - the electric motor that is used to start an engine.

switch - a device used to open, close or direct the current in an electrical circuit.

--t--

transducer - a device that changes a force into an electrical signal.

transistor - an electronic device produced by joining three sections of semiconductor materials; used as switching or amplifying device.

--v--

variable resistor - a resistor that can be adjusted so the amount of resistance produced in the circuit changes.

vehicle speed sensor (VSS) - a permanent magnet sensor, usually located on the transmission, which provides the input for the speedometer.

volt - unit of electromotive force. One volt of electromotive force applied steadily to a conductor of one-ohm resistance produces a current of one ampere.

voltage drop - voltage lost by the passage of electrical current through resistance.

voltage regulator - a device used to control the output of an alternator or generator.

voltmeter - a tool used to measure the voltage available at any point in an electrical system.

--w--

watt - a unit of measurement of electrical power. One volt multiplied by one amp equals one watt.